Number 35

GROUNDWATER DISCHARGE PLAN

FEBRUARY 1980

MT. TAYLOR URANIUM MILL PROJECT
NEW MEXICO

GULF MINERAL RESOURCES CO.

DENVER, COLORADO

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

SECTION I

INTRODUCTION AND SUMMARY

This discharge plan, submitted by Gulf Mineral Resources Co., ("Gulf"), a division of Gulf Oil Corporation, pursuant to Section 3-106 of the New Mexico Water Quality Control Commission Regulations, (the "Regulations"), presents the potential impacts to groundwater associated with operation of Gulf's Mt. Taylor Uranium Mill Project. There are three main features of the project, the operation of which have the potential to affect groundwater quality. These features are the tailings and liquid waste disposal facilities, the tailings and liquid waste pipelines, and the mill impoundment and containment pond.

The layout of this plan is designed so that these features can be analyzed individually. Therefore, this discharge plan actually consists of three separate and distinct discharge plans; one for each of the above mentioned features.

The proposed facilities to dispose of tailings and waste water (raffinate) from the Mt. Taylor Uranium Mill were sited to take advantage of remoteness and hydrogeologic conditions to minimize any potential threat of groundwater contamination. The facilities are designed so that all tailings will be buried below existing ground surface and so that most of the liquid wastes will be disposed of by evaporation. Provisions are made for burial of evaporites and for reclamation of all disturbed ground in a manner that is safe and compatible with the surrounding environment.

Tailings will be discharged in disposal trenches as a slurry in a manner that will maximize slimes deposition along the bottom of the trenches and result in interlayering of slimes and sands above the trench bottoms. The slimes will consolidate when loaded with sands and develop low permeabilities which will fill open fractures and retard seepage. Open drains will be constructed along the periphery of the disposal trench area to intercept horizontal seepage along bedding planes, shallow fractures and sandstone layers. Waste water will be decanted from the disposal trenches and routed through a small settling pond constructed below grade. The settling pond will intercept suspended slimes and the clear water will be transported to an evaporation pond for disposal. The disposal trenches will be covered and reclaimed as soon as the trenches are filled and the tailings develop enough strength to receive the load of the cover.

The evaporation pond will be contained by a zoned earthfill dam with a portion of the pond area lined. The pond will have sufficient capacity to store and evaporate all liquid wastes safely. The lining system will reduce seepage to levels that will prevent contaminants from reaching any aquifer. Most of the seepage from the combined disposal facilities will be stored in the vadose zone beneath the facilities as moisture retained by capillary forces which will prevent free drainage. Seepage analyses indicate that a small perched groundwater mound will develop beneath part of the evaporation pond. However, this seepage mound will be dissipated by lateral spreading in the unsaturated Gallup Sandstone and underlying Mancos Shale. The possibility of any of this seepage reaching a saturated zone is remote, but if it does, the quantities would be insignificant and contaminants would be attenuated to near background levels. Therefore, it is concluded that existing groundwater in the vicinity of La Polvadera Canyon will not be affected by disposal of mill wastes at the proposed site. A monitoring system will be provided to verify seepage predictions during operations and provide data for development of contingency plans, if necessary, to solve unanticipated problems.

A tailings pipeline, approximately six miles in length, will transport solid wastes from the mill process to the tailings disposal area. The tailings transport system consists of a pump station located within the mill, one slurry pipeline, and a mill liquor pipeline for carrying decant water from the evaporation pond to the mill. The liquor decant line will also serve as an emergency slurry pipeline. The slurry and liquor pipelines will be fabricated of carbon steel pipe with an internal rubber liner.

The mill includes facilities for separating the sands fraction (+65 mesh) from the total tailings when sands are required for mine backfill. The sand/slime separation equipment will operate when sands are needed for mine backfill, during which time maximum flow through the slurry line will be 1400 gallons per minute consisting of a 21 percent by weight solids slurry. When sands are not required for mine backfill, the total tailings volume, consisting of 1400 gallons per minute of about 20-40 percent by weight solids slurry, will be disposed of in the tailings disposal area.

The design of the tailings transport system incorporates features that minimize the potential for release of tailings material from the pipeline. The features include redundant instrumentation and frequent inspection schedules. In addition, the pipelines are placed within a lined pipeway that will act to contain spills or leakage if required, and catchment basins will be provided at low points along the route. It is believed that the control features will virtually eliminate the possibility of accidental spills affecting groundwater quality. Hypothetical scenarios are presented, though, to describe the potential impact on the environment from spills of various sizes. In any instance involving a spill, the affected area will be decontaminated to a level which is as low as reasonably achievable.

A mill impoundment and containment pond are planned to be constructed approximately one-half mile downstream (northeast) of the Mt. Taylor Uranium Mill. The lined containment pond is provided to contain any major process spill from the mill as well as process area runoff, washdown water, and treated sewage water. The mill impoundment will hold any storm water that exceeds the capacity of the containment pond. It is concluded, due to the nature of the liquid to be impounded or temporarily held in these facilities, that the water quality in the Menefee Formation, the aquifer most likely to be affected, will not be degraded beyond the standards of Section 3-103 of the regulations by operation of either the mill impoundment or containment pond.

This discharge plan, including all three plans incorporated herein, demonstrates that Gulf's Mt. Taylor Uranium Mill operations will be in compliance with the Regulations and that such operation will not adversely affect groundwater quality.

SECTION II

THE TAILINGS DISPOSAL SYSTEM

A. PROJECT DESCRIPTION

1. GENERAL

Gulf proposes to dispose of liquid and solid wastes from the Mt. Taylor Uranium Mill in La Polvadera Canyon, approximately 23 miles northeast of Grants, New Mexico. The La Polvadera Canyon facility will consist of a parallel series of dragline excavated trenches for burial of tailings, a slimes settling pond and an evaporation pond. During the planned project life from 1982 through year 2003, approximately 12.6 million tons of tailings will be buried. This tonnage represents one-half of the mine ore production minus five percent for dissolution during processing. The remaining 50 percent of the mill tailings will be used for mine backfill.

Tailings will be discharged as a slurry into the disposal trenches and allowed to segregate by sedimentation into layers of slimes covered by sands. This will promote consolidation of the slimes, resulting in reduced slimes permeability which will help control seepage. Slimes and near horizontal shales will control vertical seepage and open peripheral drains will intercept horizontal seepage. Waste water will be decanted from the tailings and transported to a settling pond (along with water from drains). This settling pond may not be needed but will serve as a backup facility to intercept slimes that might be decanted with the waste water. The necessity for long-term operation of this pond will be evaluated during the initial years of mill operation.

Waste water in the settling pond will be decanted and transported by pipeline to the evaporation pond for disposal. The evaporation pond will be sized to accomodate all waste waters (minus minor evaporation in the trenches) plus precipitation on the pond area and trenches. The evaporation pond is a key element in the discharge plan. This impoundment will be lined as needed to minimize seepage; it will be contained by a safe zoned earthfill embankment with appropriate freeboard. Diversion facilities will be provided to control surface runoff into the pond.

Final design of the waste disposal facilities in La Polvadera Canyon was not complete during the preparation of this discharge plan. However, the anticipated design changes from layouts presented herein will be minor and they will not adversely affect the groundwater discharge plan. The discharge plan for the tailings disposal system is based, for the most part, on the report prepared by Earth Sciences Associates (1980).

2. MILL WASTE MATERIALS

The proposed mine-mill operation will extract uranium from a six-mile trend of ore bodies lying at a 3200 foot depth along the northwest flank of Mt. Taylor. The individual ore bodies are basically flat lying tabular units with a high degree of irregularity in ore thickness and crosstrend width. The uranium mineralization occurs in the Westwater unit, an arkosic sandstone member of the Morrison Formation of Late Jurrasic Age. The ore appears to be a typical Grants Belt occurrence with a black to brown mixture of coffinite and organic humates filling pore space and coating the sandstone grains.

The solid wastes from the mill consist of about 70 percent sands and about 30 percent slimes (-200 mesh) and will be allowed to segregate by sedimentation. The slimes classify as a highly plastic "fat" clay (CH) according to the Unified Soil Classification System. Initially the low density slimes will have a permeability of about 10 feet per year, but will consolidate with loading and rapidly reach permeabilities of 0.5 foot per year. Eventually the slimes permeability will reach about 0.03 foot per year under full consolidation. The sands are essentially all finer than the No. 30 U.S. Standard Sieve size. The permeability of the sands averages about 100 feet per year. Table II-1 shows the projected tailings and liquid waste production rates to be disposed of in La Polvadera Canyon.

The liquid waste will be primarily a raffinate solution with an approximate chemical composition as shown on Table II-2. This waste water is essentially a sulfuric acid solution with a pH of about 1.5. It has a total dissolved solids content that ranges up to 95,000 mg/l with moderate to high concentrations of radionuclides. The chemical analysis shown on Table II-2 is from a solution derived from bench tests on ore samples. Other analyses of similar samples indicate considerable variations, but the analysis shown is considered to be typical. Chemical composition of the raffinate will no doubt vary with the composition of the ore being milled.

3. TAILINGS DEPOSITION

The tailings will be transported to the burial site by a slurry pipeline at approximately 20 to 40 percent solids (35 percent solids was assumed in water balance computations to be conservative). This slurry will be discharged across a long trench which will be approximately 75 feet wide at the bottom, 125 feet wide at the surface, and 50 feet deep. The trenches will be excavated by a dragline and will have a gradual longitudinal slope at the bottom of less than one percent The tailings will be discharged at one end of the trench, forming a sand beach and causing deposition of slimes along the trench bottom. Berms will be constructed at intervals along the trench bottom to promote pooling and settling of slimes. In this manner, sand beaches will eventually cover the slimes. The load of the sands will consolidate the slimes, reducing the slimes permeability. The slimes will be concentrated at or near the bottom of the trench and will provide added protection against seepage. Slimes will also seal any open fractures exposed on the bottom or sides of the trenches, resulting in reduced permeability of the foundation rocks. As the tailings are discharged, segregation of the sands and slimes will occur, as mentioned above, and raffinate will pool behind the berm. The pooled raffinate will be pumped to the intermediate settling pond. When the area behind the berm is filled, tailings deposition will continue in the same manner behind the new berm constructed downstream within the trench.

An open trench drain will be provided along the periphery of the disposal trench area to intercept horizontal seepage along bedding planes, sandstone layers and shallow fractures. Similarly, adjacent trenches will act as drains as they are opened next to an active trench. Sump pumps will be used to collect waste water if it appears in the open drains or adjacent trenches will be routed to a settling pond to separate suspended solids from the waste water.

Figure II-1 provides a three-dimensional illustration showing the tailings burial system described above. Figure II-2 shows the location and orientation

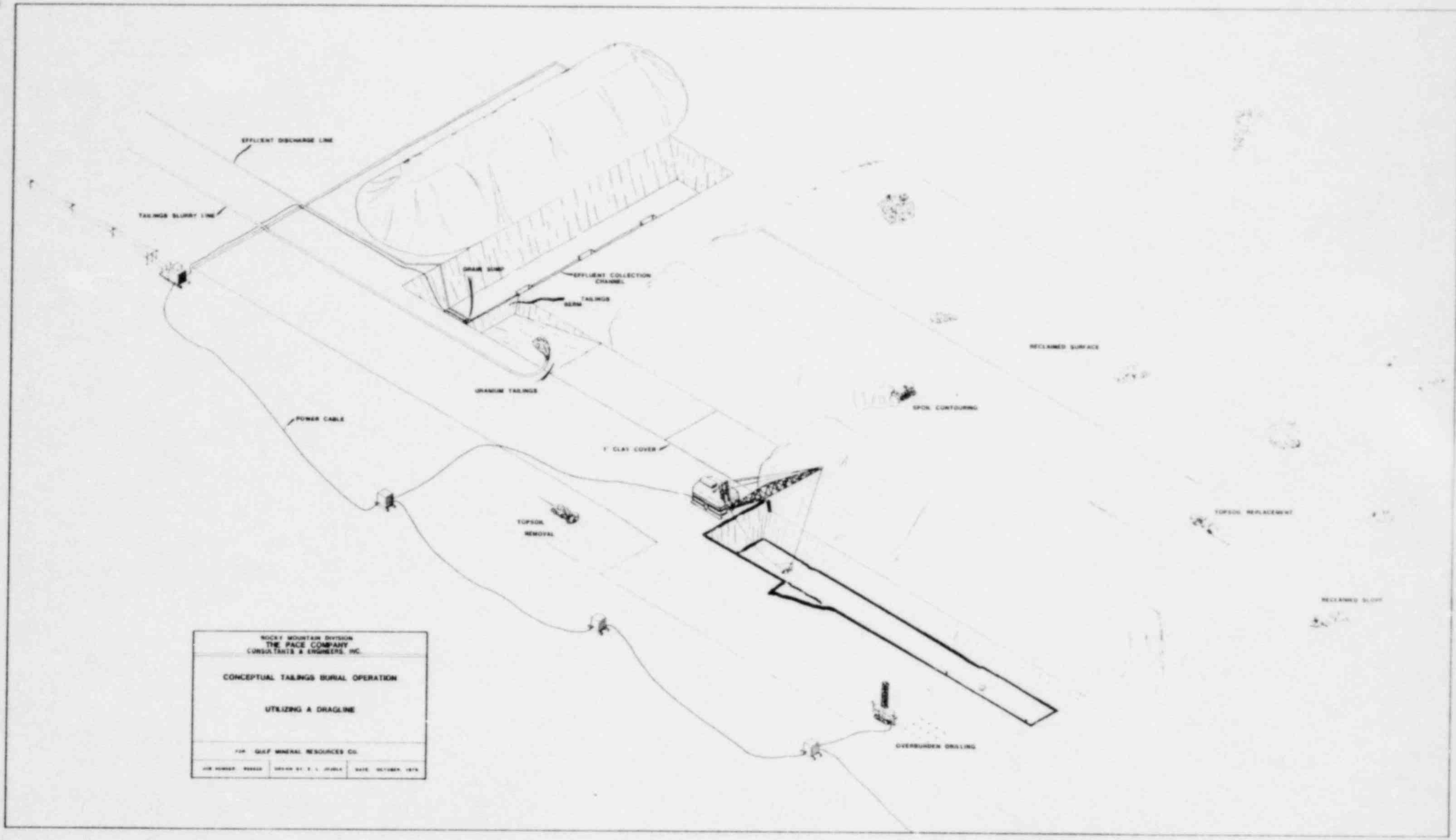

EFFLUENT DISCHARGE LINE
TAILINGS SLURRY LINE
DRAIN SUMP
EFFLUENT COLLECTION CHANNEL
TAILINGS BERM
URANIUM TAILINGS
POWER CABLE
1' CLAY COVER
TOPSOIL REMOVAL
RECLAIMED SURFACE
SPOIL CONTOURING
TOPSOIL REPLACEMENT
RECLAIMED SLOPE
OVERBURDEN DRILLING
ROCKY MOUNTAIN DIVISION
THE PACE COMPANY
CONSULTANTS & ENGINEERS, INC.
CONCEPTUAL TAILINGS BURIAL OPERATION
UTILIZING A DRAGLINE
FOR GULF MINERAL RESOURCES CO.

FIGURE II-I

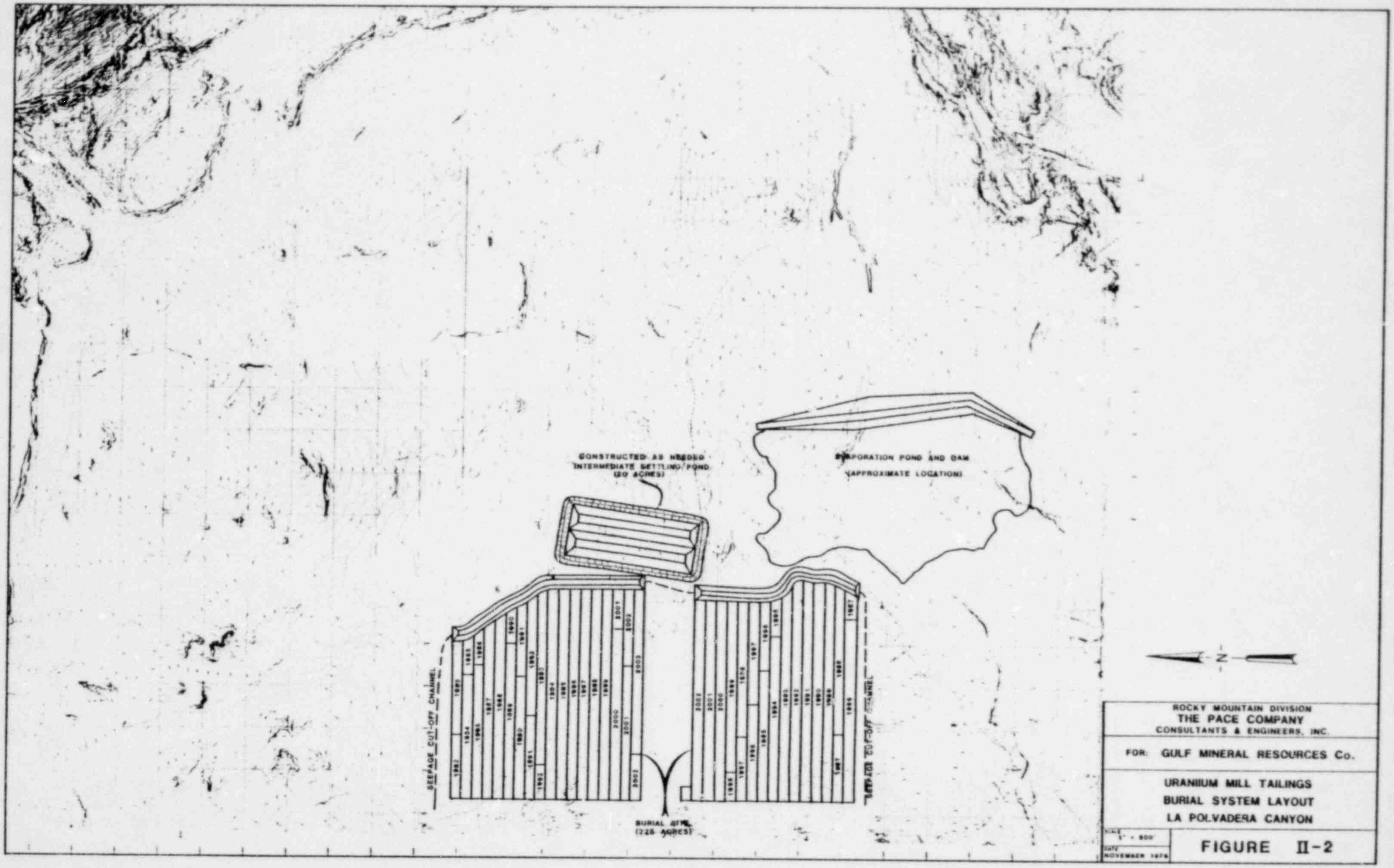

CONSTRUCTED AS NEEDED
INTERMEDIATE SETTLING POND
(20 ACRES)
EVAPORATION POND AND DAM
(APPROXIMATE LOCATION)
SEEPAGE CUT-OFF CHANNEL
BURIAL SITE
(225 ACRES)
N
ROCKY MOUNTAIN DIVISION
THE PACE COMPANY
CONSULTANTS & ENGINEERS, INC.
FOR: GULF MINERAL RESOURCES Co.
URANIIUM MILL TAILINGS
BURIAL SYSTEM LAYOUT
LA POLVADERA CANYON
NOVEMBER 1978

FIGURE II-2

TABLE II-1

PROJECTED LIQUID AND SOLID WASTE PRODUCTION RATES

Year	Mine Ore Production (tons)	Mill Tailings to Burial Trenches (tons-dry weight)	Waste Water		
			to Burial Trenches (ac-ft)	Estimated Retained Tailings Storage plus Net Evaporation Loss in Trenches (ac-ft)	Total to evaporation Pond (ac-ft)
1982	255,000	121,125	154	34	120
1983	391,000	185,725	235	49	186
1984	493,000	234,175	296	60	236
1985	663,000	314,925	401	78	323
1986	867,000	411,825	523	101	422
1987	1,071,000	508,725	646	123	523
1988	1,326,000	629,850	800	150	650
1989	1,496,000	710,600	904	169	735
1990	1,496,000	710,600	904	169	735
1991	1,496,000	710,600	904	169	735
1992	1,496,000	710,600	904	169	735
1993	1,496,000	710,600	904	169	735
1994	1,496,000	710,600	904	169	735
1995	1,496,000	710,600	904	169	735
1996	1,496,000	710,600	904	169	735
1997	1,496,000	710,600	904	169	735
1998	1,496,000	710,600	904	169	735
1999	1,496,000	710,600	904	169	735
2000	1,496,000	710,600	904	169	735
2001	1,496,000	710,600	904	169	735
2002	1,292,000	613,700	780	147	633
2003	709,000	336,775	428	83	345
Totals	26,515,000	12,594,625	16,015	3,022	12,993

TABLE II-2

CHEMICAL COMPOSITION OF RAFFINATE*

Ra^{226} pCi/1	4900 ± 100	Mn	160
Ra^{228} pCi/1	1560 ± 50	Zn	17
Th^{230} pCi/1	720 ± 10	Cu	5
Pb^{210} pCi/1	162 ± 1	Cr	5
		Pb	5
Po^{210} pCi/1	26 ± 1		
Gross - alpha pCi/1	$(9.5 \pm 0.1)10^5$	Mo	35
Gross - beta pCi/1	$(12 \pm 0.1)10^5$	V	240
		U	0.25
TDS mg/1	95,000	Se	26
SO_4	69,900	Hg	0.0002
Al	3,300		
Fe	11,000	Ni	4
Na	1,520	Ba	0.6
		Cd	0.4
K	200	CO	3
Mg	1,570	Ag	0.2
Ca	740		
Cl	1,450	B	0.25
F	14	CN	0.0002
		Phenol	0.001
P	36	pH	1.5
SiO_2	1,280	Specific gr.	1.082
$NH_4(N)$	20		
$NO_3(N)$	4		
As	16		

* All analyses are on a dissolved basis; results are given in mg/1 except as noted.

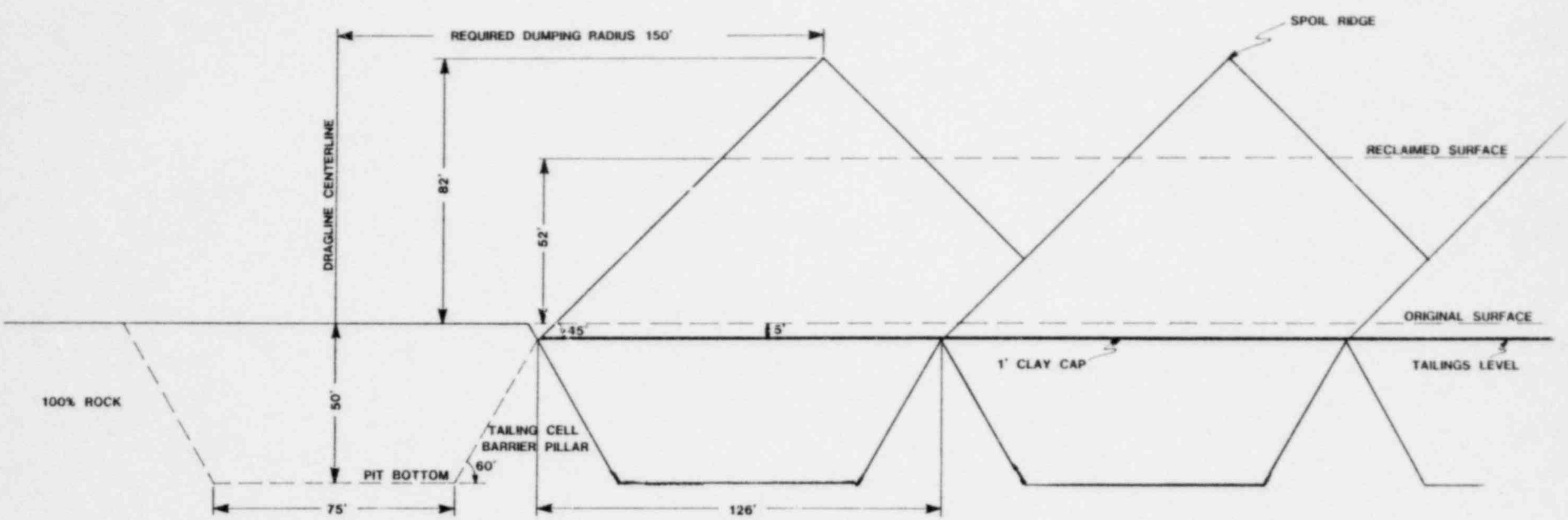
of the burial trenches in La Polvadera Canyon. Later studies showed that the evaporation pond required may encroach on the southeast corner of the trench area and some minor adjustments may be required in the trench system layout during final design.

4. BURIAL TRENCH EXCAVATION

Excavation of the parallel burial trenches will be accomplished with a dragline. The first trench or "box cut" will be excavated to the limits of the project boundary (full length of the trench) and the material (spoil) will be stockpiled beside the cut. As each succeeding parallel cut is made, the spoil is deposited on top of the dewatered tailings that have been placed in the previous cut (trench). The trench will be filled with tailings to a level five feet below existing ground level. Figure II-3 illustrates the trench section, the dragline reach and dumping height requirements, spoil height, tailings level, and final level of the surface after reclamation.

Over the life of the disposal operation, approximately 225 acres of land will be required to dispose of the tailings as shown on Figure II-2. Topographic, hydrologic and geologic criteria were used to select the disposal site in La Polvadera Canyon. The site has small elevation differences between the disposal area boundaries. Natural drainage channels are minor and any surface drainage will be diverted from the trenches with drainage ditches. The trenches will be excavated in the relatively tight Dilco and Mulatto units that are predominantly shales and siltstones. Also, the top of the underlying, more permeable, Gallup Sandstone will be 10 feet or more below any trench bottom. Other sites available in La Polvadera Canyon had excessive drainage problems, extreme elevation differences precluding efficient stripping operations, or unfavorable geologic conditions.

Prior to excavation the overburden rock will have to be blasted for dragline excavation. Assuming mostly shales with soft sandstones, a powder factor of 0.75 lbs/yd^3 ANFO is required to prepare the overburden for excavation with a dragline. Shot holes will not extend to the trench bottom. They will be placed five feet above final grade to prevent fracturing rocks forming the trench bottom. The trench bottom will be shaped with a bulldozer using rippers where necessary.



DRAGLINE RANGE DIAGRAM
BURIAL DEPTH 50'

FIGURE II-3

5. SETTLING POND

A slimes settling pond will be constructed to the east of the burial trench area. Similar dragline excavation will be used except that the excavation will be 30 feet deep, 75 feet wide at the bottom, and have 4:1 side slopes and end slopes. The layout for the settling pond shown on Figure II-2 is the maximum size considered necessary for the life of the project. Initially a settling pond 100 feet long at the bottom will be constructed. This initial pond will accomodate approximately two years of operation assuming that one-third of the slimes remain in suspension and are pumped out of the trenches with the waste water. Additional settling ponds will be constructed as needed based on observations during the first two years of operations.

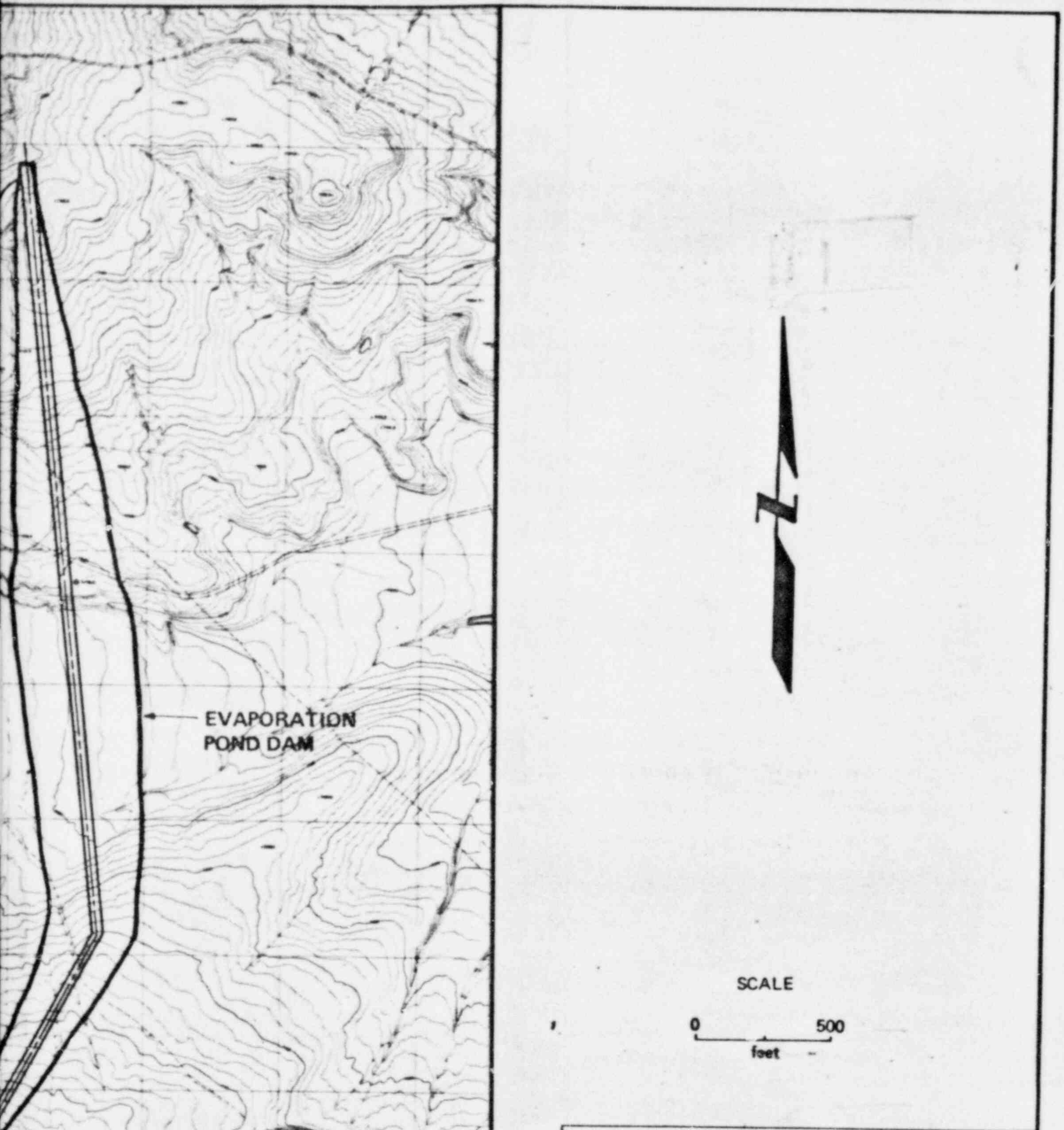
The slime settling pond is basically a backup facility in case some of the slimes remain in suspension in the waste water. The settling pond(s) will result in below-grade disposal of any slimes that escape from deposition in the trenches. Both the bottom and the sides of the settling pond will be lined with a compacted clay layer three feet thick to control seepage. If significant slimes accumulate in the settling pond, a liner may not be needed. Lining requirements will be re-evaluated prior to construction of additional settling ponds, if they are needed.

6. EVAPORATION POND

Waste water from the disposal area will be routed through the settling pond(s), allowed to clarify, decanted and transported to the evaporation pond by pipeline. The evaporation pond will be contained by an impervious core embankment with an initial height of about 40 feet and an ultimate height of about 80 feet. The crest elevation of this dam will be approximately 7145 feet. The embankment will have appropriate internal drains to control phreatic levels and collect seepage for discharge back to the pond. The quantities involved in embankment seepage will be negligible with respect to the overall pond water balance. The dam will be designed to meet all safety requirements for a fluid retention structure.

Figure II-4 shows a general plan of the evaporation pond. This pond is larger than the one shown on Figure II-2 because later studies have indicated the need for increased storage requirements. Figure II-5 shows the area-capacity


PROJECTED
(BASED ON

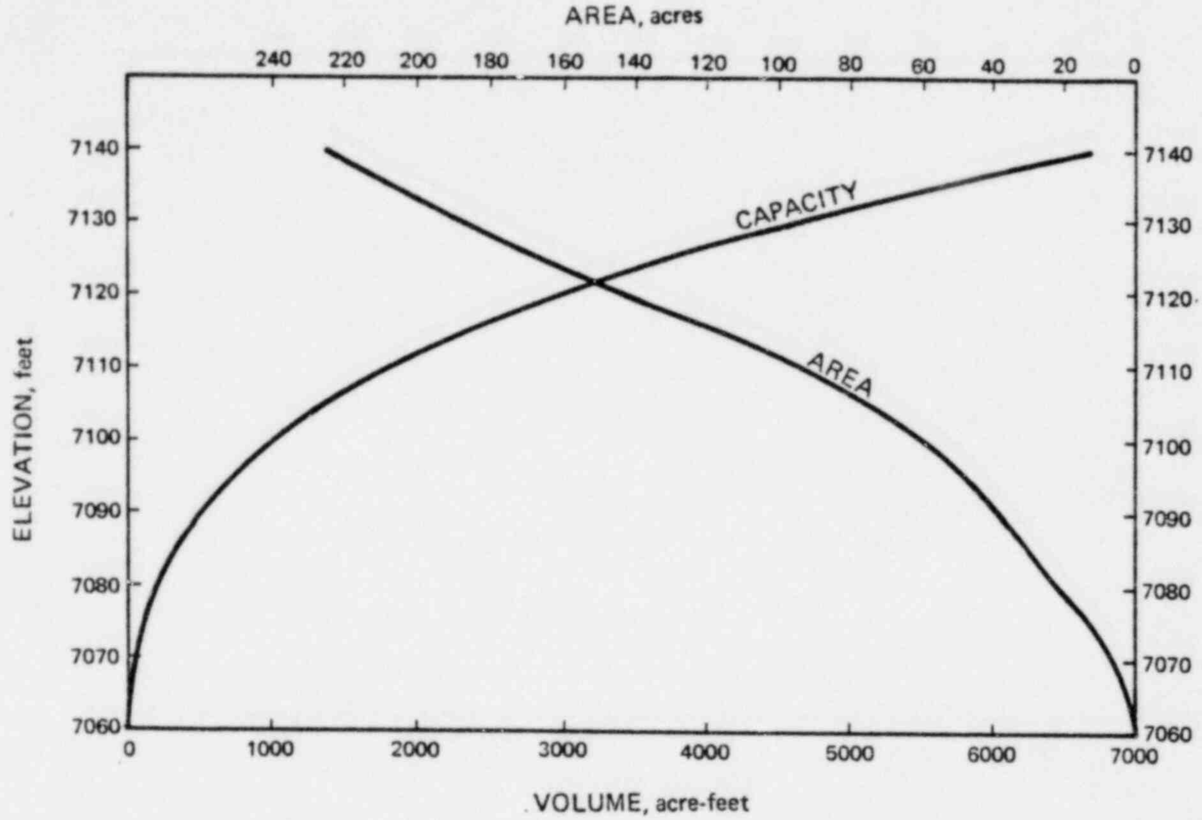


GULF MINERAL RESOURCES CO.
Mt. Taylor Uranium Mill Project

Earth Sciences Associates
Palo Alto, California

PROPOSED EVAPORATION POND

Checked by B.A. Miner	Date 12/14/79	Project No. 2150	Figure No. II-4
Approved by [signature]	Date 12/14/79		



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Mt. Taylor Uranium Mill Project

Earth Sciences Associates
Palo Alto, California

AREA CAPACITY CURVE
LA POLVADERA EVAPORATION POND

Checked by B.L. Tanner	Date 2/14/79	Project No. 2150	Figure No. II-5
Approved by W.K.	Date 2/14/79		

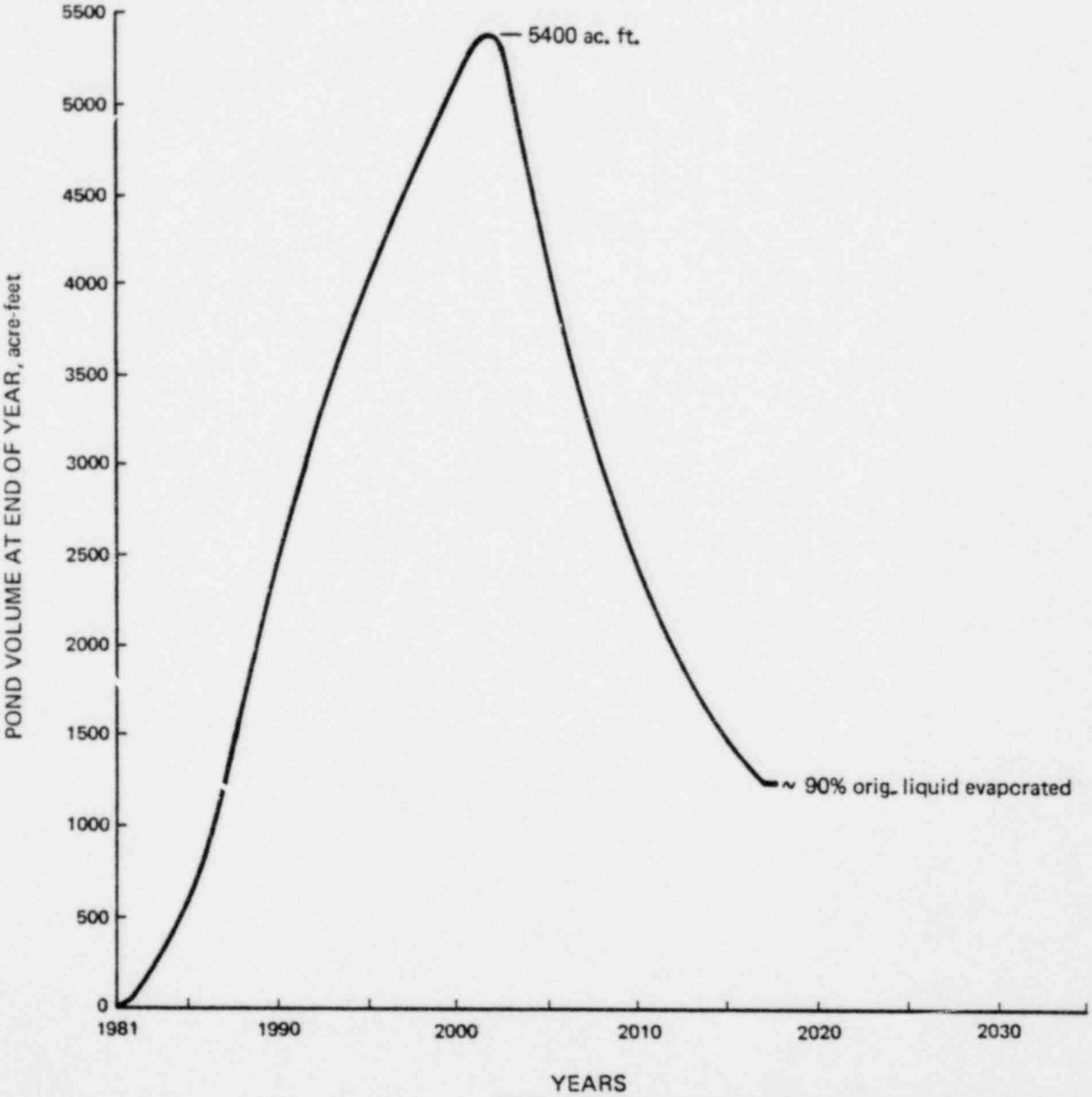
curve for this site with unconsolidated soils removed. The maximum storage capacity will be determined during final design. The projected time-volume filling and recession curve for disposal of liquid wastes is shown on Figure II-6. The maximum projected storage requirement is 5400 acre-feet which will cover a surface area of about 200 acres and have a maximum surface elevation of about 7,135 feet. The time-volume curve and associated surface areas were used for seepage analyses and design criteria for the pond lining system. The freeboard requirements and the size of the dam will be determined during final design studies currently underway.

The entire pond area will be stripped to bedrock and a liner will be placed on this surface, as needed, to control pond seepage. The lining system will consist of a compacted clay liner up to three feet thick over less than 200 acres of pond bottom, and will have a permeability of 5 x 10^{-8} cm/sec (0.05 foot/year). The liner will completely cover that portion of the pond underlain by the Gallup Sandstone and a portion of the area underlain by the Dilco. Field conditions permitting, where the Dilco is exposed, scarification and recompaction of clay shales in the Dilco may be substituted for a borrowed clay liner.

The dam and pond lining will be constructed in appropriate stages using a downstream embankment construction method. Upstream diversion facilities will be provided that will prevent runoff into the pond. This will minimize the amount of water to be evaporated and minimize the interception of natural runoff in the watershed. Suitable clay lining and embankment materials are available in La Polvadera Canyon. Soils stripped from the embankment foundation and pond areas will be used for dam construction, clay lining and/or reclamation.

7. RECLAMATION

Reclamation of the tailings burial area will begin after a trench is filled and covered with spoil. A dozer will be used to flatten the spoil ridges and to grade side slopes. Topsoil previously stripped from the area and stockpiled will be spread over the graded surface. Plowing and revegetation will be done as required by state and federal standards. The reclaimed surface will be protected against erosion with suitable drainage ditches and rock protection. Similar procedures will be used to reclaim the settling pond(s) except that



GULF MINERAL RESOURCES CO.
Mt. Taylor Uranium Mill Project

Earth Sciences Associates
Palo Alto, California

TIME–VOLUME RELATIONS
LA POLVADERA EVAPORATION POND

Checked by B. L. Turner	Date 12/14/79	Project No.	Figure No
Approved by WRH	Date 12/14/79	2150	II-6

the time required for the slimes to consolidate or dessicate will be much longer before they can accept the reclamation cover.

The evaporation pond will be reclaimed in accordance with applicable regulations. A reclamation plan will be formulated during the final design of the evaporation pond. However, present tentative plans are to remove the precipitated salts after fluids have evaporated, with burial of the salts in dragline trenches similar to those used for tailings burial. In this case, the dam would be breached and the surface drainage restored to its natural condition.

Capillarity of residual tailings salts from the entrenched tailings into the clay cap and overburden material should not present a problem to ultimate reclamation and revegetation activities because the amount of overburden placed on top of the deposited tailings is so great that capillarity through the overburden to a level which plant roots would be expected to penetrate is highly unlikely.

B. SITE CONDITIONS

1. PHYSIOGRAPHY

The La Polvadera Canyon area is a broad, rolling, bowl-shaped basin drained by several washes that converge and drain through a series of low hogback ridges into San Lucas Canyon. The western and southern limits of the area are formed by arms of the San Mateo Mesa which has an elevation of over 8,100 feet, and dominates the landscape with its vertical bluffs. The remainder of the canyon area is rimmed by relatively low but prominent hogback ridges that curve from a northeast trend to a westerly trend enclosing the canyon. The crests of the hogbacks range from 7,100 to 7,600 feet in elevation and these ridges are formed by resistant sandstone beds that dip 20 to 30 degrees away from the basin or downstream to the east and to the north.

The interior of the basin has convergent alluvial flats flanked by low rolling hills. The interior hills usually have about 100 feet of relief whereas elevations along dry washes range from about 7,000 feet at the mouth of the canyon to about 7,300 feet near the base of the San Mateo Mesa. The mesa is drained by two principal ephemeral streams from the south and west. A lesser wash drains the northern and lower-lying part of the basin.

The tailings disposal trenches will be located on a southeast-trending ridge which divides the northern part of the basin from the main canyon to the south and west. Slopes on the ridge are relatively flat, typically ranging from 8:1 to 10:1 (horizontal to vertical) and are covered with sparse vegetation including cactus, grasses and shrubs. A settling pond will also be located on the ridge immediately east of the dragline trenches.

Drainage from the tailings will be conveyed to an evaporation pond located in the main east-draining wash of La Polvadera Canyon. This wash is flat-bottomed and slopes gently eastward. The existing channels are not deeply incised, indicating that the present regime is not one of rapid downcutting. Several buried channels were located during field geophysical and subsurface explorations, but even in channels, the alluvium is only 20 to 40 feet in the evaporation pond area.

Adjacent watersheds including San Lucas Canyon are in an advanced state of headward erosion of alluvial deposits. The absence of headward erosion in La Polvadera Canyon is not typical for the region. The reason for this anomoly is probably due to a lack of precipitation. La Polvadera Canyon may be in a small rain shadow created by San Mateo Mesa.

2. CLIMATE AND SURFACE HYDROLOGY

Long-term temperature in the project area is best represented by data collected at San Mateo (Floyd Lee Ranch) during a period from 1962 through 1974. The mean annual temperature for the period of record was 49.2°F. The warmest month was July (average temperature 69.2°F) and the coldest month was January (28.9°F). The warmest temperature recorded during the period was 103°F on June 23, 1962; the coldest temperature recorded was -35°F on January 7, 1971. The site area exhibits a large diurnal range in temperature which is also conductive to night-time inversion formations.

The frost-free season in the area averages approximately 150 days with the last freezing temperatures generally occurring around the middle of May and the first fall freezing temperatures occurring in early October (Tuan, et al., 1973). Variations in the length of the season are large from year to year with freezing temperatures ending as early as late April during some years, and extending into the middle of June during other years. Fall freezing temperatures have occurred as early as mid-September and as late as the end of October.

Relative humidity in the area over the long term is estimated to range from an average 65 percent at sunrise to approximately 30 percent in midafternoon. Afternoon relative humidity on many occasions is less than 15 percent. Normally, there is an influx of moisture in July and August (the thunderstorm season) and then a gradual return to dry conditions during fall. The net evaporation rate for the region is approximately 34 inches per year.

The site is located in an arid to semiarid region; precipitation ranges from approximately 10 to 12 inches per year in the project vicinity to about 20 inches per year near Mt. Taylor (information obtained from the New Mexico State Engineer). It should be noted that the Mt. Taylor region appears to be an "island" of high precipitation. Much of the annual precipitation results from brief thunderstorms of high intensity which often cause flooding and extreme peak discharges. This has resulted in a land surface incised by many pronounced drainage channels in the general area; however, channels in La Polvadera are not incised and often indistinct. Most of the channels are usually dry. Stream discharge records are sparse and often inaccurate and/or misleading. Average annual runoff varies from approximately 0.1 to 5 inches in the region (1967 data from New Mexico State Planning Office). Typically, about 40 percent of the annual rainfall occurs in July and August when the temperatures and evaporation rates are high and soil moisture is low. These factors are largely responsible for the low annual runoff rates.

The nearest gauging stations operated by the U.S. Geological Survey, located approximately 30 miles from the project area, are on the Rio Puerco above Arroyo Chico near Guadalupe, New Mexico and on Rio San Jose at Grants Canyon at Grants, New Mexico. These stations measure runoff from terrain that in general is relatively flat. Data for these stations over their periods of record show an average annual runoff of less than 0.1 inch per year for the Rio San Jose to about 0.5 inch per year for the Rio Puerco (U.S. Geological Survey, 1976). Data collected by New Mexico Environmental Institute in 1974 indicate that for San Mateo Creek, a perennial stream, the average annual runoff is on the order of five inches per year. Colorado Canyon, an ephemeral stream, has an estimated runoff of 2.5 inches per year. The data cited above illustrate that runoff from the steeper terrain and higher elevations of the Mt. Taylor area is greater than that from the lower elevations.

3. GEOLOGIC SETTING

The Mt. Taylor project site lies in the eastern part of the Colorado Plateau geologic province near the southern boundary of the San Juan Basin. It is about 35 miles west of the San Ignacio faulted monocline that forms the boundary between the Colorado Plateau and the Rio Grande Depression.

The San Juan Basin sediments were gently folded in Jurassic time (about 155 million years before the present) and tilted very gently northwestward, in the region of the Mt. Taylor site, at an angle of two to five degrees toward the center of the basin. This tectonic activity subsided during Cretaceous time, but in early Tertiary time (50 to 60 million years ago), tectonic activity began again. This activity resulted in the formation of the present general configuration of the San Juan Basin. In late Tertiary time (10 to 20 million years ago) a regional east-west crustal extension resulted in the formation of the Rio Grande Depression and also created major folding that was accompanied by northeast-trending normal faulting east and northeast of the project area. During this same period there was considerable volcanic activity centered in the Mt. Taylor volcanic field east of the project area.

La Polvadera Canyon is at the northeast end of the San Mateo Dome, which is near the border of the Chaco Slope and the Acoma Sag elements of the San Juan Basin (Cooper and John, 1968). The San Mateo Dome trends northeasterly and the northeast flank of the dome coincides with the west side of the Mt. Taylor syncline. Contours drawn on the base of the Dakota Sandstone show that the San Mateo Dome retains its general structure at depths of 1,600 to 2,000 feet (Santos, 1966). The flanks of the dome are complexly faulted, resulting from localized adjustments during development of the dome structure. Geologic mapping of the area suggests vertical displacements of up to 200 feet and perhaps larger lateral displacements along some faults. However, correlation of geophysical logs of deep test holes throughout the area and extending north of the canyon area do not indicate major vertical displacements. Displacement along faults may be much less than surface mapping suggests. None of the faults cross tailings disposal or evaporation pond sites. Two possible faults mapped by Santos were shown to occur in the tailings disposal area. However, detailed surface and subsurface exploration work indicate these projected or possible faults do not exist.

The faults are considered to be inactive and are associated with crustal deformation during the Late Tertiary period. These faults represent relatively minor local adjustments associated with the development of the San Mateo Dome and would not be expected to produce a major seismic event even in a highly active seismic zone.

La Polvadera Canyon is located in a region of low seismic activity. There is no evidence that suggests recent seismic activity in the project area; neither instrumentally recorded data nor field evidence indicates recent fault movement. However, the area may have experienced seismic effects as great as intensity VI (Modified Mercalli Scale) resulting from earthquakes centered along the Rio Grande rift zone to the east. Using the formula $\log a = I/3 - 1/2$ presented by Richter (1958), a seismic coefficient of 0.07 g was computed for an intensity VI earthquake. For design purposes, a seismic factor of 0.10 g was selected for use in the pseudostatic stability analysis of the evaporation pond embankment. This seismic factor is very conservative and would require an earthquake with a maximum intensity that is much higher than can be reasonably expected.

The geology of the La Polvadera Canyon area is illustrated on Figure II-7 which shows the distribution of geologic units and major structural features; Table II-3 lists the bedrock units exposed or underlying the area. Rocks which crop out in the main part of La Polvadera Canyon are horizontal to gently dipping and include the Mulatto Tongue Member of the Mancos Shale, the Dilco Coal Member of the Crevasse Canyon Formation, and the Gallup Sandstone, all of Cretaceous age. In the more steeply dipping hogbacks bordering the east side of La Polvadera Canyon, the Dalton Sandstone and Gibson Coal Members of the Crevasse Canyon Formation, as well as the Satan Tongue Member of the Mancos Shale, are well exposed.

As shown in Figure II-2, the dragline trenches will be located in an upland area underlain mainly by the Mulatto Tongue and Dilco Coal units, with little or no alluvium. Trenches have been located and designed to avoid excavation into the underlying Gallup Sandstone. The evaporation pond will be located

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TABLE II-3

STRATIGRAPHY - BEDROCK UNITS IN LA POLVADERA CANYON PROJECT AREA

Geologic Formation	Description
Menefee Formation (Kmf)	Yellow-brown siltstone and sandstone with interbedded gray sandstone, complete section not exposed.
Upper Part of Point Lookout Sandstone (Kpu)	Gray and red-brown sandstone, 60 to 80 feet thick.
Satan Tongue of Mancos Shale (Kms)	Yellow-brown sandstone and siltstone with dark gray shale, 0 to 140 feet thick, occurs only along northeastern rim of La Polvadera Canyon.
Hosta Tongue of Point Lookout Sandstone (Kph)	Gray and red-brown sandstone, 100 to 140 feet thick.
Gibson Coal Member of Crevasse Canyon Formation (Kcg)	Interbedded sandstone, siltstone, shale, and coal beds, 190 to 300 feet thick.
Dalton Sandstone Member of Crevasse Canyon Formation (Kcda)	Light gray sandstone, 60 to 120 feet thick.
Mulatto Tongue Member of Mancos Shale (Kmm)	Yellow-brown shale, dark gray shale, and massive yellow-brown sandstone, 350 to 400 feet thick.
Dilco Coal Member of Crevasse Canyon Formation (Kcdi)	Interbedded sandstone, siltstone, shale, and coal beds, 100 to 150 feet thick.
Gallup Sandstone (Kg)	Buff to light gray, massive cross-bedded sandstone, 80 to 120 feet thick.
Main Body of Mancos Shale (Km)	Medium to dark gray shales with some siltstone and minor sandstone, about 1,000 feet thick.
Los Tres Hermanos Member	Generally believed to be absent in the project area but could be present in the form of thin sandstone layers.
Dakota Sandstone (Kd)	Light colored fine to medium grained quartzose sandstone and dark gray to black carbonacous shales, 100 to 170 feet thick.
Morrison Formation (Jm)	Variegated shales, claystones and discontinuous interbedded sandstones, about 200 to 600 feet thick.

Source: Modified from Santos, 1966 and Cooper and John, 1968 in the main east draining wash of La Polvadera Canyon, where it will be underlain by alluvium over Gallup Sandstone in the central part of the pond, and by the Dilco Coal unit in the higher elevations. Because of the importance of these foundation rocks in analyzing seepage potential, they are described briefly below in order of age, from youngest to oldest.

Mulatto Tongue Member of the Mancos Shale (Kmm) - The Mulatto Tongue Member is the youngest bedrock unit in the La Polvadera Canyon area, where it occurs in conformable contact over, and in fault contact with, the Dilco Coal Member of the Crevasse Canyon Formation. The Mulatto Tongue crops out in the upper reaches of the main canyon and tributary washes. Approximately 3/4 mile west of the canyon mouth, the Mulatto is down-dropped against the Dilco along a north-south trending fault. The Mulatto is also cut by an east-west trending fault located about 1-1/4 miles north of the main canyon. The Mulatto Tongue unit consists of up to 100 feet of thinly-bedded, light tan, sandy shale and silstone with a few thin beds of sandstone and dark gray shale. Gypsum occurs as infilling of fracture and bedding planes.

Dilco Coal Member of Crevasse Canyon Formation (Kcdi) - The Dilco Coal Member underlies the Mulatto Tongue Member of the Mancos Shale. The Dilco Member comprises the major bedrock type in the project area and forms the broad ridges in the central portion of La Polvadera Canyon, where it is about 120 feet thick in full section and consists of interbedded, white to brown sandstone, brown to light gray siltstone, and gray to black and purple shale beds, with minor, thin coal lenses. The sandstone is fine-to medium-grained and poorly cemented, and contains carbonaceous partings and some iron-oxide stain. The majority of the sandstone beds range from six inches to five feet in thickness, although one massive sandstone bed in the upper part of the Dilco stratigraphic section attains a maximum aggregate thickness of 15 feet. The siltstone shows variegated colors from tan to yellow to gray and purple, with iron staining, and exhibits wavy bedding. The shale is gray to black, carbonaceous, fissile to flaky, and air-slakes readily. Most of the shale is found in the lower half of the stratigraphic section.

Gallup Sandstone (Kg) - The Gallup Sandstone underlies the Dilco Coal Member and for the most part occurs in the subsurface. In parts of the main washes it is present directly beneath alluvium where the Dilco Coal member has been eroded. The only outcrop occurrence is in the area of Michael Tank, just over a mile northwest of the canyon mouth. As indicated by drilling, the Gallup Sandstone attains thickness ranging from 78 to 90 feet in the La Polvadera Canyon area, where it consists of a massive, crossbedded, white, light yellow to light gray, fine- to medium-grained, poorly cemented and friable sandstone. It contains a few inclusions and thin streaks of carbonaceous material. Joints, steeply dipping to vertical and spaced from two to 10 feet, were observed in outcrops. However, cores from drill holes revealed very few joints or fractures.

Main Body of the Mancos Shale (Km) - Although the main body of the Mancos Shale is not exposed in the canyon area, it is an important unit for seepage considerations forming a thick, relatively impervious stratum beneath the Gallup Sandstone. The upper part of the main body of the Mancos Shale is of Late Cretaceous age and is a thick lithologic unit composed predominantly of dark gray, calcareous, fissile clay shale of marine origin. In La Polvadera Canyon, the Mancos Shale is about 1000 feet thick, as indicated by geophysical logs of more than a dozen deep exploration holes. It is not exposed in the project area, but the upper 15 to 40 feet were penetrated by deep exploratory borings, which showed it to consist of interbedded, thin-bedded, tight, dark gray shale and siltstone with carbonaceous partings.

Unconsolidated Deposits - Surficial deposits in the La Polvadera Canyon area consist of alluvial and eolian deposits, talus and slopewash deposits, and residual soil deposits (saprolite). Extensive talus deposits have formed along the base of cliffs around the rim of San Mateo Mesa, and these consist of yellowish-brown to gray silt, sand, and gravel with numerous sandstone and siltstone blocks. Thin residual deposits of weathered bedrock in the canyon were mapped as saprolite by the USGS (Santos, 1966), and consist of siltstone and shale bedrock that has weathered in place to a plastic clay. Nearly all bedrock exposures are covered with residual soils up to four feet thick which are not shown separately on the geologic map.

Soil cover in the stream valleys consists of fine-grained alluvium and eolian materials with no well-defined contact between them. These soil deposits consist of moderate brown to moderate yellow-brown, sandy clay to silty sand, and occur as alternating layers. At depth and near the bedrock contact the material is generally coarser and consists of clayey, gravelly sand with varying amounts of fines. Soils are generally loose to moderately dense near the surface but gradually become stiffer and denser at depth and near the bedrock contact. The shallower low density soils tend to be collapsible. Average thickness of unconsolidated materials ranges from more than 60 feet at the canyon mouth to 20 feet in the center of smaller tributary washes. In narrow buried channels, alluvium may be more than 90 feet thick.

As noted above, the tailings disposal trenches will be located along a southeast trending ridge where alluvium and soil cover are thin or absent. In the evaporation pond area, the depth of alluvium was determined by drilling exploratory borings and seismic refraction surveys in the reservoir area and along the proposed dam axis. These studies showed that the average thickness of alluvium beneath the evaporation pond is about 20 feet. In buried channels, depth to bedrock is about 30 to 40 feet. Deep narrow bedrock channels were not found under the alluvium of the pond area during the field investigations, although they are known to be present both downstream of the proposed dam in the smaller drainage to the north.

4. EXISTING GROUNDWATER CONDITIONS

Data derived from engineering holes drilled within La Polvadera Canyon indicates that there is no groundwater present beneath the proposed location of the tailings disposal facilities or evaporation pond to a depth of at least 550 feet below the surface (at elevation 6510). Test work has shown that the alluvial deposits in the canyon are unsaturated with the possible exception of some minor perched zones beneath ephemeral stream channels (none were detected). Test holes drilled into the Mulatto Tongue, Dilco Coal Member, and the Gallup Sandstone, showed these rocks to be very dry; most samples were well below field moisture capacity.

Historical data on groundwater conditions in La Polvadera Canyon or in the immediate vicinity is limited. However, the geologic map of the San Lucas Canyon Quadrangle published by the USGS (Santos, 1966) permits extrapolation to the site from other areas where the same stratigraphic units occur. Well information for the area is very scarce and must be considered of questionable reliability.

The Polvadera Well is located in the canyon at elevation 7180 feet, southwest of the proposed tailings disposal area. It was originally drilled as an oil and gas test hole more than 6000 feet deep. The well was plugged back to an indeterminant depth and converted to a water well. It is used to water stock and has a reported yield of one to two gallons per minute. According to Cooper and John (1968), this well taps thin sandstone beds in the Mancos Shale. These beds may represent the Los Tres Hermanos members that occur in the lower part of the Mancos Shale in other areas. The pump in the Polvadera Well was pulled, the water level was measured and the well was sounded in March 1979. The well was blocked at a depth of 830 feet and the water level was 670 feet below ground surface. There are two other stock wells just outside of La Polvadera Canyon, one to the northwest (SW 1/4, Section 4, T14N, R8W) and the other to the northeast about a mile north of Laguna Polvadera. The well to the northwest reportedly produces from the Dalton Sandstone (Cooper and John, 1968) and the Laguna Polvadera well to the northeast probably produces from the Point Lookout Sandstone.

The principal aquifers beneath the canyon area are the Dakota Sandstone and sandstone members of the underlying Morrison formation. The top of the Dakota Sandstone occurs at a minimum depth of approximately 1000 feet beneath the surface. It is separated from overlying alluvium and sandstone units by more than 900 feet of the Mancos Shale, which acts as an aquiclude but does have several thin sandstone beds near its base that are saturated. Along the flanks of the San Mateo Dome, the Gallup, Dalton, and Point Lookout sandstones plunge beneath the surface to depths where they are saturated and probably act as low permeability aquifers outside the canyon area to the north and east.

Geologic structure is judged to control groundwater movement. The sandstone units are interbedded with shales which severely limit interconnection across bedding planes, especially beneath the main part of La Polvadera Canyon where beds are relatively flat-lying near the crest of the dome. Faults in the area generally should act as barriers to groundwater movement along sandstone beds because of offset of the beds and relatively impervious clay gouge in the fault zone. Fracturing of the near surface rocks adjacent to fault zones may permit limited vertical seepage adjacent to these zones in some cases. However, it is questionable whether this fracturing would persist through a thick, relatively plastic shale unit such as the Mancos Shale. At San Mateo to the south, piezometric levels decrease remarkably with depth which suggests very little hydraulic connection across confining shale beds.

There is no evidence of any groundwater recharge within La Polvadera Canyon except perhaps near its mouth. The dry nature of the alluvial soils, which are as much as 90 feet deep, suggests that there is not enough precipitation in excess of evapotranspiration even to develop a sizable perched water table, much less to penetrate to the saturated zone. However, fractured sandstones forming hogback ridges are exposed along the flanks of the dome, and there could be some recharge by direct penetration of precipitation in these outcrop areas. Any recharge in these areas would be to the Point Lookout and Dalton sandstones.

Because recharge is very limited, groundwater gradients are expected to be very gentle or almost flat. Direction of flow is unknown, but based on topography, it is assumed that gradients slope northeastward along San Lucas Canyon and its tributaries. This conforms with regional gradients for the region (Cooper and John, 1968).

Historic water quality information from the three existing wells in the area is very limited. These three wells were sampled during the March-July period of 1979 and the results of chemical analyses are shown on Table II-4. Water from the Polvadera Well is assumed to represent water from a saturated sandstone zone in the lower Mancos Shale and possibly the Dakota Sandstone. The Polvadera Well analysis indicates a sodium chloride-sulfate type water with concentrations of TDS at 2300 mg/l and chloride at 800 mg/l, both of which far exceed drinking water standards. It is unlikely that this water could, or would be used for anything other than limited stock watering in the foreseeable future.

The Laguna Polvadera Well, located outside the canyon area to the northeast, has the best quality water in the area. The quality of this water probably is representative of water from the Point Lookout Sandstone. The analysis on Table II-4 indicates this water meets New Mexico drinking water and irrigation water standards, except for iron. An earlier analysis dated December, 1977, indicates very little, or no changes in constituent concentrations.

The Section 4 Well (T14N, R8W) to the northwest reportedly produces from the Dalton Sandstone (Cooper and John, 1968). The analysis shown on Table II-4 indicates this groundwater is of poorer quality than the water from the Polvadera Well. The total dissolved solids are 2800 mg/l with 1900 mg/l sulfate which preclude its use for drinking water.

There are no wells in the vicinity of La Polvadera Canyon that tap the saturated portion of the Gallup Sandstone. Piezometric levels are unknown, but for purposes of this report, a level of 6700 feet has been assumed. This assumed elevation may be 100 feet or more too high because recent water level measurements in the Polvadera Well indicate a water level elevation of 6510 feet, or nearly 200 feet lower. Water levels are expected to be lower near the base of the Mancos Shale than in the saturated Gallup Sandstone, but probably not 190 feet lower.

The quality of water in the saturated Gallup Sandstone is probably similar to that found in the Polvadera and Section 4 Wells which produce from units that occur below and above the Gallup unit. Interpretation of electrical resistivity logs of test holes north and east of La Polvadera Canyon suggests that the Gallup unit contains water with 3000 to 5000 mg/l total dissolved solids. This agrees reasonably well with data from West Largo where the Lower Gallup contains water with 2900 mg/l total dissolved solids. It can reasonably be concluded that the Gallup Sandstone contains poor quality water where saturated that could only be used for limited stock watering.

TABLE II-4

WATER QUALITY DATA
WELLS IN THE LA POLVADERA CANYON AREA

Parameters	Polvadera Well	Laguna Well	Section 4 Well
pH	8.4	7.1	7.8
Total Dissolved Solids	2300	850	2800
Alkalinity (as $CaCO_3$)	422	260	130
Aluminum	0.43	<0.1	0.19
Arsenic	<0.07	<0.01	<0.01
Barium	<0.1	0.06	<0.03
Boron	<0.4	<0.20	3.0
Calcium	8.9	130	160
Chloride	800	6.7	35
Chromium	<0.02	<0.01	<0.01
Cobalt	<0.02	<0.02	<0.02
Copper	<0.02	<0.01	<0.02
Cyanide	<0.01	0.018	<0.010
Fluoride	2.0	0.79	1.5
Iron	8.8	2.4	2.1
Lead	0.03	<0.05	0.053
Magnesium	12	41	55
Manganese	0.06	<0.10	0.15
Mercury	<0.001	<0.001	0.0016
Molybdenum	<0.06	<0.05	<0.07
Nickel	<0.05	<0.01	<0.06
Nitrate (as N)	0.54	<0.1	0.66
Potassium	4.9	3.0	7.5
Phenols	0.14	<0.08	<0.08
Selenium	<0.02	<0.01	<0.005
Silica	0.86	7.3	3.85
Silver	<0.02	<0.02	0.046
Sodium	920	64	840
Sulfate	500	400	1900
Vanadium	<0.1	<0.1	<0.1
Zinc	1.0	1.1	2.0
Gross Beta	13 ± 6	10 ± 2	19 ± 5
Gross Alpha	<10	<3	<9
Radium 226	< 0.08	0.06 ± 0.02	1.35 ± 0.07
Radium 228	< 1	2 ± 1	<1

Analyses by LFE Environmental Laboratories, Richmond, California March-July 1979.

NOTE: All analyses on a dissolved basis, except as noted, and concentrations in mg/l, except radionuclide values which are in pCi/l $\pm\sigma$.

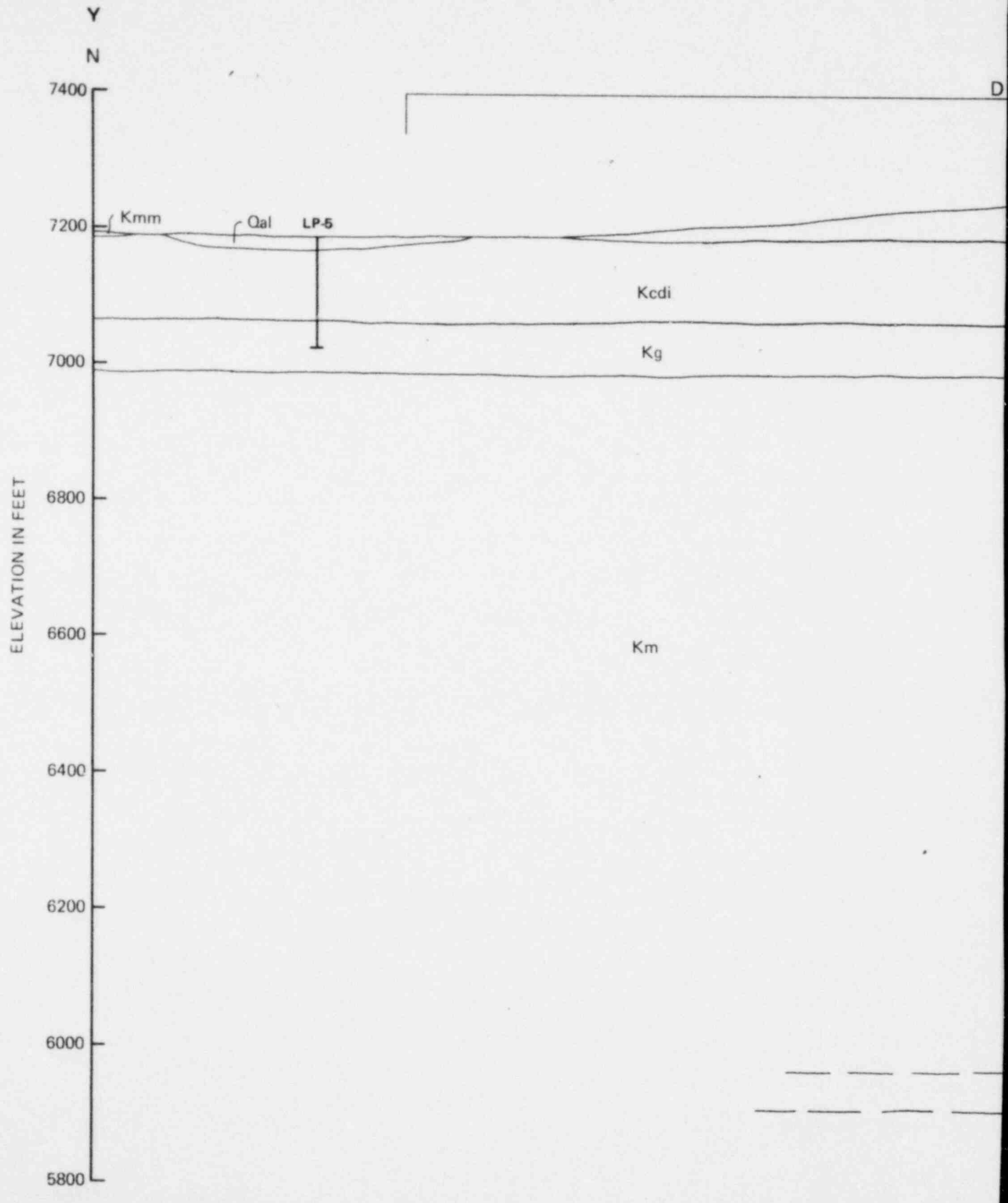
C. SEEPAGE ANALYSES

1. GEOLOGIC CONTROL OF SEEPAGE

The primary control of seepage from the tailings disposal trenches, settling pond, and evaporation pond will be the geometry and hydraulic characteristics of the underlying geologic units. The proposed facilities are situated approximately on the crest of San Mateo Dome, where exploratory borings show the bedrock to be unsaturated to depths of several hundred feet (670 feet at the Polvadera Well). Dip of the bedding in this area is near horizontal, ranging up to six degrees and more along local features such as drag folds. The disposal facilities were located on the crest of the dome, to retard seepage by limiting the available flow paths to across bedding planes or by forcing seepage to take a longer flow path along bedding planes before it has a chance to reach down-dip saturated zones.

Longitudinal and transverse geologic cross sections of the dragline trench disposal and settling pond area are shown in Figures II-8 and II-9. (Cross section locations are shown on the geologic map, Figure II-7). These cross sections were constructed from exploratory borings, deep oil and gas holes, and seismic refraction profiles, and they show the nearly horizontal orientation of the rock units underlying the disposal trenches. Because the trenches will follow the ridgeline, horizontal seepage can be effectively intercepted by means of perimeter seepage drains. As shown on cross sections Y-Y' and Z-Z', the disposal trenches and settling pond have been located so that the Gallup Sandstone will not be penetrated by the proposed excavations (50 feet in trenches; 30 feet in settling pond). Tailings will be discharged into the trenches at one end, resulting in a sand beach and causing deposition of slimes along the trench bottom. Free water will be collected by a decant line and pumped to the settling pond. The low permeability of the Dilco-Mulatto unit underlying the disposal trenches will reduce seepage potential during placement and consolidation of the tailings.

In effect, the Dilco-Mulatto unit will act as a multilayer lining of variable thickness because of the numerous beds of shale and siltstone, which will



Y
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7200
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6400
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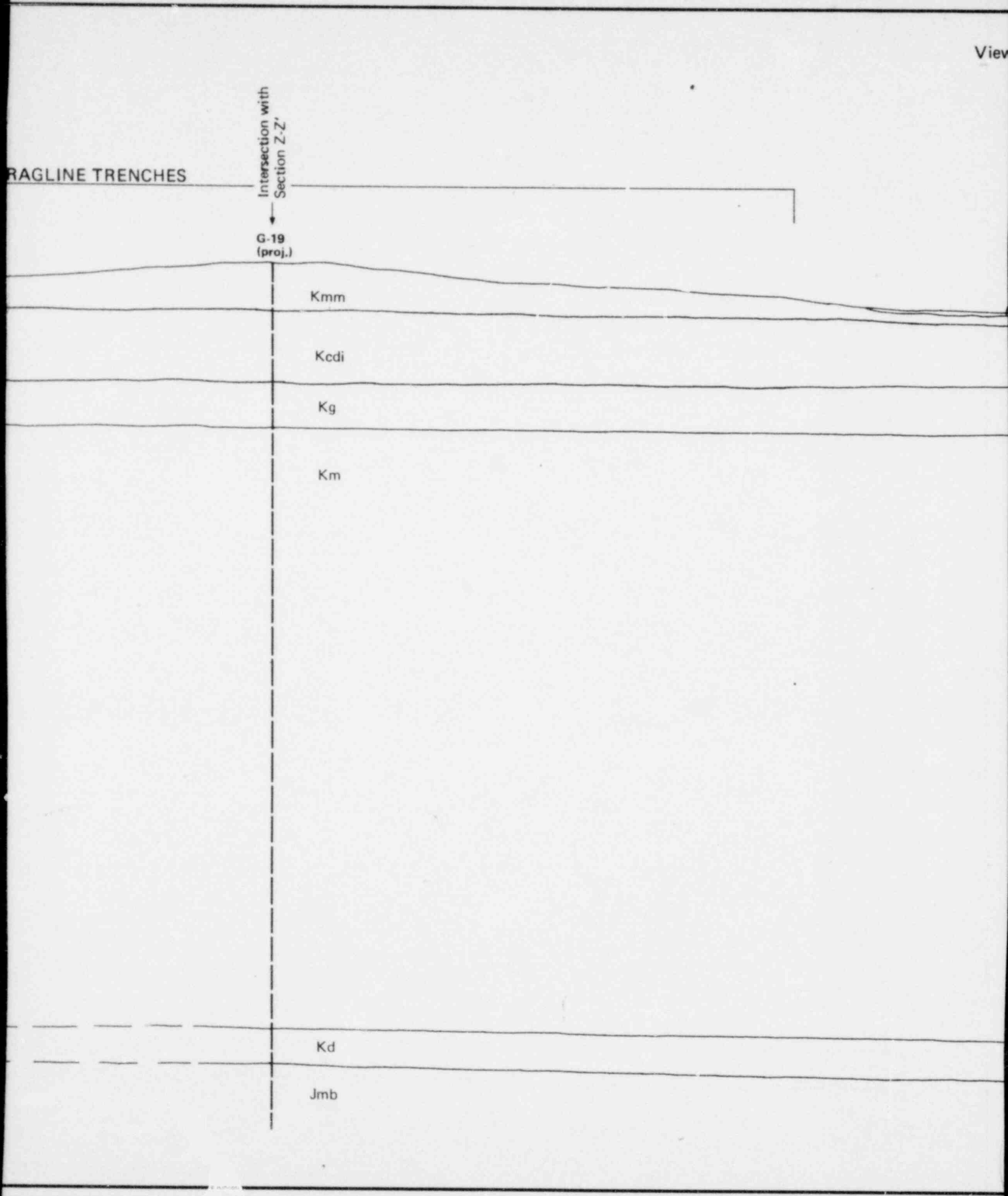
5800
ELEVATION IN FEET
Kmm
Qal
LP-5
Kcdi
Kg
Km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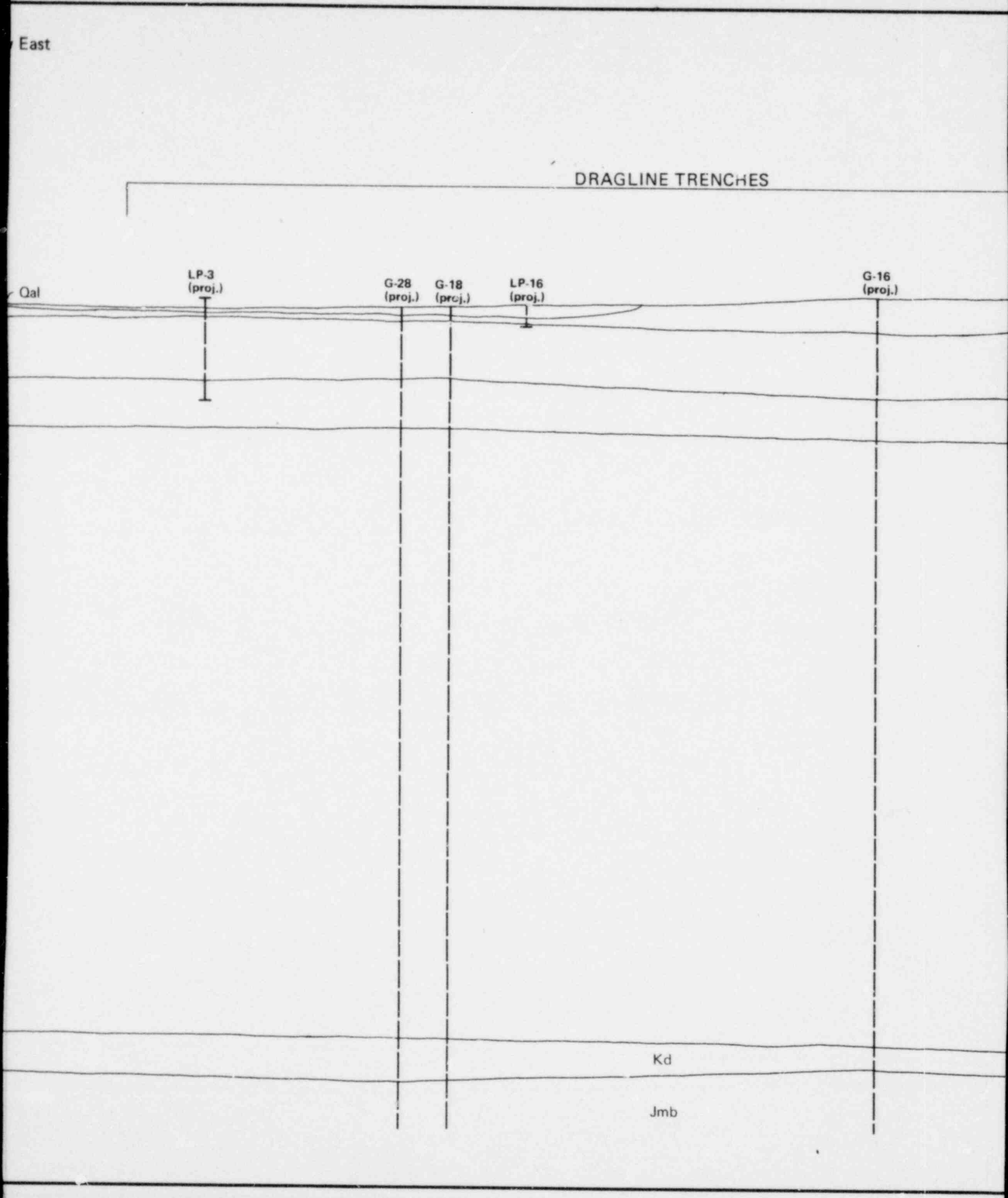
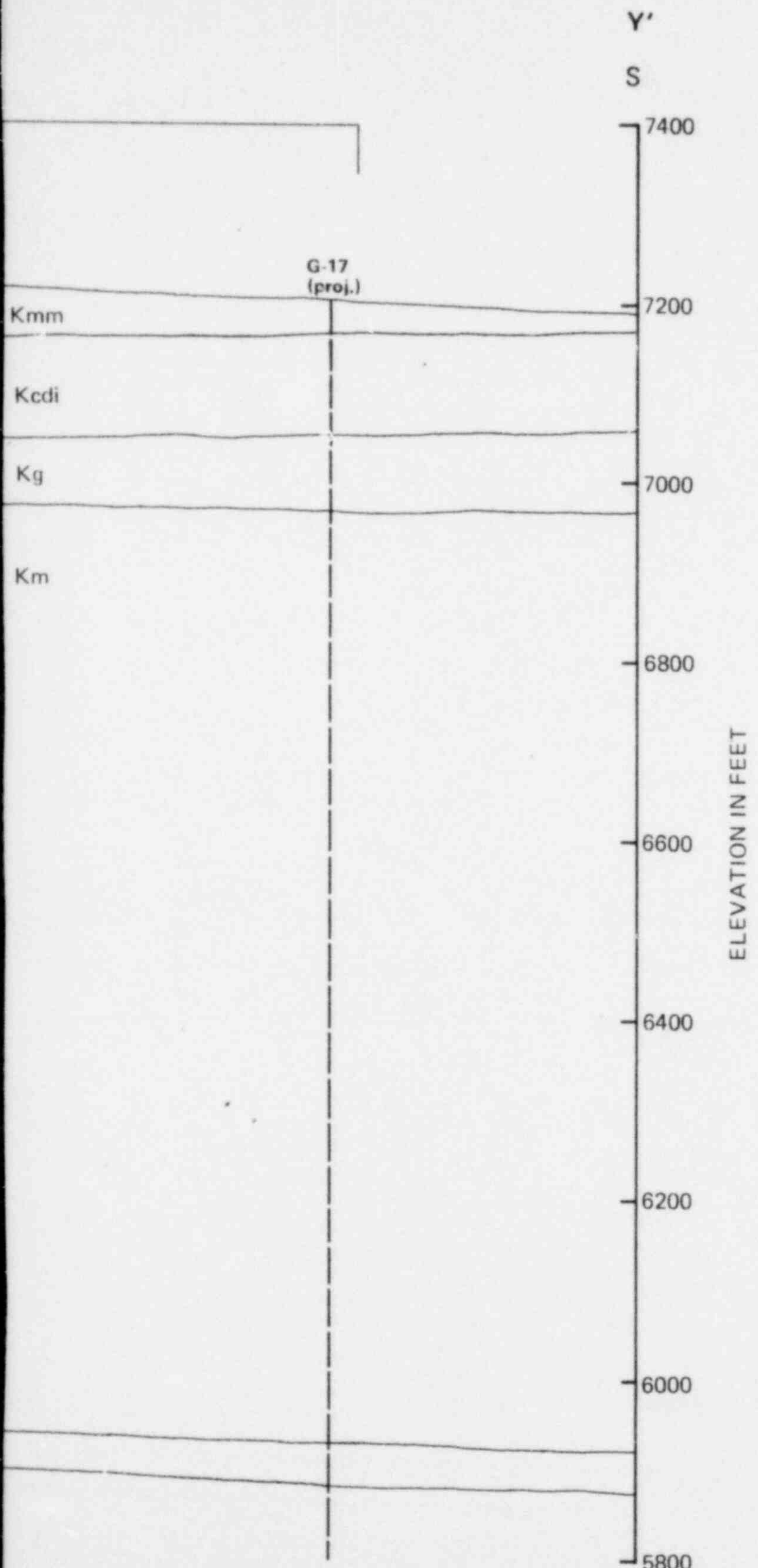
RAGLINE TRENCHES
Intersection with Section Z-Z'
G-19 (proj.)
Kmm
Kcdi
Kg
Km
Kd
Jmb


East
DRAGLINE TRENCHES
Qal
LP-3 (proj.)
G-28 (proj.)
G-18 (proj.)
LP-16 (proj.)
G-16 (proj.)
Kd
Jmb



EXPLANATION

Quaternary	
Qal	Alluvium
Cretaceous	
Kmm	Mulatto Tongue Member of Mancos Shale
Kcdi	Dilco Coal Member of the Crevasse Canyon Fm.
Kg	Gallup Sandstone
Km	Main Body of the Mancos Shale
Kd	Dakota Sandstone
Jurassic	
Jmb	Brushy Basin Member of the Morrison Fm.
G-18	Gulf Oil deep well
WPL-20	1977 Exploration auger and core hole
WB-15	1977 Borrow exploration auger hole
LP-4	1979 Exploration boring
— —	Geologic contact, dashed where boring control is poor

SCALE: HORIZONTAL=VERTICAL

0 200

feet

GULF MINERAL RESOURCES CO.

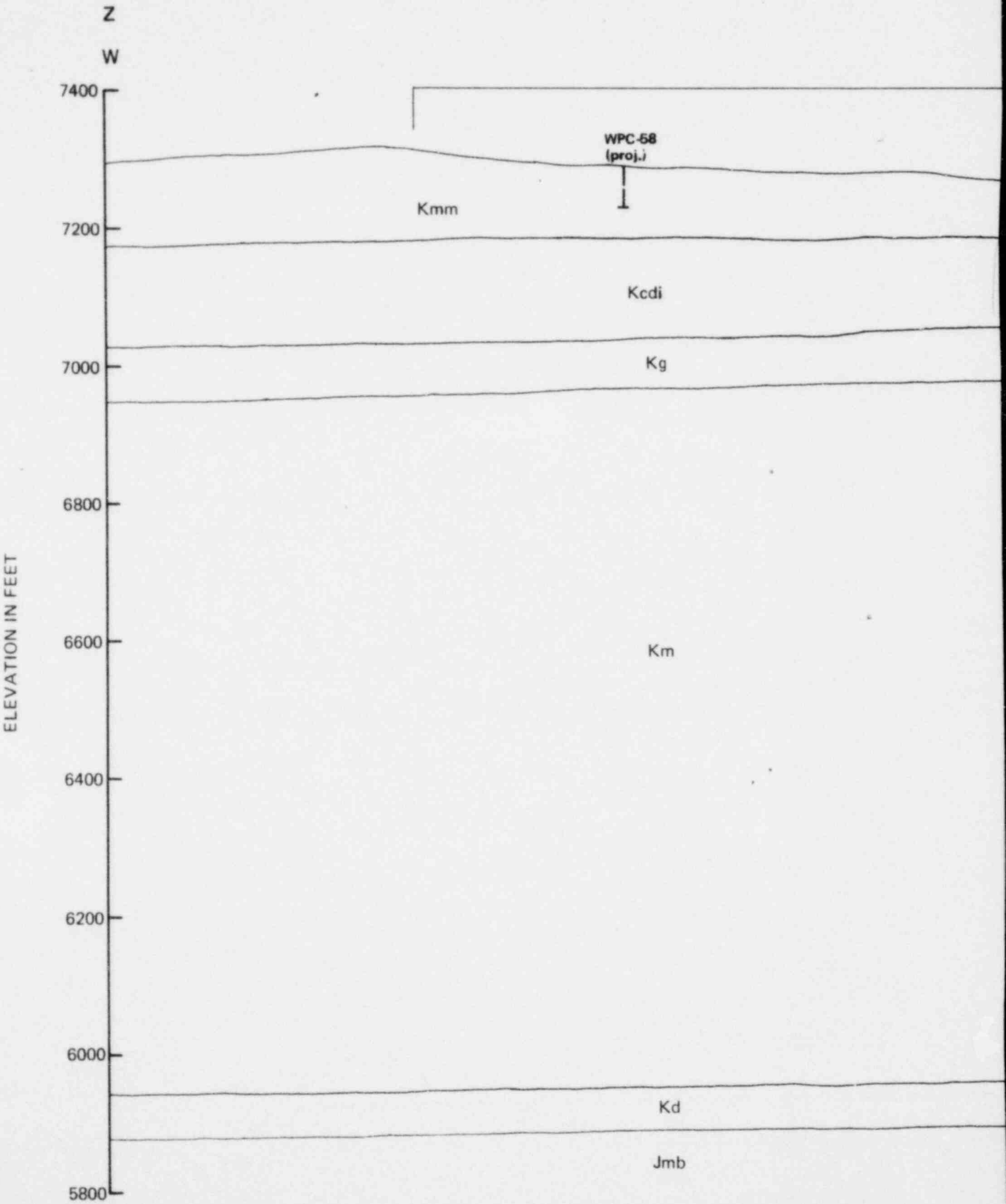
Mt. Taylor Uranium Mill Project

Earth Sciences Associates

Palo Alto, California

GEOLOGIC CROSS SECTION Y-Y'

Checked by	Date 12/14/79	Project No.	Figure No.
Approved by	Date 12/14/79	2150	II-8



Z
W
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ELEVATION IN FEET
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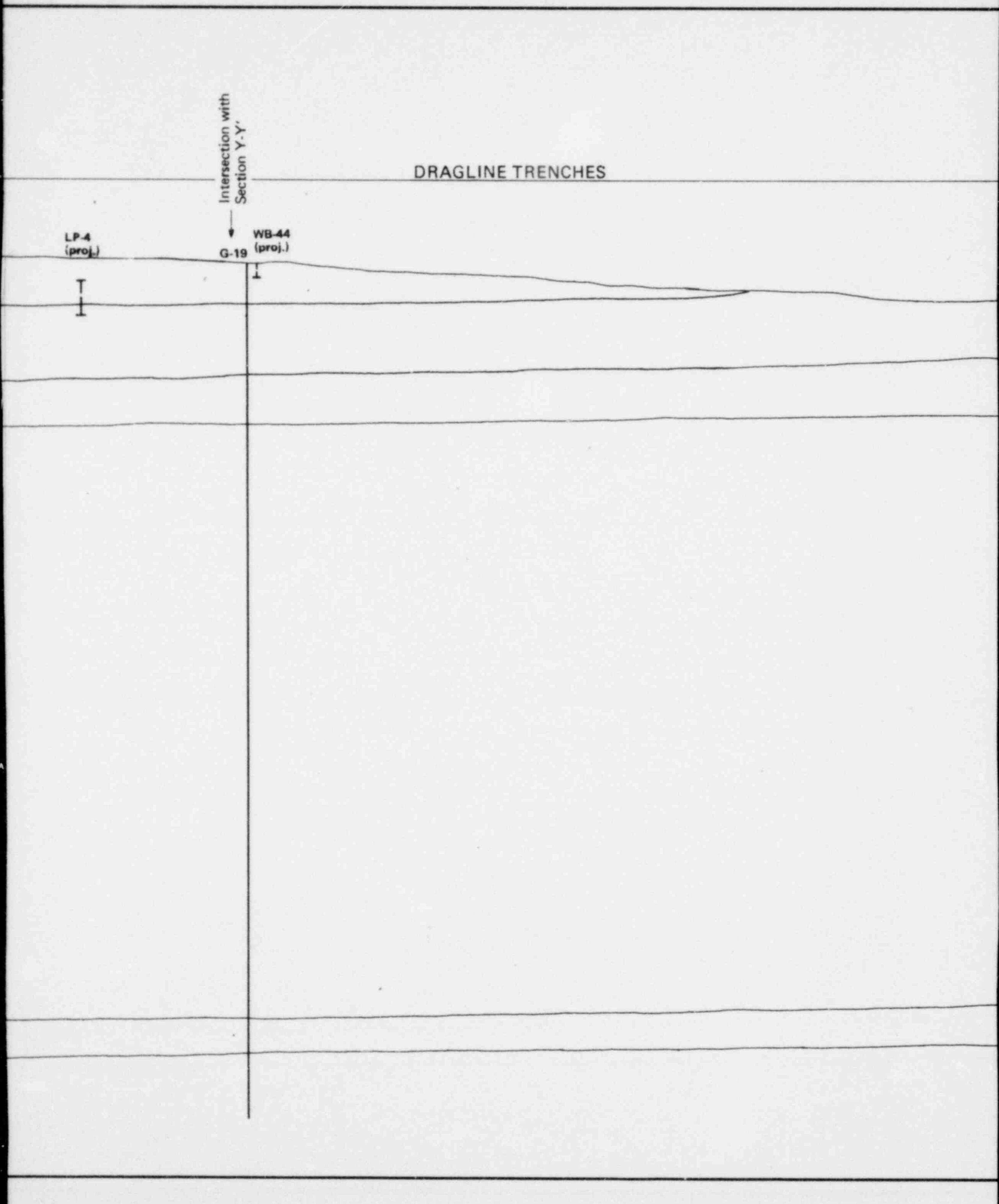
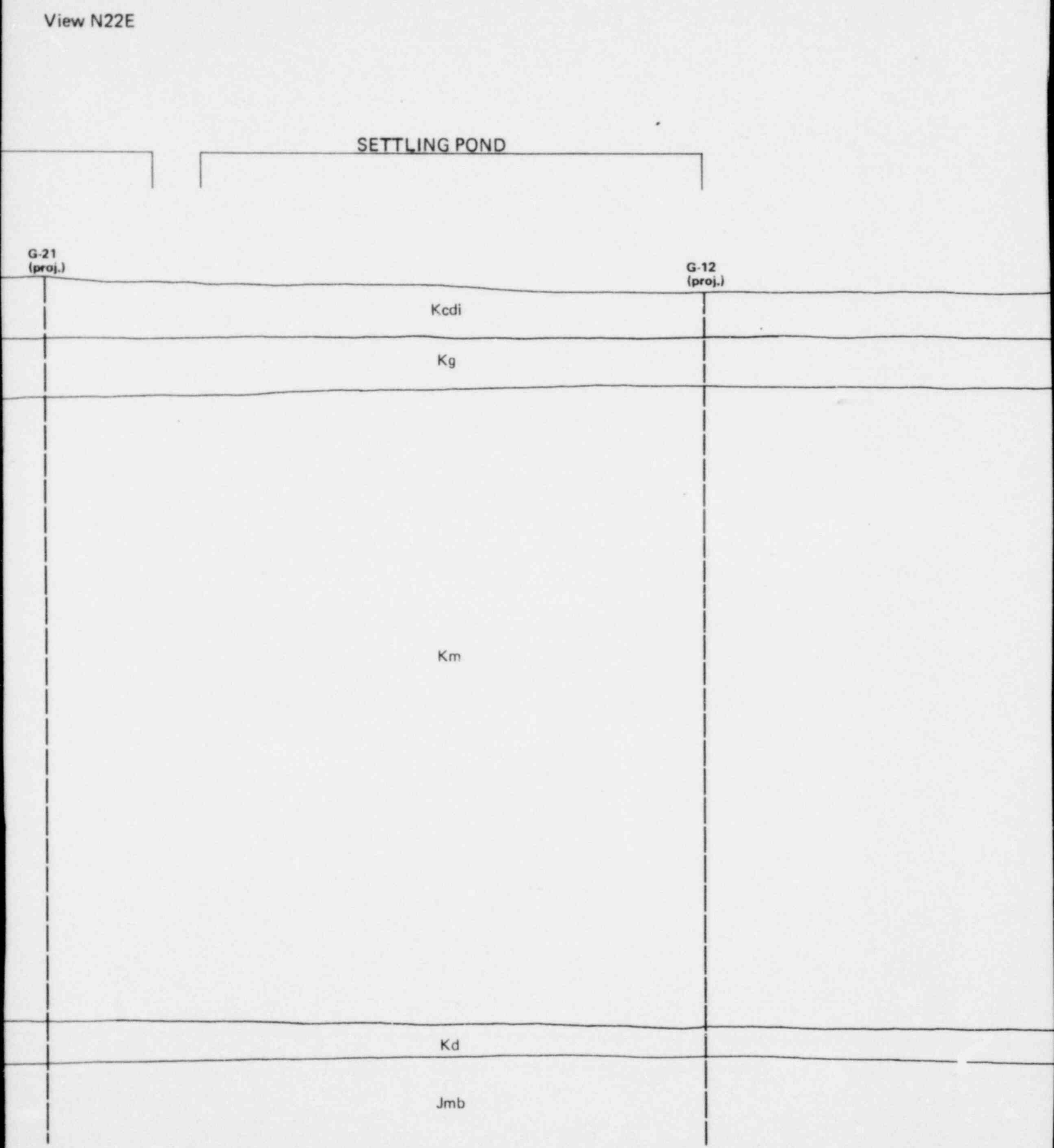
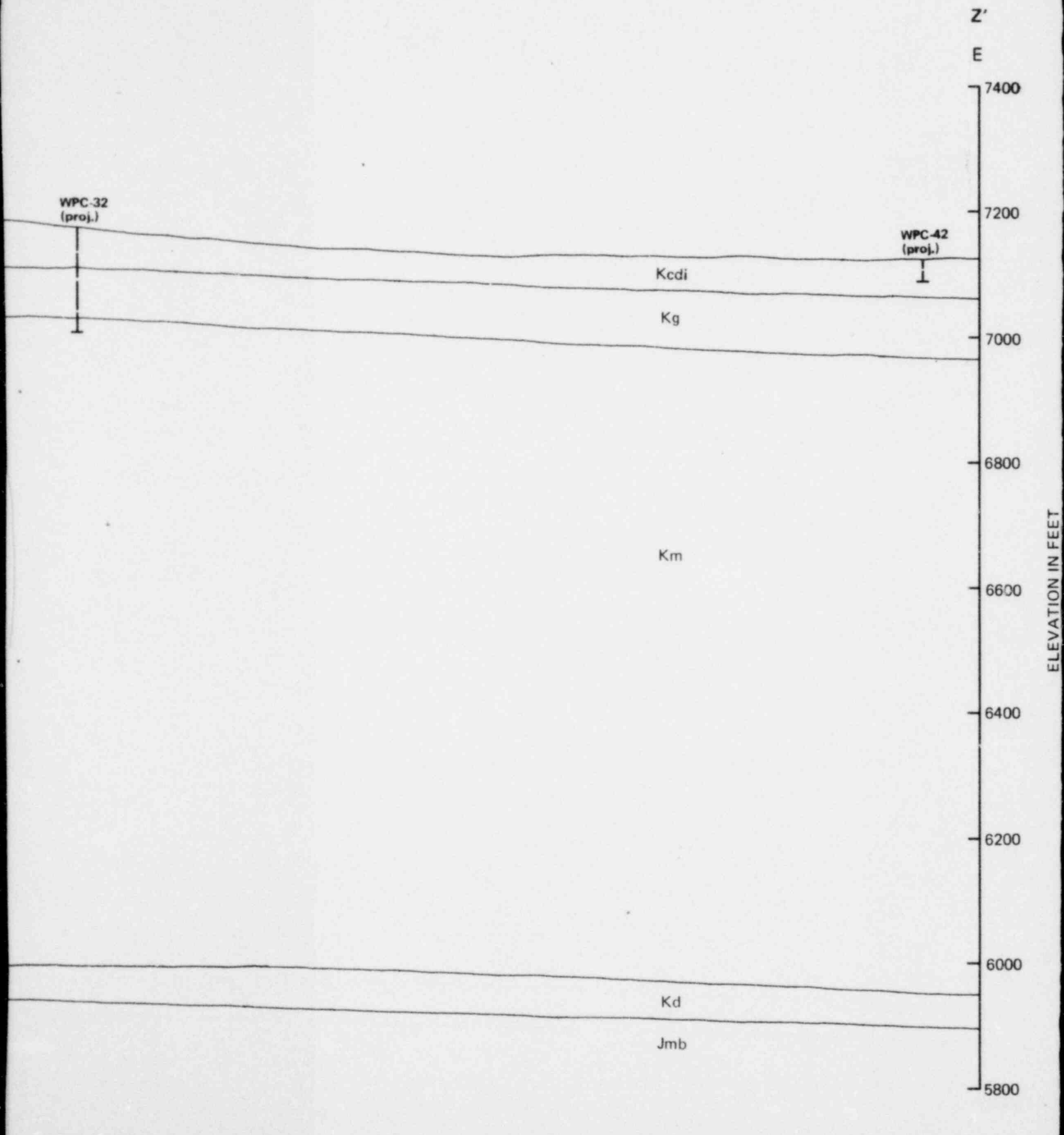
(proj.)
Kmm
Kcdi
Kg
Km
Kd
Jmb


Intersection with Section Y-Y'
DRAGLINE TRENCHES
LP-4 (proj.)
G-19
WB-44 (proj.)


View N22E
SETTLING POND
G-21
(proj.)
G-12
(proj.)
Kcdi
Kg
Km
Kd
Jmb



Z'
E
7400
7200
7000
6800
6600
6400
6200
6000
5800
ELEVATION IN FEET
WPC-32
(proj.)
WPC-42
(proj.)
Kcdi
Kg
Km
Kd
Jmb

EXPLANATION

Quaternary	
Qal	Alluvium
Cretaceous	
Kmm	Mulatto Tongue Member of Mancos Shale
Kcdi	Dilco Coal Member of the Crevasse Canyon Fm.
Kg	Gallup Sandstone
Km	Main Body of the Mancos Shale
Kd	Dakota Sandstone
Jurassic	
Jmb	Brushy Basin Member of the Morrison Fm.
G-18	Gulf Oil deep well
WPL-20	1977 Exploration auger and core hole
WB-15	1977 Borrow exploration auger hole
LP-4	1979 Exploration boring
——— — —	Geologic contact, dashed where boring control is poor

SCALE: HORIZONTAL=VERTICAL

0 — 200 feet

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Earth Sciences Associates
Palo Alto, California

GEOLOGIC CROSS SECTION Z-Z'

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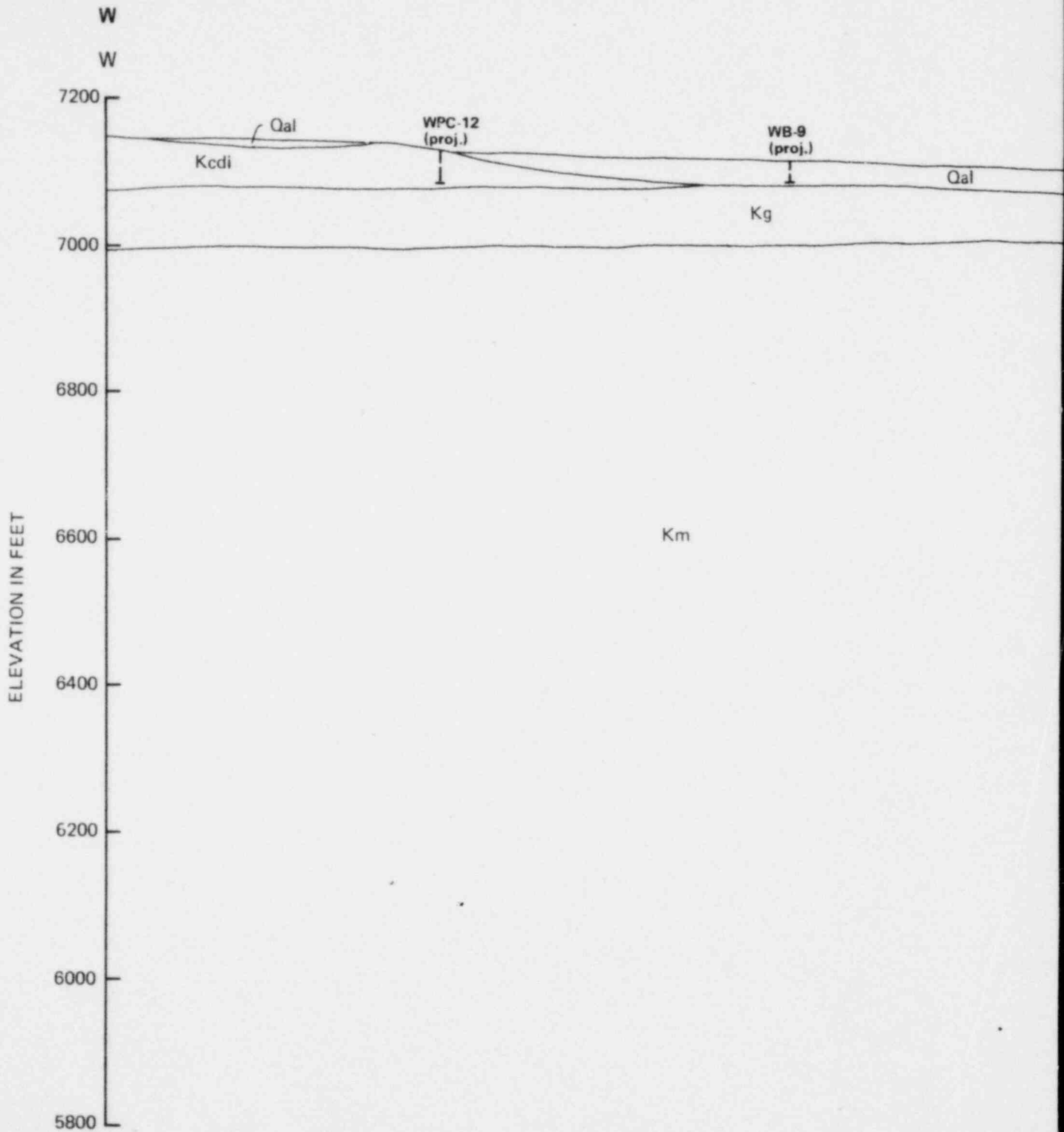
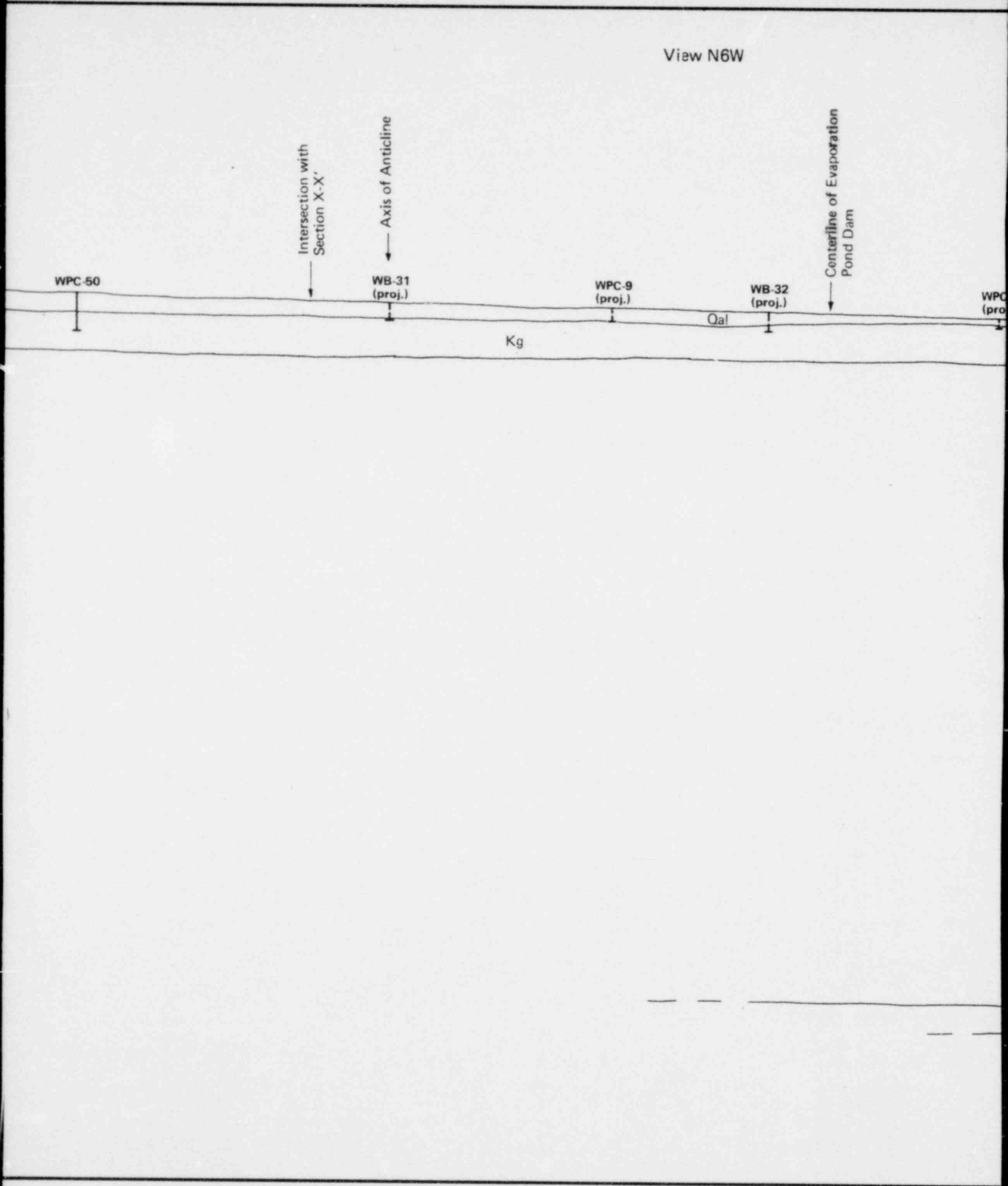
Checked by S. L. Turner	Date 12/14/79	2150	II-9
Approved by WLH	Date 12/19/79		

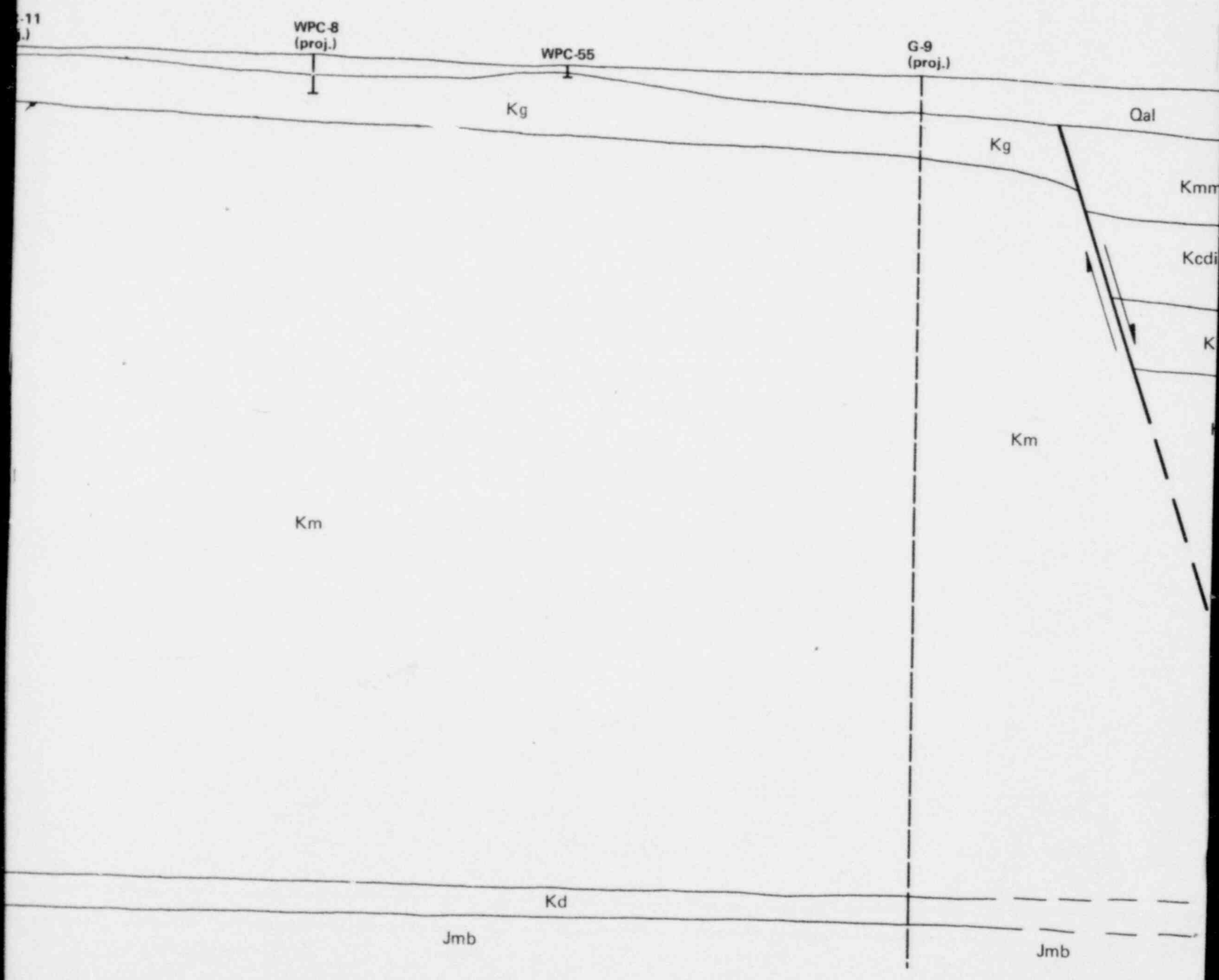
severely limit the vertical percolation. Also, the depositional method to be used will result in the formation of a slime layer along the bottom of the trench, which will be effectively consolidated as it is loaded by tailings. Consolidation of the slimes will greatly reduce their permeability; conductivities of ±0.5 foot per year would be expected with relatively small loads. In detail, seepage from the trenches will be more complex because of the bedding of the Dilco Member, which consists of interbedded shale, siltstone and sandstone. The shale and siltstone beds will not only retard downward seepage to the Gallup Sandstone, but also a complex series of perched zones may develop in the sandstone beds of the Dilco Member. This would result in maximum utilization of storage space in the Dilco unit by lateral spreading, and will improve efficiency of interception of seepage fluids by open perimeter drains.

The evaporation pond will be located in the main wash of La Polvadera Canyon, as shown on the geologic map, Figure II-7; and geologic cross sections W-W' and X-X', Figures II-10 and II-11. These figures show that in the central part of the pond, the alluvium is directly underlain by Gallup Sandstone. In these areas the Dilco and younger rocks have been removed by erosion during previous periods of downcutting within the channel area. Field and laboratory testing has shown that bedrock in the La Polvadera Canyon area is unsaturated to depths of over 500 feet, with moisture contents in the Dilco and Gallup units of as much as 20 percent (by volume) below field capacity. However, because the Gallup Sandstone is the most permeable of the bedrock units immediately underlying the pond area, and is a potential aquifer where it is saturated outside the project area, seepage from the pond will be reduced by placing a compacted clay liner over the pond bottom after excavation of alluvium. The use of a lining material will reduce pond seepage to a minimum, but total seepage will probably exceed the retained storage capacity of the Gallup and Dilco units directly beneath the pond area. A seepage mound will form under the deepest part of the pond because of the high heads developed. However, no seepage is expected to penetrate the 1000-foot thick Mancos Shale to reach the saturated Dakota Sandstone aquifer (see Figures II-10 and II-11). The seepage mound will dissipate by spreading along the top of the Mancos Shale. Before seepage could reach the saturated zone in the Gallup Sandstone more

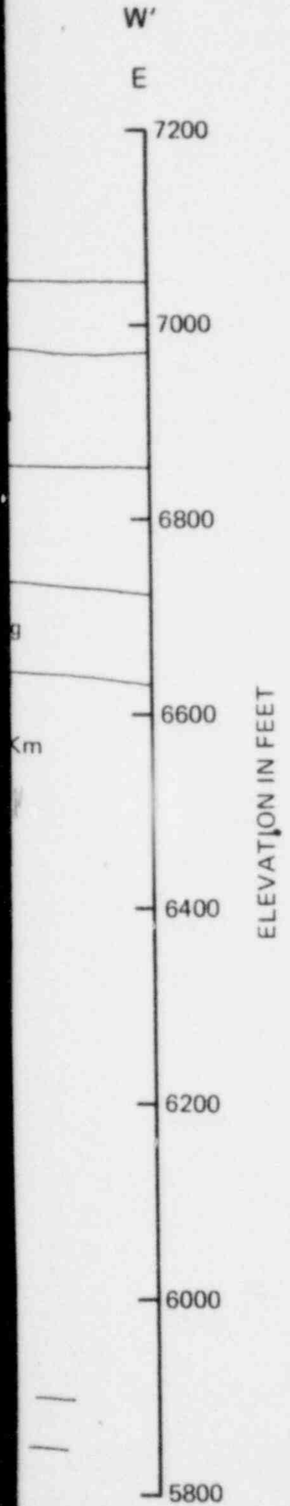

W
W
7200
7000
6800
6600
6400
6200
6000
5800
ELEVATION IN FEET
Qal
Kcdi
WPC-12
(proj.)
WB-9
(proj.)
Qal
Kg
Km



View N6W
Intersection with Section X-X'
Axis of Anticline
Centerline of Evaporation Pond Dam
WPC-50
WB-31 (proj.)
WPC-9 (proj.)
WB-32 (proj.)
Qal
Kg



WPC-8
(proj.)
WPC-55
G-9
(proj.)
Kg
Qal
Kg
Kmm
Kcdi
Km
Km
Kd
Jmb
Jmb



EXPLANATION

Quaternary	
Qal	Alluvium
Cretaceous	
Kmm	Mulatto Tongue Member of Mancos Shale
Kcdi	Dilco Coal Member of the Crevasse Canyon Fm.
Kg	Gallup Sandstone
Km	Main Body of the Mancos Shale
Kd	Dakota Sandstone
Jurassic	
Jmb	Brushy Basin Member of the Morrison Fm.
G-18	Gulf Oil deep well
WPL-20	1977 Exploration auger and core hole
WB-15	1977 Borrow exploration auger hole

Geologic contact, dashed where boring control is poor

Fault, showing relative movement

SCALE: HORIZONTAL=VERTICAL

0 — 200 feet

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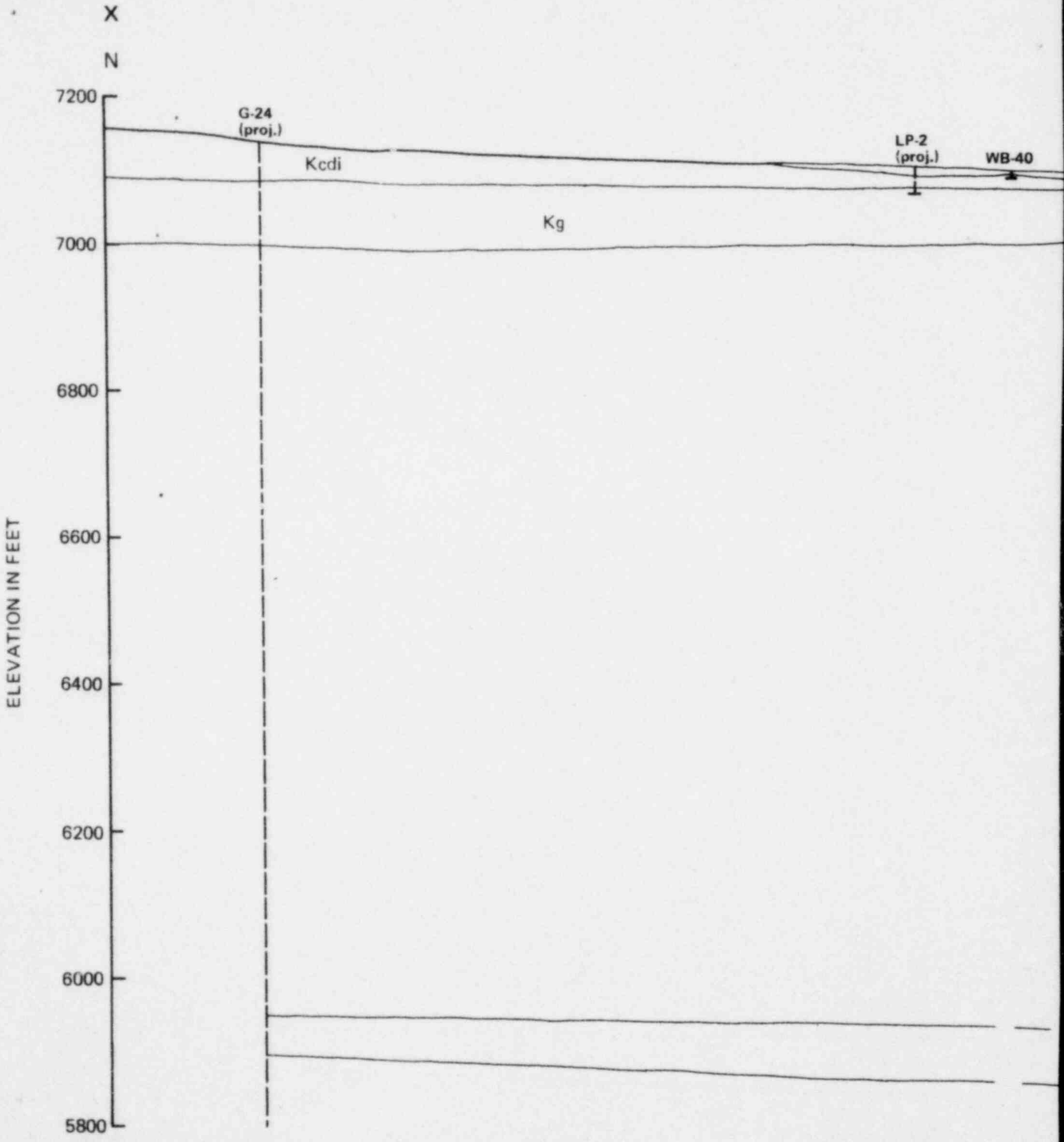
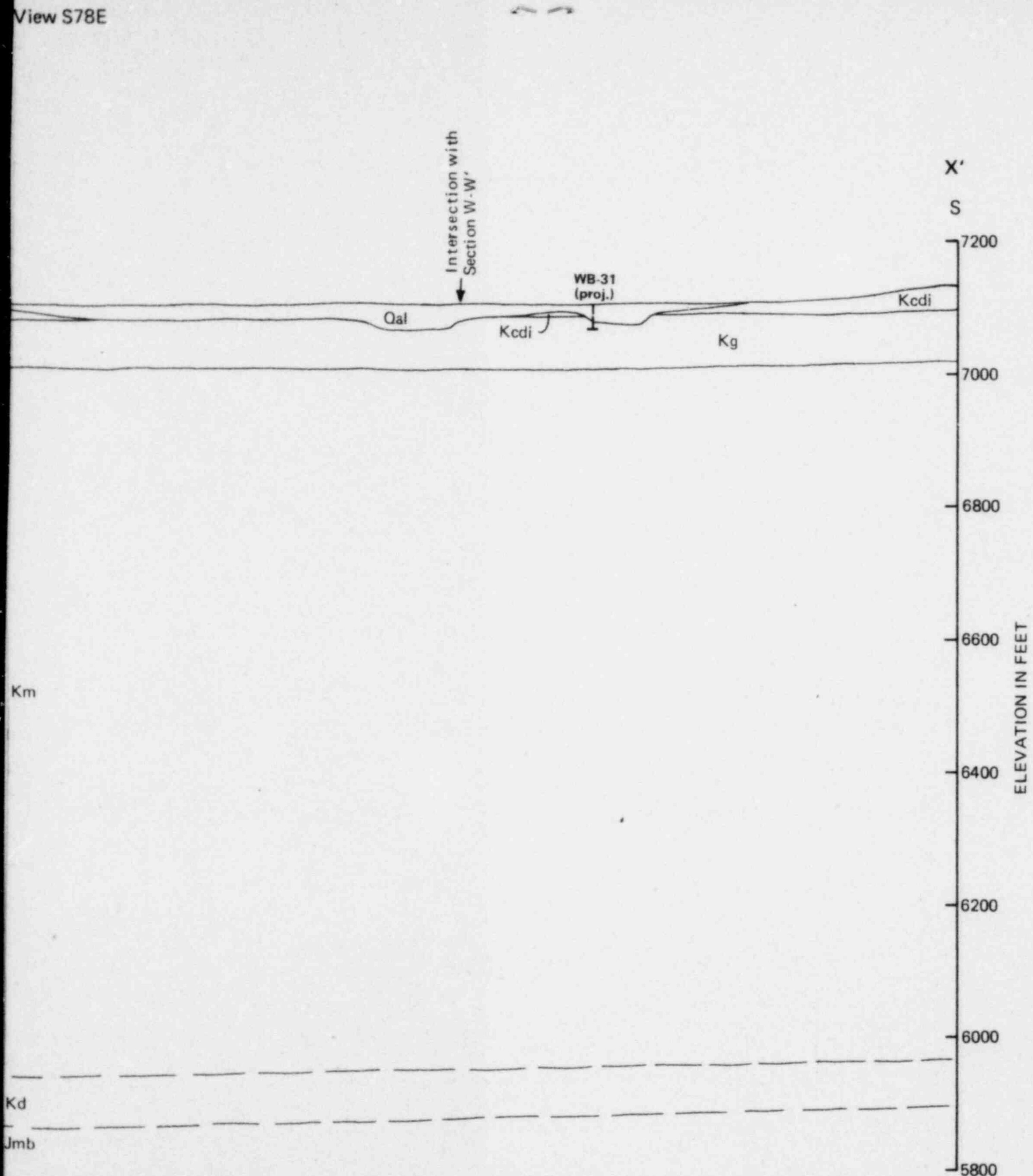
GEOLOGIC CROSS SECTION W-W'

Checked by C.L. [signature] Date 12/14/79	Project No. 2150	Figure No. II-10
Approved by [initials] Date 12/14/79		


X
N
7200
7000
6800
6600
6400
6200
6000
5800
ELEVATION IN FEET
G-24
(proj.)
Kcdi
Kg
LP-2
(proj.)
WB-40

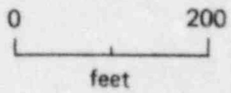

View S78E
X'
S
Intersection with Section W-W'
WB-31 (proj.)
Qal
Kcdi
Kcdi
Kg
Km
Kd
Jmb
7200
7000
6800
6600
6400
6200
6000
5800
ELEVATION IN FEET

EXPLANATION

Quaternary	
Qal	Alluvium
Cretaceous	
Kcdi	Dilco Coal Member of the Crevasse Canyon Fm.
Kg	Gallup Sandstone
Km	Main Body of the Mancos Shale
Kd	Dakota Sandstone
Jurassic	
Jmb	Brushy Basin Member of the Morrison Fm.
G-18	Gulf Oil deep well
WPL-20	1977 Exploration auger and core hole
WB-15	1977 Borrow exploration auger hole
LP-4	1979 Exploration boring

Geologic contact, dashed where boring control is poor

SCALE: HORIZONTAL=VERTICAL



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GEOLOGIC CROSS SECTION X-X'

Checked by B. L. Turner Date 12/14/79	Project No.	Figure No.
Approved by RH Date 12/14/79	2150	II-11

than one mile distant, the seepage fluids will be bound as retained moisture, as the seepage front moves through the very dry Gallup Sandstone.

2. HYDRAULIC PARAMETERS AFFECTING SEEPAGE

a. Hydraulic Conductivity

Much of the exploration program effort was placed on obtaining reliable hydraulic conductivity (field permeability) data. Three methods for performing field tests in bore holes were used. In the relatively deep core holes, water injection tests were run at various intervals isolated by hydraulic packers, and falling head hydraulic conductivity tests were performed in the same core holes. These tests were supplemented by field permeameter tests (USBR designation E-19) run in shallow bore holes (U.S. Bureau of Reclamation, 1974). The shallow (10 to 15 feet) field permeameter tests produced data with a wide scatter of results that reflected the generally higher hydraulic conductivities at these depths, where fractures are more open. The injection and falling head tests provided more reliable data because they are more representative tests of the materials involved in making seepage estimates, and are not limited to surficial materials.

The three hydraulic conductivity testing methods were used because it is difficult to obtain consistent and reliable results in unsaturated materials using any one technique exclusively. Water-pressure injection tests were particularly difficult; standard procedures had to be adjusted substantially, and longer than normal test periods were required before injection rates stabilized. Also, there was a tendency for the shales to hydrofracture along partings or for existing fractures to be forced open under pressure. This was indicated by sudden pressure drops and increased injection rates. The extent of hydrofracturing was apparently limited in most cases, because injection rates decreased within a short time and in some cases flow was reversed (probably due to swelling clay-shales). Also, seating dual packers was difficult and uncertain. As a result, the injection test results had to be evaluated carefully, and where definitive indications of hydrofracturing occurred, or failure of packers, the test data have been adjusted or eliminated. However, even with these adjustments, the results tend to indicate permeabilities higher than actual values. The fact that falling head tests gave slightly lower permeabilities suggests that some injection tests were not run long enough to obtain saturated flow conditions.

The falling head tests were run over a much longer period of time (many for more than 24-hours) and were subject to fewer variables, although there was less flexibility in isolating zones for testing. In general, there was reasonable agreement between the falling head and water injection tests. The field permeameter test (E-19) results are probably reliable, but they were limited to the upper 10 to 15 feet of weathered rock. In this zone, joints were consistently more open, which resulted in generally higher hydraulic conductivities. Most of these tests were run along ridges where stress relief leading to open fractures is the greatest. Also, rocks in this shallow zone are more exposed to leaching of soluble cementing minerals (calcite and gypsum). These shallow, permeable zones will be removed during dragline trench excavation or blanketed by the evaporation pond lining.

The measured hydraulic conductivities probably reflect vectors parallel to bedding planes or near-horizontal fluid transmission characteristics. Bedding severely limits vertical transmission potential of fluids both in individual beds and from unit to unit. Direct measurements of anisotropy were not made but the difference must be large in general. Observations of cores suggest that below 20 to 30 feet in depth, steeply dipping joints do not persist across thick shale beds. This may not always be the case, but it is logical, since the sandstones are more brittle and subject to fracturing, whereas the shales tend to deform plastically. Fractures observed in shales and siltstones of the Dilco unit at depth (none were encountered in the Mancos Shale) contain a solid filling of large gypsum crystals and appear very tight. Fracturing adjacent to fault planes may be more persistent with depth, but even this is questionable in the case of the main body of the Mancos Shale.

The field test results were carefully reviewed and compared to see whether any trends or correlations were present both overall and within each unit. Several observations can be made regarding the data. First of all, there is an apparent trend toward decreasing permeability with depth, especially in the Gallup and Dilco units. This is important for the seepage analyses because the shallower rocks will be either removed or blanketed by low permeability liners. A second important characteristic is that all test results of greater than 100 ft/yr, except for two from LP-5, are either at shallow depth, within a fault zone, or from borings drilled exclusively with air. Two borings of the 1979 exploration program were drilled without any water in order to collect samples for laboratory determinations of in-situ moisture content. Test results from these two holes and from one drilled partly without water were noticeably higher than results from holes drilled with water. In these borings, the only valid test was considered to be the falling head test, since it was the last test performed in the borehole, and was most likely to represent saturated flow conditions near the bottom of the hole.

The field permeability testing program was supplemented by limited laboratory testing. Most of the samples selected for testing were those that appeared likely to have a relatively high permeability. In addition, laboratory tests were performed on small samples, which cannot be representative of the formation as a whole. For these reasons, the laboratory test results should be viewed with caution and should not be relied upon exclusively. Representative hydraulic conductivity values were developed from field and laboratory test data for use in seepage calculations. Most investigators consider field permeability data to be distributed log-normally. Therefore, log-mean values were computed for the Dilco, Gallup, and Mancos units. Where a permeability of 0.0 ft/yr was recorded in the field tests, it was arbitrarily assigned a value of 0.001 ft/yr for these computations, as this was considered to be a value below the threshold of observation. It should be noted that, in general, laboratory tests demonstrate that permeability decreases when acidic tailings liquor is substituted for clear water as was used in field tests.

Tables II-5, II-6, and II-7 list the test results used to develop the representative values. All data were used except for the following categories:

1. Data from borings drilled in fault zones. These were not used because none of the La Polvadera Canyon facilities will be located on or adjacent to any fault zone.

2. Permeameter tests were not included because they do not extend into the zone of potential seepage.
3. Only the falling head tests were used from the two borings (LP-1 and LP-2) drilled entirely with air.
4. All tests where hydrofracturing occurred or where leaking packers made the results questionable were excluded.

The results of log mean permeability computations using the data in Tables II-5, II-6, and II-7, are as follows:

Gallup Sandstone k_{mean}=6.6 ft/yr

Dilco Coal Member k_{mean}=1.3 ft/yr

Main Body Mancos Shale k_{mean}=0.007 ft/yr

Anisotropy was not measured, but on the basis of the stratification evident in both units, especially the Dilco, and the cross bedding noted in the Gallup Sandstone, vertical permeabilities of both units are expected to be less than the mean. To be conservative, we have used vertical and horizontal conductivities of 5 ft/yr and 10 ft/yr respectively for the Gallup and 1 ft/yr and 2 ft/yr for the Dilco and Mulatto units. Although most of the field and laboratory tests data are for the Dilco, the Mulatto unit is quite similar and is considered to have similar hydraulic properties. The Mancos is essentially impervious with a mean hydraulic conductivity of 0.007 ft/yr.

Although a considerable body of hydraulic conductivity data have been collected for the rocks in La Polvadera Canyon, seepage analyses show that other factors such as liner thickness and permeability, depth to Mancos Shale beneath the facilities, and the low moisture contents of the Gallup, Dilco and Mulatto rocks, are much more important in determining the amount, rate and direction of seepage from disposal facilities.

b. Storage Characteristics

Storage characteristics of the geologic units involved in seepage will be important in preventing pond seepage from developing a significant perched saturated zone or mound. Measurements were made on selected cores from the Dilco and Gallup units for porosity, specific yield and specific retention. In-situ

TABLE II-5

HYDRAULIC CONDUCTIVITY DATA: GALLUP SANDSTONE

A. FIELD TESTS

Hole No.	Length of Test Interval, L (ft)	Field Permeability k (ft/yr)
WPC-25	15.7	1.87
WPC-25	11.0	0.0
WPC-25	9.5	2.15
WPC-25	8.3	1.72
WPC-26	11.0	66.0
WPC-26	2.1	58.75
WPC-26	1.0	70.35
WPC-27	11.0 (11.5)[a]	0.0
WPC-27	13.0	0.15
WPC-27	11.5	5.0
WPC-27	14.5	2.17
WPC-27	10.2	3.77
WPC-27	11.0	0.0
WPC-30	10.0 (11.0)[a]	4.0
WPC-31	21.5	6.2
WPC-31	43.0	0.91
WPC-31	31.0	8.6
WPC-31	28.5	1.03
WPC-31	41.5	1.5
WPC-32	31.5	1.0
WPC-32	31.5	11.3
WPC-41	74.5 (81.0)[b]	56.0
WPC-41	67.0	1.4
WPC-41	32.0	33.0
WPC-41	22.0	11.0
WPC-41	7.0	3.67
WPC-43	18.5 (21.0)[b]	24.5
WPC-50	17.0	0.0
WPC-50	21.0	1.76
LP-1	16.0	325
LP-2	23.8	3.5
LP-3	11.5	8.0
LP-5	11.5	512
LP-5	11.5	14.9
LP-5	11.5	184.0
LP-5	11.5	34.3
LP-5	24.0	3580
LP-6	16.0	3.1

TABLE II-5
(continued)

B. LABORATORY TESTS

Hole No.	Sample Depth	Permeability k (ft/yr)
WPC-32	82.0	2130
WPC-32	136.0	34
WPC-32	136.0	11.0
LP-1	66.8-69.1	1442
LP-2	33.0-33.5	993
LP-3	49.5-50.0	1034

Notes: a) Gallup Transition Zone portion of tested section. Rest is in Dilco. Total test length in parenthesis. K is for whole interval.

b) Gallup portion of tested section. Rest is in Dilco. Total length in parenthesis. K is for whole interval.

TABLE II-6

HYDRAULIC CONDUCTIVITY DATA: DILCO COAL MEMBER OF CREVASSE CANYON FORMATION

A. FIELD TESTS

Hole No. 2	Length of Test Interval	Field Permeability k (ft/yr)
WPC-30	11.5	12.0
WPC-30	11.5	5.8
WPC-31	11.5	1.0
WPC-31	21.5	1.0
WPC-32	11.5	0.0
WPC-42	21.0	0.0
WPC-42	14.0	0.23
WPC-45	61.0	0.56
WPC-45	41.0	1.7
WPC-45	16.0	0.0
WPC-45	46.9	0.03
WPC-47	21.0	0.0
WPC-47	45.5	1.14
LP-1A	22.6	31.1
LP-3	11.5	17.1
LP-3	11.5	8.5
LP-3	11.5	14.5
LP-3	11.5	51.5
LP-3	11.5	24.2
LP-3	11.5	45.5
LP-3	11.5	69.4
LP-3	121.3 (146.2)[a]	25.4
LP-3	119.9 (136.8)[b]	3.7
LP-5	25.0	4.0
LP-5	45.0	2.1
LP-5	67.0	5.9
LP-6A	80.6 (98.0)[b]	0.83
LP-6A	118.5 (134.0)[b]	0.97
LP-6A	163.2 (178.6)[a]	0.14

B. LABORATORY TESTS

Hole No.	Sample Depth	Permeability k (ft/yr)
WPC-32	58.0	0.11
LP-6	45.9-46.4	341.0

Notes: a) Dilco portion of tested section. Rest is alluvium and Gallup Sandstone. Total test length shown in parenthesis. K is for whole interval.

b) Dilco portion of tested section. Rest is Gallup Sandstone. Total test length is shown in parenthesis. K is for whole interval.

TABLE II-7

HYDRAULIC CONDUCTIVITY DATA:
MAIN BODY OF MANCOS SHALE

A. FIELD TESTS

Hole No.	Length of Test Interval, L (ft.)	Field Permeability, k (ft/yr)
WPC-19	9.0	0.7
WPC-19	30.0	0.0
WPC-31	20.0 (21.5)[a]	0.0
WPC-32	11.0	0.0
WPC-33	15.0 (31.0)[a]	0.0
WPC-33	16.0	0.0
WPC-34	16.0	0.0

B. LABORATORY TESTS

Hole No.	Sample Depth	Permeability, k (ft/yr)
WPC-32	150.0	0.03

[a]Mancos Shale portion of tested section. Total length of tested interval in both Mancos Shale and Gallup Sandstone and is shown in parenthesis.

moisture contents could not be obtained for most samples because water was used for core drilling. However, in-situ moisture contents were obtained on several samples from borings drilled with air. Measurements of moisture content from drive samples of soils and weathered rock obtained from depths of greater than 10 feet were also used to infer what moisture conditions were in the underlying rock. Only samples below 10 feet were checked because it was reasoned that direct precipitation will not penetrate deeper than this before it is consumed by evapotranspiration. Table II-8 summarizes the storage parameters resulting from direct laboratory tests.

Before any direct laboratory tests on rock were performed, the in-situ moisture contents had been conservatively estimated indirectly from moisture contents of drive samples and field capacity tests of cores to be five percent below specific retention (θ_r-θ_i). However, the laboratory testing performed on Dilco and Gallup rocks confirmed earlier conclusions that the moisture deficiencies were probably greater than five percent. Unsaturated flow will not occur until the moisture contents of bedrock units increase from their in-situ values to moisture contents exceeding specific retention. This difference of five percent by volume (θ_r-θ_i) for the Dilco and 15 percent for the Gallup represents available storage for seepage fluids. Calculations show that under the evaporation pond alone, approximately 2,673 acre-feet will be required to bring the Dilco and Gallup units up to field capacity. This available retained storage space is equivalent to nearly half the volume of the pond and approximately 21 percent of the total fluid volume to be disposed.

3. SEEPAGE ESTIMATES

a. Tailings Disposal Trenches

The mill tailings will be placed in dragline trenches excavated into the Cretaceous rocks underlying the La Polvadera Canyon site, as described in Section II.A of the Discharge Plan. The tailings will be piped to the trenches for disposal as a slurry consisting of 20-40 percent solids by weight.

TABLE II-8

STORAGE PARAMETERS (in % by volume)

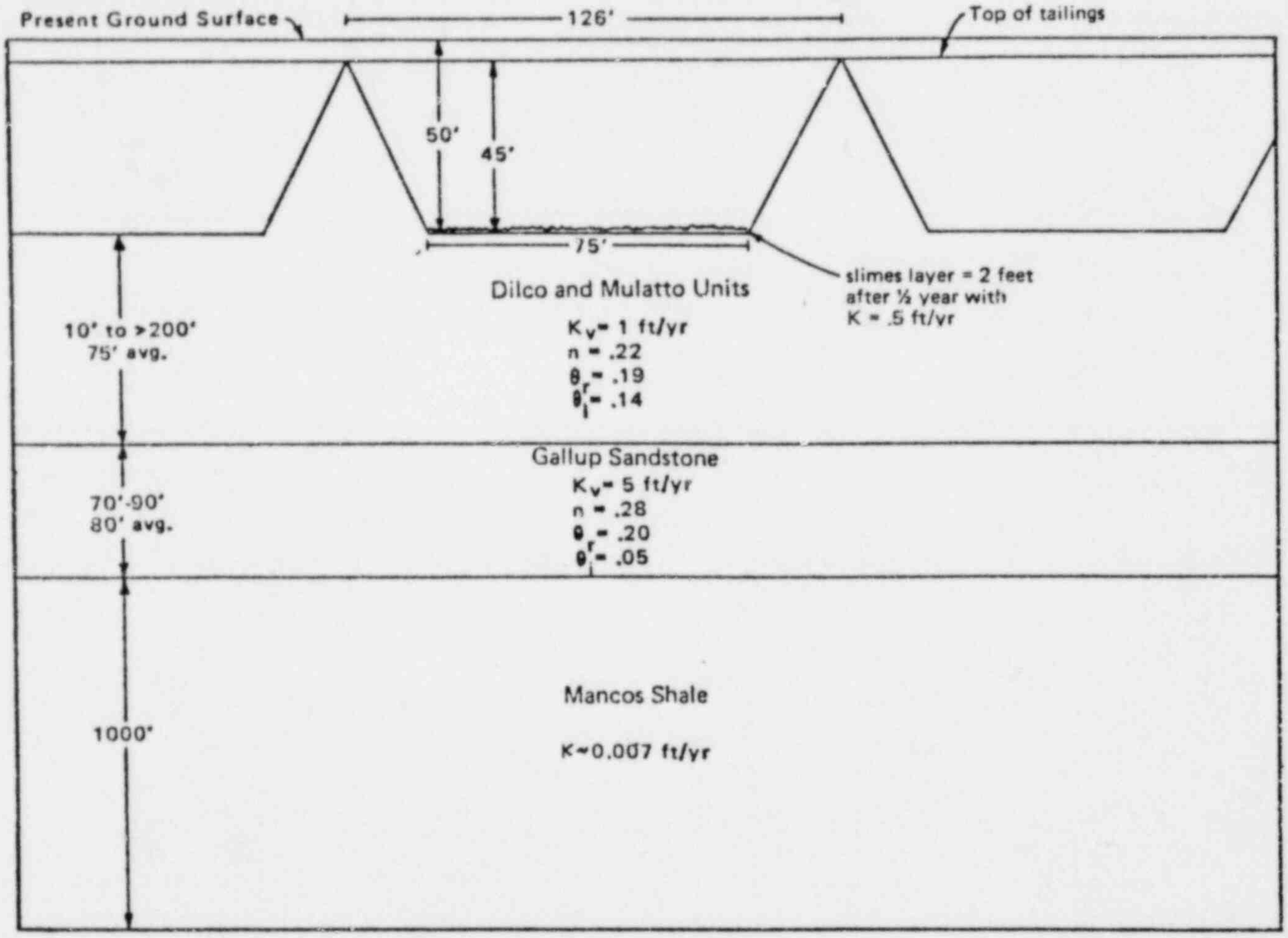
(No. of tests in parenthesis)

Geologic Unit	Porosity (n)	Specific Retention (θ_r)	Specific Yield (s_{ya})	Moisture Content (θ_i)
Dilco/Mulatto	22 (2)	19 (2)	3	14 (3)
Gallup	28 (15)	20 (15)	8	5 (3)

To investigate the seepage potential of the dragline trench disposal scheme, the computational procedure of McWhorter and Nelson (1979) was used, which takes into account the permeability and thickness of tailings, liner and foundation rocks. The seepage model used for computations is shown on Figure II-12. Computations were done by 1/4-year periods, assuming that trenches would be sized for filling in one year. Slimes permeability was estimated to reach 5 x 10^{-7} cm/sec (0.5 ft/yr) after 0.5 year. Two conditions were analyzed: a worst case condition where the Dilco unit thickness beneath the trench bottom was 10 feet; and an average condition, where the Dilco unit beneath the trench bottom was 75 feet thick. As shown in geologic cross sections Y-Y' and Z-Z' (Figures II-8 and II-9), the thickness of the Dilco units varies beneath the disposal trenches, as a result of both geologic structure and topographic relief. The trenches have been sited so that at least 10 feet of Dilco silstone and shale are present between the trench bottom and the top of the Gallup Sandstone. The thickness of Dilco and Mulatto units beneath the bottom of the trenches ranges from 10 to more than 200 feet, averaging about 75 feet over the 225-acre disposal area. Figure II-12 shows the model used for evaluating seepage from the trenches.

For the two cases (10 feet and 75 feet of Dilco), seepage and drainage amounts (specific yield estimated at eight percent for tailings) were computed. These were compared with available retained pore water storage capacity (θ_r-θ_i) of the underlying Gallup Sandstone, computed as (80 feet)(.15)(126 feet wide trench)=1512 ft^3 per lineal foot of trench. For the worst case, seepage plus drainage would equal 798 ft^3 per lineal foot of trench. For the average case, seepage plus drainage would be 518.3 ft^3 per lineal foot of trench. Neither of these estimates is as great as available storage retention, so that saturation of the Gallup is not expected to occur, even in the areas where the Dilco is relatively thin. Total estimated seepage (including drainage) is 919 acre-feet, assuming 77,290 lineal feet of trench. Retained storage capacity in the Gallup Sandstone for this length of trench is estimated at 3521 ac-ft, or more than three times estimated seepage. Therefore, foundation rocks will never reach field capacity, and saturation will not occur in the Callup Sandstone. Minor perched saturated zones are expected to occur within the Dilco

Dragline Disposal Trench
Diagrammatic Cross Section
Not to Scale



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SEEPAGE MODEL – DRAGLINE TRENCH TAILINGS DISPOSAL

Checked by B. L. Turner Date 12/14/79	Project No	Figure No
Approved by WH Date 12/14/79	2150	II-12

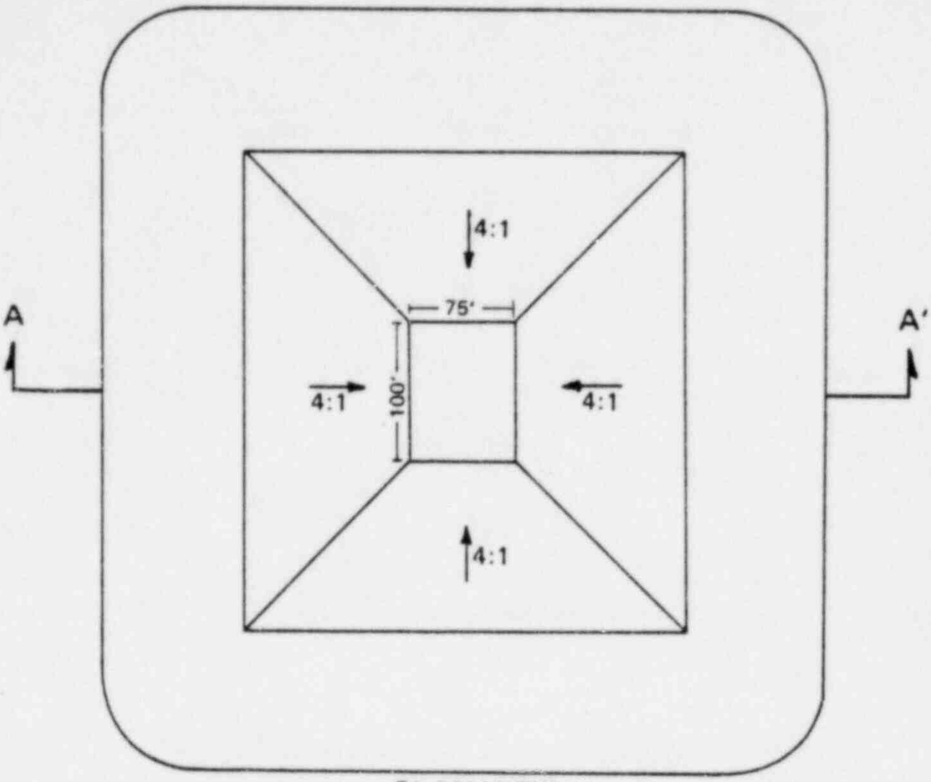
unit, but if they spread they will be intercepted by the open peripheral drains or simply result in retained storage over a wider area. As a result, contaminants that escape the trenches by seepage will be retained in storage in the vadose zone beneath the disposal area and will not reach saturated rocks that are potential aquifers.

b. Settling Pond

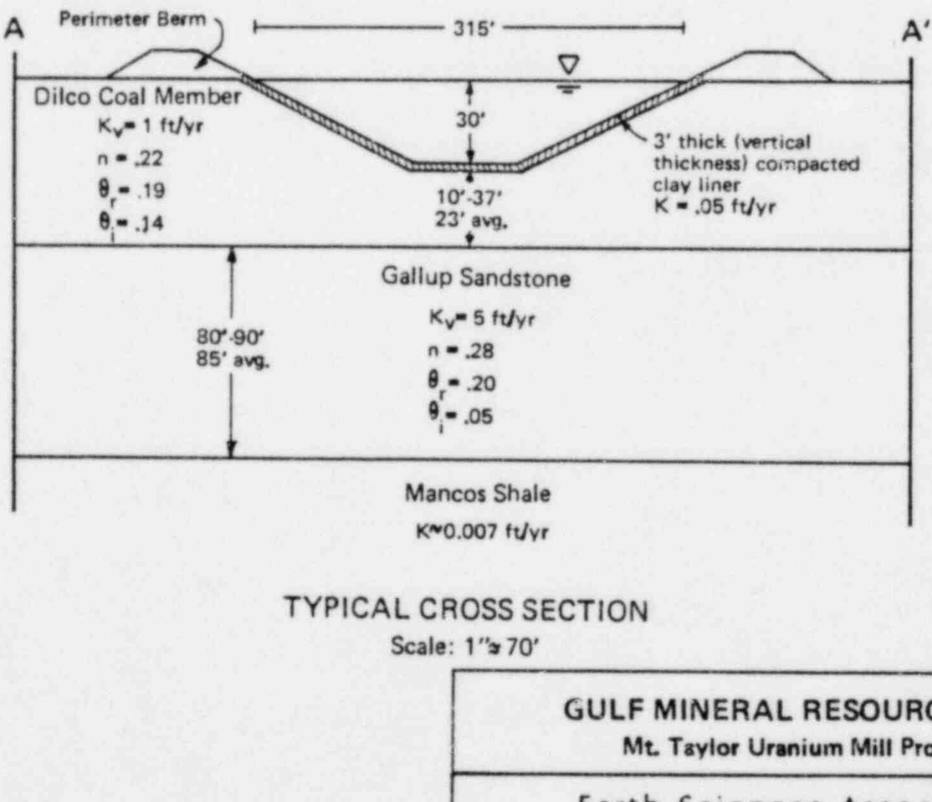
The settling pond has been designed with a three-foot thick clay liner in order to limit seepage to a volume less than that of storage available in the underlying bedrock. Storage was computed for the Dilco and Gallup units by calculating the rock volume immediately underlying the settling pond, and multiplying by the percentage of available pore storage (θ_r-θ_i) for each rock type. For the Dilco, available storage was estimated at five percent, and for the Gallup, 15 percent was used, as shown in Figure II-13.

Because of the geologic structure, and the topographic relief at the settling pond site, the thickness of Dilco beneath the pond bottom is highly variable. The thickness of 23 feet used in computations represents an approximate average over the whole settling pond area shown in Figure II-2, with an assumed pond level of about 7,160. The Dilco below the pond bottom is thinnest at the northeastern end, and thickest in the west, near the ridge crest. A mean Gallup thickness of 85 feet was used for storage calculations, based on cross section Z-Z' and on boring data. Total available storage (θ_r-θ_i) beneath the 2.46-acre settling pond is 35.56 acre-feet.

Seepage during the 22-year pond life was estimated using the computational procedure of McWhorter and Nelson (1979), modified to eliminate the slime and coarse tailings layers. If slimes are deposited on the pond bottom and sides, they will significantly reduce seepage rates and total seepage. Since slimes deposition was ignored in the analysis, an additional safety factor is provided. Seepage rates for the pond bottom were computed using a total head of: 30 feet of water in pond + 20.1 feet of suction from the Dilco bedrock = 50.1 feet. For the side slopes, total average head used was: 15 feet of water in pond + 20.1 feet of suction from the Dilco = 35.1 feet. A clay liner three feet thick (measured perpendicular to the trench bottom and sides) was used in all calcu-



PLAN VIEW
Scale: 1"≈70'



TYPICAL CROSS SECTION
Scale: 1"≈70'

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SEEPAGE MODEL— SETTLING POND		
Checked by E.L. Turner Date 12/4/79 Approved by [signature] Date 12/14/79	Project No. 2150	Figure No. II-13

lations. The seepage estimates for a 22-year pond life are as follows:

(1)	Seepage through pond bottom =	3.35 ac-ft
(2)	Seepage through pond sides =	31.03 ac-ft
	Total Seepage =	33.38 ac-ft

Since the estimated seepage is less than available storage, the Gallup beneath the pond will not become saturated. It should be noted that if the pond is located above elevation 7160, additional storage in the Dilco will be available.

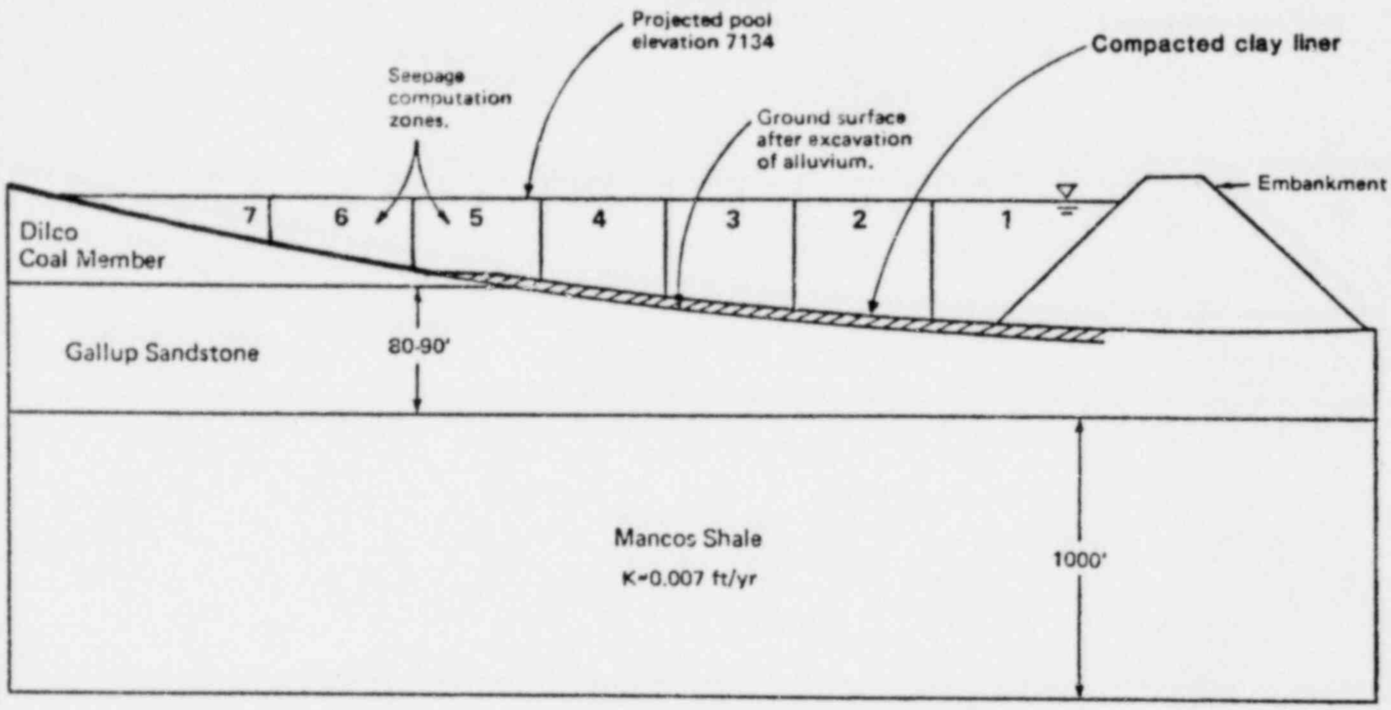
Lining requirements will be re-evaluated prior to construction of additional settling ponds, if they are necessary.

c. Evaporation Pond

The La Polvadera evaporation pond was designed to take advantage of the available pore storage in the extremely dry native foundation materials which underlie the La Polvadera Canyon area. Laboratory analysis of core samples from both the Gallup Sandstone and Dilco Coal Member indicate water contents far below specific retention for these foundation materials. Therefore, the excessively dry porous media has the potential to store water and bind it by capillary forces which are strong enough to prevent significant free drainage. This retained storage capacity is measured by the difference between the water content at specific retention and the natural in-situ water content. Laboratory testing and field observations show that this difference is up to 20 percent by volume for the native materials in La Polvadera Canyon.

Evaporation pond seepage calculations were performed using the computational procedures of McWhorter and Nelson (1979), simplified to reflect the fact that tailings will not enter the evaporation pond. The formulation depicts vertical seepage from the reservoir through a low permeability liner to the underlying unsaturated foundation material, with subsequent rise and spread of a seepage mound. Seepage is divided into four stages: Stage I - vertical seepage to the existing water table or to an impervious boundary (in this case, the Mancos Shale); Stage II - build-up of a seepage mound beneath the pond; Stage III - mound spreading; and Stage IV - mound dissipation. Figure II-14 illustrates the seepage model used for this analysis. Seepage computations were performed for each of seven zones based on proposed pond excavation contours. The steps used in determining the liner requirements were as follows:

Evaporation Pond
Diagrammatic Cross Section
Looking North
Not to Scale



Hydraulic Parameters

Dilco	Clay liner	Gallup
K_v = 1 ft/yr	K = .05 ft/yr	K_v = 5 ft/yr
n = .22		n = .28
θ_r = .19		θ_r = .20
θ_i = .14		θ_i = .05

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SEEPAGE MODEL–
EVAPORATION POND

Checked by ______ Date ______	Project No.	Figure No.
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1. Pond zones were established between 10-foot contours, for purposes of simplifying the calculations.
2. For each zone, the following were determined:
   - Thickness of underlying rock units.
   - Safe pore water storage capacity = (water content at specific retention - present water content) x (zone area) x (average thickness between pond bottom and base of Gallup Sandstone).
   - Using time-volume and area-capacity relations for the pond, the mean head for each zone was determined for two-year periods throughout the project life.
   - Using the formulas of McWhorter and Nelson, seepage through each zone was calculated using the proposed clay lining and appropriate thickness of Gallup Sandstone or Dilco. Table II-9 shows the results of these calculations.

As shown in Table II-9, saturation of the Gallup Sandstone beneath the pond will occur in Zones 1 through 5, where the heads are greatest, and inundation periods are longest. Seepage in Zones 6 through 7 will be less than available retained storage in the Dilco and Gallup rocks underlying these zones. In practice, lateral spreading of the seepage mound will cause partial saturation of other zones as well. However, because of the low natural moisture of the bedrock materials, movement of a saturation front to the saturated zone of the Gallup (more than a mile distant) will not occur.

Analyses indicate that Stage I will not be complete until after 13 years of pond operation and Stage II will take an additional 1.5 years to complete. This means that a saturation mound will start to develop after 13 years and will reach the pond bottom after 14.5 years. As soon as the mound starts developing, it will slowly spread laterally but it probably will not reach the pond margin before 16 to 18 years or more. The saturation front will probably spread several thousand feet before it is bound as pore moisture by capillary forces both in the Gallup Sandstone and underlying Mancos Shale.

d. Conclusions

Seepage estimates indicate that the tailings disposal facilities are designed to prevent seepage to the saturated zone, and that seepage will be re-

TABLE II-9

EVAPORATION POND SEEPAGE

Zone	Zone Elevation Boundaries (ft)	Retained Storage Capacity (ac-ft)	Inundation Period (yrs)	Approximate Area (ac)	Total Zonal Seepage (ac-ft)
1	7060-7075	126.0	36	14	314
2	7075-7085	178.5	34	17	418
3	7085-7095	216.0	32	18	448
4	7095-7105	337.9	30.5	27	573
5	7105-7115	556.5	25	42	711
6	7115-7125	696.0	17	48	530
7	7125-7234	562.5	7.5	38	173
Totals		2673.4		204	3167

Note: Seepage from Zones 1 through 5 exceed the retained storage capacities by 1049 ac-ft.

tained as storage in the moisture deficient rocks underlying the La Polvadera Canyon area. Table II-10 summarizes the results of seepage estimates described above, and shows that in most cases, seepage will be less than storage available immediately beneath in the foundation rocks. This has been accomplished by the use of natural clay lining materials, and careful siting of the facilities to take advantage of low permeability rocks within La Polvadera Canyon. In general, the assumptions used in preparing the seepage analyses were very conservative. Some of the factors which would tend to reduce seepage or act as safety factors are:

- Wetting and storage in the Mancos Shale was not considered. A wetting front would have to penetrate only a few feet of this unit to store any excess moisture not stored in overlying units. Even with a permeability on the order of 0.01 ft/yr, it could accept more than 425 ac-ft in 100 years over the project facilities area of about 425 acres.
- Sizing of the evaporation pond was based on zero seepage from the tailings disposal trenches. Any water leaving the trench as seepage will reduce the volume of water pumped to the evaporation pond and, therefore, reduce the pond seepage.
- The evaporation pond was sized without consideration for seepage losses through the clay liner and therefore contains excess storage capacity.
- A north-south trending fault east of the pond area should act as a barrier to lateral migration due to the offset of the bedrock. Specifically the Gallup Sandstone has been offset to come into contact with the relatively impervious Mulatto Tongue of the Mancos Shale (see Figure II-10).

In previous seepage analyses, a moisture deficiency (θ_r-θ_i) of five percent by volume was used, rather than the five to 15 percent used here. As noted in Section II.C.2, laboratory testing on unwetted samples was performed to document these low moisture contents. Although the number of samples (7) do not represent a large sampling for the La Polvadera Canyon area, they were taken from the site at depths of 28.0 to 69.1 feet and are consistent with results obtained on the overlying unconsolidated materials. Also, the test results are consistent with tests performed on cores of similar sandstones of the Menefee Formation near the mill site.

Even if the protective measures that are proposed, such as pond linings and drains were not constructed, it is questionable if contaminants would ever

TABLE II-10

SUMMARY OF SEEPAGE

LA POLVADERA CANYON TAILINGS DISPOSAL FACILITIES

	Tailings Disposal Trenches	Settling Pond	Evaporation Pond
*Available retained storage in foundation rocks ($\theta_r-\theta_i$)	3695 ac-ft	35.6 ac-ft	2673 ac-ft
Total estimated seepage losses during project life	2882 ac-ft	34.4 ac-ft	3167 ac-ft

*Note: Includes only storage directly under active area of facilities and assumes no lateral spreading of seepage by perching or capillary forces.

reach the saturated zone below the facility or spread downdip to existing aquifers. Further, it is doubtful that if seepage did reach the saturated Gallup Sandstone whether contaminants could be detected by wells outside the canyon area. Another consideration is that the aquifers that potentially could be threatened with contamination, however remote, are the Gallup Sandstone and Dakota Sandstone which naturally contain poor quality water that is undrinkable. Also, these aquifers occur at depths that are in excess of 1400 feet deep outside the canyon area and are unlikely to be developed because shallower aquifers with better quality water are available for development. The disposal area is remote from any present or projected water supply (except for the Polvadera Stock Well, which will be abandoned). These factors all provide reinforcement to the safety features of the groundwater discharge plan that will preclude any reasonable threat of groundwater contamination.

4 ATTENUATION POTENTIAL

The waste disposal facilities in La Polvadera Canyon are designed to prevent seepage from reaching saturated rock units or aquifers beneath the facilities or in the vicinity. Seepage analyses support this conclusion and indicate that materials in the vadose zone beneath the disposal facilities will not receive fluids in excess of their ability to store them indefinitely. Some minor perched saturated zones may develop in the Dilco unit beneath or adjacent to the burial trenches, but these zones will be easily contained. Also, a saturation mound is expected to develop in the Gallup Sandstone beneath the evaporation pond, but it will be contained within the presently unsaturated sandstone. Therefore, attenuation of contaminants in the waste waters is not a factor of concern for this groundwater discharge plan. However, there are a host of natural attenuation processes that will improve the quality of waste waters that seep through the lined evaporation pond and trenches.

A geochemical testing program was performed under the direction of Dr. Donald Langmuir, Consulting Geochemist (Colorado School of Mines), to determine, among other things, the attenuation potential of the bedrock. The results of this study pertaining to this discharge plan are summarized below. Batch and column tests (9 and 10 tests, respectively) were performed using raw or diluted raffinate solutions on samples of Dilco Sandstone and Shale, Gallup Sandstone, and Mancos Shale. These tests were supported by optical, petrographic, x-ray, and bulk chemical analyses of the rocks to determine the amounts and character of specific mineral phases, and concentrations of major constituents in these minerals.

The study indicated that attenuation of pollutants in the raffinate depends chiefly upon the ability of natural geologic materials to neutralize its acidity. Progressive neutralization accelerates oxidation of the ferrous iron, which in turn leads to precipitation of ferric oxyhydroxides. Neutralization also precipitates the aluminum as oxyhydroxides, aluminosulfates or silicates. These precipitates then can sorb and attenuate trace metals such as As, Cr, Cu, Mo, Ni, Pb, Ra^{226}, Se, U, and Zn. Total dissolved solids are reduced by neutralization once the Fe, Al, and Mn oxyhydroxides have formed. If neutralization is with calcium carbonate or lime, the added calcium lowers sulfate concentrations through gypsum precipitation. A reagent grade calcite was used to neutralize raffinate to pH 7.66. The resultant TDS reduction was 79 percent with corresponding reductions in most toxic species concentrations to values below detection.

Analyses of foundation rocks indicated much lower concentrations of calcite than previously suspected. The Gallup Sandstone has only about 0.2 percent $CaCO_3$ by weight. However, this amount of calcite has the capacity to neutralize an estimated 2.25 acre-feet per acre of seepage where the full thickness of Gallup Sandstone is penetrated by seepage. This would result in partial neutralization beneath the clay-lined portion of the evaporation pond because the total seepage from this part of the pond is estimated to average about 10.3 acre-feet per acre over the life of the pond, which indicates that stored seepage would not be neutralized by the Gallup Sandstone alone. However, if excessive seepage were to occur, forming a saturated mound, the spreading seepage front would probably encounter enough calcite in the Gallup Sandstone to result in neutralization before reaching the saturated zone more than a mile from the disposal sites.

Clay and mica-rich rocks of the Dilco unit and the Mancos Shale are the most abundant potential neutralizers of the raffinate. The shales will further increase the TDS of the raffinate as they neutralize it. This is also true for the rest of the sandstones in most cases because of soluble salts (Na, K, Mg, Ca, SO_4, and Cl) available to the first waste water through. However, the shales generally showed useful attenuation capacities for several of the toxic metals in the raffinate. In general, Ra^{226} and Pb were reduced in batch and column tests to values near or below New Mexico health standards. In many cases, Mo, As, Cu, and Cr, were also lowered to values near or below health standards.

It was also observed during testing that the raffinate solution has a clogging effect on porous media. Flow rate changes of more than an order of magnitude were observed when comparing transmissions of distilled water versus unfiltered raffinate. Part of this change in conductivity is due to viscosity, but it is mostly because of suspended material in the raffinate consisting of amorphous silica and organic material. The organic material in the raffinate is expected to decompose with time, but before it decomposes it will clog the pores of the lining materials and foundation rocks.

The raffinate leaving the mill is expected to have silica concentrations ranging from 0.7 to 1.5 g/l. With time, silica concentrations were observed to decrease substantially. This clearly reflects precipitation of amorphous silica with time from the raffinate in which it is initially highly supersaturated. Silica should continue to precipitate until equilibrium with amorphous silica is reached at about 115 to 120 mg/l. It was also noticed that Ra^{226} concentrations dropped with precipitation of silica, and other constituents may be removed by sorption and/or coprecipitation as well. The precipitates will contribute to clogging of liners and foundation materials as well as provide some beneficial attenuation of contaminants.

In conclusion, test data indicates that natural materials beneath the disposal site have significant chemical attenuation capacities. Precipitation of amorphous silica, calcite neutralization, and neutralization by clay and mica-rich shales would be chiefly responsible for attenuation. Reduction of hydraulic conductivities of the foundations and liners by clogging would also have significant effects. If seepage migrates further than anticipated by unsaturated and/or saturated flow, dispersion and dilution would also become important factors. Although these attenuation processes have not been relied upon for the basis of concluding that no groundwater reasonably available for use as a water supply will be degraded by the operation of the proposed tailings disposal system, they do provide an additional safety factor.

D. GROUNDWATER MONITORING

1. MONITORING SYSTEM

Liquid and solid mill waste disposal facilities in La Polvadera Canyon are designed to minimize saturation of rock units in the vadose zone beneath the facilities and to preclude deep percolation to the saturated deeper units. A small perched groundwater mound is expected to develop beneath the evaporation pond, but this seepage water will be contained within the presently unsaturated Gallup Sandstone. A network of shallow and deep monitoring wells will be constructed to detect seepage amounts exceeding design values. The location of the proposed network of deep and shallow monitoring wells are shown on Figure II-15.

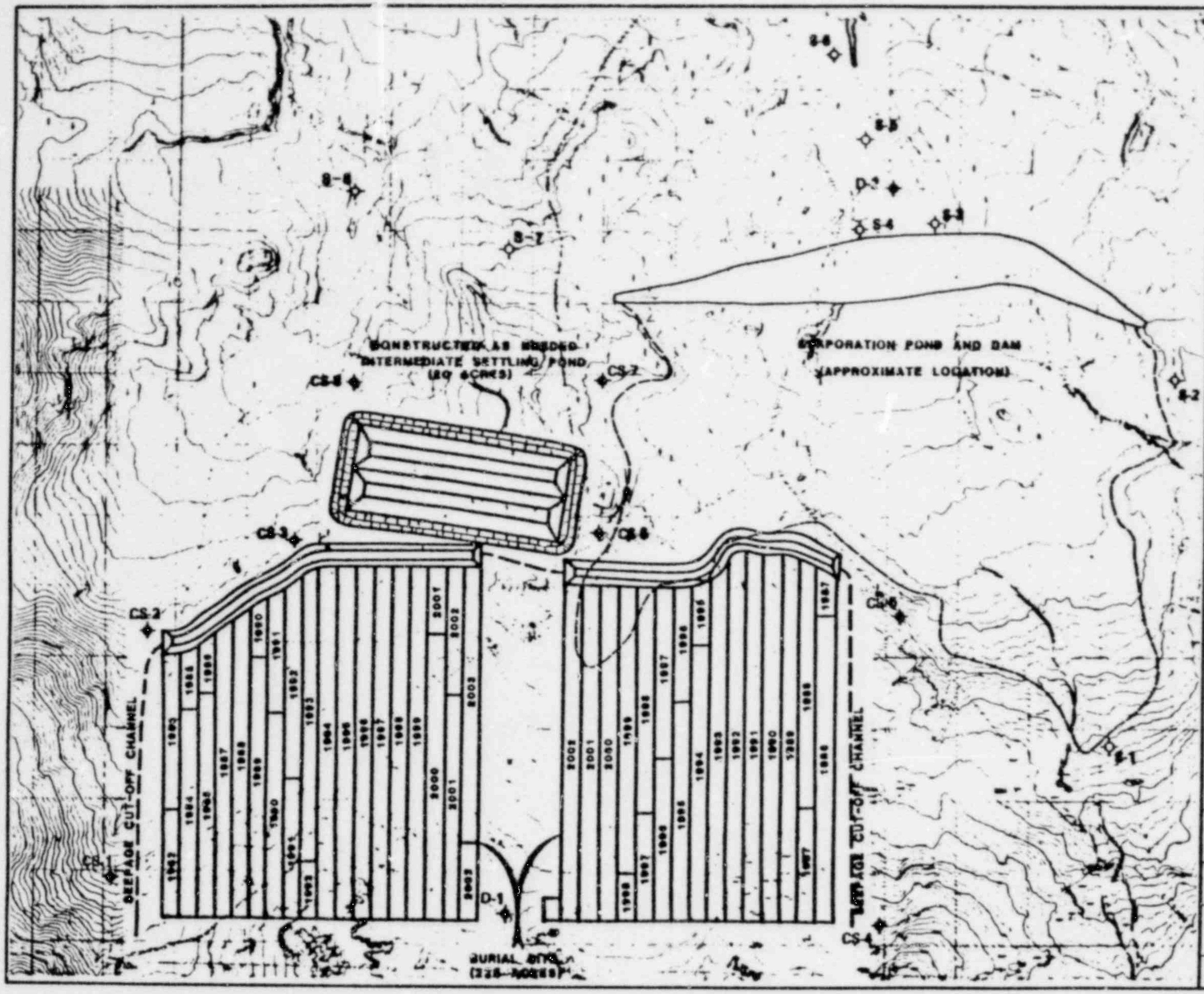
a. Shallow Monitoring System

The shallow monitoring system consists of a series of wells designed to detect development of perched saturated zones within the Gallup Sandstone and Dilco-Mulatto units. Only minor saturation is expected beneath the disposal trenches in the Dilco unit and a small mound is expected to develop beneath the evaporation pond. Monitoring the rates of mound growth and spreading along with water quality if saturation occurs, will provide data to determine if existing aquifers are threatened.

The shallow monitoring system will consist of two groups of wells. One group will consist of clusters of two wells each; one well penetrating only the Dilco Unit and another well drilled to the base of the Gallup Sandstone with the overlying Dilco Unit sealed off. The other group of shallow monitoring wells will consist of single wells open only to the Gallup Sandstone or alluvium.

All of the cluster wells and the single wells, except for S-8 and S-6, will be air-drilled wells with grouted four-inch diameter casing to prevent surface inflow of water. Casings (PVC) will be installed through any alluvium and at least 10 feet into competent rock. The remainder of the hole will be left open. The wells designed to monitor only the Gallup Sandstone will have grouted casing installed through the Dilco Unit and/or overlying alluvium.

Wells S-8 and S-6 will be located in buried channels that have cut through the Gallup Sandstone to the top of the Mancos Shale. These two wells will have



EXPLANATION

CS-1 — Cluster of 2 shallow Monitoring Wells: constructed so that 1 well is open only to the Dilco unit and 1 well is open only to the Gallup Sandstone.

S-3 — Single shallow Monitoring Well: constructed to the top of the Mancos Shale and open only to the Gallup Sandstone.

D-1 — Deep Monitoring Well: constructed to the base of the Dakota Sandstone and open to the Dakota and lower Mancos Shale.

SCALE

0 — 1000 feet

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MONITORING WELL SYSTEM

LA POLVADERA CANYON

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a 12-inch diameter well bore with four-inch casing and a gravel filter pack in the annulus. The bottom 30 feet of casing will be slotted to permit entry of water into the well casing. The upper 15 feet of annular space will be grouted to prevent infiltration of surface water into the well. These two wells are designed to detect discharge of water into the alluvium from the Gallup Sandstone. The buried channels would act as a drain and receive water from the Gallup Sandstone if a saturation mound develops and extends as far as these monitoring wells.

b. <u>Deep Monitoring System (Saturated Zone)</u>

The deep groundwater monitoring network will include two wells that will penetrate to the base of the Dakota Sandstone beneath the main body of the Mancos Shale. The wells will have a minimum five-inch diameter conductor casing, extending through the Mancos Shale, grouted in place to form a seal so that only water from the Dakota Sandstone is sampled. The locations of these wells are shown on Figure II-15.

The two deep wells are designed to detect degradation of existing groundwater from deep seepage (if any) through the Mancos Shale aquiclude. If deep seepage to the Dakota Sandstone occurs, it will have to move downward through the Mancos Shale along fracture zones. No faults or associated fracture zones were detected in the areas occupied by disposal facilities. The nearest fault zones are a north-south fault to the east and an east-west fault to the north of the facilities. A long, slow seepage path would be required to reach these faults. It would require mound development in the Gallup Sandstone and spreading laterally to either fault zone. Also, evidence strongly indicates that fracturing does not persist through the Mancos Shale.

The two deep wells will have permanent pumps installed for ease of sampling and can be used as a replacement stock water supply after the Polvadera Well has been abandoned. The Polvadera Well, along with two other old oil and gas test wells, will be sealed with cement and bentonite grout to the surface to prevent these wells from transmitting seepage water downward to degrade existing groundwater.

2. MONITORING

The well monitoring network will be constructed prior to the start of disposal operations, and baseline water level measurements will be made and samples will be collected for chemical analysis from the two deep wells (the shallow well system will be dry). After the start of operations, monthly water level measurements in all wells will be made. Water samples from the deep wells will be collected and analyzed quarterly. The shallow wells will also be sampled quarterly if sufficient water for sampling accumulates in them. The results of the monitoring program will be evaluated annually and submitted to the New Mexico Environmental Improvement Division (NMEID). Sampling and water level measurement frequency will be reviewed annually and adjusted to reflect monitoring requirements. Sampling and analytical techniques will conform with Subsection 3-107B of the amended Water Quality Control Commission Regulations dated January 11, 1977. Chemical analyses will include constituents listed under Section 3-103 for baseline monitoring and initial operational monitoring. With the review and concurrence of NMEID, analyses will be adjusted later during operations to include only constituents of concern.

3. THRESHOLD LEVELS

The criteria for setting threshold levels for corrective action in the event of degradation of existing groundwater will conform with Section 3-103 of the amended Water Quality Control Commission Regulations dated January 11, 1977. If seepage could penetrate the Mancos Shale, the first aquifer that seepage water could reach would be the Dakota Sandstone. This aquifer occurs more than 1000 feet below the lowest part of the disposal area. Chemical analysis of water from the Polvadera Well, shown in Table II-4, is the only available information believed to be representative of water from this aquifer. Additional baseline samples will be collected and analyzed prior to start of operations and will be used as more definitive criteria for threshold values. The sample from the Polvadera Well indicates concentrations of TDS at 2300 mg/l and chlorides at 800 mg/l, both of which far exceed drinking water standards. It is unlikely that this water could or would be used for anything other than limited stock watering in the foreseeable future. This, and additional analyses from deep monitoring wells, will establish threshold levels.

A realistic threshold for seepage and lateral spreading of perched groundwater is established by the seepage analyses. Saturation and perched mound development and spreading should occur in the Gallup Sandstone only beneath the evaporation pond. Saturation should not start developing until after approximately 16 years of pond operation. Therefore, if seepage water is detected in monitoring wells open to this unit before 16 to 18 years after the start of pond operations, then design threshold levels will have been exceeded. The detection of saturation in the Gallup Sandstone beneath the disposal trenches does not mean that groundwater degradation will occur, but it would indicate that seepage estimates have been exceeded and serves as an alert to this fact. If saturation in the Gallup Unit is detected beneath the disposal trenches or at an earlier time beneath the evaporation pond, seepage conditions will be re-analyzed using monitoring data to make the appropriate adjustments to provide better accuracy for seepage predictions. The monitoring program will be flexible so that additional wells can be added to fill data gaps as information is developed. The extremely long periods of time required for perched mound development and spreading provides an abundance of time to make adjustments. If the seepage rates indicated by monitoring appear to threaten the quality of existing aquifers, then preparation would be made for corrective actions. The rate of seepage movement and configuration of a seepage mound would provide information for design of corrective measures, if needed.

Detection of developme of perched saturated zones within the Dilco Unit would not indicate excessive seepage. It is reasonable to expect this to occur to some extent and it would indicate beneficial barriers against downward seepage to the more permeable Gallup Sandstone. Perched saturated zones within the Dilco Unit will be monitored closely to determine the extent and rate of seepage. Additional monitoring wells will be provided, if needed. If necessary, corrective measures will be formulated to contain lateral spreading beyond the area of the facility.

4. CONTINGENCY PLANS

The primary contingency plan is to periodically evaluate monitoring data to verify seepage estimates. If seepage predictions are exceeded, conditions will be reanalyzed to determine if existing aquifers are threatened with contamination. These updated analyses based on observed water levels and water quality will then be used to design remedial measures, if needed.

Corrective measures will be initiated if it appears that the quality of groundwater in the saturated zone of the Gallup sandstone, which may, or could conceivably be used as a domestic or agricultural water supply in the reasonably foreseeable future, could be degraded beyond the standards of Section 3-103 of the Regulations. Corrective measures could include, for instance, hydraulic barriers and/or grout curtain.

Perched saturated zones within the Dilco Unit will probably be relatively easy to intercept with open drainage trenches. Open drains will be constructed around the perimeter of the tailings burial trenches. Additional trenches will be added downslope from the planned drains if monitoring data indicates they are needed.

If deep percolation to the Dakota Sandstone is detected, then pumping the two deep monitoring wells could contain contaminants in the immediate area. However, additional deep pumping and monitoring wells would be considered, depending on the hydraulic characteristics of this aquifer and the degree of degradation. Direct contamination of the Dakota Sandstone would require an undetected fracture zone penetrating the Mancos Shale in the disposal area and failure of the pond lining systems. This is considered to be the most improbable scenario for groundwater degradation.

If seepage discharges from the Gallup Sandstone to the recent alluvium to the east, then dewatering wells would be constructed in the alluvium along the buried channels. Monitoring wells S-8 and S-6 can be used as dewatering wells. If these wells are used for dewatering the alluvium, additional monitoring wells would be developed downstream toward the mouth of La Polvadera Canyon. This system will take full advantage of the buried channels which will act as natural drains.

5. POST OPERATIONAL MONITORING

After waste disposal operations cease, monitoring of both shallow and deep wells will continue until the seepage flow system can be predicted with reasonable confidence. Tentatively, monitoring will continue at least five years after operations cease. By this time, the seepage predictions should be so well validated that monitoring can cease or at least be reduced to a few key wells monitored at extended intervals of time. Emphasis should be placed on periodic re-evaluation of monitoring data and upgrading seepage analyses so that flexibility is maintained throughout the program. A fixed, inflexible routine should be avoided so that any unpredictable conditions can be handled easily and in a timely manner. Rates of movement of any saturated flow will be very slow, providing ample time to adjust the monitoring program and to activate contingency plans if needed, after careful analysis of monitoring data.

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SECTION III

THE TAILINGS PIPELINE

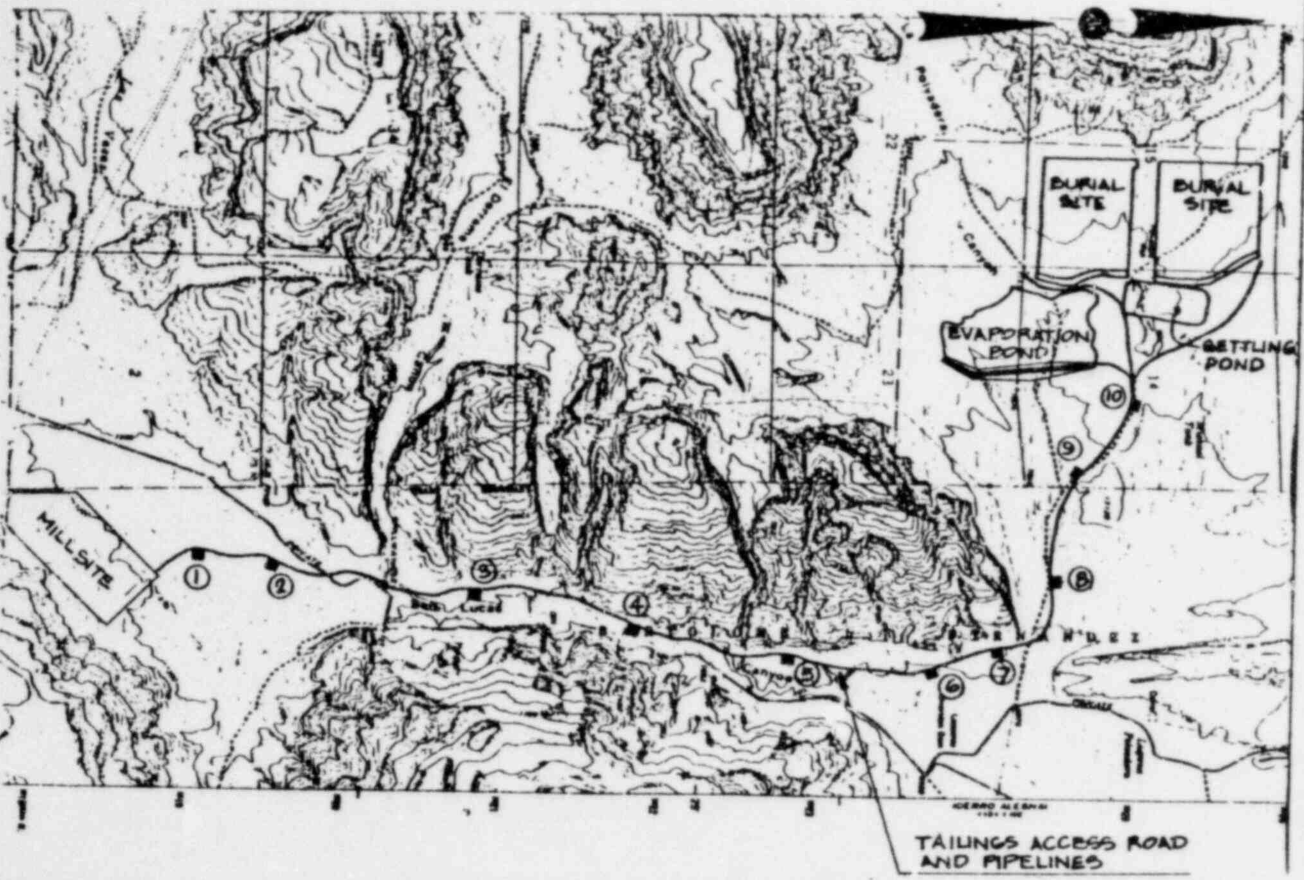
A. DESCRIPTION

The tailings pipeline parallels San Lucas Canyon from the mill site to the La Polvadera tailings disposal area, a distance of approximately six miles. The major features of the system are a diked and lined pipeway, ten containment basins located at low points along the route, and a service road immediately adjacent to the pipeway. The entire length of the road and pipeway is fenced to restrict access. The tailings pipeline route and location of the containment basins are shown on Figure III-1.

The route of the pipeline from the mill to the tailings disposal area is primarily dependent upon the topography of the area. The route which has been chosen minimizes elevation changes along the route, allows room for the construction of an access road, and is situated far enough above the bed of the arroyo in San Lucas Canyon that the pipeline will lie above the 100-year floodplain.

The mill includes facilities for separating the sands fraction from the total tailings when sands are required for mine backfill. Significant statistics associated with the design of the pipeline are listed below:

• length	6 miles
• flow	500-1500 gpm
• velocity	6-10 feet per second
• weight % solids	21-55%
• pipe size	1-6 inch; 1-8 inch
• pipe wall thickness	1/4 inch carbon steel
• pipe liner thickness	1/4 inch rubber
• pipeline couplings	victaulic
• design pressure ratings	
pipeline	1200 psig
fittings & couplings	800 psig



TAILINGS PIPELINE CATCHMENT PONDS

Pond No.	Drainage Length (Ft)	Pond Volume (Gal x 10^3)	Pond Surface Area (Sq Ft x 10^3)	100 Year Flood Impoundment (Gal x 10^3)	Free-board (Inches)
1	1285	299	16.5	125	20
2	2715	320	17.6	182	14
3	4510	377	19.3	253	10
4	4090	241	13.3	224	6
5	2740	305	16.8	181	13
6	3410	272	15.0	202	8
7	1180	272	15.0	118	19
8	1580	345	19.0	142	20
9	3890	771	42.0	278	21
10	2420	1386	33.0	203	61

FIGURE III-1
TAILINGS PIPELINE CONTAINMENT BASINS

1. PIPEWAY DESIGN

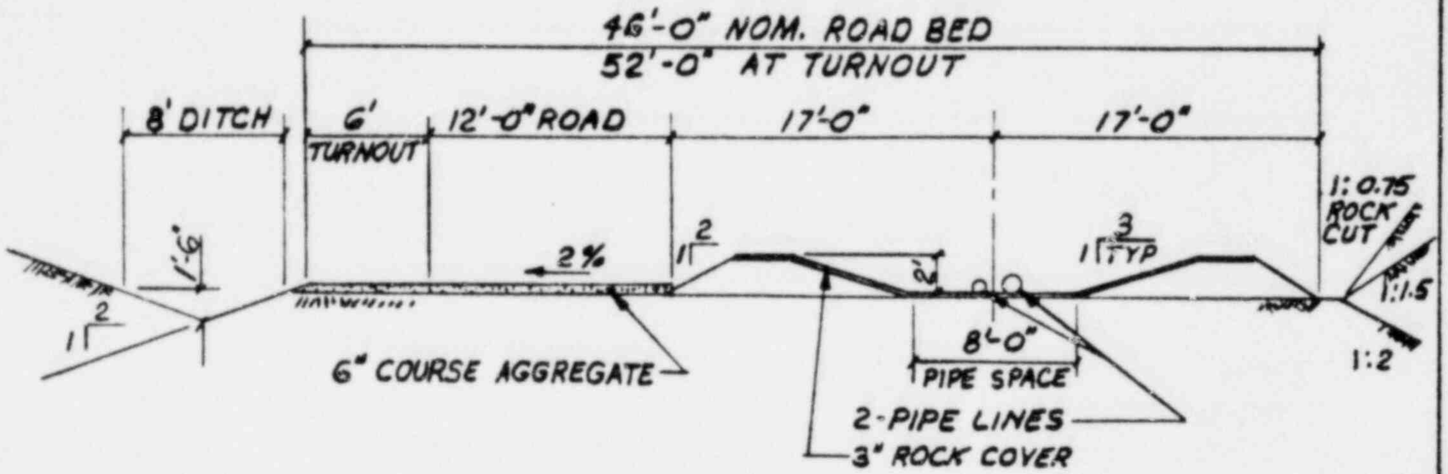
The entire length of the pipeline lies within a rip-rapped pipeway. The two foot high dikes will be constructed of earth, compacted to 95% modified proctor density, and will be rip-rapped. This design will prevent erosion within the pipeway. A schematic cross-section of the pipeway is shown in Figure III-2.

At three points along the pipeline route, the tailings pipelines will cross major drainage channels. At these crossings a concrete pipeway of the same dimension as the rip-rapped pipeway and supported by a concrete trestle will contain the pipelines. Corrugated metal pipe culverts will provide drainage for minor channels beneath the pipeway.

A service road will parallel the entire length of the pipeline. The road is designed so that visual inspection of the pipeline can be made from the road surface. In addition, a walkway will be provided atop the protective dikes for access. The entire road/pipeway is fenced and access will be limited to authorized personnel.

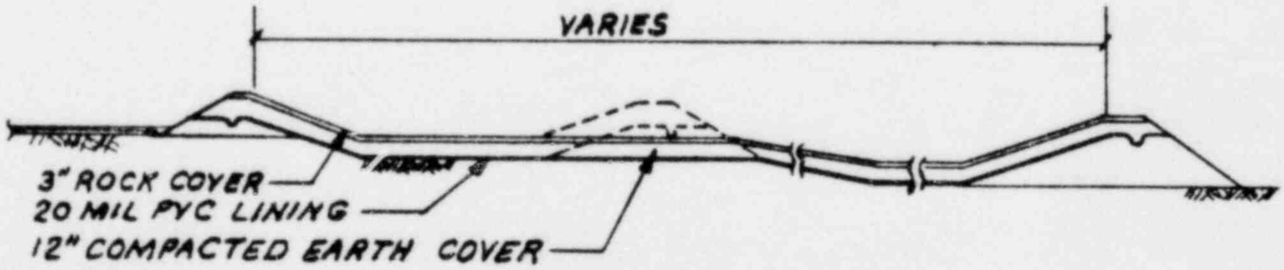
At each low point along the pipeway route a catchment basin will be constructed. Each catchment basin is sized to hold, with ample freeboard, the full volume contained between adjacent high points in the pipeline plus an additional ten minutes flow in two pipelines, and precipitation from a hundred year storm. Each catchment basin will be lined with PVC and overlain with protective earth and rock blankets. The low point catchment basins are identified on Figure III-1, along with the relevant statistics concerning each of the catchment basins. The pipeline route, including details regarding the locations of the trestles along the route and elevations along the route, can be found in the civil engineering drawings in Appendix A.

Detailed hydrological studies were undertaken of the San Lucas Canyon drainage to determine the impact of flooding on the tailings pipeline. The analysis indicates that the San Lucas Dam spillway will be over-topped during a 100 year flood and that the water level behind the dam will be approximately four feet above the spillway. It is not anticipated that water will be above the level



TYPICAL SECTION

SERVICE ROAD & TAILINGS PIPEWAY



TYPICAL SECTION

TAILINGS PIPEWAY @ CATCHMENT BASIN

1" = 10'-0"

FIGURE III-2
TAILINGS PIPELINE CROSS SECTION

of the crest of the San Lucas Dam during a 100 year flood. Figures III-3 and III-4 show the water surfaces predicted during probable maximum floods and a 100 year flood, respectively.

The flood plain studies of San Lucas Canyon indicate that the tailings pipeline will remain above the flood level expected during a 100 year storm. To provide assurance that the operation of the tailings pipeline will have a minimal potential for environmental impact due to flood damage, Gulf will cease the pumping of mill tailings when it appears that the pipeline is threatened. During periods of heavy storms and flooding, the water level behind San Lucas Dam will be monitored. When it is observed that the pipeline is endangered, an immediate and orderly shutdown of the mill tailings system will occur. This will consist of the cessation of the pumping of tailings and a flushing of the pipeline with industrial water. Prior to restarting the pipeline, a visual inspection of the entire pipeline length will be made to insure that no flood damage has occurred. Start-up of the pipeline will use industrial water until it is determined that no leakage is occurring.

2. PIPELINE

The tailings transport system is composed of two pipelines installed within a rip-rapped pipeway. During normal service, one pipeline will transport tailings slurry and one will decant excess liquor from the evaporation pond to the mill for continued use as slurry transport water. In the event of a rupture or leak of the tailings slurry pipeline which would require shut down of that pipeline, the pipeline normally utilized for liquor transport will be used for tailings slurry transport until the primary slurry pipeline is repaired. The specific details concerning the design of the pipeline system follow.

Extensive studies were undertaken to develop criteria for the design of the tailings pipeline. Included in these studies were inspection trips to mills operating with similar cross-country slurry pipes. A discussion of these

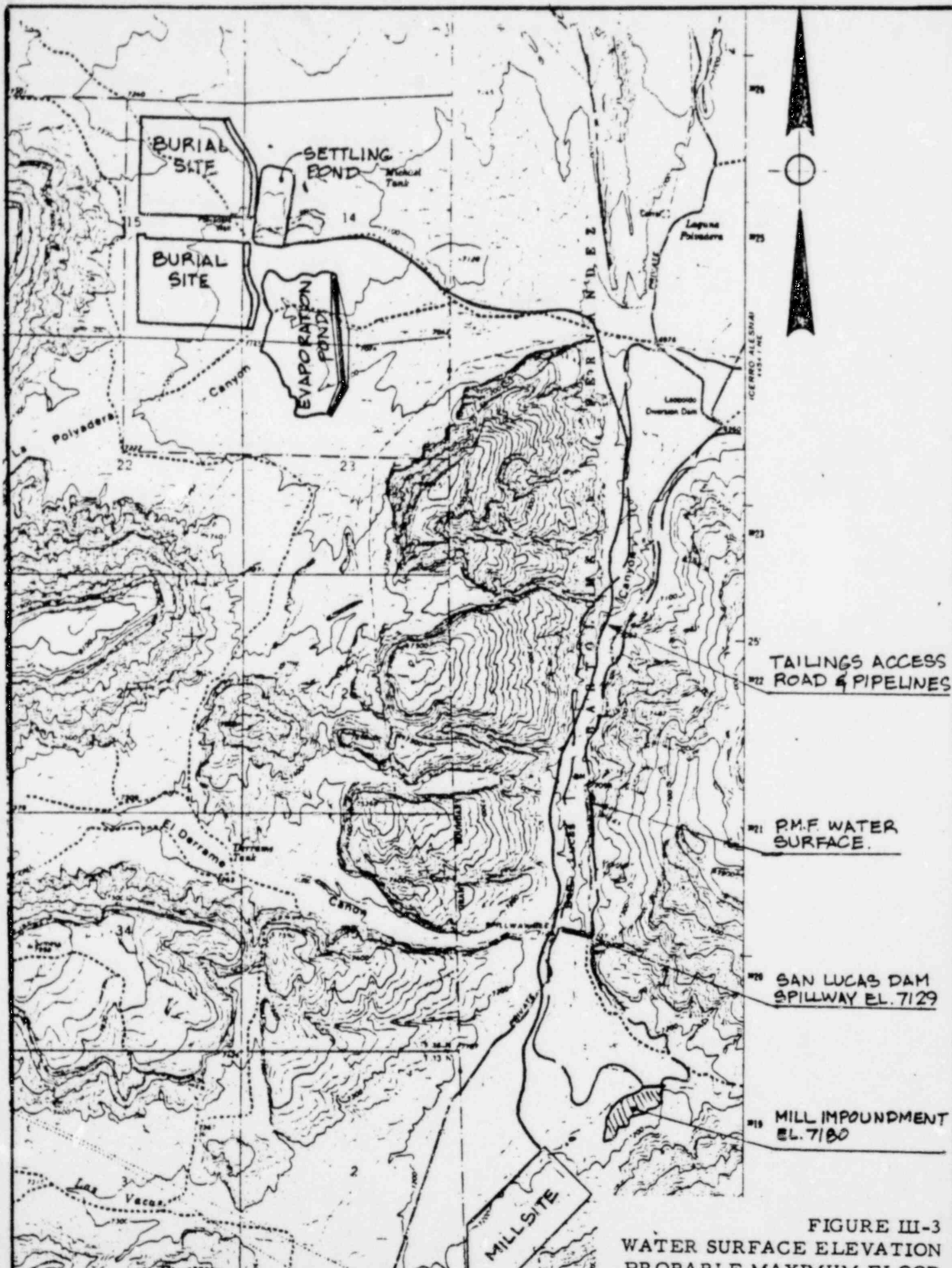


FIGURE III-3
WATER SURFACE ELEVATION
PROBABLE MAXIMUM FLOOD

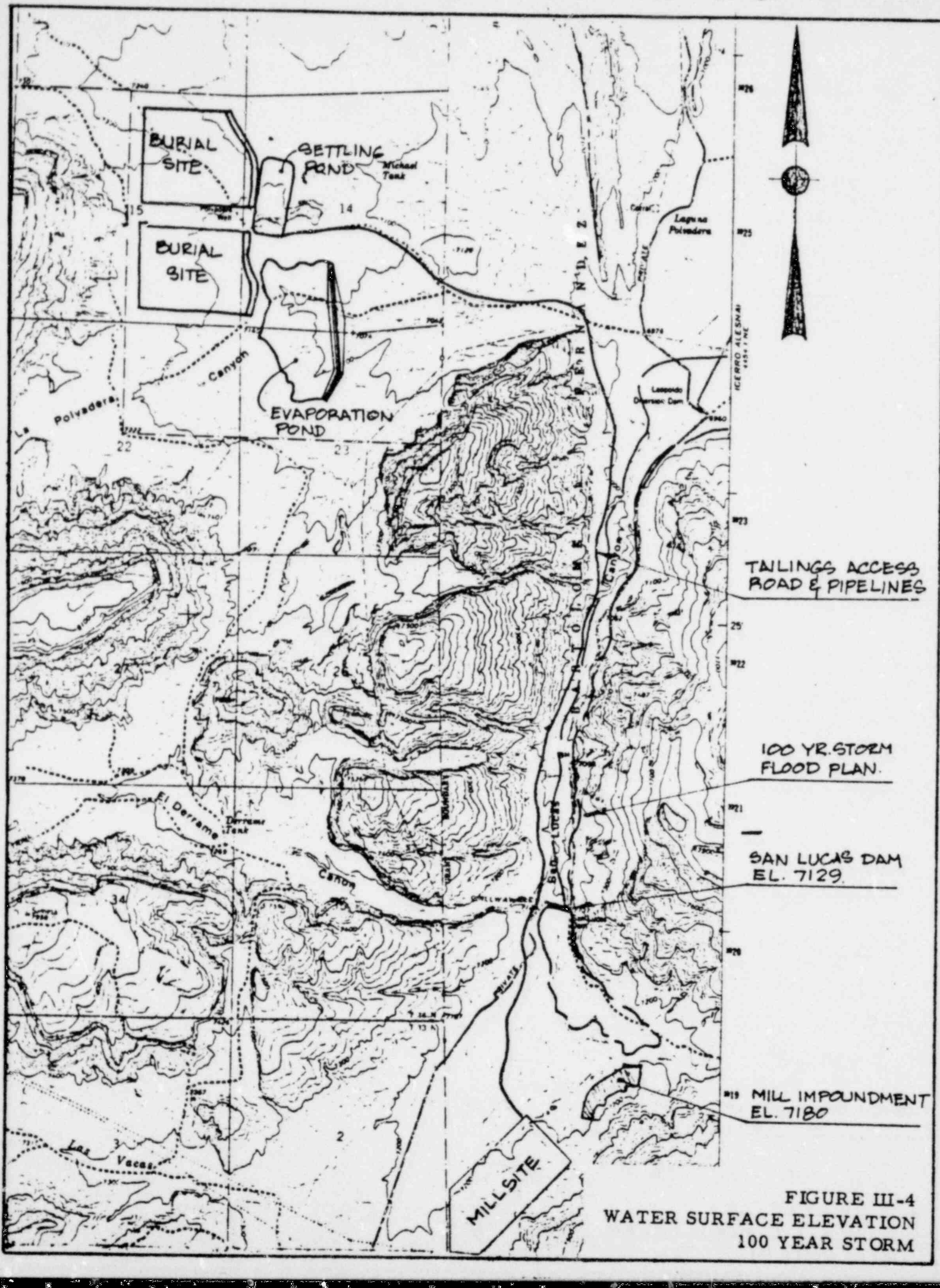


FIGURE III-4
WATER SURFACE ELEVATION
100 YEAR STORM

sites is included in Appendix B. The overriding consideration in the selection of pipeline materials, pumps, controls, etc. was safety, reliability and maintainability.

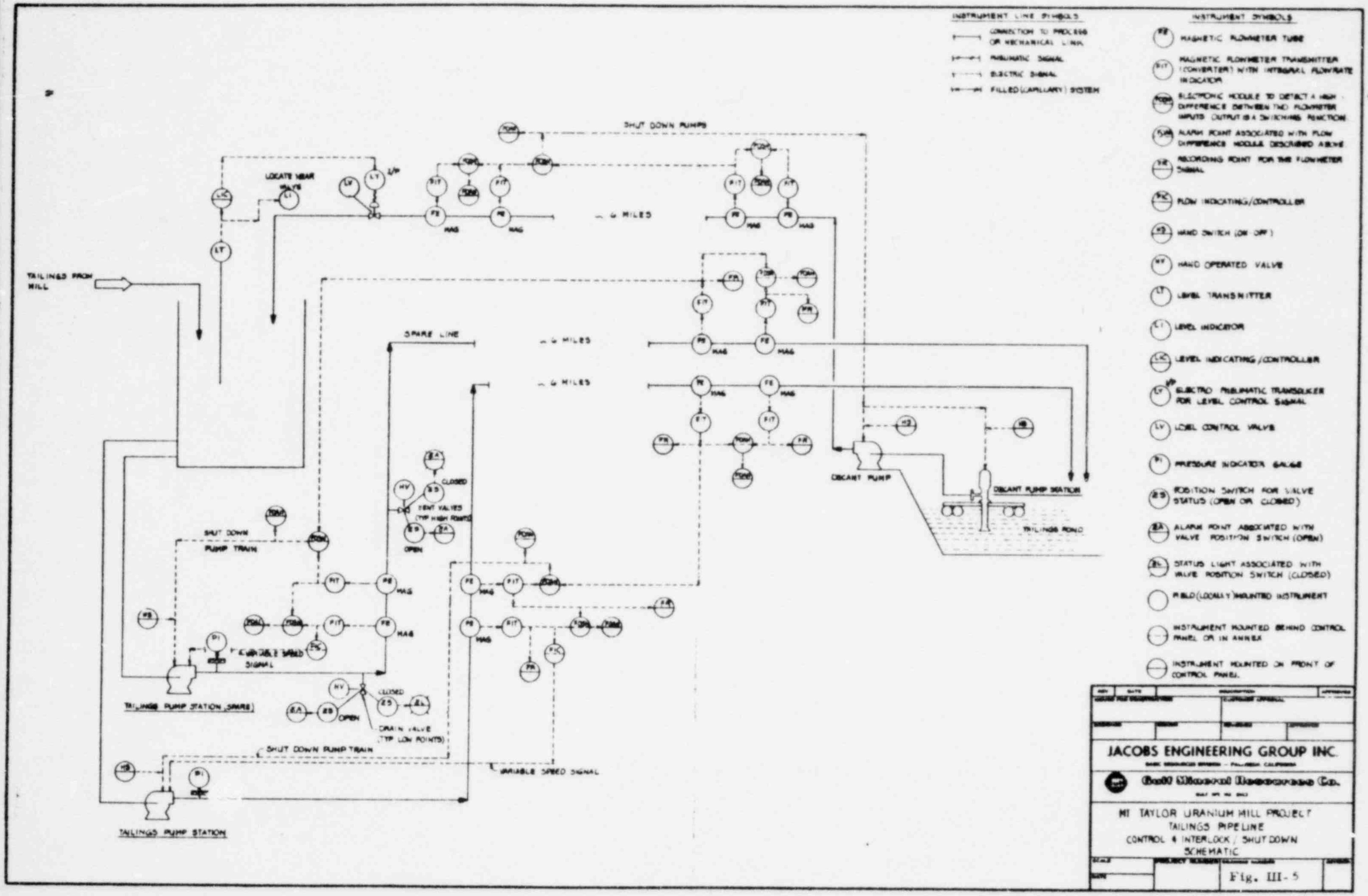
Due to the low pH of the tailings, an acid resistant piping is required. Of the two primary alternatives, rubber-lined steel piping and acid resistant plastic piping, the plastic piping was rejected because, due to the length of the pipeline, utilization of this piping would have required multiple pump stations along the pipeway route. Multiple pump stations would not only have increased the complexity of the pipeline operation but would greatly increase the risk of accidental spills along the route. For safety and ease of maintenance, it was decided to transport the tailings slurry using a single lift pump station located within the mill. Utilization of a single lift to transport the tailings a distance of six miles necessitates the use of steel pipe. Industry experience with properly designed and maintained rubber-lined pipe shows excellent service in terms of reliability, longevity, and safety (see Appendix B).

The tailings pipeline is to be constructed of rubber-lined carbon steel, schedule 30 pipe. The pipeline will have a design pressure rating of 1200 psig with fittings and couplings rated at 800 psig. The pipe sections will be joined by victaulic type couplings for ease of maintenance. A detailed specification for the pipeline rubber lining is included in Appendix C.

The pipeline will be constructed of standard length sections so that an inventory of replacement sections can be maintained. Test spools of shorter lengths will be placed at appropriate locations for ease of inspection.

3. CONTROL SYSTEMS

The tailings transport system is designed with multiple and redundant control systems that will minimize the possibility of spills and, in the event of an accident, preclude the release of unmanageable quantities of radioactive materials. A schematic drawing of the control systems is shown on Figure III-5. A discussion follows.



INSTRUMENT LINE SYMBOLS
CONNECTION TO PROCESS OR MECHANICAL LINK
PNEUMATIC SIGNAL
ELECTRIC SIGNAL
FILLED (CAPILLARY) SYSTEM
INSTRUMENT SYMBOLS
MAGNETIC FLOWMETER TUBE
MAGNETIC FLOWMETER TRANSMITTER (CONVERTER) WITH INTEGRAL FLOWRATE INDICATOR
ELECTRONIC MODULE TO DETECT A HIGH DIFFERENCE BETWEEN TWO FLOWMETER INPUTS. OUTPUT IS A SWITCHING FUNCTION
ALARM POINT ASSOCIATED WITH FLOW DIFFERENCE MODULE DESCRIBED ABOVE
RECORDING POINT FOR THE FLOWMETER SIGNAL
FLOW INDICATING/CONTROLLER
HAND SWITCH (ON OFF)
HAND OPERATED VALVE
LEVEL TRANSMITTER
LEVEL INDICATOR
LEVEL INDICATING/CONTROLLER
ELECTRO PNEUMATIC TRANSDUCER FOR LEVEL CONTROL SIGNAL
LEVEL CONTROL VALVE
PRESSURE INDICATOR GAUGE
POSITION SWITCH FOR VALVE STATUS (OPEN OR CLOSED)
ALARM POINT ASSOCIATED WITH VALVE POSITION SWITCH (OPEN)
STATUS LIGHT ASSOCIATED WITH VALVE POSITION SWITCH (CLOSED)
FIELD (LOCALLY) MOUNTED INSTRUMENT
INSTRUMENT MOUNTED BEHIND CONTROL PANEL OR IN ANNEX
INSTRUMENT MOUNTED ON FRONT OF CONTROL PANEL
TAILINGS FROM MILL
LOCATE NEAR VALVE
SHUT DOWN PUMPS
~ 6 MILES
SPARE LINE
~ 6 MILES
~ 6 MILES
DECANT PUMP
DECANT PUMP STATION
TAILINGS POND
SHUT DOWN PUMP TRAIN
VENT VALVES (TYP HIGH POINTS)
CLOSED
OPEN
VARIABLE SPEED SIGNAL
TAILINGS PUMP STATION (SPARE)
DRAIN VALVE (TYP LOW POINTS)
SHUT DOWN PUMP TRAIN
VARIABLE SPEED SIGNAL
TAILINGS PUMP STATION
JACOBS ENGINEERING GROUP INC.
MT TAYLOR URANIUM MILL PROJECT
TAILINGS PIPELINE
CONTROL & INTERLOCK / SHUT DOWN
SCHEMATIC

Fig. III-5

Pump Station

A single pump station is provided for tailings transport and is located within the mill. Any spills or releases of tailings within the pump station will be contained within sumps and the containment basin within the mill exclusion area. Pumping of tailings is accomplished by multi-stages of centrifugal pumps operating in series, that is, each pump will feed the suction of the following pump. The last pump in the train feeds the tailings pipeline. The first and last pump in the series is provided with a variable speed drive for process control. A complete series of spare pumps is provided. The pumps are sized such that they will have a maximum shutoff pressure of 650 psig, which is well below the design pressure rating of the pipeline.

Control and Interlock Systems

The primary feature of the pipeline control system is redundant flowmeters placed on both the inlet and outlet of each pipeline. The pairs of flowmeters on each end of a pipeline will automatically compare flow against each other and alert the operators of any malfunction in the instrumentation.

Flow differential of five percent between the flowmeters at the inlet and outlet of the pipeline will trigger an alarm. The operator will make an immediate inspection of the pipeline to assess the problem. Automatic shutdown of the pump train will occur if flow differential reaches 10 percent. The pipeline operator can utilize the spare pump train and spare pipeline but cannot stop the shutdown procedure of the affected line. Shutdown of the pumps will occur simultaneously with the detection of the 10 percent flow difference; however, it is estimated that the momentum of the flow of fluids within the pipeline will continue flow for a period of about ten minutes. It is conservatively estimated that the flowmeters will detect flow differentials of two percent of the flow within the pipeline.

The drain and vent valves are provided with alarms displayed in the central control room. This will alert the operator so that corrective action can be initiated. The vent valves are small valves atop the pipeline at the high points to allow for release of air. The drain valves are located at the low points of the pipeline immediately adjacent to the low point catchment basins. A flow of greater than five percent of the pipeline flow through the drain valves will trigger the differential flowmeters and alarm. Immediate pipeline inspection will follow. Automatic shutdown of the pipeline will commence if flow differential reaches 10 percent.

Of critical importance to maintaining the integrity of the pipeline are the planned maintenance and inspection schedules. Physical inspection of the entire length of the pipeline will be accomplished by having a pipeline inspector traverse the round trip distance from the mill to the tailings impoundment twice per shift, or in accordance with good engineering practice. Clock stations will be installed at both ends of the pipeline route to provide records of the inspection schedule. The pipeline inspector will be equipped with a radio for alerting the mill operators to any conditions requiring immediate attention. Therefore, in case any leak is detected, repair of the pipeline, and the removal of tailings accumulated within the catchment basin will be initiated, minimizing any potential adverse impacts to the environment.

At locations that will experience the most critical wearing of the rubber lining, short spool sections will be installed that can be easily removed for detailed inspection. The results of the inspection of the test spools will dictate when pipeline sections should be replaced. Ultrasonic testing of sections most susceptible to wear will be conducted quarterly by a qualified technician.

TABLE III-1

GROUNDWATER QUALITY
SAN LUCAS WASH, NEW MEXICO

Parameter	Well SL-1 Quat. Alluvium 10/23/79	Well SL-2 Pt. Lookout 10/18/79	Well SL-3 Menefee 10/13/79
pH	8.0	7.9	7.5
TDS (calc.)	672	595	2,299
Elec. Cond.	1,010	909	2,970
Temperature	11.9	14.7	13.8
HCO_3^-	454	419	785
$CO_3^=$	---	---	---
Cl^-	18	10	20
$SO_4^=$	202	156	1,120
F^-	0.8	0.2	0.3
NO_3^-	0.09	0.04	0.13
Na^+	70	109	460
K^+	1.7	3.0	15
Ca^{++}	75	75	205
Mg^{++}	69	27	73
SiO_2	12	9	20
As	<0.01	<0.01	<0.01
Ba	0.90	0.45	1.0
Cd	<0.005	<0.005	<0.005
Cr	<0.02	<0.02	<0.02
Pb	0.02	0.01	0.03
Hg	<0.0002	<0.0002	<0.0002
Se	<0.002	<0.002	<0.002
Ag	<0.005	<0.005	<0.005
Cu	0.010	0.005	0.020
Fe	0.10	<0.01	0.17
Mn	0.55	0.02	0.53
Zn	0.25	0.26	0.62
Al	0.2	<0.1	0.1
B	0.15	0.25	0.85
Co	<0.01	<0.01	<0.01
Mo	<0.05	<0.05	<0.05
Ni	<0.02	<0.02	<0.02

TABLE III-1
(continued)

Parameter	Well SL-1 Quat. Alluvium 10/23/79	Well SL-2 Pt. Lookout 10/18/79	Well SL-3 Menefee 10/13/79
V	<0.05	<0.05	<0.05
PO_4 (as P)	<0.01	<0.01	<0.01
Uranium	<0.013	<0.006	<0.006
Radium-226	0.06±0.03	0.41±0.03	2.9±0.03
Radium-228	<1.0	2.0±1	<1.0
Radium-226 + Radium-228	<1.06	2.41	<3.9
Gross Alpha	<5.0	<7.0	<7.0

Note: All analyses are in mg/l except pH which is in units, electricl conductivity which is in umhos/cm @ 25° C, temperature which is in degrees C, and radionuclides concentrations which are in pCi/l.

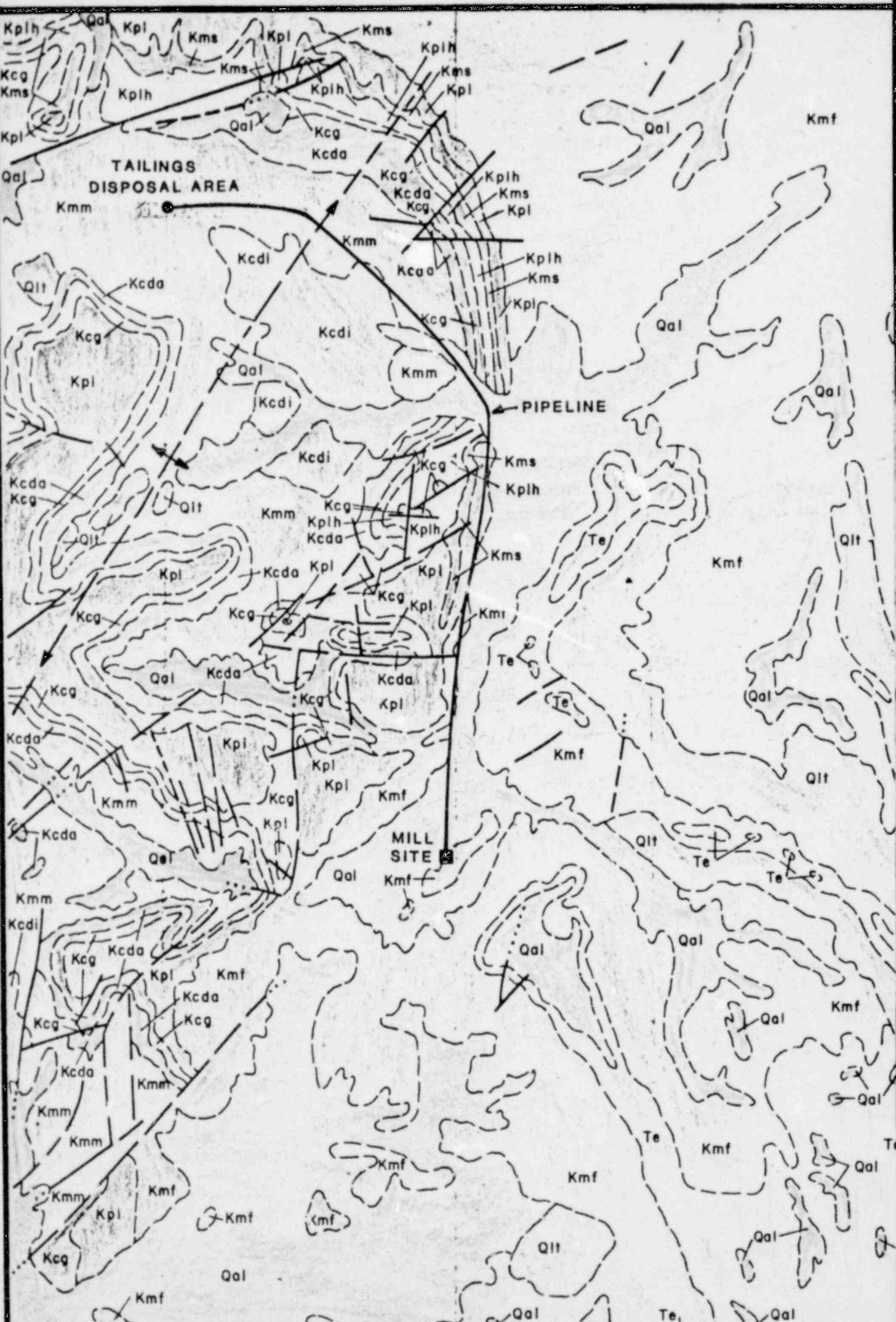
B. SITE CONDITIONS

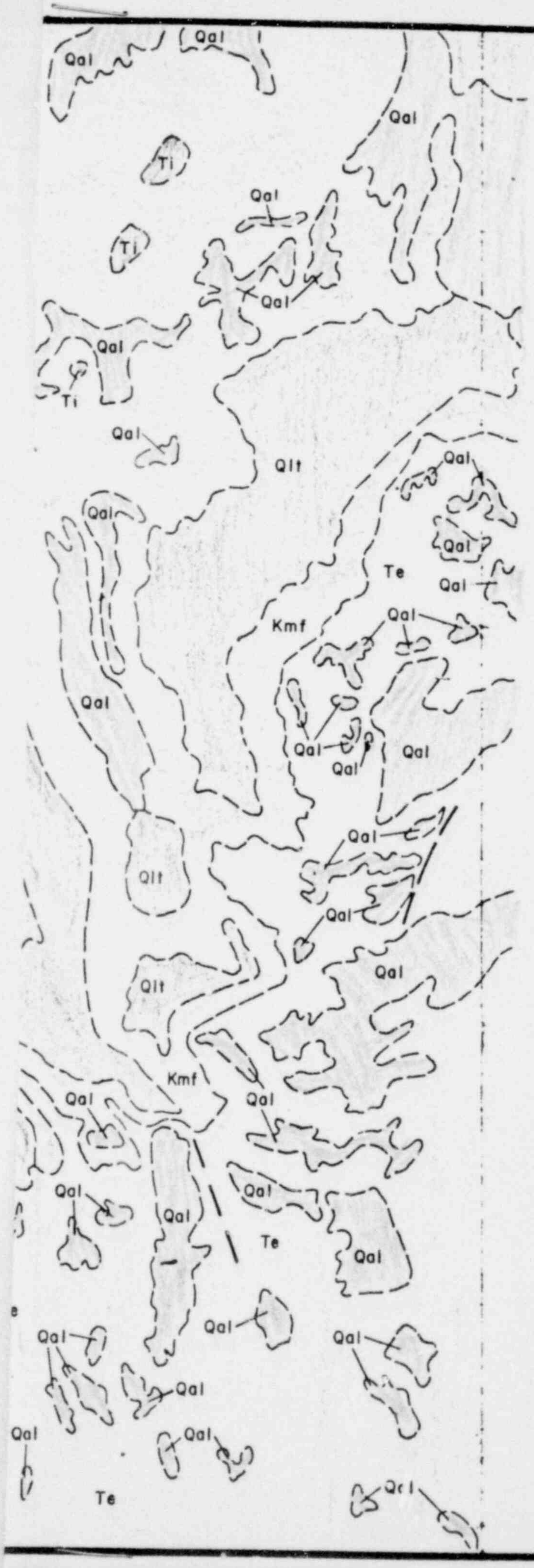
As shown on Figure III-6, the tailings pipeline heads due north approximately four miles from the mill site where it veers to the west approximately two miles to the tailings disposal area. Along its due-north course, the pipeline lays directly west of an unnamed arroyo in the San Lucas Canyon, hereafter referred to as San Lucas Wash. The pipeline will be constructed along the exposed flanks of the San Mateo Dome. The surficial deposits and exposed bedrock along this section of the pipeline route consists of Quaternary alluvium, siltstones and sandstones of the Menefee formation, and the Point Lookout Sandstone. Due to the discharge of treated mine water into San Lucas Wash, its natural hydrologic regime has been altered. As a result, the alluvial material subjacent to the stream bed is saturated, and it seems plausible that the alluvium, the Menefee and Point Lookout formations are being recharged, to some extent, by the treated discharge water.

In an attempt to understand the hydrologic regime that presently exists in San Lucas Wash, and that will continue to exist during the life of the project, a study was initiated. That study, entitled, "Hydrologic Effects - Tailings Pipeline and Mill Site Facilities, Mt. Taylor Uranium Mill Project, New Mexico, November 30, 1979," is enclosed as Appendix D to this discharge plan. The following discussion of site conditions within San Lucas Wash is extracted from the referenced study.

Based upon geologic conditions along San Lucas Wash and the results from three hydrologic test wells which were drilled therein, the recharge relationship within the Wash and a hydrogeologic cross-section of the Wash has been developed (Figures III-7 and III-8, respectively). The location of the lines of cross-section can be found in Appendix D, Plate II.

Water samples from each of the test wells were taken and the results can be found on Table III-1. The water quality in the alluvium and in the Point Lookout formation is generally good although the level of manganese in alluvial groundwater exceeds groundwater standards set forth in the Regulations. The


TAILINGS DISPOSAL AREA
PIPELINE
MILL SITE
Kplh
Kpl
Kms
Kcg
Kcda
Kcdi
Kmm
Kmf
Qal
Qlt
Te


Qal
Ti
Qlt
Kmf
Te
Qcl

N

1/2 0 1

SCALE IN MILES

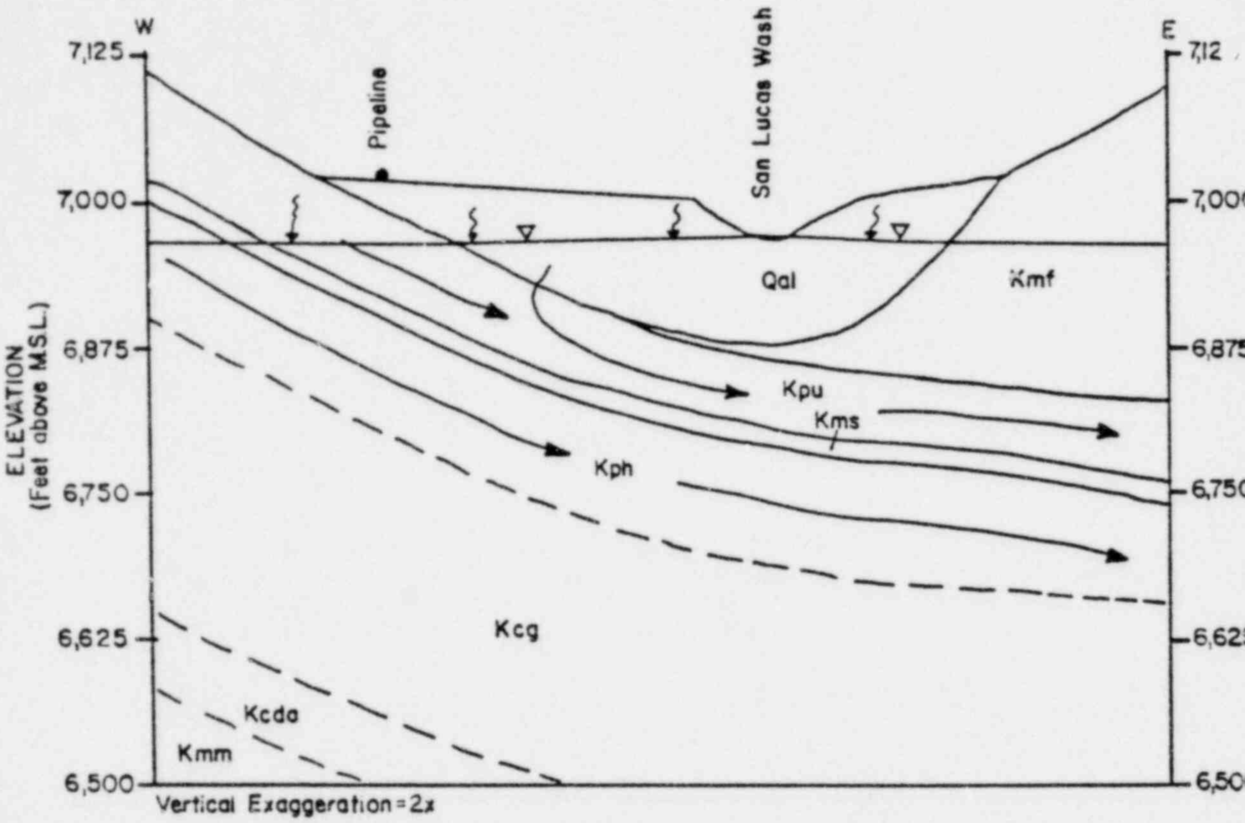
LEGEND

Qlt	LANDSLIDE AND TALUS MATERIAL
Qal	ALLUVIUM (SILT, CLAY WITH OCCASIONAL GRAVELLY LENSES)
Te	BASALT, ANDESITE AND OTHER EXTRUSIVE ROCKS
Ti	ANDESITE AND OTHER INTRUSIVE ROCKS
Kmf	MENEFEE FORMATION (INTERBEDDED SILTSTONE AND FINE TO MEDIUM GRAINED SANDSTONE)
Kpl	POINT LOOKOUT SANDSTONE, MAIN BODY
Kplh	POINT LOOKOUT SANDSTONE, HOSTA TONGUE
Kcg	CREVASSE CANYON FORMATION, GIBSON COAL MEMBER (INTERBEDDED SANDSTONE, SILTSTONE, SHALE AND COAL BEDS)
Kcda	CREVASSE CANYON FORMATION DALTON SANDSTONE MEMBER
Kcdi	CREVASSE CANYON FORMATION, DILCO COAL MEMBER (INTERBEDDED SANDSTONE, SHALE AND COAL BEDS)
Kms	MANCOS SHALE, SATAN TONGUE (INTERBEDDED SANDSTONE, SILTSTONE AND SHALE)
Kmm	MANCOS SHALE, MULATTO TONGUE (INTERBEDDED SHALE AND SANDSTONE)
	CONTACT BETWEEN GEOLOGIC FORMATION, APPROXIMATELY LOCATED.
	FAULT, DASHED WHERE LOCATED APPROXIMATELY; QUERRIED WHERE PROBABLE; DOTTED WHERE CONCEALED; U, UPTHROWN SIDE; D, DOWNTHROWN SIDE.
	ANTICLINE, SHOWING CREST LINE AND PLUNGE.

SOURCE: MODIFIED FROM COOPER AND JOHN, 1968.

GEOLOGY MAP

FIG. III-6



EXPLANATION

QUAT.
- Qal — Alluvium

CRETACEOUS
- Kmf — Menefee Formation
- Kpu — Point Lookout Sandstone, upper member
- Kms — Mancos Shale, Satan Tongue
- Kph — Point Lookout Sandstone, Hosta Tongue
- Kcg — Crevasse Canyon Formation, Gibson Coal Member
- Kcda — Crevasse Canyon Formation, Dalton Sandstone Member
- Kmm — Mancos Shale, Mulatto Tongue

Contact, dashed where approximate

Ground-water table or potentiometric surface

Probable direction of ground-water flow.

Possible infiltration in unsaturated material

SCALE 1: 3,000

0 250 500

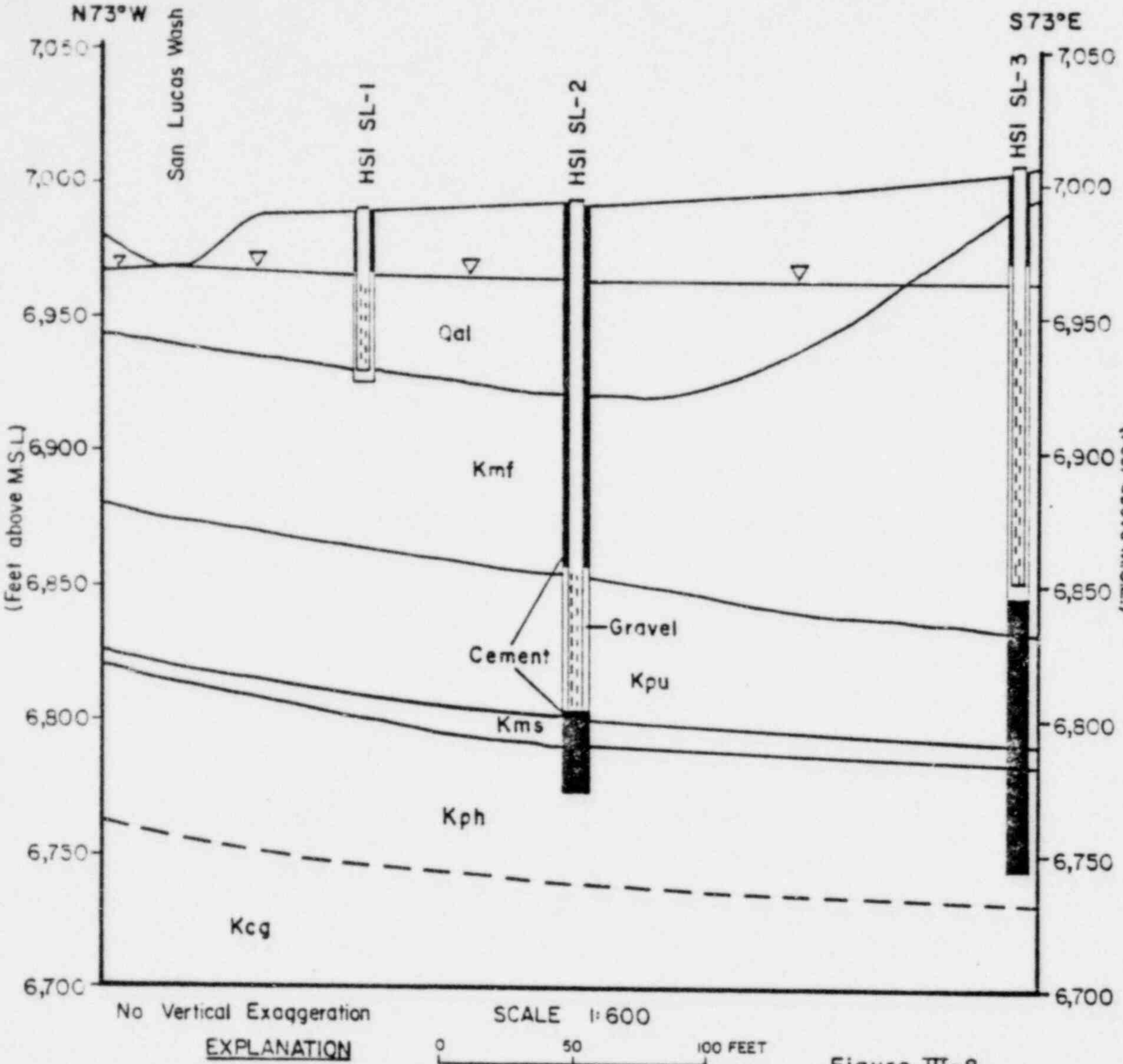
See Plate II for line of cross section

Figure III-7

GENERALIZED EAST-WEST HYDROGEOLOGIC CROSS SECTION ACROSS SAN LUCAS WASH MCKINLEY COUNTY, NEW MEXICO

GULF MINERAL RESOURCES CO. — JACOBS ENGINEERING GROUP, INC.	HYDRO-SEARCH, INC. Geologists · Hydrologists Reno · Austin · Denver Project No. 1201-79

11-79



EXPLANATION
(See Figure 2)
See Plate II for line of cross section

Figure III-8

DETAILED HYDROGEOLOGIC CROSS SECTION ACROSS SAN LUCAS WASH MCKINLEY COUNTY, NEW MEXICO

GULF MINERAL RESOURCES CO. — JACOBS ENGINEERING GROUP, INC.	HYDRO-SEARCH, INC. Geologists · Hydrologists Reno · Austin · Denver Project No. 1201-79

11-79

water in the Menefee formation is poor, with rather high TDS and sulfate levels. In addition, Menefee water exceeds groundwater standards for manganese and cobalt.

That portion of the pipeway that enters into La Polvadera Canyon will cross over the Dilco Coal Member of the Crevasse Canyon formation, the Mulatto Tongue Member of the Mancos Shale, and surficial alluvium. None of these units presently contain saturated material, except for some possible minor perched zones in the alluvium beneath intermittent stream channels.

C. ANALYSIS OF POTENTIAL DISCHARGES TO GROUNDWATER

The potential for accidents related to the operation of the tailings transport system will be minimized through proper design, construction and operation. Not withstanding the above safeguards, it is prudent to consider the consequences of accidents that could potentially release radioactive materials or hazardous chemicals to the environment. Therefore, accidents which conceivably could occur during operation have been conceptualized and their environmental impacts evaluated.

The specific activities of the radiological materials handled at a uranium mill are very low; i.e., approximately 1×10^{-8} Ci/g* for the ore and tailings, and about 6×10^{-7} Ci/g* for the refined yellowcake products. The quantities of materials handled, on the other hand, could be relatively large; i.e., 4200 tons of tailing solids per day.

Postulated pipeline accidents involving radioactivity are considered here in the following three categories:

- trivial incidents; i.e., those not resulting in a release to the environment
- small releases to the environment
- large releases to the environment.

---

*In contrast to the relatively high specific activities of a number of prominent radionuclides; e.g., approximately 10^{-1} Ci/g for Pu-239 and approximately 10^{-3} Ci/g for Co-60.

1. TRIVIAL INCIDENTS

Trivial incidents are those that result in no release of radioactive material to the environment. The tailings pipeline is placed within a diked and rip-rapped pipeway that will contain small leaks. The diked pipeway will direct the leak to the low point catchment basin. Differential flowmeters are placed on the inlet and exit of the pipeline and will detect flow differences as small as 30 gallons per minute (2% of flow). In addition, the pipeline is visually inspected twice per shift. Not withstanding the above, it is conceivable that a small leak up to 70 gallons per minute (5% of flow) could go undetected within the dikes. In such a case, the rising liquid level within the catchment basin would alert the pipeline inspector and corrective action would be initiated. The tailings slurry contained within the lined catchment basin would be removed by appropriate means and disposed of in the tailings disposal area.

2. SMALL RELEASES

Small quantities of radioactive material could be released to the environment as a result of a small leak in the upper quadrant of the tailings pipeline. Differential flows greater than 140 gallons per minute between the inlet and exit of the pipeline will initiate a pipeline shutdown. A flow between 70 and 140 gallons per minute will trigger an alarm. Immediate inspection of the pipeline will follow. A pinhole leak of less than 70 gallons per minute in the upper quadrant of the pipeline could spray over the top of the pipeway dikes and remain undetected for up to a two hour period. The total release during this time would be a maximum of 8400 gallons of tailings slurry or decant return water. Upon the discovery of a pipeline leak, the pipeline inspector will initiate action to prevent continued leakage. A crew trained in the isolation and cleanup of radioactive materials would be dispatched from the mill.

Cleanup would most likely consist of collecting all contaminated materials and disposing of them within the tailings disposal area. A final scan of the affected area would then be made in order to assure that radiation levels in the soil have been reduced to near background levels, or as low as reasonably achievable. The area would then be reclaimed to its approximate original contour and vegetative cover.

The NMEID would, of course, be notified of any such accidental spill. All monitoring and sampling data, including personnel exposure evaluations, can be reviewed by NMEID. With the concurrence of NMEID, decontamination efforts will cease.

3. LARGE RELEASES

In the unlikely event of a pipeline rupture, an automatic system would initiate pipeline shutdown. The maximum potential release would be 74,000 gallons* of tailings slurry. In order to develop a hypothetical scenario in which this total volume of tailings reaches the environment, one must assume that failure occurs in the lowest segment of the pipeline and that the dikes of the catchment basin along that segment of the pipeline in which the rupture occurred also failed, and that flow continued for ten minutes before the pipeline stabilized. In this highly unlikely situation, the total release would represent approximately 1.3 Ci of radioactivity. Upon shutdown of the pipeline, an inspection and cleanup crew would be dispatched to assess the extent of contamination. Contaminated materials would be removed and disposed of in the tailings disposal area.

---

* slurry pipeline - maximum potential release

74,000 gal = (10 min. x 2000 gpm) + (3.8 gal/ft x 14,200 ft)

2000 gpm - conservative estimate of rate of flow in tailings pipeline

3.8 gal/ft - volume of tailings in pipeline

14,200 ft - length of pipeline, out of the total of about 30,000 feet, capable of draining out in a pipeline breach. The tailings in the remainder of the pipeline would be maintained within the troughs of the pipeline.

Note: This estimate is based on a 10 inch diameter pipeline as originally planned. Although this revised discharge plan states that only 6 and 8 inch pipelines will be utilized, the estimate of the maximum volume of tailings that could be released has not been altered because it is possible that a 10 inch pipeline may be added some years after the initiation of operations.

A final scan of the affected area would then be made in order to assure that radiation levels in the soil have been reduced to near background levels, or as low as reasonably achievable. The area would then be reclaimed to its approximate original contour and vegetative cover.

The NMEID would, of course, be notified of any such accidental spill. All monitoring and sampling data, including personnel exposure evaluations, can be reviewed by NMEID. With the concurrence of NMEID, decontamination efforts will cease.

4. CONCLUSIONS

It is believed that even a large accidental release of tailings slurry or decant water would pose no threat to groundwater resources for the following reasons. (See Appendix D, Section 4.2)

1) Due to the control system and automatic shutdown sequence, a maximum of 74,000 gallons of slurry or liquid could be released.
2) It is probable that most, if not all, of the release will be contained within the diked pipeway and catchment basins;
3) Any spill confined to the pipeway and catchment basins will be removed and discharged into the tailings pond within a relatively short period of time; therefore there will be no extended ponding of spills in the basin.
4) Decontamination and reclamation efforts will remove any material contaminated by spills for disposal in the tailings pond.
5) Water table levels within the bedrock along the tailings pipeline route are probably at depths exceeding 75 feet and it is therefore highly unlikely that the seepage of the limited volume that would be discharged could migrate this distance.
6) The arroyo in San Lucas Canyon into which treated mine water from the Mt. Taylor mine is discharged varies in distance from the pipeline route, but the closest distance between the two is approximately 150 feet. It is unlikely that any portion of any spill would migrate this distance, but, if it did, the volume of the treated mine water discharge is so great compared to that which would be associated with a spill that one could expect that, due to dilution, the potential impacts on water quality within the arroyo would be minimal. If any spill ever did reach the arroyo, water samples would be taken and analyzed to verify that the water quality was within all applicable standards.

SECTION IV

THE MILL IMPOUNDMENT AND CONTAINMENT POND

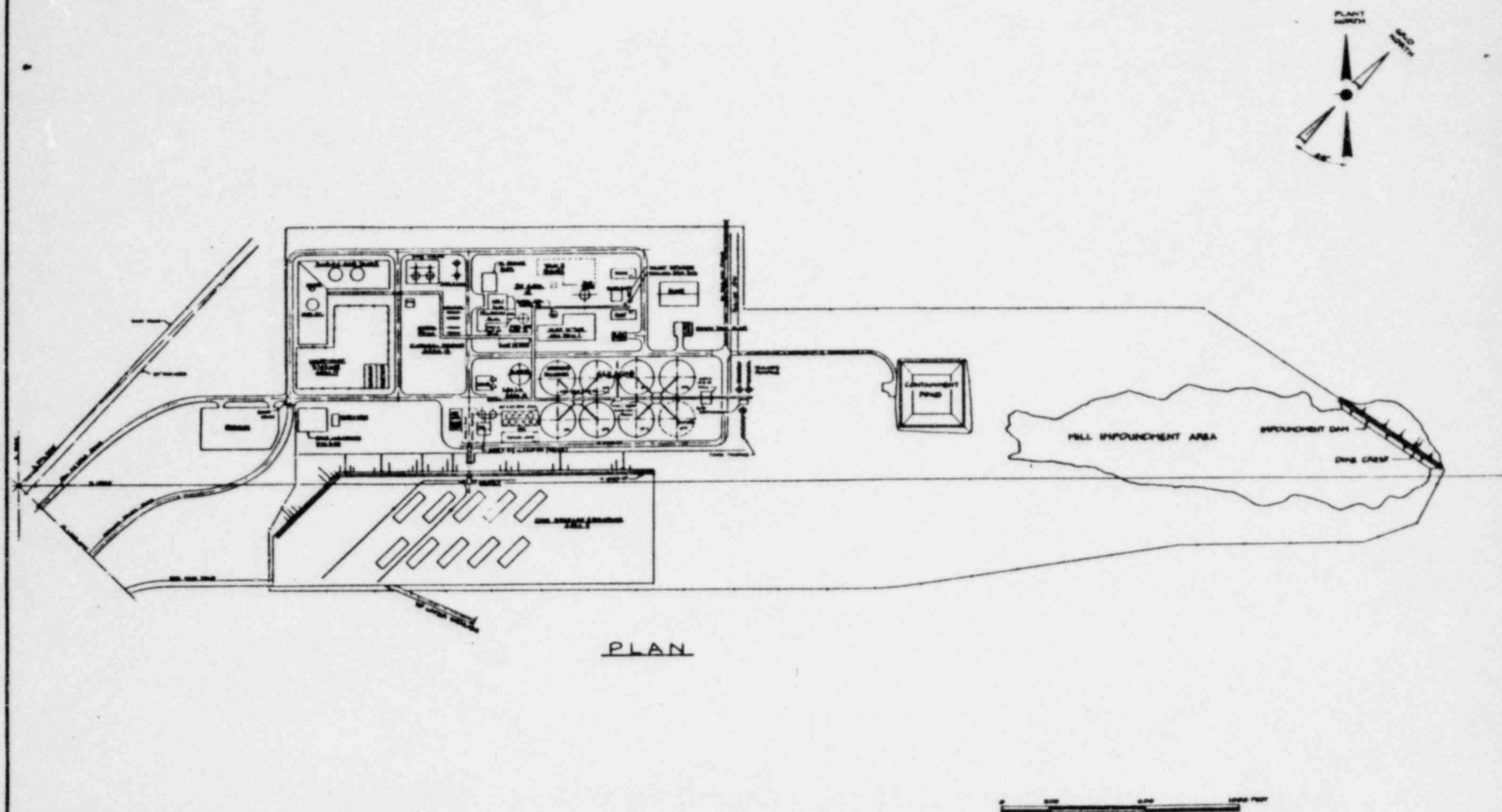
A. DESCRIPTION

Approximately one-half mile downstream (northeast) of the Mt. Taylor Uranium Mill a lined containment pond is provided to contain any major spillage from the mill, process area runoff and treated sewage water. An impoundment to hold storm water that exceeds the capacity of the containment pond is also provided (see Figure IV-1). The main features of the mill impoundment include the mill catch dam and spillway.

1. MILL IMPOUNDMENT

The principal features of the mill impoundment are shown on Figures IV-2 and IV-3. Significant statistics associated with the mill impoundment are listed below:

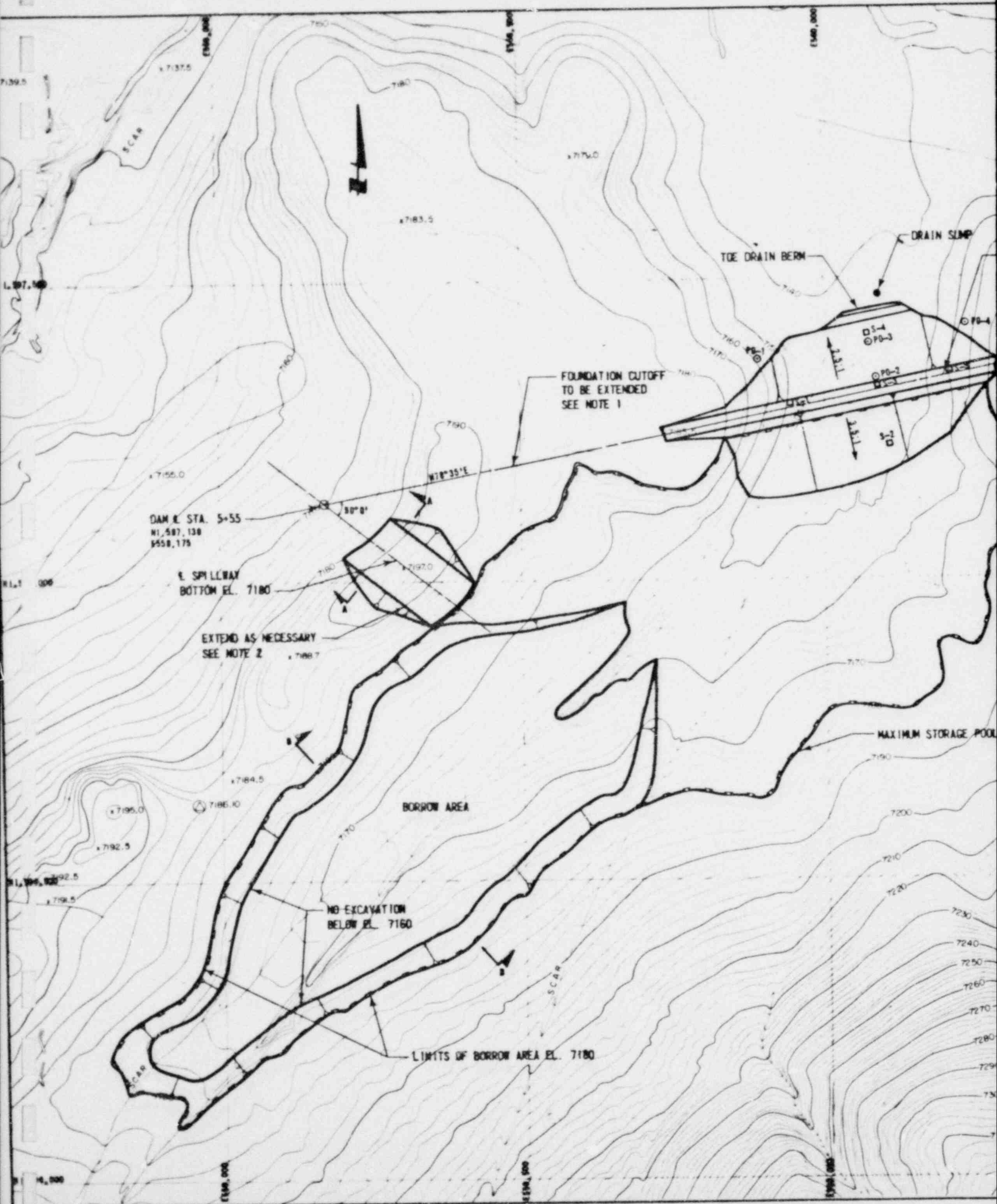
• distance from mill	± 0.5 miles downstream
• maximum impoundment surface area	16 acres
• maximum impoundment storage volume	230 acre-feet
• dam embankment type	compacted, zoned earthfill
• maximum height above stream bed	42.5 feet
• maximum height above foundation	75 feet
• upstream slope	3.5:1 (horizontal to vertical)
• downstream slope	2.5:1 (horizontal to vertical)
• crest width	25 feet
• dam foundation type	alluvium, with cutoff to rock
• length of dam	565 feet

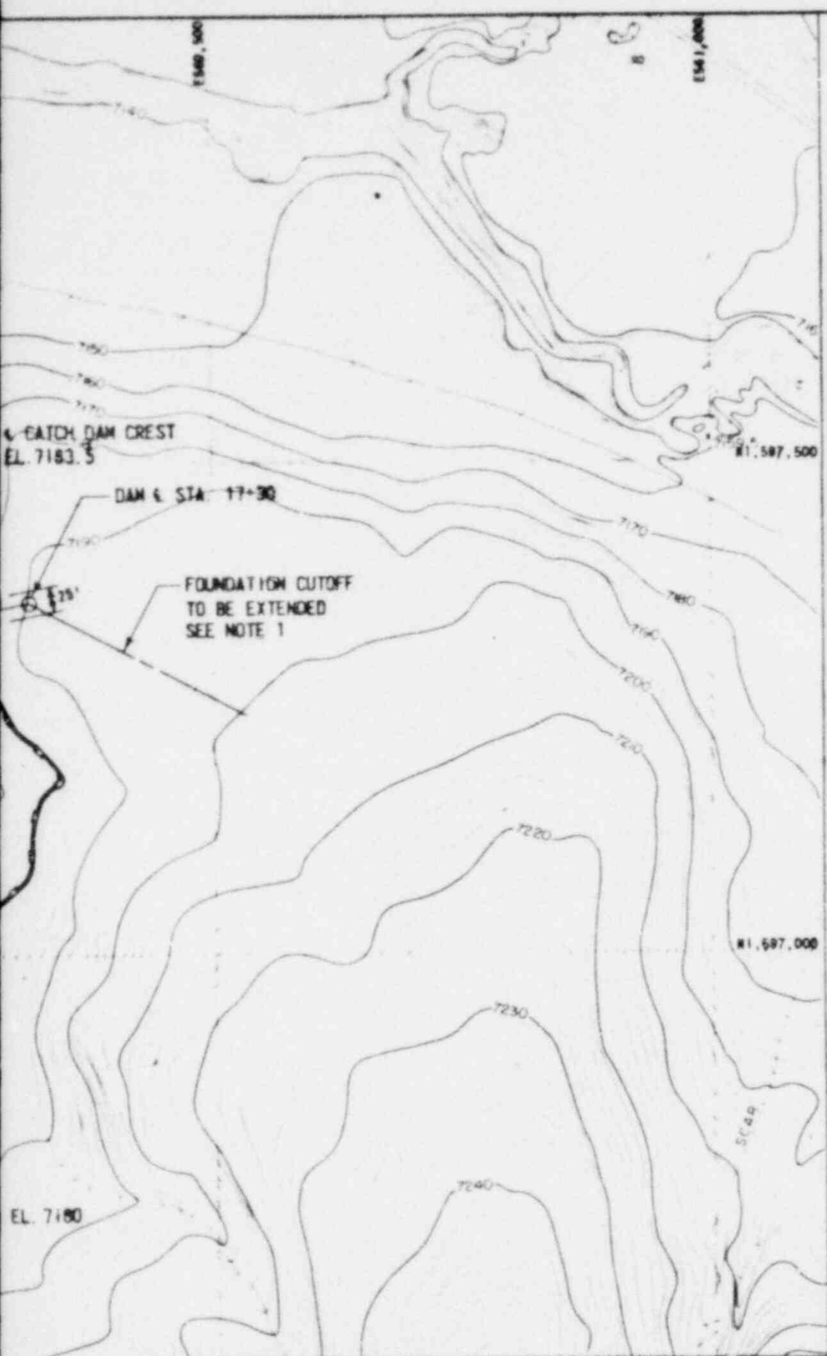


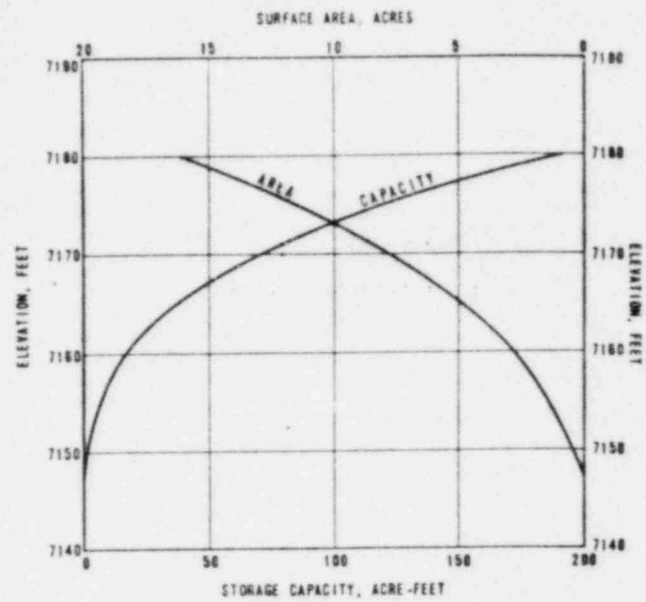
Source: Jacobs Engineering Co. 1979

FIGURE IV-1

MILL PLOT PLAN


TOE DRAIN BERM
DRAIN SUMP
S-4
PD-3
PD-1
PD-2
PD-4
FOUNDATION CUTOFF
TO BE EXTENDED
SEE NOTE 1
N78°35'E
DAM ℄ STA. 5+55
N1,597,130
E550,175
℄ SPILLWAY
BOTTOM EL. 7180
EXTEND AS NECESSARY
SEE NOTE 2
MAXIMUM STORAGE POOL
BORROW AREA
NO EXCAVATION
BELOW EL. 7160
LIMITS OF BORROW AREA EL. 7180
SCAR
x7183.5
x7155.0
x7197.0
x7184.5
x7195.0
x7192.5
x7137.5
x7175.0
x7188.7
7186.10
7160
7170
7180
7190
7200
7210
7220
7230
7240
7250
7260
7270
7280





NOTES:

1. CUTOFF TRENCH IS TO BE EXTENDED ALONG ABUTMENTS TO THE POINT WHERE BOTTOM OF THE CUTOFF TRENCH ACCEPTABLE FOUNDATION IS ABOVE ELEVATION 7180.
2. MINIMUM SPILLWAY BOTTOM WIDTH 100' SPILLWAY CUT MAY BE EXTENDED SOUTHWESTERLY AS REQUIRED FOR SLOPE PROTECTION ROCK.
3. AREA CAPACITY CURVE IS BASED ON EXISTING GROUND CONTOURS.

SCALE

100 0 100 FEET

CONTOUR INTERVAL 2 FEET

HALF REDUCTION

OPEN WELL PIEZOMETER TIP LOCATION DATA

INSTRUMENT NO.	STATION	OFFSET FROM DAM ℄	ELEVATION
PO-1	13+20	80'(D/S)	7140
PO-2	15+00	20'(D/S)	7150
PO-3	15+00	60'(D/S)	7130
PO-4	16+60	80'(D/S)	7140

DISPLACEMENT MONUMENT LOCATION DATA

INSTRUMENT NO.	STATION	OFFSET FROM DAM ℄
S-1	13+50	10'(D/S)
S-2	15+00	95'(U/S)
S-3	15+00	10'(D/S)
S-4	15+00	95'(D/S)
S-5	16+20	10'(D/S)

KEY

◎ PO-4 OPEN WELL PIEZOMETER

□ S-5 DISPLACEMENT MONUMENT

REV.	DATE	DESCRIPTION	APPROVED

ISSUED FOR CONSTRUCTION		CUSTOMER APPROVAL	
DESIGNED	DRAWN	REVIEWED	APPROVED

Gulf Mineral Resources Co.

GULF AFE NO. 1599

W. A. WAHLER & ASSOCIATES

PALO ALTO • NEWPORT BEACH • CALIF.

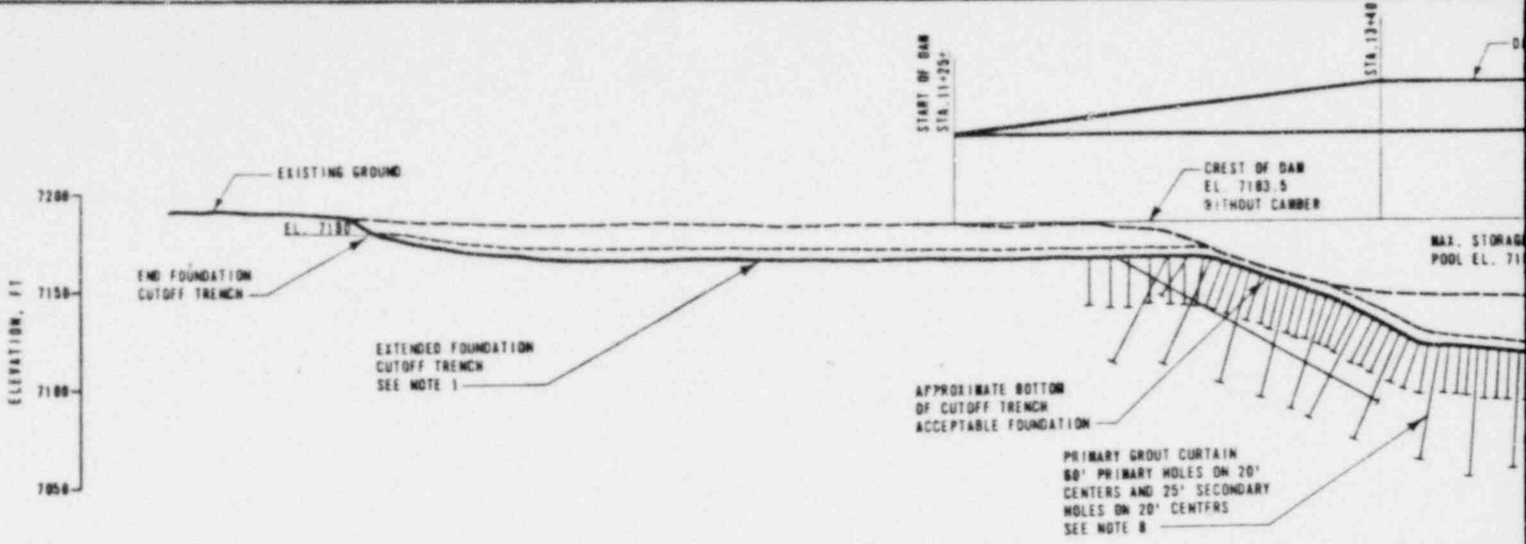
MT. TAYLOR URANIUM MILL PROJECT

SAN LUCAS CANYON MILL SITE

CATCHMENT DAM AND SPILLWAY PLAN

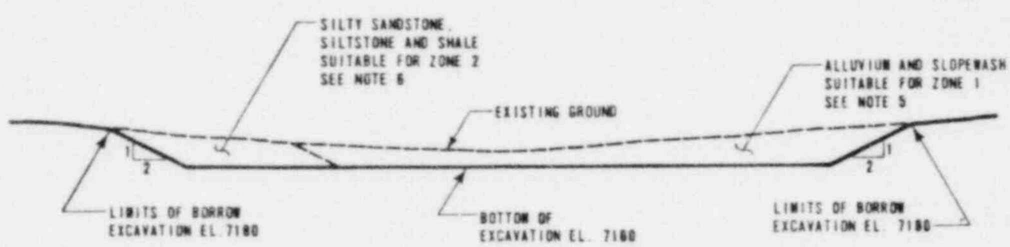
SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
DATE			

FIGURE IV-2



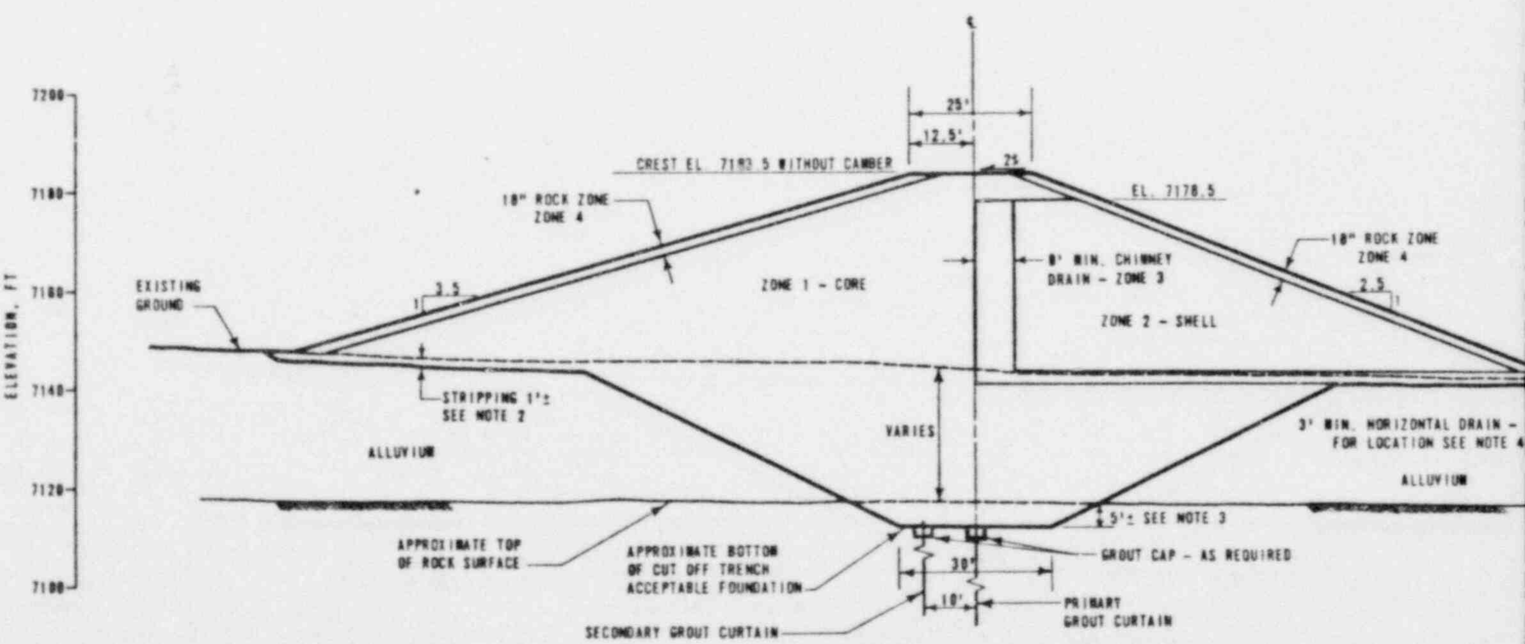
MILL SITE CATCH

SCALE



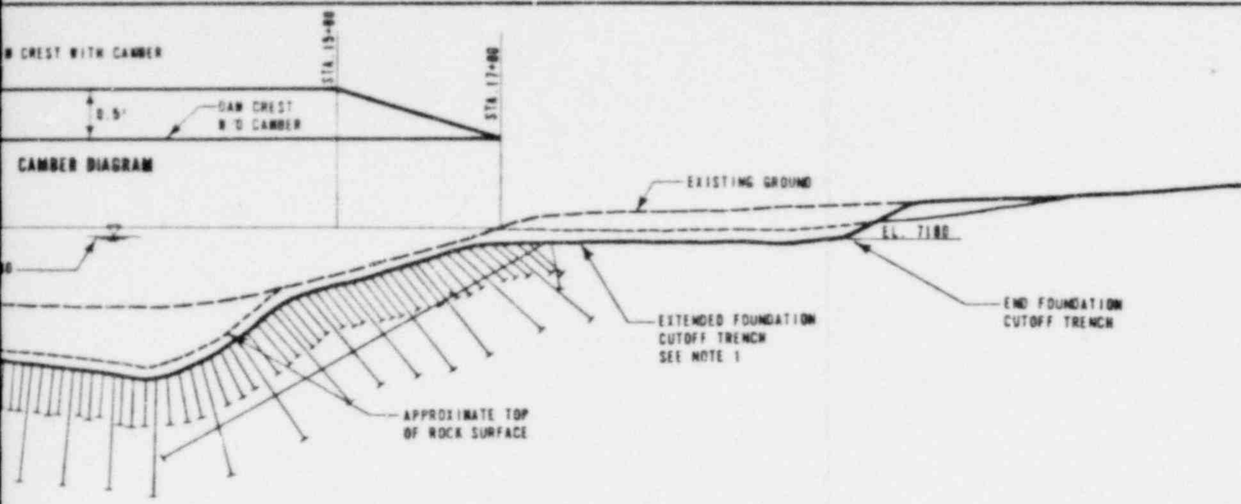
TYPICAL BORROW AREA EXCAVATION

SECTION B–B



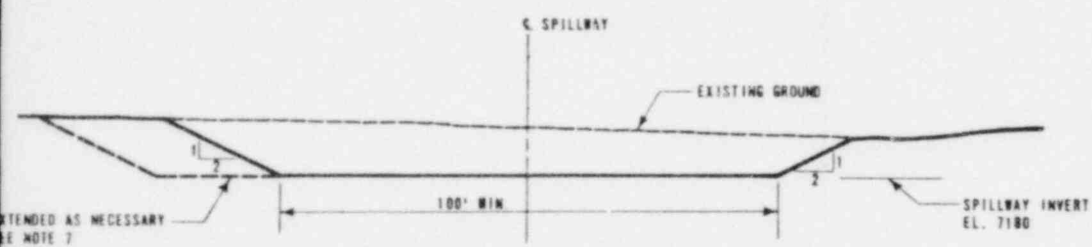
TYPICAL DAM SECTION

SCALE: 1" = 20'



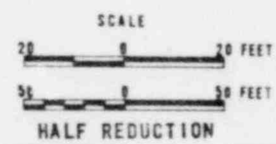
MENT DAM ℄ PROFILE

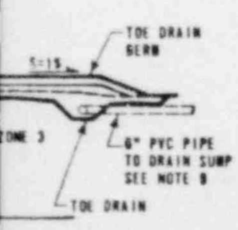
1" = 50'



SPILLWAY SECTION A–A

SCALE: 1" = 20'





NOTES:

1. CUTOFF TRENCH IS TO BE EXTENDED ALONG ABUTMENTS TO THE POINT WHERE BOTTOM OF THE CUTOFF TRENCH ACCEPTABLE FOUNDATION IS ABOVE ELEVATION 7180.
2. FOUNDATION STRIPPING DEPTH IN THE CHANNEL AREA TO BE DETERMINED BY THE ENGINEER, AVERAGE STRIPPING DEPTH APPROXIMATELY 1'±. FOUNDATION STRIPPING IN THE ABUTMENT AREA TO BE DETERMINED BY THE ENGINEER. DEPTH OF SLOPE WASH DEPOSITS TO BE REMOVED VARY BETWEEN 1' AND 5'.
3. DEPTH OF CUTOFF TRENCH EXCAVATION INTO ROCK TO BE DETERMINED BY THE ENGINEER. AVERAGE DEPTH 5'±.
4. ZONE 3 HORIZONTAL DRAIN AND BERM LOCATED BETWEEN DAM STATION 14+65 AND STATION 15+65.
5. ZONE 1 BORROW MATERIAL TO BE SELECTIVELY PLACED WITH THE FINER MATERIAL PLACED TOWARDS THE INTERIOR OF THE EMBANKMENT AND THE COARSER MATERIAL TOWARDS THE U/S SLOPE.
6. EXCAVATE WEATHERED SILTY SANDSTONE, SILTSTONE AND SHALE FOR ZONE 2 - SHELL AS REQUIRED.
7. MINIMUM SPILLWAY BOTTOM WIDTH 100'. SPILLWAY CUT MAY BE EXTENDED SOUTHWESTERLY AS REQUIRED FOR SLOPE PROTECTION ROCK.
8. PRIMARY GROUT CURTAIN LOCATED ON DAM CENTERLINE IN CHANNEL SECTION AND ABUTMENT SLOPES. SECONDARY CURTAIN LOCATED 10' UPSTREAM FROM PRIMARY CURTAIN. SECONDARY CURTAIN HOLES TO BE STAGGERED BETWEEN PRIMARY AND SECONDARY HOLES OF PRIMARY CURTAIN.
9. DRAIN SUMP TO BE LOCATED BY THE ENGINEER IN THE FIELD.

REV.	DATE	DESCRIPTION	APPROVED

ISSUED FOR CONSTRUCTION | CUSTOMER APPROVAL

DESIGNED | DRAWN | REVIEWED | APPROVED

Gulf Mineral Resources Co.

GULF AFE NO. 1599

W. A. WAHLER & ASSOCIATES

PALO ALTO • NEWPORT BEACH • CALIF.

MT. TAYLOR URANIUM MILL PROJECT

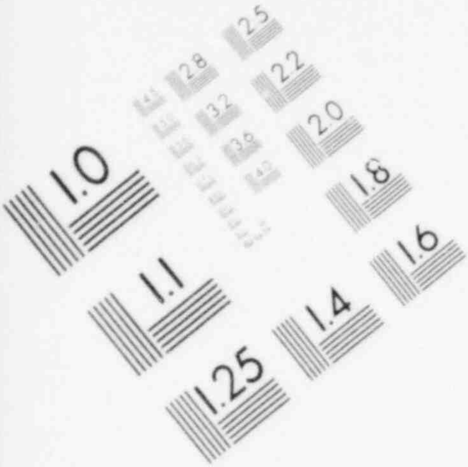
SAN LUCAS CANYON MILL SITE

CATCHMENT DAM PROFILES AND SECTIONS

SCALE | PROJECT NUMBER | DRAWING NUMBER | REVISION

DATE

FIGURE IV-3



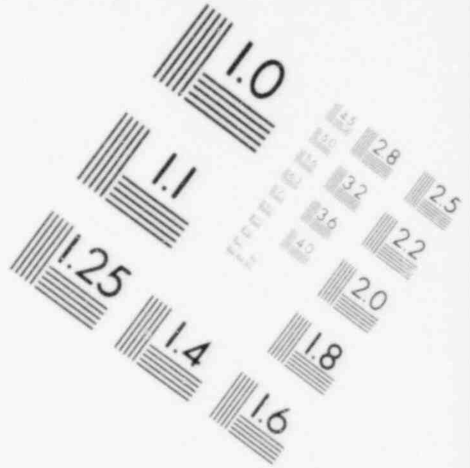
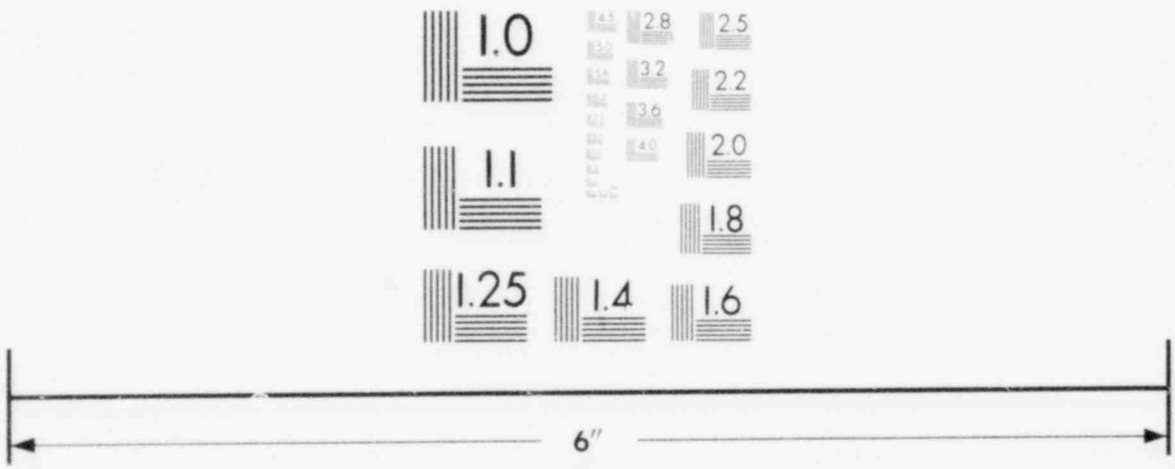
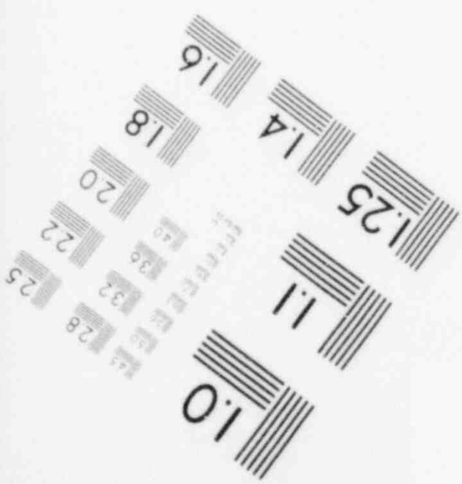


IMAGE EVALUATION
TEST TARGET (MT-3)



MICROCOPY RESOLUTION TEST CHART



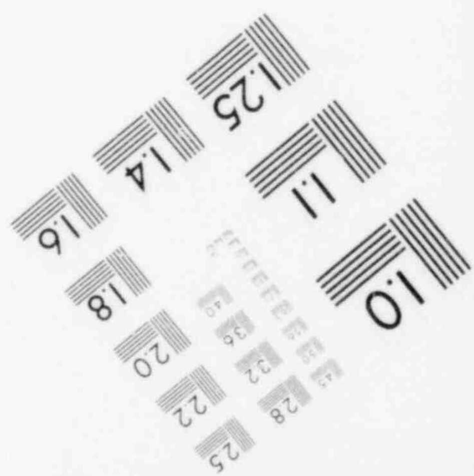


IMAGE EVALUATION
TEST TARGET (MT-3)

6"

MICROCOPY RESOLUTION TEST CHART

The proposed mill catch dam is a zoned earthfill structure designed as a conventional water-retention type dam. The proposed dam has an impervious upstream zone, a downstream shell and an internal drainage system. Both the upstream and downstream slopes will have rockfill slope protection. Borrow materials for the dam will be obtained from within the impoundment area.

The proposed dam has an alluvial foundation, but a positive cutoff is provided under the dam well into bedrock for foundation seepage control. In addition, a two-line grout curtain could be extended across the dam channel section and up both the left and right abutment slopes if necessary. The primary curtain, located on the dam centerline at the bottom of the cutoff trench, will consist of 60-foot-deep holes on 20-foot centers, and 25-foot-deep holes placed on 20-foot centers midway between the deeper holes. The secondary curtain, 10 feet upstream of the primary curtain, will consist of 25-foot-deep holes on 10-foot centers. The reader is referred to the engineering report entitled "Definitive Design for Mill Site Catchment Dam," W. A. Wahler & Assoc., 1978, Chapter IV for details regarding the design.

An open cut spillway, located on the west side of the impoundment, is incorporated to preclude dam overtopping. The dam will have 3.5 feet of freeboard above the spillway invert. The rock from the spillway excavation will be utilized in the dam for slope protection.

Laboratory tests on the proposed catch dam embankment and foundation materials are summarized in Table IV-1. The embankment materials are composed of alluvial and slopewash deposits and vary from silty sands to gravels to silty clay. The alluvial foundation materials vary from silty sands to sandy clays.

Stability analyses performed in accordance with NRC Regulatory Guideline 3.11, "Design, Construction and Inspection of Embankment Retention Systems for Uranium Mills," Revision 1, March, 1977, are summarized in Table IV-2. These analyses were performed on the embankment section with 3.5:1 (horizontal to vertical) upstream slope and 2.5:1 downstream slope. Foundation material strengths used in the analysis were conservative; however, additional sampling and testing of the exposed alluvium are planned during construction to confirm this.

Table IV-1 SUMMARY OF PRINCIPAL LABORATORY TEST RESULTS ON PROPOSED MILL SITE CATCH DAM EMBANKMENT AND FOUNDATION MATERIALS

Laboratory Test	Embankment	Foundation
Gradation		
Percent passing No. 4 sieve	99% - 100%	99% - 100%
Percent passing No. 200 sieve	19% - 58%	23% - 56%
Atterberg limits		
Liquid limit	22% - 35%	23% - 34%
Plastic limit	16% - 17%	13% - 22%
Plasticity index	5% - 19%	1% - 21%
Unit Weight		
Dry density	-	92.9 pcf - 111.0 pcf
Natural water content	3.6% - 9.6%	9.5% - 24%
Compaction		
Maximum dry density	109.8 pcf - 115.8 pcf	-
Optimum water content	13.0% - 14.0%	-
Natural water content	3.6% - 9.6%	-
Shear strength (triaxial tests)		
Unconsolidated-Undrained	c=1160 psf Ø=15°	-
Consolidated-Undrained with pore pressure measurements	c'=520 psf Ø'=22.5	c'=150 psf Ø' 35°

NOTE: c = cohesion (total stress) Ø = friction angle (total stress)
c' = cohesion (effective stress) Ø' = friction angle (effective stress)

Table IV-2 MILL SITE CATCH DAM SUMMARY OF STABILITY ANALYSES

Cases	Minimum Required Factor of Safety	Minimum Calculated Factor of Safety
End of Construction		
U/S Slope without loading	1.3	1.4[a] 1.7[b] 1.9[c]
U/S Slope with 0.1g earthquake loading	1.0	1.0[a] 1.2[b] 1.4[c]
D/S Slope without earthquake loading	1.3	1.4[a] 1.6[b] 1.8[c]
D/S Slope with 0.1g earthquake loading	1.0	1.0[a] 1.2[b] 1.4[c]
Partial Pool		
U/S Slope without earthquake loading	1.5	2.3
U/S Slope with 0.1g earthquake loading	1.0	1.6
Maximum Pool, Stead State Seepage		
U/S Slope without earthquake loading	1.5	2.9
U/S Slope with 0.1g earthquake loading	1.0	1.6
U/S Slope without earthquake loading	1.5	1.9
D/S Slope with 0.1g earthquake loading	1.0	1.3
U/S Rapid Drawdown	—[d]	1.5

NOTES: [a]Foundation strength Ø = 0, c = 500 psf
[b]Foundation strength Ø = 0, c = 750 psf
[c]Foundation strength Ø = 0, c - 1000 psf
[d]There is no N.R.C. minimum factor of safety for this case. However, the Corps of Engineers minimum required factor of safety for this case is 1.2.

2. CONTAINMENT POND

To the south of the mill impoundment a smaller containment will be constructed that will be lined to inhibit percolation (see Figures IV-1 and IV-4). The containment, with a capacity of 2,000,000 gallons, is conservatively sized to contain the spillage that would result if the largest process vessel in the mill, containing approximately 1,500,000 gallons, failed. The containment, lined with a minimum of 20 mil PVC with a 12 inch compacted earth and rock blanket, will also receive treated sewage water as well as any flow that occurs during washdown and cleanup of mill process areas and the initial runoff during rainfall. The result of providing this lined containment is that liquids containing chemical contaminants will not be placed within the larger, unlined mill impoundment, thus providing greater protection of the groundwater.

The drainage channel between the mill and the containment pond will be equipped with flow diversion structures that will automatically divert storm runoff past the lined containment pond and into the mill impoundment when the pond's capacity is exceeded. Runoff from the millsite will be collected and will flow east along the millsite drainage channel to the diversion structure. The runoff turns left through flap gates and into the containment pond. The containment pond will fill up and the liquid surface will rise until the runoff begins to flow over the overflow weir and into the side channel to the mill impoundment. This process will continue until all runoff flows over the overflow weir. The flap gates will prevent any liquid from escaping from the containment pond, both during and after the storm.

It is expected that the initial runoff from storms will flush the majority of the potential contaminants from the process area into the lined containment and that any additional runoff that exceeds the capacity of the lined area will be relatively free of chemical contaminants. The containment will be provided with pump back facilities for returning liquids to the mill process. Any major process spills involving uranium-bearing solutions would be returned for reprocessing. Drainage into the containment pond from storm runoff or area washdowns could be returned or disposed of by evaporation.

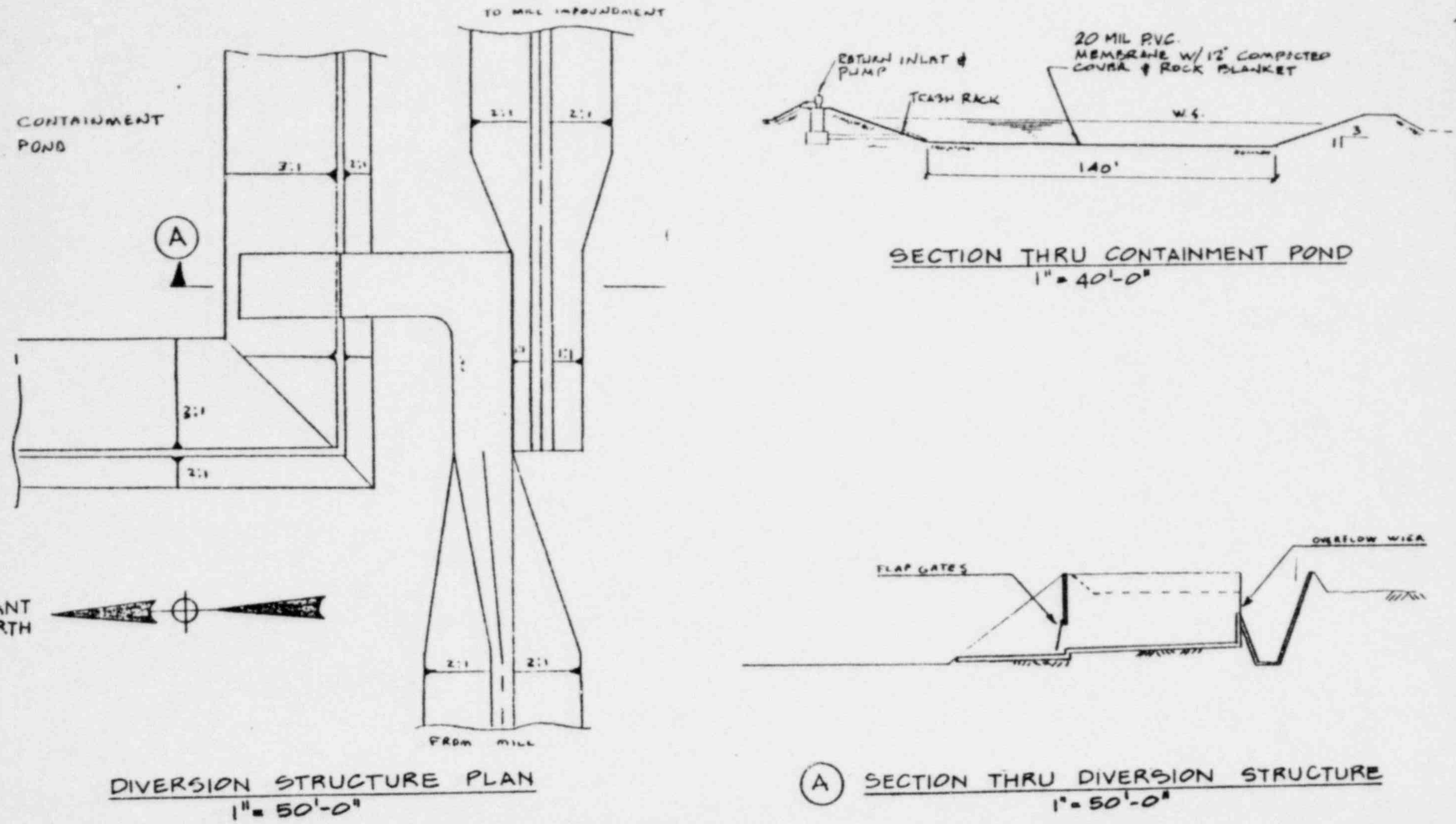


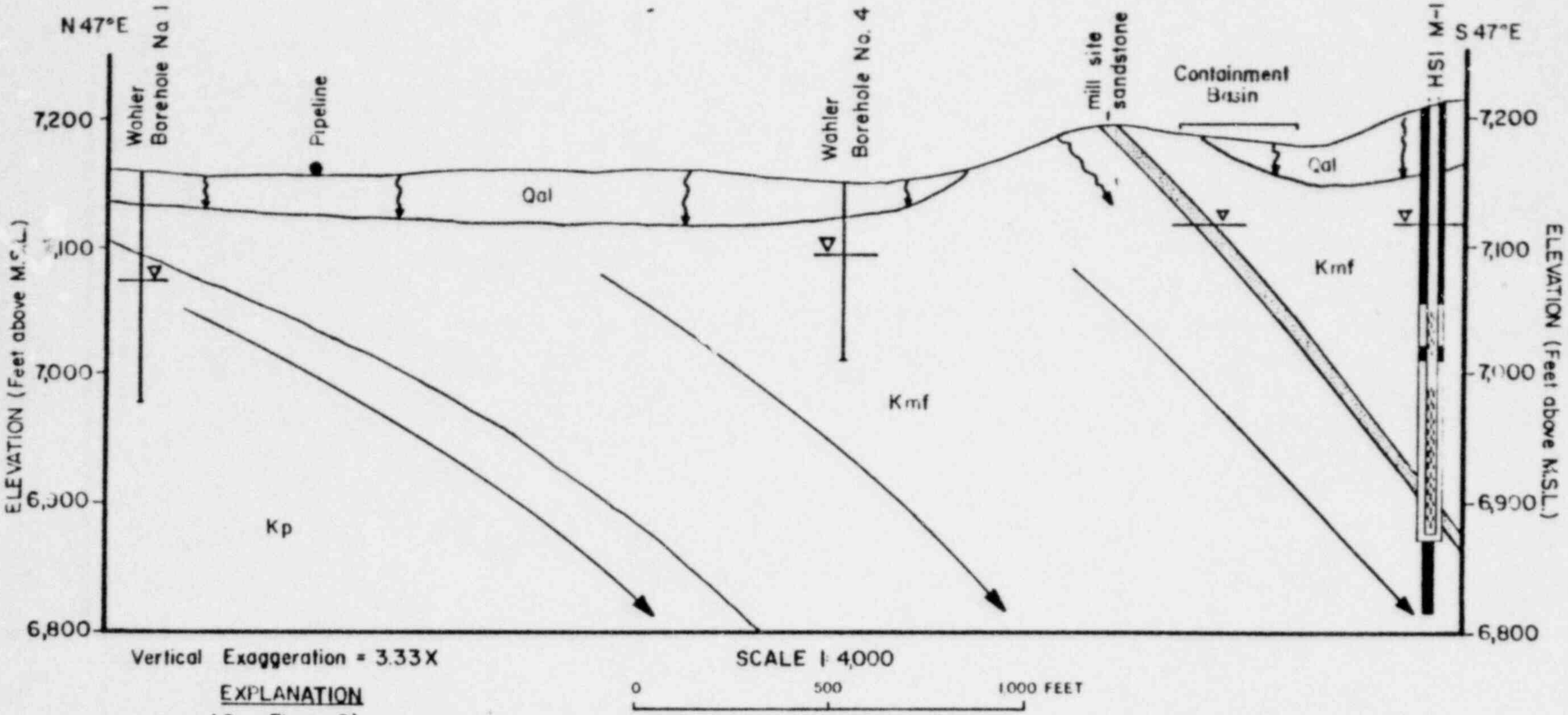
FIG. IV-4
CONTAINMENT POND SECTION
AND DIVERSION STRUCTURE

B. SITE CONDITIONS

1. GENERAL

The proposed mill catchment dam site is in a small, northeast-trending tributary of San Lucas Canyon about four miles south-southwest of the proposed La Polvadera Canyon tailings disposal area. Figure IV-5 presents a hydrogeologic cross-section across San Lucas Canyon which shows the location of the containment pond and the hydrological test holes. Figure IV-6 is a surficial geologic map of the proposed dam and reservoir, and Figure IV-7 shows geologic profiles along the dam axis and in the reservoir. The project site is on the southeastern flank of San Mateo Dom where the bedrock formation shows a northeast strike and low dips to the southeast. The Menefee formation of Cretaceous age (Kmf) comprises the bedrock material underlying the entire site and is exposed on ledges and steep slopes. Elsewhere, the Menefee formation is covered by talus, slopewash, terrace, and alluvial deposits. The Menefee formation is interbedded, light brown to grayish-orange siltstone and sandstone with interbedded gray shale and minor coal seams.

The alluvial and eolian deposits in the channel consist of interlayered, light brown, sandy silt to silty sand and moderately brown, clayey sand to sandy clay. Groundwater was encountered in some of the exploratory drillholes in the alluvium but appears to be localized. Slopewash deposits consisting of mixed sand, silt, and clay, with some fragments of basalt and sandstone, overlie the bedrock on the lower slopes. A portion of this slopewash deposit upstream of the right abutment is probably an old landslide deposit, as evidenced by subdued hummocky topography and minor slumps at the toe of the slope. An extensive talus deposit that occurs on steeper slopes high above the proposed reservoir to the east is comprised of fine and gravel-to-boulder-sized basalt derived from the basalt caprock upslope and outside the mapped area. Minor terrace deposits overlie the bedrock on the broad ridgetop of both abutments.



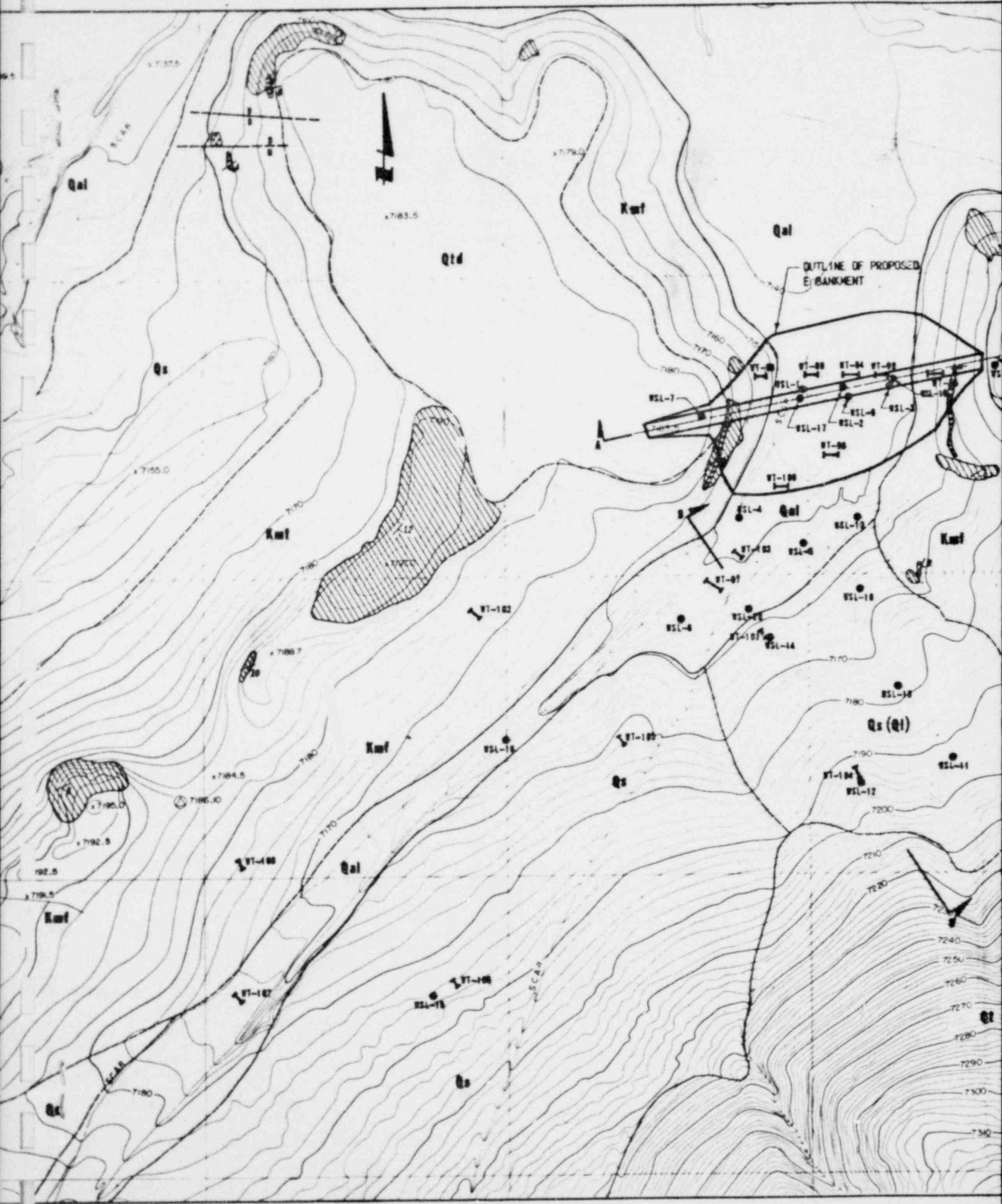
EXPLANATION
(See Figure 2)
See Plate II for line of cross section

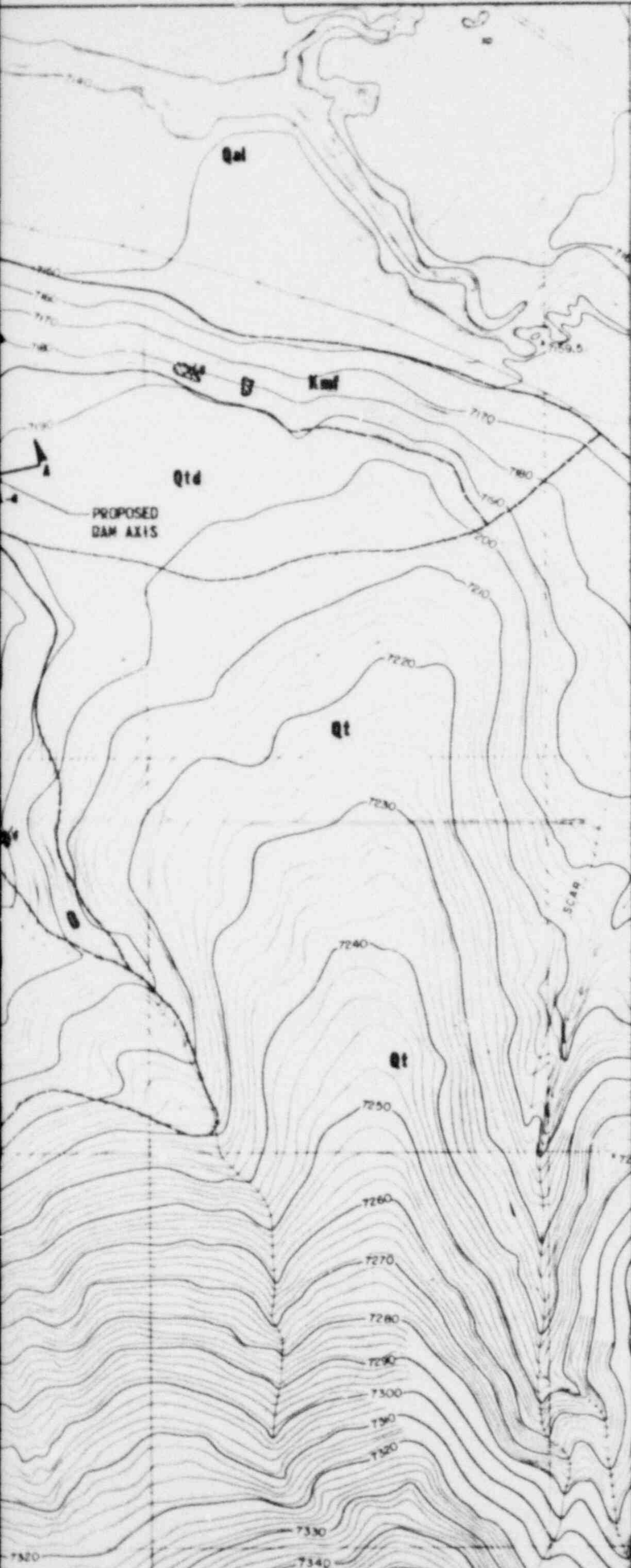
Figure IV-5

HYDROGEOLOGIC CROSS SECTION BETWEEN WAHLER BOREHOLE NO. 1 AND HYDROLOGIC TEST HOLE HSI M-1 MC KINLEY COUNTY, NEW MEXICO

GULF MINERAL RESOURCES CO. — JACOBS ENGINEERING GROUP, INC.	HYDRO-SEARCH, INC. Geologists · Hydrologists Reno · Austin · Denver Project No. 1201-79

11-79


Qal
Qtd
Kmf
Qs
Qs (Qt)
OUTLINE OF PROPOSED
EMBANKMENT
SCAR
x 7183.5
x 7179.0
x 7155.0
x 7186.7
x 7184.5
7186.10
x 7195.0
x 7192.5
7170
7180
7190
7200
7210
7220
7240
7250
7260
7270
7280
7290
7300
7310
WSL-7
WSL-17
WSL-2
WSL-4
WSL-5
WSL-10
WSL-14
WSL-16
WSL-12
VT-100
VT-102
VT-103
VT-104
VT-107
VT-97



EXPLANATION

GEOLOGIC UNITS

QUATERNARY

Qal	ALLUVIAL AND EOLIAN DEPOSITS: INTERBEDDED LIGHT BROWN SILTY SAND WITH MEDIUM BROWN CLAYEY SAND TO SANDY CLAY.
Qs	SLOPEWASH DEPOSIT: LIGHT BROWN TO YELLOW BROWN SANDY CLAY TO SILTY SAND WITH GRAVEL TO COBBLES OF BASALT AND SANDSTONE.
Qs(Ql)	POSSIBLE OLD LANDSLIDE DEPOSIT INVOLVING SLOPEWASH DEPOSIT.
Qt	TALUS DEPOSIT: MOSTLY GRAVELS TO COBBLES OF BASALT MIXED WITH LIGHT BROWN TO YELLOW BROWN CLAYEY TO SILTY SAND; OCCURS AS AN EXTENSIVE DEPOSIT DOWNSLOPE OF BASALT-CAPPED MESA.
Qtd	TERRACE DEPOSIT: MOSTLY GRAVEL TO COBBLES OF BASALT WITH SAND AND SILT. SOME ROUNDED AGATE PEBBLES; OCCURS AS CAPPING OVER BROAD RIDGES.

CRETACEOUS

Kmf	MENEFEE FORMATION: LIGHT BROWN TO GRAYISH ORANGE SILTSTONE AND SANDSTONE WITH INTERBEDDED LIGHT GRAY SHALE; GENERALLY COVERED WITH 0 TO 5 FEET OF SLOPEWASH AND RESIDUAL SOIL.
	Kmf MAPPED OUTCROPS
	Kmf RESISTANT QUARTZ SANDSTONE BED; USED AS MARKER BED FOR CORRELATION.

SYMBOL

CONTACT, DASHED WHERE APPROXIMATELY LOCATED

LINE OF CROSS SECTION

FAULT; U, UPLIFTED SIDE; D, DOWNDROPPED SIDE, DASHED WHERE APPROXIMATELY LOCATED.

10 STRIKE AND DIP OF BEDS

WSL-10 EXPLORATION DRILL HOLE

VERTICAL JOINTS

WT-100 EXPLORATION TRENCH

SCALE

100 0 100 FEET

CONTOUR INTERVAL 2 FEET

NOTES: 1. SEE FIGURE II-2 FOR GEOLOGIC SECTION

2. GEOLOGY MODIFIED FROM ELMER S. SANTOS, U.S. GEOLOGICAL SURVEY, "GEOLOGIC QUADRANGLE MAP, SAN LUCAS QUADRANGLE, NEW MEXICO" (GQ-516), 1966.

REV.	DATE	DESCRIPTION	APPROVED

ISSUED FOR CONSTRUCTION		CUSTOMER APPROVAL	
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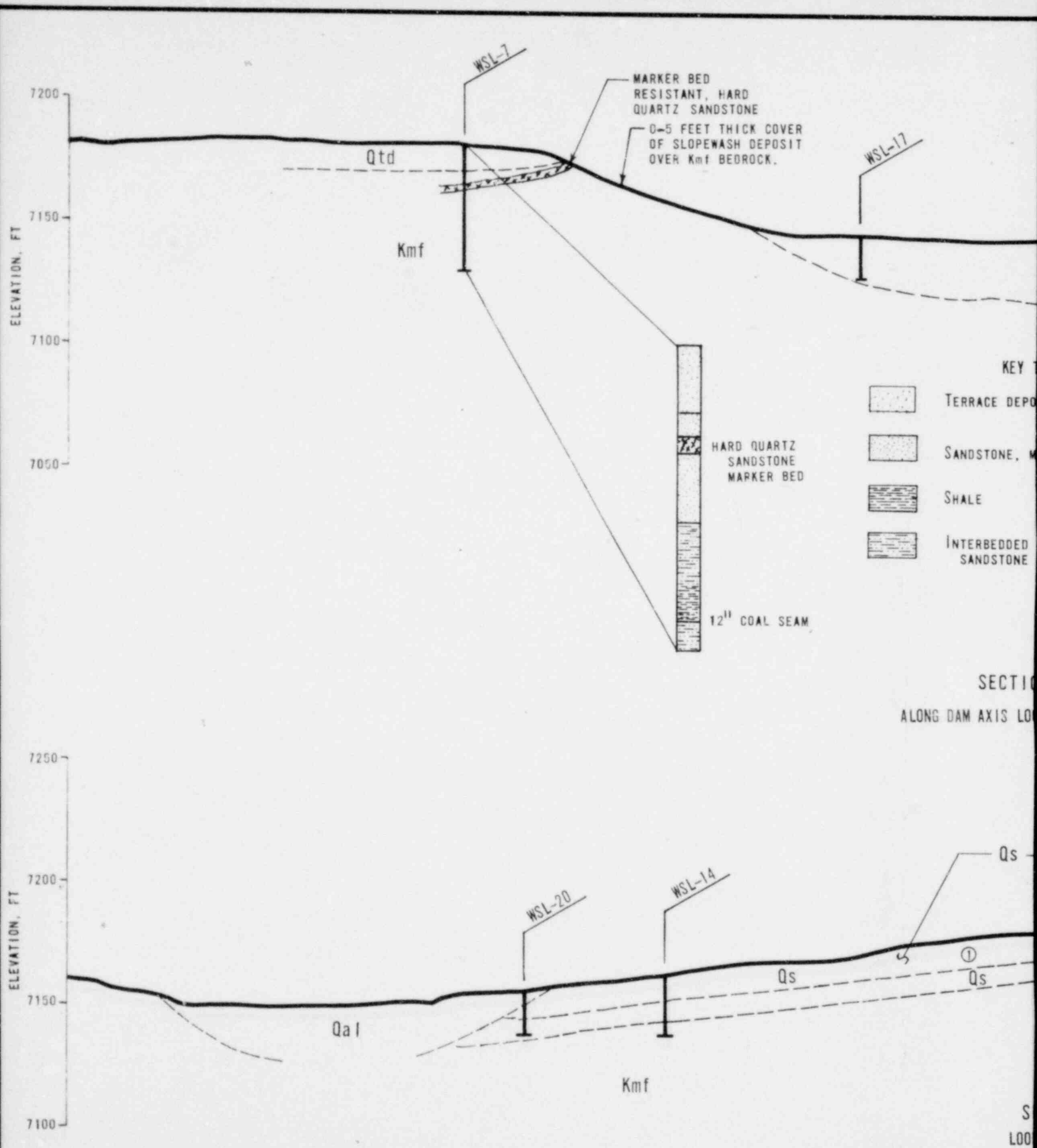
MT. TAYLOR URANIUM MILL PROJECT

SAN LUCAS CANYON MILL SITE

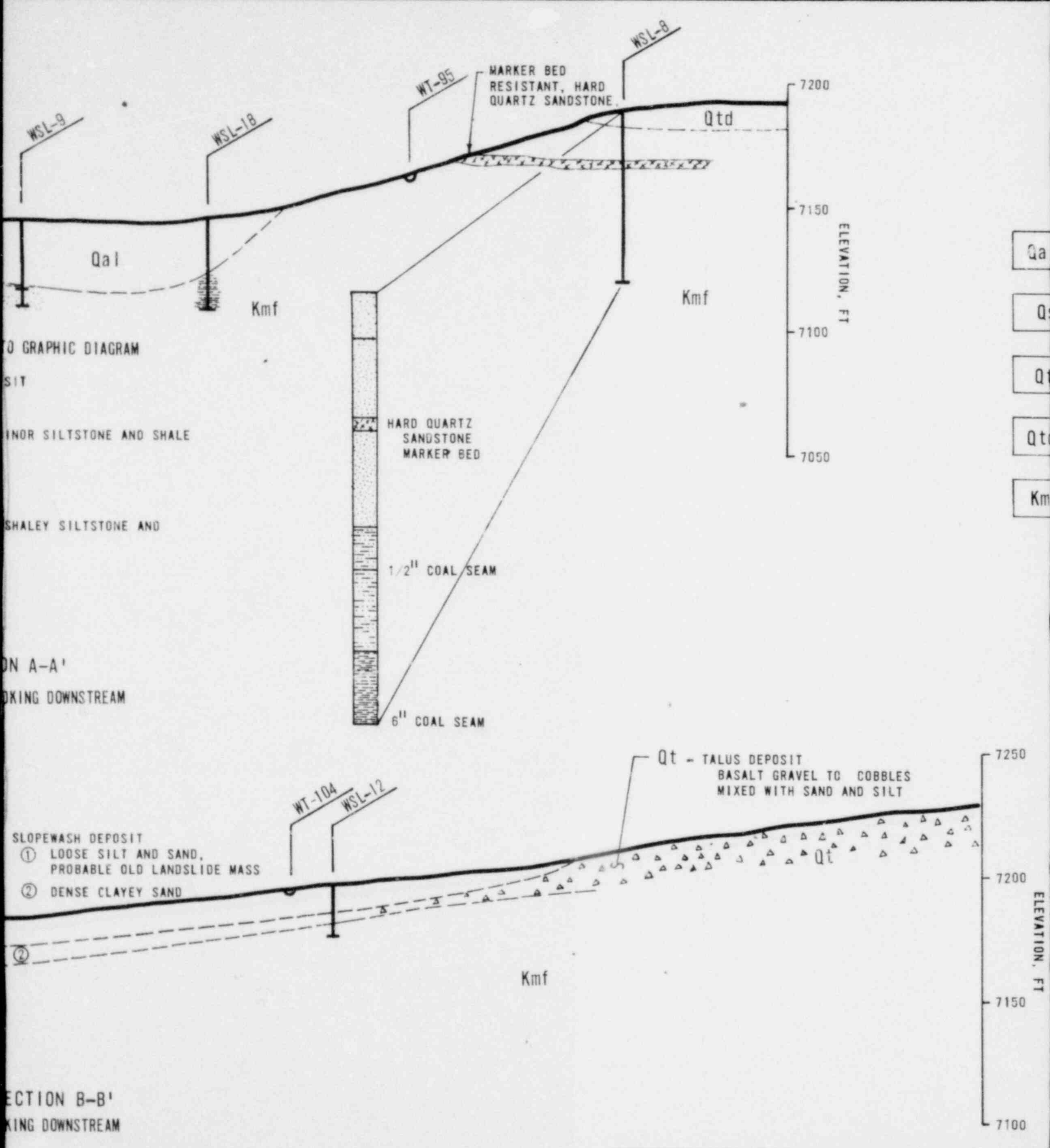
MILL CATCHMENT DAM GEOLOGY AND FIELD EXPLORATION MAP

SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
DATE			

FIGURE IV-6



WSL-7
MARKER BED
RESISTANT, HARD
QUARTZ SANDSTONE
0-5 FEET THICK COVER
OF SLOPEWASH DEPOSIT
OVER Kmf BEDROCK.
WSL-17
Qtd
Kmf
7200
7150
7100
7050
ELEVATION, FT
HARD QUARTZ
SANDSTONE
MARKER BED
12" COAL SEAM
KEY T
TERRACE DEPO
SANDSTONE,
SHALE
INTERBEDDED
SANDSTONE
SECTI
ALONG DAM AXIS LO
7250
7200
7150
7100
ELEVATION, FT
WSL-20
WSL-14
Qs
Qs
Qs
①
Qal
Kmf
S
LOO



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EXPLANATION

ALLUVIUM; LIGHT BROWN TO YELLOWISH BROWN, SILTY SAND TO CLAYEY SAND.

SLOPEWASH DEPOSIT

TALUS DEPOSIT

TERRACE DEPOSIT

MENEFEE FORMATION; INTERBEDDED SANDSTONE, SILTSTONE AND SHALE; SANDSTONE IS LIGHT YELLOW BROWN TO GRAY, MASSIVE BEDDING; SHALE AND SILTSTONE ARE THINLY BEDDED, LIGHT GRAY TO DARK GRAY WITH MINOR CARBONACEOUS SHALE AND COAL SEAMS.

NOTE: SEE FIGURE II-1 FOR LOCATION OF LINES OF SECTION.

SCALE

50 0 50 FEET

GEOLOGIC SECTIONS
MILL CATCHMENT DAM SITE

PROJECT NO.	DATE	FIGURE NO.
GUL-101	DECEMBER 1977	IV-7

Both the Menefee and Point Lookout formations dip to the southeast, with the water-bearing Point Lookout at a depth of several hundred feet below the relatively impervious Menefee. The only potential bedrock aquifer in the mill site area is a thin resistant sandstone bed within the Menefee (see Figure IV-5). A hydrogeologic test well, Well M-1, was installed to penetrate this sandstone unit immediately down dip from the location of the mill containment pond. The sandstone was intersected from 303 to 312 feet below the surface. The only other water-bearing zone intersected was a fractured carbonaceous shale at 164 feet. The remainder of the Menefee intersected consisted of relatively impervious siltstones, shales, and sandstones. Well M-1 could not be pump tested due to its low yield and large drawdown. Based upon a series of bailer and injection tests, rates of production and injection of about 1 gpm were achieved. Based upon the results of this testing, it is concluded that the Menefee is "impervious with respect to the movement of ground water and does not contain units capable of yielding useful quantities of water to wells" (App. F, pg. 29).

The contractor found it extremely difficult to obtain a water sample from the Menefee which was free of the dispersants used to clean the well due to the well's low yield. Table IV-2 shows the analysis of the sample from the Menefee eventually obtained. The contractor suggests that due to the level of phosphate measured, some residual contamination by the dispersants may still be evident.

TABLE IV-2

GROUNDWATER QUALITY
SAN LUCAS CANYON, NEW MEXICO

Parameters	Well M-1 Menefee Formation 10/16/79
pH	8.3
TDS (calc)	625
Elec. Cond.	1,050
Temperature	14.4
HCO_3^-	460
$CO_3^=$	17
Cl^-	65
$SO_4^=$	50
F^-	3.8
NO_3^-	0.62
Na^+	200
K^+	3.3
Ca^{++}	30
Mg^{++}	10
SiO_2	19
As	0.01
Ba	0.20
Cd	0.005
Cr	0.02
Pb	0.02
Hg	0.0002
Se	0.002
Ag	0.005
Cu	0.06
Fe	0.01
Mn	0.02
Zn	0.30
Al	0.7
B	0.30
Co	0.01
Mo	0.05
Ni	0.02
V	0.05
PO_4 (as P)	2.01

TABLE IV-2
(continued)

Parameters	Well M-1 Menefee Formation 10/16/79
Uranium	<0.006
Radium-226	0.13±0.03
Radium-228	<1.0
Radium-226 + Radium -228	<1.13
Gross Alpha	<6.0

Note: All analyses are in mg/l except pH which is in units, electrical conductivity which is in umhos/cm @ 25° C, temperature which is in degrees C, and radionuclides concentrations which are in pCi/l.

2. DAM FOUNDATION

The interbedded siltstone, sandstone and shales of the Menefee formation form the bedrock foundation material for the entire embankment. Individual beds range in thickness from a few inches to one foot. The shale air-slakes readily and is plastic when wet. Drill hole data indicate high water losses in the bedrock to depths of 50 feet, probably due to fracture permeability. Foundation seepage will be controlled by extending the cutoff trench into bedrock about five feet to expose competent rock and by placing a two-line grout curtain across the dam channel section and up both the left and right abutment slopes.

After proper preparation, the alluvium and bedrock materials should provide an adequate and competent foundation for the catchment dam.

Abutments

Terrace deposits exist as capping over bedrock on both of the relatively flat abutment ridges. These deposits range in thickness from approximately 7.5 feet on the right abutment to approximately 11 feet on the left abutment. The terrace deposit is a relatively permeable gravelly, silty sand, with basalt cobbles and boulders up to two feet in maximum dimension. Standard penetration test blow counts indicate a dense consistency of the terrace deposit. Since the maximum reservoir level is a few feet above the terrace deposit/bedrock contact, it will be necessary to extend the foundation cutoff trench through the terrace deposit to control seepage.

Both abutment slopes are covered with minor amounts of slopewash and residual deposits ranging in depth between one and five feet. In order to provide a good foundation contact in these areas, these deposits will be stripped in the dam contact area. The foundation cutoff trench will be excavated into rock on the abutments to control seepage.

Channel Section

The channel section of the dam is about 250 feet wide and, as indicated by drilling, is underlain by alluvium to depths of 26 feet. The alluvial deposits consist of an interlayered, heterogeneous mixture of sandy silt, clayey sand, sandy clay, and silty sand. Generally, the alluvium has a stiff or medium dense to dense consistency. Basalt boulders were also encountered at and near the bedrock contact in some drill holes in the channel section. In one hole (Figure IV-7, hole WSL-9), ground water was encountered in the alluvium at a depth of 14.5 feet but was not noted elsewhere in other holes in the alluvium except for moist, clayey sand at a depth of 15 feet in WSL-17 on the left side of the channel. The ground water appears to be a local perched water table in the alluvium.

3. RESERVOIR AREA

The existing slopes in the catchment basin are generally gentle and are underlain by alluvial and slopewash deposits. A substantial part of the borrow material for the catchment dam will come from the alluvial, slopewash, and bedrock material from the upper (southwestern) part of the reservoir.

A probable old landslide deposit on the right side of, and extending above, the reservoir area was discovered during the site investigation. No groundwater seepage was observed in the holes drilled in the probable landslide area. Although the slope is relatively gentle and no evidence of recent mass instability was observed, the potential for instability is recognized. Therefore, no borrow excavations are planned in the lower portion of the probable landslide area. Borrow excavations will be limited to the upstream portion of the reservoir, upstream of the slide. The catchment dam is located downstream of the toe of the probable landslide. Any renewed landslide activity should not endanger the dam facilities, but would probably contribute a significant amount of debris to the impoundment.

C. ANALYSIS OF POTENTIAL DISCHARGE TO GROUNDWATER

1. MILL IMPOUNDMENT

As mentioned above, and illustrated on Figures IV-5, IV-6, and IV-7, the mill impoundment will be constructed so that any water impounded will lie upon the Cretaceous Menefee formation and Quaternary alluvial deposits. Although exploratory drilling did encounter some groundwater, probably of a perched nature, in the alluvium, it is Gulf's belief that the quality of any other groundwater within the alluvial deposit downstream of the mill impoundment dam will not be impacted by seepage from the impoundment because the dam is designed with a positive cutoff trench which will be excavated into the competent bedrock for an average depth of approximately five feet. Therefore, any seepage from the mill impoundment should be confined within, or inhibited by, the relatively impervious Menefee formation.

As was mentioned earlier, the only time water will be contained within the mill impoundment will be during major storm events when area runoff exceeds the capacity of the separate containment pond.

Based upon the introduction of such water into the Menefee formation via seepage from the mill impoundment, it is Gulf's conclusion that water quality in the Menefee formation will not be degraded bey d the standards of Section 3-103.

2. CONTAINMENT POND

Due to the apparent discontinuous nature of groundwater in the surficial alluvial deposits, the groundwater source most likely to be affected by any potential leachate from the lined containment pond will be that present in the Menefee formation.

There are two operational and design concepts inherent to this containment pond which will prevent degradation of groundwater. First of all, the basin will be lined with a minimum of 20 mil PVC plus 12 inches of earth and rock cover so that migration of liquid from the pond into the underlying strata will be prevented. Secondly, any major process spill which drains to the basin will be pumped back to the mill circuit thereby limiting the retention time of such liquids in the basin to a relatively short period.

It is difficult, if not impossible, to supply information regarding the possible volume, nature and chemistry of the process liquor that might be introduced to the pond as the result of a spill. Conceivably, any chemical utilized in the mill, or any mixture thereof, could wind up in the lined containment pond if there was a spill. The chemicals that may or may not wind up in this pond are not so important as the inhibiting factors to seepage, namely that the containment pond will be lined, and it will be underlain for the most part by the relatively impervious Menefee formation.

When liquid derived from process area washdown is sent to the pond, it will be up to the operator to decide if the liquid should be pumped-backed to the mill circuit. Storm water runoff and certain process area wash water will be impounded in the pond for disposal by evaporation.

Flow from the sewage treatment plant which will be discharged into the containment pond is estimated to run about 5,000 gallons per day. It is estimated, based upon the quality of water discharged from similar sewage treatment plants, that the following limits will be met on a 30-day average:

BOD	30 mg/1
TSS	30 mg/1
fecal coliform	1000 colonies/100 ml
pH	6-9

Furthermore, the quality of this treated water should be in compliance with all the current standards of Section 3-103 of the Water Quality Control Commission Regulations.

D. MONITORING

1. MILL IMPOUNDMENT

The instrumentation for the mill impoundment dam will consist of an array of open-well piezometers and surface displacement monuments. This scheme for embankment instrumentation is intended to provide for the collection of data under a systematic surveillance program that will confirm anticipated conditions or give sufficient advance warning of unanticipated conditions that could affect the structural integrity of the dam. Piezometers will be read quarterly and embankment displacements will be measured semi-annually. The results of the instrumentation readings will be submitted to the design engineer for interpretation and evaluation.

Open-Well Piezometers

The installation and regular reading of piezometers in the catchment dam and its foundation can provide significant quantitative data on the phreatic surface within the embankment and its foundation and on variations with time. In addition, patterns of seepage and the effectiveness of underseepage control measures can be evaluated from piezometer readings. The function of the piezometers will be to measure and monitor the following parameters:

- Piezometric levels in the dam embankment and foundation
- Effectiveness of the chimney and blanket drains

Surface Displacement Monuments

The surface displacement monuments will be used to monitor horizontal and vertical displacements. These displacement measurements will provide a record of embankment surface deformations over the life of the dam. The surface displacement monuments will consist of one-inch diameter reinforcing bars set in concrete.

2. CONTAINMENT POND

Well M-1, referred to earlier in this section and utilized for monitoring the quality and quantity of groundwater in the Menefee formation, will be sampled on a semi-annual basis. Assuming that there is enough water present in the well to be bailed, it is proposed that the sample be analyzed for pH, TDS, NO_3 as N, COD and BOD. If during the intervening six month period any process spill were discharged to the containment pond, the semi-annual sample would be analyzed for U, SO_4, Cl, phenols, Cd and Ra-226 in addition to those parameters listed above.

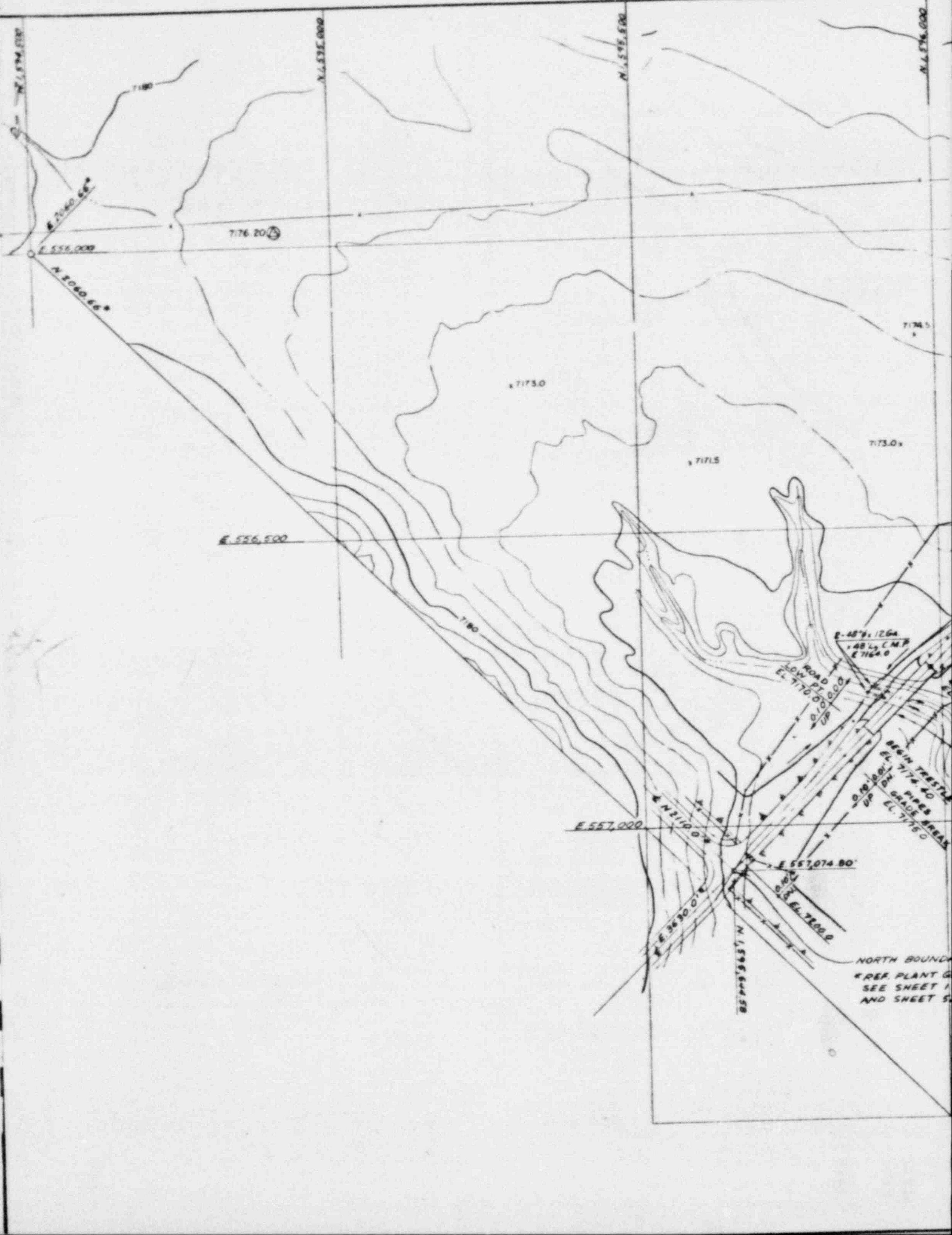
It is not believed that any water quality monitoring of the alluvium is necessary as any water presently occurring within the alluvium is of a perched nature and could not reasonably be utilized as a source of water. A piezometer will be placed in the alluvium though and monitored on a quarterly basis. If the piezometer readings show that seepage from the pond may be occurring, an alluvial water sampling program may, in consultation with NMEID, be initiated.

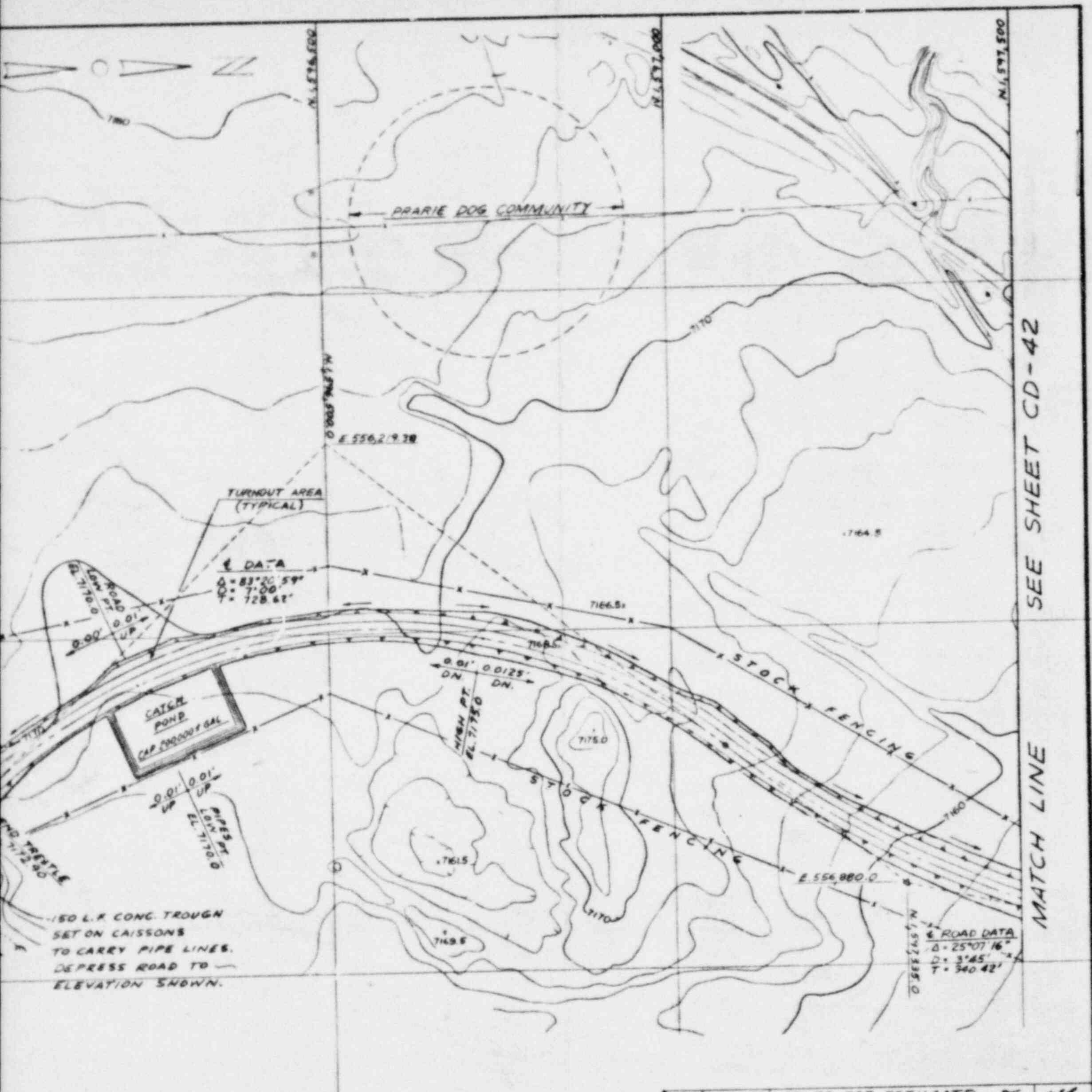
SECTION V

APPENDICES

APPENDIX A.

CIVIL DRAWINGS OF PIPELINE ROUTE


7180
E.2060.66*
7176.20
E.556,000
N.2060.66*
7173.0
7171.5
7174.5
7173.0
E.556,500
7180
ROAD
LOW PT.
EL. 7170.0
48" C.M.P.
BEGIN TRESTLE
EL. 7174.20
PIPES
GRADE BREAK
E.557,000
E.557,074.80'
E.3630.0'
N.1,598,644.58
EL. 7180.0
NORTH BOUND
* REF. PLANT G
SEE SHEET
AND SHEET



NOTE: FOR TYPICAL SECTIONS OF ROAD, PIPEWAY & TRESTLE SEE DWG 1784-CD-27.

REV.	DATE	DESCRIPTION		APPROVED
0	1-23-78	ISSUED FOR ESTIMATE		

ISSUED FOR CONSTRUCTION | CUSTOMER APPROVAL

DESIGNED: W.D.H. | DRAWN: M.R.M. | REVIEWED | APPROVED

Gulf Mineral Resources Co.

GULF AFE NO. 1599

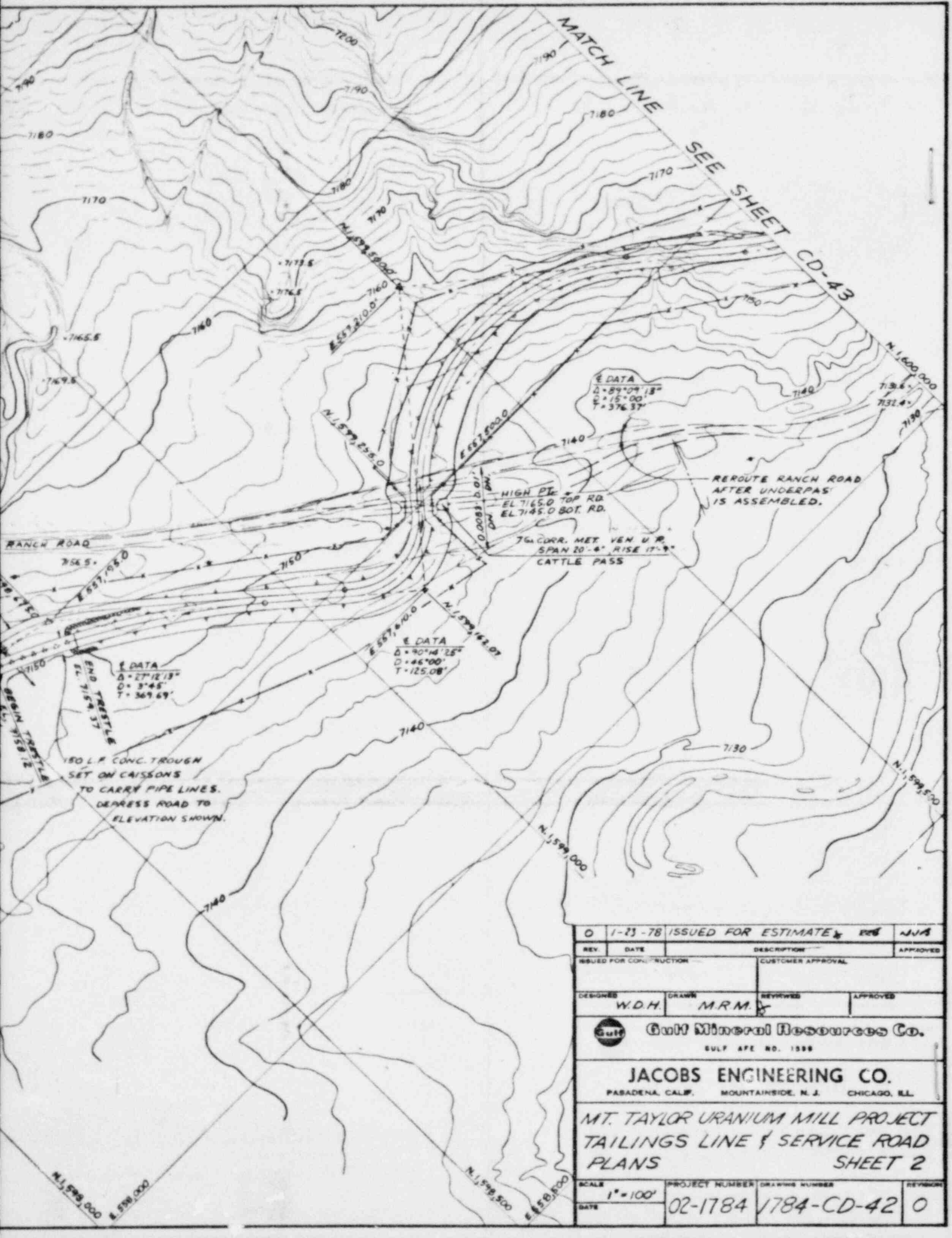
JACOBS ENGINEERING CO.

PASADENA, CALIF. MOUNTAINSIDE, N. J. CHICAGO, ILL.

MT. TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD PLANS
SHEET 1

SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
1" = 100'	02-1784	1784-CD-41	0

N
7200
7220
7210
7200
7190
7180
7170
7170
7160
7180
7154.5
7155.0
7168.5
E.556,000
7170
ROAD EL. 7164.0
(FOR NOM. FLOWS) 36"Ø, 14 GA C.M.P.
E EL. 7150.0
LOW PT. EL. 7155.0
0.0085' UP
DITCH TO CULVERT
0.0125' UP
7151.0
7160
E.556,500
CATCH POND
STOCK FENCING
7149.0
FENCING
7150
STOCK
E.557,000
7145.0
MATCH LINE SEE SHEET CD-41
N.1,597,500
E.557,500
7150



REV.	DATE	DESCRIPTION		APPROVED
0	1-23-78	ISSUED FOR ESTIMATE		

ISSUED FOR CONSTRUCTION — CUSTOMER APPROVAL

DESIGNED: W.D.H. — DRAWN: M.R.M. — REVIEWED — APPROVED

Gulf Mineral Resources Co.

GULF AFE NO. 1599

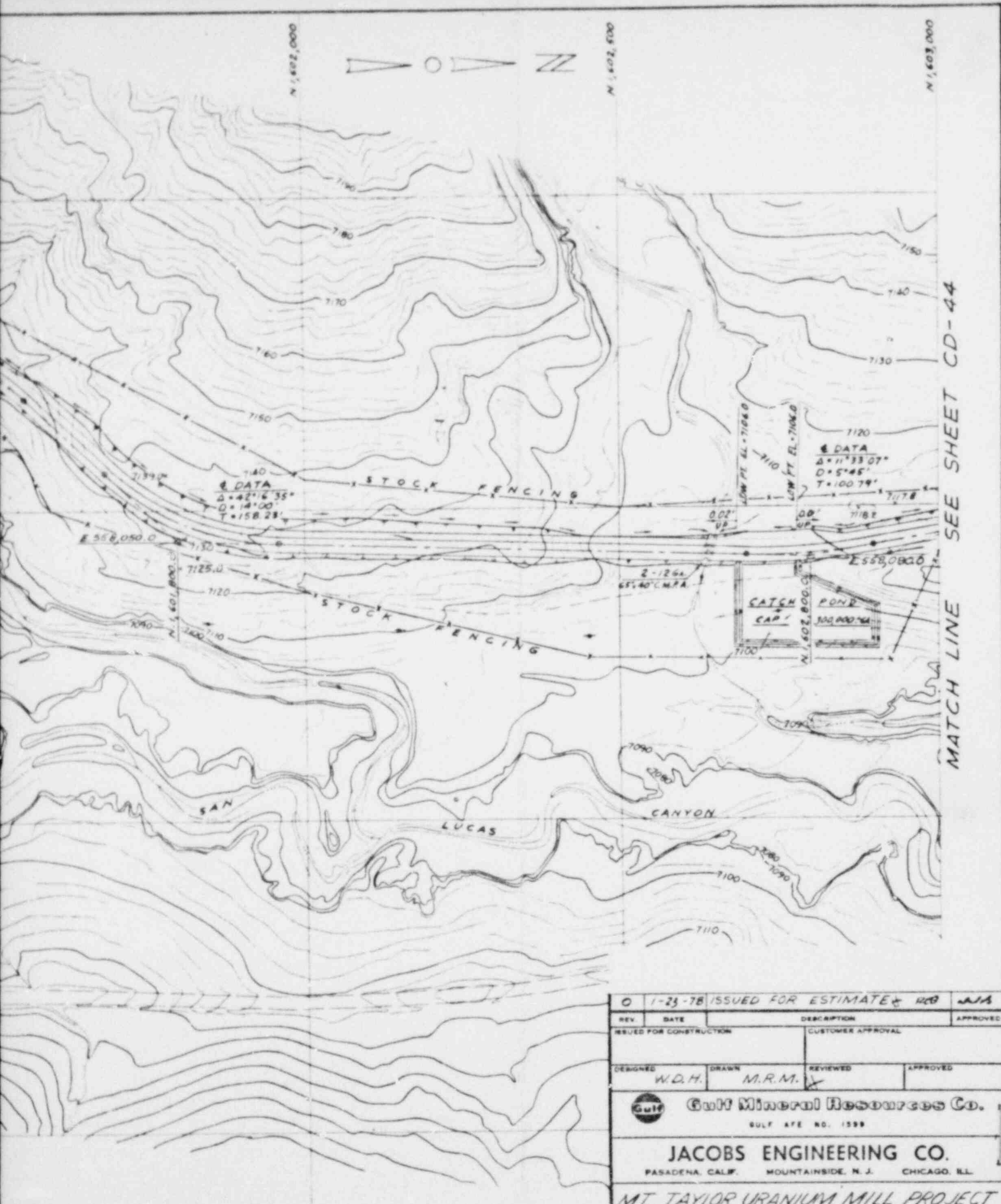
JACOBS ENGINEERING CO.

PASADENA, CALIF. — MOUNTAINSIDE, N.J. — CHICAGO, ILL.

MT. TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD
PLANS — SHEET 2

SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
1" = 100'	02-1784	1784-CD-42	0

MATCH LINE SEE SHEET CD-42
E 557,500
E 557,645.0
E 557,890.0
E 557,980.0
E 557,630.0
E 558,000
E 558,500
E 559,000
N 1,600,540.0
N 1,600,055.0
N 1,600,895.0
N 1,601,365.0
N 1,601,500
℄ DATA
Δ = 36°17'41"
D = 14°00'
T = 134.14'
℄ DATA
Δ = 75°55'12"
D = 18°00'
T = 248.33'
℄ DATA
Δ = 80°40'09"
D = 18°00'
T = 270.28'
GRADE BREAK
EL 7148.0
0.01' UP
0.02' DN
36" CMP
RANCH ROAD
CANYON
10 GA.
PLATE PIPE ARCH
SPAN 15'-10", RISE 9'-10"
CATTLE PASS
7129.0
7138.90
7110.4
7137.8
7138.2
7137.8
SAN LUCAS DAM
7120.4
7117.6
7139.6
7200
7190
7180
7170
7160
7150
7140
7130
7120
7110
7100
7090
7210
7220



REV.	DATE	DESCRIPTION	APPROVED
0	1-23-78	ISSUED FOR ESTIMATE & REB	AJA

ISSUED FOR CONSTRUCTION	CUSTOMER APPROVAL		
DESIGNED W.D.H.	DRAWN M.R.M.	REVIEWED	APPROVED

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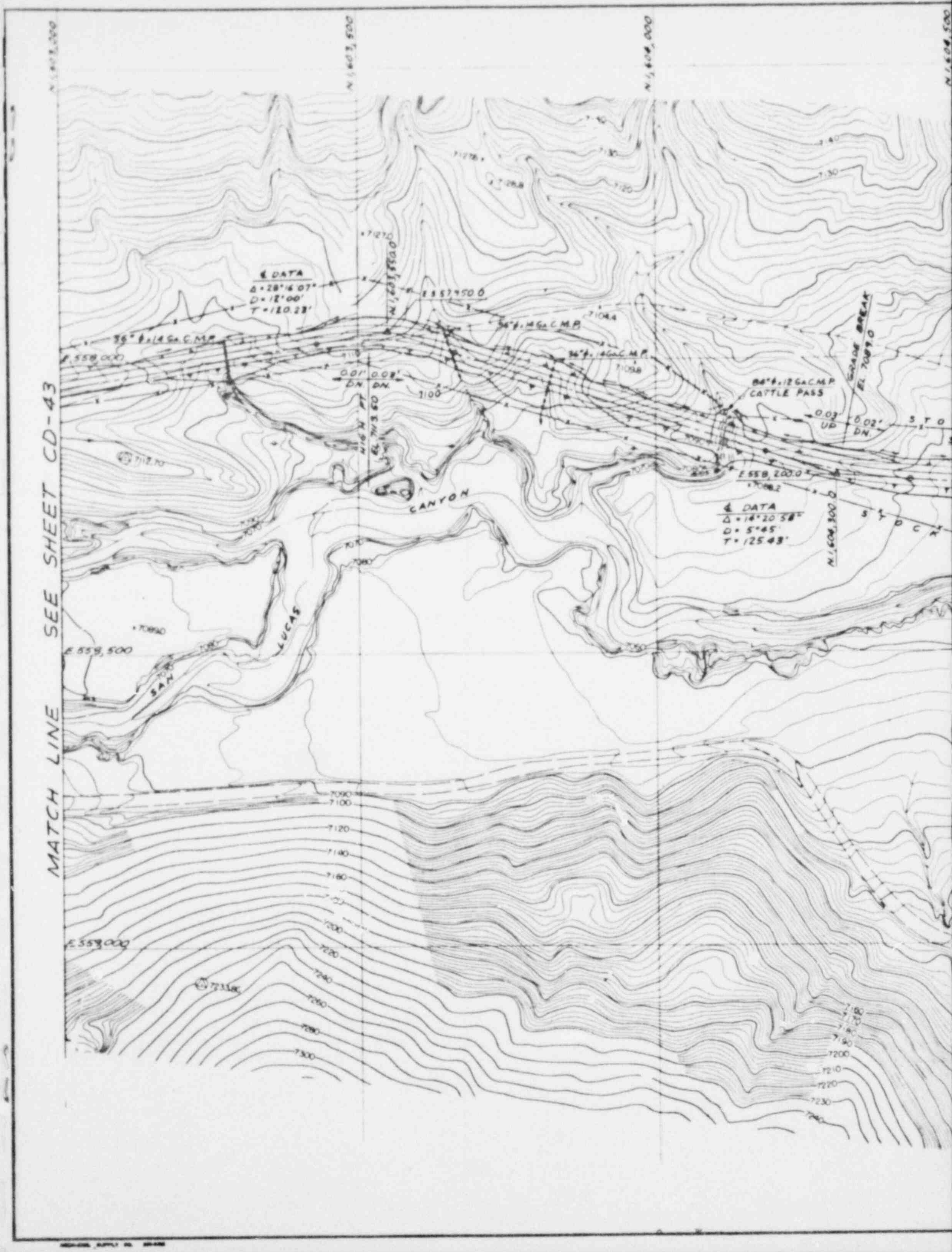
GULF AFE NO. 1599

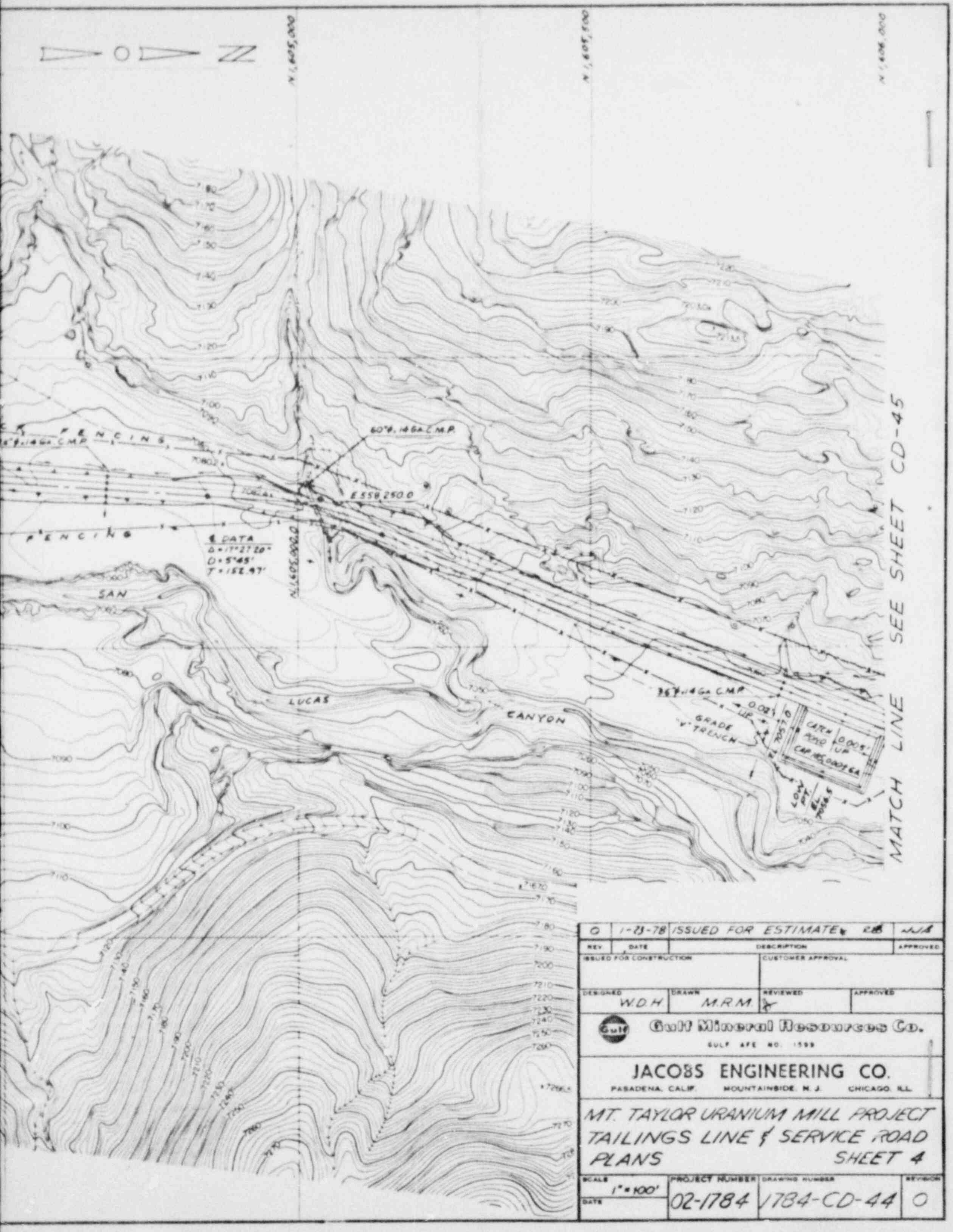
JACOBS ENGINEERING CO.

PASADENA, CALIF. MOUNTAINSIDE, N.J. CHICAGO, ILL.

MT. TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD
PLANS SHEET 3

SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
1" = 100'	02-1784	1784-CD-43	0
DATE			


MATCH LINE SEE SHEET CD-43
N.1,603,000
N.1,603,500
N.1,604,000
N.1,604,500
E.558,000
E.558,500
E.559,000
E.557,950.0
E.558,200.0
N.1,603,820.0
N.1,604,300.0
℄ DATA
Δ = 28°16'07"
D = 12°00'
T = 120.23'
℄ DATA
Δ = 14°20'58"
D = 5°45'
T = 125.43'
36" φ, 14 Ga. C.M.P.
84" φ, 12 Ga. C.M.P.
CATTLE PASS
GRADE BREAK
EL. 7089.0
HIGH PT.
EL. 7113.60
0.01' DN.
0.08' DN.
0.03' UP
0.02' DN.
SAN LUCAS CANYON
S T O C K
7100
7120
7140
7160
7200
7220
7240
7260
7280
7300



REV.	DATE	DESCRIPTION		APPROVED
0	1-23-78	ISSUED FOR ESTIMATE	RB	
ISSUED FOR CONSTRUCTION			CUSTOMER APPROVAL	
DESIGNED W.D.H.	DRAWN M.R.M.	REVIEWED	APPROVED	

Gulf Mineral Resources Co.

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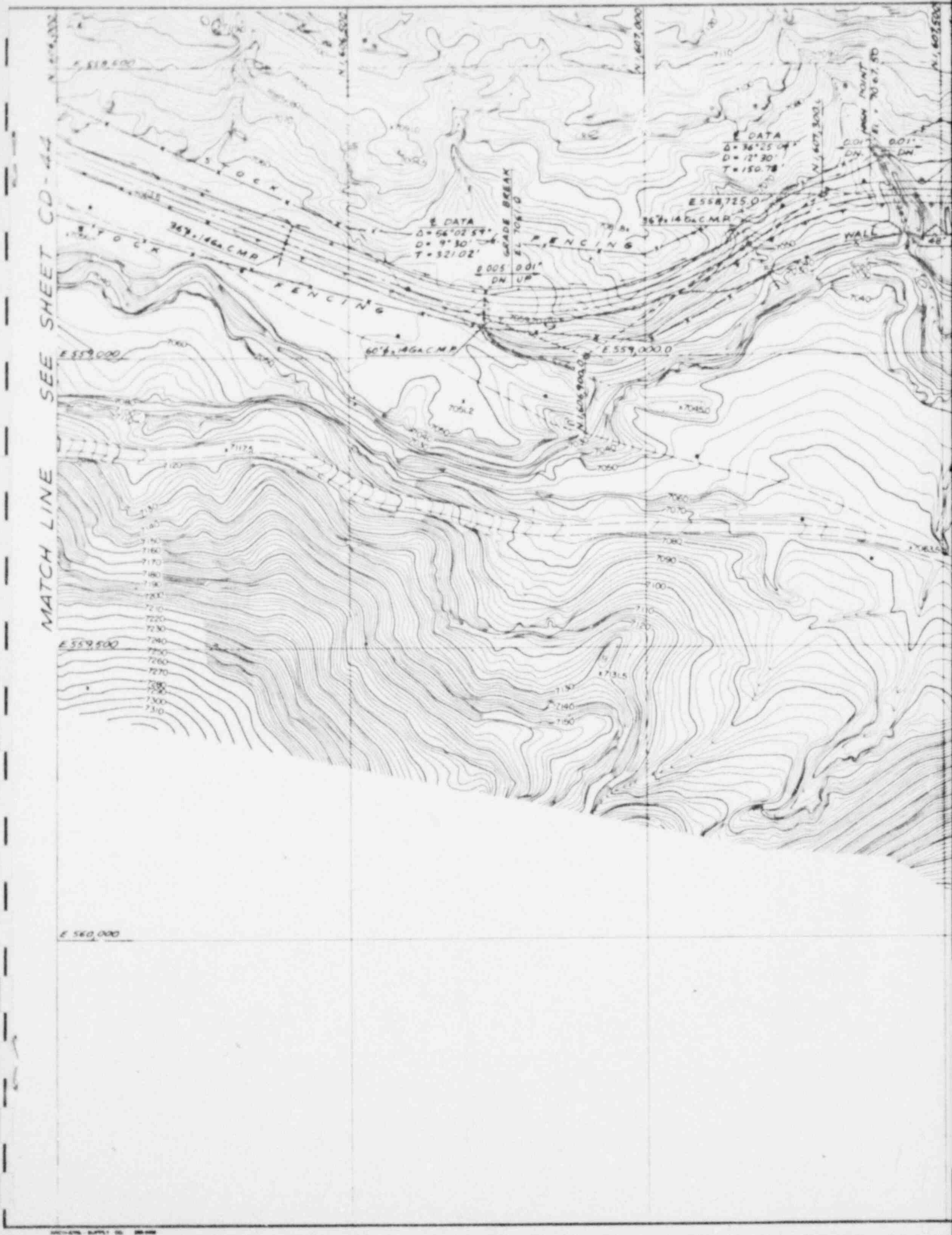
JACOBS ENGINEERING CO.

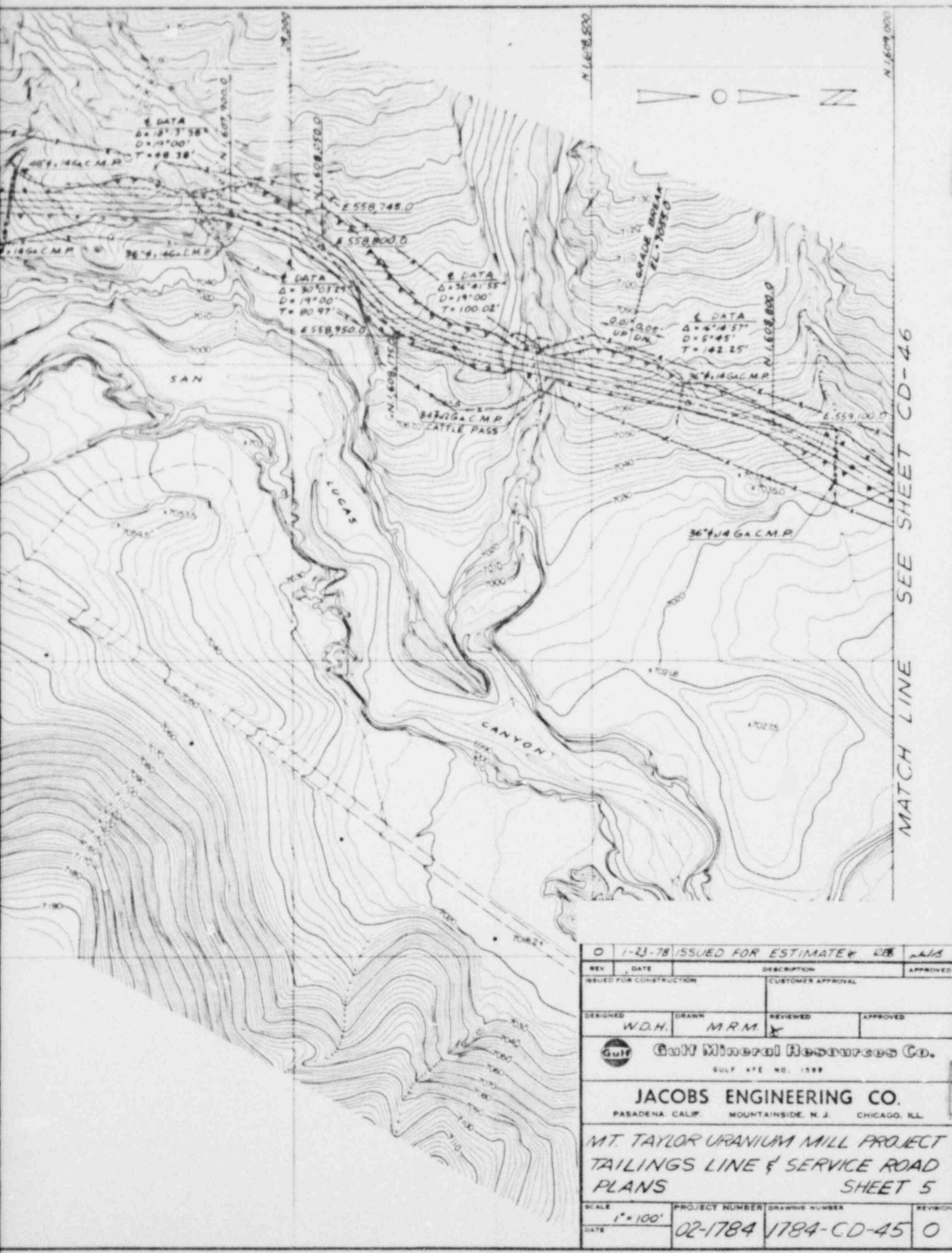
PASADENA, CALIF. MOUNTAINSIDE, N.J. CHICAGO, ILL.

MT. TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD
PLANS SHEET 4

SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
1" = 100'	02-1784	1784-CD-44	0
DATE			



MATCH LINE SEE SHEET CD-44
E 558,500
E 559,000
E 559,500
E 560,000
N 1,606,500
N 1,607,000
N 1,607,500
STOCK FENCING
36"ø, 14Ga C.M.P.
60"ø, 14Ga C.M.P.
℄ DATA
Δ = 56°02'59"
D = 9°30'
T = 321.02'
GRADE BREAK
EL 7061.0
0.005' DN
0.01' UP
℄ DATA
Δ = 36°25'04"
D = 12°30'
T = 150.78'
E 558,725.0
E 559,000.0
N 1,606,900.0
N 1,607,300.0
0.01' DN
WALL
7060
7070
7080
7090
7100
7110
7120
7130
7140
7150
7160
7170
7180
7190
7200
7210
7220
7230
7240
7250
7260
7270
7280
7290
7300
7310



REV	DATE	DESCRIPTION		APPROVED
0	1-23-78	ISSUED FOR ESTIMATE	REB	

ISSUED FOR CONSTRUCTION

CUSTOMER APPROVAL

DESIGNED	DRAWN	REVIEWED	APPROVED
W.D.H.	M.R.M.		

Gulf Mineral Resources Co.

GULF AFE NO. 1599

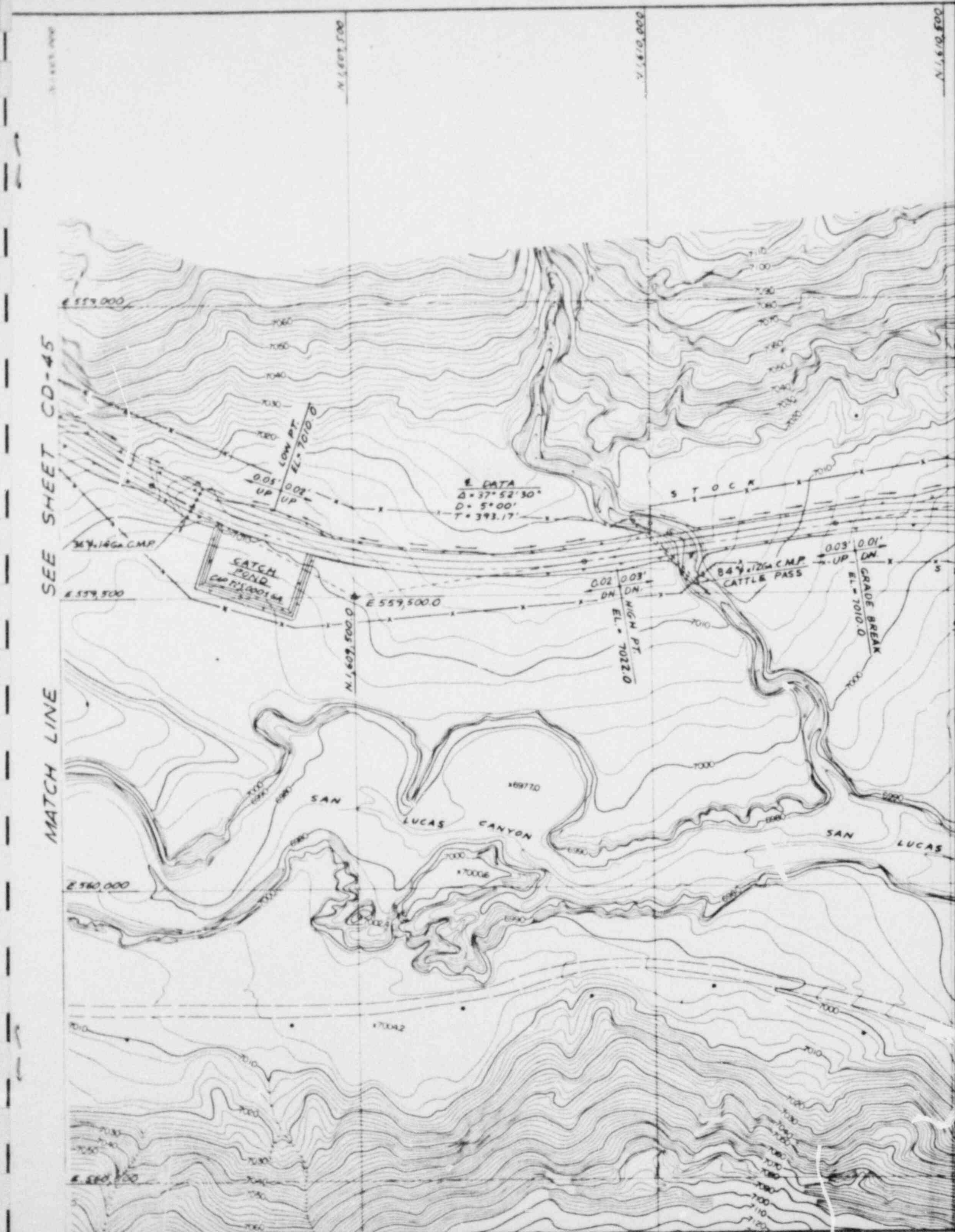
JACOBS ENGINEERING CO.

PASADENA, CALIF. MOUNTAINSIDE, N.J. CHICAGO, ILL.

MT. TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD
PLANS SHEET 5

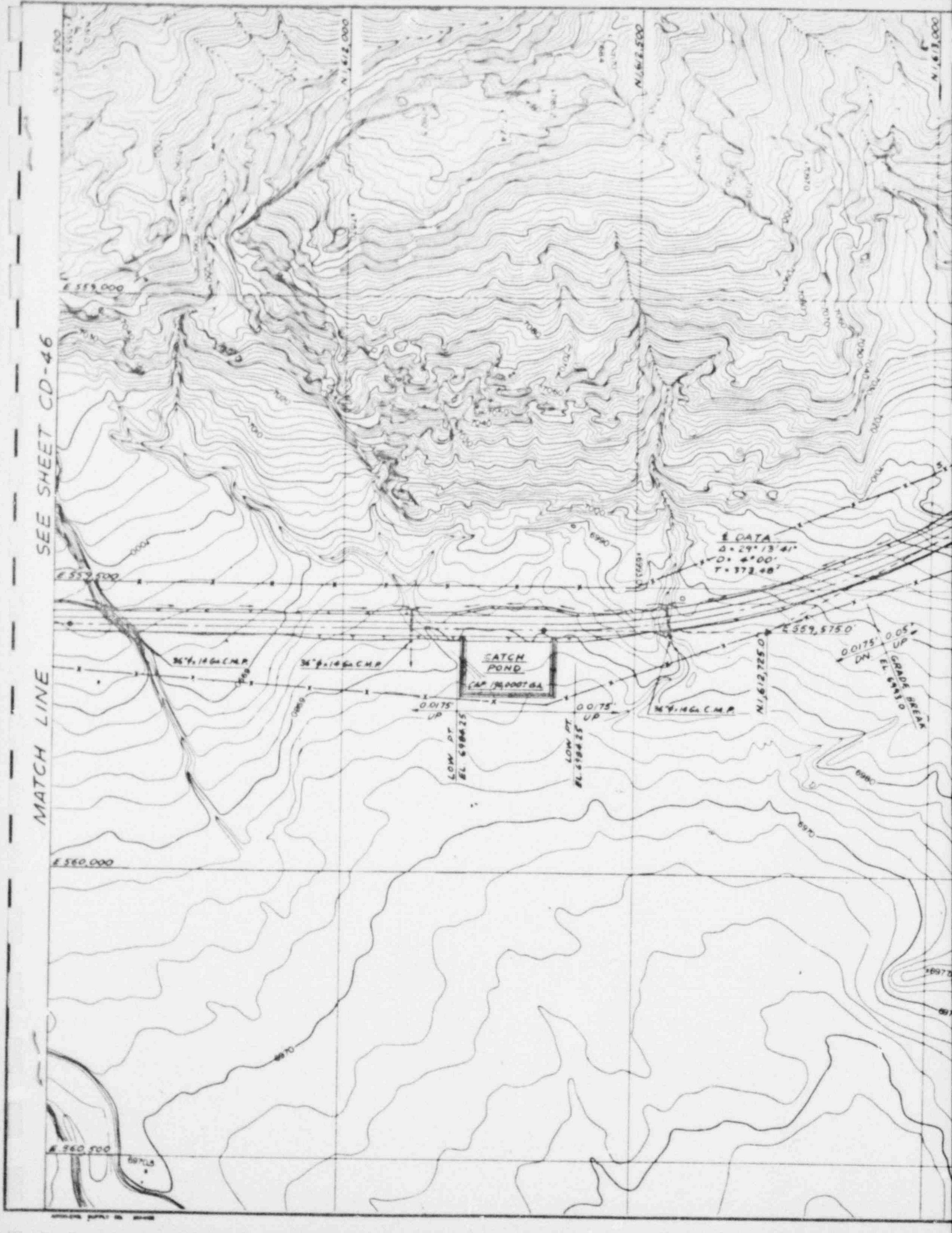
SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
1" = 100'	02-1784	1784-CD-45	0

DATE



MATCH LINE SEE SHEET CD-45
N.1,609,500
N.1,610,000
E 559,000
E 559,500
E 560,000
LOW PT. EL. = 7010.0
0.05' UP
℄ DATA
Δ = 37°52'30"
D = 5°00'
T = 393.17'
STOCK
CATCH POND
E 559,500.0
N.1,609,500.0
0.02 DN
0.03' DN
HIGH PT. EL. = 7022.0
84" 12Ga C.M.P.
CATTLE PASS
0.03' UP
0.01' DN
GRADE BREAK EL. = 7010.0
SAN LUCAS CANYON
SAN LUCAS
x6977.0
x7000.6
x7004.2

N 1,610,550.0
E559,550.0
CANYON
FENCING
36" 16 Ga. C.M.P.
DITCH TO CULVERT
FENCING
N 1,611,000
E559,575.0
N 1,611,200.0
GRADE BREAK
EL.=7000.0
0.01' UP
0.0175' DN
℄ DATA
Δ: 14°05'37"
D: 3°00'
T: 321.21'
N 1,611,500
MATCH LINE SEE SHEET CD-47
0 1-23-78 ISSUED FOR ESTIMATE
REV. DATE DESCRIPTION APPROVED
ISSUED FOR CONSTRUCTION
CUSTOMER APPROVAL
DESIGNED WDH DRAWN MRM REVIEWED APPROVED
Gulf Mineral Resources Co.
GULF AFE NO. 1399
JACOBS ENGINEERING CO.
PASADENA CALIF. MOUNTAINSIDE N.J. CHICAGO ILL.
MT TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD PLANS
SHEET 6
SCALE 1"=100'
PROJECT NUMBER 02-1784
DRAWING NUMBER 1784-CD-46
REVISION 0


MATCH LINE SEE SHEET CD-46
N 612,000
N 612,500
E 559,000
E 559,500
E 560,000
E 560,500
℄ DATA
Δ = 29° 13' 41"
D = 4°00'
T = 373.48'
E 559,575.0'
CATCH POND
CAP 190,000 GA
36"φ 14 Ga C.M.P.
36"φ 14 Ga C.M.P.
36"φ 14 Ga C.M.P.
0.0175' UP
0.0175' UP
0.0175' DN
0.05' UP
LOW PT. EL 6984.25
LOW PT. EL 6984.25
N 612,725.0
GRADE BREAK
7000
7040
7060
6990
6980
6970

REV.	DATE	DESCRIPTION	APPROVED
0	1-23-78	ISSUED FOR ESTIMATE &	RM JAB

ISSUED FOR CONSTRUCTION

CUSTOMER APPROVAL

DESIGNED	DRAWN	REVIEWED	APPROVED
W.D.H.	M.R.M.		

Gulf Mineral Resources Co.

GULF AFE NO. 1398

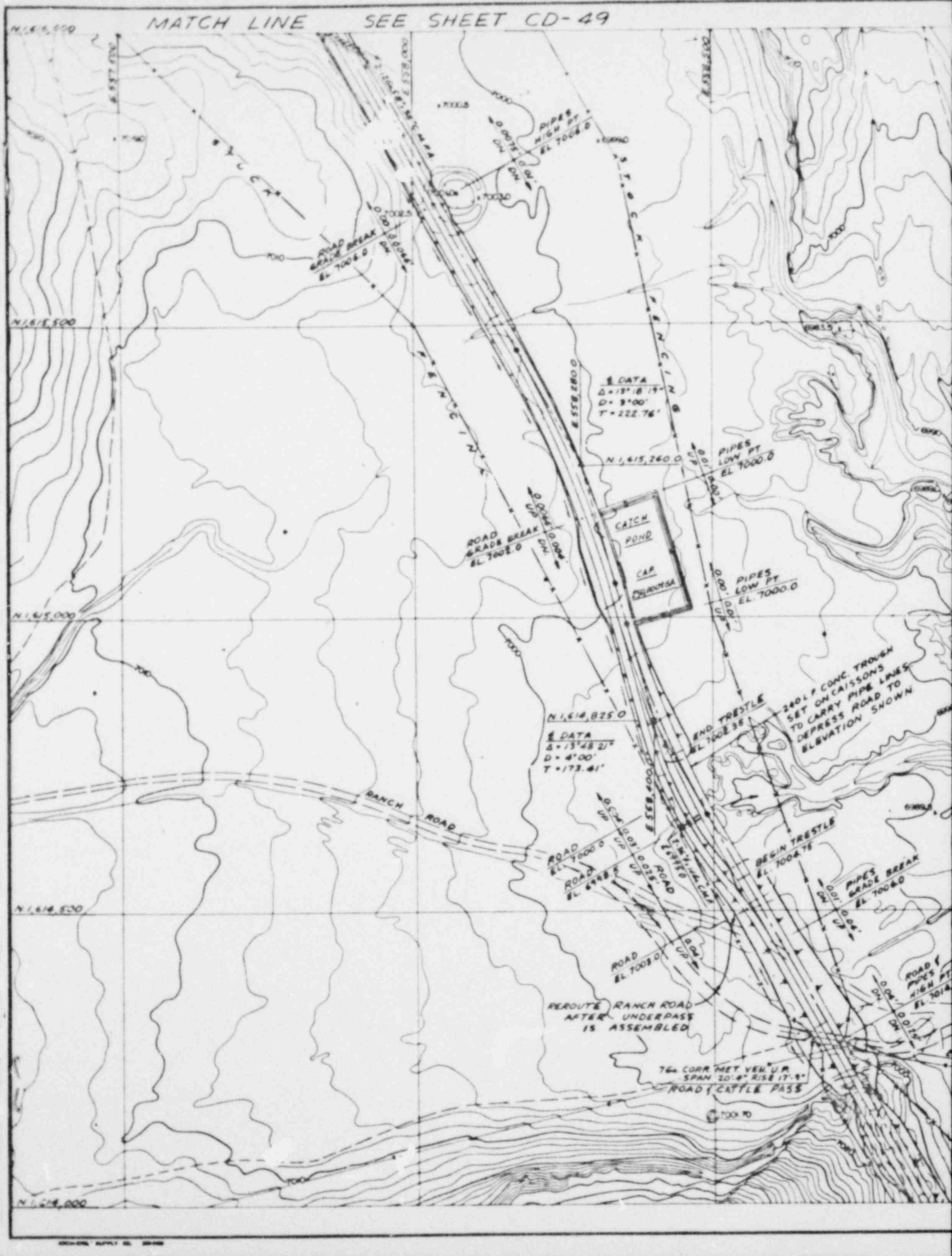
JACOBS ENGINEERING CO.

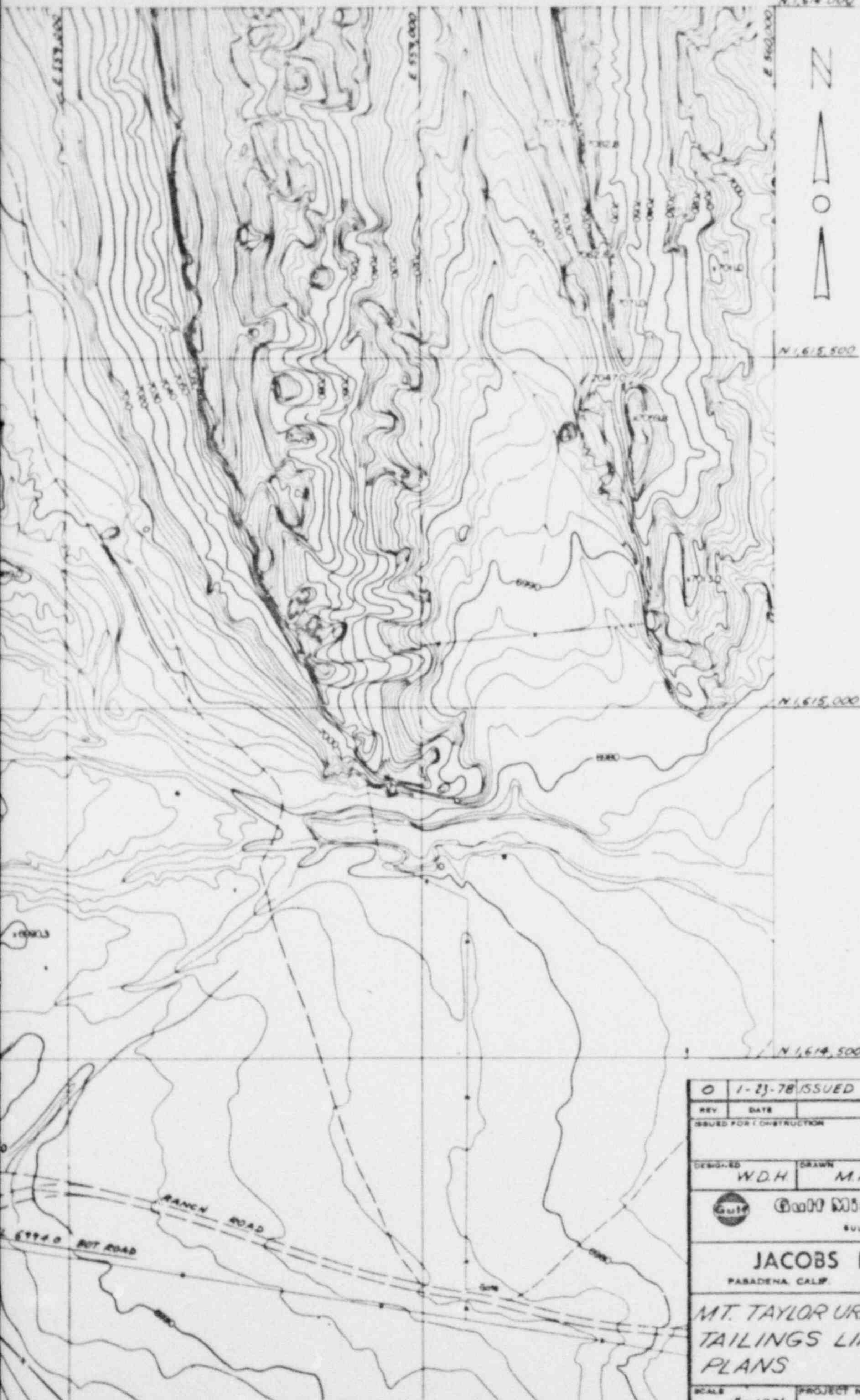
PASADENA, CALIF. MOUNTAINSIDE, N.J. CHICAGO, ILL.

M.T. TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD
PLANS
SHEET 7

SCALE	PROJECT NUMBER	DRAWING NUMBER	REVISION
1" = 100'	02-1784	1784-CD-47	0

DATE


MATCH LINE SEE SHEET CD-49
N 1,616,000
N 1,615,500
N 1,615,000
N 1,614,500
N 1,614,000
PIPES
HIGH PT
EL 7006.0
ROAD
GRADE BREAK
EL 7006.0
STOCK
FENCING
℄ DATA
Δ = 13°18'19"
D = 3°00'
T = 222.76'
N 1,615,260.0
PIPES
LOW PT
EL 7000.0
CATCH
POND
ROAD
GRADE BREAK
EL 7002.0
N 1,614,825.0
℄ DATA
Δ = 13°48'21"
D = 4°00'
T = 173.41'
END TRESTLE
240 L.F. CONC. TROUGH
SET ON CAISSONS
TO CARRY PIPE LINES
DEPRESS ROAD TO
ELEVATION SHOWN
RANCH ROAD
ROAD
EL 7000.0
ROAD
EL 6998.5
BEGIN TRESTLE
PIPES
GRADE BREAK
EL 7006.0
ROAD
EL 7003.0
ROAD &
PIPES
HIGH PT
REROUTE RANCH ROAD
AFTER UNDERPASS
IS ASSEMBLED
ROAD & CATTLE PASS



MATCH LINE SEE SHEET CD-47

REV	DATE	DESCRIPTION	APPROVED
0	1-23-78	ISSUED FOR ESTIMATE	

ISSUED FOR CONSTRUCTION

CUSTOMER APPROVAL

DESIGNED W.D.H. DRAWN M.R.M. REVIEWED APPROVED

Gulf Mineral Resources Co.

GULF AFE NO. 1399

JACOBS ENGINEERING CO.

PASADENA, CALIF. MOUNTAINSIDE, N.J. CHICAGO, ILL.

MT. TAYLOR URANIUM MILL PROJECT
TAILINGS LINE & SERVICE ROAD
PLANS SHEET 8

SCALE 1" = 100'
DATE
PROJECT NUMBER 02-1784
DRAWING NUMBER 1784-CD-48
REVISION 0

APPENDIX B.

PIPELINE HISTORICAL EXPERIENCE

APPENDIX

HISTORICAL EXPERIENCE

As part of the detailed evaluation undertaken to determine the method of transporting tailings from the mill to the La Polvadera disposal site, Gulf Mineral Resources Co. personnel and their consultants inspected pipelines experiencing the same service as that projected at Mt. Taylor.

Questa, New Mexico

Molycorp, Inc., Questa Division, a molybdenum producer in northern New Mexico, processes 16,000 tons of ore per day and disposes of tailings 10.5 miles from the mill site. Tailings are pumped to the tailings impoundment through three lines, each equipped with two stage centrifugal rubber-lined pumps. Density gages and flow meters are installed in each line at the tailings pond and pressure transmitters at the high pressure point of each line for continuous monitoring by the mill operator. Five dump sumps are strategically located along the pipeline to prevent spillage of tailings due to line breaks or during maintenance operations. Three of the sumps are equipped with monitors and pumps to facilitate immediate return of any dumped material into the tailings line system. Where practical earth berms have been constructed alongside the tailings line to contain tailings slurry in the eventuality of a line break.

Initially Questa experienced difficulty with the pipeline system due to excessive erosion at portions of the line which exceeded three percent gradient. The wear problems were resolved by substituting 12 inch pipe for 10 inch in the initial 9000 feet of the lines in which the gradient was three to five percent and more frequent maintenance in three other sections where the gradient approached three percent. In addition, portions of the pipeline have been lined with 20 mils of urethane.

A strict maintenance schedule is adhered to so that the integrity of the line is maintained. Computer schedules determine when pipe sections are rotated or removed to areas of less severe erosion. Pipe thickness is determined by ultrasonic measurement and pipes with improper wall thickness are removed from service.

Operating Data:

Flow Rate	1850-2100 gpm
Weight % Solids	37% ±
Particle Size	
Fraction	Cumulative % Retained
+28 mesh	1
35 mesh	4
48 mesh	13.5
65 mesh	25.5
100 mesh	38.5
150 mesh	48
200 mesh	56
Pipe Size	10 inch
Velocity	7.7-9 feet/second

Much of the information above was extracted from a paper entitled "Tailings Disposal at Molycorp, Inc., Questa Division" by A. Filyk.

Rossing (RUL), South Africa

Rossing uranium operations in South Africa processes 40,000 tons ore per day and transports tailings over eight miles to their tailings impoundment. Rossing employs a two stage pumping system with six rubber-lined centrifugal pumps in each stage. The tailings pipeline is constructed of rubber lined carbon steel.

Rossing initially incurred some operating problems due to excessive wear in the pipelines. The problem was solved by reducing transport velocities. Test spools were placed in the pipeline and the rubber lining has experienced no measurable wear in 1-1/2 years of operation.

Rossing employs a minimum of control instrumentation and the pipeline shutdown procedure must be initiated by the operator. Major pipe failure is detected by ammeters placed on the pump motors. Minor leaks are detected by manual surveillance. Catch basins are provided at strategic locations to contain spills in the event of leaks or pipeline failure.

Operating Data:

Pipe Size	18 inches
Velocity	13-14 feet/second
Weight % Solids	50-52%
Particle Size	

Fraction	Cumulative % Retained
+12 mesh	6.7
20 mesh	23.7
70 mesh	63.7
325 mesh	86.7

Vaal Reefs, South Africa

The gold-uranium operations at Vaal Reefs, South Africa processes 26,000 tons of ore per day and transports tailings a distance of 25 kilometers (15.5 miles). The tailings transport system consists of rubber-lined centrifugal pumps and rubber-lined carbon steel pipe. The tailings system has been in operation for over two years and has experienced no difficulties. Inspection of the rubber-lined steel pipes has shown no noticeable wear.

Operating Data:

Flow	12,000 gpm
Weight % Solids	30%
Velocity	7.5 feet/second
Pipe Size	24 inch

APPENDIX C.

RUBBER-LINED TAILINGS PIPELINE

APPENDIX

RUBBER-LINED TAILINGS PIPELINE

1. SCOPE

This specification covers the requirements for the shop fabrication of rubber-lined steel pipe to be used to convey tailings at the Mt. Taylor Uranium Mill Project, located at San Mateo, New Mexico.

2. OPERATING CONDITIONS

Site Conditions

Location	Near Grants, New Mexico
Elevation	7,250 ft above sea level
Temperature	-20°F - 100°F
Service	tailings disposal
Seismic Zone	2

Service Conditions

This will be an acid slurry composed of acidified water and ground sandstone uranium ore.

Composition of tailings slurry

Temperature	70°F - 110°F
Percent Solids	
Sp. Gr. of dry solids	2.6
pH of slurry	1.2 - 1.8

Sieve analysis of solids (estimated)

Mesh	Cumulative net %
28	3
35	10
48	30
65	50
100	64
200	78
400	85

3. DESIGN REQUIREMENTS

Steel Pipe

The steel pipe used shall be carbon steel pipe, schedule 30, ERW, ASTM A-53 GR B with 20 foot standard lengths.

All welding used in fabrication of pipe will conform to the "American Standard Code for Pressure Piping" ANSI B31.3 - latest edition.

Welds and surfaces to receive lining shall be free of protrusions, sharp edges, weld flux and spatter. Welds shall be continuous and of smooth contour, free of undercutting, cracking, pinholes and porosity. Grinding of welds and other surfaces will be required, where necessary to provide a smooth surface or contour suitable for lining.

Surface Preparation

The interior surface of the pipe, along with other surfaces which are to be covered, shall be cleaned in accordance with the Steel Structures Painting Council Surface Preparation Specifications on Blast Cleaning to white metal SP5-63 with the exception that maximum allowable grit size may be G-16.

Grit blast surfaces to be covered to achieve a sharp angular profile of 2.5 mils minimum. Grit is to be free from salts or organic contamination. Before blasting, all oil, grease or other detrimental material shall be removed to prevent contamination of blasting grit. Blasting air shall be filtered and clean.

After blast cleaning, all abrasives and dust shall be removed by blowing or vacuuming.

Rubber Lining

Materials furnished shall all be new, first quality and free from defects. Materials shall be natural rubber, metal primer and tie cement.

Rubber shall be 1/4" thick natural rubber with a shore A hardness of 40 (± 5) durometer. Rubber stock, free from pinholes, inter-ply bubbles and any defects, shall be used.

Lining Application

The primer/cement system shall be such that a minimum bond strength of 45 PLI is achieved when adhesion-tested in accordance with ASTM D-429.

Care shall be taken to prevent contamination of blasted surfaces. If oxidation or contamination of surfaces occurs prior to the application of primer, cleaning of surfaces shall be repeated.

Primer shall be applied in accordance with good lining technique to insure complete wetting of all surfaces. Dry times of primers and cements shall be such that maximum bond strength is achieved.

Lining shall be applied in such a manner as to provide an uninterrrupted seal over the entire surface to be covered and provide a workmanlike finished appearance. Lining shall be applied so that no air is trapped between the lining and steel and a continuous bond exists between them. Air pockets shall be removed in a manner compatible with the type of lining being applied.

Lining shall be installed in a static position free from undue tension in any direction.

Seams may be used only if required to allow lining installation. They shall be constructed in such a way as to minimize intrusion of lining into the flow area. Seamless lining is preferred.

Curing

Vendor shall provide autoclave for curing rubber lining of pipes.

Vendor shall recommend the curing procedures.

Testing

After the protective lining has been applied, standard electrostatic tests shall be made before and after vulcanizing. Test shall consist of grounding the steel member across the entire surface. If any defects are revealed, proper repairs are to be made and retested prior to acceptance by purchasers inspector.

All vulcanized joints shall be spark tested at 15,000 volts.

All rubber linings shall be visually inspected for possible defects, e.g.; bubbles, seam adhesions and pinholes.

Test Sample

A 6" x 12" flat test sample shall be prepared to be cured with each cure load. The test sample shall be prepared using identical cement system and rubber as in associate pipe. Sample coupons and items cured with them are to be numbered in such a way as to allow identification of pieces cured in each load.

The test sample is to be tested in accordance with ASTM D 429-73 "Adhesion of Vulcanized Rubber to Metal" or latest revision.

The minimum acceptable adhesion value for natural rubber shall be 45 PLI.

APPENDIX D.

"HYDROLOGIC EFFECTS - TAILINGS PIPELINE AND MILL SITE FACILITIES, MT. TAYLOR URANIUM MILL PROJECT, NEW MEXICO, NOV. 30, 1979."

HYDROLOGIC EFFECTS

TAILINGS PIPELINE AND MILL SITE FACILITIES

MT. TAYLOR URANIUM MILL PROJECT

NEW MEXICO

November 30, 1979

Prepared for:

Gulf Mineral Resources Co.

Jacobs Engineering Group, Inc.
251 South Lake Avenue
Pasadena, California 91101

Project No. 1201-79

Hydro - Search, Inc.
Consulting Hydrologists - Geologists

333 Flint Street
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Submitted by:

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Principal Hydrologist

TABLE OF CONTENTS

TABLES

FIGURES

PLATES

1.0 FINDINGS

Tailings Pipeline

1. Several units contain ground water within the vicinity of the tailings pipeline in San Lucas Wash. These include: Quaternary alluvium, Point Lookout Sandstone, and occasional sandstone layers in the Menefee Formation.

   In general, yields of these units are measured in terms of ten's of gallons per minute with the exception of the Menefee sandstones which yield no more than several gallons per minute.

2. Maximum credible releases from the pipeline to the environment are 12,000 gallons for a pinhole leak and 74,000 gallons for a massive failure of the slurry line and adjacent low point catch pond.

3. The alluvial materials are rated as of intermediate to high permeability. However, a combination of factors indicates that it is improbable that released pipeline fluids will reach ground water as a result of downward seepage through the alluvium. These factors include: relatively small volume of released fluids, high moisture requirement of the dry alluvial materials, depth of ground water, plugging of pore spaces in the alluvium by fines of the released liquid and as a result of swelling of clays, and availability of prompt cleanup.

4. The most likely means of rapid and widespread dispersal of the released fluids is as a result of flow into the live stream of San Lucas Wash. Because of the discharge of mine drainage to the wash (5,000 to 10,000 gpm during operation) and the relative small volume of a release, even the largest credible pipeline release would tend to be diluted to a low level.

   Means of attenuation beyond mixing include chemical reactions with aquifer materials and dissolved chemical constituents of water.

   The factors which would attenuate the concentrations of released fluids would be operative during the regional movement of surface water, either to the northeast in the San Lucas Wash drainage toward Arroyo Chico - Rio Puerco or to the north through and beyond Laguna Polvadera. The ultimate disposition would be by evapotranspiration and infiltration into the ground. The quantity of the release which infiltrates at any given location would be small. Degradation of water quality which would adversely affect present or future uses of surface and ground waters is not anticipated.

5. The bedrock units (Point Lookout and Menefee sandstones) beneath and adjacent to San Lucas Wash would receive recharge of very small increments of diluted released fluid via the alluvium of San Lucas Wash. Concentrations of dissolved chemical substances would be further decreased by dispersive mixing and chemical reactions in the aquifers during slow migration in the regional ground-water flow system toward the north and east. Attenuation would be effective and degradation of water quality which would adversely affect present or future uses of ground waters should not occur.

Mill Site

6. The mill site facilities are in a shallow, alluvial valley which is underlain by thick, impervious Menefee Formation. The Menefee and alluvium contain small amounts of localized ground water which is not of use as a water resource.

7. The Menefee will prevent downward and lateral movement of sewage wastewaters and any inadvertent releases to the environment from the mill.

   The mill catchment dam provides for a positive impervious seal through the alluvium and into the Menefee bedrock, and lateral movement of wastewaters and inadvertent releases is not expected.

   As a consequence, wastewaters and inadvertent release waters will be confined to the site, and degradation of ground and surface waters outside of the site will not occur.

2.0 INTRODUCTION

The uranium extraction mill of Gulf Mineral Resources Company (GMRC) will be situated about three miles north of the Mt. Taylor Mine which is near San Mateo, New Mexico (Figure 1). A six-mile long tailings pipeline facility will connect the mill and the tailings impoundment which will be situated to the north in La Polvadera Canyon. Safeguards to prevent uncontrolled releases from the pipeline to the environment include a lined and bermed pipeway, lined low point catch ponds, automatic shutdown of pumps in the event of a ten percent flow differential between the pumps and the tailings impoundment, and frequent visual inspection of the pipeline route. A purpose of this report is to project the effects on ground and surface waters of unforeseen and inadvertent releases of tailings slurry or decant water from the pipeline.

The mill site facilities include the mill itself, a lined containment basin about 1,000 feet to the northeast, and an unlined impoundment about 3,000 feet to the northeast. The containment basin will contain any major spillage from the mill and runoff from the process area. The impoundment will hold treated wastewater from the mill, runoff from the area between the mill and impoundment, and runoff from the process area that exceeds the capacity of the containment basin. Disposal of waters will be by evaporation, except that spills from the mill will be returned to the mill for reprocessing. A second purpose of this report is to project the effects on ground and surface waters of the planned use of these facilities.

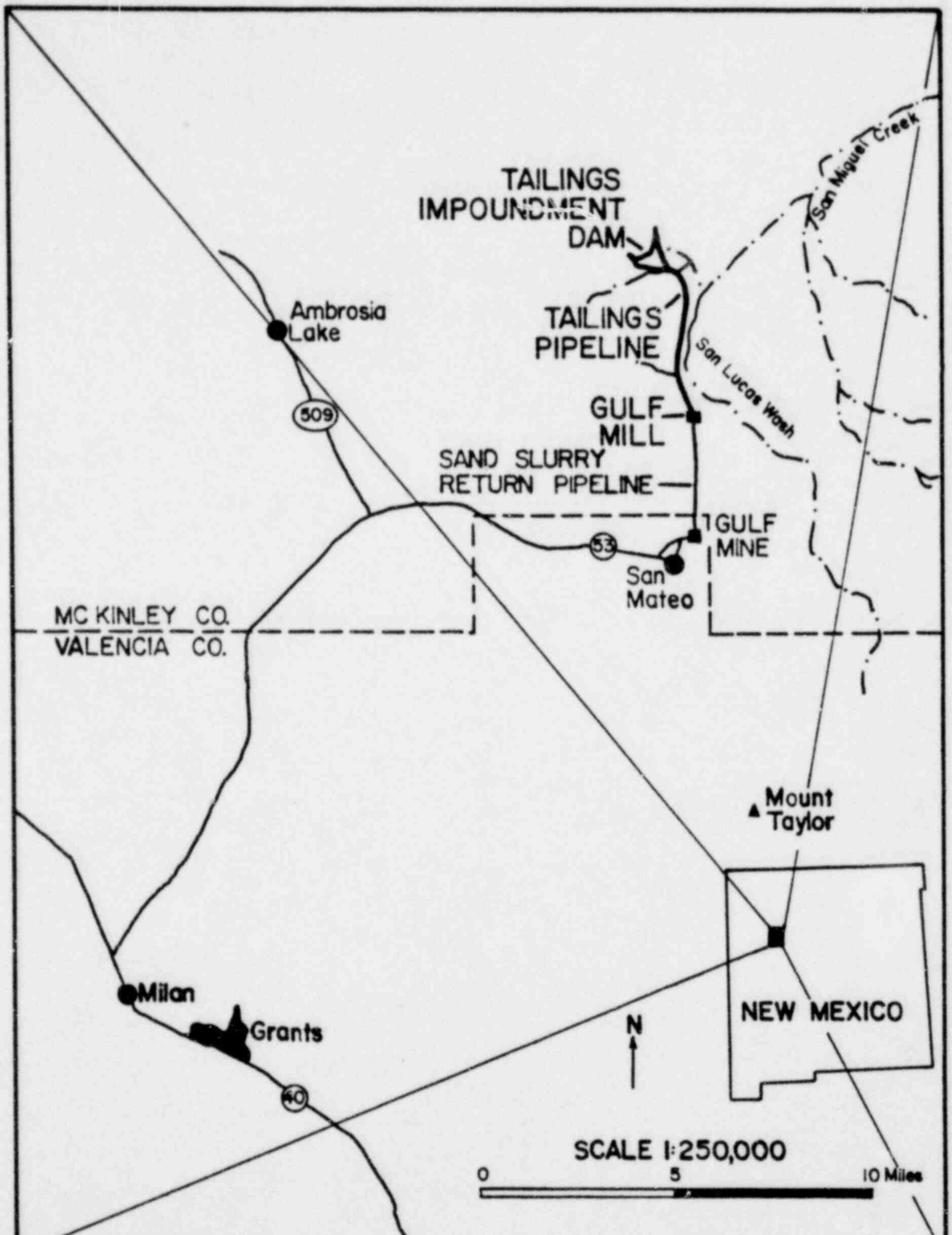

Figure 1. Location of Tailings Pipeline and Mill Site, Mount Taylor Uranium Mill Project, Gulf Mineral Resources Co., New Mexico.

The analysis in this report rests upon a data base comprised of information from the published literature and several investigations undertaken as part of the Mt. Taylor Uranium Mill Project, as cited in Chapter 6.0, SOURCES OF INFORMATION, and results of a detailed hydrogeological investigation of the pipeline route and mill site undertaken by Hydro-Search, Inc. (HSI) during the period July through November 1979.

Personnel of Hydro-Search, Inc. who have participated in this project include John V.A. Sharp, principal hydrologist and project manager; Thomas E. Lachmar, John E. Peterson, Lorraine P. Bruce, and Forrest L. Fox, hydrogeologists; Michael L. Bergstrom, hydrologist; Michael D. Cleary, geologist; Thomas K. Wheeler, senior hydrogeologist; and Paul R. Fenske, hydrologic consultant.

3.0 HYDROLOGY

3.1 SURFACE WATER

San Lucas Canyon is located in the Arroyo Chico watershed, which is part of the much larger Rio Puerco drainage (Plate I). This region is characterized by a semi-arid climate, with the Arroyo Chico watershed having an average annual precipitation of about nine inches based on precipitation records of the National Oceanic and Atmospheric Administration (NOAA).

3.1.1 Natural Flow Regime

No perennial streams exist in the San Lucas Canyon area under natural conditions. Surface water flow occurs as runoff from short term, high intensity rainstorms, and from rainfall and snowmelt during the winter.

The nearest surface water gaging station on the San Lucas Wash drainage is on Arroyo Chico approximately four miles north of Guadalupe, New Mexico. This is about 35 miles downstream from Leopoldo Diversion Dam (Plate I). This location is immediately upstream from the confluence of Arroyo Chico and Rio Puerco, and is about 40 miles north of the intersection of Rio Puerco and I-40. The gaging station records drainage from an area of approximately 1390 square miles, 58 of which lie within the San Lucas Wash watershed. Average annual discharge at this gaging station is 15,430 acre-feet (a-f) per year for the period of record from 1943 to 1978 (USGS, 1979). Approximately 800 a-f of this flow originates in the San Lucas Wash drainage above Leopoldo Diversion Dam.

Water quality data collected by the U. S. Geological Survey at the Arroyo Chico gaging station on April 13, 1978 are shown in Table 1 (USGS, 1979).

Runoff from San Lucas Wash for individual precipitation events can be estimated using the Soil Conservation Service (SCS) method for estimating runoff from small ungaged watersheds. Runoff from the six-hour and 24-hour precipitation events for a 10-year return period have been analyzed (NOAA, 1972). As estimated by this method, total runoff for the six-hour precipitation event would be 458 a-f with a peak discharge of 932 cubic feet per second (cfs). The total runoff estimated for the 24-hour precipitation event would be 2927 a-f with a peak discharge of 1978 cfs.

3.1.2 Mine Discharge Water

The flow regime of San Lucas Wash has changed as a result of the discharge of mine water, and the stream is now perennial from below San Lucas Dam to Leopoldo Diversion Dam, a distance of about two and one-half miles (Plate II). The current discharge from the mine is about 5.8 million gallons per day (mgd), or about 4,000 gallons per minute (gpm). This flow is equal to about 6500 a-f per year, or more than eight times the estimated average annual natural runoff. Discharge of water during the mining operation will be 5,000 gpm (8000 a-f per year), increasing to as much as 10,000 gpm (16,000 a-f per year) as the operation progresses.

Table 1. Water Chemistry, Surface Waters, San Lucas Wash Area, New Mexico.

	NMEID Standards	Flume #1	Flume #2	Flume #3	Laguna Polvadera, North	Arroyo Chico, at gage	Arroyo Chico,* at gage
Date sampled		10/24-25/79	10/24-25/79	10/24-25/79	10/11/79	10/11/79	4/13/78
pH	6 to 9	8.4	8.4	8.4	7.9	8.3	8.8
TDS (calc.)	1,000	622	617	608	952	1,570	2,377
Elec. Cond.		1,060	1,070	1,060	1,400	2,230	3,350
Temperature		25.4	22.3	21.4	11.7	14.2	11.5
HCO_3^-		277	277	277	395	360	382
$CO_3^=$		5.8	5.8	5.8	----	12	14
Cl^-	250	21	20	20	36	68	54
$SO_4^=$	600	220	218	211	356	777	1,300
F^-	1.6	0.8	0.8	0.8	1.4	1.2	1.1
NO_3^-	45 (10 mg/l as N)	0.75	0.84	0.71	1.33	0.22	0.13
Na^+		200	200	195	300	460	750
K^+		2.3	2.7	2.7	19	5	3.9
Ca^{++}		13	10	10	12	30	50
Mg^{++}		2	2.7	2.7	13	25	11
SiO_2		20	20	23	19	15	4.7
As	0.1	< 0.01	< 0.01	< 0.01	0.01	< 0.01	0.002
Ba	1.0	0.25	0.20	0.20	0.30	0.30	
Cd	0.01	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0.000
Cr	0.05	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.000
Pb	0.05	0.01	0.01	< 0.01	0.01	0.02	0.003
Hg	0.002	0.0009	< 0.0002	< 0.0002	0.0009	0.0004	0.0000
Se	0.05	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.000
Ag	0.05	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	
Cu	1.0	0.01	0.01	0.01	0.01	0.005	0.001
Fe	1.0	< 0.01	< 0.01	< 0.01	< 0.01	0.03	0.03
Mn	0.2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.03
Zn	10.0	0.22	0.22	0.20	0.28	0.28	0.01
Al	5	0.2	0.2	0.2	1.9	0.4	
B	0.75	0.20	0.30	0.60	0.35	0.40	0.21
Co	0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.000
Mo	1.0	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.004
Ni	0.2	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
V		< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0.0000
PO_4 (as P)		< 0.01	< 0.01	< 0.01	0.11	0.02	0.02

Note: All analyses are in mg/l except pH which is in units, electrical conductivity which is in µmhos/cm @ 25° C, and temperature which is in degrees C.

Analysis agency: The Industrial Laboratories Company, Denver Colorado.

	NMEID Standards	Flume #1	Flume #2	Flume #3	Laguna Polvadera, North	Arroyo Chico, at gage	Arroyo Chico,* at gage
Uranium, mg/l	5.0	0.10±0.006	0.08±0.004	0.12±0.006	0.19±0.009	0.11±0.006	0.0033
Radium-226, pCi/l		< 0.03	0.29±0.03	0.14±0.03	0.05±0.03	< 0.03	0.05
Radium-228, pCi/l		< 1.	< 2.	< 1.	3.±1.	< 2.	
Radium-226 + -228, pCi/l	30.0	< 1.03	< 2.29	< 1.14	3.05	< 2.03	
Gross Alpha, pCi/l		87±2	60±4	112±6	120±7	101±7	

Note: Uncertainty is one standard deviation due to counting statistics. Detection limits are one standard deviation.

Analysis agency: LFE Environmental Analysis Laboratories, Richmond, California.

* Analysis from U.S.G.S. Water-Data Report NM-78-1, 1979, pp.215-216.

The natural flow has eroded a narrow, generally steep-sided channel, 10 to 30 feet deep, into the alluvial fill (Qal) in San Lucas Canyon for approximately one and three-quarters miles downstream (north) from San Lucas Dam (Plate II). For the first one and one-half miles the stream flows either on the Point Lookout Sandstone or on a cover of alluvium overlying the Point Lookout. The Point Lookout probably receives some recharge from the stream along this reach. Estimates based upon results of a pumping test of the Point Lookout indicate that the amount of recharge is small.

For the next one-half of a mile the stream flows on a cover of alluvium overlying the relatively impervious Menefee Formation. Very little water appears to be lost into the Menefee along this reach.

For the last one-half of a mile to Leopoldo Diversion Dam, the alluvial fill, which rarely exceeds 500 feet in width in the upper part of San Lucas Canyon, becomes progressively wider, and may possibly become thicker as well. Some water is lost by seepage recharge into the alluvium in this area and upstream (south) toward San Lucas Dam. This alluvium ground water moves to the north and northeast, subjacent and parallel to the wash.

From Leopoldo Diversion Dam the mine discharge water can follow one of two courses. The first route it can take is to the north out of the northern pond of Leopoldo Diversion Dam through a ditch to Laguna Polvadera (Plate II).

From there it continues northward through another ditch around the northeastern margin of San Mateo Dome until it reaches a point near the center of Section 35, T.15N.,R.8W., where it discharges through a breach in the dike and flows toward the northeast for about three-quarters of a mile before it sinks completely into the subsurface (Plate I). The water sample designated Laguna Polvadera (Table 1) was collected at the point where the water crosses a road approximately three-eighths of a mile northeast of the breach in the dike.

If the gate out of the northern pond of Leopoldo Diversion Dam is closed, the mine discharge water flows back into San Lucas Wash out of the southern pond (Plate II). From there it flows toward the northeast into San Miguel Creek, which in turn flows into Arroyo Chico (Plate I). At the time of an aerial reconnaissance on October 4, 1979, the water in Arroyo Chico extended downstream (east) to between where Torreon Wash enters Arroyo Chico and the confluence of Arroyo Chico and Rio Puerco. In contrast, surface flow was observed at the gaging station on Arroyo Chico immediately upstream from the confluence with Rio Puerco when the water sample designated Arroyo Chico (Table 1) was taken at that location on October 11, 1979. On that day the mine discharge water was flowing into San Lucas Wash out of the southern pond of Leopoldo Diversion Dam, whereas on the day of the aerial reconnaissance the flow was being diverted northward into Laguna Polvadera out of the northern pond.

Damp sand along the channel bottom of Rio Puerco was observed to extend for approximately six miles downstream from the confluence with Arroyo Chico at the time of the aerial reconnaissance. This indicates that the surface water extends to this point when the mine discharge water is flowing into San Lucas Wash out of the southern pond of Leopoldo Diversion Dam. If the mine discharge is increased to as much as 10,000 gpm as projected and also is continuous for a number of years, the water could flow at the surface as far as the intersection of Rio Puerco and I-40, and perhaps beyond.

Identical Parshall flumes were installed at three locations in San Lucas Canyon between the point of discharge of the mine water and Leopoldo Diversion Dam (Plate II). The locations were chosen so as to estimate the amount of water lost into the subsurface geologic units along two reaches of the stream, the upper reach being underlain predominately by the Point Lookout Sandstone and the lower reach by the Menefee Formation.

Continuous discharge measurements were taken at the three flume locations from October 13 to October 16, 1979. In addition, the discharge in the pipeline was measured with an in-line flow meter maintained by GMRC. During this period the average daily discharge in the pipeline was 3950 gpm (Jack Gilmour, personal communication, 1979). The average daily discharges for selected time intervals during the same period were 4500, 3600, and 4400 gpm for flumes 1, 2, and 3, respectively. Extreme care was taken in the installation of the flumes, the flume measurements, and analysis of the data. Given the good to excellent quality of the installation, variation in measurement should have been on the order of 2 to 5 percent. We are unable to explain the low discharge value at flume 2. The small change in discharge between flumes 1 and 3 could be interpreted to mean that a relatively small amount of water, possibly on the order of 100 gpm, is lost as recharge into the subsurface along San Lucas Canyon.

The discharge to the wash is cyclical with a period of about 1.5 hours. Although differences exist between the average daily discharges at the three flume locations, the flow peaks and troughs show consistent travel times between the three flume locations. Significant decrease in the amplitude of the fluctuations occurs between flumes 1 and 2 and, to a lesser degree, between flumes 2 and 3.

3.1.3 Water Chemistry

Two water samples were taken at each of the three flume locations, one each during a minimum in flow and during a maximum in flow approximately 12 hours later. The two samples were combined into a composite sample for laboratory analysis. The results are shown in Table 1 (p.8).

Results of the three flume samples show negligible variation in water chemistry downstream from the discharge point. The water meets the quality standards (Part 3, Section 103) for discharges onto or below the surface of the ground as set by the New Mexico Water Quality Control Commission and as administered by the New Mexico Environmental Improvement Division (NMEID).

The lack of variation in chemistry downstream is suggestive of several things. First, the surface stream appears not to be receiving seepage discharge of a major quantity of ground water along San Lucas Canyon. In general, chemistry of ground-water discharge would be unlike that of the receiving surface water and, thus, accession of ground water would result in changes in water chemistry downstream. Second, under the relatively stable condition of flow during the sampling, mineral salts were not being dissolved by the flowing water from either bed or bank materials.

The October 1979 samples north of Laguna Polvadera and at Arroyo Chico are mine discharge and show an overall increase in concentration of dissolved constituents, primarily sodium and sulfate ions. This increase presumably is attributable to the combined effects of evaporation and dissolution of bed and bank materials and possibly accessions of ground water as the water moves downstream. The Arroyo Chico sample of April 1978 is considerably more concentrated than that of October 1979. It is not known whether the April 1978 sample is natural water, or whether it is mine discharge water. Mine discharge to San Lucas Wash commenced during February-March 1978.

3.2 GROUND WATER

The geologic map (Plate II) shows the distribution of the various geologic units in the San Lucas Canyon area. Five of these units are exposed at the surface along the pipeline route. They are, from oldest to youngest, the

Dilco Coal Member of the Crevasse Canyon Formation (Kcdi), the Mulatto Tongue of the Mancos Shale (Kmm), the Point Lookout Sandstone (Kp, Kpu), the Menefee Formation (Kmf), and surficial alluvium (Qal). Of these, only the alluvium, the Point Lookout Sandstone, and a few individual sandstones in the Menefee Formation generally are permeable enough to store and transmit significant quantities of ground water. Of the other geologic units proximate to the pipeline, only the Dalton Sandstone Member of the Crevasse Canyon Formation (Kcda) can be considered to have potential as an aquifer. The hydrologic characteristics of the various geologic materials which underlie or are adjacent to the pipeline route and the mill are summarized in Table 2.

3.2.1 San Lucas Canyon

Three geologic units are exposed along the pipeline route through San Lucas Canyon: the Point Lookout Sandstone, the Menefee Formation, and surficial alluvium. The hydrologic regime of San Lucas Wash has been altered by the discharge of mine water, and the potential for ground-water recharge has been enhanced. Consequently, the geologic units probably are now receiving some recharge from the surface stream on a continuous basis. Under the previous natural regime recharge was sporadic, only accompanying the occasional runoff events.

The direction of flow of ground water in the alluvium is to the north and north-northeast as underflow parallel to the stream. This flow of ground water plus infiltration at the surface recharges the body of alluvium in the general area of Leopoldo Diversion Dam, Laguna Polvadera, and over a wide area to the northeast toward the gaging stations. Ground water in

Table 2. Summary of Hydrologic Characteristics of Geologic Materials.

Geologic Unit	Symbol	Age	Lithologic Description	Maximum Thickness, feet	Apparent Relative Permeability
Alluvium	Qal	Quaternary	Moderately poorly sorted, unlithified silty to clayey sand.	80	Intermediate to high
Menefee Formation	Kmf	Late Cretaceous	Interbedded fine- to medium-grained sandstone, siltstone, shale, and coal.	~ 1,000	Overall low, occasional sandstones may be intermediate
Point Lookout Sandstone	Kp or Kpu, Kms, Kph	Late Cretaceous	Well sorted, well rounded, poorly to well indurated, fine- to medium-grained quartz sandstone. In the northern portion of the area the impervious Satan Tongue of the Mancos Shale (Kms), about 20 feet thick, occurs between the pervious upper Point Lookout Sandstone (Kpu) and the lower Hosta Tongue of the Point Lookout Sandstone (Kph).	250	Intermediate
Crevasse Canyon Formation, Gibson Coal Member	Kcg	Late Cretaceous	Interbedded fine-grained sandstone, siltstone, shale, and coal.	300	Low
Crevasse Canyon Formation, Dalton Sandstone Member	Kcda	Late Cretaceous	Well sorted, well rounded, poorly to well indurated, fine- to medium-grained quartz sandstone.	80	Intermediate
Mancos Shale, Mulatto Tongue	Kmm	Late Cretaceous	Interbedded shale, sandy shale, and fine-grained silty sandstone.	400	Very low
Crevasse Canyon Formation, Dilco Coal Member	Kcdi	Late Cretaceous	Interbedded fine-grained sandstone, siltstone, shale, and coal.	150	Low

the Point Lookout and relatively pervious sandstone layers in the Menefee probably moves down dip to the east to northeast. Except where forming the bed of the stream, recharge to the Point Lookout and Menefee is via the alluvium subjacent to the stream. These relationships are shown in Figure 2.

Three hydrogeologic test wells were constructed across San Lucas Wash about one-half of a mile south of the point where the stream enters the northern pond of Leopoldo Diversion Dam (Plate II). Well SL-1 was completed into the alluvium, Well SL-2 was completed into the upper member of the Point Lookout Sandstone, and Well SL-3 was completed into the Menefee Formation (Figure 3).

The wells were drilled by the rotary method. Wells SL-1 and SL-2 used bentonite mud as the circulating medium. A dispersant, Barafos, was used for cleanup. Well SL-3 was drilled with air with foam/water injection. The wells are 9 7/8-inch diameter with either 5 9/16-inch, 0.188-inch wall or 5 1/2-inch, 0.244-inch wall casing with torch-cut, 1/8-inch x 3-inch slotted perforations. Gravel pack was 3/8-inch pea. Sealant was neat cement with 1-2% calcium chloride. Downhole geophysical logs were taken for SL-2 and SL-3.

Following completion and development, 24-hour constant discharge pumping tests were conducted on each of the three wells. A one and one-half horsepower submersible pump was used. Drawdown and recovery water levels were measured in the pumping well and in the other two wells which were used as observation wells.

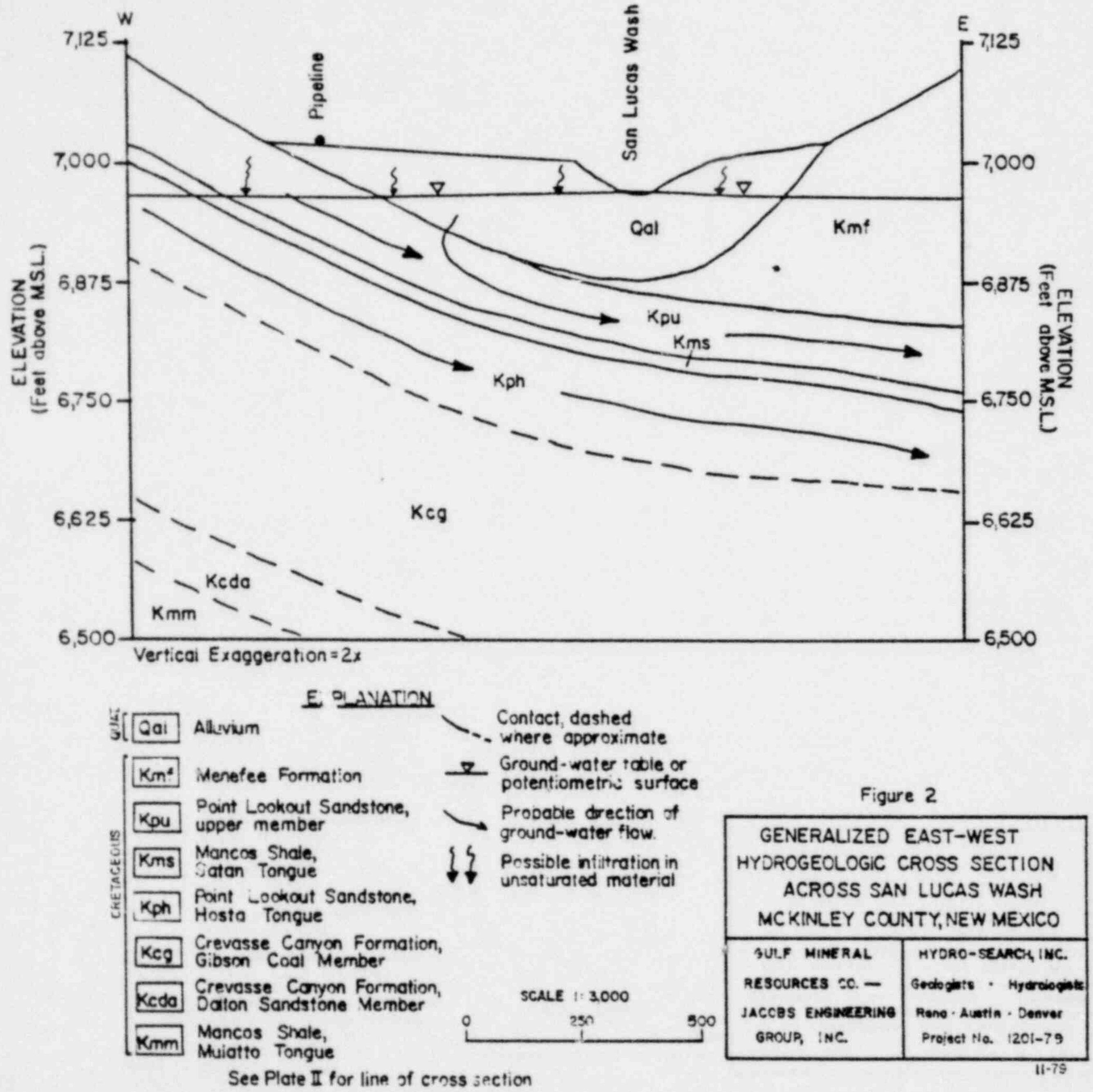

Figure 2

GENERALIZED EAST–WEST HYDROGEOLOGIC CROSS SECTION ACROSS SAN LUCAS WASH MCKINLEY COUNTY, NEW MEXICO

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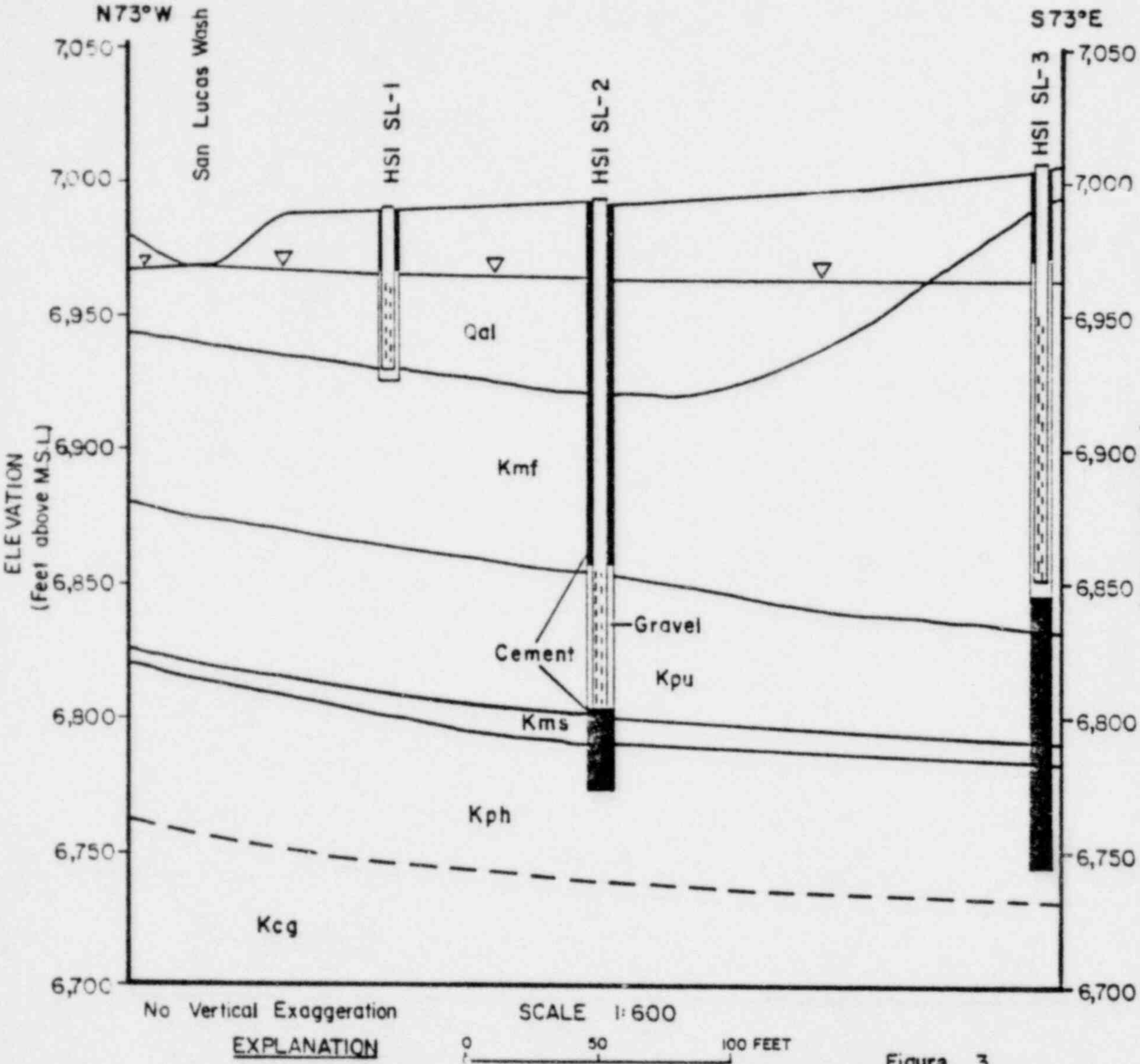
11-79



EXPLANATION

(See Figure 2)

See Plate II for line of cross section

Figure 3

DETAILED HYDROGEOLOGIC CROSS SECTION ACROSS SAN LUCAS WASH MCKINLEY COUNTY, NEW MEXICO	
GULF MINERAL RESOURCES CO. — JACOBS ENGINEERING GROUP, INC.	HYDRO-SEARCH, INC. Geologists · Hydrologists Reno · Austin · Denver Project No. 1201-79

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Well SL-1 (alluvium) was pumped at a rate of 15 gpm. Using the modified non-equilibrium formula, calculated transmissivities (T) are 5,300 gpd/ft (drawdown) and 8,600 gpd/ft (recovery). Using an intermediate value of 7,000 gpd/ft and a saturated thickness of 35 feet, hydraulic conductivity (K) is 200 gpd/ft^2. Although the stream is only 70 feet distant, no recharge effect of the stream was noted on pumping water levels of SL-1. The pumping of SL-1 did not result in discernible drawdown effects in SL-2 and SL-3.

Well SL-2 (Point Lookout) was pumped at a rate of 10 gpm. Transmissivities are 125 gpd/ft (drawdown) and 240 gpd/ft (recovery). Using an aquifer thickness of 50 feet and an intermediate value for transmissivity, hydraulic conductivity is about 3.7 gpd/ft^2. Pumping water level stabilized during the latter part of the test, suggesting the presence of a recharging body of water. It is unlikely that the apparent recharge is due to the stream, considering the intervening relatively non-pervious Menefee (Figure 3). A possible explanation is a pervious sand thickening within the Point Lookout. The pumping of SL-2 did not result in discernible drawdown effects in SL-1 and SL-3.

Well SL-3 was pumped at a rate of 5 gpm. Transmissivities are 105 gpd/ft (drawdown) and 100 gpd/ft (recovery). Using an aquifer thickness of 132 feet and an intermediate value for transmissivity, hydraulic conductivity is about 0.8 gpd/ft^2. Rate of drawdown increased during the latter stages of the test, indicating the presence of a discharging boundary and/or progressive dewatering of the water-bearing material. The pumping of SL-3 did not result in discernible drawdown effects in SL-1 and SL-2.

Table 3 summarizes results of the pumping tests.

Water samples were taken from each of the three wells at the end of pumping. Results are given in Table 4.

The mine discharge water of San Lucas Wash is a sodium-sulfate type of slightly over 600 mg/l total dissolved solids (TDS) (Table 1). The waters of SL-1 and SL-2 are calcium-magnesium-carbonate-sulfate types, again of about 600 mg/l TDS (Table 4). If the waters of SL-1 and SL-2 originated as recharge from the wash, it would be necessary for the dissolved sodium to have been replaced by calcium and magnesium. Ion exchange with the aquifer materials is a possible mechanism for this replacement. However, this is unlikely because of the low concentration of sodium ions.

The Menefee water (Well SL-3) is relatively high in TDS, and chemical relationships are not indicative as to the origin of the water.

Table 3. Summary of Results of Pumping Tests of Hydrogeologic Test Wells, San Lucas Canyon.

Well	Type of Aquifer	Water-Saturated Thickness, feet	Pump Discharge, gpm	Draw-down,* feet	Specific Capacity, gpm/ft dd	Transmissivity, gpd/ft: Pumping	Transmissivity, gpd/ft: Recovery	Hydraulic Conductivity, gpd/ft^2	Remarks
SL-1 (alluvium)	water table	35	15	12.4	1.2	5,300	8,600	200	
SL-2 (Point Lookout)	confined	50	10	73.	0.14	125	240	3.7	Water level stabilized during latter portion of pumping.
SL-3 (Menefee)	confined	132	5	35	0.14	105	100	0.8	Rate of drawdown of water level increased during latter portion of pumping.

* At end of test at 1440 minutes.

Table 4. Water Chemistry, Ground Waters, San Lucas Wash Area, New Mexico.

	NMEID Standards	Well SL-1	Well SL-2	Well SL-3	Well M-1
Date Sampled		10/23/79	10/18/79	10/13/79	10/16/79
pH	6 to 9	8.0	7.9	7.5	8.3
TDS (calc.)	1,000	672	595	2,299	625
Elec. Cond.		1,010	909	2,970	1,050
Temperature		11.9	14.7	13.8	14.4
HCO_3^-		454	419	785	460
$CO_3^=$		----	----	----	17
Cl^-	250	18	10	20	65
$SO_4^=$	600	202	156	1,120	50
F^-	1.6	0.8	0.2	0.3	3.8
NO_3^-	45 (10 mg/l as N)	0.09	0.04	0.13	0.62
Na^+		70	109	460	200
K^+		1.7	3.0	15	3.3
Ca^{++}		75	75	205	30
Mg^{++}		69	27	73	10
SiO_2		12	9	20	19
As	0.1	< 0.01	< 0.01	< 0.01	0.01
Ba	1.0	0.90	0.45	1.0	0.20
Cd	0.01	< 0.005	< 0.005	< 0.005	< 0.005
Cr	0.05	< 0.02	< 0.02	< 0.02	< 0.02
Pb	0.05	0.02	0.01	0.03	0.02
Hg	0.002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Se	0.05	< 0.002	< 0.002	< 0.002	< 0.002
Ag	0.05	< 0.005	< 0.005	< 0.005	< 0.005
Cu	1.0	0.010	0.005	0.020	0.06
Fe	1.0	0.10	< 0.01	0.17	< 0.01
Mn	0.2	0.55	0.02	0.53	0.02
Zn	10.0	0.25	0.26	0.62	0.30
Al	5.0	0.2	< 0.1	0.1	0.7
B	0.75	0.15	0.25	0.85	0.30
Co	0.05	< 0.01	< 0.01	< 0.01	< 0.01
Mo	1.0	< 0.05	< 0.05	< 0.05	< 0.05
Ni	0.2	< 0.02	< 0.02	< 0.02	< 0.02
V		< 0.05	< 0.05	< 0.05	< 0.05
PO_4 (as P)		< 0.01	< 0.01	< 0.01	2.01

Note: All analyses are in mg/l except pH which is in units, electrical conductivity which is in µmhos/cm @ 25° C, and temperature which is in degrees C.

Analysis agency: The Industrial Laboratories Company, Denver, Colorado.

	NMEID Standards	Well SL-1	Well SL-2	Well SL-3	Well M-1
Uranium, mg/l	5.0	< 0.013	< 0.006	< 0.006	< 0.006
Radium-226, pCi/l		0.06±0.03	0.41±0.03	2.9±0.03	0.13±0.03
Radium-228, pCi/l		< 1.	2.±1	< 1.	< 1.
Radium-226 + -228, pCi/l	30.0	< 1.06	2.41	< 3.9	< 1.13
Gross Alpha, pCi/l		< 5.	< 7.	< 7.	< 6.

Note: Uncertainty is one standard deviation due to counting statistics. Detection limits are one standard deviation.

Analysis agency: LFE Environmental Analysis Laboratories, Richmond, California.

Underflow to the north and northeast in the alluvium adjacent and subjacent to San Lucas Wash ca~ be estimated by the equation

$$Q = KIA$$

where:

Q = underflow, gpd,

K = hydraulic conductivity, gpd/ft^2

I = hydraulic gradient, dimensionless, and

A = cross sectional area of flow, ft^2.

Considering the situation in the vicinity of the east-west cross section (Figure 2, p.17), values for substitution are:

K = 200 gpd/ft^2 (Table 3),

$I = \frac{\Delta h}{\Delta l} = \frac{20 \text{ feet}}{2100 \text{ feet}}$ (scaled from Plate II), and

A = 45,000 ft^2 (scaled from Figure 2).

giving an estimated underflow (Q) of 86,000 gpd, or 60 gpm. This flow is indicative of the amount of water lost from San Lucas Wash by recharge to the alluvium.

Flow of water to the east and northeast in the upper Point Lookout Sandstone and Menefee can be estimated by the equation

$$Q = TIL$$

where:

T = transmissivity, gpd/ft, and

L = length of flow section, feet.

Considering the situation along San Lucas Wash between the discharge point of the mine water and the site of flume 3, values for the upper Point Lookout are:

T = 182.5 gpd/ft (Table 3),

I = 0.004 (see below), and

L = 10,500 feet (scaled from Plate II).

This gives an estimated eastward flow in the upper Point Lookout of about 7,700 gpd, or about 5 gpm. Values for the Menefee are T = 102.5 gpd/ft and L = 5,000 feet (the Menefee is below ground-water level only in the northern part of the area), giving an estimated eastward flow in the Menefee of about 2,100 gpd, or about 1.5 gpm. These flows would originate as recharge from the mine discharge of San Lucas Wash, and are negligible relative to the flow of San Lucas Wash.

For the lack of better information on regional hydraulic gradients in the two units, the hydraulic gradient determined by survey from Well SL-2 to Well SL-3 was used. These wells are completed separately in the two units, and the units appear to be isolated from each other from a short-term hydraulic standpoint. On a long-term basis under natural flow conditions, hydraulic interconnection between the two units probably is sufficient to justify the use of this gradient. However, the assumed hydraulic gradient could be in error. If the hydraulic gradient of 0.004 were low by even a factor of ten, the quantity of water flowing eastward in the upper Point Lookout and Menefee would still be small relative to the mine drainage flow of San Lucas Wash.

Interstitial pore velocities (v_i) of ground water flow can be estimated by the equation

$$v_i = \frac{KI}{7.48\Theta}$$

where Θ is the fractional effective cross sectional area of flow.

Using values of K from Table 3 and I from the above discussion, values for v_i can be calculated as follows:

	v_i, ft/day	remarks
alluvium	2	$\Theta = 0.15$
upper Point Lookout	0.01	$\Theta = 0.15$
Menefee	0.01	$\Theta = 0.10 = 2.6$ gpd/ft^2 = 102.5 gpd/ft ÷ 40 feet (thickness of water-saturated sandstone in the Menefee in SL-3).

In summary, hydraulic estimates indicate that loss of water by recharge to geologic materials is less than 100 gpm along San Lucas Wash above flume 3, and that most of this is to underflow in the alluvium. These estimates are consistent with the measured apparent decrease in flow between flumes 1 and 3 (Section 3.1.2). Flow velocities in the upper Point Lookout Sandstone and sandstone units in the Menefee are very low, on the order of several feet per year. The available evidence indicates that the ground-water bodies of these units do not involve the storage and movement of large quantities of ground water.

That portion of the tailings and decant pipelines in La Polvadera Canyon will pass over three geologic units: the Dilco Coal Member of the Crevasse Canyon Formation, the Mulatto Tongue of the Mancos Shale, and surficial alluvium. The alluvium is the only potential aquifer in this area, as both of the other two units are relatively impervious (Table 2). However, W. A. Wahler & Associates, Inc. (1978a, p.V-2) reports that the alluvial materials are "unsaturated except possibly for some minor perched zones beneath intermittent stream channels".

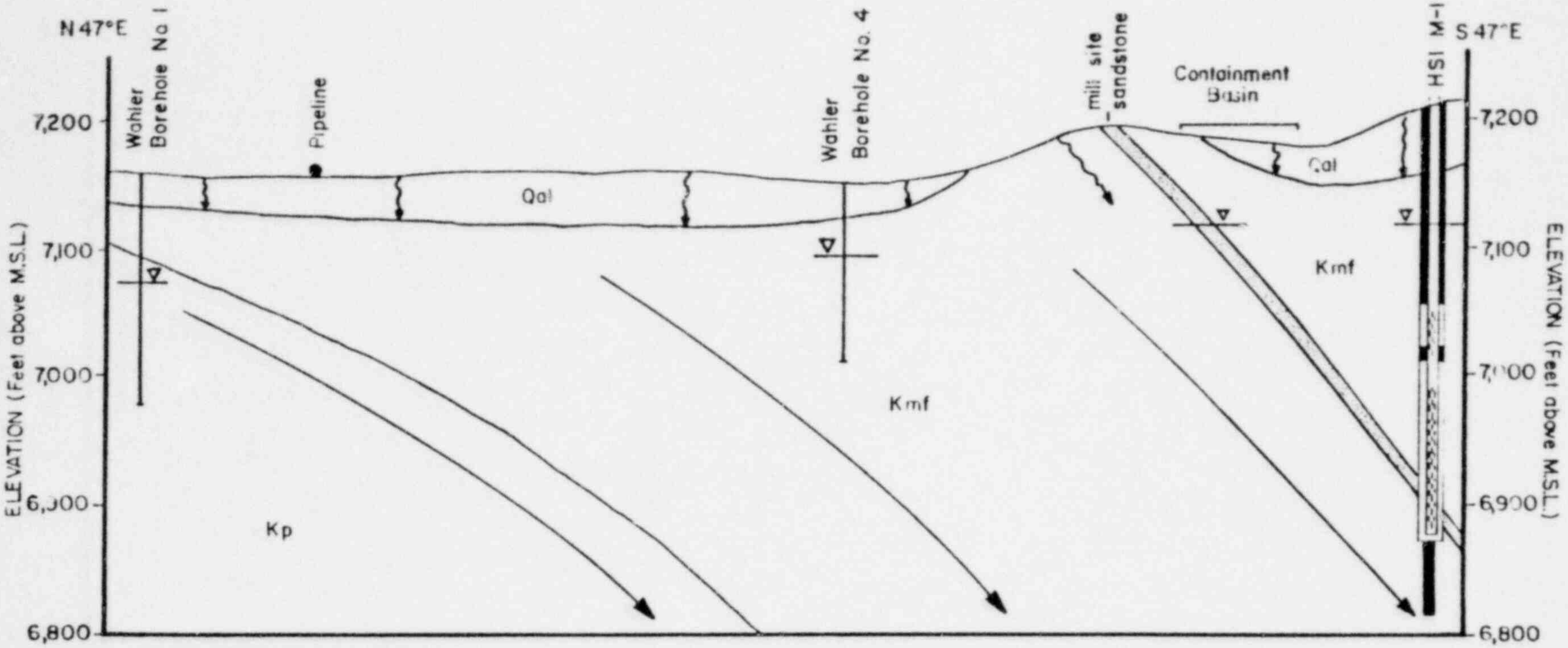
3.2.2 Mill Site and Vicinity

Three geologic units are exposed at the surface in the vicinity of the mill site: the Point Lookout Sandstone, the Menefee Formation, and surficial alluvium. Of these three units, only the Point Lookout contains ground water in quantity. Exploration drilling by W. A. Wahler & Associates, Inc. in the area covered by alluvium immediately northwest of the mill site (Plate II,

Figure 4) shows the alluvium to be several tens of feet or more in thickness and generally devoid of ground water (Wendell Quinn, personal communication, 1979). The underlying Menefee contains small quantities of ground water. The Point Lookout which underlies the Menefee is reported to produce in excess of ten gpm on airlift pumping.

The mill site facilities are underlain by a thin veneer of alluvium and thick Menefee Formation (Figure 4). Both the Menefee and Point Lookout dip to the southeast, and the water-bearing Point Lookout is at a depth of many hundreds of feet underlying the relatively impervious Menefee. Regional movement of ground water in the Point Lookout appears to be toward the east on the basis of water levels in several test holes in the alluvial flat to the west of the mill site (Barbara Turner, personal communication, 1979). Hydraulic gradient to the east is 0.001.

In the vicinity of the mill site itself, the only potential bedrock aquifer exposed at the surface is a thin resistant sandstone bed within the Menefee. The "mill site sandstone" forms the crest of the low ridge forming the northwest side of the small valley in which the mill is to be located (Plate II). A hydrogeologic test well, Well M-1, was installed to penetrate the mill site sandstone immediately down dip from the mill containment basin to determine the hydrogeologic characteristics of the pervious portion of the Menefee in this area and to serve as a possible future point for monitoring of water quality and levels. The well intersected the mill site sandstone from 303 to 312 feet, as well as another water-bearing zone in a fractured



Vertical Exaggeration = 3.33X

SCALE 1:4,000

0 500 1,000 FEET

EXPLANATION

(See Figure 2)

See Plate II for line of cross section

Figure 4

HYDROGEOLOGIC CROSS SECTION BETWEEN WAHLER BOREHOLE NO. 1 AND HYDROLOGIC TEST HOLE HSI M-1 MC KINLEY COUNTY, NEW MEXICO	
GULF MINERAL RESOURCES CO. — JACOBS ENGINEERING GROUP, INC.	HYDRO-SEARCH, INC. Geologists · Hydrologists Reno · Austin · Denver Project No. 1201-79

11-79

carbonaceous shale at 164 feet. The remainder of the Menefee materials intersected by the test well were relatively impervious siltstones, shales, and sandstones.

Following completion and development, which included introduction of dispersants and acids, Well M-1 was subjected to a series of bailer and injection tests. In general, rates of production and injection were about one gpm. Recovery from bailing was extremely slow and a progressive decrease in water-beraing capability occurred as a result of repeated episodes of bailing. The yield was so poor that difficulty was experienced, even after numerous episodes of bailing, in obtaining a water sample which was uncontaminated by development chemicals for chemical analysis. The sample eventually obtained and analyzed appears to be virtually free of contamination (Table 4, p.22). However, the presence of a few mg/l of phosphate is suggestive of a very low level of residual contamination by the dispersant.

Well M-1 could not be pump tested because of its low yield and large drawdown.

On the basis of results of Well M-1, we conclude that the Menefee in the vicinity of the mill site, including the mill site sandstone, is impervious with respect to the movement of ground water and does not contain units capable of yielding useful quantities of water to wells.

Shallow drilling by W. A. Wahler & Associates, Inc. (1978b, p.II-2) encountered localized bodies of ground water in the alluvium and weathered uppermost Menefee in the vicinity of the mill impoundment dam. This condition is expected to persist throughout the general area of the mill site facilities. However, it should be noted that foundation investigations of the mill site proper showed no free ground water in soil borings (Sergent, Hauskins & Beckwith, 1977, pp.9-10).

4.0 TAILINGS PIPELINE

4.1 PIPELINE FACILITY

4.1.1 General Features

Two identical 10-inch pipelines are installed in a pipeway with two-foot berms. Under normal service, one pipeline is for transport of tailings slurry and a second pipeline is for return of decant water to the mill or as a tailings transport spare.

Ten catch ponds are constructed at low points along the pipeline route (Plate II). The pipeway, berms, and low point catch ponds are lined with PVC to prevent seepage loss of any liquids released from the pipelines. Each catch pond is designed to contain with freeboard a volume of liquid equal to the total from: 1) the drainage length of the slurry pipeline between adjacent high points, 2) an additional ten minutes of flow in the pipeline which occurs while automatic shutdown of pumping becomes effective, and 3) intercepted precipitation from a 100-year storm.

A comprehensive discussion of the tailings pipeline facility and associated safety control features is included in the ground-water discharge plan (GMRC, 1979, pp. III-1 through III-6).

4.1.2 Release Characteristics

Three categories of pipeline accidents can be postulated considering the design of the pipeline facility and the characteristics of the safety control features (GMRC, 1979, pp. III-8 through III-11):

- trivial incidents - those not resulting in a release to the environment. In this case fluids would be confined to the lined and bermed pipeway and lined low point catch ponds. This type of accident would not have an effect upon ground and surface waters.

- small releases to the environment - this scenario involves a small leak in the upper portion of one of the pipelines which would cause the fluid to spray out beyond the lined and bermed pipeway. This presupposes a differential flow (leak) in the pipeline of five percent or less which would not trigger automatic shutdown of the pumps (> 10 percent) or an alarm (>5 percent <10 percent). As a consequence, a leak of this magnitude could go undetected by the periodic visual inspection for a maximum of 120 minutes. Thus, maximum releases would be:

  slurry pipeline, 12,000 gallons (= 120 minutes x 0.05 x 2000 gpm)

  decant pipeline, 6,000 gallons (= 120 minutes x 0.05 x 1000 gpm)

- large releases to the environment - this scenario presupposes a complete rupture in the pipeline and a complete loss of the fluid. This would cause an immediate shutdown of the pumps. The maximum release case would occur when the rupture occurs at a low point in the pipeline and the release to the environment would be caused by the accompanying failure of the adjacent low point catch pond. In this case the volume of liquid released would equal the total from: 1) an additional ten minutes of pumping while shutdown is completed and 2) the drainage length of the pipeline.

  Maximum drainage length of any catch pond is for Pond #5 which is approximately 14,200 feet (personal communication, Stan Sawchyn, Jacobs Engineering Group, Inc. 1979). Thus, maximum releases would be:

slurry pipeline, 74,000 gallons (= 10 minutes x 2000 gpm + 3.8 gals/ft x 14,200 ft)

decant pipeline, 64,000 gallons (= 10 minutes x 1000 gpm + 3.8 gals/ft x 14,200 ft)

A break in one of the two pipelines is considered the maximum release case.

The above scenario is the maximum credible case, and other combinations of types, degrees, and locations of pipeline, pipeway, and catch pond failures would result in release of smaller volumes. The maximum credible case is 0.23 acre-feet, as compared to the mine discharge of 8,000 to 16,000 acre-feet per year (p.7).

4.1.3 Liquid Characteristics

Flow of the tailings slurry will be about 2,000 gpm. The solid tails portion will be 36 percent by weight (about 17.5 percent by volume) of the slurry. The slimes fraction of the solid tails will be 21 percent by weight (about 10 percent by volume) of the slurry.

The raw raffinate is an acidic, high TDS, high sulfate water with a variety of minor and radiological constituents (Table 5). Chemical characteristics are similar to those of tailings waters at similar mills in the Grants area, although concentrations possibly will be somewhat higher in the case of the Gulf raffinate.

Table 5. Dissolved Chemical Constituents of Raffinate.*

	Raw Raffinate	Neutralized***
pH	1.5**	8.5
TDS	95,000	8,020
HCO_3^-	---	
$CO_3^=$	---	
Cl^-	1,450	1,420
$SO_4^=$	69,900	3,670
F^-	14	
NO_3^- (N)	4	
Na^+	1,520	2,950
K^+	200	7
Ca^{++}	740	517
Mg^{++}	1,570	98
NH_3^+ (N)	20	
SiO_2	1,280	
As	16	
Ba	< 0.6	
Cd	< 0.4	
Cr	5	
CN	< 0.0002	
Pb	5	
Hg	0.0002	
Se	26	0.05
Ag	< 0.2	
Cu	5	
Fe	11,000	< 0.01
Mn	160	
Phenols	< 0.001	
Zn	17	
Al	3,300	
B	0.25	
Co	3	
Mo	35	[illegible]
Ni	4	
V	240	< 0.1
P	36	
Uranium	0.25 mg/l	0.51 mg/l
Ra-226	4,900 ± 100 pCi/l	500 ± 20 pCi/l
Ra-228	1,560 ± 50 pCi/l	
Th-230	720 ± 10 pCi/l	
Pb-210	162 ± 1 pCi/l	
Po-210	26 ± 1 pCi/l	
Gross Alpha	$(9.5 \pm 0.1)10^5$ pCi/l	$(6.2 \pm 0.6)10^3$ pCi/l
Gross Beta	$(12 \pm 0.1)10^5$ pCi/l	$(3.1 \pm 0.9)10^3$ pCi/l

Note: All Chemical analyses are in mg/l except pH which is in units.

* From laboratory tests by Hazen Research, Inc., March 30, 1979.

** GMRC, 1979, p. II-4.

*** Upon neutralization to pH = 8.5.

Neutralization of raffinate to a pH in excess of 7 is accompanied by a substantial decrease in concentration of major, minor, and radiological constituents (Table 5). Again, this is similar to field experience in the Grants area where acidic tailings waters have come into contact with carbonate geologic materials.

The decant water will be similar in composition and overall concentration of dissolved constituents to the raffinate. Some increase in concentration due to evaporation should be expected.

4.2 ASSIMILATION OF POTENTIAL RELEASES

The releases to the environment discussed in Section 4.1.2 are of two distinct types. One type occurs as the result of a small pinhole leak in the upper portion of a pipeline. This permits a spray release to the ground or directly onto the wash which is not intercepted and contained by the pipeway and berm. The second type is the result of a major and simultaneous failure of pipelines and physical containment features (e.g., catch ponds). Both cases are calculated for conditions which lead to a release of maximum volume. Other combinations of types, degrees, and locations of pipeline, pipeway, and catch pond failures would result in release of relatively smaller volumes. In both cases, alarm, automatic pump shutdown, and visual inspection procedures are considered to have performed satisfactorily their functions of limiting volumes released.

The releases would enter the environment along the pipeline route in either San Lucas Canyon or La Polvadera Canyon. The pipeline traverses alluvial valley fill, Point Lookout Sandstone, and Menefee Formation throughout its length in San Lucas Canyon. San Lucas Wash, incised in the alluvium, is now a perennial stream carrying mine drainage. This flow will be in the range of 5,000 to 10,000 gpm during operation of the tailings pipeline. Along its length in La Polvadera Canyon the pipeline traverses alluvial valley fill, the Mulatto Tongue of the Mancos Shale, and the Dilco Coal Member of the Crevasse Canyon Formation. La Polvadera Wash is dry except during periods of storm runoff.

4.2.1 Releases Along San Lucas Wash

A release to the environment along San Lucas Canyon will first come into contact with either the alluvium or the Point Lookout Sandstone or the Menefee Formation. If not ponded or absorbed into the geologic material, the release will enter the perennial stream in the incised wash.

The maximum credible release consists of 74,000 gallons of fluid of which approximately 17.5 percent by volume is solids (pp. 32-33). This release would occur over a period of time in excess of 10 minutes, the time which is required for pump shutdown. Considering the length of pipeline that would be drained, total time for the release would be substantially in excess of the pump shutdown time. For the purpose of evaluating assimilation into the environment, a total release time of sixty minutes will be used.

As the fluid is discharged from the pipeline into the catch pond and then released to the environment by failure of the catch pond, a portion of the solids will settle out with some retained water. Assuming that the coarse fraction, about 7.3 percent by volume, settles out with an equal volume of retained water, the remaining and moving volume of liquid is about 63,200 gallons. The low point catch ponds occur on alluvium, and this volume of 63,200 gallons will flow across the alluvium toward San Lucas Wash. Infiltration into the alluvium will occur along the way; however, at least part of the fluid will reach San Lucas Wash.

For purposes of evaluating assimilation into the environment, two contrasting worst-case situations will be considered--63,200 gallons will be assumed to infiltrate into the alluvium and 63,200 gallons will be assumed to reach the wash.

Case I - Direct Infiltration into Alluvium

As the fluid moves laterally across the sloping surface of the alluvium, infiltration and downward movement into the alluvium will occur as unsaturated flow. In this arid region, the alluvial materials will be substantially below field capacity and will have a soil moisture deficiency. These materials will pick up and hold water permanently against gravity. The soil moisture deficiency must be satisfied for the front of unsaturated flow to progress downward in the alluvium.

If the soil mosture deficiency is taken to be 0.05, an equivalent depth of 1.25 feet of water would be required to satisfy the soil moisture deficiency to a depth of 25 feet, an average value for the depth to the water table in the alluvium (Figures 2 and 3, pp.17 and 18). The value of 0.05 for soil moisture deficiency possibly is low by a factor of two or more. This possibility is supported by values of soil moisture content reported by W. A. Wahler & Associates, Inc. (1978a, Appendix B, Table B-1) for alluvial materials from La Polvadera.

Several factors would tend to impede infiltration to the water table. First, the slimes of the liquid would tend to block pore spaces of the alluvial materials and, thus, to decrease permeability. Second, chemical reactions between the low pH raffinate and materials of the alluvium could lead to reduction in permeability. Absorption of hydrogen ions and water molecules of the raffinate by clay minerals of the alluvium could cause swelling of the clay minerals. Decrease in concentration of hydrogen ions due to absorption on clays and reaction with carbonate minerals would lead to precipitation of minerals out of solution. Both of these processes could lower permeability and, thus, impede downward infiltration.

The alluvium has intermediate to high permeability to horizontal movement of water under water-saturated conditions (Tables 2 and 3, pp.15 and 21).

The alluvium is composed of a series of individual layers of differing grain size and sorting. Under this condition, overall vertical permeability of the alluvium is a fraction of the horizontal permeability, and downward percolating waters would tend to be ponded above relatively impervious layers.

Several factors would tend to favor infiltration to the water table. First, pathways of preferential vertical permeability could exist. Plant roots and animal burrows are examples of this possibility. The vertical face of the alluvium in the wash shows plant roots to extend to a maximum depth of five to ten feet. Detailed examination of the alluvium surface in the vicinity of the pipeline route did not show frequent or large areas of animal burrows.

A second factor that might accelerate infiltration is pre-wetting of the upper skin of the alluvium by an antecedent precipitation or runoff event. This would satisfy the soil moisture deficiency and, thus, foster infiltration. On the other hand, the wetting could lead to swelling of clays and, thus, to impedance to infiltration.

In summary, the surface of the alluvium slopes toward the wash and the tendency would be for a release to move toward and enter the wash promptly. Part of the release would be left behind on the surface of the alluvium, and part would enter the live stream of the wash. For a portion of the release to infiltrate to the water table in the alluvium, it would be necessary for part or all of the release to be confined by ponding to a relatively restricted area for a discrete period of time. For example, the 63,200 gallons would have to be confined to an area with an equivalent average diameter of no more than 93 feet to provide an initial average depth of at least 1.25 feet, the amount of water required for wetting to the water table.

Considering the physical and chemical characteristics of the system and the opportunity for prompt cleanup and removal of any portion of a release which is ponded or residual on the alluvium or which is wetting the alluvium in the subsurface, the probability that any portion of the release would infiltrate to the water table is very minimal.

In the unlikely event that conditions were favorable for infiltration, it is difficult to visualize that more than a few thousands of gallons of a release would reach and mix into the alluvium ground-water body. During infiltration reactions with the alluvium materials would result in increase in pH and decrease in concentrations of minor and radiological constituents. The composition of the altered release water would probably be similar to that of the neutralized raffinate (Table 5, p.34). If monitoring of the ground-water body instituted as a result of a release discloses an unacceptable degree of degradation, remedial measures could be instituted to control the situation. These measures could include pumpback of degraded water by means of interceptor wells.

Case II - Mixing Into Water of San Lucas Wash

If the release moves across the alluvium without loss and enters San Lucas Wash over a period of 60 minutes, an average of about 1100 gpm of fluid will be mixed with a minimum of 5,000 gpm stream flow for a period of 60 minutes. This presupposes the conservative situation that mine discharge is at minimum (5,000 gpm) and no natural runoff is occurring. The resulting slug would be about 6,100 gpm for 60 minutes, or a total volume of 363,200 gallons.

A small fraction of the contaminated slug would infiltrate into the alluvium along the wash. Estimated underflow to the north and northeast at the northern mouth of San Lucas Canyon is 60 gpm (p.23). Eastward flow of ground water in the upper Point Lookout Sandstone and the interlayered sandstones of the Menefee Formation along San Lucas Canyon is estimated to be about 6.5 gpm (p.24). This flow is fed by recharge along the wash, giving a total recharge or loss from the surface stream of about 66.5 gpm. This would amount to 4,000 gallons over the 60-minute duration of the slug, and would reduce the volume of the slug by about one percent to 359,200 gallons.

Attenuation of minor and radiological constituents of the contaminated ground water in the upper Point Lookout and Menefee accompanying movement of the ground water to the east and northeast would be by longitudinal hydrodynamic dispersion and by chemical reactions with the framework minerals and dissolved constituents of the native ground water of these units. Reactions to be expected include neutralization of acid content by carbonate minerals and alkalinity of the ground waters, precipitation of constituents as a result of the increase in pH (pp.33-35), and absorption on clay minerals.

The conclusion is that contamination of bedrock ground waters along San Lucas Wash by a maximum credible release to the wash would be minimal, and could not be identified by analysis of ground water removed from these units.

The small slug of newly-recharged contaminated ground water of the alluvium would move toward the area of Leopoldo impoundment at an estimated velocity of two feet per day (p.25). The contaminated slug of approximately 4000 gallons should take the form of a thin, narrow and elongate, horizontal tabular body that slowly sinks downward as movement to the north and recharge of subsequent stream water occur. Attenuation of minor and radiological constituents of the contaminated ground water would occur as a result of the physical and chemical factors noted previously. Because of the small volume of the contaminated body of ground water relative to the total ground water in storage in the alluvium and the practical inability to locate and remove water solely from this "thin" body, the presence of this contamination probably could not be identified in samples of ground water removed from the alluvium.

The conclusion is that contamination of alluvium ground water along San

Lucas Wash by a maximum credible release to the wash would be minimal, and as a practical matter probably could not be identified.

Complete transverse and vertical mixing would occur quickly in the stream. However, virtually no longitudinal mixing would occur in the relatively few minutes required for the slug to reach the Leopoldo impoundment.

From Leopoldo the slug would move either to the northeast toward the Arroyo Chico gage or to the north of Laguna Polvadera (pp.9-11). The slug would be diluted along either course by mixing with the water already present in the stream channels and the several local impoundments and by subsequent stream flow. For example, at the end of one day the concentration of the slug containing the release would be reduced to about 0.01 of the initial concentration of the release if mixing with subsequent stream flow were complete. Along with the reduction in concentration caused by mixing with stream flow, reductions in concentration also would be brought about by chemical reactions of the types discussed above.

The ultimate disposition of the diluted contaminated surface water would be by spreading on the ground with loss by infiltration to alluvium and evapotranspiration north of Laguna Polvadera or by loss by infiltration to alluvium and evapotranspiration over the 36-mile reach of San Lucas drainage to the vicinity of the gaging station on Arroyo Chico.

The effect on ground water in the alluvium along the 36 miles of stream channel from Leopoldo impoundment to Arroyo Chico gage can be estimated as follows. First consider that the slug of contaminated water of about 359,200 gallons (p.41) is not diluted further by mixing, but is uniformly recharged to alluvium ground water to the assumed point of disappearance at Arroyo Chico gage. Assuming that the width of recharge is five feet, the total area of recharge is 950,400 ft^2 (= 5 ft x 36 miles x 5,280 ft/mile). This gives an apparent thickness of recharge of

$$0.051 \text{ feet} = \frac{359,200 \text{ gallons} \div 7.48 \text{ ft}^3/\text{gallon}}{950,400 \text{ ft}^2}.$$

Assuming a porosity of 15 percent for the alluvium, this gives a true thickness of recharge of 0.34 feet.

The above slug of contaminated alluvium ground water would take the form of a thin (0.34 feet average), narrow (five feet) and elongate (36 miles), horizontal tabular body that slowly sinks downward as movement to the northeast and east and recharge of subsequent stream water occur.

Attenuation of the contaminated ground water would occur as a result of the physical and chemical factors noted previously. Because of the small volume of the contaminated body of ground water relative to the total ground water in storage in the alluvium and the practical inability to locate and remove water solely from this "thin" body, the presence of this contamination probably could not be identified in samples of ground water removed from the alluvium.

The conclusion is that contamination of alluvium ground water northeast and east of Leopoldo impoundment by a maximum credible release to the wash would be minimal, and as a practical matter probably could not be identified.

<u>Other Smaller Releases</u>

The above discussion pertains to the maximum credible release. Similar factors apply to smaller releases. For example, a spray release of maximum volume of 6,000 to 12,000 gallons (p.32) probably would do no more than wet a thin skin of alluvium or Point Lookout Sandstone or Menefee Formation in the vicinity. The contaminated geologic material with residual spill material, either in wet or dry condition, could be cleaned up and disposed of. It is unlikely that such a release would either infiltrate to the water table either in the alluvium or Point Lookout or Menefee or flow over to the wash and enter the surface water.

A pipeline break release smaller in volume than the maximum credible release would: 1) occur away from a low point catch pond and would involve either a blockage of the pipeway and failure of the berm or failure of the associated catch pond, or 2) would be a full or partial break at one of the catch ponds other than Pond #5 which offers the maximum distance of pipeline(s) to be drained by a break and is thus the maximum case.

In these lesser cases and the case of a spray release directly to the wash, considerations of movement and attenuation involved would be those of the previous discussion as modified due to the smaller volume of contaminated water released.

4.2.2 Releases Along La Polvadera Canyon

La Polvadera Canyon is not occupied by a live stream except during storm runoff. Under runoff conditions, release of pipeline fluid to the stream course would lead to much the same results as release along San Lucas Canyon. Under the usual dry conditions, a release would flow across the alluvium and perhaps into the d[illegible]am course, but downward movement of more than a few inches to several feet is not to be expected. Contaminated alluvium materials and residual spill materials could be removed and disposed of.

5.0 MILL SITE

5.1 MILL SITE FACILITIES

The mill site facilities will be located in a shallow, northeast-trending valley which is tributary to upper San Lucas Canyon above San Lucas Dam (Plate II).

The mill catch dam will be a compacted, zoned earthfill type which will be built across the extreme northeastern part of the valley (GMRC, 1979, Section IV) (Plate II). The dam will be a water retention structure which will rest on alluvium with a cutoff trench five feet into bedrock (Menefee Formation) and a two-line grout curtain into the bedrock. Surface area and storage volume at maximum impoundment will be 16 acres and 230 acre-feet, respectively. An open cut spillway will be located on the west side of the impoundment.

The impoundment will receive about 5,000 gpd of secondary treated sewage from the mill. The only other water will be area runoff and runoff from the mill area which exceeds the capacity of the lined containment basin (see below). Water in the impoundment will be disposed of by evaporation.

The lined containment basin will be located between the mill and the impoundment (Plate II; Figure 4, p.28). The containment will have a capacity of

2,000,000 gallons, and is designed to contain the spillage of the largest process vessel in the mill (1,500,000 gallons) (GMRC, 1979, p.IV-5). Wash-down water and initial runoff water from the mill will be sent to the containment basin because these waters will be relatively high in chemical contaminants. Disposal of water in the containment basin will be by pump back to the mill or evaporation.

5.2 HYDROLOGIC EFFECTS

The mill site area is underlain by 500 to 1,000 feet of southeast-dipping Menefee Formation (Figure 4). The predominant materials of this unit, shales and siltstones, are relatively impervious. Sandstone interbeds may contain ground water under artesian condition. For example, the "mill site sandstone" which crops out in a northeast-trending belt along the northwest boundary of the mill area yields about one gpm where penetrated by Well M-1.

The mill site sandstone is the most likely unit in the Menefee in the vicinity of the mill site and within a reasonable depth to accept and permit movement of released waters from the mill facilities. Testing undertaken as part of this investigation has demonstrated that the mill site sandstone is thin (less than ten feet in thickness), of limited permeability, and yields no more than one gpm to a well (Section 3.2.2). The mill site sandstone is not a viable pathway for movement of mill site waters.

On the basis of the available information, the conclusion is that the Menefee

Formation forms an impervious base to the mill site area.

The alluvial deposits and the underlying weathered uppermost Menefee probably contain scattered, localized bodies of ground water. For example, ground water was encountered in some of the exploratory drill holes in the stream channel alluvium (W.A. Wahler & Associates, Inc., 1978b, P.II-2). Under conditions of operating the mill, it is reasonable to expect that the alluvial deposits, in general, will contain more ground water than at present. For example, the waters (treated sewage, surface runoff) impounded behind the mill catch dam will certainly saturate the alluvial materials and weathered Menefee underlying the impoundment area. However, the positive cutoff and grout curtain beneath the dam will prevent lateral flow to the northeast.

In general, waters released to the environment in the mill site area will be contained by a combination of factors: 1) an impervious underlying material, the Menefee Formation; 2) the mill catch dam, and 3) the positive cutoff and grout curtain of the dam. These waters include treated sewage and possibly inadvertent releases from the lined containment basin. Natural surface runoff will also be contained in the area. An exception is runoff originating high on the northwest-facing hill southeast of the mill. This runoff will be intercepted and conveyed to the northeast by a ditch above the right abutment of the mill catch dam and will be released to the San Lucas drainage.

Because of the containment, mill activities should have a minimal effect upon quality of ground and surface waters, and will have no adverse effect upon present or foreseeable future ground-water supplies.

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