FOX Consulting Engineers and Geologists

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PRELIMINARY
GEOLOGICAL, HYDROLOGICAL AND GEOTECHNICAL EVALUATION OF THE COKE OVEN SITE MONTROSE COUNTY, COLORADO

Prepared For:
Chem-Nuclear Systems Inc.

Job No. 1-2543-3338
July 31, 1982

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Chem-Nuclear System, Inc.
P.O. Box 1866
Bellevue, WA 98009

July 31, 1982

Job No. 1-2543-3338

Attention: Ms. Louise Dressen

Subject: Preliminary Geological, Hydrological and Geotechnical Investigation of the Proposed Coke Oven Waste Disposal Site near Naturita, Colorado (P.O. No. 401020)

Dear Ms. Dressen:

F. M. Fox and Associates, Inc. is pleased to transmit 5 copies of our Preliminary Investigation of the proposed Coke Oven Waste Disposal Site. An additional 10 copies of the report are being retained at our Denver office for distribution at your request.

The report presents geological, hydrological and geotechnical findings collected over a 3 month period. We are available to discuss the findings with you, your staff and/or other interested parties at your request.

It has been a pleasure working on your project and we are looking forward to completing the additional work necessary for site permits. If you have any questions regarding the contents of our report or desire further consultation, please do not hesitate to contact us.

F. M. FOX & ASSOCIATES, INC.

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1.0 EXECUTIVE SUMMARY

This investigation has shown that it would be feasible to construct and safely operate a co-located low level radioactive waste and uranium mill tailings disposal facility at the Coke Oven Site near Naturita, Colorado. The investigation was conducted to make a preliminary determination of the geological, hydrological and geotechnical characteristics of the site, and how those characteristics would impact or be impacted by the proposed waste facility. The investigation was conducted over a three month period and was limited in both areal extent and scope. Additional site characterization work will be required to confirm, modify and/or supplement data contained in this report.

During this investigation, we identified a number of favorable characteristics that strongly support the viability of the proposed disposal operation at the site. These include:

- A uranium processing facility is already located in the area.
- The regional geology is well known and definable.
- The site is located in a stable geologic area.
- Prevailing tectonism tends to enhance rather detract from the site.
- The site is located in a closed structural basin.
- The site contains geologic media favorable for radioactive waste disposal.
- No major geologic hazards were identified at the site.
- No major natural resource deposits which would affect site development were encountered.
- Impact of the facility on ground and surface water use would be minimal to non-existent.
- Surface drainage is conducive to site development.
- Suitable earth construction materials occur on site.

From a regional standpoint, the stratigraphy and structure of the site is well known and definable. Tectonic activity in this area occurs at relatively slow and constant rates and is such that it tends to promote downwarping and consequently deposition rather than uplift and erosion. In addition, the site is located in a structural depression formed by a doubly plunging syncline, and is thus geologically isolated from surrounding areas.

The site contains favorable geologic media which possess both low natural permeabilities and potentially excellent radionuclide attenuation characteristics. Additionally, on-site materials can be utilized for construction of liners and covers, miscellaneous fill, granular backfill, and rip-rap.

No geologic hazards that would interfere with the proposed development were encountered during this investigation. Natural resources identified in the area do not occur in economically recoverable quantities beneath the site. Site development will not prevent future extraction of these deposits, nor is it anticipated that future extraction will affect the integrity of the site.

The first aquifer encountered at the site occurs at a depth of approximately 200 feet. This aquifer is confined and is separated from the surface by a thick section of impervious shale, siltstone, and claystone. The site is not located in or near the recharge area of this aquifer. There is only one water well utilizing ground water in the basin. This well is located on the private parcel of land being actively considered for the proposed facility. There is no use of surface water in the Coke Oven Basin at this time with the exception of Dry Creek, the surface drainages of the site are small in areal extent and conducive to site development.

This preliminary investigation has identified approximately 380 acres of land, within the 720 acre project site, that are suitable for radioactive waste disposal. An additional 1480 acres of land within the 2200 acre Coke Oven basin, not examined in detail during this investigation, may also be potentially suitable for waste disposal. This additional land consists of 1000 acres of Federally owned and 480 acres of privately owned land.

It is our opinon that it is feasible to design, construct, and operate a safe radioactive waste disposal facility at the Coke Oven site. However, additional site characterization work will be required to develop a detailed license application and environmental impact analysis. It is anticipated that the reviewing agencies of the State of Colorado will require supplemental detailed information to corroborate and support the positive features of the site as listed above and to assure that no undiscovered negative features exist. These investigations may include an evaluation of the structure of the basin, an evaluation of the location, extent, orientation, offset, and age of faults within the basin to assure that these faults will not threaten the integrity of cell liners, a hydrogeologic evaluation including a multi-well pump test to confirm the isolation of the ground waters and the closed nature of the basin, and finally a detailed construction material investigation to characterize the material properties and volumes.

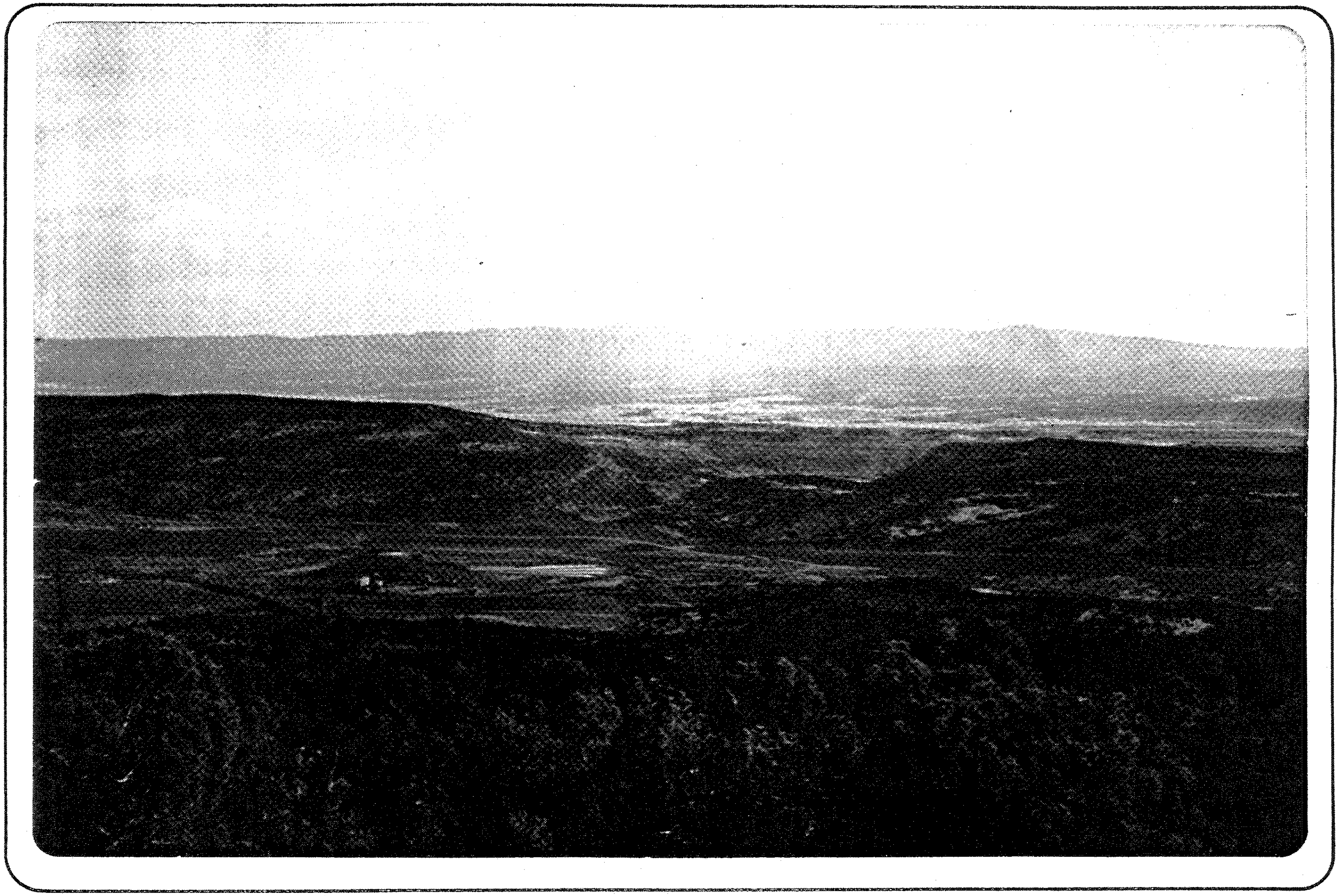
2.0 INTRODUCTION

This report presents the results of our preliminary evaluation of the geological, hydrological, and geotechnical suitability of utilizing the Coke Oven site for shallow land burial of uranium mill tailings and low level radioactive wastes. The Coke Oven site (Photo 1) is located in western Montrose County, Colorado, 2.5 miles southwest of the town of Naturita. Proposed construction at the site will consist of large below grade disposal cells for dry uranium mill tailings, smaller below grade disposal cells for low level radioactive wastes, and related office, materials handling, and vehicle maintenance facilities.

2.1 PURPOSE AND SCOPE

The major goal of this site analysis was to develop preliminary geological, geotechnical, and hydrological data of sufficient detail to determine the feasibility of the site for the proposed use, and to obtain a preliminary opinion from the Colorado Department of Health and the Colorado Geological Survey as to the suitability of the site. This portion of the investigation encompasses work performed between May 1 and July 31, 1982. Although the majority of our investigation encompasses the entire Coke Oven basin and surrounding area, the drilling and field testing portions of our study were limited, to the Coke Oven site proper which consists of portions of Sections 26, 27, 34 and 35, Township 46 North, Range 16 West (Figure 2 after page 7). This area consists of 720 acres of which 160 acres is privately owned and 560 acres is Federally controlled. This investigation may be followed by a second investigation during which the detailed data and documents to support a license application and environmental impact statement will be developed.

This investigation, along with the possible subsequent investigation,



PHOTOGRAPH 1: OVERVIEW FROM THE SOUTH OF COKE OVEN SITE

are designed to collect the information necessary to meet the appropriate sections of the following regulations:

a. Colorado Department of Health "Rules and Regulations Pertaining to Radiation Control";

b. Colorado Department of Health "Uranium Mill Tailings Licensing Guide";

c. Nuclear Regulatory Commission "Recommended Outlines for Preparing Engineering Geologic Reports for Uranium Mill Siting, Radioactive Tailing Storage and Associated Land Changes";

d. 10 CFR Part 61, Licensing requirements for near surface disposal of low-level radioactive wastes;

e. NUREG-0902, Branch Technical Position - Site Suitability, Selection and Characterization.

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

1. Review available information on the site and surrounding area including:
    a. Collect and review general geologic, seismic, and hydrologic information,
    b. Review of available information on permitted and unpermitted wells within two miles of the site,
    c. Identify surface water bodies and site drainage configuration, including size of drainage areas, drainage divides, closed drainage areas, surface gradients, and flashflood, scour and sedimentation areas.
2. Perform a geotechnical field program including:
    a. Drill, log, and sample 13 borings within the site area,
    b. Conduct field permeability tests including packer and standpipe permeability tests.

   c. Conduct natural gamma and neutron geophysical logging of 7 borings.
   d. Drill and log 2 deep (500 feet) holes to identify aquifers and aquicludes beneath the site.
   e. Collect natural gamma, neutron, resistivity, specific potential, caliper and high resolution density logs of these deep holes.
   f. Conduct reconnaissance geologic mapping of the site to corroborate published geologic maps and to cover areas not previously mapped.

3. Conduct a laboratory testing program consisting of gradation, Atterberg Limits, Proctor compaction, permeability, and moisture content tests.
4. Perform engineering analyses including:
   a. Evaluate the site geologic conditions, including (1) site stratigraphy and structure, (2) seismic and other geologic hazards, (3) geomorphic processes active at the site, and (4) potential natural resources in the area.
   b. Evaluate the site hydrologic conditions including the configuration and characteristics of aquifer(s) and confining bed(s), existing ground water quality and use, and the distribution, occurrence, quality and existing use of surface waters at the site.
   c. Evaluate the geotechnical conditions including subsoil conditions, permeabilities, availability of liner, cover, and aggregate materials, and the engineering properties of soil and bedrock units.
   d. Evaluate the site engineering feasibility, including potential impacts of the site on the proposed land use and potential impacts of the proposed land use on natural site processes.

e. Develope preliminary design and construction recommendations, including facility layout, cell design, water quality monitoring, drainage diversions, and foundation construction.

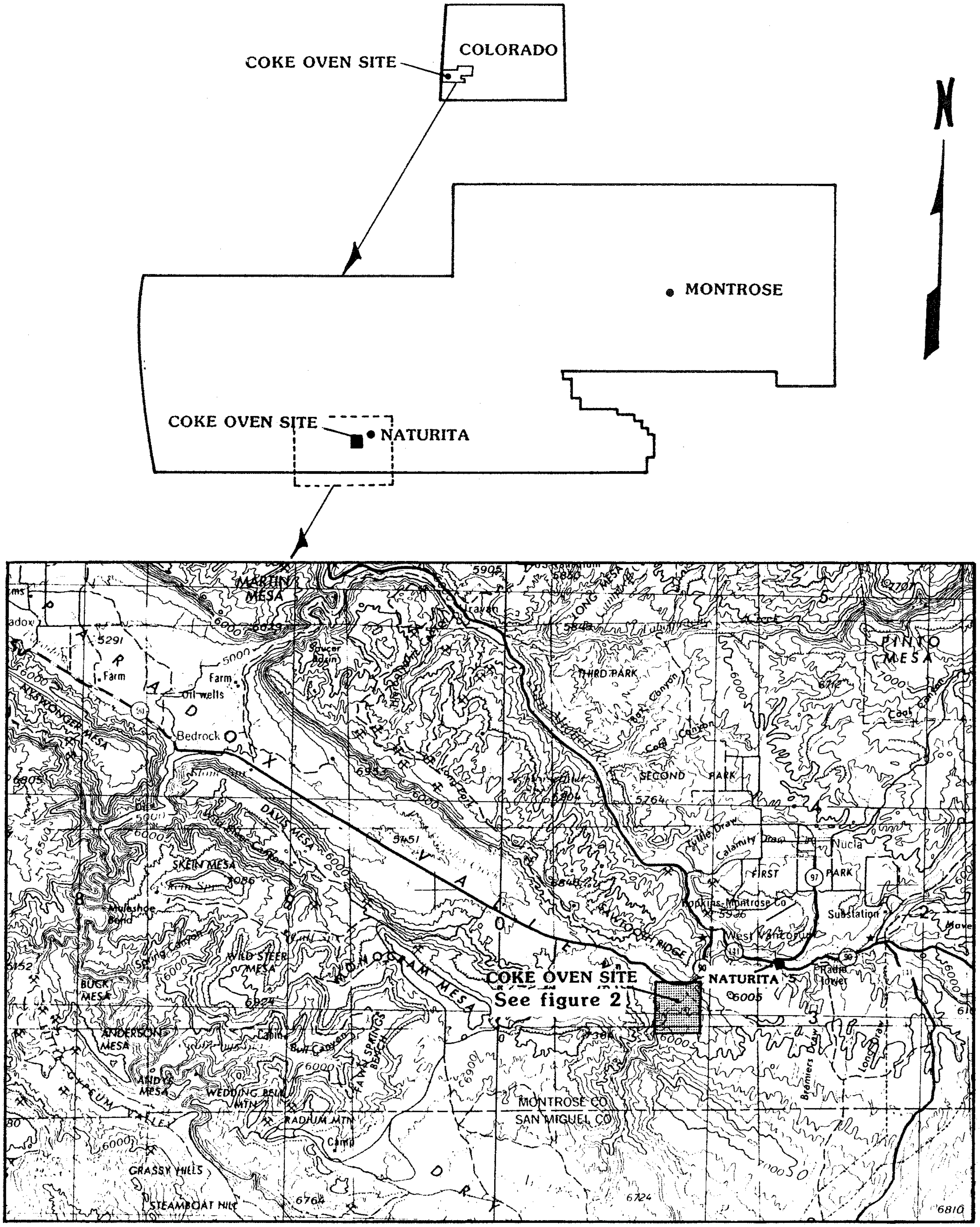
5. Prepare this technical report.

2.2 GEOGRAPHIC SETTING

The Coke Oven Site is located in the western portion of Montrose County, Colorado, 2.5 miles southwest of the town of Naturita and approximately 50 miles southwest of the County Seat at Montrose (Figure 1). The site consists of 720 acres within the 2200 acre Coke Oven basin. The basin is located at the south end of the Paradox Valley in the salt anticline (Paradox Basin) portion of the Colorado Plateau.

The area is drained by Dry Creek, an ephemeral stream which divides the basin into approximately northwest and southeast halves. This stream enters the basin to the southwest through a breach in the Dry Creek anticline and leaves the basin to the northeast two miles up gradient from its confluence with the San Miguel River. The Dry Creek drainage is the only surface break in what would otherwise be an entirely closed surface drainage basin.

Average annual precipitation is approximately 12 inches, coming primarily in April, May, and June; average evaporaton is nearly 48 inches per year. Vegetation at the site consists of sage brush, dryland grasses, and cactus (Photo 2), with sparse cottonwoods along Dry Creek and pinon and juniper pines along the dip slopes surrounding the basin. At the present time the land use of the area consists primarily of a uranium leaching operation run by Ranchers Development Company (Figure 2). Additional land use consists of horse and cattle grazing and one single family dwelling located on the private parcel of land being actively considered for this project.



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SITE LOCATION

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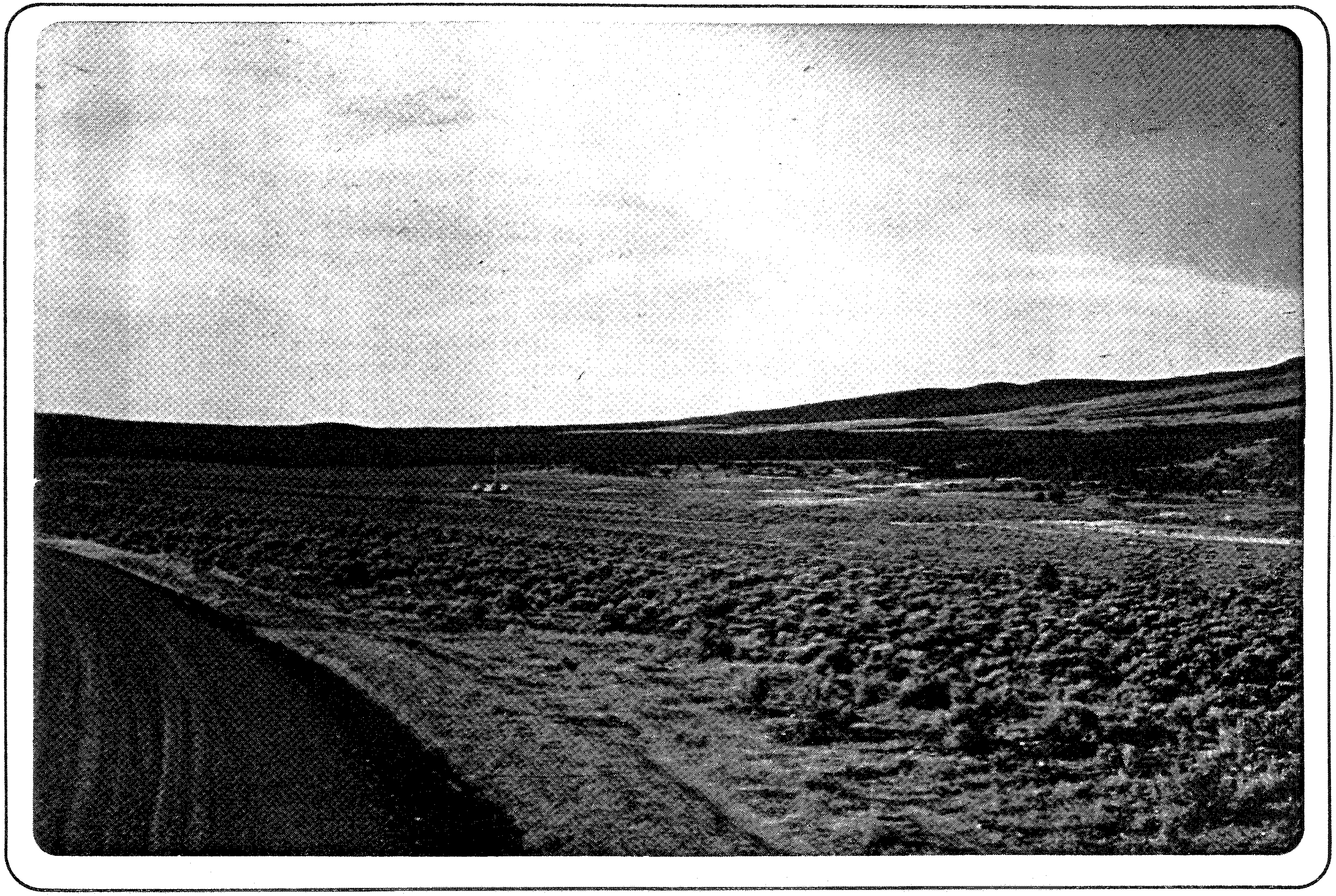
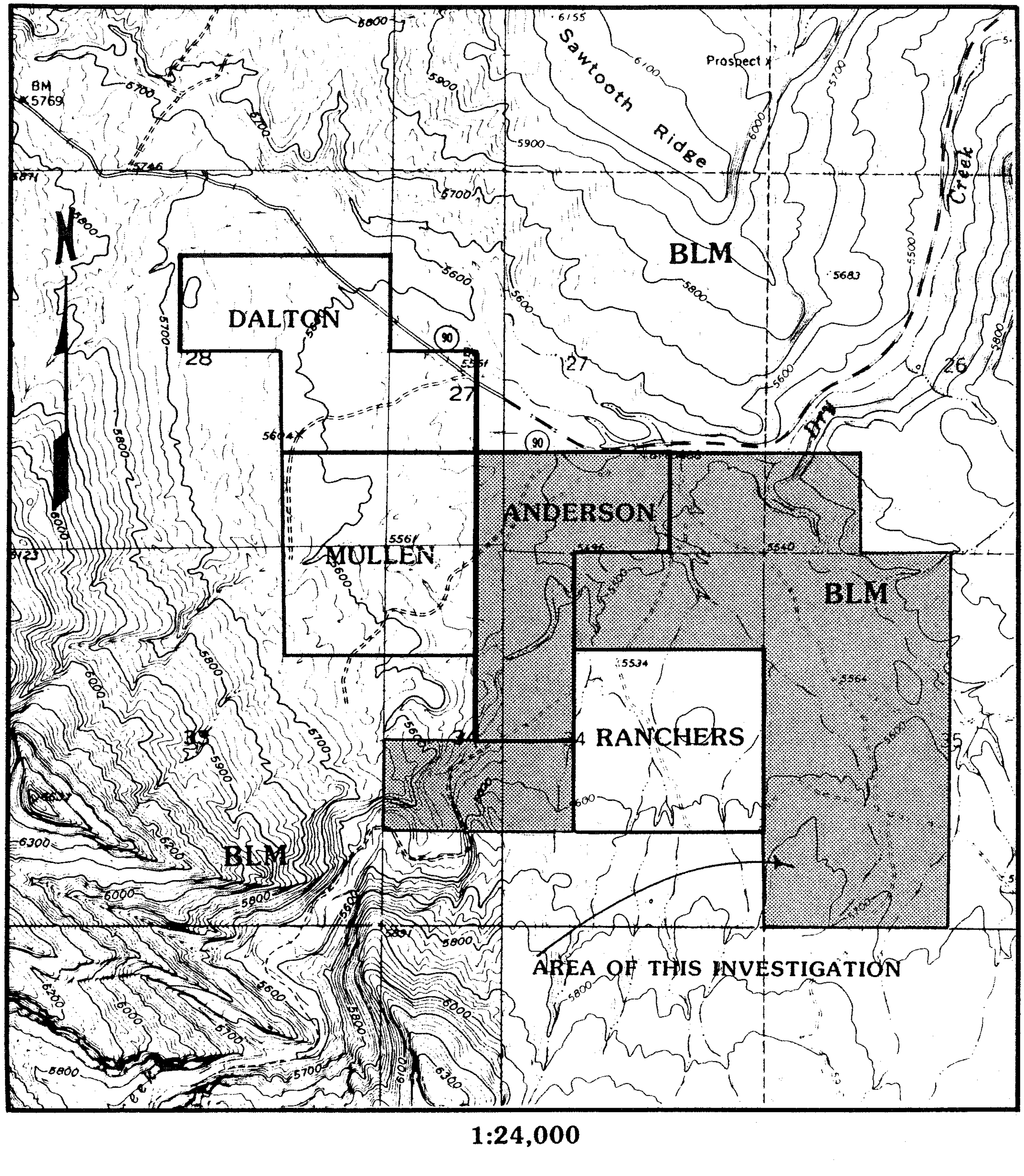
Figure	1



PHOTOGRAPH 2: VIEW FROM THE NORTHEAST OF THE SOUTHWEST PORTION OF THE SITE SHOWING ABUNDANT SAGEBRUSH GROWTH ON EOLIAN DEPOSITS



LAND OWNERSHIP OF THE COKE OVEN SITE AND VICINITY	Job No:	1-2543-3338
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	Figure	2

Site access is achieved via Colorado State Highway 90 which runs along the north end of the site.

3.0 GEOLOGY

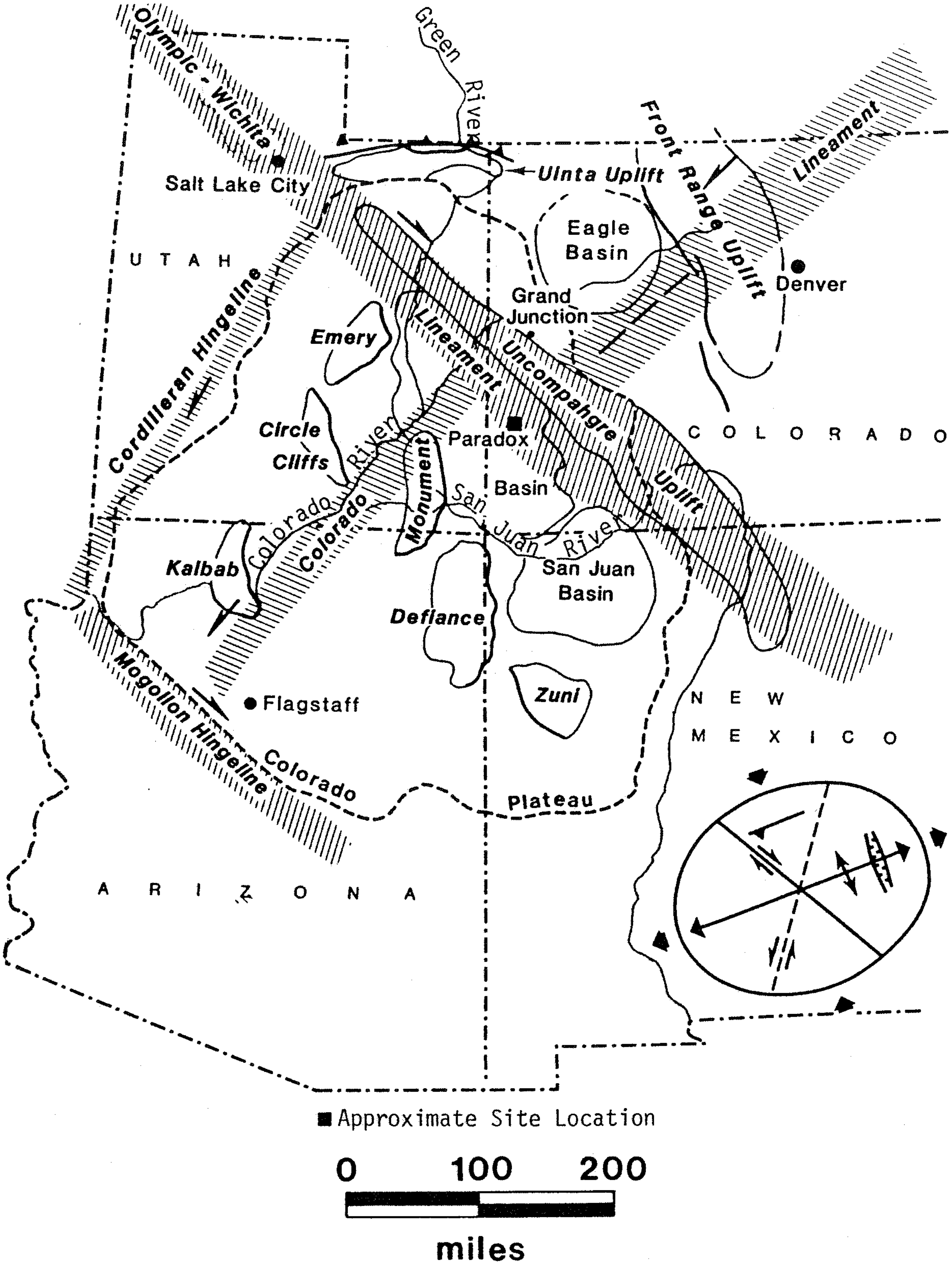
3.1 REGIONAL GEOLOGY

3.1.1 Tectonic Setting

The site is near the southeastern margin of the Paradox Basin, a poorly defined physiographic province within the Colorado Plateau province. The Colorado Plateau is composed primarily of sedimentary rocks that are relatively flat-lying and generally less deformed than surrounding areas. In places, however, the strata are upwarped, folded, faulted, and intruded by igneous rocks and salt diapirs. The major structures are broad monoclinal upwarps with intervening basins. Faults are most common in the northern part of the Plateau, where they trend generally northwest. The salt anticlines are along the Colorado - Utah border near the eastern margin of the Colorado Plateau, in an area between the east-dipping monoclinal upwarps and the Uncompahgre Uplift.

The margins of the Paradox basin are usually defined by the geographic limits of the Paradox Salt Formation of the Hermosa Group. The basin is northwest trending and ovate, although there is little surface expression of the basin except in the salt diapir region. The basin is bounded on the north and east by the Uncompahgre Uplift, on the south by the San Juan Basin and Defiance Uplift, and on the west by the Monument Upwarp (Figure 3).

The two major shear systems that transect the region (Figure 3) were initiated around 1,700 million years ago (Baars and Stevenson, 1981a and 1981b). The northwest-trending Olympic-Wichita Lineament consists of a conjugate fault swarm with generally right-lateral strike-slip displacement. The northeast-trending Colorado Lineament exhibits generally left lateral strike-slip displacement. The two systems intersect near Moab, Utah. This configuration suggests a strain ellipsoid with maximum compressional stress directed from



(from Baars and Stevenson, 1981b)

TECTONIC PROVINCE MAP

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Figure 3

the north. The structural fabric of the region was fixed by Precambrian time, and later rejuvenation, including Laramide episodes, only modified the original framework.

The Paradox basin formed adjacent to the southwestern bounding faults of the Uncompahgre Uplift, with the deepest part of the basin adjacent to the uplift (Baars and Stevenson, 1981a and 1981b). Structurally, the basin is a series of downdropped grabens. Evaporite deposition occurred during Middle Pennsylvanian time within areas of restricted marine circulation in the faulted depressions. The thickest salt accumulations occur in the deep trough adjacent to the Uncompahgre Uplift (Hite and Lohman, 1973). Salt flowage during Pennsylvanian and Permian time was probably triggered by displacement along the basement block faults as well as deposition of clastic overburden consisting of sediments eroded form the Uncompahgre Highland.

Between late Permian and the onset of the Laramide Orogeny in Late Cretaceous there appears to have been little tectonic activity in the region (Cater, 1970). The Colorado Plateau in general resisted major Laramide deformation, especially the extensive thrust faulting to the west and south. The Laramide Orogeny affected the Colorado Plateau by enhancing pre-existing structure, overturning to the east the drape folds over basement faults and forming the broad monoclines.

Shortly after the Laramide deformation, the Colorado Plateau began gentle, epeirogenic uplift and northward tilting. The effects of this episode have been primarily geomorphic.

3.1.2 Regional Stratigraphy

Rocks in the salt anticline region include crystalline rocks of Precambrian age and sedimentary rocks ranging in age from Cambrian to Quaternary (Figures 4 and 5).

System	Series	Stratigraphic Unit	Thickness (feet)	Description
Quaternary	Holocene		0-20	Talus, alluvium, colluvium, eolian deposits
	Pleistocene		0-200	Talus, fanglomerate, alluvium, lacustrine deposits
Tertiary	Pliocene		Variable	Pebble to boulder gravel
Cretaceous	Upper	Mesaverde Fm	900	Thick bedded sandstone and shale
		Mancos Sh	2,000	Dark gray, fissile shale
		Dakota SS	70-220	Interbedded sandstone, conglomerate and shale
	Lower	Burro Canyon Fm	50-300	Interbedded sandstone, conglomerate and shale
Jurassic	Upper	Morrison Fm	540-1,200	Interbedded sandstone, limestone and mudstone
		Summerville Fm	0-100	Interbedded sandstone, mudstone and shale
		Entrada SS	0-325	Massive, white sandstone and red mudstone
		Navajo SS	0-500	Buff, crossbedded sandstone
Triassic	Upper	Kayenta Fm	0-300	Red to lavender sandstone, siltstone and shale
		Wingate SS	0-500	Massive, reddish brown sandstone
		Chinle Fm	0-750	Red siltstone
	Lower	Moenkopi Fm	0-1,000	Brown siltstone and arkosic sandstone
Permian		Cutler Fm	0-9,000	Maroon conglomerate and arkosic sandstone
Pennsylvanian		Rico Fm	0-150	Maroon conglomerate and arkosic sandstone
		Hermosa Gp	Variable	Limestone, sandstone, conglomerate, gypsum and salt
Mississippian	Upper	Molas Fm	0-50	Residual karstic sandstone and conglomerate
	Lower	Leadville Fm	70-230	Gray, cherty, dolomitic limestone
Devonian	Upper	Ouray Fm	0-100	Gray, dolomitic fossiliferous limestone
		Elbert Fm	0-80	Shale, limestone, and dolomite
Cambrian	Middle (?)	Ignacio Qzt	0-100	Conglomeratic quartzite
Precambrian				Biotite granite and gneiss

GENERALIZED STRATIGRAPHIC SECTION
OF THE PARADOX BASIN REGION

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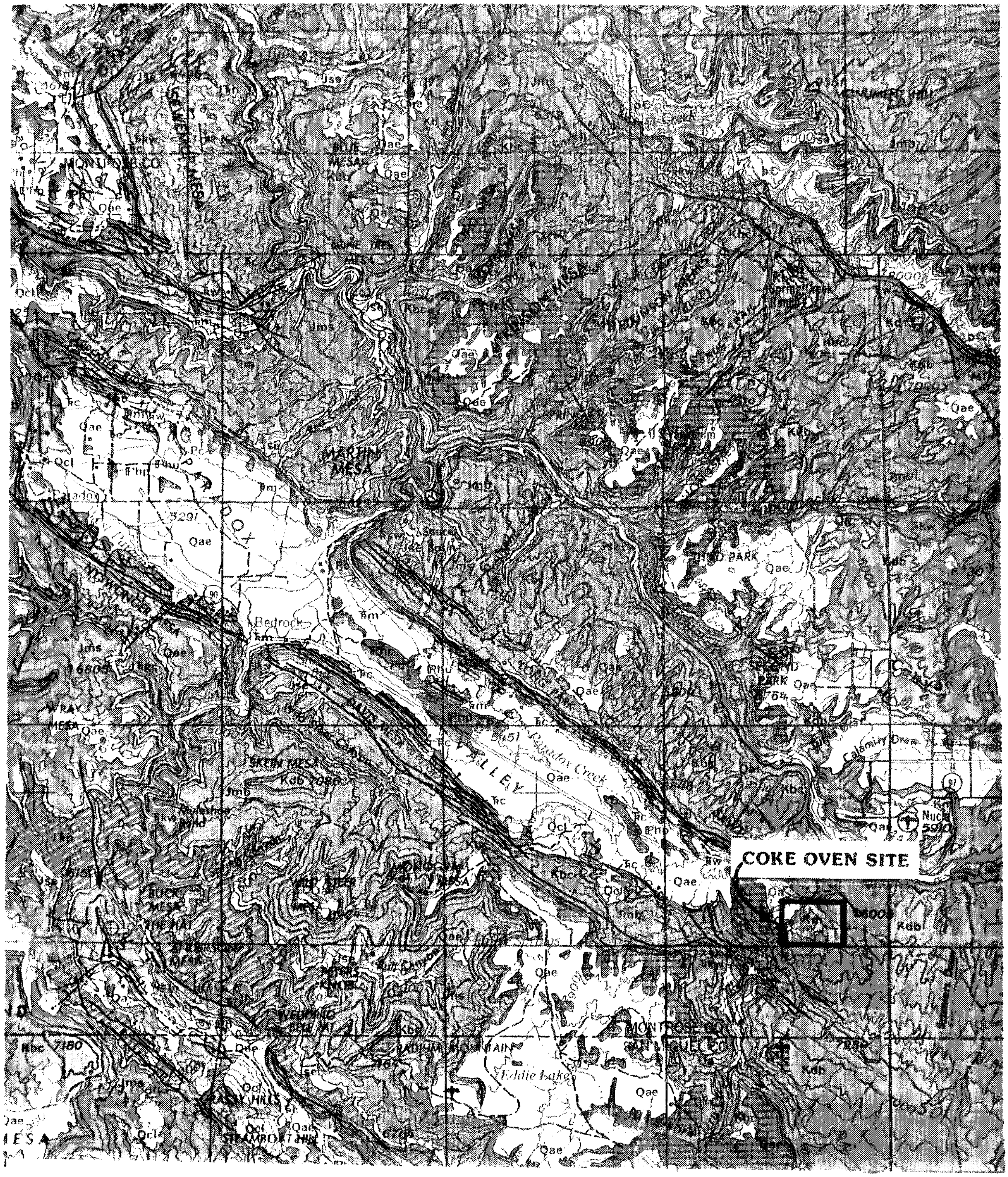
Job No: 1-2543-3338 Date: 7/31/82 Figure 4



SEE LEGEND ON FIGURE 5A

From Williams (1964)

REGIONAL GEOLOGIC MAP	Job No: 1-2543-3338
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	Figure 5

Quaternary

Qae | Qa | Qap

Alluvium and eolian deposits

Qc
Qct | Qcl

Colluvial deposits

Cretaceous

Kmu
Kmfe
Km
Kml

Mancos Shale

Kd

Dakota Sandstone

Kbc

Burro Canyon Formation

Jurassic

Jm | Jmb | Jms

Morrison Formation

Jse

Summerville Formation
and Entrada Sandstone

JŦn

Navajo Sandstone

Triassic

Ŧk

Kayenta Formation

Ŧkw

Kayenta Formation and
Wingate Sandstone

Ŧw

Wingate Sandstone

Ŧcu
Ŧcb
Ŧc

Chinle Formation

Ŧm

Moenkopi Formation

Permian

Pcwo
Pcw
Pca
Pco
Pcao
Pc
Pcc
Pcac

Cutler Formation [3]

Pennsylvanian

IPh | IPhu | IPhp

Hermosa Formation

Contact

Fault
Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side

Strike and dip of beds

SCALE: 1"= 4 MILES

REGIONAL GEOLOGIC MAP LEGEND

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Job No: 1-2543-3338	Date: 7/21/82	Figure 5A

The oldest rocks in the section are crystalline rocks, including quartzite, granite and gneiss of the Precambrian igneous and metamorphic complex. These rocks are exposed only in deep canyons and the deeply incised parts of the Uncompahgre Plateau (Cater, 1970).

The oldest Paleozoic rocks in the section are Middle Cambrian quartz sandstone and conglomerate. In the San Juan Mountains these have been called the Ignacio Quartzite. These clastics unconformably overlie the Precambrian and are unconformable overlain by Devonian rocks. Ordovician and Silurian rocks were probably removed by pre-Devonian erosion.

Upper Devonian age rocks include the Elbert and Ouray Formations. The Elbert Formation consists of sandstone, shale and shaley dolomite. It contains a basal sandstone, the McCracken Member, indicative of marine transgression. The Elbert is considered by Campbell (1981) to have been deposited in an intertidal environment. The Ouray Formation, a gray, locally dolomitized lime mudstone and skeletal limestone, conformably overlies the Elbert.

The Lower Mississippian Leadville Formation lies conformably on the Ouray Formation. The Leadville is an intertidal to subtidal gray, fossiliferous, cherty, dolomitized lime mudstone. During Late Mississippian weathering and erosion, the Leadville limestone was exposed and developed karst. The residual terra rossa, consisting of red limey sandstone and conglomerate with Leadville inclusions, has been called the Molas Formation.

Pennsylvanian activation of the Uncompahgre Uplift, development of the Paradox Basin and marine transgression resulted in deposition of the Hermosa Group. The Hermosa Group consists of three formations, the Pinkerton Trail, the Paradox and the Honaker Trail. The lowermost member, the Pinkerton Trail Formation, is brown, dense dolomite and limestone with siltstone, anhydrite, chert and shale. The Paradox Formation, the middle member of the group, conists of five zones, in ascending order: the Alkali Gulch, Barker Creek, Akah, Desert Creek and Ismay. These zones represent major depositional cycles. All zones basically consist of cyclic sequences of halite, anhydrite, gypsum, limestone and black shale. The uppermost member of the Hermosa Group, the Honaker Trail Fromation, represents the transition from the marine evaporite Paradox Formation below to the overlying continental Rico and Cutler Formations. The Honaker Trail Formation grades upward from white dense fossiliferous limestone and silty shale to shale, siltstone and sandstone.

The Rico Formation has been a subject of disagreement, including whether or not it should be a formation separate from the overlying Cutler Formation (Cater, 1970). Both consist of alternating maroon shales, siltstones, sandstones and arkose. They conformable overlie the Hermosa Group. The Rico and Cutler Formations span the Upper Pennsylvanian to Lower Permian.

The Permian - Triassic boundary is somewhat uncertain, but the Moenkopi Formation may be considered Lower Triassic. It consists of brown and gray calcareous shales, mudstones, and siltstones deposited by mudflat, fluvial and lacustrine processes (Martin, 1981). The upper Triassic System consists of the Chinle Formation and the three formations comprising the Glen Canyon Group. The Chinle Formation consists almost entirely of red continental shales and siltstones with occasional thin sandstones unconformably overlying the Moenkopi Formation. The lowermost member of the Glen Canyon Group, the Wingate Sandstone, consists almost entirely of massive reddish-brown eolian sandstone. The Kayenta Formation is red to lavender fluvial sandstone, siltstone and shale. The Navajo Sandstone, uppermost member of the group, is buff crossbedded eolian sandstone. The entire section is conformable from the Chinle Formation through the Navajo Sandstone. The position of the Triassic - Jurassic boundary is also questionable. Opinion varies from placing the Glen

Canyon Group entirely within the Triassic to placing it entirely within the Jurassic (Molenar, 1981).

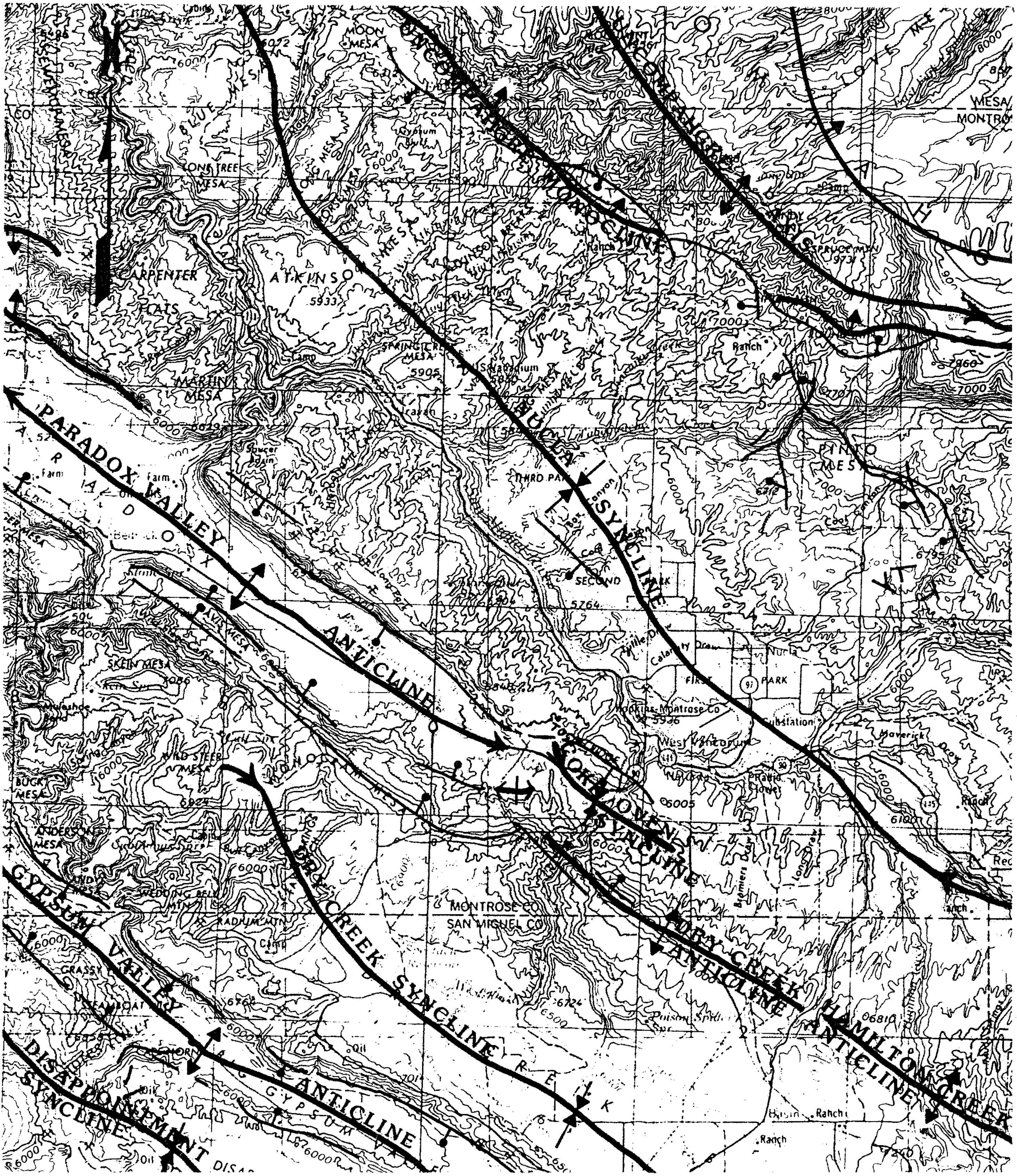
The Upper Jurassic System consists of the Entrada Sandstone, Summerville Formation and Morrison Formation. The Entrada is massive white eolian sandstone with some red mudstone. The lower mudstone sequence is in some places separated as the Carmel Formation. It unconformably overlies the Navajo Sandstone. The Summerville Formation is interbedded fluvial to marginal marine sandstone, mudstone and shale. The Morrison Formation consists of variegated sandstones, siltstones and shales with minor limestones.

The Morrison Formation is unconformably overlain by the Lower Cretaceous Burro Canyon Formation. This formation consists of alternating grayish sandstone, conglomerate and shale of fluvial origin. The Upper Cretaceous System is composed of the Dakota Sandstone, Mancos Shale and Mesaverde Formation. The Dakota, unconformably overlying the Burro Canyon Formation, consists of interbeded buff sandstone, conglomerate and shale. The Dakota Sandstone contains coaly deposits and was probably deposited on a delta plain. The Mancos Shale is gradational with the Dakota Sandstone and consists of dark gray fissile shale with thin interbeds of limestone and sandstone. The Mesavede Formation, gradational with the Mancos, consists of thick-bedded buff sandstone and gray shale.

Cretaceous bedrock is overlain by Pliocene gravel (Cater, 1970) and Quaternary deposits. The Quaternary sediments include talus, collovium, alluvium, fanglomerate and eolian and lacustrine deposits.

3.1.3. Regional Structure

The major regional structures in the Paradox basin are the salt anticlines. These anticlines are orientated in a northwesterly direction, paralleling the trend of basement faults in the region (Figure 6). Development



Anticline showing direction of plunge

Syncline showing direction of plunge

Monocline

Fault trace ball on down thrown side

1:250,000

REGIONAL GEOLOGIC STRUCTURE

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Figure 6

of the salt features is related to the deep-seated basement faults and the Uncompahgre Uplift.

The major uplifts of the Ancestral Rocky Mountain Orogeny occurred in Middle Pennsylvanian (Atokan) time. Uplifts, including the Ucompahgre, developed as tilted blocks rose from the Precambrian wrench faults. As the Uncompahgre block rose, the southwest margin subsided to form the Paradox basin. The subsidence occurred along a series of grabens. Restricted marine circulation resulted, and salt was deposited in the faulted troughs. Along with the salt deposition, arkosic clastics were shed from the rising Uncompahgre Highland.

As salt thicknesses reached up to 5,000 to 8,000 feet, they were overlain by arkosic wedges from the northeast. This initiated salt flowage toward the basement faults to the southwest. Repeated displacement along the faults may also have contributed to flowage (Baars and Stevenson, 1981a and 1981b). The faults also acted as barriers to continued lateral movement of the salt. As clastic deposition continued, the salt rose vertically along the fault block boundaries, resulting in the anticlinal trend.

Salt flowage and growth of the salt anticlines continued to probably Late Jurassic time. The major structures in the Paradox basin region were established by the end of the Pennsylvanian Period. These features show very little evidence of Laramide deformation.

As the Colorado Plateau rose epeirogenically, surface and ground water drainage increased. Ground water began to remove near-surface salt by solution. Removal of the underlying salt resulted in collapse of the anticlinal crests. Overlying units slumped into the crests, leaving slump folds and gravity faults.

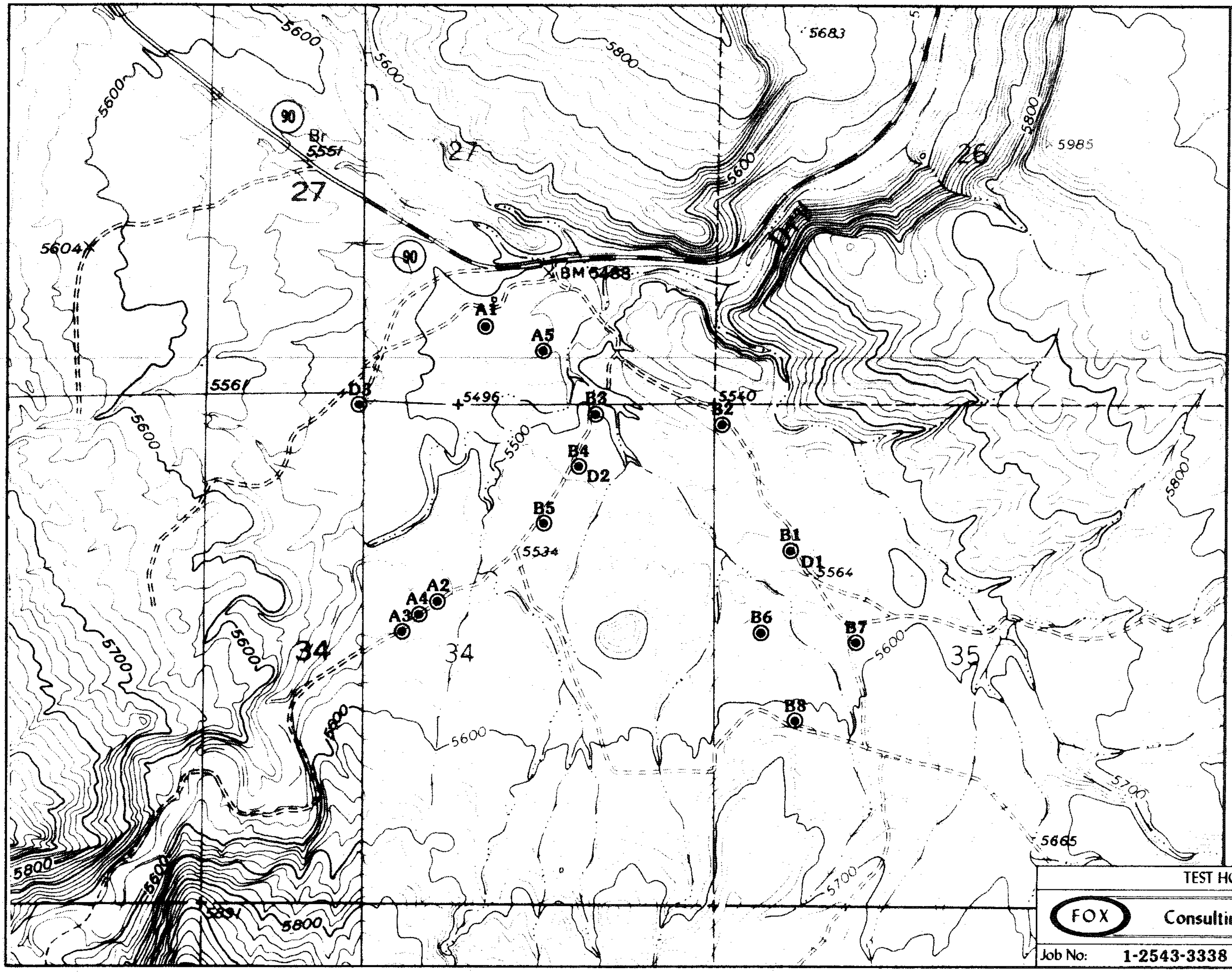
3.2 SITE GEOLOGY

A drilling and field testing program was conducted on the property between May 11, 1982 and July 7, 1982. Thirteen shallow test holes (Figure 7) were 4 inch diameter auger drilled, 4 inch diameter rotary drilled and/or cored with NX wire line coring equipment. These test borings were drilled to depths ranging from 20 feet to 112 feet. Two additional 6 1/4 inch test borings were drilled with a water well rig to depths of 500 feet. A surface casing was constructed in these two holes by installing and cementing 10 inch solid steel casing in the top 20 feet. Slotted schedule 40 polyvinyl chloride (PVC), slotted over the entire interval, was then installed to depths of 492 and 470 feet in D-1 and D-2, respectively. A third deep drill hole (D-3) was also attempted, however, a 40 foot section of saturated sand and gravel prevented installation of the surface casing. Therefore, the hole was abandoned. All drilling was supervised by a geological engineer. The engineer visually logged the borings (Figures A-1 - A-13, Appendix A) and collected soil and/or bedrock samples. Samples were obtained by collecting cuttings, using a Modified California soil sampler, and by NX coring.

Geophysical logging was conducted by Nuclear Logging Services of Nucla, Colorado in both deep borings and in 7 of the shallow borings (Figures A-14, A-15, and A-16, Appendix A). The deep hole logging consisted of the following:

High Resolution Density
Caliper
Natural Gamma
Neutron Neutron
Self Potiential
Resistivity

The self potiential (SP) logs were only moderately successful because of a lack of conductive drilling fluid in the deep holes. The shallow borings were logged with natural gamma and neutron-neutron tools.



EXPLANATION:

A1 ● Indicates boring loc-on Anderson property.

B1 ● Indicates boring located on Bureau of Land Managment property.

D1 ● Indicates deep investigation boring

0 500 1000 2000 FT

TEST HOLE LOCATION PLAN

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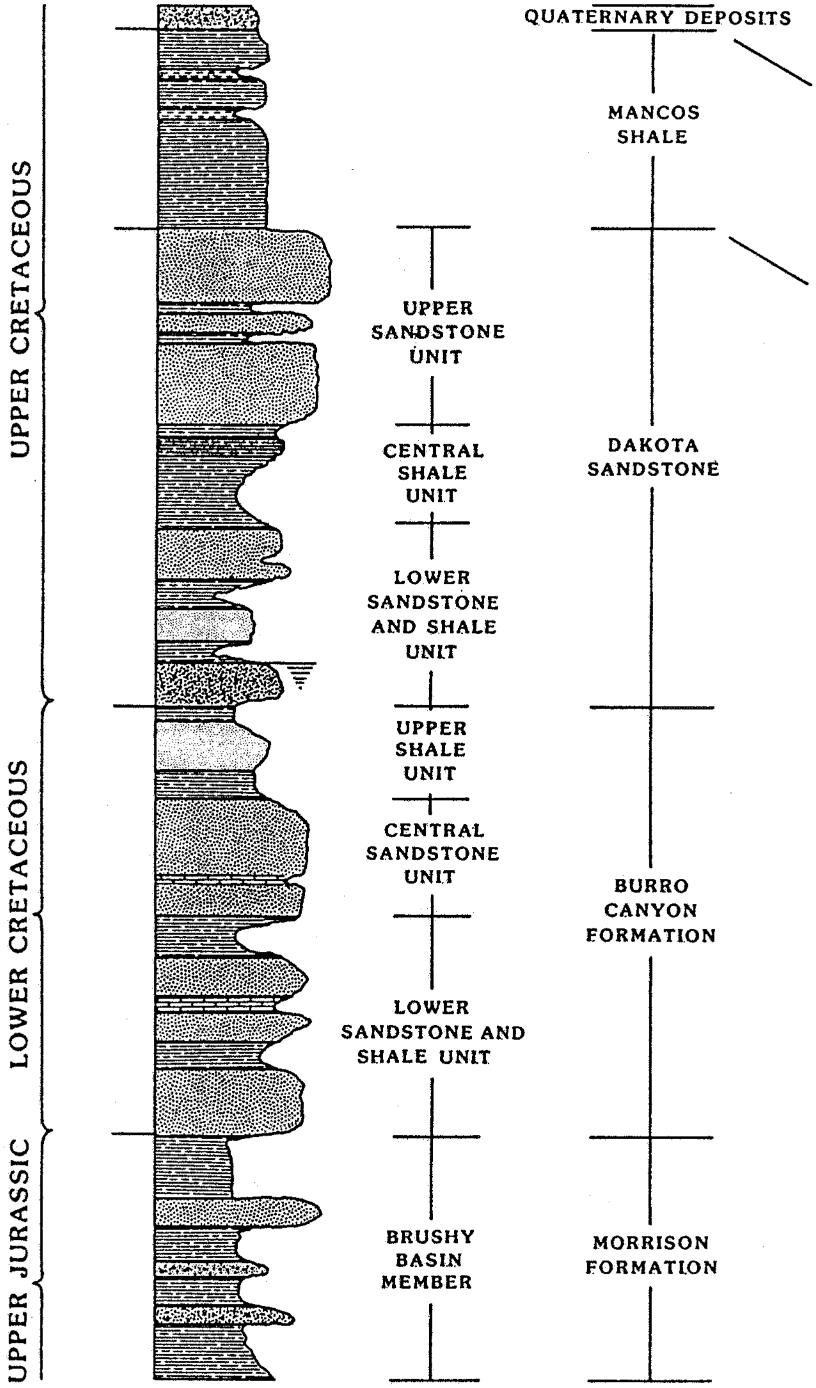
3.2.1 Stratigraphy

The oldest geologic unit encountered at the site during this investigation is the Brushy Basin Member of the Morrison Formation of upper Jurassic age (Figure 8). This unit is composed dominantly of variegated bentonitic mudstone with lesser amounts of sandstone, conglomeratic sandstone, and limestone, of predominantly fluvial origin. The only surface exposure of the Brushy Basin Member near the Coke Oven Site is in the canyon walls of Dry Creek, to the northeast and southwest of the project site, where it forms steep slopes that weather to a characteristic "popcorn" surface consistent with a high montmorillonite content. This unit was encountered in the lower 100 feet of the two deep drill holes, D-1 and D-2 (Figure 7). Drill cuttings and geophysical logs (Figures A-15 and A-16) from this interval indicated a grayish red, slightly purplish or light grayish, claystone of primarily montmorillonitic composition, with lesser, thinner siltstone interbeds. One conglomeratic sandstone bed, approximately eight feet thick, was encountered 25 feet below the upper contact of this unit (Figure 8). This sandstone, located at a depth of approximately 425 feet, is apparently saturated with fresh water.

Conformably overlying the Brushy Basin Member are the alternating conglomeratic sandstones and mudstones of the Burro Canyon Formation of lower Cretaceous age. The sandstones consist of grayish yellow to pale yellowish orange, fine to coarse grained, cross-bedded fluvial sandstone. They are composed predominantly of subrounded to subangular quartz with lesser chert, limestone, and quartzite pebbles up to 3 inches in diameter, enclosed in a matrix of silica and calcite cement. The mudstones are light greenish gray and pale green and rarely reddish brown and display somewhat lenticular bedding. They are variable in composition from silty to sandy with only rare montmorillonitic clay. The Burro Canyon also contains sparse, dense light



Qa

QUATERNARY DEPOSITS (0-15') Residual: Light-brown to brown and gray, stiff to hard, silty sandy clays
Colluvial: Light-brown to brown red, and gray, loose to dense, locally gravelly, silty, clayey sands and sandy silts.
Alluvial: Red to brown, moderately dense to dense, well graded sands and gravels.
Eolian: Light-red to light brown loose to dense, sands & silts.

Km

MANCOS SHALE (0 to 180') Dark-gray to black, soft to hard, interbedded, fissile, locally fossiliferous, marine shales, siltstones and mudstones with thin light to dark gray, fine to coarse grain, well cemented sandstone beds, dark gray, dense hard, thin bedded to nodular limestones, and soft bentonitic claystones. Lower beds intertongue with, and grade vertically into, the Dakota Sandstone

Kd

DAKOTA SANDSTONE (185 to 205') Yellowish-brown and gray, firable to quartzitic fluvial sandstone and conglomeratic sandstone with interbedded, gray to black, carbonaceous, nonmarine shale and minor coal beds. A coarse basal conglomerate that contains water is locally present and contains water.

Kbc

BURRO CANYON FORMATION (150' to 160') White, gray, and light-brown fluvial sandstone and conglomerate, interbedded with green and purplish lacustrine siltstone, shale and mudstone, and thin beds of impure limestone. Sandstones and conglomerates contain water.

Jmb

MORRISON FORMATION, Brushy Basin Shale Member (250 to 500') Chiefly gray, pale-green, red and light-purple bentonite mudstone and fluvial sandstone and conglomerate lenses, which contain water.

NOTES: ≡ Indicates location of ground water at time of drilling.

Lithologic descriptions are from logs of test holes and Williams (1964).

GENERALIZED STRATIGRAPHIC SECTION OF THE COKE OVEN SITE
Section 27&34 , T.46N, , R.16W., Montrose County, Colorado

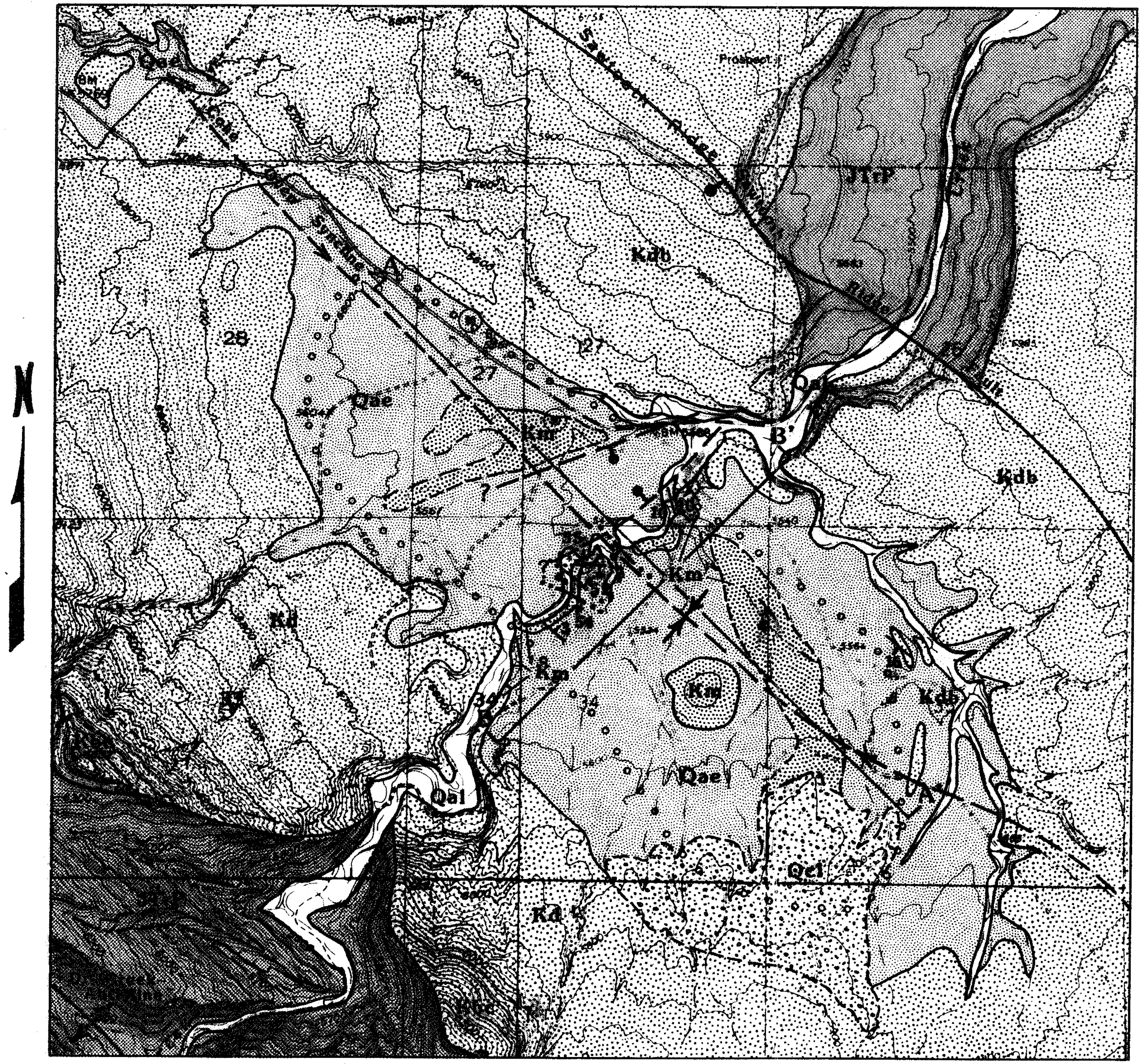
FOX Consulting Engineers and Geologists

Job No: 1-2543-3338	Date: 7/31/82	Figure 8

gray limestone which occurs as thin concretinary layers a few inches thick and occasionally as beds up to several feet thick. Both mudstone and limestone were found to be more abundant in the upper portion of the formation (Figures A-15 and A-16) where they form relatively thick units.

For the purposes of this investigation, the Burro Canyon was subdivided into three units, an upper mudstone unit, a central sandstone, and a lower sandstone and mudstone unit. The upper mudstone unit ranges from 20 to 65 feet in thickness, and appears to thicken southwestward. It consists of gray-green, friable mudstones with thin limestone interbeds. The mudstones appear to increase in sand content with depth. The central sand unit consists of an upper white to buff medium to coarse-grained conglomeratic sandstone overlying a thinner white to buff fine to medium grained sandstone that contains fresh water. Both sandstones contain thin shale interbeds. This central sand displays a fairly uniform thickness of 50 to 55 feet across the site. The lower sandstone - mudstone unit consists of light green medium to coarse grained conglomeratic sandstone and green and gray fissile mudstones. This unit varies in thickness from 73 feet in D-2 (Figure A-16) to 43 feet in Dry Creek canyon, southwest of the site (Cater, 1970, p.44). Sandstone beds within this lower unit are generally saturated with fresh water.

The Burro Canyon Formation crops out as a series of hogbacks and broken cliffs along the north flank fo the Dry Creek anticline to the southwest of the Coke Oven Site and along Sawtooth Ridge to the northeast of the project site (Figure 9). The more prominent sandstone units of this formation form light coloraed resistant cliffs and ledges over relatively unbroken slopes of the Brushy Basin Member of the Morrison Formation. The mudstones weather to hackly fragments and form slopes below the more resistant, overlying Dakota



EXPLANATION:

Quaternary

Qal Quaternary Alluvium - Sand and gravel; silty clayey, poorly sorted flood plain deposits

Qcl Quaternary Colluvium - Talus, sheetwash and slump deposits

Qae Quaternary Eolian Deposits - Sand and silty clayey, unstratified wind deposits

Crataceous

Km Mancos Shale - Marine claystone and siltstone with minor sand and limestone interbeds

Kd Dakota Sandstone - Fluvial sandstone, conglomeratic sands and carbonaceous shale

Kdb Dakota Sandstone and Burro Canyon Formation-Undifferentioted

Kbc Burro Canyon Formation - Fluvial and lacustrine sandstone and mudstone

Pre-Cretaceous

JTrP Jurassic, Triassic, and Paleozoic Sediments

Contact
dashed where approximate, dotted where concealed

Fault
showing dip of plane, ball and bar on downthrown side, dashed where approximate, dotted where concealed

Fold: Anticline/Syncline;
showing trace of axial plane and plunge of axis; dashed where approximate

Strike and dip of bedding

A A' Location of geologic cross section

Source Index

- a) This investigation
- b) Cater(1970)
- c) Dames and Moore(1980)
- d) Williams(1964)

Scale 1:24,000

2000 0 1000 2000 4000 ft

GEOLOGIC MAP of the COKE OVEN SITE

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Sandstone. The limestone beds crop out as resistant ledges within the mudstone slopes.

The Burro Canyon Formation is approximately 155 to 160 feet thick at the project site. The base of the formation was placed at the base of the lowest conglomeratic sandstone above the variegated mudstone of the Brushy Basin Member of the Morrison Formation (Figure 8 and Figures A-15 and A-16). Although this contact is remarkably persistent, locally the conglomeratic sandstone is lenticular and in places the mudstones of the Burro Canyon Formation conformably overlie, and cannot be readily distinguished from, the underlying mudstones of the Morrison Formation (Cater, 1970, p.43).

The conglomeratic cross-bedded nature of the sandstones indicates a fluvial origin for the Burro Canyon Formation. The majority of the mudstone units probably represent floodplain deposits while the limestones and some of the mudstones probably formed in lakes on the flood plains.

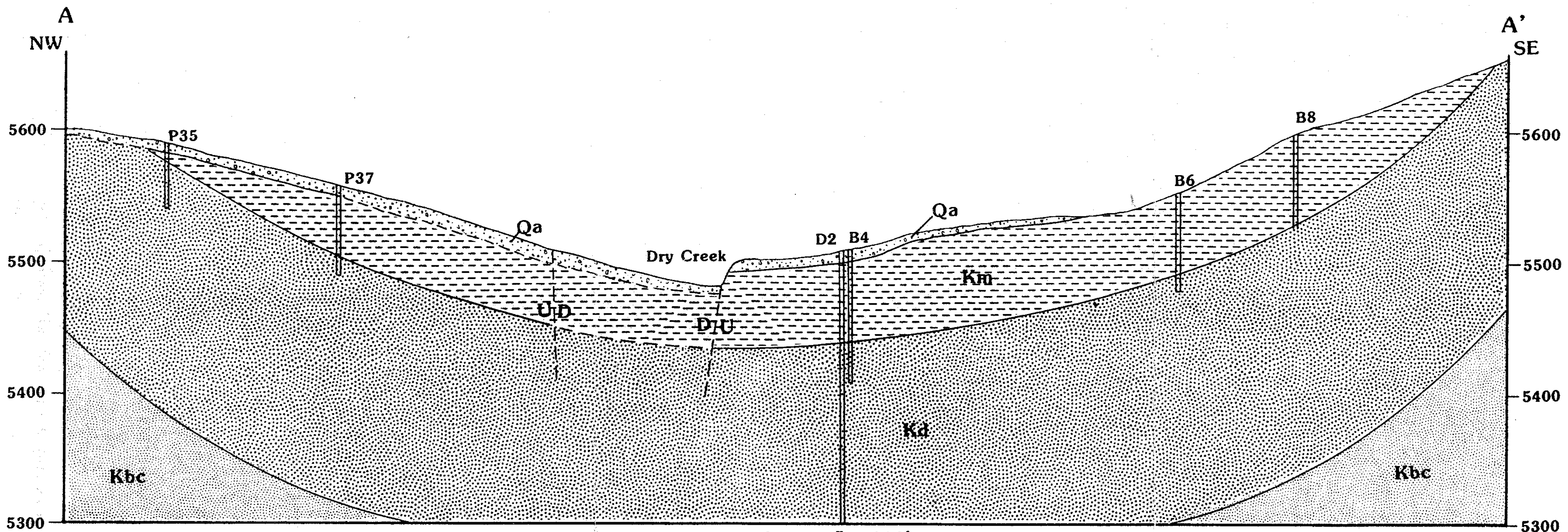
The upper Cretaceous Dakota Sandstone disconformably overlies the Burro Canyon Formation. The Dakota Sandstone is transitional between the nonmarine Burro Canyon Formation and the overlying marine Mancos Shale. The Dakota Sandstone, as examined in the two deep drill holes (Figures A-15 and A-16), and outcrops along Dry Creek southwest of the site (Cater, 1970, p. 45-46) can be segregated into three distinct units: a lower unit composed predominantly of sandstone and conglomerate, a middle unit consisting primarily of carbonaceous shale, impure coal, and sandstone, and upper unit consisting mainly of sandstone and conglomerate. Numerous beds of bentonite and fine clay occur in the upper two units. These beds occur approximately 25, 40, 65, 125, 140 and 165 feet below the Mancos/Dakota contact and range from less than one to four feet in thickness.

The sandstone is gray, yellow and buff, generally coarse grained and crossbedded, but locally fine grained and thin bedded. Upon weathering, it displays a flaggy appearance resulting from thin shaley interbeds. Scattered throughout the sandstone are irregular discontinuous lenses of conglomerate containing chert and quartz pebbles up to 2 inches in diameter. Numerous layers of gray and black carbonaceous shale, buff to tan bentonitic shale and fireclay, and occassional beds of impure coal occur as thin layers interfingered in the sandstone and conglomerate and as thicker beds in the central shale unit. The thickest coal bed encountered during this project was two feet, from 173 to 175 feet below the surface in D-1 (Figure A-15).

The Dakota is approximately 195 feet thick at the Coke Oven Site, however, significant variations in thickness, controlled largely by irregularities of the erosion surface upon which it was deposited, do occur. The lower sandstone unit ranges from 18 to 28 feet. The middle shale unit ranges from 90 to 120 feet while the upper sandstone and conglomerate ranges from 60 to 75 feet in thickenss.

The Dakota Sandstone crops out as long dip slopes which completely encircle, and extend beneath, the site thus defining the synclinal basin structure of the site.

The marine Mancos Shale, of late Cretaceous age, conformably overlies, and is gradational with the Dakota Sandstone. It is the youngest bedrock formation encountered at the site (Figure 10). The formation is remarkably uniform in composition, consisting mainly of thinly bedded, lead-gray to black shale with scattered thin interbeds of concretionary, fine grained, light gray limestone, sandy shale, and sandstone, and in the lower part two layers of bentonite 1 to 8 inches thick located 35 and 50 feet above the Mancos/Dakota contact. The limestone ccurs within the shale as irregular masses up to three feet thick that may have formed as concretions or small localized reefs. The basal portion of the formation contains some siltstone and/or silty sand-



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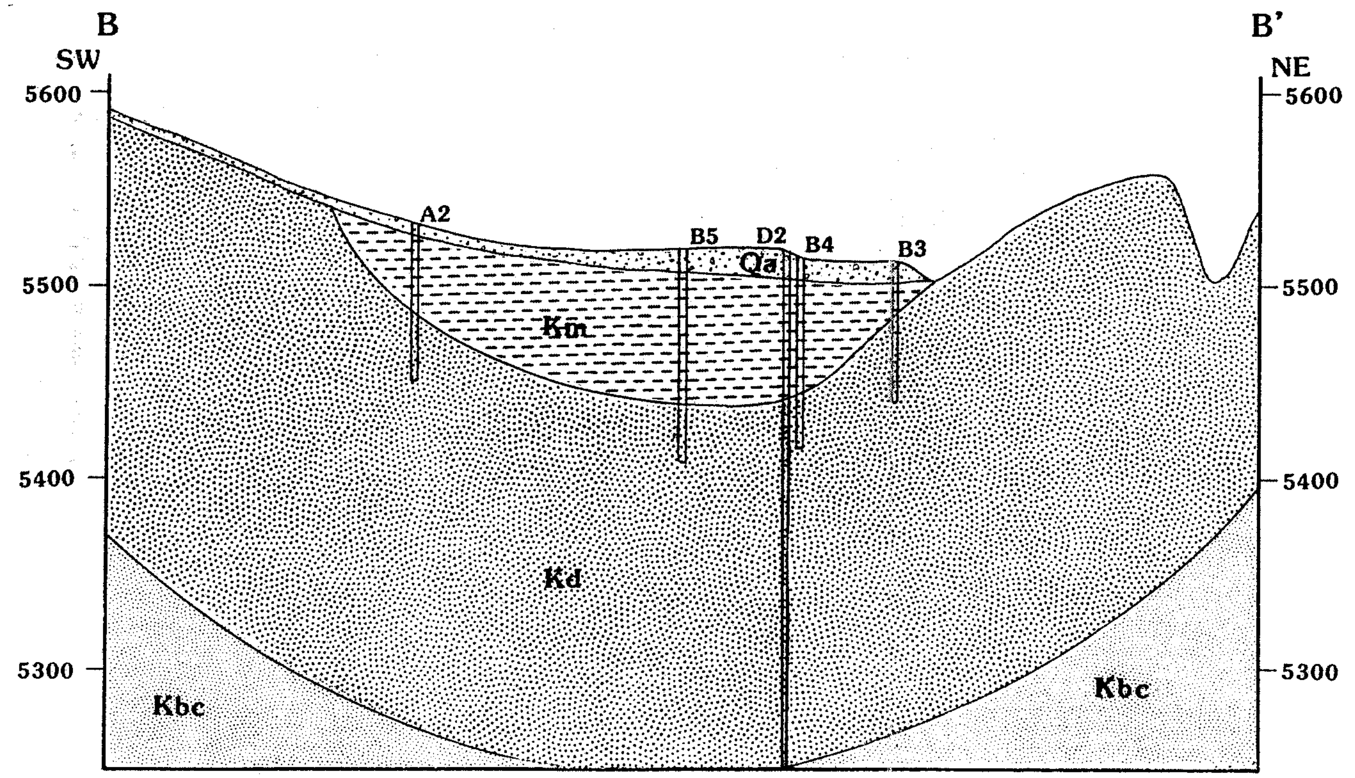
Vertical Scale: 1" 100'



Horizontal Scale: 1" 100'
Vertical Scale: 1" 1000'

EXPLANATION

▨	Qa	Alluvium,Colluvium, and Eolian deposits.
▤	Km	Mancos Shale
▨	Kd	Dakota Sandstone
▨	Kbc	Burro Canyon Formation

GENERALIZED GEOLOGIC CROSS-SECTIONS

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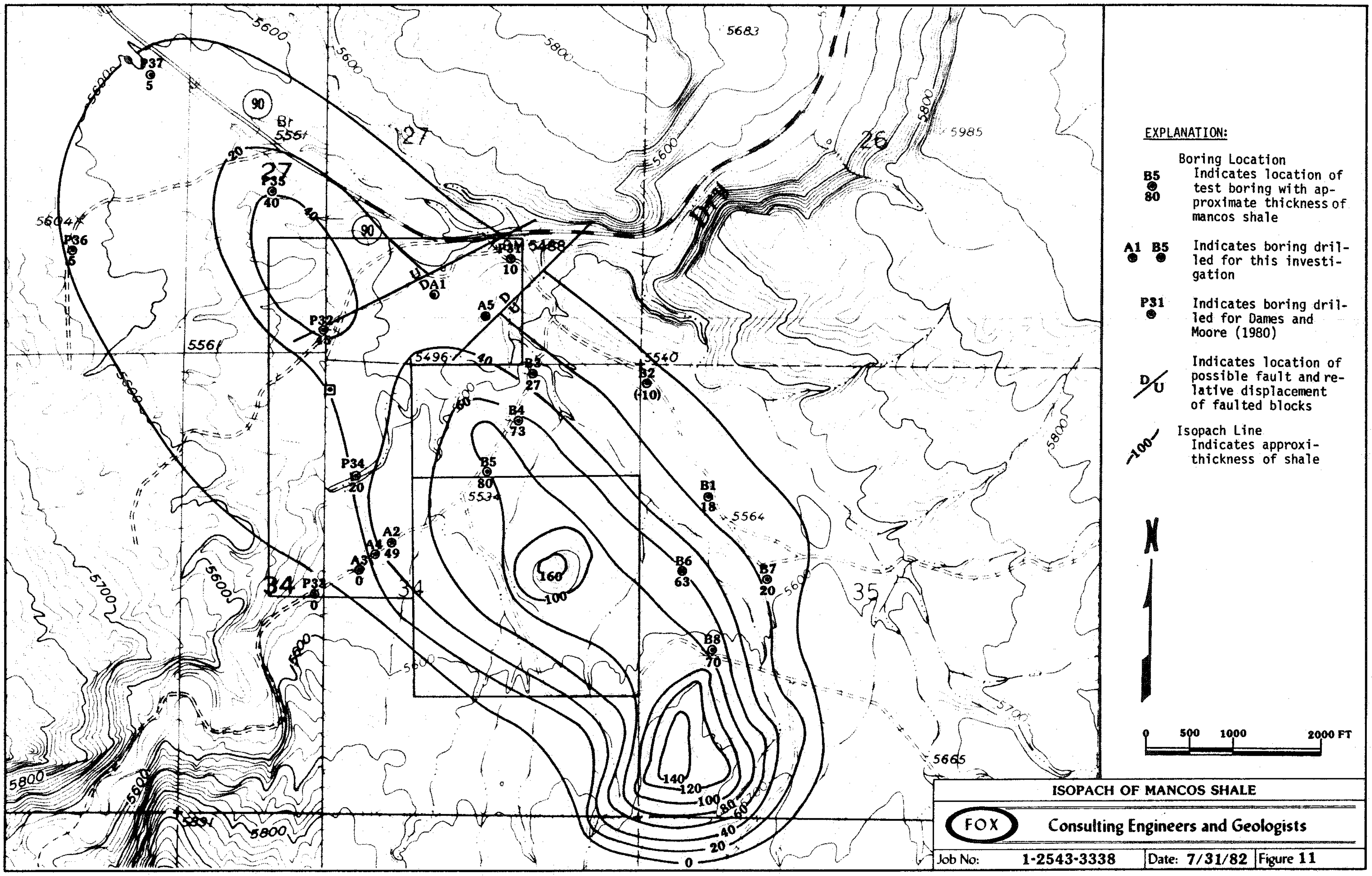
stone which is transitional to the underlying Dakota /sandstone. Late Cretaceous fossils (Gryphaia newberryi) were found in a layer exposed in the banks of Dry Creek, approximately 10 to 50 feet above the base of the formation.

Because of erosion, only the lower portion of the Mancos Shale occurs at the project site. The thickness of this unit varies from 0 to as much as 180 feet depending upon structure and topography (Figure 11). During this investigation, a number of discrepancies related to the extent of the Mancos, as reported by previous studies, were discovered. Much of the area along the southern portion of the site (Southeast 1/4, Section 34, Southwest 1/4, Section 35, Township 46 North, Range 16 West, and Northwest 1/4, Section 2 and Northeast 1/4, Section 3, Township 5 North, Range 16 West) was previously mapped as Dakota (Dames and Moore, 1980; Four Corners Environmental Research Institute, 1977; Williams, 1964) however, preliminary field reconnaissance mapping for this project revealed the presence of a thick section of Mancos Shale in this area (Figures 9 and 11). This conslusion is based upon the presence of abundant limestone float and fossils contained in the colluvial material covering this area.

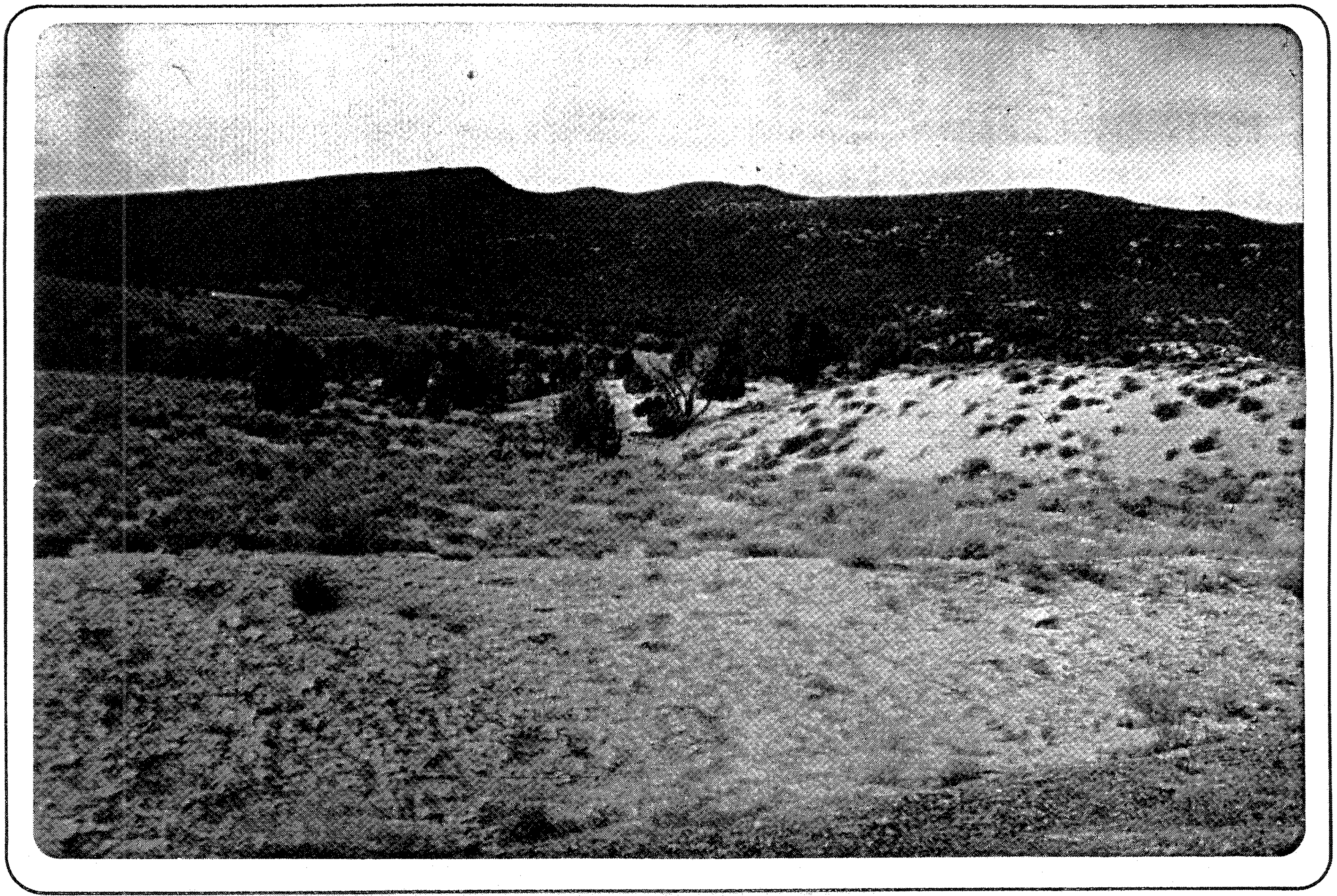
Where it is not covered by eolian silt, the Mancos crops out as monotonous light gray rolling surfaces and rounded hills (Photo 3). Natural exposures of fresh rock were only found along the steeper banks of Dry Creek in the center of the site (Figure 9). The thicker limestone beds are more resistant than the surrounding shale and thus stand out as yellowish - weathering knobs. Surfaces underlain by the Mancos are notably barren and support only sparse vegetation, primarily sagebrush and dryland grasses. This infertility stems from the thinness and tightness of the soils and the low permeability of the underlying shale, all of which promote rapid runoff of precipitaiton. In addition, the shale is relatively rich in salts, particularily sulfates, which rise to the surface during wet weather and form broad



ISOPACH OF MANCOS SHALE

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338 Date: 7/31/82 Figure 11



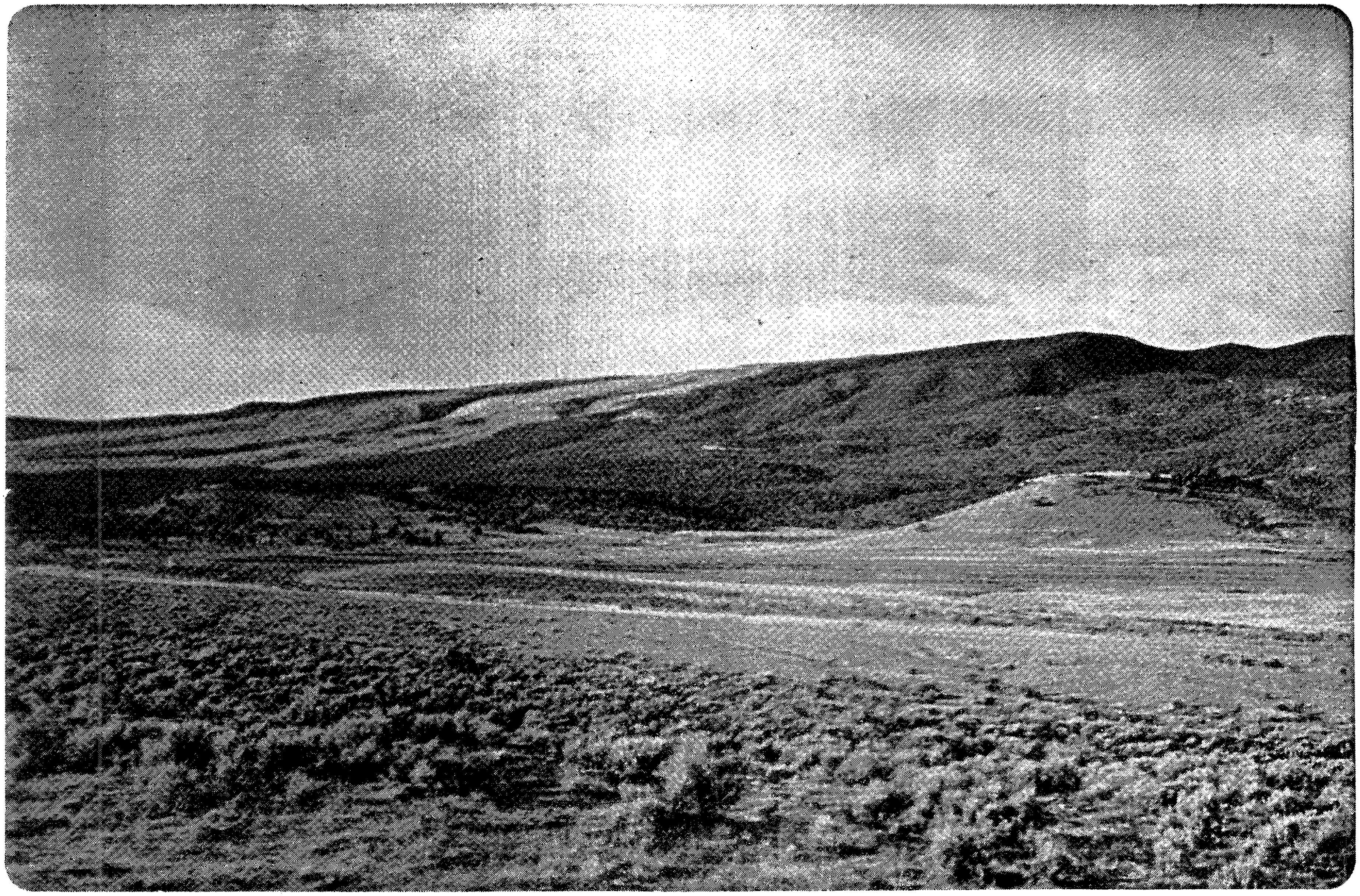
PHOTOGRAPH 3: TYPICAL VIEW OF MANCOS SHALE EXPOSURE AT THE COKE OVEN SITE

white "alkali flats" almost completely devoid of vegetation. Limestone beds support somewhat greater vegetative cover, including pinon pine, and thus have the same overall appearance as the surrounding Dakota dip slopes.

Overlying both the Mancos Shale and the Dakota Sandstone is a relatively thin mantle of Quaternary (Holocene) material, including windblown (eolian) deposits, sheetwash, alluvium, and colluvium. The windblown deposits are the most widespread and thickest of these materials. These deposits consist of indistinctly bedded light red sand, silt and clay that has been partly reworked by low energy fluvial processes. These deposits are confined to the central valley floor of the Coke Oven site (Figure 9). They range from 0 to approximately 15 feet in thickness, with the thickest sections occurring in the center of the valley along the synclinal axis. These deposits support thick growths of sagebrush that contrasts with the sparser vegetation over the Mancos Shale and the growths of pinon and juniper that flourish on the rocky Dakota dip slopes (Photo 4).

Colluvial deposits are the second most abundant surficial material found at the site. These deposits include creep and talus materials which mantle the steeper hills along the southern edge of the site. The majority of these deposits consist of a thin surficial veneer of unstratified, poorly sorted, incoherent soil and rock pebbles and cobbles which mantle the steep slopes around the large flat topped mesa in the Southwest 1/4, Southwest 1/4, Section 35, Township 46 North, Range 16 West (Figure 9). They also include some possible landslide and related slump deposits located in the Northeast 1/4, Northeast 1/4, Section 3, Township 45 North, Range 16 West.

The third surficial deposit encountered during this investigation is the alluvium associated with modern and older channel deposits of Dry Creek. This material consists of well graded fluvial sands and gravels. The only



PHOTOGRAPH 4: SHOWING THE CONTRAST IN VEGETATION OVER VARIOUS LITHOLOGIES, DENSE SAGEBRUSH COVER OVER EOLIAN DEPOSITS (foreground), SPARSE VEGETATION OVER MANCOS SHALE (center), AND PINON AND JUNIPER FOREST OF THE DAKOTA DIP SLOPES (background)

surface exposure of this material was along the channel and floodplain of Dry Creek where it contains numerous intact, or nearly intact, fragments of Mancos Shale resulting from caving and slumping of the stream bank. Older channel deposits appear to be better sorted, containing less fines and fewer fragments of Mancos Shale. These older deposits are only exposed in the cut banks of Dry Creek.

3.2.2 Structural Features

The Coke Oven site is located at the southeast end of the Paradox Valley anticline, the largest single salt-core anticline in the region (Figure 6 after page 13). The anticline formed by diapiric uplift of the underlying Paradox Formation of the Hermosa Group. Subsequent dissolution and flowage of the underlying salt resulted in collapse of the overlying strata and the formation of a large valley trough, 3 miles wide and 30 miles long, along the crest of the anticline. The flanks of the anticline remain, and now form cuesta like rims which dip away from the valley at angles rarely exceeding 9 degrees. Cater (1970) discussed the formation of the Paradox and other salt anticlines of the region in detail.

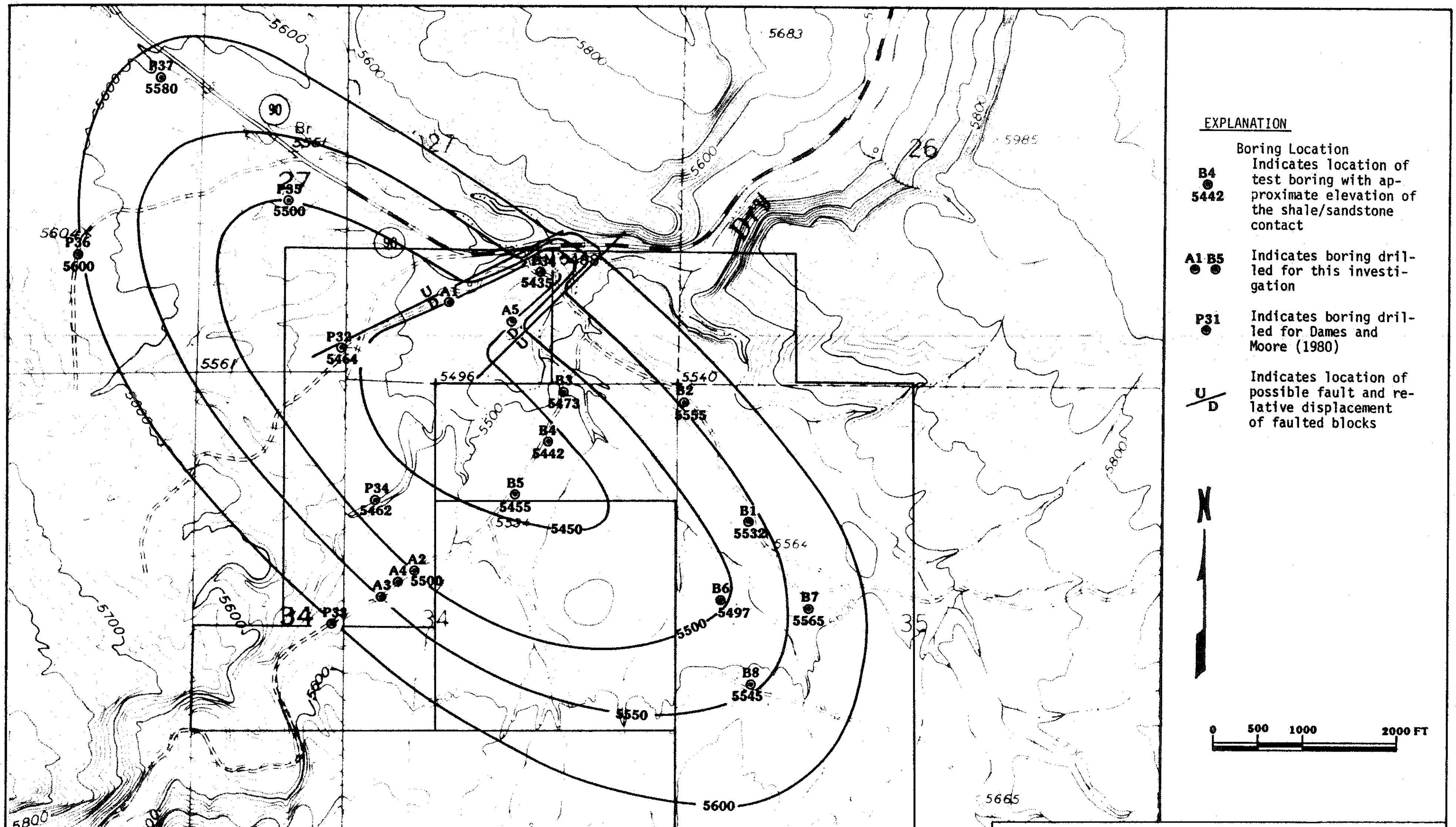
The Paradox Valley anticline comprises three structurally distinct units characterized by the type of structural features formed during collapse of the anticline (Cater, 1970). These are (1) a unit at the northwest end of the valley that collapsed by both downsagging and downfaulting, (2) a large central unit, occupying most of Paradox Valley, where the crest has collapsed by downfaulting, and (3) a unit at the southeast end of the anticline where the crest has downsagged to form a structural basin. Mesozoic rocks are preserved in the downsagged crest of the anticline at either end of the valley, but in the central part of the valley, they have largely been removed. It is the structural basin at the southeast end of Paradox

Valley, termed the Coke Oven syncline by Williams (1964), that is the subject of this investigation.

The Coke Oven syncline overlies a distinct cell or cupola of the underlying salt mass and forms a structural basin that is slightly offset to the northeast from the general trend of the Paradox Valley anticline. The Coke Oven syncline is doubly plunging and bounded by normal faults and anticlines, forming a northwest trending, elongate basin, 3.5 miles long and 1.0 miles wide. Both the structural features and the outcrops of the Dakota dip slopes define the closed basin nature of the site (Figure 12).

The basin is bordered on its northwest end, beyond the area mapped for this investigation (Figure 9), by northeast trending faults (Sections 20 and 21, Township 46 North, Range 16 West). To the south the basin is bordered by the plunging synclinal nose defined by the Dakota dip slopes. The northeast and southwest sides of the basin are bordered by the anticlines (referred to in this report as the Dry Creek and Sawtooth Ridge anticlines) between which the syncline formed by downsagging over the crestal portion of the Paradox Valley antcline. The outer flanks of these lateral anticlines are continuous with, and indistinguishable from, the flanks of the Paradox anticline as a whole. The crests of both of the lateral anticlines are cut by faults that drop the rocks inthe downsagged central basin.

The more striking of these two lateral folds is the Dry Creek anticline along the southwest side of the basin (Photo 5). This anticline separates the Coke Oven syncline from the Dry Creek Basin syncline to the south. Structural relief from the center of the downsagged basin to the crest of the Dry Creek anticline, including displacement on the faults along the crest of the anticline, is about 2600 feet (Cater, 1970, p. 55). Intrusive beds of salt of the Paradox Formation are exposed along the crestline of the anticline but were



STRUCTURE CONTOUR OF SHALE SANDSTONE CONTACT

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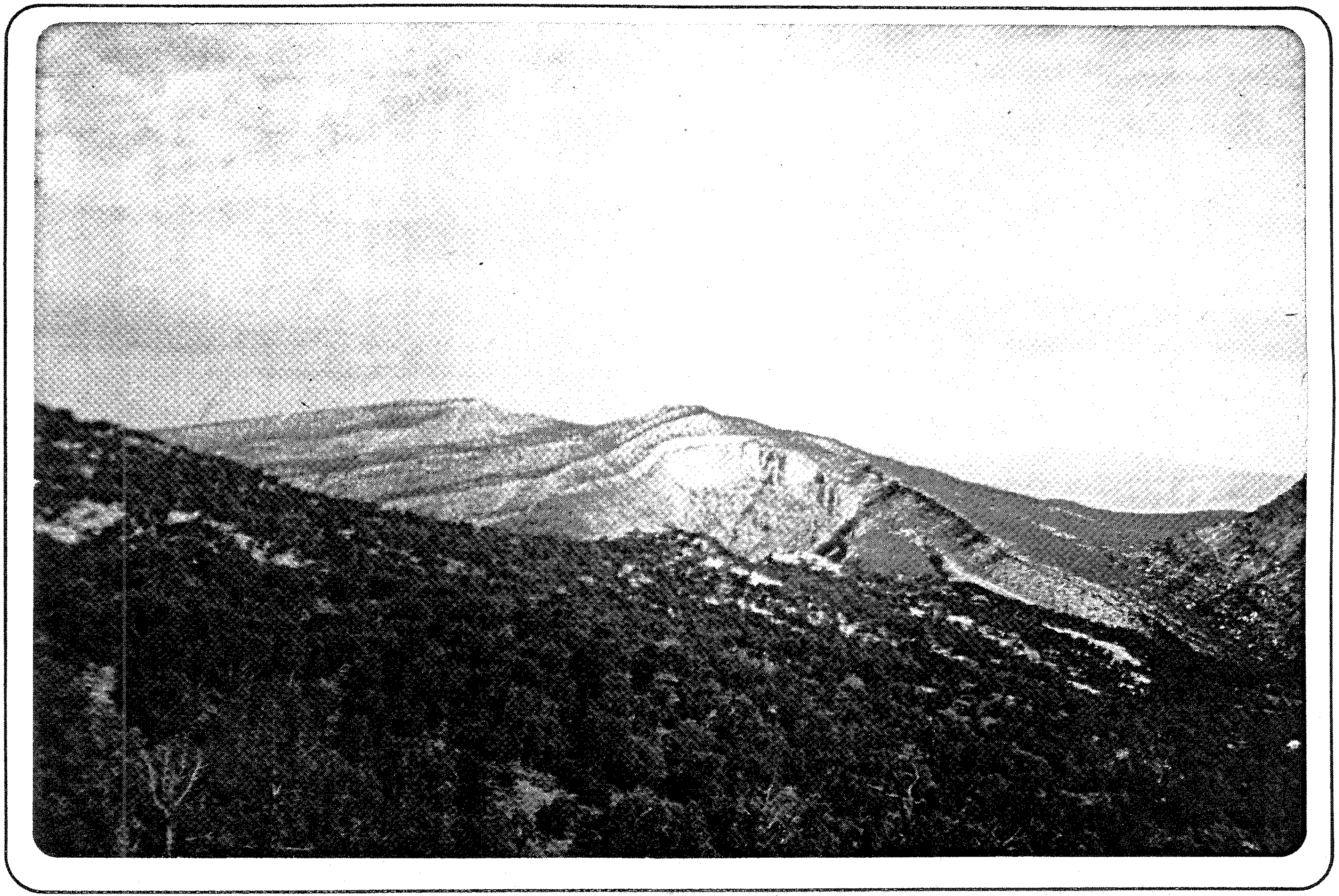


PHOTOGRAPH 5: NORTHWEST LOOKING VIEW FROM, NATURITA RIDGE, OF THE DRY CREEK ANTICLINE APPROXIMATELY ONE MILE SOUTHWEST OF THE COKE OVEN SITE

found to be at a depth of 5,000 feet 200 to 300 feet south of the crestline fault (Cater, 1970, p. 56), attesting to the steepness of the flank of the intrusive core of the Paradox Valley anticline. The northeast flank of the Dry Creek anticline dips steeply near the crest and gradually flattens out as it approaches the center of the Coke Oven syncline.

The anticline along the northeast border of the Coke Oven site is a fairly simple faulted assymetric structure. The southwest flank of this anticline (northeast flank of the Coke Oven syncline) is much steeper than the northeast flank which dips into the Nucla syncline. The crest of the anticline is cut by a southwest dipping normal fault (reffered to as the Sawtooth Ridge fault on Figure 9). The effect of these boundary structures, when combined with the internal doubly plunging synclinal structure of the Coke Oven basin, is the formation of a closed topographic and structural basin.

Cater (1970, p. 57) states that "The central part of the downsagged basin (Coke Oven syncline) is devoid of structural complexities and is unfaulted." Previous investigators (Dames and Moore, 1980) identified three small faults along the embankment of Dry Creek, in the north central portion of Section 34, Township 46 North, Range 16 West and postulated the existence of two larger faults, in the southern portion of Section 27, Township 46 North, Range 16 West on the basis of subsurface data (Figure 9). Our investigation corrobarated the existence of the observed faults, also inferred the two postulated faults, and identified one additional fault. All of these faults can be separated into two basic groups, northwest and west trending reverse faults and northeast trending normal (or reverse) faults.

The northwest trending reverse faults are all exposed in a 30 foot high erosional embankment along the southwest side of Dry Creek near the center of the site (Northwest 1/4, Northeast 1/4 and Northeast 1/4, Northwest 1/4, Section 34, Township 46 North, Range 16 West). This embankment consists of 15 to 20 feet of Mancos Shale overlain by 10 to 15 feet of Quaternary alluvium, predominantly coarse stream deposits, which is in turn overlain by a brown B soil horizon or eolian deposits. The upper portion of the Quaternary alluvium may contain a pedogenic carbonate zone, a possible paleo C-horizon.

The northernmost of these faults strikes North 50 West, parallel to the trend of the synclinal axis at this location. The dip of this fault and the width of the fault zone could not be determined, however, offset of a three inch thick limestone bed within the shale indicated an apparent displacement of approximately 7 inches. This fault could not be traced upward beyond the Mancos Shale and does not appear to displace the Quaternary/Mancos contact. This fault was not reported by previous investigators working in this area.

The next fault to the southwest strikes due west and dips 52 degrees to the north. No distinct marker beds were available to determine the apparent displacement along this struture. It is traceable from the base of the outcrop up to the Quaternary/Mancos contact but does not appear to displace this contact.

The next fault is located approximately 200 feet downstream (southwest) of the previous fault. This fault strikes North 65 West, dipping 54 degrees to the northeast. It is also a reverse fault and approximately 12 to 18 inches of vertical offset was observed along the Quaternary/Mancos contact. However, there does not appear to be an offset at the top of the alluvium at the contact with the pedogenic carbonate horizon.

The fourth fault observed along the creek bank is approximately 100 feet downstream of the third fault. This fault strikes North 65 West, dipping 57 degrees to the southwest. This fault is also a reverse fault and approximately 12 inches of vertical offset was observed along the Quaternary/Mancos contact. Once again the fault appears to terminate in the alluvium above the previous fault, these two faults define a distinct graben 100 feet wide, which has been down dropped 12 to 18 inches.

There may be one additional fault along this exposure, located approximately 40 feet to the northeast of the graben. It strikes North 55 West, dipping 60 degrees to the northeast. Although similar in nature to the graben faults, this structure displays approximately 3 feet of normal fault displacement as evidenced by an offset limestone bed, which is down-dropped to the northeast. As there is evidence of an ancient stream channel 25 feet to the northeast, the nature of the displacement and the sense of motion (i.e., extension compared to the compression) and the magnitude of the offset observed cannot be reconciled with the previously discussed faults, this structure has been assumed to represent a paleo-slump rather than a fault. However, this structure, as do the reverse faults, warrants further detailed investigation.

The second type of faults at the Coke Oven site trend northeasterly (Figure 9 after page 17). Unlike the previously discussed faults, these faults were not directly observable due to concealment by the overlying cover of eolian material. There existence was postulated through stratigraphic interpretation of exposures and subsurface data, and located on the basis of topographic features and rock outcrops. If these faults do exist, they are apparently between 2000 and 6000 feet in length, as the Dakota dip slopes, which define the structural basin, appear to be continuous across the fault projections.

It is our opinion that all the faults observed and postulated at the Coke Oven site are a direct effect of salt deformation processes. The northwest trending reverse faults were produced by a compressional stress, oriented northeast - southwest in upper portion of the sedimentary layer as it sagged in response to flowage or dissolution of the underlying salt units.

The exact sense of displacement along the postulated northeast trending faults is unclear at this stage of our investigation. However, stratigraphic relations observed in bore holes B-2 and P-31 (Figure 12 after page 23), indicate that these faults border a central graben. This would require either a northwest - southeast tensional stress, which may have resulted from a northwest flowage of the underlying salt unit into the central Paradox Valley anticline, or alternatively, these could be reverse faults produced by a north west-southeast compressional stress resulting from downsagging of the basin. Further detailed investigation will be required to determine the exact sense of displacement and origin of these faults.

We do not believe that any of these faults are capable of generating earthquakes above the general seismic background of the region. However, as salt deformation, and consequently foundering of the overlying sedimentary strata, is still continuing, these faults must be considered as active. Thus, potential continued displacement along these faults could deform the ground surface, and must be considered in locating and designing the proposed facilities.

3.3 GEOMORPHOLOGY/GEOLOGIC HAZARDS

The topogrpahy of the site is controlled by a number of factors. The primary controls are the bedrock stratigraphy and structural configuration. The site is located in a syncline formed by collapse along the crest of a salt anticline. This has resulted in a geomorphic basin with relatively resistent Dakota dip slopes (i.e., Sawtooth Ridge) surrounding the more erodable Mancos Shale. Gentle uplift of the Colorado Plateau has resulted in incision of the drainages. This process has produced the "paradoxical" drainage configuration, whereby streams cut across the major structural trend (i.e., Dry

Creek). Quaternary glaciation influenced deposition of alluvial terraces and gravel deposits, although correlation of the various intervals is not as well established as in other areas.

3.3.1 Erosion and Deposition

According to Hunt (1956) the present drainage system was probably established by the Pliocene. Biggar and others (1981) have calculated erosion rates for the Colorado Plateau and Paradox basin. Long term erosion rates for 27 areas of the Plateau were calculated on the basis of geomorphic relations which extend back to between 100,000 and 10 million years. These rates range from 0.1 to 3 feet per 1000 years, with 65% of the values equal to or less than 0.5 foot per 1000 years, and 95% equal to or less than 0.8 foot per 1000 years.

Biggar and others (1981) calculated channel incision rates based on paleomagnectic reversals in fan deposits near the Green River Canyon. They calculated a maximum rate of 1.8 feet and a minimum of 0.5 feet per 1000 years.

Deposition at present occurs primarily as formation of talus and colluvium at the base of slopes, and development of alluvial fans. Reworking of older alluvial terrace, loess and dune deposits is occuring as slopes gradually retreat.

3.3.2 Subsidence and Settlement

The geologic structure of the site indicates that subsidence and settlement, related to dissolution and removal of underlying salt, has occured in the past. The major episode was during Pennsylvanian - Permian time, but minor activity has probably continued since the Tertiary. As salt is removed, the overlying sediments slump into the void. Hite and Lohman (1973) have indicated that this process occurs very slowly as the salt, in spite of its solubility, shows great geologic persistence. Unless disturbed by drilling, salt solution is restricted to the upper surface, which is generally protected from ground water by an impervious clay or anhydrite cap. Dissolution is effective only where saturated brine can escape as continual dissolution requires both an influx of fresh water and efflux of brine. The rate of salt removal depends, amoung other things, on the influx salinity and flow velocity.

Hite and Lohman (1973) calculated the rate of salt removal from the salt content of surface waters and cap rock relationships. The complex nature of the variables involved makes exact determinations very difficult, but they calculated rates between 3 and 900 feet per million years, depending on the date of the cap rock. The evidence strongly suggests that the actual rate is on the lower end of that range.

Subsidence is probably gradual, followed by very slow settlement. Movement along slump faults is probably creep. No on-site geomorphic evidence was found to suggest rapid fault movement or overburden collapse. However, based on the evidence presented in Hite and Lohman (1973) and our interpretation of the origin of the structure of the site, it is our opinion that the basin is an area of active sediment deposition.

3.3.3 Slope Stability

The majority of the slopes surrounding the site are composed of rock outcrops of Dakota Sandstone which dip into the site. Due to the low angle (10 to 30 degrees) of these slopes and the high strength of the upper sandstone unit of the Dakota, these slopes are extremely stable and, in their natural state, present no problems for the proposed construction. However, all excavations located along the margins of the basin should be designed such that these dip slopes are not undercut thus creating a condition that would decrease the natual stability of these slopes.

The only major slopes not composed of Dakota Sandstone are those along the south edge of the basin. These slopes are composed primarily of Mancos Shale with a mantle of colluvium. They display hummocky topography and should be considered potentially unstable. Although this area was not drilled during this initial investigation, it appears that the primary mode of failure is slumping and sliding of blocks of Mancos along the underlying, more coherent Dakota strata. Additionally, minor slope stability was noted during our investigation in the form of small scale caving and slumping of the Mancos Shale along the steep cutbank of Dry Creek near the center of the site (Photo 6).

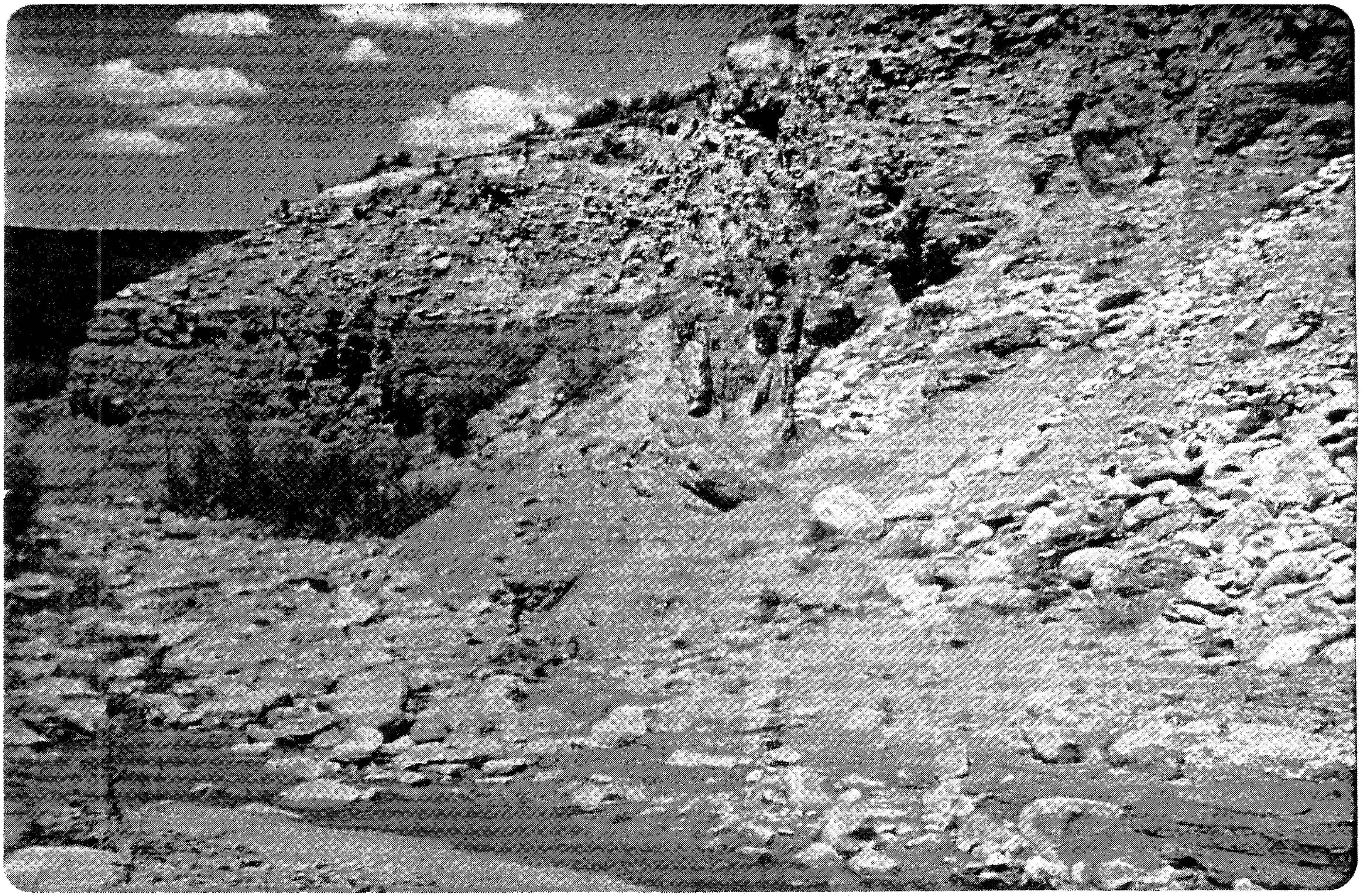
3.3.4 Fault Capability and Seismicity

The site is within the Colorado Plateau Seismotectonic Province of Kirkham and Rogers (1981). They have estimated a maximum credible earthquake magnitude of 5.5 to 6.5, making it one of the more stable provinces in Colorado. Recent faulting is rare in this province except for faults related to the Uncompahgre Plateau or collapse of the salt anticlines.

Evidence indicates that salt collapse has been active in the Quaternary, and may be active today. The faults associated with collapse are gravity faults caused by plastic deformation and slumping of overburden. The non-tectonic origin of the faults implies movement by creep and very low potential for generating even moderate earthquakes.

The salt structures have been associated with deep-seated basement faults, which have experienced recurrent movement in the geologic past. It is not known whether these deep faults are active at present. There is no surface expression of recent movement along these faults, but evidence could be masked by surficial sediments and deformation.

Kirkham and Rogers (1981) give no record of significant historic seismicity for the site area. This, together with geologic evidence at the sur-



PHOTOGRAPH 6: VIEW OF SMALL SLUMP OF MANCOS SHALE ALONG THE CUTBANK OF DRY CREEK ALONG THE WESTERN PORTION OF THE COKE OVEN SITE

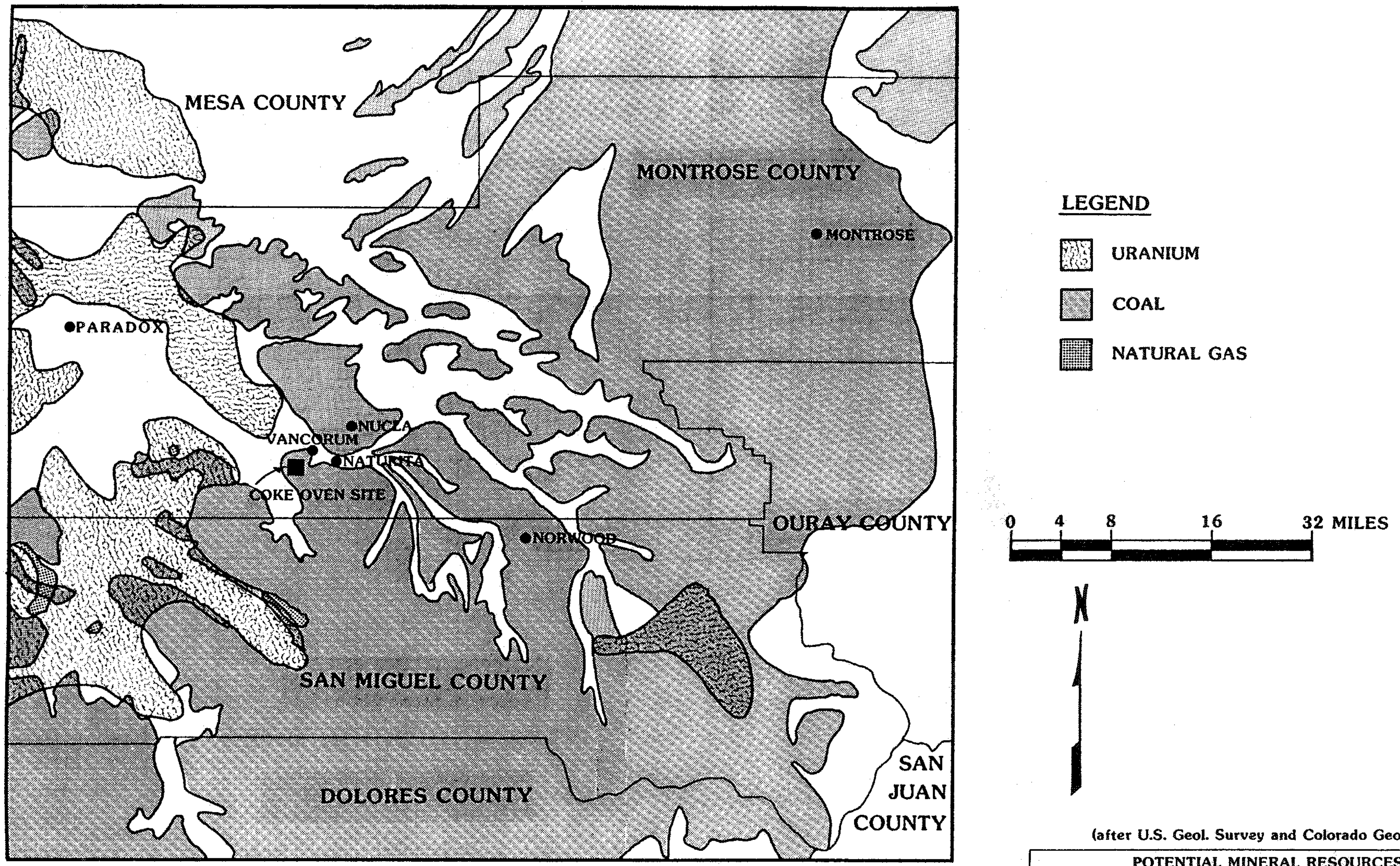
face, indicates that the basement faults will have little or no influence on the facility as compared to the shallower structures, which are non-tectonic. Therefore, the seismic hazard at the site should be minimal.

3.4 POTENTIAL MINERAL RESOURCES

The potential for economic recovery of the following commodities was evaluated as a part of this investigation: uranium; coal; gypsum; potash; sand and gravel; and oil and gas (Figure 13). Other minerals were not considered to be commercially significant in the site portion of Montrose County. Salt production in the county has been used soley in the processing of uranium ores (Del Rio, 1960), and, therefore, is not considered separately in this report.

The site is located just east of the Uravan Mineral Belt, the major uranium-producing district in Colorado. Most of the deposits are found in slightly dipping beds of the Morrison Formation, primarily within the lower Salt Wash Member. Sandstones of the Chinle Formation, which contain large deposits near Moab, Utah, are non-productive in Colorado (Del Rio, 1960). As most of the ore is found within the mineral belt rather than in similar areas outside the belt, the potential for economic uranium deposits beneath the site is considered to be lower than in areas to the west.

The site is within the Nucla-Naturita Coal Field. The coal occurs within the Dakota Sandstone. On-site drilling encountered carbonaceous shale to lignitic sub-bituminous coal in the Dakota at depths of 105 to 175 feet. This coal is found primarily in two distinct seams, 1 to 2 feet thick, located approximately 85 to 105 feet below the Dakota/Mancos contact. Due to the thin nature of the seams, the thickness of the overburden, the limited lateral extent and the low grade of the deposits, this coal is not considered to be economically recoverable.



(after U.S. Geol. Survey and Colorado Geol. Survey)

POTENTIAL MINERAL RESOURCES MAP

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Potash has been mined from the Paradox Formation of the Hermosa Group around Moab, Utah, but not from the area near the site. According to Hite and Lohman (1973), the potash will only be at favorable mining depths within those areas where the Paradox or Honaker Trail Formations of the Hermosa Group are exposed. Because of the depth of these units beneath the site, approximately 2500 feet, potash is not considered to be an economic mineral at this site.

Sand and gravel deposits exist on the site, but no testing was conducted to evaluate this material. The deposits occur in stream drainages and Quaternary terraces and colluvium. Thicknesses are variable, though generally thin, and the deposits most likely contain significant amounts of clay and silt. The low stripping ratio (1:1 or less) of these deposits does make them an attractive source of aggregate for use in construction of on-site facilities. However, the small volume of these deposits combined with the existence of commercial operations nearby, that are closer to the major market areas, make these deposits economically unattractive to commercial operations at the site.

The lack of drilling and testing in the area makes evaluation of oil and gas potential very approximate. This evaluation was made on the basis of information available in recent literature, Petroleum Information Corporation's Rocky Mountain Geological Library, and the Colorado Oil and Gas Commission.

There are no well records for Township 46 North, Range 16 West. The oil and gas wells nearest the site are in Township 45 North, Range 16 West. Six scout cards were found for that township, with wells in Sections 4, 5, 9 and 12. Four were dry and abandoned. One well in Section 4 had initial potential flow of 630 MCFGPD from three intervals in the Rico and Hermosa Formations when completed in 1958. The other well, completed in 1963, had initial potential flow of 70 MCFGPD from the Permo-Pennsylvanian interval (Rico Formation and Hermosa Groups). Neighboring gas fields (Hamm Canyon, Andy's Mesa and Hamilton) produce from structural traps. The gas traps are controlled by faults bordering the salt anticlines, where arkosic sandstones of the Honaker Trail Formation are downthrown and in fault contact with petroliferous shales and salt of the Paradox Formation (Krivanek, 1981). This type of trap could be the control on gas in Township 45 North, Range 16 West and, if so, may provide gas objectives near the site. However, operation of the site will not prevent recovery from reservoirs beneath it.

4.0 HYDROLOGY

4.1 SURFACE WATER HYDROLOGY

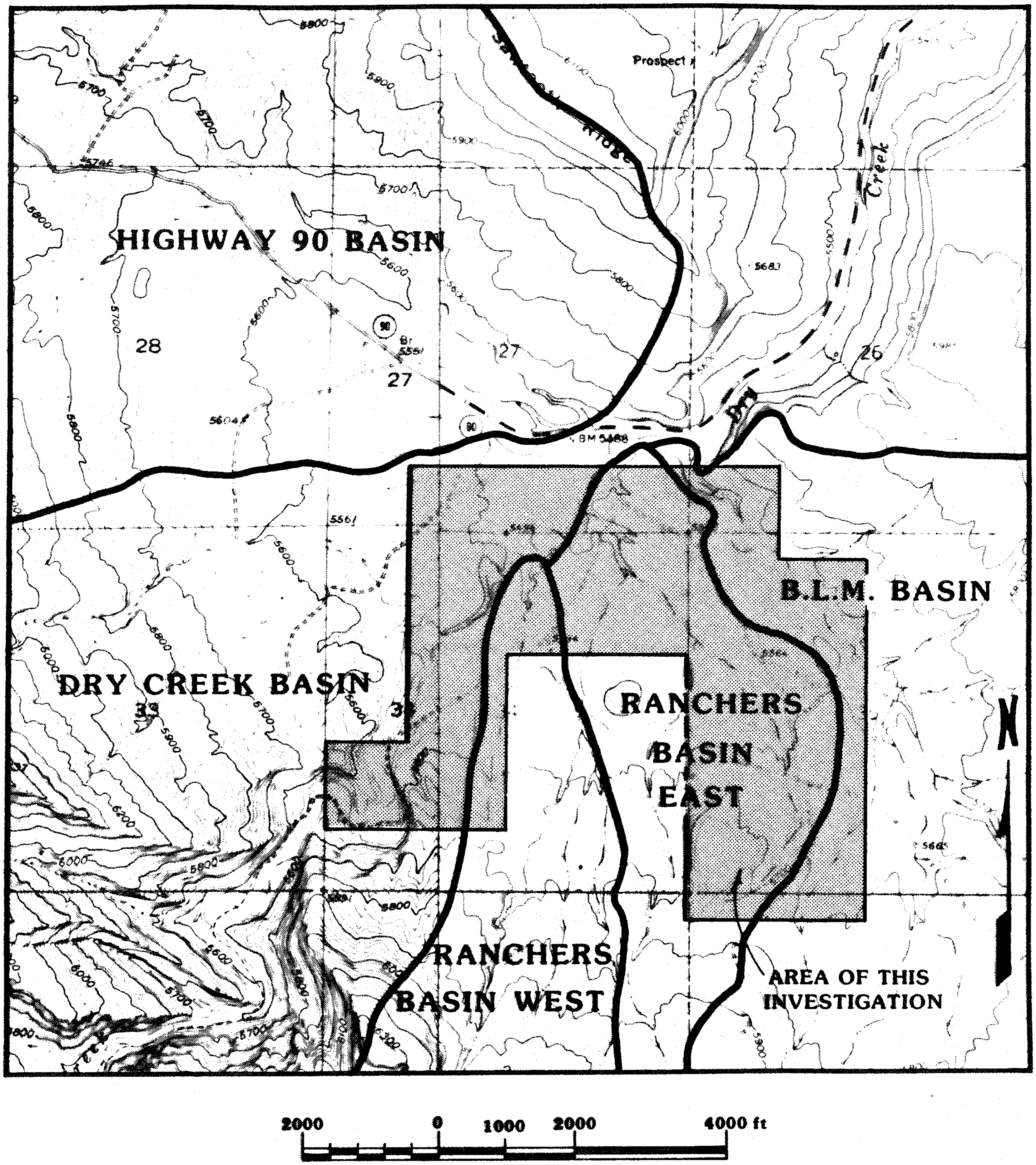
The site is within the Dry Creek drainage basin. Dry Creek flows from southwest to northeast across the area, and joins the San Miguel River near West Vancorum, approximately one mile downstream from Naturita. The San Miguel is tributary to the Dolores River, which flows into the Colorado River northeast of Moab, Utah. The Dry Creek basin drains 165 square miles. The on-site drainage has been divided into four tributary basins; the State Highway 90 basin is 6.5 square miles in area, the Ranchers east basin 0.9 square miles (Photo 7), the Ranchers west basin 1.3 square miles, and the BLM basin 5.9 square miles (Figure 13).

The drainage pattern is radial to dentritic. The radial pattern reflects drainage into the topographic basin, the dendritic pattern reflects drainage developed in alluvial and shaley materials within the basin. The tributary streams within the basin head on the surrounding divides. The average gradient for Dry Creek through the site area is 70 feet per mile (1.31%). Average gradient of the major tributaries on site is 200 feet per mile (3.8%).

4.1.1 Water Quality and Use

No surface water samples were analyzed as a part of this investigation. Data contained herein was abstracted from permit work done by Ranchers Exploration and Development Company (Four Corners Environmental Research Institute, 1977) and subsequent monitoring data (Colorado Department of Health, 1978).

Dilution factor for Dry Creek waters entering the San Miguel River averages 145, varying from 55 in 1970 to 251 in 1968. Results of water quality analyses from two San Miguel River samples are given in Table 1. Sample SM-32 was collected at the bridge crossing of Colorado Highway 97 in Naturita, sample SM-34 was collected at the bridge less than one mile downstream from



SURFACE WATER DRAINAGE BASINS OF THE COKE OVEN SITE

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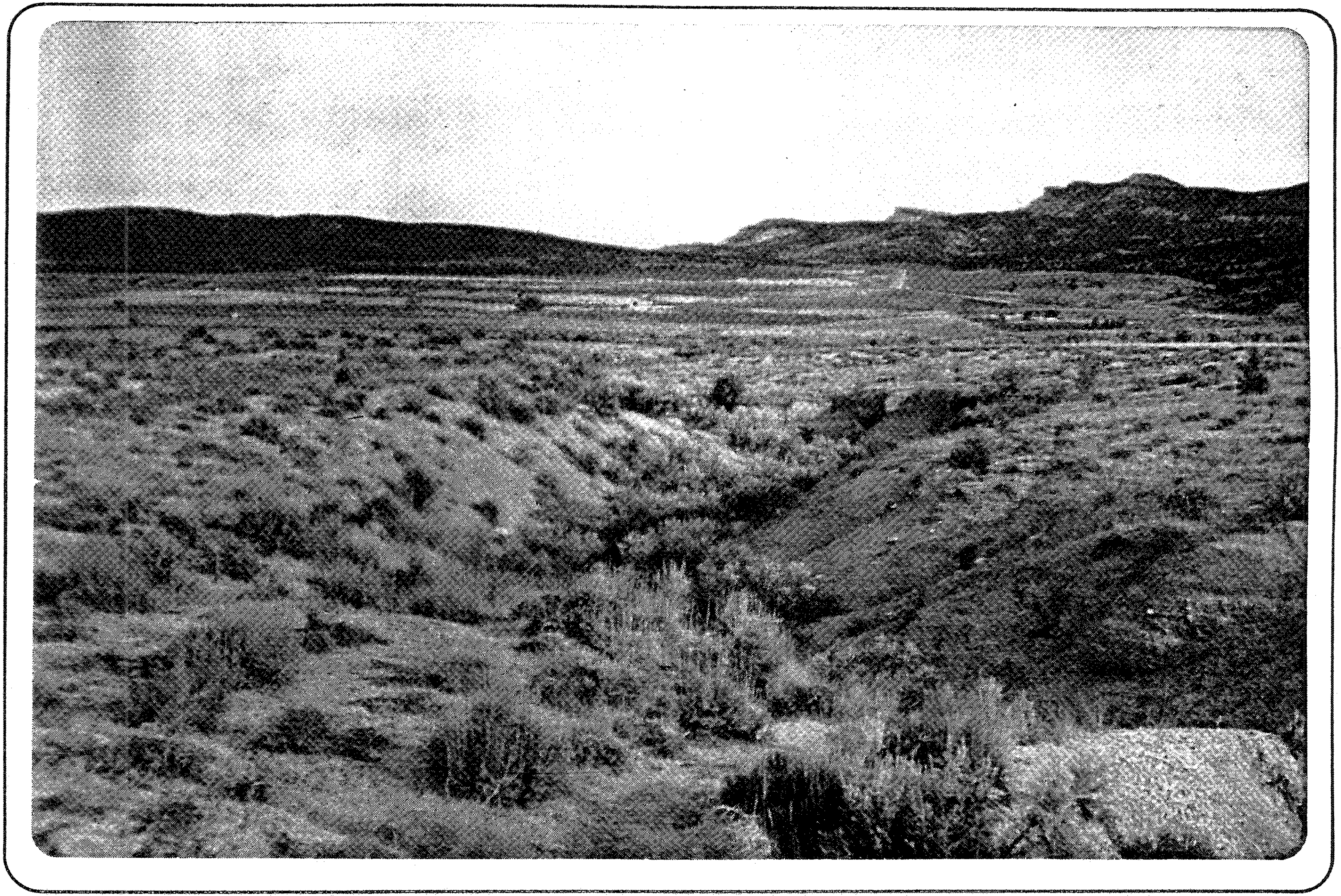
Figure 14



PHOTOGRAPH 7: NORTH LOOKING VIEW OF THE EAST (main) FORK OF THE RANCHERS BASIN EAST DRAINAGE

TABLE 1 - SAN MIGUEL WATER QUALITY ANALYSES(1)

(mg/l)	SM-32	SM-34 Dry Creek
total iron	0.10	0.15
total chromium	0.055	0.055
manganese	0.24	0.050
zinc	0.030	0.030
copper	0.040	0.040
molybdenum	0.33	.33
lead	0.11	.11
dissolved oxygen (ppm)	10.2	9.8
temperature (°F)	51	49
pH	8.4	8.4
total alkalinity ($^{\text{mg CaCo}_3/1}$)	120	29
turbidity	2	2
TSS	2	5
total phosphate	0.010	0.018
total nitrate	1	1

(1) from Four Corners Environmental Research Institute (1977)

the Naturita tailings pile. Dry Creek joins the San Miguel River between the two sample locations.

Results of two analyses on Dry Creek water is given on Table 2. These analyses display high total dissolved solids and high sulfate contents consistent with other streams flowing over Mancos Shale and salt exposures. Dry Creek is diverted for irrigation upstream from the site. There is no known use of the surface water between the site and the confluence of Dry Creek with the San Miguel River.

4.1.2 Flood Potential

Stream discharge for Dry Creek and the San Miguel River at Naturita, Colorado was obtained from publications of the U.S. Geological Survey. The records for the San Miguel River (station 1755) go back to 1918 (Patterson and Somers, 1966). The gage is located in the Southeast 1/4, Section 19, Township 46 North, Range 15 West on the left bank 20 feet downstream from the bridge on State Highway 97, 1.2 miles downstream from Naturita, Colorado. The gaged area is 1,080 square miles, and the station elevation is 5392.85 feet above mean sea level. Natural flow is affected by irrigation reservoirs and diversions, but these probably do not affect peaks (Patterson and Somers, 1966). The peak stage for the period of record occurred on April 15, 1942 and was 9.80 feet (gage height), with a corresponding discharge of 7,100 cfs.

Using the flood determination methods of Patterson and Somers, (1966), the mean annual flood for Dry Creek would be 600 cfs. This is based on a drainage area of 165 square miles and a mean elevation of 8,000 feet. The mean annual flood is defined as that event with a recurrence interval of 2.33 years. By the same methods the 50 year flood would be 1800 cfs (Patterson and Somers, 1966).

The U.S. Geological Survey (1973) possesses records for a station on Dry Creek for the period from 1966 to 1970. The station is located in the North-

TABLE 2 - DRY CREEK WATER QUALITY (mg/l)(1)

Date	S:0$_2$	Al	Fe	Mn	Ca
Oct. 1960	15	1.0	0.06	0.0	420
Nov. 1976	--	0.1	0.05	0.09	--

Mg	Na	K	HCO_3	SO_4	CL	F
535	452	15	322	3670	158	1.2
--	--	--	230	2360	78	0.5

NO_3	PO_4	TDS	pH	pci/l Beta-Gamma	Ra Pci/l
0.0	0.08	5040	7.1	50	0.1
0.1	--	6010	7.8	--	--

mg/l U	As	Se	Ba	Cd	Cu	Zn
12	0.00	0.06	--	--	--	--
37.4	0.04	0.01	0.166	0.001	0.005	0.021

V	Mo	TOC	tot. Hg	Pb	Ag	Co
--	--	--	--	--	--	--
0.012	0.001	33.4	0.0022	0.001	0.001	0.001

Ni	pci/l Ra-226	pci/l Ra-228
--	--	--
0.01	2.3±1.1	4.8±4.0

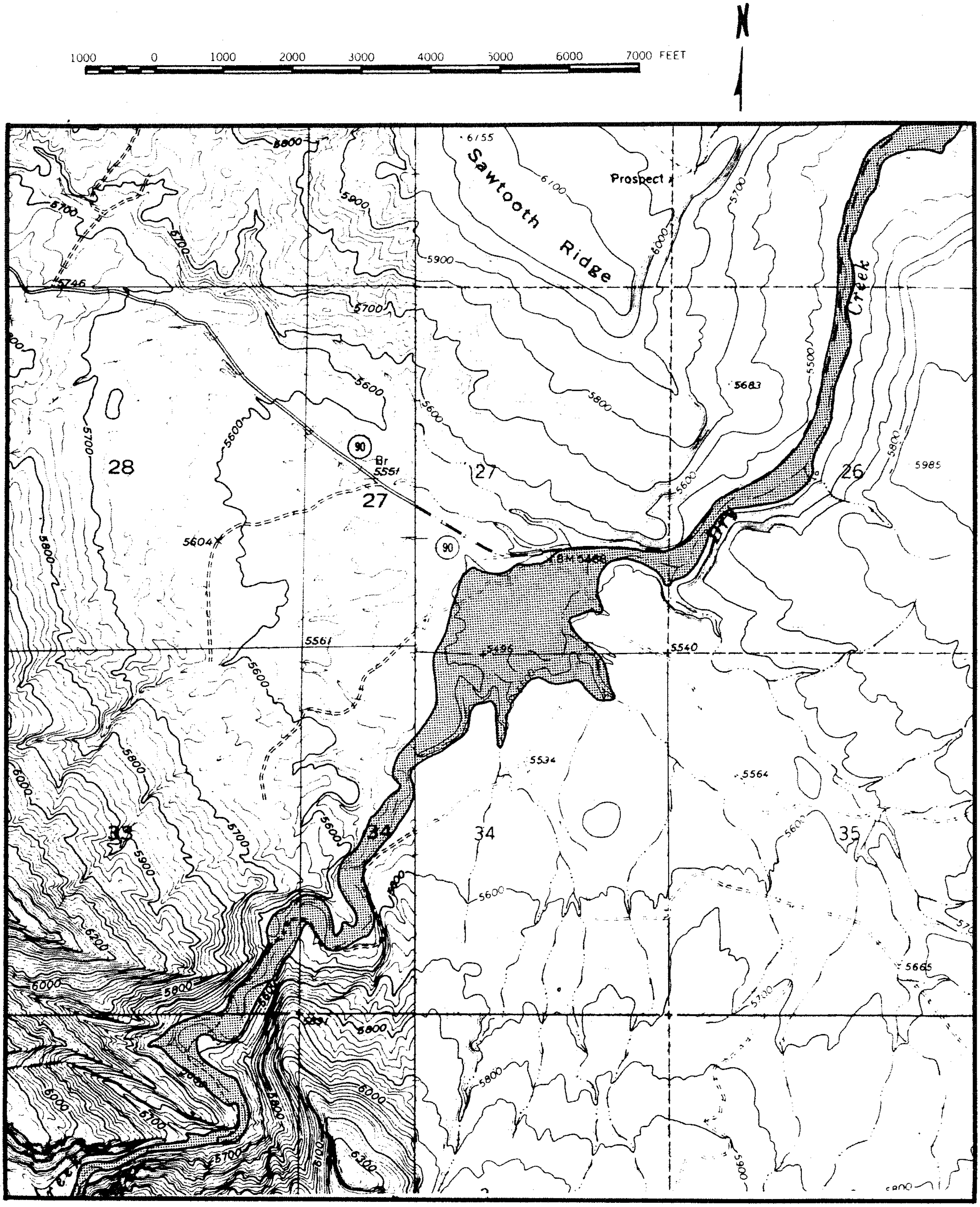
(1) from Four Corners Environmental Research Center (1977)

east 1/4, Northwest 1/4, Section 10, Township 44 North, Range 16, West, San Miguel County, on the right bank 50 feet upstream from the ford, 0.3 miles upstream from the unnamed tributary, 1.2 miles downstream from Dead Horse Creek, 14 miles south of Naturita. The elevation is 6,270 feet and the drainage area is 89.5 square miles. There are diversions for irrigation above the station. Peak discharge for the period of record was 5,660 cfs, with a corresponding gage height of 8.31 feet, on September 5, 1970. This is three times higher than the 50 year flood discharge calculated by the regression method of Patterson and Somers (1966). It also represents 80% of the maximum historic flood for the San Miguel River, as recorded in 1942. As the drainage area at the Dry Creek gauging station represents only 8% of the total San Miguel drainage at the Naturita gauging station, this flood value appears to be extremely anomalous. There are three possible explanations for the discrepancy: 1) the event was of a large recurrence interval; 2) the methods of Patterson and Somers (1966) are inappropriate for Dry Creek; or 3) the data was recorded incorrectly. We are attempting to obtain the original gauge data for these stations to evaluate the validity of this value.

The potential flood limit map (Figure 14) is very preliminary. It is based on the maximum historic flood of 5660 cfs and a resulting crest height of 8 feet. Further investigation would be necessary to establish design flood plain limits.

4.2 GROUND WATER HYDROLOGY

Very limited information exists on the hydrogeology of southwestern Colorado and the area around the site. With the exception of information on ground water use available through the Colorado State Engineer's Office, the only ground water information available is that compiled by the various uranium companies and their consultants to obtain mine permits and radio-



▨ Area of inundation assuming an 8-foot flood crest

POTENTIAL FLOOD LIMIT MAP

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Figure **15**

active lisences. We have utilized this information, augmented with data obtained during our field investigation program, in preparing the following ground water hydrology discussion.

Potential aquifers and estimated well yields of the Coke Oven site and surrounding area are summarized in Table 3. As our preliminary site investigation concentrated on the first 500 feet below the site, our groundwater discussion is limited to those aquifers which may be present within this first 500 feet. These include alluvial deposits associated with the Dry Creek drainage, the basal conglomeratic sandstone unit of the Dakota Sandstone, sandstones of the central and lower units of the Burro Canyon Formation, and thin conglomeratic sandstone layers in the Brushy Basin member of the Morrison Formation.

4.2.1 Alluvial Aquifer

Ground water was encountered in borings A-1 and A-5 (Figures A-1 and A-5) to the northwest of Dry Creek. This water is perched in the alluvial desposits above the Mancos Shale. Ground water in the alluvium is unconfined and in direct hydraulic connection with the surface water in Dry Creek. It is therefore considered to be tributary groundwater. Consequently, the hydraulic flow are approximately of the same magnitude and direction as the surface water gradient. Recharge occurs by direct infiltration of percipitation and seepage of surface water from Dry Creek. Discharge from the alluvial aquifer occurs as slow percolaton into underlying bedrock formations and as recharge to Dry Creek during low flow periods. As a result, the water table can be expected to fluctuate seasonally; reaching a maximum elevation in mid-summer after spring rains and runoff have recharged it, and declining to a minimum level in mid-winter through base flow to Dry Creek.

This shallow ground water appears to be limited to the alluvium in and adjacent to the stream bed and to the area north of the stream. Although

TABLE 3 - SUMMARY OF GROUND-WATER RESOURCES IN WESTERN COLORADO(1)

System	Formation	Thickness Feet	Water Supply
Quaternary	Valley-fill deposits	10-140	Principal source of water to large-capacity wells in the area. Yields as much as 1,000 gpm.
Cretaceous	Mancos Shale 1000-5000 feet (West of Park and Sawatch Ranges).		Supplies water to stock and domestic wells locally where it contains fractures or weathered zones, but water generally highly mineralized. Not generally considered a source of water.
	Dakota Sandstone (Includes Burro Canyon Formation in southwestern Colo.)	As thick as 300	Source of water to stock and domestic wells; yields as much as 40 gpm. Locally the water is saline.
	Morrison Formation	250-600	Source of water to stock and domestic wells locally.
Jurassic	Curtis and Summerville Formations	50-200	Source of water for stock and domestic wells.
	Entrada Sandstone	50-100	Source of water for stock and domestic wells. Locally yields more than 25 gpm.
Triassic	Glen Canyon and Wingate Sandstones and older Triassic rocks	As thick as 500	Sandstones are sources of water to stock and domestic wells.
Permian and Pennsyvanian	Permian and Pennsylvanian rocks	As thick as 13,000	Sandstone beds commonly yield saline water. Not generally considered a source of water to wells.
Mississippian	Leadville Limestone	50-200	Yields water from (fractures and solution openings. Yields as much as serveral thousands gpm locally. Extent of large yield potential is unknown.
Devonian Ordovician Cambrian	Pre-Mississippian rocks	As thick as 2,500	Yields small supplies of potable water at depths less than 2,000 feet.
Precambrian	Precambrian rocks		Wells derive water from fractures and weathered material. Source of water for domestic and stock supplies; yields are generally less than 10 gpm.

(1) After Pearl (1974)

several holes drilled northwest of Dry Creek encountered this shallow ground water, none of the test holes drilled for this project, or by previous investigators (Dames & Moore, 1980), encountered saturated alluvium south of Dry Creek.

No samples of shallow ground water were collected for this investigation. Presumably, the shallow ground water quality is similar to the surface water quality discussed above. Data on shallow ground water quality collected by previous investigators is sparse and poorly documented. Details on well construction, particularly seals between the shallow ground water and bedrock aquifers, are unknown. Analytical results, display large variations, up to an order of magnitude for some parameters, particularly chloride, conductivity, and total dissolved solids. Based on this data (Table 4), it is evident that the shallow ground water is a calcium - sulfate water with a high total dissolved solids content, that exceeds EPA Drinking Water Quality Standards (1975) for sulfate and total dissolved solids. This data is consistent with the fact that the Mancos Shale contains high concentrations of soluble salts, particularily gypsum, which are easily leached out by downward percolating rainwater.

Water quality monitoring of radionuclides and heavy metals at the Rancher's uranium leaching project (Colorado Department of Health, 1978), indicates gross alpha activity, gross beta activity, and Radium 226 activities which exceed EPA standards (EPA, 1975). Data available from the Health Department is summarized in Table 5. Again, although the locations of the wells are known, data regarding the construction of the well and the geologic materials from which the water samples were collected, is unknown. However, as all of the wells are less than 50 feet deep, presumably this water is drawn from alluvial materials or sandstone lenses in the Mancos Shale. Regardless of the source of these samples, as the Rancher's monitoring data

Table 4: Alluvial Aquifer Water Quality Data(1)

	Average	Range
Acidity as $CaCO_3$ mg/l	33.0	.1-64.0
Alkalinity as $CaCO_3$	512.00	370.00-776.00
Chloride as CL mg/l	125.00	44.0-314
Conductivity umhos/cm	4338.00	2900-6600
Hardness as $CaCO_3$ mg/l	1874.00	77.5-3890
Sulfate as SO_4 mg/l	397.00	48.0-750
Total Dissolved Solids mg/l	2835.00	1890-4340
pH units	7.55	7.00-8.20

(1) from Dames and Moore (1980)

TABLE 5: RANCHER'S WATER QUALITY MONITORING DATA (1)

Well	Location	Sampling Data	Gross Alpha	Gross Beta	U*	Ra 226	Ra 223
GW-2	middle of north fence	4-77	-	-	6.0	0.9	1.0
		9-77	-	-	-	2.5	-
		10-77	-	-	-	0.4	-
		1-78	-	-	13.3	1.5	-
GW-3	middle of west fence	9-77	-	-	-	2.5	-
		7-73	-	-	66.7	-	-
GW-4	northwest corner	9-77	-	-	-	10	-
		11-78	23c43	MDA	9.7 u 0.7	2.14c0.24	-
GW-5	middle of south fence	11-78	120c33	40c16	16.8 u 1.3	13.94c0.65	-
GW-6	100 yards west of middle of east fence	9-77	-	-	-	100	-
		1-78	-	-	$0.5x10^{-1}$	-	-
GW-7	northeast corner	1-78	-	-	-	4	-
		11-78	31c27	MDA	6.4 u 1.2	3.02c0.28	-

MDA - minimum detectable activity
* - 667 pCi U per mg uranium
c - counting error term; ± 2 standard deviations
u - measured uncertainty term; ± 2 standard diviations
(1) - from Colorado Department of Health Radioactive Materials Lisence Compliance Inspection Reports (1978-1979)
(all values are in Pci/L)

indicates some radionuclide migration, the baseline monitoring program planned for inclusion in the license application will have to be designed to assess the impact of the Rancher's project on site water quality.

At the present time there is no use of the shallow ground water in the alluvial aquifer in this area or downstream between the site and the confluence of Dry Creek with the San Miguel River.

4.2.3 Bedrock Aquifers

Based on interpretation of the geophysical logs for the deep holes drilled for this project (Figures A-15 and A-16) and informatin provided by water well drillers on well permit applications, the major bedrock aquifers within five hundred feet of the surface of the Coke Oven site include (1) the basal sandstone unit of the Dakota Sandstone, (2) the central sandstone unit of the Burro Canyon, (3) conglomeratic sandstones in the lower unit of the Burro Canyon, and (4) very thin conglomeratic sandstone beds of the upper portion of the Brushy Basin Member of the Morrison Formation (Table 6). In addition, several sandstone and shale beds of the basal Mancos and upper Dakota Sandstone along with the coal beds of the central shale unit of the Dakota are partially to nearly saturated, however, the low permeability, discontinuous nature, and limited thickness of these units results in such low yields that these units are not considered as aquifers. However, as all of our test holes were drilled with water, thus obscuring the identification of water bearing zones, it may be possible that one or more of these strata is saturated.

The water in these bedrock aquifers is considered to be confined in the central portion of the basin and assumed to be unconfined along the basin margins near the outcrop areas. The depth of water below the ground surface for each of the two drill holes, D-1 and D-2 one week after drilling, was 22 and

Table 6: Summary of Bedrock Aquifers
Beneath the Coke Oven Site

Aquifer	Lithology	Saturated Thickness (ft)	Approximate Depth (ft)	Expected Water Quality
Dakota Sandstone	basal conglomerate of the lower sand unit	15-25	225	brackish
Burro Canyon Formation	conglomeratic sandstones of the central sand unit	50-55	290	Upper 40 feet brackish, lower 10 feet fresh
Burro Canyon Formation	conglomeratic sandstones and mudstones	45-55	355	fresh
Brushy Basin Member of Morrison Fm.	conglomeratic sandstone layers	5-10	440	fresh

35 feet, respectively. The equivalent potentiometic surface is located at approximate elevations of 5495 and 5515 feet, respectively. This is indicative of the presence of a thick section of impervious material located between the aquifer and the ground surface. Presumably, recharge occurs as direct percipitation and percolation from the overlying alluvial aquifer at and over outcrop areas. The exact origin of the waters in each of the four water bearing horizons, whether connate or metoeric, cannot be made until water samples are collected and analyzed. During drilling, it was estimated that water wells completed at these two locations in these four hydrologic units would yield between 15 and 30 gallons per minute.

A pair of single well open hole, pump tests were conducted in the Coke Oven basin as part of a well permit application filed by Rancher's Exploration and Development with the Colorado State Engineer's Office (Science & Engineering Resources Inc., 1977). The first of these was a slug test conducted on the 310 to 385 foot interval which included the upper and central units of the Burro Canyon Formation. Analysis of this data indicated a transmissivity value of approximately 7 gal/day/foot. A recovery test was also conducted in this hole for the entire depth from 0 to 680 feet. Transmissivity was estimated to be 73 gal/day/ft from this test data. Although two different tests were involved, the conclusion reached was that the upper portion of the well, from 0 to 380 feet, yielded only 10% of the water obtained from the entire 0 to 680 foot interval (Science and Engineering Resources Inc., 1977).

During the pumping phase of the recovery test, and at various stages during drilling, water samples were collected for water quality analysis (Table 7). Examination of this data along with the resistivity logs (Figures A-15 and A-16) appears to indicate that water quality improves with depth,

TABLE 7: BEDROCK WATER QUALITY DATA (1)

Source of Sample	Chloride mg/l	Specific Conductivity (umhos/cm)	Temperature (°C)	pH	Bicarbonate (mg/l)	Dissolved Oxygen
Drilling	5	3600	-	7.2	-	-
260 ft. depth	30	440	-	-	-	-
385 ft. depth	20	3010	-	7.7	370	-
Pump Test # 340 ft.						
9:30 a.m.	-	970	14.8	-	-	-
10:00 a.m.	-	870	15.2	-	-	-
10:33 a.m.	-	870	15.7	-	-	-
11:44 a.m.	30	860	15.7	-	-	-
12:03 p.m.	28	870	15.2	-	-	-
12.25 p.m.	17	-	-	-	-	-
12:35 p.m.	15	880	15.2	-	380	4.5
12:55 p.m.	-	880	-	7.5	-	-

(1) From Science and Engineering Resources 1977

apparently changing from a calcium sulfate water above approximately 200 feet to a calcium biocarbonate water from 200 to 500 feet. This may indicate a lack of circulation of meteoric waters below 200 feet.

At the present time, only one permitted well is located in the basin; a domestic well located in Southwest 1/4, Southeast 1/4, Section 27, Township 46 North, Range 16 West. According to the well permit (No. 4-43-030127) this well produced 30 gpm from the 180 to 250 foot interval upon completion of drilling. Data on this well, and other deep wells drilled in the basin is summarized in Table 8. Other permitted wells within a 5 mile radius of the site include six additional wells within Township 46 North, Range 16 West and 23 wells in Township 46 North, Range 15 West (Figure 15). There are no permitted water wells in Township 45 North, Range 15 West or Range 16 West, Township 45 North, Range 17 West or in Township 46 North, Range 17 West. Of the 33 total wells within a 5 mile radius of the site, 10 are shallow alluvial wells located in the San Miguel River Valley and 21 are bedrock wells.

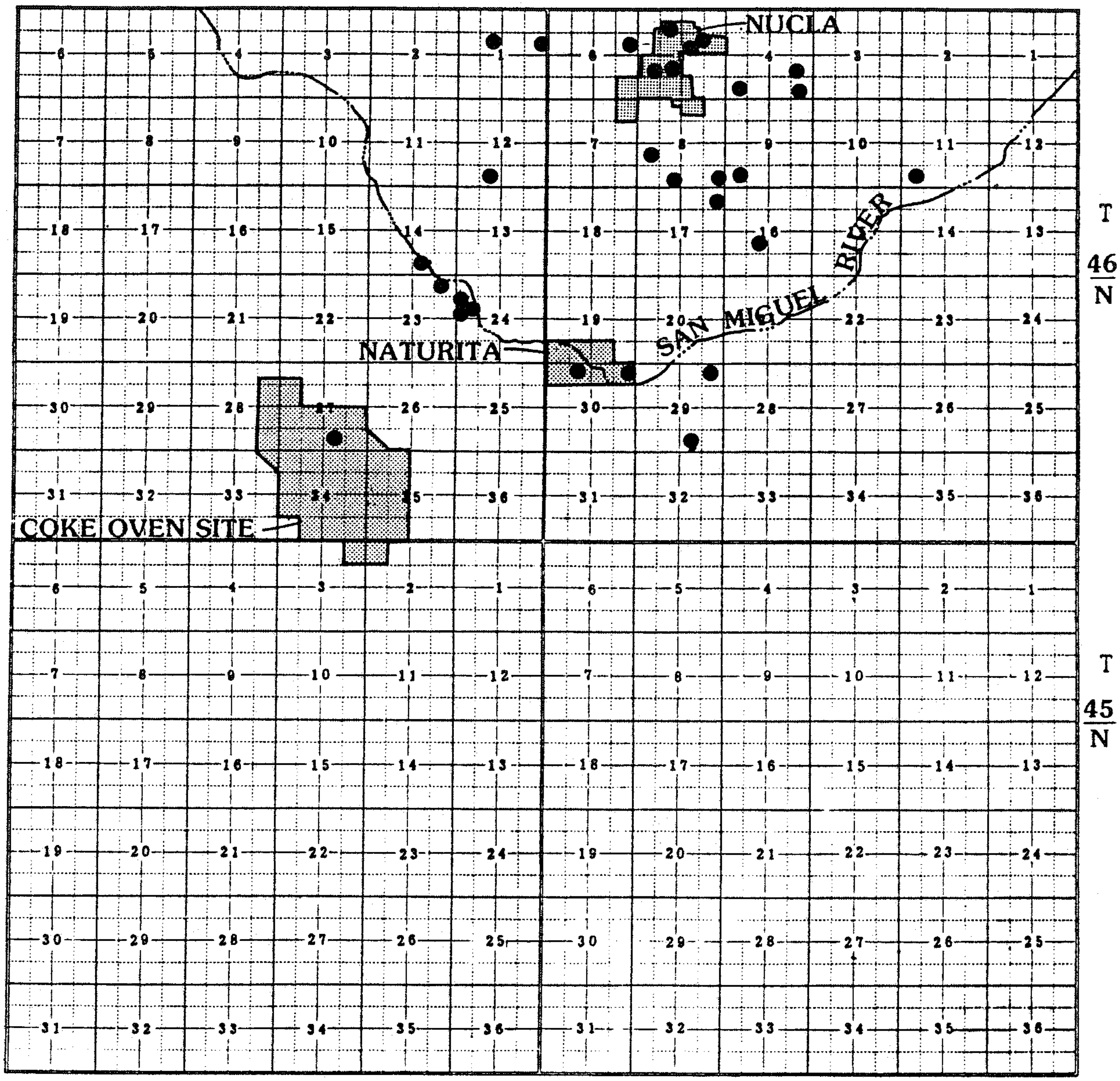
TABLE 8: Deep Hole Drill Logs of the Coke Oven Basin (1)

Well Owner	Location	Use	Yield (gpm)	Total Depth (ft)	Mancos Interval (ft)	Dakota Interval (ft)	Burro Canyon Interval (ft)	Morrison Fm (ft)
Vaughn (Anderson)	SW¼, SE¼, Sec. 27	Domestic	30	265	0-170	170-264	264	-
Ranchers No. 1	NW¼, SE¼, Sec. 24	Observation	15	680	0-110	110-300	300-430	430
Ranchers No. 2	NE¼, SE¼, Sec. 34	Observation	-	545	0-100	100-340	340-430	430
Fox D1	NW¼, NE¼, Sec. 34	Observation	-	500	0-70	70-256	256-408	408
Fox D2	SW¼, NW¼, Sec. 35	Observation	-	500	0-17	17-222	222-372	372

(1) After information on file at the Colorado State Engineer's Office and data generated by this project

COUNTY Montrose STATE Colorado

RANGE 16W RANGE 15W



Note: There are no permitted water wells in T45N, R15 and 16W or in R17W, T45 and 46N.

LOCATION OF WATER WELLS AROUND THE COKE OVEN SITE

FOX Consulting Engineers and Geologists

Job No:	1-2543-3338
Date:	7/31/82
Figure	16

5.0 GEOTECHNICAL CONDITIONS

A preliminary analysis of the geotechnical conditions for the proposed facility was conducted. The investigation was undertaken to collect preliminary information on in-situ soil conditions, potential excavation difficulties, potential construction material sources and potential borrow material characteristics by means of drilling, field testing and laboratory testing.

5.1 FIELD PERMEABILITY TESTING

The coefficient of permeability was determined in the field by two standard geotechnical methods. Four standpipe tests were conducted in drilled and cased borings. Thirteen packer permeability measurements were made in uncased borings.

The standpipe permeability tests were conducted by drilling six inch diameter borings to the desired test depth. The bottom of the borings were very carefully cleaned and four inch diameter solid polyvinyl chloride (PVC) pipe was placed and set in the boring. The test section for this type of field permeability test is the four inch diameter hole at the bottom of the casing. After the casing was set and prior to initiation of the test, the PVC pipe was filled with water and the test section allowed to saturate for approximately 24 hours. After this saturation period, the standpipe was filled with water to begin the test. Water level changes with time were recorded at the surface, giving a measurement of the average time rate of vertical water flow into the material at the bottom of the test hole. Generally, after several inches of water had percolated into the test section, additional water was added to the maintain head. Even though the total hydraulic head was allowed to fluctuate slightly, the test is considered to be a constant head test, because the change in head relative to total hydraulic head is insignificant.

The equation used to calculate the coefficient of permeability is:

$$K = q/FDh$$

q = flow rate (cm^3/s),
F = shape factor (dimensionless),
D = test section diameter (cm)
h = differential head of water (cm)

The most desirable interval for this type of test is below the existing ground water table (i.e., saturated conditions). However, the critical zone for potential seepage from this facility is substantially above the ground water surface and, therefore, unsaturated. Test results under such conditions are generally accepted as conservative, due to the additional fluid flow caused by soil suction pressures. To minimize the effects of soil suction, test sections are generally pre-wetted and tests conducted for a relatively long period of time (i.e., several days) thereby, more closely approximating saturated conditions.

Standpipe permeability tests were conducted in borings located adjacent to Test Borings A2, B1, B2, and B5. Test results are presented on Table 9.

Packer permeability tests are conducted by sealing off an interval of uncased boring with inflatable packers and pumping water into the interval. section. This type of test provides an average permeability for a relatively large test section, generally on the order of ten feet. Isolation within the boring can be achieved with a single packer if the test is conducted in the interval between the packer and the bottom of the boring, or with double packers if the test is conducted in the interval between the packers. To conduct the test, water is pumped into the test section, and a gravity head plus a pressure head is created by a water pump. This head is maintained on the test section for the duration of the test, generally a period of 30 minutes

Bore Hole No.	Packer Test Interval (ft.)	Depth to Bottom of Stand Pipe (ft.)	Test Pressure (ft. of water)	Coefficient of Permeability (cm/sec)	Lithologic Description	Remarks
A1	10.0-21.0	-	43.4	$3.27 X 10^{-4}$	SAND, silty (SP)	
A2	-	18.0	18.82	$6.95 X 10^{-8}$	CLAYSTONE	Weathered, low RQD value.
A3	-	17.4	20.21	$4.80 X 10^{-8}$	MUDSTONE	
A4	10.0-23.0	--	39.6	$8.21 X 10^{-5}$	MUDSTONE/CLAYSTONE	Weathered
B1	28.0-35.0	-	51.05	$1.44 X 10^{-5}$	SILTSTONE/SANDSTONE	Weathered, low RQD value
B1	"	-	62.60	$1.57 X 10^{-5}$	" "	" " "
B1	"	-	85.70	$6.03 X 10^{-5}$	" "	" " "
B1	61.5-68.5	-	81.5	$1.15 X 10^{-6}$	SILTSTONE	
B1	"	-	92.6	$6.53 X 10^{-7}$	"	
B1	"	-	115.7	$4.02 X 10^{-7}$	"	
B1	-	16.0	20.0	$8.18 X 10^{-8}$	CLAYSTONE	Weathered, low RQD value
B2	-	15.5	19.5	$9.11 X 10^{-8}$	"	Soft, weathered
B3	19.0-26.0	-	50.1	$1.21 X 10^{-6}$	"	Contains 0.6' Limestone bed
B3	"	-	73.2	$1.30 X 10^{-4}$	"	Possible hydraulic fracturing
B3	35.0-42.0	-	66.1	No Flow	SANDSTONE/MUDSTONE	
B3	"	-	89.2	No Flow	" "	
B5	20.0-30.0	-	48.1	$3.65 X 10^{-5}$	SHALE/LIMESTONE	Weathered, low RQD value
B5	"	-	71.2	$3.30 X 10^{-4}$	" "	
B5	56.0-63.0	-	75.5	No Flow	SHALE	
B5	"	-	85.1	No Flow	"	
B5	"	-	108.2	$3.42 X 10^{-6}$	"	Possible Hydraulic fracturing
B5	81.0-88.0	-	115.1	No Flow	SANDSTONE	Silty,high RQD values
B5	"	-	126.7	No Flow	"	
B5	-	18.1	20.3	$1.53 X 10^{-7}$	SHALE	Weathered

SUMMARY OF FIELD PERMEABILITY TESTING

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Bore Hole No.	Packer Test Interval (ft.)	Depth to Bottom of Stand Pipe (ft.)	Test Pressure (ft. of water)	Coefficient of Permeability (cm/sec)	Lithologic Description	Remarks
B6	45.0-52.0	-	76.1	No Flow	SHALE	
B6	"	-	99.2	No Flow	"	
B6	64.0-71.0	-	83.6	3.88 X 10^{-7}	SANDSTONE/SILTSTONE	
B6	"	-	95.2	2.18 X 10^{-7}	" "	
B6	"	-	118.3	No Flow	" "	
B7	22.0-29.0	-	41.6	2.74 X 10^{-4}	SILTSTONE	Fractured, low RQD values
B7	"	-	53.1	3.53 X 10-^{4}	"	" " "
B7	45.0-52.0	-	76.1	4.09 X 10^{-7}	SHALE/SANDSTONE	Low RQD value
B7	"	-	99.2	No Flow	" "	" "
B8	"	-	76.1	No Flow	SHALE	
B8	"	-	99.2	No Flow	"	

SUMMARY OF FIELD PERMEABILITY TESTING

FOX **Consulting Engineers and Geologists**

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to one hour.

The major advantage of this type of test is that, because of the large interval tested, both primary and secondary permeability (i.e., fracture porosity) can be included in the reported permeability. The most significant disadvantage with this type of test is that the test is generally run for a short duration, due to the various limitations. In unsaturated clay soil materials, such as those tested in this investigation, the short duration tests are generally conservative. That is, the measured permeability is generally higher than the actual permeability. There are two reasons for this. First, the unsaturated conditions cause a soil suction head to draw water into the soil surrounding the test section. This head is not accounted for in the calculation. Second, because of the short duration of the test, clays that have swelling characteristics do not have time to reach their full swell potential. If full swelling occurred, significantly lower measured permeabilities could result.

When the packer permeability test section is greater than ten times the diameter of the uncased boring, the equation for calculating permeability is:

K = permeability
q = constant rate of flow into the test section
L = length of test section
H = the differential head of water on the test section
r = the radius of the test boring

This equation was used for all of the packer permeability calculations.

Packer permeability testing was conducted in all of the test borings except B2 and B3. The test results of the packer permeability testing are presented on Table 9 and the test boring logs (Appendix A).

5.2 LABORATORY TESTING

After completion of the drilling and sampling program all soil and bedrock samples were inspected and classified in our soils laboratory. A testing program was formulated to give preliminary information on site soil characteristics. The laboratory testing program consisted of the following types and numbers of tests:

Number	Type	ASTM Designation
15	Mechanical Analysis	ASTM D-422
15	Atterberg Limits	ASTM D-423, 424 and 427
16	Natural Moisture	ASTM D-2216
4	Proctor Analysis	ASTM D-1557, Method A
6	Permeability	ASTM D-2434

Laboratory data is summarized on Table 10, and is presented in detail in Appendix B. Testing results are also included on the Logs of the Test Borings in Appendix A.

In addition, an analysis was conducted to determine the relationship between in-situ moisture content (Table 11) and geophysical log response for 2 of the shallow test borings. The results of this analysis indicate that no reasonable correlation can be established between the two. The geophysical probes measure hydrogen content, which can be in the form of hydrocarbons, water in pores, or water bound to clay minerals. Because of the abundance of clay seams at the site, the probe response is due to more than just moisture content, and the two cannot be correlated.

5.3 SUBSOIL CONDITIONS

Soils across the site can be divided into four general groups on the basis of soil development and manner of deposition. Group I is a residual clay developed from weathering of the Mancos Shale. Group II is a combination of sands, silts and clays resulting primarily from eolian and very low energy fluvial deposition. Group III is a coarser alluvial sand and gravel deposited

Test Hole No.	Depth of Sample (ft.)	Soil Description	Optimum Moisture Content (%)	Maximum Dry Density (pcf)	Atterberg Limits		% Silt and Clay	Soluble Sulfates (%)	Permeability 10^{-7} cm/sec	Specific Gravity		Remarks
					LL	PL						
A1	5	CLAY, sandy,drk.brn. (CL)			47	17	97					
A1	10	SAND, silty,red-brn.(SM)				NP	21					
A2	2-5	CLAY, sandy, silty, gray(CL)	9.0	127.0	31	18	47		NF*			
A2	5	CLAYSTONE, weathered (CL)			29	13	30					
A4	5	CLAY, v. silty,lt.brn.(CL)			24	11	83					
A4	15	CLAYSTONE, sandy (CL)			43	25	98					
B2	5	SANDSTONE, clayey (SC)			27	11	35					
B3	5	CLAY,silty (CL-ML)			34	14	97					
B3	10	" " "			34	15	93					
B4	0-5	SAND, v. silty (SM)	9.0	129.0	18	4	36		7.06			
B4	5	" " " "				NP	42					
B4	10	SAND, silty (SM)				NP	14					
B7	5	CLAYSTONE, silty (CL)			38	17	94					
B8	0-2	CLAY,silty, sandy (CL-ML)	13.5	120.0	26	7	74		0.33			
DH2	0-10	CLAY, silty, sandy (CL)	12.0	122.5	31	14	79		NF			

*No Flow after a minimum testing period of 10 days

SUMMARY OF LABORATORY TESTING

FOX Consulting Engineers and Geologists

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TABLE 11: MOISTURE CONTENT TEST RESULTS

TEST HOLE B-4		TEST HOLE B-6	
DEPTH	% MOISTURE	DEPTH	% MOISTURE
18	3.0	10	5.1
28	3.9	20	4.8
38	30.4	30	17.5
48	4.4	40	7.4
58	3.6	50	4.9
68	4.3	60	4.2
78	4.5	70	2.4
88	4.6		
98	14.7		

by moderate to high energy channel systems. Group IV is a colluvial soil that has developed along the slopes on the south edge of the project area. Exact distribution and thicknesses of these materials could not be determined with the limited drilling program conducted for this project, however, general locations (Figure 17) and thicknesses have been estimated. A more detailed discussion of each of the soil groups is provided below:

<u>Group I - Residual Clay</u>

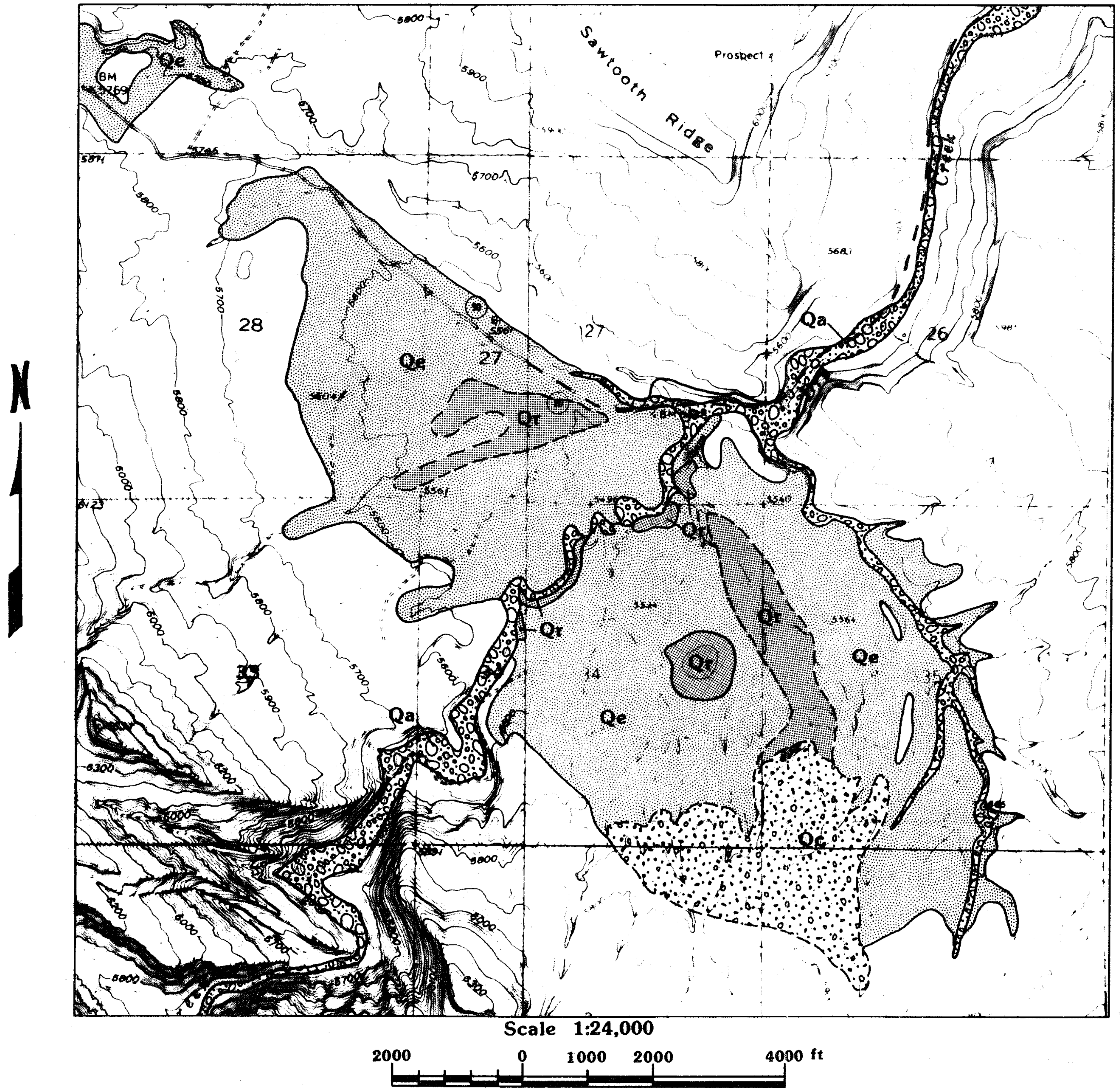
This material was found in the areas of test borings B6 and B8. It is generally only a few feet thick and it is underlain by weathered shale. It can be classified as a low plasticity clay, but does contain minor amounts of silt and sand. These residual clays have low natural permeabilities and when recompacted have permeabilities of less than 10^{-7} cm/sec. This material will be suitable for impervious liner and cover construction.

<u>Group II - Eolian Soil</u>

The eolian soil covers the major portion of the project area, and ranges in thickness from a few feet to over 10 feet. This material is generally very fine grained sand with significant amounts of clay and silt, and has a moderate to low natural permeability. Based on our drilling and laboratory testing program, we estimate that approximately 50 to 80 percent of these soils may be suitable for impervious liner and final cover construction. The remainder of these materials will be suitable for use as miscellaneous fill and possibly as daily cover material.

<u>Group III - Alluvial Sands and Gravels</u>

The alluvial sands and gravels occur in the main stream drainage of Dry Creek. This material includes some cobbles and varies from



Explanation

Qr Group I, Residual Clay
CLAY, silty, sandy, low plasticity, derived from weathered bedrock; 1 to 3 feet thick

Qe Group II, Eolian Soil
SAND, Fine grained, clayey, unstratified wind deposits; 1 to 10 feet thick

Qa Group III, Alluvial Sand and Gravel
SAND, and GRAVEL, silty, clayey, poorly sorted flood plain deposits; 5 to 40 feet thick

Qc Group IV, Colluvial Soil
CLAYS, silts, sands and angular cobbles, talus, sheetwash and slump deposits, a few feet to greater than 10 feet thick

Contact, dashed where approximate

SURFICIAL DEPOSITS of the COKE OVEN SITE

FOX Consulting Engineers and Geologists

Job No: **1-2543-3338** Date: **7/31/82** Figure **17** silty, clayey sand and gravel to clean sand and gravel. The thickness varies from a few feet to at least 40 feet. In the area of test borings A-1 and A-5, it is saturated at a depth of approximately 20 feet, and is assumed to be wet in the entire drainage. Within this material, water level is expected to fluctuate a few feet, seasonally. This type of alluvial material may also occur in minor amounts in other drainages on the site. The clean sands and gravels may be suitable for use as drainage material during site construction, although processing (screening) may be required.

Group IV - Colluvial Soil

Colluvial soil occurs in the southwest corner of Section 35 and southeast corner of Section 34. Since it was outside the permit area, this material was not drilled during the investigation; but, based on field observation, it consists of a mixture of clay, silt, sand and angular cobbles. The relative percentages of the various components cannot be determined without further investigation. The thickness of this soil is expected to be between a few feet to in excess of 10 feet. Potential construction uses for this material cannot be determined without additional information, but it is reasonable to assume that it could be used for miscellaneous fill and possibly daily cover.

The subsoil groups discussed above are generally underlain by Mancos shale. Bedrock conditions for the project area and surrounding areas have been discussed in detail in the geologic section of this report. It is important to point out however, that where Mancos shale exists near the surface it has weathered significantly to depths of 20 to 30 feet. This weathered shale should be suitable for use as a liner and final cover material, although problems with processing this material may occur as excavation approaches the unweathered shale.

The very low natural permeabilities of the near surface sandstone and shale enhances the suitability of the site. It is anticipated that both the shales and the shallow sandstones may be suitable foundation materials for wastes cells due to the number and thickness of the shale and bentonite beds between proposed disposal cells and the confined ground water within the basin.

6.0 SITE FEASIBILITY

Based on the data presented in this preliminary assessement of the Coke Oven Site, it is our opinion that a co-located low-level radioactive waste and uranium mill tailings disposal facility can be designed, constructed, and operated without short or long term detrimental impacts on the geologic or hydrologic systems operating in this area. A summary of our conclusions relative to each of the technical disciplines of this investigation is presented below.

6.1 REGIONAL AND SITE GEOLOGY

The salt anticlines, which are the major structural features of the region, were established by the end of the Pennsylvannian Period. Subsequent tectonic activity is related to flowage and dissolution of the Paradox Salt Formation beneath these structures. This activity appears to have occurred at relatively slow and constant rates since the Eocene (approximately 35 million years ago) and should not affect the stability of the facility over the next 500 years. However, the data collected for this preliminary investigation is insufficient to evaluate the proposed impacts of this activity on the stability of the site over the next 10,000 years. A more detailed analysis will be required to evaluate the stability of the facility over this time frame.

The stratigraphy of the site is definable and well described. Approximately 2,000 feet of late Pennsylvanian, Permian, Triassic and Jurassic sediments separate the Cretaceous rocks beneath the site from the Paradox Salt Formation at depth. The Cretaceous strata which make up the first 400 feet of depth beneath the site contain numerous shale, mudstone, and claystone strata which offer potentially excellent radionuclide attenuation characteristics. Eight different bentonite/claystone beds, varying in thickness from 1 inch to as much as 4 feet, separate the first aquifer beneath the site from the ground surface.

Structurally, the site consists of a doubly plunging syncline which forms an enclosed structural basin, defined by the surrounding Dakota dip slopes. Within the basin are several small reverse faults and two larger normal or reverse faults which border a small central graben. Both the overall structure of the basin and the faults within the basin are interpreted as the result of downsagging of the sedimentary strata following dissolution and/or flowage of the underlying salt formation. A detail investigation will be required to determine the rates and exact magnitudes of the displacments along thse faults and to assess the impact of these structures on the present and future structural integrity of the basin.

No major geomorphic processes or geologic hazards, that would interfere with the proposed development, were identified at the project site during this investigation.

6.2 REGIONAL AND SITE HYDROLOGY

The surface hydrology of the site is composed of five ephemeral drainages. Four of these drainage areas are on the order of 5 to 10 square miles and are entirely contained within the structural basin. These drainages present no adverse engineering problems or geologic hazards to the proposed construction. The fifth drainage, Dry Creek, cuts across the site from southwest to northeast, and is the only breach in what would otherwise be a 15 square mile closed drainage basin. This drainage presents the only potential flood and/or erosion hazard to the basin.

Ground water at the site consists of both alluvial and bedrock aquifers. the alluvial aquifers are composed of sands and gravels associated with the flood plain of Dry Creek. The water in these gravels is hydraulically connected and therefore tributary to the surface waters in Dry Creek and, therefore, not entirely contained within the structural basin. However, these gravels are limited to the north central portion of the site in an area roughly corresponding to the potential flood hazard area.

Bedrock aquifers of unconfined saturated and partially saturated lenses occur within the basal Mancos Formation and in sandstone strata and coal beds within the Dakota Sandstone. The exact relation between these water bearing zones and the surface, alluvial, and deeper bedrock waters has yet to be determined, however, their low permeability and thin nature result in such low yields that these strata are not considered to be aquifers. The first major saturated bedrock horizon that potential could yield significant water to a well is the basal conglomerate strata of the Dakota Sandstone. There are three other saturated sandstone strata within the first 500 feet below the site. The water in these aquifers may occur in an unconfined state near the margins of the basin. However, in the central, deeper portions of the basin, this water occurs in a confined state at depths of approximately 200 feet with a pieziometric surface located 20 to 30 feet below ground level. It is our opinion that this water is non-tributary and may be hydraulic isolated from surface and ground waters outside of the Coke Oven basin. At the present time there is only one permitted well in the basin and this well is located on the private property being actively considered for this project. Thus the potential impact on ground water users in the area is minimal to non-existent.

6.3 SITE GEOTECHNICAL CONDITIONS

Preliminary geotechnical data collected for this project indicates that disposal cells can be designed and constructed using primarily on-site materials. Generally, the cells are expected to be constructed over the very low permeability shales of the Mancos Formation, providing good inherent geologic containment properties for waste disposal. Additionally, sandstones and interbedded claystones in the lower Mancos and upper Dakota Formations are also believed to have low permeability characteristics and may possibly be considered suitable for waste disposal.

In the area drilled, approximately 6 million cubic yards of clay suitable for liner and cover material is expected. An additional, approximately 6 million cubic yards of miscellaneous fill, possibly suitable for use as daily cover is expected. Free draining sands and gravels also occur on the site. These materials may be suitable for use as drainage materials and/or surfacing materials. In addition, Dakota Sandstone in the ridges around the basin may provide riprap for armoring disposal cell covers, if required.

6.4 CONCEPTUAL CONSTRUCTION PLANS

It is anticipated that four types of radioactive materials will be disposed of at the proposed facility. These include uranium mill tailings along with three types of low level radioactive waste. Low level radioactive wastes contain a maximum concentration of radionuclides so that at the end of a 500 year period, remaining radioactivity does not pose a significant threat to public health and safety. A breakdown of the three classes of low level radioactive waste as defined by the Nuclear Regulatory Commission (1981) is as follows:

Class A: Segregated waste which is unstable and therefore is segregated at the disposal site; however, as it decays to acceptable levels during the operational period of the site it can be disposed of with only minimum requirements on waste form and characteristics.

Class B: Stable waste which must meet both the minimum and stability requirements (Nuclear Regulatory Commission, 1981) but as it decays to acceptable levels during the 100 year institutional control period, it does not have to be disposed of with provisions for intruder protection.

Class C: Intruder waste, which does not decay to acceptable levels within the 100 year institutional control period and, therefore, is disposed of at greater depths and with engineer barriers, as necessary.

All of the waste, both low level and mill tailings, will be disposed of in below grade cells. Due to the relative differences in the stability and degree of hazard associated with each of the waste streams, these wastes will be disposed of in different cells with potentially different cell designs. At a minimum these will include (1) uranium mill tailings cells, (2) Class A waste cells, and (3) Class B and C waste cells. At no time will these three wastes be placed in the same cell.

Typical cell designs will include bottom liners, the thickness of which will vary depending on the waste stream and the foundation materials. A leachate detection system may be incorporated into some or all of the bottom liners. Cell side wall liners may also be required for the more active waste streams. Cell covers will be necessary for radon attenuation. These covers are anticipated to be approximately 10 feet thick and may be constructed of various combinations of compacted clay and free draining material.

Cell monitoring will also be required, and will be designed to observe both physical changes in the waste (settlement) and potential leachate movement. Cell monitoring may consist of settlement monuments, leachate detection systems, and monitoring wells drilled to the first impervious foundation layer. In addition, overall site monitoring may consist of a system of shallow monitoring wells in saturated alluvium, deep monitoring wells drilled to the bottom of the Dakota Formation, surface water monitoring in Dry Creek, and surface soil monitoring stations up and downwind of the facility.

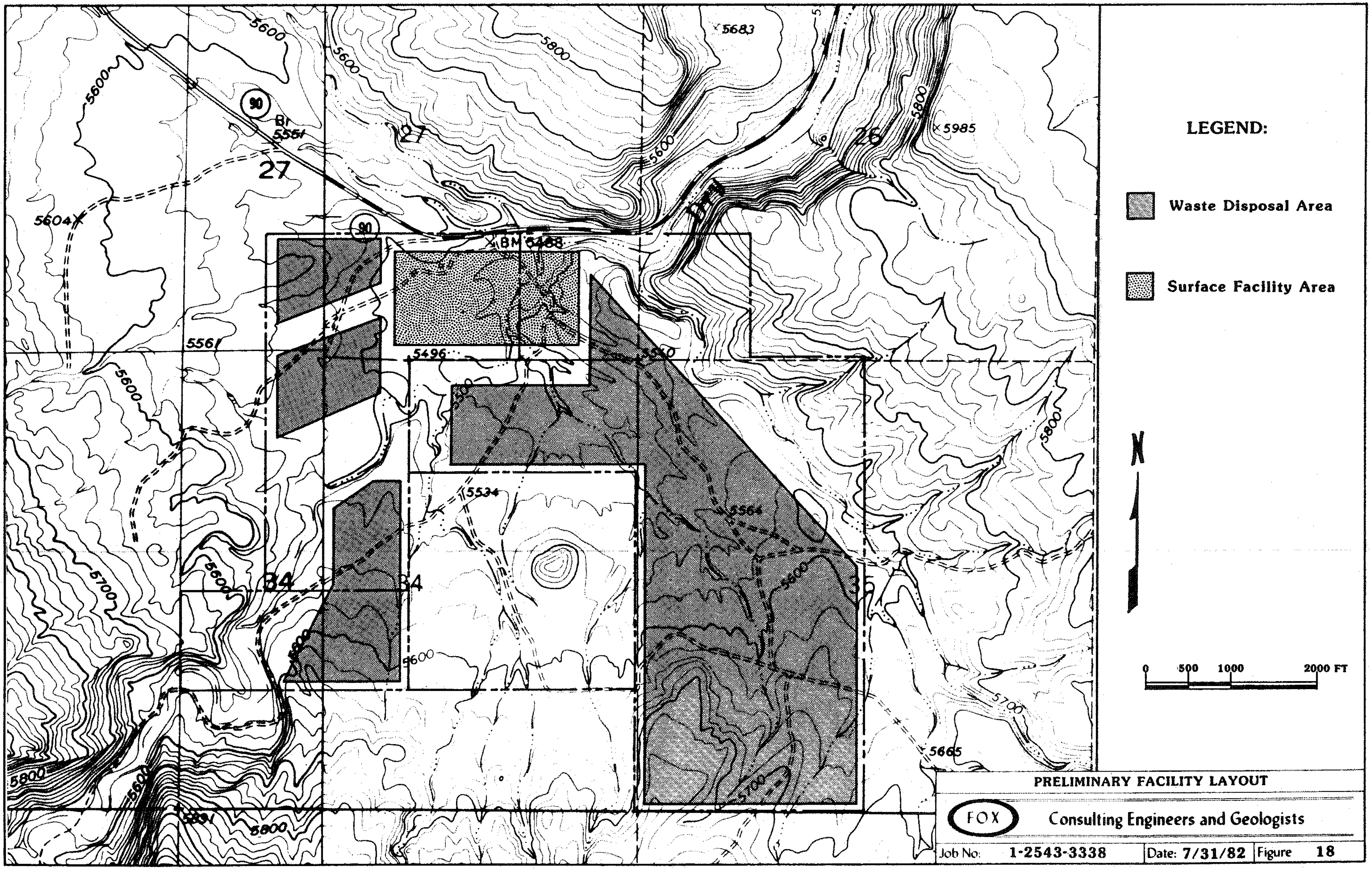
Based on very preliminary design criteria and the geologic, hydrologic, and geotechnical data developed during this investigation, a preliminary site layout has been formulated (Figue 18). This preliminary layout indicates proposed waste disposal areas within which waste cells would be located. Specific cell and waste type locations have not been chosen at this time. A 100 foot setback has been included on this site layout to separate the waste areas from adjacent properties. At this time the preliminary site layout has been restricted to the best geologic areas within the 720 acre parcel for which legal access to drill had been acquired for the drilling activities. An additional 640 acres of potentially suitable land exists outside of this area and would require additional preliminary work for evaluation.

6.5 POTENTIAL CONSTRUCTION CONSTRAINTS

The geologic, hydrologic and geotechnical conditions impose several potential construction constraints. These constraints include, excavation difficulties, surface water control, non-suitable cell construction areas within the Dry Creek drainage, and limited clay liner and cover materials.

6.5.1 Excavation Difficulties

Excavation below the depths of weathering may be difficult during cell construction. Excavation can be done below these depths but light blasting may be required. Specific depths could not be determined with data generated for this report, however, it is anticipated that excavation difficulties could be expected below depths of 15 to 40 feet in the Mancos Shale.



PRELIMINARY FACILITY LAYOUT

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338 Date: 7/31/82 Figure 18

6.5.2 Surface Water Control

Permanent surface water control will be required for site construction. Some diversion has been done by Ranchers Exploration and Development Corporation for their uranium leaching project. These diversions will require review and possible modification to incorporate them into the overall drainage plan to be developed for the proposed facility.

6.5.3 Dry Creek Drainage

The Dry Creek channel and hydrology should not be altered by the facility. Disposal cells should not be placed in areas that might be affected, but certain non-waste handling surface facilities may be allowable.

6.5.4 Clay Borrow Materials

It has been indicated that clay for impervious liner and cover construction is available on-site. The amounts of clay required cannot be determined until more detailed cell design and site layout work is conducted. Depending on the volume of clay required, off-site clay sources may be required. It is anticipated that, if required, these sources can be located within the Coke Oven Basin.

6.6 SUMMARY AND CONCLUSIONS

It is our opinion that a co-located low-level radioactive waste and uranium mill tailings disposal facility can be safely designed, constructed, and operated at the Coke Oven site. The geologic, hydrologic, and geotechnical characteristics of the site provide excellent containment characteristics. In particular, the site is located in a stable geologic area where the prevailing tectonism tends to promote deposition rather than erosion. The site is located in a closed structural basin which contains geologic media favorable for radioactive waste disposal. These include an extensive thickness of impervious shale and siltstone along with eight bentonite and claystone layers that separate the first major aquifer beneath the site from the ground surface. These units have very low natural permeabilities and should possess potentially excellent radionuclide attenuation characteristics. There are no major geologic hazards which would affect site development. There are no major natural resource deposits at the site for which future extraction might affect site integrity. There is no use of surface waters at the site and, with the exception of Dry Creek, the surface drainages at the site are small enough to be conducive to site development. There is only one water well utilizing ground water in the Coke Oven basin and this well is located on the private parcel being actively considered for the project. Finally, on site materials are available for liner, cover, and drain construction and for use as miscellaneous fill and rip-rap.

Besides the general information required in a license application, there are a number of features that will have to be examined to confirm the integrity of the site as described above. Primarily these include a detailed analysis of the faults in the basin, an analysis of the closed basin structure and the conformability of that structure with depth, an assesement of the impact the Rancher's operation has had on the water quality of the site, and a evaluation of the amounts of construction materials available at the site. We do not expect that any of these evaluations will result in negative features being discovered, however, the data generated by these evaluations will be necessary to provide a complete engineering geologic analysis in the final license application.

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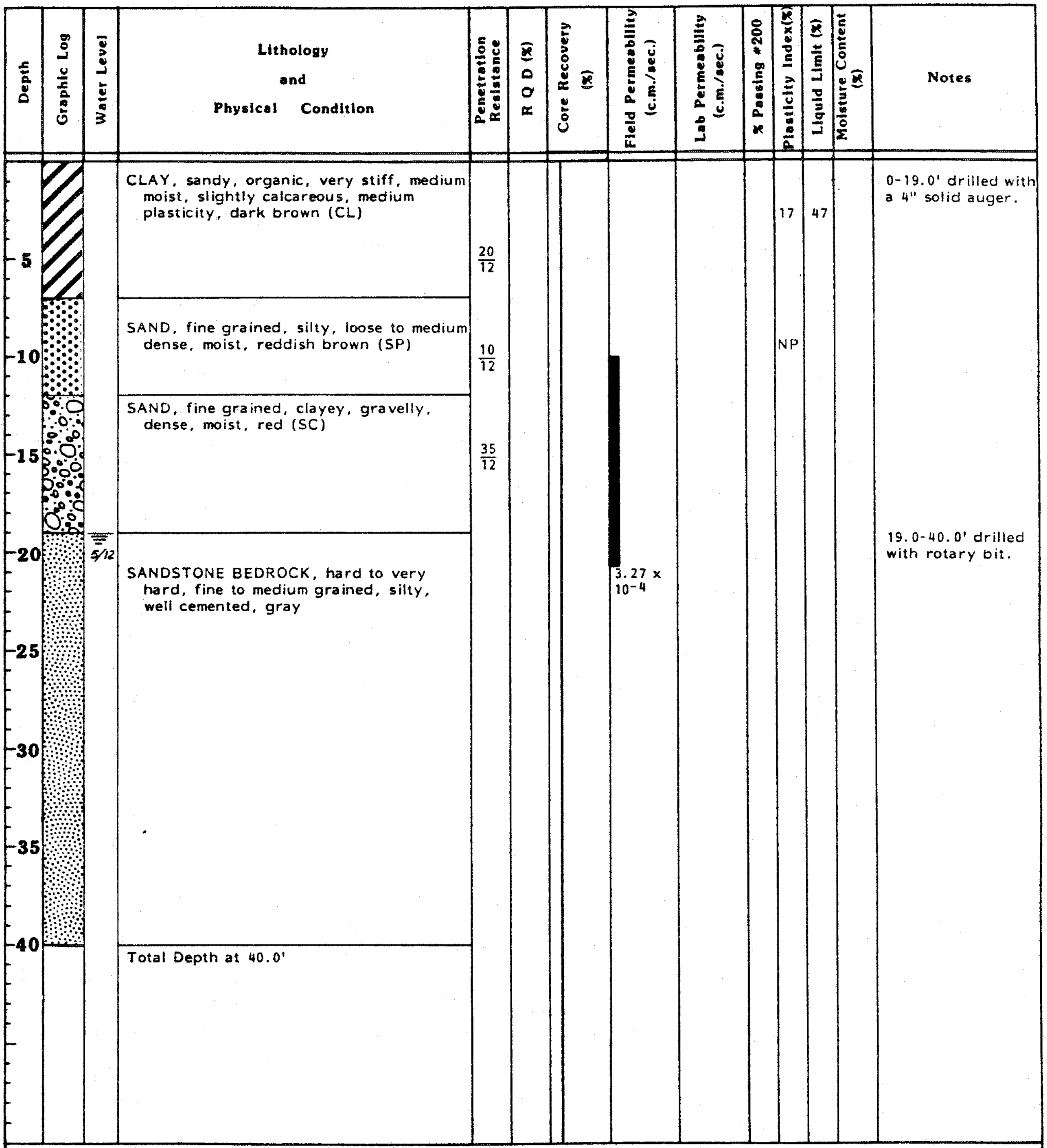
APPENDIX A: Drill Hole and Geophysical Logs

Bore Hole No. A1 Sheet 1 of 1



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			CLAY, sandy, organic, very stiff, medium moist, slightly calcareous, medium plasticity, dark brown (CL)	20/12						17	47		0-19.0' drilled with a 4" solid auger.
			SAND, fine grained, silty, loose to medium dense, moist, reddish brown (SP)	10/12						NP			
			SAND, fine grained, clayey, gravelly, dense, moist, red (SC)	35/12									
		5/12	SANDSTONE BEDROCK, hard to very hard, fine to medium grained, silty, well cemented, gray				3.27×10^{-4}						19.0-40.0' drilled with rotary bit.
			Total Depth at 40.0'										

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test
20/12 **Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler** 12 **inches.**

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5495

Date Drilled 5/12/82

Type of Rig CME-55

Total Depth 40.0'

Logged By EF

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338
Date: July 19, 1982
Figure A1

Bore Hole No. A2 Sheet 1 of 2

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			CLAY, sandy (fine grained), silty, with gravel, dense, slightly moist, gray (CL)							18	31		0-12' drilled with 4" diameter solid auger.
5				88/12					29	13	29		
			CLAYSTONE BEDROCK, very hard, dry, gray, weathered (CL)										
10				94/12									
			CLAYSTONE, silty, soft, dark gray to brown, Fe stained in fractures		29	40							Below 12' drilled with Nx wire line core barrel. Poor recovery from 12.0-14.1'
			CLAYSTONE, slightly sandy, bentonitic										
15			CLAYSTONE, soft, dark gray, with very fractured zones, contains silty lenses		36	90	18.0' - SP 6.95 x 10^{-8}						
20			MUDSTONE, very fine grained, slightly sandy, very hard, dark gray to black, calcareous, with zones of very fractured material										Lost 1.0' from 23.0 to 24.0'
25													
30					20	63							Lost 3.7' from 24.0 to 34.0'
35													
40					100	100							
45			SHALE, soft, clayey, dark gray, fractured										
			MUDSTONE, dark gray, very fine grained, slightly sandy, very hard, calcareous, with zones of very fractured material		92	97							

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

□ **Indicates Core Loss**

≡ 10/25 **Indicates Water Level and Date Recorded**

Standard Penetration Test
88/12 **Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.**

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5550'

Date Drilled 5/14/82

Type of Rig CME-55

Total Depth 84.0'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338
Date: July 19, 1982
Figure A2, pg. 1

Bore Hole No. A2 Sheet 2 of 2

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			SANDSTONE, fine-medium grained, rounded, well cemented, very hard, light gray to gray, bioturbated										
			SANDSTONE, fine to very coarse grained, gray										
55			SANDSTONE, fine to medium grained, silty, moderate to well cemented, gray										
60 65			SANDSTONE, medium to very coarse grained, silty, moderate to well cemented, gray, with beds of gray very fine grained mudstone		94	100							
			SANDSTONE, fine to medium grained, light gray										
70			SANDSTONE, fine grained, very silty, well cemented, dark gray, bioturbated		89	100							
			CLAYSTONE, medium hard, dark gray, grading to soft, light gray bentonitic claystone at base										
75 80			SANDSTONE, medium grained, very silty, well cemented, dark gray, bioturbated		85	100							
85			Total Depth at 84.0'										

EXPLANATION

Field Permeability Tests

▌ **Indicates Test Section for Packer**

· SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

88/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5550'

Date Drilled 5/14/82

Type of Rig CME-55

Total Depth 84.0'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG	Job No: 1-2543-3338
FOX Consulting Engineers and Geologists	Date: July 19, 1982
	Figure A2, pg. 2

Bore Hole No. A3 Sheet 1 of 1

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
0–5	▨		SAND, very silty, gravelly, dense, dry, red to light brown (SM)										Drilled with 4" diameter solid auger
5	░		MUDSTONE BEDROCK, sandy (medium to coarse grained), hard to very hard, well cemented, dry, buff	40/12									
10	░			91/12									
15	░						17.5' – SP 4.8 x 10^{-8}						
20			Total Depth at 20.0'										

EXPLANATION

Field Permeability Tests

▌ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

40/12 **Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler** 12 **inches.**

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5560'

Date Drilled 5/15/82

Type of Rig CME-55

Total Depth 20.0'

Logged By EF

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No. 1-2543-3338

Date: July 19, 1982

Figure A3

Bore Hole No. A4 Sheet 1 of 1

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
	▨		CLAY, very silty, sandy, gravelly, dense, dry, red to light brown (CL)										Drilled with 4" diameter solid auger.
5	▨			25/12					83	11	24		
	░		MUDSTONE BEDROCK, sandy (medium-coarse grained), hard to very hard, well cemented, dry, buff										
10	░			62/12			▮						
	┄		CLAYSTONE BEDROCK, very hard, dry, gray, weathered				▮						
15	┄			80/12			▮		98	25	43		
20	┄						▮						
			Total Depth at 23.5'				8.21×10^{-5}						
25													

EXPLANATION

Field Permeability Tests

▮ Indicates Test Section for Packer

· SP Indicates Bottom of Stand Pipe

■ Indicates Core Recovery

□ Indicates Core Loss

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

25/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

* Used 2 inch diameter California sampler

Project Chem Nuclear

Elevation 5555'

Date Drilled 6/15/82

Type of Rig CME-55

Total Depth 23.5

Logged By EF

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date July 19, 1982

Figure A4

Bore Hole No. A5 Sheet 1 of 1

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			SAND, fine to coarse grained, dense, slightly moist to moist, red (SP)										Drilled with a 6" diameter hollow auger
5													
10													
15			SAND and GRAVEL, well graded, some cobbles, clean to slightly clayey, medium dense, moist to wet (SW-GW)										
20		6/18											
25													
30													
35													
40			Total Depth at 40.0' in Sandstone Bedrock	50/1									

EXPLANATION

Field Permeability Tests

▮ Indicates Test Section for Packer

· SP Indicates Bottom of Stand Pipe

■ Indicates Core Recovery

☐ Indicates Core Loss

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

50/1 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 1.0 inches.

* Used 2 inch diameter California sampler

Project Chem Nuclear

Elevation 5480'

Date Drilled 6/18/82

Type of Rig CME-55

Total Depth 40.0'

Logged By EF

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No. 1-2543-3338

Date: July 19, 1982

Figure A5

Bore Hole No. B1 Sheet 1 of 2

Depth	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
	CLAY, very sandy, gravelly, stiff, dry, red to light brown (CL)										0-10.0' drilled with a 4" diameter solid auger
5	CLAYSTONE BEDROCK, sandy, very hard, dry, gray, weathered (CL-CH)	50/12									
10	CLAYSTONE, soft, laminated, gray, weathered, fractured	70/12	0	100							Below 10.0' drilled with an Nx wireline core barrel
15			44	90	16.0' — SP 8.18×10^{-8}						
20	SILTSTONE, very sandy, fine grained, well cemented, hard, 2 to 6 inch beds, buff to gray, weathered, bioturbated, interbedded with soft gray claystone, contains some gypsum										Lost 5.0' from 22.0-32.0'
25			0	50							
30	SANDSTONE, medium to coarse grained, silty, angular to subangular, well cemented, light to dark gray, bioturbated, oxidized										
35	SILTSTONE, sandy, fine grained, moderate to well cemented, slightly fractured, dark gray, bioturbated; contains gypsum in fractures, oxidized ground fractures		78	100							
40	SHALE, soft, laminated, dark gray, CLAYSTONE, weathered soft, white to light gray, bentonitic, massive				3.01×10^{-5}						Lost 0.5' from 42.0 to 43.0'
45	SILTSTONE, sandy, fine grained, moderate to well cemented, slightly fractured, dark gray, bioturbated; contains gypsum in fractures, oxidized ground fractures; exhibits strong horizontal parting		100	100							

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

≡ 10/25 **Indicates Water Level and Date Recorded**

Standard Penetration Test

50/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5550'

Date Drilled 6/10-6/11/82

Type of Rig CME-55

Total Depth 82.0'

Logged By EF

SUBSURFACE EXPLORATION LOG

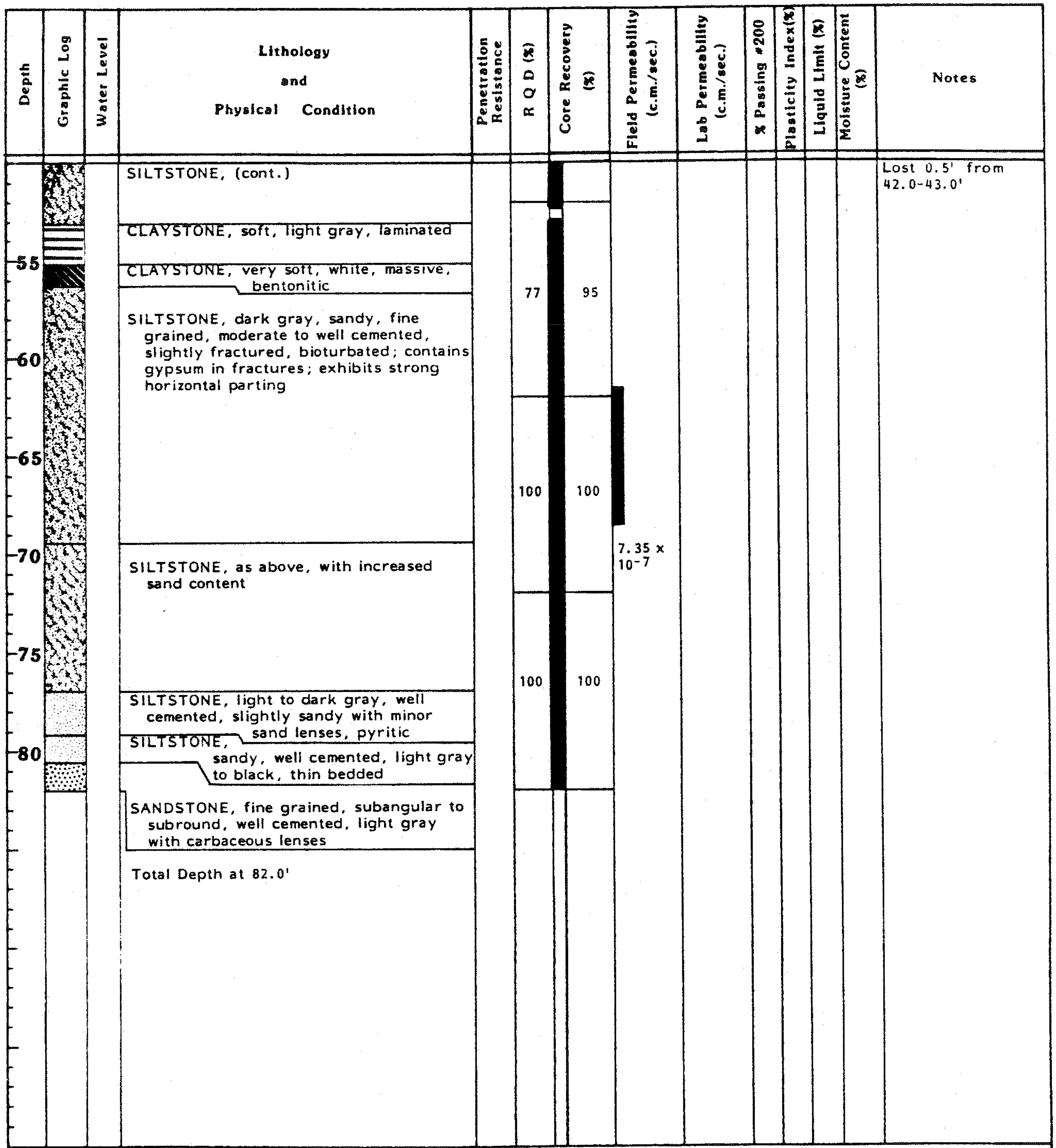
FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: July 19, 1982

Figure A6, pg. 1

Bore Hole No. B1 Sheet 2 of 2



SILTSTONE, (cont.)

CLAYSTONE, soft, light gray, laminated

CLAYSTONE, very soft, white, massive, bentonitic

SILTSTONE, dark gray, sandy, fine grained, moderate to well cemented, slightly fractured, bioturbated; contains gypsum in fractures; exhibits strong horizontal parting

SILTSTONE, as above, with increased sand content

SILTSTONE, light to dark gray, well cemented, slightly sandy with minor sand lenses, pyritic

SILTSTONE, sandy, well cemented, light gray to black, thin bedded

SANDSTONE, fine grained, subangular to subround, well cemented, light gray with carbaceous lenses

Total Depth at 82.0'

Lost 0.5' from 42.0-43.0'

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test
50/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

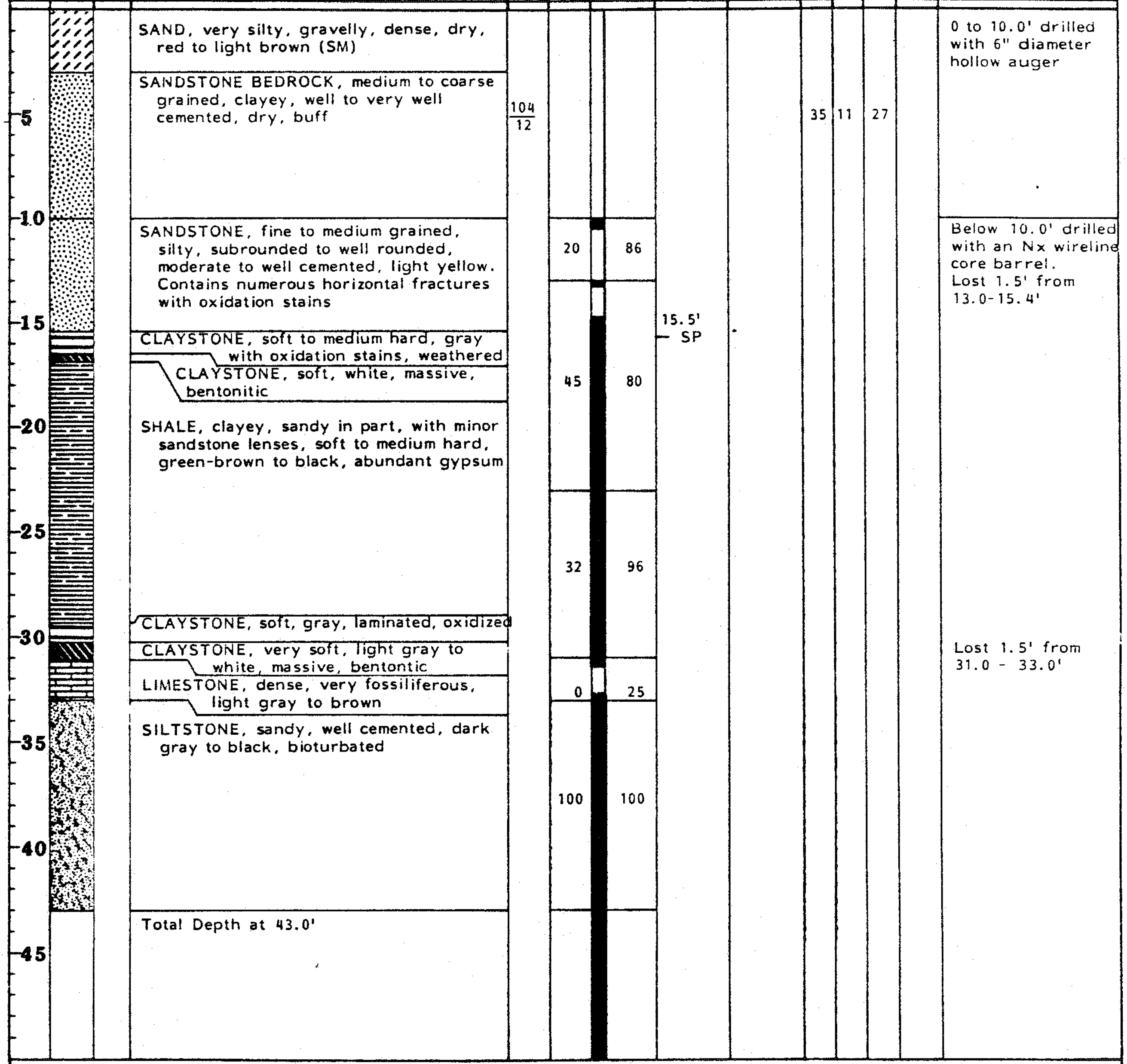
*** Used 2 inch diameter California sampler**

Project Chem Nuclear
Elevation 5550'
Date Drilled 6/10-6/11/82
Type of Rig CME-55
Total Depth 82.0'
Logged By EF

SUBSURFACE EXPLORATION LOG
FOX Consulting Engineers and Geologists

Job No: 1-2543-3338
Date: July 19, 1982
Figure A6, pg. 2

Bore Hole No. B2 **Sheet** 1 **of** 1



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			SAND, very silty, gravelly, dense, dry, red to light brown (SM)										0 to 10.0' drilled with 6" diameter hollow auger
5			SANDSTONE BEDROCK, medium to coarse grained, clayey, well to very well cemented, dry, buff	104/12					35	11	27		
10			SANDSTONE, fine to medium grained, silty, subrounded to well rounded, moderate to well cemented, light yellow. Contains numerous horizontal fractures with oxidation stains		20	86							Below 10.0' drilled with an Nx wireline core barrel. Lost 1.5' from 13.0-15.4'
15			CLAYSTONE, soft to medium hard, gray with oxidation stains, weathered				15.5' – SP						
			CLAYSTONE, soft, white, massive, bentonitic		45	80							
20			SHALE, clayey, sandy in part, with minor sandstone lenses, soft to medium hard, green-brown to black, abundant gypsum										
25					32	96							
			CLAYSTONE, soft, gray, laminated, oxidized										
30			CLAYSTONE, very soft, light gray to white, massive, bentontic										Lost 1.5' from 31.0 - 33.0'
			LIMESTONE, dense, very fossiliferous, light gray to brown		0	25							
35			SILTSTONE, sandy, well cemented, dark gray to black, bioturbated		100	100							
40													
45			Total Depth at 43.0'										

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ Indicates Core Recovery

□ Indicates Core Loss

≡ 10/25 **Indicates Water Level and Date Recorded**

Standard Penetration Test
104/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

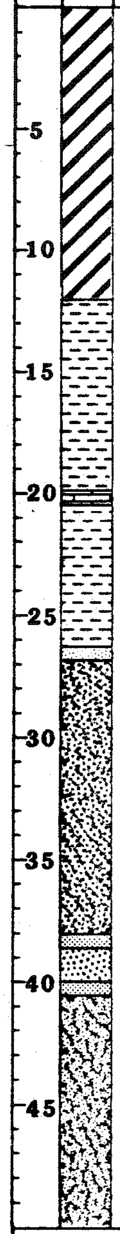
*** Used 2 inch diameter California sampler**

Project Chem Nuclear
Elevation 5545'
Date Drilled 6/14/82

Type of Rig CME-55
Total Depth 43.0'
Logged By EF

SUBSURFACE EXPLORATION LOG	Job No:	1-2543-3338
FOX Consulting Engineers and Geologists	Date:	July 19, 1982
	Figure	A7

Bore Hole No. B3 Sheet 1 of 2



Depth	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
	CLAY, silty, sandy (fine grained), stiff, dry, red to brown (CL)										0 to 15.0' drilled with a 6" diameter hollow auger
5		18/12					97	14	34		
10		35/12					93	15	34		
	CLAYSTONE, soft, dark gray/brown, weathered, oxidized, with gypsum in fractures										
15		50/12									Below 15.0' drilled with an Nx wire-line core barrel
			55	92							
20	LIMESTONE, nodular, hard, light gray to gray with calcite in fractures										
	CLAYSTONE, soft, dark gray/brown, weathered, oxidized, with gypsum in fractures										
	SILTSTONE, sandy, medium hard, dark gray, strong horizontal parting				1.21 x 10^{-6}						
	SANDSTONE, fine to medium grained, silty, subround, well cemented, light gray to SILTSTONE, sandy, hard, dark gray, bioturbated. Fractured and oxidized near fractures		50	100							
	MUDSTONE, medium hard, black, strong horizontal parting		87	100							
	SANDSTONE										
40	MUDSTONE, medium hard, black, strong horizontal parting										
	SILTSTONE, sandy, well cemented, dark gray, bioturbated				No flow at 20 psi						
45	Fractured zone from 44.2 to 45.4';										
			90	100							

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

· SP **Indicates Bottom of Stand Pipe**

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 **Indicates Water Level and Date Recorded**

Standard Penetration Test
18/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear
Elevation 5550'
Date Drilled 6/14/82

Type of Rig CME-55
Total Depth 73.0'
Logged By EF/PR

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338
Date: July 19, 1982
Figure A8, pg. 1

Bore Hole No. B3 Sheet 2 of 2

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			CLAYSTONE, soft to medium hard, laminated, gray with 0.1' bed of white bentonitic clay at bottom										
55 60			SILTSTONE, sandy, well cemented, dark gray, bioturbated, weak horizontal parting		100	100							
65			CLAYSTONE, soft to medium hard, laminated, light gray, strong horizontal parting										
			SILSTONE, sandy (very fine grained), dark gray, hard, no parting		100	100							
70			SANDSTONE, fine to medium grained, silty, dark gray, hard, slightly bioturbated										
75			Total Depth at 73.0'										

EXPLANATION

Field Permeability Tests

▮ Indicates Test Section for Packer

· SP Indicates Bottom of Stand Pipe

■ Indicates Core Recovery

□ Indicates Core Loss

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

18/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

* Used 2 inch diameter California sampler

Project Chem Nuclear

Elevation 5550'

Date Drilled 6/14/82

Type of Rig CME-55

Total Depth 73.0'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

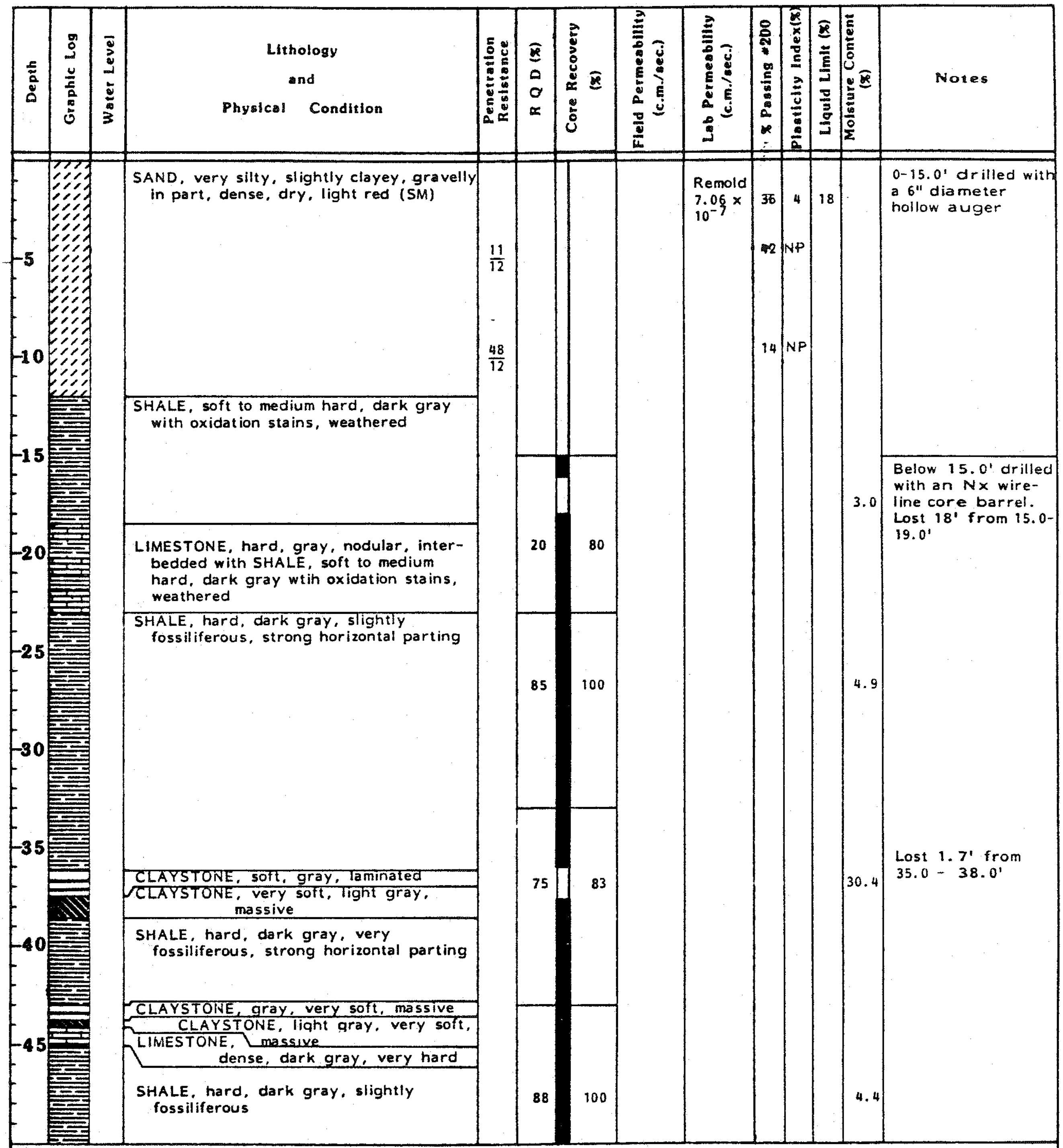
FOX Consulting Engineers and Geologists

Job No! 1-2543-3338

Date: July 19, 1982

Figure A8, pg. 2

Bore Hole No. B4 Sheet 1 of 2



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
0–5			SAND, very silty, slightly clayey, gravelly in part, dense, dry, light red (SM)	11/12				Remold 7.06 x 10^{-7}	36 42	4 NP	18		0-15.0' drilled with a 6" diameter hollow auger
10				48/12					14	NP			
15			SHALE, soft to medium hard, dark gray with oxidation stains, weathered									3.0	Below 15.0' drilled with an Nx wire-line core barrel. Lost 18' from 15.0-19.0'
20			LIMESTONE, hard, gray, nodular, interbedded with SHALE, soft to medium hard, dark gray wtih oxidation stains, weathered		20	80							
25–30			SHALE, hard, dark gray, slightly fossiliferous, strong horizontal parting		85	100						4.9	
35			CLAYSTONE, soft, gray, laminated CLAYSTONE, very soft, light gray, massive		75	83						30.4	Lost 1.7' from 35.0 - 38.0'
40			SHALE, hard, dark gray, very fossiliferous, strong horizontal parting										
45			CLAYSTONE, gray, very soft, massive CLAYSTONE, light gray, very soft, massive LIMESTONE, dense, dark gray, very hard SHALE, hard, dark gray, slightly fossiliferous		88	100						4.4	

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

· SP **Indicates Bottom of Stand Pipe**

■ **Indicates Core Recovery**

□ **Indicates Core Loss**

10/25 **Indicates Water Level and Date Recorded**

Standard Penetration Test

11/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

* Used 2 inch diameter California sampler

Project Chem Nuclear

Elevation 5515'

Date Drilled 6/15/82

Type of Rig CME-55

Total Depth 103.0'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG	Job No: 1-2543-3338
FOX Consulting Engineers and Geologists	Date: July 19, 1982
	Figure A9, pg. 1

Bore Hole No. B4 Sheet 2 of 2

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
55 60 65			SHALE, (cont.)		96	100						3.6	
			LIMESTONE, gray, hard, nodular									4.3	
70			SHALE, hard, dark gray, slightly fossiliferous, 1" white clay seam at top contact		89	100							
75			SILTSTONE, sandy (fine grained), well cemented, dark gray, bioturbated										
			SANDSTONE, medium grained, silty, well cemented, light gray, slightly bioturbated										
80			SILTSTONE, sandy (fine grained), well cemented, dark gray, bioturbated		97	100						4.5	
			SANDSTONE, very coarse grained, conglomeratic, angular, well cemented, light gray										
85			SILTSTONE, as above										
			SANDSTONE, fine grained, silty, well cemented, light gray										
90			SILTSTONE, as above, with long high angle fractures to 91.6'		58	100						4.6	
			SANDSTONE, light gray, as above										
95			SILTSTONE, as above										
			CLAYSTONE, gray, laminated, as above										
			CLAYSTONE, light gray, as above		88	100						14.7	
			SANDSTONE, as above, to 103'										

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

□ **Indicates Core Loss**

≡ 10/25 **Indicates Water Level and Date Recorded**

Standard Penetration Test

11/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5515'

Date Drilled 6/15/82

Type of Rig CME-55

Total Depth 103.0'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

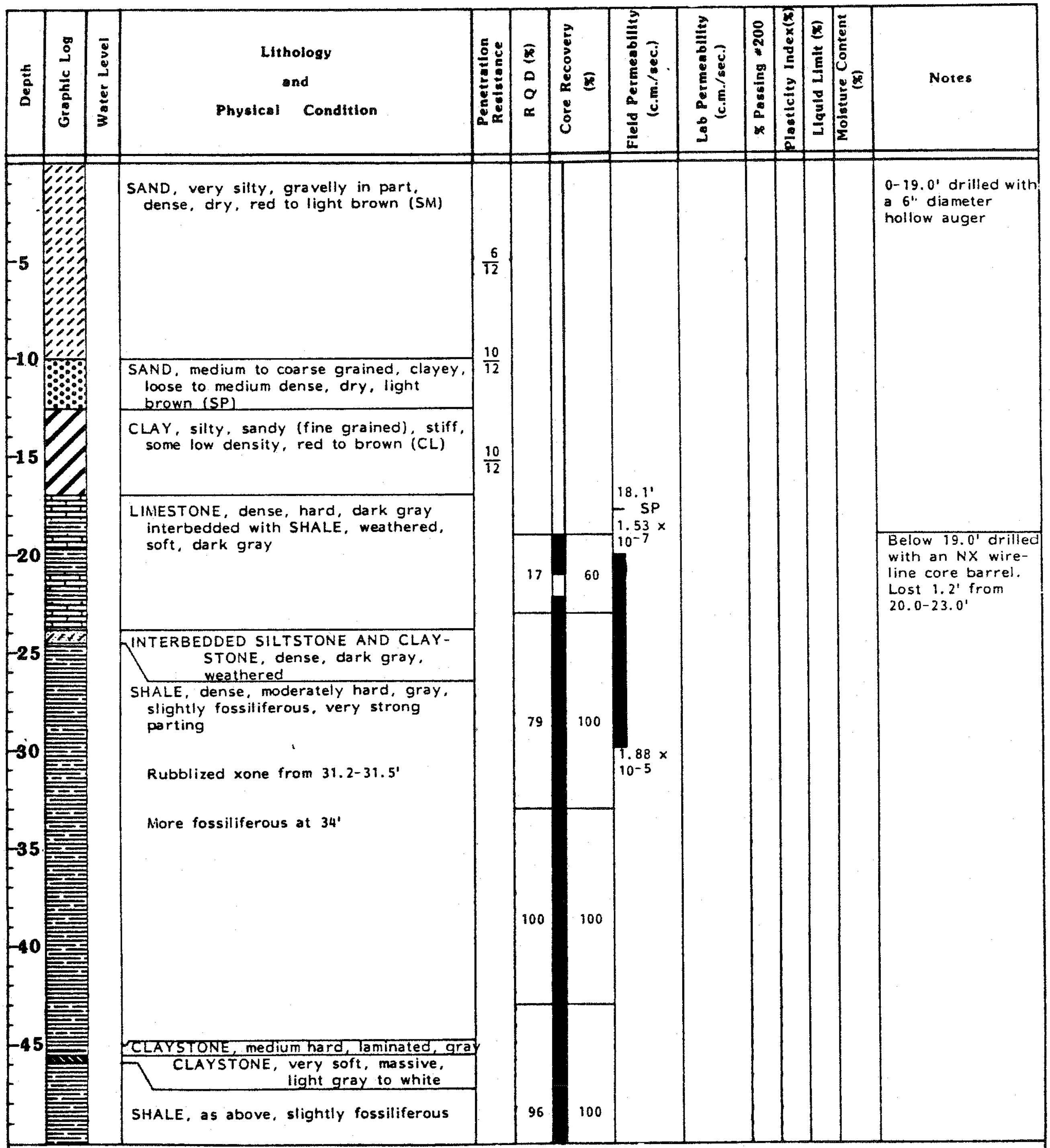
FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: July 19, 1982

Figure A9, pg. 2

Bore Hole No. B5 Sheet 1 of 3



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
0–10			SAND, very silty, gravelly in part, dense, dry, red to light brown (SM)	6/12 10/12									0-19.0' drilled with a 6" diameter hollow auger
10			SAND, medium to coarse grained, clayey, loose to medium dense, dry, light brown (SP)										
15			CLAY, silty, sandy (fine grained), stiff, some low density, red to brown (CL)	10/12									
20			LIMESTONE, dense, hard, dark gray interbedded with SHALE, weathered, soft, dark gray		17	60	18.1' — SP 1.53×10^{-7}						Below 19.0' drilled with an NX wire-line core barrel. Lost 1.2' from 20.0-23.0'
25			INTERBEDDED SILTSTONE AND CLAYSTONE, dense, dark gray, weathered										
25–45			SHALE, dense, moderately hard, gray, slightly fossiliferous, very strong parting Rubblized xone from 31.2-31.5' More fossiliferous at 34'		79 100	100 100	1.88×10^{-5}						
45			CLAYSTONE, medium hard, laminated, gray										
			CLAYSTONE, very soft, massive, light gray to white										
			SHALE, as above, slightly fossiliferous		96	100							

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP **Indicates Bottom of Stand Pipe**

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 **Indicates Water Level and Date Recorded**

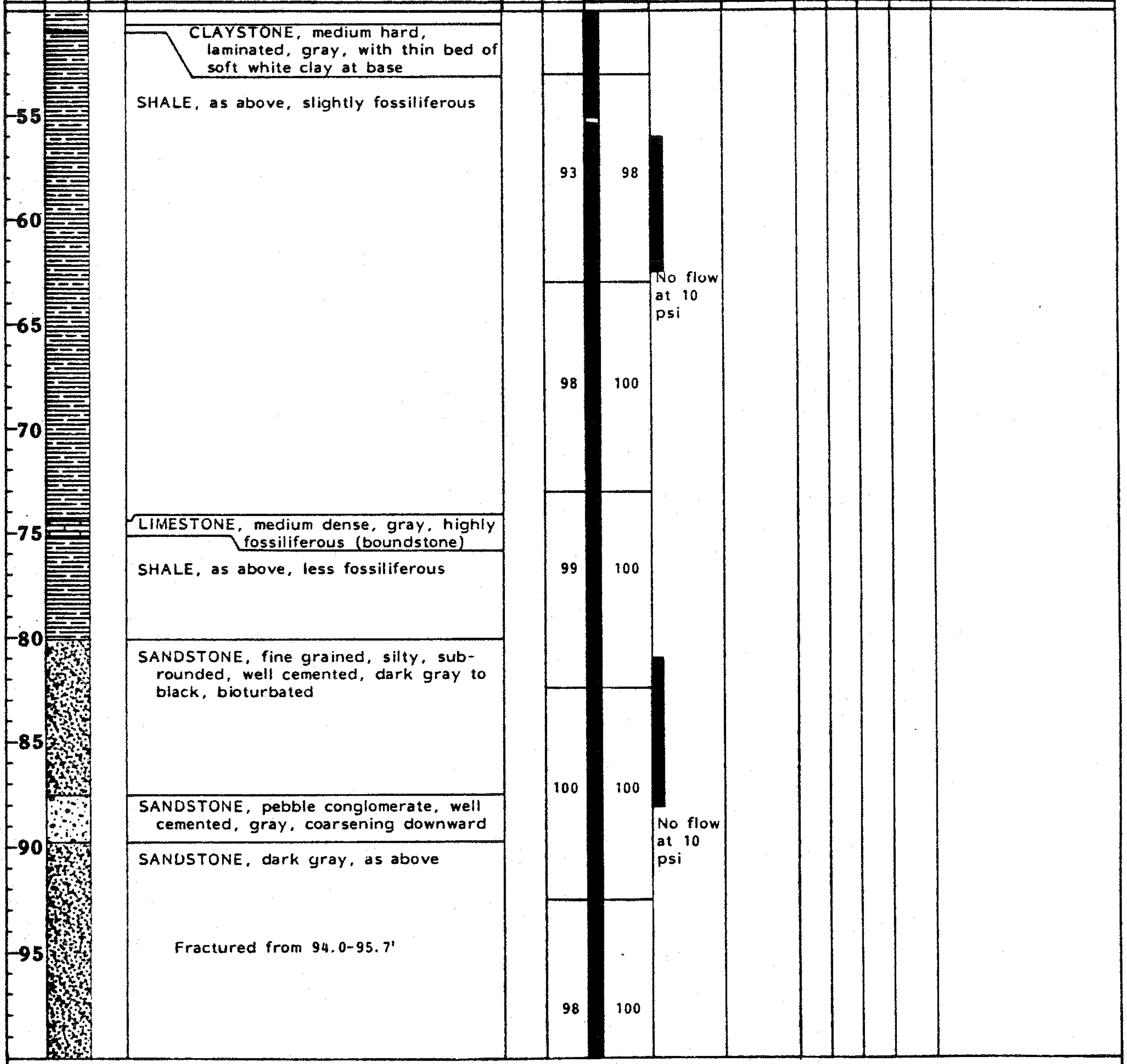
Standard Penetration Test
6/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear
Elevation 5530'
Date Drilled 6/8-6/9/82
Type of Rig CME-55
Total Depth 112.8'
Logged By EF/PR

SUBSURFACE EXPLORATION LOG	Job No: 1-2543-3338
FOX Consulting Engineers and Geologists	Date: July 19, 1982
	Figure A10, pg. 1

Bore Hole No. B5 Sheet 2 of 3



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			CLAYSTONE, medium hard, laminated, gray, with thin bed of soft white clay at base										
55			SHALE, as above, slightly fossiliferous										
60					93	98							
65							No flow at 10 psi						
70					98	100							
75			LIMESTONE, medium dense, gray, highly fossiliferous (boundstone)										
			SHALE, as above, less fossiliferous		99	100							
80			SANDSTONE, fine grained, silty, subrounded, well cemented, dark gray to black, bioturbated										
85					100	100							
			SANDSTONE, pebble conglomerate, well cemented, gray, coarsening downward				No flow at 10 psi						
90			SANDSTONE, dark gray, as above										
95			Fractured from 94.0-95.7'										
					98	100							

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

6/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5530'

Date Drilled 6/8-6/9/82

Type of Rig CME-55

Total Depth 112.8'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No 1-2543-3338

Date: July 19, 1982

Figure A10, pg. 2

Bore Hole No. B5 Sheet 3 of 3

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			SHALE, clayey, dense, laminated, dark gray, strong horizontal parting										
105			SANDSTONE, dark gray, as above		100	100							
110													
			Total Depth at 112.8'										

EXPLANATION

Field Permeability Tests

▌ Indicates Test Section for Packer

- SP Indicates Bottom of Stand Pipe

■ Indicates Core Recovery

□ Indicates Core Loss

▽ 10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

6/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

* Used 2 inch diameter California sampler

Project Chem Nuclear

Elevation 5530'

Date Drilled 6/8-6/9/82

Type of Rig CME-55

Total Depth 112.8'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

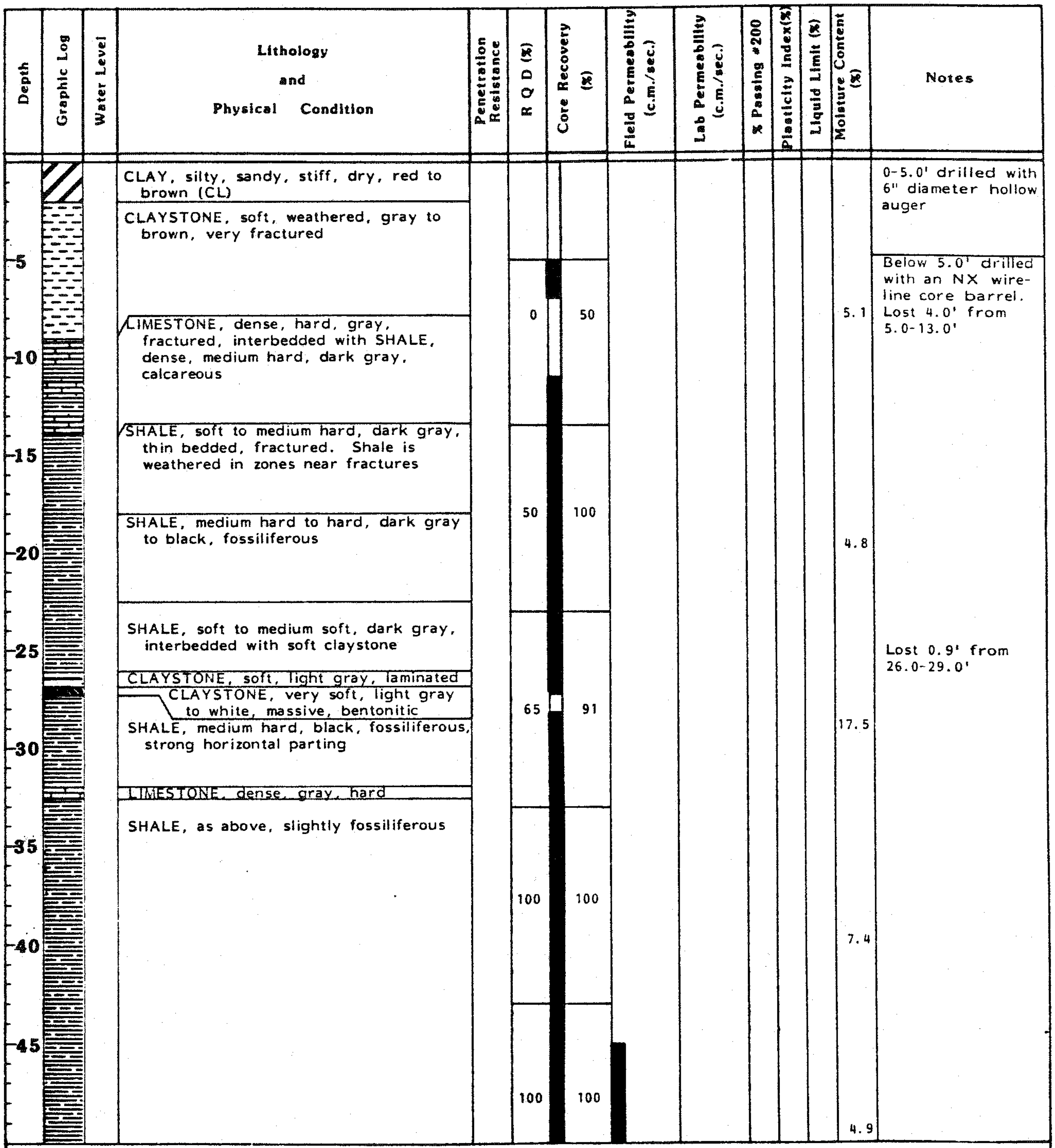
FOX Consulting Engineers and Geologists

Job No. 1-2543-3338

Date: July 19, 1982

Figure A10, pg. 3

Bore Hole No. B6 Sheet 1 of 2



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			CLAY, silty, sandy, stiff, dry, red to brown (CL)										0-5.0' drilled with 6" diameter hollow auger
5			CLAYSTONE, soft, weathered, gray to brown, very fractured										Below 5.0' drilled with an NX wire-line core barrel. Lost 4.0' from 5.0-13.0'
10			LIMESTONE, dense, hard, gray, fractured, interbedded with SHALE, dense, medium hard, dark gray, calcareous		0	50						5.1	
15			SHALE, soft to medium hard, dark gray, thin bedded, fractured. Shale is weathered in zones near fractures										
20			SHALE, medium hard to hard, dark gray to black, fossiliferous		50	100						4.8	
25			SHALE, soft to medium soft, dark gray, interbedded with soft claystone										Lost 0.9' from 26.0-29.0'
			CLAYSTONE, soft, light gray, laminated										
			CLAYSTONE, very soft, light gray to white, massive, bentonitic		65	91							
30			SHALE, medium hard, black, fossiliferous, strong horizontal parting									17.5	
			LIMESTONE, dense, gray, hard										
35 40 45			SHALE, as above, slightly fossiliferous		100 100	100 100						7.4 4.9	

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

11/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5560'

Date Drilled 6/11/82

Type of Rig CME-55

Total Depth 73.0'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG	Job No.	1-2543-3338
FOX Consulting Engineers and Geologists	Date:	July 19, 1982
	Figure	A11, pg. 1

Bore Hole No. B6 Sheet 2 of 2

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
55			SHALE, (cont.)				No Flow at 20 psi						
			CLAYSTONE, soft, gray, laminated with white bentonitic clay at bottom 0.1'		90	100							
60			SHALE, medium hard, dark gray to black, fissile, very strong horizontal parting									4.2	
65			SANDSTONE, fine grained, silty, subangular to subround, well cemented, dark gray, bioturbated with zones of less silty, light gray sandstone										
			SANDSTONE, coarse grained, well cemented, dark gray,		95	100							
70			SILTSTONE, sandy, well cemented, dark gray, bioturbated				2.95×10^{-7}					2.4	
75			Total Depth at 73.0'										

EXPLANATION

Field Permeability Tests

▮ Indicates Test Section for Packer

- SP Indicates Bottom of Stand Pipe

■ Indicates Core Recovery

□ Indicates Core Loss

≡ 10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

11/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

* Used 2 inch diameter California sampler

Project Chem Nuclear

Elevation 5560'

Date Drilled 6/11/82

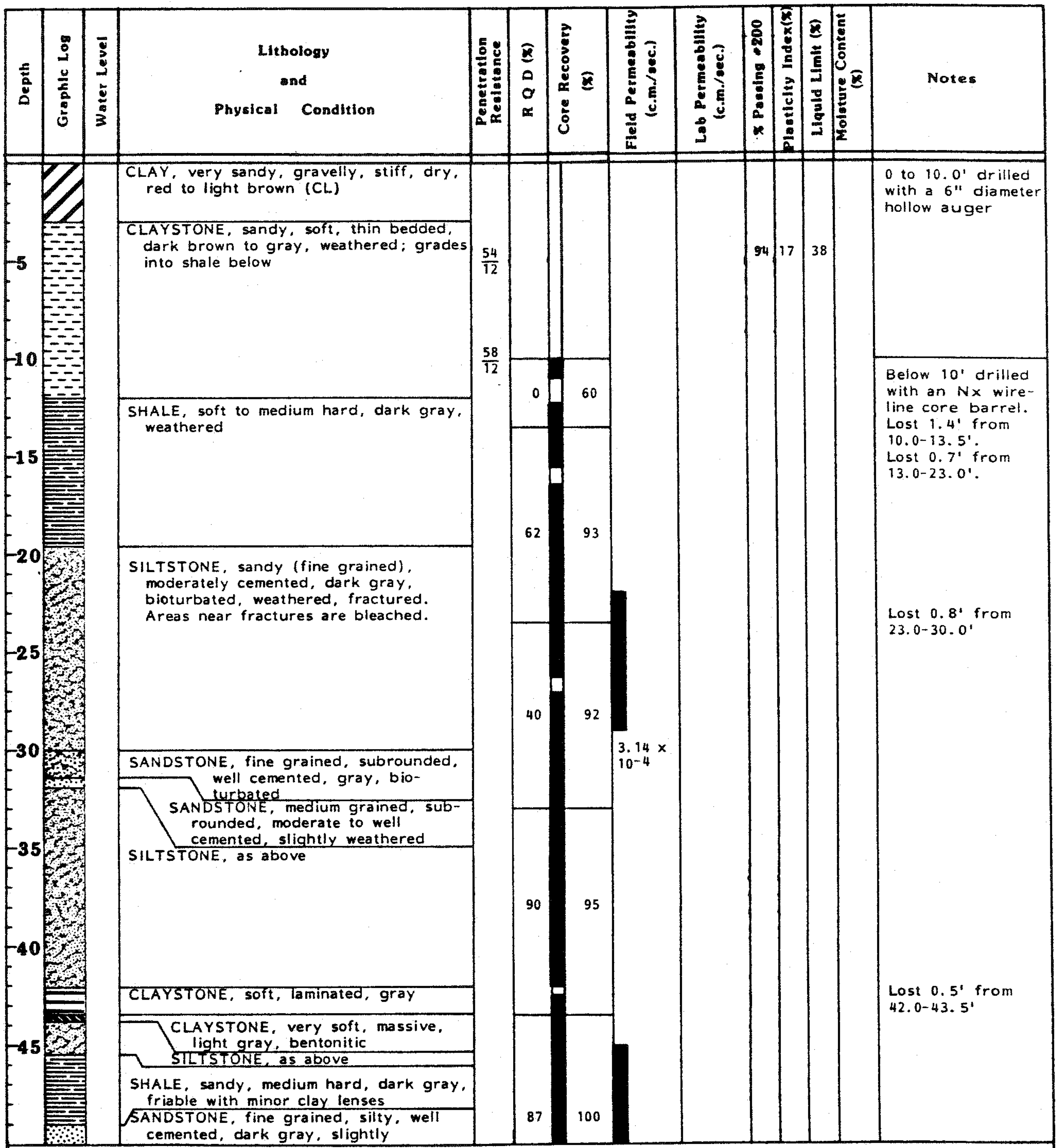
Type of Rig CME-55

Total Depth 73.0'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG	Job No:	1-2543-3338
FOX Consulting Engineers and Geologists	Date:	July 19, 1982
	Figure	A11, pg. 2

Bore Hole No. B7 Sheet 1 of 2



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			CLAY, very sandy, gravelly, stiff, dry, red to light brown (CL)										0 to 10.0' drilled with a 6" diameter hollow auger
5 10			CLAYSTONE, sandy, soft, thin bedded, dark brown to gray, weathered; grades into shale below	54/12 58/12	0	60			94	17	38		Below 10' drilled with an Nx wire-line core barrel. Lost 1.4' from 10.0-13.5'. Lost 0.7' from 13.0-23.0'.
15			SHALE, soft to medium hard, dark gray, weathered		62	93							
20 25			SILTSTONE, sandy (fine grained), moderately cemented, dark gray, bioturbated, weathered, fractured. Areas near fractures are bleached.		40	92							Lost 0.8' from 23.0-30.0'
30			SANDSTONE, fine grained, subrounded, well cemented, gray, bioturbated				3.14×10^{-4}						
			SANDSTONE, medium grained, subrounded, moderate to well cemented, slightly weathered										
35 40			SILTSTONE, as above		90	95							
			CLAYSTONE, soft, laminated, gray										Lost 0.5' from 42.0-43.5'
45			CLAYSTONE, very soft, massive, light gray, bentonitic										
			SILTSTONE, as above										
			SHALE, sandy, medium hard, dark gray, friable with minor clay lenses		87	100							
			SANDSTONE, fine grained, silty, well cemented, dark gray, slightly										

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

≡ 10/25 **Indicates Water Level and Date Recorded**

Standard Penetration Test
54/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 **inches.**

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5585'

Date Drilled 6/12-13/82

Type of Rig CME-55

Total Depth 83.5'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

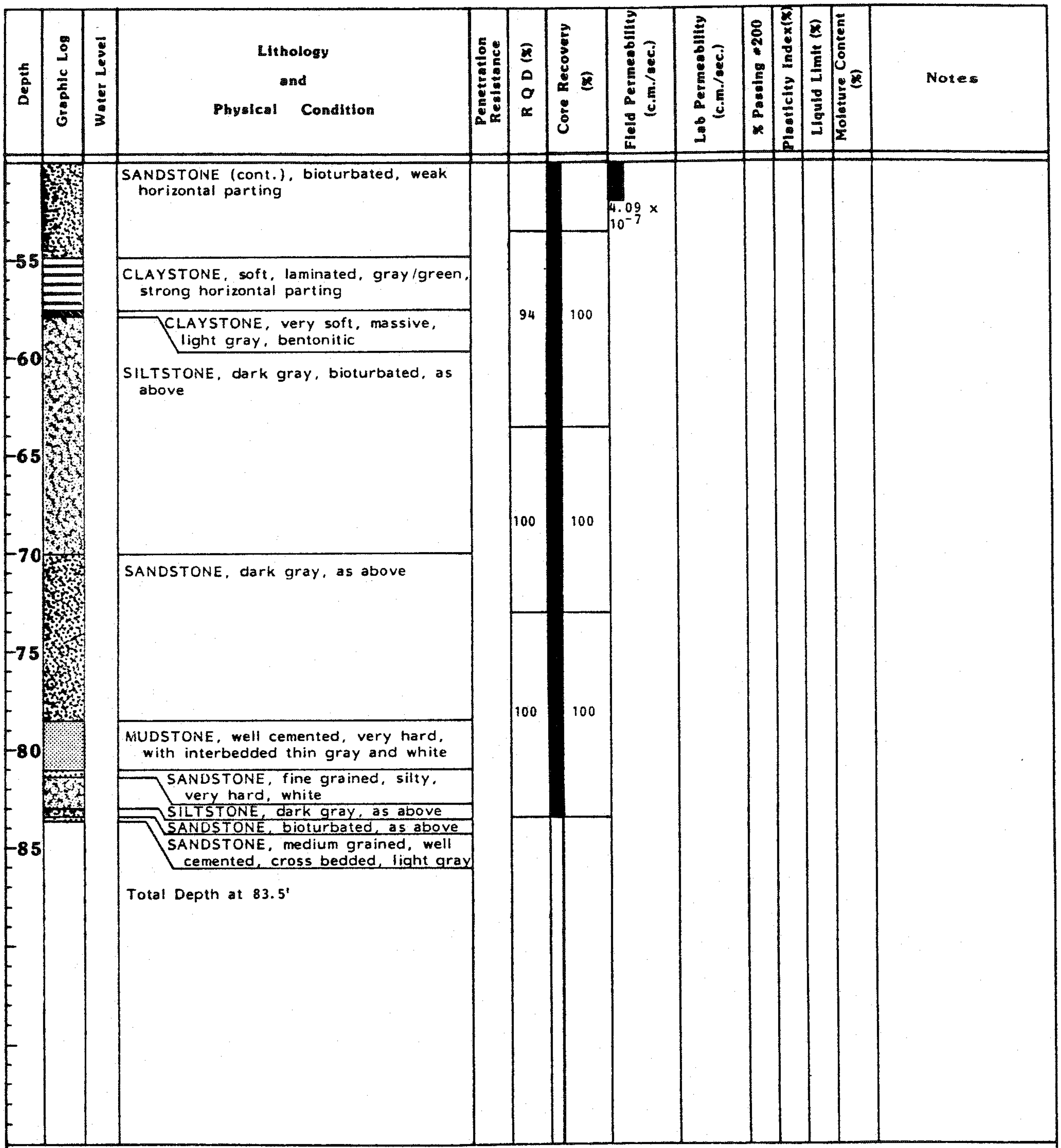
FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: July 19, 1982

Figure A12, pg. 1

Bore Hole No. B7 Sheet 2 of 2



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			SANDSTONE (cont.), bioturbated, weak horizontal parting				4.09×10^{-7}						
55			CLAYSTONE, soft, laminated, gray/green, strong horizontal parting										
			CLAYSTONE, very soft, massive, light gray, bentonitic		94	100							
60 65			SILTSTONE, dark gray, bioturbated, as above		100	100							
70 75			SANDSTONE, dark gray, as above		100	100							
80			MUDSTONE, well cemented, very hard, with interbedded thin gray and white										
			SANDSTONE, fine grained, silty, very hard, white										
			SILTSTONE, dark gray, as above										
			SANDSTONE, bioturbated, as above										
85			SANDSTONE, medium grained, well cemented, cross bedded, light gray										
			Total Depth at 83.5'										

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

· SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

54/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5585'

Date Drilled 6/12-6/13/82

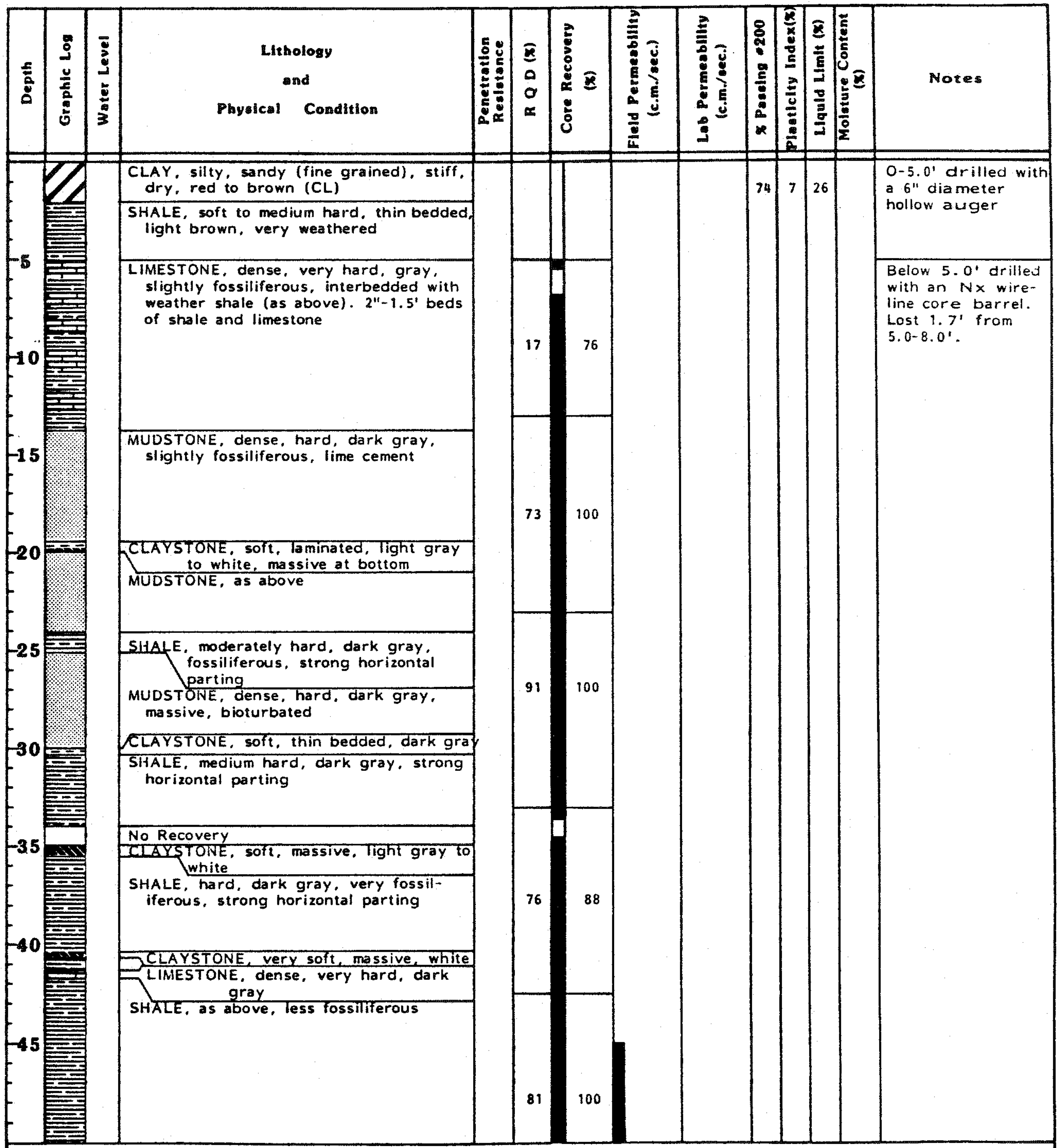
Type of Rig CME-55

Total Depth 83.5'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG	Job No: 1-2543-3338
FOX Consulting Engineers and Geologists	Date: July 19, 1982
	Figure A12, pg. 2

Bore Hole No. B8 Sheet 1 of 2



Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			CLAY, silty, sandy (fine grained), stiff, dry, red to brown (CL)						74	7	26		0-5.0' drilled with a 6" diameter hollow auger
			SHALE, soft to medium hard, thin bedded, light brown, very weathered										
5 10			LIMESTONE, dense, very hard, gray, slightly fossiliferous, interbedded with weather shale (as above). 2"-1.5' beds of shale and limestone		17	76							Below 5.0' drilled with an Nx wire-line core barrel. Lost 1.7' from 5.0-8.0'.
15			MUDSTONE, dense, hard, dark gray, slightly fossiliferous, lime cement		73	100							
20			CLAYSTONE, soft, laminated, light gray to white, massive at bottom										
			MUDSTONE, as above										
25			SHALE, moderately hard, dark gray, fossiliferous, strong horizontal parting										
			MUDSTONE, dense, hard, dark gray, massive, bioturbated		91	100							
30			CLAYSTONE, soft, thin bedded, dark gray										
			SHALE, medium hard, dark gray, strong horizontal parting										
			No Recovery										
35			CLAYSTONE, soft, massive, light gray to white										
			SHALE, hard, dark gray, very fossiliferous, strong horizontal parting		76	88							
40			CLAYSTONE, very soft, massive, white										
			LIMESTONE, dense, very hard, dark gray										
45			SHALE, as above, less fossiliferous		81	100							

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

- SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

□ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test
11/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5615'

Date Drilled 6/17/82

Type of Rig CME-55

Total Depth 72.5'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: July 19, 1982

Figure A13, pg. 1

Bore Hole No. B8 **Sheet** 2 **of** 2

Depth	Graphic Log	Water Level	Lithology and Physical Condition	Penetration Resistance	R Q D (%)	Core Recovery (%)	Field Permeability (c.m./sec.)	Lab Permeability (c.m./sec.)	% Passing #200	Plasticity Index(%)	Liquid Limit (%)	Moisture Content (%)	Notes
			SHALE, (cont.)				No Flow at 20 psi						
55					100	100							
60			No Recovery										
65			SHALE, as above		93	98							
70			SILTSTONE, sandy (fine grained), well cemented, light to dark gray, bioturbated										
			Total Depth at 72.5'										

EXPLANATION

Field Permeability Tests

▮ **Indicates Test Section for Packer**

· SP Indicates Bottom of Stand Pipe

■ **Indicates Core Recovery**

☐ **Indicates Core Loss**

10/25 Indicates Water Level and Date Recorded

Standard Penetration Test

11/12 Recorded as number of blows with a 140 pound hammer, falling 30 inches. Required to drive a standard sampler 12 inches.

*** Used 2 inch diameter California sampler**

Project Chem Nuclear

Elevation 5615'

Date Drilled 6/17/82

Type of Rig CME-55

Total Depth 72.5'

Logged By EF/PR

SUBSURFACE EXPLORATION LOG

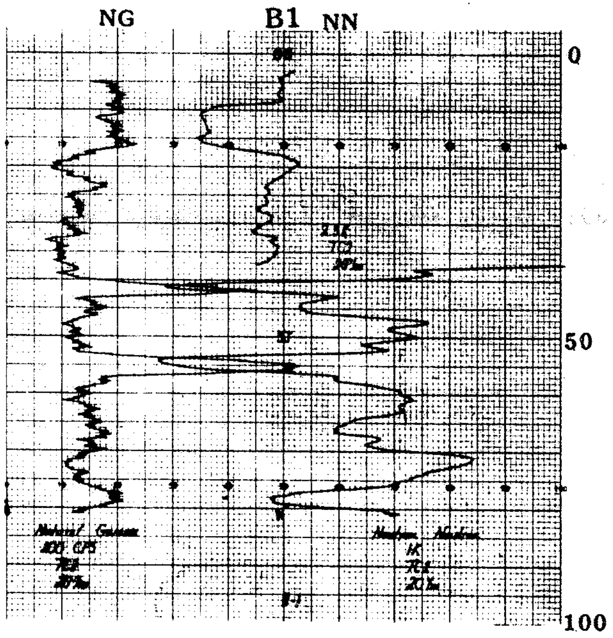
FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: July 19, 1982

Figure A13, pg. 2

B1



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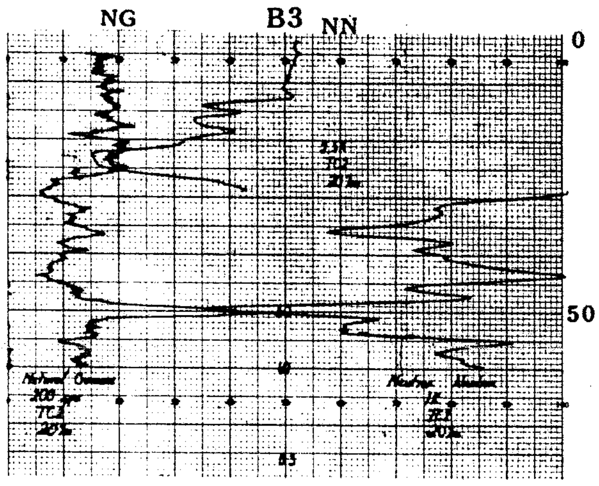

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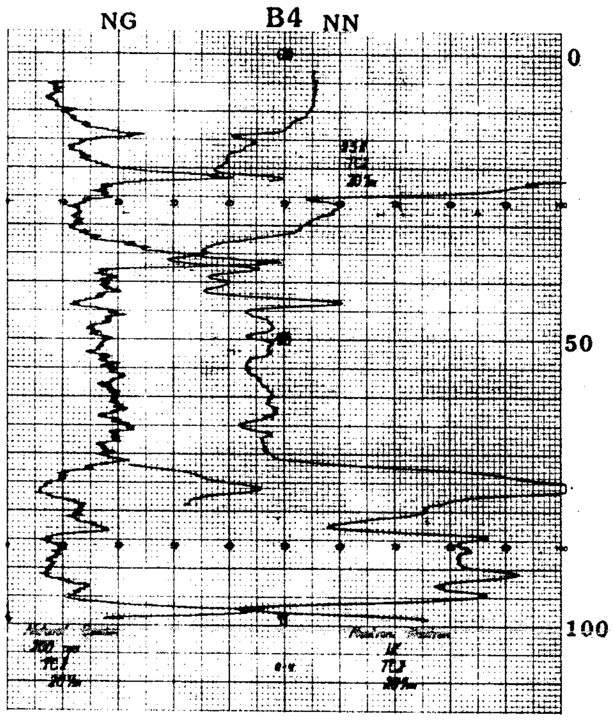

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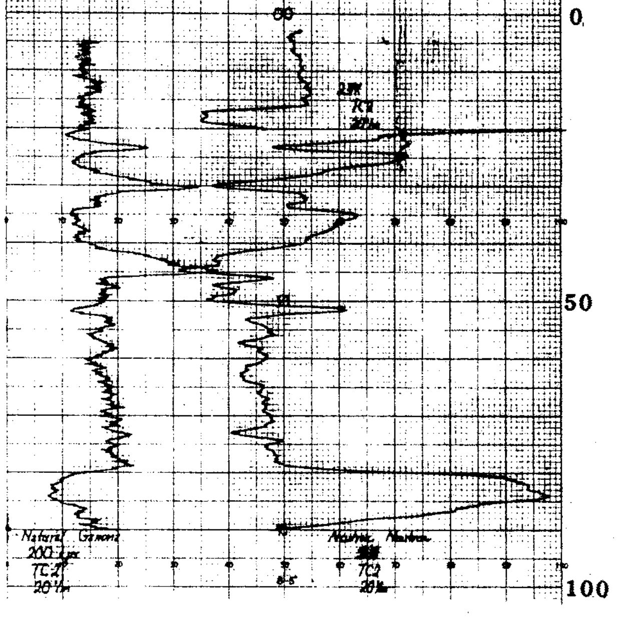

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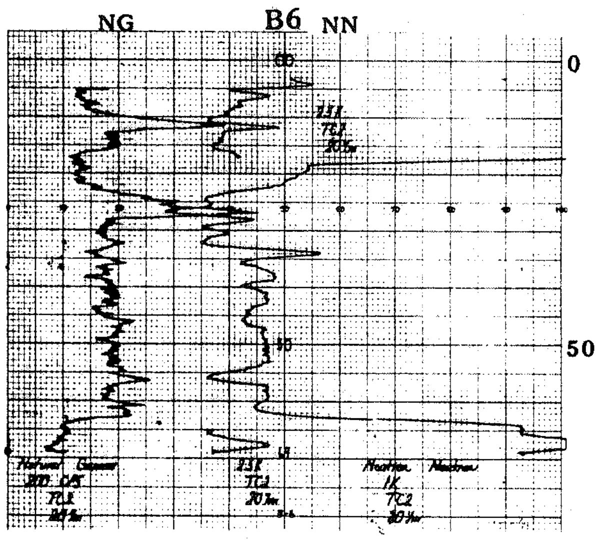

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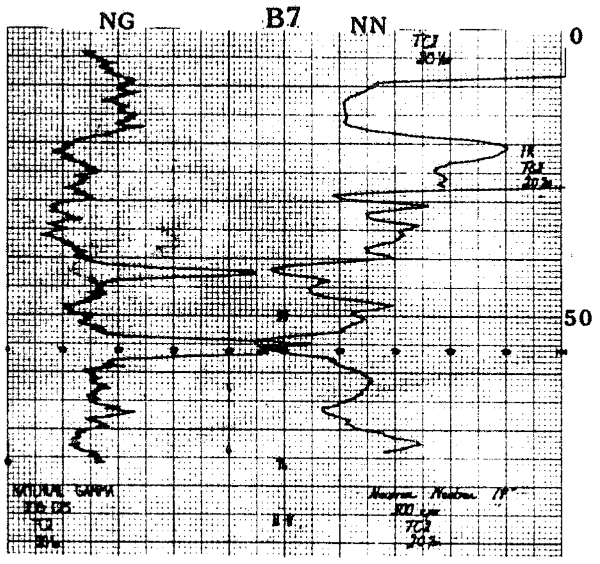
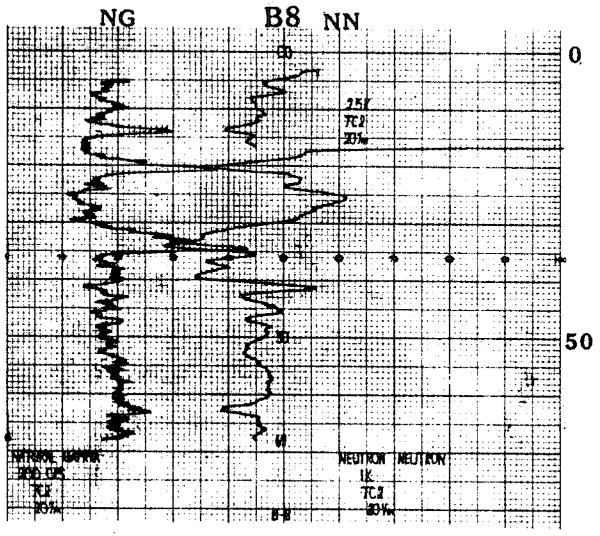


B8



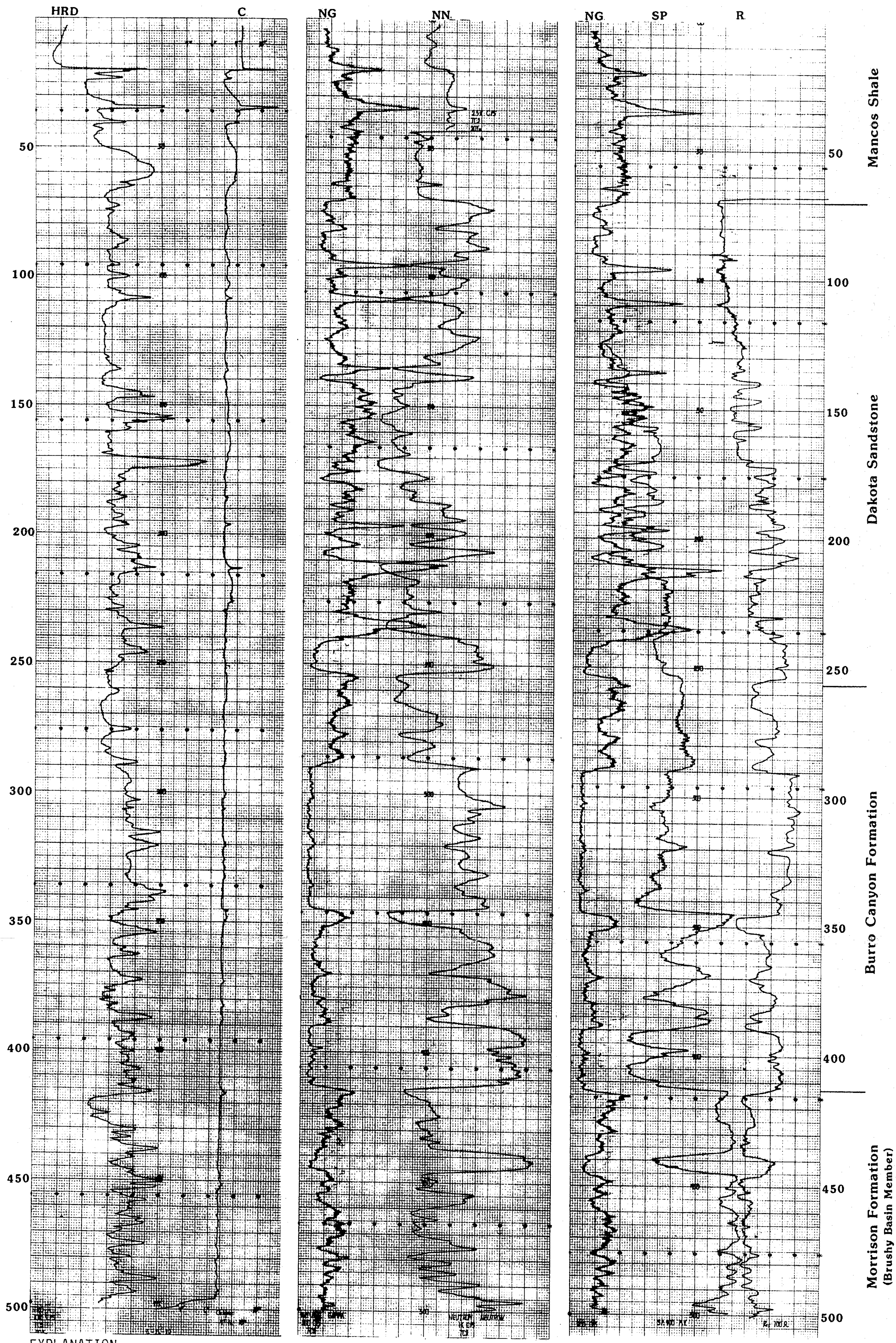
EXPLANATION

NG	Natural Gamma Log
NN	Neutron Neutron Log

GEOPHYSICAL LOGS OF CORE BORINGS

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338 | Date: 7/31/82 | Figure A14



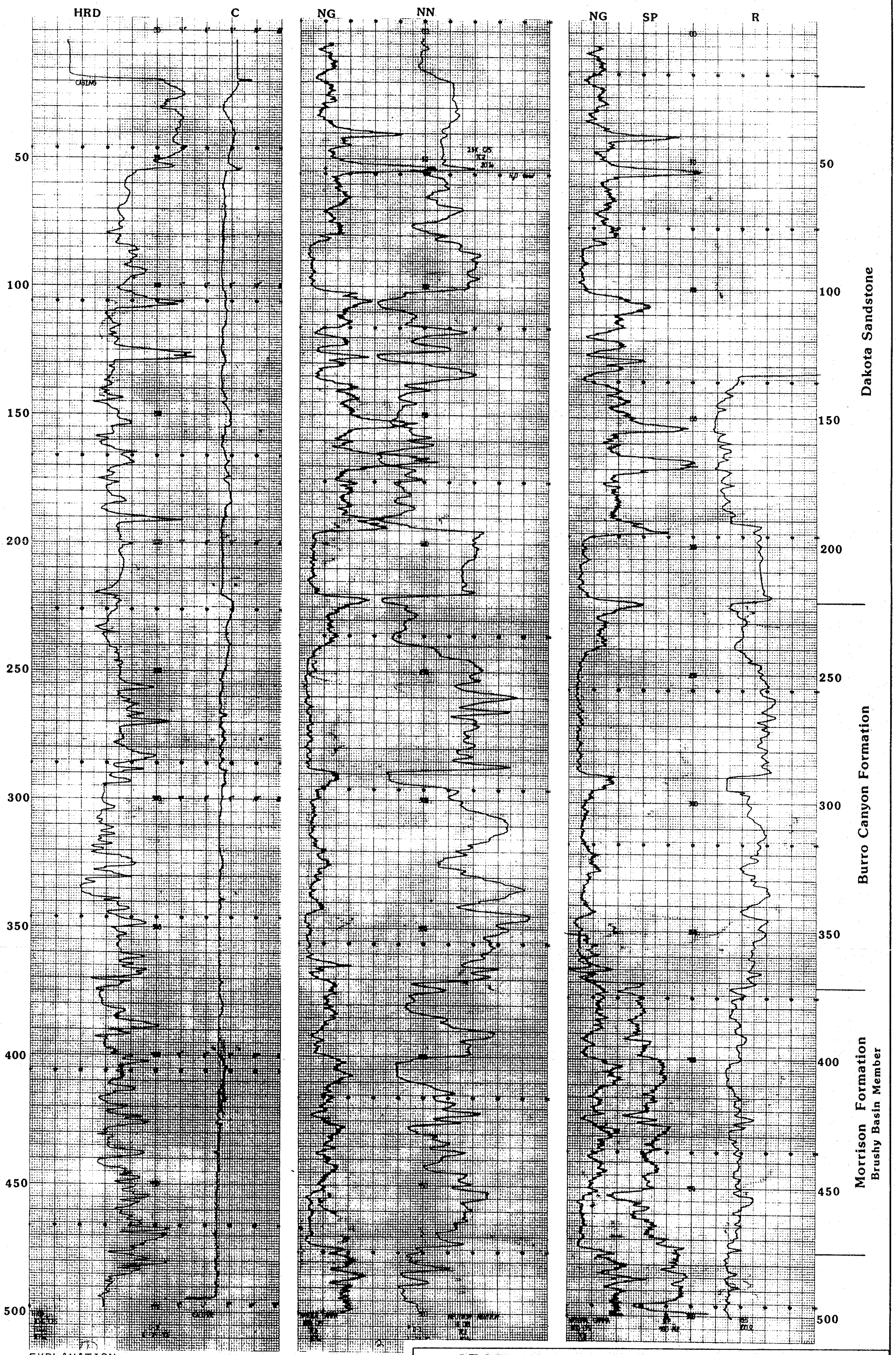
EXPLANATION

HRD High Resolution Density
C Caliper
NG Natural Gamma
NN Specific Potential
R Resistivity

GEOPHYSICAL LOGS OF DEEP HOLE NO.1

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338	Date: 7/31/82	Figure A15



EXPLANATION
HRD High Resolution Density
C Caliper
NG Natural Gamma
NN Specific Potential
R Resistivity

GEOPHYSICAL LOGS OF DEEP HOLE NO.2

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338 | Date: 7/31/82 | Figure A16

APPENDIX B: Laboratory Test Data

Test Hole No.	Depth of Sample (ft.)	Soil Description	Optimum Moisture Content (%)	Maximum Dry Density (pcf)	Atterberg Limits		% Silt and Clay	Soluble Sulfates (%)	Perme-ability 10^{-7} cm/sec	Specific Gravity		Remarks
					LL	PL						
A1	5	CLAY, sandy,drk.brn. (CL)			47	17	97					
A1	10	SAND, silty,red-brn.(SM)				NP	21					
A2	2-5	CLAY, sandy, silty, gray(CL)	9.0	127.0	31	18	47		NF*			
A2	5	CLAYSTONE, weathered (CL)			29	13	30					
A4	5	CLAY, v. silty,lt.brn.(CL)			24	11	83					
A4	15	CLAYSTONE, sandy (CL)			43	25	98					
B2	5	SANDSTONE, clayey (SC)			27	11	35					
B3	5	CLAY,silty (CL-ML)			34	14	97					
B3	10	" " "			34	15	93					
B4	0-5	SAND, v. silty (SM)	9.0	129.0	18	4	36		7.06			
B4	5	" " " "				NP	42					
B4	10	SAND, silty (SM)				NP	14					
B7	5	CLAYSTONE, silty (CL)			38	17	94					
B8	0-2	CLAY,silty, sandy (CL-ML)	13.5	120.0	26	7	74		0.33			
DH2	0-10	CLAY, silty, sandy (CL)	12.0	122.5	31	14	79		NF			
		*No Flow after a minimum testing period of 10 days										

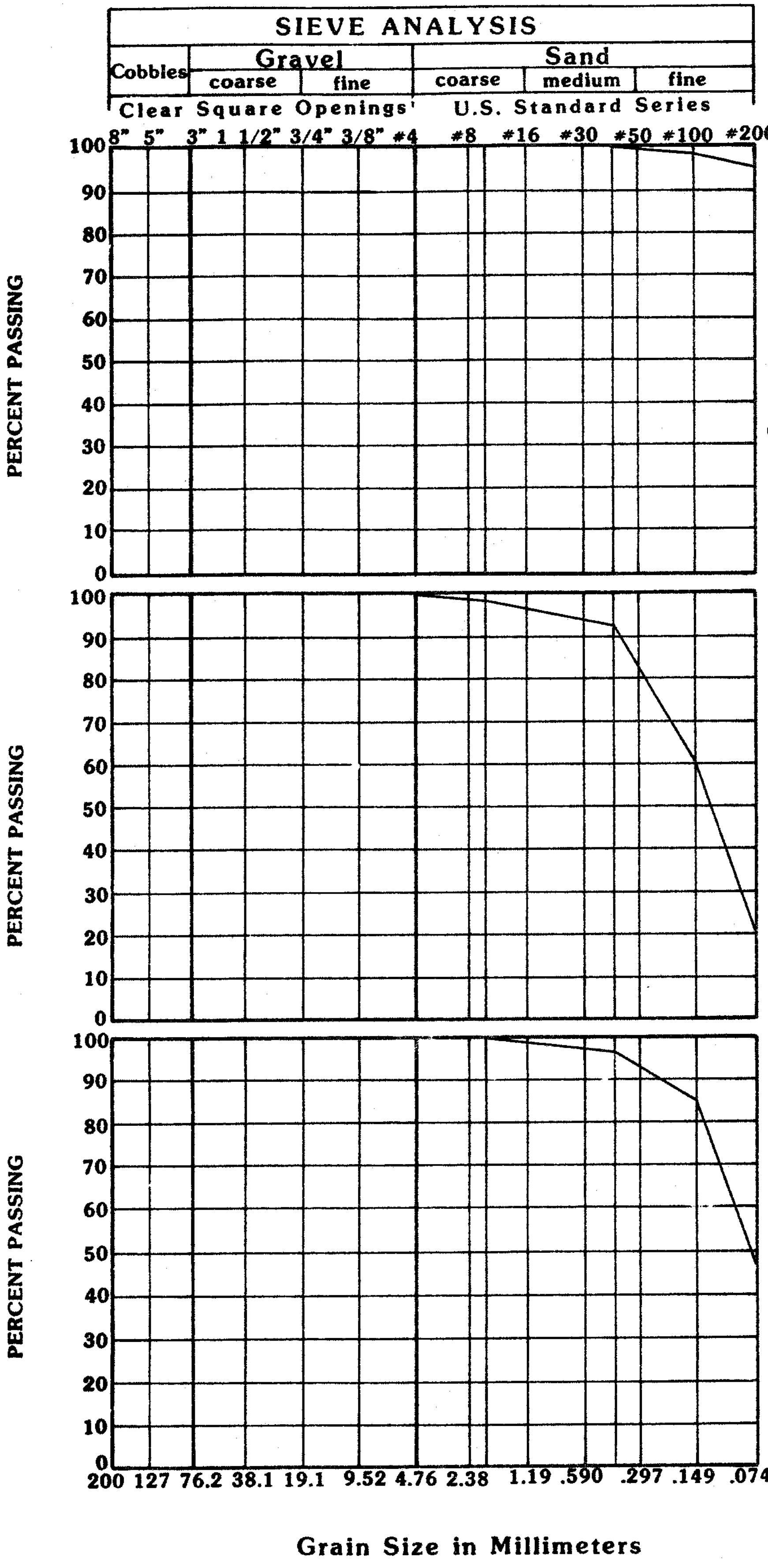
SUMMARY OF LABORATORY TESTING

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: 7-31-82

Table: 10



Sample of CLAY, Sl. Sandy

from test hole A1

at depth 5 feet.

Atterberg limits:

Liquid Limits 47

Plasticity Index 17

Classification: Unified CL

AASHTO

Group Index

Sample of SAND, Silty

from test hole A1

at depth 10 feet.

Atterberg Limits:

Liquid Limits

Plasticity Index NP

Classification: Unified SM

AASHTO

Group Index

Sample of CLAY, Sandy, Silty

from test hole A2

at depth 2-5 feet.

Atterberg Limits:

Liquid Limits 31

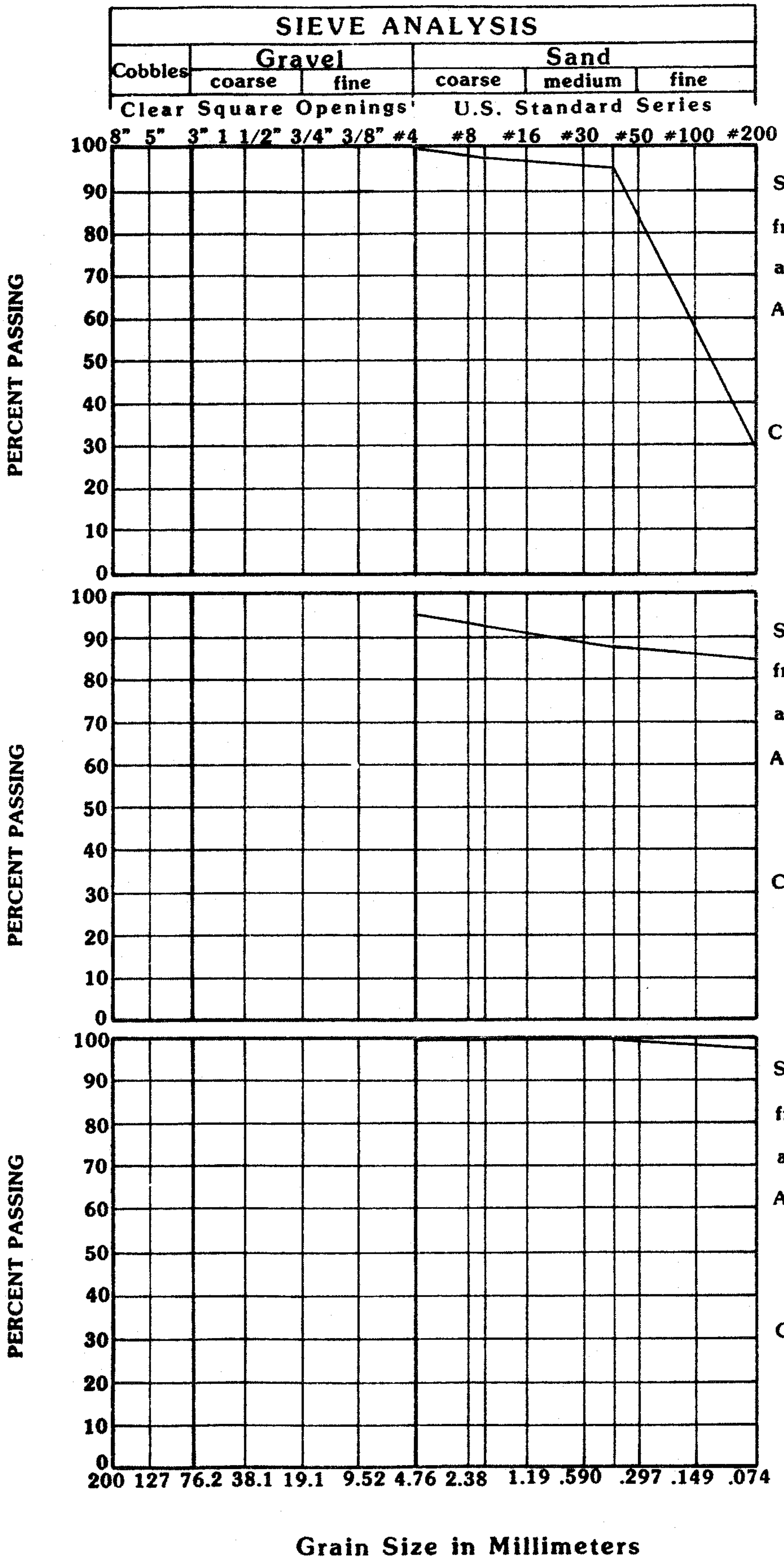
Plasticity Index 18

Classification: Unified CL

AASHTO

Group Index

MECHANICAL ANALYSIS CHART	Job No: 1-2543-3338
FOX Consulting Engineers and Geologists	Date: 7/31/82
	Figure B1



Sample of CLAYSTONE, Weathered

from test hole A2

at depth 5 feet.

Atterberg limits:

Liquid Limits 29

Plasticity Index 13

Classification: Unified CL

AASHTO

Group Index

Sample of CLAY, Silty

from test hole A4

at depth 5 feet.

Atterberg Limits:

Liquid Limits 24

Plasticity Index 11

Classification: Unified CL

AASHTO

Group Index

Sample of CLAYSTONE

from test hole A4

at depth 15 feet.

Atterberg Limits:

Liquid Limits 42

Plasticity Index 25

Classification: Unified CL

AASHTO

Group Index

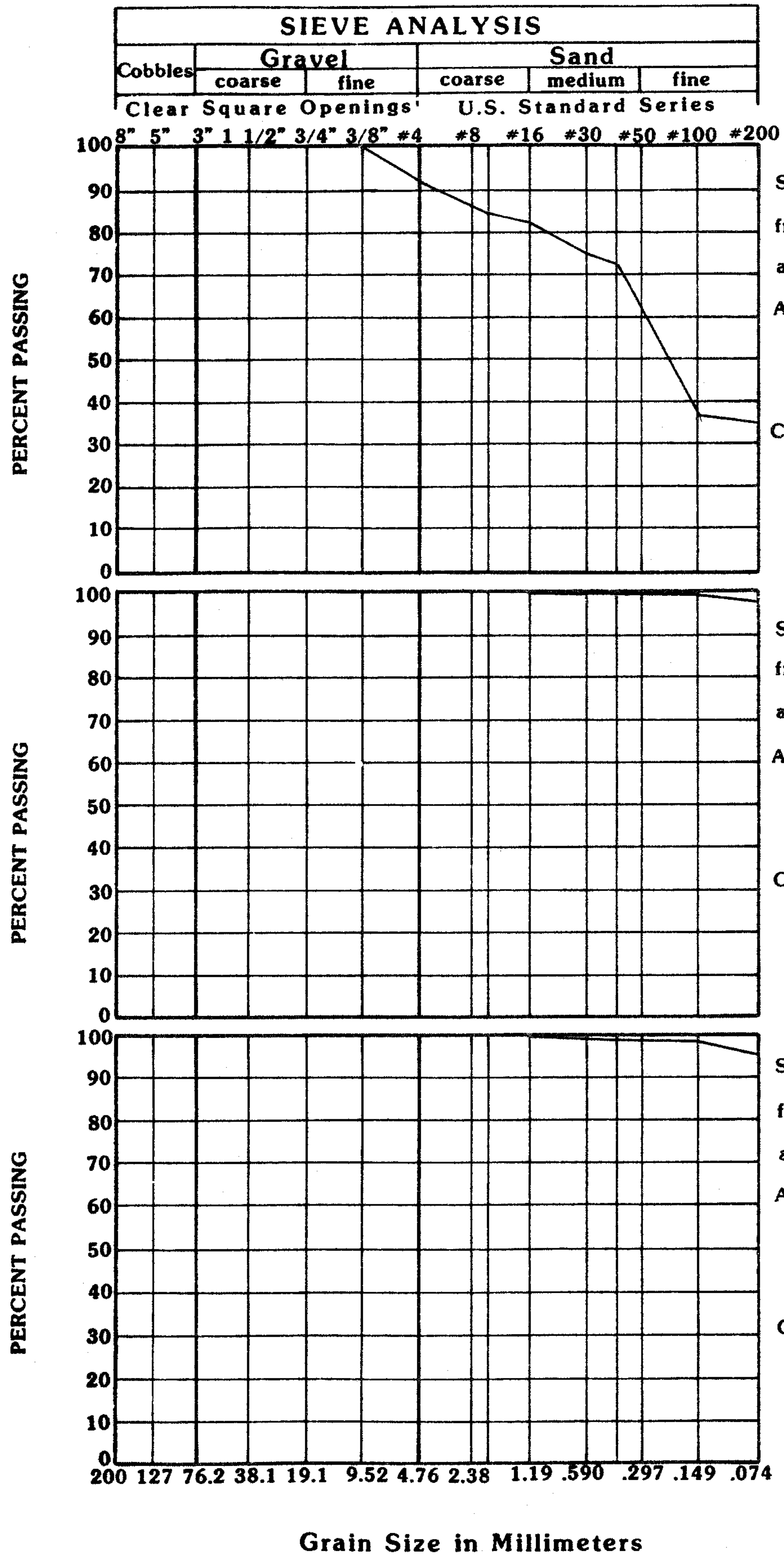
MECHANICAL ANALYSIS CHART

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: 7/31/82

Figure B2



Sample of SANDSTONE, Clayey

from test hole B2

at depth 5 **feet.**

Atterberg limits:

Liquid Limits 27

Plasticity Index 11

Classification: Unified SC

AASHTO ______

Group Index ______

Sample of CLAY, Silty

from test hole B3

at depth 5 **feet.**

Atterberg Limits:

Liquid Limits 34

Plasticity Index 14

Classification: Unified CL-ML

AASHTO ______

Group Index ______

Sample of CLAY, Silty

from test hole B3

at depth 10 **feet.**

Atterberg Limits:

Liquid Limits 34

Plasticity Index 15

Classification: Unified CL-ML

AASHTO ______

Group Index ______

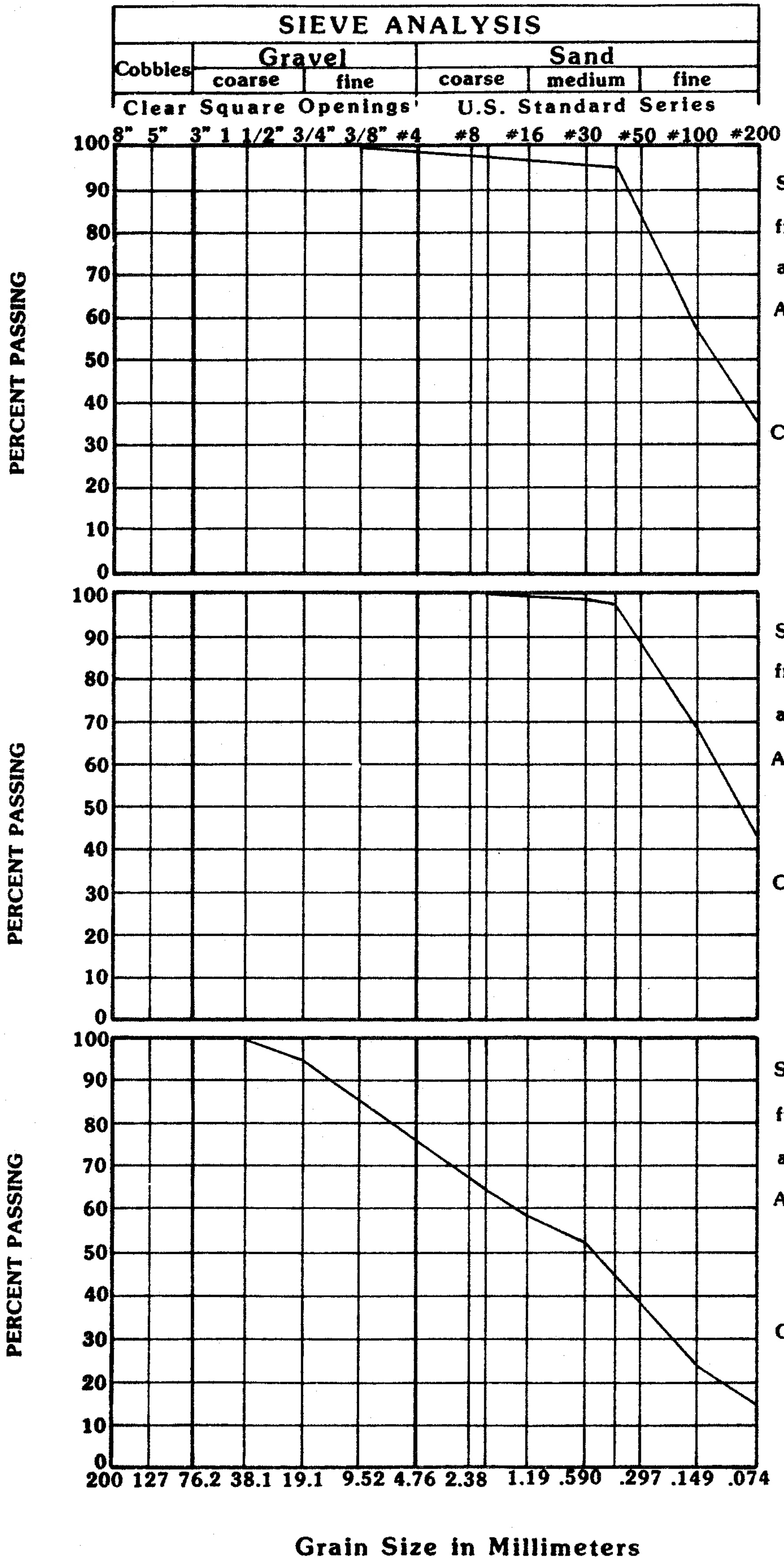
MECHANICAL ANALYSIS CHART

FOX **Consulting Engineers and Geologists**

Job No: **1-2543-3338**

Date: **7/31/82**

Figure **B3**



Sample of SAND, Silty

from test hole B4

at depth 0-5 feet.

Atterberg limits:

Liquid Limits 18

Plasticity Index 4

Classification: Unified SM

AASHTO

Group Index

Sample of SAND, Silty

from test hole B4

at depth 5 feet.

Atterberg Limits:

Liquid Limits

Plasticity Index NP

Classification: Unified SM

AASHTO

Group Index

Sample of SAND, Silty

from test hole B4

at depth 10 feet.

Atterberg Limits:

Liquid Limits

Plasticity Index NP

Classification: Unified SM

AASHTO

Group Index

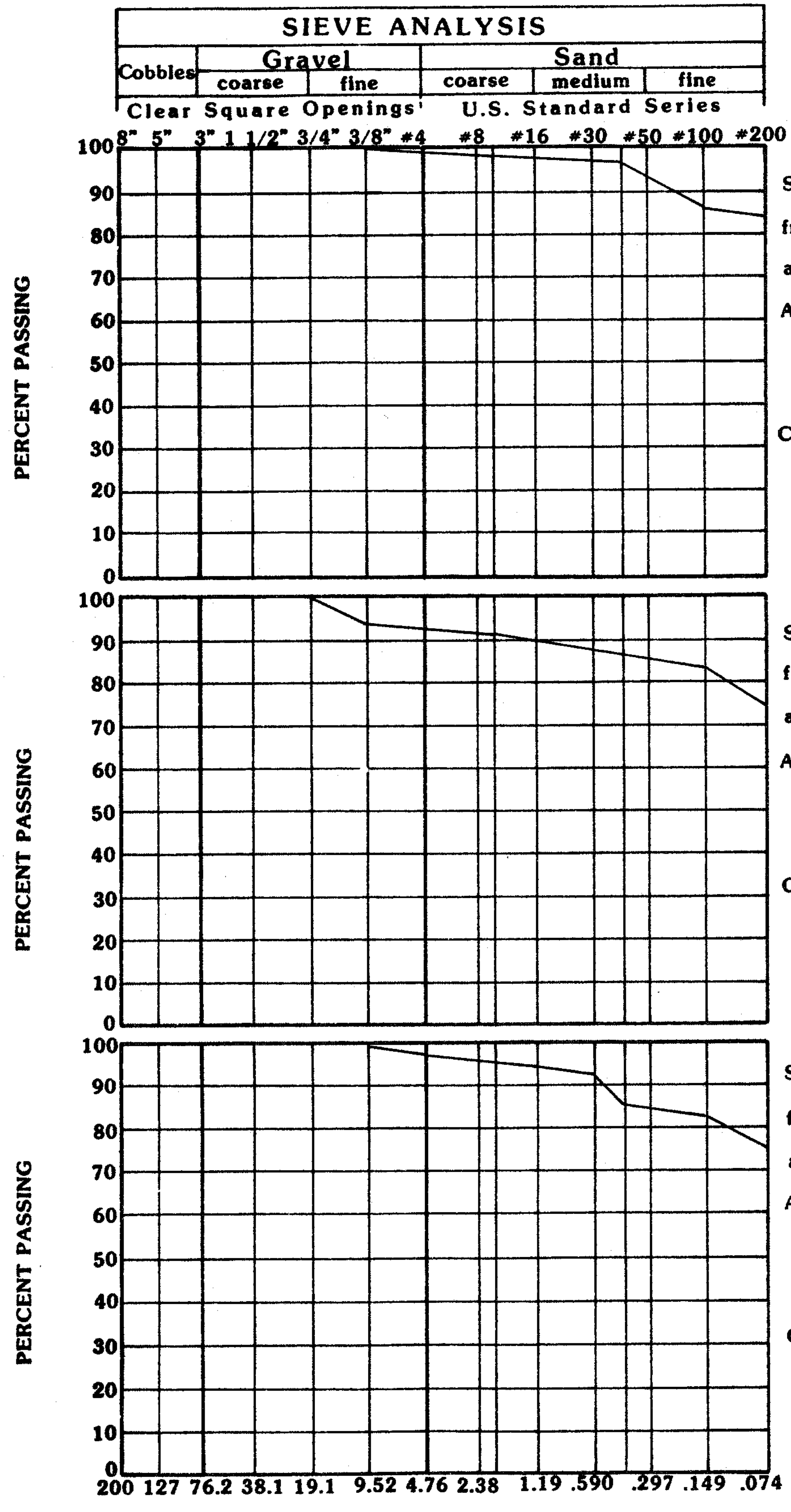
MECHANICAL ANALYSIS CHART

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: 7/31/82

Figure B4



Sample of CLAYSTONE, Silty
from test hole B7
at depth 5 **feet.**
Atterberg limits:
Liquid Limits 38
Plasticity Index 17
Classification: Unified CL
AASHTO
Group Index

Sample of CLAY, Silty, Sandy
from test hole B8
at depth 0-2 **feet.**
Atterberg Limits:
Liquid Limits 26
Plasticity Index 7
Classification: Unified CL-ML
AASHTO
Group Index

Sample of CLAY, Silty, Sandy
from test hole DH2
at depth 0-10 **feet.**
Atterberg Limits:
Liquid Limits 31
Plasticity Index 14
Classification: Unified CL
AASHTO
Group Index

MECHANICAL ANALYSIS CHART

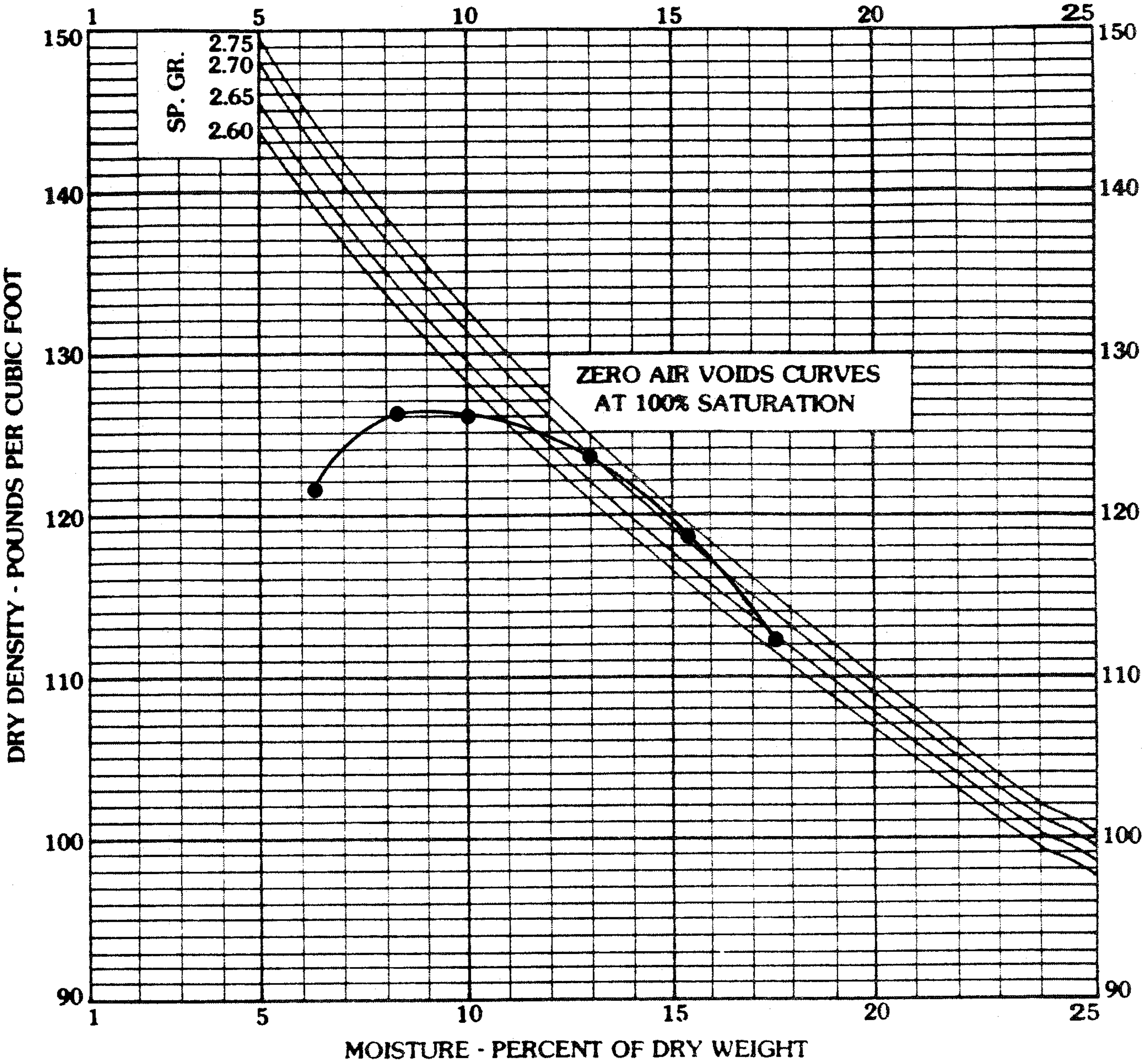
FOX Consulting Engineers and Geologists

Job No: 1-2543-3338
Date: 7/31/82
Figure B5

Job No

Hole

at depth



Maximum Dry Density: 127.0 **Optimum Moisture Content:** 9.0

Sample of CLAY, Sandy, Silty **from test hole** A2

at depth 2-5 **feet.**

Amt. of material finer than: #4 Sieve 100 **#10** 100 **#40** 97 **#200** 47

Atterburg Limits: **Liquid Limit:** 31 **Plasticity Index:** 18

Swell/Consolidation Results:

Unconfined Compressive Strength:

Remarks:

MOISTURE DENSITY TEST RESULTS

FOX

Consulting Engineers and Geologists

Job No: 1-2543-3338

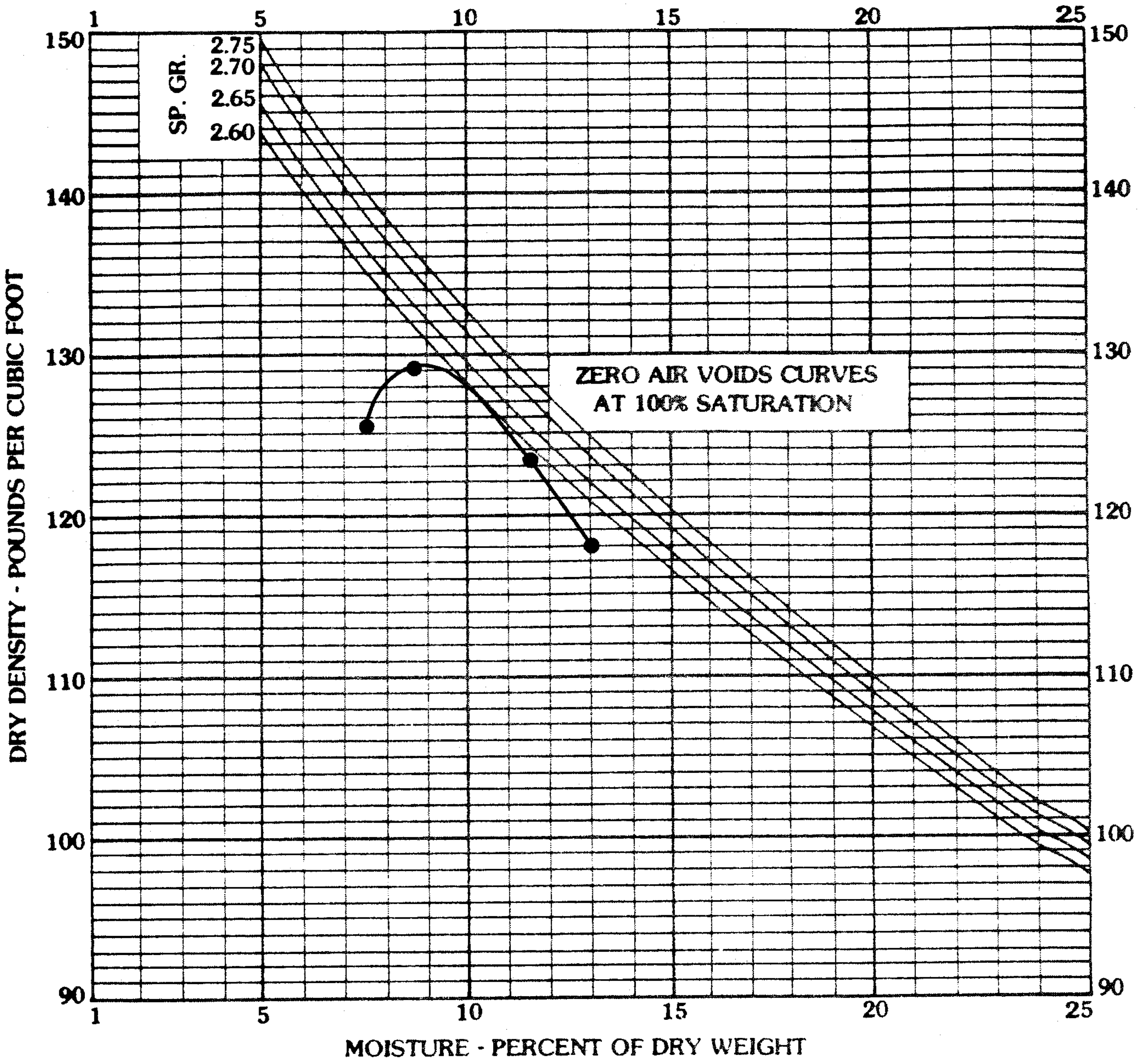
Date: 7/31/82

Figure B6

at depth

Hole

Job No



Maximum Dry Density: 129.0 **Optimum Moisture Content:** 9.0

Sample of SAND, Very Silty **from test hole** B4

at depth 0-5 **feet.**

Amt. of material finer than: #4 Sieve 99 **#10** 98 **#40** 95 **#200** 36

Atterburg Limits: Liquid Limit: 18 **Plasticity Index:** 4

Swell/Consolidation Results:

Unconfined Compressive Strength:

Remarks:

MOISTURE DENSITY TEST RESULTS

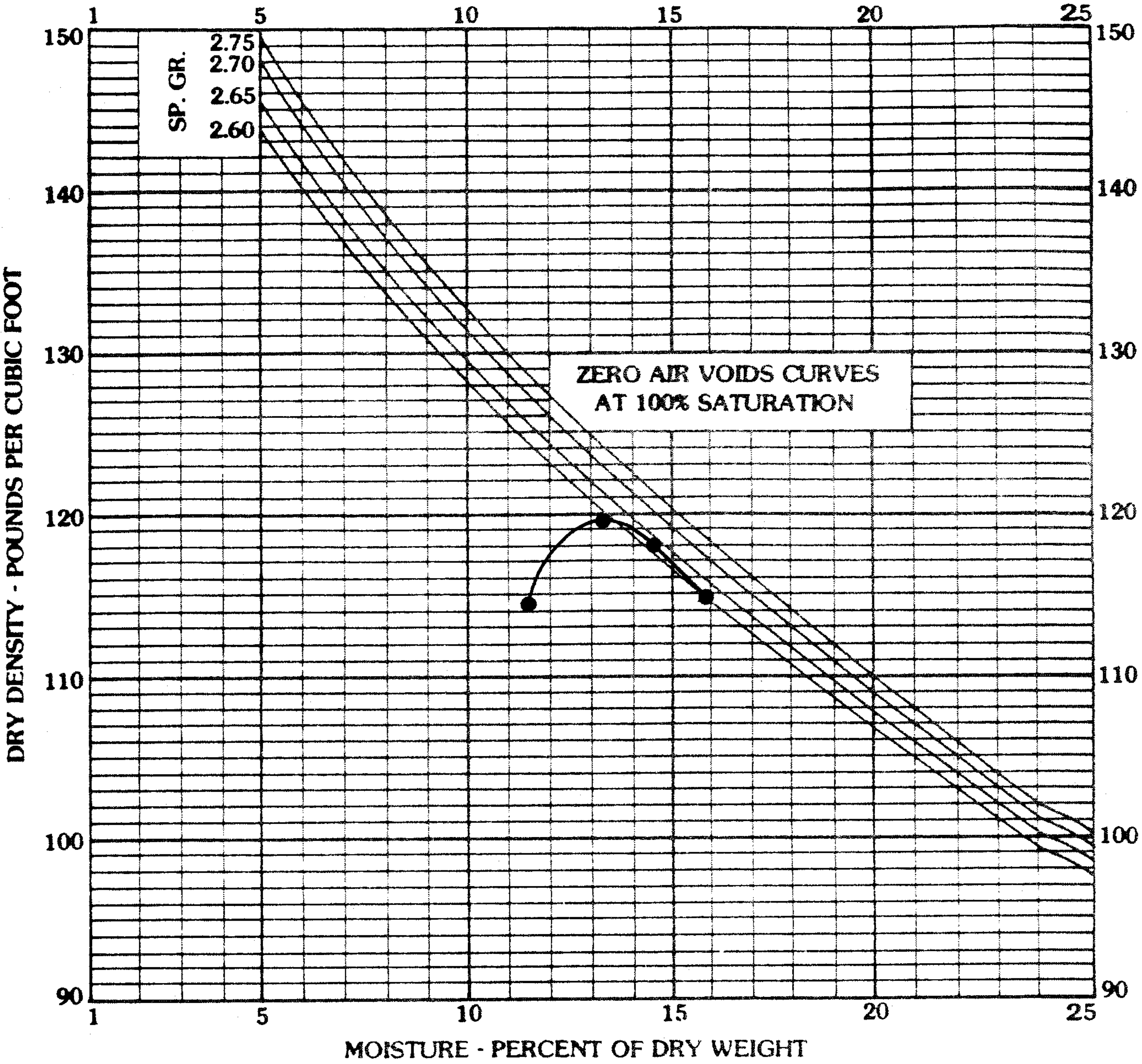
FOX

Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: 7/31/82

Figure B7



Maximum Dry Density: 120.0 **Optimum Moisture Content:** 13.5

Sample of CLAY, Silty, Sandy **from test hole** B8

at depth 0-2 **feet.**

Amt. of material finer than: #4 Sieve 92 **#10** 91 **#40** 87 **#200** 74

Atterburg Limits: **Liquid Limit:** 31 **Plasticity Index:** 14

Swell/Consolidation Results:

Unconfined Compressive Strength:

Remarks:

MOISTURE DENSITY TEST RESULTS

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: 7/31/82

Figure B8

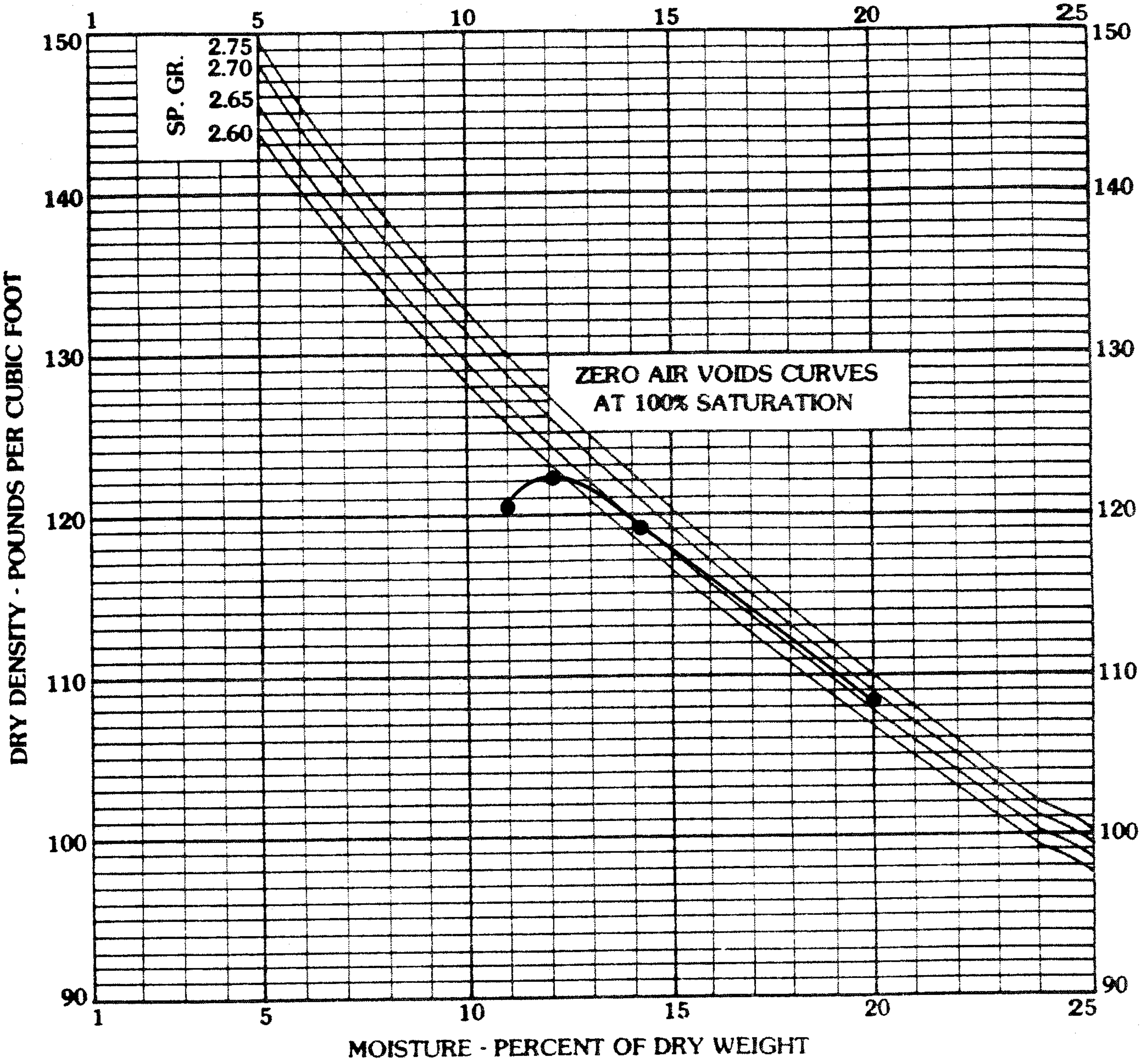
at depth

Hole

Job No

Hole DH-2 at depth 0-10

Job No



Maximum Dry Density: 122.5 **Optimum Moisture Content:** 12.0

Sample of CLAY, Silty, Sandy, **from test hole** DH2

at depth 0-10 **feet.**

Amt. of material finer than: #4 Sieve 98 **#10** 96 **#40** 85 **#200** 79

Atterburg Limits: Liquid Limit: 31 Plasticity Index: 14

Swell/Consolidation Results:

Unconfined Compressive Strength:

Remarks:

MOISTURE DENSITY TEST RESULTS

FOX Consulting Engineers and Geologists

Job No: 1-2543-3338

Date: 7/31/82

Figure B9

TABLE 11: MOISTURE CONTENT TEST RESULTS

TEST HOLE B-4		TEST HOLE B-6	
DEPTH	% MOISTURE	DEPTH	% MOISTURE
18	3.0	10	5.1
28	3.9	20	4.8
38	30.4	30	17.5
48	4.4	40	7.4
58	3.6	50	4.9
68	4.3	60	4.2
78	4.5	70	2.4
88	4.6		
98	14.7		