Environmental File

SUPPLEMENT TO ENVIRONMENTAL REPORT

MOAB, UTAH FACILITY

FOR ATLAS MINERALS

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SUPPLEMENT TO ENVIRONMENTAL REPORT

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1. INTRODUCTION

This report presents the results of our additional engineering studies of the Atlas Minerals uranium milling facility near Moab, Utah. This report was prepared in response to the 27 questions posed by the Atomic Energy Commission in a letter dated January 25, 1974 concerning the "Environmental Report, Moab, Utah Facility," by Atlas Minerals Division of Atlas Corporation, dated August 31, 1973. A previous study by Dames & Moore entitled "Report of Engineering Studies, Tailings Pond Embankment System, Moab, Utah, For Atlas Minerals," dated March 28, 1973 was included in the environmental report as Appendix A. Information and data presented in these reports were drawn upon for this response.

The Atlas Minerals uranium milling facility is located three miles northwest of the City of Moab, in Grand County, Utah, as shown on Plate 1, Vicinity Map. The location of the mill and tailings disposal areas is shown in more detail on Plate 2, Plot Plan.

Basic data developed for this supplement are presented in Appendices A and B of this report. Appendix C contains references used in the development of the report. Appendix D presents the questions posed by the Atomic Energy Commission to Atlas Minerals Corporation. Specific replies to the A.E.C. questions are presented in Section 9 of this report.

2. GEOHYDROLOGIC SETTING

2.1 GEOLOGY:

The site is situated on the northwestern end of the Moab Valley. Moab Valley is in the north-central section of the Paradox Basin, a portion of the Colorado Plateau physiographic province. The Paradox Basin is characterized by thick Pennsylvanian evaporites (Paradox member of the Hermosa formation) that locally form the core of salt anticlines such as the Moab anticline. Moab Valley is a topographic valley formed along the collapsed crest of the Moab anticline. The anticline trends northwesterly and is downfaulted along its crest. It is believed that the collapse of the anticline began in the late Cretaceous or early Tertiary period as a result of solutioning and extrusion of salt upward through the fault zones.

Rock exposed in the site vicinity, as shown on Plate 3, Local Geology, consists of sedimentary strata ranging from Pennsylvanian to Jurassic in age. Covering the valley floor and the site vicinity are deposits of river gravels, slope wash and windblown sand of Quaternary age. A detailed description of the rock units exposed in the vicinity is presented on Plate 4, Stratigraphic Description.

The plant and tailings pond are situated upon unconsolidated deposits of primarily windblown silty fine sand with interbedded stream-deposited sands. These deposits are generally of low to moderate permeability. Adjacent to the Colorado River are river-deposited sandy gravels of high permeability.

Bedrock near the site is cut by several northwest-trending en echelon faults downthrown on their northeastern side. The Moenkopi formation

and the Hermosa formation outcrop west and northwest of the tailings pond. Reports of saline water encountered in shallow wells drilled in the past in the site vicinity are believed to be associated with the salt bearing Paradox member of the Hermosa formation. The Embar Oil Company Well No. 1, drilled a short distance south of the present location of the tailings pond, encountered the Hermosa formation after drilling through 56 feet of alluvium. The well encountered a three-foot-thick layer of "salt" at a depth of 405 feet, which probably marks the top of the Paradox member.

The detailed description of the subsurface conditions encountered at borings at the site is presented graphically on Plates A-1A through A-1E, in Appendix A of this report. Information concerning water wells drilled in the past near the site is presented on Plate A-15.

2.2 GROUND WATER:

The principal aquifers in the area are the Wingate and Navajo sandstones where highly fractured, and unconsolidated Quaternary deposits in valley floors. Although other formations in the vicinity contain permeable rock strata, the formations have a generally low hydraulic conductivity and act as aquicludes or aquitards. The water bearing characteristics of rock formations in the vicinity are described on Plate 4, Stratigraphic Description.

Precipitation falling in the Moab Canyon area infiltrates alluvium in the valley bottom, fractures in exposed bedrock and permeable sandstone layers. Because precipitation in the area is quite low, less than eight inches annually, a large percentage is consumed by evapotranspiration. The ground water moves downgradient through alluvium, bedrock fracture systems, and along bedding planes. The ground water in Moab Canyon moves southeastward toward the Colorado River. The base elevation for the ground water table

near the site is controlled by the elevation of the Colorado River. The ground water gradient in Moab Valley southeast of the site is to the northwest, also toward the Colorado River.

2.3 WATER USE:

Although several wells have been drilled near the site, none are in use at present. The only known ground water use within the Moab Canyon area is from a well at Arches National Park headquarters, located approximately one and one-half miles northwest of the tailings pond. A number of wells and springs are located several miles southeast of the Colorado River in Moab Valley. All the wells and springs are located upgradient from the site and thus will not be affected by ground water at the site.

The closest known Colorado River intake is at a ranch approximately three miles downstream from the site. The water is used for irrigation.

3. SURFACE WATER HYDROLOGY

The Colorado River, which lies east of the site, drains some 25,000 square miles. The River is gaged one mile below the confluence with the Dolores River, about 31 miles upstream from the site. The average discharge for the 59 years of record (1911-1970) is 7,711 cubic feet per second. The maximum and minimum recorded flows for the period of record are 76,800 and 558 cubic feet per second, respectively. The River flow is regulated by Blue Mesa Reservoir on the Gunnison River and other reservoirs in Colorado.

The plant and tailings pond lie in the drainage area of Moab Canyon Wash as shown on Plate 1, Vicinity Map. The basin comprises about 6.1 square miles of rocky terrain with a thin soil cover and sparse vegetation. Runoff is intermittent and occurs only after intense storms. The

intermittent stream channel passes between the tailings disposal area and the plant. Adjacent to the tailings and plant area, the channel is confined by parallel dikes six to ten feet high. No stream gaging records are available for the Wash. Estimated return periods for short duration precipitation are presented on page 2-20 of the Atlas Minerals Environmental Report.

Cross sections of Moab Canyon Wash and the Colorado River at the site are presented on Plate 5, Stream Sections.

4. SEISMICITY

The seismicity of the site vicinity is discussed in detail in Section 2.5 and Appendix A of the Atlas Minerals Environmental Report. As discussed, the area, which is centrally located within the stable Colorado plateau, is one of low seismic activity. Based on tectonic considerations and the region's seismic history, a maximum horizontal ground acceleration of 5 percent gravity is postulated for the site.

5. TAILINGS DISPOSAL AREA SITE CONDITIONS

5.1 GENERAL:

The description of the tailings disposal area presented herein is based on examination of the tailings area surficial materials, the results of subsurface drilling during this investigation and previous investigations, and from verbal discussions with personnel familiar with the construction and operation of the tailings pond system.

The tailings disposal system was initiated in 1956 with the construction of an earth starter dike along the northeastern and southeastern limits of the pond. Subsequently, the original starter dikes have been extended to where, at the present time, only a small portion of the area on the west side is not enclosed by an embankment. The area has been increased

in height by the construction of supplemental dikes with tailings material or nearby natural soils. The existing system encompasses 115 acres, of which approximately 98 acres are presently within the uppermost dikes.

5.2 EMBANKMENTS:

A description of starter and supplemental dikes is presented in Appendix A of the Atlas Minerals Environmental Report. Additional borings drilled in conjunction with this study confirm the description of the dikes, except that one segment of dike 750 feet in length and located along the southwestern limit of the pond at boring 12 was found to have been constructed upon an old portion of the tailings pond. At the south end of this segment, the dike in the past extended further west, terminating against the hillslope. In order to avoid a power line when raising the height of the tailings pond, the supplemental dike was constructed over hydraulically-deposited tailings considerably softer than the dike. Subsurface sections of the tailings embankment are presented on Plates 6A through 6G. Descriptions of the subsurface conditions encountered in borings drilled in the tailings area in conjunction with this investigation are presented graphically on Plates A-1A through A-1E, in Appendix A of this report. Logs of borings drilled in conjunction with our previous study are presented in Appendix A of the Atlas Minerals Environmental Report.

5.3 EMBANKMENT COVER MATERIAL:

All exposed sides of the embankment have been covered with an approximately one-foot-thick layer of weathered bedrock or slope wash deposits from adjacent hillsides. The in-place cover material consists of reddish-brown, fine to coarse sand and gravel with some cobbles and boulders. A gradation curve of a representative sample of the cover material is

presented on Plate A-7 in Appendix A of this report. The results of a Los Angeles abrasion test performed on a representative sample of cover material indicate a 57.1 percent wear. The cover material will weather to fine sand and silt with some clays, but will for a long period of time continue to have a large percentage of broken rock pieces.

5.4 SUBSURFACE MATERIALS IN TAILINGS DISPOSAL AREA:

The tailings materials within the pond are stratified both horizontally and vertically as a result of the mode of discharge and the grain size distribution of the tailings. In the past, discharge of the tailings has been from the southeastern, northeastern and northern perimeters, as shown on Plate 2, Plot Plan. From the point of tailings discharge, the coarse grain size fraction was deposited first, both upon the "beach" over which the slurry flowed and at the beach-pond interface. The silt and clay fraction stayed in suspension much longer and was deposited in the standing pond water. Because discharge points were alternated along the discharge perimeter, interfingering of the silty fine sand and clayey silt occurred along the former pond margin. The result is that the central and western pond areas, farthest from the points of discharge, are dominantly clayey silt with thin layers of very silty very fine sand, while beach areas are predominantly silty fine sand. This relationship is quite apparent when observing the present pond surface.

As tested, the permeability of the clayey silt tailings (slimes) is on the order of 0.3 feet per year, while very silty, very fine sand tailings vary from about 1 to 3 feet per year. These materials comprise the bulk of the tailings disposal area surface. Silty fine sand tailings which comprise the embankment and "beach" areas have tested permeabilities

typically varying from about 2 to 35 feet per year with one value as high as 490 feet per year.

Underlying the tailings materials are natural soils composed primarily of silty fine sand and fine sand with some silt. Fine to coarse sand and gravel interfinger with the soils near the Colorado River. The natural soils have much higher permeabilities than the tailings materials. As tested, natural silty fine sands vary from 13 to 310 feet per year. Natural fine to coarse sands with some silt vary from 110 to 460 feet per year. Sand and gravel materials are many times as permeable as the sand soils.

Cross Section I-I' on Plate 6G illustrates the relationship of the subsurface materials and seepage movement.

5.5 GROUND WATER GRADIENT:

Plate A-11 in Appendix A of this report presents in tabular form ground water elevations measured in borings, test pits and wells near the site during this study. The regional ground water table gradient is toward the Colorado River at a slope of approximately 2 feet vertical per 1,000 feet horizontal. Natural soils underlying the tailings pond do not appear to be fully saturated and thus the seepage from the tailings pond is dominantly vertical until encountering the regional ground water table.

5.6 BIOLOGICAL, CHEMICAL AND RADIOLOGICAL DATA:

Available data concerning analyses of ground water samples from monitor wells, water wells, and the Colorado River in the site vicinity are presented in Appendix A of this report.

6. MILLING OPERATION AND FLOW DIAGRAMS

A detailed discussion of the milling facility is presented in Section 3.0 of the Atlas Minerals Environmental Report. A plot plan of the mill showing the facility with the new modifications is presented on Plate 7 of this report. Flow diagrams of the proposed mill processes are presented on Plates 8A, 8B, and 8C. These diagrams also show chemicals added to the process and a materials balance.

7. TECHNICAL EVALUATIONS

7.1 TAILINGS POND OPERATION:

7.1.1 General. The facility and its operation are described in detail in Section 3 of the Atlas Minerals Environmental Report. Most liquid and solid wastes will be disposed of in the tailings pond. It is presently planned that 200 to 220 gallons per minute of tailings slurry will be discharged to the tailings pond, of which 20 gallons per minute will be decanted, treated with barium chloride to remove radium-226, and returned to the tailings pond. The anticipated composition of liquid in the tailings pond, as presented in the Environmental Report, is recapitulated on Table 1. The values in Table 1 were obtained from the analysis of synthetic raffinate that is expected to be similar to the liquid effluent in the tailings.

7.1.2 Discharge to the Pond. In the past, tailings were discharged from the line constructed along the north, northeast and southeast embankments as shown on Plate 2, Plot Plan. This discharge system will be extended to completely encompass the disposal area and the decant point will be moved to approximately the center of the pond. Initial discharging will be from the western side in order to build up that area and force the ponded water back into the center of the tailings disposal area.

TABLE 1

EXPECTED COMPOSITION OF LIQUID IN TAILINGS

		Acid Leach and Copper-Leach Raffinate	Total Net Liquid to Tailings	Concentration In Tailings Pond
Flow Rate GPM		114	130	
		(1)	(2)	(3)
Ra-226	uCi/ml	2.18×10^{-7}	2×10^{-7}	1×10^{-7}
Th nat.	uCi/ml	0.037×10^{-6}	0.03×10^{-6}	0.05×10^{-6}
Cl	g/l	0.23	0.2	0.3
SO_4	g/l	76.9	70	100.0
As	g/l	0.0050	0.004	0.007
TDS	g/l	103.33	90	150.0
U_3O_8	g/l	0.0016	0.001	0.002
V_2O_5	g/l	0.23	0.2	0.3

pH of raffinate = 1.75 emf of raffinate = 250 MV

Notes: (1) Measured by Atlas in "Synthetic raffinate"

(2) Diluted by 16 gpm of filter cake wash, assumed to be water

(3) Ra-226 concentration is reduced because of barium treatment. Other ion concentrations will increase because of evaporation

It is believed that the tailings disposal area is of sufficient size to evaporate the projected quantity of liquid effluent. If necessary, a portion of the pond liquid will be decanted, treated and recycled through the plant or additional evaporation pond areas will be constructed. The ultimate tailings pond size will be based on the tailings discharge rate divided by the evaporation rate per acre. Should the mill effluent rate exceed the evaporation area available in the tailings pond, the mill operation will be curtailed, the alternate recycling operation commenced, and/or an alternate evaporation pond constructed.

The location of the ponded water within the tailings disposal area is controlled by moving the position of the discharge point to the area where water is closest to the dike. The use of a centered pumping decant barge will enable the pond water to be kept in a central location more readily. Control will be exercised by observing the overall pond to determine that it is essentially centered and occasionally checking to confirm that the actual 250-foot required minimum distance from the embankment is being met. The discharge points along the perimeter will be alternated as necessary to center the pond.

7.1.3 Decant System. The water level in the tailings pond will be controlled in part by the proposed new centrally located decant barge. The barge will have an electric pump and an automatic control switch which will govern the quantity of liquid cycled through the purification pond. Should the alternate evaporation pond be constructed, the barge would be outfitted to automatically control the tailings pond surface elevation.

7.2 EMBANKMENT STABILITY:

7.2.1 General. In Appendix A of the Environmental Report, the computed factor of safety of two embankment subsurface sections, B-B and C-C, were reported. This report presents the results of a re-analysis of subsurface section B-B, based on new boring data, and the results of analyses of subsurface sections D-D, E-E, G-G, and H-H. The results of these analyses are presented in the following report sections and graphically on Plates 6A through 6F. A discussion of the liquefaction potential of the embankments is also presented.

Although records of compaction control of the initial starter dikes for the tailings disposal area are not available, the results of boring test data indicate that the original starter dikes are denser than subsequent construction and that they were probably placed to an engineering standard. Succeeding supplemental dikes were placed and compacted without density control. Nevertheless, for the following reasons, it is believed that all the dikes are satisfactory for the proposed tailings disposal operation:

1. The mechanically placed fill materials in the starter dikes and supplemental dikes, even if placed without density control, have higher strength characteristics than the hydraulically placed tailings.
2. The existing pond has operated satisfactorily to the present maximum height of approximately 75 feet.
3. The critical failure circle would not intersect the starter dam materials except immediately following construction.

4. The pond operation will be such that ponded water will remain a minimum of 250 feet away from any supplemental dike section.

The factor of safety for each embankment section was computed by the ordinary method of slices technique (Fellenius Method) utilizing an electronic computer and a program developed by Dames & Moore. The strength properties of soil and tailings materials utilized in the stability analyses are shown on Plates 6A through 6F. The ground water levels used were determined from field data. Factors of safety were computed for both static loading conditions and the maximum anticipated loading of 5 percent gravity.

7.2.2 Existing Embankment. The following factors of safety against a circular failure of the existing embankments other than minor localized sloughing, under long-term seepage and for partial and full pool conditions were calculated:

Subsurface Section	Minimum Factor of Safety- Static Loading Condition	Minimum Factor of Safety- Maximum Anticipated Earthquake (.05g)
B-B	1.9	1.6
C-C	2.4	2.1
D-D	2.2	1.9
E-E	2.1	1.8
G-G	2.0	1.6
H-H	2.2	1.9

Some individual berms of the embankment have slopes as steep as 1.0 horizontal to 1.0 vertical. Some localized failures and/or sloughing along the crest of those berms could occur during the lifetime of the system. However, due to their limited height and location, the sloughing would not effect the overall stability of the embankment. The maximum damage that

could occur would be the closing of an access road or the disruption of the perimeter discharge line. Operating inspections will further reduce the possibility of such damage.

7.2.3 Proposed Future Embankment. Safety factors were calculated for the embankment conditions anticipated for the future additional 4 million tons storage. The following minimum factors of safety against a circular failure, assuming long-term seepage and partial and full pool conditions, were calculated:

Subsurface Section	Minimum Factor of Safety-Static Loading Condition	Minimum Factor of Safety-Maximum Anticipated Earthquake (.05g)
B-B	1.8	1.5
C-C	2.2	1.9
D-D	2.0	1.8
E-E	2.1	1.8
G-G	1.8	1.5
H-H	2.2	1.9

As stated in the previous section, some localized sloughing of individual berms could occur during the lifetime of the system. However, the sloughing would have no effect upon the overall stability of the embankment. The maximum damage that could occur would be the closing of an access road or the disruption of the perimeter discharge system. The contents of the disposal area, both liquid and solid, would not be released.

7.2.4 Liquefaction Potential. The primary factors which control the liquefaction potential of soils are the soil type, the relative density of the soil, the initial confining pressure, the intensity and duration of ground shaking and the ground water level. The tailings materials are of

the soil type susceptible to liquefaction under sufficient earthquake shaking. However, for the Colorado Plateau area, one of the lowest seismic areas in the United States, a maximum ground acceleration of 5 percent gravity or less is expected. Utilizing the Simplified Procedure for Evaluating Soil Liquefaction Potential,* a factor of safety in excess of 2.0 against embankment liquefaction is calculated for a relative density of 56 percent. It is therefore believed that dynamic testing and more sophisticated liquefaction analyses are not justified for this embankment.

A relative density of 85 percent for the tailings material is a maximum control value for the placement of fill. This density could not be achieved by the hydraulic fill methods employed in the past construction or proposed for future construction. Therefore, it is believed that rigid density control is an unnessary requirement for the overall embankment or for starter dikes.

7.2.5 Piping Potential. The potential of piping through the embankment or foundation under normal operation is extremely remote. Seepage pressures are low because the depth of ponded water in the tailings area is shallow, generally less than five feet in depth. Seepage velocities, as discussed subsequently, are also low, in the range of 10 to 350 feet per year for the silty fine sand "beach" tailings. Seepage velocities in the tailings slimes are much lower. The tailings generally range from about 80 to 100 percent finer than the number 60 sieve and 20 to 50 percent finer than the number 200 sieve. The natural soils which underlie the tailings area consist of silty fine sand with occasional layers of fine to coarse sand with some silt. These soils range from 20 to 90 percent finer than the number 60 sieve,

*Seed and Idriss (1971).

and 10 to 20 percent finer than the number 200 sieve. The piping ratio (15 percent size of the protecting soil divided by the 85 percent size of the protected soil) is much less than one. Therefore, the soils afford a high degree of protection against piping.

7.3 TAILINGS EMBANKMENT COVER:

All exposed exterior portions of the tailings embankment have been covered with approximately one foot of weathered bedrock or slope wash deposits from adjacent hillsides. The in-place material is described in Section 5.3 of this report. The purpose of this natural soil cover is to provide an appearance similar to the natural hillsides and to reduce wind and rain erosion of the embankment slopes. The embankment with a siltstone cover is not designed to resist erosion from a possible break in the discharge or decant line. This protection is provided by placing the discharge line on the inside of the upper embankment and by sloping the crest of the embankment to drain into the pond.

The siltstone cover is intended to be essentially maintenance free. The combination of bermed slopes and siltstone cover should provide a good erosion protection and only minor erosional channeling should develop. However, in conjunction with operating inspections of the tailings pond system, any channeling of the embankment surface will be noted. If channeling occurs, filling will be accomplished with additional cover materials.

7.4 POTENTIAL FLOOD DAMAGE ON TAILINGS DISPOSAL AREA:

An analysis of flood conditions for a flood flow with a 100-year recurrence interval is presented below. Since the Colorado River is a major waterbody encompassed by an extremely large drainage basin, the computation

of a probable maximum flood would be a major undertaking. A hydrologic investigation of that magnitude is not considered to be warranted in view of the limited nature of the tailings dam with respect to the overall project and due to the limited size of this project in relation to a major undertaking, such as the construction of a nuclear power plant (where computation of a PMF is necessary).

The Corps of Engineers* has predicted flood flow for the Colorado River at Moab:

Recurrence Interval	Flow (cfs)
10 year	67,000
50 year	85,000
100 year	91,000

The water surface elevation at the tailings pond area due to a flood of 100-year recurrence interval on the Colorado River was determined by extrapolation on a log-log scale of the following discharge-water surface elevation values provided by the U. S. Army Corps of Engineers.

Date	Discharge cfs	Water Surface Elevation Feet Mean Sea Level
1957	64,200	3,961
1917	77,000	3,963

The extrapolation to the 100-year recurrence interval flood of 91,000 cfs, yielded a water surface elevation of 3965.2 feet, mean sea level. This is the level of the toe of the embankment enclosing the tailings pond.

The flood flow in Moab Canyon Wash at the tailings embankment for the one-hour, 100-year recurrence interval storm was calculated to be 460

*B. McQuivey-personal communication, 1974.

cubic feet per second utilizing a triangular hydrograph analysis. The water surface elevation at the tailings area due to a flood of 460 cubic feet per second was determined by a backwater curve computation. The Manning "n" value for the Wash was estimated to be 0.040. The velocities in Moab Wash at a discharge of 460 cubic feet per second range from 5 to 6.3 feet per second. The water surface elevation in the wash does not reach the toe of the embankment because of the confining dikes. Although some sideslope erosion of the dikes could occur, the overall damage would be minor because of the short duration of flood flow. Any damage which did occur to the dike would be repaired following the storm.

Cross sections through the tailings embankment across the Colorado River and the Moab Canyon Wash and a profile of Moab Canyon Wash at the site are presented on Plate 5.

7.5 SUBSURFACE SEEPAGE FROM TAILINGS POND:

7.5.1 General. A discussion of the geohydrologic setting and subsurface conditions in the tailings disposal area was presented in Section 2 of this report. A discussion of seepage quantities, movement, expected constituent levels and the effects of ion exchange are discussed in the following sections.

7.5.2 Seepage Quantity from Tailings Pond. Seepage quantities calculated to have occurred from the tailings pond during the period of January, 1971 through January, 1973 were presented in Appendix A of the Atlas Minerals Environmental Report. The seepage quantity was calculated utilizing a water balance for the tailings pond system for the period. All data utilized in the water balance was provided by Atlas Minerals.

The basic formula utilized is as follows:

$$I + P = D + E + S + \text{Seepage}$$

where: I = input to tailings pond from plant

P = precipitation

D = discharge from pond

E = evaporation from pond

S = stored water in tailings discharged during the balance period

Seepage = seepage losses from tailings pond.

We understand that the input quantity to the tailings pond (I) used in the water balance was a measurement of the uranium mill intake of process water from the Colorado River. The quantity of flow was measured on a flowmeter. The measurements are estimated to be accurate to ± 5 percent. We believe that the quantity is an accurate measure of the input to the tailings pond since no additional water is added during processing and the only loss is in steam. The discharge quantity from the pond was measured at the discharge point from the purification pond. The measurements were made daily utilizing a rectangular weir, estimated to be accurate to ± 20 percent.

Evaporation and precipitation data are measured at a meteorological station at the mill by Atlas for the National Weather Service. Actual precipitation data for the water balance period is as follows:

Period	Precipitation in Inches
January 1973	1.17
January 1972-December 1972	9.02
January 1971-December 1971	7.29
Total	17.48
Average Annual for Period	8.4

The following evaporation rates were measured:

Period	Evaporation in Inches	
	1971	1972
April	7.67	8.18
May	9.66	10.84
June	12.50	11.29
July	14.10	12.15
August	11.97	12.00*
September	8.11	7.60
October	4.92	2.63
Total	68.93	64.69

*No data (evaporation estimated for this month).

The pan coefficient for the Moab area is 69 percent and the April through October evaporation season is 78 percent of the annual. Therefore, the total annual lake evaporation for the site is equal to 59.2 inches and the net is equal to 50.8 inches annually for the period. However, in the calculated water balance, a net brine evaporation rate of 50.37 inches per year, obtained from actual measurements of evaporation ponds at an industrial plant six miles south of the site, was used. The data correlate well.

Our calculations of the existing seepage were as follows:

1. The average water loss for the 25 months of record was 194.56 gallons per minute.
2. The net rate of evaporation (50.37 inches per year) is equal to 2.61 gallons per minute per acre; or 117.45 gallons per minute for the assumed 45 acres covered by water.
3. The total seepage loss was 194.56 gallons per minute, less 117.45 gallons per minute; or 77.11 gallons per minute. This number was then quoted as 75 gallons per minute total seepage loss or 1.6 gallons per minute per acre.

We believe that the calculated seepage losses by this analysis are reasonable and are the best quantitative measures available. We believe that the quoted seepage losses are accurate to ± 25 percent.

We believe that seepage losses for the new operation will be reduced based on the following:

1. Sealing is expected to occur due to the change to an acid leach system and the resulting deposition of gypsum slimes in the tailings pond.
2. The quantity of water circulated to transport the tailings will be reduced from the past 1,000 gpm to 200 gpm. Thus, the quantity of water flowing over the more permeable "beach" tailings will be reduced by a factor of about five.
3. The maximum 20-foot increase in the tailings storage area height would not materially alter the hydraulic gradient (Head ÷ flow path length) assuming the depth of ponded water remained the same. The actual seepage from the pond appears to be controlled by the low permeability layers within the pond.

7.5.3 Seepage Movement. Seepage from the tailings pond is believed to be predominantly vertical through the tailings material. Upon reaching the ground water table, the seepage would move at the regional gradient toward the Colorado River. In spring months when the Colorado River rises rapidly, the ground water gradient is locally reversed. During low flow, water from bank storage discharges to the Colorado River. Therefore, occasional reversal and lateral movement of the ground water along the river bank occurs.

The velocity of seepage moving vertically through very silty, very fine sand and clayey silt tailings which underlie the bulk of the pond area is calculated to range from 3 to 60 feet per year. The velocity of seepage occurring through silty fine sand "beach" tailings is calculated to range from 10 to 350 feet per year. Upon encountering the regional water table, seepage would mix with the ground water and move toward the Colorado River. The measured slope of the regional ground water table at the site is approximately 2 feet vertical per 1,000 feet horizontal. The average velocity of the regional ground water toward the Colorado River is calculated to range from 10 to 80 feet per year for the silty fine sand soils at the site. Much higher velocities could occur in the sand and gravel layers along the river bank or more permeable soil layers.

7.6 PRESENT CONSTITUENTS IN GROUND WATER AT THE SITE:

7.6.1 General. Chemical, radiological, and biological constituents of ground water reflect the influence of the natural environment, as well as seepage from the tailings pond. Because of its relatively slow movement, constituents present in the ground water at the site reflect many years of milling, tailings operations and ore storage in the site vicinity. Available data regarding measurements of constituents in ground water at the site are presented in Appendix A of this report. Tables 2 and 3 compare selected constituents measured during this study.

When interpreting the analyses of ground water samples, the depth interval that the monitor measures must be considered. Most of the monitor locations were originally test pits extending only one to two feet below the water table. Since pond water seepage entering the regional water table mixes very slowly with the ground water and moves downgradient at the same

TABLE 2

COMPARISON OF BIOLOGICAL CONSTITUENTS

Location/Date	M.P.N. Total Coliforms (Per 100 ML)	M.P.N. Fecal Coliforms (Per 100 ML)	B.O.D. (Mg/L)	C.O.D. (Mg/L)
Boring 8/4-25-74	2,100	36	-	-
Boring 9/4-25-74	9,300	<30	8.5	10.0
Test Pit 7/4-25-74	36	<30	21	54
Test Pit 8/4-25-74	-	-	19	40
Colorado River above Moab/2-9-74 to 10-2-73 by Utah Dept. of Health	6,443[1]	548[2]	2.73[3]	

Notes:
1. Average for 20 samples (Range 150 to 43,000)
2. Average for 19 samples (Range 4 to 43,000)
3. Average for 20 samples (Range 1.0 to 9.5)

TABLE 3

COMPARISON OF SELECTED CONSTITUENTS IN GROUND WATER, APRIL 1974

Location/ Collection Date	Concentration in Mg/L							Concentration In pCi/L		
	T.D.S.	Arsenic	Chloride	Sulfate	Vanadium	Barium	Zinc	Ra^{226}	Th^{230}	pH
Boring 1/4-12-74 (1)	585	0.00	180	98	0.029	-	-	-	-	8.10
Boring 2/4-12-74	9,500	0.08	970	4,000	0.034	-	-	-	-	7.80
Boring 8/4-25-74	4,265	0.00	1,200	1,260	0.16	0.01	.03	14	15	7.60
Boring 9/4-25-74	3,706	0.00	660	1,500	0.14	0.00	.05	0.5	63	7.75
Boring 14/4-25-74	701	0.00	94	210	0.03	0.00	0.12	0.9	2.04×10^4 (2)	7.46
Boring 15/4-25-74	745	0.00	130	175	0.04	0.01	0.02	24	29	7.47
Test Pit 1/4-12-74	10,000	0.04	1,170	4,200	0.231	-	-	-	-	7.60
Test Pit 4/4-12-74	11,750	0.03	1,540	4,350	0.752	-	-	11	19	7.52
Test Pit 5/4-12-74	12,500	0.10	2,020	4,700	1.877	-	-	-	-	7.65
Test Pit 7/4-24-74	1,850	0.00	430	530	-	0.00	0.05	1.7	9.1	7.57
Test Pit 8/4-25-74	3,233	0.00	920	950	0.13	0.05	0.03	-	-	7.63
Well A/4-25-74	5,028	0.00	2,590	350	0.47	0.05	0.15	8.6	15	7.92
Well B/4-12-74	2,051	0.00	1,010	8	0.01	0.05	0.02	35	0	7.55

Notes: (1) Possible dilution by surface water after rain.

(2) Analysis believed in error-analysis of a second sample from well by Atlas Minerals measured 4.0 pCi/l

time, the test pits monitor ground water in which a minimum of dilution has occurred. Therefore, deeper monitor wells are more indicative of the total concentration of constituents in the ground water.

7.6.2 Biological Constituents. Biological constituents are compared in Table 2. Sanitary wastes from the mill are disposed of in a sewage drain field located south of the mill as shown on Plate 2, Plot Plan. The samples analyzed were obtained at relatively shallow depths downgradient from the drain field. The low concentration of fecal coliform indicates that the biological constituents are reflective of the natural environment rather than pollution from the septic field. The total coliform concentration and the biological oxygen demand probably result almost totally from the natural environment rather than from the septic drain field.

7.6.3 Chemical Constituents. Measured constituent concentrations in the ground water near the site and in the Colorado River are presented in Appendix A of this report. Selected constituents measured during this investigation are compared in Table 3.

The Utah State Division of Health defines mandatory limits for the concentration of arsenic, barium, cadmium, chromium, cyanide, fluoride, lead, selenium, and silver in discharge to the Colorado River. Except for arsenic and barium, none of these constituents were present in any of the samples analyzed, nor are they expected to be discharged from the tailings pond or plant. Minor amounts of barium were detected in the monitor wells at the site but no concentrations were equal to or above the mandatory limit of 1.0 milligram per liter. Arsenic was noted in four monitor wells, and was above the mandatory limit of 0.05 milligrams per liter in boring 2 in the tailings disposal area and in test pit 5 below the tailings area.

Sulfate concentrations increase downgradient of the tailings area. Chloride concentrations increase somewhat downgradient of the tailings pond but it is significant to note that deeper natural waters contain quite high concentrations of chlorides. The very high chloride to sulfate ratio in Wells A and B indicate this addition of natural saline water as do past reports of unusable well water near the site. Total dissolved solids are also relatively high in Wells A and B, which is also indicative of saline natural waters at depth. The ground water in borings 14 and 15 is much lower in total dissolved solids, sulfates, and chlorides than Wells A and B. This is likely due to their shallower depth and location near the main drainage channel.

7.6.4 Radiological Constituents. Radiological measurements of constituents in ground water at the site are presented in Appendix A of this report. These constituents are compared in Table 3 for this investigation.

Radium-226 concentrations varied from 0.9 to 35 picocurries per liter. Thorium-230 concentrations varied from zero to 63 picocurries per liter except for one calculated value of 2.04 x 10^4 picocurries per liter. This later value is believed in error. The results of an analysis of another sample obtained from the boring were a concentration of 4.0 picocurries of thorium-230 per liter. A.E.C. standards for unrestricted areas for radium-226 and thorium-230 are 30 and 1,000 picocurries per liter, respectively.

The U_3O_8 concentration in monitor locations measured by Atlas Minerals on April 1, 1974 varied from 0.008 x 10^{-5} to 0.65 x 10^{-5} microcurries per milliliter. These concentrations are well below the A.E.C. standard of 2 x 10^{-5} microcurries per milliliter for unrestricted areas.

7.7 ION EXCHANGE:

Investigations to evaluate the ion exchange properties of tailings materials and natural soils as they relate to uranium and radium absorption were performed. Details of the method of analysis and results of the study are presented in Appendix B.

X-ray diffraction analyses show that the bulk of the tailings is composed of quartz with lesser amounts of plagioclase feldspar and calcite. Natural soils are also mainly quartz and feldspar with small amounts of mica.

The cation exchange capacity of the subsurface materials varies with clay content and is for tailings:

$$C.E.C. = 1.79 + 0.37\ (\%\ Clay),\ r = 0.96$$

and is for natural soils:

$$C.E.C. = 0.17 + 0.54\ (\%\ Clay),\ r = 0.74$$

The results of the equilibrium batch experiments, utilizing a synthetic effluent solution, and conducted to determine the absorption characteristics of uranium and radium on tailings and natural soils at the site, are as follows:

Sample Location	Equilibrium Distribution Coefficient in ml/g Uranium	Radium
Test Pit 5	14-40	289 ± 7
Test Pit 5	6-20	354 ± 15
Reference Soil	2-16	214 ± 15
River Bank	8-34	467 ± 15
Composite Tailings	Negative*	212 ± 20

*Released Uranium.

The volume of effluent which can be adsorbed by a unit volume of soil was calculated. For a unit volume of tailings material, 275 equivalent volumes of effluent solution can adsorb radium before saturating the capacity of the material. Natural soils have even higher capacities than the tailings.

The study indicates that uranium will not be adsorbed by tailings and may be released if present. Adsorption of uranium will occur only on the natural soils along the seepage flow path. The average velocity of the uranium ion front is calculated to be 90 times less than that of the transporting ground water. The most significant interpretation from the adsorption studies of uranium, however, is that the uranium capacity of natural soils between the tailings disposal area and the river has not been exceeded by past disposal practices. The equilibrium distribution coefficients for those soils are as high or higher than those of the referenced natural soil.

7.8 FUTURE CHEMICAL AND RADIOLOGICAL CONCENTRATIONS:

7.8.1 Concentrations in Ground Water. The expected composition of the liquid in the tailings pond is presented on Table 1. The expected composition is based on the analysis of a synthetic raffinate for the new plant operation. Under the new recycling plan, nearly all wastes will be disposed of in the tailings pond. There will be no direct discharge from the system as in the past. Due to reduced amounts of water cycled through the mill operation and pond evaporation, the chemical and radiological concentrations in the pond will be increased over those of the past operation. Therefore, it can be expected that although the concentration of some constituents in the ground water at the site will increase, the total discharge from the property will greatly decrease.

Radium-226 and uranium in seepage from the tailings pond will be highly reduced due to ion exchange. Based on the ion exchange study

presented in Appendix B, at the maximum anticipated seepage of 1.6 gallons per minute per acre, 410 cubic feet of tailings per acre per year would have the capacity to adsorb the radium-226 in the seepage. Therefore, no increases in radium-226 concentrations in the ground water are expected due to seepage from the tailings pond during the life of the disposal operation.

The uranium ion front is predicted to migrate at an average rate of 90 times less than the ground water upon reaching the natural soils. Therefore, upon reaching the regional ground water table, the uranium front would be expected to migrate at an average rate of less than one foot per year. Considering the very low expected concentration of U_3O_8 in the tailings pond liquid (2 milligrams per liter) and the dilution with natural ground water, uranium concentrations are not expected to significantly increase in the ground water at the site due to seepage from the tailings pond.

The thorium-230 concentration will remain well below the A.E.C. standard of 1×10^{-6} microcurries per milliliter since its concentration in the tailings pond will be 0.05×10^{-6} microcurries per milliliter.

Total dissolved solids and sulfate concentrations in the tailings pond will be quite high due to the acid leach process. These concentrations will be reduced in the ground water due to dilution and precipitation. However, ground water concentrations are expected to increase over present concentrations.

The chloride concentration in the tailings pond is projected to be 300 milligrams per liter. Therefore, the chloride concentration in the ground water should decrease to about the natural level.

The arsenic concentration in the tailings pond is projected to be 7 milligrams per liter. At this level, the arsenic concentration will likely

increase five to six times over present levels in the ground water. Therefore, the arsenic concentration in the pond and in the monitor wells will be monitored closely and treatment of the pond liquid will be accomplished if necessary.

The barium concentration in the ground water is not expected to increase since seepage from the treatment pond is the prime source of the barium and the treatment process is closely monitored. The barium will be primarily in the insoluble form of barium sulfate.

The pH of the ground water will be changed only slightly since the acidic seepage will be neutralized by carbonates in the existing tailings.

7.8.2 Concentrations in the Colorado River. The ground water discharged to the Colorado River will be mixed to insignificant concentrations in the river. Perfect mixing can be assumed since the ground water will enter the river along several hundred feet of bank.

Radium-226 and uranium discharges are expected to approach zero as the present concentrations are flushed from the subsurface soils.

The past and projected additions of radioactivity to the Colorado River compared with past additions are as follows:

	Past	Projected
Radium-226 (pCi/l)	0.0094*	0.0000
Natural Uranium (pCi/l)	0.54*	0.00
Thorium-230 (pCi/l)	0.0049*	0.003*

*As presented on pages 5-6 of the Atlas Mineral Environmental Report. No reduction in thorium-230 was made due to ion exchange. Assumes 80 gallons per minute of seepage.

Total dissolved solids are projected to increase in the river above upstream levels by 4 parts per million at average flow and assuming the

concentrations in the tailings pond are not reduced through the flow path. Sulfates comprise two-thirds of the total dissolved solids.

Arsenic and barium concentrations in the ground water will be maintained below the mandatory limits and therefore will be reduced to nearly undetectable concentrations in the Colorado River. No other toxic elements will be discharged.

8. BENEFIT - COST ANALYSIS

8.1 GENERAL:

Analysis of projected environmental benefits which will be realized from the operation of the renovated mill and comparison with the foreseeable environmental costs indicate that the benefits may be reasonably expected to exceed the costs and that the proposed project is well justified.

8.2 METHODOLOGY AND APPROACH:

This analysis stresses benefits and costs in environmental terms of real utility to man. In this particular project, the units of energy which will be made available for use to mankind have greater meaning in terms of work to be accomplished than do artificial dollar values. Emphasis is also made on the fact that this project will provide jobs to its working staff, to miners in newly opened mines, and indirectly to non-related workers in the supporting structure of local, regional, and national vendors who supply goods and services required for the operation of the mill.

Although environmental terms are preferred, it is impossible to compare dissimilar units of value and achieve a quantifiable balance; therefore, the values assigned to items of goods and services by people and expressed in the dollar cost is useful in providing a rough index of value to

compare factors having intrinsically disparate qualities or natures. For this reason, economic values expressed in dollars are discussed together with utilitarian worth. In this manner one gives substance and meaning to the other and allows the analyst to form a rational judgment of comparative worth. This section should be read with the awareness that it is the abundance of energy that has enabled our present quality of life by providing a leverage with which man may muitiply his work effort, and that this is the true source of capital wealth; that mineral resources are the substance of desirable consumer goods; that the flow of dollars represents wages and compensation for work performed; and that the worker will use these wages to provide life support for himself and family.

Benefits and costs are summarized in Table 4 and are discussed in the following subsections. Economic values are given on both an annual basis and as present value for the projected 15 year operating period. Interest of 10 percent per year is assumed and no adjustment is made for inflation.

8.3 BENEFITS:

The principal environmental benefit of the milling of uranium ores to produce yellow cake is the production of energy. Subordinate benefits will accrue to the populace through usage of the vanadium and copper by-products. Indirect benefits will accrue through employment, capital expenditures, purchasing of goods, services and supplies, payment of taxes, conservation of resources, and the reduction of adverse environmental effects.

8.3.1 Direct Benefit of Uranium. The direct principal benefit of the milling of the uranium into yellow cake is that, after mining, it is the first critical processing step which prepares the uranium for use in reactors for the ultimate release of its contained nuclear energy. Although

TABLE 4

BENEFIT-COST SUMMARY

BENEFITS	VALUE OF BENEFIT: ECONOMIC-DOLLARS X 100s: ANNUAL	ECONOMIC-DOLLARS X 100s: PRESENT VALUE[a]	UTILITY-UNITS AS SHOWN: ANNUAL	UTILITY-UNITS AS SHOWN: 15-YEAR TOTAL
1. Uranium (yellow cake)	$11,214[b]	$ 85,294	623 tons	9,345 tons
or as equivalent electrical power			6.7×10^{9} KWH[c]	100.7×10^{o} KWH[c]
2. Vanadium (black flake)	$ 7,665	$ 58,300	2190 tons	32,850 tons
or in terms of equivalent high speed tool steel			105,000 tons[d]	1,575,000 tons
3. Copper	$ 384[e]	$ 2,921[e]	240 tons	3,600 tons
Dollar Value of Primary Benefits	$19,263	$146,515		
4. Employment - 80 employees	$ 621	$ 4,723		
Sustenance - 280 persons			280 man-hours	4,200 man-years
5. New employment - plant				
Construction - 35 men	$ 1,000	$ 1,000		
Sustenance - 122 persons			122 man-years	122 man-years
6. Employment - new mines-75 men	$ 1,195	$ 9,089		
Sustenance - 262 persons			262 man-years	3,930 man-years
7. Infusion of construction expenditures into regional economy	$ 2,000	$ 2,000	See discussion in Section 8.3.7	
8. Infusion of operating expenditures into regional economy	$ 4,930	$ 37,497	See discussion in Section 8.2.8	
9. Taxes	$ 269	$ 2,046	See discussion in Section 8.2.9	

Footnotes on fourth page of Table 4.

TABLE 4 (Cont.)

BENEFIT-COST SUMMARY

BENEFITS		VALUE OF BENEFIT: ECONOMIC-DOLLARS X 100s		VALUE OF BENEFIT: UTILITY-UNITS AS SHOWN	
		ANNUAL	PRESENT VALUE[a]	ANNUAL	15-YEAR TOTAL
10. Conservation	U_3O_8	f.	f.	438 tons	6,570 tons
	V_2O_5	f.	f.	2,190 tons	3,280 tons
	Cu	f.	f.		
11. Reduction of radio-activity in Colorado River	Radium-226			0.009 picocurries/liter	
	Natural Uranium			0.54 picocurries/liter	
	Thorium-230			0.002 picocurries/liter	
12. Elimination of gaseous effluents by substitution for fossil fuels[g]	SO_2			150,000 tons	2,250,000 tons
	NO_x			100,000 tons	1,500,000 tons
	Particulates			5,000 tons	22,500 tons
13. Elimination of SO_2 from copper smelting by use of sulfuric acid		h. h.	h. h.	22,000 to 34,000 tons SO_2	330,000 to 510,000 tons SO_2

TABLE 4 (Cont.)

BENEFIT-COST SUMMARY

COSTS	ECONOMIC-DOLLARS X 100s ANNUAL	ECONOMIC-DOLLARS X 100s PRESENT VALUE FOR 15 YEARS	UTILITY-UNITS AS SHOWN ANNUAL	UTILITY-UNITS AS SHOWN 15-YEAR TOTAL
1. Ore[i.]	$11,726	$ 89,189	270,000 tons	4,050,000 tons
Includes 75 new men at mines			75 man-years	1,125 man-years
2. Milling[j.]	$ 4,860	$ 36,965		
Includes materials, supplies and energy			See list in Item 4, Section 5.5	
Includes labor-80 employees			80 man-years	1,200 man-years
Dollar Value at Primary Costs	$16,586	$126,154		
3. Plant modification	$ 3,000	$ 3,000		
Includes materials, supplies and energy			Details not determined	
Includes labor-average 35 employees			35 man-years	35 man-years
4. Municipal Services	$ 2,046 (No significant incremental demand) See Section 8.4.5			
5. Occupational Health	Average annual individual whole body dose[k.]			377.4 millirems
6. Land Use	Restricted future use of 200 acres See Section 8.4.8			
7. Aesthetics	(No significant change) See Section 8.4.9			
8. Theoretical increase in dissolved solids in Colorado River				4 ppm

TABLE 4 (Cont.)

FOOTNOTES

a. Factor for Present value = $(1.10)^{15} - 1 \div (1.10)^{15} (0.10) = 7.60606$
Interest rate = 9½% prime rate + ½% = 10%

b. Based upon uranium in yellow cake @ $9/pound

c. Equivalent available energy to be released upon fission and conversion to electrical energy at a generating efficiency of 30%. One short ton of U_3O_8 will yield 5.9×10^{13} BTU on complete fissioning. At 32% thermal efficiency this is equivalent to 4.5×10^9 KWH.

d. 2,190 tons of V_2O_5 is equivalent to 1,573 tons of metallic vanadium contained in approximately 105,000 tons of tool steel averaging 1.5% V. Price assumed at $1.75 per pound.

e. Approximate value as contained copper at 80¢/lb. Actual value would be adjusted for transportation of concentrate to smelter and for smelter charges.

f. Redundant credit with Benefits 1, 2 and 3.

g. Equivalency assumed by substitution of coal for uranium consumption in equivalent 1000 megawatt generating plant. Coal assay 8,524 BTU/ton, Sulfur 0.63%, Ash 7.64%. Electrostatic Precipitator efficiency 99.5%, 25% Dolomitic effect from coal.

h. Economic values of sulphuric acid included in Benefit 8.

i. F.O.B. Plant, $43.43/ton includes cost of exploration and overhead expense.

j. At average of $18.00 ton.

k. Determined from plant records.

the milling step cannot take full credit for the ultimate release and utiliza-tion of the energy, it nevertheless is a vital and critical link in the process chain.

As shown on Table 4, the mill will produce yellow cake containing 623 tons of U_3O_8 each year for a total of 9,345 contained tons over the 15-year operating period. On the basis of $9 per pound, one year's production will have a value of $11,214,000 and 15 year's production will have a present worth of $85,294,000.

The uranium contained in one year's production of yellow cake will, upon complete fission, yield 28.9 x 10^9 KWH of electricity. For 15 years of production, the contained uranium would yield 433.5 x 10^9 KWH of electrical energy. The annual production will be roughly equivalent to the annual uranium consumption for at least four 1,000 megawatt nuclear electrical genera-ting units. The projected cumulative production of 9,345 tons of U_3O_8 will represent about 2 percent of the projected 450,000 ton demand which will be required by 1985. Thus, as discussed in Section 1 of the Atlas Minerals Environmental Report, the projected production will be a significant contri-bution to the nation's energy needs.

8.3.2 Direct Benefit of Vanadium. The importance of the extrac-tion of vanadium, as vanadium pentoxide in the form of black flake, raises its status to that of a co-product, but subordinate to the principal product, uranium. The value of the vanadium contained in the ores, enables the mining and milling of uranium ores which would be otherwise uneconomic.

The recovered vanadium will provide environmental benefits to man through its utility as an excellent alloying agent for the production of high-speed tool steels and as a catalyst for the production of sulfuric acid,

petroleum products, ethylene and propylene. Dependent upon successful technological development, vanadium catalysts have a potential for emission control devices on automobiles, and could generate a high demand for this unique metal. Although vanadium also is produced as a by-product from other ores--phosphate rock, titaniferous magnetites, and from the production of petroleum coke--the uranium-vanadium ores of the Colorado Plateau remain as a principal source for this metal.

It is projected that the mill will recover 2,190 tons per year of vanadium contained in the black flake product. Over a 15-year operating period, an estimated total of 32,850 tons will be recovered. At a value of $1.75 per pound, the annual vanadium product would be worth $7,665,000 and the present value of 15 year's production would be $58,300,000.

The vanadium produced from this operation probably will be marketed for use in the form of ferrovanadium for use in the manufacture of alloy steels and in the production of catalysts for the production of sulfuric acid and petroleum products.

In the U. S. in 1971 (Minerals Yearbook, U. S. Bureau of Mines), 4,802 tons of vanadium were consumed. Of this, almost 90 percent was used for alloying purposes. The U. S. Bureau of Mines (Harold Taylor-personal communication, 1974) foresees that domestic demand will range from 5,000 to 5,200 tons per year in the near future. The projected production from the mill could supply over 40 percent of the demand and thus would constitute a significant factor in fulfilling projected domestic needs and future growth.

If the annual production from the mill were used in the production of high vanadium alloys, it would enable the production of 105,000 tons of high speed tool steel, or 1,575,000 tons over 15 years. In the U. S. from

3 to 5 million tons of such steels are produced annually. Due to environmental demands to reduce the weight of automobiles and other vehicles to gain fuel savings, the demand is increasing for high strength low alloy vanadium steels. With their superior strength to weight ratio, these alloys will come into increasing demand and greater pressure will be placed upon our domestic production capacity for vanadium ores. The projected production of vanadium, therefore, should be of significant and increasing utility.

8.3.3 Direct Benefit of Copper. Although the projected annual production of by-product copper concentrates of about 240 tons will not be significant compared to total national production, it will provide an incremental benefit to a rising national demand. Over 15 years of production, about 3,600 tons of copper will be produced. To illustrate the value of this production, and not considering smelting or transporation costs, it is herein assumed that the sales value will approximate 80 cents per pound, at which price the annual production would be worth around $384,000 and over a 15-year operating period, would yield a present value of $2,921,000.

The true utility of copper to man lies in its high electrical conductivity, its ductility in the drawing of wires and tubes, and its alloying characteristics for special purposes and casting metals. For these reasons, it is one of the most useful metals, is in high demand, and is rising in value. The annual production of copper from the mill will be used in a variety of ways ranging from the manufacture of electrical equipment to scientific applications. To demonstrate the utility of the copper concentrate which will be produced, the projected production is recast in equivalent terms of the number of homes whose requirements for copper will be met by the projected production. According to the Copper Development Association

(D. Seitz, personal communication, 1974), an average one-family dwelling in the United States, having an area of about 1,500 square feet, uses about 686 pounds of copper in its construction, appliances, and furnishings. Using this rate, the 240 tons of copper contained in one year's production would be sufficient for the construction and furnishing of about 700 houses. The projected production for 15 years, therefore, would equip about 10,500 homes.

The projected production of copper from the mill--although incidental to the production of uranium and vanadium--will be beneficial and desirable.

8.3.4 Employment of Operating Personnel. Operation of the mill after modification will not require an increase in the average number of operating personnel and the level will remain at about 80 people. The modifications, however, will enable the operations to be extended in time for an additional 15 years. Thus, 200 man-years of employment will have been secured. Based on the old payroll levels, without adjustment for inflation, about $621,000 will be paid annually in wages. The present value of income for the projected 15 years of operation is $4,723,000.

Each year of operation will provide 80 man-years employment for a total of 1,200 man-years over the projected 15-year period. The real benefit will be derived, however, from the life support, or sustenance, which the worker will provide to his dependents; therefore, based upon an average of 3.5 persons per household in Grand County (U. S. Bureau of Census, 1970), one year of plant operation will provide 280 man-years of sustenance and 15 years of plant operation will provide an estimated 3,600 man-years of sustenance.

8.3.5 New Employment From Plant Construction. It is estimated that the plant will be under construction for one year ending about July 1, 1975. A maximum work force of 80 workers will be used at the peak of activity; however, over the full year, an average of 35 workers will be employed.

It has been estimated in Section 8 of the Environmental Report, that about $1,000,000 of the cost of construction will be paid as wages for labor. As this will be paid during the course of one year, this amount also constitutes the present value.

The environmental benefit in real units is provided by the methodology of Section 8.3.4. The 35 workers will support dependents on the basis of 3.5 persons per household for a total benefit of 122 man-years of sustenance.

8.3.6 Employment at New Mines. The modifications of the mill circuits will enable the treatment of ores which previously had not been economically extractable due to the lack of acid leaching circuits in the mill. Reserves of such ores will now be mineable from new mines. Mining of these resources will extend employment of miners already working in the region for another 15 years.

It is estimated that an average of 75 workers will be employed in these new mines and will earn wages at the rate of $1,195,000 per year. The present value of the wages projected for 15 years of operation is $9,089,000.

Using the methodology of Section 8.3.4, the miners will support dependents estimated at 187 persons and therefore will earn life support at

the rate of 262 man-years for a 15-year cumulative total of 3,930 man-years of sustenance.

8.3.7 Infusion of Construction Expenditures into Regional Economy. In addition to the disbursement of expenditures for labor in the local economy, capital construction costs for plant modifications will also entail expenditures for equipment, services and supplies in the area of Moab and in the Rocky Mountain Region. It is estimated that such purchases will total, and probably exceed, $2,000,000.

In commerce and trade, the infusion of new monies to a locale or region exert a multiplier effect to the economy. Commonly such multipliers exceed a factor of two and on occasion approach three. As an economic analysis has not been made for either Grand County or the region no credit will be taken herein for any multiplier effects.

The real meaning of the infusion of $2,000,000 in the local and regional economies lies in the fact that these disbursements will pay for support services in the community requiring the employment of other people who also provide life support for their families. Thus, a large portion of the capital expenditures will eventually provide wages and salaries at many points in the monetary flow. As it is not possible in this analysis to discriminate what portions will be retained as savings or used as new capital, no credit is taken herein for benefits to be derived from such factors.

8.3.8 Infusion of Plant Operating Expenditures into the Regional Economy. It is estimated that the operation of the mill will require the expenditure of about $4,930,000 annually in the region. These milling costs include the consumption of electrical power, fuel, supplies and reagents as listed in Table 3.2 and in the list shown in Section 5.5 in the Environmental

Report. The present value of these expenditures over the projected 15-year operating period is $37,497,000.

As in the case of construction expenditures discussed in Section 8.3.7, it is not possible to determine multiplier effects within the scope of this study; however, some perspective as to real utility or meaning can be discussed in general terms.

Aside from wages paid, large expenditures will be made locally in Moab for operating supplies, such as hardware, piping and fittings, lumber and miscellaneous supplies.

Other large expenditures for reagents and fuels will be made in the Rocky Mountain Region. From about 548,000 tons to 821,000 tons of sulfuric acid will be used, the bulk of which probably will be purchased from Kennecott's by-product sulfuric acid plant near Magna, Utah. About 1,460 tons of soda ash will be purchased annually for a total of 21,400 tons over the projected 15 years of operation. This probably will be purchased from producers located near Green River, Wyoming. Other reagents and supplies will be purchased in Grand Junction and Denver. Considerable repair parts will be purchased from manufacturers in Denver and elsewhere.

The effect of the annual expenditure of $4,930,000 in the region may be visualized by synthesis. By assuming that 50 percent of the expenditure will be immediately diffused as personal income and by using the approximate per capita income for the United States in 1971 of $4,135 per person, this annual expenditure would provide the average income for one year for about 600 people and thus would be roughly equivalent to 600 man-years of sustenance.

8.3.9 Taxes. Credit is taken for the benefits which will accrue to the community through payment of state and county taxes. Each year the operation will pay approximately $109,000 in sales and use taxes, and $160,000 in county property taxes. Of the $160,000, $110,000 is the tax paid for the older plant facilities adjusted for property losses suffered in the fire. The remaining $50,000 are the estimated new taxes which will be paid due to the increased valuation of the plant improvements.

The real worth of the tax payment to the community will accrue to the public through the support of governmental and municipal services, and is not susceptible to simple analysis or quantification.

8.3.10 Conservation of Natural Resources.

8.3.10.1 General. A real benefit to the environment is the conservation of resources which might be otherwise lost to man. This includes the conservation of uranium, vanadium, and copper.

8.3.10.2 Conservation of Uranium. The uranium contained in the uranium-vanadium ores would not be available for consumption during this energy-critical period if the acid leach circuit were not added. Thus, it is considered that 438 tons of U_3O_8 will be provided annually (623 tons less 185 tons from the existing circuit). During the projected 15 years a total of 6,570 tons will be produced that might not otherwise be extracted because of factors of technology and economics. The value of this product at $9 per pound is $7,884,000 annually and 15 years production has a present value of $59,966,000. This benefit expressed in dollar terms is redundant with the benefit described in Section 8.3.1, but the element of conservation is a distinct and incremental benefit.

<u>8.3.10.3 Conservation of Vanadium.</u> As the vanadium content of the ores could not be extracted on the basis of its own value, construction of the new acid leach circuits raises this mineralization to the status of an economic ore and this makes available to man a resource that otherwise would not be extracted.

This benefit is redundant to some degree with the dollar value described in Section 8.3.2; however, the element of conservation is a distinct and separate benefit.

<u>8.3.10.4 Conservation of Copper.</u> The copper which will be recovered from the new acid leach circuits could not be extracted and recovered on the basis of its own worth, and does not affect the feasibility of the extraction of the uranium and vanadium. Conservation of the copper thus is considered to be a bonus benefit.

<u>8.3.10.5 Reduction of Radioactivity in the Colorado River.</u> As discussed previously, the operation will result in a projected reduction in radioactivity in the Colorado River. As described in Section 7.8 of this report, radium-226 will be reduced from calculated values of 0.0094 picocurries/liter in past operation to negligible concentrations in the projected operation for a credit of .009 picocurries/liter. Natural uranium will be reduced from 0.54 picocurries per liter to negligible concentrations for a credit of 0.54 picocurries per liter. Thorium-230 will be reduced from 0.0049 to 0.003 picocurries/liter for a credit of 0.002 picocurries/liter.

Since these levels all lie within the promulgated standards, the real benefit to man in terms of human health is conjectural

and almost impossible to assess. Present knowledge is not adequate to project the long-term effects of low level radiation and thus the real benefit must be considered intangible.

8.3.10.6 Elimination of Gaseous Effluents by Obviating Fossil Fuels. Utilization of uranium for the generation of electrical power will substitute for the use of fossil fuels and will obviate gaseous emissions which otherwise would be produced. Credits for SO_2, NO_x and particulates are herein synthesized by use of a model of a coal fired plant whose counterpart is under construction in Wisconsin (Wisconsin Power and Light Columbia Generating Station) and by pro-rating effects to equivalent nuclear production at the rate of 1,000 megawatts. It is assumed that 3.6 million tons of coal would be burned each year. The coal contains 0.63 percent sulfur and 7.6 percent ash, and has an average heat value of about 8,500 BTU per pound. The plant is assumed to have an electrostatic precipitator of 99.5 percent efficiency. A credit for dolomitic effect of 25 percent is taken for the reduction of SO_2. Stack emission rates are: 1.09 pounds SO_2, 0.70 pounds NO_x and 0.034 pounds of particulates per 1,000 BTU. Using this model and assuming complete fission of the uranium, the following credits are obtained by the substitution of uranium for coal.

	Tons Obviated	
	Annual	15-Year Totals
SO_2	150,000	2,250,000
NO_x	100,000	1,500,000
Particulates	5,000	22,500

The benefit to man is in improvement of health and a reduction in potential damage to flora and other fauna. Assessment of the real worth of these reductions at such low levels of emission is conjectural and will require considerable research before the actual benefit can be determined.

8.3.10.7 Reduction of SO_2 From Smelter Gasses. The mill will utilize sulfuric acid which has been produced as a by-product from the refining of copper near Salt Lake City. Although earlier recovery of SO_2 for the manufacture of sulfuric acid was economically desirable, this factor has now been superseded by the need to reduce the discharge of gaseous SO_2 into the environment. Utilization of this acid, therefore, constitutes a real environmental benefit to the populace residing in the region of the smelter.

Consumption by the mill of from 36,500 to 54,750 tons of sulfuric acid annually will eliminate 27,000 to 34,000 tons of SO_2 from the air of the Salt Lake Valley each year. During the projected 15-year operating period, a total of 330,000 to 510,000 tons of SO_2 will be eliminated.

The SO_2 not used in the mill products will ultimately be precipitated as calcium sulfate in the evaporation pond and thus will be prevented from reaching the ambient environment.

8.4 COSTS:

8.4.1 General. Costs of the projected plant modification consist of the expenditure of capital, the potential--but unknown--long-term effects of low-level radiation, and restrictions on future land use of the site. The

potential costs in governmental services and aesthetics have been examined but are considered to be unchanged upon modification of the plant.

8.4.2 Process Costs. The direct annual cost of milling is estimated at about $621,000 for labor and $4,930,000 for materials and supplies. The present value of the future expenditures extending 15 years is $37,497,000.

The real cost represented by this dollar cost is the consumption of labor, energy, materials and supplies as discussed in this report. These are set forth in Table 3.2 and in the list given in Section 5.5 in the Environmental Report.

This cost constitutes an irretrievable commitment of resources.

8.4.3 Ore. Ores which are produced and purchased for mill feed have a value estimated at $43.43 per ton delivered at the mill. Approximately 500 tons of acid leach ores and 250 tons of alkaline leach ores will be used each day for an annual rate of about 270,000 tons on a 360-day basis. In the projected 15 years of operation, about 4,050,000 tons of ore feed will be milled. The annual value of the feed will be $11,726,000 and the present value of 15 years production is $89,189,000.

8.4.4 Plant Modification. Plant modification will require the expenditure of about $3 million or more of new capital and will utilize materials and supplies to construct a new acid leach circuit and an expanded tailings/evaporation pond. It is projected that 35 man-years of labor will be used.

The expenditure of machinery through wear, the consumption of manpower and supplies constitute the real cost. These are equivalently and conveniently referred to as capital cost expressed in dollars.

8.4.5 Municipal Services. Due to factors of previous boom cycles, expansion of municipal services in nearby Moab has produced capacities for city services which are adequate to service this modest influx of new workers.

The operating staff of the mill will remain at the same level as the earlier operation.

During the peak of construction, about 70 workers will temporarily use local services. Any adverse effects which might arise would be of short-term and are not judged as being of potential significance.

Employment for new mining operations probably will be obtained from locally available workers and should not require a significant influx of new workers.

It is considered, therefore, that the projected operations will make no significant adverse demands upon local municipal services.

8.4.6 Occupational Health-Plant Workers. Environmental measurements and monitoring are discussed in Section 5 and 6 of the Environmental Report. All existing standards have been met or exceeded in past operations and will continue to be met or exceeded in the modified operations.

The most important single element is that of exposure to radioactivity by plant workers. As discussed in Section 5.1.3 of the Environmental Report, the maximum dose received during previous film badge monitoring was 920 millirems per year and that this represents less than 25 percent of the occupational limit of 5,000 millirems per year.

To determine the overall cost, however, it has been determined from the records of film badge monitoring results that the past average dose was 377.4 millirems per year, or roughly 7 percent of the permissible standard.

Since the efforts of low-level radiation over extended periods is not known, the long-term significance remains unknown.

8.4.7 Accidents. Potential sources of accidents are discussed in Section 7 of the Atlas Minerals Environmental Report.

Six events were postulated for tailings dam failure. There appears to be no chance of flash-flooding. The possibility of the occurrence of flooding from high water in the Colorado River is low and does not appear significant. Operating procedural measures mitigate against failure by overflow. The factor of safety for the dam is well above the point where structural failure is considered possible. Structural failure by earthquake is an extremely remote possibility. In the event of a tailings pipeline rupture, there is little chance that tailings would reach the Colorado River. These are not considered of sufficient significance to constitute an environmental cost.

Another fire in the solvent extraction section has been postulated but has been mitigated by a new emergency dumping system and is not taken as a probable environmental cost.

Past experience with transportation accidents indicates that effects are of very limited extent and of short duration with no apparent significant environmental costs.

8.4.8 Land Use. The land upon which the mill is located is now dedicated to a high utilitarian usage and is not considered to constitute an environmental cost.

Upon dismantlement of the mill, constraints upon future use as discussed in Section 9 of the Environmental Report will constitute an environmental cost of low order. It is expected that in the light of the constraints

imposed in items 1 through 5 of Section 9, approximately 200 acres now occupied by mill and tailings pond will have to be dedicated to use which will deny future continued occupancy or residency. This constraint is considered as an unavoidable cost.

8.4.9 Aesthetics. The proposed modifications to the plant will not change the exterior appearance of the facility and therefore would have no incremental effects.

Alterations to the tailings pond will include placement of native shale on visible slopes, which will tend to make the tailings pond blend into the existing background. This might be a benefit to aesthetic values, but neither credit nor debit is taken.

8.4.10 Effluents. Modifications to the plant indicate a theoretical increase of from 2 to 4 ppm of total dissolved solids. As this represents less than 1 percent of that contained in the Colorado River, this is considered as a cost.

8.5 ALTERNATIVES:

8.5.1 General. Alternatives are discussed in Section 10 of the Environmental Report and are assessed below.

8.5.2 Alternative Mill Sites. The discussion of alternative mill sites in Section 10.1 of the Environmental Report adequately demonstrates that such a choice would be inferior to the proposed modification of the existing plant.

8.5.3 Alternative Mill Processes. The discussion in Section 10.2 of the Environmental Report indicates that construction of a sulfuric acid plant or an alternative tailings pond site would have environmental effects of more adverse character than exist with the projected plan.

8.5.4 Not Modifying Mill Facility. According to the reasons for the projected modifications discussed in Section 1, the discussion of benefits and costs in this section and the discussion of Section 10.3 of the Environmental Report, a decision not to modify the mill would: (1) deny energy to the populace at a time when such energy is in short supply; (2) would produce serious adverse economic efforts to the local community at a time when the economic climate is in a state of great uncertainty; and would (3) deny to the populace the significant real environmental and economic benefits which will be obtained through production of the plant as proposed.

8.6 CONCLUSIONS:

Comparison of benefits with costs reveals the following salient factors: The principal benefit of the milling operation will be realized through utilization of the ultimate products--energy, vanadium, and copper products. The energy will be equivalent to electricity which will be produced in 15 years by more than four 1,000 megawatt generating plants. The vanadium will be equivalent to that used in the production of about 1.5 million tons of high speed tool steel. The copper will be equivalent to that used in over 10,000 homes. This production is valued at $19,264,000 per year or a present value for 15 years production of $146,515,000.

The actual costs of the operation will be the expenditure of manpower at the rate of 80 man-years per year or 1,200 man-years in 15 years of operation; the consumption of operating energy, materials and supplies listed in Section 5.5; the consumption of about 220,000 tons of uranium-vanadium ore; and the wear on the mill (depreciation). These costs are valued at $16,586,000 per year or a present value of 15 year's projected cost of $126,154,000. The dollar difference between the value of the product and

the cost of production is an index of the utility or worth of the projected operation. Since this difference is positive, the operation is considered beneficial. The real benefit, however, lies in the utility of the ultimate products to man.

A secondary benefit of the projected operation will be the employment of about 2,360 man-years of labor to provide an estimated 8,252 man-years of sustenance. The difference of 5,892 man-years represents the production leverage provided by the plant to multiply the productivity of the work force. Thus each worker can produce the sustenance needs of his family or a benefit-cost ratio of 3.5. The benefit-cost difference is positive and the effect beneficial.

Three intangible costs are noted: low level radiation, future restricted land use of the site, and a slight increase of dissolved solids in the Colorado River.

In assessing the potential cost of low-level radiation to occupational health, it must be remembered that the average dosage is less than 10 percent of the permissible standard and that the standards have been promulgated by responsible and expert governmental agencies at extremely conservative levels. There is no question of loss of life and the potential cost is a theoretical diminishment in the level of health. This may be put into proper perspective with realization that this average dosage is exceeded by one session of X-rays in a hospital, or is almost equivalent to the background radiation at Denver, Colorado. In these terms, this cost is not significant, particularly when compared to the 8,652 man-years of sustenance which will have been earned by the employees.

Assessment of the restricted future land use at the site must be made by comparison with the utility of the ultimate products. The gain from the products is substantial and self-evident.

When the constraint on future land use is considered within the context of the surrounding area, it is not necessarily incompatible. The land could be used for recreational purposes, such as a park, which do not permit residence. The surrounding lands are in large measure scenic and constitute a tourist attraction. Thus, the site land could be used beneficially in complete harmony with its surroundings and in such manner that the constraint would not constitute a cost.

The increase of dissolved solids through seepage into the Colorado River is theoretical and its actual cost is not determinable with present knowledge.

In total consideration of the projected operation, environmental benefits are expected to greatly exceed the costs and the operation will, on balance, be justified.

9. SPECIFIC REPLIES TO A.E.C. QUESTIONS

9.1 GENERAL:

The questions posed by the Atomic Energy Commission in their letter to Atlas Minerals Corporation, dated January 25, 1974, are presented in Appendix D. Specific replies to the questions follow.

9.2 REPLY TO A.E.C. QUESTION 1:

Section 7.2 of this report discusses embankment stability and presents the results of additional analyses. Soil test data used to develop the soil strength parameters utilized in the slope stability analyses are

presented in Appendix A of this report. In addition, the soil test data presented in Appendix A of the Atlas Minerals Environmental Report was utilized. The soil strength parameters used to calculate the factors of safety for individual embankment sections are shown on Plates 6A through 6F.

9.3 REPLY TO A.E.C. QUESTION 2:

Table 3.10 in the Atlas Minerals Environmental Report lists an emission rate of 3.0 pounds of U_3O_8 per day. Since the yellow cake material being dried is 96 percent U_3O_8, the particulate emission rate would be 3.125 pounds per day. This emission rate was arrived at as average of a number of measurements. However, one particular measurement taken on March 3, 1973 showed a 3.0 pounds U_3O_8 per day emission with a dryer throughput rate of 319 pounds of U_3O_8 per hour.

9.4 REPLY TO A.E.C. QUESTION 3:

The crushing plant west dust collector was inoperative at the time that these samples were taken. This collector is designed for the same duty as the north dust collector and cleans air from the same area. Thus it can be logically estimated that the emissions from the west collector will be very close to those from the north dust collector. Table 3.11 in the Atlas Environmental Report shows a measured emission rate of 0.039 pounds U_3O_8 per day from the north collector. The grade of ore being crushed on that particular day (February 28, 1973) was .276 percent U_3O_8. Thus the particulate emission rate from the north (or west) collector would be 14.1 pounds per day. The crusher throughput rate on this day was 135 tons per hour.

9.5 REPLY TO A.E.C. QUESTION 4:

On February 28, 1973, a U_3O_8 emission rate of .019 pounds per day from the fine ore storage dust collector was measured. The grade of ore ground on that day was .187 percent U_3O_8. Thus the particulate emission rate would be 10.2 pounds per day. The grinding throughput rate on that day was 41 tons per hour.

9.6 REPLY TO A.E.C. QUESTION 5:

The radiation units reported in the soil sampling survey were erroneously listed as mrem/hr. They should have been milliroentgens/hour.

9.7 REPLY TO A.E.C. QUESTION 6:

A plot plan of the facility showing the location of the new systems is presented on Plate 7 of this report.

9.8 REPLY TO A.E.C. QUESTION 7:

The crushing rate on February 28, 1973 was 135 tons per hour, the grinding rate was 41 tons per hour and the U_3O_8 drying rate was 319 pounds per hour.

9.9 REPLY TO A.E.C. QUESTION 8:

Flowsheets of the proposed mill processes with the chemical additions and a materials balance are presented on Plates 8A, 8B, and 8C of this report.

9.10 REPLY TO A.E.C. QUESTION 9:

The liquefaction potential of the embankments is discussed in Section 7.2.4 of this report. The possibility of piping is discussed in Section 7.2.5.

9.11 REPLY TO A.E.C. QUESTION 10:

The embankment cover material is described in Section 5.3 of this report.

9.12 REPLY TO A.E.C. QUESTION 11:

The logs of additional borings drilled in the embankment and site vicinity are presented in Appendix A of this report. The locations of the borings are shown on Plate 2, Plot Plan. Additional cross-section and results of the stability analyses calculated for these sections are presented in graphical form on Plates 6A through 6F.

9.13 REPLY TO A.E.C. QUESTION 12:

Tabulations of ground water level and assay data for the site are presented in Appendix A of this report. The time of day was not recorded for all measurements. Borings 1 through 7 and all test pits contain casing slotted throughout their entire depth. Borings 8 through 15, except boring 11, contain casing slotted only on the lower 10 feet. The depth of monitor well casing is shown on each boring log.

9.14 REPLY TO A.E.C. QUESTION 13:

As indicated on page 6-4 of the Atlas Minerals Environmental Report, the monitor wells will be sampled and measured quarterly after February 8, 1973.

9.15 REPLY TO A.E.C. QUESTION 14:

The location of the discharge line referred to on page 6 of Appendix A of the Atlas Minerals Environmental Report is shown on Plate 2, Plot Plan. The line is referred to as "Existing Tailings Discharge Line."

9.16 REPLY TO A.E.C. QUESTION 15:

The discharge and decant barge line are shown on Plate 2, Plot Plan, of this report. The discharge and decant operations are discussed in Section 7.1.2 and 7.1.3 of this report.

The basin area which is shown on the south end of the tailings disposal area was designed for use as an alternate tailings storage area. The area will not be used for this purpose in the future.

9.17 REPLY TO A.E.C. QUESTION 16:

Erosion of the embankment and a discussion of its maintenance program is presented in Section 7.3 of this report.

9.18 REPLY TO A.E.C. QUESTION 17:

Discussions of the expected concentrations that would occur in the tailings pond, in the ground water discharge to the Colorado River and at the closest River intake are presented in Section 7.8 of this report.

9.19 REPLY TO A.E.C. QUESTION 18:

The calculation of the seepage loss from the tailings pond is discussed in Section 7.5.2 of this report.

9.20 REPLY TO A.E.C. QUESTION 19:

Provisions to prevent pond water from being closer than 250 feet from the embankment are discussed in Section 7.1 of this report.

9.21 REPLY TO A.E.C. QUESTION 20:

It is planned that all the recommended modifications presented in Appendix A of the Atlas Minerals Environmental Report be incorporated in the tailings disposal area operation. The recommendations include the maintenance of the tailings pond at a minimum of 250 feet from the embankment, a specific embankment configuration and construction recommendations.

9.22 REPLY TO A.E.C. QUESTION 21:

Assays of ground water samples obtained from monitor wells at the site are presented in Appendix A of this report. A discussion of the expected constituents and their concentration in ground water at the site is presented in Section 7.6.

9.23 REPLY TO A.E.C. QUESTION 22:

Details of the methods used and the results of ion exchange investigations for the site are presented in Appendix B and are summarized in Section 7.7 of this report. The resultant effects of ion exchange upon radium-226 and natural uranium concentration in the ground water at the site are discussed in Section 7.6.2.

9.24 REPLY TO A.E.C. QUESTION 23:

The flood damage potential to the tailings storage area is discussed in Section 7.4 of this report.

9.25 REPLY TO A.E.C. QUESTION 24:

The tailings pond level control is discussed in Section 7.1 of this report.

9.26 REPLY TO A.E.C. QUESTION 25:

It is believed that the reduction in uranium dust concentration for the years 1968 through 1972 is due in part to a reduction in the grade of ore processed, and, more significantly, increased efforts toward control of process dust.

The average operating ore tonnage for the years 1968 through 1972 are presented on the following page.

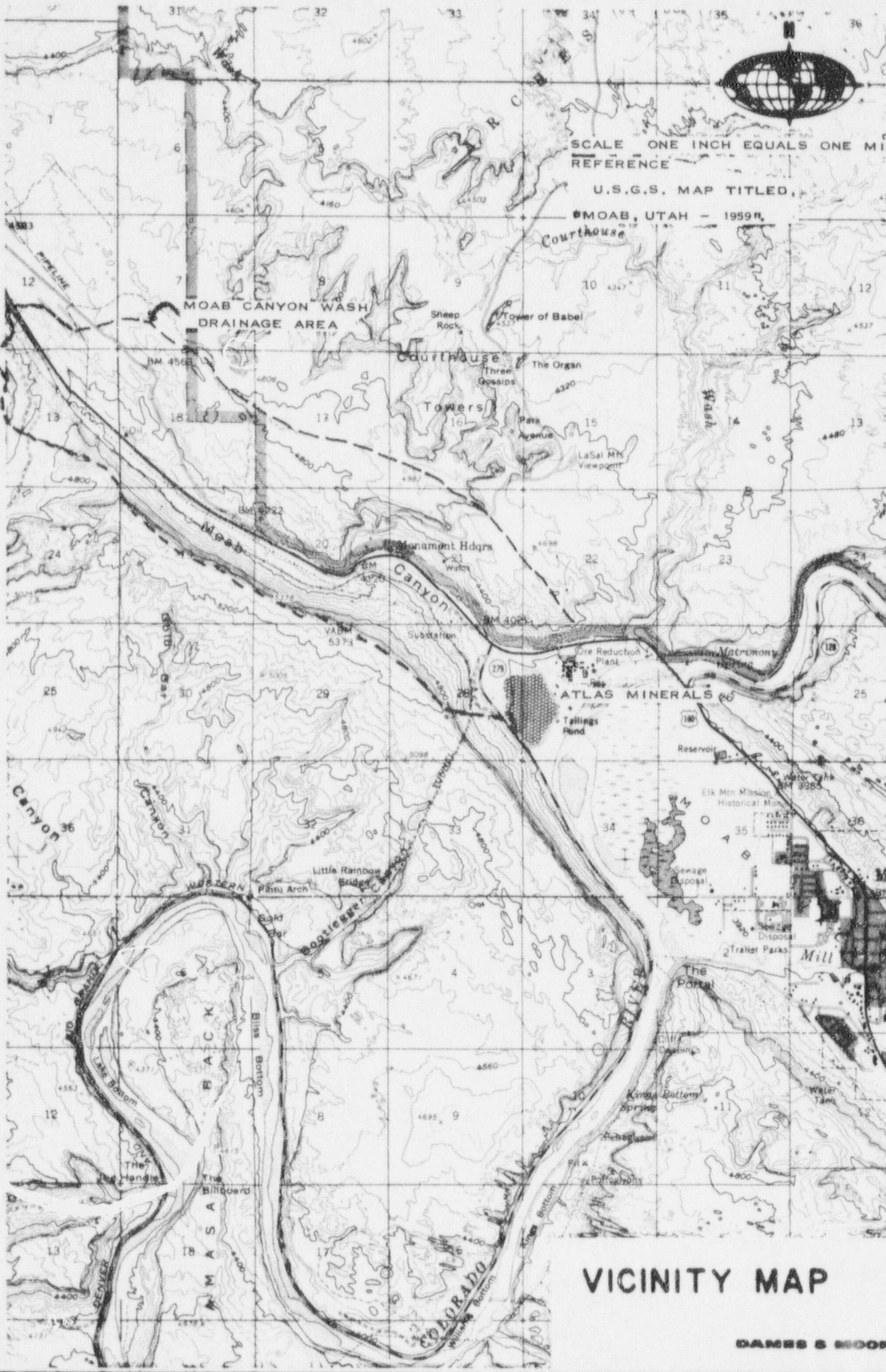
Year	Average Operating Tons Per Day	Ore Grade In Percent U_3O_8
1968	879	.247
1969	1,076	.214
1970	1,145	.231
1971	1,269	.185
1972	1,044	.168
1973	913	.160

9.27 REPLY TO A.E.C. QUESTION 26:

The acid circuit operation tonnage will be 400 to 500 tons per day (TPD) through 1977. Thereafter the tonnage will be 660 TPD. If ore is available, an additional alkaline circuit tonnage of up to 400 TPD will be processed.

9.28 REPLY TO A.E.C. QUESTION 27:

A cost-benefit analysis of the proposed milling operation is presented in Section 8 of this report.



VICINITY MAP

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PLATE 1

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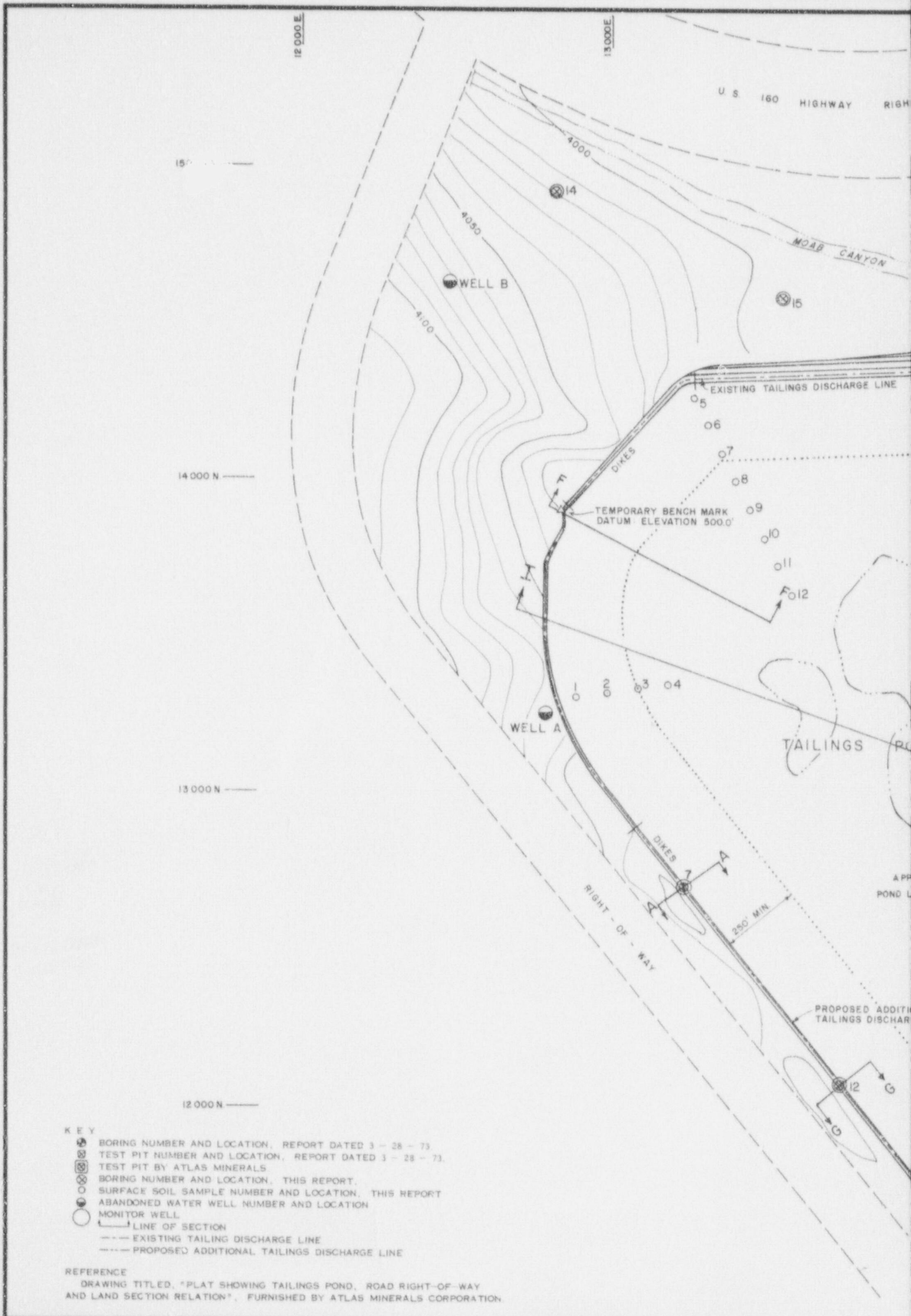
FILE 5467-007 ATLAS MIN. - MOAB

BY H.B. DATE 5-20-74
CHECKED BY

946.7 (REV. 6-61)



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ATLAS MINERALS
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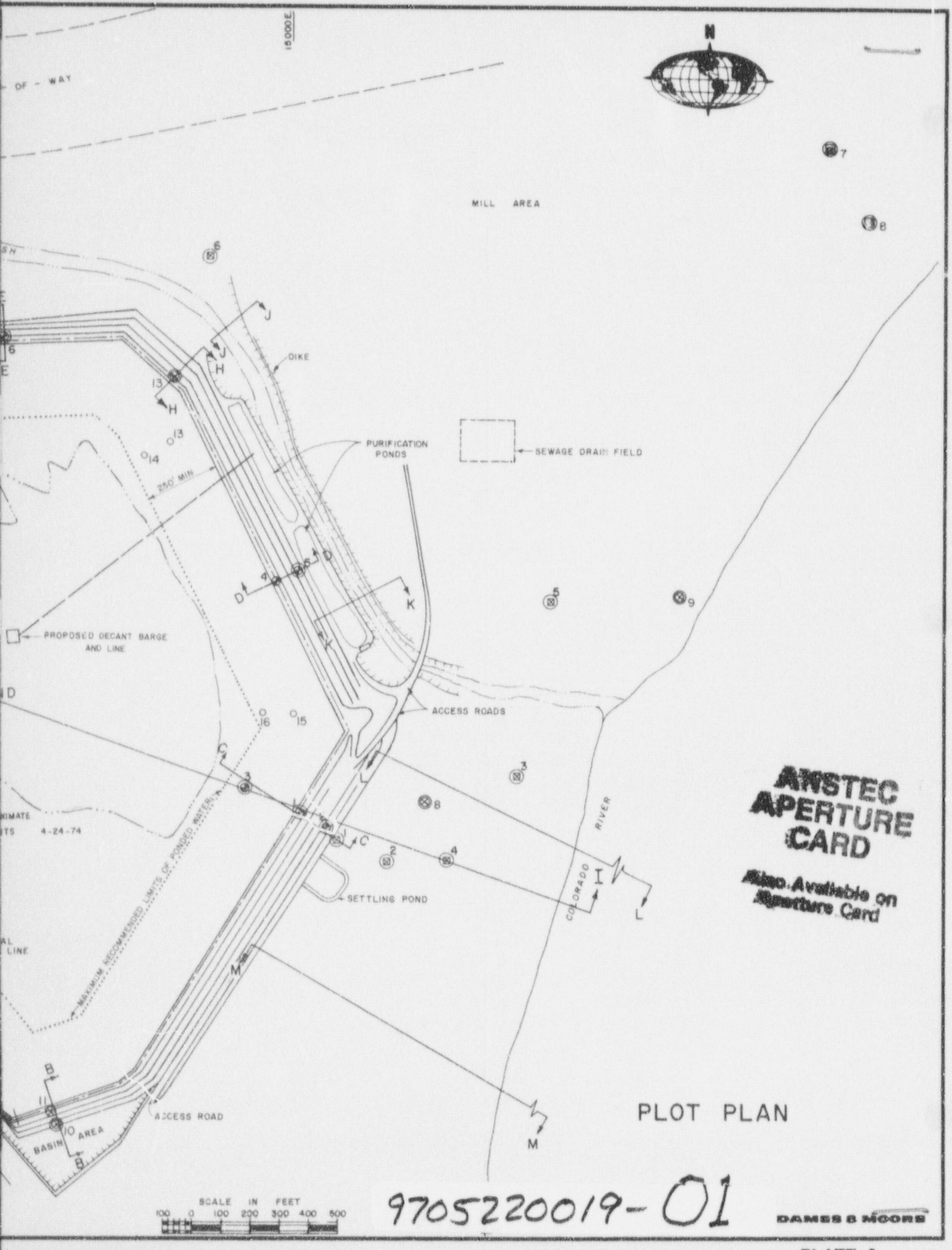

N
OF - WAY
15000E
MILL AREA
DIKE
PURIFICATION PONDS
SEWAGE DRAIN FIELD
250' MIN
PROPOSED DECANT BARGE AND LINE
ACCESS ROADS
4-24-74
MAXIMUM RECOMMENDED LIMITS OF PONDED WATER
SETTLING POND
COLORADO RIVER
ACCESS ROAD
BASIN AREA
PLOT PLAN
SCALE IN FEET
100 0 100 200 300 400 500
9705220019-01
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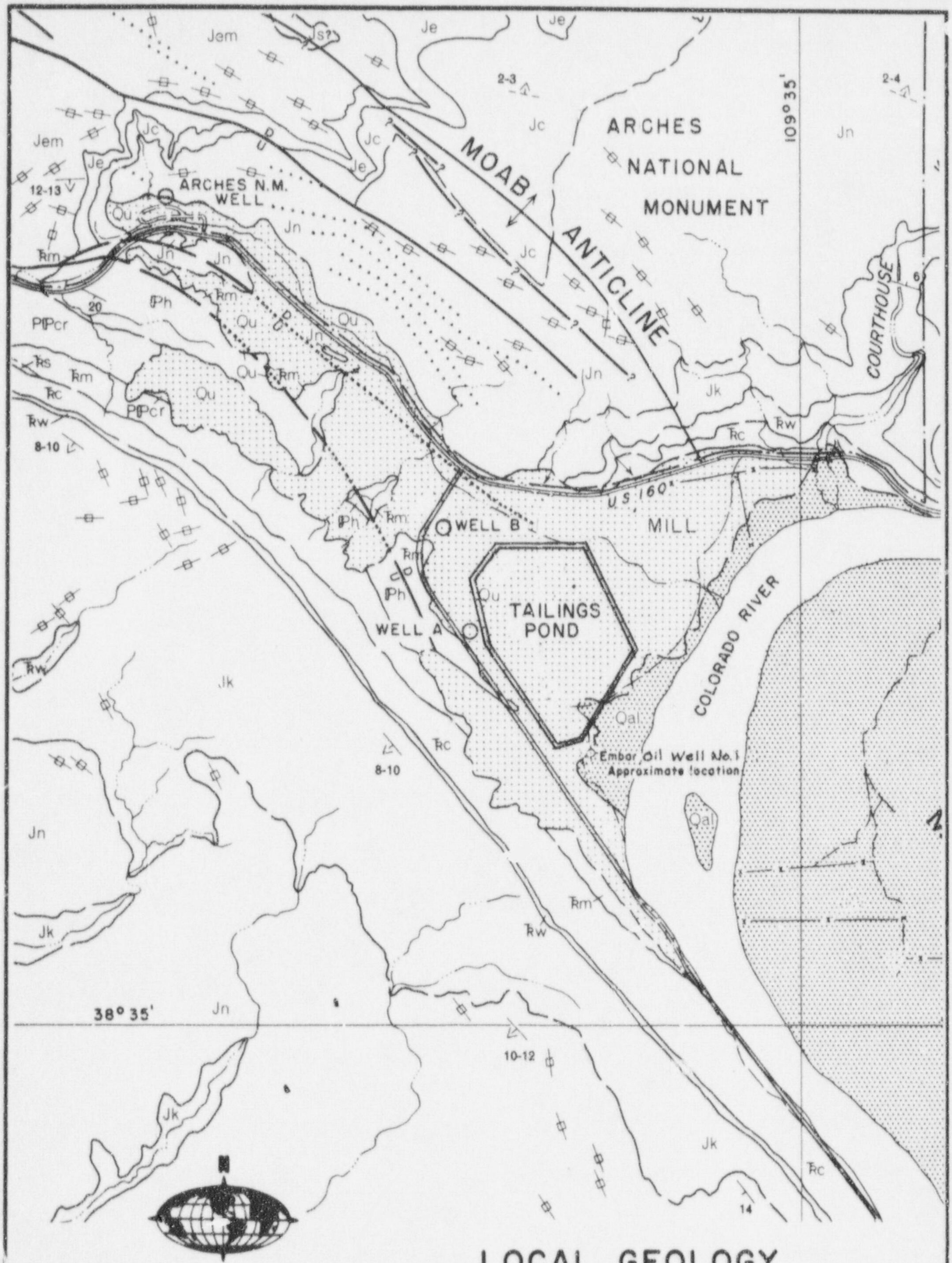
PLATE 2



LOCAL GEOLOGY

SCALE: 1" = 2000'

KEY: SEE PLATE 3, STRATIGRAPHIC DESCRIPTION, FOR SYMBOLS

REFERENCE: HEMPHILL, 1955

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PLATE 3

REVISIONS BY ______ DATE ______

FILE 5462-003 ATLAS MINERALS

BY H.B.T. DATE 5-23-74 CHECKED BY H.B.T.

946.7 (REV. 6-61)

SYMBOL	DESCRIPTION
Qal Alluvium	Stream and River deposits of primarily sands and gravels--principal aquifer in region; yield variable but generally high.
Qu Undifferentiated sand, residual mantle, and slope wash	Windblown sand, colluvium, and slopewash; silty fine sand, and poorly sorted sands, gravels, boulders--variable permeability; may yield significant amounts of ground water.
Jem / Je Entrada sandstone Moab tongue, Jem; lower part, Je	Eolian sandstone and aqueous siltstone--permeable but not known to yield ground water to wells in vicinity.
Jc Carmel formation	Muddy sandstone and sandy mudstone--not known to yield ground water to wells in vicinity; an aquiclude.
Jn Navajo sandstone	Massive eolian sandstone with occasional thin limestone--yields significant quantities of ground water where highly fractured; water quality generally high.
Jk Kayenta formation	Siltstone, sandstone, shale, occasional limestone--an aquitard with some permeable layers; not known to yield ground water to wells in area.
TRw Wingate sandstone	Massive eolian sandstone--moderately low permeability but may yield ground water where intensely fractured--water quality generally good.
TRc Chinle formation	Siltstone, sandstone, conglomeratic sandstone with gypsum veins--some permeable layers but considered an aquiclude; generally yields very saline water.
TRs Shinarump conglomerate	Sandstone, conglomerate and some mudstone--not known to yield ground water to wells in area--absent at site.
TRm Moenkopi formation	Siltstone and sandstone with veins of gypsum--probably underlies alluvium over western part of site--generally low permeability; generally yields slightly to highly saline water.
PIPcr Cutler and Rico formations, undifferentiated	Conglomerate, sandstone, siltstone and occasional limestone--contains permeable layers, may yield small amounts of ground water to wells.
IPh / IPhp Hermosa formation, IPh; Paradox member, IPhp	Limestone and shale; Paradox member contains salt beds--low permeability; yields very saline to briny water--underlies alluvium under part of site.

STRATIGRAPHIC DISCRIPTION

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PLATE 4

BY GWL DATE 5-31-74 CHECKED BY [illegible] 6-5-74 FILE ______ REVISIONS BY ______ DATE ______

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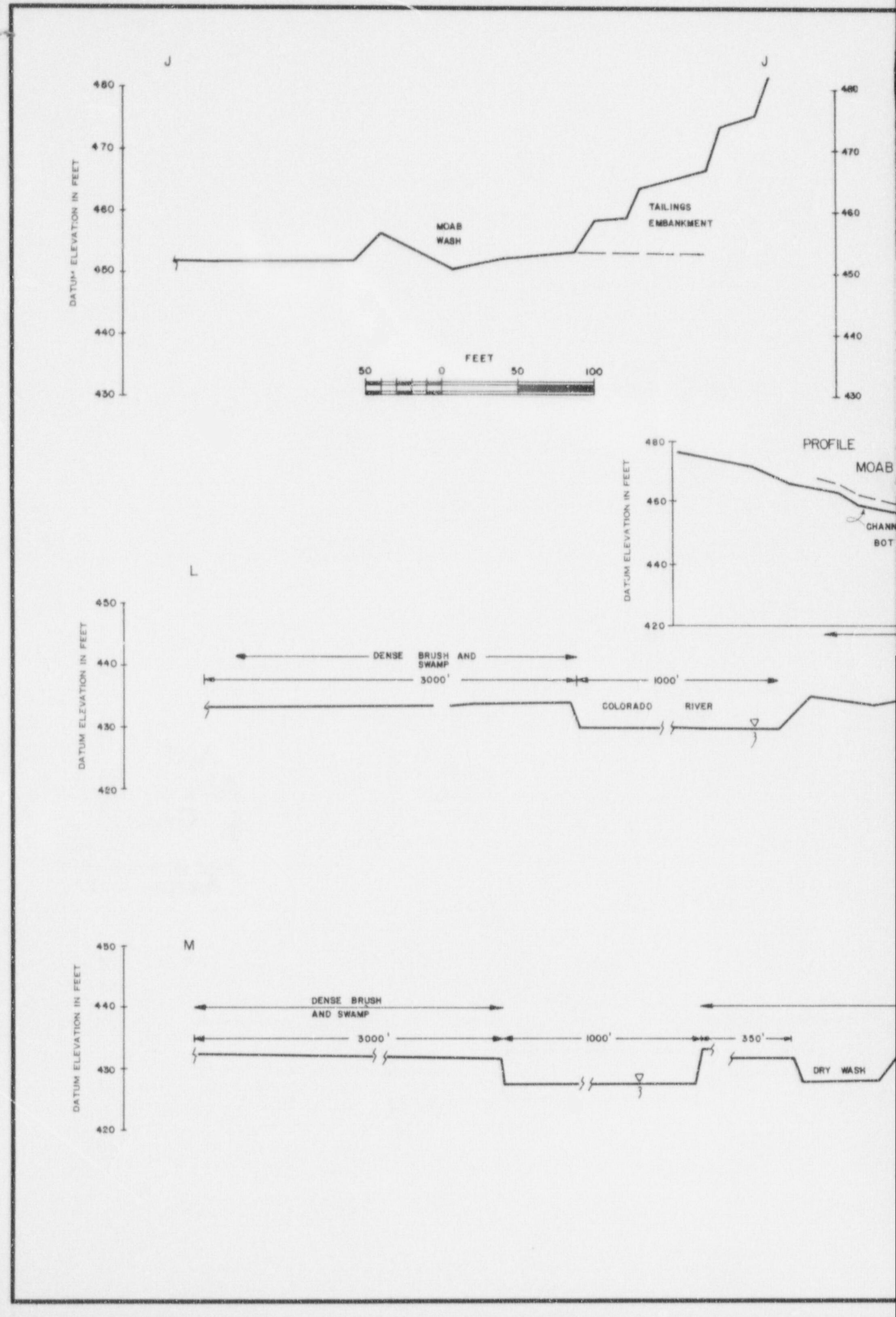
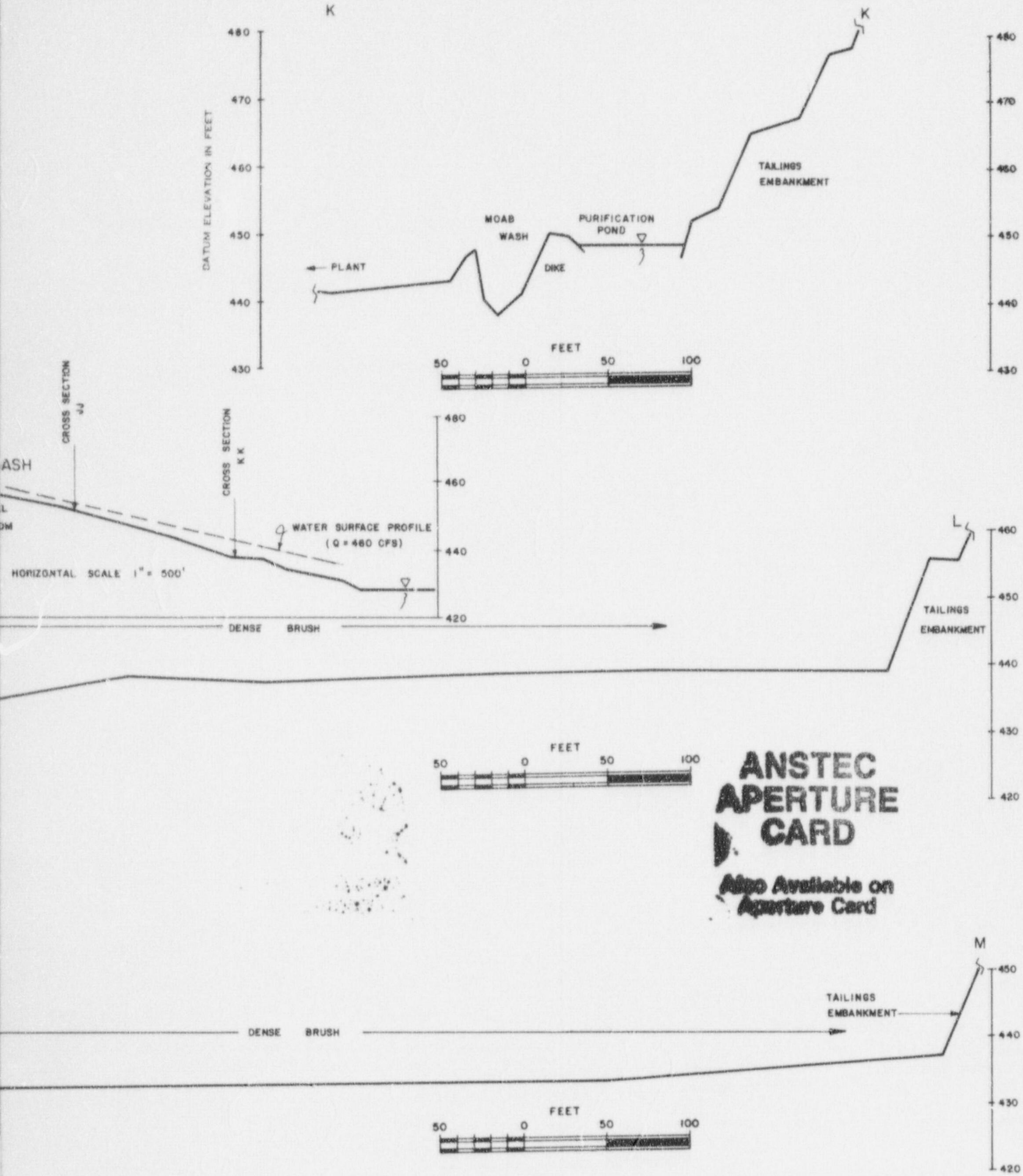

J
J
DATUM ELEVATION IN FEET
480
470
460
450
440
430
MOAB
WASH
TAILINGS
EMBANKMENT
FEET
50
0
50
100
PROFILE
MOAB
CHANN
BOT
420
L
DENSE BRUSH AND SWAMP
3000'
1000'
COLORADO RIVER
M
DENSE BRUSH
AND SWAMP
350'
DRY WASH



ANSTEC APERTURE CARD

Also Available on Aperture Card

STREAM SECTIONS

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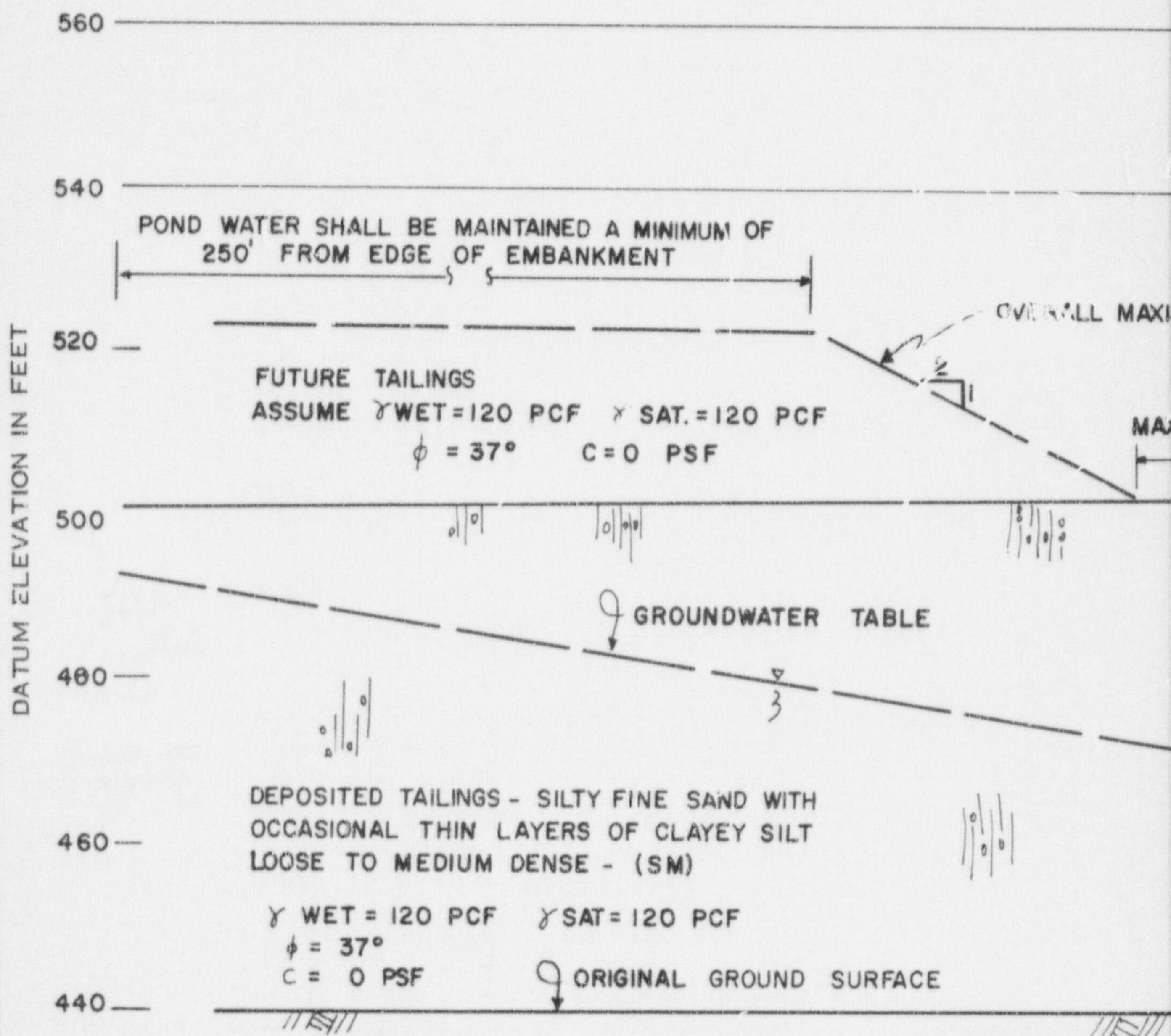
PLATE 5



NOTES:

THE LEVEL OF THE PONDED WATER WITHIN THE TAILINGS POND ON 4-12-71 WAS 494 FEET. THE DEPTH AND THICKNESS OF THE SOIL STRATA AND THE GROUND WATER GRADIENT INDICATED ON THE SUBSURFACE SECTIONS WERE OBTAINED BY INTERPOLATING BETWEEN BORINGS AND TEST PITS. INFORMATION ON ACTUAL SOIL AND GROUND WATER CONDITIONS EXIST ONLY AT THE BORING AND TEST PIT LOCATIONS AND IT IS POSSIBLE THAT THE CONDITIONS AS DEPICTED ON THESE SECTIONS MAY VARY FROM THOSE INDICATED. THE PLANT DATUM ELEVATION OF 500.0 FEET IS EQUAL TO 4028.[illegible] FEET ABOVE SEA LEVEL. SUBSURFACE SECTIONS A-A AND F-F ARE DEPICTED IN APPENDIX A OF THE ATLAS MINERALS ENVIRONMENTAL REPORT DATED 8-31-73.

FILE 5467-003

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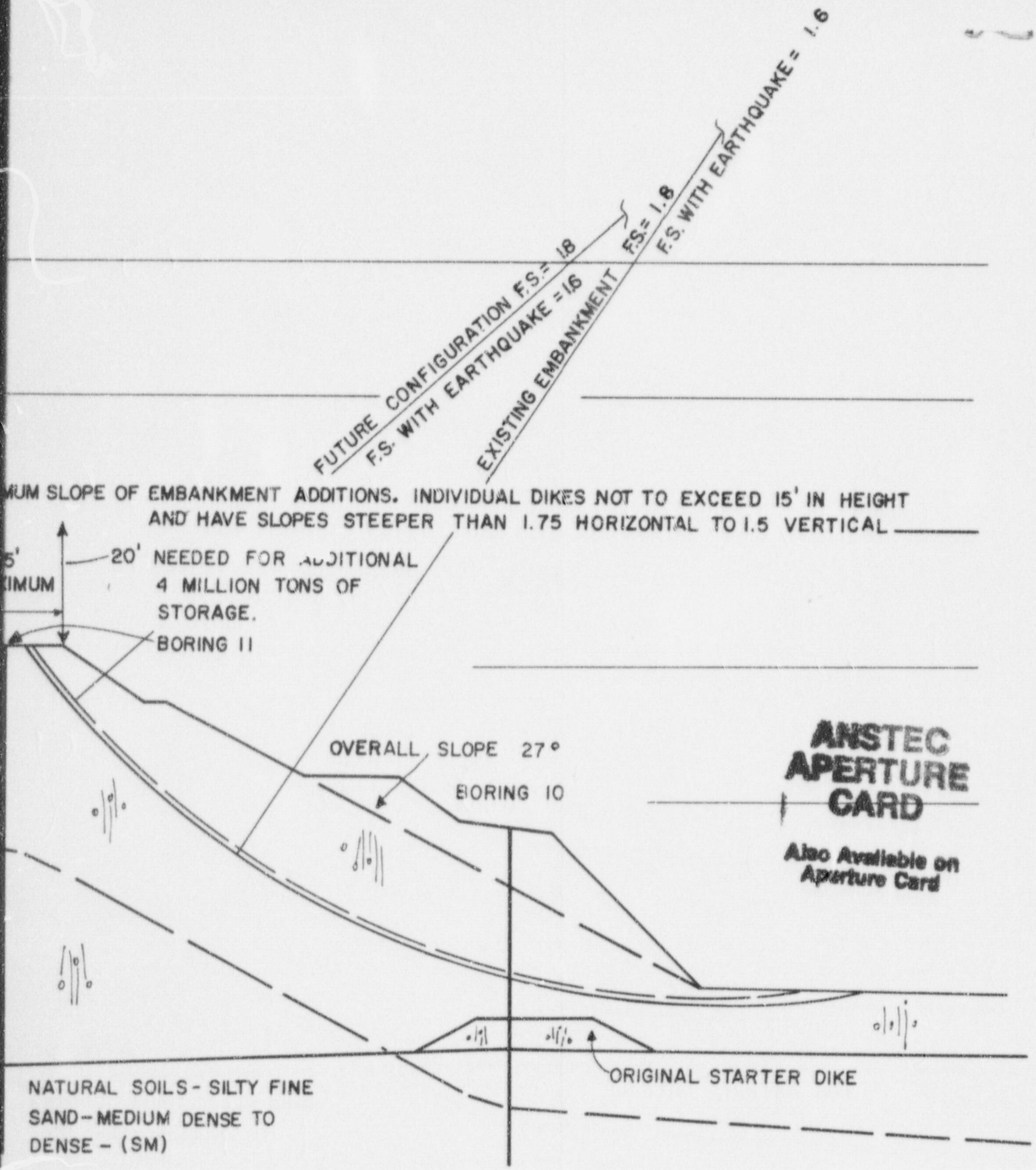


NATURAL SOILS - SILTY FINE SAND - MEDIUM DENSE TO DENSE - (SM)

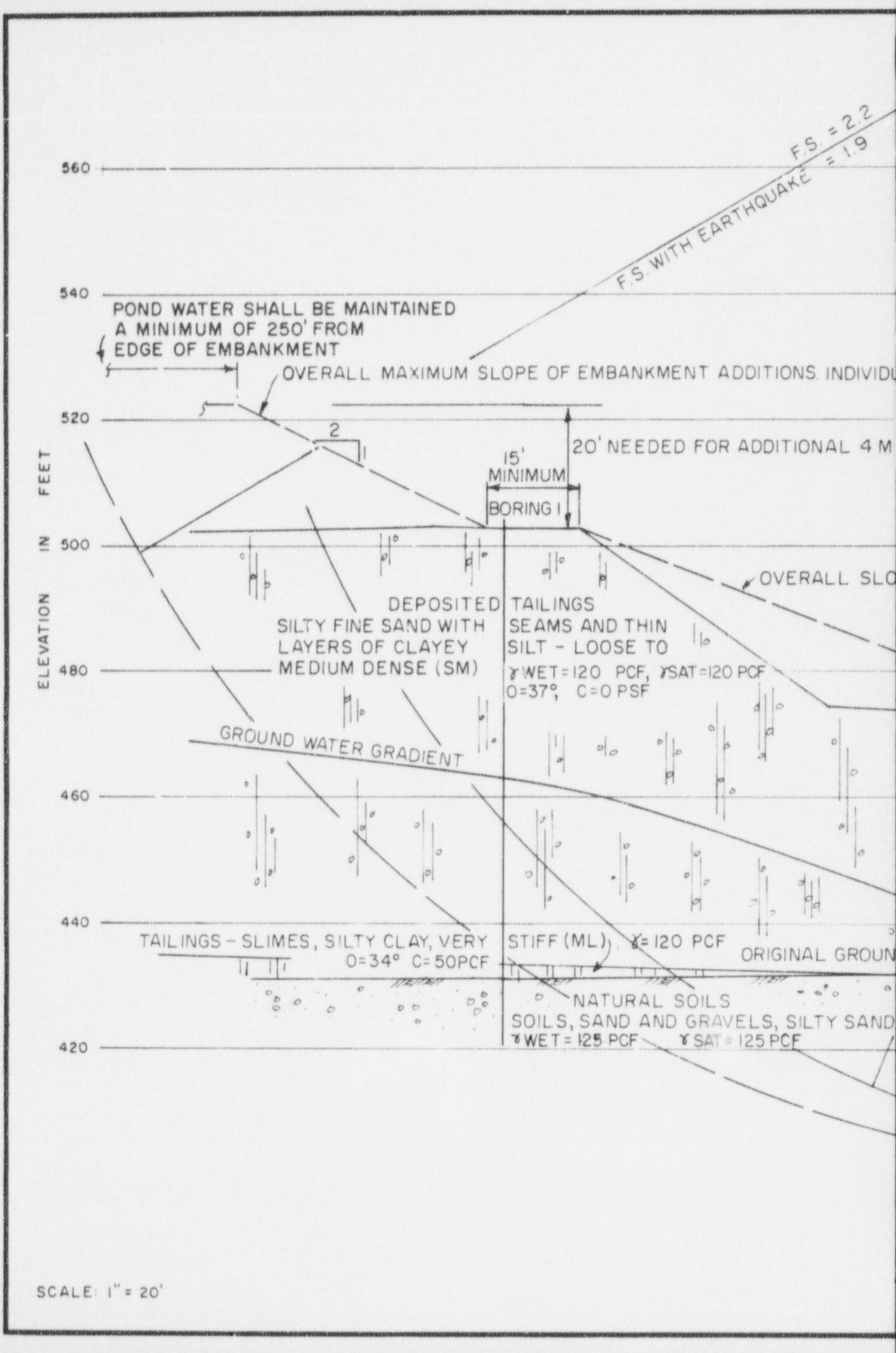
γ WET = 125 PCF
ϕ = 38°
C = 50 PSF
γ SAT = 125 PCF

SUBSURFACE SECTION B-B

9705220019-03

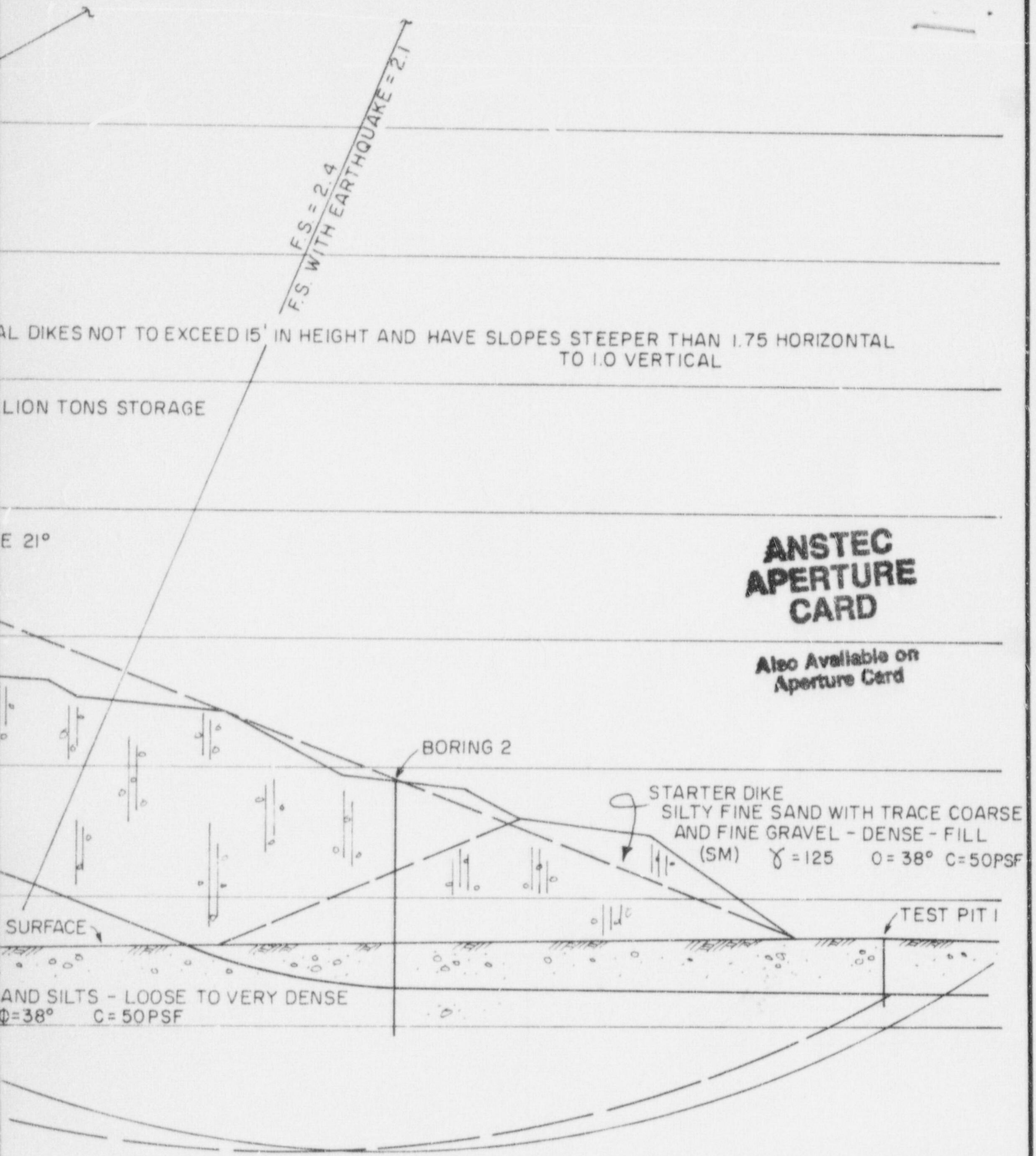
DAMES & MOORE

PLATE 6A



FILE 5467.002
ATLAS MINERALS - MOAB

466-12 (4-64)



ANSTEC APERTURE CARD

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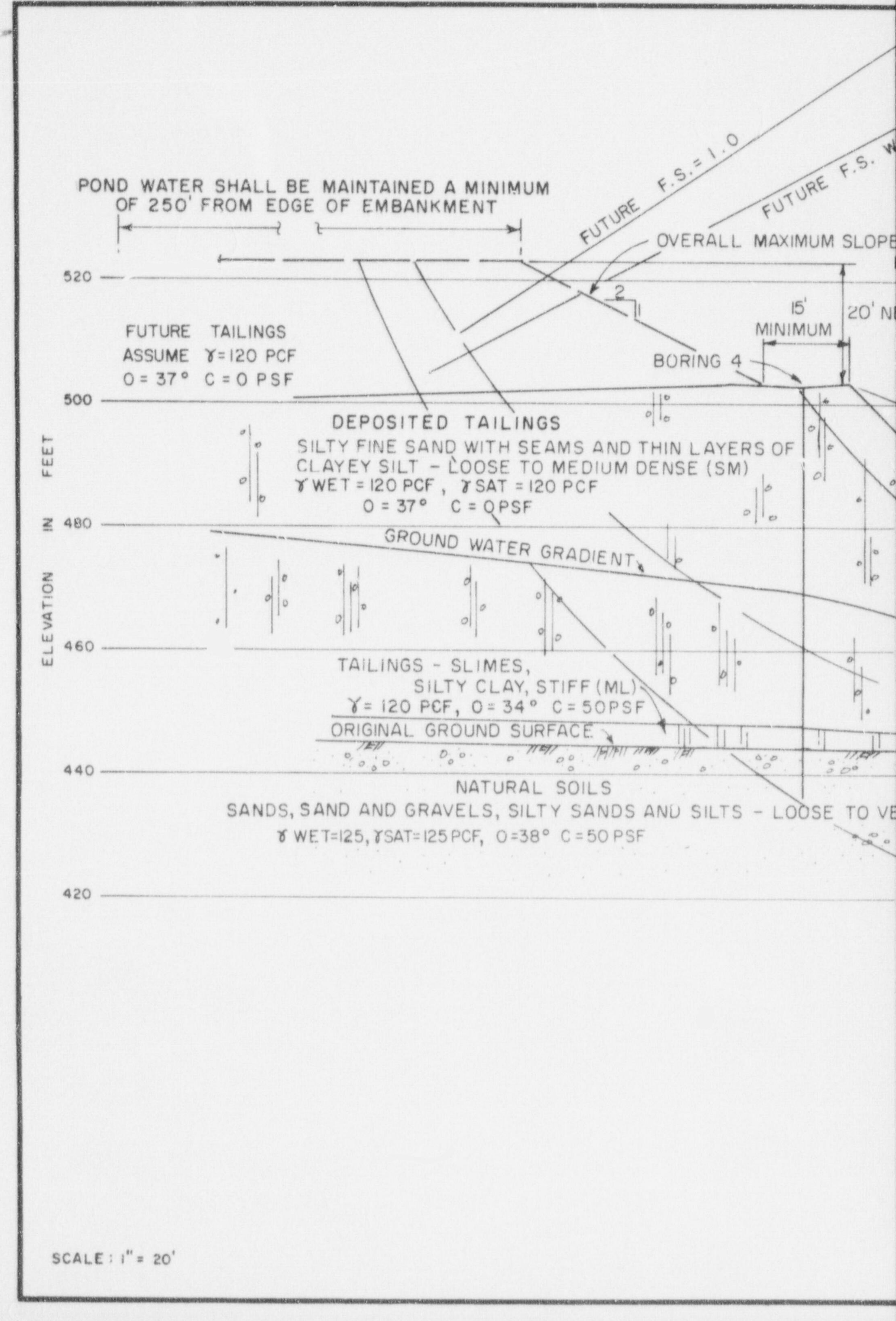
SUBSURFACE SECTION C-C

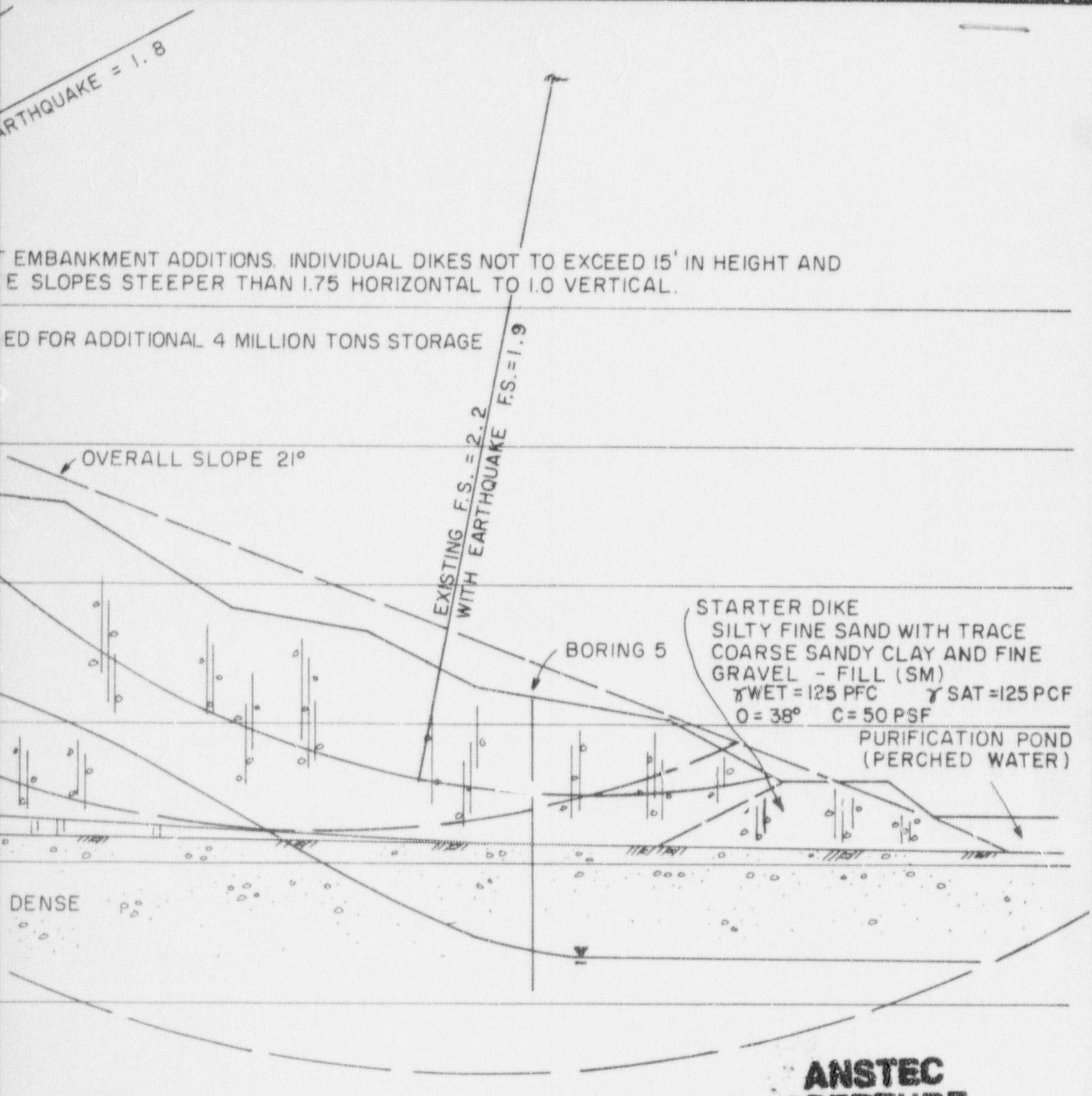
9705220019-04

DAMES & MOORE

PLATE 6B



POND WATER SHALL BE MAINTAINED A MINIMUM
OF 250' FROM EDGE OF EMBANKMENT
FUTURE F.S.= 1.0
FUTURE F.S.
OVERALL MAXIMUM SLOPE
2
1
15' MINIMUM
20'
BORING 4
FUTURE TAILINGS
ASSUME γ=120 PCF
O = 37° C = 0 PSF
DEPOSITED TAILINGS
SILTY FINE SAND WITH SEAMS AND THIN LAYERS OF
CLAYEY SILT - LOOSE TO MEDIUM DENSE (SM)
γ WET = 120 PCF , γ SAT = 120 PCF
O = 37° C = 0 PSF
GROUND WATER GRADIENT
TAILINGS - SLIMES,
SILTY CLAY, STIFF (ML)
γ = 120 PCF, O = 34° C = 50 PSF
ORIGINAL GROUND SURFACE
NATURAL SOILS
SANDS, SAND AND GRAVELS, SILTY SANDS AND SILTS - LOOSE TO VE
γ WET=125, γ SAT=125 PCF, O=38° C=50 PSF
ELEVATION IN FEET
520
500
480
460
440
420
SCALE: 1" = 20'

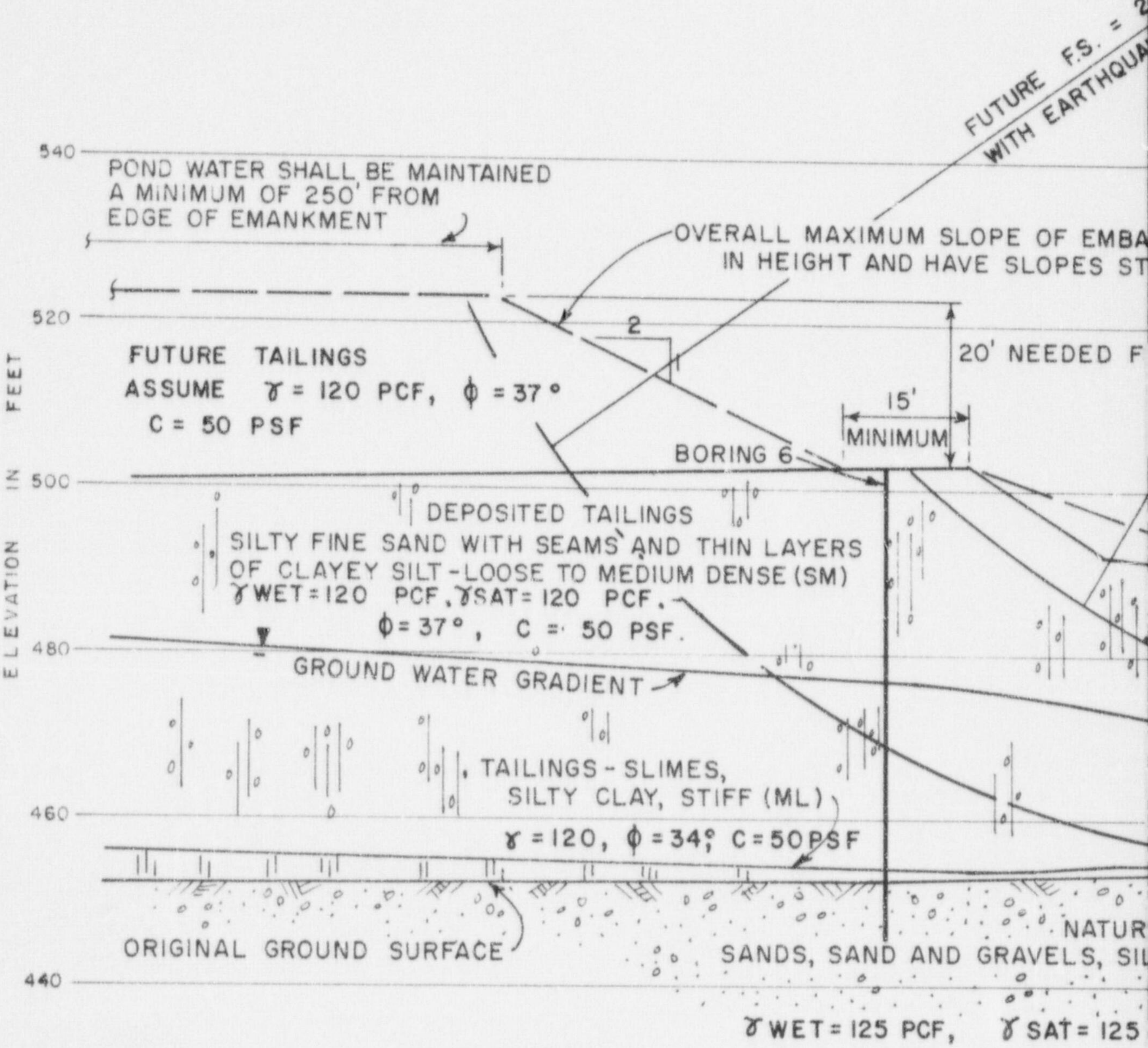


SUBSURFACE SECTION D-D

9705220019-05

DAMES & MOORE

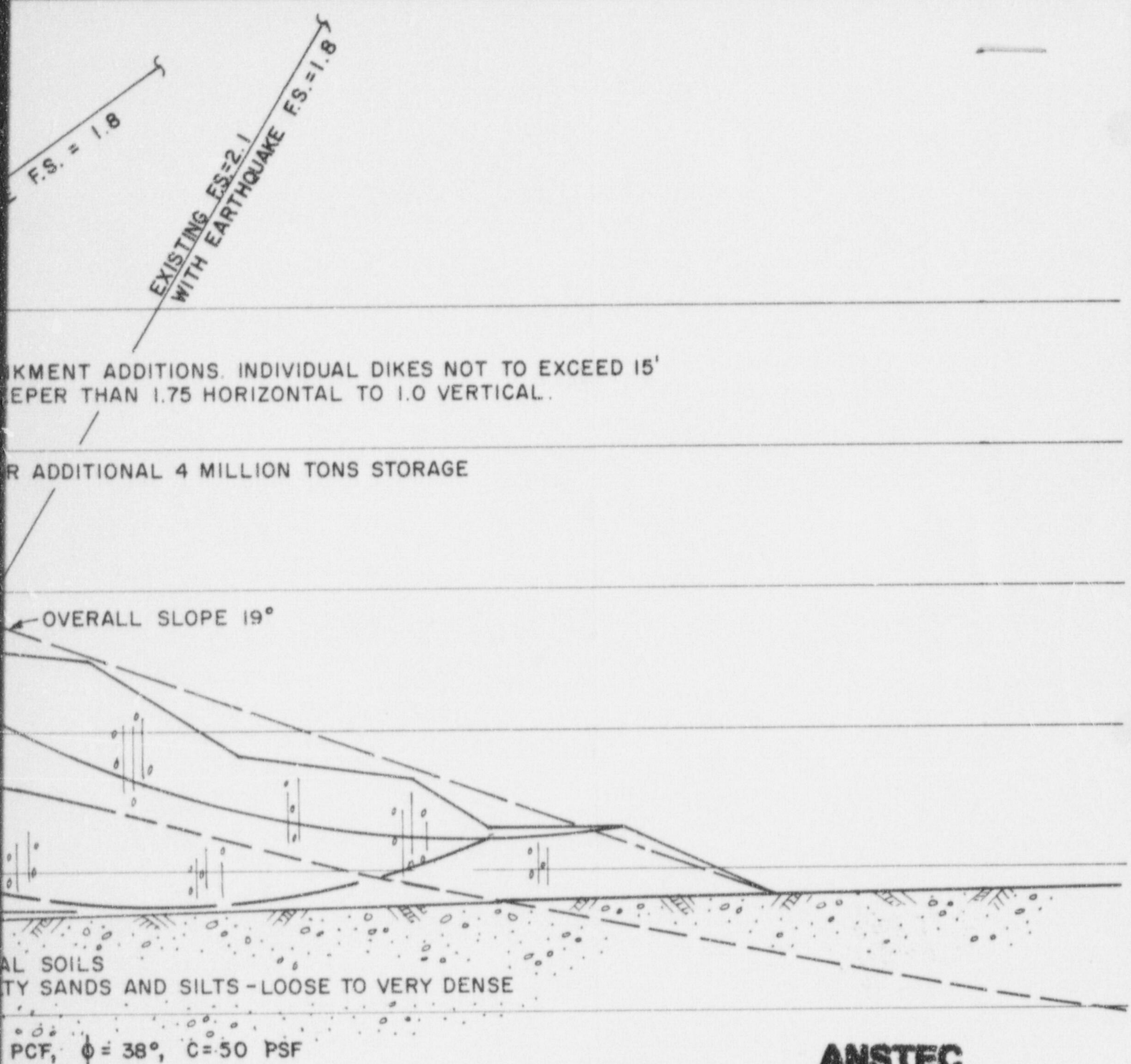
PLATE 6C



SCALE: 1" = 20'

FILE 5467-002
ATLAS MINERALS - MOAB
BY A.B.D. DATE 2-8-73
CHECKED BY DATE

466.12 (4-64)

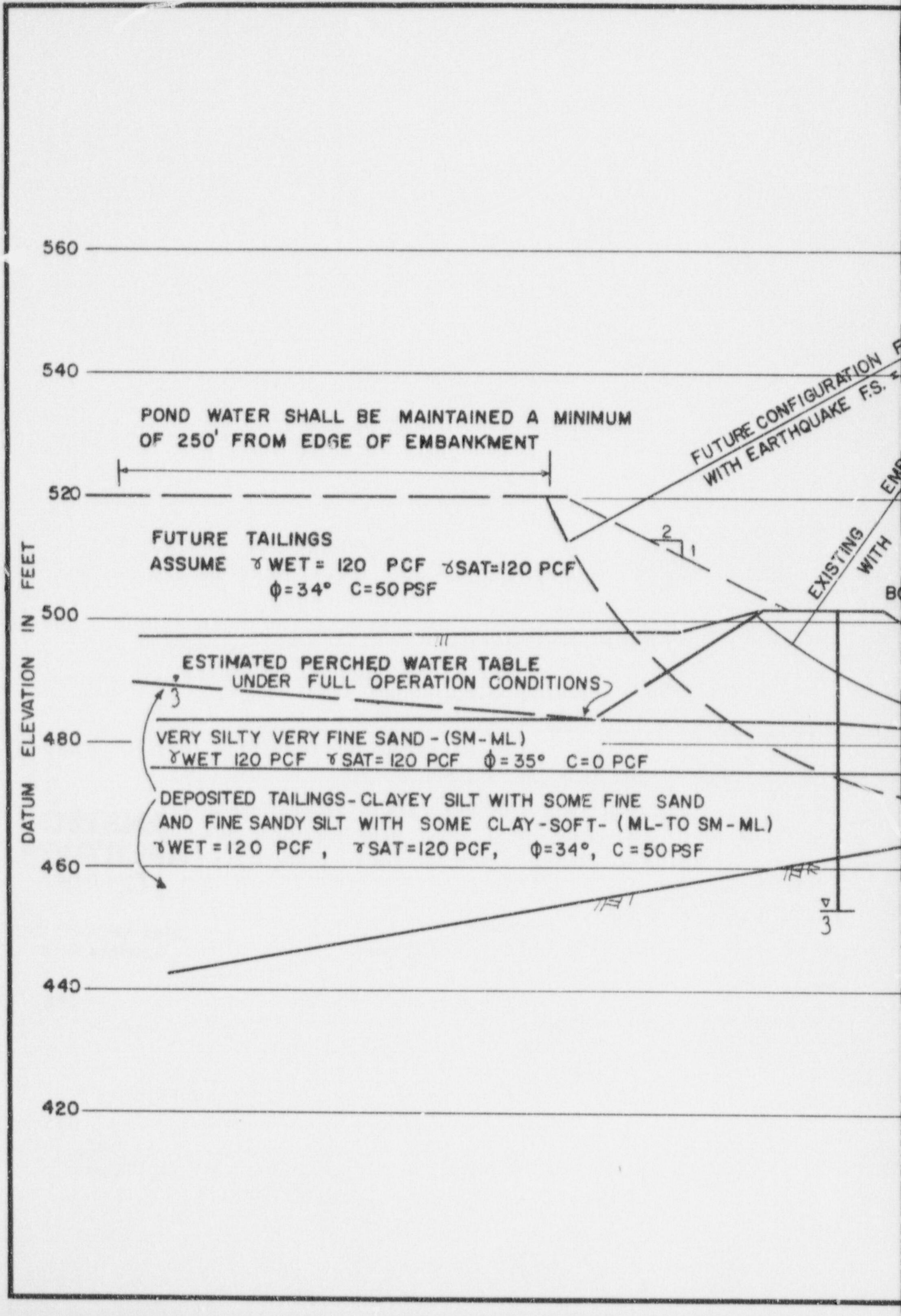


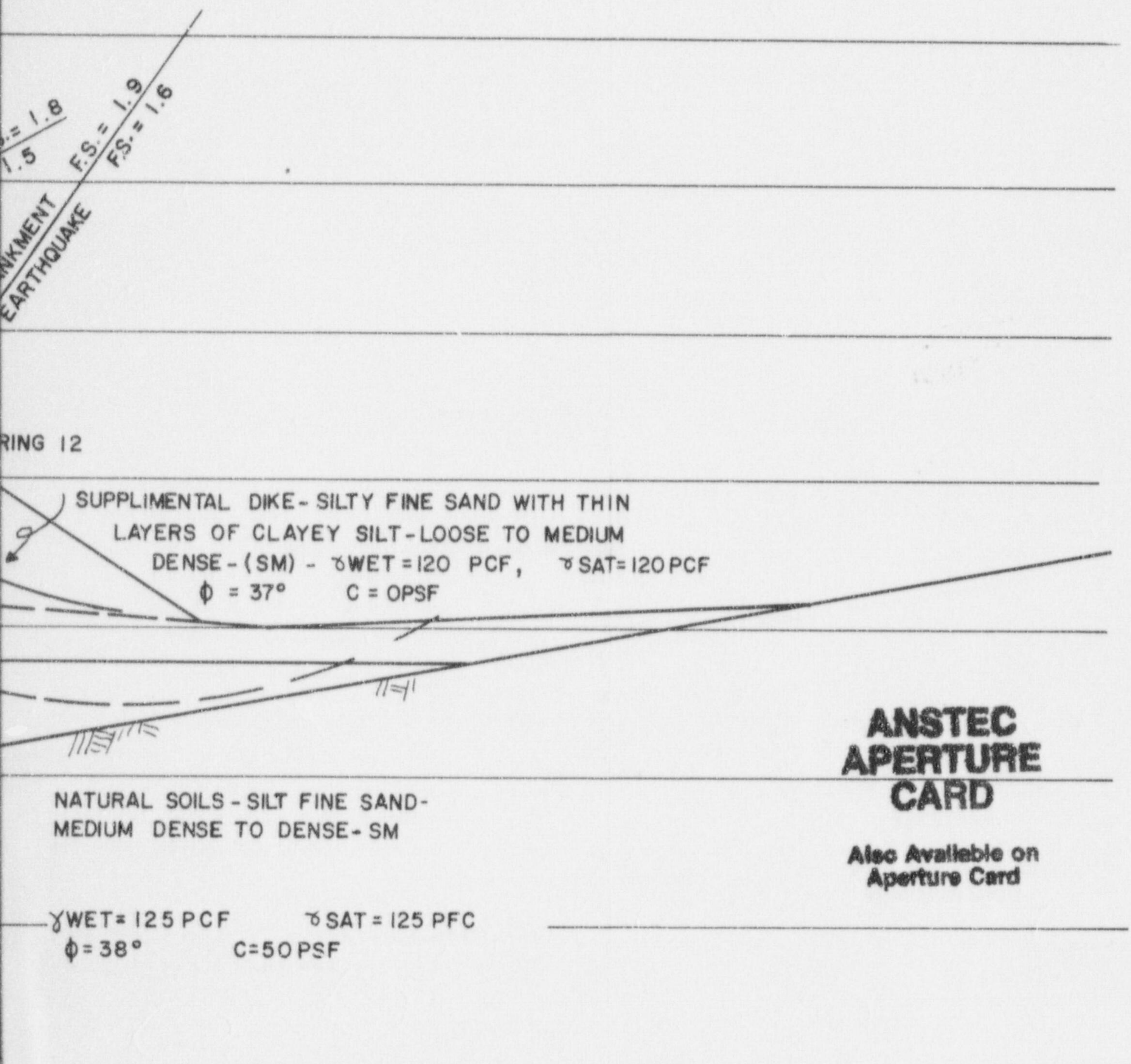
SUBSURFACE SECTION E-E

9705220019-06

DAMES & MOORE

PLATE 6D


560
540
520
500
480
460
440
420
DATUM ELEVATION IN FEET
POND WATER SHALL BE MAINTAINED A MINIMUM
OF 250' FROM EDGE OF EMBANKMENT
FUTURE CONFIGURATION
WITH EARTHQUAKE F.S.
EXISTING
WITH
FUTURE TAILINGS
ASSUME γWET = 120 PCF γSAT=120 PCF
ϕ=34° C=50 PSF
2
1
ESTIMATED PERCHED WATER TABLE
UNDER FULL OPERATION CONDITIONS
3
VERY SILTY VERY FINE SAND - (SM-ML)
γWET 120 PCF γSAT= 120 PCF ϕ = 35° C=0 PCF
DEPOSITED TAILINGS - CLAYEY SILT WITH SOME FINE SAND
AND FINE SANDY SILT WITH SOME CLAY - SOFT - (ML-TO SM-ML)
γWET = 120 PCF, γSAT=120 PCF, ϕ=34°, C = 50 PSF
3



ANSTEC APERTURE CARD

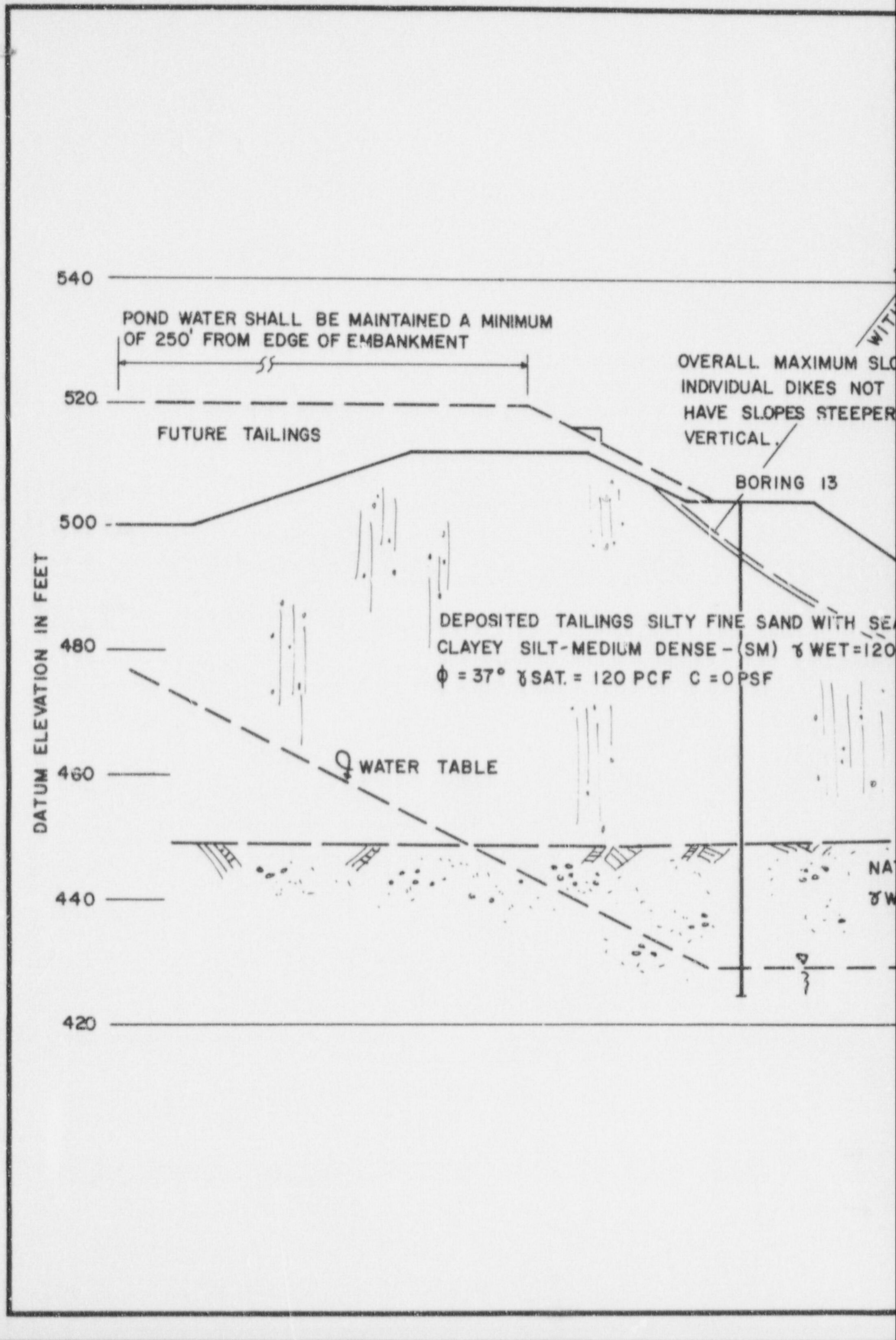
Also Available on Aperture Card

SUBSURFACE SECTION GG

9705220019-07

DAMES & MOORE

PLATE 6E



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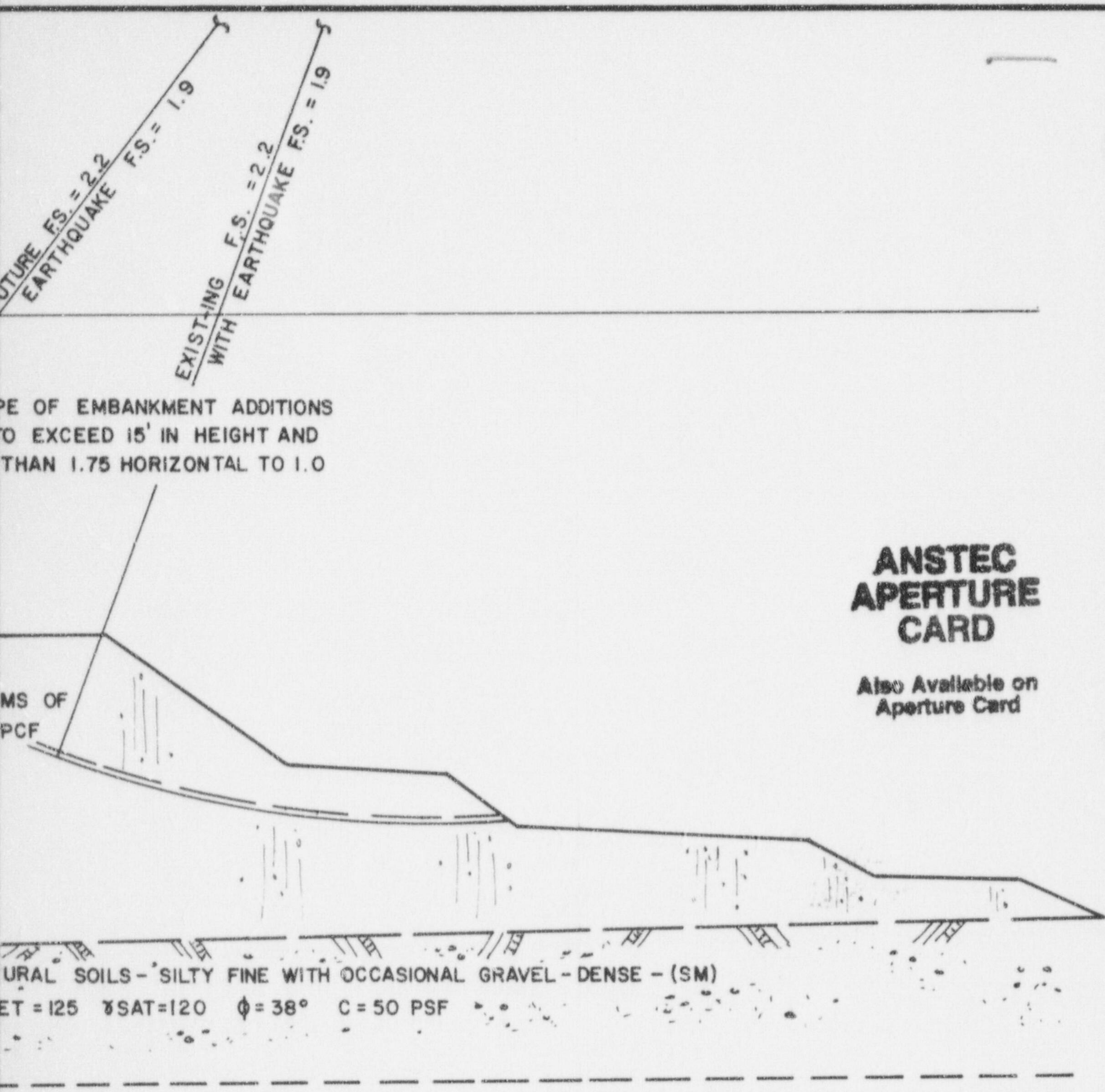
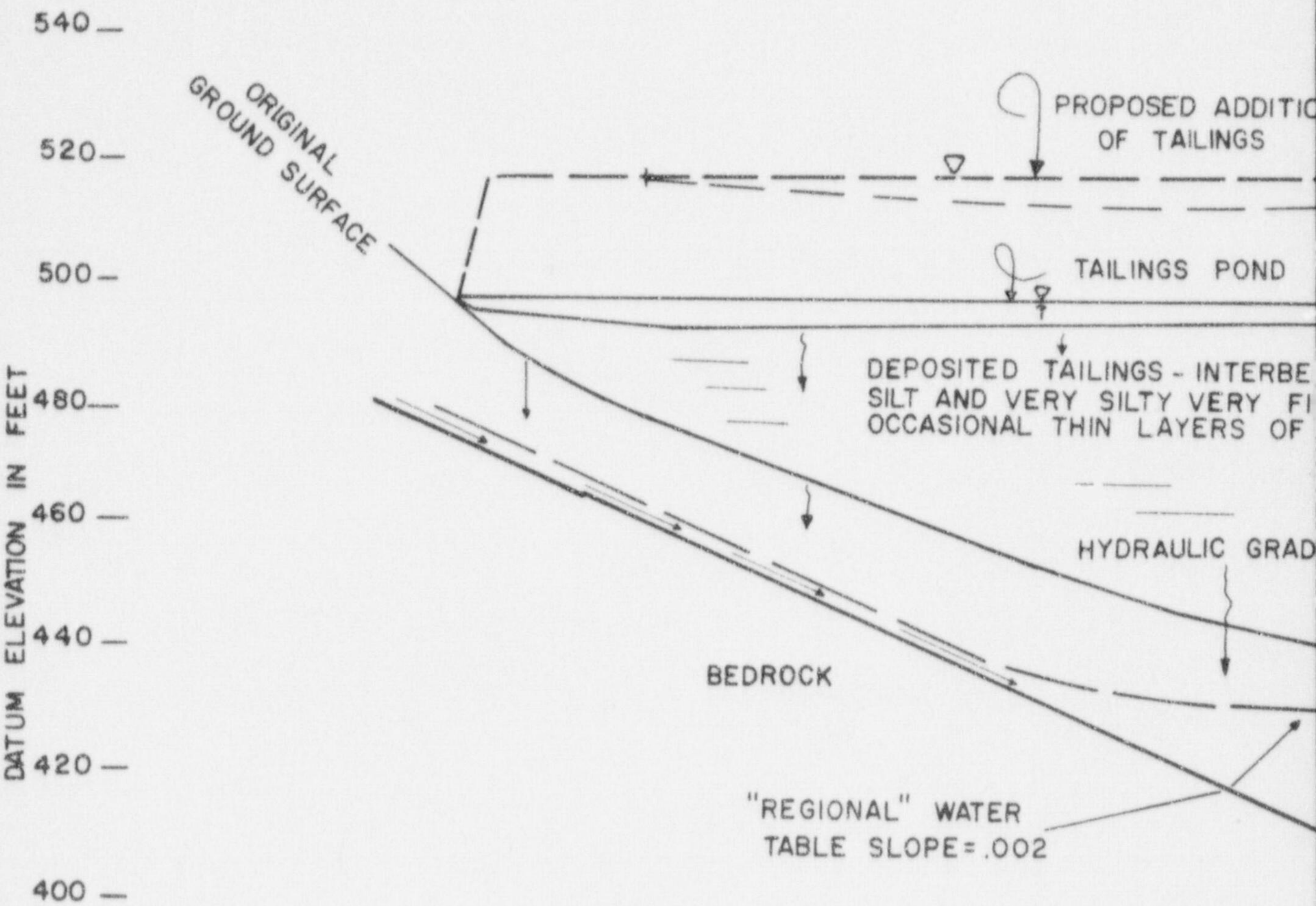


SUBSURFACE SECTION H-H

9705220019-08

DAMES & MOORE

PLATE 6F



NOTE :

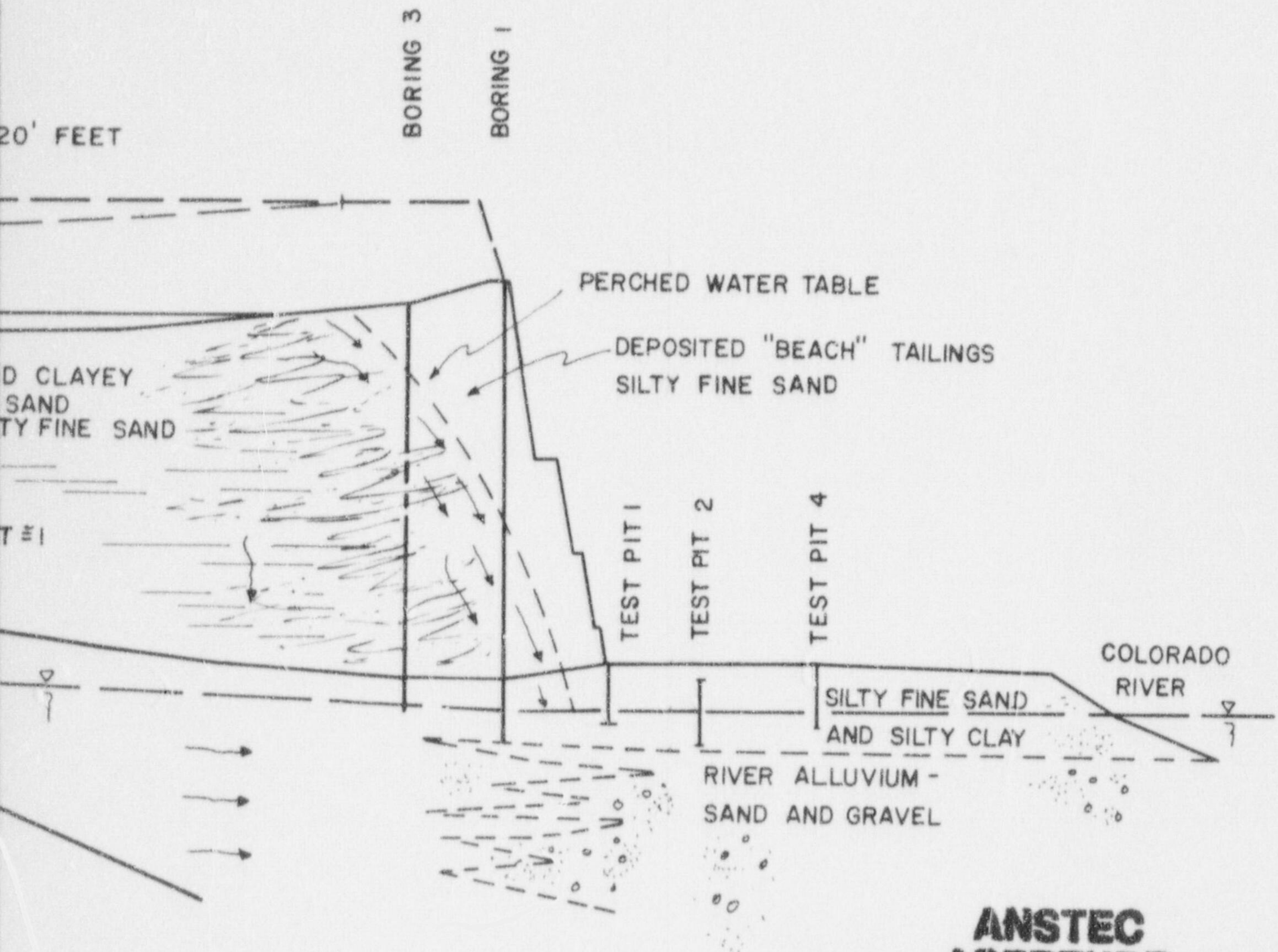
VERTICAL EXAGGERATION IS 10 TIMES HORIZONTAL

SCALE IN FEET

0 300 HORIZONTAL

30 VERTICAL 0

466.12 (4-64)



SUBSURFACE SECTION I-I

MOVEMENT OF SEEPAGE FROM TAILINGS POND

9705220019 - 09

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OVERSIZE DOCUMENT PAGE(S) PULLED

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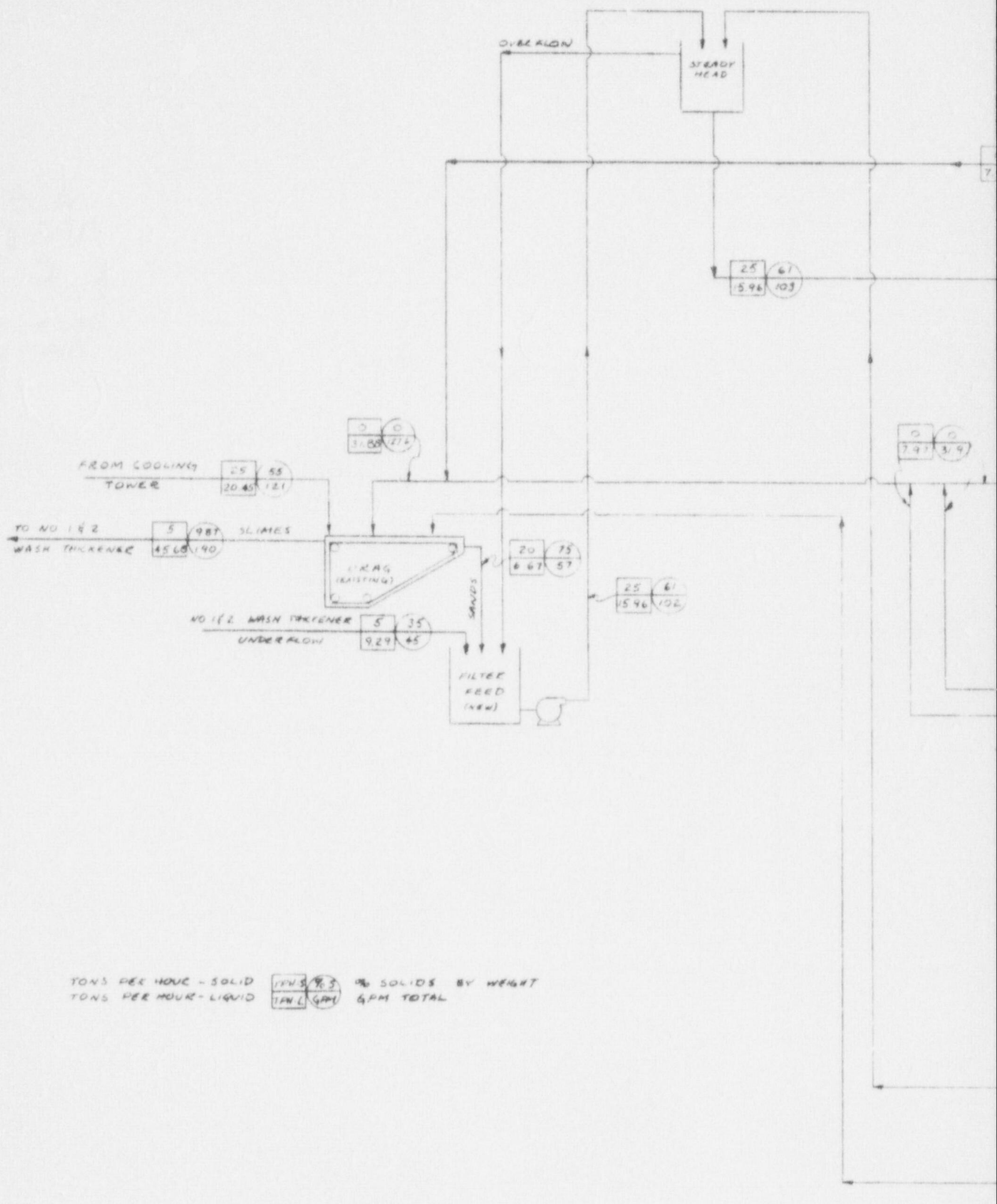
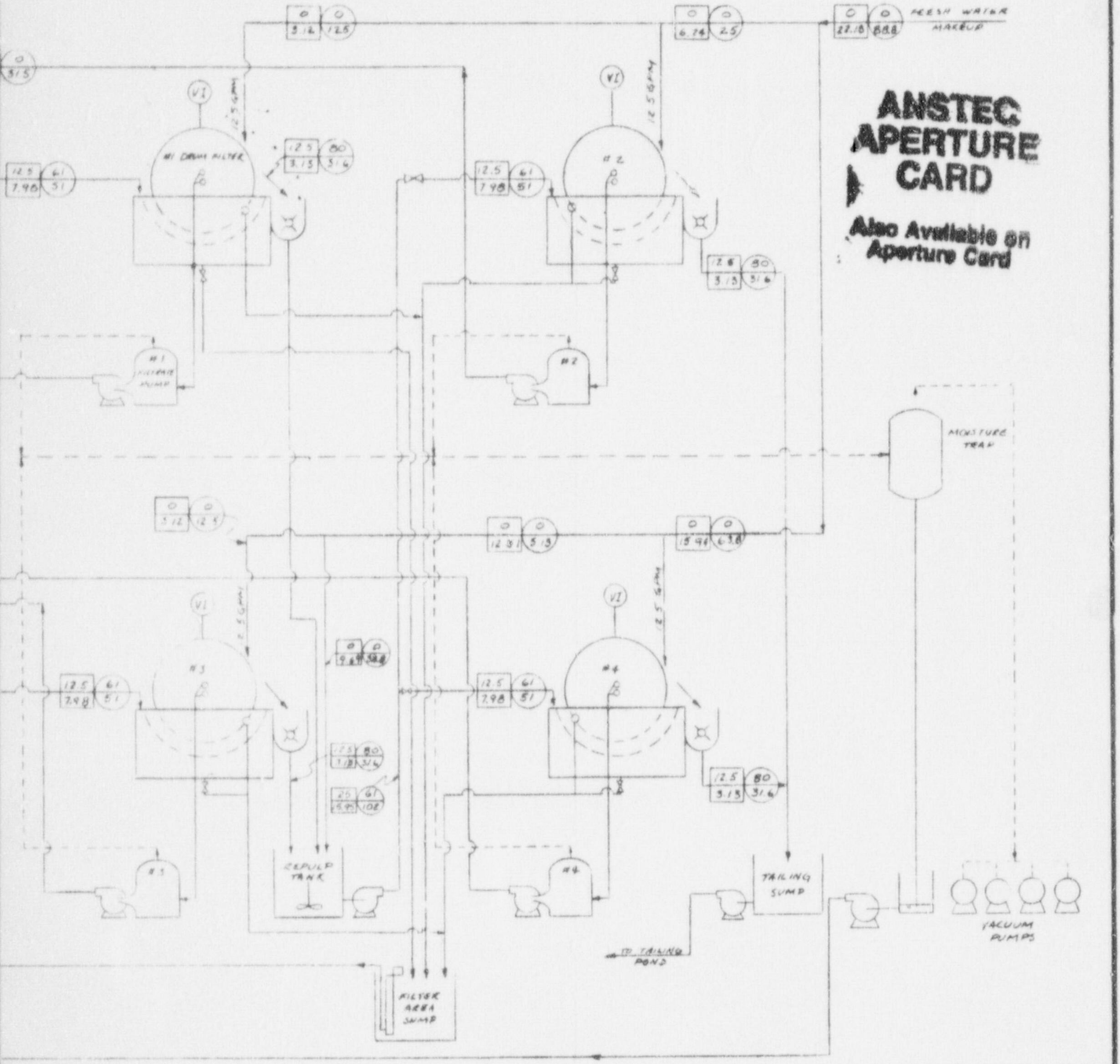


REFERENCE: PRINT ENTITLED, "FILTRATION AND FUSION AREA, PROCESS FLOW DIAGRAM, FILTRATION SYSTEM," BY STEARNS-ROGER, DATED JAN 2, 1974

FILE 5467-003
ATLAS MINERALS

466.12 (4-64)



PROCESS FLOW DIAGRAM

FILTRATION AND FUSION AREA FILTRATION SYSTEM

9705220019 - 12

DAMES & MOORE

PLATE 8C

OVERSIZE
DOCUMENT
PAGE(S) PULLED

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ACCESSION NUMBERS OF OVERSIZE PAGES:

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APPENDIX A

FIELD STUDIES, SOILS TESTING, AND GROUND WATER ANALYSES AND DATA

FIELD STUDIES:

General. The field portion of our investigation included a geologic reconnaissance of the site and Moab Canyon area, the drilling of test borings, the installation of monitor wells, and partial topographic surveying at the site. The field studies, except for the topographic survey, were performed by a qualified geological engineer from our staff.

Data developed in our previous study entitled "Report of Engineering Studies, Tailings Pond Embankment System, Moab, Utah, For Atlas Minerals," dated March 28, 1973, information provided by Atlas Minerals, and published geologic and hydrologic data were utilized for this investigation.

Geologic Reconnaissance. During our field exploration program, a geologic reconnaissance of the site vicinity was performed. The reconnaissance was performed to aid in evaluating the geology of the site, the performance of the existing tailings pond system and the hydrologic conditions of the Moab Canyon area. In addition, the reconnaissance aided in the selection of the number, location, and depth of borings.

Field Explorations. The subsurface soil and ground water conditions at the site were explored by drilling an additional eight borings with a truck-mounted rotary drill rig. Field permeability tests were performed in selected borings as described in the following section. The borings extended to depths ranging from 25 to 100 feet below existing grade. The locations of the borings drilled in conjunction with this and previous investigations with respect to topography and existing facilities are presented on

Plate 2, Plot Plan, in the text of this report. In addition, the location of abandoned wells in the vicinity are shown. All borings, except for boring 11, were outfitted as monitor wells. The monitor wells consist of slotted two-inch- or three-inch-diameter PVC pipe. The lower ten feet of each monitor well placed during this study is slotted. The entire length of pipe is slotted on all monitor wells placed during the previous investigation. The slotted portion of the monitor well was surrounded with a sand and fine gravel pack.

The field exploration program was conducted and supervised by an experienced geological engineer from our staff. Undisturbed samples of the soils penetrated in the borings were obtained by utilizing a Dames & Moore sampler as described on Plate A-3, Soil Sampler Type U. Undisturbed near-surface samples of the tailings material were obtained by hand driving 2.4-inch-diameter thin wall bits into the soil. In addition, bulk samples were obtained of typical tailings materials and the tailings embankment cover material. All soils were classified by visual and textural examination in the field. These classifications were later supplemented by inspection and testing in our laboratory. A complete log was maintained in the field of each boring. Graphical representation of the soils encountered in the borings is presented on Plates A-1A through A-1E. The nomenclature used to describe the soil types appears on Plate A-2, Unified Soil Classification System.

Field Permeability Tests. Open-end casing field permeability tests were performed at selected intervals in several borings. This was accomplished by driving the casing to the desired depth, carefully cleaning

out the soil just to the bottom of the casing and measuring the flow of induced clear water. For each test the dimensions of the casing, the differential head of water in the hole, and the rate of flow into the hole were recorded.

The formula relating the permeability of the soil stratum to the above variables is as follows:

$$K = \frac{Q}{5.5RH}*$$

where K = permeability

Q = constant rate of flow into the hole

R = internal radius of casing

H = differential head of water

The results of the field permeability testing is presented in tabular form below:

Boring No.	Depth In Feet	Soil Type	Head In Feet (H)	Diameter Casing In Feet (R)	Flow In Gallons Per Minute (Q)	Permeability In Feet Per Year (K)
8	13.0	SP-GP	12.7	0.31	.26	850
8	18.0	SP-GP	11.3	0.31	.38	1,400
8	28.0	SP-GP	11.3	0.31	2.2	8,000
15	8.0	SP	9.3	0.42	.078	256
15	13.0	SP	14.6	0.42	.205	430
15	18.0	SP	19.6	0.42	.14	220

Surveying. A surveying program was performed in order to accurately define the location and elevation of borings, cross sections of the embankment slope, and stream profile and cross sections. The survey was performed by Mr. John Keogh, Registered Utah Land Surveyor Number 1963.

SOILS TESTING:

General. Our soils laboratory testing program included moisture and density determinations, gradation tests, triaxial compression tests,

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*U. S. Bureau of Reclamation (1968), p. 543.

direct shear tests, and permeability tests. A description and the results of the tests are presented in the following sections. Data obtained from our previous investigation were utilized in our engineering analyses in addition to the data below. Data and discussions of ion exchange studies of tailings and natural soils at the site are presented in Appendix B.

Moisture and Density Tests. To aid in classifying and correlating the soils, moisture and density determinations were conducted on selected samples. The moisture and density test data obtained are presented to the left of the boring logs on Plates A-1A through A-1E.

Triaxial Compression Tests. In order to provide additional strength data of the tailings and tailings slimes encountered, an additional series of triaxial compression tests was performed on selected, undisturbed samples. Consolidated-drained tests were performed upon sand-sized tailings while consolidated undrained tests were performed upon tailings slimes. All samples were saturated to a minimum of b = 0.95 before shearing and were tested in accordance with the methods described on Plate A-4, Method of Performing Unconfined Compression and Triaxial Compression Tests.

The results of the triaxial compression tests performed for this investigation are presented in tabular form below:

Consolidated-Drained Tests

Boring No.	Depth In Feet	Soil Type	Effective Confining Pressure In PSF	Maximum Shear Stress In PSF
10	16.5	SM	1,500	3,121
10	19.5	SM	3,000	5,790
10	25.5	SM	4,500	7,753

Consolidated-Undrained Tests

Boring No.	Depth In Feet	Soil Type	Initial Effective Confining Stress In PSF	At Maximum Obliquity: Shear Stress In PSF	At Maximum Obliquity: Major Principal Effective Stress In PSF
12	34.5	ML	2,500	1,489	3,937
12	39.5	ML	4,500	1,730	4,693

Direct Shear Tests. To provide additional strength data, a series of direct shear tests was performed on selected, undisturbed samples. The tests were performed in accordance with the method described on Plate A-5, Method of Performing Direct Shear and Friction Tests.

The results of the tests performed for this investigation are tabulated below:

Boring No.	Depth In Feet	Soil Type	Normal Pressure In PSF	Peak Shearing Strength In PSF
10	34.5	SM (Natural)	2,000	2,400
10	34.5	SM (Natural)	3,500	3,850
10	44.0	SM (Natural)	4,500	4,750
11	13.5	SM (Tailings)	1,500	1,750
11	13.5	SM (Tailings)	3,000	2,600
11	35.5	SM (Tailings)	3,500	1,780
11	35.5	SM (Tailings)	5,500	4,600
12	13.5	SM (Tailings)	2,000	2,000
12	13.5	SM (Tailings)	4,000	3,150
12	44.0	SM (Natural)	3,500	4,150
12	49.5	SM (Natural)	2,500	3,280*
12	49.5	SM (Natural)	5,000	4,100
13	29.5	SM (Tailings)	3,000	3,300
13	29.5	SM (Tailings)	5,000	4,500
13	39.5	SM (Tailings)	1,500	1,800

*Piece of gravel in sample.

Laboratory Permeability Tests. To determine the permeability characteristics of the natural soils and tailings materials, a series of laboratory tests was performed upon selected, undisturbed samples. All tests were performed in accordance with the method described on Plate A-6, Method of Performing Percolation Tests.

The results of the tests are tabulated below:

Location	Depth In Feet	Soil Type	Permeability In Feet Per Year
Boring 8	5.5	SM (Natural)	13.
Boring 8	18.5	SP-GP (Natural)	99.
Boring 10	6.5	SM (Tailings)	4.0
Boring 10	12.5	SM (Tailings)	2.0
Boring 10	39.5	SP-SM (Tailings)	1200. *
Boring 11	18.5	SM (Tailings)	20.
Boring 11	69.5	SM (Natural)	310.
Boring 12	8.5	SM (Tailings)	35.
Boring 13	17.5	SM (Tailings)	14.
Boring 13	49.5	SM (Tailings)	490.
Boring 15	8.5	SP (Natural)	370.
Boring 15	13.5	SP (Natural)	110.
Boring 15	18.5	SP (Natural)	230.
Boring 15	39.5	SM (Natural)	180.
Surface Sample 2	0.5	SM-ML (Tailings)	1.3
Surface Sample 4	0.5	ML (Tailings)	0.3
Surface Sample 6	0.5	SM-ML (Tailings)	2.8
Surface Sample 8	0.5	SM-ML (Tailings)	8.0
Surface Sample 12	0.5	ML (Tailings)	0.3
Surface Sample 15	0.5	SM (Tailings)	2000. *

*Loss of soil during test-results invalid.

Gradation Tests. Additional classification data were obtained by performing gradation tests on selected soil and tailings samples. The results

of the gradation analyses performed upon typical tailings embankment cover material are presented on Plate A-7, Gradation Curve. The results of tests on other soil samples are maintained in our files.

Abrasion Tests. An abrasion test was performed on a representative sample of the tailings embankment cover material in order to obtain a semi-quantitative estimate of the durability of the materials. The abrasion test was performed in accordance with A.S.T.M. Specification C-131, Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine. This test was performed by American Testing Laboratories, Inc., of Salt Lake City, Utah. The results of the test show a wear of 57.1 percent.

GROUND WATER ANALYSES AND WATER DATA:

General. In order to determine the distribution and resultant constituent levels of seepage from the tailings pond, a series of biological, chemical, and radiological analyses was performed on ground water samples obtained from selected monitor wells. A description and the results of the analyses performed are presented in subsequent sections. In addition, data concerning water analyses from site monitor wells and the Colorado River performed by Atlas Minerals, and state and federal agencies, are tabulated. Data regarding water wells drilled in the vicinity and a tabulation of measured ground water levels are presented.

Biological Analyses. Selected ground water samples were examined for most probable number of coliform and fecal coliform bacteria concentrations, biochemical oxygen demand and chemical oxygen demand. These analyses were performed by Ford Chemical Laboratories, Inc., of Salt Lake City, Utah. The analyses were performed in accordance with "Standard Methods for

Examination of Water and Wastewater."* Results of the analyses are presented on Plate A-8, Biological Analyses.

Biological analyses performed by the Utah State Division of Health upon water samples from the Colorado River are tabulated on Plate A-14.

Chemical Analyses. Chemical analyses were performed upon water samples obtained from selected monitor wells. These tests were performed by Ford Chemical Laboratory, Inc., of Salt Lake City, Utah. The tests were performed in accordance with "Standard Methods for Examination of Water and Wastewater." The results of these analyses are presented on Plates A-9A and A-9B.

Chemical analyses of water samples obtained from monitor wells at the site performed by Atlas Minerals are presented on Plates A-12D through A-12H. Selected chemical constituents of the Colorado River analyzed by the Utah State Department of Health are tabulated on Plate A-14. A tabulation of the average monthly discharge and dissolved chemical constituents in the Colorado River near Cisco, Utah for water years 1969 through 1972 by the U. S. Geological Survey is presented on Plate A-13.

Radiological Analyses. Radiological analyses were performed upon selected water samples from monitor wells at the site to determine the concentration of radium-226 and thorium-230. These tests were performed by Accu-Labs Research, Inc., Wheatridge, Colorado, in accordance with "Standard Methods for the Examination of Water and Wastewater." The results of these analyses are presented on Plate A-10, Radiological Analyses.

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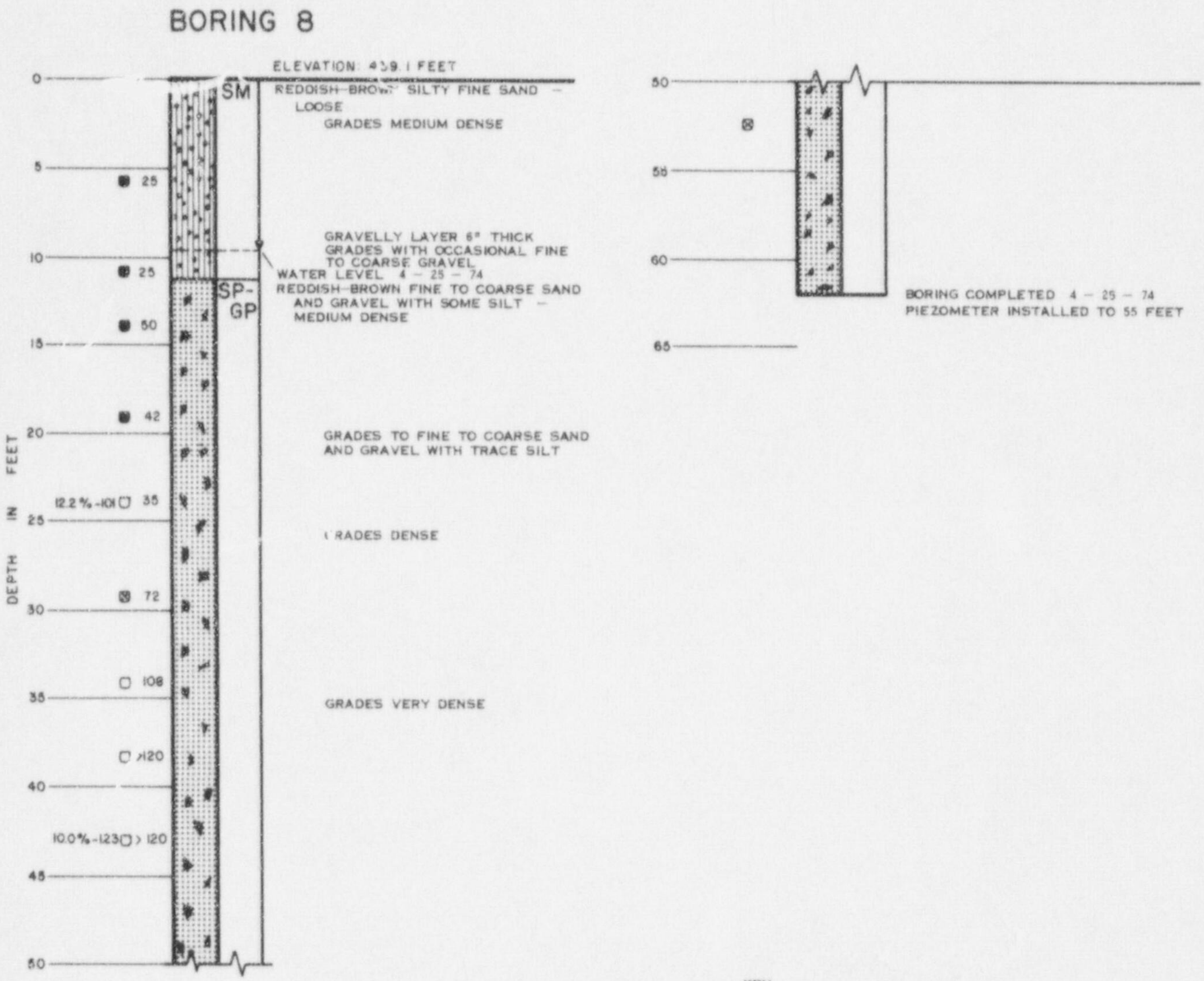
*American Public Health Association, 1971.

A tabulation of the results of the radiological analyses performed by Atlas Minerals upon water samples from monitor wells at the site is presented on Plates A-12B through A-12D. Radiological measurements of Colorado River water performed by Atlas Minerals and various governmental agencies are presented on Plate A-14.

Ground Water Levels. Ground water levels measured in borings, test pits and wells near the site during this study are tabulated on Plate A-11, Ground Water Levels. Information regarding wells drilled in the site vicinity is presented on Plate A-15.

The following plates are attached and complete this appendix:

Plates A-1A through A-1E	-	Log of Borings
Plate A-2	-	Unified Soil Classification System
Plate A-3	-	Soil Sampler Type U
Plate A-4	-	Method of Performing Unconfined Compression and Triaxial Compression Tests
Plate A-5	-	Method of Performing Direct Shear and Friction Tests
Plate A-6	-	Method of Performing Percolation Tests
Plate A-7	-	Gradation Curve
Plate A-8	-	Biological Analyses of Ground Water
Plates A-9A and A-9B	-	Chemical Analyses of Ground Water
Plate A-10	-	Radiological Analyses of Ground Water
Plate A-11	-	Ground Water Levels, April 1974
Plates A-12A through A-12H	-	Water Analyses by Atlas Minerals



KEY

A — B■C

- A FIELD MOISTURE EXPRESSED AS A PERCENTAGE OF THE DRY WEIGHT OF SOIL
- B DRY DENSITY EXPRESSED IN LBS. PER CUBIC FOOT
- C BLOWS PER FOOT OF PENETRATION USING A 140 LB. HAMMER DROPPING 30 INCHES
- ■ DEPTH AT WHICH UNDISTURBED SAMPLE WAS EXTRACTED
- ⊠ DEPTH AT WHICH DISTURBED SAMPLE WAS EXTRACTED
- □ SAMPLING ATTEMPT WITH NO RECOVERY

NOTES

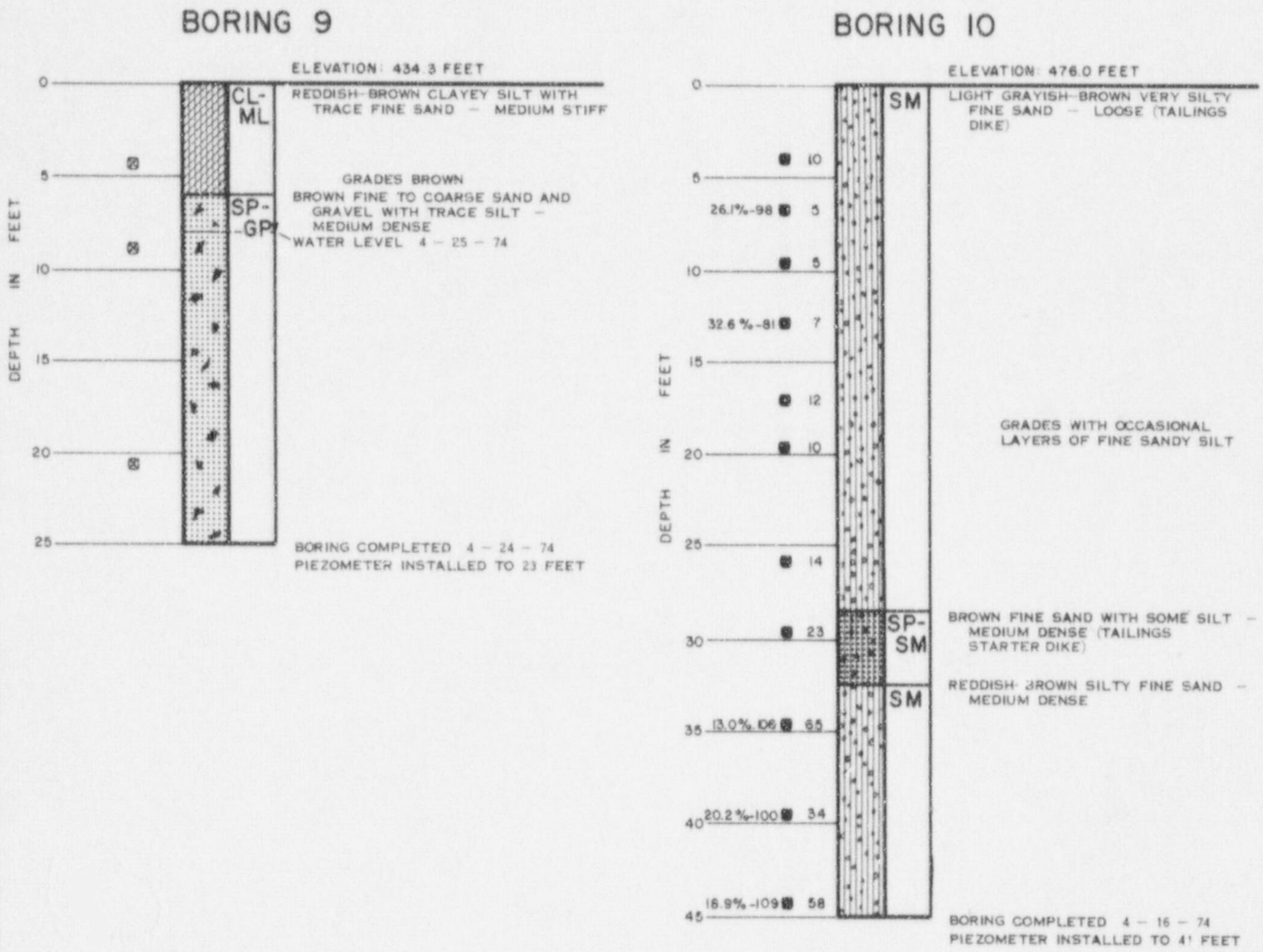
PLANT DATUM ELEVATION OF 500.0 FEET IS EQUAL TO 4028.2 FEET ABOVE SEA LEVEL.

THE LOGS OF BORINGS 1 THROUGH 7 AND TEST PITS 1 THROUGH 6 ARE PRESENTED IN APPENDIX A OF THE ATLAS MINERAL ENVIRONMENTAL REPORT.

LOG OF BORING

DAMES & MOORE

PLATE A-1A



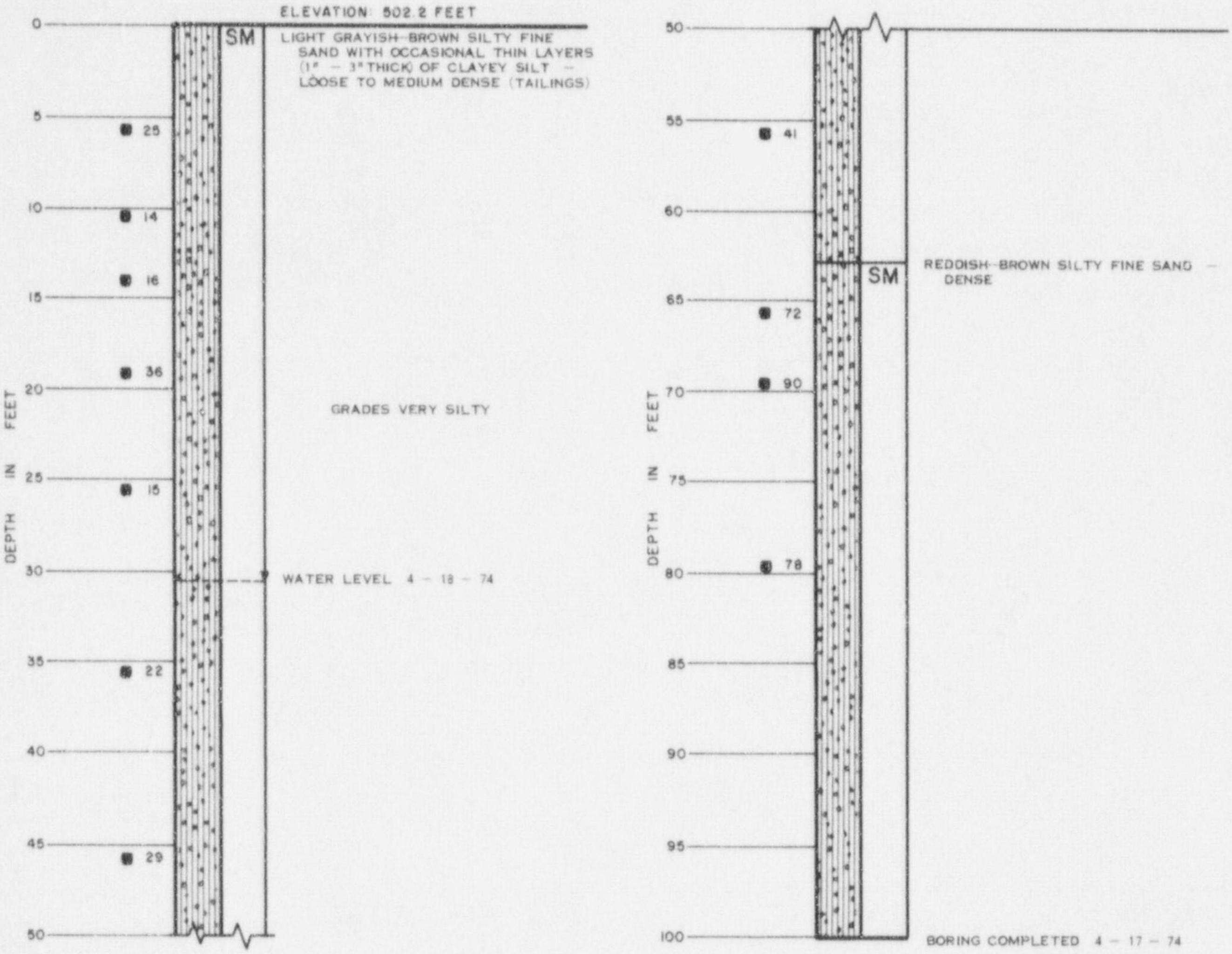
LOG OF BORINGS

DAMES & MOORE

PLATE A-1B

FILE 3867-003
ATLAS MINERALS - MOAB
CHECKED BY GKT DATE 6-5-74

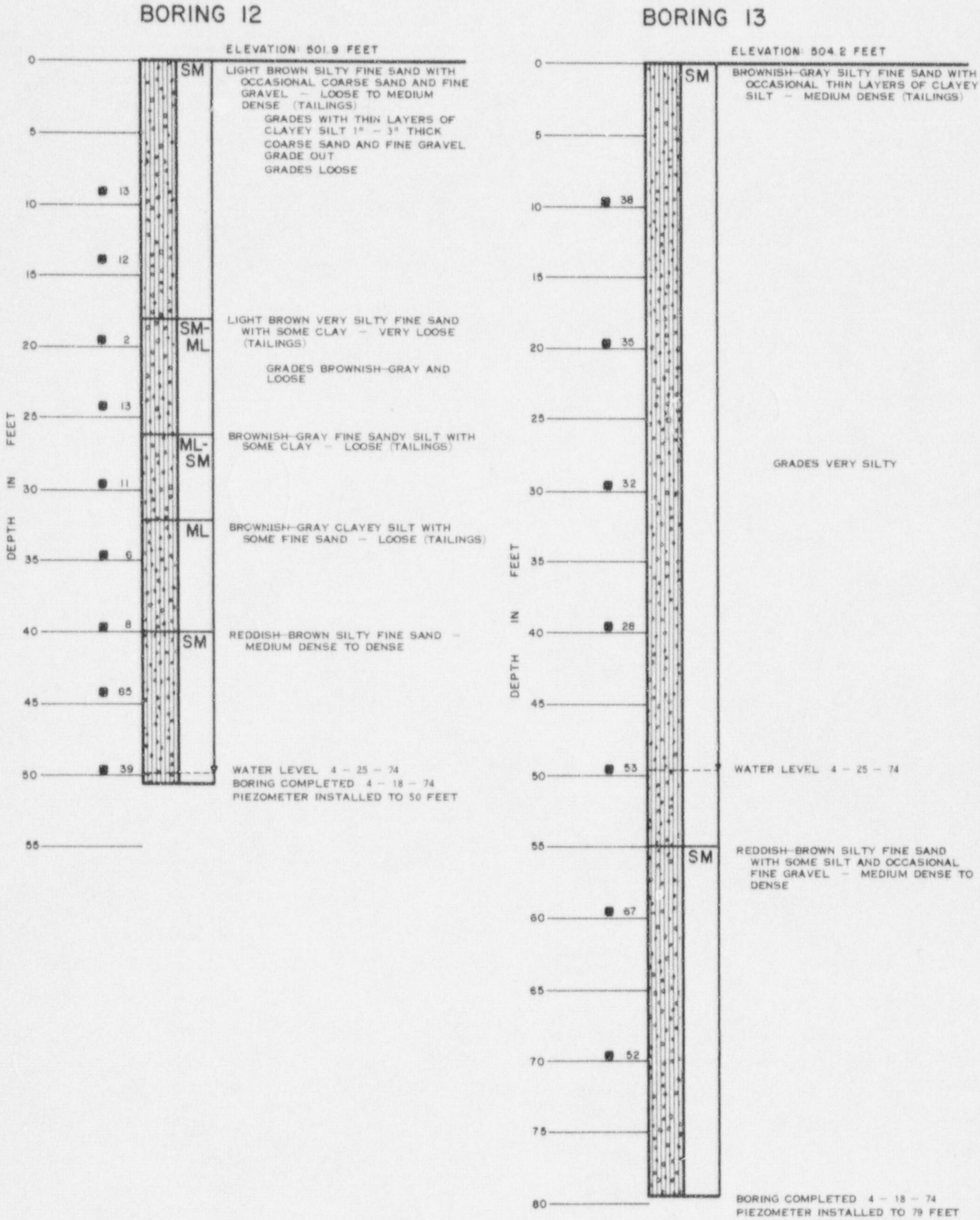
BORING 11



LOG OF BORING

DAMES & MOORE

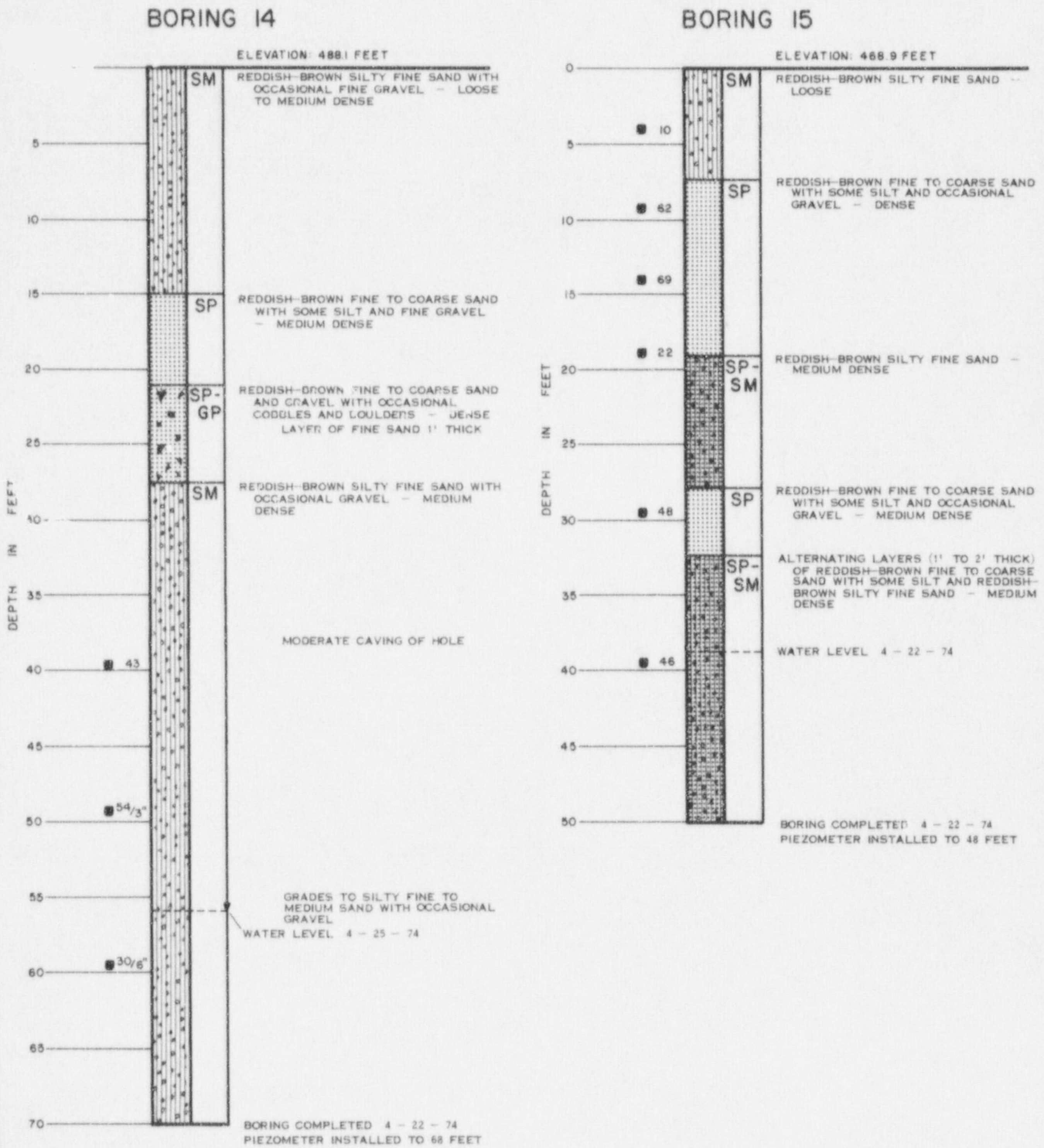
PLATE A-1C



LOG OF BORINGS

DAMES & MOORE

PLATE A-1D



LOG OF BORINGS

DAMES & MOORE

PLATE A-1E

FILE 5487-003
ATLAS MINERALS - MOAB
BY DATE
CHECKED BY GCT DATE 6-5-74
REVISIONS
BY DATE
BY DATE
PLATE OF

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

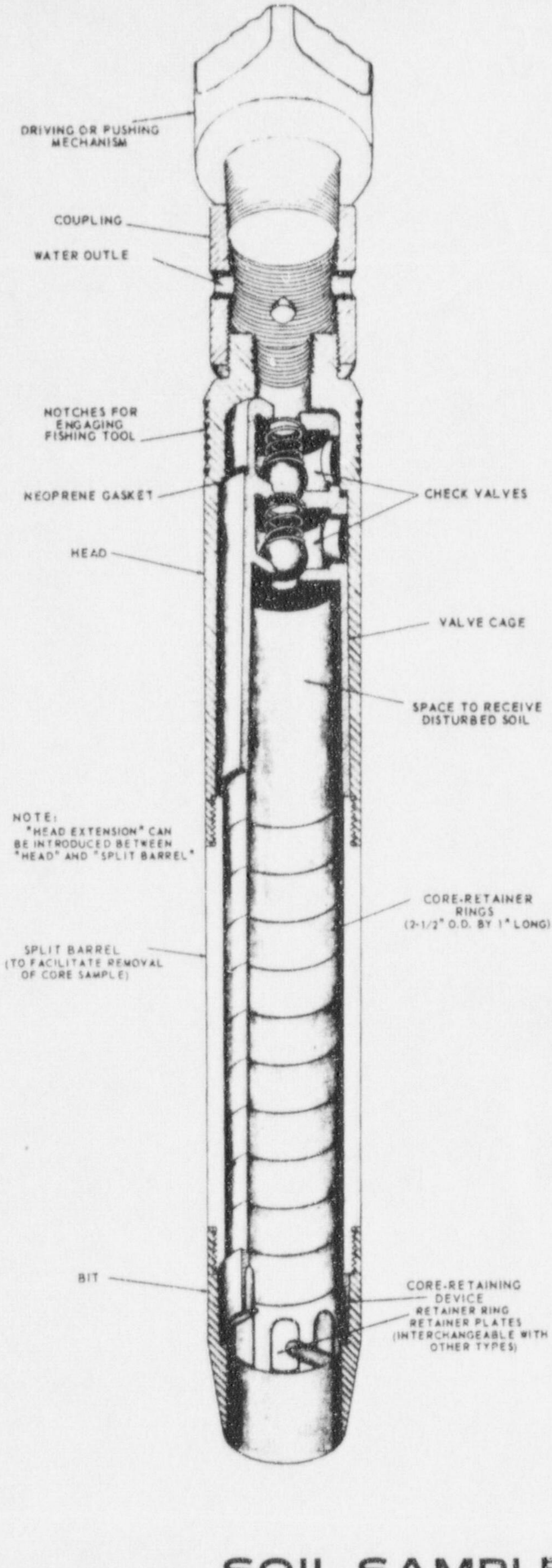
NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

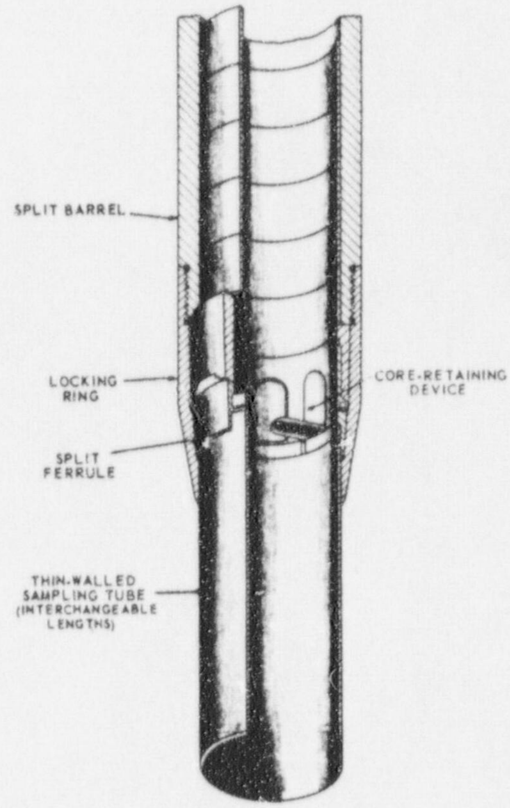
UNIFIED SOIL CLASSIFICATION SYSTEM

REVISED 11-13-73 SLC

DAMES & MOORE



ALTERNATE ATTACHMENTS



SOIL SAMPLER TYPE U

U. S. PATENT NO. 2,318,062

DAMES & MOORE

PLATE A-3

REVISIONS BY ____ DATE ____
FILE ____
BY ____ DATE ____
CHECKED BY ____
REVISED 11-13-73 SLC

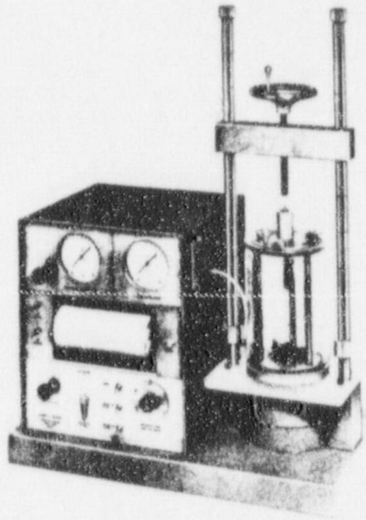
REVISED 11-13-73 SLC

BY H.B.T. DATE 12-2-66 FILE DAMES & MOORE

CHECKED BY ______ REVISIONS BY ______ DATE ______

THE SHEARING STRENGTHS OF SOILS ARE DETERMINED FROM THE RESULTS OF UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS. IN TRIAXIAL COMPRESSION TESTS THE TEST METHOD AND THE MAGNITUDE OF THE CONFINING PRESSURE ARE CHOSEN TO SIMULATE ANTICIPATED FIELD CONDITIONS.

UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS ARE PERFORMED ON UNDISTURBED OR REMOLDED SAMPLES OF SOIL APPROXIMATELY SIX INCHES IN LENGTH AND TWO AND ONE-HALF INCHES IN DIAMETER. THE TESTS ARE RUN EITHER STRAIN-CONTROLLED OR STRESS-CONTROLLED. IN A STRAIN-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO A CONSTANT RATE OF DEFLECTION AND THE RESULTING STRESSES ARE RECORDED. IN A STRESS-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO EQUAL INCREMENTS OF LOAD WITH EACH INCREMENT BEING MAINTAINED UNTIL AN EQUILIBRIUM CONDITION WITH RESPECT TO STRAIN IS ACHIEVED.



TRIAXIAL COMPRESSION TEST UNIT

YIELD, PEAK, OR ULTIMATE STRESSES ARE DETERMINED FROM THE STRESS-STRAIN PLOT FOR EACH SAMPLE AND THE PRINCIPAL STRESSES ARE EVALUATED. THE PRINCIPAL STRESSES ARE PLOTTED ON A MOHR'S CIRCLE DIAGRAM TO DETERMINE THE SHEARING STRENGTH OF THE SOIL TYPE BEING TESTED.

UNCONFINED COMPRESSION TESTS CAN BE PERFORMED ONLY ON SAMPLES WITH SUFFICIENT COHESION SO THAT THE SOIL WILL STAND AS AN UNSUPPORTED CYLINDER. THESE TESTS MAY BE RUN AT NATURAL MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SOILS.

IN A TRIAXIAL COMPRESSION TEST THE SAMPLE IS ENCASED IN A RUBBER MEMBRANE, PLACED IN A TEST CHAMBER, AND SUBJECTED TO A CONFINING PRESSURE THROUGHOUT THE DURATION OF THE TEST. NORMALLY, THIS CONFINING PRESSURE IS MAINTAINED AT A CONSTANT LEVEL, ALTHOUGH FOR SPECIAL TESTS IT MAY BE VARIED IN RELATION TO THE MEASURED STRESSES. TRIAXIAL COMPRESSION TESTS MAY BE RUN ON SOILS AT FIELD MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SAMPLES. THE TESTS ARE PERFORMED IN ONE OF THE FOLLOWING WAYS:

UNCONSOLIDATED-UNDRAINED: THE CONFINING PRESSURE IS IMPOSED ON THE SAMPLE AT THE START OF THE TEST. NO DRAINAGE IS PERMITTED AND THE STRESSES WHICH ARE MEASURED REPRESENT THE SUM OF THE INTERGRANULAR STRESSES AND PORE WATER PRESSURES.

CONSOLIDATED-UNDRAINED: THE SAMPLE IS ALLOWED TO CONSOLIDATE FULLY UNDER THE APPLIED CONFINING PRESSURE PRIOR TO THE START OF THE TEST. THE VOLUME CHANGE IS DETERMINED BY MEASURING THE WATER AND/OR AIR EXPELLED DURING CONSOLIDATION. NO DRAINAGE IS PERMITTED DURING THE TEST AND THE STRESSES WHICH ARE MEASURED ARE THE SAME AS FOR THE UNCONSOLIDATED-UNDRAINED TEST.

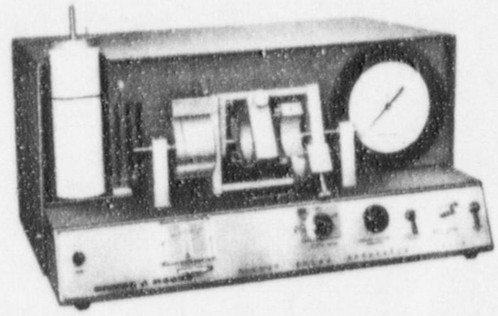
DRAINED: THE INTERGRANULAR STRESSES IN A SAMPLE MAY BE MEASURED BY PERFORMING A DRAINED, OR SLOW, TEST. IN THIS TEST THE SAMPLE IS FULLY SATURATED AND CONSOLIDATED PRIOR TO THE START OF THE TEST. DURING THE TEST, DRAINAGE IS PERMITTED AND THE TEST IS PERFORMED AT A SLOW ENOUGH RATE TO PREVENT THE BUILDUP OF PORE WATER PRESSURES. THE RESULTING STRESSES WHICH ARE MEASURED REPRESENT ONLY THE INTERGRANULAR STRESSES. THESE TESTS ARE USUALLY PERFORMED ON SAMPLES OF GENERALLY NON-COHESIVE SOILS, ALTHOUGH THE TEST PROCEDURE IS APPLICABLE TO COHESIVE SOILS IF A SUFFICIENTLY SLOW TEST RATE IS USED.

AN ALTERNATE MEANS OF OBTAINING THE DATA RESULTING FROM THE DRAINED TEST IS TO PERFORM AN UNDRAINED TEST IN WHICH SPECIAL EQUIPMENT IS USED TO MEASURE THE PORE WATER PRESSURES. THE DIFFERENCES BETWEEN THE TOTAL STRESSES AND THE PORE WATER PRESSURES MEASURED ARE THE INTERGRANULAR STRESSES.

METHODS OF PERFORMING UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS

DAMES & MOORE

Direct shear tests are performed to determine the shearing strengths of soils. Friction tests are performed to determine the frictional resistances between soils and various other materials such as wood, steel, or concrete. The tests are performed in the laboratory to simulate anticipated field conditions.



DIRECT SHEAR TESTING & RECORDING APPARATUS

Each sample is tested within three brass rings, two and one-half inches in diameter and one inch in length. Undisturbed samples of in-place soils are tested in rings taken from the sampling device in which the samples were obtained. Loose samples of soils to be used in constructing earth fills are compacted in rings to predetermined conditions and tested.

Direct Shear Tests

A three-inch length of the sample is tested in direct double shear. A constant pressure, appropriate to the conditions of the problem for which the test is being performed, is applied normal to the ends of the sample through porous stones. A shearing failure of the sample is caused by moving the center ring in a direction perpendicular to the axis of the sample. Transverse movement of the outer rings is prevented.

The shearing failure may be accomplished by applying to the center ring either a constant rate of load, a constant rate of deflection, or increments of load or deflection. In each case, the shearing load and the deflections in both the axial and transverse directions are recorded and plotted. The shearing strength of the soil is determined from the resulting load-deflection curves.

Friction Tests

In order to determine the frictional resistance between soil and the surfaces of various materials, the center ring of soil in the direct shear test is replaced by a disk of the material to be tested. The test is then performed in the same manner as the direct shear test by forcing the disk of material from the soil surfaces.

METHOD OF PERFORMING DIRECT SHEAR AND FRICTION TESTS

DAMES & MOORE

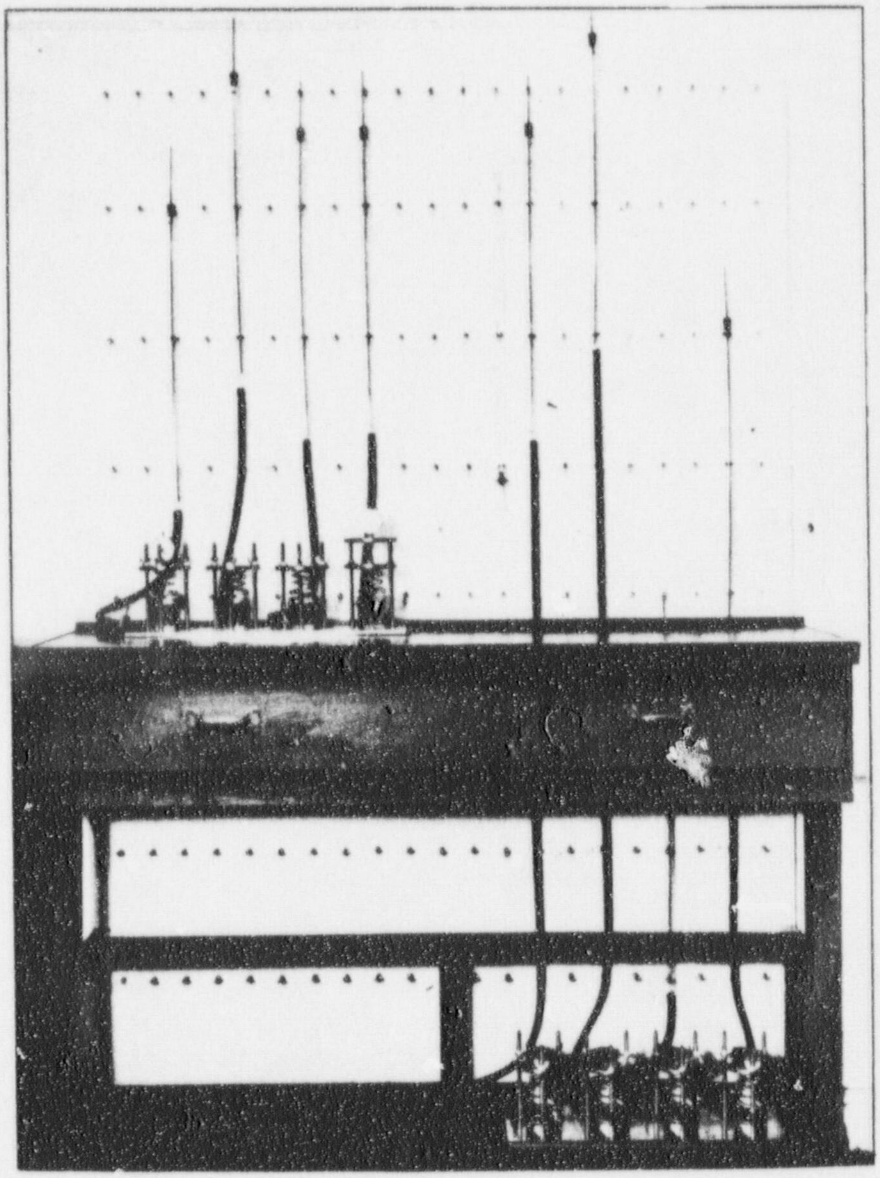
REVISIONS BY ____ DATE ____

FILE ____

BY ____ DATE ____ CHECKED BY ____

REVISED 11-13-73 SLC

The quantity and the velocity of flow of water which will escape through an earth structure or percolate through soil are dependent upon the permeability of the earth structure or soil. The permeability of soil has often been calculated by empirical formulas but is best determined by laboratory tests, especially in the case of compacted soils.



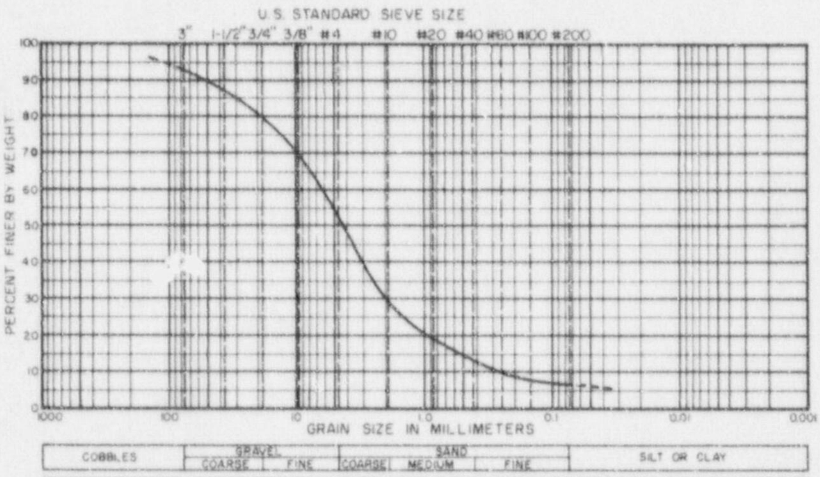
APPARATUS FOR PERFORMING PERCOLATIONS TESTS
Shows tests in progress on eight samples simultaneously.

A one-inch length of the core sample is sealed in the percolation apparatus, placed under a confining load, or surcharge pressure, and subjected to the pressure of a known head of water. The percolation rate is computed from the measurements of the volume of water which flows through the sample in a series of time intervals. These rates are usually expressed as the velocity of flow in feet per year under a hydraulic gradient of one and at a temperature of 20 degrees Centigrade. The rate so expressed may be adjusted for any set of conditions involving the same soil by employing established physical laws. Generally, the percolation rate varies over a wide range at the beginning of the test and gradually approaches equilibrium as the test progresses.

During the performance of the test, continuous readings of the deflection of the sample are taken by means of micrometer dial gauges. The amount of compression or expansion, expressed as a percentage of the original length of the sample, is a valuable indication of the compression of the soil which will occur under the action of load or the expansion of the soil as saturation takes place.

METHOD OF PERFORMING PERCOLATION TESTS

DAMES & MOORE



LOCATION	DEPTH	CLASSIFICATION
EMBANKMENT COVER	SURFACE	REDDISH-BROWN FINE TO COARSE SAND AND GRAVEL (SP-GP)

GRADATION CURVE

DAMES & MOORE

PLATE A-7

Ford Chemical
LABORATORY
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115

Volume ml.	Presumptive 24	Presumptive 48	Confirmed (BGL BB) 24	48	24	48	T	Fecal at 44.5° C. 24	48	24	48	T
10.0	/3	/3					/3					/3
1.0	2/3	1/3	2/2		1/1		3/3	0/2				0/3
10^{-1}	1/3	2/3	1/1		2/2		3/3	0/1				0/3
10^{-2}	1/3	2/3	1/1		1/2	0/1	2/3	0/1				0/3
10^{-3}	0/3	1/3			0/1	0/1	0/3					0/3
10^{-4}	0/3	0/3					0/3					0/3
10^{-5}	/3	/3					/3					/3
10^{-6}	/3	/3					/3					/3

MPN Coliform Results: 9,300 /100 ml. MPN Fecal Results: <30 /100 ml.

Volume ml.		10	10	10	10	10
Presumptive	24 hr.					
	48 hr.					
Confirmed	24 hr.					
	48 hr.					

Form 7A SATISFACTORY ☐ UNSATISFACTORY ☐ Coliform 10 ml. Volume ☐

WATER SAMPLE FOR BACTERIOLOGIC EXAMINATION

Water Sample No. 658
Name Dames & Moore
Address 250 E. Broadway
Date of Collection April 25, 1974 Time 2:35 pm

Chlorinated ☐ Unchlorinated ☐

Residual ________ ppm.

Source B-9 (5467-003)
Sampling Point
Sample Collected By GNE
Submitted By

EXAMINE FOR:
Coliform in 10 ml. volume ☐
M.P.N. Coliforms X☐
Fecal Coliform X☐
Standard plate count ☐ /ml.

Date Received April 25, 1974
Date Reported May 2, 1974

Lyle Ford
Ford Chemical Lab.

Ford Chemical
LABORATORY
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115

Volume ml.	Presumptive 24	Presumptive 48	Confirmed (BGL BB) 24	48	24	48	T	Fecal at 44.5° C. 24	48	24	48	T
13.0	/3	/3					/3					/3
1.0	3/3	/3	3/3				3/3	1/3				1/3
10^{-1}	1/3	2/3	0/1	0/1	1/2	1/1	2/3	0/1				0/3
10^{-2}	0/3	3/3			0/3	2/3	2/3					0/3
10^{-3}	0/3	0/3					0/3					0/3
10^{-4}	0/3	0/3					0/3					0/3
10^{-5}	/3	/3					/3					/3
10^{-6}	/3	/3					/3					/3

MPN Coliform Results: 2,100 /100 ml. MPN Fecal Results: 36 /100 ml.

Volume ml.		10	10	10	10	10
Presumptive	24 hr.					
	48 hr.					
Confirmed	24 hr.					
	48 hr.					

Form 7A SATISFACTORY ☐ UNSATISFACTORY ☐ Coliform 10 ml. Volume ☐

WATER SAMPLE FOR BACTERIOLOGIC EXAMINATION

Water Sample No. 659
Name Dames & Moore
Address 250 E. Broadway
Date of Collect April 25, 1974 Time 5p.m.

Chlorinated ☐ Unchlorinated ☐

Residual ________ ppm.

Source B-8 (5467-003)
Sampling Point
Sample Collected By
Submitted By

EXAMINE FOR:
Coliform in 10 ml. volume ☐
M.P.N. Coliforms X☐
Fecal Coliform X☐
Standard plate count ☐ /ml.

Date Received April 25, 1974
Date Reported May 2, 1974

Lyle Ford
Ford Chemical Lab.

Ford Chemical
LABORATORY
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115

Volume ml.	Presumptive 24	Presumptive 48	Confirmed (BGL BB) 24	48	24	48	T	Fecal at 44.5° C. 24	48	24	48	T +
10.0	/3	/3					/3					/3
1.0	1/3	0/3	1/1				1/3	0/1				0/3
10^{-1}	0/3	0/3					0/3					0/3
10^{-2}	0/3	0/3					0/3					0/3
10^{-3}	0/3	0/3					0/3					0/3
10^{-4}	0/3	0/3					0/3					0/3
10^{-5}	/3	/3					/3					/3
10^{-6}	/3	/3					/3					/3

MPN Coliform Results: 36 /100 ml. MPN Fecal Results: <30 /100 ml.

Volume ml.		10	10	10	10	10
Presumptive	24 hr.					
	48 hr.					
Confirmed	24 hr.					
	48 hr.					

Form 7A SATISFACTORY ☐ UNSATISFACTORY ☐ Coliform 10 ml. Volume ☐

WATER SAMPLE FOR BACTERIOLOGIC EXAMINATION

Water Sample No. 660
Name Dames & Moore
Address 250 E. Broadway
Date of Collection April 25, 1974 Time 2:45 pm

Chlorinated ☐ Unchlorinated ☐

Residual ________ ppm.

Source TP7 5467-003
Sampling Point
Sample Collected By
Submitted By

EXAMINE FOR:
Coliform in 10 ml. volume ☐
M.P.N. Coliforms X☐
Fecal Coliform X☐
Standard plate count ☐ /ml.

Date Received April 25, 1974
Date Reported May 2, 1974

Lyle Ford
Ford Chemical Lab.

REVISIONS BY ____ DATE ____ BY ____ DATE ____ PLATE ____ OF ____

FILE ____ BY ____ DATE ____ CHECKED BY G.L.T. DATE 6-5-74

46411 (3-68)

Ford Chemical
LABORATORY, INC.
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

May 0, 1974

CERTIFICATE OF ANALYSIS
74-1516

Dames & Moore, Eng.
250 East Broadway
Salt Lake City, Utah

Gentlemen:

The following analysis is on samples of water received on April 29, 1974 under P.O. No. SL 1131:

Sample: Water from Job No. 5467-003 (Atlas Minerals) Ground Water

	Bio-Chemical Oxygen Demand mg/l	Chemical Oxygen Demand mg/l
Sample TP7-1	21.0	54.0
Sample TP8-1	19.0	40.0
Sample B9-2	8.5	10.0

Sincerely,

FORD CHEMICAL LABORATORY, INC.

Lyle S. Ford

LSF:lh

TIME/DATE OF COLLECTION:

Sample TP 7-1	1250 HRS/4-24-74
Sample TP 8-1	1705 HRS/4-25-74
Sample B 9-2	1430 HRS/4-25-74

Note: A sample designation of "TP 4-1" means Test Pit 4, Sample 1

A sample designation of "B 2-1" means Boring 2, Sample 1

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BIOLOGICAL ANALYSES
OF GROUNDWATER

9705220019-14

DAMES & MOORE

FILE ___ BY ___ DATE ___ CHECKED BY ___ DATE ___

REVISIONS BY ___ DATE ___ BY ___ DATE ___ PLATE ___ OF ___

Ford Chemical LABORATORY, INC.
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

May 10, 1974

CERTIFICATE OF ANALYSIS
74-1524

Dames & Moore Eng.
250 East Broadway
Salt Lake City, Utah

Gentlemen:

The following analysis is on samples of water received on April 29, 1974 under P.O. No. SL 1181:

Sample: Water from Job No. 5467-003

	Vanadium as V
Tp 8-2	0.13 mg/1
B8-1	0.16 mg/1
B9-1	0.14 mg/1
B15-1	0.04 mg/1
B14-1	0.03 mg/1
Well A	0.47 mg/1
Well B	0.01 mg/1

Sincerely,

FORD CHEMICAL LABORATORY, INC.

Lyle S. Ford

LSF:1h

Ford Chemical LABORATORY, INC.
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

May 10, 1974

CERTIFICATE OF ANALYSIS
74-1522

Dames & Moore, Eng.
250 East Broadway
Salt Lake City, Utah

Gentlemen:

The following analysis is on sample of water received on April 29, 1974 under P.O. No. SL 1181.

Sample: Water from Job No. 5467-003 (Atlas Minerals)

	Sample TP5-1	Sample TP-4-1	Sample TP1-1	Sample B-1-1	Sample B-2-1
pH	7.65	7.52	7.60	8.10	7.80
Total Dissolved Solids mg/1	12,500	11,750	10,000	585.0	9,500
Chloride as Cl mg/1	2,020	1,540	1,170	180.0	970
Sulfate as SO_4 mg/1	4,700	4,350	4,200	98.0	4,000
Vanadium as V mg/1	1.877	0.752	0.231	0.020	0.034
Arsenic as As mg/1	0.10	0.03	0.04	0.00	0.08

Sincerely,

FORD CHEMICAL LABORATORY, INC.

Lyle S. Ford

LSF:1h

TIME/DATE OF COLLECTION:

Sample TP 5-1	0730 HRS/4-12-74
Sample TP 4-1	1140 HRS/4-12-74
Sample TP 1-1	1125 HRS/4-12-74
Sample B 1-1	0920 HRS/4-12-74
Sample B 2-1	1050 HRS/4-12-74

Ford Chemical LABORATORY, INC.
Bacteriological

Name Dames & Moore Eng.

Address 250 East Broadway

Salt Lake City, Utah

Sample Water from Job #5467

P.O. No. SL 1181, Bo

Turbidity	0.40
Conductivity	6,181.
pH	7.60
Total Dissolved Solids at 180° C.	4,265.
Alkalinity as $CaCO_3$	330.0
Aluminum as Al	0.00
Arsenic as As	0.00
Bicarbonate as HCO_3	399.9
Barium as Ba	0.01
Boron as B	0.00
Cadmium as Cd	0.000
Calcium as Ca	160.0
Carbonate as CO_3	0.00
Chloride as Cl	1,200.
Chromium as Cr (Hex)	0.00
Cyanide as Cn	0.00
Copper as Cu	0.01

TIME/DATE OF COLLECTION

Ford Chemical LABORATORY, INC.
Bacteriological

Name Dames & Moore Eng

Address 250 East Broadway

Salt Lake City, Utah

Sample Water from Job No. 546

under P.O. No. SL 118

Turbidity	0.46
Conductivity	2681.0
pH	7.57
Total Dissolved Solids at 180° C.	1,850.
Alkalinity as $CaCO_3$	270.0
Aluminum as Al	0.00
Arsenic as As	0.00
Bicarbonate as HCO_3	327.2
Barium as Ba	0.00
Boron as B	0.00
Cadmium as Cd	0.000
Calcium as Ca	192.0
Carbonate as CO_3	0.00
Chloride as Cl	430.0
Chromium as Cr (Hex)	0.00
Cyanide as Cn	0.00
Copper as Cu	0.01

TIME/DATE OF COLLECTION:

Ford Chemical Laboratory, Inc.

Bacteriological and Chemical Analysis
40 West Louise Avenue
Salt Lake City, Utah 84115
Phone 485-5751

Date: May 10, 1974

CERTIFICATE OF ANALYSIS

74-1524

Name: Dames & Moore Eng.
Address: 250 East Broadway
Salt Lake City, Utah

Sample: Water from Job No. 5467-003, received on April 29, 1974 under P.O. No. SL 1181, TP-8, Sample #2, Filtered

Turbidity	0.44 JTU	Fluoride as F	0.90 mg/1
Conductivity	4,685.0 umhos/cm	Total Hardness as $CaCO_3$	760.0 mg/1
pH	7.63	Iron (Total) as Fe	0.13 mg/1
Total Dissolved Solids at 180° C.	3,233.0 mg/1	Iron (Filtered) as Fe	0.07 mg/1
Alkalinity as $CaCO_3$	240.0 mg/1	Lead as Pb	0.00 mg/1
Aluminum as Al	0.00 mg/1	Magnesium as Mg	75.6 mg/1
Arsenic as As	0.00 mg/1	Manganese as Mn	0.70 mg/1
Bicarbonate as HCO_3	290.8 mg/1	Mercury as Hg	0.000 mg/1
Barium as Ba	0.05 mg/1	Nitrate as NO_3—N	3.50 mg/1
Boron as B	0.00 mg/1	Phosphate as PO_4	0.44 mg/1
Cadmium as Cd	0.023 mg/1	Potassium as K	19.20 mg/1
Calcium as Ca	178.0 mg/1	Selenium as Se	0.00 mg/1
Carbonate as CO_3	0.00 mg/1	Silica as SiO_2	0.41 mg/1
Chloride as Cl	920.0 mg/1	Silver as Ag	0.000 mg/1
Chromium as Cr (Hex)	0.00 mg/1	Sulfate as SO_4	950.0 mg/1
Cyanide as Cn	0.00 mg/1	Sodium as Na	801.0 mg/1
Copper as Cu	0.10 mg/1	Zinc as Zn	1.03 mg/1

Ford Chemical Laboratory, Inc.

TIME/DATE OF COLLECTION 1345 HRS/4-25-74

...d Chemical

...RATORY, INC.
...ical and Chemical Analysis
...EST LOUISE AVENUE
...AKE CITY, UTAH 84115
...PHONE 485-5761

Date: May 10, 1974

CERTIFICATE OF ANALYSIS

74-1525

...03, received on April 29, 1974 under ...no. 8, Sample #1, Filtered

JTU	Fluoride as F	0.88	mg/1
umhos/cm	Total Hardness as $CaCO_3$	960.0	mg/1
	Iron (Total) as Fe	0.14	mg/1
	Iron (Filtered) as Fe	0.10	mg/1
mg/1	Lead as Pb	0.00	mg/1
mg/1	Magnesium as Mg	134.0	mg/1
mg/1	Manganese as Mn	0.35	mg/1
mg/1	Mercury as Hg	0.000	mg/1
mg/1	Nitrate as NO_3—N	2.85	mg/1
mg/1	Phosphate as PO_4	0.31	mg/1
mg/1	Potassium as K	54.50	mg/1
mg/1	Selenium as Se	0.00	mg/1
mg/1	Silica as SiO_2	0.61	mg/1
mg/1	Silver as Ag	0.000	mg/1
mg/1	Sulfate as SO_4	1,260.0	mg/1
mg/1	Sodium as Na	1,058.0	mg/1
mg/1	Zinc as Zn	0.03	mg/1
mg/1			

Ford Chemical Laboratory, Inc.

1705 HRS/4-25-74

...d Chemical

...ORATORY, INC.
...ogical and Chemical Analysis
... WEST LOUISE AVENUE
...T LAKE CITY, UTAH 84115
PHONE 485-5761

Date: May 10, 1974

CERTIFICATE OF ANALYSIS

74-1531

...7-003, TP-7 received on April 29, 1974 ..., Filtered

JTU	Fluoride as F	0.80	mg/1
umhos/cm	Total Hardness as $CaCO_3$	830.0	mg/1
	Iron (Total) as Fe	0.11	mg/1
	Iron (Filtered) as Fe	0.09	mg/1
mg/1	Lead as Pb	0.00	mg/1
mg/1	Magnesium as Mg	84.0	mg/1
mg/1	Manganese as Mn	0.01	mg/1
mg/1	Mercury as Hg	0.000	mg/1
mg/1	Nitrate as NO_3—N	2.20	mg/1
mg/1	Phosphate as PO_4	0.19	mg/1
mg/1	Potassium as K	28.10	mg/1
mg/1	Selenium as Se	0.00	mg/1
mg/1	Silica as SiO_2	0.48	mg/1
mg/1	Silver as Ag	0.000	mg/1
mg/1	Sulfate as SO_4	530.0	mg/1
mg/1	Sodium as Na	259.0	mg/1
mg/1	Zinc as Zn	0.05	mg/1
mg/1			

Ford Chemical Laboratory, Inc.

1250 HRS/4-24-74

CHEMICAL ANALYSES OF GROUNDWATER

9705220019-15

DAMES & MOORE

PLATE A-9A

REVISIONS
BY _____ DATE _____
BY _____ DATE _____
PLATE _____ OF _____

FILE _____
BY _____ DATE _____
CHECKED BY GLT DATE 6/5/74

Ford Chemical LABORATORY, INC.
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: May 10, 1974

Name: Dames & Moore Eng.
Address: 250 East Broadway
Salt Lake City, Utah

CERTIFICATE OF ANALYSIS
74-1526

Sample: Water from Job #5467-003 received on April 29, 1974 under P.O. No. SL 1181, Boring 9, Sample #1, Filtered

Turbidity	0.32	JTU	Fluoride as F	0.95	mg/1
Conductivity	5,371.0	umhos/cm	Total Hardness as $CaCO_3$	835.0	mg/1
pH	7.75		Iron (Total) as Fe	0.09	mg/1
Total Dissolved Solids at 180° C.	3,706.0	mg/1	Iron (Filtered) as Fe	0.07	mg/1
Alkalinity as $CaCO_3$	275.0	mg/1	Lead as Pb	0.00	mg/1
Aluminum as Al	0.00	mg/1	Magnesium as Mg	94.0	mg/1
Arsenic as As	0.00	mg/1	Manganese as Mn	0.05	mg/1
Bicarbonate as HCO_3	359.0	mg/1	Mercury as Hg	0.000	mg/1
Barium as Ba	0.00	mg/1	Nitrate as NO_3–N	5.50	mg/1
Boron as B	0.00	mg/1	Phosphate as PO_4	0.48	mg/1
Cadmium as Cd	0.000	mg/1	Potassium as K	31.20	mg/1
Calcium as Ca	176.0	mg/1	Selenium as Se	0.00	mg/1
Carbonate as CO_3	0.00	mg/1	Silica as SiO_2	0.50	mg/1
Chloride as Cl	660.0	mg/1	Silver as Ag	0.000	mg/1
Chromium as Cr (Hex)	0.00	mg/1	Sulfate as SO_4	1,500.0	mg/1
Cyanide as Cn	0.00	mg/1	Sodium as Na	886.0	mg/1
Copper as Cu	0.93	mg/1	Zinc as Zn	0.05	mg/1

TIME/DATE OF COLLECTION 1430 HRS/4-25-74

Ford Chemical Laboratory, Inc.

Ford Chemical LABORATORY, INC.
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: May 10, 1974

Name: Dames & Moore Eng.
Address: 250 East Broadway
Salt Lake City, Utah

CERTIFICATE OF ANALYSIS
74-1528

Sample: Water from Job No. 5467-003, received on April 29, 1974 under P.O. No. SL 1181, Boring 14, Sample #1, Filtered

Turbidity	0.35	JTU	Fluoride as F	0.63	mg/1
Conductivity	1,015.0	umhos/cm	Total Hardness as $CaCO_3$	275.0	mg/1
pH	7.46		Iron (Total) as Fe	0.01	mg/1
Total Dissolved Solids at 180° C.	701.0	mg/1	Iron (Filtered) as Fe	0.08	mg/1
Alkalinity as $CaCO_3$	160.0	mg/1	Lead as Pb	0.00	mg/1
Aluminum as Al	0.00	mg/1	Magnesium as Mg	26.4	mg/1
Arsenic as As	0.00	mg/1	Manganese as Mn	0.00	mg/1
Bicarbonate as HCO_3	193.0	mg/1	Mercury as Hg	0.000	mg/1
Barium as Ba	0.00	mg/1	Nitrate as NO_3–N	0.95	mg/1
Boron as B	0.00	mg/1	Phosphate as PO_4	0.10	mg/1
Cadmium as Cd	0.000	mg/1	Potassium as K	11.0	mg/1
Calcium as Ca	66.0	mg/1	Selenium as Se	0.00	mg/1
Carbonate as CO_3	0.00	mg/1	Silica as SiO_2	0.40	mg/1
Chloride as Cl	94.0	mg/1	Silver as Ag	0.000	mg/1
Chromium as Cr (Hex)	0.00	mg/1	Sulfate as SO_4	210.0	mg/1
Cyanide as Cn	0.00	mg/1	Sodium as Na	101.0	mg/1
Copper as Cu	0.15	mg/1	Zinc as Zn	0.12	mg/1

TIME/DATE OF COLLECTION 1300 HRS/4-25-74

Ford Chemical Laboratory, Inc.

Fo[rd Chemical] LAB[ORATORY, INC.]
Bacteri[ological and Chemical Analysis]

Name: Dames & Moore Eng.
Address: 250 East Broadway
Salt Lake City, Utah

Sample: Water from Job No. ...
P.O. No. SL 1181, Bo...

Turbidity	0.64
Conductivity	1,079.
pH	7.47
Total Dissolved Solids at 180° C.	745.0
Alkalinity as $CaCO_3$	180.0
Aluminum as Al	0.00
Arsenic as As	0.00
Bicarbonate as HCO_3	218.0
Barium as Ba	0.01
Boron as B	0.00
Cadmium as Cd	0.000
Calcium as Ca	50.0
Carbonate as CO_3	0.00
Chloride as Cl	130.0
Chromium as Cr (Hex)	0.00
Cyanide as Cn	0.00
Copper as Cu	0.95

TIME/DATE OF COLLECTION

Fo[rd Chemical] LAB[ORATORY, INC.]
Bacteri[ological and Chemical Analysis]

Name: Dames & Moore Eng.
Address: 250 East Broadway
Salt Lake City, Utah

Sample: Water from Job No. ...
P.O. No. SL 1181, Bo...

Turbidity	0.48
Conductivity	7,286.
pH	7.02
Total Dissolved Solids at 180° C.	5,028.
Alkalinity as $CaCO_3$	170.0
Aluminum as Al	0.01
Arsenic as As	0.00
Bicarbonate as HCO_3	206.0
Barium as Ba	0.05
Boron as B	0.00
Cadmium as Cd	0.000
Calcium as Ca	32.0
Carbonate as CO_3	0.00
Chloride as Cl	2,590.
Chromium as Cr (Hex)	0.00
Cyanide as Cn	0.00
Copper as Cu	0.03

TIME/DATE OF COLLECTION

Chemical
RATORY, INC.
al and Chemical Analysis
ST LOUISE AVENUE
KE CITY, UTAH 84115
HONE 485-5761

Date: May 10, 1974

CERTIFICATE OF ANALYSIS

74-1527

-003, received on April 29, 1974 under
15, Sample #1, Filtered

TU	Fluoride as F	0.60	mg/1
mhos/cm	Total Hardness as $CaCO_3$	240.0	mg/1
	Iron (Total) as Fe	0.07	mg/1
	Iron (Filtered) as Fe	0.05	mg/1
mg/1	Lead as Pb	0.00	mg/1
mg/1	Magnesium as Mg	27.60	mg/1
mg/1	Manganese as Mn	0.00	mg/1
mg/1	Mercury as Hg	0.000	mg/1
mg/1	Nitrate as NO_3 – N	1.20	mg/1
mg/1	Phosphate as PO_4	0.15	mg/1
mg/1	Potassium as K	10.81	mg/1
mg/1	Selenium as Se	0.00	mg/1
mg/1	Silica as SiO_2	0.35	mg/1
mg/1	Silver as Ag	0.000	mg/1
mg/1	Sulfate as SO_4	175.0	mg/1
mg/1	Sodium as Na	135.0	mg/1
mg/1	Zinc as Zn	0.02	mg/1
mg/1			

Ford Chemical Laboratory, Inc.

1220 HRS/4-25-74

Ford Chemical
LABORATORY, INC.
Bacteriological and Chemical Analysis
40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: May 10, 1974

Name: Dames & Moore Eng.
Address: 250 East Broadway
Salt Lake City, Utah

CERTIFICATE OF ANALYSIS

74-1530

Sample: Water from Job No. 5467-003, Boring Well B, Sample #1 received on April 29, 1974 under P.O. No. SL 1181, Filtered

Turbidity	2.40 JTU		Fluoride as F	0.85	mg/1
Conductivity	2,972.0 umhos/cm		Total Hardness as $CaCO_3$	115.0	mg/1
pH	7.55		Iron (Total) as Fe	0.25	mg/1
Total Dissolved Solids at 180° C.	2,051.0	mg/1	Iron (Filtered) as Fe	0.20	mg/1
Alkalinity as $CaCO_3$	220.0	mg/1	Lead as Pb	0.00	mg/1
Aluminum as Al	0.02	mg/1	Magnesium as Mg	14.0	mg/1
Arsenic as As	0.00	mg/1	Manganese as Mn	0.04	mg/1
Bicarbonate as HCO_3	266.0	mg/1	Mercury as Hg	0.000	mg/1
Barium as Ba	0.05	mg/1	Nitrate as NO_3 – N	3.80	mg/1
Boron as B	0.00	mg/1	Phosphate as PO_4	0.20	mg/1
Cadmium as Cd	0.000	mg/1	Potassium as K	60.50	mg/1
Calcium as Ca	22.0	mg/1	Selenium as Se	0.00	mg/1
Carbonate as CO_3	0.00	mg/1	Silica as SiO_2	0.15	mg/1
Chloride as Cl	1,010.0	mg/1	Silver as Ag	0.000	mg/1
Chromium as Cr (Hex)	0.00	mg/1	Sulfate as SO_4	8.0	mg/1
Cyanide as Cn	0.00	mg/1	Sodium as Na	671.0	mg/1
Copper as Cu	0.01	mg/1	Zinc as Zn	0.02	mg/1

Ford Chemical Laboratory, Inc.

TIME/DATE OF COLLECTION 1320 HRS/4-12-74

Chemical
RATORY, INC.
ical and Chemical Analysis
EST LOUISE AVENUE
LAKE CITY, UTAH 84115
PHONE 485-5761

Date: May 10, 1974

CERTIFICATE OF ANALYSIS

74-1529

7-003, received on April 29, 1974 under
ng Well A Sample #3, Filtered

JTU	Fluoride as F	0.90	mg/1
umhos/cm	Total Hardness as $CaCO_3$	370.0	mg/1
	Iron (Total) as Fe	0.15	mg/1
	Iron (Filtered) as Fe	0.11	mg/1
mg/1	Lead as Pb	0.00	mg/1
mg/1	Magnesium as Mg	69.6	mg/1
mg/1	Manganese as Mn	0.38	mg/1
mg/1	Mercury as Hg	0.000	mg/1
mg/1	Nitrate as NO_3 – N	4.50	mg/1
mg/1	Phosphate as PO_4	0.25	mg/1
mg/1	Potassium as K	63.6	mg/1
mg/1	Selenium as Se	0.00	mg/1
mg/1	Silica as SiO_2	0.65	mg/1
mg/1	Silver as Ag	0.000	mg/1
mg/1	Sulfate as SO_4	350.0	mg/1
mg/1	Sodium as Na	1,718.0	mg/1
mg/1	Zinc as Zn	0.15	mg/1
mg/1			

Ford Chemical Laboratory, Inc.

1820 HRS/4-25-74

CHEMICAL ANALYSES OF GROUNDWATER

9705220019-16

DAMES & MOORE

PLATE A-9B

Accu-Labs Research, Inc.

9170 W. 44th Ave., Wheat Ridge, Colo. 80033 (303) 421-9590
(303) 423-2766

May 23, 1974

Mr. George W. Condrat
Dames & Moore
Suite 200
250 East Broadway
Salt Lake City, Utah 84111

Ref: 169-1156-8

ANALYTICAL REPORT

Sample Description	Radium 226 ± Precision* (pCi/l)	Thorium 230 ± Precision* (pCi/l)
TP-4	11 ± 5	19 ± 8
TP-7	1.7 ± 2.4	9.1 ± 7.4
B-8	14 ± 6	15 ± 8
B-9	0.5 ± 2.1	63 ± 11
B-15	24 ± 7	29 ± 9
B-14	0.9 ± 2.2	$2.04 \times 10^4 \pm .02 \times 10^4$
Well A	8.6 ± 4.0	15 ± 3
Well B	35 ± 8	0 ± 6

* Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

By: D. L. Helt
D. L. Helt
Analytical Supervisor

RADIOLOGICAL ANALYSES OF GROUND WATER

DAMES & MOORE

PLATE A-10

GROUND WATER LEVELS, APRIL 1974

Location	Depth To Water (Ft)/Date	Elevation of Water Table (Ft)*	Present Depth of Open Casing
Boring 1	5.4/ 4-12-74	4,025.2	10.4
Boring 2	33.1/ 4-12-74	3,953.1	33.8
Boring 3	Dry at 19.0/4-12-74	-	19.0
Boring 4	Dry at 32.3/4-12-74	-	32.3
Boring 5	36.8/ 4-12-74	3,955.4	37.3
Boring 8	9.3/ 4-25-74	3,958.0	55.0
Boring 9	8.0/ 4-25-74	3,954.5	23.0
Boring 10	Dry at 41.0/4-25-74	-	41.0
Boring 11	30.5/ 4-18-74	3,999.9	0
Boring 12	49.0/ 4-25-74	3,981.1	50.0
Boring 13	74.6/ 4-25-74	3,957.8	79.0
Boring 14	55.7/ 4-25-74	3,960.6	68.0
Boring 15	38.3/ 4-25-74	3,958.8	48.0
Test Pit 1	8.1/ 4-12-74	3,953.9	9.0
Test Pit 2	8.4/ 4-12-74	3,951.2	9.7
Test Pit 3	8.6/ 4-12-74	3,953.9	11.9
Test Pit 4	7.0/ 4-12-74	3,954.8	11.0
Test Pit 5	7.5/ 4-12-74	-	8.5
Test Pit 6	Dry at 10.0/4-12-74	-	10.0
Test Pit 7	5.0/ 4-25-74	3,954.4	7.5
Test Pit 8	5.1/ 4-25-74	3,954.9	7.5
Well A	88.0/ 4-25-74	3,957.9	131
Well B	77.7/ 4-25-74	3,960.2	114

*Feet above sea level (plant datum of 500.0 = 4,028.2 feet above sea level.)

WATER LEVEL TABULATION

DATA BY ATLAS MINERALS

Monitor Well	Ground Elevation	Well Depth (ft.)	Water Depth (feet-inches) 12/7/72	2/8/73	3/6/73	5/15/73	7/19/73	10/25/73	Water Elevations 10/25/73
B1	502.4	81.5	36-6	36-6	36-6	36-6	36-6	36-6	465.9
B2	458.0	39.0	32-6	32-6	32-6	32-6	32-6	32-6	425.5
B3	497.5	71.5	11-0	11-0	11-0	11-0	11-0	11-0	586.5
B4	502.6	66.5	33-10	33-10	33-10	33-10	33-10	33-10	468.8
B5	464.0	41.5	37-11	37-11	37-11	37-11	37-11	37-11	426.1
B6	503.3	56.5	25-10	25-10	25-10	25-10	25-10	25-10	477.5
B7	501.0	31.5	24-0	24-0	24-0	24-0	24-0	24-0	477.0
TP1	433.8	10.5	8-3	8-3	8-3	8-3	8-3	8-3	425.5
TP2	431.4	11.0	7-0	7-0	7-0	7-0	7-0	7-0	424.4
TP3	434.3	13.5	8-8	8-8	8-8	8-8	8-8	8-8	425.6
TP4	433.6	10.5	7-2	7-2	7-2	7-2	7-2	7-2	426.4
TP5	425.4	10.5	7-0	7-0	7-0	7-0	7-0	7-0	418.4
TP6	451.0	14.0	Dry	Dry	Dry	Dry	Dry	Dry	-
TP7	431.4	8.0	-	-	6-6	6-6	6-6	6-6	424.9
TP8	431.4	8.0	-	-	5-6	5-6	5-6	5-6	425.9

RADIUM (Ra^{226} uc/ml x 10^{-8}) TABULATION

DATA BY ATLAS MINERALS

Monitor Well	12/8/72	2/8/73	3/6/73	5/15/73	7/19/73	4/1/74
B1	-	5.24	1.75	6.91	2.84	-
B2	2.18	1.63	1.41	.99	2.49	3.29
B3	-	5.75	3.20	3.50	2.92	-
B4	5.00	4.77	4.90	2.82	-	-
B5	1.33	1.64	.85	.42	.49	-
B6	2.61	2.14	3.92	-	2.49	-
B7	1.48	-	-	-	.78	-
TP1	.53	.23	.21	.37	.54	2.12
TP2	.037	.004	.61	.41	1.09	1.31
TP3	1.25	.82	.70	.84	.17	.54
TP4	.10	.13	.21	1.82	.74	2.13
TP5	2.57	1.79	1.30	.27	.40	3.37
TP6	-	-	-	-	-	-
TP7	-	-	.047	.19	.86	.59
TP8	-	-	.26	.15	-	.69

No data for 10/25/73

THORIUM (Th^{230} uc/ml x 10^{-6}) TABULATION

DATA BY ATLAS MINERALS

Monitor Well	12/18/72	2/8/73	3/6/73	5/15/73	7/19/73	10/25/73	4/1/74
B1	-	.079	.004	.037	-	-	-
B2	.030	.042	.005	.007	.002	.011	.012
B3	-	.053	.005	.053	.003	-	-
B4	.018	.063	.005	.011	-	.004	-
B5	.005	.006	.014	.005	.003	-	.003
B6	.003	.015	.017	-	.004	-	-
B7	.006	-	-	-	.002	-	-
TP1	.010	.008	.005	.005	.002	.003	.005
TP2	.008	.004	.004	.008	.002	.006	.002
TP3	.004	.006	.006	.002	.003	.002	.004
TP4	.014	.008	.003	.003	.002	.004	.004
TP5	.005	.033	.008	.006	.002	.007	.001
TP6	-	-	-	-	-	-	-
TP7	-	-	.002	.002	.002	.005	.001
TP8	-	-	.002	.002	-	.006	.006

MISCELLANEOUS TABULATIONS

DATA BY ATLAS MINERALS

Monitor Well	U_3O_8 PPM 12-8-72	U_3O_8 uc/ml x 10^{-5} 4-1-74	Po^{210} uc/ml x 10^{-7} 12-8-72
B1	-	.020	-
B2	9	.079	.031
B4	12	-	.15
B5	.9	.082	.027
B6	7	-	.030
B7	2	-	.013
TP1	20	.16	.008
TP2	13	.19	.008
TP3	8	.27	.016
TP4	7	.25	.005
TP5	12	.65	.013
TP7	-	.014	-
TP8	-	.008	-

TDS AND pH TABULATION

DATA BY ATLAS MINERALS

Monitor Well	TDS (ppm) 12/8/72	TDS (ppm) 2/8/73	TDS (ppm) 10/25/73	pH 12/8/72	pH 2/8/73	pH 10/25/73	pH 4/1/74
B1	-	2,534	-	8.5	8.10	-	8.1
B2	3,374	4,315	9,076	8.2	8.00	7.05	8.3
B3	-	7,774	-	-	8.10	-	-
B4	7,984	7,697	7,576	7.7	8.15	7.45	-
B5	1,743	5,415	8,500	6.6	8.10	7.8	8.2
B6	4,756	9,344	-	7.2	8.15	-	-
B7	3,943	-	-	7.5	-	-	-
TP1	9,320	8,391	15,000	8.0	8.00	6.7	8.0
TP2	10,422	16,347	10,546	7.5	8.00	7.5	7.8
TP3	12,585	18,775	22,910	8.1	8.05	7.5	7.9
TP4	10,005	9,911	10,500	7.7	7.95	7.0	8.1
TP5	11,564	14,095	13,248	8.1	8.10	7.7	8.2
TP6	-	-	-	-	-	-	-
TP7	-	-	2,914	-	-	7.8	8.3
TP8	-	-	24,162	-	-	7.3	7.8

SO_4 (ppm) TABULATION

DATA BY ATLAS MINERALS

Monitor Well	12/8/72	2/8/73	4/1/74
B1	-	-	392
B2	1,100	4,155	3,665
B3	-	-	
B4	1,920	3,240	
B5	1,230	4,732	3,782
B6	590	-	
B7	320	-	
TP1	2,320	9,997	4,352
TP2	1,820	3,859	4,585
TP3	2,520	8,760	8,226
TP4	2,720	4,377	762
TP5	4,300	5,611	5,550
TP6	-	-	
TP7	-	229	5,018
TP8	-	4,529	4,804

MISCELLANEOUS TABULATION

DATA BY ATLAS MINERALS
(PPM)

Monitor Well	Cl 12/18/72	Cl 10/25/73	Cl 4/1/74	Na 12/18/72	Na 2/8/73	As 10/25/73	Ca 10/25/73	Ca 4/1/74
B1	879	-	85.1	-	640	-	-	32
B2	213	1,115	908	1,100	590	.03	492	468
B3	-	-	-	-	2,070	-	-	-
B4	1,021	880	-	1,920	1,890	.05	280	-
B5	128	1,086	978	1,230	1,070	-	432	460
B6	454	-	-	590	2,110	-	-	-
B7	113	-	-	320	-	-	-	-
TP1	1,121	1,264	1,078	2,320	1,620	.006	492	488
TP2	1,106	1,640	1,531	1,820	2,630	.01	652	428
TP3	2,865	5,559	3,467	2,520	4,000	.03	520	464
TP4	1,574	1,767	1,671	2,720	1,660	.003	660	592
TP5	3,021	3,197	2,070	4,300	2,710	.03	560	472
TP6	-	-	-	-	-	-	-	-
TP7	-	589	1,064	-	-	.01	520	204
TP8	-	11,440	10,890	-	-	.006	724	679

MISCELLANEOUS TABULATION

12/8/72

Monitor Well	V_2O_5 ppm	NO_3 ppm	K ppm	Cu ppm	Fe ppm	Total Hardness ppm	MHOS Specific Conductance
B1	NL	331	--	--	--	174	--
B2	NL	29	13	NL	23	1780	3600
B3	--	--	--	--	--	--	--
B4	NL	66	41	NL	3	1480	6800
B5	NL	46	70	NL	3	820	2400
B6	.4	120	18	NL	NL	1340	4500
B7	.4	29	11	NL	3	1660	2800
TP1	.4	973	42	NL	.07	2820	7800
TP2	.4	1325	51	NL	.05	3900	8500
TP3	.4	824	70	NL	10	3760	9000+
TP4	NL	662	72	NL	7	3680	9000+
TP5	4.0	364	40	NL	12	3820	9000+
TP6	--	--	--	--	--	--	--

AVERAGE MONTHLY DISCHARGE AND DISSOLVED

CHEMICAL CONSTITUENTS IN COLORADO

RIVER NEAR CISCO, UTAH, WATER YEARS 1969-1972*

Month	Discharge (CFS)	Sulfate (MG/L)	Chloride (MG/L)	Dissolved Solids (MG/L)	Dissolved Solids (Tons/Day)	pH (Units)
October	4,660	432	119	982	11,900	7.8
November	4,510	361	136	840	10,100	7.9
December	4,650	291	146	812	10,200	7.8
January	4,850	267	128	766	10,100	7.5
February	4,540	249	126	728	8,560	7.6
March	4,650	231	132	690	8,380	7.8
April	8,550	189	81	543	10,270	7.9
May	13,670	130	38	395	14,400	7.4
June	16,080	142	33	379	15,900	7.7
July	6,970	280	93	685	10,476	7.4
August	3,337	472	121	1,061	9,105	7.9
September	5,560	419	130	965	10,793	7.9

*U. S. Geological Survey, 1969-1972

SELECTED CONSTITUENTS IN THE

COLORADO RIVER ABOVE SITE[1]

Constituent	Average Concentration 1968-1972	1971	1972	1973
B.O.D. in mg/1[2]		3.2(7)	2.6(9)	2.2(4)
Total Coliform in M.P.N. per 100 ml[2]		6842(7)	7990(9)	2265(4)
Fecal Coliform in M.P.N. per 100 ml[2]		1736(6)	5195(9)	1184(4)
Arsenic in mg/1[2]		0.00(2)	0.00(2)	0.01(4)
Barium in mg/1[2]		1.50(2)	0.00(2)	0.00(4)
Radium-226 in pCi/1[3]	0.19	0.26	0.17[5]	
Uranium (total) in mg/1[3]	7.00	6.64	6.00[5]	
Radium-226 in pCi/1[4]	.33	0.10	.34[5]	
Uranium (Natural) in pCi/1[4]	7.	2.	6.[5]	
Thorium-230 in pCi/1[4]	5.2	3.2	5.0[5]	

Notes:
1. Sampling location is bridge of U. S. Highway 160 about 0.25 miles above mill.
2. Analyses by Utah State Division of Health.
3. Analyses by Radium Monitoring Network (E.P.A., 1973).
4. Analyses by Atlas Minerals.
5. Through June 1972.

Number in parenthesis after concentration is number of samples analyzed.

WATER WELL DATA

Location	Elevation (Ft)	Static Water Level/Date	Comment
Well A	4045.9	88.0'/4-25-74	Total depth of well is 131 feet; well driller's report (1961) notes water is "unusable" because of "salt;" reported yield 18 gpm; log available; well is abandoned.
Well B	4037.9	77.7'/4-25-74	Total depth of well is 114 feet; drilled at former A.E.C. ore buying station; former worker reported that water was "salty" and was not used for drinking; log available; reported yield 11 gpm; well is abandoned.
Arches N.P.	4090*	92' /12-22-58	Located 1.4 miles northwest of tailings pond; up water gradient from tailings pond and mill; total depth of well is 123 feet; reported yield 12 gpm with 8 feet drawdown; derives water from fractured Navajo sandstone; water quality relatively good.
Embar Oil	4000	85' / 10-67	Total depth of oil well is 5345 feet; apparently encountered Hermosa formation below alluvium at 56 feet; log available; oil well is abandoned.

*Price, D., 1959, p.8.

APPENDIX B

ION EXCHANGE STUDIES

Part 1

Characterization of Tailings Pond Solids and Natural Soils: Uranium and Radium Adsorption. Chemical Mineralogical, and Physical Properties. Atlas Minerals Plant, Moab, Utah

By B. F. Hajek

Auburn, Alabama

Part 2

Determination of Radium and Uranium Distribution Coefficients and Loading Curves on a Uranium Plant Tailings Pile and Underlying Soil

By Pacific Northwest Laboratories

Richland, Washington

INTRODUCTION

This report presents the results of an investigation conducted for Dames & Moore, Salt Lake City, Utah. The study was required to provide data to evaluate the ion exchange properties of tailings solids and natural soils as they relate to uranium and radium adsorption.

Other studies of the Atlas Minerals site have been conducted by Dames & Moore and Atlas Minerals. These previous studies have been included in an Environmental Impact Statement submitted to the Atomic Energy Commission. This report should supplement the previous studies.

OBJECTIVES

The objectives of this study were to:

1. Determine the chemical, mineralogical and physical characteristics that could be significant effecting the ion exchange characteristics of natural soil and tailing material at the Moab, Utah site.
2. Determine the uranium and radium adsorption characteristics that influence the leaching of these ions in the tailing pile and in natural soil between the tailing pile and the river.

METHODS

Fifteen samples, 7 from borings in the tailings pond embankment, 5 from test pits, 2 from the Colorado River bank, and 1 from soil

northeast of the plant were selected for analysis. The boring and test pit samples were selected from cores collected by Dames & Moore. The location of borings and test pits have been given previously in Plate 2 of the Report of Engineering Studies - Tailings Pond Embankment System, Moab, Utah for Atlas Minerals, March 28, 1974. The reference soil sample and river bank samples were collected during an on-site study March 19, 1974. (See Figure 1, following Part I).

The samples were air dried and analyzed at the Agronomy & Soils laboratories, Auburn University, Auburn, Alabama (physical, chemical and mineralogical properties). Five samples were sent to the Pacific Northwest Laboratories in Richland, Washington for uranium and radium adsorption determinations. The equilibrium and column methods used will be given by the Pacific Northwest Laboratories in a separate report.

Particle size distribution was determined by the pipette method after dispersion with sodium metaphosphate (1). Exchangeable bases were extracted with 1 N ammonium acetate; Ca and Mg were determined by titration, and K and Na by flame photometry (5). Sulfate was determined by extraction with 0.5 M ammonium acetate and analyzed by a turbidometric technique Phosphates were extracted with 0.5 M $NaHCO_3$, buffered at pH 8.5 and analyzed by the vanadate method (4). Cation exchange capacity (CEC) was obtained by ammonium saturation (5). The pH reported is of the supernatant of a 1:1 soil: water suspension.

Mineralogical analysis were conducted by differential thermal analysis (DTA) and x-ray diffraction of whole soil materials ground to pass a 170 mesh sieve. The DuPont 990 Thermal Analyzer was used for DTA. A Norelco x-ray unit equipped with a Cu target tube and Ni filter was used for diffraction analysis.

RESULTS

Physical and Chemical Properties

The results of soil chemical analyses are given in Table 1. Since the sum of extractable bases exceeds the cation exchange capacity, the Ca and in most samples Na and Mg were obtained from soluble compounds in addition to the soil exchange system. Under field conditions the cation exchange system is dominated by Ca and Na ions.

The cation exchange capacity, as expected, varies with clay content; for tailings,

$$CEC = 1.79 + 0.37\ (\%\ clay),\ r = 0.96$$

for natural soils,

$$CEC = 0.17 + 0.54\ (\%\ clay),\ r = 0.74$$

There is no consistant trend in pH or extractable ions that would reflect past disposal practices. This is probably due to waste-water dilution and dispersion by groundwater. However, salt deposits were observed on the soil surface between the tailings pond embankment and the river in the vicinity of test pits 2, 3, and 4 and at the river bank.

The variations in particle size distribution (Table 2) and chemical

Table 1. Chemical characteristics of soils and tailing material collected at the Atlas Minerals, Moab, Utah Plant. 2/

Sample	Depth Feet	pH 1:1	Exchangeable 1/						
			CEC	Na	Ca	Mg	K	SO4	
			meq/100g						ppm
Boring 3	5.5	10.1	6.03	6.1	10.8	2.8	.36	1.59	3
Boring 3	20.5	9.2	8.18	9.0	11.9	4.9	.40	8.34	30
Boring 3	30.5	9.2	16.18	15.2	12.0	6.0	.80	4.50	31
Boring 4	10.5	7.9	2.37	1.1	31.2	0.2	.21	29.10	10
Boring 4	15.5	9.9	4.19	2.8	9.2	1.8	.22	.71	7.5
Boring 5	6.5	7.0	1.65	0.3	70.0	tr	.06	30.30	34
Boring 5	10.5	7.2	1.68	1.3	45.0	tr	.09	30.30	17
Tip 2	5.5	8.5	6.47	2.1	11.6	3.0	.38	1.65	2
Tip 4	6.0	8.4	4.81	2.3	17.8	tr	.38	23.2	3
Tip 4	8.0	9.6	2.71	1.3	5.1	1.5	.22	.984	6
Tip 5	3.0	8.9	9.33	10.9	16.2	6.0	.16	6.84	9
Tip 5	5.0	9.0	2.18	0.2	7.2	2.0	.62	.0718	2
Ref. Soil	3-5	9.2	1.89	0.2	6.2	0.3	.14	.037	3
River bk.	5	8.3	9.65	11.7	17.1	5.9	.41	11.20	13
River bk.	8	8.7	15.68	11.7	12.2	3.2	.66	4.31	21

1/ and extractable

2/ location of sampling sites are shown on the vicinity map included at the end of this report.

Table 2. Sand, silt and clay size distribution of soils and tailing material collected at the Atlas Minerals, Moab, Utah Plant. 1/

Sample	Depth Feet	Sand 2.0-0.05 mm	Silt .05-.002 mm	Clay 0.002 mm
		%		
Boring 3	5.5	66	27	7
Boring 3	20.5	53	35	12
Boring 3	30.5	4	56	40
Boring 4	10.5	90	5	5
Boring 4	15.5	81	13	6
Boring 5	6.5	88	--	--
Boring 5	10.5	93	2	5
Tip 2	5.5	68	22	10
Tip 4	6.0	60	29	11
Tip 4	8.0	90	5	5
Tip 5	3.0	14	71	15
Tip 5	5.0	92	2	6
Ref. Soil	3-5	91	3	6
River Bk.	5	35	51	14
River Bk.	8	32	43	24

1/ Location of samples are shown on the vicinity map included at the end of this report.

properties clearly shows the layered heterogeneous nature of both the tailings and soils. However, variation of this magnitude is frequently encountered in naturally occuring sedimentary deposits.

Mineralogical

X-ray diffraction analysis shows that quartz is the major mineral in all samples (patterns included at the end of this report). Calcite can be identified in all samples. No clay minerals can be identified in whole soil analysis because of the small quantity of clay present and the layered nature of this group of minerals. X-ray analysis of 3 preferentially oriented specimen of clay and silt (river bank, natural soil, and boring 3, 30.5') show that the mineralogical composition of these materials are the same; consisting of illite, 2:1 expanding layer silicates, kaolinite, quartz, and calcite.

Differential thermal analysis showed three types of patterns:

1. No definate endotherm except the λ-β quartz inversion at 573°C. (Test pit 6 and the reference natural soil).

2. Quartz λ-β inversion and low temperature endotherms between 130 - 155°C. (boring 5, test pit 4, a surface soil sample with salt accumulation).

3. Low temperature endotherms at 75 - 110°C indicating significant amounts of 2:1 expanding silicates, λ- β quartz inversion at 573°C and endotherms at 230°-300°C. (samples high in clay, such as the clayey riverbank sample and boring 3 at 30.5').

It seems that the endotherms at 130 - 155°C that are common to the soils sampled in the most probable flow path from the tailings to the river and also detected in tailing material, but absent, in test pit 6 and the reference soil is most significant. This endotherm is most likely due to hydration water released from salts precipitated on soil surfaces. These salts could have been contributed by waste-water disposed to the tailings pond.

Uranium and Radium Adsorption. (Based on phone communication with Dr. L. L. Ames, Pacific Northwest Laboratories, Richland, Washington) (See Part 2)

Equilibrium batch experiments were conducted to determine the adsorption characteristics of uranium and radium on tailings and on soils in the vicinity of the Atlas Minerals tailings pond. Equilibrium distribution coefficients (K_d) were calculated by use of the following equation:

$$K_d = \frac{Co - C}{C} \quad ml/g,$$

in which

Co = initial solution concentration

C = solution concentration after equilibration

ml = milliliters of solution

g = grams of soil

The K_d can be used to calculate the migration rates of ions in trace concentrations or to calculate the solution volume that will completely saturate the adsorption capacity of the soil with the ion being considered (3).

It is convenient to express this volume in terms of the volume of soil through which the solution will leach, that is, unit volumes of solution (CV) per unit volume of soil. The relationship is shown in the following equation:

$$CV = \theta + (\text{soil bulk density})\,(K_d)$$

in which θ is the fractional part of the soil that is filled by water.

The average bulk density of the tailings is about 1.6 g/cc, θ should be about 0.4 or a little less. Using the composite tailings radium K_d (Table 3) the calculation shows that a unit volume of tailings can adsorb radium from 275 equivalent volumes of solution before saturating the capacity of this material. Consequently, each wetted acre of the tailings pond should have the capacity to adsorb radium from about 4.5×10^9 gallons of acid liquid waste-water. The radium Kd values for natural soils in this area are higher and should adsorb greater amounts. In a flowing system where dispersion will occur, the volume calculated should be considered as the volume at which the concentration leaving a unit volume of soil has 1/2 the radium concentration of the initial radium in the waste.

The uranium adsorption studies showed that uranium would not be adsorbed by tailings. The negative Kd of the composite tailings indicate a release of uranium. Consequently, adsorption will occur only on natural soil beneath the pond and between the tailings pile and the river. The soil volume invaded by waste water is not known. This would require additional studies to determine the flow characteristics of

Table 3. Uranium and radium equilibrium distribution coefficients.

Sample Site	Equilibrium Distribution Coefficient	
	Uranium	Radium
	ml/g	
Test Pit 5	6-20	354 ± 15
Test Pit 4	14-40	289 ± 7
Reference Soil	2-16	214 ± 15
River Bank	8-34	467 ± 15
Composite tailings	negative 1/	212 ± 20

1/ Released uranium

natural groundwater and the effects of the added water leached from the pond.

Generally, in groundwater flow systems K_d values are used to predict the average ion front velocity relative to the velocity (flow rate) of the transporting groundwater (3). Then disposal can be based on the time it takes the ion front to reach some point at a critical concentration level (3).

By use of the equation;

$$\text{velocity uranium} = \frac{\text{velocity of water}}{1 + \frac{Kd\ Bd}{\theta}}$$

and the average low uranium K_d (table 3) for test pits 4 and 5, the average migration rate of uranium would be 90 times less than water (K_d= 10, Bd= 1.6, and θ = 0.4). Using this value and a flow rate value along an average stream line to the river should give a reasonable estimate of the time it takes uranium to migrate to the river.

The most significant interpretation from adsorption studies on uranium is that the uranium capacity of natural soils between the tailing pile and the river have not been exceeded by past disposal practices. This conclusion was reached because Kd's for samples collected from pits both above and below groundwater level were positive. They were as high or higher than the reference natural soil K_d.

It seems that periodic groundwater and soil analysis with emphasis on uranium build-up should indicate any trend before adsorption limits are reached.

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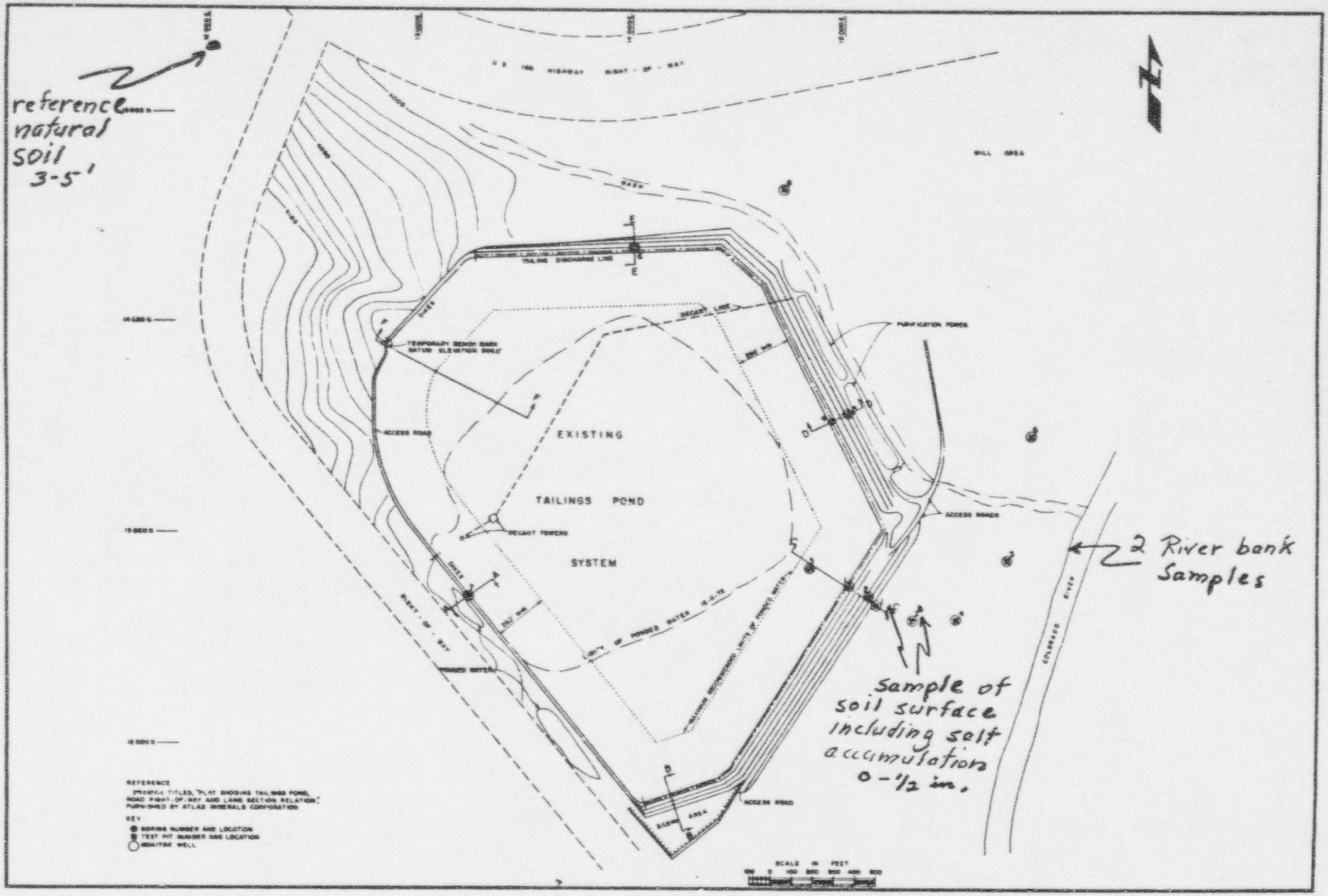

FIGURE 1. TAILING POND

DETERMINATION OF RADIUM AND URANIUM
DISTRIBUTION COEFFICIENTS AND LOADING CURVES
ON A URANIUM PLANT TAILINGS PILE
AND UNDERLYING SOIL
2311202131

PART 2

INTRODUCTION

In accordance with your Purchase Order Number SL 1185 dated March 20, 1974, five equilibrium soil adsorption determinations and two soil column loading characteristics have been determined. Two solutions were used in the above soil work as furnished or suggested by Professor B. F. Hajek. An acidic raffinate waste solution, whose composition was furnished by Dr. Hajek, is given in Table I.

TABLE I

ACIDIC RAFFINATE WASTE COMPOSITION

Constituent	g/l	Added as -
Na	7.22	
V	0.11	$NaVO_3$
As	0.004	$Na_2HA_5O_4$
Cl	0.02	NaCl
SO_4	67.07	Na_2SO_4
U	0.001	UO_3
^{226}Ra	0.007	$RaCl_2$ in HCL

H_2SO_4 to yield 4.47 g/l SO_4^{-2} and pH = 1.75

The second solution suggested by Dr. Hajek was a neutral brackish-type solution fairly high in neutral salts. To fill this request, a simulated Colorado River water analysis was used from a water quality station near the Colorado - Utah state line.[1] This location is very close to Moab, Utah, but probably is lower in pH than the groundwater at Moab. The soil (resident terrace), in any case, raised the pH of the simulated Colorado River water by a pH unit. The water composition is given in Table II.

[1]Water Resources Data for Colorado, Part 2. Water Quality Records, U. S. Department of the Interior, Geological Survey, p. 68, 1971.

TABLE II

SIMULATED COLORADO RIVER WATER

Constituent	mg/l	Added as -
Ca	82	$CaSO_4 \cdot 2H_2O, CaCl_2$
Mg	26	$MgSO_4$
Na	75	NaCl
K	3.4	KCl
HCO_3	171	$NaHCO_3$
SO_4	246	$CaSo_4 \cdot 2H_2O, MgSO_4$
Cl	57	$CaCl_2$,NaCl,KCl
U	1	UO_3
Ra	7	$RaCl_2$ in HCl

Total dissolved solids was 668.4 mg/ℓ. The actual Colorado River water also contained about twelve mg SiO_2/ℓ. The silica was not added to the simulated solution because there was no practical way to do so within the time limitations of this study.

The soils were furnished by Dr. Hajek in amounts adequate for the distribution equilibrium and column studies. The soils were labeled Test Pit 5, Test Pit 4, Riverbank Composite, Resident Terrace and Composite Tailings soils. Columns were run as requested on the resident terrace and composite tailings soils.

METHODS OF INVESTIGATION

Distribution Coefficients

Distribution coefficients (K_d's) are a special case of selectivity coefficients in that trace quantities of cations are exchanged, leaving the solution composition before and after the measurement essentially the same. The distribution coefficient for cation B^+, then, is equal to milliequivalents of cation B^+ on the exchanger divided by the milliequivalents per ml of cation B^+ left in solution after equilibration of the soil and solution.

The K_d values were obtained by placing eight grams of soil sample in 250 ml bottles. Four changes of unspiked solution were used over a period of 72 hours to equilibrate the soils with the nonradioactive ions in the solutions. The above four solutions were discarded at the end of their respective 18 hour contact times after centrifugation of the soil sample-solution. A fifth batch of solution containing uranium and radium (see Tables I and II) was shaken with the soils for 20 hours. The soil and solution were then separated by centrifugation and the solution analyzed for ranium and radium. All soil sample K_d's were determined from triplicate batch experiments with each soil.

Uranium analyses were fluorimetric because the uranium used was far from secular equilibrium and therefore could not be accurately gamma counted due to specific separations of daughter products on the soils. The radium analyses were by gamma counting but had to be corrected for radon separations, and subsequently ^{214}Pb effects, on the radium peak counted.

Columns

The data for the resident terrace soil and composite tailings soil columns are summarized in Table III.

TABLE III

COLUMN DATA

	Composite Tailings Column	Resident Terrace Column
Diameter	1.985 cm	1.985 cm
Cross Section	3.1 cm^2	3.1 cm^2
Length	21.8 cm	21.6 cm
Volume	67.5 cc	66.8 cc
Soil Wt.	105.5 g	104.2 g
Soil Bulk Density	1.56	1.56
Flow Rate	11 ml/hr upflow	11 ml/hr upflow
Bulk Velocity	3.57 cm/hr	3.57 cm/hr
Total Throughput	38 column volumes	39 column volumes

Uranium analyses of influents and effluents were fluorimetric, on acidified samples where simulated Colorado River water was used. At the pH 8 of these effluents, it was not certain that the uranium in solution was entirely stable over a period of time, and hence the acidification of effluents before analysis.

The radium was gamma counted, again with the corrections necessary for daughter product (radon) separation and decay.

The composite tailings soil column showed an unusual greenish band that proceeded down the column during operations. Some gas evolution also was observed with the acid waste influent. X-ray diffraction results showed that the bulk of the composite tailings soil was quartz (SiO_2) with a lesser amount of feldspar ($NaA\ell\ Si_3O_8$-$Ca\ A\ell_2Si_2O_8$) and 15 ± 5 wt. % calcite ($CaCO_3$). The calcite reacted with the acid waste influent until finally dissolved by it. The resident terrace soil also proved to be mainly quartz and feldspar with a smaller amount of degraded mica ($K_2A\ell_4[Si_6A\ell_2O_{20}]\ [OH,F]_4$). No calcite could be identified by X-ray diffraction and no evidence of gas evolution or coloring were apparent during column loading.

RESULTS

Distribution Coefficients

The results of the equilibrium distribution experiments are given in Table IV.

TABLE IV

DISTRIBUTION COEFFICIENT RESULTS
C.R. = Colorado River Solution,
A.R. = Acidic Raffinate Solution

Soil	Solution	Final pH	UK_d	RaK_d
Test Pit 5				
1	C.R.	7.9		
2	C.R.	7.9	12.4 to 22	354±15
3	C.R.	8.0		
Test Pit 4				
1	C.R.	7.6		
2	C.R.	7.7	22 to 40	289±7
3	C.R.	7.6		
Riverbank Composite				
1	C.R.	7.8		
2	C.R.	7.9	33 to 36	467±15
3	C.R.	7.8		
Resident Terrace				
1	C.R.	7.8		
2	C.R.	7.8	10.4 to 17	214±15
3	C.R.	7.6		
Composite Tailings				
1	A.R.	1.8		
2	A.R.	1.6	-----	172±15
3	A.R.	1.7		

The composite tailings soil consists mainly of crushed, treated uranium ore and could, therefore, be expected to contain some uranium. Two solutions similar to the acidic raffinate in composition, with the exception of H_2SO_4 and U content, were shaken with composite tailings soil to determine the leachability of the uranium already present in this soil. At pH 6.5, 1.6 to 1.9 micrograms of uranium per gram of soil were extracted in a single 20 hour contact. At pH 1.0, 16.1 micrograms of uranium per gram of composite tailings soil were extracted. The amount of uranium extracted is a function of solution pH; the lower the pH, the more uranium extracted.

Due to some unusual column results with resident terrace soil and the synthetic Colorado River water influent, an extraction of uranium in duplicate was performed on this soil. Five grams of resident terrace soil were shaken for 16 hours with 50 mℓ of synthetic Colorado River water containing no uranium or radium. The duplicate samples both contributed 150 nanograms of uranium per gram of soil. The uranium extraction of 150 nanograms per gram of soil is not large, but is evidently higher in the kinetic column flow through situation. Only a small portion of the uranium present in the two soils were extracted by this method during either of the above equilibrations. In addition, the rest of the soil samples were not tested for their uranium contents due to time limitations. The uranium distribution coefficient values are the best obtainable within the time allowed for this study. If more time were available, the extraction of uranium could be determined for each soil sample and the uranium distribution coefficients corrected with these data. The uranium distribution coefficient for the composite tailings soil is not even listed in Table IV because the correction due to extractable uranium is three orders of magnitude greater than the remaining soil samples.

The radium distribution coefficients are also listed in Table IV. Little trouble was encountered in determining these. The plus or minus number following the coefficient indicates the spread in the three values.

Columns

The pH values of the composite tailings and resident terrace soil column effluents are shown in Figures 1 and 2 respectively. Note the effects on the acidic raffinate of the calcite dissolution in the composite tailings soil column. The pH of the effluent solution finally fell to that of the influent after 17 column volumes of throughput. The resident terrace soil shown in Figure 2 was apparently buffered at a pH of approximately eight and kept the pH of the effluent at this value for the 38 column volumes passed through the resident terrace soil.

All effluents for both columns yielded background values when corrected for daughter product (radon-^{214}Pb) contributions to the radium gamma peak. Breakthrough of radium was not attained, and could not be expected before many more than 38 column volumes were loaded on the two soils. Both soils gave very high radium distribution coefficients.

The uranium loading curve complications caused by the uranium already present in the soils are seen in Figures 3 and 4 for composite tailings and resident terrace soils, respectively.

The presence of calcite or limestone in the composite tailings soil put an additional jog in the uranium curve seen in Figure 3, probably due to pH effects of limestone dissolution on the influent solution. The effluent solution uranium content approaches that of the influent solution only after 30 column volumes of synthetic acidic raffinate solution were passed through the column. At this point the column can be considered loaded with uranium, or at near-equilibrium with the influent solution, equilibrium being approached from the direction of overloading rather than the usual loading direction.

The resident terrace soil column also leached uranium, as seen in Figure 4, although not as much as the composite tailings soil. At about 28 column volumes, the column effluent contains very little uranium. This means that the soil has begun adsorbing

FIGURE 1. VARIATION IN pH WITH THROUGHPUT OF SYNTHETIC ACIDIC RAFFINATE SOLUTION THROUGH COMPOSITE TAILINGS SOIL.

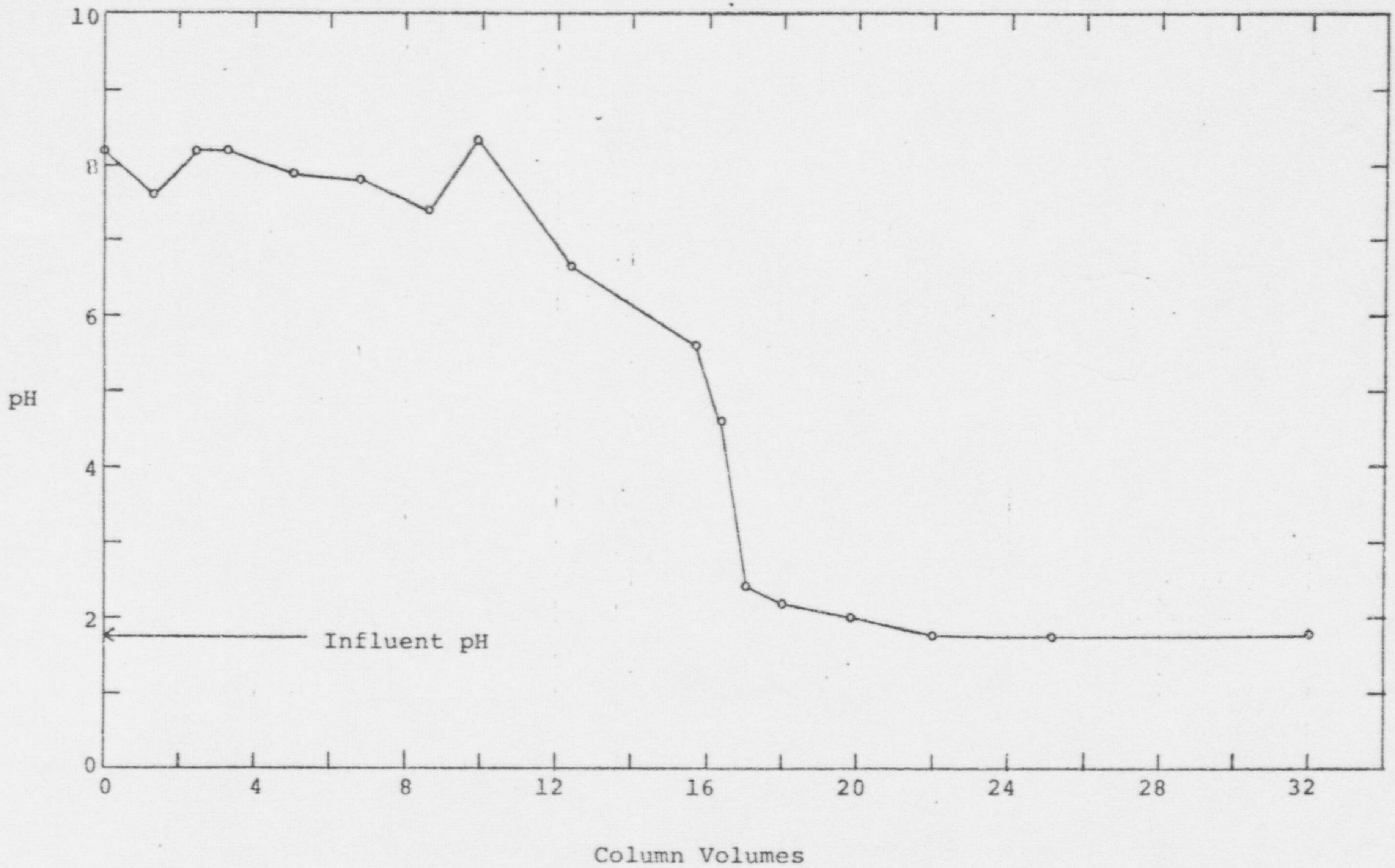

FIGURE 2. VARIATION IN pH WITH THROUGHPUT OF SYNTHETIC COLORADO RIVER WATER THROUGH RESIDENT TERRACE SOIL.

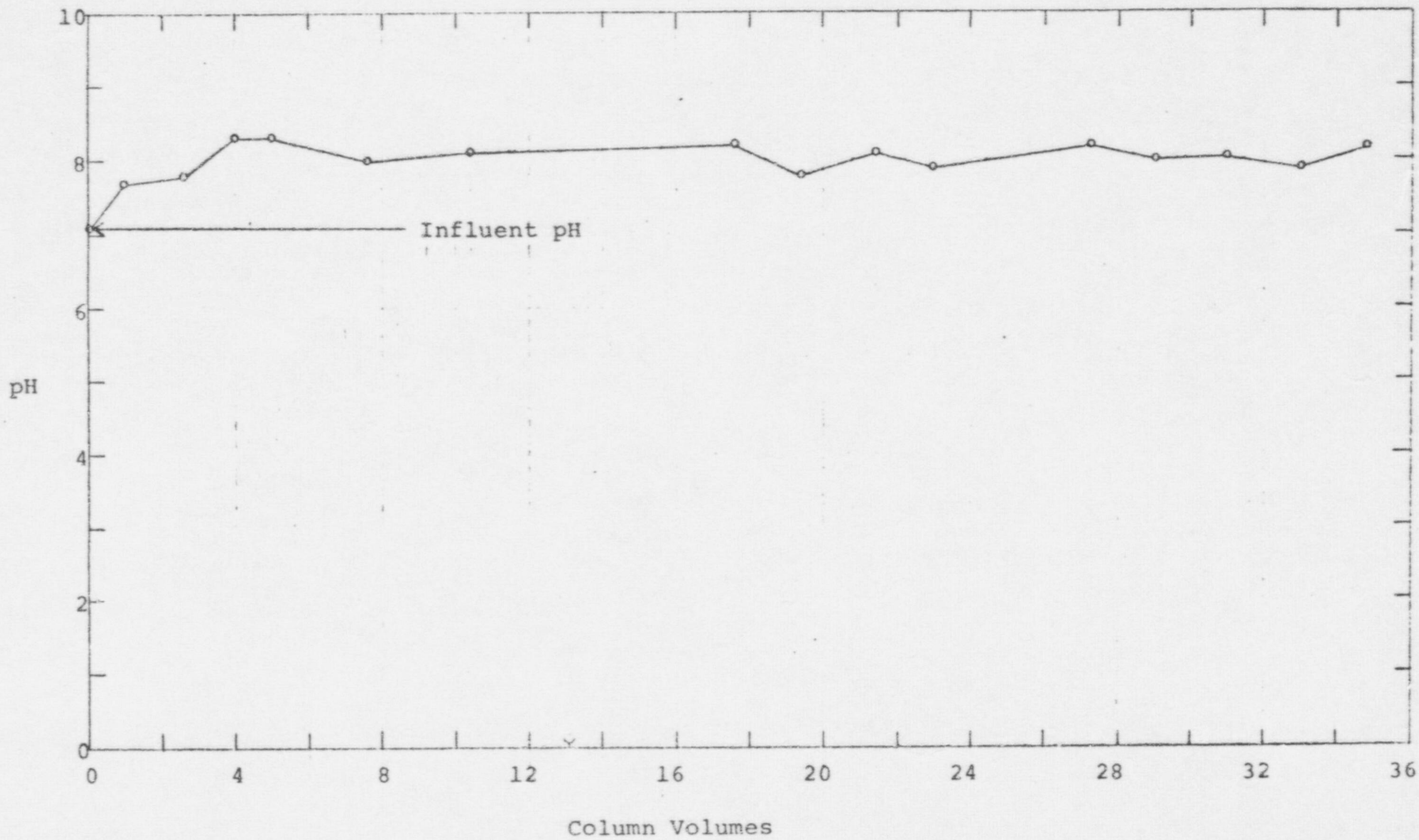

FIGURE 3. URANIUM CONCENTRATIONS IN THE EFFLUENTS FROM THE COMPOSITE TAILINGS SOIL COLUMN WITH ACIDIC RAFFINATE SOLUTION AS INFLUENT.

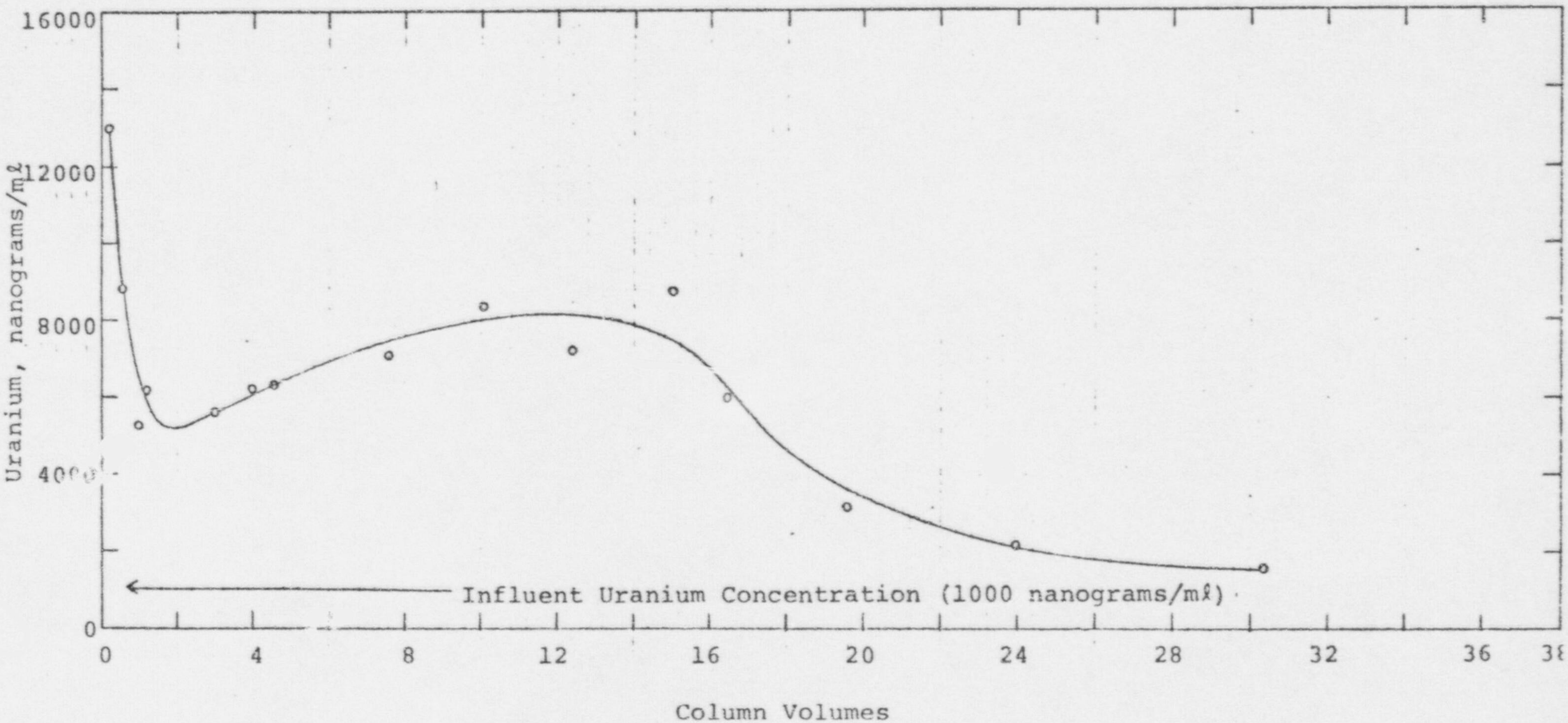

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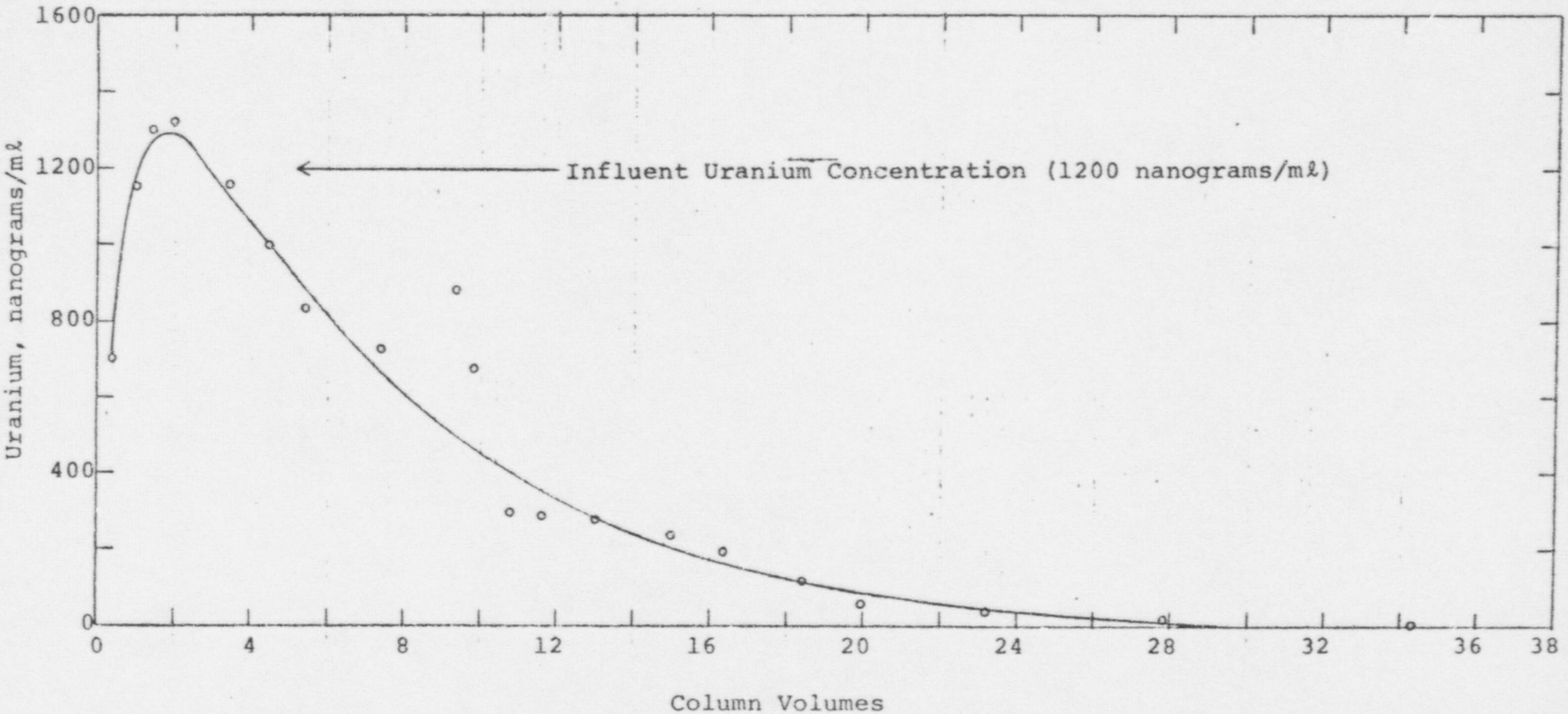
FIGURE 4. URANIUM CONCENTRATIONS IN THE EFFLUENTS FROM THE RESIDENT TERRACE SOIL COLUMN WITH SYNTHETIC COLORADO RIVER WATER AS INFLUENT.



most of the uranium in the influent solution and is no longer leaching uranium already present in the soil. The uranium distribution coefficient range obtained for the resident terrace soil in Table IV is 10.4 to 17. The very low uranium breakthrough at 32 column volumes shown in Figure 4 suggests that the uranium distribution coefficient values of 10.4 to 17 are too low for resident terrace soil. This would be expected if the soil contains uranium that is in a form readily-leached into the equilibrating solution. The composite tailings soil, for example, yields an apparent negative uranium distribution coefficient, releasing more uranium into the solution than it contained originally. Even a small amount of soluble uranium in a soil makes the uranium distribution coefficient suspect.

APPENDIX C

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APPENDIX D

Questions to Atlas Minerals Addressed to Environmental Report for Uranium Mill by the Atomic Energy Commission

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

L:TS:LSP
Docket No. 40-3453

JAN 25 1974

Atlas Minerals Inc.
ATTN: Mr. W. T. Badger
General Superintendent
Moab, Utah 84532

Gentlemen:

This letter is to advise you that we have completed a preliminary review of the environmental report submitted on August 31, 1973 by Atlas Minerals Inc. entitled "Environmental Report, Moab, Utah Facility." Based on this review, however, the staff has determined that additional information is needed in order to make a finding whether or not an environmental impact statement will be required. Specifically, Sections 2, 3, 4, 5, 6, and 11 are inadequate for purposes of detailed review and must be supplemented before a complete appraisal can be made by AEC Regulatory Staff.

Enclosed with this letter is a list of questions, "Questions to Atlas Minerals Addressed to Environmental Report for Uranium Mill," directed at specific inadequacies in the several sections of the subject report. Under separate cover we are sending you three documents; two of which are Supplement to "Applicant's Environmental Report Operating License Stage," and "Supplemental Environmental Information," both concerning milling operations of Utah International, Inc., Shirley Basin Uranium Mill, Shirley Basin, Wyoming. These two documents show generally acceptable format and content for addressing questions such as those attached. The third document is the Draft Environmental Statement related to the Exxon Nuclear Company Mixed Oxide Fabrication Plant which should be useful as an example of an acceptable Benefit-Cost Section.

In order for us to meet our schedule for review and completion of an environmental appraisal, it will be necessary for us to have your answers to the attached list of questions by March 18, 1974. If for any reason you find that this date cannot be met, please contact Mr. LeRoy Person of this office (telephone (301) #973-7631) and inform him of your expected date of completion.

Sincerely,

R. B. Chitwood, Chief
Technical Support Branch
Directorate of Licensing

Enclosure:
As stated

QUESTIONS TO ATLAS MINERALS
ADDRESSED TO ENVIRONMENTAL
REPORT FOR URANIUM MILL

Environmental Report Reference	Topic and Question or Requirement
Appendix A, p.p. 7 -	1) In the description of the starter dikes the material used is described and the method of compaction described. The lack of test compaction data and the apparent total lack of compaction control makes these starter dikes of questionable reliability. The cohensive and frictional values used in the stability analyses are not described nor is there adequate test data to establish any confidence in the factors of safety described in the report. Additional stability analyses should be conducted on more cross sections using validified test data. Additional test data should be furnished to support the analyses.
Section 3.3.4 Table 3.10 -	2) What is the rate of particulate emissions from the yellow cake dryer, for this unit only! What was throughput when this rate was measured?
Section 3.3.4 Table 3.10 -	3) What is the rate of particulate emissions from the Crushing Plant West Dust Collector, for this collector only! What was throughput when rate was measured?
Section 3.3.4 Table 3.10 -	4) What is the rate of particulate emissions from the fine ore storage bin dust collector, for this collector only! What was the throughput when rate was measured?

Environmental Report Reference	Topic and Question or Requirement
Section 2.0 Figure 2.11 -	5) "Results of Atlas Soil Sampling Survey." Fxplain the unit mrem/hr. i.e., Is there a biological effect associated with this term? Could it really mean mrad/hr?
Section 3.0 Figure 3.1 -	6) Your Mill Plot Plan shows the old facility before modification. Please submit a plot plan showing location of new systems.
Section 3.3.4.2 Table 3.11 -	7) In reference to the dust collectors stack sampling, what is the throughput on Feb. 28, 1973.
Section 3.2 -	8) Send flow sheet of proposed mill processes showing the addition of all chemicals into the mill circuit at all points along the flow sheet. Also show how this leads to a materials balance at the tailing pond after all effluents are accounted for.
Appendix A -	9) The construction of embankment from the tailings offers a minimum of compaction effort. The relative density of the coarse tailings was reported to range from 56 to 63 percent. The above values are not conservative. To ensure against liquefaction the minimum relative density should be 85 percent. Give a discussion on the possibility of piping through the embankment or the foundation.
Appendix A -	10) The cover material which is used to protect the embankment is not adequately described. Discuss size distribution and durability of the material.

Environmental Report Reference	Topic and Question or Requirement
Appendix A, -	11) The dike around the tailings pond can be broken up into five different embankment configurations. These sections vary in length from 600 to 2600 feet. In order to determine the foundation conditions only one cross section was established for each of the sections. Considering the length of each of the embankments, it is our opinion that the foundation conditions and the embankment materials can not be adequately described with only seven borings.
Appendix A, p.p. 5 -	12) Provide a tabulation of all the ground water level and assay data. Included therein should be location of measurement, date and time of measurements, the evaluations at which assay samples were collected, water evaluations, and chemical and radiological analyses results.
Appendix A -	13) The Dames and Moore Report refers to monitor wells. It is not clear, however, whether water level and assay of all the piezometers referenced is continuing, and for what duration. Please explain.
Appendix A, p.p. 2 -	14) Show the location of the discharge line referred to on page 6 of Appendix A.
Appendix A, Figure 2 -	15) Provide a description, including sketches, of the discharge facilities of the decant lines. Please explain the purpose of the basin area noted in the southern corner of the tailings pond dike.

Environmental Report Reference	Topic and Question or Requirement
Appendix A, p.p. 8 -	16) Discuss the capability of the embankment to resist erosion from normal operation of the decant facilities, and in the event of a failure of any decant or discharge line. Include a discussion of any maintenance and inspection program of the siltstone cover layer referred to on page 8.
Appendix A, p.p. 10, 11 -	17) Under the proposed recycling of tailings discharge water, provide your analysis of the maximum chemical and radiological concentrations that would occur in the tailings pond, in ground water discharge to the Colorado River, and at the closest river intake. Present the bases for your estimates.
Appendix A, B, p.p. 12, B-3 -	18) Provide the basis for your estimates of an average seepage loss of 75 gpm, and the basis for the estimate of less than half that rate for the proposed modifications, including the effects of substantially increased water levels. Discuss the sources of your precipitation data and the potential errors in your water balance estimates due to differences in periods used for evaporation and precipitation, and pond discharge. Also, please clarify whether the average monthly intake to the plant includes makeup, and discuss the basis for each parameter used.
Appendix A, p.p. 12, 15 -	19) What provisions will be incorporated to prevent water from being closer than 250 feet of the uppermost dike.

Environmental Report Reference	Topic and Question or Requirement
Dames and Moore Report -	20) Your Dames and Moore Report contains several recommendations for modifications of the pond. Is it your intention to incorporate all such recommendations? Please discuss.
General -	21) Your assay of ground water should also include chemical analyses of those constituents involved in your operation, including sanitary wastes. Please provide your program to collect such information, and indicate when you can present preliminary results therefrom to provide a basis for determining effluent concentrations which may reach the Colorado River and/or remain in the ground water.
General -	22) The ion exchange taking place at at present may at least partially account for lower downgradient concentrations. However, long-term application of this inherent capability has been known to reach a maximum. With the proposed change in operation that will result in increased concentrations, provide your analyses (including basis) for the long-term ground water concentrations to be expected in the Colorado River, and/or which may remain in the ground water.
General -	23) We cannot agree with your conclusion that floods from Moab Canyon Wash or the Colorado River cannot constitute a threat to the tailings area without further substantiation, including estimates of probable maximum flood

Environmental Report Reference	Topic and Question or Requirement
General (Cont'd)	23) discharges for the two streams and your analysis of the channel velocities and velocities on the tailings dike that would occur. Provide the basis for your estimates, including a minimum of two cross sections of each stream and contiguous flood plain, and discuss the ability of the tailings dike and channel banks to resist such occurrences. Each event on each stream should be considered separately.
General -	24) Your process of daily observing water levels in the tailings pond and, if necessary, adjusting effluent levels appears not to offer adequate assurance that excessively high water levels cannot occur. We will require automatic level control. Please provide your plan for implementing such a requirement, including what provisions you will make for such arrangements with expansion of the tailings pond.
Section 2.9.3 Table 2.4 -	25) Being as quantitative as possible, show why the table indicates a decrease in uranium dust concentration for the years 1968-1972. Also give the average operating tonnage per day for each of the five years listed in the table as well as the grade of ore for each average.
Section 2.9.3 Table 2.4 -	26) What do you estimate your operating tonnage will be when the acid leach circuit is operable (tons/day)?

Environmental Report Reference		Topic and Question or Requirement
Cost-Benefit section -	27)	The Cost-Benefit section of your report is inadequate. Enclosed for your convenience is a copy of the Draft Environmental Statement for the Exxon Nuclear Company's Mixed Oxide Fabrication Plant. Although your facility is different, this draft statement contains an acceptable cost-benefit section and should be helpful in formulating your own.