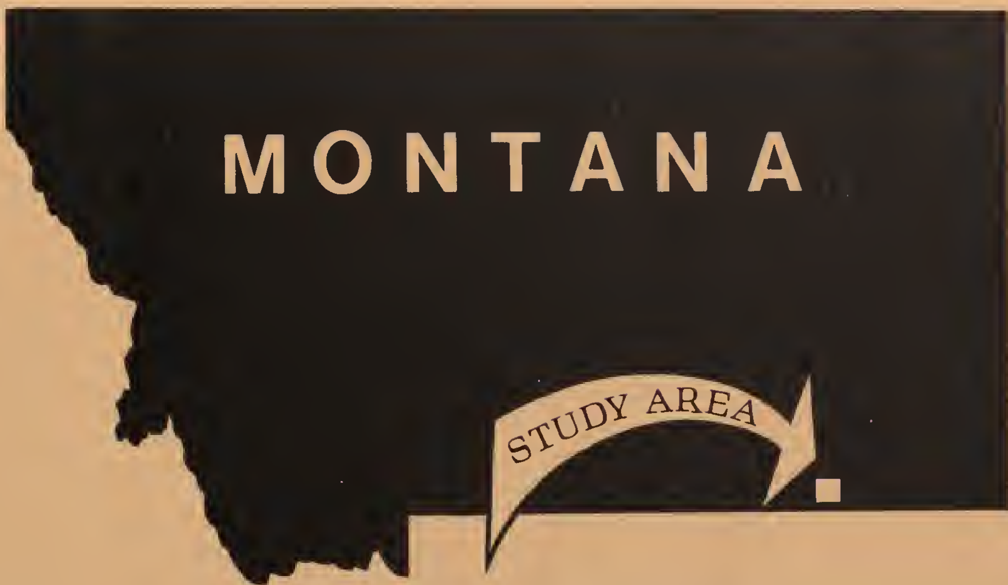

RESOURCE and POTENTIAL RECLAMATION EVALUATION

BEAR CREEK STUDY AREA -WEST MOORHEAD COALFIELD

EMRIA REPORT #8 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT
BUREAU OF RECLAMATION
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), water, 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, Bureau of Reclamation 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

BEAR CREEK STUDY AREA
WEST MOORHEAD COALFIELD, MONTANA

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CONTENTS (con't)

CONTENTS (con't)

PLATES

PLATES (con't)

FIGURES

FIGURES (con't)

TABLES

TABLES (con't)

PHOTOGRAPHS

EXHIBITS

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

OF

BEAR CREEK STUDY AREA
WEST MOORHEAD COALFIELD, MONTANA

INTRODUCTION

A growing and affluent society is creating an ever increasing need for energy. Attention has focused on the energy fuels sources existent in the western states, primarily the Rocky Mountain and the Northern Great Plains Coal Provinces, due to the abundance, ease of extraction, and the quality of the resources present. It is the responsibility of the Bureau of Land Management to assist in meeting these energy demands and, at the same time, provide sound reclamation and rehabilitative guidelines so that the lands subjected to disturbance are returned to a useful condition.

Purpose

The purpose of this study is to assure adequate baseline data for choosing optimum reclamation objectives and for establishing appropriate data and interpretation for preparation of lease stipulations for the Bear Creek Study Area.

Objectives

a. To analyze and quantify environmental impacts from surface mining of coals.

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

c. To provide environmental resource information needed to implement effective reclamation programs and for the development of meaningful lease stipulations as required.

d. To provide resource and impact information to support state and local land use planning efforts.

e. To determine the present and potential capability of the soil and geologic strata to support and maintain vegetation on known coal deposits.

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

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

Authority

Public Land Administration Act of July 14, 1960 (74 Stat. 506).

Responsibility

Bureau of Land Management

a. Select reclamation study site areas for coordinated investigation of vegetation, soil, geological structure, surface water, and ground water.

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

c. Reviews and consolidates work order and field office data.

d. Procurement of easements and rights-of-way to conduct the studies.

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

Bureau of Reclamation

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

b. Conducts drilling operations for the procurement of core samples for coal and soil analyses.

c. Installs casing in holes selected for gound water observation wells.

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

e. Arranges for greenhouse studies to assist in determining overburden materials potential for supporting vegetative growth.

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

g. Recommends to district office, Bureau of Land Management, suitable plant species for use in areas to be reclaimed.

h. Advises district office, Bureau of Land Management, on reclamation techniques.

i. Prepares geologic maps, logs and cross sections.

j. Advises the Bureau of Land Management on significant paleontological sites in the study area.

Geological Survey

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

b. 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 waters of the area.

c. Prepares sediment yield maps.

d. Prepares erodibility maps.

e. Estimates annual runoff and peak flows.

f. Collection and interpretation of data to predict alternative solutions to ground water problems encountered during mining and reclamation.

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

h. Prepares ground water and geochemical maps.

i. Tabulation of coal resources estimates.

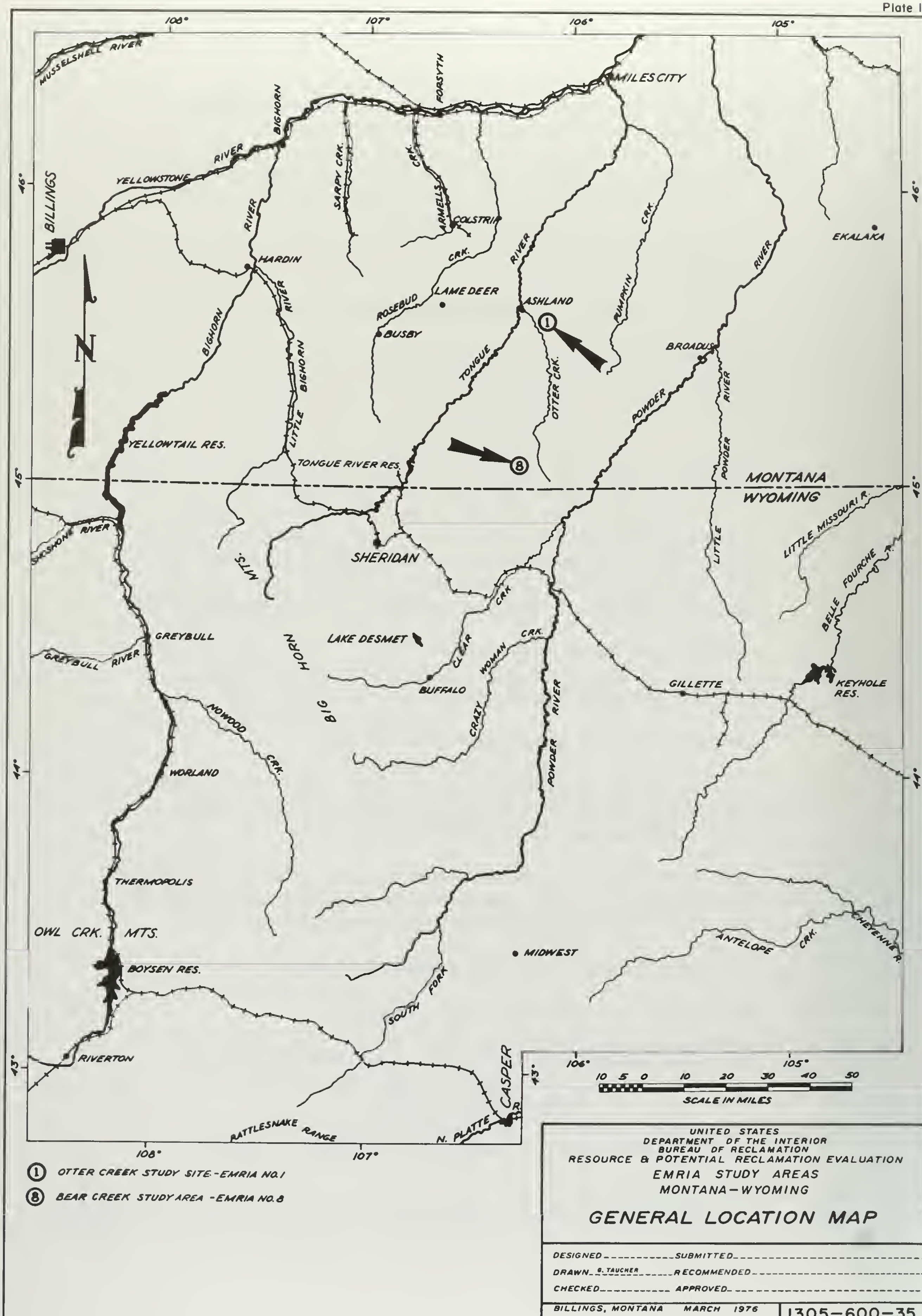
j. Table of analytical results on coal resources.

General Description

Location

The Bear Creek Study Area is located in the southeastern corner of Montana in Powder River County, approximately 35 miles south of Ashland, Montana. The general location of the area is shown on plate 1. The

Plate I


MILES CITY
FORSYTH
BILLINGS
HARDIN
COLSTRIP
LAME DEER
ASHLAND
BUSBY
BROADUS
EKALAKA
YELLOWTAIL RES.
TONGUE RIVER RES.
SHERIDAN
MONTANA
WYOMING
GREYBULL
LAKE DESMET
BUFFALO
GILLETTE
KEYHOLE RES.
WORLAND
THERMOPOLIS
OWL CRK. MTS.
BOYSEN RES.
MIDWEST
RIVERTON
CASPER
RATTLESNAKE RANGE
N. PLATTE R.
MUSSELSHELL RIVER
YELLOWSTONE RIVER
BIGHORN RIVER
LITTLE BIGHORN RIVER
SARPY CRK.
ARMELLS CRK.
ROSEBUD CRK.
TONGUE RIVER
OTTER CRK.
PUMPKIN CRK.
POWDER RIVER
LITTLE POWDER RIVER
LITTLE MISSOURI R.
BELLE FOURCHE R.
SHOSHONE RIVER
GREYBULL RIVER
NOWOOD CRK.
BIG HORN MTS.
CLEAR CRK
CRAZY WOMAN CRK.
SOUTH FORK
ANTELOPE CRK.
CHEYENNE R.
108°
107°
106°
105°
46°
45°
44°
43°
10 5 0 10 20 30 40 50
SCALE IN MILES
① OTTER CREEK STUDY SITE - EMRIA NO. 1
⑧ BEAR CREEK STUDY AREA - EMRIA NO. 8
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
EMRIA STUDY AREAS
MONTANA—WYOMING
GENERAL LOCATION MAP
DESIGNED
SUBMITTED
DRAWN B. TAUCHER
RECOMMENDED
CHECKED
APPROVED
BILLINGS, MONTANA MARCH 1976
1305—600—35

area includes about 3,200 acres in all or parts of Sections 33 and 34, T. 8 S., R. 45 E., and Sections 2, 3, 4 and 11, T. 9 S., R. 45 E., Montana Principal Meridian. The location and setting of the study area is shown on photograph 1 and plate 2. The surface is privately owned; however, most minerals, including coal, are federally owned. The ownership status of all minerals is shown on plate 3.

Cultural Features

Prior to the 1870's, this area was occupied by various tribes of plains Indians. The land provided for and satisfied their physical, sociological, and cultural needs. These people fought desperately to retain these lands which were being "invaded" by the white man. The resultant disposition of lands included the establishment of two reservations, the Crow and the Northern Cheyenne. The eastern boundary of the Northern Cheyenne Reservation lies approximately 25 miles northwest of the study area. The population density is one person per square mile. The area is steeped in significant Indian cultural values and historical occurrences. Archeological inventories have identified numerous significant sites. None were disturbed by these studies; however, it is recommended that a more intensive investigation be conducted prior to any surface mining.

Industry

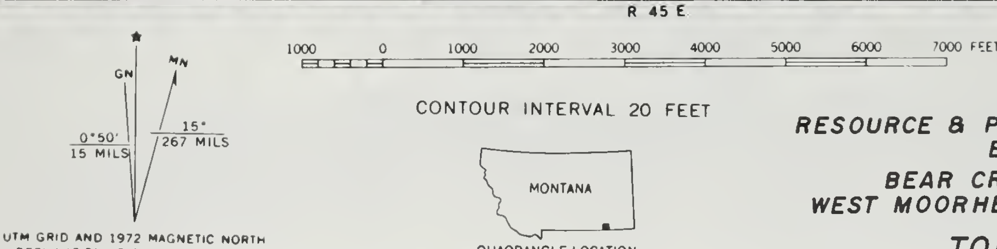
The major industries in the area are raising livestock and forage production. Another industry of lesser importance is timber processing. Small sawmills at Birney, Ashland and Lame Deer produce fence posts, corral posts, bridge timbers, and rough lumber for out-building construction.

Wildlife

The area has one of the highest population densities of deer in the state. Both mule and whitetail deer are present. The mule deer tend to inhabit the higher grassland-shrub communities while the whitetail deer tend to occupy the lower hay meadows-cultivated lands along the Bear Creek drainways. Other game species include ring necked pheasant, Hungarian partridge, cougar, pronghorn antelope, sharptail and sage grouse. Some of the primary nongame species include coyote, porcupine, bobcat, jackrabbits, and various rodents. There are no perennial-waters located on the site. The primary fish species found in the streams of the area are sauger, catfish, bullheads, crappie, perch, and various "rough" fish such as carp and suckers.

The major recreational use is in the form of sightseeing. Montana Highway 212 passes through the area approximately 35 miles north of the study area. This highway provides access for tourists through the Crow and Northern Cheyenne Reservations. It is also a direct route to the Black Hills from the north.

Plate 2

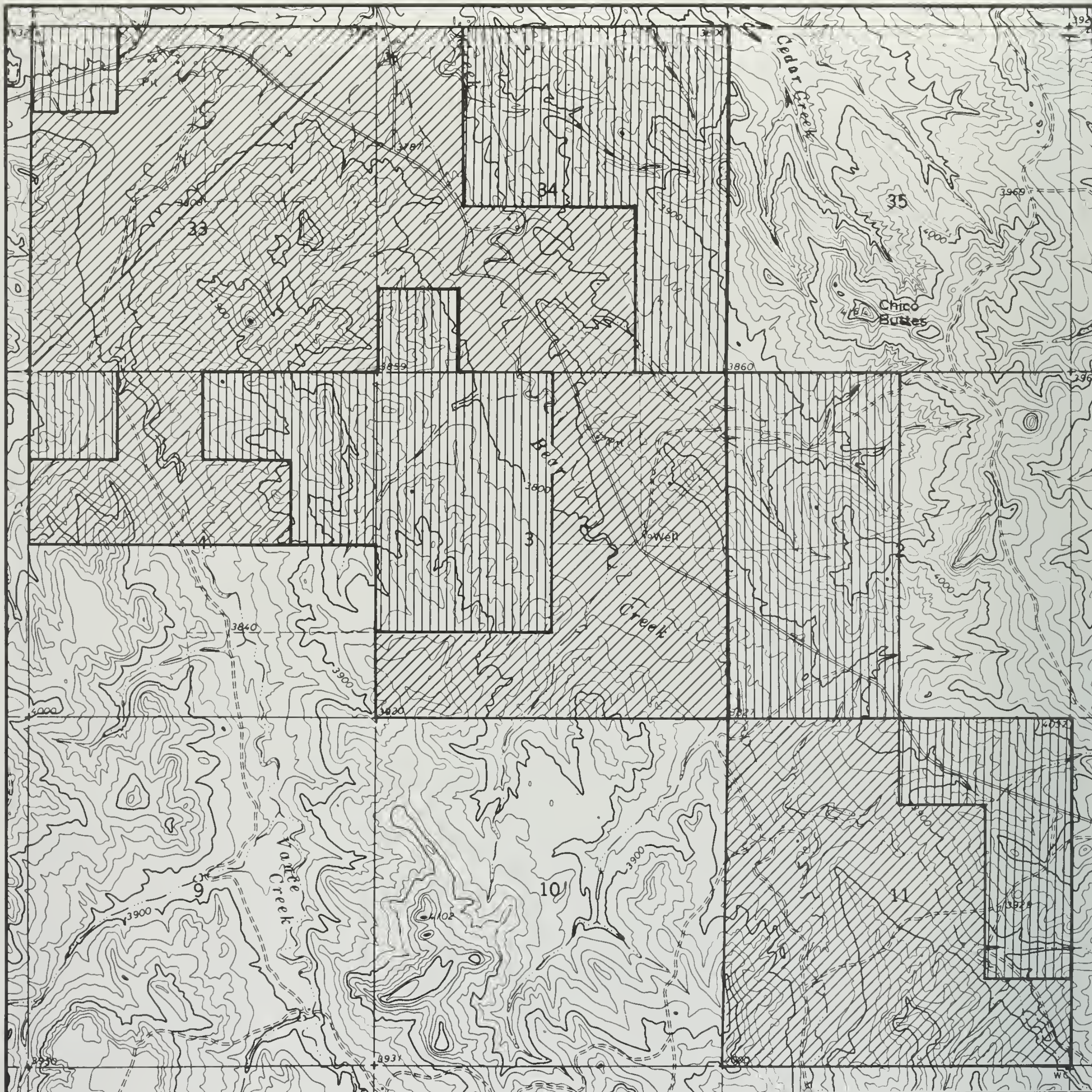


PORTION OF U.S.G.S. BEAR CREEK SCHOOL QUAD.

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

TOPOGRAPHY

Photograph 1 - Aerial view of the Bear Creek Study Area (outlined by heavy line). This photograph is a portion of the Bureau of Land Management Photograph 089 (6/1/72).



MINERALS OWNED BY THE FEDERAL GOVERNMENT

ALL MINERALS

COAL ONLY

ALL SURFACE PRIVATELY OWNED

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

MINERAL STATUS MAP

CLIMATE

The Bear Creek Study Area has a continental climate with cold winters, warm summers and large variations in seasonal precipitation. All seasons have considerable sunshine. The rainy period in May and June is an exception. The growing season, which begins in May and ends in October, is favorable for growing hardy native grasses and small grains. Most climatic factors in this area are favorable for revegetating surface-mined land.

The mountains along the Continental Divide west of the study area are responsible for considerable orographic precipitation, whereby air masses are caused to rise and precipitate their moisture, especially on the windward slopes. As a result of this loss of moisture and because the air warms and dries as it descends the eastern slopes, a rain shadow is created in the eastern districts where smaller amounts of precipitation are recorded. The average precipitation for the state is about 15 inches with an average of about 13 inches in the eastern part.

The Otter weather station near the study area receives an average of 19.10 inches of precipitation (12-year record). The monthly precipitation is listed in table 1 and the variation in annual precipitation at selected stations near potential leasing areas are shown in figure 1, appendix A. About 57 percent of the growing season precipitation occurs during late spring and early summer which is favorable for good forage production from the range grasses and for dryland small grains. Following the rainy period, usually in July, the weather turns hot, dry, and windy resulting in high evapotranspiration rates. The humidity remains relatively low with only a few humid days each summer.

Thunderstorms and occasional destructive hailstorms are caused by a semipermanent low-pressure area in southwestern United States. These storms are the result of a flow of unstable air into the area mainly in July and August. Table 2 shows the potential storm intensity and probable frequency of occurrence in Powder River County. These data also indicate the potential erosion hazard. Hail damage to native grasses is minor.

Area temperatures are variable. Extremes of 105°F. and -44°F. are on record. Table 1 lists mean monthly temperatures at the Otter Creek station. Although the summers are normally hot, only 32 days each summer have temperatures of 90°F. or higher. The nights are usually cool.

The growing season for hardy crops, (28°F.) is about 147 days between early May and early October. However, range plants usually deplete the available moisture by mid-July and mature or become dormant. Table 3 shows the average dates of the frost-free period and the growing season

TABLE 1. MEAN MONTHLY PRECIPITATION AND TEMPERATURE, OTTER STATION - ELEVATION 4100

	Period	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Precipitation in inches	1962-1974	1.10	.81	1.09	2.72	2.51	3.30	1.32	1.26	1.69	1.45	.93	.96	19.1
Temperature °F	1962-1974	19.4	27.7	33.6	44.2	53.9	62.9	71.2	70.5	58.6	48.5	34.3	23.8	45.8

TABLE 2. ESTIMATED MAXIMUM AMOUNTS OF RAINFALL IN POWDER RIVER COUNTY FOR STATED PERIODS OF DURATION AND THE FREQUENCY THAT THESE AMOUNTS OCCUR[1/]

(Based on Data from U.S. Weather Bureau Technical Paper No. 40(6))

	Frequency of once in--				
Duration	2 years Inches	5 years Inches	10 years Inches	25 years Inches	50 years Inches
30 minutes-----	0.6	0.9	1.1	1.3	1.5
1 hour---------	.8	1.1	1.3	1.6	1.9
3 hours--------	1.0	1.5	1.7	2.0	2.5
6 hours--------	1.3	1.7	2.0	2.5	2.9
12 hours-------	1.5	2.0	2.4	2.8	3.3
24 hours-------	1.7	2.4	2.8	3.2	3.7

1/ Soil Survey Powder Area - Montana-Soil Conservation Service.

TABLE 3. NUMBER OF DAYS BETWEEN SELECTED TEMPERATURES

Station	Temp.	Average Dates: Last in Spring to First in Fall	Average Days Between	Years of Record
Otter	32°	May 19 to Sept. 22	127 1/	1962-1974
Otter	28°	May 9 to Oct. 2	147 2/	1962-1974

1/ Frost-free period
2/ Growing Season - Hardy crops

for hardy crops at the Otter Creek station. Tables 4 and 5, appendix A, record the estimated moisture reserve at the beginning of the growing season and the approximate date the soil moisture is depleted.

The climate in the Bear Creek area is generally conducive to revegetation of disturbed land with adapted plant species. Soil moisture is high during the early growing season and plant growth is rapid. This is favorable for the establishment of spring planted grasses. It also promotes rapid growth of fall planted grasses, which should be well established before the erosive summer thunderstorms occur. Fall planting on summer fallow increases the moisture available for plant use. Plants seeded in the fall or early spring should be established before the available moisture is depleted in July.

The spring rains usually exceed the plant moisture requirement and the soluble salts are usually found below 24 inches in good permeable soils. Under postmining conditions, a similar equilibrium is expected.

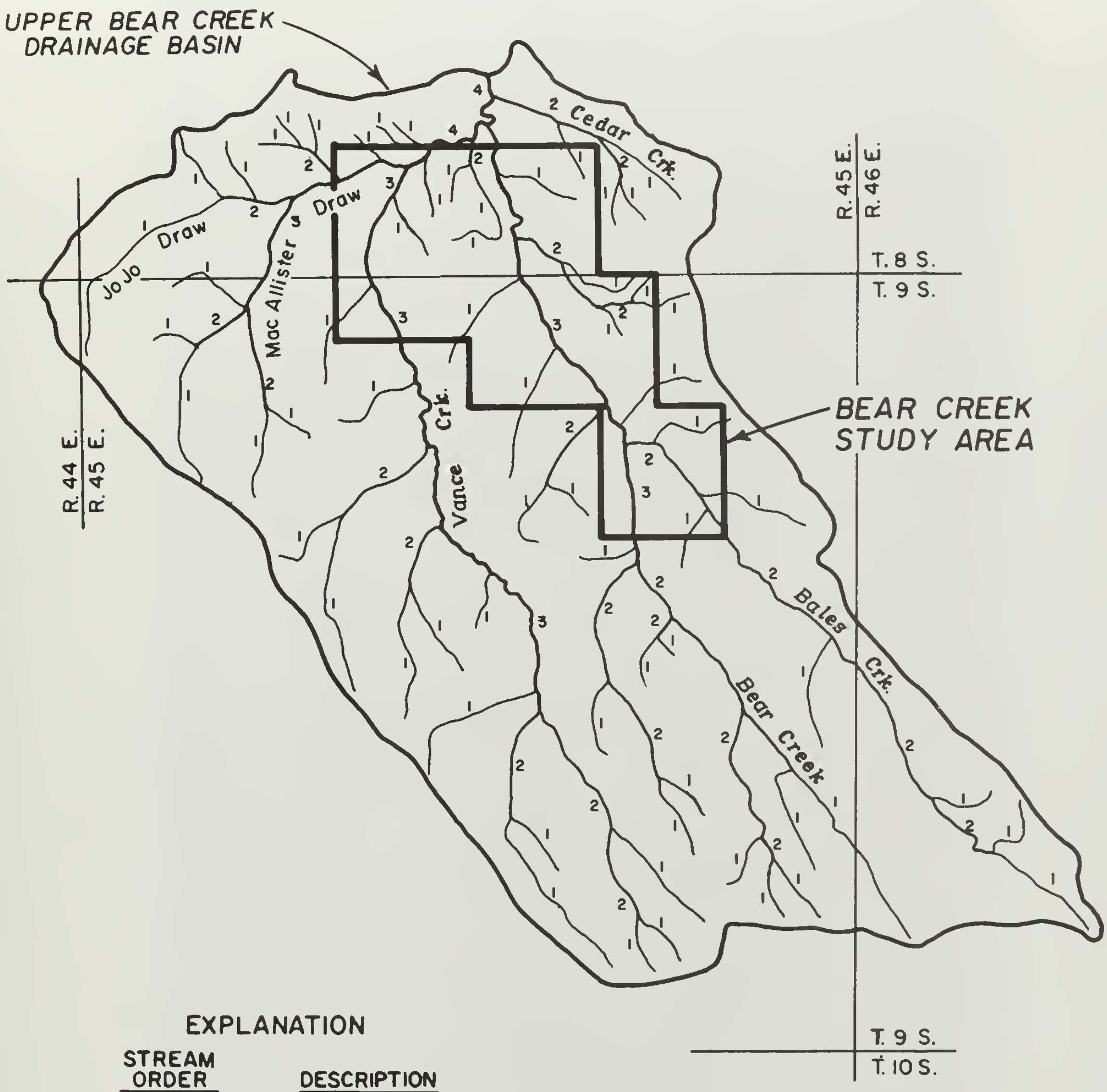
Hazardous climatic factors that may result in poor plant populations or planting failures are: (1) below normal or uneven distribution of precipitation especially in the growing season, (2) thundershowers that cause erosion, (3) late spring freezes, and (4) depletion of soil moisture by wind. Good planning and management can do much to prevent or reduce the hazard from these factors.

PHYSIOGRAPHY

The Bear Creek Study Area located on Bear and Vance Creeks, tributaries to Otter Creek, is in the Missouri Plateau section of the Great Plains physiographic province. Relief in the area is approximately 300 feet, ranging from near elevation 3750 on Bear Creek near the north boundary to near elevation 4050 near the east boundary. Topography in the study area varies from gentle slopes on and adjacent to valley floors to steep semibadland type at the higher elevations where erosion of the underlying soft shales and weakly cemented sandstone has been severe. Surface gradients range from as low as 1 percent on the valley floors to as great as 35 percent at the higher elevations.

The developed drainage pattern is dendritic and the main valleys are characterized by gentle to moderate gradients and widths up to 1/2 mile.

The drainage system and stream orders are shown on plate 4. Surface features typical of the terrain are shown on photographs 2 through 5.



EXPLANATION

STREAM ORDER	DESCRIPTION
1	Smallest tributary
2	Channel segment where 2 1st order tributaries join.
3	Channel segment where 2 2nd order tributaries join.

1 1/2 0 1 2 3

SCALE OF MILES

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD – MONTANA

DESIGNATION OF STREAM ORDERS

LANDS H.B.W.	SUBMITTED
DRAWN J. E. Allsup	RECOMMENDED
CHECKED	APPROVED

BILLINGS, MONTANA JANUARY, 1977 1305-600-109

PHOTOGRAPH 2 - BEAR CREEK STUDY AREA - WEST MOORHEAD COAL FIELD. Panoramic view looking west from a point 2,000 feet west of the southeast corner of Section 35, T. 8 S., R. 45 E. showing typical terrain in the study area. Coal and/or carbonaceous shale beds D and E crop out on the flanks of Chico Buttes in the right background.
U.S. Bureau of Reclamation Photograph P-1305-600-4(NA) 10/17/75

PHOTOGRAPH 3 - BEAR CREEK STUDY AREA - WEST MOORHEAD COAL FIELD. Panoramic view northeast across the Bear Creek flood plain from near the center of Section 3, T. 9 S., R. 45 E. Chico Buttes and other topographic highs in background are capped by a resistant sandstone.
U. S. Bureau of Reclamation Photograph P-1305-600-5(NA) 10/17/75

PHOTOGRAPH 4 - BEAR CREEK STUDY AREA - WEST MOORHEAD COAL FIELD- Panoramic view of clinker capped terrain produced by burning of the Anderson coal bed in Section 34, T. 8 S., R. 45 E.
U. S. Bureau of Reclamation Photograph P-1305-600-6(NA) 10/17/75

PHOTOGRAPH 5 - BEAR CREEK STUDY AREA - WEST MOORHEAD COAL FIELD. Panoramic view of the Chico Buttes from near the northeast corner of Section 3, T. 9 S., R. 45 E.
U. S. Bureau of Reclamation Photograph P-1305-600-7(NA) 10/17/75

GEOLOGY

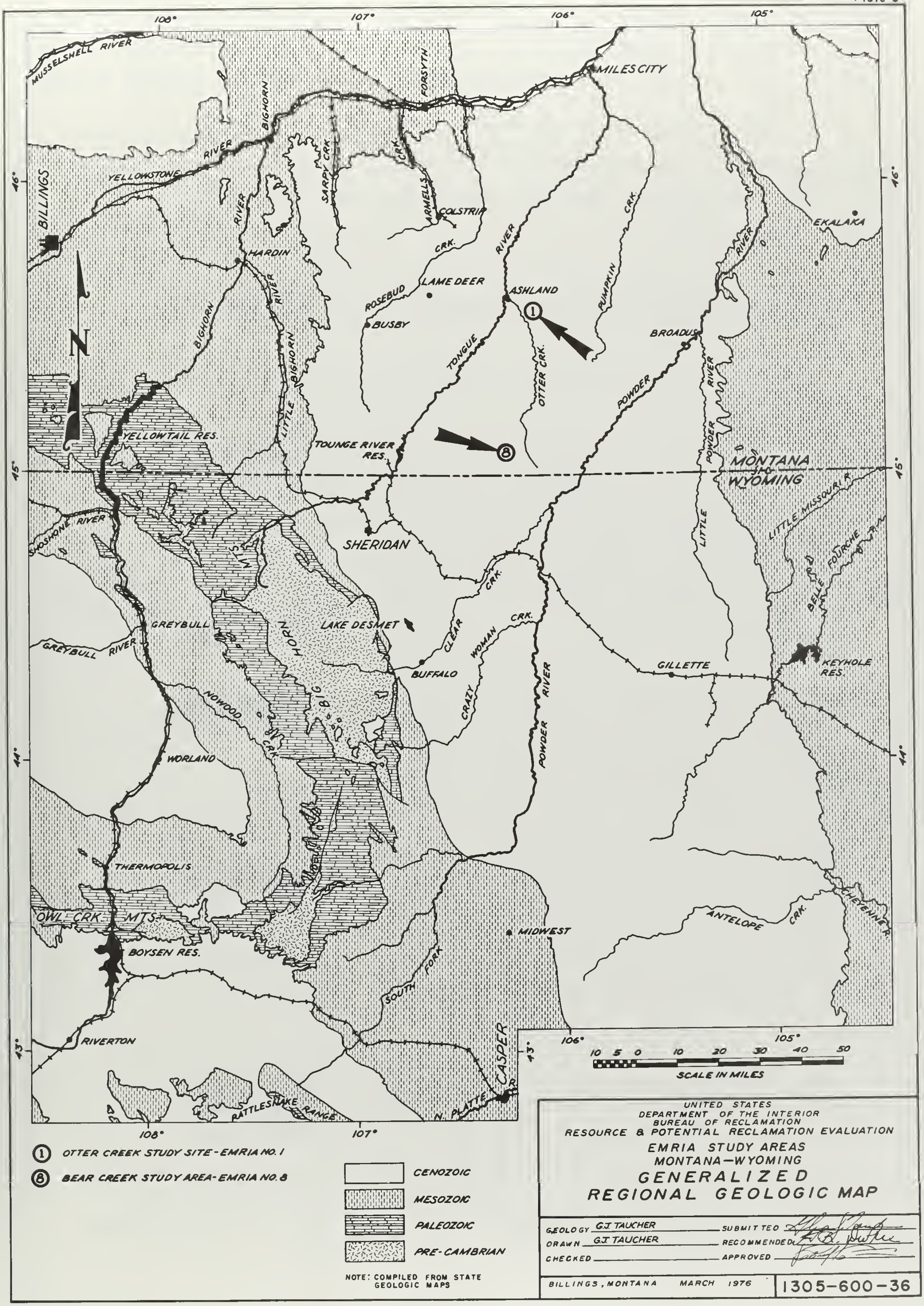
Regional Geology

The Bear Creek Study Area is located in the northern part of the Powder River Basin in southeastern Montana. This basin, a part of the unglaciated portion of the Great Plains physiographic province, is about 225 miles long, extending from the Yellowstone River in Montana to the North Platte River in Wyoming. It is about 90 miles in width, bounded on the west by the Bighorn Mountains and on the east by the Black Hills. Structurally, the basin is an asymmetrical syncline with a northwestward trending axis. An estimated 18,000 feet of sediments overlie the basement complex in the deepest part of the basin north of Glenrock, Wyoming.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. During the Paleozoic and Mesozoic Eras, a sequence of carbonates, sandstones, and shales were deposited throughout Montana and Wyoming. Thickness of these sediments on the west side of the basin varies from 9,000 feet near Yellowtail Dam to 11,500 feet near Buffalo, Wyoming. About 6,500 feet of Paleozoic and Mesozoic sediments are present in the Black Hills area on the east side of the basin.

The area was relatively stable during these periods with deposition occurring generally under a marine environment. Deformation of these strata began with the Laramide Revolution near the close of the Mesozoic Era (Late Cretaceous), at which time mountain masses such as the Bighorns and Black Hills were uplifted. Uplift continued throughout Paleocene and gradually ended in Eocene time. Materials stripped from the mountains were deposited in fans or sheets across the basin floors, gradually burying the flanks of the mountains in their own debris. By the middle of the Cenozoic Era, the basins were largely filled and the mountains peneplained. In Pliocene time, a broad regional uplift occurred and continued intermittently into Pleistocene time. This uplift raised the previously developed peneplain surface to elevations of about 10,000 feet in the Bighorn Mountains. Streams rejuvenated by the uplift excavated the basins and exhumed the buried mountain masses.

Today, Precambrian rocks are exposed in the cores of the Black Hills and Bighorn Mountains. These rocks are surrounded by sediments of the Paleozoic and Mesozoic Age. The central part of the basin is filled with Cenozoic (Tertiary) sediments. Plate 5 is a generalized map of the regional geology of the basin area.



MUSSELSHELL RIVER
MILES CITY
YELLOWSTONE RIVER
BILLINGS
HARDIN
COLSTRIP
LAME DEER
ASHLAND
BUSBY
EKALAKA
BROADUS
TOUNGE RIVER RES.
YELLOWTAIL RES.
MONTANA
WYOMING
SHERIDAN
LAKE DESMET
BUFFALO
GILLETTE
KEYHOLE RES.
GREYBULL
WORLAND
THERMOPOLIS
OWL CRK. MTS.
BOYSEN RES.
MIDWEST
RIVERTON
CASPER
RATTLESNAKE RANGE
N. PLATTE R.
SCALE IN MILES
① OTTER CREEK STUDY SITE - EMRIA NO. 1
⑧ BEAR CREEK STUDY AREA - EMRIA NO. 8
CENOZOIC
MESOZOIC
PALEOZOIC
PRE-CAMBRIAN
NOTE: COMPILED FROM STATE GEOLOGIC MAPS
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
EMRIA STUDY AREAS
MONTANA—WYOMING
GENERALIZED
REGIONAL GEOLOGIC MAP
GEOLOGY G.J. TAUCHER
DRAWN G.J. TAUCHER
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
BILLINGS, MONTANA MARCH 1976
1305-600-36

Area Geology

Investigations

All of the area involved in the Bear Creek Study Area has been mapped by the U. S. Geological Survey and the Montana Bureau of Mines and Geology. Publications covering these investigations are listed in the bibliography.

Geologic investigations were conducted in the study area by the U. S. Bureau of Reclamation between June of 1975 and March of 1976. These investigations included mapping the surface geology and drilling ten core holes.

Detailed geologic mapping of coalbeds on a scale of 1 inch equals 1,000 feet was done in the field on aerial photographs. These data were transferred to a topographic map of the same scale and are shown on plate 7. Plate 6 shows a generalized stratigraphic column of coal and carbonaceous beds mapped or penetrated by drilling.

Ten drill holes ranging from 153.6 to 321.0 feet in depth were completed in the study area. Continuous cores were obtained from all holes for geologic logging and for the selection of coal and overburden samples for laboratory analyses. The site locations of the drill holes are plotted on the Geologic and Investigations Map, plate 7. Geologic cross sections are shown on plates 8 and 9. Detailed geologic logs for drill holes are listed on plates 10 through 18, appendix B.

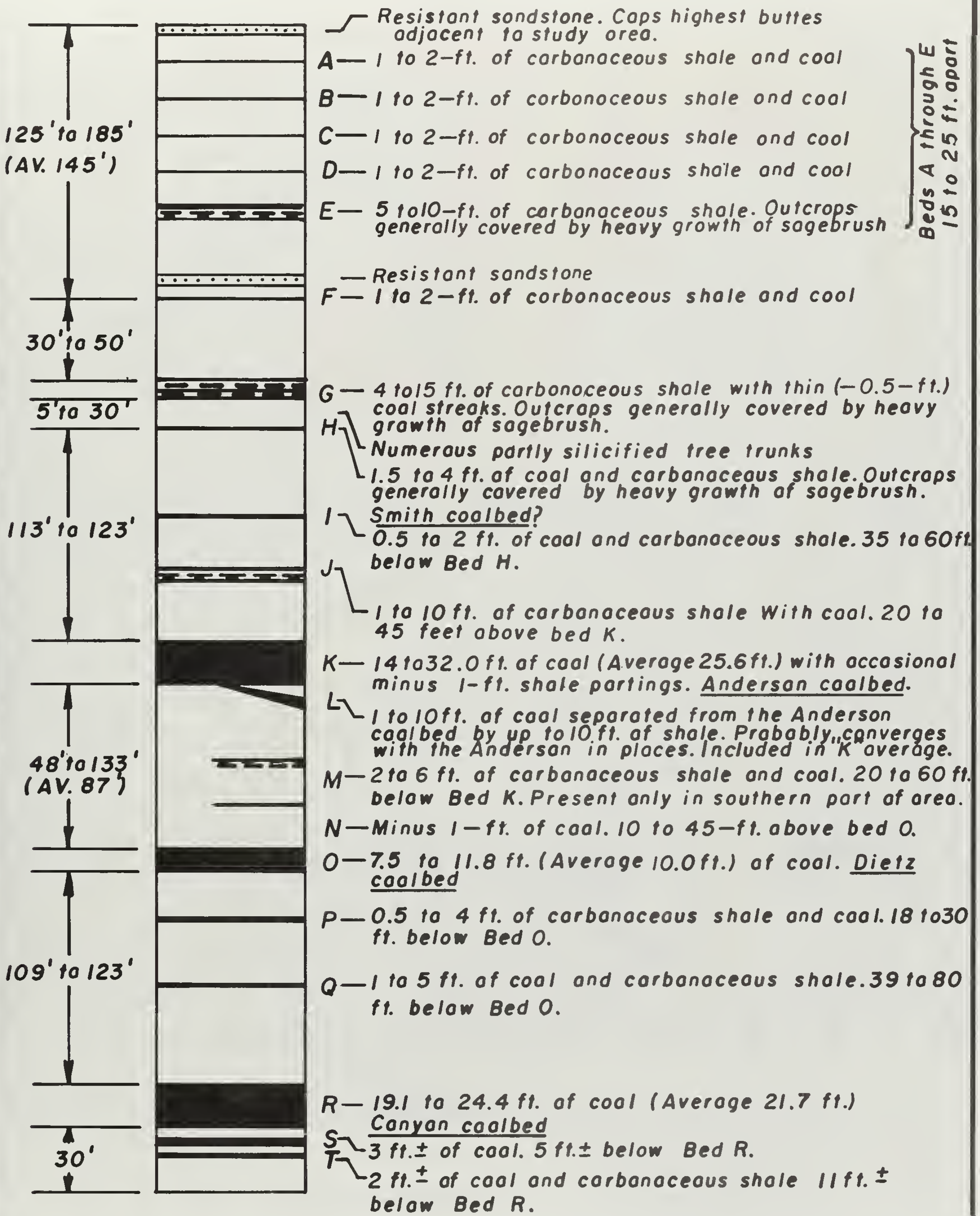
Plastic pipes ranging from 1¼ to 4 inches inside diameter were installed in all drill holes for ground water studies. These studies are being conducted by the U. S. Geological Survey and will require several years to complete.

The core drilling was performed with a Failing Model 314 rotary drill rig. Wireline drill tools with an "H" series barrel were used to recover core samples in most holes. Where reduction of the hole was necessary, Nx core samples were obtained. Use of drilling tools larger than the standard exploratory sizes was dictated by (1) necessity to maximize core recovery, (2) provide sufficient sample for laboratory and greenhouse studies from zones as thin as 5 feet, and (3) to minimize the contamination potential. Reaming was necessary where larger diameter wells for pump testing were desired.

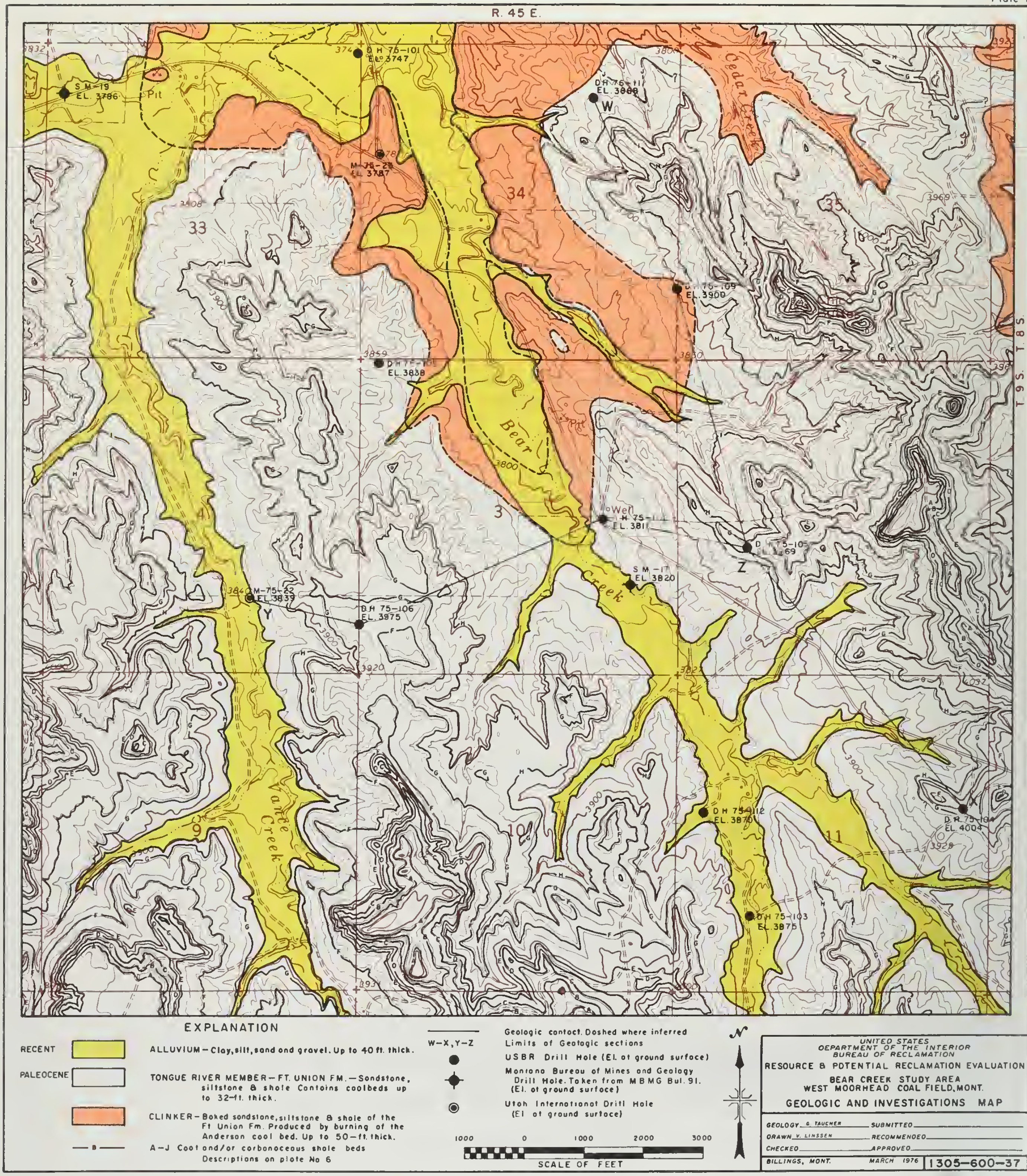
Most of the drilling was accomplished using bottom discharge bits set with tungsten carbide inserts. Both preset and field set bits were used. The chief advantage of field setting is better control of bit gage, both inside and outside, which in some of the softer rocks can be used to increase core recovery.

The recovered drill cores were placed in 5-foot-long core boxes and covered by a sheet of 4-mil polyethylene plastic. This prevented a loss of moisture and a change of physical state in the drill core until logging and sampling could be accomplished.

STRATIGRAPHIC COLUMN—COAL & CARBONACEOUS SHALE BEDS BEAR CREEK STUDY AREA, WEST MOORHEAD COAL FIELD, MONT.



PORTION OF TONGUE RIVER MEMBER—FT. UNION FORMATION


R. 45 E.
T. 9 S. T. 8 S.
Cedar Creek
Bear Creek
Vance Creek
33
34
35
3
9
10
11
Pit
S M-19 EL. 3786
D H 75-101 EL. 3747
D H 75-111 EL. 3888
W
M-75-23 EL. 3787
D H 75-109 EL. 3900
EL. 3838
Well
EL. 3811
S M-17 EL. 3820
Z
M-75-22 EL. 3839
Y
D H 75-106 EL. 3975
D H 75-112 EL. 3870
D H 75-103 EL. 3875
D H 75-104 EL. 4004
X
EXPLANATION
RECENT
ALLUVIUM – Clay, silt, sand and gravel. Up to 40 ft. thick.
PALEOCENE
TONGUE RIVER MEMBER – FT. UNION FM. – Sandstone, siltstone & shale Contains coalbeds up to 32-ft. thick.
CLINKER – Baked sandstone, siltstone & shale of the Ft Union Fm. Produced by burning of the Anderson coal bed. Up to 50-ft. thick.
A-J Coal and/or carbonaceous shale beds Descriptions on plate No 6
Geologic contact. Dashed where inferred
W-X, Y-Z Limits of Geologic sections
USBR Drill Hole (El. of ground surface)
Montana Bureau of Mines and Geology Drill Hole. Taken from M B M G Bul. 91. (El. of ground surface)
Utah International Drill Hole (El of ground surface)
1000 0 1000 2000 3000
SCALE OF FEET
UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA WEST MOORHEAD COAL FIELD, MONT.
GEOLOGIC AND INVESTIGATIONS MAP
GEOLOGY G. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONT. MARCH 1976 1305-600-37

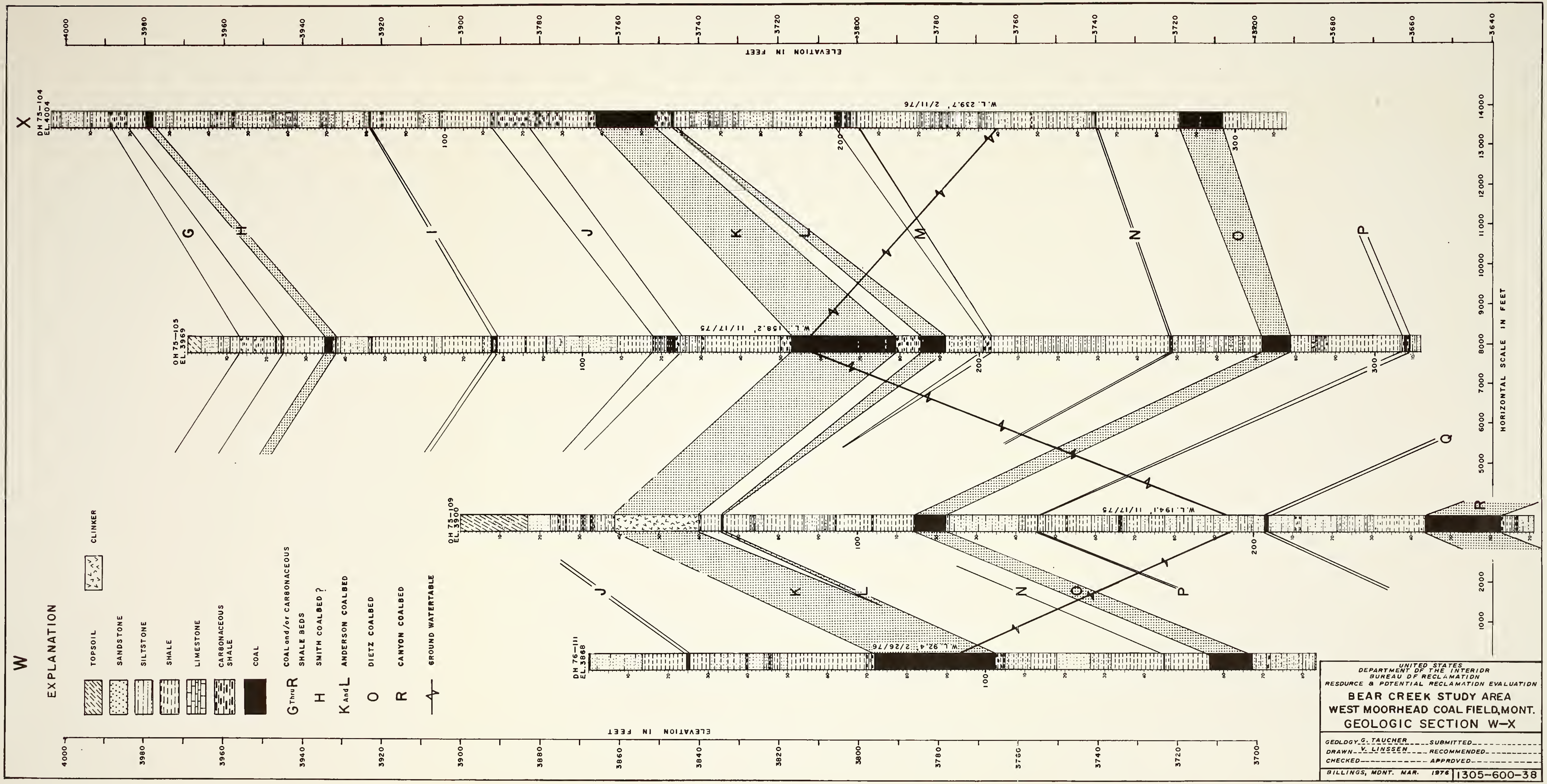
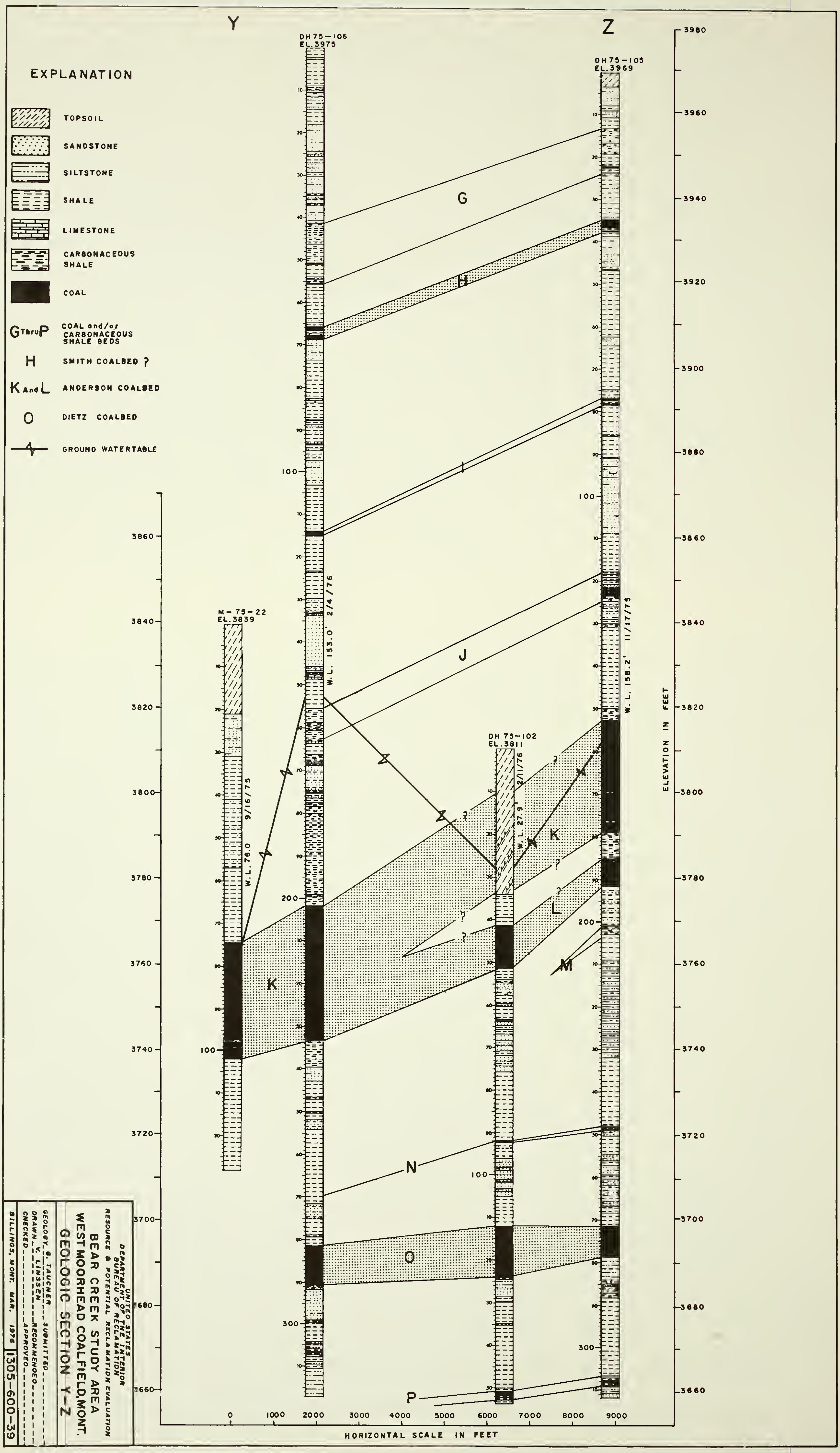

W
X
EXPLANATION
TOPSOIL
SANDSTONE
SILTSTONE
SHALE
LIMESTONE
CARBONACEOUS SHALE
COAL
CLINKER
G Thru R COAL and/or CARBONACEOUS SHALE BEDS
H SMITH COALBED ?
K And L ANDERSON COALBED
O DIETZ COALBED
R CANYON COALBED
GROUND WATERTABLE
DH 75-104 EL. 4004
DH 75-105 EL. 3969
DH 75-109 EL. 3900
DH 76-111 EL. 3868
W.L. 239.7' 2/11/76
W.L. 158.2' 11/17/75
W.L. 194.1' 11/17/75
W.L. 92.4' 2/26/76
ELEVATION IN FEET
HORIZONTAL SCALE IN FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
GEOLOGIC SECTION W-X
GEOLOGY G. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONT. MAR. 1976 1305-600-38

Plate 9



Y
Z
DH75-106
EL.3975
DH75-105
EL.3969
DH 75-102
EL.3811
M-75-22
EL.3839
EXPLANATION
TOPSOIL
SANDSTONE
SILTSTONE
SHALE
LIMESTONE
CARBONACEOUS SHALE
COAL
G Thru P COAL and/or CARBONACEOUS SHALE BEDS
H SMITH COALBED ?
K And L ANDERSON COALBED
O DIETZ COALBED
GROUND WATERTABLE
W.L. 153.0' 2/4/76
W.L. 158.2' 11/17/75
W.L. 27.9' 2/11/76
W.L. 76.0 9/16/75
ELEVATION IN FEET
HORIZONTAL SCALE IN FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COALFIELD, MONT.
GEOLOGIC SECTION Y-Z
GEOLOGY G. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONT. MAR. 1976
1305-600-39

Water was used as the drilling fluid in all holes. Local stock ponds were the sources of water for DH 75-101, -102, and -104. The remaining holes were drilled using ground water from a shallow well located along the Bear Creek Flood Plain in the north half of Section 3, T. 9 S., R. 45 E. Tests conducted by the U. S. Bureau of Reclamation soils laboratory in Miles City, Montana, indicated that the concentrations of dissolved solids ranged from about 2,600 p.p.m. for the stock pond water to about 3,500 p.p.m. for the well water.

An organic polymer, "Revert," was used in the drilling fluid in zones where lost circulation occurred. This was chiefly in highly fractured or jointed coals. Bentonite was used in DH 76-111 after circulation was lost in broken clinker.

Field checks made by adding a fluorescent dye (Fluorescein) to the drill water and checking the obtained cores under an ultra-violet light indicates that penetration by the drill fluid, if any, is less than 1 millimeter in permeable sandstones and can be readily removed in sample preparations. Impermeable siltstone and shale samples showed no evidence of dye contamination.

Stratigraphy

All sedimentary rocks in the study area are part of the Fort Union Formation of Paleocene Age. This formation consists of three lithologic units which include, from bottom to top, the Tullock, Lebo and Tongue River Members. Only the upper part of the Tongue River Member crops out or was penetrated by drilling at the study area. Recent deposits of alluvium mantle the Tongue River sediments along major drainages.

Tullock Member - consists of yellow-gray continental deposits of sandstone, shale, carbonaceous shale, and impure coal. It overlies the Late Cretaceous Hell Creek Formation.

Lebo Member - composed of drab, dark gray continental deposits of shale which contrasts sharply with the light-colored overlying Tongue River and underlying Tullock Members. Soils derived from the Lebo support very little vegetation. A basal coalbed, "Big Dirty", separates the Lebo from the Tullock Member. The combined thickness of the Tullock and Lebo Members beneath the study area is about 400 feet.

Tongue River Member - is the principle coal bearing member of the Fort Union Formation. It consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale and coal with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine grained and uncemented except as lenticular, concretionary masses of small lateral extent. Shales vary from soft, plastic clay-shale to moderately indurated claystone. The shale and siltstone zones break down readily and form slopes below 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 Bear Creek area, indicate that chemical and physical properties of the bedrock cannot generally be projected between drill holes. Weathered exposures are pale olive or yellowish gray in color; while fresh core samples vary from light to dark gray. Poorly silicified, fragmented tree trunks are common in zones. The Tongue River sediments were deposited in a continental environment which included swamps conducive to the production of thick coal beds. Coal and carbonaceous zones serve as excellent marker beds as they can generally be traced over wide areas. Thickness of the member varies from 1400 to 1600 feet in southern Montana. Drilling at the Bear Creek Study Area penetrated a 480-foot stratigraphic section in the upper part of the member. Detailed geologic logs are shown on plates 10 through 18, appendix B.

One striking feature in the Tongue River Member is the resistant clinker zones, locally called "scoria," that cap ridges or armor valley walls. The clinker which is fused or baked rock, was produced by the burning of coalbeds along and back from the outcrops. The clinker, in places where the heat was sufficiently intense, 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 coal that has burned. A coalbed 30 feet thick will produce clinker zones 50 to 75 feet thick. The clinker is highly permeable and locally supplies water for springs and wells.

Clinker in the Bear Creek Study Area was produced by burning of the Anderson coalbed. Outcrops occur mostly along the valley walls of Bear, Vance, and Cedar Creeks. Location of clinkered areas are shown on the Geologic and Investigations Map, plate 7. Some of the Anderson coal undoubtedly remains beneath the clinkered area. Evidence supporting this is the unburned rock exposure surrounded by clinker in the southeast quarter of Section 34, T. 8 S., R. 45 E. Subsurface explorations and surface mining in other areas also indicates that lower sections of thick coalbeds have 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, the contact between baked and unbaked rock is assumed to be vertical and that all coal underlying clinker has been burned.

Alluvium - recent deposits of clay, silt, sand and gravel that cover the valley floors of Vance and Bear Creeks. Gravels are composed of clinker or hard shale and sandstone fragments. Explorations indicate that this material is up to 40 feet thick.

Coalbeds

Twenty persistent coal and/or carbonaceous shale beds, A through T, crop out or were penetrated by drilling in the Bear Creek Study Area. Brief descriptions of these beds are found on the generalized stratigraphic column, plate 6. Eleven beds, A through K, were mapped in the study area as shown on the Geologic and Investigations Map, plate 7.

Only three beds of economic significance occur beneath the study area in the Tongue River Member within 200 feet of the surface. These include the Anderson (K and L), Dietz (O), and Canyon (R) coalbeds.

The Anderson coalbed is over 30 feet thick in the northern part of the study area. Subsurface explorations indicate that this bed thins to the southeast and is 14 feet thick in DH 75-104. Near DH 75-102 and -105, the bed splits into an upper (K) and lower (L) bench, both of which can be surface mined. The Anderson coalbed (K and L) averages 25.6 feet thick under overburden up to 220 feet thick in the study area. Depth to the Anderson is shown on the Overburden Thickness Map, plate 19.

The Dietz and Canyon coalbeds average 10.0 and 21.7 feet thick, respectively. Both beds lie stratigraphically below the Anderson and therefore are not as suitable for surface mining. Structure contours on top of the Dietz and overburden thickness contours indicating the cover over the Dietz and Canyon coalbeds are shown on plate 20.

Structure

The study area is located on the northeast flank of the Powder River Basin. Regional dips in the area are towards the southwest at less than 50 feet per mile. This slope is interrupted by minor folds such as those shown by the structure contours developed for the Anderson and Dietz coalbeds, plates 19 and 20. These folds trend in a southwesterly direction and appear to continue with depth at least through the Canyon coalbed. Maximum dip measured in the study area is under 3 degrees.

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 coalbeds. Displacement along these fractures could not be determined but should not exceed 5 feet. Surface mapping did not reveal any faulting.

Paleontology

Numerous poorly silicified tree fragments are scatterd throughout the area, especially in a stratigraphic horizon lying between the "G" and "H" carbonaceous beds. Aerial extent and stratigraphic location of this zone is shown on the geologic map, plate 7, and the stratigraphic column, plate 6. Two significant concentrations of tree stumps in this horizon are located about 2,000 feet west of Drill Hole 76-108 and about 1,700 feet north-northwest of Drill Hole 75-109. Stumps up to 4 feet in diameter are common at both locations. Several stumps up to several feet in diameter remain standing as in the original growth position. Occasional fragmented calcareous shells of unidentified fossils were noted on the surface and in drill core samples.

R. 45 E.

EXPLANATION

PALEOCENE — TONGUE RIVER MEMBER - FT UNION FM - Sandstone, siltstone & shale. Contains coalbeds up to 32-feet in thickness (Alluvium cover not shown.)

CLINKER - Baked sandstone, siltstone and shale of the Ft Union Fm. Produced by burning of the Anderson coalbed. Up to 50-feet thick

—3760— Structure contour on top of Anderson coalbed

....150.... Contour showing thickness of overburden above Anderson coalbed

● USBR Drill Hole

Montana Bureau of Mines and Geology Drill Hole

Utah International Drill Hole

Note: Elevations on top of Anderson coalbed

1000 0 1000 2000 3000

SCALE OF FEET

N

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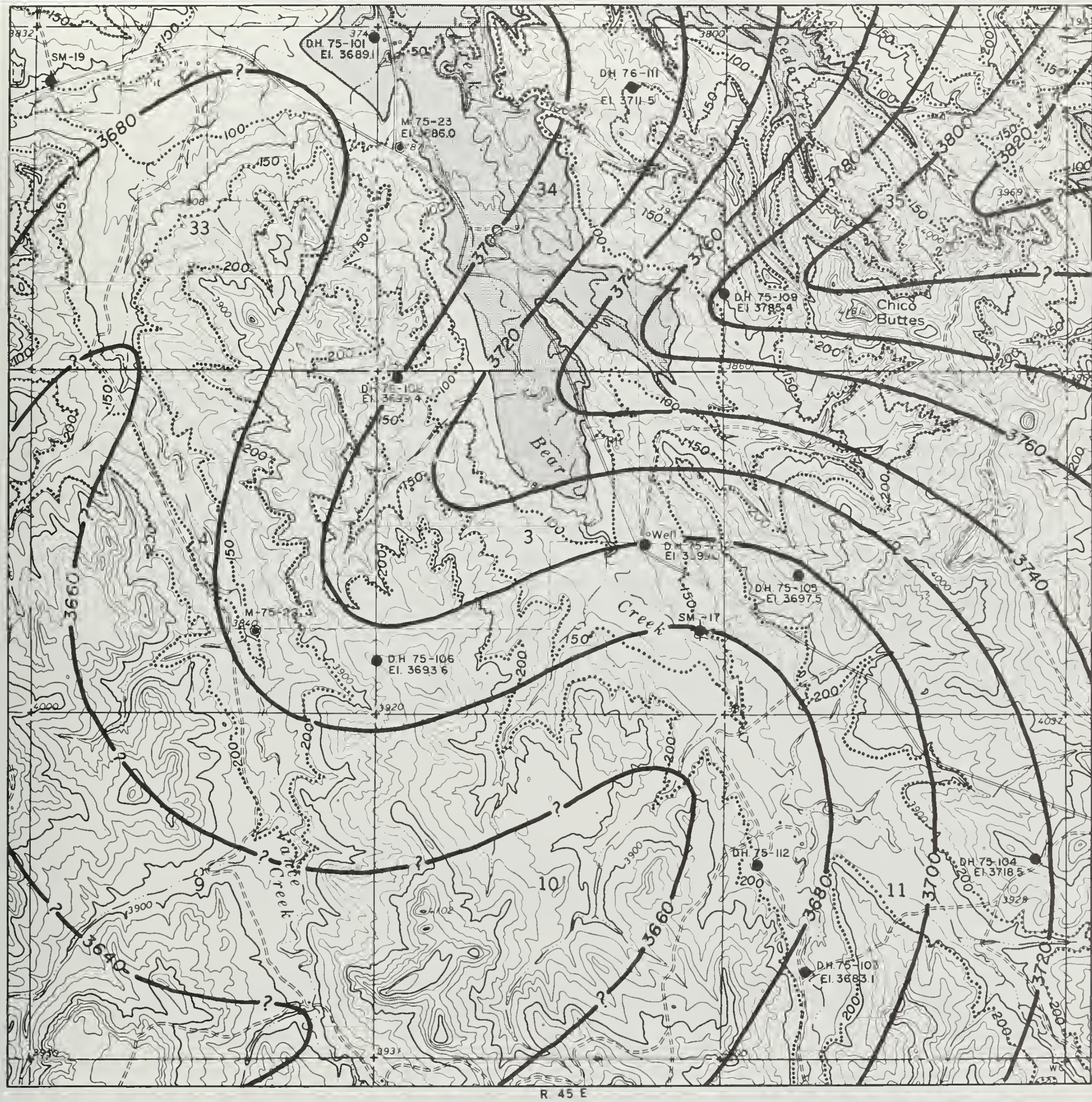
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
OVERBURDEN THICKNESS MAP
ANDERSON COALBED

GEOLOGY: G. TAUCHER — SUBMITTED: ____
DRAWN: L. E. ALLSOP — RECOMMENDED: ____
CHECKED: ____ — APPROVED: ____

BILLINGS, MONT — MARCH 1976 — 1305-600-49

Plate 20



EXPLANATION

—3760—	Structure contour on top of Dietz coalbed
····150····	Contour showing thickness of overburden, interburden and coal over the Dietz coalbed
(shaded)	Less than 200 feet of overburden, interburden and coal over the Canyon coalbed
●	USBR Drill Hole
✦	Montana Bureau of Mines and Geology Drill Hole
◉	Utah International Drill Hole

Note: Elevations on top of Dietz coalbed.

1000 0 1000 2000 3000

SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT

OVERBURDEN THICKNESS MAP
DIETZ & CANYON COALBEDS

GEOLOGY: G. TAUCHER	SUBMITTED
DRAWN: L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONT. MARCH 1976	1305-600-50

Engineering Properties

Engineering property tests were not conducted on bedrock samples from the Bear Creek Study Area. However, physical properties of these sediments should be similar to the results obtained for Fort Union samples at the Otter Creek Study Site (EMRIA Report No. 1) by the U. S. Geological Survey. Shear strengths of the materials are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, namely along beds of weak, plastic, carbonaceous shales, which are typically cut by inherent slickensides. Adequate drainage should be insured to relieve pore-water pressures in the overburden as mine excavations progress.

Saturated alluvial deposits and uncemented siltstones and fine grain sandstones will readily erode and flow into excavations. This problem was occasionally encountered in drilling when the walls of holes continued to collapse and slough. Depth of excavation below the water table will be limited until these materials are unwatered.

Excavation slopes will vary considerably between mine sites and will depend upon 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 Study Site indicate that disturbed overburden (spoils 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.

Weathering Tests

Weathering tests were conducted on nine drill core samples from the Bear Creek Study Area. The purpose of these tests was to determine which materials would weather (break down) sufficiently to allow for their possible use as topsoil in revegetation of surface-mined areas.

Samples were selected for (1) freeze-thaw, (2) wet-dry and (3) out-door tests. The criteria developed for the testing is described as follows:

Freeze-Thaw Cycle

1. 8 hours at 23.9° C (75° F), 100 percent relative humidity (wetting/thawing).

2. 16 hours (64 hours on weekends) at -17.8° C (0° F) (freezing).

Wet-Dry Cycle

1. 8 hours at 23.9° C (75° F), 100 percent relative humidity (wetting).

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

Outdoor

The outdoor exposure test included subjecting the specimens to 2.5 cm (1 in.) of precipitation during seven snowstorms and between 40 and 50 freeze-thaw cycles.

All core specimens were 5 cm (2 in.) in diameter by 5 cm (2 in.) in length. Tests were started on December 23, 1975, and completed after 43 laboratory weathering cycles on March 1, 1976.

Only one shale sample broke down sufficiently for use as a planting media (breakdown based on 30 percent of material by weight passing the No. 10 screen as per discussion with Dr. William Berg, Agronomy Department, Colorado State University). Other shale samples showed evidence of saturation and swelling and would undoubtedly break down under additional testing. Handling and placing these soils in a moist condition may be difficult due to their plastic characteristics. Sandstone and siltstone samples were more resistant to weathering than shales or silty shales. The freeze-thaw condition is more severe than the wet-dry in that it caused more rapid breakdown of most overburden samples.

COAL RESOURCES

Origin

Coal has been defined as "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, 1956). 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 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:

1) The mode of accumulation and burial of the plant debris forming the deposits.

2) The age of the deposits and their geographical distribution.

3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.

4) The chemical composition of the coal-forming debris and its resistance to decay.

5) The nature and intensity of the plant-decaying agencies.

6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussions 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 which 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 adjunct to rank classification when sufficient mega 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 coal beds, 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 temperatures 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 and oxygen than 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. Bur. 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 cakelike 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, appendix C, compares in histogram form the heating value 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 are the "Standard specifications for classification of coals by rank," adopted by the American Society for Testing and Materials (1974, table 6, appendix C).

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon on 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 (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

Analyses of coal are not available from the Bear Creek Study Area itself, but the three principal beds present under shallow cover in the study area have been analyzed at many places in the surrounding region. According to the available analyses (Matson and Blumer, 1973, tables 26, 29, and 30), coal of the Anderson bed, on an as-received basis, commonly ranges in heating value from 8,100 to 8,800 Btu, in sulfur content from 0.2 to 0.4 percent, and in ash content from 3.0 to 5.0 percent. Coal in the Dietz bed commonly ranges in heating value from 7,700 to 8,700 Btu, in sulfur content from 0.3 to 0.5 percent, and in ash content near 4.0 percent. Coal in the Canyon bed commonly ranges in heat value from 7,900 to 9,000 Btu, in sulfur content from 0.15 to 0.3, and in ash content from 4.0 to 6.0.

Tables 7 and 8 show analyses of coal from drill holes near the study area. These analyses are probably representative of the Anderson, Dietz, and Canyon beds in southeastern Powder River County, including the study area.

The coal in the Anderson, Dietz, and Canyon beds is all subbituminous C in rank.

Estimation and Classification of Coal Resources

Coal resource estimates have been prepared for the Bear Creek Study Area using standard procedures, definitions, and criteria of the U. S. Geological Survey and U. S. Bureau of Mines established 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.

Table 7 .--Proximate analyses, forms of sulfur, and heating value of coal samples from cores, Montana Bureau of Mines and Geology drill holes.

[A, as received; B, moisture free; C, moisture and ash free. Analyses by L. A. Wegelin, Montana Bureau of Mines and Geology, as reported in Matson and Blumer, 1973, p. 59-60, except that some values are rounded]

Depth (feet)	Laboratory number	Form of analysis	Proximate, percent: Moisture	Proximate, percent: Volatile matter	Proximate, percent: Fixed carbon	Proximate, percent: Ash	Form of sulfur, percent: Sulfur	Form of sulfur, percent: Sulfate	Form of sulfur, percent: Pyritic	Form of sulfur, percent: Organic	Heating value (Btu)
			Anderson bed, drill hole SM-15, sec. 16, T. 9 S., R. 46 E.								
64-78	J-6245	A	28.6	29.4	35.3	6.7	0.36	0.01	0.01	0.34	7,950
		B	--	41.2	49.4	9.4	.50	.02	.01	.47	11,130
		C	--	45.5	54.5	--	.55	.02	.01	.52	12,280
			Dietz bed, drill hole SH-7043, sec. 24, T. 8 S., R. 45 E.								
43-52	228	A	32.4	29.5	34.2	3.8	0.66	0.02	0.12	0.51	8,080
		B	--	43.7	50.7	5.6	.98	.03	.18	.76	11,957
		C	--	46.3	53.7	--	1.04	.04	.19	.81	12,670
52-55	225	A	31.7	29.0	36.0	3.4	0.31	0.02	0.06	0.23	7,966
		B	--	42.4	52.7	4.9	.46	.03	.09	.33	11,655
		C	--	44.6	55.4	--	.48	.04	.10	.35	12,257
			Canyon bed, drill hole SH-7043, sec. 24, T. 8 S., R. 45 E.								
132-140	226	A	32.2	28.1	36.0	3.8	0.23	0.02	0.12	0.08	7,826
		B	--	41.4	53.0	5.6	.34	.03	.18	.12	11,539
		C	--	43.8	56.2	--	.36	.04	.19	.13	12,223
140-148	224	A	33.5	26.6	36.7	3.3	0.18	0.02	0.07	0.09	7,523
		B	--	39.9	55.1	5.0	.27	.02	.11	.13	11,304
		C	--	42.1	58.0	--	.28	.02	.12	.14	11,894
148-153	227	A	31.4	26.5	32.6	9.5	1.25	0.02	0.42	0.80	7,419
		B	--	38.6	47.5	13.9	1.82	.03	.52	1.17	10,807
		C	--	44.8	55.2	--	2.11	.04	.72	1.36	12,549

Table 8 .--Major ash constituents of coal samples from cores, Montana Bureau of Mines and Geology drill holes

[--, not determined. Analyses by L. A. Wegelin, Montana Bureau of Mines and Geology, as reported in Matson and Blumer, 1973, p. 61]

Depth (feet)	Laboratory numbers	Constituent, percent														
		Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	Na_2O	P_2O_5	SiO_2	SO_3	TiO_2	H_2O	FeO	MnO	CO_2	Total
		Anderson bed, drill hole SM-15, sec. 16, T. 9 S., R. 46 E.														
64-78	J-6245	15.5	18.4	3.5	1.3	6.0	2.7	.98	35.7	11.6	.93	.68	1.6	.06	.20	99.15
		Dietz bed, drill hole SH-7045, sec. 24, T. 8 S., R. 45 E.														
43-55	225,228	12.1	23.5	6.9	2	10.8	1.6	1.7	13.4	25.7	.4	--	--	--	--	96.3
		Canyon bed, drill hole SH-7045, sec. 24, T. 8 S., R. 45 E.														
132-153	226,224, 227	12.7	19.6	6.9	.8	5.2	9.4	1.0	27.8	18.1	.5	--	--	--	--	102.0

Table 9 summarizes estimated coal resources in the Bear Creek Study Area in the Anderson, Dietz, and Canyon beds in two overburden categories. The resources are classified as "measured," "indicated," and "inferred" according to the degree of geologic assurance of the estimate. The focus of the present study is on coal resources that are potentially recoverable by surface-mining methods, and for this reason, resources tabulated in table 9 are for coal that is beneath no more than 200 feet of overburden.

In addition to the estimates given in table 9, the Dietz bed is estimated to contain as much as 14.5 million short tons of coal and the Canyon bed as much as 79 million short tons of coal at depths greater than 200 feet within the Bear Creek Study Area. Estimates have not been made for coal in beds below the Canyon bed; the coal in all such beds is at depths considerably greater than 200 feet.

All of the estimated coal resources shown on table 9 fall into a category called reserve base, which is 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 in place and the total coal recoverable in any specific locale.

Resources Categorized by Degree of Geologic Assurance

Three categories according to degree of geologic assurance were used in the present study.

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 coal beds, points of observation are no greater than 1/2-mile (.8 km) apart. Measured coal is projected to extend as a 1/4-mile (.4 km) wide belt from the outcrop or points of observation or measurement.

Indicated

Resources are computed partly from specified measurements and partly from projection of visible data for a reasonable distance

Table 9.—Coal resources by bed, reliability of estimate, and overburden catagory.

[In thousands of short tons; 1,770 short tons/acre-foot used in all calculations]

Bed	Average thickness (feet)	Identified resources			
		Measured	Indicated	Inferred	Total
Overburden 0 to 100 feet					
Anderson	26.0	45,700	31,500	500	77,700
Dietz	10.1	3,900	7,400	400	11,700
Total		49,600	38,900	900	89,400
Overburden 100 to 200 feet					
Anderson	28.0	16,700	16,500	1,200	34,400
Dietz	9.8	8,500	16,600	4,300	29,400
Canyon	21.2	3,800	8,800	—	12,600
Total		29,000	41,900	5,500	76,400
Total, overburden 0 to 200 feet					
Anderson	26.6	62,400	48,000	1,700	112,100
Dietz	9.9	12,400	24,000	4,700	41,100
Canyon	21.2	3,800	8,800	—	12,600
Total		78,600	80,800	6,400	165,800

on the basis of geologic evidence. The points of observation are 1/2 (.8 km) to 1-1/2 miles (2.4 km) apart. Indicated coal is projected to extend as a 1/2-mile (.8 km) wide belt that lies more than 1/4 mile (.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 and where few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from demonstrated coal for which there is geologic evidence. 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.

The inferred resources estimated in the present study are all within 2 miles of points of observation.

Characteristics Used in Resource Evaluation

Weight

The weight of the coal ranges considerably with differences in rank and ash content. In areas where true specific gravities of the coals 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 subbituminous coal is taken as 1,770 tons per acre-foot--a specific gravity of 1.30.

Thickness of Beds

The coal beds for which resources have been calculated in the study area are not differentiated according to their thicknesses, but more than 90 percent of the resource is in beds more than 10 feet thick. The Anderson bed ranges from 11.5 to 32.0 feet thick in 11 drill holes in and near the site; the Dietz bed ranges from 7.2 to 11.0 feet in 10 drill holes; and the Canyon bed is 19 and 24 feet thick, respectively, in two drill holes.

Thickness of Overburden

Coal resources in the Bear Creek Study Area are classified into two overburden categories--resources beneath 0 to 100 feet of overburden, and resources beneath 100 to 200 feet of overburden. The first of these categories identifies coal at depths currently considered shallow enough for surface mining of equivalent deposits in other parts of the Powder River Basin. The second category identifies coal potentially strippable at higher overburden-to-coal ratios and higher costs. Overburden-to-coal ratios have been calculated for both overburden categories as shown by table 10.

Table 10.--Stripping ratio by bed and overburden category.

[In cubic yards of overburden/short tons of coal]

	Overburden (feet)		
Bed	0 to 100	100 to 200	0 to 200
Anderson	2.0	4.4	2.7
Dietz	6.7	14.8	12.3
Canyon	--	7.8	7.8

Trace Elements

Swanson and others (1974) have compiled trace-element data on coals in the Powder River Basin, including data on samples from the Anderson, Dietz, and Canyon beds or their equivalents in the northern part of the basin. The following table compares average values of selected elements in coal, as reported by Swanson, Huffman, and Hamilton (1974) with the average values in the continental crust.

Concentrations at the levels reported on table 11 are not unusual compared to concentrations of these and other trace elements in coal in other regions. Only selenium, 0.8 ppm for area coals, is significantly higher than the average found in other regions. Even this amount is relatively small.

Table 11.--Elements that can affect potential utilization of coals--comparison of Northern Great Plains subbituminous coals with average values of crustal abundance.

Element	Average, northern Great Plains subbituminous coals[1]	Average, continental crust (Taylor, 1964)
As	2 (63)	1.8
Cd	0.2 (63)	0.2
Cu	12 (63)	55
F	57 (44)	625
Hg	0.09 (67)	0.08
Li	7 (63)	20
Pb	9 (63)	12.5
Sb	0.2 (55)	0.2
Se	0.8 (62)	0.05
Th	2 (63)	9.6
V	0.8 (63)	2.7
Zn	7 (63)	70

[1]Swanson and others, 1974.

HYDROLOGY

Introduction

A basic understanding of the areal hydrology is necessary to assess potential effects of mining on water resources and to suggest alternative solutions to water problems that may occur. This report describes the progress after 1 year of hydrologic instrumentation and data collection at the Bear Creek area. The report is the first phase of a continuing study to determine baseline water conditions and to define the Bear Creek hydrologic system. The continuing program will include development of a hydrologic model and long-term monitoring, which will permit a better understanding of the surface- and groundwater systems.

Streamflow and water-quality data were collected for this study during 1975 and the spring and summer of 1976. Ground-water data were obtained from existing wells in the area and from test holes which were cored for geology and overburden analyses in 1976. Hydrologic boundaries of shallow aquifers, principal direction of water movement and water chemistry were determined from the data. Field observations and reported information from local landowners were used to define local climatic conditions.

System for Describing Geographic Locations

Wells and sites described in this report are specified by location codes derived from the General Land Office system of land subdivision. The first two characters of the location code specify the township south, S, of the Montana base line; the next three, the range east, E, of the Montana principal meridian. The next two characters specify the section number within the township. The final four letters specify the location within the quarter section (160-acre tract), the quarter-quarter section (40-acre tract), the quarter-quarter-quarter section (10-acre tract), and the quarter-quarter-quarter-quarter section (2-1/2-acre tract). Subdivisions of a section are designated A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. If more than one feature is located in a 2-1/2-acre tract, consecutive digits are added to the end of the location number. For example, a well numbered 08S45E33BAAC-2 would be the second well described in the SW 1/4 of the NE 1/4 of the NE 1/4 of the NW 1/4 of section 33, Township 8 South, Range 45 East (figure 3).

Surface Water

The Bear Creek Study Area is near the head of the Bear Creek drainage basin. Streamflow is intermittent upstream and through the area. Tributaries to Bear Creek in and adjacent to the area include Vance and Bales Creeks, and Mac Alister Draw. Most streamflow occurs from

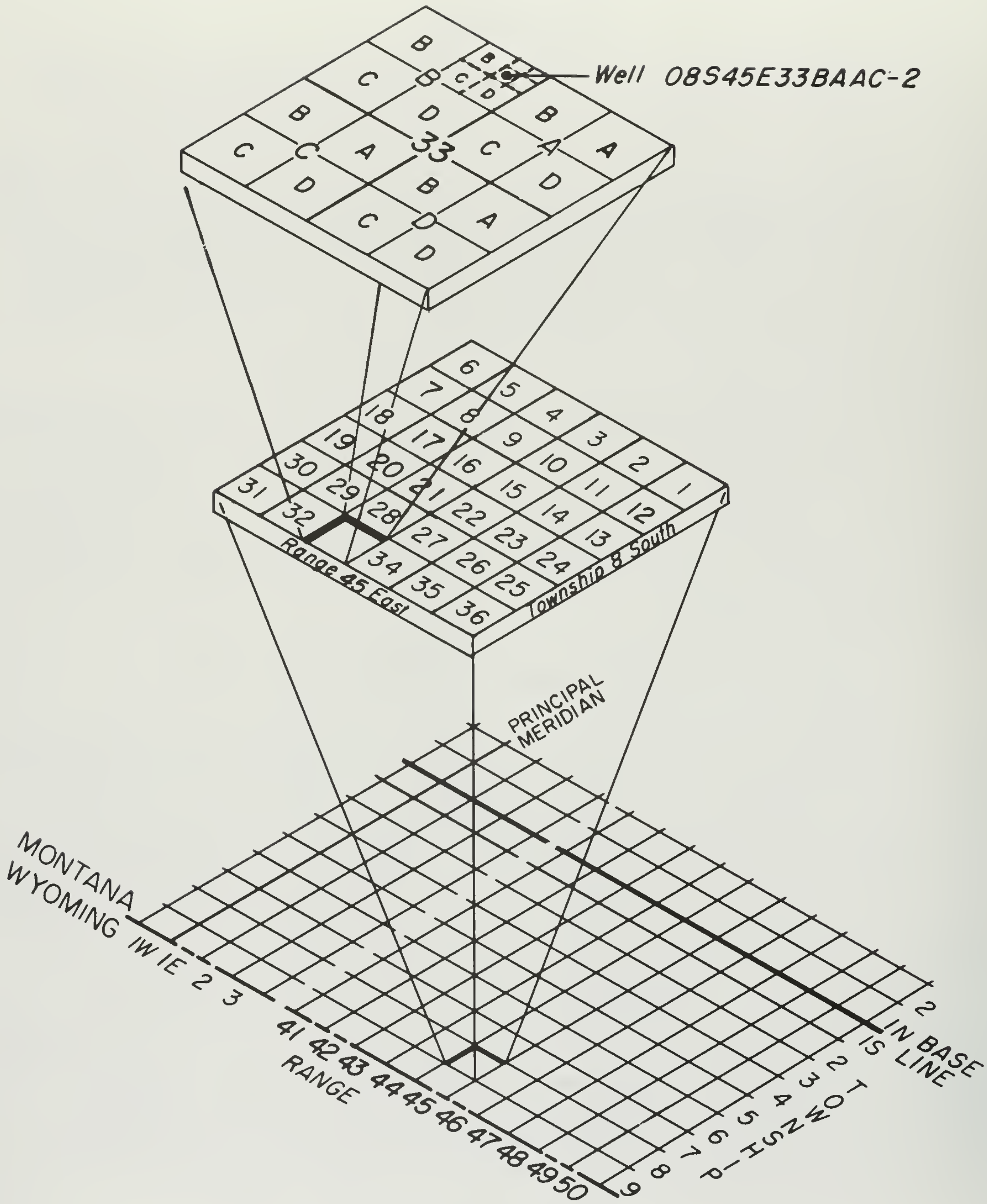


FIGURE 3 –SYSTEM FOR DESCRIBING GEOGRAPHIC LOCATIONS.

March to May during spring runoff. Discharge of Bear Creek at Otter, which is 7 miles downstream (north) from the Bear Creek Study Area, measured during May 1975 and March 1976 was 0.28 and 0.01 ft^3/s (cubic feet per second), respectively and represents rainfall runoff. During January and March 1975, measured discharge ranged from 7.1 to 53 ft^3/s and probably reflects short periods of snowmelt over frozen ground.

Flood discharge at the Bear Creek area can be estimated for Bear Creek and Vance Creek from the size of their drainage area, main channel slope, and average annual precipitation. The mean annual flood for Vance Creek is 14 ft^3/s. Bear Creek above its confluence with Vance Creek is also about 14 ft^3/s. The 25-year flood discharges are about 400 and 440 ft^3/s for Bear Creek above Vance Creek, and for Vance Creek respectively.

The quantity of water stored by stock dams and irrigation ditches depends on seasonal weather conditions that control spring runoff. The largest stock reservoir, located at 09S45E03ACCD, contains water throughout the year, except during unusually dry periods. Smaller reservoirs of less than 2 acres generally are dry by mid-summer. Irrigation ditches and spreader dikes along the wider drainage bottoms of Bear, Vance, and Bales Creeks are used to divert rainfall or snow-melt runoff into hayfields.

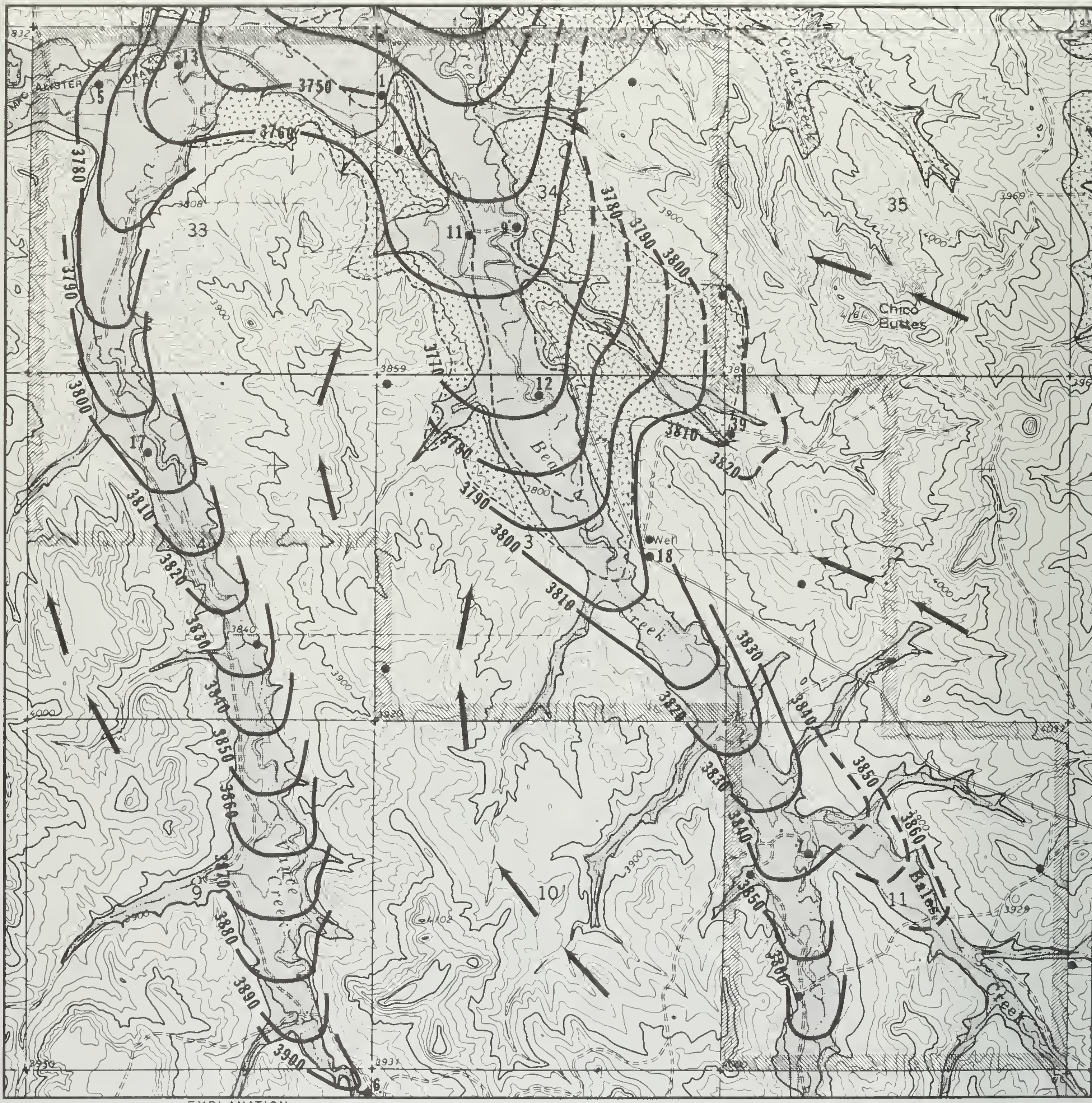
Surface-Water Quality

Five water samples from Bear Creek at Otter have been analyzed for water quality (table 12, appendix D), including one analysis for heavy metals. Dissolved-solids concentration ranges from 140 mg/l (milligrams per liter) for snowmelt over frozen ground (March 5, 1975) to 2,330 mg/l for near-base-flow conditions (May 22, 1975). The water composition is mostly sodium sulfate and sodium magnesium sulfate. Stream samples were not collected at the Bear Creek Study Area in the spring of 1976 because a season of slow thaw produced no observed runoff.

Ground Water

The Bear Creek Study Area is underlain by several aquifers. The shallowest aquifers are alluvium of Holocene age and the Tongue River Member of the Fort Union Formation and clinker of Paleocene age (plate 21). The 300-foot-thick Lebo Shale Member of the Fort Union Formation separates the Tongue River Member from underlying aquifers, which include the Tullock Member of the Fort Union Formation, Hell Creek Formation, basal Hell Creek-Fox Hills aquifer, and the Madison Group. Because the Lebo Shale is lowly permeable these underlying aquifers are likely to be little affected by surface mining at the site. Other potential aquifers between the basal Hell Creek-Fox Hills aquifer and the Madison Group include the Judith River Formation, Eagle Sandstone, and Muddy Sandstone Member of the Thermopolis Shale.

Plate 21



EXPLANATION

HOLOCENE		ALLUVIUM—Sand, silt, and clay. Up to 50 feet thick
PALEOCENE		TONGUE RIVER MEMBER–FORT UNION FORMATION.—Sandstone, siltstone, and shale. Contains coal beds up to 32 feet thick
		CLINKER—Baked sandstone, siltstone, and shale of the Fort Union Formation. Produced by burning of the Anderson coal bed. Up to 50 feet thick.
		Geologic contact. Dashed where inferred.
		Outline of study area.

—3870— — WATER-TABLE CONTOUR Shows altitude of water-table, 1974-76. Dashed where approximately located. Contour interval 10 feet. Datum is mean sea level.

•7 WELL OR TEST HOLE Number is depth to unconfined water, in feet below land surface, 1974-76. Well or test hole without number taps confined aquifers in the Tongue River Member.

⟶ Direction of water movement in Anderson and Dietz coal beds.

0 1000 2000 3000 FEET
0 300 600 900 METERS

CONTOUR INTERVAL 20 FEET

DATUM IS MEAN SEA LEVEL

BEAR CREEK STUDY AREA

HYDROGEOLOGIC MAP—UNCONFINED WATER SURFACE OF THE SHALLOW AQUIFER SYSTEM

The unconfined or water table aquifer in the Bear Creek Study Area consists of alluvium and slope wash along Bear and Vance Creeks. Alluvium occurs in valley bottoms. Slope wash, which is mostly unsaturated, mantles the Tongue River Member adjacent to the valleys. Because of its occurrence above the Tongue River Member, slope wash is not identified on plate 21.

Ten test holes were augered through the alluvium in the southwest quarter of section 34 to determine its saturated thickness and composition (figure 4). The alluvium is mostly brown, soft clay and fine gravel that contains silty and sandy clay. Similar lithology was discovered near slope wash cored at test hole 09S45E03DABB (DH75-102). The alluvium along the cross section averages about 43 feet thick and is bounded by a steep outcrop of clinker on the east and a gentle slope underlain by clinker on the west. Upstream from the clinker outcrops, the alluvium and slope wash thin gradually toward the edges of the valley. Water levels in the test holes also show that in cross section the water table is relatively flat in the alluvium. Measured water levels in wells tapping alluvium or slope wash range from 5 to 17 feet below land surface near the stream channels and from 18 to 39 feet below land surface on nearby slopes and tributary washes (plate 21).

The Tongue River Member is the shallowest confined aquifer system in the study area. This bedrock unit, which is composed mainly of shale, siltstone, fine-grained sandstone, and coal, is areally continuous throughout and beyond the limits of the study area. However, lenticular siltstone, sandstone, and channel sand within the Tongue River Member comprise many confined and semiconfined aquifers, which do not generally extend throughout the area. In some places rock units in the Tongue River Member grade abruptly into clinker formed by burning of the Anderson coal bed (plate 21).

The potentiometric surface in the Tongue River Member conforms generally with the areal topography. No water levels are available from deep test wells along the divides in the Bear Creek area. However, shallow wells in high areas near the site generally have depths to water of 20 to 40 feet below land surface. The shallow wells in the divide areas may not reflect the regional potentiometric surface because they may tap perched zones separated from deeper aquifers by relatively impermeable shale or claystone.

The Anderson, Dietz, and Canyon coalbeds appear to be the most continuous aquifers penetrated by drill holes in the Bear Creek Study Area (plates 8 and 9). These coalbeds are generally confined above and below by black carbonaceous shale or clayey siltstone. The eastern hydrologic boundary of the Anderson coalbed is the outcrop 2 to 3 miles east of the study area. Part of the water in the Anderson discharges through the clinker into the alluvium along Bear Creek. The Anderson dips west and north, extending in the subsurface to Hanging Woman Creek and Tongue River valleys, which are discharge areas for water not discharged to the alluvium along Bear Creek.

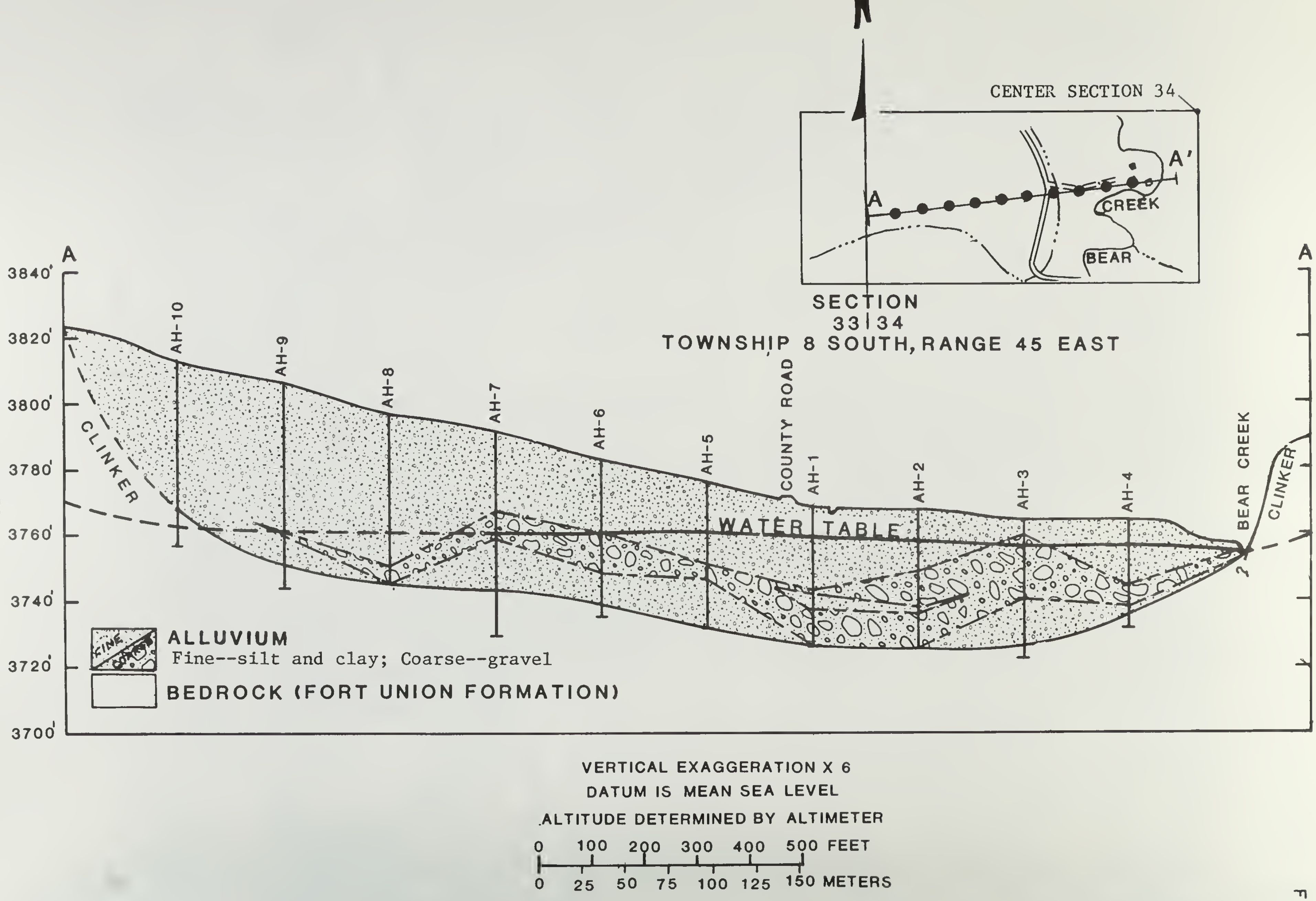


FIGURE 4 -GEOLOGIC SECTION SHOWING ALLUVIUM AT BEAR CREEK.

Figure

The hydrologic boundaries of the Dietz and Canyon coalbeds are similar to those of the Anderson coal. The Dietz and Canyon crop out 3 to 4 miles north of the study area where discharge is to the alluvium along Bear Creek. The two coalbeds thin to the west and it is likely that water recharged at the study area leaks into overlying beds 15 to 20 miles west of the area.

Hydrologic data were collected from the coalbed aquifers at test holes drilled and cored by the Bureau of Reclamation. Test well 08S45E34BBBB (DH75-101) isolated the Dietz coalbed only. The rest of the test wells each isolated two of the three coalbeds, either Anderson and Dietz or Dietz and Canyon. The Bureau of Reclamation also drilled and cased several observation wells in the Anderson coalbed and one in the Dietz coalbed near test well 09S45E03DABB (DH75-102). Also, information was collected from test holes drilled in and near the study area by Utah International Inc.

Comparison of water levels in or near the study area from wells isolating separate coal aquifers and the alluvium and slope wash aquifer shows that the potentiometric head is lower in successively deeper coal aquifer units. This suggests that the site is a recharge area for aquifers in the Tongue River Member. Test well 09S45E03DABB (DH75-102), for example, had a depth to water of 18 feet where the Anderson coalbed was isolated, a depth of 38 feet where the Dietz coalbed was isolated, and a depth of 28 feet for a composite head of both aquifers. The potentiometric surfaces of the Dietz coalbed in test well 08S45E34BBBB (DH75-101) and the Canyon coalbed in test well 08S45E34BCBC, a third of a mile to the south, are 3,730 and 3,662 feet above mean sea level, respectively; a difference in head of 68 feet.

In most places at the study area water levels in the coalbed aquifers are from 10 to 30 feet below the unconfined water surface shown on plate 21. However, where the Anderson coalbed is hydraulically connected to the alluvium and slope wash through the clinker, the potentiometric surface of the Anderson coalbed gradually approaches the unconfined water surface. For instance, the water table is less than 3 feet above the head in the Anderson coalbed at 09S45E03DABB.

Drawdown and recovery tests were performed on test wells 08S45E34CABC (completed in alluvium) and 08S45E34BCBC (completed in Canyon coal). Discharges during the test ranged from 3 gal/min (gallons per minute) from the coal well to 5 gal/min from the alluvial well. The test of the alluvium indicated a transmissivity of 1,300 ft^2/day (feet squared per day) and an average hydraulic conductivity of 42 ft/day. Transmissivity in the Canyon coalbed is 40 ft^2/day, and the average hydraulic conductivity is 2 ft/day. The data analysis assumed that the coal and alluvium can be treated as separate isotropic and homogeneous aquifers.

With regard to regional ground water movement in the Powder River structural basin, the Bear Creek area is a recharge area. A small part of the recharge at the area moves downward from the aquifers exposed at the surface to deeper aquifers and then to the north or northwest; eventually the water is discharged to the major stream valleys such as Otter Creek or the Tongue River. Discharge to these valleys either appears as base flow in the stream or is evaporated and transpired where the depth to water is shallow.

Although the Bear Creek Study Area is a recharge area in a regional sense, the local flow patterns are affected by permeability differences, topography, and evapotranspiration. Much of the recharge to the Tongue River Member, clinker, and slope wash moves laterally toward Vance or Bear Creek and is discharged to the alluvium. The direction of movement is generally normal to the water table contours (plate 21). Water in the alluvium moves downvalley, but most is either evaporated from small ponds where the land surface intersects the water table or evaporated and transpired where the depth to water in the alluvium is shallow.

Water in the Anderson and Dietz coalbeds moves northwest under a gradient of about 40 feet per mile according to water levels from wells tapping the Anderson and Dietz coalbeds:

Well number	Water level (feet above mean sea level)
08S45E34ABDA (DH76-111)	3,777
09S45E02DBAD (DH75-105)	3,811
09S45E03BBBB (DH76-108)	3,767
09S45E03CCBC (DH75-106)	3,784
09S45E03DABB (DH75-102)	3,783
09S45E11CCAA (DH75-103)	3,837

At the Bear Creek area most of the water in the Anderson bed moves into the highly permeable clinker then into the alluvium. Water movement is at an acute angle to the dip of the beds, which is generally to the west at 60 feet per mile (plates 19 and 20).

The average velocity of ground water flow through the alluvium can be estimated using a form of Darcy's law:

$$v = \frac{K\, dh/dl}{\theta}$$, where,

v = average velocity in feet per day

K = hydraulic conductivity in feet per day

dh/dl = gradient, unit change in head per unit length of flow, and

θ = porosity as a decimal fraction

Using a K of 42 ft/day determined from aquifer tests, an average water table gradient of 40 feet per mile, and an estimated porosity of 0.2, the average velocity is estimated to be about 2 feet per day. This estimate assumes average conditions and is not valid for predicting the velocities of contaminants passing through the same material, because contaminants may travel along preferential pathways not typified by average conditions. The lithology and aquifer properties are too variable in the Tongue River Member ground water system to estimate average velocity.

Ground Water Quality

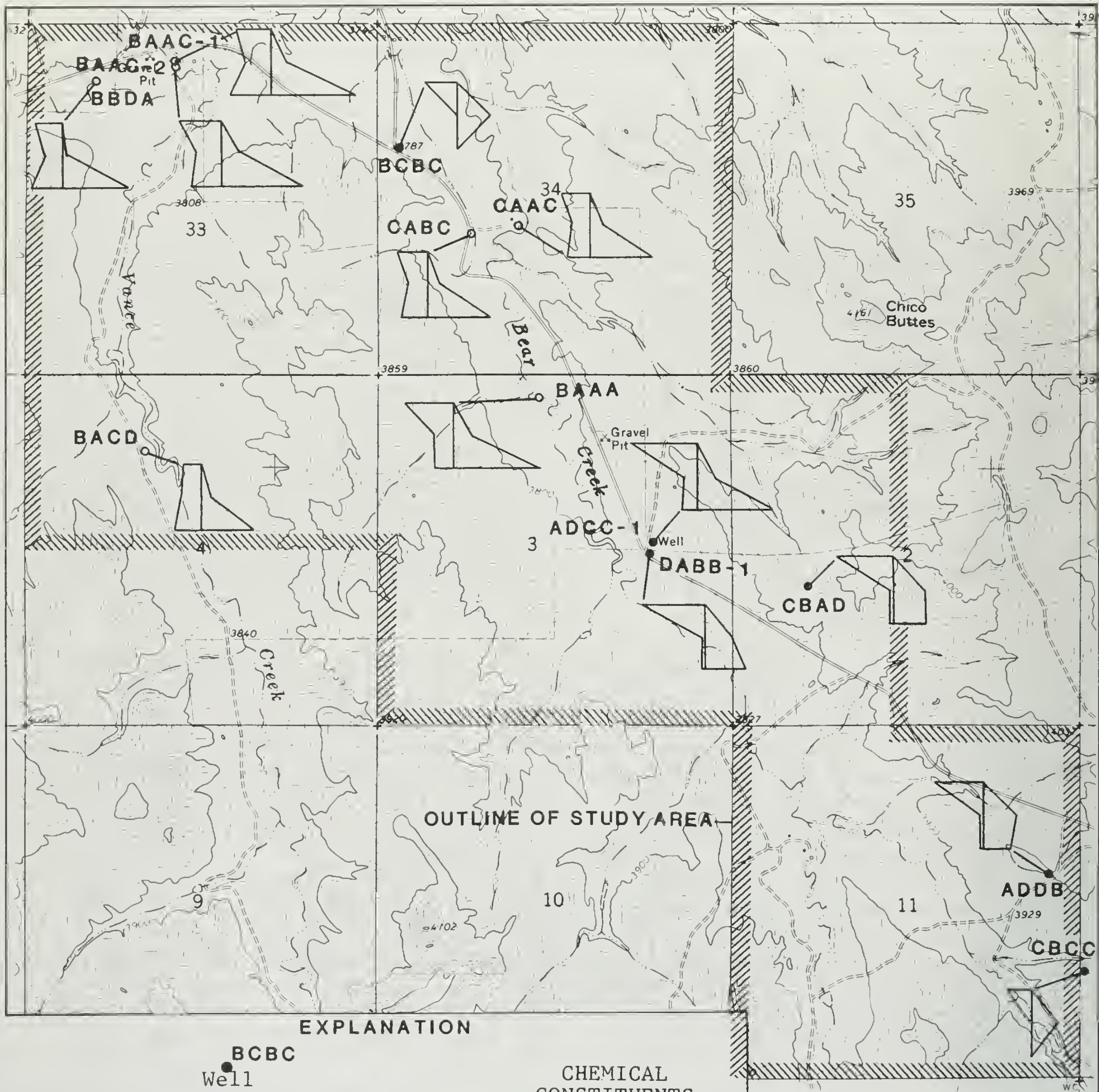
Chemical, spectrographic, and radiochemical analyses of water from various coalbeds and zones within the shallow aquifer system are presented in table 13, appendix D. Eight of the 22 samples are from wells in alluvium, which range in depth from 19 to 47 feet. The remaining samples are from wells tapping aquifers in the Tongue River Member. Wells tapping the Tongue River Member are as deep as 297 feet.

Dissolved solids in water in the alluvium at the Bear Creek Study Area are mostly magnesium, sodium, and sulfate, with substantial amounts of calcium and manganese (plate 22). The dissolved-solids concentration ranges from 2,720 to 5,040 mg/l. Dissolved solids in water in the Tongue River Member are mostly sodium sulfate and sodium bicarbonate. Dissolved-solids concentration of water from the Tongue River Member ranges from 1,110 to 4,760 mg/l.

The variability of ground water quality in the area is attributed to the flow path taken by the water, the abundance and composition of soluble minerals in the aquifer, and the presence of oxidizing and reducing environments in the aquifer. Chemical activity is greatest in the soil and subsoil, which is generally the first part of the flow path after the water is introduced as recharge. This zone, rich in CO_2 and weathered material, is an oxidizing environment. Saturated material well below the water table is generally a reducing environment.

Trends in water quality are apparent in the shallow ground water at the Bear Creek area as it moves from areas of recharge. Figure 5 is a trilinear plot of percentage reacting values for the major cations and anions in samples from streams and wells (table 14, appendix D). The average of three stream samples collected during snowmelt conditions approximate the quality of the water before it enters the aquifers. Samples from wells in the alluvium and from one well in the Tongue River Member plot fairly close together as a calcium or sodium magnesium sulfate to a magnesium sodium sulfate type water. Five samples (numbers 1, 2, 5, 15, and 19) plot as sodium bicarbonate type water. The remaining samples plot approximately between these two groupings, representing intermediate stages of ground water movement in the Bear Creek area. An exception is the composite sample (identification number 8) which is a mixture of water from slope wash and two coalbeds.

R. 45 E. Plate 22



EXPLANATION

BCBC
Well

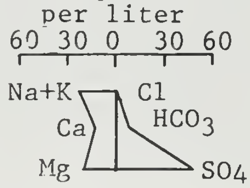
Closed circle indicates chemical analysis of water from Tongue River Member of Fort Union Formation; open circle, alluvium. Letters denote tract location of chemical analysis in table 13.

0 1000 2000 3000 4000 FEET

0 500 1000 METERS

CHEMICAL CONSTITUENTS

Milliequivalents per liter



BEAR CREEK STUDY AREA

GEOCHEMICAL MAP

EXPLANATION

•18 Water analysis from Tongue River Member. Number is identification from table 14.

o15 Water analysis from alluvium. Number is identification from table 14.

▲ Average of three surface-water analyses from Bear Creek at Otter representing heavy snowmelt runoff (from table 12).

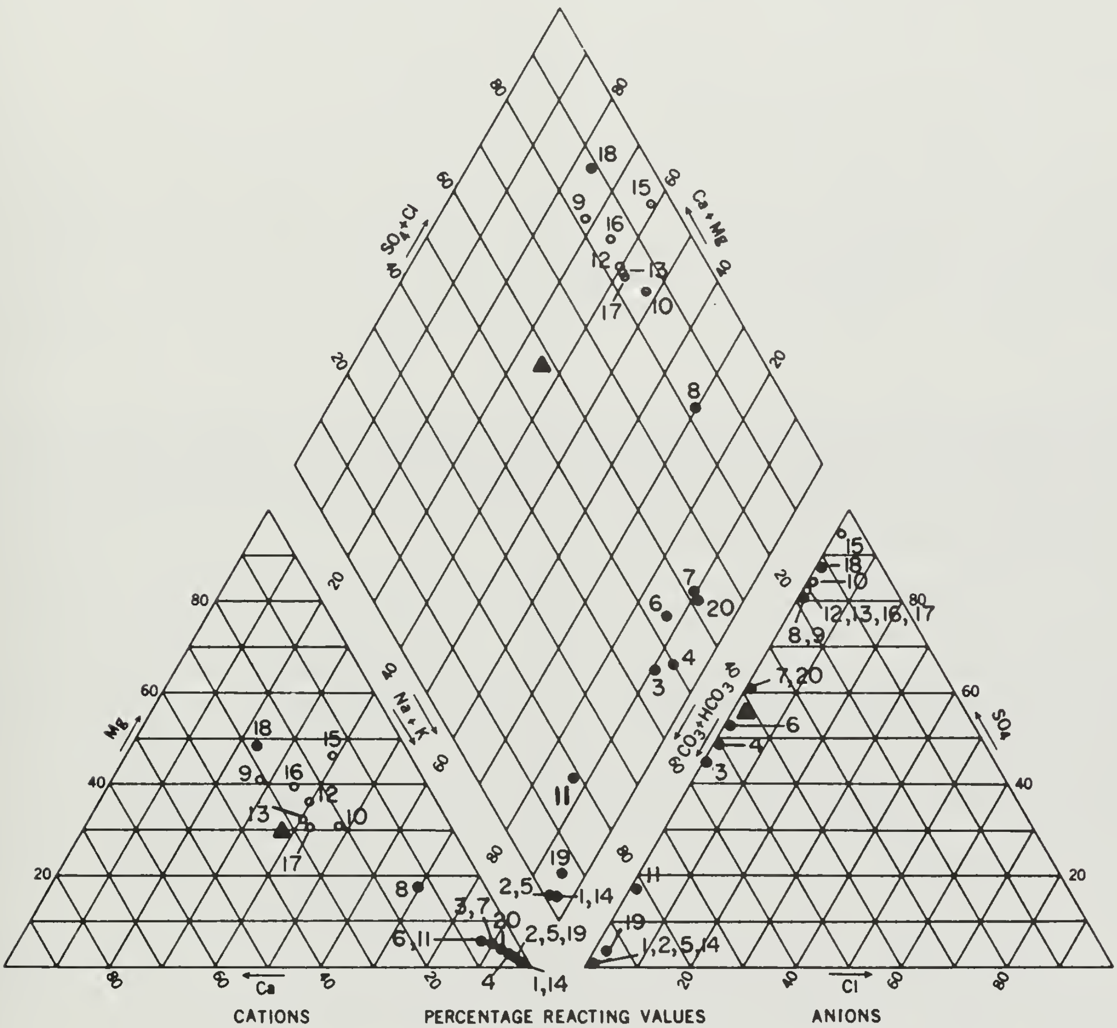


Figure 5.--Water analysis diagram of surface and ground water in the vicinity of Bear Creek Study Area.

Overall, the water quality change as water moves away from the area of recharge is a decrease in calcium, magnesium, hardness, silica, sulfate, and dissolved solids concentrations and an increase in bicarbonate concentration and pH with sodium becoming the dominant cation. Dissolved-solids concentration and relative percentages of magnesium and sulfate increase as water moves through the oxidizing environment. As the water percolates through shale and claystone of the Tongue River Member in the reducing environment, magnesium and calcium are exchanged for sodium. This results in a sodium sulfate type water. Decrease in sulfate and increase in bicarbonate observed in the deeper aquifers of the Tongue River Member may result from reactions with organic material, coal, and carbonaceous shales decreasing dissolved-solids concentration. One such reaction requires the presence of anaerobic bacteria as a catalyst:

$$SO_4^{-2} + CH_4 \xrightarrow[\text{bacteria}]{\text{reducing environment}} H_2S + HCO_3^- + OH^-$$

Water pumped from test well 09S45E02CBAD (DH75-105) gave off a slight H_2S odor, which may be a product of this reaction. Another reaction that may occur in the presence of ferrous iron is:

$$2\ Fe^{+2} + 4SO_4^{-2} + 2H_2O + 7C \longrightarrow 2FeS_2 + 4HCO_3 + 3CO_2$$

Traces of secondary marcasite or pyrite found on fractures in cores of Dietz coal from test hole 09S45E03BBBB (DH75-108) may be the result of this reaction. Effervescence of water pumped from well 08S45E34BCBC in Canyon coal could be carbon dioxide released as the pressure drops when the water is brought to land surface.

Except for common constituents, iron and strontium were the only two parameters that had high concentrations. Samples from two water wells contained high concentrations of iron. Well 09S45E03ADCC-1 yields water containing 33,000 µg/l (micrograms per liter) dissolved iron. The well was redrilled after the steel casing corroded; also the casing in a nearby well west of Bear Creek failed because of corrosion. Well 09S45E03DABB-1, which is less than 300 feet south of the first well, yields water containing 130 µg/l dissolved iron. The second well has plastic casing and is completed in the Anderson and Dietz coalbeds. Thus, the high iron concentration in water from 09S45E03ADCC-1 may be from the casing rather than the water. Well 08S45E16DBCB-1, which is about 4 miles north of the Bear Creek area, had water containing 23,000 µg/l dissolved iron. Because this well has a plastic casing, the high concentrations of iron must be derived from the ground water.

Shallow wells 09S45E03BAAA and 08S45E16DBCB-1 produced water having strontium concentrations of 4,000 and 3,700 µg/l, respectively. Concentrations of this magnitude, however, are fairly common throughout the Powder River structural basin.

Water quality information for the aquifers below the Lebo Shale at Bear Creek is limited. Hopkins (1973) suggests that water from both the Tullock Member of the Fort Union Formation and the basal Hell Creek-Fox Hills aquifer is similar--sodium bicarbonate water having an average dissolved-solids concentration of 1,300 mg/l. Water from the Judith River and Eagle Sandstone is sodium chloride water having dissolved-solids concentration greater than 6,000 mg/l. Water from the Muddy Sandstone Member of the Thermopolis Shale is sodium sulfate having more than 5,000 mg/l dissolved solids. Water from the Madison Group averages 1,150 mg/l dissolved solids in the area (Swenson and others, 1976).

Water Use and Supply

Both surface water and ground water in the Bear Creek area are low in quantity and generally poor in quality, but adequate for domestic, stock, and some irrigation uses (table 15, appendix D). Surface water supply is limited to intermittent ponding of Bear Creek and snowmelt or rainfall runoff. Only one stock reservoir, located on Bear Creek in section 3, retains water throughout the year. Diversion ditches and spreader dikes along the bottoms of Vance and Bear Creeks collect runoff to irrigate hayfields.

Wells in the alluvium and the Tongue River Member are used for domestic and stock supplies. Sustained well yields are less than 12 gal/min; reported specific capacities are less than 0.5 gal/min per foot of drawdown. An exception is alluvial well 09S45E03BAAA, which was used to supply water for drilling. The drillers reported a yield of 60 gal/min for more than 10 minutes of pumping. But it is not known whether such a yield could be maintained for long periods of time.

The U.S. Public Health Service (1962) has established maximum recommended concentrations for drinking water used in Interstate carriers. All concentrations of dissolved solids and most concentrations of dissolved sulfate for water samples collected from wells at the Bear Creek area are greater than the recommended maximum concentrations. Dissolved-solids concentrations in all samples is below upper limits for drinking by cattle (McKee and Wolfe, 1963).

No wells have been constructed in the aquifers below the Lebo Shale in or near the area. Although such wells might not flow, pumped yields should be greater than those of existing shallow wells. The Tullock Member of the Fort Union Formation, which is overlain by the confining Lebo Shale Member at about 2,300 feet below land surface, is 700 feet thick. The basal Hell Creek-Fox Hills aquifer, at a depth of about 3,400 feet, is 500 feet thick. The tops of the Judith River Formation, Eagle Sandstone, and Muddy Sandstone are at about 4,800, 5,400, and 8,300 feet below land surface, respectively.

An oil test hole drilled in the northeast corner of section 11 of the Bear Creek area shows that the Madison Group is about 1,000 feet thick and is about 10,000 feet below land surface. The potentiometric head at that location is about 100 feet below land surface (Swenson and others, 1976). Heterogeneous permeability of the carbonates in the Madison causes variability of yields of wells tapping the aquifer. Wells tapping the Madison yield from less than 200 to more than 1,000 gal/min.

Mining Effects and Reclamation Alternatives

The effects of surface mining on the area hydrology depend on the depth to which coalbeds will be stripped and the areal extent of mine development. For simplicity, two alternative programs of mining development will be discussed. Program 1 assumes mining of the Anderson coalbed (uppermost strippable coal) only. Program 2 assumes surface mining of the Anderson plus one or two coalbeds below the Anderson.

Surface mining under program 1 will drain the saturated overburden and the Anderson coalbed near the mined area. The mine floor will be lower in altitude and impose a hydraulic gradient from the alluvium to the mine in most surface-mined areas. In addition, the highly permeable Anderson clinker is between the alluvium and a potential mine in the north part of the area. Water in the alluvium could be diverted into a mine even though surface mining did not extend to the alluvium. Assuming a surface mine approximated by a one-half-mile radius semi-circled and a depth of 10 feet below static water level conditions, mine inflow is estimated by a form of Darcy's law to be less than 300 gal/min (0.67 ft^3/s). However, this flow should gradually diminish to less than 50 gal/min (0.1 ft^3/s) as hydraulic gradients approach steady-state conditions.

The area of greatest water level decline in wells can be expected to be to the east and southeast, upgradient from any potential surface mine. Mining under program 1 could potentially cause eight stock wells and one house well to become dry. Replacement wells of similar yields could be completed in one or more water-bearing zones of the Tongue River Member. The water quality could be expected to be better than water from wells presently in alluvium.

Bear Creek and its intermittent tributaries are expected to become losing streams at the study area as the alluvium is drained by mining. Intermittent streamflow is likely to be slightly decreased as water infiltrates to the alluvium. Streamflow downstream from the study area could be increased if mine drainage is returned to Bear Creek. Because the stream would be above the water table, the drainage would likely infiltrate into the alluvium in a short distance. However, channel erosion would need to be prevented at points of reintroduction during periods of heavy dewatering.

Floodwater would need to be diverted around a mine. Diversion works should be designated to carry the natural sediment load as well as to be noneroding. Diversion channels could be designed to minimize infiltration, but because the alluvium contains a high percentage of clay and is lowly permeable, infiltration is likely to be small.

Post mining water quality changes are to be expected in both surface and ground water. Surface water quality downstream from a potential mine could be degraded by poor quality water from mine drainage and by sedimentation or erosion due to improper flood control diversion.

The active mine will act as a discharge area for shallow ground water; however, any water polluted by mining operations, such as by explosives or by fuel and oil spill, may percolate to deeper aquifers if the head gradient is downward.

Water problems associated with surface mining the Anderson and one or two other coalbeds (program 2) would be similar, but more extensive than program 1. Limiting the stripping ratio to 8:1, less than presently used ratios, would restrict mining the Dietz and Canyon coalbeds to the northern part of the area downstream from the outcrop of the Anderson clinker. The mine would extend into the alluvium and would produce more water than under program 1. Mining would be likely to intercept nearly all the underflow in the Vance and Bear Creek valleys as well as most of the water presently discharged from the coalbeds. Water levels in the alluvium downstream from the area would be lowered, which could decrease hay production and injure plants whose roots extend to the water table. Probably, more than twice as much water would be produced from the mine under program 2 and its disposal would have to be controlled to prevent downstream erosion.

Reclamation of spoils appears to be possible using seasonal precipitation alone. Revegetation on the spoil piles can be improved by surface conditioning and top soiling. Surface conditioning reduces surface runoff and maximizes utilization of precipitation. Top soiling maximizes use of pre-existing soil.

Continued streamflow, ground water level, and water quality monitoring is necessary to determine seasonal fluctuations and to define the hydrologic system. Continuing data collection and instrumentation is planned to help calibrate and verify a hydrologic model for the study area. The results of the model effort should refine our knowledge of the hydrology and help provide solutions to water problems associated with alternative mining plans. The need for additional data collection must also be determined. Monitoring during and after mining also is necessary to assure optimum reclamation.

VEGETATION, SOIL WATER AND SOIL DETACHABILITY

Vegetation

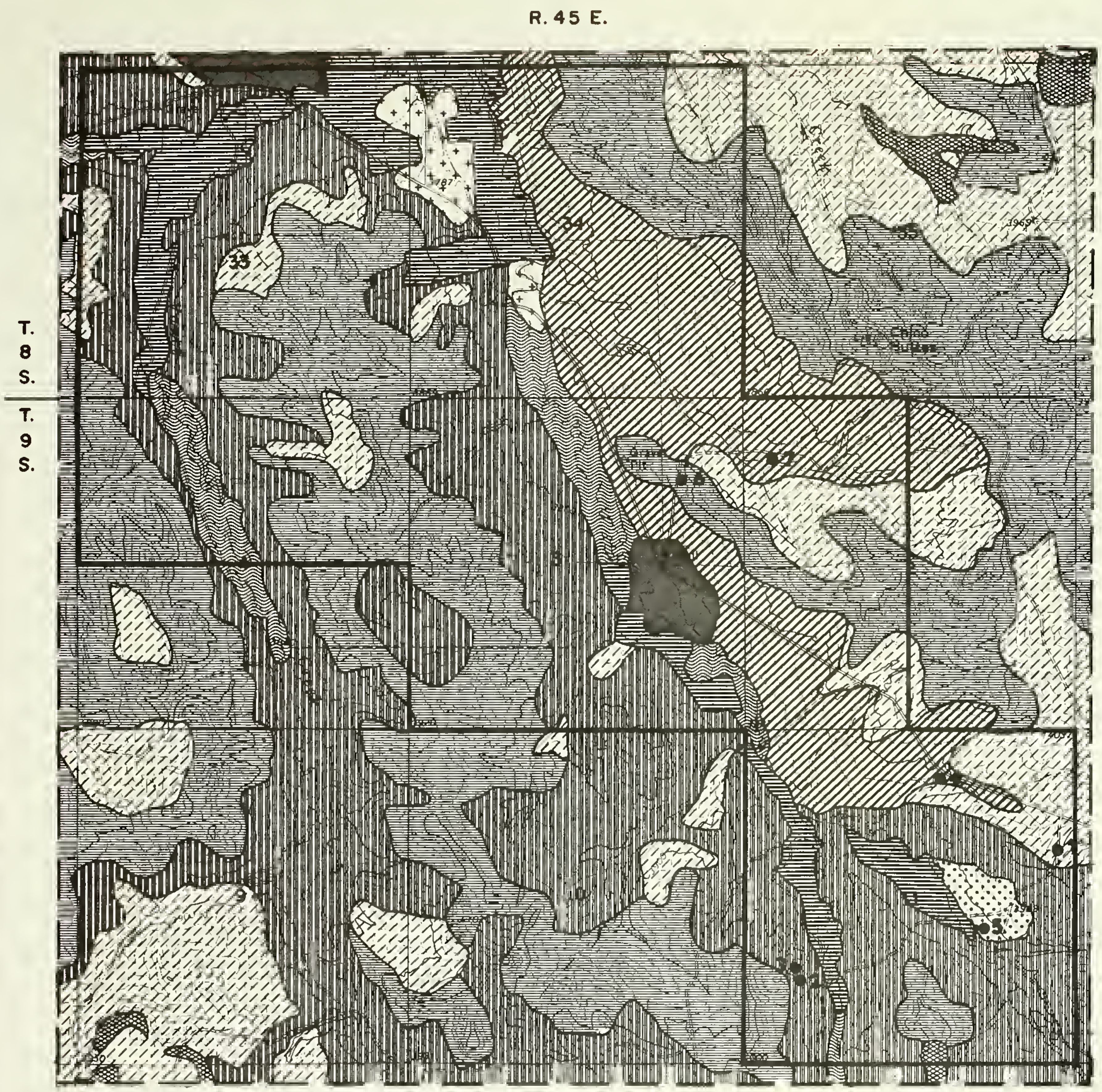
The vegetation as shown on plate 23 is largely grassland with scattered types dominated by shrubs. Ponderosa Pine savannah occupies highlands near the fringes of the study area. The most abundant grasses are western wheatgrass, green needlegrass, bluebunch wheatgrass, and blue grama. Many northerly slopes have stands of big sagebrush with an understory of bluebunch wheatgrass. As indicated by the data in table 16, these are productive grazing lands.

Some differences will be noted between species in transects and yield plots. Yields shown are averages of two 9.6 ft^2 plots placed at the ends of each 50-foot transect and represent total annual production by species present.

Total yields and estimated carrying capacity are also listed for each type. A commonly used rule-of-thumb by range managers assumes that 50 percent (by weight, not height) may be harvested without damage to vegetation. Because of variables such as distance from water, slope, and the presence of some species of low palatability on most plots, 40 percent instead of 50 percent has been used in these estimates. Adjustments were also made for poisonous plants and species of known low palatability to large herbivores. Animal units (A.U.) and their equivalents are the following: 1 = mature cow with calf, 1.25 = horse, 0.2 = sheep, 0.17 = goat, mule deer = 0.25, antelope = 0.17, black-tailed jackrabbit = 0.02. The estimates of carrying capacity shown are for domestic animals and would differ considerably if made for game species because of differences in animal food preferences. Nevertheless, they should be of some value in interpreting the data shown.

Carrying capacities are affected by range condition (amount of replacement of original vegetation) and by forage values of species present which may be original for the area, species abundance changed by man's effects, or exotic species that have replaced the original vegetation.

The total yield data give estimates of vegetation production potential of present and an index of production potential of vegetation after mining and rehabilitation. This index assumes the soil/vegetation association will be stripped by horizons, stockpiled separately, and replaced by horizons on shaped spoils of similar slope and in similar positions. Productivity of range units within the study area has been greatly increased by flood water spreading. Forage production on these meadows was not measured but would probably be at least double that of the most productive native range sites. Hay production is essential for ranches in this area of long winters and long duration of snow-covered ground. Without the hay meadows, an estimated 14 sections (about 9,000 acres) would be required for a 300 animal unit ranch.



Base from U.S. Geological Survey
Bear Creek School
7½-minute quadrangle

1000 0 1000 2000 FEET

EXPLANATION

Breaks. A mixed type, mostly grasses, with a high percentage of bare ground. Grasses present include stonyhills muhly, bluebunch wheatgrass, and junegrass (site 6, table 16).

Mixed grass. This extensive type has numerous grass species and few shrubs. Types 2 and 3 in table 16 were sampled in this type. Prominent grasses include little bluestem, bluebunch wheatgrass, blue grama, and needle-and-thread.

Green needlegrass. Other species common in this type include western wheatgrass and hairy chess (site 5, table 16)

Western wheatgrass-Blue grama covers a large portion of the east half of the area (site 7, table 16).

Big sagebrush. This type is common on north-facing slopes. Additional species include bluebunch wheatgrass, junegrass and needle-and-thread (site 1, table 16).

Western wheatgrass-green needlegrass. This type commonly occurs in valley bottoms near channels.

Pine savannah. This type is rarely found on the site. Species associated with ponderosa pine include bluebunch wheatgrass and little bluestem.

Hay meadows. These are lowland, flood-irrigated areas with mixed introduced and native species. A few of the meadows have stands of alfalfa.

Silver sagebrush-green needlegrass. This is a flood plain type of limited extent (site 4, table 16) and the most productive site sampled. Where sampled, this type was too small to map.

Crested wheatgrass. This introduced grass was apparently seeded into a stand of native grasses.

Blue grama-winterfat. This type was too limited in extent to map (site 3, table 16).

● Locations of vegetation and soil sampling sites.

—— Study area boundary.

VEGETATION MAP OF BEAR CREEK STUDY AREA--MONTANA, 1975

Table 16 .--Percent cover of vegetation, mulch, bare soil, and rock plus yields in pounds per acre of vegetation and mulch. Yields are in parentheses

	Vegetation type	Big sagebrush-bluebunch-wheatgrass		Little bluestem		Blue grama-winterfat		Silver sagebrush-green needlegrass		Green needlegrass-Western wheatgrass		Breaks		Western wheatgrass-Blue grama	
	Site number.....	1		2		3		4		5		6		7	
Shrubs		Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)
Artemisia cana	Silver sagebrush	----	---------	----	---------	----	---------	34.7	(126.0)	----	---------	----	---------	----	---------
Artemisia dracunculoides	False terragon	----	---------	0.3	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Artemisia frigida	Fringed sagewort	----	---------	0.7	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Artemisia tridentata	Big sagebrush	10.0	(271.5)	1.3	---------	----	---------	----	---------	----	---------	0.3	---------	----	---------
Eurotia lanata	Winterfat	----	---------	----	---------	6.3	(18.5)	----	---------	----	---------	----	---------	0.3	---------
Gutierrezia sarothrae	Snakeweed	----	---------	1.3	(37.5)	----	---------	----	---------	----	(4.0)	6.7	(165.5)	----	---------
Juniperus communis	Common juniper	----	---------	4.4	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Juniperus horizontalis	Creeping juniper	----	---------	4.3	(95.5)	----	---------	----	---------	----	---------	----	---------	----	---------
Opuntia polycanthus	Plains pricklypear	----	(120.0)	----	---------	----	---------	----	---------	----	(10.0)	----	---------	----	(229.0)
Grasses and grasslikes															
Agropyron smithii	Western wheatgrass	3.0	(3.0)	----	---------	----	---------	6.0	(591.0)	24.0	(520.5)	----	---------	70.0	(616.0)
Agropyron spicatum	Bluebunch wheatgrass	36.0	(224.5)	2.0	(146.0)	----	(22.5)	----	---------	----	---------	8.3	(141.5)	----	---------
Andropogon scoparius	Little bluestem	----	---------	27.0	(358.5)	----	---------	----	---------	----	---------	----	(37.7)	----	---------
Bouteloua gracilis	Blue grama	9.3	---------	----	---------	37.0	(212.5)	----	(33.5)	----	---------	3.3	(26.0)	4.7	(58.9)
Bromus commutatus	Hairy chess	----	(6.0)	----	---------	2.7	(10.5)	8.7	(43.5)	27.7	(107.5)	1.0	---------	8.0	(12.5)
Bromus tectorum	Cheatgrass	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	(0.5)
Carex filifolia	Threadleaf sedge	----	---------	2.0	(11.0)	8.3	(10.5)	----	---------	----	---------	----	---------	----	---------
Koeleria cristata	Prairie junegrass	4.0	(22.5)	2.0	(5.0)	0.3	---------	0.3	(47.5)	----	---------	5.7	---------	0.3	---------
Muhlenbergia cuspidata	Stonyhills muhly	----	---------	9.4	(45.5)	----	(19.5)	----	---------	----	---------	9.7	(55.5)	----	---------
Poa canbyi	Canbys bluegrass	----	---------	----	---------	----	---------	----	---------	----	---------	1.3	---------	----	---------
Poa secunda	Sandberg bluegrass	4.0	(0.5)	0.3	---------	----	---------	----	---------	----	(19.0)	0.3	---------	1.0	(3.5)
Stipa comata	Needle-and-thread	----	---------	----	---------	23.3	(28.5)	----	---------	----	---------	----	---------	3.0	(20.0)
Stipa viridula	Green needlegrass	3.0	(5.5)	----	---------	----	---------	39.7	(279.0)	27.3	(50.5)	----	---------	----	---------
Forbs															
Achillea millefolium	Yarrow	----	---------	0.3	(13.5)	----	---------	----	---------	----	(20.0)	----	---------	----	---------
Aster serecius	Aster	----	---------	----	(6.0)	----	---------	----	---------	----	---------	----	---------	----	---------
Aster sp.	Aster	----	---------	1.0	(17.5)	----	---------	----	---------	----	---------	----	---------	----	---------
Cirsium undulatum	Wavyleaf thistle	----	---------	----	(13.5)	----	---------	----	---------	----	---------	----	---------	----	---------
Commandra pallida	Bastard toadflax	----	---------	----	(3.5)	----	---------	----	---------	----	---------	0.7	---------	----	---------
Eriogonum sp.	Wild buckwheat	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Eriogonum multiceps	Wild buckwheat	----	---------	----	---------	----	---------	----	---------	----	---------	----	(53.0)	----	---------
Erysimum aspera	Western wallflower	----	---------	0.3	(10.5)	----	---------	----	---------	----	---------	----	---------	----	(0.5)
Hedioma hispida	Rough pennyroyal	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Lepidium densiflorum	Pepperweed	0.3	(2.5)	0.3	(1.0)	----	---------	----	(4.0)	1.0	(7.5)	----	---------	1.0	(7.0)
Liatris punctata	Blazing star	----	---------	----	---------	----	---------	----	---------	----	---------	1.0	---------	----	---------
Linum rigidum	Flax	----	---------	----	---------	1.0	(0.5)	----	---------	----	---------	----	---------	----	---------
Medicago sativa	Alfalfa	----	---------	----	---------	1.3	(9.0)	9.0	(257.5)	15.0	(273.5)	----	---------	----	---------
Oxytropis serecius	Silver loco	0.7	---------	2.7	---------	----	---------	----	---------	----	---------	3.3	(10.5)	----	---------
Petalostemum purpureum	Purple prairie clover	----	---------	----	(0.5)	----	---------	----	---------	----	---------	----	---------	----	---------
Phlox hoodii	Hoods phlox	----	(16.0)	----	(2.0)	----	(1.5)	----	---------	----	---------	0.3	(0.5)	----	---------
Plantago purshii	Wooly Indian wheat	----	---------	----	---------	0.7	(24.0)	----	---------	0.7	---------	----	---------	0.8	(32.0)
Tragopogon pratense	Oyster salsify	----	---------	----	---------	----	---------	0.3	---------	----	(78.5)	----	---------	1.3	(6.5)
Unidentified forb		----	---------	----	(3.0)	----	---------	----	---------	----	---------	----	(8.5)	----	---------
Vicia americana	American vetch	3.0	(18.0)	3.0	---------	----	---------	----	---------	----	---------	----	---------	----	---------
Mulch		18.4	(825.5)	22.7	(222.7)	12.7	(66.0)	1.3	(349.0)	4.3	(273.5)	10.7	(98.0)	9.4	(41.0)
Bare		8.3	---------	8.0	---------	5.7	---------	----	---------	----	---------	30.0	---------	0.3	---------
Rock		----	---------	10.0	---------	0.7	---------	----	---------	----	---------	17.4	---------	----	---------
Total live cover (percent) and total vegetation yields (lb/acre)		73.3	(690.0)	82.0	(770.0)	80.9	(357.5)	98.7	(1,382.0)	95.7	(1,091.0)	41.9	(498.0)	90.3	(986.0)
Estimated carrying capacity in acres per animal unit month			3.2		2.1		3.8		1.1		1.5		3.8		1.9

Table 16

Soil-Water-Vegetation Relationships

Water relationships in soils associated with vegetation types that predominate the Bear Creek Study Area were studied, first, to define soil parameters essential to the occurence of natural plant communities, and second, to derive information essential for rehabilitation procedures if coal resources are removed by surface mining. Factors affecting the availability of water are primarily responsible for kinds and amounts of vegetation that occur naturally on these range lands. It is essential to understand these factors if optimum results are to be achieved as a result of rehabilitation efforts.

Table 17, appendix E, lists all the data collected during this investigation.

Seasonal patterns of precipitation influence levels of moisture storage and depletion in soils of the Bear Creek area. Approximately 44 percent of the total precipitation falls over the period, from October 1 to May 1, when snow is most likely to accumulate. Average annual precipitation reported for Otter Creek, the nearest station to the area, is 19.1 inches; so a total of 8.4 inches can be assumed to arrive as snow. Snow falling on the area is redistributed by winds. As a result, snow accumulates in low areas and behind obstructions. There is evidence that maximum levels of storage occurring in soils and influenced by quantities of windblown snow, that characteristically accumulate. Moisture depletion starts with the initiation of plant growth. Storage is typically maintained at high levels during May and June by frequent rains that yield approximately 6½ inches of water. Storage is then depleted during July, August and September.

Summer storms (occasionally) replenish moisture storage to various levels. A maximum of 2 inches in any given week is possible; but the probability of this occurring is slight. No storms of any great magnitude occurred during the summer of 1975 prior to when soils associated with vegetation types were sampled in early September; so, minimum levels of storage measured should be indicative of the relative capabilities of vegetation to deplete moisture from soils.

Voids available for infiltration of water to depth in soils are the result of maximum levels of wetting that have been achieved over many years. Void moisture capacity (VMC) values are computed from volume weight (VW) values assuming, that the average specific gravity of soil particles is 2.65 g/cm^3. The mathematical formula, in addition to a graph, that can be used to determine void moisture capacities from volume weight values are presented in figure 6. Maximum levels of wetting achieved at different soil depths are interpreted from void-moisture capacity values.

Moisture retention capability (MRC) values indicate quantities of water absorbed to surfaces of soil particles at the level where drainage to depth by the force of gravity becomes very slow or ceases. There is evidence that 10 molecular layers of water are absorbed (Michurin and Lytayev, 1967) at the moisture-retention capability level. When the moisture content is less than the moisture retention capability, water is retained only as multimolecular films.

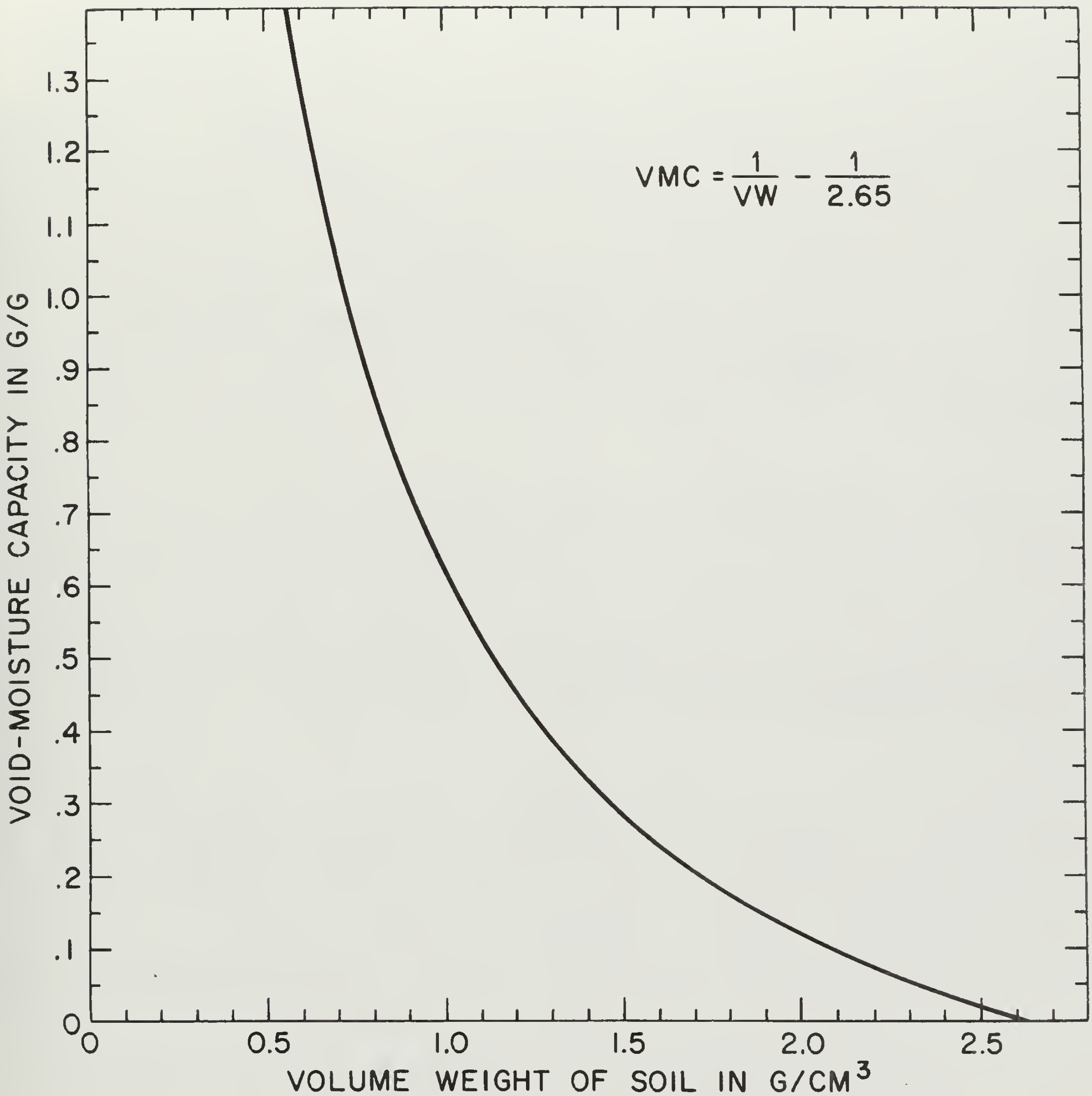


Figure 6.--Relationship between volume weight (VW) and void-moisture capacity (VMC) of soil.

Water retained by capillary forces can be present on top of adsorbed films at moisture contents greater than the moisture-retention capability. It can be shown that a maximum of sixteen molecular layers of water are adsorbed beneath capillary water when the soil is saturated. Capillary water drains off the surface of adsorbed water. Then adsorbed water drains to depth until the moisture-retention capability is achieved. If drainage to depth is impeded water accumulates first as films then as capillary water until saturation is achieved.

Water retained by capillary forces can be present to a maximum of 222 cm above a saturated zone. The retention force is $10^{2.34}$ or 222 g/cm^2, having increased 1 g/cm^2 for each centimeter in height above the water table. Ten molecular layers of water are adsorbed to particle surfaces at the limit of capillary rise; while 16 molecular layers of water are adsorbed beneath water retained by capillary forces immediately above the water table.

The moisture-retention force increases 2.46 times as each of the 16 molecular layers adsorbed to the surface of soil particles is desorbed (removed). The retention force is 1 g/cm^2 when 16 molecular layers are adsorbed increasing to 2.46 g/cm^2 when 15 molecular layers remain adsorbed. The retention force progressively increases to 6.05, 14.89, 36.64, 90.2 and to 222 g/cm^2 as the surface of the fourteenth through tenth molecular layers of adsorbed water are exposed. The magnitude of the increase in sorption force explains why the tendency for water to drain to depth decreases drastically at the moisture retention capability level.

The fact that the sorption force increases 2.46 times as each consecutive molecular layer of water is desorbed means that the increase in force is proportional or exponential. The exponent or logarithm of the sorption force expressed in g/cm^2 increases by uniform increments of 0.39 as each consecutive molecular layer of water is desorbed. Expressed exponentially the sorption force increases progressively from 10^0 to $10^{0.39}$ to $10^{0.78}$ to $10^{1.17}$ to $10^{1.56}$ to $10^{1.95}$ to $10^{2.34}$ as each consecutive molecular layer of water drains off until ten molecular layers of water remain adsorbed at the moisture retention capability level.

Moisture retention forces existing at the time the soils were sampled were measured using the wide range "filter paper" method of McQueen and Miller (1968). The retention force or moisture stress is determined from the moisture content of standard filter papers at moisture equilibrium with the soil, as illustrated by the linear relationships presented in figure 7A. Moisture retention forces are presented exponentially; with the $10^{0.39}$ increase for each molecular layer desorbed indicated by hatch marks along the calibration line. Capillary water is retained on top of multimolecular films adsorbed to the surfaces of cellulose fibers within the papers when the moisture content exceeds 0.54 grams of water per gram of paper. Ten molecular layers of water are adsorbed to the surfaces of fibers at the point where calibration lines representing adsorbed and capillary water intersect. The sorption force at that point, which is the moisture retention capability level, is $10^{2.34}$ or 222 g/cm^2. Capillary water accumulates on top of water adsorbed to fibers at contact angles between

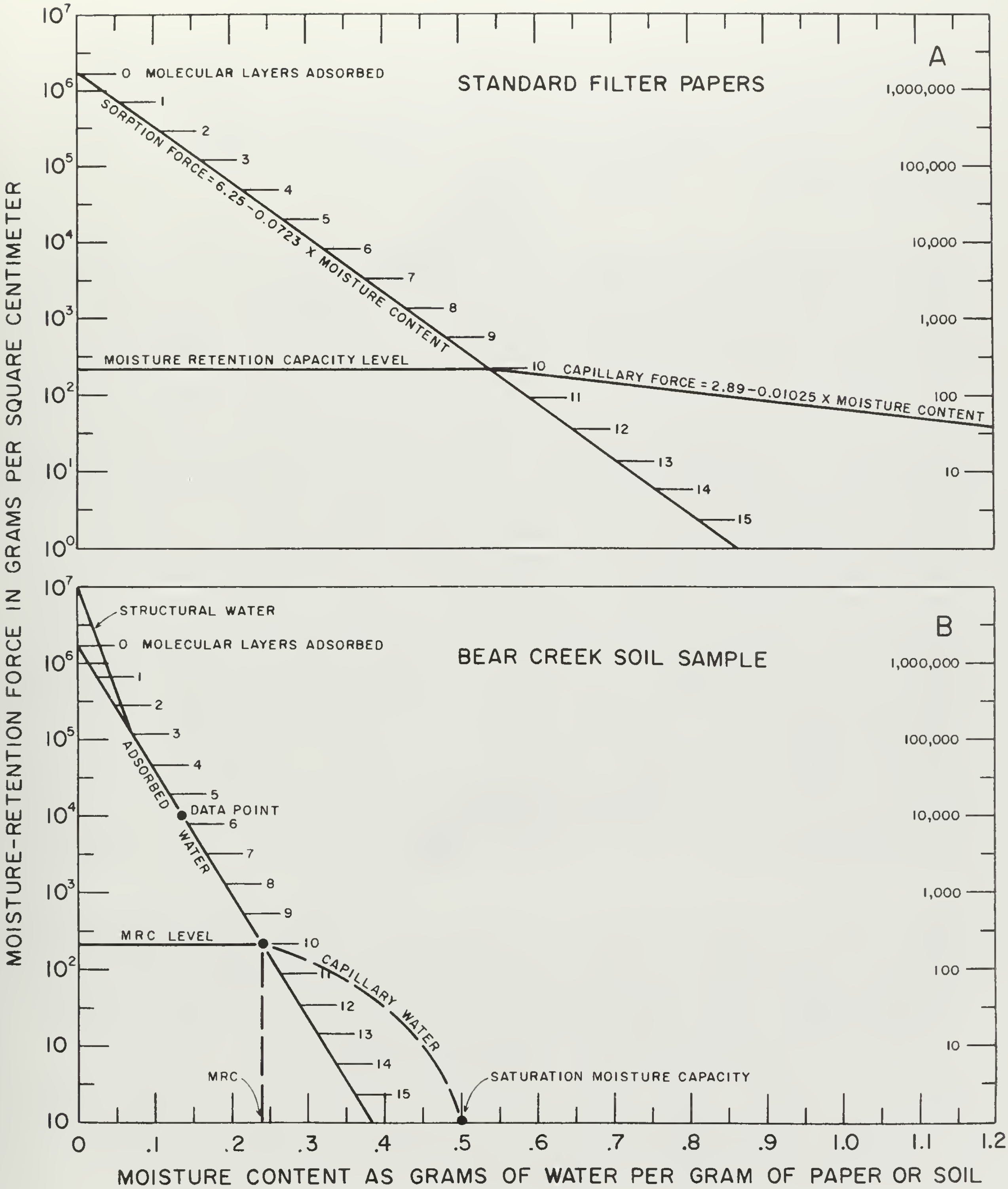


Figure 7.--The relationships of moisture-retention force to moisture content for filter paper when used as a retention sensor, and for a sample of soil.

the fibers. Water is present only as adsorbed films at paper moisture contents less than 0.54 g/g. The sorption force increases 2.46 times for each consecutive molecular layer desorbed; so the exponent of the sorption force increases by 0.39 until all the water is desorbed. The sorption force in the paper when oven dried at 110°C. is $10^{6.25}$ or 1,778,279 g/cm^2.

Moisture contents of soils and related retention forces over the moisture range from saturation to dryness can be computed, if the stress has been measured at any level where between three and ten molecular layers are adsorbed, using the graphic modeling technique of McQueen and Miller (1974) (figure 7B). Quantities of capillary water in excess of adsorbed water can also be approximated if the saturation moisture capacity is measured. Criterion for saturation of soils, prescribed by Richards and others (1954) was used in this study. Moisture retention characteristics of a soil, with a saturation moisture capacity (SMC) value of 0.50 g/g, are illustrated in figure 7B. The moisture content at the time of sampling was 0.135 g/g; while the related sorption force was $10^{4.00}$ or 10,000 g/cm^2. This value was plotted on the graph and is labeled data point. A line was then extended down through this point from the $10^{6.25}$ level on the vertical axis to the intersection with the horizontal axis. This line represents variations in sorption force with moisture content in the soil. Assuming a change of 0.39 in the exponential value of the sorption force for each layer, the number of molecular layers of water adsorbed to particle surfaces can be discerned. The moisture content at the moisture retention capability (MRC) level is also readily determined. Variations in moisture content as capillary forces decrease from the moisture retention capability level to saturation can be approximated by sketching in a line, as illustrated, using a French curve. Quantities of capillary water can vary between the lines representing adsorbed and capillary water. The line presented represents maximum probably quantities that can be retained by capillary forces.

Soils contain an extra increment of water retained at high levels of stress, that is not adsorbed to cellulose fibers in the standard filter papers. This water is contained within the lattice structure of clays, and is, therefore, defined as structural water. Quantities of structural water are approximated by extending a line down from $10^{7.00}$ or 10,000,000 g/cm^2, on the vertical axis to the point representing moisture content at a retention force of $10^{5.00}$ or 1,000,000 g/cm^2 on the line representing adsorbed water (see figure 7B). As soils dry, the water contained within the structure of clays is depleted by evaporation, especially near the soil surface. This water must be replenished when soils are rewetted. If this increment of water is not considered in computations, the computations will be slightly in error.

Linear relationships between saturation moisture capacity (SMC) values and volumetric shrink (VS) as well as moisture retention capability (MRC) values determined for soil associated with vegetation types in the Bear Creek area are presented in figure 8. Soil materials were differentiated into two types on the basis of volumetric shrink and moisture retention

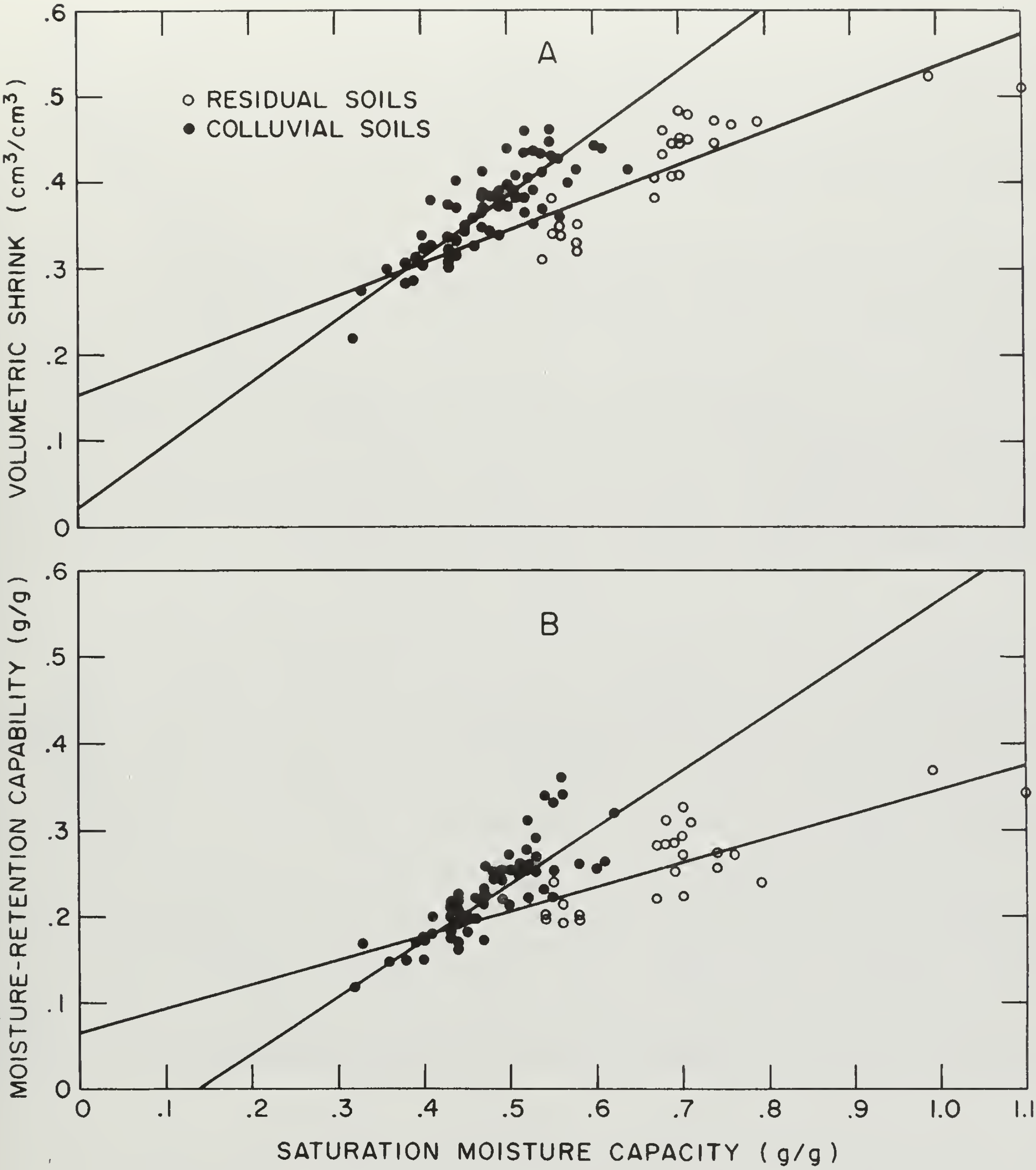


Figure 8.--Effect of kind of soil material on the relationships of saturation-moisture capacity to volumetric shrinkage and moisture-retention capacity.

capabilities relative to saturation moisture capacities. Residual soils associated with the little bluestem and breaks types (sites 2 and 6, plate 23 and table 16) demonstrated lower moisture retention capabilities as well as lower volumetric shrink relative to saturation moisture capacities than sites with soil of colluvial origin (sites 1, 3, 4, 5, and 7, plate 23 and table 16).

The linear relationships, between saturation moisture capacity and moisture retention capabilities illustrated in figure 8B, were used to develop the graphic models illustrating variations in relationships between moisture content and moisture retention force in soils of the Bear Creek area shown in figure 9. Residual soils exhibit less ability to retain water as adsorbed films, compared to voids available to retain water by capillarity, than soils of colluvial origin. Residual soils predominate much of the area defined on the vegetation map (plate 23) as breaks. These soils occur in areas with rather steep irregular slopes near the tops of ridges. The soils labeled colluvial soils occur on smooth slopes extending down from the breaks, on bottomlands, and in drainageways.

Breaks

The Breaks type (site 6, plate 23, table 16, and figure 10) occurs on steep uplands where the solum has developed in residuum. There is a surficial mantle of rock fragments, left behind as finer materials were carried away by runoff water. Large void moisture capacities (VMC) evident in the surface horizon (H1), indicate it is more completely wetter than lower portions of the solum. Capillary water in excess of 16 molecular layers can occur in the surface dm (decimeter), with voids diminishing to the level where only 9 molecular layers can be stored in the lower horizon (H2) of the solum. All available voids are assumed to be filled with water at maximum levels of storage. For this site, the maximum level of storage, apparently, is a normal occurrence. Transpiration can deplete moisture to the level where 5 molecular layers remain adsorbed. The rock mulch at the surface limits evaporation beyond this level to the upper 1.5 dm of soil, where 0.21 dm of the 1.87 dm (.54 + .21 + .33 + .79 dm) evapotranspired between maximum and minimum levels of storage is lost to evaporation (figure 10).

The limited void space available for storage of water below 3 dm deep results in storage at less than the moisture-retention capability (MRC) stress level ($10^{2.34}$ g/cm^2) in the surface horizon. As a result, up to 0.54 dm of water are available at levels of stress ranging from 10^0 to $10^{2.34}$ or 1 to 222 g/cm^2. Spring rains, no doubt, tend to replenish this portion of the water stored in the solum. Transpiration depletes moisture to the level where 5 molecular layers remain adsorbed; moisture stress increases from $10^{2.34}$ to $10^{4.3}$ or 222 to 19,998 g/cm^2. Soil at the immediate surface is depleted to the level where 1 molecular layer remains. The average sorption force required to desorb a decimeter of water from the solum was 5.68 kg/cm^2.

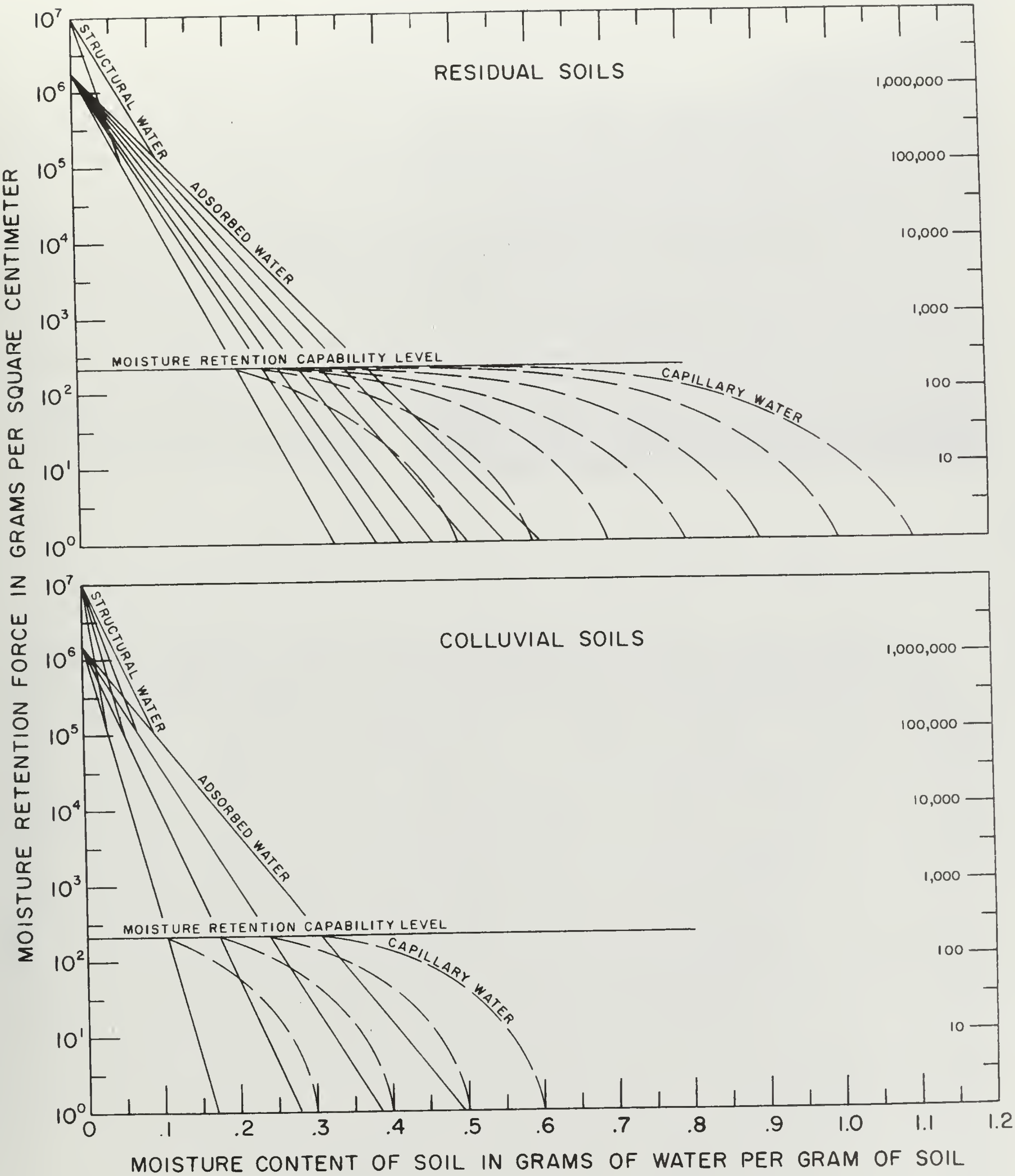


Figure 9.--Effect of different moisture-retention capabilities on the relationship between moisture content and moisture-retention force for residual and colluvial soils.

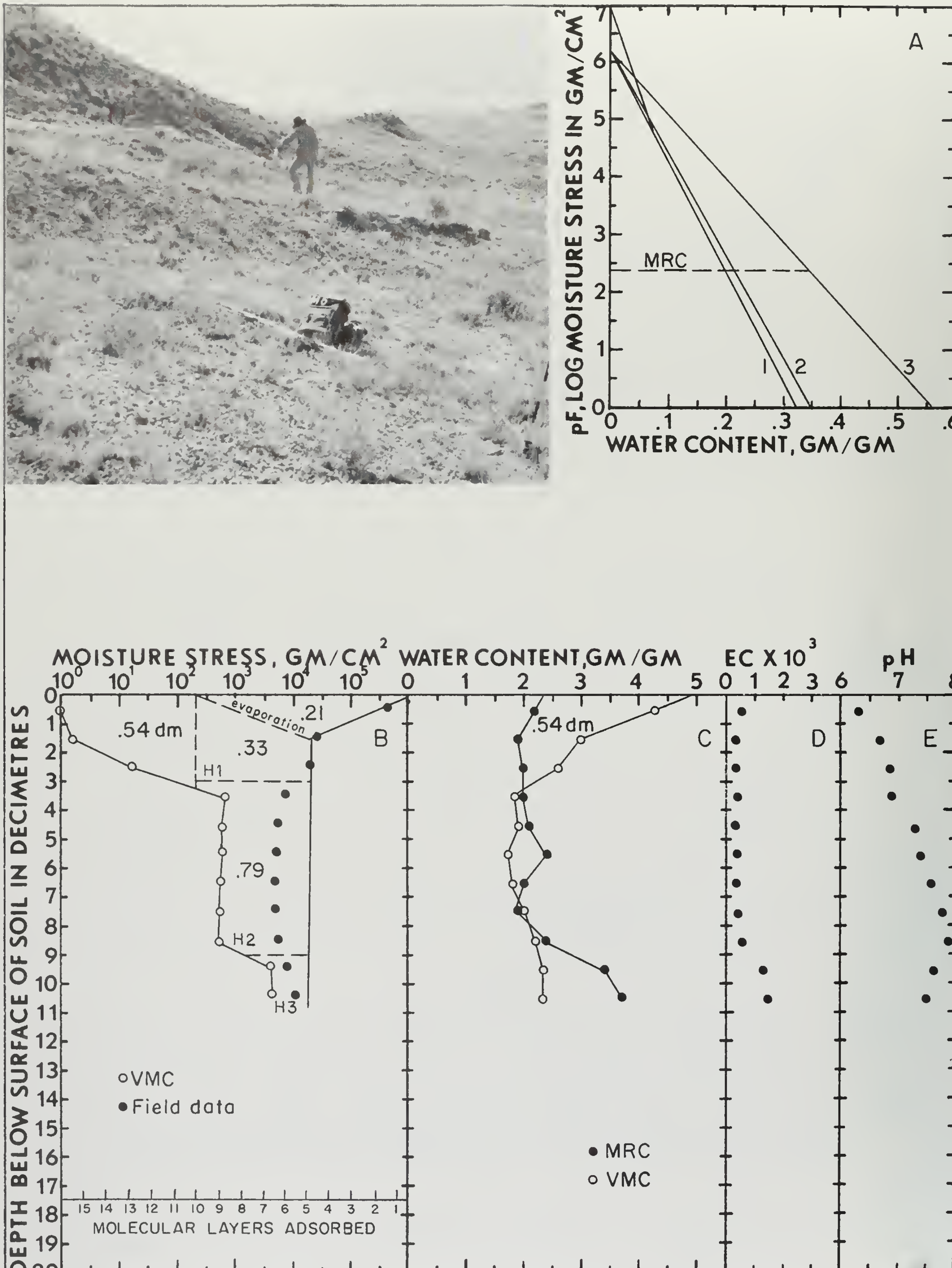


Figure 10--Soil-water properties at a site in the breaks type with a cover of stonyhills muhly, bluebunch wheatgrass and sandstone fragments (site 6, plate 23).

Little Bluestem

The Little Bluestem type (site 2, plate 23, table 16, and figure 11) occurs at the base of moderately steep slopes. The solum sampled, however, has been formed in residuum. Void moisture capacities (VMC), in excess of moisture-retention capability (MRC), again occur only in the upper 3 dm of soil (figure 11C). Below this depth voids again will permit storage of up to only 9 molecular layers of water. As with the previous site, it is assumed that voids are completely filled to maximum levels of storage most years. A total of 2.15 dm can be stored in the solum. Transpiration again depletes storage to the level where 5 molecular layers remain adsorbed. Losses by evaporation beyond this level are evident only in the upper 3 dm of soil. It is estimated that 0.47 dm is lost to evaporation. It is also assumed that spring rains tend to keep the surface horizon (H1) wetter than the moisture retention capability. Because of this perched moisture, the average force required to desorb a dm of water is only 4.56 kg/cm^2.

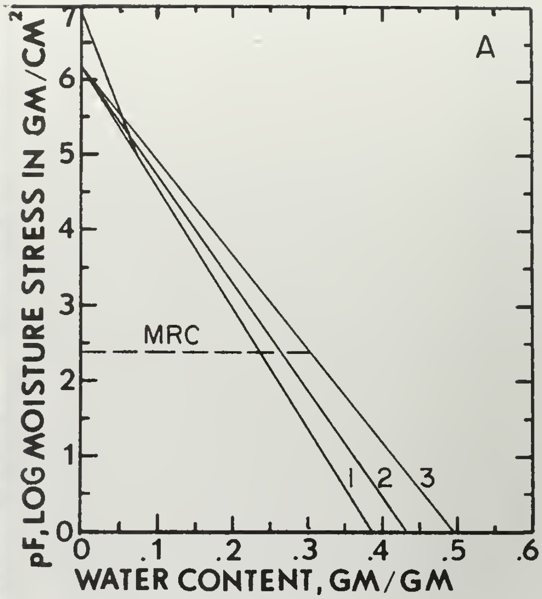
Blue Grama-Winterfat

The Blue Grama-Winterfat type (site 3, plate 23, table 16, and figure 12) also occurs near the base of moderately steep slopes on uplands; the solum sampled was formed in colluvium rather than residuum. As a result the soil has higher moisture-retention capabilities (MRC), and volumetric shrink relative to saturation moisture capacities than the soil at site 2 (see figure 8). Since large quantities cannot be retained in voids near the surface, water penetrates to greater depth, separating soil particles to the level where 13 molecular layers are adsorbed. This is the result of levels of wetting achieved during unusually wet periods. Under these conditions (max. wet, figure 12B), a total of 4.25 dm of water could be stored in the soil. Under normal conditions (normal wet, figure 12B), it is assumed that 0.91 (.53 + .38) dm initially present in the upper 2 horizons of the solum at stresses less than moisture-retention capability level rapidly drain to greater depths. Total evapotranspiration between normal-wet and minimum levels of storage would, therefore, be 2.63 dm (.53 + .38 + .22 + .27 + 1.23). The 0.45 dm of water in H3 (horizon 3) is not included in the total as it is assumed to be water that drained down from voids too large to retain water in horizons H1 and H2. Spring rains are assumed to replenish storage only to moisture-retention capability levels. Transpiration depletes moisture storage in this soil approximately to the level where 3 molecular layers remain adsorbed (figure 12). Maximum stress achieved by vegetation was 79,432 g/cm^2. Evaporation beyond this level is evident only from the upper 2 dm of soil. Loss by evaporation is estimated to be 0.27 dm. Average force required to desorb a decimeter of water is 44.53 kg/cm^2. This force is large primarily because of rapid drainage to moisture-retention capability levels, eliminating the presence of loosely adsorbed water.

Big Sagebrush-Bluebunch Wheatgrass

The Big Sagebrush-Bluebunch Wheatgrass type (site 1, plate 23, table 16, and figure 13) occupies upper portions of long, smooth slopes, extending

Figure 11



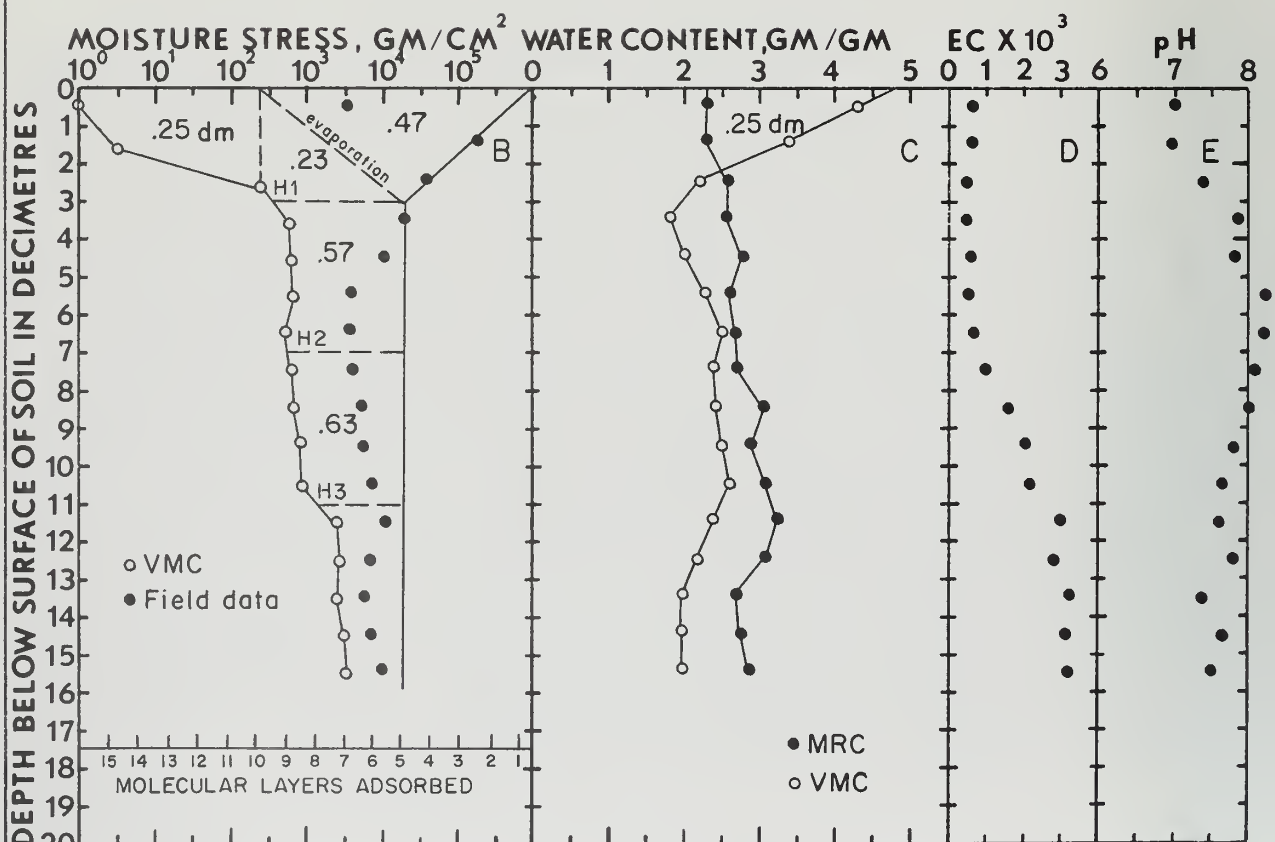
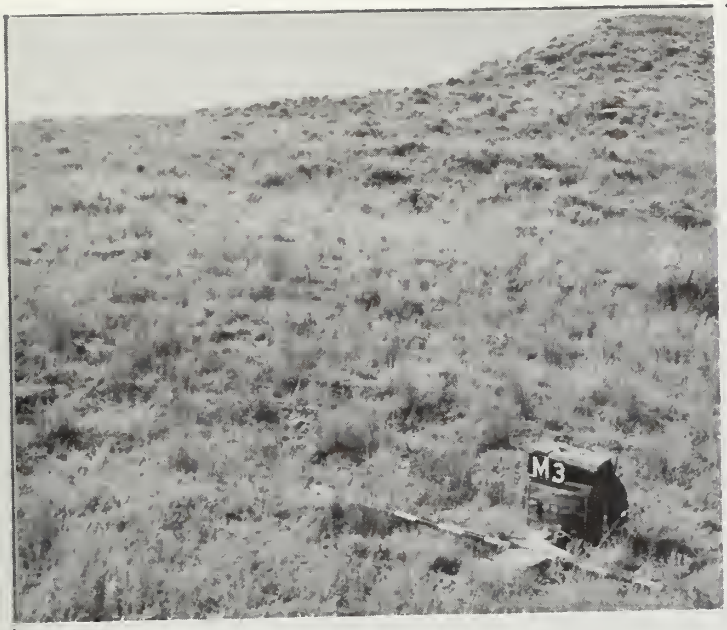
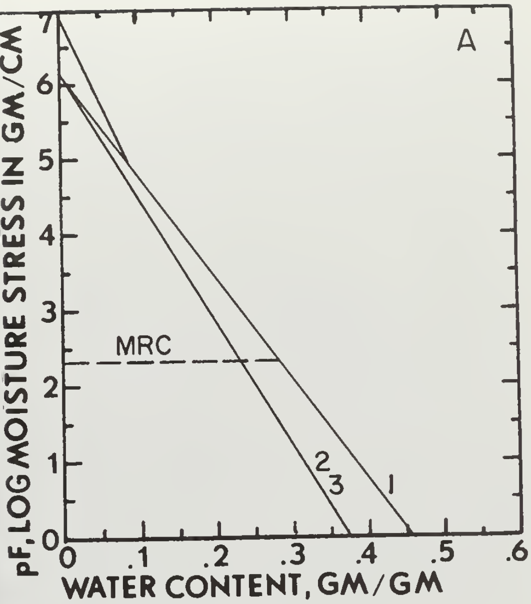


Figure 11--Soil-water properties at an upland site with a cover of little bluestem and creeping juniper (site 2, plate 23).





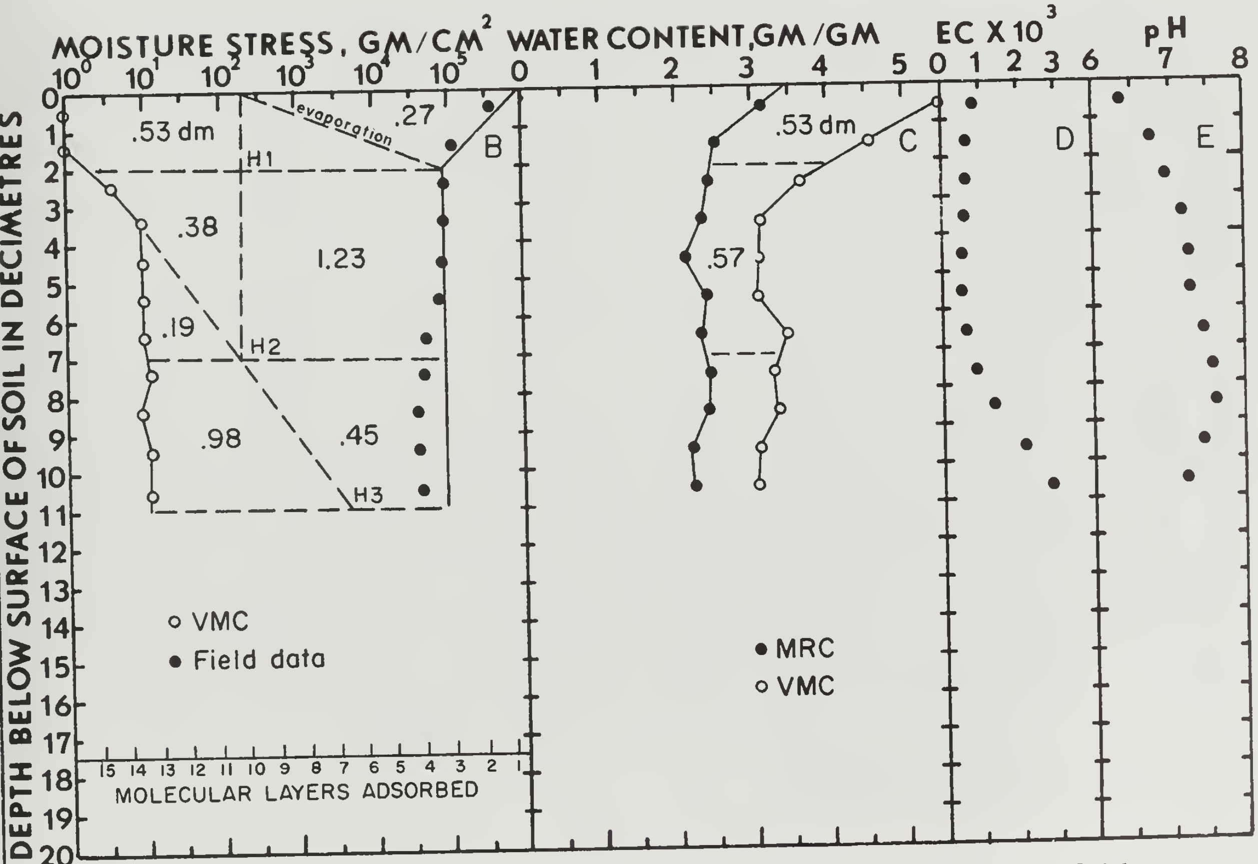


Figure 12--Soil-water properties at an upland site with a cover of blue grama grass and winterfat (site 3, plate 23).

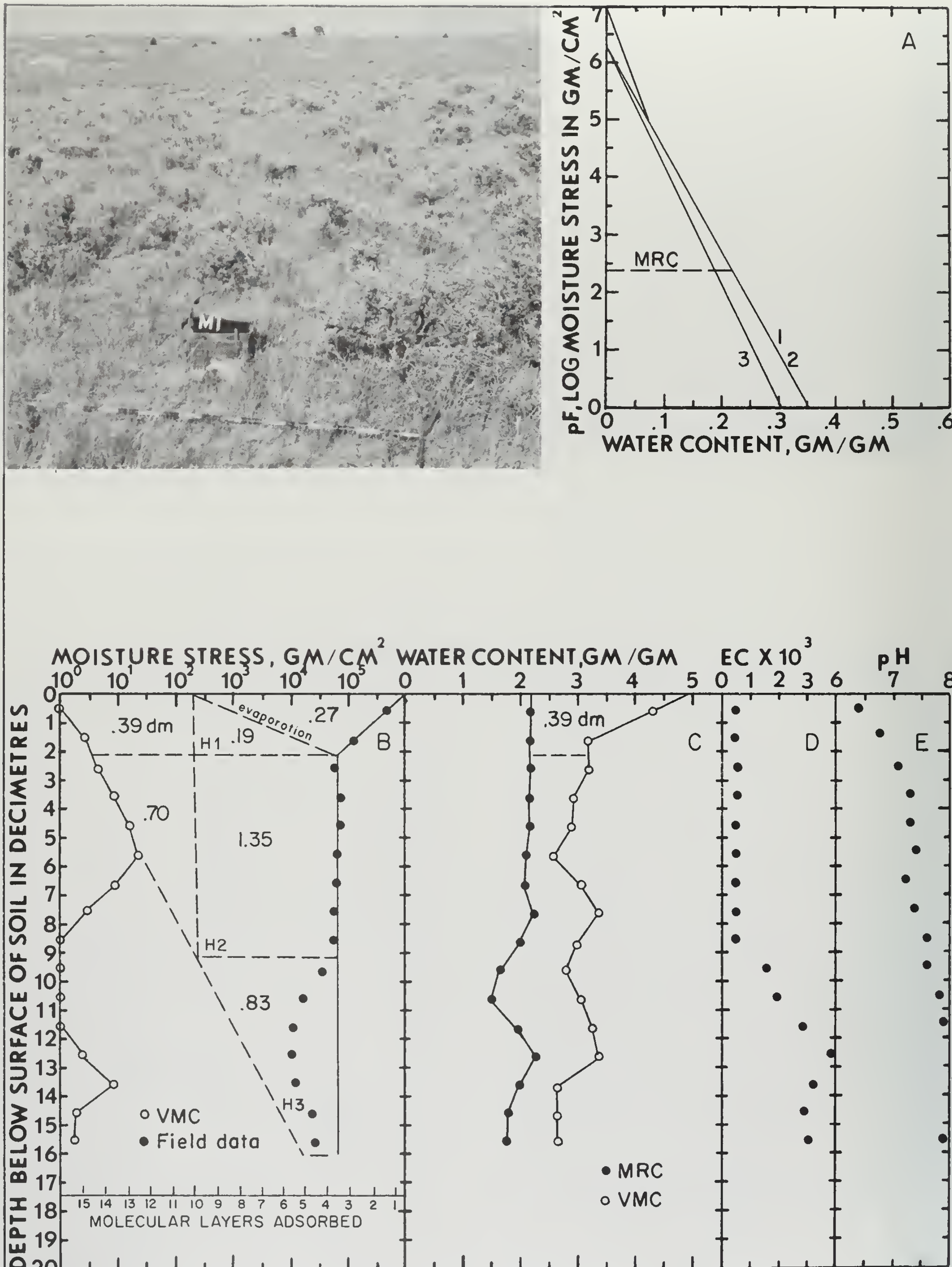


Figure 13--Soil-water properties at an upland site with a cover of big sagebrush and bluebunch wheatgrass (site 1, plate 23).

down from the breaks area. Computations indicate that 2.91 dm of water are evapotranspired between normal-wet and minimum levels of storage (figure 13B). This is equivalent to 11.64 inches of water, which is 3.24 inches in excess of the 8.4 inches of water normally derived from snowfall. It is assumed that the extra moisture is derived from snow blowing off higher ground and accumulating among the sagebrush and from rainy periods during spring. It is evident that rapid drainage to moisture retention capability occurs; void moisture capacities exceed moisture retention capabilities at all depths. As a result, infiltration of extra moisture during wetter than normal years is possible. Accumulation of such moisture above an impeding layer somewhere below 16 dm is indicated by evidence of increased void-moisture capacity at depths below 7 dm (figure 13B). Moisture in the second (H2) horizon was depleted by transpiration to the level where somewhat less than four molecular layers of water remain adsorbed. The related moisture-sorption force or stress is $10^{4.8}$ or 63,095 g/cm^2. Under drought conditions desorption to the level where three molecular layers remain is probably possible. Computations indicate that the average sorption force exerted by plants to desorb a decimeter of water is 25.33 kg/cm^2.

Green Needlegrass-Western Wheatgrass

The Green Needlegrass-Western Wheatgrass type (site 5, plate 23, table 16, figure 14) occurs on alluvium on the valley floor of Bear Creek. Computations indicate that 3.32 dm are depleted between normal-wet and minimum levels of storage for the soil sampled. This is equivalent to 13.28 inches of water, or 4.88 inches in excess of water normally expected from snowfall. This is 1.64 inches more water than is stored upslope in areas occupied by the Big Sagebrush-Little Bluestem type. It is again evident that water temporarily stored in voids at moisture contents greater than moisture-retention capability eventually drains to greater depths. Drainage below the 9 dm depth would be as films less than 10 molecular layers thick, becoming thinner with increasing depth. There is evidence that during wetter than normal years moisture accumulates in the zone below 8 dm as films thicker than moisture-retention capability levels (figure 14B).

The amount of water stored below 9 dm was not computed because the sampling was too shallow to determine the maximum depth of penetration. Storage in the second (H2) horizon was depleted almost to the level where three molecular layers remain adsorbed. The sorption force achieved was $10^{4.9}$ or 91,201 g/cm^2. Evaporation beyond this level is evident in the surface horizon. Estimated loss to evaporation from the surface horizon is 0.25 dm of water. Assuming that the minimum level of stress is the moisture retention capability level, it is estimated that an average force of 27.39 kg/cm^2 is required to desorb a decimeter of water.

Western Wheatgrass-Blue Grama

The Western Wheatgrass-Blue Grama type (site 7, plate 23, table 16, and figure 15) occurs on relatively level land adjacent to the main channels. Voids in the surface (H1) horizon exceed levels required to retain 16 molecular layers of water, so capillary water is, at least, temporarily

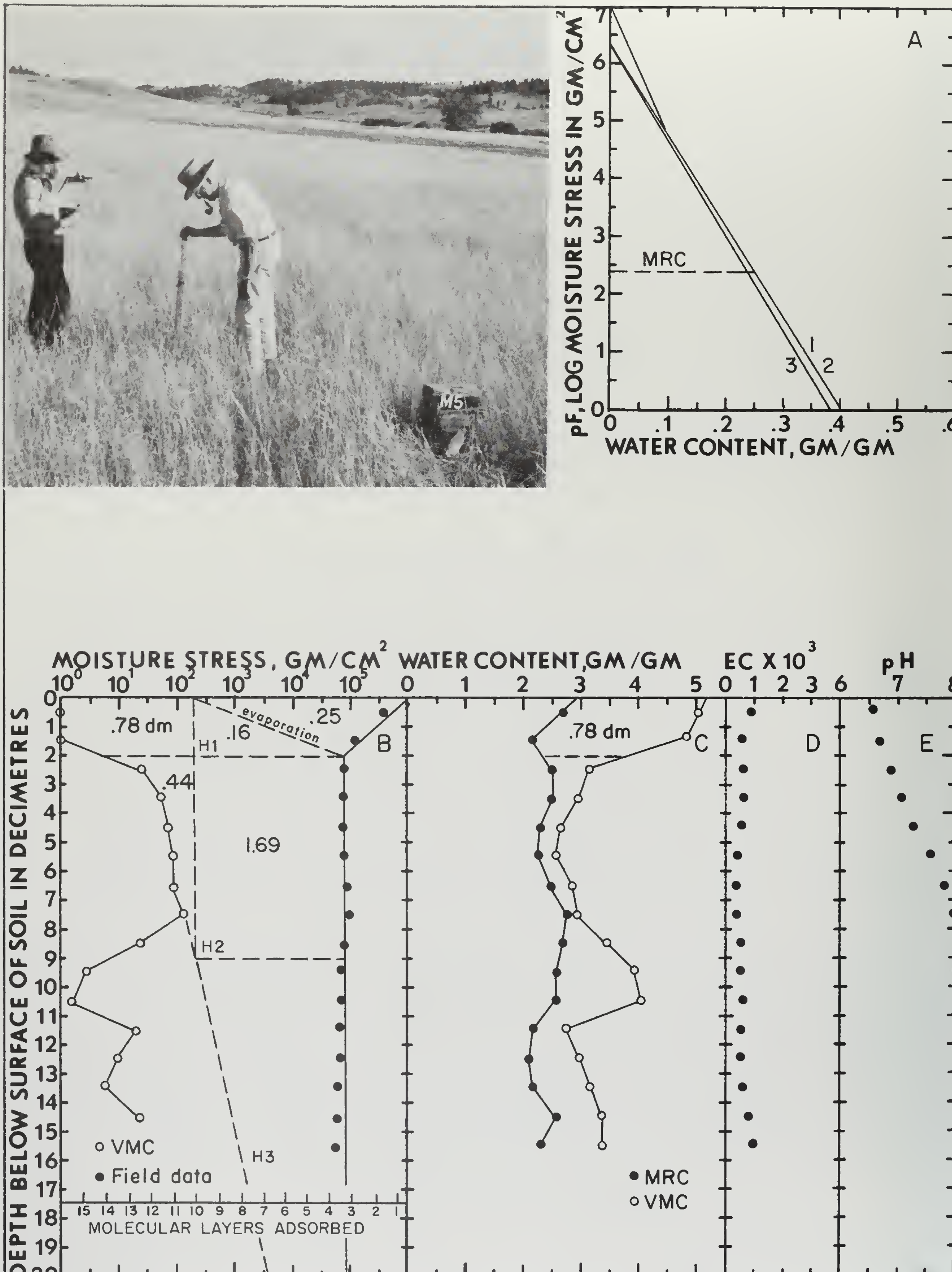


Figure 14 --Soil-water properties at a bottomland site on alluvium with a cover of green needlegrass and western wheatgrass (site 5, plate 23).

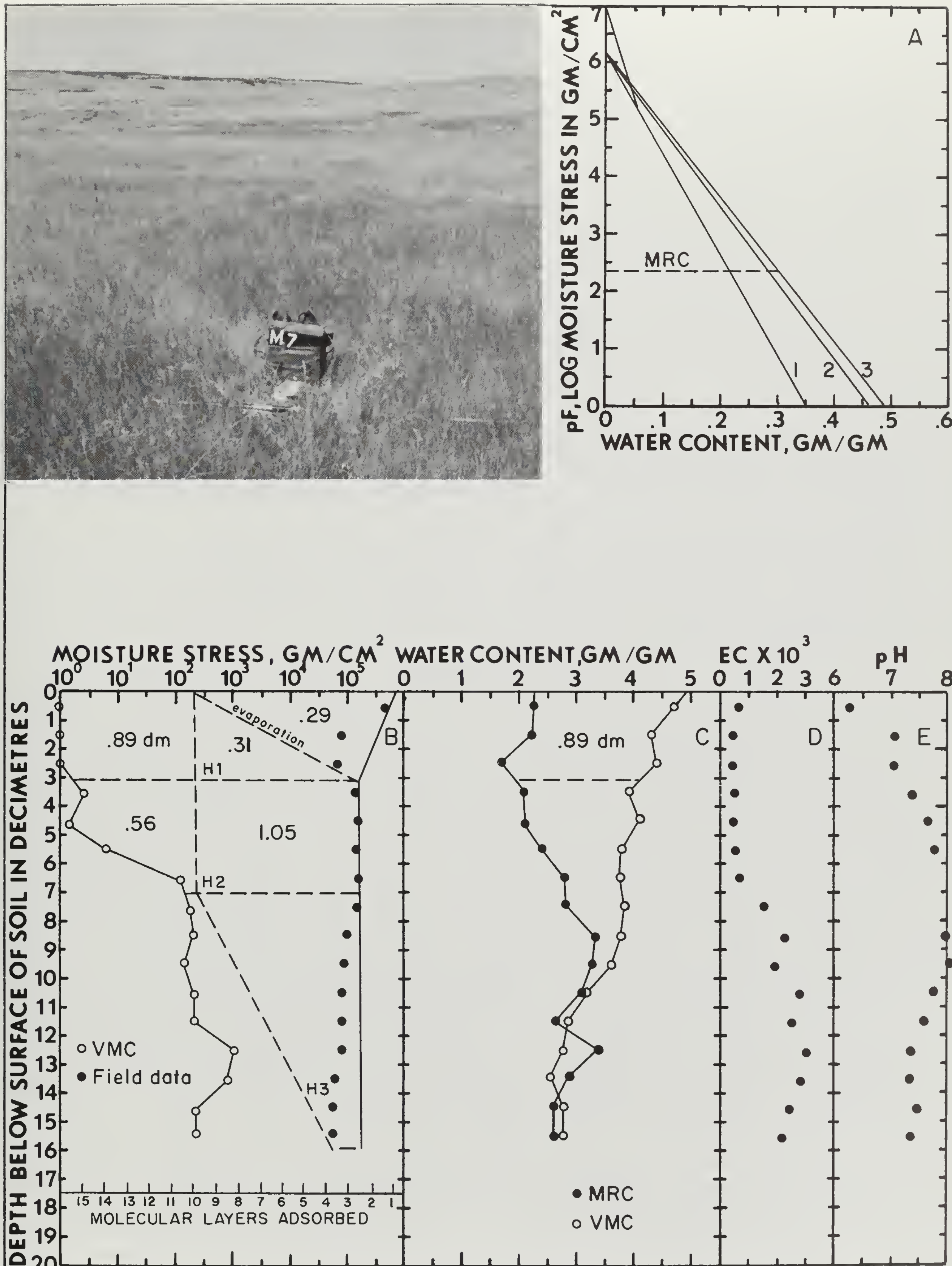


Figure 15--Soil-water properties at a bottomland site on alluvium with a cover of western wheatgrass and blue grama (site 7, plate 23).

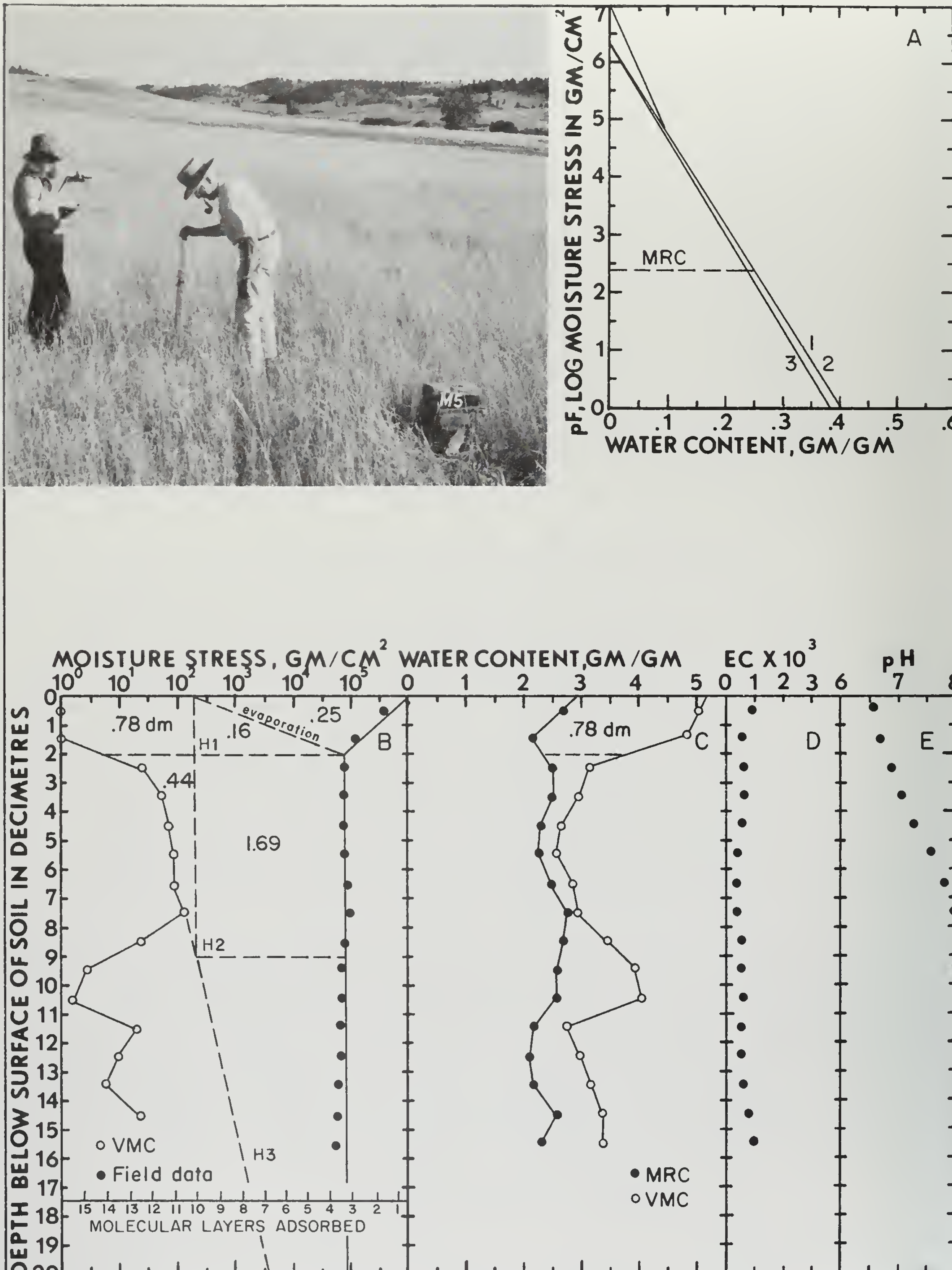


Figure 14 --Soil-water properties at a bottomland site on alluvium with a cover of green needlegrass and western wheatgrass (site 5, plate 23).

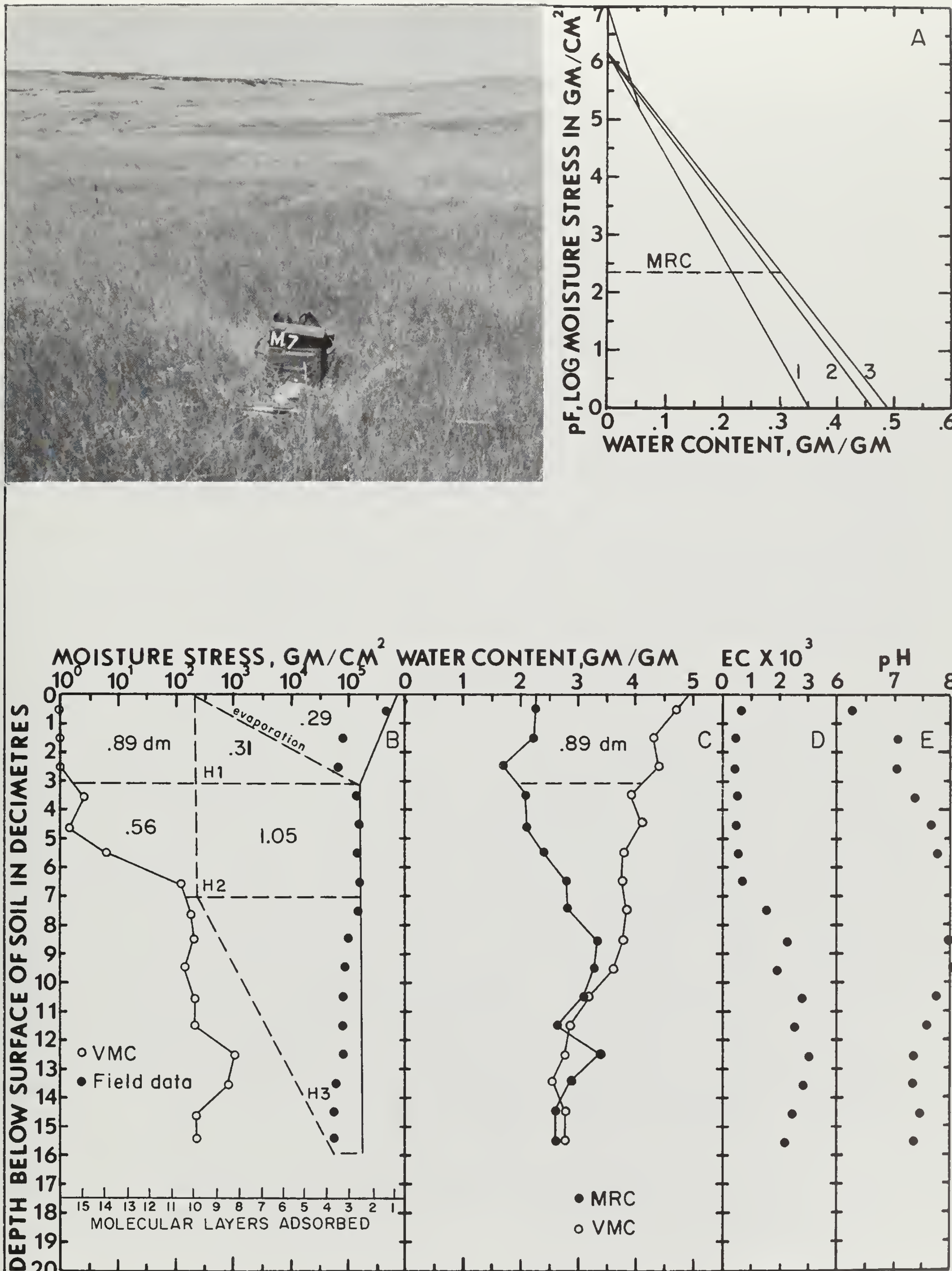


Figure 15--Soil-water properties at a bottomland site on alluvium with a cover of western wheatgrass and blue grama (site 7, plate 23).

present (figure 15B). Voids in the second horizon diminish to the level where approximately 10 molecular layers can be adsorbed. Voids capable of retaining at least 10 molecular layers of water extend down into the third (H3) horizon. This is assumed to be the result of wetting during wetter than normal years, because there is evidence of salt accumulation ($ECX10^3$) (figure 15D) with depth in the third horizon. Leaching of salt associated with frequent wetting is evident only to a depth of 7 dm. The method of computation, where void moisture capacities in excess of moisture retention capacities in the upper two horizons are added to quantities depleted below moisture retention capability, indicates that 3.10 dm or 12.4 inches of water is normally depleted from the solum between normal/wet and minimum levels of storage (figure 15B). (Again, the amount of water stored below the 2 horizon was not computed because the sampling was too shallow.)

Vegetation depleted the moisture in the second (H2) horizon slightly beyond the level where three molecular layers remain adsorbed. The level of stress achieved was 158,489 g/cm^2. The sorption force required to desorb a decimeter of water from this soil was 57 kg/cm^2. This is almost twice the force required to desorb water from the previous site. This is, of course, a result of the higher levels of stress required to desorb water to a lower level of storage. Evaporation further reduced the level of storage in the upper 3 dm of soil. Evaporation from the surface horizon was 0.29 dm.

Silver Sagebrush-Green Needlegrass

The Silver Sagebrush-Green Needlgrasss Type (site 4, plate 23, table 16, and figure 16) occurs in drainageways and on flood plains. The soil sampled has the lowest moisture retention capability encountered in the study area. Voids decrease from saturation moisture capacity (SMC) at the soil surface to adsorption moisture capacity levels at the base of the surface horizon (see VMC graphs in figure 16). Voids will permit adsorption of a minimum of 14 molecular layers of water in the second (H2) horizon. Below this depth voids again approach saturation moisture capacity levels. There is, however, evidence of accumulation of salts ($ECX10^3$) below a depth of 8 dm. This is assumed to be the depth of wetting when flooding does not occur. Computations indicate that 2.91 dm (.14 + .77 + .62 + .48 + .90 dm) or 11.64 inches are depleted from the solum for a recharge that occurred without flooding. Assuming that soil below the upper 2 horizons is wetted to the level where 14 molecular layers are adsorbed a total of 5.25 dm or 21 inches is stored when flooding occurs. Plant growth indicates that flooding is normal.

It is notable that moisture was desorbed as a result of transpiration almost to the level where three molecular layers are adsorbed (figure 16). The sorption force achieved was $10^{5.00}$ or 100,000 g/cm^2. The average sorption force required to desorb a decimeter of water is only 19 kg/cm^2. This is due to low levels of stress achieved when water is stored in excess of moisture retention capabilities. The dense plant cover minimized evaporation losses. There is evidence of evaporation only from the upper 1.5 dm of soil. Only 0.14 dm of water is normally lost by evaporation.

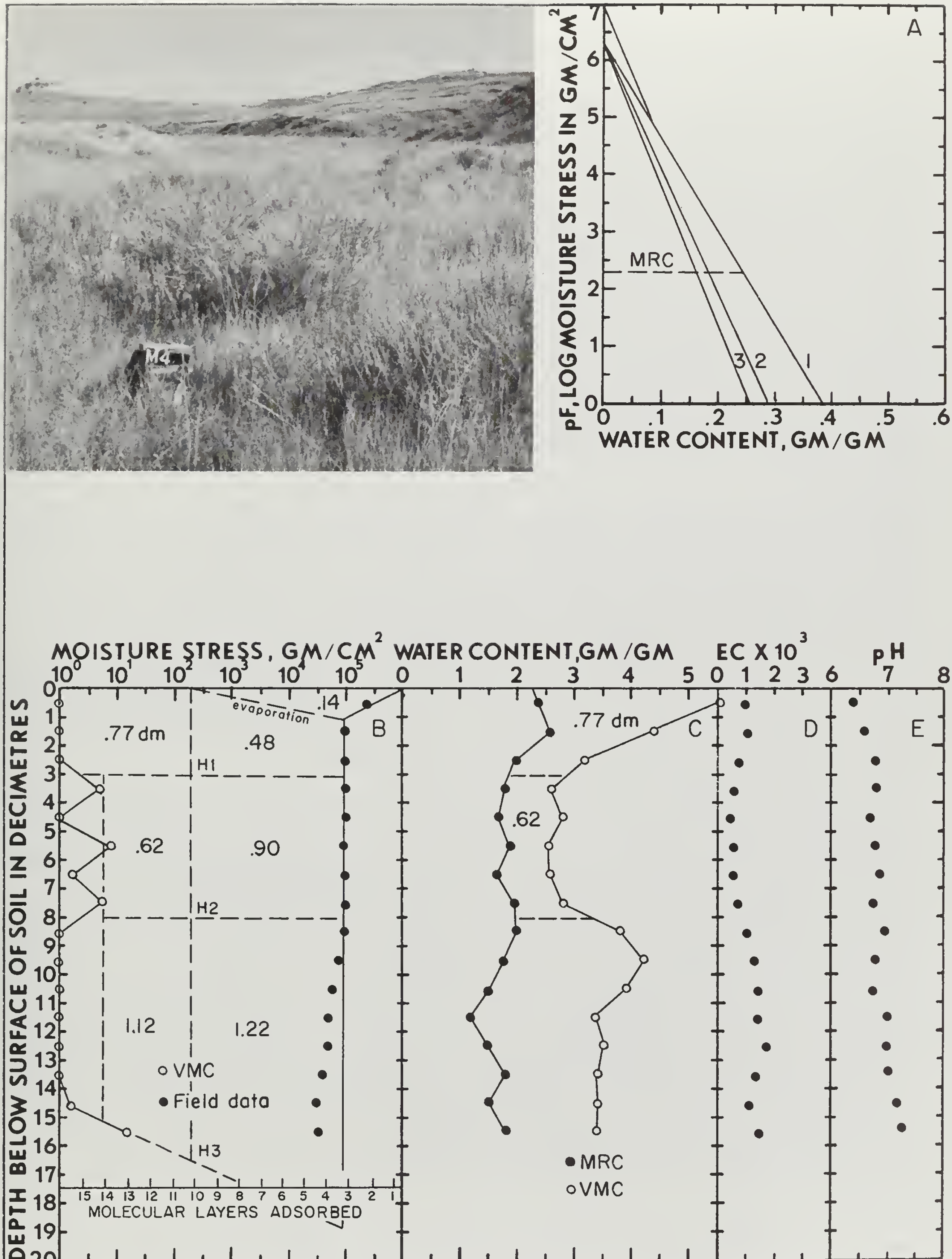


Figure 16--Soil-water properties at a site in a tributary drainageway with a cover of silver sagebrush and green needlegrass (site 4, plate 23).

Conclusions

General conclusions can be derived from comparisons of observations made at individual sites. Several factors contribute to essential differences between the various habitats. Redistribution of snow by wind and infiltration of run-in water from upslope are the primary factors influencing quantities of water stored in soils. Voids, resulting from wetting of the soil over the years, control infiltration and thus voids can, at least, temporarily limit quantities of water that can be stored. Quantities of water retained, after drainage becomes insignificant, are controlled by amounts of surface provided by soil particles to adsorb water. Voids, in turn, influence rates of drainage to depth, and thus, at least temporarily, influence the thickness of adsorbed films of water. The thickness of adsorbed films influence amounts of force plants must exert to desorb water. The kind of vegetation determines what proportion of the adsorbed films of water can be desorbed and transpired. The amount of vegetation cover influences what proportion of the water stored in the soil will be evaporated.

Quantities of moisture storage are least on uplands and generally increase with distance downslope. Moisture depleted from normal storage on sites 6, 3, and 2 (plate 23, figures 10, 11, and 12), which are characteristic of steeper uplands were 1.87, 2.15, and 2.63 dm respectively. Water normally arriving as snow is 2.1 dm or 8.4 inches. Progressing downslope to the flood plain, (sites 1, 5, 7 and 4, figures 13, 14, 15 and 16) normally store and lose 2.91, 3.32, 3.10, and 5.25 dm of water respectively. Accumulation of runoff with distance downslope, however, cannot be discounted as a source of increased soil water. Flooding definitely increases the soil water at site 4. It is quite possible that maximum levels of storage are not achieved until spring rains are at their peak.

If the area is mined, post-mining treatment that in any way affects quantities of water normally stored in replaced soil materials will influence plant production. The extent of this influence is illustrated in figure 17, where a linear relationship is presented between decimeters of water depleted between maximum and minimum levels of storage and pounds of vegetation harvested per acre. Additional data points might reveal that a family of lines would better describe the relationship shown in figure 17. Most of the points in figure 17 deviate from the line significantly with sites having only grass cover plotting above the line and those with both grasses and shrubs plotting below the line. Lowest levels of production were measured on upland slopes with greater levels of production evident on bottom lands. If treatment practices are initiated that keep the moisture where it falls, intermediate levels of production should be expected. If soil materials are replaced in similar positions on slopes of similar gradient (up to 20 percent) and length, premining patterns of moisture storage should eventually result. Present mining plans do not follow this procedure.

There is evidence that relative moisture-retention capabilities of soil materials influence forces required to desorb a given quantity of water. This fact is illustrated by the linear relationship in figure 18, between

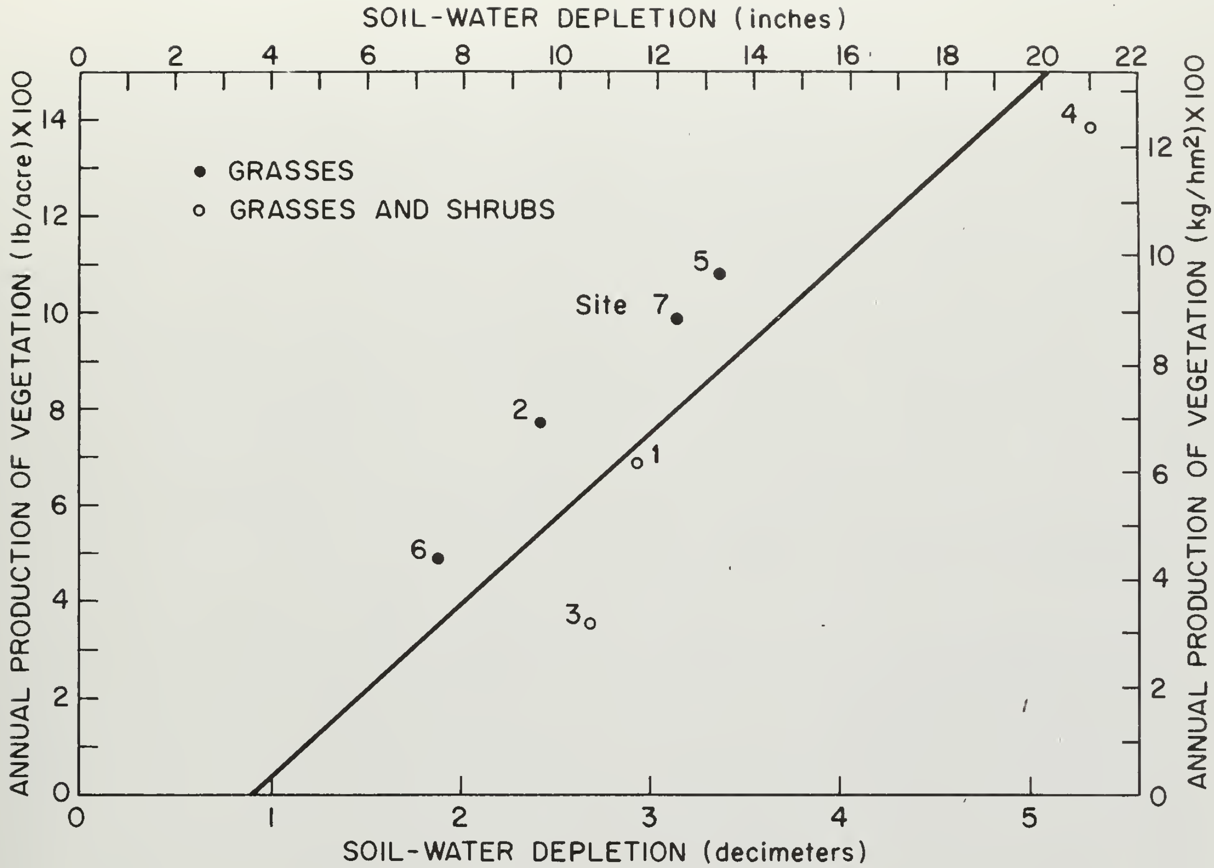


Figure 17--Relationship between water depleted from soil and annual production of vegetation.

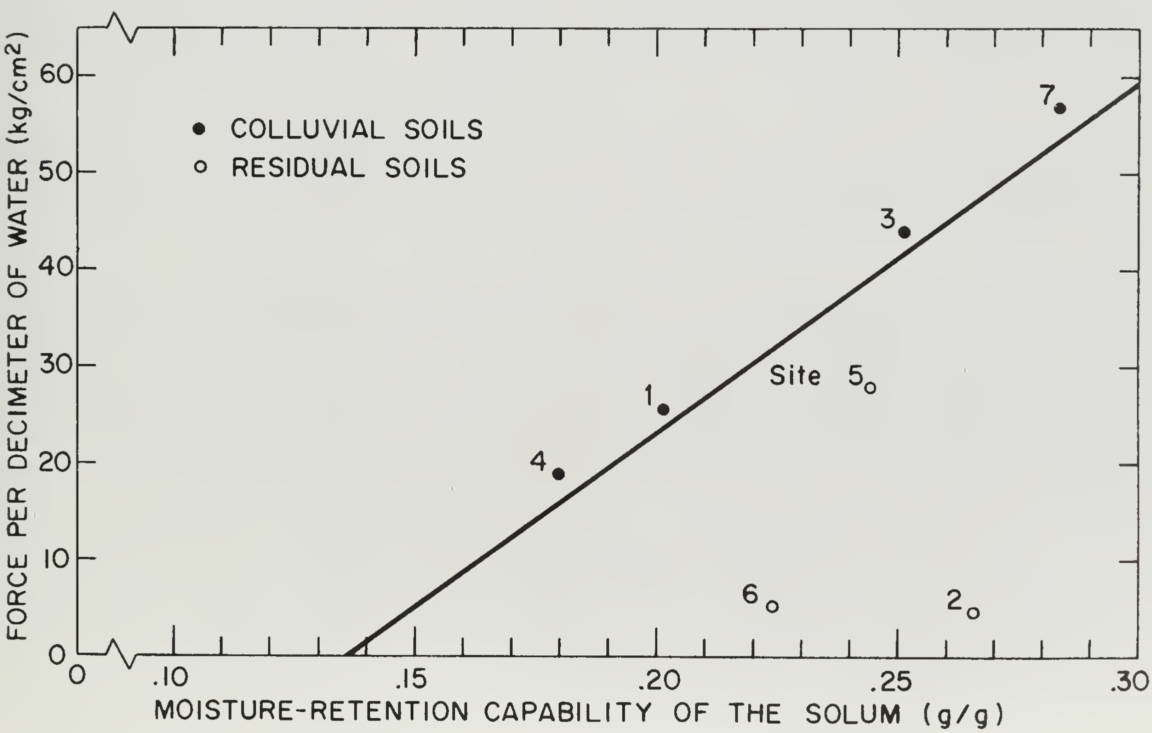


Figure 18--Relationship between the force required of vegetation to desorb water and the average moisture-retention capability of the soil profile.

average moisture-retention capability of the solum and kilograms of force per square centimeter of surface required to desorb a decimeter of water. Data derived from two of the residual soils (sites 6 and 2, figures 10 and 11), where water is stored near the surface at low levels of stress do not fit the relationship probably because a greater proportion of the water evaporates. Data from all sites where drainage to moisture-retention capability levels is possible fit the linear relationship. This relationship indicates that as moisture-retention capabilities increase, the average amount of force required to desorb a decimeter of water also increases.

Highest soil moisture retention capabilities and energy requirements for desorption of water are associated with the western wheatgrass-blue grama type. If it is necessary to use this type of soil material on the surface of reshaped spoils, the soil moisture regime would be improved by using it on low gradient slopes or bottom lands. If placed in a higher topographic position these soils could become much less productive.

Soil associated with the blue grama-winterfat type has the next highest average moisture-retention capability. Being high on the slopes it also has less water available to it. The two factors combine to produce a relatively unproductive site. The relatively high force required to desorb an increment of water may account for the presence of blue grama, a short grass, and winterfat, a northern desert shrub. Both species have characteristics that minimize the requirement for water over a given period of time. This type is not very extensive, and occurs only in spots mostly within the breaks area. It would not be practical to stockpile and selectively reposition this material.

Soil associated with the green needlegrass-western wheatgrass type has intermediate moisture-retention capabilities and energy requirements per unit of water desorbed. As a result mid grasses rather than short grasses and desert shrubs predominate. This is one of the more productive soils under present conditions. If it is stockpiled and replaced in a similar position on similar slopes, similar levels of productions could occur (green needlegrass-western wheatgrass). If positioned higher upslope, green needlegrass would probably not survive. Western wheatgrass and blue grama would probably become the dominant species. Total yields would also be reduced.

Soil associated with the big sagebrush-bluebunch wheatgrass type has the lowest moisture-retention capability of any colluvium occurring on uplands. This site is only moderately productive in spite of low energy requirements per unit of water desorbed because of the relatively low quantities of water stored. The presence of big sagebrush with grass tends to depress the forage production of the type relative to other types (site 1, figure 17). Productivity of this vegetation type, no doubt, could be increased by removal of competition from big sagebrush (Shown, Miller and Branson, 1969). Its greater permeability and lower energy requirements per unit of water desorbed will facilitate plant growth on higher areas where snow tends to blow away reducing availability of water. If replaced in a lower position this soil could be more productive than on higher areas.

Soil associated with the silver sagebrush-green needlegrass type has the lowest moisture-retention capability of all the soils sampled, and also the lowest energy requirements per unit of water desorbed (site 4, figure 18). It also produced the highest yields (figure 17). Because of its position in a drainageway, it also has the most water available for growth. Alluvial soil sites such as this would be a source of suitable material for a plant media.

In general, coarser materials with lower moisture-retention capabilities occur on steeper slopes or in tributary drainageways. Materials tend to become finer and have higher moisture-retention capabilities as land slopes diminish.

Relationships useful for characterizing stockpiled soils have been presented in figures 7, 8, and 9. Moisture-retention capabilities can be defined most precisely using a combination of the filter paper method of McQueen and Miller (1968) to measure moisture contents and related moisture stress (figure 7A), and the modeling technique of McQueen and Miller (1974) to define moisture-retention characteristics for moisture contents from saturation to dryness (figure 7B). If the required ovens and precision balances are not available, moisture retention capabilities can be approximated from saturation moisture capacities, using the relationships presented in figure 8. Vegetation type can be used to determine whether a soil would fit the residual or the colluvial relationship. In the Bear Creek area, the residual soils tend to have grasses and shrubs growing on them, while the colluvial soils have only grasses on them. If advice to stockpile materials separately has been ignored, a simple shrinkage test can be used to determine which relationship in figure 8A to use. Minimum requirements to obtain the data are a container of known volume and a dietary spring scales graduated in grams. The saturation moisture capacity can be determined from the weight per cubic centimeter of saturated soil as illustrated in figure 19. This relationship was derived using data obtained from Bear Creek soils.

Moisture-retention capabilities are a function of the amount of surface available to adsorb water per unit of weight and will not be changed by disturbance of the soil, but void moisture capacities will be changed by disturbance of the soil. Void moisture capacities are likely to be less than amounts required to permit adequate infiltration and storage of water after soil materials are replaced. Necessary voids will result only after soils have been rewetted to appropriate levels. For adequate infiltration of water, voids should be capable of holding water in excess of moisture-retention capabilities. To achieve this soils first must be wetted beyond their moisture-retention capabilities. Methods of achieving the necessary wetting of the soil are discussed in the section on recommendations.

Infiltration and Soil Detachability

Soil erosion and sediment production involve the interaction of two sets of forces. One set of forces, the erosive agents, cannot be forecast for any given time period at a given site except as probabilities based on past records. The other set of forces, the ability of the soil to resist the actions of the erosive agents, can be defined by properly designed laboratory and field tests.

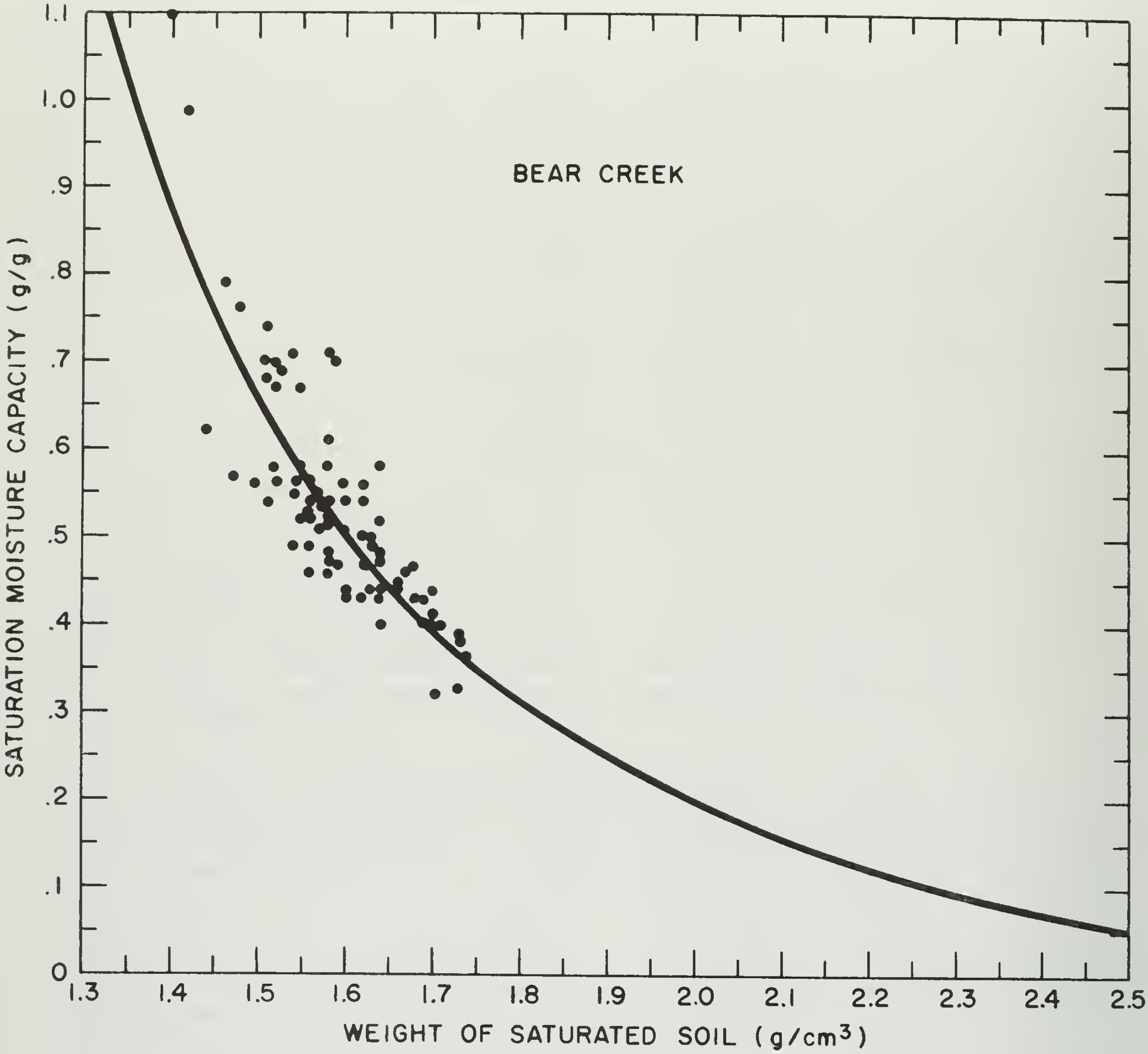


Figure 19--Curved relationship that can be used to estimate the moisture content at saturation from the weight of a known volume of saturated soil.

Detachment and transport of sediment in runoff can occur only when the rate of rainfall (or snow melt) exceeds the rate of infiltration. Therefore, the infiltration rate of the soil becomes a definable parameter of the erosive forces. If infiltration relationships are known, estimates can be made for the magnitude of storm that will produce runoff and erosion.

Infiltration measurements, conducted in an area approximately 8 miles west of this site, indicate that infiltration rates are about 5 cm/hr, except for sandy channel bottoms, residual soils formed on baked sandstone and siltstone such as mapping unit 9008, described in the Soil Inventory section of this report, and actively eroding shale-derived soils included in mapping unit 9013. Infiltration rates on the sandy channel bottoms and the baked sandstones may exceed 20 cm per hour and on the eroding shales they may be less than one centimeter per hour.

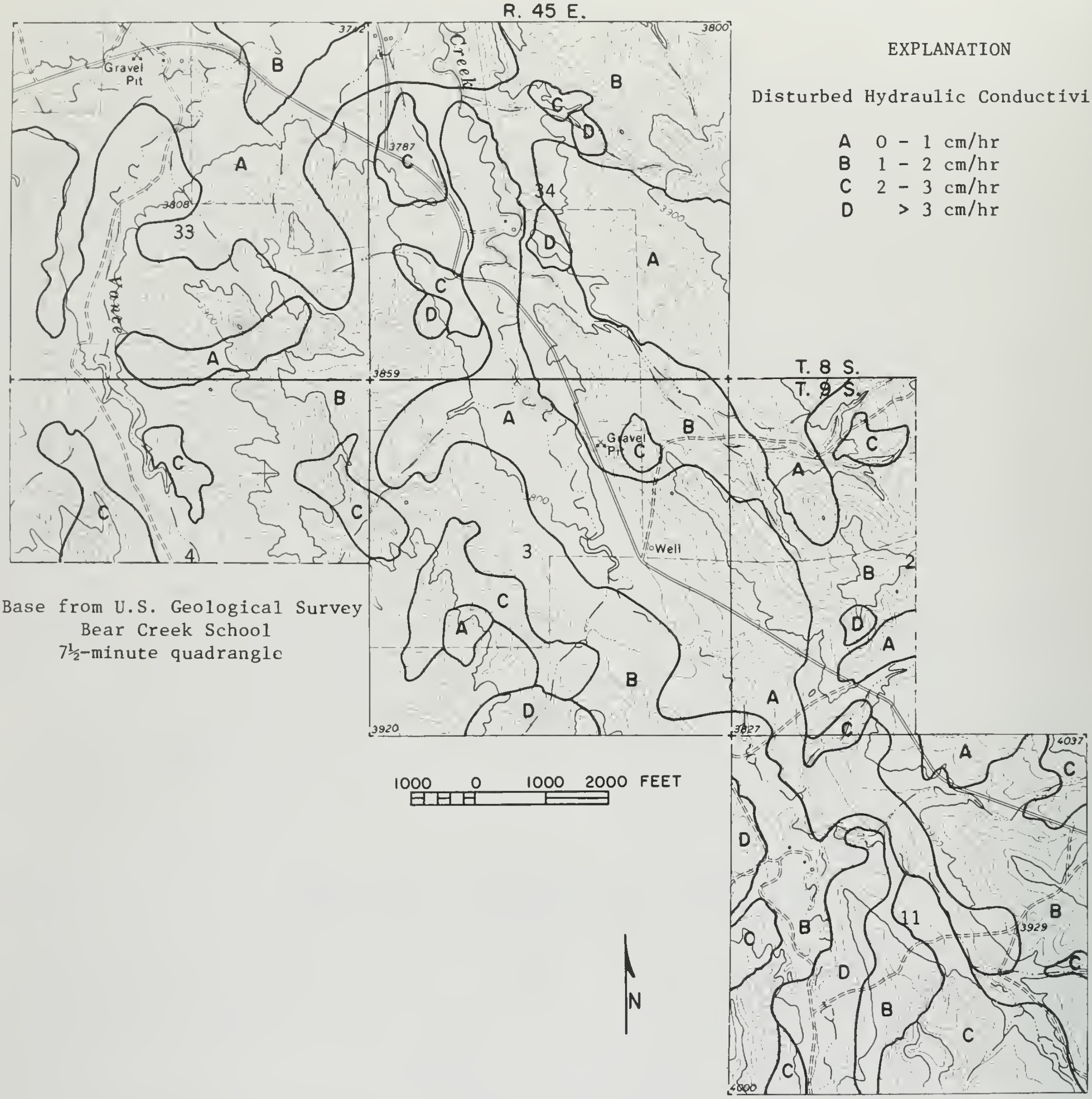
Disturbed hydraulic conductivities, (reported on plates 28 through 33), are smaller than the infiltration rates reported above.[1/] Destruction of soil structure and root channels that aid infiltration in the undisturbed soil probably account for the differences. This same distrubed condition will prevail during reclamation of mined areas so infiltration rates will be low and many storm events will produce runoff with associated erosion. Areal distributions of distrubed hydraulic conductivity classifications are shown on plate 24. The base data used are the hydraulic conductivity values given in plates 28-33.

Susceptibility of soils to erosion by flowing water was determined in the laboratory by subjecting samples to controlled erosion forces and measuring the rate of detachment (McQueen 1961). This procedure does not predict actual sediment production from the wide range of erosion events that occur at a site but it does permit grouping of the soils in relative detachability classes. The areal distribution of these classes are shown in plate 25. Remolded samples were used in these tests to simulate the condition of the soils after mining. Data for detachability of individual samples from vegetation and soil sampling sites are included in table 17, appendix E.

Detachability of soil particles appears to be influenced by the concentration of humus and roots. As the organic concentrations decrease with depth, the detachability of soil particles increases as shown in figure 20. The trend of the plot shows about a ten-fold increase in detachability rate with each meter of depth for colluvial soils. Soils with shallow organic horizons or with stratified beds of clay and sand (residual soils) do not show the same pattern of detachability with depth (see figure 20).

Erosion during reclamation of disturbed lands can usually be minimized by replacing the topsoil and by minimizing mixing of the horizons before placement on the reshaped spoils. Surface treatment to increase infiltration and retention of precipitation where it falls will aid in reclamation of disturbed lands. See reclamation recommendations.

1/ Mean hydraulic conductivity for the top horizon of 236 soil profiles was 2.34 cm/hr with a standard deviation of 1.5. The maximum was 8 and the minimum was zero.



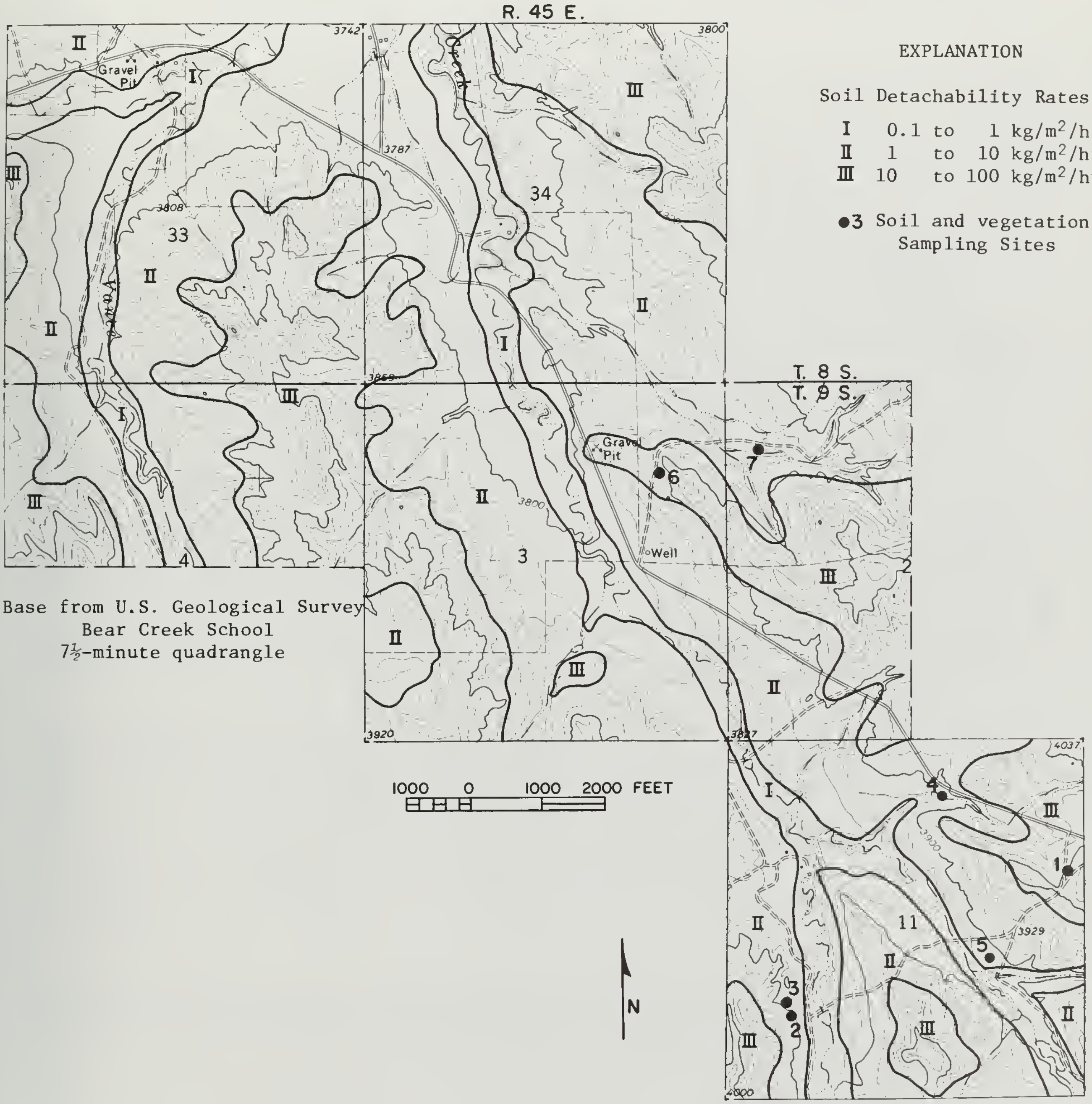
EXPLANATION

Disturbed Hydraulic Conductivities

A 0 - 1 cm/hr
B 1 - 2 cm/hr
C 2 - 3 cm/hr
D > 3 cm/hr

Base from U.S. Geological Survey
Bear Creek School
7½-minute quadrangle

MAP SHOWING DISTURBED HYDRAULIC CONDUCTIVITY OF SOILS
ON THE BEAR CREEK STUDY AREA--MONTANA, 1975



EXPLANATION

Soil Detachability Rates

I	0.1	to 1 kg/m²/hr
II	1	to 10 kg/m²/hr
III	10	to 100 kg/m²/hr

●3 Soil and vegetation Sampling Sites

Base from U.S. Geological Survey
Bear Creek School
7½-minute quadrangle

MAP SHOWING SUSCEPTIBILITY OF SOILS TO DETACHMENT BY FLOWING WATER FOR THE BEAR CREEK STUDY AREA--MONTANA, 1975

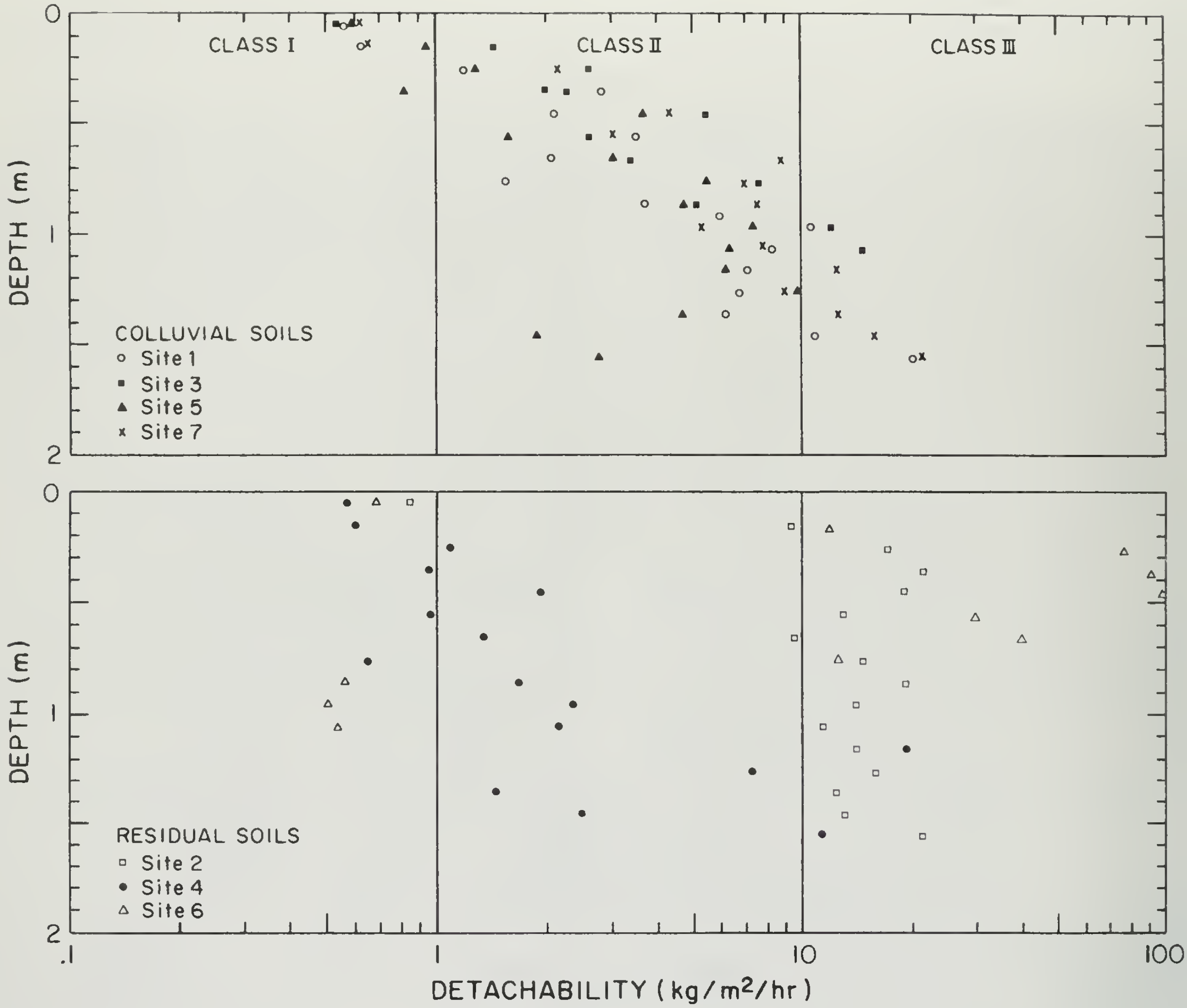


Figure 20--Relationship of detachability of soils in flowing water to depth in the profile for colluvial and residual soils.

SEDIMENT YIELDS

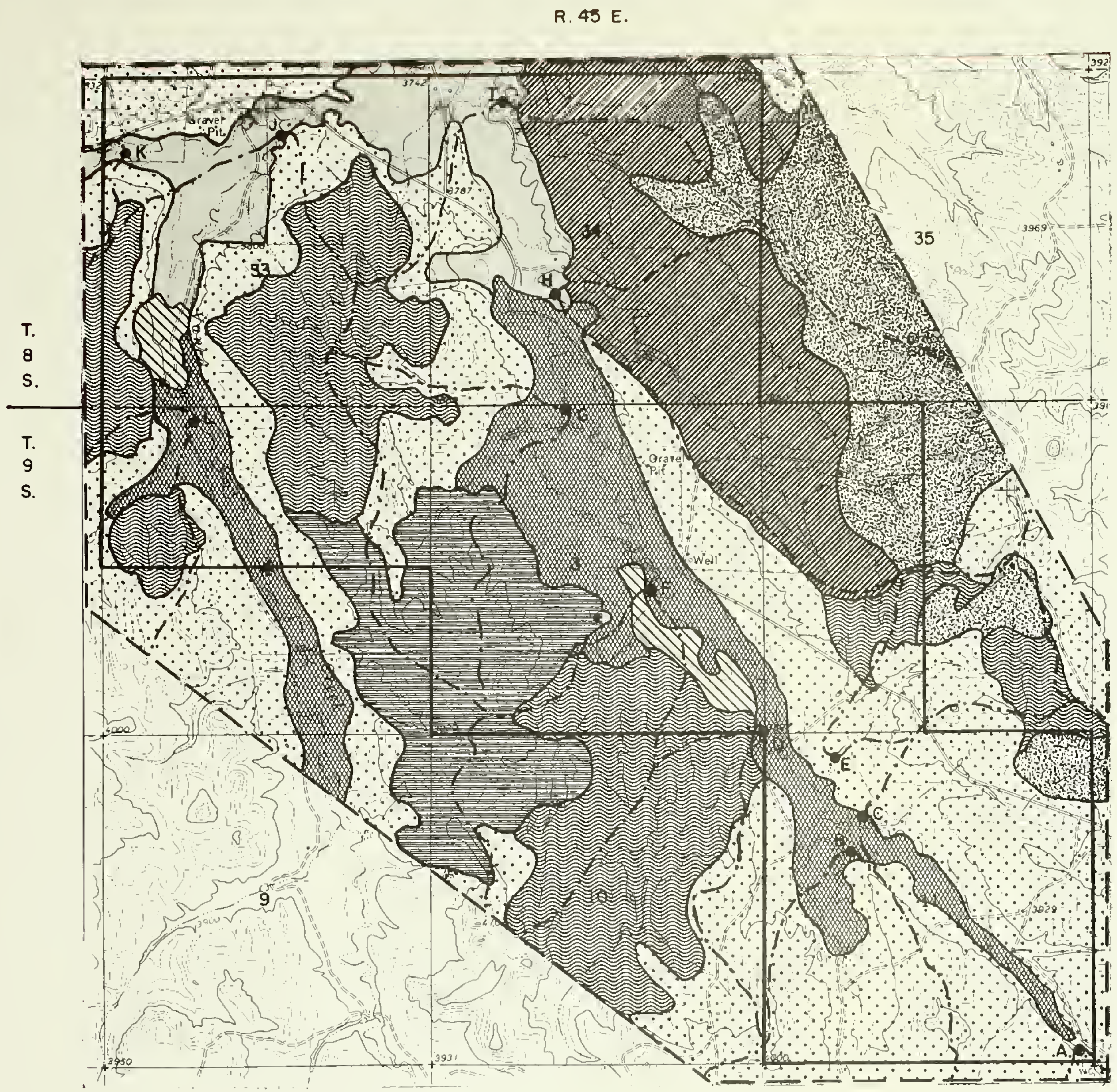
The sediment yield values presented for this area were derived using a numerical rating method (Pacific Southwest Inter-Agency Committee, 1968) (PSIAC) and have been judged to be reasonably accurate but they have not been verified by actual field measurements.

The mapping unit that is the basis of this sediment yield evaluation is the source area. A source area is here defined as a small, relatively homogenous watershed area that is part of a complete drainage basin. The primary factor used in delineating a source area is landform type. Nine factors are rated when using the PSIAC method: surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and sediment transport. All factors are assigned a numerical rating during the mapping process in order to assess the hydrologic variation for the given landforms and to provide input for the PSIAC ratings. The method was developed to make broad sediment yield classifications for large areas, such as river sub-basins, but Shown (1970) found that the method provides reasonable estimates for small (.02 - 7.5 sq. mi.) drainage basins. In applying the method on source areas, some adjustments are made because a complete drainage system is not being considered. 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 by the sediment conveyance factor (SCF) which is multiplied by the weighted average source area sediment yield to obtain the sediment yield from a drainage basin. The SCF was derived from a multiple regression equation which included drainage area, percent bare soil and a slope diversity factor as independent variables. These variables in the equation explained 62 percent of the variation of SCF.

The slope diversity factor is interpreted here as an expression of sediment deposition due to changes in slope and is defined as the sum of the average slopes of the source areas divided by the weighted average slope of the basin. The equation was developed using data from 18 well-vegetated watersheds on the Wasatch and Fort Union formations of the plains area of Montana and Wyoming. The sediment conveyance factor will change if one or more of the variables in the equation or some other associated variable is changed.

Interpretations of aerial photographs (1:40,000 scale) were used to extend the source-area sediment yield estimates to those areas that were not actually rated in the field. The aerial photographs were also used to map the channel conditions. Slope data were obtained from the 1:24,000 scale USGS topographic quadrangle. The percentage of bare soil was measured by the first-contact-point method within selected vegetation types of the study area, and estimates were made for the remaining vegetation types with the aid of the aerial photographs.

Sediment yield types for the study area are shown on plate 26. Values range from none in the bottomlands to about 2 acre feet per square mile per year in the northwest part of the study area. Data shown in the



Base from U.S. Geological Survey
Bear Creek School, Montana
7½-minute quadrangle

1000 0 1000 2000 FEET

EXPLANATION

Annual source-area sediment yield (acre-ft/mi^2)		Topography	Slope gradient Range (percent)	Slope gradient Mean (percent)	Mean bare soil (percent) (e=estimate)
	0	Bottomland (hay)	0-2	1	3e
Low	0-.2	Bottomland	0-4	3	5e
	.2-.3	Hillslope	6-14	9	8e
Moderate	.3-.5	Hillslope	5-12	7	10
	.5-.8	Hillslope, hill and valley	6-24	11	30
High	.8-1.5	Hill and valley	5-13	8	35e
	1.5-2.1	Hill and valley	9-24	17	45e

Water spreader

EMRIA study area boundary

Boundary of mapped area

Drainage divides

● A Locations of the outlets of drainage basins for which sediment yield estimates were made.

ANNUAL SOURCE-AREA SEDIMENT YIELDS FOR THE BEAR CREEK STUDY AREA--MONTANA, 1975

explanation of plate 26 indicates that estimated annual source area sediment yields are closely related to average source area slope and percent bare soil. Use of these two variables in a regression analysis explain 85 percent of the variation of the source area sediment yields determined with PSIAC method.

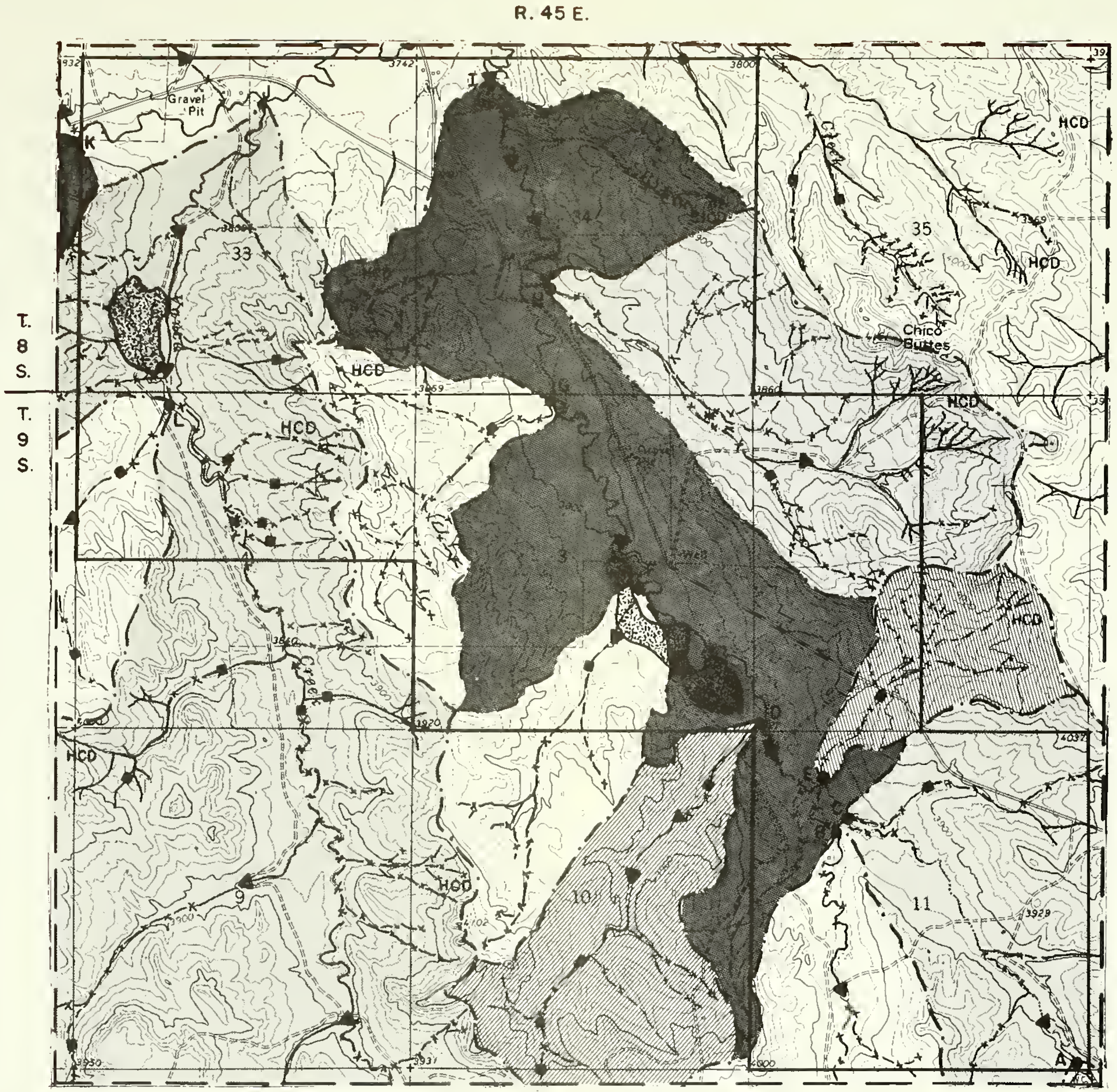
Basin sediment yield estimates were made on 12 watersheds located on or near the study area (table 18 and plate 27). Plate 27 also shows the major channel network and channel conditions.

Discussion

There are far too many variables involved to predict postmining sediment yields from the study area. Therefore, until such a time that, at a minimum, preliminary mining plans are available, no attempt will be made to assess postmining site specific conditions. However, several considerations should be brought to light with regard to sediment yields, and general recommendations can be made that should minimize sedimentation associated with surface mining. Source area sediment yields are generally moderate to moderately high for the study area as shown on plate 26. There is a greater range in source area sediment yields on the Bear Creek Study Area than on the Otter Creek Study Site (USDI, 1975), which was evaluated previously. The probable reasons for this are that the steep hillslope parts of the Bear Creek area are more barren than the steep hillslope parts of the Otter Creek area, and erosion-resisting clinker covers more of the Otter Creek site.

Estimated basin sediment yields, ranging from .04 to .47 acre-feet per square mile, which are judged to be low to moderate, are compatible with existing basin characteristics (table 18). The computed sediment conveyance factors shown in table 18 are less than one which indicates the study area, as a whole, is in a depositional phase of morphological development. The morphological cycle consists of a period when deposition is dominant within a basin followed by a shorter period when erosion and transport of sediment from the basin are dominant. Due to a complex of variables such as ground cover, slope, drainage patterns, drainage densities, sediment availability, and the current climatological regime, sediment is being trapped within the basins. Most of the basins within the study area are controlled either by reservoirs or water spreaders, which have a direct effect on the sediment conveyance efficiencies. Even though maximum source area sediment yields are greater on the Bear Creek Study Area than on the Otter Creek Study Site, the basin sediment yields on the two areas have similar ranges. The reason for this is that the sediment conveyance factors are smaller on the Bear Creek Study Area, probably because the channels and drainageways tend to be wider, thus causing more sediment deposition.

Approximately 61 percent of the total drainage density of the basins studied is in the healed gully category (vegetated channel beds) with 28 percent in the raw gully category (table 19). These data indicate that channel erosion is not an important sediment contributor in the study area. The healed and untrenched gully categories are likely to be areas of significant sediment deposition, however, it is difficult to determine the amount of deposition



Base from U.S. Geological Survey
Bear Creek School, Montana
7½-minute quadrangle

1000 0 1000 2000 FEET

CHANNEL CONDITIONS AND DRAINAGE BASINS FOR WHICH SEDIMENT YIELD ESTIMATES WERE MADE ON THE BEAR CREEK STUDY AREA--MONTANA, 1975

EXPLANATION

Basin	Drainage area (mi^2)	Estimated basin sediment yield range (acre-ft/mi^2)
A	3.3	.10-.30
B	5.0	.10-.30
C	1.3	.05-.08
D	.7	.17-.27
E	.2	.31-.47
F	.4	.21-.36
G	.4	.21-.38
H	.9	.26-.38
I	1.6	.04-.07
J	8.2	.10-.30
K	4.6	10-.30
L	.4	.14-.23

— · — Drainage divides

—— EMRIA study area boundary

— — — Boundary of mapped area

● A Locations of the outlets of drainage basins for which sediment yield estimates were made.

Water spreader

CHANNEL CONDITIONS

	Symbol	Density (mi/mi^2)
Raw gully	——	1.44
Healed gully	—x—x—	3.18
Untrenched	— — —	.46
Aggrading	....	.12
Headcut	■	
Island	*	
Dam	▲	
High channel density; usually an area with many rills or small gullies.	HCD	

Table 18--Estimated Annual Basin Sediment Yields

Basin	Drainage area	Estimated bare soil in percent	Slope diversity factor	Sediment convey-ance factor	Weighted source area sediment yield (acre-ft/mi^2)	Estimated basin sediment yield (acre-ft/mi^2)
A	3.3	PSIAC method applied to entire basin				.1-.3
B	5.0	PSIAC method applied to entire basin				.1-.3
C	1.3	8	1.44	.11	.47- .74	.05-.08
D	.7	15	1.05	.36	.47- .75	.17-.27
E	.2	6	1.03	.47	.66-1.0	.31-.47
F	.4	10	.99	.44	.48- .83	.21-.36
G	.6	40	1.04	.42	.49- .90	.21-.36
H	.9	20	0.56	.49	.54- .77	.26-.38
I	1.4	5	1.17	.18	.2 - .39	.04-.07
J	8.2	PSIAC method applied to entire basin				.1-.3
K	4.6	PSIAC method applied to entire basin				.15-.35
L	.5	35	1.03	.41	.34- .56	.14-.23

Table 19.--Densities of Various Channel Conditions in Miles Per Square Mile

Basin	Drainage area (mi^2)	Raw gully	Healed gully	Untrenched	Aggrading	Total
A	3.3	not measured				
B	5.0	not measured				
C	1.32	2.9	1.0	.14	1.0	5.04
D	.67	.45	1.4	.85	0	2.70
E	.24	.83	8.5	0	0	9.33
F	.38	.95	2.4	1.4	0	4.75
G	.37	0	6.2	0	0	6.20
H	.88	3.6	2.7	.8	0	7.10
I	1.62	2.0	.41	0	0	2.41
J	8.2	not measured				
K	4.6	not measured				
L	.42	.74	2.8	.49	0	4.03
Means		1.44	3.18	.46	.13	5.2

occurring. There are headcuts present in some of the channels (plate 27) but their advance seems to be slow. Water is diverted from channels to irrigate approximately 59 percent of the major valley bottoms which are used for hay production. These bottomlands also represent important areas of sediment deposition, especially within the water spreader systems.

Recommendations

There are numerous alternatives for which reclamation objectives could be designed. The recommendations presented here assume the objective is to return the land to similar uses and a similar level of premining productivity.

Under actual mining conditions, it can be expected that sediment control practices will vary with the site locations selected to mine and the intensity of control will also vary, such as problems associated with mining on 25 percent slope will differ from those of mining in the bottomlands. However, without intensive control measures, the sediment discharge to Bear Creek during the mining and reclamation period may increase slightly to moderately above the indicated present rates. The following are some measures that could be considered for control of sediment from the mined area: (1) Adapted grass species should be seeded on all disturbed areas. Small reservoirs could be constructed in or near the overburden area and cleaned out periodically, if necessary, to maintain storage capacity. It may be desirable to remove the dam and sediment deposit at the end of the reclamation period to prevent eventual breaching of the dam, and (2) Closed basins created during the reconstruction of the landscape and by differential settling of the reconstructed overburden could be used as sediment traps and ground water recharge facilities as well as aids to wildlife habitat improvements. It might be feasible to construct water spreader systems downslope from the mined areas (Miller and others, 1969) to dissipate the sediment-bearing flows from these areas. Areas topped with moderately-fine and fine-textured soil material could be close-spaced contour furrowed (Branson, Miller, and McQueen, 1966) or gouger pitted (Sindelar, Hodder, and Majerus, 1973) to reduce runoff and erosion and enhance vegetation establishment. It is imperative that grassed drainageways be reestablished as soon as feasible in order to prevent high rates of channel erosion.

Design of the reconstructed drainage systems will be the most important variable to contend with in the rehabilitation planning process. Sediment yields would probably be minimized if the reconstructed drainage system includes relatively wide level valley bottoms, which would cause flows to be shallow and permit sediment deposition from the flows.

SOIL

Soil and Bedrock Material

Description of Principal Soil Bodies

Soils on the Bear Creek Study Area can be placed in three major categories based primarily on their parent material, mode of development, and land form. These are: (1) soils developed primarily on deep alluvium on nearly level to gently sloping stream terraces, (2) soils developed on colluvial and residual material on fans and slopes below hills and ridge crests, and (3) soils developed on residual material on narrow ridges and divided crests. The alluvial soils comprise about 43 percent of the area, the colluvial soils on fans and slopes about 10 percent, and the residual soils about 47 percent. Most land classes have been delineated in each of the major soil categories. Therefore, no attempt has been made to show the location of the land by major soil categories.

The terrace soils formed on loamy alluvium derived from shale and sandstone material and have developed under semiarid conditions. Depth to the parent material is usually greater than 60 inches. These soils are located on the low-lying nearly level to gently sloping stream terraces of the area. Texturally, they range from medium to fine with interspersed coarse lenses. Soil color varies from a very pale to light brownish-gray surface, a pale brown to dark grayish subsurface, and a subhorizon of light brownish-gray to light yellowish-brown. Soil structure is weak to moderately well developed.

Generally, the soil-moisture relationship of these soils is good. The infiltration rate, when combined with moderate to flat slopes, is adequate for most of the precipitation to enter the soil. The moisture retention capacity of these soils is high. Soil permeability is generally moderate to moderately slow.

Except for the immature profiles, the surface soils are slightly calcareous. The subsoil and substratum are usually moderately calcareous and slightly to moderately saline. The stronger-developed soil profiles, which constitute the majority, are usually nonsaline to a depth of 18 to 24 inches. The lower horizons and substratum may contain much soluble salt. Areas with impeded drainage or recently deposited material may be saline from the surface. This soil group is generally nonsodic. There are, however, areas of limited extent which exhibit characteristics of a solonetz or solodized solonetz soil. These sodic areas have micro depression slickspots which may be void of vegetation. The thin vesicular massive surface layer rests on columnar prisms in the diagnostic horizon. These soils may be associated with saline seep. Although very limited in extent, the sodic soils have limited suitability for revegetation purposes but may be used if mixed with better material.

Master site 1 (table 20, appendix F) is representative of this soil group.

This soil group will provide a plentiful source of good to fair planting media for revegetation purposes.

The colluvial soils on slopes and fans have medium to fine textures and are generally 20 to 40 inches in depth and overlie softly consolidated shale and sandstone. Greater depths occur frequently on the toe of fans and areas adjacent to the terraces. They have developed on loamy colluvium or where the colluvium is shallow partially on residual material weathered from shale and sandstone. They occur on long gentle to steep slopes below ridge crests with sandstone and sandy shale outcrops. Erosion has been an important factor in the development of these soils. Usually profile development in this soil group is limited to a slight darkening of the surface layer. Some profiles, however, exhibit a weak to moderately developed A and B horizon. Soil color ranges from light brownish-gray at the surface to a grayish-brown subsoil. The substratum is a light brownish-gray.

Soil permeability is usually moderately slow. The resulting infiltration rate permits most of the precipitation to enter the soil on gentle slopes. On the steeper slopes, this infiltration rate is not adequate to prevent considerable runoff and erosion. The available water-holding capacity of these soils and underlying substratum is adequate for any projected use. It ranges from 6 to 10 inches of available water in a 48-inch profile.

The surface 18 inches is usually weakly calcareous and becomes more calcareous with depth. The soils are slightly to moderately saline. Substantial amounts of soluble salt occur in the subhorizons. Large quantities of soluble salts are in the sandstone and shale parent material underlying these soils. Locally the material may range from nonsaline to highly saline. Sodium is not a major problem. Sodic soils can be excluded from stockpiled soil material unless mixing will reduce the adverse effect on soil stability. It can also be placed with the spoil material.

Master sites 2, 5, and 6 (tables 21, 24 and 25, appendix F), are typical of the moderately deep soil group. Because of salinity and depth, they are fair to poorly suited as a planting media for revegetation purposes.

The residual soils on ridge crests and steep slopes are generally 20 inches or less in depth over shale and sandstone. They are commonly found on narrow ridges and crests of divides, and on the steep slopes immediately below these features. Occasional deep and frequent shallow gullies dissect the intermediate slopes. Surface erosion is moderate to severe. It is an important factor in the soil formation and affects the depth of the soil profile. Sandstone and shale outcrops are common on the crests and on steep slopes below. There is a close chemical and physical relationship between these immature soils and the weathering parent material.

Soil textures are predominantly medium to moderately fine. Surface soil color varies from light gray to a light yellowish-brown. The subsoil is light brownish-gray to brown. The substratum is light gray to yellowish-brown and it rests on stratified sandstone and shales. The soils are calcareous throughout.

Because of their position and slope, these lands have excessive surface drainage which results in much runoff and erosion. However, the surface soil has adequate infiltration capacity for reclamation use on lesser slopes. The permeability of the weathered material below the A horizon is moderate to moderately slow, but the shale and sandstone near the surface are usually less permeable and may control the depth of moisture penetration and limit the moisture retention capacity.

Generally, this shallow soil group is nonsodic but does contain considerable salinity in the subsoil and underlying weathered bedrock.

Because of the shallow soil depth, salinity, and numerous bedrock outcrops, these lands are a poor source of surfacing material for surface-mine reclamation.

Master sites 3 and 4, tables 22 and 23, appendix F, are representative of the shallow soil group.

Land Classification

A detailed land classification survey of study area lands was made to evaluate and characterize the overburden (includes soil and bedrock)1/ in relation to its suitability as a source of material for resurfacing and revegetating the area if it should be surface mined. This survey provides data on the quantity and quality of material for revegetation, ease of stripping and stockpiling 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 classification specifications (as shown on table 26) were developed to establish classes on the land suitability for the specific use proposed, i.e., as a source of material for revegetation of surface-mined tracts. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes used in the Bureau of Reclamation land classification system. Factors included in the specifications for quality consideration were: texture, salinity, sodicity, permeability or hydraulic conductivity, infiltration capacity, erodability, and available water-holding capacity. Quantity considerations were primarily the depth of the material. Factors influencing ease of stripping and stockpiling were also considered. These include indurated bedrock exposures and excessive slope.

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 being a suitable and adequate source of material for reclaiming the immediate area, it could probably provide borrow material for surfacing and improving areas with insufficient suitable material. Class 2 lands have adequate resurfacing material, but it may be limited in quantity, less desirable in quality, or difficult to strip

1/ A glossary defining terms used is exhibit 4, appendix F.

LAND CLASSIFICATION SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Overburden for Revegetation of Surface-Mined Areas
BLM/BR Cooperative Program EMRIA
Bear Creek Study Area

Table 26
United States
Dept. of the Interior
Bureau of Reclamation
July 1975

Overburden Characteristics	Symbols: Basic Subclass	Symbols: Inform. & Defic.	Class 1	Class 2	Class 3
SOILS AND/OR BEDROCK	s				
Textures			Sandy loams to clay loams.	Sandy loam to silty clay loams.	Loamy sand to clay.
Coarse		v		Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly	Loamy sand in sufficient quantity to moderately reduce productivity and moisture retention, and may increase erosiveness moderately
Fine		h		Profile should have sufficient material for top dressing; clayey type materials that are moderately permeable should be placed below 6" in the reconstructed profile.	Profile should have sufficient material for top dressing; placement of clay in reconstructed profile; permeable 10" plus; slowly permeable 30" plus.
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 clay textured material but may be 20.0 in loam sand. Values may be higher if compensated by adequate gypsum.		
Salinity (EC x 10^3)		s	Overburden with characteristics (chemical and physical) capable of producing an expected electrical conductivity at equilibrium with the natural precipitation must be readily available as follows:		
			Less than 4	Less than 8 except the surface 10" must be 4	Less than 12 except the surface 10" must be 4
Available Water Holding Capacity		q	>1.5"/foot of overburden	>1.0"/foot of overburden	>.75"/foot of overburden
Hydraulic Conductivity		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	Slightly restricted; movement of drainage water and aeration in the lower root zone will be reduced. Infiltration rate may be reduced and erosion hazard increased slightly.	Restricted in the lower root zone and internal drainage may limit choice of plant species. Restricted infiltration may create serious but controllable erosion hazard.
Indurated Sandstone Stones and cobble		x	Permissible stone in overburden that may be stockpiled and reused as surface soil 0 to 10" <5%	Permissible stone in overburden that may be stockpiled and reused as surface soil 0 to 10" <10%	Permissible stone in overburden that may be stockpiled and reused as surface soil 0 to 10" <20%
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		e	Slight	Moderate, controllable with average management.	Severe but controllable with above average management and selective placement of overburden.
TOPOGRAPHY 2/	t				
Slope		g	Permissible surface gradient g - 0 to 12 with smooth slopes	Permissible surface gradient g - 0 - 20%	Permissible surface gradient g - 0 - 35%.
Indurated Sandstone Massive and lenticular		r	None	1 to 5% of area.	5 to 20% of area.
Cover		c	Not applicable.		
DRAINAGE	d		(Present drainage conditions, surface and subsurface) are not a factor in this classification because of the anticipated land disturbance during mining. All soil properties evaluated to classify the land were also considered in evaluating material that may be placed in the subsurface drainage zone, but this evaluation did not affect the land classes.		
Class 6			Areas delineated in this class generally lack suitable material for stripping and stockpiling for surface use. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient surface soil and bedrock of suitable quality at or near the surface; (2) topography which prevents general stripping and stockpiling; (3) rocklands with large amounts of massive indurated sandstone; (4) toxic overburden (soil and bedrock), on or near the surface. Reclamation of these lands will require material from outside the delineated area, from deep geologic strata, or special treatment of available material.		

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

and stockpile. Class 3 lands are similar to class 2 except the deficiencies are greater or there is a combination of deficiencies. Land in this class is marginally suitable but under normal circumstances with good procedures for stripping and stockpiling, requirements for planting media can be met. Class 6 lands generally do not have adequate or suitable soil or other material to meet the requirements for revegetation. If these areas are disturbed by surface mining or other operations, it will be necessary to borrow material or modify the available material for revegetation of the area.

The land classification survey was accomplished using Bureau of Reclamation methods and procedures.

Field mapping was done on aerial photographs with a scale of 1:4,800. Topographic drawings at a scale of 1:12,000 with 20-foot contour intervals were used for reference. An Abney hand level was used to supplement the slope data on topographic drawings. Representative soil sites were selected and the profiles examined and evaluated in most sizable area. Additional nontypical profiles were recorded in the heterogeneous soil areas to show the variation 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. Depth to and quality of shale are important in the study area and many profiles were used to determine these characteristics.

In the field appraisal, the top 16 inches of the soil profile was exposed with a tile spade. The remaining depth was mechanically exposed as soil cores or drilled out with a hand auger. Soil structure, consistence, texture, color, and other observable features of the exposed profile, such as: salinity, sodicity, and root distributions were recorded. Samples were collected from many of the observed profiles. Lime content was checked with dilute hydrochloric acid. 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 combined with observations of other land features such as stones, exposed indurated 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 28 through 33.

Table 27 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

There is adequate suitable overburden material (soil and bedrock) for revegetation and reclamation of the study area lands if surface-mined. 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 20 percent of the land will need additional material for plant media. Nine percent of the land is in class 6 and ROW, the other 11 percent occurs as small interspersed inclusions in classes 1, 2, and 3.

No. 1 550'E.,300'N. of W¼ Cor. 0-12" for surface use., 12-42" acceptable for surface. 42-60" slightly saline. 4-8% complex side slope below sandy shale crest. Surface with weak coarse columns. Shale influence at 52"+.

No. 2 1050'N.,500'E. of W¼ Cor. 0-12" for surface use., 12-36" acceptable for surface use. 36-120" unsuitable for surface mod. saline. 4-6% side slopes below sandy shale crest. Surface with moderate, coarse prisms - structure to 36". Lime nettings at 102+.

No. 3 1250'S.,1050'E. of NW Cor. 0-18" for surface use., 18-120" slightly saline. 2-4% irregular alluvial surface. Iron mottling at 66"+.

No. 4 500'S.,250'E. of NW Cor. 0-18" for surface use. 18-36" acceptable for surface use. 36-84" mod. saline., 84-120" very slowly permeable and mod.-slightly saline. 2-4% single slope.

No. 5 1350'E.,500'N of W¼ Cor. 0-12" preferred for surface use. 12-120" acceptable for surface use. Lime nodules and nettings at 84". Thin shale horizon at 96". Alluvial remnant at base of sandy shale crests.

No. 6 1250"E.,400'S. of NW Cor. 0-12" not acceptable for surface use., 12-30" strongly saline, slowly permeable. Mod. saline becoming strongly saline at 42"+. 30-66"+ mod. saline. 8-15% side slope below sandstone & sandy shale crest. Slick spots in area.

No. 7 100'S.,100'W. of N¼ Cor. 0-12" preferred for surface use. 12-36" acceptable for surface. 36-60" very slow permeability, 60-120" mod. saline. 2-4% single slopes on alluvial foot slopes.

No. 8 1600'S.,800'W. of N¼ Cor. Surface 120" good free-working soil. 0-18" preferred for surface use, 18-120" acceptable for surface use. 2-4% general slopes on alluvial bottom-land. Highly stratified at 54". Wet at 60", water table at 96". A fine-loamy, mixed, calcareous, mesic family.

No. 9 1500'N.,1250' E. of W¼ Cor. 0-18" use for surface, 18-120" acceptable for surface use. 2-4% foot slopes, alluvial soil. Slopes below sandy shale crests. 60-84" buried horizon with continuous lime nettings. Wet 108"+.

No. 10 1050'E.,1000' N. of SW Cor. 0-18" for surface use., 18-72" acceptable for surface use. 72-120" slightly saline. Surface with weak-mod. columns over calcareous B horizon at 18". 2-4% alluvial soil at base of sandy shale crests.

No. 11 1200'N.,500' E. of SW Cor. 0-18" for surface use. 18-66"+ mod.-saline. Deeper profiles in swales. 6-8% complex side slope below sandy shale crest.

No. 12 1450'W.,50' S. of E¼ Cor. 0-12" for surface use., 12-36" best for use below 18". 36-66" moderately saline. 48-66" salt crystals. 4-15% complex side slope on edge of swale & below sandy shale crest.

No. 13 1500'W.,50'S of E¼ Cor. 0-6" for surface use. 6-24" acceptable for surface., 24-60" moderately saline. 12-15% side slope of sandy shale crest. Sandstone fragments scattered on surface.

No. 14 1200'S.,1100' W. of E¼ Cor. 0-18" for surface use., 18-42" acceptable for surface use., 42-66" mod. saline sandy shale. 10-12% complex side slop. below sandstone & sandy shale crest.

No. 15 450'S.,250'W of E¼ Cor. 0-24" for surface use., 24-54" slightly saline. Profile located on 4-6% slopes on upper end of draw. Side slopes up to 35%. Sandy shale & sandstone outcropping on crests.

No. 16 1200'N.,150' W. of SE Cor. 0-6" for surface use., 6-60" unacceptable for surface use., 24-42" mod. saline. 42-60" very slowly permeable. 4-8% complex side slope below sandy shale crest.

No. 17 850'N.,600'W. of E¼ Cor. 0-18" acceptable for surface use. 18-30" acceptable for surface use. 30-54" mod. saline. 54-78" slightly saline. 4-12% complex side slope. Site is on a colluvial remnant.

No. 18 650'N. of S¼ Cor. 0-24" for surface use., 24-60" mod. saline. 24-36" iron mottling. 6-8% complex side slope with sandy shale crests.

No. 19 1900'E.,650' S. of W¼ Cor. 0-24" for surface use. 24-48" mod.-saline. 4-6% complex side slope below sandy shale crests.

No. 20 2400'E.,100'S. of W¼ Cor. 0-12" preferred for surface use., 12-66" acceptable for surface use. Lime nettings from 12-42". 6-8% complex side slope with sandy shale crest.

No. 21 1900'W.,100'S. of E¼ Cor. 0-18" preferred for surface use., 18-66" moderately saline. Average depths over sandy shale for area is 30". Sandstone fragments scattered on surface. 4% foot slope at edge of draw. 8-35% side slopes in area with sandy shale crests.

No. 22 1150'E.,100'S. of S¼ Cor. 0-12" preferred on surface. 12-30" acceptable for surface use., 30-42" slightly saline. Profile located on 4-6% sandy shale crest with side slopes up to 35% slope.

No. 23 1250'S.,1000' E. of N¼ Cor. 0-18" preferred for surface use., 18-120" acceptable for surface use. 2-4% colluvial side slope below sandy shale crests.

No. 24 1850'S.,750'N. of N¼ Cor. 0-12" for surface use., 12-30" mod. saline. 30-66" mod. saline with restricted permeability.

No. 25 1800'S. of N¼ Cor. 0-24" preferred for surface use. 24-120" acceptable for surface use. 2% colluvial slopes below sandy shale crests.

No. 26 650'S.,300'W. of NE Cor. 0-120" not acceptable for surface use. Mod. saline. Profile over 120" deep. Too wet to auger below 96". 0-2% saline alluvial slope.

No. 27 1150'W.,250'S. of NE Cor. 0-12" for surface use., 12-120" mod. saline, stratified mtrl. Water table at 120". mesic.

No. 28 1750'N. of S¼ Cor. 0-18" preferred for surface use., 18-30" acceptable for surface use., 30-42" slightly saline, 42-60" mod. saline. 6-8% complex side slope below sandstone & sandy shale crests.

No. 29 250'N.,100'W. of E¼ Cor. 0-18" for surface use., 18-42" slightly saline, acceptable for surface. Thin A horizon of less than 6" over gravel. 8-35% slope, profile near sandy shale crest. Side slopes have fragmented sandstone.

No. 30 900'W.,150'S. of E¼ Cor. 0-120" sandy shale acceptable for surface use. Calcareous sandy shale to 48". 48-120" dark carbonaceous shales., 60-120" non-calcareous sandy shales. Becomes harder with depth. 8-35% complex side slopes near sandy shale crest.

No. 31 1050'S.,500' W. of E¼ Cor. 0-18" for surface use., 18-120" moderately saline, not acceptable for surface. Stratified sandy shales 60-120". Lime nettings 0-60". 6-8% side slope at base of sandy shale crest.

No. 32 900'S.,750'W. of NE Cor. 0-12" preferred for surface use., 12-24" acceptable for surface. 24-120" moderately saline. Surface soil has thin horizons and fine lime nettings to 18". 0-2% alluvial slopes.

No. 33 1000'S.,550' E. of N¼ Cor. 0-12" preferred for surface use. 12-90" acceptable for surface use. 90-120" slightly saline. Surface soil has thin horizons. Many lime nettings 11-30". 0-2% slope, alluvial soil adjacent to creek channel.

No. 34 500'S.,400'E. of N¼ Cor. 0-12" preferred for surface, 12-30" acceptable for surface, 30-108" mod. saline. 4" surface A horizon over a calcareous coarse/medium blocky B horizon with many coarse lime nettings. 3-4% channel influenced slopes.

No. 35 600'E.,150'S. of N¼ Cor. 0-12" preferred for surface. 12-24" slightly saline. 24-96" mod. saline. Thin surface horizons with medium prisms/medium blocks. 11-24" - many medium lime nettings. 0-2% alluvial slopes.

No. 36 900'W.,700'S. of N¼ Cor. 0-18" preferred for surface use. 18-78" acceptable for surface use. 78-120" mod. saline. Surface with thin A_2 over moderately developed B horizons. 18-30" many medium lime nettings. 30-48" many coarse lime nettings. Colluvial swale with 4% slope located below sandy shale crest. Saline slick spots in area.

No. 37 1650'N.,850'E. of S¼ Cor. 0-18" limited suitability for surface use. 18-120" mod. saline. Sandy shales throughout profile. 6-8% side slope with sandy shale and sandstone crest. Sandstone fragments on surface.

No. 38 1250'N.,250' E. of S¼ Cor. 0-24" for surface use. 24-48" slightly saline. 36-48" highly carbonaceous mtrl. 8-10% side slope below sandy shale crest with slopes to 35%.

No. 39 1350'W.,800' N. of SE Cor. 0-6" for surface use. 6-30" mod. saline. 30-120" mod. saline and very slowly permeable. Profile located on sandy shale crest with 8-35% slopes. Sandstone on surface.

No. 40 950'E.,100'N. of W¼ Cor. 0-24" preferred for surface use. 24-96" acceptable for surface use. 96-120" mod. saline. Profile has a thin B horizon with mod. development. Buried surface horizon at 42-54". 2-4% slope alluvial soil.

No. 41 150'E.,100'N of W¼ Cor. 0-24" preferred for surface., 24-48" paralithic mtrls. suitable for surface use., 48-84" slightly saline. 84-120" nonsaline very stratified white to light gray brown (dry) sandy shales. Sandy shale crest with 8-35% slopes. Flaggy sandstone surface.

No. 42 650'S.,100'E. of W¼ Cor. 0-18" preferred for surface., 18-30" acceptable for surface use., 30-84" slight-mod. saline. A/C profile on 4-8% side slope with sandy shale crests. Slopes to 35% in area.

No. 43 1200'E.,600' S. of W¼ Cor. 0-12" preferred for surface., 12-120" acceptable for surface use. Profile has weak coarse blocky B horizon becoming mod. calcareous at 18". Buried surface horizon at 66". Alluvial soil on a 2-4% irregular slope.

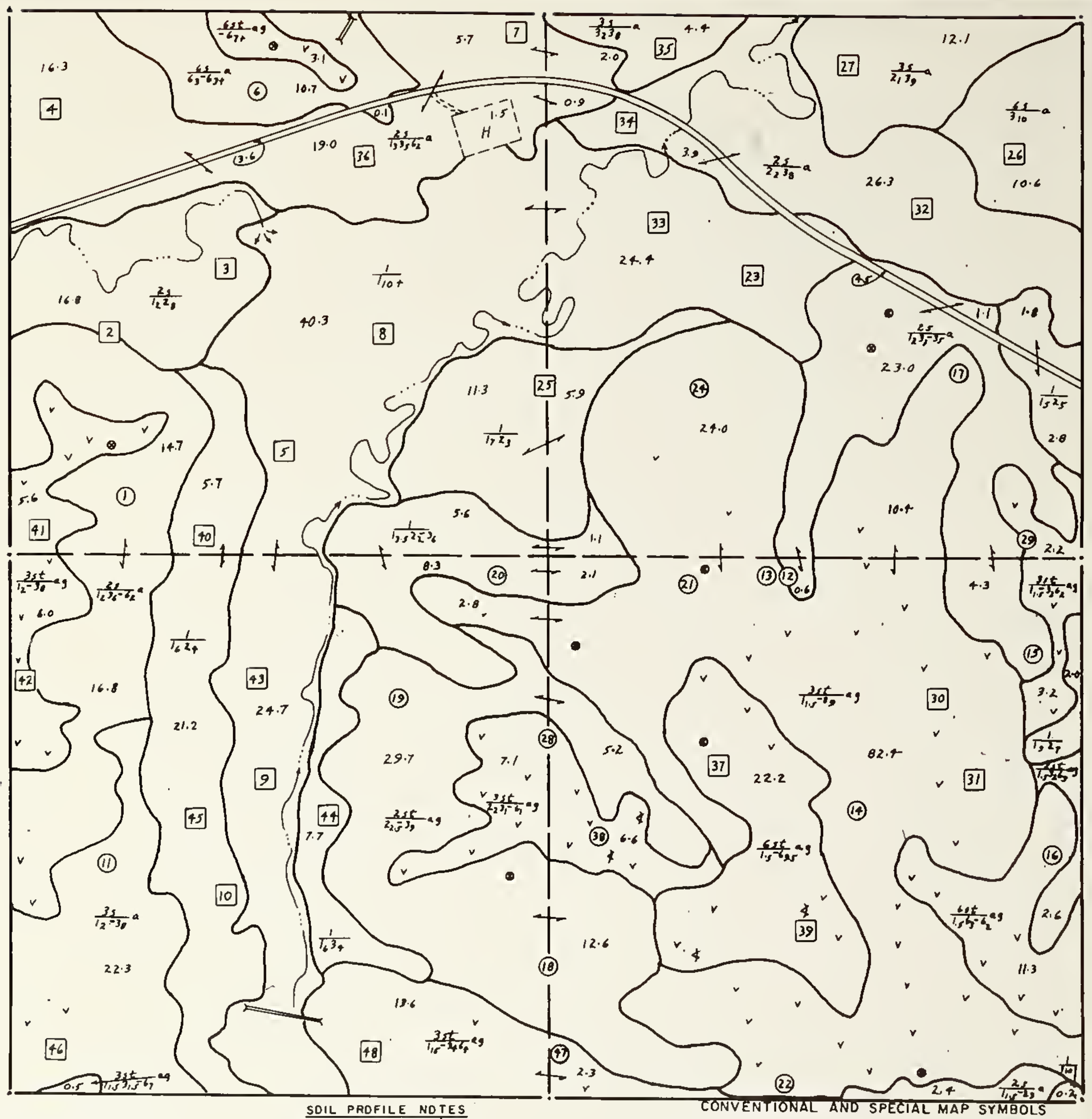
No. 44 1550'E.,1250' S. of W¼ Cor. 0-18" preferred for surface., 18-78" acceptable for surface. 78-120" slight-mod. saline. A/C profile with many fine lime nettings at 18". Alluvial soil on a moderately eroded 2-8% side slope.

No. 45 1300'S.,900' E. of W¼ Cor. 0-30" preferred for surface, 30-120" acceptable for surface. Profile has medium prisms. Lime nettings at 7"+., slightly less development & color 18-30". Alluvial soil on 2-4% irregular slopes.

No. 46 250'N.,250' E. of SW Cor. 0-24" preferred for surface. 24-60" paralithic mtrl. acceptable for surface use. 60-120" slightly saline. Carbonaceous shales at 36"+. Soft sandstone mtrl. at 108"+. 10-12% slopes near sandy shale crest.

No. 47 200'N.,50'E. of S¼ Cor. 0-6" for surface use. 6-54" paralithic mtrl. with very slow permeability. Not acceptable for use near the surface. 6-8% complex slopes below sandy shale crests.

No. 48 850'W.,200'N. of S¼ Cor. 0-6" for surface use., 6-42" highly saline. 66-120" mod. to slightly saline at 84"+. Lime nettings below 6", loose sand mtrl. at 84-96". 4-6% side slope with sandy shale crest.



400 0 400 800
SCALE OF FEET
SEC. 33, T. 8 S., R. 45 E.

LAND CLASSIFICATION SYMBOLS

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

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Salinity
- a Sodicity
- 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 8' DEPTH
(3) SOIL PROFILE NUMBER

C.L. / Lt.C / Gr.
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
.88 - - - .85 Hydraulic Conductivity in/hr. (Disturbed Samples)
24 - - - 24 Settling Volume

SOIL PROFILE SYMBOLS

Symbol	Meaning
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	Silt Clay Loam
SC	Sandy Clay
C	Clay
SIC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

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
- Soil Profile (check)

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

PITS
- Gravel
- Mine

DAMS
- Medium or small

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL	SUBMITTED
DRAWN V. LINSSEN	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA MAY 1976	1305-600-65

No. 1 300'N.,300'E. of W¼ Cor. 0-24" preferred for surface., 24-90" acceptable for surface use. Sandstone 90". Paralithic contact less 12" on crests to 90"+ in swales. 6-12% complex colluvial slopes.

No. 2 1000'E.,650'S. of W¼ Cor. 0-42" for surface use. 42-120" slight-mod. saline. Buried horizon at 42-54". Lime nettings 90-120". 2-4% complex colluvial slope.

No. 3 850'S.,450'E. of W¼ Cor. 0-36" for surface use. 36-54" mod. saline. 54-78" slightly saline. Sandstone 78". 4-6% side slope below sandy shale crest.

No. 4 900'E.,850'S. of SW Cor. 0-18" preferred for surface. 18-30" acceptable for surface use. 30-48" mod.-strongly saline. Stratified shales at 36". 4-10% complex side slope with sandy shale crest.

No. 5 1150'E.,800'S. of N¼ Cor. 0-24" preferred for surface. 24-66" acceptable for surface. 66-78" slightly saline. Sandstone 78". 4% complex slope, colluvial soil.

No. 6 1050'N.,900'W. of S¼ Cor. 0-30" preferred for surface. 30-120" acceptable for surface. Wet 72". Water table 96". 2-4% slope, channeled surface.

No. 7 1700'E.,100'S of W¼ Cor. 0-72" moderately saline not acceptable for surface. 72-120" slightly saline. 0-2% slope, alluvial soil.

No. 8 2100'S.,50'W. of N¼ Cor. 0-12" preferred for surface use. 12-120" acceptable for surface use. 4-6% complex slopes, colluvial soil.

No. 9 2150'W.,150'N. of E¼ Cor. 0-18" for surface use. 18-30" slightly saline. Very slowly permeable. 30-66" strongly saline. 8-12% complex side slope with sandy shale crests.

No. 10 350'W.,100'S. of NE Cor. 0-18" preferred for surface use. 18-66" acceptable for surface. 4-6% complex slope, alluvial soil at base of sandy shale crest.

No. 11 1000'S.,850' W. of NE Cor. 0-12" for surface use. 12-66" slight-mod. saline. Paralithic contact at 48". 4-8% complex side slope with sandy shale crest.

No. 12 850'S.,450'E. of N¼ Cor. 0-24" for surface use. 24-120" mod. saline mtrls. 6-8% complex side slope below clinker & sandy shale crests.

No. 13 1450'S.,700' E. of N¼ Cor. 0-30" for surface use. 30-120" mod. saline mtrls. 6-8% complex side slopes with sandy shale crests.

No. 14 1650'S.,250' W. of N¼ Cor. 0-120" mod. saline profile with sandy shales at 114". Lime nettings 6-48". Thin surface horizons. Slick spots in area. 4-6% irregular slope, alluvial soil.

No. 15 1100'W.,450' S. of NE Cor. 0-18" preferred for surface. 18-120" acceptable for surface use. 4-6% foot slope below sandy shale crest.

No. 16 550'E.,400'S. of N¼ Cor. 0-12" for surface use. 12-18" very stony loam. 18"+ clinker. 4-10% irregular slopes.

No. 17 550'W.,50'S. of N¼ Cor. 0-12" preferred for surface. 12-60" acceptable for surface use. 4-8% side slope along swale.

No. 18 1300'W.,800' N. of E¼ Cor. 0-30" for surface use. 30-48" slightly saline sandy shale. Sandstone at 48". 6-12% side slope with sandy shale crest. Stronger slopes in area.

No. 19 800'S.,50'W. of N¼ Cor. 0-12" preferred for surface. 12-120" acceptable for surface use. Stony loam with clinker at 96". 4-8% general slope in swale below clinker crests.

No. 20 150'S.,250'W. of N¼ Cor. 0-18" preferred for surface use. 78-120" slightly saline. 4-6% moderately sloping colluvial soil below clinker & sandy shale crests.

No. 21 500'E.,450'S. of W¼ Cor. 0-18" preferred for surface. 18-72" acceptable for surface. 72-120" slightly saline. 2-4% slope, colluvial soil from sandy shale crests.

No. 22 1200'N.,400' E. of W¼ Cor. 0-30" preferred for surface use. 30-96" slight-moderately saline. Profile 250' S. is 120" deep and similar to #22. 6-10% gently rolling slopes, colluvial soil.

No. 23 1000'W.,800' S. of N¼ Cor. 0-12" for surface use. 12-36" mod. saline. 36-96" mod. saline, slowly permeable mtrls. Solonetz profile with thin bleached surface over coarse columnar prisms. Salt crystals from 24-36. Water table 72". 0-2% nearly level slope. Slick spots in area.

No. 24 800'E.,400'S. of NW Cor. 0-12" acceptable for surface use. 12-120" mod. saline. Water table 66". Clinker fragments at 96". 0-2% irregular alluvial slopes.

No. 25 1300'N.,150' W. of S¼ Cor. 0-18" preferred for surface. 18-120" acceptable for surface use. 0-2% nearly level. complex slope, alluvial soil.

No. 26 2050'N.,250' W. of S¼ Cor. 0-18" for surface use. Sandstone fragments up to flagstone size - 50% at 6". Bedrock at 18". 6-10% gently rolling complex slope, clinker on surface.

No. 27 2050'W.,400' S. of E¼ Cor. 0-18" preferred for surface use. 36-120" very slowly permeable. 4-8% moderately sloping irregular slope, colluvial soil.

No. 28 1700'W.,650' S. of E¼ Cor. 0-12" preferred for surface use. 12-72" acceptable for surface use. 72-120" mod. saline clinker fragments at 108". 4-8% gentle to moderate slopes.

No. 29 500'W.,400'S. of E¼ Cor. 0-48" mod. saline not suitable for surface use. 48-60" very slowly permeable sandy shale mtrls. Sandstone at 60". 6-12% complex side slopes below sandy shale crests.

No. 30 1300'W.,1050' N. of SE Cor. 0-12" preferred for surface. 12-60" acceptable for surface use. 60-120" slightly saline. 2-4% alluvial slopes.

No. 31 1150'E.,850'N. of W¼ Cor. 0-6" preferred for surface. 6-120" mod. saline with slowly permeable mtrls. 42-120". Water table 96". 0-2% alluvial slopes.

No. 32 2100'E.,950'N. of W¼ Cor. 0-18" preferred for surface use. 18-48" sandy shales. Sandstone 48". 4-6% complex side slope with clinker crests.

No. 33 200'W.,200'N. of SE Cor. 0-30" for surface use. 30-120" slightly saline. 4-6% complex slope, alluvial soil.

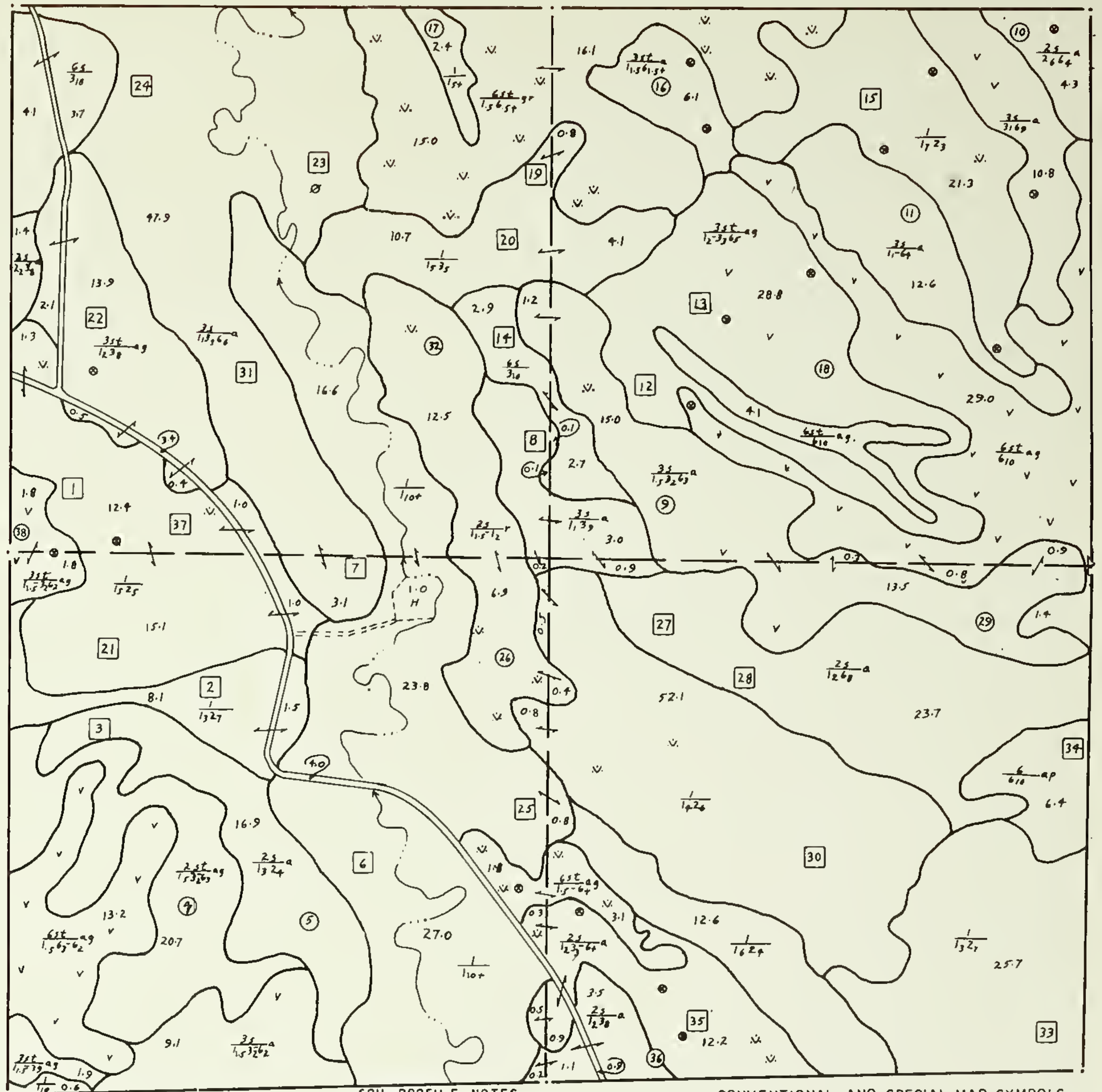
No. 34 1000'S.,50'W. of E¼ Cor. 0-120" not suitable for surface use. 0-18 non-saline very slowly permeable. 18-96" slight to moderately saline and slowly to very slowly permeable. 6-8% complex, alluvial.

No. 35 600'E.,250'N. of S¼ Cor. 0-6" preferred for surface use. 6-18" sandy shales acceptable for surface use. 18-48" mod. saline. 48-120" coal. 4-6% complex slope at base of clinker crest. Residual profiles over sandy shales on lower slopes. Soil material ranges from 6-18" over sandy shales. Sandstone from 24-66".

No. 36 550'E.,100'N. of S¼ Cor. 0-30" acceptable for surface use. 30-60" mod. saline. Sandstone at 60". 6-8% complex slopes below sandy shale & clinker crests.

No. 37 850'E.,100'S. of W¼ Cor. 0-12" preferred for surface use. 12-120" acceptable for surface use. Profile 125'E. on upper crest with massive crusty loam 24-60". Sandstone 60". Other areas with clinker outcrops on side slopes. 6-10% complex side slope on upper edge of colluvial swale.

No. 38 100'N.,50'E. of W¼ Cor. 0-12" acceptable for surface use over sandy shales at 12"+. Profile located on sandy shale crests with slopes up to 35%.



LAND CLASSIFICATION SYMBOLS

Land class; Plant media deficiency; Topographic deficiency; Informative symbols; Surface layer (Quality, Depth); Geologic material (Quality, Depth); Second layer (Quality, Depth); Divides soil material and nonsoil material

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

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

3 SOIL PROFILE NUMBER

2.8 - - - 2.8 EC mmhos/cm. Sat. Ext.
8.4-8.0 8.4 pH: 8 Soil-Water Suspension; 8.0 pH Soil-CaCl₂ Suspension
.65 Hydraulic Conductivity in/hr. (Disturbed Samples)
24 Settling Volume

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	Silt Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

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
- Soil Profile (check)

WATER FEATURES

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

PITS

- Gravel
- Mine

DAMS

- Medium or small

400 0 400 800
SCALE OF FEET
SEC. 34, T.8 S., R.45 E.

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEAR CREEK STUDY AREA

WEST MOORHEAD COAL FIELD, MONT.

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL ____ SUBMITTED ____
DRAWN V. LINSSEN ____ RECOMMENDED ____
CHECKED ____ APPROVED ____
BILLINGS, MONTANA MAY 1976 1305-600-66

No. 1 800'S.,350'E. of NW Cor.
0-30" for surface use., 30-108" slightly saline, acceptable for surface use. 108-120" mod. saline.
2-4% undulating slope alluvial soil.

No. 2 700'E.,250'N. of SW Cor.
0-18" for surface use., 18-48" mod. saline. 48-120" slightly saline, very slowly permeable. Calcareous surface with medium prisms over sodic subsurface mtrl.

No. 3 1250'E.,700'S. of NW Cor.
0-30" for surface use., 30-72" mod. saline. 72-114" sandy shale slightly saline. Weakly developed surface horizons.
4-6% complex slope, alluvial soil below sandy shale crests.

No. 4 1150'E.,350'S. of NW Cor.
0-6" for surface use., 6-24" acceptable for surface. 24-66"+ mod. salinity and sodicity. Thin residual soil with exposed shales in area.
4-6% complex side slope below sandy shale crests.

No. 5 800'W.,100'S. of N¼ Cor.
0-12" for surface use., 12"+ sandy shale limited for surface use. Lime nettings at 30"+.
Profile similar to #8.
4-6% complex slopes below sandy shale crests.

No. 6 400'S.,250'W. of N¼ Cor.
0-12" for surface use., 12-66" mod. saline. 12-30" gyp. crystals, 30-48" gray sandy sediments., 48-66"+ soft sandstone.
4-6% complex side slope.

No. 7 850'S.,750'W. of N¼ Cor.
0-12" preferred for surface use., 12-42" acceptable for surface use. 42-120" may be used for surface.
Irregular surface, colluvial remnant over stratified soft sandy shale mtrls.
4-6% complex slopes below sandy shale crests.

No. 8 1500'S.,100'W. of N¼ Cor.
0-12" for surface use., 12-30" acceptable for use 12"+., 30-66" strongly saline, unsuited for surface. Residual soil with shale outcroping in area.
4-6% complex side slopes below sandy shale crest.

No. 9 1750'S.,150'W. of N¼ Cor.
0-12" for surface use., 12-48" acceptable for surface use., 48-66"+ limited suitability for surface. Thin surface horizons. Lime modules at 48"+.
4% complex slopes, colluvial soil below sandy shale crests.

No. 10 1900'S.,550'W. of N¼ Cor.
0-18" for surface use., 18-60" limited suitability for surface.
8-10% complex side slopes below sandy shale crests.

Profile similar to #3.
No. 11 1900'S.,550'W. of N¼ Cor.
0-6" preferred for surface., 6-30", 30-60" unsuited for surface use.
For best use 18"+.
Profile located on sandy shale crest with 8-35% complex side slopes.

Profile similar to #30.
No. 12 1100'N.,1000'E. of W¼ Cor.
0-18" for surface use., 18-30" acceptable for surface use. 30-90" unsuited for surface use. Thin surface horizons.
Lime nettings from 30-48".
4-6% complex foot slopes below sandy shale crests.
Colluvial bench remnants.

No. 13 350'S.,350'E. of NW Cor.
0-12" preferred for surface., 12-120" acceptable for surface use.
2-4% irregular colluvial surface.

No. 14 1100'E.,500'N. of W¼ Cor.
0-12" for surface use., 12-48" limited use at surface. 48-66" unsuited for surface.
6-8% complex foot slope with sandstone and sandy shale crests.

Profile similar to #12.
No. 15 2050'N.,650'W. of S¼ Cor.
0-12" limited suitability for surface use. 12-60" highly saline.
0-2% irregular surface on top of crest with slick spots in area.

No. 16 1850'E.,400'N. of W¼ Cor.
0-12" for surface use. 12-36" acceptable for use 12"+. 36-60" slight to mod. salinity strongly calcareous surface soil.
8-35% side slopes on upper edge sandy shale crest.

No. 17 2350'E.,250'N. of W¼ Cor.
0-12" for surface use., 12-42" best use below surface. 42-66" acceptable for surface. Upper edge of 8-35% side slope of sandy shale crest.

Profile similar to #30.
No. 18 1300'E. of W¼ Cor.
0-12" for surface use., 12-60" limited suitability for surface use. Thin surface horizons.
4-6% foot slopes with micro panspots in area.

No. 19 1150'E.,850'N. of W¼ Cor.
0-6" for surface use., 6-18" acceptable for surface. 18-60" unsuited for surface use.
8% complex sandy shale crest.

Profile similar to #4.
No. 20 1900'S.,950'W. of N¼ Cor.
0-18" preferred for surface., 18-36" limited suitability for use at or near surface. 36-66" unsuited for surface use.
6-8% side slope with sandstone and sandy shale crest. 300'NW. swale with 60" of soil over sandy shale.

No. 21 500'E.,400'N. of W¼ Cor.
0-18" for surface use., 18-42" acceptable for surface., 42-84" mod. to high salinity. 84-120" slightly saline and sodic. Thin surface soil over oxidized soft sandstone.
Gray sandy shale 42-120".
6-8% side slope with sandy shale crest.

No. 22 150'E., of W¼ Cor.
0-12" for surface use., 12-30" best for use below surface.
8% complex side slope with sandstone and sandy shale crest.

Profile similar to #4.
No. 23 950'E.,250'S. of W¼ Cor.
0-18" preferred for surface use., 18-36" acceptable for surface., 36-54" saline and unsuited for surface use.
Complex 6-8% side slope with sandstone and shale outcrop on crest.

No. 24 1300'N.,50'E. of W¼ Cor.
0-12" for surface use., 12-36" limited suitability for surface., 36-102" strongly saline, unsuited for surface use. 102-120" for moderately saline.
4-6% foot slope of sandy shale crest.

No. 25 1200'S.,1150'E. of NW Cor.
0-12" for surface use., 12-42" gray stratified and Iron oxidized sandy shale with mixed color, limited suitability for surface use.
Sandstone 42".
6-8% side slope.

No. 26 1400'N.,250'W. of S¼ Cor.
0-6" for surface use., 6-18" acceptable for surface use. 18-120" mod. saline. Hard sandstone at 120". Thin surface soil in the area.
6-10% side slopes with sandy shale crests. Slopes up to 35% in area.

No. 27 2300'N.,100'W. of S¼ Cor.
0-12" for surface use., 12-54" limited suitability for surface use. 54-66" silty shale mtrl. unsuited for surface. Depth to shale ranges from 6-18".,350'S. 30" colluvium over sandy shales.
8-35% complex side slopes.

No. 28 1000'N.,950'W. of S¼ Cor.
0-12" for surface use., 12-36" limited suitability for surface., 36-78" unsuited for surface use. 78-120" carbonaceous shale unsuited for use near the surface.
6-8% slopes near sandy shale crest.

Profile similar to #8.
No. 29 1300'E.,950'S. of W¼ Cor.
0-12" preferred for surface use., 12-30" acceptable for surface use. 30-120" mod. to highly saline, good perm.
Alluvial soil on 6-8% foot slopes below sandy shale crest.

No. 30 1650'N.,850'W. of S¼ Cor.
0-12" acceptable for surface use., 12-36" highly saline., 36-78" mod. saline. 78-120" slightly saline sandy mtrl. Good perm. Non-calcareous below 12". Surface with thin chlorine over sandy shales.
10-12% side slope near sandy shale crest.

No. 31 1300'N.,350'E. of SW Cor.
0-18" acceptable for surface use., 18-30" mod. saline unsuitable for surface use. 30-120" sandy shales saline and sodic. Thin brittle layers of soft sandstone 72-108".
4-6% complex foot slope with shale outcroping on crests. Average soil depth of 24" on lower slopes.

No. 32 800'N.,400'E. of SW Cor.
0-12" preferred for surface use., 12-30" acceptable for surface. 30-96" highly saline mtrl. unsuitable for use near surface. Sandstone at 96". Surface 12" with thin weakly developed A_2 over columnar prisms. Salt crystals at 80".
4-6% foot slope below sandy shale crest.
Slick spots in area.

No. 33 1050'N.,700'E. of SW Cor.
0-18" for surface use. 18-60"+ mod. saline and restricted perm.
2-4% colluvial mtrl. off sandstone and sandy shale highs. Slick spots cover less than 30% of area.

No. 34 600'E.,400'S. of W¼ Cor.
0-18" for surface use., 18-36" limited for use on the surface. 36-60" for use near the surface. Salt crystals at 36".
6-8% complex side slope. Steep slopes with carbonaceous shale outcrops.

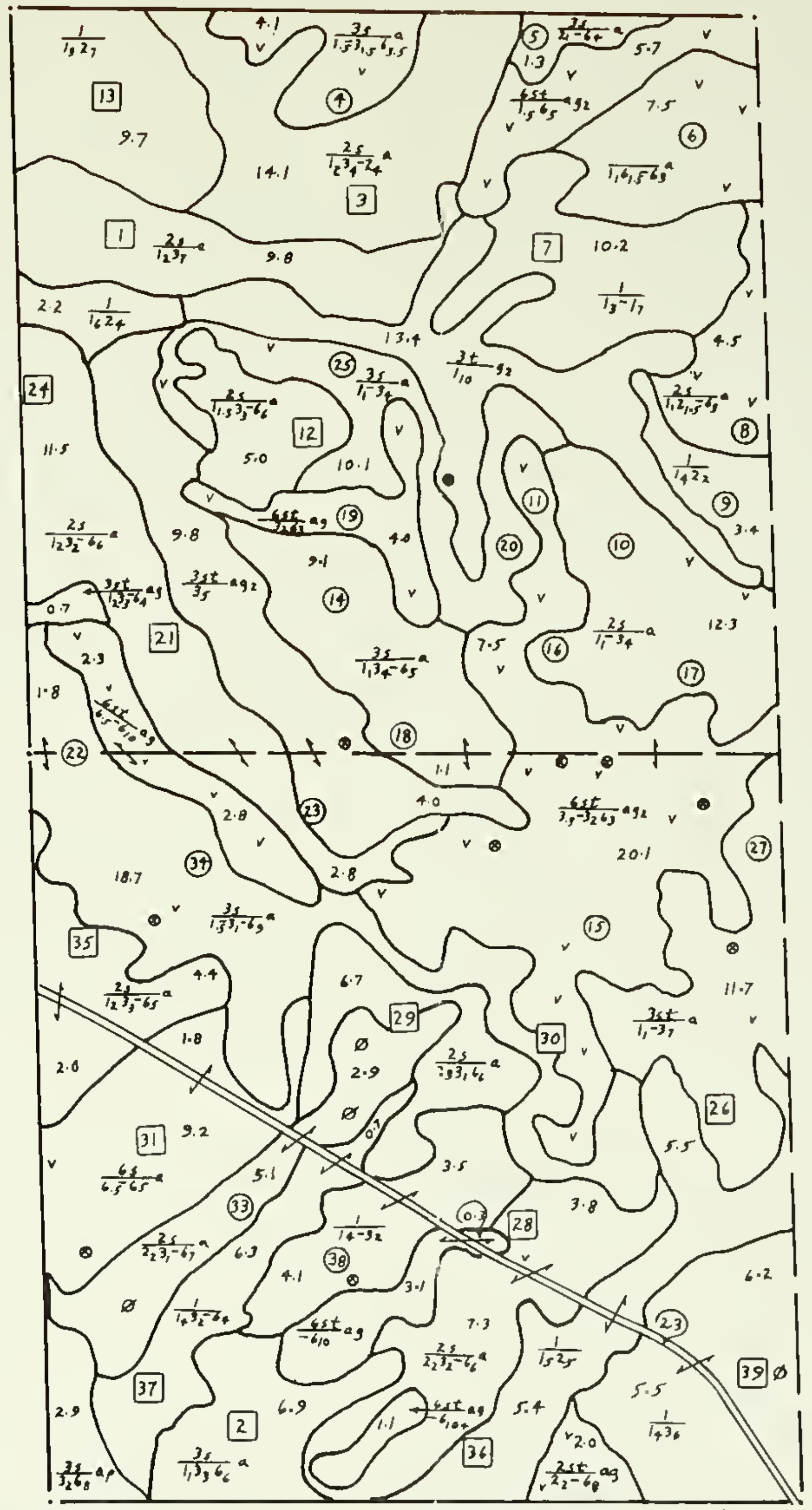
Profile similar to #8.
No. 35 650'S.,200'E. of W¼ Cor.
0-18" preferred for surface use., 18-36" acceptable for surface. 36-120" mod. saline to highly mtrls.
6-8% foot slope with sandy shale and sandstone crests.

No. 36 1150'W.,200'N. of S¼ Cor.
0-12" for surface use., 12-84" acceptable for surface use. 84-120" slightly saline for use below slightly limited for surface.
2-4% alluvial irregular slopes. Surface with thin weakly developed soil horizons to 10".

No. 37 400'N.,350'E. of SW Cor.
0-18" preferred for surface., 18-54" acceptable for surface use. 54-120" mod. saline mtrl. unsuited for surface use.
2-4% irregular colluvial soil.

No. 38 1050'E.,850'N. of SW Cor.
0-12" preferred for surface. 12-66" acceptable for surface use.
6-8% complex foot slope with sandy shale crest.

No. 39 450'N.,150'W. of S¼ Cor.
0-12" preferred for surface use., 12-48" acceptable for surface use. 48-88" best use below surface.
6-8% complex colluvial soil with scattered slick spots in area.



400 0 400 800
SCALE OF FEET
SEC. 2, T. 9 S., R. 45 E.

LAND CLASSIFICATION SYMBOLS

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

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

- a Salinity
- s Sodicity
- 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

- (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
- C.L., Lt.C, Gr.

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	Silt Clay Loam
SC	Sandy Clay
C	Clay
SIC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

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
- Soil Profile (check)

WATER FEATURES

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

PITS

- Gravel
- Mine

DAMS

- Medium or small

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA MAY 1976 1305-600-67

No. 1 2000'W.,150' S. of E¼ Cor.
0-18" acceptable for surface use. 18-120" mod. saline, unsuited for surface without leaching.
0-2% gently sloping alluvial soils below sandy shale influence. Water table influence at 60".

No. 2 2100'N.,300' E. of S¼ Cor.
0-12" preferred for surface. 12-30" acceptable for surface use. 30-120" mod. to highly saline, unsuited for surface use.
2-4% complex slopes alluvial soil.

No. 3 1700'N.,900' E. of S¼ Cor.
0-12" preferred for surface. 12-84" acceptable for surface use.
0-2% complex alluvial soil. Buried profiles from 24-36" and 84-102" with many lime nettings.

No. 4 700'W.,500' N. of SE Cor.
0-12" preferred for surface. 12-48" acceptable for surface use. 48-120" mod. to highly saline.
2-4% complex slopes, colluvial soil below sandy shale crests.

No. 5 1000'N.,350' E. of S¼ Cor.
0-12" preferred for surface. 12-48" acceptable for surface use. 48-108" slight-mod. saline. 108-120" slowly permeable mtrls.
6-12% complex slopes below sandstone and sandy shale crest.

No. 6 550'E.,500' N. of S¼ Cor.
0-18" acceptable for surface use. 18-30" very saline. 30-60"+ very slowly permeable and saline.
4-6% smooth slope, bench remnant with 40% slick spots in area. Gypsum crystals at 18-30".

No. 7 900'N.,850' E. of S¼ Cor.
0-6" preferred for surface. 6-30" acceptable for surface use. 30-120" mod. saline, but permeable.
4-12% complex colluvial slopes. Thin surface horizons. A ridge 150' NE with 12" of gr. chlorine over loam and chlorine to 66".

No. 8 1300'E.,800' N. of S¼ Cor.
0-6" preferred for surface. 6-30" acceptable for surface use.
8-35% complex side slopes sandy shale crests. Profile similar to #16.

No. 9 1600'N.,150'W. of S¼ Cor.
0-12" preferred for surface. 12-30" acceptable for surface. 30-66" unsuitable for surface use.
6-8% side slopes on edge of swale below sandy shale crests. Profile similar to #6.

No. 10 500'W.,450'N. of S¼ Cor.
0-18" preferred for surface. 18-120" acceptable for surface use.
4-8% complex side slopes with sandy shale crests. Thin surface horizons. 30-120" weakly calcareous, sandy shales.

No. 11 1050'N.,950' W. of S¼ Cor.
0-6" preferred for surface. 6-24" acceptable for surface. 24-120" for use 18"+. Profile similar to #7.
6% complex slope, colluvial soil below sandy shale crests.

No. 12 1350'E.,550' N. of SW Cor.
0-18" preferred for surface. 18-54" acceptable for surface use. Weakly developed horizons to 18". Deeper profiles occur in area.
6-8% side slopes below sandy shale crests.

No. 13 7100'E.,350' N. of SW Cor.
0-6" preferred for surface use. 6-24" acceptable for surface use. 24-54"+ limited suitability for surface use.
8-10% complex side slopes on upper edge of sandy shale crest.

No. 14 750'E.,100' N. of SW Cor.
0-12" preferred for surface use. 12-24" acceptable for surface use. 24"+ unsuited for surface use. Salt crystals at 12"+.
8-10 % side slopes with sandy shales outcropping in area. Profile similar to #45.

No. 15 1150'N.,650' E. of SW Cor.
0-18" preferred for surface use. 18-66" acceptable for surface use. 66-120" slight-mod. saline but permeable.
4-8% alluvial side slope below sandy shale and sandstone crest.

No. 16 1050'E.,150' N. of S¼ Cor.
0-36" acceptable for surface use. 36-60" suitable for surface use.
8-15% slope; colluvial remnant. Surface with scattered angillite and sandstone fragments. Sandy and silty shale crests with sandstone outcrops in area.

No. 17 200'E.,150'N. of S¼ Cor.
0-18" preferred for surface. 18-42" acceptable for surface use. 42-90" slight-mod. saline.
8-12% gravely sandy shale crests with sandstone outcrops. Colluvial bench remnant on lower slopes. 48" average depth to paralithic contact.

No. 18 500'E.,250'N. of S¼ Cor.
0-30" acceptable for surface use. 18-54" slight to moderately saline.
8-10% slope; colluvial remnant with some slopes to 35% in area. Average depth sandy shales 18". Profile similar to #17.

No. 19 900'N,550'W. of S¼ Cor.
0-18" acceptable for surface use. 18-42" mod. saline, unsuited for surface use. Salt crystals at 18-42".
6-8% side slope with sandy shale crests.

No. 20 900'E.,500'N. of SW Cor.
0-6" mod. saline, unsuited for surface. 6-18" high salinity, mod. sodicity, unsuited for surface use. 18-60" mod. to highly saline, limited suitability for use near the surface. Slickspot profile with no vegetation. Thin vesicular surface over coarse columns grading to shaley at 6".

No. 21 1700'S.,400' E. of N¼ Cor.
0-18" limited acceptability for surface use. 18-72" unsuited for surface, high salinity. 72-120" mod. salinity. Structure and organic influence to 30".
0-2% slope; alluvial soil adjacent to channel.

Profile similar to #58.

No. 22 1550'S. of N¼ Cor.
0-42" for surface use. 42-60" mod. saline. 60-120" mod. saline, slowly permeable and sodic. Lime nettings 18-42".
0-2% slope nearly level, alluvial soil.

No. 23 1850'S.,650' W. of N¼ Cor.
0-12" preferred for surface use. 12-52" acceptable for surface use. Limited surface use. Thin surface horizons. Many lime nettings from 12-36"
2-4% alluvial side slope.

Profile similar to #40.

No. 24 200'S.,50'E. of N¼ Cor.
0-18" preferred for surface. 18-30" acceptable for surface. 30-120" mod. saline, physical condition is good.
0-2% slope, alluvial soil adjacent to channel.

No. 25 1000'S.,300' E. of N¼ Cor.
0-18" preferred for surface. 18-30" acceptable for surface use. 30-120" mod. saline but leachable.
0-2% alluvial soil adjacent to ridge with clinker influence. Profile similar to #24.

No. 26 700'S.,550'W. of N¼ Cor.
0-42" acceptable for surface use. 42-120" mod. to highly saline, but leachable. Thin surface horizons with lime nettings to 42".
0-2% slope, nearly level alluvial soil.

No. 27 1200'S.,850' E. of N¼ Cor.
0-18" preferred for surface. 18-30" acceptable for surface use. 30-120" mod. saline but leachable. Gritty clinker fragments in first 108".
4-8% side slope below clinker crest.

No. 28 1300'W.,500' S. of NE Cor.
0-24" acceptable for surface use. 24"+ rock mtrl.
8-10% complex side slope of a clinker high. Depth to clinker ranges from 10 to 24".

No. 29 1150'W.,250' N. of E¼ Cor.
0-12" preferred for surface. 12-36" acceptable for surface. 36-120" slowly permeable.
2-4% complex slope below sandy shale crest. Profile similar to #30.

No. 30 1150'W.,600'N., of E¼ Cor. 0-12" preferred for surface. 12-48" acceptable for surface use. 48-120" slowly permeable, mod. saline. 4-6% side slope below sandy shale crest.

No. 31 1000'S.,600'W. of NE Cor. 0-12" preferred for surface. 12-30" acceptable for surface use. 30-66" mod. saline but leachable. 8-10% complex side slope below sandy shale crest.

No. 32 700'S.,350'W. of NE Cor. 0-12" preferred for surface. 12-120" acceptable for surface use. 0-2% complex slope; alluvial soil.

No. 33 300'W.,150'S. of NE Cor. 0-12" preferred for surface. 12-120" best for use below surface. Thin surface horizons over blocky C to 48". Moderate soil development. 4-6% slope; complex alluvial soil.

No. 34 350'W.,300'S. of E¼ Cor. 0-12" preferred for surface use. 12-24" non-saline and sodic. Very slow permeable. 24-102" mod. saline, slowly permeable. 4-6% side slope below sandy shale and sandstone crest.

No. 35 950'S.,350'W. of E¼ Cor. 0-12" for surface use. 12-30" slightly saline for use below 12". 30-120" mod. to highly saline some sodium. Weakly developed surface horizons with columnar prisms to 12". Slick spots in area. 2-4% complex alluvial slopes.

No. 36 1000'S.,650' W. of E¼ Cor.
0-66" unsuited for use near the surface. Mod. saline, very slowly permeable. Sodium increases with depth. Salt bush and slick-spots in area.
4-6% complex slope, alluvial soil.

No. 37 1700'W.,450' N. of E¼ Cor.
High salinity and sodicity cause mtrl. in this profile unsuited for use at or near the surface. Slowly permeable saline-sodic alluvial soil. Wet at 90". Salt tolerant vegetation in area.
2-4% complex slopes.

No. 38 1600'S.,800'E. of N¼ Cor.
0-24" for surface use. 24-120" slowly permeable, mod. sodium. Clinker, sandstone and sandy shales on upper crests.
2-4% complex slopes; alluvial soil.

No. 39 1350'W.,200' S. of E¼ Cor.
0-24" slight. saline, slowly perm., unsuited for surface. 24-60" strong. saline mod. and sodium. 60-120" high. to mod. saline but leachable. 24-36" many lime nettings. Wet at 90". Slick-spots in area.
2-4% complex slope; alluvial soil.

No. 40 2600'S.,50'W. of N¼ Cor.
0-12" preferred for surface use. 12-54" acceptable for surface use. 54-120" slightly saline, will leach readily. Moderately developed surface structure.
2-4% slope; alluvial soil.

No. 41 1900'N.,650' W. of S¼ Cor.
0-12" preferred for surface use. 12-30" acceptable for surface. 30-66"+ highly saline, should leach readily. 54"+ soft sandstone.
6-8% side slope below sandy shale crest.

No. 42 800'E.,550'S. of W¼ Cor.
0-18" preferred for surface. 18-66" slightly saline, can be leached readily. Gypsum crystals from 18-36".
6-8% side slope in gentle swale below sandy shale crest.

No. 43 300'S.,100'E. of W¼ Cor.
0-18" acceptable for surface use. 18-60" mod. saline, but is leachable.
6-12% side slopes on sandy shale crest. Petrified cypress stumps in area.

No. 44 1200'S.,100' E. of W¼ Cor.
0-18" preferred for surface. 18-84" acceptable for surface use. 40% slick-spots in area. Weak, coarse columnar prisms to 30". Non-calcareous surface.
2-4% alluvial slopes.

Profile is a solodized solonetz.

No. 45 1500'E. of W¼ Cor.
0-24" acceptable for surface use. 24-54" mod.-strongly saline. 54-66"+ very slowly permeable, strongly saline. Gypsum crystals at 24".
2-4% slope adjacent to sandy shale break.

No. 46 1350'E.,600' N. of W¼ Cor.
0-30" acceptable for surface use. 30-90" highly saline but leachable.
4-6% side slope below sandy shale crest.

No. 47 1250'E.,400'N. of W¼ Cor.
0-12" preferred for surface. 12-30" acceptable for surface use.
8-12% side slope of sandy shale crest. Profile similar to #50.

No. 48 1300'E.,1250' S. of NW Cor.
0-30" acceptable for surface use. Coarse very gravely outwash material at 30". A profile 120'E. has 60" loam over gravel.
4-6% complex side slope.

No. 49 1250'S.,900' E. of NW Cor.
0-18" acceptable for surface use. 18-120" mod. to highly saline but leachable.
4-6% slope alluvial soil in swale below sandy shale crest. Profile similar to #26.

No. 50 450'N.,150'E. of W¼ Cor.
0-6" preferred for surface. 6-66" acceptable for surface use. Stratified silty and sandy shales.
6-8% footslope below a sandy shale crest.

No. 51 1100'S.,250' E. of W¼ Cor.
0-6" preferred for surface use. 6-60" highly saline, unsuited for surface use.
6-8% complex side slope below sandy shale crest.

No. 52 800'E.,550'S. of W¼ Cor.
0-12" for surface use. 12-60"+ highly saline, unsuited for surface use.
Profile located on sandy shale crest with 8-35% side slopes.

No. 53 750'E.,350'N. of W¼ Cor.
0-12" preferred for surface. 12-60"+ acceptable for surface use.
Profile located on top of sandy shale crest with complex side slopes 8-35%.

No. 54 1300'E.,1250' S. of NW Cor.
0-18" acceptable for surface. 18-30" limited suitability for surface use. 30-60" gravely outwash crest.
6-8% side slope with gravely outwash crest. Profile 250'N. with 12" gr. loam over fragmented sandstone. Profile similar to #16.

No. 55 1150'E.,350'S. of NW Cor.
0-12" preferred for surface. 12-42" acceptable for surface use. 42-120" unsuited for surface use unless leached.
Alluvial footslope below sandy shale crest. Thin surface horizons. Profile similar to #26.

No. 56 750'W.,150'S. of N¼ Cor.
0-18" preferred for surface. 18-120" acceptable for surface use. Surface development to 30". 15-30" many lime nettings.
2-4% slope; alluvial soil below sandy shale crests.

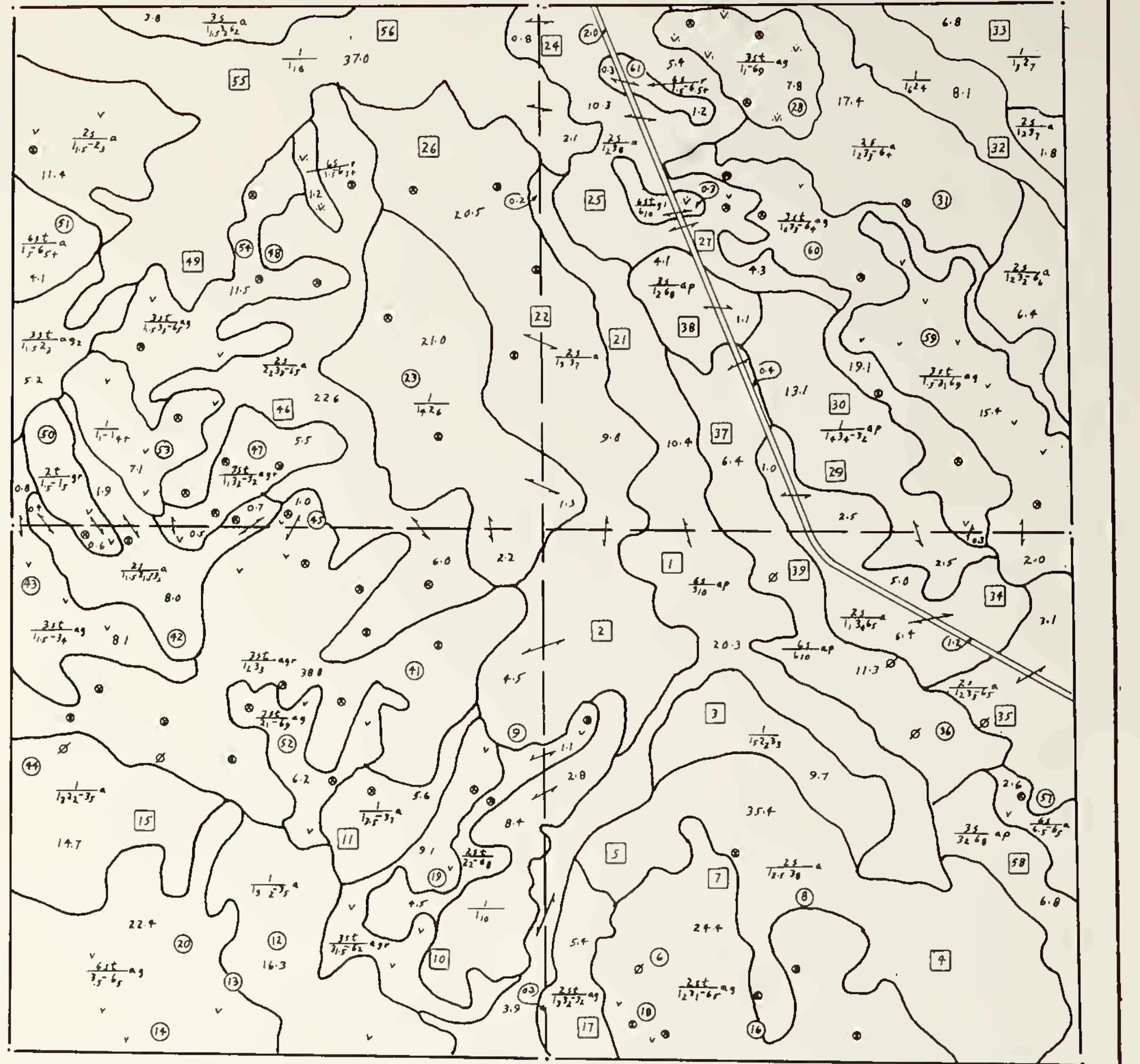
No. 57 1300'N.,150'W. of SE Cor.
0-18" acceptable for use below the surface.
10-12% side slope with sandy shale outcropping in area.

No. 58 1000'N.,300'W. of SE Cor.
0-24" acceptable for surface use. 24-48" very slowly permeable highly saline. 48-120" mod. saline not for surface use.
2-4% recent alluvium with lime nettings from 48-72". Stratified light CL/S:L from 72-120".

No. 59 950'N.,700'W. of E¼ Cor.
0-6" preferred for surface. 6-18" acceptable for surface use. 18-66" highly saline not for surface use.
8-10% complex side slope with sandy and silty shale crests.

No. 60 1250'W.,1250' S. of NE Cor.
0-12" preferred for surface. 12-66" acceptable for surface use. 66"+ slowly permeable.
8-10% complex side slope with shale outcropping at crest.

No. 61 550'E.,350'S. of N¼ Cor.
6" surface material on a small variable crest with a clinker outcrop.
6-10% side slopes with thin layer of clinker over sandy shale.



LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant media deficiency; Topographic deficiency; o g — Informative symbols

SURFACE LAYER: Quality, Depth — 2.5 3 ⊓ G 3 2 — GEOLOGIC MATERIAL: Quality, Depth

SECOND LAYER: Quality, Depth

⊓ Divides soil material and nonsoil material

INFORMATIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

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

TOPOGRAPHIC DEFICIENCIES

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

400 0 400 800
SCALE OF FEET
SEC. 3, T.8S., R.45E.

SOIL PROFILE NOTES

PROFILE REPRESENTS 8' DEPTH

(3) SOIL PROFILE NUMBER

- C.L.: 2.8---2.9 EC. mmhos/cm. Sol. Ext.; 8.4-8.0 — 8.4 pH 1:5 Soil – Water Suspension; 8.0 pH Soil – CaCl₂ Suspension
- Lt.C: .65 --- .65 Hydraulic Conductivity In/hr. (Disturbed Samples); 24 --- 24 Settling Volume
- Gr.

SOIL PROFILE SYMBOLS

Symbol	Meaning
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	Silt Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Li	Light
M	Medium
H	Heavy

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
- Soil Profile (check)

WATER FEATURES

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

PITS

- Gravel
- Mine

DAMS

- Medium or small

N

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BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
DETAIL LAND CLASSIFICATION

SOIL T. FIECHTL	SUBMITTED
DRAWN	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA MAY 1976	1305-600-68

No. 1 2100'E.,350'N. of W¼ Cor. 0-18" best for surface use. 18-108" mod. saline. 4-8% complex slopes below sandy shale crest.

No. 2 850'E.,450'S. of NW Cor. 0-12" preferred for surface use., 12-36" acceptable for surface use., 36-84" slightly saline. 4-6% complex slopes, colluvial soils below sandy shale & sandstone crest.

No. 3 400'N.,150'E. of W¼ Cor. 0-12" for surface use., 12-42" mod. saline sandy shales over hard sandstone. Lime-coated gravel on surface. Complex slopes to 35%, 10-16% is common. Located below sandy shale & sandstone crests.

No. 4 900'E.,100'N. of W¼ Cor. 0-18" preferred for surface use., 18-36" acceptable for surface use. 36-66" mod. saline. 15% complex slope below sandy shale & sandstone crest. Some steeper slopes in area.

No. 5 1100'S., 850'E., of NW Cor. 0-12" preferred for surface., 12-120" acceptable for surface. Thin stratifications of Co. S. & gravel from 36-66". Buried profile at 66". 0-2% slope - alluvial soil.

No. 6 500'W.,450'S. of N¼ Cor. 0-12" best for surface use., 12-90" mod. saline. 90-120" mod. salinity, slowly permeable. 4-6% complex colluvial slope.

No. 7 900'E.,500'S. of N¼ Cor. 0-12" preferred for surface use. 12-30" acceptable for surface use. 30-120" suitable except for surface with selective placement.

4-8% complex slope with sandy shale crest. Profile 60' N. has 12" surface material over sandy shales.

No. 8 1250'N.,1000' W. of E¼ Cor. 0-12" preferred for surface use., 12-36" acceptable for surface use., 36-66" suitable except for surface. 4-8% foot slopes below sandy shale crest with steeper slopes.

No. 9 1900'W., 500'N. of E¼ Cor. 0-18" best for surface use., 18-66" mod. saline. 6-8% complex side slopes below sandy shale crest.

No. 10 1550'S. of N¼ Cor. 0-12" preferred for surface use., 12-42" acceptable for surface use. 42-120" suitable for selective placement below surface. 4-8% complex slopes below sandy shale crests, colluvial soil.

No. 11 1250'S.,850' E. of N¼ Cor. 0-18" best for surface use., 18-30" mod. saline. 18-36" slowly permeable. 8-10% complex slope below sandy shale crest.

No. 12 650'W.,300'N. of E¼ Cor. 0-12" preferred for surface use., 12-30" acceptable for surface use., 30-42" mod. saline. 8-10% comples foot slope below sandy shale & sandstone crest.

No. 13 150'W. of S¼ Cor. 0-18" preferred for surface use., 18-108" acceptable for surface use. 0-2% slope - alluvial soil along small tributary. Profile similar to #1.

No. 14 650'N.,500' W. of S¼ Cor. 0-18" preferred for surface use., 18-66" moderately saline. 4-8% complex side slope below sandy shale & sandstone crest. Profile similar to #1.

No. 15 800'E.,400' S. of NW Cor. 0-12" preferred for surface use., 12-60" acceptable for surface use., 50'SW of #2 which has sandstone at 84". Lime nettings at 6" and weak coarse prisms. 2-4% colluvial side slope with sandy shale crests.

No. 16 950'S.,500' E. of NW Cor. 0-12" preferred for surface use., 12-36" acceptable for surface use. 6-8% complex side slope near sandy shale crest. Some slopes to 35%.

No. 17 600'S. of NW Cor. 0-12" preferred for surface use., 12-48" acceptable for surface use., 48-120" moderately saline. 0-2% colluvial soil on shale crest. Side slopes of 8-35%.

No. 18 1250'E.,300' S. of NW Cor. 0-12" preferred for surface use., 12-120" acceptable for surface use. Lime nettings at 72+. 0-2% irregular alluvial slopes.

No. 19 250'S.,200' E. of NW Cor. 0-18" preferred for surface use., 18-36" mod. saline soil material. 36-120" mod. saline sandy shales. Salt mottled from 48-120". 6-8% complex side slope below sandy shale crest.

No. 20 1400'E.,1250' N. of W¼ Cor. 0-12" preferred for surface use. 12-24" acceptable for surface use., 24-54" mod. saline. 6-8% colluvial side slope with sandy shale crests. Surface horizons have weak coarse prisms.

No. 21 1050'W.,850'S. of N¼ Cor. 0-12" preferred for surface use., 24-120" acceptable for surface use., surface horizons have weak coarse prisms. Buried soil & lime nettings at 72"+. 0-2% irregular alluvial slopes.

No. 22 1300'W.,750'S. of N¼ Cor. 0-12" preferred for surface use., 12-60" acceptable for surface use. Profile located on alluvial remnant. Channel erosion exposures show an excess of 120" of alluvial mtrl., profile similar to #21. 2-4% irregular alluvial slopes.

No. 23 1200'S.,650' W. of N¼ Cor. 0-18" preferred for surface use., 18-66" acceptable for surface use. Profile in an alluvial channel. Water table at 54".

No. 24 1700'E.,350' N. of W¼ Cor. 0-18" preferred for surface use., 18-42" acceptable for surface use., 42-120" best for use below surface. Iron stained sandy shales non to slightly saline. Gray sandy shales slight to mod. salinity. 6-8% side slope below sandy shale & sandstone crest.

No. 25 900'N.,600' E. of W¼ Cor. 0-6" preferred for surface use., 6-24" acceptable for surface use., 24-60" mod. saline. 8-16% complex side slope below sandy shale crest.

No. 26 1200'S.,1200' W. of NE Cor. 0-6" preferred for surface use., 6-30" acceptable for surface use., 30-48" carbonaceous mtrl. 6-8% complex side slope below sandy shale crest. Sandstone fragments scattered on surface.

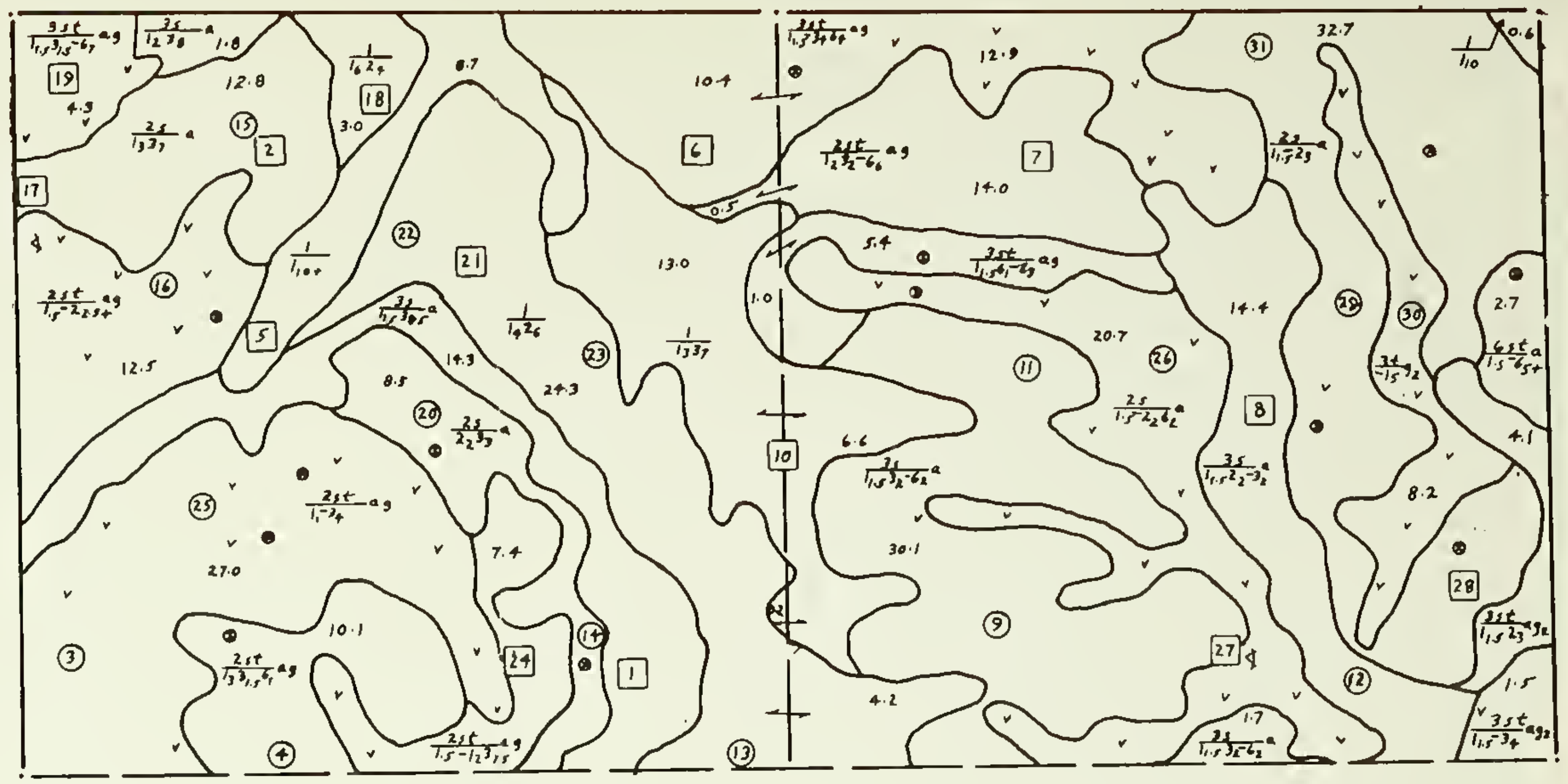
No. 27 1100'W.,400' W. of E¼ Cor. 0-6" preferred for surface use., 6-30" acceptable for surface use., 30-90" mod. saline. 90-120" very slowly permeable. 4-6% side slope with sandy shale crest. Fragmented sandstone from 12-24", semi-consolidated 24-36".

No. 28 650'N.,300'W. of E¼ Cor. 0-12" preferred for surface use., 12-72" acceptable for surface use. 72-120" best use below surface. Surface horizons have weak coarse prisms. Colluvial swale with 6% side slopes below sandy shale crests. Lime nettings at 60"+.

No. 29 1000'S.,650'W. of NE Cor. 0-18" preferred for surface use., 18-54" acceptable for surface use. Average depths of surface soils 18". A 50'W area has 24" very gravely loam over gravel & cobble exceeding 50% volume. 4-6% colluvial soil remnants on sandy shale crest.

No. 30 1050'S.,450' W. of NE Cor. 0-60"+ acceptable for surface use. Profile located on 35% side slope with sandy shales & rock outcrops. Sandstone fragments on surface. Layered gray and iron stained shale.

No. 31 950'W.,100'S. of NE Cor. 0-6" best for surface use., 6-36" acceptable for surface use., 36-60" mod. saline. 6-8% side slope below sandy shale crests. Deeper profiles in swales & lower elevations. Remnants of alluvial soils.



400 0 400 800
SCALE OF FEET
SEC. 4, T.9S., R.45E.

LAND CLASSIFICATION SYMBOLS

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

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- o Salinity
- s Sodicity
- 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 6' DEPTH

(3) SOIL PROFILE NUMBER

2.8---2.0 EC mmhos/cm. Sat. Ext.
8.4-8.0 8.4 pH: 6 Soil-Water Suspension; 8.0 pH Soil-$CaCl_2$ Suspension
.65 Hydraulic Conductivity in/hr. (Disturbed Samples)
24 Settling Volume

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	Silt Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

- Blowout
- Clay spot
- Gravelly spot
- Gumbo, slick or scabby 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
- Soil Profile (check)

WATER FEATURES

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

PITS

- Gravel
- Mine

DAMS

- Medium or small

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL SUBMITTED
DRAWN V. LINDSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA MAY 1976 1305-600-69

No. 1 600'S.200'E. of NW Cor. 0-12" preferred for surface. 12-60" acceptable for surface use. 60-120" slightly saline for use below surface materials. 2-4% alluvial slopes below bench remnants.

No. 2 1150'N.450'W. of SE Cor. 0-12" preferred for surface. 12-66" acceptable for surface use. 2-4% complex footslopes below high bench remnants.

No. 3 250'N.650'E. of W¼ Cor. 0-18" preferred for surface. 18-96" acceptable for surface use. Colluvial fair with 0-2% slopes.

No. 4 1250'S.350'E. of NW Cor. 0-12" preferred for surface. 12-72" acceptable for surface use. 2-4% complex slopes on an isolated alluvial high. Buried horizon at 48". Lime nettings from 72-84". Profile similar to #1.

No. 5 600'N.250'E. of W¼ Cor. 0-36" acceptable for surface use. 2-4% complex slopes on crest of bench remnant. Area has 8-35% complex side slopes with sandy shale outcropping.

No. 6 750'E.650'N. of W¼ Cor. 0-12" preferred for surface. 12-120" acceptable for surface use. 0-2% complex alluvial slopes. Channeling in area. Texture breaks organic. Lime nettings at 6"+. Profile similar to #2.

No. 7 1200'S.150'E. of NW Cor. 0-48" preferred for surface. 48-120" acceptable for surface use. 8-10% complex side slopes. Crests with a thin, gravely alluvial terrace remnant over sandy shale.

No. 8 700'E.150'S. of NW Cor. 0-18" acceptable for surface use. 18-120" mod. saline. 2-4% complex side slope below sandy shale crests. Thin surface horizons over Bca to 18". Scattered slickspots in area.

No. 9 1200'W.700'S. of N¼ Cor. 0-18" preferred for surface. 18-120" acceptable for surface use. Complex colluvial 2-4% slopes. Bleached thin surface horizons over columnar prisms from 6-18". Lime nettings at 84"+.

No. 10 1150'W.1050'S. of N¼ Cor. 0-18" preferred for surface. 18-72" acceptable for surface use. 72-120" slightly saline. 2-4% complex footslope below sandy shale crest. Thin bleached surface with Ap to 6". Prismatic columns becoming calcareous at 12-18". Lime nettings from 18-36".

No. 11 1200'W.900'S. of N¼ Cor. 0-18" preferred for surface. 18-72" acceptable for surface use. 72-120" slightly saline. 2-4% footslope profile with vesicular A_2 surface over columnar prisms at 18"+. Salt accumulations at 84". Lime nettings 102". Profile similar to #10.

No. 12 1000'S.500'W. of N¼ Cor. 0-18" preferred for surface. 18-120" acceptable for surface use. 2-4" footslope with sandy shale crest. Thin vesicular bleached A_2 over AB (old Ap) 1-3". Weak columnar prisms from 6-18". Noncalcareous to 13".

No. 13 550'S.300'W. of N¼ Cor. 0-18" preferred for surface. 18-60" acceptable for surface. 60-120" very slowly permeable material. 4-6% side slope below sandy shale crest. Old plow zone over calcareous B horizon from 5-12". Cca horizon 12-18".

No. 14 900'W.450'S. of N¼ Cor. 0-18" preferred for surface. 18-30" acceptable for surface use. 30-60" mod. saline. 2-4% complex side slope. Thin surface horizons over Cca from 12-30". Profile similar to #17.

No. 15 650'W.150'S. of N¼ Cor. 0-18" mod. saline surface over mod. saline-alkali sandy shales. 2-4% complex side slopes. Salts not typical for area. Profile similar to #21.

No. 16 350'E.200'S. of N¼ Cor. 0-30" acceptable for surface use. 30-78" mod. saline. 78-120" mod. saline-alkali sandy shales. 4-6% complex side slopes with sandy shale crests. 35% slickspots in area. Strong solonitz profile with a thin bleached vesicular surface over strong columnar prisms to 30". Profile between panspots.

No. 17 850'E.400'S. of N¼ Cor. 0-36" preferrably for surface. 36-60" acceptable for surface use. 6-8% footslope swale with sandy shale crest. Area contains dissected strongly sloping escarpments up to 35%. 18" average depth to sandy shales for area.

No. 18 900'S.600'E. of N¼ Cor. 0-18" preferred for surface. 18-120" acceptable for surface use. 0-2% alluvial soil off sandy shale crests. Vesicular bleached surface over 8A to 4". Weakly developed columnar prisms to 18".

No. 19 1200'S.700'W. of N¼ Cor. 0-6" preferred for surface. 6-18" acceptable for surface use. Soft sedimentary sandstone at 6"+. 8-12% side slope. Shale & sandstone outcropping on crests. Profile similar to #28.

No. 20 1550'S.150'E. of N¼ Cor. 0-12" preferred for surface. 12-120" acceptable for surface use. 2-4% complex foot slope at base of sandy shale crest. All textures a light clay loam.

No. 21 1500'S.500'E. of N¼ Cor. 0-24" preferred for surface use. 24-60" mod. saline with alk. influence. 6-8% complex side slope with sandy shale crest.

No. 22 750'S.750'W. of NE Cor. 0-18" preferred for surface. 18-48" acceptable for surface use. 2-4% complex alluvial bench with sandy shale crests. Few large pieces of sandstone and scattered slickspots in area. Strong A_2 over old plow zone 5". Strongly developed B horizon with moderate medium columns.

No. 23 1300'S.100'W. of NE Cor. 0-18" preferred for surface. 18-102" acceptable for surface use. 102-120" mod. saline. 2-4% slopes, alluvial channel, slickspots in area. Vesicular A_2 over AB to 5". Strongly developed prisms breaking to strong blocks.

No. 24 800'N.200'W. of E¼ Cor. 0-18" preferred for surface. 18-36" acceptable for surface use. 36-120" mod. saline. 4-6% alluvial foot slope below sandy shale crest. 1" vesicular A_2 over weak, coarse prismatic/blocky B. Lime nettings from 18-30". Ca from 18-30". 120'SE. 66" over sandy shales.

No. 25 900'W.700'W. of E¼ Cor. 0-18" preferred for surface use. 18-30" slightly saline. 30-48" mod. saline with carbonaceous influence. 8-12% side slope with sandstone on surface below sandy shale crest. Profile similar to #26.

No. 26 650'W.100'N. of E¼ Cor. 0-18" preferred for surface. 18-30" acceptable for surface use. 30-120" mod. saline. 6-8% complex footslope with sandy shale crests. Slickspots in area.

No. 27 1200'W.400'N. of E¼ Cor. 0-18" preferred for surface. 18-30" acceptable for surface use. 30-120" mod. saline. 6-8% complex footslopes with sandstones & sandy shale crests. Profile similar to #24.

No. 28 1350'W.850'N. of E¼ Cor. 0-12" preferred for surface. 12-24" acceptable for surface use. 24-36" mod. saline. 6-8% complex footslope with sandy shale crests. Stratified sandy shales with degree of oxidation at 12"+.

No. 29 1200'W.150'S. of E¼ Cor. 0-12" preferred for surface. 12-54" acceptable for surface use. 2-4% complex slopes with 15% slickspots in area. 0-12" thin surface horizon.

No. 30 1150'W.200'S. of E¼ Cor. 0-18" preferred for surface. 18-54" acceptable for surface use. 54-120" mod. saline. 2-4% complex footslopes of sandy shale crest. Lime nettings 18-54". Profile similar to #24.

No. 31 1350'W.300'W. of SE Cor. 0-18" preferred for surface. 18-78" acceptable for surface use. 6-8% complex footslope with sandy shale crests. Thin surface horizons over calcareous prisms to 18". Profile similar to #33.

No. 32 650'W.500'N. of E¼ Cor. 0-6" acceptable for surface use. 6-66" saline-alkali carbonaceous influenced sandy shales. 66-120" mod. saline. 8-35% complex sandy shale crest.

No. 33 1100'S.900'W. of E¼ Cor. 0-18" preferred for surface. 18-60" acceptable for surface use. 60-120" mod. to slightly saline at 84". 4-6% complex footslope with degraded slickspots in area. Thin surface horizons over Cca at 18"+.

No. 34 1150'W.700'S. of E¼ Cor. 0-18" preferred for surface. 18-72" acceptable for surface use. 2-4% complex alluvial soil with 45% degraded slickspots. Bleached platy surface with old plow layer 6". 6-18" noncalcareous prisms. Many lime nettings at 30"+.

HOLE 35 FOLLOWS 65

No. 36 2100'N.200'E. of S¼ Cor. 0-18" preferred for surface use. 18-66"+ acceptable for surface. 4-6% complex side slope below moderately sloping sandy shale crest.

No. 37 2150'N.300'E. of S¼ Cor. 0-42" acceptable for surface use. 42-120" for use below surface materials. 4% complex alluvial footslope.

No. 38 2500'W. 200'N. of E¼ Cor. 0-24" preferred for surface use. 24-120" acceptable for use below surface materials. 2-4% complex alluvial bench below sandy shale crests.

No. 39 2050'E.150'S. of W¼ Cor. 0-18" preferred for surface use. 18-120"+ acceptable for surface use. 12-16% complex side slope near sandy shale crest. Flagg sandstone outcropping on surface. Profile with little or no soil development. Sandstone at 108"+.

No. 40 1200'E.300'N. of W¼ Cor. 0-18" acceptable surface use. 18-54" acceptable for use below surface. 54-66" acceptable for surface use. 2-4% complex alluvial bottom with meandering channel.

No. 41 1100'E.500'S. of W¼ Cor. 0-18" preferred for surface. 18-66" acceptable for surface. 66-120" for use below surface materials. 0-2% complex alluvial bottom below sandy shale crests. Lime nettings from 18-30".

No. 42 500'S.250'E. of W¼ Cor. 0-30" preferred for surface use. 30-60" subsurface use. 8-35% complex side slopes with sandy shales and sandstone outcropping.

No. 43 1200'N.800'E. of SW Cor. 0-18" preferred for surface use. 18-42" acceptable for surface. 4-8% complex slopes below sandy shale crests. Ridges are from 8-35% slopes with sandy shale & sandstone outcropping. Lime nettings from 6-42".

No. 44 600'N.400'E. of SW Cor. 0-24" acceptable for surface use. 24-96" acceptable for use below surface materials. 2-4% complex slope on top sandstone & sandy shale crest. 72-96" soft sandstone. 96"+ sandstone, alkali influence in area.

No. 45 1000'E.300'N. of SW Cor. 0-24" preferred for surface use. 24-120" acceptable for surface use. 2-4% complex footslope below sandy shale crest.

No. 46 1400'E.150'N. of SW Cor. 0-12 & 84-120" acceptable for surface. 12-84" for subsurface use. 0-2% complex alluvial bottom with meandering streambed.

No. 47 1250'N.1050'W. of S¼ Cor. 0-12" preferred for surface. 12-120" acceptable for surface use. 2-4% complex alluvial bottom with meandering streambed.

No. 48 700'N.500'W. of S¼ Cor. 0-60" acceptable for surface use. 60-120" for subsurface use. 4-6% complex footslopes below sandy shale & sandstone crest. 18-36" lime nettings, 108-120" lime nettings.

No. 49 1850'E.600'S. of W¼ Cor. 0-54" acceptable for surface use. 6-8% complex side slope with sandy shale crest. Moderately deep profiles to shales in area. 36-54" texture approaching heavy sandy loam. Gray oxidized sandy shales @ 12"+.

No. 50 1500'N.550'W. of S¼ Cor. 0-30" acceptable for surface use. 54-120" for subsurface use. 4-8% complex side slope below sandy shale crest. Stratified calcareous material with baked rock fragments. Alkali influencing area.

No. 51 600'N.450'E. of S¼ Cor. 0-42" acceptable for surface use. 6-8% complex slope on top of bench remnant. Sandy shale & sandstone in area. Lime modules from 18-36". Shallower profiles in the area.

No. 52 1000'N.750'W. of SE Cor. 0-24" preferred for surface. 24-120" acceptable for surface use. 2-4% complex alluvial bottom with meandering streambed.

No. 53 1200'N.400'W. of SE Cor. 0-12" acceptable for surface. 12-48" subsurface use. 4-6% complex side slope below sandy shale crest.

No. 54 450'S.200'W. of E¼ Cor. 1-12" acceptable for surface. 12-72" subsurface use. 2-4% complex slopes on crest with 8-35% side slopes.

No. 55 850'S.350'W. of E¼ Cor. 0-12" preferred for surface use. 12-84" acceptable for surface. 84-120" subsurface use. 2-4% complex alluvial bottom below sandy shale crests. Crusty profile to 84". Salts at 102"+.

No. 56 850'W.350'N. of SE Cor. 0-12" preferred for surface. 12-60" acceptable for surface. 60-102" for subsurface use. 4-6% complex foot slope below sandy shale crest. Fragmented gravels & crusty 12-36".

No. 57 1150'N.900'E. of S¼ Cor. 0-12" preferred for surface. 12-54" acceptable for surface. 4-6% complex alluvial crest with 8-35% side slopes. Profile 300'N. with sandy shale at 24" & sandstone at 30".

No. 58 900'N.650'E. of S¼ Cor. 0-12" preferred for surface use. 12-48 acceptable for surface. 6-8% complex side slopes below sandstone & sandy shale crest. Profile at head of swale. Bedrock at 72"+.

No. 59 2000'E.250'N. of S¼ Cor. 0-24" preferred for surface use. 24-84"+ acceptable for surface. 0-6% complex side slope below sandy shale crest.

No. 60 1250'S.850'W. of N¼ Cor. 0-24" preferred for surface use. 24-120" acceptable for surface. 2-4% complex alluvial bottom. Profile similar to #59 in development but lacks depth. Lime nettings from 24-66".

No. 61 1600'S.650'W. of N¼ Cor. 0-24" preferred for surface use. 24-120" acceptable for surface. 2-8% slopes adjacent to meandering alluvial bottom.

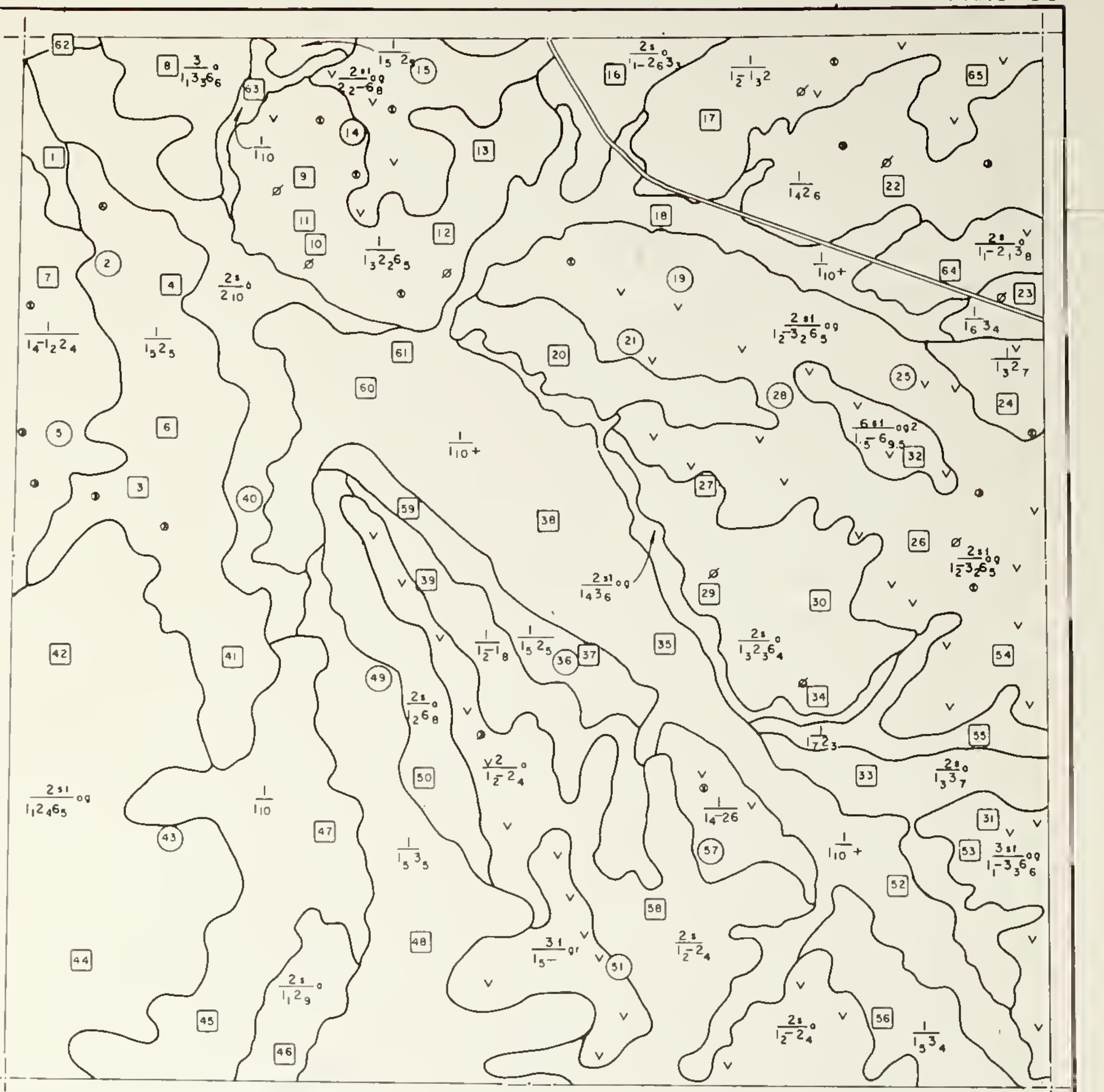
No. 62 200'E.50'S. of NW Cor. 0-24" acceptable for subsurface use. 24-90"+ acceptable for surface use. 0-2% alluvial bottom adjacent to meandering stream. Salts at surface. Water table at 60".

No. 63 1200'E.250'S. of NW Cor. 0-24" preferred for surface use. 24-120 acceptable for surface. 0-2% alluvial slope below sandy shale crests.

No. 64 1200'S.450'W. of NE Cor. 0-24" acceptable for surface. 24-120" subsurface material. 2-4% complex side slope with sandy shales outcropping in area. Salt crystals from 72-120".

No. 65 350'W.200'S. of NE Cor. 0-18" & 48-120"+ preferred for surface use. 18-48" acceptable for surface. 4-8% complex side slope with shales and sandstone outcropping in the area.

No. 35 1900'W.450'S. of E¼ Cor. 0-18" preferred for surface 18-120" acceptable for surface use. 0-2% complex slopes, alluvial channel. Thin surface horizons over stratified blocky materials at 8"+.



LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 — Plant media deficiency s — Topographic deficiency t — a g Informative symbols

SURFACE LAYER: Quality, Depth — 2_5

SECOND LAYER: Quality, Depth — 3

| — Divides soil material and nonsoil material

GEOLOGIC MATERIAL: Quality, Depth — $G3_2$

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- a Salinity
- s Sodicity
- 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 8' 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

L.t.C — .85 Hydraulic Conductivity In/hr (Disturbed Samples); 24 — 24 Settling Volume

Gr.

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	Silt Clay Loam
SC	Sandy Clay
C	Clay
SIC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

SEC. 11, T 9S., R 45 E

400 0 400 800 SCALE OF FEET

N

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
- Soil Profile (check)

WATER FEATURES

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

PITS

- Gravel
- Mine

DAMS

- Medium or small

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BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

DETAIL LAND CLASSIFICATION

SOILS T. FIECHTL SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MAY 1976 1305-600-70

Table 27 Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
1	32	Land in this class has an average minimum depth of 36 inches of good and high quality overburden that is suitable for plant media. Usually this material is soil that has formed on deep alluvial, 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, foot slopes, 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 big and silver sage and some 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 6-12 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
2s	22	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 largely medium and moderately fine textured soil that has formed deep colluvial and alluvial deposits and moderately deep residual soils. Textures range from sandy loams to clay loams. 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: clay rich layers, 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 moderate rate, but the internal water movement is adequate to provide aeration of the primary plant 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 foot slopes, side slopes, 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 fringed sagewort, rabbitbush, silver sage, and winterfat and some 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 the best use of available material in this land class. With proper selection and placement, reclamation should not be difficult and average management should assure successful permanent revegetation.
2st	10	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 to steeply sloping land areas between the ridge crests and natural drainageways. Complex slope pattern is common in this class and this makes selective stripping more difficult. There will be some mix of surface and subsurface material. There are, however, some single plane and undulating simple 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. This will also be a guide for placement in a reconstructed profile. The last paragraph describing management of Class 2s applies to this class also.

Table 27 Description of Land Classes (Con't)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
3s	11	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 is largely medium to moderately fine textured soil that has formed on alluvial and colluvial deposits. The principal limiting 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 moderately slow but internal water movement is only moderately restricted and the soluble salts can be leached. Locally clay rich soils and sodic soils occur and will be included in the stockpiled material for plant media, but they occur only as minor inclusions.	The surface relief comprises nearly level alluvial terraces and adjacent foot slopes along perennial and some 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 big and silver sage. Some tracts produce alfalfa and mixed grass hay and a few poorly drained tracts grow only salt grass.	These soils will be slightly susceptible to water erosion. This hazard can be minimized by roughing the surface of the reconstructed profile. Pitting or gouging basins will retard erosion and promote leaching of soluble salts below the primary root zone. Mulches can also be used to reduce erosion. These measures can increase the effective leaching of soluble salts and increase production capability. Successful permanent revegetation can be accomplished, but above average 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 subsoil and substratum.
3st	13 1/	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 are common along ridge crests and near sandstone outcrops. 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 that will most likely be included in the stockpiled material occur as small inclusions.	The surface relief of land in this class is characterized by complex gentle to steep slopes below ridge crests. Erosion is active on the steeper slopes and many small areas of shale and sandstone outcrops are visible. Steep slopes, sandstone and shale outcrops, and dendritic drainage patterns will make uniform stripping impossible. Native mid and short grasses grow in association with scattered big and silver sage and some 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.

1/ Includes 1 percent of 3t land.

Table 27 Description of Land Classes (Con't)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
6s	10 2/	Land is 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, and saltbush in some tracts. Scattered big and silver sage also occur in this class.	A careful review of the data and field checking to locate the small inclusions of better soil is warranted. This combined with selective stripping can do much to reduce the amount of overburden that must be borrowed or modified. Temporary irrigation, pitting, and gouging basins to increase leaching may adequately modify some material. However, borrowing from nearby deep good quality soil areas will probably be the most economical method of permanent revegetation.
6st		Land in this class has 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 steep slopes below ridge crests. Active erosion locally may expose sandstone or shale in up to 25 percent of any tract. The dendritic drainage pattern reates complex slopes that preclude uniform selective stripping of most tracts. Locally the topography is favorable for selective stripping some of the deeper soils. Native mid and tall grasses grow in association with torbes, sedges, and big and silver sage. This land is used for range.	Tracts with deeper soils and good quality geologic strata, though small, should be selectively stripped. Modification by leaching should be considered if water is available. Roughing the surface, pitting, and gouging basins can also increase 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/ Class 6 land, 6s and 6st were tabulated together.

The results of the land classification survey are recorded graphically on detailed maps, plates 28 through 33, which show the areal distribution, profile notes, and the results of laboratory tests. This information is summarized as depth of usable material, on plate 34, and an isosalinity mopan, plate 35. The following tabulation lists the acres of land in each section by classes and subclasses.

BEAR CREEK STUDY AREA
RESULTS OF LAND CLASSIFICATION

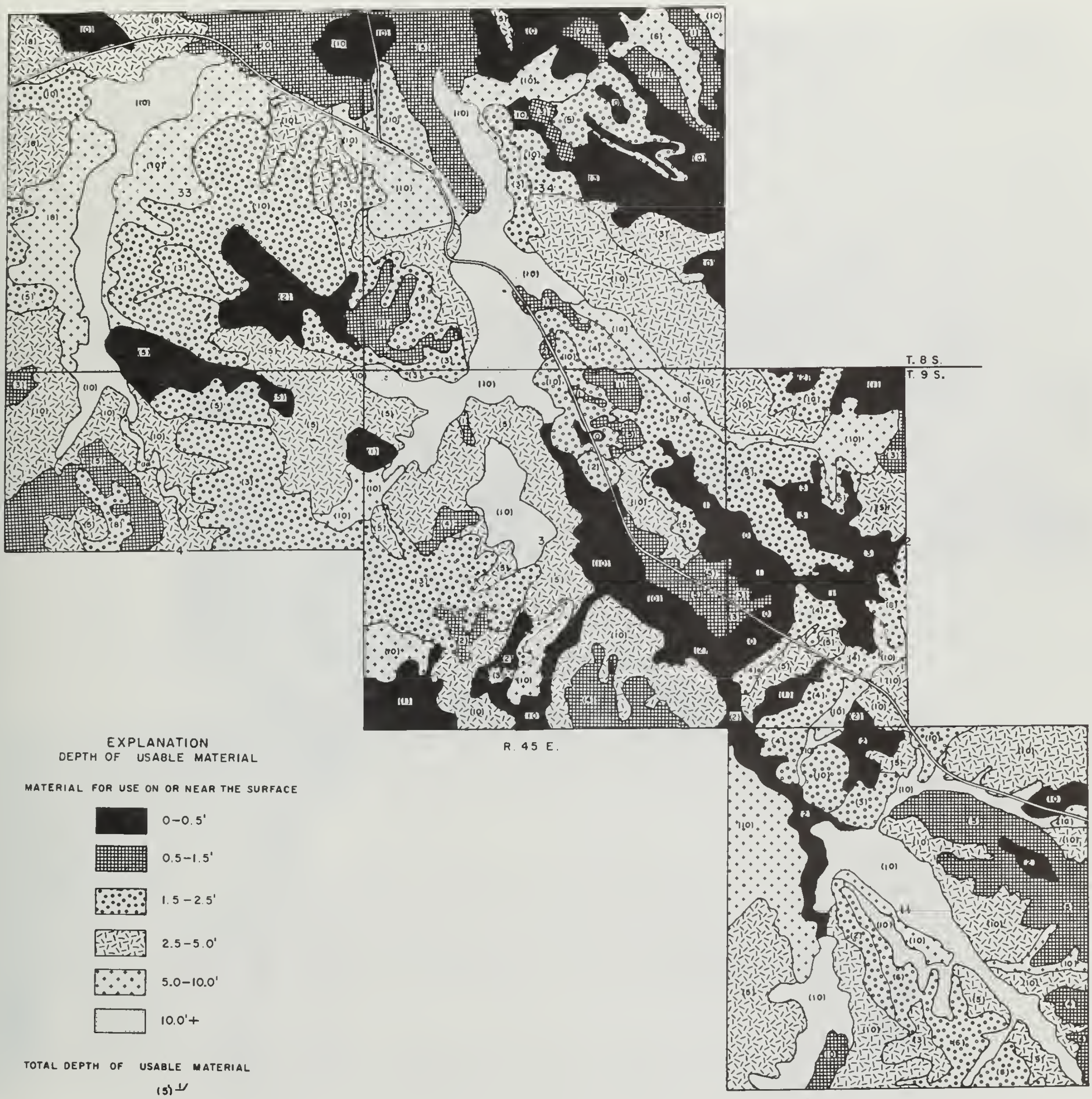
T.9S.,R.45E.	1	2s	2t	2st	3s	3t	3st	6	ROW	H	Total
Sec. 2	62.5	94.3			53.2.	13.4	28.0	66.3	2.3		320.0
Sec. 3	158.7	190.6	4.1	37.6	69.5		90.1	86.2	3.2		640.0
Sec. 4	60.7	74.7		71.5	62.6	8.2	39.6	2.7			320.0
Sec. 11	333.4	132.6		139.1	9.2	10.7	8.8	4.8	1.4		640.0
Total	615.3	492.2	4.1	248.2	194.5	32.3	166.5	160.0	6.9		1920.0
T.82.,R.45E.											
Sec. 33	164.4	152.4		50.1	38.8		166.7	58.0	8.1	1.5	640.0
Sec. 34	255.6	67.9		20.7	112.2		57.3	117.0	8.3	1.0	640.0
Total	420.0	220.3		70.8	151.0		224.0	175.0	16.4	2.5	1280.0
TOTAL	1035.3	712.5	4.1	319.0	345.5	32.3	390.5	335.0	23.3	2.5	3200.0

Analyses of the collected soil samples were used to confirm the field evaluation. Screenable testing procedures were used to evaluate soil structure stability, pH, and salinity. These were followed by tests to further evaluate indicated deficiencies uncovered in the initial tests. Exhibit 1, appendix F, explains the soil laboratory characterization program.

A soil laboratory was used in connection with the land classification survey and screenable tests were performed on all soil samples. These tests include pH, settling volume, disturbed hydraulic conductivity, and the soluble salts of a saturation extract. More detailed soil analyses were made as required. Complete soil analyses were made of samples from profiles representative of major soil categories for the land classification and soil inventory. Tests and analyses listed in exhibit 3, appendix F, were performed as needed for proper overburden evaluation.

In addition to the foregoing testing program, greenhouse pot studies were made on selected samples to indicate possible toxic or other unfavorable conditions for plant growth. With the procedures used in the greenhouse studies, the results do not reflect adverse physical conditions or nitrogen and phosphorous deficiencies.

The land classification survey provides adequate data for developing the reclamation portion of the required mining plan. It does not, however, provide adequate detail for stripping and stockpiling operations immediately prior to surface mining. Although procedures similar to those listed in the land classification can be used, additional field borings and observations supported by laboratory data may be required to more accurately



EXPLANATION
DEPTH OF USABLE MATERIAL

MATERIAL FOR USE ON OR NEAR THE SURFACE

- 0–0.5'
- 0.5–1.5'
- 1.5 – 2.5'
- 2.5–5.0'
- 5.0–10.0'
- 10.0'+

TOTAL DEPTH OF USABLE MATERIAL

(5) 1/

1/ Additional material over the amount indicated by the zipatone symbols will require special placement. High salinity is common.

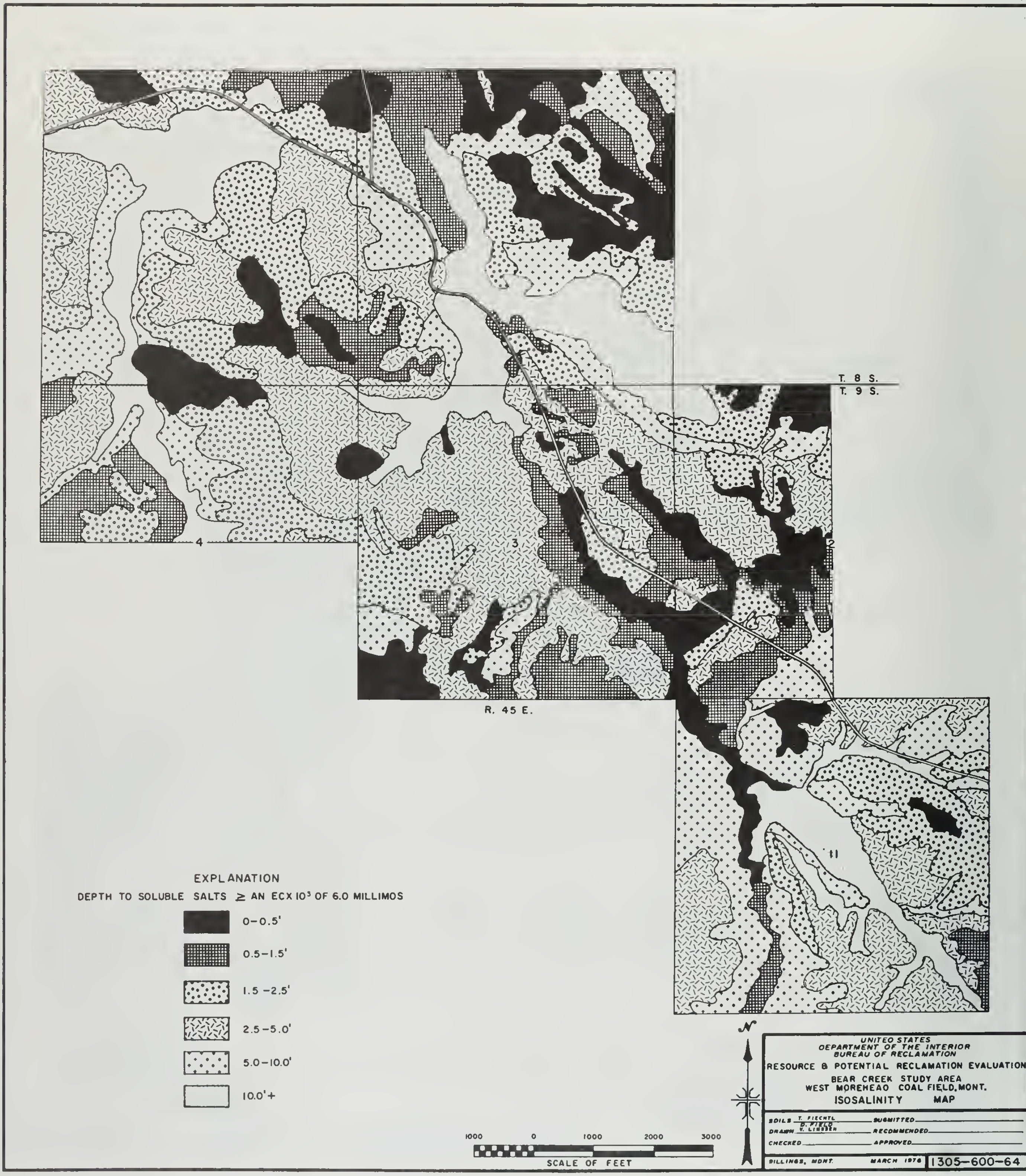
NOTE

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 the 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, but it is usually highly saline. However, the soluble salts will readily leach from material subjected to downward movement of natural precipitation.

1000 0 1000 2000 3000
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOREHEAD COAL FIELD, MONT.
DEPTH OF USABLE MATERIAL

SOILS T. FIECHTL SUBMITTED
DRAWN D. FIELD / E. LINDSEY RECOMMENDED
CHECKED APPROVED
BILLINGS, MONT. MARCH 1976 1305–600–57


33
34
T. 8 S.
T. 9 S.
4
3
2
11
R. 45 E.
EXPLANATION
DEPTH TO SOLUBLE SALTS ≥ AN ECX 10³ OF 6.0 MILLIMOS
0–0.5'
0.5–1.5'
1.5–2.5'
2.5–5.0'
5.0–10.0'
10.0'+
1000 0 1000 2000 3000
SCALE OF FEET
N
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOREHEAD COAL FIELD, MONT.
ISOSALINITY MAP
SOILS T. FIECHTL
D. FIELD
DRAWN V. LIEBSER
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
BILLINGS, MONT.
MARCH 1976
1305–600–64

determine the quantity, location, and quality of the available material suitable to be stockpiled for planting media.

Overburden Suitability

The land classification survey of study area lands was made to characterize their suitability for use as plant media if the area is surface mined. Data considered in determining the usable material from the soil mantle and the bedrock include: quality, quantity, ease of stripping and stockpiling and other factors affecting its use for revegetation.

Soil Mantle Suitability

The A and B horizons of most soils in the study area are nonsaline, nonsodic, and are well suited, if mixed, for resurfacing shaped spoils. Most of the soil organic matter is contained in these horizons. Stripping the horizons separately is impractical because the A horizon is only a 2- to 6-inch layer.

The soluble salts have leached to a depth of about 24 inches in deep loamy soil profiles with good permeability. This material includes the A, B, and part of the C horizon. It is of good quality and is suitable for use as plant media without modification. Soluble salts often remain near the surface in shallow AC profiles, in slick spot soils (saline-sodic), and in seep areas. Some of this material will leach and reclaim readily if placed over spoils with good internal drainage. Sodic material is usually only suited for subsurface layers in reconstructed profiles.

The land classification maps show the location and areal distribution of all suitability classes which record the total suitability of each delineation. The depth and quality of the soil material is shown in the land classification symbol. This information is shown on plates 28 through 33.

The mix of deep alluvial, colluvial and shallow residual soils will provide adequate good quality soil material for reclamation and revegetation to native species. Local tracts of clay-rich saline or saline sodic soil will require borrowed soil material from adjacent tracts or good quality bedrock material.

The boron content was determined on selected sample that represents major soils and the geologic section. These results are given on the soil mastersite analyses form, tables 20 through 25 and table 28, appendix F. Trace metals were determined on geologic profile No. 104. The results are on table 29, appendix F.

Bedrock Suitability

A systematic evaluation was made of the core material described in plates 10 through 18, appendix B. The evaluation was made on basis of the applicable part of the specifications used on the land classification, table 26. The bedrock core material was processed and analyzed in the laboratory and greenhouse using the same procedures as used on the soil samples. Simulated weathering was applied to selected samples to give some indication of how the material would break down when exposed to the weather. The results from these tests and the core descriptions (plates 10 to 18, appendix B) provided the basic data used in making the evaluation. Interpretations are shown on tables 30 and 31, appendix F.

Although similar criteria were used on the land classification and core evaluation, different suitability classes were used on the core material and relates only to quality. The "suitable" class is equivalent to classes 1 and 2 in the land classification, "limited suitability" to class 3, and "unsuited" to class 6. The type and quality of the geologic material is quite diverse and projection of the chemical and physical properties important to its use as a plant media cannot be accurately projected for any great distance. Therefore, the quality determination of the core material for revegetation applies only to the specific site where the core was drilled. No attempt was made to project the data to adjacent areas. The ability and ease of separating and stockpiling bedrock material for surfacing, if it should be needed, was not a factor in the classification except in very thin potentially suitable layers deep in the geologic profile.

The consolidated bedrock in the Bear Creek area is generally unsuited for use as plant media at or near the surface of a reconstructed profile in a surface-mined tract. In most geologic profiles, desirable material may occur in thin layers that would be difficult or impossible to separate and use for plant media. Material that may be made suitable by modification, i.e., leaching, mixing, soil amendments, etc., is also present if better material is not available. Most of the bedrock material lacks stability and is moderately slowly to slowly permeable. These factors increase the hazard to new seedlings from erosion and could cause massive movement of sediment through sheet erosion and piping. The lack of water penetration could also result in drouthy soil conditions and poor vegetative cover.

The deep bedrock is usually nonsaline to slightly saline and instability caused by excessive sodium is a major limitation in some layers in each geologic profile. Carbonaceous shales were considered unsuitable although the material does not appear too adverse. pH is usually neutral to slightly acid.

Greenhouse Studies

Plants germinated and grew in all bedrock samples included in the greenhouse studies. Plant yields under this controlled condition ranged from 20 to 120 percent of the control sample. The most variable yields occur in samples that had a conductivity range of 0-2 millimhos. The most uniform yields, when compared with the control samples, were in the 6-8 millimhos conductivity range. Black tips were noted in some pots and few selected samples were tested for soluble boron. No toxic levels were found in the bedrock material.

The data collected and interpretations made of the bedrock material should provide adequate information for development of revegetation procedures for a mining plan. It appears that there is sufficient suitable soil material near the surface for resurfacing spoils after mining so that bedrock material will not be needed for plant media in the primary plant root zone. Therefore, it is doubtful if additional study of the bedrock over the coal will be necessary to locate plant media. Additional study may be necessary to determine if toxic materials are present and to determine their placement during mining operations. Table 29, appendix F, records the results of analyses for trace metals in the geologic strata.

Soil Inventory

A high intensity soil inventory was made in the Bear Creek Study Area to obtain soil and environmental data. Data from the inventory shall be used to develop multiple resource management plans. Soil interpretations will be used by the BLM that relate to land management before mining activities occur.

The taxinomic classification of the soils is evenly divided between Aridisols and Entisols. The areal distribution of the Entisols is much greater. All taxinomic units and mapping units are described as to their genetic characteristics, land form position, and technical evaluation related to management. The results of this inventory are shown on plates 36 through 41, appendix F. Other soil inventory data included in appendix F are: interpretive ratings for soil uses, tables 32 and 33; engineering properties, table 34; soil profile descriptions, BLM Form 7310-12; and erosion evaluation, exhibit 2.

Description of Soils

This section describes the soil series and mapping units in the Bear Creek Study Area, Montana. The areal distribution of the soil series and associations are shown on plates 36 through 41, appendix F. The slope and textural groups and erosion class are shown by the mapping unit symbol.

The procedure in this section is first to describe the soil series and the mapping units in the series. The soil series description mentions features that apply to all soils in the series. Differences among soils of a series are pointed out in the description of the individual soils or indicated in the soil name. Soils that are mapped only in a complex or association are described under the name of the complex or association unless otherwise stated. The description of all mapping units in this study area are for dry soils. Not all mapping units are members of soil series. For example, rock outcrop is a land type and does not belong to a soil series.

An essential part of each soil series is the description of a typical soil profile, the sequence of layers beginning at the surface and continuing down to the depth beyond which roots of most plants do not penetrate. Each soil series contains a short description of a typical profile.

The following tabulation lists the acreage and percent of area occupied by each soil:

Soil		Series		Associations							
No.	Name	Map Symbols	Acres	03-02	03-12	03-013	08-020	012-013	018-013	Total Acres	%
9001	Haverson	01	10							10	.3
9002	Thurlow	02	44	14						58	1.8
9003	Midway	03	30	18	382	307				737	23.0
9004	McRae	04	18							18	.6
9006	Unnamed	06	76							76	2.4
9008	Ringling						60			60	1.9
9010	Heldt	010	1,018							1,018	31.8
9011	Cabba	011	12							12	.4
9012	Cushman				109			207		316	9.9
9013	Elso					154		60	10	224	7.0
9014	Haverson Channeled	014	109							109	3.4
9015	Haverson Saline	015	32							32	1.0
9016	Haverson Silty Clay Loam	016	110							110	3.4
9017	Hesper	017	96							96	3.0
9018	Hydro	018	99						18	117	3.0
9019	Remit	019	10							10	.3
9020	Unnamed	020					60			60	1.9
Minor	Soils				55	51		30		136	4.3
	TOTALS		1,664	32	546	513	120	297	28	3,200	100

Soil 9001, mapping unit 01, comprises 10 acres which is 0.3 percent of the area. This soil consists of deep, well-drained, medium-textured alluvium on flood plain stream terraces and fans. The alluvium is from interbedded sandstone and shale and older alluvial deposits. Locally the alluvium is channeled. The vegetative cover is principally blue grama grass and needle and thread grass among scattered big sage. The general surface gradient is less than 2 percent. The average soil temperature is 47-49°F.

Typically, the surface layer is a pale brown silt loam or fine sandy loam about 6 inches thick. It includes the A and AC horizons. Below this, the C horizons are pale brown stratified sandy loams, silt loams, loams, and thin layers of sand. Depth to shale is usually over 10 feet.

Water enters the soil readily and moves freely through the profile. Moisture retention is moderate and soluble salt content is low. These characteristics reduce management problems. Slightly adverse properties include slight erosiveness to wind and water and low fertility.

Generally, this soil is a good source of soil material for use at or near the surface in mined land reclamation. Crops produced here on this soil are range and mixed hay (alfalfa-grass).

Soil 9002, mapping unit 02, comprises 44 acres which is 1.4 percent of the area. Soil in this mapping unit formed in deep, moderately-fine-textured material. Parent material includes local colluvium and residuum derived largely from shale. It occurs on terraces, fans and footslopes in the uplands and is moderately well drained. Slopes range from 4 to 25 percent. Scattered big sagebrush and silver sagebrush grow in association with mid and short grasses. The average soil temperature is 47-49°F. Another 14 acres of this soil is in mapping unit 03-02.

The surface layer is grayish-brown silty clay loam about 6 inches thick with medium subangular blocky structure. This soil is hard when dry and sticky and plastic when wet. The subsoil layer is a dark grayish-brown silty clay loam about 18 inches thick that grades to a pale olive brown with depth. Below this, the substratum is a pale brown calcareous silty clay loam and a pale yellowish-brown silty clay. Depth to shale ranges from 30 inches to more than 60 inches.

Water enters the soil at a moderate rate but movement through the profile is slow. Soils of this mapping unit are fertile and retain large amounts of moisture. They are usually nonsaline near the surface but the amount of soluble salts may be high below 24 inches. Adverse properties that may cause slight problems are surface erosiveness and salinity of the substratum.

These soils are now used for range and production of alfalfa and mixed grass hay. They are productive; but for maximum production, water management must be planned to increase moisture intake.

Soil 9003, mapping unit 03, comprises 30 acres, which is .9 percent of the area. This soil formed in shallow, moderately-fine textured weathered silty and clayey shales. They are residual and occur on rolling and hilly uplands. The slopes range from 4 to 15 percent. Local slope inclusions will range to 35 percent. Shale outcrops are common below ridge crests and actively eroding natural drains. The wide variance in the surface condition has resulted in a complex population of mid and short grasses. The average soil temperature is 47-49°F. About 704 acres of this soil is in other mapping units (M.U.) as follows: M.U. (03-02) 18 acres, M.U. (03-012) 359 acres, and M.U. (03-013) 328 acres.

Typically, the surface layer is a light yellowish-brown clay loam and clay about 7 inches thick. This material is hard when dry and sticky and plastic when wet. Below this is weathered shale which rests on consolidated shale.

The surface material is quite variable and its quality ranges from moderately permeable nonsaline to very slowly permeable sodium-affected material. Depth of surface soil ranges from 0 to 4 inches. Management problems include: susceptibility to water erosion and low fertility which will result in barren spots and poor plant populations.

This land is used only for range.

Soil 9004, mapping unit 04, comprises 18 acres, which is 0.6 percent of the area. This soil formed in deep, medium-textured and well-drained alluvium deposited on high tabular divides, stream terraces and footslopes. The parent material was eroded from interbedded sandstone and shale. Slopes range from 0 to 12 percent. Big sagebrush and silver sagebrush grow in association with mid and short grasses. The average soil temperature is 47-49°F.

Typically, the surface layer is grayish-brown silt loam about 9 inches thick. This soil is firm when dry and slightly sticky when wet. The subsoil and substratum are quite similar. This material is pale-brown calcareous silt loam or sandy loam that extends to a depth of more than 60 inches. Depth to shale may be as much as 20 feet.

Water enters and moves through this soil readily and surface runoff is slow. This soil retains a large amount of moisture for plant use and is productive. The substratum is calcareous; and if the vegetative cover is destroyed by erosion, the exposures continue to erode and do not revegetate readily. The electrical conductivity of the entire profile is low, usually less than 3 millimhos.

The soil is used largely for range, but it is well suited for limited or full irrigation where practical.

Soil 9006, mapping unit 06, comprises 76 acres, which is 2.5 percent of the area. Soils in this mapping unit are deep and well drained and consist of medium loamy alluvial/colluvial material. The deposits have not been altered appreciably by soil forming factors. This soil occupies narrow flood plains and coalescing fans in upland valleys of 100 to 300 feet wide.

This recently deposited soil is derived from sandstone and siltstone. Channel banks may be near vertical but the general slope gradient is usually less than 4 percent. Depth to shale ranges from 60 inches to more than 10 feet. The average soil temperature is 47-49°F.

Typically, the surface layer is grayish-brown silt loam about 7 inches thick. The next layer, a light brown clay loam, is about 9 inches thick. The calcareous substratum extends to the shale and is stratified. Textures range from sandy loam to silty clay loam.

The entire soil profile is permeable but water movement is often slightly to moderately restricted in the substratum. The upper solum contains a low amount of soluble salts and retains an adequate amount of water for plant use (6-10 inches). The entire profile is friable free-working material.

Soil 9008, is mapped in association with soil 9020 in mapping unit 08-020. There is about 60 acres of this soil. It is a loamy soil that occurs on knobs, sideslopes and ridges and has formed in decomposing baked sandstone and siltstone. Depth to this slightly weathered layer ranges from 8 to about 24 inches. Mid and short grasses grow in association with scattered big sagebrush and forbes. Ponderosa pine often grow around the edge of this mapping unit.

Typically, the surface layer is a reddish-brown friable loam about 6 inches thick. The subsoil is a friable reddish-brown loam or sandy loam that rests on pale reddish to reddish-gray parent material. Soil temperature averages 47-49°F.

Water enters this soil readily and moves rapidly into the underlying baked sandstone or fractured siltstone. A moderate-to-high amount of water is retained in the upper solum, but moisture retention of the substratum is low.

This soil is used for native range.

Soil 9010, mapping unit 010, comprises 1,018 acres, which is 31.8 percent of the area. These deep, moderately-fine-textured soils formed in colluvial and alluvial parent material that rests on shale. The depth to shale ranges from 4 to more than 10 feet. Land in this mapping unit most commonly occupies footslopes and low terraces with gradients of 0-8 percent. Scattered big sagebrush and silver sagebrush grow in association with mid and short grasses. The average soil temperature is 47-49°F.

Typically, the surface layer is a light grayish-brown clay loam about 10 inches thick. This soil is hard when dry and sticky and plastic when wet. The very pale brown subsoil is strongly calcareous and has prismatic structure to 36 inches. The substratum is highly calcareous and extends to the shale.

The natural fertility of this soil is moderately high and moisture retention is good. Limitations that require above-average management for maximum production are moderate infiltration, relatively slow internal water movement and moderate salinity in the lower solum. Where the soil is exposed on steep slopes, erosion and piping occurs.

This soil is used for dryland meadow and some mixed hay.

Soil 9011, mapping unit 011, comprises 12 acres, which is 0.4 percent of the area. This soil formed in shallow medium-textured material weathered from soft sandstone and shale on narrow ridge crests and tabular divides. These well-drained soils have formed on steep slopes in the uplands under mid and short grasses that grow in association with scattered big sagebrush and some ponderosa pine. The average soil temperature is 47-49^{o}F.

Typically, the surface layer is grayish-brown silt loam about 7 inches thick. The subsoil is a pale brown strongly calcareous silt loam and loam which extends to 16 inches. The underlying consolidated siltstones and sandstones are usually fractured.

This soil is moderately permeable and runoff is moderately rapid. A limited amount of water is retained for plant use. The erosion hazard is moderate under good native grass cover and severe in exposed tracts.

This soil is used for range but has limited carrying capacity.

Soil 9012, in this study area, is in mapping units 03-012 and 012-013 only. This soil consists of moderately deep, upland soil formed on residuum over soft shales. These well-drained soils are on complex side slopes of 4 to 15 percent. Native vegetation includes mid and short grasses, scattered big sagebrush and forbes. The average soil temperature is 47-49^{o}F. About 310 acres of this soil is mapped in association with 9003 (103 a.) soil and 9013 (207 a.) soil.

The surface layer, a light grayish-brown silt loam, is about 4 inches thick and the moderately developed grayish-brown subsoil is about 11 inches thick. The substratum is a light grayish-brown loam and fine sandy loam. Soft shales occur at about 26 inches.

Organic content and fertility are medium and the runoff is slow on these moderately permeable soils. They are moderately susceptible to wind erosion.

This soil is used for range but has limited capability for dryfarming.

Soil 9013, in this study area, is in mapping units 03-013, 012-013, and 08-013 only. This soil consists of well-drained medium-textured shallow residual upland soils that have formed from softly consolidated shales. They occur on tabular divides, narrow ridges and footslopes. The vegetative cover is largely mid and short grasses. Except for the low gradient tabular divides, the slopes range from 8 to 45 percent. The average soil temperature is 47-49^{o}F. This soil is mapped in association with other soils as follows: M.U. 03-013 10 acres, M.U. 012-013 60 acres, and M.U. 018-013 10 acres.

The surface layer is light grayish-brown silt loam about 6 inches thick. The subsoil is a light grayish-brown silt loam. Softly consolidated, interbedded clayey and sandy shale underlies the subsoil and rests on consolidated shale at a depth of less than 20 inches.

Runoff is moderate from this moderately permeable soil and a limited amount, 2 to 3 inches, of moisture is retained for plant use. The erosion hazard is severe.

This soil is used for range.

Soil 9014, mapping unit 014, comprises 109 acres, which is 3.4 percent of the area. This soil formed in well-drained medium-textured alluvium that is more than 60 inches deep. It occurs on narrow channeled flood plains with 0 to 4 percent slope. The channels are 5 to 15 feet wide and 4 to 6 feet deep. This soil developed under mid and short grass cover on alluvial deposits eroded from interbedded sandstone and shale. The average temperature is 47-49^{o}F.

The surface layer is light grayish-brown silt loam about 6 inches thick. The subsoil and substratum are similar and consist of calcareous stratified grayish-brown silt loam and light grayish-brown sandy loam. This material extends to the shale which is often more than 10 feet below the surface.

This soil is used mainly for dryland hay and small grains in this area, but usually produces range.

Soil 9015, mapping unit 015, comprises 32 acres, which is 1.0 percent of the area. Consists of subirrigated medium-textured soils that formed in loamy alluvium that is more than 60 inches deep. This soil is saline and it occupies part of the flood plains of large drainageways and small stream valleys. Slope gradients range from 0 to 4 percent. The average soil temperature is 47-49^{o}F.

Typically, the surface layer is a light brownish-gray silt loam about 6 inches thick. The grayish-brown and light grayish-brown subsoil and substratum are calcareous and include stratified layers of silt loam, fine sandy loam and silty clay loam. Shale underlies this material at a depth of more than 10 feet.

The soils are moderately slowly permeable but retain about 8 inches of available water in 5 feet. They are moderately to highly salinized and are generally unsuited for crop production.

This soil is generally used for range, but here it also produces poor crops of dryland hay.

Soil 9016, mapping unit 016, comprises 110 acres, which is 3.4 percent of the area. This soil consists of well-drained moderately-fine-textured soils formed in deep alluvial deposits on flood plains and footslopes. Mid and short grasses make up the vegetative cover on the low gradient, 0-2 percent, tracts. Scattered sage grow with the grass on footslopes. The average soil temperature is 47-49^{o}F.

The surface layer, a light brownish-gray silty clay loam, is about 6 inches thick. The subsoil and substratum of the flood plain soils are light brownish-gray and grayish-brown silt loam, fine sandy loam or loam, and are deeper than 60 inches. On the footslopes the stratified material is underlain by clay. Depth to shale is usually more than 10 feet.

This moderately slowly permeable soil has slow runoff. It retains much water for plant use but the fertility is low.

This soil is used for mixed alfalfa/grass, dryland hay, and range.

Soil 9017, mapping unit 017, comprises 96 acres, which is 3.0 percent of the area. This soil formed in well-drained moderately-fine-textured deep alluvium. It is more than 60 inches deep. This soil occurs on fans and footslopes. Slopes range from 4 to 15 percent. The native vegetation is mid and short grasses. The average soil temperature is 47-49°F.

The surface layer is a light brownish-gray silty clay loam about 4 inches thick. The subsoil layer is brown silty clay loam about 14 inches thick. The substratum is a light brown silty clay loam that extends below 60 inches. Lime increases below 14 inches and salt crystals are often visible in the lower substratum.

This soil is very fertile and retains much water for plant use. Permeability is moderately slow. On the steeper slopes runoff is rapid and the erosion hazard is great.

This soil is used for range, but may be used for dryland farming.

Soil 9018, mapping unit 018, comprises 99 acres, which is 3.1 percent of the area. This soil consists of well-drained moderately-fine-textured deep alluvium. It developed under mid and short grasses. The 9018 soil occurs on fans and footslopes with 0 to 8 percent slope. The average soil temperature is 47-49°F.

The surface layer is a light brownish-gray and grayish-brown silty clay loam about 5 inches thick. The subsoil is grayish-brown silty clay loam about 17 inches thick. It has strong prismatic structure and is limey in the lower part. The substratum is a grayish-brown and light brownish-gray silty clay loam. Gypsum crystals are present below 20 inches and extend to a depth of 60 inches.

Numerous micropits dot the surface of rangeland in this mapping unit. This soil condition appears as gray spots in cultivated land. A weak thick prismatic structure is common 2 inches below the surface. Permeability is moderately slow and the erosion hazard is moderate.

This land is used for range in this area but may also be used for dryfarmed alfalfa and small grains.

About 18 acres of this soil is mapped in association with soil 9013 in mapping unit 018-013.

Soil 9019, mapping unit 019, comprises 10 acres which is 0.3 percent of the area. This soil consists of well-drained soils that formed in deep fine sandy loam material that is underlain by softly consolidated shale beds. It occurs on footslopes and fans in the uplands and has a slope gradient of 2 to 25 percent. The average soil temperature is 47-49^{O}F.

The surface layer is grayish-brown fine sandy loam about 12 inches thick. Below this the subsoil is grayish-brown and light olive brown fine sandy loam that extends to about 48 inches. The substratum is a grayish-brown silt loam containing threads and nodules of lime. The soil color lightens with depth. Permeability of this soil is moderate and the runoff ranges from moderate on low slope gradients to rapid on steep slopes. Erosion is moderate under good native cover but is severe if the soil is exposed. The hazard from wind erosion is high on exposed soils.

Soil 9020, is mapped in association with soil 9008 in mapping unit 08-020. There are about 60 acres of 9020 soil. This soil formed in loamy alluvium on fans, footslopes and swales in the uplands. They are medium-textured and are over 60 inches deep. Slope gradients range from 4 to 30 percent. The native vegetation is mid and short grasses. The average soil temperature is 47-49^{O}F.

Typically, the surface layer is brown loam about 8 inches thick. The subsoil is a dark-brown loam 5 inches thick. Below this the substratum, a pinkish-gray loam, extends to a depth of 60 inches or more and is intermixed with and underlain by baked rock fragments. The substratum may contain 15 to 35 percent rock fragments.

Fertility and permeability are generally moderate and the water holding capacity is adequate for good plant growth. Erosion is not a hazard on gentle to moderate slopes but is severe on steep slopes.

Mapping Unit 08-020, comprises 120 acres, which is 3.8 percent of the area. The soils in this association, 9008 and 9020, have been described previously and are similar to their individual description. This association occurs on uplands and consists of 50 percent 9008 silt loam soil and 50 percent 9020 loam soil. The 9008 soil occupies steep knobs, ridges, and narrow divides. The 9020 soil is located on lower footslopes, swales, and drainways. Very minor inclusions of other soils may be found in this mapping unit.

These soils are used for range.

Mapping Unit 03-012, comprises 546 acres, which is 16.0 percent of the area. The soils in this association, 9003 and 9012, have been described previously and are similar to their individual description. This association occurs on uplands and is 70 percent 9003 soil, 20 percent 9012 soil, and 10 percent minor soils. The 9003 clay loam soil occupies knobs and narrow ridges. The 9012 silt loam soil occupies swales and smoother footslopes.

These soils are used mainly for range.

Mapping Unit 012-013, comprises 297 acres, which is 9.3 percent of the area. The soils in this association, 9012 and 9013, have been described previously and are similar to their individual descriptions. This association occurs on uplands and is about 70 percent 9012 silt loam soil and 20 percent 9013 silt loam soil, and 10 percent minor soils. The 9012 soil is on smooth footslopes and in swales. The 9013 soil is on knobs and narrow ridges.

These soils are used for grazing.

Mapping Unit 018-013, comprises 28 acres, which is 0.8 percent of the area. The soils in this association, 9018 and 9013, have been described previously and are similar to their individual descriptions. This association occurs on uplands and is about 65 percent 9018 silt loam soil and 35 percent 9013 silt loam soil. The 9018 soil occupies swales and footslopes, and 9013 soil occupies the knobs, smooth rounded ridges, and divides.

These soils are used for grazing.

Mapping Unit 03-013, comprises 513 acres, which is 17.2 percent of the area. The soils in this association, 9003 and 9013, have been described previously and are similar to their individual descriptions. This association occurs on uplands and is 60 percent 9003 soil and 30 percent 9013 soil and 10 percent other soils. The 9003 clay loam soil occupies the rounded convex ridges, divides and gully side slopes. The 9013 silt loam soil is on knobs and narrow ridges.

These soils are used for grazing.

Mapping Unit 03-02, comprises 32 acres, which is 10 percent of the area. The soils in this association, 9003 and 9002, have been described previously and are similar to their individual descriptions. This association occurs on uplands and is about 55 percent 9003 soil and 45 percent 9002 soil. The 9003 clay loam soil occupies the rounded convex ridges, divides, and gully side slopes. The 9002 silty clay loam soil occupies the footslopes and remnants of alluvial fans between the gullies.

These soils are used for dryland grazing.

The following tabulation lists the classification of the soil series:

State Number	Series	Family	Subgroup	Order
9011	Cabba	Loamy, mixed (calcareous) frigid, shallow	Typic Usthorthents	Entisols
9012	Cushman	Fine, loamy mixed mesic loamy, mixed (calcareous)	Ustollic Haplargid	Aridisols
9013	Elso	Mesic, shallow, fine-loamy, mixed	Ustic Torriorthents	Aridisols
9001	Haverson	(Calcareous), mesic	Ustic Torrifluvents	Entisols
9010	Heldt	Fine, montmorillonitic, mesic	Ustertic Cambor-thids	Aridisols
9017	Hesper	Fine, montmorillonitic, mesic	Ustollic Haplargids	Aridisols
9018	Hydro	Fine, montmorillonitic, mesic, fine-silty, mixed	Glossic Ustollic Natragids	Aridisols
9005	Lambeth	(Calcareous), frigid	Ustic Torriorthents	Entisols
9004	McRae	Fine-loamy, mixed, mesic clayey, montmorillonitic	Ustollic Cambor-thids	Aridisols
9003	Midway	(Calcareous), mesic, shallow	Ustic Torriorthents	Entisols
9019	Remmit	Coarse-loamy, mixed mesic	Ustollic Cambor-thids	Aridisols
9008	Ringling	Coarse-loamy, mixed	Typic Haploboralls	Mollisols
9020	Unnamed	Fragmental, mixed	Typic Haploboralls	Mollisols
9002	Thurlow	Fine, montmorillonitic, mesic	Ustollic Haplargids	Aridisols
9066	Unnamed)) Unnamed)	Can be classified from soil profile notes and chemical and physical data.		

GREENHOUSE

Introduction

In the past, surface mining for coal generally resulted in burying of the soil and then attempts were made to revegetate the spoil. The spoil left exposed was usually from the stratum directly overlying the coal seam and often was not a suitable plant growth medium.

It is visualized that in future surface mining operations, the soil will be conserved and replaced. However, in some areas the soil will be thin or less suitable as a plant growth medium than spoil generated from certain overburden strata. The objective of this greenhouse study was to evaluate the suitability of overburden as plant growth media.

Methods

Field Capacity

The initial task in the greenhouse study was to determine the field capacity of the overburden samples. The equipment used to determine field capacity was: plastic tubes 1 3/4 inches in diameter, plastic cups, and plastic sheets. Four hundred grams of each overburden sample was weighed and placed in the plastic cylinders which had been sealed at the bottom by a plastic sheet, and packed by tapping the side of the cylinder. Twenty milliliters of water was then added (5 percent of the overburden by weight) and the top was sealed with a plastic sheet. After 24 hours, the bottom plastic sheet was removed and the dry overburden fell into the plastic cup, leaving the moist overburden in the cylinder. The dry overburden was weighed and the field capacity (FC) calculated by the following equation:

$$FC = \frac{20 \text{ g } H_2O}{400 \text{ g} - \text{Weight of dry overburden}} \times 100$$

The field capacity percentage was the basis for the amount of water each pot received daily.

Fertilizer Treatments

Two thousand grams of each bedrock and soil sample were weighed into each of two pots. Each pot was fertilized with 100 ppm of nitrogen as reagent grade $Ca(NO_3)_2$ and 80 ppm phosphorus as reagent grade $Ca(H_2PO_4)_2H_2O$. The reagents were added in solution as 10 and 50 ml aliquots respectively, then mixed into the soils and overburden. Where sufficient soil material was not available for a 2 kg sample weights, the aliquot sizes were adjusted to maintain a fertility level of 100 ppm N and 80 ppm P.

Seeding and Growth

Western wheatgrass (Agropyron smithii var. Arriba) was the test species. This species was chosen because it is one of the most abundant native grasses in the western United States and will probably be used in many revegetation programs.

At the time of seeding, approximately 250 g. of overburden was removed from each pot. Then water was added to each pot to bring them to field capacity. Forty seeds were placed in each pot and the previously removed dry overburden placed on the seeds. All pots were then covered with paper to retard evaporation and to allow the water to move to the surface by capillary rise. The pots were checked daily and upon germination, each pot was uncovered and the date recorded. The date when ten plants had emerged and the severity of salt crusting were also recorded. After germination, all pots were weighed daily and deionized water was added to bring the soil to field capacity. Maximum water use was approximately 25 percent of field capacity per day.

When the majority of the plants, in all pots, reached a height of 10 cm, the number of plants in each pot was recorded and each pot was thinned to 16 plants.

Two highly productive loam soils were included in the experiment as overall standards (A_1 horizon Platner series and A_1 horizon Kimm series). Greenhouse data on the standard soils is included at the end of table 35, appendix G. Plants were harvested after 62 days following seeding (September 28 to November 29, 1975).

Harvesting

The plants were clipped at a height of 2 cm above the soil surface to minimize contamination by soil splashed on the plants during watering. The harvested plants were then washed in 0.05 normal HCl and rinsed in distilled water so tissue analysis could be done on the plant samples. The plants were dried in a forced air oven at 70°C for 24 hours and then weighed to the nearest 0.01 gram.

Observations taken at the time of harvest included (1) the presence of shoot growth from rhizomes; (2) the degree of soil surface cracking; (3) the amount of salt crusting, and (4) the average plant height.

In comparing average plant height and plant dry weight it can be seen that there is no direct correlation. These differences are believed to be partially due to variation in light response in different seasons. Also, within experiments, a portion of the variation appears to be related to the amount of shoot growth originating from rhizomes, in that overburden samples with a low yield and tall average plant height generally had very little or no growth from rhizomes while those samples with a high plant yield and a lower average plant height generally had a relatively large amount of growth from rhizomes. Also, the clayier samples generally had the largest amount of growth from rhizomes.

Results

Large differences in Western wheatgrass growth are evident on various overburden samples (photograph 6). Because there was a wide range on plant dry weights from the standard soils in the greenhouse experiments, relative yields will be used in this discussion. Actual and relative yields are presented in table 35, appendix G. Relative yield was calculated as a percentage of yield of the Platner standard soil from the respective greenhouse experiments. For purposes of this discussion relative yields less than 33 percent will be considered low, 33-67 percent medium, and above 67 percent high.

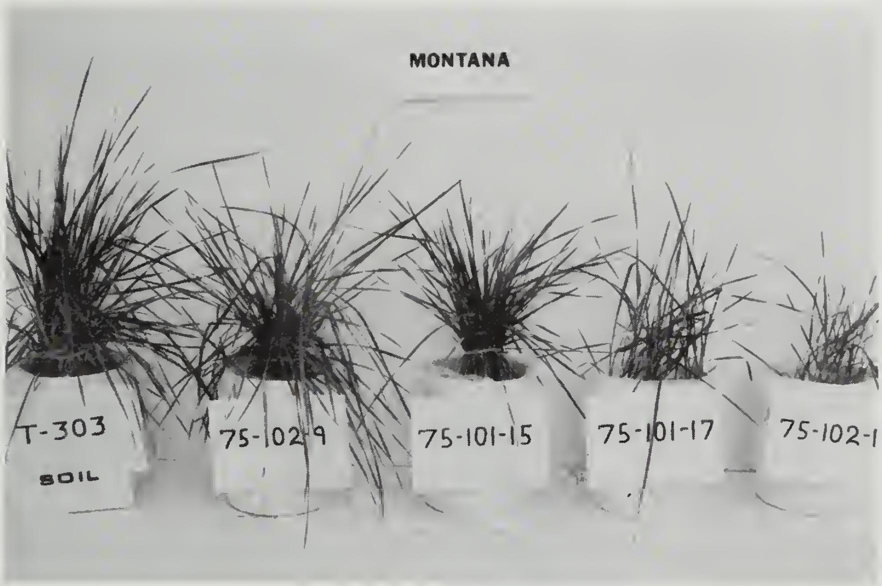
Samples of bedrock from the Bear Creek Study Area had yields ranging from low to high with 13 percent of the samples in the low range, 54 percent medium and 33 percent high (figure 21 and table 35, appendix G). Most of the bedrock samples from this area are fine-textured and show sodium problems. The majority of the bedrock samples from this area would be unsuitable as a plant growth media.

Soil profile samples from the Bear Creek Study Area generally yielded from medium to high with 28 percent having low relative yields, 53 percent medium, and 19 percent high (figure 22, table 35, appendix G). With one exception, only the surface samples yielded in the high range. In many cases, such as the samples T-46 to T-51 and T-276 to T-282 surface and subsoil samples yielded well but in the case of samples T-139 to T-146 and T-303 to T-309, some subsurface samples yielded low and would be unsuitable as plant growth media. The soil samples which yielded low were generally saline and/or sodic.

Discussion

Large differences in yield were noted among bedrock and soil samples. Overburden samples which had relative yields less than 33 percent would definitely not be suitable as plant growth media. The samples with relative yields larger than 33 percent include some strata which would make a favorable plant growth media, but also include some strata which would make unsuitable plant growth media under field conditions.

In the greenhouse study, overburden samples with the higher field capacities generally yielded the most. In the field, under arid and semi-arid conditions, these fine-textured materials would be the more drouthy soils because of greater surface runoff and evaporation. Thus, growth differences reported in this greenhouse study will give only an indication of the overburden suitability as a plant growth media. When extrapolating greenhouse results to field conditions, the physical and chemical characteristics of the overburden must be analyzed along with the greenhouse yield data to make interpretations on the suitability of the strata as a plant growth media.



PHOTOGRAPH 6 - Range in Western Wheatgrass Growth on Overburden Samples from the Bear Creek Study Area

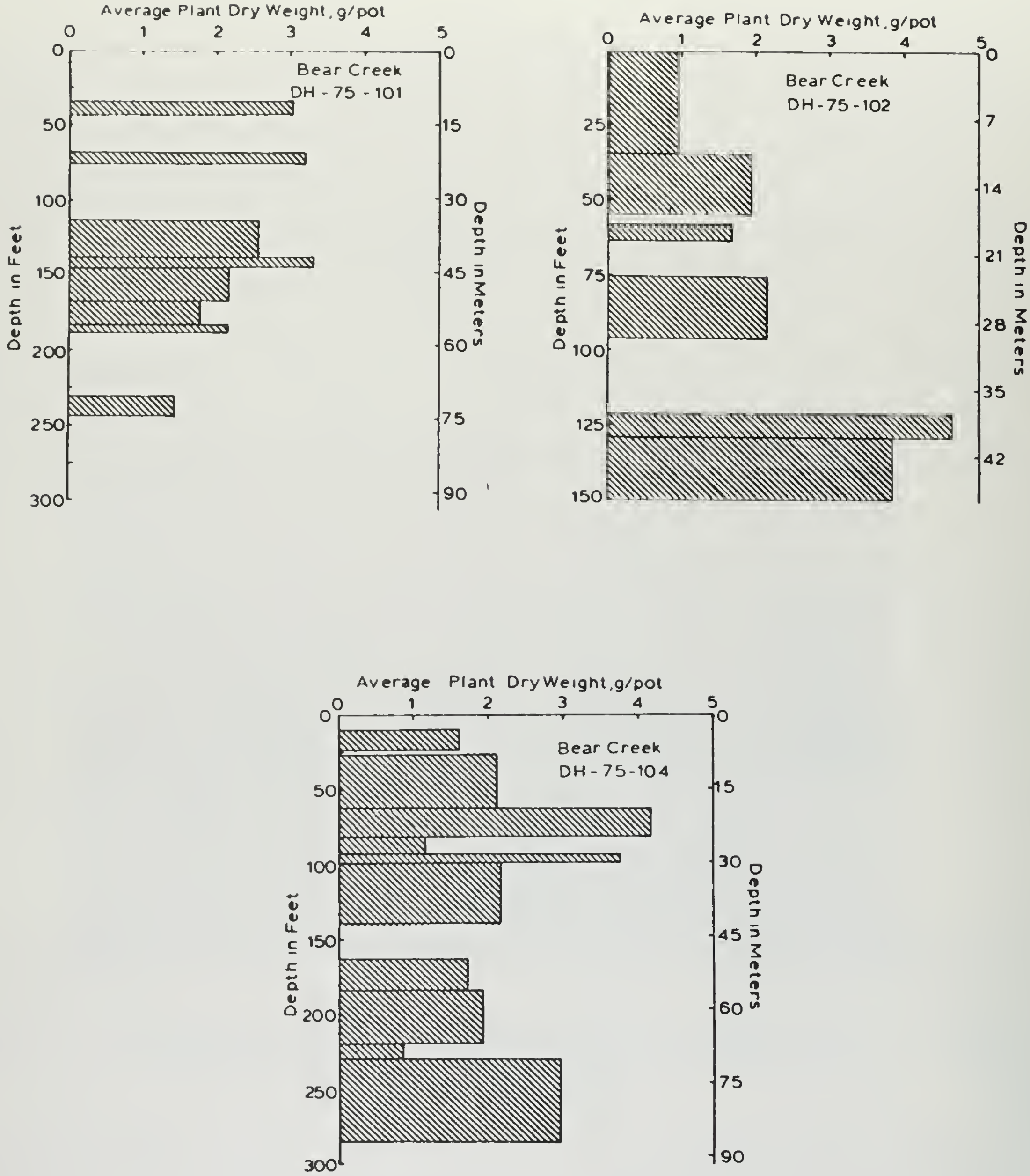


Figure 21 - Yields of western wheatgrass on bedrock from coreholes DH 75-101, -102, and -104, Bear Creek Study Area.

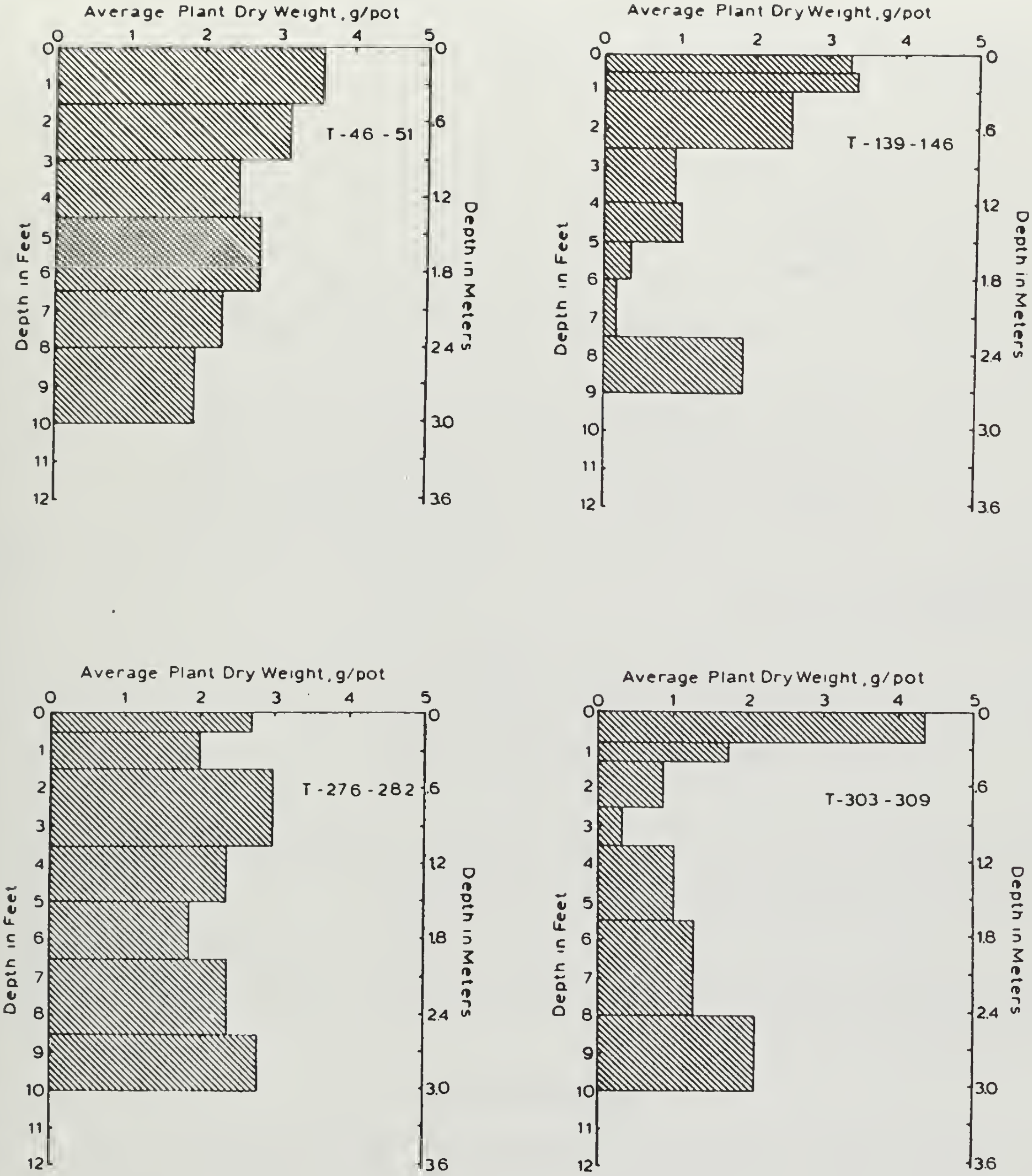


Figure 22 - Yields of western wheatgrass on soil profile samples from the Bear Creek Study Area.

Greenhouse Yields and Observations

The degree of surface cracking of the overburden were given a numerical designation as follows:

0 - none
1 - very slight
2 - slight
3 - moderate
4 - extreme

The degree of salt crusting was also observed and recorded as follows:

0 - no salt crust present
1 - 1-30% of surface area covered with salt crust
2 - 31-60% of surface area covered with salt crust
3 - 61-90% of surface area covered with salt crust
4 - 91-100% of surface area covered with salt crust

Blackened leaf tips were observed and frequency of occurrence, within pots, was recorded as follows:

0 - no plants with black leaf tips
1 - 1-4 plants with black leaf tips
2 - 5-8 plants with black leaf tips
3 - 9-12 plants with black leaf tips
4 - 13-16 plants with black leaf tips

These blackened leaf tips (5-10 mm) changed to a brown color after 1-2 weeks. Although the leaf tips died back, there was no evidence of overall yield reduction of plants so affected.

Roman numerals I and II in table 35, appendix G, refer to replications. Duplicate pots were run on all soil and bedrock samples for which there was adequate soil material.

Additional Data

Blackening of the leaf tips was observed on various samples. This blackening of the leaf tips was hypothesized to be boron toxicity, but work done by Bureau of Reclamation personnel in Billings, Montana, showed that there was no correlation between the amount of hot water soluble boron and the amount of blackened leaf tips.

In some cases, sufficient soil material was not available for the desired sample weight of 2.0 kg. It was not known whether significant yield decreases would result from these samples. Three soils with five sample weights (2.0, 1.9, 1.8, 1.6, and 1.4 kg) were tested following the previously described greenhouse procedures. The results of an Analysis of Variance (AOV) showed that there were significant differences in yields between the sample weight (0.001 level). Since the AOV showed there were significant differences, a Duncans Multiple Range test was conducted.

Results of this test showed that there were significant differences in yield at the 5 percent level between all sample weights except 2.0 versus 1.9 kg; 1.9 versus 1.6 kg; and 1.6 versus 1.4 kg. This shows that for statistical comparison purposes, a sample weight of 1.9 or 2.0 kg is needed for this study.

ALTERNATE OBJECTIVES OF RECLAMATION

A description of alternative objectives of reclamation presumes the area will be surface-mined at some future date. This excludes nonmining which, in some areas, may be the only environmental acceptable plan. The Bear Creek Study Area, however, has adequate overburden that is suitable for plant media and favorable climate for revegetation and reclamation. Therefore, nonmining is not a generally acceptable objective.

Objective No. 1 would require mining plans that return the surface mined area to the present condition or at least as near as possible to present conditions. This objective is not practical under present mining practices and it is also doubtful this objective would meet the desires of the agricultural community. The present landscape with its sandstone and shale outcrops, scarps below ledge forming sandstone and well developed drainage system has attained a balance with the climate. Physically, the present topographic conditions could be recreated but revegetation and stabilization of disturbed material with similar relief and exposures in a short time (3 to 7 years) is near impossible.

Mining plans to meet Objective No. 2 would provide for stripping and stockpiling suitable material for surfacing shaped spoils with a uniform depth of similar material. This objective can be met and would generally be accepted. The reconstructed profiles can be revegetated and should stabilize with the climate readily. It is also the most economically feasible objective.

Using applicable methods described under Recommendations for Reclamation, material for surfacing reshaped spoils would be stripped and stockpiled. The quantity of surfacing material would usually be limited to the amount needed for revegetation with native grass. Profile improvement would be limited to tracts with numerous shale and sandstone outcrops and a very thin soil mantle. Tracts with deep soil would have a reduced agricultural potential.

This objective is easily attainable in the Bear Creek area and will satisfy the needs for revegetation. However, land now producing hay and providing a feed base for the surrounding rangeland would most likely be suited only for range after revegetation is completed.

Objective No. 3 would require mining plans that would make the best use of all suitable material. This would improve the agricultural productive capacity through profile improvement. Land use capability in the reclaimed area could include land suitable for irrigation, dryland farming and range. Reconstruction of profiles suited for irrigation should be limited to the tracts now producing irrigated crops or a similar acreage along stream channels. The available water supply is limited to surface water from spring runoff. It is usually spread on the land from contour ditches or in water spreading systems. Land suited for dryland farming and range would have the largest areal distribution.

This objective should be considered and the economics evaluated in areas with potential similar to the Bear Creek Study Area. Present productive capacity of the better soils would be retained and tracts of low quality range would be improved.

Plans for the best and most economically feasible reclamation would combine Objectives No. 2 and No. 3.

RECOMMENDATIONS FOR RECLAMATION

Hydrology

The effects of surface mining on the area hydrology depend on the depth to which coal beds will be stripped and the areal extent of mine development. For simplicity, two alternative programs of mining development will be discussed. Program 1 assumes mining of the Anderson coalbed (uppermost strippable coal) only. Program 2 assumes stripping of the Anderson plus one or two coal beds below the Anderson.

Strip mining under program 1 will drain the saturated overburden and the Anderson coalbed near the mined area. Bear Creek and its intermittent tributaries are expected to become losing streams at the study area as the alluvium is drained by mining. Intermittent streamflow is likely to be slightly decreased as water infiltrates to the alluvium. Streamflow downstream from the study area could be increased if mine drainage is returned to Bear Creek. Because the stream would be above the water table, the drainage would likely infiltrate into the alluvium in a short distance. However, channel erosion would need to be prevented at points of reintroduction during periods of heavy dewatering.

Floodwater would need to be diverted around a mine. Diversion works should be designated to carry the natural sediment load as well as to be noneroding. Diversion channels could be designed to minimize infiltration, but because the alluvium contains a high percentage of clay and is lowly permeable, infiltration is likely to be small.

Water problems associated with strip mining the Anderson and one or two other coalbeds, program 2, would be similar, but more extensive than program 1. Limiting the stripping ratio to 8:1, less than presently used ratios, would restrict mining the Dietz and Canyon coalbeds to the northern part of the area. The mine would produce more water than under program 1. Mining would be likely to intercept nearly all the underflow in the Vance and Bear Creek valleys as well as most of the water presently discharged from the coalbeds. Water levels in the alluvium downstream from the area would be lowered, which could decrease hay production and injure plants whose roots extend to the water table. Probably, more than twice as much water would be produced from the mine under program 2 and its disposal would have to be controlled to prevent downstream erosion.

Post-mining water quality changes are to be expected in both surface and ground water. Surface water quality downstream from a potential mine could be degraded by poor quality water from mine drainage and by sedimentation or erosion due to improper flood control diversion. Toxic materials should be placed in zones that will not become saturated by surface or subsurface waters.

The area of greatest water level decline in wells can be expected to be to the east and southeast, upgradient from any potential strip mine. Mining under program 1 could potentially cause eight stock wells and one house well to become dry. Replacement wells of similar yields could be completed in one or more water-bearing zones of the Tongue River Member. The water quality could be expected to be better than water from wells presently in alluvium.

Continued monitoring before, during and after mining is necessary to determine changes in the hydrologic system.

Sediment Control

Source area sediment yields will be increased slightly to moderately during the mining and rehabilitation periods. The intensity of sediment control measures will determine how much, if any, additional sediment would be discharged to the main channel of Bear Creek. Assuming that the area will be returned to rangeland and hay meadow uses, the following recommendations are made for minimizing any additional sediment discharge to Bear Creek: (1) graded spoil slopes should be compatible with the adjacent unmined terrain, and slope gradients should be less than 20 percent to allow the use of tilling and seeding equipment; (2) spoils should be topsoiled, then seeded with adapted native species; (3) all slopes should be gouger pitted or contour furrowed; (4) temporary reservoirs and/or water spreaders may be necessary to trap sediment from flows occurring before areas have been graded, surface treated and seeded, or from flows caused by unusually heavy storms that may overtop furrows or pits during the rehabilitation period: (5) grassed drainageways should be constructed sufficiently wide to prevent channel erosion and to promote uniform deposition of sediment that will maintain the designed gradients of the drainageways.

When vegetation is reestablished and the soil has been reaggregated and become permeable again, source area sediment yield rates probably will be similar to present rates.

Surface Shaping and Revegetation

Successful revegetation of surface mined areas requires: (1) selection and placement of suitable overburden material, (2) proper shaping of the area surface, (3) selection of adapted plants, (4) use of proper planting and seedbed preparation procedures, (5) application of fertilizer and/or soil amendments, and (6) management of the revegetated area until the vegetation has been permanently reestablished. Selection of material for topdressing reshaped spoils of the desired topography requires proper planning before mining, but the final selection of material, methods of stripping and stockpiling will be accomplished during the actual mining process.

Selection and Placement of Material

The best material available for revegetation should be selected for surfacing the disturbed area. The surface soil, because of its higher organic content, natural fertility, and more stable structure, is usually the best available. This, however, is not always true. Surface soil in some tracts are clay rich, slowly permeable, erosive, saline or saline and sodic. Usually the soils are not suitable plant media in reclaimed surface mined tracts. Suitable bedrock material can support desirable vegetation with adequate fertilization and management. Bedrock material should not be used as seedbed material unless there is a shortage of suitable soil material near the surface. If the existing soil is unsuited or in short supply, it may be necessary to borrow soil from adjacent areas with deep soils that will be mined or from nearby undisturbed soils. It may be necessary to use bedrock material which has been determined to be suitable and can be readily separated from other overburden layers. If no suitable source is available, modification of the available material will have to be considered, i.e., leaching with irrigation water, mixing, and application of soil amendments. Most disturbed land in the Bear Creek Study Area can be topdressed with at least a few inches of surface soil that contains organic matter and is permeable.

In the selecting and identifying material to be stockpiled, three types should be designated: (1) best suited material for use on the reconstructed surface, usually surface soil (A horizon); (2) material suitable for the reconstructed surface, 6 to 12 inches (B horizon or highly-weathered C horizon); and (3) suitable material for the subhorizons of the constructed profile. In the stripping process, material in types (1) and (2) will usually be mixed because the A horizon is too thin to strip separately. The type (3) material should be stored separately. Stockpiling should be accomplished to hold erosion to a minimum.

The material selected for the surface should have the following characteristics: nonsaline, nonsodic, moderate permeability, medium to high available moisture holding capacity, and relatively stable soil structure. Most soils of this area are deficient in nitrogen and phosphorous so natural fertility should not be a major factor in the selection. The results of the land classification survey shows there is sufficient material meeting these requirements in the study area. If adequate material is not available locally or borrowing from areas is not permitted, the present surface must be returned as near as possible to its present condition.

The ideal situation would be to cover the shaped spoils to a depth of 36 inches with type (1) and (2) material. However, less desirable material will have to be used below 12 inches in the Bear Creek Study Area. Available material for subhorizons (below 12 inches) may be saline or slowly permeable. Here the reduced permeability is caused by fine textures or unstable structure. Material with salinity up to 12 millimhos per centimeter and slow permeability may be used in the 12- to 36-inch subsurface layer, but only if better material is not available. Any nontoxic material can be placed in a zone 36 to 96 inches below the surface.

With the natural precipitation (19.1 inches) some salinity reduction can be anticipated in permeable saline materials placed near the surface. Although the rate and depth of leaching cannot be predicted accurately, saline material placed on the surface few inches of the restored land surface should become suitable for tolerant plants in a short time and most plants in a reasonable time. Adequate internal drainage to allow downward movement of the precipitation is necessary. There is adequate permeable material that is moderately saline in this area to satisfy subsurface requirements.

Overburden material determined to be toxic (boron, selenium, etc.) must be properly placed during the mining operation. In Montana, it must be placed below 8 feet in the reconstructed profile. Saline material is abundant throughout the soil and bedrock substrata and it is not appreciably toxic to the species used for revegetation if returned to the subsurface layers. Saline materials will not require special handling other than that necessary to meet the requirements of revegetation. Under the conditions on the study area, salinity's primary effect would be its effect on the availability of moisture to plants because of increased osmotic pressure. Although saline material is not considered toxic here, improper placement on the surface could result in a delay in successful revegetation. Leaching by natural precipitation could require 2 years.

The depth of usable material is shown on plate 20. This map shows the shallow (0 to 5 feet) problem areas for which plant media material must be borrowed. Also shown is the location and thickness of material that may be borrowed and used in tracts that are deficient in good quality material. Plate 21 shows the material that is saline and the approximate depth to the saline layers.

Shaping of Surface

Premining planning is necessary to determine the reconstructed topography of the reclaimed area. Basically, it should conform and blend well with the surrounding natural topography. Present major drainage patterns common to the mined and adjacent areas must be maintained. Reclamation of the disturbed area may allow for improvement in drainage conditions by reducing stream gradient, provide better outlets, and reducing the gradient of contributing areas. To minimize erosion, maintain a satisfactory infiltration rate, and facilitate revegetation, reconstructed slopes, if possible, should not exceed 20 percent (Montana law states 20 percent or less).

The proper placement of material suitable for plant media and shaping of spoils in the reconstructed mine area will enhance the chances of satisfactory revegetation of strip-mined areas. But, because of the variability of soil and overburden material and the limitations in accurate placement of selected material, the reconstructed soil profile and area topography may vary some from the preconceived plan. Thus, the first step in revegetation of a disturbed area is to make a survey of the reconstructed land immediately after the subsurface material is spread on reshaped spoils. If problem spots are found, the problem can be corrected before the soil material for topdressing is applied. Criteria and methods used in the land classification for this study should be used.

Selection of Plants

To conform to present Montana law, surface mined lands must be reclaimed with native or designated species. All reclaimed areas will, therefore, produce forage for livestock and game animals. If practical, native tree and shrub species growing on the area should be transplanted to reclaimed areas. However, at the Bear Creek area there are few, if any, specimens suitable for transplanting.

Plant selection for revegetation is very important. Some consideration in selecting plants for the Bear Creek Area are salt and sodium tolerance, drought resistance, resistance to winterkill, palatability, and resistance to grazing pressure. Also of equal importance is the selection of plants compatible with soil type, slope, aspect, and drainage conditions. The local native grass species in the following list may be used for revegetation.

Green needlegrass (Stipa veridula)
Needleandthread (Stipa comata)
Blue grama (Bouteloua gracillis)
Little bluestem (Andropogonscoparius)
Western wheatgrass (Agropyron Smithii)
Intermediate wheatgrass (Agrophyron intermedium)
Prairie sandreed (Calamovilfa longifolia)
Sand dropseed (Sporobolus cryotondrus)
Bluebunch grass (Festuca idahoensis)
Indian ricegrass (Oryzopsis hymenoides)
Reed canarygrass (Phalaris arundinacea)
Slender wheatgrass (Agropyrontrachycaulm)
Smooth Brome (Bromus inermis)
Red Top (Agrostis alba)
Bluebunch wheatgrass (agropyron spicatum)
Canada Wild-rye (Elymus canadensis)
Giant Wild-rye (Elymus Condensatus)
Plains reedgrass (Calamagrostis Montanensis)
Prairie cordgrass (Spartinapectinata)
Big sage (Artemisia tridenta)
Fourwing saltbush (Artiplex canaescens)
Pubescent wheatgrass (Agropryontrichophorum)
Side-oats grama (Bouteloua Critipendula)
Buffalo grass (Buchloe dotyloides)

Following are recommended grass mixtures and seeding rates provided by the BLM:

Mixture No. 1 - "Western Wheatgrass - 6 pounds (100% germination or pure seed)
- Yellow sweet clover - 2 pounds

Mixture No. 2 - *Pubescent wheatgrass - 5 pounds
- Green needlegrass - 1 pound
- Yellow sweet clover - 2 pounds

Mixture No. 3 - **Intermediate wheatgrass - 6 pounds
- Grimm alfalfa - 2 pounds

Mixture No. 4 - *Pubescent wheatgrass - 5 pounds
- Green needlegrass - 1 pound
- Yellow sweet clover - 2 pounds

Other grasses and legumes that may be substituted in seeding mixtures are Ranger, Nomad, and Ladak alfalfa and fairway crested wheatgrass, slender wheatgrass, *tall wheatgrass and ***Reed canary grass.

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*Alkali resistant, ** saline resistant, ***wetlands

Plant species, including quick growing annuals and salt tolerant weeds, can be selected and planted in combinations to vegetate erosive sandy slopes, saline areas or tracts that may receive an above average amount of moisture from surface runoff.

Planting and Seedbed Preparation

It is recommended that surface manipulation such as gouging, ripping, contour furrowing (arcadia furrower), pitting, chiseling, etc., be employed on the contour to maximize the availability of precipitation for plant use and also retard surface erosion. Special practices such as terracing, grassed waterways, mulches, spreader dikes, and other conservation practices may be employed if required. Many areas may be severely compacted by heavy machinery and other traffic. Compacted tracts should be ripped 18 to 24 inches before preparing the seedbed. Another method of providing relief from compaction and reestablishment of voids would be replacing the soils horizon by horizon in the same relative position they had prior to mining. However, present mining plans do not follow this procedure. Most tracts to be seeded should be disked before planting. Seeding with a drill is the preferred method but good stands can be established by broadcast and hydro-seeding. Seed should be covered about one-half inch. Light compacting may be necessary to establish good contact between the seed and soil.

Surface mulch is often beneficial to protect the surface from wind and water erosion. Consideration should be given to the use of grass hay applied at the rate of 5,000 lbs/acre. Second choice would be grain straws applied at the rate of 6,000 lbs/acre. Vegetative material should be blended into the soil by rotovation, disking, etc., to maximize the value of mulching, rather than left on the surface. Gravel or crushed rock can be used as a surface mulching material in stabilizing the surface against wind erosion.

Fall planting is usually more successful than spring planting, because surface winds are less severe and there is less competition from weeds. Also the semiestablished plants get an earlier start in the spring taking advantage of the early spring moisture supply. A nurse crop is generally used to protect the new seedlings. Barley, rye, sudan grass, millets, and oats that winterkill offer protection with no spring competition. Another rapid growing annual worthy of consideration, especially on drouthy south and southwest slopes, is German millet.

Adaptations and use of these measures are in published literature, but adjustment of these practices is generally required to meet specific needs. The use of available data can result in the successful rehabilitation and probable enhancement of the area for agricultural use. The land classification survey of the reconstructed land will establish the fertilizer needs, leaching requirement to reduce soluble salts and needed conservation practices.

Fertilizer and Soil Amendments

Reshaped and resurfaced tracts should receive adequate nitrogen and phosphorous to establish new vegetation but further fertilization would not be warranted. Borrow material from the soil substratum or bedrock material that is very low in organic matter and fertility should be checked for fertilizer requirements. All land should be rechecked during the early revegetation period and the fertilizer needs should be met for successful permanent revegetation. When this requirement is met no further fertilization should be considered.

It is recommended that triple super phosphate and nitrogen fertilizer be applied to satisfy the minimum plant needs for these nutrients. Urea nitrogen could be used to get a slow release during the growing season. Fertilizers should be applied at the same time or in conjunction with the mulching so that they can be blended into the surficial materials by rotovation, disking, etc.

Management

Irrigation for revegetation of these lands should not be required except to maintain newly seeded areas in abnormally dry years. Irrigation will also create soil voids to enhance water entry and retention of this water in the soil profile. The water should be applied in a series of wettings until the desired voids in the soil have been created. Ground water in the Bear Creek Study Area is generally saline, containing from 1,000 to 5,000 ppm total dissolved solids. It should not be used for irrigation unless absolutely necessary. Surface water from spring runoff is generally of good quality and can be used without hazard. Trees may require some additional water the first and second years.

Protection of grass species on reclaimed areas from antelope or deer, the principal grazing wildlife in the area, is not needed or practical. Woody species planted along reformed drainages should be protected from deer if practical. The land being revegetated must be protected from uncontrolled grazing by livestock. Grazing should not be permitted in the early years (5 years) of the revegetation period and controlled grazing allowed only after range studies indicate grazing will not be detrimental. The dry fall and early winter periods are well suited for limited grazing when the soil is firm and the vegetation is mature.

Generally, conservation practices will entail surveillance of erosion. Any proven method such as grassed waterways, local vegetative mulching, introduction of tolerant species including weeds, if barren saline spots develop, and spraying to control weeds in tracts of nonsaline nonsodic material. If these measures are carried out for the 3- to 7-year period, this reclaimed land can produce more range forage than is harvested now.

BIBLIOGRAPHY

American Society for Testing and Materials, 1974, Standard specifications for classification of coals by rank [ASTM designation D388-66 (reapproved 1972)], in Gaseous fuels; coal and coke; Atmospheric analysis: Am. Soc. Testing Materials, pt. 26, p. 54-58.

Branson, F. A., R. F. Miller, and I. S. McQueen, 1962, Effects of contour furrowing, grazing intensities and soils on infiltration rates, soil moisture and vegetation near Fort Peck, Montana: Jour. of Range Management, v. 15, p. 151-158.

Branson, F. A., R. F. Miller, and I. S. McQueen, 1966, Contour furrowing, pitting, and ripping on range lands of the western United States: Jour. of Range Management, v. 19, p. 182-190.

Brown, R. H., and others, 1963, Methods of determining permeability, transmissibility, and drawdown: U.S. Geological Survey Water-Supply Paper 1536-I, p. 341.

Bryson, R. P., and N. W. Bass, 1973, Geology of the Moorhead coalfield, Powder River, Big Horn, and Rosebud Counties, Montana: U.S. Geol. Survey Bull. 1338, p. 116.

Ferris, J. G., D. B. Knowles, R. H. Brown, and R. W. Stallman, 1962, Theory of aquifer tests: U.S. Geol. Survey Water-Supply Paper 1536-E, p. 174.

Francis, Wilfried, 1961, Coal, its formation and composition: Edward Arnold (Publishers) Ltd., London, p. 806.

Gardner, R. 1945, Some Soil Properties Related to the Sodium Salt Problem in Irrigated Soils, U.S. Department of Agriculture Technical Bulletin 902.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geol. Survey Water-Supply Paper 1473, p. 363.

Hopkins, W. B., 1973, Water resources of the Northern Cheyenne Indian Reservation and adjacent area, southeastern Montana: U.S. Geol. Survey Hydrol. Inv. Atlas HA-468.

Johnson, M. V., and R. J. Omang, 1976, A method for estimating magnitude and frequency of floods in Montana: U.S. Geol, Survey open-file report 75-650, p. 35.

Kellogg, Charles E., 1962, The place of the Laboratory in Soil Classification and Interpretation, U.S. Department of Agriculture, Soil Conservation Service.

Lohman, S. W., 1972, Ground-water hydraulics: U.S. Geol. Survey Prof. Paper 708, p. 70.

Lowry, H. H., (ed.), 1945, Chemistry of coal utilization, Volumes I and II: John Wiley and Sons, Inc., New York, p. 1868.

Lowry, H. H., 1963, Chemistry of coal utilization, supplementary volume: John Wiley and Sons, Inc., New York, p. 1142.

Matson, R. E., and J. W. Blumer, 1973, Quality and resources of strippable coal, selected deposits, southeastern Montana: Montana Bur. Mines and Geology Bull. 91, p. 135.

Matson, R. E., G. G. Dahl, and J. W. Blumer, 1968, Strippable coal deposits on State land, Powder River County, Montana: Montana Bur. Mines and Geology Bull. 69, p. 81.

McKee, J. E., and H. W. Wolf, 1963, Water Quality criteria: California State Water Quality Control Board Publ. 3-A, p. 548.

McQueen, I. S., 1961, Some factors influencing streambank erodibility: U.S. Geol. Survey Prof. Paper 4248, p. 28-29.

McQueen, I. S., and R. F. Miller, 1968, Calibration and evaluation of a wide-range gravimetric method for measuring moisture stress: Soil Sci., v. 106, p. 225-231.

McQueen, I. S., and R. F. Miller, 1972, Soil moisture and energy relationships associated with riparian vegetation near San Carlos, Arizona: U.S. Geol. Survey Prof. Paper 655E, p. 51.

McQueen, I. S., and R. F. Miller, 1974, Approximating soil moisture characteristics from limited data: emperical evidence and tentative model, Water Resources Research; v. 10, p. 521-527.

Michurin, B. N., and I. A. Lytayev, 1967, Relationship between moisture content, moisture tension, and specific surface area in soil: Soviet Soil Sci., v. 8, p. 1093-1103.

Miller, R. F., and others, 1969, An evaluation of range floodwater spreaders: Jour. of Range Management, v. 22, p. 246-257.

Miller, R. F., and I. S. McQueen, 1972, Approximating recurring moisture relationships in desert soils: Eco-Physiological Foundation of Ecosystems Productivity in Arid Zone: Publishing House NAUKA Leningrad USSR, p. 119-122.

Miller, W. R., 1976, Water in carbonate rocks of the Madison Group in southeastern Montana--a preliminary evaluation: U.S. Geol. Survey Water-Supply Paper 2043 (in press).

Moore, E. S., 1940, Coal, its properties, analysis, classification, geology, extraction, uses and distribution: John Wiley and Sons, Inc., New York, p. 473.

Montana State Engineer's Office, 1961, Water Resources survey--Powder River County, Montana: Helena, Montana, p. 68.

Pacific Southwest Inter-Agency Committee, 1968, Report on factors affecting sediment yield in the Pacific Southwest area: Water Management Subcommittee, Sedimentation Task Force, p. 10.

Peters, William B., 1975, Economic Land Classification for the Prevention and Reclamation of Salt-Affected Lands. Paper presented at U.N. Food and Agriculture Organization Conf. on Salt-Affected Soils, USBR.

Pfleider, E. P., ed., 1968, Surface mining: New York, Am. Inst. Mining, Metall., and Petroleum Engineers, Inc., p. 1961.

Richards, L. A., and others, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Department Agr. Handbook 60, p. 160.

Schofield, R. K., 1935, The pF of the water in the soil: Internat. Congress Soil Sci. 3rd Trans., v. 2, p. 37-48.

Schopf, J. M., 1956, A definition of coal: Econ. Geol., v. 51, no. 6, p. 521-527.

Schopf, J. M., 1960, Field description and sampling of coalbeds: U.S. Geol. Survey Bull. 1111-B, p. 70.

Schopf, J. M., 1966, Definitions of peat and coal and of graphite that terminates the coal series (Graphocite): Jour. Geol., v. 74, no. 5, pt. 1, p. 584-592.

Shown, L. M., R. F. Miller, and F. A. Branson, 1969, Sagebrush conversion to grassland as affected by precipitation, soil, and cultural practices: Jour. of Range Management, v. 22, p. 303-311.

Shown, L. M., 1970, Evaluation of a method for estimating sediment yield: U.S. Geol. Survey Prof. Paper 700-B, p. B245-B249.

Sindelar, B. W., R. L. Hodder, M. E. Majerus, 1973, Surface-mined land reclamation research in Montana: Progress Report 40, Montana State University, Bozeman, Montana, p. 122.

Synder, N. H., 1950, Handbook on coal sampling: U.S. Bur. Mines Tech. Paper 133 (Revised), p. 10.

Swanson, V. E., Claude Huffman, Jr., and J. C. Hamilton, 1974, Composition and trace-element content of coal, Northern Great Plains area: Contribution to Mineral Resources Work Group, Northern Great Plains Resource Program.

Swenson, F. A., W. R. Miller, W. G. Hodson, F. N. Visher, 1976, Maps showing configuration and thickness, and potentiometric surface and water quality in the Madison Group, Powder River Basin, Wyoming and Montana: U.S. Geol. Survey Misc. Inv. Series Map I-847-C.

Taylor, O. J., 1965, Ground-water resources along Cedar Creek anticline in eastern Montana: Montana Bur. Mines and Geology Mem. 40, p. 99.

Taylor, S. R., 1964, Abundance of chemical elements in the continental crust: A new table: Geochim et Cosmochim. Acta, v. 28, no. 8, p. 1273-1285.

Tomkeieff, S. I., 1954, Coals and bitumens and related fossil carbonaceous substances: Pergamon Press Ltd., London, p. 122.

U.S. Bur. Mines, 1965, Bituminous coal, in mineral Facts and problems, 1965, p. 119-147.

U.S. Department of Agriculture, 1941, Climate and Man: Yearbook of Agriculture, p. 1248.

U.S. Geological Survey, 1975, Sediment yields, p. 149-155 in U.S. Bureau of Land Management, Resource and Potential Reclamation Otter Creek Study Site: EMRIA Report No. 1, p. 200.

U.S. Public Health Service, 1962, Drinking Water Standards, 1962: U.S. Public Health Service, Pub. 956, p. 61.

U.S. Salinity Laboratory Staff, 1954, Diagnosis and Improvement of Saline and Alkali Soils: U.S. Dept. Agriculture Handbook 60, p. 160.

Van Voast, W. A., 1974, Hydrologic Effects of Strip Coal Mining in Southeastern Montana--Emphasis: One year of mining near Decker: Montana Bur. Mines and Geology Bull. 93, p. 24.

Van Voast, W. A., and R. B. Hedges, 1975, Hydrogeologic aspects of existing and proposed strip coal mines near Decker, southeastern Montana: Montana Bur. Mines and Geology Bull. 97, p. 31.

ENGLISH TO METRIC (SI) CONVERSIONS

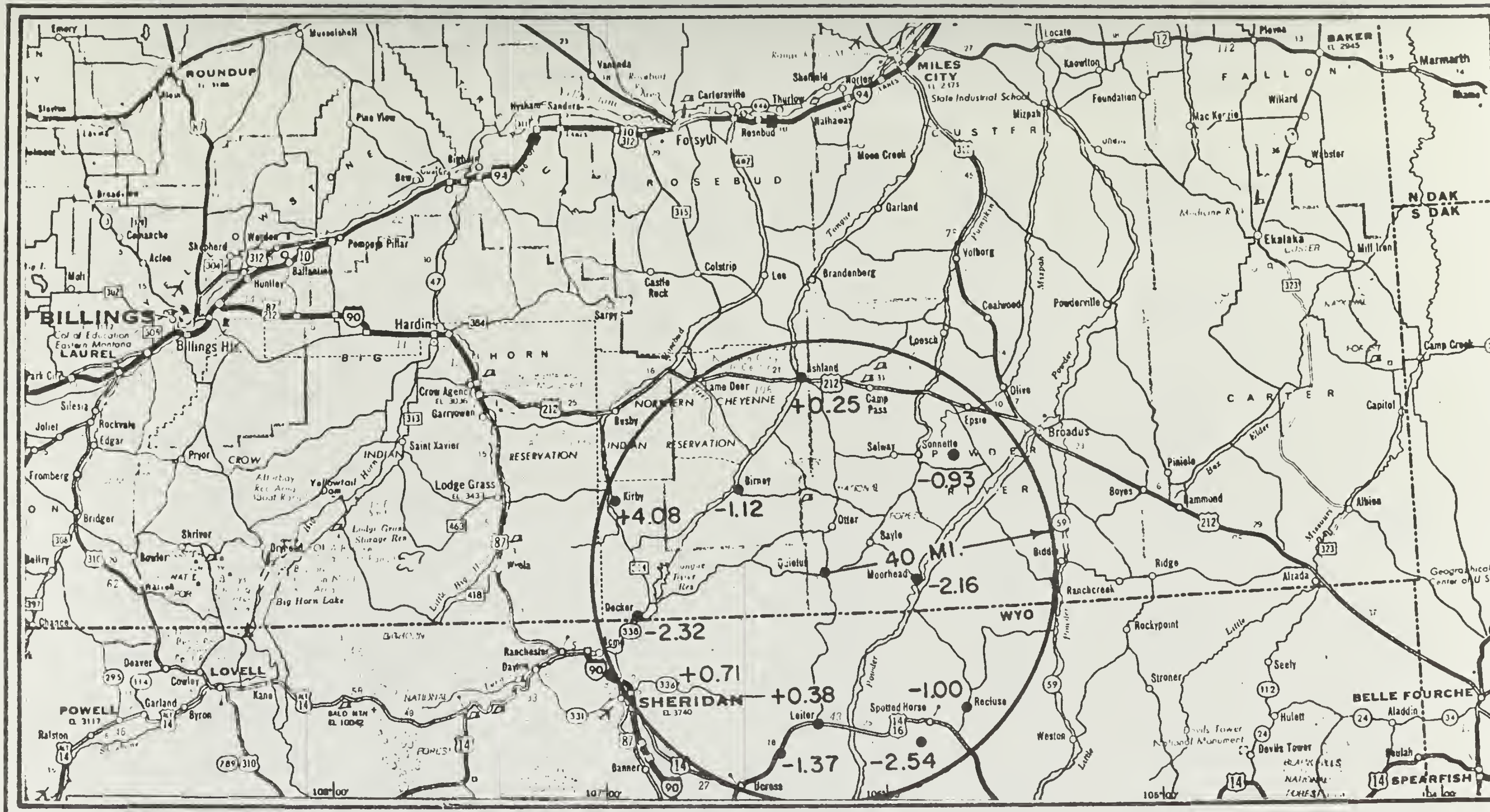
A dual system of measurements--English units and the International System (SI) of metric units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

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)
Miles	1.609	kilometers (km)
Pounds	453.60	grams (g)
Ton	0.9072	tonne (t)
Acres	0.4047	square hectometers (hm^2)
	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)
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	70.31	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 [$(m^3/s)/km^2$]
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 mass	2327.8	joules per kilogram (J/kg)
Degree Fahrenheit	$Tc = \frac{Tf-32}{1.8}$	degrees Celsius (°C)

APPENDIX A

CLIMATE

Figure 1



25 0 25 50

SCALE OF MILES

PRECIPITATION DEVIATION AT SELECTED LOCATIONS IN THE BEAR CREEK AREA

NOTES

The 40 mile circle around the Bear Creek Study Area indicates an area in which average yearly precipitation is about 14.75 in. Minus or plus (inside circle) indicates deviation from the 14.75 in. normal at selected stations.

Table 4 - Potential Consumptive Use of Moisture and Available Moisture - Native Grasses[1/]

Bear Creek Study Area - Otter Station

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (°F)	Requirement Inches	Moisture Reserve Inches	Precipitation Inches	Difference Inches[3/]
May 9					+7.26[2/]		
	May 20	12	60.6	3.09		2.51	+6.68
June					6.68		
	June 15	38	62.9	4.72		3.30	+5.26
July					5.26		
	July 15	68	71.2	6.30		1.32	+ .28[4/]
August					+ .28		
	August 15	99	70.6	5.66		1.26	-4.12
Sept.					-4.12		
	Sept. 15	130	58.5	3.00		1.69	-5.43
Oct.					-5.43		
	Oct. 1	146	49.1	.111		1.56	-3.98
Oct. 2		147		22.88 inches		11.64	

1/ Computed by Blaney-Criddle Method using the Otter Weather Station - Latitude 45°06'N.
2/ Moisture Reserve = Summation of precipitation (Oct. to April) x 80% = 7.26 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 year, the plants use the available moisture by August 10 and mature and become dormant,

Table 5 - Potential Consumptive Use of Moisture and Available Moisture - Native Grasses[1/]

Bear Creek Study Area - Moorhead Station

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. (°F)	Monthly Requirement Inches	Moisture Reserve Inches	Precipitation Inches	Difference Inches[3/]
May 6					+4.13[2/]		
	May 19	13	62.9	3.64		2.11	+2.60
June					+2.60		
	June 15	40	64.6	4.98		2.52	+0.14
July					+0.14		
	July 15	70	71.2	6.30		1.26	-4.90[4/]
August					-4.90		
	August 15	103	69.7	5.58		.97	-9.51
Sept.					-9.51		
	Sept. 13	131	68.6	4.97		1.27	-13.21
Sept. 27		145		25.47		8.13	

1/ Computed by Blaney-Criddle Method using the Moorhead Weather Station - Latitude 45°11'N
2/ Moisture Reserve = Summation of precipitation (Oct. to April) x 80% = 4.13 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, the plants use the available moisture by July 15 and mature and become dormant.

APPENDIX B

GEOLOGY

GEOLOGIC LOG OF DRILL HOLE

Sheet 1 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana

HOLE NO. DH 75-101 — LOCATION * — COORDS N. ... E. ... — Altimeter GROUND ELEV. 3747± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6/12/75 — FINISHED 7/8/75 — TOTAL DEPTH 244.7 — BEARING -

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 17.2' 7/8/75 (3729.8') — 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 6/12/75. BX drive samples 0 to 28.0'. 2-3/4" core 28.0 to 37.0'. Set 5" CS to 3.6'.

Hole at 37.0' 6/13/75. 5" CS at 3.6'. 2-3/4" core 37.0 to 47.0'. Pulled CS. Reamed hole to 35.6'. Set 5" CS to 35.6'. Still losing water. Pulled CS & reamed hole to 40.6'. Set 5" CS to 40.6'. W.L. at 5.7' at start of shift.

Hole at 47.0' 6/13/75. 5" CS at 40.6'. W.L. at 8.8'. 2-3/4" core 47.0 to 74.0'.

Hole at 74.0' 6/17/75. 5" CS at 40.6'. W.L. at 8.8'. 2-3/4" core 74.0 to 91.8'.

6/18/75. Heavy rain. Unable to get to drill site.

Hole at 91.8' 6/19/75. 5" CS at 40.6'. W.L. at 10.5'. 2-3/4" core 91.8 to 152.7'. Using revert below 122.2'. Dropped sample 91.8 to 101.8'. 8' drilling back over sample.

Soils analysis samples

Sample	From	To
#1	0	6.0
#2	6.0	11.0
#3	11.0	23.0
#4	27.5	34.6
#5	34.6	42.1
#6	44.1	47.0
#7	47.0	52.3
#8	68.7	75.3
#9	75.3	84.0
#10	91.8	107.8

Core recovery (%): 40, 26, 10, 64, 57, 13, 41, 56, 77, 100, 90, 93, 92, 98, 90, 100, 99, 96, 97, 100, 100, 20

Elevation / depth of contacts

Elevation (feet)	Depth (feet)
3741.0	6.0
3736.0	11.0
3724.0	23.0
3722.0	25.0
3719.5	27.5
3712.4	34.6
3704.9	42.1
3704.5	42.5
3702.5	44.1
3700.0	47.0
3694.7	52.3
3691.9	55.1
3691.4	55.6
3689.1	57.9
3678.3	68.7
3671.7	75.3
3663.0	84.0
3660.2	86.8
3655.2	91.8

Graphic log labels: N, O DIETZ, P

Classification and physical condition

0-6.0 SANDY CLAY: Brown & organic 0 to 1.0'; tan & moist 1.0 to 6.0'; soft; about 40% fine, uniform sand & 60% low plasticity fines; calcareous; few roots 0 to 1.0'. (CL)

6.0-11.0 SILTY CLAY: Tan; oxidized; moist to wet; soft; about 30% fine sand & 65% low to medium plasticity fines; several clean, fine sand zones 8.5 to 10.0'; calcareous (CL)

11.0-23.0 SILTY SAND: Tan; wet; calcareous; fine grain; about 10% nonplastic fines (SP-SM)

23.0-25.0 CLAYEY TO SILTY SAND: Tan; wet; soft; calcareous; about 80% fine, uniform sand & 20% non to moderately plastic fines (SM to SC)

25.0-27.5 SILTY SAND: Tan; wet; calcareous; fine to medium grain; about 10% nonplastic fines (SP-SM)

27.5-34.6 CLAYEY SAND AND GRAVEL: Tan; oxidized; wet; sample recovered contained about 70% fine to coarse, moderately hard, flat to subangular gravel composed of clinker, 15% fine to coarse sand & 15% medium plasticity fines. Fines & sand could have been washed away during drilling (GC)

FT. UNION FORMATION - PALEOCENE

34.6-42.1 SHALE & SILTY SHALE: Brown & oxidized 34.6 to 35.9'; dark gray 35.9 to 38.0'; light gray 38.0 to 42.1'; moist to wet; plastic clay shale which trims easily with knife 34.6 to 38.0'; firm, slightly calcareous, laminated silty shale 38.0 to 42.1'; 2" concretion 40.3 to 40.5'; 1 to 8" core lengths.

42.1-42.5 COAL: Wet; black; broken; clay stringers.

42.5-44.1 SHALE: Dark gray; wet; plastic; cuts easily with knife; carbonaceous near top; 2 to 6" core lengths.

44.1-47.0 SILTY SANDSTONE: Light gray; moist; uncemented; compact; very silty (approaching sandy siltstone); calcareous; very fine grain; scattered carbonaceous streaks; can be crushed between fingers; 2 to 6" core lengths.

47.0-52.3 SHALE: Medium to dark gray; moist; plastic when reworked; can be trimmed by knife; thin-bedded to laminated carbonaceous streaks 48.0 to 48.2'; core lengths 2 to 6".

* 175' S. & 50' W. of NE Corner, Section 33, T. 8 S., R. 45 E.

EXPLANATION — Core loss / Core recovery

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 1 OF 4 — HOLE NO. DH 75-101

GEOLOGIC LOG OF DRILL HOLE

Sheet 2 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — HOLE NO. DH 75-101 — Altimeter GROUND ELEV. 3747± — DIP Vertical — BEGUN 6/12/75 — FINISHED 7/8/75 — TOTAL DEPTH 244.7' — DEPTH AND ELEV. OF WATER LEVEL: 17.2' 7/8/75 (3729.8') — LOGGED BY: Taucher

Notes

Hole at 152.7' 6/20/75. 5" CS at 40.6'. W.L. at 10.8'. Repaired equipment.

Hole at 152.7' 6/24/75. 5" CS at 40.6'. W.L. at 10.8'. 2-3/4" core 152.7 to 169.5'. Tripped wire line to inspect bit.

Hole at 169.5' 6/25/75. 5" CS at 40.6'. W.L. at 8.2'. 2-3/4" core 169.5 to 218.4'. Lost all drill water at 196.3'. Used revert in hole below 202'. 10 to 25% water return 202 to 218.4'.

*175' S. & 50' W. of NE Corner, Section 33, T. 8 S., R. 45 E.

Soils analysis samples

Sample	From	To
#11	112.9	138.0
#12	138.0	145.9
#13	145.9	167.7
#14	167.7	182.4
#15	182.4	187.4

Core recovery (%): 83, 81, 60, 83, 100, 100, 80, 81, 100, 65, 86, 100

Elevation / depth of contacts

Elevation (feet)	Depth (feet)
3639.2	107.8
3634.1	112.9
3609.0	138.0
3601.1	145.9
3579.3	167.7
3564.6	182.4
3559.5	187.5
3555.2	191.8

Graphic log label: Q

Classification and physical condition

52.3-55.1 SILTY SANDSTONE: Light gray; moist; uncemented; compact; very silty (approaching sandy siltstone); calcareous; very fine grain; scattered carbonaceous streaks; can be crushed between fingers; 2 to 6" core lengths.

55.1-55.6 SILTSTONE: Light gray; very hard; cemented; sandy; can be scratched with knife.

55.6-57.9 SHALE: Medium to dark gray; wet; plastic; cuts easily with knife; 6" core lengths.

57.9-68.7 COAL: Black; wet; broken to upper 2'.

68.7-75.3 SILTY SHALE: Light gray; moist to wet; can be trimmed with knife; becoming firmer with depth; thin-bedded silty; moderately plastic; carbonaceous 70.8 to 71.8'; 1 to 6" core lengths.

75.3-84.0 SILTSTONE: Medium gray; very hard; dense; siliceous; can be scratched with knife; appears cross-bedded; 2' core lengths.

84.0-86.8 SILTSTONE: Light gray; hard; can be trimmed by knife with difficulty; clayey if reworked; 1 to 6" core lengths.

86.8-91.8 COAL WITH SHALE: Black; wet; breaks along bedding; medium gray; plastic shale (trims easily with knife) 87.9 to 88.9; several thin clay streaks 88.9 to 91.8'; 2 to 6" core lengths; few slicken sides.

91.8-107.8 SILTY SHALE: Light gray; moist to wet; firm; can be trimmed by knife with difficulty; very silty; moderately plastic; thin-bedded to massive; carbonaceous 104.6' to 104.8'; lost 8' of core between 91.8 & 101.8'; core lengths 2 to 6".

107.8-112.9 COAL WITH SHALE AND SANDSTONE: Black; wet; broken in ½ to 4" pieces; carbonaceous silty sandstone (crumbles between fingers) 110.2 to 110.7'; carbonaceous clay shale 107.8 to 108.0'.

112.9-138.0 SILTY SANDSTONE: Light gray; wet; very fine grain; silt content varies from 15 to 40%; crumbles easily between fingers; uncemented; thin-bedded to massive; begins to wash away during drilling; 1 to 6" core lengths.

138.0-145.9 SILTY SHALE: Medium gray; moist; thin-bedded; firm but can be trimmed by knife; moderately plastic; very silty; near clayey siltstone; 6" core lengths.

EXPLANATION — Core loss / Core recovery

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 2 OF 4 — HOLE NO. DH 75-101

GEOLOGIC LOG OF DRILL HOLE

Sheet 3 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — HOLE NO. DH 75-101 — Altimeter GROUND ELEV. 3747± — DIP Vertical — BEGUN 6/12/75 — FINISHED 7/8/75 — TOTAL DEPTH 244.7' — DEPTH AND ELEV. OF WATER LEVEL: 17.2' 7/18/75 (3729.8') — LOGGED BY: Taucher

Notes

Hole at 218.4' 6/26/75. 5" CS at 40.6'. W.L. at 51.3'. 2-3/4" core 218.4 to 244.7'. 20% drill water return. Moved pump to new location.

Hole at 244.7' 6/27/75. W.L. at 61.0'. Pulled 5" CS. Reamed hole to 72.5' with 7-7/8" rock bit. 100% water return.

Hole at 244.7' 6/28/75. 8" CS at 2.0'. W.L. at 6.3'. Reamed hole 72.5 to 82.5 with 7-7/8" rock bit.

Hole at 244.7' 6/29/75. 8" CS at 2.0'. W.L. at 6.1'. Reamed hole 82.5 to 132.5' with 7-7/8" rock bit. Having trouble cleaning hole of cuttings. Using revert.

Hole at 244.7' 6/30/75. 8" CS at 2.0'. W.L. at 7.3'. Reamed hole 132.5 to 202.5' with 7-7/8" rock bit. Lost circulation at 201.0'. Pumped revert in hole & regained circulation. Having trouble cleaning hole of cuttings.

Hole at 244.7' 7/1/75. 8" CS at 2.0'. W.L. at 7.9'. Reamed hole 202.5 to 244.7' with 7-7/8" rock bit. Using revert. Installed 4" plastic pipe in hole (perforations in coal zones 57.9 to 68.7 & 191.8 to 216.2'). Pulled 8" CS.

*175' S. & 50' W. of NE Corner, Section 33, T. 8 S., R. 45 E.

Soils analysis samples

Sample	From	To
#16	224.5	230.9
#17	230.9	244.7

Core recovery (%): 100, 100, 100, 84, 93, 63, 100

Elevation / depth of contacts

Elevation (feet)	Depth (feet)
3530.8	216.2
3527.7	219.3
3525.5	221.5
3522.5	224.5
3516.1	230.9
3502.3	244.7

Graphic log labels: R CANYON, S, T

Classification and physical condition

145.9-167.7 SILTSTONE: Alternating light and medium gray laminations; moist; contains some clay and very fine sand; soft; trims easily with knife; begins to wash away during drilling; shale 149.6 to 150.2 and 158.0 to 158.5'; 1 to 12" core lengths.

167.7-182.4 SILTY SHALE: Medium gray; moist; firm; can be trimmed by knife with difficulty; thin-bedded to almost laminated; some siltstone laminations; plastic when reworked; approaching claystone; becoming very silty 182.0 to 182.4'; core lengths 3 to 18".

182.4-187.5 SILTY SANDSTONE: Alternating light and medium gray bands; moist; very silty; approaching sandy siltstone; sand is very fine grain; uncemented; crumbles easily between fingers; partly washed away by drilling; several 1/8" carbonaceous streaks 183.5 to 183.8 and 184.3 to 184.5'; firm shale 183.8 to 184.3'.

187.5-191.8 SHALE: Medium gray; moist; very firm; trims by knife with difficulty; approaching claystone; very plastic when reworked; silt laminations 187.5 to 189.0'; slightly carbonaceous with no discernible bedding 189.0 to 191.8; 2 to 14" core lengths.

191.8-216.2 COAL: Black with occasional dark brown streaks; brown streaks appear to contain clay contamination; wet; few low angle slicken sides; several vertical joints; broken in 1 to 18" core lengths; firm shale 215.7 to 215.9'.

216.2-219.3 SHALE: Medium to dark gray; moist; firm; trims by knife with difficulty; plastic when reworked; carbonaceous with coal streaks 218.1 to 218.6'; begins to air slack; bedding not readily discernible; few slicken sides; 1 to 3" core lengths.

219.3-221.5 SILTY SANDSTONE: Light gray with several medium gray laminations; moist; fine grain; uncemented; trims easily with knife; 12" core lengths.

221.5-224.5 COAL: Black; wet; broken; slicken sides; contains clay contamination

224.5-230.9 SILTY SHALE: Light to medium gray; moist; firm; trims by knife with difficulty; impure coal 227.9 to 228.0, 228.5 to 228.7 & 229.4 to 230.9'; 1 to 6" core lengths.

EXPLANATION — Core loss / Core recovery

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 3 OF 4 — HOLE NO. DH 75-101

GEOLOGIC LOG OF DRILL HOLE

Sheet 4 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — HOLE NO. DH 75-101 — Altimeter GROUND ELEV. 3747± — DIP Vertical — TOTAL DEPTH 244.7' — DEPTH AND ELEV. OF WATER LEVEL: 17.2' 7/8/75 (3729.8') — LOGGED BY: Taucher

Notes

Hole at 244.7' 7/2/75. W.L. at 7.9'. 4" plastic pipe in hole. Flushed out pipe to 230' with water. Unable to clean pipe below 230'.

Hole at 244.7' 7/8/75. W.L. at 17.2'. 4" plastic pipe in hole. Pipe filled with cuttings to 165'. Washed out pipe to 244.7'. No drill water return on outside of pipe. Hole sloughed in around pipe. Unable to pull pipe with cable. Tried grouting with sand inside 4" pipe using BX and NX casing. Sand grout would not hold so pipe could be hammered out. Hole abandoned as water well. Unable to gravel pack coal zones. Moved rig to DH 75-104.

*175' S. & 50' W. of NE Corner, Section 33, T. 8 S., R. 45 E.

Notes Continued

Hole at 244.7' 3/19/76. Moved drill rig to DH 75-101.

Hole at 244.7' 3/22/76. Washed hole with drill rods to 200'. Hole bridged by debris at 23.0 and 66.0'. Encountered clay, coal fragments and pieces of plastic 170.0 to 200.0'.

Hole at 244.7' 3/23/76. W.L. at 17.5'. Washed out hole to 200'. Plastic pipe bridged from 67.0 to 69.0'. Encountered gravel and sand 186.0 to 200'. Plugged plastic pipe back to 66.0'. Flushed and bailed hole for 1½ hours.

Classification and physical condition

230.9-244.7 SILTSTONE AND CLAYEY SILTSTONE: Light gray; moist; moderately firm to firm; can be trimmed by knife; bedding not readily discernible; siltstone 230.9 to 235.5 & 242.7 to 244.7'; firm clayey siltstone 235.5 to 239.5'; slightly carbonaceous, clayey siltstone 239.5 to 242.7'; calcareous; core lengths 1 to 12".

EXPLANATION — Core loss / Core recovery

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 4 OF 4 — HOLE NO. DH 75-101

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOG OF DH 75-101

GEOLOGY: G. TAUCHER — SUBMITTED: ...
DRAWN: ... — RECOMMENDED: ...
CHECKED: ... — APPROVED: ...

BILLINGS, MONT. — MAY 1976 — 1305-600-40

GEOLOGIC LOG OF DRILL HOLE — SHEET 1 OF 2

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana
HOLE NO. DH 75-102 · LOCATION COORDS. * · GROUND ELEV. Altimeter 3811± · DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/11/75 · FINISHED 8/24/75 · TOTAL DEPTH 153.6 · BEARING –
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 20.2 9/3/75 (3790.8) · LOGGED BY Taucher · LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions

Hole started 8/11/75. NX drive samples 0 to 40.0'. 2-3/4" wire line core 40.0 to 45.0'. Reamed hole with 7" fish-tail to 40.0'.

Hole at 45.0' 8/12/75. W.L. at 7.3'. Set 5" CS to 40.6'. 2-3/4" wire line core 45.0 to 63.6'.

Hole at 63.6' 8/13/75. 5" CS at 40.6', W.L. at 13.6'. 2-3/4" wire line core 63.6 to 116.6'. Samples 103.1 to 113.1 and 113.1 to 116.6' fell out of core barrel. Redrilled both zones to recover part of core.

*2650' S. & 1230' W. of NE Corner, Section 3, T. 9 S., R. 45 E.

Core recovery (%): 84, 96, 70, 60, 70, 56, 68, 68, 100, 72, 98, 46, 88, 100, 81

Soils analysis sample

Sample	Depth from (feet)	Depth to (feet)
#1	0	34.0
#2	34.0 (Minus coal)	54.7
#3	54.7	57.7
#4	57.7	63.6
#5	63.6	75.6
#6	75.6	96.1
#7	96.1	104.6

Elevation / Depth (feet)

Elevation	Depth
3777.0	34.0
3771.5	39.5
3769.6	41.4
3759.6	51.4
3756.3	54.7
3753.3	57.7
3747.4	63.6
3735.4	75.6
3714.9	96.1

Coal bed labels: L?, N

Classification and physical condition

0-34.0 SANDY CLAY: Tan; oxidized; dry 0 to 6'; damp 6 to 13'; wet 13 to 34'; firm to 13'; becoming soft (cuts easily with knife) 13 to 34'; approximately 40% fine, mostly uniform sand; approximately 60% medium plasticity fines; occasional fine gravel; plasticity increases with depth; roots 0 to 1'; several clayey sand zones between 23 to 24 & 25.5 to 26.5'; lower part could be residual weathered shale; CL near top; CL-CH near bottom.

FT. UNION FORMATION - PALEOCENE

34.0-39.5 SHALE: Tan; oxidized; wet; moderately soft (cuts easily with knife); plastic; bedding not discernible; begins to air slack; few pebbles & carbonaceous fragments 34.0 to 35.0'; sandy 38.5 to 39.5'; core lengths 6 to 18".

39.5-41.4 SHALE: Dark gray; moist; firm (can be trimmed by knife); plastic; bedding not discernible; air slacks; 3 to 6" core lengths.

41.4-51.4 COAL: Badly broken; maximum size 2".

51.4-54.7 SHALE: Dark gray; moist; firm (can be trimmed by knife); plastic; bedding not discernible except laminated shale & sandstone zone 54.0 to 54.7'; air slacks; 3 to 6" core lengths.

54.7-57.7 SILTY SANDSTONE: Light gray; moist; uncemented; crumbles easily between fingers; fine grain; bedding discernible in places; thin carbonaceous streaks 57.0 to 57.7'; 3 to 14" core lengths.

57.7-63.6 SHALE: Dark gray; moist; firm (can be trimmed by knife); plastic; bedding not discernible; hard, silty concretion 59.7 to 60.4' & 63.3 to 63.5'; calcareous 58.7 to 59.5'; 3 to 12" core lengths.

63.6-75.6 SANDSTONE, SILTSTONE & SHALE: Alternating bands of light gray siltstone & fine grain sandstone & dark gray plastic shale; sandstone & siltstone crumble between fingers; shale is firm but can be trimmed by knife; laminated; approximately 25% shale, 40% sandstone & 40% sandy siltstone; core lengths 3 to 6".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Ci = 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 Bear Creek Study Site, West Moorhead Coal Field · PROJECT EMRIA No. 8 · STATE Montana · SHEET 1 OF 2 · HOLE NO. DH 75-102

GEOLOGIC LOG OF DRILL HOLE — SHEET 2 OF 2

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana
HOLE NO. DH 75-102 · LOCATION COORDS. * · GROUND ELEV. Altimeter 3811± · DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 8/11/75 · FINISHED 8/24/75 · TOTAL DEPTH 153.6 · BEARING –
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 20.2' 9/3/75 (3790.8) · LOGGED BY Taucher · LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions

Hole at 116.6' 8/14/75. 5" CS at 40.6' W.L. at 16.5'. 2-3/4" wire line core 116.6 to 125.9'. Tripped wire line to repair bit. Left site at 12:30 p.m. to return to duty station.

Hole at 125.9' 8/19/75. 5" CS at 40.6'. W.L. at 13.8'. Reamed hole with 4½" drag bit to 125.9' to clean out cuttings. 2-3/4" wire line core 125.9 to 143.6'.

Hole at 143.6' 8/20/75. 5" CS at 40.6'. W.L. at 17.5'. 2-3/4" core 143.6 to 153.6'. Washed hole. Pulled wire line tools. Pulled 5" CS. Reamed hole with 7-7/8" rock bit to 10'. Set 8" CS to 3.0'.

Hole at 153.6' 8/21/75. 8" CS at 3.0'. W.L. at 10.5'. Reamed hole with 7-7/8" rock bit to 153.6'. Used revert.

Hole at 153.6' 8/22/75. 8" CS at 3.0'. W.L. at 14.5'. Washed out hole with 7-7/8" rock bit. Flushed hole with 800 gal. of water. Set 4" plastic pipe to 143.6' (pipe slotted 41.0 to 52.0 & 112.0 to 123.6'). Gravel packed hole (Pea gravel) 153.6 to 108.5 & 59.0 to 38.5'. Packed hole 108.5 to 59.0' with gravel & bentonite.

NOTES CONTINUED

Hole at 153.6' 8/23/75. 8" CS at 3.0'. W.L. at 13.8'. Pulled 8" CS. Packed hole 0 to 38.5' with gravel & bentonite. Bailed hole for 1½ hrs. W.L. pulled down to 42.6'.

Hole at 153.6' 8/24/75. Bailed hole for 3½ hrs. Water almost clear after bailing. Unable to lower water level below 50.5'. Water raising in hole at the rate of 1' in 35 sec. Cleaned up drill site. Moved rig to DH 75-103.

*2650' S. & 1230' W. of NE Corner, Section 3, T. 9 S., R. 45 E.

Core recovery (%): 41, 100, 90, 93, 94, 100, 100

Soils analysis sample

Sample	Depth from (feet)	Depth to (feet)
#8	105.0	110.1
#9	123.6	128.5
#10	128.5	150.0

Elevation / Depth (feet)

Elevation	Depth
3706.0	105.0
3699.0	112.0
3687.4	123.6
3682.5	128.5
3657.4	153.6

Coal bed labels: O DIETZ, P

Classification and physical condition

75.6-96.1 SHALE: Dark gray; moist; plastic when reworked; trims by knife with difficulty; begins to air slack; bedding not readily discernible; shattered coal 91.7 to 92.2'; carbonaceous 93.5 to 93.6'; approaching claystone; core lengths 2 to 12".

96.1-105.0 SILTY SANDSTONE: Light gray fine grain silty sandstone with laminations of light gray siltstone & dark gray plastic shale; moist; crumbles between fingers; shale zones are firm but can be trimmed by knife; approximately 15% shale, 20% sandy siltstone & 65% silty sandstone; core lengths 1 to 12".

105.0-112.0 SHALE: Dark gray with about 10% light gray silt & very fine sand laminations; moist; very firm; silty; plastic when reworked; approaching claystone; trims by knife with difficulty; thin-bedded; 2 to 12" core lengths.

112.0-123.6 COAL: Badly broken; only 14" left after sampling.

123.6-128.5 SHALE, SILTSTONE & SANDSTONE: Light gray; moist; firm, plastic shale that trims by knife with difficulty 123.6 to 124.6'; ¼" coal streak at 123.7'; uncemented (cuts easily with knife) siltstone to clayey siltstone 124.6 to 126.6'; laminated, fine grain, uncemented (crumbles easily between fingers) silty sandstone 126.6 to 128.5'; calcareous 122.6 to 128.5'; core lengths 2 to 14".

128.5-150.0 SILTY SHALE: Light gray; moist; moderately firm to firm; generally cuts by knife with difficulty; thin-bedded to laminated in places; silty; plastic when reworked; slightly calcareous; 4 ¼ to 1" coal streaks 129.6 to 130.0'; hard silty, calcareous concretions 134.8 to 135.2'; core lengths 1 to 12".

150.0-153.6 CARBONACEOUS SHALE: Dark gray to black; moist; moderately firm; can be trimmed by knife; air slacks; plastic when reworked; ¼ to 1" coal streaks at 150.9, 151.0, 151.2, 151.4, 152.0, 152.3, 152.4 & 152.6'; laminated light gray silt and dark gray shale 151.4 to 152.0'; core lengths 1 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

FEATURE Bear Creek Study Site, West Moorhead Coal Field · PROJECT EMRIA No. 8 · STATE Montana · SHEET 2 OF 2 · HOLE NO. DH 75-102

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MDNT.

GEOLOGIC LOG OF DH 75-102

GEOLOGY: D. TAUCHER · SUBMITTED
DRAWN · RECOMMENDED
CHECKED · APPROVED

BILLINGS, MONT. · MAY 1976 · 1305-600-41

GEOLOGIC LOG OF DRILL HOLE — SHEET 1 OF 4

7-1337 (9-69) Bureau of Reclamation

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 75-103 — LOCATION: * — COORDS. N. E. — GROUND ELEV. 3875± (Altimeter) — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN 8/26/75 — FINISHED 9/10/75 — TOTAL DEPTH 222.8' — BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions

Hole started 8/26/75. NX drive samples 0 to 15.0'. 2-3/4" wire line core 15.0 to 20.0'. Reamed hole to 15.0'.

Hole at 20' 8/27/75. W.L. at 6.0'. 2-3/4" wire line core 20.0 to 74.2'. Reamed hole to 23.0'. Set 5" CS to 23.6'.

Hole at 74.2' 8/28/75. 5" CS at 23.6'. W.L. at 21.0'. 2-3/4" wire line core 74.2 to 104.2'.

*1270' N. & 1260' E. of SW Corner, Section 11, T. 9 S., R. 45 E.

Core recovery (%): 60, 98, 86, 70, 72, 90, 68, 100, 99, 100, 75, 100, 100, 91

Soils analysis sample	From	To
#1	0	6.0
#2	6.0	15.0
#3	15.0	20.0
#4	20.0	41.7
#5	61.0	65.2
#6	65.2	71.4
#7	71.4 / 76.8 (combined)	74.6 / 78.0
#8	79.9	88.0
#9	88.0	104.2

Elevation (feet)	Depth (feet)
3869.0	6.0
3860.0	15.0
3833.3	41.7
3814.0	61.0
3809.8	65.2
3803.6	71.4
3800.4	74.6
3798.2	76.8
3797.0	78.0
3795.1	79.9
3787.0	88.0
3783.8	91.2
3775.2	96.8

ANDERSON K, L

Classification and physical condition

0-6.0 SAND AND CLAY: Tan; dry; roots 0 to 1'; approximately 50% mostly fine sand and 50% low to medium plasticity fines; active HCl reaction (SC-CL)

FT. UNION FORMATION - PALEOCENE

6.0-15.0 SHALE: Brown; oxidized; moist; firm; trims easily with knife; dry with thin calcareous cemented zones 9.5 to 11.0'; scattered silt and sand laminations; plastic when reworked; scattered gypsum crystals; 2 to 18" core lengths.

15.0-20.0 SANDSTONE: Light grey 15.0 to 19.0'; tan & oxidized 19.0 to 20.0'; moist to wet; uncemented; pulverized by drilling (disintegrates between fingers); fine grain; thin-bedded.

20.0-41.7 SHALE: Brown & oxidized 20.0 to 31.0'; alternating medium grey & brown oxidized zones 31.0 to 32.2'; medium to dark grey 32.2 to 40.0'; dark grey & slightly carbonaceous 40.0 to 41.7'; moist to wet; plastic; firm; trims easily by knife; bedding not readily discernible; airslacks in places; calcareous cemented concretions 20.0 to 20.2 and 27.0 to 27.2'; hard claystone 41.3 to 41.7'; slicken side at 41.3'; core lengths 2 to 12".

41.7-61.0 COAL: Wet; broken in 2 to 12" lengths 41.7 to 53.0'; broken to shattered 53.0 to 61.0'; scattered 90° joints; plastic, carbonaceous shale 57.2 to 57.3';

61.0-65.2 CLAYEY SILTSTONE: Light grey; moist; moderately firm; cuts easily by knife; bedding not discernible; moderately plastic when reworked 61.0 to 61.8 & 64.0 to 65.2'; slightly calcareous; core lengths 2 to 24".

~~65.2-71.4~~ SHALE: Medium grey; moist; firm; approaching claystone; trims by knife with difficulty; slightly calcareous; plastic when reworked; hard, calcareous cemented concretion 66.6 to 66.9'; air slacks in places; core lengths 2 to 12".

71.4-74.6 SANDY SILTSTONE: Light grey; moist; crumbles between fingers; silty sandstone in places; sand is very fine grain; bedding not discernible; core lengths 8 to 24".

74.6-76.8 SHALE: Medium grey; moist; firm; trims by knife with difficulty; plastic when reworked; core lengths 2 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole ... D = Diamond, H = Haysellite, 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"

GEOLOGIC LOG OF DRILL HOLE — SHEET 2 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 75-103 — GROUND ELEV. 3875± (Altimeter) — Vertical — BEGUN 8/26/75 — FINISHED 9/10/75 — TOTAL DEPTH 222.8' — LOGGED BY Taucher

Notes

9/5/75 - Cleaned up DH 75-103 location.

Hole at 104.2' 9/4/75. 5" CS at 23.6'. W.L. at 32.5'. Washed hole to 104.2'. 2-3/4" wire line core 104.2 to 156.7'. Sample 151.7 to 156.7' fell out of barrel.

Hole at 156.7' 9/5/75. 5" CS at 23.6'. W.L. at 34.0'. Washed out hole. Redrilled zone 151.7 to 156.7' and recovered 3.5' of core. 2-3/4" wire line core 156.7 to 201.2'. 9.0' of soft siltstone washed away between 161.7 and 181.7'.

*1270' N. & 1260' E. of SW Corner, Section 11, T. 9 S., R. 45 E.

Core recovery (%): 100, 75, 61, 85, 93, 100, 70, 100, 65, 45, 88, 100

Soils analysis sample	From	To
#11	114.2	126.6
#12	126.6	131.5
#13	131.5 (composite)	143.7
#14	144.6	167.7
#15	167.7	181.0
#16	183.5	188.6

Elevation (feet)	Depth (feet)
3767.8	104.2
3762.4	109.6
3757.8	114.2
3745.8	126.2
3740.5	131.5
3739.6	132.1
3739.1	132.6
3738.1	133.6
3736.2	135.5
3732.0	139.7
3728.0	143.7
3727.1	144.6
3704.0	167.7
3690.7	181.0
3688.2	183.5
3683.1	188.6
3674.1	197.7

M, N, O DIETZ

Classification and physical condition

76.8-78.0 SANDY SILTSTONE: Light grey; moist; crumbles between fingers; silty sandstone stringers; sand is fine grain; bedding not discernible; core lengths 2 to 8".

78.0-79.9 SILTY SHALE: Light to medium grey; moist; firm; cuts by knife with difficulty; plastic when reworked; laminated in zones; core lengths 12".

~~79.9~~-88.0 SHALE: Medium gray; moist; firm; trims by knife with difficulty; plastic when reworked; bedding not readily discernible; moderately cemented; hard, sandy siltstone 84.7 to 85.3 and 86.3 to 86.7'; core lengths 1 to 12".

88.0-91.2 SILTY SANDSTONE: Light gray; moist; firm; breaks between fingers with difficulty; bedding not discernible; sand is very fine grain; approaching siltstone; core lengths 8 to 18".

91.2-96.8 SANDSTONE: Light gray; moist; moderately firm; crumbles fairly easily between fingers; sand is very fine grain; thin-bedded; begins to wash away during drilling; few clay streaks 95.0 to 96.8'; core lengths 1 to 12".

96.8-104.2 SHALEY SANDSTONE: Light grey fine grain sandstone alternating with medium gray, plastic, silty shale laminations; sandy shale 97.5 to 98.5, 100.7 to 101.3 & 103.0 to 104.2'; trims easily by knife; core lengths 10 to 14".

104.2-109.6 SHALE: Dark gray; slightly carbonaceous; moist; firm; trims by knife with difficulty; very plastic when reworked; core lengths 12 to 16".

109.6-114.2 COAL AND CARBONACEOUS SHALE: Broken coal 109.7 to 112.5'; black, carbonaceous shale or shaley coal 109.6 to 109.7 and 112.5 to 114.2'; cut by numerous slicken sides; core lengths 2 to 3".

114.2-126.2 SHALE: Medium grey; moist; firm; becoming very firm with depth; trims by knife with difficulty; 1/8" coal filled, 60° fracture at 116.2'; plastic when reworked; air slacks; approaching claystone; core lengths 6 to 18".

126.2-131.5 SANDSTONE: Light gray; moist; fine grain; silty; alternates between uncemented and weakly cemented; few carbonaceous streaks; begins to wash away during drilling; 1 to 6" core lengths.

GEOLOGIC LOG OF DRILL HOLE — SHEET 3 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 75-103 — GROUND ELEV. 3875± (Altimeter) — Vertical — BEGUN 8/26/75 — FINISHED 9/10/75 — TOTAL DEPTH 222.8' — LOGGED BY Taucher

Notes

Hole at 201.2' 9/6/75. 5" CS at 23.6'. W.L. at 36.2'. Washed out 45.0' of cuttings. 2-3/4" wire line core 201.2 to 221.3'. Pulled 5" CS. Reamed hole to 30.0' with 7-7/8" rock bit. Set 8" CS to 3.0'.

Hole at 221.3' 9/7/75. 8" CS at 3.0'. W.L. at 38.5'. Reamed hole with 7-7/8" rock bit 30.0 to 112.8'. Used revert. Set 8" CS at 4.0'.

Hole at 221.3' 9/8/75. 8" CS at 4.0'. W.L. at 36.5' Reamed hole with 7-7/8" rock bit 112.8 to 202.8'. Repaired equipment.

Hole at 221.3' 9/9/75. 8" CS at 4.0'. W.L. at 32.5'. Reamed hole with 7-7/8" rock bit 202.8 to 222.8'. Flushed hole with 1200 gallons of water. Installed 4" diameter plastic pipe to 217.7'. (Slotted 61.0 to 197.7'). Gravel packed hole to 180.0'.

Hole at 222.8' 9/10/75. 8" CS at 4.0'. W.L. at 24.0' Packed hole with bentonite & gravel 180.0 to 70.0'. Gravel packed hole 70.0 to 35.5'. Packed hole with bentonite & gravel 35.5 to 12.0'. Bailed hole to 138.0'. Unable to lower water level below

*1270' N. & 1260' E. of SW Corner, Section 11, T. 9 S., R. 45 E.

Core recovery (%): 93, 100

Soils analysis sample	From	To
#17	197.7	221.3

Elevation (feet)	Depth (feet)
3650.5	221.3
3649.0	222.8

Rock bit

Classification and physical condition

131.5-132.1 SANDY SILTSTONE: Light to medium grey; moist; firm; difficult to trim by knife; laminated shale & fine grain sandstone; core lengths 1 to 3".

132.1-132.6 SILTSTONE: Medium gray; moist; hard; cemented with calcium carbonate; broken in 1 to 2" pieces.

132.6-133.6 SHALE: Medium gray; moist; sandy; plastic; firm; trims by knife with difficulty; bedding not discernible.

133.6-135.5 SILTSTONE: Light gray; moist; crumbles between fingers; fine grain; carbonaceous streaks 133.6 to 133.9'; 6" core lengths.

135.5-139.7 SHALE: Medium gray; moist; firm; plastic; air slacks; trims by knife with difficulty; hard claystone 136.1 to 136.4'; fossiliferous 135.5 to 135.6'; 1 to 12" core lengths.

139.7-143.7 SANDSTONE: Light gray; moist; fine grain; crumbles easily between fingers; core lengths 2 to 6".

143.7-144.6 COAL AND CARBONACEOUS SHALE: Dark grey to black carbonaceous shale 143.7 to 144.2'; broken coal 144.2 to 144.6'.

144.6-167.7 SHALE WITH SILTSTONE: Medium to dark gray 144.6 to 154.0'; dark grey & slightly carbonaceous 154.0 to 158.0' dark gray carbonaceous shale with coal streaks 158.0 to 158.6'; light to medium gray 158.6 to 176.7'; moist; firm; difficult trimming by knife; plastic when reworked; approaching claystone; air slacks in places; sandy siltstone 146.1 to 147.7'; moderately plastic silty shale or shaley siltstone 161.0 to 176.7'; core lengths 1 to 18".

167.7-181.0 SILTY SANDSTONE: Light gray; wet; uncemented; crumbles between fingers easily; fine grain; silty; laminations of medium gray silt; plastic shale streaks up to 2" thick 178.0 to 181.0'; core washed away during drilling.

181.0-183.5 SILTSTONE, SHALE & SANDSTONE: Alternating laminations of light grey siltstone, fine grey sandstone and dark grey shale; moist; moderately firm; can be crushed between fingers; core lengths up to 6".

183.5-188.6 SHALE: Dark gray; moist; plastic; firm; cuts by knife with difficulty; air slacks; slightly carbonaceous; laminated in upper 1'; core lengths 1 to 12".

GEOLOGIC LOG OF DRILL HOLE — SHEET 4 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 75-103 — GROUND ELEV. 3875± (Altimeter) — Vertical — BEGUN 8/26/75 — FINISHED 9/10/75 — TOTAL DEPTH 222.8' — LOGGED BY Taucher

Notes

138.0'. Water raising in hole at the rate of 1' in 35 seconds; pulled 8" CS.

9/11/75 Moved rig to DH 75-112

*1270' N. & 1260' E. of SW Corner, Section 11, T. 9 S., R. 45 E.

Classification and physical condition

188.6-197.7 COAL: 2 to 8" pieces 188.6 to 193.0'; badly broken 193.0 to 197.7' cut by vertical fractures.

197.7-221.3 CLAYEY SILTSTONE TO SILTY SHALE: Light gray; moist; firm; cuts by knife with difficulty; thin-bedded; clayey siltstone 197.2 to 198.4'; silty shale to clayey siltstone 198.4 to 210.6'; uncemented siltstone 210.6 to 212.0'; silty shale to clayey siltstone 212.0 to 221.3'; slight to moderate plasticity when reworked; core lengths 1 to 24".

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOG OF DH 75-103

GEOLOGY R. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED
BILLINGS, MONT. — MAY 1976 — 1305-600-42

GEOLOGIC LOG OF DRILL HOLE — SHEET 1 OF 4

7-1337 (5-61) Bureau of Reclamation

FEATURE: Bear Creek Study Site, West Moorhead Coal Field. PROJECT: EMRIA No. 8. STATE: Montana
HOLE NO.: DH 75-104. LOCATION: *. COORDS.: N. E. GROUND ELEV.: Altimeter 4004±. DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 7/10/75. FINISHED: 8/10/75. TOTAL DEPTH: 321.0'. BEARING: –
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 224.1' 9/2/75 (3779.9'). 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 drilling conditions

7/10/75. Moved equipment to DH 75-104. BX drive samples 0 to 6.4'.

Hole at 6.4' 7/11/75. 2-3/4" wire line core (using air) 6.4 to 8.3'. 2-3/4" wire line core (using water) 8.3 to 40.5'. Dropped sample 29.5 to 39.5' in hole. Recovered 5.8' of sample on next run. Losing about 10% water. Reamed hole & set 5" casing to 10.6'.

Hole at 40.5' 7/12/75. W.L. at 13.6'. 5" CS at 10.6'. 2-3/4" wire line core 40.5 to 55.3'. Lost water at 45'. Mixed 4 pits of revert but could not get circulation back. Pulled 5" CS & reamed hole. Drove 5" CS to 45.6'.

Hole at 55.3' 7/13/75. W.L. at ground surface. 5" CS at 45.6'. Washed out casing. 2-3/4" wire line core 55.3 to 90.8'. Losing some water. Dropped samples 60.3 to 70.3 & 70.3 to 73.2' in hole. Recovered parts of both samples. Modified core lifter.

Hole at 90.8' 7/14/75. W.L. at 58.5'. 5" CS at 45.6'. 2-3/4" wire line core 90.8 to 136.3'. Losing some water.

*2230' S. & 420' W. of NE Corner, Section 11, T. 9 S., R. 45 E.

Core recovery (%), top to bottom: 70, 100, 0, 100, 100, 100, 83, 58, 100, 87, 100, 100, 58, 100, 100, 99, 96

Sample	From	To
#1	2.5	8.3
#2	8.3	24.0
#3	25.9	62.5
#4	62.5	80.8
#5	80.8	93.2
#6	93.2	98.6

Elevation (feet)	Depth (feet)
4001.5	2.5
3995.7	8.3
3980.0	24.0
3978.5	25.9
3941.9	62.5
3923.6	80.8
3911.2	93.2
3905.8	98.6

Graphic log labels: G, H, I

Classification and physical condition

FT. UNION FORMATION - [illegible]

0-2.5 SHALE: Grey-brown; moist; oxidized; soft; cuts easily with knife; plastic; bedding not readily discernible; core lengths 2 to 12".

2.5-8.3 SANDSTONE: Tan; oxidized; dry; uncemented; crumbles easily between fingers; very fine grain; silty; pulverized.

8.3-24.0 SHALE & SILTY SHALE: Brown & oxidized 8.3 to 14.8'; dark grey to black & carbonaceous 14.8 to 19.2'; brown & oxidized 19.2 to 22.5'; medium grey 22.5 to 24.0' with dark grey carbonaceous streaks 23.2 to 24.0'; shale is moderately plastic to plastic; sandy siltstone 10.0 to 10.5'; thin (~1") silt & sand streaks in brown, oxidized zones; calcareous 22.0 to 24.0'; begins to air slack, especially in carbonaceous zones; trims easily with knife in brown, oxidized zones; firm & more plastic (trims by knife with difficulty) in carbonaceous zones; core lengths 1 to 6".

24.0-25.9 COAL: Black; broken; some clay contamination in lower half; cut by vertical fractures.

25.9-62.5 SHALE WITH SANDY SHALE & SANDSTONE: Light to medium grey; moist; mostly shale with zones of sandy shale & sandstone; firm, plastic shale (trims by knife with difficulty) 25.9 to 29.0, 31.0 to 40.5, 41.5 to 45.0, & 45.8 to 46.3'; light grey, thin-bedded to laminated silty sandstone which crumbles easily between fingers 29.0 to 31.0 & 56.0 to 57.0'; light grey, uncemented (crumbles easily between fingers) fine grain sandstone 45.0 to 45.8 & 46.3 to 46.7'; slightly plastic, thin-bedded, firm (trims by knife with difficulty) sandy shale or shaley sandstone 40.5 to 41.5, 46.7 to 56.0, 57.0 to 59.4 & 61.3 to 62.5'; laminated, firm dark grey shale & light grey sandstone 59.4 to 61.3'; moderate to active HCl reaction; slickenside at 28.5'; 70° fracture at 53.8'; hard, cemented calcareous concretions at 42.0 to 42.2 & 43.0 to 43.3'; core lengths 1 to 18".

62.5-80.8 SANDSTONE WITH SILTY SANDSTONE & SHALE: Light grey; moist; fine grain; uncemented (crumbles between fingers), silty sandstone 62.5 to 68.5' (core loss); medium grey, sandy shale (trims by knife with difficulty) 68.5? to 70.3'; uncemented (crumbles between fingers),

GEOLOGIC LOG OF DRILL HOLE — SHEET 2 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field. PROJECT: EMRIA No. 8. STATE: Montana. HOLE NO.: DH 75-104. GROUND ELEV.: Altimeter 4004±. DIP: Vertical. BEGUN: 7/10/75. FINISHED: 8/10/75. TOTAL DEPTH: 321.0'. DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 224.1' 9/2/75 (3779.9'). LOGGED BY: Taucher.

Notes on drilling conditions

Hole at 136.3' 7/15/75. W.L. at 84.4'. 5" CS at 45.6'. 2-3/4" wire line core 136.3 to 163.2'. Losing about 15% drill fluid using revert.

Hole at 163.2' 7/16/75. W.L. at 98.1'. 5" CS at 45.6'. 2-3/4" wire line core 163.2 to 200.1'. Losing drill fluid. Revert would not seal hole. Inner tube hung up on last run. Broke wire line cable.

Hole at 200.1' 7/17/75. 5" CS at 45.6'. Repaired wire line cable. Put 1500 pounds of pea gravel around pipe in DH 75-101.

*2230' S. & 420' W. of NE Corner, Section 11, T. 9 S., R. 45 E.

Core recovery (%), top to bottom: 98, 96, 95, 100, 90, 100, 72, 85, 100, 79, 100, 100

Sample	From	To
#7	98.6	138.5
#8	162.1	183.1

Elevation (feet)	Depth (feet)
3865.9	138.5
3851.3	153.1
3842.3	162.1
3821.3	183.1

Graphic log labels: J, K, L; ANDERSON

Classification and physical condition

silty sandstone 70.3 to 72.0'; weakly cemented (crumbles between fingers with difficulty) sandstone 72.0 to 74.0'; moderately cemented, calcareous (can't break between fingers), sandstone 74.0 to 79.6'; silty, uncemented (crumbles easily between fingers), sandstone 79.6 to 80.8'; core lengths 2 to 12".

80.8-93.2 SHALE: Medium grey; moist; plastic with moderately plastic silty shale zones; coal & carbonaceous shale 81.0 to 81.1 & 84.0 to 84.4'; air slacks; trims by knife with difficulty; slight to moderate HCl reaction; slickenside at 84.4'; core lengths 2 to 6".

93.2-98.6 SILTY SANDSTONE: Light grey; brown & oxidized 97.5 to 98.0'; trims easily with knife; moist to wet; very fine grain; silty; carbonaceous streaks 93.6 to 93.7 & 94.5 to 94.6'; core lengths 6 to 18".

98.6-138.5 SHALE: Medium grey; moist; plastic; firm; approaching claystone; difficult trimming with knife; air slacks; dark grey to black carbonaceous shale 112.0 to 112.8, 113.4 to 121.2, 124.0 to 130.0 & 136.5 to 138.5'; uncemented, silty sandstone that crumbles between fingers 121.2 to 123.0'; hard, calcareous concretions 123.0 to 123.2 & 126.8 to 127.2'; becoming harder with tendency to air slack below 131.0'; 70° fracture at 101.5'; 60° fracture at 119.5'; 45° mud-lined joint at 132.3'; several slickensides 136.5 to 138.5'; 1 to 12" core lengths.

138.5-153.1 COAL: Black; moist to wet; few vertical fractures; 2 to 6" core lengths 141.1 to 149.6'; remaining core is badly broken.

153.1-162.1 SHALE, SILTY SHALE AND COAL: Dark grey; moist; plastic; soft & carbonaceous (trims easily with knife) 153.1 to 157.3'; broken coal 157.3 to 158.0'; firm (trims by knife with difficulty), silty shale 158.0 to 162.1'; 2 to 14" core lengths.

162.1-183.1 SANDY SILTSTONE TO SILTY SANDSTONE: Light to medium grey; moist; traces of clay; cuts easily with knife; varies from sandy siltstone to silty sandstone; sand is very fine grain; firm, laminated shale & siltstone 167.0 to 168.2'; firm, laminated shale & sandstone 169.7 to 170.5 & 173.0 to 174.3'; calcareous, cemented concretion 163.2 to 163.8'; core lengths 2 to 12".

GEOLOGIC LOG OF DRILL HOLE — SHEET 3 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field. PROJECT: EMRIA No. 8. STATE: Montana. HOLE NO.: DH 75-104. GROUND ELEV.: Altimeter 4004±. DIP: Vertical. BEGUN: 7/10/75. FINISHED: 8/10/75. TOTAL DEPTH: 321.0'. DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 224.1' 9/2/75 (3779.9'). LOGGED BY: Taucher.

Notes on drilling conditions

Hole at 200.1' 7/23/75. 5" CS at 45.6'. W.L. at 145.0'. 2-3/4" wire line core 200.1 to 219.7'. Losing about 40% drill water. Samples 207.9 to 210.8 & 210.8 to 219.7' fell out of barrel. Redrilled these zones to recover samples.

Hole at 219.7' 7/24/75. 5" CS at 45.6'. W.L. at 149.5'. 2-3/4" wire line core 219.7 to 273.2'. Soft zones 268.0 to 273.2' washed away. Losing 15 to 20% drill water.

Hole at 273.2' 7/25/75. 5" CS at 45.6'. Washed out cave and cuttings 190.0 to 273.3'. 2-3/4" wire line core 273.2 to 303.2'.

*2230' S. & 420' W. of NE Corner, Section 11, T. 9 S., R. 45 E.

Core recovery (%), top to bottom: 63, 86, 73, 100, 87, 75, 65, 86, 25, 38, 96, 100

Sample	From	To
#9	183.1	219.5
#10	219.5	227.8
#11	227.8	285.0
#12	297.0	304.5

Elevation (feet)	Depth (feet)
3784.9	219.5
3776.6	227.8
3718.5	285.9
3707.6	296.8

Graphic log labels: M, N, O, DIETZ

Classification and physical condition

183.1-219.5 SHALE & SILTY SHALE: Medium to dark grey & slightly carbonaceous 183.1 to 198.6'; dark grey and carbonaceous 198.6 to 199.1'; coal alternating with black carbonaceous shale 199.1 to 200.5'; black, carbonaceous shale with thin coal stringers 200.5 to 204.5'; medium grey shale 204.5 to 208.3'; light grey, slightly calcareous, silty shale 208.3 to 219.5'; shale is firm & difficult to trim with knife; soft zone 199.1 to 200.5'; cuts easily with knife; silty shale below 208.3' is more firm & approaches claystone; moist; bedding not readily discernible except below 208.3' where laminations are present; plastic when reworked; core lengths 1 to 12".

219.5-227.8 SHALEY SANDSTONE: Alternating bands of light grey, uncemented, fine grain sandstone and firm, dark grey, plastic shale; moist; trims easily with knife; slight HCl reaction; hard, calcareous cemented claystone 227.0 to 227.4'; core lengths 2 to 18".

227.8-285.9 SHALE WITH SANDSTONE: Medium grey, firm (difficult trimming with knife) shale 227.8 to 229.2'; hard, calcareous cemented claystone (scratches with knife) 229.2 to 230.0'; medium grey, firm (difficult trimming with knife) shale 230.0 to 231.5'; light grey, uncemented, fine grain sandstone with several shale stringers (trims easily with knife) 231.5 to 235.0'; firm (difficult trimming with knife) calcareous shale & claystone 235.0 to 235.9'; light grey, uncemented, fine grain sandstone with several shale streaks (trims easily with knife) 235.9 to 236.7'; firm, medium grey shale with several sandstone stringers 236.7 to 239.0' (trims by knife with difficulty); weakly cemented (crumbles between fingers), fine grain sandstone with clay contamination & several shale stringers 239.0 to 243.5'; medium grey, firm (difficult trimming with knife), shale 243.5 to 252.2' with carbonaceous streak 248.4 to 248.5'; firm (trims easily with knife), sandy shale or shaley sandstone 252.2 to 254.9'; medium gray, firm (difficult trimming with knife) shale 254.9 to 257.5'; light gray, uncemented shaley sandstone that trims easily with knife 257.5 to 262.5'; medium grey; firm (trims by knife with difficulty) shale 262.5 to 285.9' with several thin

GEOLOGIC LOG OF DRILL HOLE — SHEET 4 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field. PROJECT: EMRIA No. 8. STATE: Montana. HOLE NO.: DH 75-104. GROUND ELEV.: Altimeter 4004±. DIP: Vertical. BEGUN: 7/10/75. FINISHED: 8/10/75. TOTAL DEPTH: 321.0'. DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 224.1' 9/2/75 (3779.9'). LOGGED BY: Taucher.

Notes on drilling conditions

Hole at 303.2' 7/26/75. 5" CS at 45.6'. W.L. at 133.0'. 2-3/4" wire line core 303.2 to 313.2'; repaired logging truck & moved water pump to new location. Logged hole with geophysical probes.

Hole at 313.2' 7/27/75. 5" CS at 45.6'. W.L. at 135.0'. Pulled 5" CS. Set 8" CS to 3'; repairs on equipment.

Hole at 313.2' 7/28/75. Pulled 8" CS as it would not seal flows. Set 8" CS to 4.4'. Reamed hole with 7-7/8" rock bit to 92.5'.

Hole at 313.2' 7/29/75. 8" CS at 4.4'. Reamed hole with 7-7/8" rock bit 92.5 to 192.1'. Hole filled with mud at start of shift.

Hole at 313.2' 7/30/75. 8" CS at 4.4'. W.L. at 30.0'. Reamed hole with 7-7/8" rock bit 192.1 to 222.5'. Dropped 130' of rods in hole.

Hole at 313.2' 8/5/75. 8" CS at 4.4'. Fished for & recovered tools. Washed cave & cuttings to 222.5'.

Hole at 313.2' 8/6/75. 8" CS at 4.4'. W.L. at 137.0'. Reamed hole with 7-7/8" rock bit 222.5 to 311.4'. Used revert.

Hole at 313.2' 8/7/75. 8" CS at 4.4'. Reamed hole

NOTES CONTINUED

with 7-7/8" rock bit 311.0 to 321.0'. Washed hole with 1600 gallons of water. Pulled tools. Set 4" plastic pipe to 307'. Pipe slotted 286.0 to 297.0 & 139.0 to 154.0'. Gravel (Pea) packed hole 280 to 321'. Granular bentonite & pea gravel 155.0 to 280'. Gravel (Pea) packed hole 130 to 155'. Granular bentonite & pea gravel 0 to 130'. Pulled 8" CS.

Hole at 321' 8/9/75. W.L. at 94.5'. Bailed hole. Unable to get bailer to bottom of pipe. Washed hole to bottom with wash rods.

Hole at 321' 8/10/75. W.L. at 142.0'. Bailed hole for 3½ hours. Water fairly clean. Unable to lower water level below 250' by bailing. Moved equipment to DH 75-102.

*2230' S. & 420' W. of NE Corner, Section 11, T. 9 S., R. 45 E.

Core recovery (%): 100; No core, rock bit

Elevation (feet)	Depth (feet)
3702.7	301.7
3691.2	313.2
3683.4	321.0

Graphic log label: rock bit

Classification and physical condition

uncemented sand streaks 273.2 to 273.9'; hard, claystone concretions 263.6 to 264.2 & 274.4 to 274.5'; moist; core lengths 1 to 18".

285.9-296.8 COAL: Black; wet; badly broken in upper half; good core in lower half; 6" black, carbonaceous plastic shale near middle (unable to determine depth as coal was sampled at the drill site).

296.8-301.7 SHALE: Light grey; moist; firm; difficult trimming with knife; bedding not readily discernible; plastic; 1 to 12" core lengths.

301.7-313.2 SILTSTONE: Light grey; firm; trims by knife with difficulty; trace of clay; some very fine sand; 1 to 6" core lengths.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hayestellite, 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: Bear Creek Study Site, West Moorhead Coal Field. PROJECT: EMRIA No. 8. STATE: Montana. SHEET 1 OF 4. HOLE NO. DH 75-104.

UNITED STATES
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RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOG OF DH 75-104

GEOLOGY: S. TAUCHER. SUBMITTED:
DRAWN: RECOMMENDED:
CHECKED: APPROVED:
BILLINGS, MONT. MAY 1976 1305-600-43

GEOLOGIC LOG OF DRILL HOLE — SHEET 1 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO.: DH 75-105 — LOCATION: * — COORDS. — GROUND ELEV.: Altimeter 3969± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 9/20/75 — FINISHED: 10/7/75 — TOTAL DEPTH: 312.5' — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 158.2' 11/17/75 (3810.8) — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 9/20/75. NX drive sample 0 to 3.3'. 2-3/4" wire line core 3.3 to 19.3'. Reamed hole & set 5" CS to 18.6'.

Hole at 19.3' 9/20/75. 5" CS at 18.6'. W.L. at 12.5'. 2-3/4" wire line core 19.3 to 94.3'. Dropped sample 46.6 to 54.9'. (Recovered on next run). Pulled tools & changed bit.

Hole at 94.3' 9/22/75. 5" CS at 18.6'. W.L. at 24.6'. 2-3/4" wire line core 94.3 to 151.4'. Samples 134.9 to 144.9 & 144.9 to 151.4' dropped in hole. Redrilled & recovered most of samples.

*2110' N. & 1200' E. of SW Corner, Section 2, T. 9 S., R. 45 E.

Soils analysis samples: #1 10.6–34.6; #2 38.6–45.6; #3 45.6–92.8; #4 92.8–108.9

Classification and physical condition:

0-3.3 SANDY CLAY: Tan; dry; few roots; approximately 45% fine sand & 55% low to medium plasticity fines (CL).

FT. UNION FORMATION - PALEOCENE

3.3-7.8 SANDSTONE: Tan; dry; oxidized; fine grain; crumbles between fingers; silty; lost most of sample; pulverized.

7.8-9.0 SHALE: Brown; oxidized; damp; plastic; cuts easily with knife; calcareous; badly broken.

9.0-10.6 SANDSTONE: Tan; dry; oxidized; fine grain; silty; crumbles between fingers.

10.6-34.6 SHALE: Brown & oxidized 10.6 to 13.1'; dark gray & carbonaceous 13.1 to 16.5'; dark gray to black & carbonaceous 16.5 to 19.3'; medium to dark gray 19.3 to 24.6'; light to medium gray 24.6 to 33.3'; medium to dark gray 33.3 to 34.6'; coal 22.2 to 22.4 & 23.7 to 23.8'; moist; moderately firm to firm 10.6 to 19.3' (trims easily with knife); very firm claystone 19.3 to 24.3' (difficult trimming with knife); moderately firm 24.3 to 34.6' (trims by knife with difficulty); very plastic when reworked except low plasticity silty shale to clayey siltstone 24.3 to 34.6'; calcareous 24.3 to 34.6'; badly broken 10.6 to 15.0'; core lengths 1 to 24" 15.0 to 34.6'; 70° joint at 27.9'.

34.6-36.6 COAL: 2 to 8" core lengths.

36.6-38.6 SHALE: Medium to dark gray; firm; difficult trimming with knife; plastic; scattered carbonaceous fragments; coal 37.4 to 37.6'; 2 to 12" core lengths.

38.6-45.6 SANDSTONE: Light gray; moist; compact; clayey near top becoming silty with depth; thin-bedded; crumbles between fingers with difficulty; very fine grain (approaching siltstone); core lengths 6 to 12".

45.6-92.8 SHALE: Medium gray; moist; plastic shale 45.6 to 46.4' (difficult trimming with knife); coal 46.4 to 46.6'; plastic shale 46.6 to 62.4' (difficult trimming with knife); shaley; fine grain sandstone 62.4 to 64.3' (crumbles between fingers with difficulty); plastic shale 64.3 to 74.7' (difficult trimming by knife); laminated plastic shale & sandy shale 74.7 to 76.9' (trims by knife with difficulty); broken coal & carbonaceous shale 76.9 to 77.5'; plastic shale 77.5 to 78.1' (trims by knife with difficulty); coal 78.1 to 78.3', firm, ...

GEOLOGIC LOG OF DRILL HOLE — SHEET 2 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO.: DH 75-105 — GROUND ELEV.: Altimeter 3969± — DIP: Vertical
BEGUN: 9/20/75 — FINISHED: 10/7/75 — TOTAL DEPTH: 312.5'
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 158.2' 11/17/75 (3810.8) — LOGGED BY: Taucher

Notes:

*2110' N. & 1200' E. of SW Corner, Section 2, T. 9 S., R. 45 E.

Hole at 151.4' 9/23/75. 5" CS at 18.6'. W.L. at 35.1'. 2-3/4" wire line core 151.4 to 174.9'. Losing water 152.6 to 160.5'. 100% water loss at 160.5'. Mixed 500 gallons of revert with no drill water return. Sample 164.9 to 174.9' dropped in hole. Recovered 6.6' water level at 141.5' at end of shift.

Hole at 174.9' 9/24/75. 5" CS at 18.6'. W.L. at 41.1' at end of shift. 2-3/4" wire line core 174.9 to 244.9'. No water return except 5-10% on last run. Samples 174.9 to 184.9, 192.3 to 202.3, 214.9 to 224.9 & 224.9 to 234.9' dropped in hole. Redrilled & recovered parts of all samples. Parts of samples 192.3 to 202.3, 204.9 to 214.9, 214.9 to 224.9 & 224.9 to 234.9' washed away during drilling. Used revert.

Soils analysis samples: #5 108.9–126.0 (Minus coal); #6 129.0–152.6; #7 191.4–210.6

Classification and physical condition:

-plastic shale 78.3 to 91.0' with carbonaceous zones 85.5 to 85.7 & 90.7 to 91.0' (trims by knife with difficulty); sandy shale 91.0 to 92.8' (trims by knife with difficulty); 60 to 70° joints at 47.3, 48.1 & 48.3'; badly broken 52.9 to 54.9'; 70° joint at 67.0 & 86.8'; air slacks; moderately calcareous 54.0 to 92.8'.

92.8-108.9 SANDSTONE: Light grey; moist; fine grain; silty; cemented & calcareous 92.8 to 95.4' (scratches with knife); compact but not cemented 95.4 to 108.9' (crumbles between fingers with difficulty); thin-bedded; core lengths 1 to 24".

108.9-126.0 SHALE WITH SANDSTONE & COAL: Moist; medium gray, slightly calcareous firm plastic shale 108.9 to 117.9' (trims by knife with difficulty); dark gray to black carbonaceous shale with thin coal streaks 117.9 to 119.8'; medium grey, plastic, firm shale 119.8 to 120.8' (trims by knife with difficulty); uncemented, fine grain sandstone 120.8 to 121.3' (crumbles between fingers); soft, plastic shale 121.3 to 121.5' (cuts easily with knife); badly broken coal with numerous shale partings 121.5 to 123.3'; firm, black, carbonaceous shale 123.3 to 124.8' (trims by knife with difficulty); medium gray, firm shale 124.8 to 126.0' with uncemented fine grain sandstone 125.6 to 125.9' (trims by knife with difficulty); laminated 124.0 to 126.0'; air slacks in places; slickensides 117.9 to 119.8'; core lengths 1 to 18".

126.0-129.0 SILTSTONE: Light gray; moist; trace of clay & fine sand; low plasticity; crumbles between fingers; shaley 126.0 to 127.0'; badly broken.

129.0-152.6 SHALE: Medium gray; hard; trims by knife with difficulty; almost fissile; claystone; laminated with carbonaceous streaks 130.0 to 131.0'; slightly calcareous 131.0 to 133.5'; dark grey & carbonaceous 150.0 to 152.6'; air slacks; core lengths 1 to 6"; badly broken 143.5 to 144.0'.

152.6-179.0(?) COAL: Dropped core samples 164.9 to 174.9 & 174.9 to 184.9' in hole. Redrilled & recovered 69 & 66% of core respectively; bottom contact of coal picked from resistivity log; driller reported shale partings at 169.5 to 169.7 & 176.3 to 176.7'.

GEOLOGIC LOG OF DRILL HOLE — SHEET 3 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO.: DH 75-105 — GROUND ELEV.: Altimeter 3969± — DIP: Vertical
BEGUN: 9/20/75 — FINISHED: 10/7/75 — TOTAL DEPTH: 312.5'
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 158.2' 11/17/75 (3810.8) — LOGGED BY: Taucher

Notes:

9/31/75 Repaired equipment. W.L. at 150.0'.

Hole at 244.9' 10/1/75. 5" CS at 18.6'. W.L. at 150.0'. Washed 82' of cave & cuttings out of hole. 2-3/4" wire line core 244.9 to 311.9'. 25% water return 244.9 to 275.0'. 100% water loss below 275.0'. Used about 6,000 gallons of water. W.L. holding at 12.0'.

*2110' N. & 1200' E. of SW Corner, Section 2, T. 9 S., R. 45 E.

Soils analysis samples: #8 210.6–231.7; #9 231.7–244.9; #10 254.3–268.4; #11 278.7–285.4; #12 285.4–306.6

Classification and physical condition:

179.0(?)-185.8 SHALE: Dark gray; carbonaceous; moist; moderately firm to firm; trims with knife; air slacks; plastic; core lengths 6 to 12"; upper contact picked from resistivity log; shaley coal 185.2 to 185.8'.

185.8-191.4 COAL: Core lengths 6". Contains some clay contamination.

191.4-210.6 SHALE: Medium to dark grey; moist; firm; cuts by knife with difficulty; begins to air slack; carbonaceous 201.0 to 203.0'; broken 193.0 to 195.0' contains fine grain sand laminations 209.0 to 210.6'; core lengths 1 to 8". Driller reported washing away approximately 40% of core; core not recovered, could possibly contain uncemented sandstone streaks.

210.6-231.7 SANDSTONE WITH SILTSTONE & SHALE: Only 3' core recovery as material washed away during drilling; core recovered was very soft, laminated light grey siltstone, very fine grain sandstone & medium grey silty shale; crumbles easily between fingers; shales are slightly plastic.

231.7-247.9 SHALE: Medium to dark grey; plastic; moist; slightly carbonaceous; firm; difficult trimming by knife; air slacks; several slickensides 243.8 to 243.9'; 2 to 12" core lengths.

247.9-248.6 CARBONACEOUS SHALE & COAL: Badly broken; black; moist; shale is moderately firm; alternating coal & shale streaks; several slickensides 248.4 to 248.6'.

248.6-250.2 CLAYEY SANDSTONE: Light gray; moist; moderately firm; crushes between fingers; sand is fine grain; moderately plastic when reworked; occasional small coal fragments; core lengths 6".

250.2-254.3 SHALE: Medium to dark gray; moist; firm; difficult trimming with knife; air slacks; several 15 to 70° slickensides 252.0 to 254.3'; plastic; core lengths 2 to 12".

254.3-268.4 SANDSTONE & SHALE: Alternating laminations of light gray silty sandstone & dark gray plastic shale; moist; mostly silty sandstone in upper half grading to mostly shale in lower half; silty sandstones are uncemented, crumble between fingers & begin to wash away during drilling; shale is moderately firm & difficult to trim with a knife;

GEOLOGIC LOG OF DRILL HOLE — SHEET 4 OF 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO.: DH 75-105 — GROUND ELEV.: Altimeter 3969± — DIP: Vertical
BEGUN: 9/20/75 — FINISHED: 10/7/75 — TOTAL DEPTH: 312.5'
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 158.2' 11/17/75 (3810.8) — LOGGED BY: Taucher

Notes:

Hole at 311.9' 10/2/75. 5" CS at 18.6'. Pulled 5" CS. Set 8" CS to 2.0'. Reamed hole to 102.5' with 7-7/8" rock bit. Repaired equipment.

Hole at 311.9' 10/3/75. 8" CS at 2.0'. W.L. at 8.0' Reamed hole 102.5 to 192.5' with 7-7/8" rock bit. Lost some water in coal. 100% water return after using revert.

Hole at 311.9' 10/4/75. 8" CS at 2.0'. W.L. at 155.0'. Reamed hole 192.5 to 272.5' with 7-7/8" rock bit. Cuttings sticking & bridging over hole.

Hole at 311.9' 10/5/75. 8" CS at 2.0'. Washed 70' of cuttings from hole. Reamed hole 272.5 to 312.5' with 7-7/8" rock bit. Flushed hole with 1600 gallons of water.

Hole at 312.5' 10/6/75. 8" CS at 2.0'. Reamed bridged areas in hole. Flushed hole with 800 gallons of water. Set 4" plastic pipe in hole to 298.7'. Pipe slotted 152.6 to 191.4 & 271.5 to 278.7'. Gravel (pea) packed hole 312.5 to 265.0'. Gravel & bentonite pack 265.0 to 198.6'.

*2110' N. & 1200' E. of SW Corner, Section 2, T. 9 S., R. 45 E.

NOTES CONTINUED
Hole at 312.5' 10/7/75. 8" CS at 2.0'. Gravel (pea) packed hole 198.6 to 145.0'. Gravel & bentonite pack 145.0 to 120.0'. Bailed hole until water was reasonably clear. Water entering hole at rate of 4 gallons per minute. Pulled 8" CS. Moved rig to DH 75-109.

Classification and physical condition:

core lengths 1 to 3" in upper half & 3 to 12" in lower half.

268.4-271.5 SHALE: Medium to dark gray; moist; firm; difficult trimming by knife; almost claystone; plastic when reworked; air slacks; 60° slickenside at 269.5'; core lengths 1 to 6".

271.5-278.7 COAL: Broken in 1 to 2" fragments.

278.7-285.4 CLAYEY SILTSTONE: Light gray; moist; firm; trims by knife with difficulty; bedding not readily discernible; vertical coal streaks 283.9 to 284.9'; coal fragments 284.9 to 285.5'; low plasticity when reworked; some very fine sand; core lengths 3 to 4".

285.4-288.1 SHALE: Alternating laminations of light grey shale & dark grey, carbonaceous shale; moist; plastic; breaks along laminations; trims by knife with difficulty; core lengths 2 to 6".

288.1-306.6 SILTY SHALE: Light gray; moist; firm; difficult trimming with knife; approaching claystone; bedding not readily discernible; silty; moderately plastic to plastic; slightly calcareous; 90° joints 294.7 to 296.0 & 302.6 to 303.8'; air slacks 305.6 to 306.6'; core lengths 3 to 24".

306.6-309.1 SHALEY COAL: Black; appears to contain clay contamination; breaks along bedding planes; similar in appearance to lignite; varies from highly carbonaceous shale to shaley coal; core lengths 3 to 6".

309.1-310.9 CLAYEY SILTSTONE: Light gray; moist; firm; trims by knife with difficulty; some very fine sand; low plasticity; bedding not discernible; slightly carbonaceous; core lengths 6".

310.9-311.9 SANDSTONE: Light gray; moist; very fine grain; some silt; crumbles easily between fingers; core lengths 6"; moderately calcareous.

EXPLANATION (each sheet): 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".

Sheet footers: FEATURE Bear Creek Study Site, West Moorhead Coal Field — PROJECT EMRIA No. 8 — STATE Montana — SHEET 1 (2, 3, 4) OF 4 — HOLE NO. DH 75-105.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOG OF DH 75-105

GEOLOGY: B. Taucher — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED
BILLINGS, MONT. — MAY 1976 — 1305-600-44

GEOLOGIC LOG OF DRILL HOLE — Sheet 1 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana
HOLE NO.: DH 75-106 · LOCATION: * · GROUND ELEV.: 3975± (Altimeter) · DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/3/75 · FINISHED: 1/29/76 · TOTAL DEPTH: 317.1'
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 111.5' 1/27/76 (3863.5) · LOGGED BY: Taucher

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 11/3/75. Nx drive sample 0 to 5.0'. 2-3/4" wire line core 5.0 to 29.2'. 5" Cs set to 8.6'. Drilled with air to 10'.

Hole at 29.2' 11/4/75. 5" Cs at 8.6'. W.L. at 25.3'. 2-3/4" wire line core 29.2 to 64.7'. Losing water. Pulled 5" Cs. Reamed hole to 45.2'. 8" Cs set to 3.0'. 5" Cs set to 45.6'.

Hole at 64.7' 11/5/75. 8" Cs at 3.0'. 5" Cs at 45.6'. W.L. at 21.5'. 2-3/4" wire line core 64.7 to 134.7'.

*820' N. of SW Corner, Section 3, T. 9 S., R. 45 E.

Samples: #1 0–18.0; #2 18.0–40.6; #3 40.6–68.7 (minus coal); #4 68.7–73.5; #5 73.5–129.7
Elevation/Depth: 3957.0 / 18.0; 3934.4 / 40.6; 3906.3 / 68.7; 3901.5 / 73.5

Classification and physical condition:

FT. UNION FORMATION – PALEOCENE

0-18.0 SILTY SHALE WITH SILTSTONE: Gray-brown; oxidized; damp to moist; moderately firm; cuts easily with knife; slightly calcareous 0 to 1.0'; disintegrated, residual weathered shale 0 to 1.0'; moderately plastic silty shale 1.0 to 9.0' with laminated clayey siltstone 2.3 to 2.7'; uncemented sandy siltstone 9.0 to 14.6' with silty shale 9.5 to 10.0' & carbonaceous shale 10.5 to 11.5'; moderately plastic silty shale 14.6 to 18.0'; core lengths 1 to 6".

18.0-40.6 SILTY SANDSTONE WITH SILTY SHALE: Tan & oxidized; moist; sandstones are silty, fine grain & uncemented (crumbles easily between fingers); silty shales are moderately firm & moderately plastic (cut easily with knife); core lengths 2 to 18".
18.0-24.5 - Pulverized silty, fine grain sandstone; bedding not discernible.
24.5-25.2 - Laminated soft silty shale.
25.2-25.6 - Laminated, uncemented silty sandstone.
25.6-27.2 - Silty shale; bedding not discernible.
27.2-29.2 - Silty sandstone; trace of clay 27.2 to 27.8'.
29.2-30.2 - Silty shale; bedding not readily discernible.
30.2-40.6 - Laminated to thin-bedded silty sandstone with laminated silty shale 34.5 to 34.9, 35.5 to 35.8, & 36.8 to 37.1'; may be sandy siltstone in places.

40.6-68.7 SHALE, CARBONACEOUS SHALE & COAL: Yellow-brown & oxidized 40.6 to 41.4'; medium gray to black; moist; generally firm to hard; mostly claystone; difficult trimming by knife; air slacks in places; core lengths 1 to 18" (average 1').
40.6-41.4 - Yellow-brown, oxidized, moderately plastic silty shale.
41.4-46.4 - Black, hard, highly carbonaceous claystone (almost approaching shaley coal).
46.4-50.8 - Dark gray, hard, carbonaceous claystone; 45° joints at 47.3 & 49.4'; badly broken 50.0 to 50.8'.
50.8-51.1 - Broken coal.
51.1-55.4 - Medium gray, firm, moderately plastic silty shale (cuts fairly easy with knife); carbonaceous 51.1 to 51.4'; clayey siltstone 54.0 to 54.7'; medium to dark gray & slightly carbonaceous 54.8 to 55.4'; calcareous in zones.
55.4-55.7 - Broken, shaley coal.

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana · SHEET 1 OF 4 · HOLE NO. DH 75-106

GEOLOGIC LOG OF DRILL HOLE — Sheet 2 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana · HOLE NO.: DH 75-106 · GROUND ELEV.: 3975± (Altimeter) · Vertical · BEGUN: 11/3/75 · FINISHED: 1/29/76 · TOTAL DEPTH: 317.1' · WATER: 111.5' 1/27/76 (3863.5) · LOGGED BY: Taucher

Notes:

Hole at 134.7' 11/6/75. 8" Cs at 3.0'. 5" Cs at 45.6'. W.L. at 32.5'. 2-3/4" wire line core 134.7 to 164.7'. Returned to duty station.

Hole at 164.7' 11/12/75. 8" Cs at 3.0'. 5" Cs at 45.6'. W.L. at 61.5'. 2-3/4" wire line core 164.7 to 230.7'. Lost all drill water at 208.0'. Mixed 4 pits of revert. Unable to regain circulation. Hole caving between runs. Washed away 2' of silty sand 171.5 to 174.5'.

*820' N. of SW corner, Section 3, T. 9 S., R. 45 E.

Samples: #6 129.7–146.7; #7 146.7–201.8
Elevation/Depth: 3865.3 / 129.7; 3828.3 / 146.7

Classification and physical condition:

55.7-57.1 - Medium gray, plastic, firm shale (approaching claystone); 90° joint 56.0 to 56.5'.
57.1-64.8 - Alternating laminations & thin beds of slightly calcareous, medium gray, firm plastic shale & moderately plastic silty to sandy shale.
64.8-66.2 - Medium gray, firm, plastic shale; slightly carbonaceous 64.8 to 65.2'; 80° joint 65.7 to 66.2'.
66.2-66.7 - Broken coal.
66.7-67.3 - Plastic, calcareous medium gray shale.
67.3-67.8 - Very hard, dark gray limestone.
67.8-68.7 - Broken coal.

68.7-73.5 SILTY SANDSTONE: Light to medium gray; moist; fine grain; laminated; silty with trace of clay (low plasticity); uncemented; crushes between fingers with difficulty; calcareous; 60° joint at 73.4'; core lengths 6 to 12".

73.5-129.7 SHALE, SILTY SHALE, LIMESTONE, & SILTY SANDSTONE: Light to medium gray; moist; firm to almost hard; approaching claystone in places; shales are plastic when reworked; difficult trimming by knife; core lengths 6 to 24" (average 12").
73.5-82.6 - Medium gray claystone.
82.6-83.6 - Hard, light gray limestone (scratches with knife).
83.6-88.7 - Medium gray, hard, plastic shale (near claystone); air slacks; 45° joint at 85.7'; numerous slickensides 87.6 to 88.2'; 1" coal at 87.6'.
88.7-89.2 - Light gray, fine grain, uncemented silty sandstone (crumbles between fingers).
89.2-97.2' - Mostly moderately plastic silty shale with about 25% silty sandstone laminations, limestone 93.1 to 93.2 & 94.5 to 94.8'; 90° joint 94.6 to 95.6'.
97.2-103.1 - Light gray, uncemented silty sandstone; crushes between fingers with difficulty; laminated in zones; becoming shaley sandstone with depth.
103.1-114.0 - Medium gray, hard claystone; 70° joint at 107.8'.
114.0-115.1 - Broken coal with shale 114.7 to 114.9'.
115.1-129.7 - Medium gray, hard claystone; 60° joints at 118.5, 118.6, 119.2 & 121.5'; irregular chunk of hard limestone 123.2 to 123.9' (top contact is 60 to 70° shear, bottom contact is brecciated limestone & shale along 70° shear).

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana · SHEET 2 OF 4 · HOLE NO. DH 75-106

GEOLOGIC LOG OF DRILL HOLE — Sheet 3 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana · HOLE NO.: DH 75-106 · GROUND ELEV.: 3975± (Altimeter) · Vertical · BEGUN: 11/3/75 · FINISHED: 1/29/76 · TOTAL DEPTH: 317.1 · WATER: 111.5' 1/27/76 (3863.5) · LOGGED BY: Taucher

Notes:

Hole at 230.7' 11/13/75. 8" Cs at 3.0'. 5" Cs at 45.6'. W.L. at 189.5'. 2-3/4" wire line core 230.7 to 292.4'. No drill water return. Used 6 tanks (4,800 gal.) of water.

Hole at 292.4' 11/14/75. 8" Cs at 3.0'. 5" Cs at 45.6'. 2-3/4" wire line core 292.4 to 317.1'.

*820' N. of SW Corner Section 3, T. 9 S., R. 45 E.

Samples: #8 233.4–239.4; #9 239.4–242.8; #10 242.8–281.4; #11 290.7–298.9
Elevation/Depth: 3773.2 / 201.8; 3741.6 / 233.4; 3735.6 / 239.4; 3732.2 / 242.8; 3693.6 / 281.4; 3684.3 / 290.7; 3676.1 / 298.9

Coal beds: ANDERSON (K); DIETZ (N, O)

Classification and physical condition:

129.7-146.7 SANDSTONE: Light gray; moist; fine grain; silty; uncemented; crumbles between fingers with difficulty; laminated silty sandstone & plastic shale 129.7 to 132.6'; hard, medium gray limestone (scratches with knife) 132.6 to 133.1'; clayey sandstone 133.1 to 133.6'; sandstone 133.6 to 145.6'; laminated silty sandstone & silty shale 145.6 to 146.7'; core lengths 6 to 24".

146.7-201.8 SHALE WITH CARBONACEOUS SHALE, COAL AND SANDSTONE: Medium to dark gray; moist; shales are firm & trim by knife with difficulty; sandstones are silty, uncemented & fine grain (crumble between fingers with some difficulty); thin-bedded with laminated zones; slightly calcareous in zones; shales approach claystone; core lengths 2 to 24" (average 12").
146.7-146.9 - Firm, plastic shale.
146.9-147.3 - Hard, calcareous claystone.
147.3-148.0 - Firm, plastic shale.
148.0-148.5 - Uncemented fine grain sandstone.
148.5-155.5 - Hard, plastic claystone; 90° joint 149.0 to 151.0'; 60° joints at 153.4 & 153.8'.
155.5-163.0 - Dark gray, firm plastic carbonaceous shale 155.5 to 158.8 & 160.8 to 163.0'; black, highly carbonaceous shale or shaley coal 158.8 to 160.8'; air slacks; 60° joint at 161.5'.
163.0-163.7 - Fine grain, uncemented sandstone.
163.7-166.3 - Hard claystone.
166.3-168.8 - Dark gray to black carbonaceous claystone with silty sandstone 168.0 to 168.5' & laminated sandstone & shale 168.5 to 168.8'.
168.8-174.5 - Laminations of uncemented silty sandstone & moderately plastic silty shale (shale about 25% of sample).
174.5-176.5 - Laminations of moderately plastic silty shale & uncemented silty sandstone (sandstone about 25% of sample); hard claystone concretion 175.0 to 175.1'.
176.5-201.8 - Medium to dark gray, firm carbonaceous shale (near claystone); more carbonaceous 177.4 to 178.4, 180.0 to 189.0, & 199.0 to 201.8' air slacks.

201.8-233.4 COAL: Black, hard, badly broken.

233.4-239.4 SHALE: Dark gray to almost black; moist; carbonaceous; firm; difficult trimming by knife; plastic; air slacks; core lengths 2 to 12".

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana · SHEET 3 OF 4 · HOLE NO. DH 75-106

GEOLOGIC LOG OF DRILL HOLE — Sheet 4 of 4

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana · HOLE NO.: DH 75-106 · GROUND ELEV.: 3975± (Altimeter) · Vertical · BEGUN: 11/3/75 · FINISHED: 1/29/76 · TOTAL DEPTH: 317.1 · WATER: 111.5' 1/27/76 (3863.5) · LOGGED BY: Taucher

Notes:

Hole at 317.1' 11/15/75. 8" Cs at 3.0'. 5" Cs at 45.6'. Pulled 5" Cs. Reamed hole with 7-7/8" rock bit 0 to 80.0'.

Hole at 317.1' 11/16/75. 8" Cs at 3.0'. Reamed hole with 7-7/8" rock bit 80.0 to 160.0'.

Hole at 317.1' 11/17/75. 8" Cs at 3.0'. Reamed hole with 7-7/8" rock bit 160.0 to 240.0'.

Hole at 317.1' 11/18/75. 8" Cs at 3.0'. Reamed hole with 7-7/8" rock bit 240.0 to 317.1'.

Hole at 317.1' 11/19/75. 8" Cs at 3.0'. Cleaned out hole to 317.1'. USGS logging hole with geophysical equipment.

Hole at 317.1' 11/20/75. 8" Cs at 3.0'. USGS logging hole with geophysical equipment. Returned to duty station.

Hole at 317.1' 1/27/76. 8" Cs at 3.0'. W.L. at 111.5'. Hole open to 175.0'. 7-7/8" rockbit 175.0 to 317.3'.

Notes Continued: Hole at 317.1' 1/28/76. Run rods and bit to 317.0' and flushed hole with 1600 gallons of water. Pulled rods. Set 4" plastic pipe to 312.0'. Pipe slotted 201.0 to 234.0 and 282.0 to 292.0'. Gravel (Pea) packed hole 317.1 to 280.0'.

Hole at 317.1' 1/29/76. W.L. at 30.0'. Bentonite and gravel pack 280.0 to 235.0'. Gravel (pea) packed hole 235.0 to 200.0'. Bentonite and gravel pack 200.0 to ground surface. Bailed hole for 4 hours. Unable to lower water level below 220.0'. Hole completed.

*820' N. of SW Corner Section 3, T. 9 S., R. 45 E.

Samples: #12 298.9–310.4
Elevation/Depth: 3664.6 / 310.4; 3657.9 / 317.1

Classification and physical condition:

239.4-242.8 SILTY SANDSTONE: Mostly light gray with zones of light to medium gray laminated silty sandstone; moist; uncemented; crumbles easily between fingers; fine grain; core lengths 3 to 14".

242.8-281.4 SHALE WITH SANDSTONE: Medium to dark gray; moist; firm; difficult trimming by knife; shales air slack; hard, claystone concretions 246.6 to 247.0, 250.0 to 250.2 & 278.8 to 279.3'; laminated silty fine grain, uncemented sandstone & plastic shale 251.8 to 254.0 & 271.6 to 275.1' (mostly sandstone); broken coal 269.4 to 269.6'; 15 to 30° slickensides at 268.4, 268.6, 268.9, 269.0, 269.6 & 280.4'; core lengths 2 to 18".

281.4-290.7 COAL: Black, broken.

290.7-298.9 SILTY SANDSTONE: Dark gray, clayey & carbonaceous 290.7 to 291.7'; light gray & silty 291.7 to 298.9'; moist; fine grain; uncemented (crushes easily between fingers) 291.7 to 294.5 & 295.5 to 298.9'; weakly cemented (crushes between fingers with difficulty) 294.5 to 295.5'; moderately calcareous; ½" coal at 291.5'; core lengths 2 to 12".

298.9-310.4 SILTY SHALE: Light gray; moist; firm; trims by knife with difficulty; near claystone; thin-bedded to laminated; calcareous; plastic; medium gray & carbonaceous with 1/8" coal streaks 299.2 to 299.7'; firm, clayey siltstone 304.2 to 304.7, 305.7 to 305.8, 306.5 to 307.0 & 309.0 to 309.7'; hard calcareous claystone concretion 307.2 to 307.4'; core lengths 3 to 14".

310.4-317.1 CLAYEY SILTSTONE: Light gray; moist; moderately firm; crushes between fingers with difficulty; laminated with zones of very fine sand; low plasticity; calcareous; core lengths 1 to 6".

FEATURE: Bear Creek Study Site, West Moorhead Coal Field · PROJECT: EMRIA No. 8 · STATE: Montana · SHEET 4 OF 4 · HOLE NO. DH 75-106

EXPLANATION (each sheet): 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.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOG OF DH 75-106

GEOLOGY: D. Taucher · SUBMITTED · DRAWN · RECOMMENDED · CHECKED · APPROVED
BILLINGS, MONT · MAY 1976 · 1305-600-45

7-1337 (9-49)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 76-108 — LOCATION: 300' E. & 100' S. of NW Corner, Sec. 3, T. 9 S., R. 45 E. — GROUND ELEV. 3838± (Hand Level) — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 2/27/76 — FINISHED: 3/18/76 — TOTAL DEPTH: 174.8 — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 63.0 3/16/76 (3775.0) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 2/27/76. Nx drive samples 0 to 20.0'. Too muddy to haul water.

Hole at 20.0' 3/9/76. 2-3/4" wire line core 20.0 to 74.8'. Lost water at 20.4'. Set 5" Cs to 23.6'. 100% drill water return below 23.6'.

Hole at 74.8' 3/10/76. W.L. at 33.8'. 5" Cs at 23.6'. 2-3/4" wire line core 74.8 to 114.8'. Lost all drill water at 76.0'. Using revert below 76.0'. Gained about 40% drill water return.

Hole at 114.8' 3/11/76. W.L. at 60.4'. 5" Cs at 23.6'. 2-3/4" wire line core 114.8 to 153.0'. 40% drill water return. Stopped using revert as it would not seal hole.

3/15/76 - Repaired equipment.

CORE RECOVERY (%): 70, 70, 80, 88, 42, 40, 100, 100, 100, 90, 100, 100, 90, 100, 60

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	0	18.0
#2	20.3	43.8
#3	79.2	90.0
#4	90.0	94.8

SUITABILITY FOR RECONSTRUCTED PROFILE: Suitable / Limited Suitability / Unsuitable

Elevation (feet)	Depth (feet)
3820.0	18.0
3818.0	20.0
3817.0	20.3
3794.2	43.8
3762.2	75.8
3758.8	79.2
3743.2	94.8

ANDERSON — K — L?

CLASSIFICATION AND PHYSICAL CONDITION

0-18.0 SANDY CLAY: Tan; dry to damp; approximately 50% fine, uniform sand; 45% low plasticity fines and 5% hard, angular, shale & clinker gravels; active HCl reaction; clinker gravel concentrations 13.0 to 18.0' (SC)

FT. UNION FORMATION - PALEOCENE

18.0-20.0 SANDSTONE: Light gray; damp; uncemented; crumbles between fingers; very fine grain; slight cohesion; approximately 15% nonplastic fines; pulverized by drilling.

20.0-20.3 LIMESTONE: Medium to dark gray brown; oxidized; very hard; scratches with knife; broken in 1 to 2" pieces.

20.3-43.8 SHALE: Gray-brown & oxidized 20.3 to 41.2'; medium to dark gray 41.2 to 43.8'; moist; trims by knife with difficulty; air slacks; plastic when reworked; dark gray & carbonaceous 38.0 to 38.5, 39.0 to 40.5 & 41.2 to 43.8'; sandy shale 20.3 to 22.0'; 1/16" gypsum healed bedding planes on 6" to 2½' centers 20.3 to 36.0'; 80° joint at 40.3'; badly broken 20.3 to 30.0'; broken in 1 to 6" lengths 30.0 to 35.0' & 6 to 12" lengths 35.0 to 43.8'.

43.8-75.8 COAL: Black; wet; broken in 1 to 6" core lengths.

75.8-79.2 SHALE: Black; carbonaceous; moist to wet; plastic when reworked; trims by knife with difficulty; thin (¼ to ½") coal streaks on 3 to 6" centers 77.0 to 79.2'; core lengths 1 to 6".

79.2-90.0 SANDSTONE & SHALE: Alternating laminations of uncemented fine grain, uniform sandstone & medium to dark gray, plastic shale (50% sandstone & 50% shale); trims easily by knife; moist to wet; becoming more shaley 88.0 to 90.0'; slight HCl reaction; core lengths 3 to 18".

90.0-94.8 SHALE: Dark gray; moist; plastic when reworked; air slacks; trims by knife with difficulty; slightly carbonaceous; 2' core lengths.

94.8-105.5 SANDSTONE: Light gray; moist; very fine grain, uniform sand; trace of silt; uncemented; slight HCl reaction; crumbles easily between fingers; becoming laminated with clay 104.8 to 105.5'; pulverized by drilling.

105.5-138.6 SHALE: Medium to dark gray; moist; firm; trims by knife with difficulty; probably claystone; air slacks;

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: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 1 OF 2 — HOLE NO. DH 76-108

7-1337 (9-49)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 76-108 — LOCATION: 300' E. & 100' S. of NW Corner, Sec. 3, T. 9 S., R. 45 E. — GROUND ELEV. 3838± (Hand Level) — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 2-27-76 — FINISHED: 3-18-76 — TOTAL DEPTH: 174.8 — BEARING:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 63.0' 3/16/76 (3775.0') — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 153.0' 3/16/76. 5" Cs at 23.6'. W.L. at 63.0'. 2-3/4" wire line core 153.0 to 174.8'. Pulled drill rods & 5" Cs. Reamed hole with 7-7/8" rock bit 0 to 60.0'.

Hole at 174.8' 3/17/76. W.L. at 25.0'. 7-7/8" rock bit 60.0 to 174.8'.

Hole at 174.8' 3/18/76. W.L. at 30.0'. Set rods in hole & flushed with clear water. Set 4" plastic pipe to 168.5'. Pipe slotted 44.5 to 74.5 & 138.5 to 148.5'. Gravel (pea) packed hole in coal zones. Gravel & bentonite seal between coal zones. Bailed hole for 3 hours. Water level bailed down to 140.0'. Water raising in well at the rate of 2' per minute.

CORE RECOVERY (%): 94, 100, 72, 100, 100, 92, 95, 85, 96

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#5	94.8	105.5
#6	105.5	139.4
#7	148.8	153.0

Elevation (feet)	Depth (feet)
3732.5	105.5
3699.4	138.6
3689.2	148.8
3681.4	156.6
3681.2	156.8
3675.1	162.9
3673.7	164.3
3671.2	166.8
3663.2	174.8

N — O — DIETZ — P

CLASSIFICATION AND PHYSICAL CONDITION

plastic when reworked; bedding not readily discernible; slightly carbonaceous 118.0 to 123.0'; broken coal 124.8 to 125.3'; carbonaceous 137.0 to 138.6'; alternating laminations of light gray, fine grain, uncemented sandstone & dark gray, plastic shale (crumbles between fingers) 127.3 to 134.8'; core lengths 3 to 18".

138.6-148.8 COAL: Black; wet; broken in 1 to 6" core lengths.

148.8-156.6 SILTSTONE: Light gray; moist; moderately firm; slightly brittle but crushes between fingers with difficulty; bedding not readily discernible; micaceous; slight HCl reaction; moderately plastic clayey siltstone 155.8 to 156.6'; core lengths 3 to 12".

156.6-156.8 COAL:

156.8-162.9 SILTY SHALE: Dark gray; laminated & carbonaceous 156.8 to 159.2'; light gray 159.2 to 162.9'; moist to wet; firm; difficult trimming by knife; moderately plastic; moderate HCl reaction; core lengths 2 to 12".

162.9-164.3 SHALE: Medium grey; moist; carbonaceous; firm; difficult trimming by knife; plastic; air slacks; cut by 4 - 30 to 45° slickensides.

164.3-166.8 COAL: Broken

166.8-174.8 SILTY SHALE WITH SHALE & SANDY SILTSTONE: Moist to wet; firm; trims by knife with difficulty; slight HCl reaction; core lengths 3 to 12".
166.8-167.0 - Black, plastic, carbonaceous shale; cut by slickensides.
167.0-168.4 - Light gray sandy siltstone
168.4-172.8 - Light gray, moderately plastic, thin-bedded silty shale; 45° slickenside at 168.8'.
172.8-173.8 - Dark gray plastic carbonaceous shale with coal streaks 173.4 to 173.8'; 45° fault (slickenside) at 172.8 & 173.3'.
173.8-174.8 - Light gray, moderately plastic, thin-bedded silty shale.

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: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 2 OF 2 — HOLE NO. DH 76-108

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOG OF DH 76-108

GEOLOGY: E. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:

BILLINGS, MONTANA — MAY 1976 — 1305-600-46

GEOLOGIC LOG OF DRILL HOLE — SHEET 1 OF 3

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 75-109 — LOCATION: * — COORDS. N. ... E. ... — GROUND ELEV. 3900± (Altimeter) — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 10/8/75 — FINISHED: 11/1/75 — TOTAL DEPTH: 271.0' — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 194.1 11/17/75 (3705.9) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 10/8/75. Set up drill. NX drive samples 0 to 18.7'. Left for duty station.

Hole at 18.7' 10/14/75. Hole dry. Reamed hole & set 5" CS to 28.5'. Washed out casing. 2-5/4" wire line core 18.7 to 28.0'.

Hole at 28.0' 10/15/75. 5" CS at 28.5'. Hole dry. 2-5/4" wire line core 28.0 to 53.9'. Total drill water loss in clinker. Hole caving badly in clinker when wire line rods pulled back.

Hole at 53.9' 10/16/75. 5" CS at 28.5'. Hole dry. 2-5/4" wire line core 53.9 to 60.2'. Pulled back wire line tools 10'. Unable to get to bottom of hole. Pulled wire line tools. Chopped & washed NX CS to 61.5'. Chopped inside of NX CS with AX rods. NX core 60.2 to 63.9'.

Hole at 63.9' 10/17/75. 5" CS at 28.5'. NX CS at 61.5'. Hole dry. NX core 65.9 to 79.9'. Unable to pull NX barrel back through NX CS on last run. Pulled NX rods, barrel & casing. Reaming shell spread at joint & would not come back through NX CS. Dropped part of sample 63.9 to 70.3'. Washed away in redrill.

Core recovery (%): 84, 100, 100, 100, 98, 100, 100, 100, 52, 9, 48, 80, 45, 97, 45, 71, 32, 80, 33, 100

Sample	From	To	Elevation (feet)	Depth (feet)
#1	0	17.0	3883.0	17.0
#2	17.0	22.8	3877.2	22.8
#3	22.8	38.9	3861.1	38.9
#4	60.0	114.6	3840.0	60.0

Unit labels: ANDERSON CLINKER; K; L

CLASSIFICATION AND PHYSICAL CONDITION

0-17.0 SANDY CLAY TO CLAY & SAND: Tan; dry; becoming wet 15.5 to 17.0'; soft; cuts easily with knife; upper part is sandy clay (CL) with 40% fines, uniform sand & 60% medium plasticity fines grading into clay & sand with depth which contains 50% medium plasticity fines & 50% fine, uniform sand (SC-CL); active HCl reaction; upper part contains vertical root holes & is possibly wind blown; few shale fragments 16.5 to 17.0'.

(?) UNION FORMATION - PALEOCENE

17.0-22.8 SANDSTONE: Light gray to tan; oxidized; moist; moderately hard; crumbles between fingers with difficulty; fine grain; silty; moderate to active HCl reaction; bedding not readily discernible; core lengths 6 to 14".

22.8-38.9 [illegible]: Dark gray to brown 22.8 to [illegible]; black & carbonaceous 24.6 to 25.2'; oxidized yellow-brown 25.2 to 28.0' with black carbonaceous zone 26.5 to 26.7'; medium gray with brown oxidized streaks 26.7 to 32.7'; dark gray & carbonaceous 32.7 to 33.9'; medium gray 33.9 to 36.4'; dark gray to black & carbonaceous 36.4 to 38.9'; moist; plastic shale 22.8 to 33.[illegible] with sandstone 30.5 to 30.5 & 31.0 to 31.2'; clayey siltstone 35.1 to 36.4'; plastic shale 36.4 to 38.9'; shales are firm but can be trimmed by knife; siltstones & sandstones crumble between fingers; scattered gypsum crystals; 90° oxidized joint at 29.5'; core lengths 2 to 12".

38.9-60.0 CLINKER: Tan to red; angular fragments of baked shale; scratches with knife; maximum fragment size is 1½".

60.0-114.6 SHALE WITH SANDSTONE & SILTSTONE: Medium gray; moist; 60.0 to 74.3' firm, thin-bedded plastic shale; difficult trimming with knife; silt & sand streaks 72.8 to 74.3'; broken coal & black carbonaceous shale 60.2 to 60.8'; broken coal 65.7 to 66.3'; 1/8" gypsum filled bedding plane at 73.8'; 74.3 to 76.3' laminated, uncemented, silty, very fine grain sandstone (could be sandy siltstone) crumbles between fingers; 76.3 to 114.6' laminated to thin-bedded, firm, plastic shale; trims by knife with difficulty; air slacks; only 1' of core between 86.5 to 90.6' which consisted of soft siltstone & silty sandstone (probably washed away during drilling); fine grain

*1300' N. of SE Corner Section 34, T. 8 S., R. 45 E.

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), Approx. size of core (X-series), Outside dia. of casing (X-series), Inside dia. of casing (X-series): Ex, Ax, Bx, Nx.

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 1 OF 3 — HOLE NO. DH 75-109

GEOLOGIC LOG OF DRILL HOLE — SHEET 2 OF 3

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 75-109 — LOCATION: * — GROUND ELEV. 3900± (Altimeter) — DIP: Vertical
BEGUN: 10/8/75 — FINISHED: 11/1/75 — TOTAL DEPTH: 271.0' — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 194.1' 11/17/75 (3705.9') — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 79.9' 10/18/75. 5" CS at 28.5'. Hole dry. Set NX CS to 69.5'. Chopped out NX CS & hole to 79.9'. NX core 78.9 to 95.6'. Zones 79.9 to 85.0 & 90.6 to 92.2' core blocked (lost parts of both samples). Dropped core 83.0 to 86.5'. (Recovered part of sample in redrill). Part of sample 88.5 to 90.6' washed away.

Hole at 95.6' 10/19/75. 5" CS at 28.5'. NX CS at 69.5'. Hole dry. NX core 95.6 to 102.7' Core blocking in barrel. Dropped sample 100.9 to 102.7'. Redrilled & recovered 2.5' of sample. Drill helper hurt at site & was taken to hospital.

Hole at 102.7' 10/20/75. 5" CS at 28.5'. NX CS at 69.5'. Hole dry. NX core 102.7 to 123.1'. Dropped samples 102.7 to 103.5 & 103.5 to 105.7' in hole. No recovery in redrill.

Hole at 123.1' 10/21/75. 5" CS at 28.5'. NX CS at 69.5'. Hole dry. NX core 123.1 to 159.9'.

Hole at 159.9' 10/22/75. 5" CS at 28.5'. NX CS at 69.5'. W.L. at 130.2' Washed out 22' of cave & cuttings. NX core 159.9 to 171.5'. Returned to duty station.

Hole at 171.5' 10/28/75. 5" CS at 28.5'. NX CS at 69.5'. Hole dry. NX core

Core recovery (%): 100, 0, 89, 100, 100, 100, 93, 100, 91, 100, 98, 96, 90, 100, 100, 100

Sample	From	To
#5	125.1	142.3
#6	142.3	147.5
#7	149.0	159.0
#8	159.0	167.9
#9	167.9	177.5
#10	177.5	230.3

Elevation (feet)	Depth (feet)
3785.4	114.6
3777.5	122.5
3776.9	123.1
3757.7	142.3
3752.5	147.5
3751.0	149.0
3741.0	159.0
3732.1	167.9
3728.5	171.5
3726.5	173.5
3722.5	177.5

Unit labels: O; DIETZ; P

CLASSIFICATION AND PHYSICAL CONDITION

silty sandstone 91.6 to 92.4'; hard, cemented clayatone 82.8 to 83.0, 94.2 to 94.4, 103.7 to 103.9, & 114.5 to 114.8' core lengths 2 to 18".

114.6-122.5 COAL: 2 to 4" core lengths.

122.5-123.1 SHALE: Dark gray; moist; carbonaceous; plastic; trims by knife with difficulty; core lengths 3".

123.1-142.5 SILTY SANDSTONE TO SANDY SILTSTONE: Light gray; moist; material is borderline silt & very fine grain sand; varies between silty sandstone & sandy siltstone; generally crumbles easily between fingers; bedding not discernible; becoming clayey (moderately plastic) below 140.8'; core lengths pulverized [illegible]".

142.5-147.5 SHALE: Medium gray; moist; firm; difficult trimming with knife; near clayatone; bedding not readily discernible; plastic; ¼" coal at 145.5'; core lengths 3 to 12".

147.5-149.0 SILTSTONE: Light gray; moist; firm; crumbles between fingers with difficulty; bedding not discernible; slightly plastic; core lengths 6 to 12".

149.0-159.0 SILTY SHALE & SHALE: Light gray 149.0 to 155.1'; medium to dark gray 155.1 to 159.0'; moist; firm; trims by knife with difficulty; moderately plastic silty shale 149.0 to 155.1'; plastic shale 155.1 to 159.0'; thin-bedded; air slacks 155.1 to 159.0'; clayatone concretion 152.6 to 152.9'; core lengths 1 to 18".

159.0-167.9 CLAYEY SILTSTONE: Light gray; moist; firm; difficult trimming with knife; moderately plastic clayey siltstone 159.0 to 161.7 & 163.5 to 167.9'; very hard, calcareous cemented siltstone 161.7 to 163.5'; (scratches with knife); bedding not discernible; hard clayatone concretions 166.0 to 166.2 & 166.4 to 166.6'; core lengths 3 to 24".

167.9-171.5 SILTY SHALE: Medium gray; moist; thin-bedded; hard; near clayatone; difficult trimming by knife; moderately plastic; 3 to 18" core lengths.

171.5-173.5 SILTY SANDSTONE: Medium gray; moist; fine grain; silty; crushes between fingers with difficulty; 6 to 12" core lengths.

*1300' N. of SE Corner Section 34, T. 8 S., R. 45 E.

EXPLANATION — CORE LOSS / CORE RECOVERY

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 2 OF 3 — HOLE NO. DH 75-109

GEOLOGIC LOG OF DRILL HOLE — SHEET 3 OF 3

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana
HOLE NO. DH 75-109 — LOCATION: * — GROUND ELEV. 3900± (Altimeter) — DIP: Vertical
BEGUN: 10/8/75 — FINISHED: 11/1/75 — TOTAL DEPTH: 271.0' — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 194.1' 11/17/75 (3705.9) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

171.5 to 176.5'. Returned from duty station.

Hole at 176.5' 10/29/75. 5" CS at 28.5'. NX CS at 69.5'. Hole dry to 155'. Washed cave 155 to 176.5'. NX core 176.5 to 230.3'.

Hole at 230.5' 10/30/75. 5" CS at 28.5'. NX CS at 69.5'. Hole caved below 155'. Hole dry to 155'. Washed out hole to 230.3'. NX core 230.3 to 261.5'. Lost all drill water at 249.7'. Some water return below 256.0'.

Hole at 261.5' 10/31/75. 5" CS at 28.5'. NX CS at 69.5'. NX core 261.5 to 271.0'. Washed out hole. 155' of 1¼" plastic pipe installed in hole. Hole caved at 155'. Pulled pipe. Washed hole. Washed plastic pipe down to 271.0'. Gravel patched hole back to 85'.

Hole at 271.0' 11/1/75. 5" CS at 28.5'. NX CS at 69.5'. Pulled NX CS & gravel packed hole to 35.0'. Pulled 5" CS & gravel packed hole to surface. Hole completed at 271.0'. Moved equipment & cleaned up drill location.

*1300' N. of SE Corner, Section 34, T. 8 S., R. 45 E.

Core recovery (%): 58, 72, 100, 100, 90, 100, 100

Sample	From	To
#11	230.3	245.4
#12	262.5	267.0

Elevation (feet)	Depth (feet)
3677.8	222.2
3669.7	230.3
3656.6	243.4
3637.5	262.5
3633.0	267.0
3629.0	271.0

Unit labels: Q; CANYON; R

CLASSIFICATION AND PHYSICAL CONDITION

173.5-177.5 SILTY SHALE: Medium gray; moist; firm; trims by knife with difficulty; thin-bedded; moderately plastic; sandy in zones; 8 to 18" core lengths.

177.5-222.2 SILTY SANDSTONE WITH CLAYEY SILTSTONE: Silty sandstones are light gray; clayey siltstones are medium gray; moist; sandstones generally crush easily between fingers; siltstones are moderately firm but can be cut by knife; sandstone is very fine grain & approaches silt in size; slight HCl reaction; core lengths 1 to 12"; silty sandstone 177.5 to 180.6, 184.4 to 187.6, 189.8 to 196.0, 198.4 to 202.7, 203.7 to 210.2 & 212.0 to 221.0'; clayey siltstone 180.6 to 184.4, 187.6 to 189.8 & 196.0 to 198.4'; laminated sandstone, siltstone & low plasticity shale 221.0 to 222.2'; coal 202.7 to 203.7'; dark gray plastic, carbonaceous shale 210.2 to 212.0'.

222.2-230.3 SILTY SANDSTONE & SANDY SILTSTONE: Alternating laminations of silty, fine grain sandstone & medium gray sandy siltstone; moist; uncemented; crushes easily between fingers; low plasticity silty shale 223.8 to 225.8 & 228.0 to 228.6'; core lengths 1 to 12".

230.3-243.4 SHALE: Medium to dark gray; moist; firm; difficult trimming by knife; air slacks in zones; slightly carbonaceous; plastic; several clayey siltstone laminations 230.3 to 233.5'; core lengths 3 to 14".

243.4-262.5 COAL: Black; wet; cut by several vertical hairline fractures; 1 to 4" core lengths 245.4 to 255.1'; 6" core lengths 255.1 to 261.5'; badly broken 261.3 to 262.5'.

262.5-267.0 SILTY SHALE: Dark gray & carbonaceous 262.5 to 263.7'; light gray 265.7 to 267.0'; moist; firm; moderately plastic to plastic; becoming more silty with depth; difficult trimming with knife; bedding not readily discernible; silty sandstone (crumbles between fingers) 265.5 to 266.1 & 266.6 to 266.7'; core lengths 5 to 12"; 70° slickenside at 265.7'.

267.0-271.0 SILTY SANDSTONE: Light gray; moist; firm; bedding not readily discernible; crumbles between fingers with difficulty; fine grain; silt content decreasing with depth; 5 to 8" core lengths.

EXPLANATION — CORE LOSS / CORE RECOVERY

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana — SHEET 3 OF 3 — HOLE NO. DH 75-109

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOG OF DH 75-109

GEOLOGY: R. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:

BILLINGS, MONTANA — MAY 1978 — 1305-600-47

GEOLOGIC LOG OF DRILL HOLE

7-1337 (8-68) Bureau of Reclamation — SHEET 1 OF 2

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana

HOLE NO.: DH 76-111 — LOCATION: 925' S. & 1450' W. of NE corner, Section 34, T. 8 S., R. 45 E. — GROUND ELEV.: Altimeter 3868± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 2/2/76 — FINISHED: 2/26/76 — TOTAL DEPTH: 183.5 — BEARING: ---

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 92.4 2/26/76 (3775.6) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 2/2/76. Nx drive samples 0 to 6.0'. Too muddy to haul water.

Hole at 6.0' 2/3/76. 2-3/4" wire line core 6.0 to 44.0'. Set 5" Cs at 8.6'. 50% water loss in coal seam at 25'.

Hole at 44.0' 2/4/76. 5" Cs at 8.6'. W.L. at 42.0'. Reamed hole to 43.4' & set 5" Cs. 2-3/4" wire line core 44.0 to 65.5'.

Hole at 65.5' 2/5/76. 5" Cs at 43.4'. W.L. at 6.5'. 2-3/4" wire line core 65.5 to 102.0'. Lost all drill water at 79.0' Could not seal with revert (Used 4 pits of revert). Hole caving in broken coal below 74.3'.

CORE RECOVERY (%): 100, 100, 84, 93, 100, 60, 100, 100, 100, 80, 100, 100, 97, 67

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	0.5	13.4
#2	13.4	30.5
#3	30.5	50.0
#4	50.0	71.7

ELEVATION / DEPTH (FEET)

Elevation	Depth
3867.5	0.5
3854.6	13.4
3837.5	30.5
3796.3	71.7

Coal beds: J; ANDERSON K

CLASSIFICATION AND PHYSICAL CONDITION

0-0.5 SANDY CLAY: Tan; roots; moist; approximately 40% fine sand & 60% low plasticity fines (CL).

FT. UNION FORMATION - PALEOCENE

0.5-13.4 SILTY SANDSTONE: Tan; oxidized; dry to moist; fine grain; some silt (maximum 15%); moderately firm 0.5 to 5.5'; firm with calcium carbonate component 5.5 to 10.0'; moderately firm with some calcium carbonate cement 10.0 to 13.4'; can be crushed between fingers with difficulty; core lengths 2 to 12".

13.4-30.5 SILTY SHALE: Tan & oxidized 13.4 to 16.8'; tan to gray with some oxidation 16.8 to 24.3'; medium to dark gray below 24.3'; plastic; moist; moderately hard; cuts by knife with some difficulty; air slacks; highly oxidized 80° joint at 18.0'; 60° oxidized joints at 18.2 & 21.5'; hard, broken coal 24.5 to 25.5'; contains occasional silt laminations below 28.0'; very slight HCl reaction; core lengths 3 to 18'.

30.5-50.0 CLAYEY SANDSTONE: Alternating laminations of light gray, very fine grain sandstone & medium gray, low plasticity silty shale; moist; moderately firm; crumbles between fingers easily; core lengths 3 to 12".
30.5-39.5 - laminated sandstone & shale (sandstone comprises about 60% of material).
39.5-40.0 - moderately firm shale.
40.0-44.0 - sandstone, uncemented; washed away during drilling.
44.0-46.0 - silty sandstone with carbonaceous shale 45.3 to 45.6'.
46.0-48.0 - medium gray, plastic shale.
48.0-50.0 - light gray, uncemented sandstone

50.0-71.7 SHALE: Medium to dark gray; moist; firm; difficult trimming by knife; near claystone; air slacks; plastic when reworked; bedding not readily discernible; becoming dark gray & carbonaceous 69.7 to 71.7'; 70 to 80° joints at 59.0, 63.0 & 65.5'; core lengths 2 to 18".

71.7-102.5 COAL: Black; wet; broken in 1 to 6" lengths; soft in areas.

102.5-105.0 SHALE: Black; carbonaceous; moist; moderately firm; trims by knife with some difficulty; plastic; ½" coal streak at 104.5'; scattered near horizontal slickensides; 80° joint 102.5 to 103.5'; air slacks; broken in 1 to 6" pieces.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hostelliite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Ci = 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 Bear Creek Study Site West Moorhead Coal Field — PROJECT EMRIA No. 8 — STATE Montana — SHEET 1 OF 2 — HOLE NO. DH 76-111

GEOLOGIC LOG OF DRILL HOLE

7-1337 (8-68) Bureau of Reclamation — SHEET 2 OF 2

FEATURE: Bear Creek Study Site, West Moorhead Coal Field — PROJECT: EMRIA No. 8 — STATE: Montana

HOLE NO.: DH 76-111 — LOCATION: 925' S. & 1450' W. of NE Corner, Section 34, T. 8 S., R. 45 E. — GROUND ELEV.: Altimeter 3868± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 2/2/76 — FINISHED: 2/26/76 — TOTAL DEPTH: 183.5 — BEARING: ---

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 92.4 2/26/76 (3775.6) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 102.0' 2/11/76. 5" Cs at 43.4'. Hole dry. 2-3/4" wire line core 102.0 to 141.7'. No drill water return. Too muddy to haul water. Walked out to main road.

2/10/76 - Too muddy to drive to drill site. Unable to haul water.

Hole at 141.7' 2/12/76. 5" Cs at 43.4'. W.L. at 91.5'. 2-3/4" wire line core 141.7 to 157.9'. No drill water return. Road to drill getting muddy. Pulled rods & walked to main road.

Hole at 157.9' 2/18/76. 5" Cs at 43.4'. W.L. at 92.0'. 2-3/4" core 157.9 to 183.5'. Hole caving between runs.

Hole at 183.5' 2/19/76. 5" Cs at 43.4'. W.L. at 92.5'. Pulled 5" Cs. 7-7/8" rockbit 0 to 100.0'. Lost drill return at 95.0'. Using revert.

Hole at 183.5' 2/20/76. W.L. at 71.5'. 7-7/8" rockbit 100.0 to 140.0'. Unable to get water return.

Hole at 183.5' 2/23/76. W.L. at 92.5'. Mixed & pumped 4 pits of drill mud down hole.

Hole at 183.5' 2/24/76. W.L. at 90.0'. Mixed 10 sacks of bentonite & 3 sacks of revert & circulated into hole. 7-7/8" rockbit 140.0 to 180.0'. 70% drill water return. Mud thinning rapidly because of water entering hole

Notes Continued from Anderson coalbed.

Hole at 183.5' 2/25/76. W.L. at 90.0'. Ran rods in hole to wash out cuttings. Bailed hole dry 4 times. Set 175.5' of 4" plastic pipe in hole. Pipe slotted 71.0 to 101.0 & 157.0 to 167.0'. Gravel packed outside of slotted pipe. Gravel & bentonite packed hole between coal beds. Water entering hole at rate of 2 G.P.M.

2/26/76 - W.L. at 92.4'. Bailed hole for 3 hours until water was reasonably clean. Moved rig to DH 76-108. Hole completed.

CORE RECOVERY (%): 60, 87, 35, 67, 100, 95, 100, 100, 100, 85, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#5	105.0	111.5
#6	111.5	118.0
#7	126.5	131.7
#8	131.7	156.5
#9	167.2	180.0

ELEVATION / DEPTH (FEET)

Elevation	Depth
3765.5	102.5
3763.0	105.0
3756.5	111.5
3750.0	118.0
3741.5	126.5
3736.3	131.7
3711.5	156.5
3700.8	167.2
3685.0	183.0
3684.5	183.5

Coal beds: N; O; DIETZ

CLASSIFICATION AND PHYSICAL CONDITION

105.0-111.5 SHALEY SANDSTONE: Alternating laminations of light gray, very fine grain, uncemented sandstone & dark gray, plastic shale (60% sandstone & 40% shale); moist; firm; trims by knife with some difficulty; washed away in zones; core lengths 3 to 12".

111.5-118.0 SHALE: Dark gray; moist; firm; trims by knife with some difficulty; plastic; air slacks; bedding not readily discernible; core lengths 3 to 6".

118.0-126.5 SANDSTONE: Washed away; driller reported fine grain, uncemented sandstone.

126.5-131.7 SILTY SHALE & SANDSTONE: Alternating laminations of light gray, silty, fine grain sandstone & dark gray, silty, moderately plastic shale (70% shale & 30% sandstone); moist; moderately firm; trims easily by knife; core lengths 1 to 6".

131.7-156.5 SHALE: Medium to dark gray; moist; moderately firm; cuts by knife with difficulty; bedding not readily discernible; becoming medium gray & more silty below 146.5'; air slacks; coal 144.9 to 145.1'; 50° slickenside at 145.5'; core lengths 3 to 12".

156.5-167.2 COAL: Black; wet; firm; broken in 1 to 6" pieces.

167.2-180.0 SHALEY SANDSTONE: Light gray; moist; moderately firm; crumbles between fingers with great difficulty; generally laminated silty to sandy shale & shaley sandstone; sand is very fine grain; slightly calcareous; slightly carbonaceous 171.0 to 172.0'; core lengths 3 to 18".

180.0-183.0 SILTSTONE: Light gray; very hard; cemented; scratches with knife; siliceous; slight HCl reaction; 2 to 12" core lengths.

183.0-183.5 SHALEY SANDSTONE: Light gray; moist; moderately firm but can be crushed between fingers; sand is very fine grain; moderately plastic when reworked; core lengths 1 to 3".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hostelliite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Ci = 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 Bear Creek Study Site West Moorhead Coal Field — PROJECT EMRIA No. 8 — STATE Montana — SHEET 2 OF 2 — HOLE NO. DH 76-111

DH 75-112

Bear Creek Study Site, West Moorhead Coal Field* — EMRIA No. 8 — Montana — SHEET 1 OF 1

DH 75-112 — Altimeter 3870± — Vertical

Begun 9/16/75 — Finished 9/19/75 — Total depth 92.5'

Water level: 24.1' 9/19/75 (3845.9') — Logged by Taucher

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 9/16/75. NX drive samples 0 to 20.0'. Hole reamed to 18.2'. Installed 5" CS to 18.6'.

Hole at 20.0' 9/17/75. 5" CS at 18.2'. W.L. at ground surface. 2-3/4" wire line core 20.0 to 84.2'. Pulled 18.2' of 5" CS. Reamed hole & set 5" CS to 28.8'. Broken shale 28.8 to 35.0' caving in hole. Pulled 28.8' of 5" CS. Reamed & set 5" CS to 38.8'. Flushed hole with 400 gallons of water. Pulled wire line rods. Set NX rods in hole & forced water out of hole with air. Sample 30.2 to 39.2' fell out of barrel. Redrilled & recovered 3.5' of core.

Hole at 84.2' 9/18/75. 5" CS at 38.8'. W.L. at 24.1'. Reamed hole to 4½". Bailed hole dry in 30 minutes. Water entering hole at rate of 1½ to 2 G.P.M. Pulled 5" CS. Set 8" CS to 5'. Reamed hole with 7-7/8" rock bit to 84.2'. Hole deepened with rock bit to 92.5'. Used revert.

Hole at 92.5' 9/19/75. 8" CS at 5.0'. W.L. at 24.1'. Flushed hole with 600 gallons of water. Installed 4" dia. plastic pipe to 92.5'. (Slotted 48.0 to 78.5'). Gravel (pea) packed entire hole. Bailed hole dry. Water entering hole at rate

NOTES CONTINUED

of 15 gallons/10 minutes (1.5 gallons/minute). Hole completed.

*2320' S. & 480' E. of NW Corner, Section 11, T. 9 S., R. 45 E.

CORE RECOVERY (%): 62, 96, 30, 94, 45, 100, 39, 100, 54, 95, 100, 84, 94; rock bit

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	0	15.0
#2	15.0	48.9
#3	78.2	84.2

ELEVATION / DEPTH (FEET)

Elevation	Depth
3864.5	5.5
3855.0	15.0
3821.1	48.9
3801.2	68.8
3800.2	69.8
3799.2	70.8
3791.8	78.2
3785.8	84.2
3777.5	92.5

Coal bed: ANDERSON K; L

CLASSIFICATION AND PHYSICAL CONDITION

0-5.5 CLAYEY SAND: Tan; dry; few roots 0 to 0.5'; approximately 55% fine, uniform sand & 45% low plasticity fines (SC).

5.5-15.0 SANDY CLAY: Tan; dry to damp; oxidized; approximately 40% fine, uniform sand & 60% medium plasticity fines; few pebbles especially in 14.0 to 15.0' zone; calcareous; (CL); more plastic (CL-CH) 9.5 to 10.5'.

FT. UNION FORMATION - PALEOCENE

15.0-48.9 SHALE WITH SILTSTONE & SANDSTONE: Brown & highly oxidized 15.0 to 16.0'; brown to dark gray & slightly oxidized 16.0 to 28.5'; medium to dark gray 28.5 to 48.9'; moist; plastic shale (trims easily by knife) 15.0 to 20.2'; uncemented, silty, fine grain sandstone (crumbles between fingers) 20.2 to 20.3'; moderately plastic silty shale (trims easily with knife) 20.2 to 20.8'; sandy siltstone (crumbles between fingers) 20.8 to 26.0(?)'; plastic shale (trims easily by knife) 26.0(?) to 28.0'; hard, cemented siltstone 28.0 to 28.4'; plastic, slightly carbonaceous shale (trims easily with knife) 28.4 to 29.0'; clayey siltstone (trims easily by knife) 29.0 to 29.6'; plastic, slightly carbonaceous shale (trims easily by knife) 29.6 to 48.9' with hard, cemented siltstone 31.5 to 32.0 & 41.2 to 41.4'; bedding not readily discernible; core lengths 1 to 12"; shale is moderately broken 28.8 to 35.0'.

48.9-68.8 COAL: Generally unfractured; petrified wood fragments 61.7 to 61.9 & 67.8 to 68.8'; plastic shale 64.9 to 65.2'; 2 to 18" core lengths.

68.8-69.8 SHALE: Light gray; moist; firm; trims by knife with difficulty; core lengths 3 to 8".

69.8-70.8 COAL: Broken.

70.8-78.2 SILTY SHALE: Light gray; moist; firm; can be trimmed by knife; bedding not readily discernible; core lengths 12 to 18"; lost 1.6' of core from 70.8 to 74.2'.

78.2-84.2 SANDSTONE: Light gray; moist; firm & slightly clayey 78.2 to 79.0'; very fine grain, uncemented sandstone which crushes easily between fingers 79.0 to 84.2'; cross-bedded; begins to wash away during drilling; core lengths 2 to 8".

84.2-92.5 ROCKBIT: No core.

Bear Creek Study Site West Moorhead Coal Field — EMRIA No. 8 — Montana — 1 — 1 — DH 75-112

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

GEOLOGIC LOGS OF DH 76-111 & 75-112

GEOLOGY: G. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:
BILLINGS, MONT. — MAY 1976 — 1305-600-48

APPENDIX C

COAL RESOURCES

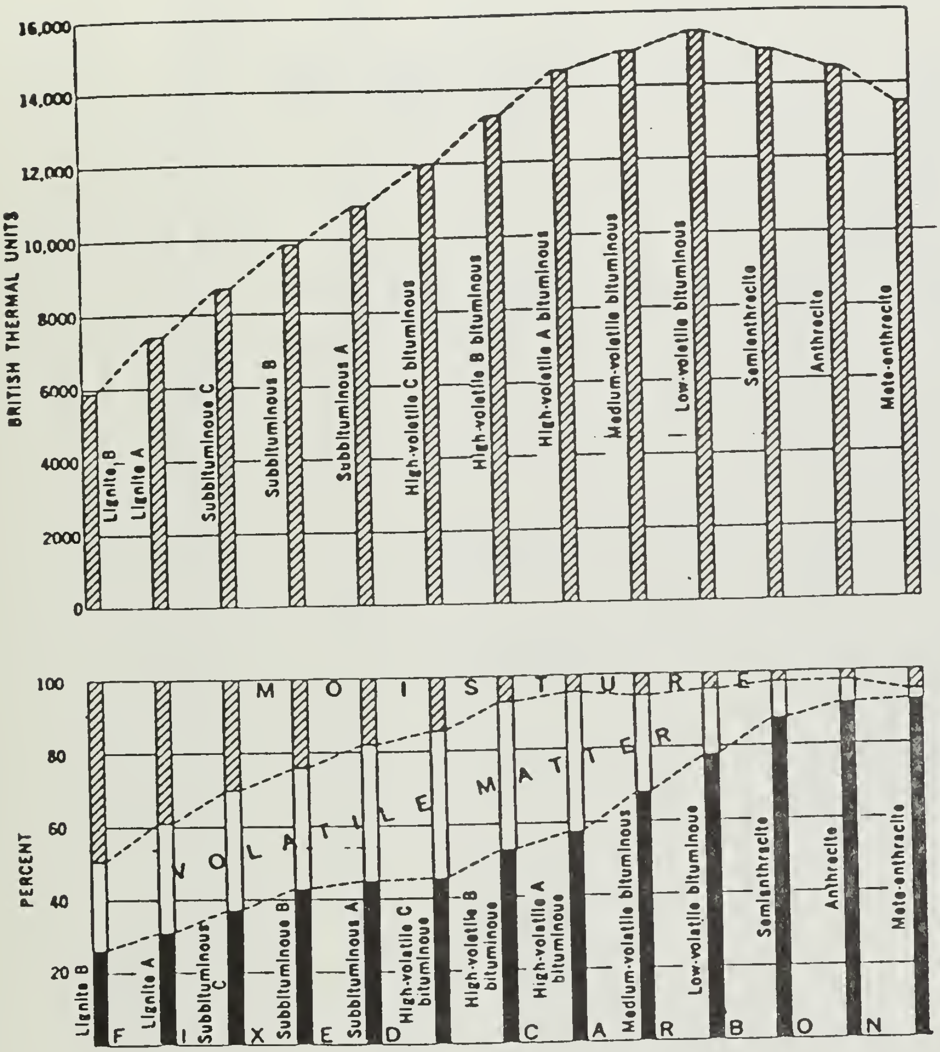


Figure 2.--Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks.

Table 5 Classification of coals by rank[1]
[American Society for Testing and Materials Standard D388-66 (Reapproved 1972)]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis): Equal or Greater Than	Fixed Carbon: Less Than	Volatile Matter Limits, percent (Dry, Mineral, Matter-Free Basis): Greater Than	Volatile Matter: Equal or Less Than	Calorific Value Limits, Btu per pound (Moist,[2] Mineral-Matter-Free Basis): Equal or Greater Than	Calorific Value: Less Than	Agglomerating Character
I. Anthracite	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	
	3. Semianthracite[3]	86	92	8	14	...	...	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	
	3. High volatile A bituminous coal	...	69	31	...	14 000[4]	...	
	4. High volatile B bituminous coal	...	...	...	...	13 000[4]	14 000	
	5. High volatile C bituminous coal	...	...	...	...	11 500 10 500	13 000 11 500	 agglomerating
III. Subbituminous	1. Subbituminous A coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	...	...	...	...	9 500	10 500	
	3. Subbituminous C coal	...	...	...	...	8 300	9 500	
IV. Lignitic	1. Lignite A	...	...	...	...	6 300	8 300	
	2. Lignite B					...	6 300	

[1]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which 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 shall be 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 there are notable exceptions in high volatile C bituminous group.

APPENDIX D

HYDROLOGY

TABLE 12 -CHEMICAL AND SPECTROGRAPHIC ANALYSES OF WATER SAMPLES FROM BEAR CREEK AT OTTER.

DATE	TIME	TEMPERATURE (DEG C)	AIR TEMPERATURE (DEG C)	INSTANTANEOUS DISCHARGE (CFS)	TURBIDITY (JTU)	SPECIFIC CONDUCTANCE (MICROMHOS)	DISSOLVED OXYGEN (MG/L)	PERCENT SATURATION	BIOCHEMICAL OXYGEN DEMAND 5 DAY (MG/L)	PH (UNITS)	CARBON DIOXIDE (CO2) (MG/L)
JAN., 1975											
20...	1315	.0	7.0	7.1	20	535	10.8	83	11	8.3	.9
MAR.											
05...	0930	.0	.0	53	30	225	11.8	91	14	7.0	11
19...	1020	2.0	9.0	15	50	620	11.2	91	8.3	7.6	5.5
MAY											
22...	1440	1[illegible].0	16.5	.28	3	3000	6.3	69	--	8.0	9.3
MAR., 1976											
16...	1600	.0	10.5	.01	18	970	6.8	59	2.4	8.4	1.5

DATE	ALKALINITY AS CACO3 (MG/L)	BICARBONATE (HCO3) (MG/L)	CARBONATE (CO3) (MG/L)	TOTAL NITROGEN (N) (MG/L)	TOTAL ORGANIC NITROGEN (N) (MG/L)	AMMONIA NITROGEN (N) (MG/L)	TOTAL KJELDAHL NITROGEN (N) (MG/L)	TOTAL NITRITE PLUS NITRATE (N) (MG/L)	TOTAL PHOSPHORUS (P) (MG/L)	TOTAL ORGANIC CARBON (C) (MG/L)	HARDNESS (CA,MG) (MG/L)
JAN., 1975											
20...	90	110	0	1.6	1.4	.04	1.4	.16	.27	34	150
MAR.											
05...	57	69	0	1.5	1.4	.05	1.4	.06	.24	--	90
19...	112	137	0	1.2	1.0	.08	1.1	.14	.23	--	190
MAY											
22...	479	584	0	.62	.57	.03	.60	.02	.02	--	1000
MAR., 1976											
16...	191	233	0	.74	.62	.11	.73	.01	.15	--	250

DATE	NONCARBONATE HARDNESS (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	SODIUM ADSORPTION RATIO	PERCENT SODIUM	DISSOLVED POTASSIUM (K) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED SILICA (SIO2) (MG/L)
JAN., 1975											
20...	60	27	20	43	1.5	36	12	4.2	160	.1	8.5
MAR.											
05...	33	21	9.0	14	.6	24	5.8	2.6	47	.1	6.1
19...	76	31	27	54	1.7	37	8.1	6.5	190	.3	6.7
MAY											
22...	540	160	150	390	5.3	45	18	13	1300	.6	14
MAR., 1976											
16...	63	39	38	120	3.3	49	11	4.2	310	.4	7.8

DATE	TOTAL ARSENIC (AS) (UG/L)	TOTAL BERYLLIUM (BE) (UG/L)	DISSOLVED BORON (B) (UG/L)	TOTAL CADMIUM (CD) (UG/L)	TOTAL CHROMIUM (CR) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)	DISSOLVED IRON (FE) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MANGANESE (MN) (UG/L)	TOTAL MOLYBDENUM (MO) (UG/L)
JAN., 1975											
20...	2	<.0	140	10	10	90	1600	150	<100	110	1
MAR.											
05...	--	--	70	--	--	--	--	160	--	--	--
19...	--	--	120	--	--	--	--	140	--	--	--
MAY											
22...	--	--	330	--	--	--	--	80	--	--	--
MAR., 1976											
16...	--	--	210	--	--	--	--	120	--	--	--

DATE	TOTAL NICKEL (NI) (UG/L)	TOTAL LITHIUM (LI) (UG/L)	TOTAL SELENIUM (SE) (UG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	DISSOLVED SOLIDS (TONS PER DAY)	DISSOLVED SOLIDS (TONS PER AC-FT)	TOTAL NITROGEN (NO3) (MG/L)	TOTAL MERCURY (HG) (UG/L)	SUSPENDED SEDIMENT (MG/L)	SUSPENDED SEDIMENT DISCHARGE (T/DAY)
JAN., 1975										
20...	<50	20	0	329	6.31	.45	6.9	.0	79	1.5
MAR.										
05...	--	--	--	140	20.1	.19	6.5	--	51	7.3
19...	--	--	--	391	16.2	.53	5.5	--	92	3.7
MAY										
22...	--	--	--	2330	1.76	3.17	2.7	--	56	.04
MAR., 1976										
16...	--	--	--	646	.02	.88	3.3	--	--	--

TABLE 13 -CHEMICAL, SPECTROGRAPHIC, AND RADIOCHEMICAL ANALYSES OF GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA

SAMPLE NUMBER	LOCATION NUMBER	LOCAL NUMBER	AQUIFER	DATE OF SAMPLE	TIME	DEPTH (FT) (00003)	SAMPLE NUMBER (00008)	TEMPER-ATURE (DEG C) (00010)	FLOW RATE (GPM) (00058)	TUR-BID-ITY (JTU) (00070)
1.	09S45E07CCAD		(COMPOSITE)	75-06-26	1330	273	--	12.5	10	2
2.	09S45E12CBCC		(SANDSTONE)	74-01-30	1030	231	--	10.5	--	--
3.	09S45E11ADDB	UM 75-104	(ANDERSON & DIETZ)	76-03-09	1320	297	--	13.0	<.50	460
4.	09S45E11BCDA-1		(ALLUVIUM)	75-06-03	1025	19	--	8.0	10	--
5.	09S46E08BACB		(DIETZ & SAND)	75-06-18	1100	145	753838	11.0	--	56
6.	09S46E09BAAD		(DIETZ	75-[illegible]-19	1030	90	753844	12.0	12	72
7.	09S45E02CBAD	UM 75-105	(ANDERSON & DIETZ)	75-11-13	1330	179	--	13.0	8.7	70
8.	09S45E03DABB-1	UM 75-102	(ANDERSON & DIETZ)	75-11-11	0900	125	--	11.5	6.0	15
9.	09S45E03ADCC-1		(COMPOSITE)	74-01-30	1100	36	--	10.0	10	--
10.	09S45E03ADCC-1		(COMPOSITE)	75-06-24	0930	36	--	10.5	9.0	28
11.	09S45E04BACD		(ALLUVIUM)	76-02-11	1045	26	--	9.0	12	4
12.	09S45E03BAAA		(ALLUVIUM)	76-02-04	0915	25	--	7.0	60	35
13.	09S46E05ABAB		(CANYON)	75-06-18	1215	148	753837	11.0	--	36
14.	08S45E34CABC	AM 75-001	(ALLUVIUM)	76-02-05	1430	25	--	10.5	5.3	250
15.	08S45E34CAAC		(ALLUVIUM)	74-01-30	1200	18	--	7.5	--	--
16.	08S45E34BCBC	M 75-23	(CANYON)	76-02-03	1300	211	--	12.5	2.7	40
17.	08S45E33BBDA		(ALLUVIUM)	74-02-02	1745	24	--	8.5	--	--
18.	08S45E33BAAC-1		(ALLUVIUM)	74-01-30	1115	30	--	9.5	--	--
19.	08S45E33BAAC-2		(ALLUVIUM)	74-02-01	1430	47	--	8.0	--	--
20.	08S45E16DBCB-1		(COMPOSITE)	75-06-30	1030	35	755033	11.0	--	200
21.	08S45E16DBCB-2		(CANYON)	75-06-30	1235	153	755034	11.5	6.0	3
22.	08S45E08DCBB		(DIETZ)	75-06-26	1430	185	753978	14.0	2.0	35

TABLE 13 -CHEMICAL, SPECTROGRAPHIC, AND RADIOCHEMICAL ANALYSES OF GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA --CONTINUED

SAMPLE NUMBER	SPECIFIC CONDUCTANCE (MICROMHOS) (00095)	PH (UNITS) (00400)	CARBON DIOXIDE (CO2) (MG/L) (00405)	ALKALINITY AS CACO3 (MG/L) (00410)	BICARBONATE (HCO3) (MG/L) (00440)	CARBONATE (CO3) (MG/L) (00445)	TOTAL FILTRABLE RESIDUE (MG/L) (00515)	TOTAL NON-FILTRABLE RESIDUE (MG/L) (00530)	TOTAL NITROGEN (N) (MG/L) (00600)	TOTAL ORGANIC NITROGEN (N) (MG/L) (00605)	AMMONIA NITROGEN (N) (MG/L) (00610)	DISSOLVED NITRATE (N) (MG/L) (00618)
1.	2150	8.0	23	1160	1420	0	--	--	3.8	.30	2.5	--
2.	1690	[1]8.1	16	1010	1230	0	--	--	--	--	--	.72
3.	3700	7.6	53	1210	1480	0	--	--	2.6	.00	2.8	--
4.	3550	[1]7.2	94	764	930	0	--	--	--	--	--	2.5
5.	3900	7.9	24	976	1190	0	3500	800	4.4	.48	.92	--
6.	2330	8.1	21	1390	1690	0	--	--	2.8	.10	2.7	--
7.	4650	7.4	91	1140	1430	0	--	--	4.6	.60	4.0	--
8.	4550	7.2	126	980	1250	0	3400	25	4.9	.00	5.0	--
9.	6500	[1]7.1	95	640	780	0	--	--	--	--	--	7.2
10.	6300	6.9	162	659	803	--	5000	88	9.8	.80	9.0	--
11.	3550	7.2	53	434	529	0	--	--	.37	.27	.04	--
12.	5900	7.3	58	580	724	0	5800	120	1.2	.87	.13	--
13.	3180	7.7	52	1350	1640	0	2600	45	5.2	.50	2.8	--
14.	4280	7.2	61	497	606	0	--	--	2.2	1.1	.04	--
15.	4000	[1]7.6	23	470	570	0	--	--	--	--	--	.66
16.	2180	7.6	61	1240	1510	0	1400	140	2.2	.20	1.9	--
17.	3700	[1]6.0	170	87	106	0	--	--	--	--	--	1.3
18.	6000	[1]7.4	48	616	750	0	--	--	--	--	--	11
19.	6100	[1]7.8	20	640	780	0	--	--	--	--	--	.47
20.	5340	6.7	155	399	486	0	5400	260	6.9	3.5	3.4	--
21.	2990	8.0	28	1440	1750	0	1700	4	3.6	.50	3.0	--
22.	5840	7.6	53	1080	1320	0	4000	170	6.2	.50	5.7	--

Table 13

Sheet 3 of 7

TABLE 13 -CHEMICAL, SPECTROGRAPHIC, AND RADIOCHEMICAL ANALYSES OF GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA--CONTINUED

SAMPLE NUMBER	TOTAL KJEL-DAHL NITRO-GEN (N) (MG/L) (00625)	TOTAL NITRITE PLUS NITRATE (N) (MG/L) (00630)	TOTAL PHOS-PHORUS (P) (MG/L) (00665)	HARD-NESS (CA,MG) (MG/L) (00900)	NON-CAR-BONATE HARD-NESS (MG/L) (00902)	DIS-SOLVED CAL-CIUM (CA) (MG/L) (00915)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L) (00925)	DIS-SOLVED SODIUM (NA) (MG/L) (00930)	SODIUM AD-SORP-TION RATIO (00931)	PERCENT SODIUM (00932)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L) (00935)	DIS-SOLVED CHLO-RIDE (CL) (MG/L) (00940)
1.	2.8	.97	.10	39	0	8.9	4.0	520	36	96	5.0	17
2.	--	--	--	36	0	6.5	4.8	450	33	96	3.2	16
3.	.59	2.0	.19	200	0	39	26	890	27	90	11	12
4.	--	--	--	976	212	160	140	550	7.7	55	8.9	9.4
5.	1.4	3.0	.31	130	0	24	16	840	33	93	7.2	11
6.	2.8	.04	.07	61	0	12	7.2	610	34	95	5.7	12
7.	4.6	.01	.12	[illegible]	0	62	34	1000	25	87	9.8	2.6
8.	4.9	.01	.04	260	0	52	32	1100	30	90	10	11
9.	--	--	--	1100	420	190	142	1120	15	69	20	15
10.	9.8	.04	--	--	--	--	160	1100	14	66	--	--
11.	.31	.06	.01	1700	1300	300	240	310	3.2	28	8.1	13
12.	1.0	.20	.03	2000	1400	330	290	850	8.2	48	12	22
13.	3.3	1.9	.06	230	0	57	22	720	21	87	7.2	16
14.	1.1	1.1	.18	1700	1200	280	250	520	5.4	39	9.1	.9
15.	--	--	--	1600	1100	290	210	500	5.5	40	12	15
16.	2.1	.07	.11	32	0	6.3	3.8	560	44	97	4.5	22
17.	--	--	--	1600	1500	150	290	460	5.1	39	7.4	20
18.	--	--	--	2600	2000	410	380	610	5.2	34	37	21
19.	--	--	--	2100	1500	390	270	700	6.6	42	39	23
20.	6.9	.02	.14	2400	2000	360	370	340	3.0	23	16	8.8
21.	3.5	.13	.09	56	0	10	7.4	660	39	96	5.6	23
22.	6.2	.03	.11	230	0	44	29	1200	35	91	12	16

TABLE 13 -CHEMICAL, SPECTROGRAPHIC, AND RADIOCHEMICAL ANALYSES OF GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA --CONTINUED

SAMPLE NUMBER	DIS-SOLVED SULFATE (SO4) (MG/L) (00945)	DIS-SOLVED FLUO-RIDE (F) (MG/L) (00950)	DIS-SOLVED SILICA (SIO2) (MG/L) (00955)	DIS-SOLVED ARSENIC (AS) (UG/L) (01000)	DIS-SOLVED BARIUM (BA) (UG/L) (01005)	DIS-SOLVED BERYL-LIUM (BE) (UG/L) (01010)	DIS-SOLVED BISMUTH (BI) (UG/L) (01015)	DIS-SOLVED BORON (B) (UG/L) (01020)	DIS-SOLVED CAD-MIUM (CD) (UG/L) (01025)	DIS-SOLVED CHRO-MIUM (CR) (UG/L) (01030)	DIS-SOLVED COBALT (CO) (UG/L) (01035)	DIS-SOLVED COPPER (CU) (UG/L) (01040)
1.	5.5	2.0	8.5	1	--	--	--	80	--	--	--	2
2.	2.5	2.0	8.0	--	--	--	--	--	--	--	--	--
3.	970	.9	8.7	0	--	--	--	140	--	--	--	4
4.	1361	.3	11	--	--	--	--	--	--	--	--	--
5.	930	1.0	7.3	18	95	<7	<16	50	0	<16	<16	1
6.	9.1	1.5	6.8	0	580	<3	<10	<10	0	<10	<10	<3
7.	1300	1.0	7.3	1	80	[illegible]	<10	110	0	<20	<20	<5
8.	1600	1.0	7.1	2	30	<10	<40	<50	0	<20	<20	<5
9.	2800	.5	14	--	--	--	--	--	--	--	--	--
10.	--	--	14	4	3	0	<3	950	<5	<2	<3	1
11.	1900	.3	13	0	--	--	--	120	--	--	--	0
12.	3100	.3	15	0	40	<20	<80	210	0	<40	<80	<20
13.	280	1.3	8.1	1	480	<7	<15	50	0	<15	<15	<4
14.	2300	.4	16	2	--	--	--	320	--	--	--	5
15.	2200	.4	21	--	--	--	--	--	--	--	--	--
16.	9.4	2.5	7.0	0	300	<6	<25	90	0	<15	<25	<5
17.	2300	.1	26	--	--	--	--	--	--	--	--	--
18.	3100	.7	31	--	--	--	--	--	--	--	--	--
19.	2900	.7	25	--	--	--	--	--	--	--	--	--
20.	2700	.5	22	49	50	<6	<30	750	2	<25	<25	10
21.	66	2.8	7.4	2	430	<3	<15	<12	0	<12	<12	5
22.	1700	1.4	12	2	60	<5	<30	85	0	<25	<25	30

TABLE 13 -CHEMICAL, SPECTROGRAPHIC, AND RADIOCHEMICAL ANALYSES OF GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA--CONTINUED

SAMPLE NUMBER	DIS-SOLVED IRON (FE) (UG/L) (01046)	DIS-SOLVED LEAD (PB) (UG/L) (01049)	DIS-SOLVED MAN-GANESE (MN) (UG/L) (01056)	DIS-SOLVED MOLYB-DENUM (MO) (UG/L) (01060)	DIS-SOLVED NICKEL (NI) (UG/L) (01065)	DIS-SOLVED SILVER (AG) (UG/L) (01075)	DIS-SOLVED STRON-TIUM (SR) (UG/L) (01080)	DIS-SOLVED VANA-DIUM (V) (UG/L) (01085)	DIS-SOLVED ZINC (ZN) (UG/L) (01090)	DIS-SOLVED TIN (SN) (UG/L) (01100)	DIS-SOLVED ALUM-INUM (AL) (UG/L) (01106)	DIS-SOLVED GALLIUM (GA) (UG/L) (01120)
1.	230	--	--	--	--	--	--	--	--	--	--	--
2.	40	--	0	--	--	--	--	--	--	--	--	--
3.	0	--	--	--	--	--	--	--	--	--	--	--
4.	20	--	20	--	--	--	--	--	--	--	--	--
5.	[2]30	<16	35	14	<16	<2	1200	<16	140	<16	200	<7
6.	[2]30	<10	<5	<5	<10	<1	560	<10	20	<10	120	<5
7.	[2]<20	<20	750	<15	<20	<2	1000	<20	20	<18	50	<8
8.	[2]130	<20	<20	<10	<20	<5	2000	<10	70	<40	50	<10
9.	870	--	370	--	--	--	--	--	--	--	--	--
10.	[2]33000	<3	30	<2	<3	<0	480	<2.0	<10	<3	<5	<2
11.	570	--	--	--	--	--	--	--	--	--	--	--
12.	[2]3000	<80	700	100	<80	<8	4000	<40	20	<80	<40	<40
13.	[2]400	<15	180	<7	30	<2	1000	<15	250	<15	90	<7
14.	30	--	--	--	--	--	--	--	--	--	--	--
15.	30	--	1600	--	--	--	--	--	--	--	--	--
16.	[2]40	<25	<20	30	<25	<3	270	<15	20	<25	80	<10
17.	0	--	460	--	--	--	--	--	--	--	--	--
18.	60	--	1400	--	--	--	--	--	--	--	--	--
19.	50	--	1100	--	--	--	--	--	--	--	--	--
20.	[2]23000	<25	770	54	<25	<3	3700	<25	50	<30	130	<10
21.	[2]75	<12	<12	15	<12	<2	640	<12	10	<15	35	<6
22.	[2]80	<25	<20	75	<25	<3	2700	<20	30	<30	80	<10

TABLE 13 -CHEMICAL, SPECTROGRAPHIC, AND RADIOCHEMICAL ANALYSES OF GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA--CONTINUED

SAMPLE NUMBER	DIS-SOLVED GER-MANIUM (GE) (UG/L) (01125)	DIS-SOLVED LITHIUM (LI) (UG/L) (01130)	DIS-SOLVED TI-TANIUM (TI) (UG/L) (01150)	DIS-SOLVED ZIR-CONIUM (ZR) (UG/L) (01160)	DIS-SOLVED GROSS BETA AS CS-137 (PC/L) (03515)	SUS-PENDED GROSS BETA AS CS-137 (PC/L) (03516)	DIS-SOLVED RA-226 (RADON METHOD) (PC/L) (09511)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L) (70301)	DIS-SOLVED SOLIDS (TONS PER DAY) (70302)	DIS-SOLVED SOLIDS (TONS PER AC-FT) (70303)	HY-DROX-IDE (OH) (MG/L) (71830)	DIS-SOLVED NITRATE (NO3) (MG/L) (71851)
1.	--	--	--	--	--	--	--	1270	--	1.73	--	--
2.	--	--	--	--	--	--	--	1110	--	--	0	3.2
3.	--	--	--	--	--	--	--	2690	--	3.66	--	--
4.	--	--	--	--	--	--	--	2720	--	--	0	11
5.	<24	130	<8	<24	<8.7	35	.41	2430	--	3.29	--	--
6.	<10	90	<5	<15	--	--	--	1500	--	2.04	--	--
7.	<30	130	<10	<40	--	--	--	3140	--	4.26	--	--
8.	<40	160	<10	<40	44	1.0	.25	3430	--	4.66	--	--
9.	--	--	--	--	--	--	--	4700	--	--	0	32
10.	<3	30	3	<6	<17	1.3	.35	4760	116	6.47	--	--
11.	--	--	--	--	--	--	--	3050	--	4.15	--	--
12.	<80	170	<40	<180	170	11	.06	4980	--	6.77	--	--
13.	<22	180	<7	<22	9.9	3.3	.12	1920	--	2.61	--	--
14.	--	--	--	--	--	--	--	3680	--	5.00	--	--
15.	--	--	--	--	--	--	--	3520	--	--	0	2.9
16.	<30	90	<20	<50	10	8.2	.17	1360	--	1.85	--	--
17.	--	--	--	--	--	--	--	3350	--	--	0	5.7
18.	--	--	--	--	--	--	--	5040	--	--	0	50
19.	--	--	--	--	--	--	--	4760	--	--	0	2.1
20.	<30	420	30	<35	74	11	2.3	4090	--	5.55	--	--
21.	<15	110	<6	<18	48	<.4	.09	1650	--	2.24	--	--
22.	<30	120	<10	<35	16	6.9	.44	3670	--	4.99	--	--

TABLE 13 -CHEMICAL, SPECTROGRAPHIC, AND RADIOCHEMICAL ANALYSES OF GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA --CONTINUED

SAMPLE NUMBER	TOTAL NITRO-GEN (NO3) (MG/L) (71887)	DIS-SOLVED MERCURY (HG) (UG/L) (71890)	ELEV. OF LAND SURFACE DATUM (FT. ABOVE MSL) (72000)	TOTAL DEPTH OF WELL (FT) (72008)	DIS-SOLVED URANIUM (DIRECT FLUORO-METRIC) (PC/L) (80010)	DIS-SOLVED URANIUM (U) (UG/L) (80020)	DIS-SOLVED GROSS ALPHA AS U-NAT. (UG/L) (80030)	SUS-PENDED GROSS ALPHA AS U-NAT. (UG/L) (80040)	DIS-SOLVED GROSS BETA AS SR90 /Y90 (PC/L) (80050)	SUS-PENDED GROSS BETA AS SR90 /Y90 (PC/L) (80060)
1.	17	.2	3900	285	--	--	--	--	--	--
2.	--	--	3930	293	--	--	--	--	--	--
3.	11	.0	4004	307	--	--	--	--	--	--
4.	--	--	3840	19	--	--	--	--	--	--
5.	19	.0	3967	240	--	.64	50	67	<7.6	28
6.	13	.0	3858	120	--	--	--	--	--	--
7.	20	.0	3949	299	--	--	--	--	--	--
8.	22	.0	3811	144	--	.60	<45	.7	35	.9
9.	--	--	3822	82	--	--	--	--	--	--
10.	44	.2	3822	82	--	1.0	<68	1.9	<14	1.1
11.	1.6	.0	3810	28	--	--	--	--	--	--
12.	5.3	.0	3790	45	25	--	<99	6.8	150	8.6
13.	23	.0	3827	180	--	.25	<30	8.3	8.5	2.6
14.	9.7	.0	3769	35	--	--	--	--	--	--
15.	--	--	3760	21	--	--	--	--	--	--
16.	9.6	.0	3787	253	--	.09	<20	12	8.2	6.7
17.	--	--	3778	25	--	--	--	--	--	--
18.	--	--	3765	30	--	--	--	--	--	--
19.	--	--	3770	50	--	--	--	--	--	--
20.	31	.6	3715	66	--	1.4	250	31	61	8.5
21.	16	.3	3715	188	--	.06	70	<.4	38	<.4
22.	28	.6	3880	212	--	.10	<43	16	13	5.5

[1] LABORATORY-DETERMINED PH
[2] SAMPLE TREATED TO PRESERVE IRON

TABLE 14 -PERCENTAGE REACTING VALUES OF MAJOR CHEMICAL CONSTITUENTS IN GROUND WATER FROM THE VICINITY OF THE BEAR CREEK STUDY AREA.

IDENTI-FICATION NUMBER	LOCATION NUMBER	SAMPLE IDENTIFICATION	DATE/Y/M/D	TIME	DEPTH OR DISCHARGE		PERCENTAGES NA+K	CA+MG	CA	MG	HCO3+CO3	CL+SO4+NO3	CL	SO4	NO3	BALANCE
1.	09S45E07CCAD	(COMPOSITE)	1975 6 26	1330	-1.0	BC	96.71	3.29	1.89	1.40	97.51	2.49	2.00	0.48	-1.00	1.02
2.	09S45E12CBCC	(SANDSTONE)	1974 1 30	1030	-1.0	BC	96.47	3.53	1.59	1.94	97.56	2.44	2.17	0.25	-1.00	1.02
3.	09S45E11ADDB	DH 75-104 (ANDERSON & DIETZ)	1976 3 9	1320	-1.0	BC	90.52	9.48	4.52	4.96	54.16	45.84	0.75	45.04	-1.00	1.04
4.	09S46E08BACB	(DIETZ & SAND)	1975 6 18	1100	-1.0	BC	93.59	6.41	3.05	3.35	49.78	50.22	0.79	49.36	-1.00	1.00
5.	09S46E09BAAD	(DIETZ)	1975 6 19	1030	-1.0	BC	95.73	4.27	2.15	2.12	98.13	1.87	1.20	0.67	-1.00	1.02
6.	09S45E02CBAD	DH 75-105 (ANDERSON & DIETZ)	1975 11 13	1330	-1.0	BC	87.52	12.48	6.89	5.59	46.34	53.66	0.14	53.46	-1.00	1.01
7.	09S45E03DABB-1	DH 75-102 (ANDERSON & DIETZ)	1975 11 11	900	-1.0	BC	90.20	9.80	4.87	4.93	37.86	62.14	0.57	61.50	-1.00	1.02
8.	09S45E03ADCC-1	(COMPOSITE)	1974 1 30	1100	-1.0	BC	69.94	30.06	13.47	16.59	17.88	82.12	0.59	81.50	-1.00	1.02
9.	09S45E04BACD	(ALLUVIUM)	1976 2 11	1045	-1.0	BC	28.29	71.71	30.93	40.78	17.84	82.16	0.75	81.38	-1.00	1.00
10.	09S45E03BAAA	(ALLUVIUM)	1976 2 4	915	-1.0	BC	48.04	51.96	21.22	30.73	15.41	84.59	0.81	83.77	-1.00	0.99
11.	09S46E05ABAB	(CANYON)	1975 6 18	1215	-1.0	BC	87.13	12.87	7.87	5.00	81.06	18.94	1.36	17.54	-1.00	0.92
12.	08S45E34CABC	AH 75-001 (ALLUVIUM)	1976 2 5	1430	-1.0	BC	39.82	60.18	24.35	35.83	17.17	82.83	0.04	82.76	-1.00	1.01
13.	08S45E34CAAC	(ALLUVIUM)	1974 1 30	1200	-1.0	BC	41.00	59.00	26.90	32.10	16.81	83.19	0.76	82.40	-1.00	1.03
14.	08S45E34BCBC	M 75-23 (CANYON)	1976 2 3	1300	-1.0	BC	97.50	2.50	1.25	1.24	96.81	3.19	2.41	0.76	-1.00	1.02
15.	08S45E33BBDA	(ALLUVIUM)	1974 2 2	1745	-1.0	BC	39.20	60.80	14.52	46.28	3.46	96.54	1.12	95.40	-1.00	0.97
16.	08S45E33BAAC-1	(ALLUVIUM)	1974 1 30	1115	-1.0	BC	34.70	65.30	25.83	39.46	15.88	84.12	0.76	83.32	-1.00	0.98
17.	08S45E33BAAC-2	(ALLUVIUM)	1974 2 1	1430	-1.0	BC	43.01	56.99	26.62	30.37	17.43	82.57	0.88	81.65	-1.00	1.01
18.	08S45E16DBCB-1	(COMPOSITE)	1975 6 30	1030	-1.0	BC	23.90	76.10	28.25	47.85	12.36	87.64	0.39	87.22	-1.00	1.01
19.	08S45[illegible]-2	(CANYON)	1975 6 30	1235	-1.0	BC	96.30	3.70	1.67	2.03	93.41	6.59	2.10	4.45	-1.00	1.03
20.	08S45E08DCBB	(DIETZ)	1975 6 26	1430	-1.0	BC	91.98	8.02	3.85	4.18	37.64	62.36	0.78	61.50	-1.00	1.01

Table 14

TABLE 15 -CLASSIFICATION VALUES FOR GROUND WATER FOR IRRIGATION FROM THE VICINITY OF THE BEAR CREEK STUDY AREA.

SAMPLE NUMBER	LOCATION NUMBER	DATE SAMPLED	SAMPLING DEPTH OR DISCHARGE		SAR	CONDUCTIVITY	GEOLOGIC UNIT
1.	09S45E07CCAD	(COMPOSITE) 6-26-1975--1330	BC	-1	36.00	2150.	125TGRV
2.	09S45E12CBCC	(SANDSTONE) 1-30-1974--1030	BC	-1	33.00	1690.	
3.	09S45E11ADDB DH 75-104	(ANDERSON & DIETZ) 3- 9-1976--1320	BC	-1	27.00	3700.	125TGRV
4.	09S46E08BACB	(DIETZ & SAND) 6-18-1975--1100	BC	-1	33.00	3900.	125TGRV
5.	09S46E09BAAD	(DIETZ) 6-19-1975--1030	BC	-1	34.00	2530.	125TGRV
6.	09S45E02CBAD DH 75-105	(ANDERSON & DIETZ) 11-13-1975--1330	BC	-1	25.00	4650.	125TGRV
7.	09S45E03DABB-1 DH 75-102	(ANDERSON & DIETZ) 11-11-1975--[illegible]	BC	-1	30.00	4550.	125TGRV
8.	09S45E03ADCC-1	(COMPOSITE) 1-30-1974--1100	BC	-1	15.00	6500.	125TGRV
9.	09S45E03ADCC-1	(COMPOSITE) 6-24-1975-- 930	BC	-1	14.00	6300.	125TGRV
10.	09S45E04BACD	(ALLUVIUM) 2-11-1976--1045	BC	-1	3.20	3550.	110ALVM
11.	09S45E03BAAA	(ALLUVIUM) 2- 4-1976-- 915	BC	-1	8.20	5900.	110ALVM
12.	09S46E05ABAB	(CANYON) 6-18-1975--1215	BC	-1	21.00	3180.	125TGRV
13.	08S45E34CABC AH 75-001	(ALLUVIUM) 2- 5-1976--1430	BC	-1	5.40	4280.	110ALVM
14.	08S45E34CAAC	(ALLUVIUM) 1-30-1974--1200	BC	-1	5.50	4000.	110ALVM
15.	08S45E34BCBC M 75-23	(CANYON) 2- 3-1976--1300	BC	-1	44.00	2180.	125TGRV
16.	08S45E33BBDA	(ALLUVIUM) 2- 2-1974--1745	BC	-1	5.10	3700.	110ALVM
17.	08S45E33BAAC-1	(ALLUVIUM) 1-30-1974--1115	BC	-1	5.20	6000.	110ALVM
18.	08S45E33BAAC-2	(ALLUVIUM) 2- 1-1974--1430	BC	-1	6.60	6100.	110ALVM
19.	08S45E16DBCB-1	(COMPOSITE) 6-30-1975--1030	BC	-1	3.00	5340.	125TGRV
20.	08S45E16DBCB-2	(CANYON) 6-30-1975--1235	BC	-1	39.00	2990.	125TGRV
21.	08S45E08DCBB	(DIETZ) 6-26-1975--1430	BC	-1	35.00	5840.	125TGRV

APPENDIX E

VEGETATION, SOIL WATER AND SOIL DETACHABILITY

TABLE 17.--SOIL-WATER-VEGETATION-RELATIONSHIP DATA AND SOIL-DETACHABILITY DATA FOR THE SITES SAMPLED

SYMBOLS: H, HORIZON; DM, DEPTH IN DECIMETERS; VW, VOLUME WEIGHT IN GRAMS PER CUBIC CENTIMETER; SM, SOIL-MOISTURE CONTENT IN GRAMS PER GRAM; PF, LOG OF MOISTURE STRESS IN GRAMS PER SQUARE CENTIMETER; MRC, MOISTURE-RETENTION CAPABILITY AT PF 2.34 IN GRAMS PER GRAM; VMC, VOID-MOISTURE CAPACITY IN GRAMS PER GRAM; SMC, SATURATION-MOISTURE CAPACITY IN GRAMS PER GRAM; VS, VOLUMETRIC SHRINK IN CUBIC CENTIMETERS PER CUBIC CENTIMETER; EC, ELECTRICAL CONDUCTIVITY OF SATURATED SOIL IN MILLIMHOS PER CENTIMETER; PH, LOG OF HYDROGEN CONTENT IN MOLS PER LITER; ROOTS, WEIGHT OF ROOTS CONTAINED PER CUBIC DECIMETER OF SOIL; DET, DETACHABILITY OF SOIL BY FLOWING WATER IN KILOGRAMS PER HOUR FROM A SQUARE METER OF SURFACE; CPR, COARSE PARTICLE RATIO - WEIGHT OF PARTICLES OF DIAMETER GREATER THAN .25 MILLIMETERS DIVIDED BY TOTAL WEIGHT OF SOIL PARTICLES; MW, MOISTURE CONTENT WHEN WET IN GRAMS PER GRAM; MD, MOISTURE CONTENT WHEN DRY IN GRAMS PER GRAM; MDM, MOISTURE STORAGE DEPLETED IN DECIMETERS.

M 1

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.24	.044	5.67	.225	0.43	0.46	.28	0.52	6.45	13.8	0.6	.007
1	2	1.44	.074	5.08	.231	0.32	0.47	.35	0.49	6.85	3.4	0.6	.006
	3	1.44	.084	4.75	.221	0.32	0.52	.36	0.60	7.15	5.2	1.2	.006
	4	1.61	.075	4.88	.216	0.29	0.43	.32	0.48	7.25	2.5	2.8	.006
	5	1.50	.079	4.86	.225	0.29	0.44	.34	0.54	7.25	2.7	2.1	.007
	6	1.46	.075	4.82	.206	0.26	0.44	.37	0.51	7.45	2.6	3.5	.012
	7	1.40	.081	4.75	.213	0.30	0.43	.31	0.52	7.20	1.7	2.0	.020
	8	1.39	.086	4.76	.228	0.34	0.47	.35	0.53	7.40	1.8	1.5	.008
2	9	1.49	.083	4.62	.200	0.30	0.45	.34	0.54	7.65	0.9	3.7	.005
	10	1.51	.075	4.54	.172	0.28	0.40	.32	1.56	7.58	1.1	10.4	.008
	11	1.46	.076	4.21	.146	0.31	0.36	.30	2.00	7.80	0.6	8.2	.011
	12	1.41	.112	4.03	.198	0.33	0.44	.38	2.94	7.95	0.7	7.1	.007
	13	1.39	.129	3.99	.225	0.34	0.47	.41	3.85	8.25	0.6	6.8	.008
3	14	1.55	.110	4.07	.198	0.27	0.43	.37	3.21	8.15	0.2	6.2	.008
	15	1.55	.084	4.36	.174	0.27	0.40	.34	2.94	8.18	0.4	10.9	.005
	16	1.55	.080	4.40	.170	0.27	0.39	.28	3.05	7.92	0.3	20.1	.003

M 2

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.24	.056	3.52	.225	0.43	0.56	.34	0.63	7.15	19.0	0.8	.011
	2	1.39	.088	5.24	.230	0.34	0.58	.33	0.66	7.05	3.9	9.4	.002
1	3	1.66	.095	4.56	.256	0.22	0.67	.38	0.51	7.38	2.1	17.3	.001
	4	1.79	.111	4.31	.224	0.18	0.70	.41	0.45	7.88	1.0	21.8	.000
	5	1.74	.157	4.05	.281	0.20	0.67	.41	0.61	7.85	0.6	19.4	.000
	6	1.65	.172	3.62	.257	0.23	0.74	.45	0.48	8.28	0.3	13.1	.001
2	7	1.60	.184	3.60	.273	0.25	0.79	.47	0.68	8.28	0.5	9.7	.000
	8	1.62	.180	3.64	.271	0.24	0.76	.47	0.98	8.08	0.2	15.0	.000
	9	1.63	.197	3.76	.311	0.24	0.68	.43	4.03	8.02	0.1	19.3	.000
	10	1.60	.184	3.78	.293	0.25	0.70	.45	2.08	7.75	0.3	14.1	.000
3	11	1.58	.187	3.85	.306	0.26	0.71	.48	2.23	7.70	0.1	11.6	.000
	12	1.62	.179	4.10	.326	0.24	0.70	.48	3.05	7.62	0.1	14.3	.001
	13	1.69	.188	3.84	.307	0.22	0.71	.45	2.84	7.78	0.2	16.2	.001
	14	1.74	.169	3.80	.271	0.20	0.70	.44	3.21	7.42	0.2	12.5	.000
	15	1.72	.167	3.92	.281	0.20	0.68	.46	3.09	7.70	0.1	13.2	.000
	16	1.72	.163	4.00	.285	0.20	0.69	.44	3.21	7.65	0.2	22.0	.000

M 3

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.02	.053	5.60	.322	0.60	0.62	.37	1.04	6.45	25.0	0.5	.002
1	2	1.20	.074	5.14	.260	0.46	0.57	.40	0.76	6.85	7.3	1.4	.001
	3	1.35	.080	5.01	.254	0.37	0.52	.36	0.84	7.05	3.7	2.6	.001
	4	1.45	.076	5.01	.241	0.31	0.49	.34	0.74	7.20	4.5	2.3	.004
	5	1.45	.072	4.96	.221	0.31	0.46	.32	0.62	7.28	4.7	5.4	.012
	6	1.45	.085	4.92	.252	0.31	0.48	.34	0.66	7.35	3.0	2.6	.004
2	7	1.45	.092	4.74	.241	0.31	0.48	.38	0.83	7.50	1.8	3.4	.005
	8	1.41	.097	4.73	.250	0.33	0.53	.39	1.04	7.58	1.4	7.7	.002
	9	1.39	.104	4.63	.253	0.34	0.60	.44	1.49	7.70	1.1	5.2	.002
	10	1.45	.093	6.30	.238	0.31	0.52	.38	2.27	7.50	1.0	12.1	.002
3	11	1.45	.091	4.70	.232	0.31	0.53	.35	3.05	7.30	0.3	14.9	.002

M 4

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.07	.055	5.37	.245	0.56	0.56	.36	1.00	6.45	18.7	0.6	.001
	2	1.22	.083	5.00	.260	0.44	0.58	.41	1.14	6.65	8.2	0.6	.000
1	3	1.44	.063	4.99	.196	0.32	0.46	.36	0.78	6.75	5.3	1.1	.000
	4	1.57	.056	5.01	.177	0.26	0.40	.32	0.69	6.75	4.4	1.0	.002
	5	1.52	.054	5.00	.158	0.28	0.33	.27	0.54	6.67	4.0	1.9	.004
	6	1.56	.062	4.95	.168	0.26	0.44	.32	0.60	6.80	1.5	1.0	.003
	7	1.56	.054	4.99	.168	0.26	0.39	.31	0.64	6.95	3.1	1.3	.003
	8	1.51	.064	4.97	.198	0.28	0.43	.32	0.83	6.78	3.5	0.6	.003
	9	1.33	.064	4.97	.199	0.38	0.44	.33	1.09	6.97	2.3	1.7	.002
	10	1.25	.061	4.90	.178	0.42	0.43	.33	1.39	6.82	1.8	2.3	.002
	11	1.31	.055	4.79	.148	0.39	0.40	.30	1.52	6.85	1.0	2.2	.002
	12	1.40	.046	4.70	.116	0.34	0.32	.22	1.54	7.15	0.7	19.4	.010
	13	1.38	.059	4.69	.148	0.35	0.38	.31	1.76	7.12	0.7	7.3	.005
	14	1.40	.073	4.61	.176	0.34	0.43	.30	1.49	7.15	1.2	1.4	.007
	15	1.65	.065	4.52	.148	0.23	0.38	.28	1.19	7.20	0.5	2.5	.014
	16	1.65	.077	4.56	.179	0.23	0.41	.33	1.60	7.28	0.8	11.3	.008

M 5

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.14	.053	5.58	.264	0.50	0.54	.37	1.00	6.65	17.0	0.6	.001
1	2	1.17	.077	5.10	.232	0.48	0.49	.38	0.71	6.70	5.9	0.9	.001
	3	1.45	.086	4.90	.252	0.31	0.51	.39	0.68	6.88	2.8	1.3	.005
	4	1.50	.085	4.91	.250	0.29	0.51	.39	0.70	7.12	2.8	0.8	.001
	5	1.57	.080	4.89	.231	0.26	0.45	.35	0.61	7.32	2.0	3.7	.004
	6	1.50	.080	4.89	.230	0.29	0.47	.38	0.51	7.60	1.5	1.5	.002
	7	1.51	.084	4.95	.254	0.28	0.49	.39	0.43	7.78	0.9	3.0	.001
	8	1.50	.089	4.98	.276	0.29	0.52	.43	0.51	7.98	0.9	5.5	.000
2	9	1.39	.096	4.85	.269	0.34	0.53	.44	0.57	8.08	0.8	4.8	.000
	10	1.31	.092	4.86	.260	0.39	0.52	.46	0.54	8.22	0.7	7.4	.001
	11	1.29	.091	4.85	.255	0.40	0.50	.43	0.60	8.38	0.6	6.3	.000
	12	1.56	.080	4.82	.219	0.27	0.44	.40	0.56	8.52	0.5	6.1	.001
	13	1.51	.078	4.81	.212	0.29	0.50	.40	0.60	8.60	0.4	9.6	.001
	14	1.45	.083	4.78	.222	0.31	0.55	.45	0.68	8.48	0.3	4.6	.001
	15	1.41	.102	4.73	.264	0.33	0.61	.44	0.88	8.45	0.3	1.8	.003
3	16	1.41	.090	4.71	.230	0.33	0.54	.43	0.96	8.50	0.6	2.8	.003

M 6

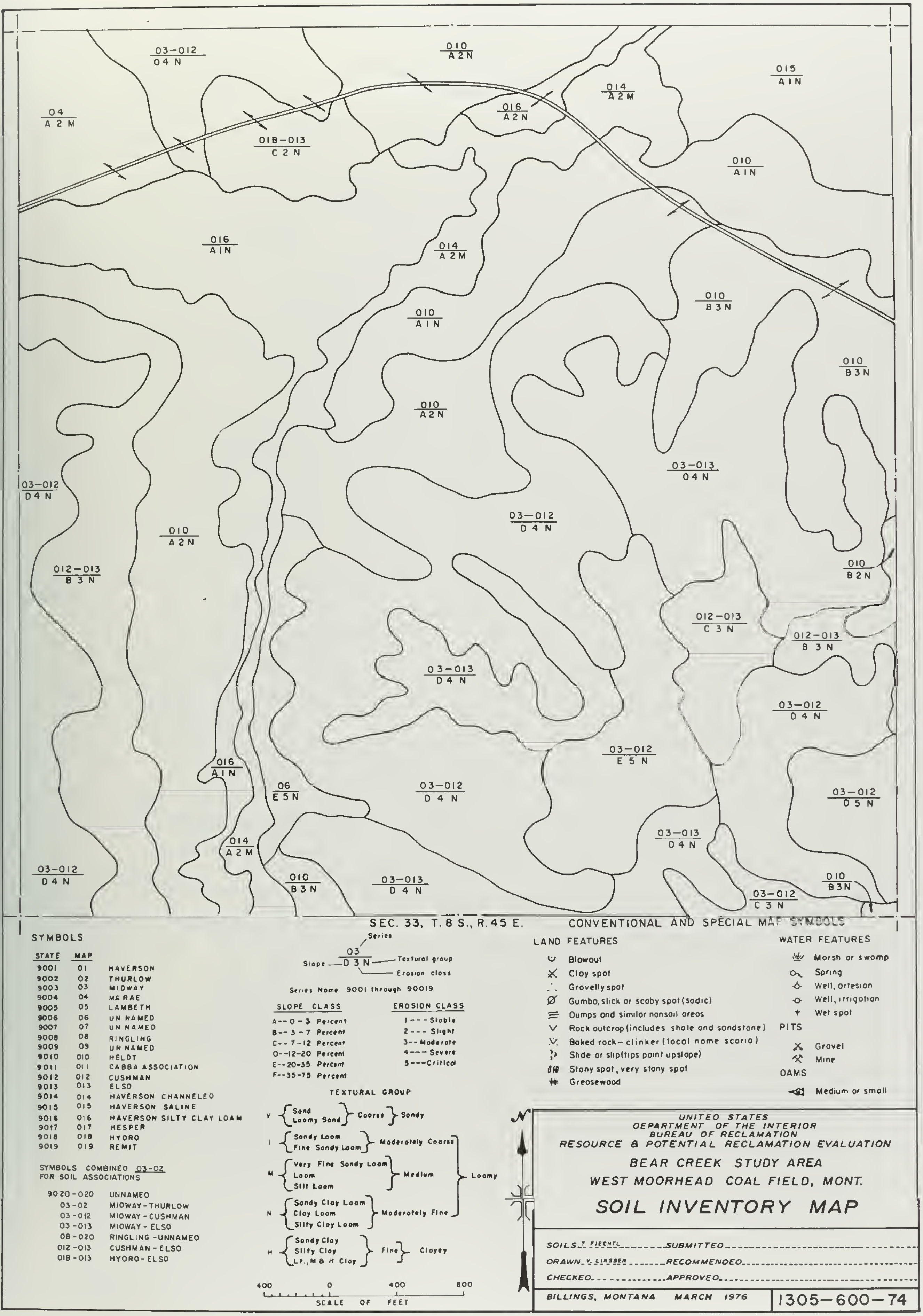
H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.24	.059	5.63	.215	0.43	0.55	.34	0.58	7.35	12.2	0.7	.002
	2	1.49	.091	4.40	.194	0.30	0.56	.34	0.34	7.70	2.6	11.8	.004
1	3	1.56	.102	4.26	.201	0.26	0.54	.31	0.39	7.92	1.2	77.1	.013
	4	1.78	.124	3.85	.202	0.18	0.58	.32	0.37	7.90	1.5	90.5	.009
	5	1.77	.138	3.71	.214	0.19	0.56	.35	0.34	8.35	0.3	102.9	.005
	6	1.82	.132	3.67	.239	0.17	0.55	.38	0.42	8.45	0.4	29.9	.011
	7	1.78	.131	3.65	.198	0.18	0.54	.34	0.42	8.65	0.3	39.4	.017
	8	1.73	.136	3.50	.195	0.20	0.58	.33	0.44	8.75	0.4	11.5	.003
2	9	1.67	.152	3.73	.237	0.22	0.79	.47	0.64	8.90	0.2	0.6	.001
3	10	1.64	.206	3.88	.342	0.23	1.10	.51	1.19	8.60	0.1	0.5	.000
	11	1.64	.208	4.03	.368	0.23	0.99	.52	1.52	8.55	0.2	0.5	.000

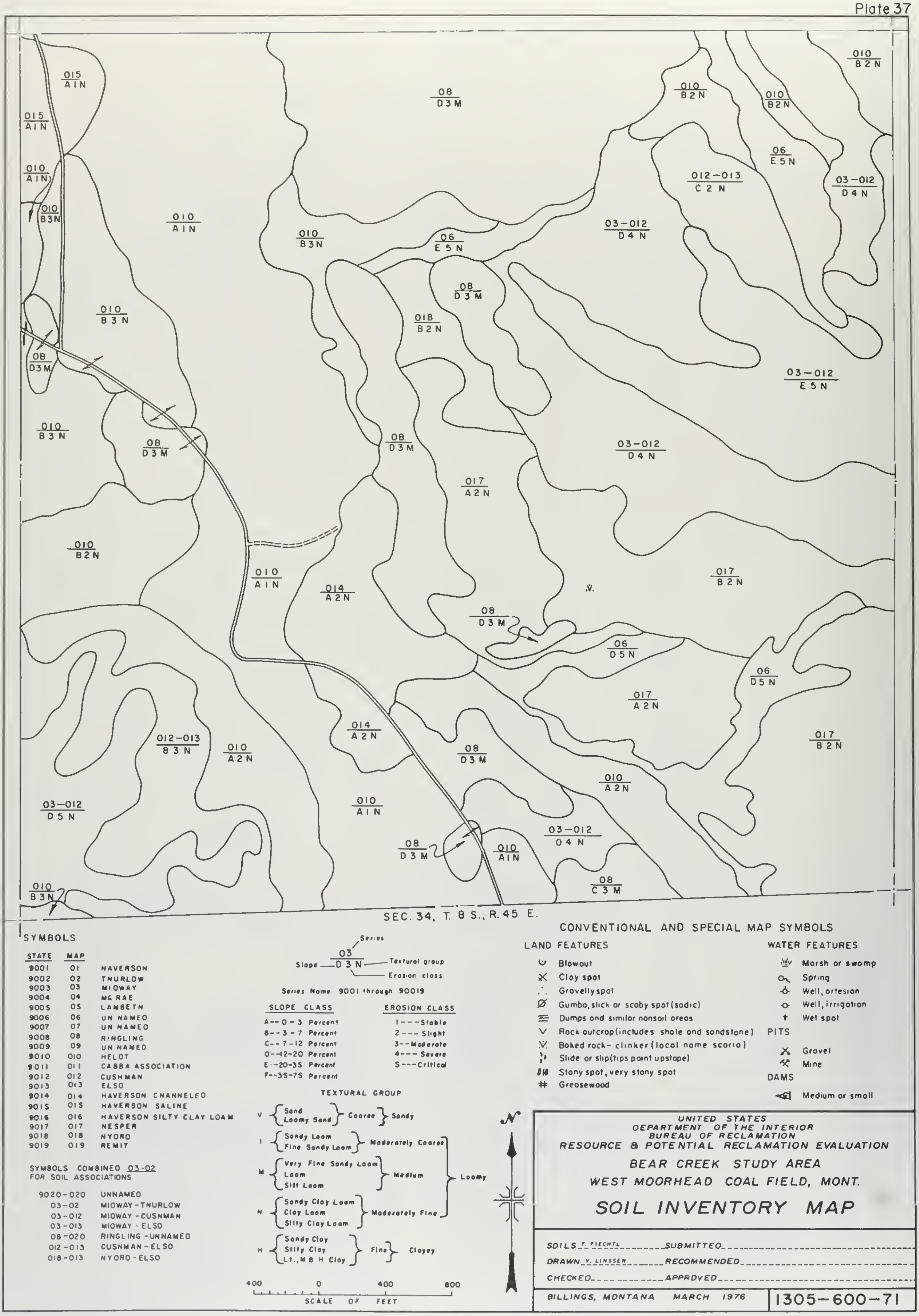
M 7

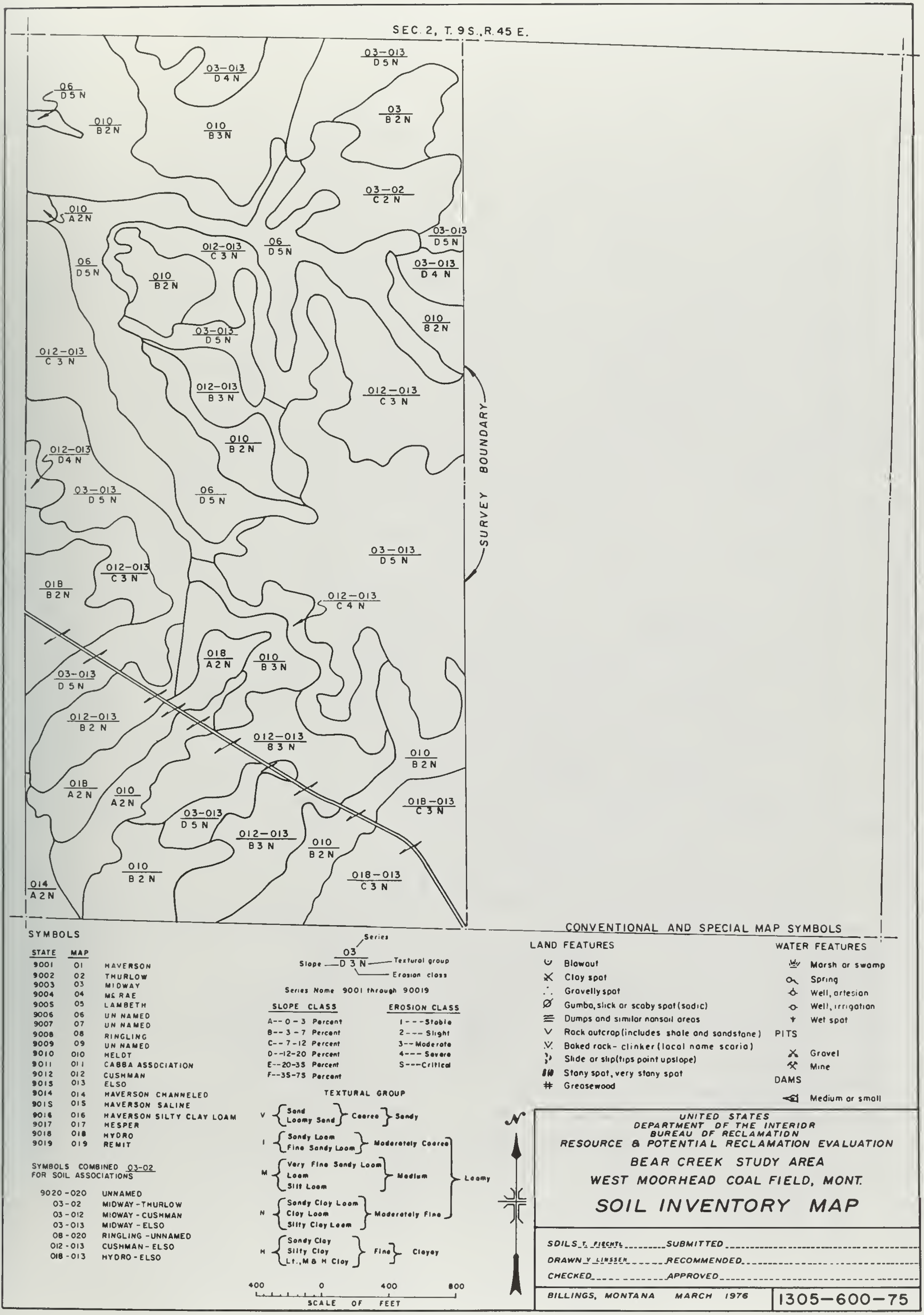
H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.18	.055	5.66	.230	0.47	0.49	.37	0.75	6.35	22.4	0.6	.002
	2	1.24	.075	4.92	.220	0.43	0.49	.38	0.54	7.08	2.4	0.6	.002
1	3	1.23	.060	4.84	.200	0.44	0.44	.33	0.51	7.15	3.0	2.1	.001
	4	1.31	.069	5.18	.253	0.39	0.46	.46	0.57	7.38	1.8	2.0	.001
	5	1.28	.069	5.20	.258	0.41	0.47	.37	0.49	7.68	1.3	4.3	.000
	6	1.32	.076	5.15	.272	0.38	0.50	.37	0.60	7.85	1.8	3.0	.000
2	7	1.33	.091	5.20	.340	0.37	0.56	.43	0.78	8.30	1.9	8.7	.000
	8	1.31	.098	5.16	.362	0.38	0.56	.42	1.56	8.25	1.6	7.0	.000
	9	1.31	.104	4.64	.333	0.38	0.55	.43	2.27	8.05	0.8	7.5	.000
	10	1.38	.110	4.94	.330	0.35	0.55	.46	2.00	8.15	0.2	5.3	.000
	11	1.46	.105	4.91	.308	0.31	0.52	.40	2.94	7.75	0.3	8.0	.000
	12	1.53	.097	4.45	.263	0.28	0.47	.36	2.55	7.65	0.1	12.6	.000
	13	1.55	.116	4.90	.338	0.27	0.54	.41	3.13	7.40	0.0	9.0	.000
	14	1.59	.108	4.78	.290	0.25	0.53	.39	2.87	7.45	0.4	12.6	.000
	15	1.54	.101	4.75	.264	0.27	0.51	.40	2.50	7.50	0.2	16.0	.000
3	16	1.54	.083	4.32	.269	0.27	0.47	.35	2.27	7.45	0.3	21.0	.002

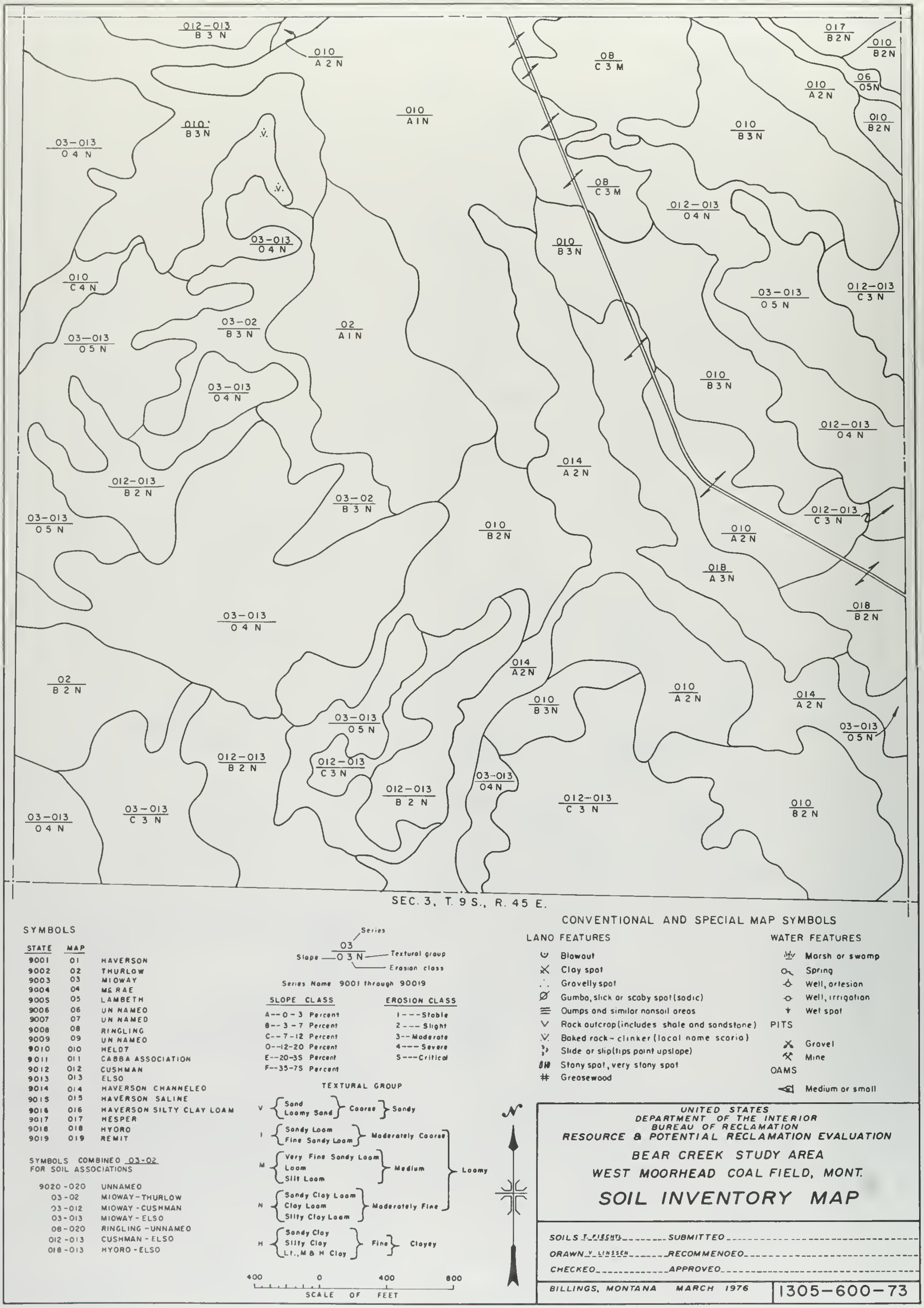
APPENDIX F

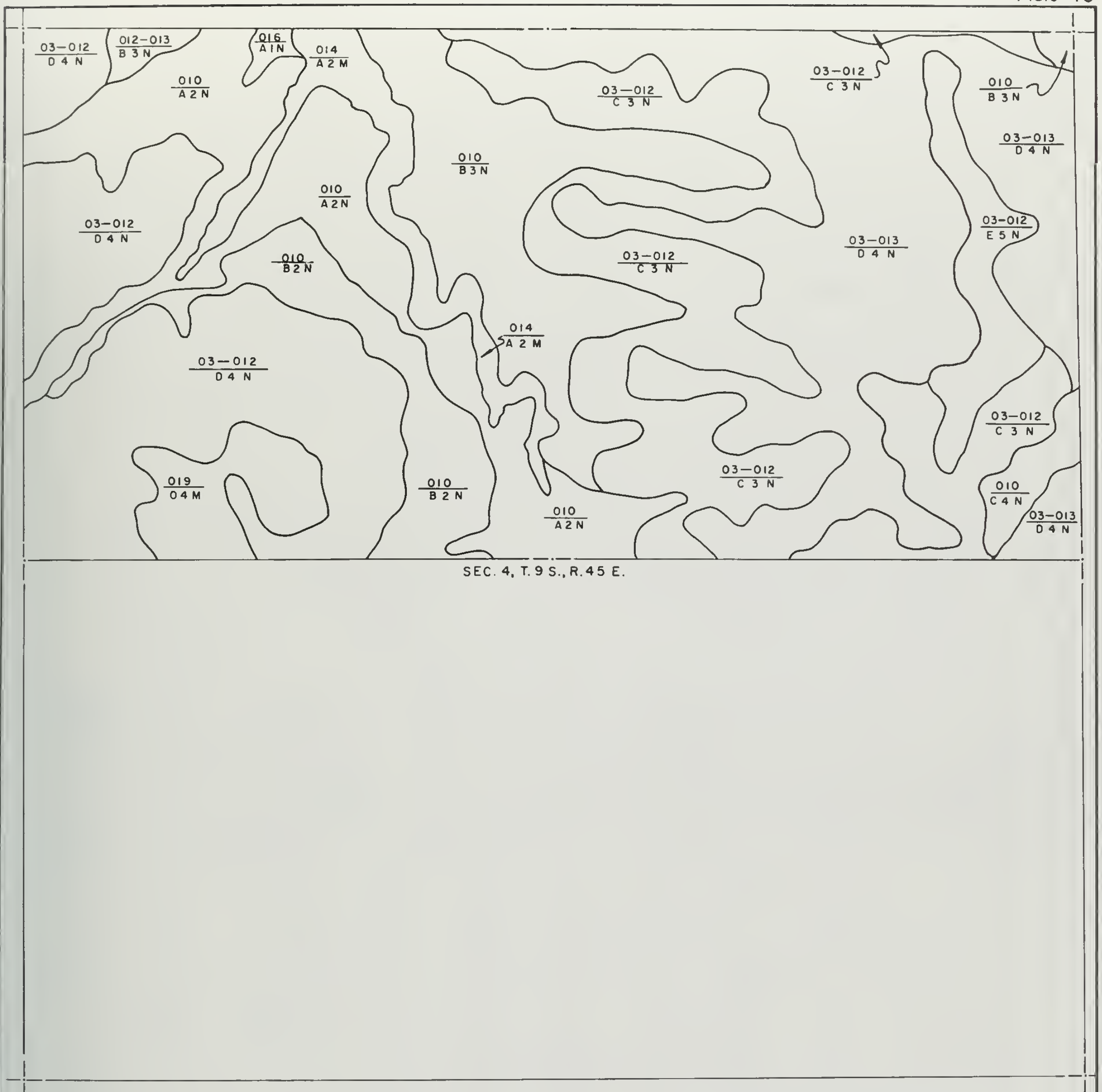
SOIL


03-012 / D4N
010 / A2N
015 / A1N
04 / A2M
014 / A2M
016 / A2N
018-013 / C2N
010 / A1N
016 / A1N
014 / A2M
010 / B3N
010 / A1N
010 / B3N
010 / A2N
03-013 / D4N
03-012 / D4N
03-012 / D4N
010 / A2N
012-013 / B3N
010 / B2N
012-013 / C3N
012-013 / B3N
03-013 / D4N
03-012 / D4N
03-012 / E5N
016 / A1N
06 / E5N
03-012 / D4N
03-012 / D5N
014 / A2M
03-013 / D4N
03-012 / D4N
010 / B3N
03-013 / D4N
010 / B3N
03-012 / C3N
SEC. 33, T. 8 S., R. 45 E.
SYMBOLS
STATE MAP
9001 01 HAVERSON
9002 02 THURLOW
9003 03 MIDWAY
9004 04 McRAE
9005 05 LAMBETH
9006 06 UN NAMED
9007 07 UN NAMED
9008 08 RINGLING
9009 09 UN NAMED
9010 010 HELDT
9011 011 CABBA ASSOCIATION
9012 012 CUSHMAN
9013 013 ELSO
9014 014 HAVERSON CHANNELED
9015 015 HAVERSON SALINE
9016 016 HAVERSON SILTY CLAY LOAM
9017 017 HESPER
9018 018 HYDRO
9019 019 REMIT
SYMBOLS COMBINED 03-02 FOR SOIL ASSOCIATIONS
9020-020 UNNAMED
03-02 MIDWAY-THURLOW
03-012 MIDWAY-CUSHMAN
03-013 MIDWAY-ELSO
08-020 RINGLING-UNNAMED
012-013 CUSHMAN-ELSO
018-013 HYDRO-ELSO
Series
03
Slope — D 3 N — Textural group
Erosion class
Series Name 9001 through 90019
SLOPE CLASS
A--0-3 Percent
B--3-7 Percent
C--7-12 Percent
D--12-20 Percent
E--20-35 Percent
F--35-75 Percent
EROSION CLASS
1---Stable
2---Slight
3---Moderate
4---Severe
5---Critical
TEXTURAL GROUP
V Sand, Loamy Sand — Coarse — Sandy
I Sandy Loam, Fine Sandy Loam — Moderately Coarse
M Very Fine Sandy Loam, Loam, Silt Loam — Medium — Loamy
N Sandy Clay Loam, Clay Loam, Silty Clay Loam — Moderately Fine
H Sandy Clay, Silty Clay, Lt., M & H Clay — Fine — Clayey
400 0 400 800
SCALE OF FEET
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
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
SOIL INVENTORY MAP
SOILS T. FIECHTL SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA MARCH 1976
1305-600-74


SEC. 34, T. 8 S., R. 45 E.
SYMBOLS
STATE MAP
9001 01 NAVERSON
9002 02 TNURLOW
9003 03 MIOWAY
9004 04 McRAE
9005 05 LAMBETN
9006 06 UN NAMEO
9007 07 UN NAMEO
9008 08 RINGLING
9009 09 UN NAMED
9010 010 HELOT
9011 011 CABBA ASSOCIATION
9012 012 CUSHMAN
9013 013 ELSO
9014 014 HAVERSON CNANNELEO
9015 015 HAVERSON SALINE
9016 016 HAVERSON SILTY CLAY LOAM
9017 017 NESPER
9018 018 NYORO
9019 019 REMIT
SYMBOLS COMBINEO 03-02 FOR SOIL ASSOCIATIONS
9020-020 UNNAMEO
03-02 MIOWAY - TNURLOW
03-012 MIOWAY - CUSNMAN
03-013 MIOWAY - ELSO
08-020 RINGLING - UNNAMEO
012-013 CUSNMAN - ELSO
018-013 NYORO - ELSO
Series
03
Slope — D 3 N — Textural group — Erosion class
Series Nome 9001 through 90019
SLOPE CLASS
A--0-3 Percent
B--3-7 Percent
C--7-12 Percent
D--12-20 Percent
E--20-35 Percent
F--35-75 Percent
EROSION CLASS
1---Stable
2---Slight
3--Moderate
4---Severe
5---Critical
TEXTURAL GROUP
V { Sond, Loomy Sand } Cooree } Sandy
I { Sandy Loom, Fine Sandy Loom } Moderately Cooree
M { Very Fine Sandy Loom, Loom, Silt Loom } Medium
N { Sandy Cloy Loom, Cloy Loom, Silty Clay Loam } Moderately Fine
Loomy
H { Sandy Cloy, Silty Cloy, Lt., M & H Cloy } Fine } Cloyey
400 0 400 800
SCALE OF FEET
CONVENTIONAL AND SPECIAL MAP SYMBOLS
LAND FEATURES
Blowout
Cloy spot
Grovelly spot
Gumbo, slick or scoby spot (sodic)
Dumps ond similor nonsoil oreos
Rock outcrop (includes shole ond sondstone)
Boked rock - clinker (locol nome scorio)
Slide or slip (tips point upslope)
Stony spot, very stony spot
Greosewood
WATER FEATURES
Morsh or swomp
Spring
Well, artesion
Well, irrigotion
Wet spot
PITS
Grovel
Mine
DAMS
Medium or smoll
N
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
SOIL INVENTORY MAP
SOILS T. FIECHTL SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA MARCH 1976
1305-600-71


SEC. 2, T. 9 S., R. 45 E.
03-013 D5N
03-013 D4N
06 D5N
010 B2N
010 B3N
03 B2N
03-02 C2N
010 A2N
03-013 D5N
012-013 C3N
06 D5N
06 D5N
010 B2N
03-013 D4N
010 B2N
03-013 D5N
012-013 C3N
012-013 B3N
012-013 C3N
010 B2N
012-013 D4N
03-013 D5N
06 D5N
SURVEY BOUNDARY
03-013 D5N
012-013 C3N
018 B2N
012-013 C4N
018 A2N
010 B3N
03-013 D5N
012-013 B2N
012-013 B3N
010 B2N
018 A2N
010 A2N
018-013 C3N
03-013 D5N
012-013 B3N
010 B2N
010 B2N
018-013 C3N
014 A2N
SYMBOLS
STATE MAP
9001 01 HAVERSON
9002 02 THURLOW
9003 03 MIDWAY
9004 04 McRAE
9005 05 LAMBETH
9006 06 UN NAMED
9007 07 UN NAMED
9008 08 RINGLING
9009 09 UN NAMED
9010 010 HELDT
9011 011 CABBA ASSOCIATION
9012 012 CUSHMAN
9015 013 ELSO
9014 014 HAVERSON CHANNELED
9015 015 HAVERSON SALINE
9016 016 HAVERSON SILTY CLAY LOAM
9017 017 HESPER
9018 018 HYDRO
9019 019 REMIT
SYMBOLS COMBINED 03-02 FOR SOIL ASSOCIATIONS
9020-020 UNNAMED
03-02 MIDWAY-THURLOW
03-012 MIDWAY-CUSHMAN
03-013 MIDWAY-ELSO
08-020 RINGLING-UNNAMED
012-013 CUSHMAN-ELSO
018-013 HYDRO-ELSO
Series
03
Slope D 3 N Textural group
Erosion class
Series Name 9001 through 90019
SLOPE CLASS
A-- 0-3 Percent
B-- 3-7 Percent
C-- 7-12 Percent
D--12-20 Percent
E--20-35 Percent
F--35-75 Percent
EROSION CLASS
1---Stable
2---Slight
3--Moderate
4---Severe
5---Critical
TEXTURAL GROUP
V Sand, Loamy Sand - Coarse - Sandy
I Sandy Loam, Fine Sandy Loam - Moderately Coarse
M Very Fine Sandy Loam, Loam, Silt Loam - Medium
N Sandy Clay Loam, Clay Loam, Silty Clay Loam - Moderately Fine
H Sandy Clay, Silty Clay, Lt., M & H Clay - Fine - Clayey
Loamy
400 0 400 800
SCALE OF FEET
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
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
SOIL INVENTORY MAP
SOILS T. FIECHTL SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA MARCH 1976
1305-600-75


012-013 / B 3 N
010 / A 2 N
08 / C 3 M
017 / B2N
010 / B2N
010 / A2N
06 / 05N
010 / B2N
010 / A I N
010 / B 3 N
03-013 / 0 4 N
010 / B3N
08 / C 3 M
012-013 / 0 4 N
03-013 / 0 4 N
010 / B3N
010 / C 4 N
03-013 / 0 5 N
012-013 / C 3 N
03-02 / B 3 N
02 / A I N
03-013 / 0 5 N
010 / B 3 N
03-013 / 0 4 N
012-013 / 0 4 N
012-013 / B 2 N
014 / A 2 N
03-02 / B 3 N
03-013 / 0 5 N
010 / B 2 N
012-013 / C 3 N
010 / A 2 N
018 / A 3 N
018 / B2N
03-013 / 0 4 N
014 / A2N
02 / B 2 N
010 / B 3N
010 / A 2 N
014 / A 2 N
03-013 / 0 5 N
03-013 / 05N
012-013 / B 2 N
012-013 / C 3 N
03-013 / 04N
012-013 / B 2 N
012-013 / C 3 N
010 / 82 N
03-013 / 0 4 N
03-013 / C 3 N
SEC. 3, T. 9 S., R. 45 E.
SYMBOLS
STATE MAP
9001 01 HAVERSON
9002 02 THURLOW
9003 03 MIOWAY
9004 04 MC RAE
9005 05 LAMBETH
9006 06 UN NAMEO
9007 07 UN NAMED
9008 08 RINGLING
9009 09 UN NAMEO
9010 010 HELD7
9011 011 CABBA ASSOCIATION
9012 012 CUSHMAN
9013 013 ELSO
9014 014 HAVERSON CHANNELEO
9015 015 HAVERSON SALINE
9016 016 HAVERSON SILTY CLAY LOAM
9017 017 HESPER
9018 018 HYORO
9019 019 REMIT
SYMBOLS COMBINEO 03-02 FOR SOIL ASSOCIATIONS
9020-020 UNNAMEO
03-02 MIOWAY-THURLOW
03-012 MIOWAY-CUSHMAN
03-013 MIOWAY-ELSO
08-020 RINGLING-UNNAMEO
012-013 CUSHMAN-ELSO
018-013 HYORO-ELSO
Series
03
Slope — 0 3 N — Textural group
Erosion class
Series Nome 9001 through 90019
SLOPE CLASS
A--0-3 Percent
B--3-7 Percent
C--7-12 Percent
O--12-20 Percent
E--20-35 Percent
F--35-75 Percent
EROSION CLASS
1---Stable
2---Slight
3--Moderate
4---Severe
5---Critical
TEXTURAL GROUP
V Sand, Loamy Sand — Coarse — Sandy
I Sandy Loam, Fine Sandy Loam — Moderately Coarse
M Very Fine Sandy Loam, Loam, Silt Loam — Medium
N Sandy Clay Loam, Clay Loam, Silty Clay Loam — Moderately Fine
Loamy
H Sandy Clay, Silty Clay, Lt., M & H Clay — Fine — Clayey
400 0 400 800
SCALE OF FEET
CONVENTIONAL AND SPECIAL MAP SYMBOLS
LANO FEATURES
Blowout
Clay spot
Gravelly spot
Gumbo, slick or scaby spot (sodic)
Oumps 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
N
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.
SOIL INVENTORY MAP
SOILS T. FIECHTL SUBMITTEO
ORAWN V. LINSSEN RECOMMENOEO
CHECKEO APPROVEO
BILLINGS, MONTANA MARCH 1976
1305-600-73



SYMBOLS

STATE	MAP	
9001	01	HAVERSON
9002	02	THURLOW
9003	03	MIDWAY
9004	04	McRAE
9005	05	LAMBETH
9006	06	UN NAMED
9007	07	UN NAMED
9008	08	RINGLING
9009	09	UN NAMED
9010	010	HELDT
9011	011	CABBA ASSOCIATION
9012	012	CUSHMAN
9013	013	ELSO
9014	014	HAVERSON CHANNELED
9015	015	HAVERSON SALINE
9016	016	HAVERSON SILTY CLAY LOAM
9017	017	HESPER
9018	018	HYDRO
9019	019	REMIT

SYMBOLS COMBINED 03-02
FOR SOIL ASSOCIATIONS

9020-020	UNNAMED
03-02	MIDWAY-THURLOW
03-012	MIDWAY-CUSHMAN
03-013	MIDWAY-ELSO
08-020	RINGLING-UNNAMED
012-013	CUSHMAN-ELSO
018-013	HYDRO-ELSO

Series: 03 / Slope: 0, Textural group: 3, Erosion class: N — "03 / 0 3 N"

Series Name 9001 through 90019

SLOPE CLASS	EROSION CLASS
A--0-3 Percent	1---Stable
B--3-7 Percent	2---Slight
C--7-12 Percent	3--Moderate
D--12-20 Percent	4---Severe
E--20-35 Percent	5---Critical
F--35-75 Percent	

TEXTURAL GROUP

- V {Sand, Loamy Sand} Coarse } Sandy
- I {Sandy Loam, Fine Sandy Loam} Moderately Coarse } Loamy
- M {Very Fine Sandy Loam, Loam, Silt Loam} Medium } Loamy
- N {Sandy Clay Loam, Clay Loam, Silty Clay Loam} Moderately Fine } Loamy
- H {Sandy Clay, Silty Clay, Lt., M & H Clay} Fine } Clayey

400 0 400 800
SCALE OF FEET

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

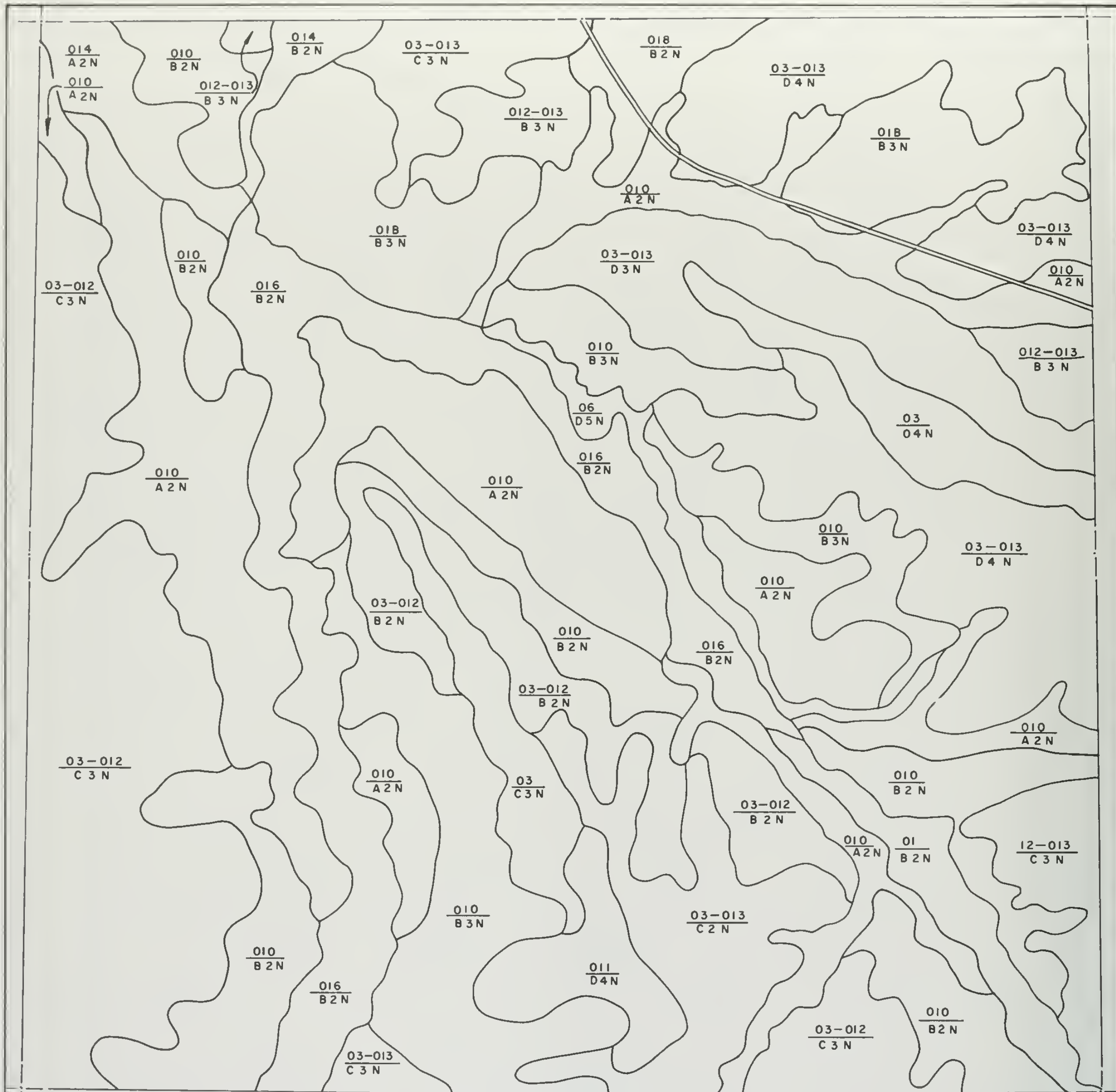
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

SOIL INVENTORY MAP

SOILS T. FIECHTL SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH 1976 1305-600-72



SEC. 11, T. 9 S., R. 45 E.

SYMBOLS

STATE	MAP	
9001	01	HAVERSON
9002	02	THURLOW
9003	03	MIDWAY
9004	04	McRAE
9005	05	LAMBETH
9006	06	UNNAMED
9007	07	UNNAMED
9008	08	RINGLING
9009	09	UNNAMED
9010	010	HELOT
9011	011	CABBA ASSOCIATION
9012	012	CUSHMAN
9013	013	ELSO
9014	014	HAVERSON CHANNELED
9015	015	HAVERSON SALINE
9016	016	HAVERSON SILTY CLAY LOAM
9017	017	HESPER
9018	018	HYDRO
9019	019	REMIT

SYMBOLS COMBINED 03-02
FOR SOIL ASSOCIATIONS

9020-020	UNNAMED
03-02	MIDWAY-THURLOW
03-012	MIDWAY-CUSHMAN
03-013	MIDWAY-ELSO
08-020	RINGLING-UNNAMED
012-013	CUSHMAN-ELSO
018-013	HYDRO-ELSO

Series: 03
Slope — D 3 N — Textural group; Erosion class

Series Name 9001 through 90019

SLOPE CLASS	EROSION CLASS
A--0-3 Percent	1---Stable
B--3-7 Percent	2---Slight
C--7-12 Percent	3--Moderate
D--12-20 Percent	4---Severe
E--20-35 Percent	5---Critical
F--35-75 Percent	

TEXTURAL GROUP

- V {Sand, Loamy Sand} Coarse } Sandy
- I {Sandy Loam, Fine Sandy Loam} Moderately Coarse } Loamy
- M {Very Fine Sandy Loam, Loam, Silt Loam} Medium } Loamy
- N {Sandy Clay Loam, Clay Loam, Silty Clay Loam} Moderately Fine } Loamy
- H {Sandy Clay, Silty Clay, Lt, M & H Clay} Fine } Clayey

400 0 400 800
SCALE OF FEET

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

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEAR CREEK STUDY AREA
WEST MOORHEAD COAL FIELD, MONT.

SOIL INVENTORY MAP

SOILS T. FIECHTL SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONTANA MARCH 1976 | 1305-600-76

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Table 20

Study Area: Bear Creek
Location. Sec. 34 Twp. 8 S. Range 45 E.
800' E. and 400' S. of NW Corner; Profile #24
Climate. Continental, Semiarid
Land Use: Improved hay meadow

Relief: Subnormal
Elevation: 3800
Slope: Aspect: N.
Vegetation: Alfalfa, smooth brome, fescue, other grasses
Erosion: Slight

Stoniness: None
Drainage: Surface - Well drained
Ground Water: 66"
Land Form: Low alluvial terrace

Parent Material: Fort Union Formation
Soil Series: Heldt-9010
Soil Classification:
Profile Description By: T. Fiechtl Date 7/75

LAB NO.	DEPTH (Cm.)	PROFILE DESCRIPTION
	0-7.5	AB--Pale brown (10YR 6/2) clay loam, dark grayish brown (10YR 4/2) moist; weak coarse angular blocky structure separates to moderate medium angular blocky structure; hard, friable, slightly sticky, slightly plastic; roots plentiful, fine; strongly calcareous; abrupt boundary.
T-303	7.5-25	B_2--Grayish brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium prisms breaking to moderate fine angular blocks; hard, friable, slightly sticky, slightly plastic; strongly calcareous; gradual boundary.
4	25-37.5	B_{3ca}--Brown (10YR 5/3) clay loam, brown to dark brown (10YR 4/3) moist; moderate coarse prisms separates to moderate medium angular blocks; slightly hard, friable, slightly sticky, slightly plastic; roots plentiful, fine; strongly calcareous; gradual boundary; many fine lime nettings.
5	37.5-75	C_{1ca}--Very pale brown (10YR 7/3) clay loam, brown (10YR 5/3) moist; weak coarse prisms separates to moderate coarse blocky structure; slightly hard, friable, slightly sticky, slightly plastic; roots plentiful, fine; strongly calcareous; gradual boundary.
6	75-105	C_{2ca}--Pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; weak coarse blocks separating to weak medium blocky structure; hard, friable, slightly sticky, slightly plastic; strongly calcareous; roots few, fine; gradual boundary.
7	105-167	C_{3ca}--Very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; weak coarse blocks separating to weak medium blocks; hard, friable, slightly sticky, slightly plastic; strongly calcareous, gradual boundary.
8	167-244	
309	244-305	

LABORATORY DESCRIPTION

DETERMINATION		DATA						
LABORATORY NUMBER								
DEPTH	(cm)	0-25	25-37.5	37.5-75	75-105	105-167	167-244	244-305
PARTICLE SIZE ANALYSIS	(percent)							
Very Coarse Sand	(2.0-1.0mm)						0.7	12.3
Coarse Sand	(1.0-0.5mm)						2.1	8.1
Medium Sand	(0.5-0.25mm)						3.9	5.0
Fine Sand	(0.25-0.10mm)						33.9	23.0
Very Fine Sand	(0.10-0.05mm)						19.9	13.5
Total Sand	(2.0-0.05mm)	22.7	17.0	17.2	20.3	25.7	60.5	61.9
Silt	(0.05-0.002mm)	47.1	48.0	47.4	48.9	48.2	24.4	22.9
Clay	(< 0.002 mm)	30.2	35.0	35.4	30.8	26.1	15.1	15.2
TEXTURAL CLASS (LAB)		CL	SICL	SICL	CL	L	FSL	FSL
BULK DENSITY	(g/cm^3)							
HYDRAULIC CONDUCTIVITY	(cm/hr)							
6th hr		1.87	1.11	0.46	0.43	0.51	1.42	0.66
24th hr		1.32	1.02	0.41	0.23	0.45	1.22	0.56
SETTLING VOLUME	(ml)	24	23	23	31	30	22	25
MOISTURE RETENTION	(percent)							
1/10 bar		30.4	33.4	30.2	31.5	28.4	19.6	21.3
1/3 bar		22.1	26.2	24.4	25.2	21.7	15.7	14.9
15 bar		11.8	14.6	16.1	15.6	11.9	7.3	8.2
SOIL REACTION-pH								
Paste								
1:5 H_2O		8.1	8.7	9.0	9.3	9.1	9.0	9.1
1:2 0.01 M $CaCl_2$		7.1	8.0	8.8	8.9	8.6	8.9	9.0
ORGANIC CARBON	(percent)							
AVAILABLE PHOSPHORUS	(ppm)							
$CaCO_3$ EQUIVALENT	(percent)							
GYPSUM REQUIREMENT	(me/100g)	+0.5	-6.5	-8.0	-5.9	-3.0	-3.0	-2.8
SATURATION EXTRACT								
Saturation Percentage		48.1	53.7	54.6	57.1	50.6	35.3	31.9
EC_e @ 25°C	(mmhos/cm)	1.9	12.	16.	16.	14.	11.	12.
Ca^{++}	(me/l)	7.14	21.96	21.96	21.96	20.86	21.41	22.50
Mg^{++}	(me/l)	7.96	80.51	101.32	111.27	86.84	62.42	68.75
Na^+	(me/l)	9.39	96.52	136.09	138.26	117.39	89.56	100.00
K^+	(me/l)	0.84	0.47	0.58	0.75	0.91	0.99	1.11
CO_3^-	(me/l)	0.00	0.16	0.00	0.00	0.32	0.00	0.00
HCO_3^-	(me/l)	5.60	2.96	1.64	1.84	1.36	1.36	1.72
Cl^-	(me/l)	0.04	1.24	2.42	2.32	2.20	1.68	1.84
SO_4^-	(me/l)	16.50	193.00	252.00	257.00	216.00	165.00	184.00
NO_3^-	(me/l)	0.04	0.06	0.06	0.06	0.05	0.03	0.04
SAR	(	3.4	13.	17.	17.	16.	14.	15.
Na	(me/100g)	0.45	5.18	7.43	7.89	5.94	3.16	3.19
Ca+Mg	(me/100g)	0.72	5.50	6.73	7.60	5.45	2.96	2.91
1:5 EXTRACT								
EC_5 @ 25°C	(mmhos/cm)							
Ca+Mg	(me/100g)							
EXCHANGEABLE SODIUM	(percent)	2.1	8.5	11.	9.6	12.	8.8	10.
ACIDITY								
IN KCl exchange acidity								
Total	(me/100g)							
Al^{+++}	(me/100g)							
CATION EXCHANGE CAPACITY	(me/100g)	29.0	23.9	21.3	22.6	17.6	11.2	13.0
NaOAc@pH 8.2								
BORON	(ppm)	.8	1.2	1.0	1.5	1.0	.8	.9

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bear Creek
Location. Sec. 3 Twp. 9 S. Range 45 E.
2600' S. and 50' W. of N½ corner; Profile #40
Climate: Continental, Semiarid
Land Use: Range

Relief: Normal
Elevation: 3820
Slope: Aspect: SW
Vegetation: Native grass, sage, and forbes
Erosion: Slight

Stoniness: None
Drainage: Surface - Well drained
Ground Water: --
Land Form: Colluvial slopes

Parent Material: Fort Union Formation
Soil Series: Thurlow-9002
Soil Classification:
Profile Description By: T. Fiechtl Date 8/75

LAB NO.	DEPTH (Cm.)	PROFILE DESCRIPTION
	0-5	A_1--Pale brown (10YR 6/3) loam; yellowish brown (10YR 5/4) moist; moderate coarse platy separates to moderate medium crumb structure; slightly hard, friable, nonsticky, nonplastic; noncalcareoua; roots plentiful, fine; abrupt boundary.
T-589	5-12.5	B_1--Pale brown (10YR 6/3) clay loam, grayish brown (10YR 5/2) moist; moderate medium prisms breaking to moderate medium blocka; slightly hard, friable; slightly sticky, slightly plastic, non-calcareous; gradual boundary.
	12.5-32.5	B_{2t}--Grayish brown (10YR 5/2) clay loam, dark grayish brown (10YR 4/2) moist; strong medium prisms separatea to moderate medium angular blocky structure; hard, friable, slightly sticky, slightly plastic; clay films, common, thin, ped face; roots plentiful, fine; noncalcareous; clear boundary.
T-590	32.5-45	B_{3ca}--Pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; moderate medium prisms breaking to moderate medium blocky structure; hard, friable, slightly aticky, slightly plastic; roota plentiful, fine; strongly calcareous; gradual boundary.
	45-75	C_{1ca}--Very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; moderate coarse prisms separating to moderate medium blocky structure; hard, friable, slightly sticky, slightly plastic; roots plentiful, fine; strongly calcareous.
T-591	75-135	IIC_{2ca}--Brownish yellow (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; weak coarse prisms separates weak medium blocky structure; hard, friable; roots few, fine; strongly calcareous; abrupt horizon, old buried horizon with lime nettings plentiful, coarse.
92	135-182	$IIIC_{3ca}$--Brownish yellow (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; weak coarse blocky structure separating to weak medium blocks; slightly hard, friable, very sticky, slightly plastic; violently calcareous.
93	182-243	
94	243-305	

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER							
DEPTH	(cm)	0-32.5	32.5-75	75-135	135-182	182-243	243-305
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)	14.7	10.0	15.0	26.4	19.1	25.9
Silt	(0.05-0.002 mm)	49.7	55.6	51.8	47.2	51.7	46.4
Clay	(<0.002 mm)	35.6	34.4	33.2	26.4	29.2	27.7
TEXTURAL CLASS (LAB)		SICL	SICL	SICL	L	SICL	CL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(cm/hr)						
6th hr		2.74	1.02	0.51	.96	1.32	1.42
24th hr		2.34	1.02	0.51	1.02	1.32	1.32
SETTLING VOLUME	(ml)	24	24	24	21	22	23
MOISTURE RETENTION	(percent)						
1/10 bar		31.3	33.6	34.2	30.5	32.5	31.0
1/3 bar		25.0	27.2	25.6	20.5	24.1	22.0
15 bar		14.4	13.4	14.1	10.6	12.8	11.6
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.9	8.7	9.2	9.2	9.0	9.2
1:2 0.01 M $CaCl_2$		7.3	8.1	8.3	8.3	8.5	8.4
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-.5	+0.5	-0.4	+0.6	-5.4	
SATURATION EXTRACT							
Saturation Percentage		46.1	47.1	53.1	47.4	57.5	51.5
EC_e @ 25°C	(mmhos/cm)	0.68	0.78	1.8	8.4	10.	8.5
Ca^{++}	(me/l)	4.06	2.09	1.65	20.86	21.41	15.37
Mg^{++}	(me/l)	2.44	3.17	7.69	73.27	85.94	66.04
Na^+	(me/l)	0.76	3.32	12.00	47.83	58.70	53.04
K^+	(me/l)	0.35	0.10	0.14	0.43	0.54	0.56
CO_3^-	(me/l)	0.00	0.00	0.88	0.00	0.08	0.00
HCO_3^-	(me/l)	4.40	4.40	3.12	1.68	1.48	1.60
Cl^-	(me/l)	0.04	1.00	1.56	1.20	1.62	1.98
SO_4^-	(me/l)	232	1.80	13.92	135.00	158.00	121.00
NO_3^-	(me/l)	0.03	0.02	0.19	0.23	0.97	2.98
SAR		0.4	2.0	5.6	7.0	8.0	8.3
Na	(me/100g)	0.04	0.16	0.64	2.27	3.38	2.73
Ca+Mg	(me/100g)	0.30	0.25	0.50	4.46	6.17	4.19
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)						
Ca+Mg	(me/100g)						
EXCHANGEABLE SODIUM	(percent)	0.2	1.1	2.9	3.0	3.6	3.9
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)						
NaOAc@pH 8.2		37.7	38.4	35.5	31.7	32.3	31.7
BORON	(ppm)	.4	.4	.6	.6	.8	.4

Table 21

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Table 22

Study Area: Bear Creek	Relief: Normal	Stoniness: None	Parent Material: Fort Union Formation
Location. Sec. 4 Twp. 9 S. Range 45 E.	Elevation: 3860		Soil Series: Cushman-9012
700' E. and 500' S. of N¼ corner; Profile #7	Slope: Aspect: SW	Drainage: Surface - Excessive	Soil Classification:
Climate: Continental, Semiarid	Vegetation: Native grasses, sage, sedges, forbes	Ground Water: --	
Land Use: Range	Erosion: Moderate	Land Form: Residual upland slopes	Profile Description By: T. Fiechtl Date: 8/75

LAB NO.	DEPTH (Cm.)	PROFILE DESCRIPTION
T-139	0-2.5	A_1--Very pale brown (10YR 7/3) loam, pale brown (10YR 6/3) moist; moderately coarse platy structure breaking to a weak fine angular blocky; slightly hard, soft, slightly sticky, slightly plastic; roots fine, plentiful; slightly calcareous; abrupt boundary.
	2.5-15	AB--Light brownish gray (10YR 6/3) clay loam, grayish brown (10YR 5/3) moist; weak coarse prisms separating to moderate medium angular blocks; hard, friable, slightly sticky, plastic; roots plentiful, fine; slightly calcareous; gradual boundary.
140	15-30	B_2--Light brownish gray (10YR 6/3) clay loam, grayish brown (10YR 5/3) moist; moderate coarse prisms breaking to moderate angular blocks; hard, friable, slightly sticky, plastic; roots plentiful, fine; strongly calcareous; abrupt boundary.
141	30-75	B_3--Light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; moderate coarse prisms separating to moderate coarse angular blocks; hard, friable, slightly sticky, plastic; roots plentiful, fine; strongly calcareous; gradual boundary.
142	75-121	C_1--Light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4) moist; weak coarse prisms breaking to weak coarse blocks; slightly hard, friable, sticky, plastic; roots few, fine; strongly calcareous; gradual boundary.
143	121-152	CR_1--Brownish yellow (10YR 6/6) clay loam, yellowish brown (10YR 5/6) moist; clay loam sandy shale, stratified; strongly calcareous; abrupt boundary.
144	152-182	
145	182-228	
146	228-274	

LABORATORY DESCRIPTION

DETERMINATION		DATA							
LABORATORY NUMBER									
DEPTH	(cm)	0-15	15-30	30-75	75-121	121-152	152-182	182-228	228-274
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)	21.5	17.9	10.5	5.9		0.6	7.5	1.5
Silt	(0.05-0.002 mm)	49.2	53.4	55.7	56.9		45.2	53.1	63.0
Clay	(<0.002 mm)	29.3	28.7	33.8	37.2		54.2	39.4	35.5
TEXTURAL CLASS (LAB)		CL	SICL	SICL	SICL		SIC	SICL	SICL
BULK DENSITY	(g/cm^3)								
HYDRAULIC CONDUCTIVITY	(cm/hr)								
6th hr		4.37	0.48	0.28	1.12	0.51	0.00	2.54	0.81
24th hr									
SETTLING VOLUME	(ml)	23	27	31	26	34	37	28	36
MOISTURE RETENTION	(percent)								
1/10 bar		29.7	29.4	32.6	32.3	37.8	42.6	39.5	36.2
1/3 bar		22.2	21.5	25.7	25.7	31.6	36.2	33.6	30.8
15 bar		10.2	10.3	13.2	16.8	19.8	21.2	19.5	18.8
SOIL REACTION-pH									
Paste									
1:5 H_2O		8.4	9.1	8.7	8.7	8.4	8.2	5.8	8.2
1:2 0.01 M $CaCl_2$									
ORGANIC CARBON	(percent)								
AVAILABLE PHOSPHORUS	(ppm)								
$CaCO_3$ EQUIVALENT	(percent)								
GYPSUM REQUIREMENT	(me/100g)	-0.4	+1.3	-0.4	-5.5	-8.4	-6.3	-12.	-5.8
SATURATION EXTRACT									
Saturation Percentage		45.7	45.3	56.5	56.1	73.1	85.2	61.5	92.8
EC_e @ 25°C	(mmhos/cm)	0.68	0.90	10.	17.	17.	16.	21.	13.
Ca^{++}	(me/l)	2.69	1.59	22.50	21.96	21.41	21.41	23.05	21.41
Mg^{++}	(me/l)	1.36	1.27	51.56	86.84	92.27	84.13	126.64	61.51
Na^+	(me/l)	3.86	7.35	99.13	160.43	156.96	154.35	203.48	119.57
K^+	(me/l)	0.27	0.24	0.60	0.78	0.92	0.93	1.08	0.89
CO_3^-	(me/l)	0.16	0.00	0.00	0.16	0.00	0.00	0.00	0.00
HCO_3^-	(me/l)	5.88	5.60	2.52	1.24	1.40	1.44	1.72	2.52
Cl^-	(me/l)	0.06	1.02	4.08	4.18	4.30	3.42	5.88	2.80
SO_4^-	(me/l)	0.66	2.63	139.00	258.00	262.00	250.00	342.00	197.00
NO_3^-	(me/l)	0.04	0.03	0.05	0.42	0.35	0.44	2.42	1.37
SAR		2.7	6.1	16.	22.	21.	21.	24.	19.
Na	(me/100g)	0.18	0.33	5.60	9.00	11.47	13.15	12.51	11.10
Ca+Mg	(me/100g)	0.18	0.13	4.18	6.1	8.31	8.99	9.21	7.7
1:5 EXTRACT									
EC_5 @ 25°C	(mmhos/cm)								
Ca+Mg	(me/100g)								
EXCHANGEABLE SODIUM	(percent)	1.9	4.4	7.0	22.	20.	9.8	23.	10.
ACIDITY									
1N KCl exchange acidity									
Total	(me/100g)								
Al^{+++}	(me/100g)								
CATION EXCHANGE CAPACITY	(me/100g)	25.5	24.3	26.4	24.1	27.8	37.8	35.2	27.7
NaOAc@pH 8.2									
BORON	(ppm)	.4	.4	.4	.4	.2	.2	.4	.4

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Table 23

Study Area: Bear Creek
Location. Sec. 3 Twp. 9 S. Range 45 E.
900'N. and 550' W. of SW corner; Profile #19
Climate. Continental, Semiarid
Land Use: Range

Relief: Normal
Elevation: 3860
Slope: Aspect: NW
Vegetation: Native grass, sage, sedge, forbes.
Erosion: Critical

Stoniness: None
Drainage: Surface - Well drained
Ground Water: --
Land Form: Residual upland slopes

Parent Material: Fort Union Formation
Soil Series: Midway-9003
Soil Classification:
Profile Description By: T. Fiechtl Date: 8/75

LAB NO.	DEPTH (Cm.)	PROFILE DESCRIPTION
T-506	0-45	AB--Pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; weak coarse blocky separates to moderate medium blocky; hard, friable, slightly sticky, slightly plastic; roots plentiful, fine; strongly calcareous; abrupt boundary.
507	45-105	C--Very pale brown (10YR 7/3) clay loam, pale brown (10YR 6/3) moist; moderate coarse blocky breaking to moderate medium blocks; slightly hard, friable, slightly sticky, slightly plastic; strongly calcareous; abrupt boundary.
	105 +	R--Sandstone, hard bedrock.

LABORATORY DESCRIPTION

DETERMINATION		DATA		
LABORATORY NUMBER				
DEPTH	(cm)	0-45	45-105	105+
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)	3.1	1.7	
Silt	(0.05-0.002 mm)	65.3	70.5	
Clay	(< 0.002 mm)	31.6	27.8	
TEXTURAL CLASS (LAB.)		SICL	SICL	
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(cm/hr)			
6th hr		1.42	0.66	
24th hr		1.52	0.76	
SETTLING VOLUME	(ml)	33	50	
MOISTURE RETENTION	(percent)			
1/10 bar		34.4	36.1	
1/3 bar		28.8	31.6	
15 bar		15.5	19.7	
SOIL REACTION-pH				
Paste				
1:5 H_2O		8.5	9.0	
1:2 0.01 M $CaCl_2$		8.1	8.8	
ORGANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
$CaCO_3$ EQUIVALENT	(percent)			
GYPSUM REQUIREMENT	(me/100g)	-5.1	-6.2	
SATURATION EXTRACT				
Saturation Percentage		52.0	73.1	
EC_e @ 25°C	(mmhos/cm)	7.1	12.	
Ca^{++}	(me/l)	23.88	22.50	
Mg^{++}	(me/l)	22.62	55.18	
Na^{+}	(me/l)	56.96	109.57	
K^{+}	(me/l)	0.38	0.72	
CO_3^{-}	(me/l)	0.00	0.00	
HCO_3^{-}	(me/l)	2.44	1.20	
Cl^{-}	(me/l)	1.26	3.08	
SO_4^{-}	(me/l)	94.5	178.00	
NO_3^{-}	(me/l)	0.02	0.04	
SAR		12.	18.	
Na	(me/100g)	2.96	8.01	
Ca+Mg	(me/100g)	2.42	5.67	
1:5 EXTRACT				
EC_5 @ 25°C	(mmhos/cm)			
Ca+Mg	(me/100g)			
EXCHANGEABLE SODIUM	(percent)	9.1	16.	
ACIDITY				
IN KCl exchange acidity				
Total	(me/100g)			
Al^{+++}	(me/100g)			
CATION EXCHANGE CAPACITY	(me/100g)	33.0	33.3	
NaOAc@pH 8.2				
BORON	(ppm)	.2	1.5	

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bear Creek
Location: Sec. 34 Twp 8 S. Range 45 E.
1650' S., 250' W. of N¼ corner; Profile #14
Climate: Continental, Semiarid
Land Use: Range

Relief: Normal
Elevation: 3850
Slope: Aspect: S.
Vegetation: Native grass, sedges, sage and forbes
Erosion: Slight

Staniness: None
Drainage: Surface - Well drained
Ground Water: --
Land Form: Upland colluvial slopes

Parent Material: Fort Union
Soil Series: Hydro-9018
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/75

LAB NO.	DEPTH (Cm.)	PROFILE DESCRIPTION
T-244	0-7.5	A12--Light gray (10YR 7/2), clay loam, brown (10YR 4/3), moist; weak very thick platy structure breaking to weak fine crumb; loose dry, loose moist; roots plentiful, fine; strongly calcareous; abrupt boundary.
T-244	7.5-15	B_{2t}--Brown (7.5YR 5/2) clay loam, dark brown (10YR 3/3), moist: strong medium columnar prisms separates to strong medium angular blocky structure; hard, firm, slightly sticky, plastic; many thin clay films on ped face; roots plentiful, fine; slightly calcareous; gradual boundary.
T-245	15-30.5	B_{3ca}--Pale brown (10YR 6/3) clay loam, yellowish brown (10YR 5/4) moist; moderate coarse prisms breaking to strong medium angular blocks; slightly hard, friable, slightly sticky, slightly plastic; roots plentiful, fine; strongly calcareous; gradual boundary.
T-246	30.5-76	C_{ca}--Pale yellow (10YR 4/3) clay loam, yellowish brown (10YR 5/4) moist; weak coarse prisms separating to moderate medium blocks; slightly hard, friable, slightly sticky, slightly plastic; roots plentiful, fine; strongly calcareous; gradual boundary.
T-247	76-122	C_{2ca}--Pale brown (10YR 6/3) clay loam, yellowish brown (10YR 5/4) moist; weak coarse blocky structure separating to moderate medium blocks; slightly hard, friable, slightly sticky, slightly plastic; strongly calcareous.
T-248	122-168	C_{3ca}--Pale brown (10YR 6/3) clay loam, yellowish brown (10YR 5/4) moist; weak coarse blocky structure breaking to weak medium blocks; strongly calcareous; gradual boundary.
T-249	168-213	
T-250	213-254	
T-251	254-290	

LABORATORY DESCRIPTION

DETERMINATION		DATA							
LABORATORY NUMBER									
DEPTH	(cm)	0-15	15-30.5	30.5-76	76-122	122-168	168-213	213-254	254-290
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)	24.7	19.3	21.7	13.1	125	12.9	11.1	13.6
Silt	(0.05-0.002 mm)	41.2	43.5	44.8	54.3	52.8	51.7	51.8	49.6
Clay	(< 0.002 mm)	34.1	37.2	33.5	32.6	34.7	35.4	37.1	36.8
TEXTURAL CLASS (LAB)		CL	SICL	CL	SICL	SICL	SICL	SICL	SICL
BULK DENSITY	(g/cm^3)								
HYDRAULIC CONDUCTIVITY	(cm/hr)								
6th hr		1.21	1.21	1.73	1.02	0.81	0.51	0.56	0.71
24th hr		1.17	1.42	1.82	1.12	0.96	0.61	0.61	0.76
SETTLING VOLUME	(ml)	23	23	24	25	28	30	29	30
MOISTURE RETENTION	(percent)								
1/10 bar		45.3	39.3	33.6	37.8	36.3	36.2	35.7	33.6
1/3 bar		25.1	28.1	23.9	27.5	27.7	26.9	27.6	26.0
15 bar		13.9	16.0	13.0	17.9	15.2	15.9	18.0	15.0
SOIL REACTION-pH									
Paste									
1:5 H_2O		7.6	8.8	8.8	8.9	9.0	8.8	8.9	8.9
1:2 0.01 M $CaCl_2$		7.3	8.7	8.7	8.8	8.8	8.5	8.5	8.6
ORGANIC CARBON	(percent)								
AVAILABLE PHOSPHORUS	(ppm)								
$CaCO_3$ EQUIVALENT	(percent)								
GYPSUM REQUIREMENT	(me/100g)	+1.7	-11.0	-9.8	-10.3	-10.0	-9.4	-10.1	-9.5
SATURATION EXTRACT									
Saturation Percentage		49.9	66.0	58.3	71.8	63.6	64.5	63.9	79.5
EC_e @ 25°C	(mmhos/cm)	4.1	15.	15.	12.	12.	12.	11.	9.1
Ca^{++}	(me/l)	6.64	22.78	22.78	20.86	21.13	21.41	20.86	20.58
Mg^{++}	(me/l)	18.09	107.20	100.86	86.84	81.87	78.70	69.20	51.11
Na^+	(me/l)	28.83	92.40	101.17	102.24	111.01	113.15	100.53	81.28
K^+	(me/l)	0.88	0.78	0.75	1.20	1.17	1.35	1.33	1.13
CO_3^-	(me/l)	0.00	0.00	0.00	0.24	0.00	0.08	0.00	0.00
HCO_3^-	(me/l)	8.44	2.20	1.24	1.12	1.12	1.40	1.24	0.88
Cl^-	(me/l)	0.72	0.08	0.08	0.40	0.70	0.60	0.60	0.46
SO_4^-	(me/l)	41.70	191.60	201.20	192.40	206.40	201.20	184.00	144.40
NO_3^-	(me/l)								
SAR		8.2	11.	13.	14.	15.	16.	15.	14.
Na	(me/100g)	1.44	6.10	5.90	7.34	7.06	7.30	6.42	6.46
Ca+Mg	(me/100g)	1.23	8.58	7.21	7.74	6.55	6.46	5.75	5.70
1:5 EXTRACT									
EC_5 @ 25°C	(mmhos/cm)	0.62	3.6	3.3	4.2	4.2	4.3	4.2	4.1
Ca+Mg	(me/100g)								
EXCHANGEABLE SODIUM	(percent)	5.8	9.6	8.1	11.	9.6	10.	5.6	
ACIDITY									
IN KCl exchange acidity									
Total	(me/100g)								
Al^{+++}	(me/100g)								
CATION EXCHANGE CAPACITY	(me/100g)	26.6	27.0	29.0	27.0	27.0	22.4	27.8	
NaOAc@pH 8.2									
BORON	(ppm)	.5	4.0	7.5	5.0	7.5	7.5	7.5	

Table 24

GPO 833-278

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Bear Creek
Location. Sec. 34 Twp. 8 S. Range 45 E.
[illegible]' S. and 950' W. of N¼ corner; Profile #32
Climate. Continental, Semiarid
Land Use: Range

Relief: Excessive
Elevation: 3820
Slope: Aspect: N.
Vegetation: Native grass, sage, forbes
Erosion: Slight

Stoniness: None
Drainage: Surface - Well drained
Ground Water: --
Land Form: Residual ridges and slopes

Parent Material: Fort Union Formation
Soil Series: Relan-9008
Soil Classification:
Profile Description By: T. Fiechtl Date: 7/75

LAB NO.	DEPTH (Cm.)	PROFILE DESCRIPTION
T-358	0-5	A_1--Light reddish brown (5YR 6/3) loam, reddish brown (5YR 5/3) moist; weak medium blocky structure separating to moderate medium crumb; loose, soft, nonsticky, nonplastic; roots plentiful, fine; noncalcareous; clear boundary; horizon with less than 25% gravel.
	5-17.5	B_1--Light reddish brown (5YR 6/3) silt loam, reddish brown (5YR 5/3) moist; moderate coarse prisms separates to moderate medium angular blocks; slightly hard, friable, slightly sticky, nonplastic; roota plentiful, fine; strongly calcareous; clear boundary, horizon with less than 25% gravel.
T-359	17.5-37.5	C_{ca}-- Yellowish red (5YR 5/6) light clay loam, reddish brown (5YR 4/3) moist; weak coarse prism separates to moderate coarse blocky structure; slightly hard, friable, slighty sticky, slightly plastic; roots plentiful, fine; strongly calcareous; gradual boundary; horizon has less than 25% gravels.
T-360	37.5-75	IIC_{2ca}--Light brown (7.5YR 7/3) gravely clay loam, brown (7.5YR 5/3) moist; stratified sandy shale; hard, firm, slightly sticky, slightly plastic; 50% gravels; strongly calcareous; abrupt boundary; sandy shale material.
T-361	75-120	$IIIC_{3ca}$--Light brown (7.5YR 5/3) gravely silty clay loam, brown (7.5YR 5/3) moist; stratified ailty shalea with carbonaceous influence; hard, firm, sticky, plastic; 50% gravels; strongly calcareous; abrupt boundary.
	120 +	R--Baked rock material, hard.

LABORATORY DESCRIPTION

DETERMINATION		DATA			
LABORATORY NUMBER					
DEPTH	(cm)	0-17.5	17.5-37.5	37.5-75	75-120
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				21.9
Coarse Sand	(1.0-0.5 mm)				17.6
Medium Sand	(0.5-0.25 mm)				5.3
Fine Sand	(0.25-0.10 mm)				10.2
Very Fine Sand	(0.10-0.05 mm)				6.3
Total Sand	(2.0-0.05 mm)	45.7	44.5	37.0	61.3
Silt	(0.05-0.002 mm)	37.7	36.9	39.4	20.5
Clay	(< 0.002 mm)	16.6	18.6	23.6	18.2
TEXTURAL CLASS (LAB)		L	L	L	Co.SL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(cm/hr)				
6th hr		2.11	1.32	0.66	0.71
24th hr		2.03	1.32	0.68	0.68
SETTLING VOLUME	(ml)	22	21	23	25
MOISTURE RETENTION	(percent)				
1/10 bar		31.9	30.4		30.6
1/3 bar		18.7	19.1		22.4
15 bar		10.8	11.2		16.1
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.8	8.4	8.2	8.2
1:2 0.01 M $CaCl_2$		6.7	7.3	7.2	7.2
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
$CaCO_3$ EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	+0.6	+0.2		+0.3
SATURATION EXTRACT					
Saturation Percentage		38.2	41.8	41.7	41.7
EC_e @ 25°C	(mmhos/cm)	0.36	0.36	0.50	0.66
Ca^{++}	(me/l)	2.14	2.09	2.80	4.06
Mg^{++}	(me/l)	1.09	1.00	1.45	1.99
Na^+	(me/l)	0.27	0.41	0.63	0.78
K^+	(me/l)	0.44	0.18	0.23	0.33
CO_3^-	(me/l)	0.00	0.00	0.00	0.00
HCO_3^-	(me/l)	1.96	1.32	1.80	2.76
Cl^-	(me/l)	0.52	0.02	0.28	0.32
SO_4^-	(me/l)	0.84	0.85	1.86	2.39
NO_3^-	(me/l)				
SAR		0.2	0.3	0.4	0.4
Na	(me/100g)	0.01	0.02	0.03	0.03
Ca+Mg	(me/100g)	0.12	0.13	0.18	0.25
1:5 EXTRACT					
EC_5 @ 25°C	(mmhos/cm)	0.24	0.14		0.20
Ca+Mg	(me/100g)				
EXCHANGEABLE SODIUM	(percent)	0.4	0.4		0.1
ACIDITY					
IN KCl exchange acidity					
Total	(me/100g)				
Al^{+++}	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	19.8	22.3		34.8
NaOAc@pH 8.2					
BORON	(ppm)	.4	.4		.3

Table 25

GPO 833-276

Table 28. Result of Boron Analyses

Location Sec.	T.	R.	Profile No.	Depth feet	Soil	Bedrock	Boron[1/] ppm
33	8S	45E SENW	8	0-1.5	X		0.25
				1.5-3.0	X		0.25
				3.0-4.5	X		0.25
				4.5-6.5	X		1.00
				6.5-8.0	X		0.25
				8.0-10.0	X		0.38
33	8S	45E SWSW	11	0-1.5	X		0.25
				1.5-2.5	X		0.38
				2.5-3.5		X	0.25
				3.5-4.5		X	0.25
				4.5-5.5		X	0.25
33	8S	45E NENE	75-101[2/]	34.6-42.5		X	0.38
				65.8-75.3		X	0.20
				112.9-138		X	0.25
				138-145.9		X	0.38
				145.9-167.7		X	0.25
				167.7-182.4		X	0.38
				182.4-187.4		X	0.50
				230.9-244.7		X	0.20
34	8S	45E SWSW	4	0-1.5	X		0.38
				1-2.5	X		0.38
				2.5-3	X		0.20
				3.0-4.0		X	0.20
34	8S	45E NENW	20	0-0.5	X		0.38
				0.5-1.5	X		0.38
				1.5-3.5	X		0.38
				3.5-5.0	X		0.50
				5.0-6.5	X		0.38
				6.5-8.5	X		0.20
				8.5-10.0	X		0.15
3	9S	45E SWSW	15	0-0.4	X		0.20
				0.4-1.2	X		0.38
				1.2-1.5	X		0.25
				1.5-3.0	X		0.25
				3.0-5.5	X		0.88
				5.5-7.0		X	0.38
				7.0-10.0		X	0.50
3	9S	45E NENE	75-102[2/]	0-34.0	X		0.38
				34.0-54.7		X	1.75
				57.7-63.6		X	0.25
				75.1-96.1		X	0.20
				121.6-128.5		X	0.20
				128.5-150.0		X	0.20
4	9S	45E NENW	6	0-1.0	X		0.25
				1.0-2.5	X		0.25
				2.5-4.5	X		0.25
				4.5-6.0	X		0.20
				6.0-7.5	X		0.15
				7.5-10.0		X	0.20
11	9S	45E SENE	75-104[2/]	0-8.3		X	0.28
				8.3-24.0		X	0.22
				25.9-62.5		X	0.50
				62.5-80.8		X	0.22
				80.8-93.2		X	0.20
				93.2-98.6		X	0.15
				98.6-138.5		X	0.25
				162.1-183.1		X	0.25
				183.1-219.5		X	0.25
				219.5-227.8		X	0.25
				227.8-285.0		X	0.25

1/ Hot water soluble
2/ Geologic cores

Table 29 - Results of Analyses for Trace Metals
(ppb in soil)

Sample No.	Depth (ft)	Ag	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	Pb	Se	Sr	V	Zn
104-2	8.3- 24.8	<10	1,800	<40	225	100	< 4	7	< 10	20	60	1,300	220	100	<120	16	140	90	980	<40	20
-3	25.0- 62.5	10	120	<40	500	90	< 4	6	<10	20	60	70	640	140	<140	16	200	40	3000	<40	24
-4	62.5- 80.0	<10	200	50	225	50	< 4	3	<10	<20	30	16	80	40	<140	10	40	80	80	<40	26
-5	80.8- 93.2	<10	180	<40	200	50	< 4	5	<10	<20	30	18	140	40	<360	10	140	100	610	<40	12
-6	93.2- 98.6	<10	440	<40	250	50	< 4	3	<10	<20	30	100	80	40	<160	10	80	100	180	<40	16
-7	98.6-138.5	<10	940	< 40	250	80	<4	7	<10	20	30	180	220	120	<200	16	160	50	980	<40	20
-8	162.1-183.1	<10	680	<40	250	50	<4	12	< 10	20	120	1,300	100	100	< 60	20	80	70	420	<40	120
-9	183.1-219.5	<10	300	<40	250	140	<4	10	<10	20	60	170	320	340	<100	20	160	40	2400	< 40	48
-10	219.5-227.8	20	1,400	<40	250	70	<4	11	<10	20	80	2,200	140	100	<100	28	80	50	300	40	400
-11	227.8-285.0	<10	2,200	<40	250	80	< 4	5	<10	20	100	1,100	100	40	<240	44	80	100	240	<40	100

NOTE: **ppb in soil soluble in 2 ml hot H_2O for every gram of soil.**

REPORT OF MASTER SITE SOIL ANALYSES
US BUREAU OF RECLAMATION
MISSOURI SOURIS PROJECTS OFFICE
BISMARCK, NORTH DAKOTA

Table 30

DATE RECEIVED: ____________

AREA Bear Creek SECTION ______ TOWNSHIP ______ RANGE ______ Geologic Samples INVESTIGATOR Herman DuPree SOIL TYPE ______ LAND CLASS ______ DATE REPORTED ______

Lab Number	Boring Number	Depth in Feet	Field Texture	Particle Size Analysis % Sand	V.Co 2.0-1.0	Co 1.0-0.5	Med 0.5-0.25	Fine 0.25-0.10	V.Fine 0.10-0.05	% Silt	% 2µ Clay	Lab Text	Moisture Retention % Pressure in Bars 0.10	0.33	15	Hyd Cond in/hrs 8 Hr	24 Hr	Sel Vol ml	pH @ 25 H_2O 1:5	$CaCl_2$ Paste	$EC \times 10^3$ @ 25°C	$EC_e \times 10^3$ @ 25°C	Saturation Extract Cations, me/l Ca	Mg	Na	K	Σ Cations	Anions, me/l CO_3	HCO_3	Cl	SO_4	NO_3	SAR	SP	me/100g Ca	Mg	Na	K	Total Extractable Cations me/100g Ca	Mg	Na	K	Exchangeable Cations me/100g Ca	Mg	Na	K	ESP	% Base Sat	Gyp me/100g	Gyp Req me/100g	% $CaCO_3$ Equiv.	% Org-C	% Field Mois. Cap	Bulk Density g/cm^3	Field Hyd Cond. in/hr	Field Infiltration in/hr	CEC meq/g
1	DH75 101	$00-6^{0}$											33.7	25.3	15.0	0.12	0.08	25	8.2	7.7											2920																									
2		$6^{0}-11^{0}$											25.2	17.4	9.6	0.20	0.20	25	8.7	8.1											2640																									
3		$11^{0}-23^{2}$		80.9	3.6	11.1	19.9	38.1	8.2	9.4	9.7	LS	14.6	9.6	5.3	1.64	1.44	18	8.8	8.0	0.62	3.2	5.82	10.86	19.26	0.53	36.47	0.00	2.84	0.82	30.30	0.05	6.7	41.7	0.24	0.45	0.80	0.02			1.11	0.24			0.31	0.22	5.4		0.8	-0.6							5.7
4		$27^{5}-34^{2}$											23.7	17.0	10.4	0.48	0.40	21	8.7	7.9											1120																									
5		$34^{6}-42^{5}$		3.4						87.3	9.3	Si	34.3	29.6	18.9	0.06	0.06	40	8.5	7.9	0.52	2.2	3.05	8.41	11.43	0.59	25.48	0.00	4.44	0.44	19.70	0.02	4.4	62.5	0.32	0.53	0.71	0.04			1.42	0.39			0.71	0.35	4.6		0.9	0.0							15.3
6		$44^{1}-47^{2}$											28.6	15.8	6.9	0.48	0.56	22	3.9	3.2											1680																									
7		$47^{9}-52^{2}$											34.6	26.3	18.0	0.00	0.00	55	7.8	7.3											670																									
8		$68^{8}-75^{2}$		2.1						67.7	30.2	SiCL	30.2	25.5	14.2	0.03	0.00	60	8.1	7.5	0.46	2.9	7.41	9.95	19.48	1.08	37.92	0.00	6.24	0.00	30.60	0.003	6.6	48.6	0.36	0.48	0.95	0.05			1.52	0.34			0.57	0.29	9.0		1.2	-0.7							6.3
10		$91^{8}-106^{5}$		5.6						70.0	24.4	SiL	29.0	24.0	11.9	0.00	<0.01	60	8.6	7.6	0.60	3.0	5.71	7.96	41.00	1.04	55.71	0.00	10.20	0.08	44.20	0.03	16	43.3	0.25	0.32	1.78	0.05			2.63	0.32			0.85	0.27	11.		0.7	-0.4							7.6
1		$112^{9}-138^{0}$		56.1	0.0	0.3	0.5	10.0	45.3	34.5	9.4	VFSL	26.0	12.6	5.1	0.02	0.01	50	7.7	7.3	0.50	5.1	5.38	7.96	41.52	0.83	58.63	0.00	4.88	0.58	50.40	0.05	11	42.8	0.23	0.31	1.78	0.04			2.09	0.16			0.31	0.12	10		0.6	-0.2							3.1
2		$138^{0}-145^{2}$		12.6						61.9	25.5	SiL	31.4	23.5	13.1	0.00	0.00	130	8.5	7.2	0.50	4.0	5.00	7.60	38.70	0.83	52.13	0.32	7.48	0.16	32.00	0.04	15	52.0	0.26	0.34	2.01	0.04			4.08	0.38			2.07	0.34	18		0.2	+2.1							11.2
13		$145^{9}-167^{2}$		26.6						57.8	15.6	SiL	31.8	20.6	7.2	0.00	0.00	80	7.9	7.3	0.60	4.7	2.09	2.89	36.04	0.73	35.20	0.00	6.72	0.44	44.00	0.03	23	41.9	0.09	0.12	1.51	0.03			2.67	0.26			1.16	0.23	15		0.7	-0.4							7.7
14	DH8 101	$167^{7}-182^{4}$		4.9						69.5	25.6	SiL	31.4	24.9	11.0	0.00	0.00	140	8.3	7.3	0.50	3.7	1.70	2.44	33.57	0.69	38.40	0.56	8.32	0.12	28.00	0.04	34	47.0	0.08	0.11	1.58	0.03			3.43	0.33			1.88	0.30	16		0.1	+2.5							11.6
15		$182^{9}-187^{5}$		32.6						50.8	16.6	SiL	31.2	19.8	7.7	0.04	0.02	90	7.0	6.5	0.80	5.8	9.11	15.92	43.65	1.11	69.79	0.00	5.44	0.40	62.60	0.03	80	47.5	0.43	0.76	2.07	0.05			2.84	0.27			0.77	0.22	29		1.2	-0.2							9.8
17		$230^{9}-244^{1}$		13.7						64.4	21.9	SiL	31.2	25.0	8.2	0.00	<0.01	60	8.4	7.5	0.50	3.7	3.46	4.98	30.57	0.88	39.89	0.24	8.44	0.28	29.50	0.02	11	55.5	0.19	0.28	1.26	0.05			2.14	0.27			0.44	0.22	81		1.7	-0.9							5.4
1	DH75 102	$0^{0}-34^{2}$		28.6						41.3	30.1	CL	35.6	27.2	15.3	0.00	<0.01	37	8.6	8.3	2.0	10	20.31	43.42	77.13	0.98	143.83	0.00	1.56	1.80	133.60	0.29	14	76.3	1.55	3.31	6.04	0.07			1.38	0.57			1.34	0.50	62		5.9	-4.8							21.7
2		$34^{2}-54^{2}$		17.2						39.8	43.0	C	40.7	31.7	18.5	0.00	0.00	80	8.2	7.5	11	6.	10.65	17.12	48.70	1.13	72.60	0.00	6.24	0.00	61.60	0.05	14	72.5	0.77	0.88	3.53	0.08			6.01	0.65			2.48	0.57	11.		1.7	+1.4							23.4
3		$54^{2}-57^{2}$		6.9						42.0	51.1	SiC	23.5	18.8	9.3	0.36	0.40	27	6.5	5.9																																					
4		$57^{2}-63^{6}$		1.4						51.0	47.6	SiC	46.7	35.5	22.0	0.00	0.00	200	8.9	8.1	0.80	2.8	1.15	1.36	27.57	0.64	30.72	0.96	10.92	0.00	16.60	0.04	25.	93.4	0.11	0.13	2.58	0.06			7.49	0.74			4.91	0.68			0.2	+5.1							18.4
5		$63^{6}-75^{6}$		43.1						40.1	16.8	L	29.7	20.9	7.2	0.00	0.00	110	8.2	7.3																																					
6		$75^{6}-96^{1}$		6.5						62.2	31.3	SiCL	36.0	30.7	19.1	0.00	0.00	160	8.2	7.5	0.80	3.9	3.18	3.44	34.61	0.86	42.09	0.32	7.64	0.08	33.90	0.06	19.	83.8	0.14	0.16	2.90	0.04			5.76	0.63			2.86	0.52	18.		1.0	+2.4							15.9
7		$96^{1}-104^{6}$											30.8	19.1	7.9	0.04	0.02	35	7.5	7.1	0.70	5.1																																			
8		$105^{0}-110^{1}$													15.1	0.00	0.00	120	8.6	7.8	0.50	3.0									495																									
9		$121^{6}-128^{5}$		27.0						55.0	18.0	SiL			8.9	0.00	0.00	80	9.2	7.8	0.4	3.8	1.65	2.35	34.61	0.80	39.42	0.00	11.56	0.84	39.60	0.03	24.	38.8	0.06	0.09	1.34	0.03			2.69	0.28			1.35	0.25	20.		0.5	+0.6							6.8
10		$128^{5}-150^{0}$		2.7						64.5	32.8	SiCL			15.3	0.00	0.00	100	9.1	7.7	0.52	3.4	1.81	2.62	30.36	0.93	35.62	0.00	11.12	0.28	25.20	0.02	20.	49.7	0.09	0.13	1.50	0.05			2.97	0.39			1.47	0.34	18.		0.2	+1.8							8.4
1	DH75 104	$2^{5}-8^{2}$											11.8	9.6	3.5	1.44	1.28	20	8.0	7.7											690																									
2		$8^{2}-24^{8}$		16.0						55.2	28.8	SiCL	41.5	31.9	16.2	0.07	0.07	37	8.3	7.7	0.86	4.5	2.73	4.88	39.74	0.77	49.12	0.32	8.76	0.24	43.60	0.03	19.	68.4	0.26	0.33	2.72	0.05			6.53	0.54			3.61	0.49	15.		1.1	+2.8							25.0
3		$25^{0}-62^{5}$		9.3						54.9	35.8	SiCL	40.1	32.9	18.6	0.00	<0.01	75	8.8	8.2	1.5	7.5	14.27	38.45	46.39	1.03	100.09	0.00	4.96	1.04	97.60	0.90	90	89	0.48	2.65	3.19	0.07			5.20	0.49			2.01	0.42	79		3.8	-1.0							25.4
4		$62^{5}-80^{0}$		62.0	1.1	3.7	6.8	28.4	22.0	19.8	18.2	VFSL	33.3	23.4	10.6	0.00	0.00	100	9.6	8.6	0.50	2.1	0.44	0.54	19.87	0.27	21.12	0.56	6.60	0.32	13.00	0.60	28	75.7	1.03	0.04	1.50	0.02			6.83	0.37			3.33	0.35	25.		0.5	+4.9							22.7
5		$80^{8}-93^{3}$		2.4						65.6	32.0	SiCL	40.1	31.6	15.4	0.00	0.00	120	9.5	8.4	0.70	3.9	2.42	2.71	35.00	0.62	40.75	0.64	1.48	0.26	34.60	0.04	22	68.4	0.17	0.19	2.39	0.09			7.04	0.54			4.65	0.50	20		0.4	+3.6							23.5
6		$93^{3}-96^{6}$		48.5						28.5	23.0	L	39.0	28.7	11.8	0.00	0.00	140	9.5	8.5	0.50	2.7	0.66	0.81	25.87	0.36	27.70	0.64	7.76	0.12	18.60	0.04	30	62.9	0.04	0.05	1.63	0.02			7.14	0.38			5.51	0.36	23.		1.0	+4.9							23.9
7		$98^{6}-138^{5}$		2.5						49.7	47.8	SiC	45.5	34.6	18.4	0.00	0.00	120	8.9	7.9	1.0	4.3	5.13	3.53	36.91	0.82	44.39	0.56	6.56	0.08	31.41	0.03	20.	74	0.23	0.26	2.67	0.06			1.55	0.64			4.88	0.58	24		1.0	+4.6							20.5
8		$162^{1}-183^{1}$											32.1	21.4	7.1	0.00	0.02	80	9.2	7.8	0.52	3.5	1.81	0.33	30.45	0.66	33.45	0.90	11.44	0.30	24.10	0.03	30	45.1	0.08	0.02	1.40	0.03			2.82	0.26			1.42	0.23	15		0.9	+0.8							9.5
9		$183^{1}-219^{5}$											41.0	31.1	17.2	0.00	0.00	100	8.6	8.2	1.4	8.0	14.60	14.11	65.83	1.37	95.91	0.00	6.52	0.10	82.80	0.03	17	64.8	0.95	0.91	4.27	0.09			2.83	0.63			3.56	0.54	18		1.2	+1.2							19.4
10		$219^{5}-227^{8}$											37.2	30.4	15.2	0.00	0.00	90	9.3	8.2	0.70	3.4	1.21	1.54	30.65	0.53	33.93	0.69	9.12	0.12	21.70	0.03	26	67.7	0.08	0.10	2.08	0.04			6.18	0.48			4.10	0.44	20		0.6	+4.0							20.2
1		$227^{8}-285^{0}$											34.7	26.7	15.6	0.00	0.00	170	9.5	8.2	0.60	2.6	0.55	0.81	24.26	0.48	26.10	1.09	6.36	0.24	16.20	0.77	29	69.7	0.04	0.06	1.69	0.03			5.75	0.52			4.06	0.49	23		0.3	+4.4							17.7
12		$296^{7}-304^{11}$											32.7	26.8	11.5	0.00	0.00	140	8.9	7.6											690																									

Table 31-Suitability of Bedrock Material for Use as Plant Media for Revegetation - Bear Creek Site, Montana

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
101-1	0-6	Soil	Limited Suitability	Clay-salinity
101-2	6-11	Soil	Suitable	Clay
101-3	11-23	Soil	Suitable	Moisture retention
	23.0-27.5	Soil	Suitable	
101-4	27.5-34.6	Soil	Suitable	Gravel
101-5	34.6-42.1	Sh SiSh	Limited Suitability	Clay-perm
	42.1-44.1	Coal		
101-6	44.1-47.0	SiSs	Unsuitable	Acid
101-7	47.0-52.3	Sh	Unsuitable	Instability-clay
	52.3-68.8	Coal		
101-8	68.8-75.3	SiSh	Unsuitable	Instability-clay
101-9	75.3-84.0	SiSt	Unsuitable	Indurated
	84.0-91.8	Coal		
101-10	91.8-107.8	SiSh	Unsuitable	Instability-clay
	107.8-112.9	Coal		
101-11 to 15	112.9-187.5	SiSs SiSh	Unsuitable	Instability-clay
	187.5-191.8	Cb Sh	Unsuitable	Clay-perm
	191.8-216.2	Coal		
	216.2-219.3	Sh	Unsuitable	Clay-perm
	219.3-221.5	SiSs	Unsuitable	Amount
	221.5-224.5	Coal		
101-16	224.5-230.9	SiSh	Unsuitable	Depth to quantity
101-17	230.4-224.7	SiSh	Unsuitable	Clay-perm

Sh - shale
CbSh - carbonaceous shale
Ss - sandstone
SiSt - Siltstone
Cec - Cation exchange capacity
SiSh - silty shale
Sst - sandy siltstone
SiSs - silty sandstone
Css - clayey sandstone
C Sist - clayey siltstone
S Sist - sandy siltstone
/ - with
BR - baked rock

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
102-1	0-34	Soil	Unsuitable	Salinity-stability
102-2	34-54.7	Sh	Unsuitable	Instability-clay
102-3	54.7-57.7	SiSs	Limited Suitability	Acidity
102-4	57.7-63.6	Sh	Unsuitable	Instability-clay
102-5	63.6-75.6	Ss	Unsuitable	Instability-perm
		SiSt		
		Sh		
102-6	75.6-96.1	Sh	Unsuitable	Instability-clay
102-7	96.1-104.6	SiSs	Limited Suitability	Clay lenses-perm
102-8	105.0-110.1	Sh	Unsuitable	Instability-clay
	112-123.6	Coal		
102-9	123.6-128.5	Sh	Unsuitable	Instability-clay
		SiSt		
		Ss		
102-10	128.5-1150.0	SiSh	Unsuitable	Instability-clay

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
103-1	0-6	Soil	Suitable	
103-2	6-15	Sh	Unsuitable	Salinity
103-3	15.0-20.0	Ss	Limited Suitability	Low Cec-instability
103-4	20.0-41.7	Sh	Unsuitable	Instability-clay
	41.7-61.0	Coal		
103-5	61.0-65.2	C Sist	Unsuitable	Instability-clay
103-6	65.2-71.4	Sh	Unsuitable	Instability-clay
103-7	71.4-74.6	S Sist	Unsuitable	Instability-perm
	746-799	Sh	Unsuitable	Clay lamination-perm
		Ss		
		SiSt		
103-8	79.9-88.0	Sh	Unsuitable	Instability-clay
103-9	88.0-104.2	Sh	Unsuitable	Clay laminations-perm
		Ss		
		SiSt		
103-10	104.2-109.6	Sh	Unsuitable	CbSh-instability
	109.6-114.2	Coal		
103-11	114.2-126.2	Sh	Unsuitable	Instability-clay
103-12	126.2-131.5	Ss	Limited Suitability	Low Cec-sli. instability
103-13	131.5-143.7	Sh	Unsuitable	Clay laminations-perm
		Ss		
		SiSt		
	143.7-146.6	Coal		
103-14	146.6-167.7	Sh	Unsuitable	Instability-clay
103-15	167.7-181.0	SiSs	Unsuitable	Instability-perm
	181.0-183.5	Sh	Unsuitable	Clay lenses-perm
		Ss		
		SiSt		
103-16	183.5-188.6	Sh	Unsuitable	Instability-clay
	188.6-197.7	Coal		
103-17	197.7-221.3	C Sist	Unsuitable	Instability-clay
		SiSh		

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
104-1	2.5-8.3	Ss	Limited Suitability	Salinity-low Cec
104-2	8.3-24.0	Sh SiSt	Limited Suitability	Instability-clay
104-3	25.0-62.5	Sh/SiSh	Unsuitable	Instability-clay
104-4	62.5-80.8	Ss SiSs Sh	Unsuitable	Instability-sodium
104-5	80.8-93.2	Sh	Unsuitable	Clay-sodium
104-6	93.2-98.6	SiSs	Unsuitable	Instability-sodium
104-7	98.6-138.5	Sh	Unsuitable	Instability-clay
	138.5-153.1	Coal		
	153.1-162.1	SiSh Coal	Unsuitable	Clay
104-8	162.1-183.1	S Sist	Unsuitable	Instability-perm
104-9	183.1-219.5	Sh SiSh	Unsuitable	Instability-clay
104-10	219.5-227.8	ShSs	Unsuitable	Clay lenses
104-11	227.8-285.9	Sh/Ss	Unsuitable	Instability-clay
	285.9-296.8	Coal		
104-12	296.8-304.5	Sh	Unsuitable	Instability-clay

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
105-1	10.6-34.6	Sh	Limited Suitability	Clay-salinity
	34.6-36.6	Coal		
	36.6-38.6	Sh	Unsuitable	Clay-CbSh
105-2	38.6-45.6	Ss	Suitable	
105-3	45.6-92.8	Sh	Unsuitable	Clay-instability
105-4	928-108.9	Ss	Unsuitable	Sodium-instability
105-5	108.9-126.0	Sh Ss Coal	Unsuitable	Thin bedded-quantity
	126.0-129.0	Ss	Unsuitable	Quantity-instability
105-6	129.0-152.6	Sh	Unsuitable	Instability-clay
	152.6-179.0	Coal		
	179.0-185.8	Sh	Unsuitable	CbSh-clay
	185.8-191.4	Coal		
105-7	191.4-210.6	Sh	Unsuitable	Instability-clay
105-8	210.6-231.7	Ss SiSt Sh	Unsuitable	Instability-clay
105-9	231.7-244.9	Sh	Unsuitable	Instability-clay
	244.9-254.2	Sh CbSh Sh	Unsuitable	Thin bedded-clay
105-10	254.3-268.4	Ss Sh	Unsuitable	Instability-clay
	268.4-278.7	Sh Coal		
105-11	278.7-285.4	C Sist	Unsuitable	Instability-clay
105-12	285.4-306.6	Sh SiSh	Unsuitable	Instability-clay

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
106-1	0-9.5	SiSh SiSt	Limited Suitability	Clay-perm
	9.5-11.5	Sh CbSh	Unsuitable	CbSh-clay
	11.5-18.0	SiSh	Limited Suitability	Clay-perm
106-2	18.0-40.6	SiSs	Suitable	Clay laminations
	40.6-41.4	SiSh	Limited Suitability	Clay-perm
106-3	41.4-68.7	Sh CbSh Coal	Unsuitable	Clay laminations
106-4	68.7-73.5	SiSs	Limited Suitability	Instability-perm
106-5	73.5-129.7	Sh SiSh SiSs	Unsuitable	Instability-sodium
106-6	129.7-146.7	Ss	Unsuitable	Instability-sodium
106-7	146.7-201.8	Sh CbSh Ss & Coal	Unsuitable	Clay-instability
	201.8-233.4	Coal		
106-8	233.4-239.4	Sh	Unsuitable	Clay
106-9	239.4-242.8	Ss	Unsuitable	Depth to quantity
106-10	242.8-281.4	Sh/Ss	Unsuitable	Instability-clay
	281.4-290.7	Coal		
106-11	290.7-298.9	SiSs	Limited Suitability	Clay-perm
106-12	298.9-310.4	SiSh	Unsuitable	Instability-clay

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
108-1	0-18.0	Soil	Suitable	
	18.0-20.3		Unsuitable	Limestone
108-2	20.3-43.8	Sh	Suitable	
	43.8-75.8	Coal		
	75.8-79.2	CbSh		
108-3	79.2-90.0	Ss&Sh	Suitable	
108-4	90.0-94.8	Sh	Limited Suitability	Clay-perm
108-5	94.8-105.5	Ss	Suitable	
108-6	105.5-138.6	Sh	Limited Suitability	Clay-perm
	138.6-148.8	Coal		
108-7	148.8-153.0	SiSt	Unsuitable	Instability-perm

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
109-1	0-17.0	Soil	Limited Suitability	Instability-salinity
109-2	17.0-22.8	Ss	Unsuitable	Instability-perm
109-3	22.8-38.9	Sh	Limited Suitability	Clay-salinity
		SiSt		
		Ss		
	38.9-60.0	BR	Unsuitable	Anderson clinker
109-4	60.0-114.6	Sh	Unsuitable	Instability-clay
		Ss		
		SiSt		
	114.6-122.5	Coal		
109-5	123.1-142.3	SiSs	Unsuitable	Instability-sodium
		Sst		
109-6	142.3-147.5	Sh	Unsuitable	Instability-clay
	147.5-149.0	Ss	Unsuitable	Instability-thickness
109-7	149.0-159.0	SiSh	Unsuitable	Instability-clay
		Sh		
109-8	159.0-167.9	C Sist	Unsuitable	Instability-clay
109-9	167.9-177.5	SiSh	Unsuitable	Instability-clay
		SiSs		
109-10	177.5-230.3	SiSt	Unsuitable	Instability-clay
		C Sist		
109-11	230.3-243.4	Sh	Unsuitable	Instability-clay
	243.4-262.5	Coal		
109-12	262.5-267.0	SiSh	Unsuitable	Instability-clay

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-1	Soil	Suitable	
111-1	1.0-13.4	SiSs	Limited Suitability	Instability-perm
111-2	13.4-30.5	SiSh	Limited Suitability	Instability-clay
111-3	30.5-50.0	Css	Suitable	Clay lenses-perm
111-4	50.0-71.7	Sh	Unsuitable	Clay-perm
	71.7-102.5	Coal		
	102.5-105.0	CbSh		
111-5	105.0-111.5	ShSs	Suitable	
111-6	111.5-118.0	Sh	Limited Suitability	Clay-perm
	118.0-126.5	Ss	Suitable	Low Cec
111-7	126.5-131.7	SiSh	Unsuitable	Instability-clay
		Ss		
111-8	131.7-156.5	Sh	Unsuitable	Instability-clay
	156.5-167.7	Coal		
111-9	167.2-180.0	ShSs	Unsuitable	Instability-clay

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
112-1	0-5.5	Soil	Suitable	
	5.5-15.0	Soil	Limited Suitability	Clay-perm
112-2	15.0-48.9	Sh SiSt	Unsuitable	Clay lenses
	48.9-68.8	Coal		
	68.8-69.8	Sh	Unsuitable	Clay-quantity
	69.8-70.8	Coal		
112-3	74.2-84.2	SiSh Ss	Unsuitable	Instability-clay

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Table 32 Interpretative Ratings for Soil Uses

Map Symbol (1)	Soil Name (2)	Suitability						Degree of Limitation and Soil Features Affecting				
								Ponds				
		Dryland Farming (3)	Irrigation (4)	Topsoil (5)	Sand/Gravel (6)	Road Fill (7)	Other (8)	Location (9)	Compactability.. Stability Embankment (10)	Road Location (11)	Shallow Excavations (12)	Building Sites (13)
	Cabba Assn. 15-50%	Not Suitable	Not Suitable	Fair	Not Suitable	Poor	Range.. Wildlife	Favorable	Poor-Fair	Poor	Unfavorable	Good
	Cushman - Elso 4-8%	Severe Limitationa	Not Suitable	Fair-Poor	Not Suitable	Poor	Dryland Crops.. Range.. Wildlife	Favorable	Poor-Fair	Poor	Favorable-Unfavorable	Good
	Cushman Elso 8-15%	Severe Limitations	Not Suitable	Fair-Poor	Not Suitable	Poor	Range.. Woodland.. Wildlife	Favorable	Poor-Fair	Poor	Favorable-Unfavorable	Good
	Haverson Channeled	Severe Limitations	Not Suitable	Good	Not Suitable	Fair	Range.. Woodland.. Wildlife	Favorable	Poor	Fair	Favorable	Fair
	Haverson SiCL	Severe Limitations	Not Suitable	Fair-Good	Not Suitable	Poor	Dryland Crops.. Range.. Wildlife	Favorable	Poor-Fair	Poor	Unfavorable	Poor
	Haverson Saline	Severe Limitations	Not Suitable	Poor	Not Suitable	Poor	Range.. Wildlife	Favorable	Poor	Poor	Unfavorable	Poor
	Heldt 0-2%	Severe Limitations	Not Suitable	Good (16")	Not Suitable	Good-Fair	Dryland Crops.. Range.. Wildlife	Favorable	Good-Fair	Good-Fair	Unfavorable	Fair
	Heldt 2-4%	Severe Limitations	Not Suitable	Good (16")	Not Suitable	Good-Fair	Dryland Crops.. Range.. Wildlife	Favorable	Good-Fair	Good-Fair	Unfavorable	Fair
	Heldt 4-8%	Severe Limitations	Not Suitable	Good (16")	Not Suitable	Good-Fair	Dryland Crops.. Range.. Wildlife	Favorable	Good-Fair	Good-Fair	Unfavorable	Fair
	Hesper 0-2%	Good	Slow Perm.	Good (12")	Not Suitable	Good-Fair	Dryland Crops.. Range.. Wildlife	Favorable	Good-Fair	Good-Fair	Unfavorable	Fair
	Hesper 2-4%	Good	Slow Perm.	Good (12")	Not Suitable	Good-Fair	Dryland Crops.. Range.. Wildlife	Favorable	Good-Fair	Good-Fair	Unfavorable	Fair

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Table 33 Interpretative Ratings for Soil Uses

Map Symbol (1)	Soil Name (2)	Suitability: Dryland Farming (3)	Suitability: Irrigation (4)	Suitability: Topsoil (5)	Suitability: Sand/Gravel (6)	Suitability: Road Fill (7)	Suitability: Other (8)	Degree of Limitation and Soil Features Affecting: Ponds: Location (9)	Ponds: Compactability.. Stability Embankment (10)	Road Location (11)	Shallow Excavations (12)	Building Sites (13)
	Hesper 4-8%	Good	Slow Perms.	Good (12")	Unsuitable	Poor	Dryland Crops.. Range Wildlife	Favorable	Good to Fair	Poor	Unfavorable	Fair
	Hydro 2-4%	Fair-Good	Not Suitable	Fair (10")	Unsuitable	Poor	Dryland Crops.. Range Wildlife	Favorable	Fair	Poor	Unfavorable	Fair
	Hydro 4-8%	Fair-Good	Not Suitable	Fair (10")	Unsuitable	Poor	Dryland. Crops.. Range Wildlife	Favorable	Fair	Poor	Unfavorable	Fair
	Hydro-Elso 8-15%	Fair-Poor	Not Suitable	Fair-Poor	Unsuitable	Poor	Range Wildlife	Unfavorable	Poor	Poor	Unfavorable	Poor-Fair
	Midway 2-8%	Severe Limitations	Not Suitable	Poor	Unsuitable	Poor	Range Wildlife	Favorable	Fair	Fair	Unfavorable	Poor
	Midway Elso 8-35%	Severe Limitations	Not Suitable	Poor	Unsuitable	Poor	Range Wildlife	Favorable	Poor-Fair	Fair	Unfavorable	Poor
	Midway-Elso Rocky 15-35%	Severe Limitations	Not Suitable	Poor	Poor	Poor	Range Wildlife	Favorable	Fair	Poor	Unfavorable	Poor
	Midway-Thurlow 8-15%	Severe Limitations	Not Suitable	Poor-Fair	Poor	Poor	Dryland Crops.. Range.. Wildlife	Favorable	Fair	Fair	Unfavorable	Fair
	Terrace Escarpment	Severe Limitations	Not Suitable	Poor	Poor	Fair-Poor	Range Wildlife	Favorable	Fair-Poor	Fair-Poor	Unfavorable	Poor
	Thurlow 0-2%	Good	Mod. Slow Perms.	Good (15")	Poor	Poor	Dryland Crops.. Range.. Wildlife	Favorable	Fair-Good	Fair-Good	Unfavorable	Fair
	Thurlow 2-4%	Good	Mod. Slow Perms.	Good (15")	Poor	Poor	Dryland Crops.. Range.. Wildlife	Favorable	Fair-Good	Fair-Good	Unfavorable	Fair

Table 34

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

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)	Hydrologic Soil Group (6)	Shrink-Swell Potential (7)	Corrosivity: Uncoated Steel (8)	Corrosivity: Concrete (9)	Classification: USDA Ext. (10)	Classification: Unified (11)	Classification: AASHO (12)	Coarse Fraction (percent) (13)
9001	-	0-60	>60	None	B	Low	High	Low to Moderate	Loam-SiL UFSL-SiCL	ML or CL	A-4 or A-6	-
9002	-	0-60	>60	None	B	Moderate	Moderate	Low	SiCL-SiC	CL	A-6	-
9003	-	0-7 7	<20	None	D	High	High	Low	CL Shale	CL or CH	A-6 or A-7	-
9004	-	0-65	>60	None	B	Low	Moderate to High	Low	SiL-SiCL	ML	A-4	-
9005												
9006	-	0-60	>60	None	B	Low	Low to Moderate	Low to Moderate	L-SiL-SiC L-FSL	ML or CL	A-4 or A-6	-
9007												
9008	-	0-16 16	<20	None	D	Low	Low	Low	Gr.& vgr.L Baked Shale	FM or SM	A-2	25 - 55
9009												
9010	-	0-44 44-66	>60	None	B	Moderate	Moderate to High	Low Low to Mod	SiCL SiCL-SiL	CL CL	A-6 or A-7 A-6	-
9011	-	0-16 16	<20	None	D	Low	Low	Low	Loam-SiL Stone-Shale	ML	A-4	-
9012	-	0-26 26	20-40	None	C	Moderate	Moderate to High	Low	Loam-CL Stone-Shale	CL	A-6	-
9013	-	0-20 20	<20	None	D	Low	Moderate to High	Low	SiL-Shale	ML	A-4	-
9014	-	0-60	>60	None	B	Low	Low to Moderate	Low to Moderate	L-SiL-CL	ML or CL	A-4 or A-6	-
9015	-	0-60	>60	Surface	B	Low	High	Moderate to High	SiL & Loam	ML	A-4	-
9016	-	0-20 20-60	>60	None	B	Moderate to High	High	Low to Moderate	SiCL-SiC L-SiL-CL	CL or CH ML or CL	A-6 or A-7 A-4 or A-6	- -
9017	-	0-60	>60	None	B	Moderate	Moderate	Low	SiCL-CL	CL	A-6	-
9018	-	0-43 43-62	>60	None	B	Mod.to High Moderate	High High	Low Low to Mod	SiCL SiCL	CL CL	A-6 or A-7 A-6	- -
9019	-	0-60	>60	None	B	Low to Moderate	Low-High	Low Low	FSL SiL	SM ML	A-4 A-4	- -
9020	-	0-26 26-60	>60	None	B	Low Low	Low Low	Low Low	SiL-L Gr. Loam	ML SM	A-4 A-2	10 30

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 following 32 pages)

SUPPORTING DATA

Vegetation - Soil Description (BLM Form 7310-9) followed by Determination of Erosion Condition Class (BLM Form 7310-12) for the following profiles in the order listed:

Profile No. 14 - Sec. 34, T. 8 S., R. 45 E.
Profile No. 32 - Sec. 34, T. 8 S., R. 45 E.
Profile No. 24 - Sec. 34, T. 8 S., R. 45 E.
Profile No. 40 - Sec. 3, T. 9 S., R. 45 E.
Profile No. 19 - Sec. 19, T. 9 S., R. 45 E.
Profile No. 7 - Sec. 4, T. 9 S., R. 45 E.
Profile No. 8 - Sec. 33, T. 8 S., R. 45 E.
Profile No. 20 - Sec. 34, T. 8 S., R. 45 E.
Profile No. 4 - Sec. 34, T. 8 S., R. 45 E.
Profile No. 5 - Sec. 33, T. 8 S., R. 45 E.
Profile No. 11 - Sec. 33, T. 8 S., R. 45 E.
Profile No 6 - Sec. 4, T. 9 S., R. 45 E.
Profile No. 29 - Sec. 11, T. 9 S., R. 45 E.
Profile No. 17 - Sec. 33, T. 8 S., R. 45 E.
Profile No. 33 - Sec. 2, T. 9 S., R. 45 E.
Profile No. 35 - Sec. 3, T. 9 S., R. 45 E.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION-SOIL DESCRIPTION

1. State: 25
2. District: 02
3. Planning Unit: 213
4. Vegetation-Soil Unit: Mixed / 9015
5. Soil Map Symbol: 015 B2N
6. Surname: Thomas Frochil
7. Date: 7 mo 75 yr
8. Area: --
9. County: 75
10. Location: Sec. 34, T. 8 S, R. 45 E
11. Photo No.: —
12. Writeup No.: 14
13. File No.: —
14. Parent Rock: Sandstone
15. Formation Name: Fort Union
16. Surface Conditions (percent): Stone 0 Rock 0
17. Land Conditions: Alkaline mod. Saline mod. Water table —
18. Landform: Colluvium
19. Slope (percent): 4-6%; Single [ ] Complex [✓]
20. Aspect: S
21. Elevation: 3850
22. Present Erosion: Slight; Type: Sheet; SSF — Class —
23. Hydrologic Group: —
24. Precipitation (in): 14.75; 1st, 2nd ✓, 3rd ✓, 4th
25. Temperature: — Air — Soil
26. Frost-free: Days 144 > 28°
27. Drainage Class: well
28. Infiltration: Mod. - Mod. slow
29. Percolation: Mod.
30. ERD: — in
31. AWC: 7.7 in

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
A12	0-3"	D 10YR 7/2 M 10YR 4/3	—	SiL	1vcpl/1fcr	D: lo M: lo	—	2f	—	ve	a
B2t	3-6"	D 7.5YR 5.5/3 M 10YR 3.5/3	—	CL	3mcpr/3m sbk	D: h M: fi	3npf	2f	—	e	g
B3ca	6-12	D: 10YR 6/3 M: 10YR 4.5/3	—	CL	2cpr/3m sbk	D: sh M: fr	—	2f	—	es	g
Cca	12-30"	D: 10YR 6/3 M: 10YR 4.5/4	—	CL	1cpr/2m bk	D: sh M: fr	—	2f	—	es	g
C2ca	30-48	D: 10YR 6/3 M: 10YR 5/4	—	CL	1cbk/2m bk	D: sh M: fr	—	—	—	es	g
C3ca	48-66	—	—	CL	1cbk/1mbk	—	—	—	—	es	g
	66-84	—	—	CL	—	—	—	—	—	—	—
	84-96	—	—	CL	—	—	—	—	—	—	—
	96-104	—	—	CL	—	—	—	—	—	—	—

Complex soil association with
Up to 35% panspots in area.
This log is not typical Hydro in having high lime,
lacking development of typical.

(Instructions inside back cover)

PC 243-251 (8) (14) 1650'S., 250'W of N1/4 Cor

Form 7310-9 (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By YY | Date 7/75

Location (32) Sec 34, 8S 45E 2100'E 950 W of N 1/4 Cor

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 1/2" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills 1/2" 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				
		38			

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
25	02	213	Mixed / 9010	010 / A2N	Thomas-Fechtl	7 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	15	Sec. 34, T. 8S, R. 45E	—	—	—	Sandstone

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone — Rock —	Alkaline low Saline high Water table 66"	Alluvium

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
0-2% ☐ Single ☑ Complex	N	3800	Slight; Type Sheet; SSF — Class —	—

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
14.75; 1st, 2nd ✓, 3rd ✓, 4th	— Air — Soil	Days 144 > 28°	Well drained	Mod. slow	Mod. slow	— in	7.7 in

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	0-3"	D: 10YR 6/2; M: 10YR 4/2	—	CL	1 c 6bk / 2 m 3bk	D: h; M: fr		2f	—	es	g
B2	3-10"	D: 10YR 4.5/2; M: 10YR 3/2	—	CL	2 m pr / 2 f 3bk	D: h; M: fr		2f	—	es	g
B3ca	10-15"	D: 10YR 5/3; M: 10YR 4/3	—	CL	2 c pr / 2 m 2bk	D: sh; M: fr		2f	—	es	g
C1ca	15-30	D: 10YR 6.5/3; M: 10YR 4.5/3	—	CL	1 c pr / 2 c bk	D: sh; M: fr		2f	—	es	g
2ca	30-42	D: 10YR 6.5/3; M: 10YR 5.5/3	—	CL	1 c bk / 1 m bk	D: h; M: fr		1f	—	es	g
3ca	42-60"	D: 10YR 7.3; M: 10YR 5.5/3	—	CL	1 c bk / 1 m bk	D: h; M: fr		—	—	es	

10"+ lime mottlings

30-42" Lignite fragments

96"+ Scoria fragments., Stratafied & sluffing

Water Table @ 66"..

Vegetation: Alf. & tame grasses

Soil Mapped Kieldt SiCL., 0-2% slopes

(Instructions inside back cover)

Form 7310–9 (December 1970)

FC 302-309 (7) (24) 800' E., 800' S. of NW Cor.

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By [signature] | Date ~7/75

Location Sec 34-85-45E (24) 800'S., 400'S of NW Cor.

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	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

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 213	4. Vegetation–Soil Unit Mixed / 9002	5. Soil Map Symbol 02/B3N	6. Surname Thomas Fiechtl	7. Date 8 mo 75 yr
8. Area –	9. County 75	10. Location Sec. 3, T. 9 S, R. 45 E	11. Photo No. –	12. Writeup No. 40	13. File No. –	14. Parent Rock Sandstone

15. Formation Name Fort Union	16. Surface Conditions (percent) Stone – Rock –	17. Land Conditions Alkaline low Saline slight Water table –	18. Landform Alluvium
19. Slope (percent) 2-4% ☐ Single ☑ Complex	20. Aspect SW / 21. Elevation 3820	22. Present Erosion Slight Type Sheet SSF – Class –	23. Hydrologic Group –

24. Precipitation (in) 14.75 1st, 2nd ✓, 3rd ✓, 4th	25. Temperature – Air – Soil	26. Frost-free Days 144 > 28°	27. Drainage Class Medium	28. Infiltration Moderate	29. Percolation Moderate	30. ERD – in	31. AWC 5.5"+ in

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	0-2"	D: 10YR 6/3 M: 10YR 5/4	—	L	2 c pl / 2 m cr	D: sh M: fr	—	2 +	—	—	a
B_1	2-5"	D: 10YR 6/3 M: 10YR 5/2	—	CL	2 m pr / 2 m bk	D: sh M: fr	—	2 +	—	—	g
B_{2t}	5-13"	D: 10YR 5/2 M: 10YR 4/2	—	CL	3 m pr / 2 m sbk	D: h M: fr	2 n pf	2 +	—	—	c
B_{3ca}	13-18"	D: 10YR 6/3 M: 10YR 5/3	—	CL	2 m pr / 2 m bk	D: h M: fr	—	2 +	—	es	g
C_{1ca}	18-30"	D: 10YR 6.5/3 M: 10YR 6/3	—	CL	2 c pr / 2 m bk	D: h M: fr	—	2 +	—	es	g
IIC_{2ca}	30-54"	D: 10YR 6/4 M: 10YR 5/4	—	CL	1 c pr / 1 m bk	D: h M: fr	—	—	—	es	a
C_{3ca}	54-60+"	D: 10YR 6/4 M: 10YR 5/4	—	CL	1 c bk / 1 m bk	D: sh M: fr	—	—	—	er	g

0-5" old Ap horizon.
Lime mottlings common @ 30-54" with few 54"+.. 120" total profile depth..
Vegetation: G. Needle, W. Wheat, D. Brome, June Grass, Indian Wheat, Grama, Winter Fat, various scattered sages

(Instructions inside back cover)

Form 7310–9 (December 1970)

FC 5-89-594(b) (40) 2600' S., 50' W. of N 1/4 Cor.

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By	Date
W	8 1 75
Location (40) 3 TRS. R45E 2600'S 50'W qNW4	
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	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

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
25	02	213	Mixed / 9003	02 C4N	Thomas Fiechtl	8 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
–	075	Sec. 3, T. 9S, R. 45E	–	19	–	Sandstone & Sandy Shales

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone – Rock –	Alkaline low, Saline high, Water table –	Residual

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
6-8% ☐ Single ☑ Complex	NW	3960	mod. to severe; Type Rill & Gully; SSF – Class –	–

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
14.75; 1st, 2nd ✓, 3rd ✓, 4th	– Air – Soil	Days 144 > 28°	Well Drained	Mod. Slow	Mod. Slow	– in	3.5+ in

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	0-18	D 10YR 6/3 M 10YR 5/3	–	CL	1c bk/ 2m bk	D - h M - fr	–	2f	–	es	a
C	18-42	D 10YR 7/3 M 10YR 6/3	–	CL	2c bk/ 2m bk	D - sh M - fr	–	1f	–	es	a
R	42"+	Sand Stone, hard									

Vegetation: W. Wheat, Slender W., June grass, B. Grama, C. Needle
various Forbes & Sage

(Instructions inside back cover)

Form 7310–9 (December 1970)

FC 506-507 (2) (19) 900'N., 550'W of SW. Cor

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
rv	8/75
Location 3., 9S., 45E (19) 900' N., 550' W of SW Cor	
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	75			

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 25	2. District 02	3. Planning Unit 213	4. Vegetation–Soil Unit Mixed / 9012	5. Soil Map Symbol 012 / 83N	6. Surname Thomas Frechtl	7. Date 8 mo 75 yr
8. Area --	9. County 075	10. Location Sec. 9, T. 9S, R. 45E	11. Photo No. —	12. Writeup No. 7	13. File No. —	14. Parent Rock Sandstone
15. Formation Name Fort Union	16. Surface Conditions (percent) Stone 0 Rock 0	17. Land Conditions Alkaline — Saline Non-Mod. Water table —				18. Landform Colluvium over Residual [illegible]
19. Slope (percent) 4-8% ☐ Single ☑ Complex	20. Aspect SW	21. Elevation 3860	22. Present Erosion Moderate Type Sheet, Rill & Gullies SSF — Class —			23. Hydrologic Group —
24. Precipitation (in) 14.75 1st, 2nd ✓, 3rd ✓, 4th	25. Temperature – Air – Soil	26. Frost-free Days 144 > 28°	27. Drainage Class well drained	28. Infiltration Mod.	29. Percolation Slow-Moderate	30. ERD — in / 31. AWC 5.8 in

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
A1	0-1"	D 10YR 7/3 M 10YR 6/3	—	L	2 copl / 1 f abk	D sh M s	—	2f	—	e	a
AB	1-6"	D 10YR 6/3.5 M 10YR 5/3.5	—	CL	1 cpr / 2 m abk	D - h M - fr	—	2f	—	e	g
B2	6-12	D 10YR 6/3.5 M 10YR 5/3.5	—	CL	2 cpr / 3 m abk	D - h M - fr	—	2f	—	es	a
B3	12-30	D 10YR 6/4 M 10YR 5/4	—	CL	2 cpr / 2 c abk	D - h M - fi	—	2f	—	es	g
C1	30-48	D 10YR 6/4.5 M 10YR 5/4.5	—	CL	1 cpr / 1 c bk	D - sh M - fr	—	1f	—	ev	g
CR1	48-60	varying from 7.5YR 5/6 - 10YR 4/3 (M)	—	S Sh CL	—	—	—	—	—	—	a
2	60-72	—	—	S Sh CL	—	—	—	—	—	—	a
3	72-90	—	—	S Sh CL	—	—	—	—	—	—	a
4	90-108	—	—	S Sh CL	—	—	—	—	—	—	a

(Instructions inside back cover)

Form 7310–9 (December 1970)

FC 139-146(8) (7) 900'E., 500'S of NE 1/4 Cor.

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: NY | Date: 8/75

Location: 4-9-45 (7) 900'E, 500'S of N1/4C

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 1/2" to 6" deep occur in exposed places at approximately 10' intervals (7) 8 9	Rills 1/2" 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				
		46			

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: 25
2. District: 020
3. Planning Unit: 213
4. Vegetation–Soil Unit: Mixed / 9001
5. Soil Map Symbol: B2N
6. Surname: Thomas Fiechtl
7. Date: — mo — yr
8. Area: —
9. County: 075
10. Location: Sec. 33, T. 9 S, R. 45E
11. Photo No.: —
12. Writeup No.: —
13. File No.: —
14. Parent Rock: Sand Stone
15. Formation Name: Fort Union
16. Surface Conditions (*percent*): Stone 0 – Rock 0
17. Land Conditions: Alkaline low; Saline high; Water table 76"
18. Landform: Alluvial
19. Slope (*percent*): 2-4%; [X] Single [ ] Complex
20. Aspect: NE
21. Elevation: 3800
22. Present Erosion: Slight to none; Type: Sheet; SSF — Class —
23. Hydrologic Group: —
24. Precipitation (*in*): 14.75; 1st, 2nd ✓, 3rd ✓, 4th
25. Temperature: — Air — Soil
26. Frost-free: Days 144 -> 28°
27. Drainage Class: Well drained
28. Infiltration: Mod.
29. Percolation: Mod. slow
30. ERD: — in
31. AWC: 8.0 in

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	0-7"	D 10YR 6/3 M 10YR 5/3	—	CL	2 c pl / 2 f sbk	D - sh M - fr	—	2f	—	e	g
B	7-18	D 10YR 7/4 M 10YR 5/4	—	CL	1 c pr / 3 c sbks	D - sh M - fr	—	2f	—	es	g
C1	18-36	D 10YR 7/4 M 10YR 5/4	—	L	massive / 3 c bks	D - sh M - vfr	—	2f	—	es	g
2	36-54	D 10YR 6/3 M 10YR 5/3	—	FSL	—	D - h M - vfr	—	1f	—	es	—
3	54-78	D 10YR 6/3 M 10YR 7/3	—	CL	—	D - h M - fr	—	—	—	es	—
	78-102	D 10YR 5/4 M 10YR 5/3	—	CL	—	D - h M - fr	—	—	—	es	—

Vegetation: Alfalfa & tame grasses (cultivated)
Soil mapped Havrelon, channeled

(Instructions inside back cover)

Form 7310–9 (December 1970)

FC 46-51., (8) 1600'S., 800'W of N1/4 Cor.

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: [handwritten initials] Date: 7/75

Location: 33-8-45 (8) 1600'S, 800'W of N1/4 C

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 [illegible] 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 1/2" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills 1/2" 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

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
25	02	213	Mixed / 9010	010 / B2A	Thomas Ziecktl	7 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
—	15	Sec. 34, T. 8 S, R. 45 E	—	—	—	Baked Rock

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone 0 Rock 0	Alkaline — Saline Slight Water table —	Residual

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
4-6% ☐ Single ☑ Complex	S	3800	Slight; Type Sheet; SSF — Class —	—

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
14.75; 1st, 2nd ✓, 3rd ✓, 4th	— Air — Soil	Days 144 > 28°	Well drained	Moderate	Moderate	— in	7.7" in

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.	0-2"	D: 10YR 5/3 M: 10YR 4/3	—	SiL	1 m abk / 1 m cr	D: lo M: lo	—	2f		es	g
B2	2-6"	D: 10YR 4.5/3 M: 10YR 3.5/3	—	CL	2 m pr / 2 m abk	D: sh M: fr	1 m pf	2f		es	g
B3ca	6-18	D: 10YR 6/3 M: 10YR 5/3	—	CL	2 c pr / 2 c cbk	D: sh M: fr	—	2f		es	g
C1	18-42	D: 10YR 6.5/4 M: 10YR 5/4	—	CL	1 c pr / 1 c cbk	D: sh M: fr	—	1f		es	g
2	42-60	D: 10YR 6.5/3 M: 10YR 5.5/3	—	CL	—	—	—	—		es	g
3	60-78	—	—	CL	—	—	—	—		es	—
	78-102	—	—	CL	—	—	—	—		e	—
	102-120	—	—	CL	—	—	—	—		e	—

(Instructions inside back cover)

Form 7310–9 (December 1970)

FC 275-282 (8) (29) 1650'S., 250'W. of N 1/4 Cor.

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 W | Date 7/75

Location 34-S-45 (20) 1650'S., 250'W 7-W'14C

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 ... 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	28			

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 25
2. District 02
3. Planning Unit 213
4. Vegetation–Soil Unit Mixed / 9012
5. Soil Map Symbol 012 B2N
6. Surname Thomas Stricktl
7. Date 7 mo 75 yr
8. Area —
9. County 75
10. Location Sec. 34, T. 8, R. 45E
11. Photo No. —
12. Writeup No. —
13. File No. —
14. Parent Rock Sandstone
15. Formation Name Fort Union
16. Surface Conditions (percent) Stone 0 Rock 0
17. Land Conditions Alkaline — Saline Mod-Mod. Water table 78"
18. Landform Colluvium over Residual shales
19. Slope (percent) 4-10% ☐ Single ☑ Complex
20. Aspect W
21. Elevation 3840
22. Present Erosion Slight Type Sheet & Rill SSF — Class —
23. Hydrologic Group —
24. Precipitation (in) 14.75 1st, 2nd ✓, 3rd ✓, 4th
25. Temperature — Air — Soil
26. Frost-free Days 144 -> 28°
27. Drainage Class Well drained
28. Infiltration Mod.
29. Percolation Slow-Mod Slow
30. ERD — in
31. AWC 6½ in

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 7/3 M 10YR 5/3	—	CL	1 c sbk / 1 m sbk	D - sh M - fr	—	2f	—	ve	
B1	6-9	D 10YR 6/3 M 10YR 5/3	—	CL	2 m pr / 2 m sbk	D - sh M - fr	—	2f	—	e	
B2	9-13	D 10YR 5/3 M 10YR 4/3	—	CL	2 m pr / 2 m sbk	D - sh M - fr	1 mpf	2f	—	es	
B3	13-18	D 10YR 6/3 M 10YR 4/4	—	CL	2 c pr / 2 c sbk	D — M - vfr	—	2f	—	es	
C1	18-30	D 10YR 6/3 M 10YR 5/3	—	CL	1 c pr / 1 c sbk	D — M - vfr	—	2f	—	es	
C2	30-36	D 10YR 6/3 M 10YR 5.5/3	—	CL	—	—	—	1f	—	es	
CR	36+	sandy Shale	—	—	—	—	—	—	—	—	

Textures approaching Silty Clay Loam with 96"+ approaching a SiC., Water table @ 78"+..

Vegetation: Alfalfa & tame grasses

(Instructions inside back cover)

FC 182-185 (4) ④ 900'E., 850'S. of SW Cor.

Form 7310–9 (December 1970)

X2

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By	Date
RT	7/75
Location 34-8-45 (4) 900'E 850'S. of SW Cor	
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				
		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

VEGETATION–SOIL DESCRIPTION

1. State 25	2. District 02	3. Planning Unit 213	4. Vegetation–Soil Unit Alfalfa / 9010	5. Soil Map Symbol 010/82M	6. Surname Thomas Frecht	7. Date 7 mo [illegible] yr
8. Area –	9. County 075	10. Location Sec. 32, T. 8S, R. 45E	11. Photo No. –	12. Writeup No. –	13. File No. –	14. Parent Rock Sandstone

15. Formation Name Fort Union	16. Surface Conditions (percent) Stone – Rock –	17. Land Conditions Alkaline — Saline — Water table —	18. Landform Alluvium
19. Slope (percent) 4-8% ☐ Single ☑ Complex	20. Aspect NE / 21. Elevation 3850	22. Present Erosion Slight Type Sheet SSF – Class –	23. Hydrologic Group –

24. Precipitation (in) 14.75 1st, 2nd ✓, 3rd –, 4th	25. Temperature – Air – Soil	26. Frost-free Days 144 -> 28°	27. Drainage Class Well drained	28. Infiltration Mod.	29. Percolation Slow - Mod. Slow	30. ERD – in	31. AWC 9.5 in

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	10YR 6/3 10YR 3/3	—	FSL	1 m abk	D: so M: fr	—	2 f	—	—	a
B2	6-24	10YR 5/3 10YR 4/3	—	L	2 c pr / 2 c abk	D: h M: fr	—	2 f	—	e	c
Cca	24-42	10YR 5/4 10YR 6/4	—	L	1 c pr / 2 c abk	D: h M: fr	—	2 f	—	e	a
C2	42-60	10YR 6/4 10YR 5/4	—	L	massive / 2 c abk	D: sh M: fr	—	1 f	—	e	c
C	60-84	10YR 6/4 10YR 5/4	—	L	—	D: sh M: fi	—	—	—	e	d
C	84-96	10YR 6/4 10YR 5/4	c 3 p	CL	—	D: h M: vfi	—	—	—	es	a
C	96-120	10YR 7/[illegible] 10YR 6/3	—	L	—	D: sh M: fr	—	—	—	e[illegible]	a
R	Shale	10YR 6/[illegible] 10YR 3/[illegible]	—	SiC	—	—					

Vegetation: Alfalfa, with scattered [illegible] grasses (annual)
Profile contains [illegible] B2 horizon... Some free water @ 84"+, also lime nodules & mottlings... [illegible] horizons of shale @ 96"+. Shale is SiC.

(Instructions inside back cover) ⑤ 1350' E., 500' N of W 1/4 Cor. Form 7310–9 (December 1970)

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By YY | Date 7/75

Location 33-8-45
(5) 1350'N., 500'N. of W 1/4 Co

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 1/2" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills 1/2" 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	23			

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 25 | 2. District 02 | 3. Planning Unit 213 | 4. Vegetation–Soil Unit Mixed / 9012 | 5. Soil Map Symbol 012/C3N | 6. Surname Thomas Becht l | 7. Date 7 mo 75 yr

8. Area — | 9. County 075 | 10. Location Sec. 33, T. 8 S, R. 45 E | 11. Photo No. — | 12. Writeup No. — | 13. File No. — | 14. Parent Rock Sand Stone

15. Formation Name: Fort Union | 16. Surface Conditions (percent) Stone 0 Rock 0 | 17. Land Conditions Alkaline — Saline Mod. Water table — | 18. Landform Residual Side Slope

19. Slope (percent) 8-35% ☐ Single ☒ Complex | 20. Aspect NE | 21. Elevation 3840 | 22. Present Erosion slight – [illegible]. Type Sheet, Rill, SSF — Class — | 23. Hydrologic Group —

24. Precipitation (in) 14.75 1st, 2nd, 3rd, 4th | 25. Temperature — Air — Soil | 26. Frost-free Days 144 > 28° | 27. Drainage Class Excessively Drained | 28. Infiltration Mod. slow | 29. Percolation Slow - Mod. slow | 30. ERD — in | 31. AWC 7.7 in

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	0-3"	D: 10YR 6/3 M: 10YR 5/4	—	CL	1 c pl / 1 c gr	D: so M: vfr	—	2f	—	e	a
B2	3-12"	D: 10YR 5/4 M: 10YR 5/3	—	CL	2 m pr / 2 m sbk	D: h M: fr	—	2f	—	es	g
B3	12-18"	D: 10YR 6/3 M: 10YR 5/3	—	CL	2 m pr / 2 m sbk	D: h M: fr	—	2f	—	es	a
C1	18-30"	D: 10YR 6/3 M: 10YR 5/3	—	> CL	2 c-vc sbk	D: h M: fi	—	2f	—	es	g
2	30-42"	D: 10YR 6/3 M: 10YR 5/1	M: 10YR 5/6	> CL (shaley)	—	—	—	1f	—	ve	a
CR	42-60	D: 10YR 6/3 M: 10YR 5/2.5	—	Sandy Shale	—	—	—	—	—	ve	a
	60-60	D: 10YR 5/2 M: 10YR 4/1.5	—	Sandy Shale	—	—	—	—	—	ve	a

Sandy shales high in silt (%)
Vegetation: W. Wheat, G. needle, Needle & Thread, B. Grama
June Grass, Blue Grass, alf., G. needle in swales,
Winter Fat, Snake Weed, etc. Shrubs, S. Sage, Fringe
Sage Wort. Surface Moderate to severely eroded.

(Instructions inside back cover)

FC 63-67(5) (11) 1200' N., 500' W of SW Cor.

Form 7310–9 (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: r | Date: 7/75

Location: 33-8-45 (11) 1200' N., 500' W of SW Cor

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	38			

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
25	02	213	Mixed / 9010	11c B3N	Thomas: Hechtl	7 mo 75 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	075	Sec. 4, T. 1, R. 45E		--	--	Sandstone

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone 0 Rock 0	Alkaline low Saline high Water table —	Colluvium over Residual mtl.

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
6-8% ☐ Single ☑ Complex	N	3820	Slight - Moderate; Type Sheet & Rill; SSF — Class —	—

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
14.75 (1st, 2nd ✓, 3rd ✓, 4th)	— Air — Soil	Days 144 > 28°	Excessive	Slow - Mod. slow	Mod.	— in	8.8 in

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
A1	0-2"	D 10YR 6.5/4 M 10YR 5/3	—	L	2 vc pl / 2 c cr	D lo M lo	—	2f	—	ve	
B1	2-6"	D 10YR 6/3 M 10YR 5/3	—	CL	1 c pr / 2 m abk	D sh M fr	—	2f	—	e	
B2	6-12	D 10YR 6/3 M 10YR 5/3	—	CL	3 m pr / 3 m abk	D sh M fr	—	2f	—	es	
B3	12-30	D 10YR 7/4 M 10YR 5/3	—	CL	1 c pr / 2 m abk	D sh M fr	—	2f	—	es	
C1	30-54	D 10YR 7/3 M 10YR 6/4	—	CL	1 c abk	D h M fr	—	1f	—	es	
C2	54-72	D 10YR 6/3 M 10YR 5/4.5	—	CL	—	D h M fr	—	—	—	es	
C3	72-90	D 10YR 6/3.5 M 10YR 5/3.5	—	L	—	D h M fr	—	—	—	ev	
CR	90-120	D 10YR 6/3 M 10YR 6/3	— sandy shale	CL	—	—	—	—	—	none	

Upper 12" of C1 contains few lime mottlings

Vegetation: W. wheat., B. grama, D. Brome, Indian Ri. grass, N. needle, Winter fat, R. brush, various forbes.

(Instructions inside back cover)

FC 118-193 (4) (6) 500' W. 450' S of N 1/4 Cor.

Form 7310–9 (December 1970)

Form 7310-12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By: W | Date: 7/75

Location: 4-9-45 (6) 500'W., 450'S of N1/4 Co.

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	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

VEGETATION–SOIL DESCRIPTION

1. State 25 | 2. District 02 | 3. Planning Unit 213 | 4. Vegetation–Soil Unit Mixed / 9010 | 5. Soil Map Symbol 010 BEN | 6. Surname Thomas Frechl | 7. Date 7 mo 75 yr

8. Area – | 9. County 075 | 10. Location Sec. 11, T. [illegible], R. [illegible] | 11. Photo No. – | 12. Writeup No. – | 13. File No. – | 14. Parent Rock Sandstone & Sandy Shale

15. Formation Name Fort Union | 16. Surface Conditions (percent) Stone – Rock – | 17. Land Conditions Alkaline slight Saline slight-mod. Water table — | 18. Landform Colluvium

19. Slope (percent) [illegible] ☐ Single ☒ Complex | 20. Aspect S | 21. Elevation 3920 | 22. Present Erosion slight Type Sheet & Rill SSF – Class – | 23. Hydrologic Group —

24. Precipitation (in) 14.75 1st, 2nd ✓, 3rd ✓, 4th | 25. Temperature – Air – Soil | 26. Frost-free Days 144 > 28° | 27. Drainage Class Mod. | 28. Infiltration Mod. slow | 29. Percolation Mod. slow | 30. ERD – in | 31. AWC 5.5+ in

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
A2	< 1	(D) 10YR 6/2 (M) " 5/2	–	[illegible]	2 m pl / 2 m bk	(D) sh (M) fr	—	[illegible]	–	—	a
A3	1-5"	(D) 10YR 6/3 (M) 5/3	–	[illegible]	1 m pr 2 c bk	(D) h (M) fr	—	[illegible]	–	—	g
B2t	5-10"	(D) 10YR 5/3 (M) 4/2	–	CL	2 m pr / 2 m bk	(D) h (M) fr	[illegible]	[illegible]		—	a
B22t	10-13"	(D) 10YR 5/3 (M) 4/2		CL	3 m pr / 3 f bk	(D) h (M) fr	[illegible]	2f	–	—	g
B3ca	13-18"	(D) 10YR 5/3 (M) 5/3		[illegible]	2 c pr / 2 m bk	(D) h (M) fr	—	2f		e	g
C1ca	18-30"	(D) 10YR 6.5/3 (M) 5/3	–	CL	2 c pr / 2 m bk	(D) h (M) fr	—	—	–	es	g
C2ca	30-54	(D) 10YR 7/2 (M) 5/2		CL	Mass [illegible]	(D) h (M) fr	—	—	–	es	d
	54-78	10YR 6/2 5/3	–	[illegible]	–				–	es	—
	78-96	10YR 6.5/3 5/3		[illegible]	—				–	es	—
	96-120+	10YR 6/2 5/1	–	[illegible]	–					es	

(Many) fine lime mottlings @ 18-30". Gray-out spots 50% of area with a few pan spots in area.

Veg: W. Wheat, [illegible], E Prune, J grass, [illegible], C wheat

(Instructions inside back cover)

Form 7310–9 (December 1970)

(29) 1700' W., 1535' of E 1/4 [illegible]

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 W | Date 9/75

Location 11 -93- 45E
(29) 1700'W., 150'S of E1/4 Corner

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	23			

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 25	2. District 02	3. Planning Unit 213	4. Vegetation–Soil Unit [illegible] / 9010	5. Soil Map Symbol 010 / C3 N	6. Surname Thomas Frechtl	7. Date 7 mo 75 yr
8. Area --	9. County 075	10. Location Sec. 22, T. [illegible], R. [illegible]	11. Photo No. —	12. Writeup No. —	13. File No. —	14. Parent Rock Sand Stone
15. Formation Name Fort Union	16. Surface Conditions (percent) Stone -- Rock --	17. Land Conditions Alkaline slightly Saline slightly Water table —				18. Landform Colluvium
19. Slope (percent) 4-12% ☐ Single ☑ Complex	20. Aspect N	21. Elevation 3850	22. Present Erosion Moderate Type Sheet & Rill SSF — Class —			23. Hydrologic Group —
24. Precipitation (in) 14.15 1st, 2nd ✓, 3rd ✓, 4th	25. Temperature — Air — Soil	26. Frost-free Days 144 > 28°	27. Drainage Class Excessive	28. Infiltration Very slow-slow	29. Percolation mod.	30. ERD -- in / 31. AWC [illegible] in

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
A1	0-4	D 10YR 6/3 M 10YR 5/3	—	L	1 vc pl / 1 m abk	D-sh M-fr	—	2 f	—	ve	[illegible]
B1t	4-10	D 10YR 6/4 M 10YR 5/4	—	CL	2 m pr / 2 m abk	D-sh M-fr	—	2 f	—	e	g
B2t	10-18	D 10YR 5/4 M 10YR 4/3	—	CL	3 m pr / 3 m abk	D-sh M-fr	2t pf	2 f	—	es	g
B3ca	18-30	D 10YR 6/3 M 10YR 5/4	—	CL	2 m pr / 2 m abk	D sh M fr	—	2 f	—	es	g
C1	30-54	D 10YR 6/4 M 10YR 5/4	—	CL	1 c pr / 1 c abk	D-sh M-fr	—	1 f	—	es	g
2	54-78	D 10YR 7/3 M 10YR 6/3	—	FSL	massive / 1 m abk	D-so M—	—	—	—	ev	g
R	78"+	—	—	—	—	—	—	—	—	—	—

Vegetation determined by site & location: Wheat.
G. [illegible], [illegible] Reed, [illegible], B. [illegible], Forbes & Sage
Auger stopped @ 2 attempts by Sand Stone.

(Instructions inside back cover)

[illegible] E 1/4 [illegible]

Form 7310–9 (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 𝑁 | Date 7/75

Location 33-8-5-4 (17) 950' N., 650' W of E1/4 Cor

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				

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
25	02	213	Mixed / 9007	27 B3N	Thomas Frecht	2 mo 7_ yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
—	071	Sec. 2, T. 9S, R. 45E	—	—	—	Sandstone & Sandy Shale

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone — Rock —	Alkaline Mod. Saline Slight Water table —	Colluvium over Sandy shales.

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
2-4%; Single [ ] Complex [✓]	N	3890	Moderate; Type Sheet. 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 144 > 28°	Mod. Well	Slow	Slow	— in	7.7 in

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	0-4	D: 10YR 6.5/2 M: 10YR 5/2	—	[illegible]	1 m cpr / 2 m sbk	D: h M: fr	—	[illegible]	—	ve	—
B2	4-12	D: 10YR 6/3 M: 10YR 5/3	—	[illegible]	2 m pr / 2 m sbk	D: h M: fr	—	[illegible]	—	e	[illegible]
B3ca	12-18	D: 10YR 6/3 M: 10YR 5/3	many lime mottles	[illegible]	1 m pr / 2 m sbk	D: h M: fr	—	[illegible]	—	es	[illegible]
C1	18-30	D: 10YR 4/4 M: 10YR 5/4	—	[illegible]	1 m pr / 1 m sbk	D: h M: fr	—	[illegible]		es	[illegible]
C2	30-42	D: 10YR 6.5/4 M: 10YR 5/4	—	[illegible]	massive	D: h M: fr	—	[illegible]		es	[illegible]
C3	42-60	D: 10YR 6/3 M: 10YR 5/3	—	[illegible]	massive	D: h M: fr	—	[illegible]	—	es	[illegible]

a thin (1/2") vesicular – thick platy A2 horizon forming over a medium very weak cpr. This is a transitional zone in development reforming in old Ap. Pansgut is mapped in association with weak Hydro soil.

Vegetation: [illegible], [illegible], [illegible], W. Wheat, R. brush.
[illegible] in a [illegible] regime, 35% surface [illegible].

(Instructions inside back cover)

Form 7310–9 (December 1970)

(33) 1050'N, 700'E of SW Cor.

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
M	8/75
Location 2. T9S., R45E (33) 1050'N., 700'E of SW Cor	
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				
		42			

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
25	02	213	Mixed, 9015	15 / B2N	Thomas Frichtl	– mo – yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
–	75	Sec. 3, T. 9S, R. 45E	–	–	–	Sandstone

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Fort Union	Stone – Rock –	Alkaline Mod. Saline Mod. Water table —	Alluvium

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
2-4% ☐ Single ☑ Complex	SW	3860	Slight; Type Sheet; SSF – Class –	—

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
14.75; 1st, 2nd ✓, 3rd ✓, 4th	– Air – Soil	Days 141 > 28°	Moderate	Mod. - Mod. Slow	Moderate	– in	5.5 in

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
A2	0-1	D 10YR 5/3 M 10YR 4/2		L	2 mpl/ 2 vfgr	D: so M: fr	—	2f	—	e	
AB	1-4	D 10YR 5/3 M 10YR 4/2		CL	1 mpr/ 2 m sbk	D: sh M: fr	—	2f	—	es	a
B2	4-8	D 10YR 5/3 M 10YR 4/3		CL	2 mpr/ 3 f sbk	D: sh M: fr	2 mpf	2f	—	es	g
B3ca	8-12	D 10YR 6/3 M 10YR 5/3		CL	1 mpr/ 2 m sbk	D: h M: fr	—	2f	—	es	g
C1	12-30	D 10YR 6.5/3 M 10YR 5/3		CL	1 mpr/ 1 m sbk	D: sh M: fr	—	2f	—	es	c
C2	30-48	D 10YR 6.5/3 M 10YR 5/3		CL	—	—	—	—	—	es	c
C3	48-66	D 10YR 6/3 M 10YR 5/3		CL	—	—	—	—	—	es	c

Surface 4" appears to be old Ap with somewhat bleached surface 1" and a very weak cpr @ 2-4"; 5-35% pan spots area; 30-48" depth with many lime mottlings ..., decreasing % of sands @ 48"+, CL SSh @ 114" with high % silts.

Vegetation mainly crested wheat with alfalfa.

(Instructions inside back cover) Form 7310–9 (December 1970)

FC 560-565 (7) (35) 900'S., 350' W of E 1/4 Cor.

Form 7310–12
(May 1973)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

By VH | Date 8/75

Location 3-9-45 (35) 900'S., 350'W of E1/4 Cor.

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 – 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 1/2" to 6" deep occur in exposed places at approximately 10' intervals 7 8 9	Rills 1/2" 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 dr area 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)

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 saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called plerotic water; phreatic water.

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, Lime, from 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.

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 G

GREENHOUSE

Table 35—Bear Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	Germination: Days After Seeding for Ten Plants to Emerge II	Germination: Number of Seeds Germinated I	Germination: Number of Seeds Germinated II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	Harvest: Plant Dry Weight (gm) II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	Harvest: Average Plant Height (cm) II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
75-101- 5	34.6 - 42.5	2	7	7	31	25	1	1	3.13	2.90	73	22	30	0	1	19.5
75-101- 8	68.8 - 75.3	2	7	8	26	24	0	2	2.70	3.70	77	23	32	1	1	19.7
75-101-11	112.9 - 138.0	2	7	8	31	26	1	0	2.79	2.29	61	25	29	0	0	13.1
75-101-12	138.0 - 145.9	2	8	9	24	24	0	1	3.36	3.26	80	25	26	0	1	21.0
75-101-13	145.9 - 167.7	2	8	9	37	34	2	0	2.39	1.92	52	24	26	1	0	15.4
75-101-14	167.7 - 182.4	2	8	7	23	23	0	1	1.16	2.43	43	17	28	0	1	17.8
75-101-15	182.4 - 187.5	2	9	7	35	35	0	1	1.97	2.31	52	24	26	1	0	14.3
75-101-17	230.9 - 244.7	2	8	11	31	17	0	0	1.50	1.36	34	22	23	1	1	14.1
75-102- 1	0.0 - 34.0	2	23	18	20	22	2	2	0.96	0.88	22	17	25	1	1	20.0
75-102- 2	34.0 - 54.7	2	9	8	20	20	0	1	1.81	2.02	46	21	27	1	1	21.2
75-102- 4	57.7 - 63.6	2	8	9	24	16	0	0	2.11	1.44	43	23	26	0	1	21.2
75-102- 6	75.1 - 96.1	2	7	7	17	23	1	0	2.43	1.83	51	20	29	0	1	18.0
75-102- 9	121.6 - 128.5	2	6	8	36	30	0	1	4.65	4.60	111	27	30	1	1	21.6
75-102-10	128.5 - 150.0	2	7	7	19	30	0	3	3.95	3.72	92	29	32	0	1	29.2
75-104- 2	8.3 - 24.8	2	7	9	23	30	0	1	1.57	1.65	39	22	24	1	1	16.7
75-104- 3	25.9 - 62.5	2	8	8	23	34	1	0	2.11	2.11	51	24	27	1	2	15.5
75-102- 4	62.5 - 80.8	2	7	7	34	38	0	1	3.88	4.43	100	24	24	2	1	17.4
75-104- 5	80.8 - 93.2	2	8	8	19	19	0	0	1.29	1.08	29	18	26	1	4	13.8

Table 35 (cont.) Bear Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
75-104- 6	93.2 - 98.6	2	8	7	31	31	2	1	3.75	3.77	91	26	34	1	1	19.4
75-104- 7	98.6 - 138.5	2	8	7	23	32	0	1	1.94	2.44	53	23	31	0	0	20.0
75-104- 8	162.1 - 183.1	2	8	10	31	29	0	0	1.63	1.80	41	19	22	1	0	13.5
75-104- 9	183.1 - 219.5	2	8	8	28	22	1	1	2.06	1.81	47	25	27	0	1	16.1
75-104-10	219.5 - 227.8	2	8	8	28	26	0	0	0.84	0.95	22	16	23	2	2	12.4
75-104-11	227.8 - 285.0	2	8	7	21	28	1	1	2.72	3.17	71	25	32	1	1	16.5
T - 46	0.0 - 1.5	2	6	6	35	34	0	0	3.56	3.59	86	24	30	1	1	16.2
T - 47	1.5 - 3.0	2	6	6	35	36	1	1	2.79	3.50	76	25	28	1	0	13.0
T - 48	3.0 - 4.5	2	6	6	38	40	1	1	2.80	2.14	60	23	26	1	1	11.8
T - 49	4.5 - 6.5	2	7	7	29	37	2	0	3.01	2.43	66	27	24	1	2	13.9
T - 50	6.5 - 8.0	2	7	7	26	37	1	0	2.27	2.28	55	24	29	3	1	13.5
T - 51	8.0 - 10.0	2	6	8	24	25	1	0	1.92	1.87	46	20	22	1	1	12.9
T - 63	0.0 - 1.5	2	6	6	37	39	3	0	2.29	2.31	55	25	24	0	1	17.7
T - 64	1.5 - 2.5	2	8	8	33	39	3	1	1.63	1.53	38	21	26	1	0	18.0
T - 65	2.5 - 3.5	2	8	7	33	31	2	2	1.12	1.39	30	21	26	1	1	18.2
T - 66	3.5 - 4.5	2	8	7	23	31	3	0	1.38	1.66	37	26	27	1	1	18.5
T - 67	4.5 - 5.5	2	8	8	36	29	3	2	1.41	2.10	42	20	27	1	1	19.8

Table 35 (cont.) Bear Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
T - 118	0.0 - 1.0	2	6	6	40	40	0	0	2.95	3.15	73	25	27	1	0	17.5
T - 119	1.0 - 2.5	2	7	7	36	34	1	1	2.59	2.44	61	23	27	1	2	21.1
T - 120	2.5 - 4.5	2	8	9	19	22	0	2	1.25	1.24	30	23	25	2	1	18.9
T - 121	4.5 - 6.0	2	11	11	35	30	2	1	1.29	1.06	28	18	22	1	2	18.9
T - 122	6.0 - 7.5	2	14	13	20	18	0	0	1.10	1.03	26	17	19	2	1	16.5
T - 123	7.5 - 10.0	2	8	13	22	28	2	2	1.26	0.71	24	22	18	3	1	21.0
T - 139	0.0 - 0.5	2	6	6	36	40	1	1	3.67	2.87	79	26	27	0	1	18.7
T - 140	0.5 - 1.0	2	6	6	39	38	0	0	3.01	3.68	81	19	31	2	1	19.3
T - 141	1.0 - 2.5	2	8	7	38	37	2	0	2.50	2.48	60	21	31	0	2	20.3
T - 142	2.5 - 4.0	2	13	10	24	21	1	4	0.93	0.96	23	18	19	0	1	19.2
T - 143	4.0 - 5.0	2	10	9	24	32	2	4	0.93	1.13	25	16	18	0	1	24.7
T - 144	5.0 - 6.0	2	15	15	20	25	3	3	0.30	0.42	9	12	12	0	3	20.9
T - 145	6.0 - 7.5	2	28	24	11	16	4	4	0.12	0.24	4	9	13	1	0	24.5
T - 146	7.5 - 9.0	2	8	8	31	33	1	4	2.05	1.63	44	24	21	1	0	23.1
T - 182	0.0 - 1.5	2	6	6	34	36	1	0	3.03	3.13	74	26	28	2	1	16.0
T - 183	1.5 - 2.5	2	7	7	35	36	2	1	2.04	2.08	50	23	24	1	0	17.1
T - 184	2.5 - 3.0	2	16	**	23	6	4	3	0.43	0.08	6	7	5	0	3	18.5
T - 185	3.0 - 4.0	2	18	20	20	14	4	3	0.10	0.20	4	6	8	0	2	16.9

** Sample had less than 10 plants germinated.

Table 35 (cont.) Bear Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
T - 244	0.0 - 0.5	2	6	6	40	39	1	1	4.02	3.66	93	26	30	1	0	15.3
T - 245	0.5 - 1.0	2	8	8	30	35	0	2	1.34	1.20	31	19	25	2	1	16.9
T - 246	1.0 - 2.5	2	11	10	31	27	0	1	1.46	1.40	34	23	21	1	1	14.4
T - 247	2.5 - 4.0	2	11	8	32	28	1	3	1.52	1.31	34	21	22	0	0	14.5
T - 248	4.0 - 5.5	2	10	8	29	28	0	1	1.54	1.23	33	22	25	0	0	15.0
T - 249	5.5 - 7.0	2	18	13	36	24	2	2	0.92	1.54	30	20	23	0	0	15.3
T - 250	7.0 - 8.0	2	13	10	25	26	1	2	1.16	1.07	27	22	25	0	0	15.3
T - 251	8.0 - 9.5	2	7	9	39	30	0	2	2.36	1.87	51	24	24	0	0	14.7
T - 276	0.0 - 0.5	2	6	6	40	37	0	0	2.87	2.50	65	27	29	1	1	12.5
T - 277	0.0 - 1.5	2	6	6	40	38	0	0	1.89	2.10	48	22	25	0	0	10.9
T - 278	1.5 - 3.5	2	6	6	39	38	0	0	3.05	2.81	71	25	28	1	1	10.8
T - 279	3.5 - 5.0	2	7	7	40	39	0	0	2.42	2.25	56	25	27	1	0	10.8
T - 280	5.0 - 6.5	2	9	7	35	33	0	0	1.77	1.86	44	23	25	2	1	10.9
T - 281	6.5 - 8.5	2	7	8	36	39	1	0	2.63	2.03	56	21	24	2	1	13.1
T - 282	8.5 - 10.0	2	9	8	36	31	2	0	2.70	2.80	66	25	32	3	1	12.9
T - 303	0.0 - 0.8	2	6	6	38	37	4	0	4.24	4.40	104	22	30	1	2	14.1
T - 304	0.8 - 1.3	2	7	9	37	31	2	2	1.98	1.47	42	23	22	2	1	17.0
T - 305	1.3 - 2.5	2	10	8	23	24	3	2	0.83	0.93	21	17	22	1	0	19.2

Table 35 (cont.) Bear Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
T - 306	2.5 - 3.5	2	**	**	3	9	4	4	0.25	0.39	8	13	13	0	1	17.9
T - 307	3.5 - 5.5	2	18	14	13	16	3	3	0.77	1.24	24	17	26	0	0	22.0
T - 308	5.5 - 8.0	2	11	10	35	26	0	0	1.44	1.11	31	18	23	1	0	14.3
T - 309	8.0 - 10.0	2	8	8	40	37	0	0	1.96	2.19	50	23	28	0	0	18.7
T - 358	0.0 - 0.6	2	6	6	38	37	0	0	3.08	3.30	77	24	26	1	0	14.5
T - 359	0.6 - 1.3	2	7	7	38	36	0	0	2.56	2.36	59	21	24	1	0	14.8
T - 360	1.3 - 2.5	2	6	7	30	32	2	1	2.08	2.16	51	22	26	0	0	10.8
T - 361	2.5 - 4.0	2	8	7	34	35	1	1	1.78	1.78	45	20	22	1	0	13.4
T - 492	0.0 - 0.4	2	6	6	38	38	0	0	2.71	3.10	70	24	25	1	0	12.8
T - 493	0.4 - 1.2	2	6	6	36	38	1	1	2.27	2.10	53	23	26	1	1	12.4
T - 494	1.2 - 1.5	2	6	6	38	37	2	0	2.63	2.50	62	24	25	1	1	11.4
T - 495	1.5 - 3.0	2	7	6	40	38	0	0	2.16	2.23	53	22	27	0	1	11.2
T - 496	3.0 - 5.5	2	7	7	37	39	2	0	2.17	1.98	50	19	28	1	1	13.4
T - 497	5.5 - 7.0	2	8	9	33	33	4	0	1.79	2.09	47	23	27	0	1	17.0
T - 498	7.0 - 10.0	2	10	9	33	39	3	0	1.41	1.61	36	19	24	2	2	14.9
T - 506	0.0 - 1.5	2	8	8	38	34	1	1	2.79	2.09	59	26	30	2	1	20.7
T - 507	1.5 - 3.0	2	18	13	17	16	3	4	0.42	0.59	12	13	16	0	1	19.7

** Sample had less than 10 plants germinated.

Table 35 (cont.) Bear Creek Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
T - 560	0.0 - 1.0	2	6	6	38	39	1	1	2.94	2.66	67	25	28	1	1	14.9
T - 561	1.0 - 2.5	2	8	9	30	29	3	2	1.53	1.43	36	22	24	1	1	17.0
T - 562	2.5 - 4.0	2	14	16	26	27	3	0	1.03	0.81	22	21	18	1	1	16.4
T - 563	4.0 - 5.5	2	13	13	26	29	2	1	0.94	0.86	22	19	21	1	2	16.0
T - 564	5.5 - 7.5	2	10	15	17	23	0	1	1.33	1.14	30	22	21	2	1	18.8
T - 565	7.5 - 9.5	2	10	8	27	28	1	1	1.44	1.35	34	22	26	1	1	17.3
T - 589	0.0 - 1.0	2	6	6	40	36	1	0	2.64	3.32	72	23	34	1	1	17.0
T - 590	1.0 - 2.5	2	6	6	37	37	0	0	2.13	2.22	52	25	26	0	1	15.6
T - 591	2.5 - 4.5	2	7	6	38	40	3	1	2.20	1.95	50	25	26	1	2	14.2
T - 592	4.5 - 6.0	2	8	8	35	35	2	2	2.01	2.03	49	23	28	0	2	14.3
T - 593	6.0 - 8.0	2	8	8	34	38	3	0	2.14	2.04	52	19	22	1	2	15.7
T - 594	8.0 - 10.0	2	7	7	35	36	0	0	2.97	2.64	68	26	27	2	1	15.7
STANDARD SOILS																
Kimm	surface	2	6	6	40	34	0	0	4.05	5.18	111	22	38	0	0	20.6
Kimm C_{ca}	0.5 - 1.0	2	6	6	35	39	0	0	3.33	3.39	81	25	29	0	0	16.3
Platner	surface	2	6	6	34	39	0	0	3.73	4.56	415	27	29	0	0	15.2