TAILINGS STORAGE AND EVAPORATION POND EVALUATION
LONG PARK AND PARADOX VALLEY SITES
URAVAN URANIUM MILL
MONTROSE COUNTY, COLORADO
FOR UNION CARBIDE CORPORATION

DAMES & MOORE JOB No. 00822-138-06
SALT LAKE CITY, UTAH
MAY 23, 1980

8007220049

16593

ANCHORAGE
ATLANTA
BILLINGS
BOCA RATON
BOSTON
CHICAGO
CINCINNATI
CRANFORD
DENVER
FAIRBANKS
HONOLULU
HOUSTON
LEXINGTON, KY

LOS ANGELES
NEW ORLEANS
NEWPORT BEACH
NEW YORK
PHOENIX
PORTLAND
SALT LAKE CITY
SAN FRANCISCO
SANTA BARBARA
SEATTLE
SYRACUSE
WASHINGTON, D.C.
WHITE PLAINS

DAMES & MOORE

CONSULTANTS IN THE ENVIRONMENTAL AND APPLIED EARTH SCIENCES

ATHENS
JAKARTA
KUWAIT
LONDON
MADRID
MELBOURNE
PERTH

RIYADH
SINGAPORE
SYDNEY
TEHRAN
TOKYO
TORONTO
VANCOUVER

SUITE 200, 250 EAST BROADWAY · SALT LAKE CITY, UTAH 84111 · (801) 521-9255
CABLE: DAMEMORE TWX: 910-925-5692

May 23, 1980

Union Carbide Corporation
Metal Division
137 47th Street
Niagara Falls, New York 14302

Attention: Dr. Jack Kagetsu

Gentlemen:

This letter transmits 35 copies of our report entitled "Tailings Storage and Evaporation Pond Evaluation, Long Park and Paradox Valley Sites, Uravan Uranium Mill, Montrose County, Colorado, for Union Carbide Corporation."

Preliminary findings and conclusions were presented and discussed with Dr. Kagetsu and members of the engineering staff in several meetings and telephone conversations throughout the course of study.

It has been a pleasure to assist you in this project. If you have any questions or if we can be of service during the review process, please call us.

Very truly yours,

DAMES & MOORE

James R. Boddy

James R. Boddy
Project Manager

JRB/ll

cc: Mr. Jack Frost - Union Carbide (1)
Mr. Pete Rekemeyer - Union Carbide (1)

TABLE OF CONTENTS

Note: A detailed Table of Contents, List of Tables and List of Plates appear at the front of each appendix.

LIST OF TABLES

LIST OF PLATES

SUMMARY

This study presents alternatives and preliminary design concepts for tailings disposal and effluent evaporation ponds for the Uravan mill. It is anticipated the mill will have a design life of 17 years and the future design daily throughput of the mill will remain at the present rate of 1,500 dry tons per day.

Three major groups of options were evaluated: 1) filtered tailings impounded at a new site; 2) the construction of a new mill effluent evaporation pond; and 3) a combination of the filtered tailings impoundment and mill effluent evaporation pond system located at a new site. The scope of the study has generally been limited to evaluation of alternatives that include Long Park and Paradox Valley as possible new tailings impoundment and/or evaporation pond sites. Detailed discussions of site development options for Long Park are presented in this report. Because of adverse geologic conditions found within Paradox Valley the discussions pertaining to the Paradox Valley sites are less detailed.

It has been assumed for this study that a filtration system will be used in the mill circuit, resulting in the tailings leaving the mill at a moisture content of 25 percent. Thus, the tailings may be transported to the selected site by means of truck haulage. The mill effluent, estimated at about 510 gpm, will be transported to the new proposed evaporation pond system by pipeline.

Long Park - The Long Park site is located about 5 miles from Uravan, 9.7 miles via the Long Park county road. The site is a relatively flat upland basin sloping toward the northeast at a grade of about 4 percent with a drainage area of about 1.8 square miles. The average elevation of the site is about 6,300 feet, approximately 900 feet higher than the mill area. There are about 6 to 25 feet of alluvial soil cover overlying about 6 to 10 feet of highly weathered claystone and siltstone. This stratum is somewhat thicker to the northeast. A closely jointed sandstone underlies the siltstone and claystone. No ground water exists in the upper 100 feet except for some perched water in the southwest corner of the site. Existing mineral properties, mine workings and numerous drill holes are located throughout Long Park. Most mine workings are in excess of 100 feet below the surface. Shafts and adits would have to be plugged in order to develop the site.

Six options for the tailings disposal and/or evaporation ponds have been developed for the Long Park site. These options are listed as follows:

Option 1 - Complete below-grade burial of tailings in the central portion of Long Park (Plate 6).

Option 2 - Partial burial of tailings on the west side of Long Park (Plate 7).

Option 3 - Partial burial of tailings on the east side of Long Park (Plate 8).

Option 4 - An evaporation pond composed of a single reservoir to impound effluent located in the central portion of Long Park (Plate 9).

Option 5 - An evaporation system of a series of low embankments within Long Park (Plate 10).

Option 6 - A combination of an evaporation pond and a tailings impoundment system (Plate 11).

The options included in the filtered tailings impoundment system at Long Park include the construction of 9.7 miles of improved roadway, generally following the alignment of the Long Park county road. A 24-foot wide road would be paved with 5 inches of asphalt overlying 8 inches of select granular base course all placed on existing subgrade soils. A truck and pup combination having a 114,000 pound GVW is proposed for haulage. It is anticipated that 5 trucks would be hauling at two shifts per day.

Low seepage is expected below the tailings impoundment area. Since the tailings are deposited in a low moisture condition, only 62.5 gpm of water is entering the impoundment. As a result of 1) the characteristics of the tailings to retain some of the water in their natural state and 2) evaporation occurring in the near-surface deposited tailings, overall seepage losses will be much less than the amounts of the water inputted with the tailings.

It should be noted that site development concepts for new tailings impoundment consider only the utilization of conventional earthwork equipment for construction. It is anticipated that excavation into the competent sandstone bedrock in excess of five feet would require blasting. Since the bedrock is quite near the surface over the site, the option considering complete burial of the tailings will be limited to shallow trenches (10 to 20 feet deep). Thus, to develop an impoundment for 17 years of operation, a large site area of about 350 acres will be required. Such a large-area site development does not permit complete isolation of the impoundment within the Long Park site. As presently conceptualized the impoundment will cover all the relatively flatter areas within Long Park. The existing county road which passes through Long Park will thus pass through the impoundment area. Some roadway realignment will be requ d. Further, the tailings deposition in a large area impoundment will exhalt a higher amount of radon than that of a smaller impoundment when considering the areas to have equal protective covering.

In order to limit quantities of earthwork involved with the development of a complete burial option, it is assumed that the final reclamation grade would be approximately parallel to the present surface grade at Long Park (about 4 percent). Without long-term erosion protection, runoff over such a grade could cause serious channeling of the silty reclamation cover.

Thus, for environmental, design, and economic considerations, two additional options were evaluated for partial burial systems with the objectives of improving the above discussed shortcomings of the complete burial option as well as conforming with the performance objectives required by the NRC.

Long Park-Option 2, the layout and typical cross section of which are shown on Plates 7 and 14, respectively, appear to be the most advantageous. Option 2 consists of a 175-acre area located against the hillside along the northwestern boundary of Long Park. The average excavation depth within the impoundment will be on the order of 10 to 15 feet (20 feet maximum). An embankment with a maximum height on the order of 50 feet would be constructed along the east side of the impoundment. Diversion channels would re-route flood water during the operating life. Reclamation would include an adequate cover and sideslopes no steeper than 5H:1V.

The advantages of Option 2 include the fact that excavation and reclamation cover quantities required to develop Option 2 are considerably less than for any of the other options. Further, because of its location within the Long Park area the Option 2 site is 1) the most isolated from wind, 2) the most remote site within Long Park, 3) has the smallest of the rainfall catchment areas for any of the options, and 4) is such that the final reclamation cover may be placed at very mild surface grades, thus reducing erosion potential. Based on the above Option 2 is the most attractive site.

When considering the evaporation pond options at Long Park, the most advantageous system would be Option 5 - multiple evaporation pond system (Plate 10). This system includes a series of low embankments to contain 10 clay-lined evaporation ponds over an area of about 350 acres. The system includes the construction of 9.7 miles of pipeline from the mill to Long Park. The major advantage of this system when compared with the other system at Long Park (single-reservoir storage) is the operational and safety options associated with being allowed to adjust inflows and levels of any of the ponds on an individual basis. Option 5 requires more embankment fill and construction is less economical. Option 5 evaporation pond layout does not consider space for a tailings impoundment area at Long Park.

Option 6, the option whereby an evaporation pond system and a tailings impoundment area would both be constructed at Long Park is shown on Plate 11. A multiple-pond evaporation system would be constructed on the west side of Long Park while the dry tailings would be placed in an impoundment on the east side. Diversion channels would re-route flood water during the design life.

Paradox Valley - Three separate sites, referred to as Paradox 1, 2 and 3 as shown on Plate 1, were considered in Paradox Valley. Paradox 1 and 2 are 1,000-acre sites on either side of the Dolores River and are located near the northern escarpment of the valley. The sites grade to the south-southwest at about 5 percent. Near-surface gypsum deposits are present at the south end of the sites. Toward the north, alluvial soil exists up to depths exceeding 45 feet and overlies sandstone and limestone. The Paradox 3 site is located at the southeast end of the valley. The area has deposits of granular alluvial soils up to about 35 feet thick. The Mancos shale underlying the soil varies in thickness from about 5 to 40 feet. Dakota sandstone underlies the shale.

In regard to the Paradox Valley sites, of major concern are the numerous faults found to be associated with the ongoing salt deformation and/or collapse of the anticline in the valley. These faults are considered active, although not capable of generating earthquake forces. Surface ruptures to either clay liners or reclamation covers must be considered as possible detrimental effects to the long-term stability of tailings containment areas.

* * *

The final selection of a tailings and mill effluent disposal system must involve the consideration of economics, operational feasibility, possible interfacing and/or interference with ongoing mining operations, safety, environmental effects and regulatory positions. Of the tailings disposal options considered, as stated previously, Long Park - Option 2 is the most advantageous.

TAILINGS STORAGE AND EVAPORATION POND EVALUATION
LONG PARK AND PARADOX VALLEY SITES
URAVAN URANIUM MILL
MONTROSE COUNTY, COLORADO
FOR
UNION CARBIDE CORPORATION

INTRODUCTION

This report presents the results of our evaluation of the tailings disposal and effluent evaporation pond options at the Long Park and Paradox Valley sites for Union Carbide's Uravan uranium mill in Montrose County, Colorado. The report evaluates alternatives to the continued deposition of tailings into the existing tailings ponds located at the mill by investigating options that consider the haulage of dewatered tailings to either the Long Park site or one of three sites at Paradox Valley. The locations of the sites with respect to surrounding surface features are shown on Plate 1, Vicinity Map. The specific sites studied are shown in more detail on Plates 2 through 5, Plot Plans.

This work was authorized verbally on February 20, 1980 by Dr. Jack Kagetsu of Union Carbide Corporation and was performed under Union Carbide's Contract No. EC 615 5230.

PURPOSE AND SCOPE

The purpose of this study was to perform a geotechnical evaluation of various options for the haulage and disposal of dewatered tailings and for the evaporation of mill effluent at sites within the Long Park and Paradox Valley areas.

The disposal sites evaluated were limited to four sites; one site at Long Park, two in the central area of Paradox Valley (Paradox 1 and 2 sites), and one at southeast end of Paradox Valley (Paradox 3 site).

In accomplishing this purpose, the following scope of work was performed:

1. Review available information on potential sites in 1) the central area of Paradox Valley, 2) in Long Park, and 3) in the southeast end of Paradox Valley. This work includes:
    a. Collection of general land use geologic, seismologic, and hydrologic information.
    b. Determination of haulage distance and relative haulage costs.
    c. A reconnaissance of the area by key study personnel.
    d. Comparative evaluation of each site considering general site amenability, and proximity to borrow areas.
    e. Meetings with Union Carbide representatives to determine selection of site location for further evaluation.
2. Perform a geotechnical field program that includes:
    a. The drilling, logging, and sampling of 17 borings within the site areas. Drilling 7 borings at Long Park; 2 at the Paradox 2 site; and 8 at the Paradox 3 site.
    b. Conducting 18 packer tests and 1 slug test; 8 packer tests at Long Park, 3 at Paradox 2, and 7 at Paradox 3. Also, performing 1 slug test at Paradox 3.
    c. Installing 3 piezometers at Long Park and 4 at Paradox 3.
    d. Excavating a total of 30 test pits in conjunction with the site investigations at Long Park and Paradox Valley.
    e. Conducting a reconnaissance of the general area to identify and sample potential off-site borrow material for liners, drains, riprap and road construction.
3. Conduct a laboratory program consisting of gradation, Atterberg limits, compaction, permeability, moisture and density, consolidation, compression strength, and water quality testing.

4. Perform engineering analyses consisting of:

    a. Evaluating site factors which include geologic, seismologic and hydrologic conditions.

    b. Determining configuration, embankment design concepts, cut slope angles, etc. of tailings disposal and effluent pond alternatives.

    c. Lining, underdrain, or dewatering design concepts, if required.

    d. Reclamation cover and stabilization conceptual considerations.

    e. Evaporation pond and tailings impoundment size, depth, dimensions and internal diking determinations.

    f. Pond embankment design concepts.

    g. Pond lining requirements and design concepts.

    h. Concepts related to the sequence of excavation, pit preparation, disposal, covering, and reclamation of pits during the life of the operation.

    i. Determining earthwork quantities.

    j. Conceptualizing truck unloading operations and means of distribution of tailings throughout the impoundment.

    k. Evaluating tailings haulage concepts which includes selection of truck haulage equipment, preparation of pavement design, determination of earthwork and pavement quantities and the evaluation of road reclamation requirements.

    l. Evaluating a pipeline system for the transport of mill effluent.

5. Prepare this summary report.

TAILINGS DISPOSAL AND MANAGMENT OBJECTIVES

The design of tailings impoundments for the Uravan mill will be governed to a large degree by the State of Colorado Department of Health. Further, the state requirements will be in close accordance with the regulations, guidelines, and branch positions of the Nuclear Regulatory Commission. The NRC's draft Generic Environmental Impact Statement (GEIS) (USNRC, 1979) and proposed amendments to 10CFR40 (U.S. Federal Register, 1979) identify regulatory actions to be taken in order to ensure that the uranium mill operations and mill tailings disposal are carried out in a safe and environmentally sound manner. In the GEIS, technical siting and design requirements are given, the objectives of which pertain to long-term stability of tailings isolation, direct and airborne radioactive emissions tailings disposal covering, seepage of toxic materials, and emissions control during operations and isolation of tailings.

As stated as part of these performance objectives:

> The "prime option" for disposal of tailings is placement below-grade, either in mines or specially excavated pits. The evaluation of alternative sites and disposal methods performed by mill operators in support of their proposed tailings disposal program (provided in applicant environmental reports) should reflect this. In some instances, below-grade disposal may not be the most environmentally sound approach, such as might be the case if a high quality ground water formation is relatively close to the surface or not very well isolated by overlying soils and rock. Also, geologic and topographic conditions might make full, below-grade burial impracticable; for example, bedrock may be sufficiently near-surface that blasting would be required to excavate a disposal pit at excessive cost, and more suitable alternate sites are not available. In these cases, it must be demonstrated that an above-grade disposal program will provide reasonably equivalent isolation of the tailings from natural erosional forces.
>
> If tailings are disposed of above ground, the following siting and design criteria should be adhered to:
>
> a. Upstream rainfall catchment areas should be minimized so as to decrease the size of the maximum possible flood which could erode or wash out sections of the tailings disposal area.

b. Topographic features should provide good protection from the wind.

c. Embankment slopes should be relatively flat after abandonment so as to minimize erosion potential and to provide conservative factors of safety assuring long-term stability and isolation. The broad objective should be to contour final slopes to grade which are as close as possible to those which would be provided if tailings were disposed of below grade; this would, for example, lead to slopes of about 10 horizontal to 1 vertical (10H:1V) or less steep. In general, slopes should not be steeper than about 5H:1V. Where steeper slopes are proposed, reasons why a slope less steep than 5H:1V would be impracticable should be provided, and compensating factors and conditions which make such slopes acceptable should be identified.

d. A full, self-sustaining vegetative cover should be established or riprap employed to retard wind and water erosion. Special concern should be given to slopes of embankments.

e. The impoundment should not be located near a potentially active fault where an earthquake could result in a ground acceleration exceeding that which the impoundment could reasonably be expected to withstand.

f. The impoundment, where feasible, should be designed to incorporate features which will promote deposition. For example, design features which promote deposition of sediment suspended in any runoff which flows into the impoundment area might be utilized; the objective of such a design feature would be to enhance the thickness of cover over time.

It is the intent of this study to present design concepts for tailings and effluent impoundment in accordance with these above-referenced performance objectives.

GENERAL PROJECT DESCRIPTION

The major elements of the Uravan operation are described in the Environmental Report (Union Carbide, 1978). At present, the mill has a design process capacity of 1,500 dry tons of ore per calendar day. The remaining design life of the mill is 17 years, with an anticipated annual tailings disposal rate of 547,000 dry tons per year (9.3 million tons of of tailings over the design life).

For the purposes of this study, tailings will be transported from the mill area in a filtered or dewatered, condition. Filters will be used so that the moisture of the tailings will be reduced to a level that will allow this disposal in unlined impoundment areas. It is anticipated that the tailings produced by this process will have a moisture content upon leaving the mill of approximately 25 percent. A report by Dames & Moore dated January 5, 1979 titled "Handling and Placement Characteristics, Belt-Filtered Tailings, Uravan Uranium Mill" reported the following testing results of the tailings.

LABORATORY TEST RESULTS OF DRY TAILINGS

Property	Results
Initial moisture content	22.6 - 35.7% (two samples)
Percent fines (minus #200 sieve)	23.5%
Permeability	1.7 ft/yr (at relative density of 80%)
	2.9 ft/yr (at relative density of 40%)

In addition to the tailings, liquid effluent from the mill will be a maximum of about 510 gpm. This effluent will be transported from the mill by pipeline to lined evaporation ponds.

Design parameters in addition to those presented above for tailings and effluent disposal are presented in the appropriate sections throughout the text of the report.

TAILINGS IMPOUNDMENT AND EVAPORATION POND CONSIDERATIONS AT LONG PARK

SITE CONSIDERATIONS

GENERAL

Site alternatives were evaluated to assess feasibility of the Long Park site for development to: 1) impound filtered tailings; 2) construct mill effluent evaporation ponds; or 3) a combination filtered tailings impoundment-mill effluent evaporation pond system.

Impoundment of filtered tailings was evaluated for the following three alternative storage configurations:

1. Option 1 - Complete below-grade burial of tailings in the central portion of the site (see Plate 6).

2. Option 2 - Partial burial of tailings on the west side of Long Park (see Plate 7).

3. Option 3 - Partial burial of tailings on the east side of Long Park (see Plate 8).

Two options were evaluated for site development exclusively as an evaporation pond area. These options are as follows:

1. Option 4 - A single reservoir impounded by a single dam located in the narrow canyon northeast of Long Park (see Plate 9).

2. Option 5 - A series of lower embankments within Long Park (see Plate 10).

Additionally, a combination evaporation pond-tailings impoundment system (Option 6) was developed (see Plate 11).

In conjuction with the tailings impoundment option, a tailings transportation system would be required. A small truck fleet carrying tailings from the mill to Long Park via an improved existing county road is proposed.

Transporation of mill effluent for evaporation would require the construction of a pipeline system.

The following sections present 1) the surface and subsurface descriptions, 2) a brief discussion of the existing mine workings and, 3) the six options for the aforementioned site development alternatives. Detailed discussions describing the various options addressed are presented in Appendices F and G, Evaporation Pond Evaluations and Evaluation of Tailings Disposal, respectively.

SURFACE SUBSURFACE DESCRIPTION

The Long Park site is an irregular shaped 900-acre parcel of land located approximately five miles south of Uravan, Colorado, as shown on Plate 1, Vicinity Map and in more detail on Plate 2, Plot Plan-Long Park. The site is on a relatively flat high mesa area directly north of Paradox Valley. The site grades generally southwest to northeast at an average grade of about 4 percent, with maximum vertical relief of approximately 120 feet.

Site access is via the unpaved Long Park Road which is county maintained. Several abandoned and active mine workings are present at the surface and in the subsurface at the site. The remainder of the site is open sagebrush-covered upland valley.

The land on which the evaporation pond, and/or tailings impoundment area would be constructed and along which the Long Park road runs is a complex mixture of ownership and jurisdictions including private, BLM and AEC withdrawal land (U.S. Bureau of Land Management, 1975).

The Long Park site is in the headwater region of an unnamed stream that is tributary to the San Miguel River. The site has a small drainage area of approximately 1.8 square miles with natural drainage courses being ephemeral. The high elevations at the site preclude regional flooding, although minor local flooding on the small drainage course is expected.

A thin veneer of Quaternary alluvial deposits ranging from 6 to 25 feet in thickness overlies gently northeast-dipping variegated siltstone, sandstone and claystone of the Jurassic Morrison Formation. No faults are known or suspected to exist at the Long Park site. Individual bed thicknesses range from 1 or 2 feet to beds in excess of 30 feet. Generally, the upper 6 to 10 feet of bedrock are closely jointed, highly weathered siltstone and claystone of the Brushy Basin Member of the Morrison Formation. The Brushy Basin Member is underlain by the Salt Wash Member of the Morrison Formation which consists primarily of slightly weathered, closely jointed sandstone.

On the basis of field tests, the permeability of the underlying rock strata at the sites investigated is moderately high. The rock units near the surface are highly fractured and jointed which results in a secondary permeability which is essentially independent of rock types.

Perched ground water was encountered in the southwest portion of the site. The remainder of the site was dry to the depths investigated. There were no water wells on record within the project area or its vicinity.

A detailed graphical representation of the subsurface conditions as encountered in the exploration borings and test pits conducted for this study is presented in Appendix C, Geotechnical Investigation. Additional discussion of the geology is presented in Appendix A, Geology and Seismicity.

EXISTING MINE WORKINGS

Existing mineral properties, mine workings and numerous drill holes are located throughout Long Park. Shafts and adits would have to be adequately sealed, and mining below the facilities would not likely be possible. Most mine workings are reportedly at depths of 100 feet or more and it has been assumed that those would not have to be backfilled. However, those workings would have to be monitored for seepage and surface subsidence, and any contaminated seepage would be removed by pumping. It is estimated that 12 to 18 shafts and adits presently exist throughout the entire Long Park area.

TAILINGS IMPOUNDMENT OPTIONS

GENERAL

The tailings impoundment options discussed in the succeeding section were evaluated and compared during this study in an effort to select the most feasible method of impoundment. Filters will be used in the mill circuit and will result in the tailings leaving the mill at a moisture content of about 25 percent. The tailings will be transported to the impoundment in their dewatered condition by using a truck haul system. Both complete and partial burial of tailings were considered.

Site development concepts consider the utilization of conventional earthwork equipment for construction. It is anticipated that excavation into the competent sandstone bedrocks in excess of five feet would require blasting. Since the bedrock is quite near the surface over the site area, the option considering complete burial of the tailings will be limited to shallow trenches (10 to 20 feet deep). Thus, to develop an impoundment for 17 years of operation, a large site area of about 350 acres will be required. Such a large-area site development does not permit complete isolation of the impoundment within the Long Park site. As presently conceptualized the impoundment will cover all the relatively flatter areas within Long Park. The existing county road which passes through Long Park will thus pass through the impoundment area. Some roadway realignment will be required. Further the tailings deposition in a large area impoundment will exhalt a higher amount of radon than that of a smaller impoundment when considering the areas to have equal protective covering.

In order to limit quantities of earthwork involved with the development of a complete burial option, it is assumed that the final reclamation grade would be approximately parallel to the present surface grade at Long Park (about 4 percent). Without long-term erosion protection, runoff over such a grade could cause serious channeling of the silty reclamation cover.

Thus, for environmental, design, and economic considerations, two additional options were evaluated for partial burial systems with the objectives of improving the above discussed shortcomings of the complete burial option as well as conforming with the performance objectives stated in the previous section entitled TAILINGS DISPOSAL AND MANAGEMENT OBJECTIVES.

The following sections present general discussion of the tailings haulage system, tailings impoundment and detailed summaries of the proposed impoundment options.

TAILINGS HAULAGE SYSTEM

Site access from the mill will be provided via a partially realigned and improved existing county road (Long Park Road). Road improvement will involve the construction of a 24-foot wide paved roadway consisting of a five-inch bituminous asphalt wearing surface overlying 8.0 inches of select granular base course material placed on prepared existing subgrade soils. Some amount of realignment of the existing centerline will be required as some of the existing roadway has small radius turns. The proposed route of the roadway is shown on Plate 12, Haul Road and Alternative Pipeline Routes.

Based on economic considerations, a truck and pup combination having a gross vehicle weight (GVW) of 114,000 pounds is proposed for haulage of the filtered tailings.

For the options considering total burial, tailings will be end-dumped from access roads developed along the sides of the trench. For options considering partial burial, initially the tailings will be end-dumped from roads developed along the embankment crest and afterward from the roads that will be developed on the reclaimed surface as disposal progresses across the impoundment area. Considerations have been given to the time required for the tailings placed to adequately drain and gain the necessary bearing capacity to support 1) the reclamation cover and 2) the roads developed on the reclaimed surface. Spreading and compaction of tailings is anticipated to be performed utilizing conventional wide-track-mounted dozers (Cat D-8, etc.).

TAILINGS IMPOUNDMENT

Since dewatered tailings are to be deposited in the tailings impoundment, it is not intended that the impoundment bottoms be lined. The expensive process of dewatering the tailings achieves the objective of reducing seepage to the maximum extent that is reasonably achievable. Seepage will depend on the content of the water within the near-dry tailings. Since 1,500 tons of tailings with a moisture content of 25 percent will be impounded daily, a total rate of water entering the impoundment is 62.5 gpm. A certain amount of this water will be retained within the tailings material. For a typical fine sand material, assumed to have similar water retention characteristics as the Uravan Tailings, the specific retention is about 20 percent, where the specific retention is defined as the percentage that will be retained against gravity drainage from a saturated material to the total volume of the material. Consequently, after densification through placement equipment and the consolidation of the in-place deposited tailings, about 45 percent of the tailings water is free water and will be allowed to either 1) drain from the deposit into the underlying bedrock or 2) to evaporate at the surface.

The remainder of the liquid will be held by capillary and surface tension forces in the tailings matrix. Infiltration due to rainfall is negligible in comparison with the net quantity of seepage. Therefore, the net long-term quantity of seepage from the tailings disposal area corresponds to approximately 27.9 gpm over a 17-year period. Further discussion of the seepage is presented in Appendix D, Ground Water Hydrology and Seepage Analysis.

Based on the relatively minor seepage expected, low permeability or impermeable liners are not considered necessary for impoundment construction. However, since a majority of the proposed impoundments will have bottoms developed in closely jointed weathered bedrock, conditioning of the surface bottom should be performed by discing, moisture conditioning and subsequently compacting the upper 12 inches of the exposed impoundment bottom to eliminate the potential for tailings migration in otherwise exposed open joints. The average expected permeability of the in-place tailings is about 2×10^{-7} cm/sec.

A conceptual plan for construction of diversion channels for surface water runoff control in the watershed areas of the proposed tailings impoundments at the Long Park site is illustrated on Plates 6, 7 and 8 for Options 1, 2 and 3, respectively. The diversion channels would be abandoned at the end of the milling operations. For each structure, the proposed channel configuration is trapezoidal with bottom width of 20 feet, sideslopes of 2H:1V and average slope of 0.01 ft/ft along its alignment. The hydrologic design basis and conceptual design details for the diversion channels are presented in Appendix E.

Reclamation cover will be developed from proposed cut material located within the impoundment area. The lowermost two feet of reclamation soils immediately overlying tailings will consist of clayey materials developed from the upper several feet of highly weathered shale bedrock exposed within the impoundment site. Additional random soils composed of silty sand, sandy silts and additional clayey soils will be placed to provide additional erosion protection as required by the NRC. Evaluation to determine the minimum thickness of cover necessary were performed and presented in the Uravan Environmental Report (Union Carbide, 1978). Based on the data previously submitted, a two-foot thick cover of clayey material will reduce the radon emission to well below 2 pci/m^2-sec above natural background levels.

Embankment slopes will be graded to provide a final slope not steeper than 5 horizontal to 1 vertical (5H:1V). Self-sustaining vegetation would be established on the reclamation cover for surface grades of two percent or less. Long-term erosion protection of the 5H:1V sideslopes of the embankment will be provided by placement of approximately 12 inches of gravel or rock riprap on the slopes.

Initial embankments required for site development in the options considering partial burial of the tailings would be constructed using upstream slopes of 2H:1V with downstream slopes being constructed 3H:1V. A minimum crest width of 40 feet would be provided for truck access.

Excavations in existing site soils would be constructed with slope ratios of 2H:1V for cuts adjacent to proposed embankments. For the option considering total burial, cuts excavated along the sides of trenches could be constructed 1.50H:1V.

Summaries of specific site design parameters for the various impoundment options are presented on Tables 1A through 1C, Design Parameters for Tailings Impoundment.

OPTIONS CONSIDERED

Option 1 Impoundment in Trenches Below Existing Grade

Filters will be used in the mill circuit resulting in tailings leaving the mill at a moisture content of about 25 percent, and the tailings will be transported from the mill by truck haulage. Impoundment of the dewatered tailings would be in a series of trenches excavated to a shallow depth ranging between 10 and 20 feet depending on a the depth to and thickness of the underlying Brushy Basin shale. Over the site area excavation below the depth of 10 to 20 feet would extend into non-rippable Salt Wash sandstone or Brushy Basin shale and would require blasting. Trenches would generally have a plan dimension of approximately 250 x 2,000 feet. Layout of a proposed 350-acre trench burial system is shown on Plate 6, Tailings Impoundment Alternatives, Long Park-Option 1. A sectional view of Option 1 showing existing topography, proposed final ground trench excavations is shown on Plate 13, Section C-C' - Tailings Impoundment Alternatives, Long Park-Option 1. On the average, each trench will provide tailings storage for between five to ten months of mill production or between 250,000 and 500,000 tons of dry tailings.

Initially, one trench will be constructed with the excavated material being stockpiled for future reclamation use. Subsequent trench excavation would begin sometime after the initiation of tailings placement in the first trench, thereby allowing future excavated materials to be utilized for reclamation of the preceding tailings trench as final storage capacity of tailings is achieved. This excavation and reclamation process would continue throughout site development.

Preliminary estimates of required excavation and reclamation fill quantities indicate that a sufficient quantity of fill soils will be available from proposed cut areas to provide a reclamation cover sufficient to reduce the radon emission to below the $2pci/m^2$-sec above material background levels. In addition, these fill soils will be available for site grading at the perimeters to conform to the surrounding topography and to achieve final slopes of no steeper than 5H:1V. Soils obtained from the shale material at the bottoms of the excavations will be used to provide a two-foot thick reclamation cover required to be placed on top of the tailings. The remainder of the reclamation cover will be composed of random silty fine sands and sandy silts also excavated from the pits.

As stated in the subsection entitled GENERAL within the tailings impoundment options section, the relatively shallow depth to bedrock, and the design condition that the tailings be below grade will require that Option 1 will have a significantly larger parcel of land to be developed for the required impoundment volume than that for either of the two partial burial options. In addition, a substantially larger quantity of excavation and reclamation earthwork is involved. Final reclamation grading will be performed such that the surface contouring will be similar to that of the existing ground surface. Thus, the final grading will result in grades of about 4 percent, and positive erosion protection such as riprap may be required throughout the entire 350-acre tract of land. Flattening of final site grades such that erosion protection would not be required or reduced would involve large amounts of additional earthwork.

Option 2 - Impoundment Located On West Side of Long Park

Impoundment of filtered tailings on the west side of Long Park will involve the development of a 175-acre area of the total site. This impoundment option will take advantage of a natural basin to develop maximum storage in a limited amount of surface area. An average excavation depth of between 10 and 15 feet throughout the site would be required to develop the necessary volume of storage and provide borrow material for the construction of a low embankment required along the east side of the impoundment area, in addition to providing a source for reclamation cover material. The proposed impoundment configuration, developed to provide an estimated 9.3 million tons of tailings storage (17-year design life) is shown on Plate 7, Tailings Impoundment Alternative, Long Park-Option 2. A profile view illustrating the Option 2 impoundment concept is shown on Plate 14, Section B-B', Tailings Impoundment Alternative, Long Park-Option 2.

Overall site development would include the construction of a low embankment along the east boundary of the area.

A possible construction sequence could be developed such that initially diversion channels and a portion of the impoundment bottom area would be excavated and the material used for embankment construction. The excavation in the bottom of the impoundment would be that segment nearest the embankment. After bottom preparation of the area, tailings would be deposited and spread to final elevation. It is anticipated that the exposed tailings slope will be stable at a slope 2.5H:1V. Subsequent excavation of the segment of impoundment bottom adjacent to the first segment would begin sometime after the initial tailings placement in the first deposition segment. This excavated material would be utilized for reclamation of the tailings placed in the first segment. The excavation and reclamation process would continue throughout the site development. The feasibility of this and other construction alternatives would have to be studied in detail at a further date.

Preliminary estimates of required excavation and reclamation fill quantities indicate that a sufficient quantity of fill can be developed from soils excavated within the impoundment area. Should it be determined that more fill soils are required for reclamation, they would be available from either diversion channel excavation or from nearby borrow areas located outside of the impoundment area.

Because of its location within the Long Park area the Option 2 site is 1) the most isolated from wind, 2) the most remote site within Long Park, 3) has the smallest of the rainfall catchment areas for any of the options, and 4) is such that the final reclamation cover may be placed at very mild surface grades, thus reducing erosion potential. Further, Option 2 provides the most economical alternative of the three options discussed for tailings impoundment. Impoundment development could be achieved on 175 acres of land with the least amount of earthwork required for the three options considered. Based on the above Option 2 is the most attractive site.

Option 3 - Impoundment Located on East Side of Long Park

Impoundment of filtered tailings on the east side of Long Park would involve the development of a 205-acre portion of the total Long Park site. This impoundment option would take significant advantage of an existing moderately deep natural basin for development of a majority of the storage volume. Excavation to depths ranging between 10 and 15 feet throughout the site area would be necessary to develop required storage volumes and provide a borrow source for the construction of a low embankment along the western impoundment boundary as well as a source of final reclamation cover. The proposed impoundment configuration as shown on Plate 8, Tailings Impoundment Alernative, Long Park-Option 3, can be developed to provide an estimated 9.3 million dry tons of storage (17-year design life). Proposed site development is shown in profile on Plate 14, Section B-B', Long Park-Option 3.

Site development will involve the construction of an earthen embankment along the west side of the impoundment. Fill materials for embankment construction would be developed from within the impoundment area immediately upstream of the embankment toe. By using a construction sequence similar to that described for Option 2, upon completion of the initial embankment configuration, subsequent required excavation within the impoundment area would provide a continuous supply of soil for reclamation as final tailings grades are achieved.

Preliminary estimates of required excavation and reclamation fill quantities indicate that a sufficient quantity of fill soils will be available from proposed cut areas to provide a reclamation cover atop impounded tailings, including construction of the final embankment configuration using slope ratios of 5[illegible]. The reclamation cover will be of sufficient thickness to reduce the radon emission to below the required 2pci/m^2-sec above natural background levels.

Option 3 requires 205 acres for development as opposed to 175 acres for Option 2. Excavation and reclamation cover quantities required to develop Option 2 are considerably less than for Option 3. However, because Option 2 and Option 3 could both be developed simutaneously at the Long Park site, if the existing tailings now impounded at the Uravan mill need to be moved, a combination of these two options could be considered.

EVAPORATION POND ALTERNATIVES

GENERAL

This section summarizes alternatives for disposal of liquid effluent from the mill by means of evaporation. Major system components are a pipeline system which would approximately follow the county road alignment for the mill to Long Park and an evaporation pond system to be located within Long Park. Two options for design of the pond system were considered: (a) a single reservoir impounded by a single dam located in the narrow canyon northeast of Long Park (Option 4), and (b) a series of lower embankments within Long Park (Option 5). A combination evaporation pond - tailings disposal system (Option 6) is considered in a subsequent section of this report.

A more complete discussion of design considerations, basic data, evaluation methodology and study results is presented in Appendix F, Evaporation Pond Evaluations.

PIPELINE SYSTEM

The pipeline route assumed for this study follows the approximate alignment of the existing county road as shown on Plate 12. Both six-inch and eight-inch diameter piplines were considered. The eight-inch line was selected on the basis of economics. Design parameters and considerations for transport of liquid effluent from the mill are summarized on Table 2. The design is summarized on Table 3.

Construction, operation and reclamation of the required 10-mile pipeline would be a major undertaking with considerable technical and environmental considerations. Significant design considerations include minimizing the potential for accidental release of the liquid effluent due to natural causes, accidents, or vandalism; maintenance of liquid temperatures above 40°F to reduce crystallization within the line; inspection and monitoring of pipeline performance; economic factors; and rights-of-way. The route was selected based upon the following factors:

1. Rights-of-way along the existing county road might be easier to obtain than a route across diverse surface ownership and mineral claims.
2. The route would be highly accessible and avoids major cliffs and canyons.
3. The route is relatively direct.
4. Additional land disturbance would be reduced.

It is felt that a buried line would be best from the standpoint of protection against accidental breakage, vandalism and temperature maintenance. The major drawback with a buried line is that inspection of the condition of the line and monitoring for leaks would be very difficult. Maintenance of temperature in the line during periods of shutdowns would be sufficient for periods of 12 hours, and probably much more, for a buried line. For an above-grade line or for extended subsurface standing lines during very cold weather, insulation would be required. If removal of crystal buildup within the line is needed, a specially designed in-pipe reamer would be required.

A system for collection of accidentally released liquid would likely be required. Such a system could consist of a ditch paralleling the line which leads to lined collection ponds. For short, critical sections a pipe-within-a-pipe could be used in lieu of ditches. Ponds will be needed at the bottom of all low sections to hold the effluent should the line have to be drained. In the event of a line break, some effluent would probably seep into ditch banks and the pond bottoms.

To monitor for major breaks in the line, a series of pressure sensors coupled with senders would alert operators to a serious pressure drop and would aid in identifying the location of the break. Monitoring the line for minor leaks would require an elaborate system of detectors and senders. Such a system would likely be subject to many false alarms, many failures and would be a high maintenance item. As a minimum, the line could be periodically pressure checked and instrumented for determining total flow at various points to detect long-term discrepancies in input and output.

At the end of operations, it is assumed that all pipe and contaminated equipment would have to be recovered and either decontaminated or disposed of in the tailings area, and all disturbed land revegetated.

EVAPORATION PONDS

Single and multiple evaporation pond layouts have been evaluated as presented in Options 4 through 6 in the following sections. Parameters and considerations for evaporation pond design are summarized on Table 4. Basic designs of the embankments, lining systems and diversion systems were uniform for all the evaporation ponds. Typical sections are presented on Plate 15, Typical Dam Section for Evaporation Ponds. Table 5 summarizes construction data for the various evaporation pond options.

Embankments have been designed with 3 horizontal to 1 vertical (3H:1V) upstream and downstream slopes with a central core and chimney drain. Upstream sloping cores might be justified for final design and could reduce clay volume requirements. However, the present design is believed to be conservative and satisfactory for preliminary design and cost estimation purposes. Stripping and stockpiling of the upper six inches of soil across the site for final reclamation was assumed. In all cases, the existing county road would have to be partially relocated.

Seepage control of the proposed evaporation ponds at the Long Park site would be achieved by the placement of properly compacted three-foot thick clay liner composed of weathered Brushy Basin shale. Permeability of recompacted samples of the shales averages about 1.0×10^{-7} cm/sec based on laboratory permeability tests.

The estimated average seepage rate during the 17-year operation for single pond system (Option 4 as presented herein) is approximately 53 gpm. Because of sequential and/or intermittent filling of the multiple pond system (Option 5 as presented herein, seepage loss rates are interdependent on the systems operations. However, based on preliminary evaluation, average rates of seepage loss for the multiple pond system will be less than that estimated for the single pond (Option 4). Further discussion of seepage losses is presented in Appendix D.

During operation, wave action upon the clay liner would have to be watched and erosion cuts maintained. Areas of particularly troublesome erosion due to their steepness and orientation with respect to prevailing wind would probably require slope protection.

Impoundments have been sized based on the time rate of filling and average annual evaporation rate. Moderate volumes of effluent will be impounded at the cessation of operations which will in turn require several years for complete evaporation.

Contaminated soils and equipment would have to be disposed of in the same manner as tailings from the mill. For this study, it has been assumed for reclamation that the evaporation ponds will be covered in the same manner as the tailings.

OPTIONS CONSIDERED

Option 4 - Single Evaporation Reservoir

Layout and major features of Option 4 are shown on Plate 9. The reservoir would be impounded by a single 120-foot high dam and would create a reservoir of 260 acres after 17 years. Channels would divert normal runoff around the impoundment, but the dam is sized to store the probable maximum flood series without diversion. One mile of county road would be rerouted.

Major construction data are summarized on Table 5.

Option 4 requires considerably less earthwork for the embankment and liner, is a simpler design hydrologically, requires less area, and less road relocation than Options 5 or 6. However, the quantity of liquid impounded at the cessation of operations is greater and the time required for complete evaporation and reclamation would be much longer. The high head of water in the system creates higher seepage rates.

Option 5 - Multiple Evaporation Pond System

Layout and major features of Option 5 are shown on Plate 10. The area would be divided into 10 evaporation ponds. Ditches and a central channel through Long Park would divert PMF and normal runoff from the ponds. A conceptual plan for construction of diversion channels for surface water runoff control in the watershed area for the Option 5 site is illustrated on Plate 10. Two miles of county road would be rerouted. Table 5 summarizes major construction data.

The hydrologic design basis for the diversion channels is presented in Appendix E.

Option 5 requires considerably more earthwork, distribution piping is more complex, and disturbs much more land than Option 4. However, the scheme is more flexible and will require less time to reclaim since the volume of storage at the cessation of operations will be smaller than for Option 4.

COMBINED EVAPORATION PONDS AND TAILINGS IMPOUNDMENT

GENERAL

Development of a combined system of tailings disposal and evaporation ponds at Long Park has been considered. Construction and operation of the combined system would be similar to that discussed for the individual options, as presented previously.

Option 6, discussed in the following section, considers construction of multiple evaporation ponds on the west side of Long Park and tailings disposal on the east side.

OPTION 6 - COMBINED EVAPORATION AND TAILINGS DISPOSAL AREA

The layout and major features of a combined evaporation pond-tailings disposal system is shown on Plate 11. A multiple-pond system would be constructed on the west side of Long Park while tailings from ongoing milling would be disposed of on the east side, as discussed for

Option 3 previously. Ditches and a central channel would divert PMF and normal runoff around the ponds and disposal area until abandonment. Two and one-half miles of county road would be rerouted. Table 5 summarizes major construction data for the evaporation pond system. Major construction data for the tailings disposal system is presented in Table 1C.

Drawbacks of Option 6 include the deferral time for final reclamation of the impounded tailings, operational complexities due to the combined operations and reclamation activities, and a reduction in flexibility of design and operation.

PARADOX VALLEY

GENERAL

Three sites located in the Paradox Valley were considered for development of tailings impoundments or mill water evaporation ponds. Locations of these sites designated as Paradox 1, 2 and 3 are shown in relationship to one another and surrounding major topographic features on Plate 1, Vicinity Map. Each site is shown in more detail on Plates 3, 4 and 5.

SITE DESCRIPTION

Paradox 1 and 2 are 1000-acre sites on either side of the Dolores River and are located near the northern escarpments of the valley. The sites grade to the south-southwest at about 5 percent. Near-surface gypsum deposits are present at the south end of the sites. Toward the north, alluvial soil exists up to depths exceeding 45 feet and overlies sandstone and limestone. The Paradox 3 site is located at the southeast end of the valley. The area has deposits of granular alluvial soils up to about 35 feet thick. The Mancos shale underlying the soil varies in thickness from about 5 to 40 feet. Dakota sandstone underlies the shale.

In regard to the Paradox Valley sites, of major concern are the numerous faults found to be associated with the ongoing salt deformation and/or collapse of the anticline in the valley. These faults are considered active, although not capable of generating earthquake forces. Surface ruptures to either clay liners or reclamation covers must be considered as possible detrimental effects to the long-term stability of tailings containment areas. Detailed discussions of site geology are presented in Appendices A and B.

SITE DEVELOPMENT

As a result of the adverse geologic conditions associated with the salt anticline located throughout the Paradox Valley, feasibility of site development for either evaporation ponds or tailings impoundments is considered limited. Limited discussions of the site development options considered will be presented in the following paragraphs.

Two options considering the development of evaporation ponds at the Paradox 2 area and one considering tailings impoundment at Paradox 3 were evaluated. Layouts of the Paradox 2 evaporation options are presented on Plates 16 and 17. One option includes a single reservoir impounded by a single embankment. The second is for a series of lower embankments creating a number of smaller evaporation ponds. Both options consider the construction of a pipeline system to transport the effluent from the mill. Also, both systems include synthetic material as a pond liner. The option at Paradox 3 considers filtered tailings hauled by 80,000 pound GVW trucks from the mill, along State Highway 141 and 90, to the Paradox 3 site. The tailings would be dumped and spread as partial buried tailings in a 250-acre impoundment. The layout and section for this system are presented on Plates 18 and 19.

General site design parameters for the various options are presented on Tables 4 through 5.

CONCLUSIONS

The selection of a system to dispose of all future tailings and mill effluent generated by the Uravan mill will involve the consideration of many factors. Such factors must include economics, operational feasibility, possible interference and interfacing with on-going mining operations, safety, environmental effects and regulatory positions.

This study has included the evaluation of tailings and mill waste water disposal at two specific sites: 1) Long Park and 2) Paradox Valley. For the purposes of the study, it has been assumed that a filtration system will be used to dewater, the tailings to a moisture content of 25 percent whereby the tailings can be transported utilizing trucks.

Based on the preformance objectives set forth by the NRC, the "prime option" is below-grade disposal. However, because of the topography and geology of the sites in general, the most advantageous system of tailings impoundment, and the most closely following all performance objectives as stated in the technical siting and design requirements of the Nuclear Regulatory Commission GEIS, is Long Park-Option 2, the partial burial of tailings on the west side of Long Park. The partial burial system is placed in an area whereby the rainfall catchment is small, there is relatively good protection from wind, the site is isolated from both resident and transient populations and the area appears to be in the most reasonable location to promote long-term geologic deposition.

The most advantageous system evaluated for the mill effluent is Long Park-Option 5, a series of lower embankments within Long Park. By having a series of small ponds, the major advantage is the operational and safety options of adjusting inflows and levels of any of the ponds.

Of major concern is, if either of Option 2 or 5 is selected, the other option cannot be constructed. Should both a tailings impoundment and evaporation pond system be desired at Long Park, the alternative would be to select a system such as Option 6, the combination evaporation pond - tailings impoundment system.

Because of the potential for surface rupture caused by fault movements from solutions and/or collapse within the Paradox Valley Salt Anticline, the long-term stability of the sites in Paradox Valley is questionable. Even with further geologic study at Paradox 3 to further investigate faults, the site will probably not conclusively be found to be stable over the long term.

TABLE 1A

TAILINGS IMPOUNDMENT SITE DESIGN PARAMETERS
LONG PARK - OPTION 1

Total Impoundment Surface Area - 350 acres

Estimated Tailings Impoundment Capacity - 9.3 x 10^6 tons

Site Preparation (Stripping) - 300 acres

Embankment Construction - none

Impoundment Bottom Preparation - 300 acres

Excavation Required - 6.9 x 10^6 c.y.

Reclamation cover - 5.96 x 10^6 c.y.

Revegatation - 350 acres

Surface or Slope Protection - 350 acres

Total Site Drainage Area - 2.0 square miles

Length of Diversion Ditches Required - 26,500 lf

Excavation for Diversion Ditches - 3.9 x 10^5 c.y.

Diversion Ditch Riprap - 7,250 feet of lined channel

Length of Long Park Road to be Relocated - 8,000 ft

TABLE 1B

TAILINGS IMPOUNDMENT SITE DESIGN PARAMETERS
LONG PARK - OPTION 2

Total Impoundment Surface Area -	175 acres
Estimated Tailings Impoundment Capacity -	9.3×10^6 tons
Site Preparation (Stripping) -	175 acres
Embankment Construction -	450,000 c.y.
Impoundment Bottom Preparation -	160 acres
Excavation Required -	2.7×10^6 c.y.
Reclamation cover -	2.75×10^6 c.y.
Revegatation -	175 acres
Surface or Slope Protection -	10 acres
Total Site Drainage Area -	1.2 square miles
Impoundment Site Drainage Area -	175 acres
Length of Diversion Ditches Required -	10,750 lf
Excavation for Diversion Ditches -	1.6×10^5 c.y.
Diversion Ditch Riprap -	none
Length of Long Park Road to be Relocated -	1,000 ft

TABLE 1C

TAILINGS IMPOUNDMENT SITE DESIGN PARAMETERS
LONG PARK - OPTION 3

Total Impoundment Surface Area - 205 acres

Estimated Tailings Impoundment Capacity - 9.3×10^6 tons

Site Preparation (Stripping) - 205 acres

Embankment Construction - 450,000 c.y.

Impoundment Bottom Preparation - 190 acres

Excavation Required - 3.75×10^6 c.y.

Reclamation Cover - 2.84×10^6 c.y.

Revegatation - 205 acres

Surface or Slope Protection - 10 acres

Total Site Drainage Area - .8 square miles

Impoundment Site Drainage Area - 205 acres

Length of Diversion Ditches Required - 9000 lb

Excavation for Diversion Ditches - 1.3×10^5 c.y.

Diversion Ditch Riprap - none

Length of Long Park Road to be Relocated - 750 ft

TABLE 2

DESIGN PARAMETERS FOR LIQUID EFFLUENT PIPELINE TO EVAPORATION PONDS

Pipeline Design Rate = 500 gal/min

Liquid Temperature at Mill = 75 to 80°F
Liquid pH = 1.5 to 2
Liquid Density = 10 lb/gal
Crystalization Temperature = 4.4°C (40°F)
Project Life = 17 years

Measures to minimize any release of liquid include:

a. Pipeline protected from vandalism or accidental breakage.

b. Automatic (electronic) means of detecting a pipeline failure must be incorporated into design (alarm).

c. Means of preventing escape of liquid needed should line break (e.g., ditches and ponds).

d. Collection ponds needed at low points in the line to collect liquid when draining line and in event of an emergency.

e. Means of inspection to evaluate condition desirable.

f. Liquid must not drop below 40°F (crystallization temperature for extended period).

TABLE 3

EFFLUENT PIPELINE DESIGN SUMMARY FOR LONG PARK

Length Main Pipeline = 53,705 feet

Number of Pumping Stations = 19 pumps

Length of Power Line = 7.88 miles

Number of Substations = 5 substations

Electrical Consumption = 5.96 million KWH/year

a. Pipe would be 8-inch diameter Driscopipe 8600 or equal.

b. Line would be buried 5 feet to protect against vandalism and to maintain temperature except in rock where line would be at surface in insulated box. Standing time to 40°F is 12 hours.

c. Emergency effluent collection-holding ponds would be constructed.

d. A series of pressure sensors would be installed along pipeline to monitor for major breaks in line.

e. Periodic pressure testing of line and continuous metering of flow to evaluate pipeline condition.

TABLE 4

DESIGN PARAMETERS FOR EVAPORATION PONDS

Liquid Discharge to Ponds = 500 gpm

Average Annual Precipitation = 10.5 inches/yr

Average Annual Runoff from Undisturbed Areas = 1.05 inches/yr

Average Annual Reservoir Evaporation = 38.8 inches/yr - Long Park

Probable Maximum Precipitation = 11.9 inches (72-hr General Storm)

= 8.1 inches (1-hr Thunderstorm)

100-year Precipitation = 4.0 inches (36-hr Duration)

1,000-year Seismic Event = 0.12 g

Seepage Rate = Negligible

a. System must be capable of diverting the PMF or storing the PMF series (1.4 x PMF + 100-year storm).

b. Topsoil will be stripped and stockpiled for subsequent reclamation.

c. Facilities must be dismantled and area reclaimed. Contaminated soil and equipment must be disposed of in the tailings disposal site.

TABLE 5

CONSTRUCTION DATA FOR EVAPORATION POND ALTERNATIVES

OPTION	EMBANKMENT VOLUMES (thousands cu yds)				DITCH VOLUMES (thousands cu yds)		LINER VOLUMES (thousands cu yds)	ROAD RE-LOCATION (feet)
	SHELL	CORE	RIPRAP	DRAINS & FILTERS	EXCAVATIONS	RIPRAP		
LONG PARK - OPTION 4 SINGLE RESERVOIR	487	245	8.2	50.0	54.6	0	1,370	5,300
LONG PARK - OPTION 5 MULTIPLE RESERVOIR	2,300	1,520	90.0	530.0	164.0	18.7	1,700	10,800
LONG PARK - OPTION 6 COMBINED EVAPORATION AND TAILINGS DISPOSAL	1,981	1,393	78.7	485.5	95.9	18.7	1,440	12,800

SCALE IN MILES

VICINITY MAP

REFERENCE
U.S.G.S. MAP TITLED, "MOAB, UTAH, COLORADO", 1956, REVISED 1969.

DAMES & MOORE

PLATE 1

REVISIONS
BY ______ DATE ______

BY *H.J.T.* DATE *4-17-80* FILE *02922-[illegible] URAVAN*
CHECKED BY ______

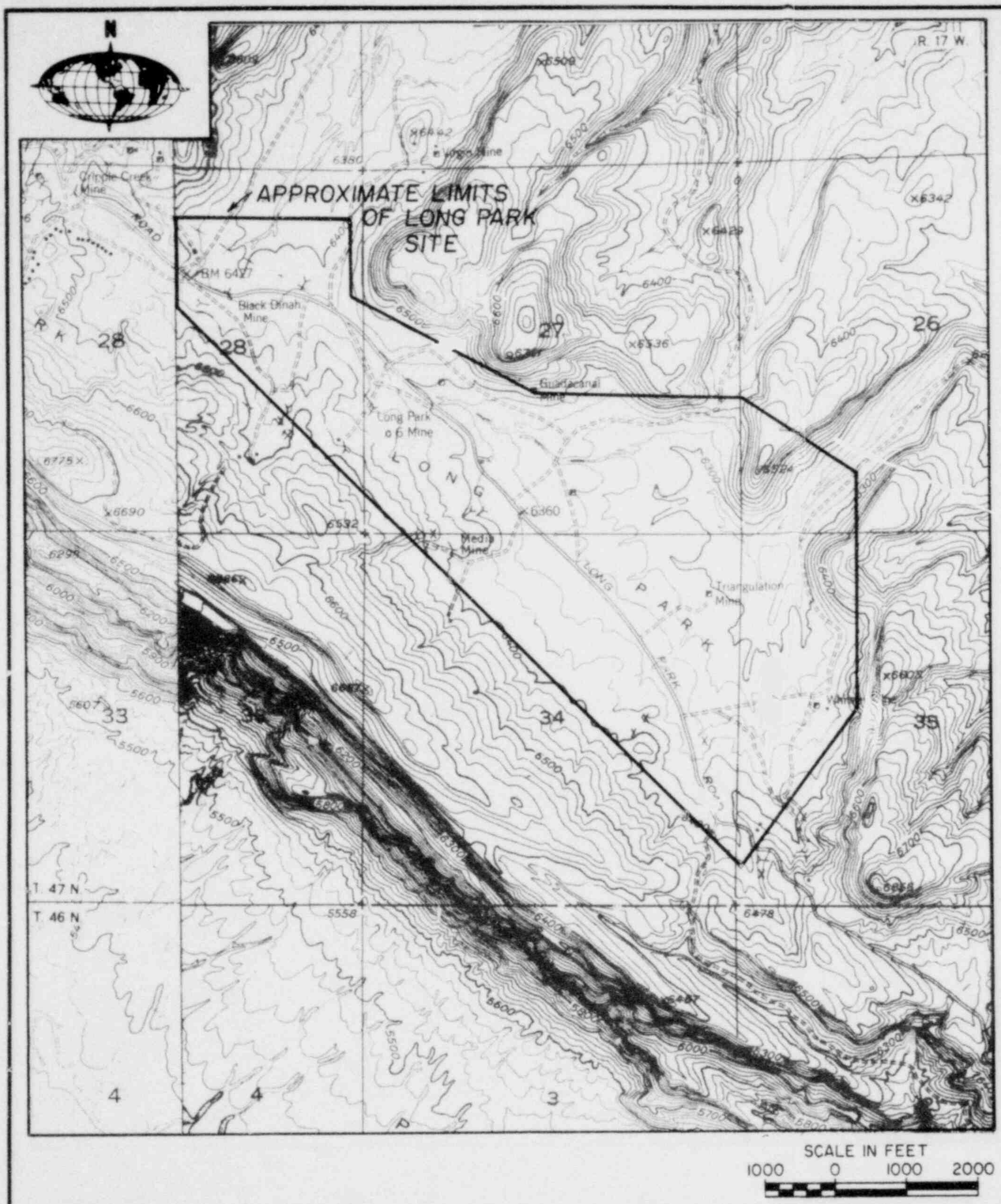
946.7 (REV. 6-61)

REVISIONS
BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______

946.7 (REV. 6-61)



PLOT PLAN - LONG PARK

REFERENCE
U.S.G.S. QUADRANGLE MAPS TITLED, "URAVAN, COLORADO", AND "DAVIS MESA, COLORADO",

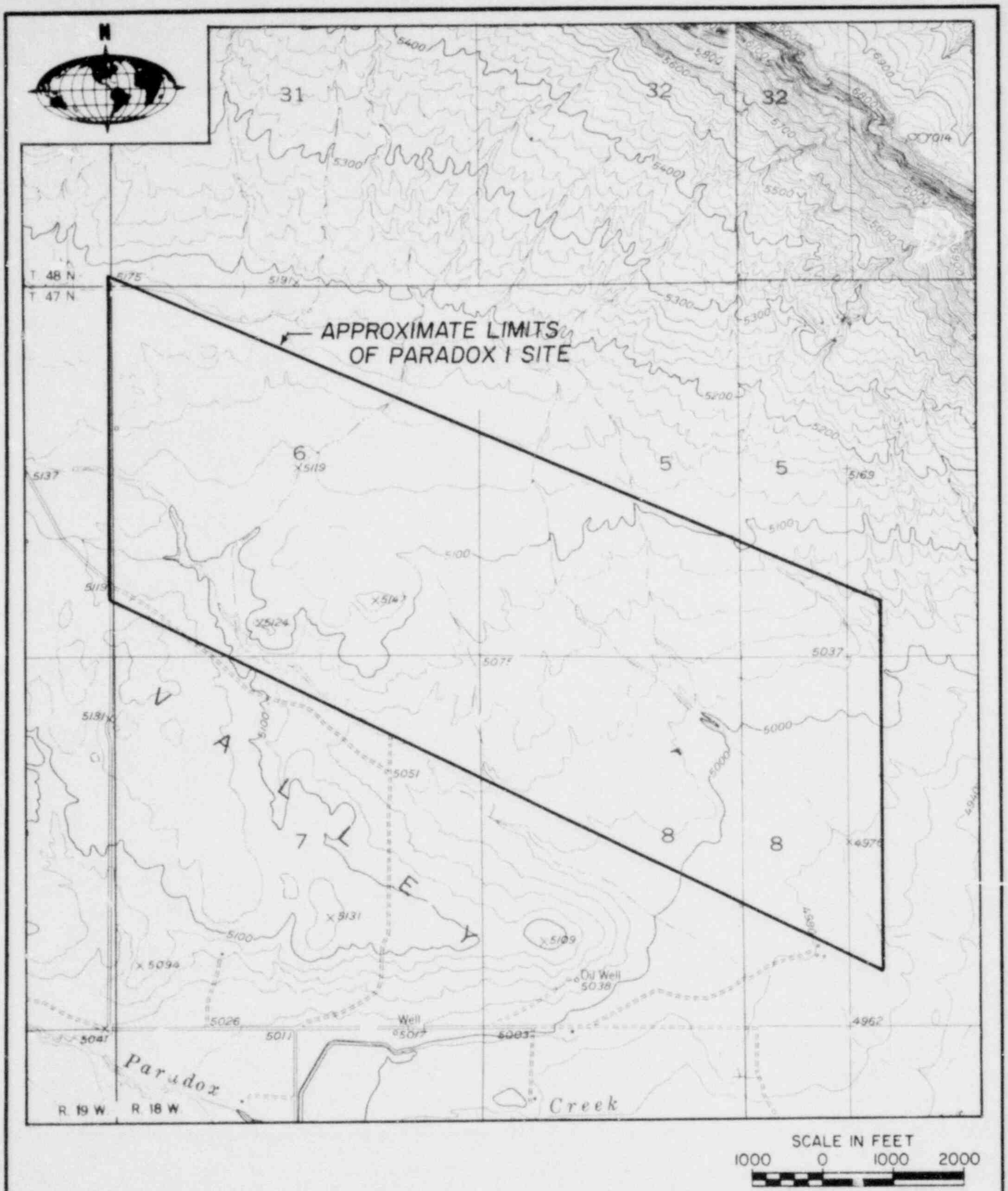
DAMES & MOORE

PLATE 2

REVISIONS BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______



PLOT PLAN – PARADOX I

REFERENCE
U.S.G.S. QUADRANGLE MAPS TITLED, "PARADOX, COLORADO", AND "DAVIS MESA, COLORADO"

DAMES & MOORE

PLATE 3

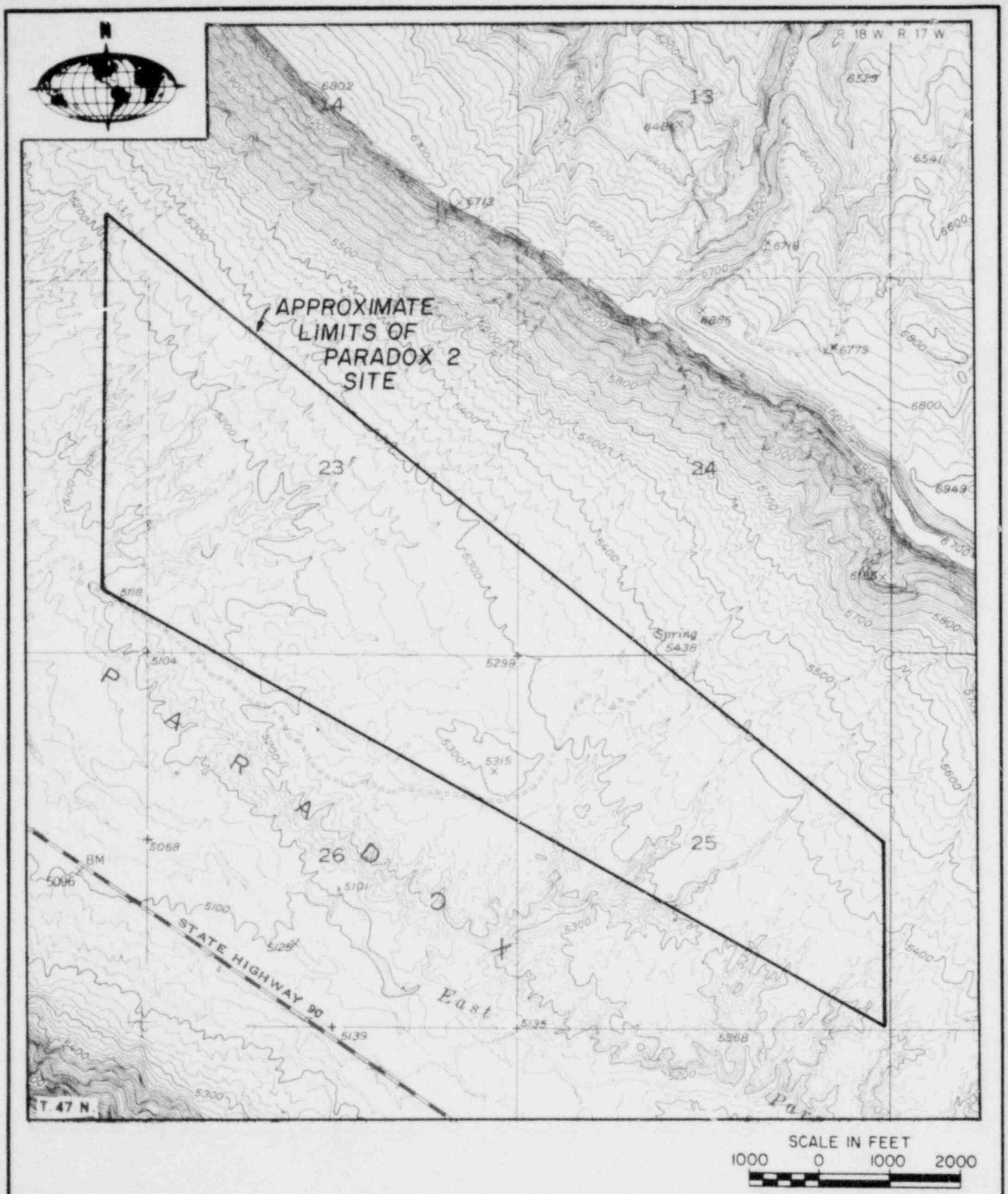
946.7 (REV. 6-61)

REVISIONS BY ______ DATE ______

FILE ______

BY ______ DATE ______ CHECKED BY ______

946.7 (REV. 6-61)



PLOT PLAN - PARADOX 2

REFERENCE
U.S.G.S. QUADRANGLE MAP TITLED,
"DAVIS MESA, COLORADO".

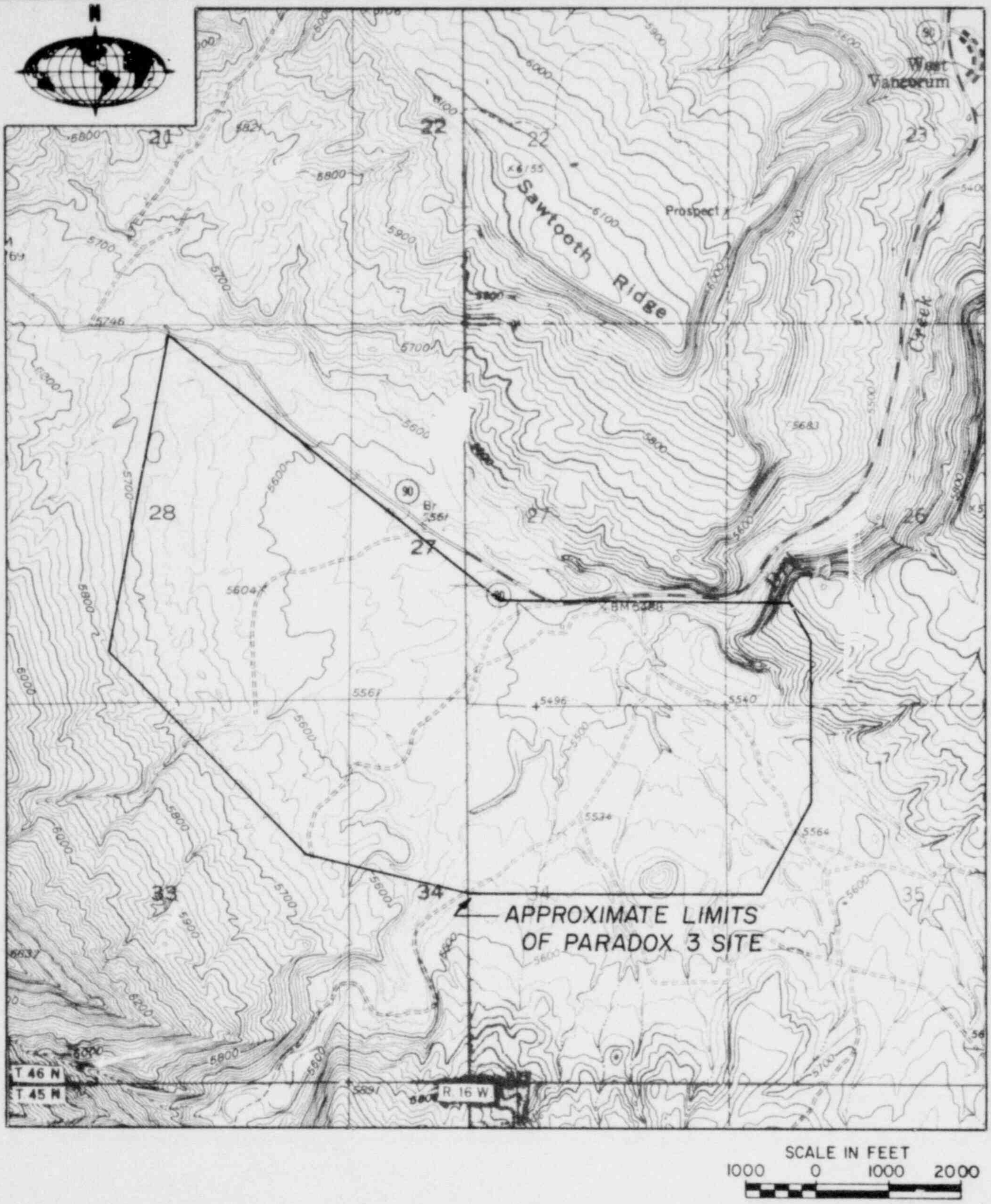
DAMES & MOORE

PLATE 4

REVISIONS BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______



PLOT PLAN - PARADOX 3

REFERENCE
U.S.G.S. QUADRANGLE SHEETS TITLED, "NATURITA", AND "NATURITA NW".

DAMES & MOORE

PLATE 5

946.7 (REV. 6-61)

NOTES

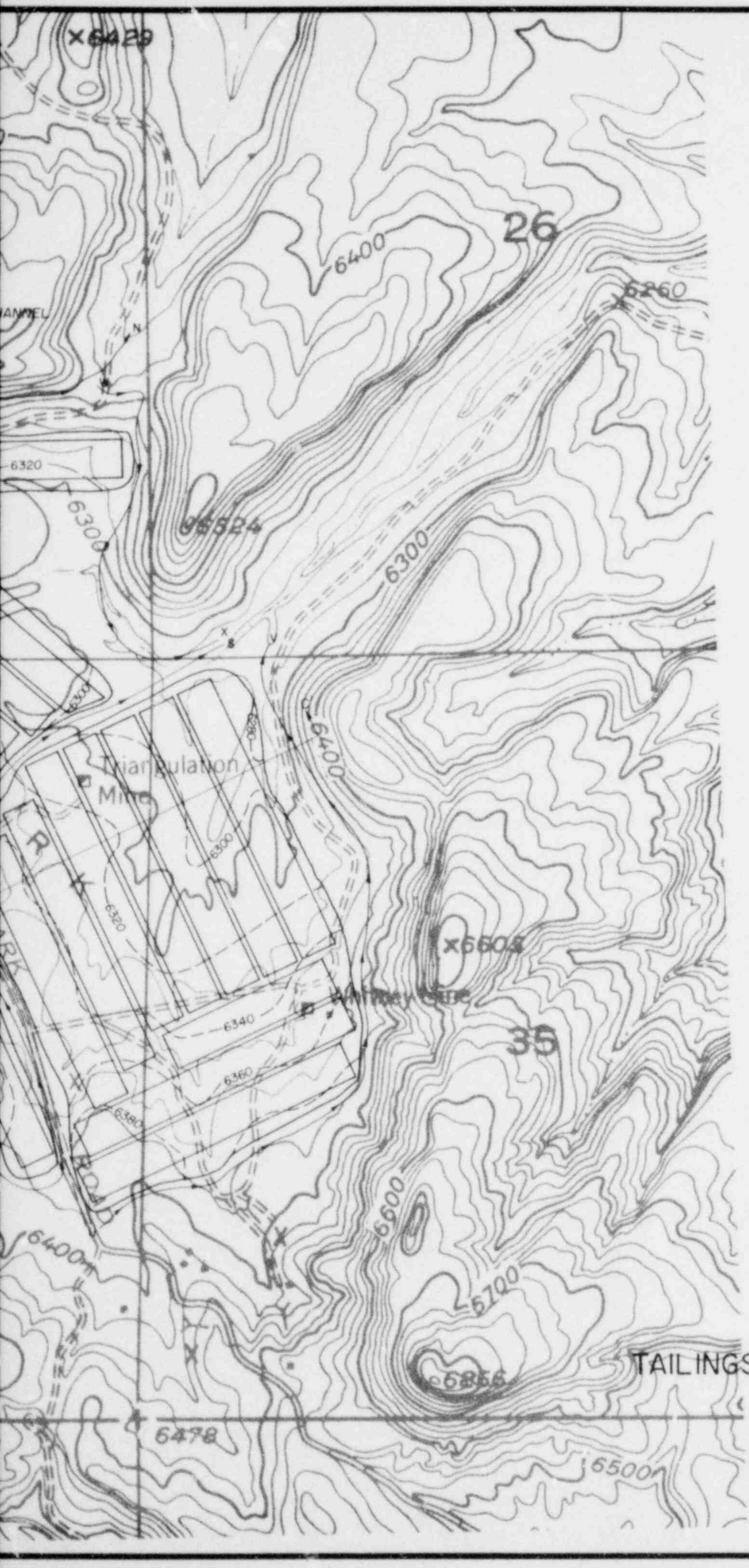
FOR SUBSURFACE DETAILS ALONG SECTION C—C' SEE PLATE 13.

INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"URAVAN, COLORADO" 1960.

JOB NUMBER ______ DRAWN BY ______ DATE ______

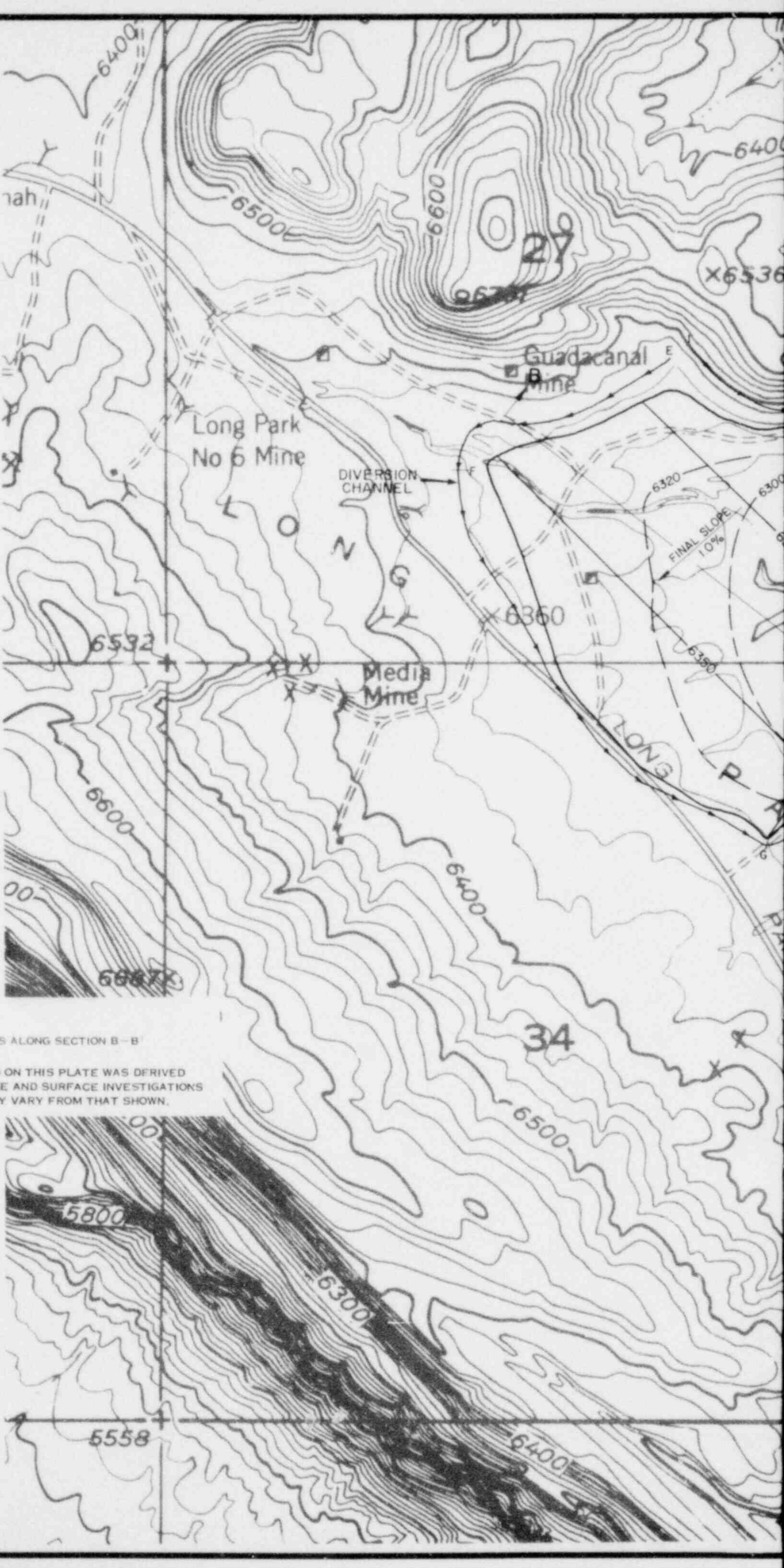
466 11 (10-79)



TAILINGS IMPOUNDMENT ALTERNATIVE
LONG PARK-OPTION I

DAMES & MOORE

PLATE 6



NOTES

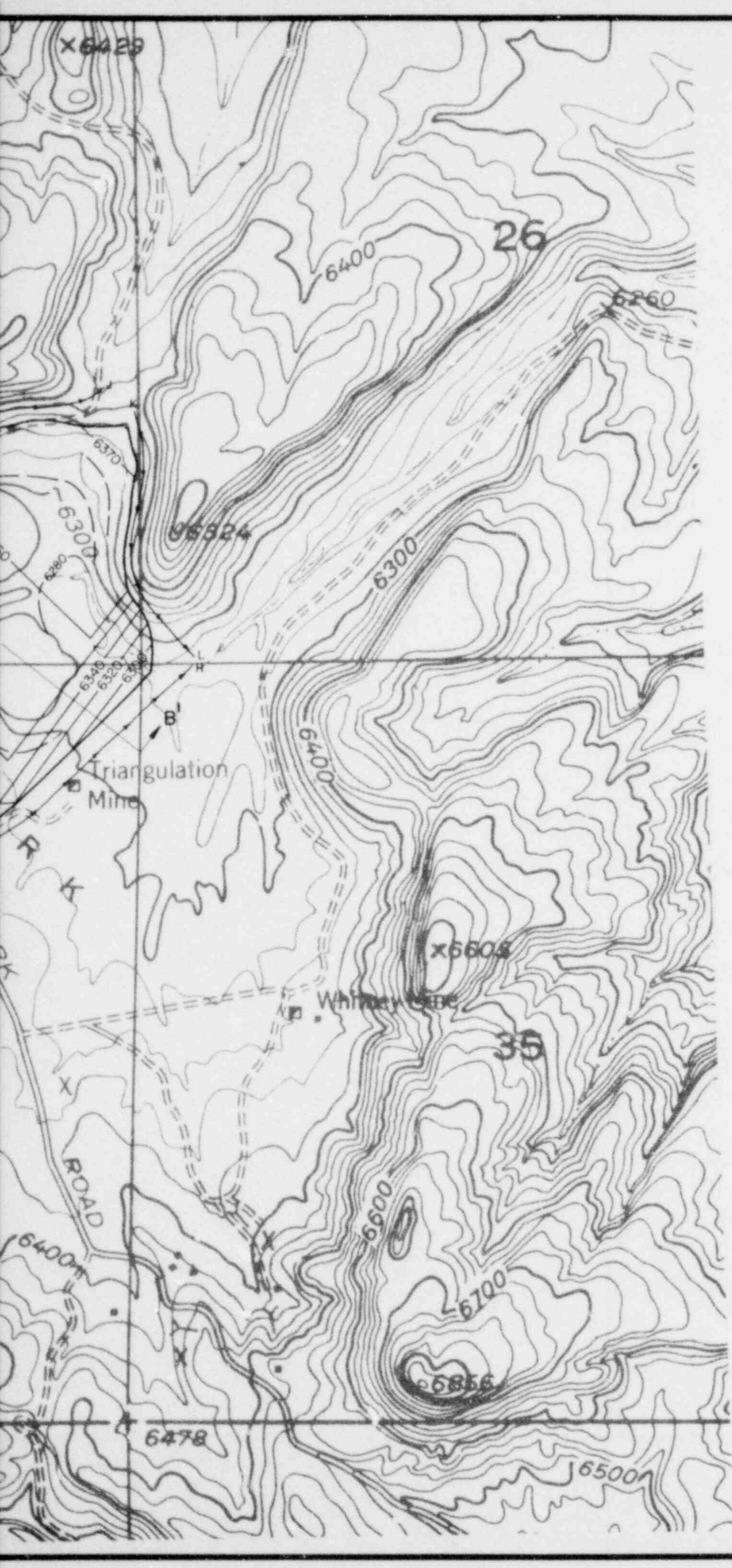
FOR SUBSURFACE DETAILS ALONG SECTION B–B' SEE PLATE 14.

INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"URAVAN, COLORADO" 1960.

JOB NUMBER [illegible]·138 DRAWN BY SMeyer DATE

466 11 (10-79)



N

KEY

— — PROPOSED CUT BOTTOM GRADE

—— PROPOSED FINAL RECLAIMED GRADE

DIVERSION CHANNEL – ARROWS SHOW DIRECTION OF FLOW, LETTERS REFER TO CHANNEL SECTIONS DISCUSSED IN APPENDIX E.

FEET

500 0 500 1000

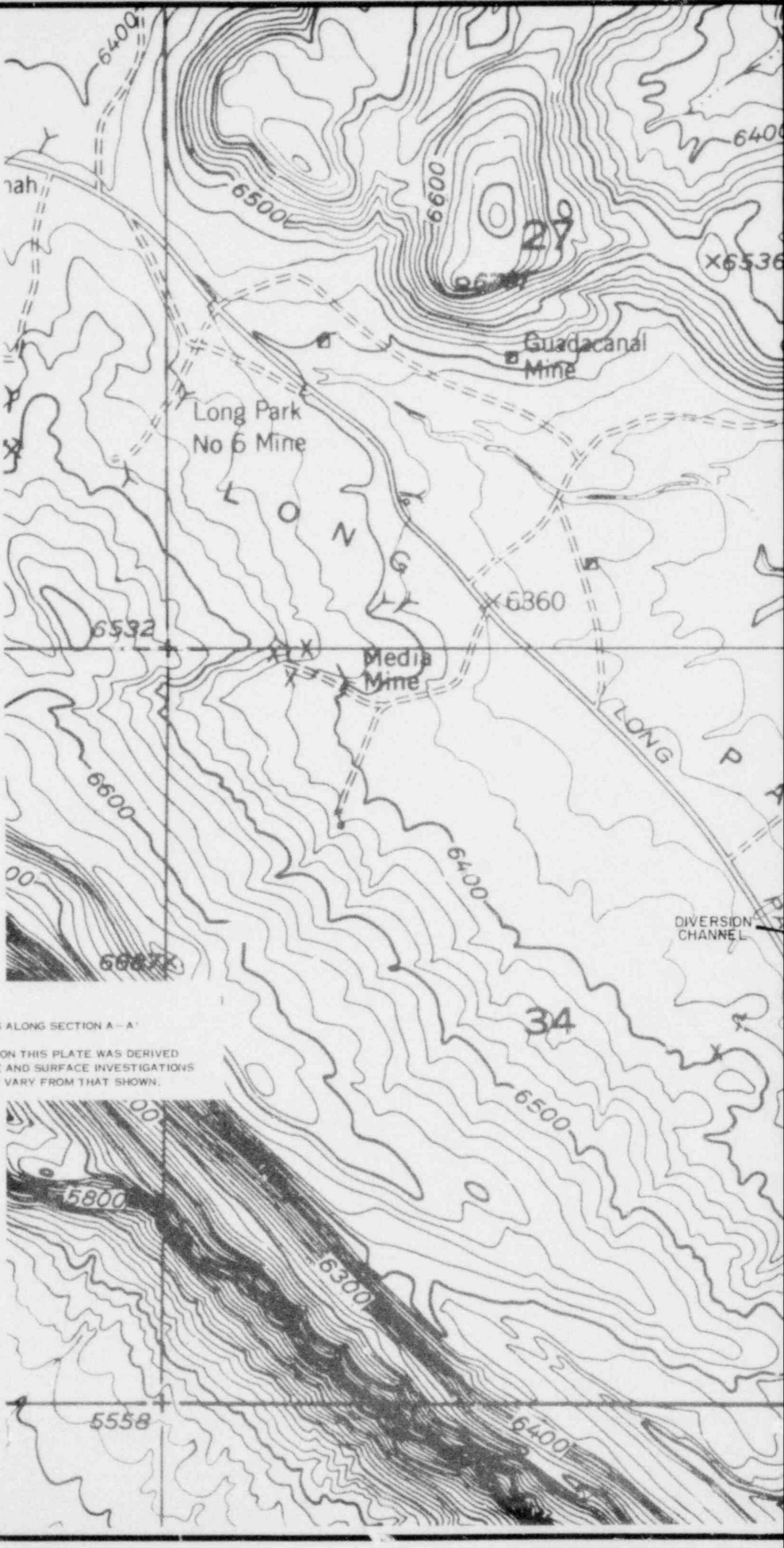
TAILINGS IMPOUNDMENT ALTERNATIVE

LONG PARK - OPTION 2

DAMES & MOORE

PLATE 7

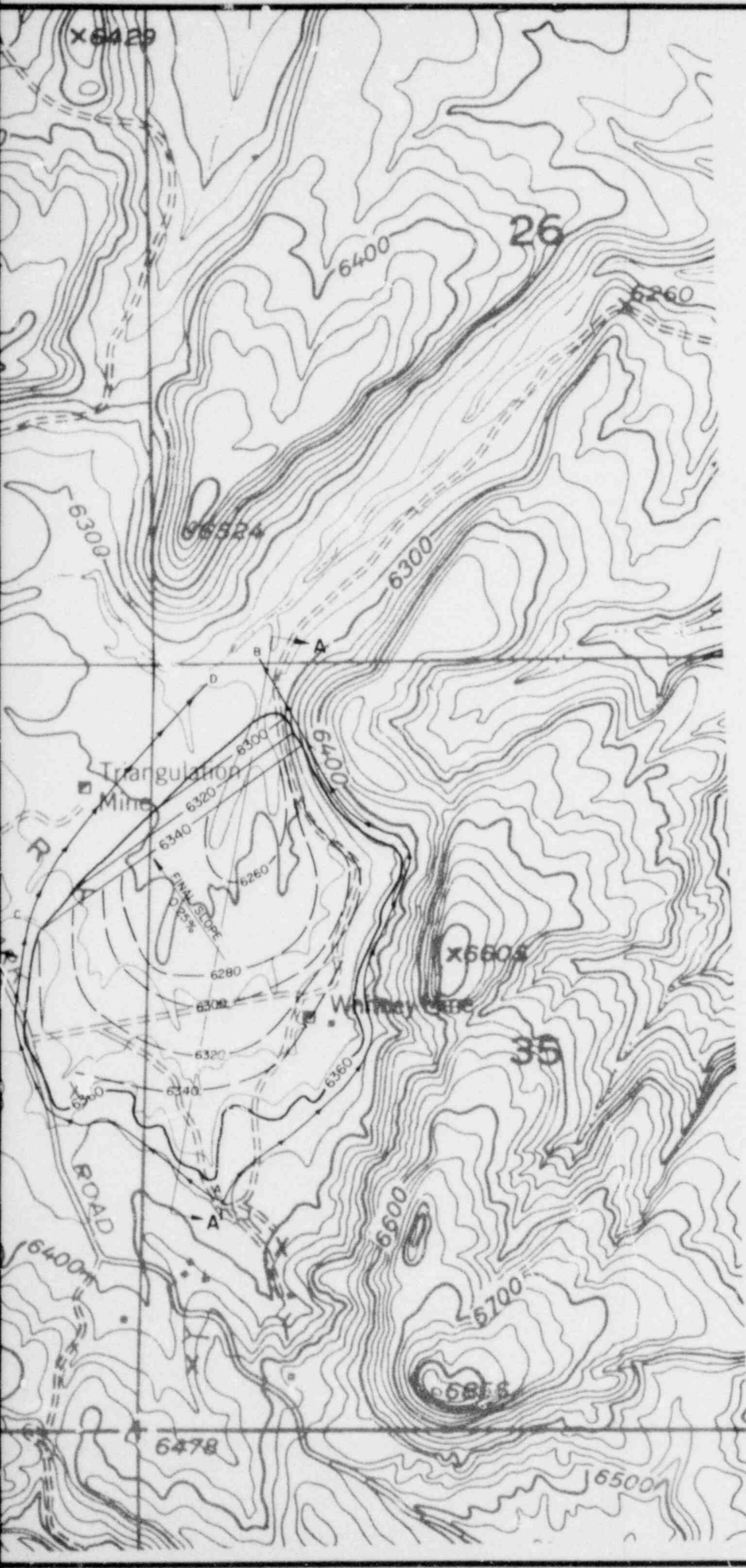
JOB NUMBER DRAWN BY DATE



NOTES
FOR SUBSURFACE DETAILS ALONG SECTION A – A'
SEE PLATE 14.
INFORMATION PRESENTED ON THIS PLATE WAS DERIVED
FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS
AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"URAVAN, COLORADO" 1960.

466.11 (10-79)



KEY

— — PROPOSED CUT BOTTOM GRADE

—·— PROPOSED FINAL RECLAIMED GRADE

B →→ C DIVERSION CHANNEL - ARROWS SHOW DIRECTION OF FLOW, LETTERS REFER TO CHANNEL SECTIONS DISCUSSED IN APPENDIX E.

FEET

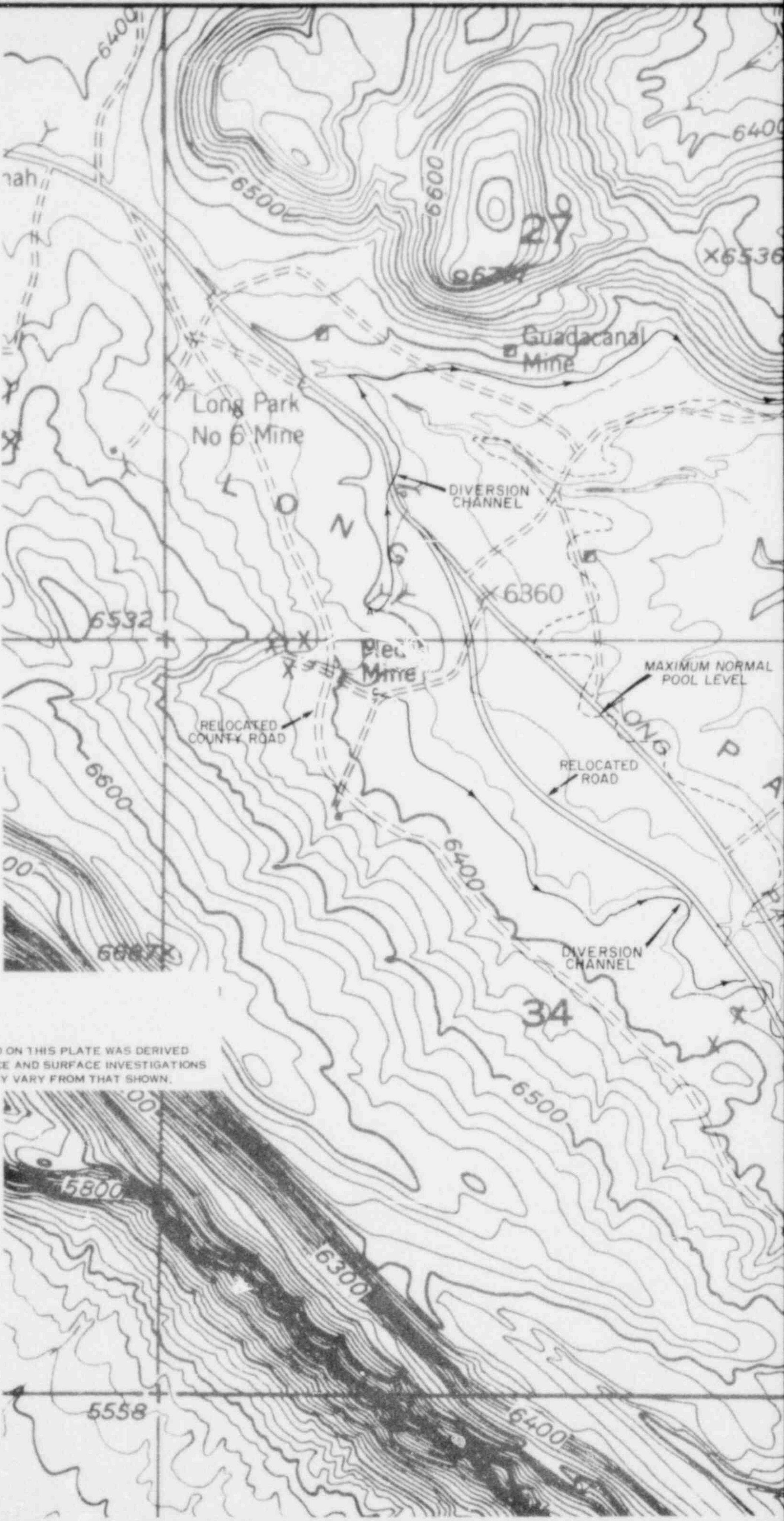
500 0 500 1000

TAILINGS IMPOUNDMENT ALTERNATIVE

LONG PARK - OPTION 3

DAMES & MOORE

PLATE 8

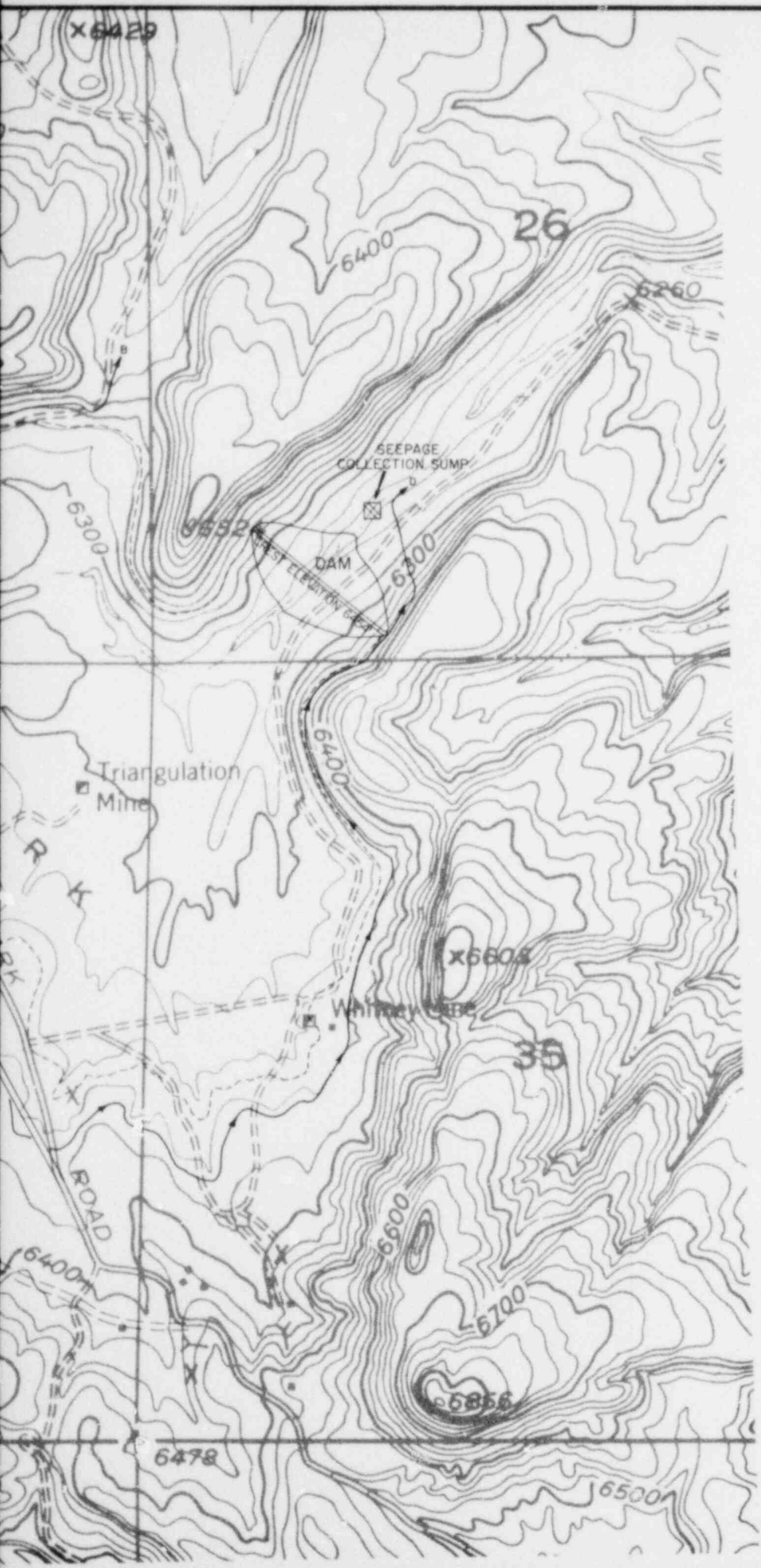


NOTES
INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED "URAVAN, COLORADO" 1960.

FILE [illegible]
BY ______ DATE ______
CHECKED BY ______ DATE ______

REVISIONS
BY ______ DATE ______
BY ______ DATE ______
PLATE ______ OF ______



N

KEY :

A → B DIVERSION CHANNEL – ARROWS SHOW DIRECTION OF FLOW, LETTERS REFER TO CHANNEL SECTIONS DISCUSSED IN APPENDIX E.

FEET

500 0 500 1000

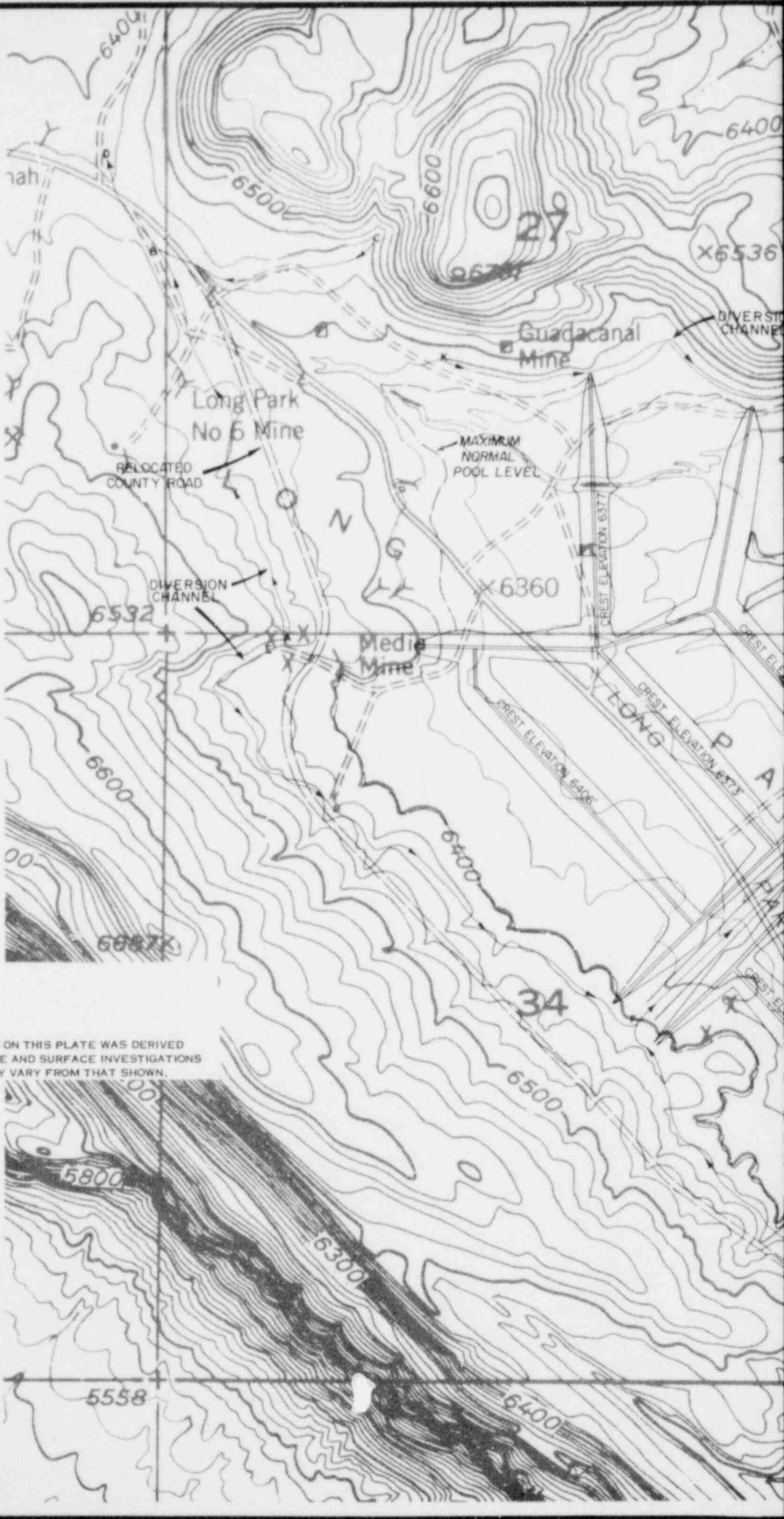
EVAPORATION POND ALTERNATIVE

LONG PARK - OPTION 4

DAMES & MOORE

PLATE 9

JOB NUMBER
DRAWN BY
DATE



NOTES
INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED "URAVAN, COLORADO" 1960.

466.11 (10-79)

N

KEY :

DIVERSION CHANNEL - ARROWS SHOW DIRECTION OF FLOW. LETTERS REFER CHANNEL SECTIONS DISCUSSED IN APPENDIX E.

FEET
500 0 500 1000

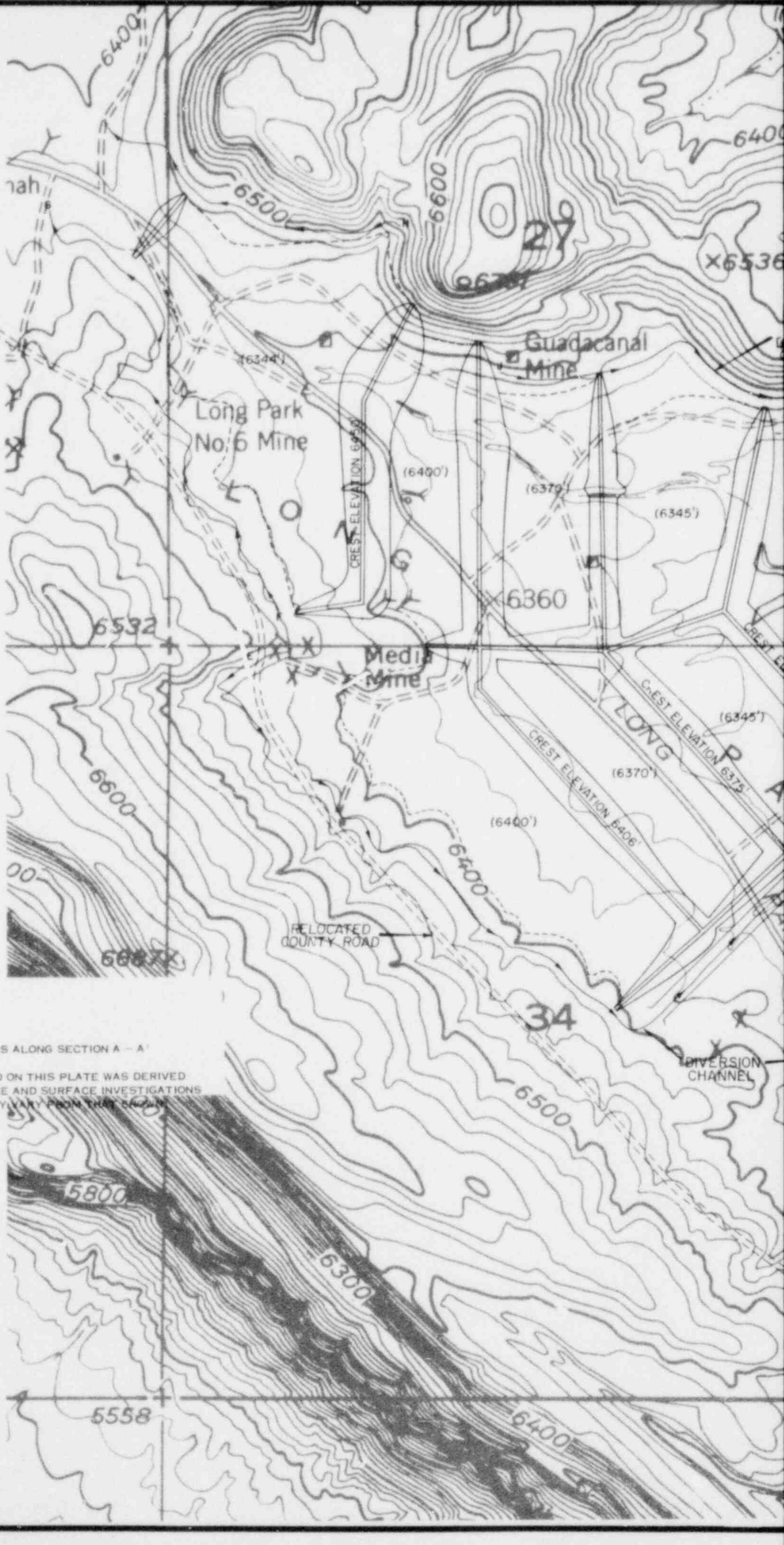
EVAPORATION POND ALTERNATIVE

LONG PARK - OPTION 5

DAMES & MOORE

PLATE 10

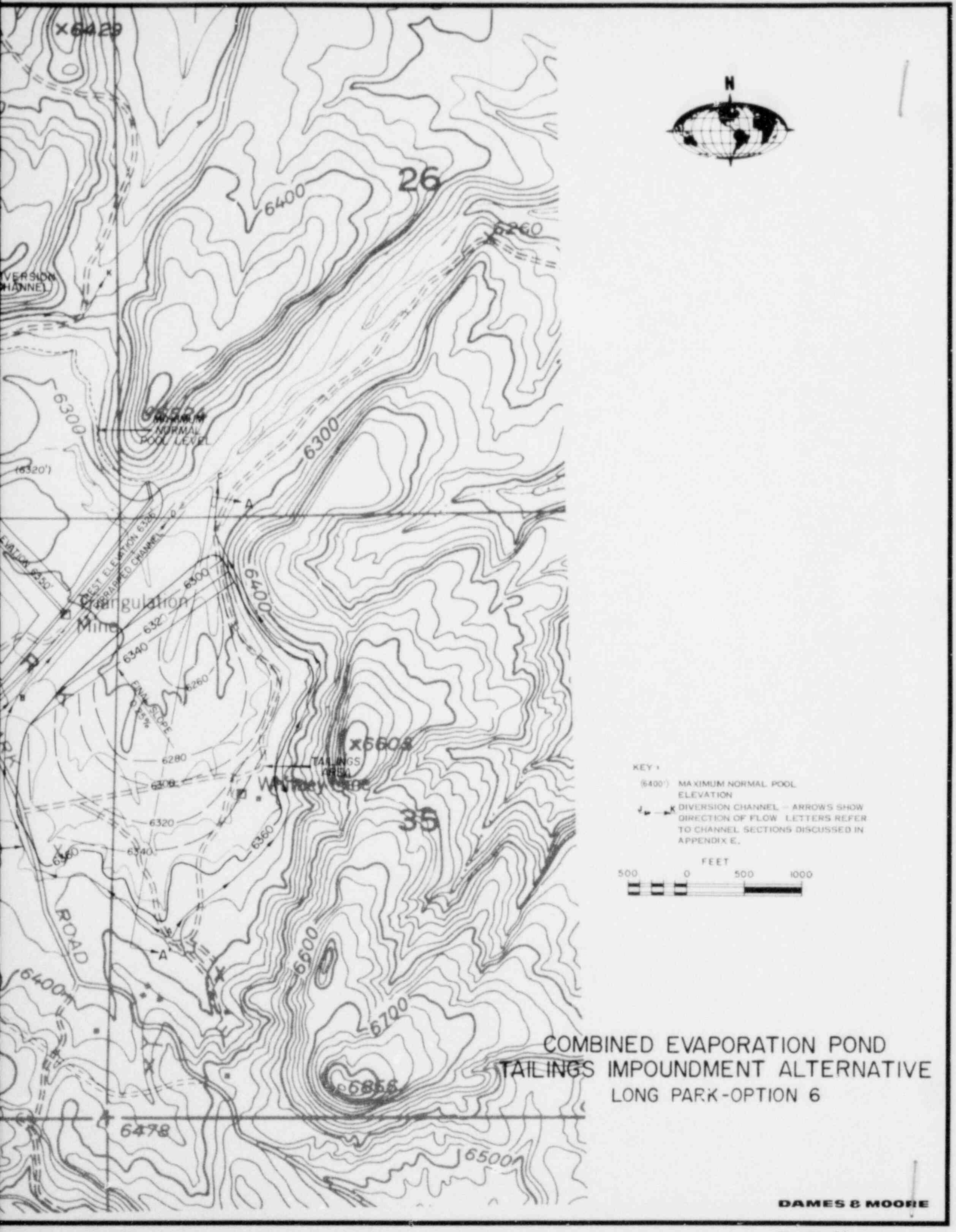
JOB NUMBER ________ DRAWN BY ________ DATE ________



NOTES
FOR SUBSURFACE DETAILS ALONG SECTION A – A'
SEE PLATE 14.
INFORMATION PRESENTED ON THIS PLATE WAS DERIVED
FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS
AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"URAVAN, COLORADO" 1960.

466.11 (10-79)

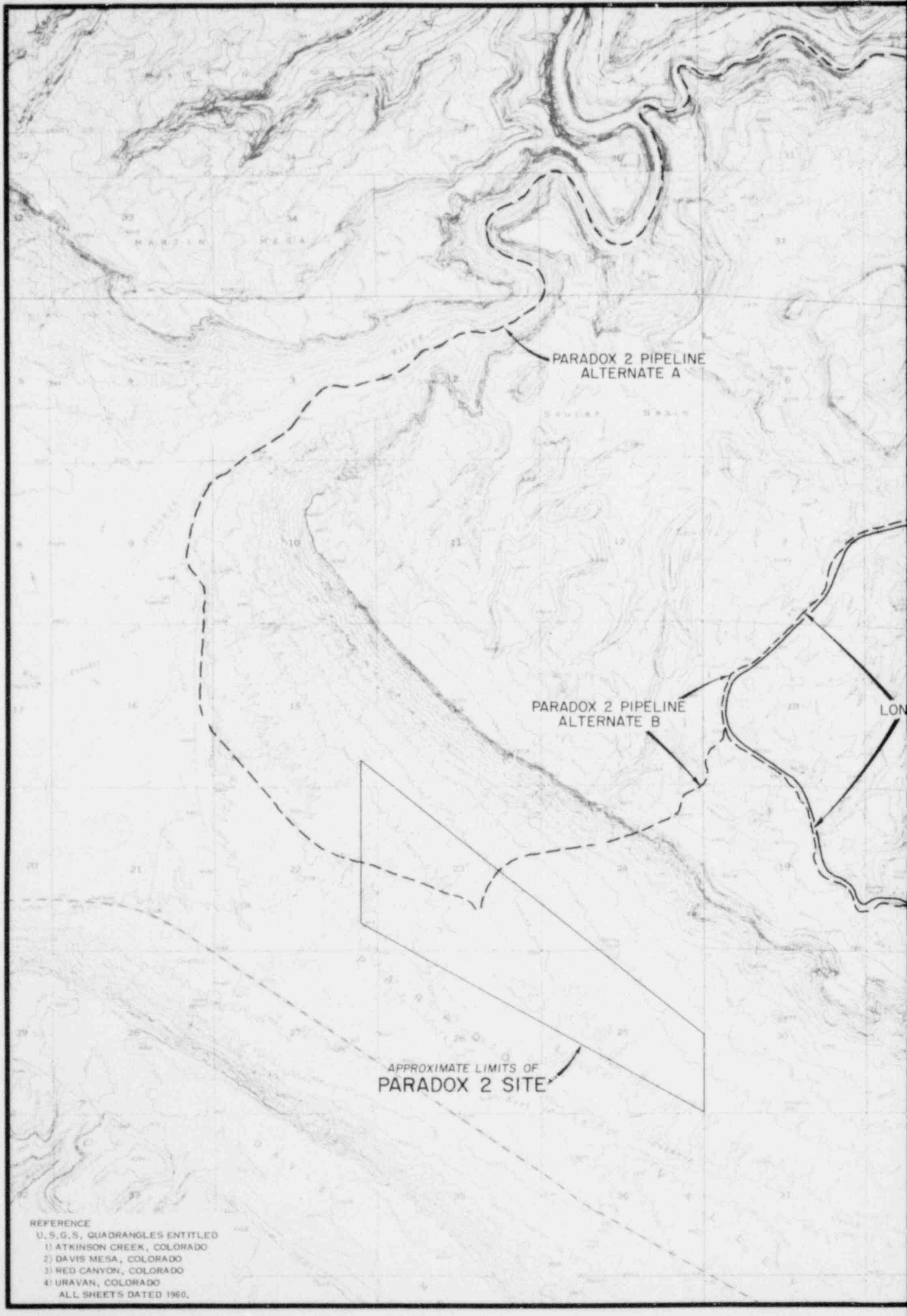


COMBINED EVAPORATION POND
TAILINGS IMPOUNDMENT ALTERNATIVE
LONG PARK-OPTION 6

DAMES & MOORE

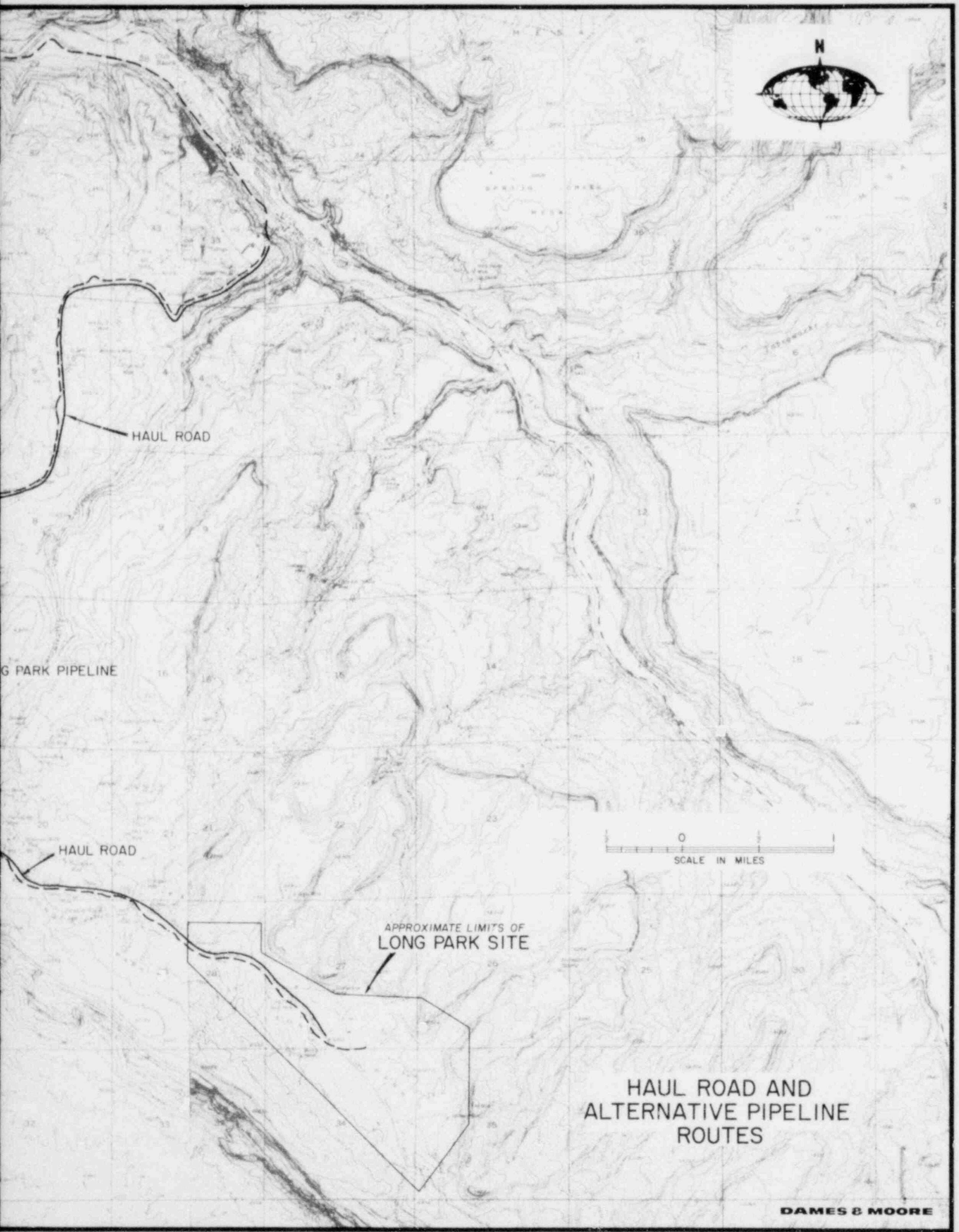
PLATE 11

JOB NUMBER ________ DRAWN BY ________ DATE ________



REFERENCE
U.S.G.S. QUADRANGLES ENTITLED
1) ATKINSON CREEK, COLORADO
2) DAVIS MESA, COLORADO
3) RED CANYON, COLORADO
4) URAVAN, COLORADO
ALL SHEETS DATED 1960.

466.11 (10-79)

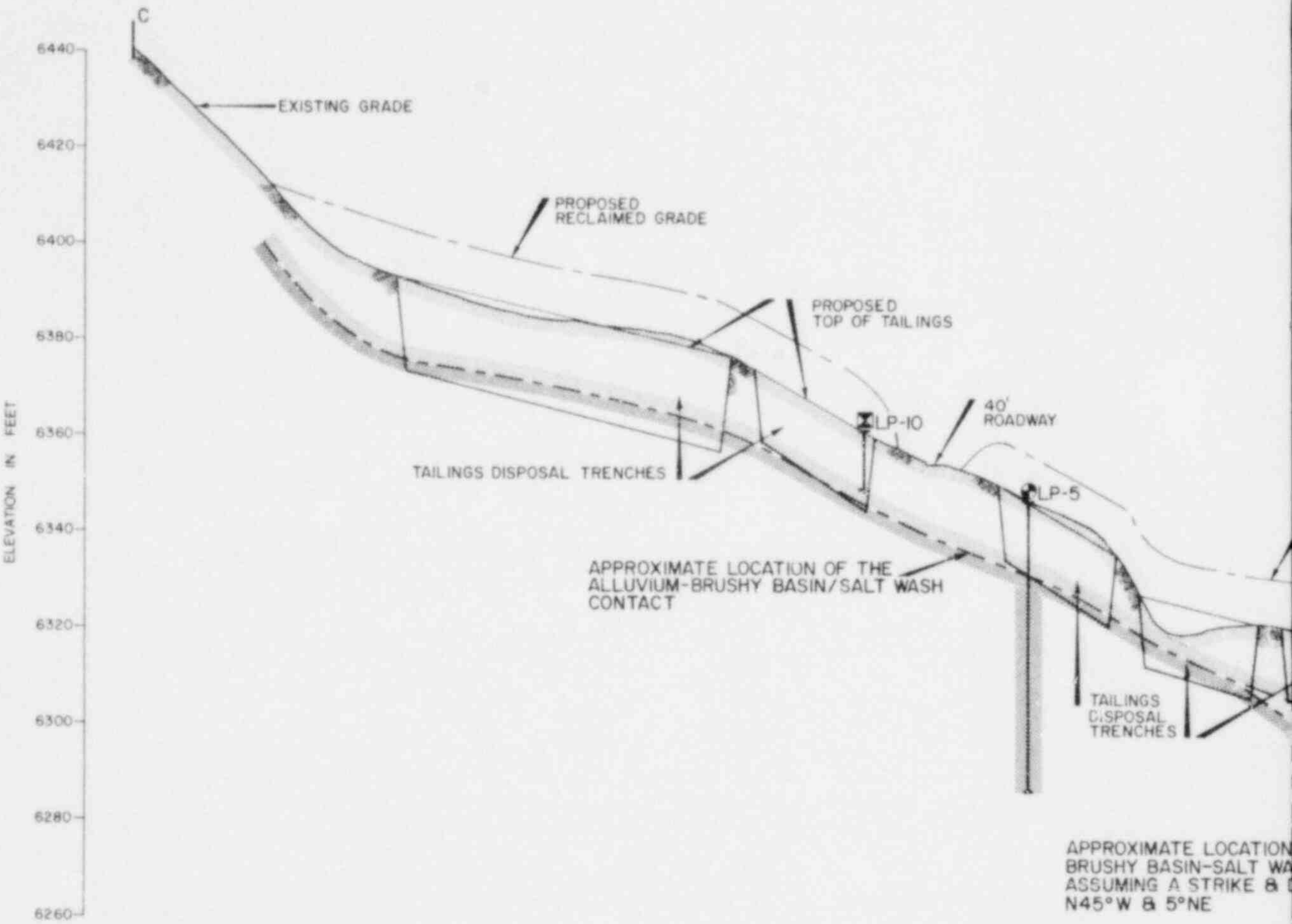


HAUL ROAD AND ALTERNATIVE PIPELINE ROUTES

DAMES & MOORE

PLATE 12

JOB NUMBER ________ DRAWN BY ________ DATE ________



EXPLANATIONS

KEY :

LP-5 LOCATION OF BORINGS PROJECTED INTO THE PLANE OF THE PROFILE

LP-10 LOCATION OF TEST PITS PROJECTED INTO THE PLANE OF THE PROFILE

LEGEND :

▨ ALLUVIUM DEPOSITS

▨ BRUSHY BASIN MEMBER MORRISON FORMATION

▨ SALT WASH MEMBER MORRISON FORMATION

NOTES :

FOR THE LOCATION OF SECTION C-C' SEE PLATE 6

THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA, SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

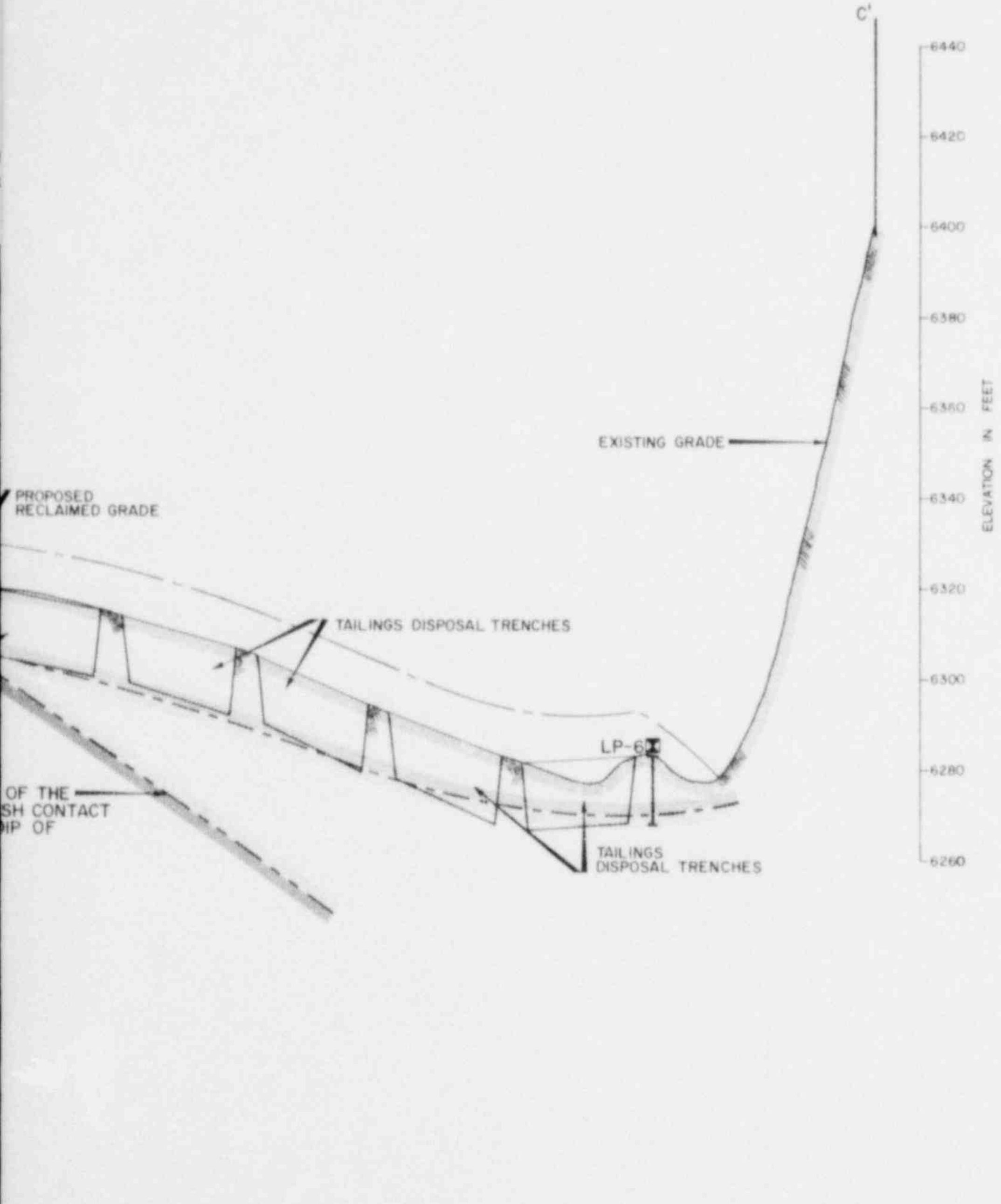
ELEVATIONS REFER TO MSL DATUM.

HORIZONTAL SCALE IN FEET

100 0 100 200 300 400 500

VERTICAL EXAGGERATION 10X

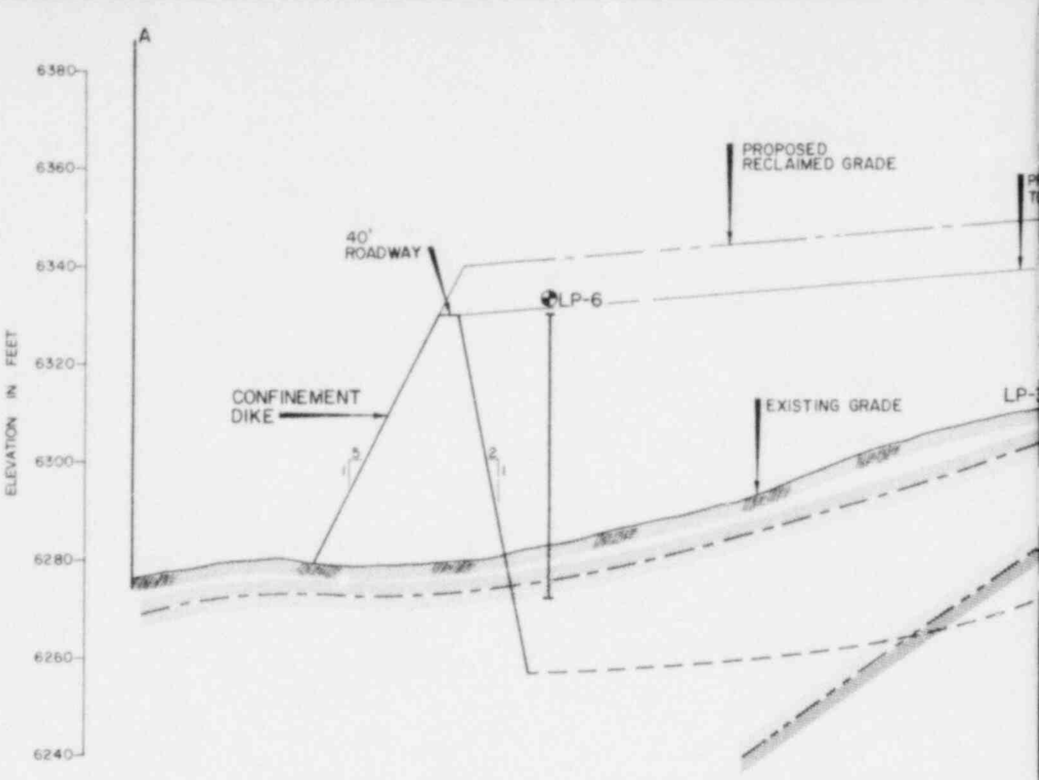
466 11 (10-79)

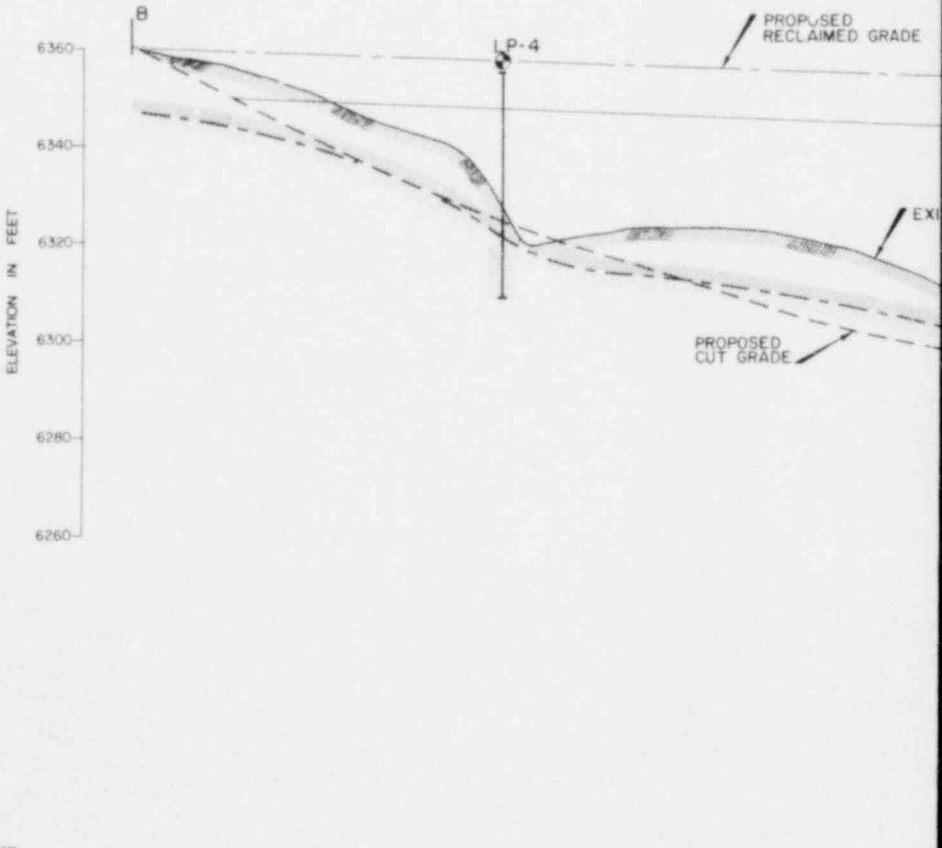


SECTION C-C'
TAILINGS IMPOUNDMENT ALTERNATIVE
LONG PARK-OPTION I

DAMES & MOORE

JOB NUMBER ______ DRAWN BY ______ DATE ______





EXPLANATIONS

KEY :

LP-6 LOCATION OF BORINGS PROJECTED INTO THE PLANE OF THE PROFILE

LP-5 LOCATION OF TEST PITS PROJECTED INTO THE PLANE OF THE PROFILE

LEGEND :

▨ ALLUVIUM DEPOSITS

▨ BRUSHY BASIN MEMBER MORRISON FORMATION

▨ SALT WASH MEMBER MORRISON FORMATION

NOTES :

FOR THE LOCATION OF SECTIONS A–A' & B–B' SEE PLATES 8 AND 7 RESPECTIVELY

THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

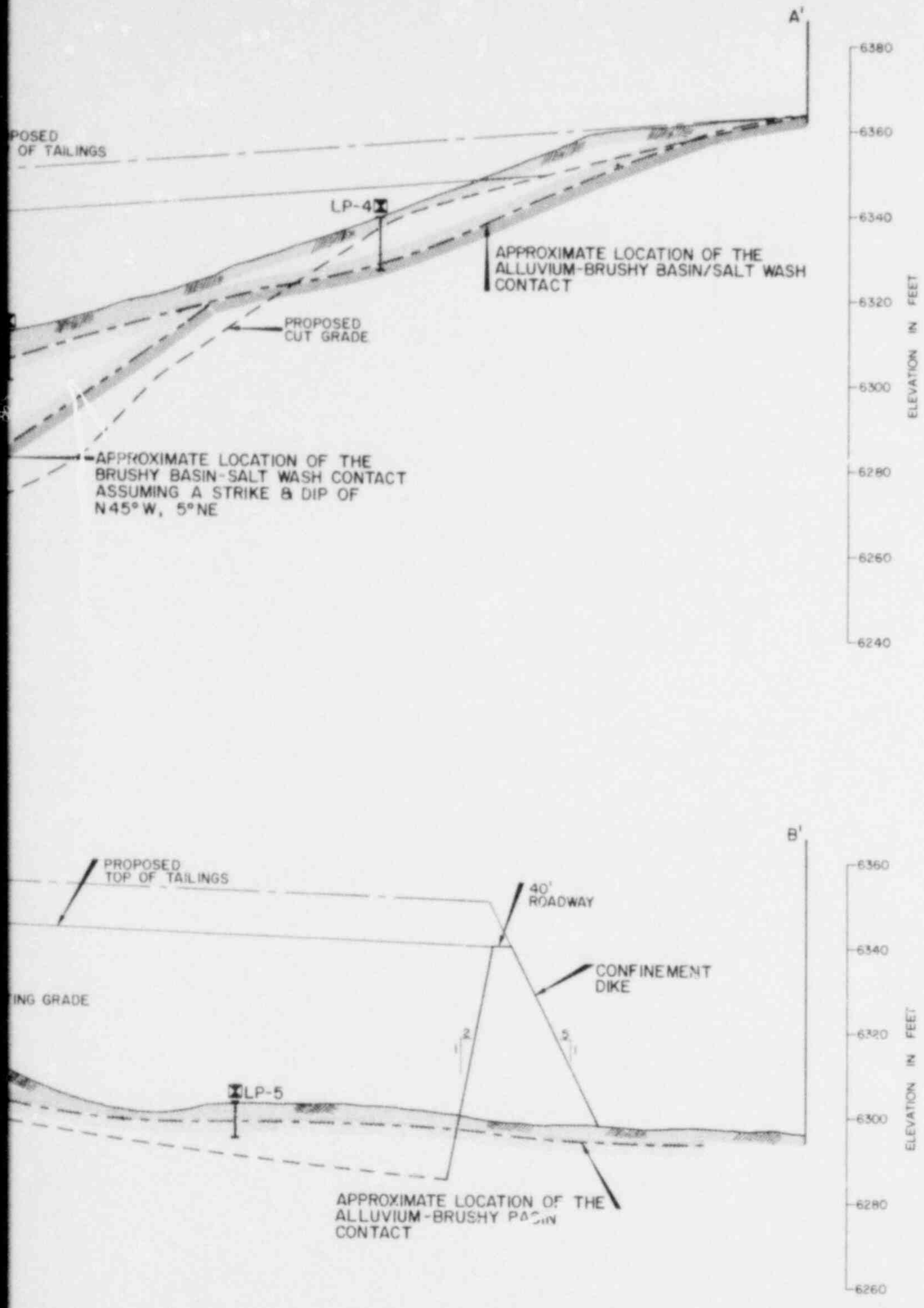
ELEVATIONS REFER TO MSL DATUM.

HORIZONTAL SCALE IN FEET

100 0 100 200 300 400 500

VERTICAL EXAGGERATION 10X

466.11 (10-79)



SECTIONS A-A' AND B-B'
TAILINGS IMPOUNDMENT ALTERNATIVES
LONG PARK-OPTION 3
LONG PARK-OPTION 2

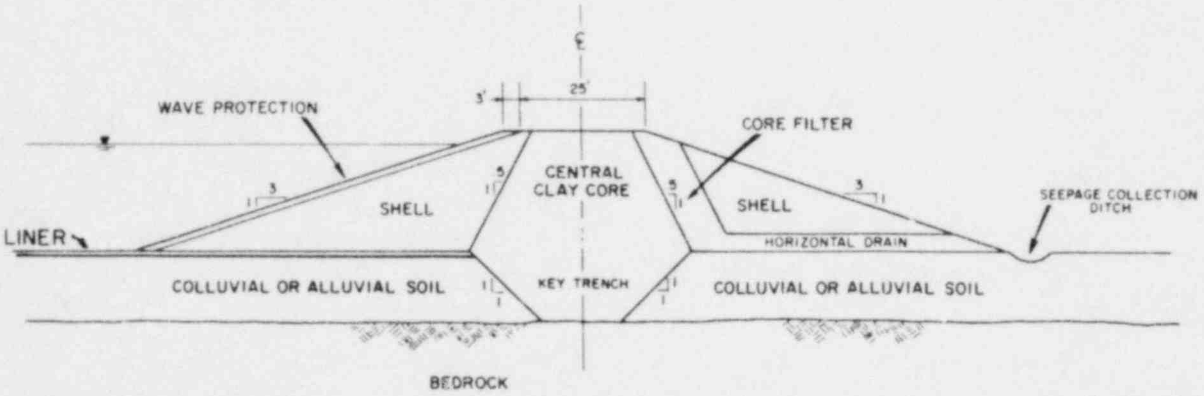
DAMES & MOORE

PLATE 14

BY ______ DATE ______
CHECKED BY ______

FILE 0082 138 Drawn

REVISIONS
BY ______ DATE ______

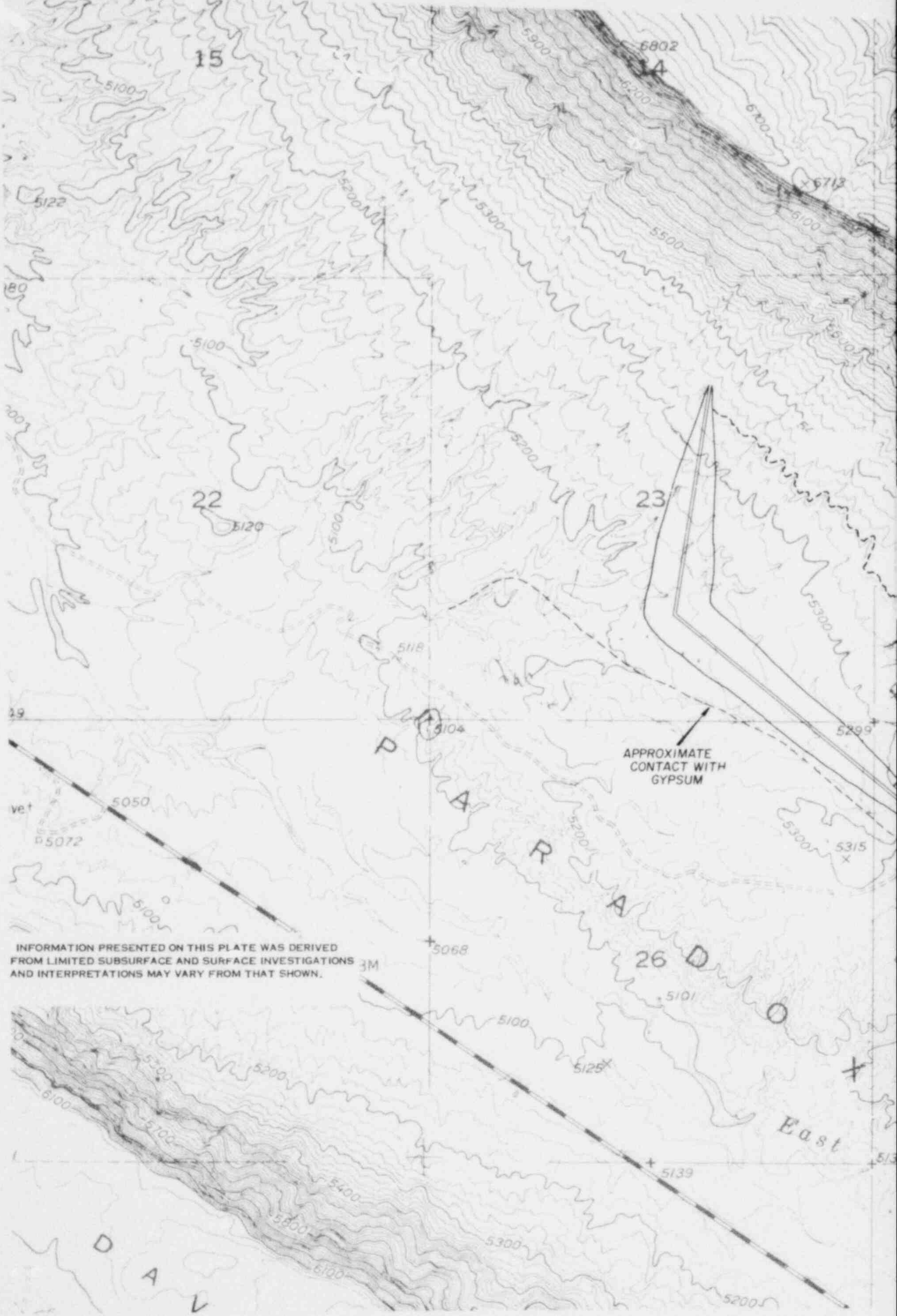


TYPICAL DAM SECTION FOR EVAPORATION PONDS

DAMES & MOORE

946.7 (REV. 6-61)

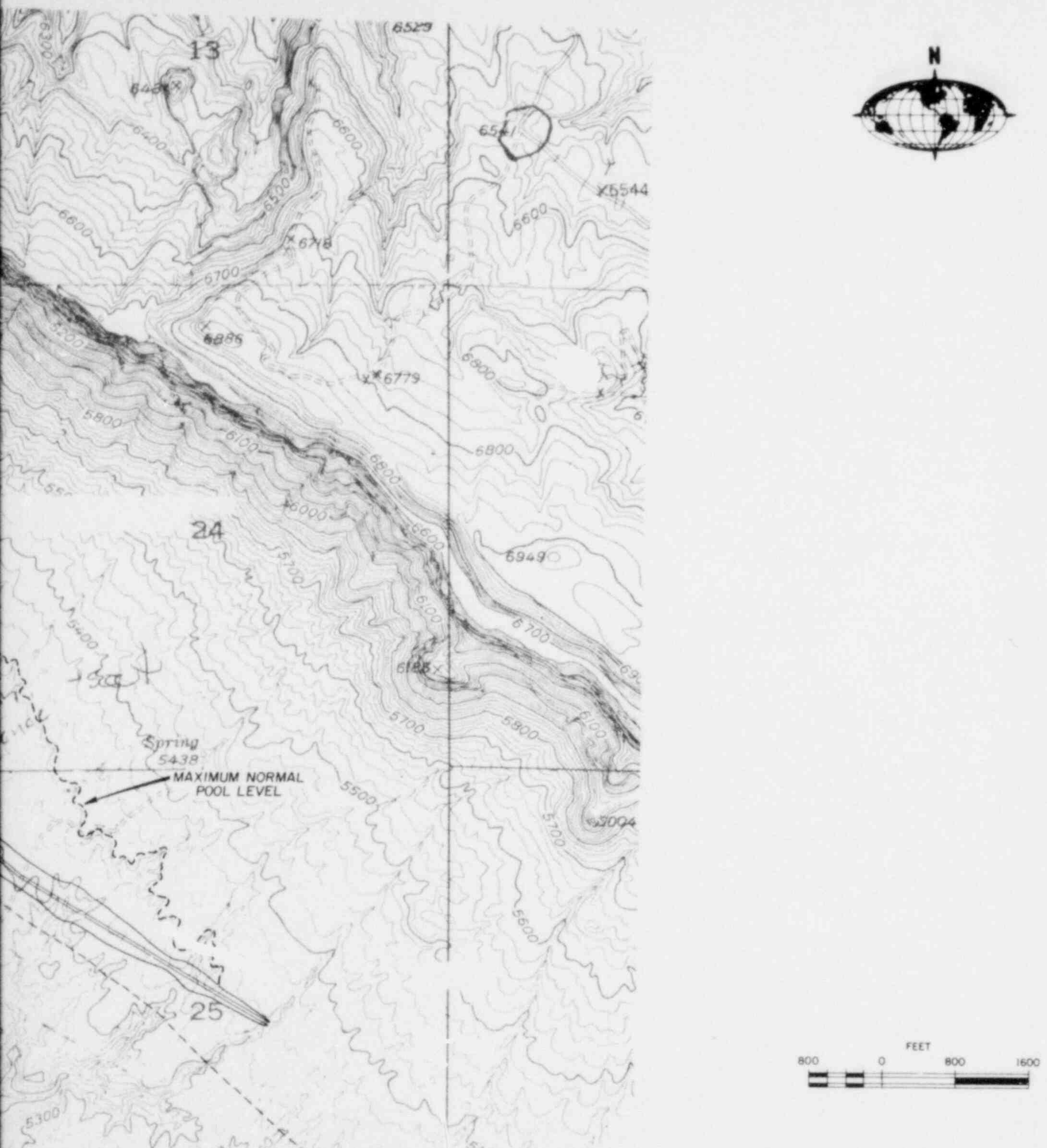
JOB NUMBER _______ DRAWN BY _______ DATE _______



INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"URAVAN, COLORADO" 1960.

466.11 (10-79)



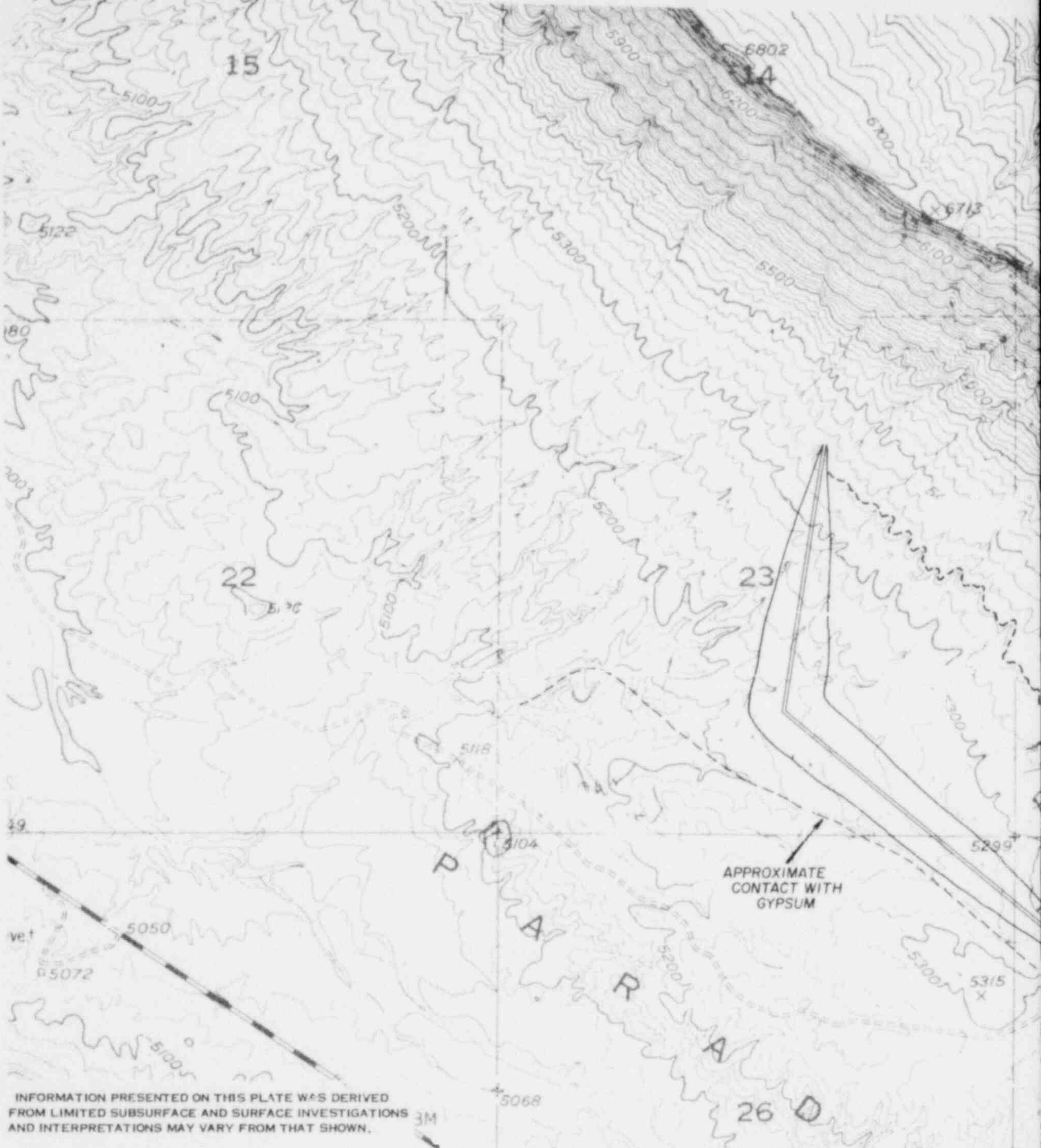
EVAPORATION POND ALTERNATIVE

PARADOX 2 - OPTION I

DAMES & MOORE

PLATE 16

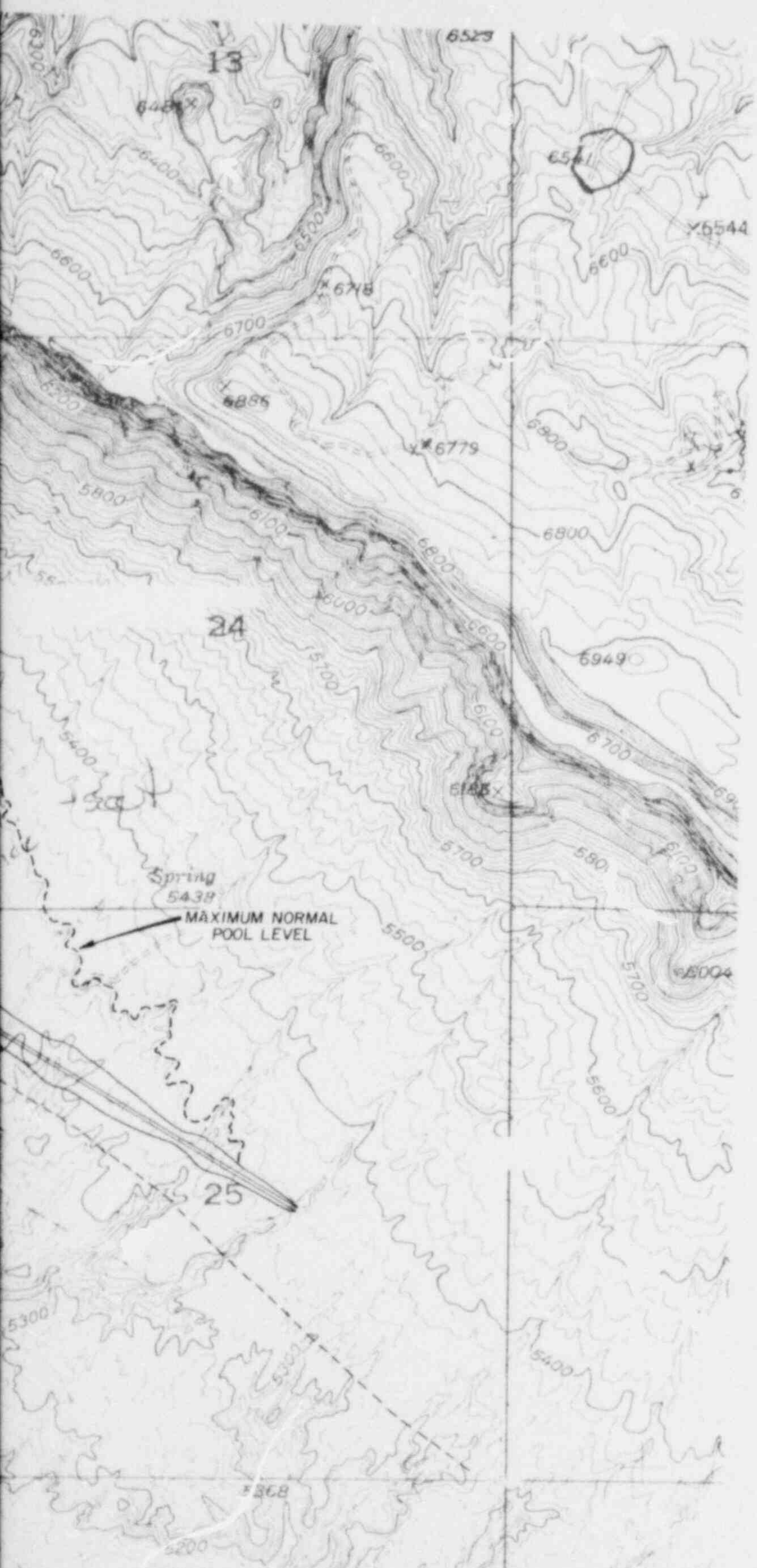
JOB NUMBER DRAWN BY DATE



INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"URAVAN, COLORADO" 1960.

456.11 (10-79)



EVAPORATION POND ALTERNATIVE
PARADOX 2 - OPTION I

DAMES & MOORE

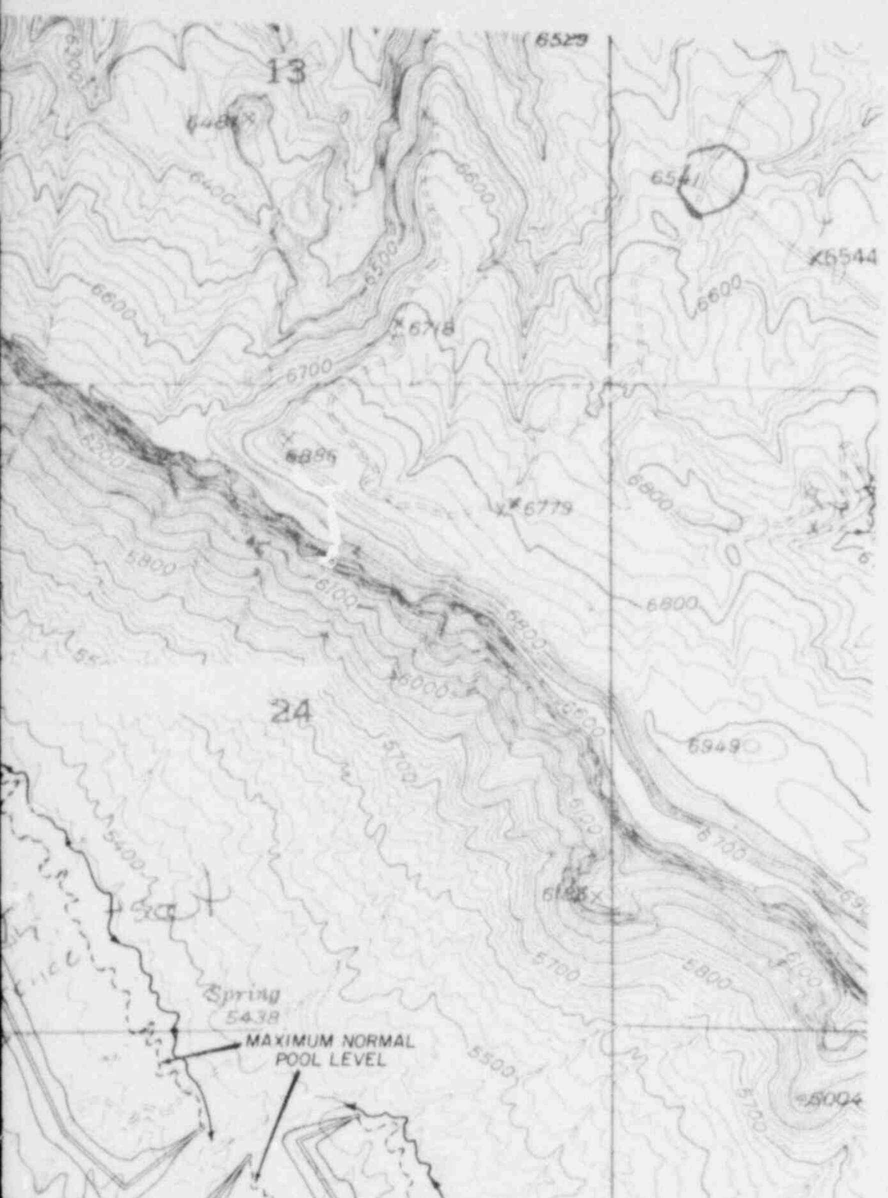
PLATE 16

INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
" DAVIS MESA, COLORADO" 1960.

JOB NUMBER ______ DRAWN BY ______ DATE ______

466.11 (10-79)



DIVERSION CHANNEL – ARROWS SHOW DIRECTION OF FLOW

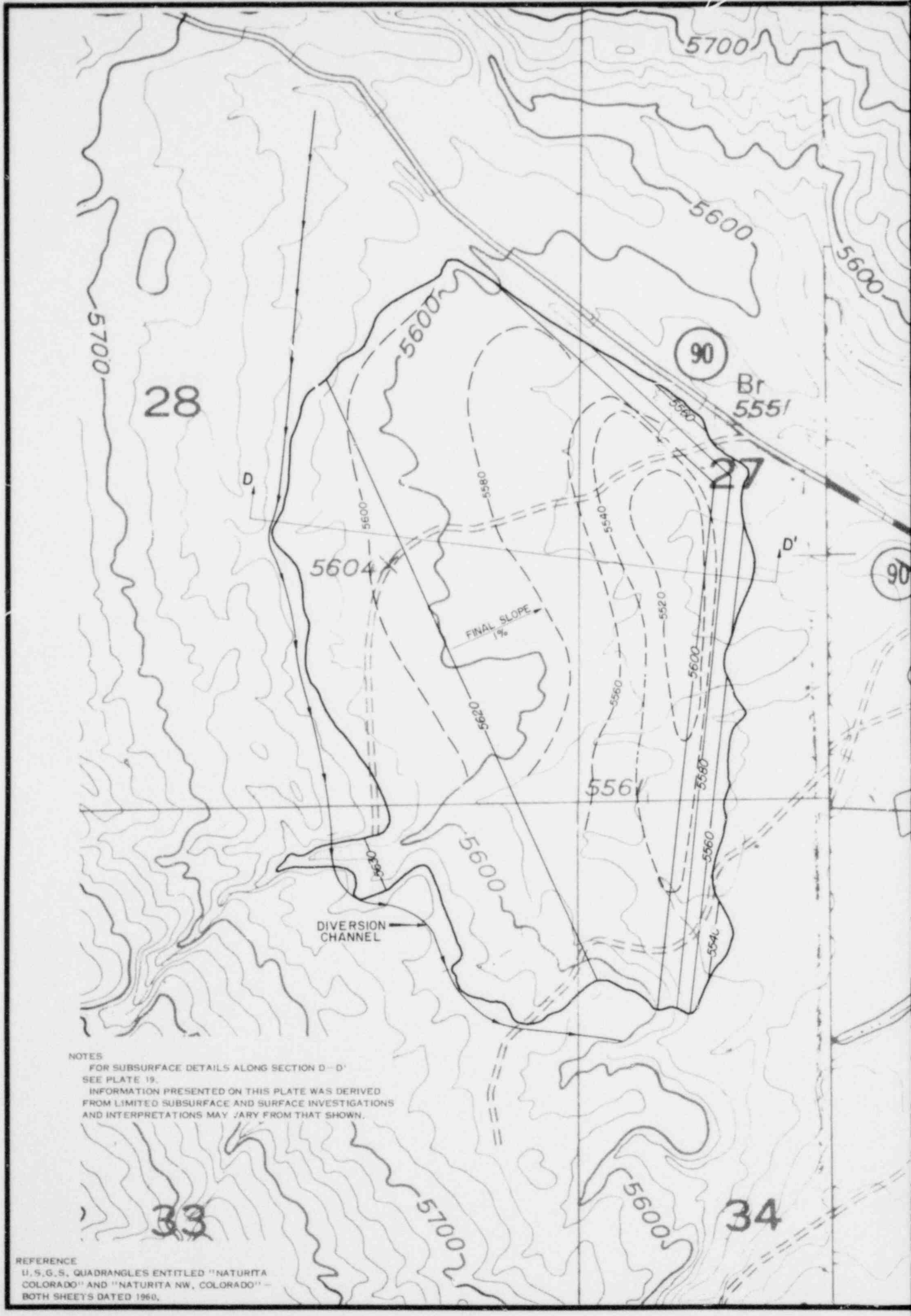
EVAPORATION POND ALTERNATIVE

PARADOX 2-OPTION 2

DAMES & MOORE

PLATE 17

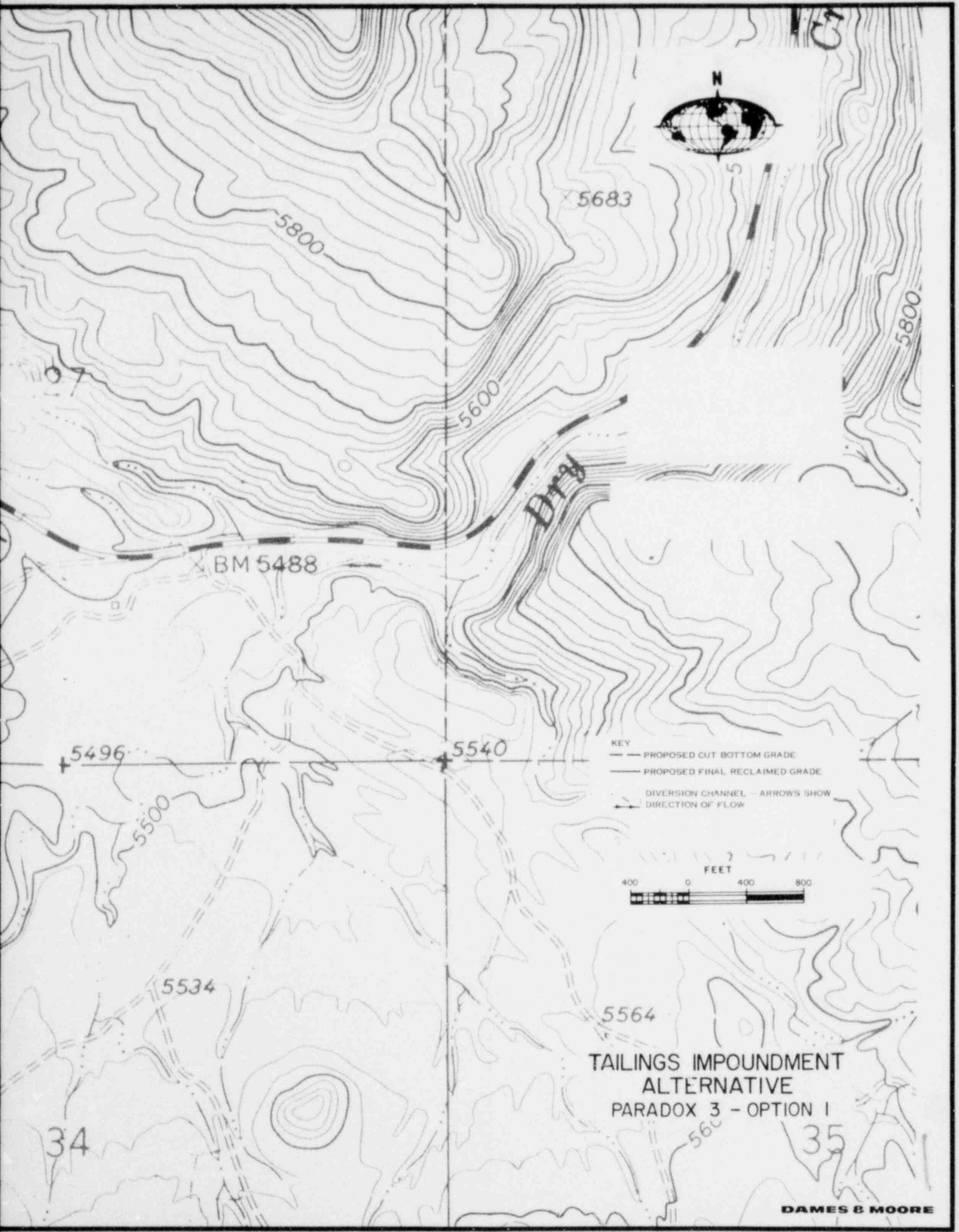
JOB NUMBER ________ DRAWN BY ________ DATE ________



NOTES
FOR SUBSURFACE DETAILS ALONG SECTION D—D' SEE PLATE 19.
INFORMATION PRESENTED ON THIS PLATE WAS DERIVED FROM LIMITED SUBSURFACE AND SURFACE INVESTIGATIONS AND INTERPRETATIONS MAY VARY FROM THAT SHOWN.

REFERENCE
U.S.G.S. QUADRANGLES ENTITLED "NATURITA COLORADO" AND "NATURITA NW, COLORADO" — BOTH SHEETS DATED 1960.

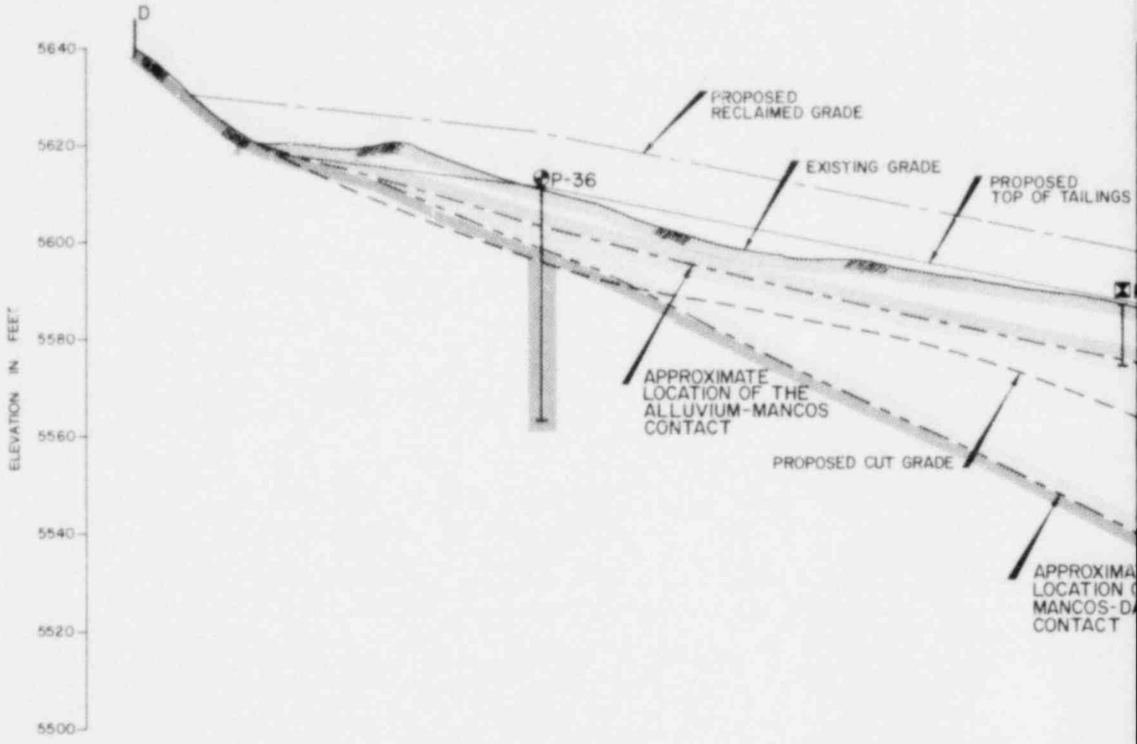
466 11 (10-79)



TAILINGS IMPOUNDMENT
ALTERNATIVE
PARADOX 3 - OPTION I

DAMES & MOORE

PLATE 18



EXPLANATIONS

KEY:

P-36 LOCATION OF BORINGS PROJECTED INTO THE PLANE OF THE PROFILE

P-32 LOCATION OF TEST PITS PROJECTED INTO THE PLANE OF THE PROFILE

LEGEND:

- ░ ALLUVIUM DEPOSITS
- ░ MANCOS SHALE
- ▓ DAKOTA SANDSTONE

NOTES:

FOT THE LOCATION OF SECTION D-D' SEE PLATE

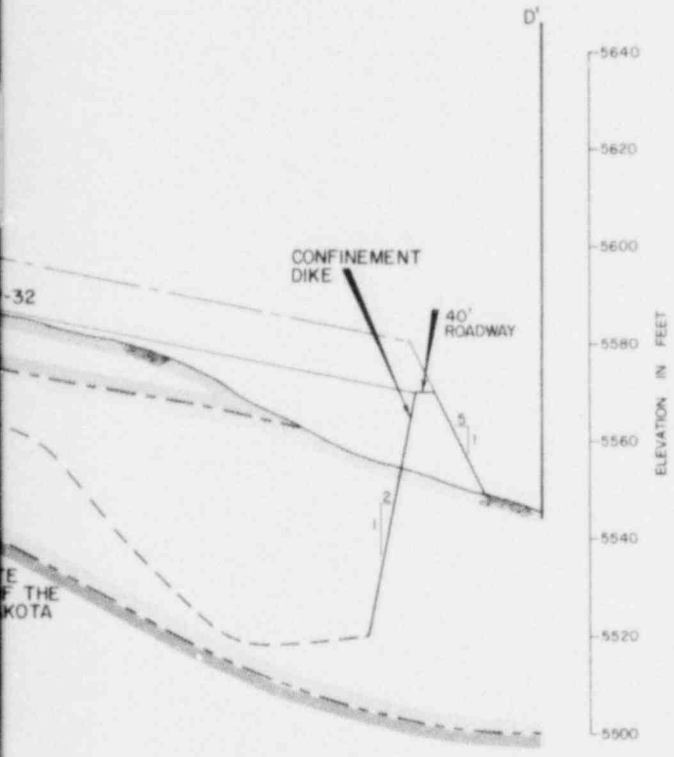
THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

ELEVATIONS REFER TO MSL DATUM.

HORIZONTAL SCALE IN FEET

100 0 100 200 300 400 500

VERTICAL EXAGGERATION 10X



SECTION D-D'
TAILINGS IMPOUNDMENT ALTERNATIVE
PARADOX 3-OPTION I

DAMES & MOORE

PLATE 19

APPENDIX A

TABLE OF CONTENTS

APPENDIX A

LIST OF TABLES

APPENDIX A

LIST OF PLATES

APPENDIX A

GEOLOGY AND SEISMICITY

GENERAL

Discussions of regional stratigraphy, regional structure, tectonic history, potentially active faults and historical seismicity are included in the Environmental Report prepared for the Uravan Uranium Project by Dames & Moore (dated 31 August 1978).

The four alternative sites are situated in a linear northwest-trending band that is 20 miles long and 2 miles wide. In terms of seismicity, we believe that there is virtually no distinction from one site to the next. Faults are known or suspected to exist under Paradox 1, 2 and 3 sites; none at Long Park. As discussed in the remainder of this appendix and in Appendix B, Paradox Valley Anticline Faults, the faults are considered to be incapable of generating earthquakes exceeding the general seismic "background" of the region. The stress regime responsible for the faults is probably still active, hence the faults are considered active from a ground rupture standpoint.

Table A-I, Stratigraphic Table, contains brief descriptions of the lithologic character, thickness and age of the sedimentary rock formations exposed in the salt anticline region of Southwestern Colorado. The remaining paragraphs of this appendix contain brief descriptions of the geology of the four sites considered as alternatives for tailings disposal.

LONG PARK

The distribution of geologic units at the Long Park site is shown on Plate A-1A, Geologic Map-Long Park. Subsurface data are presented on Plate A-1B, Geologic Section-Long Park, and logs of boring and test pits (Appendix C).

REVISIONS BY ______ DATE ______

FILE ______

BY ______ CHECKED BY ______ DATE ______

TABLE A-I

STRATIGRAPHIC TABLE

Sedimentary rock formations exposed in the salt anticline region of southwestern Colorado

System	Series	Stratigraphic unit		Thickness (feet)	Character
Quaternary	Holocene			0-20	Talus, alluvium, and wind-deposited material.
	Pleistocene			0-200	Talus, landslide deposits (in part of Holocene age), fanglomerate, lake beds, and undifferentiated stream deposits.
			Unconformity		
Tertiary (?)	Pliocene (?)			(1)	Gravel composed of pebbles and boulders of porphyritic igneous rock.
			Unconformity		
Cretaceous	Upper		Mesaverde Formation	(2)	Thick-bedded yellowish-gray sandstone and light-gray shale.
		(P3)	Mancos Shale	2,000±	Dark-gray fissile shale.
		(P3)	Dakota Sandstone	70-220	Yellow lenticular sandstone and conglomerate; interbedded carbonaceous shale and impure coal.
			Unconformity		
	Lower	(LP)	Burro Canyon Formation	50-300	White, gray, and red sandstone and conglomerate; interbedded green and reddish-purple shale.
Jurassic	Upper	(LP)	Morrison Formation	300-750	Brushy Basin Member; variegated bentonitic shale and mudstone; rusty-red and red sandstone and conglomerate; local thin limestone beds.
				240-440	Salt Wash Member; white, gray, buff, and rusty-red sandstone; red, reddish-brown, green, and gray mudstone; scattered thin limestone beds.
			Summerville Formation	0-100	Thin-bedded red, gray, green, and brown sandstone, sandy shale, and mudstone.
		San Rafael Group	Entrada Sandstone	0-225	Slick Rock Member; orange, buff, and white fine-grained massive and crossbedded sandstone.
				0-100	Dewey Bridge Member; red, buff, and orange horizontally bedded mudstone, siltstone, and sandstone.
			Unconformity		
		Glen Canyon Group	Navajo Sandstone	0-500+	Buff and gray crossbedded fine-grained sandstone.
Triassic (?)	Upper		Kayenta Formation	0-300	Irregularly bedded red, buff, gray, and lavender fine- to coarse-grained sandstone, siltstone, and shale. A few lenses of conglomerate.
Triassic	Upper		Wingate Sandstone	0-500	Fine-grained reddish-brown thick-bedded, massive, and crossbedded cliff-forming sandstone.
			Chinle Formation	0-750	Red to orange-red siltstone with interbedded lenses of red sandstone, shale, and limestone-pebble and clay-pellet conglomerate. Lenses of quartz-pebble conglomerate and grit at the base.
			Unconformity		
	Middle (?)	(P2)	Moenkopi Formation	0-500	Upper member; chocolate-brown ripple-bedded shale; thin lenses of arkosic sandstone.
	Lower			0-290	Middle member; chocolate-brown arkose, arkosic conglomerate, and ripple-bedded shale.
Triassic (?)				0-300	Lower member; reddish- to yellowish-brown indistinctly bedded poorly sorted mudstone. Local gypsum beds near base.
			Unconformity		
Permian		(P2)	Cutler Formation	0-9,000+	Maroon, red, light-red-mottled, and purple conglomerate, arkose, and arkosic sandstone; thin beds of sandy mudstone.
Pennsylvanian	Upper and Middle		Rico Formation	0- 50?	Maroon, red, light-red-mottled, and purple conglomerate, arkose, and arkosic sandstone; interbedded red and gray marine limestone.
			Local unconformity		
	Middle	(P1)	Hermosa Formation	2,000-2,200	Limestone member; gray fossiliferous limestone and thin beds of shale; minor arkose.
		(P2)		(2)	Paradox Member; sandstone, arkose, carbonaceous shale, limestone, gypsum, and salt.

(1)
(2) – NOTES FROM ORIGINAL PUBLICATION

(LP) – DENOTES FORMATIONS EXPOSED AT LONG PARK

(P1) – DENOTES FORMATIONS UNDERLYING PARADOX 1

(P2) – DENOTES FORMATIONS UNDERLYING AND EXPOSED IN PARADOX 2

(P3) – DENOTES FORMATIONS EXPOSED AT PARADOX 3

REFERENCE
CATER, 1970, PAGE 7.

In general, the rocks underlying Long Park consist of the Jurassic Morrison Formation and the Cretaceous Burro Canyon Formation in a uniform and conformable northeast-dipping sequence. As shown on Table A-I, Stratigraphic Table, the Morrison Formation consists of two members, the Salt Wash Member (lower) and the Brushy Basin Member (upper).

The Salt Wash Member is principally sandstone while the Brushy Basin Member is principally shale. The Burro Canyon Formation overlies the Morrison Formation and consists of sandstone and conglomerate.

Preferential erosion of the Brushy Basin Member has resulted in the general topographic configuration of Long Park. A veneer of alluvial deposits of presumed Quaternary age has accumulated over the Morrison Formation. The alluvial deposits at Long Park vary in thickness from 5 feet to 20 feet.

Rocks of the Morrison and Burro Canyon Formations at Long Park dip 3 to 10 degrees to the northeast. No faults have been mapped at Long Park and none were observed during our field exploration at this site.

PARADOX 1 AND 2

The Paradox 1 and Paradox 2 sites are situated in geologically similar settings on the northeast side of the axis of Paradox Valley. The distribution of geologic units at these two sites is shown on Plate A-2A, Geologic Map-Paradox 1, and Plate A-3A, Geologic Map-Paradox 2. Subsurface data are presented on Plate A-2B, Geologic Section-Paradox 1, Plate A-3B, Geologic Section-Paradox 2, and logs of borings and test pits for the Paradox 2 site (Appendix C). No subsurface investigation was performed at Paradox 1.

In general, the rocks underlying Paradox 1 and Paradox 2 consist of the Pennsylvania Hermosa Formation. At Paradox 2 the Permian Cutler Formation is locally exposed and the Triassic Moenkopi Formation is thought to be present in the subsurface (see Plate A-3B).

As shown on Table A-I, Stratigraphic Table, the Hermosa Formation consists of two members. The Paradox Member (lower) includes a number of lithologies but is principally salt. The upper member is unnamed and consists of limestone. The Cutler Formation is principally conglomerate and sandstone. The Moenkopi Formation consists of interbedded mudstone, shale, sandstone and conglomerate and includes local gypsum beds near the base.

Alluvial and colluvial deposits of presumed Quaternary age cover all of the Paradox 1 site and most of the Paradox 2 site. The thickness of alluvial and colluvial deposits at Paradox 1 is unknown. The thickness of alluvial and colluvial deposits at Paradox 2 is variable, but exceeds 45 feet in the NW 1/4, Sec. 23, T47N, R18W.

The structure of the rocks exposed in the Paradox Valley is very complex and caused by plastic deformation of the salt comprising the Paradox Member of the Hermosa Formation (see Appendix B). In general, the rocks strike northwest, parallel to the axis of Paradox Valley which represents the collapsed crest of the Paradox Valley Salt Anticline. Cater (1970, p. 57, 58) discusses in detail the structure of the Paradox Valley Anticline.

Several faults have been mapped on Paradox 2 by Cater (1955a) (see Plate A-3A). These faults are generally parallel to the axis of Paradox Valley and probably formed in response to salt deformation and/or collapse of the crest of the anticline. One fault has been interpreted by Withington (1955) to exist in the subsurface under Paradox 1 (see Plate A-2B). This fault is probably formed in response to similar stresses as those causing the faults elsewhere in the Paradox Valley.

None of the faults mapped by Cater (1955a) or Withington (1955) are shown to cut deposits of presumed Quaternary age. However, since the faults are thought to have formed in response to salt deformation (solution and flowage) and since the salt deformation processes are probably continuing, the faults are considered active. Movement on these faults probably occurs as creep without the buildup of large stresses. Consequently, these faults are probably not capable of generating earthquakes which exceed the magnitude of the general "background" seismicity of the region.

PARADOX 3

The distribution of geologic units at the Paradox 3 site is shown on Plate A-4A, Geologic Map-Paradox 3. Subsurface data are presented on Plate A-4B, Geologic Section-Paradox 3, and logs of borings and test pits (Appendix C).

In general, the rocks underlying Paradox 3 consist of the Cretaceous Dakota Sandstone and the Cretaceous Mancos Shale. Alluvial deposits of presumed Quaternary age blanket much of the site. The maximum thickness of alluvial deposits was found to be 35 feet in the SE 1/4, Sec. 27, T46N, R16W.

The Paradox 3 site lies near the center of a structural basin described by Cater (1970, p. 54) as "the downsagged unit at the southeast end of the [Paradox Valley] anticline." Cater (1970, p. 54-57) discusses the structure of the downsagged unit and believes that it formed during collapse of the crest of the Paradox Valley Anticline. He states (p. 57) that "The central part of the downsagged basin is devoid of structural complexities and in unfaulted."

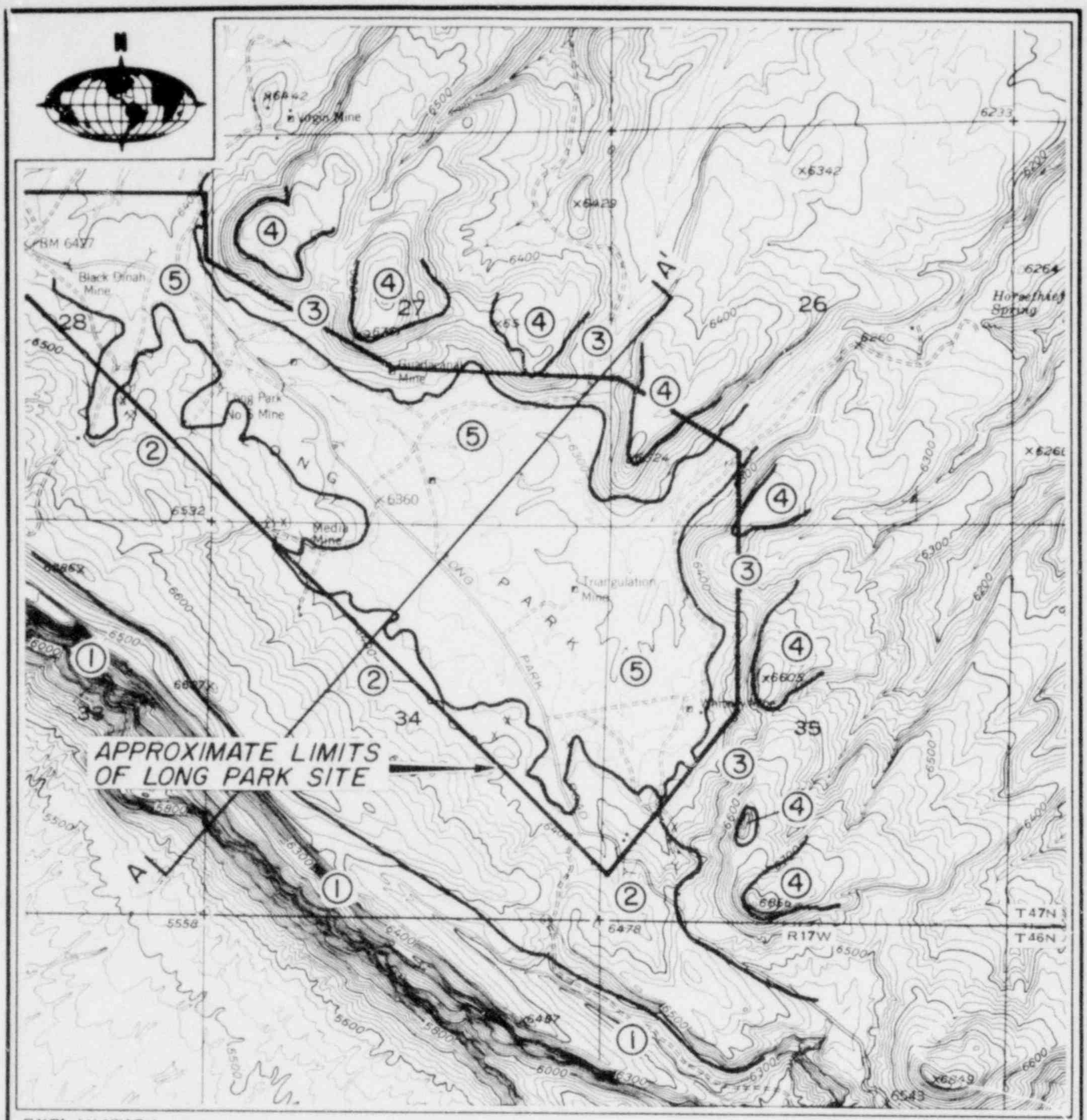
During our field exploration at Paradox 3, three small faults were observed in the southeast bank of Dry Creek in the NE 1/4, SW 1/4, Sec. 34, T46N, R16W. Two of these faults appear to displace the base of the alluvial deposits of presumed Quaternary age and are therefore considered active. The distribution of geologic units interpreted from our borings suggests that two other faults may be present on this site. Faults observed and suspected to exist at Paradox 3 are discussed further in Appendix B.

REVISIONS
BY ____ DATE ____

FILE ____

BY ____ DATE ____
CHECKED BY ____

946.7 (REV. 6-61)



EXPLANATION

GEOLOGIC UNITS:

① UNDIFFERENTIATED PRE-MORRISON FORMATIONS
② JURASSIC MORRISON FORMATION – SALT WASH MEMBER (SANDSTONE)
③ JURASSIC MORRISON FORMATION – BRUSHY BASIN MEMBER (SHALE)
④ CRETACEOUS BURRO CANYON FORMATION (SANDSTONE AND CONGLOMERATE)
⑤ QUATERNARY ALLUVIAL DEPOSITS

SYMBOLS:

——— CONTACT SEPARATING UNITS

A└──┘A' LOCATION OF SECTION (SEE PLATE A-1B)

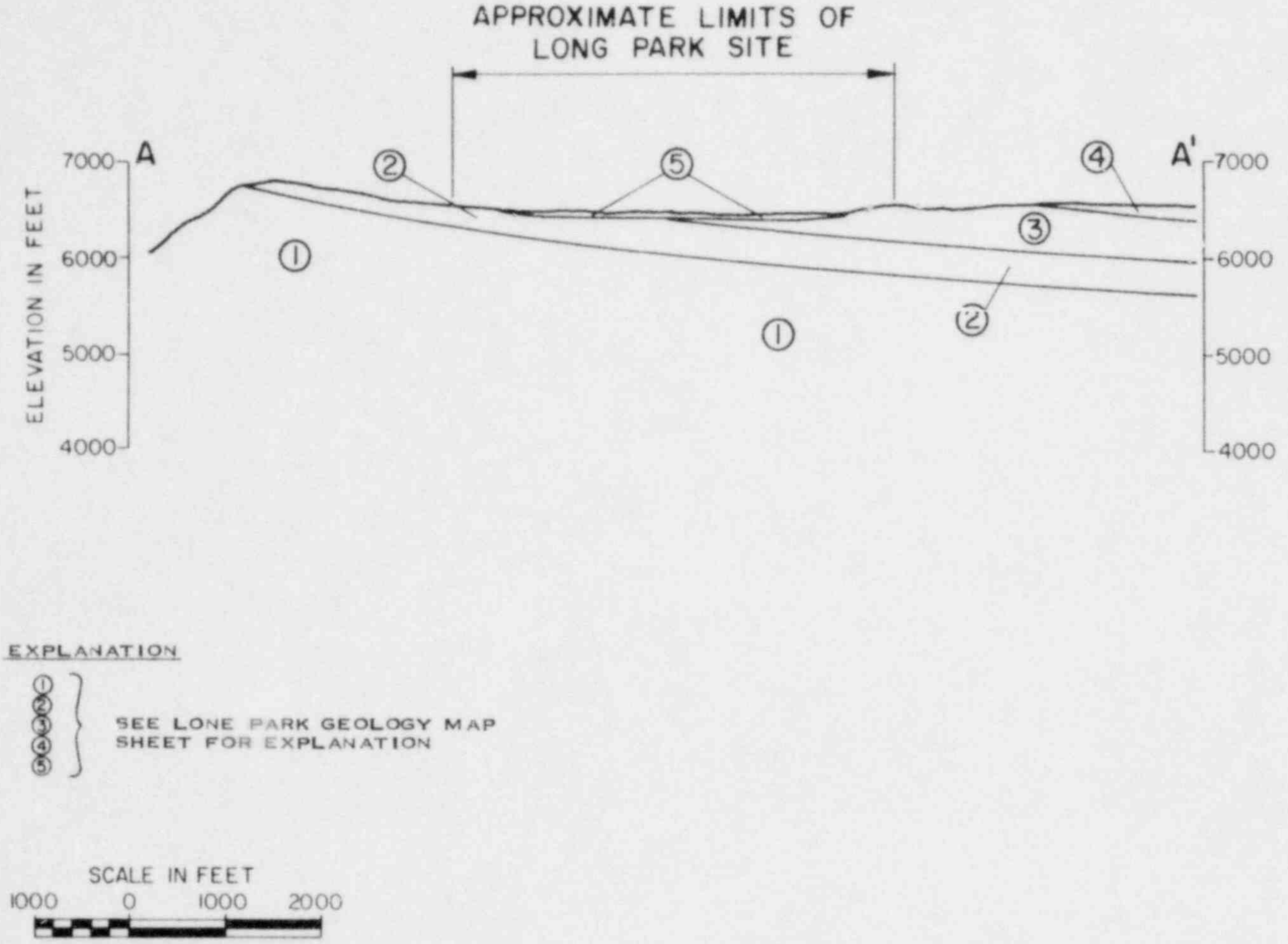
SCALE IN FEET
1000 0 1000 2000

GEOLOGIC MAP-LONG PARK

REFERENCE:
BASE MAP U.S.G.S. URAVAN 7 1/2 MINUTE TOPOGRAPHIC QUAD. GEOLOGY AFTER U.S.G.S. GQ 78

DAMES & MOORE

PLATE A-1A



GEOLOGIC SECTION-LONG PARK

REFERENCE:
U.S.G.S. GQ 78

DAMES & MOORE

PLATE A-1B

REVISIONS
BY ____ DATE ____

FILE ____

BY ____ DATE ____
CHECKED BY ____

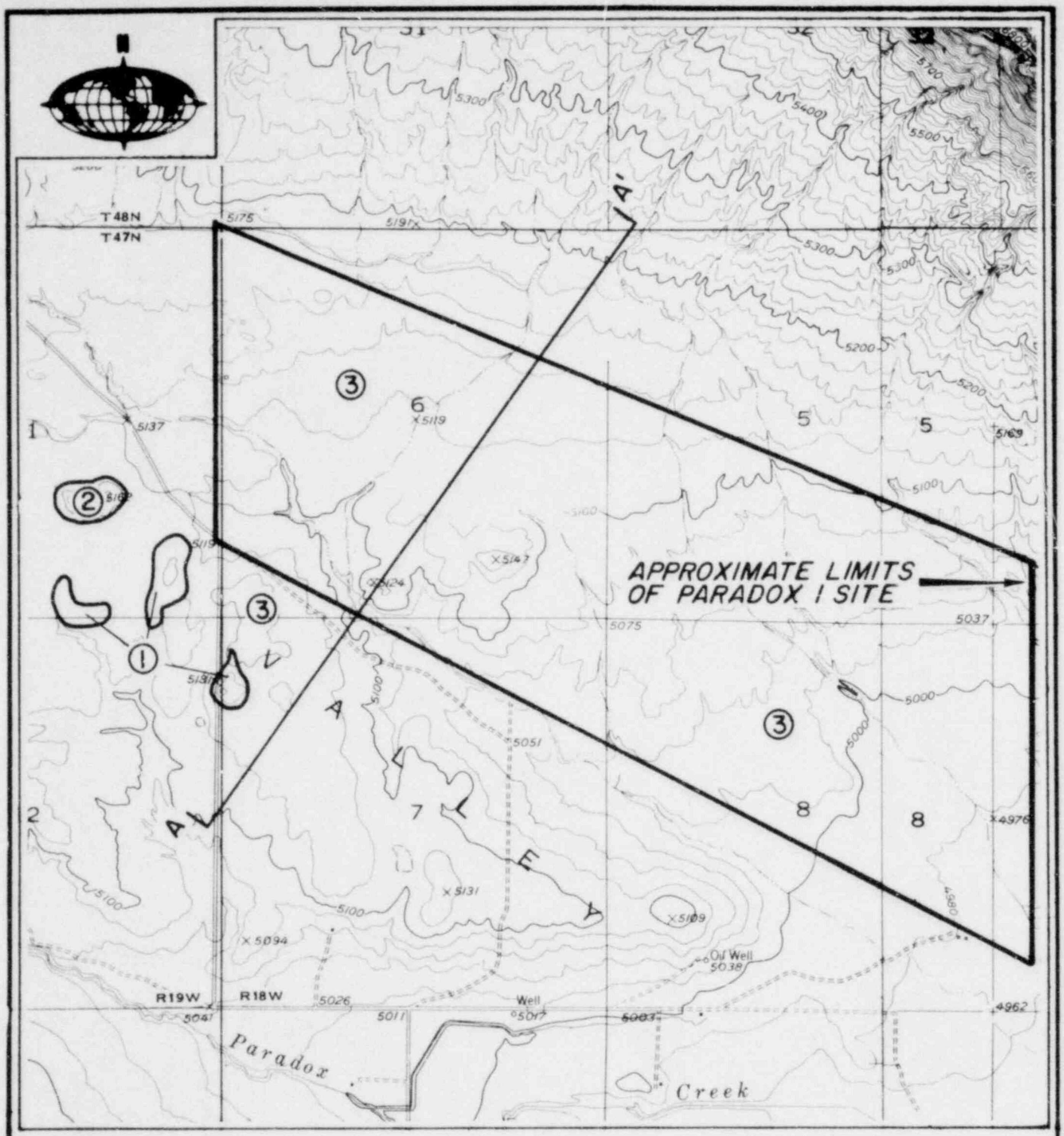
946.7 (REV. 6-61)

REVISIONS BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______

946.7 (REV. 6-61)



EXPLANATION

GEOLOGIC UNITS:

① PENNSYLVANIAN HERMOSA FORMATION – PARADOX MEMBER (SALT)
② PENNSYLVANIAN HERMOSA FORMATION – LIMESTONE MEMBER
③ QUATERNARY ALLUVIAL DEPOSITS

SYMBOLS:

CONTACT SEPARATING UNITS
A A' LOCATION OF SECTION (SEE PLATE A-2B)

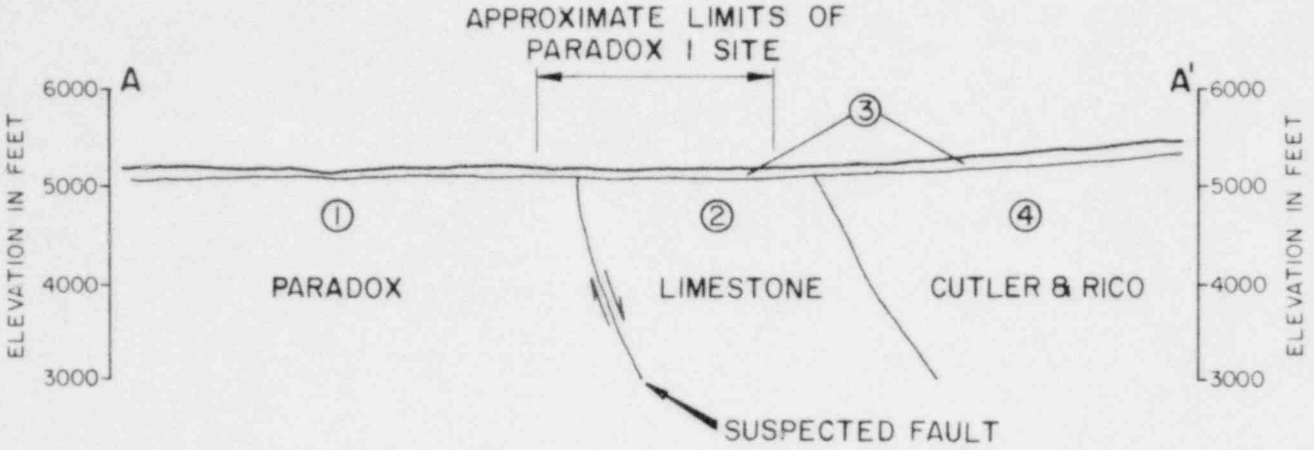
SCALE IN FEET
1000 0 1000 2000

GEOLOGIC MAP-PARADOX I

REFERENCE:
BASE MAP U.S.G.S. DAVIS MESA AND PARADOX 7 1/2 MINUTE TOPOGRAPHIC QUADS. GEOLOGY AFTER U.S.G.S. GQ 71 AND GQ 72

DAMES & MOORE

PLATE A-2A



EXPLANATION

①
②
③ SEE PARADOX 1 GEOLOGY MAP SHEET FOR EXPLANATION

④ PERMIAN CUTLER AND RICO FORMATION UNDIFFERENTIATED

GEOLOGIC SECTION-PARADOX I

REFERENCE:
U.S.G.S. GQ 72

DAMES & MOORE

PLATE A-2B

REVISIONS
BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______

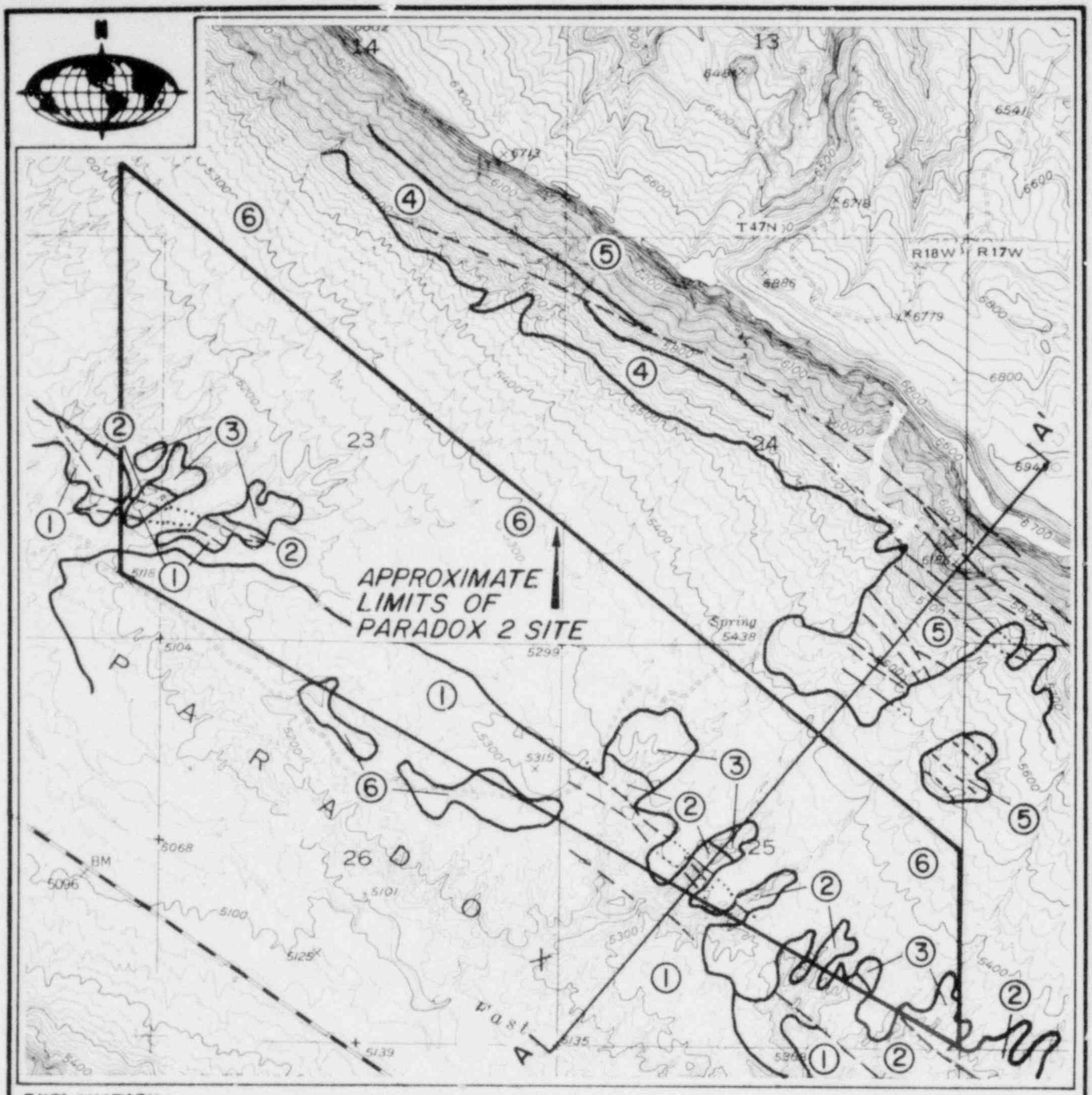
946.7 (REV. 6-61)

REVISIONS BY ________ DATE ________

FILE ________

BY ________ DATE ________
CHECKED BY ________

946.7 (REV. 6-61)



EXPLANATION

GEOLOGIC UNITS

① PENNSYLVANIAN HERMOSA FORMATION – PARADOX MEMBER (SALT)
② PENNSYLVANIAN HERMOSA FORMATION – LIMESTONE MEMBER
③ PERMIAN CUTLER FORMATION – (CONGLOMERATE AND SANDSTONE)
④ TRIASSIC MOENKOPI FORMATION – (MUDSTONE TO CONGLOMERATE)
⑤ UNDIFFERENTIATED POST – MOENKOPI FORMATIONS
⑥ QUATERNARY ALLUVIAL AND COLLUVIAL DEPOSTIS

SYMBOLS

CONTACT SEPARATING UNITS

FAULT, DOTTED WHERE CONCEALED

A A' LOCATION OF SECTION (SEE PLATE A-3B)

SCALE IN FEET
1000 0 1000 2000

GEOLOGIC MAP-PARADOX 2

REFERENCE
BASE MAP U.S.G.S. DAVIS MESA 7 1/2 MINUTE TOPOGRAPHIC QUAD. GEOLOGY AFTER U.S.G.S. GQ 71

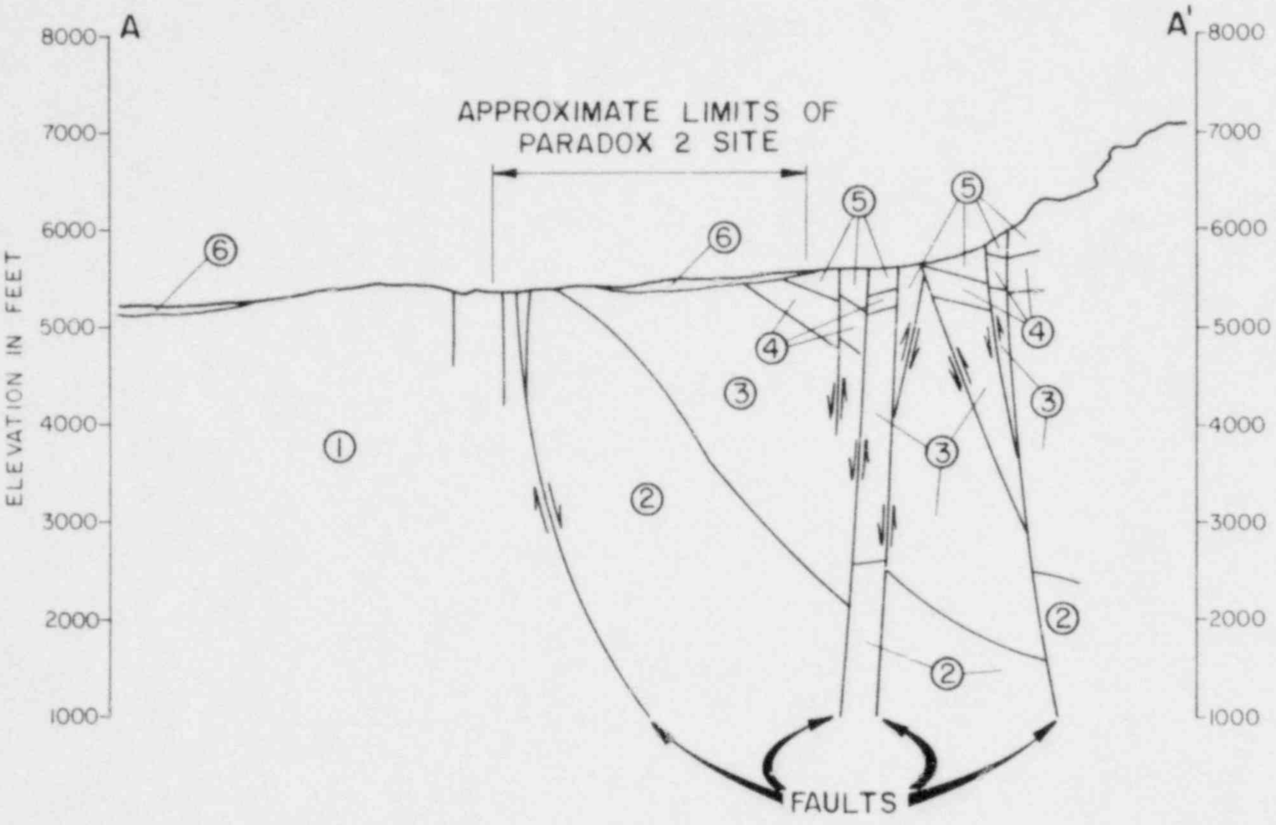
DAMES & MOORE

PLATE A-3A

REVISIONS BY ______ DATE ______

FILE ______

BY ______ DATE ______ CHECKED BY ______



EXPLANATION

①
②
③
④
⑤
⑥

SEE PARADOX 2 GEOLOGY MAP SHEET FOR EXPLANATION

SCALE IN FEET
1000 0 1000 2000

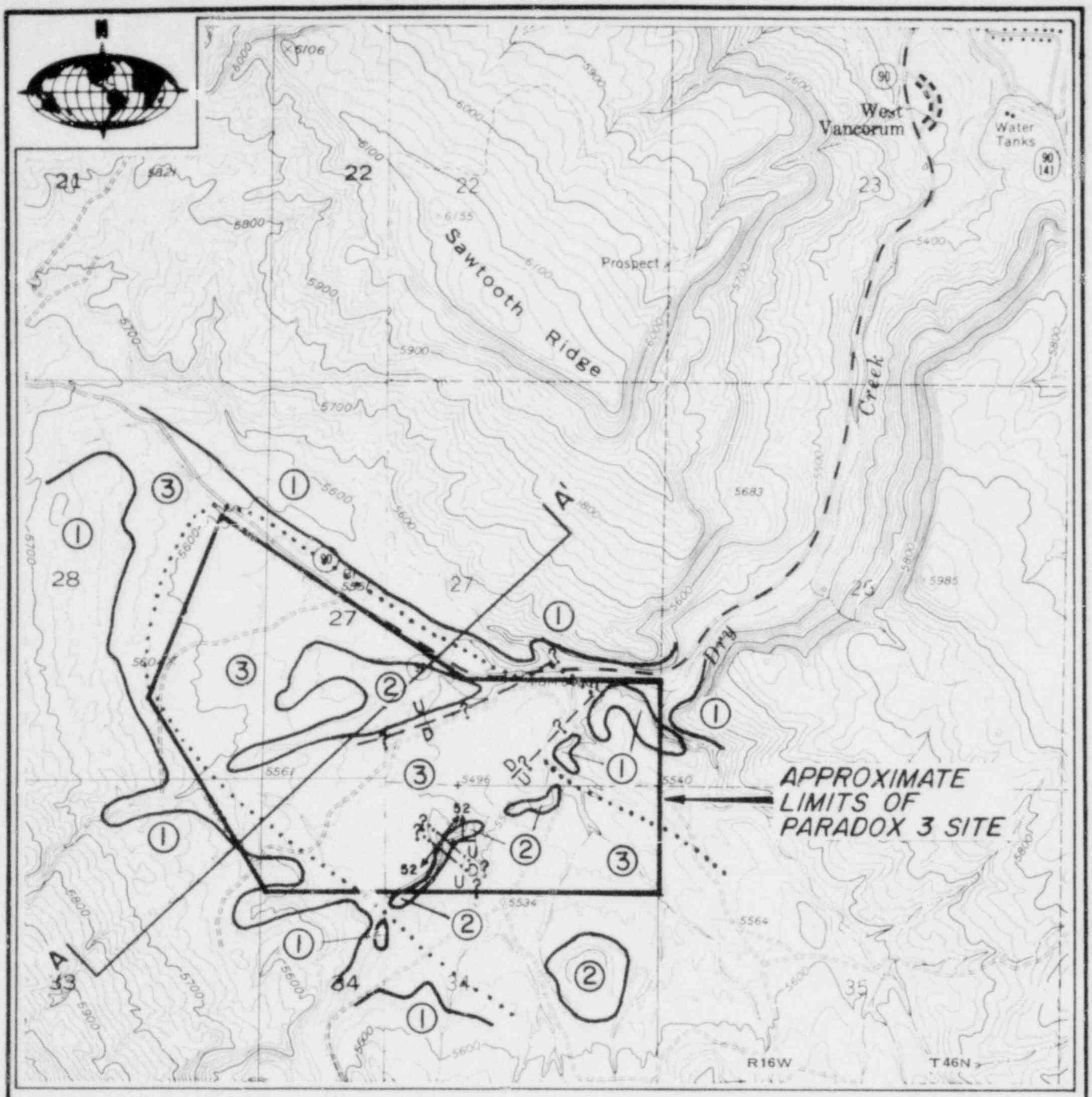
GEOLOGIC SECTION-PARADOX 2

REFERENCE:
U.S.G.S. GQ 71

DAMES & MOORE

PLATE A-3B

946.7 (REV. 6-61)



APPROXIMATE LIMITS OF PARADOX 3 SITE

EXPLANATION

GEOLOGIC UNITS:

① CRETACEOUS DAKOTA SANDSTONE

② CRETACEOUS MANCOS SHALE

③ QUATERNARY ALLUVIAL DEPOSITS

SYMBOLS:

——··· CONTACT SEPERATING UNITS - DOTTED WHERE CONCEALED

?··52↑ U/D ·? FAULT - DOTTED WHERE CONCEALED, DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE UNCERTAIN, ARROW AND NUMBER INDICATE DIP DIRECTION AND MAGNITUDE, "U" ON UP THROWN SIDE, "D" ON DOWN THROWN SIDE

A⌊__⌋A' LOCATION OF SECTION (SEE PLATE A - 4B)

SCALE IN FEET

1000 0 1000 2000

GEOLOGIC MAP-PARADOX 3

REFERENCE:
BASE MAP U.S.G.S. NATURITA AND NATURITA NW 7 1/2 MINUTE TOPOGRAPHIC QUAD. GEOLOGY MODIFIED FROM U.S.G.S. GQ 65 AND I-360.

DAMES & MOORE

PLATE A-4A

REVISIONS BY ______ DATE ______

FILE ______

BY ______ DATE ______ CHECKED BY ______

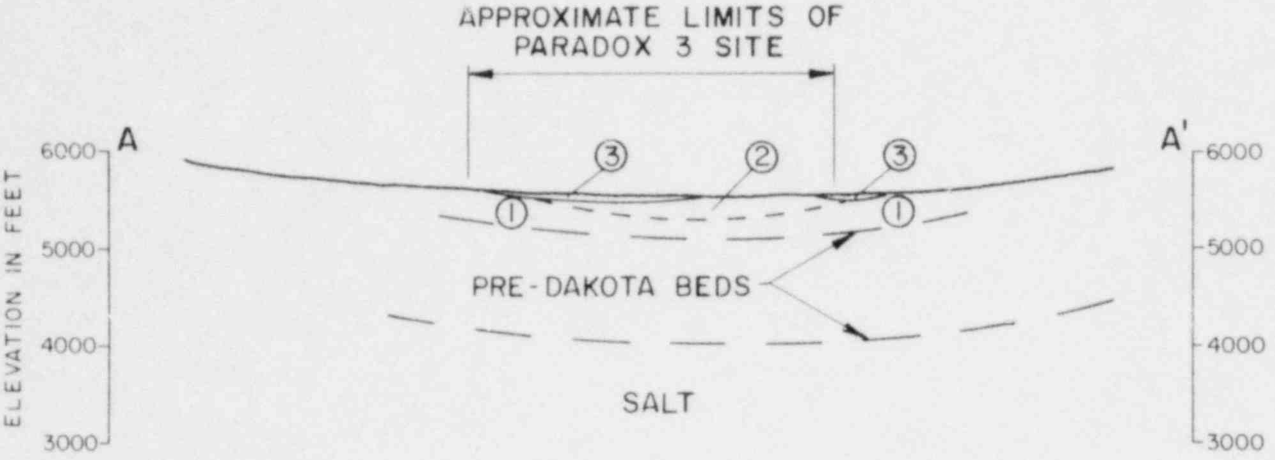
946.7 (REV. 6-61)

REVISIONS
BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______

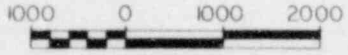
946.7 (REV. 6-61)



EXPLANATION

① ② ③ SEE PARADOX 3 GEOLOGY MAP SHEET FOR EXPLANATION

SCALE IN FEET



GEOLOGIC SECTION-PARADOX 3

DAMES & MOORE

PLATE A-4B

APPENDIX B

TABLE OF CONTENTS

APPENDIX B

LIST OF PLATES

APPENDIX B

PARADOX VALLEY ANTICLINE FAULTS

INTRODUCTION

The faults in the vicinity of the four sites are thought to be related only to salt deformation (solution and flowage) and are, therefore, not considered to be capable of generating earthquakes exceeding the general "background" seismicity of the region. The faults are considered important with respect to surface rupture hazards as described below.

ORIGIN OF FAULTS

Discussions pertaining to the origin and development of the salt anticlines are presented in Cater's publication (1970, p. 63 ff.). To briefly summarize, initiation of salt deformation began shortly after deposition of the salt because of tectonic activity (p. 64). Some salt flowage and intrusion occurred durng deposition of latest Paleozoic and Mesozoic sediments (p. 64). Following deposition of latest Cretaceous sediments, anticlines formed along the older salt structures in response to deep-seated deformation controlled by Paleozoic basement structures (p. 65).

Collapse of the crests of the salt anticlines occurred in two apparently widely separated stages. The first stage followed rather closely the late Cretaceous folding; the second stage followed epierogenic uplift of the entire Colorado Plateau in middle and late Tertiary time and is still continuing (p. 65).

The first stage was characterized by formation of collapse grabens in places along the anticline crests. The grabens may have formed during relaxation of stresses that caused folding (p. 65).

Uplift of the Colorado Plateau rejuvenated stream cutting and increased ground water circulation. Erosion in stream canyons eventually exposed the salt causing rapid solution and removal. With removal of the salt, renewed collapse of the anticline crests began. Collapse of the crests and associated faulting probably progressed in both directions away from the points where the salt cores of the anticlines were first exposed. Streams working headward removed material from both the salt cores and the overlying sedimentary cover.

Cater (1970, p. 66) believes that downsagging of the sedimentary cover occurred where originally the anticline was gently arched; faulting without downsagging occurred where originally the anticline was strongly arched. The main part of Paradox Valley is bounded by faults, and faults have been observed near the axis of the valley as shown on Plate B-1, Structural Geology, Paradox Valley Region. Therefore, Paradox Valley is interpreted to be the collapsed remnant of the strongly arched part of the anticline.

Cater (1970 p. 66) believes that much of the collapse was caused by flowage of the salt from parts of the anticlines covered by sediments to parts where the sediments had been removed. Cater states "The basinlike downwarp at the southeast end of the Paradox Valley anticline appears to be almost if not entirely due to this process of salt removed by flowage" (p. 66). The basinlike downwarp is where the Paradox 3 site is located as shown on Plate B-1.

To support his hypothesis of the importance of salt flowage as the dominant factor in formation of the downsagged basin, Cater points out that exposures of salt in the southeast end of Paradox Valley are 200 feet higher in elevation than the ground surface in the center of the downsagged basin 2-1/2 miles to the southeast (p. 66). In addition, he notes that sedimentary rocks not less than 1,500 feet thick are present above the salt in the center of the downsagged basin.

Cater's hypothesis of successive stages in the development of the downsagged basin at the southeast end of Paradox Valley is presented in sketch form on Plate B-2, Development of Downsagged Basin, Paradox 3 Site.

PARADOX 1 AND 2

As discussed in Appendix A, faults are thought to be present in the subsurface at Paradox 1; faults are exposed at Paradox 2. Since the stresses responsible for formation of the faults are probably continuing, these faults must be considered active. Consequently, we believe that the surface fault rupture hazard at Paradox 1 and 2 is significant.

PARADOX 3

INTRODUCTION

Because previous geologic studies in the area (Cater, 1970, 1955b, Williams, 1964) recorded no faults at the Paradox 3 site, a detailed discussion of the faults is appropriate. As stated in Appendix A, the Paradox 3 site lies near the center of a structural basin described by Cater (1970, p. 54) as "the downsagged unit at the southeast end of the [Paradox Valley] anticline." Cater (1970, p. 54-57) discusses the structure of the downsagged unit and believes that it formed by salt flowage during collapse of the crest of the Paradox Valley anticline. He states (p. 57) that "the central part of the downsagged basin is devoid of structural complexities and is unfaulted."

During our field exploration at Paradox 3, three small faults were observed and two others were postulated chiefly on the basis of subsurface data.

OBSERVED FAULTS

Three faults were observed within a zone 150 feet long in the NE 1/4, SE 1/4, NE 1/4, NW 1/4, Sec. 34, T46N, R16W on the southeast bank of Dry Creek. The locations of these faults are shown on Plate B-3, Geologic Map-Paradox 3. At this location, erosion in Dry Creek has created a 30-foot-high embankment in which 15 to 20 feet of Cretaceous Mancos Shale is exposed. The Mancos is covered by 10 to 15 feet of coarse river deposits of presumed Quaternary age. The upper three feet of the river deposits appear to contain a light gray pedogenic carbonate zone (Cca horizon) overlain by brown B horizon or aeolian deposits.

The northeasternmost fault strikes west and dips 52 degrees to the north. It is visible from the Quaternary/Mancos contact to the bottom of the stream cut and does not appear to displace the Quaternary/ Mancos contact.

The other two faults are 100 feet apart, strike about N 50°W and dip away from each other at 52 degrees. Approximately 15 to 18 inches of apparent reverse separation was observed on each fault at the Quaternary/Mancos contact. A small graben bounded by the reverse faults is evident in the photograph presented on Plate B-4, Photograph of Reverse Faults at Paradox 3.

No evidence of deformation of the ground surface was observed. Because of the difficult access to the exposure, we did not examine closely the Quaternary deposits for evidence of deformation. However, it appears that the faults terminate in the Quaternary sediments above the Mancos but below the pedogenic carbonate horizon.

POSTULATED FAULTS

Two concealed faults are postulated to exist in the S 1/2, Sec. 27, T46N, R16W as shown on Plate B-3. The basis for postulating the existence of these two faults is interpretation of stratigraphy from exposures and subsurface data. The postulated faults have been located on the basis of topographic features.

If these postulated faults exist, they are apparently less than about 4,000 feet long. Based on examination of aerial photographs, beds of sandstone appear to be continuous across the projections of these postulated faults.

As previously stated, we believe that the faults observed and postulated on Paradox 3 site are a direct result of salt deformation only. The northwest-trending reverse faults observed in the southeast bank of Dry Creek probably formed in response to southwest-trending compressional stresses created in the top part of the sedimentary layer as it sagged in response to flowage of the underlying salt.

The sense of separation of the postulated southwest-trending faults is not known. If they are reverse faults, some component of compression in a northwest direction would be required. Such compression could occur in the top of the sedimentary layer as it sagged.

If the postulated faults are normal faults, some component of extension in a northwest direction would be required. The salt under the downsagged basin probably flowed in a northwest direction; northwest extensional stresses could have been created by such salt flowage.

SIGNIFICANCE OF FAULTS

As stated above, we believe that the faults in the vicinity of Paradox Valley are directly related to salt deformation. Cater (1970, p. 65) stated that the first stage of collapse of the salt anticline crests probably followed closely the late Cretaceous folding. The second stage of collapse followed epeirogenic uplift of the Colorado Plateau in middle and late Tertiary time and is still continuing.

Therefore, the processes of salt removal by flowage and solution are continuing. Consequently, the stresses responsible for formation of the faults in the vicinity of Paradox Valley are still active, hence the faults must be considered active.

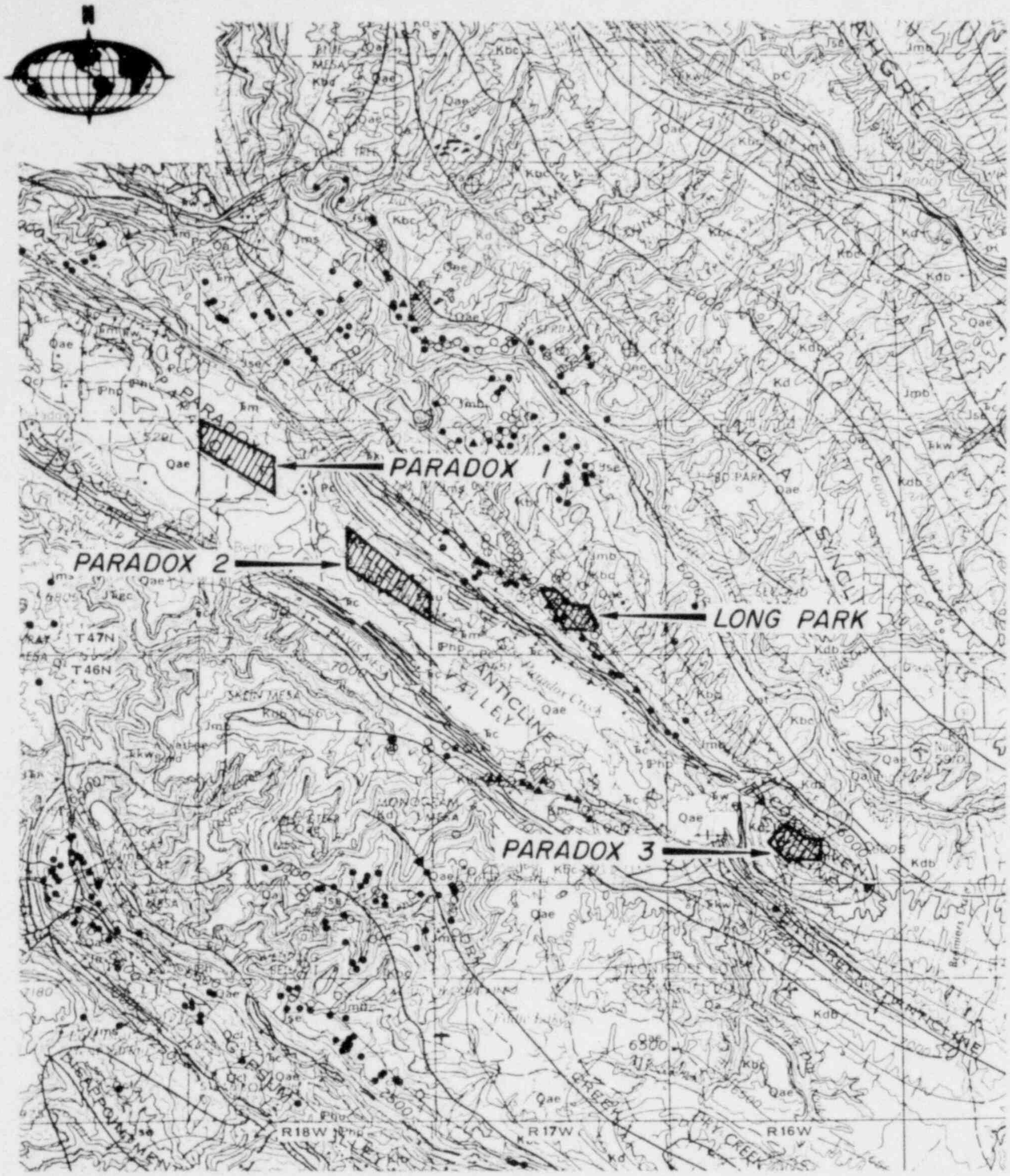
We do not believe that these faults are capable of generating earthquakes exceeding the general seismic background of the region. However, continued displacement along the fault could deform the ground surface.

REVISIONS
BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______

946.7 (REV. 6-61)



STRUCTURAL GEOLOGY
PARADOX VALLEY REGION

REFERENCE
WILLIAMS, 1964, U.S.G.S. MAP I-360

DAMES & MOORE

PLATE B-1

BY [illegible] DATE 9-15-86 CHECKED BY ____ FILE CCE3 [illegible] REVISIONS BY ____ DATE ____

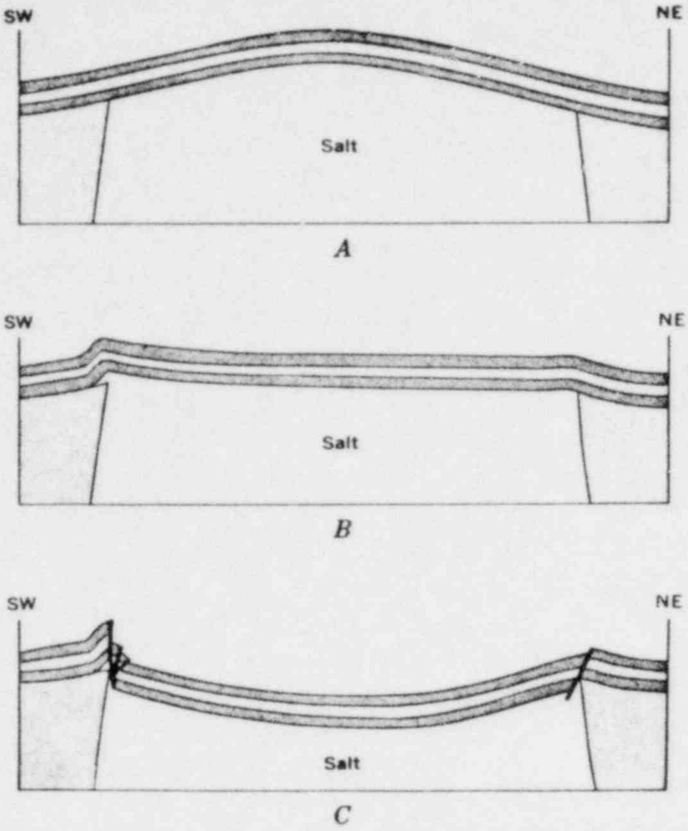
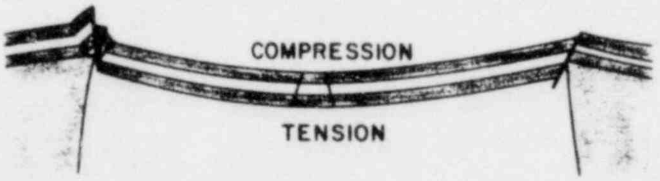


Figure 19.- Successive stages in the development of the downsag and the faulted marginal anticline at the southeast end of Paradox Valley. Reference: Cater (1970,page 66).



DEVELOPMENT OF DOWNSAGGED BASIN

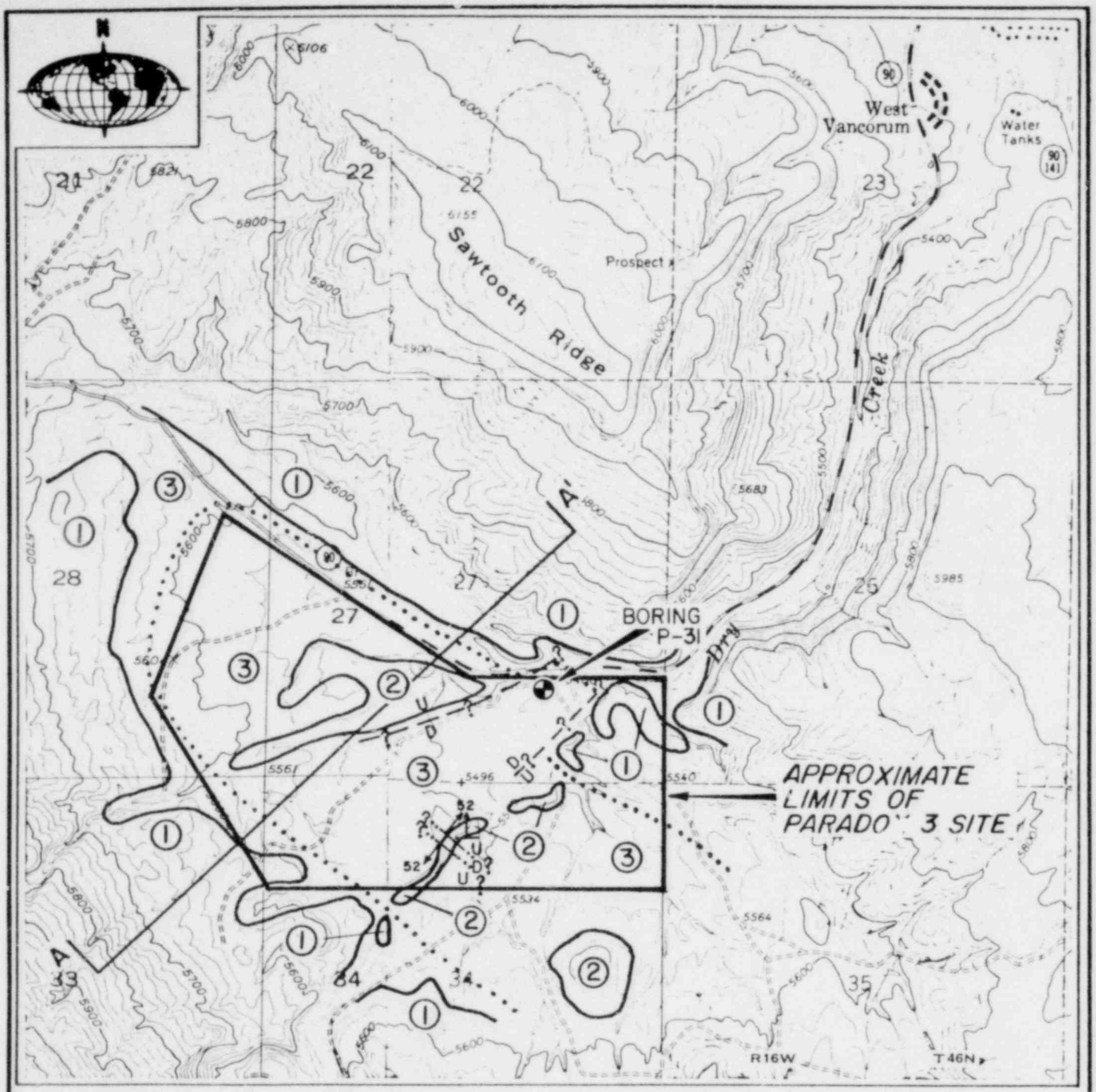
PARADOX 3 SITE

DAMES & MOORE

946.7 (REV. 6-61)

PLATE B-2

BY Dhc DATE 4-15-80
CHECKED BY ____
FILE 00822[illegible]38
REVISIONS
BY ____ DATE ____



EXPLANATION

GEOLOGIC UNITS:

① CRETACEOUS DAKOTA SANDSTONE

② CRETACEOUS MANCOS SHALE

③ QUATERNARY ALLUVIAL DEPOSITS

SYMBOLS:

——...	CONTACT SEPERATING UNITS – DOTTED WHERE CONCEALED
?-$\overset{52}{\uparrow}$-$\frac{U}{D}$-?	FAULT – DOTTED WHERE CONCEALED, DASHED WHERE APPROXIMATELY LOCATED, QUERIED WHERE UNCERTAIN, ARROW AND NUMBER INDICATE DIP DIRECTION AND MAGNITUDE, "U" ON UP THROWN SIDE, "D" ON DOWN THROWN SIDE
A⌊___⌋A'	LOCATION OF SECTION (SEE PLATE A – 4B)

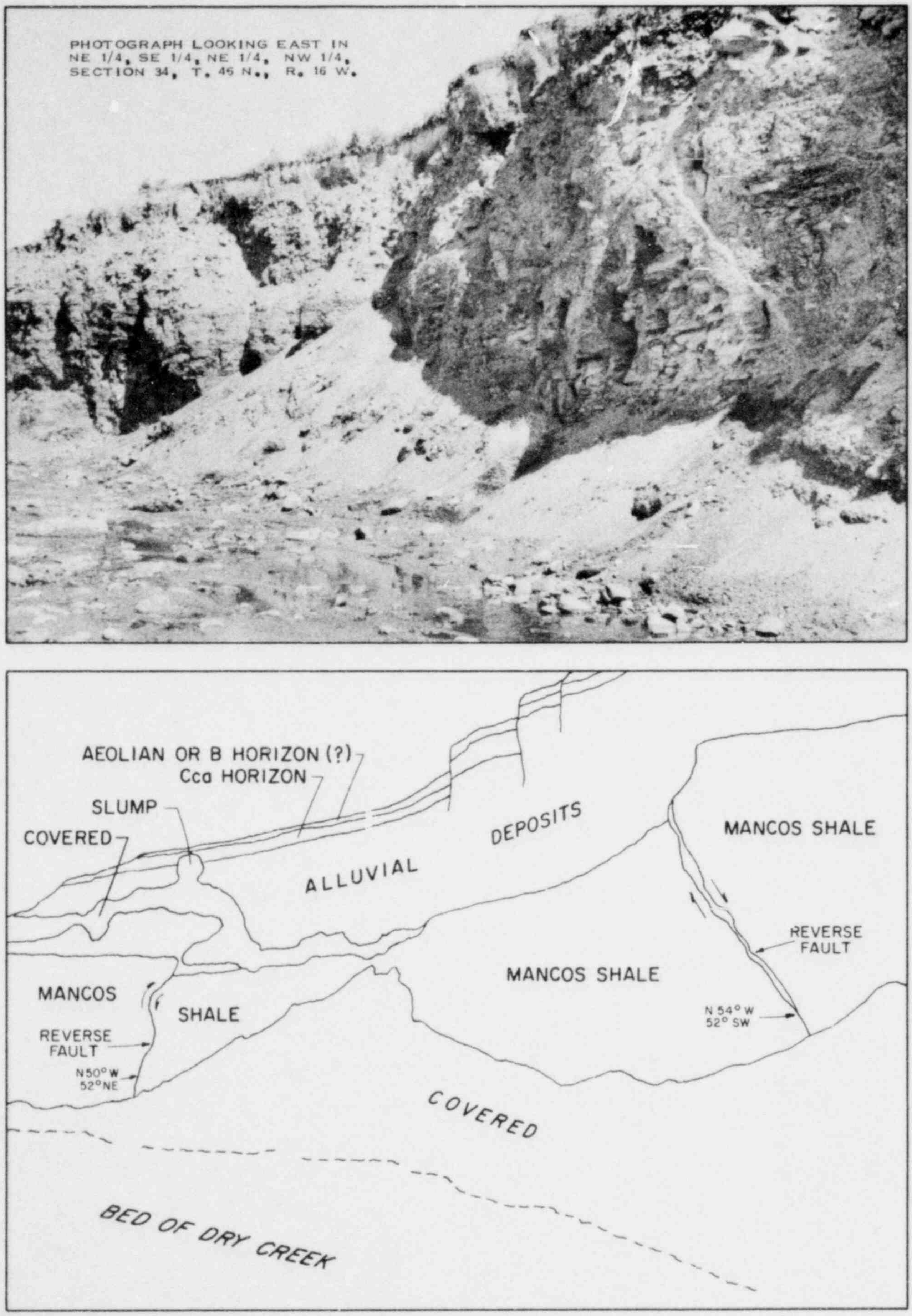
SCALE IN FEET
1000 0 1000 2000

GEOLOGIC MAP-PARADOX 3

REFERENCE:
BASE MAP U.S.G.S. NATURITA AND NATURITA NW 7 1/2 MINUTE TOPOGRAPHIC QUAD. GEOLOGY MODIFIED FROM U.S.G.S. GQ 65 AND I-360.

DAMES & MOORE

PLATE B-3



PHOTOGRAPH LOOKING EAST IN
NE 1/4, SE 1/4, NE 1/4, NW 1/4,
SECTION 34, T. 46 N., R. 16 W.

PHOTOGRAPH OF REVERSE FAULTS
AT PARADOX 3

APPENDIX C

TABLE OF CONTENTS

APPENDIX C

LIST OF TABLES

APPENDIX C

LIST OF PLATES

APPENDIX C

GEOTECHNICAL INVESTIGATION

FIELD EXPLORATION

GENERAL

The field exploration portion of this investigation consisted of a detailed subsurface investigation and preliminary geologic reconnaissance of the three sites: Long Park; Paradox 2; and Paradox 3, and a regional geologic reconnaissance to locate potential sources of riprap, base course and clay borrow material. The field program began on March 3 and was completed on March 28, 1980. Land acquisition and site access were arranged by Union Carbide's Land Department.

SUBSURFACE INVESTIGATIONS

General

Subsurface material and ground water conditions at the three sites were explored by drilling a total of 17 borings and excavating 30 test pits. Bulk samples of potential evaporation pond liner material were obtained from shale and claystone exposures east of the Long Park site. Additionally, bulk samples of near-surface subgrade soils were obtained at both Long Park and Paradox 2 for evaluation of pavement subgrade performance characteristics. The borings were advanced using a truck-mounted CME-55 drill rig in conjuction with standard rotary drilling techniques with air as drilling fluid. The test pits were excavated with an MF-60 rubber-tired backhoe with a 15-foot reach. In some instances, test pits were extended deeper than 15 feet by excavating into the side and bottom of drainage channels.

A total of 7 borings and 11 test pits were located on the Long Park site. The borings ranged in depth from 38 to 88 feet penetrating both near-surface soils and extending into bedrock. The test pits ranged from

6 to 18 feet in depth, and all but two, LP-2 and LP-10, were terminated in bedrock. The locations of the borings and test pits are shown on Plate C-1, Boring, Test Pit and Sampling Locations - Long Park.

Ground water was encountered in two borings, LP-1 and LP-3, having static water levels at 34.25 and 43.75 feet, respectively, below existing site grade. Piezometers were installed in LP-1, LP-3 and LP-5 to enable future monitoring of ground water levels. Details of the piezometers installed are tabulated below:

Boring	Total Depth (In Feet)	Slotted Inverval (In Feet)
LP-1	43.0	0 - 43
LP-3	88.0	0 - 88
LP-5	60.0	40 - 60

A water sample was taken from LP-3 for analysis. Testing procedures and results are presented in the laboratory testing portion of this Appendix.

Two borings and seven test pits were conducted at Paradox 2. The borings, P-22 and P-24, were drilled to depths of 52 and 65 feet, respectively. Test pits were excavated to depths ranging from 4.5 to 12 feet. Only three of the seven test pits were terminated in bedrock. The locations of the borings and test pits are shown on Plate C-2, Boring, Test Pit and Sampling Locations - Paradox 2.

Ground water was not encountered in any of the borings or test pits.

Eight borings and 12 test pits were conducted at Paradox 3. The borings ranged in depth from 45.5 to 64 feet. Test pits ranged in depth from 6.5 to 14 feet and 6 of the 12 were terminated in bedrock. The locations of the borings and test pits are shown on Plate C-3, Boring, Test Pit and Sampling Location - Paradox 3.

Ground water was encountered in all but two of the borings, P-33 and P-35, and in two of the test pits, P-36 and P-39. Ground water levels are presented in conjunction with the boring logs and test pit logs on Plates C-4A through C-4I and C-5A through C-5E, respectively.

Piezometers were installed in four borings to enable future monitoring of ground water level. Details of the piezometers installed are tabulated below:

Boring	Total Depth (In Feet)	Slotted Interval (In Feet)
P-34	19	9 - 19
P-36	47	37 - 47
P-37	45.5	35.5 - 45.5
P-38	24	22 - 24

Ground water samples were taken from borings P-31, P-32, and P-36 for water quality analysis. Test procedures and results are presented in the laboratory testing portion of this appendix.

The drilling and test pit programs at all three sites were conducted under the direct supervision of experienced members of our geotechnical staff who maintained continuous logs of each boring and test pit, noting progress and material changes. The field logs and samples were returned to our laboratory where they were reviewed and edited for consistency. The edited boring logs for the three sites are presented on Plates C-4A through C-4I, Log of Borings. Results of the test pit exploration program are presented on Plates C-5A through C-5E, Log of Test Pits.

Relatively undisturbed samples of the soils encountered were obtained from the borings at frequent intervals utilizing a Dames & Moore "U" type sampler described on Plate C-6, Soil Sampler Type U. This sampler was driven using a 140-pound weight dropping 30 inches with the number of blows being recorded for each succeeding six inches of penetration or portion thereof. In addition, Standard Penetration Tests

(SPT) were performed in accordance with ASTM* D-1586-67 Method for Penetration Test and Split-Barrel Sampling of Soils.

Blow count data recorded for the driving of either sampler are presented on the boring logs, Plates C-4A through C-4I.

Representative undisturbed samples of bedrock encountered were obtained in general accordance with ASTM D-2113-70 Method for Diamond Core Drilling for Site Investigation utilizing a Christensen double-tube NX core barrel. Core recovery data and rock quality designation (RQD) were calculated on the basis of field measurements.

Soil types were classified in accordance with the terminology described on Plate C-7, Unified Soil Classification System. Rock types were classified in accordance with terminology described on Plate C-8, Geotechnical Terminology for Rock Description. Description of additional terminology used in describing rock not contained on Plate C-8 are as follows:

> Core Recovery - the length of core recovered as a percentage of the total length of coring attempted. The heavy vertical lines dissected by short horizontal lines shown on the Boring Logs represent core attempt intervals commonly known as "core runs."
>
> RQD (rock quality designation) is defined as the sum of lengths of sound pieces of core which are four inches in length or longer divided by the core run length attempted, expressed as a percentage.

Site Access

A moderate amount of roadwork was required on Paradox 2 and 3 sites to facilitate drill rig access. This was accomplished using a CAT D-4 tractor on Paradox 2 and CAT D-7 tractor on Paradox 3.

---

*American Society for Testing and Materials.

GEOLOGIC SITE RECONNAISSANCE

A geologic field reconnaissance was performed by experienced members of our staff at all three site locations, Long Park, Paradox 2 and Paradox 3. Soil materials, rock outcrops and pertinent structural features were noted and recorded. The results of the reconnaissance were used to update available USGS* geologic maps of the area as shown on Plates A-1A, A-3A and A-4A, entitled Geologic Map - Long Park, Geologic Map - Paradox 2 and Geologic Map - Paradox 3, respectively.

In addition, a regional geologic reconnaissance was conducted for the purpose of locating gravel sources for riprap and road base course and clay sources for evaporation pond liner, containment dike cores and clay reclamation cover material. The locations of potential gravel and clay borrow sources are presented on Plate C-9, Potential Gravel Sources, and Plate C-10, Potential Clay Borrow Sources, respectively.

Gravel source materials indicated on Plate C-9 are generally river terrace deposits of rounded to subround sandy gravels, cobbles and boulders composed primarily of sandstone, quartzite, basalt and granitic rock.

Clay borrow source materials indicated on Plate C-10, Area I, consist of claystone derived from the Brushy Basin Member of the Morrison Formation. Clay borrow available at Area II located at the east end of Paradox 3 would be derived from clayey units of the Mancos Shale.

FIELD PERMEABILITY TESTING

Field permeability tests were performed in selected borings. Tests were accomplished by inflating a single pneumatic packer above an open interval of the core hole, or inflating two packers spaced 10 feet

---

*United States Geological Survey.

apart, within the core hole and pumping clear water to the test section. For each test, water pressure head and constant flow rates into the core hole were recorded. For all tests performed at the site the radius of the core hole was 0.11 feet.

The formula relating permeability of the stratum to the above variables is (U.S. Bureau of Reclamation, 1968):

$$k = \frac{Q}{2 \quad LH} \quad \log_e \quad \frac{L}{r}$$

where k = permeability

Q = constant flow rate into the test interval

L = length of test interval

H = pressure head of water

r = radius of test interval

where any consistent set of units is used.

Results of field permeability testing are presented in Table C-1.

One "slug" test was performed in a piezometer installed in boring P-38. This test was performed to estimate in-situ soil permeability in a saturated soil horizon. The slug test data was analyzed by the time lag method suggested by Hvorslev (1949):

$$k = \frac{A}{F(t_2-t_1)} \log_e \frac{(h_1)}{(h_2)}$$

where k = permeability

A = cross-sectioned area of piezometer

F = shape factor

t = time

h = difference between piozometer level and initial ground water level

The slug test data were also analyzed with a curve matching technique suggested by Lohman (1972). Both analyses indicated a permeability of approximately 400 ft/yr. Results of the test are presented on Plate C-11, Slug Test Data.

TABLE C-1

SUMMARY OF FIELD PERMEABILITY TESTING - PACKER TESTS

Boring Number	Test Interval In Feet	Initial Condition U=Unsaturated S=Saturated	Material	Pressure Head In Feet Of Water	Flow gpm	Permeability Ft/Yr	Permeability x 10^{-5} cm/sec
LP-4	20 - 46	U	Sandstone & Claystone	28	35.0	2,780	268
LP-4	30 - 46	U	Claystone	63	29.0	1,510	146
LP-4	35 - 46	U	Claystone	70	28.0	1,750	169
LP-5	20 - 40	U	Sandstone & Siltstone	58	16.0	758	73
LP-5	30 - 40	U	Sandstone & Siltstone	125	5.6	212	20
LP-6	40 - 58	U	Siltstone & Claystone	38	28.0	2,200	213
LP-6	50 - 58	U	Siltstone & Claystone	31	25.0	4,500	435
P-22	21 - 31	U	Gypsum	73	25.0	1,610	156
P-22	31 - 41	U	Gypsum	53	28.0	2,490	241
P-22	41 - 52	U	Sandstone	111	0.5	21	2
P-38*	22 - 24	S	SP-SM	--	--	400	38
P-32	14 - 24	U	Shale Interbedded w/ss	102	17.0	1,810	175
P-32	24 - 34	U	Siltstone	106	16.0	710	69
P-32	35 - 45	U	Mudstone	131	0.3**	--	--
P-32	49.5 - 59.5	S	Shale & Sandstone	145	1.5	48	4
P-34	24.4 - 34.5	U	Shale	120	2.2	87	8
P-34	45.5 - 55.5	S	Sandstone	141	0.2	7	.6
P-37	24.4 - 34.4	U	Sandstone	64	26.0	1,920	185

---

* "Slug" Test

** Flow stopped during test.

LABORATORY TESTING

GENERAL

A laboratory testing program was conducted to determine the index properties, shear strength, permeability and compaction characteristics of near-surface soils and rock encountered during field exploration conducted at the Long Park, Paradox 2 and Paradox 3 sites. In addition, samples of total tailings obtained at the Uravan mill were evaluated to determine consolidation characteristics.

Laboratory tests performed included moisture and density determinations, Atterberg limits, grain size, permeability, consolidation, triaxial compression and compaction tests.

Samples of ground water obtained at the Long Park and Paradox 3 sites were subjected to chemical analyses and water quality determinations.

Details of the tests conducted for this study, together with the test results, are presented in the following sections.

MOISTURE AND DENSITY TESTS

Moisture and density determinations were performed in order to aid in classifying materials and to provide a basis for correlation of engineering properties. The results of these tests are shown to the left of each boring log and test pit log adjacent to the representative sample location on Plates C-4A through C-4I and C-5A through C-5E. Explanation of the method of data presentation is illustrated on Plate C-4A.

ATTERBERG LIMITS

Liquid limit and plastic limit determinations were performed in accordance with ASTM D-423-66 and D-424-59, Standard Test Methods, for fine grain soils and decomposed bedrock encountered at the sites. The results of these tests were used for correlation and estimation of engineering properties and are presented in Table C-2, Atterberg Limits Test Results.

TABLE C-2

ATTERBERG LIMITS TEST RESULTS

Sample Origin	Depth -feet-	Liquid Limit - Percent-	Plastic Limit - Percent-	Plasticity Index	Soil Classification*
Boring LP-6	20.5	34.0	22.6	11.4	CL
Test Pit LP-5	6.0	63.9	20.9	43.0	CH
Test Pit LP-10	6-11	52.6	22.2	30.4	CH
Test Pit LP-10	8.0	39.1	21.3	17.8	CL
Boring P-31	5.5	28.6	16.2	12.4	CL
Test Pit P-31	5-7	28.6	16.2	12.4	CL
Test Pit P-31	8-10	44.8	24.7	20.1	CL
Test Pit P-38	7-9	28.2	18.8	9.4	CL
Road Subgrade Long Park	1-2	26.1	15.3	10.8	CL
Road Subgrade Paradox 2 (Sample 1)	1-2	33.7	19.4	14.3	CL
Bulk Sample B-1	--	55.2	23.0	32.2	CH
Bulk Sample B-2	--	37.3	22.7	14.6	CL
Bulk Sample B-3	--	--------- Non Plastic ------			SP
Bulk sample B-4	--	50.3	24.6	25.6	CH
Bulk Sample B-5	--	48.7	24.9	23.8	CL

---

*Soil classifications are in accordance with the Unified Soil Classification System as presented on Plate C-7.

GRAIN SIZE ANALYSES

Both partial and complete grain size analyses were performed on selected samples of soils encountered at the sites to aid in classification and provide information to evaluate permeability characteristics. In addition, one sample of potential base course material obtained from Southwestern Ready Mix Company located near Natarita, Colorado was tested for the purpose of qualitative evaluation of pavement performance characteristics. These tests were performed in accordance with ASTM-422-63, Standard Test Methods. The results of complete grain size analyses are presented on Plates C-12A through C-12D, Gradation Curves; the results of partial grain size analyses are tabulated on Table C-3, Partial Grain Size Analyses Test Results.

WEATHERING POTENTIAL

Two bulk samples of potential clay liner material were tested to evaluate their tendency to weather when exposed to moisture. Cobble-size rock fragments of the respective samples were placed in pans and photographed. Pans were then partially filled with approximately one-half inch of water. Behavior of the samples was then observed.

Bulk samples from Test Pits LP-3 (6.5-11.0 feet) and LP-11 (4.5-6.0 feet) completely weathered to a sandy silty clay within several minutes after exposure to water.

COMPACTION TESTS

Compaction tests were performed on bulk samples of materials considered suitable for construction in conjunction with either evaporation pond or tailings storage embankments and for use in reclamation. In addition, selected samples of potential pond liner materials were evaluated. Tests were performed in accordance with the ASTM D-698-70 Standard Test Methods. The results of the compaction tests are presented on Plates C-13A through C-13C, Compaction Test Data.

TABLE C-3

PARTIAL GRAIN SIZE ANALYSES TEST RESULTS

Sample Origin	Depth in Feet	Percent Soil Passing #200 Sieve	Soil Classifications*
Boring LP-1	5.5	75.5	ML
Boring LP-3	7.5	29.1	SM
Boring LP-5	7.0	55.9	SM/MC
Boring LP-6	5.5	57.2	ML/SM
Boring LP-7	5.5	66.1	ML
Test Pit LP-2	6.5	37.1	SM
Test Pit LP-4	5-6	54.4	ML/SM
Test Pit LP-8	9-10	46.3	SM/ML
Boring P-24	5.0	41.3	SM
Boring P-24	10.0	23.2	SM/GM
Boring P-24	25.0	25.7	SM
Boring P-32	10.0	14.6	GM/SM
Boring P-33	10.5	52.3	ML/SM
Boring P-34	5.5	15.0	SM
Boring P-34	16.5	6.2	GM/GP
Boring P-36	5.5	46.9	SM/ML
Test Pit P-32	6-8	30.9	SM
Test Pit P-36	6-8	59.6	ML/SM
Bulk Sample B-3	-	2.2	SP

---

* Soil classifications are in accordance with the Unified Soil Classification System as presented on Plate C-7.

CONSOLIDATION TESTS

Compressibility data developed for evaluation of tailings density utilization in volume storage evaluation for proposed tailings impoundments were obtained by performing consolidation tests on representative remolded samples of total tailings obtained at the Uravan mill site. The test method followed is described on Plate C-14, Method of Performing Consolidation Tests. Data from these tests are presented graphically on Plate C-15, Consolidation Test Data.

PERMEABILITY TESTS

Constant head and falling head permeability tests were performed on samples of both undisturbed natural soils and recompacted samples from both near-surface soils and underlying weathered shales obtained at the three sites. In addition, recompacted samples of potential liner material developed from weathered claystone and decomposed shale obtained from potential offsite borrow areas were also evaluated. The method of performing these tests is decribed on Plate C-16, Method of Performing Percolation Tests. The results of the tests are tabulated on Table C-4, Permeability Test Results.

TRIAXIAL COMPRESSION TESTS

Two multiphase unconsolidated undrained (UU) triaxial compression tests were performed on undisturbed samples of near-surface soils from Long Park. These triaxial tests were performed using multiphase testing techniques on partially saturated samples i.e., at in-situ moisture content. These tests were performed in accordance with the general procedures described on Plate C-17, Method of Performing Unconfined Compression and Triaxial Compression Tests. The results of these tests are summarized on Table C-5, Unconsolidated Undrained Triaxial Test Results.

TABLE C-4

PERMEABILITY TEST RESULTS

Boring Number	Depth -Feet-	Soil* Classification	Moisture Content -Percent-	Dry Unit Weight -pcf-	Coefficient of Permeability cm/sec	Coefficient of Permeability ft/yr
LP-1	10.5	ML	7.1	93.2	$6.1\text{x}10^{-5}$	63
LP-6	10.5	ML/SM	8.0	96.3	$5.3\text{x}10^{-5}$	55
LP-6	25.5	Claystone	11.8	112.3	$6.7\text{x}10^{-8}$	$6.9\text{x}10^{-2}$
P-31	15.0	SM	12.0	127.9	$1.5\text{x}10^{-6}$	1.5
					$(1.5\text{x}10^{-6})$	(1.5)
P-35	5.0	SM	2.7	101.3	$3.0\text{x}10^{-4}$	309
					$(1.0\text{x}10^{-4})$	(103)

Test Pit Number	Depth -Feet-	Soil* Classification	Moisture Content -Percent-	Dry Unit Weight -pcf-	Percent** Compaction	Coefficient of Permeability cm/sec	Coefficient of Permeability ft/yr
LP-3	6.5-11.0	CH	22.4	98.5	94.7	$1.0\text{x}10^{-7}$	0.1
						$(1.5\text{x}10^{-8})$	(0.01)
LP-7	6.5	SM	5.1	100.8	N/A	$9.7\text{x}10^{-5}$	100
						$(1.4\text{x}10^{-5})$	(14)
LP-10	6.5	SM	4.9	91.3	N/A	$3.4\text{x}10^{-4}$	350
						$(8.8\text{x}10^{-5})$	(91)
LP-11	4.5-5.5	Claystone	17.9	107.3	93.9	$2.4\text{x}10^{-7}$	0.25
P-31	8.0-10.0	Shale	19.4	98.3	89.8	$3.5\text{x}10^{-7}$	0.36

Bulk Sample Number	Depth -Feet-	Soil Classification	Moisture Content -Percent-	Dry Unit Weight -pcf-	Percent** Compaction	Coefficient of Permeability cm/sec	Coefficient of Permeability ft/yr
P-1	1-2	CL	21.4	102.0	95.3	$1.4\text{x}10^{-4}$	144
						$(6.5\text{x}10^{-8})$	0.07
P-2	1-2	CL	22.6	86.3	91.3	$3.7\text{x}10^{-5}$	38
						$(2.5\text{x}10^{-7})$	(0.26)
B-1	--	CH	20.9	108.2	90.9	$1.0\text{x}10^{-7}$	0.10

---

*In accordance with the USC System see Plate C-7.

**Reference ASTM D-698-70.

Note: Values in parentheses are those results obtained from tests conducted using tailings effluent on the previously listed sample.

TABLE C-5

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST RESULTS

Boring Number	Depth -Feet-	Soil* Classification	Moisture Content -Percent-	Dry Unit Weight -pcf-	Confining Stress -psf-	Deviator Stress -psf-	Strain At Failure -Percent-
LP-2	10.5	SM/SC	10.2	92.0	1,000	10,002	3.52
					2,000	14,871	3.00
					4,000	20,280	5.79
LP-6	15.5	ML	7.6	97.3	1,500	12,485	1.43
					2,500	14,608	1.25
					5,000	20,317	3.31

---

* In accordance with the Unified Soil Classification System, see Plate C-7.

CHEMICAL ANALYSES AND WATER QUALITY DETERMINATION

Chemical analyses and water quality determinations were performed on ground water samples obtained at both Long Park and Paradox 3. These tests were performed to assess preliminary baseline ground water quality. Testing included the determination of acidity, alkalinity, conductivity, hardness, and pH in addition to measuring dissolved chloride, sulfate and total solids content. Tests were conducted in general accordance with specifications contained in the U.S. Environmental Protection Agency Publication EPA-600-479-020, Methods of Chemical Analyses of Water and Wastes, by Ford Chemical Laboratory Inc., Salt Lake City, Utah.

The results of their analyses and determinations are presented on Table C-6, Chemical Analyses and Water Quality Test Results.

TABLE C-6

CHEMICAL ANALYSES AND WATER QUALITY TEST RESULTS

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

DATE: 04/24/80

CERTIFICATE OF ANALYSIS

DAMES & MOORE, ENG.
250 E. BROADWAY
SALT LAKE CITY, UT
84111

80-009353

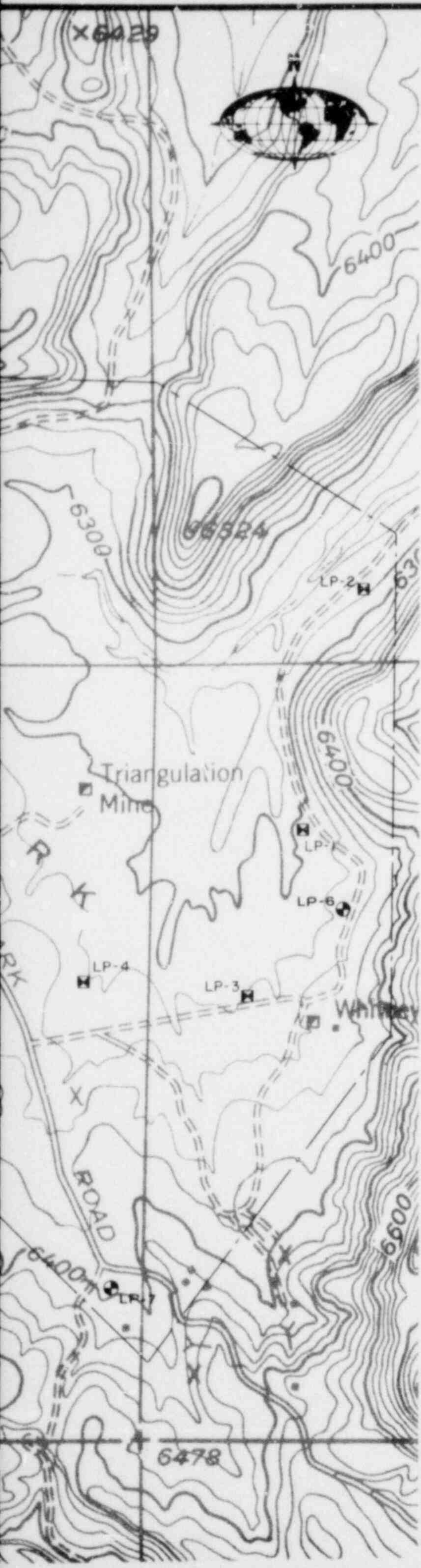
SAMPLE: WATER RECEIVED 4/1/80 UNDER JOB #00822-138-06 FROM VICINITY OF URAVAN, CO. FOR ANALYSIS.

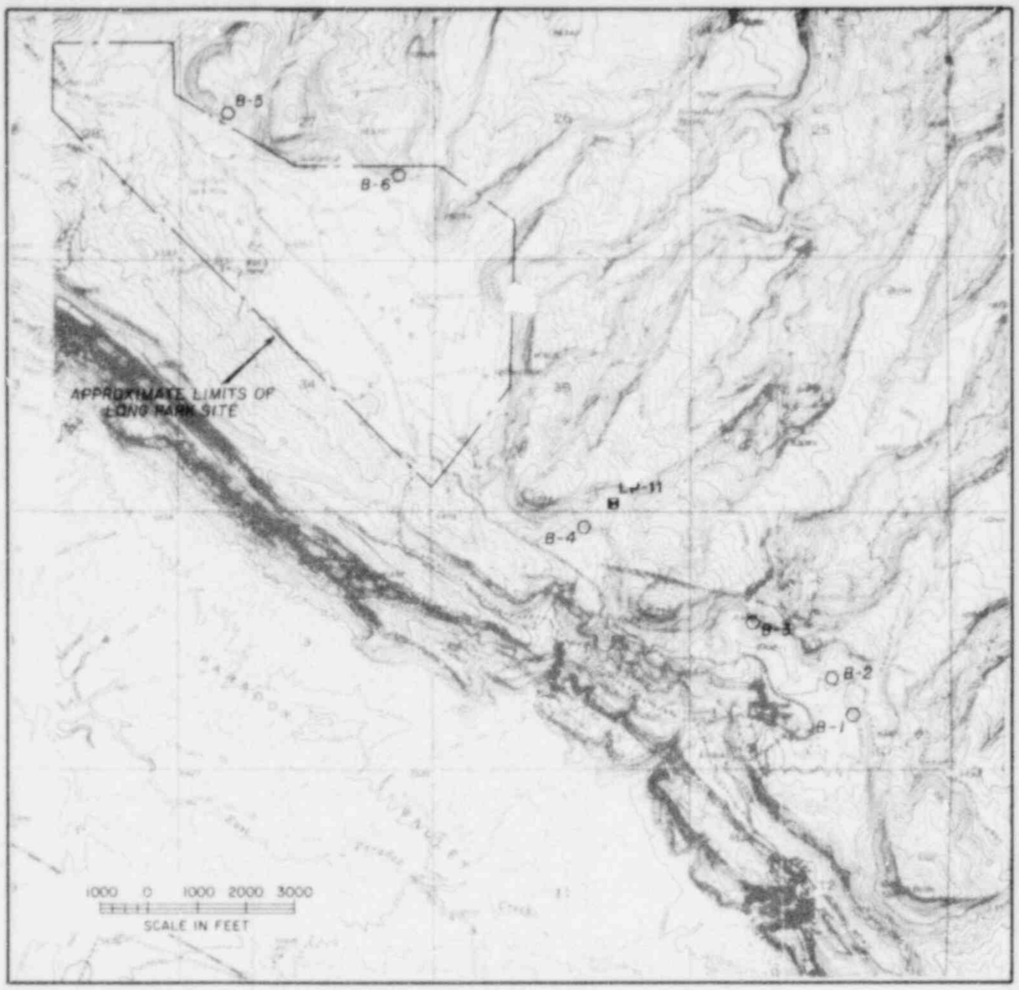
	SAMPLE P-31-1	SAMPLE P-31-2	SAMPLE P-32	SAMPLE LP-5	SAMPLE P-36
Acidity as $CaCO_3$ mg/l	18.0	26.0	<.1	24.0	64.0
Alkalinity as $CaCO_3$ mg/l	370.00	480.00	776.00	326.00	422.00
Chloride as Cl mg/l	314	44.0	52.0	46.0	90.0
Conductivity umhos/cm	6,600	2,900	4,300	1,500	3,550
Hardness as $CaCO_3$ mg/l	3,890	820	77.5	676	2,710
Sulfate as SO_4 mg/l	490	750	300	300	48.0
Total Dissolved Solids mg/l	4,340	1,890	2,800	980	2,310
pH Units	7.60	7.40	8.20	7.10	7.00

FORD CHEMICAL LABORATORY, INC.

REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
"URAVAN, COLORADO" 1960.

JOB NUMBER
DRAWN BY
DATE
466 11 (10-79)





KEY

● LP-3 BORING LOCATION AND NUMBER

■ LP-1 TEST PIT LOCATION AND NUMBER

○ B-4 BORROW SOURCE SAMPLING LOCATION AND NUMBER

△ B-1 ROADWAY SUBBASE SAMPLE LOCATION

FEET

500 0 1000

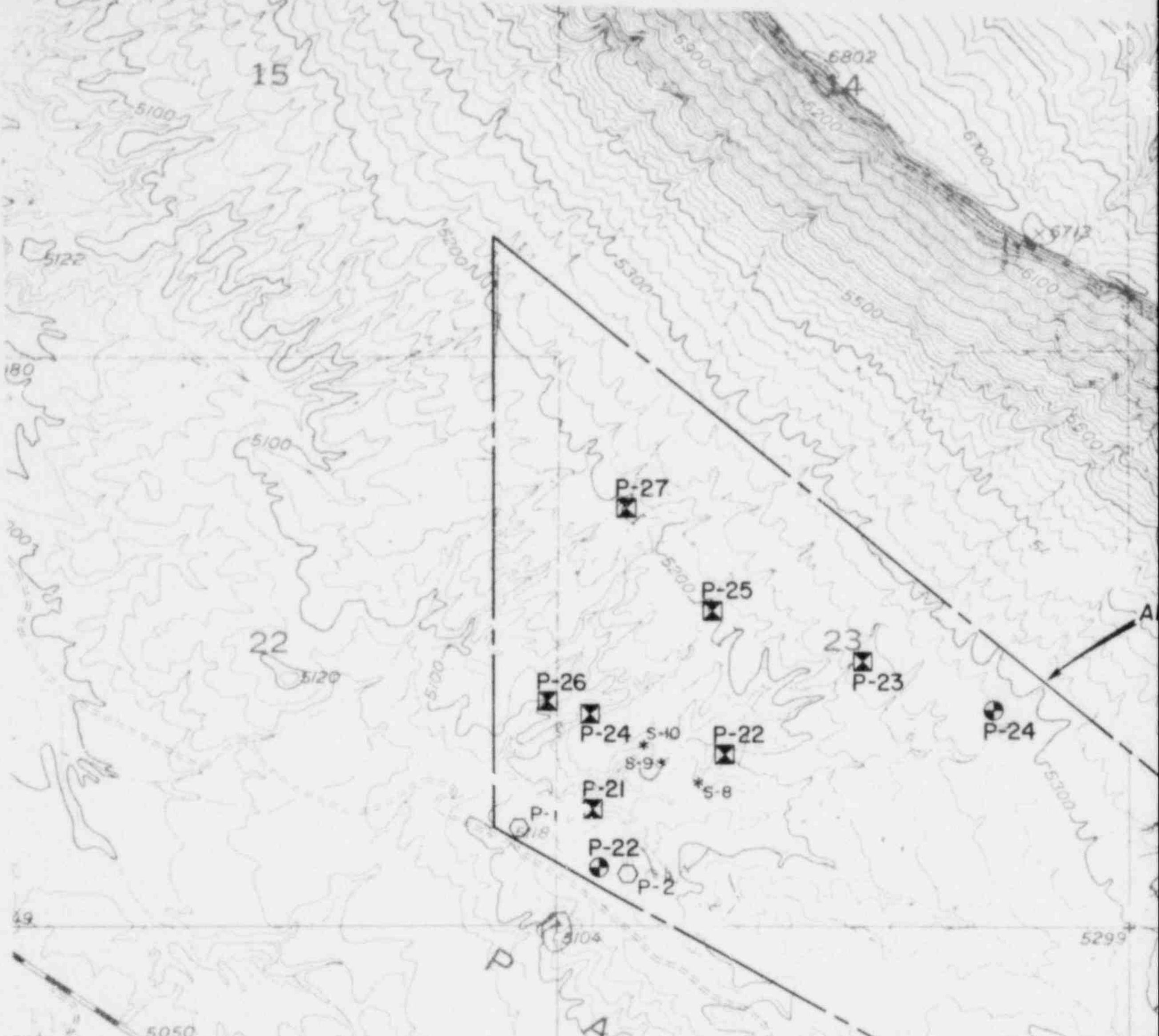
BORING, TEST PIT, AND SAMPLING LOCATIONS

LONG PARK

DAMES & MOORE

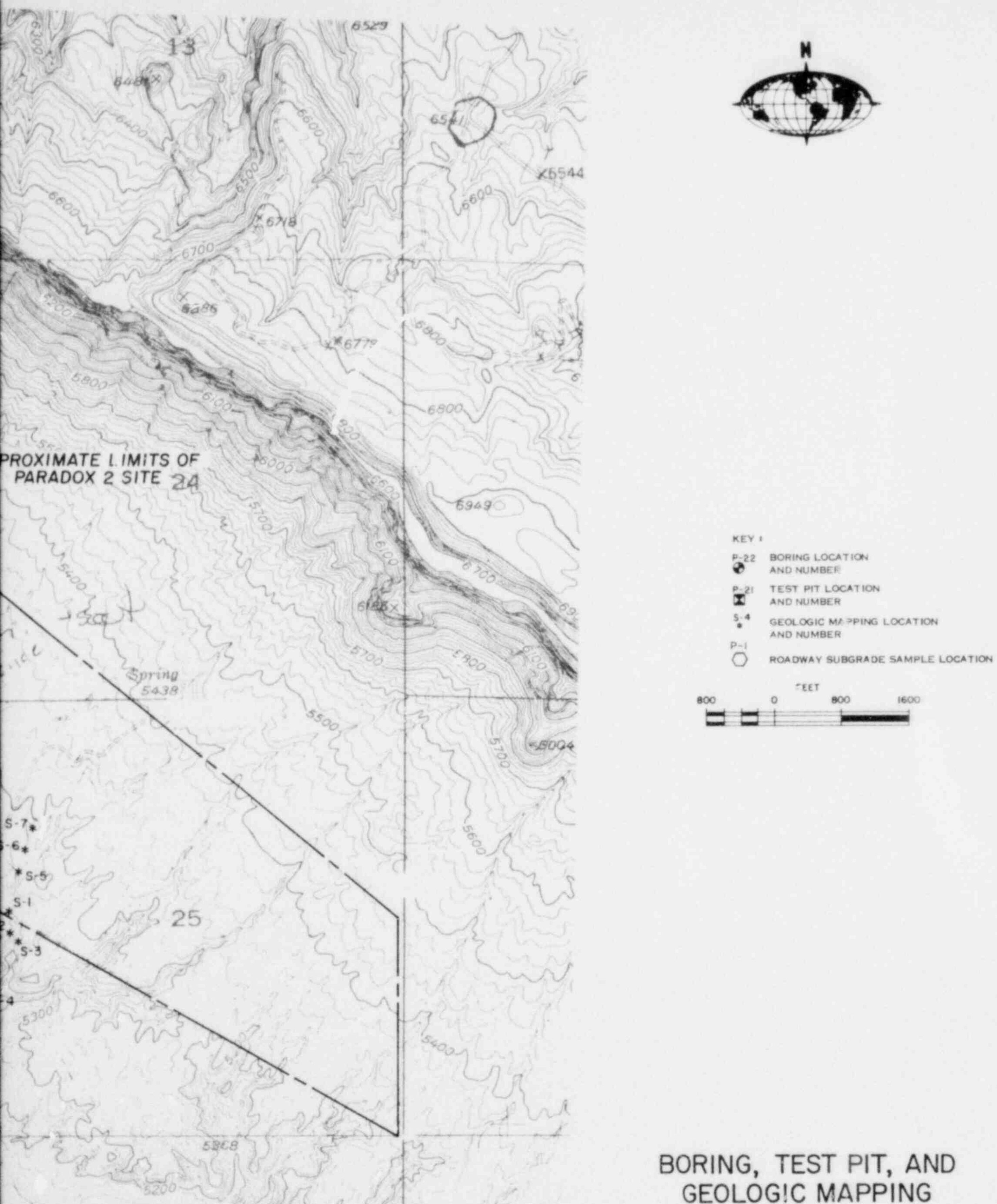
PLATE C-1

JOB NUMBER ________ DRAWN BY ________ DATE ________



REFERENCE
U.S.G.S. QUADRANGLE ENTITLED
" DAVIS MESA, COLORADO" 1960.

406 11 (10-79)



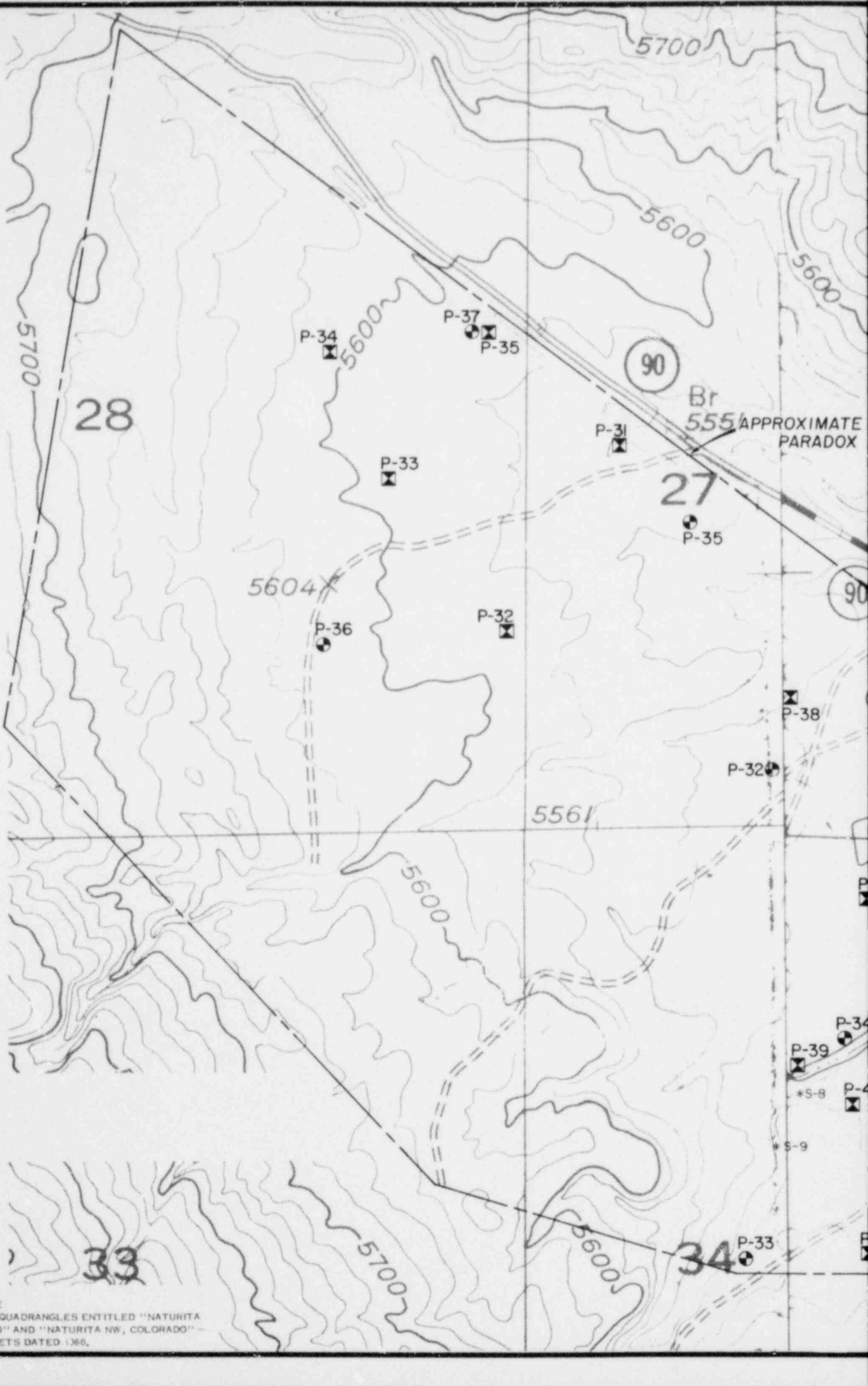
BORING, TEST PIT, AND GEOLOGIC MAPPING LOCATIONS

PARADOX 2

DAMES & MOORE

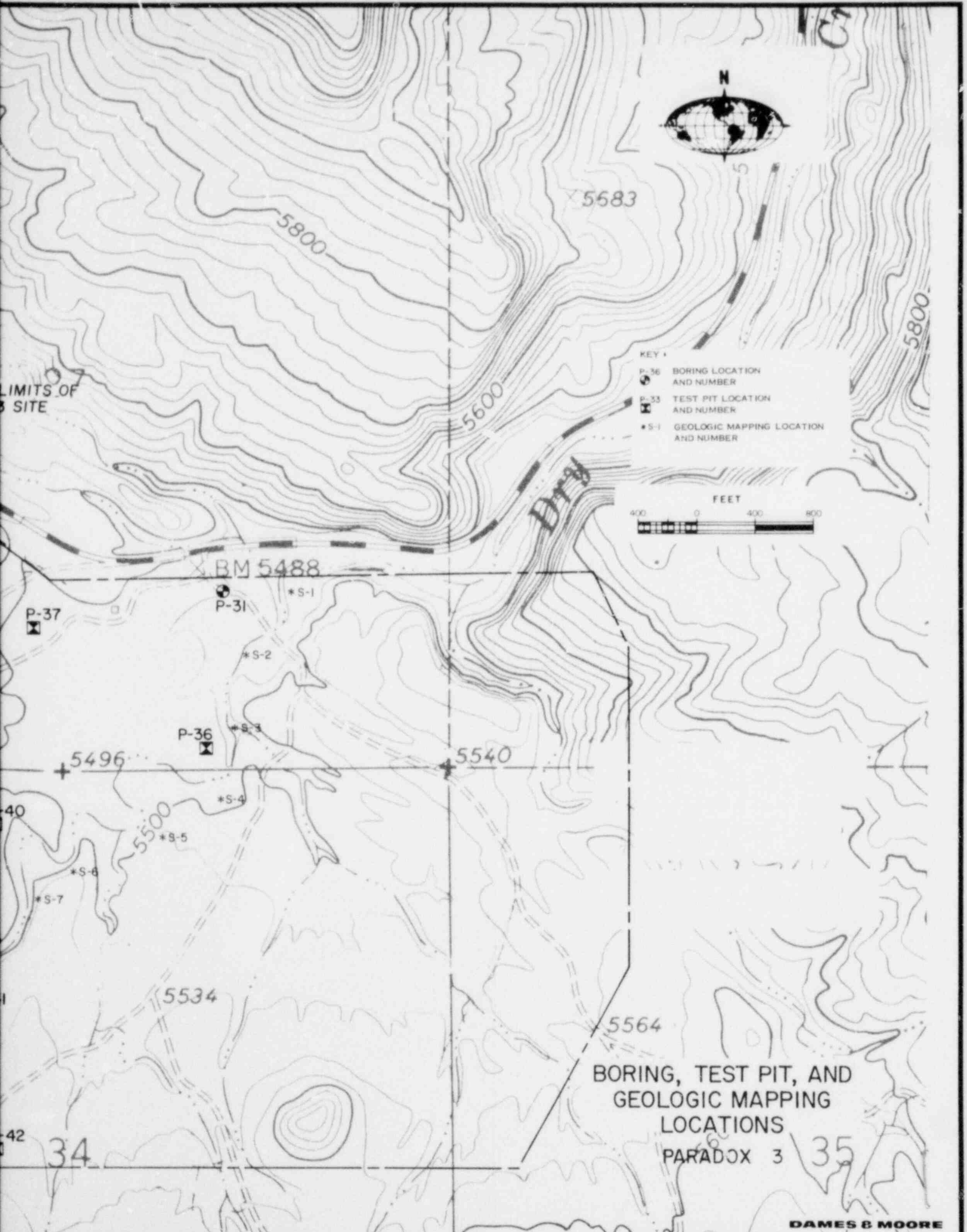
PLATE C-2

JOB NUMBER ______ DRAWN BY ______ DATE ______



REFERENCE
U.S.G.S. QUADRANGLES ENTITLED "NATURITA COLORADO" AND "NATURITA NW, COLORADO" — BOTH SHEETS DATED 1960.

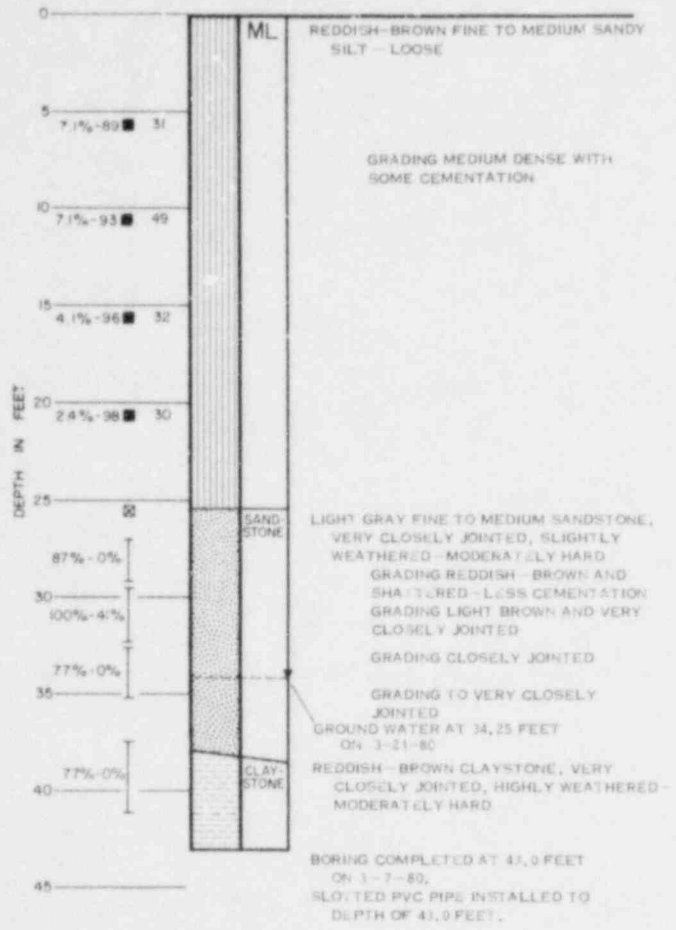
466.11 (10-79)



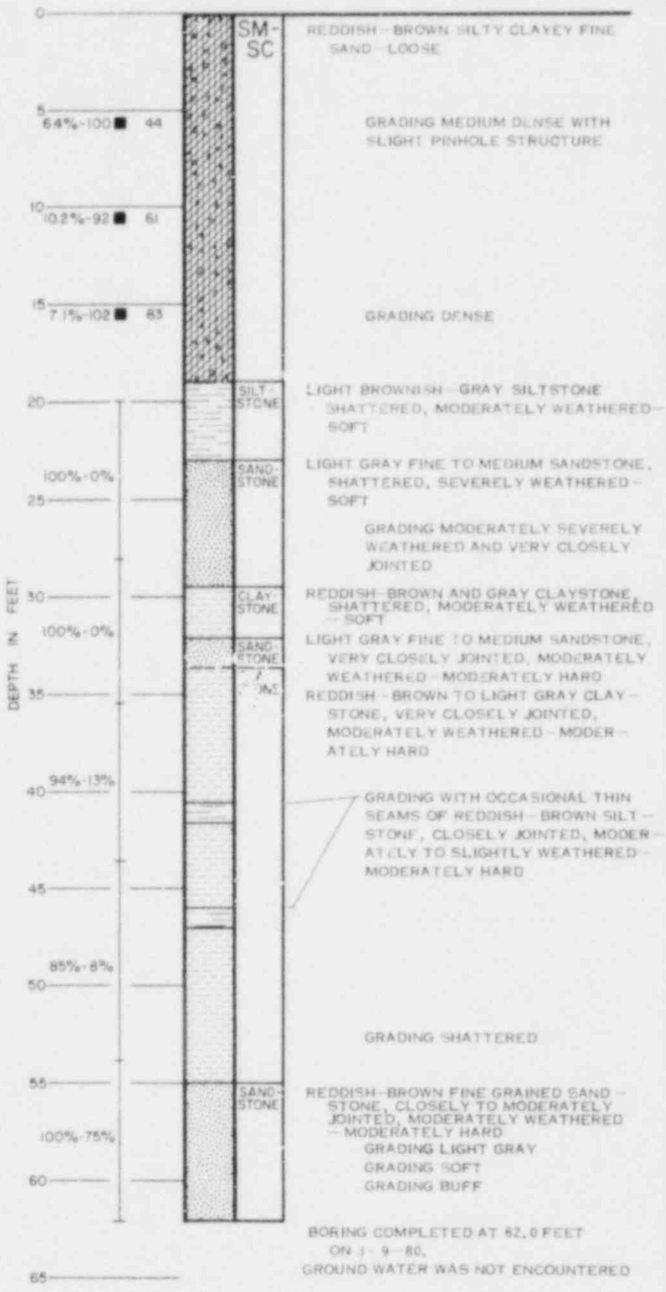
BORING, TEST PIT, AND GEOLOGIC MAPPING LOCATIONS
PARADOX 3

PLATE C-3

BORING LP-1



BORING LP-2



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

◪ SPLIT SPOON SAMPLE

⊠ BULK SAMPLE

5%-70% INDICATES DEPTH AND LENGTH OF CORE RUN

RQD (ROCK QUALITY DETERMINATION) PERCENT OF THE TOTAL CORE RUN HAVING AN UNFRACTURED LENGTH OF 4" OR MORE

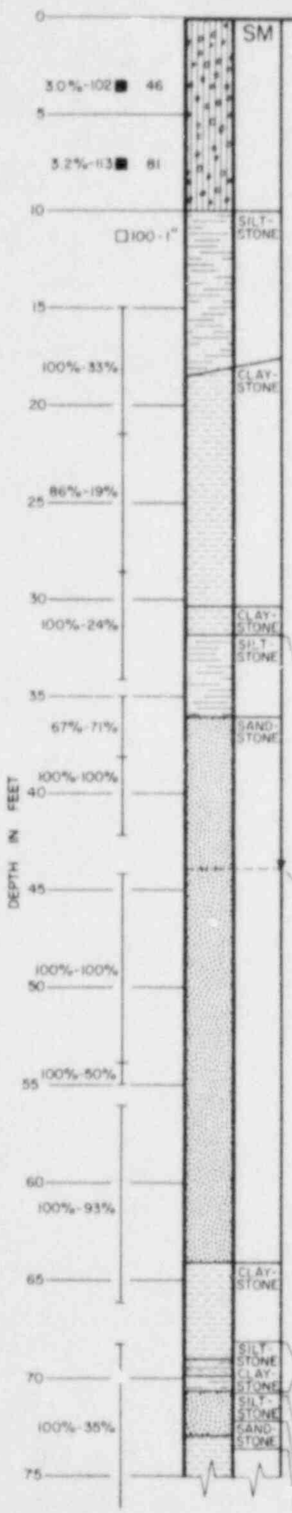
PERCENT OF CORE RUN RECOVERED

LOG OF BORINGS

DAMES & MOORE

PLATE C-4A

BORING LP-3



REDDISH-BROWN SILTY FINE TO MEDIUM SAND-MEDIUM DENSE

GRADING WITH SOME LIGHT GRAY SANDSTONE GRAVEL AND SLIGHT PINHOLE STRUCTURE

GRAYISH-PURPLE SILTSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD

GREENISH-GRAY CLAYSTONE, FISSURED, VERY HIGHLY WEATHERED-SOFT

GRADING VERY CLOSELY JOINTED AND MODERATELY HARD

GRADING CLOSELY JOINTED AND MODERATELY WEATHERED

GRADING REDDISH-BROWN

GRADING GREENISH-GRAY

GRADING REDDISH BROWN AND SHATTERED

REDDISH-BROWN CLAYSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED, MODERATELY HARD

GREENISH-GRAY SILTSTONE, CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD

LIGHT REDDISH-BROWN FINE SANDSTONE, MODERATELY JOINTED, SLIGHTLY WEATHERED-MODERATELY HARD

GRADING REDDISH-BROWN

GRADING LIGHT GRAYISH-BROWN AND WIDELY JOINTED

GROUND WATER AT 43.75 FEET ON 3-21-80

GRADING CLOSELY JOINTED

GRADING CLOSELY JOINTED WITH 1/4 INCH TO 1 INCH CLAYSTONE SEAMS

GRADING MODERATELY JOINTED

REDDISH-BROWN CLAYSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD

GRADING WITH GREENISH-GRAY LAYERS

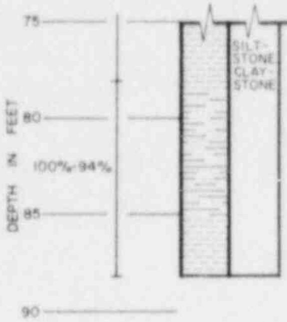
INTERBEDDED GREENISH-GRAY SILTSTONE AND REDDISH-BROWN CLAYSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD

MOTTLED REDDISH-GRAY SILTSTONE, CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD

LIGHT GRAY FINE SANDSTONE, MODERATELY JOINTED, SLIGHTLY WEATHERED-MODERATELY HARD

INTERBEDDED REDDISH-BROWN SILTSTONE AND CLAYSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD

BORING LP-3 (CONTINUED)



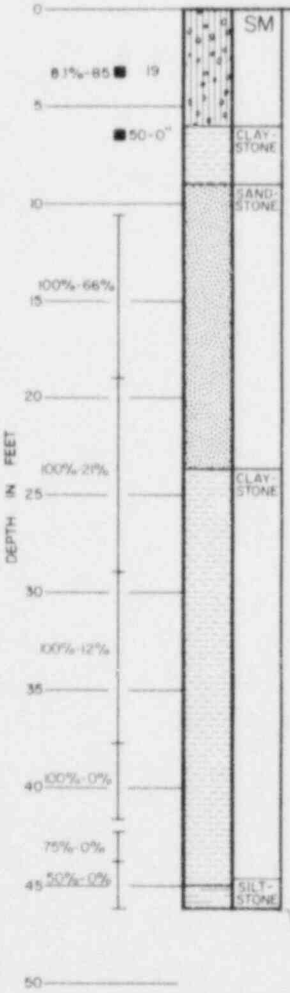
GRADING BROWNISH-GRAY

GRADING LIGHT GRAY AND VERY SLIGHT WEATHERING

GRADING REDDISH-BROWN

BORING COMPLETED AT 88.0 FEET ON 3-6-80.
SLOTTED PVC PIPE INSTALLED TO DEPTH OF 88.0 FEET.

BORING LP-4



REDDISH-BROWN SILTY FINE SAND-LOOSE

GRADING WITH SLIGHT CEMENTATION

BROWN CLAYSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED-SOFT

LIGHT GRAY FINE TO MEDIUM SANDSTONE, CLOSELY JOINTED, MODERATELY WEATHERED-SOFT

GRADING MODERATELY JOINTED

GRADING SOFT TO MODERATELY HARD

REDDISH-BROWN CLAYSTONE, SHATTERED, SLIGHTLY WEATHERED-SOFT

GRADING BROWNISH-GRAY AND VERY CLOSELY JOINTED

GRADING SHATTERED TO VERY CLOSELY JOINTED

GRADING LIGHT REDDISH-BROWN

GRADING WITH SOME SHATTERED ZONES

LIGHT GRAY SILTSTONE, SHATTERED TO VERY CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD

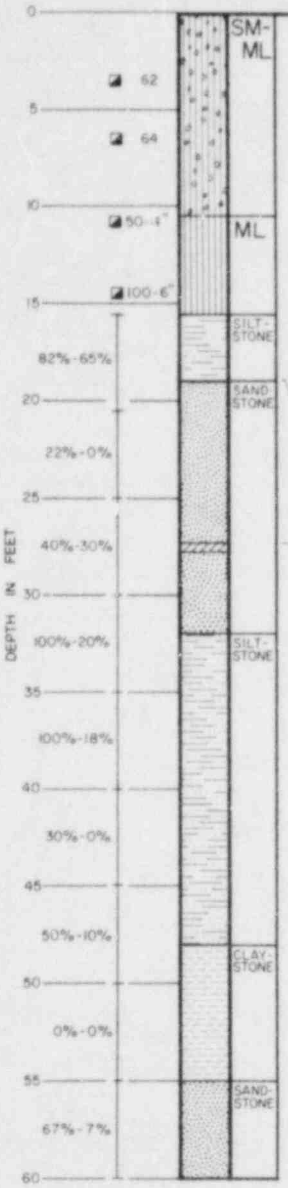
BORING COMPLETED AT 46.0 FEET ON 3-8-80.
GROUND WATER WAS NOT ENCOUNTERED

LOG OF BORINGS

DAMES & MOORE

PLATE C-4B

BORING LP-5



REDDISH-BROWN SILT AND FINE TO MEDIUM SAND WITH TRACE CLAY – VERY DENSE

GREEN FINE SANDY SILT WITH TRACE CLAY – VERY DENSE

REDDISH – BROWN SILTSTONE WITH OCCASIONAL THIN CLAY SEAMS, MODERATELY JOINTED, SLIGHTLY WEATHERED, MODERATELY HARD

BUFF FINE TO MEDIUM SANDSTONE, VERY CLOSELY JOINTED, SLIGHTLY WEATHERED – MODERATELY HARD

CLAY SEAM

GRADING SLIGHTLY TO MODERATELY WEATHERED AND MODERATELY JOINTED

RED SILTSTONE, SHATTERED TO VERY CLOSELY JOINTED, MODERATELY WEATHERED – SOFT TO MODERATELY HARD

GRADING GREENISH – GRAY

GRADING CLOSELY JOINTED

GRADING LIGHT GRAY WITH 1/2 INCH CLAYSTONE SEAMS AND VERY CLOSELY JOINTED

GRADING GRAYISH – BROWN AND MODERATELY WEATHERED

BROWNISH – GRAY CLAYSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED – SOFT

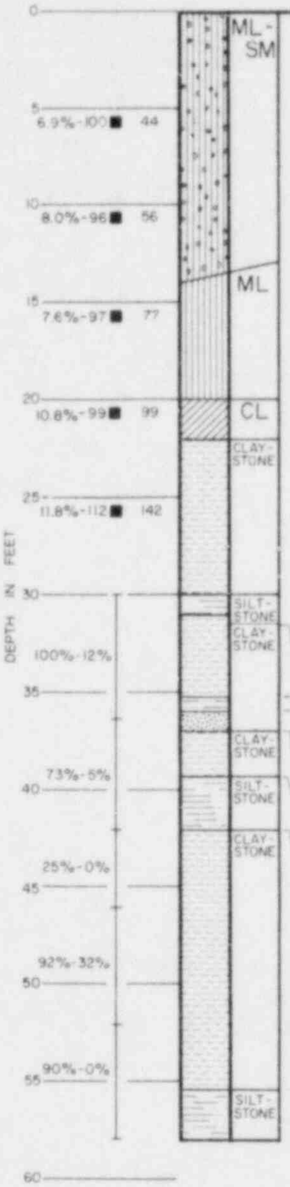
BUFF FINE TO MEDIUM SANDSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

BORING COMPLETED AT 60.0 FEET ON 3–6–80.

SLOTTED PVC PIPE INSTALLED TO DEPTH OF 60.0 FEET

GROUND WATER WAS NOT ENCOUNTERED

BORING LP-6



REDDISH-BROWN CLAYEY SILT AND FINE TO MEDIUM SAND – LOOSE

GRADING MEDIUM DENSE

REDDISH – BROWN FINE SANDY SILT WITH SOME CLAY – HARD

LIGHT GRAY SILTY CLAY – HARD (COMPLETELY WEATHERED CLAYSTONE)

REDDISH – BROWN CLAYSTONE, CLOSELY JOINTED, SEVERELY WEATHERED – SOFT

GREENISH – GRAY SILTSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED – HARD

GREEN CLAYSTONE, SHATTERED, MODERATELY WEATHERED – SOFT

GRADES VERY CLOSELY JOINTED

GRADES TO BUFF SILTSTONE

GRADES TO GREENISH – GRAY FINE SANDSTONE

BROWN CLAYSTONE, SHATTERED, MODERATELY WEATHERED – SOFT

LIGHT GREENISH – GRAY SILTSTONE, SHATTERED TO VERY CLOSELY JOINTED, MODERATELY TO SEVERELY WEATHERED – SOFT

BROWNISH – GRAY CLAYSTONE, SHATTERED TO VERY CLOSELY JOINTED, MODERATELY TO SEVERELY WEATHERED – SOFT

GRADING MODERATELY HARD

GRADING REDDISH – BROWN AND SOFT

GRADING WITH OCCASIONAL GREENISH – GRAY SILTSTONE LAYERS

LIGHT GRAY SILTSTONE, CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

BORING COMPLETED AT 58.0 FEET ON 3–10–80.

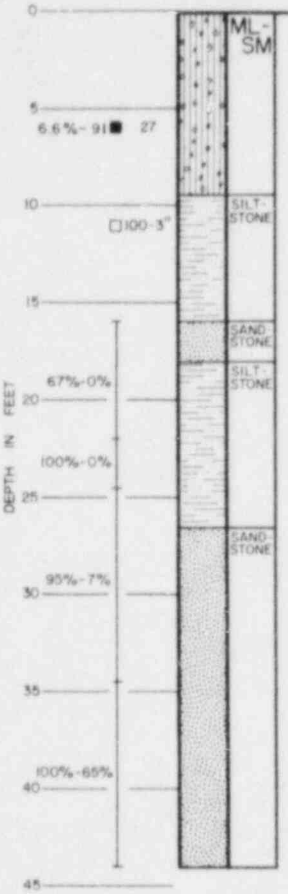
GROUND WATER WAS NOT ENCOUNTERED

LOG OF BORINGS

DAMES & MOORE

PLATE C-4C

BORING LP-7



REDDISH-BROWN FINE SANDY SILT WITH SOME GRAVEL SIZE ROCK FRAGMENTS - LOOSE

GRADING MEDIUM DENSE

REDDISH-BROWN SILTSTONE, SHATTERED, MODERATELY WEATHERED-SOFT

LIGHT GRAY SANDSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED-HARD

GREENISH-GRAY SILTSTONE, SHATTERED MODERATELY WEATHERED-MODERATELY HARD

1/2 INCH TO 1 INCH REDDISH-BROWN CLAYSTONE SEAMS

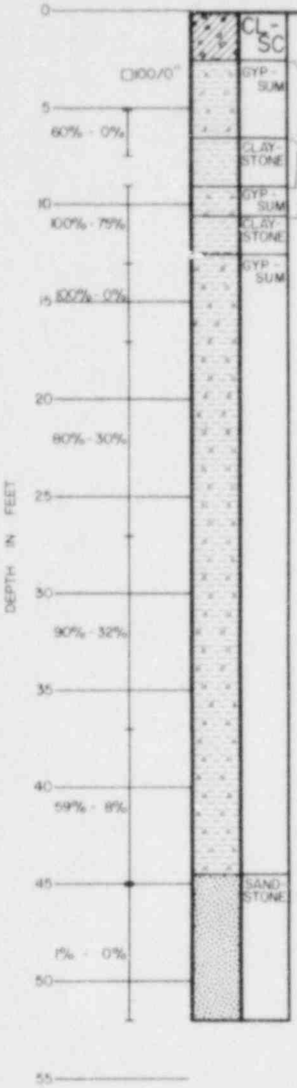
LIGHT GRAY FINE SANDSTONE WITH OCCASIONAL CLAYSTONE SEAMS 1/2 INCH TO 2 INCHES THICK, VERY CLOSELY JOINTED, MODERATELY WEATHERED-MODERATELY HARD TO HARD

BORING COMPLETED AT 44.0 FEET ON 3-7-80.
GROUND WATER WAS NOT ENCOUNTERED

LOG OF BORINGS

DAMES & MOORE

BORING P-22



LIGHT BROWN SILTY SANDY CLAY, WITH ROOTS TO 18" - MEDIUM DENSE

TRANSLUCENT WHITE TO DARK GRAY CALCAREOUS GYPSUM, CLOSELY JOINTED, MODERATELY WEATHERED - MODERATELY HARD TO SOFT

DARK TO LIGHT BROWN, GRAY AND ORANGISH-BROWN THINLY LAMINATED CLAYSTONE WITH 1/8" LAYERS OF GYPSUM, CLOSELY JOINTED, VERY SEVERELY WEATHERED - VERY SOFT

TRANSLUCENT WHITE TO DARK GRAY CALCAREOUS GYPSUM, VERY CLOSELY JOINTED, MODERATELY WEATHERED - MODERATELY HARD TO SOFT

GRADES MORE CALCAREOUS

GRADES LESS CALCAREOUS AND SLIGHTLY WEATHERED

GRADING WITH BROWN SILTY ZONES (POSSIBLY SILT FILLED SOLUTION CAVITIES), SEVERELY WEATHERED - VERY SOFT

GRADING WITH SILT FILLED JOINTS, MODERATELY WEATHERED - SOFT

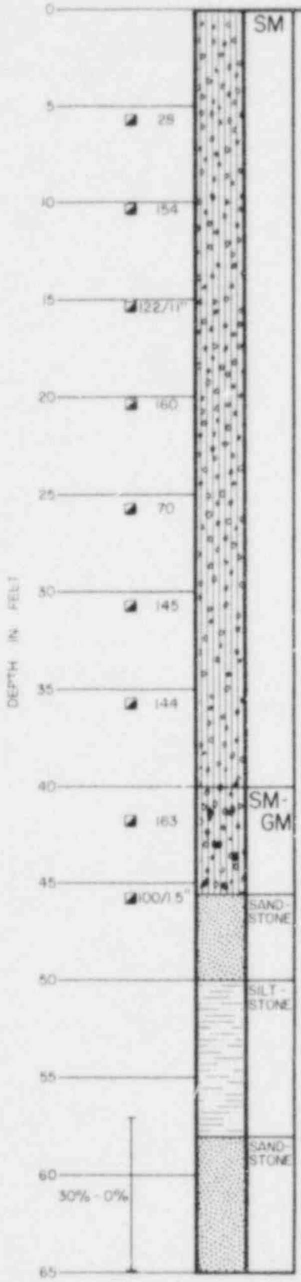
GRADING WITHOUT SILT, SLIGHTLY WEATHERED - MODERATELY HARD TO SOFT

TAN FINE GRAIN SANDSTONE WITH INTERLAYER BLACK SANDSTONE, VERY SEVERELY WEATHERED - SOFT TO VERY SOFT WITH OCCASIONAL MODERATELY HARD LAYERS

BORING COMPLETED AT 52.0 FEET
ON 3 - 12 - 80

GROUND WATER WAS NOT ENCOUNTERED

BORING P-24



REDDISH-BROWN SILTY FINE SAND WITH OCCASIONAL GRAVEL - MEDIUM DENSE

GRADING WITH SOME GRAVEL - VERY DENSE

GRADING WITH OCCASIONAL COBBLES AND BOULDERS

RED SILTY FINE TO COARSE SAND AND GRAVEL - VERY DENSE

RED FINE TO MEDIUM GRAIN SANDSTONE HIGHLY WEATHERED - SOFT

GRADING WHITE TO LIGHT GREEN FINE GRAIN SANDSTONE

GRADING RED

RED SILTSTONE SEVERELY WEATHERED - SOFT

INTERLAYERED WHITE AND RED FINE GRAIN SANDSTONE SHATTERED, MODERATELY TO SEVERELY WEATHERED - MODERATELY HARD TO SOFT

BORING COMPLETED AT 65.0 FEET
ON 3 - 13 - 80

GROUND WATER WAS NOT ENCOUNTERED

LOG OF BORINGS

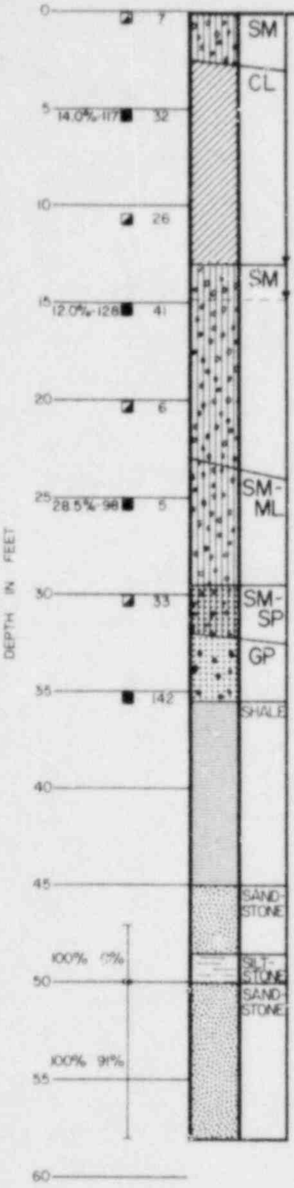
DAMES & MOORE

PLATE C-4E

REVISIONS
BY DATE
BY DATE
PLATE OF

FILE
BY DATE
CHECKED BY DATE

BORING P-31



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

BROWN FINE SANDY CLAY – VERY STIFF

GRADING CLAYEY WITH POCKETS OF WHITE GYPSUM

GROUND WATER AT 13.0' IN OVERBURDEN ON 3 – 19 – 80

BROWN TO GREENISH-GRAY SILTY FINE SAND – MEDIUM DENSE

GROUND WATER AT 14.9' IN BEDROCK ON 3 – 20 – 80

GRADES BROWN SILTY FINE TO COARSE SAND

GRADING BROWN TO REDDISH-BROWN – LOOSE

BROWN SILTY FINE SAND AND FINE SANDY SILT WITH TRACE CLAY – LOOSE

BROWN FINE TO COARSE SAND, SOME SILT AND TRACE FINE GRAVEL – DENSE

BROWN SANDY FINE AND COARSE GRAVEL WITH TRACE SILT – DENSE

GRAY SHALE, HIGHLY WEATHERED – SOFT

GRADING MODERATELY WEATHERED MODERATELY HARD

GROUND WATER ENCOUNTERED AT 40.5'

LIGHT GRAY FINE GRAIN SANDSTONE, CLOSELY JOINTED, SLIGHTLY WEATHERED – MODERATELY HARD

BLACK SILTSTONE, CLOSELY JOINTED, SLIGHTLY WEATHERED – MODERATELY HARD

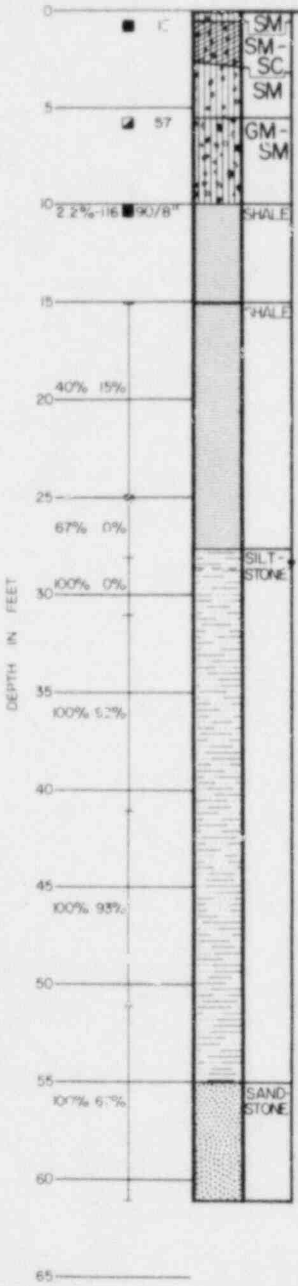
LIGHT GRAY FINE GRAIN SANDSTONE WITH CARBONACEOUS STRINGERS, CLOSELY TO MODERATELY JOINTED, FRESH – MODERATELY HARD

GRADING WITHOUT CARBONACEOUS STRINGERS

GRADING WITH CARBONACEOUS STRINGERS

BORING COMPLETED AT 58.0 FEET ON 3 – 19 – 80

BORING P-32



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

BROWN SILTY FINE SAND WITH SOME CLAY – LOOSE

BROWN SILTY FINE SAND – DENSE

MOTTLED BROWN, YELLOW AND RED SILTY SAND AND FINE GRAVEL – VERY DENSE

GRAY SHALE, SEVERELY WEATHERED – SOFT

GRADING VERY CLOSELY JOINTED, MODERATELY WEATHERED – SOFT

LIGHT GRAY CALCAREOUS SHALE WITH GYPSUM CRYSTALS ON JOINTS, SHATTERED, SEVERELY WEATHERED – SOFT

MEDIUM GRAY CALCAREOUS SILTSTONE, SHATTERED, SLIGHTLY WEATHERED – MODERATELY HARD

GROUND WATER AT 28.6' ON 3 – 21 – 80

GRADING DARK GRAY IN COLOR

GRADING CLOSELY JOINTED

6" DARK BLACK CLAY SEAM AT 50.5'

GROUND WATER ENCOUNTERED AT 51.0'

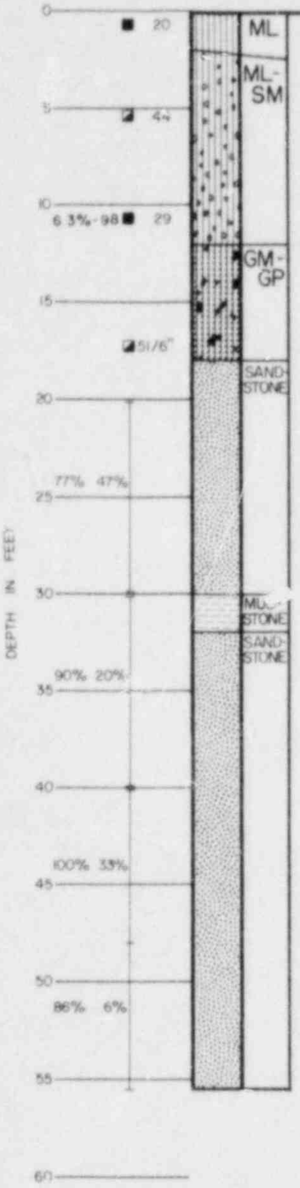
BLACK FINE TO MEDIUM GRAIN SANDSTONE

GRADING MOTTLED LIGHT AND DARK GRAY BIOTURBATED FINE TO MEDIUM GRAIN SANDSTONE, CLOSELY JOINTED, SLIGHTLY WEATHERED – MODERATELY HARD

BORING COMPLETED AT 61.0 FEET ON 3 – 20 – 30

LOG OF BORINGS

BORING P-33



BROWN FINE SANDY SILT WITH ROOTS – STIFF

BROWN SILT AND FINE SAND – DENSE

GRADING WITH TRACE MEDIUM TO COARSE SAND

BROWN SANDY FINE GRAVEL WITH SOME SILT – VERY DENSE

TAN TO LIGHT GRAY FINE TO MEDIUM GRAIN SANDSTONE WITH OCCASIONAL CARBONACEOUS SEAMS AND PARTINGS SHATTERED, SEVERELY WEATHERED – MODERATELY HARD

GRADING CLOSELY JOINTED AND MODERATELY WEATHERED

DARK BROWN MUDSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED – SOFT

LIGHT GRAY AND TAN FINE GRAINED SANDSTONE WITH NUMEROUS SMALL SCALE FAULTS AND FRACTURES COATED WITH GYPSUM, CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

GRADES MASSIVE LIGHT GRAY IN COLOR WITHOUT FAULTS

GRADING WITH OCCASIONAL SHATTERED ZONES

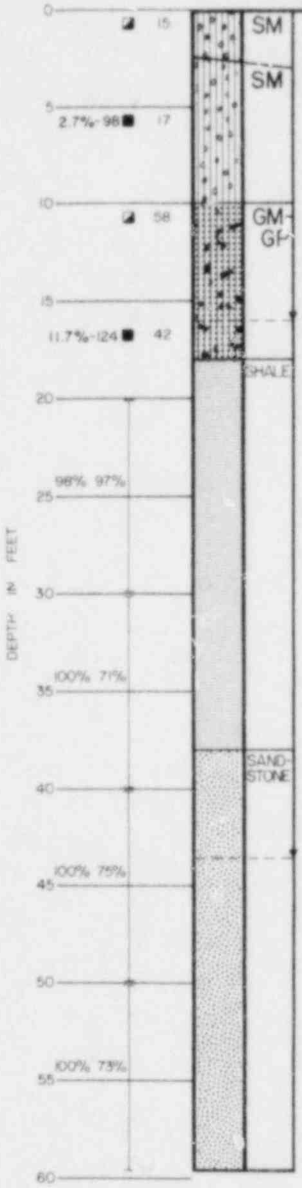
GRADING WITH CARBONACEOUS STRINGERS AND POCKETS OF GRANULAR PYRITE

GRADING WITH SMALL SCALE HEALED FAULTS BETWEEN 52.0' AND 53.2'

BORING COMPLETED AT 55.5 FEET ON 3 – 22 – 80

GROUND WATER WAS NOT ENCOUNTERED

BORING P-34



BROWN SILTY FINE SAND WITH ROOTS – MEDIUM DENSE

BROWN FINE SILTY SAND WITH TRACE MEDIUM SAND – LOOSE

BROWN SANDY FINE GRAVEL WITH TRACE SILT – VERY DENSE

GRADING WITH COARSE GRAVEL AND COBBLES

GROUND WATER IN OVERBURDEN AT 16.0' ON 3 – 23 – 80

BLACK SHALE, VERY WIDELY JOINTED, SLIGHTLY WEATHERED – MODERATELY HARD

GRADING CLOSELY JOINTED, MODERATELY WEATHERED – SOFT, BETWEEN 32.7' TO 35.0'

MOTTLED WHITE TO LIGHT GRAY AND BLACK FINE TO MEDIUM GRAIN SANDSTONE (BIOTURBATED) WIDELY JOINTED SLIGHTLY WEATHERED – MODERATELY HARD

GRADING WITH PYRITE REPLACEMENT ALONG ORGANIC FIBROSE

GROUND WATER IN BEDROCK AT 43.4' ON 3 – 23 – 80

BLACK MUDSTONE BETWEEN 46.0' AND 47.0'

GRADING WITH OCCASIONAL NON-BIOTURBATED ZONES, CLOSELY JOINTED

GRADING MODERATELY JOINTED

BORING COMPLETED AT 59.67 FEET ON 3 – 23 – 80

SLOTTED PVC PIPE INSTALLED TO A DEPTH OF 19.0 FEET

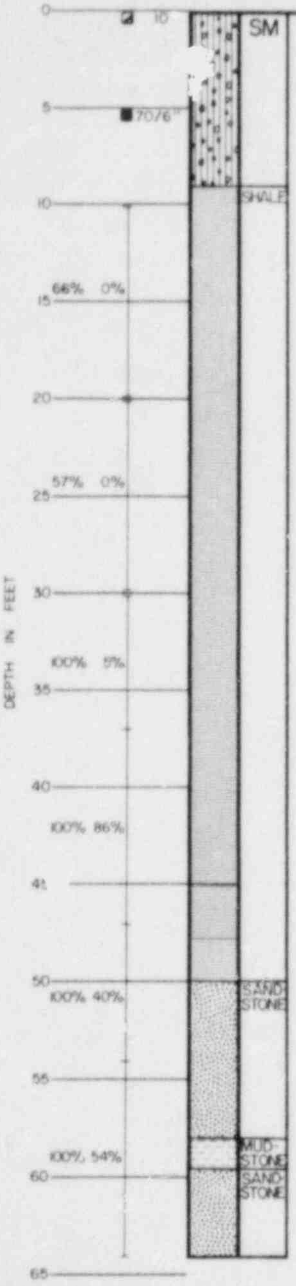
LOG OF BORINGS

REVISIONS
BY DATE
BY DATE
BY PLATE OF

FILE
BY DATE
CHECKED BY DATE

DAMES & MOORE

BORING P-35



BROWN SILTY FINE SAND WITH TRACE CLAY AND ROOTS IN UPPER 24" – LOOSE

GRADING WITHOUT CLAY WITH WHITE CALCAREOUS MOTTLING – VERY DENSE

GRADING WITH SOME COARSE SAND AND GRAVEL

LIGHT TO MEDIUM GRAY CALCAREOUS SHALE, WITH GYPSUM CRYSTALS ON JOINTS, SHATTERED, MODERATELY WEATHERED – SOFT

12" YELLOWISH-BROWN SILT AND GYPSUM LAYER AT 13.0'

GRADING MODERATELY HARD

GRADING VERY CLOSELY JOINTED

GRADING WITHOUT GYPSUM CRYSTALS ON JOINTS

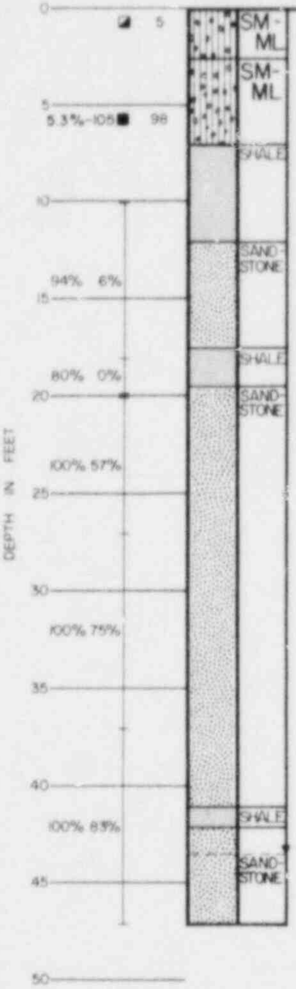
MOTTLED WHITE AND GRAY FINE TO MEDIUM GRAIN (BIOTURBATED) SANDSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

12" BLACK MUDSTONE LAYER AT 58.3' – SOFT

BORING COMPLETED AT 64.0 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

BORING P-36



BROWN SILTY FINE SAND AND FINE SANDY SILT WITH ROOTS – LOOSE

MOTTLED BROWN AND WHITE CALCAREOUS SILT AND FINE TO MEDIUM SAND – DENSE

GRAY SHALE, SHATTERED, SLIGHTLY WEATHERED – SOFT

6" YELLOWISH-BROWN SILT AND GYPSUM LAYER AT 9.0'

MOTTLED TAN, WHITE AND BLACK FINE TO MEDIUM GRAIN SANDSTONE, VERY CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

DARK GRAY SHALE, SHATTERED, SLIGHTLY WEATHERED – SOFT

LIGHT GRAY WITH LIMANITIC STAINING FINE TO MEDIUM GRAIN SANDSTONE, CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

GRADING WITH GRAY BIOTURBATED ZONES

GRADING MOTTLED GRAY AND WHITE FINE GRAIN BIOTURBATED SANDSTONE

12" GRAY SHALE LAYER AT 41.0' – SOFT

GROUND WATER AT 43.3' ON 3 – 25 – 80

BORING COMPLETED AT 47.0 FEET ON 3 – 25 – 80

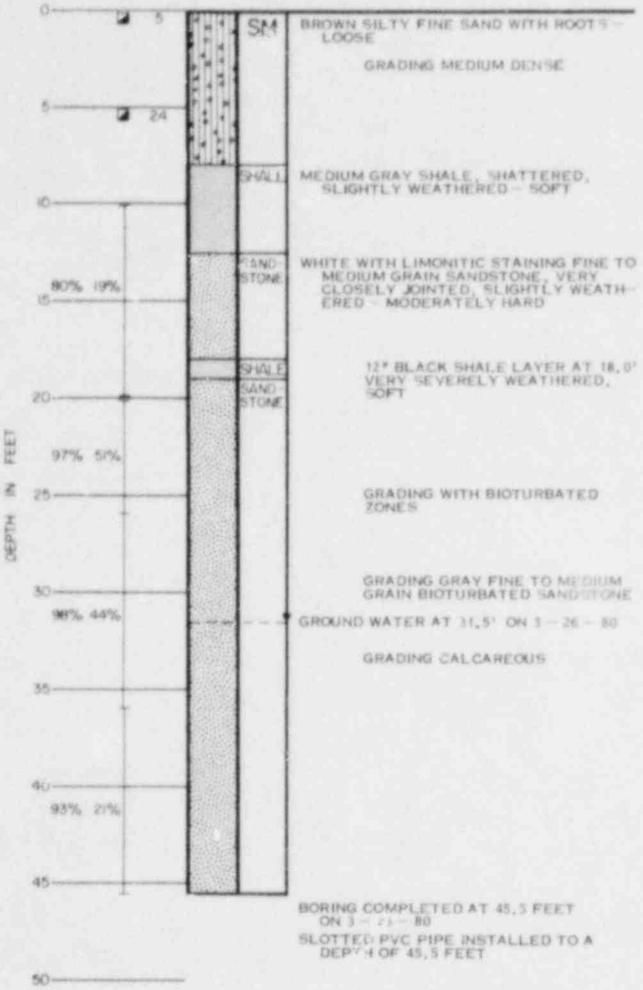
SLOTTED PVC PIPE INSTALLED TO A DEPTH OF 47.0 FEET

LOG OF BORINGS

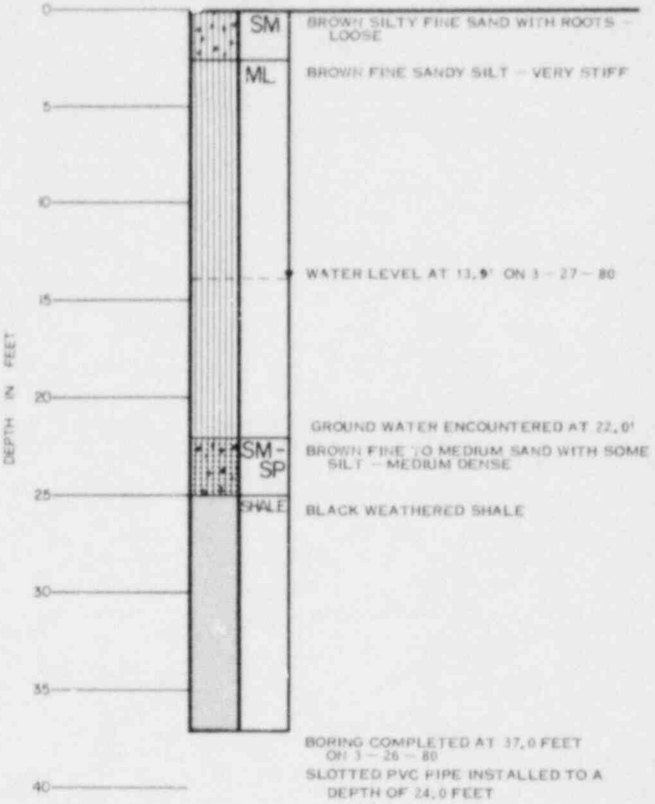
DAMES & MOORE

PLATE C-4H

BORING P-37



BORING P-38



LOG OF BORINGS

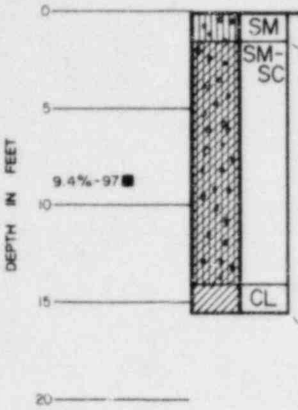
DAMES & MOORE

PLATE C-4I

REVISIONS
BY DATE
BY DATE
PLATE OF

FILE
BY DATE
CHECKED BY DATE

TEST PIT LP-1



RED TO BROWN SILTY FINE SAND, MAJOR ROOTS IN UPPER 12" — LOOSE

REDDISH-BROWN SILTY CLAYEY FINE SAND WITH OCCASIONAL TRACE GRAVEL ROOTS PRESENT — LOOSE

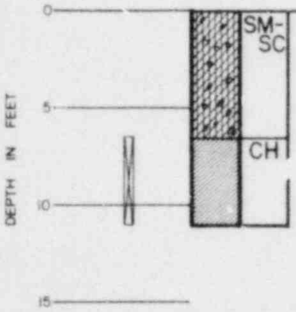
GRADE DENSE AT 9.0'

WHITE TO REDDISH-BROWN FINE SANDY CLAY WITH GRAVEL SIZE FRAGMENTS OF WHITE FINE TO MEDIUM SANDSTONE

TEST PIT COMPLETED AT 15.5 FEET ON 3 — 10 — 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-3



REDDISH-BROWN SILTY CLAYEY FINE SAND, MAJOR ROOTS IN UPPER 17" — LOOSE

GRADES WITH TRACE OF COARSE GRAVEL AT 5.5'

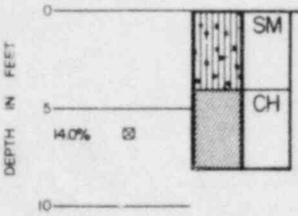
LIGHT GREEN CLAY (DECOMPOSED SHALE) — HARD

GRADING LIGHT GRAY AT 9.0'

TEST PIT COMPLETED AT 11.0 FEET ON 3 — 10 — 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-5



REDDISH-BROWN SILTY FINE SAND, MAJOR ROOTS IN UPPER 17" — LOOSE

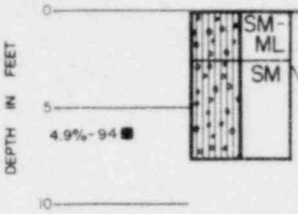
GRADES WITH SOME FINE AND COARSE GRAVEL AND DENSE AT 2.5'

LIGHT GREENISH-GRAY CLAY (DECOMPOSED SHALE) — HARD

TEST PIT COMPLETED AT 8.0 FEET ON 3 — 10 — 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-2



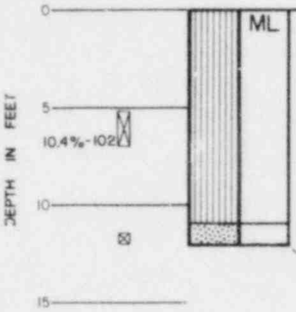
BROWN SILTY FINE TO MEDIUM SAND AND FINE TO MEDIUM SANDY SILT WITH SOME FINE AND COARSE GRAVEL AND TRACE COARSE SAND, MAJOR ROOTS IN UPPER 17" — LOOSE

BROWN SILTY FINE TO COARSE SAND WITH SOME FINE AND COARSE GRAVEL — DENSE

TEST PIT COMPLETED AT [illegible] FEET ON 3 — 10 — 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-4



REDDISH-BROWN FINE SANDY SILT WITH SOME CLAY, MAJOR ROOTS IN UPPER 24" — STIFF

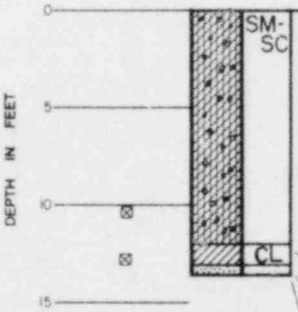
GRADING WITH OCCASIONAL 1" LENSES OF FINE TO COARSE SAND

LIGHT GREEN FINE GRAINED SANDSTONE

TEST PIT COMPLETED AT 12.0 FEET ON 3 — 10 — 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-6



REDDISH-BROWN SILTY CLAYEY FINE SAND MAJOR ROOTS IN UPPER 24" — LOOSE

GRADING WITH MORE SILT AND CLAY

GRADING WITH 6" LENSES OF FINE TO COARSE SAND TRACE GRAVEL AT 10.0'

LIGHT GREENISH-GRAY SILTY CLAY (DECOMPOSED SHALE) — HARD

LIGHT GREENISH-GRAY FINE GRAINED SANDSTONE

TEST PIT COMPLETED AT 13.5 FEET ON 3 — 10 — 80

GROUND WATER WAS NOT ENCOUNTERED

LOG OF TEST PITS

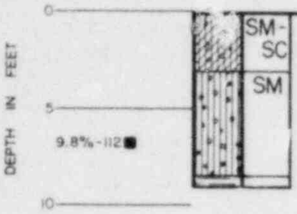
DAMES & MOORE

PLATE C-5A

REVISIONS
BY ______ DATE ______
BY ______ DATE ______
PLATE ______ OF ______

FILE [illegible]
[illegible]
BY [illegible] DATE [illegible]
CHECKED BY ______ DATE ______

TEST PIT LP-7



REDDISH-BROWN SILTY CLAYEY FINE SAND, MAJOR ROOTS IN UPPER 12" - LOOSE TO MEDIUM DENSE

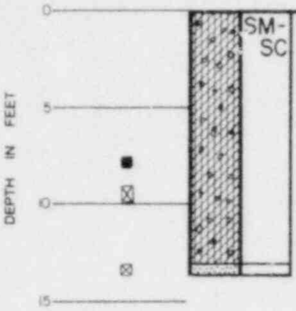
REDDISH-BROWN SILTY FINE SAND WITH TRACE MEDIUM TO COARSE SAND - DENSE

LIGHT BROWNISH-GRAY SILTSTONE

TEST PIT COMPLETED AT 9.0 FEET ON 3 - 10 - 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-8



REDDISH-BROWN SILTY CLAYEY FINE SAND, MAJOR ROOTS IN UPPER 24" - LOOSE TO MEDIUM DENSE

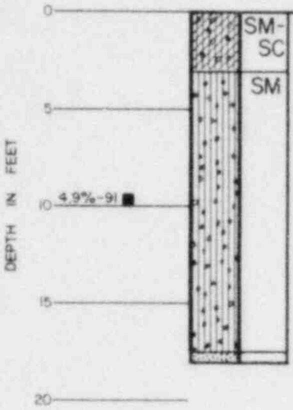
GRADING DENSE TO VERY DENSE AT 2.5'

LIGHT GREENISH-GRAY FINE TO MEDIUM GRAINED SANDSTONE - MODERATELY WEATHERED

TEST PIT COMPLETED AT 13.5 FEET ON 3 - 10 - 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-9



REDDISH-BROWN SILTY CLAYEY FINE SAND, MAJOR ROOTS IN UPPER 24" - LOOSE TO MEDIUM DENSE

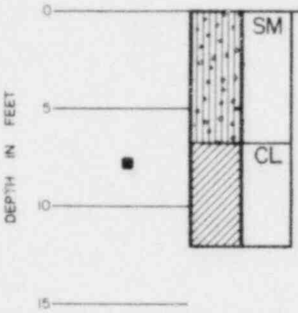
REDDISH-BROWN SILTY FINE SAND WITH OCCASIONAL 1" TO 2" LAYERS OF FINE SILTY FINE TO COARSE SAND - MEDIUM DENSE TO DENSE

LIGHT GREENISH-BROWN FINE TO MEDIUM GRAINED SANDSTONE

TEST PIT COMPLETED AT 18.0 FEET ON 3 - 11 - 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-10



REDDISH-BROWN SILTY FINE SAND, MAJOR ROOTS IN UPPER 24" - LOOSE TO MEDIUM DENSE

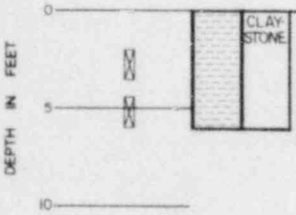
GRADING DENSE WITH OCCASIONAL LAYERS OF SILTY FINE TO COARSE SAND AT 3.0'

REDDISH-BROWN FINE SANDY CLAY - VERY STIFF

TEST PIT COMPLETED AT 12.0 FEET ON 3 - 11 - 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT LP-11



BROWN CLAYSTONE, CLOSELY JOINTED, MODERATELY WEATHERED - MODERATELY HARD

GRADING TO GREEN AND MOTTLED BROWN

TEST PIT COMPLETED AT 6.0 FEET ON 3 - 11 - 80

GROUND WATER WAS NOT ENCOUNTERED

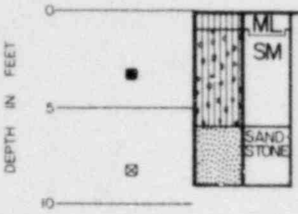
REVISIONS
BY DATE
BY DATE
PLATE OF

FILE
BY DATE
CHECKED BY DATE

LOG OF TEST PITS

DAMES & MOORE

TEST PIT P-21



BROWN FINE SANDY SILT, MAJOR ROOTS IN UPPER 2' – LOOSE

MOTTLED LIGHT BROWN AND LIGHT TAN SILTY FINE TO COARSE SAND WITH OCCASIONAL COARSE GRAVEL, COBBLES BOULDERS, GYPSIFEROUS – LOOSE TO MEDIUM DENSE

GRADES BROWN AT 5 FEET

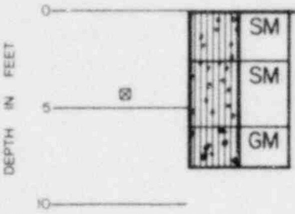
LIGHT GREENISH–BROWN SILTY FINE SANDSTONE, CLOSELY JOINTED, SEVERELY WEATHERED – SOFT

GRADES LESS WEATHERED AT 9 FEET

TEST PIT COMPLETED AT 9,0 FEET ON 3 – 11 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-22



REDDISH–BROWN SILTY FINE SAND, MAJOR ROOTS IN UPPER 17" – LOOSE

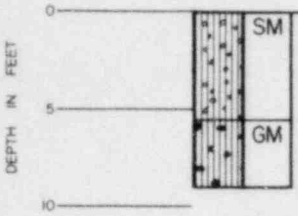
REDDISH–BROWN SILTY FINE TO COARSE SAND WITH SOME SUBROUNDED TO ROUNDED GRAVEL – VERY DENSE

REDDISH–BROWN SILTY SANDY FINE AND COARSE SUBROUNDED TO ROUNDED GRAVEL – VERY DENSE

TEST PIT COMPLETED AT 8,0 FEET ON 3 – 11 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-23



REDDISH–BROWN SILTY FINE SAND, MAJOR ROOTS TO 2' – LOOSE

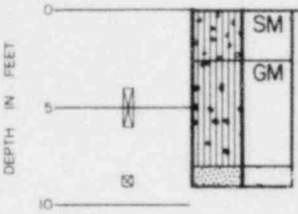
GRADING WITH SOME MEDIUM TO COARSE SAND WITH TRACE FINE ANGULAR GRAVEL AND WITH OCCASIONAL BOULDERS, MEDIUM DENSE

BROWN SILTY SANDY FINE AND COARSE ANGULAR GRAVEL, COBBLES, BOULDERS – DENSE

TEST PIT COMPLETED AT 9,0 FEET ON 3 – 11 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-24



REDDISH–BROWN SILTY FINE SAND, MAJOR ROOTS TO 2' – LOOSE

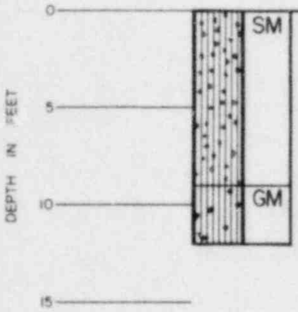
REDDISH–BROWN SILTY SANDY FINE AND COARSE SUBROUNDED GRAVEL – MEDIUM DENSE

REDDISH–BROWN AND GREENISH–GRAY LAYERED FINE TO MEDIUM SANDSTONE (STEEPLY DIPPING TO NORTH)

TEST PIT COMPLETED AT 9,0 FEET ON 3 – 11 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-25



REDDISH–BROWN SILTY FINE SAND WITH OCCASIONAL COARSE GRAVEL, MAJOR ROOTS IN UPPER 2' – LOOSE TO MEDIUM DENSE

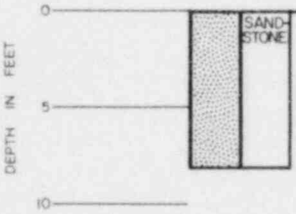
GRADES WITH SOME 6" LENSES OF MEDIUM TO COARSE SAND WITH SOME GRAVEL

REDDISH–BROWN SILTY SANDY FINE AND COARSE GRAVEL WITH OCCASIONAL BOULDERS – DENSE

TEST PIT COMPLETED AT 12,0 FEET ON 3 – 11 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-26

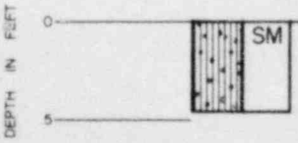


MOTTLED REDDISH–BROWN AND LIGHT TAN FINE TO COARSE GRAINED SANDSTONE WITH INTERLAYERS OF REDDISH–BROWN FINE GRAINED SANDSTONE – SEVERELY WEATHERED

TEST PIT COMPLETED AT 8,0 FEET ON 3 – 11 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-27



REDDISH–BROWN SILTY FINE SAND, MAJOR ROOTS IN UPPER 2' – LOOSE TO MEDIUM DENSE

GRADES WITH SOME FINE AND COARSE GRAVEL AND SOME BOULDERS

GRADES VERY DENSE WITH DEPTH

TEST PIT COMPLETED AT 4,5 FEET ON 3 – 11 – 80

GROUND WATER WAS NOT ENCOUNTERED

LOG OF TEST PITS

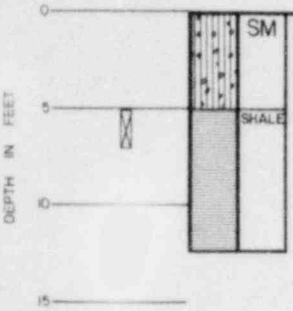
DAMES & MOORE

PLATE C-5C

FILE ______
BY ______ DATE ______
CHECKED BY ______ DATE ______

REVISIONS
BY ______ DATE ______
BY ______ DATE ______
PLATE ______ OF ______

TEST PIT P-31



BROWN SILTY FINE SAND WITH TRACE MEDIUM TO COARSE SAND, MAJOR ROOTS IN UPPER 24" – LOOSE

GRADES MEDIUM DENSE TO DENSE

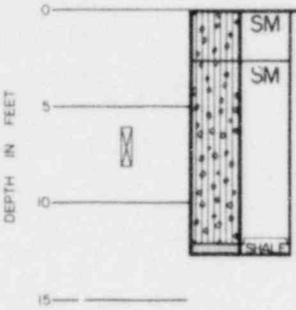
LIGHT GRAY SHALE WITH POCKETS AND STRINGER OF 1 MM GYPSUM CRYSTALS, SHATTERED, HIGHLY WEATHERED – SOFT

GRADES DARK GRAY IN COLOR, CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

TEST PIT COMPLETED AT 12.25 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-32



BROWN SILTY FINE SAND WITH MAJOR ROOTS – LOOSE

LIGHT BROWN WITH WHITE CALCAREOUS, MOTTLING SILTY FINE TO COARSE SAND WITH TRACE FINE GRAVEL – DENSE TO VERY DENSE

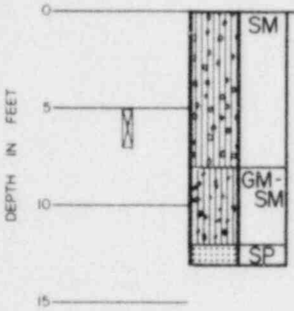
GRADES GRAVELLY WITH OCCASIONAL COBBLES

MEDIUM GRAY SHALE, CLOSELY JOINTED, MODERATELY WEATHERED – MODERATELY HARD

TEST PIT COMPLETED AT 12.5 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-33



BROWN SILTY FINE SAND, WITH ROOTS – LOOSE

GRADES WITH WHITE CALCAREOUS MOTTLING – DENSE

GRADING WITH TRACE COARSE SAND AND FINE GRAVEL

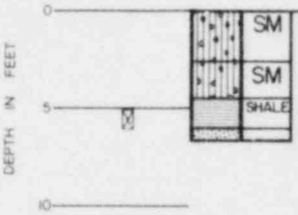
BROWN SILTY FINE AND COARSE GRAVEL AND SAND – DENSE

YELLOWISH-BROWN FINE TO MEDIUM SAND WITH TRACE SILT – DENSE

TEST PIT COMPLETED AT 13.0 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-34



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

LIGHT BROWN SILTY FINE TO COARSE SAND WITH TRACE FINE GRAVEL – DENSE

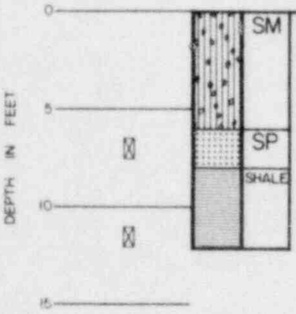
GRAY AND YELLOW STREAKED WEATHERED SHALE

LIGHT BROWN TO WHITE FINE TO MEDIUM GRAINED SANDSTONE

TEST PIT COMPLETED AT 6.5 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-35



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

GRADING WITH WHITE CARBONATION MOTTLING AND DENSE

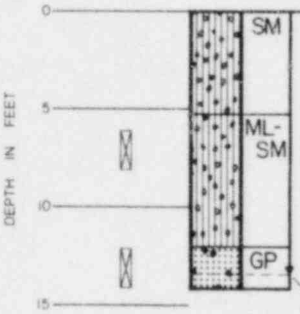
BROWN FINE TO COARSE SAND TRACE SILT – DENSE

GREENISH-GRAY TO BROWN SHALE, VERY CLOSELY JOINTED, MODERATELY WEATHERED – SOFT

TEST PIT COMPLETED AT 12.0 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-36



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

GRADING MEDIUM DENSE

BROWN SILT AND FINE SAND – MEDIUM DENSE

BROWN SANDY FINE AND COARSE GRAVEL WITH TRACE SILT – MEDIUM DENSE

GROUND WATER LEVEL AT 13.3 FEET

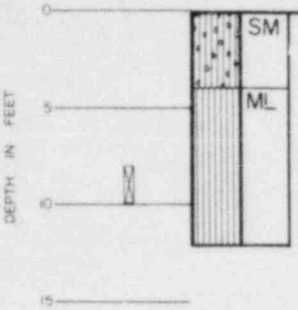
TEST PIT COMPLETED AT 14.0 FEET ON 3 – 24 – 80

LOG OF TEST PITS

DAMES & MOORE

PLATE C-5D

TEST PIT P-37



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

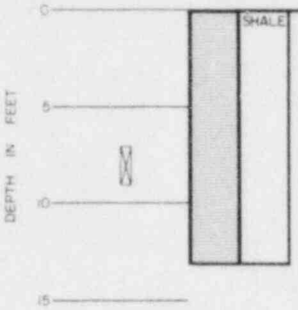
GRADING WITH WHITE CALCARECUS MOTTLING AND MEDIUM DENSE

BROWN FINE SANDY SILT WITH TRACE CLAY – STIFF

TEST PIT COMPLETED AT 12,0 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-38



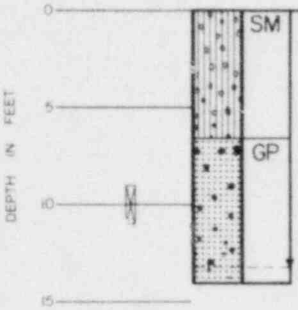
GRAY SHALE SHATTERED, HIGHLY WEATHERED – SOFT

GRADING CLOSELY JOINTED, SLIGHTLY TO MODERATELY WEATHERED – MODERATELY HARD

TEST PIT COMPLETED AT 13,0 FEET ON 3 – 24 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-39



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

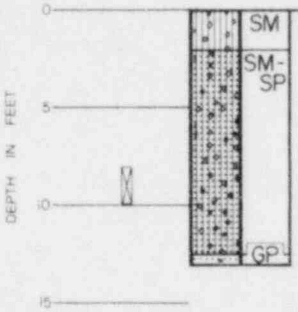
GRADING SILTY FINE TO MEDIUM SAND – DENSE

BROWN SANDY FINE AND COARSE GRAVEL WITH TRACE SILT – DENSE

WATER LEVEL AT 13,25 FEET

TEST PIT COMPLETED AT 14,0 FEET ON 3 – 25 – 80

TEST PIT P-40



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

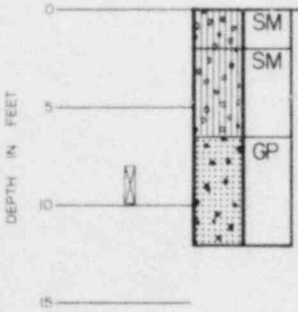
BROWN FINE SAND WITH SOME SILT – MEDIUM DENSE

BROWN SANDY FINE AND COARSE GRAVEL WITH TRACE SILT – DENSE

TEST PIT COMPLETED AT 13,0 FEET ON 3 – 25 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-41



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

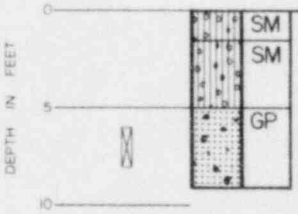
BROWN SILTY FINE TO COARSE SAND WITH SOME GRAVEL – CARBONACEOUS DENSE

BROWN SANDY FINE AND COARSE GRAVEL, COBBLES AND BOULDERS WITH TRACE SILT – VERY DENSE

TEST PIT COMPLETED AT 12,0 FEET ON 3 – 25 – 80

GROUND WATER WAS NOT ENCOUNTERED

TEST PIT P-42



BROWN SILTY FINE SAND WITH ROOTS – LOOSE

LIGHT BROWN TO TAN SILTY FINE TO COARSE SAND WITH TRACE FINE GRAVEL – CARBONACEOUS – DENSE

LIGHT BROWN SANDY FINE AND COARSE GRAVEL, COBBLES AND BOULDERS WITH TRACE SILT – VERY DENSE

TEST PIT COMPLETED AT 9,0 FEET ON 3 – 25 – 80

GROUND WATER WAS NOT ENCOUNTERED

LOG OF TEST PITS

DAMES & MOORE

PLATE C-5E

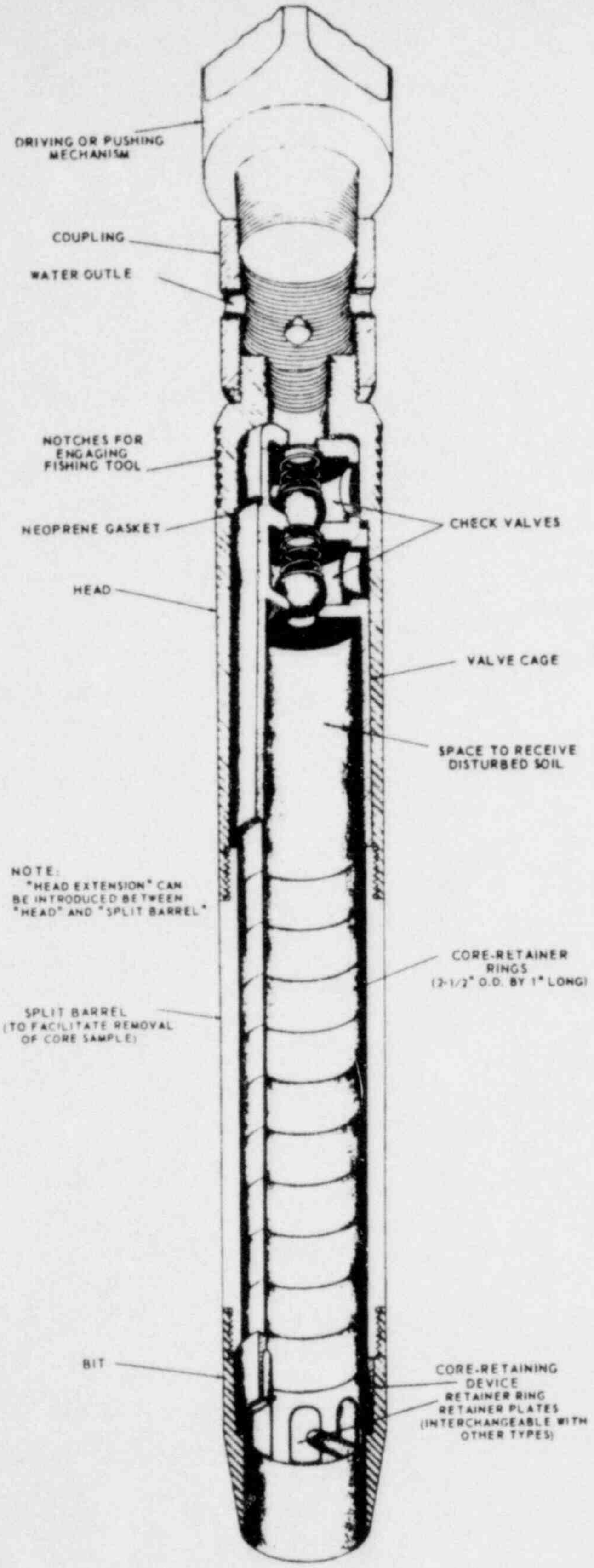
FILE [illegible]
[illegible]
BY ____ DATE ____
CHECKED BY ____ DATE ____

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

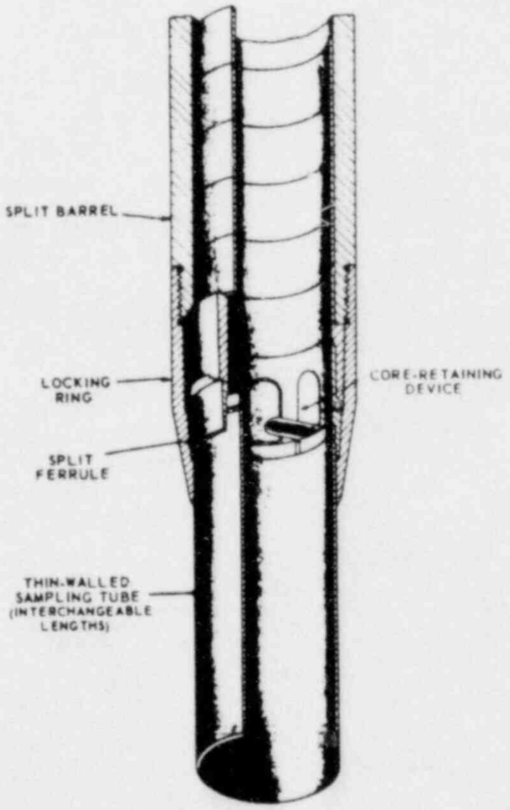
REVISED 11-13-73 SLC

BY ____ DATF ____ REVISIONS

CHECKED ____ BY ____ FILE ____ BY ____ DATE ____



ALTERNATE ATTACHMENTS



SOIL SAMPLER TYPE U

DAMES & MOORE

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

PLATE C-6

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	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
		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 MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SAND (LITTLE OR NO FINES)	▨	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
			▨	SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)	▨	SM	SILTY SANDS, SAND-SILT MIXTURES
			▨	SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	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
	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

ROCK QUALITY

Description Of Rock Quality	RQD* (Rock Quality Designation) (Percent)
Very Poor	0 to 25
Poor	25 to 50
Fair	50 to 75
Good	75 to 90
Excellent	90 to 100

JOINT SPACING

Joint Description	Spacing - Inches
Fissured	<0.24
Shattered	0.24 to 0.8
Very Close	0.8 to 2.4
Close	2.4 to 8.0
Moderate	8.0 to 24.0
Wide	24.0 to 80.0
Very Wide	>80.0

ROCK HARDNESS

Soft -	Can be gouged deeply or carved with a pocket knife.
Moderately Hard -	Can be readily scratched with knife blade. Scratch leaves heavy trace of dust and is readily visible after the powder has been blown away.
Hard -	Can be scratched with difficulty; scratch produced little powder and is often faintly visible.
Very Hard -	Cannot be scratched with pocket knife.

WEATHERING

Fresh -	Rock fresh, crystals bright, few joints may show slight staining. Rock rings under hammer if crystalline.
Very Slight -	Rock generally fresh, joints stained, some joints may show thin clay coatings, crystals in broken face show bright. Rock rings under hammer if crystalline.
Slight -	Rock generally fresh, joints stained, and discoloration extends into rock up to one inch. Joints may contain clay. In granitoid rocks some occasional feldspar crystals are dull and discolored. Crystalline rocks ring under hammer.
Moderate -	Significant portions of rock show discoloration and weathering effects. In granitoid rocks, most feldspars are dull and discolored; some show clayey. Rock has dull sound under hammer and shows significant loss of strength as compared with fresh rock.
Moderately Severe -	All rock except quartz discolored or stained. In granitoid rocks, all feldspars dull and discolored and majority show kaolinization. Rock shows severe loss of strength and can be excavated with geologist's pick. Rock goes "clunk" when struck.
Severe -	All rock except quartz discolored or stained. Rock "fabric" clear and evident, but reduced in strength to strong soil. In granitoid rocks, all feldspars kaolinized to some extent. Some fragments of strong rock usually left.
Very Severe -	All rock except quartz discolored or stained. Rock "fabric" discernible, but mass effectively reduced to "soil" with only fragments of strong rock remaining.
Complete -	Rock reduced to "soil." Rock "fabric" not discernible or discernible only in small scattered locations. Quartz may be present as dikes or stringers.

---

* RQD - The percentage of a core run with an unfractured length of four inches or more.

GEOTECHNICAL TERMINOLOGY FOR ROCK DESCRIPTION

DAMES & MOORE

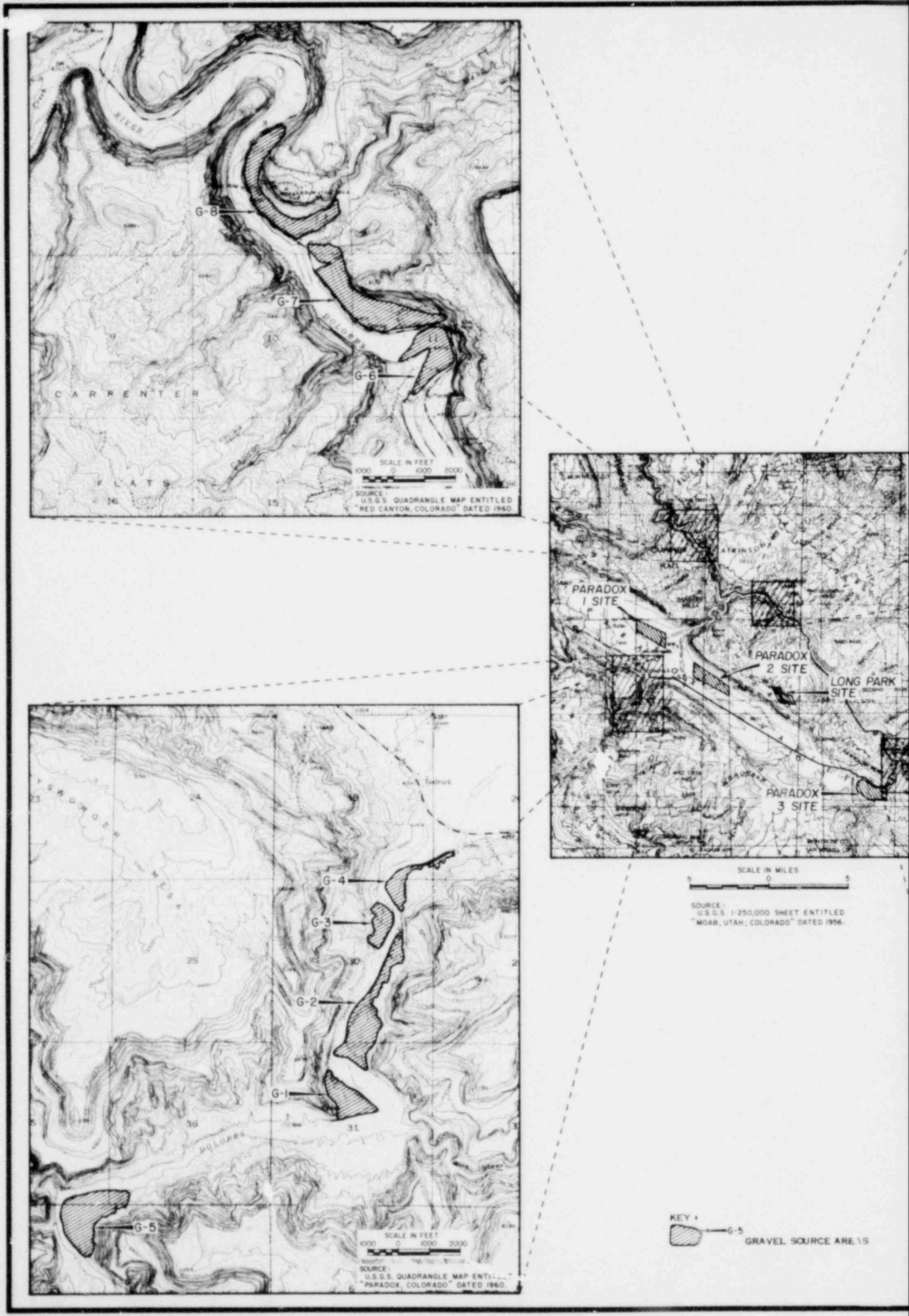
REVISIONS BY ______ DATE ______

BY ______ DATE ______ CHECKED BY ______ DATE 5-23-77 FILE SL OF[illegible] 5-78

946.7 (REV. 6-61)

PLATE C-8

JOB NUMBER ______ DRAWN BY ______ DATE ______

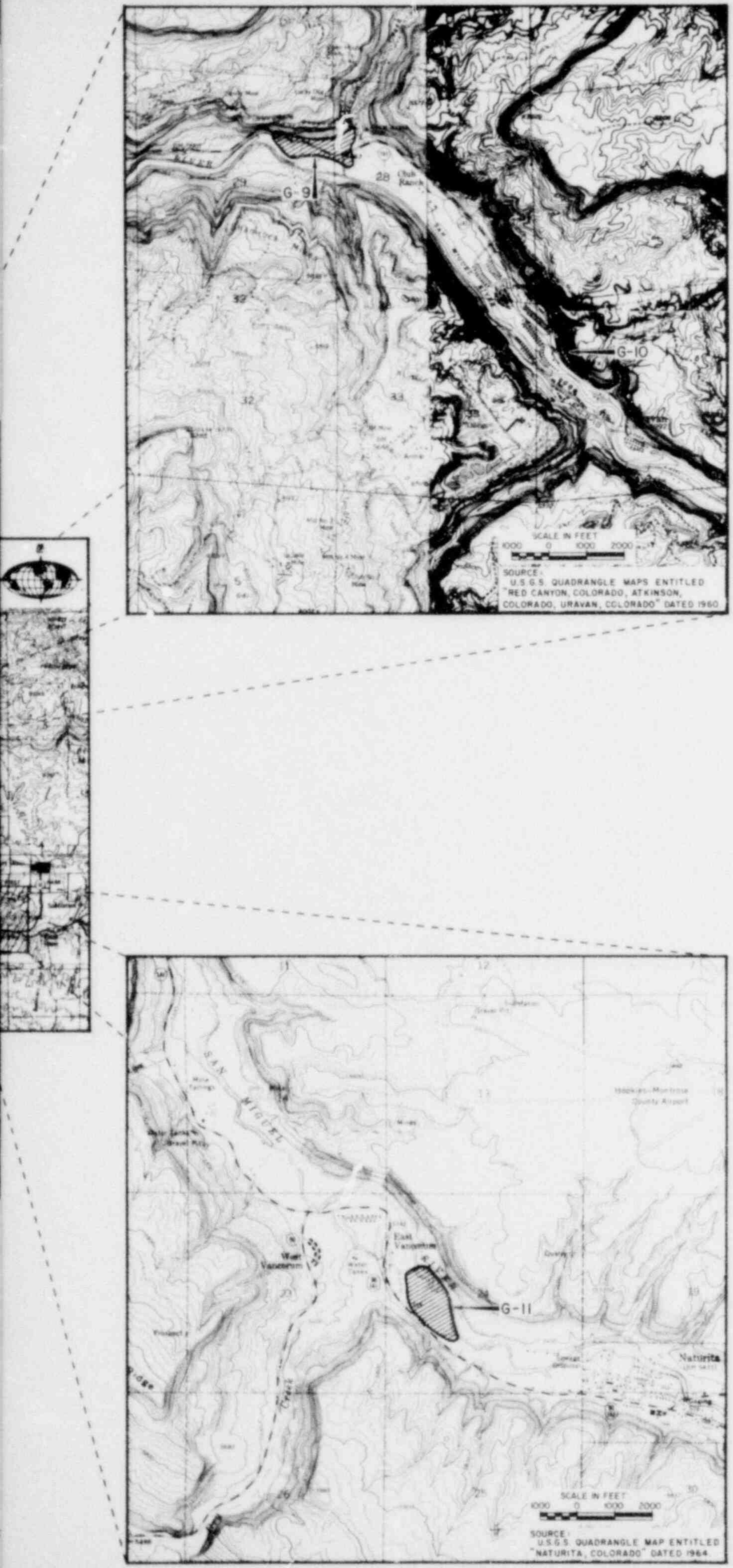


SOURCE:
U.S.G.S. QUADRANGLE MAP ENTITLED "RED CANYON, COLORADO" DATED 1960.

SOURCE:
U.S.G.S. 1:250,000 SHEET ENTITLED "MOAB, UTAH; COLORADO" DATED 1956.

SOURCE:
U.S.G.S. QUADRANGLE MAP ENTITLED "PARADOX, COLORADO" DATED 1960.

456.11 (10-79)



SOURCE:
U.S.G.S. QUADRANGLE MAPS ENTITLED "RED CANYON, COLORADO, ATKINSON, COLORADO, URAVAN, COLORADO" DATED 1960.

SOURCE:
U.S.G.S. QUADRANGLE MAP ENTITLED "NATURITA, COLORADO" DATED 1964.

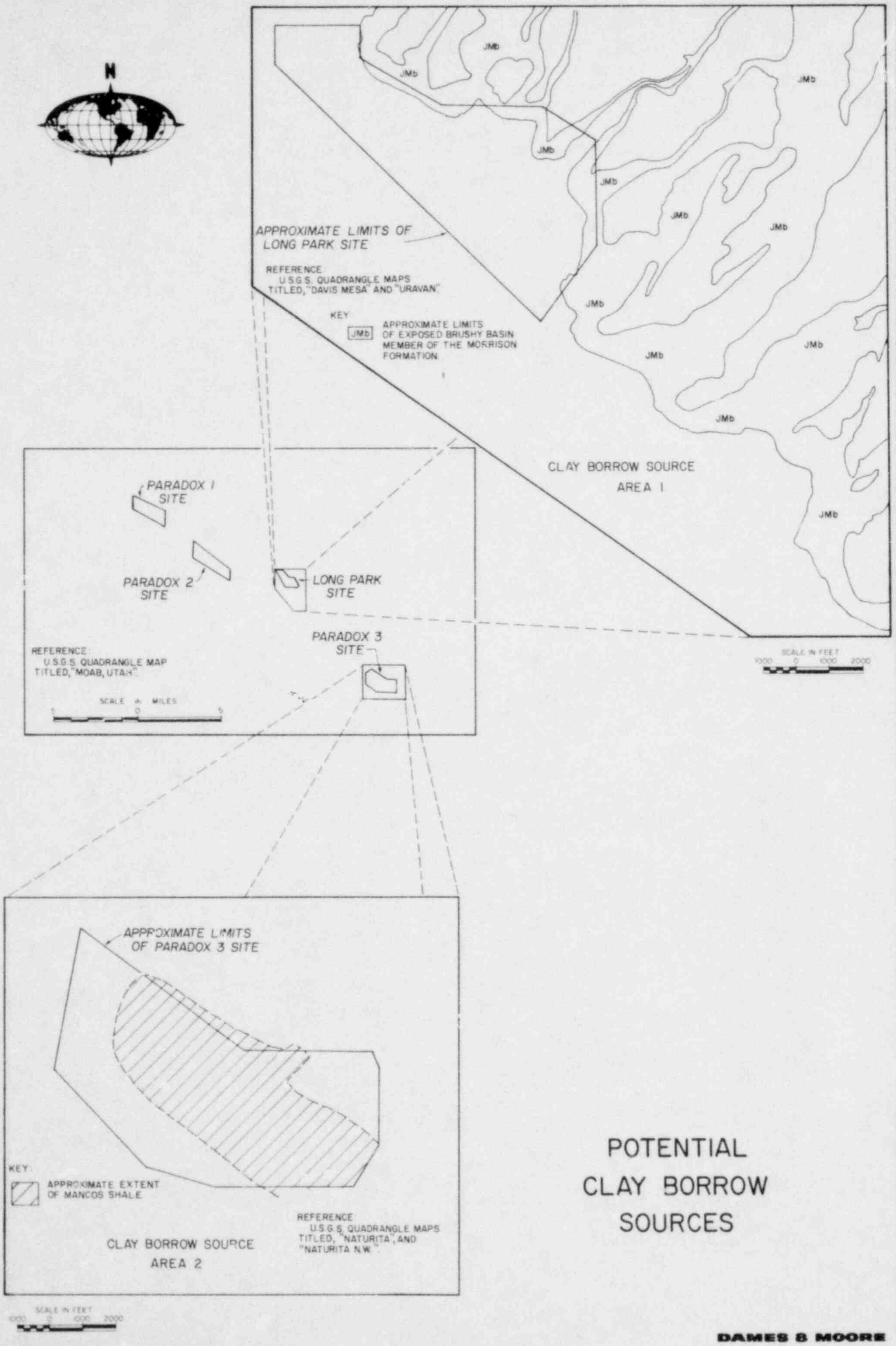
POTENTIAL GRAVEL SOURCES
FOR RIPRAP AND ROADWAY BASE COURSE

DAMES & MOORE

PLATE C-9

FILE
BY DATE
CHECKED BY DATE

REVISIONS
BY DATE
BY DATE
PLATE OF



POTENTIAL
CLAY BORROW
SOURCES

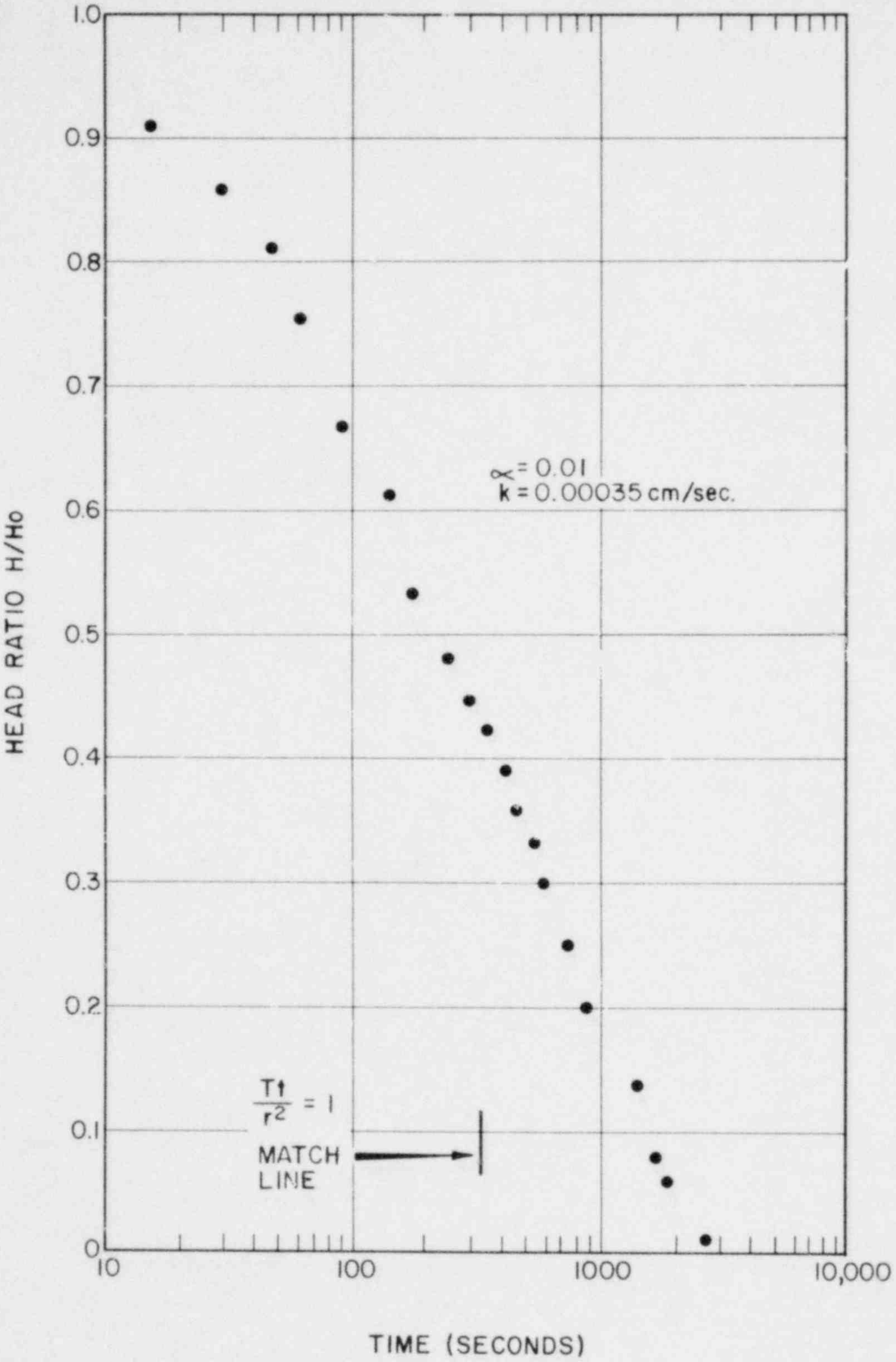
DAMES & MOORE

PLATE C-10

REVISIONS
BY ______ DATE ______

FILE ______

BY ______ DATE ______
CHECKED BY ______



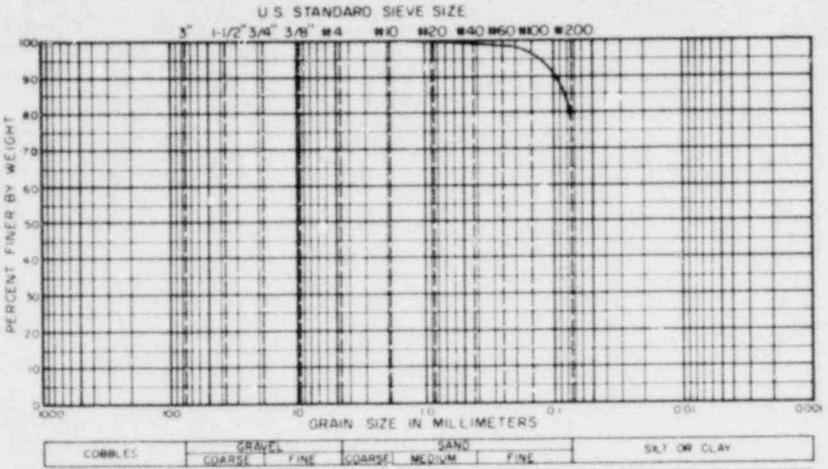
SLUG TEST DATA
PIEZOMETER P-38

REFERENCE
PLATE 2, U.S.G.S. PROFESSIONAL PAPER 708
LOHMAN (1972).

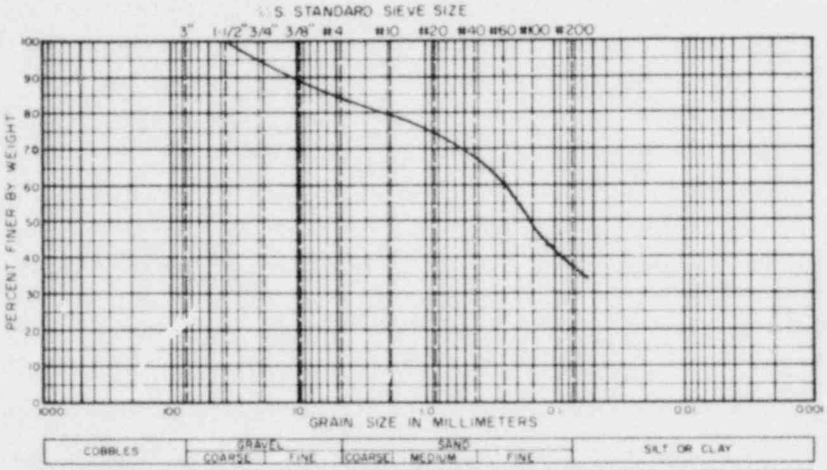
DAMES & MOORE

PLATE C-11

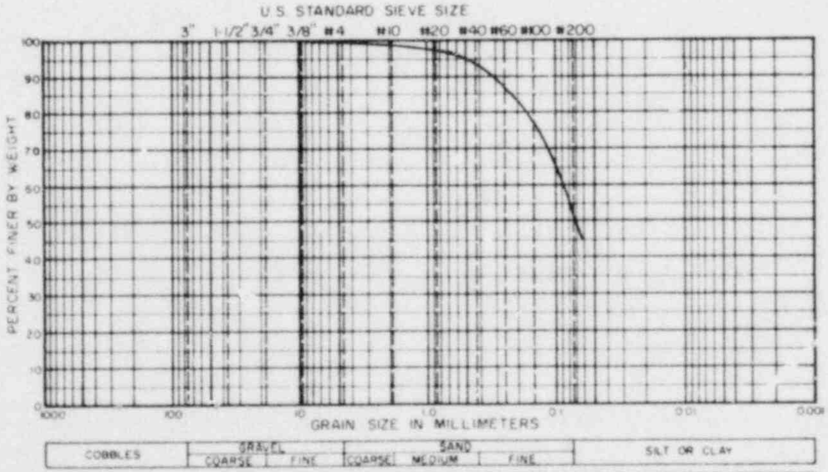
946.7 (REV. 6-61)



LOCATION	DEPTH	CLASSIFICATION
BORING LP-1	5.5 FT.	REDDISH-BROWN FINE TO MEDIUM SANDY SILT (ML)



LOCATION	DEPTH	CLASSIFICATION
TEST PIT LP-2	6.0 FT. TO 6.5 FT.	BROWN SILTY FINE TO COARSE SAND WITH SOME FINE AND COARSE GRAVEL (SM)



LOCATION	DEPTH	CLASSIFICATION
TEST PIT LP-4	5.0 FT. TO 6.0 FT.	REDDISH-BROWN SILT AND FINE SAND (ML-SM)

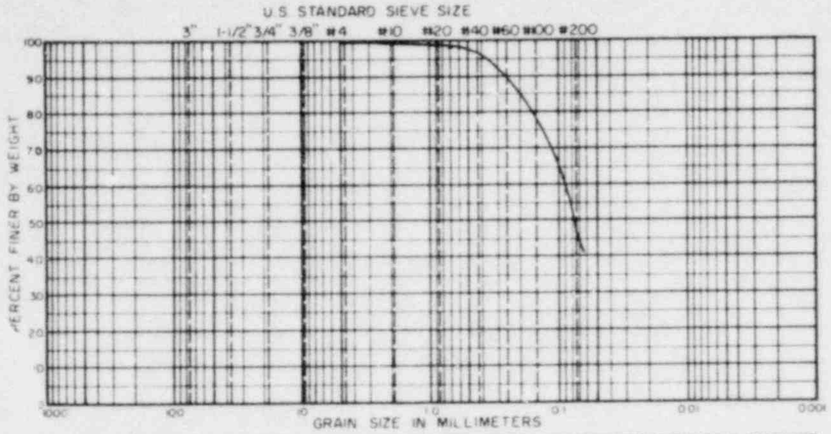
GRADATION CURVES

Union Carbide - Uravan
BY [illegible] DATE 9-11-80
CHECKED BY [illegible] DATE [illegible]

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

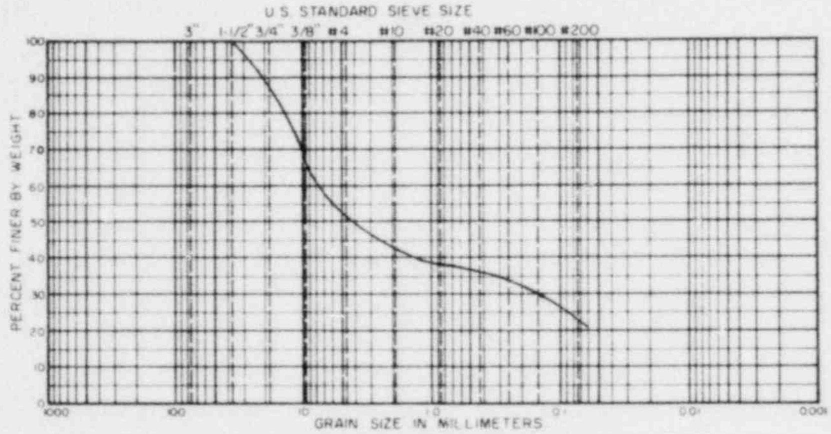
DAMES & MOORE

PLATE C-12A



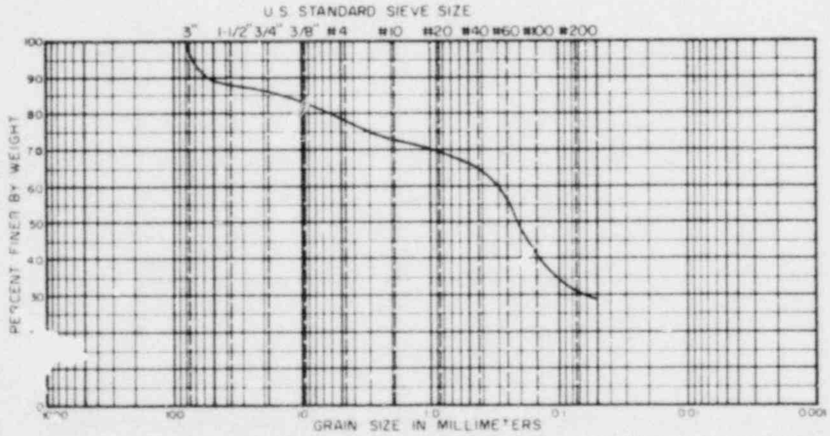
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
TEST PIT LP-9	9.0 FT. TO 10.0 FT.	REDDISH-BROWN FINE SAND AND SILT (SM)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
BORING P-24	10.0 FEET	BROWN SILTY FINE TO COARSE SAND WITH SOME FINE AND COARSE GRAVEL (SM)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
TEST PIT P-3?	6.0 FT. TO 8.0 FT.	LIGHT BROWN SILTY FINE TO COARSE SAND WITH SOME FINE AND COARSE GRAVEL (SM)

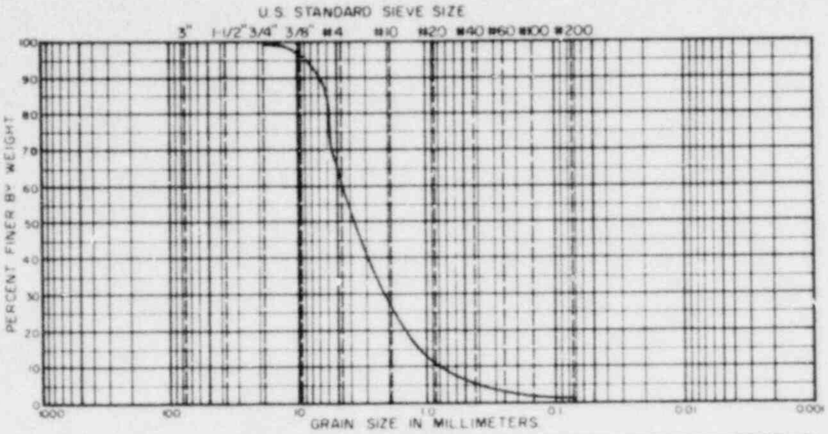
GRADATION CURVES

DAMES & MOORE

PLATE C-12B

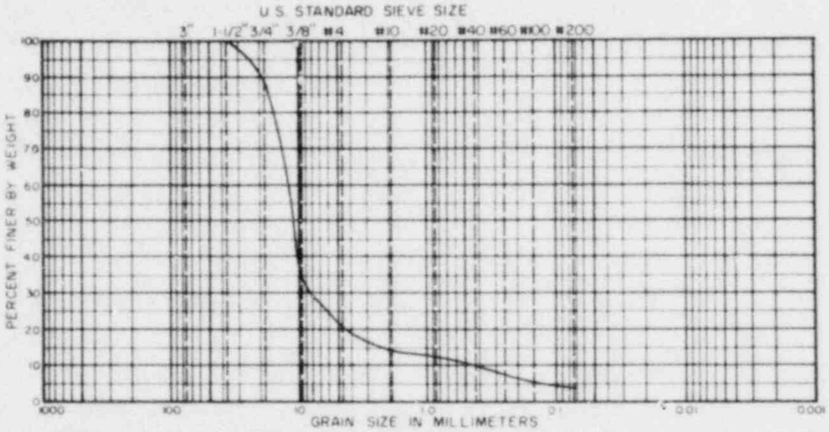
BY ______ DATE ______
CHECKED BY ______ DATE ______

BY ______ DATE ______
BY ______ DATE ______
PLATE ______ OF ______



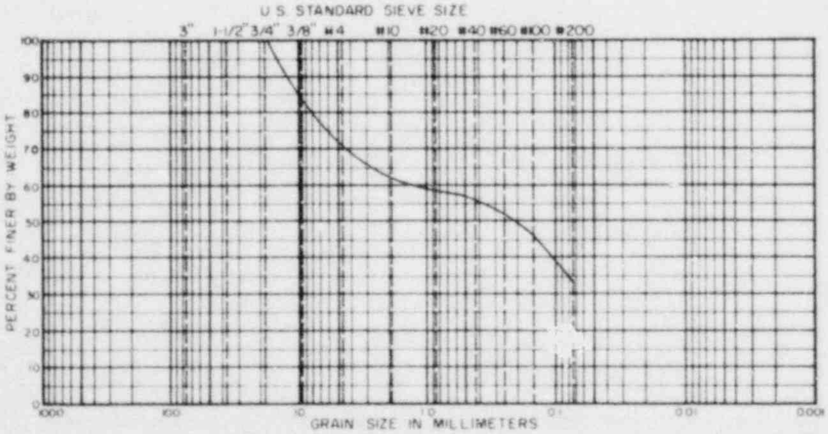
COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
BULK B-3 LONG PARK		GREENISH-GRAY WEATHERED SILTSTONE (SP)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
SOUTHWESTERN READY-MIX BULK		BROWN SANDY FINE AND COARSE GRAVEL WITH TRACE SILT (GP)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
TEST PIT P-22	4.0 FT.	BROWN SILTY FINE TO COARSE SAND WITH SOME FINE GRAVEL (SM)

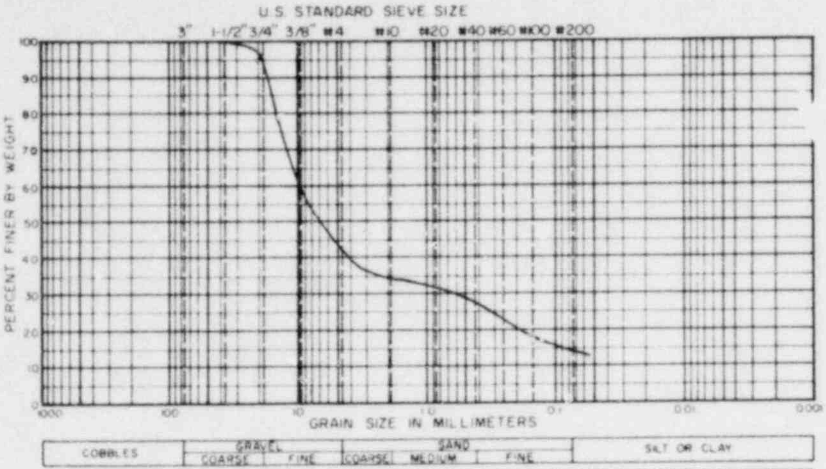
GRADATION CURVES

FILE [illegible]
UNION CARBIDE - URAVAN
BY H.J.T. DATE 4-11-80
CHECKED BY ______ DATE ______

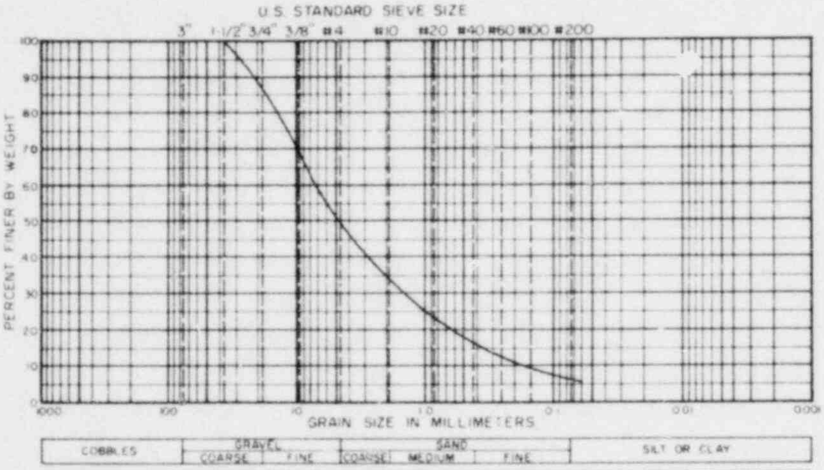
REVISIONS
BY ______ DATE ______
BY ______ DATE ______
PLATE ______ OF ______

DAMES & MOORE

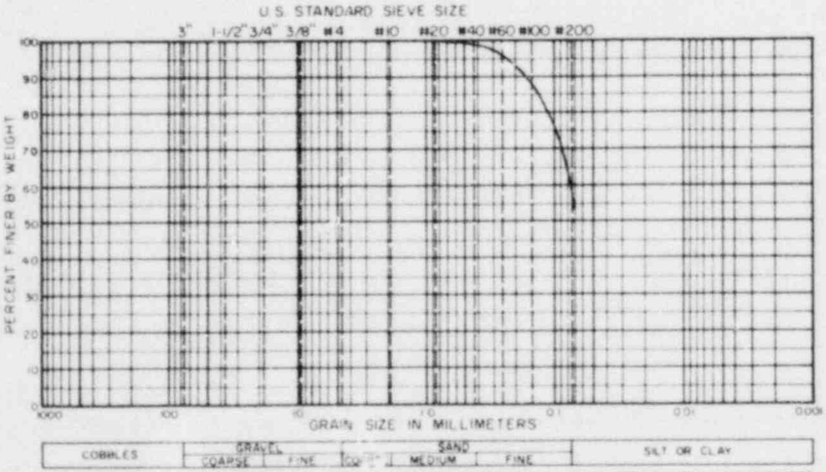
PLATE C-12C



LOCATION	DEPTH	CLASSIFICATION
BORING P-32	10.0 FT.	BROWN SILTY FINE TO COARSE SAND AND GRAVEL (GM-SM)



LOCATION	DEPTH	CLASSIFICATION
BORING P-34	16.5 FT.	BROWN SANDY FINE AND COARSE GRAVEL WITH TRACE SILT (GM-GP)



LOCATION	DEPTH	CLASSIFICATION
TEST PIT P-36	6.0 FT. TO 8.0 FT.	BROWN SILT AND FINE SAND (ML-SM)

GRADATION CURVES

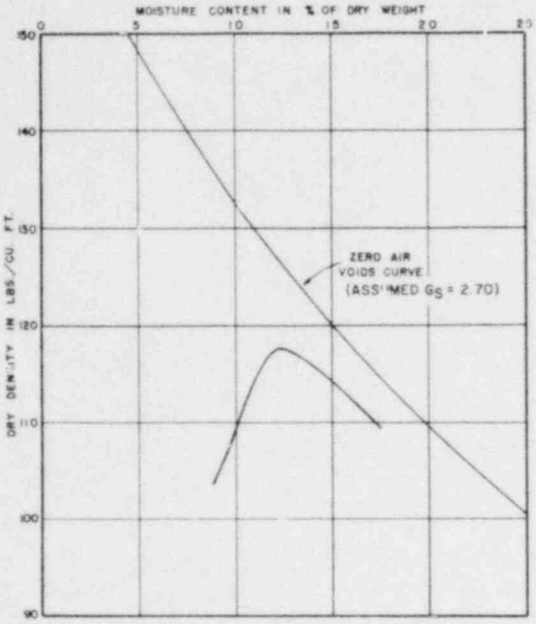
DAMES & MOORE

PLATE C-12D

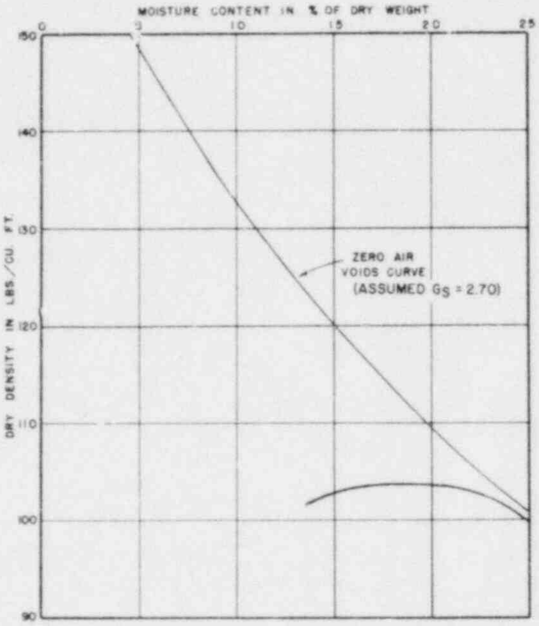
REVISIONS
BY ____ DATE ____
BY ____ DATE ____
PLATE ____ OF ____

[illegible]
BY [illegible] DATE [illegible]
CHECKED BY ____ DATE ____

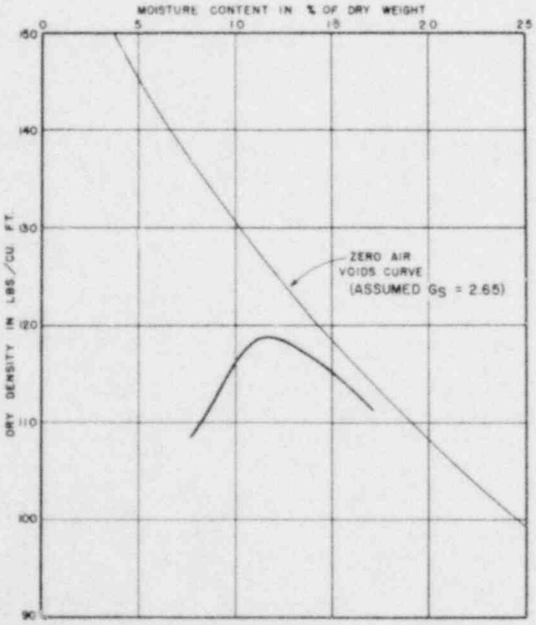
SAMPLE NO. 1 DEPTH 5' – 6'
SOIL REDDISH-BROWN FINE SANDY **SILT** WITH SOME CLAY (ML)
LOCATION TEST PIT LP-4
OPTIMUM MOISTURE CONTENT 12.0 PERCENT
MAXIMUM DRY DENSITY 117.2 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



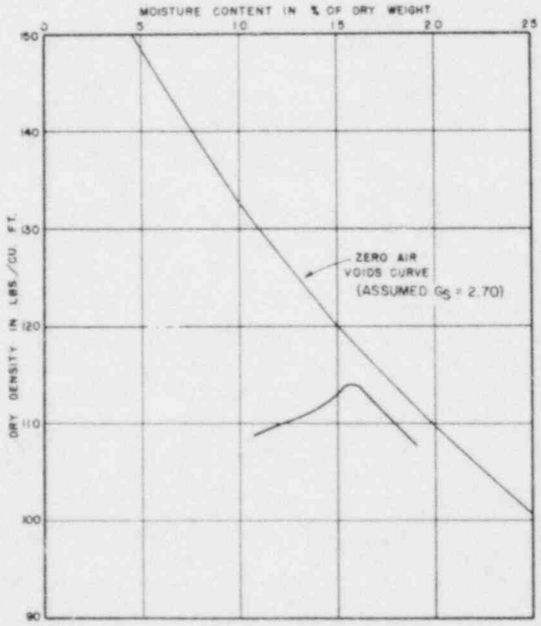
SAMPLE NO. 1 DEPTH 6' – 11'
SOIL LIGHT GREEN SILTY CLAY (CH)
LOCATION TEST PIT LP-3
OPTIMUM MOISTURE CONTENT 19.0 PERCENT
MAXIMUM DRY DENSITY 104.0 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM-D-698-70, METHOD C



SAMPLE NO. 2 DEPTH 9' – 10'
SOIL REDDISH-BROWN SILTY CLAYEY FINE SAND (SM-SC)
LOCATION TEST PIT LP-8
OPTIMUM MOISTURE CONTENT 12.0 PERCENT
MAXIMUM DRY DENSITY 118.5 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



SAMPLE NO. 2 DEPTH 4.5' – 5.5'
SOIL MOTTLED GREENISH-GRAY WEATHERED CLAYSTONE (CL)
LOCATION TEST PIT LP-11
OPTIMUM MOISTURE CONTENT 15.9 PERCENT
MAXIMUM DRY DENSITY 114.2 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



COMPACTION TEST DATA

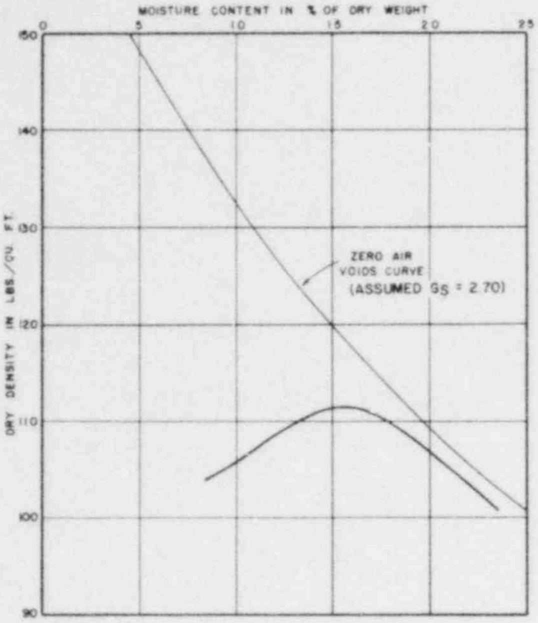
DAMES & MOORE

PLATE C-13A

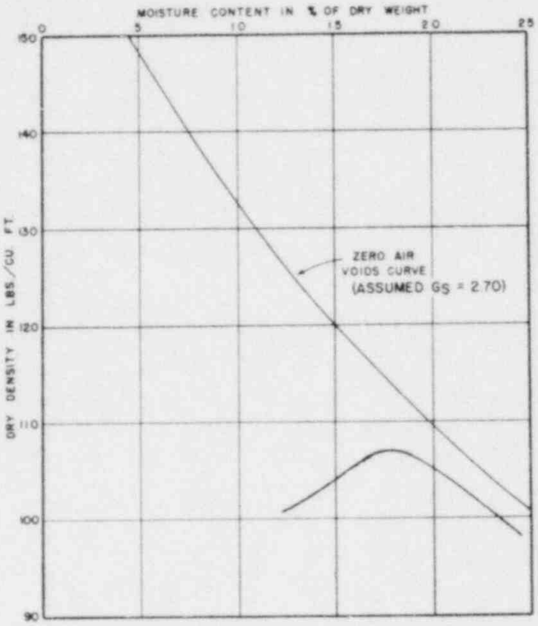
REVISIONS
BY ____ DATE ____
BY ____ DATE ____
PLATE ____ OF ____

FILE 05822-132
[illegible]
BY [illegible] DATE [illegible]
CHECKED BY ____ DATE ____

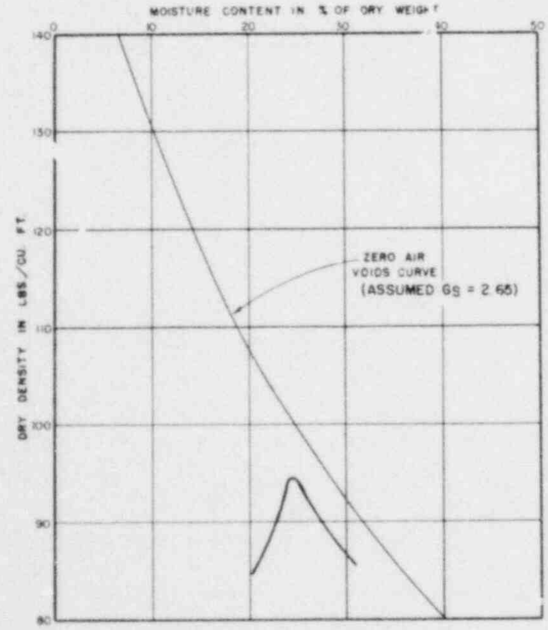
SAMPLE NO. DEPTH
SOIL GREENISH-GRAY WEATHERED SILTSTONE (SP)
LOCATION BULK B-3 LONG PARK
OPTIMUM MOISTURE CONTENT 15.6 PERCENT
MAXIMUM DRY DENSITY 111.2 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM-D-698-70, METHOD C



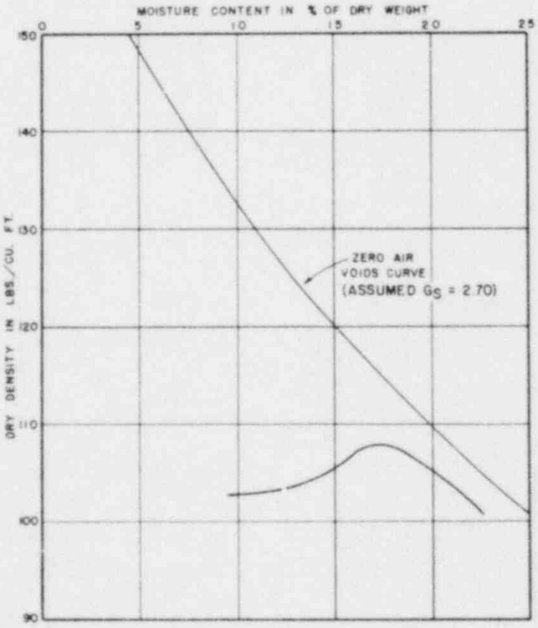
BULK
SAMPLE NO. P-1 DEPTH 1'-2'
SOIL REDDISH-BROWN SILTY CLAY (CL)
LOCATION ROAD SUBGRADE PARADOX 2
OPTIMUM MOISTURE CONTENT 18.1 PERCENT
MAXIMUM DRY DENSITY 107.0 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD A



BULK
SAMPLE NO. P-2 DEPTH 1'-2'
SOIL REDDISH-BROWN SANDY CLAY (CL)
LOCATION ROAD SUBGRADE PARADOX 2
OPTIMUM MOISTURE CONTENT 24.7 PERCENT
MAXIMUM DRY DENSITY 94.5 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



SAMPLE NO. 1 DEPTH
SOIL GREENISH-GRAY WEATHERED SHALE (CH)
LOCATION BULK B-1 LONG PARK
OPTIMUM MOISTURE CONTENT 17.5 PERCENT
MAXIMUM DRY DENSITY 108.2 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM-D-698-70, METHOD C



COMPACTION TEST DATA

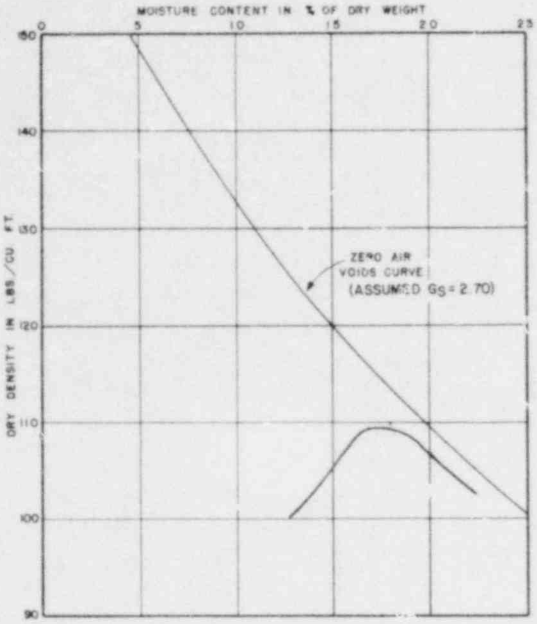
DAMES & MOORE

REVISIONS
BY DATE
BY DATE
PLATE OF

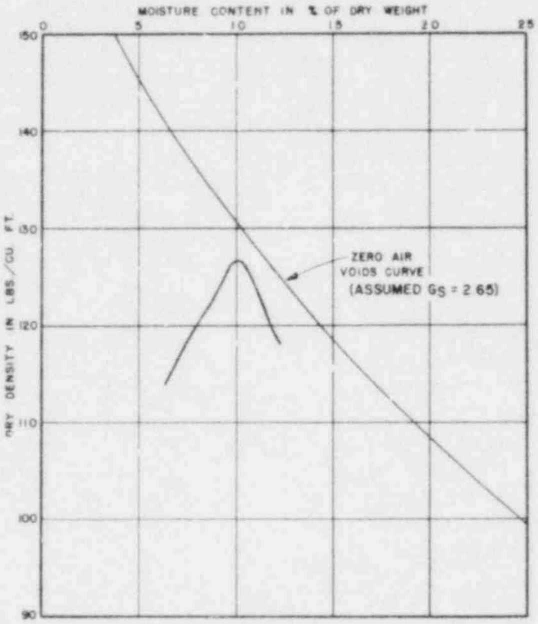
FILE 00882-138
Union Carbide - Uranium
BY H.A.T. DATE 3-6-80
CHECKED BY DATE

PLATE C-13B

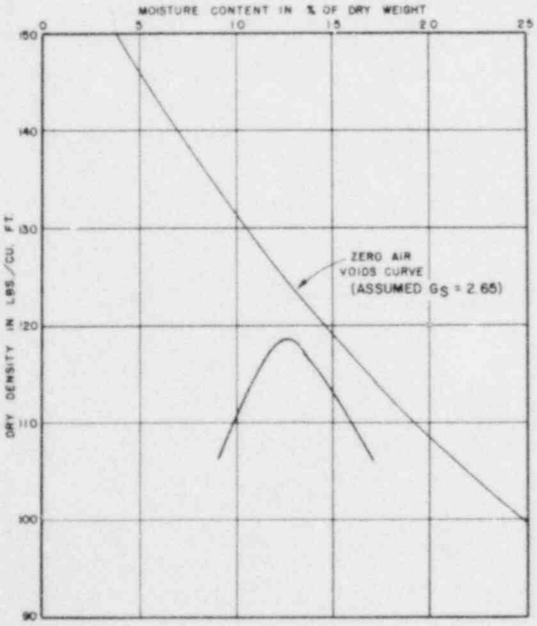
SAMPLE NO. 1 DEPTH 5' - 7'
SOIL LIGHT GRAY WEATHERED SHALE (CL)
LOCATION TEST PIT P-31
OPTIMUM MOISTURE CONTENT 17.5 PERCENT
MAXIMUM DRY DENSITY 109.5 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



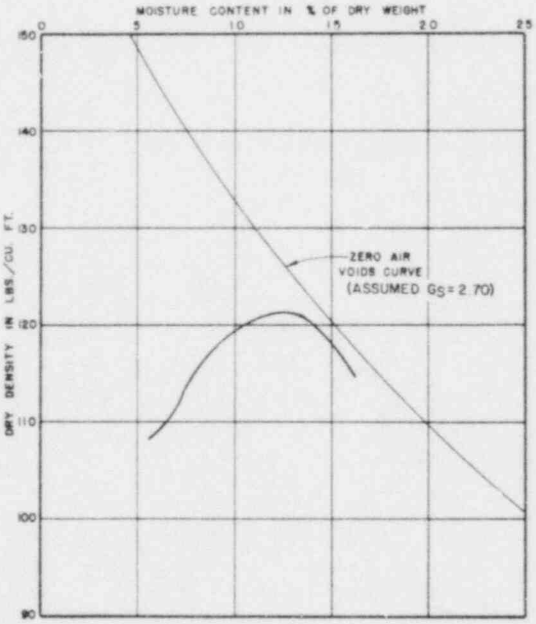
SAMPLE NO. 1 DEPTH 6' - 8'
SOIL LIGHT BROWN SILTY FINE TO COARSE SAND WITH SOME FINE AND COARSE GRAVEL (SM)
LOCATION TEST PIT P-32
OPTIMUM MOISTURE CONTENT 10.3 PERCENT
MAXIMUM DRY DENSITY 126.8 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



SAMPLE NO. 1 DEPTH 6'-8'
SOIL BROWN SILT AND FINE SAND (ML-SM)
LOCATION TEST PIT P-36
OPTIMUM MOISTURE CONTENT 12.7 PERCENT
MAXIMUM DRY DENSITY 118.5 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



SAMPLE NO. 1 DEPTH 7' - 9' ELEVATION
SOIL GRAY WEATHERED SHALE
LOCATION TEST PIT P - 38
OPTIMUM MOISTURE CONTENT 12.9 PERCENT
MAXIMUM DRY DENSITY 121.0 LBS. PER CUBIC FOOT
METHOD OF COMPACTION ASTM D-698-70, METHOD C



COMPACTION TEST DATA

DAMES & MOORE

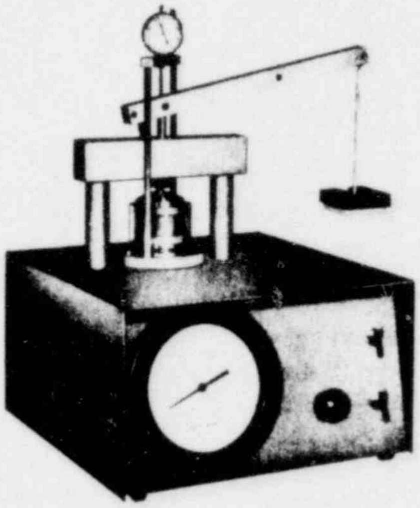
FILE 00822-132
UNION CARBIDE-URAVAN
BY H.E.F. DATE 4-10-80
CHECKED BY DATE

REVISIONS
BY DATE
BY DATE
PLATE OF

PLATE C-13C

CONSOLIDATION TESTS ARE PERFORMED TO EVALUATE THE VOLUME CHANGES OF SOILS SUBJECTED TO INCREASED LOADS. TIME-CONSOLIDATION AND PRESSURE-CONSOLIDATION CURVES MAY BE PLOTTED FROM THE DATA OBTAINED IN THE TESTS. ENGINEERING ANALYSES BASED ON THESE CURVES PERMIT ESTIMATES TO BE MADE OF THE PROBABLE MAGNITUDE AND RATE OF SETTLEMENT OF THE TESTED SOILS UNDER APPLIED LOADS.

EACH SAMPLE IS TESTED WITHIN 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.



DEAD LOAD-PNEUMATIC
CONSOLIDOMETER

IN TESTING, THE SAMPLE IS RIGIDLY CONFINED LATERALLY BY THE BRASS RING. AXIAL LOADS ARE TRANSMITTED TO THE ENDS OF THE SAMPLE BY POROUS DISKS. THE DISKS ALLOW DRAINAGE OF THE LOADED SAMPLE. THE AXIAL COMPRESSION OR EXPANSION OF THE SAMPLE IS MEASURED BY A MICROMETER DIAL INDICATOR AT APPROPRIATE TIME INTERVALS AFTER EACH LOAD INCREMENT IS APPLIED. EACH LOAD IS ORDINARILY TWICE THE PRECEDING LOAD. THE INCREMENTS ARE SELECTED TO OBTAIN CONSOLIDATION DATA REPRESENTING THE FIELD LOADING CONDITIONS FOR WHICH THE TEST IS BEING PERFORMED. EACH LOAD INCREMENT IS ALLOWED TO ACT OVER AN INTERVAL OF TIME DEPENDENT ON THE TYPE AND EXTENT OF THE SOIL IN THE FIELD.

METHOD OF PERFORMING CONSOLIDATION TESTS

DAMES & MOORE

PLATE C-14

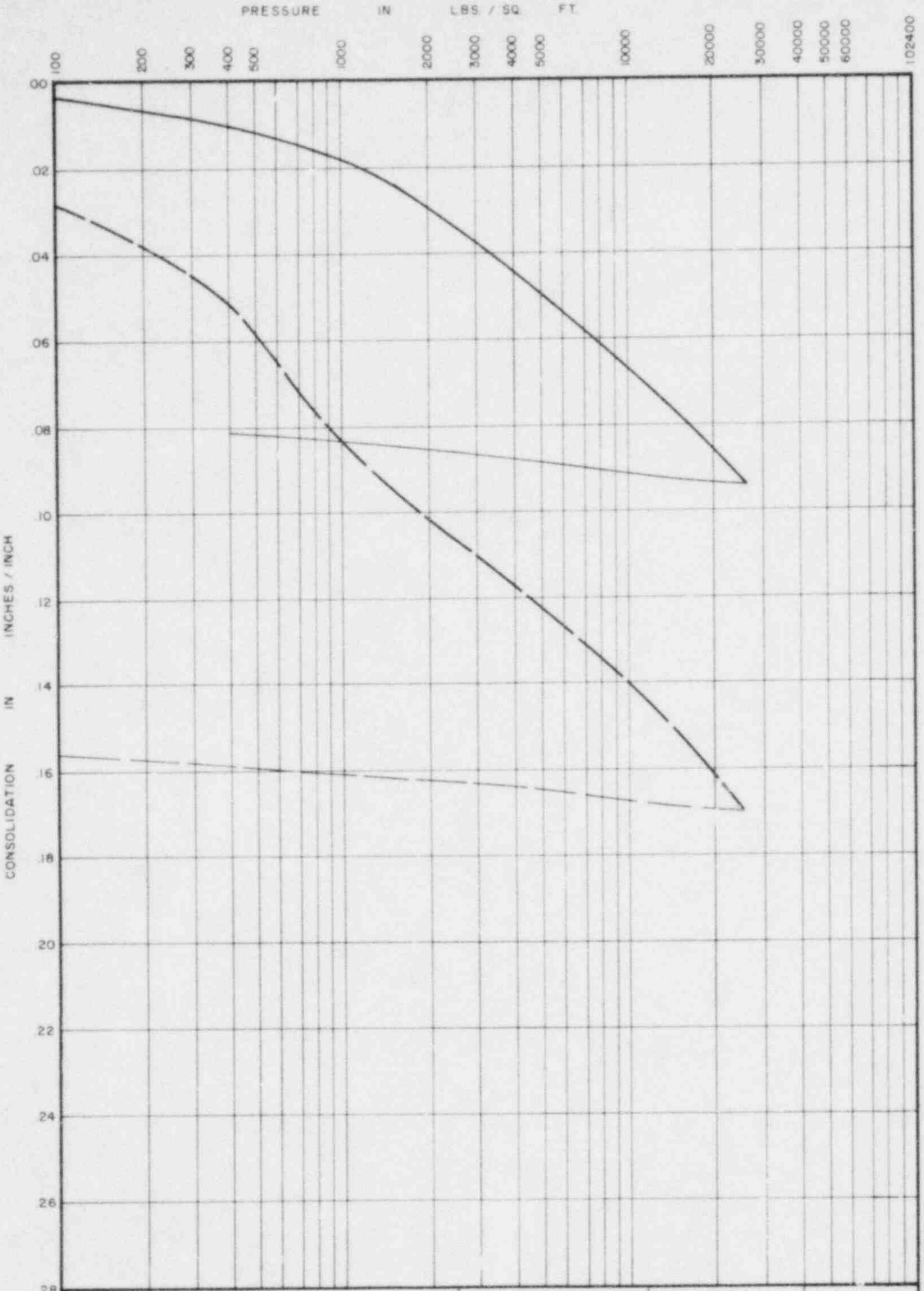
REVISIONS
BY ______ DATE ______

BY ______ DATE ______ FILE ______
CHECKED BY ______

REVISED 11-13-73 SLC

REVISIONS
BY ______ DATE ______
BY ______ DATE ______
PLATE ______ OF ______

FILE 08880-138
UNION CARBIDE URAVAN
BY [illegible] DATE 4-8-80
CHECKED BY ______ DATE ______



BORING		SOIL TYPE	MOISTURE CONTENT IN PERCENT		DRY DENSITY IN LBS / CU. FT.	SYMBOL
NO.	DEPTH		BEFORE	AFTER		
		MILL TAILINGS	23.5	20.6	95.5	———
		MILL TAILINGS	35.3	22.2	84.6	— — —

CONSOLIDATION TEST DATA

DAMES & MOORE

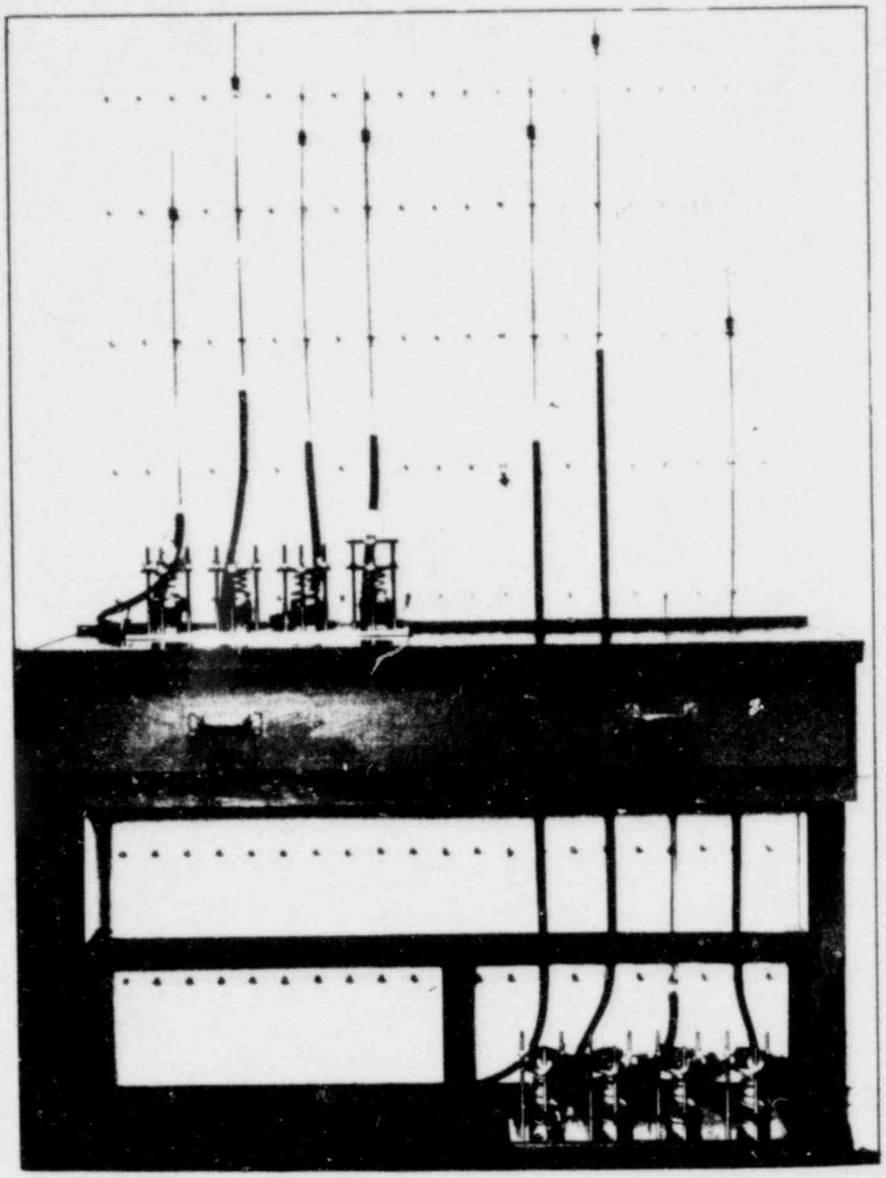
PLATE C-15

REVISIONS BY ______ DATE ______

FILE ______

BY ______ CHECKED BY ______ DATE ______

REVISED 11-13-73 S L C



APPARATUS FOR PERFORMING PERCOLATIONS TESTS

Shows tests in progress on eight samples simultaneously.

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.

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.

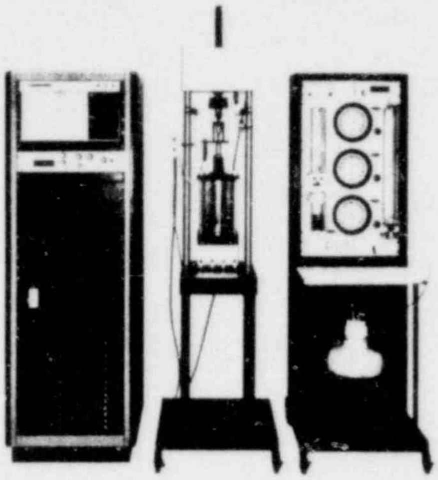
During the performance of the test, continuous readings of the deflection of the sample are taken by means of micrometer dial gauges. The amount of compression or expansion, expressed as a percentage of the original length of the sample, is a valuable indication of the compression of the soil which will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

METHOD OF PERFORMING PERCOLATION TESTS

DAMES & MOORE

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

REVISIONS
BY ______ DATE ______
FILE ______
BY ______ DATE ______
CHECKED BY ______

946.7 (REV. 6-61)

APPENDIX D

TABLE OF CONTENTS

APPENDIX D

LIST OF TABLES

APPENDIX D

GROUND WATER HYDROLOGY AND SEEPAGE ANALYSIS

GENERAL

The purpose of this appendix is to describe in more detail qualitative and quantitative aspects of the existing site specific ground water hydrology and to evaluate proposed seepage control measures for the options investigated in this report. Regional aspects of the geology and ground water hydrology are presented in the Environmental Report (Dames & Moore, 1978). Results of field and laboratory permeability tests are presented in Appendix C. Factors considered in the discussion include geology, field and laboratory testing results, liquor chemical characteristics, clay and synthetic lining materials, and expected long-term impacts of the seepage.

HYDROGEOLOGIC SETTING

Detailed descriptions of the geology are presented in Appendices A and B of this report. Detailed presentations of laboratory and field permeability data are presented in Appendix C. A brief summary is presented herein.

Gently dipping rock strata, principally Mesozoic sandstone, shale and siltstone, have been deeply incised by streams. The collapse and erosion of the crestal parts of salt anticlines have formed valleys where Paleozoic rock, including evaporites, are exposed, such as the Paradox Valley. Thin alluvial deposits occur in the valleys and canyons.

LONG PARK

Silty fine sand colluvium approximately 5 feet to 20 feet thick overlies the Brushy Basin and Salt Wash Members of the Morrison Formation. These rock strata consist of variegated siltstone, sandstone and claystone. Beds dip gently to the northeast at 5 to 10 degrees.

Laboratory and field permeability tests were performed to estimate hydraulic characteristics of the geologic materials at the Long Park site. Samples of undisturbed and recompacted colluvium displayed a permeability range of 5.3×10^{-5} to 3.4×10^{-4} cm/sec and average 1.4×10^{-4} cm/sec. Field permeability tests were performed in sandstone, siltstone and claystone beds of the Morrison Formation. Permeability values obtained were essentially independent of rock type and depended primarily on the degree of fracturing and jointing. A horizontal permeability range of 2.0×10^{-4} to 2.68×10^{-3} cm/sec was displayed with an average of 1.89×10^{-3} cm/sec for rock strata tested at the Long Park site.

PARADOX 1 AND 2

At the Paradox 1 and 2 sites colluvium varying from silty clay to sandy gravel with boulders, and ranging from less than 3 feet thick to over 45 feet in thickness, overlies complexly deformed and faulted Paleozoic sandstones, limestones, and gypsum. The structural features and faulting are related to the formation of the salt anticline.

No permeability tests were perfomed on samples of colluvium obtained from the Paradox 2 site. Based on field textural classifications, the permeability of colluvium at the Paradox 2 site is probably slightly higher than values obtained at the Long Park site. Field permeability tests were performed on gypsum and sandstone units in the Hermosa Formation. An average permeability of 1.99 x 10-3 cm/sec based on two tests was obtained for the gypsum. The high permeability of the gypsum is partially attributed to the presence of solution cavities. One test performed in sandstone yielded a permeability of 2×10^{-6} cm/sec.

PARADOX 3

At the Paradox 3 site a synclinal structural basin formed in Mancos shale and underlying Dakota sandstone is overlain by alluvial sediments. The alluvial sediments are approximately 35 feet thick near the center of the structural basin in stream valleys and thin toward the margins of the basin.

Permeability results for tests performed on alluvial materials displayed a range of 1.5 x 10^{-6} to 4 x 10^{-3} cm/sec with an average of 3.5 x 10^{-3} cm/sec. Field permeability tests conducted in selected intervals of the Mancos shale and Dakota sandstone yielded permeability values which were primarily dependent on the amount of fracturing and jointing independent of rock type. Values ranged from 6 x 10^{-6} cm/sec to 1.85 x 10^{-3} cm/sec with an average of 7.3 x 10^{-4} cm/sec.

AQUIFERS

LONG PARK

Borings performed during the field investigation phase of this project penetrated the upper portion of the Salt Wash Member at their deepest extent. Perched ground water was encountered in two borings in the southwestern portion of the site (see Appendix C). All other borings were dry.

One water quality sample was obtained; the tested sample exceeds U.S. Environmental Protection Agency (1978) drinking water standards for total dissolved solids and sulfate. Detailed results of the water quality analysis are presented in Table C-6, Appendix C. No water well filings for wells within a two-mile radius of the site are recorded with the Colorado State Engineer. The many mine workings under the Long Park site are up to 100 or more feet below the surface and do not require dewatering to our knowledge. Therefore, any aquifers present under the Long Park site are at least several hundred feet below ground surface.

Based on the above information and the regional geology, the Navajo and Wingate sandstones are the uppermost potential aquifers at the Long Park site. Since no well logs or boring data for these units exist at the site, it is not possible to determine if usable quantities of water are available in these units below Long Park. Based on generalized stratigraphic information, the top of the Navajo sandstone is at least 250 feet below the surface at the Long Park Site.

PARADOX VALLEY

Paradox 1 and 2

No field investigations were performed at the Paradox 1 site. Based on regional geologic information and site geomorphology, geologic conditions are likely similar at the two sites and are treated as one herein.

Borings advanced to a maximum of approximately 70 feet at the Paradox 2 site did not encounter any ground water. No water well filings for wells within a two-mile radius of the site are on file with the Colorado State Engineer.

Many test and monitoring wells have been placed near the Dolores River as part of a proposed salinity control project (U.S Bureau of Reclamation, 1978). Water quality analyses performed on some samples obtained from monitoring wells have indicated total dissolved solids in excess of 200,000 parts per million with sodium chloride the major component. The high salinity occurs due to dissolution of salt from the Paradox Member of the Hermosa Formation. Because of the close proximity of the salt member to the Paradox 1 and 2 sites, ground water under the site is probably moderately to highly saline.

Paradox 3 Site

Ground water encountered in several borings and test pits at the Paradox 3 site ranged in depth from 13 to 43 feet below ground surface. Ground water was perched in the alluvium overlying the Mancos shale near the stream, but was not present in the alluvium away from the stream gullies.

Ground water was also present in the Dakota sandstone below the Mancos shale. In general, it was confined near the center of the structural basin and unconfined towards the perimeter of the basin. Water quailty analyses of three ground water samples had total dissolved solids and sulfates in excess of U.S. Environmental Protection Agency (1978) recommended drinking water standards. A detailed summary of the water quality analyses is presented on Table C-6, Appendix C.

One well was on file for the area within a two-mile radius of the site. The records indicate the domestic well is located in the northwest quarter of the southwest quarter of section 27, T.46N., R.16W. and is 265 feet deep. The well is reportedly cased and grouted to 180 feet. Yield was recorded at 30 gpm with 250 feet of drawdown.

SEEPAGE FROM TAILINGS DISPOSAL AND EVAPORATION PONDS

GENERAL

A brief evaluation of seepage from tailings disposal and evaporation pond options is presented herein. Detailed evaluations of seepage quantity and quality will likely be required for a final design.

Filtering of the tailings will remove a major quantity of effluent available for seepage and will result in a substantial reduction of seepage from tailings disposal areas. Seepage quantities from evaporation ponds for the options investigated in this study could be substantial. However, very flat topography is required to minimize the height of evaporation pond retaining dams. This was not available on the sites investigated for this project.

SEEPAGE QUALITY

The effluent from the milling process has a low pH and is moderately high in dissolved solids, sulfates, nitrates and chlorides and contains trace amounts of heavy metals, radium, thorium and uranium. Analyses of the mill effluent are presented in the Environmental Report.

The quality of seepage exiting either a tailings disposal area or evaporation pond will depend on a number of parameters including buffering and ion exhcnage capacity of the soil, attenuation properties of the soil, pH of the seepage, quantity and velocity of the seepage. In general, the trace metals and radioactive species are rapidly attenuated by natural soils, while chlorides and nitrates are relatively mobile. Detailed evaluation of seepage quality as a function of travel distance and time were not within the scope of this feasibility investigation. It is our opinion that seepage quality will not present any major problems for most of the options investigated in this report, but more detailed analyses will be required if an option is selected for final design.

TAILINGS SEEPAGE QUANTITY

Estimation of seepage from tailings disposal areas requires a knowledge of the initial moisture content of the tailings, specific retention and permeability of the tailings. Laboratory test data and estimated values of the above mentioned parameters are presented on Table D-1.

Based on the data presented in Table D-1, the following statements can be made. The tailings will be disposed of at a rate of 1,500 dry tons per day. At an initial moisture content of 25%, the liquid input to tailings disposal corresponds to a flow of 62.6 gpm. With a tailings specific retention of 20%, the net amount available for seepage is 27.9 gpm. The remainder of the liquid will be held by capillary and surface tension forces in the tailings matrix. Infiltration due to rainfall is negligible in comparison with the net quantity of seepage. Therefore, the net long-term quantity of seepage from the tailings disposal area corresponds to approximately 27.9 gpm over a 17-year period.

The actual seepage rate during operations may be lower than 27.9 gpm because of the low permeability of the tailings and compacted bottom materials. The total seepage quantity is small when distributed over an area of several hundred acres. The total long-term estimated seepage quantity applies to all sites.

The seepage entering natural materials underlying the sites will also depend partially on the operational sequence of placing the tailings.

Placing a clay liner at the base of the excavation would reduce seepage rates, but the same total seepage quantity would be available. Therefore, placing the liner would not reduce long-term seepage quantities. Consideration was given to placing drains on a lined bottom

TABLE D-1

PHYSICAL PROPERTIES OF THE TAILINGS

Initial Moisture Content	25%
Specific Retention⁽¹⁾	20%
Moisture Content at 20% Specific Retention⁽²⁾	13.9%
Permeability⁽³⁾	6.7×10^{-7} cm/sec
Permeability at 40% relative density⁽⁴⁾	2.8×10^{-6} cm/sec
at 80% relative density⁽⁴⁾	1.6×10^{-6} cm/sec
Coefficient of Compressibility⁽³⁾	8.4×10^{-6} cm^2/g

---

(1) Estimated based on tailings gradation and graph on page D22, Johnson (1967)

(2) Moisture content based on an assumed dry density of 90 pcf

(3) From consolidation data at 6,400 psf confining pressure, see Plate C-15.

(4) Falling head laboratory test (Dames & Moore, 1979)

at the base of the tailings. The low permeability of the tailings would require very close drain spacing and makes drain performance questionable. It is our opinion that the filtering process constitutes a maximum reasonably achievable seepage control measure for the tailings disposal operations and additional alternative control measures do not appear justified. The mill liquor separated from the tailings is to be disposed of in evaporation ponds which will be lined to control seepage.

EVAPORATION POND SEEPAGE

General

On the basis of field tests, the permeability of the underlying rock strata at the sites investigated is moderately high. The rock units near the surface are highly fractured and jointed which results in a secondary permeability which is essentially independent of rock type. Evaporation ponds will, therefore, require a liner of compacted clay or synthetic material. Seepage quantities estimated herein are based upon a three foot thickness of compacted clay liner or a synthetic liner.

Seepage quantity estimates provided herein are conservative and are presented for site comparison purposes only. The estimates are based on vertical flow through the lining material and Darcy's Law, assuming that materials under the liner are free draining. Since Darcy's Law is valid only for steady state saturated flow, no account has been taken for lower seepage rates during transient flow conditions. Several years may be required before steady state flow would be realized. Mounding under the evaporation ponds due to seepage was not considered. Mounding may occur on claystone lenses and other barriers to vertical seepage. Mounding would substantially reduce the amount of seepage because of the lower gradient available for flow. Seepage through the retaining dams has been neglected since it is small in comparison with the computed quantities.

LONG PARK

Clay lining material at the Long Park site can be obtained from outcrops of the Brushy Basin shale. Permeability of recompacted claystone samples from the Brushy Basin Member averages approximately 1 x 10^{-7} cm/sec, based upon laboratory permeameter tests.

The estimated average seepage rate during the 17-year operation for Option 4 (single reservoir) is approximately 54 gpm. This estimate is based on the use of Darcy's law with the general assumptions stated previously, optimization of basin morphology by obtaining dam construction material from within the basin, and calculation of seepage on an average annual basis as a function of pond elevation and area. As stated previously, this estimate is conservatively high.

PARADOX 2

Gypsum is present at or near the surface on the southern portion of the Paradox 2 site. Gypsum is highly susceptible to solutioning, particularly in the presence of low pH fluids. Since seepage exiting the evaporation ponds will have a low pH initially, evaporation ponds were located north of the approximate gypsum contact to prevent possible problems with excessive seepage and/or embankment stability.

No readily available clay sources are near the Paradox 2 site. Mancos shale is available from the Paradox 3 site, a distance of approximately 17 miles. It is our opinion that synthetic liners are applicable at the Paradox 2 site for cost reasons. Because of the long haul distance required to bring clay to the site, synthetic liners can be installed for less cost. Lining materials will also have to be reclaimed at the end of operations and moved to a tailings disposal area to meet NRC objectives. Therefore, the long-term performance of the liners considered necessary for permanent installations is not a major consideration of the 17-year operation of the ponds.

A synthetic liner must be chemically resistant to the acidic fluids and small amounts of hydrocarbons present in the mill effluent. In addition, it must have sufficient strength to resist punctures and tears during placement and operation, resist degradation by ultraviolet light and microbial action and be easily seamed in the field. Materials which will meet these criteria after a preliminary review are chlorinated polyethylene and chlorosulfonated polyethylene.

There is not a well established standard method for estimating seepage from synthetic liners. Seepage from tears and faulty seams are of more concern than seepage through the liner itself. We have assumed for the purposes of feasibility comparison that seepage will be equivalent to three feet of clay material with a permeability of 1×10^{-7} cm/sec.

Seepage quantity estimates for the Paradox 2 options are based on the same set of assumptions used to estimate seepage for the Long Park options. Average seepage rates during operations are estimated as 50 gpm and 36 gpm for Options 1 and 2, respectively.

POTENTIAL FOR AQUIFER DEGRADATION FROM SEEPAGE

LONG PARK

The potential for aquifer degradation at the Long Park site is low. Aquifers are at least several hundred feet below the surface. If the natural moisture content of the underlying soils and rock strata is below its specific retention, seepage from the 17-year operation probably will not reach underlying aquifers.

The frequency of fracturing and jointing in the rock strata likely decreases with depth. Therefore, as depth increases seepage will increasingly tend to perch on claystone layers and move horizontally downdip (northeast).

APPENDIX E

TABLE OF CONTENT

APPENDIX E

LIST OF TABLES

APPENDIX E

SURFACE WATER HYDROLOGY

GENERAL DESIGN CONSIDERATIONS

The proposed tailings disposal and management objectives are discussed in the main text.

The tailings retention facilities and evaporation ponds for the various alternatives must be designed to withstand flooding from potential maximum flooding conditions. Considerations of potential maximum flooding conditions include both Probable Maximum Flood (PMF) and 100-year flood inflows (U.S. Nuclear Regulatory Comission, 1977). The PMF is defined as the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region (U.S. Nuclear Regulatory Commision, 1977).

Estimates of PMF conditions for design purposes are usually based on the observed and deduced characteristics of flood-producing storms and associated hydraulic factors, modified on the basis of hydrometeorological analyses to represent the most severe runoff conditions considered to be "reasonably possible." The hydrologic analyses for the tailings retention facilities were performed using currently acceptable techniques and practices. The design base for determination of flood surcharge storage requirements in the proposed tailings impoundments and evaporation ponds is discussed in the following paragraphs. The proposed alternative flooding protection measures for the various options (i.e., diversion channels) are also discussed. All notes and computations for the hydrologic analyses for evaluation of total operating freeboard requirements for the proposed tailings impoundments and evaporation ponds and conceptual design of diversion channels including local flooding evaluation, are presented herein. The PMF derivations were prepared by first estimating appropriate design storm Probable Maximum Precipitation (PMP) amounts independently for both general-type and local-storm (thunderstorm) conditions for the areas tributary to and including the proposed tailings facilities and evaporation ponds.

DESIGN BASE FOR TOTAL OPERATING FREEBORAD REQUIREMENTS, INCLUDING FLOOD SURCHARGE EVALUATION

POTENTIAL MAXIMUM FLOOD VOLUME CONDITIONS

According to the criteria recommended by the U.S NRC (1977), runoff above a tailings retention system that would be of a toxic nature should be temporarily stored for evaporation. The tailings retention system must be designed so as to provide for the required storage at any particular time. The flood surcharge capacity of a tailings retention system should provide for storage of a probable maximum flood series (defined as the PMF and an antecedent flood equivalent to about 40 percent of the PMF occuring about 3 to 5 days before the larger flood) preceded or followed by a 100-year flood, assuming a pond elevation equivalent to that resulting from the average annual runoff. Also, adequate freeboard must be provided to prevent overtopping by wind-generated waves and to account for settlement of the dam embankment and foundation.

Since extended storm rainfall periods are particularly important when runoff is to be controlled by storage, the probable maximum flood series considering the general-type PMP storm would be more severe than the local-storm PMP in determining inflow volumes to the proposed tailings impoundments and evaporation ponds. Appropriate design storm PMP amounts were developed independently for both general-type and local-storm (thunderstorm) conditions for the areas tributary to these proposed facilities. The PMP analyses were based on and performed in conformance with, the PMP definition (American Meteorological Society, 1959): "The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage area for a certain time of year."

Estimated PMP amounts for the general storm and local-storm conditions for a 6-hour duration from Hydrometeorological Report No. 49 (U.S. Department of Commerce and U.S. Department of the Army, 1977) are 4.6 and 9.6 inches, respectively. However, the general-type PMP storm extended to a recommended 72-hour duration would be 11.9 inches, whereas no extension for a duration longer than 6 hours is considered for the local-storm PMP. In addition, the 100-year rainfall for a duration of 6 hours was estimated from Technical Paper No. 40 (U.S. Department of Commerce, 1963) to be 2.4 inches. Based on recommendations by the U.S. Soil Conservation Service, this value extended to a 36-hour duration (considered maximum) would be 4.0 inches. The combined design storm rainfall amount over the total contributing drainage area above each proposed tailings impoundment or evaporation pond would then be an estimated 20.7 inches.

Total storm runoff to each proposed tailings impoundment or evaporation pond that would result from the design storm rainfall is estimated to be 20.7 inches, conservatively assuming no rainfall losses to evaporation or to deep ground water percolation during the storm sequence. However, total estimated inflow volumes to the proposed facilities would vary depending upon the contributing drainage areas. The potential maximum water surface elevations in the pond levels, under this potential storm runoff condition, would also vary, depending upon each impoundment configuration.

COINCIDENT WIND-WAVE ACTIVITY

It is unlikely that a sustained wind of very high velocity would occur simultaneously over the maximum potential flood levels in either the tailings or evaporation ponds. However, wind-generated waves and wind setup relations should be considered for a maximum overland wind velocity of 50 miles per hour (mph), with the ponds at the potential maximum flood levels. The recommended minimum freeboard requirement for each tailings impoundment or evaporation pond at the potential maximum flood water level, based on a wind velocity of 50 mph, is 3 feet. This recommendation is in accordance with the minimum freeboard requirements for the design of small dams as presented in Design of Small Dams (U.S. Dept. of the Interior, 1973).

TOTAL OPERATING FREEBOARD REQUIREMENTS

The estimated allowances required for storm runoff storage and coincident wind-wave activity under the proposed options of tailings development and evaporation pond designs are dependent upon the area-capacity relationships developed for each impoundment and are included in their conceptual designs. These operating freeboard requirements would have to always be maintained, to be in conformance with the criteria addressed by the U.S. Nuclear Regulatory Commission. The freeboard values would provide storage for total storm runoff from the probable maximum flood series, and afford protection against associated wind-wave activity.

EVAPORATION POND SIZING EVALUATION

SOURCES OF DATA

Hydrologic data required to size the evaporation pond for the Long Park site were obtained from a previous study entitled, "Environmental Report for the Uravan Mill, Union Carbide Corporation" (1978) and from a series of reports issued by the Bureau of Reclamation related to a project designed to capture saline ground water discharge to the Dolores River from the Paradox Valley. Field data have included pan evaporation and precipitation data monitored at the proposed Radium Evaporation Pond Site in Dry Fork and at Bedrock, Colorado. Bureau of Reclamation reports also include design data for evaporation ponds being considered in that project.

The design storm rainfall hydrologic design base for evaluation of flood surcharge storage requirements in the evaporation ponds was discussed previously. The amount of discharge from the mill to the evaporation ponds was determined from data generated in the Environmental

Report and discussions with Union Carbide personnel. Design parameters for evaluation of the liquid effluent pipeline and evaporation ponds are presented in Tables 2, 3 and 4 in the main text.

DESIGN PARAMETERS

Several evaporation pond designs were considered for the Long Park site. The objective of the designs was to locate the ponds in such a manner that natural topography would be used to minimize dam volumes, maximize the area, and minimize the storage volume. Single and multiple reservoir schemes were examined. In general, the multiple reservoir system required more construction materials for dam building but resulted in less storage volume at the end of the 17-year operation.

Annual average precipitation was obtained from the Environmental Report and compared favorably with the Bureau of Reclamation report. Precipitation was estimated at 10.4 inches per year. An annual average evaporation rate for the Long Park site was estimated from pan evaporation data generated by the U.S. Bureau of Reclamation at the Radium Evaporation Pond Site and at Bedrock, Colorado, and from long-term data for Montrose, Colorado.

Two years of freshwater-pan evaporation data were available for Dry Creek Basin (1975 and 1976). For these 2 years, the average pan evaporation was 55.2 inches compared to 42.1 inches at Montrose station where a 37-year period of record is available. The Radium Evaporation Pond site, located in Dry Creek Basin, is about 500 feet higher in elevation than Montrose, but there is considerably more wind in Dry Creek Basin that is normally from the southwest and very dry. For the Montrose station, the winter evaporation rates were filled in by use of a correlation with temperature. The synthetically derived average annual pan evaporation rate for Montrose, assuming no winter freezing, is 58.3 inches for the 36-year data collection period. Because of the lack of sufficient data at Dry Creek Basin, the Bureau of Reclamation decided to use this Montrose average in their operation study. This is a conservative estimate because if the proportion for the 2 years of concurrent data holds, the annual evaporation rate at Dry Creek Basin would be 76.0 inches.

To convert the fresh water pan evaporation data to design value for the ponds, a pan coefficient of 0.7 and a brine coefficient of 0.95 was applied to the 58.3 inches pan evaporation rate. This gives an evaporation rate of 38.8 inches per year for the Dry Creek station which lies at an elevation approximately the same as Long Park. This value was therefore used for the Long Park site.

A filling sequence for the evaporation pond or sequence of evaporation ponds was determined by balancing the inflow precipitation and evaporation over the pond area and runoff from the upland area over the projected 17-year life of the pond. This was done on an average annual basis with the following equation:

$$I + (P-E)\ PA + C_{Ro}\ P(TA-PA) = AS$$

where

I = Liquor Inflow
P = Precipitation
E = Evaporation
PA = Pond Area
TA = Total Drainage Area
C_{Ro} = Runoff Coefficient
S = Storage

In all cases examined, the equilibrium evaporation area was not reached at the end of 17 years because of the storage available. After determining the dam height using estimated annual average hydrologic conditions, the flood surcharge storage requirement was added to the site plus an additional 3-foot or 4-foot freeboard for waves depending upon the fetch for cases where diversion channels were incorporated, the diversion channels were designed to divert the entire potential maximum flood flows.

Pond elevation-area and elevation-capacity data for the various evaporation pond options considered are presented on Tables E-1 through E-3.

TABLE E-1

STAGE-AREA AND CAPACITY DATA FOR LONG PARK - OPTION 4

Elevation (MSL)	Area (Acres)	Stored Volume (Acre-ft)
6,260	0	0
6,280	23	230
6,300	73	1,190
6,320	160	3,520
6,340	246	7,580
6,355	320	11,825

TABLE E-2

STAGE-AREA AND CAPACITY DATA
FOR LONG PARK - OPTION 5

Annual Precipitation -	10.4 in/yr
Average Annual Evaporation -	38.8 in/yr
Upland Runoff Coefficient -	0.1
Assumed Inflow of Tailing Liquor	510 gpm

STAGE-AREA AND STAGE-VOLUME INFORMATION

Elevation (MSL)	Area (Acres)	Stored Volume (Acre-ft)
	Pond 1	
6,278	0	0
6,300	25	275
6,320	48	1,000
	Pond 2	
6,300	0	0
6,320	7	70
6,340	21	[illegible]
6,345	24	465
	Pond 3	
6,315	0	0
6,320	5	12
6,340	26	322
6,345	31	892
	Pond 4	
6,340	0	0
6,360	20	200
6,370	30	450
	Pond 5	
6,340	0	0
6,360	18	180
6,370	27	405

TABLE E-2 (Cont)

Elevation (MSL)	Area (Acres)	Stored Volume (Acre-ft)
	Pond 6	
6,274	0	0
6,280	5	15
6,300	24	305
6,320	42	965
	Pond 7	
6,300	0	0
6,320	10	100
6,340	17	370
6,345	19	460
	Pond 8	
6,336	0	0
6,360	17	204
6,370	24	409
	Pond 9	
6,360	0	0
6,380	10	100
6,400	31	510
	Pond 10	
6,360	0	0
6,380	18	180
6,400	54	900
	Pond 11	
6,360	0	0
6,380	20	200
6,400	41	810

TABLE E-3

STAGE-AREA AND CAPACITY DATA FOR LONG PARK - OPTION 6

Elevation (MSL)	Area (Acres)	Stored Volume (Acre-ft)
	Pond 1	
6,278	0	0
6,300	25	275
6,320	48	1,000
	Pond 2	
6,300	0	0
6,320	7	70
6,340	21	350
6,345	24	463
	Pond 3	
6,315	0	0
6,320	5	12
6,340	26	322
6,345	31	465
	Pond 4	
6,340	0	0
6,360	20	200
6,370	30	450
	Pond 5	
6,340	0	0
6,360	18	180
6,370	27	405
	Pond 6	
6,360	0	0
6,380	18	180
6,400	54	900

TABLE E-3 (Cont)

Elevation (MSL)	Area (Acres)	Stored Volume (Acre-ft)
	Pond 7	
6,360	0	0
6,380	22	220
6,400	23	670
	Pond 8	
6,395	0	0
6,400	6	15
6,420	30	375
6,440	55	1,225
6,444	60	1,455

EVAPORATION AFTER CESSATION OF OPERATIONS

A considerable amount of time will be required for the reclamation of the evaporation ponds due to the quantity of liquid in storage at the end of operations and the continued precipitation and runoff to the ponds. The volume in storage at the end of the 17 years has been computed to vary form 5500 to 8500 acre-feet and may take up to 30 to 40 years to evaporate based upon average hydrologic conditions.

PROBABLE MAXIMUM FLOOD (PMF) DESIGN BASES FOR SIZING DIVERSION CHANNELS AND LOCAL FLOODING EVALUATION

In order to lower total operating freeboard requirements for the proposed tailings disposal areas and evaporation ponds, consideration is made to construction of diversion channels at the Long Park site. These are proposed as viable alternatives for runoff control for most of the total drainage areas above the proposed facilities.

PROBABLE MAXIMUM PRECIPITATION (PMP)

The total watershed areas above the Long Park is estimated at 1.8 square miles. In order to estimate the maximum rates of runoff from this small watershed area, the design storm duration should be at least equa to the runoff time of concentration from the watershed, defined as the time required for travel of runoff from the most hydraulically distant point of the watershed to the outlet, or design point under consideration. A 6-hour local-storm PMP was considered for the site, since this storm condition would produce the greatest peak PMF discharge in the watershed.

RAINFALL RUNOFF

Rainfall excess values for the design PMP storms were determined from the United States Soil Conservation Service runoff curves for the accumulative design storm rainfall amounts and appropriate runoff curve numbers (U.S. Dept. of the Interior, 1973). A runoff curve number represents the relative value of the watershed hydrologic soil-cover complex as a direct runoff producer. A greater amount of direct runoff is expected from a storm for a watershed with a higher runoff curve number than from one with a lower number.

Based on the soils and land-use information presented in the report "Dolores River Basin, Colorado and Utah" (Colorado Water Conservation Board and U.S. Dept. of Agriculture, 1972) and on site reconnaissance, a runoff curve number of 85 was estimated for the small watershed areas above the proposed site facilities for evaluating potential maximum flooding conditions under local-storm conditions. Nearly-saturated antecedent soil moisture conditions were assumed for all analyses. The total rainfall excess values estimated for the design local-storm PMP and general-storm PMP are 7.77 and 5.01 inches, repectively.

SMALL WATERSHED FLOOD ANALYSES

Estimation of peak PMP rates of flow for the contributing watershed areas above the proposed diversion channels were made for sizing the structures using the following formula (Haan and Barfield, 1978).

$$q_p = q_p' \, AQ$$

where q_p' = peak discharge in cubic feet per second per square mile per inch of runoff ($ft^3/sec/mi^2/in$), obtained by using Figure 2.40 (a curve relating watershed time of concentration, t_o = the peak discharge, q_p') in Hydrology and Sedimentology of Surface Mined Lands by Haan and Barfield.

A = watershed area, in square miles

Q = runoff volume in inches

q_p = peak discharge from watershed in cfs.

The proposed diversion channels are discussed in a subsequent section of this appendix for the Long Park.

OPEN-CHANNEL FLOW ANALYSES

The theoretical PMF water surface profile of the flow in a diversion channel would resemble a complex series of gradually-varied flow lines dependent upon the channel geometry and local topography. For the purposes of this study, the flow in diversion channels was modelled as uniform steady flow.

The depth of flow at a cross section can be calculated by various analytical techniques. Due to the site characteristics and simplified flow regime, the slope-area method (Henderson, 1966) was selected. The flow regime, based on the Manning equation, may be expressed for uniform flow by the following equation:

$$Q = \frac{1.486}{n} AR^{2/3} S^{1/2}$$

where:

A = cross-sectional area of flow, in square feet (ft^2)

R = hydraulic radius, in feet (ft)

S = slope of the energy gradient in the direction of flow, in ft/ft

n = hydraulic roughness coefficient, dimensionless

Q = discharge, in cfs

Based on published data on roughness characteristics of natural channels (Barnes, 1967), excavated channels in earth (Haan and Barfield, 1978), and related field experience, the hydraulic roughness coefficient, n, was estimated as 0.025 for assumed trapezoidal channel cross sections in earth for the proposed diversion channels. Average slopes of the energy gradients, S, were approximated by an average channel bed slope of 0.01 ft/ft assumed along the alignment of the proposed diversion channels. The above values were substituted into the Manning equation for the estimated peak discharge conditions in the watershed in the analyses for the proposed diversion channels. Potential maximum PMF water levels in these channels were then estimated.

For the conceptual design of the diversion channels, the estimated potential maximum PMF water depths serve as preliminary design bases for sizing the proposed diversion channels that could convey estimated PMF peak discharges. Typical channel section geometry consisting of a trapezoidal section with a 20-foot bottom width and sideslopes of 2H:1V was assumed for preliminary design. Variations in channel depth were based on estimated volumes of flow for a given channel section and assumed to vary linearly between the head and outlet of individual sections. The proposed diversion channel design dimensions required to convey the design discharges for the Long Park site are presented on Table E-4, Diversion Channel Design Dimensions.

TABLE E-4

DIVERSION CHANNEL DESIGN DIMENSIONS

		Head End of Channel			Outlet End of Channel		
Site	Channel Section	Channel Depth (feet)	Design Discharge (cfs)	Average Maximum Velocity (fps)	Channel Depth (feet)	Design Discharge (cfs)	Average Maximum Velocity (fps)
Long Park - Option 1	M - N	2	200	6.6	5	1,690	13.1
	O - P	1	<100	<6	7	3,515	16.1
	T - P	1	<100	<6	7	3,515	16.1
	P - R	10	7,030	19.6	10	7,030	19.6
	R - S	11	8,890	20.4	11	8,890	20.4
	T - R	1	<100	<6	5	1,860	13.4
	U - V	3	800	10.4	4	1,300	13.4
	W - X	1	<100	<6	2	200	6.6
Long Park - Option 2	E - F	2	400	8.4	5	2,100	13.9
	F - G	5	2,100	13.9	7	3,640	16.3
	G - H	7	3,640	16.3	7	3,640	16.3
	I - J	1	<100	<6	2	200	6.6
	K - L	1	<100	<6	2	200	6.6
Long Park - Option 3	A - B	1	<100	<6	3	630	9.7
	A - C	2	390	8.3	5	1,860	13.4
	C - D	5	1,860	13.4	5	1,860	13.4
Long Park - Option 4	A - B	2	<200	6.6	5	1,800	13.4
	C - D	2	<200	6.6	10	6,700	19.6

TABLE E-4 (Cont)

Site	Channel Section	Head End of Channel Channel Depth (feet)	Design Discharge (cfs)	Average Maximum Velocity (fps)	Outlet End of Channel Channel Depth (feet)	Design Discharge (cfs)	Average Maximum Velocity (fps)
Long Park -	A - B	1	<100	<6	7	3,500	16.0
Option 5	C - B	2	400	8.4	5	2,100	13.9
	B - D	6	2,500	14.8	6	3,000	15.2
	E - F	2	<200	6.6	5	2,000	13.6
	G - F	1	<100	<6	5	2,000	13.6
	F - H	9	5,400	18.2	9	5,400	18.6
	I - J	1	<100	<6	3	630	9.7
	K - L	1	<100	<6	3	500	9.2
Long Park -	A - B	2	390	8.3	5	1,860	13.4
Option 6	B - D	9	5,375	18.7	9	5,375	18.7
	A - C	1	<100	<6	3	630	9.7
	E - B	1	<100	<6	7	3,515	16.1
	F - G	1	<100	<6	7	3,515	16.1
	J - K	1	<100	<6	5	1,500	12.8
	I - H	1	<100	<6	3	800	10.3

APPENDIX F

TABLE OF CONTENTS

APPENDIX F

EVAPORATION POND ALTERNATIVES

GENERAL

This section summarizes alternatives for disposal of liquid effluent from the mill by means of evaporation. Major system components are a pipeline system which conveys liquid effluent from the mill to the disposal area and the evaporation pond. The evaporation pond consists of embankments, a liner over the basin interior and diversion canals. Two types of evaporation pond systems were considered - a single embankment and reservoir and multiple reservoirs.

PIPELINE SYSTEM

Pipeline routes assumed for this study follow the approximate alignments shown on Plate 12. Both six-inch and eight-inch diameter piplines were considered, with the eight-inch line being selected on the basis of economics. Design parameters and considerations for transport of liquid effluent from the mill are summarized on Table 2.

Construction, operation and reclamation of the required pipeline system will be a major undertaking with considerable technical and environmental considerations. Significant design considerations include minimizing the potential for accidental release of the liquid effluent due to natural causes, accidents, or vandalism; maintenance of liquid temperatures above 40°F to reduce crystallization within the line; inspection and monitoring of pipeline performance; economic factors; and rights-of-way.

It is our opinion that a buried line would be advantageous from the standpoint of protection against accidental breakage, vandalism and temperature maintenance. The major drawback with a buried line is that inspection of the condition of the line and monitoring for leaks would be very difficult. Maintenance of temperature in the line during periods of shutdowns would be sufficient for periods of 12 hours, and much more for a buried line. For an above-grade line or for extended subsurface standing time during very cold weather, insulation would be required. If removal of crystal buildup within the line is needed, a specially designed in-pipe reamer would be required.

A system for collection of accidentally released liquid would likely be required. Such a system could consist of a ditch paralleling the line which leads to lined collection ponds. For short, critical sections a pipe-within-a-pipe could be used in lieu of ditches. Ponds will be needed at the bottom of all low sections to hold the effluent should the line have to be drained. In the event of a line break, some effluent would probably seep into ditch banks and the pond bottoms.

To monitor for major breaks in the line, a series of pressure sensors coupled with senders would alert operators to a serious pressure drop and would aid in identifying the location of the break. Monitoring the line for minor leaks would require an elaborate system of detectors and senders. Such a system would likely be subject to many false alarms, many failures and would be a high maintenance item. As a minimum, the line could be periodically pressure checked and instrumented for determining total flow at various points to detect long-term discrepancies in input and output.

A mobile pipeline distribution system will be required in the evaporation pond area. This line will be moved periodically as the pond elevation increases. For multiple reservoir alternatives a more elaborate mobile system will be required to distribute the inflow to the ponds.

At the end of operations, it is assumed that all pipe and contaminated equipment would have to be recovered and disposed of in the tailings disposal area, and all disturbed land along the pipeline route revegetated.

EVAPORATION PONDS

The evaporation ponds consist of embankments, a liner and diversion canals. Design and operational considerations for the embankments include hydrologic factors, seepage control, embankment stability and reclamation.

Hydrologic Factors

Detailed discussions of the surface water hydrology are presented in Appendix E and Table 4. A brief summary is presented herein.

Embankment heights required for the options considered were determined primarily by the hydrologic budget which consists of a balance between precipitation, evaporation, uplands runoff, effluent inflow and changes in storage. To determine required embankment heights, it was conservatively assumed that seepage is negligible. Canals to divert runoff upstream of the pond areas were incorporated into the preliminary design to meet NRC objectives. The hydrologic budget was computed on an annual basis assuming average hydrologic conditions. After determining the dam height required on the basis of the annual average hydrologic budget, additional height was provided for storage of a probable maximum flood series with coincident wave activity.

Seepage Control

Detailed discussions of seepage estimates are presented in Appendix D. A brief summary is presented herein.

For the purposes of this feasibility invetigation it has been assumed that a clay liner three feet in thickness will adequately control seepage from the evaporation ponds. Where a clay source is not readily available a synthetic liner was assumed. The clay liner placed over the entire basin interior, in our opinion, represents the maximum reasonably achievable control of seepage from the evaporation ponds.

Embankment Stability and Wave Protection

Embankments have been designed with 3 horizontal to 1 vertical 3H:1V) upstream and downstream slopes with a central core and chimney drain. Upstream sloping cores might be justified for final design and could reduce clay volume requirements as well as reduce the amount of contaminated soils at project termination. However, the present design is believed to be conservative and satisfactory for preliminary design purposes.

Slope stability was not evaluated quantitatively. Stable slopes were conservatively estimated from guidelines for zoned earth fill embankments presented in "Design of Small Dams" (U.S. Bureau of Reclamation, 1973). The final design of the evaporation pond embankment will require a detailed evaluation of slope and foundation stability under static loading and earthquake loading equivalent to .12g.

Wave protection will be required on the upstream slopes of the embankment to ensure stability of the dam. It has been assumed that three feet of riprap material will be sufficient for the embankments considered for this study.

During operation, wave action upon the clay liner would have to be inspected and erosion cuts maintained. Areas of particularly troublesome erosion due to their steepness and orientation with respect to prevailing wind would probably require wave protection measures. Plate 15 displays a typical section of the evaporation pond embankment with major design features and dimensions.

Reclamation

Impoundments have been sized on the basis of the time rate of filling and average annual evaporation rate. Considerable volumes of liquid will be impounded at the cessation of operations which will in turn require many years for the liquid to evaporate. Where the external drainage area is moderately large, an equilibrium pool of several tens of acres will result unless additional diversion canals are constructed as the pool area decreases. In such cases, a small reclamation pond with minimal drainage area would be required.

Reclaimed liner soils would be properly disposed of and covered by an initial two feet of clayey soils with the remaining soils being composed of random excavated materials to develop a minimum reclamation cover thickness sufficient to meet the radon emission standard of 2 pci/m^2-sec.

LONG PARK OPTIONS

GENERAL

One pipeline route was considered for the Long Park options as shown on Plate 12. The route was selected based upon the following factors:

1. Rights-of-way along the existing county road might be easier to obtain than a route across diverse surface ownership and mineral claims.
2. The route would be highly accessible and avoids major cliffs and canyons.
3. The route is relatively direct.
4. Additional land disturbance would be reduced.

Construction data are summarized on Table 3 - Effluent Pipeline Design Summary for Long Park.

Borrow materials for dam and liner construction can be obtained locally. Shell material would be obtained from reservoir areas to increase storage and optimize basin morphology to decrease seepage. Clay materials for clay core and liner are available within three miles of the site as shown on Plate C-10, Appendix C.

OPTION 4 - SINGLE EVAPORATION RESERVOIR

Layout and major features of Option 4 are shown on Plate 9, Plot Plan. The reservoir would be impounded by a single 120-foot high dam and would create a reservoir of 260 acres after 17 years. Ditches would divert normal runoff around the impoundment, but the dam is sized to store the probable maximum flood series without diversion. One mile of county road would be rerouted. Major construction data for Option 4 are summarized on Table 5.

Option 4 requires considerably less earthwork for the embankment and liner, is a simpler design hydrologically, requires less area and less road relocation than Options 5 or 6. However, the quantity of liquid impounded at the cessation of operations is greater and the time required for complete evaporation and reclamation would be much longer. Option 4 is very inflexible with respect to avoiding problem areas or land ownership problems.

OPTION 5 - MULTIPLE EVAPORATION POND SYSTEM

Layout and major features of Option 5 are shown on Plate 10. The area would be divided into 10 evaporation ponds. Ditches and a central channel through Long Park would divert PMF and normal runoff from the ponds. A conceptual plan for construction of diversion channels for surface water runoff control in the watershed area for the Option 5 site is illustrated on Plate 10. Two miles of county road would be rerouted. Table 5 summarizes major construction data. The hydrologic design bases for the diversion channels are presented in Appendix E.

Option 5 requires considerably more earthwork, disturbs more land and distribution piping is more complex than Option 4. However, the scheme is more flexible and will require less time to reclaim since the volume of storage at the cessation of operations will be smaller than for Option 4.

OPTION 6 - MULTIPLE EVAPORATION POND SYSTEM

Option 6 is a combined tailings disposal and evaporation pond system as displayed on Plate 11. The evaporation pond system designed for Option 6 is similar to Option 5. The only major difference between Option 5 and Option 6 is a partial loss of flexibility because of the adjacent tailings disposal operation. Table 5 contains major construction data for Option 6.

APPENDIX G

TABLE OF CONTENTS

APPENDIX G

EVALUATION OF TAILINGS IMPOUNDMENT

INTRODUCTION

This Appendix presents detailed descriptions of the tailings disposal options for the Long Park site previously summarized in the text of this report. Descriptions of the requirements and operational sequence for the proposed options is followed by a preliminary engineering analysis. The preliminary engineering analyses evaluates slope stability for both constructed embankments and excavation that would be utilized during the tailings disposal operation.

LONG PARK TAILINGS IMPOUNDMENT OPTIONS

GENERAL

Two alternative tailing disposal concepts are proposed for the Long Park site, whereby one provides a method to impound filtered tailings completely below existing site grade and the other utilizes existing topographic features to develop tailings impoundment partially below the existing ground surface.

OPTION 1

GENERAL

Option 1 consists of the excavation and preparation of a series of trenches contructed to receive and impound filtered tailings completely below existing site grade. The proposed trench configuration is shown in plan view on Plate 6. Major construction data are presented on Table 1A. A cross-sectional view of the proposed tailing disposal plan for Option 1 illustrating interpreted subsurface conditions is shown on Plate 13.

OPERATIONAL SEQUENCE

The following presents the general sequence of construction of events as presumed for the initial phases of impoundment construction and site development for Option 1:

1. Site preparation.
2. Locating and backfilling existing mine shafts and adits located within the proposed impoundment.
3. Excavation of tailings storage trenches and construction of diversion channels.
4. Impoundment bottom preparation.
5. Placement of tailings.
6. Reclamation.

Site Preparation

A minimal amount of site preparation will be required in development of Option 1. The existing ground surface throughout the impoundment area should be grubbed and stripped of all significant vegatation including sagebrush and trees as required during the operation. Since it is not anticipated that a significant amount of the excavated soils will be utilized for embankment construction or other engineered fills, removal of soil containing the major root mat (topsoil) will not be essential. Final grades are estimated as approximately 4 percent and therefore will require surface erosion protection. Stripping and stockpiling of topsoils for revegetation would not be required as a result.

Backfilling of Existing Mine Shafts and Adits

All existing mine shafts and adits within the impoundment area would be located and backfilled to a minimum depth of 30 feet below the proposed final impoundment bottom grades. It is our understanding that drifts associated with these mine shafts and adits are a minimum of 100 feet below present site grade and therefore present no significant potential for subsidence or stability problems for the proposed tailings impoundment.

Existing mine shafts and adits would be "plugged" to a minimum depth of 30 feet below the base of the impoundment with the remaining open shaft above the plug being backfilled with a low shrinkage concrete or cement-stabilized compacted earthfill. A Type V high sulfate resistant, cement would be utilized in preparation of either concrete or stabilized fill.

Trench Excavations and Diversion Channel Construction

Excavation of tailings impoundment trenches and diversion channel construction would follow grubbing and stripping of the vegatation and near-surface soils. Impoundment trenches generally having approximate plan dimensions of 250 x 2000 feet, would be excavated to depths ranging between 10 and 20 feet, providing an average storage capacity ranging between 250,000 and 500,000 tons of dry tailings per trench, or between 5 and 10 months of anticipated tailings production.

It is not planned to excavate into bedrock where blasting would be required to achieve final grade. Excavation of near-surface soils and highly weathered bedrock would be performed using conventional earthwork equipment such as bull dozers and scrapers. In some instances, ripping may be required in conjunction with excavation.

Materials excavated from the initial trench would be stockpiled for future use as reclamation soil. Cut slope ratios of 1.5 horizontal to 1.0 vertical (1.5H:1.0V) would be utilized to provide a stable trench slope geometry. Upon completion of the initial trench, including proper bottom preparation, tailings disposal could be initiated. After a portion of the disposal trench is filled to final disposal grade, excavation of a second trench could be initiated with excavated materials from the second trench used as reclamation cover for the partially filled preceding trench. This same construction sequence would be utilized throughout the disposal operation so that excavated materials could be used as reclamation cover without necessitating stockpiling, there by minimize handling of materials. The final trench would be reclaimed with soil excavated and stockpiled from the initial trench or developed from adjacent borrow areas.

Diversion channels would be contructed in conjuction with the development of the initial tailings impoundment trench. Details regarding design and construction of these diversion channels are discussed in Appendix E. Diversion channels locations are shown on Plate 6.

Impoundment Trench Bottom Preparation

Results of seepage analyses (see Appendix D) indicate small rates of seepage loss through trench bottoms. As a result, liners specifically constructed to further reduce seepage losses are not considered necessary. However, it is anticipated that the impoundment trench bottoms will be formed in closely jointed, weathered bedrock and may expose numerous old exploration drill holes. In order to minimize possible migration of tailings into otherwise exposed joints and drill holes, the upper 12 inches of exposed weathered bedrock would be disked, moisture conditioned and compacted. Total area requiring this type of treatment is estimated to be on the order of 300 acres for Option 1.

TAILINGS HAULAGE AND PLACEMENT

Based on the results of an economic evaluation performed to select an optimal truck size to haul belt-filtered tailings from the mill to the Long Park site, a truck and pup combination having a gross vehicle weight (GVW) of 114,000 pounds would be used. Both trailers associated with this trucking configuration would be end-dump type. Improvements to the existing county road would be required from the mill to Long Park consisting of the placement of 5 inches of bituminous asphalt over 8 inches of base course on a properly prepared subgrade. Anticipated road right-of-way (ROW) is 50 feet with a pavement width of 24 feet.

Upon arrival at Long Park, tailings haul trucks would be directed to the trench currently being used for tailings disposal. Tailings would be end-dumped from the trucks into the trenches utilizing roads established on either the ends or sides of the proposed trenches. After a sufficient period of time tailings would then be distributed and compacted with wide track bull dozers.

RECLAMATION

Reclamation would proceed concurrently with tailings disposal. Soils excavated from the development of new disposal trenches would be utilized to reclaim filled trenches. Clayey soils derived from weathered bedrock at the trench bottoms would be utilized to provide the initial 2 feet of reclamation soil with the remaining soils being composed of random excavated materials to develop a minimum reclamation cover sufficient to meet the radon emission standard of 2 pci/m^2-sec.

Final reclaimed grade will be approximately the same as the existing site grade of 4 percent, and therefore will require erosion protection. A minimum of 12 inches of gravel and cobbles or rock would be placed over the entire reclaimed surface to minimize future long-term erosion.

OPTION 2 AND OPTION 3

GENERAL

Options 2 and 3 are sufficiently similar in site development concepts that they may be discussed in parallel. Options 2 and 3 differ in concept from Option 1 such that tailings would be disposed of partially below and partially above existing site grades as opposed to the completely below grade disposal conceivd as Option 1.

Major construction data for Options 2 and 3 are presented on Table 1B and 1C respectively. Plan views for the proposed tailing disposal concepts are shown for Options 2 and 3 on Plates 7 and 8, respectively. Cross-sections illustrating projected subsurface conditons and excavation geometry for Options 2 and 3 are presented on Plate 14.

OPERATIONAL SEQUENCE

The following presents a general sequence of construction events required for tailings disposal as proposed in Options 2 and 3.

1. Site preparation.
2. Locating and backfilling existing mine shafts and adits within the confines of the proposed impoundment.

3. Initial embankment construction and construction of diversion channels.
4. Impoundment excavation.
5. Impoundment bottom preparation.
6. Placement of tailings.
7. Reclamation.

Site Preparation

Site preparation would include the removal of all vegatation, topsoil and otherwise unsuitable subgrade soils from the proposed embankment alignment. This will initially require the stripping of approximately 15 acres for both Option 2 and Option 3. In addition, borrow areas developed within the impoundment area for the purpose of constructing the initial embankment configuration would also be stripped. All stripped topsoils may be stockpiled for future use in revegetation of reclaimed impoundment.

Stripping of the remaining impoundment area would progress as required for tailing disposal with additional stripped topsoils being similarly used for revegetation.

Backfilling of Existing Mine Shafts and Adits

All existing mine shafts and adits within the impoundment area would be located and backfilled to a minimum depth of 30 feet below the proposed final impoundment bottom grades. It is our understanding that drifts associated with these mine shafts and adits are a minimum of 100 feet below present site grade and therefore present no significant potential for subsidence or stability problems for the proposed impoundment.

Existing mine shafts and adits would be "plugged" at a minimum depth of 30 feet below final excavated impoundment grade, with the remaining opening above the plug being backfilled with a low shrinkage concrete or cement-stabilized compacted earth fill. A Type V high sulfate resistant, cement would be utilized in preparation of either concrete or stabilized fills.

Initial Embankment and Diversion Channel Construction

Placement of tailings above existing site grade requires the construction of an compacted earth embankment to begin the tailings disposal operation. The initial embankment would be constructed with fill obtained from excavation within the impoundment area. Additional suitable fill soils could be obtained from construction of the diversion channels if necessary. The estimated volume of compacted fill required for construction of the initial embankment for both Options 2 and 3 is approximately 450,000 cubic yards.

An initial embankment configuration utilizing two horizontal to one vertical (2H:1V) sideslopes on the upstream side and 3H:1V sideslopes on the downstream side is proposed. A minimum crest width of 40 feet is also proposed to facilitate truck access for tailings disposal. Similar excavation equipment and techniques as described for Option 1 are applicable to Options 2 and 3.

Excavations adjacent to the initial embankment would have slopes not steeper than 2H:1V. Excavations other than those adjacent to the initial embankment may be cut using slope ratios of 1.5H:1V. Seepage through the initial embankment would be small and therefore seepage control in the embankment would not required.

Diversion channels would be constructed in conjunction with construction of the initial embankment. Details of diversion channels construction are presented in Appendix E.

Impoundment Excavation

Excavation for tailings impoundment and bottom preparation would be performed as additional storage is required. Tailings would be placed on a 2H:1V slope.

Materials excavated from the impoundment area could be used as reclamation cover without stockpiling to minimize material handling.

Impoundment Bottom Preparation

Impoundment bottom preparation would be performed in a similar manner to that discussed previouly for Option 1. Areas of approximately 160 and 190 acres for Options 2 and 3, respectively, will require bottom preparation.

Placement of Tailings

Options 2 and 3 would utilize the same system to haul tailings to Long Park as discussed for Option 1.

Upon entering the Long Park disposal area, trucks would be routed to the edge of a previously reclaimed section. Tailings would then be end-dumped into the prepared impoundment area and after a sufficient period of time would be distributed and compacted utilizing wide track bull dozers. Earthwork operations involved in excavation within the impoundment, and subsequent preparation of the bottom area would be planned such that a continually advancing toe of the impounded tailings pile would not encroach on an unprepared bottom surface.

Upon achieving final tailings grade reclamation soils developed from within the impoundment area would be placed over the tailings.

Reclamation

Reclamation of the tailings impoundment areas would be an ongoing process performed in conjuction with continuing site development required to expand the impoundment over the proposed project life. The initial two-foot thick lift of reclamation soils to be placed directly over finished tailings grade would consist of clayey soils developed from the highly weathered bedrock exposed at the bottom of the impoundment area. Sufficient quantities of clayey reclamations soils can be developed from within the impoundment excavation based on preliminary examination. If additional clay soils are required, suitable borrow areas maybe developed from exposures of the Brushy Basin shales east of the site. Additional cover of random reclamation soils derived from within the impoundment would be placed over the 2-foot clay cover. Additional reclamation soils could be obtained from the general area outside the impoundment if required.

During the course of impoundment or after the completion of tailings disposal, final reclamation grade of the initial embankment section can be achieved. To meet NRC objectives, final reclaimed slopes would not be steeper than five horizontal to one vertical and may be established in either of two alternative ways. Final slope grades may be attained by the addition of properly constructed engineered fills to the existing downstream embankment face. Alternatively, the upper portions of the existing embankment could be cut, with cut materials being placed and compacted on the lower portions of the embankment to develop a balanced cut and fill 5H:1V downstream slope. Cuts on the crest of the initial embankment would not extend to within 10 feet of the final tailings surface, thereby maintaining the minimal reclamation cover required. The final reclaimed slope (5H:1V) would require the placement of a 1-foot cover of gravel and cobbles or rock to prevent erosion.

Final slopes over the impondment area would be less than 1%. Suitable reclamation over the impoundment area would consist of placement of stockpiled topsoil and self-sustaining revegetation.

Diversion channels would not be backfilled to minimize runoff over the impoundment area.

STABILITY ANALYSES

LONG PARK

GENERAL

Preliminary evaluation of slope stability for both excavated and constructed slopes was performed using chart solutions developed by Huang (1975). The following section presents design assumptions and results of the analyses.

DESIGN PARAMETERS AND ASSUMPTIONS

Based on the results of laboratory tests presented in Appendix C, the following design parameters were assigned for evaluating slope stability at the Long Park site:

Short-Term Excavation Stability

Total unit weight: 110 pounds per cubic foot

Undrained shear strength: 2,000 pounds per square foot

Embankment Stability (End of Construction Case)

Total unit weight: 128 pounds per cubic foot

Total angle of friction*: 23 degrees

Total cohesion*: 600 pounds per square foot

Embankment Stability (Long-Term Steady Seepage Case)

Total unit weight: 128 pounds per cubic foot

Effective angle of friction*: 30 degrees

Effective cohesion*: 100 pounds per square foot

The following design assumptions were conservatively made in conjunction with the analyses performed:

1. Soils forming cut slopes in excavations and underlying soils are assumed homogeneous and isotropic, with depth to bedrock.
2. The thickness of the soil to bedrock is generally less than the cut slope height.
3. Compacted earthfill embankments and underlying foundations are homogeneous, isotropic, and exhibit similar shear strength characteristics.
4. A maximum initial embankment height of 75 feet at the end of construction just prior to tailing deposition (Option 3).

---

* Conservatively estimated based on index characteristics.

5. A maximum embankment height considered for long-term stability of 50 feet (Option 3). Pore pressures in the embankment section are assumed to be approximated by an R_u** value ranging between 0.20 and 0.30, depending on slope geometry.

RESULTS OF ANALYSES

Since the results of analyses performed were used to develop conceptual designs and are based on preliminary site information, stability analyses evaluated for seisimic loading conditions were not performed. Results of static stability analyses performed for site develoment at Long Park are tabulated as follows:

**R_u = Pore pressure/Soil overburden pressure.

Short-Term Excavation Stability

Depth of Excavation in Feet	Cut Slope Ratio H:V	Minimum Factor of Safety
10	1:1	>10.0
20	1:1	5.1
30	1:1	3.4
10	1.5:1	>10.0
20	1.5:1	5.2
30	1.5:1	3.5
10	2:1	>10.0
20	2:1	5.4
30	2:1	3.6

Embankment Stability (End of Construction Case)

Embankment Height in Feet	Slope Ratio H:V	Minimum Factor of Safety
40	1.5:1	1.6
75	1.5:1	1.4
40	2:1	2.1
75	2:1	1.6
40	3:1	2.7
75	3:1	1.9

Embankment Stability (Long-Term Steady Seepage Case)

Embankment Height in Feet	Slope Ratio H:V	Estimated R	Minimum Factor of Safety
50	2:1	0.30	1.10
50	2.5:1	0.28	1.30
50	3:1	0.25	1.45
50	4:1	0.20	2.0

APPENDIX H

American Meteorological Society, 1959, Glossary of Meteorology

Barnes, Harry H., Jr., (U.S. Geological Survey), 1967, Roughness characterisitics of Natural Channels, Geological Survey Water-Supply Paper 1849, U.S. Government Printing Office, Washington, D.C.

Cater, F.W., 1955a, Geology of the Davis Mesa Quadrangle, Colorado: U.S. Geological Survey, MAP GQ-71.

_____, 1955b, Geology of the Naturita NW Quadrangle, Colorado: U.S. Geological Survey, MAP GQ-65.

_____, 1970, Geology of the Salt Anticline Region in Southwestern Colorado: U.S. Geological Survey Professional Paper 637, 80 pp.

_____, A.P. Bulter and E.J. McKay, 1955, Geology of the Uravan Quadrangle, Colorado: U.S. Geological Survey, MAP GQ-78.

Colorado Water Conservation Board and United States Department of Agriculture, 1972, Water and Related Land Resources, Dolores River Basin, Colorado and Utah; Denver, Colorado.

Dames & Moore, 1978, Environmental Report, Uravan Uranium Project, Montrose County, Colorado for Union Carbide Corp.

_____, Jan 5, 1979, Handling and Placement Characteristics Belt-Filtered Tailings Uravan Uranium Mill, Uravan Colorado, for Union Carbide Corporation.

Haan, C.T. and W. Barfield, 1978, Hydrology and Sedimentology of Surface Mined Lands, University of Kentucky.

Hansen, E.M., F.K. Schwaz and J.T. Reidel, 1977, Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages, Hydrometeorological Report No. 49, U.S. Government Printing Office.

Henderson, F.M., 1966, Open Channel Flow, McMillan Book Company, New York.

'Huang, T.H., Stability Charts for Earth Embankments, Procedings 54GH Annual Meeting of the Transportation Research Board, Washington, D.C., January 1975.

Hvorslev, M.J., 1951, Time Lag and Soil Permeability in Ground-Water Observation, Bulletin No. 36, Waterways Experiment Station, Corps of Engineers, Vicksburg, Miss.

Johnson, A.I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials "Geological Survey Water - Supply Paper 1662-D, United States Government Printing Office.

Kays W.B., 1977, Construction of Linings for Reservoirs, Tanks and Pollution Control Facilities, John Wiley & Sons.

Lohman S.W., 1972, Ground Water Hydraulics, U.S. Geol. Survey Prof. Paper 708.

Mittal H.K. and N.R. Molgenstern, 1976, Seepage Control in Tailings Dams, Canadian Geotechnical Journal Vol. 13 No. 3, P277-293.

U.S. Bureau of Land Management, April, 1975, Surface Management Quad SW-7, Uravan, Colorado.

U.S. Department of Commerce, Weather Bureau, 1963, Rainfall Frequency Atlas of the U.S. for Duration of 30 minutes to 24 hours and Return Periods of 1 to 100 Years, Technical Paper no. 40, January, 1963.

_____, and U.S. Department of Army, 1977, Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages, Hydrometeorological Rpt 49.

U.S. Department of the Interior, Bureau of Reclamation, 1973, Design of Small Dams, 2nd Ed., U.S. Government Printing Office, Washington, D.C.

_____, 1978, Written Communication of Flood Estimates for Semi-arid Watersheds.

_____, 1978, Colorado River Basin Salinity Control Project, Paradox Valley Unit-Definite Plan Report.

U.S. Department of Transportation, Bureau of Public Roads, 1967, Use of Riprap for Bank Protection, Hydraulic Engineering Circular no. II, U.S. Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency Publication EPA-606-479-020, Methods of Chemical Analyses of Water and Wastes.

U.S. Geological Survey, 1979, Water Resources Data for Colorado, Vol. 3. Dolores River Basin, Green River Basin, and San Juan River Basin, Water Year 1978.

U.S. Nuclear Regulatory Commission, 1977, Design, Construction and Inspection of Embankment Retention Systems for Uranium Mills, Regulatory Guide 3.11, Rev. 2, December, 1977.

U.S. Soil Conservation Service, 1972, Hydrology, National Engineering Handbook, Section 4, U.S. Government Printing Office, Washington, D.C.

Willimas, P.L., 1964, Geology, Structure and Uranium deposits of the Moab Quadrangle, Colorado and Utah: U.S. Geological Survey MAP I-360.

Withington, C.F., 1955, Geology of the Paradox Quadrangle, Colorado: U.S. Geological Survey, MAP GQ-72.