Soil Survey for
Black Hills Bentonite, LLC
Wyoming Mining Permit 339C
Mayoworth Amendment 4

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APPENDIX D-7. SOIL

Black Hills Bentonite, LLC
Wyoming Mining Permit 339C
Mayoworth 2007 Study Area

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D7-1. Introduction

D7-1.1 Objectives

The objective of this soil inventory is to provide essential soil data for mine and reclamation planning. Specific tasks for the soil resource inventory were to:

1. Develop soil map units and delineate boundaries on appropriate aerial photographs.
2. Define soil physical and chemical characteristics.
3. Determine suitability and recommend salvage depths of topsoil/subsoil for each soil map unit to be affected.

D7-1.2 Study Area

The 2007 soil study area associated with Black Hills Bentonite, L.L.C.'s proposed amendments to Wyoming Mining Permit 339C consists of 520 acres located approximately 10 miles northwest of Kaycee and ½ mile north-northwest of Mayoworth in Johnson County, Wyoming. The proposed mining activity will include portions of sections 15, 22, 23 and 26 in Township 45 North and Range 83 West.

The study area is positioned on semi-arid foot-slope topography adjacent to the southeastern edge of the Big Horn Mountain Range in the western Powder River Basin, a large structural basin measuring approximately 250 miles north-south by 110 miles east-west. Geomorphology of the Powder River Basin is characterized by tertiary sedimentary deposits of interbedded sandstone, shale, siltstone and coal.

The study area is characterized by Cretaceous deposits intermittently capped by upland terrace benches and low, gravel-capped ridges of alluvial origin. Within the study area, these are periodically dissected by gullies and draws creating areas of rough, eroded and broken terrain. Drainage of the study area is southerly and easterly into the North Fork of the Powder River.

Bentonite deposits in the area occur within the Frontier (Upper Cretaceous), Mowry and Thermopolis Shale (Lower Cretaceous) geologic formations. Subsequent geologic uplifts created relatively steeply dipping beds associated with erosionally resistant, steep facial scarps and small valleys in less resistant, soft shale. Soil development strongly reflects the highly variable nature of inter-bedded parent materials consisting of fissile or clay shale, sandstone, siltstone and bentonite clay beds. Soil chemical and physical properties vary accordingly. Saline-sodic conditions are common, especially in soils dominated by smectitic clays.

The Western Regional Climate Center summaries (1948 to 2007) from the Kaycee WY (485055) reporting station (WRCC, 2007) indicate an annual average of 12.2 inches precipitation with most occurring in the spring months April through June. Average snowfall is 42.5 inches. Monthly average temperatures range between 52 and 70°F for growing season months of May-September, and daily temperatures commonly range from low 40's^{o}F to the low 90's^{o}F for those same months. Coldest months are December through February when below zero readings are not unusual. The soil moisture regime borders between ustic and aridic. The soil temperature regime is mesic.

Plant communities are dominated by Wyoming big sagebrush (*Artemisia tridentata*), bluegrama (*Bouteloua gracilis*) and western wheatgrass (*Pascopyrum smithii*) but greasewood (*Sarcobatus*

vermiculatus) and rubber rabbitbrush (*Chrysothamnus nauseosus*) are also common. Barren outcrops of shale and bentonite occur intermittently throughout the proposed study area. Elevations within the study area range between 5,280 and 5,680 feet above sea level.

D7- 2 Methods

D7-2.1 Compilation of Available Information

Soil series descriptions and interpretive records for soils potentially occurring within the 2007 study area were obtained from the Natural Resource Conservation Service (NRCS) Johnson County soil surveys to assist with soil identification, mapping, and interpretations. This information was supplemented with additional information supplied by a contracted soil survey previously conducted by Black Hills Bentonite on immediately adjacent properties in 1984. Soil series and families were verified based on field observations and laboratory results. Aerial photographs were used to identify project boundaries and assist with soil mapping.

D7-2.2 Field Methods

Fieldwork was conducted to approximate standards of the National Cooperative Soil Surveys (USDA, 1998) by Lyle King, soil scientist with Shell Valley Consulting Associates, Inc. Field surveys were conducted in October and November, 2007. Soil map units were delineated on aerial photographs (1 inch = 400 feet). Typical pedons were described and sampled by soil horizon using hand-dug exposures. A total of 91 soil samples from 24 soil pedons were submitted for laboratory analyses. Several additional field checks were also strategically located and examined throughout the study area (field sheets were completed on some check pits but none were sampled) to verify mapping and classification. Profile description summary tables (including GPS NAD 83 coordinate points) are included in Addendum D7.B. Profile locations are illustrated on the Soil Map (Addendum D7.E). Samples collected from representative soil profiles were analyzed for topsoil suitability parameters by Energy Laboratories, Inc. in Casper, Wyoming (Addendum D7.A, Tables D7.A1 & D7.A2). Analytical parameters and methods follow those recommended by WDEQ Guideline 1. Photographs of representative profiles are provided for each soil map unit in Addendum D7.C. Profile locations and samples are labeled as BH (Black Hills), KC (Kaycee area Mayoworth) and a chronologic numerical value.

Soil horizons were identified according to criteria in *Keys to Soil Taxonomy* (USDA, 2006) and described according to *Field Book for Describing and Sampling Soils* (USDA, 1998). Profiles were described on modified NRCS field pedon description forms. Generally, features documented for each horizon include boundary type, depth, color, texture, structure, estimated clay content, and reaction to 1 Normal hydrochloric acid (HCL) solution. Descriptions of clay films, rock fragment content, gypsum accumulation and root content were also provided when appropriate. Site features documented include GPS location (NAD 83), elevation, landscape/landform description, hillslope profile position, aspect, slope percent, slope complexity, slope shape, parent material, bedrock type, surface coarse fragments and dominant vegetation.

D7-3 Soil Classification, Map Units and Salvage Depths

D7-3.1 Soils Classification

Soil classifications (Table D7.1) were determined to the series level using NRCS soil series descriptions at: http://soils.usda.gov/technical/classification/osd/index.html. Taxonomic classifications were supplemented using *Keys to Soil Taxonomy* (USDA, 2006) when appropriate.

D7-3.2 Soil Mapping, Recommended Salvage Depths and Pedon Descriptions
Soil map unit designations are illustrated on Soil Map, Addendum D7.E. Designations are supplemented with numbers representing recommended salvage depths (topsoil/subsoil) in inches (Table D-7.2). Depths of suitable soil within the project area are highly influenced by the variable in-situ chemical nature of parent material, variable depths to bedrock and difficult, eroded topography associated with dissecting drainages. Soil map unit complexes describe areas with complex soil patterns of more than one map unit that are difficult to separate at the utilized mapping scale (1 inch: 400 feet). Salvage depths within soil complex map units follow those of the individually described component soils. Recommended topsoil/subsoil salvage depths range from 0 to 60 inches based on WLQD Guideline #1 suitability ratings (Addendum D7.A, Table D7.A1). Pedon descriptions are provided in Addenda D7.B and D7.C. Proposed affected acreages for each soil map unit are listed in Table D7.3.

D7-4 Map Unit Descriptions

Generally, soil map units on the study area were grouped by approximate availability of suitable material for salvage or taxonomic development as summarize below:

- 100 Series. These soils have no recommended topsoil or subsoil. They are of very limited extent within the proposed amendment area.
- 200 Series. Generally, suitable soils with recommended approximate topsoil/subsoil salvage depths of 6 and 12 inches, respectively. Subsoil salvage depths are limited by paralithic and lithic contact.
- 300 Series. Shallow and moderately deep soils with recommended topsoil/subsoil salvage depths ranging from 0-6 and 0-19 inches, respectively. Subsoil salvage depths are limited by underlying sodic conditions.
- 400 Series. Moderately deep soils associated with recommended topsoil/subsoil salvage depths of 6 and 30-54 inches, respectively.
- 500 Series. Deep soils with suitable topsoil/subsoil depths of 6/54 inches, respectively.
- Mapping Complexes (Steep and Ravine). Mapping complexes of previously described soils that are not easily separable at map scale utilized. Recommended topsoil/subsoil salvage depths are variable and following those previously recommended for component soils.
- OC: Barren Shale and Clay Outcrop with no salvageable material.
- ML: Previously affected and currently active mining areas.

Table D7.1. Soil Series and Family Classification

Map Units	***Description***	***Sampled Pedons***	***Family Classification***
100&101	**Shingle-saline & Shingle**	BHKC2 (100) & (101) not sampled/won't be affected	Loamy, mixed, superactive, calcareous, mesic, shallow Ustic Torriorthents
200	**Danko taxadjunct**	BHKC10	Clayey, smectitic, calcareous, mesic, shallow Ustic Torriorthents
210	**Tassel**	BHKC6 &BHKC26 (the later as inclusion in Map Unit 220)	Loamy, mixed, superactive, calcareous, mesic, shallow Ustic Torriorthents
*	**Tassel taxadjunct** *(component soil in map unit 401)	*BHKC24	Loamy, mixed, superactive, mesic, shallow Ustic Torriorthents

220	**Rhoame**	BHKC27	Fine, smectitic, nonacid, mesic Ustic Torriorthents
230&231	**Samsil taxadjunct**	BHKC8,BHKC11 (230) BHKC16 (231)	Clayey, smectitic, calcareous, mesic, shallow Aridic Ustorthents
300&301	**Renohill taxadjunct**	BHKC22	Fine, smectitic, mesic Ustic Haplargids
310	**Arvada**	BHKC14	Fine, smectitic, mesic Ustertic Natrargids
320	**Petrie**	BHKC9	Fine, smectitic, calcareous, mesic Ustertic Torriorthents
330	**Forkwood**	BHKC1	Fine-loamy, mixed, superactive, mesic Ustic Haplargids
400&401	**Cragola**	BHKC4 (400) BHKC5 (401)	Loamy-skeletal, mixed, active, calcareous, mesic, shallow Ustic Torriorthents
402	**Cragola taxadjunct**	BHKC19; BHKC20	Fine-loamy, mixed, active, calcareous, mesic, Ustic Torriorthents
410	**Big Horn taxadjunct**	BHKC13	Fine, smectitic, mesic Ustic Paleargids
420	**Gaynor**	BHKC17	Fine, smectitic, calcareous, mesic Ustic Torriorthents
430	**Bowbac**	BHKC3, BHKC7	Fine-loamy, mixed, superactive, mesic Ustic Haplargids
500	**Cushman**	BHKC12	Fine-loamy, mixed, superactive, mesic Ustic Haplargids
510	**Embry**	BHKC15 & BHKC25	Coarse-loamy, mixed, superactive, nonacid, mesic Ustic Torriorthents

Table D7.2. Soil Map Units, Descriptions and recommended salvage depths

Map Unit	*Description*	*Topsoil Salvage Depths (inches)*	*Subsoil Salvage Depths (inches)*
100	**Shingle-saline; 0-5% slopes**	0	0
101	**Shingle; 0-5% slopes**	won't be affected	
200	**Danko taxadjunct; 10-30%**	6	6
210	**Tassel; 10-15% slopes** **Tassel taxadjunct**	6 6	9 6
220	**Rhoame; 8-25% slopes; <30% Tassel inclusions**	6	12
230*	**Samsil taxadjunct;5-15% slopes; <10% OC**	6	12
231	**Samsil/Sandstone Rock Outcrop; 15-40% slopes**	6	12 or lithic contact
300	**Renohill taxadjunct; 3-6% slopes**	4	0
301	**Renohill taxadjunct; 5-15% slopes; <20% Tassel inclusions**	4	0
310	**Arvada; 3-6% slopes**	6	7
320	**Petrie; 5-20% slopes; <30% Limon inclusions**	6	16
330	**Forkwood; 0-8% slopes**	6	10
400	**Cragola, 0-6% slopes**	6	30
401	**Cragola Complex; 30-50% slopes; <30% inclusions Tassel, Samsil, Renohill, others**	6	24
402	**Cragola taxadjunct, 10-25% slopes**	6	54
410	**Big Horn taxadjunct; 0-3% slopes**	6	30
420*	**Gaynor; 5-10% slopes**	6	30
430	**Bowbac; 15-25% slopes**	6	36
500	**Cushman; 0-8% slopes**	6	54
501	**Cushman; 10-20% slopes**	6	36-54
502	**Cushman/Rock Outcrop Complex; 10-20% slopes**	6	36-54
510	**Embry; 0-5% slopes**	6	54
SC	**Steep complex; 30-50% slopes; Component soils: <30% OC with others variable (Cragola, Tassel taxadjunct, Samsil, Renohill, Big Horn, Gaynor)**	6	Variable; ranges from 0-24
RC	**Ravine Complex, Component soils are Barren Outcrops (40%), Samsil (40%) Petrie (10%)**	Variable; ranges from 0-6	Variable; ranges from 0-16
OC & OC-s	**Barren Shale and Clay Outcrops (OC)** **Saline seep Barren Outcrop (OC-s)**	0	0
ML	**Previously affected/Currently active mine land**	0	0

*****230/420 & 420/230 map units combine these 2 units in complexes dominated by the first mentioned soil type. Topsoil salvage is 6 inches and subsoil salvage is 30 inches **or** paralithic contact with soft platy shale (Samsil).

Table D7.3. Projected Disturbance Acreage by Soil Map Unit for the North Fork Amendment within the 2007 Study Area

Map Unit	*Description*	*Projected Disturbance Acreage*
100	**Shingle-saline; 0-5% slopes**	0
101	**Shingle; 0-5% slopes**	0
200	**Danko taxadjunct; 10-30%**	0
210	**Tassel; 10-15% slopes**	0
220	**Rhoame; 8-25% slopes; <30% Tassel inclusions**	0.1
230	**Samsil taxadjunct;5-15% slopes; <10% OC**	1.7
231	**Samsil/Sandstone Rock Outcrop; 15-40% slopes**	3.3
300	**Renohill taxadjunct; 3-6% slopes**	0
301	**Renohill taxadjunct; 5-15% slopes; <20% Tassel inclusions**	0
310	**Arvada; 3-6% slopes**	0
320	**Petrie; 5-20% slopes; <30% Limon inclusions**	0.7
330	**Forkwood; 0-8% slopes**	0
400	**Cragola, 0-6% slopes**	0
401	**Cragola Complex; 30-50% slopes; <30% inclusions Tassel, Samsil, Renohill, others**	0.1
402	**Cragola taxadjunct**	0
410	**Big Horn taxadjunct; 0-3% slopes**	0
420	**Gaynor; 5-10% slopes**	0
430	**Bowbac; 15-25% slopes**	0
500	**Cushman; 0-8% slopes**	0.2
501	**Cushman; 10-20% slopes**	0
502	**Cushman/Rock Outcrop Complex; 10-20% slopes**	0
510	**Embry; 0-5% slopes**	0
SC	**Steep complex; 30-50% slopes; Component soils: <30% OC with others variable (Cragola, Tassel taxadjunct, Samsil, Renohill, Big Horn, Gaynor)**	6.6
RC	**Ravine Complex, Component soils are Barren Outcrops (40%), Samsil (40%) Petrie (10%)**	0
OC & OC-s	**Barren Shale and Clay Outcrops (OC) Saline seep Barren Outcrop (OC-s)**	3.3
ML	**Previously affected/Currently active mine land**	
230/420	**Samsil Taxadjunct: 5-15%slope, <10% outcrop and Gaynor: 5-15% slope complex**	

D7-4 Soil and Map Unit Descriptions (continued)

100 Series

Shingle Soils

Map Unit 100; Shingle-saline (0/0); 0-5% slopes; Sampled Profile BHKC2
Map Unit 101 Shingle; 0-5% slopes. Won't be affected.

Shingle-saline soils are very shallow to bedrock and formed in residuum/colluvium derived from interbedded shale and sandstone. The particle size control section has about 30 percent clay. Within thestudy area, the Shingle–saline map unit is influenced by a continuous natural seep which has created alkaline and sodic conditions at the soil surface which are unsuitable for salvage.

200 Series

Danko taxadjunct Soils

Map Unit 200 (6/6 inches); Danko taxadjunct; 10-30% slopes; Sampled Profile BHKC10

Danko soils are shallow clay soils with strongly alkaline horizons and fine textured very strongly alkaline C horizons. Within the study area, this map unit occurs in a narrow band that is intermittently juxtaposed with and parallel to bentonite and shale outcrops of the Thermopolis Shale geologic formation. It overlies shale bedrock at depths of 10 to 20 inches. These soils are typically 50 to 80 percent barren with native vegetation limited to alkaline tolerant species.

The taxadjunct is less red in color than the described series. Only minor amounts of this map unit will be affected by the proposed mining activity. Recommended topsoil and subsoil salvage depths are 6 and 6 inches, respectively. Salinity, sodicity and boron concentrations become unsuitable at depths greater than 12 inches.

Tassel and Tassel taxadjunct Soils

Map Unit 210 (6/9 inches); Tassel; 10-15% slopes; Sampled Profiles BHKC6, BHKC26* (*inclusion in map unit 220).
Tassel taxadjunct occurs as a component soil in Map Unit 401; (6/6 inches); Sampled Profile BHKC24

Tassel soils consist of very shallow or shallow, well drained soils formed in residuum weathered from calcareous sandstone on uplands. These are well drained soils with moderately rapid permeability. The taxadjunct soil is non-calcareous and occurs as a component soil in map unit 401. These map units are generally limited in extent to small acreages on the western portion of the study area. Recommended topsoil and subsoil salvage depths are 6 and 9 inches, respectively for Tassel sandy loam and 6/6 inches (topsoil and subsoil) for the taxadjunct.

Rhoame Soils
Map Unit 220 (6/12 inches); Rhoame, 8-25% slopes; Sampled profile BHKC27

The Rhoame series consists of deep, well drained soils that formed in thick, fine textured, non-calcareous sediments derived mainly from partly metamorphosed shale. Throughout the study area, coarse fragment content ranges up to 35 percent within this map unit, although it is only 5 percent in the A horizon of the described profile. This map unit occurs along stable terrace benches and valley filling side-slopes within the study area. The control section of this profile is clay loam with clay content approaching 40 percent. Recommended topsoil and subsoil salvage depths for this map unit are 6 and 12 inches, respectively. Salvage depths below 18 inches are restricted by unsuitable saline-sodic conditions.

Samsil Soils
Map Unit 230; Samsil taxadjunct (6/12 inches); 5-15% slopes; Sampled Profiles BHKC8, BCKC11 & BHKC16
Map Unit 231; Samsil/Sandstone Rock Outcrop, 15-40% slopes (variable: 6 inches/12-lithic contact)

Samsil soils are shallow, well drained soils formed in alluvium or residuum weathered from shale. They are found on gently sloping to very steep hills, ridges and breaks of dissected shale plains. Permeability is slow. Depth to bedded shale within the study area ranges from 6 to 18 inches. Horizons above the shale range from loose to hard when dry, and friable or firm when moist. Characteristically these horizons contain free carbonates and reaction is slight to moderately alkaline. The C and upper Cr horizons commonly also have accumulations of carbonate, gypsum and other salts. Recommended topsoil and subsoil salvage depths for Samsil soils are 6 and 12 inches, respectively. However when these soils are associated with sandstone rock outcrop, salvage depths for both topsoil and subsoil are limited by hardness of sandstone lithic contact relative to salvage equipment capabilities. Salvage of lithic and/or paralithic sandstone materials within these map units can be substituted as suitable material for reclamation capping of unsuitable spoil material in areas lacking adequate suitable topsoil/subsoil material. Samsil taxadjunct has less clay than those of the described series which have control sections with 50 to 65 percent clay.

300 Series

Renohill taxadjunct Soils
Map Unit 300; Renohill taxadjunct (4/0 inches); 3-6% slopes; Sampled Profile BHKC22
Map Unit 301; Renohill taxadjunct (4/0 inches); 5-15% slopes; <20% Tassel inclusions.

The Renohill series consists of well drained soils that are moderately deep to soft bedrock. These soils form in alluvium, colluvium, and residuum on bedrock controlled plateaus, alluvial fans, hills and ridges. In the study area, depth to mixed shale/sandstone paralithic material ranges from 20 to 40 inches which is immediately underlain by soft bedrock of the same materials. Rock fragments are shale channers at less than 5 percent by volume. The control section is clay loam and reaction is alkaline. This taxadjunct profile is sodic at depths below 4 inches and saline-sodic at depths below 11 inches. Therefore, recommended topsoil/suboil salvage depths are 4/0 inches, respectively.

Arvada Soils
Map Unit 310 (6/7 inches); Arvada; 3-6% slopes; Sampled Profile BHKC14

Arvada soils are very deep, well drained soils formed in alluvium and colluvium derived from sodic shale. Permeability is slow. They developed on alluvial fans, fan remnants, fan terraces and hillslopes. In the study area, these soils are limited to a small acreage in the NE¼SE¼ section 26 T45N R83W. Sodium concentrations become unsuitable at about 13 inches. Recommended topsoil and subsoil salvage depths are 6 and 7 inches, respectively.

Petrie Soils
Map Unit 320 (6/16 inches); Petrie, 5-20% slopes;<30% Limon inclusions; sampled profile BHKC9

Petrie soils are deep, well drained soils that formed in alluvium derived from sodic sedimentary rock. These soils are on fan aprons, fan pediments, and alluvial terraces. In the study area these soils occur intermittently along fan aprons and terraces associated with dissecting drainages of the Thermopolis Shale Geologic formation. The majority of the carbonates and gypsum are autogenetic with only minor secondary accumulations with depth. Sodium concentrations become unsuitable at about 22 inches in depth. Recommended topsoil and subsoil salvage depths are 6 and 16 inches, respectively.

Forkwood Soils
Map Unit 330 (6/10 inches); 0-8% slopes; Sampled Profile BHKC1

Forkwood soils are very deep, well drained and formed in alluvium on terraces, alluvial fans, fan remnants, hills, ridges and pediments. In the study area, Forkwood soils only occur in a small acreage in the NE¼SE¼ section 26 T45N R83W. Depth to the base of the argillic horizon is 10 to 33 inches, and depth to continuous horizons of carbonate accumulation is 10 to 33 inches. Rock fragments range from 0 to 15 percent. EC ranges from 0 to 4 mmhos/cm throughout the profile. Bedrock is deeper than 60 inches. Field assessment of this profile at the 16 to 25 inch depth interval (not sampled) indicated similarities with the underlying 25-44 interval. Recommended topsoil and subsoil salvage depths for this map unit are therefore 6 and 10 inches, respectively. Salvage depths below 16 inches are restricted by unsuitable sodic conditions.

400 Series

Cragola and Cragola taxadjunct Soils

Map Unit 400 (6/30 inches);Cragola, 0-6% slopes; Sampled Profile BHKC4
Map Unit 401 (6/24 inches); Steep Cragola, 30-50% slopes; <30% inclusions Tassel, Samsil, Renohill, others; Sampled Profile BHKC5
Map Unit 402 (6/54 inches); Cragola taxadjunct, 10-25% slopes; Sampled Profile BHKC19

The Cragola series consists of shallow, well to somewhat excessively drained soils that formed in alluvium and colluvium over soft inter-bedded shale and sandstone. Cragola soils are on structural benches, hills, and ridges. Cragola taxadjunct is deeper with fewer coarse fragments than the described series. Typically, these soils are calcareous throughout. Depth to the paralithic contact ranges from 10 to 20 inches. Gravel is 35 to 60 percent. Cobbles are 0 to 20 percent. Recommended topsoil and subsoil salvage depths for Cragola soils are 6 and 24-30 inches, respectively. Cragola taxadjunct soils are deeper with recommended salvage depths of 6 and 54 inches for topsoil and subsoil, respectively.

Big Horn taxadjunct Soils

Map Unit 410 (6/30 inches); Big Horn taxadjunct, 0-3% slopes, Sampled profile: BHKC13

Big Horn soils are very deep, well drained soils that formed in old alluvium. They occur primarily on the upper plateau and high terraces bordering the northeastern edge of the study area. The NRCS described series has coarse fragments ranging from 0 to 12 percent and 0-3 percent cobbles in most of the solum, although the later increases with depth. The described taxadjunct (BHKC13) is shallower and has >90 percent coarse fragments at 36 inches, both are slight deviations from the described series. Recommended topsoil and subsoil salvage depths are 6 and 30 inches, respectively.

Gaynor Soils

Map Unit 420 (6/30 inches); 5-10% slopes; Sampled Profile BHKC17

Gaynor soils are moderately deep, well drained soils that formed in material weathered from sedimentary rocks. They are found on hill sides and ridge crests. These soils are usually calcareous at the surface but are leached for a few inches in the sampled pedon. Depth to the underlying paralithic contact is 20 to 40 inches. Conductivity is less than 1 millimhos and exchangeable sodium percentage usually ranges from less than 1 percent throughout the control section. In the examined pedon, control section texture is clay loam with 37 percent clay. Amounts and placement of visible secondary calcium carbonate and calcium sulfate are erratic. Recommended topsoil and subsoil salvage depths are 6 and 30 inches, respectively.

Bowbac Soils

Map Unit 430 (6/36 inches);Bowbac, 15-25% slopes; sampled profiles BHKC3, BHKC7

Bowbac soils are moderately deep, well drained soils formed in alluvium, eolian deposits or residuum derived primarily from argillaceous, weakly consolidated sandstone. Within the study area, these soils occupy hillslopes, small plateaus, ridges and buttes. Depth to soft sandstone ranges to approximately 40

inches. Depth to continuous carbonate accumulation ranges from 10 to 35 inches, and depth to the base of the argillic horizon ranges from 10 to 35 inches. Coarse fragments range from 0 to 15 percent and are soft sandstone channers or semi rounded gravel. Textures are sandy loam. Recommended topsoil and subsoil salvage depths are 6 and 36 inches, respectively.

500 Series

Cushman Soils

Map Unit 500 (6/54 inches);Cushman, 0-8% slopes; sampled profile BHKC12
Map Unit 501 (6/36-54 inches);Cushman, 10-20% slopes; <10% Rock Outcrop inclusions
Map Unit 502 (6/36-54 inches);Cushman/Rock Outcrop Complex, 10-20% slopes; 30% Rock Outcrop

Cushman soils are well drained and moderately deep to bedrock. These soils formed in slopewash alluvium and residuum from interbedded shales and siltstone and fine-grained argillaceous sandstone. Cushman soils are found intermittently on hillslopes and ridges in the northern portion of the study area. Sandstone rock outcrops are commonly associated with these map units. Recommended topsoil and subsoil salvage depths are 6 and 36-54 inches, respectively.

Embry Soils

Map Unit 510 (6/54 inches); Embry 0-5% slopes; Sampled Profiles BHKC15 & BHKC25

Embry soils are also very deep, well-drained soils formed in alluvium and eolian deposits derived from sandstone. Within the study area, these soils are located intermittently along toe-slopes and terraces associated with ephemeral drainages. These soils are non-calcareous throughout. Rock fragments range up to 35 percent and are mainly gravel size sandstone fragments. Control section texture is sandy clay loam with about 24 percent clay content. This soil is slightly acid to moderately alkaline. Recommended topsoil and subsoil salvage depths are 6 and 54 inches, respectively.

Complex and Outcrop Series

Steep Complex (SC)

This complex was used to designate steeply-dipping, south-facing escarpment faces located between the level, upper plateau in the northern portion of the study area and the erosionally dissected topography typical of the Thermopolis Shale formation in the mid-portions. Slopes range from 30 to 40 percent and component soils are variously barren outcrop, sandstone rock outcrop, Cragola, Tassel taxadjunct, Samsil, Renohill, Big Horn and Gaynor. Salvage depths are variable according to previous descriptions of each of these component soils.

Ravine Complex (RC)

This complex was used to designate various eroded topography associated with occasional intermittent drainages dissecting the study area within the Thermopolis Shale Geologic formation. Slopes are highly variable (0-50 percent) and are much shorter in length than those included with the Steep Complex map unit. Component soils are variously barren outcrop, Samsil and Petrie. Salvage depths are variable according to previous descriptions of each of these component soils.

Barren Shale and Clay Outcrops (OC)

This map unit consists of nearly non-vegetated outcrops of saline-sodic marine shales and surface eruptions of bentonite outcrops. It is intermittent within the Thermopolis Shale geologic formation and a component of the Steep Complex map unit as described above. There is no suitable soil material in this map unit and recommended salvage depths are 0/0 inches for topsoil and subsoil.

Previously Affected/Currently Active Mined Land (ML)

This map unit occupies a very small portion of the study area in the NE¼SE¼ section 26 T45N R83W. It includes lands affected by a soil stockpile and access disturbances associated with immediately adjacent mining activity. There is no suitable soil material in this map unit and recommended salvage depths are 0/0 inches for topsoil and subsoil.

D7-5 References

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Addendum D7.A

Laboratory Results

Table D7.1. Topsoil Laboratory Analyses and Suitability Analyses: Black Hills Bentonite Mayoworth 2007 StudyArea, Permit 339C.

Soil Series/ Sample Number	Depth Interval (inches)	pH	EC @ 25 C mmhos/cm	Sat. (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Carbonates (CaCO3) (%)	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	SAR	Se (ppm)	B (ppm)	Coarse Fragment (%)
Forkwood/ BHKC1	0-6	7.1	1.57	56	65	15	20	SL - SCL	0.9	12	4.4	0.99	0.3	0.044	0.51	ND
	6-13	7.2	0.46	54	63	15	22	SCL	0.7	3.3	0.98	0.62	0.4	0.059	0.53	ND
	13-25	8.1	0.91	57	65	11	24	SCL	1.0	0.23	0.10	1.6	3.9	0.042	0.85	6
	25-44	**8.7**	1.72	**80**	67	15	18	SL	1.2	1.2	0.57	16	***16.8***	0.054	0.67	7
	44-60	**8.7**	3.43	**97**	61	15	24	SCL	1.0	2.4	1.4	32	***23.6***	0.052	0.54	4
Shingle/ BHKC2	0-6	***10***	3.84	**290**	53	19	28	SCL	0.8	0.56	0.37	38	***55.5***	0.114	0.29	6
	6-12	***9.6***	3.92	**236**	42	26	32	CL	1.3	0.58	0.44	38	***53.5***	0.070	0.57	5
Bowbac/ BHKC3	0-6*	7.2	0.90	57	67	13	20	SL - SCL	1.3	25	9.3	15	3.7	0.062	0.53	1
	6-12	8.4	0.43	79	63	16	21	SCL	7.4	2.8	0.76	2.8	2.1	0.010	0.51	ND
	12-20	***9.3***	0.59	71	81	11	8.0	LS	3.5	2.5	0.65	6.1	4.9	0.008	0.31	ND
Cragola/ BHKC4	0-6	7.2	2.98	**87**	62	14	24	SCL	1.0	28	12	2.1	0.5	ND	0.66	2
	6-16	7.7	2.22	66	38	29	33	CL	18.4	18	11	1.1	0.3	0.015	0.95	2
	16-36	7.8	3.93	**90**	72	12	16	SL	13.7	24	29	5.4	1.0	0.040	1.00	11
Cragola/ BHKC5	0-4	7.7	0.70	61	66	15	19	SL	14.4	24	11	5.0	1.2	0.100	0.50	**25**
	4-10	7.6	0.52	60	57	17	26	SCL	11.2	3.5	1.8	0.76	0.5	0.074	0.54	13
	10-18	7.9	0.48	63	53	17	30	SCL	6.4	2.7	2.2	0.92	0.6	0.034	0.35	5
	18-30	8.4	0.67	61	63	15	22	SCL	3.8	1.4	2.8	3.7	2.6	0.030	0.40	7
Tassel/ BHKC6	0-8	7.3	3.11	**95**	80	8.0	12	SL	0.7	27	10	5.0	1.2	ND	0.51	ND
	8-18	8.5	2.44	47	79	9.0	12	SL	1.0	3.6	1.7	28	***17.2***	0.008	0.50	ND
	18-24	8.2	7.58	79	70	9.0	21	SCL	0.3	24	8.2	66	***16.6***	0.009	0.45	ND
Bowbac/ BHKC7	0-4	6.7	2.40	57	76	8.0	16	SL	0.2	17	6.3	2.7	0.8	ND	0.40	ND
	4-16	7.1	3.32	**98**	81	8.0	11	SL	0.2	33	12	4.5	1.0	ND	0.41	ND
	16-29	7.3	2.94	66	74	10	16	SL	0.2	29	12	1.8	0.4	ND	0.47	ND
	29-42	8.0	0.64	42	76	8.0	16	SL	1.2	3.8	2.4	1.5	0.8	ND	0.44	ND

Bold Text =Marginal topsoil suitability ***Bold/Italic Text & Highlight=Unsuitable as topsoil***

Table D7.1. (page 2 continued)

Soil Series/ Sample Number	Depth Interval (inches)	pH	EC @ 25 C mmhos/cm	Sat. (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Carbonates (CaCO3) (%)	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	SAR	Se (ppm)	B (ppm)	Coarse Fragment (%)
Samsil/BHKC8	0-4	7.5	0.62	53	55	17	28	SCL	1.4	5.1	1.8	0.45	0.2	ND	0.91	1
	4-8	7.6	0.66	57	37	29	34	CL	2.8	5.0	1.7	0.66	0.4	0.006	0.90	ND
	8-18	7.6	0.82	69	27	37	36	CL	3.8	3.4	1.2	0.76	0.5	ND	1.10	17
Petrie/BHKC9	0-4	7.6	1.18	65	35	27	38	CL	2.0	6.2	1.1	2.0	1.1	ND	1.10	1
	4-14	7.7	0.76	63	32	31	37	CL	2.2	5.9	0.83	1.9	1.0	0.006	1.20	3
	14-22	7.8	3.80	72	25	31	44	**C**	1.8	25	4.0	21	5.5	0.012	1.30	5
	22-36	**8.6**	10.3	**127**	23	27	50	**C**	2.0	20	12	98	***24.5***	0.036	1.30	18
	36-60	**8.6**	11.9	**103**	20	30	50	**C**	3.6	19	16	120	***27.9***	0.038	2.30	7
Danko/BHKC10	0-4	7.8	3.00	71	19	37	44	**C**	5.5	27	2.0	11	3.0	0.008	2.00	1
	4-12	7.8	5.82	80	21	29	50	**C**	4.4	25	3.1	45	**12.0**	0.008	3.60	1
	12-18	**8.6**	**11.3**	**127**	11	31	58	**C**	5.3	20	6.9	110	***30.0***	0.023	***6.00***	18
Samsil/BHKC11	0-6	7.2	2.80	**89**	55	17	28	SCL	2.2	28	9.2	2.3	0.5	0.079	0.79	4
	6-18	7.4	2.42	75	49	23	28	SCL	1.9	27	5.5	1.4	0.4	0.050	0.97	5
	18-24	7.4	2.50	70	63	11	26	SCL	3.2	28	4.1	1.4	0.4	0.049	1.50	**26**
Cushman/BHKC12	0-5	6.9	1.14	57	66	12	22	SCL	0.3	8.5	3.2	1.0	0.4	0.083	0.58	ND
	5-10	7.0	2.57	64	69	11	20	SL - SCL	0.4	25	9.1	2.2	0.5	0.028	0.39	2
	10-21	7.1	2.68	61	62	16	22	SCL	0.5	24	10	2.7	0.7	0.034	0.41	ND
	21-36	7.6	3.32	77	60	15	25	SCL	2.5	23	14	9.2	2.2	0.048	0.96	ND
	36-60	8.0	4.73	61	54	17	29	SCL	1.6	25	16	20	4.4	0.063	4.00	ND
Big Horn taxadjunct/BHKC13	0-5	7.7	0.86	70	36	22	42	**C**	4.2	5.0	2.0	0.60	0.3	ND	0.72	1
	5-10	8.1	0.51	72	30	24	46	**C**	7.2	2.0	1.7	1.8	1.3	ND	1.40	21
	10-20	8.4	0.54	69	33	25	42	**C**	5.8	1.5	1.6	2.9	2.4	ND	1.40	15
	20-30	8.0	3.19	**94**	36	23	41	**C**	4.0	21	19	5.3	1.2	0.023	4.60	ND
	30-36	8.0	2.92	61	36	39	25	L	3.7	28	10	2.6	0.6	0.022	3.40	2

Bold Text =Marginal topsoil suitability ***Bold/Italic Text & Highlight=Unsuitable as topsoil***

Table D7.1. (page 3 continued)

Soil Series/ Sample Number	Depth Interval (inches)	pH	EC @ 25 C mmhos/cm	Sat. (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Carbonates (CaCO3) (%)	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	SAR	Se (ppm)	B (ppm)	Coarse Fragment (%)
Arvada/BHKC14	0-5	7.1	1.55	58	67	15	18	SL	0.8	9.2	3.9	3.8	1.5	ND	1.30	ND
	5-13	7.6	1.05	59	61	18	21	SCL	0.9	3.7	1.3	6.4	4.1	0.005	1.20	ND
	13-22	8.0	3.59	57	67	11	22	SCL	2.8	3.6	1.4	30	***19.2***	0.014	0.94	10
	22-32	**8.6**	**10.6**	**134**	40	24	36	CL	3.0	19	12	100	***25.5***	0.061	4.20	ND
	32-60	8.4	**10.3**	**104**	67	13	20	SL - SCL	1.7	22	16	93	***21.6***	0.011	2.90	3
Embry/BHKC15	0-4	5.9	0.57	**140**	44	30	26	L	0.5	2.7	1.1	0.52	0.4	ND	0.98	ND
	4-14	6.3	0.30	68	56	22	22	SCL	ND	1.7	0.72	0.70	0.7	ND	0.67	ND
	14-24	6.7	0.19	**95**	69	15	16	SL	0.2	1.0	0.45	0.94	1.1	0.006	0.74	1
Samsil/BHKC16	0-6	7.0	0.31	**92**	17	44	39	SiCL	0.7	2.6	0.29	0.44	0.4	0.011	1.30	1
	6-12	6.4	0.15	**98**	27	35	38	CL	0.6	1.6	0.13	0.47	0.5	0.008	1.10	20
Gaynor/BHKC17	0-5	7.4	0.46	**84**	43	26	31	CL	0.9	3.6	1.4	0.26	0.2	0.005	0.59	ND
	5-12	7.9	0.34	80	42	21	37	CL	1.3	2.8	0.99	0.38	0.3	0.005	0.65	2
	12-22	7.9	0.36	**95**	52	22	26	SCL	1.4	2.4	1.0	0.31	0.2	0.005	0.88	ND
	22-36	8.1	0.33	**118**	34	34	32	CL	4.0	2.3	1.1	0.50	0.4	0.015	1.30	4
Cragola taxadjunct/BHKC19	0-5	8.2	0.34	**113**	38	26	36	CL	5.2	2.8	1.0	0.14	0.1	ND	0.94	ND
	5-12	8.4	0.31	**105**	38	32	30	CL	5.8	2.0	1.4	0.24	0.2	ND	0.84	1
	12-24	8.5	0.40	79	48	24	28	SCL	5.1	1.6	2.3	0.73	0.5	ND	1.00	2
	24-36	8.5	0.36	**106**	46	26	28	SCL	4.2	1.5	2.1	0.65	0.5	ND	2.10	1
	36-60	**8.8**	1.32	**116**	48	22	30	SCL	7.2	1.0	2.2	9.6	7.6	0.008	3.20	3
Cragola taxadjunct/ BHKC20	0-5	8.0	0.53	**86**	48	20	32	SCL	6.9	4.5	1.3	0.39	0.2	ND	0.80	ND
	5-10	8.3	0.29	**117**	34	30	36	CL	7.9	2.5	0.98	0.49	0.4	ND	0.84	ND
	10-22	**8.6**	0.52	**103**	38	28	34	CL	11.1	1.6	1.0	2.9	2.6	ND	1.00	ND
	22-36	***9.1***	0.84	**101**	48	17	35	SCL - SC	5.2	0.76	0.54	7.6	9.4	ND	1.40	ND
	36-60	8.5	**10.0**	**121**	48	46	6.0	SL	8.7	23	32	74	***14.2***	**0.430**	3.70	2

Bold Text =Marginal topsoil suitability ***Bold/Italic Text & Highlight=Unsuitable as topsoil***

Table D7.1. (page 4 continued)

Soil Series/ Sample Number	Depth Interval (inches)	pH	EC @ 25 C mmhos/cm	Sat. (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Carbonates (CaCO3) (%)	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	SAR	Se (ppm)	B (ppm)	Coarse Fragment (%)
Renohill taxadjunct/BHKC22	0-4	8.5	0.84	**95**	64	16	20	SL - SCL	3.2	0.95	0.42	6.3	7.7	ND	0.94	ND
	4-11	**8.8**	2.19	**92**	36	26	38	CL	6.5	1.8	0.77	20	***17.9***	ND	2.30	2
	11-20	**8.6**	**8.59**	**102**	29	29	42	**C**	4.0	25	11	75	***17.6***	0.030	3.70	2
	20-36	8.2	7.53	**102**	37	27	36	CL	3.4	24	9.2	62	***15.2***	0.007	2.80	1
	36-50	8.2	7.92	**85**	32	30	38	CL	3.2	25	9.6	65	***15.8***	0.008	2.80	ND
Tassel taxadjunct/BHKC24	0-7	7.1	0.39	76	76	10	14	SL	2.3	2.8	1.1	0.23	0.2	ND	0.56	ND
	7-12	7.4	0.19	66	83	9.0	8.0	LS	0.3	1.5	0.58	0.22	0.2	ND	0.28	ND
Embry/BHKC25	0-4	7.6	0.59	74	58	16	26	SCL	1.6	4.4	1.3	0.53	0.3	ND	0.61	2
	4-14	7.9	0.34	**85**	60	16	24	SCL	1.2	2.2	0.57	1.2	1.0	ND	0.68	2
	14-26	8.0	0.64	60	59	21	20	SL - SCL	4.3	3.0	0.71	3.5	2.6	ND	0.62	2
	26-44	8.0	1.18	64	71	13	16	SL	2.5	4.0	1.0	7.8	4.9	0.008	0.50	5
	44-60	8.3	0.44	67	63	18	19	SL	2.6	2.2	0.52	2.2	1.9	0.008	0.37	2
Tassel/BHKC26	0-5	8.2	0.40	80	67	14	19	SL	4.4	1.8	0.51	2.3	2.2	0.006	0.54	3
	5-15	8.7	1.13	65	71	10	19	SL	1.2	1.9	0.41	10	9.2	0.008	0.35	ND
	15-31	8.0	7.82	**90**	77	13	10	SL	0.8	26	13	69	***15.7***	0.024	1.30	ND
Rhoame/BHKC27	0-7	8.2	0.43	**81**	74	15	11	SL	2.9	3.4	0.42	1.0	0.7	0.007	0.37	2
	7-18	8.4	6.07	**107**	33	28	39	CL	2.0	23	9.3	46	**11.5**	0.032	2.60	4
	18-36	**9.0**	**8.05**	**195**	35	27	38	CL	2.0	17	9.0	72	***19.9***	0.020	2.00	ND
	36-60	**8.6**	**11.0**	**113**	47	22	31	SCL	1.2	21	15	110	***25.7***	0.025	0.96	2

* = lab data mislabeled 0-4 inches **Bold Text =Marginal topsoil suitability** ***Bold/Italic Text & Highlight=Unsuitable as topsoil***

pH = negative log concentration of H^+, Sat (%) = Saturation percentage, EC = Electrical conductivity, dS/m=deciSeimens/meter. **S=sand, SC=sandy clay, C=clay, CL=clay loam, SCL=sandy clay loam, SL=sandy loam, LS=loamy sand, SiL=silt loam**

Addendum D7.B

Profile Descriptions

LEGEND: bnd=boundary, c=clear, s=smooth, a=abrupt, w=wavy, gr = granular, sg = single grain, sbk = subangular blocky, d/m/s/p = dry/moist/sticky/plastic, l=loose, s = soft, sh = slightly hard, h=hard, fr = friable, vfr = very friable, fi=firm, vfi=very firm, eh=extremely firm, ns = non-sticky, ss = slightly sticky, ef = extremely firm Reaction to 10% HCl: nr = noneffervescent, vsl = very slightly effervescent, sl = slightly effervescent; str = strongly effervescent, v = violently effervescent, NE=not evaluated

Profile BHKC1 map unit 330, Soil Series Forkwood; 13T 356101E 4855307N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-6/ A,W	SL	0	10 YR 5/3 10 YR 3/2	1 f sbk breaking to gr	NE	
Shovel Pit	Bt	6-13/ C,W	SCL	0	10 YR 5/2 10 YR 4/2	1 & 2 f/m sbk	NE in matrix ST in masses	Clay skins in root channels, sand bridging common
Shovel Pit	Btk	13-25/ G,W	SCL	0	10 YR 5/2 10 YR 4/2	2 m/c prismatic marks to _____	SL in matrix ST in masses & threads	SL in matrix, ST in masses and threads, Clay skins in root channels, sand bridging common
Auger	Bk	25-44	SL	0	10 YR 4/2 10 YR 4/2	augered	SL in matrix ST in masses	SL in matrix, ST in masses and threads (Broke here for sampling)
Auger	Bk	44-60	SCL	-		augered		

Profile BHKC2 map unit 100; Shingle-saline; 13T 13356211E 4855311N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	E	0-1 C,S	SCL	0	10 YR 6/2 10 YR 5/2	2 m, pl	NE	surface crust <1/8 " thick, color 10YR 7/1
Shovel Pit	C	1-15+	CL	0	G2 3/10B	massive	NE	redox mottles 2.5Y 6/6 & gleying common throughout C Horizon @ 1"+ depth

Profile BHKC3 map unit 430; Bowbec 13T 356077E 4855370N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-6/ A,W	SL	0	10 YR 5/4 10 YR 4/2	gr	SL	
Shovel Pit	Bk	6-12/ C,G	SCL	0	10 YR 6/2 10 YR 5/4	3 m sbk	V	Pores almost completely filled w/carbonates
Shovel Pit	Cr	12-20+	LS	0	10 YR 7/2 10 YR 6/12	massive	ST	soft calcareous sandstone

Profile BHKC4 map unit 400; Cragola; 13T 355924E 4855352N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-6/ C,I	SCL	-	10 YR 5/4 10 YR 4/2	gr	ST	-
Shovel Pit	Bk	6-16/ C,W	CL	10% gravel	10 YR 6/2 10 YR 5/4	3 m sbk	V	-
Shovel Pit	II C	16-36+	SL	90% gravels & cobbles	10 YR 7/2 10 YR 6/12	massive	V	36-60" gravels continue based on visual observations of adjacent hillslope

Profile BHKC5 map unit 401; Cragola-steep 13T 355910E 4855398N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
cut bank	A	0-4"/ C,S	SL	50% gravel	10 YR 6/2 10 YR 5/2	gr	Sl	-
cut bank	AC	4-10/ G,W	SCL	25% gravel	10 YR 5/2 10 YR 4/2	1 f/m sbk	V	-
cut bank	Ck	10-18/ G,W	SCL	-	10 YR 6/2 10 YR 5/2	massive	V	-
cut bank	Cr	18-30+	SCL	-	10 YR 6/2 10 YR 5/2	massive	V	-

Profile BHKC6 map unit 210; Tassel; 13T 356112E 4855460N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-8/ C,S	SL	0	10 YR 6/2 10 YR 4/2	1 m sbk breaks to sg	NE	Surface horizon influenced by eolian deposits
Shovel Pit	C	8-18/ C,S	SL	0	10 YR 6/3 10 YR 5/3	massive	SL/ST threads/ masses	Bottom end of Cr horizon is mixed shale & sandstone
Shovel Pit	Cr	18-24+	SCL	0	10 YR 6/3 10 YR 5/3	massive	SL/ST matrix/ masses	Probably related dry soil to profile BHKC-2

Profile BHKC7 map unit 430; Bowbac; 13T 356155E 4855523N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-4 C,S	SL	0	10 YR 4/4	10 YR 3/4	1 f/m sbk breaking to gr	NE	-
Shovel Pit	Bw	4-16/ C,S	SL	0	10 YR 5/4	10 YR 4/4	1 f/m sbk	NE	-
Shovel Pit	Bt	16-29/ C,S	SL	0	10 YR 5/3	10 YR 4/4	2 m/c abk + prismatic	NE	
Shovel Pit	Bk	29-42	SL	0	10 YR 6/3	10 YR 5/4	massive	V	Violent in both matrix & masses & threads -
	R	42+	-	0			massive	-	soft sandstone

Profile BHKC8 map unit 230; Samsil; 13T 355881E 4856122N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-4/ C,W	SCL	0	10 YR 5/2	10 YR 5/3	cr	NE	
Shovel Pit	AC	4-8/ C,W	CL	0	10 YR 5/4	10 YR 4/3	1 f/m sbk	V	calcareous shale-disseminated.
Shovel Pit	Cr	8-18+	CL	0	10 YR 6/3	10 YR 5/4	massive	V	shale chips abundant in both lower horizons.

Profile BHKC9 map unit 320, Petrie; 13T 355696E 4856910N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
cut bank	A	0-4/ C,S	CL	0	2.5 Y 5/2	2.5Y 4/2	1 f/m platy / gr	NE	
cut bank	AC	4-14/ G,S	CL	0	2.5Y 5/2	2.5Y 3/2	1 m sbk	SL	
cut bank	C1	14-22/ G,S	C	0	2.5Y 5/2	2.5Y 3/2	mssive	SL	
cut bank	C2	22-36/ G,S	C	0	2.5Y 5/2	2.5Y 4/2	masive	SL	Common masses of calcite & gypsum in lowest layer.
cut bank	C3	36-60	C	0	2.5Y 5/2	2.5Y 3/2	massive		Redox mottles common in A & AC, mottle color 10YR6/8

Profile BHKC10 map unit 200; Danko taxadjunct; 13T 355736E 4856896N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-4/ C,S	C	0	10 YR 4/2	10 YR 3/1	1 f sbk → gr	ST	carbonates disseminated throughout
Shovel Pit	Ck	4-12/ C,W	C	0	10 YR 5/3	10 YR 4/2	massive	V	very common calcite masses & threads.
Shovel Pit	C	12-18	C	0	10 YR 3/1	10 YR 3/2	massive	V	below 18" soft shale chips/clay compressed by increased moisture content..

Profile BHKC11 map unit 230; Samsil; 13T 355564E 4857520N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-6/ C,W	SCL	0	10 YR 4/3	10 YR 4/4	1 f sbk → gr	NE	Similar to BHKC-8 with slightly greater development in Bw.
Shovel Pit	Bw	6-18/ G,W	SCL	10% shale & sandstone	10 YR 5/3	10 YR 4/3	2 m sbk	V-dis	
Shovel Pit	Cr	18-24+	SCL	40% shale & sandstone	10 YR 4/3	10 YR 3/4	massive→ platy		

Profile BHKC12 map unit 500;Cushman; 13T 355989E 4856500N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-5/ C,S	SCL	0	--	10 YR 5/2	gr	NE	
Shovel Pit	Bt	5-10/ C,S	SCL	0	10 YR 4/3	10 YR 4/2	3 f abk	NE	common sand bridging & clay films
Shovel Pit	Bt2	10-21/ G,S	SCL	0	10 YR 4/3	10 YR 4/2	3 m abk	NE	
Shovel Pit	Bk1	21-36	SCL	0	10 YR 5/2	10 YR 4/2	massive	V-matrix	very common calcite threads & masses
Auger	Bk2	36-60	SCL	0	--	--		V-matrix	

Profile BHKC13 map unit 410; 13T Big Horn taxadjunct; 13T 354639E 4858195N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
cut bank	A	0-5 C,S	C	<3% pebbles	10 YR 4/0	10 YR 4/2	gr	ST	
cut bank	Bt	5-10/ C,S	C	0	10 YR 4/2	10 YR 4/2	3 f sbk	ST	
cut bank	Btk	10-20/ G,W	C	0	10 YR 5/2	10 YR 4/2	3 m abk & prismatic	V	common carbonate masses
cut bank	Bk1	20-30/ G,S	C	0	2.5Y 6/2	2.5Y 4/2	1 m prismatic →sbk	ST	common carbonate threads & masses
cut bank	Bk2	30-36/ C,S	L	0	2.5Y 4/3	2.5Y 4/2	massive	ST	many threads + seams throughout
-	Bk3	36+	-	>90%	not evaluated deeper because of coarse fragment content				soft gypsum threads & intermittent pebbles (25%).

Profile BHKC14 map unit 310, Arvada; 13T 356028E 4855655N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
cut bank	A	0-5/ G,W	SL	0	10 YR 6/2	10 YR 5/3	gr	NE	
cut bank	Bt	5-13/ G,W	SCL	0	10 YR 5/3	10 YR 4/2	2 f/m sbk	SL	clay skins in root channels
Shovel Pit	Btkn	13-22/ C,S	SCL	5% moderate channers	10 YR 5/3	10 YR 4/2	3 m columnar →3 m/c abk	V	Clay skins common throughout; calcite in masses/ threads/ seams common
Shovel Pit	Bky	22-32 G.S	CL	0	10 YR 4/2	10 YR 4/2	massive	V	calcite in soft masses threads seams-common; gypsum crystals & masses-many
Shovel Pit	C	32-60	SCL	0	10 YR 4/2	10 YR 4/2	massive	ST	ST masses-few

Profile BHKC15 map unit 510; Embry; 13T 356177E 4856517N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-4/ C,S	L	0	10 YR 5/2	10 YR 3/2	gr	NE	
Shovel Pit	Bw	4-14/ C,S	SCL	0	10 YR 5/3	10 YR 4/2	2 f/m sbk	NE	clay skins and sand bridging common
Shovel Pit	C	14-24/ C,G	SL	0	10 YR 4/2	10 YR 4/2	massive	NE	
Shovel Pit	Cr	24+	-	-	-		-	NE	soft shaley sandstone

Profile BHKC16 map unit 230; Samsil; 13T 355886E 4856692N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-2/ C,S	SiCL	15% channers	2.5Y 5/2	2.5Y 4/2	2 m platy	NE	1/4" surface crust
Shovel Pit	AC	1-6	CL	60% platy shale	2.5Y 5/2	2.5Y 4/2	2 m platy	NE	
Shovel Pit	Cr	6-12+	CL	90% platy shale	2.5Y 4/1	2.5Y 3/2	platy	SL	Fe + Mg stains few to many

Profile BHKC17 map unit 420; Gaynor; 13T 355680E 4857054N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-5/ G,S	CL	0	2.5Y 4/2		gr	NE	
Shovel Pit	AC	5-12/ C,S	CL	0	2.5Y 4/3	2.5Y 4/3	1 f sbk	SL-matrix ST-mases	
Shovel Pit	Ck	12-22	SCL	0	2.5Y 5/3	2.5Y 5/3	1 m abk	ST	
Shovel Pit	Cr	22-36	CL		2.5Y 5/2	2.5Y 5/2	platy	ST	many masses+ threads throughout

Profile BHKC18 map unit 420; Gaynor; 13T 355560E 4857834N (not sampled)

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-7/ C,S	SCL 32%	0	2.5Y 4/2		gr	NE	
Shovel Pit	AC	7-12/ G,S	CL 36%	0	2.5Y 5/3	2.5Y 5/3	massive	SL	
Shovel Pit	Ck	12-24+	SICL34%	0	2.5Y 5/3	2.5Y 5/3	2 m sbk	V	Soft $CaCO_3$ masses to 24" less abundant than BHKC17

Profile BHKC19 map unit 402; Cragola taxadjunct; 13T 355511E 4857986N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
cut bank	A	0-5/ C,S	CL	15% gravels	10 YR 5/3	10 YR 3/2	gr	ST	-
cut bank	Bk1	5-12/ G,S	CL	5% gravels	2.5Y 5/3	2.5Y 4/2	3 f/m abk	V	Clay skins abundant on ped faces & root channels.
cut bank	Bk2	12-24/ G,W	SCL	5% gravels	2.5Y 5/2	2.5Y 4/3	3 m columnar →m abk	V	Clay skins abundant on ped faces & root channels. many masses & threads
cut bank	Bk2	24-36/ G,W	SCL	5% gravels	2.5Y 5/3	2.5Y 4/3	massive	V	common soft masses
cut bank	Bk3	36-60	SCL	35% gr + cobbles	2.5Y 5/3	2.5Y 4/3	massive	V	Calcite accumulated around cobbles & in layers and seams

Profile BHKC20 map unit 402; Cragola taxadjunct; 13T 355275E 4857877N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
cut bank	A	0-5/ C,S	SCL	10% gravels	2.5Y 6/3 2.5Y 4/2	gr	NE-top 3" ST-lower 2"	-
cut bank	Bt	5-10/ G,S	CL	3% gravels r	2.5Y 6/2 2.5Y 4/2	3 f/m abk	ST	common thin clay skins on peds and root channel
cut bank	Btk1	10-22/ C,S	CL	30% gravels	2.5Y 5/2 2.5Y 5/2	2 m columnar → 3 c abk	V	many masses & threads, common thin clay skins on peds and root channel
cut bank	Bk	22-36/ C,S	SCL-SC	15% gravels	2.5Y 5/2 2.5Y 5/2	massive	V	many masses, nests & threads
cut bank	Bky	36-60	SL	25% gr + cobbles	2.5Y 5/2 2.5Y 5/2	massive	ST	in soft masses

Profile BHKC21 map unit 202; Samsil; 13T 355213E 4857772N. Not Sampled

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	C	0-3/ C,S	CL	--	2.5Y 5/3 2.5Y 5/2	3 f/m platy	ST	
Shovel Pit	AC	3-8/ G,S	C	Shale fragments	2.5Y 5/3 2.5Y 4/3	1 m sbk & 3 m platy	ST	
Shovel Pit	C	8-12/ G,S	C	Shale fragments	2.5Y 5/3 2.5Y 4/3	1 m sbk & 3 m platy	ST	
Shovel Pit	Cr	12-24	C	Soft Shale	2.5Y 4/2 2.5Y 3/3	platy fragments	SL	

Profile BHKC22 map unit 300; Renohill taxadjunct (sodic) 13T 355001E 4857345N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-4/ C,S	SCL	0	2.5Y 6/3 2.5Y 4/3	2 f sbk	V	
Shovel Pit	Bt	4-11/ C,S	CL	0	2.5Y 5/3 2.5Y 4/2	3 f/m sbk	V	Clay skins on ped faces & root channels
Shovel Pit	Bk	11-20/ G,S	C	Shale Chips 5%	2.5Y 5/3 2.5Y 4/2	massive very hard	V	calcite masses & many pores nearly continuously filled
Shovel Pit	Bk2	20-36	CL	Shale Chips 5%	2.5Y 5/3 2.5Y 4/2	massive very hard	ST	Common soft masses
Augured	Cr	36-50	CL	Shale Chips 5%		massive		Hard Rock @ 50"

Profile BHKC23 map unit 300; Renohill taxadjunct (sodic); 13T 354825E 4857488N. Not sampled.

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)	Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-5/ C,S			2.5Y 6/3 2.5Y 4/3		NE	
Shovel Pit	Btk	5-13			2.5Y 5/3 2.5Y 4/2		V	
Shovel Pit	Bk	13-60			2.5Y 5/3 2.5Y 4/2		V	

Profile BHKC24 map unit SC; Tassel taxadjunct; 13T 354789E 4857471N

Obs. Method	Horizon	Depth (in)/ bnd	Texture	Rock Fragments	Color (dry)-(moist)		Structure	Reaction to 1 N HCl	Notes
Shovel Pit	A	0-7/ C,S	SL	30% gravels & cobbles	2.5Y 6/3	2.5Y 4/2	2 f sbk → gr	NE	noncalcareous
Shovel Pit	Cr	7-12+	LS	--			massive	NE	

Profile BHKC25 map unit 510; Embry; 13T 354198E 4858226N

Obs. Method	**Horizon**	**Depth (in)/ bnd**	**Texture**	**Rock Fragments**	**Color (dry)-(moist)**		**Structure**	**Reaction to 1 N HCl**	**Notes**
cut bank	A	0-4/ C,W	SCL	1%	2.5Y 5/3	2,5Y 3/2	gr	NE	
cut bank	Bw?	4-14/ C,S	SCL	3%	2.5Y 4/2	2.5Y 4/2	2 m columnar 3 m abk	NE	
cut bank	C1	14-26	SL-SCL	30% gr f	2.5Y 6/3	2.5Y 5/2	massive	NE-matrix	ST-rock bottoms & few masses
cut bank	C1	26-44	SL	30% gr f	2.5Y 6/3	2.5Y 5/2	massive	NE	And few masses
cut bank	C2	44-60	SL	< 1%	2.5Y 6/3	2.5Y 5/2	massive	NE-matrix SL-masses	

Profile BHKC26 map unit 210; Tassel; 13T 354216E 4858214N

Obs. Method	**Horizon**	**Depth (in)/ bnd**	**Texture**	**Rock Fragments**	**Color (dry)-(moist)**		**Structure**	**Reaction to 1 N HCl**	**Notes**
cut bank	A	0-5/ C,W	SL	20% gravels		2.5Y 5/4	2 f sbk→ gr	NE	
cut bank	AC	5-15/ G,W	SL	0	2.5Y 5/3	2.5Y 4/3	2 m/c abk	ST	disseminated
cut bank	Cr	15-31+	SL	--	2.5Y 5/3	2.5Y 4/3	massive	ST	common calcite threads & masses; soft calcaneous sandstone

Profile BHKC27 map unit 220; Rhoame 13T 354243E 4858224N

Obs. Method	**Horizon**	**Depth (in)/ bnd**	**Texture**	**Rock Fragments**	**Color (dry)-(moist)**		**Structure**	**Reaction to 1 N HCl**	**Notes**
cutbank & shovel pit	A	0-7	SL	5% gravels		2.5Y 4/2	1 f abk →gr	NE	
	Cr	7-18	CL	0	2.5Y 4/3	2.5Y 4/2	1 m columnar →2 m sbk	NE-matrix	SL in few $CaCO_3$ masses
	C1	18-36	CL	0	2.5Y 4/3	2.5Y 4/2	massive	NE-matrix -	SL in very few $CaCO_c$ masses
	C2	36-60	SCL	0	2.5Y 4/3	2.5Y 4/2	massive		

Addendum D7.C

Representative Pedon Photographs

Figure D7.C1. Profile BHKC2; Shingle-saline.

Figure D7.C2. Profile BHKC10; Danko taxadjunct

Figure D7.C3. Profile BHKC26; Tassel.

Figure D7.C4. Profile BHKC24; Tassel taxadjunct

Figure D7.C5. Profile BHKC27; Rhoame.

Figure D7.C6. Profile BHKC11; Samsil.

Figure D7.C8. Profile BHKC22; Renohill taxadjunct.

Figure D7.C9. Profile BHKC14; Arvada.

Figure D7.C10. Profile BHKC9; Petrie.

Figure D7.C11. Profile BHKC1; Forkwood.

Figure D7.C12. Profile BHKC4; Cragola.

Figure D7.C13. Profile BHKC19; Cragola taxadjunct.

Figure D7.C14. Profile BHKC13; Big Horn taxadjunct.

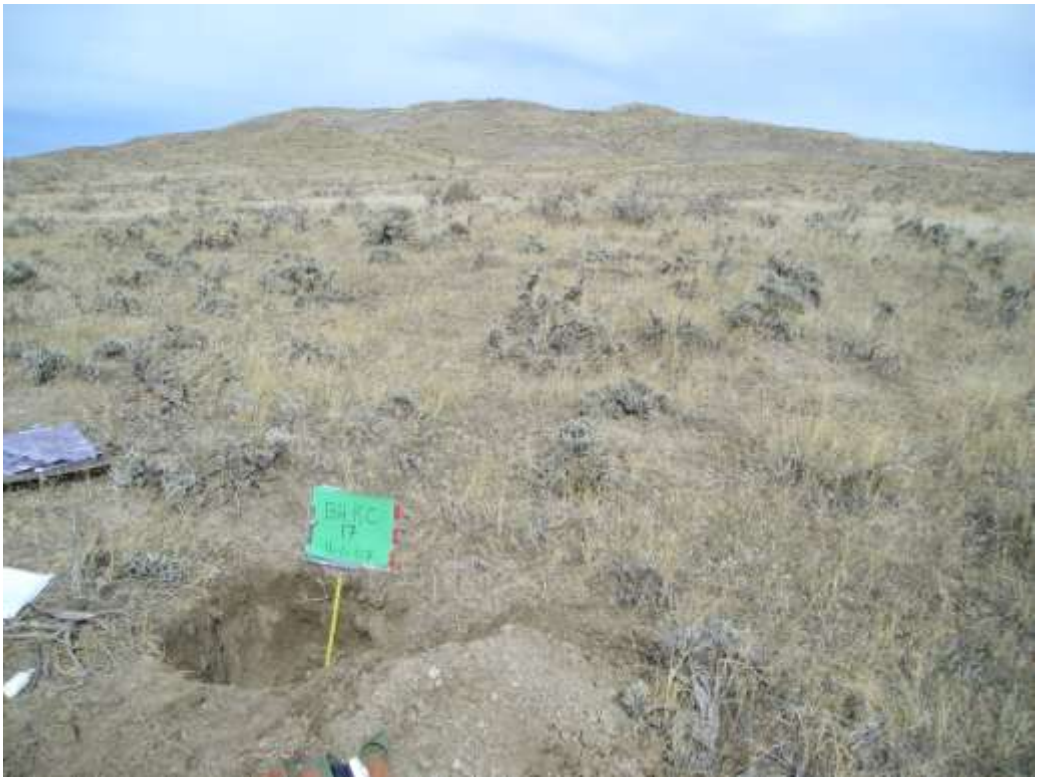

Figure D7.C15. Profile BHKC17; Gaynor.

Figure D7.C16. Profile BHKC7; Bowbac.

Figure D7.C17. Profile BHKC12; Cushman.

Figure D7.C18. Profile BHKC25; Embry.

Addendum D7.D

Field Pedon Description Forms

Addendum D7.E

Soil Map