RESOURCE AND POTENTIAL RECLAMATION EVALUATION

Beulah Trench

emria Report No. 10 1977

United States Department of the Interior
Bureau of Land Management
Water & Power Resources Service
Geological Survey

EMRIA

(Energy Mineral Rehabilitation Inventory and Analysis)

EMRIA is a coordinated approach to the collection, analysis, and interpretation of overburden (soil and bedrock), hydrology, vegetation, and energy resource data. The main objective of the effort is to assure adequate baseline data for choosing reclamation goals and establishment of lease stipulations through site-specific preplanning for surface mining and reclamation.

These reports are prepared through the efforts of the Department of the Interior, principally by the Bureau of Land Management, Water and Power Resources Service, and Geological Survey. Assistance is also provided by other Federal and State agencies.

Reports under this effort are:

EMRIA Report	Location
1	Otter Creek, Montana
2	Hanna Basin, Wyoming
3	Taylor Creek, Colorado
4	Alton, Utah
5	Bisti West, New Mexico
6	Foidel Creek, Colorado
7	Red Rim, Wyoming
8	Bear Creek, Montana
9	Horse Nose Butte, North Dakota
10	Beulah Trench, North Dakota
11	Pumpkin Creek, Montana
12	Hanging Woman, Montana
13	White Tail Butte, Wyoming

BEULAH TRENCH STUDY AREA
MERCER COUNTY, NORTH DAKOTA

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD
MERCER COUNTY, NORTH DAKOTA

INTRODUCTION

Recent energy shortages have forced our society to seek new domestic sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. It is the responsibility of the Department of the Interior and, principally, the Bureau of Land Management to assist in meeting these energy demands and, at the same time, provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

PURPOSE

The purpose of this report is to provide information for establishing reclamation objectives and lease requirements. Detailed data is given on geology, coal resources, overburden (soil and bedrock), greenhouse, vegetation, and hydrology. Less detailed information is provided on climate and physiography.

REPORT OBJECTIVES

1. To analyze and quantify the environmental impacts from surface mining of coal.

2. To provide resource and impact information for leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

4. To provide resource and impact information to support state and local regional development and land use planning efforts.

5. To determine the present and potential capability of the soil and bedrock to support and maintain vegetation on known coal deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining reclamation plans for proposed land disturbing activities in the vicinity of the study area.

AUTHORITY

Federal Land Policy and Management Act of 1976 and Surface Mining Control and Reclamation Act of 1977.

RESPONSIBILITY

Bureau of Land Management

1. Selects study area for coordinated investigations of climate, geology, hydrology, overburden, vegetation, and sedimentation.

2. Acts as Contracting Officer in the coordination, establishment and execution of work orders.

3. Procures easements and rights-of-way to conduct the studies.

4. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

5. Determines postmining land uses.

Water and Power Resources Service 1/

1. Conducts a land classification for determining suitability of bedrock material for use in revegetation of shaped spoils.

2. Conducts drilling operations for the procurement of core samples for coal and soil analysis.

3. Characterizes and interprets suitability of overburden material as well as substrata immediately below the coal resources for purposes of revegetation.

4. Arranges for greenhouse studies for determining overburden materials potential for supporting vegetative growth.

5. Conducts mechanical weathering tests of core samples to determine stability of overburden materials.

6. Recommends to District Office, Bureau of Land Management, suitable plant species for use in areas to be reclaimed.

7. Advises District Office, Bureau of Land Management, on reclamation techniques.

8. Prepares geologic maps, logs, and cross sections.

9. Advises the Bureau of Land Management on paleontological finds in the study area.

1/ Formerly the Bureau of Reclamation

U.S. Geological Survey

1. Conducts vegetation and soil studies which result in vegetation maps and related soil characteristics.

2. Assesses reclamation potential based on water available from precipitation, the effects of surface mining on area hydrology, and the measures required to prevent adverse effects on surface and ground water of the area.

3. Prepares sediment yield maps.

4. Prepares erodibility maps.

5. Collects and interprets data to predict alternative solutions to ground water problems encountered during mining and reclamation.

6. Implements a monitoring system to define baseline conditions and document ground water changes in flow and quality caused by mining and reclamation.

7. Prepares ground water maps.

8. Tabulates coal resources estimates.

9. Prepares a table of analytical results of coal resources.

GENERAL DESCRIPTION

Location

The Beulah Trench Study Area is located in west-central North Dakota (Mercer County), approximately 5 miles northwest of Beulah. Plate 1 shows the general location. The area includes approximately 2,700 acres in all or parts of Sections 14, 22, 26, and 34 of T. 145N., R. 88W. and Sections 4, 6, and 8 of T. 144N., R. 88W. Photograph 1 and Plate 2 show the area setting and topography. All surface is privately owned. All coal is federally owned as shown on Plate 3. Photographs 2 through 4 show the typical terrain in the Beulah Trench Study Area.

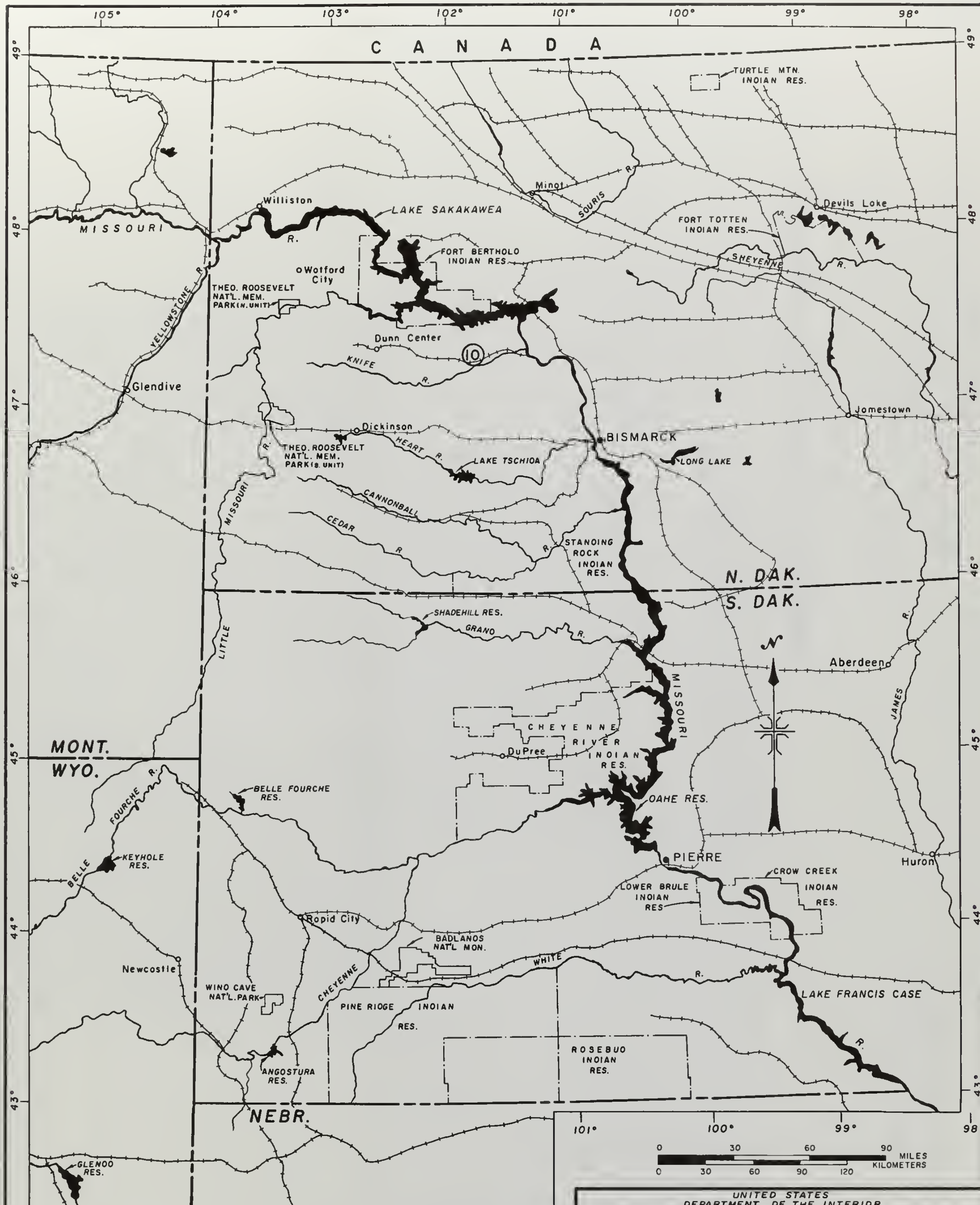
Present Land Uses

Most of the land within the Beulah Trench Study Area is currently used for grazing cattle. Some hay and small grains are being produced along the floors of larger drainages and on gentle slopes, but only a small percentage of the total acreage is regularly cultivated.

Although the area is not being specifically managed for wildlife habitat or watershed protection, these uses should also be recognized.

The study area is not forested except for some scrubby growth along a few drainages. Little except firewood and a few fence posts could be produced from the few trees that do exist.

No commercial gravel pits or quarries are presently operating within the area underlain by federally owned coal. A small gravel pit showing some recent activity is located in the northeast corner of Section 14, T. 145N., R. 88W.



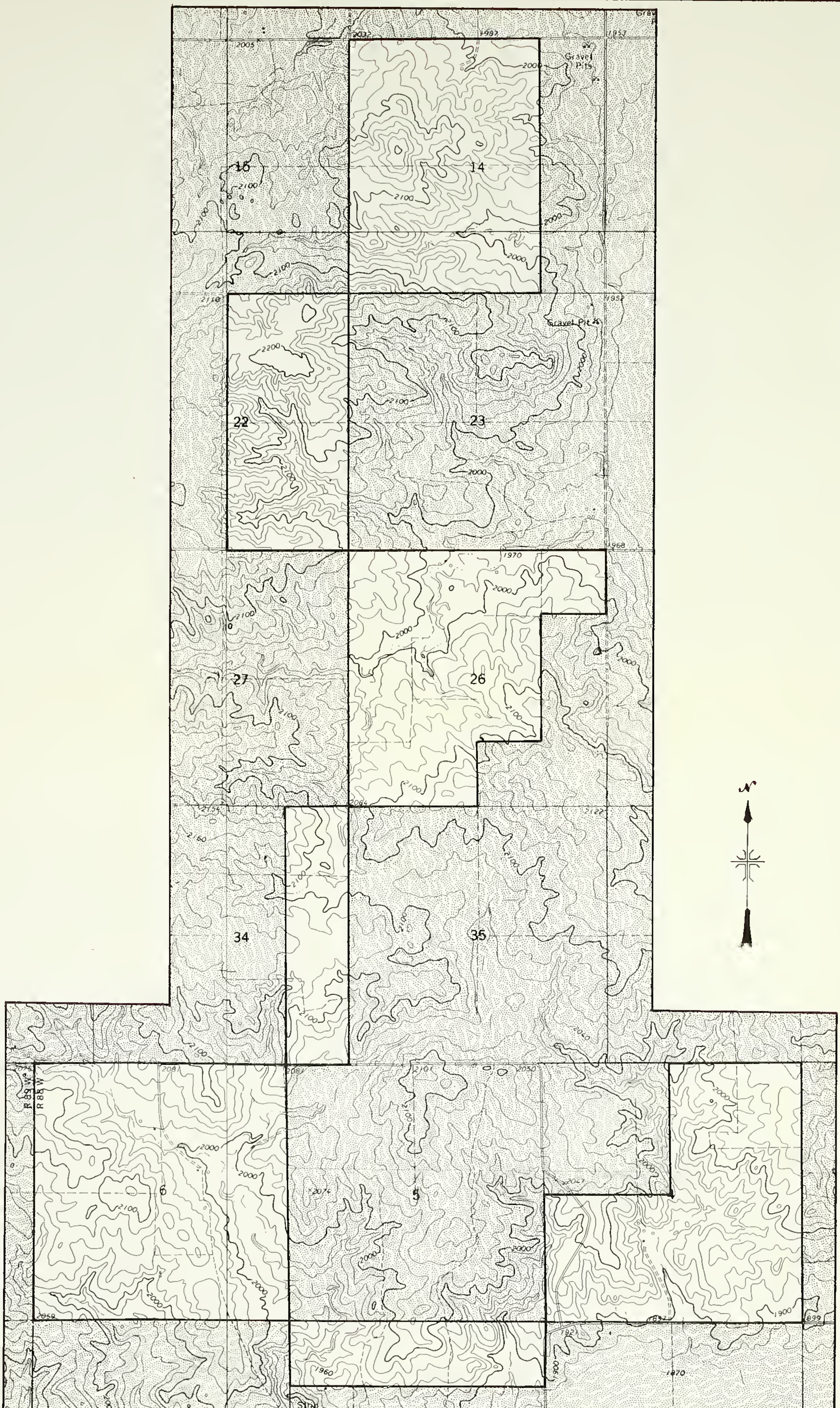
(10) BEULAH TRENCH STUDY AREA - EMRIA No. 10

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COAL FIELD, NORTH DAKOTA

GENERAL LOCATION MAP

DESIGNED V. LINSSEN SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED G.J.T. APPROVED
BILLINGS, MONTANA MARCH 1976 1305-600-77

T145 N
T144 N



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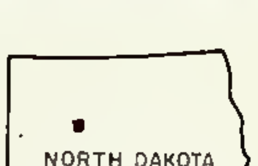
0 400 800 1200 1600 2000 2400 METERS

CONTOUR INTERVAL — 20 FEET
MULTIPLY FEET BY 0.3048 TO OBTAIN METERS

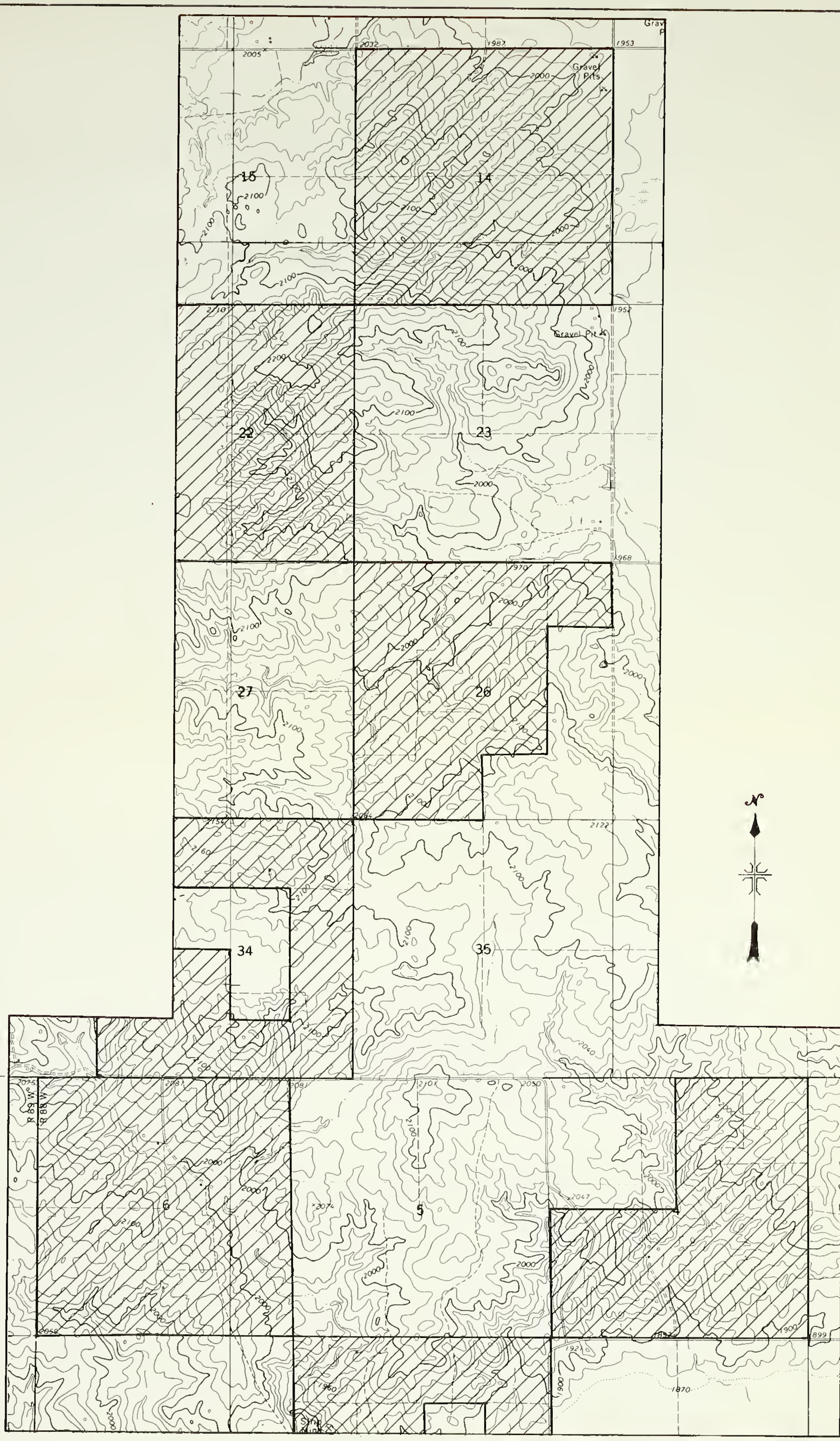


QUADRANGLE LOCATIONS
PORTIONS OF U.S.G.S. BEULAH, BEULAH N.W., BEULAH N.E., & ZAP QUADRANGLES

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD
TOPOGRAPHY

Note: Study area not shaded

Plate 2



MINERALS OWNED BY THE FEDERAL GOVERNMENT

COAL ONLY

ALL SURFACE AREA EXCEPT SEC. 36, IS PRIVATELY OWNED. SEC. 36 IS STATE OWNED.

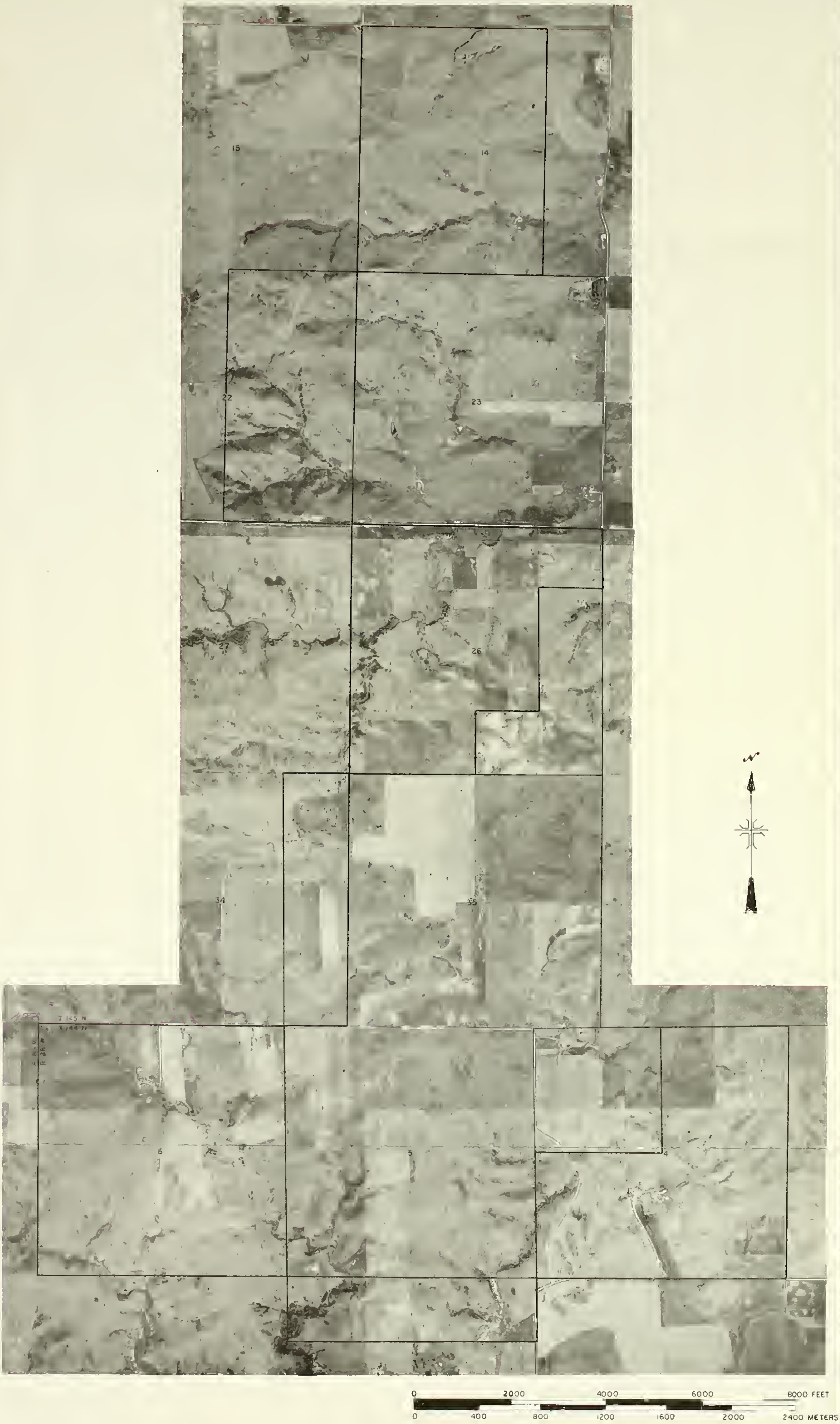
0 2000 4000 6000 8000 FEET
0 400 800 1200 1600 2000 2400 METERS

CONTOUR INTERVAL — 20 FEET
MULTIPLY FEET BY 0.3048 TO OBTAIN METERS

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD

MINERAL STATUS MAP

Plate 3



MULTIPLY FEET BY 0.3048 TO OBTAIN METERS

RESOURCE & POTENTIAL RECLAMATION
EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD

AERIAL PHOTOGRAPH

Photograph 1

Photograph 2 - BEULAH TRENCH STUDY AREA - WEST RENNERS COVE COALFIELD, NORTH DAKOTA - Panoramic view looking west into Sec. 23, T. 145 N., R. 88 W.
Photograph taken from gravel road along the east side of the SE ¼ of Sec. 23.
U.S. Bureau of Reclamation Photograph P1305-600-18. 11/30/77

Photograph 3 - BEULAH TRENCH STUDY AREA - WEST RENNERS COVE COALFIELD, NORTH DAKOTA
Panoramic view looking northwest across the study area from near the S.W. corner of Sec. 4, T. 144 N., R. 88 W.
U.S. Bureau of Reclamation Photograph P1305-600-19. 11/30/77

Photograph 4 - BEULAH TRENCH STUDY AREA - WEST RENNERS COVE COALFIELD, NORTH DAKOTA - View eastward toward the Pleistocene drainage channel from near the N.W. corner of Sec. 14, T. 145 N., R. 88 W.
U.S. Bureau of Reclamation Photograph P1305-600-20. 11/30/77

OBJECTIVE OF RECLAMATION

Mine operators must comply with all established mining and reclamation laws. Federal mining regulations contained in the Surface Mining Control and Reclamation Act of 1977 (P.L. 95-87) are the minimum that are acceptable. They may be superseded by more stringent State regulations. These regulations set forth the main objective that must be fulfilled by reclamation programs.

Section 816.133(a) of 30 CFR (Federal regulations) stipulates that: "All affected areas shall be restored in a timely manner: (1) to conditions that are capable of supporting the uses which they were capable of supporting before any mining; or (2) to higher or better uses achievable under criteria and procedures of this section.

Chapter 38-14.1, Section 69-05.2-23-01 of the North Dakota Century Code (proposed North Dakota State Program 1/) states that: "All disturbed areas shall be restored in a timely manner to conditions that are capable of supporting the uses which they are capable of supporting before mining, or to higher or better uses achievable under the criteria and procedures of Section 69-05.2-23-04."

Both Federal and State regulations present specific guidelines for determining premining land uses and acceptable postmining land uses. Unless an alternative postmining land use is desired by the landowner(s) and approved by the North Dakota Public Service Commission, the main objective of reclamation in the Beulah Trench Study Area will be to restore the disturbed land to a condition capable of supporting the uses that it supports today. These uses are rangeland, hayland, and cropland (small grains).

1/ The North Dakota State Program for regulating mining and reclamation will take effect upon approval by the Office of Surface Mining, U.S. Department of the Interior.

PHYSICAL PROFILE

CLIMATE

Climate in the Beulah Trench Study Area (Mercer County, North Dakota) is characterized by warm summers, harsh cold winters, long periods of sunshine, and a moderate amount of precipitation during the growing season. Data obtained from the recording station in Beulah, North Dakota, (approximately 5 miles southeast of the study area) were used to evaluate temperature, precipitation, and related climatic factors for the study area.

Temperature

Based on data recorded between 1955 and 1974 at Beulah, temperature extremes of 104° F. and -39° F. may occur in this study area. Average monthly temperatures and probable extremes for the area are listed in Table 1.

Frontal systems pass through this area frequently throughout the year and can cause large temperature changes within a 24-hour period. Several large, rapid flucuations in temperature can occur over a one to two week period.

The average growing season for hardy crops is approximately 134 days between mid-May and mid to late September. [1/] Tables 2 and 3, respectively, describe the probable growing season lengths and freeze dates in spring and fall. Typically, native range plants and small grains deplete the available soil moisture by mid-July. Tables 4 and 5, Appendix B, record the estimated moisture reserve at the beginning of the growing season and the approximate date the soil moisture is depleted by native grasses and small grains.

Precipitation

The average annual precipitation in this study area is about 16.13 inches, with nearly 75 percent of this amount falling during the growing season (May through September). June is the wettest month, averaging 3.35 inches. Average monthly precipitation values are included in Table 1.

Average snowfall for the area is about 27 inches, with almost 96 percent of this value occurring between November and April (see Table 1). Effective precipitation from snowfall is considered to be 80 percent of the total snowfall.

A map showing precipitation deviation at selected locations within a 40 mile radius of Beulah, North Dakota, is provided in Figure 1, Appendix B.

1/Includes days when the minimum temperature exceeds 28° F.

Table 1 - Temperature and Precipitation Data - Mercer County, North Dakota*

Month	Temperature[1]						Precipitation[1]				
	Average daily maximum	Average daily minimum	Average	2 years in 10 will have-- Maximum temperature higher than--	2 years in 10 will have-- Minimum temperature lower than--	Average number of growing degree days[2]	Average	2 years in 10 will have-- Less than--	2 years in 10 will have-- More than--	Average number of days with 0.10 inch or more	Average snowfall
	°F	°F	°F	°F	°F	Units	In	In	In		In
January----	18.8	-3.7	7.6	48	-37	0	.36	.11	.55	1	4.5
February---	24.7	1.2	13.0	52	-31	0	.32	.07	.51	1	4.2
March------	37.3	14.6	26.0	73	-23	63	.41	.13	.62	1	4.2
April------	53.6	28.3	41.0	85	9	124	1.72	.52	2.67	4	3.5
May--------	67.6	39.7	53.7	94	21	425	2.72	1.28	3.90	6	.5
June-------	77.0	49.9	63.5	97	34	705	3.35	1.79	4.61	7	.0
July-------	84.2	54.3	69.2	101	41	905	2.79	1.07	4.16	5	.0
August-----	84.5	52.5	68.5	104	37	884	1.65	.51	2.55	3	.0
September--	71.0	40.6	55.8	98	21	474	1.27	.48	1.90	3	.2
October----	60.4	31.0	45.7	89	13	230	.65	.13	1.05	2	.5
November---	38.9	16.5	27.7	69	-12	34	.57	.12	.92	2	4.6
December---	25.8	4.2	15.0	56	-31	17	.32	.12	.48	1	4.8
Year-----	53.7	27.4	40.6	104	-39	3,861	16.13	12.80	19.29	36	27.0

1/ Recorded between 1955-74 at Beulah, North Dakota.

2/ A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily temperatures, dividing the sum by two, and subtracting the temperature below which growth is minimal for the principal crops in the area (40° F).

* This table is taken from: Soil Survey of Mercer County, North Dakota; U.S.D.A. - Soil Conservation Service, 1978.

Table 2
Growing Season Length (Mercer County, North Dakota)*

Probability	Daily minimum temperature during growing season[1]		
	Higher than 24° F	Higher than 28° F	Higher than 32° F
	Days	Days	Days
9 years in 10	134	117	99
8 years in 10	142	122	104
5 years in 10	156	134	115
2 years in 10	170	145	126
1 year in 10	178	151	131

Table 3
Freeze Dates in Spring and Fall (Mercer County, North Dakota)*

Probability	Temperature[1]		
	24° F or lower	28° F or lower	32° F or lower
Last freezing temperature in spring:			
1 year in 10 later than--	May 16	May 31	June 4
2 years in 10 later than--	May 11	May 24	May 31
5 years in 10 later than--	May 1	May 12	May 23
First freezing temperature in fall:			
1 year in 10 earlier than--	September 17	September 7	September 2
2 years in 10 earlier than--	September 23	September 13	September 6
5 years in 10 earlier than--	October 5	September 23	September 16

1/ Recorded between 1955-74 at Beulah, North Dakota

* These tables are taken from: Soil Survey of Mercer County, North Dakota; U.S.D.A. - Soil Conservation Service, 1978.

The magnitude of storms of various recurrence intervals in this area were determined using the curve shown in Figure 19 (follows page 50). The following data give a general idea of storm intensity in the Beulah Trench Study Area:

Recurrence Interval (years)	Precipitation (inches)
2.33	1.67
10.00	2.55
25.00	3.07
50.00	3.45

Other Climatic Characteristics

The prevailing wind direction is west-northwesterly except in May, June, July, and August, when it is easterly. The windiest month is April, during which the wind speed averages about 13 miles per hour.

June and July are the months most susceptible to hail activity. Hail damage to small grains may be severe; damage to range plants is less severe.

The interaction of climate and aspect generally does not limit crop or range productivity in this area. The surface relief is relatively subdued and, although the south facing slopes are more droughty, the reduction in plant productivity is minimal.

Thunderstorms occur on about 35 days in an average year. In at least 1 year in 5, the following rainfall intensities can be expected: 1.1 inches in 30 minutes, 1.5 inches in 1 hour, 1.8 inches in 3 hours, 1.9 inches in 6 hours, 2.3 inches in 12 hours, and 2.7 inches in 24 hours.

Annual evaporation from Class A pans is estimated at 36 inches. Eighty-four percent of this evaporation occurs during the period of May through October. The annual evaporation from lakes is also about 36 inches.

The area receives about 60 percent of the sunshine that could possibly occur each year.

Effect of Weather on Area Revegetation

Most climatic factors in the Beulah Trench Study Area appear favorable for revegetation of surface-mined land. Spring is the most favorable planting time in this area since soil moisture is high during the early part of the growing season. The spring rains usually provide moisture to the soil in excess of the plant moisture requirement. With favorable soil moisture conditions, seedlings will grow rapidly and become established before the available moisture is depleted in about mid-July.

Climatic factors that may adversely affect revegetation efforts in this study area include: (1) below normal or uneven distribution of precipitation, especially during the growing season; (2) severe thunderstorms and/or strong winds that result in surface erosion; (3) late spring freezes; and (4) depletion of soil moisture by wind.

PHYSIOGRAPHY AND DRAINAGE

The Beulah Trench Study Area lies in the glaciated portion of the Great Plains Physiographic Province. The topography of the area is characterized by rolling hills bordered on the east and south by wide, flat Pleistocene meltwater channels. Photographs 2 through 4 are typical views of the area.

Maximum relief is about 340 feet, ranging from an elevation of approximately 2210 feet on hilltops in the northwestern portion of the area to an elevation of about 1870 feet in the meltwater channel that crosses the southeast corner of the study area. Surface gradients range from nearly level in the meltwater channels to about 12 percent on some upland sideslopes.

Drainage of the study area is accomplished through a well developed dendritic system that is tributary to the meltwater channels which border the study area on the east and south. The southern part of the channels drain southward into Spring Creek, which flows southeastward and joins the Knife River about 1 mile southwest of Beulah, North Dakota. Drainage from the extreme northern end of the study area flows northward through the northern portion of the meltwater channel into Lake Sakakawea.

GEOLOGY

Regional Geology

The West Renners Cove Coalfield is located in the Williston Basin in west-central North Dakota. This basin, a part of the Great Plains Physiographic Province, is a synclinal structure extending from South Dakota into Canada, a distance of about 500 miles.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. A sequence of carbonates, sandstones, and shales, mostly of marine origin, were deposited throughout North Dakota during the Paleozoic and Mesozoic Eras. These sediments, about 14,000 feet thick in the deepest part of the Williston Basin, thin rapidly eastward and are not present in the southeastern part of the State. Several unconformities exist throughout the Paleozoic and Mesozoic sequences in North Dakota, the most notable being the pre-Mesozoic erosional surface which truncates all Paleozoic sediments.

Deformation of the Rocky Mountains to the west and associated uplifting of the Great Plains area in North Dakota began with the Laramide Revolution at the close of Cretaceous time. Intermittent uplifting continued through the Paleocene and ended in Eocene time. Materials eroded from the mountains were spread in thick sheets over most of the Great Plains by the middle of the Cenozoic Period. A second regional uplift which occurred during Pliocene and Pleistocene times elevated sediments to their present position. Streams rejuvenated by the uplift began stripping Tertiary strata from the Great Plains and exhuming the buried mountain masses to the west.

During the Pleistocene Epoch, several continental ice sheets invaded most of North Dakota. A sequence of till, outwash, and associated glacial debris was deposited during the advance and retreat of each ice sheet.

Today, shales, siltstones, and sandstones of Cretaceous and Tertiary age cover the western part of North Dakota. Pleistocene and Holocene glacial, eolian, and alluvial deposits mantle the bedrock in much of the area. Plate 4 is a generalized bedrock geologic map showing the southern limits of glaciation.

Area Geology

Investigations

Surface and subsurface investigations were conducted by the Water and Power Resources Service at the Beulah Trench Study Area from May through August of 1977. These investigations included mapping the surface geology and drilling a series of core holes.

Geologic mapping on a scale of 1 to 12,000 was done in the field on aerial photographs. The data was transferred to a topographic map of the same scale and is shown on Plate 5. Plate 6 is a stratigraphic column describing lignite beds shown on Plate 5.

Twelve drill holes (DH 77-101 through -112) ranging from 90.2 to 279 feet in depth were completed in the study area. Continuous cores were obtained from all holes for geologic logging and selection of coal and overburden samples for laboratory analyses. The locations of drill holes are plotted on the Geologic and Investigations Map, Plate 5. Plates 7 through 9 are geologic profiles correlating lignite horizons between drill holes. Detailed geologic logs are shown on Plates 10 through 21, Appendix C.

Drilling was performed with a DAMCO model 1250 rotary drill using wire line tools with an "H" series core barrel. Except for drive sampling in overlying glacial deposits with a Bx casing drive barrel, all drilling was done using bottom discharge core bits set with tungsten carbide inserts.

Water was used as drill fluid in all holes. An organic polymer, "Revert," was used in the drilling fluid in fractured or jointed rock where circulation was lost.

The drill core was immediately placed in core boxes and wrapped with plastic to prevent drying until it could be logged and sampled.

After completion, all drill holes in the study area were backfilled with concrete.

Stratigraphy

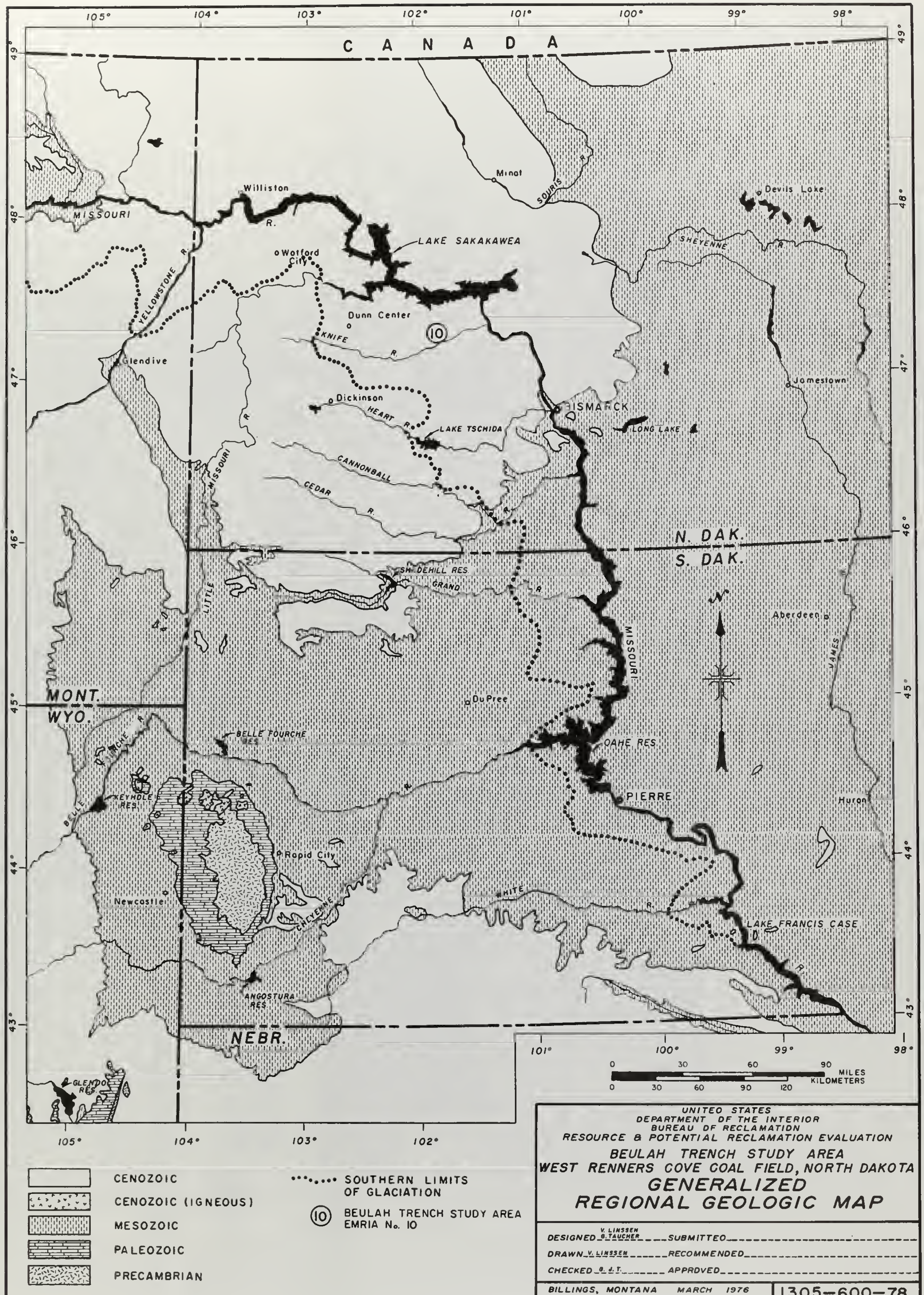
The oldest rocks exposed in the study area are of Paleocene Age. In North Dakota, the U.S. Geological Survey has divided the Paleocene Series into the Ludlow-Cannonball, Tongue River, and Sentinel Butte Members of the Fort Union Formation. These subdivisions will be used in this section of the report. Only the Sentinel Butte, the youngest member of the Fort Union Formation, is involved in the study area. Sandstones, siltstones, and shales of this member are locally mantled by Quaternary glacial, eolian, and alluvial deposits. Photographs 2 through 4 show the typical rolling terrain which has been altered by glaciation.

Fort Union Formation - Paleocene

Cannonball-Ludlow Member - These sediments underlie but do not crop out in the study area. The Cannonball is the youngest known marine strata in the Northern Great Plains region. It consists of shale and thin-bedded sandstone which thins and interfingers westward with the continental deposited Ludlow.

Tongue River Member - consists of an alternating sequence of fluvial deposited sandstone, siltstone, and shale with associated beds of lignite. It is similar to the overlying Sentinel Butte Member, and in places, cannot be distinguished from it.

Sentinel Butte Member - consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale, and lignite with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine



CANADA
105°
104°
103°
102°
101°
100°
99°
98°
49°
48°
47°
46°
45°
44°
43°
Minot
SOURIS R.
Devils Lake
Williston
MISSOURI
R.
LAKE SAKAKAWEA
SHEYENNE R.
o Watford City
YELLOWSTONE R.
Dunn Center
10
KNIFE
R.
Glendive
Jamestown
Dickinson
HEART R.
BISMARCK
LONG LAKE
LAKE TSCHIDA
MISSOURI
R.
CANNONBALL
CEDAR
R.
N. DAK.
S. DAK.
SHADEHILL RES.
GRAND
R.
LITTLE
Aberdeen
MISSOURI
JAMES
MONT.
WYO.
DuPree
BELLE FOURCHE RES.
FOURCHE R.
OAHE RES.
KEYHOLE RES.
BELLE
PIERRE
Huron
Rapid City
Newcastle
WHITE
R.
CHEYENNE
LAKE FRANCIS CASE
R.
ANGOSTURA RES.
NEBR.
GLENDO RES.
0 30 60 90 MILES
0 30 60 90 120 KILOMETERS
CENOZOIC
CENOZOIC (IGNEOUS)
MESOZOIC
PALEOZOIC
PRECAMBRIAN
SOUTHERN LIMITS OF GLACIATION
10 BEULAH TRENCH STUDY AREA EMRIA No. 10
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COAL FIELD, NORTH DAKOTA
GENERALIZED
REGIONAL GEOLOGIC MAP
DESIGNED V. LINSSEN G. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED G. J. T. APPROVED
BILLINGS, MONTANA MARCH 1976
1305-600-78

EXPLANATION

HOLOCENE — ALLUVIUM – Unconsolidated clay, silt, sand and gravel. Includes Pleistocene channel fill and terrace deposits

PLEISTOCENE — GLACIAL TILL – Heterogenous mixture of clay, silt, sand, gravel, cobbles and boulders deposited by a Wisconsin Age ice sheet. It occurs as a veneer, or as remnant patches on the bedrock surface. Thickness varies from 0 to 37 feet.

PALEOCENE — SENTINEL BUTTE MEMBER (FT. UNION FORM. Sandstone, siltstone, shale and coal up to 500' thick. Partly covered by Alluvium or Glacial Till.

CLINKER – Baked sandstone, siltstone, and shale of the Sentinel Butte Member produced by burning of the Beulah-Zap Coalbed.

CONTACTS

—— D —— Base of Beulah-Zap Coalbed.

—— D_1 —— Base of Upper Bench of Beulah-Zap Coalbed.

—— D2 —— Base of Lower Bench of Beulah-Zap Coalbed.

Base of Beulah-Zap Coalbed where coal has been burned along the outcrop.

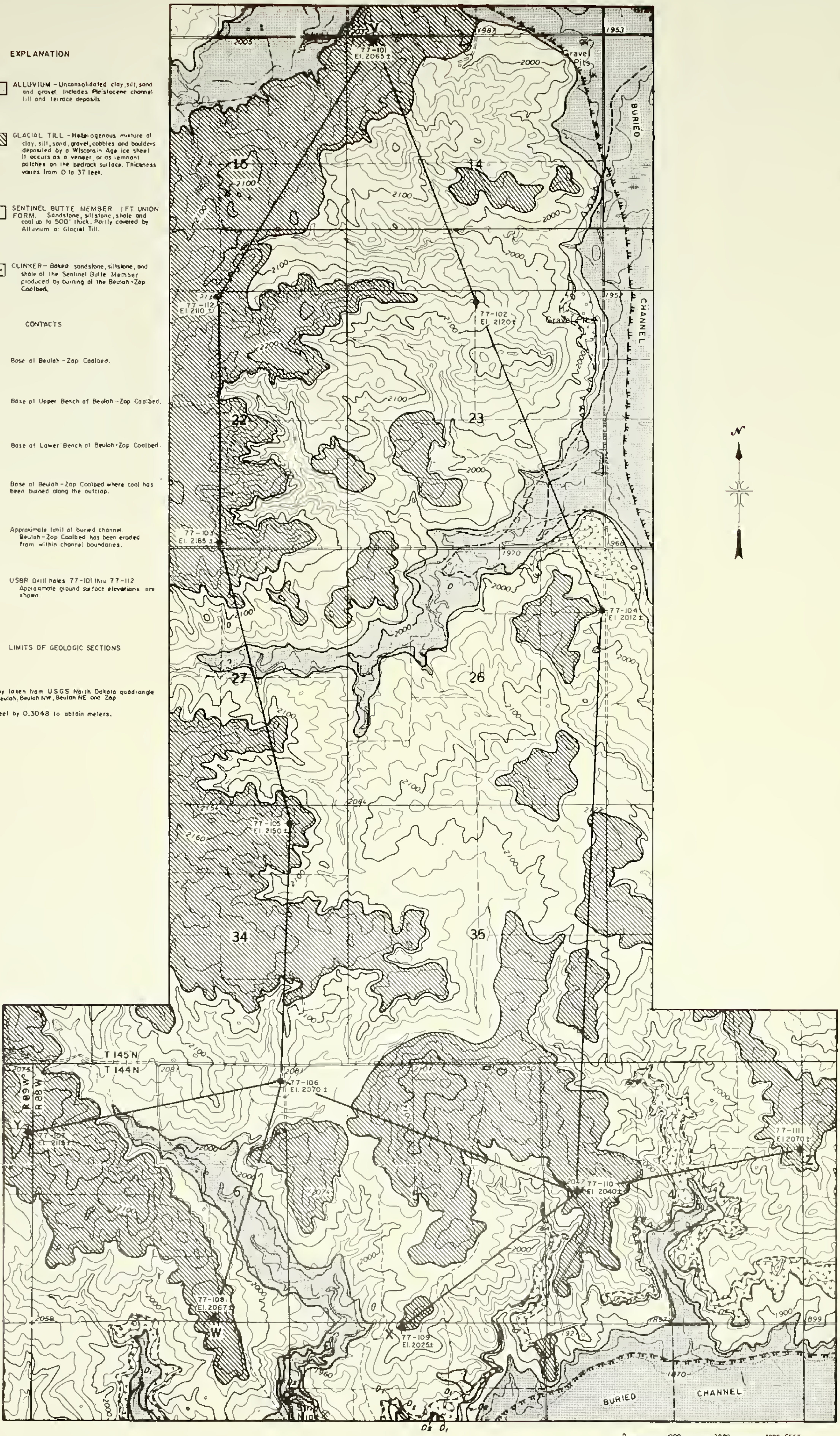
Approximate limit of buried channel. Beulah-Zap Coalbed has been eroded from within channel boundaries.

77-103 El. 2185 ± — USBR Drill holes 77-101 thru 77-112. Approximate ground surface elevations are shown.

V-W
V-X
Y-Z — LIMITS OF GEOLOGIC SECTIONS

NOTE: Topography taken from USGS North Dakota quadrangle sheets: Beulah, Beulah NW, Beulah NE and Zap

Multiply feet by 0.3048 to obtain meters.



0 1000 2000 3000 FEET
0 300 600 900 METERS

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST, RENNERS COVE COALFIELD – NORTH DAKOTA

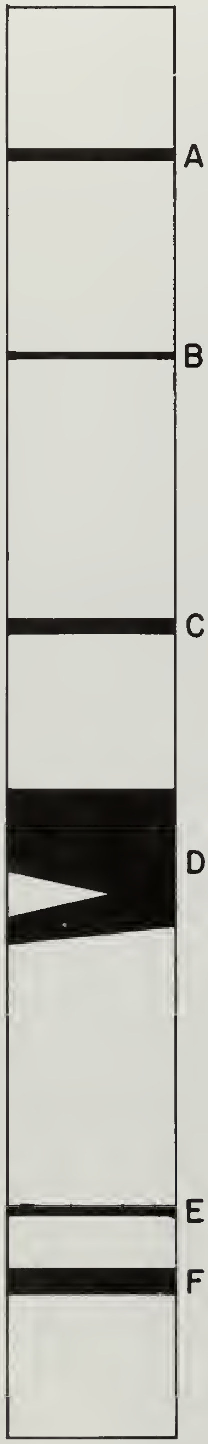
GEOLOGIC INVESTIGATIONS MAP

GEOLOGY L. PARISH — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — JULY 1978 — 1305-600-167

Plate 5

STRATIGRAPHIC COLUMN—LIGNITE BEDS
BEULAH TRENCH STUDY AREA—WEST RENNERS COVE COALFIELD
NORTH DAKOTA
PART OF SENTINEL BUTTE MEMBER



A — LIGNITE— 0.1 to 2.6 ft. thick. Averages 1.2 ft where present. Thickest zones often split by rock partings. 82 to 139 ft. above bed D.

B — LIGNITE — 0.0 to 1.5 ft. thick. Averages 0.8 ft. Absent in some areas. 44 to 93 ft. above bed D.

C — LIGNITE—0.0 to 4.5 ft. thick. Averages 1.5 ft. Absent in some areas. Thickest zones often split by rock partings. 7 to 45 ft. above bed D.

D — LIGNITE (BEULAH-ZAP BED) — 16.3 to 23.5 ft. thick. Averages 20.4 ft. Split in southwestern part of study area.

E — LIGNITE — 0.7 to 1.0 ft. thick. Averages 0.9 ft. 32 to 50 ft. below bed D.

F — LIGNITE — 3.3 to 3.7 ft. thick. Averages 3.4 ft. 45 to 60 ft. below bed D.

NOTE: Multiply feet by 0.3048 to obtain meters.

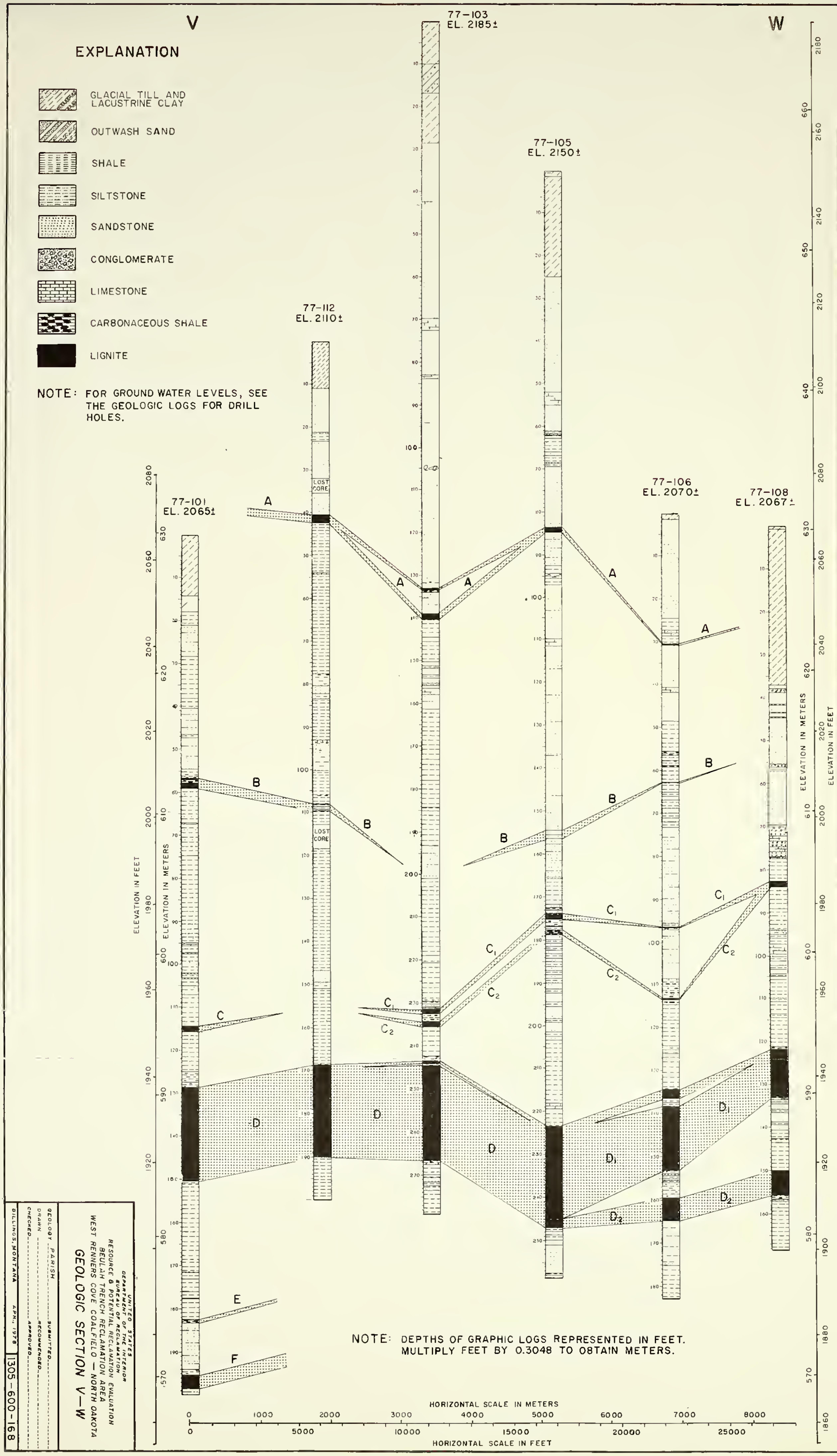
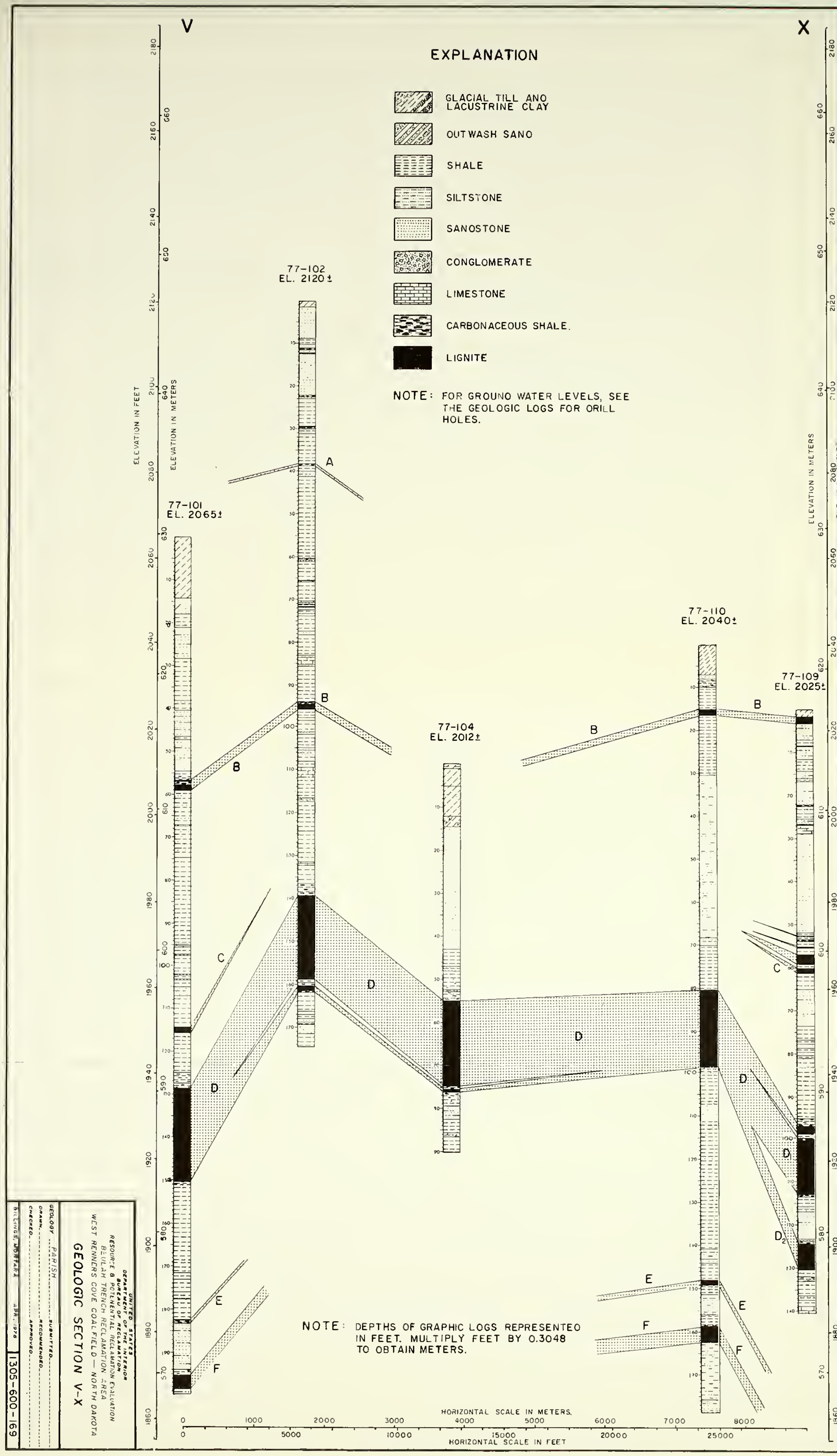

V
W
EXPLANATION
GLACIAL TILL AND LACUSTRINE CLAY
OUTWASH SAND
SHALE
SILTSTONE
SANDSTONE
CONGLOMERATE
LIMESTONE
CARBONACEOUS SHALE
LIGNITE
NOTE: FOR GROUND WATER LEVELS, SEE THE GEOLOGIC LOGS FOR DRILL HOLES.
77-101 EL. 2065±
77-112 EL. 2110±
77-103 EL. 2185±
77-105 EL. 2150±
77-106 EL. 2070±
77-108 EL. 2067±
LOST CORE
ELEVATION IN FEET
ELEVATION IN METERS
NOTE: DEPTHS OF GRAPHIC LOGS REPRESENTED IN FEET. MULTIPLY FEET BY 0.3048 TO OBTAIN METERS.
HORIZONTAL SCALE IN METERS
HORIZONTAL SCALE IN FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD — NORTH DAKOTA
GEOLOGIC SECTION V–W
GEOLOGY PARISH
DRAWN
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
BILLINGS, MONTANA
1305-600-168

Plate 7


V
X
EXPLANATION
GLACIAL TILL AND LACUSTRINE CLAY
OUTWASH SAND
SHALE
SILTSTONE
SANDSTONE
CONGLOMERATE
LIMESTONE
CARBONACEOUS SHALE.
LIGNITE
NOTE: FOR GROUND WATER LEVELS, SEE THE GEOLOGIC LOGS FOR DRILL HOLES.
ELEVATION IN FEET
ELEVATION IN METERS
77-101 EL. 2065±
77-102 EL. 2120±
77-104 EL. 2012±
77-110 EL. 2040±
77-109 EL. 2025±
A
B
C
D
D2
E
F
NOTE: DEPTHS OF GRAPHIC LOGS REPRESENTED IN FEET. MULTIPLY FEET BY 0.3048 TO OBTAIN METERS.
HORIZONTAL SCALE IN METERS
HORIZONTAL SCALE IN FEET
UNITED STATES
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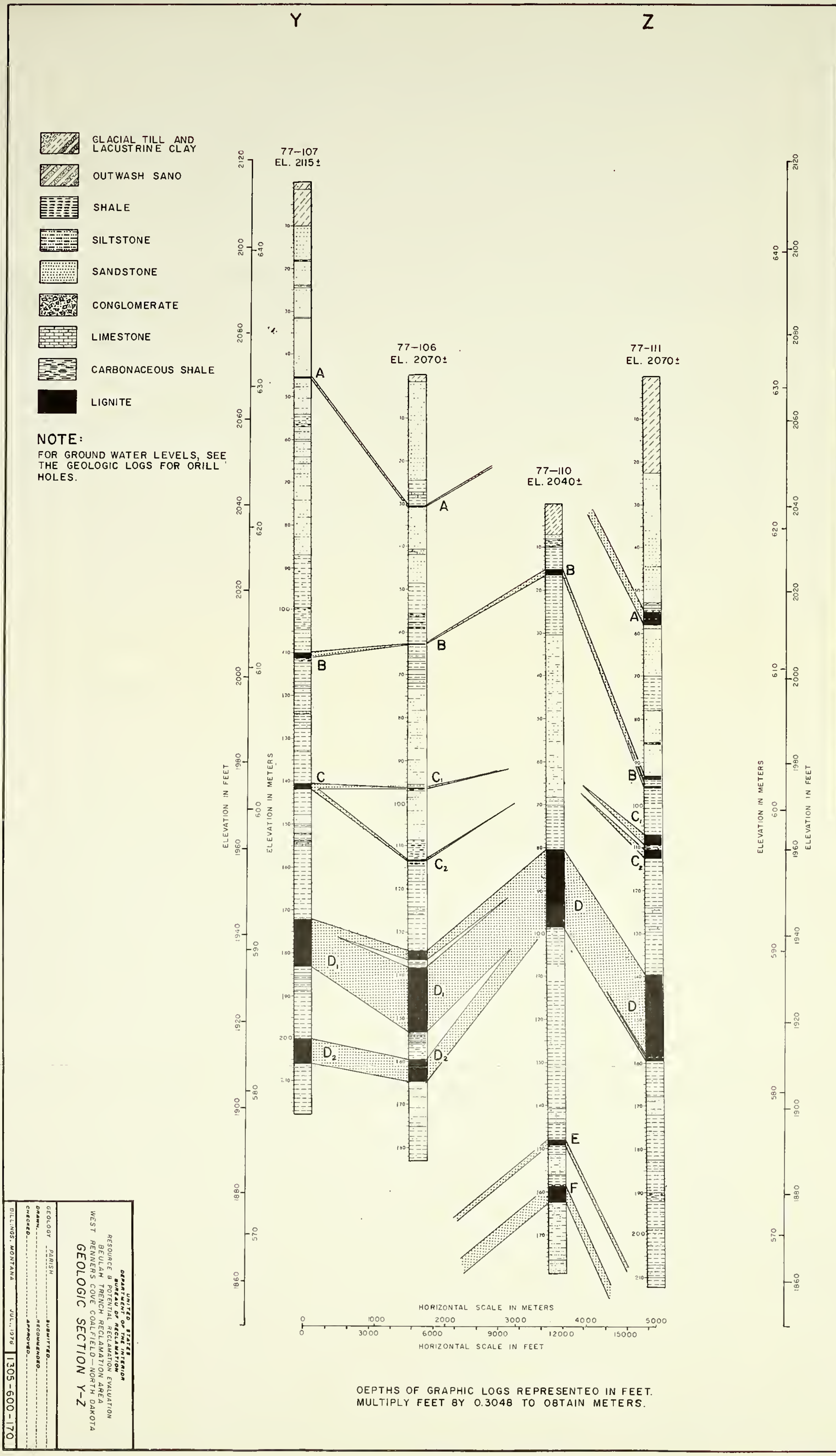
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
GEOLOGIC SECTION V-X
GEOLOGY PARISH SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA APR. 1978
1305-600-169

Plate 8



Y
Z
GLACIAL TILL AND LACUSTRINE CLAY
OUTWASH SANO
SHALE
SILTSTONE
SANDSTONE
CONGLOMERATE
LIMESTONE
CARBONACEOUS SHALE
LIGNITE
NOTE:
FOR GROUND WATER LEVELS, SEE THE GEOLOGIC LOGS FOR ORILL HOLES.
77–107
EL. 2115±
77–106
EL. 2070±
77–110
EL. 2040±
77–111
EL. 2070±
A
B
C
C1
C2
D
D1
D2
E
F
ELEVATION IN FEET
ELEVATION IN METERS
HORIZONTAL SCALE IN METERS
HORIZONTAL SCALE IN FEET
OEPTHS OF GRAPHIC LOGS REPRESENTEO IN FEET.
MULTIPLY FEET BY 0.3048 TO OBTAIN METERS.
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD—NORTH DAKOTA
GEOLOGIC SECTION Y-Z
GEOLOGY PARISH SUBMITTED
DRAWN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA JUL., 1976
1305-600-170

Plate 9

grained and uncemented. Shales vary from soft, plastic clayshale to moderately indurated claystone. Shale and siltstone zones readily break down and form slopes beneath sandstone ledges. Correlation of clastic sediments over short distances is difficult due to facies changes, channeling and variation in bedding thickness. Laboratory analyses conducted on core samples from the Beulah Trench Study Area indicate that chemical and physical properties of the bedrock cannot generally be projected between drill holes. Weathered exposures are generally pale olive or yellowish-gray in color, while fresh core samples vary from light to dark gray. Marcasite and/or pyrite nodules are found along zones of higher permeability, such as fractures and bedding planes. The Sentinel Butte Member was deposited in a continental environment which included swamps conducive to the production of thick lignite beds. Lignite zones serve as excellent marker beds as they can generally be traced over wide areas. This member is about 500 feet thick.

Striking features in the Sentinel Butte and Tongue River Members are the resistant clinker zones, locally called "scoria," that cap knobs or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of lignite beds along and back from their outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of lignite that has burned. A lignite bed 20 feet thick will produce clinker zones 40 to 60 feet thick. The clinker is highly permeable and locally supplies water for springs and wells.

Clinker in the Beulah Trench Study Area was produced by burning the Beulah-Zap lignite bed. Outcrops occur along valley walls in the southern and northeastern parts of the study area. These are shown on the Geologic Investigations Map, Plate 5. Some of the Beulah-Zap lignite probably remains beneath the clinker because subsurface explorations and surface mining in other areas indicate that lower sections of thick coalbeds are not always burned beneath clinkered areas. An extensive drilling program would be required to determine the amount of coal which underlies the thermally altered rock. For the purpose of this report, it is assumed (1) that all lignite has burned beneath clinkered areas and (2) that the contact between baked and unbaked rock is vertical.

Golden Valley Formation - Eocene - consists of about 200 feet of alternating shales, siltstones, and crossbedded sandstones. These sediments, which overlie the Sentinel Butte Member, have been eroded from the study area.

Arikaree Formation - Miocene - consists of about 400 feet of lacustrine limestone interfingering with crossbedded sandstone.

Channel Deposits - Pleistocene - consists of sand and gravel of an undetermined thickness that underlies alluvial deposits in the valley floors along the eastern and southern edges of the study area. The approximate western and northern boundaries of the buried channels are shown on the Geologic Investigations Map, Plate 5.

Glacial Till - Pleistocene - consists of a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders deposited by one or more continental glaciers. It occurs as a thin veneer or remnant patches on the bedrock surface.

Alluvium - Holocene - consists of unconsolidated clay, silt, sand, and gravel that covers valley floors.

Lignite Beds

Six persistent lignite and/or lignitic shale beds, A through F, were penetrated by drilling in the Beulah Trench Study Area. Brief descriptions of these beds are found on the generalized stratigraphic column, Plate 6.

Probably only one bed is of economic significance in the study area. It, the D or Beulah-Zap Coalbed, is shown on the Geologic Investigations Map, Plate 5, as it either crops out or would crop out if projected to the ground surface. It ranges from 16.3 to 23.5 feet thick and averages 20.4 feet. Overburden and coal above the Beulah-Zap Coalbed range from 10 feet or less to over 200 feet in the study area. Depth to the Beulah-Zap Coalbed is shown on the Overburden Thickness Map, Plate 22.

Structure

The study area is located in the Williston Basin. Sediments are essentially flat lying. Structure contours drawn on top of the Beulah-Zap Coalbed, Plate 22, indicate that a north-south synclinal trough trends across the area. The feature may be the result of differential compaction and may not be expressed at depth.

Small local faults exist throughout the area as indicated by the slickensides exhibited in drill core samples. These are generally restricted to weak, plastic, carbonaceous shales immediately above or below lignite beds. Displacement along these fractures could not be determined but probably do not exceed 5 feet.

Paleontology

Geologic investigations did not reveal any significant or unusual paleontological sites in the study area. Fossils in the Sentinel Butte Member are generally obscured by the mantle of glacial, eolian, or alluvial soils. Fossils found in drill core samples included calcareous shells and carbonaceous tree fragments. None of these were collected for identification.

Mineral Resources

Natural gas and oil are the only minerals, other than coal, that may be present in the study area. Exploration holes have been drilled in the region in the past, and extensive new investigation in the Williston Basin to the

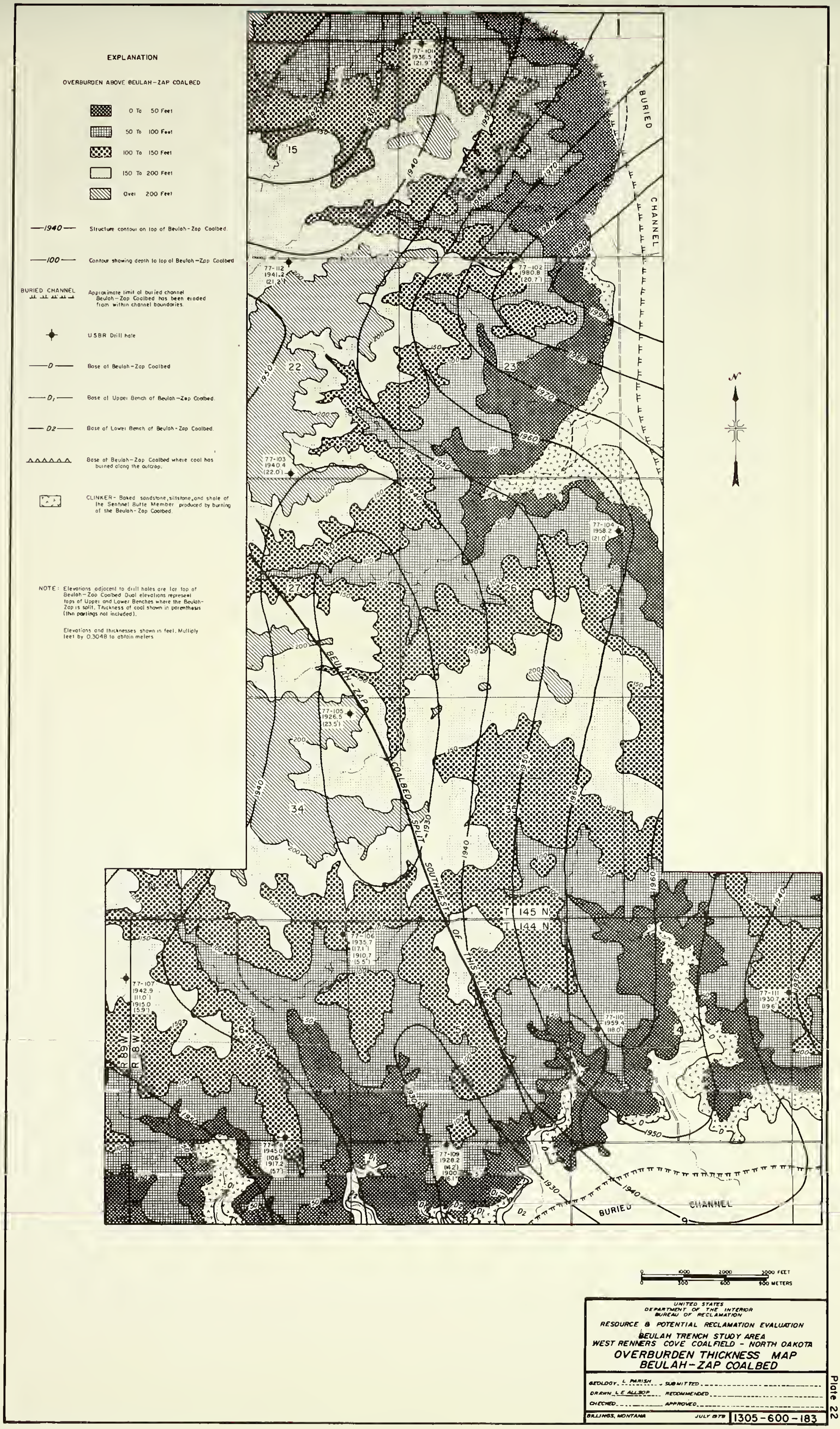

EXPLANATION
OVERBURDEN ABOVE BEULAH-ZAP COALBED
0 To 50 Feet
50 To 100 Feet
100 To 150 Feet
150 To 200 Feet
Over 200 Feet
1940 Structure contour on top of Beulah-Zap Coalbed.
100 Contour showing depth to top of Beulah-Zap Coalbed
BURIED CHANNEL Approximate limit of buried channel. Beulah-Zap Coalbed has been eroded from within channel boundaries.
USBR Drill hole
D Base of Beulah-Zap Coalbed
D1 Base of Upper Bench of Beulah-Zap Coalbed.
D2 Base of Lower Bench of Beulah-Zap Coalbed.
Base of Beulah-Zap Coalbed where coal has burned along the outcrop.
CLINKER- Baked sandstone, siltstone, and shale of the Sentinel Butte Member produced by burning of the Beulah-Zap Coalbed.
NOTE: Elevations adjacent to drill holes are for top of Beulah-Zap Coalbed. Dual elevations represent tops of Upper and Lower Benches where the Beulah-Zap is split. Thickness of coal shown in parenthesis (thin partings not included).
Elevations and thicknesses shown in feet. Multiply feet by 0.3048 to obtain meters.
BURIED CHANNEL
BEULAH-ZAP COALBED SPLIT SOUTHWEST OF THIS LINE
T 145 N
T 144 N
R 89 W
R 88 W
77-101 1936.5 (21.9')
77-112 1941.2 (21.2')
77-102 1980.8 (20.7')
77-103 1940.4 (22.0')
77-104 1958.2 (21.0')
77-105 1926.5 (23.5')
77-106 1935.7 (17.1') 1910.7 (5.5')
77-107 1942.9 (11.0') 1915.0 (5.9')
77-110 1959.4 (18.0')
77-111 1930.7 (19.6')
77-108 1945.0 (10.6') 1917.2 (5.7')
77-109 1928.2 (14.2') 1900 (6.1')
0 1000 2000 3000 FEET
0 300 600 900 METERS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA
OVERBURDEN THICKNESS MAP
BEULAH-ZAP COALBED
GEOLOGY L. PARISH SUBMITTED
DRAWN L.E. ALLSOP RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA JULY 1979 1305-600-183

Plate 22

west of the study area may extend into it and lead to new discoveries. At the present time, however, no producing wells are located within the study area boundaries.

Engineering Geology

Stability of Excavation Slopes

Engineering property tests were not conducted on bedrock samples from the Beulah Trench Study Area. The Beulah Trench rock is somewhat softer and contains more shale, but physical property tests results for it should be similar to those of the Fort Union Formation at the Otter Creek Study Site, Montana (EMRIA Report No. 1).

Much of the bedrock at the Beulah Trench Study Area consists of bentonitic shales which are susceptible to minor shrinking and swelling. Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, especially along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage should be maintained to relieve pore water pressure in the overburden as mine excavations progress.

Saturated alluvial deposits and uncemented siltstones and fine-grained sandstones will readily erode and flow into excavations. This problem is sometimes encountered in drilling when the walls of holes collapse and slough. Depth of excavation below the water table will be limited until these materials are dewatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types, and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at the Otter Creek Site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet in width designed on the slope surface.

Stability of the Present Landscape

In its present undisturbed state, the Beulah Trench Study Area experiences no problems with land stability. Landslides do not occur because of the gentle slopes. Likewise, subsidence is not a problem because mines are not present, readily soluble bedrock does not underlie the area, and no large withdrawals of ground water have occurred.

Overburden Expansion

Overburden volumes expand as the materials are broken up during mining and void spaces increased. The increase in volume (bulking) differs for various types of soil and rock. Soft sandstones and shales in the Wasatch and

Fort Union Formations will probably expand about 25 percent. In some cases, the surface of the replaced overburden will be higher after than before mining.

The table below shows the anticipated change in topography that will occur in the study area at selected drill holes if all coalbeds 2 feet or greater in thickness are surface mined. This assumes that (1) stripping will occur to depths of 267 feet; (2) 100 percent of the coal in the mined beds is removed, (3) overburden is replaced on a cut-by-cut basis (4) spoils are smoothly graded and, (5) overburden expands 25 percent.

Drill Hole	Depth of cut (1)	Thickness of coal removed (2)	Thickness of replaced overburden (3)	Difference in elevation
77-101	150 ft.±	22 ft.±	160 ft.±	+10 ft.±
77-102	159	20	174	+15
77-103	267	22	306	+39
77-104	75	20	69	-6
77-105	247	23	280	+33
77-106	165	23	178	+13
77-107	206	17	236	+30
77-108	156	16	175	+19
77-109	130	21	136	+6
77-110	99	18	101	+2
77-111	159	24	169	+10
77-112	190	21	211	+21

(1) Base of Beulah-Zap Coalbed
(2) Includes 100 percent of all coalbeds 2 or more feet thick.
(3) Overburden x 1.25 (bulking factor) = Replaced Overburden.

Instability of the Postmining Landscape[1/]

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains. They are: (1) area-wide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include the physical and chemical characteristics of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur.

Area-wide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with the progression of time.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in more blocky and, initially, more porous spoils than does coarse-textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

1/ Groenwold, G.H., and Rehm, B.W., 1980.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in mid-winter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks are concentrated by final, mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in mid-winter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

Piping appears to be a severe and long-term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoil.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

Piping, like the other instability problems, most commonly develops in areas contoured by dozers. Scraper-contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

Weathering Tests

Weathering tests were conducted on core samples from the Beulah Trench Study Area to determine which materials would break down sufficiently to allow for their use as topsoil in revegetation of surface-mined areas. Samples were selected for (1) freeze-thaw, (2) wet-dry, and (3) outdoor testing. The criteria developed for the testing is described as follows:

Freeze-Thaw Cycle

1. 8 hours at 75^{o}F. (23.9^{o}C.), 100 percent relative humidity (wetting/thawing).

2. 16 hours (64 hours on weekends) at 0^{o}F. (-17.8^{o}C.) (freezing).

Wet-Dry Cycle

1. 8 hours at 75^{o}F. (23.9^{o}C.), 100 percent relative humidity (wetting).

2. 16 hours (64 hours on weekends) at 100^{o}F. (37.8^{o}C.), 10 percent relative humidity (drying).

Outdoor

The outdoor exposure test included subjecting the specimens to several snowstorms and a series of freeze-thaw cycles.

Test results showed that the freeze-thaw condition was more severe than the wet-dry because it caused more rapid breakdown of most core samples. Generally, shale samples tended to swell and disintegrate under saturated conditions, but the material produced may be difficult to place and handle because of its plasticity. Sandstone and siltstone samples were more resistant to weathering than either shales or silty shales (see Table 6 and Photographs 5 through 14).

Material Sources

Earth materials suitable for most construction can be found within the Beulah Trench Study Area. Material types and the local sources are noted below:

Impervious - clayey or silty material that can be used for construction of embankments or as canal lining. It can be obtained from the glacial till that covers part of the uplands or from local zones within the alluvium of the valley floors.

Pervious - clean sand or gravel suitable for use as filters or other types of structures where free drainage is required. It can probably be found in the Pleistocene channel fill of the valleys along the southern and eastern edges of the study area.

Concrete Aggregate - clean sand and gravel similar to the pervious material noted previously. It may also be found in local deposits within the bordering channel fills, but the nearest aggregate sources that have been approved by the Water and Power Resources Service are near the Missouri River approximately 20-35 miles southeast of the study area.

Clinker (Scoria) - thermally altered rock formed by heat from the burning of coalbeds. It is usually reddish in color, reasonably hard and brittle. It crushes easily and is commonly used for road fill and surfacing. It can be found in several places within the study area where the Beulah-Zap Coalbed has burned along its outcrop.

Riprap - durable, reasonably well graded mixture of rock fragments generally ranging from about 6 inches to 2 or 3 feet in diameter used for surface protection from running water. Ideally, individual fragments should be angular to remain stable on steep slopes. High quality riprap material is not available in the Beulah Trench Study Area. The bedrock is too soft, and although there are scattered glacial boulders in the area, gathering them would be very expensive and they are too rounded to remain stable on anything but gentle slopes. Probably the closest sources of suitable rock are the Black Hills of South Dakota or the granitic basement rocks of extreme eastern North Dakota.

WEATHERING TESTS

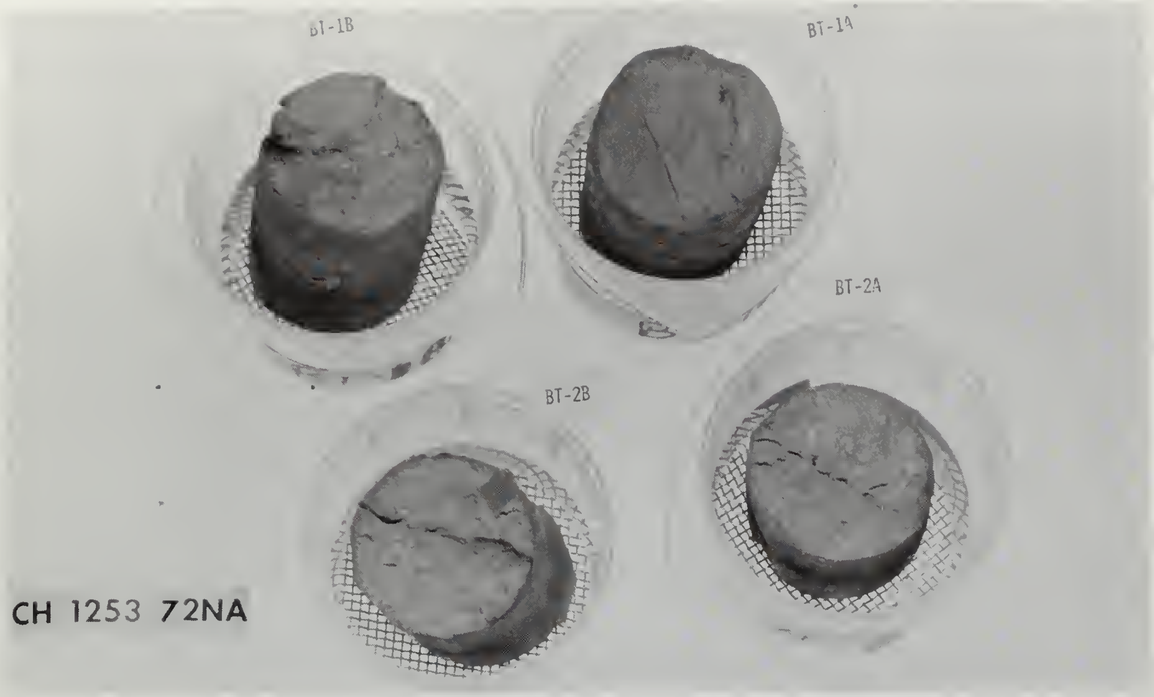
Overburden Samples From Beulah Trench, North Dakota

Sample I.D.	Remarks
Shale DH 77-101 Depth (ft) 61.0-62.0 (BT-1)*	See Photographs 5 and 9 Laboratory weathering: Slaking at 10 cycles; continued slaking at 20 cycles. %BD = 23 Outdoor: Cracking and slaking at 1 year. %BD = 31
Shale DH 77-101 Depth (ft) 85.5-86.5 (BT-2)	See Photographs 5 and 9 Laboratory weathering: Slight slaking and peeling at 20 cycles. %BD = 5 Outdoor: Severe cracking and slaking at 1 year. %BD = 100
Shale DH 77-102 Depth (ft) 88.5-89.7 (BT-3)	See Photographs 6 and 9 Laboratory weathering: Slight surface slaking and cleavage at 10 cycles; continued slaking at 20 cycles. %BD = 40 Outdoor: Severe slaking at 1 year %BD = 40
Sandstone DH 77-103 Depth (ft) 66.2-67.2 (BT-4)	See Photographs 6 and 9 Laboratory weathering: No change at 20 cycles. %BD = 0 Outdoor: Some swelling at 1 year %BD =21

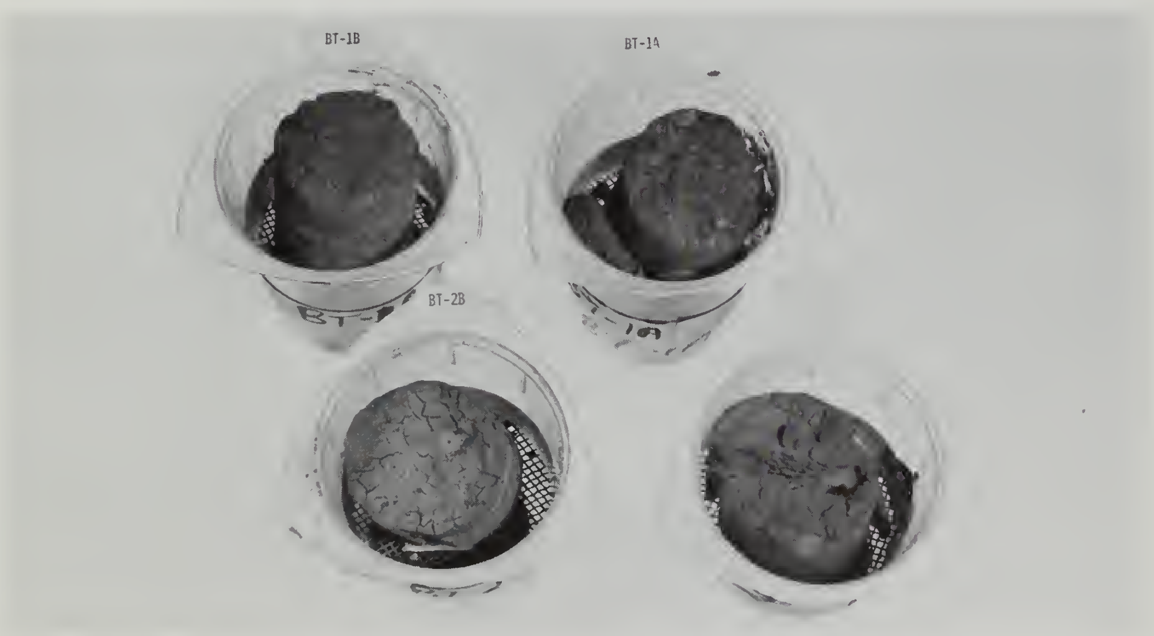
* Laboratory Sample No.

Sample I.D.	Remarks
Shale DH 77-103 Depth (ft) 167.0-168.0 (BT-5)	See Photographs 6 and 10 Laboratory weathering: Delamination at 10 cycles; some slaking at 20 cycles. &BD = 21 Outdoor: Cracking and delamination at 1 year. %BD = 15
Sandstone DH 77-105 Depth (ft) 80.6-81.6 (BT-6)	Sample not tested. It was already broken down when received. %BD = 100
Silt DH 77-105 Depth (ft) 128.0-129.0 (BT-7)	Sample not tested. It was already broken down when received. %BD = 100
Shale DH 77-105 Depth (ft) 214.0-215.0 (BT-8)	See Photographs 7 and 10 Laboratory weathering: Slight surface slaking, peeling, and cracking at 20 cycles. %BD = 2 Outdoor: Some slaking at 1 year. %BD = 36
Clay DH 77-106 Depth (ft) 46.0-46.9 (BT-9)	See Photographs 8 and 10 Laboratory weathering: Very slight slaking at 20 cycles. %BD = 2 Outdoor: Very little change at 1 year. %BD = 6
Shale DH 77-106 Depth (ft) 116.0-117.0 (BT-10)	See Photographs 8 and 10 Laboratory weathering: Slight surface slaking, peeling, and cracking at 20 cycles. %BD = 4 Outdoor: Cracking and slaking at 1 year. %BD = 56

Sample I.D.	Remarks
Composite sample DH 77-106 Depth (ft) 0-183 (BT-11)	See Photographs 11 through 14 Laboratory weathering: Some cracking and slaking of core specimens at 20 cycles. Outdoor: Considerable breakdown of core specimens at 1 year.



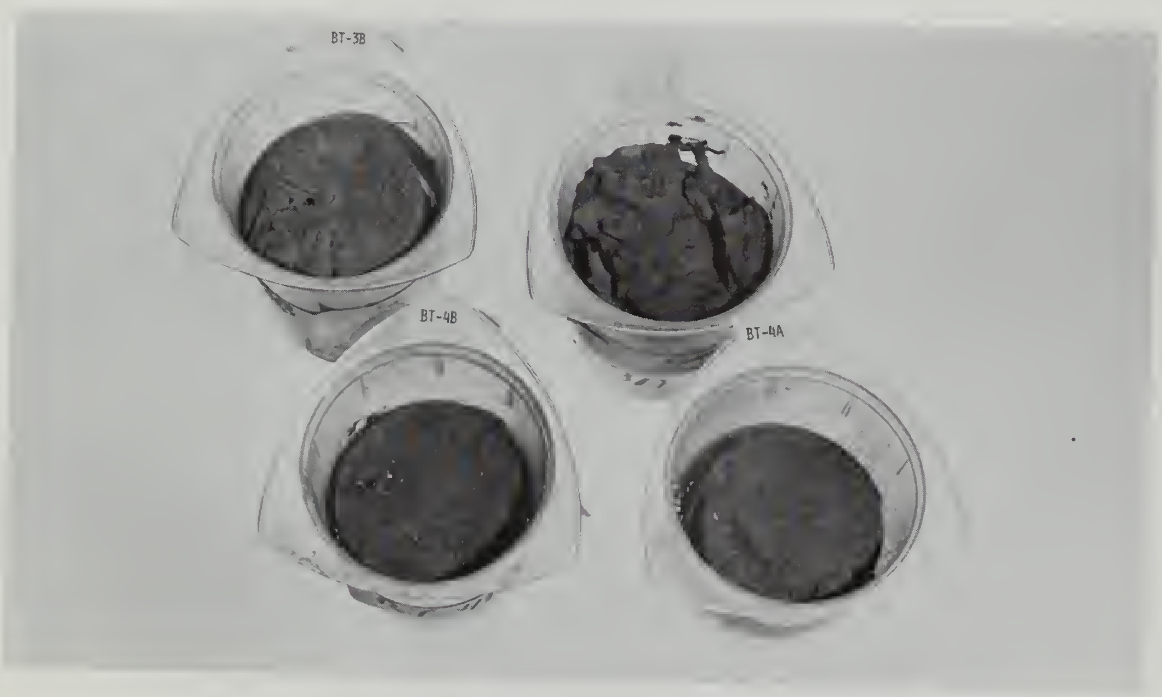
a. Original condition of test specimens



b. Condition of test specimens after weathering.

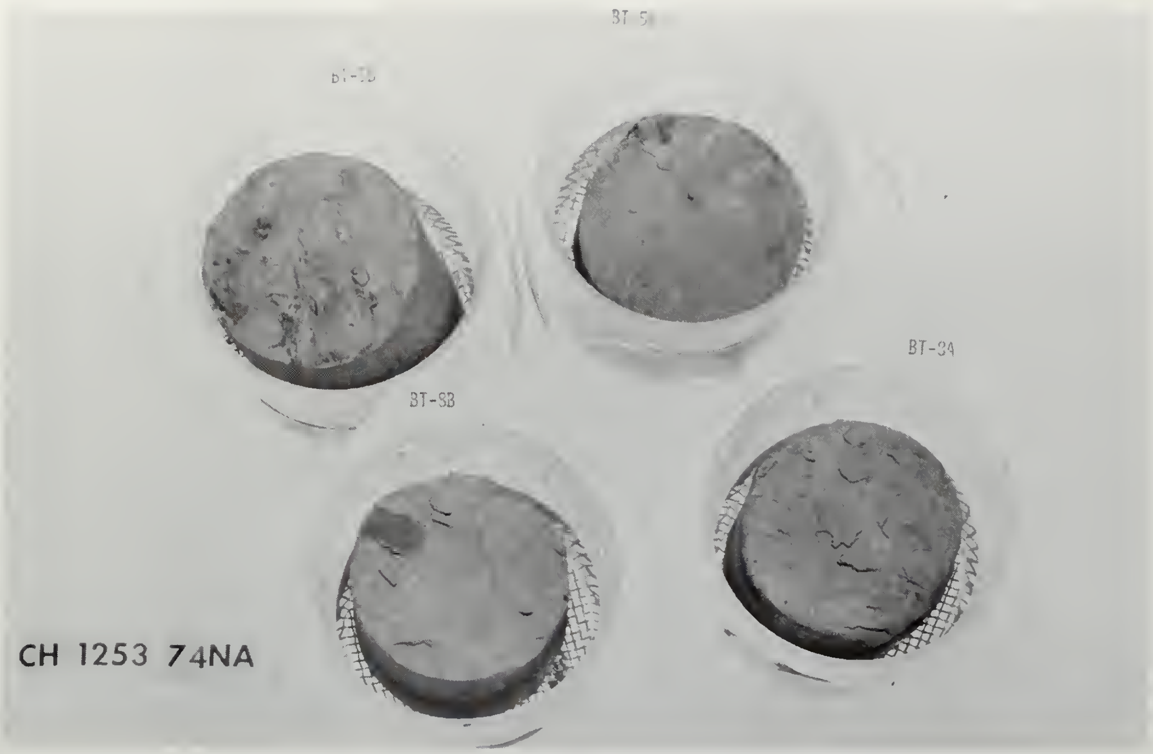
Photo 5 - Results of weathering tests for shale samples BT-1 and BT-2. Specimens A subjected to 20 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.

a. Original condition of test specimens.

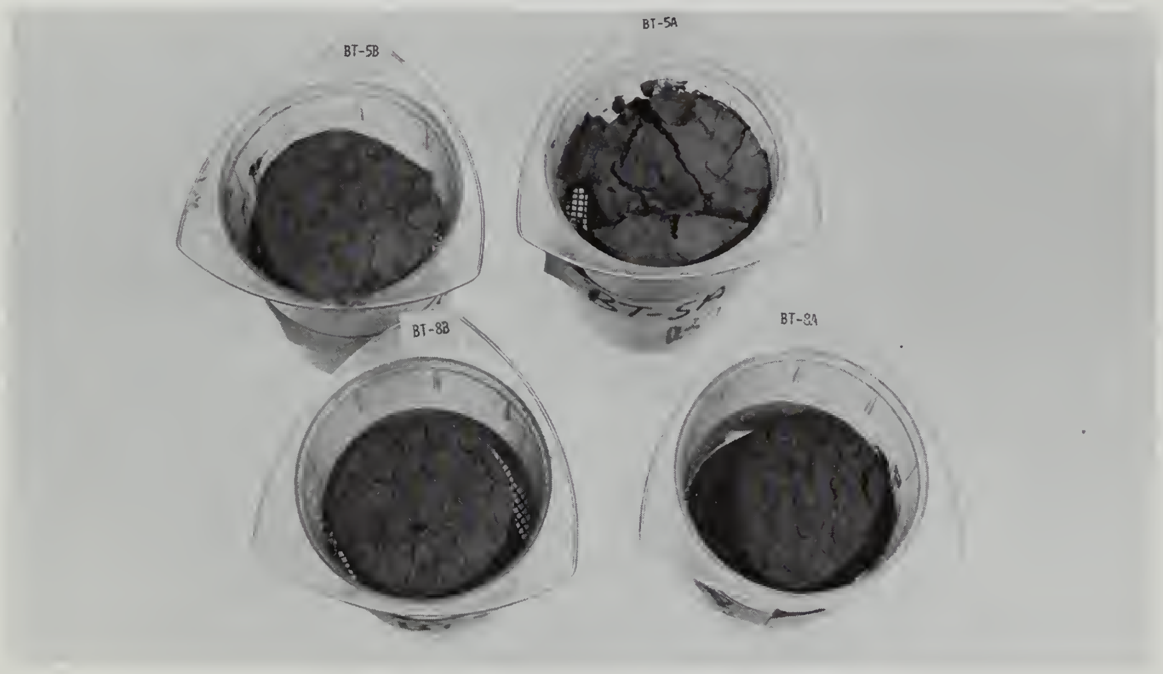


b. Condition of test specimens after weathering.

Photo 6 - Results of weathering tests for shale sample BT-3 and sandstone sample BT-4. Specimens A subjected to 20 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.



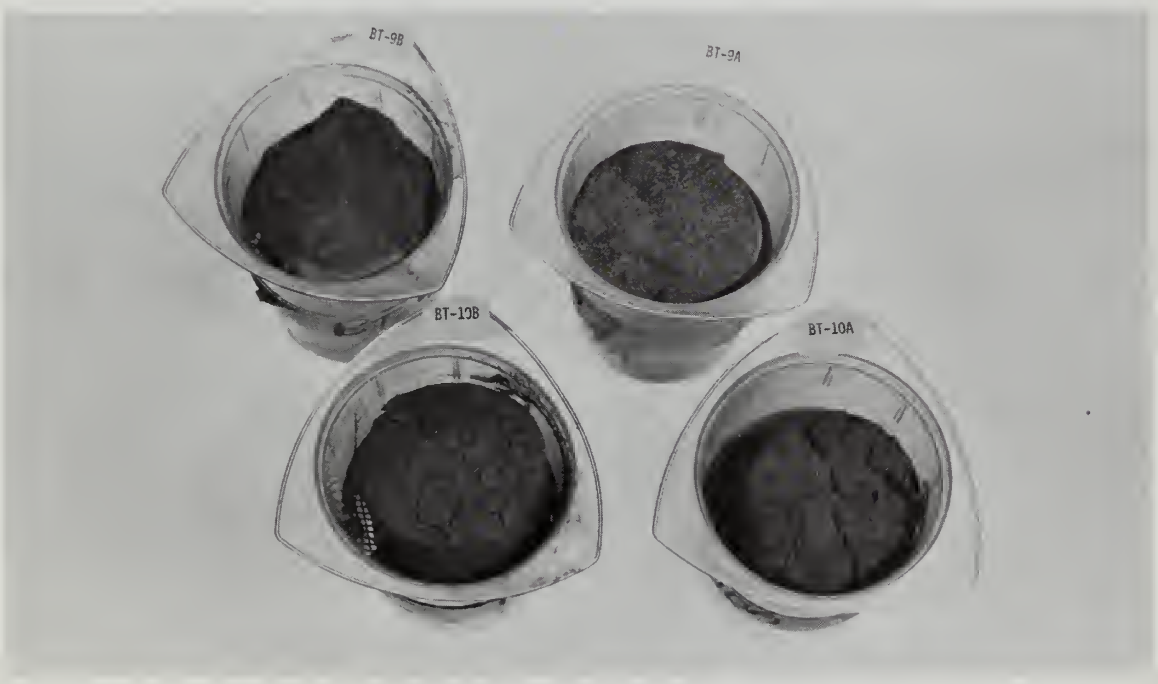
a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 7 - Results of weathering tests for shale samples BT-5 and BT-8. Specimens A subjected to 20 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.

a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Photo 8 - Results of weathering tests for clay sample BT-9 and shale sample BT-10. Specimens A subjected to 20 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.

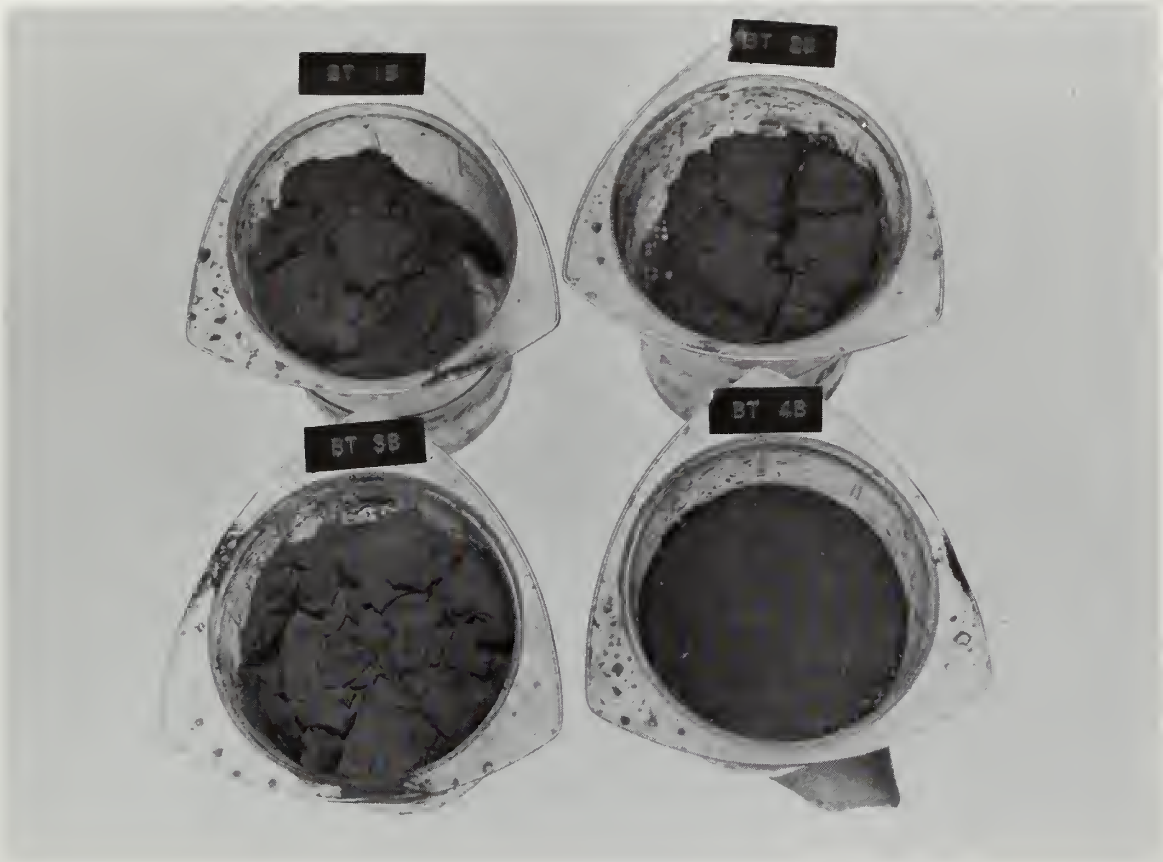


Photo 9 —Results of one-year outdoor exposure tests for specimens BT-1B through BT-4B.

Photo 10 - Results of one-year outdoor exposure tests for specimens BT-5B, BT-8B, BT-9B, and BT-10B.

Photo 11 - Original condition of composite sample BT-11A.

Photo 12 — Condition of composite sample BT-11A after 20 laboratory weathering cycles.

Photo 13 - Original condition of composite sample BT-11B.

Photo 14 - Condition of composite sample BT-11B after one year of outdoor weathering.

Seismic

The Beulah Trench Study Area lies within a relatively stable part of North America. All of North Dakota is within Zone 1 of the Algermisson Seismic Risk Map. In this zone, distant earthquakes can cause minor damage to structures with fundamental periods greater than 1.0 second (Corresponds to intensities V and VI of the Modified Mercalli Intensity Scale of 1931).

No earthquakes of intensity V or above (Modified Mercalli) have occurred within North Dakota during historical times. Earthquakes centered in Iowa, Minnesota, Montana, Nebraska, and a few Canadian shocks have been felt in the State. A list of earthquakes that have been felt in North Dakota follows, but much of the information on exact location and intensity is unknown.

Date	Intensity (Modified Mercalli)	Distance From Beulah Trench	Located Near
Oct. 9, 1872	Unknown	420 miles	Sioux City, IA
Nov. 15, 1877	Unknown	Unknown	IA or NE
May 15, 1909	Unknown	Unknown	SK, Canada
Oct. 26, 1946	IV	105 miles	Williston, ND
Aug. 17, 1959	IX	480 miles	Hebgen Lake, MT
July 8, 1968	IV	75 miles	Huff, ND
July 9, 1975	Unknown	235 miles	Morris, MN

COAL RESOURCES [1/]

Estimation and Classification of Coal Resources

Coal resource estimates have been prepared for the Fort Union lignite within the Beulah Trench Study Area using standard procedures, definitions, and criteria established by the U.S. Geological Survey and U.S. Bureau of Mines for making coal resource appraisals in the United States. The term "coal resources" as used in this report means the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

Tabulation of Estimated Coal Resources

Tables 10 and 11 summarize the estimated coal resources of the Beulah Trench Study Area. The resources in the study site are classed as measured, indicated, and inferred according to the degree of geologic assurance of the estimate:

Measured

Resources are computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced and the thickness and extent of coals are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differs from region-to-region according to the character of the coalbeds, the points of observation are no greater than 1/2 mile (0.8 km) apart. Measured coal is projected to extend as a 1/4 mile (0.4 km) wide belt from the outcrop or points of observation or measurement.

Indicated

Resources are computed partly from specific measurements and partly from projections of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are 1/2 (0.8 km) to 1-1/2 miles (2.4 km) apart. Indicated coal is projected to extend as a 1/2 mile (0.8 km) wide belt that lies more than 1/4 miles (0.4 km) from the outcrop or points of observation or measurement.

Inferred

Quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region, because few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from measured and indicated coal for which geologic evidence exists. The points of observation are 1-1/2 (2.4 km) to 6 miles (9.6 km) apart. Inferred coal is projected to extend as a 2-1/4 mile (3.6 km) wide belt that lies more than 3/4 mile (1.2 km) from the outcrop or points of observation or measurement.

1/ The following supplements are included for reference in Appendix D: (1) a general discussion of coal type, rank, etc.; and (2) a technical paper describing chemical analyses of lignite from the Sentinel Butte Member of the Fort Union Formation, Beulah Trench Study Area.

Estimated identified coal resources of the Beulah Trench Study Area, West Renners Cove coal field, North Dakota

[*D-S indicates split in D bed. In thousands of tons]

		0-200 feet of overburden											
		2½-5 feet				5-10 feet				>10 feet			
Sec.	Bed*	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total
						T. 144 N., R. 88 W.							
4	C	530	950	1,500	2,980	---	---	---	---	---	---	---	---
	D	---	---	---	---	4,300	11,000	---	15,300	---	---	---	---
	F	330	900	1,300	2,530	---	---	---	---	---	---	---	---
	Total	860	1,850	2,800	5,510	4,300	11,000	---	15,300	---	---	---	---
6	D	---	---	---	---	90	1,400	---	1,490	4,000	8,300	---	12,300
	D-S	26	230	---	256	1,500	3,900	---	5,400	---	---	---	---
	Total	26	230	---	256	1,590	5,300	---	6,890	4,000	8,300	---	12,300
8	C	500	940	---	1,440	---	8	---	8	---	---	---	---
	D	---	---	---	---	---	---	---	---	1,700	3,400	---	5,100
	D-S	56	210	---	266	670	810	---	1,480	---	---	---	---
	F	---	15	---	15	---	---	---	---	---	---	---	---
	Total	556	1,165	---	1,721	670	818	---	1,488	1,700	3,400	---	5,100
						T. 145 N., R. 88 W.							
14	D	---	---	---	---	---	---	---	---	4,100	17,200	1,400	22,700
	F	180	---	---	180	---	---	---	---	---	---	---	---
	Total	180	---	---	180	---	---	---	---	4,100	17,200	1,400	22,700
22	C	---	---	---	---	---	---	---	---	---	---	---	---
	D	---	---	---	---	---	---	---	---	2,100	6,500	---	8,600
	Total	---	---	---	---	---	---	---	---	2,100	6,500	---	8,600
26	D	---	---	---	---	---	---	---	---	1,400	1,800	550	3,750
	Total	---	---	---	---	---	---	---	---	1,400	1,800	550	3,750
34	C	92	170	---	262	---	---	---	---	---	---	---	---
	D	---	---	---	---	---	---	---	---	3,600	5,600	---	9,200
	D-S	230	150	---	380	160	210	---	370	---	---	---	---
	Total	322	320	---	642	160	210	---	370	3,600	5,600	---	9,200
Total for area		1,944	3,565	2,800	8,309	6,720	17,328	---	24,048	16,900	42,800	1,950	61,650

Estimated identified coal resources of the Beulah Trench Study Area, West Renners Cove coal field, North Dakota--Continued

		200-300 feet of overburden												
		2½-5 feet				5-10 feet				>10 feet				Section
Sec.	Bed*	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	total
						T. 144 N., R. 88 W.								
4	C	---	---	---	---	---	---	---	---	---	---	---	---	2,980
	D	---	---	---	---	---	---	---	---	---	---	---	---	15,300
	F	---	---	---	---	---	---	---	---	---	---	---	---	2,530
Total		---	---	---	---	---	---	---	---	---	---	---	---	20,810
6	D	---	---	---	---	---	---	---	---	---	---	---	---	13,790
	D-S	---	---	---	---	200	120	---	320	---	---	---	---	5,976
Total		---	---	---	---	200	120	---	320	---	---	---	---	19,766
8	C	---	---	---	---	---	---	---	---	---	---	---	---	1,448
	D	---	---	---	---	---	---	---	---	---	---	---	---	5,100
	D-S	---	---	---	---	---	---	---	---	---	---	---	---	1,746
	F	---	---	---	---	---	---	---	---	---	---	---	---	15
Total		---	---	---	---	---	---	---	---	---	---	---	---	8,309
						T. 145 N., R. 88 W.								
14	D	---	---	---	---	---	---	---	---	---	1,000	---	1,000	23,700
	F	---	---	---	---	---	---	---	---	---	---	---	---	180
Total		---	---	---	---	---	---	---	---	---	1,000	---	1,000	23,880
22	C	39	---	---	39	---	---	---	---	---	---	---	---	39
	D	---	---	---	---	---	---	---	---	3,400	5,300	---	8,700	17,300
Total		39	---	---	39	---	---	---	---	3,400	5,300	---	8,700	17,339
26	D	---	---	---	---	---	---	---	---	---	61	---	61	3,811
Total		---	---	---	39	---	---	---	---	---	61	---	61	3,811
34	C	---	---	---	---	---	---	---	---	---	---	---	---	262
	D	---	---	---	---	---	---	---	---	1,700	3,400	---	5,100	14,300
	D-S		490	---	490	---	200	---	200	---	---	---	---	1,440
Total		---	490	---	490	---	200	---	200	1,700	3,400	---	5,100	16,002
Total for area		39	490	---	529	200	320	---	520	5,100	9,761	---	14,861	109,917

Summary of estimated identified coal resources of Beulah Trench Study Area

[In thousands of tons]

	Overburden thickness (feet)			
	0-200	200-300	>300	Total
Coal beds 2½-5 feet thick				
Measured resources	1,944	39	---	1,983
Indicated resources	3,565	490	---	4,055
Inferred resources	2,800	---	---	2,800
Total	8,309	529	---	8,838
Coal beds 5-10 feet thick				
Measured resources	6,720	200	---	6,920
Indicated resources	17,328	320	---	17,648
Inferred resources	---	---	---	---
Total	24,048	520	---	24,568
Coal beds >10 feet thick				
Measured resources	16,900	5,100	---	22,000
Indicated resources	42,800	9,761	---	52,561
Inferred resources	1,950	---	---	1,950
Total	61,650	14,861	---	76,511
Total identified resources	94,007	15,910	---	109,917

All of the estimated resources in beds thicker than 5 feet (1.5 m) and at depths of 1000 feet (305 m) or less fall into a category called reserve base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves are that portion of the identified coal resource that can be economically mined at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the reserve base. On a national basis the estimated recovery factor for the total reserve base is 50 percent. More precise recovery factors can be computed by determining the total coal recoverable in any specific locale.

Characteristics Used in Resource Evaluation

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal; the thickness of the coalbeds; and the thickness of the overburden. Rank and grade are described in more detail in Appendix D.

Weight

The weight of the coal ranges considerably with differences in rank and ash content. In areas such as Beulah Trench, where true specific gravities of the coal have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of lignite is taken as 1,750 tons per acre-foot -- a specific gravity of 1.29.

Thickness of Beds

Because of the important relationship of coalbed thickness to utilization potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. Thickness categories for lignite are thin -- 2.5 to 5 feet (0.75 to 1.5 m); intermediate -- 5 to 10 feet (1.5 to 3 m); and thick -- more than 10 feet (3 m). About 6 percent of the estimated resources of the study area is in the thin category, about 9 percent is in the intermediate category, and about 85 percent is in the thick category.

Thickness of Overburden

All of the estimated coal resources in the Beulah Trench Study Area are overlain by less than 300 feet (90 m) of overburden.

Summary of Resources

Total estimated identified original resources in the Beulah Trench Study Area are 109,917,000 tons. The coalbed thickness class of 2.5-5 feet contains 8,838,000 tons. The coalbed thickness class of 5-10 feet contains 24,568,000 tons and the coalbed thickness class of greater than 10 feet contains 76,511,000 tons of the estimated resources.

The estimated resources presented in this report are original resources; that is, resources in the ground before the beginning of mining operations.

OVERBURDEN - SOIL AND BEDROCK

Principal Soil Bodies

Soils of the Beulah Trench Study Area can be grouped into three major categories based on their parent material, mode of development, and land form position. They are: (1) residual soils developed over soft sandstone, siltstone, or shale which occur on gentle to steeply sloping uplands, (2) glacial soils occurring in uplands on morainal ridges and rounded gently sloping hills, and (3) alluvial and colluvial soils located along intermittent streams and on lower footslopes and fans at major changes in surface gradient. Most soils in this study area show surface layers relatively high in organic matter content, owing to their development under a cool mid-grass type vegetation.

Residual Soils

Residual soils occupy about 58 percent of the study area. They have developed from weathered sandstone, siltstone, and shale of the Fort Union Formation (Sentinel Butte Member). Slopes are variable on tracts occupied by these soils, ranging from 3 to 35 percent. Depth of the solum (A and B horizons) is largely slope-dependent, with shallow soils occupying steeper slopes near the origin of branching natural drains and deeper soils occurring on gentle sideslopes and ridges. The shallow soils are generally 4 to 18 inches in depth; the deeper soils often exceed 40 inches in depth.

The surface layer of the residual soils is typically friable, grayish brown to dark grayish brown, and noncalcareous. Textures range from sandy loam to clay loam. The surface layer is underlain by a light brownish gray to yellowish brown, calcareous, clay loam subsoil. Water readily infiltrates these soils and percolates freely through the surface horizon. However, downward movement of moisture is generally restricted in the finer-textured subsurface horizons. Penetration of roots may be retarded where the soil mantle is thin.

In this study area, a few localized tracts of residual soil have developed over baked rock ("clinker"). Generally, these tracts are less than 4 acres in size. The thermally altered bedrock extends to the unaltered sedimentary strata that underlie the burned out coal layer. The soils occurring on these tracts are typically friable, nonsaline, nonsodic, permeable, and retain about 1.5 inches of plant-available moisture per foot. The clinker has imparted a distinct reddish brown color to these soils. Due to its highly fractured state, the baked rock is very porous. Therefore, the residual soils developing over this baked material may be excessively drained.

At present, small grains are being produced on the deeper residual soils occupying gentle sideslopes. The shallow soils on steeper grades are being used primarily for range.

The Point Site soil profiles in Tables 19, 20, and 21, Appendix E, describe the residual soils occurring in this study area. The profile described in Table 22, Appendix E, is typical of the local residual soils developing over baked rock.

Glacial Soils

Soils formed in glacial parent material (till) occupy nearly 33 percent of the study area. Morainal ridges in the area are composed of a relatively thin, discontinuous glacial mantle. Moderate amounts of gravel, cobble, and boulders are common on the surface. The glacial mantle extends outward from the ridges and blends into lower lying residual soils. The depth of the solum and the glacial parent material ranges from less than 48 inches to nearly 10 feet. Slopes range from 3 to 15 percent. Soils are shallow on steeper slopes where till material is thin, whereas deeper soils exist on gently sloping tracts where the glacial mantle is relatively deep.

The surface layer of the glacial soils is typically a dark grayish brown loam 4 to 18 inches thick. The subsurface layer is commonly a grayish brown clay loam 18 to 48 inches in thickness. The soil profile is permeable to this depth. It is also noncalcareous and retains about 2 inches of available moisture per foot. The subsoil consists of light brownish gray or light yellowish brown clay loam till material that extends down to the bedrock strata of the Fort Union Formation. This fine-textured, calcareous material has slow to moderate permeability.

Glacial soils on the rocky morainal ridges are presently used for range, while those on the more gentle slopes are being dry-farmed for small grains.

The Point Site soil profiles in Tables 23 and 24, Appendix E, typify the glacial soils occurring in this study area.

Alluvial and Colluvial Soils

Alluvial and colluvial soils occupy about 9 percent of the study area. These soils are quite similar in appearance since they both consist of local material transported short distances by water. They occur in the uplands, on lower footslopes and fans, and along intermittent drainages. They represent an important source of topsoiling material due to their depth and quality. Depth of the soil ranges from 3 to 10 feet.

The surface layer of the colluvial soils is typically a dark grayish brown, friable loam. This layer is nonsaline, nonsodic, permeable, and retains about 2 inches per foot of available moisture. The subsurface layers are grayish brown to brown and friable. Textures range from sandy clay loam to clay loam.

The surface horizon of the alluvial soils is commonly a very friable, dark gray fine sandy loam. It is nonsaline, nonsodic, and noncalcareous. The subsurface horizons consist of light grayish brown clay loam with randomly interspersed thin layers (1 to 2 inches) of sandy material. These subsurface horizons are nonsaline, nonsodic, and moderately to strongly calcareous. The available moisture retained in these soils is approximately 2.2 inches per foot.

The alluvial/colluvial soils occupying gently sloping fans and footslopes are presently being used for small grain production. On steeper sideslopes and along intermittent drainages, these soils are being used for range.

The Point Site profile in Table 25, Appendix E, is typical of the alluvial soils occurring in this study area. Tables 26 and 27, Appendix E, describe the profiles of colluvial soils representative of this study area.

Land Suitability Survey

A detailed land suitability survey of the Beulah Trench Study Area was made to evaluate and characterize the overburden (includes soil and bedrock)[1/] as a source of material for resurfacing and revegetating the area. This survey provides data on the quantity and quality of material for revegetation, ease of stripping and stockpiling the usable material, and other factors which affect the lands' suitability as a source of material for revegetation. Basic data on the physical and chemical properties of the natural soil bodies and bedrock material under present conditions are also provided by the survey.

Land suitability specifications, shown on Table 28, were developed to establish classes for the specific use proposed, i.e., as a source of material for revegetation of surface-mined land. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes used in the Water and Power Resources Service land classification system.

Factors included in the specifications for quality consideration were: texture, salinity, sodicity, hydraulic conductivity, percent stones (>3 inches), erodibility, and available water holding capacity. Quantity considerations were based primarily on the depth of the material. Other factors influencing the ease with which suitable material could be selectively stripped and stockpiled were also considered. These included the presence of glacial erratics or indurated bedrock (outcrops) and steep, rough, or complex slopes.

Class 1 lands provide the most desirable and plentiful source of soil material for revegetation. A large supply of highly suitable material, which is relatively easily stripped and stockpiled, should be available from this class of land. In addition to having an adequate amount of suitable material for reclaiming the immediate area, Class 1 land can probably provide borrow material for topdressing areas with insufficient suitable material. Class 2 lands have adequate resurfacing material, but it may be limited in quantity, less desirable in quality, or somewhat difficult to strip and stockpile. Class 3 lands are similar to those in Class 2, except the deficiencies are

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1/ A glossary defining terms is included in Exhibit 4, Appendix E.

LAND SUITABILITY SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Overburden for Revegetation of Surface-Mined Areas
BLM/WPRS Cooperative Program EMRIA
Beulah Trench Study Area

United States
Department of the Interior
Water and Power Resources Service

Overburden Characteristics	Symbols: Basic Subclass	Symbols: Information and Deficiencies	Class 1	Class 2	Class 3
SOILS AND/OR BEDROCK	s				
Textures			Fine sandy loams to clay loams	Sandy loam to silty clay loams	Loamy sand to clay
Coarse		v		Sandy loam or gravelly material sufficiently coarse to slightly reduce productivity and moisture retention	Loamy sand or gravelly material in sufficient quantity to moderately reduce productivity and moisture retention
Fine		h		Profile should have sufficient material for topdressing; clayey materials that are slowly permeable should be placed below 18" in the reconstructed profile	Profile should have sufficient material for topdressing; placement of clay should be below 10" in the reconstructed profile; material objectionable to plant roots should be placed below root zone
Depth		d	> 36" of overburden that is suitable for plant media	> 18" of overburden that is suitable for plant media	> 10" of overburden that is suitable for plant media
Sodicity		a	SAR not to exceed 9.0 in clayey soils, but may be up to 20.0 in soils with loamy sand textures. Values can be slightly higher if compensated by adequate residual gypsum.		
Salinity ($ECx10_3$)		s	Less than 4	Less than 8 but should have 10" of material of less than 4 for surface	Less than 12 but should have 10" of material of less than 4 for surface
Available Water Holding Capacity		q	> 1.5"/foot of soil	> 1.0"/foot of soil	> 0.75"/foot of soil
Hydraulic Conductivity		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion	Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate	Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion
Cobble and Stones (>3")		x	Less than 5% in soil mass	Less than 10% in soil mass	Less than 20% in soil mass
Weatherability[1/]			Will break down readily upon exposure to the weather	May require short period to break down upon exposure	May require extended period to break down
Erodibility			Susceptible to slight erosion	Susceptible to moderate erosion	Susceptible to severe erosion but can be controlled with proper management and placement
TOPOGRAPHY[2/]	t				
Slope		g	Permissible surface gradient 0 to 12 with smooth slopes	Permissible surface gradient 0 - 12%; undulating to complex slopes	Permissible surface gradient 0 - 35%; hilly to steep slopes
Glacial Erratics or Indurated Bedrock Outcrops		r	None	1 to 5% of area	5 to 20% of area
Cover		c	Not applicable		
DRAINAGE	d		Because of anticipated land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material, are not a factor in the classification.		
Class 6			Areas delineated in this class generally lack suitable material for stripping and stockpiling as surface material. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient soil or bedrock of suitable quality at or near the surface, (2) topography which prevents stripping of suitable material, including steep slopes (single or complex), (3) abundance of glacial erratics or hard bedrock outcrops, and (4) toxic overburden (soil or bedrock) at or near the surface. Revegetation of these lands will require modification of the available material or borrowed material from nearby Class 1 or 2 lands.		

1/ Applicable only to bedrock material.
2/ Not applicable to bedrock material.

more pronounced or there is a combination of deficiencies. Land in this class is marginally suitable for revegetation but, under normal circumstances with good procedures for stripping and stockpiling, requirements for planting media can generally be met. Class 6 lands commonly lack adequate or suitable soil or bedrock material to meet the requirements for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from areas with adequate supplies or modify the material available for revegetation of the area.

Table 29 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

The land suitability survey was accomplished using Water and Power Resources Service methods and procedures. Field mapping was done on aerial photographs with a scale of 1:4,800. Topographic drawings at a scale of 1:24,000 with 20-foot contour intervals were used for reference. An Abney hand level was used to supplement the slope data on topographic drawings.

Representative (Point Site) soil profiles typical of extensive areas of Class 1, 2, 3, and 6 lands were described, sampled, and analyzed in detail. Additional profiles were recorded in the heterogeneous soil areas to show variations within the delineated areas. This information was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are often located in transitional tracts between soil types to more accurately locate boundaries.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger or hydraulic coring machine was then used to penetrate the overburden to a depth of 10 feet unless hard bedrock was encountered. Soil structure, texture, consistence, color, and other observable features of the exposed profile such as salinity, sodicity, and root distributions were recorded. Lime content was checked with dilute hydrochloric acid. Samples were collected from many of the exposed profiles. Evaluation of the soil material for hydraulic conductivity and available water holding capacity in relation to the reclaimed profile was a major consideration in the field evaluation. Using these basic soil evaluations along with observations of other land features such as surface stones, exposed hard bedrock, and slope, a land suitability class was tentatively assigned each delineated area while in the field. The suitability classes, when finalized, were recorded on land classification maps, Plates 23 through 29.

A soil laboratory was used in connection with the land suitability survey and screenable tests were performed on all soil samples. These tests included disturbed hydraulic conductivity, salinity, pH, and moisture retention (15 bars). More detailed soil analyses were then made as required. Exhibit 1, Appendix E, describes the screenable testing procedures used in the laboratory.

Complete soil analyses were performed on all samples from Point Site profiles representative of the major soil categories for the land suitability survey and the soil inventory. The analyses listed in Exhibit 3, Appendix E, were performed as needed for proper overburden evaluation.

In addition to the foregoing testing program, greenhouse studies were conducted on soil and bedrock samples from this study area to indicate possible toxic or other unfavorable conditions for plant growth (see GREENHOUSE section).

Results of Land Suitability Survey

The results of the land suitability survey are recorded graphically on detailed maps, Plates 23 through 29, which show the areal distribution of the various land classes, soil deficiencies, topographic deficiencies, profile notes of soil borings, and the results of laboratory analyses. This information is also summarized on Plates 30 and 31. Plate 30 describes the location and depth of overburden that is suitable for use at or near the surface in reconstructed profiles. Plate 31 shows the location and quantity of subhorizon material that can be used below the primary plant root zone in reconstructed profiles. Soil deficiencies are also shown. The following tabulation lists the acres of land in each section by class:

Beulah Trench Study Area

Location	Land Classes - Acreage				
T. 145 N., R. 88 W.	1	2	3	6	Total
Sec. 14	177.7	287.3	15.0		480
Sec. 22	113.1	20.9	186.0		320
Sec. 26	217.1	147.5	86.2	29.2	480
Sec. 34	110.1	30.3	19.6		160
Total	618.0	486.0	306.8	29.2	1440
Percent	42.9	33.8	21.3	2.0	100
T. 144 N., R. 88 W.					
Sec. 4	105.4	217.9	156.7		480
Sec. 6	431.7	182.5	25.8		640
Sec. 8	30.2	18.9	94.2	16.7	160
Total	567.3	419.3	276.7	16.7	1280
Percent	44.3	32.8	21.6	1.3	100
Percent of Study Area	43.6	33.2	21.5	1.7	100

No. 1 200'N., 100'E. of SW. Cor.
0-12" best for surface use., 12-54" suitable for surface use., 54-114" use for subsurface.
8-12% complex side slope below rolling residual and till crests.
0-1" SiL A1; 1-3" SiL AB; 3-6" CL B2 (m2pr/m2bk); 6-13" CL B3ca; 13-30" CL Cca; 30"+ Ces. Oxidized soft sandy shales 66-84"; mottled 84"+.
Lab texture 0-12" Hv L.

Depth	SAR	GYP
48-66"	5.2	
66-84"	9.0	0.0

No. 2 1120'N., 530' E. of SW. Cor.
0-12" best for surface use., 12-36" suitable for surface use., 36-114" use for subsurface.
4-6% complex gently sloping till crest with side slopes from 8-35%.
0-2" SiL A1; 2-8" CL B2 (m2pr/m2bk); 8-14" CL B3ca; 14"+ Cca.

Depth	SAR	Text.
0-12"		Hv L
36-54"	5.6	

No. 3 1060'S., 130' E. of $W\frac{1}{4}$ Cor.
0-18" best for surface use., 18-66" suitable for surface use., 66-78" use for subsurface.
8-10% complex side slope below till crest with cobble and boulders, some 8-35% slopes in area.
0-2" SiL A1; 2-7" CL B21 (m1pr/m2bk); 7-12" CL B22 (2mpr/2mbk); 12-18" CL B3ca; 18"+ Cca. 54"+ Cca; salt crystals 42"+.

No. 4 930'E., 180' S. of $W\frac{1}{4}$ Cor.
0-12" best for surface use., 12-54" suitable for surface use., 54-120" use for subsurface.
4-6% complex gentle slopes along till crest with cobble and boulders.
0-2" SiL A1; 2-8" CL B2 (m2pr/m2bk); 8-14" CL B3ca; 14"+ Cca; carbonaceous shales from 54-90"; mottled sandy shales 90"+.

Depth	SAR	GYP
0-12"		
30-54"	10.7	+0.4
90-108"	9.3	+0.8

No. 5 1600'E., 530' S. of $W\frac{1}{4}$ Cor.
0-18" best for surface use., 18-90" suitable for surface use.
12-16% complex side slope below till crest, cobble and boulders and 30% slopes in the area.
0-1" SiL A1; 1-3" SiL AB; 3-11" CL B2 (m2pr/m2bk); 11-18" CL B3ca; 18"+ Cca; salt accumulations 54"+; sandy shales at 78"+.

No. 6 930'W., 660' N. of $S\frac{1}{4}$ Cor.
0-18" preferred surface material; 18-54" acceptable for surface use; 54-72" for subsurface use.
8-10% side slope midway below residual till crest with scattered boulders. Slopes in area 8-35%.
0-1" SiL A1; 1-3" SiL AB; 3-14" CL B2 (m2pr/m2bk); 14-24" CL B3ca; 24-30" Cca; 30"+ sandy shales.
Lab texture 0-18" Hv SL.

No. 7 1300'W., 190' N. of $S\frac{1}{4}$ Cor.
0-24" best for surface use., 24-42" use for subsurface., 42-120" place below root zone.
2-6% complex foot slope. Slick spots in area.
0-5" SiCL AB; 5-11" CL B21 (m1cpr/m2bk); 11-18" CL B22 (clpr/clbk); 18-30" SiCL B3ca (with baked rock fragments); 30-42" Cca; sandy shales 42"+; salt accumulations 48"+.

Depth	SAR
48-72"	20.1

No. 8 100'N. of $S\frac{1}{4}$ Cor.
0-18" best for surface use material; 18-30" suitable for surface use; 30-60" place below root zone.
4-6% complex slopes till area with boulders on surface.
0-4" SiL Ap; 4-11" SiCL B21t (m2pr/m2bk); 11-15" CL B22t (c2pr/c2bk); 15-18" SiCL B3ca; 18"+ Cca; surface 18" high in organic matter content; mottling 36"+.

No. 9 750'E., 530' N. of SW. Cor.
0-18" best for surface use., 18-114" suitable for surface use.
16-20% complex side slope below residual and till crests.
0-1" FSL A1; 1-3" FSL AB; 3-8" FSL B2 (m1pr/m2bk); 8-24" B3ca; 24"+ Cca. Sandy shales at 102". Lab texture Hv SL.

No. 10 260'N. of SE. Cor.
0-24" best for surface use., 24-48" suitable for surface use., 48-120" use for subsurface.
4-6% complex foot slope below rolling residual and till material. A profile 300'W. has gravely SL over sandy shales at 30".
0-7" SiL Ap; 7-12" CL B2 (c2pr/m2bk); 12-24" CL B3; 24"+ Cca.
Till profile with gravely outwash bars in area.

Depth	SAR	GYP
0-24"		
48-72"	16.7	0.0
96-120"	6.2	

No. 11 900'N., 800'E. of $S\frac{1}{4}$ Cor.
0-24" best for surface use., 24-42" suitable for surface use.
8-16% complex side slope below till crest with cobble and boulders; sandy shale outcrops in 20% of area.
0-1" SiL A1; 1-4" SiL AB; 4-24" CL B2 (m2pr/m2bk); 24-42" CL B3ca; 42"+ Cca; considerable cobble in profile.

No. 12 900'N. of $S\frac{1}{4}$ Cor.
0-24" best for surface use., 24-30" suitable for surface use., 30-120" use for subsurface.
2-4% complex foot slope below till influence 0-5" CL Ap 5-12" B2t (m2pr/m2bk); 12-30" CL B3ca; 30"+ Cca; sandy shales 78"+ with carbonaceous materials at 114" (non-calcareous) colluvial bottom.

Depth	SAR	GYP
30-54"	10.8	-1.6
54-66"	7.8	
66-78"	7.3	

No. 13 1060'S., 800' W. of $E\frac{1}{4}$ Cor.
0-18" best for surface use., 18-36" suitable for surface use.
Profile located on gentle side slope, some slopes from 4-35%.
Burned rock on surface of area.
0-4" CL AB; 4-12" CL w/gr. B21 (m2pr/f2bks) with baked rock fragments; 12-18" CL B22 (clpr/c2bk); 18"+ Cca.

No. 14 900'S., 75'W. of $E\frac{1}{4}$ Cor.
0-36" best for surface use., 36-60" suitable for surface use., 60-120" use for subsurface.
6-8% complex side slope below crest with cobble, some 8-35% slopes in mapping unit.
0-2" SiL A1; 2-4" SiL AB; 4-11" CL B21 (m2pr/m2bk); 11-30" B22 (c2pr/c2bk); 30-42" CL B3ca; 42"+ Cca.
Lime accumulations at 42"+; Ces from 60"+ in sandy shales.

Depth	SAR
0-18"	
18-42"	
78-102"	3.2
102-120"	1.9

No. 15 900'W., 400' N. of $E\frac{1}{4}$ Cor.
0-18" best for surface use., 18-48" suitable for surface use.
8-12% complex till side slope with boulders on surface, some slopes to 30%.
0-2" SiL A1; 2-14" CL B2 (m2pr/m/f2bk); 14-18" B3ca; 18"+ Cca.

No. 16 2450'W., 180' N. of $E\frac{1}{4}$ Cor.
0-24" best for surface use., 24-96" suitable for surface use.
2-4% slopes in a wet alluvial bottom.
0-2" SiCL A1; 2-4" SiCL AB; 4-18" CL B2 (clpr/clbk); 18-24" CL B3; salt crystals 24"+.

Depth	SAR
72-96"	6.4

No. 17 660'E., 660' E. of $N\frac{1}{4}$ Cor.
0-6" best for surface use., 6-24" suitable for surface use., 24-108" use for subsurface.
6-12% complex side slope, some slopes to 15% in area till soil with cobble and boulders.
0.6" CL calcareous AB over strongly calcareous Cca. Salt accumulations with crystals at 24"+.

Depth	SAR	GYP
0-6"		
24-42"	15.1	-4.4

No. 18 580'W. 100'S. of NE. Cor.
0-24" best for surface use., 24-48" suitable for surface use., 48-114" use for subsurface.
4-6% complex side slope adjacent to gentle swale till soils.
0-1" SiL; 1-5" AB SiL; 5-18" CL B2 (m2pr/m2bk); 18-24" CL B3ca; 24"+ Cca.

Depth	SAR	Text.
0-24"		Hv L
48-66"	6.9	Lt CL

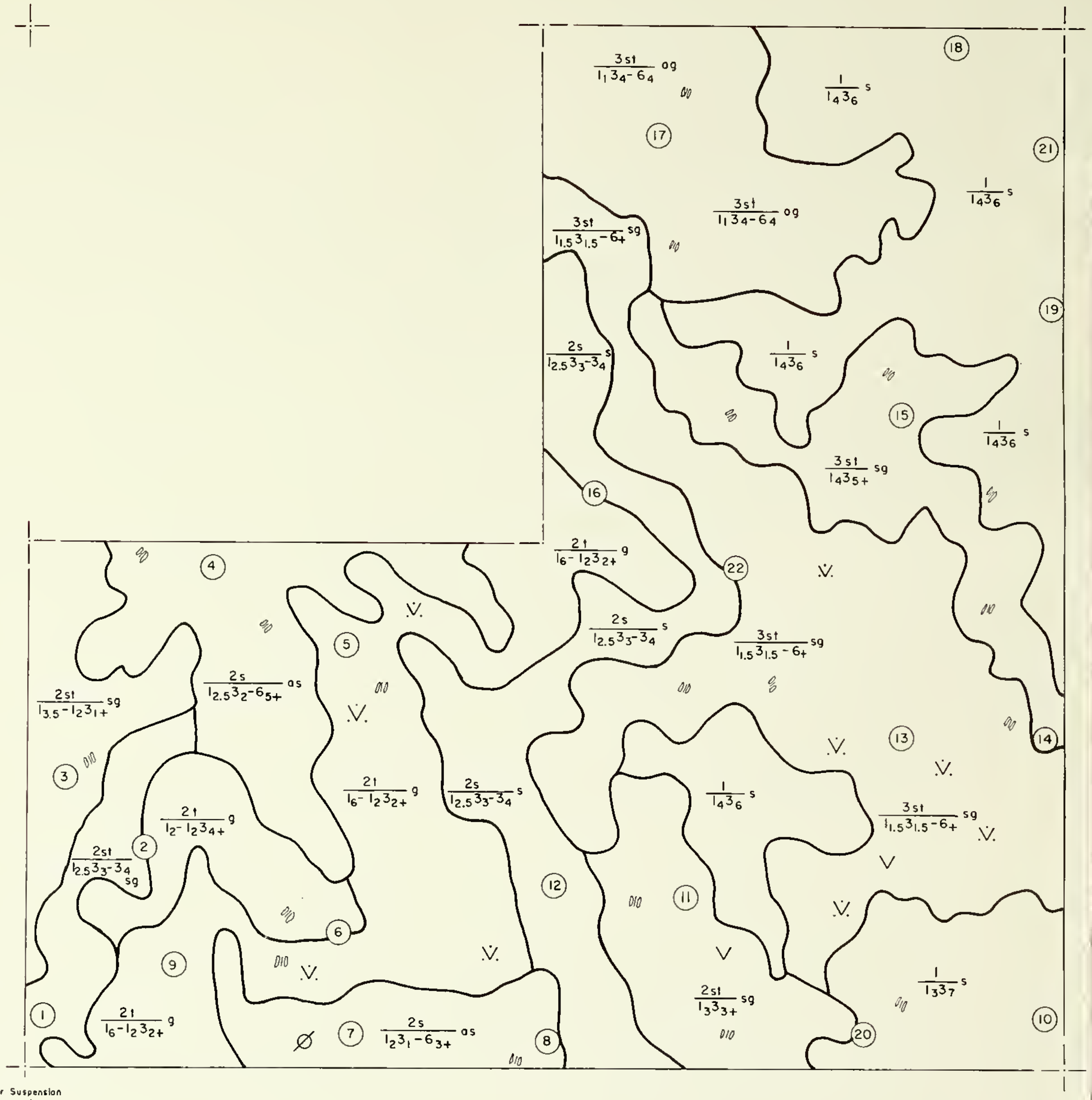
No. 19 1060'N. of $E\frac{1}{4}$ Cor.
0-30" best for surface use., 30-90" suitable for surface use.
Profile located on 6-8% side slope. Till soils.
0-5" CL Ap; 5-24" CL B2 (m2pr/m2bk); 24-30" CL B3ca; 30"+ Cca.

No. 20 1000'W., 180' N. of SE. Cor.
0-24" best for surface use., 24-78" suitable for surface use.
6-10% complex side slope; slopes exceeding 20% in mapping unit, till soils.
0-2" SiL A1; 2-24" CL B2 (m2pr/m2bk); 24-30" CL B3ca; 30"+ Cca; lime accumulations 66"+.

No. 21 600'S., 50' W. of NE. Cor.
0-6" best for surface use., 6-72" suitable for surface use., 72-120" use for subsurface.
6-9% complex slopes along till crests some slopes up to 16% in area.
0-5" SiL AB; 5-36" CL Cca; salt accumulations 12"+.

Depth	Text.
0-12"	Lt CL

No. 22 1730'W., 100'S. of $E\frac{1}{4}$ Cor.
0-18" best for surface use., 18"+ rock fragments.
12-16% side slope over burned rock. Some slopes vary from 8-35% in area.
0-1" loam A1; 1-7" loam AB; 7-15" C; 15"+ R.



STRUCTURE ABREVIATIONS

Size
- very fine ......vf
- fine ....f
- medium ....m
- coarse c
- very coarse vc

Grade
- structureless ..0
- weak 1
- moderate 2
- strong 3

Type
- platy ....pl
- prismatic ......pr
- columnar ....cpr
- blocky ....bk
- angular blocky .abk
- subangular blocky .sbk
- granular ....gr
- crumb ....cr
- single grain ...sg
- massive ....m

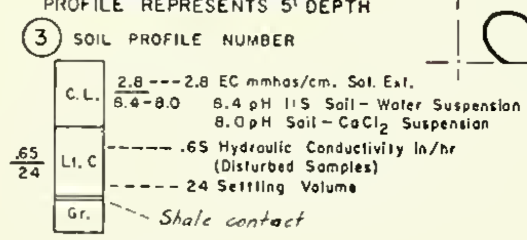
MISCELLANEOUS ABREVIATIONS
- calcic horizon ......Ca
- sodium adsorption-ratio ...SAR
- settling volume .....SV
- creviced rock ....CR

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)
- o Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

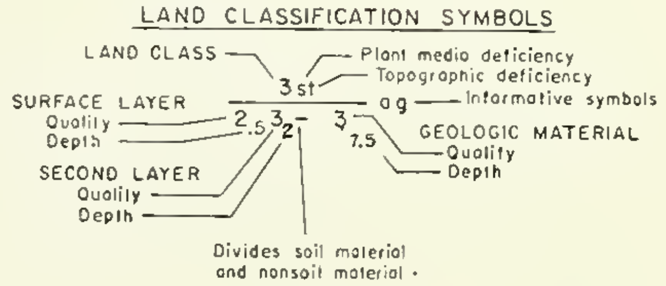
TOPOGRAPHIC DEFICIENCIES
- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erotics
- c Cover

SOIL PROFILE NOTES
PROFILE REPRESENTS 5' DEPTH



SOIL PROFILE SYMBOLS
- Cb Cobble
- Gr Gravel
- S Sand
- LS Loamy Sand
- SL Sandy Loam
- L Loam
- SiL Silt Loam
- SCL Sandy Clay Loam
- CL Clay Loam
- SiCL Silty Clay Loam
- SC Sandy Clay
- C Clay
- SiC Silty Clay
- Sh Shale
- Ss Sandstone
- F Fine
- Li Light
- M Medium
- H Heavy

LAND CLASSIFICATION SYMBOLS



CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS
- Gravel
- Mine

OAMS
- Medium or small

1:4800
SECTION 4, T. 144 N.-R. 88 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD — NORTH DAKOTA
DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA OCTOBER 1977	1305-600-184

No. 1 800'W., 150'N. of SE. Cor.
0-18" best for surface use., 18-120" suitable for surface use.
4-6% complex side slope below gentle crest. Cobble and boulders scattered on surface of area.
0-1" SiL Al; 1-3" SiL AB; 3-6" B21t SiL (mlpr/m2bk); 6-12" B22t (m2pr/m/f2bk); 12-18" B3 (m2pr/m2bk); 18"+ Cca. Loamy till profile. Lime accumulations 18"+. Salt crystals 78"+.

No. 2 650'E. of S¼ Cor.
0-18" best for surface use., 18-78" suitable for surface use.
8-16% complex side slope adjacent to swale. Cobble and large boulders scattered on surface.
0-1" SiL Al; 1-3" SiL AB; 3-8" B22t loam; 8-18" B3ca loam; 18"+ Cca.; mottled sandy shales at 66"+.
Lab texture 0-18" SCL.

No. 3 1540'N. of S¼ Cor.
0-36" best for surface use., 36-54" suitable for surface use.
4-9% complex side slope from moderately sloping till terrace.
0-1" SiL Al; 1-3" SiL AB; 3-6" SiCL B21t (m2pr/m2bk); 6-10" SiCL B22t (m2pr/m2bk); 10-42" B3. Lime accumulations 42"+.

No. 4 1400'N., 1400' E. of SW Cor.
0-18" best for surface use., 18-120" suitable for surface use.
8-15% complex hilly side slope adjacent to swale.
0-2" SL Al; 2-10" B2 (mlpr/m2bk) loam; 10-18" B3 (clpr/m2bk); 18"+ Cl SCL. Mottling at 12"+. Area mainly loam and FSL over sandy shales.
Lab texture 0-18" SL.

No. 5 1160'N., 400' E. of SW Cor.
0-12" best for surface use., 12-78" suitable for surface use., 78-120" use for subsurface.
4-6% side slope below moderately sloping crest with cobble and boulders scattered on surface. Slopes in area to 15%.
0-1" SiL Al; 1-3" SiL AB; 3-9" SiCL B2t (m2pr/m2bk); 9-14" SiCL B3ca; 14-36" Cca. Lime accumulations 18-30". Mottling 78"+. Salt crystals 66"+.
Lab texture 0-12" CL.

No. 6 600'E., 500'N. of SW Cor.
0-18" best for surface use., 18-66" use for subsurface.
8-35% complex side slope adjacent to draw.
0-6" SiCL AB; 6-8" B21t (mlpr/m/t2bk); 8-12" Cca; 12"+ sandy shales with salt crystals.
Lab texture 0-18" SCL.

Depth	SAR	GYP
18-30"	11.2	-0.8
30-42"	9.2	-7.6

No. 7 800'S., 600'W. of E¼ Cor.
0-12" best for surface use., 12-36" use for subsurface.
2-4% complex slopes into a colluvial bottom along a natural drain.
0-5" FSL Ap; 5-12" FSL Cl; gravely SL from 12-18"; 18"+ V. gr. sands; textures and depths over sands, gravel varies.

No. 8 1060'W., 800' S. of E¼ Cor.
0-18" best for surface use., 18-84" suitable for surface use.
4-6% complex colluvial side slope below moderately sloping till crests.
0-6" SiCL Ap; 6-10" SiCL B22t (mlpr/m2bk); 10-16" B3 (clpr/c2bk); 16"+ Cca. Lime nettings at 16"+. Sandy shales at 30"+.
Lab texture 18-30" Hv CL' 30-48" CL.

No. 9 1060'W., 940' N. of SE. Cor.
0-24" best for surface use., 24-120" use for subsurface.
8-16% complex side slope below till crests.
0-7" loam Ap; 7-18" B2t (m2pr/m2bk); 18-24" CL B3.
Profile located midway on side slope.
Lab texture 0-12" SL/SCL.

No. 10 300'W. of E¼ Cor.
0-18" best for surface use., 18-48" suitable for surface use., 48-120" use for subsurface.
4-6% complex side slope below till crests. Some 14% slopes in area.
0-2" FSL Al; 2-7" CL AB (Ap); 7-18" B2 (clpr/m2bk); 18-30" B3ca; 30"+ Cca till. Fine sands at 48"+.

No. 11 2000'W. of E¼ Cor.
0-30" best for surface use., 30-54" suitable for surface use., 54-120" use for subsurface.
2-4% complex slopes colluvial area adjacent to stream channel.
0-5" loam Ap; 5-11" SiL B21t (clpr/m2bk); 11-16" B22t (mlpr/m/f2bk); 16-30" B3; Cca 30"+. Salt crystals and mottling influence at 54". Till at 78"+.

Depth	SAR	GYP
66-78"	14.0	-3.2
102-120"	9.4	-0.4

No. 12 1100'S., 220' W. of NE. Cor.
0-6" best for surface use., 6-24" suitable for surface use., 24-96" use for subsurface use.
6-10% complex side slope below rolling till crests. Some slopes to 16% .
0-6" CL Al; 6"+ R., sandy shale mottling influence at 6"+ and salts at 24"+.
Lab texture 0-6" CL.

No. 13 1400'W., 560' S. of NE. Cor.
0-48" best for surface use., 48-120" suitable for surface use.
8-10% complex side slope below moderately sloping crest. Some slopes to 16% +.
0-2" FSL Al; 2-10" B12 FSL (c2pr/flbk); 10-24" FSL B22 (clpr/flbk); 24-48" FSL B3; 48-72" FSL Cca. Dark surface soil.

No. 14 500'S., 100' E. of N¼ Cor.
0-24" best for surface use., 24-42" suitable for surface use., 42-90" use for subsurface.
4-6% complex foot slope.
0-6" SiCL Ap; 6-18" B2t (m2pr/m2bk); 18-30" B3ca; 30"+ Cca. Lime nettings 18"+. Mottled sandy shales with salt crystals at 30"+.
Lab textures 0-18" L; 18-30" CL.

No. 15 1500'S., 500'E. of N¼ Cor.
0-36" best for surface use., 36-120" suitable for surface use.
2-4% complex slopes in a colluvial soil area along a swale tributary.
0-7" loam Ap; 7-24" SiCL B2 (m2pr/m2bk); 24-36" SiCL B3; 36"+ Cl.
60"+ gravely sandy clay loam with salt crystals. Weakly calcareous at 60"+. Lighter texture common loam average for area.

No. 16 1700'S., 100' E. of N¼ Cor.
0-24" best for surface use., 24-120" suitable for surface use.
2-4% complex slopes alluvial bottom with profile varying from gravely to clayey.
0-4" SiCL Al; 4-8" SiCL BA; 8-18" B2 SiCL (clpr/m2bk); 18-24" SiCL B3; gleying influence at 18"+; iron mottling at 36"+.
Wet profile with water table at 54". Shale influence at 66"+.

No. 17 1900'E., 340' N. of W¼ Cor.
0-30" best for surface use., 30-120" suitable for surface use.
8-10% complex side slope in a moderately sloping area with some slopes to 16%.
0-1" SL Al; 1-3" loam AB; 3-7" L. B12t (mlpr/m2bk); 7-15" FSL B3 (clpr/mlbk); 15-30" Cl; 30"+ soft sandy shales.
Lab texture 0-12" SL.

No. 18 1440'E., 100' S. of W¼ Cor.
0-30" best for surface use., 30-114" suitable for surface use.
4-9% complex side slope near gently rolling crest. Scattered cobble and boulders in area.
0-1" SiL Al; 1-3" SiL AB; 3-7" CL B21t (m2pr/f2bk); 7-16" SiCL B22t (m2pr/m/f2bk); 16-30" SiCL B3ca; 30"+ Cca with gravel coated with lime.
Lab texture 0-18" Lt. CL.

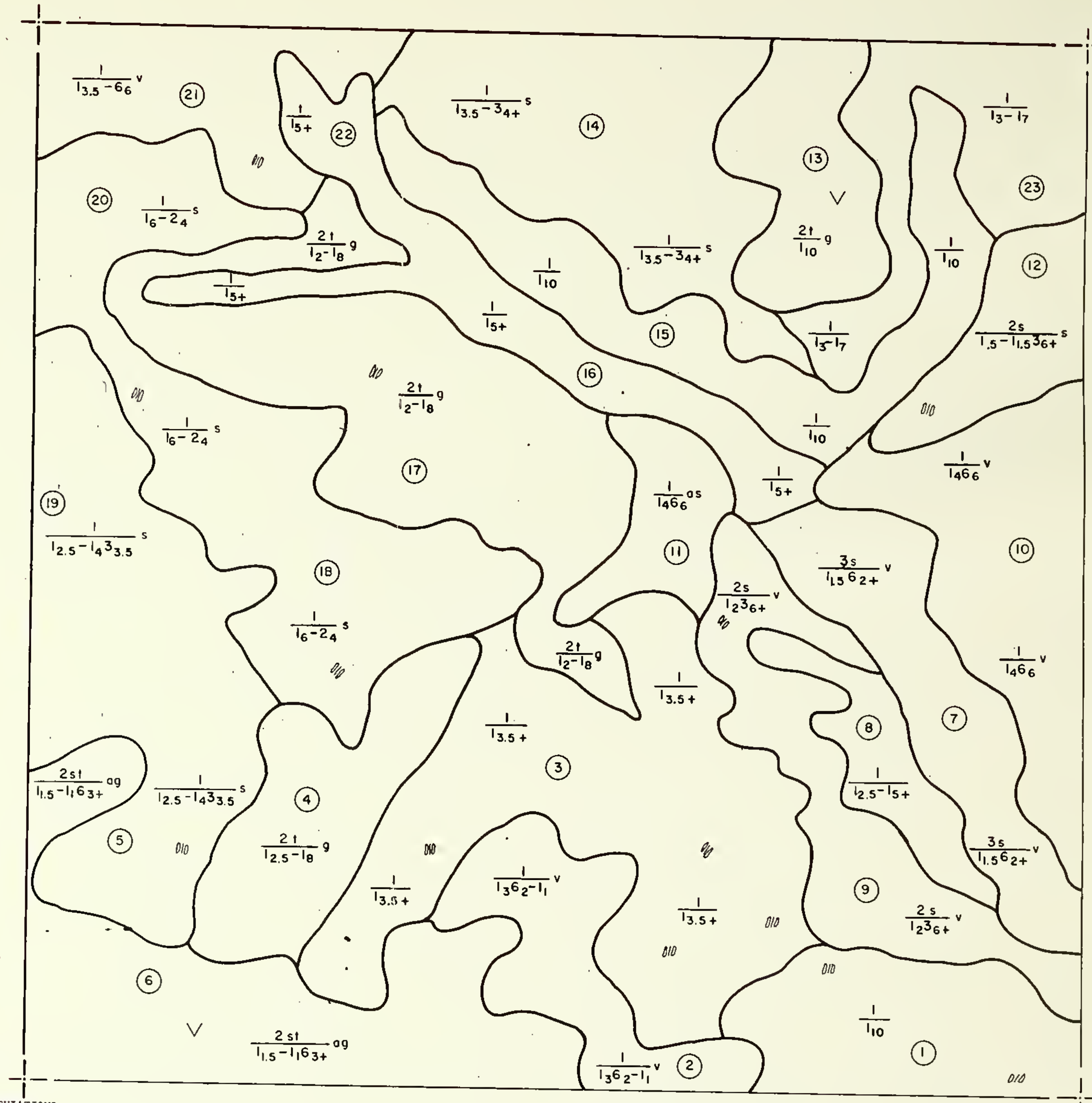
No. 19 150'N. of W¼ Cor.
0-24" best for surface use., 24-54" suitable for surface use.
6-8% complex slopes; rolling topography.
0-4" FSL Ap; 4-9" FSL B21t (clpr/m2bk); 9-12" SCL B22 (clpr/mlbk); 12-24" loam B3; 24-36" SiCL Cl; 36-54" SiL C2.
Profile not typical for mapping unit. 12" heavy loam over sandy shale material is common.
Lab texture 0-24" SL.

No. 20 900'S., 150' E. of NW. Cor.
0-12" best for surface use., 12-102" suitable for surface use.
4-6% complex side slope below gentle till crest with surface cobble and boulders.
0-2" SiL Al; 2-9" B2t (m2pr/m/f2bk); 9-12" B3ca; 12"+ Cca; salt crystals 54"+. Sandy shales occur at 6' in area.

No. 21 700'E., 350'S. of NW. Cor.
0-18" best for surface use., 18-42" suitable for surface use., 42-78" use for subsurface.
6-8% side slope below a gentle crest, some slopes to 20%, scattered surface cobble and boulders.
0-2" FSL Al; 2-6" FSL BA(Ap); 6-10" loam B2 (m2pr/m2bk); 10-16" loam B3.
Surface textures influenced by till on crests.

No. 22 1500'E., 550' S. of NW. Cor.
0-18" best for surface use., 18-54" suitable for surface use.
2-6% complex slopes colluvial material adjacent to stream channel.
0-2% SiL A2; 2-5" loam AB; 5-14" loam B2 (mlpr/mlbk); 14"+ II Cl gr. loam. Undifferentiated alluvium.
Lab texture 0-12" SL.

No. 23 750'S., 300'W. of NE. Cor.
0-30" best for surface use., 30-120" suitable for surface use.
6-14% complex side slope below sandy crest.
0-5" SCL Ap; 5-12" SCL B2 (vc2pr/c/m2bk); 12-30" CL B3; 30"+ C.
Lab texture 0-12" Hv SL.



INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial eratics
- c Cover

LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant media deficiency; Topographic deficiency
og — Informative symbols
SURFACE LAYER: Quality, Depth — 2_s3_2 — 3 75 — GEOLOGIC MATERIAL: Quality, Depth
SECOND LAYER: Quality, Depth
Divides soil material and nonsoil material

SOIL PROFILE NOTES
PROFILE REPRESENTS 5' DEPTH

(3) SOIL PROFILE NUMBER

C.L. 2.8 --- 2.8 EC mmhos/cm. Sat. Ext.
8.4-8.0 — 8.4 pH 1:5 Soil - Water Suspension; 8.0 pH Soil - $CaCl_2$ Suspension
Lt. C .65/24 — .65 Hydraulic Conductivity in/hr (Disturbed Samples); 24 Settling Volume
Gr. — Shale contact

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

STRUCTURE ABREVIATIONS
Size
- very fine ......vf
- fine ....f
- medium ....m
- coarse c
- very coarse vc

Grade
- structureless ..0
- weak 1
- moderate 2
- strong 3

Type
- platy ....pl
- prismatic ......pr
- columnar ....cpr
- blocky ....bk
- angular blocky .abk
- subangular blocky .sbk
- granular ....gr
- crumb ....cr
- single grain ...sg
- massive ....m

MISCELLANEOUS ABREVIATIONS
- calcic horizon ......Ca
- sodium adsorption-ratio ...SAR
- settling volume .....SV
- creviced rock ....CR

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS
- Gravel
- Mine

DAMS
- Medium or small

N

1:4800
SECTION 6, T. 144 N.-R. 88 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL SUBMITTED
DRAWN L.E. ALLSOP RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA OCTOBER 1977 1305-600-185

No. 1 1400'E., 560'S. of NW Cor.
0-24" best for surface use., 24-66" suitable for surface use.
4-8% complex foot slope below rocky till slopes.
0-2" A1 FSL (c1pl); 2-6" AB Loam (c1pr/m2bk); 6-12" (c2pr/m2bk); 12-30" B3ca (c2bk); 30-48" Cca; 48-66" C2. Small lime coated gravel at 10"+.
Lab texture 30-40" Lt CL.

No. 2 1620'E., 840'S. of NW Cor.
0-12" best for surface use., 12-54" suitable for surface use.
4-6% complex side slope near gullied sloping rocky crest. Slopes to 16% in area.
0-2" A1 Loam; 2-7" B21 (m1pr/m2bk); 7-12" B3ca; 12-30" Cca. Cobble and boulders 10% of surface.

No. 3 700'S., 620'E. of NW Cor.
0-18" best, preferred for surface use., 18-36" suitable for surface use., 36-42" use for subsurface.
2-4% complex slopes. Undifferentiated colluvial bottom.
0-4" A SiL 4-10" B12 (m1pr/m1bk); 10-36" Cl; 36"+ GrCL with cobble-size rock; some salt mottling at 36"+.

No. 4 1100'E., 900'S. of NW Cor.
0-12" best for surface use., 12-42" suitable for surface use., 42-84" use for subsurface.
4-8% complex side slopes with boulders; some slopes of 20%.
0-3" A1 SiL; 3-9" B2 (m2pr/m2bk); 9-13" B3ca SiL (vc1pr/m2bk); 13-18" Cca. 54"+ salt crystals in mottled sandy shales. A horizon 10YR 4/2.

No. 5 740'W., 400'S. of N¼ Cor.
0-18" best for surface use., 18-78" suitable for surface use., 78-96" use for subsurface.
4-8% complex side slope below gentle and steep crests with slopes to 16%.
0-3" SiL A1; 3-6" AB SiL (old Ap); 6-14" B21 SiCL (c1pr/m2bk); 14-18" B3ca; Cca 18"+. Sandy shales below 40".

No. 6 920'S., 120'W. of N¼ Cor.
0-18" best for surface use., 18-30" suitable for surface use., 30-84" use for subsurface.
4-6% complex side slope with some slope to 16%.
0-5" AB (Ap) CL; 5-9" B21t (c2pr/m2bk) CL hard dry; 9-13" CL B22t (c2pr/m/f2bk); 13-18" B3ca; 18-30" Cca; 30"+ sandy shale material. Lime accumulations at 13"+. Salt mottling and crystals at 30"+. Adjacent area has slick spots.

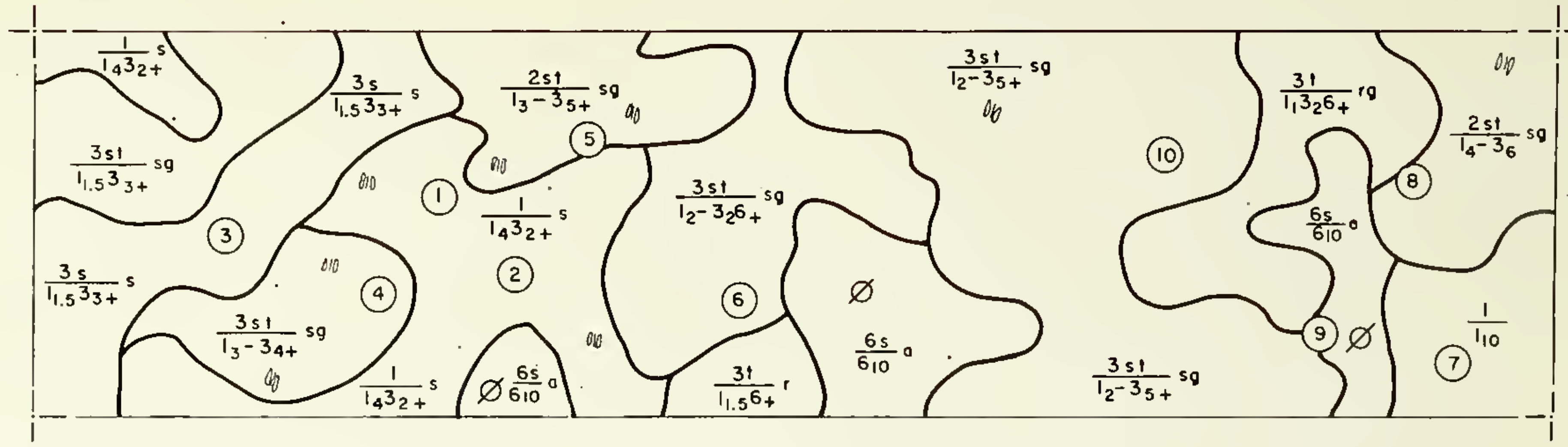
Depth	SAR	GYP
30-48"	8.1	
66-84"	12.7	-2.0

No. 7 1120'S., 400'W. of NE Cor.
0-30" best for surface use., 30-102" suitable for surface use.
2-6% slopes into swale below crest with slopes to 10%.
0-7" SiCL AB; 7-15" CL B21t (m2pr/f2bk); 15-18" CL B22t (m2pr/f2abk) with baked ink fragments; 18-30" CL B3; 30"+ Cl. Till firm at 54"+. Lime accumulations from 54-102".
Lab texture 18-30" CL; 30-54" Hv SL.

No. 8 460'S., 460'W. of NE Cor.
0-6" best for surface use., 6-30" suitable for surface use., 30-84" use for subsurface.
4-6% side slope below gently sloping till crests with some 16% slopes.
0-6" CL AB; 6-14" CL Cca; 14"+ sandy shale. Salt crystals at 54"+.
Lab texture 0-12" L.

No. 9 1000'S., 820'W. of NE Cor.
0-120" saline sodic material unsuited for plant media.
2-4% complex slopes, colluvial outwash area influence from baked rock and carbonaceous shales.
0-2" CL A2; 2-7" CL B21t (c1pr/c/m2bk); 7-15" B22t (m2pr/f2bk); 15-24" B3ca; 24"+ Cca. Baked rock fragments 12-36".

No. 10 1350'W., 400'S. of NE Cor.
0-18" best for surface use., 18-66" suitable for surface use., 66-120" use for subsurface.
8-10% complex side slopes into a swale. Rolling terrain hills from 8 to 35% slopes. Cobble in area.
0-2" SiL A1; 2-8" CL B21 (m2pr/f2bk); 8-11" CL B22 (m2pr/m2bk); 11-18" CL B3; 18"+ Cca. Lime accumulations at 18"+. Salt accumulations at 66"+. Carbonaceous shale influenced at 108"+.
Lab texture 0-18" L.



EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant media deficiency; Topographic deficiency
ag — Informative symbols
SURFACE LAYER — Quality, Depth (2.5)
SECOND LAYER — Quality, Depth (3 2)
GEOLOGIC MATERIAL — Quality, Depth (3 7.5)
Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

(3) SOIL PROFILE NUMBER

2.8---2.8 EC mmhos/cm. Sat. Ext.
8.4-8.0 8.4 pH 1:5 Soil - Water Suspension; 8.0 pH Soil - $CaCl_2$ Suspension
.65 Hydraulic Conductivity in/hr (Disturbed Samples)
24 Settling Volume
Shale contact

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

STRUCTURE ABREVIATIONS

Size
very fine ......vf
fine ....f
medium ....m
coarse c
very coarse vc

Grade
structureless ..0
weak 1
moderate 2
strong 3

Type
platy ....pl
prismatic ......pr
columnar ....cpr
blocky ....bk
angular blocky .abk
subangular blocky .sbk
granular ....gr
crumb ....cr
single grain ...sg
massive ....m

MISCELLANEOUS ABREVIATIONS
calcic horizon ......Ca
sodium adsorption-ratio ...SAR
settling volume .....SV
creviced rock ....CR

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS
- Gravel
- Mine

DAMS
- Medium or small

1:4800
SECTION 8, T. 144 N.-R. 88 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD – NORTH DAKOTA

DETAIL LAND CLASSIFICATION

SOILS T. KIECHTL SUBMITTED
DRAWN L. E. ALLSOP RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA OCTOBER 1977 1305-600-186

No. 1 2000'E. of E½ Cor.
Best for surface use. 24-108" below primary root zone.
4-6% complex slopes into a swale with slickspots. Rolling till crests with cobble and boulders surround the area.
0-1" SiL A1; 1-4" SiL AB; 4-18" SiCL B2t (c2pr/m/f2bk)
18-24" CL B3ca; 24"+ Cca. Salt accumulation 24"+. Mottling influence at 54"+.
Slickspots with (m2cm/m2bk) - 30% of area.

Depth	SAR	GYP
36"-54"	14.6	-3.4

No. 2 1300'S.,700'W. of N¼ Cor.
0-24" best for surface use., 24-72" suitable for surface use., 72-120" for subsurface use. 8-12% complex side slope near till crest. Slopes in area 8-16%.
0-1" SiL A1; 1-4" SiCL AB; 4-18" SiCL B2t (m2pr/m2bk); 18-30" CL B3; 30"+ Cca.
Average depth to shales in area 36".

Depth	SAR	GYP
30"-48"	3.8	0.0
72"-90"	8.6	
90"-108"	9.7	+1.6

No. 3 1700'S.,650'W. of N¼ Cor.
0-18" best for surface use., 18-36" for subsurface use., 36-120" place below primary root zone.
8-15% complex slopes and crest with cobble and boulders in area. A/C profiles are common. This profile represents small sandy area.
Lab texture 0-6" SL.

No. 4 1000'E., 450' of W¼ Cor.
0-12" best for surface use., 12-66" suitable for surface use. 66-120" use for subsurface.
8-35% complex side slope below till crest. Cobble and sandstone on surface. Side slopes show influence of sandy shales.
0-1" SiL A1; 1-6" CL B2; 6-10" Loam B3ca; 10-18" FSL Cca.
Lab texture 0-12" SL/SCL.

No. 5 900'N., 400'E. of W¼ Cor.
0-18" best for surface use. 18-120" suitable for surface use.
2-4% complex foot slope below till and sandy shale crest with surface cobble and boulders.
Slopes of 10-16% are common.
0-2" SiL A1; 2-5" SiL AB; 5-10" SiCL B2 (m2pr/m/f2bk); 10-18" CL B3; 18"+ Cca., Lime accumulations at 24"+. Lime and salt accumulations at 42"+.
Lab texture 0-18" SCL.

No. 6 700'E., 200'S. of Cor.
0-36" best for surface use. 36-60" use for subsurface.
4-6% complex side slope with 10% slopes as inclusions.
0-1" SiL A1; 1-5" loam AB (old Ap.); 5-16" loam B2 (m1pr/m2bk); 16-36; B3 (noncal.).

No. 7 750'W., 150'S. of NE. Cor.
0-24" best for surface use., 24-120" suitable for subsurface use.
2-4% complex slopes into alluvial swale below till crests.
0-7" SiCL Ap; 7-14" SiCL B2 (c1pr/cm2bk); 14-24" SiCL B3; 24"+ Cca.
Buried horizon from 84-102".
Lab texture 0-24" HvL.

No. 8 1360'N., 200'E. of S¼ Cor.
0-42" best for surface use., 42-120" suitable for surface use.
2-6% complex colluvial foot slope below rolling till crests.
0-1" SiL A1; 1-3" SiL AB; 3-10" SiCL B21 (m2pr/m2bk); 10-24" CL B22 (m2pr/m2bk); 24-42" CL B3 with 6" B2 @ 36-42"; Cca 42"+.
Lime and salt accumulations at 42"+ becoming concentrated at 90"+.
Lab texture 0-12" L.

No. 9 540'N., 100'W. of S¼ Cor.
0-6" best for surface use., 6-42" suitable for surface use., 42-120" use for subsurface.
4-8% side slope below moderately steep to steep crests. Some slopes to 16% A/C profile with a 5" surface AB; Cca 5"+. Firm till; lime and salt accumulations at 42"+. Sandy shale fragments and mottling at 66"+.
SAR 42-66"
Lab texture 0-6"

No. 10 900'W., 100'N. of S¼ Cor.
0-36" best for surface use., 36-48" suitable for surface use., 48-120" use for subsurface.
4-8% complex swale with slick spots.
Small area of rolling till crests with cobble and boulders on surrounding areas.
0-1" SiL A2; 1-4" SiCL AB; 4-9" SiCL B21 (m1pr/t2bk); 9-18" SiCL B22; 18-36" SiCL B3; 36-42" Cca.
Surface horizons strongly influenced by depressions in 30% of area. Lime and salt accumulations 42"+.

Depth	SAR
18-36"	5.2
72-90"	5.1

No. 11 700'W., 100'N. of S¼ Cor.
0-24" best for surface use., 24-54" suitable for surface use., 54-108" use for subsurface.
6-10% complex side slopes ranging to 35% till influenced soil over sandy shales.
0-1" SiL A; 1-3" SiL AB; 3-10" CL B21 (m1pr/m2bk); 10-18" CL B22 (c1pr/cm2bk); 18-24" CL B3ca; 24"+ Cca. Till contains sandy shale fragments. Bedrock at 108"+; some white mottling at 90"+.
Lab texture 24-36" Hv L.

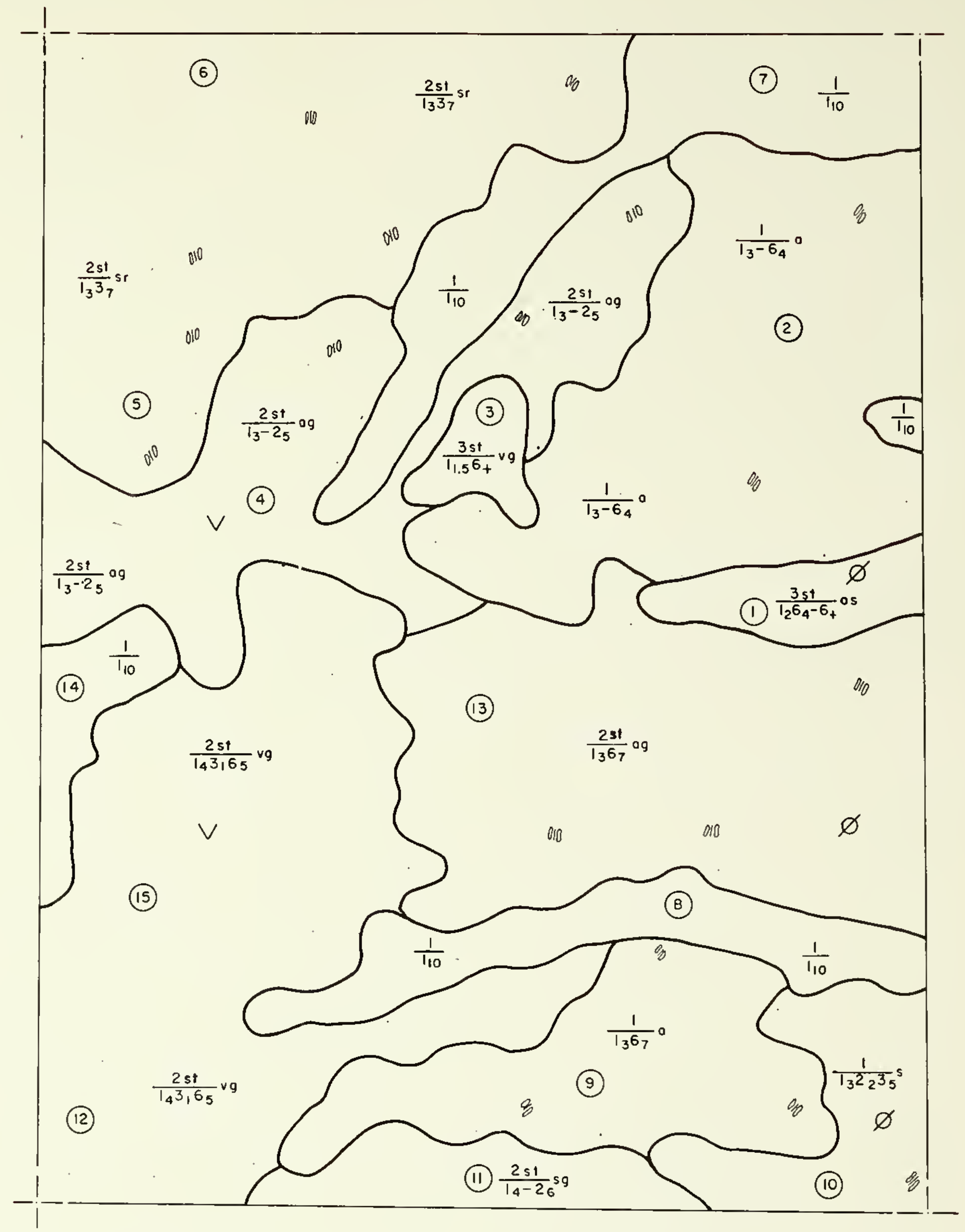
No. 12 400'N., 200'E. of SW. Cor.
0-24" best for surface use., 24-66" suitable for surface use., 66-120" use for subsurface.
10-12% complex side slope below moderately steep till crests.
0-2" FSL A1; 2-12" B2 (c1pr/c1bk); 12-24" FSL B3; Cca 24"+; (colluvial slope)
Lab texture 0-12" SL.

No. 13 2250'N., 600'W. of S¼ Cor.
0-12" best for surface use., 12-42" suitable for surface use., 42-60"+ use for subsurface.
6-8% complex side slope near crest with some steep hilly side slopes to 35% cobble and boulders on ridges.
0-1" SiL A1; 1-8" CL B21 (m1pr/m/f2bk); 8-12" CL B22 (m2pr/m2bk); 12"+ Cca.
Large gravel scattered in profile.
Lab texture 0-12" CL.

Depth	SAR
24-42"	2.2
42-60"	6.8

No. 14 400'S., 100'E. of W¼ Cor.
0-42" best for surface use., 42-120" suitable for surface use.
2-4% complex foot slopes below steep hilly till ridges with some slopes to 10%.
0-3" SiL A1; 3-12" SiCL B21 (m2pr/m2bk); 12-30" CL (m2pr/m2bk); 30-42" CL B3; 42"+ Cca. Many lime concretions 42-66"; 66-78" buried horizon; 78"+ Cca.
Lab texture 0-12" Hv L.

No. 15 1350'N., 500'E. of SW Cor.
0-30" best for surface use., 30-72" suitable for surface use., 72-120" use for subsurface.
14-16% complex side slope below till crest with up to 35% slope. Sandy material outcrops on steeper side slopes.
0-1" SiL A1; 1-3" SiL AB; 3-8" CL B21t (c2pr/c/m2bk); 8-18" CL B22 (c2pr/m2bk); 18-27" CL B3.
Lab texture-
0-18" Hv SL
30-48" Hv SL



EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3st — Plant media deficiency; Topographic deficiency
og — Informative symbols
SURFACE LAYER — Quality, Depth
SECOND LAYER — Quality, Depth
GEOLOGIC MATERIAL — Quality, Depth
Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Staniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial eratics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

(3) SOIL PROFILE NUMBER

2.8 --- 2.8 EC mmhos/cm. Sat. Ext.
8.4-8.0 — 8.4 pH 1:5 Soil - Water Suspension; 8.0 pH Soil - CaCl2 Suspension
.65 — Hydraulic Conductivity In/hr (Disturbed Samples)
24 — Settling Volume
Shale contact

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

STRUCTURE ABREVIATIONS

Size
very fine ......vf
fine ....f
medium ....m
coarse c
very coarse vc

Grade
structureless ..0
weak 1
moderate 2
strong 3

Type
platy ....pl
prismatic ......pr
columnar ....cpr
blocky ....bk
angular blocky .abk
subangular blocky .sbk
granular ....gr
crumb ....cr
single grain ...sg
massive ....m

MISCELLANEOUS ABREVIATIONS
calcic horizon ......Ca
sodium adsorpation-ratio ...SAR
settling volume .....SV
creviced rock ....CR

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scaby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS
- Gravel
- Mine

DAMS
- Medium or small

1:4800
SECTION 14, T. 145N.-R.88 W.

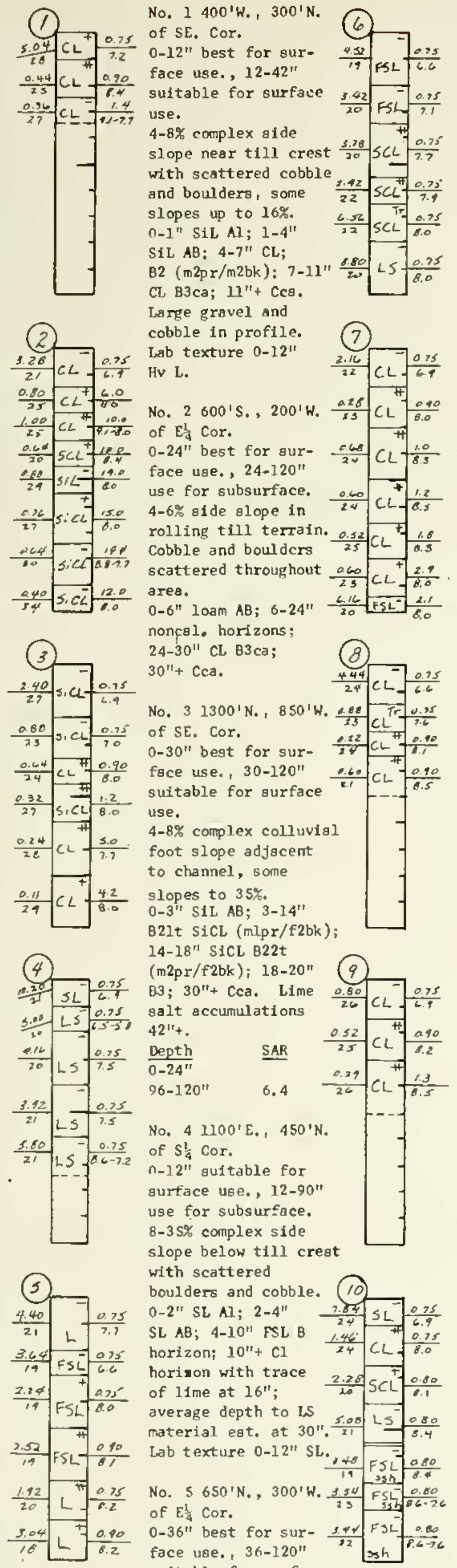
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONTANA — OCTOBER 1977 — 1305-600-187



No. 1 400'W., 300'N. of SE. Cor.
0-12" best for surface use., 12-42" suitable for surface use.
4-8% complex side slope near till crest with scattered cobble and boulders, some slopes up to 16%.
0-1" SiL Al; 1-4" SiL AB; 4-7" CL; B2 (m2pr/m2bk); 7-11" CL B3ca; 11"+ Ccs. Large gravel and cobble in profile.
Lab texture 0-12" Hv L.

No. 2 600'S., 200'W. of E¼ Cor.
0-24" best for surface use., 24-120" use for subsurface.
4-6% side slope in rolling till terrain. Cobble and boulders scattered throughout area.
0-6" loam AB; 6-24" noncal. horizons; 24-30" CL B3ca; 30"+ Cca.

No. 3 1300'N., 850'W. of SE. Cor.
0-30" best for surface use., 30-120" suitable for surface use.
4-8% complex colluvial foot slope adjacent to channel, some slopes to 35%.
0-3" SiL AB; 3-14" B21t SiCL (mlpr/f2bk); 14-18" SiCL B22t (m2pr/f2bk); 18-20" B3; 30"+ Cca. Lime salt accumulations 42"+.

Depth	SAR
0-24"	
96-120"	6.4

No. 4 1100'E., 450'N. of S¼ Cor.
0-12" suitable for surface use., 12-90" use for subsurface.
8-35% complex side slope below till crest with scattered boulders and cobble.
0-2" SL Al; 2-4" SL AB; 4-10" FSL B horizon; 10"+ Cl horizon with trace of lime at 16"; average depth to LS material est. at 30".
Lab texture 0-12" SL.

No. 5 650'N., 300'W. of E¼ Cor.
0-36" best for surface use., 36-120" suitable for surface use.
6-8% complex side slope below till moraine.
0-2" SiL; 2-10" loam B21 (m2pr/m2bk); 10-24" loam B22 (c2pr/c2bk); 24-36" B3 FSL; 36"+ Ccs. Lime nettings 60-102".
Lab texture 0-24" Hv SL.

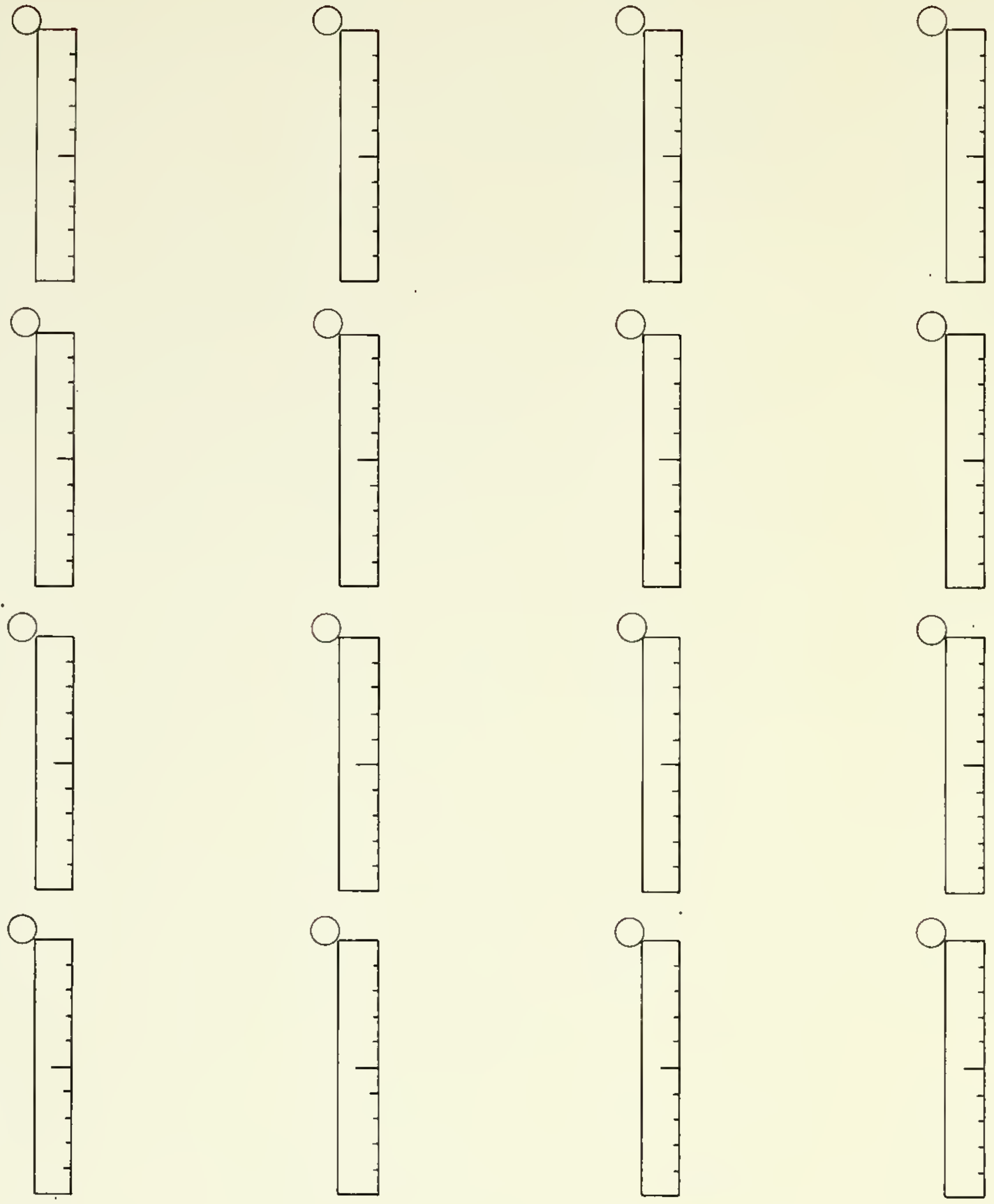
No. 6 750'S., 400'W. of NE. Cor.
0-42" best for surface use., 42-96" suitable for surface use., 96-120" use for subsurface.
8-12% complex side slope below 8-35% sloping crests.
0-2" FSL Al; 2-12" FSL B21 (c2pr/mlbk); 12-24" FSL B22 (clbt/mlbk); 24-42" FSL B3. Lime accumulations 44-66". Average depth to bedrock 36".

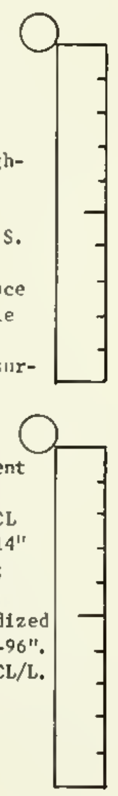
No. 7 1400'S., 400'E. of N¼ Cor.
0-12" best for surface use., 12-120" suitable for surface use.
4-8% complex side slopes with cobble and boulders scattered on the surface.
0-1" SiL Al; 1-7" CL B21 (m2pr/m2bk) 7-12" B22t (m2pr/m2bk); 12-18" B3ca; 18"+ Cca. Lime coated gravel in 7-12" zone. Till profile with firm till at 78-114".
Lab texture 0-18" CL.

No. 8 650'E., 100'S. of N¼ Cor.
0-30" best for surface use., 30-60" suitable for surface use.
4-8% complex side slope with 8-15% slopes in area.
0-1" SiL Al; 1-4" SiL AB; 4-27" CL B2t (m2pr/m2bk); 27-30" CL B3ca; 30"+ Cca. Lime accumulations at 30"+.

No. 9 2400'W., of E¼ Cor.
0-18" best for surface use., 18-60" suitably acceptable for surface use.
2-4% slopes on bench remnant.
0-1" SiL Al; 1-4" SiL BA; 4-8" B21t (m2pr/f2bk); 8-14" CL B22t (m2pr/m2bk); 14-17" CL B3ca; Cca 17"+. Large gravel and/or cobble throughout profile.

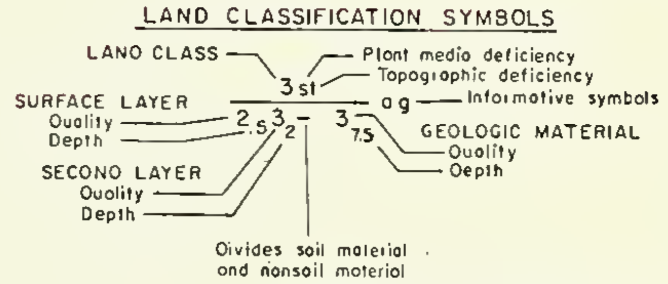
No. 10 1250'W., 400'S. of E¼ Cor.
0-18" best for surface use., 18-48" suitable for surface use., 48-120" use for subsurface.
8-10% complex side slopes with some slopes to 35% adjacent to swale.
0-2" SiL Al; 2-10" CL B2 (m2pr/m2bk); 10-14" CL B3ca (clpr/m2bk); 14"+ Cca. Mottling at 66"+ with an oxidized sandy layer from 84-96".
Lab texture 0-12" SCL/L.





EXPLANATION

LAND CLASSIFICATION SYMBOLS



INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plont medio)

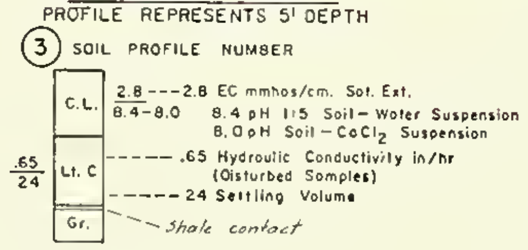
- o Sodicity
- s Solinity
- h Cloy (very fine texture)
- v Coarse (very sondy texture)
- p Restricted permeobility
- q Avoiloble moisture copocity
- d Depth of suitoble overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including grodient ond complexity)
- r Mossive lenticulor sondstone ond/or Glociol erotics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH



SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Grovel
S	Sond
LS	Loomy Sond
SL	Sondy Loom
L	Loom
SIL	Silt Loom
SCL	Sondy Cloy Loom
CL	Cloy Loom
SICL	Silty Cloy Loom
SC	Sondy Cloy
C	Cloy
SIC	Silty Cloy
Sh	Shole
Ss	Sondstone
F	Fine
Li	Light
M	Medium
H	Heavy

STRUCTURE ABREVIATIONS

Size
- very fine ......vf
- fine ....f
- medium ....m
- coarse c
- very coarse vc

Grade
- structureless ..0
- weak 1
- moderate 2
- strong 3

Type
- platy ....pl
- prismatic ......pr
- columnar ....cpr
- blocky ....bk
- angular blocky .abk
- subangular blocky .sbk
- granular ....gr
- crumb ....cr
- single grain ...sg
- massive ....m

MISCELLANEOUS ABREVIATIONS
- calcic horizon ......Ca
- sodium adsorpation-ratio ...SAR
- settling volume .....SV
- creviced rock ....CR

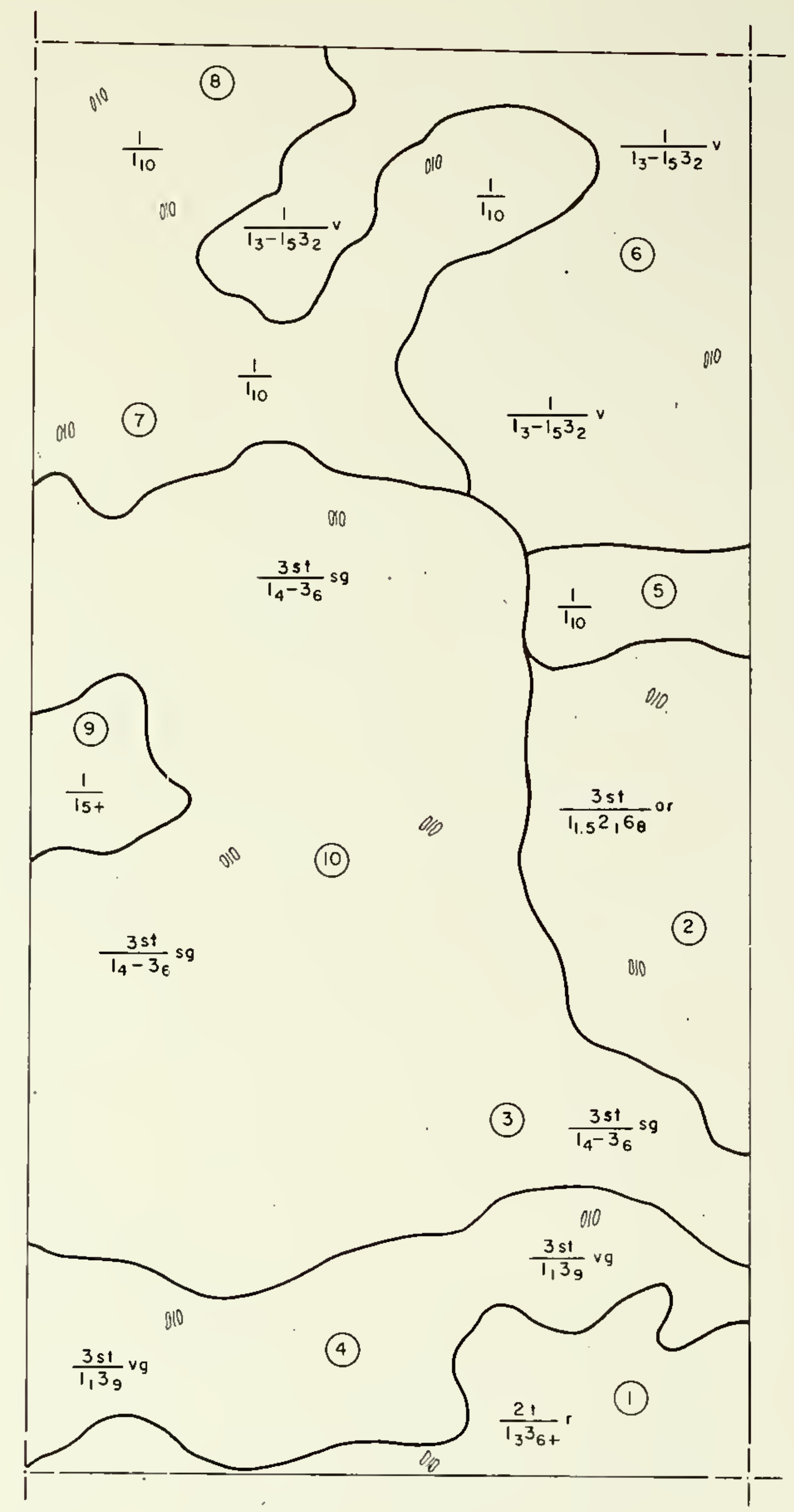
CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Cloy spot
- Grovelly spot
- Gumbo, slick or scoby spot (sodic)
- Oumps ond similor nonsoil oreos
- Rock outcrop (includes shale ond sondstone)
- Boked rock – clinker (local nome scorio)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greosewood

WATER FEATURES
- Morsh or swomp
- Spring
- Well, ortesion
- Well, irrigotion
- Wet spot

PITS
- Grovel
- Mine

OAMS
- Medium or smoll



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SECTION 22, T. 145 N. -R. 88 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD – NORTH DAKOTA

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED

BILLINGS, MONTANA OCTOBER 1977 1305-600-188

No. 1 700'E., 220'N. of SW. Cor.
0-48" best for surface use., 48-72" suitable for surface use., 72-108" use for subsurface.
4-6% complex gently sloping area with some slopes to 15%.
0-6" FSL Ap; 6-15" loam 82 (clpr/c/m2bk); 15-48" SCL B3; 48"+ Cl.

No. 2 700'N., 600' W. of S¼ Cor.
0-30" preferred surface material., 30-114"+ for subsurface use.
4-8% complex sandy crest, cobble and boulders acattered on surface.
0-2" SL Al; 2-6" SL AB; 6-15" FSL B2 (clpr/clbk); 15-30" FSL B3; 30"+ Cl., cresty aoft sandy shale at 72"+.
Lab texture 0-18" LS/SL.

No. 3 1600'N., 300'W. of S¼ Cor.
0-36" best for surface use., 36-120" suitable for surface use.
2-4% complex slopes into a colluvial swale below gently rolling sandy shale crests.
0-7" loam Ap; 7-14" SiL B21 (m2pr/m2bk); 14-24" CL B22t; 24-36" CL B3; 36-48" CL Clca; 42"+ C2. Lime accumulations from 36-48".
Lab texture 90-108" SL.

No. 4 1500'W., 650' S. of E¼ Cor.
0-24" best for surface use., 24-102" use for subsurface.
4-6% complex alopes along sandy crest with slopes to 16% in area.
0-7" SL Ap; 7-14" SL B2 (clpr/clbk); 14-24" SL B3; 24"+ Cl. Iron mottling at 84"+; traces of lime at 72".
Lab texture 0-24" SL; 42-60" LS.

No. 5 1650'W., 150' N. of E¼ Cor.
0-36" beat for surface use., 36-120" auitable for surface uae.
4-6% complex slopes into a swale; colluvial aoil.
0-1" SiL Al; 1-4" SiL AB; 4-10" SiL B21 (mlpr/m2bk); 10-24" CL B22 (clpr/mlbk); 24-36" CL B3; 36"+ Cca.
Lab texture 0-12" Lt. CL; 54-78" SCL/SL.

No. 6 2100'E. of W¼ Cor.
0-12" best for surface use., 12-102" use for subsurface.
2-4% complex foot slope with slick spots and surface cobble and boulders.
0-3" FSL A2; 3-6" CL (m2cpr/f2bk); 6-12" CL B3ca (vclpr/c/mlbk); 12"+ Cca.
Lime and salt accumulations 12"+.
Sandy shales at 54"+.
Strong shale influence at 24"+.

Depth	SAR	GYP
12-24"	15.2	-0.8
54-78"	26.7	

No. 7 1000'S., 600' E. of W¼ Cor.
0-12" best for surface use., 12-120" use for subsurface.
8-35% complex side slope adjacent to amall tributary.
0-2" FSL Al; 2-5" FSL AB; 5-9" FSL B2 (c2pr/m2bk); 9"+ FS Cl. Mottling influence at 60"+.
Narrow wet alluvial bottom within mapping unit.
Lab texture 0-12" Lt. SL; 12-36" Lt. SL.

No. 8 1100'E., 650' N. of W¼ Cor.
0-24" beat for surface uae., 24-108" suitable for aurface use.
Alluvial bottom.
0-2" SiL Al; 2-7" SiL AB; 7-12" SiL B21 (m2pr/m2bk); 12-18" SiL B22 (c2pr/m2bk); 18-30" B3ca; 30"+ Cca; stratafied SL/SCL 42-60"; water table at 84"; sands at 108"+.
Lab texture 30-42" SCL.

No. 9 1320'E., 1000' S. of NW. Cor.
0-24" best for surface material., 24-72" use for subsurface.
4-6% alope near crest of hill with scattered cobble and boulders. Slopes to 15% in thia mapping unit.
0-1" SiL Al; 1-3" SiL BA; 3-7" SiCL B21 (m2pr/m2bk); 7-11" SiCL B22 (c2pr/m2bk); 11-24" SiCL B3ca; 24"+ Cca.
Baked shales (scoria) at 36"+.
Lab texture 0-12" CL.

No. 10 700'S., 500' E. of NW. Cor.
0-12" best for surface use., 12-90" suitable for surface use., 90-108" use for subsurface.
6-8% complex side slope near till crest.
0-6" CL Ap; 6-9" CL B2 (m2pr/m2bk); 9-15" CL B3ca; 15"+ Cca; ahaley till from 42-90".
Salt accumulations at 42"+.

Depth	SAR
90-108"	7.2

No. 11 550'E. of N¼ Cor.
0-24" preferred surface material., 24-60" acceptable for subsurface uae.
2-4% complex alluvial bottom.
0-1" SiL Al; 1-3" SiL AB; 3-7" SiL B21 (mlpr/mlbk); 7-14" SiL B22 (c2pr/c2bk); 14-27" SCL B3ca; 27"+ IC; gr. sands.

No. 12 1300'S. 100'W. of N¼ Cor.
0-18" best for surface use., 18-30" use for subsurface.
4-6% complex foot slope below gently rolling crest.
0-2" SiL Al; 2-4" SiCL AB; 4-12" SiCL B2t (m2pr/f2bk); 12-16" SiCL B3 (c2pr/m2bk); 16-36" SiCL Cca. Lime and salt accumulations at 54"+.

Depth	SAR	Text.
0-18"	2.3	CL
30-48"	12.1	

No. 13 1300'S., 800' E. of N¼ Cor.
0-24" best for surface use., 24-54" suitable for surface use., 54-72" use for subsurface.
4-6% complex foot slope below gentle till crest.
0-6" CL Ap; 6-10" CL B21 (m2pr/m2bk); 10-15" CL B22 (c2pr/c/m2bk); 15-24" SiCL B3; 24"+ SiCL Cca.
Lime accumulations at 24"+.

Depth	SAR	Text.
0-24"		SCL/L
54-72"	11.0	

No. 14 1050'W., 820' S. of NE. Cor.
0-18" best for aurface use., 18-30" suitable for surface uae., 30-120" use for subsurface.
4-8% complex side slope below till creat, some slopes to 15%.
0-7" CL Ap; 7-14" CL B2 (vc2bk/c2bk); 12-14" structure approaching weak coarse prismatic clay pair to 14"; 14-18" CL B3ca; 18-30" CL Cca; 30" CL till; aalt accumulations at 14"+; very hard surface and dense subhorizons.

Depth	SAR	GYP
30-54"	9.2	-2.0
78-102"	10.6	-2.4

No. 15 450'E., 400'S. of NE. Cor.
0-12" best for surface use., 12-72" suitable for surface use., 72-120" uae for subsurface.
2-4% complex slopes with colluvial soil adjacent to swale.
0-1" SiL Al; 1-4" SiCL AB; 4-8" SiCL B2 (c2pr/m2bk); 8-14" SiCL B3ca; 14"+ Cca; reddish-brown soil 42"+; salt crystals 96"+; till influenced outwash to 42" over deep reddish-brown subhorizons; dense till influencing 96"+.
Soil not extensive enough for mapping unit.

No. 16 1950'W., 600' N. of E¼ Cor.
0-6" best for surface use., 6-120" use for subsurface.
6-8% side slope below till crest, some slopes to 16%.
0-1" SiL Al; 1-6" CL AB; 6"+ Cca; salt accumulations at 30"+; strong shale influence in till 18-54"; sandy shales at 54"+.

Depth	SAR	GYP	Text
0-6"			L
6-18"	9.5	even	
78-102"	16.6		

No. 17 1720'N. 500' W. of S¼ Cor.
0-42" best for surface use., 42-120" suitable for surface use.
Swale with 2-4% complex slopes and colluvial soil.
0-6" SiL Ap; 6-12" SiCL B21t (c2pr/m2bk); 12-24" SiCL (c2pr/m2bk); 24-42" SCL B3; 42-54" Cca.

Depth	Text.
24-42"	Lt. SCL
42-54"	Lt. SCL
54-78"	Lt. SCL
78-96"	Hv SCL
96-120"	Hv SCL

No. 18 1100'E., 200' N. of SW. Cor.
0-36" best for surface use., 36-72" suitable for surface use., 72-120" use for aubsurface.
6-8% complex side slope; profile is located in a gullied swale.
0-7" FSL Ap; 7-18" CL B21 (c2pr/c/m2bk); 18-30" CL B22 (c2pr/c/m bk); 30-36" SCL B3.

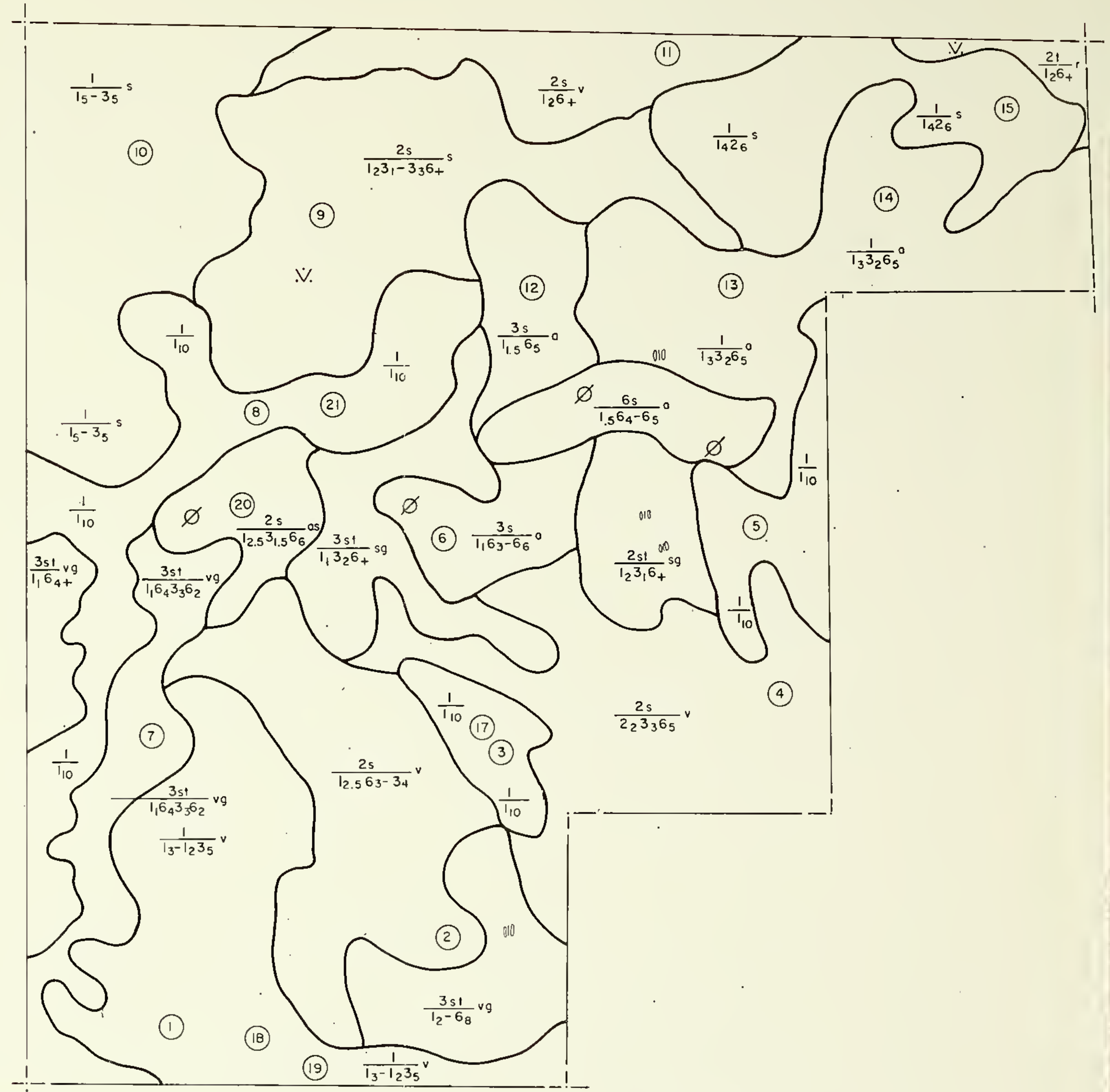
Depth	Text.
0-18"	Hv SL
18-36"	Hv SL
36-54"	Hv SL
54-72"	SL

No. 19 1300'E. of SW. Cor.
0-18" best for surface use., 18-42" auitable for surface use., 42-120" use for subsurface.
6-8% complex sloping surface. Profile near crest.
0-6" FSL Ap; 6-18" FSL Cl; sandy ahale fragmenta influencing textures 84"+.
Profile sandier with depth.
Lab texture 0-6" SCL/SL.

No. 20 1000'E., 200' N. of W¼ Cor.
0-24" best for surface use., 24-120" suitable for aurface use.
2-4% complex slope.
Residual bench remnant.
0-1" SiL A2; 1-7" CL AB (old Ap.); 7-12" CL B2t (m2cpr/f2bk); 12-30" CL B3ca; 30"+ R. Salt crystals 72"+.

Depth	SAR	Text.
0-12"		Hv CL
12-30"		Lt C
30-48"	3.9	Lt C

No. 21 1500'E., 700'N. of W¼ Cor.
0-30" beat for aurface use., 30-84" auitable for aurface uae., 84-120" use for aubsurface.
Alluvial bottom with complex 0-2% slopea.
0-2" SiL Al; 2-7" SiL AB; 7-12" SiL B2t (vclpr/c/mlbk); 12-18" loam B22 (clpr/c/mlbk); 18-30" loam B3; 30"+ Cca.
Lime ruttinga 42"+. Salt accumulations 108-120".
Lab texture 0-12" Hv SL.



EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3st — Plant media deficiency; Topographic deficiency
ag — Informative symbols
SURFACE LAYER: Quality, Depth — 2.5
3-2 SECOND LAYER: Quality, Depth
3 / 7.5 GEOLOGIC MATERIAL: Quality, Depth
Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial eratics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

(3) SOIL PROFILE NUMBER

C.L. — 2.8 --- 2.8 EC mmhos/cm. Sat. Ext.
8.4-8.0 — 8.4 pH 1:5 Soil - Water Suspension; 8.0 pH Soil - $CaCl_2$ Suspension
Lt. C — .65 --- .65 Hydraulic Conductivity in/hr (Disturbed Samples); 24 --- 24 Settling Volume
Gr. — Shale contact

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

STRUCTURE ABREVIATIONS

Size
- very fine ......vf
- fine ....f
- medium ....m
- coarse c
- very coarse vc

Grade
- structureless ..0
- weak 1
- moderate 2
- strong 3

Type
- platy ....pl
- prismatic ......pr
- columnar ....cpr
- blocky ....bk
- angular blocky .abk
- subangular blocky .sbk
- granular ....gr
- crumb ....cr
- single grain ...sg
- massive ....m

MISCELLANEOUS ABREVIATIONS
- calcic horizon ......Ca
- sodium adsorpation-ratio ...SAR
- settling volume .....SV
- creviced rock....CR

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scoby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock - clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS
- Gravel
- Mine

DAMS
- Medium or small

1:4800
SECTION 26, T. 145 N. - R. 88 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

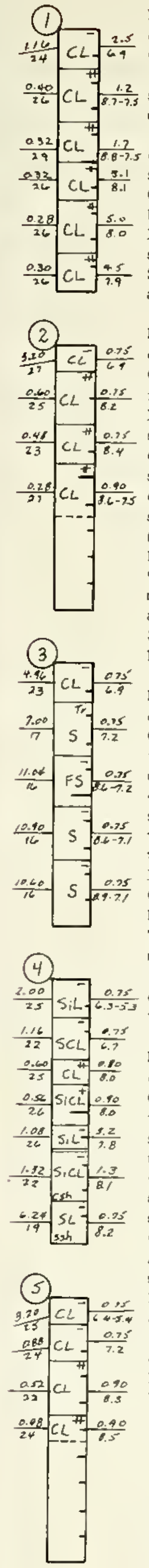
RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD — NORTH DAKOTA

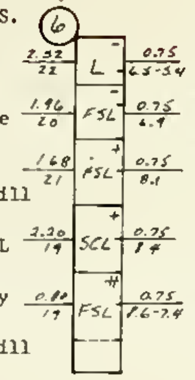
DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL ____ SUBMITTED ____
DRAWN L.E. ALLSOP ____ RECOMMENDED ____
CHECKED ____ APPROVED ____

BILLINGS, MONTANA — OCTOBER 1977 — 1305-600-189



No. 1 1150'W., 400'S. of E¼ Cor.
0-18" best for surface use., 18-120" suitable for surface use.
2-4% complex slopes on bench remnant; till soils.
0-5" CL Ap; 5-15" CL B2t (2mpr/m/f2bk); 15"+ Cca. Thin clay skins on vertices.
Salt crystals and till at 42"+.



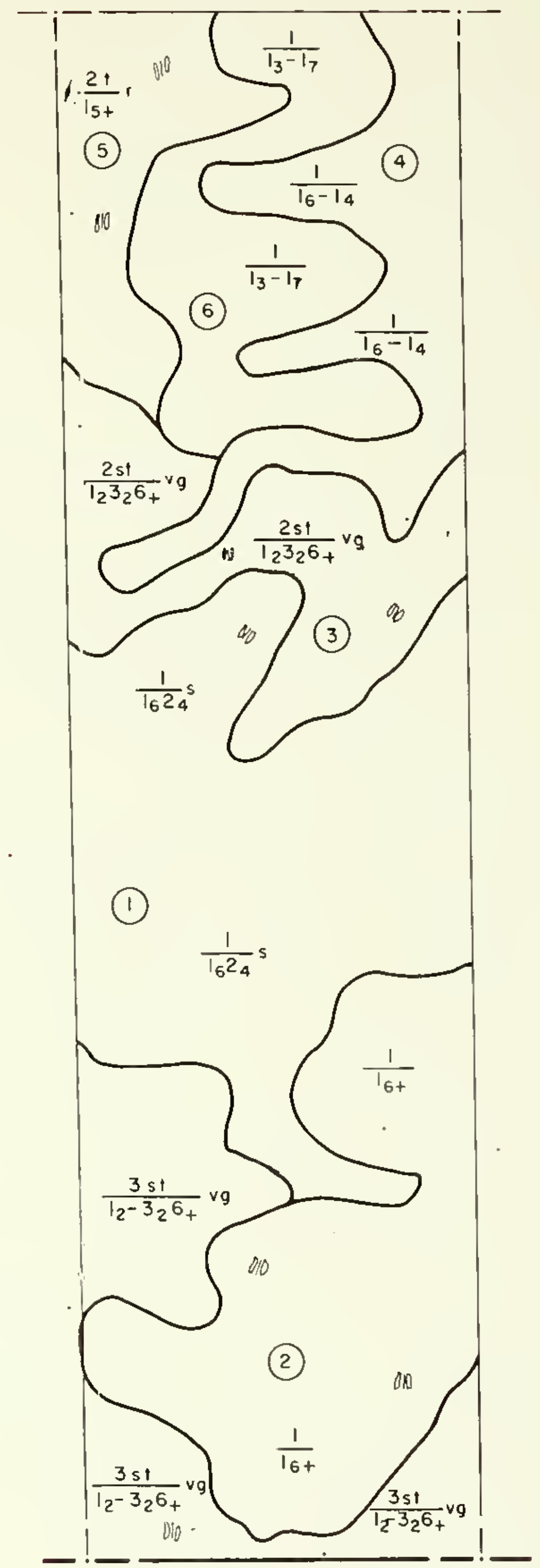
No. 6 1000'S., 900'W. of NE. Cor.
0-36" preferred surface material., 36-108" acceptable for surface use.
2-4% complex side slope slopes to 16% in area.
0-2" FSL A1; 2-5" SiL AB; 5-10" SiL B2 (m2pr/m2bk); 10-36" FSL B3; 36"+ C. Lime accumulations at 84"+.
Average depth to sandy shales from 20 to 42".

No. 2 650'N., 650'W. of SE. Cor.
0-12" best for preferred surface use., 12-78" suitable for surface use.
6-8% complex side slope below rolling crests to 16% till soils.
0-2" CL A1; 2-9" CL B21t (f2pr/f2bk); 9-13" CL B22t (m2pr/m2bk); 13"+ Cca. Lime and salt accumulations 36"+; till 12"+.
Lab texture 0-12" SCL.

No. 3 500'N., 450'W. of E¼ Cor.
0-18" best for surface use., 18-120" use for subsurface.
4-8% complex side slope below gentle till crest adjacent to draw. Slopes to 16% in area.
0-2" CL Ap; 2-7" CL B21t (m2pr/m2bk); 7-14" CL B22t (m2pr/m2bk); 14-18" B3 IIC 18"+ sands. Thin clay skins on vertices.

No. 4 500'S., 200'W. of NE. Cor.
0-30" best for surface use., 30-120" suitable for surface use.
4-6% complex foot slope adjacent to swale colluvial soil.
0-1" FSL A1; 1-3" SiL AB; 3-14" SiL B2 (m2pr/m2bk); 14-30" SCL B3 Cca 36"+; carbonaceous influence at 66"+. Salt crystals at 78"+.
Lab texture 66-78" SCL; 78-102" Hv SL.

No. 5 1200'W., 500'S. of NE. Cor.
0-30" best for surface use., 30-66" suitable for surface use.
0-2% complex slope into gentle swale near till crest.
Slopes to 16% in area.
0-1" SiL A1; 1-3" CL BA; 3-8" B21 (c2pr/m2bk); 8-16" CL B22 (m2pr/m2bk); 16-30" CL B3; 30"+ Cca.
Lab texture 0-12" L.



EXPLANATION

LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant media deficiency; Topographic deficiency
a g — Informative symbols
SURFACE LAYER: Quality, Depth — 2.5
SECOND LAYER: Quality, Depth — 3 2
GEOLOGIC MATERIAL: Quality, Depth — 3 7.5
Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

- a Sodicity
- s Salinity
- h Clay (very fine texture)
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- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Staniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial eratics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

(3) SOIL PROFILE NUMBER

C.L. — 2.8 – – –2.8 EC mmhos/cm. Sol. Ext.
8.4–8.0 — 8.4 pH 1:5 Soil – Water Suspension; 8.0 pH Soil – $CoCl_2$ Suspension
Lt. C — .65 / 24 — .65 Hydraulic Conductivity in/hr (Disturbed Samples); 24 Settling Volume
Gr. — Shale contact

SOIL PROFILE SYMBOLS

Cb	Cobble
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LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
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SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
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Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

STRUCTURE ABREVIATIONS

Size
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- fine ....f
- medium ....m
- coarse c
- very coarse vc

Grade
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- moderate 2
- strong 3

Type
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- prismatic ......pr
- columnar ....cpr
- blocky ....bk
- angular blocky .abk
- subangular blocky .sbk
- granular ....gr
- crumb ....cr
- single grain ...sg
- massive ....m

MISCELLANEOUS ABREVIATIONS

- calcic horizon ......Ca
- sodium adsorpation-ratio ...SAR
- settling volume .....SV
- creviced rock ....CR

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES
- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scoby spot (sodic)
- Dumps and similar nonsoil areas
- Rock outcrop (includes shale and sandstone)
- Baked rock – clinker (local name scoria)
- Slide or slip (tips point upslope)
- Stony spot, very stony spot
- Greasewood

WATER FEATURES
- Marsh or swamp
- Spring
- Well, artesian
- Well, irrigation
- Wet spot

PITS
- Gravel
- Mine

DAMS
- Medium or small

1:4800
SECTION 34, T. 145 N. – R. 88 W.

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

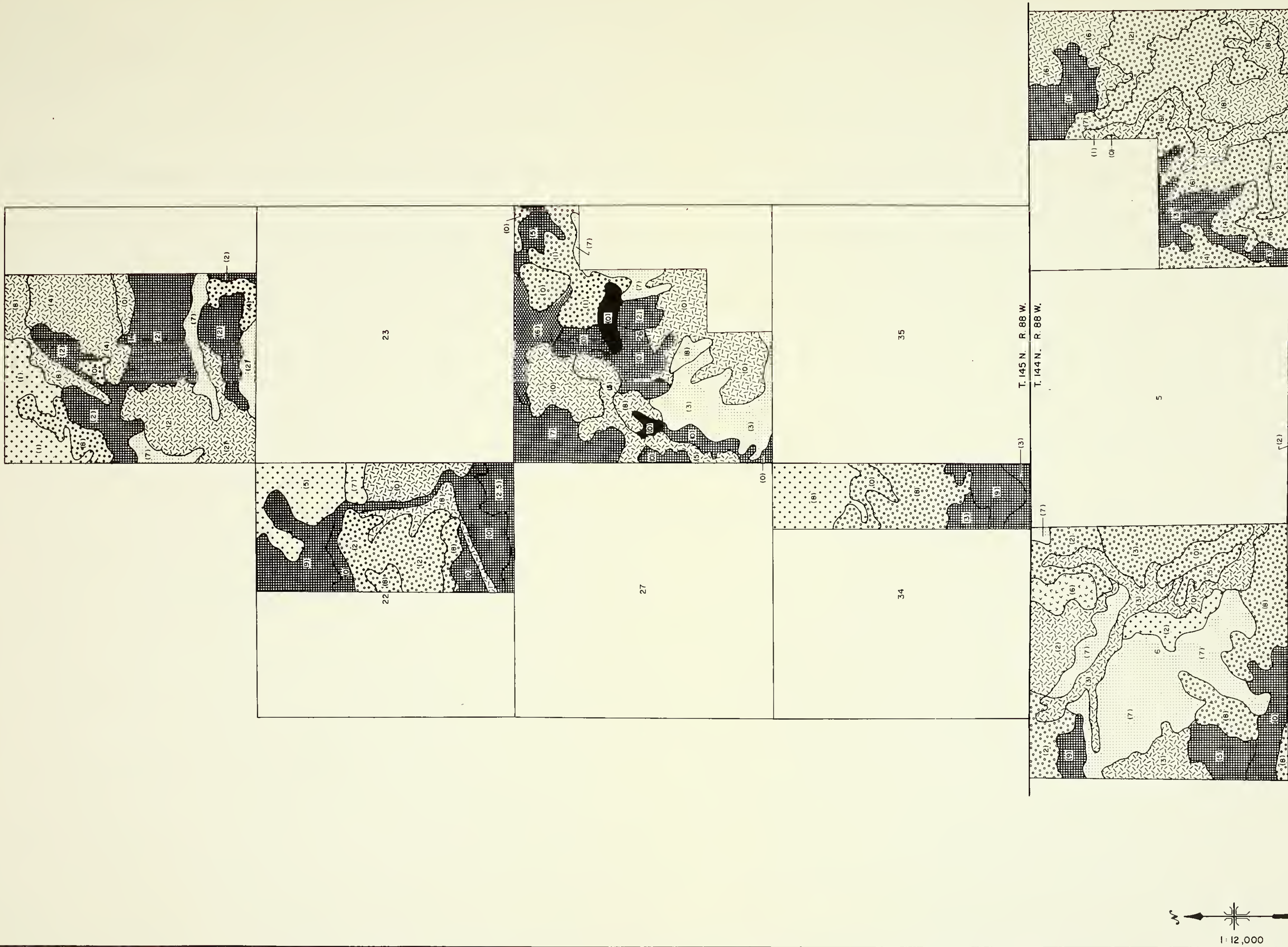
RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD – NORTH DAKOTA

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED

BILLINGS, MONTANA — OCTOBER 1977 — 1305-600-190



EXPLANATION

DEPTH OF TOPDRESSING MATERIAL AND OTHER MATERIAL FOR USE ON OR NEAR THE SURFACE

0 – 0.5
0.5 – 1.0
1.0 – 1.5
1.5 – 2.0
2.0 – 2.5
2.5 – 3.0
3.0 – 3.5
3.5 – 4.0

DEPTH OF OTHER USABLE MATERIAL (7)

NOTE

Usable material, as used in this report includes that portion of the overburden (soil mantle and bedrock) that is capable of sustained plant production. The material for use on or near surface is nonsaline and permeable. It has good tilth, retains adequate moisture and contains no known toxic elements. Additional material requiring special placement is similar. The location, quality and amount of material suitable for subsurface placement is shown on the subsurface material map.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

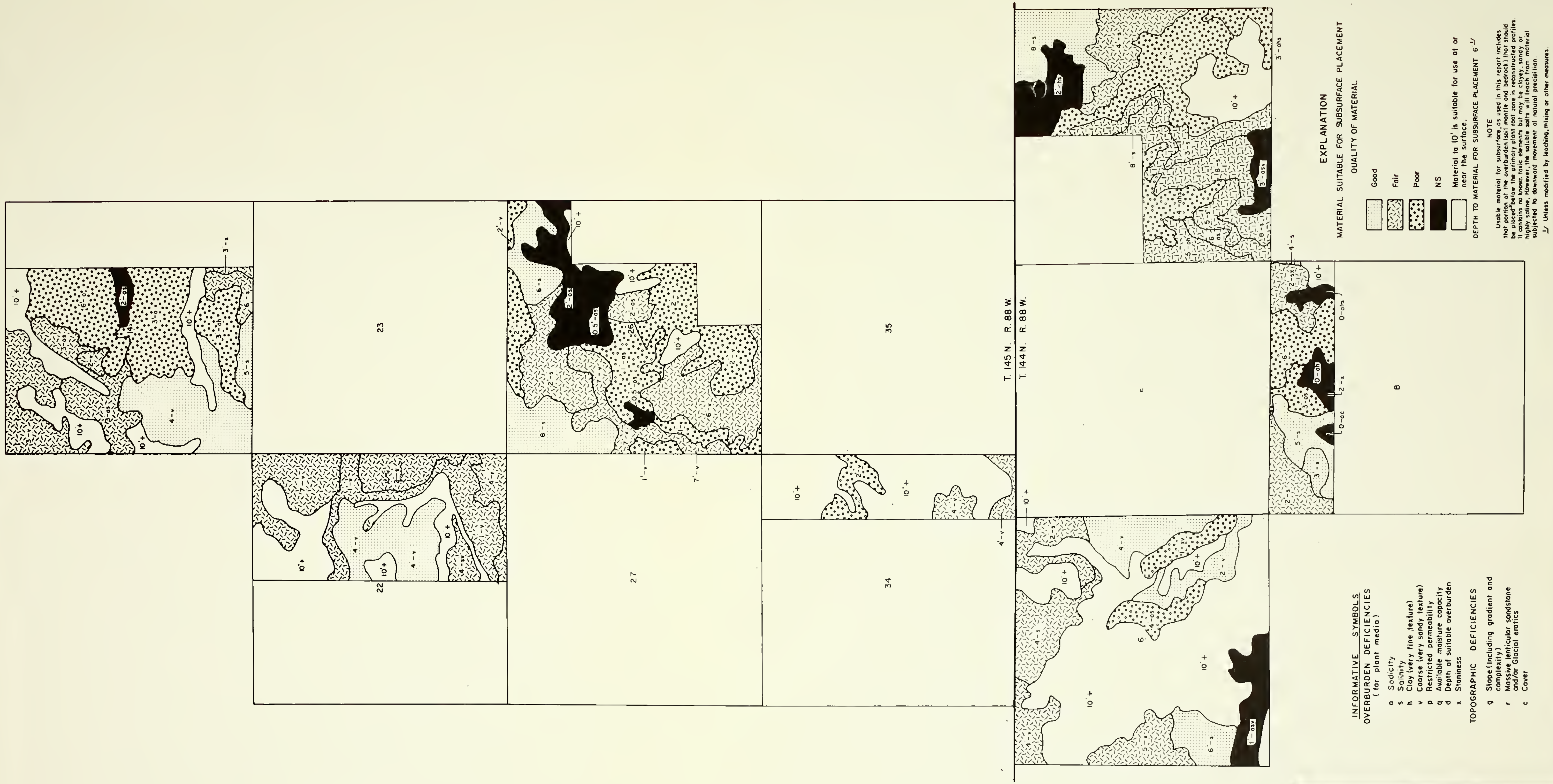
RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD – NORTH DAKOTA

DEPTH OF USABLE MATERIAL

SOILS T. FIECHTL SUBMITTED
DRAWN L.E. ALLSOP RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA NOVEMBER 1977 1305-600-191



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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD – NORTH DAKOTA

SUBSURFACE MATERIAL

SOILS T. FIECHTL SUBMITTED
DRAWN L.E. ALLSOP RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA NOVEMBER 1977 1305-600-192

Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
1	44	Land in this class has an average minimum depth of 36 inches of good quality surface material that is suitable for plant media. Usually this material is soil that has formed on deep alluvial, glacial, colluvial, and residual material. Medium texture is most common. Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil material in this class is nonsaline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous.	The surface relief comprises nearly level to gently sloping terraces, fans, footslopes, and undulating uplands. Some of this land produces alfalfa and mixed grass hay. Topographic features will not hinder stripping and stockpiling. Selective stripping can be accomplished easily. Native mid and short grasses grow in association with scattered woody species, and forbes.	These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper surface material (A & B horizons) should be stripped and stockpiled separately from the subhorizon material.
2s	9	Land in this class has an average minimum depth of 18 inches of fair and good quality overburden that is suitable for plant media. Usually this material is moderately coarse and mod. fine textured soil that has formed deep colluvial, alluvial, glacial deposits and moderately deep residual soils. Textures range from fine sandy loam to clay loam. Good quality geologic material may be considered as a part of the 18 inch requirement. Below 18 inches the overburden is usually calcareous. Soil limitations other than depth include: permeable subsoil with high salinity, and layers that are saline and sodic. Soil aggregates of these soils have fair to good stability and water enters the material at a moderste rate. The internal water movement is adequate to provide aeration of the primary root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity.	The surface relief comprises nearly level to rolling footslopes, sideslopes, swales, and undulating uplands. Topographic features will not hinder stripping and stockpiling desirable material; also, selective stripping can be accomplished easily. Native mid and short grasses grow in association with scattered woody species and forbes.	Selection of suitable material for use at or near the surface will require a review of the field data. Selective stripping and stockpiling to isolate surface and subsurface material followed by selective placement is necessary for best use of available material in this land class. With proper selection and placement reclamation should not be difficult and average management should assum successful permanent revegetation.
2st	25 1/	The general description of overburden characteristics of class 2s applies to this class. The most common soil limitations are depth of soil mantle, and permeable material that is highly saline.	The surface relief comprises gently sloping to moderately sloping hilly lands. Till moraines and complex slope pattern is common in this class which makes selective stripping more difficult. There will be some mix of surface and subsurface material. There are, however, some single plane and undulating slope patterns but they are not common.	A review of the field data to determine the effect of unavoidable mixing of surface and subsurface material is needed to determine best stripping depths. The data obtained should be a guide for placement in a reconstructed profile. The last paragraph describing management of class 2s applies to this class also.

1/ Includes land of 2t classification.

Description of Land Classes (Cont'd)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
3s	3	Land in this class has an average minimum depth of 10 inches of good quality overburden that is suitable for plant media. Usually this material is largely moderately coarse to moderately fine textured soil that has formed on alluvial and colluvial deposits. The principal adverse soil factor is the limited quantity of nonsaline and nonsodic material for use at or near the surface. The subsoil and substratum are often highly saline and contain moderate to high amounts of sodium. However, the gypsum requirement is usually a negative value and laboratory tests indicate fair to good permeability. Land in this class retains a large quantity of water for plant use. The infiltration rate is moderate. Although the internal water movement is moderately restricted the soluble salts can be leached. Isolated areas of clay rich soils and sodic soils occur and will be included in the stockpiled material for plant media, but the quantity of this material will be small.	The surface relief comprises nearly level alluvial terraces and adjacent footslopes along intermittent streams. Topographic features will not hinder stripping and stockpiling desirable material and selective stripping can be accomplished easily. Native mid and short grasses grow in association with scattered woody plants, and various forbes. Areas are used for grazing and crop production.	These soils will be slightly susceptible to erosion. This hazard can be minimized by roughing the surface of the reconstructed profile. Mechanical roughing will retard erosion and promote leaching of soluble salts below the primary root zone. Mulches can also be used to reduce erosion. These measures increase the effective leaching of soluble salts and increase productive capability. Successful permanent revegetation can be accomplished, but good planning and management will be required. For best use of the soil in this class, the surface material must be stripped and stockpiled separately from the subhorizon material.
3st	18	Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material consists of medium and moderately fine residual soil and/or weathered shaley parent material. The major soil limitation is quantity of nonsaline and nonsodic material. Shale exposures occur along steeper slopes. Immediately below the shallow soil mantle, the shaley parent material is often highly saline and occasionally sodic. Locally the geologic material is permeable and the soluble salts can be leached. Clay rich and sodium affected layers occur as small inclusions and will most likely be included in stockpiled material.	The surface relief of land in this class is characterized by complex gently rolling and hilly slopes, rocky till moraines, and residual side slopes. Erosion is active on the steeper slopes and many small areas of shale, sandstone, and baked rock outcrops are visible. Steep slopes, sandstone and shale outcrops, dendritic drainage patterns will make uniform stripping impossible. Native mid and short grasses grow in association with scattered woody plants, and forbes. This land is used for range.	Selective stripping with emphasis on stripping small tracts of deep soil separately should be considered. In addition to a review of the data, a field check to locate these tracts is advisable. Similar surface treatment of reconstructed profiles as described in 3s should be followed.

Description of Land Classes (Cont'd)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
6s	1.7 2/	Land in this class has less than 10 inches average depth of fair and good quality overburden that is suitable for plant media. These soils have formed on deep alluvium and are highly saline and/or sodium affected. Restrictive permeability and clay rich horizons or layers occur locally. One or a combination of the above factors make these soils unsuitable for plant media. Some of the highly saline material may have sufficient permeability to be modified by leaching excess soluble salts. Also some small tracts with good quality surface soil occur in this class as inclusions.	The surface relief in this class comprises nearly level to very gently sloping recent alluvial valleys and adjacent terraces. Topographic features will not hinder selective stripping and stockpiling. Native mid and short grasses occupy the better soils and grow as a minority with forbes, sedges, various woody species.	A careful review of the data and field checking to locate small inclusions of better soil is warranted. This action combined with selective stripping can do much to reduce the amount of overburden that must be borrowed or modified. Temporary irrigation if available, mechanical roughing, may adequately modify some material. However, borrowing from nearby deep and good quality soil areas will probably be the most economical method of permanent revegetation.
6st		Land in this class has been less than 10 inches average depth of fair and good quality overburden that is suitable for plant media. These shallow residual soils have formed on weathered shaley material. Sandstone and shale outcrops are common. The underlying residual formation is quite variable in physical and chemical properties, but highly saline, highly sodium affected, slowly permeable, and clay rich layers are the most common limitations. These limitations occur singly or in combination in most delineated areas in this class. However, small inclusions of deeper surface soils and of permeable nonsaline, nonsodic geologic material are also present in most delineated areas.	The surface relief in this class comprises areas of complex hilly till areas. Active erosion may expose sandstone or shale. The dendritic drainage pattern creates complex slopes that preclude uniform selective stripping. Locally the topography is favorable for selective stripping some of the deeper soils. Native mid and tall grasses grow in association with various woody species, forbes. This land is used for range.	Tracts with deeper soils and good quality geologic strata, though small, should be selectively stripped. Roughing the surface by mechanical means increases infiltration and leaching. Borrow material will be required for successful permanent revegetation. The postmining soil profile and vegetative cover will be an improvement over present conditions.

2/ Includes land of 6s and 6st.

The results in the preceding table indicate that 98.3 percent of the land in the Beulah Trench Study Area contains an adequate supply of suitable overburden (soil and/or bedrock) for revegetation if surface mining occurs. Suitable plant material will usually exceed the revegetation requirements in Classes 1 and 2, will be adequate in Class 3, and will be deficient in Class 6. About 10 percent of the land will require additional material for plant media. Two percent of the land is Class 6 and rights-of-way; the remaining 8 percent occurs as small interspersed inclusions in Classes 1, 2, and 3.

The land suitability survey provides adequate data for developing the reclamation portion of the mining plan; however, it does not provide adequate detail for stripping and stockpiling operations during the surface mining operation. Additional field borings and observations supported by laboratory data may be required to more accurately determine the quantity, quality, and location of suitable material to be stripped and stockpiled.

Overburden Suitability

Soil Mantle Suitability

In general, the deep residual, glacial, and alluvial/colluvial soils in this study area should provide an adequate supply of suitable topsoiling material for revegetation if surface mining occurs.

The A and B horizons of most soils in the study area appear well suited for topdressing shaped mine spoils. These horizons are nonsaline and nonsodic. Mixing of these horizons during the stripping process should not appreciably change the quality of the material.

Soluble salts have been leached to a depth below 30 inches in deep, loamy soils with good permeability. For most soils in this study area, the leached zone includes the A, B, and part of the C horizons. Soluble salts often remain near the surface in shallow A-C soils, saline-sodic soils, and seep areas. Soil materials with high levels of salt and/or exchangeable sodium should be placed well below the plant rooting zone in reconstructed profiles.

The quantity of soil material suitable for surface placement in reconstructed profiles is indicated on Plate 30. Plate 31 describes the quality and depth to material which is suitable for subsurface placement.

Local tracts of clay-rich, saline, or saline-sodic soil will require borrowed material from nearby areas with abundant, good quality soil material or from suitable bedrock, if readily available in the area.

Bedrock Suitability

A systematic evaluation was made of the bedrock core samples described in Plates 10 through 21, Appendix C. The applicable portions of the land classification standards (Table 28) provided criteria for the evaluation of these materials.

Although similar criteria were used for both the land classification survey and the bedrock core evaluation, different suitability classes were assigned to the core materials. These classes relate primarily to the quality of the bedrock materials for use as plant media in revegetation. The classes are "suitable," "limited suitability," and "unsuitable." The suitable class corresponds to Class 1 and the best Class 2 materials in the land classification survey; the limited suitability class includes the less desirable Class 2 materials and Class 3; and the unsuitable class is equivalent to Class 6.

Core samples were collected and analyzed in the laboratory utilizing the same procedures used to analyze the soil samples. Results of the laboratory analyses performed on "Representative Site" core samples are listed in Tables 30 through 39, Appendix E. These data include determinations of selected trace metal concentrations, which may be particularly useful in identifying bedrock materials which are potentially toxic or deficient in various elements. Results of routine analyses performed on the remaining core samples are included in Tables 40 through 45, Appendix E.

The results of the laboratory analyses provided the basic data used in classifying the bedrock materials as to their suitability for use as plant media. The suitability of the bedrock materials is indicated on each geologic log (Plates 10 through 21, Appendix C) under the column titled: "Suitability For Reconstructed Profile." Overall, 24 percent of the bedrock materials overlying the Beulah-Zap coalbed in this study area were determined to be suitable for use as plant media, 29 percent were of limited suitability, and 47 percent were unsuitable.

Notable deficiencies of the "unsuitable" bedrock materials often included one or more of the following: salinity, sodicity, fine texture (clay-rich), slow permeability, and instability.

The type and quality of bedrock materials in the Beulah Trench Study Area are highly diverse. Consequently, the physical and chemical properties important to their use as plant media cannot be projected over a wide range of conditions. Therefore, the quality determination of the bedrock materials for use as plant media applies only to the specific site where each core was drilled. No attempt was made to project the data to adjacent areas. Also, the ease of separating and stockpiling bedrock materials for resurfacing was not considered in the suitability evaluation.

Soil Inventory

This section provides additional information on the soils occurring in the Beulah Trench Study Area. Most of the information is derived from soil survey data compiled by the Soil Conservation Service[2/].

Data presented in this section include the following:

2/ Soil Survey of Mercer County, North Dakota, USDA - Soil Conservation Service, 1978.

1. A Soil Inventory Map of the Beulah Trench Study Area showing the soil series/associations mapped by the Soil Conservation Service - Plate 32, Appendix E.

2. Soil Series Descriptions (National Cooperative Soil Survey) - Tables 46 through 61, Appendix E.

3. Interpretive ratings for selected soil uses - Table 62, Appendix E.

4. Engineering properties of the soils - Table 63, Appendix E.

5. Soil Profile Descriptions (BLM Form 7310-9) and Erosion Evaluations (BLM Form 7310-12) - Exhibit 2, Appendix E.

In general, Mollisols and Entisols are the predominant soil orders (taxonomic units) occurring in this study area (Table 64). The Mollisols have the widest areal distribution, representing about 90 percent of the study area. The Entisols comprise the remaining 10 percent (Table 65).

Moisture Relations in Soils

Moisture relations in soils of the Beulah Trench Study Area reflect the influence of a climate that can fluctuate annually from semiarid to subhumid. As much as 11 (280 mm) of the 16 inches (410 mm) of precipitation normally falling in this region is rain, so approximately 5 inches (130 mm) is snowmelt. High winds commonly redistribute the fallen snow. Areas in which windblown snow accumulates thus receive additional moisture, while areas where snow is blown off are deprived of potential moisture storage. Snowmelt storage in soils is supplemented by spring rains and peak storage usually occurs in mid to late spring. Maximum runoff probably occurs when intense storms occur during periods of high soil-moisture storage.

Void space and quantities of particle surface available to store water are the two factors that control moisture relations in soils. These two factors are, therefore, the basis for the concepts, analyses, and interpretations presented in this section. A complete discussion of the concepts used has been presented by Miller and McQueen (1978, in press).

All the measurements required to define moisture relations were obtained as products of the method of McQueen and Miller (1968) for measuring the force with which moisture is retained. The data resulting from these measurements appears in Table 66, Appendix E. The retention force is determined from the moisture content of standard filter papers at equilibrium with moisture in samples augered from consecutive depth increments in soil profiles. All the soil obtained from each auger increment is retained so its volume weight (VW) (bulk density) can be determined. Void-moisture capacities, which represent amounts of void space available for infiltration, and storage of water are computed from VW values for each depth increment. In the computation of void-moisture capacity (VMC) values, which are in percent of dry weight, it is assumed that soil particles have a density of 2.65 g/cm^3 and that the density of water is 1 g/cm^3. The equation used is

$$VMC = 100 \left(\frac{1}{VW} - \frac{1}{2.65}\right)$$

and this relationship is presented graphically in Figure 3. The influence of differences in amounts of adsorptive surface in soils on quantities of water that can be retained, over the moisture range from saturation to ovendry, were determined using the modeling technique proposed by McQueen and Miller (1974). The soil, for which a graphic model is presented in Figure 4, has one-half the adsorptive surface per unit of weight as compared to the filter paper standard. As a result, quantities of water adsorbed as multimolecular films to external particle surfaces of this soil are consistently one-half the quantities adsorbed to surfaces of fibers in the paper.

A similar graphic model of the moisture content-retention force relation can be created for any sample of soil if moisture content and retention-force data are acquired under conditions where only adsorbed water is present. The line representing quantities of water adsorbed is extended down from $10^{6.25}$ g/cm^2 on the vertical axis through a point representing the moisture content of the soil and the retention force determined from the filter paper at equilibrium with the soil. Soils that contain expanding lattice clays, unlike the filter paper, can adsorb water within their structure. There is evidence (Miller and McQueen, 1972) that this water, which is labeled structural water in Figure 4, is removed when the retention forces are between $10^{5.00}$ and $10^{7.00}$ g/cm^2.

Water adsorbed as multimolecular films tend to drain down from the adsorption-moisture capacity (AMC) level where 17 molecular layers are adsorbed and the retention force is 10^0 or 1 g/cm^2. Drainage continues to the moisture-retention capability (MRC) level where 10 molecular layers remain adsorbed and the retention force is 222 or $10^{2.346}$ g/cm^2. The retention force increases from 1 to 2.46 and gradually to 6.05, 36.6, and finally to 222 g/cm^2 as drainage flows proportionately. The final large increase results in drainage becoming insignificant at the MRC level where the retention force is $10^{2.346}$ or 222 g/cm^2. During this process, the retention force increases 2.46 times as each molecular layer of water is desorbed. The logarithm of 2.46 is 0.391; therefore, the exponent of the retention force increases by 0.391 as each molecular layer is desorbed.

Molecular dimensions of void spaces in a given depth increment of soil can be used to approximate infiltration rates. The average size of void available for infiltration and storage of water can be approximated in terms of molecular dimensions of water. This is done by dividing VMC values by MRC values and multiplying by 10 because 10 molecular layers are adsorbed at the MRC levels. Infiltration data at sites where a large rainfall-simulating infiltrometer (Lusby and Toy, 1976) was used were made available by Lusby (unpublished data, 1976) for comparison with void-dimension data. The data plot has a linear relationship (Figure 5) that permits estimation of rates of infiltration within confidence limits of plus or minus 9 mm/hr. Since void size and adsorptive surface are controlling factors, the relationship is applicable anywhere.

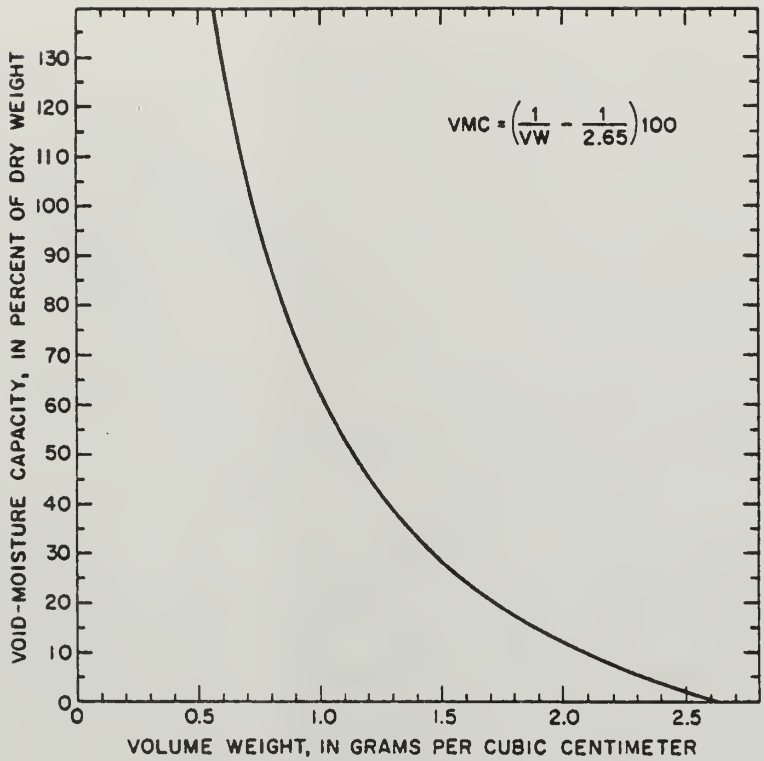


Figure 3 .--Relationship used to determine void-moisture capacity (VMC) of soils from volume weight (VW).

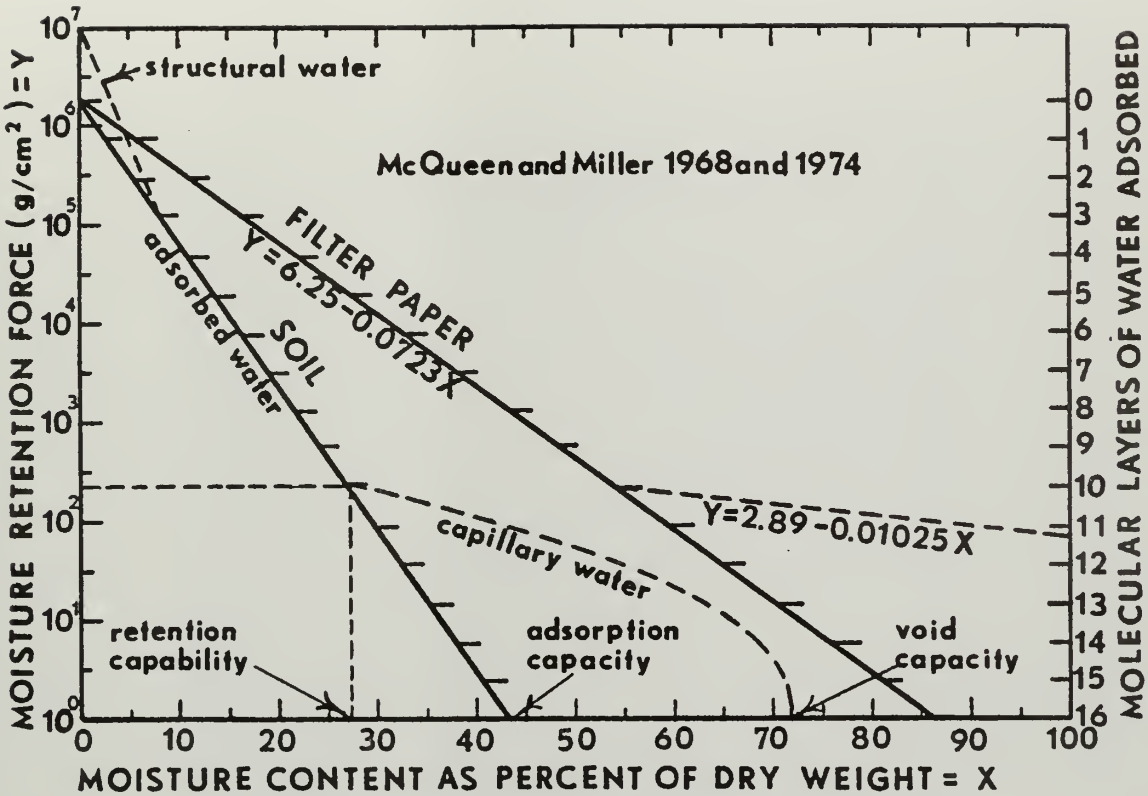


Figure 4 .--Filter-paper calibration graph (McQueen and Miller, 1968) for determining moisture-retention force from moisture content of standard filter papers at equilibrium with moisture in samples of soil. Also, a graph illustrating the moisture-retention relation in a soil with one-half as much adsorptive surface per unit weight as the filter paper.

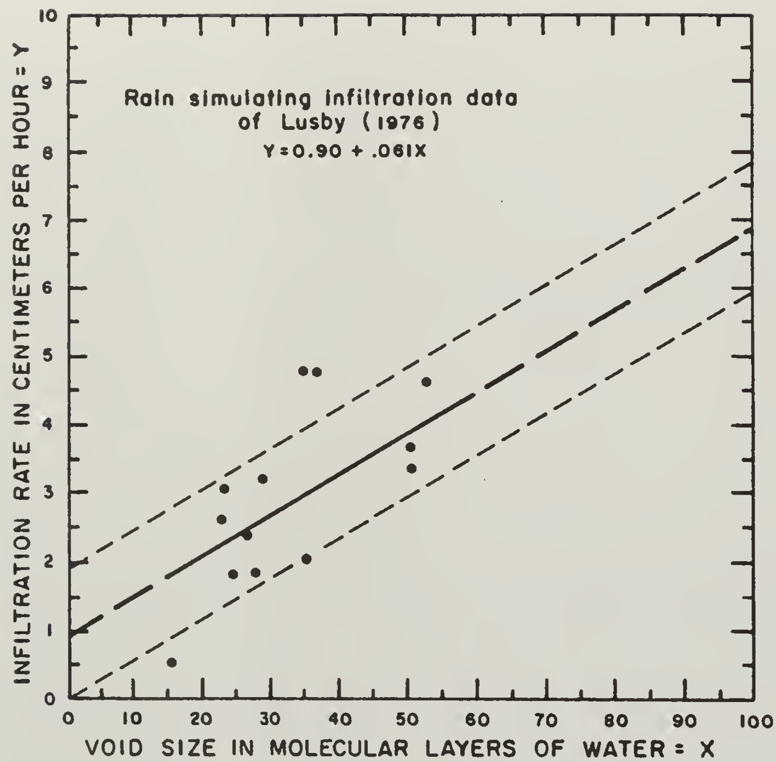


Figure 5.--Relation between size of voids and rate at which water infiltrates into soils. Dashed lines are placed at + and — one standard error of estimate.

Table 64

Soil Taxonomic Units - Beulah Trench Study Area

Map Symbol	Series	Family	Subgroup	Order
008	Ringling	Fragmental, mixed	Typic Haploborolls	Mollisols
011	Cabba Complex	Loamy, mixed (calcareous), frigid, shallow	Typic Ustorthents	Entisols
050	Amor	Fine-loamy, mixed	Typic Haploborolls	Mollisols
051	Arnegard	Fine-loamy, mixed	Pachic Haploborolls	Mollisols
055	Cohagen	Loamy, mixed (calcareous), frigid, shallow	Typic Ustorthents	Entisols
059	Harriet Clay	Fine, mixed, frigid	Typic Natraquolls	Mollisols
064	Rhoades	Fine, montmorillonitic	Leptic Natriborolls	Mollisols
066	Searing	Fine-loamy, mixed	Typic Haploborolls	Mollisols
067	Sen	Fine-silty, mixed	Typic Haploborolls	Mollisols
069	Straw	Fine-loamy, mixed	Cumulic Haploborolls	Mollisols
073	Vebar	Coarse-laomy, mixed	Typic Haploborolls	Mollisols
074	Temvik	Fine-silty, mixed	Typic Haploborolls	Mollisols
075	Williams Clay	Fine-loamy, mixed	Typic Argiborolls	Mollisols
077	Zahl	Fine-loamy, mixed	Entic Haploborolls	Mollisols
078	Werner	Loamy, mixed, shallow	Entic Haploborolls	Mollisols
080	Regent	Fine, montmorillonitic	Typic Argiborolls	Mollisols

Table 65

Acreage of Soil Series/Associations - Beulah Trench Study Area

Series			Associations												
Name	Map No.	Acres	008-011	050-078	055-073	066-008	065-064	073-055	074-075	075-077	075-078	077-075	080-064	Total Acres	Percent
Ringling	008		183.9											183.9	6.7
Cabba	011	272.6												272.6	10.0
Amor	050			348.9										348.9	10.8
Arnegard	051	120.0												120.0	4.4
Cohagen	055				486.1									486.1	17.9
Harriet	059	6.2												6.2	.2
Rhoades	064	9.4												9.4	.4
Searing	066	20.9				54.0								74.9	2.8
Sen	067						22.9							22.9	.8
Straw	069	169.7												169.7	6.2
Vebar	073	135.5						124.5						260.0	9.6
Temvik	074								14.3					14.3	.5
Williams	075	410.8								61.8	11.4			484.0	17.9
Zahl	077											210.4		210.4	7.7
Werner	078													0.0	0.0
Regent	080	4.0											52.7	56.7	2.1
Total Acres		1149.1	183.9	348.9	486.1	54.0	22.9	124.5	14.3	61.8	11.4	210.4	52.7	2720.0	100.0
Percent of Area		42.2	6.7	12.8	17.9	2.0	.8	4.6	.6	2.3	.5	7.7	1.9		

Soils of the Beulah Trench Study Area

Soils of the Beulah Trench Study Area have developed in materials derived from one or more of the following parent materials: (1) Holocene alluvium of the Walsh Formation, (2) Quaternary ground moraine of the Coleharbor Formation, or (3) Tertiary sedimentary beds of the Sentinel Butte Formation. A dark, humic surface horizon has developed to various depths as the result of grasses growing on calcareous soils. In all the habitats sampled, void capacities in excess of adsorbed-moisture capacities are present to the base of the humic surface horizon.

Study Sites

Soils were sampled in September 1976 during a period of minimum soil-moisture storage. Although fall rains had wetted the surface soils, the lower moisture contents at greater depth were the result of depletion during the preceding growing season.

Soil sites were selected to represent all the significant vegetation habitats in the study area. The locations of the 18 study sites are shown in Figure 6. The sites are discussed in groups which are based on common characteristics.

Quantities of water that can be present in soils between the limits provided by void-moisture capacity (VMC) and minimum levels of storage (MS) are divided into adsorbed and drainable portions as shown in Figures 7 through 12. Adsorbed moisture is computed as the difference between moisture-retention capability (MRC) and MS values. Drainable moisture is computed as the difference between VMC and MRC values. Both are computed to the maximum depth where drainable moisture may occur. Moisture contents initially computed as percent of the dry weight of soil are converted to numbers indicating depths of adsorbed or drainable water. This is done by multiplying percent moisture by the average VW of the depth increment involved. The product of this multiplication is then multiplied by the depth of the soil increment. The result is the amount of water expressed as a depth of water in millimeters. These are the values shown within the graphs of Figures 7 through 12.

Upland Soils with High Moisture-Retention Capabilities

Upland soils developed in materials derived from glacial till have the highest MRC values of the soils sampled. Three such soils are characterized in Figure 7. Sites 14 and 15 were sampled in an area mapped as Zahl loam by the Soil Conservation Service (SCS). The location of site 11 was mapped as Williams loam. Each of these three soils showed limited capacity for moisture storage in excess of MRC because VMC was equal to or less than MRC at the base of the profile. Void space in the lower portions of soil profiles 15 to 11 was still filled with moisture at the end of the growing period. This deeply stored water provides a reserve moisture supply for the perennial grass cover during droughts. These reserves may be temporarily eliminated when the soil is stripped for mining, but these reserves will be replenished in wet years.

Kinds and quantities of vegetation growing on a soil are influenced by the retention force which must be overcome to desorb moisture from the soil (Table 67). Since surface soils had been recently wetted, the average retention force was computed using only the data from the drier underlying soils.

Infiltration into these soils decreases as the soil is wetted to greater depths. Surface horizon voids can accommodate 34 to 38 molecular layers of water, and all but 10 molecular layers can drain to greater depths. Based on the relation shown in Figure 5, infiltration rates will decrease from about 3 cm/hr to about 1.5 cm/hr as the drainable portion of the voids is filled. Rainfall rates exceeding the infiltration rate could result in air entrapment, preventing any further infiltration and causing total runoff. The different moisture storage potentials, as indicated by the values in Figure 7 (101 mm vs. 138 and 169) probably resulted from more snow accumulation on the sloping sites (11 and 15) than the flatter hilltop site (14). The slow rate of snowmelt apparently facilitates deep percolation into the soils.

Soils with Impeded Drainage

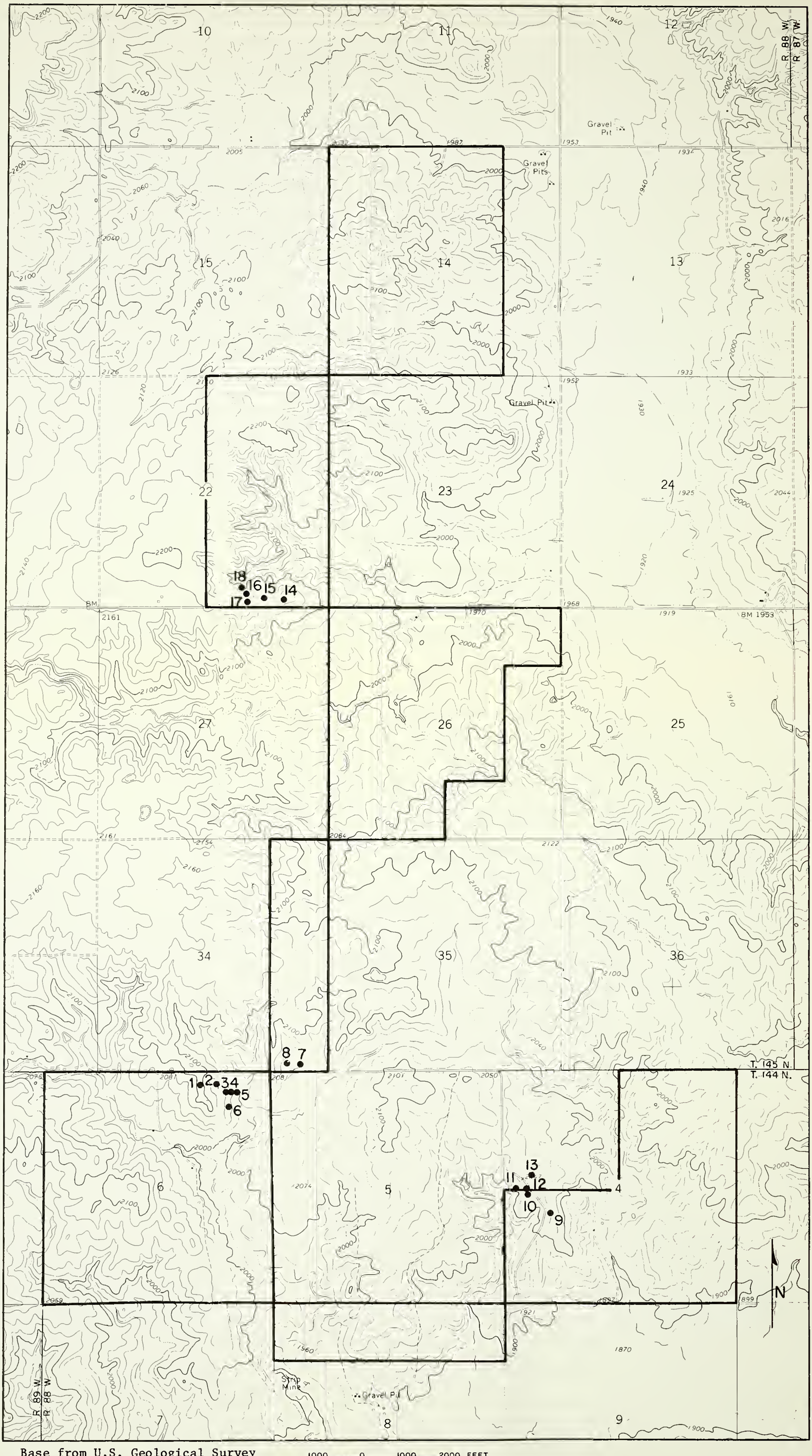
The three soils characterized in Figure 8 all have surface horizons with intermediate MRC's and subsoils with high MRC's. This results in impeded drainage at the point where MRC exceeds VMC because all the void space can become filled with moisture that is not free to drain. Water held with minimal force can then be perched above this restriction. The retention force holding the perched water depends on how much void space is available to hold the moisture. The smaller the VMC directly above the restriction, the greater the force with which the moisture is held and the smaller the reservoir of soil moisture available for use by vegetation.

Site 6 has the lowest capacity for storing adsorbed moisture (98 mm) as shown in Figure 8. This indicates that perching of moisture above the drainage restriction at 0.7 m would occur more often at site 6 than at the other two sites. Perched water would be held at retention forces less than $10^{2.34}$ g/cm^2 and thus would be more readily available to the vegetation. Such a condition favors the occurrence of tallgrasses which are prevalent on site 6 but absent on the other two sites (see Table 68).

The average retention force in the soil during a dry period at the end of the growing season is a function of the predominant vegetation on the site. The short and midgrasses can exert the greatest force to desorb moisture, while the tallgrasses are capable of exerting lesser forces (Table 68).

Loamy Soils with Intermediate MRC's

Three loamy soils with intermediate MRC's are characterized in Figure 9. The SCS mapped sites 7 and 8 as Arnegard loam, which occupies alluvial lowlands; site 10 was mapped as Williams loam, which is a residual soil on uplands. While the Arnegard loam had sufficient void space to permit



Base from U.S. Geological Survey
Beulah, Beulah NE, Beulah NW and Zap
7½-minute quadrangles

Figure 6.--Locations of sampling sites for defining moisture relations in soils of the Beulah Trench EMRIA study area, North Dakota--1976.

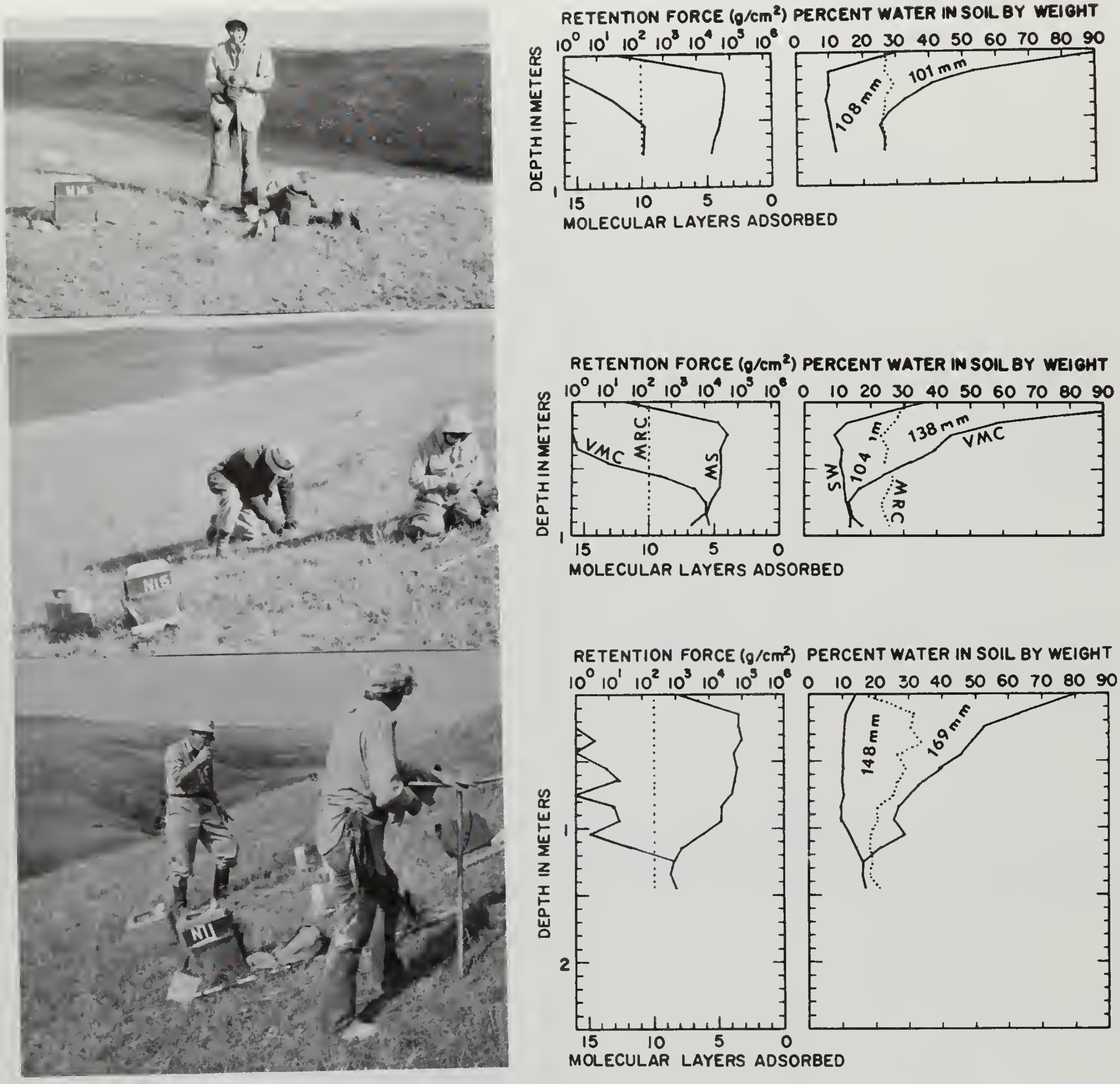


Figure 7 --Moisture relations in upland soils with high moisture-retention capabilities (MRC's).

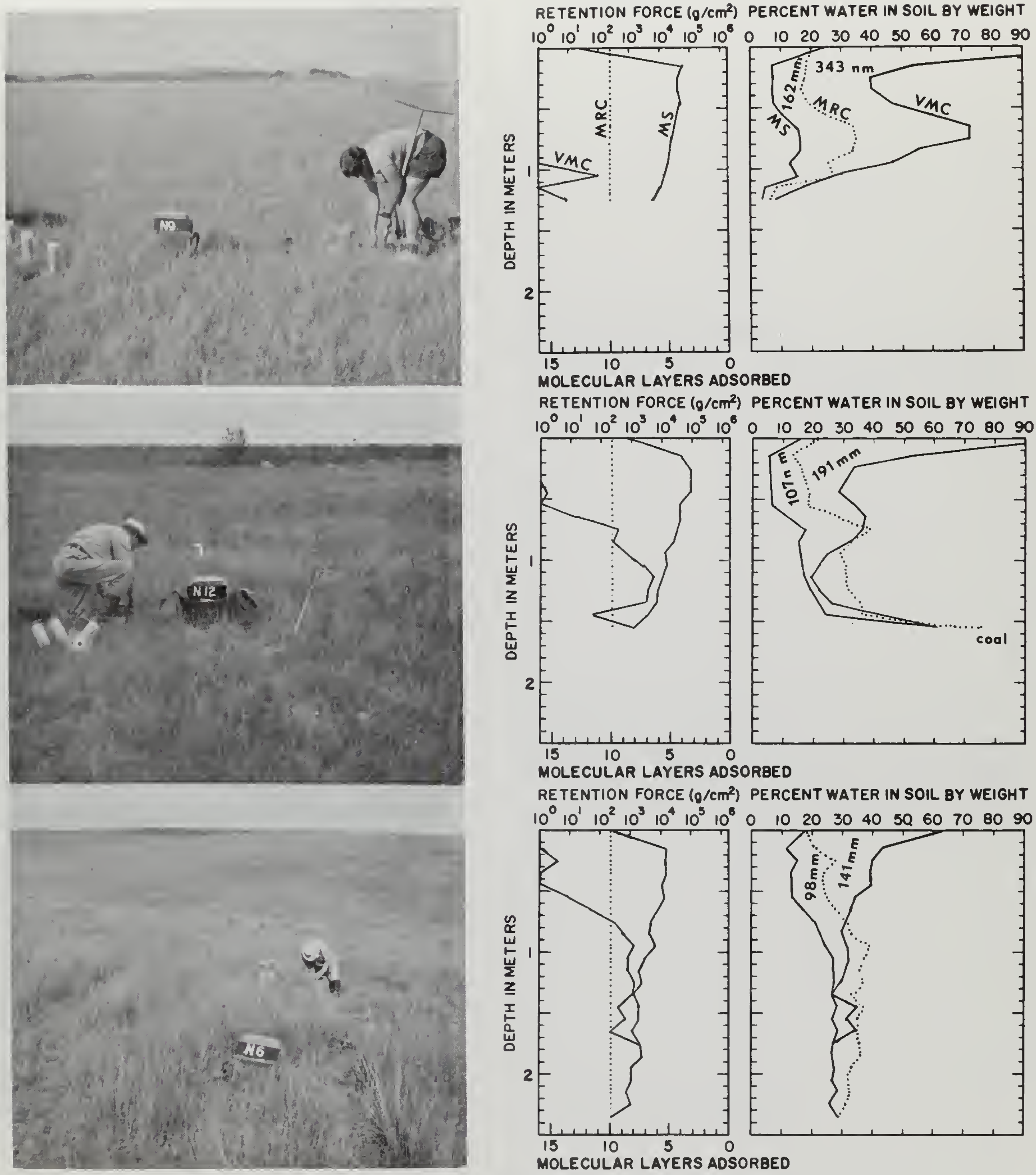


Figure 8 --Moisture relations in soils with impeded drainage.

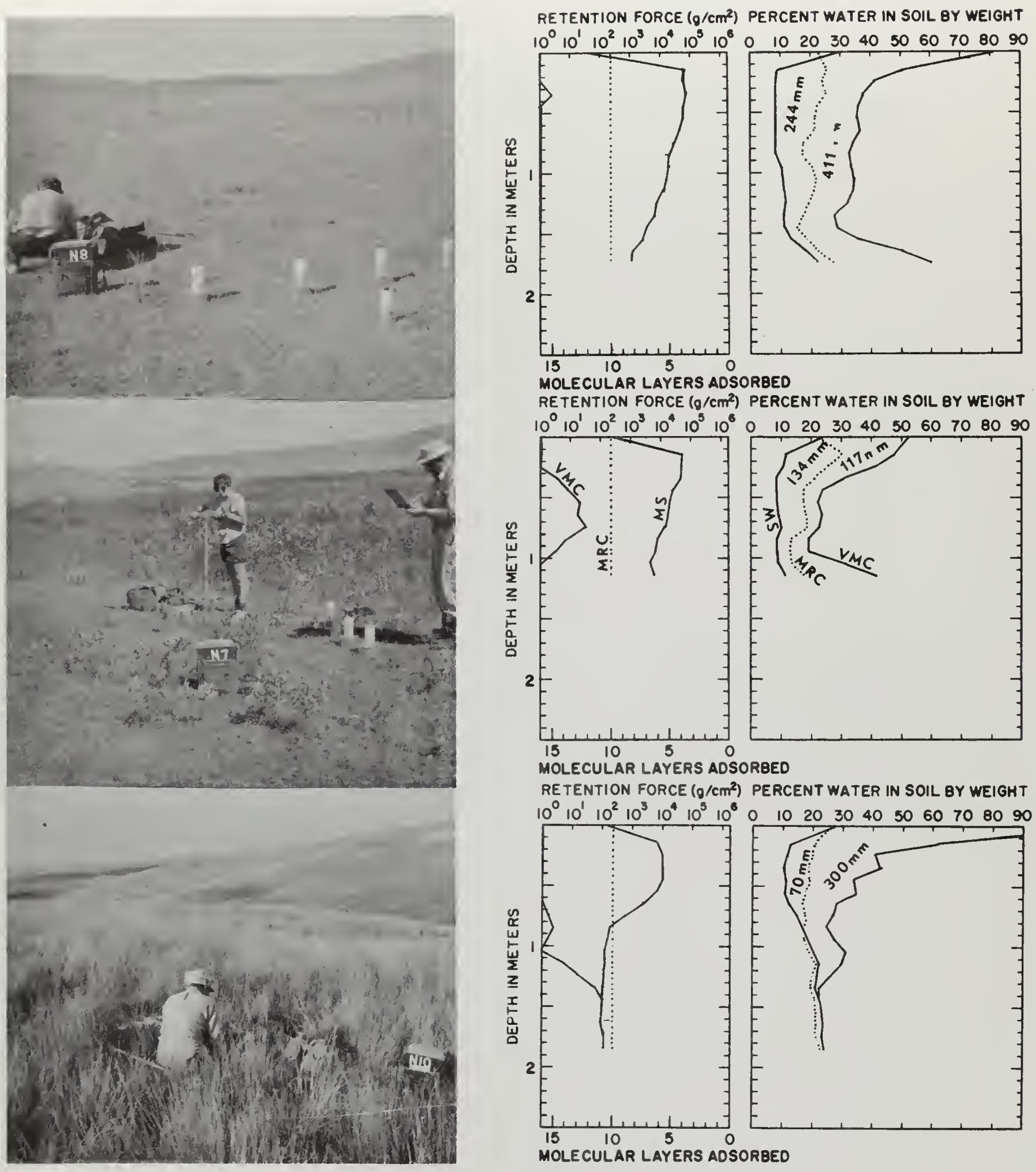


Figure 9 --Moisture relations in loamy soils with intermediate MRC's.

Table 67--Vegetation cover, in percent, and average retention force, in g/cm^2, for upland soils with high moisture-retention capabilities

Site	14	15	11
Bare	14	10	31
Mulch	12	7	13
Forbs	1	5	4
Shrubs	26	7	10
Shortgrasses	47	58	18
Midgrasses	--	13	24
Tallgrasses	--	--	--
Total live cover	74	83	56
Average retention force	66,422	34,234	74,840

Table 68--Vegetation cover, in percent, and average retention force, in g/cm^2, for soils with impeded drainage

Site	9	12	6
Bare	5	13	3
Mulch	17	10	4
Forbs	11	3	5
Shrubs	9	9	12
Shortgrasses	36	5	3
Midgrasses	22	60	6
Tallgrasses	--	--	67
Total live cover	78	77	93
Average retention force	34,217	60,399	12,216

drainage, inadequate void space in the Williams loam hampered drainage. This is another cause where impeded drainage probably causes moisture to perch and makes it readily available because retention forces are low. This in turn influences the kinds of native vegetation prevalent on the sites (Table 69). A mixture of mid and shortgrasses predominates on the Arnegard loam, with snowberry occurring in swales and little bluestem, a tallgrass, predominates on Williams loam where drainage is restricted at a depth of 1.5 m.

Loamy Soils Under Different Land Uses

The soil sites characterized in Figure 10 were sampled for a comparison between the effects of heavy grazing, no grazing, and cultivation on similar soils. Sites 3, 4, and 5 were located in close proximity near the toe of slope mapped as Arnegard loam by the SCS. Site 13 was a cultivated site in Williams loam. It is included here because it exhibited similar moisture retention characteristics. Drainage is severely restricted at the bases of all four profiles where void-moisture capacities (VMC) are less than moisture-retention capabilities (MRC) (see Figure 10). The voids at the bases of the profiles were still filled with moisture at the end of the growing season.

There were distinct patterns of moisture depletion under the different land uses. Under heavily grazed rangeland (site 3), moisture in the lower half of the profile was still stored at MRC levels, but in the ungrazed land (site 4) and the cultivated sites, moisture was depleted below MRC to the base of the profile. The probable reason for the lower moisture use on the grazed site was that overgrazing had decreased the vigor of the plants.

At sites 3 and 4, there was a steady decrease in moisture-retention force gradient upward from the base to near the surface, heading toward a retention of less than five molecular layers of water at the surface. (The immediate surface had been wetted prior to sampling by rainfall.) This was the effect of evaporation drying the soil beyond the capability of the vegetation. The soil moisture of the cropland sites (5 and 13) was held at more uniform forces throughout the profile. This indicates that evaporation was less effective in removing moisture at those sites. This may have been a result of shading by crops, but most likely was due to the practice of fallowing in alternate years. With fallowing, moisture from 2 years is stored in the profile. Then, during the cool autumn evenings, the temperature gradient between the warm soil and cooler air causes soil moisture to migrate toward the soil surface. This phenomenon can counteract the effect of evaporation.

Soil moisture in the lower part of the profile was not depleted as completely under wheat (site 13) as it was under sorghum (site 5). The longer growth period of sorghum was probably the reason. Differences in degree of moisture use by vegetation and the influence of fallowing on moisture storage should be given consideration when reclaimed lands are managed.

The influence of heavy grazing on survival of grasses is evident in Table 70. Grazing reduced the presence of midgrasses and increased the proportion of shortgrasses. Shrubs decreased while forbs increased, and the proportion of bare ground increased.

Differences in land use have not significantly influenced the size of surface voids at the Arnegard loam sites. Infiltration rates were computed to be 27, 24, and 25 cm/hr, respectively, for sites 3, 4, and 5. This is probably attributable to the structural stability of the humic surface horizons. Where fallowing had been practiced, soils have more void space at the base of the profile. Storage of extra water accumulated from fallowing has apparently forced soil particles apart, creating more void space. Less force is required to desorb water perched in these more spacious voids than if drainage to greater depths had occurred.

Soils with Low Moisture-Retention Capabilities on Different Exposures

The sites characterized in Figures 11 and 12 permit evaluation of the effects of exposure and position on associated vegetation. All five sites occur on soils with relatively low moisture-retention capabilities and were mapped as Cohagen or Vebar fine sandy loam. At site 17 where the exposure is to the east, shortgrasses predominate somewhat over midgrasses. Site 18, which is dominated by midgrasses (Table 71), has an exposure to the north. At site 16, which has an eastern exposure and lies below a ridgetop where snow probably accumulates, snowberry is the predominant vegetation. Average retention forces decrease as the cover shifts from shortgrass to midgrass to snowberry.

Site 1 occurs on top of a hill and site 2 occurs downslope from site 1. Flow to greater depths would be impeded at a depth of 0.9 m in the downslope soil by a zone where voids permit only 3 (13-10) molecular layers of water to flow past (see Figure 12). This has resulted in creation of more void space above the impeding zone than is evident in the soil on top of the hill at similar depths. Availability of perched water is reflected by the fact that less adsorbed water was depleted from the downslope site than from the hilltop site (102 mm vs. 147 mm). Midgrasses again predominate over shortgrasses at site 2 where water is caused to perch closer to the surface (Table 71). The level of retention force achieved is, again, lowest on the site where midgrasses predominate.

Computed initial infiltration rates into the surface soils for sites 1, 2, 16, 17, and 18 were 3.6, 2.7, 3.0, 2.7, and 3.1 cm/hr, respectively. These rates would diminish as soils are wetted to greater depths. Accumulation of water in excess of retention-capability levels probably occurs in all soils. Rather small quantities of water that were retained with forces greater than retention-capability levels were depleted from storage. At greater depths, water retained at retention-capability levels is evident at all sites except site 16. Rockiness prevented the sampling of site 16 to sufficient depth to determine if water was held at moisture-retention capability levels in the lower part of the profile.

The larger amount of drainable void space at site 2 than at site 1 (460 vs. 268 mm, figure 12) is probably the result of more snow accumulating on the slope than on the hilltop.

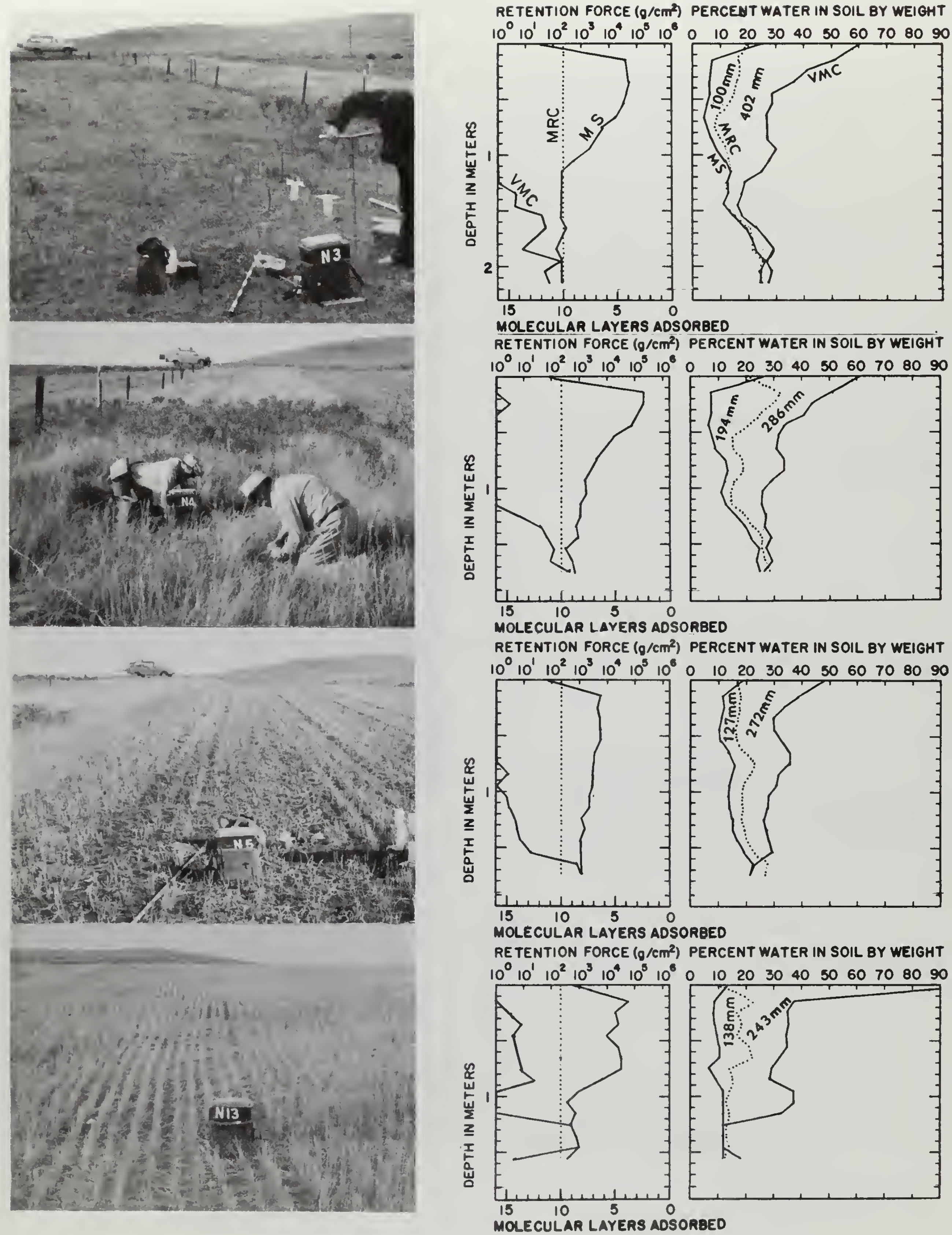


Figure 10--Moisture relations in loamy soils under different land uses.

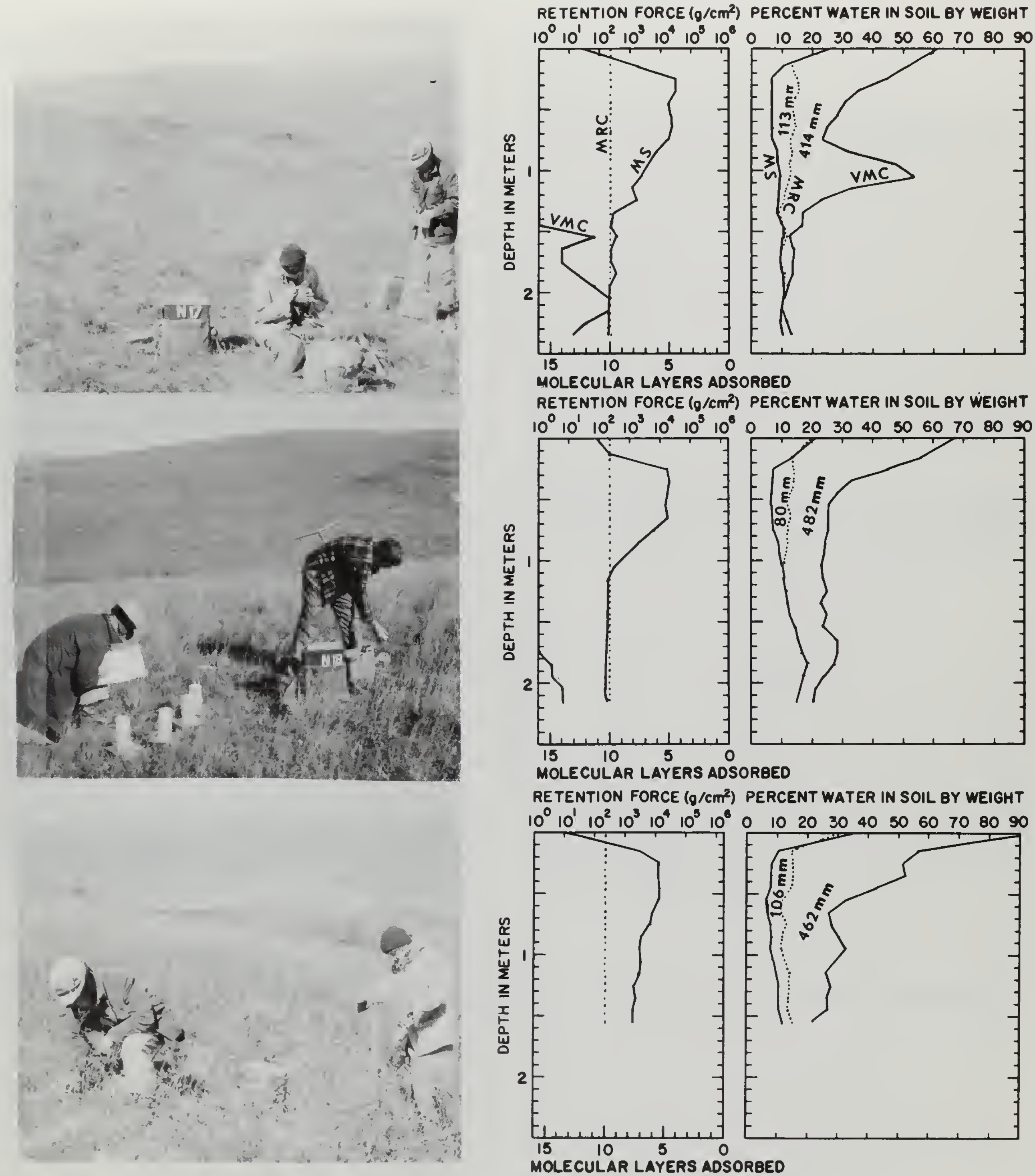


Figure 11--Moisture relations in soils with low MRC's on different exposures.

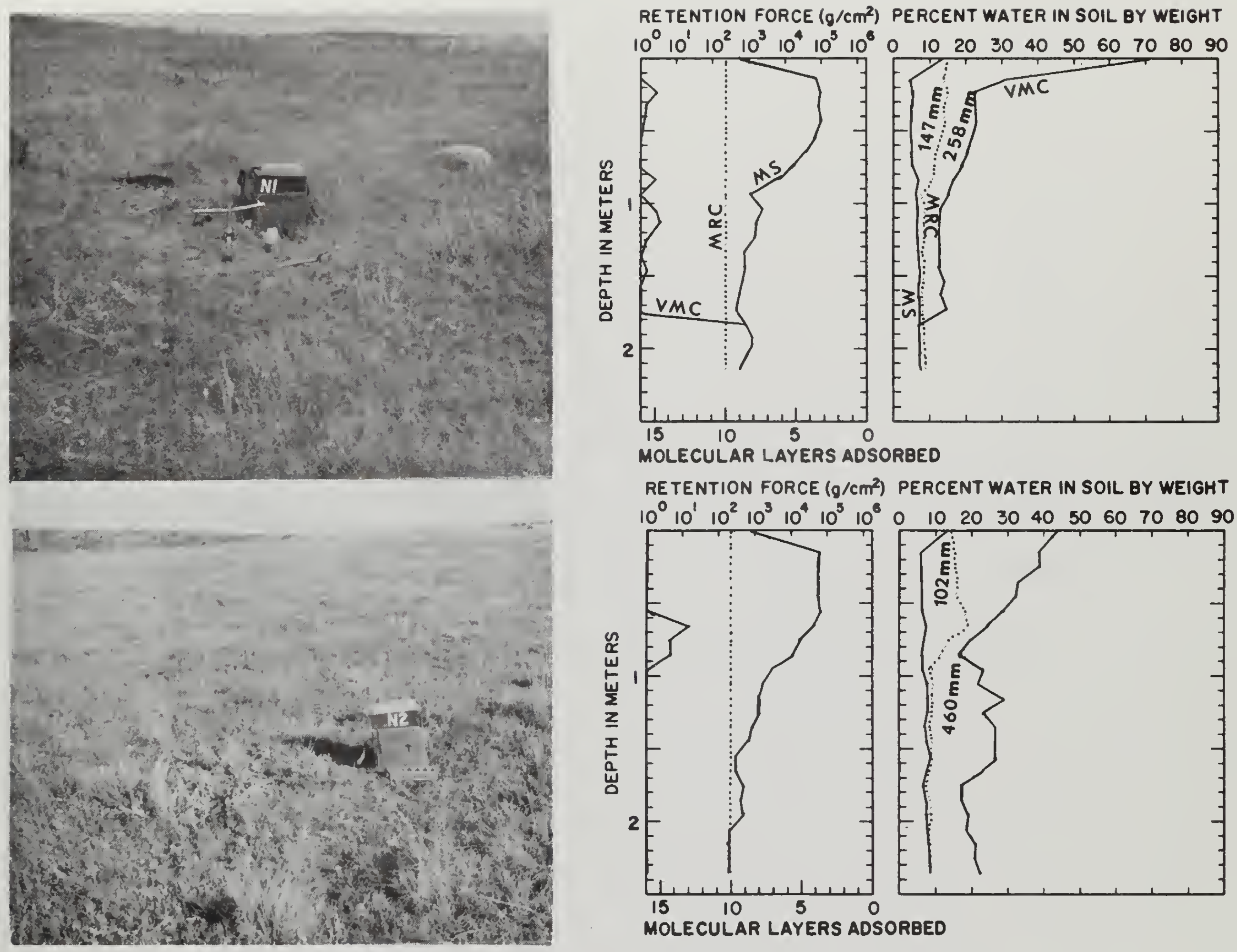


Figure 12 --Moisture relations in soils with low MRC's on different exposures.

Table 69--Vegetation cover, in percent, and average retention force, in g/cm^2, for loamy soils with intermediate MRC's

Site	8	7	10
Bare	9	39	5
Mulch	14	15	7
Forbs	2	14	1
Shrubs	3	3	16
Shortgrasses	71	15	--
Midgrasses	1	14	--
Tallgrasses	--	--	71
Total live cover	77	46	88
Average retention force	29,448	30,537	3,898

Table 70--Vegetative cover, in percent, and average retention force, in g/cm^2, for loamy soils of different land uses

Site	3	4	5[1/]	13[1/]
Bare	11	3	--	--
Mulch	12	6	--	--
Forbs	8	6	--	--
Shrubs	2	7	--	--
Shortgrasses	59	9	--	--
Midgrasses	8	73	--	--
Tallgrasses	--	--	--	--
Total live cover	77	91	--	--
Average retention force	14,386	40,857	3,347	18,929

[1/] No measurements were made.

Table 71--Vegetation, in percent, and average retention force, in g/cm^2, for soils with low MRC's

Site	17	18	16	1	2
Bare	7	4	3	3	10
Mulch	22	12	24	--	11
Forbs	2	9	1	4	3
Shrubs	8	2	34	8	11
Shortgrasses	32	13	14	63	25
Midgrasses	29	60	24	21	40
Tallgrasses	--	--	--	1	--
Total live cover	71	84	73	97	79
Average retention force	12,845	4,997	6,142	29,024	16,804

GREENHOUSE[1/]

In the past, surface mining for coal has generally resulted in soil material being buried beneath a mixture of spoils. Spoils exposed at the surface often originated from bedrock strata directly overlying the coal seam, resulting in a poor quality plant medium. In many cases, this has led to a severe problem in revegetation of surface-mined lands. The Surface Mining Control and Reclamation Act of 1977 (P.L. 95-87) was enacted in an effort to enhance proper reclamation of surface-mined lands. In regard to selection of the most suitable overburden (soil and bedrock) materials for use in revegetation, this Federal law stipulates that: "All topsoil shall be removed in a separate layer from the areas to be disturbed, unless use of substitute or supplementary materials is approved by the Regulatory Authority . . . if use of substitute or supplementary materials is approved, all materials to be redistributed shall be removed" (30 CFR 816.22(b)). Note: In the Beulah Trench Study Area, the State of North Dakota, Public Service Commission, is the present Regulatory Authority.

The objectives of this greenhouse experiment were to: (1) characterize soil and bedrock strata through studies relating to revegetation of surface-mined lands, and (2) conduct soil and plant analyses of selected materials for identifying potential problems relating to toxicity and/or nutrient deficiencies that may limit plant growth.

Methods

Soil Preparation

After removal from the shipping bag, the material was mixed and 100 grams were set aside for laboratory analysis. Two kilograms of the material were then placed in each of two plastic lined half-gallon round-paper cartons and labeled in the following manner: Each carton carried the number used by the Water and Power Resources Service for cataloguing purposes during recovery.

Field Capacity

A part of the sample was placed in a plastic hydraulic conductivity tube and water was added to wet the soil two-thirds to three-quarters of the way down the tube. At the end of the wetting period (48 hours), the top 3 cm of soil were discarded while the middle section was placed in a soil moisture can, leaving about 2 to 5 cm of wet soil at the bottom of the tube. The soil moisture cans, which had been previously weighed, were then weighed with the wet soil and placed in a forced air oven to dry at 100 degrees centigrade for at least 24 hours. They were then weighed again and the percent field capacity was calculated by the formula:

(Weight of can + wet soil) - (weight of can + dry soil) ÷ (weight of can + dry soil) x 100 = % field capacity.

1/ This study was conducted by the Department of Agronomy, Colorado State University, Fort Collins, Colorado, for the Water and Power Resources Service, U.S. Department of the Interior under Contract No. 6-07-DR-50130 and Amendatory Agreement No. 1 to the same contract.

Field capacity was determined primarily to serve as a guide for ensuring proper water management in the greenhouse.

Fertilizer Treatment

Before planting, a fertilizer application consisting of 100 ppm of nitrogen as reagent grade $Ca(NO_3)_2$ and 80 ppm of phosphorus as reagent grade $Ca(H_2PO_4)_2$, in 5 and 50 milliliter aliquots, respectively, was added to each pot. The application was made along with the preplant watering. Before the fertilizer or water were added, 150 grams of soil were removed from each pot and saved to be replaced in the pot after the seeds were added. All except 100 ml of the total water were added 24 hours before planting.

Planting

The pots were planted with 40 seeds of western wheatgrass (Agropyron Smithii var. Arriba). The seeds were evenly spaced in the pots and covered with 150 grams of soil that had been removed prior to fertilization. After smoothing the surface of the potted contents, the last 100 mls of water were added and the pots were covered with brown paper to prevent evaporation. The pots were checked every day to ensure that the topsoil remained moist. As the seeds started to germinate, the pot was uncovered to prevent the development of spindly plants. After 2½ weeks, or at approximately 10 cm height, the plants for all pots were counted and recorded. Then, the plants were thinned to 16 per pot and randomized. Pots were rotated 1/3 of the way around the table every third to fourth day to ensure that all pots were subject to the same lighting. The greenhouse lights were set to allow 15-16 hours of daylight.

Daily Management

All pots were weighed daily and the soil was brought to field capacity with distilled water. Twenty-one days after planting, N as reagent grade $(NH_3)_2SO_4$ was added to each pot at the rate of 50 ppm. Thereafter, the same rate (50 ppm) was added once a week. At the time the plants were thinned from the pots, salt crusting and cracking were evaluated.

Harvest

The crop of western wheatgrass was harvested approximately 50 days after planting. Before the plants were cut, they were measured and the average height was recorded. The harvesting procedure entailed cutting the plants at approximately 2 cm above the surface of the soil, washing the plants in a .1 N HCl acid bath, rinsing twice in distilled water, placing in paper bags, and drying at 60 degrees centigrade for 48 hours. After drying in a forced air furnace, the plants were weighed to the nearest one hundredth of a gram. Selected samples were then prepared for laboratory analysis.

Soil and Overburden Analysis

Electrical Conductivity

The electrical conductivity (EC) was determined on a 1:1 soil/water suspension by using a solu-bridge. Insufficient sample did not allow for obtaining a saturation extract, thus, soluble salts were determined on the 1:1 suspension. For interpretive purposes, the electrical conductivity obtained from the 1:1 suspension was multiplied by a factor of 2 to reflect the approximate EC of a saturation extract. The data are, however, reported for a 1:1 suspension.

Iron, Zinc, Copper and Manganese

The above listed elements were determined on the Atomic Absorption Spectrophotometer for a DTPA extract.

pH

pH was determined with a combination electrode pH meter on a 1:1 soil/water suspension.

SAR

Sodium adsorption ratios were determined according to the procedure in Agriculture Handbook No. 60. The SAR value reported is based on a 1:1 extract. For interpretation purposes, the SAR was converted using a calculation involving field capacity to approximate the SAR of a saturation extract.

Extractable Phosphorus

Phosphorus was extracted with sodium bicarbonate and determined colorimetrically.

Plant Tissue Analysis

Na, K, Ca, Mg, Fe, Zn, Mn, and Cu were determined on the Atomic Absorption Spectrophotometer from a Perchloric acid digest. P was extracted by the Bartons Reagent method and determined colorimetrically.

Note: Laboratory data are lacking for some materials because of insufficient sample and/or because of the lack of funding for carrying out all analyses.

Criteria for Interpretation

The criteria as applied in this study are based on existing data used for evaluating soil-plant growth relationships on agronomic crops.

The use of these criteria are necessary due to the lack of information available for the soil-plant-climatic environments associated with mined lands in the areas under investigation.

The criteria used for evaluating salinity and sodium problems are thought to be very reliable. However, the limits defined for the other soil and plant chemical characteristics must be considered as a first approximation, using existing diagnostic data, in an attempt to identify and/or isolate potential problems associated with the growth of plants on these types of materials.

Soil Diagnostic Criteria

The following criteria are based on current Colorado State University soil testing evaluation procedures.

Available P

0 to 3 ppm - very low
4 to 7 ppm - low
8 to 11 ppm - medium
11 + - high

Available Zinc

0 to 0.5 ppm - very low
0.51 to .99 ppm - low
1.0 to 1.5 ppm - medium
1.5 + ppm - high

Available Iron

0 to 2.0 ppm - low
2.1 to 4.0 ppm - medium
4.0 + ppm - high

Available Copper and Manganese

0 to 0.5 ppm - low
0.5+ ppm - high

SAR

0 to 10 - low sodium hazard
10 to 15 - medium sodium hazard - potential problem
15+ - high to very high probability that a sodium problem exists and will seriously affect reclamation potential

Note: The SAR values reported are based on a 1:1 extract. For interpretive purposes the following conversion was made to approximate the SAR of a saturation extract. This procedure is not recommended for common use. Saturation extracts were not used because of insufficient sample.

$$\text{SAR of Saturation Extract} = \sqrt{\frac{100}{\%\ \text{Saturation at Field Capacity}}} \times \text{SAR of 1:1 Extract}$$

Salinity

<4 mmho's electrical conductivity - low
4 to 8 mmho's electrical conductivity - moderate salinity problem
>8 mmho's electrical conductivity - high salinity problem

Plant Diagnostic Criteria

The following criteria are based on a general interpretation of existing plant analysis data. These criteria are presented here mainly to evaluate the relationship between soil test values and plant uptake data rather than as an indicator of a critical deficiency problem. The latter is not possible because of the lack of adequate data. No attempt has been made to identify toxicity levels.

Total Phosphorus

<0.1% critical
.1-.2% marginal
>0.2% adequate

Total Zinc

<10.0 ppm critical
10-20 ppm marginal
>20 ppm adequate

Total Copper

<5 ppm - potentially deficient
5-10 ppm - adequate
>10 ppm - for some plants, copper levels in excess of this amount may indicate a potential toxicity problem.

Total Manganese

<.2 ppm - potentially deficient
>.2 ppm - adequate

Total Potassium

0 to 1.0% - potentially deficient
1.0 to 2.0% - intermediate
>2.0% - adequate

Total Calcium

0 to 0.25% - potentially deficient
0.25% or greater - adequate

Total Magnesium

0 to 0.25% - potentially deficient
0.25% or greater - adequate

Note: In many cases, the selected criteria were made arbitrarily because the critical values for various stages of growth of western wheatgrass are not known. The selected ranges are used in this text as the reference level for comparing yield vs. plant vs. soil test data. The levels used must not be interpreted as being valid for making concrete interpretations. False conclusions will result if they are used as such.

Statistical Analysis

Statistical analysis of the data are not available for inclusion in this report. The data are being statistically analyzed, using both a cluster and discriminate analysis procedure.

Results and Discussion

Studies Performed

1. The greenhouse study was conducted to determine the relative yield potential of western wheatgrass and to correlate yield response with soil laboratory characterization data. In addition, surface cracking and salt crusting characteristics of the materials were observed and recorded.

2. Preplant and post-harvest soil analyses of selected properties were carried out on some materials to determine what changes, if any, may occur in the chemical nature of the materials when exposed to a weathering and crop environment.

Summary of Results

Greenhouse and laboratory characterization data for all materials tested from this site are shown in Table 72, Appendix F.

A total of 21 samples were classed unsuitable for plant growth media because of high salinity and sodium. These materials are identified on Table 73. A total of eight samples were classed unsuitable as plant growth media because of high salinity. These also are shown on Table 73. Suitability ratings and a general appraisal of materials not listed in Table 73 are shown on Table 74.

The results obtained from this study indicate the following:

1. In many cases, the post-harvest soil analyses for SAR and salinity were better related to yield than the pre-plant soil analyses data. This suggests that considerable chemical alteration occurred during the crop growing period.

Table 73

Beulah Trench Materials Classed as Being Unsuitable due to High Salinity and SAR

Materials Classified as Unsuitable due to Salinity and SAR

Sample No.	% Relative Yield	Remarks
77-107-7	97	Soil test data suggest that this material is unsuitable due to salinity and sodium. High field capacity might explain why this material yielded higher than material with similar salinity and sodium levels with lower field capacity. Even though the relative yield is high, this material is classed as unsuitable.
77-103-9	68	High SAR; moderate salinity.
77-107-10	60	High SAR; moderate salinity.
77-103-12	56	High SAR; moderate salinity.
77-103-8	55	High SAR; moderate salinity.
77-107-8	54	High SAR; high salinity.
77-102-3	38	High SAR; high salinity.
77-103-11	38	High SAR; high salinity.
77-107-11	38	High SAR; high salinity.
77-107-9	33	High SAR; high salinity.
77-103-10	31	High SAR; high salinity.
T-1514	36	High SAR; high salinity.
77-102-4	25	High SAR; high salinity.
77-102-5	25	High SAR; high salinity.
77-102-6	25	High SAR; high salinity.
77-102-7	24	High SAR; high salinity.
T-1513	24	High SAR; high salinity.
77-103-14	22	High SAR; high salinity.
77-103-15	21	High SAR; high salinity.
77-103-13	16	High SAR; salinity level low by preplant data, no post-plant data available.
T-1512	9	High SAR; high salinity.

Materials classified as Unsuitable Due to Salinity

Sample No.	% Relative Yield	Electrical Conductivity (Recalculated) Preplant	Post-Plant
77-103-3	71	6.6	9.0
T-1472	51	8.0	11.6
T-1489	50	12.0	13.0
T-1528	50	8.6	10.0
T-1488	49	11.2	12.4
T-1529	49	8.8	10.4
T-1473	48	11.6	11.4
T-1511	46	10.6	12.2

Interpretive Summary for all Materials not Shown in Table 73. (Beulah Trench Site).

Sample No.	% Relative Yield	Suitability Rating	Remarks
T-1490	100	Suitable	Slight surface cracking.
77-107-1	143	Suitable	Slight surface cracking.
T-1515	112	Suitable	No apparent problem.
T-1496	111	Suitable	No apparent problem.
T-1487	105	Suitable	Post-plant soil salinity level is moderate.
T-1497	102	Suitable	Pre-plant Zinc level is very low. Post-plant is adequate.
T-1502	99	Suitable	Pre-plant Zinc level is very low. Post-plant is adequate.
T-1484	97	Suitable	No apparent problem.
77-103-1	97	Suitable	Slight surface cracking.
77-107-7	97	Questionable	Moderate salinity; slight salt crusting and surface cracking.
T-1469	94	Suitable	Slight salt crusting.
T-1509	94	Suitable	Slight salt crusting.
T-1522	92	Suitable	No apparent problem.
T-1517	91	Suitable	No apparent problem. Low field capacity.
77-103-4	90	Suitable	Pre and post plant Cu level is low. Low field capacity.
T-1493	87	Suitable	No apparent problem. Low field capacity.
T-1501	87	Questionable	Pre and post plant Cu and Zn levels low. Low field capacity.
T-1527	87	Suitable	Surface cracking; pre and post Zn level low.
T-1494	86	Questionable	Salinity moderate; surface cracking moderate.
T-1498	86	Questionable	Salinity slight to moderate; pre and post plant Cu and Zn levels low. Low field capacity.
T-1524	86	Suitable	Slight salt crusting; post plant Cu level low. Low field capacity.
T-1508	84	Suitable	Pre and post plant Cu and Zn levels are low. Low field capacity.
T-1486	83	Suitable	Pre and post plant Cu and Zn levels are low. Surface cracking.
T-1503	83	Suitable	Pre and post plant Cu and Zn levels are low.
T-1516	83	Suitable	No apparent problem. Field capacity is low.
T-1520	83	Suitable	No apparent problem. Field capacity is low.
77-107-2	82	Suitable	Pre and post Cu level low. Field capacity low.
T-1471	81	Questionable	Salt crusting and surface cracking.
T-1525	78	Questionable	Pre and post Zn level low. Salt crusting. Low field capacity.
T-1491	76	Questionable	Pre-plant Zn low. Salt crusting and surface cracking. Low field capacity.
77-102-1	76	Questionable	Pre and post Cu level low. Surface cracking. Low field capacity.
77-102-2	74	Questionable	Moderate salinity. Salt crusting and surface cracking.
77-103-7	74	Questionable	Salt crusting. Pre and post Cu level low. Low field capacity.
T-1492	74	Questionable	Pre-plant Zn level low. Low field capacity.
T-1507	71	Questionable	Pre and post plant Cu and Zn levels low. Low field capacity.
T-1523	71	Questionable	No apparent problem.
77-103-6	71	Questionable	Moderate salinity. Pre and post Cu level low. Low field capacity.

Sample No.	% Relative Yield	Suitability Rating	Remarks
T-1485	68	Questionable	Preplant Zn low. Salt crusting and surface cracking.
77-103-5	68	Questionable	Preplant Zn low. Pre and post-plant Cu low. Field capacity low.
T-1495	67	Questionable	Salt crusting.
T-1518	66	Questionable	Surface cracking and low field capacity.
T-1510	62	Questionable	Moderate salinity and surface cracking.
T-1504	61	Questionable	Low preplant Zn. Low pre and post-plant Cu. Surface cracking. Low field capacity.
T-1506	61	Questionable	Pre and post plant Zn and Cu levels low. Low field capacity.
T-1526	61	Questionable	Salt crusting and surface cracking.
77-107-3	60	Questionable	Pre and post Cu levels low. Low field capacity.
T-1470	60	Questionable	Surface cracking.
T-1521	59	Unsuitable	Surface cracking; low field capacity.
77-107-4	57	Unsuitable	Moderate salinity. Surface cracking.
T-1500	52	Unsuitable	Pre and post Zn and Cu levels low. Low field capacity.
T-1505	50	Unsuitable	Preplant Zn low. Pre and post plant Cu low. Field capacity low.
T-1499	46	Unsuitable	Preplant Zn low. Pre and post plant Cu low. Field capacity low.
77-107-6	41	Unsuitable	Moderate salinity. Surface cracking and salt crusting.
77-107-5	36	Unsuitable	Moderate salinity. Surface cracking and salt crusting.
T-1519	24	Unsuitable	Surface cracking. Low field capacity.
77-103-2	6	Unsuitable	Post plant Cu low. Surface cracking. Very low field capacity.

2. The pre-plant vs. post-harvest soil zinc levels changed in many cases from being low, based on pre-plant soil analysis, to marginal or adequate, based on the post-harvest data. However, this rarely occurred in the case of Cu. Low Cu levels as indicated by pre-plant soil test data remained low, based on post-harvest data.

3. Ninety-five percent of all materials tested very low in available P. The remaining materials tested low. It appears that P must be considered as a major limiting factor for plant growth on all materials.

4. The data indicate a strong relationship between field capacity and yield. This is particularly true for samples represented in Table 72, Appendix F, which have relative yield values less than 90%. Except for low zinc and copper levels, and occasional moderate salinity levels, the most common characteristic among samples yielding 90% or less of relative yield is a low field capacity. The concern of this investigation is that the particle size distribution of these materials could have changed due to weathering, and if this did occur, the water management program in the greenhouse could have been seriously affected. There appears to be a strong indication that yields decreased with decreases in field capacity values. On the other hand, surface cracking was observed on a large number of materials from which low yields were obtained. Thus, there is strong evidence that poor physical condition also may be responsible for lower yields.

5. Low soil zinc and copper levels were common in materials which yielded less than 90% relative yield. Insufficient data make it difficult to predict whether or not these elements may be a limiting factor in plant growth. Plant analysis data from other sites indicate that the zinc and copper level is below what would be considered as potentially deficient for some agronomic crops. However, the existing data are not adequate for determining whether these levels are critical for western wheatgrass or other native species.

6. For all materials classed as "Questionable" in Table 74, it is recommended that if they are to be considered for use as plant growth media, additional evaluations should be conducted. There remains a strong possibility that factors other than those tested for could be limiting growth. This investigator believes that the numerous potential problems identified from the observations made are merely indicators of the overall low productivity potential for many of the low yielding materials and that management problems would be increased significantly if these materials were used as plant growth media. The results strongly indicate that the greenhouse study was very useful for stratifying materials relative to their productivity potential, and suggest that additional factors other than those measured may be responsible for poor productivity.

7. There appears to be a consistent relationship between increased sodium and/or salinity and decrease in yield.

In summary, the more significant findings of this study were:

1. Post-harvest soil test data on geologic materials was a very significant factor in making interpretations, particularly as related to salinity and sodium. In some cases these data related better to yield response than did the pre-plant soil data. More research is needed to evaluate the significance of changes in the chemical and physical properties of these materials as a result of weathering.

2. The significance of what are described as low soil zinc and copper levels on yield and performance of western wheatgrass needs to be further evaluated.

3. Low field capacity and surface cracking relationships may be very significant in evaluating the suitability of materials as plant growth media.

4. Although particle size data were not available, some attention must be given to the erosion potential associated with some of these materials.

5. Mg to Ca ratios of the 1:1 saturation extract were, in some cases, sufficiently high to warrant concern about potential magnesium induced calcium deficiencies. However, because the water soluble cations were determined on a 1:1 dilution basis, it was difficult to assess this relationship. In addition, it appears that the effect of high Mg to Ca ratios also is related to salinity levels. Both the ratios of Mg to Ca and salinity levels changed as a function of pre vs. post plant soil or geologic overburden condition. The significance of these changes on yield are being evaluated through statistical analyses of the data. These results are not yet available. The frequency of occurrence of high Mg to Ca ratios indicates that this relationship needs further investigation and evaluation.

VEGETATION

Present Conditions

Aerial cover of vegetation and soil surface conditions (bare soil, rock, and mulch) at each sampling site were measured by the first-contact point-quadrat method. A frame containing 10 vertical pins was placed at three step intervals. Totals of 90 to 600 pin projections were used--the larger number being used in the more extensive types. Current growth of vegetation and amounts of mulch were measured in 9.6-ft^2 plots. Two or three plots were clipped in each type. Plant materials were oven dried and weighed, and are reported as pounds per acre (Table 75). Estimated carrying capacities are based on these yields with adjustments made for amount of plant material that should be left to maintain productivity (50 percent), distance from water, slopes, and palatability. These estimates are for cattle; different values would be required for other classes of livestock and game species.

Results of vegetation measurements in adjacent ungrazed and grazed sites are shown in Table 75. There were ungrazed comparison areas, usually ungraded road rights-of-way, for 9 of the 11 vegetation types sampled. The ungrazed comparison areas vary in suitability for estimates of climax vegetation. Site 5 is completely fenced and thus has no livestock use or vehicular traffic. Site 3, with seven comparison areas, is negotiable only by four-wheeled vehicles, and there was no evidence of it having been grazed. Site 2 has some vehicular traffic and may have received some minimal use by livestock. Locations of the sites are shown on the vegetation map that was compiled from 1:24,000 scale black-and-white aerial photographs of the area (see Plate 33, Appendix G).

Where possible, yield measurements were made in these ungrazed areas. When carrying capacities of adjacent grazed pastures were computed, additional adjustments were made for the apparent changes due to less productive species being present as a result of past grazing use. To obtain improvement in some of the pastures, it is probable that stocking rates should be even lower than those shown on Table 75. Range condition estimates were based on principles proposed by Dyksterhuis (1949), range site and condition guides provided by the U.S. Soil Conservation Service, and personal judgment based on experience.

Changes resulting from heavy use by livestock, that are apparent in the data (Table 75), include a reduction in live plant cover and a general shift from palatable and productive species to less palatable and less productive species. Estimates of range condition ranged from a low of 33 percent (fair) to 59 percent (good) for the grazed areas. All of the ungrazed areas were considered to be in excellent condition (above 75 percent of climax).

Topographic relationships of the different vegetation types and changes caused by grazing can be more readily seen in Figure 13 than in Table 75. Figure 13 also shows, in more detail than does the vegetation map (Plate 33, Appendix G) the changes that occur in plant communities over short distances. These changes are caused by differences in slopes, exposures, and soils.

The area referred to as "flat" may, at other similar sites, be gently rolling with slopes of 5 percent or more. For quantitative measures of changes due to grazing, Table 75 must be examined.

Vegetation types shown in Table 75 are grouped in three broad topographic categories as follows: (1) relatively flat areas (Needleandthread-Blue grama), (2) sloping areas (Prairie sandreed-Little bluestem), and (3) relatively flat alluvium or floodplains (Western snowberry-Prairie sandreed). The steep, north-facing slope, sites 3A and 3A', is considered different enough to be listed separately. Names of the types are derived from the nongrazed sample areas which represent the potential vegetation for the study area. Good arguments could be made for using present vegetation as represented by the grazed areas. However, the use of potential vegetation is in agreement with the concept by Küchler (1964) in his "Potential Natural Vegetation of the United States."

The weighted average range condition for the grazed areas is 48 percent or high fair condition. Some of the better lands of the study area, roughly estimated as 50 percent, are cultivated; thus, estimated productivity based on grasslands sampled is an underestimate of overall land productivity. However, based on the weighted average carrying capacity (2.06 acres per animal unit month), some 11.6 sections (7,416 acres) would be required to support a livestock operation of 300 animal units. Supplemental feed from cultivated land would considerably reduce this estimate.

Productivity similar to or greater than that of the present potential vegetation would be a feasible objective of reclamation following mining. Meeting this objective will require that the productive soils now present be moved to newly shaped spoils and that many of the desirable species present on the ungrazed sites be reestablished. Shaping of the land to reduce some of the steeper slopes now present should result in more land area suitable for cultivation and, probably, higher productivity.

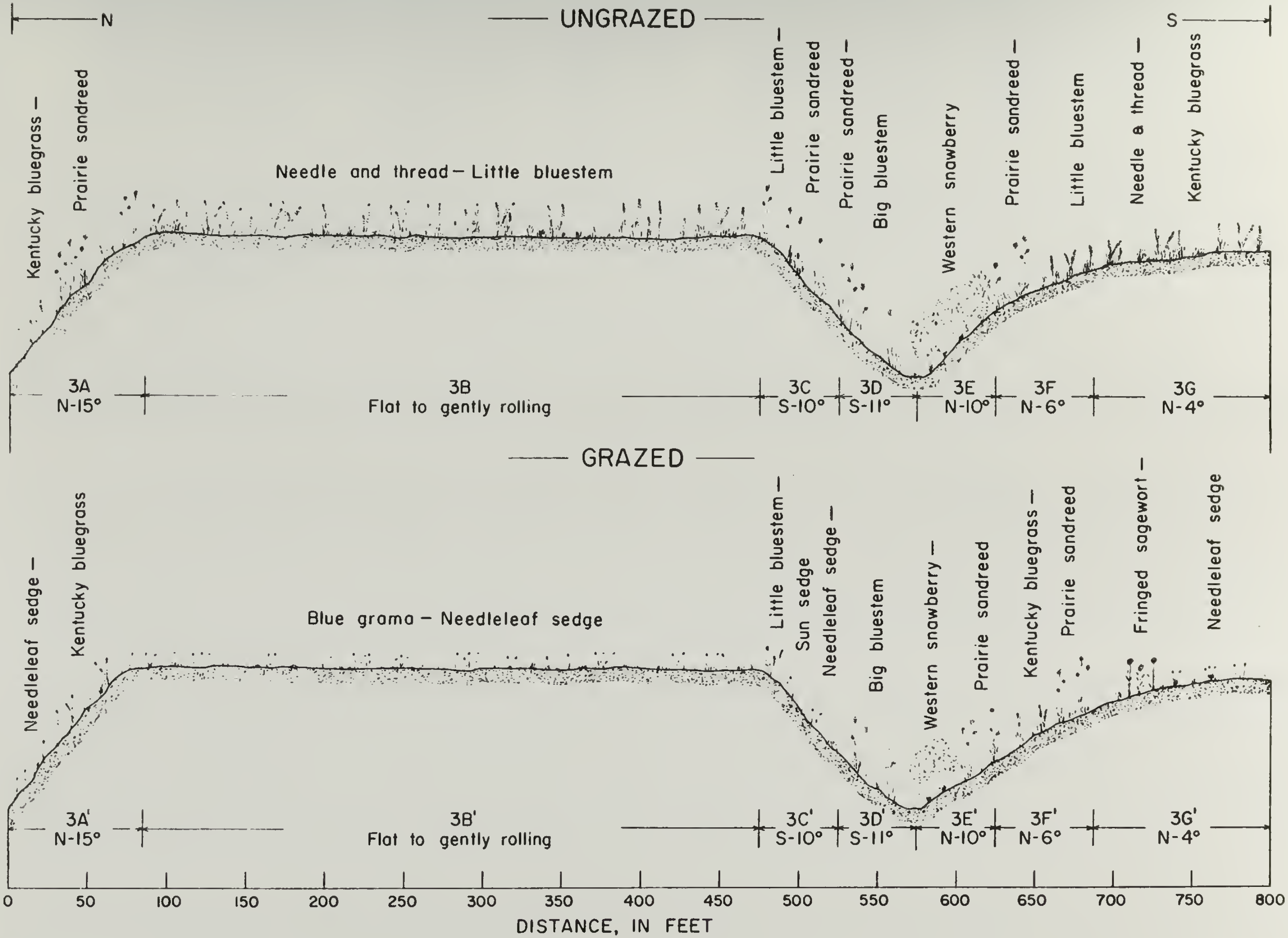


Figure 13 --Diagramatic representation of plant communities on ungrazed areas (3A, 3B, etc.) and adjacent grazed areas (3A', 3B', etc.). Slopes in degrees, exposures of north or south, and horizontal distances occupied by each plant community are shown.

Percent cover of vegetation, mulch, bare soil, and rock, plus yields of vegetation and mulch in pounds per acre. Range condition and carrying capacity for each site are also shown

Vegetation types. . .		Kentucky bluegrass-Prairie sandreed			Needleandthread-Blue grama								Prairie sandreed-Little bluestem																	Western snowberry-Prairie sandreed	
Site numbers.		3A		3A'	3B		3B'	5A		5A'	2		3C		3C'	1		3D		3D'	3E		3E'	3F		3F'	3G		3G'	4	
Grazing treatment . .		Ungrazed		Grazed	Ungrazed		Grazed	Ungrazed		Grazed	Ungrazed		Ungrazed		Grazed	Grazed		Ungrazed		Grazed	Ungrazed		Grazed	Ungrazed		Grazed	Ungrazed		Grazed	Grazed	
Topography.		N-15°		N-15°	Flat		Flat	Flat		Flat	S-2°		S-20°		S-20°	S-12°		S-11°		S-11°	N-9°		N-9°	N-6°		N-6°	N-4°		N-4°	Flat alluvium	
Genus and species	Common name	Cover	Yield	Cover	Cover	Yield	Cover	Cover	Yield	Cover	Cover	Yield	Cover	Yield	Cover	Cover	Yield	Cover	Yield	Cover	Cover	Yield	Cover	Cover	Yield	Cover	Cover	Yield	Cover	Cover	Yield
Shrubs																															
Artemisia frigida	Fringed sagewort	—	—	4	T	(11.5)	12	2	(26.0)	4	3	(19.3)	—	—	2	—	(57.0)	—	(0.4)	3	—	—	—	—	—	8	T	(0.5)	18	—	—
Gutierrezia sarothrae	Snakeweed	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rosa arkansana	Prairie wild rose	1	(39.0)	—	1	(12.5)	T	—	—	—	T	—	—	(10.0)	—	2	(2.0)	—	—	—	—	—	—	—	—	—	—	—	—	1	(19.3)
Salix sp.	Willow	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—
Symphoricarpos occidentalis	Western snowberry	—	—	—	—	—	—	3	(12.0)	—	1	—	—	—	—	—	(30.7)	—	—	—	57	(648.5)	46	—	—	—	—	—	—	22	(802.3)
Grasses and grass-likes																															
Agropyron smithii	Western wheatgrass	9	—	6	3	—	1	9	(140.0)	5	—	(7.3)	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	(107.0)
Agropyron subsecundum	Bearded wheatgrass	7	(180.5)	4	—	—	—	—	—	—	T	—	—	—	—	—	—	T	—	7	2	—	—	—	—	—	—	—	—	2	—
Agropyron trachycaulum	Slender wheatgrass	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(42.5)	—	1	(5.0)	—	—	—	—	1	—
Agrostis scabra	Ticklegrass	—	—	—	—	—	—	—	(1.0)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Andropogon gerardi	Big bluestem	—	—	—	—	—	—	—	—	—	T	—	—	—	—	—	—	11	(397.0)	7	—	—	—	—	—	—	—	—	—	—	—
Andropogon scoparius	Little bluestem	6	(35.0)	T	3	(165.0)	—	—	—	—	6	(122.0)	49	(738.5)	19	13	(166.3)	14	(28.0)	T	4	—	—	23	(187.0)	—	1	(10.0)	—	—	—
Aristida longiseta	Red threeawn	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bouteloua curtipendula	Sideoats grama	6	(42.0)	8	—	—	—	—	—	—	1	—	—	—	—	—	(0.3)	1	(15.0)	5	4	—	—	T	(4.0)	—	—	—	—	—	—
Bouteloua gracilis	Blue grama	—	—	—	T	—	12	18	(64.5)	39	8	(12.0)	—	(0.2)	4	—	(24.7)	—	—	—	—	—	—	—	—	—	—	—	4	1	—
Bromus inermis	Smooth brome	—	—	—	—	—	—	T	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—
Calamovilfa longifolia	Prairie sandreed	17	(45.0)	—	—	(2.0)	—	—	—	—	5	—	12	(85.5)	5	8	(66.7)	56	(491.0)	5	12	—	—	36	(293.0)	8	—	—	2	—	—
Carex eleocharis	Needleleaf sedge	—	—	11	7	—	12	6	(16.5)	11	1	—	—	(8.5)	8	3	(18.0)	1	—	9	—	—	9	4	(32.5)	7	T	(8.0)	16	—	—
Carex filifolia	Threadleaf sedge	—	—	3	—	—	6	—	—	1	9	—	—	—	—	2	(48.0)	—	—	1	—	—	T	2	(20.5)	—	—	—	6	—	—
Carex heliophila	Sun sedge	—	—	—	5	(11.0)	2	6	—	—	1	(16.0)	—	(5.0)	10	3	(27.3)	1	(29.5)	4	1	(48.5)	—	—	—	—	2	(22.5)	3	2	(2.3)
Koeleria cristata	Prairie vinegrass	1	—	2	6	—	7	3	(38.0)	T	1	(17.0)	—	(9.5)	5	2	—	—	(23.5)	5	—	—	1	3	(21.0)	5	1	(19.0)	12	T	—
Muhlenbergia cuspidata	Stonyhills muhly	—	—	—	T	—	—	2	(16.5)	—	—	—	—	—	—	T	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Panicum wilcoxianum	Wilcox panicum	—	—	—	—	—	—	—	—	—	—	(6.3)	—	—	—	T	(1.7)	—	—	—	—	—	—	2	(19.5)	2	—	—	—	—	—
Poa pratensis	Kentucky bluegrass	40	(417.5)	10	14	—	T	5	—	1	—	—	12	(11.5)	—	2	—	1	(26.0)	1	2	—	16	1	(10.5)	13	13	(142.5)	—	33	(182.7)
Poa sp.	Bluegrass	—	—	3	—	—	T	—	—	—	—	—	—	(6.0)	—	—	—	—	—	—	—	—	—	—	—	—	T	(1.0)	—	—	—
Setaria sp.	Bristlegrass	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stipa comata	Needleandthread	—	—	3	14	(234.0)	1	19	(235.5)	3	13	(288.7)	—	(5.5)	4	11	(87.0)	1	(18.0)	—	—	—	—	—	—	7	40	(450.5)	3	1	—
Stipa viridula	Green needlegrass	—	—	—	13	—	—	8	—	—	—	—	12	—	—	—	—	—	—	—	—	—	—	—	—	—	11	(125.5)	—	8	(70.3)
Forbs																															
Achillea lanulosa	Yarrow	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	T	(4.0)	—	—	—	—	T	(13.0)
Anemone sp.	Windflower	—	(5.5)	T	—	(23.0)	1	—	—	T	1	(18.7)	—	(5.0)	2	T	(0.3)	—	T	—	—	—	—	T	(2.0)	—	—	—	—	—	(5.7)
Antennaria aprica	Pussytoes	—	—	—	—	—	—	T	—	—	T	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	(18.0)	—	—	—
Artemisia glauca	Green sage	—	—	1	2	(131.5)	T	2	(2.5)	T	1	(6.0)	—	(12.0)	—	1	(13.7)	1	—	—	—	—	—	—	—	—	—	—	9	—	—
Artemisia ludoviciana	White sage	—	(8.5)	—	2	(101.0)	T	—	—	—	2	(37.0)	—	—	—	4	(35.3)	3	(46.0)	—	1	(22.5)	—	6	(46.0)	—	1	(13.0)	—	T	—
Aster multiflorus	Many-flowered aster	—	(2.5)	—	1	(10.5)	1	2	(67.0)	—	—	(3.3)	—	(15.5)	—	—	(2.7)	1	—	3	—	—	—	2	(15.0)	—	—	—	—	1	(86.0)
Cerastium sp.	Chickweed	—	—	1	—	—	—	T	—	—	—	—	—	—	—	T	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Chrysopsis villosa	Hairy goldaster	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	(1.0)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cirsium undulatum	Wavyleaf thistle	—	(22.0)	1	—	(13.5)	1	T	—	—	T	—	—	(6.5)	—	—	—	—	—	1	—	(17.0)	—	T	(5.5)	2	T	(4.0)	—	—	(5.0)
Comandra pallida	Bastard toadflax	—	—	—	T	(52.5)	—	—	—	—	T	(12.0)	—	—	—	1	(0.7)	—	—	—	—	—	—	—	—	—	T	(2.0)	—	—	—
Euphorbia glyptosperma	Ridge-seeded spurge	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Gaillardia aristata	Gaillardia	2	(3.5)	1	2	(32.0)	—	—	—	—	T	(77.0)	3	(36.0)	—	6	—	1	(17.0)	2	1	—	—	7	(56.0)	—	7	(63.0)	—	—	—
Galium boreale	Northern bedstraw	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	(11.5)	—	3	(24.5)	—	—	—	—	—	—
Grindelia squarrosa	Gumweed	—	—	1	—	—	T	T	—	3	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—	—	3	—
Haplopappus spinulosus	Spiny sideranthus	—	—	—	—	—	—	—	—	T	T	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Helianthus rigidus	Stiff sunflower	—	—	—	—	—	—	—	—	—	—	—	—	(59.0)	—	2	(28.0)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hymenopappus tenuifolius	Hymenopappus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(2.0)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lactuca sp.	Wild lettuce	—	—	—	—	(2.0)	—	—	—	—	—	(24.3)	—	(4.5)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Liatris punctata	Blazing star	—	—	1	1	(4.5)	—	—	—	—	1	(2.3)	—	—	—	T	(1.7)	—	—	—	—	—	—	—	—	—	5	(60.0)	—	—	—
Lygodesmia juncea	Skeletonweed	—	—	—	T	(4.0)	—	—	—	—	—	—	2	(10.0)	—	1	—	—	—	—	—	—	—	—	—	—	1	(12.0)	—	—	—
Mimulus sp.	Monkeyflower	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	T	—
Monarda fistulosa	Wild bergamot	—	(19.5)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(24.0)	—	—	—	—	—	—	—	—	—
Petalostemum purpureum	Purple prairieclover	—	—	—	—	—	—	—	—	—	T	—	—	—	—	T	(1.3)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phlox hoodii	Hood's phlox	—	—	—	—	—	—	—	—	—	—	(5.0)	—	—	—	—	(5.7)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Psoralea argophylla	Silver psoralea	—	—	—	—	—	—	—	—	—	T	(0.3)	—	—	—	—	(29.7)	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Ratibida columnifera	Prairie coneflower	—	—	—	—	—	—	—	—	1	—	(17.7)	—	—	—	T	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Solidago missouriensis	Missouri goldenrod	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	(3.3)	T	—	—	—	—	—	—	—	—	—	—	—	—	—
Solidago altissima	Tall goldenrod	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	T	—
Solidago rigida	Stiffleaf goldenrod	—	—	—	—	—	—	—	(1.0)	—	—	—	—	—	—	T	—	—	(0.6)	—	—	—	—	—	—	—	3	(33.5)	—	—	—
Sphaeralcea coccinea	Salmon-colored mallow	—	—	—	—	(3.0)	—	—	—	—	—	(6.7)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Taraxicum officinale	Dandelion	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	—	—	—	—	—
Thelesperma gracile	Greenhead	—	—	—	—	—	—	—	—	—	—	(2.0)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thermopsis rhombifolia	Goldenpea	—	—	—	—	—	—	—	—	—	T	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tragopogon pratensis	Oyster salsify	—	—	—	T	—	T	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(5.0)	1	—	—	—	—	—	—	—	—
Trifolium sp.	Clover	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Unidentified forbs	—	—	1	—	—	—	—	—	—	—	(0.3)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	T	(5.5)	—	—	(3.3)
Mulch		11	(957.5)	32	25	(383.0)	33	13	(392.5)	25	39	(233.3)	10	(1012.5)	35	37	(166.7)	8	(875.0)	35	16	(9543.0)	26	10	(1935.5)	38	13	(796.5)	14	13	(366.7)
Bare soil		—	—	6	T	—	11	T	—	4	1	—	—	—	2	—	—	—	—	6	—	—	—	—	—	5	—	—	11	—	—
Rock		—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total live cover (percent) or total vegetation yield (lb/acre)		89	(820.5)	62	75	(813.5)	56	85	(618.5)	70	60	(701.2)	90	(1028.7)	63	63	(655.1)	92	(1092.0	59	84	(819.5	74	90	(746.0)	55	87	(990.5)	75	87	(1296.9)
Range condition in percent				57			33			55					59		55			49			45			54			42	35	
Carrying capacity in acres per animal unit month				2.1			2.4			2.9					1.4		2.3			1.6			1.8			2.3			1.7	2.9	

HYDROLOGY

The area as defined for the EMRIA No. 10 study does not of itself make a viable unit for hydrologic analysis. Consequently, the study area for hydrologic purposes was redefined as shown in Figure 14. The area is a 28-square-mile basin tributary to Antelope Creek. The ground water investigation was extended beyond the area boundaries, whereas the surface water investigation was contained within the boundaries.

Ground Water

Usable water can be obtained from the consolidated rocks of Late Cretaceous and Tertiary age and from the unconsolidated deposits of Quaternary age. The most important bedrock aquifers occur within the consolidated rocks of the Fox Hills Sandstone, Hell Creek, and Fort Union Formations. The aquifers consist mainly of fine- to medium-grained sandstone, and potential well yields generally will not exceed 150 gal/min (Croft, 1973). The water is used mainly for domestic and livestock purposes. It is generally a sodium bicarbonate type that contains large amounts of dissolved constituents and is not suitable for irrigation.

The glaciofluvial sand and gravel deposits of Beulah Trench (Antelope Creek aquifer) are an important aquifer in the study area.

Wells in the central part of the aquifer should yield 100 to 500 gal/min (Croft, 1973). Domestic and livestock water supplies depend almost entirely on ground water from these aquiferous units. The aquifers of the Sentinel Butte Member of the Fort Union Formation and the unconsolidated Antelope Creek aquifer were considered most likely to be impacted by mining.

Sentinel Butte Aquifers

The stratigraphy and lithology of the Sentinel Butte Member have been described previously. The member consists mostly of fine-grained clastic sediments and lignite. Generally the sandstone is poorly cemented, poorly sorted, and has a large clay content; therefore, it has low porosity and hydraulic conductivity. The porosity of the sandstone ranges from less than 5 to a maximum of about 50 percent. Most of the sandstone in the Sentinel Butte occurs as a basal unit (Fig. 15) at an altitude of about 1,700 feet NGVD (National Geodetic Vertical Datum of 1929).

Hydraulic conductivity of poorly consolidated or unconsolidated sediments can be estimated from grain size and cementation characteristics. Croft (1973) gives a table for estimating hydraulic conductivity of such sediments. A value for hydraulic conductivity of 5 to 20 feet per day was estimated for the basal Sentinel Butte sandstone unit. The fine-grained siltstone and claystone, which comprise about 65 percent of the member, have a hydraulic conductivity of between 0.1 and 2.0 feet per day, as estimated by Croft's technique.

Four water samples collected from wells tapping the aquifer in the basal Sentinel Butte sandstone were analyzed for dissolved ionic species. Sodium constituted more than 95 percent of the cations. Sodium concentrations ranged from 390 to 870 mg/L, whereas calcium and magnesium concentrations were less than 8 mg/L in all samples. Bicarbonate plus carbonate constituted from 80 to 84 percent of the anions, and sulfate ranged from 1 to 17 percent. Chloride concentrations ranged from less than 1.0 to 18 percent. Trace metals, iron, and manganese were low in all samples analyzed. Total dissolved solids ranged from 1,010 to 2,150 mg/L.

Lignite beds form aquifers in many parts of western North Dakota. The Beulah-Zap lignite bed forms a shallow generally confined aquifer. Hydraulic conductivity and direction of ground water flow in this lignite bed are probably controlled by fractures and joints; therefore, these properties vary from one location to another. Analyses of the Beulah-Zap lignite using a technique described by Alger (1966) yielded fairly consistent values for hydraulic conductivity of 0.5 foot per day to 2.0 feet per day. However, the validity of this type of analysis for aquifer material such as lignite is not clear.

In the study area the vertical hydraulic gradient from the surface downward to the Beulah-Zap lignite ranges from 0.82 foot per foot to about 0.59 foot per foot. The vertical gradient from the Beulah-Zap lignite downward to the basal Sentinel Butte sandstone unit ranges from 0.62 to 0.37 foot per foot. These data indicate that the vertical hydraulic gradient in the Sentinel Butte decreases with increasing depth.

The horizontal hydraulic gradient in the basal Sentinel Butte sandstone unit could not be defined with available data. The gradient in the Beulah-Zap lignite is about 5 feet per mile.

The water levels in the basal Sentinel Butte sandstone unit are fairly persistent across the study area and appear to be controlled by the level of Lake Sakakawea. The lake acts as a constant head boundary for the aquifers in the basal Sentinel Butte sandstone and provides the major part of the recharge to this aquifer. Some recharge also is derived from small amounts of leakage through overlying sediments. There are no known areas of discharge for the basal Sentinel Butte sandstone in the study area.

Ground water in the Beulah-Zap lignite moves from the highlands area in the west toward the Antelope Creek tributary valley. Water-level data indicate unconfined conditions near the outcrop along the Antelope Creek tributary valley, and here the lignite acts as a water-table aquifer. Discharge from the lignite occurs along the valley flanks as seepage from small springs. Although no flow measurements were made, visual inspections indicate the spring flows are minimal. During the growing season, water is probably discharged from the lignite by evapotranspiration.

Recharge to the Beulah-Zap lignite results from downward leakage from overlying sediments and by infiltration of precipitation in areas of outcrop and thin overburden cover.

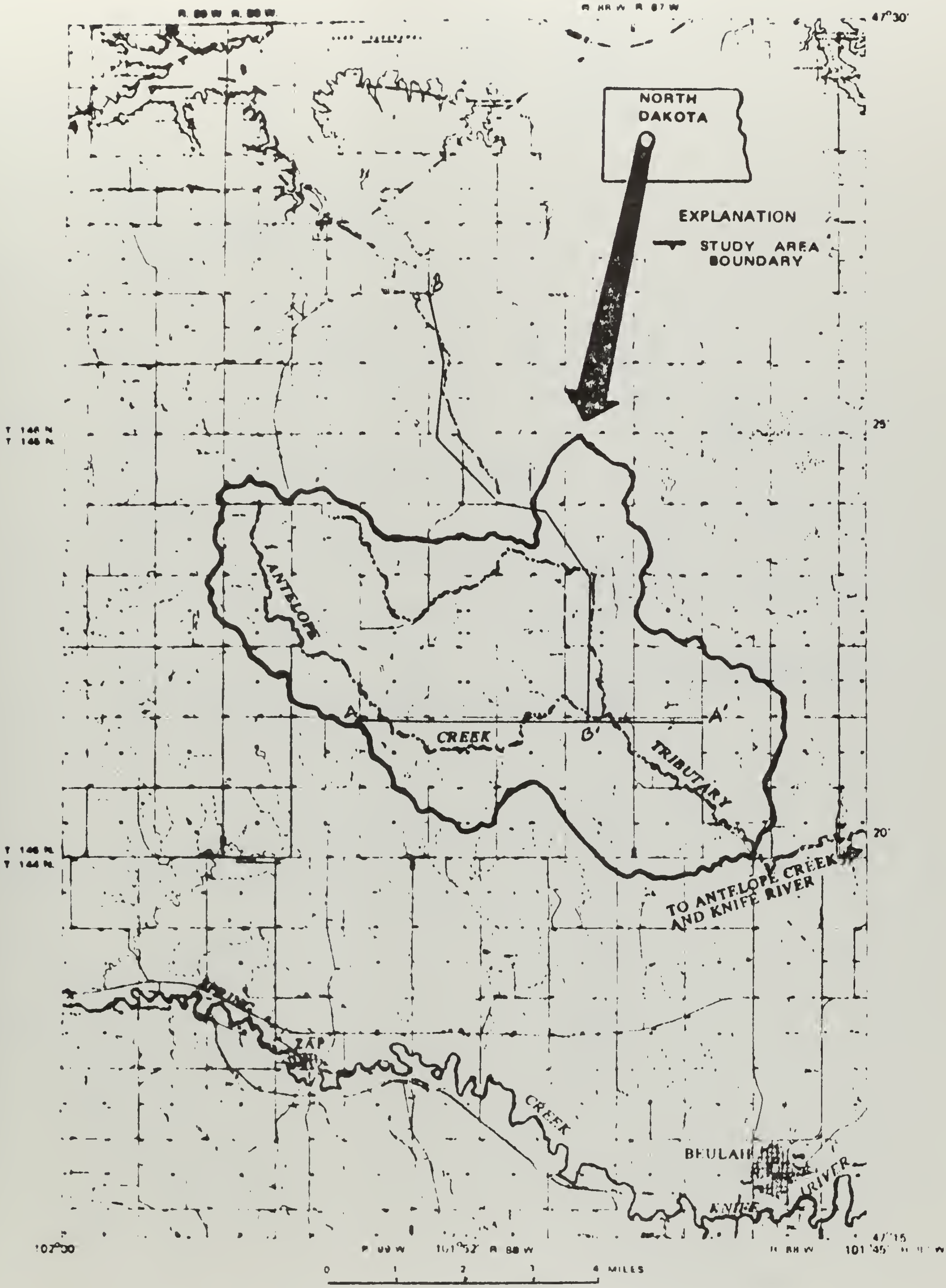


Figure 14 – **Location of Antelope Creek tributary study area in Mercer County, North Dakota.**

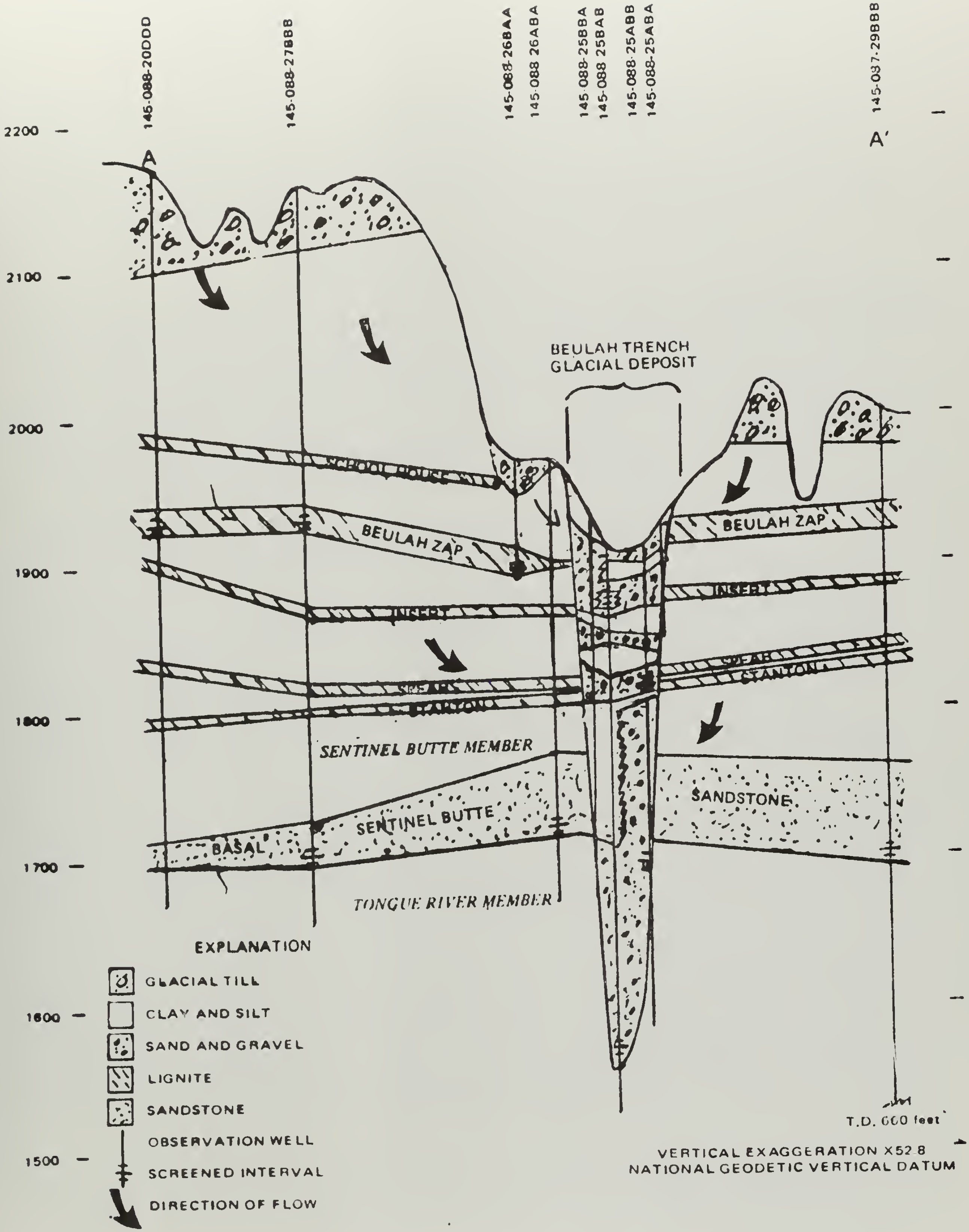


Figure 15 - Geohydrologic cross section across Beulah Trench glacial deposit.

In three water samples collected from wells in the Beulah-Zap lignite aquifer, sodium plus potassium constituted 29, 70, and 95 percent of the cations, and bicarbonate constituted 40, 67, and 85 percent of the anions present. Total dissolved solids were 723, 1,050, and 1,170 mg/L.

Composition of the water in the Beulah-Zap lignite appears to be variable based on the three samples. Trace metals were found only in low concentrations, probably due to the low solubility of these trace metals in alkaline water such as those in the Beulah Trench area. Only barium (100 ug/L) concentrations in the waters of the Beulah-Zap lignite aquifer appear to exceed those determined in the overlying aquifers.

Antelope Creek Aquifer

The Antelope Creek aquifer underlies the Beulah Trench between Lake Sakakawea and Spring Creek and the Knife River. The valley is less than 1 mile wide and is approximately 16 miles long in the study area. The deposits forming the aquifer consist of glaciofluvial sand and gravel interbedded with silt and clay (Fig. 16). Overlying these deposits are from 10 to 30 feet of alluvium composed of sandy silt and clay. The aquifer reaches a maximum local thickness of 330 feet. The glaciofluvial material overlies the Tongue River Member of the Fort Union Formation.

The sand and gravel deposits of the aquifer for the most part are unconsolidated and are highly permeable.

The Antelope Creek aquifer has two basic units; a thick and continuous sand and gravel unit at the base, overlain by a unit of interbedded sand, gravel, silt, and clay. The basal sand and gravel unit has a maximum known thickness of 140 feet near the southern end of the area, decreases to less than 50 feet near the central part, and again increases to a thickness of 120 feet at the northern end. The hydraulic conductivity of the basal unit, as estimated from grain-size and grain-sorting characteristics, is from 100 to 200 feet per day.

The basal unit is a highly permeable conduit connecting Lake Sakakawea and the Knife River. However, at this time data are not sufficient to determine whether or not movement of water from the lake to the Knife River occurs. Lake Sakakawea acts as a constant head boundary for the basal aquifer unit. The pool elevation of the lake is reflected in water levels of wells in the basal unit. A well located in SE¼ sec. 21, T. 146 N., R. 88 W., at the north end of the Antelope Creek aquifer, less than 1/2 mile from the edge of Beaver Bay on Lake Sakakawea, has water-level elevations about the same as the pool elevation of the lake. As the lake level fluctuates, the water level in this well reflects the change very rapidly. A well in SW¼ sec. 2, T. 145 N., R. 88 W., is located approximately 4 miles from Beaver Bay; its water level also reflects the level of the lake, but with a dampened effect and with several days delay.

When Lake Sakakawea is at maximum pool elevation (1,850 feet), the lake recharges the Antelope Creek aquifer. As the lake level drops, the ground-water flow direction is reversed, and ground water flows from the aquifer to Lake Sakakawea.

The horizontal hydraulic gradient in the basal unit is very gradual and fluctuates with changes in the level of the lake. The vertical hydraulic gradient in the basal aquifer unit is less than 0.1 foot per foot.

The interbedded sand, gravel, silt, and clay of the upper unit has an estimated hydraulic conductivity of 10 to 40 feet per day.

Water levels in wells screened in sand and gravel beds in the upper part of the Antelope Creek aquifer indicate that ground water moves from the surface downward. The vertical hydraulic gradient from the surface to a depth of 100 feet ranges from 0.45 foot per foot to about 0.33 foot per foot. The gradient decreases with increasing depth. The vertical gradient from a depth of 100 feet to the basal aquifer unit becomes less, ranging from 0.26 foot per foot to less than 0.10 foot per foot. The horizontal hydraulic gradient measured in the sand and gravel beds in the upper unit ranges from 16 to 4 feet per mile. North of a well in the NW¼ sec. 13, T. 145 N., R. 88 W., the ground water flow in the upper unit is northward toward Lake Sakakawea, and south of this well ground-water flow is southward toward the Knife River, indicating that the area near this well is a ground water divide.

The upper part of the Antelope Creek aquifer is recharged by infiltration or precipitation.

Fifteen water samples collected from various zones in the Antelope Creek aquifer were analyzed to determine their chemical composition. Cation compositions within the Antelope Creek aquifer were found to be a mixed type including calcium, magnesium, and sodium. The dominant anion was bicarbonate.

Sodium plus potassium comprised from 15 to 77 percent of the cations present, and bicarbonate plus carbonate from 65 to 87 percent of the anions. Total dissolved solids ranged from 383 to 1,320 mg/L. Ground water pH was relatively constant, ranging from 7.20 to 7.90.

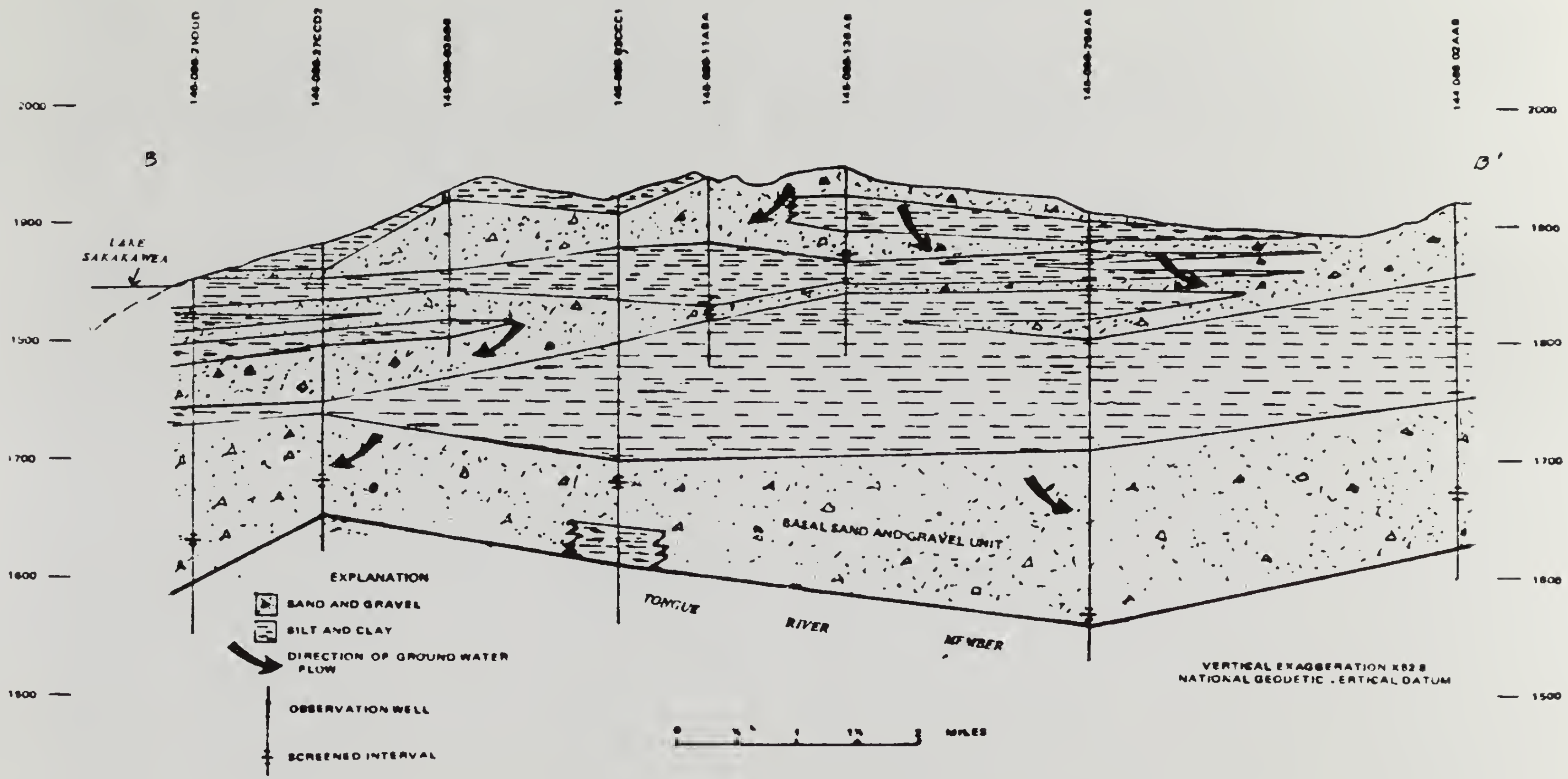
Surface Water

The study area is drained by an unnamed tributary of Antelope Creek. This tributary enters Antelope Creek about 9 miles above its confluence with the Knife River. The drainage is generally well connected, although there are isolated areas of shallow potholes or depressions and scattered manmade stock-watering ponds.

Antelope Creek tributary is an ephemeral stream with most of the flow usually occurring during the spring snowmelt period. Although only 20 percent of the yearly precipitation occurs as snow during the months of October to March, most of the annual runoff is from snowmelt because frozen ground conditions permit little infiltration during the usually rapid melting of the snowpack.

Application of a regression equation, based on other small basin streamflow records and physical parameters from western North Dakota to the study area, suggests a mean annual runoff of 2,050 acre-feet with a mean standard error of 33 percent.

Figure 16



Geologic cross section through the Beulah Trench glacial deposit in the study area

Water quality samples were obtained at seven surface water sites in the study area. Samples were taken during the rainfall-runoff period of June 15 and 16, 1977, and during the spring runoff of March 1978.

Water in the Antelope Creek tributary at the lower end of the study area was a calcium-magnesium bicarbonate type for all samples analyzed. Calcium never exceeded 45 percent of the cations, and magnesium never exceeded 30 percent of the cations. Water quality at this site did not vary significantly between rainfall runoff and snowmelt runoff. Total dissolved-solids concentrations were relatively low, remaining within a narrow range between 76 and 136 mg/L and varying inversely with measured discharge.

Antelope Creek tributary water in NW¼ sec. 26, T. 145 N., R. 88 W., was principally of calcium-magnesium bicarbonate-sulfate type. Although the discharge varied by about one order of magnitude between samples, the snowmelt runoff remained quite similar in composition; calcium never exceeded 45 percent and magnesium never exceed 35 percent of the cations, and bicarbonate never exceeded 55 percent and sulfate never exceeded 46 percent of the anions. The average dissolved-solids concentration in these samples was 151 mg/L. However, the quality of water from the June 15, 1978, rainfall runoff event was significantly different from the snowmelt samples of March 22, 1978, even though discharges were about the same. In the rainfall runoff sample, calcium and magnesium comprised 34 percent of the cations each, while bicarbonate comprised 26 percent and sulfate 73 percent of the anions. The dissolved-solids concentration was 626 mg/L, which is much higher than for snowmelt runoff. This variation is probably due to increased amounts of ground water entering the stream, either spatially or temporally due to the resumption of infiltration after the ground thawed.

Suspended sediment samples were collected for a runoff period in June 1977 and for several periods of runoff in 1978. The sediment concentrations vary for a given discharge by one to two orders of magnitude. This variability precludes quantitative conclusions, but the data indicate a roughly inverse relationship between concentration and discharge. A greater contribution of sediment during the summer rainfall events than during the spring runoff event is suggested by the data.

Hydrologic Classification of Land Types Using Rainfall Simulation

The Beulah Trench Study Area was divided into four major land classes, A, B, C, and D. These classes possess runoff characteristics which are similar over its areal extent. Rainfall-simulation runs were made on two of the land classes in September 1976 to determine the hydrologic characteristics. These baseline data will be the basis for comparison with future changes which might occur from surface mining, or other changes in land use.

A hydrologic classification map of the area was prepared using aerial photographs (Plate 34). Locations where the simulation runs were made are also shown on Plate 34. Responses similar to those obtained from the applied simulated rainfall could be expected from areas of the same hydrologic class shown on the map. The simulation sites were chosen to be representative of the soil, vegetation, and relief within each hydrologic class. Photographs of the sites are shown in Figures 17 and 18. Runoff and sediment-yield values may have to be altered somewhat to compensate for radically dissimilar slopes and soil depth. Data obtained at the sites are shown in Table 76.

Methods used to obtain the data from each simulation site listed in Table 76 are as follows:

1. Runoff--Measured in a Parshall flume with 1-inch throat. Readings of stage made at 1-minute intervals and converted to discharge in cubic feet per second. From these data, a runoff hydrograph was constructed and total volume of runoff was computed and expressed in inches per unit area. Also from these data, an infiltration-rate curve was constructed by subtracting the runoff from the rainfall applied for each 1-minute interval and expressed as the infiltration rate in inches per hour.

2. Precipitation--Measured in a network of rain gages within the study area. Rainfall for the total area was computed using the Thiessen polygon method.

3. Sediment yield--Water samples were obtained from the outflow at 3-minute intervals and were analyzed for sediment concentration. The sediment concentrations were plotted and a concentration curve was drawn between points. From this curve, a concentration was obtained for each minute to compute the sediment load. Total sediment load is expressed in pounds and in tons per square mile.

4. Area--Obtained from a topographic survey of the site and expressed in square feet.

5. Weighted mean slope--Obtained by measuring the area between contours and weighting the slope of that area according to the percentage the area is of the whole.

6. Antecedent moisture--Obtained from gravimetric samples of the top 10 centimeters of soil. Samples were usually taken at four locations within the site and averaged for the final result. Expressed as percentage by weight. Two runs are normally made at each site. The first is made in a dry condition and the second after water in the soil has come to a gravimetric equilibrium. Soil-moisture samples were taken before each run.

7. Clay--Obtained from soil samples taken from the top 10 centimeters of soil at numerous locations within the site. Samples were analyzed for percentage by weight of material less than 0.002 millimeters in diameter.

8. Root concentration--The amount of fibrous root material in the top 10 centimeters of soil. Expressed in grams per 100 grams of soil.

Plate 34

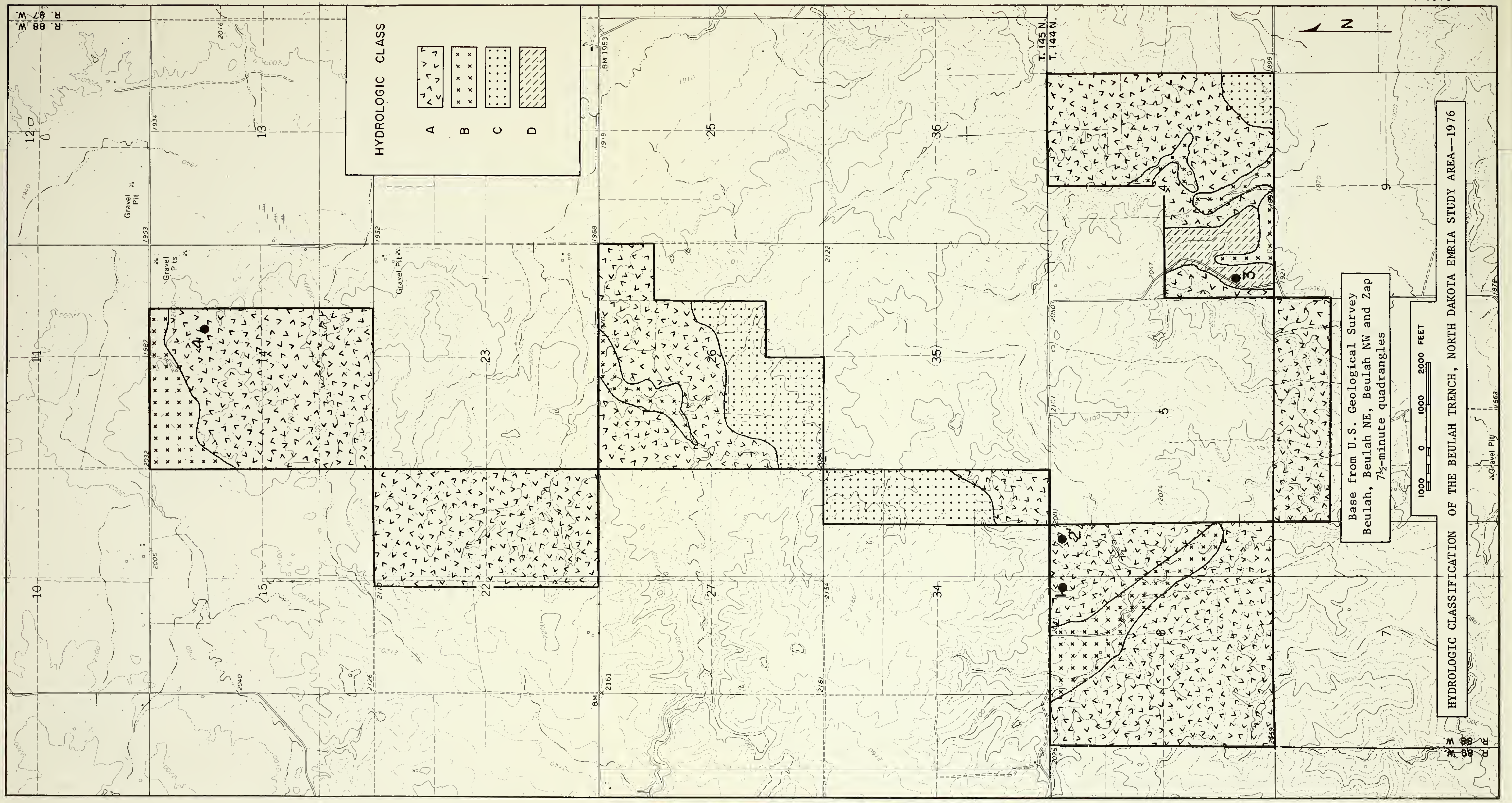

HYDROLOGIC CLASS
A
B
C
D
N
T. 145 N.
T. 144 N.
R. 88 W.
R. 87 W.
R. 89 W.
R. 88 W.
Gravel Pit
Gravel Pits
BM 1953
Base from U.S. Geological Survey
Beulah, Beulah NE, Beulah NW and Zap
7½-minute quadrangles
1000 0 1000 2000 FEET
HYDROLOGIC CLASSIFICATION OF THE BEULAH TRENCH, NORTH DAKOTA EMRIA STUDY AREA--1976

Figure 17 --Rainfall simulation is shown on site 1 in the top photograph. A point frame for measuring the vegetation is shown on site 2 in the bottom photograph.

Figure 18--Rainfall simulation on site 3 in the top photograph and on site 4 in the bottom photograph.

Table 76 --Data obtained from simulation sites at Beulah Trench study area.
(1 in second part of site designation indicates dry run; 2 indicates wet run)

Variable	Site 1-1	1-2	2-1	2-2	3-1	3-2	4-1	4-2
Date	9-21-76	9-21-76	9-17-76	9-18-76	9-25-76	9-27-76	9-23-76	9-24-76
Area (sq. ft.)	2,510	2,510	2,290	2,290	2,275	2,275	2,662	2,662
Weighted mean slope (percent)	14.2	14.2	9.8	9.8	24.1	24.1	9.4	9.4
Antecedent moisture (percent)	14.2	17.0	17.1	19.8	13.8	22.6	19.1	27.7
Clay (percent)	20.6	20.6	20.5	20.5	30.5	30.5	37.2	37.2
Root concentration (g/100 g)	2.559	2.559	3.032	3.032	4.168	4.168	2.998	2.998
Bare soil and rock (percent)	1.3	1.3	2.3	2.3	.3	.3	5.0	5.0
Precipitation (inches)	1.39	1.69	1.61	1.83	1.85	1.98	1.64	1.73
Runoff (inches)	.58	.67	.31	.21	.19	.14	.61	.63
Sediment								
pounds	5.92	13.08	3.00	1.58	1.67	.97	5.11	7.99
tons per sq. mi.	32.9	72.6	18.3	9.6	10.2	5.9	26.8	41.8
Reconstructed runoff (inches)	.67	.55	.22	.04	0	0	.49	.45
Surface soil bulk density g/cm^3	1.19	1.25	.99	1.0	.83	.94	1.06	1.04

9. Bare soil and rock--Obtained from three 20-foot transects within each site using a point frame and the first contact point method. Pins lowered to the vegetation or ground surface at 2-inch intervals are recorded at first encountering of aerial vegetation, mulch, bare soil, or rock. Expressed as hits per 100 pins or percent cover.

10. Reconstructed runoff--Rainfall applied normally varies somewhat about the standard of 1.5 inches in 45 minutes. In order to compare runoff results on a standard basis, a runoff hydrograph is reconstructed by determining the runoff that would result from subtracting the infiltrated water determined during the simulation event from the water applied during a standard storm of 1.5 inches in 45 minutes for each minute increment.

Chemical Analyses

Samples of the outflow from each site were obtained at 3-minute intervals for chemical analyses. These samples were composited in sequential groups so that three or four samples were obtained for the entire runoff period. An analysis was made on each composite sample for the items listed in Table 77, Appendix H. An analysis of the water applied is used as a standard and other values listed are either an increase (+) or decrease (-) of these values in the runoff water.

Maximum Daily Precipitation - Frequency of Recurrence

A frequency of recurrence of maximum daily precipitation during the months April through October at Dickinson, North Dakota is shown in Figure 19. From this curve, the following data on the magnitude of storms of various recurrence intervals were obtained. The data give a general idea of storms at the study area.

Recurrence interval (years)	Precipitation (inches)
2.33	1.67
10.00	2.55
25.00	3.07
50.00	3.45

Hydrologic Classes

A description of each simulation site and of each hydrologic class follows. A list of precipitation events of different recurrence intervals and durations that were obtained from Weather Bureau Technical Paper 40 are also shown for each site. The volume of runoff that might be expected from storms of this type was computed using infiltration rates obtained from the dry-condition simulation events.

Class A

This class consists of rolling uplands generally covered with a dense sod made up of native grasses and used for livestock grazing. The amount of clay in the soil may vary considerably from one location to another, but generally appears to increase from south to north. The following data were obtained from the simulation sites:

Site 1

Weighted mean slope = 14.2 percent

Clay = 20.6 percent

Bare soil and rock = 1.3 percent

Location - section 6

Aspect - east

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude in inches (M), and antecedent moisture, in percent (AM)

RI/D/M	AM = 14.2	AM = 17.0
2/30/0.80	.25	.17
10/20/1.30	.66	.54
25/30/1.60	.94	.81
50/30/1.80	1.16	1.03
2/60/1.10	.21	.11
10/60/1.70	.71	.57
25/60/2.00	.97	.81
50/60/2.30	1.22	1.06

Site 2

Weighted mean slope = 9.8 percent

Clay = 20.5 percent

Bare soil and rock = 2.3 percent

Location - section 6

Aspect - west

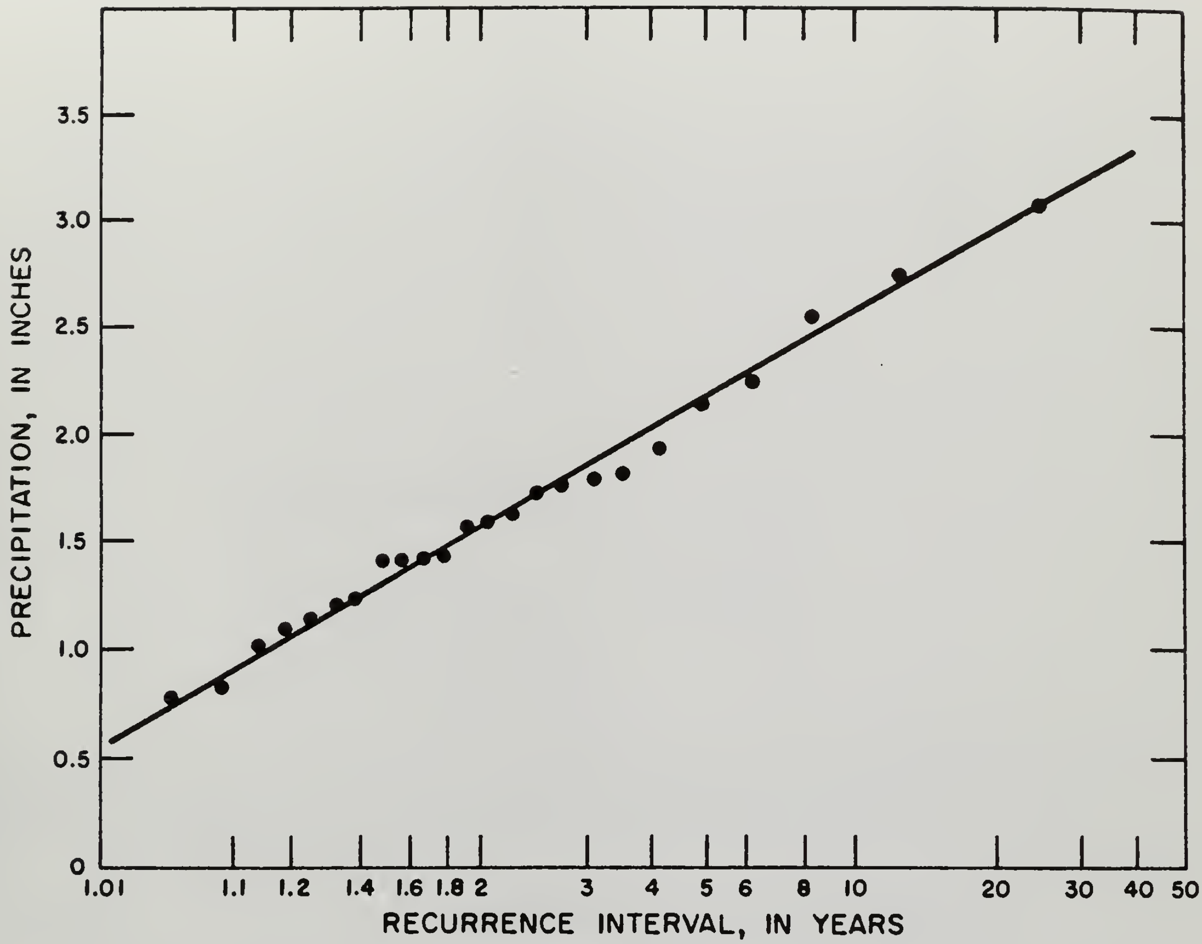


Figure 19 --Recurrence of maximum yearly 24-hour rainfall (Apr-Oct) at Dickinson, North Dakota.

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

RI/D/M	AM = 17.1	AM = 17.0
2/30/0.80	.02	.00
10/30/1.30	.42	.00
25/30/1.60	.72	.52
50/30/1.80	.94	.74
2/60/1.10	.00	.00
10/60/1.70	.05	.00
25/60/2.00	.26	.05
50/60/2.30	.52	.27

Site 4

Weighted mean slope = 9.4 percent

Clay = 37.2 percent

Bare soil and rock = 5.0 percent

Location - section 14

Aspect - south

Expected runoff, in inches, from storms of designated recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

RI/D/M	AM = 19.1	AM = 27.7
2/30/0.80	.12	.09
10/30/1.30	.55	.50
25/30/1.60	.89	.82
50/30/1.80	1.12	1.03
2/60/1.10	.00	.00
10/60/1.70	.41	.37
25/60/2.00	.68	.64
50/60/2.30	.96	.91

Class B

This class consists of cultivated land bordering stream channels or drainageways. Slopes are very flat and, because of this fact, runoff would probably not be excessive although infiltration rates may not be very high. No simulation runs were made on this class because it is all private cultivated land.

Class C

This class consists of cultivated rolling hills. No simulation runs were made on this type. The soil texture is probably similar to those sites in class A. Because the sod cover present on class A soils is absent here, erosion rates are probably much greater. Infiltration rates may be increased on recently tilled soils.

Class D

This class consists of an area in section 4 that overlies a coal seam that is close to the surface. Although the clay content of the soil is fairly high, the permeability of the soil is good because of a dense root network and a porous, rocky underlying strata composed of baked rock (clinker). The following data were obtained from simulation site 3:

Weighted mean slope = 24.1 percent

Clay = 30.5 percent

Bare soil and rock = 0.3 percent

Location - section 4

Aspect - northeast

Expected runoff, in inches, from storms of designed recurrence interval, in years (RI), duration, in minutes (D), magnitude, in inches (M), and antecedent moisture, in percent (AM)

RI/D/M	AM = 13.8	AM = 22.6
2/30/0.80	.00	.00
10/30/1.30	.18	.05
25/30/1.60	.48	.26
50/30/1.80	.70	.48
2/60/1.10	.00	.00
10/60/1.70	.00	.00
25/60/2.00	.03	.00
50/60/2.30	.10	.00

Hydrologic Responses of Simulation Sites

The curves for runoff, sediment concentrations, and infiltration rates are shown in Figures 20 through 27. The horizontal segments on the left ends of the infiltration curves represent the rainfall rates, which were exceeded by the infiltration rates early in the runs.

Sediment Yields

The sediment-yield values presented for this area were derived using a numerical rating method developed by the Pacific Southwest Inter-agency Committee (PSIAC) (1968). They have been judged to be reasonably accurate but they have been only partially verified by field measurements.

The mapping units that are the basis of this evaluation are sediment source areas. A source area is a small drainage area occurring on a single landform type or an inseparable complex of landforms and usually is only part of a complete drainage basin. The PSIAC method is used to assess the hydrologic variation of the given landforms as well as to make estimates of sediment yield from them. Numerical ratings are assigned for each of the nine factors of the PSIAC method to representative sediment-source areas in accordance with the degree of influence each factor has on the sediment yield from the area. These nine factors are surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and sediment transport. The method was developed to make broad sediment-yield classifications for large areas, such as river subbasins, but Shown (1970) found that the method provides reasonable estimates for small drainage basins (.02-7.5 mi^2). In applying the method on source areas, some adjustments are made because a complete drainage system is not being considered. Alluvial-fan and flood-plain development are not considered in the topography factor and sediment-transport capabilities are not considered for channels that originate in upslope source areas and that cross through the source area being rated. These factors are taken into account later when making estimates of sediment discharge from drainage basins.

Interpretations of aerial photographs (1:24,000) were used to extend the source-area sediment-yield estimates to those areas that were not rated during field investigations. This was accomplished with a stereo plotter and resulted in the source-area sediment-yield map which is Plate 35, Appendix H. The slope data shown in Plate 35, Appendix H, were obtained from the 1:24,000 USGS topographic quadrangles.

The complete main channel system was classified and mapped according to channel type and condition (Plate 36, Appendix H) to aid in assessing channel erosion and sediment transport. The channel classification was done by interpretation of the aerial photography, and only those channels that were larger than third or fourth order according to Strahler's (1952) classification were delineated.

Estimates of average annual sediment discharge for basins A through E (Plate 36, Appendix H) were made by applying sediment-conveyance factors to the area-weighted average source-area sediment yields. The sediment-conveyance factor represents that proportion of sediment that is yielded from one source area and not left stranded on another source area, plus sediment that is conveyed through main channels and principal tributaries and not deposited in the channels or on bottomlands or alluvial fans. The method reported by Frickel and others (1975) was used to estimate the sediment-conveyance factors. The channel information shown on Plate 36, Appendix H, was used in making the estimates.

Where a basin was downstream from another, the sediment discharged from the upper basin was routed through the main channel of the lower basin. Adjustments were made in some cases where deposition along the channel in the lower basin was apparent from aerial photographs. The sediment discharge at the mouth of the lower basin, therefore, includes contributions from that basin and all of the basins upstream.

Source-Area Sediment Yields

Source-area sediment yields (Plate 35, Appendix H) for most of the study area are low, although variable, owing to the relatively high organic matter contents of the surface soils and the excellent vegetation cover of the rangelands. Sediment yields from the croplands are higher than from the rangelands and are highest from hummocky, cultivated fields. The lack of protective cover while the fields are in fallow, the destruction of aggregates by tillage operations, and compaction by many farming operations causes reduced infiltration and greater runoff and erosion from the croplands. The sediment-yield estimates do not include fine-grained particles of soil that are suspended and transported from the area by wind. Other than some rilling at times in some of the cultivated fields, there is very little channel erosion in the area because the channels are stabilized with vegetation; also, the excellent cover of the rangelands, conservation practices on the croplands, and various impoundments of water prevent the regular occurrence of floods large enough to erode the channels. Headcuts exist in some channels as indicated on Plate 36, Appendix H; however, their headward migration appears to be very slow.

Sediment Discharge from Drainage Basins

Estimated annual sediment discharges from drainage basins are, in general, extremely low (Table 78), owing to several other causes in addition to the low rates of erosion on and sediment yield from source areas. First, all of the basins, with the exception of basin C, have some closed drainage areas which support potholes. This reduces the contributing areas of the basins, particularly of basins A and B where it is estimated that 60 percent of their areas do not contribute to flow at their mouths. Second, all of the basins contain stock ponds or natural sumps which trap considerable sediment. Thirdly, from interpretation of aerial photographs and observation of channels in the area, it is apparent that there is significant infiltration of water from flows occurring in the main channels of the alluvial-filled valleys (trenches). This reduces the capability of the flow to transport sediment; therefore, particularly the coarser fraction of the sediment is deposited on lowland fields and channel beds.

Another factor causing low sediment discharges from basins is that most channels, whether trenched or untrenched, have vegetated beds (Plate 36).

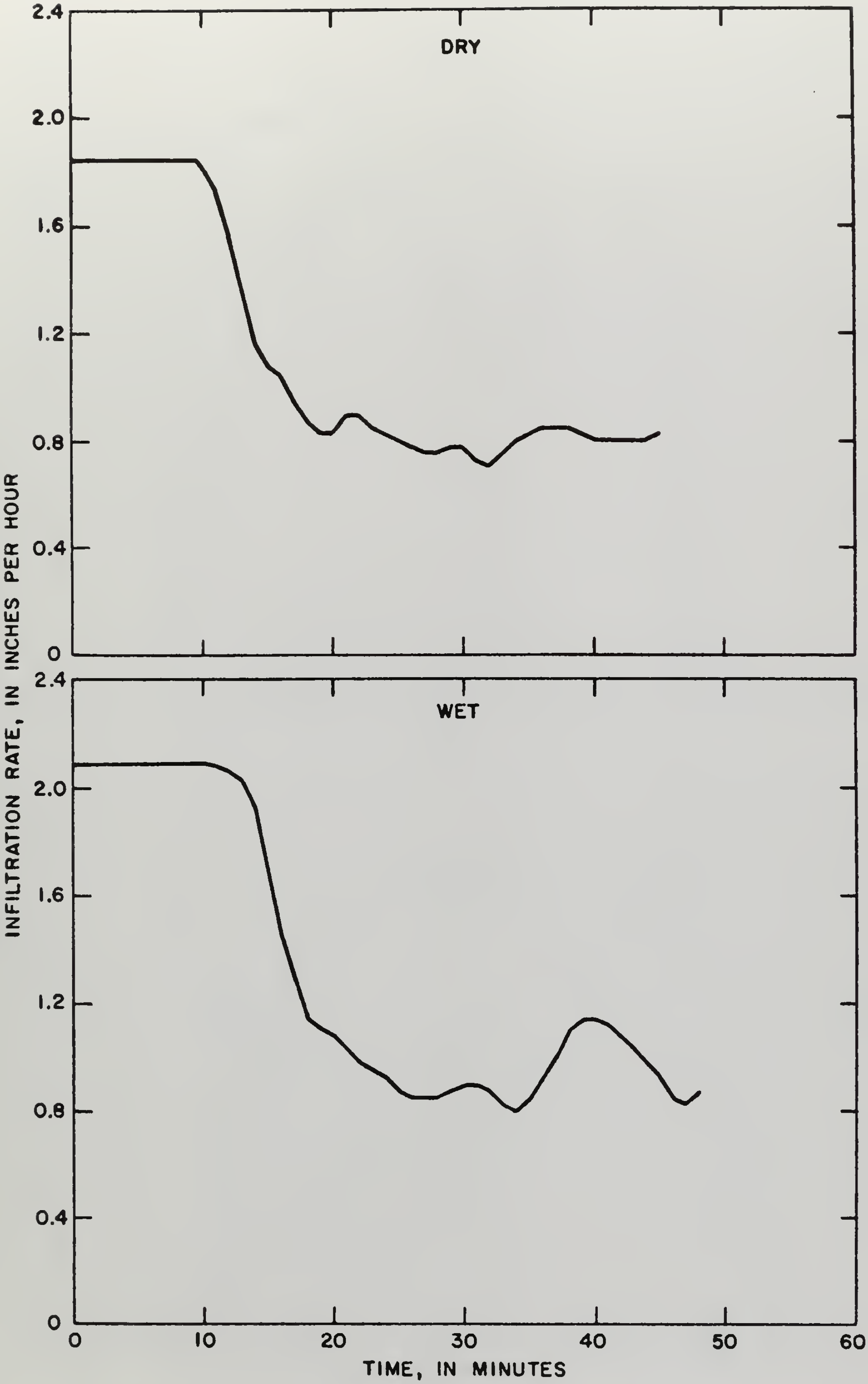


Figure 20--Infiltration curves for site 1.

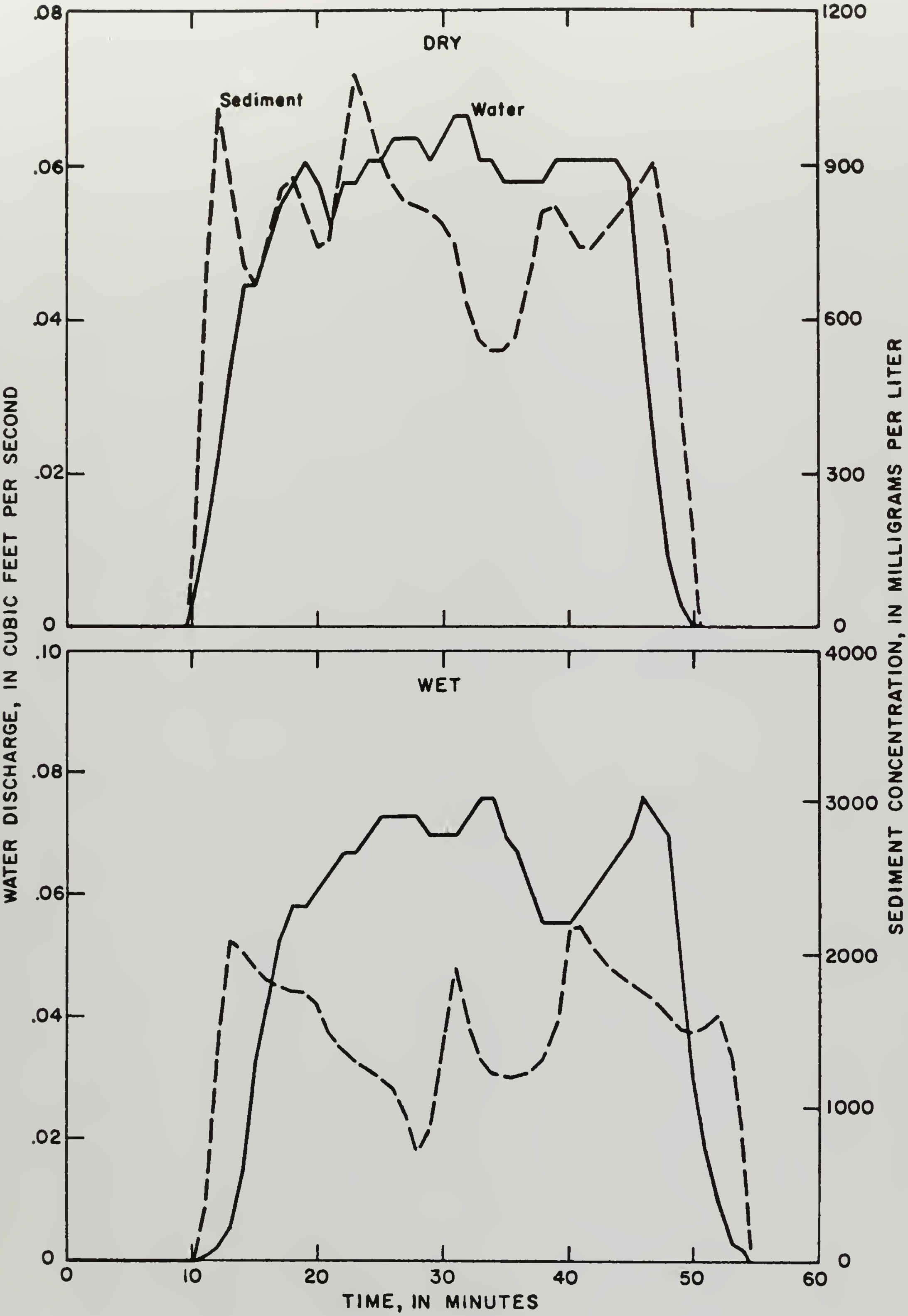


Figure 21 --Runoff and sediment-concentraction curves for site 1.

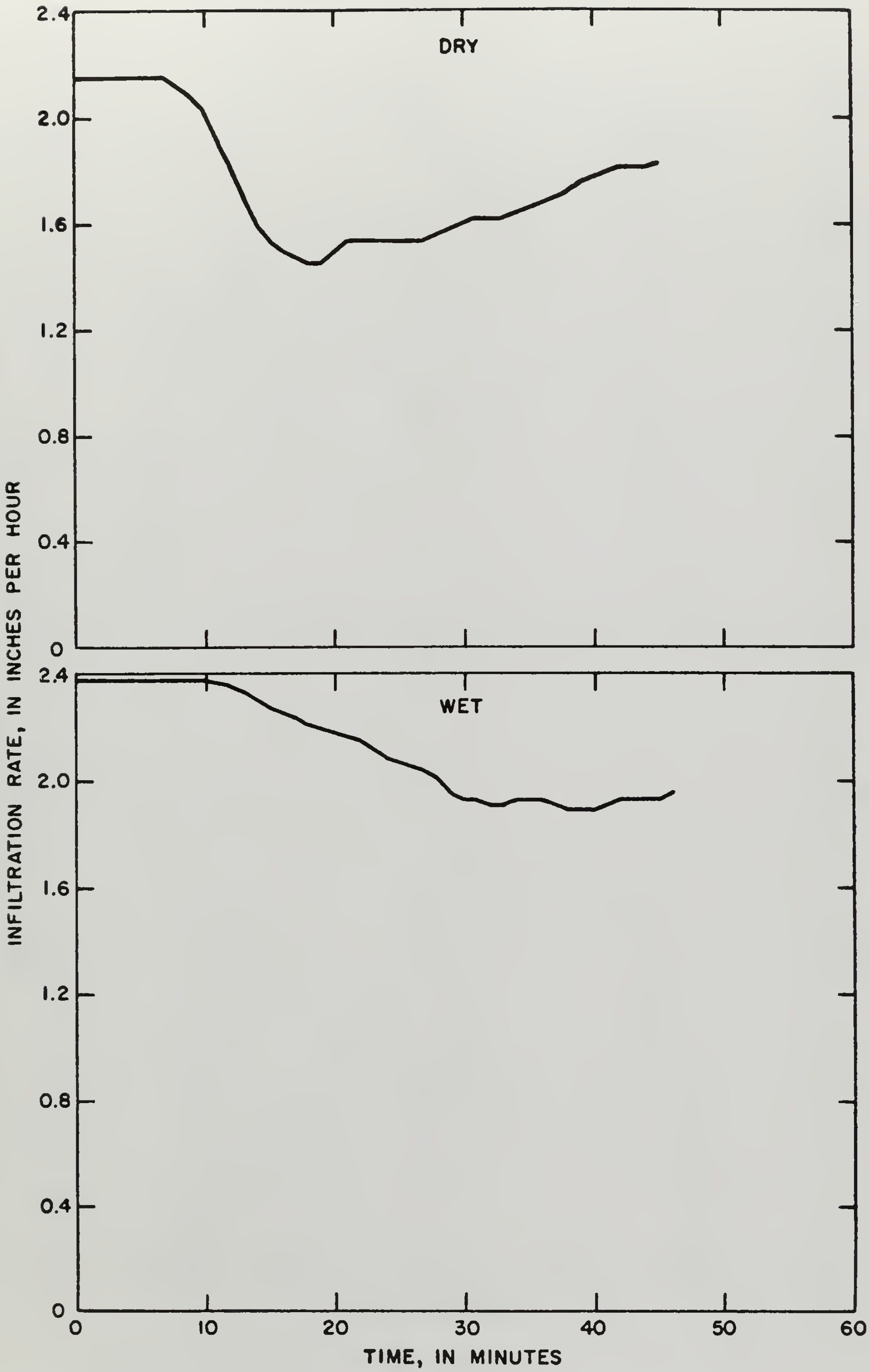


Figure 22 --Infiltration curves for site 2.

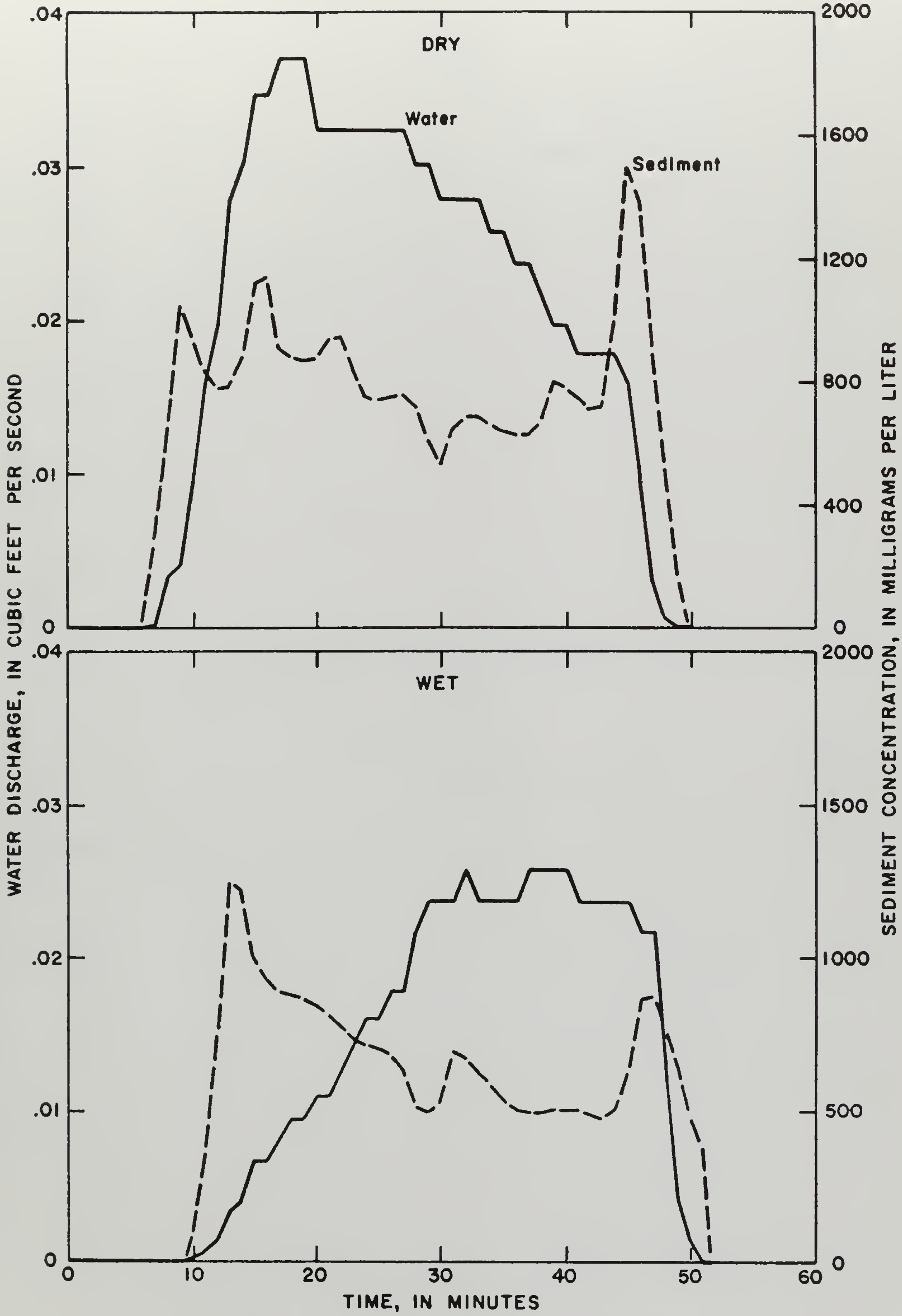


Figure 23--Runoff and sediment concentration curves for site 2.

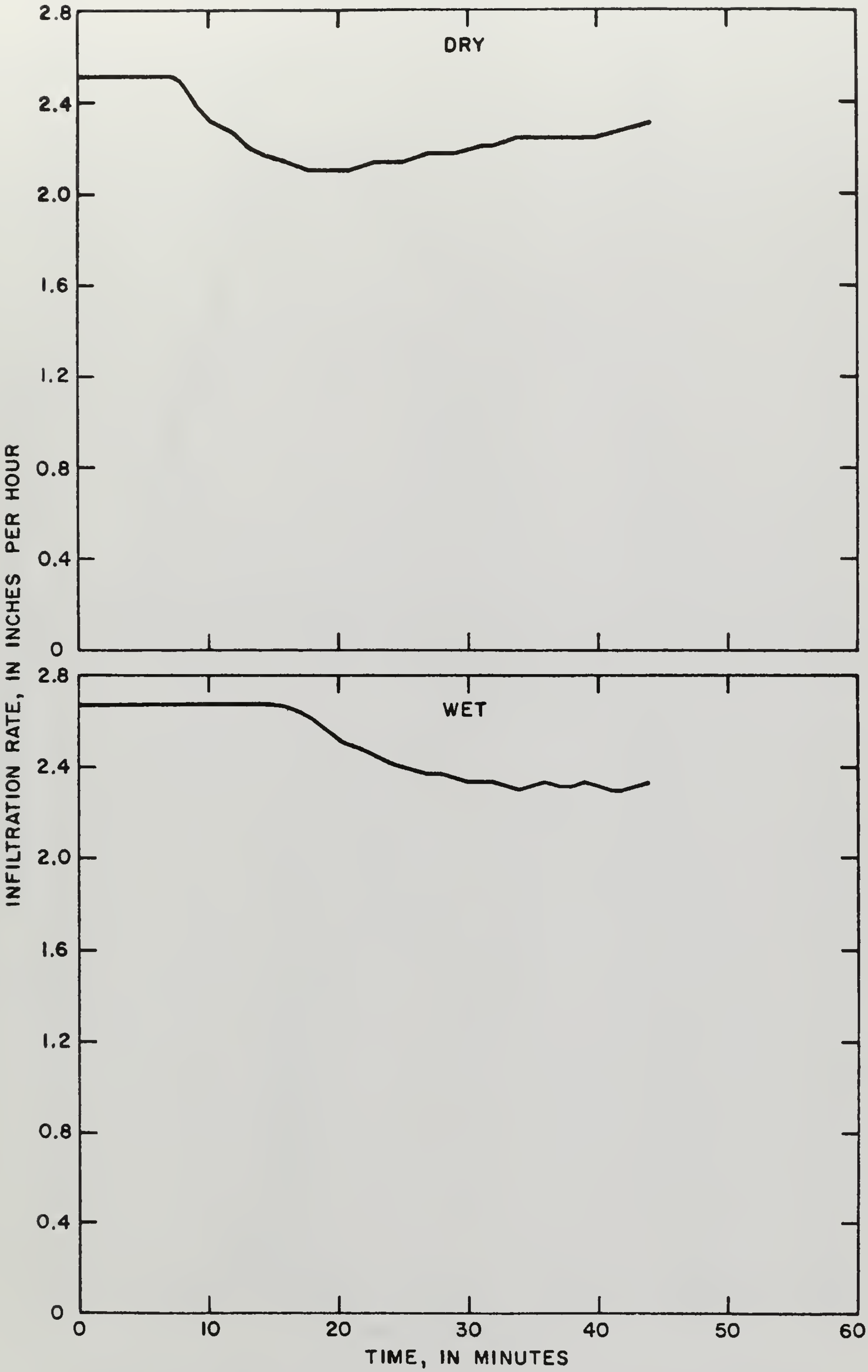


Figure 24--Infiltration curves for site 3.

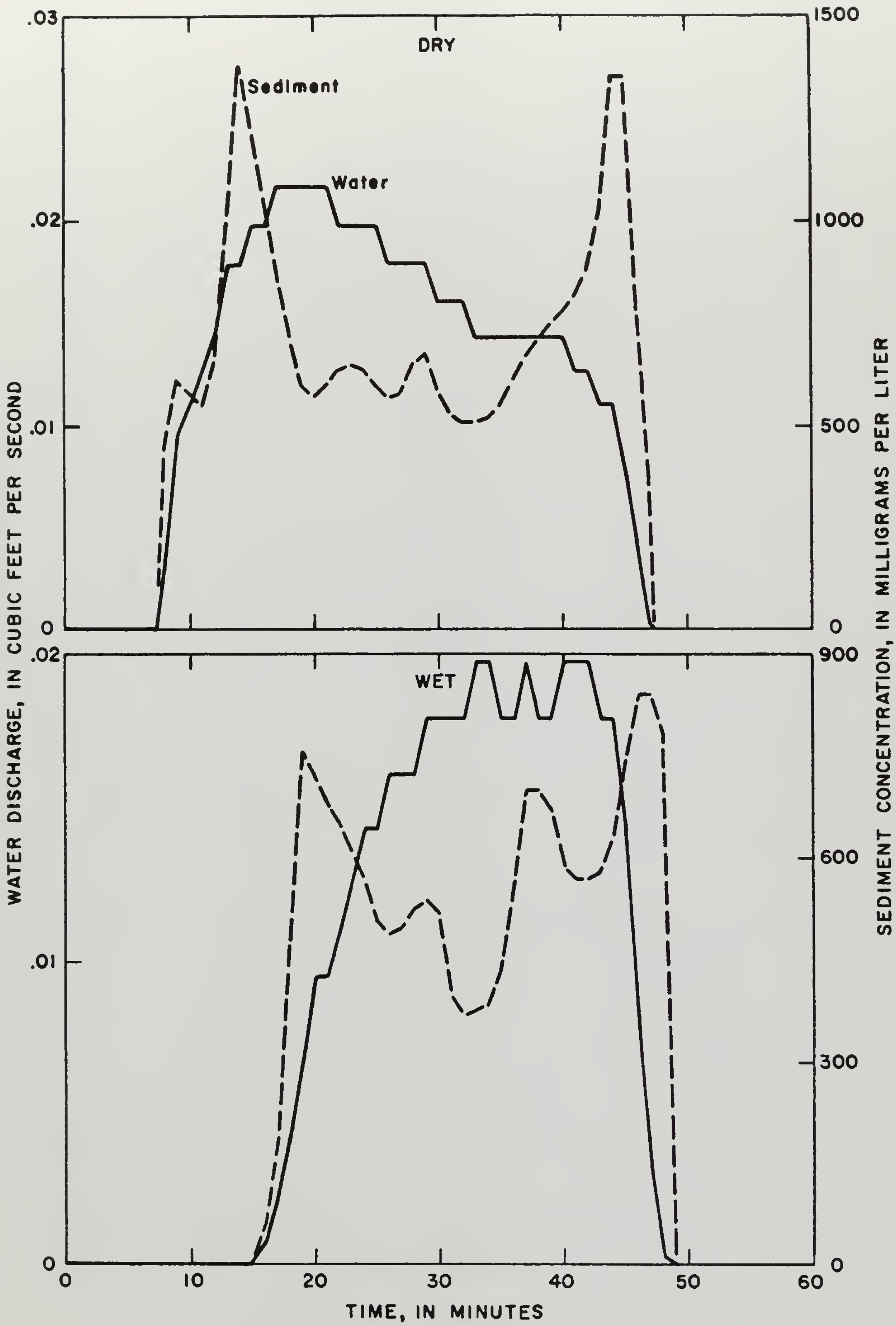


Figure 25 --Runoff and sediment-concentration curves for site 3.

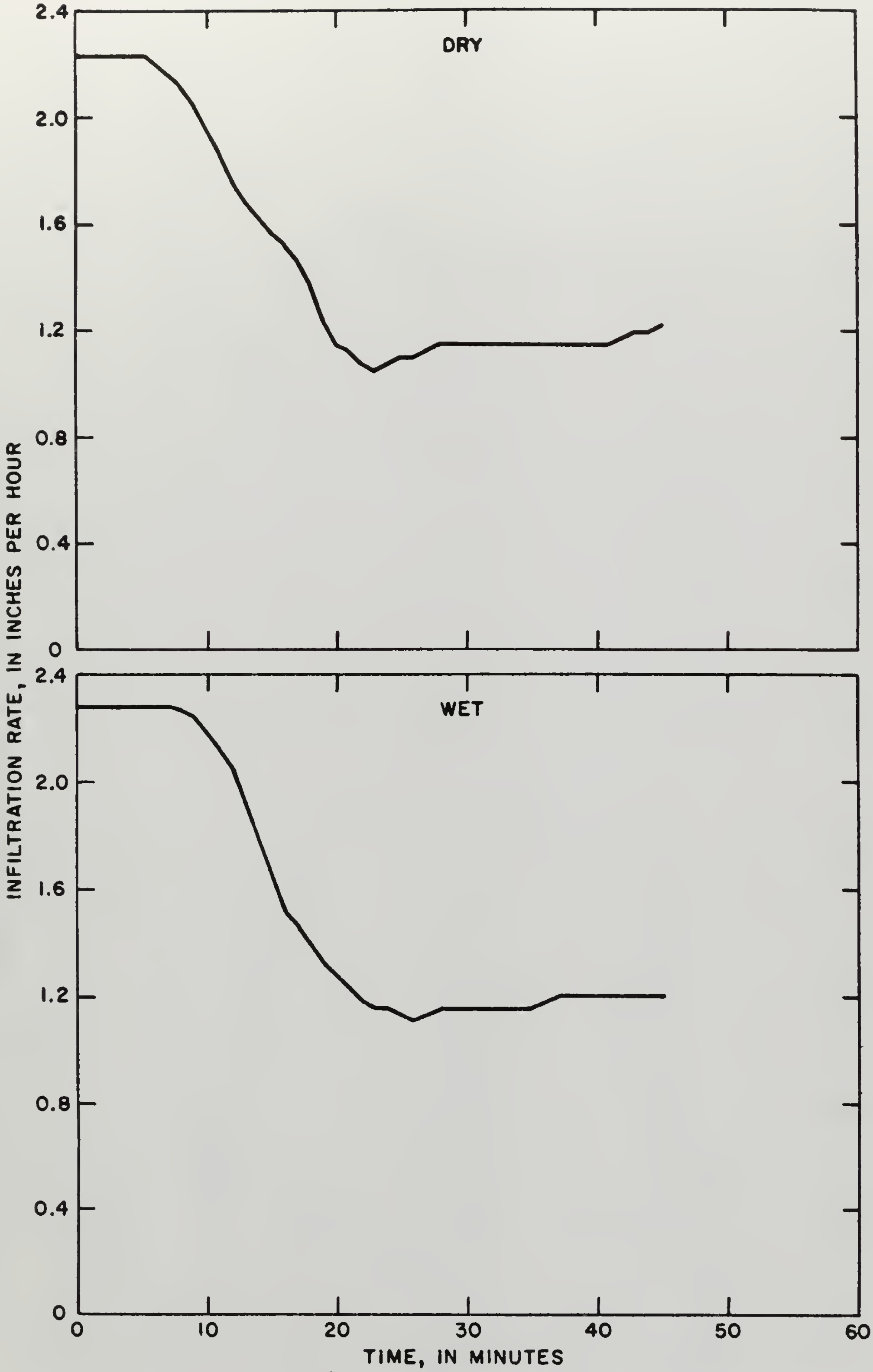


Figure 26 --Infiltration curves for site 4.

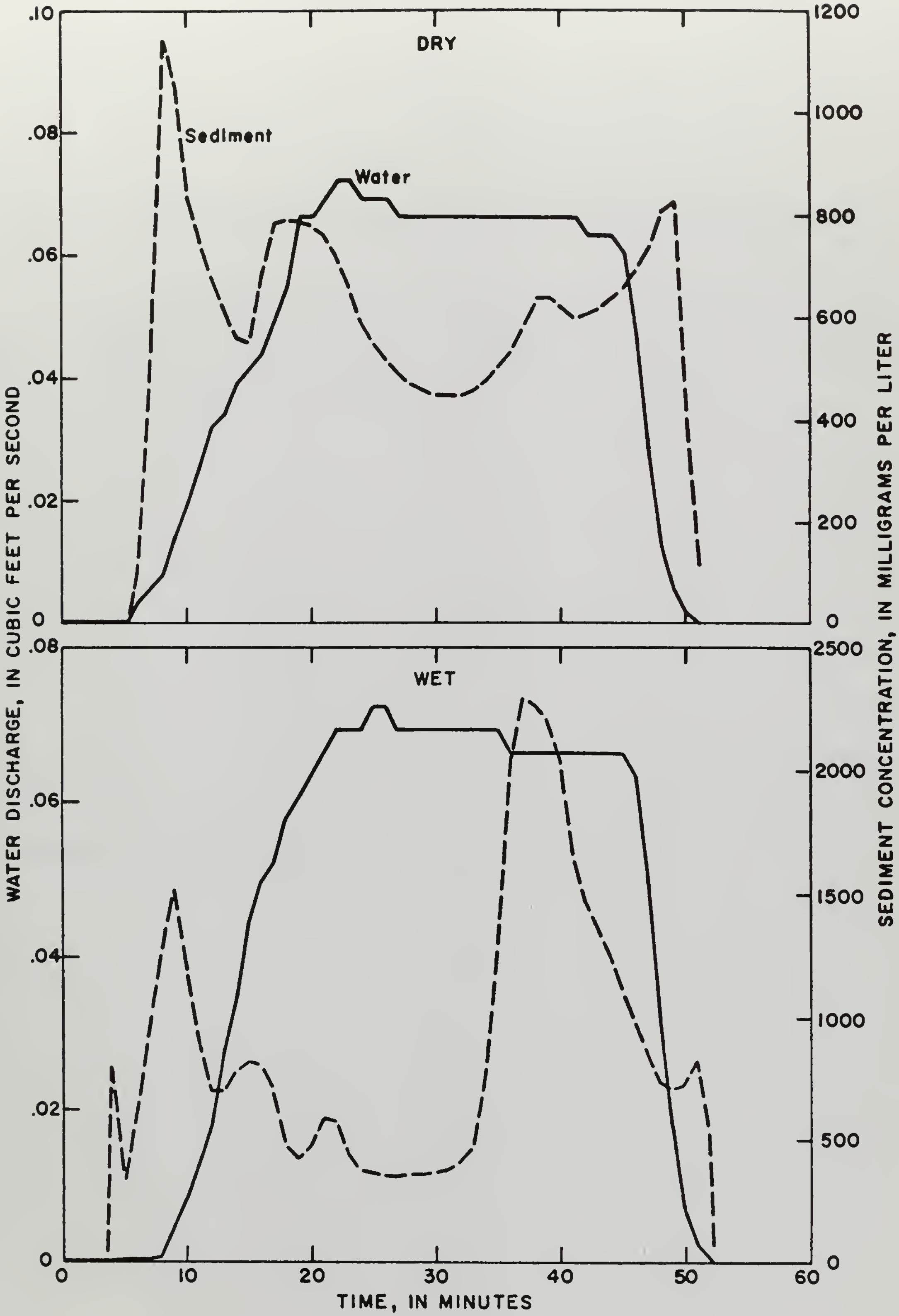


Figure 27 --Runoff and sediment-concentration curves for site 4.

Table 78 —Estimates of sediment discharge from drainage basins

Basin[1]	Drainage area (mi^2)	Weighted mean source area sediment yield ($acre-ft/mi^2/yr$)	Contributing area factor	Estimated sediment conveyance factor	Sediment discharge ($acre-ft/mi^2/yr$)
A	5.05	.12-.23	.4	.75	.04-.07
B	9.42	.1-.2	.4	.75	.03-.06
C	.87	.15-.26	1.0	.85	.1-.2
D	23.74	.13-.26	.7	.55	.05-.1
E	2.39	.11-.24	.7	.6	.05-.1
F	9.12	.12-.25	.9	.45	.05-.1

[1]Locations of the basins are shown on Plate 36

The vegetation causes flow velocities to be slow enough that more sediment is deposited in addition to that deposited because of infiltration of flows into the alluvial bottomlands. Another readily apparent factor that reduces sediment discharge is that some sediment is deposited on the alluvial fans that occur in numerous tributary channels where their gradients decrease at the contacts between the valley side slopes and the alluvial fills in the valley bottoms (Plate 36).

The above mentioned sediment-transport and deposition processes were all considered in assigning the sediment-conveyance factors shown on Table 78, and these processes result in the extremely low sediment discharges from the study basins at points D and F, shown on Plate 36. The sediment that is discharged at those points apparently is silt and clay-sized particles which do not require large flows for transport.

CONCLUSIONS

CLIMATE

Most climatic factors in the Beulah Trench Study Area appear favorable for revegetation of surface-mined land. The spring rains usually provide moisture to the soil in excess of the plant moisture requirement. With favorable soil moisture conditions, seedlings will grow rapidly and become established before the available soil moisture is depleted by about mid-July. The length of the growing season (estimated at 134 days between mid-May and mid- to late- September) also appears conducive to revegetation efforts using native range plants or small grains.

Climatic factors that may adversely affect revegetation efforts in this study area include: 1) below normal or uneven distribution of precipitation, especially during the growing season; 2) severe thunderstorms and/or strong winds that cause erosion; 3) late spring freezes; and 4) depletion of soil moisture by wind.

PHYSIOGRAPHY AND DRAINAGE

The Beulah Trench Study Area lies in the glaciated portion of the Great Plains Physiographic Province. The topography of the area is characterized by rolling hills bordered on the east and south by wide, flat Pleistocene meltwater channels. Maximum relief in the study area is about 340 feet.

Drainage in the study area is accomplished through a well developed dendritic system. The extreme northern end of the study area drains northward through the buried channel into Lake Sakakawea. The remainder of the study area drains southward into Spring Creek, a tributary of the Knife River.

GEOLOGY

The Beulah Trench Study Area lies in a part of the Williston Basin known as the West Renners Cove Lignite Field.

Bedrock is of Paleocene Age and belongs to the Sentinel Butte Member of the Fort Union Formation. It mostly consists of soft shale and sandstone with lesser amounts of siltstone and lignite.

Six persistent lignite and/or lignitic shale beds were penetrated by drilling in the area. Probably only one, the Beulah-Zap Coalbed, is of economic significance. It averages about 20.4 feet thick and is usually covered by less than 200 feet of overburden.

Engineering property tests were not conducted on bedrock samples from the Beulah Trench Study Area, but results should be similar to those for comparable material at the Otter Creek Study Site, Montana. Those tests revealed that shear strengths of the material are low, especially in a saturated condition. Slides can easily develop adjacent to high walls in surface mines, primarily along beds of weak, plastic, carbonaceous shales.

Saturated alluvial deposits and uncemented siltstones and fine grained sandstones will readily erode and flow into excavations.

Excavation slopes will vary between minesites and will be dependent on exposure time, moisture conditions, material types, and depth of cut. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden, and excavation below the water table will be limited until the material is drained.

Studies at the Otter Creek Site indicate that disturbed overburden should have slopes not greater than 4 to 1 and berms of 50 to 100 feet in width designed on the slope surface.

Volume changes in the overburden will occur with disturbance. An increase in volume of about 25 percent should be expected. In some cases the surface of the replaced overburden will be higher after mining.

Three types of instability are common on reclaimed coal-mined areas of the Northern Great Plains. They are: 1) areawide settling, 2) localized collapse, and 3) piping. Each form of instability is affected by certain variables in the postmining landscape. These variables include the physical and chemical characteristics of the overburden, the methods and equipment used in stripping and contouring operations, and the season when these activities occur. One or more of these types of landscape instability may occur on reclaimed land in the Beulah Trench Study Area.

Weathering tests performed on bedrock samples from the study area revealed that shales break down more rapidly than either sandstones or siltstones, but the material produced may be difficult to place and handle due to its plasticity.

Most types of earth materials suitable for construction are available in the study area. Only concrete aggregate and high quality riprap material will probably have to be obtained from outside the study area.

The area lies in a stable seismic region and no significant earthquake damage has been experienced in the past.

COAL RESOURCES

The Beulah-Zap Coalbed is probably the only bed that can be profitably mined in the study area. The thicker zones of the Schoolhouse Coalbed will probably be recovered during stripping operations, but it is generally too thin to be an economic consideration.

Coal of the Beulah-Zap Coalbed ranks as lignite A and has heat values ranging from 6,990 to 7,840 Btu/lb. It is classified as a humic coal. The average ash content of the 24 samples tested was 8.5 percent and the average sulfur content was 0.93 percent.

Total estimated identified original coal resources in the Beulah Trench Study Area are 109,917,000 tons. The coalbed thickness class of 2.5-5 feet contains 8,838,000 tons. The coalbed thickness class of 5-10 feet contains 24,568,000 tons and the coalbed thickness class of greater than 10 feet contains 76,511,000 tons of the estimated resources.

All of the estimated resources in the study area are overlain by less than 300 feet of overburden.

OVERBURDEN - SOIL AND BEDROCK

Data considered in determining the usable overburden material (soil and bedrock) for use in revegetation included: quality, quantity, ease of stripping and stockpiling, and other factors directly affecting their use for revegetation.

Based on the results of the land suitability survey, the deep residual, glacial, and alluvial/colluvial soils in the study area should provide an adequate supply of good quality topsoiling material for revegetation if surface mining occurs.

The A and B horizons of most soils in this study area are nonsaline, nonsodic, and well suited for topdressing shaped mine spoils. In most cases, these horizons may be mixed without an appreciable change in the quality of the material

Soluble salts have been leached to a depth of about 30 inches in deep, loamy profiles with good permeability. The leached zone usually includes the A, B, and part of the C horizons. Saline material, if utilized as subsoil, should leach and reclaim readily if placed over spoils with good internal drainage. Sodic material should be selectively placed well below the plant rooting zone in reconstructed profiles.

Local tracts of clay-rich, saline, or saline-sodic soil will require borrow material from nearby lands with abundant good quality material or from suitable bedrock, if readily available in the area.

Based on the results of laboratory analyses, 24 percent of the bedrock materials overlying the Beulah-Zap Coalbed in this study area were determined to be suitable for use as plant media; 29 percent were of limited suitability; and 47 percent were unsuitable.

Notable deficiencies of the bedrock materials classified as unsuitable often included one or more of the following: salinity, sodicity, fine texture (clay-rich), slow permeability, and instability.

Moisture Relations in Soils

The humic surface soils at all of the sites sampled had sufficient void space to promote moderate to high infiltration and permeability rates. These humic soils would be more resistant to compaction and loss of porosity when disturbed than deeper materials in the overburden. It would be advantageous, therefore, to place these soils back on the land surface following mining. Volume-weight (bulk density) measurements would show whether or not adequate porosity existed after the soils were repositioned.

Soil moisture can be "perched" as several additional molecular layers beyond the 10 layers that normally exist when drainage stops. A subsoil layer that impedes drainage causes the "perching." When the moisture is "perched," it is held at low retention forces making it readily available to vegetation. Productive midgrasses and tall grasses dominate the sites where moisture "perching" occurs naturally in the study area.

Drainage constrictions could be created during the repositioning of the materials following mining by compacting a layer of nonhumic subsoil material before placing the humic soil on the surface. Sufficient depths of the humic soil should be used so that a water table would not form above the constricting layer. If a water table developed, salts could migrate by capillarity toward the soil surface and be detrimental to the vegetation.

Many of the soils studied had reserves of moisture stored near the bases of the profiles. These reserves are probably utilized by the vegetation during droughts. Some of those reserves may be lost during the handling and storage period accompanying mining. If so, the moisture reserves might not be restored until the occurrence of a series of "wet" years, particularly in the absence of constricting layers in the subsoils.

GREENHOUSE

Western wheatgrass was chosen as the primary test species because it is one of the most abundant native species in the Western United States and will probably be used in many revegetation programs.

Based on the results of soil and plant analyses and calculation of relative yields, the soil and bedrock samples were assigned ratings of <u>suitable</u>, <u>questionable</u>, or <u>unsuitable</u> for use as revegetative media.

The soil samples were rated 38 percent suitable, 33 percent questionable, and 29 percent unsuitable. Twelve percent of the bedrock samples were rated suitable; 21 percent were questionable; and 67 percent were unsuitable.

Salinity and/or sodicity problems appeared to be the major limiting factors for most of the materials classed as unsuitable.

VEGETATION

The richness of the flora of the Beulah Trench Study Area is indicated by the fact that some 62 species were sampled, including 5 shrubs, 22 grasses, and 35 forbs. A complete species list would have shown many more species to be present.

In general, the pastures have been heavily grazed for many years and this has caused range conditions to decline. Estimates of range condition varied from a low of 33 percent of climax (fair) to 59 percent (good) with an average of 48 percent or high fair condition. All of the sampled ungrazed areas adjacent to pastures were in excellent condition.

For mapping purposes, the vegetation was arranged into three general categories as related to topography: 1) relatively flat areas (Needleand-thread-Blue grama), 2) sloping areas (Prairie sandreed-Little bluestem), and 3) relatively flat alluvium or flood plains (Western snowberry-Prairie sandreed). The names of these groups were derived from the vegetation on ungrazed areas which represents potential vegetation for the study area.

Productivity similar to or greater than that of the present potential vegetation is a feasible objective for reclamation following mining.

HYDROLOGY

Ground Water

Stripping of overburden and removal of coal would result in temporarily increased discharge from the lignite and other shallow aquifers. Recharge to the shallow water-table aquifers in overburden is from direct infiltration of precipitation. Recharge to the lignite aquifers is from downward leakage from shallower aquifers. In areas of thick bedrock and glacial till cover, recharge and vertical movement of precipitation to the lignite aquifer is very slow. This fact coupled with the increased water withdrawals at a mine site could temporarily lower water levels drastically in areas upgradient from a new mine site. However, the apparent low permeability of the lignite and clay-silt bedrock of the Sentinel Butte may reduce or at least delay the decline in water levels at large distances away from a proposed mine site. It is reasonable to assume that large declines in water levels in wells in lignite and shallower aquifers would not extend more than 1 to 2 miles from an active mine site.

Water levels in deeper aquifers would not be adversely affected, as the heads are lower in progressively deeper aquifers. However, mining and dewatering of shallow aquifers should result in changes in hydraulic gradients and a reduction in local recharge to aquifers beneath the Beulah-Zap lignite.

If a normal dragline procedure is used to remove overburden, replacement of material is in reverse order of the original state. Thus, sediments that are high in soluble and exchangeable sodium would be deposited near the surface in an environment of rapid oxidation and alteration. Available pyrite would be quickly oxidized; however, the resulting acidity would probably be buffered by solution of carbonate minerals and subsequent cation exchange of divalent cations for sodium. Resultant leachate from spoil piles should then have high concentrations of sodium, bicarbonate, and sulfate, and lower concentrations of calcium and magnesium.

Leachate and ground water flowing into mine pits from exposed aquifers may be expected to contain more dissolved material than normal ground or surface waters. Therefore, shallow ground water beneath mine sites may increase in dissolved solids concentration. If mine sites are located at or near the edge of the Antelope Creek aquifer, it seems probable that shallow ground water in areas of the aquifer that are below the mine sites will deteriorate with time.

The available geochemical and hydrologic data of the Sentinel Butte and Antelope Creek aquifers would indicate that small local plumes of water rich in sodium and sulfate could result from mining along the edge of the valley. Water samples from shallow areas in reclaimed spoils at Gascoyne, North Dakota (Croft, orral commun., 1978), were strong sodium sulfate waters with total dissolved solids as high as 24,000 mg/L.

Present hydrologic data indicate that parts of the Antelope Creek aquifer which lie in T. 145 N., R. 88 W., sections 13 and 24, are major recharge areas for the upper Antelope Creek unit. Effluent from strip pits or runoff from rain and snow which infiltrates through spoils could easily move into the shallow ground water system in these areas. An extensive unit of fine-grained sediment that divides the aquifers into upper and lower units may prevent the transport of solute to the lower aquifer unit.

The potential for contamination of ground water with toxic levels of trace metals would be very small. Solution and transport of toxic organics derived from coal, however, could present a serious problem; but few studies on this topic have been made.

Further geochemical studies are necessary to make accurate predictions of the potential for an increase in concentration and transport of any given chemical species from a mine site to potable ground water supplies.

Surface Water

The impacts of mining on the quantity and timing of runoff will be dependent on mining practices but will probably be very minor. There could be some realignment of small tributaries of the main streams, but the overall drainage area should remain essentially unchanged. Alteration of existing stream channels within the mining area to intercept and divert surface runoff could cause alterations in the existing flow regimen downstream. As spoils or reclaimed areas probably will, at least initially, have greater infiltration capacity than undisturbed material, there would be a decrease in runoff from snowmelt or rainfall events. There is the possibility, with the increased infiltration, of the development of springs and consequent temporal extension of base flow in the streams. The overall flow regimen of Antelope Creek tributary will probably be altered only slightly unless there are deliberate impoundments or other alterations on the same mainstream.

There should be little change in the chemical quality of water diverted around the active mining areas. However, runoff from the spoils and (or) reclaimed areas will probably show increased salinity. Recharge to the streams will be affected by increased infiltration in spoils, and reclaimed land could be expected to have a high salinity.

Hydrologic Classification of Land Types Using Rainfall Simulation

Simulated rainfall at an intensity of about 2 inches per hour was applied to four very small watersheds, about 2300 to 2700 square feet in area. Runoff volumes varied from very low to moderate. Sediment yields were all low, but they varied somewhat.

Both runoff and sediment yield were inversely related to the root contents and bulk densities of the surface soils. Lowest runoff and sediment yield were from the only site underlain by clinker (baked rock), even though the site was on the steepest slope. A site with nearly the highest runoff and sediment yield had the greatest clay amount, and the vegetation showed effects of prolonged overgrazing.

Sediment Yields

Erosion rates and source-area sediment yields on the study area are low because of the relatively high organic matter content of the soils and the excellent cover of the rangelands. Sediment yields from the croplands are higher than from the rangelands owing to the lack of cover part of the time and to disturbance of soil structure. Sediment discharge rates from drainage basins in the area are also very low because, in addition to low erosion rates, sediment is deposited in stock ponds, potholes, sumps, drainageways, and on alluvial fans between source areas and the outlets of basins.

Source-area sediment yield rates will be increased during mining and rehabilitation periods. Sediment-yield rates should return to about the same as present after perennial vegetation becomes fully established on the rangelands and after the structure and void space of salvaged topsoil is reestablished both on rangelands and croplands. Sediment discharge to Spring Creek and to the stream in the Beulah Trench may be slightly to moderately increased if some of the present rangeland is converted to cultivated cropland after mining.

RECOMMENDATIONS FOR RECLAMATION

INTRODUCTION

Should surface mining occur in the Beulah Trench Study Area, the coal mine operator will be required to restore all disturbed areas "in a timely manner to conditions that are capable of supporting the uses which they are capable of supporting before mining, or to higher or better uses . . ." (Chapter 38-14.1, Section 69-05.2-23-01, North Dakota Century Code).

Unless an alternative postmining land use is desired by the landowner(s) and approved by the North Dakota Public Service Commission, the main objective of reclamation will be to restore the mined land to a condition capable of supporting the uses that it supports today. These uses are rangeland, hayland, and cropland (small grains).

STABILITY OF THE POSTMINING LANDSCAPE [1/]

The design of a stable postmining landscape in the Beulah Trench Study Area will require the integration of several critical factors: These include: 1) a detailed knowledge of the distribution of overburden materials, with emphasis on the delineation of highly sodic spoils, 2) proper equipment selection, and 3) a consideration of seasonal factors. For reclamation to be successful, consideration must be given to the entire landscape, not merely the soil zone.

Three forms of landscape instability are common on reclaimed coal-mined areas in the Northern Great Plains. These are areawide settling, local collapse, and piping.

Areawide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This form of subsidence will probably be most pronounced during the first year following reclamation and will continue at a decreasing rate for a number of years. The two major factors influencing areawide settling are: 1) texture of the overburden, and 2) equipment used in spoil contouring operations.

A significant quantity of overburden in the Beulah Trench Study Area consists of fine textured material (shale). When disturbed, this material usually results in more blocky and, initially, more porous spoils than does coarse textured overburden (sandstone). Therefore, a greater degree of areawide settling may be expected in this area as compared to an area where coarse textured materials are predominant.

Equipment used in contouring operations is a critical factor influencing areawide settling. Settlement is significantly less in scraper-countoured areas than in dozer-contoured areas due to the fact that scrapers more

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1/ Groenwold,`G.H. and Rehm, B.W., 1980 (modified) effectively break down large overburden blocks and compact the spoil mass. Therefore, the degree of areawide settlement may be reduced by employing scrapers rather than dozers in spoil contouring operations.

Local large-scale collapse often develops soon after contouring is completed. Development typically ends within 1 year. This form of instability is predominant in precontouring valleys where large, frozen spoil blocks are concentrated by mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. To restrict the development of local collapse features, the use of scrapers rather than dozers should be considered for contouring operations during the winter months.

Piping appears to be a severe and long-term problem in some postmining landscapes. This form of instability usually begins soon after contouring ceases and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years.

Piping is apparently controlled by a combination of physical and chemical conditions in the spoils. All piping begins as a crack, either on the surface of exposed spoils or at the topsoil-spoil interface. In the latter case, the overlying topsoil collapses into the pipe and is carried away. Repeated topsoil application is usually unsuccessful in stopping the growth and development of piping. Cracking of spoils is restricted to areas of highly dispersive sodic materials. The cracks allow access for large volumes of surface runoff to flow into the subsurface of the spoils. However, surface cracking alone will not necessarily result in the development of piping. Piping will develop only if an avenue for water movement can result from fracturing within the mass of spoils due to settling between differentially compacted areas (i.e., scraper-contoured area adjacent to dozer-contoured area) or within areas of poorly compacted spoils (i.e., dozer contouring only).

Piping usually develops in nearly flat areas, where runoff is minimal and infiltration is maximized. Thus, the final surface slopes in reclaimed areas must also be recognized as controlling factors in the development of piping.

Given the proper conditions of slope, near-surface dispersive materials, and a permeable zone in the base of the spoils, piping may continue to develop and disrupt the restored landscape for many years. Selective placement of excessively sodic overburden encountered in this study area may prove to be the only effective means of controlling piping.

Because the postmining landscape in the Beulah Trench Study Area will be unstable, structures should not be built unless they are specifically designed to absorb differential settlement. Also, reconstructed drainage channels will require periodic maintenance to ensure that ponded areas do not develop in areas of localized settling.

GRADING AND HANDLING OF SPOIL MATERIALS

Mine operators will be required by law to grade all disturbed areas "to the gentlest topography consistent with adjacent unmined landscape elements . . . ." All spoil shall be transported, backfilled, compacted (where advisable to insure stability or to prevent leaching), and graded to eliminate all highwalls, spoil piles, and depressions (Chapter 38-14.1, Section 69-05.2-21-01(2)(a), North Dakota Century Code).

Where possible, all final grading and preparation of graded land prior to the redistribution of topsoil should be conducted along the contour to minimize erosion and maximize landscape stability.

Present North Dakota law states: "Spoil materials that are found by the (Public Service) Commission to be excessively saline, sodic, or both, are considered to be toxic-forming materials and shall be covered with a minimum of 4 feet of nontoxic material, provided such material is available" (Chapter 38-14.1, Section 69-05.2-21-03(1), North Dakota Century Code). Based on the results of laboratory tests performed on samples from 11 drill holes in the Beulah Trench Study Area (see Tables 30 through 45, Appendix E), it appears as though a significant number of the bedrock strata are excessively sodic. However, these materials generally underlie at least 40 feet of nontoxic overburden. Therefore, an adequate quantity of nontoxic soil and bedrock should be available to sufficiently bury the sodic spoils. Highly sodic spoils should not be buried in proximity to a drainage course where they may pose a threat of water pollution.

EROSION CONTROL

Reducing runoff and erosion and increasing the on-site conservation of moisture for vegetative establishment are feasible objectives for reclaimed land in the Beulah Trench Study Area. The following procedure is recommended as a means toward achieving these objectives: 1) reduce the mean surface slope in the reclaimed area, 2) scarify the surface of the regraded spoils, 3) replace the subsoil/topsoil and prepare a seedbed, 4) conduct seeding and planting operations as soon as possible after topsoil redistribution, and 5) apply mulch to the newly seeded areas.

Reducing the mean surface slope in the reclaimed area will provide a more gently sloping landscape. A more level landscape will allow for an increase in infiltration and moisture retention and a decrease in runoff and sediment yield. The increase in moisture retention will be highly desirable for seedling establishment in the reclaimed area.

Prior to the redistribution of suitable plant growth material, the surface of the regraded spoils should be ripped or chiseled in order to 1) eliminate slippage surfaces at the spoil-topsoil interface, and 2) provide a favorable subsurface medium for air/water infiltration and root penetration. Ripping or chiseling should be conducted along the contour wherever possible to prevent runoff and ensure maximum stability.

Subsoil and topsoil are often compacted by heavy machinery during the redistribution process. These materials should be loosened by chiseling or other means prior to actual seedbed preparation (disking/harrowing). The loosened material will allow roots to readily penetrate its matrix and will also facilitate a higher rate of air/water infiltration. All tillage operations should be conducted along the contour to prevent excess runoff and substantial loss of the plant growth material.

Seeding and/or planting should be conducted as soon as possible after the topsoil has been spread and a seedbed has been prepared. The establishment of a permanent vegetative cover as quickly as possible will be the most effective method of controlling erosion in the reclaimed area. A temporary cover of small grains, grasses, or legumes may be required to protect the topsoil until such time as a permanent cover can be established.

Suitable mulch should be applied on all newly seeded areas to control erosion, conserve soil moisture, and enhance seed germination. For the Beulah Trench Study Area, consideration should be given to the use of 1) hay or straw mulch applied at a rate of about 2 tons/acre, or 2) an "in situ mulch" of standing stubble from spring planted small grains. If hay or straw mulch is applied, it should be anchored (disked or "crimped") to the soil surface to prevent substantial losses of the material due to blowing.

REVEGETATION

Revegetation of surface-mined land in the Beulah Trench Study Area will require: 1) removal, segregation, and redistribution of suitable plant growth material, 2) selection of adapted plant species, and 3) use of proper planting and seedbed preparation procedures.

Removal, Segregation, and Redistribution of Suitable Plant Growth Material

Prior to the actual mining operation, all suitable plant growth material should be removed and either redistributed immediately on regraded areas or segregated in separate stockpiles.

North Dakota regulations require that both topsoil and subsoil be salvaged for replacement as plant media (Chapter 38-14.1, Section 69-95.2-15-02(2), North Dakota Century Code). This is accomplished in a 2-lift process with the most desirable plant growth material ("topsoil") being removed in the first lift and the remaining suitable material ("subsoil") being salvaged in the second lift. Based on the results of the Land Suitability Survey included in this report, it appears that a minimum of 12 inches of good quality topsoil can be removed in the first lift from most soils in the study area (see Plate 30). This material is typically nonsaline and nonsodic, permeable, and contains a moderate amount of organic matter. The depth and quality of subsoil material in this study area is highly variable (see Plate 31).

If stockpiling of the suitable plant growth material is necessary, the stockpiles should be selectively placed on a stable area and protected from erosion, compaction and contaminants (toxic spoils). Establishment of a quick growing vegetative cover on the stockpiles is probably the most effective method of protection; however, other measures such as snow fences, mulches, or chemical binders may also be considered.

Before the suitable plant growth material is redistributed, the regraded land should be scarified (ripped) to eliminate slippage surfaces and enhance root penetration. The redistribution of subsoil and topsoil, respectively, should then proceed in a manner that achieves an approximate uniform thickness consistent with the postmining land use(s) and prevents excess compaction of the spoils and suitable plant growth material.

Finally, nutrients (fertilizer) and soil amendments should be added to the surface soil layer in the amounts determined by soil tests. All soil analyses should be performed by a qualified laboratory using procedures approved by the Public Service Commission (North Dakota).

Selection of Adapted Plants

To comply with established State regulations, the mine operator will be required to establish on all disturbed areas a "diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area. . ." (Chapter 38-14.1, Section 69-05.2-22-01, North Dakota Century Code). Introduced species may be substituted for native species only if appropriate field trials have demonstrated that the introduced species are of equal or superior utility for the approved postmining land use(s), or are necessary to achieve a quick, temporary, and stabilizing cover. The Public Service Commission must approve the use of introduced species.

Some important considerations in selecting revegetative species for the Beulah Trench Study Area should include: drought resistance, salt and sodium tolerance, resistance to winterkill, palatability, and resistance to grazing pressure. Of equal importance is plant compatibility with soil type, slope, aspect, and drainage conditions.

Table 79 lists the plants and seeding rates which are suggested for native grassland plantings, tame grass plantings (areas to be returned to cropland after 3-4 years), and salt affected soil plantings.[2/]

Seedbed Preparation and Planting

Suitable plant growth material is often compacted by heavy machinery during the redistribution process. To provide a plant medium favorable for air and water infiltration, as well as root penetration, the topsoil/subsoil should be chiseled to a depth of 18 to 24 inches prior to seedbed preparation. Disking/harrowing should then be conducted until a suitable seedbed is achieved.

Seeding of grasses and legumes with a press drill is usually the preferred technique, but good stands may also be established by broadcasting or hydroseeding. In order to provide favorable growing conditions, the seeds should be covered by 1/2 to 1 inch of soil and the surface lightly compacted to produce a good seed-soil contact.

Natural woodland complexes (woody draws) occur to a minor extent in this study area. These complexes should be avoided during the mining operation, if at all possible, as they are irreplaceable ecosystems and the majority of the prairie animal community is dependent on them. If disturbance of these complexes cannot be avoided, the trees and shrubs should be salvaged for transplanting in reconstructed drainages.

2/ From: Guidelines for Reclaiming Coal Mine Lands; North Dakota Public Service Commission, 1976.

Seeding and planting operations should be conducted during the first normal period for favorable planting conditions following the redistribution of suitable plant growth material. In the Beulah Trench Study Area, early spring or late fall planting of grasses and legumes appear most desirable. If spring planting is selected, the plants should be seeded between early March and late April in order that seedlings may emerge before the spring rains begin. Late fall planting should be conducted after mid-October to prevent germination. If this method is selected, consideration should be given to a light seeding of oats (10-15 lbs/acre) in August to provide stubble for erosion control and snow trapping.

POST-RECLAMATION MANAGEMENT

Responsibility of the Mine Operator

In North Dakota, the coal mine operator will be responsible for management of the reclaimed area for a minimum of 10 years. The success of revegetation will then be determined for each approved postmining land use according to the following:[4/]

1. For rangeland and hayland, the following requirement must be achieved for the last two consecutive years of the responsibility period:

   (a) "Ground cover and productivity . . . shall be equal to or greater than, with 90 percent statistical confidence for herbaceous vegetation and 80 percent statistical confidence for woody vegetation, the approved standard[5/], and

   (b) The diversity, seasonality, and permanence of the vegetation . . . , determined from the major species and groups, shall be equivalent to that of the approved standard" (Chapter 38-14.1, Section 69-05.2-22-07(3)(a), North Dakota Century Code).

2. For cropland, "crop production . . . shall be equal to or greater than, with 90 percent statistical confidence, that of the approved standard for the last two consecutive growing seasons of the responsibility period" (Chapter 38-14.1, Section 69-05.2-22-07(3)(b), North Dakota Century Code).

On lands reclaimed to rangeland, livestock grazing "shall be practiced for at least the last 4 years of the responsibility period at a capacity approximately equal to that for similar well managed lands" (Chapter 38-14.1, Section 69-05.2-22-06, North Dakota Century Code). The Public Service Commission, in consultation with the landowner(s), will determine when the revegetated area is ready for livestock grazing.

4/ The postmining land uses in the Beulah Trench Study Area are assumed to be rangeland, hayland, and cropland (small grains).

5/ Approved standard refers to an undisturbed "reference" area chosen for comparative purposes to determine success of revegetation on the reclaimed site.

NATIVE GRASSLAND PLANTINGS 3/

Species	Seeding Rate (lbs/acre)
Western wheatgrass	6
Pubescent wheatgrass*	1½
Little bluestem**	2
Sideouts grama	3
Green needlegrass	4
Alfalfa or	1
Sweetclover	½
Total	17-17½

* If seed not available, substitute slender wheatgrass.
** If seed not available, substitute prairie sandreed or switchgrass.

IMPROVED VARIETIES OF GRASS/LEGUME PLANTING FOR CROPLAND*

Species	Pasture or Hayland		Wildlife Planting
	Dry Site	Moist Site	
Crested wheatgrass	7	2	
Smooth bromegrass		5	
Pubescent wheatgrass**	3	3	
Intermediate wheatgrass			4
Tall wheatgrass			3
Alfalfa	1½	1½	3
Sweetclover	½	½	1
Total	12	12	11

* In pounds of seed per acre.
** If seed not available, substitute slender or intermediate wheatgrass.

SALT AFFECTED SOIL PLANTINGS

Species	Seeding Rate (lbs/acre)
Tall wheatgrass	4
Slender wheatgrass	3
Western wheatgrass	7
Sweetclover	2
Total	16

3/ Origin of native seed produced should be limited to North Dakota, South Dakota, eastern Montana, eastern Wyoming, and northern Nebraska.

Responsibility of the Landowner

The landowners in the Beulah Trench Study Area will resume responsibility for management of the reclaimed lands following termination of the mine operator's responsibility period. To ensure that the reclaimed land remains stable and productive, the landowners should implement proper range and soil/crop management practices.

On areas returned to rangeland, grazing should be limited to a capacity that the reclaimed land is capable of supporting. Overgrazing reclaimed lands will result in a reduced vegetative cover, accelerated erosion, and an overall decrease in productivity.

On lands returned to cropland, the main objective of the landowner in cultivating the land should be sustained profitable production. To aid in achieving this objective, soil/crop management practices including contour tillage, fertilization, crop rotation, weed and insect control, mulching, etc., should be utilized whenever possible.

RESTORATION OF WATER RESOURCES

The proposed surface mining activities in the Beulah Trench Study Area will result in some restorable changes and some nonrestorable changes in the ground water, surface water, and geochemical regimes.

Ground Water

The bedrock aquifers in the sandstones above the lignite and the lignite aquifers in the mined area will be destroyed. Since it is impractical to restore these aquifers, alternative sources must be used. This would usually mean developing wells in the underlying aquifers, notably the basal sandstone unit of the Sentinel Butte Member. Some of the springs and seeps along the valley walls will be destroyed as the relatively impermeable beds causing lateral flow will be removed during mining. These cannot be restored, but their loss is not especially critical since they generally have very low yields and do not contribute much to usable water supplies.

The aquifers that lie outside the mined area in the same plane should not be disturbed except for a temporary lowering of water levels for a short distance from the mined area. In local areas it may be necessary to seek a supply from deeper aquifers. The Antelope Creek aquifer could receive increased recharge during the dewatering of the area being mined. However, some of the water would eventually have reached the aquifer by a more circuitous route.

Ground water recharge in the reclaimed area will depend on placement factors such as: postmining topography, layering and compaction of the overburden materials, postmining land use, and moisture conservation practices and(or) irrigation. The fractured state of the spoils initially could result in increased recharge to the deeper bedrock aquifers and to the Antelope Creek aquifer. As subsidence and weathering occur, the spoils should become less permeable and recharge rates will decrease. The various moisture conservation techniques will influence the amount of recharge through control of infiltration and runoff. Practices that maximize infiltration will tend to recharge the Antelope Creek aquifer either in the proximate area of the mining or downstream.

The ground water supply in the reclaimed areas will be difficult to estimate, owing to the lenticular nature of the aquifers. Generally, adequate supplies for domestic and stock use could be obtained from the basal sandstone unit of the Sentinel Butte Member. Larger supplies of water are available from the Antelope Creek aquifer.

The shallow ground water beneath the reclaimed areas will probably show an increase in dissolved-solids concentration. It is probable that some shallow areas of the Antelope Creek aquifer could deteriorate with time. Maximum plant use could minimize the amount of water moving from the spoils into the aquifers. Dewatering in the mine areas could cause deterioration in the Antelope Creek aquifer if discharges are disposed of in the stream.

Surface Water

There should be minimal disruption of surface water use in the area. The streams are ephemeral and primary use is stock watering in ponds constructed for this purpose. The stock ponds are generally in the upper reaches of the tributaries and will not be affected by mining.

Areas of natural wetlands storage and the original water courses should be reestablished when mined land is reclaimed. Runoff characteristics can be improved to retain water for revegetation and to prevent excessive erosion. Contour furrowing, gouging, or similar land treatments can be applied to the steeper slopes. Channel areas should be reseeded to sod-forming grasses or transplanted with native sod.

Runoff water should be channeled around mine areas when possible to minimize changes in the chemical quality. Runoff from the spoils and reclaimed areas should be minimized to avoid increased salinity in the streams.

SUMMARY OF RECLAMATION POTENTIAL

Based on the resource data presented in this report, the potential for restoring surface-mined land in the Beulah Trench Study Area to a condition capable of supporting the present uses (rangeland, hayland, and cropland) appears good to excellent. The most critical factors directly influencing revegetation: 1) climate, and 2) availability of suitable plant growth material, both appear favorable in this study area.

The climatic regime in this area appears conducive to the production of native grasses and small grains. The moisture available to plants from snowmelt and spring precipitation is usually adequate for germination and establishment. Although the growing season in this area is estimated at 134 days between mid-May and mid- to late- September, the native grasses and small grains will typically mature or become dormant by about mid-July when the available soil moisture is depleted.

Most soils in this study area will yield about 12 inches of good quality topsoil which is nonsaline, nonsodic, and permeable. Given adequate moisture and a moderate amount of fertilization, this material should provide an excellent revegetative medium. The quantity of suitable subsoil, though variable in this study area, appears adequate in most cases for reconstructing a desirable root zone.

RECLAMATION ALTERNATIVES

The present land uses in the Beulah Trench Study Area are rangeland, hayland, and cropland (small grains). Numerous alternative land uses could be considered when developing a reclamation plan for the area; however, only two alternatives appear economically feasible at the present time. These are: 1) improve rangeland/cropland productivity, and 2) convert some of the existing rangeland to cropland.

The most critical element necessary for improving rangeland and cropland productivity is additional moisture. Supplemental irrigation [6/], coupled with an intensive snow management program could provide this additional moisture. Implementation of proper range/crop management practices, i.e., limited grazing, contour furrowing, etc., would also improve productivity by controlling erosion and conserving soil moisture.

Most of the acreage in the study area is currently used for rangeland due to the rolling nature of the topography. During the reclamation process, a good opportunity will exist to convert some of this land to cropland. This would involve: 1) contouring the landscape to a more gently sloping condition conducive to cultivation, and 2) replacing the subsoil/topsoil in a rather uniform thickness over the area in order to provide an adequate rooting zone for the selected crops to be grown.

6/ Assumes that adequate ground water supplies of suitable quality could be obtained from the Antelope Creek aquifer (Beulah Trench).

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APPENDIX A

ENGLISH TO METRIC CONVERSIONS

ENGLISH TO METRIC (SI) CONVERSIONS

A dual system of measurements--English units and the International System (SI) of metric units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

Multiply English Units	By	To Obtain SI Units
Inches	25.40	millimeters (mm)
	2.54	centimeters (cm)
	0.254	decimeters (dm)
	0.0254	meters (m)
Feet	0.3048	meters (m)
Square Feet	0.0929	square meters (m^2)
Miles	1.609	kilometers (km)
Pounds	453.60	grams (g)
Ton	0.9072	tonne (t)
Acres	0.4047	hectares (ha)
	0.004047	square kilometers (km^2)
Square miles	2.590	square kilometers (km^2)
Cubic inches	16.39	cubic centimeters (cm^3)
Gallons	.003785	cubic meters (m^3)
Acre-feet	.001233	cubic hectometers (hm^3)
	1233.00	cubic meters (m^3)
Feet per mile	0.1894	meters per kilometer (m/km)
Inches per hour	2.54	centimeters per hour (cm/h)
Feet per day	.3048	meters per day (m/d)
Pounds per square inch	70.32	grams per square centimeter (g/cm^2)
Atmospheres	1033.27	grams per square centimeter (g/cm^2)
Bars	1019.78	grams per square centimeter (g/cm^2)
Pounds per cubic foot	0.01602	grams per cubic centimeter (g/cm^3)
Pounds per acre	1.1206	kilograms per square hectometer (kg/hm^2)
Feet squared per day	0.0929	meters squared per day (m^2/d)
Cubic feet per second	0.02832	cubic meters per second (m^3/s)
Gallons per minute	0.06309	liters per second (l/s)
Cubic feet per second per square mile	0.01093	cubic meters per second per square kilometer [($m^3/s)/km^2$]
Cubic feet per day per square foot	0.3048	cubic meters per day per square meter ($(m^3/d)/m^2$)
Pounds per square yard per hour	0.5426	kilograms per square meter per hour ($kg/m^2/h$)
Pounds per square foot per hour	4.8827	kilograms per square meter per hour ($kg/m^2/h$)
Btu per pound	0.556	kilogram calories per kilogram (kcal/kg)
Degree Fahrenheit	$Tc = \frac{Tf-32}{1.8}$	degrees Celsius (°C)

APPENDIX B

CLIMATE

Figure 1

Precipitation Deviation at Selected Locations in the Beulah Trench Study Area.

10 0 10 20 30

Scale of Miles

Notes

The 40 mile circle around the Beulah Trench Study Area indicates an area in which average yearly precipitation is about 16.39 inches. Minus or plus (inside circle) indicates deviation from the 16.39 inch normal at selected stations.

Table 4 - Potential Consumptive Use of Moisture and Available Moisture - Native Grasses 1/

Beulah Trench Study Area

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (°F.)	Monthly Requirement Inches	Moisture Reserve Inches	Precipitation Inches	Difference Inches 3/
May 11					+3.63 2/		
	May 21	11	60.6	4.24		2.57	+1.96
June					+1.96		
	June 15	37	63.5	4.85		3.97	+1.08
July					+1.08		
	July 15	67	69.5	6.12		2.62	-2.42 4/
August					-2.42		
	August 15	98	68.5	5.35		2.08	-5.69
Sept.					-5.69		
	Sept. 12	126	57.1	2.89		1.42	-7.16
Sept. 25		139		23.45			

1/ Computed by Blaney-Criddle Method using the Beulah Weather Station - Latitude 47°16'.
2/ Moisture Reserve = Summation of precipitation (Oct. to April) x 80% = 3.63 inches.
3/ Difference = Moisture reserve plus precipitation minus moisture use.
4/ Natural precipitation during most years is inadequate to meet potential moisture needs. In average years, plants use available moisture by July 15 and mature and become dormant.

Table 5 - Potential Consumptive Use of Moisture and Available Moisture - Small Grains 1/

Beulah Trench Study Area

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (°F.)	Monthly Requirement Inches	Moisture Reserve Inches	Precipitation Inches	Difference Inches 3/
May 11					+3.63 2/		
	May 21	11	60.6	1.92		2.57	+4.28
June					+4.28		
	June 15	37	63.5	4.48		3.97	+3.77
July					+3.77		
	July 15	67	69.5	8.58		2.62	-2.19 4/
August					-2.19		
	August 15	98	68.5	5.99		2.08	-6.10
Sept.					-6.10		
	Sept. 12	126	57.1	.99		1.42	-5.67
Sept. 25		139		21.96			

1/ Computed by the Blaney-Criddle Method using the Beulah Weather Station - Latitude 47°16'
2/ Moisture Reserve = Summation of precipitation (Oct. to April) x 80% = 3.63 inches.
3/ Difference = Moisture reserve plus precipitation minus moisture use.
4/ Natural precipitation during most years is inadequate to meet potential moisture needs.

APPENDIX C

GEOLOGY

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Beulah Trench Study Area, West Renners Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-101 — LOCATION: 20' S. & 520' E. of NW Corner, Sec. 14, T. 145 N., R. 88 W. — GROUND ELEV. 2065± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN 5/16/77 — FINISHED 5/27/77 — TOTAL DEPTH 200.0

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 49.3' 5/27/77 (2015.7±) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

5/16/77 - Moved drill rig & equipment to Beulah, ND.

5/17/77 - Located drill holes & moved equipment to DB77-101. Bx drive samples 0 to 5.0'.

Hole at 5.0' 5/18/77. Hole dry at 5.0'. Bx drive sample 5.0 to 10.0'. BxCa rotation 10.0 to 40.0'. Nx core 40.0 to 80.0'. Nx Ca set to 10.0'. Using revert below 40.0'. Uncemented sandstone washed away from 40.4 to 45.8 & 50.0 to 54.4'.

Hole at 80.0'. Nx Ca at 10.0'. W.L. at 23.6'. Nx core samples 80.0 to 131.4'. Dropped core 95.6 to 100.0, 107.5 to 110.0 & 117.8 to 120.0'. Recovered core except for 117.8 to 120.0' zone. Ground up core 117.8 to 122.1'.

Hole at 131.4' 5/20/77. NxCa at 10.0'. W.L. at 23.5'. Nx core 131.4 to 169.4'. Using revert. Lost all water below 139.0'. Returned to duty station.

SOILS ANALYSIS SAMPLE

Sample	Depth (feet) from	to
#1	0	14.1
#2	14.1	18.0
#3	18.0	28.4
#4	28.4	40.4
#5	40.4	54.4
#6	59.0	74.8
#7	74.8	95.0

Elevation (feet)	Depth (feet)
2050.9	14.1
2047.0	18.0
2044.0	21.0
2036.6	28.4
2024.6	40.4
2010.6	54.4
2008.3	56.7
2008.0	57.0
2007.1	57.9
2006.0	59.0
1990.2	74.8

CLASSIFICATION AND PHYSICAL CONDITION

0-14.1 SANDY CLAY: Tan; oxidized; dry 0 to 3.0'; moist 3.0 to 14.0'; active HCl reaction; approximately 60% medium plasticity fines, 35% fine to coarse sand & 5% hard, subrounded gravel (maximum size 2½"), gravel concentration 0 to 2.0'; scattered lignite fragments; clayey sand in places; CL with SC zones; glacial fill.

14.1-18.0 SAND: Light gray to tan; slightly oxidized; moist; moderate HCl reaction; fine, uniform sand (50-100 sieve); varies from clean to 10% very low plasticity fines SP to SP-SM; glacial outwash (?).

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

18.0-21.0 SILTY SHALE: Yellowish-brown & highly oxidized 18.0 to 19.0'; tan & oxidized 19.0 to 21.0'; moist; soft; cuts easily with knife; weak HCl reaction; appears to be badly weathered or crushed by glacier; low plasticity; lignite fragments.

21.0-28.4 SILTY TO CLAYEY SANDSTONE: Tan; oxidized; moist; soft; uncemented; crumbles easily between fingers; sand is very fine grain (approaching silt); ranges from non to slightly plastic; core lengths up to 12".

28.4-40.4 SHALE: Medium gray to tan; oxidized; moist; firm; plastic; trims by knife with some difficulty; bedding not readily discernible; highly oxidized with iron-rich, ½-inch concretions 30.0 to 30.5 & 34.8 to 35.0'; becoming slightly sandy 38.0 to 40.4'; very weak acid reaction; core lengths 3 to 24".

40.4-54.4 SILTY TO CLAYEY SANDSTONE: Banded light & medium gray; moist; uncemented; crumbles between fingers; firm where clayey; sand is very fine grain (approaching silt in zones); very weak HCl reaction; clayey 46.5 to 47.2'; varies from slightly to moderately plastic; washed away by drilling 40.6 to 45.8 & 50.0 to 54.4'.

54.4-56.7 SHALE: Light gray becoming dark gray & carbonaceous with depth; firm; plastic; cuts by knife with difficulty; air slacks especially in carbonaceous zones; non-calcareous; core lengths 6 to 8".

EXPLANATION: CORE LOSS / CORE RECOVERY. Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE: Beulah Trench Study Area, West Renners Cove Coalfield — PROJECT: EMRIA — STATE: N. Dakota — SHEET 1 OF 3 — HOLE NO. 77-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Beulah Trench Study Area, West Renners Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-101 — LOCATION: 20' S. & 520' E. of NW Corner, Sec. 14, T. 145 N., R. 88 W. — GROUND ELEV. 2065± — DIP: Vertical

BEGUN 5/16/77 — FINISHED 5/27/77 — TOTAL DEPTH 200.0

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 49.3' 5/27/77 (2015.7±) — LOGGED BY: Taucher

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 169.4' 5/23/77. NxCa at 10.0'. W.L. at 49.4'. Nx core 169.4 to 180.0'. No drill water return. Returned from duty station. Repairs to pickup.

Hole at 180.0' 5/24/77. NxCa at 10.0'. W.L. at 63.4'. Nx core 180.0 to 200.0'. Unable to recover gray silty sand (washed away) 184.2 to 192.2'. No drill water return. Pulled NxCa.

5/27/77 - W.L. at 49.3'. Backfilled hole with cement & pea gravel.

Note: Water used for drilling was sterilized with chlorine tablets.

5 pound lignite samples taken at:
129.2 - 131.4'
133.2 - 136.4
139.0 - 141.8
144.0 - 146.6
149.0 - 150.4

SOILS ANALYSIS SAMPLE

Sample	Depth (feet) from	to
#8	95.0	114.3
#9	115.6	128.5
#10	150.4	170.0

Elevation (feet)	Depth (feet)
1950.7	114.3
1949.4	115.6
1936.5	128.5
1914.6	150.4
1881.8	183.2
1871.0	194.0
1869.6	195.4
1866.5	198.5
1865.0	200.0

CLASSIFICATION AND PHYSICAL CONDITION

56.7-57.0 LIGNITE: Black; broken; hard.

57.0-57.9 SHALE: Black; carbonaceous; firm; plastic; moist; air slacks; broken.

57.9-59.0 LIGNITE: Black; broken; hard.

59.0-74.8 SANDY SHALE: Banded light & medium gray; moist; firm; trims by knife with some difficulty; moderately plastic; sand is very fine grain (near silt); clayey fine grain sandstone in zones; moderate to active HCl reaction 66.5 to 74.8'; 1" limestone concretion at 67.2'; scattered 1/8 to 1/4" pyrite or marcasite nodules; core lengths 3 to 30".

74.8-114.3 SHALE: Medium gray; moist; firm; difficult trimming by knife; plastic; non to moderate HCl reaction; banded in most places; air slacks; dark gray, hard limestone 95.0 to 95.6'; several 1" silty sandstone streaks 97.0 to 98.0 & 102.0 to 104.0'; 70° poorly defined fracture at 98.3'; firm, light gray, clayey, fine grain sandstone 105.0 to 107.0'; 45° fault at 112.2' with 1/4" gouge; bedding near horizontal; occasional minus 1/4" marcasite nodules; core lengths 3 to 30".

114.3-115.6 LIGNITE: Black; hard; moist; broken.

115.6-128.5 SHALE: Medium gray with scattered lignite fragments 115.6 to 125.0'; dark gray & carbonaceous 125.0 to 128.5'; shaley lignite 127.5 to 127.7'; plastic; firm; air slacks; slight HCl reaction in zones; core lengths 1 to 6".

128.5-150.4 LIGNITE: Dark brown to black; moist; dull to almost metallic luster; broken along bedding planes that range from horizontal to dips of 10°; hard.

150.4-183.2 SHALE: Medium gray; moist; firm; difficult trimming by knife; plastic; air slacks; bedding is near horizontal; noncalcareous; black & carbonaceous 151.0 to 151.2'; white, gypsum rich (?) zone 152.0 to 152.1'; dark gray & carbonaceous 168.7 to 168.8'; 1/2" lignite at 171.5'; 1/2" lignite on 35° plane at 173.0'; 1/2" lignite at

EXPLANATION: CORE LOSS / CORE RECOVERY. Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE: Beulah Trench Study Area, West Renners Cove Coalfield — PROJECT: EMRIA — STATE: N. Dakota — SHEET 2 OF 3 — HOLE NO. 77-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Beulah Trench Study Area, West Renners Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-101 — LOCATION: 20' S. & 520' E. of NW Corner, Sec. 14, T. 145 N., R. 88 W. — GROUND ELEV. 2065± — DIP: Vertical

BEGUN 5/16/77 — FINISHED 5/27/77 — TOTAL DEPTH 200.0

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 49.3' 5/27/77 (2015.7±) — LOGGED BY: Taucher

CLASSIFICATION AND PHYSICAL CONDITION

176.0'; hard, claystone concretion at 177.6 to 177.7' & 182.6 to 182.7'; dark gray to black carbonaceous shale with several 1/2" lignite streaks 182.5 to 183.2'; core lengths 3 to 24".

183.2-194.0 SILTY SANDSTONE: Most of sample washed away during drilling; sample recovered consisted of uncemented light gray fine grain silty sandstone; crumbles easily between fingers; laminated to banded; no HCl reaction.

194.0-195.4 SHALE: Medium to dark gray; slightly carbonaceous; air slacks; plastic; firm; difficult trimming by knife; core lengths 3 to 6".

195.4-198.5 LIGNITE: Black; moist; broken.

198.5-200.0 CLAYEY SILTSTONE: Light gray; firm; moist; crushes between fingers with difficulty; slightly plastic; active HCl reaction; core lengths 1 to 6".

EXPLANATION: CORE LOSS / CORE RECOVERY. Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn. Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing.

FEATURE: Beulah Trench Study Area, West Renners Cove Coalfield — PROJECT: EMRIA — STATE: N. Dakota — SHEET 3 OF 3 — HOLE NO. 77-101

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-101

GEOLOGY: G. TAUCHER — FIELD APPROVAL:
DRAWN: — TECHNICAL APPROVAL:
CHECKED: — APPROVED:

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-171

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Beulah Trench Study Area, West Rennar Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-102 — LOCATION: 2650' E. & 200' S. of NW Corner, Sec. 23, T. 145 N., R. 88 W. — GROUND ELEV. 2120± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN 6-28-77 — FINISHED 7-5-77 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 174.7 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 64.2' 7/5/77 (2055.8) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 6/28/77. Bx Ce drive samples 0 to 10.0'. Core recovery short due to compaction.

Hole at 10.0' 6/29/77. Hole dry. Bx Ce drive samples 10.0 to 12.0'. Hq wireline core 12.0 to 74.0'. 5" Cs set to 12.0'.

Hole at 74.0' 6/30/77. 5" Cs at 12.0'. W.L. at 20.0'. Hq wireline core 74.0 to 133.1' Dropped core 111.8 to 114.0 & 117.4 to 124.0'. Recovered small portion in redrill.

CORE RECOVERY (%): 100, 98, 100, 100, 100, 100, 100, 100, 100, 100, 0, 100, 100, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	1.5	23.0
#2	23.0	50.0
#3	50.0	75.0
#4	75.0	100.0

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
2118.5	1.5
2097.0	23.0

CLASSIFICATION AND PHYSICAL CONDITION

0-1.5 SILTY SAND: Dark gray; dry; organic; approximately 35% nonplastic fines & 65% fine, uniform sand; roots; may be residual weathered sandstone (SM).

FORT UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

1.5-23.0 SANDSTONE WITH SHALE: Tan; oxidized; moist; uncemented; crumbles easily between fingers; bedding not readily discernible; fine, uniform sand; residual weathered (soil-like) 1.5 to 5.0'; caliche concentration 4.5 to 5.0'; highly plastic, soft, oxidized, brown shale 8.7 to 10.2, 11.0 to 11.3, 12.2 to 12.4 and 22.1 to 22.4'; shale contains some gypsum crystals; core lengths 3 to 12".

23.0-124.4 SHALE WITH SANDSTONE & LIGNITE: Shale is tan & oxidized 23.0 to 27.0'; medium gray below 27.0'; moist; firm; (trims easily with knife); plastic; air slacks; scattered 1/8- to 1/2-inch marcasite nodules along poorly defined bedding planes; gypsum concentration 26.0 to 26.1'; hard, gray limestone 29.2 to 29.3'; oxidized, laminated shale (60%) & fine grain, uncemented silty sandstone (40%) 30.0 to 31.2'; black carbonaceous shale 38.1 to 38.5' with ½" lignite at 38.5'; laminated, fine grain, uncemented silty sandstone (crumbles between fingers) with numerous marcasite nodules up to ½" in size from 40.0 to 41.2'; black & carbonaceous 60.4 to 60.7'; clayey, mottled fine grain sandstone 60.7 to 61.0' (could be healed fault gouge?); very hard, cemented, sandy limestone 65.5 to 66.0 and 70.4 to 70.8'; light gray, uncemented silty, fine grain sandstone 70.8 to 71.3, 71.6 to 71.7, 71.9 to 72.5, 73.2 to 73.9, 77.5 to 78.3 and 83.0 to 83.3'; hard, light gray calcareous cemented sandstone 83.5 to 85.1'; light gray, uncemented sandstone 85.1 to 85.6'; lignite 93.9 to 94.1' & 94.4 to 95.6'; shale is banded with streaks (20%) of silty sandstone 97.6 to 105.4'; uncemented, laminated silty to clayey sandstone that is difficult to crush between fingers 105.4 to 108.0'; hard, calcareous siltstone 109.5 to 111.8 and 116.7 to 117.4'; core lengths 3 to 24" and average 12".

124.4-139.2 SHALE: Medium gray & slightly

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: N. Dakota — SHEET 1 OF 2 — HOLE NO. 77-102

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-102 — LOCATION: 2650' E. & 200' S. of NW Corner, Sec. 23, T. 145 N., R. 88 W. — GROUND ELEV. 2120± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN 6/28/77 — FINISHED 7/5/77 — DEPTH OF OVERBURDEN -- — TOTAL DEPTH 174.7 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 64.2' 7/5/77 (2055.8) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 133.1' 7/1/77. 5" Cs at 12.0'. W.L. at 17.7'. Hq wireline core 133.1 to 174.7'.

7/5/77 - W.L. at 64.2'. Pulled 5" Cs.. Filled hole with concrete. Hauled drill cuttings away from drill hole.

CORE RECOVERY (%): 100, 100, 23, 100, 24, 100, 100, 100, 100, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#5	100.0	124.4
#6	124.4	139.2
#7	161.8	174.7

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
1995.6	124.4
1980.8	139.2
1961.1	158.9
1959.7	160.3
1958.7	161.3
1958.4	161.6
1958.2	161.8
1945.3	174.7

CLASSIFICATION AND PHYSICAL CONDITION

carbonaceous 124.4 to 136.4'; dark gray & highly carbonaceous 136.4 to 139.2'; moist; firm; trims by knife with some difficulty; laminated to banded; air slacks; silty near top; becoming more plastic with depth; very hard, dense, dark gray limestone 131.6 to 132.4'; 60° slickenside at 136.8'; occasional marcasite nodules along bedding planes; core lengths 1 to 24".

139.2-158.9 LIGNITE: Black; hard; wet; broken on 1 to 6" centers; soft and shattered below 156.0'.

158.9-160.3 SHALE: Dark grey to black; moist; plastic; carbonaceous; cuts easily with knife; air slacks; 6" core lengths.

160.3-161.3 LIGNITE: Black; wet; broken.

161.3-161.6 SHALE: Medium gray to black with carbonaceous streaks; moist; plastic; trims easily by knife.

161.6-161.8 LIGNITE: Black; wet; broken.

161.8-174.7 SHALE AND SANDSTONE: Shale is medium gray; moist; firm and trims easily by knife; sandstone is silty, fine grain & crumbles between fingers; weak HCl reaction; core lengths 1 to 18"; medium gray, banded silty shale with silt and sand stringers 161.9 to 166.3'; alternating laminations of silty, fine grain sandstone & silty shale 166.3 to 169.3'; light grey, silty sandstone 169.3 to 171.5'; banded plastic shale 171.5 to 174.7'.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: N. Dakota — SHEET 2 OF 2 — HOLE NO. 77-102

Scale: METERS 0–9 / FEET 0–30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-102

GEOLOGY G. TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-172

GEOLOGIC LOG OF DRILL HOLE

7-1337 (9-69) Bureau of Reclamation — SHEET 1 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-103 — LOCATION: 2560' W. & 75' N. of SE Corner Sec. 22, T. 145 N., R. 88 W. — GROUND ELEV. 2185'± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7/11/77 — FINISHED 7/25/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 279.0 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 109.6' 7/25/77 (2075.4) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions

7/6, 7/7 & 7/8/77: Repairs on drill motor in Bismarck, North Dakota. 7/11/77—Moved drill to site from Bismarck. BxCs drive samples 0 to 15.0 ft. Set 5-in. Cs to 13.0 ft.

Hole at 15.0 ft. 7/12/77. Hole dry. 5-in. Cs at 13.0 ft. BxCs drive samples 15.0 to 16.2 ft. Hq wireline core 15.0 to 54.6 ft.

Hole at 54.6 ft. 7/13/77. W.L. at 24.0 ft. 5-in. Cs at 13.0 ft. Hq wireline core 54.6 to 95.8 ft. Dropped but recovered core 86.0 to 95.8 ft.

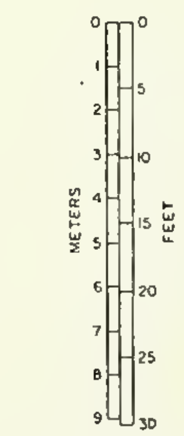
Hole at 95.8 ft. 7/14/77. W.L. at 64.0 ft. 5-in. Cs at 13.0 ft. Hq wireline core 95.8 to 134.0 ft. Lost all drill water at 105.8 ft. Lost samples 100.8 to 104.1, 113.6 to 123.0 and 124.0 to 131.7 ft.

Soils analysis samples

Sample	From (ft)	To (ft)
#1	0	10.0
#2	10.0	16.8
#3	16.8	28.6
#4	28.6	55.0
#5	55.0	81.0
#6	81.0	107.0
#7	107.0	133.3
#8	140.4	150.3
#9	150.3	161.2
#10	161.2	177.9
#11	177.9	193.2
#12	193.2	201.0
#13	201.0	220.5
#14	220.5	244.6
#15	266.6	279.0

Elevation / depth of contacts

Elevation (ft)	Depth (ft)
2168.2	16.8
2156.4	28.6
2052.0	133.0
2051.0	134.0
2046.1	138.9
2044.6	140.4
2034.7	150.3
2023.8	161.2
2007.1	177.9
1991.8	193.2
1984.0	201.0
1940.4	244.6
1918.4	266.6
1906.0	279.0



Classification and physical condition

0-10.0 SANDY CLAY: dark gray and organic 0 to 0.5 ft.; tan to white with caliche 0.5 to 2.0 ft.; scattered caliche inclusions to 7 ft.; tan and oxidized 2.0 to 10.0 ft.; dry to damp; approximately 55% medium plasticity fines, 40% fine to coarse sand and 5% mostly fine gravel; scattered lignite inclusions, glacial till (CL)

10.0-16.8 SILTY SAND: tan; oxidized; damp; active HCl reaction; approximately 20% very low to nonplasticity fines, 20% fine, hard, subangular gravel and 60% fine to coarse sand; glacial outwash(?); (SM)

16.8-28.6 SANDY CLAY: tan; oxidized; moist; active HCl reaction; approximately 55% medium plasticity fines, 40% fine to coarse sand and 5% mostly fine gravel; lignite inclusions; glacial till (CL)

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

28.6-133.3 SANDSTONE: tan and oxidized 28.6-112.0 ft.; light gray and unoxidized 112.0 to 133.3 ft.; moist to wet; generally uncemented, crumbling easily between fingers; fine; uniform; mostly clean with some zones containing up to 15% silt or clay fines; slightly cemented with $CaCO_3$ 42.5 to 43.0 ft.; hard, light gray calcareous sandstone (can't crush between fingers) 69.7 to 72.7 and 82.9 to 83.8 ft.; highly oxidized 88.8 to 98.8 ft.; highly oxidized with iron-rich concretions and carbonaceous fragments 105.1 to 106.0 ft. (lost water): zone 105.1 to 106.0 ft. is vuggy and appears leached by ground water; uncemented sandstone washed away 100.8 to 104.1, 113.6 to 123.0 and 124.0 to 131.7 ft.; ¼ in. lignitic shale at 131.7 ft.

133.0-134.0 LIGNITE AND SHALE: black, broken lignite 133.3 to 133.6 and 133.8 to 134.0 ft.; black, plastic, lignitic shale 133.6 to 133.8 ft.

134.0-138.9 Driller reported uncemented, fine grain Silty Sandstone that washed away during drilling

138.9-140.4 LIGNITE: black; moist; broken

EXPLANATION: Core loss / Core recovery

Type of hole: D = Diamond, H = Heystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 1 OF 3 — HOLE NO. 77-103

GEOLOGIC LOG OF DRILL HOLE — SHEET 2 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-103 — LOCATION: 2560' W. & 75' N. of SE Corner Sec. 22, T. 145 N., R. 88 W. — GROUND ELEV. 2185'± — DIP Vertical
BEGUN 7/11/77 — FINISHED 7/25/77 — TOTAL DEPTH 279.0
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 109.6' 7/25/77 (2075.4) — LOGGED BY Taucher

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions

Hole at 134.0 ft. 7/15/77. W.L. at 114.6 ft. 5 in. Cs at 13.0 ft. Hq wireline core 134.0 to 151.8 ft. No drill water return. Returned to Bismarck.

Hole at 151.8 ft. 7/18/77. W.L. at 111.6 ft. 5 in. Cs at 13.0 ft. Hq wireline core 151.8 to 162.7 ft. No drill water return. Returned from Bismarck.

Hole at 162.7 ft. 7/19/77. W.L. at 102.7 ft. 5 in. Cs at 13.0 ft. Dropped & partly recovered core 172.9 to 182.9 ft. Located additional drill holes with geologist.

Hole at 182.9 ft. 7/20/77. W.L. at 106.2 ft. 5 in. Cs at 13.0 ft. Hq wireline core 182.9 to 221.8 ft. Lost core 185.0 to 188.7 ft.

Classification and physical condition

140.4-150.3 SHALE WITH SANDSTONE: medium gray; moist; firm; trims by knife with some difficulty; plastic; air slakes; weak HCl reaction in zones. Silty 142.5 to 143.7 ft.; medium gray shale 143.7 to 150.3 ft. with silty, fine grain, uncemented sandstone at 144.5 to 145.5 ft.; 1 to 2 in. hard, calcareous, claystone, concretions 147.2, 147.5, & 148.0 ft.; core lengths 2 to 12 in.

150.3-161.2 SANDSTONE: light gray; moist; uncemented; fine grain; contains up to 20% silt in zones; alternating laminations of silty fine grain uncemented sandstone (70%) and medium gray silty shale 150.3 to 156.4 ft.; light gray, hard calcareous sandstone 156.4 to 157.8 ft.; uncemented silty sandstone 157.8 to 161.2 ft.; core lengths 6 to 18 in.

161.2-177.9 SHALE: medium gray; moist; firm; trims by knife with some difficulty; air slakes; weak HCl reaction; 60° joint at 170.5, 172.6, and 173.6 ft.; broken 173.6 to 177.9 ft.; bedding not readily discernible in most places; core lengths 6-18 in.

177.9-193.2 SHALE: medium gray; moist; firm; trims by knife with some difficulty; air slakes. Slight HCl reaction; bedding not readily discernible; laminated, silty, fine grain sandstone and medium grain plastic shale 184.2 to 185.0 ft.; lost core 185.0 to 188.7 ft.; core lengths 1 to 12 in.

193.2-201.0 SILTY SANDSTONE: light gray with scattered dark gray carbonaceous laminations; moist to wet; 10 to 15% silt; sand is fine, uniform and uncemented (crumbles easily between fingers); slight HCl reaction; core lengths 6 to 18 in.

201.0-244.6 SHALE WITH SANDSTONE AND LIGNITE: Shale is medium to dark gray; plastic, firm and difficult trimming with knife; sandstone is light gray, fine grain, generally silty and uncemented (crumbles between fingers); moist; shale air slakes; shale 201.0 to 218.8 ft. with laminated silty sandstone 204.0 to 204.2, 204.4 to 204.6, 205.0 to 205.2 and 206.0 to 206.2 ft.; sandstone 218.8 to 220.5 ft. with laminated sandstone and shale 220.0 to 220.5 ft.;

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 2 OF 3 — HOLE NO. 77-103

GEOLOGIC LOG OF DRILL HOLE — SHEET 3 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-103 — LOCATION: 2560' W. & 75' N. of SE Corner Sec. 22, T. 145 N., R. 88 W. — GROUND ELEV. 2185± — DIP Vertical
BEGUN 7/11/77 — FINISHED 7/25/77 — TOTAL DEPTH 279.0
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 109.6' 7/25/77 (2075.4) — LOGGED BY Taucher

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions

Hole at 221.8 ft. 7/21/77. W.L. at 109.2 ft. 5 in. Cs at 13.0 ft. Hq wireline core 221.8 to 264.0 ft. No drill water return.

Hole at 264.0 ft. 7/22/77. W.L. at 107.6 ft. 5 in. Cs at 13.0 ft. Hq wireline core 264.0 to 279.0 ft. Pulled 5 in. Cs.

7/25/77. W.L. at 109.6 ft. Hole sterilized with chlorine water & backfilled with concrete (total depth)

Classification and physical condition

banded to laminated shale 220.5 to 229.3 ft. with laminated silty sandstone and silty shale 221.2 to 221.8 ft and scattered claystone concretions up to 1 in. in size; shale is carbonaceous 228.7 to 229.3 ft.; alternating laminations of silty sandstone (60%) and silty shale (40%) 229.3 to 231.3 ft.; broken lignite 231.3 to 232.3 ft.; carbonaceous shale cut by numerous slickensides 232.3 to 234.1 ft.; broken lignite 234.1 to 235.5 ft.; shale 235.5 to 242.2 ft. with 20° joint at 238.4 ft black carbonaceous shale cut by slickensides 242.2 to 244.6 ft. with broken lignite 242.2 to 242.3 and 243.2 to 244.3 ft.

244.6-266.6 LIGNITE: black; wet; broken on 1 to 6 in. centers; hard; brittle; shattered 262.5 to 266.6 ft.

266.6-279.0 SHALE: medium gray; moist, firm, difficult trimming by knife; air slakes; dark gray and carbonaceous 266.6 to 267.3 ft.; alternating laminations of silty, fine grain, uncemented sandstone (50%) and silty shale (50%) 271.4 to 271.6 and 272.2 to 273.4 ft.; clayey fine grain sandstone 269.9 to 270.5 ft.; core lengths 3 to 18 in.

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 3 OF 3 — HOLE NO. 77-103

Depth on logs in feet. Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-103

GEOLOGY G TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED
BILLINGS, MONTANA — JANUARY 1980 — 1305-600-173

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-104 — LOCATION: 1300' S. & 25' W. of NE Corner Sec. 26, T. 145 N., R. 88 W. — GROUND ELEV. 2012+ — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 7/25/77 — FINISHED: 8/1/77 — DEPTH OF OVERBURDEN: — TOTAL DEPTH: 90.2 — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 69.2' 8/1/77 (1942.8) — LOGGED BY: Parish — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 7/25/77. BxCs drive samples 0 to 14.0 ft. Set 5 in. Cs to 13.0 ft.

Hole at 14.0 ft. 7/26/77. 5 in. Cs at 13.0 ft.; W.L. at 10.6 ft. Hq wireline core 14.0 to 90.2 ft. Core washed away 33.7 to 43.0 ft. Pulled 5 in. Cs.

8/1/77 W.L. at 69.2 ft. Back-filled hole with concrete.

CORE RECOVERY (%): 100, 100, 100, 100, 100, 0, 100, 100, 100, 100, 100, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	1.0	14.4
#2	14.4	33.7
#3	43.0	54.8
#4	76.4	90.2

SUITABILITY FOR RECONSTRUCTED PROFILE: Suitable / Limited Suitability / Unsuitable

ELEVATION (FEET)	DEPTH (FEET)
2011.0	1.0
2007.0	5.0
2000.0	12.0
1997.6	14.4
1969.0	43.0
1958.2	54.8
1937.1	74.9
1936.5	75.5
1935.6	76.4
1932.5	79.5
1924.5	82.5
1926.4	85.6
1925.4	86.4
1921.8	90.2

CLASSIFICATION AND PHYSICAL CONDITION

0-1.0 TOPSOIL: dark brown; dry; about 90% low plasticity fines and 10% fine sand; no HCl reaction; crumbly.

1.0-5.0 CLAY: mottled tan and white; dry; crumbly to firm; abundant caliche; strong HCl reaction; oxidized; approximately 90% low plasticity fines and 10% fine sand. (CL)

5.0-12.0 CLAYEY SAND: light brown with rusty spots; damp, crumbly; no HCl reaction; finely laminated with scattered clayey zones; approximately 60% fine sand and 40% low plasticity fines. (SC)

12.0-14.4 CLAY: dark brown; damp; firm; oxidized; scattered gypsum crystals; no HCl reaction; approximately 80% medium to high plasticity fines and 20% fine sand; sandy clay with about 40% very fine sand and 1-2 in. rounded gravel 13.6 to 14.4 ft. (CH)

FT. UNION FORMATION-SENTINEL BUTTE MEMBER-PALEOCENE

14.4-43.0 SILTY SANDSTONE: light brown; oxidized; moist; uncemented; crumbly; no HCl reaction; scattered gypsum crystals; a few thin clayey zones; contains about 70 to 80% extremely fine sand and 20% to 30% slight plasticity fines; core lengths up to 12 in.; highly oxidized around thin iron-rich concretions 18.6 to 18.8, 22.7 to 23.2 and 30.1 to 30.3 ft.; sandstone washed away during drilling 33.7 to 43.0 ft.

43.0-54.8 SHALE: medium gray becoming dark gray and carbonaceous with depth; moist; laminated; firm; plastic; cuts easily with knife; scattered silty to sandy zones; air slakes; no HCl reaction; light gray and sandy 47.0 to 48.0 ft.; hard, highly cemented siltstone 52.3 to 52.6 ft.; core lengths up to 2 ft.

54.8-74.9 LIGNITE: black; hard; broken.

74.9-75.5 SHALE: dark gray; moist; carbonaceous; firm; plastic; cuts with knife with some difficulty; air slakes; no HCl reaction; core lengths 6 in.

75.5-76.4 LIGNITE: black; wet; broken; hard.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 1 OF 2 — HOLE NO. 77-104

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-104 — LOCATION: 1300' S. & 25' W. of NE Corner Sec. 26, T. 145 N., R. 88 W. — GROUND ELEV. 2012+ — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 7/25/77 — FINISHED: 8/1/77 — DEPTH OF OVERBURDEN: — TOTAL DEPTH: 90.2 — BEARING:

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 69.2' 8/1/77 (1942.8) — LOGGED BY: Parish — LOG REVIEWED BY:

CLASSIFICATION AND PHYSICAL CONDITION

76.4-79.5 SHALE: medium gray; carbonaceous and darker near top; moist; firm; plastic; cuts with knife with difficulty; air slakes; no HCl reaction core lengths up to 18 in.

79.5-82.5 SILTY SANDSTONE: medium grain moist; laminated; crumbly; very fine grain; uncemented; no HCl reaction; core lengths up to 12 in.

82.5-85.6 SILTY TO SANDY SHALE: medium gray; moist; firm; plastic; cuts by knife with difficulty; laminated; air slakes; strong HCl reaction; core lengths up to 24 in.

85.6-86.4 SILTY SANDSTONE: light gray; hard; cemented; calcareous; very fine grain; scratches with knife; 2 to 5 in. core lengths

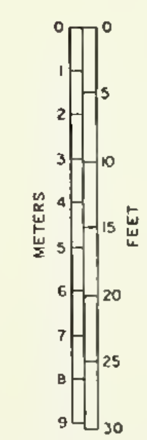
86.4-90.2 SHALE: dark gray; moist; laminated; firm; plastic; cuts with knife with some difficulty; strong HCl reaction; core lengths up to 18 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 2 OF 2 — HOLE NO. 77-104



Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-104

GEOLOGY G. TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-174

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield. PROJECT: EMRIA. STATE: North Dakota.
HOLE NO.: 77-105. LOCATION: 1210' W. & 370' S. of NE Corner Sec. 34, T. 145 N., R. 88 W. GROUND ELEV.: 2150±. DIP (ANGLE FROM HORIZ.): Vertical.
BEGUN: 5/25/77. FINISHED: 6/20/77. DEPTH OF OVERBURDEN: . TOTAL DEPTH: 258.5. BEARING: .
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 180.0' 6/20/77 (1970.0). LOGGED BY: Taucher. LOG REVIEWED BY: .

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 5/25/77. Mounted wireline winch on rig. 8x drive samples 0 to 9.0 ft. Drag bit 9.0 to 9.5 ft. BxCa rotation 9.5 to 25.0 ft. 8x drive samples 25.0 to 30.0 ft. Set 5 in. Cs to 13.0 ft.

Hole at 30.0 ft. 5/26/77. 5 in. Cs at 13.0 ft. W.L. at 12.5 ft. Nx drive samples 30.0 to 55.0 ft. Hq wireline core 55.0 to 83.0 ft. Using revert.

5/27/77. Did not go to rig due to heavy rain & muddy field conditions. Returned to duty station.

Hole at 73.0 ft. 6/6/77. Returned from duty station. 5 in. Cs at 13.0 ft. W.L. at 49.6 ft. Hq wireline core 73.0 to 83.3 ft.

Hole at 83.3 ft. 6/7/77. 5 in. Cs at 13.0 ft. W.L. at 22.6 ft. Hq wireline core 83.3 to 112.3 ft. Using revert.

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	0	25.0
#2	25.0	43.0
#3	43.0	61.1
#4	61.1	69.5
#5	69.5	92.4 minus lignite
#6	92.4	97.0

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
2125.0	25.0
2088.9	61.1
2080.5	69.5
2057.6	92.4
2053.0	97.0

CLASSIFICATION AND PHYSICAL CONDITION

0-25.0 SANDY CLAY (GLACIAL TILL): dark gray and slightly organic 0 to 1.5 ft.; tan and oxidized 1.5 to 25.0 ft.; dry to 10.0 ft.; moist 10.0 to 25.0 ft.; active HCl reaction; caliche concentration 1.5 to 3.5 and 9.5 to 10.0 ft.; boulder (not recovered) 9.0 to 9.5 ft.; approximately 60% medium plasticity fines, 35% fine to coarse sand and 5% fine, hard, subrounded gravel; scattered lignite inclusions; upper 1.5 ft.; may be wind deposited

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE:

25.0-61.1 SANDSTONE: tan; oxidized; moist; some silt; very fine uniform sand; uncemented; crumbles easily between fingers; weak HCl reaction in zones. Moderate HCl reaction 52.0 to 55.0 ft.; scattered minus ½ in. iron-rich, hard concretions generally along bedding planes; occasional thin (minus 1 in.) plastic shale streaks; bedding not readily discernible; core length minus 1 in. to 6 in.

61.1-69.5 SHALE WITH SANDSTONE: tan; oxidized; moist; shale is firm with scattered, hard claystone streaks; shale is moderately plastic and trims easily by knife; tan, uncemented, fine grain sandstone that crumbles easily between fingers 61.8 to 62.0, 63.0 to 63.8, 66.0 to 66.8 and 68.5 to 68.7 ft.; numerous 45 to 90° highly oxidized fractures; core lengths minus 6 in.

69.5-92.4 SANDSTONE WITH LIGNITE: tan and oxidized 69.5 to 83.6 ft.; black, soft, broken lignite 83.6 to 84.7 ft.; gray to tan and slightly oxidized 84.7 to 85.7 ft.; light grey and unoxidized 85.8 to 92.4 ft.; moist, uncemented, fine grain sandstone that crumbles easily between fingers 69.5 to 83.6 ft.; bedding not readily discernible 69.5 to 83.6 ft.; banded, silty, fine grain sandstone that crushes between fingers with some difficulty 84.7 to 92.4 ft.; material 84.7 to 92.4 ft. is more firm than 69.5 to 83.6 ft. zone; 6-1/8 in. gypsum streaks along horizontal to 30° bedding planes 85.0 to 86.0 ft.; weak HCl reaction; core lengths up to 12 in.

92.4-97.0 SHALE: medium gra[illegible] firm; trims by knife with some difficulty; moderately plastic to plastic; bedding not readily discernible; dark

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield. PROJECT: EMRIA. STATE: North Dakota. SHEET 1 OF 3. HOLE NO. 77-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield. PROJECT: EMRIA. STATE: North Dakota.
HOLE NO.: 77-105. LOCATION: 1210' W. & 370' S. of NE Corner Sec. 34, T. 145 N., R. 88 W. GROUND ELEV.: 2150±. DIP (ANGLE FROM HORIZ.): Vertical.
BEGUN: 5/25/77. FINISHED: 6/20/77. DEPTH OF OVERBURDEN: . TOTAL DEPTH: 258.5. BEARING: .
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 180.0' 6/20/77 (1970.0). LOGGED BY: Taucher. LOG REVIEWED BY: .

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 112.3 ft. 6/8/77. 5 in. Cs at 13.0 ft. W.L. at 25.0 ft. Hq wireline core 112.3 to 134.6 ft. Dropped sample 116.6 to 122.6 ft. Washed away trying to redrill. Repairs on wireline overshot.

Hole at 134.6 ft. 6/9/77. 5 in. Cs at 13.0 ft. W.L. at ground surface. Hq wireline 134.6 to 164.0 ft. Dropped samples 140.0 to 144.0 and 162.0 to 164.0 ft. Washed away trying to redrill. Repairs on wireline overshot.

Hole at 164.0 ft. 6/10/77. 5 in. Cs at 13.0 ft. W.L. at 62.0 ft. Hq wireline core 164.0 to 194.0 ft. Used revert. Returned to duty station.

Hole at 194.0 ft. 6/13/77. 5 in. Cs at 13.0 ft. W.L. at 104.8 ft. Returned from duty station. Hq wireline core 194.0 to 202.4 ft.

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#7	97.0	116.6
#8	116.6	141.0
#9	141.0	165.8
#10	165.8 minus	190.0 lignite
#11	190.0	203.4

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
1984.2	165.8
1960.0	190.0

CLASSIFICATION AND PHYSICAL CONDITION

gray, carbonaceous shale cut by numerous 30 to 60° slickensides 94.5 to 95.5 ft.; core lengths 1 to 24 in.

97.0-165.8 SANDSTONE: light gray; moist; fine grain; uncemented; crumbles easily between fingers; approximately 10% nonplastic fines; bedding not generally discernible; firm, moderately hard calcareous sandstone 110.0 to 111.6 ft.; 70° joint at 110.8 ft.; several ½ in. lignite streaks 154.8 to 156.3 ft.; becoming finer grained sandstone with about 20% silt and clay fines (low plasticity) 157.5 to 165.6 ft.; hard, calcareous sandstone 165.6 to 165.8 ft.; core lengths ½ to 12 in.

165.8-190.0 SHALE WITH SANDSTONE AND LIGNITE: Shale is medium gray; moist; firm, plastic and trims by knife with some difficulty; sandstone is light gray, moist, silty, uncemented, fine grain and crumbles easily between fingers; Lignite is black, broken and moist; slight HCl reaction; core lengths 1 to 24 in.
165.8-171.8-Shale with 5% silty sand laminations; contains scattered marcasite nodules (½ in.) along bedding.
171.8-173.9-fine grain sandstone with shale 172.3 to 172.7 and lignite 172.7 to 172.9 ft.
173.9-174.2-Silty to sandy, slightly carbonaceous shale
174.2-175.2-Lignite
175.2-178.8-Slightly carbonaceous shale with shaley lignite 176.7 to 177.0 and 177.7 to 178.7 ft.; numerous slickensides
178.8-190.0-Laminated medium plastic shale (60%) and silty fine grain sandstone (40%); slight to moderate HCl reaction; contains marcasite nodules along bedding

190.0-203.4 SANDSTONE WITH SHALE: alternating laminations of light gray, fine grain, uncemented, silty sandstone that crumbles between fingers and medium gray, moderately plastic silty shale; sandstone is about 65% of material; slight HCl reaction; core lengths 1-12 in.

203.4-223.5 SHALE: medium gray; moist; firm; silty; moderately to highly [illegible] places; trims easily with knife; slight HCl reaction; dark gray sandy limestone

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield. PROJECT: EMRIA. STATE: North Dakota. SHEET 2 OF 3. HOLE NO. 77-105

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield. PROJECT: EMRIA. STATE: North Dakota.
HOLE NO.: 77-105. LOCATION: 1210' W. & 370' S. of NE Corner Sec. 34, T. 145 N., R. 88 W. GROUND ELEV.: 2150±. DIP (ANGLE FROM HORIZ.): vertical.
BEGUN: 5/25/77. FINISHED: 6/20/77. DEPTH OF OVERBURDEN: . TOTAL DEPTH: 258.5. BEARING: .
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 180.0' 6/20/77 (1970.0). LOGGED BY: Taucher. LOG REVIEWED BY: .

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 202.4 ft. 6/14/77. 5 in. Cs at 13.0 ft. W.L. at 60.0 ft. Hq wireline core 202.4 to 247.0 ft.

6/15/77 Unable to work because of heavy rain and muddy field conditions.
6/16/77 Unable to work because of heavy rain and muddy field conditions

Hole at 247.0 ft. 6/17/77. 5 in. Cs at 13.0 ft. W.L. at 157.3 ft. Hq wireline core 247.0 to 258.5 ft. Pulled 5 in. Cs.

6/20/77 W.L. at 180.0 ft. Backfilled hole with concrete. Hauled away cuttings.

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#12	203.4	223.5
#13	247.0	251.0
#14	251.0	257.4

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
1946.6	203.4
1926.5	223.5
1903.	247.
1899.	251.
1892.6	257.4
1891.5	258.5

CLASSIFICATION AND PHYSICAL CONDITION

(scratches with knife) 218.1-219.3 ft.; sandy shale below 219.3 ft.; 70° joint at 213.5 ft.; carbonaceous 223.2 to 223.5 ft.; core lengths 6 to 18 in.

223.5-247.0 LIGNITE: black; hard; broken; wet; dull to almost metallic luster; ½ in. carbonaceous shale at 245.0 ft.; breaks along horizontal planes on ½ to 6 in. centers

247.0-251.0 SANDSTONE AND SHALE: alternating laminations of light grey, silty, fine grain sandstone that crumbles easily between fingers and medium gray plastic shale that trims by knife with some difficulty; sandstone is 50% of material; core lengths 6 to 12 in.

251.0-257.4 SANDSTONE: light grey; moist; uncemented; fine, uniform sand with trace of silt; crumbles easily between fingers; slight HCl reaction; bedding not readily discernible; core lengths 3-12 in.

257.4-258.5 SHALE WITH SANDSTONE: alternating laminations of medium grey, firm, plastic shale (70%) and light grey, uncemented, fine grain sandstone (30%); active HCl reaction; core lengths 3 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield. PROJECT: EMRIA. STATE: North Dakota. SHEET 3 OF 3. HOLE NO. 77-105

METERS / FEET

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-105

GEOLOGY: G. TAUCHER — FIELD APPROVAL:
DRAWN: — TECHNICAL APPROVAL:
CHECKED: — APPROVED:
BILLINGS, MONTANA — JANUARY 1980 — 1305-600-175

7-1337 (6-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-106 — LOCATION: 290' S. & 25' W. of NE Corner Sec. 6, T. 144 N., R. 88 W. — GROUND ELEV. 2070± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 6/21/77 — FINISHED 6/28/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 183.0 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 68.7' 6/28/77 (2101.3) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 6/21/77. BxCa drive samples 0 to 15.0 ft. 5 in. Cs set to 13.0 ft. Hq wireline 15.0 to 32.2 ft. 50% water loss at 25.0 ft. Advanced 5 in. Cs to 27.0 ft.

Hole at 32.2 ft. 6/22/77. BxCs at 27.0 ft. W.L. at 4.3 ft. Hq wireline core 32.2 to 102.1 ft.

Soils analysis samples (depth, feet):

Sample	From	To
#1	1.5	24.6
#2	24.6	30.7
#3	30.7	48.5
#4	48.5	73.2
#5	73.2	96.5

Core recovery (%): 100 throughout.

Elevation (feet)	Depth (feet)
2068.5	1.5
2045.4	24.6
2039.3	30.7
2021.5	48.5
1996.8	73.2
1973.5	96.5

Classification and physical condition:

0-1.5 SANDY CLAY (GLACIAL TILL): tan; oxidized; moist to wet; approximately 60% medium plasticity fines, 35% fine to coarse sand and 5% gravel; active HCl reaction; roots (CL)

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

1.5-24.6 SANDSTONE: tan; oxidized; dry 1.5 to 14.5 ft.; wet 14.5 to 24.6 ft.; uncemented; crumbles easily between fingers; fine; uniform sand; contains 10 to 15% silt; ½ in. lignite at 24.6 ft.; core lengths up to 6 in.

24.6-30.7 SILTY SHALE: tan to medium gray; moist; oxidized; moderately soft; trims easily with knife; thin bedded; silty; approaching clayey siltstone in places; very hard, cemented sandy limestone 27.1 to 28.5 ft.; scattered slickensides; broken; very slight HCl reaction; lignite 30.4 to 30.7 ft.; core lengths up to 12 in.

30.7-48.5 SANDSTONE: tan and oxidized 30.7 to 47.5 ft.; light gray and unoxidized 47.5 to 48.5 ft.; fine grain; uncemented; crumbles easily between fingers; trace of nonplastic fines; moist; occasional thin (1/8 in.) carbonaceous streaks; bedding not readily discernible; very slight HCl reaction; moderately cemented calcareous sandstone 40.5 to 41.7 ft.; core lengths up to 12 in.

48.5-73.2 SILTY SHALE: medium gray; moist; moderately firm, trims easily with knife; appears banded; moderately plastic to plastic; air slakes; dark gray and carbonaceous 55.4 to 56.4 and 57.5 to 57.6 ft.; 1/8 in. lignite at 58.7 and 59.0 ft.; soft, broken lignite 62.6 to 62.8 ft.; laminated medium plastic silty shale (60%) and silty to clayey, fine grain slightly calcareous sandstone (40%) 65.0 to 73.2 ft.; 60° joint at 54.0, 59.6, 61.0, 64.1, 68.0 and 69.3 ft.; occasional minus ½ in. marcasite nodules along bedding planes; core lengths 6 to 18 in.

73.2-96.5 CLAYEY SANDSTONE: light gray; moist to wet; firm, crumbles between fingers with some difficulty when wet; banded to almost laminated in zones; moderately plastic; contains up to 30% clay fines; sand is fine and uniform; scattered marcasite nodules up to ½ in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 1 OF 3 — HOLE NO. 77-106

7-1337 (6-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-106 — LOCATION: 290' S. & 25' W. of NE Corner Sec. 6, T. 144 N., R. 88 W. — GROUND ELEV. 2070± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 6/21/77 — FINISHED 6/28/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 183.0 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 68.7' 6/28/77 (2101.3) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole at 102.1 ft. 6/23/77. 5 in. Cs at 27.0 ft. W.L. at 44.6 ft. Hq wireline core 102.1 to 163.3 ft. Core washed away between 102.1 and 108.6 ft. Dropped but redrilled and recovered core from 129.7 to 132.5 ft.

Hole at 163.3 ft. 6/24/77. 5 in. Cs at 27.0 ft. W.L. at 67.7 ft. Hq wireline core 163.3 to 183.0 ft. Pulled 5 in. Cs. Moved to DH 77-102.

6/27/77 Repaired powerwagon in Bismarck.

6/28/77 W.L. at 68.7 ft. Filled hole with concrete. Cleaned up and hauled away cuttings.

Soils analysis samples (depth, feet):

Sample	From	To
#6	96.5	108.6
#7	108.6	134.3
	136.6	138.2
#8	153.0	159.3
#9	164.8	183.0 minus lignite

Core recovery (%): 100, 0, 100, 100, 100, 100, 100, 100, 100, 100

Elevation (feet)	Depth (feet)
1961.4	108.6
1935.7	134.3
1933.4	136.6
1931.8	138.2
1917.0	153.0
1910.7	159.3
1905.2	164.8
1887.0	183.0

Classification and physical condition:

in size; moderate HCl reaction; hard, light gray calcareous sandstone nodule (2 in.) at 84.8 ft.; ½ in. hard, iron-rich claystone at 91.0 ft.; silty to sandy shale 95.4 to 96.5 with lignite at 96.3 to 96.5 ft.; core lengths 3 to 24 in.

96.5-108.6 SILTY SANDSTONE: light gray; wet; uncemented; crumbles easily between fingers; washes away during drilling; micaceous; fine grain; pulverized by drilling; approximately 15% silt; carbonaceous 96.5 to 97.0 ft.

108.6-134.3 SHALE AND SANDY SHALE: medium gray; wet; firm; trims by knife with some difficulty; very weak HCl reaction in zones; air slakes; moderately plastic to plastic; core lengths 3 to 18 in.
108.6-114.6 - plastic dark gray carbonaceous shale cut by numerous slickensides; lignite 113.2 to 113.8 ft.
114.6-118.2 - banded to laminated sandy shale
118.2-124.2 - plastic shale
124.2-125.2 - light gray, banded, fine grain, clayey sandstone
125.2-126.0 - alternating laminations of silty shale and clayey sandstone
126.0-134.3 - plastic shale; carbonaceous 134.2 to 134.3 ft.

134.3-136.6 LIGNITE: black; wet; broken

136.6-138.2 SHALE: medium gray; plastic; wet; air slakes; cuts easily with knife; several small lignite streaks

138.2-153.0 LIGNITE: black; wet; dull to metallic luster; broken in 1 to 3 in. pieces 138.2-150.0 ft.; shattered below 150.0 ft.

153.0-159.3 SHALE WITH SANDSTONE: medium to dark gray; wet; slightly carbonaceous; plastic; trims easily with knife; no HCl reaction; clayey fine grain sandstone streaks up to 3 in. thick 153.0 to 156.0 ft.; core lengths 12 to 24 in.

159.3-164.8 LIGNITE: black; wet; dull to metallic luster; 1 to 3 in. pieces to 163.5 ft; shattered 163.5 to 164.8 ft.

164.8-183.0 CLAYEY SANDSTONE WITH SHALE AND LIGNITE: medium gray; moist to wet; firm; trims by knife; sand is very fine grain; (approaching silt); varies from

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 2 OF 3 — HOLE NO. 77-106

7-1337 (6-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-106 — LOCATION: 290' S. & 25' W. of NE Corner Sec. 6, T. 144 N., R. 88 W. — GROUND ELEV. 2070± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 6/21/77 — FINISHED 6/28/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 183.0 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 68.7 6/28/77 (2101.3) — LOGGED BY Taucher — LOG REVIEWED BY

Classification and physical condition:

banded clayey sandstone to sandy shale; weak HCl reaction in zones; broken lignite 172.6 to 174.0 ft.; silty sandstone 174.0 to 175.2 ft.; more shaley (sandy shale) below 175.2 ft. core lengths 3 to 12 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 3 OF 3 — HOLE NO. 77-106

METERS 0–9 / FEET 0–30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-106

GEOLOGY G TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-176

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Beulah Trench Study Area, West Beouer Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-107 — LOCATION: 1400' S. & 50' W. of NE Corner Sec. 1, T. 144 N., R. 89 W. — GROUND ELEV. 2115± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN 7-27-77 — FINISHED 8-8-77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 217.6 — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 65.1 8-8-77 (2049.9') — LOGGED BY: Parish 0 to 132.8, Taucher 132.8 to 217.6 — LOG REVIEWED BY

Column headings: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM / TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Notes on drilling conditions:

Hole started 7/27/77. BxCs drive samples 0 to 15.0 ft. Hq wireline core 15.0 to 65.6 ft. Set 5 in. Cs to 15.0 ft.

Hole at 65.6 ft. 7/28/77. 5 in. Cs at 15.0 ft. W.L. at 43.7 ft. Hq wireline core 65.6 to 132.8 ft.

Core recovery (%): 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

Soils analysis samples:

Sample	From	To
#1	1.3	10.0
#2	10.0	30.0
#3	30.0	45.2
#4	45.6	60.4
#5	60.4	86.8
#6	86.8	109.[illegible]

Elevation / Depth (feet):

Elevation	Depth
2113.7	1.3
2105.0	10.0
2069.8	45.2
2069.4	45.6
2061.0	54.0
2058.0	57.0
2028.2	86.8

Classification and physical condition:

0-1.3 TOPSOIL: medium gray; dry; roots; organic; approximately 85% low plasticity fines and 15% fine, uniform sand; crumbly to firm; no HCl reaction

1.3-10.0 SANDY CLAY: brown; dry to damp; abundant caliche especially 1.3 to 6.0 ft.; active HCl reaction; crumbly to firm; approximately 60% low to moderate plasticity fines; approximately 35% fine to coarse sand; approximately 5% hard, subrounded gravel (CL)

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

10.0-45.2 SANDSTONE: tan to light brown; moist; oxidized; uncemented; fine grain; no HCl reaction; crumbly; approximately 5 to 10% nonplastic fines. Scattered marcasite nodules up to 1½ in. in size; clayey sandstone (SC) 18.0 to 18.2 and 24.0 to 24.7 ft.; hard, cemented claystone 31.5 to 31.7 ft.

45.2-45.6 LIGNITE: black; moist; broken; hard

45.6-54.0 SILTY SANDSTONE: tan to brown; oxidized; moist; uncemented; crumbly; fine grain; silty lenses; no HCl reaction; near vertical oxidized joint 46.0 to 48.5 ft.; and 52.0 to 53.0 ft.; core lengths up to 2 ft.

54.0-57.0 SHALE: medium gray grading to near black; carbonaceous shale with depth; laminated; moist; firm; trims by knife with some difficulty; plastic air slakes; no HCl reaction; hard, light gray sandy streaks 55.0 to 55.2 ft.; black and carbonaceous 56.5 to 57.0 ft.; ¼ in. lignite streak at 57.0 ft.; core lengths up to 1 ft.

57.0-86.8 SILTY SANDSTONE: light brown to tan; moist; banded; crumbly; uncemented fine grain; scattered thin silty to clayey lenses; hard, cemented sandstone 60.5 to 61.0 and 64.2 to 65.6 ft.; silty, very fine grain sandstone 65.6 to 86.8 ft.; core lengths up to 1 ft.

86.8-104.5 SANDY SHALE: medium gray to nearly black; moist; firm; trims by knife with difficulty; air slakes; plastic; 45° joint at 96.7 ft.; 70° joint at 96.9 ft.; very dark and highly carbonaceous 99.5 to 104.5 ft.; near vertical joint 99.5 to 100.5 ft.; core lengths 1 to 24 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 1 OF 3 — HOLE NO. 77-107

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-107 — LOCATION: 1400' S. & 50' W. of NE Corner Sec. 1, T. 144 N., R. 89 W. — GROUND ELEV. 2115± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN 7-27-77 — FINISHED 8-8-77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 217.6 — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 65.1 8-8-77 (2049.9') — LOGGED BY: Parish 0 to 132.8', Taucher 132.8 to 217.6 — LOG REVIEWED BY

Notes on drilling conditions:

Hole at 132.8 ft. 7/29/77. 5 in. Cs at 15.0 ft. W.L. at 43.6 ft. Hq wireline core 132.8 to 155.1 ft. Dropped core 132.8 to 140.4 ft. (Recovered 3.3 ft.)

Hole at 155.1 ft. 8/1/77. 5 in. Cs at 15.0 ft. W.L. at 53.2 ft. Hq wireline core 155.1 to 164.0 ft. Lost core 155.4 to 160.2 ft. (unable to recover)

Hole at 164.0 ft. 8/2/77. 5 in. Cs at 15.0 ft. W.L. at 53.6 ft. Hq wireline core 164.0 to 217.6 ft. Dropped core 164.0 to 167.4 ft. (unable to recover)

Core recovery (%): 100, 100, 100, 100, 43, 100, 100, 0, 100, 0, 100, 100, 100, 100

Soils analysis samples:

Sample	From	To
#7	111.1	132.8
#8	132.8	152.0
#9	152.0	172.[illegible]
#10	183.[illegible]	200.0

Elevation / Depth (feet):

Elevation	Depth
2010.5	104.5
2005.4	109.6
2003.9	111.1
2002.5	112.5
1982.4	132.6
1982.2	132.8
1942.9	172.1
1931.9	183.1
1915	200

Classification and physical condition:

104.5-109.6 CLAYEY SILTSTONE: medium gray; damp; moist; firm; laminated; cuts by knife with difficulty; no HCl reaction; core lengths up to 30 in.

109.6-111.1 LIGNITE: black; hard; broken; moist

111.1-112.5 SHALE: black; moist; firm; trims by knife with difficulty; carbonaceous; plastic; air slakes; no HCl reaction; core lengths up to 3 in.

112.5-132.6 SANDY SHALE: medium gray; moist to wet; firm; difficult trimming by knife; laminated; scattered sandy zones; weak HCl reaction; carbonaceous 116.5 to 116.8 ft.; laminated sandstone and shale 116.8 to 119.3, 123.7 to 124.2 and 126.2 to 127.7 ft.; core lengths up to 36 in.

132.6-132.8 SANDY LIMESTONE: dark gray; very hard; scratches with knife; calcareous

132.8-172.1 SHALE WITH SANDSTONE AND LIGNITE: medium gray; moist; moderately firm; trims easily with knife; bedding not readlly discernible; weak HCl reaction; air slakes; black, broken 1ignite 140.5 to 141.7 ft.; laminated, uncemented, fine grain sandstone (crumbles between fingers) 147.6 to 149.9 and 150.6 to 152.0 ft.; laminated silty fine grain sandstone and silty to sandy shale 152.3 to 153.6 ft.; very hard sandy limestone or calcareous sandstone 154.0 to 155.0 ft.; core lengths 6 to 24 in.

172.1-183.1 LIGNITE: black; wet; broken in ½ to 2 in. core lengths, hard

183.1-200.0 SANDY SHALE: medium gray; moist; firm; trims by knife with difficulty; medium to high plasticity; banded to laminated; scattered small (-½ in.) marcasite inclusions; plastic shale 183.1 to 184.5 ft.; alternating laminations of silty to clayey sandstone and sandy shale 184.5 to 189; sandy shale becoming laminated 198.0 to 200.0 ft.; 25° joint at 199.0 ft.; core lengths 6 to 30 in.

200.0-205.9 LIGNITE: black; wet; [illegible]

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 2 OF 3 — HOLE NO. 77-107

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Beulah Trench Study Area, West Rennar Covo Coalfield — PROJECT: EMRIA — STATE: North Dakota

HOLE NO. 77-107 — LOCATION: 1400' S. & 50' W. of NE Corner Sec. 1, T. 144 N., R. 89 W. — GROUND ELEV. 2115± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN 7/27/77 — FINISHED 8/8/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 217.6 — BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 65.1 8/8/77 (2049.9) — LOGGED BY: Parish 0 to 132.8', Taucher 132.8 to 217.6' — LOG REVIEWED BY

Notes on drilling conditions:

8/3/77 W.L. at 52.6 ft.. Pulled 5 in. Cs. Moved to DH 77-108

8/8/77 W.L. at 65.1 ft. Back-filled hole with concrete and hauled away drill cuttings

Core recovery (%): 100, 100, 100

Soils analysis samples:

Sample	From	To
#11	205.9	217.6

Elevation / Depth (feet):

Elevation	Depth
1909.1	205.9
1897.4	217.6

Classification and physical condition:

205.9-217.[illegible] SANDY SHALE: medium grey; moist; firm to very firm; trims by knife with difficulty; scattered clayey sandstone laminations; 30 to 60° slickenside at 212.0 ft.; core lengths 3 to 12 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota — SHEET 3 OF 3 — HOLE NO. 77-107

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE CDALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-107

GEOLOGY G. TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-177

7-1337 (8-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield
PROJECT: EMRIA
STATE: North Dakota
HOLE NO.: 77-108
LOCATION: 1525' W. & 25' N. of SE Corner, Sec. 6, T. 144 N., R. 88 W.
GROUND ELEV.: 2067±
DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8/3/77
FINISHED: 8/12/77
DEPTH OF OVERBURDEN:
TOTAL DEPTH: 168.5
BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 77.3 8/12/77 (1989.7)
LOGGED BY: Taucher
LOG REVIEWED BY:

Column headings: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE, DEPTH (FEET): FROM, TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE, LIMITED SUITABILITY, UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 8/3/77. BxCs drive samples 0 to 10.0 ft. Bx Cs rotation 10.0 to 37.4 ft. Lost water 20.0 to 25.0 ft. Set 5 in. Cs to 28.0 ft.

Hole at 37.4 ft. 8/4/77. 5 in. Cs at 28.0 ft. W.L. at 3.6 ft. Hq wireline 37.4 to 97.3 ft. Using revert.

Hole at 97.3 ft. 8/5/77. 5 in. Cs at 28.0 ft. W.L. at 76.3 ft. Hq wireline 97.3 to 132.3 ft.

Core recovery (%): 100, 82, 58, 50, 62, 80, 92, 100, 100, 100, 100, 100, 100

Soils analysis samples:

Sample	From	To
01	0.6	37.0
02	37.0	57.0
03	57.0	77.3
04	77.3	95.9

Elevation / depth of contacts:

Elevation (feet)	Depth (feet)
2066.4	0.6
2030.0	37.0
1989.7	77.3
1971.1	95.9

Classification and physical condition:

0-0.6 SANDY CLAY: dark gray; organic; dry; roots; approximately 40% fine uniform sand and 60% medium plasticity clay; residual weathered glacial till; topsoil (CL)

0.6-37.0 SANDY CLAY: white to tan with large amounts of caliche 0.6 to 5.0 ft.; tan 5.0 to 37.0 ft.; oxidized; dry 0.6 to 5.0 ft.; damp to moist with depth 5.0 to 37.0 ft.; active HCl reaction 0.6 to 5.0 ft.; moderate HCl reaction below 5.0 ft.; approximately 55% medium plasticity fines, 40% fine to coarse sand and 5% hard, subrounded gravel; lignite inclusions; glacial till (CL)

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

37.0-77.3 SANDSTONE WITH CONGLOMERATE: tan; oxidized; moist; generally uncemented and fine grain; varies from clean to zones with 15% nonplastic fines; crumbles easily between fingers; uncemented, silty to clayey conglomerate zones with rounded to subangular gravels up to 1 in. in diameter 37.9 to 38.9, 41.5 to 41.6, 43.5 to 43.6, 44.5 to 44.6, 55.5 to 56.2, 57.0 to 57.5, 69.7 to 72.2, 73.4 to 74.6 and 75.9 to 77.0 ft. moderately cemented calcareous sandstone (scratches with knife) 72.2 to 73.4, 74.6 to 75.9 and 77.0 to 77.3 ft.; weak to moderate HCl reaction; generally pulverized by drilling

77.3-95.9 SHALE WITH LIGNITE: medium gray; moist; trims by knife with some difficulty; moderately plastic to plastic; air slakes; banded to almost laminated; broken lignite 82.7 to 84.1 ft.; becoming silty and sandy shale below 89.0 ft.; silty sandstone 94.0 to 95.0 ft.; scattered marcasite inclusions; 70° joint with ½ in. carbonaceous filling 87.7 to 88.5 ft.; core lengths 3 to 24 in.

95.9-122.0 SHALE WITH SANDSTONE: medium gray; moist; medium firm but trims easily with knife; plastic; air slakes; weak HCl reaction generally in sandy areas; 80° irregular joint 97.5 to 98.5 ft.; scattered marcasite nodules up to ½ in. in diameter concentrated generally along bedding planes; core lengths 3 to 30 in.; very hard, medium gray, calcareous cemented, fine grain sandstone 97.3 to 99.7 ft.; medium gray;

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield PROJECT: EMRIA STATE: North Dakota SHEET 1 OF 2 HOLE NO. 77-108

7-1337 (8-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield
PROJECT: EMRIA
STATE: North Dakota
HOLE NO.: 77-108
LOCATION: 1525' W. & 25' N. of SE Corner, Sec. 6, T. 144 N., R. 88 W.
GROUND ELEV.: 2067±
DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8/3/77
FINISHED: 8/12/77
DEPTH OF OVERBURDEN:
TOTAL DEPTH: 168.5
BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 77.3 8/12/77 (1989.7)
LOGGED BY: Taucher
LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole at 132.3 ft. 8/8/77. 5 in. Cs at 28.0 ft. W.L. at 72.7 ft. Hq wireline core 132.3 to 140.5 ft. No drill water return

Hole at 140.5 ft. 8/9/77. 5 in. Cs at 28.0 ft. Hq wireline core 140.5 to 168.5 ft. No drill water return. Pulled 5 in. Cs. Moved rig to DH77-109

8/12/77 W.L. at 77.3 ft. Filled hole with concrete.

Core recovery (%): 100, 100, 100, 100, 100, 100, 100, 100

Soils analysis samples:

Sample	From	To
05	95.9	122.0
06	132.6	140.5
07	140.5	149.8
08	155.5	168.5

Elevation / depth of contacts:

Elevation (feet)	Depth (feet)
1945.0	122.0
1934.4	132.6
1926.5	140.5
1917.2	149.8
1911.5	155.5
1898.5	168.5

Classification and physical condition (continued):

uncemented, silty, fine grain sandstone 99.7 to 100.3 ft.; alternating laminations of medium gray, moderately plastic silty shale (40%) and light gray, uncemented, fine grain sandstone (60%) 100.3 to 105.6 ft.; laminated shale and uncemented sandstone 110.0 to 110.8 and 113.5 to 114.5 ft.; black, carbonaceous shale 121.4 to 122.0 ft.

122.0-132.6 LIGNITE: black; wet; hard; broken on 1 to 3 in. centers 122.0 to 128.0 ft., soft and shattered 128.0 to 132.6 ft.

132.6-140.5 SANDSTONE WITH SHALE: medium gray; moist; uncemented; crumbles between fingers with difficulty; shale zones are moderately plastic and trim by knife; medium gray, plastic shale 132.6 to 133.0 ft.; with ½ in. lignite filled 40° fracture at 132.9 ft.; hard, calcareous cemented, fine grain sandstone 133.0 to 133.4 ft.; laminated sandstone (70%) and shale (30%) 133.4 to 140.8 ft.; 1/8 in. lignite bands at 134.0 and 134.2 ft.

140.5-149.8 SHALE: medium gray; moist; moderately firm, trims easily by knife; bedding not readily discernible; air slakes; plastic; laminated shale and uncemented sandstone 142.5 to 143.5 ft.; becoming soft 148.0 to 149.8 ft.; core lengths 6 to 18 in.

149.8-155.5 LIGNITE: black; hard; broken on ½ in. centers; wet

155.5-168.5 SHALE: medium gray; moist; firm; difficult trimming by knife; air slakes; plastic; bedding not readily discernible; slightly carbonaceous and cut by numerous slickensides 155.5 to 156.5 ft.; scattered uncemented sandstone laminations (30%) 157.0 to 158.5 ft., core lengths 6 to 30 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield PROJECT: EMRIA STATE: North Dakota SHEET 2 OF 2 HOLE NO. 77-108

METERS 0–9 / FEET 0–30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-108

GEOLOGY G TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA JANUARY 1980 1305-600-178

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-109 — LOCATION: 2280' E. & 75' S. of NW Corner Sec. 8, T. 144 N., R. 88 W. — GROUND ELEV. 2025± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/9/77 — FINISHED 8/16/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 140.8 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 70.4 8/16/77 (1954.6) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 8/9/77, BxCs drive samples 0 to 13.0 ft. Set 5 in. Cs to 13.0 ft.

Hole at 13.0 ft. 8/10/77. W.L. at 1.5 ft. 5 in. Cs at 13.0 ft. Hq wireline core 13.0 to 81.1 ft.

Hole at 81.0 ft. 8/11/77. 5 in. Cs at 13.0 ft. W.L. at 55.8 ft. Hq wireline core 81.1 to 140.8 ft. Pulled 5 in. Cs. Moved rig.

8/16/77 W.L. at 70.4 ft. Hole backfilled with concrete

Core recovery (%): 100 throughout.

Soils analysis sample	Depth from (feet)	Depth to (feet)
#1	3.2	28.8
#2	28.8	51.8
#3	51.8	65.0 minus lignite
#4	65.0	73.6
#5	73.6	100.4

Elevation (feet)	Depth (feet)
2023.3	1.7
2021.8	3.2
1996.2	28.8
1973.2	51.8
1960.0	65.0
1951.4	73.6

Classification and physical condition

0-1.7 SANDY CLAY: gray; slightly organic; dry; roots; active HCl reaction; approximately 40% fine sand, 55% medium plasticity fines and 5% hard, subrounded gravel; could be reworked glacial till (CL)

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

1.7-3.2 LIGNITE: black; dry; weathered to powder

3.2-28.8 SILTY SANDSTONE WITH SHALE: tan; moiat; oxidized; fine grain; uncemented; contains 5 to 30% silt and clay fines; laminated in placea with silty shale; 1/8 in. gypaum banda located along bedding planea on 1 to 12 in. centers; aandatone crumblea between fingera; shale is soft and cuts easily with knife; core lengths 1 to 12 in.; silty mottled aandatone 3.2 to 7.0 ft.; silty shale 7.0 to 8.5 ft.; weathered black lignite 8.5 to 8.6 ft.; silty sandatone 8.6 to 11.5 ft.; silty shale with silty aandstone atreaks 11.5 to 14.2 ft.; silty aandstone 14.2 to 16.0 ft.; laminated silty shale and silty aandstone 16.0 to 16.8 ft.; laminated silty sandatone 16.8 to 22.2 ft.; soft silty ahale 22.2 to 25.5 ft.; laminated, silty 25.5 to 26.8 ft.; calcareous cemented, hard aandstone 26.8 to 28.8 ft.

28.8-51.8 SANDSTONE: tan; oxidized; moist; uncemented; crumbles easily between fingers; fine grain; scattered gypsum inclusions up to 1/8 in. thick generally along bedding planea on 6 to 12 in. centera; core lengths 6 to 30 in.

51.8-65.0 SHALE WITH LIGNITE: medium to dark gray; moist; plastic; air slakes; moderately firm; cuts by knife with some difficulty; 2 in. cemented shale cut by pyrite filled fractures 52.0 to 52.2 ft.; black, broken lignite 52.6 to 52.8, 55.1 to 55.4, 56.8 to 59.2 and 60.1 to 61.2 ft.; shaley lignite 53.4 to 53.8 ft.: gypsum crystals up to ½ in. in thickness scattered throughout 51.8 to 55.0 ft. zone; 2 opposing 45 to 60° joints at 55.8 & 56.0 ft.; core lengths 3 to 24 in.

65.0-73.6 SILTY SANDSTONE: light grey; moist; firm; contains some clay; slightly plastic; silty; sand is fine

EXPLANATION

Core loss / Core recovery

Type of hole: D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-109 — LOCATION: 2280' E. & 75' S. of NW Corner Sec. 8, T. 144 N., R. 88 W. — GROUND ELEV. 2025± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/9/77 — FINISHED 8/16/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 140.8 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 70.4 8/16/77 (1954.6) — LOGGED BY Taucher — LOG REVIEWED BY

Core recovery (%): 100 throughout.

Soils analysis sample	Depth from (feet)	Depth to (feet)
#6	115.6	124.3
#7	130.4	140.8

Elevation (feet)	Depth (feet)
1924.6	100.4
1912.1	112.9
1909.4	115.6
1900.7	124.3
1894.6	130.4
1884.2	140.8

Classification and physical condition

grain; laminated in placea; crumbles between fingers with difficulty; weak HCl reaction in zones; core lengths 6 to 24 in.

73.6-100.4 SHALE WITH LIGNITE: medium to dark gray; moiat; plastic; air slakes; firm; difficult trimming by knife; banded; weak HCl reaction; 1 in. hard, cemented, calcareous sandstone at 76.6 ft.; alternating laminations of silty shale (50%) and silty, uncemented sandstone (50%) 76.9 to 81.8 ft.; becoming dark gray and carbonaceous 95.0 to 98.8 and 99.6 to 100.4 ft.; broken lignite 96.8 to 98.5 ft.; core lengths 6 to 30 in.

100.4-112.9 LIGNITE: black; moist to wet; hard: broken in ½ to 6 in. lengths

112.9-115.6 SHALE: medium gray; moist; plastic; air slakes; carbonaceous 112.9 to 113.5 ft.; 30° slickenside at 114.3 ft.

115.6-124.3 SILTY SANDSTONE WITH SHALE: sandstone is light gray, silty, uncemented and crumbles between fingers; shale is medium gray, plastic and trims easily with knife; moist; laminated silty sandstone and silty shale (30%) 115.6 to 116.9 ft.; silty sandstone 116.9 to 123.3 ft.; laminated silty sandstone (60%) and silty shale (40%) 123.3 to 123.6 ft.; plastic, carbonaceous dark gray shale 123.6 to 124.3 ft.; core lengths 12 to 36 in.

124.3-130.4 LIGNITE: black; wet; hard; broken on ½ to 3 in. centers

130.4-140.8 SHALE: medium grey; moist; firm; difficult trimming by knife; air slakes; mottled with some carbonaceous material 132.0 to 133.0 ft.; 45° slickenside (small fault) at 133.4 ft.; and 135.2 ft.: sandy shale 136.3 to 137.3 ft.; very hard, dark gray limestone 138.8 to 140.1 ft.; core lengths 3 to 24 in.

EXPLANATION

Core loss / Core recovery

Type of hole: D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-109

GEOLOGY G. TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-179

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Beulah Trench Study Area, West Renner Cove Coalfield PROJECT EMRIA STATE North Dakota
HOLE NO. 77-110 LOCATION 2650' S. & 650' E. of NW Corner Sec. 4, T. 144 N., R. 88 W. GROUND ELEV. 2040± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8-19-77 FINISHED 8-24-77 DEPTH OF OVERBURDEN TOTAL DEPTH 178.9' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 91.7' (1948.3') 9-1-77 LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
DAMCO 1250 truck mounted.

DRILLER
John Fricke

METHOD
Bx casing drive samples 0-15'. Hq wireline core 15-178.9'. Drilled dry 0-15'. Water and Revert used as drill fluid. 100% water loss at 97' and 141.9-148.0'. No other losses reported.

CASING RECORD
None used.

PROGRESS RECORD

Depth	Date
0-52'	8/19/77
52-72.8'	8/22/77
72.8-141.9'	8/23/77
141.9-178.9'	8/24/77

HOLE COMPLETION
Backfilled 9/1/77.

WATER LEVELS
Taken before hole was completed

Depth	Date
21.5'	8/22/77
40.6'	8/23/77
87.0'	8/24/77

After completion.
91.7' 9/1/77

SOILS ANALYSIS SAMPLE

Sample	Depth (feet) From	To
#1	0	8
#2	8	15
#3	16.5	30.4
#4	30.4	50
#5	50	68.4
#6	70.2	80.6

Core recovery (%): 100 throughout.

Elevation (feet)	Depth (feet)
2033.0	7
2032.0	8
2025.0	15
2023.5	16.5
2009.6	30.4
1971.6	68.4
1969.8	70.2
1959.4	80.6
1941.4	98.6

CLASSIFICATION AND PHYSICAL CONDITION

0-7.0' CLAY (GLACIAL TILL): about 70% low to medium plasticity fines, 25% fine to coarse sand, 5% gravel to 1", strong HCl reaction, abundant caliche 1-5', dry to moist at depth, tan grading to brown (CL).

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE
7.0-8.0' SANDSTONE: gray, moist, uncemented, crumbles easily, fine grained, no HCl reaction, bedding not discernible.

8.0-10.5' SHALE: black, moist, carbonaceous, weathered, soft, crumbly, no HCl reaction, bedding not discernible.

10.0-15.0' SHALE: gray, damp, soft, crumbled, plastic, no HCl reaction, bedding not discernible.

15.0-16.5' LIGNITE: black, moist, soft, crumbly.

16.5-30.4' SANDY SHALE: gray, moist, soft, cuts easily with knife, plastic in some zones, laminated, bedding nearly horizontal, no HCl reaction, core lengths to 18".

30.4-68.4' CLAYEY SANDSTONE: gray, damp, uncemented, crumbly, fine grained, laminated, contains considerable clay, bedding nearly horizontal, no HCl reaction, core lengths to 3'.

68.4-70.2' SHALEY SANDSTONE: light gray, damp, hard, cemented, fine grained, calcareous, beds nearly horizontal, laminated, core lengths to 4".

70.2-80.6' SHALE: gray, damp, firm, difficult to cut with knife, plastic, air slakes, bedding not discernible, no HCl reaction, core lengths to 3'.

80.6-98.6' LIGNITE: black, moist, hard, crumbled.

98.6-140.9' SANDY SHALE: gray, damp, firm, difficult to cut with knife, laminated, beds nearly horizontal, air slakes, moderate to weak HCl reaction, scattered pyrite, very sandy near top, core lengths to 3'.
107.8-111.0' Sandstone-gray, damp, uncemented, clayey, crumbly, fine grained, crossbedded.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Beulah Trench Study Area, West Renner Cove Coalfield PROJECT EMRIA STATE North Dakota SHEET 1 OF 2 HOLE NO. 77-110

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Beulah Trench Study Area, West Renner Cove Coalfield PROJECT EMRIA STATE North Dakota
HOLE NO. 77-110 LOCATION 2650' S. & 650' E. of NW Corner Sec. 4, T. 144 N., R. 88 W. GROUND ELEV. 2040± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8-19-77 FINISHED 8-24-77 DEPTH OF OVERBURDEN TOTAL DEPTH 178.9' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 91.7' (1948.3') 9-1-77 LOGGED BY Parish LOG REVIEWED BY

SOILS ANALYSIS SAMPLE

Sample	Depth (feet) From	To
#7	98.6	120
#8	120	140.9
#9	140.9	158.9
#10	162.6	178.9

Core recovery (%): 100 throughout.

Elevation (feet)	Depth (feet)
1899.1	140.9
1896.9	143.1
1895.9	144.1
1892.0	148
1891.0	149
1888.7	151.3
1884.0	156
1881.1	158.9
1877.4	162.6
1864.1	175.9
1861.1	178.9

CLASSIFICATION AND PHYSICAL CONDITION

140.9-143.1' CLAYEY SANDSTONE: gray, damp, uncemented, crumbles with difficulty, fine grained, crossbedded, strong HCl reaction, core lengths to 1'.

143.1-144.1' SANDSTONE: light gray, cemented, hard, fine grained, bedding nearly horizontal, core lengths to 8".

144.1-148.0' SHALE: gray, damp, firm, difficult to cut with knife, plastic, air slakes, some lignite streaks, bedding nearly horizontal, core lengths to 8".

148.0-149.0' LIGNITE: black, hard, brittle, core lengths to 2".

149.0-151.3' SHALE: dark gray grading to greenish gray, damp, firm but cuts easily with knife, plastic, bedding not discernible, no HCl reaction, core lengths to 1'.

151.3-156.0' CLAYEY SANDSTONE: greenish-gray grading to gray at depth, damp, uncemented, crumbles with difficulty, fine grained, laminated, bedding nearly horizontal, no HCl reaction, core lengths to 1'.

156.0-158.9' SHALE: gray, damp, firm, cuts with difficulty, air slakes, plastic, bedding not discernible, carbonaceous near bottom, no HCl reaction, core lengths to 18".

158.9-162.6' LIGNITE: black, hard, brittle, shattered.

162.6-175.9' SILTSTONE: tan grading to light greenish-gray at depth, damp, firm, crumbly, sandy, bedding not discernible, no HCl reaction, core lengths to 2½'.

175.9-178.9' SILTY SANDSTONE: light gray, damp, uncemented, crumbles easily, very fine grained, no HCl reaction, bedding not discernible, core lengths to 8".

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Beulah Trench Study Area, West Renner Cove Coalfield PROJECT EMRIA STATE North Dakota SHEET 2 OF 2 HOLE NO. 77-110

METERS 0–9 / FEET 0–30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-110

GEOLOGY G. TAUCHER FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA JANUARY 1980 1305-600-180

7-1337 (9-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE — SHEET 1 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-111 — LOCATION: 1800' S. & 10' W. of NE Corner, Sec. 4, T. 144 N., R. 88 W. — GROUND ELEV. 2070± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/12/77 — FINISHED 9/1/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 212.2 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 95.4 9/1/77 (1974.6) — LOGGED BY Taucher to 59.0' Parish 59.0-212.2 ft. — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 8/12/77. Bx drive samples 0 to 24.5 ft.; 5 in. Cs set to 18.0 ft.

Hole at 24.5 ft. 8/1?/77. 5 in. Cs at 18.0 ft. Hole caved at 20.0 ft.; Hq wireline core 24.5 to 64.7 ft.; Advanced 5 in. Cs to 23.0 ft. to cover water loss at 22.5 ft. Lost drill water 56.7 to 58.0 ft. Using revert.

Hole at 64.7 ft. 8/16/77. W.L. at 55.0 ft. 5 in. Cs at 23.0 ft. Hq wireline core 64.7 to 112.0 ft. No drill water return.

Soils analysis samples (depth in feet):

Sample	From	To
#1	0	22.4
#2	22.4	54.0
#3	59.0	70.0
#4	70.0	78.0
#5	78.0	93.1

Elevation / Depth (feet):

Elevation	Depth
2047.6	22.4
2016.0	54.0
2015.0	55.0
2013.7	56.3
2013.3	56.7
2012.0	58.0
2011.0	59.0
1992.0	78.0
1976.9	93.1
1976.1	93.9
1974.5	95.5
1974.1	95.9

Classification and physical condition:

0-22.4 SANDY CLAY: medium gray and slightly organic 0 to 0.8 ft.; white to tan with large amounts of caliche 0.8 to 5.0 ft.; tan and oxidized 5.0 to 22.4 ft.; moderate to active HCl reaction; approximately 55% medium plasticity fines, 40% sand and 5% gravel; lignite inclusions; 70° caliche lined joint at 8.0 ft.; glacial till (CL)

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

22.4-54.0 SANDSTONE: tan; oxidized; moist; uncemented; fine grain; crumbles easily between fingers; banded; iron-rich conglomerate (pebbles up to ½ in. in diameter) 44.3 to 44.4 ft.; ½ in. lignite at 53.5 ft.; carbonaceous 52.8 to 53.2 ft.

54.0-55.0 SHALE: tan; oxidized; moist; soft; trims easily with knife; plastic; air slakes; carbonaceous 54.7 to 55.0 ft.

55.0-56.3 LIGNITE: black; broken; moist

56.3-56.7 SILTY SHALE: gray; moist; very soft; silty; laminated with carbonaceous material; cuts easily with knife.

56.7-58.0 LIGNITE: black; moist; broken

58.0-59.0 SANDSTONE: light gray to tan; moist; oxidized; scattered marcasite nodules; silty; uncemented; fine; uniform

59.0-70.0 SANDSTONE: gray; moist; crumbles easily between fingers; horizontal laminations; cross-bedded in places; no HCl reaction; core lengths up to 12 in.

70.0-78.0 SHALE: gray; moist; firm; cuts easily with knife; plastic; bedding not discernible; scattered pyrite nodules; near vertical joint at 74.8 ft.; core lengths up to 24 in.

78.0-93.1 SANDSTONE: gray; moist; uncemented; crumbles easily between fingers; fine grain; laminated; bedding near horizontal; no HCl reaction; core lengths up to 12 in.; black, carbonaceous zone 85.5 to 85.9 ft.

93.1-93.9 LIGNITE: black; moist; hard; shattered

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Beulah Trench Study Area West Renner Cove Coalfield — PROJECT EMRIA — STATE North Dakota — SHEET 1 OF 3 — HOLE NO. 77-111

7-1337 (9-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE — SHEET 2 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-111 — LOCATION: 1800' S. & 10' W. of NE Corner, Sec. 4, T. 144 N., R. 88 W. — GROUND ELEV. 2070± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/12/77 — FINISHED 9/1/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 212.2 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 95.4' 9/1/77 (1974.6) — LOGGED BY Parish — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole at 112.0 ft. 8/17/77. W.L. at 61.6 ft. 5 in. Cs at 23.0 ft. Hq wireline core 112.0 to 172.0 ft. Dropped but recovered core. Dropped & could not recover core 130.0 to 132.7 ft.

Hole at 172.0 ft. 8/18/77. 5 in. Cs at 23.0 ft. W.L. at 78.7 ft. Hq wireline core 172.0 to 212.2 ft. No water return. Pulled 5 in. Cs. & moved rig to DH 77-110

Soils analysis samples (depth in feet):

Sample	From	To
#6	93.9	110.4 minus lignite
#7	112.4	124.0
#8	124.0	139.3
#9	161.3	172.0
#10	172.0	192.0
#11	192.0	212.2

Elevation / Depth (feet):

Elevation	Depth
1963.0	107.0
1960.5	109.5
1959.6	110.4
1957.6	112.4
1946.0	124.0
1944.8	125.2
1941.8	128.2
1940.6	129.4
1930.7	139.3
1911.7	158.3
1911.2	158.8
1902.2	167.8
1898.0	172.0

Classification and physical condition:

93.9-95.5 SHALE: gray; moist; firm but cuts easily with knife; plastic; appears to have been crushed; numerous slickensides; scattered lignite fragments; bedding destroyed; no HCl reaction

95.5-95.9 LIGNITE: black; moist; soft; shaley; shattered

95.9-107.0 SHALE: gray; damp; firm; cuts by knife with difficulty; plastic; air slakes; bedding not discernible; no HCl reaction; abundant pyrite or marcasite near bottom; core lengths up to 12 in.

107.0-109.5 LIGNITE: black; moist; hard; brittle; numerous pyrite or marcasite inclusions near top

109.5-110.4 SHALE: black; moist; firm; cuts by knife with difficulty; carbonaceous; plastic; bedding not discernible; 70° slickenside at 110.2 ft.; no HCl reaction; core lengths up to 3 in.

110.4-112.4 LIGNITE: black; moist; hard; brittle

112.4-124.0 SHALE: dark gray; moist; firm; cuts by knife with difficulty; plastic; bedding not discernible; shattered with numerous slickensides 121.0-124.0 ft.; abundant pyrite nodules; no HCl reaction

124.0-125.2 SANDSTONE: light gray; cemented; hard; will not cut with knife; crossbedded; calcareous; fine grain

125.2-128.2 SANDY SHALE: dark gray; damp; firm; difficult to cut with knife; plastic; bedding nearly horizontal; no HCl reaction; core lengths up to 12 in.

128.2-129.4 SANDSTONE: light gray; dry; cemented; hard; will not cut with knife; calcareous; crossbedded

129.4-139.3 SHALE: dark gray; damp; firm; cuts by knife with difficulty; air slakes; plastic; bedding not discernible; no HCl reaction; core lengths up to 12 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Beulah Trench Study Area West Renner Cove Coalfield — PROJECT EMRIA — STATE North Dakota — SHEET 2 OF 3 — HOLE NO. 77-111

7-1337 (9-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE — SHEET 3 OF 3

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield — PROJECT: EMRIA — STATE: North Dakota
HOLE NO. 77-111 — LOCATION: 1800' S. & 10' W. of NE Corner, Sec. 4, T. 144 N., R. 88 W. — GROUND ELEV. 2070± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/12/77 — FINISHED 9/1/77 — DEPTH OF OVERBURDEN — TOTAL DEPTH 212.2 — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 95.4' 9/1/77 (1974.6) — LOGGED BY Parish — LOG REVIEWED BY

Elevation / Depth (feet): 1857.8 / 212.2

Classification and physical condition:

139.3-158.3 LIGNITE: black; moist; wet; hard: brittle, fractured

158.3-158.8 SHALE: dark gray; damp; firm; difficult to cut with knife; bedding not discernible; no HCl reaction; plastic

158.8-159.4 LIGNITE: black; moist; hard; brittle; shattered

159.4-167.8 SHALE: gray; moist; firm; cuts easily with knife; plastic; bedding not discernible; no HCl reaction; core lengths up to 24 in.

167.8-172.0 CLAYEY SANDSTONE: gray; moist; uncemented; crumbles between fingers with some difficulty; fine grain; laminated; bedding nearly horizontal; no HCl reaction; core lengths up to 18 in.

172.0-112.2 SANDY SHALE: gray; moist; firm; cuts by knife with difficulty; scattered sandy zones; bedding nearly horizontal; air slakes in carbonaceous zones; plastic; no HCl reaction; except in sandy zones where there is a strong reaction; core lengths up to 18 in.; laminated and sandy 182.5 to 185.0 ft.; black and carbonaceous 190.0 to 192.0 ft.; laminated and sandy 198.0 to 200.0 ft.; laminated and sandy 207.0 to 210.5 ft.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Beulah Trench Study Area West Renner Cove Coalfield — PROJECT EMRIA — STATE North Dakota — SHEET 3 OF 3 — HOLE NO. 77-111

METERS 0–9 / FEET 0–30

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH OAKOTA

GEOLOGIC LOG OF DH 77-111

GEOLOGY G. TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-181

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield
PROJECT: EMRIA
STATE: North Dakota
HOLE NO.: 77-112
LOCATION: 50' S. & 2700' E. of NW Corner, Sec. 22, T. 145 N., R. 88 W.
GROUND ELEV.: 2110±
DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8-25-77
FINISHED: 8-31-77
DEPTH OF OVERBURDEN:
TOTAL DEPTH: 200.0'
BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 20.0' (2090.0') 9-1-77
LOGGED BY: Pariah
LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
DAMCO 1250
truckmounted

DRILLER
John Fricke

METHOD
Bx casing drive samples 0-11.7'

Hq wireline core 11.7-200.0'. Water and Revert used as drill fluid. 100% water loss 22.6-30'. No other losses noted.

CASING RECORD
Set 5" casing to 28' 8-25-77. Pulled on completion of hole.

PROGRESS RECORD

Depth	Date
0-53'	8-25-77
53-84.7'	8-26-77
84.7-107.9'	8-29-77
107.9-160.2'	8-30-77
160.2-200'	8-31-77

HOLE COMPLETION
Backfilled 9-1-77

WATER LEVELS
Taken before hole was completed.

Depth	Date
46.7'	8-26-77
19.4'	8-29-77
9.0'	8-30-77
9.9'	8-31-77

After completion.
20.0' 9-1-77
May be questionable.

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	0	11
#2	11	23.3
#3	23.3	40.6
#4	42.4	60
#5	60	77.8
#6	77.8	83.5
#7	83.5	93.2
#8	93.2	100.2

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
2099.0	11
2088.7	21.3
2086.7	23.3
2078.0	32
2074.7	35.3
2069.4	40.6
2067.6	42.4
2032.2	77.8
2029.5	80.5
2027.7	82.3
2026.5	83.5
2016.8	93.2

Lost Core

CLASSIFICATION AND PHYSICAL CONDITION

0-11.0' CLAY (GLACIAL TILL): about 65% low to medium plasticity fines, 25% fine to coarse sand, 10% gravel to 1", strong HCl reaction, scattered caliche, dry, firm to crumbly, dark brown (CL).

FT. UNION FORMATION - SENTINEL BUTTE MEMBER - PALEOCENE

11.0-21.3' SANDSTONE: tan, damp, uncemented, soft, crumbly to loose, fine to medium grained, clean, bedding not discernible, no HCl reaction.

21.3-23.3' SHALE: rusty brown, moist, soft, cuts easily with knife, plastic, bedding not discernible, no HCl reaction,
21.3-21.5' Sandy, hard, broken by numerous slickensided fractures of various dips

23.3-40.6' SANDSTONE: tan to light gray, moist, uncemented, soft, crumbles easily, fine to medium grained, slightly laminated, beds nearly horizontal, no HCl reaction, core lengths to 16".
Note: Lost core 32.0-35.3'

40.6-42.4' LIGNITE: black, hard, brittle, broken

42.4-77.8' SANDY SHALE: gray, moist, soft, cuts easily with knife, plastic, laminated, beds nearly horizontal, no HCl reaction, core lengths to 2½'.
Note: Lost most of core 42.4-53.0'.
54.0-54.3' Limestone-hard, light gray
59.1' slickensides, dips 45°
59.5' slickensides, dips 45°

77.8-80/5' CLAYEY SANDSTONE: gray, moist, uncemented, firm but cuts easily with knife, fine grained, laminated, bedding nearly horizontal, weak HCl reaction, core lengths to 16".
77.8-78.1' carbonaceous streaks

80.5-82.3' SANDSTONE: light gray, dry, hard, cemented, fine grained, calcareous, laminated, bedding nearly horizontal, core lengths to 1'.

82.3-83.5' CLAYEY SANDSTONE: gray, damp, uncemented, firm but cuts easily with knife, fine grained, bedding not discernible, moderate HCl reaction, core lengths to 1.2'.

83.5-93.2' SANDY SHALE: gray, damp, firm, but cuts easily with knife, plastic.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . . O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield PROJECT: EMRIA STATE: North Dakota SHEET 1 OF 2 HOLE NO. 77-112

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield
PROJECT: EMRIA
STATE: North Dakota
HOLE NO.: 77-112
LOCATION: 50' S. & 2700' E. of NW Corner, Sec. 22, T. 145 N., R. 88 W.
GROUND ELEV.: 2110±
DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 8-25-77
FINISHED: 8-31-77
DEPTH OF OVERBURDEN:
TOTAL DEPTH: 200.0'
BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 20.0' (2090.0') 9-1-77
LOGGED BY: Pariah
LOG REVIEWED BY:

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#9	100.2	125.0
#10	125	146.9
#11	149.7	168.8
#12	190	200

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
2009.8	100.2
1963.1	146.9
1960.3	149.7
1959.0	151
1941.2	168.8
1920.0	190
1910.0	200

Lost Core

CLASSIFICATION AND PHYSICAL CONDITION

laminated, beds nearly horizontal, some local crossbedding, strong HCl reaction, core lengths to 18".

93.2-100.2' CLAYEY SANDSTONE: gray, damp, uncemented, firm but cuts easily with knife, fine grained, laminated, beds nearly horizontal, weak HCl reaction, core lengths to 3'.
93.2-93.4' calcareous, hard, light gray

100.2-146.9' SANDY SHALE: gray, damp, firm but cuts easily with knife, laminated, many sandy zones, air slakes, beds nearly horizontal, scattered pyrite nodules, weak HCl reaction, core lengths to 2'.
Note: lost sample 112.9-118.6'
106.0-106.5' Carbonaceous, dark gray
107.9-110.0' fractured zone with numerous slickensides and coal streaks
130.6' joint dipping 70°
132.0' slickensides dipping 60°

146.9-149.7' SANDSTONE: light gray, dry, cemented, hard, calcareous, fine grained, bedding not discernible, core lengths to 5".

149.7-151.0' CLAYEY SANDSTONE: gray, damp, uncemented, firm, cuts easily with knife, fine grained, bedding not discernible, moderate HCl reaction, core lengths to 1'.

151.0-168.8' SANDY SHALE: gray, damp, firm, difficult to cut with knife, laminated, bedding nearly horizontal, air slakes, scattered pyrite nodules, strong HCl reaction, core lengths to 2'.
159.5' joint dipping 60°

168.8-190.0' LIGNITE: black, damp, hard, brittle, broken

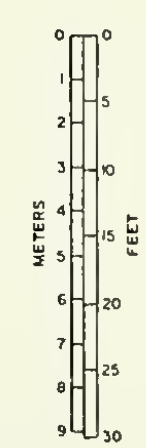
190.0-200.0' SHALE: dark gray, damp, firm, barely cuts with knife, air slakes, bedding not discernible, strong HCl reaction, core lengths to 6".

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . . O = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . . P = Pocker, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Beulah Trench Study Area, West Renner Cove Coalfield PROJECT: EMRIA STATE: North Dakota SHEET 2 OF 2 HOLE NO. 77-112



Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
WATER AND POWER RESOURCES SERVICE

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD - NORTH DAKOTA

GEOLOGIC LOG OF DH 77-112

GEOLOGY G. TAUCHER — FIELD APPROVAL
DRAWN — TECHNICAL APPROVAL
CHECKED — APPROVED

BILLINGS, MONTANA — JANUARY 1980 — 1305-600-182

APPENDIX D

COAL RESOURCES

Chemical Analyses of Lignite from the Sentinel Butte Member of the Fort Union Formation, Beulah Trench Study Area [2/]

by

Ricky T. Hildebrand

and

Joseph R. Hatch

Twenty-four samples of lignite were collected by the U.S. Geological Survey from 12 core holes in the Beulah Trench EMRIA (Energy Mineral Rehabilitation Inventory and Analyses) Study Area (see Table 8). The samples are from three beds in the Sentinel Butte Member of the Fort Union Formation of Paleocene age and are briefly described in Table 8. Using the bed designation given in Table 8, 3 of the samples are from the C bed, 19 samples are from the D (Beulah-Zap) bed, and 2 samples are from the F bed. Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, and ash-fusion-temperature determinations for the samples are given in Table 9. These analyses were provided by the Coal Analysis Section of the Department of Energy, Pittsburgh, Pennsylvania. Analyses for ash content, and 30 major and minor oxides and trace elements in the laboratory ash (Table 12), and analyses of 9 trace elements in whole lignite (Table 13) for the samples were provided by the Analytical Laboratories of the U.S. Geological Survey in Denver, Colorado. Most analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976). Analyses for As, Co, Cr, Sb, Se, and Th are performed by Instrumental Neutron Activation Analysis (INAA) on whole lignite. Table 14 contains the data listed in Table 12 converted to a whole-lignite basis and includes the whole-lignite analyses listed in Table 13. Twenty-six additional elements not listed in Tables 12, 13, and 14 were looked for but not found in amounts greater than their lower limit of detection (Table 15).

Unweighted statistical summaries of analytical data on the 24 lignite samples in Tables 12, 13, and 14 are listed in Tables 16, 17, and 18 respectively. For comparison, data summaries of proximate, ultimate, and forms-of-sulfur analyses, and heat of combustion for 32 other Fort Union region lignite samples (Swanson and others, 1974) and major, minor, and trace elements for 80 other Fort Union region lignite samples (Hatch and Swanson, 1976) are included. Data summaries for Cd, Ge, Nb, and P_2O_5 in lignite ash are not included in Tables 17 and 18 because they were detected in an insufficient number of samples to calculate meaningful statistics.

To be consistent with the precision of the semiquantitative emission spectrographic technique, arithmetic and geometric means of elements determined by this method are reported as the midpoint of the enclosing six-step brackets (see subtitle of Table 12, or Swanson and Huffman (1976, p. 6), for an explanation of six-step brackets).

2/ Supplement to COAL RESOURCES section.

COAL [1/]

Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade) are characteristics of the varieties of coal" (Schopf, 1966, p. 588). Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern-day peat deposits are formed. The peat then underwent a long, extremely complex process called "coalification," during which diverse physical and chemical changes occurred as the peat changed to coal and as the coal assumed the characteristics by which we differentiate members of the series from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

> The mode of accumulation and burial of the plant debris forming the deposit.
>
> The age of the deposits and their geographical distribution.
>
> The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.
>
> The chemical composition of the coal-forming debris and its resistance to decay.
>
> The nature and intensity of the plant-decaying agencies.
>
> The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussion of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113,; Francis, 1961, p. 361), but the classification by rank -- that is, by degree of metamorphism in the progressive series that begins with peat and ends with graphocite (Schopf, 1966) -- is the most commonly used system. Classification by types of plant materials is commonly used as a descriptive

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1/ Supplement to COAL RESOURCES section.

adjunct to rank classification when sufficient megascopic and microscopic information is available, and classification by type and quantity of impurities (grade) is also frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources -- such factors as the weight of the coal, the thickness and areal extent of the individual coalbeds, and the thickness of overburden are generally considered.

Rank of Coal

The position of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperature and pressure to which the coal has been subjected and the duration of time of subjection. Because it is, by definition, largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constituents -- the higher rank coals have more carbon and less hydrogen then the lower ranks.

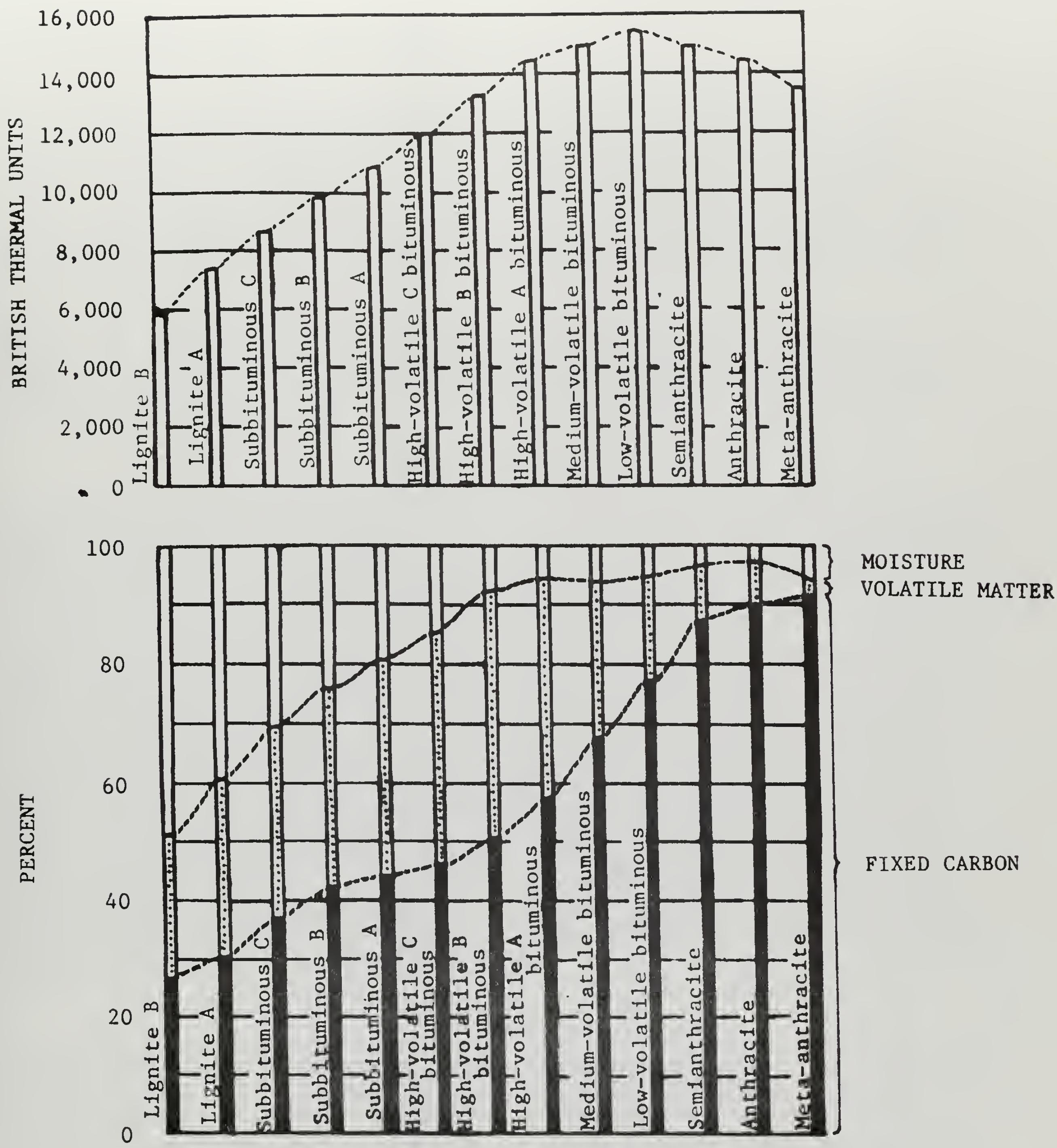
Two standardized forms of coal analyses -- the proximate analysis and the ultimate analysis -- are generally used in the world today, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bureau of Mines, 1965, p. 121-122):

> The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cokelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference.

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound: one Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree fahrenheit (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure 2 compares, in histogram-form, the heating values and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used, but the most commonly employed is that entitled "Standard specifications



Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks (modified from Trumbull, 1960).

for classification of coals by rank," adopted by the American Society for Testing and Materials (1974) (Table 7).

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value, supplemented by determination of agglomerating (caking) characteristics. As pointed out by the ASTM (1974, p. 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Synder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

Twenty-four samples listed on Tables 8 and 9 show an apparent rank of lignite A. Because of the lack of definitive information about the distribution of lignites of various groups in the Fort Union, it is considered to be all lignite A in rank in the area of the study.

Type of Coal

Classification of coals by type -- that is, according to the types of plant materials present -- takes many forms, such as the "rational analysis" of Francis (1961) or the semicommercial "type" classification commonly used in the coalfields of the eastern United States (U.S. Bureau of Mines, 1965, p. 123). However, most of the type classifications are based on the same, or similar, gross distinctions in plant material as those used by Tomkeieff (1954, Table II and p. 9), who divided the coals into three series: humic coals, humic-sapropelic coals, and sapropelic coals, based upon the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants; and the sapropelic coals are largely composed of the more resistant waxy, fatty, and resinous parts of plants, such as cell walls, spore-coatings, pollen, resin particles, and coals composed mainly of algal material. Most coals fall into the humic series, with some coals being a mixture of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and, when found is commonly regarded as an organic curiosity. In common with most of the U.S. coals, Fort Union lignite falls largely in the humic series.

Grade of Coal

Classification of coal by grade, or quality, is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization. Most detailed coal resource evaluations of the past do not categorize known coal resources by grade, but coals of the United States have been classified by sulfur content in a gross way (DeCarlo and others, 1966).

The range and average of the ash and sulfur content of 642 coals from all parts of the United States were determined by Fieldner, Rice, and Moran (1942).

Classification of coals by rank[1]

[American Society for Testing and Materials Standard D388-66 (Reapproved 1972); 1 Btu equals 0.252 kilogram-calories. Leaders (---) indicate category is not used in rank determination of group]

Class	Group	Fixed carbon limits, percent (dry, mineral-matter-free basis)		Volatile matter limits, percent (dry, mineral matter-free basis)		Calorific value limits, Btu per pound (moist,[2] mineral-matter-free basis)		Agglomerating Character
		Equal or greater than	Less than	Greater than	Equal or less than	Equal or greater than	Less than	
I. Anthracitic	1. Meta-anthracite	98	---	---	2	---	---	nonagglomerating
	2. Anthracite	92	98	2	8	---	---	nonagglomerating
	3. Semianthracite[3]	86	92	8	14	---	---	nonagglomerating
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	---	---	commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	---	---	commonly agglomerating[5]
	3. High volatile A bituminous coal	---	69	31	---	14 000[4]	---	commonly agglomerating[5]
	4. High volatile B bituminous coal	---	---	---	---	13 000[4]	14 000	commonly agglomerating[5]
	5. High volatile C bituminous coal	---	---	---	---	11 500 10 500	13 000 11 500	commonly agglomerating[5] agglomerating
III. Subbituminous	1. Subbituminous A coal	---	---	---	---	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	---	---	---	---	9 500	10 500	nonagglomerating
	3. Subbituminous C coal	---	---	---	---	8 300	9 500	nonagglomerating
IV. Lignitic	1. Lignite A	---	---	---	---	6 300	8 300	nonagglomerating
	2. Lignite B					---	6 300	nonagglomerating

[1] This classification does not include a few coals, principally nonbanded varieties, that have unusual physical and chemical properties and that come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3] If agglomerating, classify in low-volatile group of the bituminous class.

[4] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis are classified according to fixed carbon, regardless of calorific value.

[5] **It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class and that there are notable exceptions in the high-volatile C bituminous group.**

Table 8.--USGS sample number, hole number, location, depth interval and Bed designation for 24 samples from the Beulah Trench Study Area — — — Mercer County, N. Dak.

[All samples are from the Sentinel Butte member of the Fort Union Formation of Paleocene age]

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Bed designation
D194858	77-101	NW¼NW¼ sec. 14, T. 145 N., R. 88 W.	39.4- 41.6 (129.2-136.4)	D
D194859	--do--	----------------do----------------	42.4- 45.8 (139.0-150.4)	Do.
D194860	--do--	----------------do----------------	59.7- 60.4 (196.0-198.0)	F
D194861	77-102	NE¼NW¼ sec. 23, T. 145 N., R. 88 W.	42.4-47.6 (139.2-156.2)	D
D194862	77-103	SW¼SE¼ sec. 22, T. 145 N., R. 88 W.	74.6- 81.3 (244.6-266.6)	Do.
D194863	77-104	NE¼NE¼ sec. 26, T. 145 N., R. 88 W.	16.7- 22.8 (54.8- 74.9)	Do.
D194864	77-105	NE¼NE¼ sec. 34, T. 145 N., R. 88 W.	68.2- 71.2 (223.7-233.7)	Do.
D194865	--do--	----------------do----------------	71.2- 74.4 (233.7-244.0)	Do.
D194866	77-106	NE¼NE¼ sec. 6, T. 144 N., R. 88 W.	40.9-41.6 (134.3-136.6)	Do.
D194867	--do--	----------------do----------------	42.5- 45.7 (135.5-150.0)	Do.
D194868	--do--	----------------do----------------	48.7-49.4 (159.7-162.1)	Do.
D194869	77-107	SE¼NE¼ sec. 1, T. 144 N., R. 89 W.	52.5-55.8 (172.1-183.1)	Do.
D194870	--do--	----------------do----------------	61.0-62.8 (200.0-205.9)	Do.
D196052	77-108	SW¼SE¼ sec. 6, T. 144 N., R. 94 W.	37.2-40.3 (122.0-132.3)	Do.

Table 8.--USGS sample number, hole number, location, depth interval and Bed designation for 24 samples from the Beulah Trench Study Area - - - Mercer County, N. Dak.--Continued

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Bed designation
D196053	77-108	SW¼SE¼ sec. 6, T. 144 N., R. 94 W.	45.7-47.4 (149.8-155.5)	Do.
D196054	77-109	NE¼NW¼ sec. 8, T. 144 N., R. 88 W.	17.3-18.0 (56.8-59.2)	C
D196055	--do--	----------------do----------------	30.6-34.1 (100.4-111.9)	D
D196056	--do--	----------------do----------------	38.0-39.7 (124.8-130.4)	Do.
D196057	77-110	NW¼SW¼ sec. 4, T. 144 N., R. 88 W.	24.6-30.1 (80.6- 98.6)	Do.
D196058	do--	----------------do----------------	48.4-49.6 (158.9-162.6)	F
D196059	77-111	SE¼NE¼ sec. 4, T. 144 N., R. 88 W.	32.6-33.4 (107.0-109.5)	C
D196060	--do--	----------------do----------------	33.6-34.3 (110.4-112.4)	C
D196061	--do--	----------------do----------------	42.5-48.2 (139.3-158.3)	D
D196062	77-112	NE¼NW¼ sec. 22, T. 145 N., R. 88 W.	51.5-57.9 (168.8-190.0)	Do.

Table 9 .--Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.

[All analyses except Kcal/kg, Btu/lb, free-swelling index, and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways: first, as received; second, moisture free; third, moisture and ash free. All analyses by Coal Analysis Section, U.S. Department of Energy, Pittsburg, Pa. °C = (°F-32)5/9; Kcal/kg = 0.556 (Btu/lb)]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D194858	31.7	27.0	30.6	10.7	6.2	40.8	0.7	41.1	0.6	3,680	6,620
	---	39.5	44.8	15.7	3.9	59.7	1.0	18.9	.9	5,390	9,690
	---	46.9	53.1	---	4.6	70.8	1.2	22.4	1.0	6,390	11,490
D194859	34.5	27.3	29.4	8.8	6.6	40.0	.6	43.0	1.1	3,700	6,650
	---	41.7	44.9	13.4	4.2	61.1	.9	18.8	1.7	5,640	10,160
	---	48.1	51.9	---	4.9	70.5	1.1	21.8	1.9	6,520	11,740
D194860	31.1	26.9	27.4	14.6	6.2	38.2	.9	39.8	.4	3,480	6,270
	---	39.0	39.8	21.2	4.0	55.4	1.3	17.6	.6	5,050	9,100
	---	49.5	50.5	---	5.1	70.3	1.7	22.4	.7	6,410	11,550
D194861	36.6	25.3	30.0	8.1	6.7	39.7	.6	44.5	.3	3,620	6,510
	---	39.9	47.3	12.8	4.2	62.6	.9	18.9	.5	5,710	10,270
	---	45.8	54.2	---	4.8	71.8	1.1	21.6	.5	6,540	11,770
D194862	34.5	27.0	31.1	7.4	6.6	41.3	.6	43.4	.7	3,770	6,780
	---	41.2	47.5	11.3	4.2	63.1	.9	19.4	1.1	5,750	10,360
	---	46.5	53.5	---	4.8	71.1	1.0	21.9	1.2	6,490	11,670
D194863	35.7	27.1	29.8	7.4	6.8	40.5	.5	43.9	.8	3,740	6,730
	---	42.1	46.3	11.5	4.4	63.0	.8	18.9	1.2	5,820	10,470
	---	47.6	52.4	---	5.0	71.2	.9	21.4	1.4	6,570	11,830
D194864	30.0	25.1	27.0	17.9	6.4	41.7	.6	32.2	1.3	3,430	6,170
	---	35.9	38.6	25.6	4.4	59.6	.9	7.9	1.9	4,890	8,810
	---	48.2	51.8	---	5.9	80.0	1.2	10.6	2.5	6,570	11,830
D194865	36.0	26.2	30.9	6.9	6.7	41.3	.6	43.6	.9	3,770	6,790
	---	40.9	48.3	10.8	4.2	64.5	.9	18.1	1.4	5,890	10,600
	---	45.9	54.1	---	4.7	72.3	1.1	20.3	1.6	6,600	11,880
D194866	27.6	26.0	27.0	19.4	5.3	36.6	.6	36.9	1.2	3,420	6,160
	---	35.9	37.3	26.8	3.1	50.6	.8	17.1	1.7	4,730	8,510
	---	49.1	50.9	---	4.2	69.1	1.1	23.3	2.3	6,460	11,630
D194867	34.1	26.6	32.4	6.9	6.6	42.6	.6	42.5	.7	3,860	6,950
	---	40.4	49.2	10.5	4.3	64.6	.9	18.5	1.1	5,860	10,540
	---	45.1	54.9	---	4.8	72.2	1.0	20.7	1.2	6,540	11,780
D194868	34.9	26.9	33.7	4.5	6.6	43.8	.7	44.0	.4	3,960	7,140
	---	41.3	51.8	6.9	4.2	67.3	1.1	19.9	.6	6,090	10,960
	---	44.4	55.6	---	4.5	72.3	1.2	21.4	.7	6,540	11,770
D194869	36.5	26.2	30.2	7.1	6.7	40.6	.6	44.0	.9	3,730	6,710
	---	41.3	47.6	11.2	4.2	63.9	.9	18.2	1.4	5,870	10,570
	---	46.5	53.5	---	4.7	72.0	1.1	20.5	1.6	6,610	11,900

Table 9 .--Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.--continued.

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D194858	16.6	0.08	0.12	0.38	0.0	1,150	1,165	1,180
	---	.12	.18	.56				
	---	.14	.21	.66				
D194859	20.9	.16	.36	.58	.0	1,140	1,150	1,165
	---	.24	.55	.89				
	---	.28	.63	1.02				
D194860	16.8	.02	.10	.27	.0	1,140	1,165	1,190
	---	.03	.15	.39				
	---	.04	.18	.50				
D194861	21.2	.01	.03	.31	.0	1,140	1,165	1,195
	---	.02	.05	.49				
	---	.02	.05	.56				
D194862	18.4	.01	.18	.49	.0	1,080	1,110	1,140
	---	.02	.27	.75				
	---	.02	.31	.84				
D194863	22.9	.05	.25	.51	.0	1,200	1,255	1,310
	---	.08	.39	.79				
	---	.09	.44	.90				
D194864	17.6	.15	.30	.81	.0	1,140	1,165	1,200
	---	.21	.43	1.16				
	---	.29	.58	1.55				
D194865	22.5	.02	.28	.63	.0	1,170	1,230	1,305
	---	.03	.44	.98				
	---	.04	.49	1.10				
D194866	13.3	.16	.13	.93	.0	1,115	1,145	1,320
	---	.22	.18	1.28				
	---	.30	.25	1.75				
D194867	17.5	.04	.25	.44	.0	1,165	1,190	1,210
	---	.06	.38	.67				
	---	.07	.42	.75				
D194868	19.4	.01L	.05	.32	.0	1,295	1,310	1,325
	---	.01L	.08	.49				
	---	.01L	.08	.53				
D194869	21.2	.05	.42	.47	.0	1,165	1,180	1,200
	---	.08	.66	.74				
	---	.09	.74	.83				

Table 9 .--Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.--continued.

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D194870	37.6	25.5	28.8	8.1	6.8	38.9	0.5	44.5	1.3	3,600	6,480
	---	40.9	46.2	13.0	4.2	62.3	.8	17.8	2.1	5,770	10,380
	---	47.0	53.0	---	4.8	71.6	.9	20.4	2.4	6,630	11,930
D196052	38.4	26.3	29.0	6.3	7.0	40.0	.5	45.3	.9	3,730	6,710
	---	42.7	47.1	10.2	4.4	64.9	.8	18.1	1.5	6,050	10,890
	---	47.6	52.4	---	4.9	72.3	.9	20.2	1.6	6,740	12,130
D196053	38.3	26.1	27.9	7.7	6.9	38.4	.6	45.0	1.4	3,640	6,550
	---	42.3	45.2	12.5	4.3	62.2	1.0	17.8	2.3	5,900	10,620
	---	48.3	51.7	---	4.9	71.1	1.1	20.3	2.6	6,740	12,130
D196054	40.3	26.1	28.1	5.5	7.2	38.7	.5	46.4	1.6	3,690	6,640
	---	43.7	47.1	9.2	4.6	64.8	.8	17.7	2.7	6,170	11,110
	---	48.2	51.8	---	5.0	71.4	.9	19.5	3.0	6,800	12,240
D196055	39.5	25.9	29.2	5.4	7.0	39.4	.6	46.9	.7	3,650	6,570
	---	42.8	48.3	8.9	4.3	65.1	1.0	19.5	1.2	6,030	10,860
	---	47.0	53.0	---	4.7	71.5	1.1	21.4	1.3	6,630	11,930
D196056	39.6	27.1	28.9	4.4	7.3	40.4	.7	46.6	.5	3,750	6,740
	---	44.9	47.8	7.3	4.8	66.9	1.2	18.9	.8	6,200	11,160
	---	48.4	51.6	---	5.2	72.1	1.2	20.4	.9	6,690	12,040
D196057	39.6	24.9	28.6	6.9	7.2	38.8	.6	45.7	.9	3,620	6,510
	---	41.2	47.4	11.4	4.6	64.2	1.0	17.4	1.5	5,990	10,780
	---	46.5	53.5	---	5.2	72.5	1.1	19.6	1.7	6,760	12,170
D196058	39.6	25.6	29.0	5.8	7.3	39.8	.6	45.8	.7	3,740	6,740
	---	42.4	48.0	9.6	4.8	65.9	1.0	17.5	1.2	6,200	11,150
	---	46.9	53.1	---	5.3	72.9	1.1	19.4	1.3	6,850	12,340
D196059	35.7	26.3	28.7	9.3	6.7	39.1	.5	42.3	1.9	3,720	6,700
	---	40.9	44.6	14.5	4.3	60.8	.8	16.4	3.0	5,790	10,420
	---	47.8	52.2	---	5.0	71.1	.9	19.2	3.5	6,770	12,180
D196060	33.8	29.7	28.2	8.3	6.8	41.0	.6	41.3	1.9	3,920	7,060
	---	44.9	42.6	12.5	4.6	61.9	.9	17.0	2.9	5,930	10,670
	---	51.3	48.7	---	5.3	70.8	1.0	19.4	3.3	6,780	12,200
D196061	37.9	26.7	29.3	6.1	7.1	39.9	.6	45.7	.6	3,730	6,720
	---	43.0	47.2	9.8	4.7	64.3	1.0	19.3	1.0	6,010	10,820
	---	47.7	52.3	---	5.2	71.3	1.1	21.4	1.1	6,670	12,000
D196062	38.1	26.2	27.8	7.9	6.9	38.2	.6	45.8	.6	3,590	6,470
	---	42.3	44.9	12.8	4.3	61.7	1.0	19.3	1.0	5,810	10,450
	---	48.5	51.5	---	4.9	70.7	1.1	22.1	1.1	6,660	11,980

Table 9 .--Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.--continued.

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D194870	24.7	0.11	0.67	0.50	0.0	1,140	1,150	1,165
	---	.18	1.07	.80				
	---	.20	1.23	.92				
D196052	30.6	.01	.47	.45	.0	1,155	1,210	1,265
	---	.02	.76	.73				
	---	.02	.85	.81				
D196053	30.6	.02	.74	.63	.0	1,125	1,180	1,235
	---	.03	1.20	1.02				
	---	.04	1.37	1.17				
D196054	33.1	.01	.43	1.18	.0	1,125	1,180	1,235
	---	.02	.72	1.98				
	---	.02	.79	2.18				
D196055	32.8	.02	.14	.52	.0	1,325	1,380	1,435
	---	.03	.23	.86				
	---	.04	.25	.94				
D196056	32.7	.03	.11	.39	.0	1,345	1,400	1,455
	---	.05	.18	.65				
	---	.05	.20	.70				
D196057	33.4	.02	.37	.52	.0	1,125	1,180	1,235
	---	.03	.61	.86				
	---	.04	.69	.97				
D196058	32.8	.08	.29	.31	.0	1,155	1,215	1,270
	---	.13	.48	.51				
	---	.15	.53	.57				
D196059	29.3	.06	.63	1.24	.0	1,095	1,155	1,210
	---	.09	.98	1.93				
	---	.11	1.15	2.25				
D196060	27.1	.19	.36	1.38	.0	1,095	1,155	1,205
	---	.29	.54	2.08				
	---	.33	.62	2.38				
D196061	31.8	.03	.18	.44	.0	1,100	1,150	1,215
	---	.05	.29	.71				
	---	.05	.32	.79				
D196062	32.1	.01	.20	.41	.0	1,100	1,150	1,215
	---	.02	.32	.66				
	---	.02	.37	.76				

Major- and minor-oxide and trace-element composition of the laboratory ash of 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.

[Values in percent or parts per million. Lignite ashed at 525°C. L means less than value shown; N, not detected; B, not determined. S after element title indicates determinations by semiquantitative emission spectrography. The spectrographic results are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc., but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc.; precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus or minus two brackets at 95 percent confidence level]

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
D194858	15.7	39	11	16	4.00	0.51	0.50	5.2	1.0	1.0L	D194858
D194859	10.7	28	11	17	5.30	1.08	.80	6.6	.40	1.0L	D194859
D194860	20.0	54	12	9.0	4.50	3.08	1.6	5.2	.70	1.0L	D194860
D194861	10.2	38	12	14	6.20	9.40	.70	3.2	1.1	1.0L	D194861
D194862	10.5	25	9.4	13	5.40	8.30	.40	8.4	.60	1.0L	D194862
D194863	9.5	22	9.8	20	6.90	4.40	.30	6.3	.70	1.0L	D194863
D194864	19.6	55	9.4	7.2	3.30	4.70	.60	4.3	1.4	1.0L	D194864
D194865	9.1	14	5.8	19	6.20	9.40	.30	7.7	.60	1.0L	D194865
D194866	32.1	69	11	3.6	1.93	2.53	1.1	2.4	1.5	1.0L	D194866
D194867	9.2	17	10	18	6.30	9.50	.20	6.3	.60	1.0L	D194867
D194868	6.6	6.6	5.5	22	8.00	13.4	.30	4.7	.60	1.0L	D194868
D194869	9.5	22	8.1	17	6.60	1.65	.40	12	.60	1.0L	D194869
D194870	11.5	28	7.4	10	4.80	7.20	1.1	13	.50	1.0L	D194870
D196052	10.9	15	6.2	17	4.50	.55	.40	18	.40	1.0	D196052
D196053	11.1	24	6.2	13	4.90	5.00	1.1	16	.40	1.0	D196053
D196054	9.5	16	6.7	14	8.40	1.84	.70	12	.60	1.0	D196054
D196055	8.7	23	11	24	7.30	1.43	.50	3.6	.70	2.0	D196055
D196056	7.4	13	5.1	26	7.60	1.25	.50	5.1	.40	2.0	D196056
D196057	10.1	24	8.1	15	5.40	8.80	.50	5.6	.80	1.0	D196057
D196058	9.2	17	7.6	15	5.70	10.0	.50	10	.70	1.0	D196058
D196059	16.9	36	7.4	8.7	2.70	.83	1.0	17	.60	1.0L	D196059
D196060	12.3	25	9.9	14	4.40	1.43	.90	8.1	.50	1.0	D196060
D196061	9.9	20	8.5	17	7.50	2.35	.40	9.4	.60	2.0	D196061
D196062	12.7	40	9.3	12	4.20	7.10	1.0	6.3	.90	1.0	D196062

Sample number	SO3 (percent)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	Li (ppm)	Mn (ppm)	Sample number
D194858	16	500	5,000	N	1.0L	50	30	N	38	990	D194858
D194859	22	1,000	2,000	5	1.0L	80	30	N	23	1,010	D194859
D194860	6.8	500	2,000	3	1.0L	35	30	N	27	660	D194860
D194861	14	700	10,000	N	1.0L	70	30	N	41	490	D194861
D194862	23	700	5,000	3	1.0L	42	30	N	38	200	D194862
D194863	25	1,500	7,000	N	1.0L	50	30	N	23	860	D194863
D194864	17	700	3,000	3	1.0L	55	30	30	31	390	D194864
D194865	33	1,500	7,000	N	1.0L	45	15	N	18	1,380	D194865
D194866	8.5	500	1,500	3	1.0L	60	50	N	43	225	D194866
D194867	25	1,500	7,000	3	1.0L	40	15	N	43	740	D194867
D194868	22	2,000	10,000	7	1.0L	35	10	N	13	430	D194868
D194869	30	1,500	5,000	3	1.0L	40	15	N	18	670	D194869
D194870	28	1,500	5,000	3	1.0L	35	15	N	20	270	D194870
D196052	33	1,000	5,000	N	1.0L	38	B	N	16	1,720	D196052
D196053	30	1,000	5,000	3	1.0L	53	B	N	20	360	D196053
D196054	37	1,500	7,000	3	2.0	45	20	N	13	1,320	D196054
D196055	27	1,000	7,000	3	1.0L	32	20	N	32	1,000	D196055
D196056	25	1,500	5,000	10	1.0L	93	15	N	10L	1,040	D196056
D196057	25	1,500	10,000	3	1.0L	66	20	70	34	500	D196057
D196058	27	1,000	10,000	15	1.0L	47	30	50	31	120	D196058
D196059	22	700	3,000	N	1.0L	45	B	N	18	920	D196059
D196060	31	1,000	1,500	7	1.0	104	20	30	24	1,680	D196060
D196061	27	1,000	7,000	N	1.0L	45	15	N	32	620	D196061
D196062	18	700	5,000	3	1.0L	51	20	N	31	560	D196062

Major- and minor-oxide and trace-element composition of the laboratory ash of 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.--continued.

Sample number	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Sample number
D194858	7	20L	10L	40	15	3,000	150	30	2	18	D194858
D194859	20	20L	70	35	20	3,000	150	50	3	270	D194859
D194860	N	N	50	30	10	2,000	70	30	3	84	D194860
D194861	7L	N	20	25	15	7,000	100	30	2	64	D194861
D194862	10	N	20	25	10	5,000	70	30	3	60	D194862
D194863	7L	N	20	25	10	5,000	50	30	2	30	D194863
D194864	15	30	20	25	15	2,000	100	30	3	68	D194864
D194865	7L	N	20	30	10L	7,000	30	20	2L	86	D194865
D194866	7	30	10	25L	15	1,500	150	50	3	62	D194866
D194867	7	20L	15	25	15	7,000	100	70	3	28	D194867
D194868	7	N	30	25	20	10,000	50	100	7	32	D194868
D194869	10	N	15	30	15	5,000	30	30	3	32	D194869
D194870	15	N	20	35	10	3,000	70	20	3	62	D194870
D196052	15	N	20	25L	10L	2,000	20	20	B	41	D196052
D196053	30	N	30	25L	10	5,000	70	30	B	35	D196053
D196054	15	N	20	25L	20	3,000	70	50	3	69	D196054
D196055	N	N	15	35	15	5,000	50	50	3	53	D196055
D196056	30	N	50	30	20	5,000	70	70	5	60	D196056
D196057	15	20L	30	25	15	7,000	70	50	3	67	D196057
D196058	15	30	50	35	70	10,000	70	100	10	62	D196058
D196059	15	N	20	25L	10	1,500	70	30	B	34	D196059
D196060	15	30	50	35	30	2,000	150	70	7	135	D196060
D196061	7	N	20	25	10	7,000	30	30	3	42	D196061
D196062	15	N	15	25	15	5,000	70	30	3	112	D196062

Sample number	Zr-S (ppm)
D194858	150
D194859	100
D194860	100
D194861	150
D194862	100
D194863	150
D194864	200
D194865	100
D194866	200
D194867	150
D194868	70
D194869	150
D194870	70
D196052	100
D196053	100
D196054	70
D196055	150
D196056	100
D196057	200
D196058	300
D196059	150
D196060	200
D196061	150
D196062	150

Content of nine trace elements in 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.

[Analyses on air-dried (32°C) lignite. L, less than the value shown; N, not detected]

Sample number	As (ppm)	Co (ppm)	Cr (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D194858	7.0	0.6	7.5	35	0.10	0.3	1.0	1.9	1.2	D194858
D194859	11	2.0	N	40	.09	1.0	.8	1.3	1.6	D194859
D194860	6.1	3.1	11	75	.07	.4	.9	2.3	1.6	D194860
D194861	5.4	.8	4.9	30	.06	.3	.6	1.5	.9	D194861
D194862	7.5	.8	4.2	20	.10	.4	1.0	1.5	.8	D194862
D194863	1.8	.7	2.2	20L	.08	.1	.4	.8	.7	D194863
D194864	4.2	1.9	10	30	.19	.5	1.2	2.9	2.0	D194864
D194865	3.4	.6	1.9	20L	.11	.1	.6	1.0	.6	D194865
D194866	7.2	1.9	27	80	.14	1.0	1.7	5.3	2.9	D194866
D194867	3.0	.8	N	20L	.06	.1	.5	1.0	.7	D194867
D194868	4.0	.7	1.2	20L	.05	.1	N	.3	.3	D194868
D194869	5.0	.8	2.3	20L	.08	.2	.6	1.4	1.1	D194869
D194870	19	1.4	N	35	.16	.3	N	.7	.7	D194870
D196052	8.9	.6	1.6	20	.14	.2	.5	.8	.9	D196052
D196053	18	1.1	3.8	30	.16	.3	.6	.5	.8	D196053
D196054	11	1.1	3.1	20	.07	.4	.3	.5	1.2	D196054
D196055	1.4	.4	2.3	15	.02	.1	.3	1.0	.6	D196055
D196056	7.0	1.2	2.5	20	.04	.3	.5	.5	1.4	D196056
D196057	3.9	1.1	4.2	15	.06	.4	.7	1.1	1.1	D196057
D196058	15	5.4	3.2	15	.13	1.1	.5	1.5	1.3	D196058
D196059	14	1.7	8.6	35	.11	.3	.4	.9	1.3	D196059
D196060	10	3.1	8.4	35	.09	.4	.8	1.4	2.0	D196060
D196061	6.1	.6	2.2	20	.12	.2	.5	.9	.8	D196061
D196062	4.4	.9	5.6	35	.10	.3	.6	1.2	1.1	D196062

Major-, minor-, and trace-element composition of 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area Mercer County, N. Dak.

[Values in percent or parts per million. As, Co, Cr, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) lignite; all other values calculated from analyses of ash. S means analysis by semiquantitative emission spectrography. L, less than the value shown; N, not detected; B, not determined]

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	As (ppm)	B-S (ppm)	Sample number
D194858	2.9	0.91	1.8	0.38	0.059	0.065	0.57	0.094	7.0	70	D194858
D194859	1.4	.62	1.3	.34	.086	.071	.49	.026	11	100	D194859
D194860	5.0	1.3	1.3	.54	.46	.27	.73	.084	6.1	100	D194860
D194861	1.8	.65	1.0	.38	.71	.059	.23	.067	5.4	70	D194861
D194862	1.2	.52	.97	.34	.65	.035	.62	.038	7.5	70	D194862
D194863	.98	.49	1.4	.39	.31	.024	.42	.040	1.8	150	D194863
D194864	5.0	.97	1.0	.39	.68	.098	.59	.16	4.2	150	D194864
D194865	.59	.28	1.2	.34	.63	.023	.49	.033	3.4	150	D194865
D194866	10	1.9	.83	.37	.60	.29	.54	.29	7.2	150	D194866
D194867	.73	.49	1.2	.35	.65	.015	.41	.033	3.0	150	D194867
D194868	.20	.19	1.0	.32	.66	.016	.22	.024	4.0	150	D194868
D194869	.98	.41	1.2	.38	.12	.032	.80	.034	5.0	150	D194869
D194870	1.5	.45	.82	.33	.61	.11	1.0	.034	19	150	D194870
D196052	.76	.36	1.3	.30	.044	.036	1.4	.026	8.9	100	D196052
D196053	1.2	.36	1.0	.33	.41	.10	1.2	.027	18	100	D196053
D196054	.71	.34	.95	.48	.13	.055	.80	.034	11	150	D196054
D196055	.93	.51	1.5	.38	.092	.036	.22	.036	1.4	100	D196055
D196056	.45	.20	1.4	.34	.069	.031	.26	.018	7.0	100	D196056
D196057	1.1	.43	1.1	.33	.66	.042	.40	.048	3.9	150	D196057
D196058	.73	.37	.99	.32	.68	.038	.64	.039	15	100	D196058
D196059	2.8	.66	1.0	.27	.10	.14	2.0	.061	14	100	D196059
D196060	1.4	.64	1.2	.33	.13	.092	.70	.037	10	150	D196060
D196061	.92	.45	1.2	.45	.17	.033	.65	.036	6.1	100	D196061
D196062	2.4	.62	1.1	.32	.67	.11	.56	.068	4.4	100	D196062

Sample number	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Hg (ppm)	Sample number
D194858	700	N	0.16L	0.6	7.5	7.9	35	5	N	0.10	D194858
D194859	200	.5	.11L	2.0	N	8.6	40	3	N	.09	D194859
D194860	500	.7	.20L	3.1	11	7.0	75	7	N	.07	D194860
D194861	1,000	N	.10L	.8	4.9	7.1	30	3	N	.06	D194861
D194862	500	.3	.11L	.8	4.2	4.4	20	3	N	.10	D194862
D194863	700	N	.10L	.7	2.2	4.8	20L	3	N	.08	D194863
D194864	700	.7	.20L	1.9	10	11	30	7	7	.19	D194864
D194865	700	N	.09L	.6	1.9	4.1	20L	1.5	N	.11	D194865
D194866	500	1	.32L	1.9	27	19	80	15	N	.14	D194866
D194867	700	.3	.09L	.8	N	3.7	20L	1.5	N	.06	D194867
D194868	700	.5	.07L	.7	1.2	2.3	20L	.7	N	.05	D194868
D194869	500	.3	.10L	.8	2.3	3.8	20L	1.5	N	.08	D194869
D194870	700	.3	.12L	1.4	N	4.0	35	1.5	N	.16	D194870
D196052	500	N	.11L	.6	1.6	4.1	20	B	N	.14	D196052
D196053	500	.3	.11L	1.1	3.8	5.9	30	B	N	.16	D196053
D196054	700	.3	.19	1.1	3.1	4.3	20	2	N	.07	D196054
D196055	700	.2	.09L	.4	2.3	2.8	15	1.5	N	.02	D196055
D196056	300	.7	.07L	1.2	2.5	6.9	20	1	N	.04	D196056
D196057	1,000	.3	.10L	1.1	4.2	6.7	15	2	7	.06	D196057
D196058	1,000	1.5	.09L	5.4	3.2	4.3	15	3	5	.13	D196058
D196059	500	N	.17L	1.7	8.6	7.6	35	B	N	.11	D196059
D196060	200	1	.12	3.1	8.4	13	35	2	3	.09	D196060
D196061	700	N	.10L	.6	2.2	4.5	20	1.5	N	.12	D196061
D196062	700	.3	.13L	.9	5.6	6.5	35	2	N	.10	D196062

Major-, minor-, and trace-element composition of 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.--continued.

Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sample number
D194858	6.0	160	1	3L	1.5L	690L	6.3	0.3	2	1.0	D194858
D194859	2.5	110	2	2L	7	470L	3.7	1.0	2	.8	D194859
D194860	5.4	130	N	N	10	870L	6.0	.4	2	.9	D194860
D194861	4.2	50	.7L	N	2	450L	2.6	.3	1.5	.6	D194861
D194862	4.0	21	1	N	2	460L	2.6	.4	1	1.0	D194862
D194863	2.2	82	.7L	N	2	420L	2.4	.1	1	.4	D194863
D194864	6.1	76	3	7	5	860L	4.9	.5	3	1.2	D194864
D194865	1.6	130	.7L	N	2	400L	2.7	.1	1L	.6	D194865
D194866	14	72	2	10	3	1,400L	8.0L	1.0	5	1.7	D194866
D194867	4.0	68	.7	2L	1.5	400L	2.3	.1	1.5	.5	D194867
D194868	.9	28	.5	N	2	290L	1.7	.1	1.5	N	D194868
D194869	1.7	64	1	N	1.5	420L	2.9	.2	1.5	.6	D194869
D194870	2.3	31	1.5	N	2	500L	4.0	.3	1	N	D194870
D196052	1.7	190	1.5	N	2	480	2.7L	.2	1L	.5	D196052
D196053	2.2	40	3	N	3	490	2.8L	.3	1	.6	D196053
D196054	1.2	130	1.5	N	2	420	2.4L	.4	2	.3	D196054
D196055	2.8	87	N	N	1.5	760	3.0	.1	1.5	.3	D196055
D196056	.7L	77	2	N	3	650	2.2	.3	1.5	.5	D196056
D196057	3.4	51	1.5	2L	3	440	2.5	.4	1.5	.7	D196057
D196058	2.9	11	1.5	3	5	400	3.2	1.1	7	.5	D196058
D196059	3.0	160	2	N	3	740L	4.2L	.3	1.5	.4	D196059
D196060	3.0	210	2	3	7	540	4.3	.4	3	.8	D196060
D196061	3.2	61	.7	N	2	870	2.5	.2	1	.5	D196061
D196062	3.9	71	2	N	2	550	3.2	.3	2	.6	D196062

Sample number	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D194858	500	1.9	1.2	20	5	0.3	2.8	20	D194858
D194859	300	1.3	1.6	15	5	.3	29	10	D194859
D194860	500	2.3	1.6	15	7	.7	17	20	D194860
D194861	700	1.5	.9	10	3	.2	6.5	15	D194861
D194862	500	1.5	.8	7	3	.3	6.3	10	D194862
D194863	500	.8	.7	5	3	.2	2.9	15	D194863
D194864	500	2.9	2.0	20	7	.7	13	50	D194864
D194865	700	1.0	.6	3	2	.2L	7.8	10	D194865
D194866	500	5.3	2.9	50	15	1	20	70	D194866
D194867	700	1.0	.7	10	7	.3	2.6	15	D194867
D194868	700	.3	.3	3	7	.5	2.1	5	D194868
D194869	500	1.4	1.1	3	3	.3	3.0	15	D194869
D194870	300	.7	.7	7	2	.3	7.1	7	D194870
D196052	200	.8	.9	2	2	B	4.5	10	D196052
D196053	500	.5	.8	7	3	B	3.9	10	D196053
D196054	300	.5	1.2	7	5	.3	6.6	7	D196054
D196055	500	1.0	.6	5	5	.2	4.6	15	D196055
D196056	300	.5	1.4	5	5	.3	4.4	7	D196056
D196057	700	1.1	1.1	7	5	.3	6.8	20	D196057
D196058	1,000	1.5	1.3	7	10	1	5.7	30	D196058
D196059	200	.9	1.3	10	5	B	5.7	20	D196059
D196060	200	1.4	2.0	20	10	1	17	20	D196060
D196061	700	.9	.8	3	3	.3	4.2	15	D196061
D196062	700	1.2	1.1	10	3	.3	14	20	D196062

Table 15.--Elements looked for but not detected in lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.

[Approximate lower detection limits in lignite ash, as determined by the six-step spectrographic method of the U. S. Geological Survey, are included for all elements]

Element name	Symbol	Lower limit of detection (ppm) in coal ash
Silver	Ag	1
Gold	Au	50
Bismuth	Bi	20
Cerium	Ce	500
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Gd	100
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lanthanum	La	100
Lutetium	Lu	70
Neodymium	Nd	150
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Terbium	Tb	700
Tellerium	Te	5,000
Thallium	Tl	100
Thulium	Tm	50
Tungsten	W	200

Table 16 --Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures of 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.

[All values are in percent except Kcal/kg, Btu/lb and ash-fusion temperatures and are reported on the as-received basis. °C = (°F-32)5/9; Kcal/kg = 0.556(Btu/lb). L, less than value shown. Leaders (---) indicate no data. For comparison, geometric means for 32 other Fort Union region lignite samples, Montana and North Dakota (Swanson and others, 1974, table 8) are included]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Fort Union region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	35.9	27.6	40.3	35.7	1.1	34.9
Volatile matter	26.4	24.9	29.7	26.4	1.0	27.4
Fixed carbon	29.3	27.0	33.7	29.3	1.1	30.1
Ash	8.4	4.4	19.4	7.8	1.5	6.4
Hydrogen	6.7	5.3	7.3	6.7	1.1	6.7
Carbon	40.0	36.6	43.8	40.0	1.0	40.7
Nitrogen	.6	.5	.9	.6	1.1	.6
Oxygen	43.4	32.2	46.9	43.2	1.1	43.9
Sulfur	.9	.3	1.9	.8	1.6	.6
Heat of combustion						
Kcal/kg	3,690	3,430	3,970	3,690	1.0	3,770
Btu/lb	6,640	6,160	7,140	6,640	1.0	6,780
Forms of sulfur						
Sulfate	0.06	0.01L	0.19	0.04	2.8	0.02
Pyritic	.31	.03	.74	.23	2.2	.13
Organic	.59	.27	1.38	.53	1.6	.36
Ash-fusion temperatures, °C						
Initial deformation	2,115	1,980	2,455	2,110	1.1	---
Softening temperature	2,190	2,030	2,555	2,185	1.1	---
Fluid temperature	2,275	2,080	2,655	2,270	1.1	---

Table 17 --Arithmetic mean, observed range, geometric mean and geometric deviation of ash content and contents of nine major and minor oxides in the laboratory ash of 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.

[All samples were ashed at 525°C; all values except geometric deviation are in percent. For comparison, geometric means of 80 other Fort Union region lignite samples, Montana and North Dakota (Hatch and Swanson, 1977, table 5a) are included]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Fort Union region geometric mean
		Minimum	Maximum			
(Ash)	12.1	6.6	32.1	11.4	1.4	9.0
SiO_2	28	6.6	69	25	1.7	13
Al_2O_3	8.7	5.1	12	8.4	1.3	8.6
CaO	15	3.6	26	14	1.5	22
MgO	5.6	1.93	8.40	5.22	1.4	7.01
Na_2O	5.3	.510	13.4	3.22	2.7	1.43
K_2O	.66	.20	1.6	.58	1.7	.059
Fe_2O_3	8.2	2.4	18	7.2	1.7	5.0
TiO_2	.70	.40	1.5	.66	1.4	.49
SO_3	24	6.8	37	22	1.5	19

Ash and sulfur contents of U.S. coals on an as-received basis:

Number or Samples	Ash, percent		Sulfur, percent	
	Range	Average	Range	Average
642	2.5-32.6	8.9	0.2-7.7	1.9

The ash and sulfur content of the 24 lignite samples from the Beulah Trench Study Area, as received, are ash range, 4.4-19.4 percent; average, 8.5 percent; sulfur range, 0.3-1.9 percent; average, 0.93 percent.

Table 18.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 34 elements in 24 lignite samples from the Sentinel Butte Member, Fort Union Formation, Beulah Trench Study Area, Mercer County, N. Dak.

[All analyses are in percent or parts per million and are reported on a whole-lignite basis. As, Co, Cr, F, Hg, Sb, Se, Th, and U values used to calculate statistics were determined directly on whole lignite. All other values used were calculated from determinations made on lignite ash. L, less than value shown. For comparison, geometric means for 80 other Fort Union region lignite samples, Montana and North Dakota (Hatch and Swanson, 1977, table 5b) are included]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Fort Union region geometric mean
		Minimum	Maximum			
			Percent			
Si	1.9	0.20	10	1.3	2.3	0.55
Al	.58	.19	1.9	.51	1.7	.41
Ca	1.2	.82	1.8	1.1	1.2	1.4
Mg	.36	.28	.54	.36	1.2	.38
Na	.43	.044	.71	.27	2.7	.095
K	.075	.015	.29	.055	2.2	.006
Fe	.67	.22	2.0	.57	1.8	.32
Ti	.055	.018	.29	.045	1.9	.028
			Parts per million			
As	7.9	1.4	19	6.3	2.0	4
B	100	70	150	100	1.3	100
Ba	700	200	1,000	700	1.5	300
Be	.5	.2	1.5	.3	2.3	.15
Co	1.3	.4	5.4	1.1	1.8	1.5
Cr	5.1	1.2	27	3.1	2.7	1.5
Cu	6.4	2.3	19	5.7	1.6	3.8
F	28	15	80	23	1.8	26
Ga	3	.7	15	2	2.0	1.5
Hg	.10	.02	.19	.09	1.7	.09
Li	3.5	.7L	14	2.8	1.9	2.4
Mn	91	11	210	71	2.0	29
Mo	1.5	.5	3	1	2.1	1
Ni	3	1.5L	10	3	1.7	1.5
Pb	2.9	1.7	6.3	2.6	1.6	3.8
Sb	.4	.1	1.1	.3	2.0	.2
Sc	2	1L	7	1.5	1.7	1.5
Se	.7	.3	1.7	.6	1.6	.6
Sr	500	200	1,000	500	1.6	500
Th	1.3	.3	5.3	1.1	1.9	2.4
U	1.2	.3	2.9	1.0	1.6	.6
V	10	2	50	7	2.1	3
Y	5	2	15	5	1.7	3
Yb	.5	.2L	1	.3	1.8	.2
Zn	8.1	2.1	29	6.4	2.0	2.3
Zr	15	5	70	15	1.8	10

Explanation of statistical terms used in summary tables

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode). The GM is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by statistically analyzing and summarizing trace-element data on a logarithmic basis.

If the frequency distributions are lognormal, the GM is the best estimate of the mode, and the estimated range of the central two-thirds of the observed distribution has a lower limit equal to GM/GD and an upper limit equal to GM·GD. The estimated range of the central 95 percent of the observed distribution has a lower limit equal to GM/GD^2 and an upper limit equal to $GM \cdot GD^2$ (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means listed in the summary tables are Sichel's *t* statistic (Miesch, 1967).

A common problem in statistical summaries of trace-element data arises when the element content of one or more samples is below the limit of analytical detection. This results in a "censored" distribution. Procedures developed by Cohen (1959) are used to compute unbiased estimates of the GM, GD, and arithmetic mean when the data are censored.

Discussion

The apparent ranks for the 24 samples from the Beulah Trench Study Area were calculated using the data in Table 9 and the formulae in ASTM designation D-388-77 (American Society for Testing and Materials, 1978). The heat of combustion (moist, mineral-matter-free basis) for all 24 samples from the Beulah Trench Study Area ranges from 3,890 Kcal/kg (6,990 Btu/lb) to 4,360 Kcal/kg (7,840 Btu/lb) with an arithmetic mean of 4,080 Kcal/kg (7,330 Btu/lb). The apparent rank for all samples is lignite A.

A statistical comparison (student's *t*-test or approximate *t*-test, 95 percent confidence) of geometric means for the U.S. Department of Energy data for the 24 Beulah Trench area lignite samples with 32 other Fort Union region lignite samples (Swanson and others, 1974) shows that the Beulah Trench area lignite has significantly higher contents of sulfate and organic sulfur. Contents of moisture, volatile matter, fixed carbon, ash, hydrogen, carbon, nitrogen, oxygen, total sulfur, pyritic sulfur, and heat of combustion are not significantly different.

A statistical comparison of geometric means for lignite ash and 9 major and minor oxides in ash for the 24 Beulah Trench area lignite samples with data for 80 other samples of Fort Union region lignite (Hatch and Swanson, 1977) shows that Beulah Trench area lignite has a significantly higher ash content, significantly higher SiO_2, Na_2O, K_2O, Fe_2O_3, and TiO_2, and significantly lower CaO and MgO content in ash. Contents of Al_2O_3 and SO_3 in ash are not significantly different. When compared at the 99 percent confidence level, the Fe_2O_3 contents in ash are not significantly different.

A statistical comparison of geometric means for the contents for 32 different elements in Beulah Trench area lignite (whole-lignite basis) with data for 80 other samples of Fort Union region lignite shows that the Beulah Trench area lignite has significantly higher contents of Si, Na, K, Fe, Ti, As, Ba, Be, Cr, Cu, Ga, Mn, Ni, U, Zn, and Zr, and significantly lower contents of Ca, Pb, and Th. The contents of Al, Mg, B, Co, F, Hg, Li, Mo, Sb, Sc, Se, and Sr are not significantly different. When compared at the 99 percent confidence level, the contents of As, Ga, and Zr are not significantly different.

Differences in the oxide composition of lignite ash and the element contents in lignite result from differences in the total and relative amounts of the various inorganic minerals, the elemental composition of these minerals, and the total and relative amounts of any organically bound elements. The chemical form and distribution of a given element are dependent on the geologic history of the lignite bed. A partial listing of the geologic factors that influence element distribution includes chemical composition of original plants; amounts and compositions of various detrital, diagenetic, and epigenetic minerals; temperatures and pressures during burial; and extent of weathering. No evaluation of these factors has been made for any of the lignite beds in the Beulah Trench Study Area.

Compared to other U.S. lignite (Swanson and others, 1976; Hatch and Swanson, 1977), lignite of the Fort Union region is characterized by relatively low ash, low sulfur, low heat of combustion, and high moisture content. The contents of such elements as As, Be, Hg, Mo, Sb, and Se are low in Fort Union lignite when compared to most other U.S. lignite.

Acknowledgments

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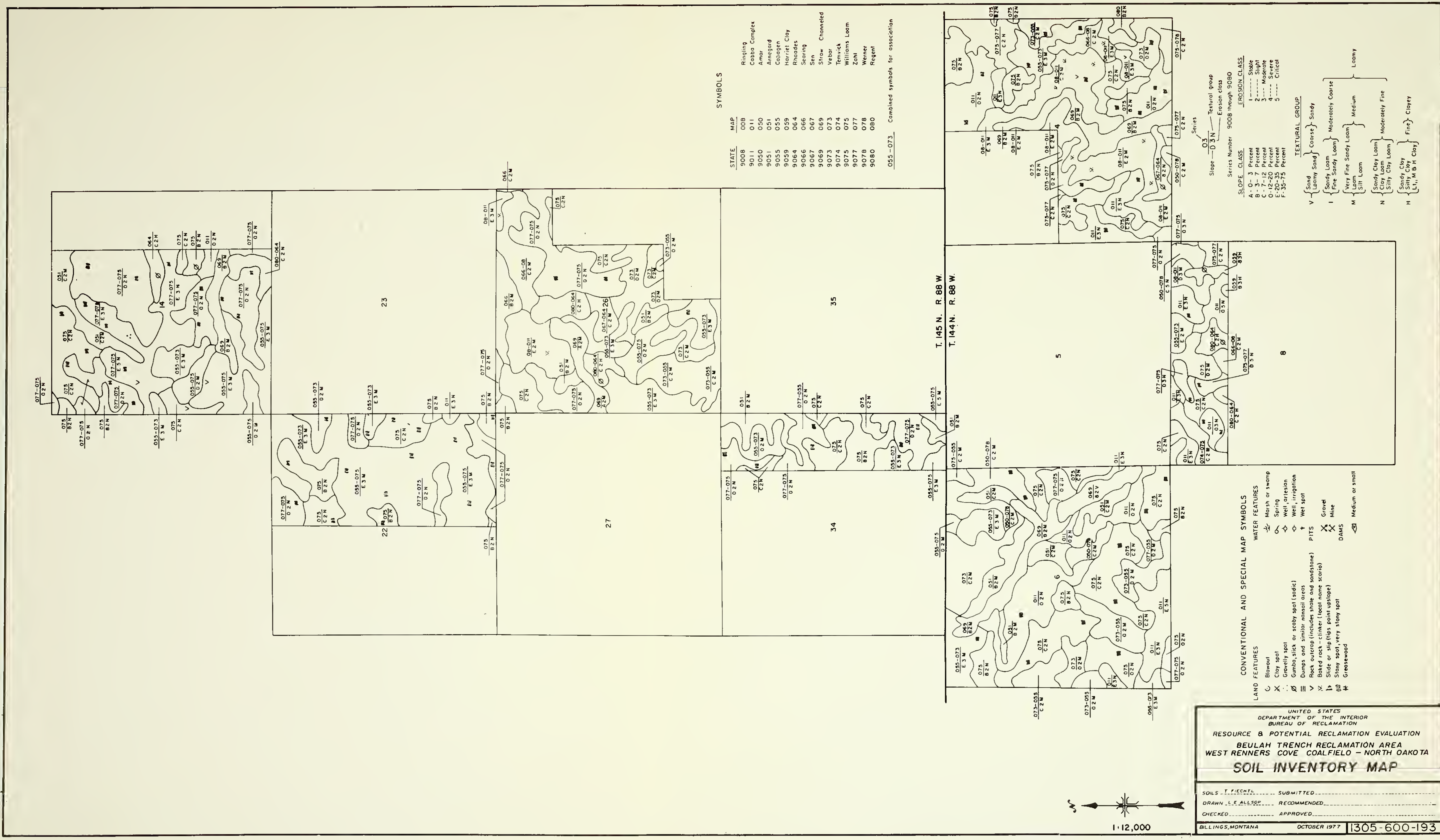
APPENDIX E

OVERBURDEN - SOIL AND BEDROCK


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH RECLAMATION AREA
WEST RENNERS COVE COALFIELD – NORTH DAKOTA
SOIL INVENTORY MAP
SOILS T. FIECHTL SUBMITTED
DRAWN L.E. ALLSOP RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA OCTOBER 1977 1305-600-193
1:12,000
T. 145 N. R. 88 W.
T. 144 N. R. 88 W.

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Bureau of Reclamation

Table 19

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 6 Twp. 144 N. Range 88 W.
750' S., 300' W. of N.E. Corner
Climate: Semiarid
Land Use: Cultivated
Point Site Number: 23

Relief: Complex, 6-14%
Elevation: 2000'
Slope: Aspect: South
Vegetation: Small grain
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water: None
Land Form: Side slope

Parent Material: Sandstone, soft shale
Soil Series: Amor
Soil Classification: Fine - loamy, mixed Typic Haploborolls
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
T 1524 Bis-7041	0-12	A_p	0-5 inches, dark grayish brown (10YR 4/2) sandy clay loam, very dark grayish brown (10YR 3/2) moist; weak, very coarse blocky structure breaks to weak medium and coarse blocky structure; slightly hard dry, friable moist, slightly sticky, nonplastic wet; plentiful fine roots; noncalcareous; abrupt boundary.
		B_2	5-12 inches, dark brown (10YR 4/3) sandy clay loam, dark brown (10YR 3/3) moist; weak, very coarse, prismatic structure breaks to medium and coarse blocky structure; slightly hard dry, friable moist, sticky and slightly plastic wet; plentiful fine roots; noncalcareous; gradual boundary.
T 1525 Bis-7042	12-36	B_3	12-36 inches, brown (10YR 5/3) clay loam, dark grayish brown (10YR 4/2) moist; weak, coarse blocky structure breaks to weak medium blocky structure; slightly hard dry, friable moist, sticky and plastic wet; plentiful fine roots; noncalcareous; abrupt boundary.
T 1526 Bis-7043	36-54	C_1	36-54 inches, light gray (10YR 7/2) silty clay loam, clayey shales, grayish brown (10YR 5/2) moist; massive structure; hard dry, friable moist, sticky, plastic wet; few fine roots; slightly calcareous with fine lime filaments and soft masses; abrupt boundary.
T 1527 Bis-7044	54-72		54-72, same as horizon above.
T 1528 Bis-7045	72-96	C_2	72-96 inches, light gray (10YR 7/2) silty clay loam, grayish brown (10YR 5/2) moist; massive structure; hard dry, very friable moist, sticky, plastic wet; noncalcareous; abrupt boundary.
T 1529 Bis-7046	96-120	C_3	96-120 inches, light gray (10YR 7/1) silty clay loam, gray (10YR 6/1) moist; massive structure; hard dry, firm moist, sticky, plastic wet; noncalcareous. Mottling influence varies from yellow (10YR 7/6) to a brownish yellow (10YR 6/5).

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		7041	7042	7043	7044	7045	7046
DEPTH	(in)	0-12"	12-36"	36-54"	54-72"	72-96"	96-120"
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.5					
Coarse Sand	(1.0-0.5 mm)	2.6					
Medium Sand	(0.5-0.25 mm)	15.4					
Fine Sand	(0.25-0.10 mm)	31.5					
Very Fine Sand	(0.10-0.05 mm)	8.6					
Total Sand	(2.0-0.05 mm)	58.6	24.0	50.6	18.8	3.1	4.8
Silt	(0.05-0.002 mm)	23.0	53.6	29.2	56.3	57.3	46.7
Clay	(< 0.002 mm)	18.4	22.4	20.2	24.9	39.6	48.5
TEXTURAL CLASS (LAB.)		SL	SiL	L	SiL	SiCL	SiC
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.35	0.31	0.58	0.18	0.11	0.02
24th hr		0.33	0.31	0.62	0.20	0.11	0.04
SETTLING VOLUME	(ml)	20	23	22	24	29	30
MOISTURE RETENTION	(percent)						
1/10 bar		26.6	36.4	28.3	41.5	41.4	37.2
1/3 bar		16.8	25.4	18.8	29.4	33.8	31.6
15 bar		7.2	10.3	8.4	12.2	17.4	17.4
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.3	8.6	8.2	8.6	8.3	7.8
1:2 0.01 M $CaCl_2$		6.9	7.7	7.2	7.8	7.7	7.5
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	0.0	-0.2	-0.6	-0.4	-4.8	-8.8
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	0.28	0.32	0.34	0.45	4.00	3.50
Ca^{++}	(me/l)	3.29	1.43	3.13	0.99	25.75	25.00
Mg^{++}	(me/l)	1.27	2.08	2.08	2.53	37.42	45.56
Na^{+}	(me/l)	0.24	1.00	0.38	2.49	8.30	12.30
K^{+}	(me/l)	0.10	0.05	0.07	0.06	0.50	0.85
CO_3^{-}	(me/l)	0.00	0.08	0.08	0.08	0.00	0.00
HCO_3^{-}	(me/l)	3.88	3.28	4.88	3.20	1.32	1.16
Cl^{-}	(me/l)	0.08	0.12	0.04	0.76	0.16	0.24
SO_4^{-}	(me/l)	0.37	0.90	0.35	2.14	70.79	80.99
NO_3^{-}	(me/l)	0.02	0.02	0.02	0.02	0.05	0.05
SAR	(me/l)	0.2	0.8	0.3	1.9	1.5	2.1
Na	(me/100g)	0.01	0.06	0.02	0.15	0.67	0.88
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.10	0.14	0.16	0.16	1.50	2.10
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	0.6	0.6	0.4	1.4	2.2	3.3
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	14.5	17.7	15.9	19.9	20.9	19.4
NaOAc@pH 8.2							
BORON	(mg/l)						

GPO 833-796

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Table 20

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 26 Twp. 145 N. Range 88 W.
1000' E., 200' N. of W¼ Corner
Climate: Semiarid
Land Use: Range
Point Site Number: 2

Relief: Complex, 2-4%
Elevation: 2100'
Slope: Aspect: North
Vegetation: Mid and short grasses, forbs
Erosion: Slight

Stoniness: None
Drainage: Well-drained
Ground Water: None
Land Form: Residual Bench

Parent Material: Sandstone, soft shale
Soil Series: Regent
Soil Classification: Fine, montmorillonitic Typic Argiborolls
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
T 1509 Bis-7026	0-12	A_1 0-1 inch, grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate, coarse, crumb structure; soft dry, loose moist, slightly sticky, and nonplastic; plentiful fine roots; noncalcareous; abrupt boundary.
		B_{21t} 1-7 inches, grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; weak, medium prismatic structure separates to moderate, medium blocky structure; hard dry, friable moist sticky and slightly plastic wet; plentiful fine roots; noncalcareous; abrupt boundary.
		B_{22t} 7-12 inches, grayish brown (10YR 5/2) heavy clay loam, dark grayish brown (10YR 4/2) moist; moderate, medium, columnar prismatic structure breaks to moderate, fine blocky structure; hard dry, friable moist, sticky and plastic wet; plentiful fine roots; noncalcareous; gradual boundary.
T 1510 Bis-7027	12-30	B_{3ca} 12-30 inches, light brownish gray (10YR 6/2) heavy clay loam, grayish brown (10YR 5/2) moist; weak, coarse, prismatic structure, breaks to moderate, medium blocky structure; very hard dry, firm moist, sticky and plastic wet; few fine roots; slightly calcareous; abrupt boundary.
T 1511 Bis-7028	30-48	C_{r1} 30-48 inches, light brownish gray (10YR 6/2) silty clay loam, clayey shales, grayish brown (10YR 5/2) moist, light yellowish brown (10YR 6/4) mottling; massive structure; hard dry, very friable moist, sticky and plastic wet; violently calcareous; gradual boundary.
T 1512 Bis-7029	48-72	C_{r2} 48-72 inches, brown (10YR 5/3) silty clay loam, grayish brown (10YR 5/2) moist; mottling varies from yellow (10YR 8/6) dry to a strong brown (7.5YR 5/6) moist; massive structure; hard dry, very friable moist; violently calcareous; gradual boundary.
T 1513 Bis-7030	72-96	C_{r3} 72-96 inches, pale brown (10YR 6/5) silty clay loam, grayish brown (10YR 5/2) moist, mottling varies from yellow (10YR 8/6) dry to yellowish brown (10YR 5/6) moist; massive structure; hard dry, very friable moist; noncalcareous.
T 1514 Bis-7031	96-120	96-120, same as above horizon.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		7026	7027	7028	7029	7030	7031
DEPTH	(in)	0-12"	12-30"	30-48"	48-72"	72-96"	96-120"
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
Total Sand	(2.0-0.05 mm)	8.3	2.2	1.1	10.3	4.4	14.5
Silt	(0.05-0.002 mm)	56.9	54.4	57.8	56.3	62.7	58.1
Clay	(<0.002 mm)	34.8	43.4	41.1	33.4	32.9	27.4
TEXTURAL CLASS (LAB.)		SiCL	SiC	SiC	SiCL	SiCL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.01	*4/5	*9/10	*	*	0.01
24th hr		0.02	*	*	*	*	0.01
SETTLING VOLUME	(ml)	26	31	40	50	65	50
MOISTURE RETENTION	(percent)						
1/10 bar		41.7	43.2	44.8	50.0	51.4	46.1
1/3 bar		33.1	34.0	37.4	39.3	39.8	36.3
15 bar		18.7	21.3	23.8	22.8	21.8	18.0
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.9	8.8	8.1	8.1	8.2	8.2
1:2 0.01 M $CaCl_2$		7.1	7.3	7.5	7.6	7.7	7.5
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.2	+1.2	-5.7	-8.6	-8.1	-7.5
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	0.85	0.82	5.00	7.00	7.00	5.50
Ca^{++}	(me/l)	5.49	1.37	24.30	22.65	22.65	22.31
Mg^{++}	(me/l)	4.34	1.27	20.23	39.23	38.24	29.28
Na^+	(me/l)	2.77	6.83	32.17	64.57	70.30	60.26
K^+	(me/l)	0.58	0.25	0.76	1.04	1.33	1.02
CO_3^-	(me/l)	0.40	0.32	0.00	0.00	0.00	0.00
HCO_3^-	(me/l)	9.16	6.08	2.24	1.60	1.80	1.40
Cl^-	(me/l)	0.04	0.28	0.44	0.04	0.08	0.00
SO_4^-	(me/l)	0.41	1.79	78.10	115.00	129.00	108.00
NO_3^-	(me/l)	0.02	0.02	0.02	0.15	0.49	0.61
SAR	(me/l)	1.2	5.9	6.8	12.0	12.0	12.0
Na	(me/100g)	0.16	0.49	2.70	5.49	7.09	4.85
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.22	0.26	3.10	4.00	4.10	3.80
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	0.7	4.6	5.9	5.8	3.9	9.8
ACIDITY							
1N KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	26.3	25.1	23.6	23.6	23.6	22.3
NaOAc@pH 8.2							
BORON	(mg/l)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

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Table 21

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 26 Twp. 145 N. Range 88 W. 1300' E. of S.W. Corner
Climate: Semiarid
Land Use: Cultivated
Point Site Number: 19

Relief: Complex side slope
Elevation: 2100'
Slope: Aspect: North
Vegetation: Small grain
Erosion: Slight

Stoniness: None
Drainage: Well-drained
Ground Water: None
Land Form: Residual

Parent Material: Sandstone, soft shales
Soil Series: Vebar
Soil Classification: Coarse-loamy mixed Typic Haploborolls
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
T 1502 Bis-7019	0-6	A_p 0-6 inches, grayish brown (10YR 5/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak, medium blocky structure separating to weak, fine blocky structure; loose dry, loose moist, nonsticky, nonplastic wet; plentiful fine roots; noncalcareous; abrupt boundary.
T 1503 Bis-7020	6-18	B_1 6-18 inches, pale brown (10YR 6/3) fine sandy loam, grayish brown (10YR 4/3) moist; weak, very coarse blocky structure separating to weak, coarse and medium blocks; soft dry, loose moist, nonsticky and nonplastic wet; few fine roots; noncalcareous; gradual boundary.
T 1504 Bis-7021	18-42	C_2 18-42 inches, very pale brown (10YR 7/2) fine sandy loam, soft consolidated sandy shale, pale brown (10YR 6/2) moist; massive structure; hard dry, loose moist, nonsticky, nonplastic wet; weakly calcareous at 36 inches; gradual boundary. Common very fine roots to 28 inches.
T 1505 Bis-7022	42-60	C_3 42-60 inches, very pale brown (10YR 7/2) loamy fine sand, pale brown (10YR 6/2) moist; massive structure; slightly hard dry, loose moist; nonsticky and nonplastic wet; gradual boundary, hard sandy shale fragments at 84 inches.
T 1506 Bis-7023	60-84	60-84 inches, same as above (C_3).
T 1507 Bis-7024	84-102	84-102 inches, same as above (C_3).
T 1508 Bis-7025	102-120	C_4 102-120 inches, very pale brown (10YR 7/2) fine sand, pale brown (10YR 6/2) moist; massive structure; loose dry, loose moist, nonsticky and nonplastic wet; noncalcareous.
		Note: Paralithic contact begins at approximately 28 inches in depth.

LABORATORY DESCRIPTION

DETERMINATION		DATA						
LABORATORY NUMBER		7019	7020	7021	7022	7023	7024	7025
DEPTH	(in)	0-6"	6-18"	18-42"	42-60"	60-84"	84-102"	102-120"
PARTICLE SIZE ANALYSIS	(percent)							
Very Coarse Sand	(2.0-1.0 mm)	0.8	0.2	0.1	0.1	0.1	0.1	0.1
Coarse Sand	(1.0-0.5 mm)	1.6	0.5	0.5	0.6	1.5	1.2	3.0
Medium Sand	(0.5-0.25 mm)	6.2	2.6	1.4	5.3	9.9	11.2	21.5
Fine Sand	(0.25-0.10 mm)	44.2	49.7	50.2	56.1	56.4	56.2	49.9
Very Fine Sand	(0.10-0.05 mm)	14.2	19.4	20.4	15.5	11.1	11.0	7.3
Total Sand	(2.0-0.05 mm)	67.0	72.4	72.6	77.6	79.0	79.7	81.8
Silt	(0.05-0.002 mm)	18.0	13.0	14.2	9.6	9.1	9.1	7.6
Clay	(<0.002 mm)	15.0	14.6	13.2	12.8	11.9	11.2	10.6
TEXTURAL CLASS (LAB)		FSL	FSL	FSL	FSL	FSL	FSL	LFS
BULK DENSITY	(g/cm^3)							
HYDRAULIC CONDUCTIVITY	(in/hr)							
6th hr		1.66	1.33	0.67	0.91	0.83	1.02	1.10
24th hr		1.91	1.66	0.79	1.02	0.79	0.87	1.14
SETTLING VOLUME	(ml)	20	20	21	21	20	21	20
MOISTURE RETENTION	(percent)							
1/10 bar		24.3	24.1	24.3	25.8	23.9	24.1	20.3
1/3 bar		16.0	15.9	18.1	16.8	15.8	15.8	14.4
15 bar		10.1	9.2	9.2	8.2	7.9	7.8	6.5
SOIL REACTION-pH								
Paste								
1:5 H_2O		7.3	7.2	8.1	8.3	8.3	8.3	8.0
1:2 0.01 M $CaCl_2$		6.8	6.9	7.4	7.2	7.5	7.5	7.4
ORGANIC CARBON	(percent)							
AVAILABLE PHOSPHORUS	(ppm)							
$CaCO_3$ EQUIVALENT	(percent)							
GYPSUM REQUIREMENT	(me/100g)	-0.4	-0.6	-0.5	-0.4	-0.4	-0.4	-0.4
SATURATION EXTRACT								
Saturation Percentage								
EC_e @ 25°C	(mmhos/cm)	0.45	0.54	0.36	0.44	0.34	0.44	0.34
Ca^{++}	(me/l)	3.79	4.61	2.96	2.20	1.48	1.65	1.59
Mg^{++}	(me/l)	1.36	1.45	1.00	1.90	1.09	1.72	1.27
Na^+	(me/l)	0.24	0.38	0.53	1.72	1.29	1.48	1.10
K^+	(me/l)	0.11	0.05	0.05	0.09	0.07	0.11	0.11
CO_3^-	(me/l)	0.00	0.08	0.08	0.08	0.08	0.24	0.24
HCO_3^-	(me/l)	3.80	4.96	3.40	3.16	3.04	2.88	2.76
Cl^-	(me/l)	0.00	0.04	0.08	0.56	0.20	0.28	0.12
SO_4^-	(me/l)	0.47	0.65	0.19	1.84	0.42	1.49	0.71
NO_3^-	(me/l)	0.10	0.06	0.23	0.16	0.04	0.05	0.07
SAR	(me/l)	0.1	0.2	0.4	1.2	1.1	1.1	0.9
Na	(me/100g)	0.01	0.01	0.02	0.07	0.05	0.06	0.04
Ca+Mg	(me/100g)							
1:5 EXTRACT								
EC_5 @ 25°C	(mmhos/cm)							
Ca+Mg	(me/l)							
EXCHANGEABLE SODIUM	(percent)	0.5	0.5	0.5	0.8	1.0	0.9	1.2
ACIDITY								
IN KCl exchange acidity								
Total	(me/100g)							
Al^{+++}	(me/100g)							
CATION EXCHANGE CAPACITY	(me/100g)	16.8	15.5	14.3	12.8	12.3	12.0	11.0
NaOAc@pH 8.2								
BORON	(mg/l)							

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Table 22

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 4 Twp. 144 N. Range 88 W.
1500' W., 100' S. of E¼ Corner
Climate: Semiarid
Land Use: Range
Point Site Number: 22

Relief: Complex, 8-35%
Elevation: 2000'
Slope: Aspect: South
Vegetation: Short grasses
Erosion: Moderate

Stoniness: None
Drainage: Well drained
Ground Water: None
Land Form: Residual

Parent Material: Baked shales
Soil Series: Brandenburg
Soil Classification: Fragmental, mixed, frigid Typic Ustorthents
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
T 1522 Bis-7039	0-6	A_{11} 0-1 inch, brown (7.5YR 5/2) loam, 20% gravels, dark brown (7.5YR 4/2) moist; moderate, fine blocky structure separates to moderate, medium crumb structure; soft dry, loose moist, nonsticky, nonplastic wet; noncalcareous; abrupt boundary.
		A_{12} 1-6 inches, reddish brown (5YR 5/3) gravely loam, reddish brown (5YR 4/3) moist; weak, medium prismatic structure breaks to weak, fine blocky structure; soft dry, loose dry, nonsticky, nonplastic wet; plentiful fine roots; gradual boundary.
T 1523 Bis-7040	6-18	C_1 6-18 inches, reddish brown (2.5YR 4/3) gravely loam, dark reddish brown (2.5YR 3/3) moist; weak, medium blocky structure breaks to weak, fine, blocky structure; soft dry, loose moist, nonsticky, nonplastic wet; plentiful fine roots; abrupt boundary.
		C_{r2} 18 inches plus, pink (5YR 7/4) fragmented baked shales, reddish brown (2.5YR 5/3) moist.

LABORATORY DESCRIPTION

DETERMINATION		DATA	
LABORATORY NUMBER		7039	7040
DEPTH	(in)	0-6"	6-18"
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0 mm)		
Coarse Sand	(1.0-0.5 mm)		
Medium Sand	(0.5-0.25 mm)		
Fine Sand	(0.25-0.10 mm)		
Very Fine Sand	(0.10-0.05 mm)		
Total Sand	(2.0-0.05 mm)	29.9	31.7
Silt	(0.05-0.002 mm)	52.2	48.3
Clay	(<0.002 mm)	17.9	20.0
TEXTURAL CLASS (LAB.)		SiL	L
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th hr		0.47	0.17
24th hr		0.51	0.19
SETTLING VOLUME	(ml)	29	29
MOISTURE RETENTION	(percent)		
1/10 bar		53.9	49.8
1/3 bar		33.8	34.3
15 bar		19.5	17.6
SOIL REACTION-pH			
Paste			
1:5 H_2O		7.3	7.4
1:2 0.01 M $CaCl_2$		6.4	7.2
ORGANIC CARBON	(percent)		
AVAILABLE PHOSPHORUS	(ppm)		
$CaCO_3$ EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)	+0.2	0.0
SATURATION EXTRACT			
Saturation Percentage			
EC_e @ 25°C	(mmhos/cm)	0.56	0.53
Ca^{++}	(me/l)	4.99	3.57
Mg^{++}	(me/l)	3.17	2.44
Na^+	(me/l)	0.29	0.67
K^+	(me/l)	0.42	0.17
CO_3^-	(me/l)	0.00	0.00
HCO_3^-	(me/l)	6.04	4.56
Cl^-	(me/l)	0.08	0.12
SO_4^-	(me/l)	0.34	1.08
NO_3^-	(me/l)	0.02	0.02
SAR	(me/l)	0.1	0.4
Na	(me/100g)	0.02	0.04
Ca+Mg	(me/100g)		
1:5 EXTRACT			
EC_5 @ 25°C	(mmhos/cm)	0.12	0.12
Ca+Mg	(me/l)		
EXCHANGEABLE SODIUM	(percent)	0.3	0.2
ACIDITY			
IN KCl exchange acidity			
Total	(me/100g)		
Al^{+++}	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)	25.3	23.7
NaOAc@pH 8.2			
BORON	(mg/l)		

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 4 Twp. 144 N. Range 88 W.
600' S., 50' W. of N.E. Corner
Climate: Semiarid
Land Use: Range
Point Site Number: 21

Relief: Complex, 6-9%
Elevation: 2140'
Slope: Aspect: East
Vegetation: Mid and short grasses
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water: None
Land Form: Crests and side slopes

Parent Material: Till
Soil Series: Zahl
Soil Classification: Fine-loamy, mixed Entic Haploborolls
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
T 1484 Bis-7001	0-12	AB 0-5 inches, dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate, coarse blocky structure breaks to moderate, medium blocky structure; very hard dry, friable moist, sticky, non-plastic wet; plentiful fine roots; slightly calcareous; abrupt boundary.
T 1485 Bis-7002	12-36	C_{ca} 5-36 inches, light brownish gray (10YR 6/2) clay loam, brown (10YR 5/3) moist; weak, coarse blocky structure breaks to weak, medium blocky structure; slightly hard dry, very friable moist, sticky, plastic wet; few, fine roots; strongly calcareous; gradual boundary.
T 1486 Bis-7003	36-54	C_2 36-72 inches, very pale brown (10YR 7/3) clay loam, brown (10YR 5/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; strongly calcareous, abrupt boundary.
T 1487 Bis-7004	54-72	54-72, same as above horizon (C_2).
T 1488 Bis-7005	72-102	C_{3cs} 72-102 inches, pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; massive structure; hard dry, friable moist, sticky, plastic wet; slightly calcareous; abrupt boundary.
T 1489 Bis-7006	102-120	C_4 102-120 inches, pale brown (10YR 6/3) sandy clay loam, brown (10YR 5/3) moist; mottling varying from a light olive brown (2.5Y 5/6) to a reddish yellow (7.5YR 6/6); massive structure; slightly hard dry, very friable moist, sticky, slightly plastic wet; slightly calcareous. Lime coated gravels scattered throughout the profile.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		7001	7002	7003	7004	7005	7006
DEPTH	(in)	0-12"	12-36"	36-54"	54-72"	72-102"	102-120"
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
Total Sand	(2.0-0.05 mm)	35.6	31.4	31.0	31.5	29.3	47.7
Silt	(0.05-0.002 mm)	38.0	39.9	39.7	38.9	38.8	24.5
Clay	(< 0.002 mm)	26.4	28.7	29.3	29.6	31.9	27.8
TEXTURAL CLASS (LAB.)		L	CL	CL	CL	CL	SCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6^{th} hr		0.15	0.02	0.01	0.02	0.02	0.06
24^{th} hr		0.11	0.04	0.02	0.02	0.04	0.10
SETTLING VOLUME	(ml)	25	24	30	28	26	21
MOISTURE RETENTION	(percent)						
1/10 bar		37.0	35.4	36.2	35.4	34.9	28.6
1/3 bar		26.1	25.7	27.2	25.8	25.9	19.8
15 bar		13.2	11.6	14.0	13.9	15.4	11.3
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.1	8.7	9.1	8.9	8.1	8.0
1:2 0.01 M $CaCl_2$		7.2	7.8	8.1	8.0	7.8	7.8
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-1.1	-0.2	+0.4	0.0	-12.0	-12.0
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	0.89	0.65	0.68	2.10	6.00	9.00
Ca^{++}	(me/l)	8.83	1.32	0.49	2.09	24.50	24.05
Mg^{++}	(me/l)	3.71	4.07	2.53	10.53	74.67	104.52
Na^+	(me/l)	0.29	1.43	5.26	10.91	24.00	30.13
K^+	(me/l)	0.28	0.07	0.11	0.22	0.54	0.59
CO_3^-	(me/l)	0.16	0.40	0.40	0.16	0.00	0.00
HCO_3^-	(me/l)	6.76	4.60	5.12	3.40	2.08	1.72
Cl^-	(me/l)	0.00	0.06	0.28	0.66	2.24	3.60
SO_4^-	(me/l)	0.78	0.57	1.99	16.66	110.10	146.80
NO_3^-	(me/l)	0.02	0.02	0.11	0.06	0.10	0.16
SAR	(me/l)	0.1	0.9	4.3	4.3	3.4	3.8
Na	(me/100g)	0.02	0.08	0.33	0.75	1.65	1.48
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.26	0.16	0.20	0.40	3.40	3.30
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	0.3	0.5	3.3	3.1	1.1	1.1
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	20.9	18.4	19.1	20.4	23.8	15.7
NaOAc @ pH 8.2							
BORON	(mg/l)						

Table 23

Table 24

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 4 Twp. 144 N. Range 88 W.
600' W., 100' S. of N.E. Corner
Climate: Semiarid
Land Use: Range
Point Site Number: 18

Relief: Complex, 6-8%
Elevation: 2140'
Slope: Aspect: West
Vegetation: Mid and short grasses
Erosion: Slight

Stoniness: None
Drainage: Moderately well-drained
Ground Water: None
Land Form: Side slope

Parent Material: Till
Soil Series: Williams
Soil Classification: Fine-loamy, mixed Typic Argiborolls
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)		PROFILE DESCRIPTION
T 1469 Bis-6996	0-24	A_1	0-1 inch, grayish brown (10YR 5/2) silt loam, very dark gray (10YR 3/1) moist; moderate, coarse platy structure breaks to weak, fine blocky structure; slightly hard, very friable moist; sticky and nonplastic wet; plentiful fine roots; abrupt boundary.
		AB	1-5 inches, grayish brown (10YR 5/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate, coarse blocky structure breaks to moderate, medium blocky structure; hard dry, friable moist, sticky, nonplastic wet; plentiful fine roots; gradual boundary.
		B_{21t}	5-9 inches, grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate, medium prismatic structure breaks to moderate, fine blocky structure; hard dry, friable moist, sticky and plastic wet; few, thin, clay skins on ped faces; plentiful fine roots; gradual boundary.
		B_{22t}	9-17 inches, brown (10YR 5/3) clay loam, dark grayish brown (10YR 4/2) moist; moderate, medium prismatic structure breaks to moderate, medium blocky structure; hard dry, friable moist, sticky, plastic wet; few, thin, clay skins on ped faces; plentiful roots; noncalcareous; abrupt boundary.
		B_{3ca}	17-24 inches, brown (10YR 5/3) clay loam, dark grayish brown (10YR 4/2) moist; moderate, medium to coarse prismatic structure breaks to moderate, coarse blocky structure; hard dry, friable moist, sticky, plastic wet; few, fine roots, slightly calcareous; gradual boundary.
T 1470 Bis-6997	24-48	C_{ca}	24-48 inches, light brownish gray (10YR 6/2) clay loam, grayish brown (10YR 5/2) moist; moderate, coarse blocky structure breaks to moderate, medium blocky structure; hard dry, friable moist, sticky, plastic wet; few, fine roots; strongly calcareous; gradual boundary.
T 1471 Bis-6998	48-66	C_2	48-66 inches, very pale brown (10YR 7/3) light clay loam, light brownish gray (10YR 6/3) moist; hard dry, friable moist; slightly sticky, slightly plastic wet; slightly calcareous; gradual boundary; sand shale particles in material.
T 1472 Bis-6999	66-90		66-90, same as horizon above.
T 1473 Bis-7000	90-114	C_3	90-114 inches, pale brown (10YR 6/3) light clay loam, grayish brown (10YR 5/2) moist; mottling varies from yellowish red (5YR 5/6) to a reddish yellow (7.5YR 7/6); hard dry, friable moist, slightly sticky, slightly plastic wet; slightly calcareous; lime coated gravels scattered throughout the profile.

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		6996	6997	6998	6999	7000
DEPTH	(in)	0-24"	24-48"	48-66"	66-90"	90-114"
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	38.9	31.5	32.2	43.8	39.9
Silt	(0.05-0.002 mm)	35.6	37.6	38.4	32.3	37.4
Clay	(<0.002 mm)	25.5	30.9	29.4	23.9	22.7
TEXTURAL CLASS (LAB.)		L	CL	CL	L	L
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6^{th} hr		0.02	0.01	0.01	0.04	0.02
24^{th} hr		0.04	0.02	0.02	0.06	0.02
SETTLING VOLUME	(ml)	24	25	35	26	28
MOISTURE RETENTION	(percent)					
1/10 bar		35.2	36.1	37.0	33.8	34.4
1/3 bar		23.9	27.1	29.4	23.9	27.4
15 bar		13.8	16.0	17.2	12.7	17.4
SOIL REACTION-pH						
Paste						
1:5 H_2O		7.7	8.6	9.3	8.6	8.1
1:2 0.01 M $CaCl_2$		6.8	7.6	8.0	7.6	7.7
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	-0.8	0.0	+1.4	-2.6	-6.8
SATURATION EXTRACT						
Saturation Percentage						
EC_e @ 25°C	(mmhos/cm)	0.90	0.66	1.00	7.50	7.50
Ca^{++}	(me/l)	7.34	1.48	0.38	24.15	24.70
Mg^{++}	(me/l)	4.52	2.62	1.27	61.68	58.72
Na^+	(me/l)	0.48	2.73	8.17	34.52	38.91
K^+	(me/l)	0.32	0.08	0.07	0.51	0.58
CO_3^-	(me/l)	0.00	0.24	0.40	0.00	0.00
HCO_3^-	(me/l)	8.44	4.72	5.80	2.44	1.96
Cl^-	(me/l)	0.08	0.02	0.40	2.80	5.30
SO_4^-	(me/l)	0.82	0.61	2.17	109.90	110.40
NO_3^-	(me/l)	0.02	0.06	0.10	0.10	1.15
SAR	(me/l)	0.2	1.9	9.0	5.3	6.0
Na	(me/100g)	0.03	0.15	0.46	1.85	2.19
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	0.22	0.20	0.30	1.10	2.20
Ca+Mg	(me/l)	0.3	1.1	7.7	1.6	15.0
EXCHANGEABLE SODIUM	(percent)					
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY NaOAc@pH 8.2	(me/100g)	19.5	18.8	21.1	15.1	17.1
BORON	(mg/l)					

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Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 26 Twp. 145 N. Range 88 W.
1500' E., 700' N. of W½ Corner
Climate: Semiarid
Land Use: Range
Point Site Number: 21

Relief: Nearly level
Elevation: 2000'
Slope: Aspect: Northeast
Vegetation: Mid and short grasses, shrubs
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water: None
Land Form: Alluvial bottom

Parent Material: Sandstone, soft shale
Soil Series: Strawlike
Soil Classification: Coarse-loamy, mixed Cumulic Haploborolls
Profile Description By: T Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
T 1515 Bis-7032	0-12	A_{11}	0-2 inches, dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; weak, medium, blocky structure separates to weak, fine blocky structure; slightly hard dry, very friable moist; sticky and nonplastic wet; noncalcareous; abrupt boundary.
		A_{12}	2-7 inches, dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; weak, medium prismatic structure breaks to moderate, medium blocky structure; slightly hard dry, very friable moist, sticky and nonplastic wet; plentiful fine roots; noncalcareous; abrupt boundary.
		B_{21}	7-12 inches, dark gray (10YR 4/1) silt loam, very dark gray (10YR 3/1) moist; weak, coarse prismatic structure breaks to moderate, medium, blocky structure; hard dry, friable moist, sticky and nonplastic wet; plentiful fine roots; noncalcareous; gradual boundary.
T 1516 Bis-7033	12-30	B_{22}	12-18 inches, dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure breaks to weak, coarse, blocky structure; hard dry, friable moist, slightly sticky and nonplastic wet; plentiful fine roots; noncalcareous; gradual boundary.
		B_3	18-30 inches, grayish brown (10YR 5/2) loam, weak, coarse prismatic structure breaks to weak, medium blocky structure; slightly hard dry, very friable moist, nonsticky and nonplastic wet; plentiful fine roots; noncalcareous; abrupt boundary.
T 1517 Bis-7034	30-42	C_{ca}	30-42 inches, pale brown (10YR 6/2) fine sandy loam, grayish brown (10YR 5/2) moist; weak, coarse blocky structure breaks to weak, medium blocky structure; slightly hard dry, loose moist, nonsticky and nonplastic wet; few fine roots; strongly calcareous; gradual boundary.
T 1518 Bis-7035	42-66	C_2	42-66 inches, light brownish gray (10YR 6/2) loam, grayish brown (10YR 5/2) moist; massive structure; slightly hard dry, very friable moist, slightly sticky and nonplastic wet; few fine roots; slightly calcareous; gradual boundary; fine lime threads.
T 1519 Bis-7036	66-84	C_3	66-84 inches, light brownish gray (10YR 6/2) sandy clay loam, grayish brown (10YR 5/2) moist; massive structure; slightly hard dry, very friable moist, sticky, slightly plastic wet; slightly calcareous with fine lime threads; abrupt boundary.
T 1520 Bis-7037	84-108	IIC_4	84-108 inches, light brownish gray (10YR 6/2) sands, grayish brown (10YR 5/2) moist; massive structure; loose dry, loose moist, nonsticky and nonplastic wet; noncalcareous; abrupt boundary.
T 1521 Bis-7038	108-120	C_5	108-120 inches, light brownish gray (10YR 6/2) sandy clay loam, grayish brown (10YR 5/2) moist; massive structure; slightly hard dry, very friable moist; sticky and slightly plastic wet; slightly calcareous; less than 20% gravels.

LABORATORY DESCRIPTION

DETERMINATION		DATA						
LABORATORY NUMBER		7032	7033	7034	7035	7036	7037	7038
DEPTH	(in)	0-12"	12-30"	30-42"	42-66"	66-84"	84-108"	108-120"
PARTICLE SIZE ANALYSIS	(percent)							
Very Coarse Sand	(2.0-1.0 mm)	1.6	0.5	0.2	0.1	0.6	0.2	4.2
Coarse Sand	(1.0-0.5 mm)	3.3	2.6	2.5	2.3	4.6	6.3	9.3
Medium Sand	(0.5-0.25 mm)	10.4	11.4	15.2	14.1	13.8	25.9	20.1
Fine Sand	(0.25-0.10 mm)	26.9	36.3	42.1	41.6	33.5	44.0	28.4
Very Fine Sand	(0.10-0.05 mm)	10.7	12.5	12.6	11.0	11.1	7.7	7.5
Total Sand	(2.0-0.05 mm)	52.9	63.3	72.6	69.1	63.6	84.1	69.5
Silt	(0.05-0.002 mm)	30.9	22.9	15.8	18.5	23.4	9.8	17.9
Clay	(< 0.002 mm)	16.2	13.8	11.6	12.4	13.0	6.1	12.6
TEXTURAL CLASS (LAB.)		FSL	FSL	FSL	FSL	FSL	LS	SL
BULK DENSITY	(g/cm^3)							
HYDRAULIC CONDUCTIVITY	(in/hr)							
6^{th} hr		0.04	0.87	1.16	0.83	0.59	2.16	0.37
24^{th} hr		0.06	0.75	1.25	0.79	0.51	2.49	0.37
SETTLING VOLUME	(ml)	21	20	18	20	20	12	19
MOISTURE RETENTION	(percent)							
1/10 bar		36.0	23.5	18.8	31.3	25.5	13.2	22.3
1/3 bar		31.5	14.7	11.8	13.8	17.0	8.2	15.4
15 bar		9.0	7.2	5.4	6.1	6.8	3.2	6.4
SOIL REACTION-pH								
Paste								
1:5 H_2O		7.4	7.8	8.3	8.7	9.0	9.0	8.6
1:2 0.01 M $CaCl_2$		6.4	7.0	7.4	7.7	7.9	7.8	7.5
ORGANIC CARBON	(percent)							
AVAILABLE PHOSPHORUS	(ppm)							
$CaCO_3$ EQUIVALENT	(percent)							
GYPSUM REQUIREMENT	(me/100g)	+0.2	-0.4	-0.8	-0.8	-0.4	-0.2	-0.3
SATURATION EXTRACT								
Saturation Percentage								
EC_e @ 25°C	(mmhos/cm)	0.78	0.45	0.35	0.48	0.90	0.60	0.52
Ca^{++}	(me/l)	5.34	3.79	2.96	1.98	1.04	1.10	2.91
Mg^{++}	(me/l)	3.44	1.72	1.36	3.62	6.06	1.72	1.90
Na^+	(me/l)	0.38	0.19	0.24	0.86	4.83	4.74	2.97
K^+	(me/l)	1.24	0.39	0.32	0.52	0.60	0.18	0.25
CO_3^-	(me/l)	0.16	0.08	0.08	0.08	0.24	0.08	0.08
HCO_3^-	(me/l)	8.68	4.96	3.88	4.00	3.80	3.64	3.64
Cl^-	(me/l)	0.08	0.08	0.00	0.04	0.00	0.12	0.44
SO_4^-	(me/l)	0.99	0.29	0.57	2.31	8.70	3.89	4.02
NO_3^-	(me/l)	0.02	0.02	0.02	0.02	0.05	0.02	0.02
SAR	(me/l)	0.2	0.1	0.2	0.5	2.6	4.0	1.9
Na	(me/100g)	0.02	0.01	0.01	0.03	0.17	0.13	0.10
Ca+Mg	(me/100g)							
1:5 EXTRACT								
EC_5 @ 25°C	(mmhos/cm)	0.32	0.16	0.14	0.14	0.20	0.14	0.16
Ca+Mg	(me/l)							
EXCHANGEABLE SODIUM	(percent)	0.4	0.6	0.9	0.6	2.5	3.8	1.5
ACIDITY								
IN KCl exchange acidity								
Total	(me/100g)							
Al^{+++}	(me/100g)							
CATION EXCHANGE CAPACITY	(me/100g)	18.4	13.4	9.4	9.7	10.5	5.8	10.8
NaOAc@pH 8.2								
BORON	(mg/l)							

Table 25

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 26 Twp. 145 N. Range 88 W.
1100' E., 200' N. of S.W. Corner
Climate: Semiarid
Land Use: Cultivated
Point Site Number: 18

Relief: Complex side slope
Elevation: 2100'
Slope: Aspect: North
Vegetation: Small grain
Erosion: Slight

Stoniness: None
Drainage: Well-drained
Ground Water: None
Land Form: Colluvial foot slope

Parent Material: Sandstone, soft shale
Soil Series: Parshall
Soil Classification: Coarse-loamy, mixed Pachic Haploborolls
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
T 1496 Bis-7013	0-18	A_p 0-7 inches, very dark grayish brown (10YR 3/2) heavy fine sandy loam, very dark gray (10YR 3/1) moist; weak very coarse blocky structure separating to coarse blocky structure; slightly hard dry, friable moist, nonsticky and nonplastic wet; plentiful fine roots; noncalcareous abrupt boundary.
		B_{21} 7-18 inches, very dark grayish brown (10YR 3/2) heavy clay loam, very dark gray (10YR 2/2) moist; moderate, coarse prismatic structure breaks to moderate coarse and medium blocky structure; slightly hard dry, friable moist, sticky and plastic wet; plentiful fine roots; noncalcareous; gradual boundary.
T 1497 Bis-7014	18-36	B_{22} 18-30 inches, dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate coarse, prismatic structure breaks to moderate coarse and medium blocky structure; plentiful roots; noncalcareous; gradual boundary.
		B_3 30-36 inches, grayish brown (10YR 5/2) sandy clay loam, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure breaks to weak, coarse blocky structure; slightly hard dry, friable moist, slightly sticky, slightly plastic wet; few fine roots; trace of lime at 36 inches; gradual boundary.
T 1498 Bis-7015	36-54	C_1 36-54 inches, grayish brown (10YR 5/2) sandy clay loam, dark grayish brown (10YR 4/2) moist; massive structure; slightly hard dry, very friable moist, slightly sticky, slightly plastic wet; noncalcareous; gradual boundary.
T 1499 Bis-7016	54-72	C_2 54-72 inches, brown (10YR 5/3) fine sandy loam, dark brown (10YR 4/3) moist; massive structure; soft dry, loose moist; nonsticky and nonplastic wet; noncalcareous; few scattered large gravel lime coated from 60-72 inches; gradual boundary.
T 1500 Bis-7017	72-96	C_3 72-96 inches, very pale brown (10YR 7/4) loamy sand, light yellowish brown (10YR 6/4) moist; massive structure; soft dry, loose moist, nonsticky and nonplastic; noncalcareous; abrupt boundary.
T 1501 Bis-7018	96-120	C_4 96-120 inches, very pale brown (10YR 7/3) fine sand; light brownish gray (10YR 6/2) moist, reddish yellow (7.5YR 7/6) mottling from 96-108 inches; massive structure; soft dry, loose moist, noncalcareous; dark fine shale particles from 108-120 inches.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		7013	7014	7015	7016	7017	7018
DEPTH	(in)	0-18"	18-36"	36-54"	54-72"	72-96"	96-120"
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)		0.5	0.4	1.1	0.3	0.2
Coarse Sand	(1.0-0.5 mm)		6.3	4.8	6.2	6.8	10.2
Medium Sand	(0.5-0.25 mm)		15.5	14.4	17.5	25.3	37.3
Fine Sand	(0.25-0.10 mm)		29.0	32.8	38.7	41.8	27.9
Very Fine Sand	(0.10-0.05 mm)		6.7	9.0	8.1	5.9	8.8
Total Sand	(2.0-0.05 mm)	50.6	58.0	61.4	71.6	80.1	84.4
Silt	(0.05-0.002 mm)	32.2	25.6	24.7	16.3	13.1	7.6
Clay	(< 0.002 mm)	17.2	16.4	13.9	12.1	6.8	8.0
TEXTURAL CLASS (LAB)		L	FSL	FSL	FSL	LS	LS
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6^{th} hr		0.04	0.83	0.15	1.45	2.45	1.97
24^{th} hr		0.04	0.91	0.15	1.45	2.33	1.93
SETTLING VOLUME	(ml)	21	20	18	18	17	17
MOISTURE RETENTION	(percent)						
1/10 bar		34.7	25.5	28.8	20.6	18.9	15.8
1/3 bar		31.4	15.6	15.7	12.4	11.9	10.4
15 bar		10.0	7.9	7.3	6.8	6.3	5.2
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.8	7.9	7.8	7.7	8.2	8.3
1:2 0.01 M $CaCl_2$		6.3	6.6	6.8	7.2	7.4	7.4
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.5	-0.4	-0.3	-0.4	-0.2	-0.2
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	0.62	0.35	0.32	0.44	0.48	0.34
Ca^{++}	(me/l)	4.39	2.31	1.87	3.51	2.80	2.96
Mg^{++}	(me/l)	1.54	0.90	0.81	1.00	0.63	0.63
Na^+	(me/l)	0.38	0.43	0.57	0.72	0.62	0.53
K^+	(me/l)	0.12	0.06	0.05	0.07	0.03	0.06
CO_3^-	(me/l)	0.16	0.08	0.00	0.08	0.00	0.00
HCO_3^-	(me/l)	4.04	2.08	2.12	3.40	2.84	2.32
Cl^-	(me/l)	0.00	0.76	0.08	0.12	0.08	0.40
SO_4^-	(me/l)	0.88	0.36	0.42	0.36	0.60	0.58
NO_3^-	(me/l)	0.23	0.21	0.05	0.34	0.27	0.39
SAR	(me/l)	0.2	0.3	0.5	0.5	0.5	0.4
Na	(me/100g)	0.02	0.02	0.02	0.02	0.02	0.02
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.14	0.10	0.10	0.14	0.40	0.12
Ca+Mg	(me/l)	0.4	0.5	0.5	0.6	0.6	0.7
EXCHANGEABLE SODIUM	(percent)						
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	18.1	14.1	12.8	12.0	11.3	9.9
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 26

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Table 27

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Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Beulah Trench, North Dakota
Location. Sec. 26 Twp. 145 N. Range 88 W.
1720' N., 500' W. of S¼ Corner
Climate: Semiarid
Land Use: Cultivated
Point Site Number: 17

Relief: Complex, 2-4%
Elevation: 2100'
Slope: Aspect: South
Vegetation: Small grain
Erosion: Slight

Staniness: None
Drainage: Well-drained
Ground Water: Wet at 36 inches
Land Form: Colluvial swale

Parent Material: Sandstone, soft shale
Soil Series: Arnegard
Soil Classification: Fine-loamy, mixed Pachic Haploborolls
Profile Description By: T. Fiechtl Date: 8/76
Correlated By: Gary Muckel Date: 9/79

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
T 1490 Bis-7007	0-24	A_p 0-6 inches, dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate, coarse, blocky structure separating to moderate, medium blocky structure.
		B_{21t} 6-12 inches, very dark grayish brown (10YR 3/2) light silty clay loam, very dark gray (10YR 3/1) moist; moderate, coarse prismatic structure breaks to moderate, medium blocky structure; hard dry, friable moist, slightly sticky, slightly plastic wet; few thin, clay films on ped faces; plentiful fine roots; noncalcareous; gradual boundary.
		B_{22t} 12-24 inches, dark grayish brown (10YR 4/2) light silty clay loam, very dark grayish brown (10YR 3/2) moist; moderate, coarse prismatic structure breaks to moderate, medium blocky structure; hard dry, friable moist, slightly sticky and slightly plastic wet; few, thin clay films on ped faces; plentiful fine roots; noncalcareous; abrupt boundary.
T 1491 Bis-7008	24-42	B_3 24-42 inches, brown (10YR 5/3) sandy clay loam, dark brown (10YR 4/3) moist; moderate, coarse prismatic structure breaks to moderate, medium blocky structure; soft dry, very friable moist, slightly sticky and slightly plastic wet; plentiful fine roots; noncalcareous; abrupt boundary.
T 1492 Bis-7009	42-54	C_{ca} 42-54 inches, pale brown (10YR 6/3) sandy clay loam, brown (10YR 5/3) moist; moderate, coarse, blocky structure breaks to moderate, medium blocky structure; slightly hard dry, very friable moist, slightly sticky and slightly plastic wet; few fine roots; strongly calcareous; gradual boundary.
T 1493 Bis-7010	54-78	C_2 54-78 inches, pale brown (10YR 6/3) sandy clay loam, brown (10YR 5/3) moist; massive structure; soft dry, very friable moist, slightly sticky and slightly plastic wet; strongly calcareous; gradual boundary.
T 1494 Bis-7011	78-96	C_3 78-96 inches, brown (10YR 5/3) clay loam, yellowish brown (10YR 5/4) moist; massive structure; hard dry, friable moist, sticky and plastic wet; strongly calcareous; gradual boundary.
T 1495 Bis-7012	96-120	C_4 96-120 inches, light brownish gray (10YR 6/2) clay loam, grayish brown (10YR 5/2) moist, light gray (2.5YR 7/2) mottling; massive structure very hard dry, friable moist; sticky and plastic wet; violently calcareous.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		7007	7008	7009	7010	7011	7012
DEPTH	(in)	0-24"	24-42"	42-54"	54-78"	78-96"	96-120"
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)		0.2	0.4	0.4		
Coarse Sand	(1.0-0.5 mm)		5.2	5.1	3.9		
Medium Sand	(0.5-0.25 mm)		16.0	18.3	10.0		
Fine Sand	(0.25-0.10 mm)		29.5	37.2	30.3		
Very Fine Sand	(0.10-0.05 mm)		8.3	8.6	12.2		
Total Sand	(2.0-0.05 mm)	41.5	59.2	69.6	56.8	32.3	36.4
Silt	(0.05-0.002 mm)	36.1	23.6	15.8	25.4	39.6	35.2
Clay	(< 0.002 mm)	22.4	17.2	14.6	17.8	28.1	28.4
TEXTURAL CLASS (LAB.)		L	FSL	FSL	FSL	CL	CL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th hr		0.14	0.08	0.87	0.10	0.01	0.01
24th hr		0.14	0.10	0.94	0.12	0.01	0.02
SETTLING VOLUME	(ml)	23	20	18	20	33	31
MOISTURE RETENTION	(percent)						
1/10 bar		34.6	27.8	20.2	27.1	40.5	38.8
1/3 bar		23.2	18.5	13.2	18.6	31.9	30.6
15 bar		12.0	8.6	6.7	8.6	15.3	14.4
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.9	8.1	8.5	8.5	8.8	8.9
1:2 0.01 M $CaCl_2$		6.7	7.1	7.5	7.7	7.9	7.8
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.3	-0.5	-0.7	-0.7	0.0	-0.9
SATURATION EXTRACT							
Saturation Percentage							
EC_e @ 25°C	(mmhos/cm)	0.74	0.58	0.72	1.60	1.50	1.70
Ca^{++}	(me/l)	3.57	3.57	2.74	4.72	3.07	3.40
Mg^{++}	(me/l)	2.08	2.26	3.08	8.96	5.79	5.61
Na^{+}	(me/l)	0.43	0.38	1.00	6.17	11.39	9.00
K^{+}	(me/l)	0.37	0.25	0.27	0.44	0.14	0.10
CO_3^{-}	(me/l)	0.08	0.24	0.16	0.00	0.24	0.24
HCO_3^{-}	(me/l)	3.44	4.56	3.60	2.88	3.48	4.16
Cl^{-}	(me/l)	0.20	0.24	0.52	0.32	0.24	0.44
SO_4^{-}	(me/l)	1.45	0.60	2.60	17.45	14.97	11.87
NO_3^{-}	(me/l)	0.04	0.02	0.02	0.12	0.09	0.06
SAR	(me/l)	0.30	0.20	0.60	2.40	5.40	4.20
Na	(me/100g)	0.02	0.01	0.03	0.25	0.70	0.53
Ca+Mg	(me/100g)						
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.12	0.16	0.14	0.26	0.40	0.34
Ca+Mg	(me/l)						
EXCHANGEABLE SODIUM	(percent)	0.3	0.1	0.5	1.8	4.0	3.1
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	22.5	15.2	11.3	15.3	25.7	19.3
NaOAc@pH 8.2							
BORON	(mg/l)						

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

OVERBURDEN ANALYSIS
Representative Sample 77-101

Study Area: BEULAH TRENCH RECLAMATION AREA | Relief: ____ | Stoniness: ____ | Parent Material: ____

Location. Sec. ____ Twp. ____ Range ____ | Elevation: ____ | Soil Series: ____

Slope Aspect: ____ | Drainage: ____ | Soil Classification: ____

Climate: ____ | Vegetation: ____ | Ground Water: ____

Land Use: ____ | Erosion: ____ | Land Form: ____ | Profile Description By: ____ Date: ____

DETERMINATION		DATA					
Laboratory Number		77-101-1	77-101-2	77-101-3	77-101-4	77-101-5	77-101-6
Sack Number		8590	8591	8592	8593	8594	8595
Depth (ft)		0-14.1	14.1-18.0	18.0-28.4	28.4-40.4	40.4-54.4	59.0-74.8
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.6	0.6	0.7	0.7	1.2	0.9
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.02	0.02	0.04	0.08	0.06	0.06
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	2.2	1.0	0.8	3.6	3.8	6.2
IRON	Fe	28.0	31.4	13.6	22.8	27.4	54.0
MERCURY	Hg	0.024	0.032	0.037	0.045	0.016	0.013
LITHIUM	Li						
MANGANESE	Mn	8.4	14.8	7.0	8.6	5.6	7.0
MOLYBDENUM	Mo						
NICKEL	Ni	0.4	0.6	0.4	1.2	2.2	2.6
PHOSPHOROUS	P						
LEAD	Pb	4.4	2.0	1.2	2.0	1.8	2.8
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	8.0	4.0	0.8	1.2	3.2	4.0

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		77-101-1	77-101-2	77-101-3	77-101-4	77-101-5	77-101-6
Sack Number		8590	8591	8592	8593	8594	8595
DEPTH	(Ft)	0-14.1	14.1-18.0	18.0-28.4	28.4-40.4	40.4-54.4	59.0-74.8
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	6.8					
Coarse Sand	(1.0-0.5 mm)	36.2					
Medium Sand	(0.5-0.25 mm)	24.3					
Fine Sand	(0.25-0.10 mm)	11.8					
Very Fine Sand	(0.10-0.05 mm)	2.4					
TOTAL SAND	(2.0-0.05 mm)	81.5		43.5	9.7	27.0	17.4
SILT	(0.05-0.002 mm)	10.0		38.4	55.7	52.6	59.6
CLAY	(0.002 mm)	8.5		18.1	34.6	20.4	23.0
TEXTURAL CLASS (LAB)		LCoS		L	SiCL	SiL	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.04	1.04	0.19	0.06	0.12	*1/5
24th Hr.		0.08	1.04	0.20	0.06	0.14	*1/3
SETTLING VOLUME	(ml)	30	17	24	32	23	112
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		16.0	5.8	11.9	21.2	14.4	35.2
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.0	9.0	8.5	8.2	8.7	9.9
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-1.2	-0.8	-1.8	-3.4	-1.2	+2.8
SATURATION EXTRACT							
Saturation Percentage		60.4	25.5	56.2	79.4	61.6	91.0
EC_e@ 25°C	(mmhos/cm)	0.45	1.6	2.9	4.2	2.9	1.3
Ca++	(me/1)	1.04	6.53	18.94	23.38	9.94	0.22
Mg++	(me/1)	1.09	3.62	14.38	25.42	11.94	0.09
Na+	(me/1)	2.25	7.03	5.55	9.42	10.62	12.24
K+	(me/1)	0.12	0.32	0.62	0.94	1.59	0.23
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.08	0.40
HCO_3-	(me/1)	2.44	2.04	1.20	1.32	2.36	5.00
Cl-	(me/1)	0.28	2.94	0.44	1.10	1.16	0.00
SO_4-	(me/1)	1.87	11.98	33.96	52.29	28.13	6.21
NO_3-	(me/1)	0.04	0.05	0.05	0.07	0.10	0.23
SAR	(me/1)	2.2	3.1	1.4	1.9	3.2	31.0
Na	(me/100g)	0.14	0.18	0.31	0.75	0.65	1.11
Ca+Mg	(me/100g)	0.13	0.26	1.87	3.87	1.29	0.03
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.20	2.24	0.58	1.35	0.68	0.66
Ca+Mg	(me/1)	3.60	2.20	5.10	8.20	3.00	1.40
EXCHANGEABLE SODIUM	(percent)	2.2	2.7	0.1	2.0	4.3	25.0
ACIDITY							
1N KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	8.7	3.7	8.2	10.9	8.7	8.7
NaOAc@pH 8.2							
BORON	(mg/1)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 30

Table 31

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

OVERBURDEN ANALYSIS
Representative Sample 77-101

Study Area: BEULAH TRENCH RECLAMATION AREA
Relief: ______
Stoniness: ______
Parent Material: ______

Location. Sec. ____ Twp. ____ Range ____
Elevation: ______
Soil Series: ______

Slope Aspect: ______
Drainage: ______
Soil Classification: ______

Climate: ______
Vegetation: ______
Ground Water: ______

Land Use: ______
Erosion: ______
Land Form: ______
Profile Description By: ______ Date: ______

DETERMINATION		DATA			
Laboratory Number		77-101-7	77-101-8	77-101-9	77-101-10
Sack Number		8596	8597	8598	8599
Depth (Ft)		74.8-95.0	95.0-114.3	115.4-128.6	150.4-170.0
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.0	1.1	0.0	0.5
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.08	0.12	0.16	0.10
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	6.2	4.4	7.6	7.6
IRON	Fe	102.0	68.0	80.0	96.0
MERCURY	Hg	0.021	0.016	0.021	0.021
LITHIUM	Li				
MANGANESE	Mn	13.6	7.8	13.6	6.6
MOLYBDENUM	Mo				
NICKEL	Ni	4.4	3.8	5.0	3.6
PHOSPHOROUS	P				
LEAD	Pb	4.4	4.8	8.0	5.6
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn	8.80	8.80	12.0	10.0

LABORATORY DESCRIPTION

DETERMINATION		DATA			
Laboratory Number		77-101-7	77-101-8	77-101-9	77-101-10
Sack Number		8596	8597	8598	8599
DEPTH	(Ft)	74.8-95.0	95.0-114.3	115.4-128.6	150.4-170.0
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	6.1	13.6	3.0	5.9
SILT	(0.05-0.002 mm)	61.9	56.0	47.4	55.2
CLAY	(0.002 mm)	32.0	30.4	49.6	38.9
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiC	SiCL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		*1/10	*1/10	*½	*1/10
24th Hr.		*1/5	*1/5	*2/3	*1/5
SETTLING VOLUME	(ml)	312	394	80	314
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		36.3	40.9	22.6	38.8
SOIL REACTION-pH					
Paste					
1:5 H_2O		10.0	10.0	8.7	9.7
1:2 0.01 M $CaCl_2$					
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	+4.4	+5.2	+2.0	+3.2
SATURATION EXTRACT		128.9	132.6	105.3	119.1
Saturation Percentage		1.2	1.1	2.2	1.4
EC_e@ 25°C	(mmhos/cm)				
Ca++	(me/l)	0.16	0.16	1.92	0.11
Mg++	(me/l)	0.09	0.09	1.90	0.09
Na+	(me/l)	11.77	10.52	16.93	13.01
K+	(me/l)	0.13	0.10	0.71	0.18
CO_3-	(me/l)	0.72	0.56	0.24	0.80
HCO_3-	(me/l)	6.64	5.72	4.72	6.16
Cl-	(me/l)	0.00	0.00	0.00	0.00
SO_4-	(me/l)	4.35	3.60	15.37	5.48
NO_3-	(me/l)	0.11	0.21	0.53	1.00
SAR	(me/l)	33.0	30.0	12.0	41.0
Na	(me/100g)	1.52	1.39	1.78	1.55
Ca+Mg	(me/100g)	0.03	0.03	0.40	0.02
1:5 EXTRACT					
EC_5@ 25°C	(mmhos/cm)	1.2	1.1	2.2	1.4
Ca+Mg	(me/l)	1.30	1.40	2.30	0.80
EXCHANGEABLE SODIUM	(percent)	44.0	48.0	14.0	32.0
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	8.5	8.6	11.3	10.6
NaOAc@pH 8.2					
BORON	(mg/l)				

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

OVERBURDEN ANALYSIS
Representative Sample 77-102

Study Area: BEULAH TRENCH RECLAMATION AREA — Relief: — Stoniness: — Parent Material:

Location. Sec. — Twp. — Range — Elevation: — Soil Series:

Slope Aspect: — Drainage: — Soil Classification:

Climate: — Vegetation: — Cround Water:

Land Use: — Erosion: — Land Form: — Profile Description By: — Date:

DETERMINATION		DATA					
Laboratory Number / Sack Number		77-102-1 11,262	77-102-2 11,263	77-102-3 11,264	77-102-4 11,265	77-102-5 11,266	77-102-6 11,267
Depth (Ft)		1.5-23.0	23.0-50.0	50.0-75.0	75.0-100.0	100.0-124.4	124.4-138.2
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.6	1.6	2.2	1.7	1.2	3.3
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	3.64	0.30	0.20	0.24	0.14	0.32
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	2.0	10.8	14.0	12.6	7.6	10.6
IRON	Fe	18.0	130.0	190.0	156.0	124.0	190.0
MERCURY	Hg	0.050	0.100	0.140	0.100	0.069	0.110
LITHIUM	Li						
MANGANESE	Mn	44.0	20.0	22.6	19.0	13.0	20.0
MOLYBDENUM	Mo	0.3	0.3	0.3	0.3	0.3	0.3
NICKEL	Ni	1.3	4.1	6.0	8.8	6.4	8.4
PHOSPHOROUS	P						
LEAD	Pb	1.8	5.0	8.0	7.0	6.2	7.6
STRONTIUM	Sr						
SELENIUM	Se	0.003	0.003	0.0081	0.15	0.080	0.12
VANADIUM	V						
ZINC	Zn	3.0	12.6	14.4	15.4	12.0	21.0

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number / Sack Number		77-102-1 11,262	77-102-2 11,263	77-102-3 11,264	77-102-4 11,265	77-102-5 11,266	77-102-6 11,267
DEPTH	(Ft)	1.5-23.0	23.0-50.0	50.0-75.0	75.0-100.0	100.0-124.4	124.4-138.2
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.2					
Coarse Sand	(1.0-0.5 mm)	11.9					
Medium Sand	(0.5-0.25 mm)	31.4					
Fine Sand	(0.25-0.10 mm)	24.4					
Very Fine Sand	(0.10-0.05 mm)	7.4					
TOTAL SAND	(2.0-0.05 mm)	75.3	4.3	7.7	4.7	13.5	2.1
SILT	(0.05-0.002 mm)	14.1	69.8	5.2	62.4	59.2	62.6
CLAY	(0.002 mm)	10.6	25.9	87.1	32.9	27.3	35.3
TEXTURAL CLASS (LAB)		SL	SiL	C	SiCL	SiCL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		1.08	0.02	*1/10	*1/10	*1/10	*1/10
24th Hr.		1.06	0.02	*1/5	*1/5	*1/5	*1/5
SETTLING VOLUME	(ml)	20.0	35.0	274.0	208.0	270.0	337.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar			22.2	38.2	46.4	45.7	42.4
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.6	8.8	9.8	9.9	10.0	9.9
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)		+0.8	+2.5	+4.7	+10.7	+10.7
SATURATION EXTRACT							
Saturation Percentage		29.1	74.4	132.0	160.0	147.1	144.9
EC_e@ 25°C	(mmhos/cm)	0.84	2.76	1.90	1.46	1.15	3.8
Ca++	(me/l)	1.92	5.98	0.27	0.38	0.11	0.05
Mg++	(me/l)	0.81	5.88	0.09	0.09	00.00	0.09
Na+	(me/l)	5.55	17.74	17.70	13.10	11.19	14.97
K+	(me/l)	0.08	0.30	0.15	0.10	0.08	0.12
CO_3-	(me/l)	0.00	0.00	0.17	0.00	0.00	0.42
HCO_3-	(me/l)	2.76	3.19	6.52	6.56	6.09	6.86
Cl-	(me/l)	1.46	0.86	1.24	1.06	1.05	1.42
SO_4-	(me/l)	3.83	29.30	14.06	14.84	4.88	7.00
NO_3-	(me/l)	0.12	0.06	3.90	0.12	0.11	0.20
SAR	(me/l)	4.7	7.3	42.0	27.0	48.0	56.0
Na	(me/100g)	0.16	1.30	2.30	2.10	1.60	2.20
Ca+Mg	(me/100g)	0.08	0.88	0.04	0.07	0.02	0.02
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.12	0.76	0.69	0.73	0.66	0.72
Ca+Mg	(me/l)	0.46	2.87	1.47	1.44	1.47	1.83
EXCHANGEABLE SODIUM	(percent)	4.5	6.6	48.0	52.0	57.0	66.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	10.0	19.0	22.0	21.0	20.0	16.0
NaOAc@pH 8.2							
BORON	(mg/l)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 32

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

OVERBURDEN ANALYSIS

Representative Sample 77-102; -103

Study Area: BEULAH TRENCH RECLAMATION AREA Relief: ______ Stoniness: ______ Parent Material: ______

Location. Sec. ____ Twp. ____ Range ____ Elevation: ______ Soil Series: ______

Slope Aspect: ______ Drainage: ______ Soil Classification: ______

Climate: ______ Vegetation: ______ Ground Water: ______

Land Use: ______ Erosion: ______ Land Form: ______ Profile Description By: ______ Date: ______

DETERMINATION		DATA					
Laboratory Number Sack Number		77-102-7 11,268	77-103-1 11,269	77-103-2 11,270	77-103-3 11,271	77-103-4 11,272	77-103-5 11,273
Depth (Ft)		169.9-174.7	0-10.0	10.0-16.8	16.8-28.6	28.6-55.0	55.0-81.0
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	1.0	0.8	2.2	1.2	0.8	0.6
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.36	0.22	0.22	1.10	0.20	0.20
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	10.4	2.4	2.6	1.0	0.6	0.4
IRON	Fe	252.0	60.0	60.0	66.0	62.0	49.8
MERCURY	Hg	0.086	0.050	0.050	0.050	0.050	0.050
LITHIUM	Li						
MANGANESE	Mn	16.8	44.0	46.0	64.0	16.0	11.6
MOLYBDENUM	Mo	0.3	0.3	0.3	0.3	0.3	0.3
NICKEL	Ni	4.5	1.0	1.0	0.6	0.4	0.1
PHOSPHOROUS	P						
LEAD	Pb	6.6	3.2	3.2	0.8	0.8	0.6
STRONTIUM	Sr						
SELENIUM	Se	0.11	0.003	0.0023	0.0072	0.003	0.003
VANADIUM	V						
ZINC	Zn	20.0	6.2	6.4	1.5	1.0	0.8

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number Sack Number		77-102-7 11,268	77-103-1 11,269	77-103-2 11,270	77-103-3 11,271	77-103-4 11,272	77-103-5 11,273
DEPTH	(Ft)	169.9-174.7	0-10.0	10.0-16.8	16.8-28.6	28.6-55.0	55.0-81.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)					0.2	0.4
Coarse Sand	(1.0-0.5 mm)					2.4	15.3
Medium Sand	(0.5-0.25 mm)					14.5	9.0
Fine Sand	(0.25-0.10 mm)					44.7	40.8
Very Fine Sand	(0.10-0.05 mm)					10.4	10.2
TOTAL SAND	(2.0-0.05 mm)	11.7	35.9	Insufficient	34.5	72.2	75.7
SILT	(0.05-0.002 mm)	57.1	35.4	Sample	39.3	14.7	11.7
CLAY	(0.002 mm)	31.2	28.7		26.2	13.1	12.6
TEXTURAL CLASS (LAB)		SiCL	CL		L	FSL	FSL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		*1/10	0.02		0.02	0.71	0.[illegible]
24th Hr.		*1/5	0.02		0.01	0.71	0.71
SETTLING VOLUME	(ml)	405.0	27.0		28.0	24.0	22.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		37.7	10.8		16.7		
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.7	9.0	8.3	8.7	8.9	8.8
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+7.7	+0.1			+0.2	0.0
SATURATION EXTRACT							
Saturation Percentage		111.3	53.3	20.4	55.8	37.7	39.9
EC_e@ 25 C	(mmhos/cm)	1.61	1.0	1.5	4.2	0.91	0.8
Ca++	(me/l)	0.16	1.92	5.54	3.57	2.58	1.92
Mg++	(me/l)	0.18	5.25	5.61	3.98	2.53	1.99
Na+	(me/l)	15.16	4.40	4.88	35.63	3.68	4.26
K+	(me/l)	0.10	0.18	0.39	0.18	0.16	0.10
CO_3-	(me/l)	0.36	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	6.42	2.77	2.17	1.78	1.60	2.09
Cl-	(me/l)	1.30	1.73	2.46	0.73	1.52	0.29
SO_4-	(me/l)	7.30	7.38	9.58	43.05	5.21	5.37
NO_3-	(me/l)	0.20	0.15	2.31	1.10	1.74	0.18
SAR	(me/l)	37.0	2.3	2.1	18.0	2.3	3.0
Na	(me/100g)	1.7	0.23	0.10	2.00	0.14	0.17
Ca+Mg	(me/100g)	0.04	0.38	0.22	0.42	0.20	0.16
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.56	0.25		1.7	0.11	0.13
Ca+Mg	(me/l)	2.23	1.35		21.44	0.66	0.63
EXCHANGEABLE SODIUM	(percent)	51.0	3.2			2.5	3.7
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	17.0	17.0			12.0	12.0
NaOAc@pH 8.2							
BORON	(mg/l)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 33

Table 34

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

OVERBURDEN ANALYSIS
Representative Sample 77-103

Study Area: BEULAH TRENCH RECLAMATION AREA | Relief: | Stoniness: | Parent Material:
Location. Sec. ____ Twp. ____ Range ____ | Elevation: | | Soil Series:
| Slope Aspect: | Drainage: | Soil Classification:
Climate: | Vegetation: | Ground Water: |
Land Use: | Erosion: | Land Form: | Profile Description By: ____ Date: ____

DETERMINATION		DATA					
Laboratory Number		77-103-6	77-103-7	77-103-8	77-103-9	77-103-10	77-103-11
Sack Number		11,274	11,275	11,276	11,277	11,278	11,279
Depth (Ft)		81.0-107.0	107.0-133.3	140.4-150.3	150.3-161.2	161.2-171.9	171.9-193.2
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.4	0.6	2.2	0.9	1.4	2.2
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.20	0.24	0.46	0.50	0.40	0.34
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	1.0	1.2	18.0	4.0	18.0	16.0
IRON	Fe	86.0	92.0	170.0	72.0	216.0	232.0
MERCURY	Hg	0.050	0.050	0.385	0.199	0.450	0.366
LITHIUM	Li						
MANGANESE	Mn	26.0	24.0	16.0	5.0	22.2	30.0
MOLYBDENUM	Mo	0.3	0.3	0.3	0.3	0.3	0.3
NICKEL	Ni	0.6	1.3	5.6	2.6	6.0	5.0
PHOSPHOROUS	P						
LEAD	Pb	1.0	1.4	8.0	3.2	9.4	5.4
STRONTIUM	Sr						
SELENIUM	Se	0.044	0.045	0.016	0.003	0.020	0.015
VANADIUM	V						
ZINC	Zn	1.5	2.7	10.4	10.0	14.6	21.4

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		77-103-6	77-103-7	77-103-8	77-103-9	77-103-10	77-103-11
Sack Number		11,274	11,275	11,276	11,277	11,278	11,279
DEPTH	(Ft)	81.0-107.0	107.0-133.3	140.4-150.3	150.3-161.2	161.2-171.9	171.9-193.2
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.1	0.2				
Coarse Sand	(1.0-0.5 mm)	4.8	20.5				
Medium Sand	(0.5-0.25 mm)	23.6	15.1				
Fine Sand	(0.25-0.10 mm)	40.0	33.4				
Very Fine Sand	(0.10-0.05 mm)	7.3	8.5				
TOTAL SAND	(2.0-0.05 mm)	75.8	77.7	10.4	27.5	1.2	3.2
SILT	(0.05-0.002 mm)	13.1	11.9	54.4	49.0	56.3	61.1
CLAY	(0.002 mm)	11.1	10.4	35.2	23.5	42.5	35.7
TEXTURAL CLASS (LAB)		FSL	SL	SiCL	L	SiC	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.91	0.79	*3/4	*1/10	*1/10	*1/10
24th Hr.		0.87	0.79	*4/5	*1/5	*1/4	*1/5
SETTLING VOLUME	(ml)	22.0	20.0	43.0	156.0	248.0	329.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar				32.3	25.5	34.9	46.0
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.5	8.2	9.1	9.8	9.7	9.9
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-1.0	-0.5		+5.7	+6.2	+7.5
SATURATION EXTRACT							
Saturation Percentage		37.5	32.5	96.6	114.9	141.5	160.6
EC_e@ 25°C	(mmhos/cm)	2.2	0.94	1.5	1.1	1.3	1.3
Ca++	(me/1)	10.65	5.05	0.93	0.11	0.11	0.05
Mg++	(me/1)	10.95	3.80	0.81	0.09	0.09	0.09
Na+	(me/1)	6.41	1.63	13.34	10.62	13.06	12.77
K+	(me/1)	0.08	0.13	0.34	0.10	0.13	0.09
CO_3-	(me/1)	0.00	0.00	0.20	0.28	0.33	0.37
HCO_3-	(me/1)	1.74	1.56	4.73	3.59	5.52	4.75
Cl-	(me/1)	0.20	0.29	0.18	0.11	0.13	0.19
SO_4-	(me/1)	25.72	8.44	9.44	6.15	6.17	6.25
NO_3-	(me/1)	0.05	0.07	0.48	0.23	0.30	0.20
SAR	(me/1)	2.0	0.8	14.0	34.0	41.0	48.0
Na	(me/100g)	0.24	0.05	1.30	1.20	1.80	2.10
Ca+Mg	(me/100g)	0.81	0.28	0.17	0.02	0.03	0.02
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.31	0.11	0.43	0.47	0.60	0.71
Ca+Mg	(me/1)	2.04	0.95	0.39	1.94	1.54	2.27
EXCHANGEABLE SODIUM	(percent)	1.0	0.4	11.0	26.0	38.0	41.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	11.0	9.7	19.0	21.0	19.0	18.0
NaOAc@pH 8.2							
BORON	(mg/1)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 35

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
OVERBURDEN ANALYSIS
Representative Sample 77-103; -105

Study Area: BEULAH TRENCH RECLAMATION AREA ____ Relief: ____ Stoniness: ____ Parent Material: ____

Location. Sec. ____ Twp. ____ Range ____ Elevation: ____ ____ Soil Series: ____

____ Slope Aspect: ____ Drainage: ____ Soil Classification: ____

Climate: ____ Vegetation: ____ Ground Water: ____ ____

Land Use: ____ Erosion: ____ Land Form: ____ Profile Description By: ____ Date: ____

DETERMINATION		DATA					
Laboratory Number		77-103-12	77-103-13	77-103-14	77-103-15	77-105-1	77-105-2
Sack Number		11,280	11,281	11,282	11,283	8600	8601
Depth (Ft)		193.2-201.0	201.0-220.5	220.5-244.6	266.6-279.0	0-25.0	25.0-43.0
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	1.0	1.0	2.2	1.3	0.7	0.5
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.22	0.56	0.40	0.28	0.08	0.02
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	3.4	18.0	20.0	10.0	3.2	0.6
IRON	Fe	106.0	276.0	240.0	260.0	31.0	27.0
MERCURY	Hg	0.151	0.385	0.446	0.366	0.013	0.013
LITHIUM	Li						
MANGANESE	Mn	2.0	26.0	26.0	12.0	19.6	4.0
MOLYBDENUM	Mo	0.3	0.3	0.3	0.3		
NICKEL	Ni	2.7	5.0	9.0	5.0	0.3	0.4
PHOSPHOROUS	P						
LEAD	Pb	2.4	6.2	7.2	7.6	2.6	3.0
STRONTIUM	Sr						
SELENIUM	Se	0.003	0.009	0.019	0.021		
VANADIUM	V						
ZINC	Zn	11.2	21.4	24.8	16.2		

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		77-103-12	77-103-13	77-103-14	77-103-15	77-105-1	77-105-2
Sack Number		11,280	11,281	11,282	11,283	8600	8601
DEPTH	(Ft)	193.2-201.0	201.0-220.5	220.5-244.6	266.6-279.0	0-25.0	25.0-43.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						0.5
Coarse Sand	(1.0-0.5 mm)						15.8
Medium Sand	(0.5-0.25 mm)						24.5
Fine Sand	(0.25-0.10 mm)						23.0
Very Fine Sand	(0.10-0.05 mm)						5.9
TOTAL SAND	(2.0-0.05 mm)	47.9	2.9	4.4	3.2	29.3	69.7
SILT	(0.05-0.002 mm)	31.8	58.3	54.2	62.4	36.5	16.0
CLAY	(0.002 mm)	20.3	38.8	41.4	34.4	34.2	14.3
TEXTURAL CLASS (LAB)		L	SiCL	SiC	SiCL	CL	SL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		*1/10	*1/10	*1/10	*1/10	*	0.75
24th Hr.		*1/5	*1/5	*1/4	*1/4	0.06	0.63
SETTLING VOLUME	(ml)	153.0	327.0	350.0	292.0	27.0	20.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		38.8	40.7	37.6	41.4	16.4	7.1
SOIL REACTION-pH							
Paste							
1:5 H_2O		10.1	9.9	9.8	9.2	8.2	8.6
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+6.2	+8.4	+6.6	+7.6	-4.0	-0.6
SATURATION EXTRACT							
Saturation Percentage		132.4	142.4	125.5		67.8	33.5
EC_e@ 25°C	(mmhos/cm)	1.3	1.2	1.5	1.4	3.4	1.2
Ca++	(me/l)	0.05	0.05	0.11	0.27	26.24	6.42
Mg++	(me/l)	0.09	0.09	0.09	0.09	15.56	2.99
Na+	(me/l)	12.67	12.53	15.83	14.78	5.36	3.30
K+	(me/l)	0.06	0.09	0.11	0.11	0.65	0.25
CO_3-	(me/l)	0.31	0.62	0.36	0.21	0.00	0.00
HCO_3-	(me/l)	3.77	5.23	5.65	7.07	1.40	1.72
Cl-	(me/l)	0.11	0.11	0.14	0.21	2.32	1.06
SO_4-	(me/l)	8.07	5.28	8.42	6.19	40.83	9.43
NO_3-	(me/l)	0.13	0.19	0.26	0.24	0.65	0.24
SAR	(me/l)	48.0	47.0	50.0	35.0	1.2	1.5
Na	(me/100g)	1.70	1.80	2.00	2.00	0.36	0.11
Ca+Mg	(me/100g)	0.02	0.02	0.02	0.04	2.84	0.32
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.66	0.67	0.70	0.64	1.16	0.38
Ca+Mg	(me/l)	0.74	2.09	1.97	2.03	11.20	1.50
EXCHANGEABLE SODIUM	(percent)	46.0	41.0	43.0	45.0	0.1	2.6
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	16.0	21.0	18.0	20.0	9.7	5.8
NaOAc@pH 8.2							
BORON	(mg/l)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 36

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
OVERBURDEN ANALYSIS

Representative Sample 77-105

Study Area: BEULAH TRENCH RECLAMATION AREA Relief: ____ Stoniness: ____ Parent Material: ____

Location. Sec. ____ Twp. ____ Range ____ Elevation: ____ ____ Soil Series: ____

____ Slope Aspect: ____ Drainage: ____ Soil Classification: ____

Climate: ____ Vegetation: ____ Ground Water: ____ ____

Land Use: ____ Erosion: ____ Land Form: ____ Profile Description By: ____ Date: ____

DETERMINATION		77-105-3	77-105-4	77-105-5	77-105-6	77-105-7	77-105-8
Laboratory Number		77-105-3	77-105-4	77-105-5	77-105-6	77-105-7	77-105-8
Sack Number		8602	8603	8604	8605	8606	8607
Depth (Ft)		43.0-61.1	61.1-69.5	69.5-92.4	92.4-97.0	97.0-116.6	116.6-141.0
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.0	0.0	0.0	0.0	0.0	0.0
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.04	0.04	0.04	0.06	0.02	0.02
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	0.6	2.0	0.8	4.0	0.4	0.4
IRON	Fe	23.4	33.8	46.0	50.0	28.2	54.0
MERCURY	Hg	0.011	0.029	0.013	0.011	0.011	0.011
LITHIUM	Li						
MANGANESE	Mn	7.0	15.8	6.6	11.2	6.0	13.4
MOLYBDENUM	Mo						
NICKEL	Ni	0.4	0.4	1.0	4.2	0.8	0.8
PHOSPHOROUS	P						
LEAD	Pb	1.6	1.6	1.2	6.8	2.0	2.2
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	1.4	1.6	1.8	2.8	1.4	1.8

LABORATORY DESCRIPTION

DETERMINATION		77-105-3	77-105-4	77-105-5	77-105-6	77-105-7	77-105-8
Laboratory Number		77-105-3	77-105-4	77-105-5	77-105-6	77-105-7	77-105-8
Sack Number		8602	8603	8604	8605	8606	8607
DEPTH	(Ft)	43.0-61.1	61.1-69.5	69.5-92.4	92.4-97.0	97.0-116.6	116.6-141.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.4		0.2		0.1	0.5
Coarse Sand	(1.0-0.5 mm)	4.7		7.2		2.9	9.3
Medium Sand	(0.5-0.25 mm)	16.8		21.8		16.7	29.9
Fine Sand	(0.25-0.10 mm)	48.9		28.5		45.2	33.2
Very Fine Sand	(0.10-0.05 mm)	7.4		12.3		14.2	6.8
TOTAL SAND	(2.0-0.05 mm)	78.2	35.9	70.0	6.1	79.1	79.9
SILT	(0.05-0.002 mm)	11.1	30.3	19.6	56.9	10.9	12.1
CLAY	(0.002 mm)	10.7	33.8	10.4	37.0	10.0	8.2
TEXTURAL CLASS (LAB)		FSL	CL	FSL	SiCL	FSL	LS
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		1.38	0.22	0.63	0.08	1.50	1.10
24th Hr.		1.41	0.22	0.67	0.06	1.46	1.06
SETTLING VOLUME	(ml)	19.0	26.0	20.0	30.0	18.0	18.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		6.3	17.5		20.2	6.6	5.0
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.8	8.6	7.9	8.4	8.9	8.9
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.4	-0.8	-2.6	-1.6	-0.6	-0.5
SATURATION EXTRACT							
Saturation Percentage		36.5	65.0	37.7	68.1	37.6	31.6
EC_e @ 25 °C	(mmhos/cm)	1.1	1.1	3.5	1.6	1.3	1.1
Ca^{++}	(me/l)	4.94	5.21	24.37	8.45	5.98	5.87
Mg^{++}	(me/l)	2.99	3.89	21.26	6.97	4.88	2.99
Na^+	(me/l)	3.20	2.44	4.54	2.06	2.53	2.87
K^+	(me/l)	0.24	0.39	0.54	1.21	0.52	0.54
CO_3^-	(me/l)	0.00	0.00	0.00	0.08	0.00	0.16
HCO_3^-	(me/l)	1.76	1.92	4.96	2.96	1.84	3.60
Cl^-	(me/l)	1.28	0.58	0.52	0.48	0.54	0.36
SO_4^-	(me/l)	7.63	8.42	41.88	13.44	11.09	6.94
NO_3^-	(me/l)	0.16	0.15	0.19	0.27	0.12	0.19
SAR	(me/l)	1.6	1.1	1.0	0.7	1.1	1.4
Na	(me/100g)	0.12	0.16	0.17	0.14	0.10	0.09
Ca+Mg	(me/100g)	0.29	0.59	1.72	1.05	0.41	0.28
1:5 EXTRACT							
EC_5 @ 25 °C	(mmhos/cm)	0.15	0.28	0.54	0.51	0.27	0.17
Ca+Mg	(me/l)	1.40	2.20	5.50	3.80	1.60	1.60
EXCHANGEABLE SODIUM	(percent)	4.0	0.9	1.1	1.1	2.2	3.1
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	5.3	11.7	5.3	9.7	5.1	3.9
NaOAc@pH 8.2							
BORON	(mg/l)						

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
OVERBURDEN ANALYSIS
Representative Sample 77-105

Study Area: BEULAH TRENCH RECLAMATION AREA   Relief: ______   Stoniness: ______   Parent Material: ______

Location. Sec. ____ Twp. ____ Range ____   Elevation: ______   ______   Soil Series: ______

______   Slope Aspect: ______   Drainage: ______   Soil Classification: ______

Climate: ______   Vegetation: ______   Ground Water: ______   ______

Land Use: ______   Erosion: ______   Land Form: ______   Profile Description By: ______ Date: ______

DETERMINATION		DATA					
Laboratory Number		77-105-9	77-105-10	77-105-11	77-105-12	77-105-13	77-105-14
Sack Number		8608	8609	8610	8611	8612	8613
Depth (Ft)		141.0-165.8	165.8-190.0	190.0-203.4	203.4-223.5	247.0-251.0	251.0-257.4
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.0	1.4	0.8	1.8	0.8	0.3
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.06	0.12	0.04	0.14	0.12	0.06
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	0.6	2.4	0.6	3.0	6.2	1.4
IRON	Fe	27.8	26.6	27.8	44.0	52.0	66.0
MERCURY	Hg	0.011	0.011	0.011	0.011	0.011	0.011
LITHIUM	Li						
MANGANESE	Mn	7.2	8.4	5.4	7.6	6.8	7.0
MOLYBDENUM	Mo						
NICKEL	Ni	1.0	4.4	2.6	4.6	3.8	1.0
PHOSPHOROUS	P						
LEAD	Pb	2.0	3.2	1.2	4.0	6.0	2.2
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	2.0	8.0	4.0	10.0	8.0	6.0

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		77-105-9	77-105-10	77-105-11	77-105-12	77-105-13	77-105-14
Sack Number		8608	8609	8610	8611	8612	8613
DEPTH	(Ft)	141.0-165.8	165.8-190.0	190.0-203.4	203.4-223.5	247.0-251.0	251.0-257.4
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.5					
Coarse Sand	(1.0-0.5 mm)	3.1					
Medium Sand	(0.5-0.25 mm)	20.6					
Fine Sand	(0.25-0.10 mm)	39.5					
Very Fine Sand	(0.10-0.05 mm)	12.6					
TOTAL SAND	(2.0-0.05 mm)	76.3	8.8	28.1	2.1	8.3	48.6
SILT	(0.05-0.002 mm)	11.4	63.4	48.5	62.5	55.8	35.0
CLAY	(0.002 mm)	12.3	27.8	23.4	35.4	35.9	16.4
TEXTURAL CLASS (LAB)		FSL	SiCL	L	SiCL	SiCL	L
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		1.14	0.02	*1/3	*1/5	*1/10	*1/10
24th Hr.		0.98	0.02	*1/2	*1/5	*1/10	*1/10
SETTLING VOLUME	(ml)	19.0	29.0	84.0	216.0	428.0	198.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		6.9	21.1	28.7	35.0	45.9	
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.9	8.8	9.7	9.9	9.8	10.2
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.6	-0.2	+1.1	+4.0	+5.2	+2.8
SATURATION EXTRACT							
Saturation Percentage		38.6	74.0	90.3	136.7	149.3	98.5
EC_e@ 25°C	(mmhos/cm)	1.3	1.9	2.5	1.3	1.2	1.1
Ca^{++}	(me/l)	4.89	4.28	0.82	0.16	0.16	0.49
Mg^{++}	(me/l)	3.62	3.89	0.63	0.09	0.09	0.18
Na^+	(me/l)	5.02	11.53	21.81	12.67	11.33	10.04
K^+	(me/l)	0.59	0.92	0.37	0.15	0.13	0.10
CO_3^-	(me/l)	0.16	0.16	0.08	0.56	0.72	0.64
HCO_3^-	(me/l)	2.88	3.84	3.16	5.04	5.12	4.52
Cl^-	(me/l)	0.30	0.00	0.00	0.00	0.00	0.00
SO_4^-	(me/l)	9.38	13.18	18.18	6.04	4.60	5.06
NO_3^-	(me/l)	0.21	0.35	0.35	0.33	0.36	0.15
SAR	(me/l)	2.4	5.7	26.0	36.0	32.0	17.0
Na	(me/100g)	0.19	0.85	1.97	1.73	1.69	0.99
Ca+Mg	(me/100g)	0.37	0.60	0.13	0.03	0.04	0.07
1:5 EXTRACT							
EC@ 25°C	(mmhos/cm)	0.22	0.46	0.73	0.94	1.06	0.76
Ca+Mg	(me/l)	1.40	1.50	1.40	0.40	1.20	0.80
EXCHANGEABLE SODIUM	(percent)	2.1	0.6	17.0	38.0	45.0	49.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	5.3	10.7	9.7	10.7	12.5	6.1
NaOAc@pH 8.2							
BORON	(mg/l)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 37

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

OVERBURDEN ANALYSIS

Representative Sample 77-106; -107

Study Area: BEULAH TRENCH RECLAMATION AREA Relief: ____ Stoniness: ____ Parent Material: ____

Location. Sec. ____ Twp. ____ Range ____ Elevation: ____ ____ Soil Series: ____

____ Slope Aspect: ____ Drainage: ____ Soil Classification: ____

Climate: ____ Vegetation: ____ Ground Water: ____ ____

Land Use: ____ Erosion: ____ Land Form: ____ Profile Description By: ____ Date: ____

DETERMINATION		DATA					
Laboratory Number		77-106-1	77-107-1	77-107-2	77-107-3	77-107-4	77-107-5
Sack Number		8614	11,296	11,297	11,298	11,299	11,300
Depth (Ft)		1.6-24.6	1.3-10.0	10.0-30.0	30.0-45.0	45.6-60.4	60.4-86.8
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.0	0.8	1.2	0.3	0.8	1.7
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.02	0.08	0.20	0.22	0.12	0.16
GOBALT	Co						
CHROMIUM	Gr						
COPPER	Cu	0.2	3.2	0.8	0.6	4.6	3.4
IRON	Fe	13.0	70.0	98.0	86.0	118.0	78.0
MERCURY	Hg	0.011	0.080	0.050	0.050	0.096	0.106
LITHIUM	Li						
MANGANESE	Mn	4.0	40.0	76.0	16.0	34.0	26.0
MOLYBDENUM	Mo		0.3	0.3	0.3	0.3	0.3
NICKEL	Ni	0.2	1.2	1.2	0.5	1.8	1.7
PHOSPHOROUS	P						
LEAD	Pb	1.0	1.6	0.6	0.6	1.4	3.4
STRONTIUM	Sr						
SELENIUM	Se		0.003	0.0031	0.003	0.0036	0.0044
VANADIUM	V						
ZINC	Zn	0.8	1.7	1.4	1.4	2.5	6.0

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		77-106-1	77-107-1	77-107-2	77-107-3	77-107-4	77-107-5
Sack Number		8614	11,296	11,297	11,298	11,299	11,300
DEPTH	(Ft)	1.6-24.6	1.3-10.0	10.0-30.0	30.0-45.0	45.6-60.4	60.4-86.8
PARTICLE SIZE ANALYSIS	(oercent)						
Very Coarse Sand	(2.0-1.0 mm)	0.1		1.6	0.1		
Coarse Sand	(1.0-0.5 mm)	1.3		8.3	19.5		
Medium Sand	(0.5-0.25 mm)	7.3		31.2	18.3		
Fine Sand	(0.25-0.10 mm)	54.1		30.5	37.2		
Very Fine Sand	(0.10-0.05 mm)	11.5		5.6	6.1		
TOTAL SAND	(2.0-0.05 mm)	74.3	35.3	77.2	81.2	37.8	40.4
SILT	(0.05-0.002 mm)	13.4	35.3	9.4	10.9	40.8	37.5
CLAY	(0.002 mm)	12.3	29.4	13.4	7.9	21.4	22.1
TEXTURAL CLASS (LAB)		FSL	CL	SL	LS	L	L
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		1.64	0.02	1.23	1.71	0.13	0.08
24th Hr.		1.56	0.02	1.41	1.86	0.13	0.08
SETTLING VOLUME	(ml)	21.0	31.0	19.0	19.0	25.0	25.0
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		8.0	15.4			14.1	12.7
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.9	9.2	9.1	8.3	7.8	8.6
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-0.03	+1.2	+0.4	+0.2	-1.2	-1.2
SATURATION EXTRACT							
Saturation Percentage		40.7	68.6	33.3	32.7	59.2	65.2
EC_e@ 25°C	(mmhos/cm)	0.62	0.37	0.78	0.96	1.5	1.2
Ca++	(me/l)	1.59	0.38	1.87	4.23	9.66	8.18
Mg++	(me/l)	0.72	0.72	1.36	2.80	6.69	4.34
Na+	(me/l)	3.30	2.82	4.69	3.40	2.68	1.87
K+	(me/l)	0.10	0.05	0.05	0.08	0.09	0.15
CO_3-	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	1.60	2.64	1.81	0.90	2.34	1.46
Cl-	(me/l)	1.16	0.07	0.31	0.68	0.42	0.05
SO_4-	(me/l)	2.67	0.82	5.42	8.46	15.56	13.18
NO_3-	(me/l)	0.12	0.07	0.12	0.10	0.32	0.40
SAR	(me/l)	3.1	3.8	3.7	1.8	0.9	0.7
Na	(me/100g)	0.13	0.19	0.16	0.11	0.12	0.12
Ca+Mg	(me/100g)	0.09	0.07	0.12	0.24	0.97	0.81
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.10	0.16	0.80	0.10	0.36	0.38
Ca+Mg	(me/l)	1.30	0.80	0.58	0.58	2.81	3.28
EXCHANGEABLE SODIUM	(percent)	3.2				1.1	0.9
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	7.2				19.0	16.0
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 38

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
OVERBURDEN ANALYSIS
Representative Sample 77-107

Table 39

Study Area: BEULAH TRENCH RECLAMATION AREA Relief: ____ Stoniness: ____ Parent Material: ____

Location. Sec. ____ Twp. ____ Range ____ Elevation: ____ Soil Series: ____

Slope Aspect: ____ Drainage: ____ Soil Classification: ____

Climate: ____ Vegetation: ____ Cround Water: ____

Land Use: ____ Erosion: ____ Land Form: ____ Profile Description By: ____ Date: ____

DETERMINATION		DATA					
Laboratory Number		77-107-6	77-107-7	77-107-8	77-107-9	77-107-10	77-107-11
Sack Number		11,301	11,302	11,303	11,304	11,305	11,306
Depth (Ft)		86.8-109.6	111.1-132.8	132.8-152.0	152.0-172.1	183.1-200.0	205.9-217.6
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	1.9	1.8	3.1	1.6	1.2	3.7
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.12	0.20	0.14	0.30	0.16	0.06
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	5.2	4.0	8.0	11.8	9.8	7.6
IRON	Fe	74.0	80.0	138.0	88.0	114.0	84.0
MERCURY	Hg	0.260	0.170	0.186	0.212	0.273	0.334
LITHIUM	Li						
MANGANESE	Mn	17.0	11.8	12.0	11.8	12.4	8.6
MOLYBDENUM	Mo	0.3	0.3	0.3	0.3	0.3	0.3
NICKEL	Ni	2.9	6.0	6.8	6.0	6.8	3.6
PHOSPHOROUS	P						
LEAD	Pb	4.6	4.6	7.0	9.0	7.4	5.0
STRONTIUM	Sr						
SELENIUM	Se	0.0101	0.013	0.013	0.036	0.016	0.038
VANADIUM	V						
ZINC	Zn	11.4	7.4	8.0	21.8	9.0	4.4

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		77-107-6	77-107-7	77-107-8	77-107-9	77-107-10	77-107-11
Sack Number		11,301	11,302	11,303	11,304	11,305	11,306
DEPTH	(Ft)	86.8-109.6	111.1-132.8	132.8-152.0	152.0-172.1	183.1-200.0	205.9-217.6
PARTICLE SIZE ANALYSIS	(oercent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	17.6	10.4	15.2	3.4	8.7	3.4
SILT	(0.05-0.002 mm)	48.0	57.4	45.4	62.2	62.1	63.3
CLAY	(0.002 mm)	34.4	32.2	39.4	34.4	29.2	33.3
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiCL	SiCL	SiCL	SiCL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.02	*1/4	*1/10	*1/10	*1/10	*1/10
24th Hr.		0.02	*1/2	*1/4	*1/4	*1/4	*1/3
SETTLINC VOLUME	(ml)	29.0	65.0	200.0	140.0	142.0	160.0
MOISTURE RETENTION	(percent)						
I/10 bar							
I/3 bar							
I5 bar		17.7	24.6	34.5	28.6		
SOIL REACTION-pH							
Paste							
I:5 H_2O		8.4	9.3	9.6	9.6	9.8	9.8
I:2 0.01 M $CaCl_2$							
ORCANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
CYPSUM REQUIREMENT	(me/100g)	-0.5	+4.9	+7.4	+3.4	+6.4	+9.2
SATURATION EXTRACT							
Saturation Percentage		84.4	127.2	141.2	147.6	138.3	
EC_e@ 25°C	(mmhos/cm)	1.2	1.0	1.4	0.86	1.0	1.5
Ca++	(me/l)	6.15	0.27	0.16	0.11	0.11	0.11
Mg++	(me/l)	5.07	0.18	0.09	0.09	0.09	0.00
Na+	(me/l)	2.68	10.00	14.59	8.56	10.71	16.40
K+	(me/I)	0.35	0.20	0.13	0.13	0.11	0.15
CO_3-	(me/l)	0.00	0.13	0.26	0.14	0.43	0.76
HCO_3-	(me/I)	3.43	4.12	5.19	3.67	5.74	8.49
CI-	(me/l)	0.11	0.05	0.17	0.04	0.06	0.15
SO_4-	(me/I)	10.21	5.50	8.52	3.75	2.87	5.75
NO_3-	(me/l)	0.25	0.20	0.45	0.18	0.18	0.52
SAR	(me/l)	1.5	21.0	41.0	27.0	34.0	70.0
Na	(me/100g)	0.23	1.30	2.10	1.30	1.50	2.10
Ca+Mg	(me/100g)	0.95	0.05	0.03	0.18	0.17	0.01
I:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.34	0.41	0.62	0.47	0.52	0.66
Ca+Mg	(me/I)	2.64	1.13	1.65	1.72	1.03	1.12
EXCHANCEABLE SODIUM	(percent)	0.2	17.0	39.0	22.0	37.0	51.0
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	20.0	19.0	21.0	23.0	18.0	19.0
NaOAc@pH 8.2							
BORON	(mg/I)						

*Denotes that no water was transmitted through soil column prior to or during the specified testing period; fraction denotes the estimated proportional length of soil column penetrated by water during the specified period.

Table 40

Laboratory Analysis of Geologic Core Sample No. 77-104

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT Beulah Trench PROJECT

GEOLOGIST Taucher LOCATION: SECTION ___ T. ___ R. ___ DATE ___

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC x 10^3 mS/cm		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr cm/hr	24 hr cm/hr	TSC me/l	Cat. Mg. me/l	SAR		SAND	SILT	CLAY		
1	77-104	1.0-14.4			8.5		36	5.6 .78		.36	.37									
2	"	14.4-43.0			8.3		45	5.0 .68		.52	.56									
3	"	43.0 54.8			9.7	8.5	170	4.6 .63		0	0									
4	"	76.4 90.2			9.4	8.1	120	3.0 .38		0	0									

Laboratory Analysis of Geologic Core Sample No. 77-106

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT Beulah Trench PROJECT ____

GEOLOGIST Taucher LOCATION: SECTION ____ T. ____ R. ____ DATE ____

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC x 10^3 mS/cm		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr cm/hr	24 hr cm/hr	TSC me/l	Cat. Mg. me/l	SAR		SAND	SILT	CLAY		
2	77-106	24.6-30.7			8.0		34	3.2 .40		.29	.34									
3	"	30.7-48.5			7.7		19	1.1 .14		5.24	3.56									
4	"	48.5-73.2			8.5		34	2.8 .34		.15	.21									
5	"	73.2-96.5			9.5	8.4	43	2.6 .32		.03	.02									
6	"	96.5-108.6			8.2		20	1.0 .13		1.42	1.20									
7	"	108.6-134.3 136.6-138.2			9.4	8.2	150	2.8 .34		0	0									
8	"	153.0-159.3			9.3	8.3	225	2.2 .28		0	0									
9	"	164.8-183.0			9.8	8.8	180	4.6 .62	1.3	0	0									

Table 42

Laboratory Analysis of Geologic Core Smaple No. 77-108

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT Beulah Trench PROJECT ______

GEOLOGIST Taucher LOCATION: SECTION ____ T. ____ R. ____ DATE ______

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC x 10^3 mS/cm		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr cm/hr	24 hr cm/hr	TSC me/l	Cat. Mg. me/l	SAR		SAND	SILT	CLAY		
1	77-108	0.6-37.0			7.9		26	3.6 .46		.26	.21									
2	"	37.0-57.0			8.5		20	1.4 .18		1.40	1.16									
3	"	57.0-77.3			8.4		19	1.2 .16		1.60	1.52									
4	"	77.3-95.9			8.6	7.5	32	1.7 .21		.16	.16									
5	"	95.9-122.0			8.8	7.6	34	1.4 .18		.13	.14									
6	"	132.6-140.5			9.2	7.8	42	1.7 .21		.02	.02									
7	"	140.5-149.8			9.4	8.0	130	2.4 .30		0	0									
8	"	155.5-168.5			9.4	8.0	160	3.1 .39		0	0									

Table 43

Laboratory Analysis of Geologic Core Sample No. 77-109

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT Beulah Trench PROJECT ______

GEOLOGIST Taucher LOCATION: SECTION ____ T. ____ R. ____ DATE ______

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC x 10^3 mS/cm		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr cm/hr	24 hr cm/hr	TSC me/l	Cat. Mg. me/l	SAR		SAND	SILT	CLAY		
1	77-109	3.2- 28.8			8.0		24	8.00 1.30		0.44	0.44									
2	"	28.8- 51.8			7.4		18	7.00 1.00		0.84	1.16									
3	"	51.8- 65.0			8.5		43	4.00 0.53		0.0	0.02									
4	"	65.0- 73.6			9.6	8.5	100	3.20 0.40		0.0	0.0									
5	"	73.6- 100.4			9.5	8.5	135	2.70 0.33		0.0	0.0									
6	"	115.6- 124.3			9.0	8.0	28	1.60 0.20		0.23	0.21									
7	"	130.4- 140.8			9.2	8.1	80	2.40 0.30		0.0	0.0									

Laboratory Analysis of Geologic Core Sample No. 77-110

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION
SOIL LABORATORY - MILES CITY, MONTANA

UNIT Beulah Trench PROJECT ____
GEOLOGIST Taucher LOCATION: SECTION ____ T. ____ R. ____ DATE ____

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC x 10^3 mS/cm		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr cm/hr	24 hr cm/hr	TSC me/l	Cat. Mg. me/l	SAR		SAND	SILT	CLAY		
1	77-110	1.0-8.0			8.8	7.7	33	1.2 0.16		0.16	0.16									
2	"	8.0-15.0			6.0	5.6	30	13.0 2.3		0.48	0.48									
3	"	16.5-30.4			7.1		34	5.4 0.75		0.10	0.14									
4	"	30.4-50.0			9.5	8.2	110	4.4 0.59		0.0	0.0									
5	"	50.0-68.4			9.8	8.7	165	3.4 .44		0.0	0.0									
6	"	70.2-80.6			9.6	8.4	190	4.2 0.55		0.0	0.0									
7	"	98.6-120.0			9.9	8.9	185	4.0 0.53		0.0	0.0									
8	"	120.0-140.9			9.7	8.3	190	4.0 0.53		0.0	0.0									
9	"	140.9-158.9			9.6	8.6	200	3.8 0.50		0.0	0.0									
10	"	162.6-178.9			9.7	8.6	190	1.8 0.32		0.0	0.0									

Table 45

Laboratory Analysis of Geologic Core Sample No. 77-111

UNITED STATES - DEPARTMENT OF THE INTERIOR - BUREAU OF RECLAMATION - UPPER MISSOURI REGION

SOIL LABORATORY - MILES CITY, MONTANA

UNIT Beulah Trench PROJECT ____

GEOLOGIST Taucher LOCATION: SECTION ____ T. ____ R. ____ DATE ____

LAB NO.	PROFILE NO.	DEPTH METERS	TEXTURE		pH		SET. VOL. ml	EC x 10^3 mS/cm		FRAG. HYD. COND.		SODIUM ABSORPTION RATIO			GYP. REQ me/100g	PARTICLE SIZE PERCENTAGE			HCL	%
			FIELD	LAB	1-5	$CaCl_2$		1-5	SAT. EXT.	8 hr cm/hr	24 hr cm/hr	TSC me/l	Cat. Mg. me/l	SAR		SAND	SILT	CLAY		
1	77-111	0.0-22.4			8.1		26	3.40 0.44		0.09	0.11									
2	"	22.4-54.0			4.4	4.1	20	4.00 0.53		1.12	1.32									
3	"	59.0-70.0			7.5		26	3.20 0.40		0.52	0.46									
4	"	70.0-78.0			7.9		31	3.00 0.38		0.12	0.11									
5	"	78.0-93.1			8.4		21	2.60 0.32		1.12	1.16									
6	"	93.9-110.4			8.5		36	2.20 0.28		0.09	0.09									
7	"	112.4-124.0			8.9	7.9	140	3.60 0.46		0.0	0.0									
8	"	124.0-139.3			9.4	8.0	190	2.70 0.33		0.0	0.0									
9	"	161.3-172.0			9.3	8.5	260	2.30 0.29		0.0	0.0									
10	"	172.0-192.0			9.6	8.2	180	4.00 0.53		0.0	0.0									
11	"	192.0-212.2			9.6	8.2	150	4.00 0.53		0.0	0.0									

Established Series
Rev. JCM/CAM
6/73

RINGLING SERIES

The Ringling series is a member of the fragmental, mixed family of Typic Haploborolls. Typically, Ringling soils have reddish brown channery loam A1 horizons, and reddish brown very channery loam C horizons with the volume of rock fragments increasing with increasing depth from 35 to 80 percent and grading to loose porcellanite or burned shale and sandstone bedrock at a depth of about 13 inches.

Typifying Pedon: Ringling channery loam - native sod cover
(Colors are for dry soil unless otherwise noted.)

A1 0-3"--Reddish brown (5YR 4/4) channery loam, dark reddish brown (5YR 3/3) moist; weak fine crumb structure; soft, very friable, nonsticky, nonplastic; many very fine roots; many very fine interstitial pores; 30 percent thin hard burned shale fragments; neutral; clear wavy boundary. (3 to 8 inches thick)

C1 3-13"--Reddish brown (5YR 5/3) very channery loam, dark reddish brown (5YR 3/3) moist; massive; soft, very friable, nonsticky, nonplastic; many very fine roots; 35 percent increasing with increasing depth to 80 percent flat fragments of hard baked shale; neutral; abrupt boundary. (0 to 15 inches thick)

C2 13-60"--Hard platy red baked shale coated with lime and having pendants of lime on undersides; soil from C1 horizon partly fills the voids between rock fragments in the upper part.

Type Location: Big Horn County, Montana; 525 feet SE of center sec. 17, T.5S., R.38E.

Range in Characteristics: Depth to fractured bedrock ranges from 5 to 20 inches. Rock fragments range from 30 percent in the A1 horizon to as much as 80 percent in the lower C1 horizon. Lime coating occurs on rock fragments in places but the loam matrix is noncalcareous. The underlying shale is noncalcareous in some pedons. The A1 horizon has hue of 7.5YR through 10R, value of 4 or 5 dry, and chroma of 2 or 3 moist. Mean annual soil temperature ranges from 44° to 47°F. Average summer soil temperature ranges from 60° to 64°F.

Competing Series and their Differentiae: These are the Castner, Cathedral, Comodore, Maginnis, and Wibaux soils. All of these soils except Wibaux have a lithic contact at depths of 20 inches or less. Also, Castner soils have a Cca horizon and Maginnis soils have 2.5Y or 10YR hue and have clay texture. Wibaux soils lack mollic epipedons, are usually dry, and have mean annual soil temperature of about 47°F.

Setting: Ringling soils are on strongly rolling or steeply sloping uplands. They formed in residuum weathered from hard red baked shale or porcellanite rocks in areas having 13 to 16 inches mean annual precipitation with mean annual soil temperature ranging from 44° to 46°F. and mean summer soil temperature higher than 60°F.

Principal Associated Soils: These are the Barvon, Bitterroot, Danvers, and Judith soils. Barvon and Bitterroot soils have mollic epipedons and paralithic contacts. Danvers and Judith soils are very deep soils on old alluvial deposits.

Drainage and Permeability: Well-drained; rapid permeability.

Use and Vegetation: Ringling soils are used entirely for range. Native vegetation is bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass, and annuals with scattered to dense stands of western yellow pine.

Distribution and Extent: Ringling soils are widely distributed on the higher elevations of the residual shale plains in southeastern Montana. They are moderately extensive.

Series Established: Reconnaissance Soil Survey of Central Montana, 1946.

Remarks: The Ringling soils were formerly classified as Lithosols.

National Cooperative Soil Survey
U. S. A.

Established Series
Rev. DKC/SHB
11/76

CABBA SERIES

The Cabba series consists of well drained soils that formed in material weathered from soft sedimentary rock and have sedimentary beds at depths of 8 to 20 inches. Cabba soils are on uplands and are moderately sloping to very steep. The mean annual precipitation is about 14 inches and the mean annual air temperature is about 45°F.

Taxonomic Class: Loamy, mixed (calcareous), frigid, shallow Typic Ustorthents.

Typical Pedon: Cabba cobbly clay loam, native grassland. (Colors are for dry soil unless otherwise noted.)

A1--0 to 2 inches; grayish brown (2.5Y 5/2) cobbly clay loam, grayish brown (2.5Y 4/2) moist; moderate fine crumb structure; slightly hard, friable, slightly sticky and slightly plastic; many fine roots and pores; 15 to 20 percent cobbles, gravel and stones; neutral (pH 7.3); gradual wavy boundary. (2 to 5 inches thick)

AC--2 to 7 inches; grayish brown (2.5Y 5/2) gravelly light clay loam, dark grayish brown (2.5Y 4/2) moist; moderate very fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; 20 percent pebbles; many fine roots and pores; neutral (pH 7.3); gradual wavy boundary. (2 to 10 inches thick)

C1--7 to 18 inches; very pale brown (10YR 7/2) gravelly loam, grayish brown (10YR 5/2) moist; massive; evidence of rock structure in small fragments of weakly consolidated siltstone; slightly hard, friable, nonsticky and slightly plastic; many fine roots and pores; 20 percent pebbles; slightly effervescent; coatings of lime on soft rock fragments; clear wavy boundary. (6 to 15 inches thick)

C2--18 to 60 inches; light gray (10YR 7/2) soft sedimentary bedrock, grayish brown (10YR 5/2) moist; can be chipped out only with a sharp instrument when dry but softens quickly on soaking in water, and becomes material that rubs to a loam texture; roots in cracks and some roots through plates; massive rock; mildly alkaline (pH 7.8.)

Type Location: Granite County, Montana; 1000 feet north and 1500 feet east of the southwest corner of section 35, T.10N., R.12W.

Range in Characteristics: Depth to sedimentary beds is 8 to 20 inches. Mean annual soil temperature ranges from 40° to 47°F. The hue is 10YR or 2.5Y. Rock fragments range from 0 to 35 percent and are mainly of gravel size.

The A horizon has hue of 10YR or 2.5Y, value of 5 or 6 dry, 3 or 4 moist, and chroma of 1 or 2. It ranges from fine sandy loam through silt loam.

The C horizon has hue of 10YR through 5Y, value of 5 through 8 dry, 4 through 7 moist, and chroma of 1 through 3. It is loam, silt loam, silty clay loam or light clay loam and has 20 to 35 percent clay. The underlying sedimentary beds rub to silt loam or loam. This horizon is mildly or moderately alkaline.

Competing Series: These are the Abac and Cohagen series in the same family and the related Cabbart, Kuro, Midway and Wayden series. Abac soils have hue of 5YR or redder. Cabbart soils have an aridic moisture regime that borders on an ustic regime. Cohagen soils have sandy loam C horizons. Kuro soils contain 36 to 45 percent clay. Midway soils have soil temperature warmer than 47°F. Wayden soils have 36 to 50 percent clay.

Geographic Setting: Cabba soils are moderately sloping to very steep and are on uplands at elevations of 2000 to 4800 feet. They formed in material weathered from 12 to 19 inches with areas receiving less than 14 inches having cooler temperatures and lower evaporation. Most of the precipitation falls in the spring and early summer. Mean annual temperature ranges from 41° to 45°F. The (32°F.) growing season is 90 to 135 days.

Geographically Associated Soils: These are the Barvon, Campspass, Farland, Judith, Ringling, Shane and Thebo soils. Barvon soils have a mollic epipedon and are 20 to 40 inches deep to siltstone. Campspass and Farland soils have argillic horizons. Judith soils have a calcareous horizon immediately beneath the mollic epipedon. Ringling soils are fragmental. Shane soils contain more than 60 percent clay. Thebo soils contain more than 35 percent clay.

Drainage and Permeability: Well drained; moderate permeability.

Use and Vegetation: Used for rangeland. Native plants are bluebunch wheatgrass, little bluestem, needleandthread, western wheatgrass, green needlegrass, annual, and low-density stands of ponderosa pine.

Cabba Series

Distribution and Extent: Widely distributed in Montana. Cabba soils are of moderate extent.

Series Established: Granite County, Montana, 1969.

Remarks: The nature of the sedimentary beds is currently under study. The classification of the series may need to be changed if these soils lack a paralithic contact at shallow depth.

National Cooperative Soil Survey
U. S. A.

Established Series
Rev. DDO/GBM
12/8/78

AMOR SERIES

The Amor series consists of well drained, moderately permeable soils that are moderately deep to soft sandstone bedrock. They formed in material weathered from stratified soft sandstone, siltstone and loamy shales. These soils are on uplands and have slopes of 1 to 25 percent. Mean annual temperature is 42° F and mean annual precipitation is 15 inches.

Taonomic Class: Fine-loamy, mixed Typic Haploborolls.

Typical Pedon: Amor loam - on a 3 percent south facing plane slope in a cultivated field. When described the soil was moist below 8 inches. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 8 inches; dark grayish brown (10YR 4/2) loam; very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure parting to weak medium and fine granular; slightly hard, friable, slightly sticky and nonplastic; many roots and pores; neutral; abrupt smooth boundary. (5 to 9 inches thick)

B2--8 to 13 inches; brown (10YR 5/3) loam; dark brown (10YR 3/3) moist; a few stains of dark grayish brown (10YR 4/2) on faces of peds; weak coarse prismatic structure parting to weak coarse and medium subangular blocky; hard, friable, slightly sticky and slightly plastic; common roots; many fine pores; neutral; gradual wavy boundary (4 to 15 inches thick)

B3--13 to 19 inches; light brownish gray (2.5Y 6/2) loam; dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure parting to weak medium subangular blocky; hard, friable, slightly sticky and slightly plastic; common fine roots; common fine pores; slight effervescence; mildly alkaline; gradual wavy boundary. (0 to 12 inches thick)

C1ca--19 to 31 inches; light gray (2.5Y 7/2) loam; grayish brown (2.5Y 5/2) moist; weak medium subangular blocky structure; slightly hard, friable, slightly sticky and nonplastic; few fine roots; common fine pores; few masses of segregated lime; violent effervescence; moderately alkaline; gradual wavy boundary. (0 to 16 inches thick)

C2r--31 to 60 inches; pale yellow and light gray (2.5Y 7/3 and 5Y 7/2) stratified soft fine grained sandstone and siltstone; light olive gray and light olive brown (5Y 6/2 and 2.5Y 5/3) moist; slight effervescence; moderately alkaline.

Type Location: Bowman County, North Dakota, 6-1/2 miles west and 1 mile north of Bowman; 340 feet west and 180 feet north of southeast corner of southwest quarter Sec. 2, T. 131 N., R. 103 W.

Range in Characteristics: Depth to soft sandstone typically is 30 to 40 inches but ranges from 20 to 40 inches. Depth to free carbonates ranges from 10 to 35 inches. The 10- to 40-inch control section averages between 15 and 40 percent fine sand and coarser.

The A horizon has hue of 10YR, value of 3 through 5 and 2 or 3 moist, and chroma of 2 or 3. It is loam, silt loam or light clay loam. Some pedons contain up to 15 percent rock fragments. It is slightly acid or neutral.

The B2 horizon has hue of 10YR or 2.5Y, value of 4 through 6 and 3 through 5 moist, and chroma of 2 or 3. It is sandy clay loam, fine sandy loam, loam or clay loam. It has weak or moderate prismatic structure. It is neutral to moderately alkaline.

The B3 horizon has hue of 10YR or 2.5Y, value of 5 through 7 and 3 through 6 moist, and chroma of 2 through 4. It is fine sandy loam, loam or clay loam. It ranges from slight to strong effervescence. It is neutral to moderately alkaline.

The Cca horizon has hue of 2.5Y, value of 6 or 7 through 6 moist and chroma of 2 through 4. It is loam, silt loam, or light clay loam. Lime is both diffused and in soft accumulations. It contains from 6 to 30 percent calcium carbonate equivalent.

The underlying beds are stratified soft fine grained sandstone, siltstone and shale. Some pedons have lime accumulations below the top of the bedrock.

Competing Series: These are the Azaar, Duffy, Max, Quigley, Rottulee, Searing, Shambo, Tansem and Twin Creek series in the same family and the Arnegard, Boxwell, Chama, Morton, Reeder, Sen, Stady and Vebar series. Azaar soils have indurated sandstone bedrock within depths of 20 to 40 inches. Duffy soils have granitic bedrock substrata within depths of 40 inches. Max, Quigley, Shambo, Tansem and Twin Creek soils lack paralithic beds within depths of 20 to 40 inches. Rottulee soils have hue of 7.5YR or redder throughout. Searing soils have redder hues and reddish colored porcelainite beds within depths of 20 to 40 inches. Arnegard and Stady soils lack paralithic beds within depths of 20 to 40 inches. In addition, the Arnegard soils have mollic epipedons more than 20 inches thick and the Stady soils have sand and gravel between depths of 20 and 40 inches. Boxwell soils have drier climate. Chama, Morton, and Sen soils are fine-silty. Reeder soils have argillic horizons. Vebar soils are coarse-loamy.

Geographic Setting: Amor soils are on nearly level to moderately steep uplands. Slope gradients typically range from 1 to 10 percent, but some are as steep as 25 percent. The soils formed in residuum weathered from stratified soft sandstone, siltstone and loamy shales. Mean annual temperature ranges from 38 to 45° F and precipitation comes in the spring and summer.

Geographically Associated Soils: These are the competing Arnegard, Reeder, Shambo and Vebar soils and the Cabba and Flasher soils. Arnegard soils are on concave swales and footslopes. Reeder soils are on less sloping upland areas adjacent to the Amor soils. Shambo soils are on terraces and nearly level areas. Vebar soils are on adjacent uplands. Cabba and Flasher soils have paralithic beds at depths of less than 20 inches. They are on adjacent steeply sloping uplands.

Drainage and Permeability: Well drained. Runoff ranges from slow to rapid as slope increases. Permeability is moderate.

Use and Vegetation: Commonly cropped to small grains, flax, corn, hay and grass in a crop summerfallow rotation. Native vegetation is mid and short prairie grasses as green needlegrass, needleandthread, western wheatgrass and blue grama.

Distribution and Extent: Southwestern North Dakota, northwestern South Dakota and possibly eastern Montana. The series is moderate extent.

Series Established: Bowman County, North Dakota, August 1969.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. FWW-GBM
11/16/78

ARNEGARD SERIES

The Arnegard series consists of deep, well drained soils that formed in calcareous loamy alluvium on upland swales, fans and footslopes. Permeability is moderate. Slopes range from 0 to 9 percent. Mean annual temperature is 42° F, and mean annual precipitation is 14 inches.

Taxonomic Class: Fine-loamy, mixed Pachic Haploborolls.

Typical Pedon: Arnegard loam - cultivated. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 11 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak coarse and medium subangular blocky structure parting to weak fine granular; very friable; many roots; neutral; clear wavy boundary. (8 to 18 inches thick)

B21--11 to 17 inches; dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak coarse and medium prismatic structure parting to moderate fine subangular blocky; few thin clay films on faces of peds; common roots; common pores; neutral; gradual wavy boundary.

B22--17 to 25 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure parting to moderate medium and fine angular blocky; friable; few thin clay films on faces of peds; few roots; common pores; neutral; clear wavy boundary. (Combined thickness of the B2 horizon is 8 to 30 inches.)

B3--25 to 32 inches; grayish brown (2.5Y 5/2) loam, very dark grayish brown (2.5Y 3/2) moist; weak coarse prismatic structure parting to weak coarse and medium subangular blocky; friable; neutral; clear wavy boundary. (0 to 10 inches thick)

Clca--32 to 45 inches; light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak coarse and medium subangular blocky structure; friable; few roots; few fine pores; soft bodies of segregated lime; strong effervescence; moderately alkaline; gradual wavy boundary. (7 to 16 inches thick)

C2--45 to 60 inches; light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; very weak coarse and medium subangular blocky structure; friable; strong effervescence; moderately alkaline.

Type Location: McKenzie County, North Dakota; 300 feet east of the NW corner of sec. 14, T. 150 N., R. 101 W.

Range in Characteristics: The solum thickness ranges from 20 to 58 inches. The mollic epipedon ranges from 16 to more than 30 inches in thickness and includes all or part of the B horizon. The soil typically has segregated or finely divided carbonates within depths of 40 inches but ranges to as deep as 60 inches.

The A horizon has hue of 10YR, value of 3 or 4 and 2 or 3 moist, and chroma of 2. It is loam or silt loam and is slightly acid or neutral. Some pedons have B1 horizons.

The B2 horizon has hue of 10YR or 2.5Y, value of 2 to 4 moist, and chroma of 2 or 3. It is loam, silt loam or light clay loam containing less than 30 percent clay. It is neutral or mildly alkaline.

The Cca horizon has hue of 2.5Y or 10YR, value of 5 to 7 dry and 4 or 5 moist, and chroma of 2 to 4. It is typically loam but includes fine sandy loam to clay loam. It is mildly or moderately alkaline.

The C horizon has hue of 2.5Y or 10YR, value of 5 to 7 dry and 4 or 5 moist, and chroma of 2 to 4. It typically is loam but includes loamy fine sand, fine sandy loam and clay loam. It is neutral to moderately alkaline.

ARNEGARD SERIES--2

Competing Series: These are the Falkirk, Garza, Roseglen and Shawa series in the same family and the Bowbells, Bowdle, Goshen, Grail, Grassna, Mandan, Onita, Parshall, Shambo, Straw and Svea series. Falkirk soils have gravelly loam IIC horizons and glacial till within depths of 40 inches. Garza soils lack cambic horizons. Roseglen soils contain less sand and have formed in lacustrine sediments. Shawa soils lack B horizons and formed in alluvium primarily from igneous rocks. Bowbells soils have argillic horizons. Bowdle soils are fine-loamy over sandy or sandy-skeletal. Goshen and Onita soils have argillic horizons and warmer climates. Grail soils have fine-textured argillic horizons. Grassna soils are fine-silty. Mandan soils are coarse-silty. Parshall soils are coarse-loamy. Shambo soils have mollic epipedons less than 16 inches thick. Straw soils contain carbonates throughout and are stratified. Svea soils have wetter climates.

Geographic Setting: Arnegard soils are on upland swales, fans and footslopes on the residual plains and glacial till plains. They formed in mixed loamy alluvium from calcareous sedimentary rock and glacial till. Slopes typically are 1 or 2 percent but range from 0 to 9 percent. The mean annual temperature is 38 to 45° F, and the mean annual precipitation is 12 to 16 inches, most of which falls during spring and summer.

Geographically Associated Soils: These are the Amor, Farland, Grail, Grassna, Max, Morton, Parshall, Sen, Shambo, Temvik, Vebar and Williams soils. Amor, Morton, Sen and Vebar soils have thinner mollic epipedons formed in residual materials and are on nearby convex slopes. Farland and Shambo soils have thinner mollic epipedons and are on nearby terraces. Max, Williams and Temvik soils have thinner mollic epipedons and formed in glacial till. Grail, Grassna and Parshall soils are in similiar positions.

Drainage and Permeability: Well drained. Runoff is slow or medium. Permeability is moderate.

Use and Vegetation: Most areas are cropped to spring wheat, oats, barley, and hay. Native vegetation is mid, tall and short grasses such as western wheatgrass, green needlegrass, big bluestem and blue grama.

Distribution and Extent: Arnegard soils are extensive and are in western North Dakota, eastern Montana and northwestern South Dakota.

Series Established: McKenzie County, North Dakota, 1937.

Remarks: Soils that formed in loess or similiar silty materials were formerly included in the Arnegard series but now are placed in the Grassna series.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. RLM-PKW-SRB
12/8/78

COHAGEN SERIES

The Cohagen series consists of shallow, well to excessively drained soils formed in materials weathered from soft sandstone bedrock on uplands. These soils have moderate or moderately rapid permeability. Slopes range from 3 to 50 percent. Mean annual temperature is about 42° F and mean annual precipitation is about 16 inches.

Taxonomic Class: Loamy, mixed (calcareous), frigid, shallow Typic Ustorthents.

Typical Pedon: Cohagen fine sandy loam - on a south facing convex slope of 18 percent in native grass. (Colors for dry soil unless otherwise stated. Where described the soil was moist throughout.)

A1--0 to 3 inches; grayish brown (10YR 5/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak fine subangular blocky structure parting to weak medium granular; slightly hard, very friable; many roots; slight effervescence; mildly alkaline; clear wavy boundary. (2 to 6 inches thick)

C1--3 to 8 inches; light brownish gray (2.5Y 6/2) fine sandy loam, dark grayish brown (2.5Y 4/2) moist; weak medium and fine subangular blocky structure; slightly hard, very friable; common roots, slight effervescence; mildly alkaline; gradual boundary.

C2--8 to 17 inches; light yellowish brown and light olive brown (2.5Y 6/4 and 5/5) fine sandy loam, olive brown (2.5Y 4/4) moist; weak medium subangular blocky structure; hard; friable; common grading to few roots; 25 percent soft sandstone fragments; slight effervescence; moderately alkaline; clear wavy boundary. (Combined C1 and C2 horizons are 8 to 14 inches thick)

Cr--17 to 40 inches; pale yellow and light yellowish brown (2.5Y 7/4 and 6/4) soft massive calcareous sandstone, light olive brown (2.5Y 5/4) moist; slightly hard and brittle; soft and easily crushed; a few roots in cracks in upper part; a few seams of lime.

Type Location: Oliver County, North Dakota; 4 miles north and 2 1/2 miles west of Hanover, North Dakota; 250 feet north and 280 feet west of the SE corner of the SW quarter of sec. 29, T. 143 N., R. 85 W.

Range in Characteristics: The depth to soft sandstone is typically about 18 inches but ranges between 10 and 20 inches. The control section commonly is fine sandy loam or sandy loam but the range includes loamy very fine sand.

The A horizon has hue of 10YR, or 2.5Y, value of 4 through 6 and 3 or 4 moist and chroma of 2 or 3. It typically is fine sandy loam or sandy loam but some is loamy fine sand or loam.

The upper part of the C horizon has hue of 10YR or 2.5Y value of 5 or 6 and 4 or 5 moist and chroma of 2 through 4. It has weak to moderate grades of subangular blocky or prismatic structure or is massive. The Cr horizon is platy or massive weakly consolidated soft calcareous sandstone with a 2.5Y or 5Y hue. It crushes to a fine sandy loam or loamy fine sand.

Competing Series: These are the Abac, and Cabba series in the same family and the Blackhall, Cabbart, Castner, Dast, Delphill, Dilts, Flasher, Lisam, Norbert, Oceanet, Rentsac, Scroggin, Wayden and Yawdim series. Abac soils have 5YR or redder hue throughout their sola. Cabba and Cabbart soils have loam, silt loam or clay loam control sections. Blackhall soils are usually dry. Castner and Rentsac soils have a lithic contact within depths of 20 inches. Dast, Delphill, and Scroggin soils have a paralithic contact within depths of 20 to 40 inches. Dilts, Lisam, Norbert, Wayden and Yawdim soils have clayey control sections. Flasher soils are sandy. Oceanet soils have mesic temperatures.

Geographic Setting: The Cohagen soils are on undulating to hilly uplands. The Cohagen soils formed in fine sandy loam residuum weathered from the soft sandstone bedrock. The climate is cool, semiarid with long cold winters and warm moist spring and summer. The mean annual precipitation is 14 to 18 inches, more than 70 percent of which falls in the spring and summer. The mean annual temperature is 40 to 45° F; mean January temperature is about 10 to 25° F.

COHAGEN SERIES--2

Geographically Associated Soils: These are the competing Dast and Flasher series and the Tally, and Vebar series. These are commonly in a landscape sequence with Cohagen, Dast and Flasher soils on the crests of hills and steeper slopes and Vebar, Tally and Parshall soil on the lower slopes and nearly level areas. Parshall, Tally and Vebar soils have mollic epipedons.

Drainage and Permeability: Well to excessively drained. Medium or rapid runoff. Permeability is moderate or moderately rapid in the soil and moderate to slow in the sandstone.

Use and Vegetation: Used for range and pasture. A few areas are cultivated with adjacent thicker soils. Native vegetation is little bluestem, needleandthread, prairie sandreed, upland sedges and western wheatgrass.

Distribution and Extent: Sedimentary plains of western North Dakota, eastern Montana and northwestern South Dakota. The soil is of moderate extent.

Series Established: Oliver County, North Dakota, 11/22/71.

Remarks: The Cohagen soils were classified as Lithosols in the former system.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. SRB
6/24/74

HARRIET SERIES

The Harriet series is a member of the fine, montmorillonitic, frigid family of Typic Natraquolls. (Leptic Natriborolls). (See Remarks). Typically, these soils have very dark gray loam A2 horizons about 2 inches thick, black, and very dark grayish brown strongly alkaline clay loam B2t horizons that have moderate columnar and prismatic structure, and stratified loam, very fine sandy loam, and clay loam C horizons.

Typifying Pedon: Harriet loam-grassland
(Colors are for moist soil unless otherwise stated.)

A2 -- 0-2"--Very dark gray (2.5Y 3/1) loam, gray (2.5Y 5/1 and 6/1) dry; medium platy structure; friable; many fine roots, common fine pores; few salt crystals visible when soil is dry; moderately alkaline; abrupt wavy boundary. (1 to 5 inches thick)

B21 -- 2-6"--Black (2.5Y 2/1) heavy clay loam, dark gray (2.5Y 4/1) dry; moderate medium columnar structure; extremely hard, firm; common roots; coatings of very dark gray (2.5Y 3/1) moist, gray (2.5Y 5/1) dry on column tops and sides; slight effervescence on inside of columns; strongly alkaline; clear wavy boundary.

B22t-- 6-18"--Very dark grayish brown (2.5Y 3/2) clay loam, grayish brown (2.5Y 5/2) dry; moderate coarse prismatic and weak medium subangular blocky structure; very hard, firm; few roots; common medium pores; common fine white salt crystals; strong effervescence; strongly alkaline; gradual wavy boundary. (Combined B_2 Horizons - 3 to 20 inches thick).

C1sa-- 18-28"--Dark grayish brown (2.54 4/2) loam, grayish brown and light brownish gray (2.5Y 5/2 and 6/2) dry; weak coarse prismtic structure; very hard, firm; occasional fine roots; few medium and fine pores; fine salt crystals visiable when dry; violent effervescence; strongly alkaline; abrupt smooth boundary. (0 to 20 inches thick)

IIC2-- 28-38"--Light olive brown (2.5Y 5.3) very fine sandy loam, light yellowish brown (2.5Y 6/3) dry; very weak coarse prismatic and weak coarse and medium subangular blocky structure; very hard; friable; few fine pores; common very fine salt crystals visible when dry; strong effervescence; strongly alkaline; abrupt smooth boundary. (0 to 20 inches thick).

IIAb-- 38-40"--Very dark gray (2.5Y 3/1) clay loam, dark gray (2.5Y 4/1) dry; few medium distinct mottles of olive brown (2.5Y 4/3) moist; weak coarse prismatic structure; very hard, firm; occasional fine roots; strong effervescence; strongly alkaline; abrupt boundary. (0 to 10 inches thick)

IIC3-- 40-60"--Olive brown (2.5Y 4/3) stratified loam and clay loam, light yellowish brown (2.5Y 6/3) dry; weak coarse and medium subangular blocky structure; very hard; friable; strong effervescence; strongly alkaline.

Type Location: Burleigh County, North Dakota; twenty feet north of road right-of-way and 40 feet west of entrance to Cypert Park; 950 feet west and 40 feet north of the SE corner of the SW quarter of Sec. 34, T. 139 N., R. 79 W.

Range of Characteristics: Solum thickness ranges from 10 to 24 inches. Typically, salts are visible at depths of 4 to 11 inches and are throughout the solum and substratum in some pedons. pH ranges from neutral in the upperhorizons to strongly alkaline in the lower horizons. Some pedons have dark A1 horizons 1 to 2 inches thick. The A2 horizon has 10YR or 2.5Y hue, value of 3 or 4 and 5 or 6 dry, and chroma of 1. The A2 horizon is loam, silt loam or very fine sandy loam. The B2t horizon has 10YR, 2.5Y, or 5Y hue, value of 2 or 3 and 4 or 5 dry and chroma of 1 or 2. It shifts from clay laom to clay and is estimated to average between 35 and 50 percent clay. The B21t horizon has moderate to strong medium to coarse columnar structure and the B22t horizon has weak to moderate prismatic structure that parts to weak to moderate angular or subangular blocky structure. A B3 horizon is in some pedons. The C horizon has 10YR, 2.5Y or 5Y hue, value of 3 through 5 and 4 through 7 dry, and chroma of 1 through 3. It is loam, very fine sandy loam, clay loam, silty clay loam or silty clay. Few or common faint to prominent mottles are in the C horizon. Dark colored buried A horizons or strata of coarser materials are below depths of 30 inches in some pedons.

Competing Series and Their Differentiae: Competing series in other families are the Cavour, Dimmick, Durrstein, Exline, Heil, Miranda, Ranslo, Ryan and Stirum series. The Cavour, Exline, and Miranda soils are better drained. In addition the Cavour and Miranda soils are formed in glacial till and the Exline soils formed in stratified silt and clay lacustrine sediments. Dimmick soils lack natric horizons. The Durrstein soils are mesic. Heil soils lack free lime in the sola and are formed in clayey local alluvium. Ranslo soils have thicker A1 and A2 horizons. Ryan soils have mollic epipedons more than 40 inches thick and lack A2 horizons. Stirum soils have fine sandy loam or loam B2t horizons.

Setting: Harriet soils are on level, low terraces and bottomlands along streams. Slope gradient is less than 1 percent. The soils formed in calcareous stratified medium to moderately fine textured alluvium. The climate is semiarid. Mean annual temperature is 38 to 45° F., and mean annual precipitation is 14 to 18 inches. Most of the precipitation comes in the spring and summer.

Principal Associated Soils: These are the Farland, Havrelon, Korchea, Lamoure, La Prairie, Lehr, Magnus, Savage, Straw, and Velva soils on terraces and bottomlands. None of these soils have natric horizons and all except the Lamoure soils are better drained.

Drainage and Permeability: Poorly drained. A water table is at depths of less than 3 to 5 feet part of the time in most years. Runoff is slow. Permeability is very slow.

Use and Vegetation: Used mainly for pasture. Native vegetation is saltgrass, nut tall alkaligrass, western wheatgrass, and foxtail barley.

Distribution and Extent: Western and central North Dakota, northern South Dakota. The series is of moderate extent.

Series Established: Hand County, South Dakota, 1959.

Remarks: The Harriet soils were classified as solodized-Solonetz in the former system. Placement of the Harriet series with the Aquolls seems most appropriate although they do not always meet the morphological requirements of the Aquolls (i.e., mottling and/or low chroma).

Established Series
Rev. GBM
12/8/78

RHOADES SERIES

The Rhoades series consists of deep, well or moderately well drained, very slowly permeable soils formed in stratified loamy and clayey materials derived from saline-alkali soft shales. These soils are on upland plains, terraces and swales and have slopes of 0 to 25 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Fine, montmorillonitic Leptic Natriborolls.

Typical Pedon: Rhoades loam - grassland. (Colors are for dry soil unless otherwise stated.)

A2--0 to 4 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate medium prismatic structure separating to moderate and strong coarse to fine platy; friable; many roots; common fine pores; peds coated with light gray (10YR 6/1) uncoated sand grains; neutral; abrupt smooth boundary. (2 to 5 inches thick)

B2t--4 to 11 inches; grayish brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) moist; strong coarse columnar structure separating to moderate fine angular blocky in lower part; extremely hard, firm, sticky, plastic; common roots between columns; few medium common fine pores; columns capped with a light gray (10YR 7/1) layer; dark grayish brown (10YR 4/2) clay films on faces of peds; few gypsum crystals in lower part; moderately alkaline; clear wavy boundary. (5 to 20 inches thick)

B3--11 to 16 inches; grayish brown (2.5Y 5/2) clay loam, very dark grayish brown (2.5Y 3/2) moist; weak coarse prismatic structure separating to moderate medium and fine subangular blocky extremely hard, firm, common fine pores; thin clay films; common gypsum crystals; many soft masses of lime; noneffervescent between lime masses; strongly alkaline; gradual wavy boundary. (0 to 15 inches thick)

C1cs--16 to 35 inches; light brownish gray (2.5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; weak coarse prismatic structure separating to moderate medium and fine subangular blocky; extremely hard, firm; common fine pores; few masses of lime; common coarse and fine gypsum crystals; strong effervescence; strongly alkaline; gradual boundary. (10 to 25 inches thick)

C2--35 to 49 inches; olive gray (5Y 5/2) clay loam, olive (5Y 4/3) moist; weak fine and medium subangular blocky structure; extremely hard, firm; few large nests of gypsum crystals; common soft masses of lime; strong effervescence, strongly alkaline; clear wavy boundary. (10 to 25 inches thick)

Cr--49 to 60 inches; olive gray (5Y 5/2) soft massive silty clay shale; strong effervescence.

Type Location: Stark County, North Dakota; 380 feet south and 125 feet west of the NE corner of the SE1/4 of sec. 11, T. 140 N., R. 99 W.

Range in Characteristics: Depth to soft shale is over 40 inches. Some pedons have thin A1 horizons. The A1 and A2 horizons have a combined thickness of 1 to 5 inches. The A2 horizon has hue of 10YR, value of 4 through 6 and 2 through 5 moist, and chroma of 2 dry or moist. The A1 and A2 horizons are loam, silt loam or very fine sandy loam, fine sandy loam, silty clay loam, clay loam, or silty clay. The B2t horizon has hue of 10YR or 2.5Y, value of 3 through 5 and 2 or 3 moist, and chroma of 2 dry or moist. It is silty clay loam, clay loam, clay or silty clay averaging between 35 and 50 percent clay. It has coarse or medium columnar structure that separates to blocky in some pedons. It is firm or very firm. Clay films and organic stains are on faces of columns. Some pedons have B3cs horizons.

The C horizon has hue of 2.5Y or 5Y, value of 5 through 7 and 4 or 5 moist and chroma of 2 through 4 dry or moist. It commonly is clay loam, loam, silty clay loam, silty clay or clay. It has few to common salt crystals.

RHOADES SERIES--2

Competing Series: These are the Exline series in the same family and the Absher, Auger, Belfield, Daglum and Lennep series. Exline soils have A horizons with color chroma of 1 and have formed in lacustrine sediments. Absher soils lack mollic epipedons. Adger and Daglum soils lack visible gypsum crystals or nests within depths of 16 inches. Belfield and Lennep soils have tonguing or interfingering of A2 material extending over 2 inches into their natric horizons.

Geographic Setting: Rhoades soils are on nearly level to sloping upland plains, terraces and concave swales. Slope gradients commonly are 1 to 9 percent but range from 0 to 25 percent. The soils formed in stratified loamy and clayey materials derived from saline-alkali soft shales. Mean annual temperature ranges from 40 to 45^{o} F, and mean annual precipitation from 13 to 17 inches.

Geographically Associated Soils: The competing Belfield and Daglum soils are in complexes with Rhoades soils in many localities. Arnegard, Grail, Lawther, Morton, Regent and Vebar soils are on nearby swales, terraces and uplands. All lack the A2 horizons and B2t horizons that have strong columnar structure.

Drainage and Permeability: Moderately well and well drained. Runoff is slow or moderately rapid, depending upon slope. Permeability is very slow.

Use and Vegetation: Mostly in grassland used for range and pasture. Native vegetation is short and mid prairie grasses such as western wheatgrass, blue grama, sedges, and also some legumes, prickly pear and clubmoss. Some areas are cultivated mostly to small grains.

Distribution and Extent: Southwestern North Dakota, northwestern South Dakota, and eastern Montana. The soil is extensive.

Series Established: McKenzie County, North Dakota, 1932.

Remarks: The series, as presently defined, includes some soils formerly placed in the Moline and Wade series. Soils formerly included in the Rhoades series but now separated are in the Absher, Feckton, Belfield and Daglum series.

Additional Data: Type location lab sample number S61ND-45-6. Other lab samples S54SD-53-1, S54SD-53-2 and S61ND-45-8.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
6/6/80

SEARING SERIES

The Searing series consists of deep, well drained, moderately permeable soils that formed in material weathered from porcelanite over scattered porcelanite. These soils are on uplands and have slopes ranging from 1 to 15 percent. Mean annual temperature is 42° F, and mean annual precipitation is 15 inches.

Taxonomic Class: Fine-loamy over fragmental, mixed Typic Haploborolls.

Typical Pedon: Searing loam - cultivated. (Colors for dry soil unless otherwise stated.)

Ap--0 to 6 inches; brown (7.5YR 4/2) loam, dark brown (7.5YR 3/2) moist; weak medium subangular blocky and moderate medium and fine granular structure; slightly hard, friable; common roots, many fine pores; neutral; abrupt smooth boundary. (4 to 10 inches thick)

B21t--6 to 12 inches; dark reddish gray (5YR 4/2) loam, dark reddish brown (5YR 3/2) moist; moderate coarse prismatic structure parting to moderate coarse and medium angular blocky; hard, friable; common roots, many fine pores; many clay films of dark brown (7.5YR 3/2) moist; neutral; clear wavy boundary.

B22--12 to 16 inches; reddish brown (5YR 4/3) loam, dark reddish brown (5YR 3/3) moist; weak coarse prismatic structure parting to moderate coarse and medium angular blocky; hard, friable; common fine roots and pores; a few porcelanite chips; mildly alkaline; clear wavy boundary. (B2 horizon is 6 to 16 inches thick)

C1--16 to 23 inches; reddish yellow (5YR 6/6) loam, yellowish red (5YR 4/6) moist; weak coarse and medium subangular blocky structure; slightly hard, friable; few roots; common fine pores; 10 percent porcelanite chips; strong effervescence; moderately alkaline. (4 to 15 inches thick)

C2--23 to 28 inches; reddish yellow (5YR 6/6) channery loam, yellowish red (5YR 5/6) moist; weak fine subangular blocky structure; slightly hard, friable; about 50 percent partly weathered hard porcelanite chips; strong effervescence; moderately alkaline; clear wavy boundary. (0 to 5 inches thick)

C3--28 to 60 inches; yellowish red (5YR 5/6) shattered hard beds of platy porcelanite and clinkers with some sandy material between the layers; strong effervescence.

Type Location: Bowman County, North Dakota; about 1/4 mile north of Gasgoyne; 805 feet east and 2,595 feet north of the SW corner of sec. 33, T. 131 N., R. 99 W.

Range in Characteristics: The thickness of solum and depth to free carbonates ranges from 10 to 24 inches and depth to shattered reddish clinker or porcelanite ranges from 20 to 40 inches. Porcelanite, as sand grains or channery fragments, is mixed throughout the solum in some pedons.

The A horizon has hue of 5YR, 7.5YR, or 10YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It is loam, silt loam, or clay loam.

The B horizon has hue of 5YR, 7.5YR, or 10YR, value of 4 to 6 and 3 or 4 moist, and chroma of 2 to 4. It is a loam, silt loam, or clay loam averaging between 18 and 30 percent clay. It has weak to strong prismatic structure that parts to moderate or strong blocky structure. There is only a slight clay increase in the B horizon. Clay films are lacking in some pedons. Pedons formed in noncalcareous porcelanite beds, are low in lime but are included in the range of the series.

The upper C horizon is loam or clay loam with 5 to 30 percent porcelanite coarse fragments.

The lower C horizon is shattered porcelanite with some sandy material on flat surfaces. White lime coatings are on surfaces in some pedons.

SEARING SERIES--2

Competing Series: There are no other soils in this family. Similar soils are the Brandenburg, Ringling, Stady, and Twin Creek. Brandenburg and Ringling soils have porcelanite at a depth of less than 20 inches. Stady soils have gravel and sand at depths of 20 to 40 inches. Twin Creek soils formed in alluvium from red sandstone and shale and, in addition, lack fragmental material within depths of 40 inches.

Geographic Setting: Searing soils are on nearly level to rolling uplands with slope gradients of 1 to 15 percent. The soil formed in sedimentary material weathered in place on porcelanite or clinkers from burned-out coal veins. The climate is cool, semiarid, with mean annual temperature of 38^{o} to 45^{o} F, and mean annual precipitation of 13 to 17 inches. Three-fourths of the moisture falls in the spring and summer.

Geographically Associated Soils: These are the Brandenburg, Flasher, Ringling, and Yawdim soils on the steep slopes and hills; Amor, Morton, Sen, Regent, and Vebar soils on nearby sloping areas and the Grail, Arnegard, Shambo, and Farland on nearly level swales and terraces. The noncompeting Amor, Flasher, Morton, Sen, Regent, Vebar, and Yawdim soils do not have fragmental material at a depth of 20 to 40 inches.

Drainage and Permeability: Well drained. Runoff is medium. Permeability is moderate.

Use and Vegetation: Use for small grains, some row crops, hay, and range. Native vegetation: Medium and short prairie grasses, such as western wheatgrass, green needlegrass, blue grama, and some forbs.

Distribution and Extent: Widely distributed in small tracts in the sedimentary plains of western North Dakota, eastern Montana, and Wyoming. The series is of moderate extent.

Remarks: The Searing series was formerly classified fine-loamy, mixed Typic Haploborolls.

Series Established: Sheridan County, Wyoming, 1932.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. KWT-SRB
5/13/76

SEN SERIES

The Sen series is a fine-silty, mixed Typic Haploborolls. Typically, Sen soils have grayish brown silt loam Ap horizons, grayish brown and light yellowish brown friable silt loam B2 horizons, pale yellow and white silt loam Cca horizons and soft sedimentary beds at depths of about 34 inches.

<u>Typical Pedon</u>: Sen silt loam - on a northeast facing slope of 4 percent in a cultivated field. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 6 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate medium granular structure; slightly hard, friable, slightly sticky, nonplastic; common roots; neutral; abrupt smooth boundary. (5 to 8 inches thick)

B21--6 to 10 inches; grayish brown (10YR 5/2) silt loam, very dark grayish brown (10YR 3/2) moist; weak coarse prismatic structure parting to moderate coarse and medium subangular blocky; slightly hard, friable, slightly sticky, nonplastic; common roots; neutral; clear wavy boundary.

B22--10 to 17 inches; light yellowish brown (2.5Y 6/3) silt loam, olive brown (2.5Y 4/3) moist; moderate coarse prismatic structure parting to moderate medium subangular blocky; slightly hard, friable, sticky, slightly plastic; common roots; mildly alkaline; clear wavy boundary. (Combined thickness of B2 8 to 16 inches)

C1ca--17 to 23 inches; pale yellow (2.5Y 7/3) silt loam, light olive brown (2.5Y 5/4) moist; weak coarse prismatic structure parting to moderate, medium subangular blocky; slightly hard, friable, sticky, slightly plastic; common roots; medium-sized rounded soft masses of lime; violent effervescence; mildly alkaline; clear wavy boundary.

C2ca--23 to 34 inches; white (2.5Y 8/2) silt loam, light yellowish brown (2.5Y 6/4) moist; weak medium subangular blocky structure; slightly hard, friable, sticky, slightly plastic; common roots; many small iron concretions; strong effervescence; moderately alkaline; clear wavy boundary. (Combined thickness of C1 & C2 horizons 5 to 20 inches)

C3--34 to 39 inches; pale yellow (5Y 7/3) soft beds that crush to loam, pale olive (5Y 6/3) moist; weak coarse platy structure; soft, friable, slightly sticky; slight effervescence; moderately alkaline; abrupt smooth boundary. (0 to 15 inches thick)

C4--39 to 60 inches; pale olive (5Y 6/3) stratified soft beds that crush to loam and fine sandy loam, light yellowish brown (2.5Y 6/4) moist; massive; soft, very friable; very slight effervescence; moderately alkaline.

<u>Type Location</u>: Slope County, North Dakota; about 3½ miles north of West Rainey Butte; 180 feet west and 650 feet south of the northeast corner of the SE¼ of Sec. 36, T. 139 N., R. 99 W.

<u>Range in Characteristics</u>: The depth to soft bedrock typically is 30 to 40 inches, but ranges from 20 to 40 inches. The soil ranges from neutral in the upper horizons to strongly alkaline in the lower horizons. Depth to carbonates ranges from 10 to 20 inches. The 10- to 40-inch control section averages between 18 and 35 percent clay and less than 15 percent fine and coarser sand. The <u>A horizon</u> has hue of 10YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3 dry or moist. It is loam, silt loam, or silty clay loam. The <u>B2 horizon</u> has hue of 10YR or 2.5Y, value of 4 through 6 and 3 through 5 moist, and chroma of 2 through 4 dry or moist. It typically is silt loam, but some is loam or silty clay loam. It has weak or moderate prismatic structure that parts to weak or moderate, medium or coarse subangular blocky structure. Some pedons have <u>B3 horizons</u> with hue of 2.5Y or 10YR, value of 6 or 7 and 4 through 6 moist, and chroma of 2 through 4 dry or moist. It is silt loam, loam or silty clay loam. It has weak or moderate prismatic or blocky structures. It has slight to strong effervescence. The <u>Cca horizon</u> has hue of 2.5Y, value of 5 through 8 and 4 through 6 moist, and chroma of 2 through 4 dry or moist. It typically is silt loam or silty clay loam, but some is loam. Lime is both diffused and in soft accumulations. The Cca horizon contains 10 to 30 percent calcium carbonate equivalent. The underlying beds are soft massive or platy siltstone or silty shale.

SEN SERIES--2

Competing Series and Their Differentiae: These are the Bryant, Peritsa, and Temvik series in the same family and the Amor, Andes, Arnegard, Azaar, Boxwell, Chama, Farland, Floweree, Grassna, Morton, Ralph, Reeder, and Shambo series. Bryant, Peritsa and Temvik soils all lack siltstone within depths of 40 inches. Amor, Reeder, and Shambo soils are fine-loamy. In addition, Reeder soils have argillic horizons, and Shambo soils lack sedimentary beds within depths of 40 inches. Andes soils lack B2 horizons. Arnegard and Grassna soils have mollic epipedons more than 16 inches thick. Azaar soils have hard indurated sandstone at depths of 20 to 40 inches and are fine-loamy. Boxwell soils are usually dry and are fine-loamy. Chama soils contain lime within depths of 10 inches and contain over 15 percent lime in the B horizon. Morton and Farland soils have argillic horizons. In addition, the Farland soils lack siltstone within depths of 40 inches. Floweree soils are usually dry and lack siltstone within depths of 40 inches. Ralph soils are usually dry and have argillic horizons.

Setting: Sen soils are nearly level to rolling on upland plains. Slope gradients commonly are 3 to 8 percent, but range from 1 to 15 percent. The soils formed in calcareous siltstone. The climate is cool, semiarid. Mean annual temperature ranges from about 38° F. to 45° F., and mean annual precipitation from 14 to 17 inches. Most of the precipitation comes in the spring and summer.

Principal Associated Soils: These are the competing Amor, Chama, Farland, Grassna, and Morton soils and the Cabba, Grail, and Savage soils. Amor soils are on nearby upland plains where the bedrock contains more sand. Chama soils are on convex areas in the same landscape as the Sen soils. Farland soils are on nearly level terraces. Grassna soils are in concave swales and on footslopes. Morton soils are on well drained uplands and are in complex with Sen soils in some places. Cabba soils are on the crests of hills and steep side slopes. They lack B horizons and have siltstone within depths of 20 inches. Grail soils are in concave swales and fans and Savage soils are on nearly level terraces. Both soils contain more than 35 percent clay and have argillic horizons.

Drainage and Permeability: Well drained. Runoff is slow, medium or rapid. Permeability is moderate.

Use and Vegetation: Soils are cropped to small grains in a crop-summerfallow rotation. Native vegetation is mid and short prairie grasses as green needlegrass, needleandthread, western wheatgrass, blue grama, and a variety of forbs.

Distribution and Extent: Western North Dakota, northwestern South Dakota, and possibly eastern Montana. The series is of moderate extent.

Series Established: Burleigh County, North Dakota, 11/19/71.

Remarks: The Sen soils would have been classified as Chestnut soil in the former system.

Additional Data: Typifying pedon laboratory data No. SU70ND-44-2. Other data, S58ND-17-1 and S59ND-17-1 in Soil Survey Investigations Report No. 2.

National Cooperative Soil Survey
U. S. A.

Established Series
Rev. COC/SHB
11/76

STRAW SERIES

The Straw series consists of deep, well drained soils that formed in mixed alluvium. Straw soils are nearly level to moderately sloping and are on low terraces, alluvial fans and floodplains. The mean annual precipitation is about 16 inches and the mean annual air temperature is about 43°F.

Taxonomic Class: Fine-loamy, mixed Cumulic Haploborolls.

Typical Pedon: Straw loam, cultivated. (Colors are for dry soil unless otherwise noted.)

Ap--0 to 10 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; moderate fine crumb structure; slightly hard, very friable, slightly sticky and slightly plastic; many fine and few medium roots; many fine and medium pores; slightly effervescent; mildly alkaline (pH 7.6); clear wavy boundary. (4 to 8 inches thick)

A12--10 to 27 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak coarse prismatic structure; slightly hard, very friable, slightly sticky and slightly plastic; common fine and very fine roots; many fine and very fine pores; strongly effervescent; moderately alkaline (pH 8.0); diffuse boundary. (16 to 26 inches thick)

C1--27 to 38 inches; grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; massive; hard, very friable, slightly sticky and slightly plastic; few fine and very fine roots; many fine and very fine pores; few fine masses of segregated lime; strongly effervescent; moderately alkaline (pH 8.0); gradual wavy boundary.

C2--38 to 54 inches; light brownish gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) moist; massive; hard, very friable, slightly sticky and slightly plastic; few fine and very fine roots; common fine and very fine pores; strongly effervescent; moderately alkaline (pH 8.3); clear smooth boundary.

IIC3--54 to 66 inches; light brownish gray (10YR 6/2) loamy sand, dark grayish brown (10YR 4/2) moist; massive; soft, very friable, nonsticky and nonplastic; strongly effervescent; mildly alkaline (pH 7.6).

Type Location: Cascade County, Montana; 500 feet south and 100 feet west of NE corner of the SE1/4 of section 25, T.18N., R.6E.

Range in Characteristics: The mollic epipedon ranges from 16 to 40 inches thick. The 10- to 40-inch control section averages 20 to 35 percent clay. Some pedons have thin lenses of sandy loam and loamy sand at depths of less than 40 inches. The mean annual soil temperature is 40° to 46°F. The soil is usually calcareous throughout but some pedons are noncalcareous in the upper 7 inches. The hue of the soil is 10YR or 2.5Y.

The A horizon has value of 3 through 5 dry and 2 or 3 moist. It is loam, silt loam, clay loam or sandy clay loam. In some pedons, lime threads, films, and nodules are present in the lower part of the A12 horizon and in the C horizon. Some pedons have old buried A horizons in the underlying material. The C horizon has lenses of nonconforming texture in some pedons. Reaction is neutral to moderately alkaline in the A horizon and mildly or moderately alkaline in the C horizon.

Competing Series: These are the Brycan, Frolic, Jodero, McGaffey and Nutrioso series in the same family, and the Havrelon series. Brycan soils have a cambic horizon, are noncalcareous throughout the solum and have chroma of 3 through 6 in the B2 and C horizons. Frolic soils are noncalcareous. Havrelon soils lack a mollic epipedon. Jodero soils have a mollic epipedon more than 40 inches thick. McGaffey soils have hue of 5YR or redder. Nutrioso soils have a mollic epipedon less than 24 inches thick.

Geographic Setting: Straw soils are nearly level to moderately sloping and are on low terraces, alluvial fans and flood plains with rare or occasional flooding, and are at elevations of 2,500 to 4,500 feet. They formed in calcareous loamy alluvium from mixed rock sources. The climate is cool with a mean annual temperature of 40° to 46°F. The mean annual precipitation is 13 to 19 inches, most of which falls in spring or early summer. The (32°F.) growing season is 105 to 135 days.

Geographically Associated Soils: These are the Banks, Korchea, Nesda and Rivra soils and the competing Havrelon soils. All of these soils except Korchea lack mollic epipedons. Korchea soils have a mollic epipedon less than 16 inches thick.

Drainage and Permeability: Well drained; slow runoff; moderate permeability.

Use and Vegetation: Straw soils are used for dryland cropland, irrigated cropland and for range. The primary native vegetation is rough fescue, western wheatgrass, needleandthread, little bluestem, bluebunch wheatgrass, green needlegrass, forbs and shrubs.

Distribution and Extent: Eastern Montana and possibly in Wyoming and North Dakota. The series is of moderate extent.

Series Established: Judith Basin County, Montana, 1960.

National Cooperative Soil Survey
U. S. A.

Established Series
Rev. GBM
6/28/79

VEBAR SERIES

The Vebar series consists of well drained, moderately rapidly permeable soils that formed in residuum weathered from soft calcareous sandstone. Depth to soft standstone ranges from 20 to 40 inches. These soils are on uplands and have slopes ranging from 0 to 50 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Coarse-loamy, mixed Typic Haploborolls.

Typical Pedon: Vebar fine sandy loam - on a SW facing plane slope of 5 percent in native grassland. (Colors are for dry soil unless otherwise stated. Where described the soil was moist throughout.)

A1--0 to 5 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark brown (10YR 2/2) moist; weak coarse and medium prismatic structure parting to weak fine subangular blocky structure; slightly hard, very friable, slightly sticky, nonplastic; many roots and fine pores; slightly acid; gradual wavy boundary. (4 to 10 inches thick)

B21--5 to 14 inches; dark grayish brown (10YR 4/2) fine sandy loam, dark brown (10YR 3/3) moist; moderate coarse prismatic structure parting to weak medium subangular blocky structure; slightly hard, very friable, slightly sticky, nonplastic; many fine roots and pores; slightly acid; gradual wavy boundary. (4 to 12 inches thick)

B22--14 to 19 inches; brown (10YR 5/3) fine sandy loam, brown (10YR 4/3) moist; moderate coarse prismatic structure parting to weak medium and fine subangular blocky structure; slightly hard, very friable, slightly sticky, nonplastic; common fine roots and pores; neutral; clear wavy boundary. (0 to 10 inches thick)

B3--19 to 26 inches; brown (10YR 5/3) fine sandy loam, brown (10YR 4/3) moist; weak coarse prismatic structure; slightly hard, very friable, nonsticky, nonplastic; few roots, common fine pores; neutral; clear, very wavy boundary. (0 to 12 inches thick)

C--26 to 32 inches; light yellowish brown (2.5Y 6/4) fine sandy loam, light olive brown (2.5Y 5/4) moist; massive; slightly hard, very friable, nonsticky, nonplastic; few hard sandstone fragments; few small sandstone fragments; few small lime accumulations; strong effervescence (2 percent lime); mildly alkaline; clear wavy boundary. (2 to 10 inches thick)

Cr--32 to 60 inches; light yellowish brown (2.5Y 6/4) soft massive calcareous sandstone; lense of hard sandstone 3 inches thick at 43 inches; some lime accumulations around hard fragments; strong effervescence (6 percent lime) in upper part; slight effervescence in lower part (1 percent lime); moderately alkaline.

Type Location: Stark County, North Dakota; about 6 miles south and 5 1/2 miles east of Dickinson; 355 feet south and 70 feet east of the NW corner of the NE quarter of sec. 16, T. 138 N., R. 95 W.

Range in Characteristics: Solum thickness typically is about 26 inches and ranges between 15 and 40 inches. Depth to soft sandstone ranges from 20 to 40 inches. The mollic epipedon ranges from 7 to 16 inches in thickness. In most pedons the soft sandstone contains free carbonates. Some pedons have an accumulation of lime at the bottom of the solum or the upper part of the sandstone.

The A1 horizon has hue of 10YR, value of 3 to 5 and 2 or 3 moist, and chroma of 2 or 3 dry or moist. It typically is fine sandy loam, but some is sandy loam or light loam. The A horizon ranges from slightly acid to mildly alkaline.

The B2 horizon has hue of 10YR or 2.5Y, value of 4 to 6 and 3 or 4 moist, and chroma of 2 to 4 dry or moist. It typically is fine sandy loam, but some is sandy loam or light loam. The B horizon has weak or moderate coarse or medium prismatic structure that parts easily to weak or moderate subangular blocky structure. It is slightly acid to mildly alkaline in the upper part and neutral to moderately alkaline in the lower part.

VEBAR SERIES--2

The C horizon has hue of 10YR, 2.5Y or 5Y, value of 5 to 7 and 4 to 6 moist, and chroma of 2 to 4 dry or moist. Typically it is fine sandy loam or loamy fine sand, but some is sandy loam. The soft sandstone crushes to loamy fine sand or fine sandy loam. Thin ledges or concretion-like pipes of hard sandstone are in some pedons.

Competing Series: These are the Belain, Bitterroot, Hopley, Mott, Panguitch, Relan, Tally, and Victor series in the same family and Cohagen, Lihen, Manning, Parshall, Rhame, Telfer, and Velva series. Bitterroot and Hopley soils are dominately loam in the series control section. Belain soils have a lithic contact of depth of 20 to 40 inches. Mott, Panguitch, Tally and Victor soils lack paralithic beds between depths of 20 and 40 inches. In addition, Panguitch soils contain 20 to 35 percent by volume of coarse fragments and are formed in alluvium derived from volcanic materials; and the Victor soils have a sandy-skeletal substrata at depths of about 40 inches. Relan soils have hue of 7.5YR or redder throughout the series control section. Cohagen soils lack mollic epipedons and have paralithic beds at depths of less than 20 inches. Lihen, Manning, Parshall, Telfer and Velva soils lack paralithic beds between depths of 20 and 40 inches. In addition, the Lihen and Parshall soils have mollic epipedons more than 16 inches thick; and Telfer soils are sandy and the Velva soils have an irregular decrease in organic matter content; and Manning soils have sand and gravel at depths of 16 to 40 inches. Rhame soils are usually dry.

Geographic Setting: Vebar soils are on nearly level to rolling uplands. Slopes are plain or convex. Slope gradients range from 0 to 50 percent. The soils formed in residuum weathered from soft calcareous sandstone. The climate is cool and semiarid. Mean annual temperature ranges from 38 to 45° F and mean annual precipitation from 14 to 17 inches. Most of the precipitation comes in the spring and summer.

Geographically Associated Soils: These are the competing Cohagen, Parshall and Tally soils and the Armor, Arnegard, Flasher, Morton, Sen and Shambo soils. Cohagen soils are on steep hilltops and ridges. Parshall and Tally soils are on concave swales, terraces, and less sloping areas. Amor, Arnegard, Morton, Sen and Shambo soils contain more clay and silt and less sand than the Vebar soils. They are on nearby uplands, swales, and terraces. Flasher soils have paralithic beds at depths of less than 20 inches and have sandy textures. They are on nearby hilltops and ridges.

Drainage and Permeability: Well drained. Surface is slow or medium. Permeability is moderately rapid above paralithic beds.

Use and Vegetation: Soils are cropped to corn and small grains. Some is used for hay or pasture. Native grasses are needleandthread, prairie sandreed, prairie junegrass and sun sedge.

Distribution and Extent: Western North Dakota, eastern Montana, northwestern South Dakota, and western Nebraska. The series is extensive.

Series Established: Wibaux County, Montana, 1943.

Additional Data: S 54NDak-45-2, pages 258 and 259, Soil Survey Investigations No. 2.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. LCB-GBM
2/14/80

TEMVIK SERIES

The Temvik series consists of deep, well drained, moderately slowly permeable soils that formed in a silty mantle overlying glacial till. These soils are on upland plains and have slopes of 1 to 15 percent. Mean annual temperature is 42° F, and mean annual precipitation is 16 inches.

Taxonomic Class: Fine-silty, mixed Typic Haploborolls.

Typical Pedon: Temvik silt loam - near the crest of a convex north facing 1 percent slope in a cultivated field. (Colors are for dry soil unless otherwise stated. Where described the soil was moist throughout.)

Ap--0 to 7 inches; dark grayish brown (10YR 4/2) silt loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky and weak fine granular structure; slightly hard, very friable, slightly sticky, slightly plastic; many roots; many very fine pores; neutral; abrupt smooth boundary. (Ap and A1 horizons 5 to 13 inches thick.)

B21--7 to 11 inches; dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; moderate coarse prismatic structure parting to moderate medium prismatic and weak medium subangular blocky; slightly hard, very friable, slightly sticky, slightly plastic; many roots; many pores; thin clay films on vertical faces and common thin clay films on horizontal faces of peds; few thin tongues of Ap extend into this horizon; neutral; gradual wavy boundary.

B22--11 to 20 inches; brown (10YR 5/3) silt loam, dark brown (10YR 4/3) moist; moderate coarse and medium prismatic structure parting to moderate coarse and medium subangular blocky; slightly hard, very friable, slightly sticky, slightly plastic; common roots; common fine pores; thin clay films on faces of peds; neutral; clear wavy boundary. (Combined B2 horizons 10 to 24 inches thick.)

B3--20 to 24 inches; pale brown (10YR 6/3) silt loam, brown (10YR 4/3) moist; weak coarse prismatic structure parting to moderate medium subangular blocky; slightly hard, very friable, slightly sticky, slightly plastic; few roots; common fine pores; few pebbles and stones at the base of this horizon; neutral; clear wavy boundary. (0 to 9 inches thick)

IIC1ca--24 to 36 inches; light brownish gray (2.5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; common fine distinct yellowish brown (10YR 5/4) mottles; weak coarse prismatic structure parting to weak coarse and medium subangular blocky; hard, friable, sticky, plastic; about 3 percent gravel; many medium and few large soft masses of lime; strong effervescence; moderately alkaline; gradual wavy boundary.

IIC2ca--36 to 44 inches; light olive gray (5Y 6/2) clay loam, olive brown (2.5Y 4/4) moist; few small prominent strong brown (7.5YR 5/6) mottles; weak coarse and fine subangular blocky structure; hard, friable, sticky, plastic; about 3 percent gravel; common masses of lime; strong effervescence; moderately alkaline; gradual boundary. (Combined Cca is 12 to 24 inches thick.)

IIC3--44 to 60 inches; light olive gray (5Y 6/2) clay loam, olive gray (5Y 5/2) moist; weak subangular blocky structure; hard, firm, sticky, plastic; about 3 percent gravel; few small soft masses of lime; strong effervescence; moderately alkaline.

Type Location: Emmons County, North Dakota; about 1/2 mile north of Hazelton; 280 feet east and 2,605 feet north of the SW corner of sec. 20, T. 135 N., R. 76 W.

Range in Characteristics: The solum typically is about 24 inches thick and ranges between 16 and 34 inches. The silty material is 20 to 40 inches thick over the underlying glacial till. This silty material contains between 18 and about 28 percent clay. The soil ranges from neutral in the upper horizons to strongly alkaline in the lower horizons. The mollic epipedon ranges from 7 to 16 inches in thickness.

The A horizon has hue of 10YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3 dry or moist. It typically is silt loam and less commonly light silty clay loam, loam, or light clay loam and contains between 10 and 30 percent very fine sand.

The B2 horizon has hue of 10YR or 2.5Y, value of 4 through 6 and 3 or 4 moist, and chroma of 2 through 4 dry or moist. It typically is silt loam and less commonly light silty clay loam, loam, or light clay loam and contains between 10 and 30 percent very fine sand. The lower part of the B2 horizon and the B3 horizon extends into the underlying glacial till in some pedons. Some pedons have B3ca horizons.

The IICca horizon has hue of 2.5Y or 5Y, value of 5 through 7 dry and 4 through 6 moist, and chroma of 2 through 4 dry or moist. It is clay loam or heavy loam. It has few through many soft masses of segregated lime and contains from 4 to 20 percent calcium carbonate equivalent.

The lower IIC horizon has hue of 2.5Y or 5Y, value of 4 through 7 and 4 through 6 moist, and chroma of 2 through 4 dry or moist. It is heavy loam or clay loam glacial till containing 2 to 8 percent coarse fragments. Soft bedded sandstone, siltstone, or shale is below depths of 40 inches in some pedons.

Competing Series: These are the Bryant, Chama, Golva, Omio, Peritsa, and Sen series in the same family and the Agar, Eakin, Farland, Grassna, Linton, Lowry, Max, Williams, and Wilton series. Bryant soils formed entirely in glacial drift and contain more sand in the upper part of the solum. Chama and Golva soils have calcic horizons and lack glacial till IIC horizons. Omio and Sen soils have soft siltstone bedrock within depths of 40 inches. Peritsa soils contain free carbonates within depths of 14 inches or less and have hue of 5YR or redder throughout the soil. Agar, Eakin, and Lowry soils have mesic temperatures. Farland soils have argillic horizons and silty sediments to depths of 40 inches or more. Grassna soils have mollic epipedons commonly 24 inches or more tbick. Linton soils are coarse-silty. Max and Williams soils are fine-loamy. In

TEMVIK SERIES—2

addition, Williams soils have argillic horizons. Wilton soils are pachic.

Geographic Setting: Temvik soils are on nearly level to rolling upland plains. Slopes are dominantly smooth plane or convex. Slope gradients typically are 1 to 5 percent but range to 15 percent. The soil formed in a silty mantle overlying loam or clay loam glacial till. Mean annual temperature ranges from 38° to 45° F and mean annual precipitation from 15 to 18 inches.

Geographically Associated Soils: These are the competing Grassna, Linton, and Williams soils and the Mandan soils. Grassna soils are in concave swales. Linton soils are formed where the silty deposits are more than 40 inches thick. Williams soils are on adjacent glacial till plains and typically on higher lying parts of the landscape. The associated Mandan soils have mollic epipedons more than 16 inches thick and contain less than 18 percent clay throughout the series control section. They are in concave swales.

Drainage and Permeability: Well drained; surface runoff is moderate or moderately rapid. Permeability is moderate in the upper part of the profile and moderately slow in the IIC horizons.

Use and Vegetation: Soils are commonly cropped to flax, small grains, and corn. Some areas are used for hay and pasture. Native vegetation is green needlegrass, needleandthread, western wheatgrass, blue grama, upland sedges, and forbs.

Distribution and Extent: Central North Dakota and north-central South Dakota adjacent to the Missouri River. The series is of large extent.

Series Established: Burleigh County, North Dakota, 1971.

Remarks: The silty mantle is thinner than typical for the range of the series and thus there is more sand in the 10- to 40-inch control section than normal for the series.

Additional Data: S54NDak-15-1 and S54NDak-15-2 published in Soil Survey Investigations Report No. 2.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
12/8/78

WILLIAMS SERIES

The Williams series consists of deep, well drained, moderately slow or slowly permeable soils formed in calcareous glacial till. These soils are on glacial till plains and have slopes of 0 to 35 percent. Mean annual temperature is about 40° F, and mean annual precipitation is about 14 inches.

Taxonomic Class: Fine-loamy, mixed Typic Argiborolls.

Typical Pedon: Williams loam - cultivated. (Colors are for dry soil unless otherwise stated.)

Ap--0 to 6 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky structure parting to moderate fine granular; very friable; many roots; many fine pores; few pebbles; neutral; abrupt smooth boundary. (4 to 9 inches thick)

B21t--6 to 10 inches; brown (10YR 4/3) clay loam, dark brown (10YR 3/3) moist; strong medium prismatic structure parting to strong medium and fine angular blocky; friable, sticky; many roots; many fine pores; many very dark brown and very dark grayish brown (10YR 2/2 and 10YR 3/2) moist clay films on faces of peds and surfaces of pores; few pebbles; neutral; clear wavy boundary.

B22t--10 to 15 inches; grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; moderate medium prismatic structure parting to strong medium subangular blocky; friable; common roots; few coarse and few fine pores; many very dark grayish brown (10YR 3/2) moist clay films on faces of peds and surfaces of pores; clay films decrease in amount and thickness with increasing depth; mildly alkaline; clear wavy boundary. (Combined B2t horizons 5 to 20 inches thick)

B3ca--15 to 24 inches; light olive brown (2.5Y 5/4) light clay loam, olive brown (2.5Y 4/4) moist; moderate coarse prismatic structure parting to moderate medium and fine subangular blocky; friable; few roots; common fine pores; few dark grayish brown (10YR 4/2) moist clay films; few pebbles coated with lime on under sides; few soft masses of lime; strong effervescence; mildly alkaline; gradual wavy boundary. (0 to 15 inches thick)

C1ca--24 to 36 inches; light olive brown (2.5Y 5/4) and light gray (2.5Y 7/2) loam, olive brown (2.5Y 4/4) moist; weak coarse prismatic structure parting to weak medium subangular blocky; friable; few roots; few cobbles and one large boulder at 36 inches; many soft masses of lime; violent effervescence; moderately alkaline; gradual wavy boundary. (3 to 20 inches thick)

C2--36 to 60 inches; light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; few prominent yellowish brown (10YR 5/6) and light gray (10YR 7/2) mottles; weak medium and fine subangular blocky structure; friable in upper part and gradually becoming firm at 60 inches; few fine roots; few pores; few pebbles and cobbles; strong effervescence; moderately alkaline.

Type Location: Mountrail County, North Dakota; about 11 miles north and 4 miles west of White Earth; 1,050 feet east and 60 feet south of the NW corner of sec. 5, T. 158 N., R. 94 W.

Range in Characteristics: Solum thickness and depth to free carbonates ranges from 10 to 30 inches. The soil typically contains 1 to 10 percent rock fragments but ranges up to 20 percent. The A horizon has 10YR hue, value of 3 through 5 and 2 or 3 moist and chroma of 2. Some pedons in native grassland have a moist chroma of less than 1.5 in the upper 1 to 3 inches. It typically is loam but some is clay loam, sandy loam, fine sandy loam, or silt loam. The B horizon has 10YR or 2.5Y hue, value of 4 through 6 and 3 through 5 moist, and chroma of 2 or 3. It is loam or clay loam and contains 24 to 35 percent clay. It has strong or moderate, medium or coarse prismatic structure that parts to strong or moderate, medium or fine angular or subangular blocky structure. The Cca horizon has disseminated and segregated lime in the form of soft masses. The C horizon has 2.5Y or 5Y hue, value of 5 through 8 and 3 through 6 moist, and chroma of 2 through 4. It is loam or clay loam.

WILLIAMS SERIES—2

Competing Series: These are the Adiv, Daniels, Dooley, Empedrado, Fairfield, Farnuf, Felor, Lefor, Livona, Martinsdale, Moen, Reeder, Roundley, Trag, Vida, Watrous, Wemple, and Yegen series in the same family and the Barnes, Bowbells, Joplin, Kevin, Max, and Yeoman series. Adiv soils have formed in alluvium and have argillic horizons within depths of 2 to 4 inches. Daniels and Martinsdale soils have formed in alluvium and have IIC and IIIC horizons. Dooley soils have formed in alluvial or eolian sediments over glacial till and have sandy clay loam B2t horizons. Empedrado soils have formed in igneous material on uplands and fans and commonly have thicker sola. Fairfield soils have formed in alluvium and are less than 10 inches deep to the base of the argillic horizons. Farnuf soils have formed in alluvium and commonly are more alkaline. Felor soils formed in loamy sediments overlying clayeey sediments. Lefor, Reeder and Roundley soils have a paralithic contact within depths of 20 to 40 inches. Livona soils have formed in eolian sediments over glacial till. Moen and Watrous soils have lithic contact within depths of 20 to 40 inches. Trag soils lack horizons of carbonate accumulations. Vida soils have formed in till and are less than 10 inches deep to the base of the argillic horizon. Wemple soils have formed in alluvium and are underlain with material high in volcanic ash. Yegen soils have formed in uplands and fans and have sandy clay loam B2t horizons. Barnes, Max, and Yeoman soils lack argillic horizons. Bowbells soils are pachic. Joplin and Kevin soils are drier.

Geographic Setting: Williams soils are on nearly level to steep slopes of glacial till plains. Slopes commonly are less than 9 percent but range from 0 to 35 percent. The soils formed in calcareous glacial till of mixed minerology. Mean annual temperature ranges from 38° to 45°F and mean annual precipitation from 13 to 17 inches.

Geographically Associated Soils: These are the competing Bowbells and Max soils and the Arnegard, Hamerly, Niobell, Noonan, Parnell, Tonka, and Zahl soils. Bowbells soils are on nearby nearly level concave swales. Max soils are on nearby more convex slopes. Arnegard soils are pachic and are on nearby concave swales. Hamerly soils are somewhat poorly drained and have calcic horizons within depths of 16 inches. They are associated with Williams soils in some areas. Niobell and Noonan soils have natric horizons and are in complex with Williams soils in some areas. Tonka and Parnell soils are poorly and very poorly drained and are in nearby basins. Zahl soils have a thinner sola and lack argillic horizons. They are on nearby steeper convex slopes.

Drainage and Permeability: Well drained. Medium or rapid runoff. Permeability is moderately slow or slow.

Use and Vegetation: Cultivated areas are used for growing small grains, flax, corn, hay, or pasture. Native vegetation is western wheatgrass, needleandthread, blue grama, green needlegrass, and prairie junegrass.

Distribution and Extent: North-central South Dakota, central and northwestern North Dakota, and northeastern Montana. The soil is extensive.

Series Established: Williams County, North Dakota, 1906.

Additional Data: See data in Soil Survey Investigation Report No. 2.

National Cooperative Soil Survey
U.S.A.

Established Series
Rev. GBM
11/16/78

ZAHL SERIES

The Zahl series consists of deep, well drained, moderately slow or slowly permeable soils that formed in calcareous glacial till. These soils are on glacial till plains, moraines and valley sideslopes and have slopes of 1 to 35 percent. Mean annual temperature is 40° F, and mean annual precipitation is 14 inches.

Taxonomic Class: Fine-loamy, mixed Entic Haploborolls.

Typical Pedon: Zahl loam - native grassland. (Colors are for dry soil unless otherwise stated.)

A1--0 to 5 inches; dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; weak medium subangular blocky structure parting to weak medium granular; friable; many roots; many fine pores; strong effervescence; mildly alkaline; clear wavy boundary. (4 to 8 inches thick)

C1ca--5 to 20 inches; light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak medium and fine subangular blocky structure; friable; common roots; many fine pores; few small stones; many soft masses of lime; violent effeverscence; moderately alkaline; gradual wavy boundary. (8 to 20 inches thick)

C2--20 to 60 inches; light yellowish brown and light olive brown (2.5Y 6/4 and 2.5Y 5/4) clay loam, olive brown and light olive brown (2.5Y 4/4 and 2.5Y 5/4) moist; common faint and distinct mottles and streaks of olive gray and gray (5Y 5/2 and 5Y 5/0) moist; laminar parting to weak medium and fine subangular blocky structure; friable; few roots to depth of 40 inches; few stones; strong effervescence; moderately alkaline.

Type Location: Mountrail County, North Dakota; about 7 miles east and 1 mile north of Stanley; 305 feet west of the NE corner of the NW1/4 of sec. 14, T. 156 N., R. 90 W. on south side of road right-of-way fence.

Range in Characteristics: The 10- to 40-inch control section is loam or clay loam averaging between 20 and 30 percent clay, 20 to 40 percent fine and coarser sand and 1 to 10 percent pebbles and stones. The A horizon has hue of 10YR or 2.5Y, value of 3 through 5 and 2 or 3 moist, and chroma of 2. However, some pedons have a thin A1 horizon with a chroma of 1. The A horizon is loam or clay loam. It is gravelly in some pedons. Some pedons have AC horizons. The C horizon has hue of 2.5Y or 5Y, value of 5 through 7 and 4 through 6 moist, and chroma of 2 through 4. Some pedons have bedded shale below depths of 40 inches.

Competing Series: These are the Barvon series in the family and the Arnegard, Buse, Esmond, Max, Williams and Zahill series. Barvon soils are 20 to 40 inches deep to sandstone or shale. Arnegard soils are pachic. Buse and Esmond soils have chromas of 1 in the upper 7 inches or more of the A horizon. Max soils have cambic horizons. Williams soils have argillic horizons. Zahill soils lack mollic epipedons.

Geographic Setting: Zahl soils are on nearly level to steep slopes of glacial till plains, moraines and valley sides. Slopes are commonly 6 to 15 percent but range from 1 to 35 percent. The soil formed in calcareous glacial till. Mean annual temperature is 38° to 45° F, and mean annual precipitation ranges from 12 to 16 inches.

Geographically Associated Soils: These are the competing Arnegard, Max and Williams soils and the Bowbells, Parnell and Tonka soils. Arnegard and Bowbells soils are on smooth slopes and concave positions. Bowbells soils are pachic. Max and Williams soils commonly are on more gentle slopes. Parnell and Tonka soils are in low basins and are poor and very poorly drained.

Drainage and Permeability: Well drained. Runoff is rapid. Permeability is moderately slow or slow.

Use and Vegetation: Used mainly for range and pasture. Some areas are cropped to small grains. Native vegetation is little bluestem, western wheatgrass and needleandthread.

ZAHL SERIES--2

Distribution and Extent: Central and northwestern North Dakota, north central South Dakota and northeastern Montana. The soil is extensive.

Series Established: Wibaux County, Montana, 1944.

Remarks: In some areas these soils are borderline Calciborolls.

Additional Data: Laboratory sample SU72ND-28-6 North Dakota Agricultural Experiment Station.

National Cooperative Soil Survey
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Established Series
Rev. SRB
4/19/76

WERNER SERIES

The Werner series is a loamy, mixed, shallow Entic Haploborolls. Typically, Werner soils have dark grayish brown loam A1 horizons, grayish brown friable loam AC horizons, light yellowish brown loam Cca horizons, and soft argillaceous sandstone and shale at a depth of about 17 inches.

Typical Pedon: Werner loam - on an east-northeast facing convex slope of 18 percent in native grass. (Colors are for dry soil unless otherwise stated. Where described, the soil was moist throughout.)

A1--0 to 6 inches; dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure parting to moderate very fine subangular blocky; hard, friable, slightly sticky, slightly plastic; many roots; many fine pores; few small stones; neutral; clear wavy boundary. (4 to 10 inches thick)

AC--6 to 13 inches; grayish brown (2.5Y 5/2) loam, very dark grayish brown (2.5Y 3/2) moist; weak medium prismatic structure parting to weak medium and fine subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; many roots; common fine pores; few small pebbles; few fine soft masses of carbonates; slight effervescence; mildly alkaline; clear wavy boundary. (3 to 7 inches thick)

C1ca--13 to 17 inches; light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; weak medium prismatic structure parting to weak fine subangular blocky structure; hard, friable, slightly sitcky, slightly plastic; common roots; few fine pores; few pebbles; common fine soft masses of carbonates; strong effervescence; moderately alkaline; clear wavy boundary. (0 to 5 inches thick)

C2r--17 to 30 inches; pale yellow (2.5Y 7/4) soft argillaceous sandstone; massive but fractures to plates; few roots in cracks; carbonate accumulations in cracks; slight effervescence; moderately alkaline; gradual boundary. (6 to 40 inches thick)

C3r--30 to 60 inches; light gray (5Y 7/2) soft shale and sandstone strata, olive gray (5Y 5/2) moist; light yellowish brown and yellow (10Y 6/4 and 2.5Y 7/6) on faces of plates and blocks; slight effervescence; moderately alkaline.

Type Location: Burleigh County, North Dakota; about 4½ miles north and 1 mile west of Bismarck; 1585 feet north and 150 feet west of the SE corner, Sec. 31, T. 140 N., R. 80 W.

Range in Characteristics: Depth to soft bedrock ranges from 7 to 20 inches. The solum contains as much as 5 percent fragments coarser than 2 mm and a few stones larger than 3 inches in diameter. The soil ranges from neutral in the upper horizons to strongly alkaline in the lower horizons. The A1 horizon has 10YR or 2.5Y hue, value of 4 or 5, and 2 or 3 moist and chroma of 2 or 3 dry or moist. It typically is loam but some is silt loam, clay loam, silty clay loam, very fine sandy loam, or sandy loam. It typically lacks free carbonates except where mixed by tillage. The AC horizon has 10YR or 2.5Y hue, value of 4 through 6 and 3 or 4 moist and chroma of 2 through 4 dry or moist. It is very fine sandy loam, silt loam, loam, or light clay loam and contains 1 to 10 percent calcium carbonate equivalent. Some of the carbonates are in soft masses on the faces of peds and around pores. The Cca horizon has 2.5Y hue, value of 5 through 7 and 4 or 5 moist, and chroma of 2 through 4 dry or moist. The underlying material is soft massive or platy fine grained sandstone or interbedded sandstone, siltstone, and shale.

Competing Series and Their Differentiae: There are no other series in the family. Other competing series are the Abac, Andes, Barvon, Cabba, Cohagen, Kloten, and Wayden series. Abac, Cabba, Cohagen, and Wayden soils all lack mollic epipedons. In addition, Cohagan soils are coarse-loamy. The Andes and Barvon soils have bedrock at depths of 20 to 40 inches. Wayden soils are clayey. Kloten soils have a lithic contact within 20 inches of the surface.

Setting: Werner soils are on nearly level to very steep convex ridge crests and side slopes of upland plains and sides of valleys. Slope gradients range 3 to 50 percent. The soils formed in residuum weathered from soft sandstone and shale. The climate is cool, semiarid.

WERNER SERIES--2

Mean annual temperature ranges from 38 to 45° F., and mean annual precipitation from 14 to 17 inches. Most of the precipitation comes in the spring and summer.

Principal Associated Soils: These are the competing Cabba, Cohagen, and Waden soils and the Amor, Max, Morton, Sen, Vebar, Williams, and Zahl soils. Cabba, Cohagen, and Waden soils are on similar landscapes as Werner. Amor, Morton, Sen, and Vebar soils are on smoother and typically less sloping parts of the landscape. Max, Williams, and Zahl soils are on nearby glaciated plains. All of the noncompeting soils are deeper.

Drainage and Permeability: Well drained; medium or rapid runoff; moderate permeability in the solum and moderately slow or slow in the C horizon.

Use and Vegetation: Used for range and pasture. A few areas are cultivated. Native vegetation is threadleaf sedge, blue grama, western wheatgrass, needleandthread, and a variety of forbs.

Distribution and Extent: Western North Dakota, northeastern Montana, and northwestern South Dakota. The soil is of moderate extent.

Series Established: Burleigh County, North Dakota, 1971.

Remarks: The Werner series would have been classified as Lithosols in the former system.

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Established Series
Rev. GBM
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REGENT SERIES

The Regent series consists of moderately deep, well drained, slowly permeable soils formed in residuum weathered from alkaline soft shales. These soils are on upland plains and have slopes of 2 to 25 percent. Mean annual temperature is 42^{o} F, and mean annual precipitations is 16 inches.

Taxonomic Class: Fine, montmorillonitic Typic Argiborolls.

Typical Pedon: Regent silty clay loam - cultivated. (Colors are for dry soil unless otherwise stated.)

A1--0 to 10 inches; dark grayish brown (10YR 4/2) silty clay loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky and moderate fine granular structure; firm, plastic; common fine roots; common fine pores; neutral; clear smooth boundary. (5 to 10 inches thick)

B21t--10 to 18 inches; grayish brown (2.5Y 5/2) silty clay, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure separating to strong fine angular blocky; firm, plastic; few roots; common fine pores; dark grayish brown (10YR 4/2) clay films on faces of peds; mildly alkaline; clear wavy boundary. (3 to 10 inches thick)

B22t--18 to 26 inches; light brownish gray (2.5Y 6/2) silty clay, olive brown (2.5Y 4/3) moist; weak coarse prismatic structure separating to moderate medium subangular blocky; firm, plastic; few roots; common very fine pores; thin clay films on faces of peds; few faint white masses of lime; mildly alkaline; gradual wavy boundary. (4 to 12 inches thick)

B3ca--26 to 39 inches; pale olive (5Y 6/3) silty clay loam, olive (5Y 5/3) moist; weak coarse prismatic structure separating to moderate medium subangular blocky; firm, plastic; few fine pores; common fine threads and few nodules of lime; strongly effervescent; moderately alkaline; clear wavy boundary. (0 to 22 inches thick)

Cr--39 to 62 inches; pale olive (5Y 6/3) soft platy shale; moderately alkaline.

Type Location: Stark County, North Dakota; northwest corner sec. 3, T. 139 N., R. 97 W.

Range in Characteristics: Depth to soft shale bedrock typically is 30 to 40 inches but ranges from 20 to 40 inches. The mollic epipedon ranges from 7 to 16 inches in thickness.

The A horizon has hue of 10YR or 2.5Y, value of 4 or 5, 2 or 3 moist, and chroma of 2 or 3 dry or moist. It is clay loam, silty clay loam or silty clay. Reaction is slightly acid or neutral.

The B2t horizon has hue of 10YR, 2.5Y or 5Y, value of 4 through 6, 2 through 4 moist, and chroma of 2 or 3 dry or moist. It is silty clay loam or silty clay and typically averaging between 35 and 50 percent clay. Reaction is mildly alkaline to strongly alkaline. Most pedons have lime accumulation in either the B3ca or Cca horizon. These horizons commonly contain less than 15 percent $CaCO_3$ equivalent.

The Cr horizon is soft alkaline shale which is stratified with silty layers in some pedons.

Competing Series: These are the Absarokee, Bearpaw, Danvers, Delsan, Mondamin, Savage and Work series in the same family and the Darret, Grail, Moreau, Morton, and Winifred series. The Absarokee soils have hard sandstone bedrock at depths of 20 to 40 inches. Bearpaw, Danvers, Delson, Mondamin, Savage and Work soils lack bedrock within depths of 40 inches. In addition, Davers, Delson and Work series formed in alluvium; Bearpaw formed in glacial till; Mondamin soils formed in glaciolacustrine sediments; and Savage soils formed in alluvium and loess. Darret soils have redder hue and mixed mineralogy. Grail soils have mollic epipedons over 16 inches thick and have formed in alluvium. Moreau and Winifred soils lack argillic horizons. Morton soils are fine-silty.

Geographic Setting: Regent soils are on long and plane or slightly convex slopes of upland plains. The slope gradients commonly are 2 to 4 percent but range to 25 percent. The soils formed in residuum weathered from alkaline soft shales. Mean annual temperature ranges from 38 to 45^{o} F. and mean annual precipitation from 12 to 16 inches.

REGENT SERIES--2

Geographically Associated Soils: These are mainly the competing Grail, Moreau and Morton soils. Grail soils are in concave swales and fans at lower elevations and Moreau soils are on the steeper convex slopes. Morton soils are in nearby landscapes. Beckton, Rhoades and Savage soils are adjacent to Regent soils in some localities. Both Beckton and Rhoades soils have B2t horizons having strong columnar structure and have strongly alkaline subsoils and substrata. In addition, Rhoades soils have thin A2 horizons. Both are commonly on slightly lower, less sloping areas than Regent soils. Savage soils are on nearly level terraces in nearby stream valleys.

Drainage and Permeability: Well drained. Runoff is slow or moderately rapid, depending upon the slope gradient. Permeability is slow.

Use and Vegetation: Cultivated areas are used for growing small grains, flax, hay and pasture. Native vegetation is mid and short grasses such as western wheatgrass, green needlegrass, blue grama, buffalograss and some forbs and upland sedges.

Distribution and Extent: Southwestern North Dakota, eastern Montana, northwestern South Dakota. The soil is extensive.

Series Established: Wibaux County, Montana, 1944

Additional Data: S54ND-45-3, S54ND-21-1, S58NE-13-1, S58ND-45-4, S58ND-45-9 and S58ND-45-10 in Soil Survey Investigations Report No. 2, pages 109-203.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

BEULAH TRENCH RECLAMATION AREA
TABLE 62 INTERPRETIVE RATINGS FOR SOIL USES

Map Symbol (1)	Soil Name (2)	Suitability						Degree of Limitation and Soil Featurea Affecting				
		Dryland Farming (3)	Irrigation (4)	Topsoil (5)	Sand/ Gravel (6)	Road Fill (7)	Other (8)	Ponds Location (9)	Ponds Embankment (10)	Road Location (11)	Shallow Excavationa (12)	Building Sites (13)
44	Arnegard 3-6, 6-9%	Good	Good	Good	Poor	Fair	Wildlife Crops Range	Poor	Fair	Fair	Fair	Fair
88	Harriet	Poor	Poor	Poor	Poor	Poor	Wildlife Range	Poor	Poor	Poor	Poor	Poor
87	Rhoadea 1-9	Poor	Poor	Poor	Poor	Poor	Wildlife Range	Good	Fair	Poor	Poor	Poor
71	Searing Loam 1-6	Fair	Fair	Good	Poor	Fair-Poor	Wildlife Range	Poor	Poor	Fair	Fair	Fair
67	Straw-Channeled	Poor	Poor	Good	Poor	Fair	Wildlife Range	Fair	Fair	Fair	Poor	Poor
55	Vebar 6-9	Poor	Poor	Fair	Poor	Fair	Wildlife Range	Poor	Poor	Poor	Poor	Fair
36	Williama-Loam 3-6, 6-9	Good	Fair	Good	Poor	Fair-Poor	Wildlife Range	Fair	Fair	Fair	Good	Fair
8	Grail 3-6	Good	Fair	Good	Poor	Poor	Wildlife Range	Fair	Fair	Fair-Poor	Fair	Poor
77	Bowdle 3-6	Poor	Poor	Good	Fair	Good	Wildlife Range	Poor	Poor	Good	Fair	Fair
74	Regent 3-6	Good	Poor	Good	Poor	Poor	Wildlife Range	Good	Good	Poor	Poor	Poor
100	Amor 3-6	Good	Fair	Good	Poor	Fair	Wildlife Range	Fair	Poor	Fair	Fair	Fair
36	Williams-Zahl 3-6, 6-9	Good	Poor	Good-Poor	Poor	Fair-Poor	Wildlife Range	Fair	Fair	Fair	Fair	Fair
38	Zahl-Williama 9-15	Fair	Poor	Poor-Good	Poor	Fair-Poor	Wildlife	Fair	Fair	Fair	Fair	Fair
35	Amor-Werner 6-9, 9-15	Fair	Poor	Fair	Poor	Fair-Poor	Wildlife Range	Poor	Poor	Fair	Fair	Fair
28	Temrick-Williama 6-9	Good	Fair	Good	Poor	Fair	Wildlife Range	Fair	Fair	Fair	Fair	Fair
76	Sen-Rhoadea 3-6, 6-9	Fair-Poor	Poor	Good-Poor	Poor	Fair-Poor	Wildlife Range	Good	Fair	Fair-Poor	Fair-Poor	Fair-Poor
74	Regent-Rhoadea 1-9	Fair-Poor	Poor	Good-Poor	Poor	Poor	Wildlife Range	Good	Fair	Poor	Poor	Poor
71	Searing-Ringling 6-9	Poor	Poor	Poor	Fair	Fair	Wildlife Range	Poor	Poor	Fair	Poor	Poor
83	Vebar-Cohagen 3-9, 9-35	Poor	Poor	Fair	Poor	Fair	Wildlife Range	Fair	Fair	Fair	Fair	Fair
83	Cohagen-Vebar 9-35	Poor	Poor	Poor-Good	Poor	Fair	Wildlife Range	Poor	Fair	Fair	Fair	Fair
98	Ringling-Cabba 9-35	Poor	Poor	Poor	Fair	Fair	Wildlife Range	Poor	Poor	Fair	Poor	Poor

Table 63

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

BEULAH TRENCH
ENGINEERING PROPERTIES OF SOILS
MEASUREMENTS AND INTERPRETATIONS

Map Symbol (1)	Soil Name (2)	Depth From Surface of Typical Profile (inches) (3)	Depth To: Bedrock (4)	Depth To: Seasonal High Water Table (inches) (5)	Hydrological Soil Group (6)	Shrink Swell Potential (7)	Corrosivity: Uncoated Steel (8)	Corrosivity: Concrete (9)	Classification: USDA Text. (10)	Classification: Unified (11)	Classification: AASHO (12)	Coarse Fraction (13)
44	Arnegard	0-40	>5	>5 B-	Mod.	Low	Mod.	Low	Loam	ML	A-4	85-95
	3-6, 6-9	40-60				Low	Mod.	Low	CL	ML or CL	A-4 or A-6	85-100
88	Harriet	0-40	>5	0-6 C-	Mod.-Slow	Mod.-High	High	High	SiCL	CL or CH	A-6 or A-7	85-100
		40-46		B-	Mod.	Mod.-High	High	High	Loam	ML	A-4	85-95
		46-60		C-	Slow	Mod.-High	High	High	SiC	CL or CH	A-6 or A-7	95-100
87	Rhoades	0-15	2.5	>10 C-	Slow-Mod.-Slow	High	High	Mod.	SiC & SiCL	CL or CH	A-7	95-100
		15-60			Mod.-Slow	Mod.-V.High	High	High	CL & SiCL	CL or CH	A-6 or A-7	95-100
71	Searing	0-40	3.5	>10 B-	Mod.-Mod.-Rapid	Low	Mod.	Low		ML or SM	A-2 or A-4	35-75
	1-6	40-60	---	-- A-	Rapid	---	---	---	Baked Rock	---	---	---
67	Straw-Channeled	0-60	>5	>5 B-	Mod.	Low-Mod.	Mod.	Low	Loam	ML or ML-CL	A-4	15-25
55	Vebar 6-9	0-39	20-40	>10 B-	Mod. Rapid	Low	Low	Low	FSL	SM or ML	A-2 or A-4	90-100
		39-60			---	Low	Mod.	Low	Soft S. Stone	---	---	---
36	Williams 3-6, 6-9	0-21	>5	>10 B-	Mod.-Mod.-Slow	Mod.-High	Mod.	Mod.	Loam & CL	ML or CL	A-6 or A-7	85-95
8	Grail 3-6	0-60	>5	>5 C-	Slow-Mod.-Slow	Mod.-High	High	Low	SiCL & SiC	CL or CH	A-7	95-100
77	Bowdle	0-20	2	>5 B-C	Mod.-Mod.-Slow	Mod.-High	Mod.	Low	Loam & CL	ML or CL	A-6 or A-7	50-75
		20-60	--	-- A-	Rapid	---	---	---	Band & Gr.	---	---	---
74	Regent 3-6	0-38	2.5-3.3	>10 C-	Slow-Mod.-Slow	Mod.-High	High	Mod.	SiCL & SiC	CL	A-6 or A-7	95-100
100	Amor 3-6	0-35	2.5-3.3	>10 B-	Mod.	Low	Mod.	Low	Loam	ML	A-4	90-100
		35-60		-	---	Low	Mod.	Low	Soft S. Stone	--	---	---
38	Zahl	0-6	>10	>10 B-	Mod.	Mod.	Mod.	Mod.	Loam	ML or ML-CL	A-4	80-95
--	Werner	0-18	18-20	>10 B-	Mod.	Low to Mod.	Mod.	Low	Loam & SiL	ML or CL	A-4 or A-6	75-90
28	Temwick	0-24	>5	>10 B-	Mod.	Low to Mod.	Mod.	Low	SiL	ML	A-4	95-100
		24-60		C-	Mod.-Slow				CL	CL	A-6 or A-7	85-100
76	Sen	0-34	24-42	>10 B-	Mod.	Mod.	Mod.	Low	Loam	ML	A-4	95-100
			34-60	Soft Shale	---	Mod.	Mod.	Low	--	--	---	---
98	Ringling	0-19	5-20	>10 B-	Mod.-Rapid-Mod.	Low	Mod.	Low	Gr. Loam	ML or SM	A-2 or A-4	85-75
		19-60	--	-- -	---	---	Mod.	Low	Baked Rock	--	---	---
83	Cahagen	0-17	5-20	>10 B-	Mod.-Mod-Rapid	Low	Mod.	Low	Gr. Loam	ML or SM	A-2 or A-4	85-75
		19-60	--	--- -	---	---	Mod.	Low	Baked Rock	---	---	---
81	Cabba	0-14	5-20	>10 -	---	Low-Mod.	High	Low	Soft Shale	ML or CL	A-4 or A-6	95-100
		14-60	--	-- -	---	Low-Mod.	High	Mod.	Soft Shale	ML or CL	A-4 or A-6	95-100

Table 66.--Data for defining moisture relations in soils

M DEPTH	RETENTION FORCE		VOLUME WEIGHT	AVERAGE VOLUME WEIGHT *	SOIL MOISTURE	MOISTURE RETENTION CAPABILITY	ADSORPTION CAPABILITY	VOID CAPACITY *	VOID CAPACITY *	SOIL MOISTURE	PERMEABILITY *
M	G/SQCM	PF	G/CC	G/CC	%	%	%	%	MOLECULAR LAYERS OF WATER	MOLECULAR LAYERS OF WATER	CM/HR
BEULAH TRENCH SITE 1 DATE OF SAMPLING: 9/15/76											
0.10	1614.	3.21	0.98	0.98	11.48	14.75	23.59	64.74	43.9	7.8	3.6
0.20	72992.	4.86	1.70	1.47	4.94	13.94	22.30	30.12	21.6	3.5	2.2
0.30	96613.	4.99	1.75	1.67	4.86	15.04	24.06	22.32	14.8	3.2	1.8
0.40	80291.	4.94	1.55	1.66	4.78	14.23	22.77	22.44	15.8	3.4	1.9
0.50	97593.	4.99	1.69	1.65	4.64	14.42	23.08	23.00	15.9	3.2	1.9
0.60	65446.	4.82	1.70	1.67	4.87	13.30	21.28	22.07	16.6	3.7	1.9
0.70	38574.	4.59	1.63	1.73	5.22	12.28	19.64	20.20	16.5	4.2	1.9
0.80	18516.	4.27	1.85	1.76	5.70	11.25	18.01	19.05	16.9	5.1	1.9
0.90	7106.	3.85	1.81	1.85	6.81	11.10	17.75	16.42	14.8	6.1	1.8
1.00	1210.	3.08	1.88	1.88	6.36	7.85	12.56	15.37	19.6	8.1	2.1
1.10	2477.	3.39	1.96	1.97	6.39	8.75	14.00	13.05	14.9	7.3	1.8
1.20	1637.	3.21	2.06	2.00	6.55	8.43	13.49	12.24	14.5	7.8	1.8
1.30	1485.	3.17	1.98	1.96	6.53	8.29	13.26	12.84	15.5	7.9	1.8
1.40	800.	2.90	1.89	1.97	6.87	8.02	12.84	13.00	16.2	6.6	1.9
1.50	814.	2.91	2.04	1.97	7.24	8.47	13.56	13.09	15.5	8.5	1.8
1.60	690.	2.84	1.97	1.90	7.29	8.36	13.38	14.81	17.7	8.7	2.0
1.70	554.	2.75	1.70	1.94	7.22	8.05	12.88	13.85	17.2	9.0	1.9
1.80	486.	2.69	2.15	1.89	7.39	8.10	12.97	15.15	18.7	9.1	2.0
1.90	893.	2.95	1.43	2.22e	7.37	8.73	13.97	7.37e	8.4e	8.4	1.4e
2.00	1267.	3.10	2.95	2.20e	7.64	9.49	15.18	7.64e	8.1e	8.1	1.4e
2.10	916.	2.96	2.38	2.20e	7.70	9.15	14.64	7.70e	8.4e	8.4	1.4e
2.20	592.	2.77	2.14	2.14	8.19	9.21	14.73	9.06	9.8	8.9	1.5
BEULAH TRENCH SITE 4 DATE OF SAMPLING: 9/15/76											
0.10	529.	2.72	1.04	1.04	20.67	22.91	36.65	58.15	25.4	9.0	2.4
0.20	219742.	5.34	1.11	1.12	7.45	28.13	45.01	51.28	18.2	2.6	2.0
0.30	187194.	5.27	1.22	1.23	7.40	26.82	42.92	43.88	16.4	2.8	1.9
0.40	122638.	5.09	1.35	1.27	7.32	23.98	38.37	40.84	17.0	3.1	1.9
0.50	83527.	4.92	1.25	1.40	6.91	20.38	32.61	33.86	16.6	3.4	1.9
0.60	16924.	4.23	1.59	1.44	7.77	15.04	24.06	31.62	21.0	5.2	2.2
0.70	8548.	3.93	1.48	1.46	9.14	15.42	24.67	30.75	19.9	5.9	2.1
0.80	4362.	3.64	1.30	1.40	12.41	18.59	29.75	33.68	18.1	6.7	2.0
0.90	2576.	3.41	1.41	1.40	13.51	18.60	29.76	33.65	18.1	7.3	2.0
1.00	1766.	3.25	1.49	1.51	12.18	15.86	25.38	28.69	18.1	7.7	2.0
1.10	1834.	3.26	1.62	1.57	10.86	14.22	22.75	26.08	18.3	7.6	2.0
1.20	1014.	3.01	1.60	1.57	12.29	14.81	23.69	25.82	17.4	8.3	2.0
1.30	1043.	3.02	1.51	1.54	16.29	19.70	31.52	27.25	13.8	8.3	1.7
1.40	687.	2.84	1.51	1.56	19.37	22.18	35.49	26.53	12.0	8.7	1.6
1.50	921.	2.96	1.65	1.50	21.61	25.71	41.14	29.01	11.3	8.4	1.6
1.60	333.	2.52	1.33	1.53	24.49	25.68	41.09	27.42	10.7	9.5	1.6
1.70	597.	2.78	1.62	1.49	23.75	26.71	42.74	29.46	11.0	8.9	1.6
1.80	684.	2.83	1.51	1.51	24.92	28.52	45.63	28.46	10.0	8.7	1.5
BEULAH TRENCH SITE 5 DATE OF SAMPLING: 9/15/76											
0.10	208.	2.32	1.21	1.21	16.86	16.76	26.81	45.20	27.0	10.1	2.5
0.20	6154.	3.79	1.31	1.31	11.35	18.04	28.86	38.35	21.3	6.3	2.2
0.30	4460.	3.65	1.42	1.41	11.68	17.85	28.57	33.35	18.7	6.7	2.0
0.40	5509.	3.74	1.48	1.49	11.04	17.21	27.54	29.59	17.2	6.4	1.9
0.50	5463.	3.74	1.55	1.46	10.29	16.02	25.63	29.76	18.6	6.4	2.0
0.60	5875.	3.77	1.41	1.42	10.57	16.66	26.66	32.80	19.7	6.3	2.1
0.70	3783.	3.58	1.29	1.36	13.57	19.85	31.75	35.90	18.1	6.8	2.0
0.80	3527.	3.55	1.37	1.36	15.75	22.78	36.45	35.82	15.7	6.9	1.9
0.90	3144.	3.50	1.42	1.44	14.99	21.30	34.07	31.54	14.8	7.0	1.8
1.00	2674.	3.43	1.54	1.46	13.64	19.17	30.67	30.67	16.0	7.2	1.9
1.10	2341.	3.37	1.42	1.52	13.76	18.67	29.87	28.09	15.0	7.4	1.8
1.20	2245.	3.35	1.59	1.52	13.96	16.62	30.12	27.88	14.8	7.4	1.8
1.30	1223.	3.09	1.56	1.56	14.88	18.39	29.43	26.39	14.3	8.1	1.8
1.40	1618.	3.21	1.53	1.53	15.12	19.44	31.10	27.46	14.1	7.8	1.8
1.50	1070.	3.03	1.51	1.51	17.08	20.75	33.20	26.35	13.7	8.2	1.7
1.60	1108.	3.04	1.50	1.46	19.12	23.32	37.31	29.84	12.8	8.2	1.7
1.70	1164.	3.07	1.43	1.63	22.74	27.91	44.66	23.80	8.5	8.1	1.6
1.80	1298.	3.11	1.45	1.69e	21.54	26.84	42.94	21.54e	8.0e	8.0	1.4e

*e following a value denotes an estimate

Table 66.--Data for defining moisture relations in soils--Continued

M DEPTH	RETENTION FORCE		VOLUME WEIGHT	AVERAGE VOLUME WEIGHT	SOIL MOISTURE	MOISTURE RETENTION CAPABILITY	ADSORPTION CAPABILITY	VOID CAPACITY	VOID CAPACITY	SOIL MOISTURE	PERMEABILITY
M	G/SQCM	PF	G/CC	G/CC	%	%	%	%	MOLECULAR LAYERS OF WATER	MOLECULAR LAYERS OF WATER	CM/HR
BEULAH TRENCH SITE 2 DATE OF SAMPLING: 9/15/76											
0.10	2510.	3.40	1.24	1.24	10.86	14.89	23.83	42.89	28.8	7.3	2.7
0.20	57426.	4.76	1.31	1.31	5.93	15.62	24.98	38.81	24.9	3.8	2.4
0.30	57620.	4.76	1.37	1.31	6.00	15.77	25.22	39.61	24.5	3.8	2.4
0.40	56223.	4.75	1.25	1.41	6.15	16.06	25.69	33.32	20.8	3.8	2.2
0.50	56554.	4.75	1.61	1.44	6.27	16.37	26.20	31.95	19.5	3.8	2.1
0.50	69016.	4.84	1.45	1.49	6.58	18.24	29.19	29.24	16.0	3.6	1.9
0.70	47151.	4.67	1.43	1.61	7.58	16.82	30.11	24.48	13.0	4.0	1.7
0.80	18377.	4.26	1.95	1.73	7.06	13.91	22.26	19.94	14.3	5.1	1.8
0.90	11074.	4.04	1.83	1.83	6.67	11.82	18.91	16.83	14.2	5.6	1.8
1.00	3387.	3.53	1.72	1.63	6.13	8.82	14.10	23.50	26.7	7.0	2.5
1.10	1675.	3.22	1.35	1.67	7.53	9.73	15.56	22.13	22.8	7.7	2.3
1.20	1456.	3.16	1.94	1.50	7.73	9.79	15.66	29.00	29.6	7.9	2.7
1.30	1393.	3.14	1.21	1.64	7.61	9.58	15.33	23.36	24.4	7.9	2.4
1.40	881.	2.95	1.77	1.55	7.18	8.49	13.59	26.65	31.4	8.5	2.8
1.50	726.	2.86	1.69	1.55	7.80	8.99	14.39	26.70	29.7	8.7	2.7
1.60	335.	2.52	1.20	1.56	8.83	9.26	14.81	26.40	28.5	9.5	2.6
1.70	338.	2.53	1.79	1.64	8.01	8.41	13.46	23.41	27.8	9.5	2.6
1.80	537.	2.73	1.92	1.80	7.07	7.65	12.56	17.74	22.6	9.0	2.3
1.90	450.	2.65	1.70	1.81	7.62	8.28	13.24	17.45	21.1	9.2	2.2
2.00	539.	2.73	1.82	1.75	7.69	8.55	13.67	19.49	22.8	9.0	2.3
2.10	213.	2.33	1.72	1.77	8.01	7.98	12.77	18.68	23.4	10.0	2.3
2.20	203.	2.31	1.78	1.71	8.54	8.47	13.55	20.85	24.6	10.1	2.4
2.30	206.	2.31	1.62	1.70	8.93	8.87	14.19	21.02	23.7	10.1	2.3
2.40	198.	2.30	1.71	1.71	9.00	8.90	14.24	20.76	23.3	10.1	2.3
BEULAH TRENCH SITE 3 DATE OF SAMPLING: 9/15/76											
0.10	208.	2.32	1.04	1.04	19.26	19.15	30.64	57.97	38.3	10.1	2.7
0.20	37157.	4.57	1.14	1.11	7.36	17.13	27.41	51.97	30.3	4.3	2.8
0.30	51320.	4.71	1.16	1.26	6.85	17.41	27.86	41.47	23.8	3.9	2.4
0.40	60547.	4.78	1.49	1.34	6.17	16.48	26.36	37.09	22.5	3.7	2.3
0.50	42252.	4.63	1.36	1.49	6.34	15.27	24.43	29.25	19.2	4.2	2.1
0.60	35326.	4.55	1.63	1.50	5.70	13.09	20.95	28.89	22.1	4.3	2.2
0.70	10465.	4.27	1.51	1.55	4.73	9.33	14.93	26.78	28.7	5.1	2.7
0.80	5594.	3.75	1.51	1.54	5.23	8.17	13.07	27.20	33.3	6.4	2.9
0.90	3584.	3.55	1.60	1.53	7.07	10.25	16.40	27.58	26.9	6.9	2.5
1.00	2075.	3.32	1.49	1.47	9.20	12.27	19.62	30.22	24.6	7.5	2.4
1.10	577.	2.76	1.33	1.52	12.01	13.45	21.52	28.01	20.8	8.9	2.2
1.20	210.	2.32	1.75	1.60	14.06	13.99	22.39	24.88	17.8	10.1	2.0
1.30	212.	2.33	1.71	1.76	12.21	12.16	19.45	19.20	15.8	10.0	1.9
1.40	201.	2.30	1.81	1.80	12.66	12.53	20.05	17.73	14.2	10.1	1.8
1.50	197.	2.29	1.89	1.84	11.71	11.57	18.51	16.53	14.3	10.1	1.8
1.60	196.	2.29	1.83	1.79	15.21	15.02	24.03	18.00	12.0	10.1	1.6
1.70	286.	2.46	1.66	1.63	19.93	20.54	32.86	23.70	11.5	9.7	1.6
1.80	197.	2.30	1.39	1.55	21.83	21.57	34.51	26.66	12.4	10.1	1.7
1.90	147.	2.17	1.61	1.49	22.95	21.97	35.16	29.42	13.4	10.4	1.7
2.00	193.	2.29	1.47	1.55	26.15	25.78	41.25	26.96	10.5	10.1	1.5
2.10	197.	2.29	1.56	1.51	24.74	24.43	39.09	28.40	11.6	10.1	1.6
2.20	234.	2.37	1.51	1.51	24.58	24.75	39.60	28.61	11.6	9.9	1.6
BEULAH TRENCH SITE 7 DATE OF SAMPLING: 9/15/76											
0.10	939.	2.97	1.12	1.12	20.71	24.70	39.52	51.21	20.7	8.4	2.2
0.20	50748.	4.71	1.08	1.17	11.82	29.96	47.93	47.54	15.9	3.9	1.9
0.30	46307.	4.67	1.32	1.26	10.30	25.44	40.70	41.43	16.3	4.0	1.9
0.40	43775.	4.64	1.40	1.47	6.59	20.89	33.43	30.21	14.5	4.1	1.8
0.50	22506.	4.35	1.70	1.63	8.37	17.26	27.62	23.71	13.7	4.9	1.7
0.60	19944.	4.30	1.78	1.66	8.76	17.58	28.13	22.47	12.8	5.0	1.7
0.70	16785.	4.22	1.50	1.63	9.40	18.15	29.05	23.47	12.9	5.2	1.7
0.80	13697.	4.14	1.62	1.66	10.01	18.52	29.64	22.68	12.2	5.4	1.6
0.90	7909.	3.90	1.85	1.76	8.27	13.76	22.01	19.16	13.9	6.0	1.7
1.00	6453.	3.81	1.80	1.75	8.21	13.16	21.05	19.40	14.7	6.2	1.8
1.10	4558.	3.66	1.60	1.44	9.00	13.59	21.74	31.79	23.4	6.6	2.3
1.20	5820.	3.77	0.91	0.91	10.98	17.28	27.65	71.89	41.6	6.4	3.4

Table 66.--Data for defining moisture relations in soils--Continued

M DEPTH	RETENTION FORCE		VOLUME WEIGHT	AVERAGE VOLUME WEIGHT*	SOIL MOISTURE	MOISTURE RETENTION CAPABILITY	ADSORPTION CAPABILITY	VOID CAPACITY*	VOID CAPACITY*	SOIL MOISTURE	PERMEABILITY*
M	G/SQCM	PF	G/CC	G/CC	%	%	%	%	MOLECULAR LAYERS OF WATER	MOLECULAR LAYERS OF WATER	CM/HR
					BEULAH TRENCH SITE 6 DATE OF SAMPLING: 9/15/76						
0.10	796.	2.90	1.05	1.05	16.09	18.77	30.04	57.65	30.7	8.6	2.8
0.20	15344.	4.19	1.29	1.24	11.20	21.22	33.96	42.97	20.2	5.3	2.1
0.30	13630.	4.13	1.38	1.29	14.96	27.67	44.26	39.90	14.6	5.4	1.8
0.40	14102.	4.15	1.19	1.30	12.86	23.94	38.30	36.99	16.3	5.4	1.9
0.50	10484.	4.02	1.33	1.30	13.59	23.84	38.15	38.96	16.3	5.7	1.9
0.60	11860.	4.07	1.39	1.39	13.88	24.94	39.91	34.02	13.6	5.6	1.7
0.70	7854.	3.90	1.46	1.43	16.63	27.62	44.19	32.39	11.7	6.0	1.6
0.80	4477.	3.65	1.43	1.46	20.68	31.10	49.77	30.64	9.8	6.6	1.5
0.90	3918.	3.59	1.50	1.48	22.35	32.89	52.63	29.85	9.1	6.8	1.5
1.00	6457.	3.81	1.51	1.45	24.13	38.66	61.86	31.07	8.0	6.2	1.4
1.10	2780.	3.44	1.35	1.44	26.48	36.89	59.03	31.63	8.6	7.2	1.4
1.20	1959.	3.29	1.46	1.47	26.82	35.42	56.67	30.51	8.6	7.6	1.4
1.30	2240.	3.35	1.58	1.49	27.09	36.54	58.46	29.38	8.0	7.4	1.4
1.40	1282.	3.11	1.42	1.56e	26.50	32.96	52.74	26.50e	8.0e	8.0	1.4e
1.50	1752.	3.24	1.72	1.39	28.16	36.61	58.58	34.25	9.4	7.7	1.5
1.60	1751.	3.24	1.02	1.45	26.90	34.98	55.96	31.24	8.9	7.7	1.4
1.70	1047.	3.02	1.61	1.39	28.20	34.13	54.60	34.40	10.1	8.3	1.5
1.80	2024.	3.31	1.53	1.55e	26.86	35.67	57.08	26.86e	7.5e	7.5	1.4e
1.90	2380.	3.38	1.66	1.56e	26.46	36.00	57.59	26.46e	7.4e	7.4	1.4e
2.00	1008.	3.00	1.63	1.54e	27.36	32.94	52.70	27.36e	8.3e	8.3	1.4e
2.10	1028.	3.01	1.56	1.55e	26.58	32.08	51.32	26.58e	8.3e	8.3	1.4e
2.20	880.	2.94	1.58	1.51e	28.29	32.41	51.85	28.29e	8.7e	8.7	1.4e
2.30	918.	2.96	1.76	1.57	26.00	30.91	49.46	25.84	8.4	8.4	1.4
2.40	244.	2.39	1.38	1.38	28.15	28.47	45.55	34.94	12.3	9.9	1.6
					BEULAH TRENCH SITE 8 DATE OF SAMPLING: 9/15/76						
0.10	255.	2.41	0.90	0.90	23.30	23.68	37.89	72.84	30.8	9.8	2.8
0.20	66640.	4.82	1.23	1.14	9.27	25.45	40.72	50.33	19.8	3.6	2.1
0.30	71375.	4.85	1.27	1.26	8.56	24.00	38.40	41.45	17.3	3.6	2.0
0.40	75947.	4.88	1.29	1.34	8.71	24.89	39.82	37.14	14.9	3.5	1.8
0.50	60478.	4.79	1.45	1.36	8.32	22.23	35.57	35.92	16.2	3.7	1.9
0.60	56552.	4.75	1.34	1.37	8.28	21.65	34.64	35.45	16.4	3.8	1.9
0.70	45603.	4.66	1.31	1.35	8.50	20.90	33.44	36.27	17.4	4.1	2.0
0.80	28960.	4.46	1.40	1.39	8.17	17.87	28.59	34.19	19.1	4.6	2.1
0.90	19463.	4.29	1.46	1.41	8.70	17.36	27.77	33.16	19.1	5.0	2.1
1.00	20147.	4.30	1.37	1.40	10.06	20.23	32.37	33.56	16.6	5.0	1.9
1.10	17836.	4.25	1.38	1.38	10.99	21.51	34.42	34.55	16.1	5.1	1.9
1.20	13752.	4.14	1.40	1.39	11.24	20.83	33.32	34.03	16.3	5.4	1.9
1.30	7615.	3.89	1.40	1.43	11.68	19.37	31.00	32.27	16.7	6.0	1.9
1.40	6961.	3.84	1.48	1.52	10.64	17.29	27.66	28.03	16.2	6.2	1.9
1.50	3511.	3.55	1.68	1.51	10.69	15.45	24.72	28.64	18.5	6.9	2.0
1.60	2763.	3.44	1.36	1.36	13.45	18.72	29.96	35.57	19.0	7.2	2.1
1.70	1208.	3.08	1.06	1.14	16.26	22.53	36.05	50.27	22.3	8.1	2.3
1.80	1112.	3.05	0.99	0.99	22.38	27.30	43.68	63.06	23.1	8.2	2.3
					BEULAH TRENCH SITE 9 DATE OF SAMPLING: 9/15/76						
0.10	218.	2.34	0.66	0.66	19.87	19.84	31.75	114.21	57.6	10.0	4.4
0.20	59269.	4.77	1.23	1.09	6.97	18.46	29.54	53.96	29.2	3.8	2.7
0.30	36708.	4.59	1.39	1.29	7.56	17.81	28.49	39.67	22.3	4.2	2.3
0.40	42870.	4.63	1.26	1.28	7.00	16.93	27.09	40.12	23.7	4.1	2.3
0.50	49001.	4.69	1.20	1.19	7.55	18.94	30.30	46.37	24.5	4.0	2.4
0.60	42659.	4.63	1.10	1.03	10.43	25.18	40.29	59.82	23.8	4.1	2.3
0.70	31991.	4.51	0.77	0.91	15.13	33.92	54.27	72.34	21.3	4.5	2.2
0.80	24794.	4.39	0.85	0.91	16.54	34.87	55.79	72.24	20.7	4.7	2.2
0.90	22388.	4.35	1.11	1.06	16.21	33.36	53.38	54.92	16.5	4.9	1.9
1.00	19775.	4.30	1.28	1.18	12.91	25.85	41.37	47.32	18.3	5.0	2.0
1.10	12712.	4.10	1.14	1.47	15.03	27.40	43.84	30.24	11.0	5.5	1.6
1.20	9498.	3.98	1.99	1.82	5.00	8.61	13.78	17.22	20.0	5.8	2.1
1.30	5571.	3.75	2.33	2.33	4.01	6.26	10.02	5.27	8.4	6.4	1.6

*e following a value denotes an estimate

Table 66.--Data for defining moisture relations in soils--Continued

M DEPTH	RETENTION FORCE		VOLUME WEIGHT	AVERAGE VOLUME WEIGHT *	SOIL MOISTURE	MOISTURE RETENTION CAPABILITY	ADSORPTION CAPABILITY	VOID CAPACITY *	VOID CAPACITY *	SOIL MOISTURE	PERMEABILITY *
M	G/SQCM	PF	G/CC	G/CC	%	%	%	%	MOLECULAR LAYERS OF WATER	MOLECULAR LAYERS OF WATER	CM/HR
BEULAH TRENCH SITE 10 DATE OF SAMPLING: 9/15/76											
0.10	389.	2.59	0.66	0.66	23.47	25.06	40.10	113.75	55.4	9.4	3.7
0.20	6698.	3.83	1.26	1.01	13.12	21.16	33.85	61.62	29.1	6.2	2.7
0.30	10939.	4.04	1.10	1.28	11.31	20.00	32.01	40.42	20.2	5.7	2.1
0.40	11016.	4.04	1.49	1.25	10.77	19.08	30.52	42.43	22.2	5.6	2.3
0.50	10960.	4.04	1.16	1.40	10.86	19.21	30.73	33.79	17.6	5.7	2.0
0.60	7102.	3.85	1.55	1.39	10.91	17.78	28.45	34.24	19.3	6.1	2.1
0.70	2496.	3.40	1.45	1.52	12.12	16.61	26.57	28.02	16.9	7.3	1.9
0.80	634.	2.80	1.55	1.55	15.33	17.38	27.82	25.69	15.4	8.8	1.8
0.90	188.	2.27	1.65	1.60	16.85	16.56	26.50	24.88	15.0	10.2	1.8
1.00	156.	2.19	1.59	1.54	15.30	17.62	28.19	27.19	15.4	10.4	1.8
1.10	121.	2.08	1.39	1.45	20.03	18.78	30.04	31.02	15.5	10.7	1.9
1.20	127.	2.10	1.39	1.48	22.35	21.06	33.70	29.61	14.1	10.6	1.8
1.30	106.	2.03	1.68	1.58	21.39	19.78	31.65	25.65	13.0	10.8	1.7
1.40	118.	2.07	1.67	1.67	20.94	19.58	31.32	22.29	11.4	10.7	1.6
1.50	113.	2.05	1.65	1.66e	22.36	20.81	33.30	22.36e	10.7e	10.7	1.6e
1.60	103.	2.01	1.74	1.65e	22.95	21.16	33.85	22.95e	10.8e	10.8	1.6e
1.70	91.	1.96	1.65	1.63e	23.51	21.40	34.25	23.51e	11.0e	11.0	1.6e
1.80	105.	2.02	1.55	1.64e	23.26	21.48	34.37	23.26e	10.8e	10.8	1.6e
1.90	111.	2.05	1.83	1.62e	23.93	22.24	35.59	23.93e	10.8e	10.8	1.6e
BEULAH TRENCH SITE 11 DATE OF SAMPLING: 9/15/76											
0.10	4907.	3.69	0.89	0.89	13.27	20.27	32.43	75.25	37.1	6.5	3.2
0.20	76832.	4.89	1.05	0.99	10.96	31.45	50.32	63.12	20.1	3.5	2.1
0.30	80877.	4.91	1.04	1.11	10.43	30.42	48.67	52.46	17.2	3.4	2.0
0.40	100853.	5.00	1.24	1.15	10.69	33.54	53.66	49.02	14.6	3.2	1.8
0.50	56605.	4.75	1.19	1.20	10.12	26.45	42.32	45.46	17.2	3.8	1.9
0.60	71723.	4.86	1.18	1.30	10.25	28.78	46.04	39.35	13.7	3.6	1.7
0.70	62345.	4.79	1.52	1.38	10.04	27.01	43.22	34.67	12.8	3.7	1.7
0.80	48498.	4.69	1.44	1.57	10.44	26.20	41.92	25.80	9.8	4.0	1.5
0.90	24744.	4.39	1.76	1.54	9.77	20.58	32.93	27.16	13.2	4.7	1.7
1.00	22966.	4.36	1.42	1.57	9.87	20.44	32.71	25.99	12.7	4.8	1.7
1.10	5416.	3.73	1.52	1.52	12.23	19.00	30.40	28.17	14.8	6.4	1.8
1.20	1512.	3.18	1.61	1.68	14.31	18.21	29.14	21.75	11.9	7.9	1.6
1.30	879.	2.94	1.92	1.86e	16.12	19.06	30.49	16.12e	8.5e	8.5	1.4e
1.40	728.	2.86	2.28	1.86e	16.01	18.47	29.55	16.01e	8.7e	8.7	1.4e
1.50	1218.	3.08	2.22	1.82e	17.25	21.30	34.08	17.25e	8.1e	8.1	1.4e
BEULAH TRENCH SITE 12 DATE OF SAMPLING: 9/15/76											
0.10	2787.	3.45	0.76	0.76	13.86	19.31	30.90	94.14	48.7	7.2	3.9
0.20	39010.	4.59	1.29	1.11	5.71	13.47	21.55	52.16	38.7	4.2	3.3
0.30	78858.	4.90	1.29	1.40	5.54	16.02	25.64	33.57	20.9	3.5	2.2
0.40	84283.	4.93	1.63	1.45	6.00	17.73	28.37	31.00	17.5	3.4	2.0
0.50	80454.	4.91	1.44	1.50	6.35	18.50	29.60	28.86	15.6	3.4	1.9
0.60	40933.	4.61	1.43	1.40	7.72	18.44	29.50	33.73	18.3	4.2	2.0
0.70	38854.	4.59	1.32	1.34	11.98	28.23	45.17	36.40	13.1	4.2	1.7
0.80	30093.	4.48	1.27	1.35	17.53	38.71	61.94	36.30	9.4	4.5	1.5
0.90	25601.	4.41	1.46	1.43	15.34	32.63	52.21	32.25	9.9	4.7	1.5
1.00	13810.	4.14	1.56	1.59	15.53	28.79	46.06	25.11	8.7	5.4	1.4
1.10	15354.	4.19	1.75	1.68	16.15	30.61	48.97	21.94	7.2	5.3	1.3
1.20	11300.	4.05	1.72	1.74	17.27	30.73	49.17	19.68	6.4	5.6	1.3
1.30	6858.	3.84	1.75	1.67	19.43	31.47	50.35	22.07	7.0	6.2	1.3
1.40	6818.	3.83	1.54	1.58	22.04	35.67	57.08	25.56	7.2	6.2	1.3
1.50	3542.	3.55	1.44	1.27	24.68	35.73	57.17	41.26	11.5	6.9	1.6
1.60	1199.	3.08	0.81	0.81	61.14	75.36	120.57	85.33	11.3	8.1	1.6

*e following a value denotes an estimate

Table 66.--Data for defining moisture relations in soils--Continued

DEPTH	RETENTION FORCE		VOLUME WEIGHT	AVERAGE VOLUME WEIGHT*	SOIL MOISTURE	MOISTURE RETENTION CAPABILITY	ADSORPTION CAPABILITY	VOID CAPACITY*	VOID CAPACITY*	SOIL MOISTURE	PERMEABILITY*
M	G/50CM	PF	G/CC	G/CC	%	%	%	%	MOLECULAR LAYERS OF WATER	MOLECULAR LAYERS OF WATER	CM/HR
BEULAH TRENCH SITE 13 DATE OF SAMPLING: 9/15/76											
0.10	2783.	3.44	0.81	0.81	11.17	15.56	24.89	85.93	55.2	7.2	4.3
0.20	57890.	4.76	1.64	1.33	8.62	22.68	36.28	37.22	16.4	3.8	1.9
0.30	20851.	4.32	1.56	1.60	8.40	17.02	27.23	24.88	14.6	4.9	1.8
0.40	24536.	4.39	1.60	1.59	8.83	18.57	29.72	25.07	13.5	4.8	1.7
0.50	10643.	4.03	1.62	1.61	9.67	17.01	27.21	24.53	14.4	5.7	1.8
0.60	23798.	4.38	1.60	1.60	10.09	21.11	33.78	24.65	11.7	4.8	1.6
0.70	29171.	4.46	1.59	1.67	10.03	21.99	35.19	22.02	10.0	4.6	1.5
0.80	32603.	4.51	1.83	1.76	6.24	14.06	22.50	19.16	13.6	4.4	1.7
0.90	6636.	3.82	1.85	1.77	9.41	15.15	24.24	18.66	12.3	6.2	1.7
1.00	1172.	3.07	1.64	1.51	11.53	14.16	22.66	28.63	20.2	8.1	2.1
1.10	415.	2.62	1.03	1.54	11.83	12.73	20.36	27.10	21.3	9.3	2.2
1.20	867.	2.94	1.96	1.66	11.90	14.04	22.46	22.68	16.2	8.5	1.9
1.30	556.	2.74	1.97	2.02e	11.67	13.01	20.82	11.67e	9.0e	9.0	1.4e
1.40	779.	2.89	2.48	2.04e	11.31	13.16	21.06	11.31e	8.6e	8.6	1.4e
1.50	1031.	3.01	1.84	2.02e	11.67	14.09	22.55	11.67e	8.3e	8.3	1.4e
1.60	391.	2.59	1.77	1.77	11.60	12.40	19.84	18.81	15.2	9.4	1.8
BEULAH TRENCH SITE 14 DATE OF SAMPLING: 9/15/76											
0.10	321.	2.51	0.81	0.81	25.94	27.08	43.33	85.41	31.5	9.6	2.8
0.20	62493.	4.80	1.16	1.09	10.05	27.04	43.27	53.68	19.8	3.7	2.1
0.30	74261.	4.87	1.31	1.28	10.35	29.38	47.00	40.51	13.8	3.5	1.7
0.40	71381.	4.85	1.36	1.42	9.58	26.86	42.97	32.61	12.1	3.6	1.6
0.50	57552.	4.76	1.59	1.50	10.09	26.50	42.40	28.85	10.9	3.8	1.6
0.60	50718.	4.71	1.55	1.58	10.37	26.27	42.03	25.58	9.7	3.9	1.5
0.70	34974.	4.54	1.60	1.56	11.74	26.91	43.06	26.36	9.8	4.4	1.5
0.80	29460.	4.47	1.53	1.53	11.98	26.31	42.10	27.53	10.5	4.6	1.5
BEULAH TRENCH SITE 15 DATE OF SAMPLING: 9/15/76											
0.10	198.	2.30	0.71	0.71	29.94	29.60	47.36	102.73	34.7	10.1	3.0
0.20	25609.	4.41	1.31	1.05	12.83	27.25	43.61	57.23	21.0	4.7	2.2
0.30	46688.	4.67	1.14	1.22	9.31	23.04	36.87	44.26	19.2	4.0	2.1
0.40	32239.	4.51	1.21	1.30	11.20	25.15	40.25	38.97	15.5	4.5	1.8
0.50	32400.	4.51	1.56	1.43	10.82	24.33	38.92	32.02	13.2	4.4	1.7
0.60	31246.	4.49	1.53	1.63	11.78	26.25	42.01	23.71	9.0	4.5	1.5
0.70	28655.	4.46	1.79	1.85	11.66	25.45	40.71	16.40	6.4	4.6	1.3
0.80	15443.	4.19	2.22	1.98	12.27	23.28	37.25	12.86	5.5	5.3	1.2
0.90	11502.	4.06	1.92	1.95e	13.68	24.43	39.08	13.63e	5.6e	5.6	1.2e
0.95	13923.	4.14	1.72	1.72	13.75	25.54	40.86	20.35	8.0	5.4	1.4
BEULAH TRENCH SITE 16 DATE OF SAMPLING: 9/15/76											
0.10	89.	1.95	0.82	0.82	27.25	24.76	39.61	83.93	33.9	11.0	3.0
0.20	2924.	3.47	1.27	1.07	10.54	14.80	23.68	55.89	37.8	7.1	3.2
0.30	12293.	4.09	1.11	1.12	8.41	15.22	24.35	51.36	33.7	5.5	3.0
0.40	12466.	4.10	0.98	1.11	8.27	15.01	24.01	52.43	34.9	5.5	3.0
0.50	13515.	4.13	1.23	1.24	7.88	14.54	23.27	42.77	29.4	5.4	2.7
0.60	12712.	4.10	1.51	1.44	6.38	11.63	18.60	31.92	27.5	5.5	2.6
0.70	8034.	3.90	1.57	1.54	6.67	11.46	18.33	27.00	23.6	6.0	2.3
0.80	6639.	3.82	1.56	1.51	7.96	12.83	20.52	28.29	22.1	6.2	2.2
0.90	3590.	3.54	1.42	1.46	8.11	11.72	18.75	30.57	26.1	6.9	2.5
1.00	3064.	3.49	1.41	1.43	7.92	11.21	17.94	32.39	28.9	7.1	2.7
1.10	3395.	3.53	1.45	1.50	8.49	12.21	19.53	29.07	23.8	7.0	2.4
1.20	2881.	3.46	1.63	1.58	9.87	13.82	22.12	25.75	18.6	7.1	2.0
1.30	1769.	3.25	1.65	1.53	10.54	13.72	21.95	27.49	20.0	7.7	2.1
1.40	2175.	3.34	1.32	1.56	10.16	13.63	21.81	26.30	19.3	7.5	2.1
1.50	1804.	3.26	1.72	1.56	10.15	13.25	21.20	26.34	19.9	7.7	2.1
1.60	1744.	3.24	1.64	1.64	11.25	14.61	23.38	23.06	15.8	7.7	1.9

*e following a value denotes an estimate

Table 66 .--Data for defining moisture relations in soils--Continued

DEPTH	RETENTION FORCE		VOLUME WEIGHT	AVERAGE VOLUME WEIGHT *	SOIL MOISTURE	MOISTURE RETENTION CAPABILITY	ADSORPTION CAPABILITY	VOID CAPACITY *	VOID CAPACITY *	SOIL MOISTURE	PERMEABILITY *
M	G/SQCM	PF	G/CC	G/CC	%	%	%	%	MOLECULAR LAYERS OF WATER	MOLECULAR LAYERS OF WATER	CM/HR
BEULAH TRENCH SITE 17 DATE OF SAMPLING: 9/15/76											
0.10	103.	2.01	1.03	1.03	21.50	19.82	31.72	59.11	29.8	10.8	2.7
0.20	2108.	3.32	1.13	1.12	10.15	13.56	21.69	51.31	37.8	7.5	3.2
0.30	29027.	4.46	1.21	1.21	6.76	14.83	23.73	44.94	30.3	4.6	2.7
0.40	32781.	4.52	1.29	1.36	6.95	15.68	25.08	35.89	27.9	4.4	2.3
0.50	20398.	4.31	1.57	1.47	6.83	13.78	22.04	30.44	22.1	5.0	2.2
0.60	23491.	4.37	1.53	1.52	6.72	13.99	22.38	28.01	20.0	4.8	2.1
0.70	23915.	4.38	1.45	1.60	6.92	14.47	23.14	24.81	17.1	4.8	1.9
0.80	18588.	4.27	1.81	1.63	6.56	12.99	20.78	23.77	18.3	5.1	2.0
0.90	8296.	3.92	1.62	1.45	8.15	13.68	21.88	31.19	27.8	6.0	2.3
1.00	4362.	3.64	0.93	1.18	6.44	12.65	20.24	46.89	37.1	6.7	3.2
1.10	2535.	3.40	1.00	1.10	9.37	12.87	20.59	53.19	41.3	7.3	3.4
1.20	1232.	3.09	1.37	1.42	9.43	11.67	18.68	32.70	28.0	8.1	2.6
1.30	1718.	3.24	1.89	1.65	8.28	10.74	17.18	22.85	21.3	7.7	2.2
1.40	331.	2.52	1.69	1.83	6.57	8.98	14.35	16.91	18.8	9.5	2.0
1.50	231.	2.36	1.91	1.84	10.03	10.09	16.14	16.49	16.4	9.9	1.9
1.60	406.	2.61	1.43	1.98	10.48	11.24	17.99	12.76	11.3	9.3	1.6
1.70	213.	2.33	2.10	1.93	10.00	9.96	15.94	13.99	14.0	10.0	1.8
1.80	214.	2.33	1.77	1.95	9.66	9.63	15.41	13.49	14.0	10.0	1.8
1.90	352.	2.55	1.99	1.95	10.05	10.61	16.98	13.68	12.9	9.5	1.7
2.00	210.	2.32	2.08	2.03	10.24	10.19	16.31	11.50	11.3	10.1	1.6
2.10	201.	2.30	2.03	2.08e	10.25	10.15	16.24	10.25e	10.1e	10.1	1.5e
2.20	194.	2.29	2.17	2.10e	9.85	9.72	15.56	9.85e	10.1e	10.1	1.5e
2.30	199.	2.30	2.13	2.03	9.58	9.47	15.16	11.41	12.0	10.1	1.6
2.40	192.	2.28	1.80	1.80	10.21	10.06	16.09	17.88	17.8	10.1	2.0
BEULAH TRENCH SITE 18 DATE OF SAMPLING: 9/15/76											
0.10	114.	2.06	0.94	0.99	16.72	17.45	27.92	63.71	38.5	10.7	3.1
0.20	218.	2.34	0.92	1.07	13.71	13.70	21.92	55.95	40.8	10.0	3.4
0.30	17517.	4.24	1.29	1.20	7.25	14.14	22.63	45.56	32.2	5.1	2.9
0.40	20653.	4.31	1.38	1.41	6.98	14.12	22.58	33.04	23.4	4.9	2.3
0.50	17124.	4.23	1.56	1.51	6.65	13.30	21.27	28.55	21.5	5.2	2.2
0.60	15664.	4.19	1.58	1.57	6.37	12.13	19.41	25.93	21.4	5.3	2.2
0.70	17340.	4.24	1.57	1.58	6.72	13.07	20.92	25.65	19.6	5.1	2.1
0.80	6515.	3.81	1.58	1.58	7.51	12.06	19.29	25.55	21.2	6.2	2.2
0.90	1935.	3.29	1.59	1.61	8.83	11.65	18.63	24.32	20.9	7.6	2.2
1.00	827.	2.92	1.67	1.62	9.66	11.33	18.12	23.98	21.2	8.5	2.2
1.10	338.	2.53	1.61	1.63	9.97	10.47	16.75	23.46	22.4	9.5	2.3
1.20	198.	2.30	1.63	1.62	10.39	10.27	16.43	23.84	23.2	10.1	2.3
1.30	204.	2.31	1.64	1.59	11.65	11.55	18.48	25.00	21.6	10.1	2.2
1.40	207.	2.32	1.52	1.65	11.83	11.74	18.79	23.03	19.6	10.1	2.1
1.50	199.	2.30	1.78	1.60	12.67	12.53	20.04	24.76	19.8	10.1	2.1
1.60	194.	2.29	1.50	1.62	14.71	14.51	23.22	23.98	16.5	10.1	1.9
1.70	171.	2.23	1.58	1.51	15.69	15.26	24.41	28.37	18.6	10.3	2.0
1.80	182.	2.26	1.46	1.51	17.22	16.86	26.98	28.41	16.8	10.2	1.9
1.90	171.	2.23	1.50	1.53	19.10	18.58	29.73	27.62	14.9	10.3	1.8
2.00	160.	2.20	1.63	1.62	16.94	16.36	26.18	24.06	14.7	10.4	1.8
2.10	168.	2.23	1.73	1.69	15.93	15.47	24.75	21.57	13.9	10.3	1.8
2.20	175.	2.24	1.70	1.70	15.27	14.89	23.83	21.10	14.2	10.3	1.8

*e following a value denotes an estimate

SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
William B. Peters, Luvern L. Resler, and Robert Vader 1/

Soil is characterized by laboratory methods to confirm judgment in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is

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to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio [Richards, 1954].

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase I of the scheme, all samples would be characterized for (1) soil structure stability through measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, selected samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, selected samples suspected through the testing results of Phases I and II to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase I to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases I, II, and IV to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

Exhibit 2
(Includes the following 18 pages)

SUPPORTING DATA

Soil Profile Descriptions (BLM 7310-9) Followed by Determination of Erosion Condition Class (BLM 7310-12) for the Following Profiles in the Order listed:

Profile No. 23 - Sec. 6, T. 144 N., R. 88 W.
Profile No. 22 - Sec. 4, T. 144 N., R. 88 W.
Profile No. 21 - Sec. 4, T. 144 N., R. 88 W.
Profile No. 18 - Sec. 4, T. 144 N., R. 88 W.
Profile No. 21 - Sec. 26, T. 145 N., R. 88 W.
Profile No. 20 - Sec. 26, T. 145 N., R. 88 W.
Profile No. 19 - Sec. 26, T. 145 N., R. 88 W.
Profile No. 18 - Sec. 26, T. 145 N., R. 88 W.
Profile No. 17 - Sec. 26, T. 145 N., R. 88 W.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Beulah Trench

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
ND	--	--	/			8 mo 76 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	Mercer	(23) Sec. 6, T. 144, R. 88		(23)		Fort Union

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union - Sentinel Butte	Stone – Rock –	Alkaline — Saline — Water table —	Residual / Footslope

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
6-14; ☐ Single ☒ Complex	--	2000	— Type SSF --- Class –	–

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
– 1st, 2nd, 3rd, 4th	-- Air -- Soil	Days --- > 28°	Well Drained	Mod. Slow	Mod.	-- in	2" per ft

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION ~~(pH)~~ Lime	42. BOUNDARY
Ap	0-5"	(D) 10YR 4/2 (M) 10YR 3/2		SCL	vc 1bk/ c-m 1bk	(D) sh (M) fr	—	2f	—	-	a
B2	5-12"	(D) 10YR 4/2 (M) 10YR 3/2		SCL	vc 1pr/ c-m 2bk	(D) sh (M) fr	—	2f	—	-	g
B3	12-36"	(D) 10YR 5/3 (M) 10YR 4/2		CL	c 1bk/ m 1bk	(D) sh (M) fr	—	2f	—	—	a
C1	36-72"	(D) 10YR 7/2 (M) 10YR 5/2		SiCL	massive	(D) h (M) fr	—	1f	—	e	a
C2	72-96"	(D) 10YR 7/2 (M) 10YR 5/2		SiCL	massive	(D) h (M) vfr	—	—	—	—	a
C3	96-120"	(D) 10YR 7/1 (M) 10YR 6/1	7.5YR 7/6 & 5YR 4/5	SiCL	massive	(D) h (M) fi	—	—	—	—	

Few lime coated calcareous gravels 30-36"..
Lime threads at 36"+ (e 1 f & s m)..
Sandy shales giving mottling influence 72-96"..
Thin layer of carbonaceous matl. from 99-105"..
Profile located in grain stubble..

(Instructions inside back cover). 1524-29 (Amor) Form 7310-9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By | Date 8/76
Location (23) 6., T144 – R88
Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 (5)	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles (7) 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 (2)	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 (5) 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 (6)	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 (3)	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		(31)			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
ND	--	--	---/---	----	---	8 mo 76 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	Mercer	(22) Sec. 4, T. 144, R. 88	---	(22)	---	Fort Union

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union Sentinel Butte	Stone – Rock –	Alkaline — Saline — Water table —	Residual

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
8-35% ☐ Single ☑ Complex	S	2000	— Type SSF --- Class –	–

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
– 1st, 2nd, 3rd, 4th	-- Air -- Soil	Days --- > 28°	Well Drained	Mod.-Mod. Rapid	Mod-Rapid	-- in	1.9" profile

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. ~~STONES~~ % VOL. gravel	41. REACTION ~~(pH)~~ Lime	42. BOUNDARY
A1	0-1"	(D) 7.5YR 5/2 (M) 7.5YR 4/2	—	L	f 2 sbk / m 2 cr	(D) So (M) Lo	—	2f	20%	—	a
AB	1-7"	(D) 5YR 5/3 (M) 5YR 4/3	—	grL	m 1 pr / f 1 sbk	(D) So (M) Lo	—	2f	35%	—	g
C	7-18"	(D) 2.5YR 4/3 (M) 2.5YR 3/3	—	grL	m 1 sbk / f 1 sbk	(D) So (M) Lo	—	2f	40%	—	a
R	18"+	5YR 7/4 to 2.5YR 5/3	—	–	–	—	—	–	—	—	

Fragmented baked shales at 18"+..

(Instructions inside back cover) 1522-23 (Ringling 1 Form 7310-9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By | Date 9/76

Location 4., T44., R89 (22)

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally lesa than 1" in height. (6) 7 8	Occura with each event. Soil and debris depoaited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunea and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles (7) 8	Extreme movement apparent, large and numerous deposita against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstaclea (9) 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestala generally evident, plant roots exposed (10) 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 (6)	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterna are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rilla 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 (6)	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 3	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 (6)	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15
SITUATION	TOTAL		(50)		

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Beulah Trench

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
N.D.	--	--	/			8 mo 76 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	---	(21) Sec. 4, T. 144, R. 88		(21)		Till

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union - Sentinel Butte	<10% total; Stone —; Rock —	Alkaline —; Saline —; Water table —	Glaciated Uplands

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
9-12%; Single ☐ Complex ☑	E	2140	Sheet & or Rill; Type; SSF --- Class –	–

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
– 1st, 2nd, 3rd, 4th	-- Air -- Soil	Days ---> 28°	Well Drained	Mod.	Mod.	-- in	2.2"/ft

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
AB	0-5"	(D) 10YR 4/2 (M) 10YR 3/2	—	SiL	c2bk/m2bk	(D) vh (M) fr	—	2f	—	e	a
Cca	5-36"	(D) 10YR 6.5/2 (M) 10YR 5/3	—	CL	c1bk/m1bk	(D) sh (M) vfr	—	1f	—	es	g
C2	36-72"	(D) 10YR 7/3 (M) 10YR 5/3	—	CL	massive	(D) h (M) fr	—	—	—	es	a
Cca	72-102"	(D) 10YR 6/3 (M) 10YR 5/3	—	CL	massive	(D) h (M) fr	—	—	—	e	a
C4	102-120"	(D) 10YR 6.5/3 (M) 10YR 5.5/3	2.5Y 5/6 / 7.5YR 6/6	SCL	massive	(D) sh (M) vfr	—	—	—	e	

Calcareous gravels & cobble scattered throughout profile..
Salt accumulations (Cca) at 72"+..
Vegetation: Green needle, Grama, J. Grass, L. Bluestem, various forbes, Wild Rose.

(Instructions inside back cover) 1484-89 (Zahl). Form 7310–9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

(21)

By

Date 8/76

Location Sect. 4., T144N., R88E..

Treatment affecting the SSF

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 (3)	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 (6)	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 (2)	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns (4) 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 (3)	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 (3)	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		(24)			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Beulah Trench

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
ND	--	--	----/----	----	----	8 mo 76 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	Mercer	(18) Sec. 4, T. 144, R. 88	----	(18)	----	Till

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union - Sentinel Butte	Stone -- Rock --	Alkaline — Saline — Water table —	Till

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
4-6% ☐ Single ☑ Complex	W	2140	— Type SSF --- Class -	-

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
- 1st, 2nd, 3rd, 4th	-- Air -- Soil	Days --- > 28°	Mod. Well Drained	Mod.	Mod.	-- in	2.2"/ft

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-1"	(D) 10YR 5/2 (M) 10YR 3/1	—	SiL	c2pl/ fm1bk	(D) sh (M) vfr	—	2f	—	—	a
AB	1-5"	(D) 10YR 5/2 (M) 10YR 4/2	—	SiL	c2bk/ m2bk	(D) h (M) fr	—	2f	—	—	g
B_{21t}	5-9"	(D) 10YR 5/2 (M) 10YR 4/2	—	CL	m2pr/ f2 bk	(D) h (M) fr	lnpf	2f	—	—	g
B_{22t}	9-17"	(D) 10YR 5/3 (M) 10YR 4/2	—	CL	m2pr/ m2bk	(D) h (M) fr	lnpf	2f	—	—	a
B_{3ca}	17-24"	(D) 10YR 5/3 (M) 10YR 4/2	—	CL	m-c2pr/ c2bk	(D) h (M) fr	—	2f	—	e	g
Cca	24-48"	(D) 10YR 6/2 (M) 10YR 5/2	—	CL	c2bk/ m2bk	(D) h (M) fr	—	1f	—	es	g
C2	48-90"	(D) 10YR 7/3 (M) 10YR 6/3	—	<CL	—	(D) h (M) fr	—	—	—	e	g
3Cca	90-114"	(D) 10YR 6/3 (M) 10YR 5/2	5YR 5/6 to 7.5YR 7/6	<CL	—	(D) h (M) fr	—	—	—	e	

0-5" horizons old Ap reforming.. Lime coated gravels & cobble scattered through-out profile. Till containing sandy shale influence at 48"+.. Salt accumulations 90"+..
Vegetation: G. Needle, J. Grass, Grama, various forbes.

(Instructions inside back cover) 1469-73 (Williams) Form 7310-9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

(18)

By	Date 9/76
Location Sect. 4., T144N., R88W	
Treatment affecting the SSF	

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particlea 4 (5)	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show alight movement 4 5 (6)	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposita against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments ahow no movement caused by wind or water 0 1 (2)	If present, coarse fragmenta have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns (4) 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence (4) 5 6	Well defined, amall, and few with intermittent deposits 7 8 9	Flow patterns contain ailt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 (5) 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gulliea in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numeroua and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		(29)			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Beulah Trench

VEGETATION–SOIL DESCRIPTION

1. State: N.D | 2. District: -- | 3. Planning Unit: -- | 4. Vegetation–Soil Unit: ---/--- | 5. Soil Map Symbol: ---- | 6. Surname: --- | 7. Date: 8 mo 76 yr

8. Area: -- | 9. County: Mercer | 10. Location (21) Sec. 26, T. 145, R. 88 | 11. Photo No.: --- | 12. Writeup No.: (21) | 13. File No.: --- | 14. Parent Rock: Sandstone

15. Formation Name: Fort Union – Sentinel Butte | 16. Surface Conditions (percent): Stone -- Rock -- | 17. Land Conditions: Alkaline — Saline — Water table — | 18. Landform: Alluvial

19. Slope (percent) 0-2 ☐ Single ☑ Complex | 20. Aspect: NE | 21. Elevation: 2000 | 22. Present Erosion: Type — SSF --- Class – | 23. Hydrologic Group: –

24. Precipitation (in): 1st, 2nd, 3rd, 4th – | 25. Temperature: -- Air -- Soil | 26. Frost-free: Days --- > 28° | 27. Drainage Class: Well drained | 28. Infiltration: Mod. | 29. Percolation: Mod | 30. ERD: -- in | 31. AWC: 2.2" per ft

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION ~~(pH)~~ lime	42. BOUNDARY
A1	0-2"	(D) 10YR 4/1 (M) 10YR 3/1	—	SiL	m1bk/ f1bk	(D) sh (M) vfr	—	2f	—	—	a
AB	2-7"	(D) 10YR 4/1 (M) 10YR 3/1	—	SiL	m1pr/ m2bk	(D) sh (M) vfr	—	2f	—	—	a
B21	7-12"	(D) 10YR 4/1 (M) 10YR 3/1	—	SiL	c1pr/ m2bk	(D) h (M) fr	—	2f	—	—	g
B22	12-18"	(D) 10YR 4/2 (M) 10YR 5/2	—	L	c1pr/ c1bk	(D) h (M) fr	—	2f	—	—	g
B3	18-30"	(D) 10YR 5/2 (M) 10YR 4/2	—	L	c1pr/ m1bk	(D) sh (M) vfr	—	2f	—	—	a
Cca	30-42"	(D) 10YR 6/2 (M) 10YR 5/2	—	FSL	c1bk/ m1bk	(D) sh (M) lo	—	1f	—	es	g
2	42-66"	(D) 10YR 6/2 (M) 10YR 5/2	—	L	massive	(D) sh (M) vfr	—	1f	—	e	g
3	66-84"	(D) 10YR 4/2 (M) 10YR 5/2	—	SCL	massive	(D) sh (M) vfr	—	–	—	e	a
IIC4	84-108"	(D) 10YR 6.5/2 (M) 10YR 5/2	—	S	massive	(D) lo (M) lo	—	–	—	—	a
C5cs	108-120"	(D) 10YR 6/2 (M) 10YR 5/2	—	SCL	massive	(D) sh (M) vfr	—	–	<20% gravels.	e	

0-7" old plow zone.. 42"+ fine lime threads (c/rsf)..
108"+ salt accumulations..

(Instructions inside back cover)   1515-21   (Straw)   Form 7310-9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By

Date 8/76

Location (21) 26,.T145..R88

Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 (5)	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 (6)	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water (3) 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 (5) 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 (6)	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 (3)	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		(37)			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State: ND | 2. District: -- | 3. Planning Unit: -- | 4. Vegetation–Soil Unit: \ / | 5. Soil Map Symbol: ---- | 6. Surname: | 7. Date: 8 mo 76 yr

8. Area: -- | 9. County: Mercer | 10. Location (20) Sec. 26, T. 145, R. 88 | 11. Photo No.: | 12. Writeup No.: (20) | 13. File No.: | 14. Parent Rock: Sandstone

15. Formation Name: Fort Union - Sentinel Butte | 16. Surface Conditions (percent): Stone -- Rock -- | 17. Land Conditions: Panspot Soil; Alkaline ✓ Saline ✓ Water table — | 18. Landform: Residual

19. Slope (percent): 2-4; ☐ Single ☑ Complex | 20. Aspect: N | 21. Elevation: 2100 | 22. Present Erosion: —; Type —; SSF --- Class – | 23. Hydrologic Group: -

24. Precipitation (in): -; 1st, 2nd, 3rd, 4th | 25. Temperature: -- Air -- Soil | 26. Frost-free Days ---> 28° | 27. Drainage Class: Well drained | 28. Infiltration: Mod. | 29. Percolation: Mod. | 30. ERD: -- in | 31. AWC: 2.2" per ft

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH) Lime	42. BOUNDARY
A1	0-1"	(D) 10YR 5/2 (M) 10YR 3/2	—	SiL	2 cr	(D) so (M) lo	—	2f	—	—	a
AB	1-7"	(D) 10YR 5/2 (M) 10YR 4/2	—	CL	m1pr/m2bk	(D) h (M) fr	—	2f	—	—	a
B2t	7-12"	(D) 10YR 5/2 (M) 10YR 4/2	—	>CL	m2pr/f2bk	(D) h (M) fr	1npf	2f	—	—	g
B3ca	12-30"	(D) 10YR 6/2 (M) 10YR 5/2	—	>CL	c1pr/m2bk	(D) vh (M) fi	—	1f	—	e	a
C1	30-48"	(D) 10YR 6/2 (M) 10YR 5/2	10YR 6/4	SiCL	Massive	(D) h (M) vfr	—	—	—	ve	g
2	48-72"	(D) 10YR 6.5/3 (M) 10YR 5/2	10YR 8/6 to 7.5YR 5/6	SiCL	Massive	(D) h (M) vfr	—	—	—	ve	g
3	72-120"	(D) 10YR 6.5/3 (M) 10YR 5/2	10YR 8/6 to 10YR 5/6	SiCL	Massive	(D) h (M) vfr	—	—	—	—	

0-7" old Ap with a cpr reforming at 7".
Sandy shales 30"+.
Profile located 6 to 8' either side from pan soils. Pan soils (Above) 40% of area. Bench position below rolling till crests with cobble & boulders.

(Instructions inside back cover) 1509-14 (Request) Form 7310-9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS
SOIL SURFACE FACTORS (SSF)

By | Date 8/76

Location (29) - 26..T45..R98

Treatment affecting the SSF

SOIL MOVEMENT*	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 (5)	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER*	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles (7) 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK*	If present, the distribution of fragments show no movement caused by wind or water 0 1 2	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 (5)	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING*	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 (6)	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS*	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 (6)	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 (3)	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		(35)			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Beulah Trench

VEGETATION–SOIL DESCRIPTION

1. State N.D	2. District --	3. Planning Unit --	4. Vegetation–Soil Unit /	5. Soil Map Symbol ----	6. Surname	7. Date 8 mo 76 yr
8. Area --	9. County Mercer	10. Location (19) Sec. 26, T. 145, R. 88	11. Photo No.	12. Writeup No. (L9)	13. File No.	14. Parent Rock Sandstone

15. Formation Name Fort Union — Sentinel Butte	16. Surface Conditions (percent) Stone -- Rock --	17. Land Conditions Alkaline — Saline — Water table —	18. Landform Residual
19. Slope (percent) 6-8; Single [ ] Complex [✓]	20. Aspect N; 21. Elevation 2100	22. Present Erosion Slight; Type Rill & or Sheet; SSF --- Class –	23. Hydrologic Group –

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
– 1st, 2nd, 3rd, 4th	-- Air -- Soil	Days ---> 28°	Welldrained	Mod. Rapid	Mod	-- in	1.2"/ft

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST — MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
Ap	0-6"	(D) 10YR5-5/2 (M) 10YR 4/2		FSL	m1bk/ f1bk	(D) lo (M) lo	—	2f	—	—	a
C1	6-18"	(D) 10YR6/2 (M) 10YR 5/2		FSL	vc1bk c-m1bk	(D) so (M) lo	—	1f	—	—	g
2	18-42"	(D) 10YR7/3 (M) 10YR 6/3		FSL	massive	(D) h (M) lo	—	—	—	—	g
3	42-102"	(D) 10YR7/2 (M) 10YR 6/3		LFS	massive	(D) sh (M) lo	—	—	—	—	g
4	102-120	(D) 10YR7/2 (M) 10YR6/2		FS	massive	(D) lo (M) lo	—	—	—	—	

Profile located on crest in grain stubble.. Softly consolidated (sandy shales) at 18"+.. Weakly calcareous 36-48".. Profile sandier with depth.
Vegetation in similar sandy areas not cultivated - L. Bluestem, G. Needle, Grama, J. Grass, Various forbs, Buckbrush, W. Rose, S. Sage.

(Instructions inside back cover) 1502-08 (Ohagen) Form 7310–9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

(19)

By	Date
Location Section 26, 145 N., 88 E	
Treatment affecting the SSF	

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 (3)	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 (3)	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 (2)	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 (3)	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 (5) 6	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 (3)	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		(22)			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Beulah Trench

VEGETATION–SOIL DESCRIPTION

1. State ND	2. District --	3. Planning Unit --	4. Vegetation–Soil Unit ----/----	5. Soil Map Symbol ----	6. Surname ----	7. Date 8 mo 76 yr
8. Area --	9. County Mercer	10. Location (18) Sec. 26, T. 145, R. 88	11. Photo No. ----	12. Writeup No. (18)	13. File No. ----	14. Parent Rock Sandstone
15. Formation Name Fort Union - Sentinel Butte	16. Surface Conditions (percent) Stone — Rock —	17. Land Conditions Alkaline — Saline — Water table —				18. Landform Alluvial
19. Slope (percent) 6-8% ☐ Single ☑ Complex	20. Aspect N	21. Elevation 2100	22. Present Erosion Type Sheet & or Rill SSF --- Class –			23. Hydrologic Group –
24. Precipitation (in) – 1st, 2nd, 3rd, 4th	25. Temperature -- Air -- Soil	26. Frost-free Days ---> 28°	27. Drainage Class Well drained	28. Infiltration Mod.	29. Percolation Mod.	30. ERD -- in; 31. AWC 20" part

32. HORIZON	33. THICKNESS	34. COLOR DRY/MOIST — MATRIX	34. MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
Ap	0-7"	(D) 10YR 3/2 (M) 10YR 3/1	—	>FSL	vc1bk/ c1bk	(D) sh (M) fr	—	2f	—	—	a
B21	7-18"	(D) 10YR 3/2 (M) 10YR 2/2	—	<CL	c2pr/ c-m2bk	(D) sh (M) fr	—	2f	—	—	g
B22	18-30"	(D) 10YR 4/2 (M) 10YR 3/2	—	CL	c2pr/ c-m bk	(D) sh (M) fr	—	2f	—	—	g
B3	30-36"	(D) 10YR 4.5/2 (M) 10YR 3/2	—	SCL	c1pr/ c1bk	(D) sh (M) fr	—	1f	—	—	g
C1	36-54"	(D) 10YR 5/2 (M) 10YR 4/2	—	SCL	massive	(D) sh (M) vfr	—	—	—	—	g
c	54-72"	(D) 10YR 5/3 (M) 10YR 4/3	—	FSL	massive	(D) so (M) lo	—	—	—	—	g
	72-96"	(D) 10YR 7/4 (M) 10YR 6/4	—	LS	massive	(D) so (M) lo	—	—	—	—	a
	96-120"	(D) 10YR 7/3 (M) 10YR 6/2	—	FS	massive	(D) so (M) lo	—	—	—	—	

Mottling 7.5YR 7/6 from sandy shales 96-108". Trace of lime at 36". Few scattered large gravels lime coated 60-72". Dark fine mtrl. (shale) from 108-120". Profile located in grain stubble.

(Instructions inside back cover) 1496-150 (Parshall) Form 7310–9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By	Date 8/76
Location (18) 26..T 145..R88	
Treatment affecting the SSF	

DETERMINATION OF EROSION CONDITION CLASS

Cultivated

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 (5)	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. 6 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 (3)	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles 7 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 (2)	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 (3)	Slight pedestalling, in flow patterns 4 5 6	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 (6)	Well defined, small, and few with intermittent deposits 7 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 (3)	Some rills in evidence at infrequent intervals over 10' 4 5 6	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL				
		(25)			

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

Beulah Trench

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
N.D	--	--	/	----		8 mo 76 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	Mercer	(17) Sec. 26, T. 145, R. 88		(17)		Sandy Shales

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union – Sentinel Butte	Stone -- Rock --	Alkaline — Saline — Water table	Colluvial

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
2-4 ☐ Single ☑ Complex	NW	2100	— Type SSF --- Class –	–

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
– 1st, 2nd, 3rd, 4th	-- Air -- Soil	Days --- > 28°	Mod. welldrained	Mod.	Mod.	-- in	1.9"/ft

32. HORIZON	33. THICKNESS	34. COLOR (DRY / MOIST) MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
Ap	0-6"	(D) 10YR 4/2 (M) 10YR 3/2		SiL	c 2 bk / m 2 bk	(D) sh (M) vfr	—	2f	—	—	a
B21t	6-12"	(D) 10YR 3/2 (M) 10YR 3/1		< SiCL	c 2 pr / m 2 bk	(D) h (M) fr	1npf	2f	—	—	g
B22t	12-24"	(D) 10YR 4/2 (M) 10YR 3/2		< SiCL	c 2 pr / m 2 bk	(D) h (M) fr	1npf	2f	—	—	a
B3	24-42"	(D) 10YR 5/3 (M) 10YR 4/3		SCL	c 2 pr / m 2 bk	(D) so (M) vfr	—	2f	—	—	a
Cca	42-54"	(D) 10YR 6/3 (M) 10YR 5/3		SCL	c 2 bk / m 2 bk	(D) sh (M) vfr	—	1f	—	es	g
C2	54-78	(D) 10YR 6/3 (M) 10YR 5/3		SCL	massive	(D) so (M) vfr	—	—	—	es	g
3	78-96	(D) 10YR 5/3 (M) 10YR 5/4		CL	massive	(D) h (M) fr	—	—	—	es	g
	96-120	(D) 10YR 6/2 (M) 10YR 5/2	(2.5Y 7/2)	CL	massive	(D) vh (M) fr	—	—	—	ev	

Profile wet at 96"+ showing influence from water table.
Light critical for colors. Site in a grain field.
Salt accumulations (Ccs) at 78"+-.

(Instructions inside back cover) 1490-95 (Arnegard) Form 7310-9a (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By | Date 8/76
Location (17) 26.. T14S.. R88
Treatment affecting the SSF

DETERMINATION OF EROSION CONDITION CLASS

SOIL SURFACE FACTORS (SSF)

SOIL MOVEMENT *	No visual evidence of movement 0 1 2 3	Some movement of soil particles 4 5	Moderate movement of soil is visible and recent. Slight terracing generally less than 1" in height. (6) 7 8	Occurs with each event. Soil and debris deposited against minor obstructions. 9 10 11	Subsoil exposed over much of area, may have embryonic dunes and wind scoured depressions 12 13 14
SURFACE LITTER *	Accumulating in place 0 1 2 3	May show slight movement 4 5 6	Moderate movement is apparent, deposited against obstacles (7) 8	Extreme movement apparent, large and numerous deposits against obstacles 9 10 11	Very little remaining *(use care on low productive sites)* 12 13 14
SURFACE ROCK *	If present, the distribution of fragments show no movement caused by wind or water 0 1 (2)	If present, coarse fragments have a truncated appearance or spotty distribution caused by wind or water 3 4 5	If present, fragments have a poorly developed distribution pattern caused by wind or water 6 7 8	If present, surface rock or fragments exhibit same movement and accumulation of smaller fragments behind obstacles 9 10 11	If present, surface rock or fragments are dissected by rills and gullies or are already washed away 12 13 14
PEDESTALLING *	No visual evidence of pedestalling 0 1 2 3	Slight pedestalling, in flow patterns 4 5 (6)	Small rock and plant pedestals occurring in flow patterns 7 8 9	Rocks and plants on pedestals generally evident, plant roots exposed 10 11	Most rocks and plants pedestalled and roots exposed 12 13 14
FLOW PATTERNS *	No visual evidence of flow patterns 0 1 2 3	Deposition of particles may be in evidence 4 5 6	Well defined, small, and few with intermittent deposits (7) 8 9	Flow patterns contain silt and sand deposits and alluvial fans 10 11 12	Flow patterns are numerous and readily noticeable. May have large barren fan deposits. 13 14 15
RILLS	No visual evidence of rills 0 1 2 3	Some rills in evidence at infrequent intervals over 10' 4 5 (6)	Rills ½" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills ½" to 6" deep occur in exposed area at intervals of 5 to 10' 10 11 12	May be present at 3" to 6" deep at intervals less than 5' 13 14
GULLIES	May be present in stable condition. Vegetation on channel bed and side slopes 0 1 2 (3)	A few gullies in evidence which show little bed or slope erosion. Some vegetation is present on slopes. 4 5 6	Gullies are well developed with active erosion along less than 10% of their length. Some vegetation may be present. 7 8 9	Gullies are numerous and well developed with active erosion along 10 to 50% of their lengths or a few well developed gullies with active erosion along more than 50% of their length 10 11 12	Sharply incised gullies cover most of the area and over 50% are actively eroding 13 14 15

SITUATION	TOTAL
	(37)

Erosion Condition Classes: Stable 0–20; Slight 21–40; Moderate 41–60; Critical 61–80; Severe 81–100

(Instructions on reverse)

LABORATORY ANALYSES AND PROCEDURES

Disturbed Hydraulic Conductivity was determined by the use of plastic tubes (Richards, et. al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 34b:112-113).

pH of 1:15 Soil Suspension (Richards, et. al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical of Soils, 1964)

pH Reading in $CACl_2$ Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

Saturation Extract taken from saturation soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 2 and 3:84-88, 27:107 and 4:89-90), C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical of Soils, 1964).

Carbonates and bicarbonates were determined by acid titration and chlorides were determined by the Mohr volumetric method (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 82:145-146 and 84:146), C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1: 945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical of Soils, 1964), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis chloride only, p. 69).

Sodium, Potassium, Calcium and Magnesium were determined by atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973) and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133, and 143).

Nitrate was determined by phenoldsulfonic acid (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 15:100), (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy 84-5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, 133:233-237).

Exchangeable Sodium and Potassium were extracted by ammonium acetate solution. Cation-Exchange Capacity was extracted by ammonium acetate and sodium acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 72-3:1033, 72-3.2.1:1033-1034 and 57-1:891-895).

Exchangeable Sodium Percentage was determined by calculation (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 20a:101).

Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et. al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22c:104).

Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22d: 104-105).

Boron was determined by extracting with hot water (Bear, et al., Chemical of Soils, 490-494) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063).

Trace Metals were determined by atomic absorption either by flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases,"Book 5 - Laboratory Analysis, 50-157) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition).

Organic Carbon - The Walkley-Block method is used, and diphenylamine is the indicator. (Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 90-3:1372-1375).

Bulk Density - Clod method. Density measured by water displacement. (Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 30-4:381-383).

Moisture Retention was determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

Particle-Size Analyses were determined by pipeting analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 41:122-124).

GLOSSARY

Annual Plant (annuals), A plant that completes its life cycle and dies in 1 year or less.

Aspect, The direction toward which a slope faces. Exposure.

Available Nutrient, The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water, The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock, Any part of the consolidated geologic formation, soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding, Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer, Substances in soil or water that act chemically to resist changes in reaction or pH.

Calcareous Soil, Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water, The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization, Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Compaction, The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop (See Nurse Crop)

Conifer, A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour, An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant, A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous, Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling, Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage, The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand, Density of stocking expressed in number of trees per acre.

Broadcast Seeding, A method of establishing a stand of vegetation by sowing seed on the ground surface.

Dissolved Solids, The difference between the total and suspended solids in water.

Disturbed Land, Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer, Tractor with a stell plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology, The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem, A total organic community in a defined area or time frame.

Effective Precipitation, That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent, Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment, All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility, The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion, The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition), A chemical element required for the normal growth of plants.

Evapotranspiration, A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation, The act of removing overburden material.

Fertilizer, Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade, The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent water-soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer (nitrogen (N), phosphorous (P), and potassium (K)).

Fill, Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage, Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land, Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minimum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on farms are commonly called woodland or farm forests.

Germination, Sprouting; beginning of growth.

Gradation, A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size, Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover, Any living or dead vegetative material producing a protecting mat on or just above the soil surface.

Ground Water, Subsurface water occupying the <u>saturation zone</u>, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called <u>plerotic water</u>; <u>phreatic water</u>.

Growing Season, Determined by the Lowery-Johnson Method.

Gully Erosion, Removal of soil by running water, with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding, Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious, Prohibits fluid flow.

Infiltration, Water entering the ground water system through the land surface.

Intermittent Stream, A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification, Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning, The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching, The removal of materials in solution by the passage of water through soil.

Leachate, Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume, A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime, from the strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural line are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime - limestone + heat (calcined) CaO
Hydrated lime - quicklime + H_2O $Ca(OH)_2$
Slaked lime - same as hydrated but slaking equipment is used for adding water
Milk of lime - water mixture containing lime in solution + lime in suspension

Micro-Climate, A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients, Nutrients in only small, trace, or minute amounts.

Mined-Land, Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch, A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation, Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural Seeding (Volunteer), Natural distribution of seed over an area.

Neutralization, The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil, A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation, The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop, A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives way to the permanent crop. Sometimes referred to as a companion crop.

Nutrients, Any element taken into a plant that is essential to its growth.

Overburden, The earth, rock, and other materials which lie above the coal.

Percolation, Downward movement of water through soils.

Permeability, The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH, The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume (-Log of H+ activity).

Pollution, Environmental degradation resulting from man's activities or natural events.

Pond, A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land, The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate, Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation, The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile, The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land, Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation, The natural or artificial restocking of an area with forest trees.

Regrading, The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation, Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Revegetation, Plants or growth which replaces original ground cover following land disturbance.

Ripping, The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff, That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil, A soil having a combination of a harmful quantity of salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil, A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone, A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation, Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment, Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin, A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed, The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seep, A more or less poorly defined area where water oozes from the earth in small quantities.

Shale, Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt, Small mineral soil grains the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil), Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Conserving Crops, Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity, The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile, A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure, The combination or arrangement of primary soil particles into secondary particles, units, or beds.

Solum, The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil, The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile), Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.

Stratified, Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip, To mine a deposit by first taking off the overlying burden.

Strip Mine, Refers to a procedure of mining which entails the complete removal of all material from over the product to be mined in a series of rows or strips; also referred to as "open cut," "open pit," or "surface mine."

Strip Mining (See Surface Mining)

Stripping, The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil, The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum, Alluvial, colluvial and bedrock material that lies below the soil profile.

Surface Soil, That part of the upper soil of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 inches) in non-arable soils.

Suspended Solids, Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace, Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope, A slope that is intersected by one or more terraces.

Texture, The character, arrangement and mode of aggregation of particles which make up the earth's surface.

Topdressing Material, Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth, The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography, The shape of the ground surface, such as hills, mountains or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil), Includes acid spoil with pH below 4.0. Also refers to spoil having amounts of minerals such as aluminum, manganese, and iron that adversely affect plant growth.

Transpiration, The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material), Soil material in a form of loose aggregation.

Vegetation, General term including grasses, legumes, shrubs, trees naturally occurring and planted intentionally.

Vegetative Cover, The entire vegetative canopy on an area.

Volunteer, Springing up spontaneously or without being planted; a volunteer plant.

Weathering, The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife, Undomesticated vertebrate animals, except fish, considered collectively.

APPENDIX F

GREENHOUSE

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1469 through T-1473

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield % 1/	Ave. Plant Height (cm.)	Field Cap. %
T-1469,a	0-2.0	2000	7 b	1.96	94	30	22.7
T-1470	2.0-4.0	2000	8 c	1.26	60	31	23.0
T-1471	4.0-5.5	2000	8 b, c	1.67	81	33.5	24.6
T-1472,a	5.5-7.5	2000	7 c	1.07	51	28.0	21.1
T-1473	7.5-9.5	2000	10 b, c	1.00	48	28.0	23.7

a=Data from 1 replication only   b=Salt crusting present   c=Surface cracking present

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1469	3	.54	13.1	1.5	33.7	7.8	0.3	0.2	2.2	1.5	0.2	0.26
T-1470	2	.66	11.4	1.5	10.6	8.3	0.3	1.4	1.1	1.5	1.6	0.13
T-1471	2	.50	13.3	1.2	8.7	8.5	0.7	6.9	0.6	1.2	6.6	0.13
T-1472	3	.92	13.0	.9	8.0	8.1	4.0	3.2	14.3	27.0	14.6	0.51
T-1473	3	1.24	15.7	1.2	8.9	8.0	5.8	3.9	24.2	38.2	22.0	0.64

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1469		.66	17.7	1.2	9.0	7.7	1.2	0.2	6.8	3.6	.4	.43
T-1470		.85	11.0	1.4	6.7	8.2	1.4	1.3	4.2	6.5	2.9	.30
T-1471		.77	11.3	1.1	7.9	8.6	1.9	6.3	1.7	5.7	11.9	.36
T-1472		.76	11.4	.8	7.3	8.2	5.8	3.5	23.1	38.7	19.3	.82
T-1473		.96	12.6	1.1	7.4	8.1	5.7	3.5	24.3	41.3	19.7	.87

1/ Indicates yeild of western wheatgrass received on each sample versus the yield obtained on the control soil.

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1484 through T-1489

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
T-1484	0-1.0	2000	6	2.00	97	31.5	25.7
T-1485	.1.0-3.0	2000	7 b, c	1.44	68	30.5	21.7
T-1486	3.0-4.5	2000	7 c	1.74	83	29.0	23.8
T-1487	4.5-7.0	2000	7	2.21	105	34.0	24.9
T-1488	7.0-8.5	2000	9 c	1.02	49	27.0	27.0
T-1489	8.5-10.0	2000	9 b, c	1.08	50	24.5	22.7

b=Salt crusting present c= Surface cracking present

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1484	3	1.26	16.2	1.93	16.1	8.1	0.4	0.2	3.1	1.4	0.3	.26
T-1485	2	.31	13.8	1.41	8.3	8.5	0.3	0.7	1.0	2.1	0.9	.18
T-1486	2	.20	13.6	1.20	9.7	8.5	0.5	3.2	0.7	1.7	3.6	.18
T-1487	2	.46	13.2	1.11	7.1	8.4	1.1	3.4	1.4	4.8	6.0	.26
T-1488	1	.75	15.6	1.27	8.1	8.0	5.6	2.2	25.6	52.4	13.6	.66
T-1489	2	1.05	18.3	1.57	6.6	8.0	6.0	2.4	27.6	57.2	14.5	.79

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1484		.92	13.0	1.70	8.6	8.1	1.1	0.1	7.9	2.9	0.3	.41
T-1485		.56	11.2	1.37	6.6	8.4	1.8	0.6	5.0	11.1	1.7	.46
T-1486		.57	12.5	1.15	8.1	8.5	1.6	2.9	1.9	7.6	6.3	.39
T-1487		.83	12.0	1.11	7.8	8.4	2.2	3.4	3.6	11.8	9.4	.42
T-1488		1.02	13.3	1.24	7.5	8.2	6.2	2.3	26.8	51.7	14.5	.95
T-1489		1.03	17.3	1.61	5.9	8.2	6.5	2.3	27.6	61.4	15.6	.98

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1490 through T-1495

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
*T-1490	0-2.0	2000	6 c	2.1	100	24.5	22.8
T-1491	2.0-3.5	2000	6 b, c	1.6	76	30.5	17.8
T-1492	3.5-4.5	2000	6	1.55	74	30.0	15.9
T-1493	4.5-6.5	2000	7 c	1.82	87	30.0	19.0
T-1494	6.5-8.0	2000	8 c	1.80	86	31.0	25.8
T-1495	8.0-10.0	2000	7	1.40	67	29.0	24.2

*This soil used as a control for experiment

b=Salt crusting c=Surface cracking

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1490	5	.88	18.6	0.70	39.5	7.6	0.4	0.4	2.4	1.3	0.5	0.41
T-1491	3	.21	8.5	.54	10.4	8.2	0.3	0.1	1.6	1.2	0.1	.26
T-1492	3	.24	9.5	.55	7.6	8.3	0.3	0.3	1.2	1.3	0.3	.28
T-1493	2	.46	10.4	.61	8.6	8.3	0.6	1.8	1.4	2.5	2.5	.26
T-1494	2	.60	13.9	.99	6.8	8.3	1.1	4.3	1.6	3.0	6.5	.15
T-1495	3	.91	11.5	.95	7.2	8.4	1.0	3.8	1.6	2.8	5.7	.13

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1490		1.03	23.9	.61	16.2	7.1	1.5	0.1	8.4	3.9	0.2	0.84
T-1491		.59	9.1	.51	5.3	7.7	1.2	0.1	6.9	3.6	0.3	0.63
T-1492		.63	7.0	.42	5.2	7.9	1.3	0.2	6.2	4.8	0.6	0.87
T-1493		.56	8.6	.60	5.8	8.0	1.7	1.9	5.1	7.2	4.6	0.63
T-1494		.77	12.0	.93	6.8	8.2	2.2	4.3	4.9	8.0	10.8	0.21
T-1495		.77	10.2	.82	6.5	8.2	1.8	3.0	4.7	6.5	6.7	0.27

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1496 through T-1501

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
T-1496	0-1.5	2000	a, 7	2.33	111	36.0	22.1
T-1497	1.5-3.0	2000	6	2.14	102	32.0	15.7
T-1498	3.0-4.5	2000	6	1.81	86	30.0	16.1
T-1499	4.5-6.0	2000	6	.97	46	24.5	14.1
T-1500	6.0-8.0	2000	6	1.09	52	28.5	13.1
T-1501	8.0-10.0	2000	6	1.83	87	31.0	16.0

a=data from 1 replication only

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1496	4	.66	29.4	.59	36.0	7.5	0.2	0.2	1.2	0.7	0.2	.15
T-1497	3	.14	13.7	.53	35.5	7.7	0.2	0.1	1.1	0.7	0.1	.10
T-1498	3	.10	10.6	.44	15.1	7.7	0.1	0.2	1.0	0.5	0.2	.08
T-1499	3	.10	10.2	.29	9.8	7.9	0.2	0.2	1.4	0.5	0.2	.08
T-1500	2	.13	5.4	.16	6.3	8.1	0.2	0.3	1.3	0.4	0.3	.05
T-1501	2	.15	5.9	.13	4.0	8.0	0.2	0.2	1.3	0.3	0.2	.08

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1496		.97	31.8	.51	23.8	6.7	1.2	0.1	8.0	2.7	0.2	.31
T-1497		.51	18.5	.48	11.8	7.0	1.3	0.2	8.2	3.1	0.3	.22
T-1498		.43	15.7	.46	9.7	7.0	1.8	0.2	11.4	4.3	0.5	.19
T-1499		.82	11.7	.30	7.2	7.6	1.3	0.2	8.8	2.1	0.4	.34
T-1500		.32	5.3	.13	4.2	7.9	1.0	0.2	6.8	1.4	0.4	.30
T-1501		.49	6.2	.05	2.8	7.8	1.1	0.2	7.7	1.7	0.4	.25

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1502 through T-1508

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
T-1502	0-0.5	2000	6	2.09	99		20.6
T-1503	0.5-1.5	2000	6	1.73	83		31.7
T-1504	1.5-3.5	2000	7, c	1.28	61		16.4
T-1505	3.5-5.0	2000	6	1.06	50		15.6
T-1506	5.0-7.0	2000	6	1.28	61		15.4
T-1507	7.0-8.5	2000	7	1.48	71		14.5
T-1508	8.5-10.0	2000	7	1.76	84		16.9

c=surface cracking

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1502	4	.28	10.6	.20	19.1	7.6	0.2	0.1	1.3	0.7	0.1	.10
T-1503	2	.23	6.4	.09	7.0	7.8	0.2	0.2	1.4	0.5	.20	.05
T-1504	2	.47	5.0	.07	6.6	8.0	0.2	.30	1.4	0.6	.30	.08
T-1505	1	.49	4.9	.05	6.0	8.1	0.2	.60	1.0	0.7	.50	.08
T-1506	1	.17	4.4	.04	6.9	8.2	0.2	.80	0.8	0.6	.60	.08
T-1507	1	.25	5.2	.15	9.7	8.2	0.2	.70	0.8	0.7	.60	.13
T-1508	1	.16	5.4	.04	4.8	8.1	0.2	.60	0.6	0.6	.50	.13

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1502		.57	14.2	.15	11.8	7.2	0.9	0.1	5.8	2.1	0.2	0.36
T-1503		.25	7.5	.03	4.2	7.7	1.0	0.1	6.7	1.9	0.3	0.14
T-1504		.59	5.4	.02	5.3	7.9	1.3	0.2	8.4	2.8	0.6	0.30
T-1505		.52	5.3	.03	4.5	7.9	1.1	0.4	6.4	3.3	0.8	0.33
T-1506		.32	5.7	.01	6.1	7.8	1.1	0.6	5.5	3.5	1.1	0.42
T-1507		.40	6.8	.09	6.1	7.5	1.1	0.4	5.7	3.5	1.0	0.50
T-1508		.48	7.8	.05	3.8	7.6	0.8	0.4	3.9	2.8	0.8	0.33

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1509 through T-1514

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
T-1509	0-1.0	2000	8	1.98	94	33.0	30.5
T-1510	1.0-2.5	2000	9, c	1.30	62	31.0	33.5
T-1511	2.5-4.0	2000	7, b, c	.96	46	25.0	37.5
T-1512a	4.0-6.0	2000	11, b, c	.19	9	10.0	17.3
T-1513a	6.0-8.0	2000	12, b	.51	24	18.0	34.0
T-1514	8.0-10.0	2000	11, b	.55	26	18.0	29.5

a=Data from 1 replication only b=Salt crusting present c=Surface cracking present

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1509	3	.68	17.8	2.4	23.4	7.9	0.4	0.9	1.6	1.2	1.1	.33
T-1510	2	.53	13.6	2.0	11.5	8.2	0.5	4.7	.9	.7	4.2	.20
T-1511	2	.33	10.0	1.8	9.4	7.8	5.3	5.6	24.0	18.8	26.0	.79
T-1512	2	1.20	14.2	1.7	6.0	7.8	7.6	9.4	21.7	30.9	48.2	.92
T-1513	3	.60	17.0	1.8	5.9	7.8	7.7	10.0	21.0	30.6	54.7	1.17
T-1514	2	.72	16.5	2.1	3.2	7.7	7.7	10.2	22.2	26.9	50.7	.99

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1509		1.27	15.0	1.65	13.9	7.8	1.7	1.0	8.2	5.5	2.5	8.1
T-1510		.74	11.2	1.86	8.6	7.9	2.0	4.6	4.8	4.2	9.7	7.3
T-1511		.46	11.4	1.70	7.7	7.9	6.1	7.2	29.3	24.1	36.9	1.53
T-1512		.83	12.5	1.50	5.5	7.9	8.3	10.4	25.4	36.5	57.5	1.76
T-1513		.60	11.4	1.40	4.3	7.9	8.2	11.0	23.1	35.5	59.9	1.63
T-1514		.58	12.7	15.7	2.5	7.8	7.8	10.7	22.2	27.6	53.4	1.48

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1515 through T-1521

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
T-1515	0-1.0	2000	7	2.36	112	34.5	21.7
T-1516	1.0-2.5	2000	7	1.75	83	31.5	16.2
T-1517	2.8.-3.5	2000	7	1.90	91	32.0	16.9
T-1518	3.5-5.5	2000	6, b	1.39	66	30.0	14.7
T-1519	5.5-7.0	2000	6, b	1.19	24	28.0	15.6
T-1520	7.0-9.0	2000	6	1.75	83	29.0	15.2
T-1521	9.0-10.0	2000	8	1.24	59	28.5	15.2

b-exhibited surface cracking

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1515	4	2.42	25.8	.88	27.9	7.3	0.2	.20	1.1	0.9	.17	.59
T-1516	3	1.43	13.0	.72	11.8	8.0	0.2	.10	1.6	0.7	.10	.31
T-1517	2	0.48	10.0	.72	6.5	8.1	0.3	.10	1.4	0.7	.10	.26
T-1518	2	.49	9.3	.88	6.5	8.2	0.5	.20	0.8	1.6	.20	.38
T-1519	2	.87	9.8	.85	5.6	8.4	0.3	1.8	0.4	2.3	2.1	.48
T-1520	2	.57	8.6	.51	4.5	8.4	0.3	2.3	0.6	0.8	2.0	.18
T-1521	2	.70	17.4	.76	11.7	8.1	0.3	1.1	1.1	0.7	1.0	.20

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1515		1.99	27.2	.53	27.5	7.0	1.1	0.1	6.2	3.0	.3	1.30
T-1516		.65	11.7	.57	8.2	7.8	1.1	0.1	6.8	2.6	.1	.79
T-1517		.86	10.1	.62	7.0	8.0	.8	0.1	5.3	1.8	.1	.70
T-1518		.54	9.8	.73	7.3	8.0	1.0	0.2	3.4	4.4	.3	.97
T-1519		.47	9.5	.70	7.4	8.1	1.3	1.2	2.5	6.4	2.5	1.05
T-1520		.64	8.2	.42	4.9	8.1	.7	1.1	2.2	1.9	1.6	.46
T-1521		.59	14.1	.60	8.0	8.0	1.0	.8	4.9	2.5	1.4	.60

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1522 through T-1523

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
T-1522	0-0.5	2000	7	1.93	92	31.5	30.4
T-1523	0.5-1.5	2000	8	1.49	71	30.0	29.5

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/1 1:1 dil. Ca	Mg	Na	K
T-1522	5	1.49	25.1	1.52	20.7	7.3	0.3	0.2	1.6	1.2	0.2	.28
T-1523	3	1.07	14.5	1.69	13.7	7.7	0.3	0.2	1.8	1.2	0.3	.18

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1522		1.62	24.5	1.13	17.6	7.2	1.4	0.2	7.9	4.4	0.4	.68
T-1523		1.21	16.9	1.44	10.4	7.5	1.4	0.2	8.3	4.8	0.5	.40

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples T-1524 through T-1529

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
T-1524	0-1.0	2000	6, c	1.81	86	30.0	16.2
T-1525	1.0-3.0	2000	7, c	1.65	78	30.0	18.4
T-1526	3.0-4.5	2000	7, b, c	1.29	61	26.5	19.9
T-1527	4.5-6.0	2000	7, b	1.83	87	34.0	23.8
T-1528	6.0-8.0	2000	9, b	1.04	50	27.0	31.0
T-1529	8.0-10.0	2000	11, b	1.03	49	26.5	23.3

b-soil surface cracking   c-salt crust formed

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
T-1524	3	.70	12.1	.54	14.6	7.8	.20	.10	1.1	.70	.10	.15
T-1525	2	.26	9.6	.79	9.2	8.1	.20	.20	1.3	.90	.20	.08
T-1526	1	.73	12.8	2.04	6.4	8.2	.30	.60	.80	1.5	.60	.08
T-1527	1	.34	10.6	1.07	3.2	8.3	.40	1.5	.60	1.9	1.7	.08
T-1528	1	.62	15.9	1.39	4.0	7.9	4.3	1.3	26.4	34.8	7.2	.61
T-1529	1	.78	10.9	3.06	1.3	7.7	4.4	1.5	26.5	39.9	8.6	.76

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
T-1524		.78	17.0	.41	13.5	7.1	1.0	.10	6.0	2.3	0.2	.37
T-1525		.26	10.0	.71	6.5	7.9	1.0	.10	6.0	3.0	0.3	.29
T-1526		.26	7.9	1.06	3.9	8.0	1.6	.50	6.0	8.0	1.2	.44
T-1527		.34	10.3	1.00	3.5	8.2	1.5	1.3	3.6	8.2	2.9	.37
T-1528		.36	7.6	1.26	4.4	8.0	5.0	1.4	27.8	37.8	7.7	1.02
T-1529		.95	11.2	3.42	1.5	7.6	5.2	1.5	26.3	40.3	9.1	1.20

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples 77-102-1 through 77-102-7

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
77-102-1	1.5-23.0	2000	7, c	1.58	76	30.0	13.6
2	23.0-50.0	2000	9, c	1.55	74	30.0	32.7
3a	50.0-75.0	2000	10, b, c	.84	38	23.5	62.9
4	75.0-100.0	2000	12, b, c	.52	25	19.0	---
5	100.0-124.4	2000	13, b, c	.53	25	20.0	54.5
6	124.4-138.2	2000	14, b, c	.52	25	20.0	54.9
7a	161.9-174.7	2000	8, b, c	.50	24	20.5	64.2

b=salt crusting c=surface cracking

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
77-102-1	6	1.08	11.00	.21	1.7	8.1	.30	2.8	.7	.5	2.1	.10
2	5	6.80	39.4	6.6	10.7	8.0	2.1	6.4	4.2	4.2	13.6	.65
3	2	9.70	47.6	8.4	11.2	8.0	2.1	6.7	4.3	4.4	33.0	.18
4	2	11.10	42.6	6.9	9.7	8.3	3.0	30.5	1.2	1.2	22.5	.03
5	2	7.50	32.9	2.9	6.7	8.6	2.0	27.0	.60	0.7	22.7	.03
6	2	12.80	51.4	7.0	13.5	8.8	2.2	27.6	.7	0.7	22.0	.08
7	2	11.30	75.4	6.0	7.8	8.5	1.7	25.2	.6	0.5	15.0	.20

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
77-102-1		2.3	14.2	.33	2.7	7.7	1.0	2.3	3.9	1.5	3.7	.30
2		7.5	54.2	7.10	16.6	8.0	3.5	5.6	11.2	9.2	17.6	1.38
3		11.4	74.3	9.80	26.3	8.1	4.0	29.3	2.0	1.5	38.3	.76
4		11.8	61.3	8.0	19.8	8.5	4.1	37.9	1.2	1.1	40.2	.66
5		11.9	62.7	5.6	14.7	8.5	5.4	49.5	.9	1.2	51.6	.40
6		14.1	79.8	7.1	30.7	8.4	5.0	37.2	1.7	1.4	46.6	.54
7		15.6	98.2	7.4	17.1	8.5	3.0	28.1	1.3	.9	29.4	.46

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples 77-103-1 through 77-103-15

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
77-103-1	0-10.0	2000	8, c	2.04	97	32.5	23.5
2a	10-16.8	2000	7, c	.13	6	8.0	11.8
3	16.8-28.6	2000	11, b	1.50	71	30.0	25.3
4	28.6-55.0	2000	7	1.89	90	31.0	17.3
5	55.0-81.0	2000	8	1.42	68	29.0	16.1
6	81.0-107.0	2000	7	1.48	71	30.0	15.0
7	107.0-133.3	2000	6, b	1.55	74	29.5	15.1
8	140.4-150.3	2000	9, b, c	1.16	55	28.5	39.4
9	150.3-161.2	2000	9, b, c	1.43	68	29.5	39.9
10	161.2-177.9	2000	13, b, c	.64	31	23.5	65.7
11	177.9-193.2	2000	12, b, c	.80	38	21.0	45.6
12	193.2-201.0	2000	11, b, c	.25	56	29.0	66.6
13	201.0-220.5	2000	11, b, c	.31	16	21.5	48.5
14	220.5-244.6	2000	10, c	.22	22	19.5	54.9
15	266.6-279.0	2000	12, c	.22	21	19.0	---

a=data from 1 replication only b=salt crusting present c=surface cracking present

SOIL LABORATORY DATA
(Pre-Plant)

Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 Ca	Mg	Na	K
77-103-1	2	4.32	12.7	1.47	4.7	8.2	.7	2.0	1.2	3.1	3.0	.28
2	--	no data	--	--	--	--	--	--	--	--	--	--
3	4	1.50	13.4	2.00	7.9	7.8	3.3	.4	6.2	17.2	1.9	.87
4	2	.55	5.0	.17	1.3	8.0	.3	2.2	.6	.7	1.8	.15
5	2	.34	6.0	.13	4.6	8.2	.3	2.7	.6	.7	2.3	.15
6	3	.52	10.2	.21	3.8	7.9	.7	1.9	2.2	2.5	2.9	.23
7	3	1.17	11.5	.34	3.9	8.0	.3	.5	1.4	1.2	.6	.20
8	2	6.70	43.3	5.10	10.2	8.0	1.6	9.7	1.7	1.4	12.1	.51
9	2	5.30	17.2	2.05	2.4	8.6	1.4	15.4	.8	.6	12.8	.15
10	2	8.90	53.1	5.30	11.7	8.3	1.9	19.3	.8	.7	16.4	.13
11	3	13.60	64.2	9.80	18.9	8.4	1.7	20.1	.6	.5	15.2	.08
12	2	6.45	19.5	1.56	3.10	8.8	2.9	27.7	1.2	0.9	22.7	.04
13	2	14.40	88.8	11.45	17.00	8.8	1.7	19.1	0.7	0.6	15.1	.17
14	2	16.30	62.0	11.25	18.60	8.5	1.7	20.2	0.6	0.6	15.5	.08
15	2	11.50	80.2	5.10	6.40	8.6	1.7	13.5	0.8	0.6	15.3	.08

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
77-103-1		3.6	10.4	1.41	6.7	8.2	1.8	1.7	4.0	8.9	4.4	.45
2		.71	10.6	.46	6.7	8.0	1.7	1.0	8.2	5.5	2.5	1.1
3		1.3	15.5	1.80	9.2	7.9	4.5	0.5	32.3	22.6	2.7	1.28
4		.5	9.1	.34	2.1	7.4	1.5	1.5	5.6	4.6	3.4	.47
5		.5	6.4	.25	2.3	7.7	1.8	1.9	6.7	5.7	4.6	.50
6		.6	11.0	.34	2.8	7.5	2.1	1.2	9.8	8.6	3.7	.54
7		1.9	16.0	.44	6.0	7.4	1.6	0.5	8.5	5.8	1.2	.71
8		9.0	47.6	7.8	18.7	7.9	3.4	9.5	5.9	5.0	22.2	1.33
9		7.9	20.0	3.37	3.3	8.4	3.7	24.6	1.7	1.9	32.8	.79
10		11.6	70.3	7.70	22.6	8.3	4.7	31.8	3.1	1.7	43.4	.67
11		12.8	107.0	9.30	26.8	8.4	4.8	29.6	2.6	1.9	43.6	.56
12		8.7	24.9	1.97	4.1	8.7	3.6	31.2	1.6	1.2	36.0	.02
13		12.1	102	10.4	21.0	8.6	--	--	--	--	--	--
14		15.9	84.3	9.8	28.7	8.1	4.0	34.8	1.7	1.3	42.2	.77
15		15.0	91.4	6.4	17.7	8.4	3.9	34.4	1.6	1.3	40.8	.71

GREENHOUSE AND LABORATORY DATA

Site Name: Beulah Trench, North Dakota

Sample Set Represented: Samples 77-107-1 through 77-107-11

GREENHOUSE DATA

Sample No.	Depth (ft.)	Pot Wt. (gms.)	Germination Time (days)	Yield gms./pot	Relative Yield %	Ave. Plant Height (cm.)	Field Cap. %
77-107-1a	1.3-10.0	2000	6, c	3.00	143	3.5	23.5
2	10.0-30.0	2000	8	1.72	82	29.5	14.2
3a	30.0-45.2	2000	7	1.25	60	28.0	13.9
4	45.6-60.4	2000	8, c	1.19	57	30.0	77.1
5a	60.4-86.8	2000	8 b, c	.75	36	26.0	21.9
6	86.8-109.6	2000	9, b, c	.86	41	24.5	26.7
7	111.1-132.8	2000	8, b, c	2.04	97	35.0	41.4
8	132.8-152.0	2000	10, b, c	1.14	54	32.5	48.4
9	152.0-172.1	2000	9, b, c	.69	33	24.0	50.9
10	183.1-200.0	2000	10, b, c	1.26	60	31.0	53.9
11	205.9-217.6	2000	12, b, c	.80	38	29.0	59.8

a=data from 1 replication only   b=salt crusting present   c=surface cracking present

SOIL LABORATORY DATA
(Pre-Plant)

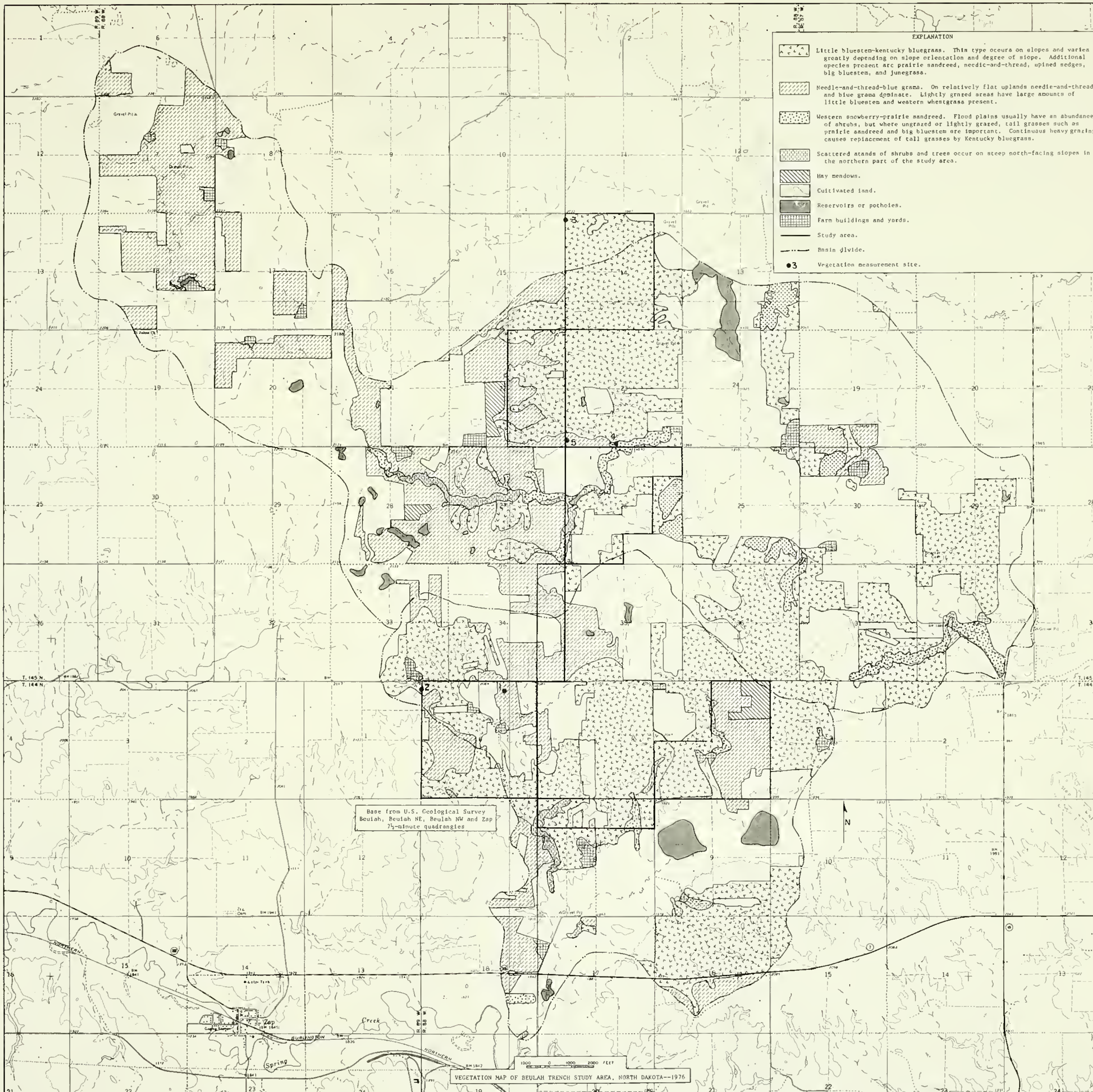
Sample No.	Avail. Plant Nutrients (ppm) P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Water Soluble Cations meq/l 1:1 dil. Ca	Mg	Na	K
77-107-1	--	--	--	--	--	--	--	--	--	--	--	--
2	3	.58	6.2	.15	3.6	8.0	.3	2.8	.4	.4	1.8	.08
3	3	.46	6.2	.22	1.2	7.7	.3	1.4	1.1	.8	1.3	.10
4	8	.95	27.0	1.97	2.8	7.6	.9	.9	4.5	3.4	1.8	.31
5	1	3.41	13.7	1.53	4.7	8.0	.7	.7	4.2	2.3	1.1	.36
6	2	6.2	20.2	3.31	10.6	7.8	.9	1.0	4.0	3.1	1.8	.59
7	2	5.7	19.8	1.52	7.3	8.2	1.3	11.7	1.0	.8	11.0	.38
8	2	5.2	26.9	2.13	5.6	8.2	2.2	23.7	1.2	.9	24.0	.28
9	3	10.6	18.5	5.6	4.5	8.5	1.3	13.4	.9	.7	12.2	.20
10	2	6.0	33.3	2.82	5.4	8.6	1.4	17.7	.6	.5	13.1	.94
11	2	4.74	54.7	4.33	9.5	8.5	2.4	32.2	.8	.6	26.7	.08

(Post Plant)

Sample No.	P	Zn	Fe	Cu	Mn	pH 1:1	Elect. Cond. 1:1	SAR	Ca	Mg	Na	K
77-107-1		.80	8.4	1.35	5.4	8.1	1.6	2.0	4.4	6.5	4.7	.43
2		.68	10.5	.30	5.6	7.6	1.1	2.0	3.8	2.2	3.3	.37
3		.72	10.3	.34	2.3	7.1	1.7	.9	8.3	4.4	2.2	.76
4		1.39	30.1	2.25	3.3	7.4	3.6	.7	23.3	14.9	2.8	.94
5		4.15	23.7	2.36	5.6	7.9	3.2	.4	20.3	10.2	1.7	1.34
6		9.2	16.3	2.55	13.1	7.7	3.2	.8	17.6	12.9	2.1	1.46
7		9.7	29.7	2.24	11.0	8.0	3.6	14.3	4.1	3.9	28.8	1.28
8		12.1	43.3	4.66	14.0	8.3	4.9	29.5	2.6	2.3	46.0	.91
9		12.6	29.9	7.32	9.1	8.3	3.5	16.9	3.0	2.8	28.6	1.10
10		10.5	58.1	4.99	15.5	8.4	3.5	24.7	1.9	1.5	32.4	.68
11		10.6	68.7	7.25	25.6	8.3	4.9	32.0	2.4	1.4	43.8	.66

APPENDIX G

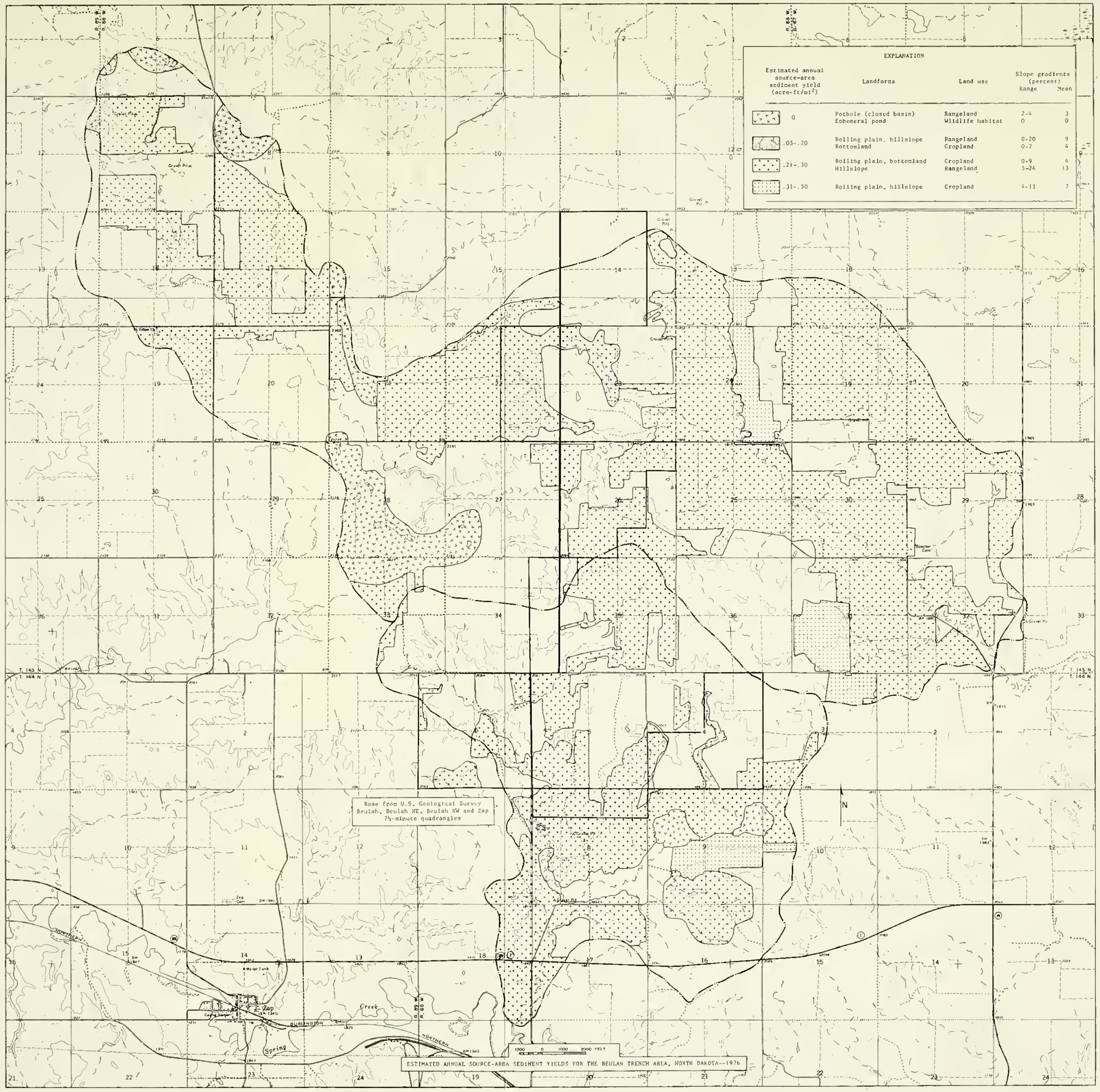
VEGETATION



VEGETATION MAP OF BEULAH TRENCH STUDY AREA, NORTH DAKOTA--1976

APPENDIX H

HYDROLOGY



ESTIMATED ANNUAL SOURCE-AREA SEDIMENT YIELDS FOR THE BEULAH TRENCH AREA, NORTH DAKOTA--1976

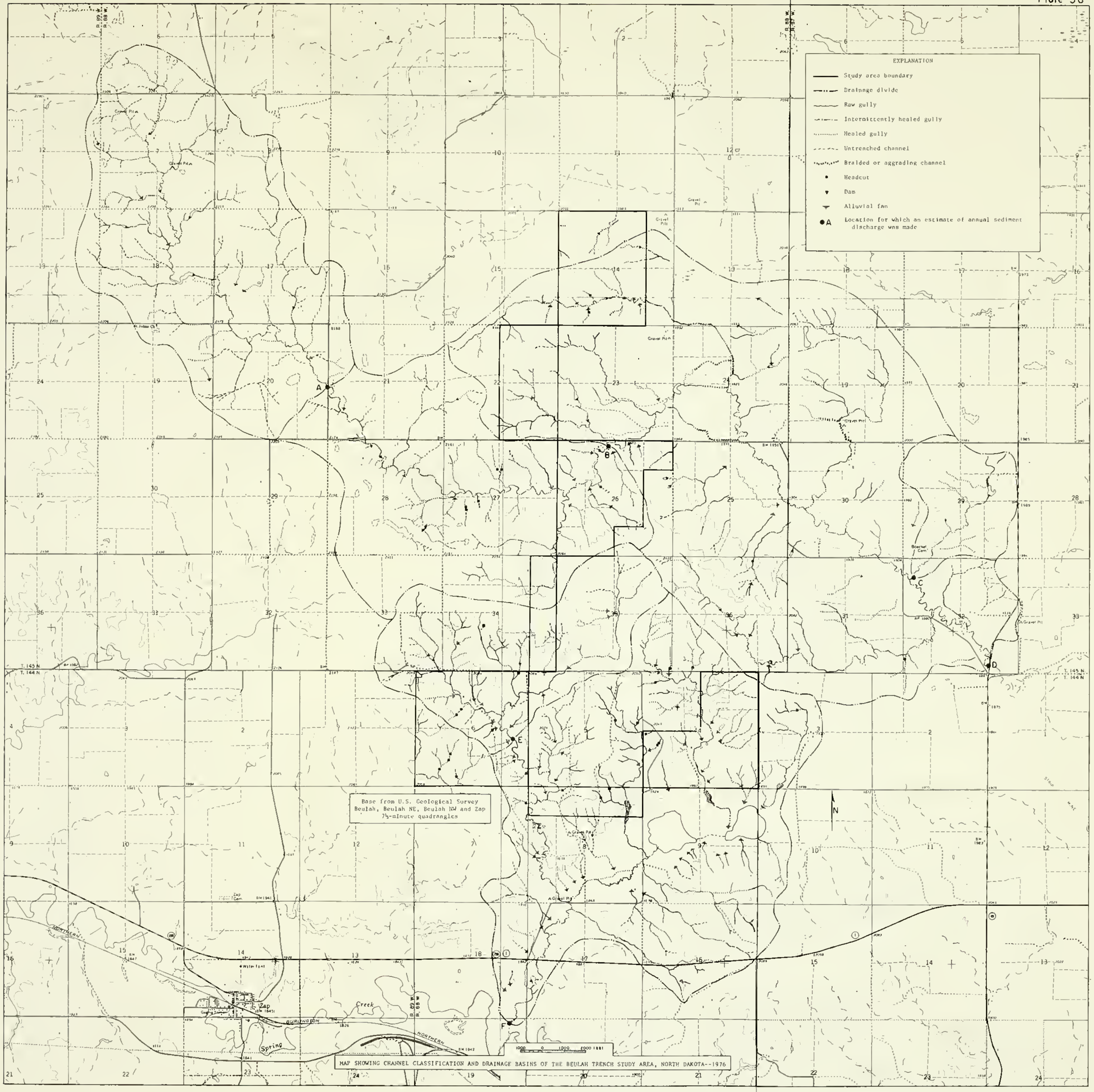

EXPLANATION
Study area boundary
Drainage divide
Raw gully
Intermittently healed gully
Healed gully
Untrenched channel
Braided or aggrading channel
Headcut
Dam
Alluvial fan
A Location for which an estimate of annual sediment discharge was made
Base from U.S. Geological Survey
Beulah, Beulah NE, Beulah NW and Zap
7½-minute quadrangles
1000 0 1000 2000 FEET
MAP SHOWING CHANNEL CLASSIFICATION AND DRAINAGE BASINS OF THE BEULAH TRENCH STUDY AREA, NORTH DAKOTA--1976
T. 145 N.
T. 144 N.
R. 89 W.
R. 88 W.
R. 87 W.
Zap
Spring
Creek
NORTHERN
A
B
C
D
E
F
N

Table 77

--Changes in water chemistry (+ or -) of runoff water as compared to applied water.
(1 in second part of site designation indicates dry run; 2 indicates wet run)

					Variable											
					Cations (mg/L)					Anions (mg/L)					Total Cations	Total Anions
Site	Composite	pH	Specific Conduct.	Residue mg/L	Calcium	Magnesium	Potassium	Sodium	Bicarb.	Carbonate	Chloride	Flouride	Sulfate	NO_2+NO_3	MEQ/L	MEQ/L
Beulah 1-1	Applied	7.2	485	321	20	8.9	7.2	74	147	0	2.6	0.3	110	4.5	5.133	5.110
	1	-.8	+ 58	+ 78	+12	+ .7	+7.8	+12	+12	0	+ .2	-.1	+50	-2.8	+1.378	+1.038
	2	-.6	+ 71	+ 47	+ 9	-2.2	+5.8	+ 2	+ 9	0	+ .1	0	+40	-3.1	+ .504	+ .762
	3	-.1	+ 51	+ 41	+ 6	-2.6	+4.8	+ 2	+ 7	0	- .2	0	+40	-3.3	+ .295	+ .706
Beulah 1-2	Applied	7.3	820	553	29	15	9.4	130	218	0	3.6	0.3	230	4.7	8.576	8.814
	1	-.1	+133	+ 94	+11	-3	+4.6	+20	+33	0	+1.4	0	+40	+ .2	+1.290	+1.428
	2	-.1	+147	+116	+10	-2	+3.6	+30	+58	0	+ .2	0	+60	-3.8	+1.732	+1.938
	3	-.3	+ 77	+ 62	+ 7	-3	+2.6	+20	+25	0	0	0	+40	-4.2	+1.039	+ .946
Beulah 2-1		No samples obtained												1.3	8.709	8.921
														- .7	-1.086	- .943
														0	- .930	-1.044
Beulah 2-2		No samples obtained												- .9	- .962	- .859
Beulah 3-1	Applied	7.6	827	545	36	18	8.3	120	252	0	3.6	0.3	220	1.3	8.709	8.921
	1	-.5	- 16	- 12	+ 6	-3	+1.3	-10	- 8	0	+ .1	0	0	- .7	- .349	- .180
	2	-.2	- 8	0	+ 6	-3	+1.0	0	-11	0	+ .4	0	0	0	+ .078	- .169
	3	-.1	- 1	+ 16	+ 5	-3	+ .9	0	- 7	0	0	0	+20	- .9	+ .026	+ .238
Beulah 3-2	Applied	7.6	827	545	36	18	8.3	120	252	0	3.6	0.3	220	1.3	8.709	8.921
	1	-.2	- 16	- 12	+ 6	-3	+1.3	-10	- 8	0	+ .1	0	0	+5.7	-2.042	-2.294
	2	-.2	- 8	0	+ 6	-3	+1.0	0	-11	0	+ .4	0	0	0	-2.407	-2.565
	3	-.1	- 1	+ 16	+ 5	-3	+ .9	0	- 7	0	0	0	+20	0	-2.238	-2.516
Beulah 4-1	Applied	7.6	827	545	36	18	8.3	120	252	0	3.6	0.3	220	1.3	8.709	8.921
	1	-.8	-207	-119	- 5	-4	+5.7	-37	-92	0	+2.0	0	-60	+5.6	-1.429	- .950
	2	-.8	-210	-144	- 6	-6	+3.7	-37	-93	0	+ .2	-.1	-50	- .2	-1.405	-1.187
	3	-.8	-198	-140	- 8	-5	+3.7	-45	-90	0	+ .2	-.1	-50	- .5	-1.515	-1.793
Beulah 4-2	Applied	7.6	827	545	36	18	8.3	120	252	0	3.6	0.3	220			
	1	-.6	-111	- 54	- 6	-4	+2.7	-20	-48	0	+2.2	0	-30			
	2	-.6	-129	- 68	- 5	-4	+1.7	-20	-58	0	- .5	0	-10			
	3	-.5	-135	-100	- 7	-4	+1.3	-20	-55	0	- .7	0	-40			