BASELINE SOIL SURVEY
SPRING CREEK AREAS A AND B EXPANSION AREA
SPRING CREEK COAL MINE

Prepared for:
Cloud Peak Energy
Spring Creek Mine
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Table of Contents

List of Tables

Introduction

A baseline soil survey of the a proposed expansion area for Spring Creek Mine, called Areas A and B, has been completed by Terra Soil and Environmental Solutions, LLC, based in Belgrade, Montana.

The primary goal of the project was to conduct a soil survey to describe all soils on the proposed permit area and their suitability for reclamation purposes. Standards outlined from the national cooperative soil survey guided the process. Two objectives provided direction towards completion of this goal. The primary objective was need to meet the principal requirements for a baseline soil survey as outlined in the Montana Department of Environmental Quality's Soil, Overburden and Spoil Guidelines (1998). A principal requirement outlined in these guidelines is to create a baseline soil survey that provides the most useful information possible for soil salvaging and land reclamation purposes. Therefore, to meet this requirement the second objective was to employ sufficient and efficient sampling and data recording methodologies to maximize the amount of substantive information gained at each sample location.

To accomplish the goals of the soil survey, a soil-landscape approach to mapping was employed. This approach considers landscape attributes along with soil properties as the basis for map unit concepts. This allows for partitioning the landscape into recognizable management units. For variable landscapes such as what is encountered within Areas A and B, this approach has a distinct advantage because it allows for greater potential accuracy and detail in soil mapping, as soil types and properties are often related to observable changes in landscape attributes.

Methods And Materials

Project Area

The Spring Creek Baseline Area consists of two separate fields. Baseline Area A is located in Sections 11, 12, and 13, Township 8S, Range 39E, Big Horn County, Montana and consists of approximately 307.8 acres. Baseline Area B is located in Sections 13 and 24, Township 8S, Range 39E, Big Horn County, Montana, and consists of approximately 54 acres. Although of relatively minor spatial extent, the topography of the baseline areas varies from gently sloping terrain and playas to moderately steep hillslopes and plateaus.

Soil Survey

All soil mapping, sampling, and description procedures used were in accordance with procedures of the USDA-NRCS National Soil Survey Handbook (1996) and Soil Survey Manual (1993). The resulting soil mapping units consist of both complexes and consociations. Consociations are soil map units that consist primarily of one soil type, or component. In a survey of fine spatial detail consociations are the preferred map unit type as this minimizes the uncertainty present when identifying individual soil components in a soil map unit complex. This assists with any future soil salvage operation. Therefore, identification of consociations occurred wherever possible. However, due to the highly variable geologic strata, topography, and mixed soil depths that occur over short distances throughout the area, resulting map units also consist of soil complexes.

The soil mapping procedure employed a combination of techniques. These included interpretation of available aerial imagery and topographic map overlays, field observations of soil-landform patterns and soils, and digitization mapped of soil boundaries using a GIS.

Field maps used in soil mapping were created using a GIS using aerial imagery, topographic maps, and other spatial data available from the Montana Geographic Information Clearinghouse at http://nris.mt.gov/gis/default.asp. All spatial data was enlarged to a scale of 1:4800. Initial soil boundary lines were digitized based on discernible differences in attributes such as aerial imagery photo tone, landforms, and slope steepness. Maps at the scale of 1:4800 were then created using aerial imagery for a base. These maps were printed and laminated for subsequent mapping in the field.

During field soil mapping, traversing of the area occurred in a pattern largely dictated by topography and landscape. This allowed for identification of landscape and vegetation patterns throughout the survey area. Observable landscape attributes such as changes in geologic parent material, landform, slope steepness, aspect, and plant community types allowed for modification of initial soil map boundaries. Association of these observed changes with patterns on aerial imagery allowed for delineation of soil map units on field maps.

Documentation

Soils were sampled to a minimum depth of 84 inches or until a lithic, paralithic, or extremely skeletal or fragmental horizon was encountered, whichever occurred first, using a spade, sharpshooter, and/or bucket auger. The number and distribution of soil profile description pits is approximately equivalent to the requirements for an Order 1 soil survey.

A standard soil note was used at the majority of sample sites. Soil data collected at these sites included the following:

- horizon designations,
- horizon depth and thickness,
- soil color (moist and dry),
- soil texture class, including modifiers where necessary,
- estimated clay percent,
- soil structure,
- soil consistence,
- chemical reaction (effervescence),
- rock type, soil pH, effervescent,
- soil pH,
- soil horizon boundary,
- field sieved rock fragments,
- amount and size of roots,
- amount and size of pores,
- clay films (if present),
- concentrations / ped, and void surface features.

In addition to the above, detailed information about landscape and plant community attributes were collected at each sample site. GPS coordinates were recorded with a hand held Garmin GPS receiver. These data were collected in the field as UTM, NAD83 coordinates.

At sites that served as “checks” to determine the presence of soil types mapped and as support for the full pedon note described above an abbreviated note form was used to record soils data. These note forms were used to record a subset of the soil attributes described above that served to verify mapped soils. The kind and amount of landscape, plant community, and location data collected was the same at all documentation sites regardless of the type of field note used.

In addition to the soil pedon notes, soil mapping notes were used to describe map units as identified in the field. These notes recorded the distribution of landscape components within the area encompassed by a map unit delineation. Detailed information is collected about the kind and proportion of different landscape components present while only an abbreviated soil profile description is recorded. The same landscape, plant community and GPS data was collected at the sample location (plot center) for mapping notes as per all field documentation sites.

Lab Samples

Soil samples for laboratory analysis were collected at all reference sample locations where a full soil pedon note was described according to established field sampling techniques and specific procedures outlined in the Montana DEQ's Soil, Overburden and regraded Spoil Guidelines (1998). Soils for laboratory analysis were sampled to 84 inches (Figure 1), to a lithic contact, or to 6 inches below a paralithic contact, whichever occurred first. Samples from each genetic horizon were delivered to Agvise Laboratories in North Dakota for analysis of organic matter (LOI method), percent carbonates (Pressure Method), electrical conductivity (EC) of a saturation extract, soluble cations (Ca^{++}, Na+, and Mg++) from a saturation extract for calculating the sodium adsorption ratio (SAR), soil pH, and texture (percent sand, silt and clay).

Samples collected for lab analysis were transported back to Belgrade, Montana where they were air dried at room temperature and partially de-aggregated and sieved. Those samples with abundant hard rock fragments (>15%) were completely disaggregated with a rubber pestle and mortar and run through a 2 mm sieve prior to shipping. Only the fine-earth portion of the sample was sent to the lab in those instances. For the majority of samples, final disaggregation and sieving with a 2 mm sieve was completed at Agvise Labs using a motorized disaggregator. A direct chain of custody was maintained at all times for samples shipped between Terra Soils and Agvise Labs. Sieve analysis for samples with abundant rock fragments was completed by Terra Soils while all other analyses were completed by Agvise Labs.

A review was conducted of past soil survey data available from previously permitted mining areas at the Spring Creek Mine. These reports and other literature point out that boron and molybdenum toxicities are unlikely to occur in Areas A and B based on environmental conditions. For Boron these include: high pH and high calcium levels, low organic matter levels, dry climate, and overall low soil moisture levels. All of the above reduce the probability of boron toxicities which, even without these environmental conditions, are rare in general.

High molybdenum forage occurs primarily in wet soils that most often have a thick A-horizon with or without a peat layer at the surface (**Tisdale, et.al. 1985**). There are no wet soils present in the present survey area.

As a result, laboratory tests for these elements were not included in the baseline soil survey analyses. Analysis for soil selenium was also not included in the Area A and B baseline soil survey. Thus far, no selenium problems have been identified at the Mine. An inventory of selenium-accumulating plant species was included as part of the baseline vegetation inventory. Any future soil analysis for selenium would be dependent on unexpected results from the vegetation sampling.

Soil Series Correlation

Analysis and correlation of field described soil pedons to soil series concepts was conducted after all of the data had been collected. This approach allowed the full dataset to be used in defining the population of soils present and in partitioning that dataset into soil concepts. To accomplish this, all soil profile descriptions, both with and without lab data, were stratified into groups of similar soils. Stratification was a sequential process where soils were grouped based on similarities of selected soil properties. For example, the initial sort might be based on the predominant parent material. After conducting this first grouping, a second sort might be based on landform attributes (type, slope, etc). Then a third sort is based on soil depth, and so on until reasonably homogeneous groups of soil profiles were created. These groups then became the basis for developing the ranges of soil properties for each soil type identified in Areas A and B. These concepts could then be compared with accepted official series descriptions from the National Cooperative Soil Survey.

Correlation of soil concepts to official series descriptions was completed using search tools available at http://soils.usda.gov/technical/classification/osd/index.html. This USDA website allows for custom searches based on soil taxonomy and other attributes to correlate soils with official series descriptions. A correlation document has been created that describes variations between the named series used and actual data distributions for Areas A and B.

Creation of Final Maps

Field mapping was completed on maps created using a GIS at an approximate scale of 1:4800. These maps consisted of National Agricultural Inventory Program (NAIP) aerial imagery as a base. The 1 meter resolution of this imagery allows for easy identification of landform features and vegetation community patterns crucial for accurately mapping soils. This base was overlaid with topographic maps at the same scale.

Field soil maps were later re-compiled and digitized directly in ArcGIS10.0 at a scale of 1:4800. The same map layers, the NAIP aerial imagery and topographic maps, were used in a GIS for this process. The process used to create the final soil polygon overlay involved several steps. Major details are outlined below:

- The overall boundary of the survey area was created by converting the AutoCAD Area A and B boundary layer to ArcGIS shapefile format. This allowed for the use of this layer as a base from which to edit soil boundaries. This boundary was then edge-matched with the existing Spring Creek soil survey.
- Soil boundaries that were easily transferrable from the paper field maps, i.e. those that were easily identifiable based on changes in aerial imagery photo tone, were first digitized.Imagery photo tone is often useful for identifying boundaries betsween vegetation community types and landscape features..
- The topographic map layer was then displayed onto the aerial imagery layer. Soil map unit boundaries that were based largely on topographic breaks were then digitized onto the map.
- Soil boundaries in upland areas were subsequently digitized to the topographic base map
- At the boundary between the original Spring Creek soil survey and this soil survey, edge matching occurred through employment of topology rules in ArcGIS. These rules enforced matching of lines from both surveys to within a tolerance of 1 foot .
- The finished ArcGIS soil map layer was then converted into an AutoCAD file. Individual files were created for soil polygons, map unit symbols, and the boundary between the South Fork and Pearson Creek Areas.

Map Joining With Existing Permitted Area

A portion of the baseline soil survey area lies adjacent to previously permitted areas within Spring Creek Mine. A baseline soil survey of these areas (South Fork) was completed in 1990 (Lupcho, 1990). Current mapping provided for contiguous mapping between the Areas A and B soil survey and the existing soil survey.

All soils data from the current work has been correlated to the existing soil series in the National Cooperative Soil Survey database. The original baseline soil surveys for the Spring Creek Mine did not use existing soil series from within the National Cooperative Soil Survey database. Therefore, joining of the two surveys along the boundary was based on examining the similarities and differences of soil properties as described for each survey's respective soil series and map units.

Correlating soils between the two surveys was the first step in providing a contiguous map between the two surveys. In some instances, it was necessary to make small line adjustments on the South Fork side in order to obtain a clean join. No attempt was made to rectify soil lines in the South Fork Area beyond what was necessary for joining coverages. Map unit symbols from the original Spring Creek soil mapping legend were used on the South Fork side where reasonable. Map units from the Areas A and B soil survey were extended across comparable map units in the original mapping legend or where small slivers of the Areas A and B survey delineations extended across the map boundary.

Soil Interpretations

Soil interpretive tables and soil salvage volume tables are provided. Most of the interpretive tables are based on standard technical guides developed as part of the National Cooperative Soil Survey program in Montana. The interpretive factors of wind erodibility group (WEG), K-factors for water erosion, and available water holding capacity (AWC) relate to individual soil layers. The land capability classes are based on attributes of the full soil profile as well as landscape features.

USDA land capability classifications were assigned to the major components of soil map units as a means to assess land potential in the survey area prior to disturbance. This interpretation provides a comprehensive rating system that groups soils based on their potential for agricultural use. Although lands in the survey area will not be used as cropland, the same documented criteria can be used to assess land potential in general which is the intended purpose here.

Results and Discussion

Soil Series

Soil series are utilized to represent the central tendency of a group of pedons sampled in the field that have similar characteristics. However, raw soils data collected in the field seldom fit the complete range of characteristics for a soil series. This is especially true in areas of complex topography and/or mixed geologic parent materials.

Over a large area, soil series can be very useful for broadly describing the types of soils that can be expected. For more site specific uses of soils data over a smaller area, however, more detailed information about the true range of soil properties for soils mapped are often required. Reclamation planning or assessing soil suitability for reclamation is just such a case. All of the soil profiles sampled in Areas A and B have been correlated to existing soil series within the USDA-NRCS database. In some cases, modifications to soil series were employed to accurately correlate the existing field data to series concepts. These take one of three forms:

- soil series variants,
- series variants, and
- series taxadjuncts.

A soil phase fits within the general range of soil characteristics for the named soil series but indicates that a specific non-soil characteristic or group of characteristics vary from the central series concept. These characteristics usually relate to the use, management and/or behavior of the soil. For example, a “dry” phase would indicate that the specific soil receives less moisture than that described for the official series description. Variants fit the same soil classification as the named series but are outside the range of soil characteristics used to define the series concept. Taxadjuncts have one or more soil properties outside the range of the series and also outside the limits of a higher taxonomic class. Thus, the soil classification of a taxadjunct is different from that of the named series. The differences in soil properties are small enough, however, that major soils interpretations are not affected (Soil Survey Staff, 1993).

Table 1 provides a correlation record of all soil series, phases, variants and taxadjuncts used in the baseline soil survey of Areas A and B. Differences between the mapped soils and the official series description for the named series are given when such differences may have a direct impact on land reclamation.

Soil Correlation Record

Table 1. Soil Series Correlation Record.

Soil correlation for proposed expansion areas A and B. Soil concepts used are grouped by family particle-size and/or general parent material criteria**.**

Fine Family Soils			
Soil Series	**State**	**Areas A and B**	**Differences in Area A and B Soils from Official Series Description**
Big Horn	WY	Big Horn Series, deep	• Soils are primarily deep with the depth to soft sedimentary beds ranging from 42 to 84 inches • Depth to significant secondary lime varies from 10 to 16 inches
		Big Horn Taxadjunct	• Depth to significant secondary lime ranges from 10 to 16 inches • Taxadjunct reflects contrasting particle size classes

Scoria Derived Soils			
Soil Series	**State**	**Areas A and B**	**Differences in Area A and B Soils from Official Series Description**
Spearman	MT	Spearman Series, dry	• Dry phase due to 10 inches of annual precipitation at Spring Creek • Surface colors barely meet requirement for mollic epipedon.
	MT	Spearman Taxadjunct, deep / dry	• Dry phase due to 10 inches of annual precipitation at Spring Creek • Channers in profile range from 25 to 30 percent • Taxadjunct reflects paralithic contact at 32 inches rather than fragmental horizon, and presence of weak argillic horizon
Wibaux	WY	Wibaux Taxadjunct	• Depth to fragmental material ranges from 12 to 16 inches • Taxadjunct reflects fragmental particle size class

Fine-Loamy Soils			
Soil Series	**State**	**Areas A and B**	**Differences in Area A and B Soils from Official Series Description**
Shingle	WY	Shingle Series	• Depth to lime is 3 inches • Area A and B soils have a Bk horizon with finely disseminated carbonates
Forkwood	WY MT	Forkwood Series	• Depth to lime ranges from 2 to 4 inches
		Forkwood Variant	• Variant due to clay substrate below 35 inches. Clay content ranges from 40 to 50 percent at these depths
Loamy-Skeletal Soils			
Soil Series	**State**	**Areas A and B**	**Differences in Area A and B Soils from Official Series Description**
Earsman	Co	Earsman Taxadjunct, stony, dry	• Stony phase due to 2% stones on the surface • Dry phase due to 10 inches of annual precipitation at Spring Creek • Skeletal component consists of stones, cobbles, and gravels • Taxadjunct reflects mesic temperature regime
Labre	MT	Labre Taxadjunct, dry	• Dry phase due to 10 inches of annual precipitation at Spring Creek • Depth to lime ranges from 6 to 10 inches • Increased sand percentage • Taxadjunct reflects warmer temperature and dryer moisture conditions
Coarse-Loamy Soils			
Soil Series	**State**	**Areas A and B**	**Differences in Area A and B Soils from Official Series Description**
Phiferson	WY NE	Phiferson	• Soils are primarily deep to very deep with depths ranging from 50 to 84 inches. • Depth to carbonates from 25 to 30 inches

Table 2. Soil Classifications

Big Horn	Fine, smectitic, mesic Ustic Paleargid
Big Horn Taxadjunct clayey over loamy	Clayey over loamy, smectitic over mixed, mesic Ustic Haplargid
Earsman Taxadjunct mesic	Loamy-skeletal, mixed, superactive, calcareous, mesic Lithic Ustic Torriorthent
Forkwood	Fine-loamy, mixed, superactive, mesic Ustic Haplargid
Labre Taxadjunct mesic, aridic	Loamy-skeletal, mixed, superactive, mesic Aridic Haplustoll
Phiferson	Coarse-loamy, mixed, superactive, mesic Aridic Haplustoll
Shingle	Loamy, mixed, superactive, calcareous, mesic, shallow Ustic Torriorthent
Spearman	Fine-loamy over fragmental, mixed, superactive, mesic Aridic Haplustoll
Spearman Taxadjunct fine loamy	Fine-loamy, mixed, superactive, mesic Aridic Argiustoll
Wibaux Taxadjunct fragmental	Fragmental, mixed, mesic Ustic Torriorthent

Typical Profile Descriptions

BIG HORN SERIES

Taxonomy	Fine, smectitic, mesic Ustic Paleargid	
Location Northing / Easting : UTM NAD83 Zone 12	5000556	349605
Parent Material Origin / Kind :	Interbedded shale and sandstone	Residuum
Landform / Landform position :	Low hillslope	Footslope
Slope / Aspect :	8%	North
Vegetation understory / Tree composition :	Big sage, prairie junegrass, cheatgrass	None

Representative profile for the Big Horn series as sampled on a flat to mildly sloping bench with neutral aspects. Soils are moderately well drained.

Representative Pedon: Big Horn loam.

A--0 to 6 inches; dark yellowish brown (10YR 4/4) loam, brown (10YR 4/3) moist; moderate, thin platy structure; hard, friable, slightly sticky and non-plastic; 18 percent clay; common very fine and few fine roots; common, very fine, dendritic pores; non effervescent; 5 percent, hard, sandstone and shale gravels; neutral (pH 6.8); gradual smooth boundary.

Bt--6 to 11 inches; dark yellowish brown (10YR 3/4) clay loam, brown (10YR 4/3) moist; strong, coarse angular blocky structure; very hard, firm, slightly sticky and moderately plastic; 40 percent clay; few very fine, fine, and medium roots; few, very fine and medium, dendritic pores; common, distinct, dark brown (10YR 3/3) clay films on ped faces; non effervescent; 10 percent, hard, shale channers; slightly alkaline (pH 7.8); clear smooth boundary.

Bk--11 to 26 inches; yellowish brown (10YR 5/4) clay loam, yellowish brown (10YR 5/4) moist; coarse angular blocky structure; slightly hard, firm, moderately sticky and moderately plastic; 36 percent clay; few very fine and medium roots; common, very fine, dendritic pores; violently effervescent; lime mainly disseminated with a few, largely inconspicuous, fine threads of secondary lime; 10 percent, hard, shale channers; moderately alkaline (pH 8.3); clear smooth boundary.

C--26 to 41 inches; yellowish brown (10YR 5/4) clay loam, dark yellowish brown (10YR 4/4) moist; massive; soft, firm, moderately sticky, moderately plastic; violently effervescent; strongly alkaline (pH 8.8); few, very fine roots; common, very fine, dendritic pores; 20 percent, hard, shale channers; clear smooth boundary.

Cr--41+ inches; fractured, thinly bedded shale.

Local Range in Characteristics: Depth to secondary lime ranges from 10 to 12 inches. Soil textures in the particle size control section are primarily clay loam and clay. Soil texture in the top 6 inches range from loam to clay loams, and clay content can range from 18 to 34 percent. Soil depths can range from 40 to 84 inches in the deep and very deep phases. Soil pH varies from neutral in the upper profile to moderately to strongly alkaline with depth.

** Based on available field and laboratory data for Areas A and B.*

BIG HORN TAXADJUNCT

Taxonomy	Clayey over loamy, smectitic over mixed, mesic Ustic Haplargid	
Location Northing / Easting : UTM NAD83 Zone 12	4999496	351207
Parent Material Origin / Kind :	Shale	Residuum
Landform / Landform position :	Low hillslope	Footslope
Slope / Aspect :	5%	North
Vegetation understory / Tree composition :	Big sage, slender wheatgrass,	None

Representative profile for the Big Horn Taxadjunct as sampled on a flat to mildly sloping bench with neutral aspects. Soils are moderately well drained.

Representative Pedon: Big Horn Taxadjunct - clay loam.

A--0 to 4 inches; dark yellowish brown (10YR 4/4) clay loam, brown (10YR 4/3) moist; moderate, very thin, platy structure; hard, friable, slightly sticky and non-plastic; 37 percent clay; common very fine and few fine roots; common, very fine, dendritic pores; non effervescent; 2 percent, hard, shale gravels; slightly alkaline (pH 7.5); gradual smooth boundary.

Bt--4 to 9 inches; dark yellowish brown (10YR 4/4) clay, brown (10YR 4/3) moist; moderate, medium, prismatic structure; very hard, very firm, moderately sticky and moderately plastic; 43 percent clay; common, very fine, and few, fine and medium roots; few, very fine and medium, dendritic pores; common, distinct, dark brown (10YR 3/2) clay films on ped faces; non effervescent; 2 percent, hard, shale gravels; slightly alkaline (pH 7.6); clear smooth boundary.

Bk--9 to 30 inches; yellowish brown (10YR 5/3) clay loam, yellowish brown (10YR 4/3) moist; moderate, coarse angular blocky structure; slightly hard, firm, moderately sticky and moderately plastic; 39 percent clay; few very fine and medium roots; common, very fine, dendritic pores; violently effervescent; few, fine, distinct carbonate masses in the matrix; 5 percent, hard, shale channers; moderately alkaline (pH 8.4); clear smooth boundary.

2C1--30 to 39 inches; gray (10YR 5/1) fine sandy loam, dark gray (10YR 4/1) moist; massive; moderately hard, firm, non-sticky and non-plastic; 19 percent clay; few very fine roots; few, very fine, irregular pores; violently effervescent; 5 percent, hard, shale channers; strongly alkaline (pH 9.0); gradual smooth boundary.

2C2—39 to 84 inches; grayish brown (10YR 5/2) fine sandy loam, dark grayish brown (10YR 4/2) moist; massive and single-grained; soft, very friable, non-sticky and non-plastic; 11 percent clay; common, very fine, interstitial pores; violently effervescent; strongly alkaline (pH 8.6); 5 percent, hard, shale gravels.

Local Range in Characteristics: Depth to secondary lime ranges from 10 to 12 inches. Lithologic discontinuity ranges from 30 to 35 inches and results in soil textures ranging from loams, clay loams, and clays in the upper 30 inches to sandy loams and loamy sands below 30 inches. Soil depths are very deep below 84 inches. Soil pH varies from neutral in the upper profile to moderately to strongly alkaline with depth.

* *Based on available field and laboratory data for Areas A and B.*

SPEARMAN TAXADJUNCT

Taxonomy	Fine-loamy, mixed, superactive, mesic Ustic Haplargid	
Location Northing / Easting : UTM NAD83 Zone 12	4998951	351181
Parent Material Origin / Kind :	Shale	Residuum
Landform / Landform position :	Rolling Low Hills	Backslope
Slope / Aspect :	5%	North-Northwest
Vegetation understory / Tree composition :	Big sage, bluebunch wheatgrass, prairie junegrass	Ponderosa Pine

Representative profile for the Spearman Taxadjunct as sampled on gently rolling plain with no dominant aspect. Soils are moderately well drained.

Representative Pedon: Spearman Taxadjunct - loam.

A--0 to 4 inches; dark reddish brown (2.5YR 3/3) channery loam, dusky red (2.5YR 3/2) moist; 23 percent clay; moderate, fine, granular structure; soft, friable, slightly sticky and non-plastic; non effervescent; neutral (pH 7.1); common, very fine and few, fine and medium roots; common, very fine, dendritic pores; 20 percent, moderately hared, subangular shale channers and 5 percent, moderately hard, subangular shale flagstones; clear smooth boundary.

Bt--4 to 18 inches; dark reddish brown (2.5YR 3/4) clay loam, dark reddish brown (2.5YR 3/4) moist; 29 percent clay; moderate, medium, subangular blocky structure; soft, firm, moderately sticky and moderately plastic; non effervescent; neutral (pH 7.3); common, very fine and few, fine and medium roots; many, very fine and few, fine dendritic pores; 30 percent, moderately hard, subangular shale channers; few, faint and distinct, reddish brown (5YR 4/3), clay films on ped faces; clear smooth boundary.

Bt2- 18 to 32 inches; red (2.5YR 4/6) loam, reddish brown (2.5YR 4/4) moist; 27 percent clay; moderate, very fine, subangular blocky structure; soft, firm, moderately sticky and very plastic; non effervescent; slightly alkaline (pH 7.6); 30 percent, moderately hard, subangular shale channers; few, very fine and fine roots; common, very fine, dendritic pores; few, faint, (5YR 4/3), clay films on ped faces; abrupt smooth boundary.

C-- 32 to 36+ inches; soft, fractured thinly bedded shale and scoria

Local Range in Characteristics: Depth to illuvial clay ranges from 4 to 8 inches. Soil textures in the particle size control section are primarily clay loam and clay. Soil depths are mainly greater than 30 to 40 inches but can range to deep (40 to 60 inches). Soil pH is primarily neutral.

* *Based on available field and laboratory data for Areas A and B.*

EARSMAN TAXADJUNCT

Taxonomy	Loamy-skeletal, mixed, superactive, calcareous, mesic Lithic Ustic Torriorthent	
Location Northing / Easting : UTM NAD83 Zone 12	5000354	349650
Parent Material Origin / Kind :	Shale/Sandstone	Residuum
Landform / Landform position :	Bench	Crest and Summit
Slope / Aspect :	1%	N/A
Vegetation understory / Tree composition :	Bluebunch wheatgrass, big sage, cheatgrass	Ponderosa Pine

Representative profile for the Earsman sandy loam as sampled on a relatively flat bench position with no dominant aspect. Soils are moderately well drained.

Representative Pedon: Earsman Taxadjunct - sandy loam.

A--0 to 3 inches; brown (7.5YR 4/4) very stony sandy loam, dark brown (7.5YR 3/4) moist; 14 percent clay; weak, very thin, platy structure parting to weak, very fine, granular structure; loose, very friable, non sticky and non plastic; strong effervescence; moderately alkaline (pH 8.4); 30 percent, hard, angular sandstone stone, 20 percent, hard, angular sandstone cobbles and 10 percent, hard, angular sandstone gravels; common, very fine and few, fine and medium roots; common, very fine and few, fine dendritic pores; clear smooth boundary.

Bk--3 to 10 inches; brown (7.5YR 4/4) very stony sandy loam, dark brown (7.5YR 3/4) moist; 18 percent clay; weak, very fine, subangular blocky structure; soft, friable, non sticky and non plastic; violent effervescence; moderately alkaline (pH 8.2); 30 percent, hard, angular sandstone stone, 20 percent, hard, angular sandstone cobbles and 10 percent, hard, angular sandstone gravels; common, very fine and few, fine and medium roots; common, very fine and few, fine dendritic pores; common, medium, distinct, irregular, carbonate masses on ped faces; clear smooth boundary.

C—10 to 15 inches; brown (7.5YR 5/4) extremely stony sandy loam, brown (7.5YR 4/4) moist; 20 percent clay; single grained and massive structure; loose, very friable, non sticky and non plastic; violent effervescence; moderately alkaline (pH 8.3); 40 percent, hard, angular sandstone stone, 20 percent, hard, angular sandstone cobbles and 10 percent, hard, angular sandstone gravels; few, very fine, fine, medium, and coarse roots; common, very fine, irregular pores; common, medium, distinct, irregular, carbonate masses on faces of peds; abrupt wavy boundary

R-- 15+ inches; hard sandstone bedrock

Local Range in Characteristics: Depth to bedrock is shallow but may range to moderately deep in some pedons. Stony phase indicates stones on surface ranging 10 to 18 inches in size. Soil textures are sandy loams.

** Based on available field and laboratory data for Areas A and B.*

FORKWOOD SERIES

Taxonomy	Fine-loamy, mixed, superactive, mesic Ustic Haplargid	
Location Northing / Easting : UTM NAD83 Zone 12	5000104	351367
Parent Material Origin / Kind :	Shale	Residuum
Landform / Landform position :	Plain	N/A
Slope / Aspect :	3%	North – Northeast
Vegetation understory / Tree composition :	Crested wheatgrass	None

Representative profile for the Forkwood series as sampled on a flat to mildly sloping bench with neutral aspects. Soils are moderately well drained.

Representative Pedon: Forkwood loam.

A--0 to 4 inches; dark reddish brown (5YR 3/4) loam, reddish brown (5YR 4/3) moist; 26 percent clay; moderate, fine, subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; non-effervescent, neutral (pH 7.4); few, very fine and common, fine roots; common, very fine and few, fine dendritic pores; gradual smooth boundary.

Bt--4 to 12 inches; dark reddish brown (5YR 3/4) clay loam, reddish brown (5YR 4/3) moist; 34 percent clay; strong, medium, prismatic structure; hard, firm, moderately sticky and moderately plastic; non effervescent; moderately alkaline (pH 7.9); few, very fine and fine roots; common, very fine dendritic pores; few, distinct, dark reddish brown (5YR 3/4), clay films on ped faces; abrupt smooth boundary.

Bk--12 to 22 inches; yellowish red (5YR 4/6) clay loam, reddish brown (5YR 4/4) moist; 36 percent clay; moderate, coarse, angular blocky structure; moderately hard, firm, moderately sticky and moderately plastic; violently effervescent; moderately alkaline (pH 8.4); few, very fine roots; common, very fine, dendritic pores; finely disseminated carbonates in the soil matrix and common, distinct, light gray (5YR 7/1), carbonate masses around rock fragments; gradual smooth boundary.

C--22 to 84 inches; yellowish red (5YR 4/6) loam, reddish brown (5YR 4/4) moist; 24 percent clay; massive structure; soft, firm, moderately sticky and slightly plastic; violently effervescent; strongly alkaline (pH 8.8); 20 percent, moderately hard, angular, shale channers.

Local Range in Characteristics: Depth to secondary lime ranges from 10 to 12 inches. Soil textures in the particle size control section are primarily loam and clay loam. Below 35 inches, textures are predominantly loams and clay loams on level to nearly level slopes. However, some pedons located on footslope positions adjacent to hilly terrain may have clay textures below 35 inches, with clay content ranging from 40 to 50 percent. Soil depths are mainly greater than 30 inches but range to 50 inches in the deep phase. Soil pH varies from neutral in the upper profile to moderately to strongly alkaline with depth.

** Based on available field and laboratory data for Areas A and B.*

LABRE TAXADJUNCT

Taxonomy	Loamy-skeletal, mixed, superactive, mesic Aridic Haplustoll	
Location Northing / Easting : UTM NAD83 Zone 12	4999674	351230
Parent Material Origin / Kind :	Shale	Residuum
Landform / Landform position :	Undulating Plains	Shoulder / Backslopes
Slope / Aspect :	4%	West
Vegetation understory / Tree composition :	Big sage, bluebunch wheatgrass, needle and thread, prairie junegrass	None

Representative profile for the Labre Series as sampled on a shoulder position with a west aspect. Soils are very well drained.

Representative Pedon: Labre Taxadjunct - sandy loam.

A--0 to 7 inches; dark reddish brown (5YR 3/4) channery sandy loam, dark reddish brown (10YR 3/3) moist; 13 percent clay; weak, very fine, subangular blocky structure; soft, friable, non sticky and non plastic; non effervescent; slightly alkaline (pH 7.6); 20 percent, moderately hard, angular shale channers; many, very fine and few, fine and medium roots; many, very fine, irregular pores; gradual smooth boundary.

Bk--7 to 21 inches; reddish brown (5YR 4/4) very channery sandy loam, dark reddish brown (5YR 3/4) moist; 13 percent clay; moderate, medium, subangular blocky structure; slightly hard, friable, non sticky and non plastic; violent effervescent; moderately alkaline (8.1); 35 percent, moderately hard, angular shale channers; common, very fine and few, fine and medium roots; common, very fine, dendritic pores; common, medium, distinct, carbonate masses around rock fragments.

C--21 to 45 inches; reddish brown (5YR 4/4) extremely channery sandy loam, reddish brown (5YR 4/3) moist; 13 percent clay; single grained and massive structure; loose, friable, non sticky and non plastic; violent effervescent; moderately alkaline (pH 8.3); 70 percent, moderately hard, angular shale channers and flagstones; few, very fine roots;

many, coarse, prominent, carbonate masses around rock fragments.

Local Range in Characteristics: Depth to lime varies from 5 to 10 inches. Fragments in the C horizon(s) ranges up to 90 percent in some pedons. Some pedons may be very deep and greater than 84 inches.

PHIFERSON SERIES

Taxonomy	Coarse-loamy, mixed, superactive, mesic Aridic Haplustoll	
Location Northing / Easting : UTM NAD83 Zone 12	4999515	351352
Parent Material Origin / Kind :	Sanstone	Residuum
Landform / Landform position :	Rolling hills	Backslope
Slope / Aspect :	8%	Northwest
Vegetation understory / Tree composition :	Crested wheatgrass, slender wheatgrass	None

Representative profile for the Phiferson Series as sampled on a footslope position with no primarily northeast to northwest aspects. Soils are moderately well drained.

Representative Pedon: Phiferson sandy loam.

A--0 to 6 inches; dark brown (7.5YR 4/3) sandy loam, dark brown (7.5YR 3/3) moist; 13 percent clay; moderate, medium, subangular blocky structure; loose, friable, non sticky and non plastic; non effervescent; neutral (pH 6.8); common, very fine and fine and few, medium roots; common, very fine, interstitial pores; clear smooth boundary.

Bw--3 to 28 inches; reddish brown (5YR 4/4) sandy loam, reddish brown (5YR 4/3) moist, 19 percent clay; moderate, medium, angular blocky structure; slightly hard, friable, non sticky and non plastic; non effervescent; neutral (pH 7.2); few, very fine and fine roots; common, very fine, dendritic pores; clear smooth boundary.

Bk--28 to 35 inches; brown (7.5YR 4/4) sandy clay loam, brown (7.5YR 4/3) moist; 23 percent clay; moderate, fine and medium, subangular blocky structure; soft, friable, non sticky and non plastic; violent effervescent; moderately alkaline (pH 8.4); few, very fine roots; very, very fine, dendritic pores; gradual smooth boundary.

Cr--35+ inches; soft, moderately weathered sandstone

Local Range in Characteristics: Depth to soft, weathered sandstone varies from 35 to 60 inches. Textures are sandy loams throughout the profile with little to no rock fragments in the profile. Depth to lime ranges from 25 to 35 inches.

** Based on available field and laboratory data for Areas A and B.*

SHINGLE SERIES

Taxonomy	Loamy, mixed, superactive, calcareous, mesic, shallow Ustic Torriorthent	
Location Northing / Easting : UTM NAD83 Zone 12	5000418	349618
Parent Material Origin / Kind :	Sandstone / shale	Residuum
Landform / Landform position :	Hillslope	Backslope
Slope / Aspect :	55%	North / Northwest
Vegetation understory / Tree composition :	Big sage, broom snakeweed, bluebunch wheatgrass, yarrow	Juniper, ponderosa pine

Representative profile for the Shingle Series as sampled on a backslope with a northwest aspect. Soils are well drained.

Representative Pedon: Shingle clay loam.

A--0 to 3 inches; yellowish brown (10YR 5/4) channery clay loam, brown (10YR 5/3) moist; 32 percent clay; weak, thin, platy structure; soft, firm, moderately sticky and moderately plastic; non effervescent; moderately alkaline (pH 7.9); 20 percent , moderately hard, angular shale channers; common, very fine and medium and few, fine roots; common, very fine, dendritic pores; clear smooth boundary.

Bk--3 to 12 inches; light yellowish brown (10YR 6/4) channery sandy loam, yellowish brown (10YR 5/4) moist; 20 percent clay; moderate, coarse, subangular blocky structure; slighty hard, firm, moderately sticky and moderately plastic; violent effervescent; moderately alkaline (pH 8.3); 15 percent, moderately hard, angular shale channers; few, very fine, fine, and medium and common, coarse roots; common, very fine and few, fine, dendritic pores; clear smooth boundary.

Cr--12+ inches; soft, moderately weathered, thinly bedded shale and mudstone.

Local Range in Characteristics: Depth to interbedded shale varies from 10 to 20 inches. Some pedons may have up to 40 percent channers in the profile. Lime may be present in the surface horizon in some pedons.

** Based on available field and laboratory data for Areas A and B.*

SPEARMAN SERIES

Taxonomy	Fine loamy over fragmental, mixed, superactive, mesic Aridic Haplustoll	
Location Northing / Easting : UTM NAD83 Zone 12	4998300	351065
Parent Material Origin / Kind :	Shale / Sandstone	Residuum
Landform / Landform position :	Rolling Low Hills	Swale
Slope / Aspect :	7%	South
Vegetation understory / Tree composition :	Big sage, slender wheatgrass	None

Representative profile for the Spearman Series as sampled on a swale position with a south aspect. Soils are well drained.

Representative Pedon: Spearman loam.

A--0 to 4 inches; dark brown (7.5YR 3/3) loam, dark brown (7.5YR 3/2) moist; 20 percent clay; moderate, very thin, platy structure; slightly hard, firm, non sticky and non plastic; non effervescent; neutral (pH 6.9); 10 percent, moderately hard, angular shale channers; common, very fine and few, fine and medium roots; common, very fine, dendritic pores; clear smooth boundary.

Bw--4 to 9 inches; brown (7.5YR 4/3) channery loam, dark brown (7.5YR 3/3) moist; 25 percent clay; moderate, medium, subangular blocky structure; slightly hard, firm, slightly sticky and slightly plastic; non effervescent; slightly alkaline (pH 7.5); 20 percent, moderately hard, angular shale channers; common, very fine and few, fine roots; common, very fine and few, fine, dendritic pores; clear smooth boundary.

Bk--9 to 15 inches; reddish brown (5YR 4/4) channery sandy clay loam, reddish brown (5YR 4/3) moist; 25 percent clay; moderate, medium and coarse, angular blocky structure; slightly hard, firm, moderately sticky and slightly plastic; violent effervescent; moderately alkaline (pH 8.1); 20 percent, moderately hard, angular shale channers; few, very fine and fine roots; common, very fine and few, fine, dendritic pores; finely disseminated carbonates in the soil matrix; abrupt smooth boundary.

C1--15 to 25 inches; reddish brown (5YR 5/4) very channery sandy clay loam, reddish brown (5YR 4/4) moist; 29 percent clay; massive and single grain structure; slightly hard, firm, moderately sticky and slightly plastic; violent effervescent; moderately alkaline (pH 8.1); 45 percent, moderately hard, angular shale channers; few, very fine roots; common, medium, distinct, carbonate masses around rock fragments; diffuse smooth boundary

C2--25 to 35+ inches; fragmental scoria bedrock.

Local Range in Characteristics: Depth to hard, fractured scoria bedrock ranges from 22 to 35 inches. Textures in the upper portion of the profile are primarily loam and channery loam with 20 to 25 percent clay. Soil salinity is low or very low throughout. SAR levels are very low.

WIBAUX TAXADJUNCT

Taxonomy	Fragmental, mixed, mesic Ustic Torriorthent	
Location Northing / Easting : UTM NAD83 Zone 12	4998392	351044
Parent Material Origin / Kind :	Sandstone / Shale	Residuum
Landform / Landform position :	Rolling Low Hills	Shoulder
Slope / Aspect :	18%	Southwest
Vegetation understory / Tree composition :	Big sage, bluebunch wheatgrass	None

Representative profile for the Wibaux Taxadjunct as sampled on a shoulder position with a southwest aspect. Soils are well drained.

Representative Pedon: Wibaux Taxadjunct - sandy loam.

A--0 to 4 inches; dark reddish brown (5YR 3/4) channery sandy loam, dark reddish brown (5YR 3/3) moist; 17 percent clay; weak, very fine, subangular blocky structure; soft, friable, non sticky and non plastic; non effervescent; neutral (pH 7.1); 30 percent, moderately hard, angular shale channers; common, very fine and fine roots; common, very fine, dendritic pores; gradual smooth boundary.

C1--4 to 13 inches; reddish brown (5YR 4/4) extremely channery sandy clay loam, reddish brown (5YR 4/3) moist; 25 percent clay; massive and single grain structure; slightly hard, friable, non sticky and non plastic; non effervescent; neutral (pH 7.1); 70 percent, moderately hard, angular shale channers and flagstones; few, very fine and fine roots; common, very fine, dendritic pores; gradual smooth boundary

C--13 to 20+ inches; fragmental scoria bedrock.

Local Range in Characteristics: Depth to hard, fractured scoria bedrock ranges from 10 to 25 inches. Depth to greater that 60 percent rock fragments by volume ranges from 4 to 8 inches. Textures in the upper portion of the profile are primarily channery sandy loam with 13 to 20 percent clay. Soil salinity and SAR is low or very low throughout.

Soil Map Units

Soil map units for the Areas A and B soil survey were designed to best capture and delineate the variability of soils within the survey area at a scale of 1:4800. Table 3 below lists the soil maps units for the survey area. A map legend based not on soil series but on landscape characteristics such as landform attributes, vegetation, and geologic parent materials is given in Table 4.

Standard Soil Map Unit Legend

Table 3. Soil Map Unit Legend for Areas A and B

MU Sym.	Map Unit Name
100D	Shingle clay loam, 4 to 8 percent slopes
100F	Shingle – Big Horn, deep complex, 30 to 70 percent slopes
101B	Forkwood loam, 0 to 2 percent slopes
101D	Forkwood Variant complex, 4 to 15 percent slopes
110C	Big Horn, deep, 2 to 8 percent slopes
111C	Big Horn Taxadjunct clay loam, 2 to 8 percent slopes
112D	Spearman Taxadjunct, deep, undulating
120D	Wibaux Taxadjunct complex, 4 to 15 percent slopes
121D	Wibaux Taxadjunct – Spearman, dry complex, 2 to 15 percent slopes
130B	Earsman Taxadjunct sandy loam, stony and dry, 0 to 4 percent slopes
131D	Labre Taxadjunct, dry complex, undulating
140C	Phiferson sandy loam, 2 to 8 percent slopes
RO	Rock Outcrop

Field Mapping Legend

Table 4. Soil-Landscape mapping legend for Areas A and B

Map Unit	Land Type	PM	Landform	PM	Slopes	Aspect	Soils		Plant Comm.	Other
							Depths	Textures		
Scoria parent materials – residual hillslopes, knobs and swales – 4 to 15 percent slopes										
120D	grass	scoria	knobs and swales	resid.	4-15%	variable	sh-dp	xcn SL & SCL and CL & L	artr-pssp6-koma	non-skeletal in swales
121D	shrb/gr	scoria & sed beds	rolling hills & swales	resid	4-15%	variable	md-vdp	vcn & xcn SL, SCL & Loam	artr-pssp6-eltr	---
112D	grass	sed beds & scoria	knobs & backslopes	resid.	4-15%	north / nw	md	Loam-CL	artr-pssp6-koma-pose	sparse juco
131D	grass	sst beds & scoria	knobs & backslopes	resid	4-15%	variable	dp-vdp	vch & xch SL	artr-pssp6-heco-koma	some fragmental
Sandstone bench & ridges – 0 to 4 percent slopes										
130B	open canopy / shrb-grass	sandstone	benches and ridges	resid.	0-4%	na	sh	vst & xst SL	pipo-pssp6-artr-brte	stony surface phase
Alluvial parent materials over sedimentary beds – 0 to 2 percent slopes										
101B	grass	alluvium / sed beds	playa / plain	alluv	0-2%	na	vdp	Loam/CL	agcr-koma	alluvium over residuum pm
Depositional areas of mixed sedimentary beds – 2 to 15 percent slopes										
101D	grass	sedi. beds	footslopes	col / resid	4-15%	north	vdp	Loam/CL	artr-eltr-pose	---

Map Unit	Land Type	PM	Landform	PM	Slopes	Aspect	Soils		Plant Comm.	Other
							Depths	Textures		
Erosional areas of mixed sedimentary beds – 0 to 8 percent slopes										
100D	grass	sed beds	backslope	resid	4-8%	nw	sh-mdp	CL	agcr-ella-koma	---
110C	shrb – grass	sed beds	footslope	resid	2-8%	north	dp – vdp	CL/Clay	artr-pssp-brte	fractured thinly bedded shale
111C	grass	sha/sst beds	footslope	resid	2-8%	nw	vdp	Clay over SL	agcr-ella	contrasting particle size class
140C	grass	sst beds	backslope & footslope	resid.	2-8%	variable	mdp-dp	SL	agcr-ella	---
Erosional areas of mixed sedimentary beds – 20 to 70 percent slopes										
100F	open canopy / grass	sed beds	hillslope	resid.	30-70%	north – tending	sh-md	Cl	pipo-juco-artr-gusa-pssp6-koma	cobbly / flagstone surface

Map Unit Descriptions

Map Unit 100D

Parent Material: Mixed sedimentary beds

Vegetation Type: Grassland

Landform(s): Hillslope

Soil Deposition: Residuum

Slope Range: 4 to 8%

Aspect: Northwest

Other Features Grassland footslope

Soil	Comp	Landform Position(s)	Slope	Plant Community
Shingle	90%	Backslopes and footslopes	4-8%	Agcr-Ella-Koma-Basc
Big Horn, deep	5%	Toeslopes and concave areas	2-6%	Artr-Pssp

Map Unit Notes: Map Unit 100D occurs in footslope area, has low subsoil levels of salinity and SAR throughout and may have deeper soils in concave areas where deposition has occurred.

Map Unit 100F

Parent Material: Mixed sedimentary beds

Vegetation Type: Open Woodland and shrubland

Landform(s): Hillslope

Soil Deposition: Residuum

Slope Range: 20 to 70%

Aspect: North – Northwest

Other Features Channery and flagstone surface

Soil	Comp	Landform Position(s)	Slope	Plant Community
Shingle	70%	Backslopes and footslopes	40-70%	Pipo-Juco-Gusa-Pssp6
Big Horn, deep	20%	Toeslopes, swales, and concave areas	30-40%	Artr-Pssp6
Earsman Taxadjunct, mesic	5%	Shoulders and summit	20-25%	Pipo-Pssp6
Rock Outcrop	5%			

Map Unit 101B

Parent Material: Alluvium with sedimentary beds

Vegetation Type: Mainly seeded introduced species

Landform(s): Playa and Plains

Soil Deposition: Alluvium over residuum

Slope Range: 0 to 2%

Aspect: na

Other Features Historically cultivated land

Soil	Comp	Landform Position(s)	Slope	Plant Community
Forkwood	90%	Depositional basin	0-2%	Agcr-Koma
Big Horn	10%	Depositional basin	30-40%	Artr-Pssp6

Map Unit 101D

Parent Material: Mixed sedimentary beds

Vegetation Type: Scattered woodland - Big Sage grassland

Landform(s): Hillslope

Soil Deposition: Colluvium and residuum

Slope Range: 4 to 15%

Aspect: North

Other Features Transition from steeper, eroded slopes to playa/plains; Dissected

Soil	Comp	Landform Position(s)	Slope	Plant Community
Forkwood Variant	90%	Footslope	4-15%	Juco -Artr-Gusa-Pssp6
Big Horn, deep	10%	Convex area on footslopes	10-15%	Artr-Eltr

Map Unit 110C

Parent Material: Mixed sedimentary beds

Vegetation Type: Big Sage grassland

Landform(s): Hillslope

Soil Deposition: Residuum

Slope Range: 2 to 8%

Aspect: North

Other Features

Soil	Comp	Landform Position(s)	Slope	Plant Community
Big Horn, deep	90%	Footslope	2-8%	Artr-Koma-Pose-Brte
Forkwood	10%	Footslope	2-8%	Artr-Koma-Pssp

Map Unit 111C

Parent Material: Mixed sedimentary beds

Vegetation Type: Grassland

Landform(s): Hillslope

Soil Deposition: Residuum

Slope Range: 2 to 8%

Aspect: Northwest

Other Features Historically cultivated

Soil	Comp	Landform Position(s)	Slope	Plant Community
Big Horn Taxadjunct, Clayey over Loamy	100%	Footslope	2-8%	Agcr-Ella-Eltr

Map Unit 112D

Parent Material:	Mixed sedimentary beds and scoria
Vegetation Type:	Shrub grassland
Landform(s):	Undulating low hills
Soil Deposition:	Residuum
Slope Range:	2 to 10%
Aspect:	Variable
Other Features	No distinct aspect; undulating low angle hills and knobs; channery surface

Soil	Comp	Landform Position(s)	Slope	Plant Community
Spearman Taxadjunct, fine-loamy	80%	Backslope	4-10%	Artr-Pssp-Koma
Forkwood Variant	15%	Swales	2-6%	Artr-Koma-Agcr
Rock Outcrop	5%			

Map Unit 120D

Parent Material: Scoria

Vegetation Type: Big sage grasslands

Landform(s): Hills

Soil Deposition: Residuum

Slope Range: 4-10%

Aspect: Variable

Other Features No distinct aspect; knobs and swales

Soil	Comp	Landform Position(s)	Slope	Plant Community
Wibaux Taxadjunct, fragmental	75%	Shoulders and backslopes	6-15%	Artr-Pssp-Koma
Big Horn, deep	20%	Swales	4-10%	Artr-Koma-Ella
Very Shallow soils	5%	Summits	4-8%	Artr-Pose

Map Unit 121D

Parent Material: Scoria

Vegetation Type: Big sage grasslands

Landform(s): Hills

Soil Deposition: Residuum

Slope Range: 2-15%

Aspect: Variable

Other Features No distinct aspect; backslopes, knobs and swales

Soil	Comp	Landform Position(s)	Slope	Plant Community
Wibaux Taxadjunct, fragmental	75%	Shoulders and backslopes	6-15%	Artr-Pssp-Koma
Spearman, dry	25%	Swales	4-10%	Artr-Ella-Eltr

Map Unit 130B

Parent Material: Sandstone

Vegetation Type: Open woodland

Landform(s): Hills

Soil Deposition: Residuum

Slope Range: 0-4%

Aspect: na

Other Features Sparse understory; stony and very stony surface phase

Soil	Comp	Landform Position(s)	Slope	Plant Community
Earsman Taxadjunct, mesic	90%	Bench	0-2%	Pipo-Juco-Artr Brte-Pssp
Shingle	10%	Shoulder	2-4%	Pipo-Juco-Artr Pssp

Map Unit 131D

Parent Material: Mixed scoria and sandstone

Vegetation Type: Big sage grassland

Landform(s): Undulating Plain

Soil Deposition: Residuum

Slope Range: 2-8%

Aspect: na

Other Features Low angle undulating landscape; channery surface;

Soil	Comp	Landform Position(s)	Slope	Plant Community
Labre Taxadjunct, mesic/aridic	80%	Linear and convex areas	2-8%	Artr-Pssp-Heco-Koma-Brte
Forkwood	10%	Swales	2-4%	Artr-Pssp-Koma
Wibaux Taxadjunct, fragmental	10%	Linear and convex areas	2-8%	Artr-Pssp-Heco

Map Unit 140C

Parent Material: Sandstone

Vegetation Type: Shrub grassland

Landform(s): Rolling Hillslope

Soil Deposition: Residuum

Slope Range: 2-8%

Aspect: na

Other Features Low angle rolling plain/hills

Soil	Comp	Landform Position(s)	Slope	Plant Community
Phiferson	100%	Backslopes and Shoulders	2-8%	Artr-Agcr

Map Join With Existing Spring Creek Permitted Area (South Fork Area)

Joining the Areas A and B soil survey with the original soil survey involved two primary steps. The first step was correlating or matching soil types from the original soil survey to adjacent soil series in the current survey. This entailed examination of the similarities and differences between soil types used in the original Spring Creek soil survey and adjacent soil series mapped in Areas A an B. Table 5 outlines these similarities and differences. The right hand column in Table 5 describes differences between soil concepts described in the South Fork soils document and the soil series to which they were correlated. In most cases, correlation could occur easily as soil types from the South Fork side were often quite similar to the adjacent soil series in the current survey area.

If correlation could not easily occur between adjacent soil map units due to differences in soil characteristics, soil boundary line adjustments were made on the South Fork side of the line to accommodate the correlation. Area A and B map units were extended across the correlation line into the South Fork Area when comparable map units existed in the South Fork mapping legend and when small slivers of Area A and B delineations extend across the map boundary. Details of map unit correlations between South Fork and Pearson Creek areas are provided in Table 6.

Table 5. Correlation of soil types that spatially adjoin along survey boundaries between original Spring Creek soil survey and soil survey of Areas A and B.

Original Name	Series Name	Distinctions
Colbar	Not used	Area along join where Colbar was mapped has heavier textured, fine family soils – Bighorn series
Cushman	Big Horn Taxadjunct	Decent match except Cushman is in the fine-loamy particle size family while the Big Horn Taxadjunct has a clayey over loamy contrasting particle size class
Cushman	Forkwood Variant	Good match except the Forkwood Variant has clay textures below 95 inches.
Depler	Not used	Area along join where Colbar was mapped has heavier textured, fine family soils – Bighorn series.
Kimlan	Forkwood, deep	Forkwood series is fine-loamy with 18 to 35% clay and 15 to 35% fine and coarser sand in the control section.
Shinler	Shingle	Soil series from which Shinler name was coined. Good match except the Shingle series has a mesic soil temperature regime.
Sperlin	Spearman	Spearman series is fine-loamy with 18 to 35% clay in the control section and is moderately deep to fragmental scoria beds
Travella	Not used	Area along join where Travella was mapped has deeper, fine-loamy soils- Forkwood, deep series
Wixen	Wibaux	Wibaux series is considered to be a deep, fragmental soil formed from scoria bedrock while Wixen is described as shallow to hard, fractured, scoria bedrock.
Wixen	Earsman Taxadjunct	Wixen is described as shallow to hard, fractured scoria bedrock while the Earsman is shallow to sandstone and shale bedrock.
Wixen	Shingle	Both shallow soils and a decent match. Wixen is loamy-skeletal with a frigid temperature regime while Shingle lacks rock fragments and has a mesic temperature regime.
Wixen	Labre	Wixen is described as a shallow soil to hard, fractured bedrock while the Labre is extremely channery and moderatley deep to very deep.

Table 6. Correlation record between Spring Creek and Areas A and B soil surveys

South Fork Map Units		Areas A and B Map Units	
Sym.	***Map Unit Name***	***Sym.***	***Map Unit Correlation Notes***
8D	Wiberg-Sperlin Loams, rolling (≈8 to 15% slopes)	121D	Sperlin match to Spearman series on swales on south side of unit; Wixen component match to Wibaux on backslopes and shoulders; Wiberg and Shinler not used.
9	Shinler-Wixen Stony Soils, Hilly (25 to 50% slopes)		
11	Colbar and Kimlen Clay Loams, 1 to 4% slopes	101B	Colbar not used; joins on west side over short area and Kimlen close match to Forkwood; SC map unit 19 not used.
19	Shinler-Travella Soils, undulating to rolling (2 to 16% slopes)		
C	Cushman	111C	Sliver on south side of Area A.
CO	Colbar	110C	SC map unit CO changed to 110C to match.
D	Depler-Shinler Silty Clay Loams, Undulating	110C	Depler component of SC map unit D does not match 110C; 110C extended across join line.
SH	Shinler	100F	Slopes from 30 to 70%.
SW	Shinler/Wixen, Stony Soils, Hilly	130B	Slopes mainly less than 8 percent.
		100D	Slopes mainly 8 to 15 percent.
		100F	Slopes 30 to 70%.
W	Wixen/Wiberg Complex	130B	Slopes less than 8 percent.
		100F	Mod deep component does not exist in SC unit W. Match for the other components.
		131D	Skeletal soils rather than shallow to fractured bedrock, although may be minor components that would classify as fragmental..
W	Wixen/Wiberg Complex	111C	Small sliver in Area A extended into SC Unit W.

Note: Yellow highlighted entries indicate where map units from the Areas A and B soil survey extended into the South Fork soil survey.

Laboratory Data

All laboratory data is reported in Table 7. Data is organized by soil series alphabetically for easy reference.

Table 7. Laboratory analysis data sorted by soil series and phase

Sample ---	Horiz. ---	Depth in	Texture ---	RF's %	Clay %	OM %	EC dS/m	pH ---	SAR ---
Big Horn Series									
004-1	A	0-6	L	5	18	3.3	0.43	6.8	0.25
004-2	Bt	6-11	CL	10	40	2.9	0.38	7.8	0.15
004-3	Bk	11-27	CL	10	36	2.3	0.32	8.3	0.24
004-4	C	27-42	CL	20	36	1.5	0.86	8.7	3.28
---	Cr	42+	Thinly bedded, fractured shale						
Big Horn Taxadjunct – clayey over loamy									
014-1	A	0-4	CL	0	37	2.5	0.34	7.5	0.10
014-2	Bt	4-9	Clay	0	43	2.6	0.27	7.6	1.65
014-3	Bk	9-30	CL	5	39	1.9	0.26	8.4	1.15
014-4	2C1	30-39	SL	5	19	0.6	0.4	9.0	2.82
014-5	2C2	39-84	SL	5	11	0.4	2.17	8.6	3.96
Earsman Taxadjunct – mesic; stony and dry									
002-1	A	0-3	stv SL	60	14	3.1	0.42	8.2	0.09
002-2	Bk	3-8	stv SL	60	18	3.2	0.34	8.3	0.06
002-3	C	8-13	stx SL	70	20	3.2	0.35	8.3	0.09
---	R	13+	Hard sandstone bedrock						
Forkwood Series									
001-1	A	0-4	L	0	26	3.3	0.59	7.4	0.07
001-2	Bt	4-12	CL	0	34	2.3	0.37	7.9	0.12
001-3	Bk	12-22	CL	5	36	2.0	0.25	8.4	0.23
001-4	C	22-84	cn L	20	24	1.2	0.96	8.8	1.20
Forkwood Variant, clayey									
011-1	A	0-2	L	0	24	5.5	0.60	8.2	0.05
011-2	Btk	2-17	CL	5	30	3.2	0.41	8.4	0.14
011-3	Bk	17-37	SCL	10	28	2.6	0.37	8.4	0.34
011-4	C	37-84	gr Clay	20	45	2.3	0.77	8.2	0.55
Labre Taxadjunct – mesic and aridic; dry									
013-1	A	0-7	cn SL	20	13	2.6	0.63	7.6	0.42
013-2	Bk	7-21	cnv SL	35	13	2.0	0.35	8.1	0.20
013-3	C	21-40+	cnx SL	75	13	1.9	0.47	8.3	0.53

Sample ---	Horiz. ---	Depth in	Texture ---	RF's %	Clay %	OM %	EC dS/m	pH ---	SAR ---
Phiferson Series, very deep									
015-1	A	0-6	SL	0	13	1.5	0.30	6.8	0.07
015-1	Bw	6-28	SL	0	19	1.3	0.13	7.2	0.17
015-1	Bk	28-35	SCL	10	23	1.3	0.26	8.4	0.27
---	Cr	35+	Moderately weathered sandstone						
Shingle Series									
003-1	A	0-3	cn CL	20	32	4.7	0.37	7.9	0.09
003-2	Bk	3-12	cn SL	15	20	1.5	0.35	8.3	0.27
---	Cr	12+	Moderately weathered sandstone bedrock						
Spearman Series, dry									
021-1	A	0-2	L	10	20	6.7	0.80	6.9	0.11
021-2	Bw	2-9	cn L	20	25	2.6	0.56	7.5	0.25
021-3	Bk	9-14	cn SCL	20	25	2.1	0.81	8.1	0.39
021-4	C	14-24	cnv SCL	45	25	2.0	0.49	8.1	0.20
---	2C	24+	Fractured scoria beds						
Spearman Taxadjunct – fine-loamy									
022-1	A	0-4	cn L	25	23	4.6	0.44	7.1	0.24
022-2	Bt1	4-19	cn CL	30	29	2.3	0.25	7.3	0.11
022-3	Bt2	19-32	cn L	30	27	2.6	0.31	7.6	0.32
---	Cr	32+	Fractured scoria bedrock						
Wibaux Taxadjunct - fragmental									
020-1	A	0-4	SL	20	17	3.8	0.43	7.1	0.15
020-2	C1	4-13	cnx SCL	70	25	3.6	0.35	7.1	0.22
---	C2	13+	Fractured scoria beds						

Note: Yellow highlighted entries indicate suspect levels that may be unsuitable depending on details of the revegetation plan and the effect of related soil factors. Red highlighted entries indicate soil properties that are unacceptable for use as soil material reclamation.

Sodium Adsorption Ratio (SAR)

Montana defines suspect levels for SAR as greater than 10 for potential topsoil material and greater than 15 for potential subsoil material (MDEQ, 1998). The soil survey indicated high levels of sodium would be unlikely due to lack of any indicators of soil sodicity. Primary indicators include the presence of salt tolerant plants such as greasewood and inland salt grass, neither of which is present in the survey area. Also, there was no widespread soil physical evidence of sodicity. None of the laboratory samples exceeded the thresholds outlined above, with only a few samples even approaching a value of 3.

Soil Salinity (EC)

Soil salinity is simply the amount of soluble salts in a soil, and is measured by the electrical conductivity (EC) of the saturated paste extract. The salinity of a soil is important because high salt levels make it difficult for plants to obtain water (Bohn, et al., 1985). Saline soils are conventionally defined as having EC values of greater than 4.0 deciSiemens per meter (dS/m), however sensitive plants can be affected at 2.0 dS/m and highly tolerant plants (e.g., the native species of the Powder River Basin) are productive at EC levels greater than 8.0 dS/m. In the arid western United States, naturally occurring saline soils are more typical because arid regions are subject to high evaporation rates, thus allowing salt concentration to occur (Soil Improvement Committee, California Plant Health Association, 2002).

EC levels in soil samples collected at Areas A and B are generally low and reflect the natural salt regime present at the site. EC values primarily are below 1.00 dS/m, with a high value of 2.17 found in one soil (Table 7). Subsurface bulges in EC are a result of the deposition of salts by repeated precipitation events at the terminus of the leaching front. The local climatic precipitation regime and water movement through the soil profile determines the depth of salt accumulation. Although precipitation at Spring Creek is historically low, the lack of any subsurface bulge in EC indicates that naturally occurring salts in the local soils are low.

The lack in soil salinity is reflected, in part, by the abundance of Wyoming big sagebrush over much of the area and the lack of inland salt grass, which is an indicator of soil salinity and high EC. Big sage generally does not do well in highly saline soils. Few restrictions, with respect to high EC levels, are present for salvaging soils in Areaa A and B.

Soil pH

Soil pH is perhaps the most important chemical characteristic of the soil and indicates the intensity of the acidic or basic condition of the soil. pH serves as a general index to the availability of plant nutrients, potential toxicity problems, and sodic soil conditions. The suspect level for soil pH in Montana is set at 8.5. A soil pH of 6.0 to 8.4 is ideal for most range crops. As the pH increases above or decreases below this ideal range, the availability of phosphorus, calcium, magnesium, iron, manganese, zinc, copper, cobalt, and boron may be limiting.

The pH levels of the soil samples collected in Areas A and B are primarily within the ideal range. Suspect pH values were recorded for samples at three of the sample sites. Two are fine family soils, and both of these are Big Horn series soils. The other soil falls in the fine-loamy family. In each case, the high pH values were obtained for a soil horizon deeper in the profile or immediately above underlying bedrock. None of the three suspect values were associated with correspondingly high SAR levels.

Rock Fragments

No limitations were encountered with respect to the amount of rock fragments present in non-scoria soils except for the very shallow Earsman Taxadjunct found along benches and bench / plateau edges and other ledge areas. Some of the shallow soil profiles sampled contained soft, weathered rock fragments that are defined as para-fragments. However, these are not regarded similarly to hard rock fragments and have little or no effect on usability of the soil resource.

In scoria derived soils, the depth to extremely channery (≥ 60 percent rock fragments) or fragmental material is the main limitation for use as soil salvage material for reclamation. The fine earth material (< 2mm fraction) associated with scoria parent material has excellent soil properties of low EC, low SAR, good texture and good soil pH levels for use in reclamation. For this reason, it is recommended that scoria derived soils with an average rock fragment content of up to 50 percent scoria channers be considered as suitable subsoil material for the establishment of mixed shrub/bluebunch wheatgrass or ponderosa pine (north aspect) plant communities in reclamation.

Soil Texture

Regarding the suitability of soils for reclamation under Montana standards, clay contents of greater than 35% (fine family or clayey soils) present some limitations. Soils that have textures with clay content less than 35% (fine-family, loamy, or coarse-loamy) generally are considered suitable for reclamation.

Soil textures found across much of the survey area are clay loams, loams, sandy clay loams, and sandy loams with clay content ranging for 13 to 35 percent for samples analyzed. The lowest clay content was found primarily in scoria derived soils, with clay content ranging from 13 to 29 percent. Within the fine-loamy family of soils, those that were derived from mixed sedimentary parent materials primarily had the heavier textures of loams, clay loams, and sandy clay loams. Clay contents ranged mostly from

20 to 35 percent in these soils.

Although many of the soils in the survey area do not present limitations for reclamation related to texture, there are fine-family soils present throughout the area. Most of these are the Big Horn or Big Horn Taxadjunct series. Montana's soil suitability standards for reclamation indicate that clay, silty clay, and sandy clay textures fall within the suspect range for soil suitability (MDEQ, 1998). There are no sandy clay textures present in the survey area. This means that for Areas A and B, soils with clay contents above 40 percent fall within the suspect class. This does not indicate that these soils cannot be used for reclamation. It does mean that other management considerations should be considered when reclaiming with clayey soils.

Most of the soils mapped as fine-textured soils in the survey area have individual soil horizons, usually an argillic horizon, that has clay textures with more than 40 percent clay. Clay content in soil horizons either above or below this horizon, or both, is usually lower. For these soils, mixing that occurs during soil salvaging operations should limit concerns with regard to clay or silty clay textures in specific soil horizons, especially since none of the horizons in question have EC or SAR issues associated with them.

Soil Interpretations and Suitability

Multiple soil interpretations can be derived from a soil survey, based upon the primary management goals of the survey. The primary goal, and therefore the interpretative focus, for this soil survey is determining suitability of soils for land reclamation. This understanding has driven the process and methodology for inventorying soils in Areas A and B. A primary soil interpretation here is the determination of volume estimates of total available topsoil and subsoil material suitable for land reclamation. Other, more traditional soil interpretations important to soil salvaging and land reclamation procedures are presented in this section and will be discussed initially.

The traditional soil survey interpretations presented in Table 8 are for soils in their original, pre-disturbance condition. They provide clues into how the reconstructed soils will perform after disturbance. Soil interpretations provided are for wind erodibilty group (WEG), water erosion potential ("k" factor) and available water holding capacity (AWC). These interpretations are presented on a soil layer basis as different layers in the soil will have different WEG, K, and AWC values. Individual horizons have been lumped together into topsoil, subsoil and substratum layers for this table.

Basic Soil Survey Interpretations

Table 8. Soil Interpretations by layer for major map unit components by map units. wind erodibilty group (WEG), "k" factor, and available water holding capacity (AWC)

MU	Component	% of Map Unit	Layer	Texture	RF's	WEG	K	AWC
100D	Shingle	90	TS	l, cl, sicl	0-20	4L	0.37	0.17-0.23
			SS	sl, scl	0-20	4L	0.37	0.13-0.20
			Substr	mixed sedimentary beds				
	Big Horn, deep	10	TS	loam, cl	0-10	6	0.37	0.17-0.22
			SS	cl	10-20	4L	0.32	0.15-0.19
			Substr	mixed sedimentary beds				
100F	Shingle	70	TS	l, cl, sicl	0-20	4L	0.37	0.17-0.23
			SS	sl, scl	0-20	4L	0.37	0.13-0.20
			Substr	mixed sedimentary beds				
	Big Horn, deep	20	TS	loam, cl	0-10	6	0.37	0.17-0.22
			SS	cl	10-20	4L	0.32	0.15-0.19
			Substr	mixed sedimentary beds				
101B	Forkwood	90	TS	loam, cl	0-5	6	0.37	0.17-0.22
			SS	cl	0-10	4L	0.32	0.15-0.19
			Substr	cn l	20-30	4L	0.37	0.17-0.19
101D	Forkwood Variant	90	TS	loam, cl	0-2	6	0.37	0.17-0.22
			SS	scl, cl	5-15	4L	0.32	0.15-0.20
			Substr	gr clay	15-30	4L	0.37	0.11-0.13
110C	Big Horn, deep	90	TS	loam, cl	0-10	6	0.37	0.17-0.22
			SS	cl	10-20	4L	0.32	0.15-0.19
			Substr	mixed sedimentary beds				
111C	Big Horn Taxadjunct	100	TS	cl	0-2	6	0.37	0.15-0.19
			SS	cl, clay	0-2	4L/4	0.32	0.09-0.19
			Substr	sl	0-10	3	0.37	0.11-0.14
112D	Spearman Taxadjunct	80	TS	cn l	20-30	6	0.43	0.20-0.22
			SS	cn l, cn cl	20-35	6	0.37	0.15-0.19
			Substr	fractured scoria bedrock				
120D	Wibaux Taxadjunct	75	TS	sl	15-30	3	0.43	0.13-0.15
			SS	xcn scl	55-80	5	0.32	0.05-0.06
			Substr	fractured scoria bedrock				
	Big Horn Taxadjunct	20	TS	cl	0-2	6	0.37	0.15-0.19
			SS	cl, clay	0-2	4L/4	0.32	0.09-0.19
			Substr	sl	0-10	3	0.37	0.11-0.14

MU	Component	% of Map Unit	Layer	Texture	RF's	WEG	K	AWC
121D	Wibaux Taxadjunct	75	TS	sl	15-30	3	0.43	0.13-0.15
			SS	xcn scl	55-80	5	0.32	0.05-0.06
			Substr	fractured scoria bedrock				
	Spearman, dry	25	TS	l, cn l	5-25	6	0.37	0.18-0.22
			SS	cn-vcn scl	20-60	4L	0.37	0.06-0.14
			Substr	fractured scoria beds				
130B	Earsman Taxadjunct	90	TS	stv sl	45-65	3	0.43	0.04-0.07
			SS	xst sl	60-80	3	0.43	0.02-0.06
			Substr	hard sandstone bedrock				
131D	Labre Taxadjunct	80	TS	cn sl	15-25	3	0.43	0.09-0.12
			SS	vcn sl	30-45	3	0.43	0.07-0.10
			Substr	xcn sl	60-80	3	0.43	0.02-0.04
140C	Phiferson	95	TS	sl	0-2	3	0.43	0.12-0.14
			SS	sl	0-2	3	0.43	0.12-0.14
			Substr	scl	5-10	3	0.43	0.12-0.14

Wind Erodibility Group (WEG)

Wind erodibility group (WEG) indicates a bare soil's susceptibility to erosion due to wind. Based on USDA-NRCS guidelines, soils are assigned to one of nine classes, 1 through 8 plus an additional 4L class. WEG 1 soils have the highest potential for wind erosion and primarily are sands and sandy loams. WEG 8 has the lowest wind erosion potential and consists of rock fragments at the surface. Primary soil properties that determine wind erosion potential in the Spring Creek area are soil texture, clay content, and calcareous conditions. In general, loamy and clay loam soils with less than 35 percent clay that are not calcareous have the lowest potential for wind erosion, and are assigned to WEG 6. A wind erodibilty index "I" in tons per acre per year can be assigned to the soil layer based on the WEG group. This factor is used in equations for predicting wind erosion.

The majority of soils in Areas A and B have high or moderate wind erosion potential. These soils fall within wind erodibilty groups 3, 4, or 4L. Wind erodibilty group 3 soils have sandy loam or fine sandy loam textures and are primarily found in scoria parent materials. Clay, silty clay, and non-calcareous clay loam textures with more than 35 percent clay are grouped in WEG 4. Although much of the area consists of loams and clay loams, these are most often calcareous and therefore are grouped into WEG 4L.

Based on results in Table 8, the post-reclamation soil resource will have a high proportion of surface soils with a high wind erosion potential. Limiting the amount of carbonates in the topsoil lift, where reasonable, may have some positive impact on the overall wind erosion potential of reclaimed areas.

Soil Erodibility "k" Factor

The "k" factor is the soil erodibility factor used in the Universal Soil Loss Equation (USLE) or Revised Universal Soil Loss Equation (RUSLE) to predict water erosion. The primary soil property used in determining a soil's susceptibility to water erosion is soil texture. In addition, permeability of the limiting soil horizon, soil organic matter, soil structure, and the amount of rock fragments on the soil surface play a role. The "k" factor relates only to the fine-earth fraction (less than 2 mm) of a soil. For the topsoil and subsoil classes listed for each soil, the most limiting value of the soil horizons within those classes is listed. Because the "k" factor only takes into account the fine earth fraction of soil, the erodibility value does not condiser any mulch affect based on rock fragments that would armor the soil surface. Most soils in Areas A and B have limited amounts of rock fragments. These will have little effect on water erosion potential.

Soil erodibility (k) factors for Areas A and B soils fall within a range of 0.32 to 0.43. Higher k-values reflect a higher potential rate of water erosion. The values above are in the mid to upper range for soils, reflecting a moderate to high potential for water erosion. Loam and clay loam surface textures result in the highest "k" factor, while clays and sandy loams have lower water erosion. However, subsoil textures high in clay can negatively affect the inherent erodibilty of any surface texture by reducing overall permeability of the soil profile, thereby increasing surface runoff.

Reclaimed soils in general have a high potential for water erosion due to their unconsolidated nature and the lack of soil structure in subsoil layers. This coupled with relatively high k-values for available soil materials in the area indicates sediment control measures could be necessary to limit water erosion on reclaimed landscapes. Abrupt texture changes between surface and underlying soil horizons increase the potential for water erosion. Soil salvaging and laydown operations should avoid re-creating near-surface, abrupt texture differences when possible.

Available Water Holding Capacity

Available water holding capacity (AWC) is defined as the amount of water that a soil can store that is available for use by plants. It is the water held between field capacity and the wilting point adjusted downward for rock fragments and for salts in solution. Field capacity is the water retained in a freely drained soil about 2 days after thorough wetting. The wilting point is the water content at which plants irreversibly wilt. Primary factors affecting a soil’s ability to hold water are soil texture, amount of rock fragments, and soil structure. Rock fragments reduce the volume of soil available to hold water. Factors that increase soil water holding capacity are high levels of soil organic matter and granular structure.

Values presented in Table 8 represent the full range in water holding capacity based on soil textures and rock fragment percents reported for each soil layer. Units are in inches of water per inch of soil. Many of all the soils in the survey area can hold moderate to high amounts of plant available water. The low values of below 0.10 in the some soils are primarily due to shallow depth, sandy textures, and/or high volume of rock fragments in the soil profile.

Although low to moderate AWC is present in some soils in the survey area, reclaimed soils overall will have better water holding capacity. This is primarily because reclaimed soils are uniformly very deep, mixing of soil horizons increases the micro porosity of soils, and rock fragments are more evenly distributed. The increase in the micro porosity of soils as opposed to the larger macro pores in sandy soils increases water holding capacity of the soil material.

An important note is that native or pre-disturbance spoil substrates have lower water holding capacity relative to salvaged spoil due to more rock fragments in the material. Therefore, salvaged spoil layers will hold more plant available water than the pre-disturbance, sedimentary beds the spoils are replacing.

Other soil interpretations of interest for land reclamation include soil permeability and the risk of equipment compaction. These have not been included within this report but interpretations for these factors can be determined through use of USDA National Cooperative Soil Survey technical guides. Permeability for the soils sampled in Areas A and B ranges from moderate to slow. Many of the soils fall into the moderately slow to slow category while only those with sandy loam textures would be moderately permeable. The highest risk of compaction exists for soils with fine sandy loam, silt loam, or silty clay loam textures. Clay and clay loam textures are lumped with sandy loam, loam and several other textures as having a medium potential for equipment compaction (Soil Survey staff, 1998).

Land Capability Classification

Table 9. Land capability classes by map unit component.

MU	Component	Prop.	Slope	Capability Class	Limiting Factor(s)
100D	Shingle	0.90	4-8	6e	shallow to bedrock; steepness
	Big Horn, deep	0.10	4-8	3e	slope steepness
100F	Shingle	0.70	40-70	7e	shallow to bedrock; steepness
	Big Horn, deep	0.20	25-35	6e	slope steepness
101B	Forkwood	0.90	0-2	3c	dry climate; frost free days
101D	Forkwood Variant	0.90	4-15	4e	steepness
110C	Big Horn, deep	0.90	2-8	3e	steepness; water erodibility
111C	Big Horn Taxadjunct	1.00	2-8	3e	steepness, water erodibility
112D	Spearman Taxadjunct	0.85	4-10	4e	slope steepness
	Forkwood Variant	0.10	4-8	3e	slope steepness
120D	Wibaux Taxadjunct	0.75	4-15	6e	steepness; wind erodibility; low AWC
	Big Horn Taxadjunct	0.20	4-8	3e	steepness, water erodibility
121D	Wibaux Taxadjunct	0.75	6-15	6e	steepness; wind erodibility; low AWC
	Spearman, dry	0.25	4-8	4e	steepness; low AWC
130B	Earsman Taxadjunct	0.90	0-4	6s	shallow to bedrock; surface stones; low AWC
131D	Labre Taxadjunct	0.80	4-15	4e	wind erodibility; steepness
	Forkwood	0.10	4-8	3e	erodibility
140C	Phiferson	0.95	2-8	3e	low AWC; wind erodibility

The United States Land Capability Classification system provides a comprehensive approach to addressing the general question of land potential. Its primary purpose is to determine, for any piece of land, the “combination of agricultural use and conservation measures which allow the most intensive agricultural use of the land without risk of soil erosion” (Hudson, 1971). Although the land capability classification system was designed primarily for agricultural purposes, the potential could be viewed as the ability to produce rangeland vegetation or the soil’s susceptibility to wind and water erosion.

Land capability classification is a system of grouping soils based on their capability to produce common cultivated crops and pasture plants over a long period of time. The USDA land capability system classifies land has 8 major classes. The first 4 classes (I–IV) are lands generally considered to be suitable for cultivation. The last 4 classes (V–VIII) are not considered suitable for cultivation. Exceptions exist due to human modification and management of the landscape. The lower the class rating, the better the land potential is for agricultural production and also the more land use options there are available. The primary factors that determine class placement in Areas A and B are maximum slope, soil depth, and surface texture.

Each main class consists of a subclass. Each subclass represents the dominant limitation that determines the capability class. Subclasses are indicated by a lower class case letter following the main class designation. Letters used are: e = erosion, w = wetness, c = climate and s = soil. The strong erosion bias in the system causes most Montana soils to fall within the “e” subclass.

Capability class designations for pre-disturbance soils in Areas A and B range from class 3e to class 7e, reflecting the wide range of soil depths and slope steepness in the area (Table 9). Areas of sedimentary rock outcrops fall within land capability class 8, which is defined as land that has no capability for cultivation.

Even though there is a wide range in capability classes in pre-mined soils, much of the reconstructed landscapes will most likely fit within land capability class 4e. This assumes that suitable reclamation procedures are followed and reclamation is successful. This is because reconstructed landscapes are either strongly sloping with 8 to 15 percent slopes or have a high potential for wind and/or water erosion.

Soil Salvage Depths

Table 10. provides recommended salvage depths for soils mapped in Areas A and B

along with some comments on their use. Overall, soil resources for the area are limited due to abundant shallow soils which often occur on steep, eroding slopes. Where deeper soils are present, they tend to have heavier textures which are primarily clay loam or clay. For this reason recommendations for soil salvage are aggressive towards salvaging the maximum amount of suitable soil material possible. Soil salvage seeks to attain the following goals:

- Maximize the total amount of soil available for reclamation while avoiding unsuitable material,
- Mix surface horizon materials in the topsoil lift with a portion of the underlying Bt horizon in soils with an abrupt texture change near the surface,
- Utilize suitable clay soils in the reclamation provided they are sufficiently low in soluble salts (EC), sodium (SAR), and soil pH,
- Salvage all soil materials in skeletal or fragmental soils down to the horizon or layer with high percentages of rock fragments, and
- Where appropriate, utilize mixing during soil salvage and laydown operations to dilute limited amounts of suspect soil materials due to abundant rock fragments or high clay.

Table 10. Recommended salvage depths based on field and lab data.

Type	TS	SS	Comments
Fine-loamy/Loamy Soils			
Type	**TS**	**SS**	**Comments**
Shingle	**---**	**0-6**	Limited soil salvage potential due to shallow depth and steep slopes.
Forkwood	**0-12**	**12-84**	Mixing of A and Bt horizons in topsoil lift; Some strongly alkaline subsoil layers below 24 inches; mixing of subsoil during salvage operations will be beneficial.
Forkwood Variant	**0-12**	**12-36**	Mixing A and Bt horizons in topsoil lift; high clay content above 45 percent below 36 inches.
Fine Family/Clayey Soils			
Type	**TS**	**SS**	**Comments**
Big Horn	**0-12**	**12-42**	Mixing A and Bt horizons beneficial in topsoil lift; some strongly alkaline soils below 26 inches modified by mixing with soils above in subsoil layer.
Big Horn Taxadjunct, clayey overy loamy	**0-6**	**6-84**	Topsoil lift elevated in clay; 6 to 30 inch depths high in clay but mixing with soil from 30 to 84 inches in subsoil lift will be beneficial..
Scoria Parent Material			
Type	**TS**	**SS**	**Comments**
Spearman, dry	**0-12**	**12-24**	Salvage to bedrock or fractured scoria beds.
Spearman Taxadjunct, fine-loamy	**0-6**	**6-32**	Salvage to fractured scoria beds.
Wibaux Taxa., fragmental	**---**	**0-6**	Shallow to fractured scoria beds; limited material available with extremely channery soils.
Coarse-loamy / Loamy-skeletal Soils			
Type	**TS**	**SS**	**Comments**
Phiferson	**0-12**	**12-36**	Salvage to sandstone bedrock; moderate alkalinity in some parts of the subsoil moderated by mixing.
Earsman Taxa., mesic	**---**	**---**	Limited or no salvage potential; very stony to extremely stony, shallow soils.
Labre Taxa., mesic	**0-6**	**6-24**	High fragment percentage below 24 inches limits material for subsoil.

Soil Volume

The total estimated volume of soil available in the Areas A and B is 10,178,268 cubic feet of topsoil and 40,948,967 cubic feet of subsoil material (Table 11). This translates to an average subsoil depth of 26.5 inches if the subsoil were spread over the entire 15,645,411 square feet within the expansion boundary and 7.8 inches of topsoil based on the same assumption. Average total soil replacement depth would be 34.3 inches.

These totals are based on a highly aggressive salvaging approach. This approach would include using clay textured soil materials from the Big Horn Taxadjunct series and the Forkwood Variant. Most lands within the expansion area are treated as potentially salvageable, including very steep slopes and escarments with slopes up to 60 or 70 percent. No soil salvaging is recommended for map unit 130B due to very stony, shallow soils present in this map unit.

Clay textured soil materials are highlighted in the Table 11 with a red highlight. These volume estimates would be eliminated if current MDEQ guidelines for suitable soil textures are strictly followed. The subsoil lift for the Big Horn Taxadjunct in map units 111C and 120D would not be conducted. This would reduce the estimated volume of available subsoil by 5.8 percent. The total estimated volume of soil available for reclamation would be reduced by 4.7 percent from the above change and average replacement depths for subsoil would be reduced to 24.5 inches.

The yellow highlighted entry in the volume table identifies a very steep map unit and associated salvage depths and volumes that are likely to be impractical to salvage. Removing these volumes from the soil base reduces the estimated available topsoil by 3.0 percent, the volume of available subsoil by 3.6 percent. Average replacement depths for eliminating the very steep map units are reduced to 7.56 inches for topsoil and 25.6 inches for subsoil. Removing both the very steep slopes and clay textured soils reduces the estimated available topsoil by 3.0 percent and the estimated available subsoil by 8.3 percent, and the estimated total available soil for reclamation by 6.7 percent. Final average replacement depths would be reduced to 7.5 inches for topsoil and 23.7 inches for subsoil.

Table 11. Soil volume calculations by map unit component for Areas A and B.

MU	Area (ft^2)	Component	Prop.	Depth (ft)		Volume (ft^3)	
				TS	SS	Topsoil	Subsoil
100D	92,357	Shingle	0.90	0	0.5	0	41561
		Big Horn, deep	0.10	1.0	2.0	9236	23089
100F	1,696,864	Shingle	0.70	0	0.5	0	593902
		Big Horn, deep	0.20	1.0	2.0	339373	848432
		Earsman Taxa.	0.05	0	0	0	0
		Rock Outcrop	0.05	0	0	0	0
101B	5,348,591	Forkwood	0.90	1.0	4.0	4813732	24068660
		Big Horn, deep	0.10	1.0	2.0	534859	1337148
101D	1,259,393	Forkwood Variant	0.90	1.0	2.0	1133454	2266907
		Big Horn, deep	0.10	1.0	2.0	125939	314848
110C	1,401,570	Big Horn, deep	0.90	1.0	2.0	1261413	3153533
		Forkwood	0.10	1.0	4.0	140157	700785
111C	256,150	Big Horn Taxadjunct	1.00	0.5	4.5	128075	1152675
112D	195,754	Spearman Taxadjunct	0.85	0.5	2.0	83195	332782
		Forkwood Variant	0.10	1.0	2.0	19575	39151
		Rock Outcrop	0.05	0	0	0	0
120D	1,401,570	Wibaux Taxadjunct	0.75	0	0.5	0	525589
		Big Horn Taxadjunct	0.20	0.5	4.5	140157	1261413
		Very Shallow soils	0.05	0	0	0	0
121D	974,982	Wibaux Taxadjunct	0.75	0	0.5	0	365618
		Spearman, dry	0.25	1.0	1.0	243746	243746

MU	Area (ft²)	Component	Prop.	Depth (ft)		Volume (ft³)	
				TS	SS	Topsoil	Subsoil
130B	1,000,565	Earsman Taxadjunct	0.90	0	0	0	0
		Shingle, dry	0.10	0	0.0	0	0
131D	1,624,515	Labre Taxadjunct	0.80	0.5	1.5	649806	1949418
		Forkwood	0.10	1	4.0	162452	812258
		Wibaux Taxa.	0.10	0	0.5	0	81226
140C	393,100	Phiferson	1.00	1.0	2.0	393100	786200
Total Area (ft²) **15,645,411**		Volume Totals				10,178,268	40,948,967
		Avg. Depth (ft)				0.651	2.617
		Avg. Depth (in)				7.8	31.4

Eliminating very steep slopes and clay textures from consideration as sources of soil salvage material will only reduce the average potential soil resource by 3.1 inches of equivalent depth. This leaves over 30 inches of topsoil and subsoil material available for reclamation. The likelihood that salvaging would occur on very steep slopes was all ready slim due to practical and safety reason. The fact there is sufficient soil material available without soils included form these steep areas reinforces the decision not to salvage soils on steep slopes.

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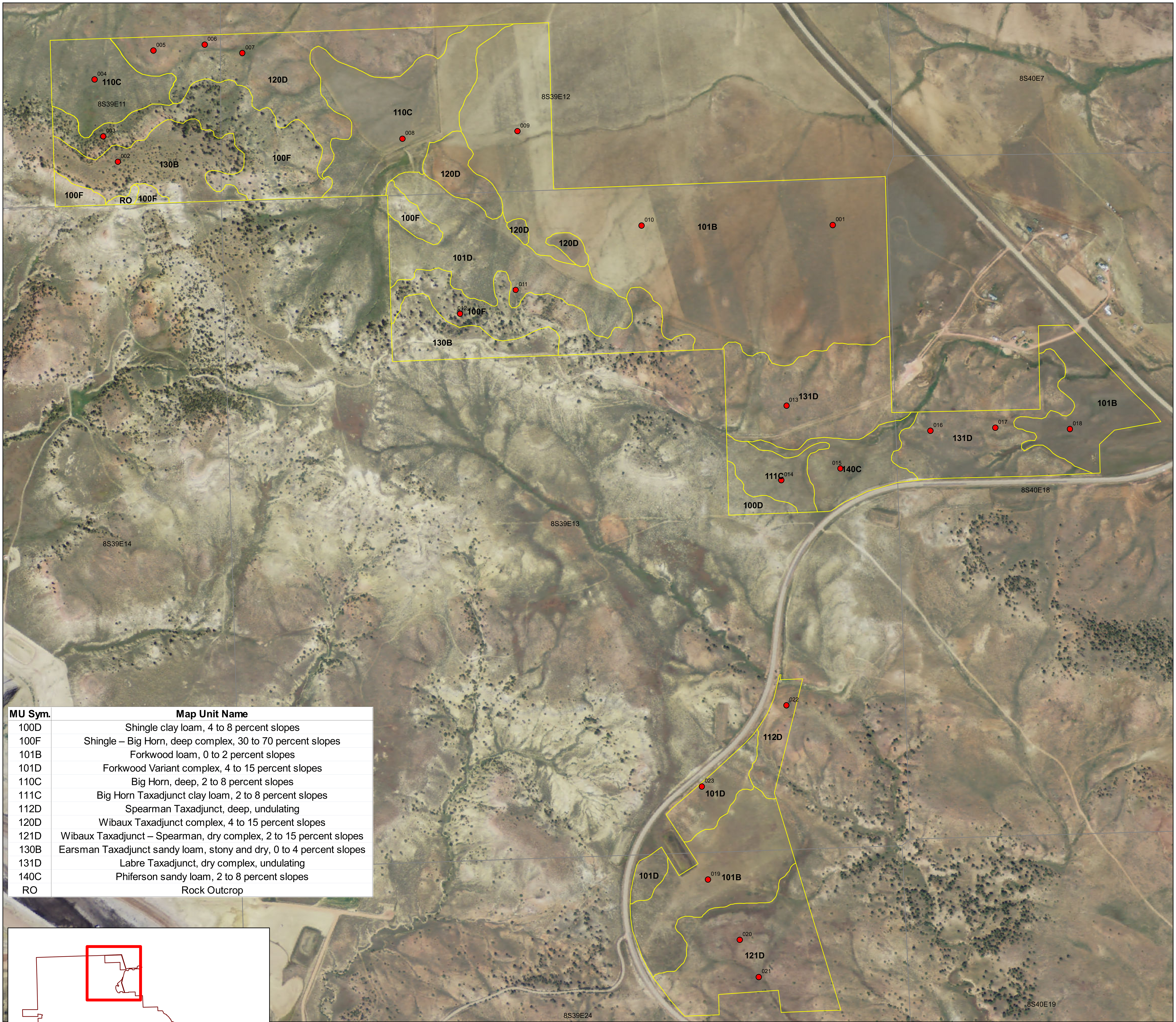
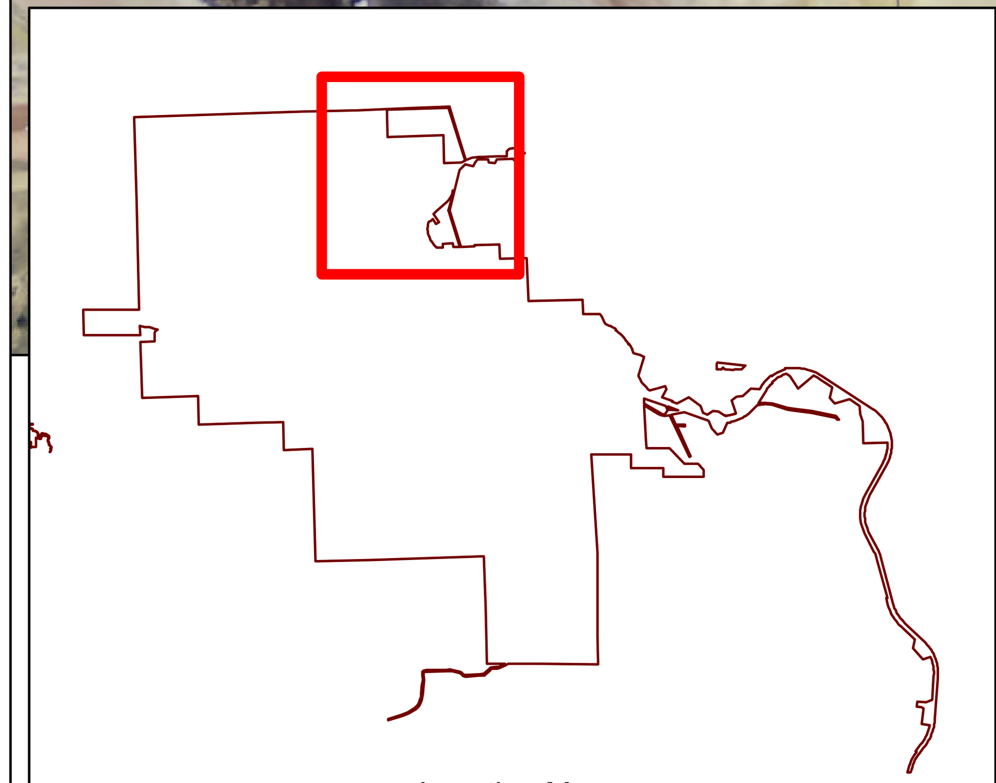


MU Sym.	Map Unit Name
100D	Shingle clay loam, 4 to 8 percent slopes
100F	Shingle – Big Horn, deep complex, 30 to 70 percent slopes
101B	Forkwood loam, 0 to 2 percent slopes
101D	Forkwood Variant complex, 4 to 15 percent slopes
110C	Big Horn, deep, 2 to 8 percent slopes
111C	Big Horn Taxadjunct clay loam, 2 to 8 percent slopes
112D	Spearman Taxadjunct, deep, undulating
120D	Wibaux Taxadjunct complex, 4 to 15 percent slopes
121D	Wibaux Taxadjunct – Spearman, dry complex, 2 to 15 percent slopes
130B	Earsman Taxadjunct sandy loam, stony and dry, 0 to 4 percent slopes
131D	Labre Taxadjunct, dry complex, undulating
140C	Phiferson sandy loam, 2 to 8 percent slopes
RO	Rock Outcrop



Location Map
Not to Scale

Soil Map Unit Boundaries
Soil Sample Locations

0 200 400 800
Feet

N

DATE	
BY	
10/12	

CLOUD PEAK ENERGY

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AREAS A AND B AMENDMENT AREA BASELINE SOILS MAP

SCALE: 1" = 400'