APPENDIX 2.6-B

SOIL MAPPING UNIT DESCRIPTIONS

"Aa" – Alice clay, 0 to 6 percent slope

The Alice clay mapping unit consists of very deep, well drained soils on upland hillslopes and river valley terraces. It occurs on moderately coarse textured alluvium and windblown material at elevations from 3000 to 5500 feet.

The mean annual precipitation is estimated to be 14 to 18 inches. The mean annual air temperature is approximately 49 degrees Fahrenheit. The frost-free season ranges from 120 to 150 days.

Slopes range from 0 to 15 percent. Parent material consists of moderately coarse textured material that is mainly alluvium but may include some eolian sands and loess.

A typical profile contains a 9 inch grayish brown fine sandy loam surface layer. The transition subsoil is a grayish brown fine sandy loam that is approximately 4 inches thick. The substratum is a light brownish gray fine sandy loam that extends to approximately to 26 inches in depth.

Permeability within the Alice soil is moderately rapid. Runoff is low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is severe and the wind erosion hazard is severe.

Productivity and Reclamation Potential

There are twenty seven plant species that are common to this map unit: Needle and thread, Little bluestem, Prairie sandreed, Blue grama, Western wheatgrass, Big bluestem, Hairy grama, Sand bluestem, Sedge, Sideoats grama, Switchgrass, Blacksamson Echinacea, Breadroot scurfpea, Fringed sagewort, Louisiana sagewort, Prairie coneflower, Stiff sunflower, Heath aster, Leadplant, Plains pricklypear, Rose, Sand sagebrush, Silverleaf scurfpea, Slimflower scurfpea, Violet prairieclover, Wormwood, and Yucca .

In a favorable year (above average moisture), the production is approximately 2,300 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content. This map unit is a good source for roadfill. This map unit is a good source for topsoil.

"Ar" - Arvada fine sandy loam, 0 to 6 percent slope

The Arvada fine sandy loam mapping unit consists of very deep, well drained soils formed in alluvium and colluvium that was derived from sodic shale. It occurs on alluvial fans, fan remnants, fan terraces and hillslopes at elevations from 2,600 to 6,000 feet.

The mean annual precipitation is estimated to be 9 to 14 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 100 to 160 days.

Slopes range from 0 to 25 percent. Parent material consists of moderately fine textured alluvium and colluvium derived from sedimentary rocks.

A typical profile contains a 4 inch light gray fine sandy loam surface layer. The transition subsoil is a brown clay that is approximately 10 inches thick. The substratum is a brown clay loam that extends to approximately to 20 inches in depth.

Permeability within the Arvada soil is very slow. Runoff is high on the gentler slopes and very high on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty two plant species that are common to this map unit: Blue grama, Buffalograss, Thickspick wheatgrass,Western wheatgrass, Sideoats grama, Needle and thread, Alkali sacaton, Bluegrass, Inland saltgrass, Nuttall's alkaligrass, Prairie sandreed, Sand dropseed, Sedge, Tumblegrass, Big sagebrush, Broom snakeweed, Ericameria nauseosa ssp. nauseosa var nauseosa, Fringed sagewort, Greasewood, Nuttall's saltbush, Plains pricklypear, and Plains springparsley.

In a favorable year (above average moisture), the production is approximately 840 lbs/acres. In an unfavorable (drought) year, the production is approximately 420 lbs/acres.

According to NRCS information, this map unit is a poor source for roadfill; limitations include low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include sodium content, too clayey and rock fragments. This map unit is a fair source of overall reclamation material; limitations include sodium content, too alkaline, too clayey, low organic matter content and water erosion.

"As" - Ascalon fine sandy loam, 0 to 6 percent slope

The Ascalon fine sandy loam mapping unit consists of very deep, well drained soils that formed in moderate coarse textured calcareous material. It occurs on upland hillslopes and tableland plains at elevation ranges from 4,000 feet to 6,000 feet.

The mean annual precipitation is estimated to be 13 to 17 inches. The mean annual air temperature is approximately 49 degrees Fahrenheit. The frost-free season ranges from 130 to 160 days.

Slopes range from 0 to 25 percent. Parent material consists of thick, moderately coarse textured, calcareous material.

A typical profile contains a 4 inch grayish brown fine sandy loam surface layer. The transition subsoil is a grayish brown fine sandy loam that is approximately 3 inches thick. The substratum is a brown sandy clay loam that extends to approximately to 14 inches in depth.

Saturated hydraulic conductivity within the Ascalon soil is high. Runoff is low on the gentler slopes and high on the steeper slopes. The water erosion hazard is severe and the wind erosion hazard is severe.

Productivity and Reclamation Potential

There are twenty seven plant species that are common to this map unit: Needle and thread, Little bluestem, Prairie sandreed, Blue grama, Western wheatgrass, Big bluestem, Hairy grama, Sand bluestem, Sedge, Sideoats grama, Switchgrass, Blacksamson Echinacea, Breadroot scurfpea, Fringed sagewort, Louisiana sagewort, Prairie coneflower, Stiff sunflower, Heath aster, Leadplant, Plains pricklypear, Rose, Sand sagebrush, Silverleaf scurfpea, Slimflower scurfpea, Violet prairieclover, Wormwood, and Yucca.

In a favorable year (above average moisture), the production is approximately 2,300 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content. This map unit is a good source for roadfill. This map unit is a good source for topsoil.

"Bc" - Barnum very fine sandy loam, 0 to 6 percent slope

The Barnum very fine sandy loam mapping unit consists of very deep, well drained soils formed in calcareous alluvium from red bed sediments. It occurs on flood plains and alluvial terraces with an elevation range from 4,000 feet to 6,600 feet.

The mean annual precipitation is estimated to be 10 to 14 inches. The mean annual air temperature is approximately 47 degrees Fahrenheit. The frost-free season ranges from 110 to 135 days.

Slopes range from 0 to 8 percent. Parent material consists of calcareous alluvium from red bed sediments.

A typical profile contains a 4 inch reddish brown very fine sandy loam surface layer. The transition subsoil and substratum is a reddish brown loam stratified with thin lenses of fine sandy loam and light clay loam that extends to approximately to 60 inches in depth.

Permeability within the Barnum soil is moderate or moderately slow because of stratification. Runoff is low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty three plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Needle and thread, Sideoats grama, Little bluestem, Bluegrass, Big bluestem, Fringed sagewort, Wormwood, Sedge, Switchgrass, Yellow Indiangrass, Blue grama, Breadroot scurfpea, Broom snakeweed, Hairy grama, Heath aster, Louisiana sagewort, Prairie coneflower, Silverleaf scurfpea, Leadplant, Skunkbush sumac, and Slimflower scurfpea.

In a favorable year (above average moisture), the production is approximately 2,300 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content and water erosion. This map unit is a fair source for roadfill; limitations include low strength and shrink-swell. This map unit is a fair source for topsoil; limitations include salinity.

"Bo" - Boneek silt loam, 0 to 6 percent slope

The Boneek silt loam mapping unit consists of deep and very deep, well drained soils formed in silty sediments underlain by sandstone or siltstone. It occurs on nearly level to moderately sloping high terraces and uplands at elevations from 2950 to 3940 feet.

The mean annual precipitation is estimated to be 15 to 18 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 0 to 15 percent. Parent material consists of silty mantle overlying sandstone or siltstones, or in loess or silty alluvium.

A typical profile contains a 3 inch brown silt loam surface layer. The transition subsoil is a brown silt loam that is approximately 3 inches thick. The substratum is a brown silty clay that extends to approximately to 10 inches in depth.

Permeability within the Boneek soil is moderately slow in the solum and moderate in the underlying material. Runoff is low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty three plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Needle and thread, Sideoats grama, Little bluestem, Bluegrass, Big bluestem, Fringed sagewort, Wormwood, Sedge, Switchgrass, Yellow Indiangrass, Blue grama, Breadroot scurfpea, Broom snakeweed, Hairy grama, Heath aster, Louisiana sagewort, Prairie coneflower, Silverleaf scurfpea, Leadplant, Skunkbush sumac, and Slimflower scurfpea.

In a favorable year (above average moisture), the production is approximately 2,200 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content and water erosion. This map unit is a fair source for roadfill; limitations include low strength. This map unit is a good source for topsoil.

"Br" - Broadhurst clay, 6 to 15 percent slope

The Broadhurst clay mapping unit consists of very deep, well drained soils formed in clayey material derived from acid shales. It occurs on fans and terraces at elevations from 2950 to 3940 feet.

The mean annual precipitation is estimated to be 15 to 18 inches. The mean annual air temperature is approximately 47 degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 0 to 15 percent. Parent material consists of clayey material derived from acid shales.

A typical profile contains a 3 inch light brownish gray clay surface layer. The transition subsoil is a grayish brown clay that is approximately 13 inches thick. The substratum is a grayish brown and light brownish gray clay that extends to approximately to 41 inches in depth.

Permeability within the Broadhurst soil is very slow except after dry periods when the initial intake in cracks is rapid. Runoff is medium on the gentler slopes and very high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are nine plant species that are common to this map unit: Western wheatgrass, Thickspick wheatgrass, Green needlegrass, American vetch, Onion, Plains springparsley, Big sagebrush, Nuttall's saltbush, and Plains pricklypear.

In a favorable year (above average moisture), the production is approximately 1,700 lbs/acres. In an unfavorable (drought) year, the production is approximately 800 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, water erosion, too clayey, too acid and salinity. This map unit is a poor source for roadfill; limitations include low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include too clayey, salinity, too acid and slope.

"Bw" – Butche cobbly loam, 6 to 40 percent slope

The Butche cobbly loam mapping unit consists of shallow, well drained to excessively drained soils formed in loamy materials weathered from sandstone. It occurs on sloping to very steep uplands at elevations from 3000 to 5500 feet.

The mean annual precipitation is estimated to be 13 to 18 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 1 to 60 percent. Parent material consists of loamy materials weathered from noncalcareous sandstone.

A typical profile contains a 4 inch dark grayish brown cobbly loam surface layer. The transition subsoil is a pale brown cobbly loam that is approximately 6 inches thick. The substratum is very pale brown indurated sandstone that extends to approximately to 60 inches in depth.

Permeability within the Butche soil is moderate or moderately rapid. Runoff is low on the gentler slopes and high on the steeper slopes. The water erosion hazard is negligible and the wind erosion hazard is negligible.

Productivity and Reclamation Potential

There are twenty seven plant species that are common to this map unit: Little bluestem, Sideoats grama, Big bluestem, Needle and thread, Switchgrass, Yellow Indiangrass, Bluegrass, Prairie dropseed, Prairie sandreed, Sedge, Western wheatgrass, Dropseed, Blacksamson Echinacea, Breadroot scurfpea, Broom snakeweed, Dotted gayfeather, Louisiana sagewort, Blue grama, Fringed sagewort, Hairy grama, Leadplant, Ponderosa pine, Silverleaf scurfpea, Skunkbush sumac, Slimflower scurfpea, True mountain mahogany, and Wormwood.

In a favorable year (above average moisture), the production is approximately 1,600 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,000 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, droughty and depth to bedrock. This map unit is a poor source for roadfill; limitations include depth to bedrock and cobble content. This map unit is a poor source for topsoil; limitations include depth to bedrock, slope and rock fragments.

"Cn" – Colby silt loam, 6 to 15 percent slope

The Colby silt loam mapping unit consists of very deep, well drained and somewhat excessively drained soils formed in calcareous loess. It occurs on nearly level to steep hills and plains at elevations from 2620 to 3610 feet.

The mean annual precipitation is estimated to be 13 to 20 inches. The mean annual air temperature is approximately 45 to 55 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 0 to 60 percent. Parent material consists of calcareous silty loess.

A typical profile contains a 4 inch grayish brown silt loam surface layer. The transition subsoil is a light brownish gray silt loam that is approximately 4 inches thick. The substratum is a pale brown silt loam that extends to approximately to 20 inches in depth.

Permeability within the Colby soil is moderate. Runoff is low on the gentler slopes and very high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty three plant species that are common to this map unit: Needle and thread, Little bluestem, Western wheatgrass, Sedge, Prairie sandreed, Sideoats grama, Blue grama, Green needlegrass, Hairy grama, Inland saltgrass, Plains muhly, Big sagebrush, Blacksamson Echinacea, Broom snakeweed, Fringed sagewort, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Plains pricklypear, Prairie coneflower, Violet prairieclover, Wormwood, and Yucca.

In a favorable year (above average moisture), the production is approximately 1,600 lbs/acres. In an unfavorable (drought) year, the production is approximately 800 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content, water erosion and carbonate content. This map unit is a poor source for roadfill; limitations include low strength and slope. This map unit is a poor source for topsoil; limitations include slope and carbonate content.

"Cy" - Cushman very fine sandy loam, 6 to 15 percent slope

The Cushman very fine sandy loam mapping unit consists of well drained soils that are moderately deep to bedrock and formed in slopewash alluvium and residuum from interbedded shales and siltstone and fine-grained argillaceous sandstone. It occurs on buttes, fan remnants, hills, piedmonts, ridges and terraces at elevations from 3,500 to 6,000 feet.

The mean annual precipitation is estimated to be 10 to 14 inches. The mean annual air temperature is approximately 45 degrees Fahrenheit. The frost-free season ranges from 105 to 130 days.

Slopes range from 0 to 20 percent. Parent material consists of moderately fine textured slopewash alluvium and residuum.

A typical profile contains a 2 inch light brownish gray very fine sandy loam surface layer. The transition subsoil is a brown clay loam that is approximately 6 inches thick. The substratum is a yellowish brown clay loam that extends to approximately to 14 inches in depth.

Permeability within the Cushman soil is moderate. Runoff is medium. The water erosion hazard is slight and the wind erosion hazard is slight.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Needle and thread, Sideoats grama, Little bluestem, Prairie sandreed, Sand dropseed, Fringed sagewort, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Silverleaf scurfpea, American vetch, Big sagebrush, Blue grama, Bluegrass, Breadroot scurfpea, Buffalograss, Heath aster, Leadplant, Prairie coneflower, Rose, Sedge, Skunkbush sumac, Slimflower scurfpea, and Western yarrow.

In a favorable year (above average moisture), the production is approximately 2,300 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content, droughty and depth to bedrock. This map unit is a poor source for roadfill; limitations include depth to bedrock, low strength and shrink-swell. This map unit is a fair source for topsoil; limitations include depth to bedrock.

"Dg" – Demar loam, 0 to 6 percent slope

The Demar loam mapping unit consists of deep or very deep, moderately well drained soils formed in clayey alluvium from acid clay shales. It occurs on micro-highs on nearly level to gently sloping alluvial terraces having pronounced micro-relief at elevations from 2950 to 3940 feet.

The mean annual precipitation is estimated to be 12 to 18 inches. The mean annual air temperature is approximately 47 degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 0 to 6 percent. Parent material consists of clayey alluvium derived from acid clay shales.

A typical profile contains a 5 inch pale brown loam surface layer. The transition subsoil is a brown silty clay loam that is approximately 7 inches thick. The substratum is a grayish brown silty clay that extends to approximately to 24 inches in depth.

Permeability within the Demar soil is very slow. Runoff is medium. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are fifteen plant species that are common to this map unit: Western wheatgrass, Blue grama, Needle and thread, Buffalograss, Green needlegrass, Prairie sandreed, Sedge, American vetch, Broom snakeweed, Fringed sagewort, Louisiana sagewort, Scarlet globemallow, Big sagebrush, Ericameria nauseosa ssp. nauseosa var.nauseosa, and Plains pricklypear.

In a favorable year (above average moisture), the production is approximately 1,600 lbs/acres. In an unfavorable (drought) year, the production is approximately 900 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content, water erosion, too clayey, too acid and salinity. This map unit is a poor source for roadfill; limitations include depth to bedrock, low strength and shrink-swell. This map unit is a fair source for topsoil; limitations include too clayey and sodium content.

"Gr" – Grummit clay, 0 to 6, 6 to 15 and 15 to 60 percent slope

The Grummit clay mapping unit consists of shallow, well drained soils formed in clayey residuum from acid shale on uplands. It occurs on gently sloping to very steep uplands at elevations from 2950 to 3940 feet.

The mean annual precipitation is estimated to be 12 to 18 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 2 to 60 percent. Parent material consists of clayey residuum weathered from acid shales.

A typical profile contains a 3 inch light brownish gray clay surface layer. The transition subsoil is a grayish brown clay that is approximately 4 inches thick. The substratum is a grayish brown and gray clay that extends to approximately to 17 inches in depth.

Permeability within the Grummit soil is moderate or moderately slow in the upper part and moderate in the underlying material. Runoff is low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Little bluestem, Western wheatgrass, Sideoats grama, Green needlegrass, Blue grama, Big bluestem, Hairy grama, Needle and thread, Prairie sandreed, Rocky Mountain juniper, Sedge, Big sagebrush, Blacksamson Echinacea, Broom snakeweed, Rose, Silver buffaloberry, Skunkbush sumac, Breadroot scurfpea, Fringed sagewort, Leadplant, Louisiana sagewort, Prairie coneflower, Silverleaf scurfpea, Slimflower scurfpea, Violet prairieclover, and Yucca.

In a favorable year (above average moisture), the production is approximately 1,400 lbs/acres. In an unfavorable (drought) year, the production is approximately 800 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, droughty, too clayey, depth to bedrock and too acid. This map unit is a poor source for roadfill; limitations include depth to bedrock and slope. This map unit is a poor source for topsoil; limitations include depth to bedrock, slope, too clayey and too acid.

"Ha" - Haverson loam, 0 to 6 percent slope

The Haverson loam mapping unit consists of very deep, well drained soils that formed in alluvium from mixed sources. It occurs on floodplains and low terraces at elevations from 2950 to 3940 feet.

The mean annual precipitation is estimated to be 14 to 18 inches. The mean annual air temperature is approximately 49 degrees Fahrenheit. The frost-free season ranges from 125 to 180 days.

Slopes range from 0 to 9 percent. Parent material consists of highly stratified, calcareous, recent alluvium derived from mixed sources.

A typical profile contains a 3 inch pale brown loam surface layer. The transition subsoil is a pale brown loam that is approximately 3 inches thick. The substratum is a light brownish gray loam that extends to approximately to 12 inches in depth.

Permeability within the Haverson soil is moderate. Runoff is negligble on the gentler slopes and medium on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty four plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Prairie sandreed, Needle and thread, Blue grama, Buffalograss, Bluegrass, Fringed sagewort, Sedge, Heath aster, Western yarrow, Wormwood, Big bluestem, Big sagebrush, Boxelder, Common chokecherry, Green ash, Leadplant, Little bluestem, Louisiana sagewort, Plains cottonwood, Silver buffaloberry, Skunkbush sumac, and Western snowberry.

In a favorable year (above average moisture), the production is approximately 2,800 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,600 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content. This map unit is a fair source for roadfill; limitations include shrink-swell. This map unit is a good source for topsoil.

"He" - Hisle silt loam, 0 to 6 percent slope

The Hisle silt loam mapping unit consists of moderately deep, well drained and moderately well drained soils formed in clayey sediments weathered from clay shale on uplands. It occurs on nearly level to moderately sloping on uplands at elevations around 3,020 feet.

The mean annual precipitation is estimated to be 12 to 16 inches. The mean annual air temperature is approximately 45 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 0 to 15 percent. Parent material consists of clays transported locally or weathered in place from clay shales.

A typical profile contains a 1 inch light gray silt loam surface layer. The transition subsoil is a light brownish gray clay that is approximately 1 inch thick. The substratum is a light brownish gray clay that extends to approximately to 9 inches in depth.

Permeability within the Hisle soil is very slow, but after dry periods initial intake commonly is rapid because of cracks. Runoff is medium on the gentler slopes and very high on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty two plant species that are common to this map unit: Blue grama, Buffalograss, Thickspick wheatgrass, Western wheatgrass, Sideoats grama, Needle and thread, Alkali sacaton, Bluegrass, Inland saltgrass, Nuttall's alkaligrass, Prairie sandreed, Sand dropseed, Sedge, Tumblegrass, Big sagebrush, Broom snakeweed, Ericameria nauseosa ssp. nauseosa var. nauseosa, Fringed sagewort, Greasewood, Nuttall's saltbush, Plains pricklypear, and Plains springparsley.

In a favorable year (above average moisture), the production is approximately 1,100 lbs/acres. In an unfavorable (drought) year, the production is approximately 500 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include sodium content, droughty, too clayey, depth to bedrock and salinity. This map unit is a poor source for roadfill; limitations include low strength, depth to bedrock and shrink-swell. This map unit is a poor source for topsoil; limitations include too clayey, salinity, depth to bedrock and sodium content.

"Ky" – Kyle clay, 0 to 6 percent slope

The Kyle clay mapping unit consists of very deep and well drained soils formed in sediments weathered from clay shale on uplands. It occurs on nearly level to strongly sloping on uplands and colluvial fans at elevations from 2620 to 3610 feet.

The mean annual precipitation is estimated to be 12 to 19 inches. The mean annual air temperature is approximately 47 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 0 to 15 percent. Parent material consists of clayey sediments weathered from calcareous clay shale.

A typical profile contains a 4 inch grayish brown clay surface layer. The transition subsoil is a grayish brown clay that is approximately 4 inches thick. The substratum is a grayish brown clay that extends to approximately to 16 inches in depth.

Permeability within the Kyle soil is very slow, except after dry periods when the initial intake into cracks is rapid. Runoff is medium on the gentler slopes and very high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are nineteen plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Sideoats grama, Needle and thread, Blue grama, Bluegrass, Buffalograss, Sedge, Big sagebrush, Fringed sagewort, Heath aster, Louisiana sagewort, Plains pricklypear, Silverleaf scurfpea, Western yarrow, American vetch, Breadroot scurfpea, Scarlet globemallow, and Slimflower scurfpea.

In a favorable year (above average moisture), the production is approximately 2,300 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, water erosion, too clayey and sodium content. This map unit is a poor source for roadfill; limitations include low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include too clayey and sodium content.

"Lo" – Lohmiller silty clay loam, 0 to 6 percent slope

The Lohmiller silty clay loam mapping unit consists of very deep, well drained soils formed in alluvium on bottom lands. It occurs on flood plains and high bottom lands of rivers and streams and on alluvial fans of foot slopes at elevations from 2620 to 3610 feet.

The mean annual precipitation is estimated to be 10 to 19 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 0 to 8 percent. Parent material consists of calcareous alluvium from sedimentary rock.

A typical profile contains a 4 inch grayish brown silty clay loam surface layer. The transition subsoil is a grayish brown clay loam that is approximately 4 inches thick. The substratum is a grayish brown clay loam that extends to approximately to 60 inches in depth.

Permeability within the Lohmiller soil is slow or moderately slow. Runoff is low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty four plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Prairie sandreed, Needle and thread, Blue grama, Buffalograss, Bluegrass, Fringed sagewort, Sedge, Heath aster, Western yarrow, Wormwood, Big bluestem, Big sagebrush, Boxelder, Common chokecherry, Green ash, Leadplant, Little bluestem, Louisiana sagewort, Plains cottonwood, Silver buffaloberry, Skunkbush sumac, and Western snowberry.

In a favorable year (above average moisture), the production is approximately 2,600 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,500 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, water erosion and too clayey. This map unit is a poor source for roadfill; limitations include low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include too clayey.

"Mm" – Mathias extremely stony very fine sandy loam, 15 to 40 percent slope

The Mathias extremely stony very fine sandy loam mapping unit consists of very deep, well drained soils formed in colluvial sediments weathered from interbedded sandstone and shale on uplands. It occurs below sandstone outcrops on mountain side slopes at elevations from 2,950 to 5,600 feet.

The mean annual precipitation is estimated to be 15 to 18 inches. The mean annual air temperature is approximately 45degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 15 to 70 percent. Parent material consists of material weathered from interbedded fine grain sandstone and shale.

A typical profile contains a 2 inch dark grayish brown extremely stony very fine sandy loam surface layer. The transition subsoil is a light brownish gray very fine sandy loam that is approximately 7 inches thick. The substratum is a brown very fine sandy loam that extends to approximately to 13 inches in depth.

Permeability within the Mathias soil is moderate. Runoff is high on the gentler slopes and very high on the steeper slopes. The water erosion hazard is negligible and the wind erosion hazard negligible.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Sedge, Little bluestem, Sideoats grama, Achnatherum richardsonii, Big bluestem, Dropseed, Green needlegrass, Leadplant, Prairie dropseed, Prairie junegrass, Rose, Switchgrass, Yellow Indiangrass, Bearded wheatgrass, Ponderosa pine, Slender wheatgrass, Western wheatgrass, Rocky Mountain juniper, Breadroot scurfpea, Dotted gayfeather, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Prairie coneflower, Silverleaf scurfpea, Slimflower scurfpea, and Columbia needlegrass.

In a favorable year (above average moisture), the production is approximately 2,900 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,700 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content, cobble content and stone content. This map unit is a poor source for roadfill; limitations include slope, cobble content and stone content. This map unit is a poor source for topsoil; limitations include slope, rock fragments and hard to reclaim (rock fragments).

"Ne" – Nevee silt loam, 6 to 15 percent slope

The Nevee silt loam mapping unit consists of deep and very deep, well drained soils formed in reddish silty alluvial-colluvial sediments on terraces and uplands. It occurs on nearly level to steep on terraces, uplands, and alluvial fans at elevations from 2950 to 3510 feet.

The mean annual precipitation is estimated to be 15 to 18 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 1 to 30 percent. Parent material consists of silty alluvium weathered from reddish colored silty shale, siltstone, or sandstone.

A typical profile contains a 4 inch reddish brown silt loam surface layer. The transition subsoil is a yellowish red silt loam that is approximately 4 inches thick. The substratum is a reddish yellow silt loam that extends to approximately to 24 inches in depth.

Permeability within the Nevee soil is moderate. Runoff is very low on the gentler slopes and high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are nineteen plant species that are common to this map unit:Little bluestem, Sideoats grama, Needle and thread, Sedge, Blue grama, Hairy grama, Western wheatgrass, Buffalograss, Green needlegrass, Blacksamson Echinacea, Breadroot scurfpea, Fringed sagewort, Heath aster, Louisiana sagewort, Plains pricklypear, Rose, Silverleaf scurfpea, Slimflower scurfpea, and Wormwood.

In a favorable year (above average moisture), the production is approximately 2,000 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,200 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; water erosion and carbonate content. This map unit is a poor source for roadfill; limitations include depth to bedrock and low strength. This map unit is a poor source for topsoil; limitations include slope and carbonate content.

"Nf" – Nihill gravelly loam, 15 to 50 percent slope

The Nihill gravelly loam mapping unit consists of very deep, well drained soils formed in gravelly alluvium from mixed sources. It occurs on Pleistocene terraces and terrace remnants at elevations from 2,600 to 6,800 feet.

The mean annual precipitation is estimated to be 10 to 19 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 105 to 130 days.

Slopes range from 0 to 80 percent. Parent material consists of calcareous gravelly alluvium from mixed sources.

A typical profile contains a 5 inch dark brown gravelly loam surface layer. The transition subsoil is a light yellowish brown very gravelly clay loam that is approximately 25 inches thick. The substratum is a very pale brown very gravelly sandy clay loam that extends to approximately to 60 inches in depth.

Permeability within the Nihill soil is moderate. Runoff is medium on the gentler slopes and high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are eighteen plant species that are common to this map unit: Sedge, Needle and thread, Sideoats grama, Blue grama, Hairy grama, Bluegrass, Little bluestem, Sand dropseed, Western wheatgrass, Blacksamson Echinacea, Broom snakeweed, Fringed sagewort, Hairy goldenaster, Louisiana sagewort, Plains pricklypear, Skunkbush sumac, Violet prairieclover, and Wormwood.

In a favorable year (above average moisture), the production is approximately 1,100 lbs/acres. In an unfavorable (drought) year, the production is approximately 600 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content and droughty. This map unit is a fair source for roadfill; limitations include slope. This map unit is a poor source for topsoil; limitations include slope, hard to reclaim (rock fragments) and rock fragments.

"No" – Norka loam, 0 to 6 percent slope

The Norka loam mapping unit consists of very deep well drained soils that formed in thick, calcareous, eolian or alluvial materials high in very fine sand. It occurs on hills, ridges, slope breaks and valley sideslopes at elevations from 2620 to 3610 feet.

The mean annual precipitation is estimated to be 13 to 18 inches. The mean annual air temperature is approximately 48 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 0 to 12 percent. Parent material consists of thick, calcareous, eolian or alluvial materials often containing a large proportion of very fine sand.

A typical profile contains a 4 inch grayish brown loam surface layer. The transition subsoil is a grayish brown silt loam that is approximately 3 inches thick. The substratum is a grayish brown light silty clay loam that extends to approximately to 13 inches in depth.

Permeability within the Norka soil is moderate. Runoff is low on the gentler slopes and high on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Needle and thread, Sideoats grama, Little bluestem, Prairie sandreed, Sand dropseed, Fringed sagewort, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Silverleaf scurfpea, American vetch, Big sagebrush, Blue grama, Bluegrass, Breadroot scurfpea, Buffalograss, Heath aster, Leadplant, Prairie coneflower, Rose, Sedge, Skunkbush sumac, Slimflower scurfpea, and Western yarrow.

In a favorable year (above average moisture), the production is approximately2,300 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content. This map unit is a good source for roadfill. This map unit is a good source for topsoil.

"Nu" – Nunn clay loam, 0 to 6 and 6 to 15 percent slope

The Nunn clay loam mapping unit consists of very deep, well drained soils that formed in loess and mixed alluvium. It occurs on terraces or alluvial fans, and in drainageways at elevations from 2620 to 3610 feet.

The mean annual precipitation is estimated to be 14 inches. The mean annual air temperature is approximately 48 degrees Fahrenheit. The frost-free season ranges from 120 to 210 days.

Slopes range from 0 to 25 percent. Parent material consists mixed alluvium.

A typical profile contains a 6 inch grayish brown clay loam surface layer. The transition subsoil is a grayish brown clay loam that is approximately 4 inches thick. The substratum is a pale brown clay loam that extends to approximately to 24 inches in depth.

Permeability within the Nunn soil is moderately slow to slow. Runoff is negligible on the gentler slopes and very high on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Needle and thread, Sideoats grama, Little bluestem, Prairie sandreed, Sand dropseed, Fringed sagewort, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Silverleaf scurfpea, American vetch, Big sagebrush, Blue grama, Bluegrass, Breadroot scurfpea, Buffalograss, Heath aster, Leadplant, Prairie coneflower, Rose, Sedge, Skunkbush sumac, Slimflower scurfpea, and Western yarrow.

In a favorable year (above average moisture), the production is approximately 1,900 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,100 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, too clayey and water erosion. This map unit is a fair source for roadfill; limitations include shrink-swell. This map unit is a poor source for topsoil; limitations include too clayey.

"Pa" – Paunsaugunt gravelly loam, 6 to 15 percent slope

The Paunsaugunt gravelly loam mapping unit consists of well drained soils that are shallow to limestone and formed in residuum from limestone and calcareous sandstone. It occurs on mesas and hillsides at elevations from 6,000 to 8,400 feet.

The mean annual precipitation is estimated to be 16 to 22 inches. The mean annual air temperature is approximately 43 degrees Fahrenheit. The frost-free season ranges from 70 to 100 days.

Slopes range from 2 to 70 percent. Parent material consists of residuum on limestone and calcareous sandstone.

A typical profile contains a 3 inch brown gravelly loam surface layer. The transition subsoil is a grayish brown cobbly sandy loam that is approximately 5 inches thick. The substratum is a light brownish gray very cobbly sandy loam that extends to approximately to 15 inches in depth.

Permeability within the Paunsaugunt soil is moderate. Runoff is medium on the gentler slopes and rapid on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty nine plant species that are common to this map unit:

Little bluestem, Sideoats grama, Needle and thread, Blue grama, Bluegrass, Dropseed, Hairy grama, Idaho fescue, Prairie dropseed, Sedge, Prairie junegrass, Bearded wheatgrass, Skunkbush sumac, Achnatherum richardsonii, Blacksamson Echinacea, Breadroot scurfpea, Broom snakeweed, Columbia needlegrass, Dotted gayfeather, Fringed sagewort, Green needlegrass, Heath aster, Louisiana sagewort, Prairie coneflower, Silverleaf scurfpea, Slender wheatgrass, Slimflower scurfpea, True mountain mahogany, and Western wheatgrass.

In a favorable year (above average moisture), the production is approximately 1,600 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,000 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include droughty and depth to bedrock. This map unit is a poor source for roadfill; limitations include depth to bedrock. This map unit is a poor source for topsoil; limitations include depth to bedrock, slope and rock fragments.

"Pg" – Penrose channery loam, 15 to 40 percent slope

The Penrose channery loam mapping unit consists of shallow, well and somewhat excessively drained soils formed in thin, calcareous, loamy materials weathered in place from limestone and interbedded limy materials. It occurs on hills, plains, ridges, hogbacks, cuestas, and mesa tops at elevations from 3,000 to 6,500 feet.

The mean annual precipitation is estimated to be 11 to 15 inches. The mean annual air temperature is approximately 51 degrees Fahrenheit. The frost-free season ranges from 125 to 165 days.

Slopes range from 1 to 65 percent. Parent material consists of residuum and slope alluvium derived from limestone and interbedded limy materials.

A typical profile contains a 4 inch light brownish gray channery loam surface layer. The transition subsoil is a light gray channery loam that is approximately 11 inches thick. The substratum is limestone bedrock that extends to approximately to 15 inches in depth.

Permeability within the Penrose soil is moderate to moderately slow. Runoff is low on the gentler slopes and very rapid on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are six plant species that are common to this map unit: Sideoats grama, Blue grama, Achnatherum scribneri, Indian ricegrass, Juniper, and Little bluestem.

In a favorable year (above average moisture), the production is approximately 800 lbs/acres. In an unfavorable (drought) year, the production is approximately 300 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, droughty and depth to bedrock. This map unit is a poor source for roadfill; limitations include depth to bedrock. This map unit is a poor source for topsoil; limitations include depth to bedrock, slope and rock fragments.

"Pe" – Pierre clay, 0 to 6 and 6 to 15 percent slope

The Pierre clay mapping unit consists of moderately deep, well drained soils formed in clayey residuum weathered from shale bedrock on uplands. It occurs on nearly nearly level to steep uplands at elevations from 1300 to 3600 feet.

The mean annual precipitation is estimated to be 10 to 13 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 0 to 30 percent. Parent material consists of residuum weathered from clay shale.

A typical profile contains a 2 inch grayish brown clay surface layer. The transition subsoil is a light brownish gray clay that is approximately 5 inches thick. The substratum is a light brownish gray clay that extends to approximately to 20 inches in depth.

Permeability within the Pierre soil is very slow, except after dry periods when the initial intake may be rapid due to cracks. Runoff is low on the gentler slopes and medium to very high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are nineteen plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Sideoats grama, Needle and thread, Blue grama, Bluegrass, Buffalograss, Sedge, Big sagebrush, Fringed sagewort, Heath aster, Louisiana sagewort, Plains pricklypear, Silverleaf scurfpea, Western yarrow, American vetch, Breadroot scurfpea, Scarlet globemallow, and Slimflower scurfpea.

In a favorable year (above average moisture), the production is approximately 2,200 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,200 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, depth to bedrock, droughty, too clayey and sodium content. This map unit is a poor source for roadfill; limitations include depth to bedrock, low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include depth to bedrock, too clayey and sodium content.

"Sa" – Samsil clay, 15 to 40 percent slope

The Samsil clay mapping unit consists of shallow, well drained soils formed in alluvium or residuum weathered from shale. It occurs on gently sloping to very steep hills, ridges and breaks of dissected shale plains at elevations from 2620 to 3610 feet.

The mean annual precipitation is estimated to be 14 to 19 inches. The mean annual air temperature is approximately 47 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 2 to 60 percent. Parent material consists of alluvium or residuum weathered from shale.

A typical profile contains a 2 inch light brownish gray clay surface layer. The transition subsoil is a light grayish brown clay that is approximately 5 inches thick. The substratum is a light grayish brown clay that extends to approximately to 11 inches in depth.

Permeability within the Samsil soil is slow. Runoff is medium on the gentler slopes and very high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Little bluestem, Western wheatgrass, Sideoats grama, Green needlegrass, Blue grama, Big bluestem, Hairy grama, Needle and thread, Prairie sandreed, Rocky Mountain juniper, Sedge, Big sagebrush, Blacksamson echinacea, Broom snakeweed, Rose, Silver buffaloberry, Skunkbush sumac, Breadroot scurfpea, Fringed sagewort, Leadplant, Louisiana sagewort, Prairie coneflower, Silverleaf scurfpea, Slimflower scurfpea, Violet prairieclover, and Yucca.

In a favorable year (above average moisture), the production is approximately 1,400 lbs/acres. In an unfavorable (drought) year, the production is approximately 800 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, droughty, too clayey, depth to bedrock and water erosion. This map unit is a poor source for roadfill; limitations include depth to bedrock, slope, low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include depth to bedrock, slope and too clayey.

"Sc" – Satanta loam, 0 to 6 percent slope

The Satanta loam mapping unit consists of very deep well drained soils that formed in eolian deposits. It occurs on plains or high stream terraces in the Central High Tablelands at elevations from 2000 to 4500 feet.

The mean annual precipitation is estimated to be 14 to 22 inches. The mean annual air temperature is approximately 56 degrees Fahrenheit. The frost-free season ranges from 140 to 200 days.

Slopes range from 0 to 15 percent. Parent material consists of eolian deposits.

A typical profile contains a 4 inch dark grayish brown loam surface layer. The transition subsoil is a dark grayish brown loam that is approximately 4 inches thick. The substratum is a very dark grayish brown loam that extends to approximately to 19 inches in depth.

Saturated hydraulic conductivity within the Satanta soil is moderately high. Runoff is low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Needle and thread, Sideoats grama, Little bluestem, Prairie sandreed, Sand dropseed, Fringed sagewort, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Silverleaf scurfpea, American vetch, Big sagebrush, Blue grama, Bluegrass, Breadroot scurfpea, Buffalograss, Heath aster, Leadplant, Prairie coneflower, Rose, Sedge, Skunkbush sumac, Slimflower scurfpea, and Western yarrow.

In a favorable year (above average moisture), the production is approximately 2,200 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content. This map unit is a good source for roadfill. This map unit is a good source for topsoil.

"Sn" – Shingle clay loam, 15 to 40 percent slope

The Shingle clay loam mapping unit consists of well drained soils that are very shallow or shallow to bedrock and formed in residuum and colluvium derived from interbedded shale and sandstone or in alluvium from mudstone. It occurs on bedrock controlled hillslopes and ridges at elevations from 3,200 to 6,500 feet.

The mean annual precipitation is estimated to be 10 to 14 inches. The mean annual air temperature is approximately 45 degrees Fahrenheit. The frost-free season ranges from 105 to 130 days.

Slopes range from 0 to 80 percent. Parent material consists of colluvium and residuum weathered from soft, interbedded sandstone and shale or in alluvium from mudstone.

A typical profile contains a 4 inch light brownish gray clay surface layer. The transition subsoil is a light yellowish brown clay loam that is approximately 4 inches thick. The substratum is a light yellowish brown clay loam that extends to approximately to 15 inches in depth.

Permeability within the Shingle soil is moderate. Runoff is medium on the gentler slopes and high on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are twenty nine plant species that are common to this map unit: Little bluestem, Sideoats grama, Needle and thread, Western wheatgrass, Big bluestem, Blue grama, Green needlegrass, Hairy grama, Prairie sandreed, Sedge, Plains muhly, Rocky Mountain juniper, American vetch, Blacksamson echinacea, Breadroot scurfpea, Broom snakeweed, Fringed sagewort, Leadplant, Louisiana sagewort, Missouri goldenrod, Nineanther prairieclover, Oligoneuron rigidum var. rigidum, Prairie coneflower, Rose, Silver buffaloberry, Silverleaf scurfpea, Skunkbush sumac, Slimflower scurfpea, and Violet prairieclover.

In a favorable year (above average moisture), the production is approximately 1,400 lbs/acres. In an unfavorable (drought) year, the production is approximately 800 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, droughty and depth to bedrock. This map unit is a poor source for roadfill; limitations include depth to bedrock, slope, low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include depth to bedrock, slope and rock fragments.

"Gs" – Snomo clay, 6 to 15 percent slope

The Snomo clay mapping unit consists of deep or very deep, well drained soils formed in clayey materials weathered from acid shale on the uplands. It occurs on gently sloping to moderately steep uplands at elevations from 2620 to 3610 feet.

The mean annual precipitation is estimated to be 14 to 18 inches. The mean annual air temperature is approximately 45 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 2 to 20 percent. Parent material consists of clayey materials weathered from acid shale.

A typical profile contains a 2 inch light gray silty clay surface layer. The transition subsoil is a light gray clay that is approximately 3 inches thick. The substratum is a light brownish gray clay that extends to approximately to 14 inches in depth.

Permeability within the Snomo soil is moderate. Runoff is very low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is moderate and the wind erosion hazard is moderate.

Productivity and Reclamation Potential

There are nineteen plant species that are common to this map unit: Little bluestem, Sedge, Western wheatgrass, Sideoats grama, Blue grama, Bur oak, Ponderosa pine, Prairie sandreed, Big bluestem, Switchgrass, Yellow Indiangrass, Fringed sagewort, Louisiana sagewort, Blacksamson Echinacea, Breadroot scurfpea, Heath aster, Silverleaf scurfpea, Slimflower scurfpea, and Wormwood.

In a favorable year (above average moisture), the production is approximately 1,700 lbs/acres. In an unfavorable (drought) year, the production is approximately 800 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, droughty, too clayey, too acid and water erosion. This map unit is a poor source for roadfill; limitations include low strength and shrink-swell. This map unit is a poor source for topsoil; limitations slope, too clayey and too acid.

"Ta" – Tilford silt loam, 0 to 6 percent slope

The Tilford silt loam mapping unit consists of very deep or deep, well drained soils formed in local alluvium and residuum from weathered reddish shales on uplands and terraces. It occurs on nearly level to rolling on uplands, stream terraces and fans at elevations from 2950 to 3510 feet.

The mean annual precipitation is estimated to be 14 to 18 inches. The mean annual air temperature is approximately 45 degrees Fahrenheit. The frost-free season ranges from 110 to 140 days.

Slopes range from 0 to 15 percent. Parent material consists of silty local alluvium and residuum derived from reddish colored silty shales.

A typical profile contains a 5 inch dark brown silt loam surface layer. The transition subsoil is a dark reddish gray silt loam that is approximately 4 inches thick. The substratum is a reddish brown silt loam that extends to approximately to 16 inches in depth.

Permeability within the Tilford soil is moderate. Runoff is low on the gentler slopes and medium on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty six plant species that are common to this map unit: Western wheatgrass, Green needlegrass, Needle and thread, Sideoats grama, Little bluestem, Prairie sandreed, Sand dropseed, Fringed sagewort, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Silverleaf scurfpea, American vetch, Big sagebrush, Blue grama, Bluegrass, Breadroot scurfpea, Buffalograss, Heath aster, Leadplant, Prairie coneflower, Rose, Sedge, Skunkbush sumac, Slimflower scurfpea, and Western yarrow.

In a favorable year (above average moisture), the production is approximately 2,500 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content and water erosion. This map unit is a fair source for roadfill; limitations include low strength. This map unit is a good source for topsoil.

"Wt" – Winetti gravelly sandy loam, 0 to 6 percent slope

The Winetti gravelly sandy loam mapping unit consists of very deep, somewhat excessively drained, moderately rapidly permeable soils that formed in mixed alluvium from sedimentary rocks. It occurs on long, narrow, gently sloping bottoms or valleys and strongly sloping toeslopes at elevations from 7,100 to 8,000 feet.

The mean annual precipitation is estimated to be 12 to 18 inches. The mean annual air temperature is approximately 44 degrees Fahrenheit. The frost-free season ranges from 80 to 100 days.

Slopes range from 0 to 8 percent. Parent material consists of mixed alluvium from sandstone, limestone and shale.

A typical profile contains a 4 inch brown gravelly sandy loam surface layer. The transition subsoil is a light yellowish brown gravelly loamy sand that is approximately 3 inches thick. The substratum is a light yellowish brown very gravelly sandy loam that extends to approximately to 17 inches in depth.

Permeability within the Winetti soil is moderately rapid. Runoff is medium. The water erosion hazard is negligible and the wind erosion hazard is negligible.

Productivity and Reclamation Potential

There are twenty eight plant species that are common to this map unit: Western wheatgrass, Big bluestem, Switchgrass, Yellow Indiangrass, Green needlegrass, Little bluestem, Prairie sandreed, Sideoats grama, Bluegrass, Sedge, Blue grama, American elm, Common chokecherry, Eastern cottonwood, Fringed sagewort, Green ash, Hairy grama, Heath aster, Leadplant, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Silver buffaloberry, Violet prairieclover, Western snowberry, Western yarrow, Woods' rose, and Wormwood.

In a favorable year (above average moisture), the production is approximately 3,800 lbs/acres. In an unfavorable (drought) year, the production is approximately 2,300 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content and droughty. This map unit is a good source for roadfill. This map unit is a poor source for topsoil; limitations include hard to reclaim (rock fragments), rock fragments.

"202" – Worfka clay loam, 15 to 40 percent slope

The Worfka clay loam mapping unit consists of well drained soils that are very shallow or shallow to bedrock and formed in slopewash alluvium and residuum derived from interbedded calcareous shale and argillaceous sandstone. It occurs on ridge crests, shoulders, footslopes and toeslopes as well as uplands, ridges and hills at elevations from 3,500 to 6,500 feet.

The mean annual precipitation is estimated to be 10 to 14 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 130 to 150 days.

Slopes range from 0 to 30 percent. Parent material consists of alluvium and residuum weathered from calcareous shales and argillaceous sandstone.

A typical profile contains a 2 inch light brownish gray light clay loam surface layer. The transition subsoil is a grayish brown clay loam that is approximately 5 inches thick. The substratum is a pale brown clay loam that extends to approximately to 13 inches in depth.

Permeability within the Worfka soil is slow. Runoff is medium on the gentler slopes and rapid on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are five plant species that are common to this map unit: Green needlegrass, Western wheatgrass, Bluebunch wheatgrass, Big sagebrush, and Blue grama.

In a favorable year (above average moisture), the production is approximately 1,000 lbs/acres. In an unfavorable (drought) year, the production is approximately 450 lbs/acres.

According to NRCS information, this map unit is a poor source of overall reclamation material; limitations include low organic matter content, droughty, too clayey, depth to bedrock and water erosion. This map unit is a poor source for roadfill; limitations include depth to bedrock, low strength and shrink-swell. This map unit is a poor source for topsoil; limitations include depth to bedrock, slope and too clayey.

"Zn" – Zigweid loam, 6 to 15 and 6 to 40 percent slope

The Zigweid loam mapping unit consists of very deep, well drained soils formed in alluvium from mixed sedimentary sources. It occurs on fan aprons, alluvial fans, fan piedmonts, fan remnants, terraces, ridges and hills at elevations from 3,500 to 6,600 feet.

The mean annual precipitation is estimated to be 10 to 14 inches. The mean annual air temperature is approximately 46 degrees Fahrenheit. The frost-free season ranges from 105 to 130 days.

Slopes range from 0 to 20 percent. Parent material consists of calcareous, moderately fine textured sediments derived from interbedded shale and soft sandstone.

A typical profile contains a 4 inch light brownish gray loam surface layer. The transition subsoil is a brown clay loam that is approximately 13 inches thick. The substratum is a brown clay loam that extends to approximately to 34 inches in depth.

Permeability within the Zigweid soil is moderate. Runoff is medium on the gentler slopes and rapid on the steeper slopes. The water erosion hazard is very slight and the wind erosion hazard is very slight.

Productivity and Reclamation Potential

There are twenty three plant species that are common to this map unit: Needle and thread, Little bluestem, Western wheatgrass, Sedge, Prairie sandreed, Sideoats grama, Blue grama, Green needlegrass, Hairy grama, Inland saltgrass, Plains muhly, Big sagebrush, Blacksamson Echinacea, Broom snakeweed, Fringed sagewort, Louisiana sagewort, Missouri goldenrod, Oligoneuron rigidum var. rigidum, Plains pricklypear, Prairie coneflower, Violet prairieclover, Wormwood, and Yucca.

In a favorable year (above average moisture), the production is approximately 1,800 lbs/acres. In an unfavorable (drought) year, the production is approximately 1,000 lbs/acres.

According to NRCS information, this map unit is a fair source of overall reclamation material; limitations include low organic matter content. This map unit is a poor source for roadfill; limitations include low strength and shrink-swell. This map unit is a fair source for topsoil; limitations include slope.

APPENDIX 2.6-C

SOIL SERIES DESCRIPTIONS

BROADHURST
SILTY CLAY

Soil Mapping Unit "Br"
Lab/BKS Sample ID: G08020803-001_006SDF

Typical Pedon: Broadhurst silty clay- native grass. When described the soil was dry below 20 inches. (Colors are for dry soil unless otherwise stated.)

The Broadhurst series consists of very deep, well drained soils formed in clayey material derived from acid shales on colluvial fans and terraces. These soils have very slow permeability. Slopes range from 0 to 15 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 47 degrees F.

A - 0-3 inches. Light brownish gray (10YR 6/2) silty clay, moist; weak thick platy structure; very hard, very firm, sticky and plastic; few roots; moderately acid (pH 5.8); abrupt smooth boundary, noneffervescent.

C1 – 3-8 inches. Dark gray (10YR 4/1D, 10YR 3/1W) silty clay, moist; weak coarse blocky and subangular blocky structure; very hard, very firm, sticky and plastic; few roots; moderately acid (pH 5.7); gradual smooth boundary, noneffervescent.

C2 – 8-24 inches. Dark gray (10YR 4/1D, 10YR 3/1W) silty clay, moist; massive; extremely hard, very firm, sticky and plastic; moderately acid (pH 5.7); clear smooth boundary, noneffervescent.

C4 – 24-40 inches. Dark gray (10YR 4/1D, 10YR 3/1W) silty clay, moist; massive; extremely hard, very firm, sticky and plastic; moderately acid (pH 5.8); clear smooth boundary, noneffervescent.

C5n – 40-54 inches. Very dark grayish brown (2.5Y 3/2 DW) silty clay, moist; massive; hard, very firm, sticky and plastic; common fine fragments of shale; common fine nests of gypsum and other salts; very strongly acid (pH 5.0). noneffervescent.

C6n – 54-60 inches. Dark gray (10YR 4/1D, 10YR 3/1W) silty clay, moist; massive; hard, very firm, sticky and plastic; common fine fragments of shale; common fine nests of gypsum and other salts; very strongly acid (pH 4.5). noneffervescent.

Type Location - Butte County, South Dakota; refer to waypoint 17 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Colors throughout the soil are largely inherited from the parent rock. The control section averages between 60 and 70 percent clay. The soil has an Ustic moisture regime that borders on Aridic. Consistence is hard to extremely hard when dry and very firm when moist. When the soil is dry, cracks 1/2 to 1 inch wide and several feet long extend downward for 20 inches or more. The soil typically is very strongly acid but ranges from extremely acid to moderately acid.

A and AC horizons have hue of 10YR or 2.5Y, value of 5 or 6 and 3 or 4 moist, and chroma of 1 or 2.

The C horizon has hue of 10YR, 2.5Y, or 5Y; value of 5 or 6 and 3 or 4 moist; and chroma of 1 or 2. Few or common partially weathered very fine fragments of shale are in the C horizon in most pedons. Nests of gypsum and other salts are few or common in the lower part of the C horizon.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Very-fine, smectitic, acid, mesic Torrertic Ustorthents

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 0-60 inches. Saturation percentage was marginal at 8-24 inches. pH was unsuitable (acidic) at 54-60 inches. Estimated stripping depth is 8 inches.

Geographic Setting (According to Official Series Description) - Broadhurst soils are on colluvial fans and terraces. Slope gradients range from 0 to 15 percent. These soils formed in clayey material derived from acid shales. Mean annual air temperature ranges from 43 to 48 degrees F, and mean annual precipitation ranges from 15 to 18 inches.

KYLE
NONCALCAREOUS VARIANT

Soil Mapping Unit "Ky"
Lab/BKS Sample ID: G08020803-007_011

Typical Pedon: Kyle silty clay loam - on a west-facing plane slope of 2 percent in native grass. (Colors are for dry soil unless otherwise stated.)

The Kyle series consists of very deep and well drained soils formed in sediments weathered from clay shale on uplands. Permeability is very slow. Slopes range from 0 to 15 percent. Mean annual precipitation is about 16 inches, and mean annual air temperature is about 47 degrees F.

A - 0-2 inches. Grayish brown (2.5YR 5/2) silty clay loam, moist; moderate medium and fine granular structure; hard, firm, sticky and plastic; thin crust in upper 1/4 inch of light brownish gray (2.5Y 6/2); common fine roots; neutral; clear wavy boundary, slightly alkaline (pH 7.4); noneffervescent.

Bt - 2-17 inches. Olive brown (2.5Y 4/3DW) silty clay, moist; weak coarse blocky structure parting to weak medium blocky; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; few fine roots; gradual wavy boundary; moderately alkaline (pH 7.9); very slightly effervescent.

C1n – 17-24 inches. Dark grayish brown (2.5Y 4/2D, 2.5Y 3/2W) silty clay, moist; weak coarse subangular blocky structure parting to weak medium and fine blocky; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; few fine roots; clear wavy boundary; moderately alkaline (pH 8.0); noneffervescent.

C2 – 24-39 inches. Dark grayish brown (2.5Y 4/2D, 2.5Y 3/2W) silty clay, moist; weak medium subangular blocky structure in upper part becoming massive in lower part; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; common fine and medium nests of gypsum; strong effervescence; slightly alkaline; gradual wavy boundary. moderately alkaline (pH 7.9); noneffervescent.

C3n – 39-60 inches. Dark grayish brown (2.5Y 4/2DW) silty clay, moist; massive; very hard, firm, sticky and plastic; few fine accumulations of carbonate and gypsum; moderately alkaline (pH 7.9). noneffervescent.

Type Location - Fall River County, South Dakota; refer to waypoint 27 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The soil typically does not have carbonates to depths of 4 to 6 inches, but some pedons contain carbonates to the surface. When the soil is dry, cracks 1/2 inch to 2 inches wide and several feet long extend downward through the solum. The control section averages 60 to 65 percent clay. The soil does not have a mollic epipedon but the upper 10 inches of the solum has an average organic carbon content between 0.6 and 1.7 percent. When the soil is dry, a porous surface crust 1/8 inch to 1/2 inch thick with dry color value of 6 or 7 is typical. Gypsum and other salts are below depths of 20 inches.

The A horizon has hue of 10YR, 2.5Y or 5Y, value of 5 or 6 and 3 to 5 moist, and chroma of 1 to 3. It typically is clay but some is silty clay. It is neutral or slightly alkaline.

The Bw and Bss horizons have hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. Both dry and moist colors of the surface of peds range from 1/2 to 1 value darker than the crushed peds. They are extremely hard or very hard when dry and extremely firm or very firm when moist. They are slightly alkaline or moderately alkaline.

The BCss horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. It has few to common accumulations of gypsum and other salts in most pedons. It is slightly alkaline or moderately alkaline.

Some pedons have a Bk horizon that has colors similar to the BC horizon. It has few to common accumulations of carbonate. It is slightly alkaline or moderately alkaline.

The Cy horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. It is clay and some pedons contain up to 35 percent fragments of shale below 40 inches. It has few to many accumulations of gypsum or other salts. Unweathered shale typically is at depths greater than 5 feet but is as shallow as 40 inches in some pedons. It is slightly alkaline or moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Very-fine, smectitic, mesic Aridic Haplusterts

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 2-60 inches. Saturation percentage was marginal at 24-39 inches. Sodium absorption ratio was marginal at 17-60 inches. Estimated stripping depth is 17 inches.

Geographic Setting (According to Official Series Description) - Kyle soils are nearly level to strongly sloping on uplands and colluvial fans. Slopes are plane to convex, and slope gradients range from 0 to 15 percent. Gilgai microrelief is in most areas. The soil formed in clayey sediments weathered from calcareous clay shale. Mean annual air temperature ranges from 45 to 53 degrees F, and mean annual precipitation ranges from about 12 to 19 inches.

KYLE
NONCALCAREOUS VARIANT

Soil Mapping Unit "Ky"
Lab/BKS Sample ID: G08020803-012_016

Typical Pedon: Kyle silty clay loam- on a west-facing plane slope of 2 percent in native grass. (Colors are for dry soil unless otherwise stated.)

The Kyle series consists of very deep and well drained soils formed in sediments weathered from clay shale on uplands. Permeability is very slow. Slopes range from 0 to 15 percent. Mean annual precipitation is about 16 inches, and mean annual air temperature is about 47 degrees F.

A - 0-2 inches. Brown (10YR 4/3D, 10YR 4/2W) silty clay loam, moist; moderate medium and fine granular structure; hard, firm, sticky and plastic; thin crust in upper 1/4 inch of light brownish gray (2.5Y 6/2); common fine roots; neutral; clear wavy boundary, moderately alkaline (pH 8.0); noneffervescent.

Bt1 - 2-15 inches. Brown (10YR 4/3D, 10YR 4/2W) silty clay, moist; weak coarse blocky structure parting to weak medium blocky; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; few fine roots; gradual wavy boundary; moderately alkaline (pH 8.0); very slightly effervescent.

Bt2n – 15-26 inches. Dark grayish brown (2.5Y 4/2DW) silty clay, moist; weak coarse subangular blocky structure parting to weak medium and fine blocky; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; few fine roots; clear wavy boundary; moderately alkaline (pH 8.0); very slightly effervescent.

C1 – 26-36 inches. Dark grayish brown (2.5Y 4/2DW) silty clay, moist; weak medium subangular blocky structure in upper part becoming massive in lower part; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; common fine and medium nests of gypsum; strong effervescence; slightly alkaline; gradual wavy boundary. moderately alkaline (pH 8.0); very slightly effervescent.

C2 – 36-60 inches. Olive brown (2.5Y 4/3DW) clay, moist; massive; very hard, firm, sticky and plastic; few fine accumulations of carbonate and gypsum; moderately alkaline (pH 8.0); slightly effervescent.

Type Location - Fall River County, South Dakota; refer to waypoint 36 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The soil typically does not have carbonates to depths of 4 to 6 inches, but some pedons contain carbonates to the surface. When the soil is dry, cracks 1/2 inch to 2 inches wide and several feet long extend downward through the solum. The control section averages 60 to 65 percent clay. The soil does not have a mollic epipedon but the upper 10 inches of the solum has an average organic carbon content between 0.6 and 1.7 percent. When the soil is dry, a porous surface crust 1/8 inch to 1/2 inch thick with dry color value of 6 or 7 is typical. Gypsum and other salts are below depths of 20 inches.

The A horizon has hue of 10YR, 2.5Y or 5Y, value of 5 or 6 and 3 to 5 moist, and chroma of 1 to 3. It typically is clay but some is silty clay. It is neutral or slightly alkaline.

The Bw and Bss horizons have hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. Both dry and moist colors of the surface of peds range from 1/2 to 1 value darker than the crushed peds. They are extremely hard or very hard when dry and extremely firm or very firm when moist. They are slightly alkaline or moderately alkaline.

The BCss horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. It has few to common accumulations of gypsum and other salts in most pedons. It is slightly alkaline or moderately alkaline.

Some pedons have a Bk horizon that has colors similar to the BC horizon. It has few to common accumulations of carbonate. It is slightly alkaline or moderately alkaline.

The Cy horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. It is clay and some pedons contain up to 35 percent fragments of shale below 40 inches. It has few to many accumulations of gypsum or other salts. Unweathered shale typically is at depths greater than 5 feet but is as shallow as 40 inches in some pedons. It is slightly alkaline or moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Very-fine, smectitic, mesic Aridic Haplusterts

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 2-60 inches. Saturation percentage was marginal at 2-16 and 26-36 inches. Sodium absorption ratio was marginal at 15-36 inches. Estimated stripping depth is 2 inches.

Geographic Setting (According to Official Series Description) - Kyle soils are nearly level to strongly sloping on uplands and colluvial fans. Slopes are plane to convex, and slope gradients range from 0 to 15 percent. Gilgai microrelief is in most areas. The soil formed in clayey sediments weathered from calcareous clay shale. Mean annual air temperature ranges from 45 to 53 degrees F, and mean annual precipitation ranges from about 12 to 19 inches.

HISLE
SILT LOAM

Soil Mapping Unit "He"
Lab/BKS Sample ID: G08020803-017_021

Typical Pedon: Hisle silt loam - on an east-facing plane slope of 3 percent in native grass at 3,020 feet elevation. When described the soil was moist below a depth of 2 inches. (Colors are for dry soil unless otherwise stated.)

The Hisle series consists of moderately deep, well drained and moderately well drained soils formed in clayey sediments weathered from clay shale on uplands. Permeability is very slow. Slopes range from 0 to 15 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 45 degrees F.

A - 0-2 inches. Light gray (10YR 7/2) silt loam, moist; weak very thin platy structure parting to weak fine granular; soft, very friable; surface crust about 1/8 inch thick; abrupt smooth boundary; neutral (pH 6.8); noneffervescent.

Bt – 2-15 inches. Grayish brown (10YR 5/2D, 10YR 4/2W) silty clay loam, moist; weak medium prismatic structure parting to strong medium and fine blocky; very hard, firm, sticky and plastic; gradual wavy boundary; neutral (pH 7.3); noneffervescent.

C1k – 15-32 inches. Light yellowish brown (2.5Y 6/3D, 2.5Y 4/3W) clay loam, moist; common medium distinct dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) mottles; fine earth is massive; hard, firm, sticky; 50 to 70 percent by volume of fragments of shale; few fine accumulations of carbonate and salt; clear wavy boundary; moderately alkaline (pH 8.0); strongly effervescent.

C2k – 32-52 inches. Brown (10YR 5/3D, 10YR 4/3W) clay loam, fractured soft shale; dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) iron stains and mottles in the seams; moderately alkaline (pH 8.0); strongly effervescent.

C3 – 52-60 inches. Light brownish gray (10YR 6/2D, 10YR 4/2W) silt loam, fractured soft shale; dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) iron stains and mottles in the seams; moderately alkaline (pH 8.1). slightly effervescent.

Type Location - Shannon County, South Dakota; refer to waypoint 39 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The depth to bedded shale typically is about 20 to 26 inches and ranges from 20 to 40 inches. Colors of the soil commonly are inherited from the underlying shale. A few small pebbles are on the surface and mixed throughout the solum in some pedons.

The E horizon has hue of 10YR or 2.5Y, value of 5 to 8 and 3 to 5 moist, and chroma of 1 to 3. It is silt loam or loam and ranges from slightly acid to slightly alkaline. When dry, the surface is crusted up to 1/8 inch thick.

The Btn horizon has hue of 10YR, 2.5Y, or 5Y, value of 5 to 7 and 4 to 6 moist, and chroma of 1 to 4. It is clay or silty clay averaging between 50 and 60 percent clay. It ranges from slightly to strongly alkaline. The Btn horizon has weak or moderate, fine to coarse columnar structure parting to moderate or strong, fine to coarse blocky structure in the upper part. Accumulations of salts and carbonates are in the lower Btn horizon of some pedons.

The Bkz horizon has hue of 10R to 5Y, value of 5 to 8 and 3 to 5 moist, and chroma of 1 to 4. It is silty clay or clay. It has few to many accumulations of carbonate and typically has accumulations of gypsum and salts. It ranges from slightly to strongly alkaline. It contains up to 15 percent fragments of shale by volume.

The C horizon has hue of 10R to 5Y, value of 5 to 8 and 3 to 5 moist, and chroma of 1 to 4. It is clay, or silty clay. Fragments of shale increase with depth and range up to 80 percent by volume. It ranges from slightly to strongly alkaline. Most pedons contain accumulations of carbonate and salts.

The Cr horizon is shale and hue of 10R to 5Y. It ranges from slightly acid to moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer or have slightly less clay than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Leptic Torrertic Natrustalfs

Suitability for Topsoil (According to WDEQ Guideline 1) - No unsuitable or marginal values were present. Strongly calcareous at 15 inches. Estimated stripping depth is 60 inches.

Geographic Setting (According to Official Series Description) - Hisle soils are nearly level to moderately sloping on uplands. Slope gradients range from 0 to 15 percent. Hisle soils formed in clays transported locally or weathered in place from clay shales. The mean annual soil temperature ranges from 45 to 53 degrees F, and mean annual precipitation ranges from 12 to 16 inches.

HISLE
NONCALCAREOUS VARIANT

Soil Mapping Unit "He"
Lab/BKS Sample ID: G08020803-022_026

Typical Pedon: Hisle silty clay loam - on an east-facing plane slope of 3 percent in native grass at 3,020 feet elevation. When described the soil was moist below a depth of 2 inches. (Colors are for dry soil unless otherwise stated.)

The Hisle series consists of moderately deep, well drained and moderately well drained soils formed in clayey sediments weathered from clay shale on uplands. Permeability is very slow. Slopes range from 0 to 15 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 45 degrees F.

A - 0-4 inches. Light gray (10YR 7/2) silty clay loam, moist; weak very thin platy structure parting to weak fine granular; soft, very friable; surface crust about 1/8 inch thick; abrupt smooth boundary; neutral (pH 6.6); noneffervescent.

Bt1 – 4-14 inches. Light olive brown (2.5Y 5/3D, 2.5Y 4/3W) silty clay loam, moist; weak medium prismatic structure parting to strong medium and fine blocky; very hard, firm, sticky and plastic; gradual wavy boundary; neutral (pH 7.1); noneffervescent.

Bt2 – 14-27 inches. Light olive brown (2.5Y 5/3D, 2.5Y 4/3W) silty clay loam, moist; few faint yellowish brown (10YR 5/6) mottles; weak medium and fine subangular blocky structure; very hard, firm, sticky and plastic; many small pebbles and fragments of shale; few fine dark concretions (Fe and Mn oxides); common fine threads and accumulations of carbonate and salt; clear wavy boundary; slightly alkaline (pH 7.8); noneffervescent.

Bt3n – 27-38 inches. Olive brown (2.5Y 4/3D, 2.5Y 4/2W) silty clay, fractured soft shale; dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) iron stains and mottles in the seams; moderately alkaline (pH 8.1); noneffervescent.

Cn – 38-60 inches. Olive brown (2.5Y 4/3D, 2.5Y 4/2W) silty clay, fractured soft shale; dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) iron stains and mottles in the seams; moderately alkaline (pH 7.9); noneffervescent.

Type Location - Shannon County, South Dakota; refer to waypoint 40 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The depth to bedded shale typically is about 20 to 26 inches and ranges from 20 to 40 inches. Colors of the soil commonly are inherited from the underlying shale. A few small pebbles are on the surface and mixed throughout the solum in some pedons.

The E horizon has hue of 10YR or 2.5Y, value of 5 to 8 and 3 to 5 moist, and chroma of 1 to 3. It is silt loam or loam and ranges from slightly acid to slightly alkaline. When dry, the surface is crusted up to 1/8 inch thick.

The Btn horizon has hue of 10YR, 2.5Y, or 5Y, value of 5 to 7 and 4 to 6 moist, and chroma of 1 to 4. It is clay or silty clay averaging between 50 and 60 percent clay. It ranges from slightly to strongly alkaline. The Btn horizon has weak or moderate, fine to coarse columnar structure parting to moderate or strong, fine to coarse blocky structure in the upper part. Accumulations of salts and carbonates are in the lower Btn horizon of some pedons.

The Bkz horizon has hue of 10R to 5Y, value of 5 to 8 and 3 to 5 moist, and chroma of 1 to 4. It is silty clay or clay. It has few to many accumulations of carbonate and typically has accumulations of gypsum and salts. It ranges from slightly to strongly alkaline. It contains up to 15 percent fragments of shale by volume.

The C horizon has hue of 10R to 5Y, value of 5 to 8 and 3 to 5 moist, and chroma of 1 to 4. It is clay, or silty clay. Fragments of shale increase with depth and range up to 80 percent by volume. It ranges from slightly to strongly alkaline. Most pedons contain accumulations of carbonate and salts.

The Cr horizon is shale and hue of 10R to 5Y. It ranges from slightly acid to moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Leptic Torrertic Natrustalfs

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 27-60 inches. Estimated stripping depth is 60 inches.

Geographic Setting (According to Official Series Description) - Hisle soils are nearly level to moderately sloping on uplands. Slope gradients range from 0 to 15 percent. Hisle soils formed in clays transported locally or weathered in place from clay shales. The mean annual soil temperature ranges from 45 to 53 degrees F, and mean annual precipitation ranges from 12 to 16 inches.

NEVEE
SILT LOAM

Soil Mapping Unit "Ne"
Lab/BKS Sample ID: G08020803-027_031

Typical Pedon: Nevee silt loam- on a southwest-facing slope of 8 percent in native grass. When described, the soil was dry throughout. (Colors are for dry soil unless otherwise stated.)

The Nevee series consists of deep and very deep, well drained soils formed in reddish silty alluvial-colluvial sediments on terraces and uplands. Permeability is moderate. Slopes range from 1 to 30 percent. Mean annual precipitation is about 16 inches, and mean annual air temperature is about 46 degrees F.

A - 0-4 inches. Reddish brown (5YR 4/4) silt loam, moist; weak fine granular structure; soft, very friable; many fine roots; clear smooth boundary; slightly alkaline (pH 7.7); noneffervescent.

AC - 4-21 inches. Brown (7.5YR 5/4D, 7.5YR 4/4W) silty clay loam, moist; massive; slightly hard, very friable; common fine roots; few fine accumulations of carbonate; gradual wavy boundary; slightly alkaline (pH 7.7); strongly effervescent.

C1k – 21-36 inches. Reddish brown (5YR 5/4D, 5YR 4/4W) silt, moist; massive; hard, very friable; few fine roots; gradual wavy boundary; strongly alkaline (pH 8.6); strongly effervescent.

C2k – 36-45 inches. Yellowish red (5YR 5/6D, 5YR 4/4W) silt loam, moist; massive; hard, very friable; many coarse fragments of siltstone; gradual wavy boundary; strongly alkaline (pH 8.7); strongly effervescent.

C3k – 45-60 inches. Yellowish red (5YR 5/6D, 5YR 4/4W) loam, moist; extremely hard, friable; strongly alkaline (pH 8.7); strongly effervescent.

Type Location - Butte County, South Dakota; refer to waypoint 41 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to bedrock typically ranges from 40 to 60 inches or more. Depth to free carbonates is less than 10 inches. The control section is silt loam, loam, or very fine sandy loam averaging between 10 and 18 percent clay. Some pedons have up to 35 percent coarse fragments greater than 3 inches in the surface.

The A horizon has hue of 5YR to 10YR, value of 4 to 6 and 3 or 4 moist, and chroma of 2 to 6. Where the color value is as dark or darker than 5.5 and 3.5 moist, the horizon has chroma of 4 or more or is too thin for a mollic epipedon. It is typically silt loam, but some pedons are loam or very fine sandy loam. It ranges from neutral to moderately alkaline. Some pedons have an AC horizon. It has colors an textures of the A horizon.

The C horizon has hue of 2.5YR to 7.5YR, value of 5 to 7 and 4 to 6 moist, and chroma of 3 to 6. It is loam, silt loam, or very fine sandy loam, but some pedons are silty clay loam in the lower part. It typically has few to many, fine or medium accumulations of carbonate in the upper part. It ranges from slightly to strongly alkaline.

The Cr horizon is reddish colored silty shale, siltstone, or sandstone and is below depths of 40 inches. It ranges from slightly to strongly alkaline.

Range in Characteristics (according to field observations, lab analysis): No significant range in characteristics was found.

Taxonomic Class - Coarse-silty, mixed, superactive, calcareous, mesic Aridic Ustorthents

Suitability for Topsoil (According to WDEQ Guideline 1) – Electrical conductivity was unsuitable at 21-60 inches. Sodium absorption ratio was unsuitable at 21-60 inches. Boron was unsuitable at 21-36 inches. Selenium was marginal at 21-60 inches. Strongly effervescent at 4 inches. Estimated stripping depth is 21 inches.

Geographic Setting (According to Official Series Description) - Nevee soils are nearly level to steep on terraces, uplands, and alluvial fans. Surfaces are dominantly smooth plane, and slope gradients range from 1 to 30 percent. The Nevee soils formed in silty alluvium weathered from reddish colored silty shale, siltstone, or sandstone. Mean annual air temperature is 43 to 48 degrees F, and mean annual precipitation ranges from 15 to 18 inches.

BARNUM
SILT LOAM

Soil Mapping Unit "Bc"
Lab/BKS Sample ID: G08020803-032_035

Typical Pedon: Barnum silt loam-rangeland. (Colors are for dry soil unless otherwise stated.)

The Barnum series consists of very deep, well drained soils formed in calcareous alluvium from red bed sediments. Barnum soils are on flood plains and alluvial terraces. Slopes are simple and range from 0 to 8 percent. The mean annual precipitation is about 12 inches, and the mean annual temperature is about 47 degrees F.

A - 0-6 inches. Reddish brown (5YR 4/4) silt loam, moist; moderate very fine granular structure; soft, very friable; calcium carbonate disseminated; clear smooth boundary; slightly alkaline (pH 7.8); noneffervescent.

C1k - 6-17 inches. Reddish brown (5YR 5/4D, 5YR 4/4W) silt loam, moist; massive with lenses of unaltered parent sediment; slightly hard, very friable; calcium carbonate disseminated and as soft masses in some lenses; moderately alkaline (pH 8.3); strongly effervescent.

C2k – 17-39 inches. Reddish brown (5YR 5/4D, 5YR 4/4W) silt loam, moist; massive with lenses of unaltered parent sediment; slightly hard, very friable; calcium carbonate disseminated and as soft masses in some lenses; strongly alkaline (pH 8.6); strongly effervescent.

C3kn – 39-60 inches. Yellowish red (5YR 4/6D, 5YR 4/4W) silt loam, moist; massive with lenses of unaltered parent sediment; slightly hard, very friable; calcium carbonate disseminated and as soft masses in some lenses; strongly alkaline (pH 8.5); strongly effervescent.

Type Location - Johnson County, Wyoming; refer to waypoint 42 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - These soils typically contain free carbonates throughout but may be leached a few inches in some pedons. Organic carbon ranges from .6 to 3 percent in the upper 10 inches and decreases irregularly with depth. The mean annual soil temperature is about 47 to 53 degrees F. The particle size control section is highly stratified and typically averages loam or light clay loam with 18 to 35 percent clay and more than 15 percent fine or coarser sand. Strata of sandy loam, silt loam, silty clay loam, and fine sandy loam are common. Rock fragments are variable between strata but average from 0 to 10 percent pebbles. Exchangeable sodium ranges from 4 to 15 percent throughout the soil. EC typically ranges from 2 to 8 mmhos throughout under natural conditions but may range to 16 mmhos where poorly irrigated.

The A horizon has hue of 7.5YR through 2.5YR, value of 4 through 6 dry, 3 through 5 moist, and chroma of 2 through 6. Reaction is slightly through strongly alkaline.

The C horizon has hue of 5YR through 10R, value of 4 through 7 dry, 3 through 5 moist, and chroma of 2 through 6. Some strata have visual accumulations of salts and carbonates which are typically discontinuous throughout the extent of the pedon. Reaction is slightly through strongly alkaline. Some pedons may have buried horizons below 40 inches.

Range in Characteristics (according to field observations, lab analysis): Textures are finer than typical for the series.

Taxonomic Class - Fine-loamy, mixed, superactive, calcareous, mesic Ustic Torrifluvents

Suitability for Topsoil (According to WDEQ Guideline 1) - Electrical conductivity was unsuitable at 6-39 inches. Sodium absorption ratio was unsuitable at 6-39 inches. Selenium was unsuitable at 6-17 inches. Strongly effervescent at 6 inches. Estimated stripping depth is 6 inches.

Geographic Setting (According to Official Series Description) - Barnum soils are on flood plains and alluvial terraces. These soils formed in calcareous alluvium derived from red beds containing siltstone, shale, and sandstone. Slopes are 0 to 8 percent. Elevations are 4,000 to 6,600 feet. The mean annual precipitation is about 12 inches and ranges from 10 to 14 inches with about half falling as snow or rain in April, May, and early June. The mean annual temperature is about 43 to 49 degrees F. The frost-free season is estimated to range from 110 to 135 days depending upon elevation, aspect, and air drainage

Ascalon
CLAY LOAM

Soil Mapping Unit "As"
Lab/BKS Sample ID: G08020803-036_039

Typical Pedon: Ascalon clay loam- grassland. (Colors are for dry soil unless otherwise stated.)

The Ascalon series consists of very deep, well drained soils that formed in moderate coarse textured calcareous material. Ascalon soils are on upland hillslopes and tableland plains. Slopes range from 0 to 25 percent. The mean annual precipitation is about 41 centimeters (16 inches) and the mean annual air temperature is about 10 degrees C (49 degrees F) at the type location.

A - 0-2 inches. Grayish brown (10YR 5/2) clay loam, moist; moderate very fine granular structure; soft, very friable; 3 percent pebbles; clear smooth boundary; slightly acid (pH 6.2); noneffervescent.

Bt - 2-14 inches. Dark grayish brown (10YR 4/2DW) clay, moist; moderate medium prismatic structure parting to moderate medium subangular blocks; very hard, very friable; many distinct clay films on faces of peds; 3 percent pebbles; gradual smooth boundary; slightly alkaline (pH 7.4); noneffervescent.

C1k – 14-38 inches. Light yellowish brown (2.5Y 6/3D. 2.5Y 5/2W) clay loam, moist; weak medium subangular blocky structure; hard, very friable; concretions, thin seams and streaks of calcium carbonate; few faint clay films on faces of some peds; 5 percent pebbles, gradual smooth boundary; strongly alkaline (pH 8.5); violently effervescent.

C2k – 38-60 inches. Pale yellow (2.5Y 7/3) loam, moist; massive; slightly hard, very friable; 5 percent pebbles; concretions, thin seams and streaks of calcium carbonate; strongly alkaline (pH 8.8); strongly effervescent.

Type Location - Washington County, Colorado; refer to waypoint 43 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to bedrock typically ranges from 40 to 60 inches or more. Depth to free carbonates is less than 10 inches. The control section is silt loam, loam, or very fine sandy loam averaging between 10 and 18 percent clay. Some pedons have up to 35 percent coarse fragments greater than 3 inches in the surface.

The A horizon has hue of 5YR to 10YR, value of 4 to 6 and 3 or 4 moist, and chroma of 2 to 6. Where the color value is as dark or darker than 5.5 and 3.5 moist, the horizon has chroma of 4 or more or is too thin for a mollic epipedon. It is typically silt loam, but some pedons are loam or very fine sandy loam. It ranges from neutral to moderately alkaline. Some pedons have an AC horizon. It has colors an textures of the A horizon.

The C horizon has hue of 2.5YR to 7.5YR, value of 5 to 7 and 4 to 6 moist, and chroma of 3 to 6. It is loam, silt loam, or very fine sandy loam, but some pedons are silty clay loam in the lower part. It typically has few to many, fine or medium accumulations of carbonate in the upper part. It

ranges from slightly to strongly alkaline.

The Cr horizon is reddish colored silty shale, siltstone, or sandstone and is below depths of 40 inches. It ranges from slightly to strongly alkaline.

Mean annual soil temperature: 8 to 15 degrees C (47 to 58 degrees F).
Mean summer soil temperature: 15 to 26 degrees C (59 to 78 degrees F).
Mollic epipedon: thickness ranges from 18 to 51 centimeters (7 to 20 inches)
Depth to secondary calcium carbonate: 20 to 76 centimeters (8 to 30 inches)
Depth to the base of the Bt horizon: 38 to 76 centimeters (15 to 30 inches)
Organic carbon: ranges from .6 to 2 percent in the mollic epipedon and decreases uniformly with depth.
Rock fragments: range from 0 to 15 percent but are usually less than 5 percent.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Fine-loamy, mixed, superactive, mesic Aridic Argiustolls

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 2-14 inches. Sodium absorption ratio was unsuitable at 38-60 inches. Violently effervescent at 14 inches. Estimated stripping depth is 14 inches.

Geographic Setting (According to Official Series Description) –
Parent material: thick, moderately coarse textured, calcareous material.
Landform: hills and plains
Slope: 0 to 25 percent
Elevation: 1219 to 1829 meters (4000 to 6000 feet).
Mean annual precipitation: 33 to 43 centimeters (13 to 17 inches), with peak periods of precipitation occurring during the spring and summer.
Mean annual temperature: 10 to 12 degrees C (49 to 53 degrees F).
Average summer temperature: 20 to 23 Degree C (68 to 73 degrees F).
Frost-free season: about 130 to 160 days.

CUSHMAN
LOAM

Soil Mapping Unit "Cy"
Lab/BKS Sample ID: G08020803-040_043

Typical Pedon: Cushman loam - on south facing slope of about 3 percent under native grass vegetation. (Colors are for dry soil unless otherwise stated.)

The Cushman series consists of well drained soils that are 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 on buttes, fan remnants, hills, piedmonts, ridges and terraces. Slopes are 0 to 20 percent. The mean annual precipitation is about 13 inches, and the mean annual air temperature is about 45 degrees F

A - 0-2 inches. Light brownish gray (10YR 6/2) loam, moist; moderate medium granular structure; soft, friable, slightly sticky and slightly plastic; common very fine, fine, and few medium roots; clear smooth boundary; neutral (pH 6.6); noneffervescent.

Bt - 2-7 inches. Brown (10YR 5/3) clay loam, moist; weak medium prismatic structure parting to moderate medium subangular blocky; slightly hard, friable, moderately sticky and moderately plastic; common very fine, fine and few medium roots; few faint clay films on faces of peds and lining pores; clear smooth boundary; slightly alkaline (pH 7.4); noneffervescent.

Btk – 7-13 inches. Brown (10YR 4/3DW) clay loam, moist; moderate coarse prismatic structure parting to strong medium angular blocky; hard, firm, moderately sticky and moderately plastic; few fine, medium and coarse roots; common distinct clay films on faces of peds, lining pores and root channels; clear wavy boundary; moderately alkaline (pH 8.1); strongly effervescent.

Ck – 13-25 inches. Dark grayish brown (10YR 4/2D, 10YR 3/2W) clay loam, moist; moderate coarse prismatic structure parting to moderate fine and very fine subangular blocky; hard, firm, moderately sticky and moderately plastic; few fine roots; few faint clay films on faces of peds; calcium carbonate on faces of peds and in pores as common distinct irregularly shaped filaments and masses; clear smooth boundary; moderately alkaline (pH 8.3); strongly effervescent.

Type Location - Sheridan County, Wyoming; refer to waypoint 50 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to a paralithic contact and bedrock is typically about 28 to 32 inches but ranges from 20 to 40 inches. Depth to continuous horizons of carbonate accumulation is 7 to 26 inches. Depth to the base of the argillic horizon ranges from 10 to 26 inches. Rock fragments range from 0 to 15 percent and are soft shale channers or semirounded sandstone pebbles. The soil is dry in the moisture control section more than half the time cumulative that the soil temperature at a depth of 20 inches is 41 degrees F., which occurs about April 21-27, and is dry in all parts of the moisture control section for at least 60 consecutive days from July 15 to October 25 and for at least 90 cumulative days during this period. The mean annual soil temperature is 47 to 53 degrees F., and the soil temperature at a depth of 20 inches is 41 degrees F. or more for 175 to 192 days. EC ranges from 0 to 2 mmhos throughout.

The A horizon has hue of 10YR or 2.5Y, value of 4 to 6 dry, 3 to 5 moist, and chroma of 2 to 4. Reaction is neutral or slightly alkaline.

The Bt horizon has hue of 10YR or 2.5Y, value of 4 to 6 dry, 3 to 5 moist, and chroma of 2 to 4. Texture of the Bt is clay loam or loam with 20 to 35 percent clay and more than 15 percent but less than 35 percent fine sand or coarser. Reaction is neutral to moderately alkaline.

The Btk horizon has hue of 10YR or 2.5Y, value of 5 to 7 dry, 4 to 6 moist, and chroma of 2 to 4. Texture is loam or clay loam with 20 to 35 percent clay. Reaction is moderately alkaline or strongly alkaline. Calcium carbonate ranges from 3 to 12 percent.

The Bk horizon has hue of 10YR and 2.5Y, value of 6 to 8 dry, 4 to 6 moist, and chroma of 2 to 4. Texture is loam or clay loam with 20 to 30 percent total clay of which about 2 to 4 percent is carbonate clay. Reaction is typically moderately alkaline but may be strongly alkaline when sodic shales are present. Calcium carbonate equivalent is 5 to 15 percent, but some horizons may exceed 15 percent but are discontinuous or too thin to be considered as a calcic.

The Cr is weakly consolidated sedimentary rock. It is primarily calcareous shale; but siltstone or thinly interbedded fine grained argillaceous sandstone is common. The rock is typically moderately alkaline or strongly alkaline when crushed, but slightly alkaline or neutral shales are not uncommon.

Range in Characteristics (according to field observations, lab analysis): No significant range in characteristics was found.

Taxonomic Class - Fine-loamy, mixed, superactive, mesic Ustic Haplargids

Suitability for Topsoil (According to WDEQ Guideline 1) - No marginal or unsuitable parameters were found. Strongly effervescent at 7 inches. Estimated stripping depth is 25 inches.

Geographic Setting (According to Official Series Description) - Cushman soils are on buttes, fan remnants fan piedmonts, hills and ridges. Slopes range from 0 to 20 percent. The soils formed in moderately fine textured slopewash alluvium and residuum. Surface erosion is common in overgrazed areas, and some thin eolian deposits overlie these soils in some areas. Elevations are 3,500 to 6,000 feet. The mean annual precipitation is 13 inches and ranges from 10 to 14 inches with over half of the annual precipitation falling in April, May, and June and less than one inch falling in each month of July, August, September and October. The mean annual temperature is 43 to 51 degrees F. The frost-free season is about 105 to 130 days depending upon elevation, aspect, and air drainage.

ZIGWEID
SILTY CLAY LOAM

Soil Mapping Unit "Zn"
Lab/BKS Sample ID: G08020803-044_048

Typical Pedon: Zigweid silty clay loam - on a 3 percent southwest facing slope utilized as rangeland. (Colors are for dry soil unless otherwise stated.)

The Zigweid series consists of very deep, well drained soils formed in alluvium from mixed sedimentary sources on fan aprons, alluvial fans, fan piedmonts, fan remnants, terraces, ridges and hills. Slopes range from 0 to 20 percent. Permeability is moderate. The mean annual precipitation is about 13 inches, and the mean annual air temperature is about 46 degrees F.

A - 0-3 inches. Light brownish gray (10YR 6/2) silty clay loam, moist; moderate fine and medium granular structure; slight hard, friable, nonsticky and nonplastic; many very fine and fine roots throughout; clear smooth boundary; slightly alkaline (pH 7.4); noneffervescent.

B1 - 3-14 inches. Brown (10YR 5/3D, 10YR 4/2W) silty clay loam, moist; moderate medium prismatic structure parting to moderate fine and medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; many very fine and fine roots throughout and few medium throughout; carbonates are disseminated throughout; gradual wavy boundary; slightly alkaline (pH 7.7); very slightly effervescent.

B2 – 14-26 inches. Dark grayish brown (10YR 4/2DW) silty clay loam, moist; moderate medium prismatic structure parting to moderate fine and medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; many very fine and fine roots throughout; common fine irregular light gray (10YR 7/2) carbonate threads throughout; gradual wavy boundary; slightly alkaline (pH 7.6); very slightly effervescent.

C1 – 26-36 inches. Yellowish brown (10YR 5/4D, 10YR 4/3W) silt loam, moist; moderate medium prismatic structure parting to moderate fine and medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; many very fine and fine roots throughout; common fine irregular light gray (10YR 7/2) carbonate threads throughout; gradual wavy boundary; slightly alkaline (pH 7.5); very slightly effervescent.

C2 – 36-60 inches. Brown (10YR 5/3D, 10YR 4/2W) loam, moist; moderate medium subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common very fine and fine roots throughout; common fine irregular light gray (10YR 7/2) carbonate threads throughout; slightly alkaline (pH 7.7); strongly effervescent.

Type Location - Campbell County, Wyoming; refer to waypoint 56 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to carbonates ranges from 0 to 8 inches. Depth to the Bk horizon and the base of the cambic horizon ranges from 10 to 22 inches. The particle-size control section and soil profile are clay loam or loam. Clay ranges from 18 to 35 percent, silt from 20 to 55 percent, and sand from 15 to 50 percent with more than 15 percent but less than 35 percent fine sand or coarser. Rock fragments range from

0 to 15 but are typically less than 5 percent and are mostly soft shale chips. The moisture control section is usually dry in all parts for 90 cumulative days following the summer solstice and for 60 consecutive days during this period. The mean annual soil temperature is 47 to 53 degrees F. The soil temperature at a depth of 20 inches is 41 degrees F. or warmer for 175 to 192 days.

The A horizon has hue of 5Y, 2.5Y or 10YR, value of 4 to 6 dry, 3 to 5 moist, and chroma of 2 or 3. It is loam or clay loam. Reaction is neutral to moderately alkaline.

The Bw horizon has hue of 5Y, 2.5Y or 10YR, value of 5 or 6 dry, 4 or 5 moist, and chroma of 2 to 4. It is loam or clay loam. Reaction is slightly alkaline or moderately alkaline.

The Bk horizon has hue of 5Y, 2.5Y or 10YR, value of 5 to 7 dry, 4 to 6 moist, and chroma of 2 to 4. It is loam or clay loam. It has 5 to 14 percent calcium carbonate equivalent and may have a few scattered crystals of calcium sulfate. Reaction is moderately alkaline or strongly alkaline.

Some pedons have a C horizon with similar properties as the Bk horizon. Some pedons may have sandy clay loam textures below 40 inches. It typically has 3 to 5 percent less calcium carbonate than the overlying Bk horizon.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Fine-loamy, mixed, superactive, mesic Ustic Haplocambids

Suitability for Topsoil (According to WDEQ Guideline 1) - No marginal or unsuitable parameters were found. Strongly effervescent at 36 inches. Estimated stripping depth is 60 inches.

Geographic Setting (According to Official Series Description) - These soils are on fan aprons, alluvial fans, terraces, fan piedmonts, fan remnants, ridges and hills. In many areas they are dissected. Slopes range from 0 to 20 percent. These soils formed in calcareous, moderately fine textured sediments derived from interbedded shale and soft sandstone. Elevations are 3,500 to 6,600 feet. The mean annual precipitation is 13 inches with over half of the annual precipitation falling in April, May, and June and less than one inch falling in each month of July, August, September, and October. Precipitation ranges from 10 to 14 inches. The mean annual temperature is about 46 degrees F., and ranges from 43 to 51 degrees F. The frost-free season is about 105 to 130 days.

BUTCHE
CLAY LOAM

Soil Mapping Unit "Bw"
Lab/BKS Sample ID: G08020803-049_050

Typical Pedon: Butche clay loam - on a west-facing convex slope of 25 percent under native grass. When described the soil was moist to 10 inches. (Colors are for dry soil unless otherwise stated.)

The Butche series consists of shallow, well drained to excessively drained soils formed in loamy materials weathered from sandstone. Permeability is moderate or moderately rapid. Slopes range from 1 to 60 percent. Mean annual precipitation is about 17 inches, and mean annual temperature is about 46 degrees F.

A - 0-2 inches. Dark grayish brown (2.5Y 4/2DW) loam, moist; weak fine granular structure; soft, very friable; coarse fragments make up about 20 percent by volume; clear wavy boundary; slightly alkaline (pH 7.6); noneffervescent.

C - 2-8 inches. Grayish brown (2.5Y 5/2DW) sandy loam, moist; weak medium and coarse subangular blocky structure; slightly hard, very friable; coarse fragments make up about 30 percent by volume; abrupt wavy boundary; slightly alkaline (pH 7.6); very slightly effervescent.

Type Location - Custer County, South Dakota; refer to waypoint 57 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The soil has an Ustic moisture regime that borders on Aridic. Depth to sandstone ranges from 7 to 20 inches. Coarse fragments ranging in size from channery sandstone fragments up to massive slabs of sandstone about 3 feet in diameter are on the surface and mixed throughout the A and C horizons. Some pedons also have rounded cobble and stones of igneous and metamorphic rocks unrelated to the underlying sedimentary sandstone. The coarse fragments and flagstones make up 10 to 35 percent by volume of the soil mass. The control section typically is loam averaging between 15 and 25 percent clay and more than 15 percent fine sand or coarser.

The A horizon has hue of 10YR or 7.5YR, value of 4 to 6 and 2 to 4 moist, and chroma of 1.5 to 3 dry or moist. Where the color value is as dark or darker than 5.5 and 3.5 moist, the A horizon is too thin for a mollic epipedon. The A horizon is cobbly loam, cobbly fine sandy loam, stony loam, stony fine sandy loam, channery loam, loam, sandy loam, or fine sandy loam. It is slightly acid or neutral.

The C horizon typically has 10YR hue, but some pedons have hue of 7.5YR or 5YR due to variations in color of the underlying sandstone, value of 5 to 7 and 4 to 6 moist, and chroma of 2 to 6. The C horizon is cobbly loam, channery loam, stony loam, stony fine sandy loam, channery fine sandy loam, loam, sandy loam and fine sandy loam. It ranges from slightly acid to slightly alkaline. In some pedons there is an incipient cambic horizon 1 to 2 inches thick that is intermediate in color between the A and C horizon and has more pronounced structure than the C horizon. It is not continuous and is irregular in its shape and occurrence.

The R horizon is very hard sandstone and is hard and difficult to penetrate. It lacks free carbonates.

Range in Characteristics (according to field observations, lab analysis): No significant range in characteristics was found.

Taxonomic Class - Loamy, mixed, superactive, nonacid, mesic Aridic Lithic Ustorthents

Suitability for Topsoil (According to WDEQ Guideline 1) - No marginal or unsuitable parameters were found. Estimated stripping depth is 8 inches.

Geographic Setting (According to Official Series Description) - Butche soils are sloping to very steep on uplands with gradients ranging from 1 to 60 percent. The Butche soils are formed in loamy materials weathered from noncalcareous sandstone. The mean annual temperature ranges from 45 to 49 degrees F, and mean annual precipitation from 13 to 18 inches. Elevations range from 3000 to 5500 feet.

SAMSIL
CLAY LOAM

Soil Mapping Unit "Sa"
Lab/BKS Sample ID: G08020805-001_002

Typical Pedon: Samsil clay loam - on a convex, southwest-facing slope of 15 percent in native grass. When described the soil was moist to 12 inches, dry from 12 to 21 inches, and moist below 21 inches. (Colors are for dry soil unless otherwise stated.)

The Samsil series consists of shallow, well drained soils formed in alluvium or residuum weathered from shale. Permeability is slow. Slope ranges from 2 to 60 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 47 degrees F.

A - 0-3 inches. Light brownish gray (2.5Y 6/2) clay loam, moist; moderate fine granular structure; slightly hard, friable, sticky and plastic; common fine roots; few very fine fragments of shale; clear wavy boundary; slightly alkaline (pH 7.5); noneffervescent.

AC - 3-10 inches. Gray (10YR 5/1D) clay, moist; weak medium subangular blocky structure parting to weak medium granular; hard, friable, sticky and plastic; common fine roots; common fine fragments of soft shale; clear wavy boundary; moderately alkaline (pH 8.4); strongly effervescent.

Ck – 10-18 inches. Very dark gray (10YR 3/1D) silt loam, moist; massive; hard, friable, sticky and plastic; common fine roots; about 50 percent by volume of fragments of soft shale; common distinct olive yellow (2.5Y 6/6) stains on faces of shale fragments; few fine and medium accumulations of carbonate; gradual wavy boundary; moderately alkaline (pH 8.2); strongly effervescent.

Type Location - Pennington County, South Dakota; refer to waypoint 60 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The control section is clay and contains 50 to 65 percent clay. The depth to bedded shale ranges from 6 to 20 inches. Horizons above the shale range from loose to hard when dry, and friable or firm when moist. These horizons contain free carbonates. Effervescence ranges from slight to strong and reaction is slightly alkaline or moderately alkaline. The C1 and C2 horizons and upper part of the Cr horizons commonly have accumulations of carbonate, gypsum, and other salts. Colors throughout, including mottles and stains, are inherited from the shale.

The A horizon has hue of 5Y, 2.5Y, or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 2 to 4. It is clay, silty clay, silty clay loam or clay loam and commonly contains few to common fragments of shale ranging from 2 to 25 mm in diameter. It has fine or medium subangular blocky or fine or very fine granular structure. The upper 1/4 to 1/2 inch commonly is a fragile crust or mulch or very fine granules when dry.

The AC horizon has hue of 5Y, 2.5Y, or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 4. It contains up to 35 percent fragments of shales by volume that range from less than 2 mm to 30 mm in diameter.

The C horizon has hue of 5Y, 2.5Y or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 4. It is clay. The C horizon contains from 35 to more than 50 percent fragments of shale by volume that range from less than 2 mm to 35 mm in diameter.

The Cr horizon has the same range in color as the overlying C horizons. It ranges from medium acid to moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer and have less clay than typical for the series.

Taxonomic Class - Clayey, smectitic, calcareous, mesic, shallow Aridic Ustorthents

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 3-10 inches. Electrical conductivity was marginal at 10-18 inches. Sodium absorption ratio was marginal at 3-18 inches. Selenium was marginal at 10-18 inches. Strongly effervescent at 3 inches. Estimated stripping depth is 3 inches.

Geographic Setting (According to Official Series Description) - Samsil soils are on gently sloping to very steep hills, ridges and breaks of dissected shale plains. Surfaces mainly are convex, and slope gradients range from 2 to 60 percent or more. The soil formed in alluvium or residuum weathered from shale. Mean annual air temperature ranges from 45 to 48 degrees F, and mean annual precipitation ranges from 14 to 19 inches.

PAUNsAUGUNT
LOAM

Soil Mapping Unit "Pa"
Lab/BKS Sample ID: G08020805-004_006

Typical Pedon: Paunsaugunt loam-rangeland. (Colors are for dry soil unless otherwise stated.)

The Paunsaugunt series consists of well drained, moderately permeable soils that are shallow to limestone. They formed in residuum from limestone and calcareous sandstone. Paunsaugunt soils are on mesas and hillsides with slopes ranging from 2 to 70 percent. The average annual precipitation is about 15 inches. The mean annual temperature is about 43 degrees F.

A - 0-2 inches. Brown (10YR 5/3) loam, moist, crushed; weak medium subangular blocky structure that parts to weak fine granular structure; soft, friable, common fine and medium roots; common fine and very fine interstitial pores; 30 percent cobbles; strongly calcareous; carbonates are disseminated; clear smooth boundary; slightly acid (pH 6.4); noneffervescent.

Bo - 2-6 inches. Dark yellowish brown (10YR 4/4D) loam, moist, crushed; weak medium subangular blocky structure that parts to weak fine granular structure; soft, friable, common fine and medium roots; common fine and very fine interstitial pores; 30 percent cobbles; strongly calcareous; carbonates are disseminated; clear smooth boundary; neutral (pH 7.3); noneffervescent.

Ck – 6-18 inches. Very pale brown (10YR 7/4D) clay loam, moist; crushed; weak fine subangular blocky structure parting to weak fine granular structure; soft, friable; many medium and coarse roots; few fine and very fine pores; 45 percent cobbles; strongly calcareous; carbonates are disseminated; abrupt wavy boundary; moderately alkaline (pH 7.4); strongly effervescent.

Type Location - Garfield County, Utah; refer to waypoint 63 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The mean annual soil temperature is 41 to 47 degrees F., and a mean summer soil temperature immediately above bedrock of about 59 to 64 degrees F. The soil moisture regime is typic ustic.

The mollic epipedon is 4 to 12 inches thick and constitutes over one-third the thickness of soil above bedrock. The depth to bedrock ranges from 10 to 20 inches. Rock fragments average 35 to 60 percent in the particle-size control section. Clay content ranges from 15 to 27 percent.

The A horizon has hue of 7.5YR or 10YR, value of 3 to 5 dry, and chroma of 1 to 3 dry and moist. Reaction is mildly to moderately alkaline.

The C horizon has hue of 7.5YR or 10YR, value of 5 to 7 dry, 3 to 5 moist and chroma of 2 or 3. It is very channery, very gravelly or very cobbly loam, or very cobbly sandy loam.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Loamy-skeletal, mixed, superactive, frigid Lithic Haplustolls

Suitability for Topsoil (According to WDEQ Guideline 1) - No marginal or unsuitable parameters were found. Strongly effervescent at 6 inches. Estimated stripping depth is 18 inches.

Geographic Setting (According to Official Series Description) - The Paunsaugunt soils are on undulating mesas, gently sloping to very steep hills, and mountainsides. Elevations range from 6,000 to 8,400 feet. The soils formed in residuum on limestone and calcareous sandstone. Slope gradients are 2 to 70 percent. The average annual precipitation is 16 to 22 inches and the freeze free period ranges from 70 to 100 days. The mean annual temperature is 39 to 45 degrees F., and the average summer temperature is 59 to 64 degrees F.

BOnEEk
SILTY CLAY LOAM

Soil Mapping Unit "Bo"
Lab/BKS Sample ID: G08020805-007_011

Typical Pedon: Boneek silty clay loam - on a northeast-facing plane slope of 4 percent under native grass at 3500 feet elevation. (Colors are for dry soil unless otherwise stated.)

The Boneek series consists of deep and very deep, well drained soils formed in silty sediments underlain by sandstone or siltstone. Permeability is moderately slow in the solum and moderate in the underlying material. Slopes range from 0 to 15 percent. Mean annual precipitation is about 17 inches, and mean annual temperature is about 46 degrees F.

A - 0-6 inches. Dark yellowish brown (10YR 4/4D) silty clay loam, moist; moderate thin platy structure parting to weak fine granular; slightly hard, very friable; many fine roots; clear wavy boundary; neutral (pH 7.1); noneffervescent.

Btk - 6-17 inches. Brown (10YR 5/3D) silty clay loam, moist; moderate medium prismatic structure parting to moderate medium and fine subangular blocky; very hard, friable, slightly sticky and slightly plastic; common fine roots; shiny films on faces of peds; clear wavy boundary; moderately alkaline (pH 8.1); noneffervescent.

C1k – 17-33 inches. Light yellowish brown (10YR 6/2D) silty clay loam, moist; weak medium and coarse subangular blocky structure; very hard, friable, slightly sticky and slightly plastic; few fine roots; common fine and medium accumulations of carbonate; gradual wavy boundary; strongly alkaline (pH 8.5); strongly effervescent.

C2k – 33-42 inches. Grayish brown (10YR 5/2D) silty clay loam, moist; few fine and medium prominent mottles of strong brown (7.5YR 5/8) moist; weak coarse subangular blocky structure; very hard, friable; few fine roots; clear wavy boundary; moderately alkaline (pH 8.0); strongly effervescent.

C3k – 42-60 inches. Light olive brown (2.5Y 5/3D) silty clay loam, moist; thin platy rock structure; faces of fractures stained strong brown (7.5YR 5/6) moist; few coatings of carbonates on faces of fractures, but matrix is noncalcareous; moderately alkaline (pH 8.1); strongly effervescent.

Type Location - Butte County, South Dakota; refer to waypoint 64 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to bedrock is 40 to 60 inches or more. Depth to carbonates ranges from 11 to 24 inches. Thickness of the mollic epipedon ranges from 7 to 15 inches and extends into the Bt horizon of some pedons.

The A horizon has hue of 10YR or 7.5YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It typically is silt loam, but some pedons are loam. It is slightly acid or neutral.

The Bt1 horizon has hue of 7.5YR or 5YR, value of 4 or 6 and 3 or 4 moist, and chroma of 2 to 4. It is silty clay loam or silty clay. Average clay content ranges from 35 to 45 percent with less than

15 percent fine sand or coarser. It is slightly acid or neutral.

The Bt2 horizon has hue of 10YR or 7.5Y, value of 5 or 6 and 3 or 5 moist, and chroma of 2 to 4. It is silty clay loam averaging between 30 and 40 percent clay and less than 15 percent fine sand or coarser. It is neutral or slightly alkaline.

The Bk and C horizons have hue of 10YR or 2.5Y, value of 5 through 7 and 4 or 5 moist, and chroma of 1 to 3. They typically are silt loam or silty clay loam, but some pedons are loam. They are slightly alkaline to strongly alkaline. Few to many, fine or medium accumulations of carbonate are in the Bk horizon.

The Cr horizon has hue of 10YR or 7.5YR.

Range in Characteristics (according to field observations, lab analysis): No significant range in characteristics was found.

Taxonomic Class - Fine, smectitic, mesic Aridic Argiustolls

Suitability for Topsoil (According to WDEQ Guideline 1) - Electrical conductivity was marginal at 33-42 inches. pH was marginal (Alkaline) at 17-33 inches. Selenium was marginal at 33-42 inches. Strongly effervescent at 17 inches. Estimated stripping depth is 17 inches.

Geographic Setting (According to Official Series Description) - Boneek soils are nearly level to moderately sloping on high terraces and uplands. Surfaces are plane to slightly convex and slope gradients range from 0 to 15 percent. The soils formed in a silty mantle overlying sandstone or siltstones, or in loess or silty alluvium. Mean annual temperature ranges from 43 to 48 degrees, and mean annual precipitation ranges from 15 to 18 inches. Most of the precipitation comes in the spring and summer.

ARVADA
SILTY CLAY LOAM

Soil Mapping Unit "Ar"
Lab/BKS Sample ID: G08020805-012_016

Typical Pedon: Arvada silty clay loam - rangeland. (Colors are for dry soil unless otherwise stated.)

The Arvada series consists of very deep, well drained soils formed in alluvium and colluvium derived from sodic shale. Arvada soils are on alluvial fans, fan remnants, fan terraces and hillslopes. Slopes are 0 to 25 percent. The mean annual precipitation is about 12 inches, and the mean annual air temperature is about 46 degrees F.

A - 0-3 inches. Light gray (10YR 7/2) silty clay loam, moist; moderate very thin platy structure parting to moderate very fine granular; soft, very friable, nonsticky and nonplastic; many fine and very fine roots; abrupt smooth boundary; slightly acid (pH 6.3); noneffervescent.

Bt - 3-18 inches. Dark grayish brown (2.5Y 4/2DW) clay loam, moist; moderate medium columnar structure parting to moderate medium angular blocky; extremely hard, firm, sticky and very plastic; common medium roots; many prominent clay films on faces of peds and in root channels; ESP is 20 percent; clear smooth boundary; slightly alkaline (pH 7.6); noneffervescent.

Btn– 18-28 inches. Dark grayish brown (2.5Y 4/2D, 2.5Y 5/2W) silty clay, moist; massive; hard, friable, sticky and plastic; common medium soft masses of calcium carbonate and gypsum as crystals in thin seams and as filaments or threads; 20 percent exchangeable sodium; moderately alkaline (pH 7.9); very slightly effervescent.

C1n – 28-43 inches. Grayish brown (2.5Y 5/2D, 2.5Y 4/2W) silt loam, moist; massive; hard, friable, sticky and plastic; common medium soft masses of calcium carbonate and gypsum as crystals in thin seams and as filaments or threads; 20 percent exchangeable sodium; moderately alkaline (pH 8.2); very slightly effervescent.

C2nsa – 43-60 inches. Very dark grayish brown (10 YR 3/2DW) silt loam, moist; massive; hard, friable, sticky and plastic; common medium soft masses of calcium carbonate and gypsum as crystals in thin seams and as filaments or threads; 20 percent exchangeable sodium; moderately alkaline (pH 8.3); slightly effervescent.

Type Location - Sheridan County, Wyoming; refer to waypoint 72 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to effervescent material ranges from 0 to 19 inches. Depth to layers with greater than 15 percent exchangeable sodium is 4 to 10 inches. The depth to the base of the Bt horizon is 15 inches or more. A thin A horizon occurs in some pedons. A light colored platy E horizon is generally present but is absent in some pedons. Gravel is typically less than 5 percent but ranges from 0 to 15 percent. The moisture control section is usually dry for 60 consecutive days during the 90 day period following the summer solstice. The mean annual soil temperature is 47 to 53 degrees F., and the soil temperature at a depth of 20 inches is 41 degrees F. or more for 175 to 195 days. The soil has an aridic moisture regime that borders on ustic.

The E and A horizons have hue of 10YR, 2.5Y or 5Y, value of 4 to 7, 4 or 5 moist, and chroma of 2 to 4. Texture is fine sandy loam, loam, silt loam, clay loam or very fine sandy loam. Reaction ranges from neutral through strongly alkaline. EC ranges from 0 to 4 mmhos/cm.

The Btn horizon has hue of 7.5YR, 10YR, 2.5Y or 5Y, value of 4 to 6 dry, 4 or 5 moist, and chroma of 2 to 4. Texture is clay, clay loam, silty clay or silty clay loam and has 35 to 60 percent clay, 10 to 50 percent silt, and 5 to 45 percent sand. This horizon is strongly alkaline or very strongly alkaline (pH 8.8 to 10.0), has 15 to 34 percent exchangeable sodium, and an EC of 4 to 16 mmhos/cm. Some pedons when buffered by gypsum are moderately alkaline. The Btkn horizon, when present, has a calcium carbonate equivalent of 3 to 12 percent and an exchangeable sodium percent of 10 to 30. A thin Bt horizon is present above the Btn in some pedons. Some pedons have a Btkny horizon.

The Bkny horizon has hue of 7.5YR, 10YR or 2.5Y, value of 5 or 6 dry, 4 or 5 moist. Textures are clay, clay loam, silty clay or silty clay loam. Reaction ranges from strongly alkaline or very strongly alkaline (pH 8.6 to 10.0). This horizon contains 4 to 15 percent calcium carbonate equivalent. Some pedons when buffered by gypsum are moderately alkaline. Exchangeable sodium typically ranges from 10 to 30 percent but decreases with increasing depth. Electrical conductivity is 4 to 16 mmhos/cm. Some pedons have a C horizon.

Some pedons have a C horizon below 40 inches. It has properties similar to those of the Bkny horizon.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Ustertic Natrargids

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 18-28 inches. Electrical conductivity was marginal at 28-60 inches. Sodium absorption ratio was marginal at 28-43 inches and was unsuitable at 43-60 inches. Selenium was marginal at 18-60 inches. Strongly effervescent at 3 inches. Estimated stripping depth is 18 inches.

Geographic Setting (According to Official Series Description) - The Arvada soils are on alluvial fans, fan remnants, terraces and hillslopes. The soils formed in moderately fine textured alluvium and colluvium derived from sedimentary rocks. Slopes range from 0 to 25 percent. Elevations range from 2,600 to 6,000 feet. The average annual precipitation is about 12 inches but ranges from 9 to 14 inches with about half the precipitation occurring during April, May, and early June. The mean annual air temperature is about 43 to 53 degrees F., and the mean summer temperature is 63 degrees F. The frost-free season is estimated to range from 100 to 160 day

LOHMILLER
LOAM

Soil Mapping Unit "Lo"
Lab/BKS Sample ID: G08020805-017_022

Typical Pedon: Lohmiller loam - on a plane slope of less than 1 percent in a cultivated field. When described the soil was moist throughout. (Colors are for dry soil unless otherwise stated.)

The Lohmiller series consists of very deep, well drained soils formed in alluvium on bottom lands. Permeability is slow or moderately slow. Slopes range from 0 to 8 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 46 degrees F.

A - 0-3 inches. Light gray (10YR 6/1) loam, moist; moderate medium granular structure; hard, friable; many fine roots; neutral; clear smooth boundary; slightly alkaline (pH 7.4); noneffervescent.

AC - 3-15 inches. Dark grayish brown (2.5Y 4/2W) silty clay, moist; weak thin platy structure parting to weak fine granular; very hard, firm; common fine roots, clear smooth boundary; moderately alkaline (pH 7.9); noneffervescent.

C1 – 15-23 inches. Dark grayish brown (2.5Y 4/2W) silty clay, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; slighty alkaline (pH 7.8); noneffervescent.

C2n – 22-34 inches. Dark grayish brown (2.5Y 4/2W) silty clay, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; moderately alkaline (pH 8.0); very slightly effervescent.

C3k – 34-38 inches. Grayish brown (2.5Y 5/2W) silty clay, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; moderately alkaline (pH 8.0); very slightly effervescent.

C4n – 38-60 inches. Dark grayish brown (2.5Y 4/2W) clay, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; moderately alkaline (pH 8.0); very slightly effervescent.

Type Location - Fall River County, South Dakota; refer to waypoint 73 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Carbonates are within 10 inches of the surface. The control section averages from 35 to 50 percent clay.

The A horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. Some pedons have value of 4 dry and 3 moist in the upper 4 inches. It typically is silty clay loam or clay loam but is silty clay in some pedons. It ranges from neutral to moderately alkaline.

The C horizon has hue of 10YR, 2.5Y, or 5Y; value of 5 to 7 and 4 to 6 moist; and chroma of 2 to 4. It typically is clay loam or silty clay loam but is silty clay or clay in some pedons. It is stratified with thin layers of loamy sand, fine sandy loam, loam, sandy clay or silt loam. It is

slightly alkaline or moderately alkaline. Some pedons have accumulations of carbonates.

Range in Characteristics (according to field observations, lab analysis): Textures have slightly more clay than typical for the series.

Taxonomic Class - Fine, smectitic, calcareous, mesic Torrertic Ustifluvents

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 3-60 inches. Saturation percentage was marginal at 15-34 inches and 38-60 inches. Sodium absorption ratio was unsuitable at 3-60 inches. Electrical conductivity was marginal at 15-23 inches and was unsuitable at 23-60 inches. Selenium was marginal at 15-60 inches. Estimated stripping depth is 3 inches.

Geographic Setting (According to Official Series Description) - Lohmiller soils are on flood plains and high bottom lands of rivers and streams and on alluvial fans of foot slopes. Slopes are typically less than 2 percent but range from 0 to 8 percent. The soils formed in calcareous alluvium from sedimentary rock. Mean annual air temperature ranges from 45 to 48 degrees F, and mean annual precipitation ranges from 10 to 19 inches.

PIERRE
SANDY CLAY LOAM

Soil Mapping Unit "Pe"
Lab/BKS Sample ID: G08020805-023_028

Typical Pedon: Pierre sandy clay loam - on a convex slope of 7 percent in native grass. (Colors are for dry soil unless otherwise stated.)

The Pierre series consists of moderately deep, well drained soils formed in clayey residuum weathered from shale bedrock on uplands. Permeability is very slow. Slopes range from 0 to 30 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 46 degrees F.

A - 0-3 inches. Grayish brown (2.5Y 5/2) sandy clay loam, moist; moderate fine subangular blocky structure parting to weak very fine granular; hard, firm, sticky and plastic; 1 percent pebbles; clear smooth boundary; slightly alkaline (pH 7.8); noneffervescent.

AC- 3-15 inches. Dark grayish brown (2.5Y 4/2W) sandy clay loam, moist; moderate medium and coarse prismatic structure; extremely hard, very firm, very sticky and very plastic; common distinct intersecting slickensides; few fine accumulations of iron; 1 percent pebbles; gradual wavy boundary; moderately alkaline (pH 8.3); strongly effervescent.

C1k – 15-27 inches. Grayish brown (2.5Y 5/2W) clay loam, moist; moderate coarse prismatic structure; extremely hard, very firm, very sticky and very plastic; common distinct intersecting slickensides; few fine nests of iron and common fine accumulations of gypsum; 1 percent pebbles; gradual wavy boundary; strongly alkaline (pH 8.5); violently effervescent.

C2n – 27-38 inches. Dark grayish brown (2.5Y 4/2W) loam, moist; common distinct strong brown (7.5YR 5/6) and yellowish brown (10YR 5/6) iron stains; many fine accumulations of gypsum and carbonate; 1 percent pebbles; gradual wavy boundary; strongly alkaline (pH 8.5); slightly effervescent.

C3k – 38-51 inches. Dark grayish brown (2.5Y 4/2W) loam, moist; common distinct strong brown (7.5YR 5/6) iron stains; 1 percent pebbles; moderately alkaline (pH 8.4); strongly effervescent.

C4n – 51-60 inches. Dark grayish brown (2.5Y 4/2W) sand loam, moist; common distinct strong brown (7.5YR 5/6) iron stains; 1 percent pebbles; moderately alkaline (pH 8.4); very slightly effervescent.

Type Location - Haakon County, South Dakota; refer to waypoint 74 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The soil contains carbonates at or within 6 inches of the surface. The depth to soft shale bedrock ranges from 20 to 40 inches but commonly is at depths of 25 to 35 inches. The horizon above the shale has 0 to 60 percent, by volume soft shale fragments. The control section is 50 to 60 percent clay. When the soil is dry, cracks 1/2 inch to 2 inches wide and several feet long extend downward through the

solum. The soil does not have a mollic epipedon, but the upper 10 inches of the solum has an average organic carbon content between 0.6 and 1.7 percent. The soil has a SAR of 1 to 7.

The A horizon has hue of 10YR to 5Y, value of 4 to 6 and 3 to 5 moist, and chroma of 1 to 3. It typically is clay but is silty clay in some pedons. It ranges from slightly acid to moderately alkaline. When the soil is dry it has a light gray (2.5Y 7/2) smooth, porous, platy surface crust ranging from 1/4 to 1 inch in thickness. Where the horizon has mollic colors, it is too thin to be a mollic epipedon. Some pedons do not have an AB horizon.

The Bss horizons have hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 1 to 3. They are extremely hard or very hard when dry and extremely firm to firm when moist. They range from neutral to moderately alkaline.

Bk and C horizons are present in some pedons.

The Cr horizon is soft shale bedrock and ranges from slightly acid to moderately alkaline. Bedding planes are evident in the partially weathered shale in some pedons. Gypsum and other salts are concentrated in very thin seams within the shale in some pedons.

Range in Characteristics (according to field observations, lab analysis): Textures are coarser and have less clay than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Aridic Leptic Haplusterts

Suitability for Topsoil (According to WDEQ Guideline 1) - pH was marginal (alkaline) at 15-38 inches. Sodium absorption ratio was unsuitable at 15-60 inches. Electrical conductivity was unsuitable at 27-60 inches. Selenium was marginal at 15-60 inches. Strongly effervescent at 3 inches. Estimated stripping depth is 15 inches.

Geographic Setting (According to Official Series Description) - Pierre soils are on nearly level to steep uplands. Slope gradient typically is 3 to 15 percent, but ranges from 0 to 30 percent. The soils formed in residuum weathered from clay shale. Gilgai microrelief is in most areas. Mean annual air temperature is 44 to 53 degrees F, and mean annual precipitation ranges from 12 to 16 inches. Growing season is 125 to 140 days; average growing season precipitation is 10 to 13 inches; and growing degree days are 2600 to 3100. Elevation is 1300 to 3600 feet.

HAVERSON
CLAY LOAM

Soil Mapping Unit "Ha"
Lab/BKS Sample ID: G08020805-029_033

Typical Pedon: Haverson clay loam - grassland. (Colors are for dry soil unless otherwise stated.)

The Haverson series consists of very deep, well drained soils that formed in alluvium from mixed sources. Haverson soils are on floodplains and low terraces and have slopes of 0 to 9 percent. The mean annual precipitation is about 15 inches and the mean annual air temperature is about 49 degrees F.

A - 0-4 inches. Brown (10YR 4/3D, 10YR 4/2W) clay loam, moist; strong fine granular structure; slightly hard, very friable; clear smooth boundary; slightly alkaline (pH 7.8); noneffervescent.

AC - 4-15 inches. Brown (10YR 4/3D, 10YR 4/2W) silty clay loam, moist; weak coarse subangular blocky structure; very hard, friable; clear smooth boundary; slightly alkaline (pH 7.7); very slightly effervescent.

C1 – 15-35 inches. Brown (10YR 4/3D, 10YR 4/2W) silty clay loam, moist; massive; hard, friable; gradual smooth boundary; slightly alkaline (pH 7.6); slightly effervescent.

C2n – 35-46 inches. Brown (10YR 4/3D, 10YR 4/2W) silty clay loam, moist; massive; slightly hard, very friable; few fine irregularly shaped masses and seams of lime; slightly alkaline (pH 7.8); slightly effervescent.

C3 – 46-60 inches. Brown (10YR 4/3D, 10YR 4/2W) silty clay loam, moist; massive; slightly hard, very friable; few fine irregularly shaped masses and seams of lime; slightly alkaline (pH 7.8); slightly effervescent.

Type Location - Weld County, Colorado; refer to waypoint 75 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Mean annual soil temperature ranges from 47 to 55 degrees F. and mean summer soil temperature ranges from 59 to 78 degrees F. Organic carbon ranges from 0.5 to 2.0 percent in the surface horizon but decreases irregularly with depth. The particle-size control section is stratified with strata ranging from sandy loam to clay loam, but averaging approximately loam. On a weighted average basis, clay ranges from 18 to 35 percent, silt from 10 to 50 percent, and sand from 20 to 60 percent with more than 15 percent but less than 35 percent being fine or coarser sand. Rock fragments are generally less that 5 percent and range from 0 to 20 percent. Some visible calcium carbonate may occur at any depth in these soils, but it is not concentrated into any consistent horizon of accumulation. This soil is not dry in all parts of the moisture control section for more than one-half the time the soil temperature is above 41 degrees F. (195 to 210 days) and is not dry for 45 consecutive days following July 15.

The A horizon has hue of 2.5Y or 10YR, value of 4 to 6 dry, 3 to 5 moist and chroma of 2 or 3. When the value of the surface horizon is as dark as 5 dry and 3 moist, the horizon is thin enough so that if mixed to 7 inches it is too light colored or contains too little organic carbon to qualify as

a mollic epipedon or are finely stratified. The A horizon usually has granular primary structure but it has subangular blocky structure in some pedons. It is soft or slightly hard. It is neutral through moderately alkaline.

The C horizon has hue of 2.5Y, 10YR or 7.5YR, value of 5 or 6 dry, 4 or 5 moist and chroma of 2 or 3. It is slightly alkaline to very strongly alkaline. It has from less-than-one to about 15 percent calcium carbonate equivalent, which differs erratically from stratum to stratum.

Range in Characteristics (according to field observations, lab analysis): Textures are finer and have more clay than typical for the series.

Taxonomic Class - Fine-loamy, mixed, superactive, calcareous, mesic Aridic Ustifluvents

Suitability for Topsoil (According to WDEQ Guideline 1) - Sodium absorption ratio was marginal at 15-35 inches and unsuitable at 35-60 inches. Estimated stripping depth is 35 inches.

Geographic Setting (According to Official Series Description) - The Haverson soils are on floodplains and low terraces of major rivers. Slope is 0 to 9 percent. The soils formed in highly stratified, calcareous, recent alluvium derived from mixed sources. At the type location the average annual precipitation is 14 to 18 inches with peak periods of precipitation occurring during the early spring and summer. The mean annual air temperature ranges from 47 to 52 degrees F. and the mean summer temperature is 77 degrees F. The frost-free season is 125 to 180 days.

DEMAR
LOAM

Soil Mapping Unit "Dg"
Lab/BKS Sample ID: G08020805-034_038

Typical Pedon: Demar loam - on a plane slope of less than 1 percent. When described the soil was moist to 5 inches and dry below. (Colors are for dry soil unless otherwise stated.)

The Demar series consists of deep or very deep, moderately well drained soils formed in clayey alluvium from acid clay shales. These soils are on terraces. They have very slow permeability. Slopes range from 0 to 6 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 47 degrees F.

A - 0-2 inches. Pale brown (10YR 6/3) loam, moist; weak thin platy structure parting to weak fine granular; slightly hard, friable, slightly sticky; many roots; abrupt wavy boundary; strongly acid (pH 5.3); noneffervescent.

Bt - 2-21 inches. Grayish brown (2.5Y 5/2D) silty clay, moist; moderate medium blocky structure; very hard, very firm, sticky and plastic; very few roots; clear smooth boundary; slightly alkaline (pH 7.7); noneffervescent.

Btn – 21-29 inches. Very dark grayish brown (2.5Y 3/2D) clay, moist; few fine prominent yellowish brown (10YR 5/6) mottles; weak coarse subangular blocky structure; very hard, very firm, sticky and plastic; very few roots; common fine nests of gypsum and other salts; gradual boundary; neutral (pH 6.9); very slightly effervescent.

C1 – 29-46 inches. Dark grayish brown (2.5Y 4/2D) silty clay loam, moist; many coarse prominent brownish yellow (10YR 6/6) mottles; weak coarse subangular blocky structure; very hard, very firm; partially weathered shale fragments make up about 40 percent by volume; common bands of crystals of gypsum; gradual boundary; slightly alkaline (pH 7.6); very slightly effervescent.

C2 – 46-60 inches. Grayish brown (2.5Y 5/2D) silty clay loam, moist; many coarse prominent brownish yellow (10YR 6/6) and yellowish brown (10YR 5/6) iron stains along fractures; neutral (pH 7.3); very slightly effervescent.

Type Location - Butte County, South Dakota; refer to waypoint 76 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The depth to bedded shale ranges from 40 to 60 inches or more. These soils range from neutral to strongly acid in the upper 12 inches and from very strongly acid to extremely acid below this depth.

The E horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 or 3. It typically is loam but is clay loam in some pedons.

The Bt horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 or 3. The clay content of the Bt horizon is between 35 and 60 percent. Structure of the Bt horizon ranges from weak or moderate, medium or coarse columnar in the Bt1 horizon and moderate or

strong, medium or coarse blocky in the Bt2 horizon.

The Bz horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 to 5 moist, and chroma of 2 to 3. It has common or many accumulations of gypsum and other salts.

The C horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 or 3. It contains 20 to 50 percent fragments of shale.

Range in Characteristics (according to field observations, lab analysis): No significant range in characteristics was found.

Taxonomic Class - Fine, smectitic, mesic Torrertic Haplustalfs

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 2-29 inches. Sodium absorption ratio was marginal at 2-29 inches and unsuitable at 29-60 inches. Selenium was marginal at 46-60 inches. Estimated stripping depth is 2 inches.

Geographic Setting (According to Official Series Description) - Demar soils are on micro-highs on nearly level to gently sloping alluvial terraces having pronounced micro-relief. Slope gradients range from 0 to 6 percent. These soils formed in clayey alluvium derived from acid clay shales. The mean annual air temperature ranges from 45 to 49 degrees F, and mean annual precipitation ranges from 12 to 18 inches.

PENROSE
CLAY LOAM

Soil Mapping Unit "Pg"
Lab/BKS Sample ID: G08020805-039_042

Typical Pedon: Penrose clay loam-grassland. (Colors are for dry soil unless otherwise stated.)

The Penrose series consists of shallow, well and somewhat excessively drained, moderate to slowly permeable soils formed in thin, calcareous, loamy materials weathered in place from limestone and interbedded limy materials. Penrose soils are on hills, plains, ridges, hogbacks, cuestas, and mesa tops. Slopes are 1 to 65 percent. Mean annual precipitation is about 13 inches and mean annual temperature is about 51 degrees F.

A - 0-4 inches. Light brownish gray (2.5Y 6/2) clay loam, moist; moderate fine granular structure; soft, very friable, slightly sticky and slightly plastic; 25 percent channers; calcareous; clear smooth boundary; slightly alkaline (pH 7.6); slightly effervescent.

C1k - 4-17 inches. Dark grayish brown (10YR 4/2D) clay loam, moist; massive; slightly hard, very friable, slightly sticky and slightly plastic; 20 percent limestone channels; calcareous; abrupt smooth boundary; slightly alkaline (pH 7.7); strongly effervescent.

C2k – 17-36 inches. Grayish brown (10YR 5/2D) silt loam, limestone bedrock; moderately alkaline (pH 8.0); very slightly effervescent.

Cr – 36-48 inches. Grayish brown (10YR 5/2D) silt loam, limestone bedrock; slightly alkaline (pH 7.8); very slightly effervescent.

Type Location - Fremont County, Colorado; refer to waypoint 77 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) –

Soil moisture: The soil moisture control section is moist intermittently April through August; aridic moisture regime bordering on ustic.
Mean annual soil temperature: 52 to 59 degrees F.
Mean summer soil temperature: 68 to 76 degrees F.
Depth to lithic contact: 10 to 20 inches to limestone
Depth to secondary calcium carbonate: 0 to about 5 inches and is not more than 1/4 the thickness of the control section
Gypsum content: 0 to 1.5 percent by weight
Calcium carbonate equivalent: 40 to 75 percent
Electrical conductivity: 0 to 14 millimhos/cm in a major part of the control section
Continuous subhorizons of secondary calcium carbonate and/or sulfate do not occur within the control section although some visible accumulation occurs in some pedons

Particle-size control section (weighted average):
Clay content: 18 to 35 percent
Sand content: 15 to 70 percent
Rock fragments: 0 to 35 percent, dominantly to 10 inches in diameter.

A horizon:
Hue: 7.5YR through 2.5Y
Value: 5 through 8, 3 through 6 moist
Chroma: 1 through 4.
Calcium carbonate equivalent: 35 to 70 percent
Reaction: mildly alkaline or moderately alkaline.
Rock fragments: 0 to 35 percent

C horizon:
Hue: 7.5YR through 2.5Y
Textures of the fine earth fraction: loam, silt loam, clay loam
Clay content: 18 to 35 percent
Rock fragments: 0 to 35
Calcium carbonate equivalent: 40 to 75 percent
Reaction: moderately alkaline or strongly alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Loamy, carbonatic, mesic Lithic Ustic Torriorthents

Suitability for Topsoil (According to WDEQ Guideline 1) – Boron was unsuitable at 36-48 inches. Strongly effervescent at 4 inches. Estimated stripping depth is 36 inches.

Geographic Setting (According to Official Series Description) –
Parent material: residuum and slope alluvium derived from limestone and interbedded limy materials.
Landform: hills, mesas, and ridges
Slopes: 1 to 65 percent
Elevation: 3,000 to 6,500 feet
Mean annual temperature: 50 to 53 degrees F
Mean annual precipitation: 11 to 15 inches
Precipitation pattern: peak periods between April and August, dries between November and February
Frost-free period: 125 to 165 days.

DEMAR
SILTY CLAY LOAM

Soil Mapping Unit "Dg"
Lab/BKS Sample ID: G08020805-043_047

Typical Pedon: Demar silty clay loam - on a plane slope of less than 1 percent. When described the soil was moist to 5 inches and dry below. (Colors are for dry soil unless otherwise stated.)

The Demar series consists of deep or very deep, moderately well drained soils formed in clayey alluvium from acid clay shales. These soils are on terraces. They have very slow permeability. Slopes range from 0 to 6 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 47 degrees F.

A - 0-3 inches. Pale brown (10YR 6/3) silty clay loam, moist; weak thin platy structure parting to weak fine granular; slightly hard, friable, slightly sticky; many roots; abrupt wavy boundary; slightly acid (pH 6.1); noneffervescent.

Bt - 3-17 inches. Very dark grayish brown (10YR 3/2D) silty clay, moist; moderate medium blocky structure; very hard, very firm, sticky and plastic; very few roots; clear smooth boundary; extremely acid (pH 4.1); noneffervescent.

C1 – 17-30 inches. Dark grayish brown (10YR 4/2D) clay, moist; few fine prominent yellowish brown (10YR 5/6) mottles; weak coarse subangular blocky structure; very hard, very firm, sticky and plastic; very few roots; common fine nests of gypsum and other salts; gradual boundary; extremely acid (pH 3.6); noneffervescent.

C2 – 30-42 inches. Dark grayish brown (10YR 4/2D) clay, moist; many coarse prominent brownish yellow (10YR 6/6) mottles; weak coarse subangular blocky structure; very hard, very firm; partially weathered shale fragments make up about 40 percent by volume; common bands of crystals of gypsum; gradual boundary; extremely acid (pH 3.7); noneffervescent.

Cr – 42-60 inches. Dark grayish brown (10YR 4/2D) clay, moist; many coarse prominent brownish yellow (10YR 6/6) and yellowish brown (10YR 5/6) iron stains along fractures; extremely acid (pH 3.6); noneffervescent.

Type Location - Butte County, South Dakota; refer to waypoint 79 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The depth to bedded shale ranges from 40 to 60 inches or more. These soils range from neutral to strongly acid in the upper 12 inches and from very strongly acid to extremely acid below this depth.

The E horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 or 3. It typically is loam but is clay loam in some pedons.

The Bt horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 or 3. The clay content of the Bt horizon is between 35 and 60 percent. Structure of the Bt horizon ranges from weak or moderate, medium or coarse columnar in the Bt1 horizon and moderate or strong, medium or coarse blocky in the Bt2 horizon.

The Bz horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 to 5 moist, and chroma of 2 to 3. It has common or many accumulations of gypsum and other salts.

The C horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 or 3. It contains 20 to 50 percent fragments of shale.

Range in Characteristics (according to field observations, lab analysis): No significant range in characteristics was found.

Taxonomic Class - Fine, smectitic, mesic Torrertic Haplustalfs

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 3-60 inches. pH was unsuitable (acidic) at 3-60 inches. Estimated stripping depth is 3 inches.

Geographic Setting (According to Official Series Description) - Demar soils are on micro-highs on nearly level to gently sloping alluvial terraces having pronounced micro-relief. Slope gradients range from 0 to 6 percent. These soils formed in clayey alluvium derived from acid clay shales. The mean annual air temperature ranges form 45 to 49 degrees F, and mean annual precipitation ranges from 12 to 18 inches.

SATANTA
LOAM

Soil Mapping Unit "Sc"
Lab/BKS Sample ID: G08020806-001_005

Typical Pedon: Satanta loam - in a cultivated field. (Colors are for dry soil unless otherwise stated.)

The Satanta series consists of very deep well drained soils that formed in eolian deposits. These soils are on plains or high stream terraces in the Central High Tablelands (MLRA 72). Slopes range from 0 to 15 percent. Mean annual temperature is 13 degrees C. (56 degrees F.) and mean annual precipitation is 48 centimeters (19 inches) at the type location.

A - 0-4 inches. Dark grayish brown (10YR 4/2) loam, moist; weak fine granular and weak medium platy structure; friable, slightly hard; many fine and medium roots throughout; clear smooth boundary; strongly acid (pH 5.3); noneffervescent.

Bt - 4-12 inches. Dark yellowish brown (10YR 3/4D) clay loam, moist; weak medium platy structure; friable, slightly hard; many fine and medium roots throughout; abrupt smooth boundary; neutral (pH 7.1); noneffervescent.

BC – 12-17 inches. Brown (10YR 4/3D) sandy clay loam, moist; moderate medium subangular blocky and weak medium platy structure; friable, slightly hard; common fine roots throughout; 10 percent continuous distinct clay films on faces of peds; gradual smooth boundary; slightly alkaline (pH 7.6); strongly effervescent.

C1k – 17-28 inches. Brown (10YR 5/3D) sandy clay loam, moist; moderate medium subangular blocky and moderate medium prismatic structure; friable, hard; common fine roots throughout; common fine moderate continuity tubular pores; 10 percent continuous distinct clay films on faces of peds; gradual smooth boundary; moderately alkaline (pH 7.9); strongly effervescent.

C2k – 28-43 inches. Grayish brown (10YR 5/2D) sandy clay loam, moist; moderate medium prismatic and moderate medium subangular blocky structure; friable, hard; common fine roots throughout; common fine and medium moderate continuity tubular pores; 10 percent continuous distinct clay films on faces of peds; clear smooth boundary; moderately alkaline (pH 7.9); strongly effervescent.

Type Location - Haskell County, Kansas; refer to waypoint 82 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) –

Calcium carbonate equivalent in the series control section: less than 15 percent
Coarse fragments: 0 to 10 percent gravel by volume
Depth to carbonates: 30 to 91 centimeters (12 to 36 inches)
Mollic epipedon thickness: 20 to 51 centimeters (8 to 20 inches)
Phases recognized: Sandy substratum, gravelly substratum, dry, elevation greater than 1219 meters (4,000 feet)

A horizon:
Hue: 10YR
Value: 4 to 5, 2 to 3 moist
Chroma: 2 to 3
Reaction: slightly acid to slightly alkaline
Texture: loam, very fine sandy loam, clay loam, fine sandy loam
Comments: Some pedons have a BA horizon that is intermediate in color and texture between the A and Bt horizons.

Bt horizon:
Hue: 7.5YR to 2.5Y
Value: 4 to 6, 3 to 5 moist
Chroma: 2 to 4
Reaction: neutral to moderately alkaline
Texture: loam, sandy clay loam, clay loam with 15 to 35 percent fine and coarser sand and less than 50 percent sand

Bk or 2Bkb horizons:
Hue: 7.5YR to 2.5Y
Value: 4 to 6, 3 to 5 moist
Chroma: 2 to 6
Reaction: slightly to strongly alkaline
Texture: loam, sandy clay loam, clay loam with 15 to 35 percent fine and coarser sand and less than 50 percent sand

C or 3Ck horizons:
Hue: 10YR, 2.5Y
Value: 5 to 7, 4 to 6 moist
Chroma: 2 to 6
Reaction: slightly or moderately alkaline
Texture: loam, silt loam, clay loam, sandy clay loam, very fine sandy loam, loamy fine sand, fine sandy loam
Comments: Some pedons have a BCk horizon that has few carbonates that occur as seams, threads or concretions.

Range in Characteristics (according to field observations, lab analysis): Textures are coarser than typical for the series.

Taxonomic Class - Fine-loamy, mixed, superactive, mesic Aridic Argiustolls

Suitability for Topsoil (According to WDEQ Guideline 1) - pH was marginal (acidic) at 0-4 inches. Strongly effervescent at 12 inches. Estimated stripping depth is 43 inches.

Geographic Setting (According to Official Series Description) –
Landscape: terraces on nearly level to undulating plains
Landform: plains, high stream terraces
Slopes: 0 to 15 percent
Elevation: 610 to 1372 meters (2000 to 4500 feet)

Parent material: eolian deposits
Mean annual air temperature: 7 to 14 degrees C. (45 to 57 degrees F.)
Mean annual precipitation: 35 to 56 centimeters (14 to 22 inches)
Frost-free period: 140 to 200 days
Thornthwaite Annual PE Index: 25 to 40

SNOMO
SILTY CLAY LOAM

Soil Mapping Unit "Gs"
Lab/BKS Sample ID: G08020806-006_011

Typical Pedon: Snomo silty clay loam- on an 8 percent north-facing slope in scattered trees with native grass understory. (Colors are for dry soil unless otherwise stated.)

The Snomo series consists of deep or very deep, well drained soils formed in clayey materials weathered from acid shale on the uplands. These soils have moderate permeability. Slopes range from 2 to 20 percent. Mean annual precipitation is about 17 inches and mean annual air temperature is about 45 degrees F.

A - 0-3 inches. Light gray (10YR 6/1) silty clay loam, moist; weak thick platy structure parting to weak fine granular; hard, friable, slightly sticky and slightly plastic; many fine and medium roots; clear smooth boundary; very strongly acid (pH 4.8); noneffervescent.

Bt1 - 3-17 inches. Grayish brown (10YR 5/2D) silty clay, moist, rubbed dark grayish brown (10YR 4/2) moist; weak coarse prismatic structure parting to weak medium and fine subangular blocky; very hard, friable, sticky and plastic; common fine roots; clear smooth boundary; very strongly acid (pH 4.8); noneffervescent.

BtC – 17-33 inches. Dark grayish brown (10YR 4/2D) silty clay, moist; weak coarse prismatic structure parting to weak medium subangular blocky; hard, friable, sticky and plastic; few fine roots; few fine fragments of shale; clear wavy boundary; moderately acid (pH 5.7); noneffervescent.

C1n – 33-42 inches. Grayish brown (10YR 5/2D) silt loam, moist; few fine distinct mottles of yellow (2.5Y 8/6) massive; slightly hard, friable, sticky and plastic; few fine roots; many fine fragments of shale, abrupt wavy boundary; slightly acid (pH 7.6); noneffervescent.

C2n – 42-52 inches. Brown (10YR 5/3D) silt loam, moist; massive; slightly hard, friable, sticky and plastic; many coarse fragments of brittle shale; extremely acid; clear wavy boundary; moderately acid (pH 7.9); noneffervescent.

C3n – 52-60 inches. Pale brown (10YR 6/3D) silt loam, moist; yellow (5Y 8/6) and yellowish red (5YR 5/8) coatings on fracture faces of shale; moderately acid (pH 7.9); noneffervescent.

Type Location - Butte County, South Dakota; refer to waypoint 83 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Bedded shale typically is between a depth of 40 and 60 inches but is below 60 inches in some pedons. Colors throughout the soil are inherent to the shale.

The A horizon has hue of 10YR, value of 5 to 7 and 3 or 4 moist, and chroma of 1 or 2. It is silty clay or clay and contains 0 to 15 percent by volume of fine fragments of shale less than 3 mm in size. It is extremely acid to slightly acid. Some pedons have a thin distinct E horizon as evidenced by prominent clean silt and sand grains.

The Bw horizon has hue of 10YR, 2.5Y, and 7.5YR, value of 5 or 6 and 3 or 4 moist, and chroma of 2 to 4. Moist value typically is one unit higher when rubbed. It has 0 to 20 percent by volume of fine fragments of shale less than 3 mm in size. It is strongly acid to extremely acid.

The BC and C horizons have hue of 10YR or 2.5Y, value of 5 or 6 and 3 to 5 moist, and chroma of 1 to 3. Moist value typically is one unit higher when rubbed. They have 15 to 50 percent by volume of fine to coarse fragments of shale ranging from 1 to 25 mm in size. They are very strongly acid or extremely acid.

The Cr horizon is multicolored in hue of 10YR, 2.5Y, or 5Y; and is very hard and brittle but has a hardness of less than 3 on the Moh's scale of hardness. It is very strongly acid or extremely acid.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer and have less clay than typical for the series.

Taxonomic Class - Very-fine, smectitic, mesic Torrertic Dystrustepts

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 3-33 inches. pH was unsuitable (acidic) at 0-17 inches. Saturation percentage was marginal at 45-52 inches. Boron was unsuitable at 33-60 inches. Estimated stripping depth is 0 inches.

Geographic Setting (According to Official Series Description) - Snomo soils are on gently sloping to moderately steep uplands. Slope gradients range from 2 to 20 percent. The soil formed in clayey materials weathered from acid shale. Mean annual temperature ranges from 43 to 48 degrees F, and precipitation from 14 to 18 inches.

LOHMILLER
SILTY CLAY LOAM

Soil Mapping Unit "Lo"
Lab/BKS Sample ID: G08020806-012_016

Typical Pedon: Lohmiller silty clay loam- on a plane slope of less than 1 percent in a cultivated field. (Colors are for dry soil unless otherwise stated.)

The Lohmiller series consists of very deep, well drained soils formed in alluvium on bottom lands. Permeability is slow or moderately slow. Slopes range from 0 to 8 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 46 degrees F.

A - 0-5 inches. Light gray (10YR 6/1) silty clay loam, moist; moderate medium granular structure; hard, friable; many fine roots; neutral; clear smooth boundary; slightly alkaline (pH 7.4); noneffervescent.

C1n - 5-18 inches. Very dark grayish brown (10YR 3/2D) silty clay loam, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; moderately alkaline (pH 8.2); noneffervescent.

C2n – 18-37 inches. Brown (10YR 4/3D) silty clay, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; moderately alkaline (pH 8.4); noneffervescent.

C3n – 37-47 inches. Brown (10YR 5/3D) silty clay loam, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; moderately alkaline (pH 8.3); very slightly effervescent.

C4n – 47-60 inches. Dark grayish brown (10YR 4/2D) clay loam, moist; massive; very hard, firm; thin bedding planes evident; common very fine roots; moderately alkaline (pH 8.1); very slightly effervescent.

Type Location - Fall River County, South Dakota; refer to waypoint 84 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Carbonates are within 10 inches of the surface. The control section averages from 35 to 50 percent clay.

The A horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. Some pedons have value of 4 dry and 3 moist in the upper 4 inches. It typically is silty clay loam or clay loam but is silty clay in some pedons. It ranges from neutral to moderately alkaline.

The C horizon has hue of 10YR, 2.5Y, or 5Y; value of 5 to 7 and 4 to 6 moist; and chroma of 2 to 4. It typically is clay loam or silty clay loam but is silty clay or clay in some pedons. It is stratified with thin layers of loamy sand, fine sandy loam, loam, sandy clay or silt loam. It is slightly alkaline or moderately alkaline. Some pedons have accumulations of carbonates.

Range in Characteristics (according to field observations, lab analysis): No significant range in characteristics was found.

Taxonomic Class - Fine, smectitic, calcareous, mesic Torrertic Ustifluvents

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 18-37 inches. Saturation percentage was marginal at 0-18 inches. Sodium absorption ratio was marginal at 5-18 inches and 37-47 inches and was unsuitable at 18-37 inches. Electrical conductivity was marginal at 5-18 inches and 37-60 inches and was unsuitable at 18-37 inches. Estimated stripping depth is 5 inches.

Geographic Setting (According to Official Series Description) - Lohmiller soils are on flood plains and high bottom lands of rivers and streams and on alluvial fans of foot slopes. Slopes are typically less than 2 percent but range from 0 to 8 percent. The soils formed in calcareous alluvium from sedimentary rock. Mean annual air temperature ranges from 45 to 48 degrees F, and mean annual precipitation ranges from 10 to 19 inches.

KYLE
LOAM

Soil Mapping Unit "Ky"
Lab/BKS Sample ID: G08020806-017_020

Typical Pedon: Kyle loam- on a west-facing plane slope of 2 percent in native grass. (Colors are for dry soil unless otherwise stated.)

The Kyle series consists of very deep and well drained soils formed in sediments weathered from clay shale on uplands. Permeability is very slow. Slopes range from 0 to 15 percent. Mean annual precipitation is about 16 inches, and mean annual air temperature is about 47 degrees F.

A - 0-2 inches. Grayish brown (2.5YR 5/2) loam, moist; moderate medium and fine granular structure; hard, firm, sticky and plastic; thin crust in upper 1/4 inch of light brownish gray (2.5Y 6/2); common fine roots; neutral; clear wavy boundary; slightly acid (pH 6.3); noneffervescent.

Bt1 - 2-7 inches. Very dark grayish brown (10YR 3/2D) silty clay loam, moist; weak coarse blocky structure parting to weak medium and fine blocky; very hard, very firm, sticky and plastic; common fine roots; gradual wavy boundary; neutral (pH 7.3); noneffervescent.

Bt2 – 7-17 inches. Brown (10YR 4/3D)silty clay loam, moist; weak coarse subangular blocky structure parting to weak medium and fine blocky; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; few fine roots; clear wavy boundary; moderately alkaline (pH 7.9); strongly effervescent.

Ck – 17-30 inches. Brown (10YR 4/3D) clay loam, moist; weak coarse subangular blocky structure parting to weak medium and fine blocky; extremely hard, very firm, very sticky and very plastic; few intersecting slickensides; few fine roots; clear wavy boundary; moderately alkaline (pH 8.0); strongly effervescent.

Type Location - Fall River County, South Dakota; refer to waypoint 85 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The soil typically does not have carbonates to depths of 4 to 6 inches, but some pedons contain carbonates to the surface. When the soil is dry, cracks 1/2 inch to 2 inches wide and several feet long extend downward through the solum. The control section averages 60 to 65 percent clay. The soil does not have a mollic epipedon but the upper 10 inches of the solum has an average organic carbon content between 0.6 and 1.7 percent. When the soil is dry, a porous surface crust 1/8 inch to 1/2 inch thick with dry color value of 6 or 7 is typical. Gypsum and other salts are below depths of 20 inches.

The A horizon has hue of 10YR, 2.5Y or 5Y, value of 5 or 6 and 3 to 5 moist, and chroma of 1 to 3. It typically is clay but some is silty clay. It is neutral or slightly alkaline.

The Bw and Bss horizons have hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. Both dry and moist colors of the surface of peds range from 1/2 to 1 value darker than

the crushed peds. They are extremely hard or very hard when dry and extremely firm or very firm when moist. They are slightly alkaline or moderately alkaline.

The BCss horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. It has few to common accumulations of gypsum and other salts in most pedons. It is slightly alkaline or moderately alkaline.

Some pedons have a Bk horizon that has colors similar to the BC horizon. It has few to common accumulations of carbonate. It is slightly alkaline or moderately alkaline.

The Cy horizon has hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 2 to 4. It is clay and some pedons contain up to 35 percent fragments of shale below 40 inches. It has few to many accumulations of gypsum or other salts. Unweathered shale typically is at depths greater than 5 feet but is as shallow as 40 inches in some pedons. It is slightly alkaline or moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer and have less clay than typical for the series.

Taxonomic Class - Very-fine, smectitic, mesic Aridic Haplusterts

Suitability for Topsoil (According to WDEQ Guideline 1) - Saturation percentage was marginal at 2-7 inches. Strongly effervescent at 7 inches. Estimated stripping depth is 30 inches.

Geographic Setting (According to Official Series Description) - Kyle soils are nearly level to strongly sloping on uplands and colluvial fans. Slopes are plane to convex, and slope gradients range from 0 to 15 percent. Gilgai microrelief is in most areas. The soil formed in clayey sediments weathered from calcareous clay shale. Mean annual air temperature ranges from 45 to 53 degrees F, and mean annual precipitation ranges from about 12 to 19 inches.

SAMSIL
NON CALCAREOUS VARIANT

Soil Mapping Unit "Sa"
Lab/BKS Sample ID: G08020806-021_023

Typical Pedon: Samsil clay loam- on a convex, southwest-facing slope of 15 percent in native grass. When described the soil was moist to 12 inches, dry from 12 to 21 inches, and moist below 21 inches. (Colors are for dry soil unless otherwise stated.)

The Samsil series consists of shallow, well drained soils formed in alluvium or residuum weathered from shale. Permeability is slow. Slope ranges from 2 to 60 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 47 degrees F.

A - 0-2 inches. Light brownish gray (2.5Y 6/2) clay loam, moist; moderate fine granular structure; slightly hard, friable, sticky and plastic; common fine roots; few very fine fragments of shale; clear wavy boundary; neutral (pH 6.7); noneffervescent.

AC - 2-9 inches. Light yellowish brown (2.5Y 6/3D) silty clay, moist; weak medium subangular blocky structure parting to weak medium granular; hard, friable, sticky and plastic; common fine roots; common fine fragments of soft shale; clear wavy boundary; slightly alkaline (pH 7.8); noneffervescent.

C - 9-18 inches. Grayish brown (2.5Y 5/2D) silt, moist; massive; hard, friable, sticky and plastic; common fine roots; about 50 percent by volume of fragments of soft shale; common distinct olive yellow (2.5Y 6/6) stains on faces of shale fragments; few fine and medium accumulations of carbonate; gradual wavy boundary; slightly alkaline (pH 7.6); noneffervescent.

Type Location - Pennington County, South Dakota; refer to waypoint 88 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The control section is clay and contains 50 to 65 percent clay. The depth to bedded shale ranges from 6 to 20 inches. Horizons above the shale range from loose to hard when dry, and friable or firm when moist. These horizons contain free carbonates. Effervescence ranges from slight to strong and reaction is slightly alkaline or moderately alkaline. The C1 and C2 horizons and upper part of the Cr horizons commonly have accumulations of carbonate, gypsum, and other salts. Colors throughout, including mottles and stains, are inherited from the shale.

The A horizon has hue of 5Y, 2.5Y, or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 2 to 4. It is clay, silty clay, silty clay loam or clay loam and commonly contains few to common fragments of shale ranging from 2 to 25 mm in diameter. It has fine or medium subangular blocky or fine or very fine granular structure. The upper 1/4 to 1/2 inch commonly is a fragile crust or mulch or very fine granules when dry.

The AC horizon has hue of 5Y, 2.5Y, or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 4. It contains up to 35 percent fragments of shales by volume that range from less than 2 mm to 30 mm in diameter.

The C horizon has hue of 5Y, 2.5Y or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 4. It is clay. The C horizon contains from 35 to more than 50 percent fragments of shale by volume that range from less than 2 mm to 35 mm in diameter.

The Cr horizon has the same range in color as the overlying C horizons. It ranges from medium acid to moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer and have less clay than typical for the series.

Taxonomic Class - Clayey, smectitic, calcareous, mesic, shallow Aridic Ustorthents

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 2-9 inches. Estimated stripping depth is 18 inches.

Geographic Setting (According to Official Series Description) - Samsil soils are on gently sloping to very steep hills, ridges and breaks of dissected shale plains. Surfaces mainly are convex, and slope gradients range from 2 to 60 percent or more. The soil formed in alluvium or residuum weathered from shale. Mean annual air temperature ranges from 45 to 48 degrees F, and mean annual precipitation ranges from 14 to 19 inches.

PIERRE
SILTY CLAY LOAM

Soil Mapping Unit "Pe"
Lab/BKS Sample ID: G08020806-024_027

Typical Pedon: Pierre silty clay loam - on a convex slope of 7 percent in native grass. (Colors are for dry soil unless otherwise stated.)

The Pierre series consists of moderately deep, well drained soils formed in clayey residuum weathered from shale bedrock on uplands. Permeability is very slow. Slopes range from 0 to 30 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 46 degrees F.

A - 0-2 inches. Grayish brown (2.5Y 5/2) silty clay loam, moist; moderate fine subangular blocky structure parting to weak very fine granular; hard, firm, sticky and plastic; 1 percent pebbles; clear smooth boundary; strongly acid (pH 5.4); noneffervescent.

Bt- 2-18 inches. Brown (10YR 5/3) silty clay, moist; moderate medium and coarse prismatic structure; extremely hard, very firm, very sticky and very plastic; common distinct intersecting slickensides; few fine accumulations of iron; 1 percent pebbles; gradual wavy boundary; slightly alkaline (pH 7.7); strongly effervescent.

C1n – 18-31 inches. Grayish brown (10YR 5/2) silty clay, moist; moderate coarse prismatic structure; extremely hard, very firm, very sticky and very plastic; common distinct intersecting slickensides; few fine nests of iron and common fine accumulations of gypsum; 1 percent pebbles; gradual wavy boundary; slightly alkaline (pH 7.8); strongly effervescent.

C2n – 31-37 inches. Light brownish gray (2.5Y 6/2) silty clay, moist; common distinct strong brown (7.5YR 5/6) and yellowish brown (10YR 5/6) iron stains; many fine accumulations of gypsum and carbonate; 1 percent pebbles; gradual wavy boundary; slightly alkaline (pH 7.7); very slightly effervescent.

Type Location - Haakon County, South Dakota; refer to waypoint 89 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The soil contains carbonates at or within 6 inches of the surface. The depth to soft shale bedrock ranges from 20 to 40 inches but commonly is at depths of 25 to 35 inches. The horizon above the shale has 0 to 60 percent, by volume soft shale fragments. The control section is 50 to 60 percent clay. When the soil is dry, cracks 1/2 inch to 2 inches wide and several feet long extend downward through the solum. The soil does not have a mollic epipedon, but the upper 10 inches of the solum has an average organic carbon content between 0.6 and 1.7 percent. The soil has a SAR of 1 to 7.

The A horizon has hue of 10YR to 5Y, value of 4 to 6 and 3 to 5 moist, and chroma of 1 to 3. It typically is clay but is silty clay in some pedons. It ranges from slightly acid to moderately alkaline. When the soil is dry it has a light gray (2.5Y 7/2) smooth, porous, platy surface crust ranging from 1/4 to 1 inch in thickness. Where the horizon has mollic colors, it is too thin to be a mollic epipedon. Some pedons do not have an AB horizon.

The Bss horizons have hue of 2.5Y or 5Y, value of 5 or 6 and 4 or 5 moist, and chroma of 1 to 3. They are extremely hard or very hard when dry and extremely firm to firm when moist. They range from neutral to moderately alkaline.

Bk and C horizons are present in some pedons.

The Cr horizon is soft shale bedrock and ranges from slightly acid to moderately alkaline. Bedding planes are evident in the partially weathered shale in some pedons. Gypsum and other salts are concentrated in very thin seams within the shale in some pedons.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Aridic Leptic Haplusterts

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 2-37 inches. pH was marginal (acid) at 0-2 inches. Strongly effervescent at 2 inches. Estimated stripping depth is 2 inches.

Geographic Setting (According to Official Series Description) - Pierre soils are on nearly level to steep uplands. Slope gradient typically is 3 to 15 percent, but ranges from 0 to 30 percent. The soils formed in residuum weathered from clay shale. Gilgai microrelief is in most areas. Mean annual air temperature is 44 to 53 degrees F, and mean annual precipitation ranges from 12 to 16 inches. Growing season is 125 to 140 days; average growing season precipitation is 10 to 13 inches; and growing degree days are 2600 to 3100. Elevation is 1300 to 3600 feet.

GRUMMIT
SILTY CLAY

Soil Mapping Unit "Gr"
Lab/BKS Sample ID: G08020806-028_030

Typical Pedon: Grummit silty clay - on a convex slope of 5 percent in native grass. When described, the soil was moist to bedded shale. (Colors are for dry soil unless otherwise stated.)

The Grummit series consists of shallow, well drained soils formed in clayey residuum from acid shale on uplands. Permeability is moderate or moderately slow. Slopes range from 2 to 60 percent. Mean annual precipitation is about 15 inches, and mean annual temperature is about 46 degrees F.

A - 0-2 inches. Light brownish gray (10YR 6/2) silty clay, moist; moderate fine granular structure; loose, friable; many fine roots; many very fine fragments of shale; clear smooth boundary; neutral (pH 6.8); noneffervescent.

AC - 2-8 inches. Grayish brown (10YR 5/2) silty clay, moist; weak coarse subangular blocky structure; hard, friable; many fine roots; 25 percent very fine fragments of shale; gradual wavy boundary; slightly alkaline (pH 7.4); noneffervescent.

C - 8-20 inches. Grayish brown (10YR 5/2) silty clay, moist; common distinct mottles of yellowish brown (l0YR 5/6); weak coarse subangular blocky structure; hard, friable; partially weathered fragments of shale make up 35 percent by volume; common roots; clear smooth boundary; slightly alkaline (pH 7.7); noneffervescent.

Type Location - Butte County, South Dakota; refer to waypoint 90 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to shale ranges from 10 to 20 inches. Colors throughout the soil are inherited from the shale. The horizons overlying the bedded shales typically average 50 to 65 percent clay but ranges from 35 to 65 percent clay. The low clay percentage is due to sand-size shale fragments. Consistence ranges from loose to hard when dry but is friable when moist. The soil ranges from strongly acid to extremely acid.

The A horizon has hue of 10YR or 2.5Y, value of 5 or 6 and 3 or 4 moist, and chroma of 1 or 2 dry or moist. It typically is clay but is clay loam in some pedons. It has weathered fragments of shale that make up 5 to 35 percent by volume. The A horizon contains less than 1 percent more organic matter than the C.

The C horizon has hue of 10YR, 2.5Y, or 5Y; value of 5 or 6 and 3 or 4 moist; and chroma of 1 or 2. Weathered fragments of shale make up 20 to over 50 percent by volume of the C horizon.

The fissile shale is very hard and brittle and will not disperse in water or in sodium hexametaphosphate.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer

than typical for the series.

Taxonomic Class - Clayey, smectitic, acid, mesic, shallow Aridic Ustorthents

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 0-20 inches. Estimated stripping depth is 20 inches.

Geographic Setting (According to Official Series Description) - Grummit soils are gently sloping to very steep on uplands. Slope gradients range from 2 to 60 percent. The soil formed in clayey residuum weathered from acid shales. Mean annual temperature ranges from 43 to 50 degrees F, and mean annual precipitation is about 12 to 18 inches.

BONEEK
CLAY LOAM

Soil Mapping Unit "Bo"
Lab/BKS Sample ID: G08020806-031_035

Typical Pedon: Boneek clay loam - on a northeast-facing plane slope of 4 percent under native grass at 3500 feet elevation. (Colors are for dry soil unless otherwise stated.)

The Boneek series consists of deep and very deep, well drained soils formed in silty sediments underlain by sandstone or siltstone. Permeability is moderately slow in the solum and moderate in the underlying material. Slopes range from 0 to 15 percent. Mean annual precipitation is about 17 inches, and mean annual temperature is about 46 degrees F.

AC - 0-4 inches. Very dark grayish brown (10YR 3/2D) clay loam, moist; moderate thin platy structure parting to weak fine granular; slightly hard, very friable; many fine roots; clear wavy boundary; slightly alkaline (pH 7.6); very slight effervescent.

C1n - 4-19 inches. Dark grayish brown (10YR 4/2D) silt loam, moist; moderate medium prismatic structure parting to moderate medium and fine subangular blocky; very hard, friable, slightly sticky and slightly plastic; common fine roots; shiny films on faces of peds; clear wavy boundary; slightly alkaline (pH 7.8); slight effervescent.

C2n – 19-40 inches. Brown (10YR 4/3D) silt loam, moist; weak medium and coarse subangular blocky structure; very hard, friable, slightly sticky and slightly plastic; few fine roots; common fine and medium accumulations of carbonate; gradual wavy boundary; moderately alkaline (pH 8.4); noneffervescent.

C3n – 40-48 inches. Dark yellowish brown (10YR 4/4D) silty clay loam, moist; few fine and medium prominent mottles of strong brown (7.5YR 5/8); weak coarse subangular blocky structure; very hard, friable; few fine roots; clear wavy boundary; moderately alkaline (pH 8.4); noneffervescent.

C4n – 48-60 inches. Very dark grayish brown (10YR 3/2D) silt loam, moist; thin platy rock structure; faces of fractures stained strong brown (7.5YR 5/6) moist; few coatings of carbonates on faces of fractures, but matrix is noncalcareous; moderately alkaline (pH 8.3); noneffervescent.

Type Location - Butte County, South Dakota; refer to waypoint 91 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to bedrock is 40 to 60 inches or more. Depth to carbonates ranges from 11 to 24 inches. Thickness of the mollic epipedon ranges from 7 to 15 inches and extends into the Bt horizon of some pedons.

The A horizon has hue of 10YR or 7.5YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It typically is silt loam, but some pedons are loam. It is slightly acid or neutral.

The Bt1 horizon has hue of 7.5YR or 5YR, value of 4 or 6 and 3 or 4 moist, and chroma of 2 to 4. It is silty clay loam or silty clay. Average clay content ranges from 35 to 45 percent with less than 15 percent fine sand or coarser. It is slightly acid or neutral.

The Bt2 horizon has hue of 10YR or 7.5Y, value of 5 or 6 and 3 or 5 moist, and chroma of 2 to 4. It is silty clay loam averaging between 30 and 40 percent clay and less than 15 percent fine sand or coarser. It is neutral or slightly alkaline.

The Bk and C horizons have hue of 10YR or 2.5Y, value of 5 through 7 and 4 or 5 moist, and chroma of 1 to 3. They typically are silt loam or silty clay loam, but some pedons are loam. They are slightly alkaline to strongly alkaline. Few to many, fine or medium accumulations of carbonate are in the Bk horizon.

The Cr horizon has hue of 10YR or 7.5YR.

Range in Characteristics (according to field observations, lab analysis): Textures have slightly less clay than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Aridic Argiustolls

Suitability for Topsoil (According to WDEQ Guideline 1) - Saturation percentage was marginal at 4-19 inches and 40-60 inches. Sodium absorption ratio was unsuitable at 19-60 inches. Electrical conductivity was unsuitable at 19-60. Selenium was marginal at 48-60 inches. Estimated stripping depth is 19 inches.

Geographic Setting (According to Official Series Description) - Boneek soils are nearly level to moderately sloping on high terraces and uplands. Surfaces are plane to slightly convex and slope gradients range from 0 to 15 percent. The soils formed in a silty mantle overlying sandstone or siltstones, or in loess or silty alluvium. Mean annual temperature ranges from 43 to 48 degrees, and mean annual precipitation ranges from 15 to 18 inches. Most of the precipitation comes in the spring and summer.

SAMSIL
SILTY CLAY LOAM

Soil Mapping Unit "Sa"
Lab/BKS Sample ID: G08020806-021_023

Typical Pedon: Samsil silty clay loam - on a convex, southwest-facing slope of 15 percent in native grass. When described the soil was moist to 12 inches, dry from 12 to 21 inches, and moist below 21 inches. (Colors are for dry soil unless otherwise stated.)

The Samsil series consists of shallow, well drained soils formed in alluvium or residuum weathered from shale. Permeability is slow. Slope ranges from 2 to 60 percent. Mean annual precipitation is about 15 inches, and mean annual air temperature is about 47 degrees F.

AC - 0-7 inches. Dark grayish brown (10YR 4/2D) silty clay loam, moist; moderate fine granular structure; slightly hard, friable, sticky and plastic; common fine roots; few very fine fragments of shale; clear wavy boundary; slightly alkaline (pH 7.5); very slightly effervescent.

C – 7-19 inches. Dark grayish brown (10YR 4/2D) silty clay, moist; weak medium subangular blocky structure parting to weak medium granular; hard, friable, sticky and plastic; common fine roots; common fine fragments of soft shale; clear wavy boundary; slightly alkaline (pH 7.6); slightly effervescent.

Type Location - Pennington County, South Dakota; refer to waypoint 92 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - The control section is clay and contains 50 to 65 percent clay. The depth to bedded shale ranges from 6 to 20 inches. Horizons above the shale range from loose to hard when dry, and friable or firm when moist. These horizons contain free carbonates. Effervescence ranges from slight to strong and reaction is slightly alkaline or moderately alkaline. The C1 and C2 horizons and upper part of the Cr horizons commonly have accumulations of carbonate, gypsum, and other salts. Colors throughout, including mottles and stains, are inherited from the shale.

The A horizon has hue of 5Y, 2.5Y, or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 2 to 4. It is clay, silty clay, silty clay loam or clay loam and commonly contains few to common fragments of shale ranging from 2 to 25 mm in diameter. It has fine or medium subangular blocky or fine or very fine granular structure. The upper 1/4 to 1/2 inch commonly is a fragile crust or mulch or very fine granules when dry.

The AC horizon has hue of 5Y, 2.5Y, or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 4. It contains up to 35 percent fragments of shales by volume that range from less than 2 mm to 30 mm in diameter.

The C horizon has hue of 5Y, 2.5Y or 10YR, value of 4 to 7 and 3 to 6 moist, and chroma of 1 to 4. It is clay. The C horizon contains from 35 to more than 50 percent fragments of shale by volume that range from less than 2 mm to 35 mm in diameter.

The Cr horizon has the same range in color as the overlying C horizons. It ranges from medium acid to moderately alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures are slightly finer than typical for the series.

Taxonomic Class - Clayey, smectitic, calcareous, mesic, shallow Aridic Ustorthents

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 7-19 inches. Saturation percentage was marginal at 7-19 inches Estimated stripping depth is 7 inches.

Geographic Setting (According to Official Series Description) - Samsil soils are on gently sloping to very steep hills, ridges and breaks of dissected shale plains. Surfaces mainly are convex, and slope gradients range from 2 to 60 percent or more. The soil formed in alluvium or residuum weathered from shale. Mean annual air temperature ranges from 45 to 48 degrees F, and mean annual precipitation ranges from 14 to 19 inches.

SHINGLE
LOAM

Soil Mapping Unit "Sn"
Lab/BKS Sample ID: G08020806-021_023

Typical Pedon: Shingle loam-rangeland. (Colors are for dry soil unless otherwise stated.)

The Shingle series consists of well drained soils that are very shallow or shallow to bedrock. They formed in residuum and colluvium derived from interbedded shale and sandstone or in alluvium from mudstone. Shingle soils are on bedrock controlled hillslopes and ridges. Slopes are 0 to 80 percent. The mean annual precipitation is about 13 inches, and the mean annual temperature is 45 degrees F.

A - 0-4 inches. Light brownish gray (10YR 6/2) loam, moist; moderate very fine granular structure; soft, very friable, moderately sticky and moderately plastic; calcium carbonate disseminated; clear smooth boundary; neutral (pH 7.2); very slightly effervescent.

C – 4-8 inches. Light yellowish brown (2.5Y 6/3) loam, moist; weak medium subangular blocky structure; hard, friable, moderately sticky and moderately plastic; calcium carbonate disseminated; gradual smooth boundary; slightly alkaline (pH 7.5); strongly effervescent.

Type Location - Goshen County, Wyoming; refer to waypoint 93 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to soft bedrock and paralithic contact ranges from 4 to 20 inches. The mean annual soil temperature is 47 to 53 degrees F. The soils commonly are calcareous throughout, but some pedons are leached to 6 inches. The particle size control section averages 20 to 35 percent clay and has more than 15 percent but less than 35 percent fine or coarser sand. The soil is usually dry. The moisture control section is usually moist in April, May and early June. It is dry for 60 consecutive days or more during the 90 day period following the summer solstice. EC is 0 to 2 mmhos throughout.

The A horizon has hue of 5Y through 7.5YR, value of 5 through 7 dry, 3 through 6 moist, and chroma of 1 through 6. Reaction is neutral through strongly alkaline. Some pedons have a light gravel lag on the surface. Texture is loam, silt loam, clay loam, silty clay loam, cobbly loam, and gravelly clay loam. Rock fragments or shale channers range from 0 to 35 percent.

A Bw or AC horizon, when present, has the combined properties of the A and C horizons.

The C horizon has hue of 5Y through 7.5YR, value of 4 through 7 dry, 3 through 6 moist, and chroma of 1 through 6. It is loam, silt loam, clay loam or silty clay loam. Rock fragments or shale channers range from 0 to 35 percent. Reaction is slightly alkaline through strongly alkaline.

Range in Characteristics (according to field observations, lab analysis): Textures have less clay than typical for the series.

Taxonomic Class - Loamy, mixed, superactive, calcareous, mesic, shallow Ustic Torriorthents

Suitability for Topsoil (According to WDEQ Guideline 1) - No marginal or unsuitable parameters were found. Strongly effervescent at 4 inches. Estimated stripping depth is 8 inches.

Geographic Setting (According to Official Series Description) - The Shingle soils occur on all hillslope positions. Slopes are 0 to 80 percent. These soils formed in colluvium and residuum weathered from soft, interbedded sandstone and shale or in alluvium from mudstone. Elevation is 3,200 to 6,500 feet. The mean annual precipitation is about 10 to 14 inches, most of which falls in April, May, and June. The mean annual temperature is about 45 degrees F.but ranges from 43 to 51 degrees F. The frost-free season is about 105 to 130 days.

BOnEEk
NONCALCAREOUS VARIANT

Soil Mapping Unit "Bo"
Lab/BKS Sample ID: G08020806-040_045

Typical Pedon: Boneek silty clay - on a northeast-facing plane slope of 4 percent under native grass at 3500 feet elevation. (Colors are for dry soil unless otherwise stated.)

The Boneek series consists of deep and very deep, well drained soils formed in silty sediments underlain by sandstone or siltstone. Permeability is moderately slow in the solum and moderate in the underlying material. Slopes range from 0 to 15 percent. Mean annual precipitation is about 17 inches, and mean annual temperature is about 46 degrees F.

A - 0-2 inches. Brown (10YR 5/3) silty clay, moist; moderate thin platy structure parting to weak fine granular; slightly hard, very friable; many fine roots; clear wavy boundary; neutral (pH 6.9) noneffervescent.

C1 - 2-8 inches. Very dark grayish brown (10YR 3/2D) silty clay, moist; weak coarse subangular blocky structure; hard, very friable; many fine roots; clear wavy boundary; slighty alkaline (pH 7.6); noneffervescent.

C2n – 8-20 inches. Very dark grayish brown (10YR 3/2D) silty clay, moist; moderate medium prismatic structure parting to moderate medium and fine subangular blocky; very hard, friable, slightly sticky and slightly plastic; common fine roots; shiny films on faces of peds; clear wavy boundary; slighty alkaline (pH 7.5); noneffervescent.

C3n – 20-32 inches. Very dark grayish brown (10YR 3/2D) silty clay loam, moist; weak medium and coarse subangular blocky structure; very hard, friable, slightly sticky and slightly plastic; few fine roots; gradual wavy boundary; slighty alkaline (pH 7.6); noneffervescent.

C4n – 32-44 inches. Very dark grayish brown (10YR 3/2D) silty clay, moist; weak coarse subangular blocky structure; very hard, friable; few fine roots; violent; clear wavy boundary; slighty alkaline (pH 7.6); noneffervescent.

C5n – 44-60 inches. Dark brown (10YR 3/3D) silty clay, moist; thin platy rock structure; faces of fractures stained strong brown (7.5YR 5/6) moist; few coatings of carbonates on faces of fractures, but matrix is noncalcareous; slighty alkaline (pH 7.8); noneffervescent.

Type Location - Butte County, South Dakota; refer to waypoint 94 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to bedrock is 40 to 60 inches or more. Depth to carbonates ranges from 11 to 24 inches. Thickness of the mollic epipedon ranges from 7 to 15 inches and extends into the Bt horizon of some pedons.

The A horizon has hue of 10YR or 7.5YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It typically is silt loam, but some pedons are loam. It is slightly acid or neutral.

The Bt1 horizon has hue of 7.5YR or 5YR, value of 4 or 6 and 3 or 4 moist, and chroma of 2 to 4.

It is silty clay loam or silty clay. Average clay content ranges from 35 to 45 percent with less than 15 percent fine sand or coarser. It is slightly acid or neutral.

The Bt2 horizon has hue of 10YR or 7.5Y, value of 5 or 6 and 3 or 5 moist, and chroma of 2 to 4. It is silty clay loam averaging between 30 and 40 percent clay and less than 15 percent fine sand or coarser. It is neutral or slightly alkaline.

The Bk and C horizons have hue of 10YR or 2.5Y, value of 5 through 7 and 4 or 5 moist, and chroma of 1 to 3. They typically are silt loam or silty clay loam, but some pedons are loam. They are slightly alkaline to strongly alkaline. Few to many, fine or medium accumulations of carbonate are in the Bk horizon.

The Cr horizon has hue of 10YR or 7.5YR.

Range in Characteristics (according to field observations, lab analysis): Textures have slightly more clay than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Aridic Argiustolls

Suitability for Topsoil (According to WDEQ Guideline 1) - Marginal texture (clay) was found from 2-20 inches and 32-60 inches. Saturation percentage was marginal at 0-60 inches. Estimated stripping depth is 2 inches.

Geographic Setting (According to Official Series Description) - Boneek soils are nearly level to moderately sloping on high terraces and uplands. Surfaces are plane to slightly convex and slope gradients range from 0 to 15 percent. The soils formed in a silty mantle overlying sandstone or siltstones, or in loess or silty alluvium. Mean annual temperature ranges from 43 to 48 degrees, and mean annual precipitation ranges from 15 to 18 inches. Most of the precipitation comes in the spring and summer.

BONEEK
LOAM

Soil Mapping Unit "Bo"
Lab/BKS Sample ID: G08020806-046_050

Typical Pedon: Boneek loam - on a northeast-facing plane slope of 4 percent under native grass at 3500 feet elevation. (Colors are for dry soil unless otherwise stated.)

The Boneek series consists of deep and very deep, well drained soils formed in silty sediments underlain by sandstone or siltstone. Permeability is moderately slow in the solum and moderate in the underlying material. Slopes range from 0 to 15 percent. Mean annual precipitation is about 17 inches, and mean annual temperature is about 46 degrees F.

A - 0-2 inches. Brown (10YR 5/3) loam, moist; moderate thin platy structure parting to weak fine granular; slightly hard, very friable; many fine roots; clear wavy boundary; neutral (pH 7.1) noneffervescent.

Bt - 2-8 inches. Brown (7.5 YR 4/3D) loam, moist; weak coarse subangular blocky structure; hard, very friable; many fine roots; clear wavy boundary; slighty alkaline (pH 7.6); noneffervescent.

C1k – 8-17 inches. Brown (7.5 YR 5/3D) loam, moist; moderate medium prismatic structure parting to moderate medium and fine subangular blocky; very hard, friable, slightly sticky and slightly plastic; common fine roots; shiny films on faces of peds; clear wavy boundary; moderately alkaline (pH 7.9); strongly effervescent.

C2k – 17-24 inches. Brown (10YR 5/3D) loam, moist; weak coarse prismatic structure parting to moderate medium subangular blocky; very hard, friable, slightly sticky and slightly plastic; common fine roots; many fine and medium accumulations of carbonate; gradual wavy boundary; moderately alkaline (pH 8.3); strongly effervescent.

C3k – 24-38 inches. Dark grayish brown (10YR 4/2D) clay loam, moist; weak medium and coarse subangular blocky structure; very hard, friable, slightly sticky and slightly plastic; few fine roots; common fine and medium accumulations of carbonate; gradual wavy boundary; moderately alkaline (pH 8.3); strongly effervescent.

Type Location - Butte County, South Dakota; refer to waypoint 95 on map included in this report.

Range in Soil Characteristics (According to Official Series Description) - Depth to bedrock is 40 to 60 inches or more. Depth to carbonates ranges from 11 to 24 inches. Thickness of the mollic epipedon ranges from 7 to 15 inches and extends into the Bt horizon of some pedons.

The A horizon has hue of 10YR or 7.5YR, value of 4 or 5 and 2 or 3 moist, and chroma of 2 or 3. It typically is silt loam, but some pedons are loam. It is slightly acid or neutral.

The Bt1 horizon has hue of 7.5YR or 5YR, value of 4 or 6 and 3 or 4 moist, and chroma of 2 to 4. It is silty clay loam or silty clay. Average clay content ranges from 35 to 45 percent with less than 15 percent fine sand or coarser. It is slightly acid or neutral.

The Bt2 horizon has hue of 10YR or 7.5Y, value of 5 or 6 and 3 or 5 moist, and chroma of 2 to 4. It is silty clay loam averaging between 30 and 40 percent clay and less than 15 percent fine sand or coarser. It is neutral or slightly alkaline.

The Bk and C horizons have hue of 10YR or 2.5Y, value of 5 through 7 and 4 or 5 moist, and chroma of 1 to 3. They typically are silt loam or silty clay loam, but some pedons are loam. They are slightly alkaline to strongly alkaline. Few to many, fine or medium accumulations of carbonate are in the Bk horizon.

The Cr horizon has hue of 10YR or 7.5YR.

Range in Characteristics (according to field observations, lab analysis): Textures are coarser and have less clay than typical for the series.

Taxonomic Class - Fine, smectitic, mesic Aridic Argiustolls

Suitability for Topsoil (According to WDEQ Guideline 1) - Selenium was marginal at 24-38 inches. Strongly effervescent at 8 inches. Estimated stripping depth is 24 inches.

Geographic Setting (According to Official Series Description) - Boneek soils are nearly level to moderately sloping on high terraces and uplands. Surfaces are plane to slightly convex and slope gradients range from 0 to 15 percent. The soils formed in a silty mantle overlying sandstone or siltstones, or in loess or silty alluvium. Mean annual temperature ranges from 43 to 48 degrees, and mean annual precipitation ranges from 15 to 18 inches. Most of the precipitation comes in the spring and summer.

APPENDIX 2.6-D

ORIGINAL LABORATORY DATA SHEETS

POWERTECH (USA) INC.

ENERGY LABORATORIES, INC. * 400 W Boxelder Rd * Gillette, WY 82718-5315
Toll Free 866.686.7175 * 307.686.7175 * FAX 307.682.4625 * gillette@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020803

Report Date: 03/28/08
Date Received: 02/28/08

		Analysis	OM	Coarse Fragments	Sand	Silt	Clay	Texture	SAT	pH-sat paste	EC-sat paste	Ca-sat paste	Mg-sat paste	Na-sat paste	SAR-sat paste
		Units	%	%	%	%	%		wt%	s_u_	millimhos/cm	meq/l	meq/l	meq/l	millieeqs
Sample ID	Client Sample ID	Depth	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results
G08020803-001	Hole #17	0-3	3.0	< 0.1	8	46	46	SIC	75.7	6.8	0.61	3.00	0.73	0.24	0.2
G08020803-002	Hole #17	3-8	1.6	< 0.1	5	48	50	SIC	72.0	6.7	0.39	2.38	0.54	0.27	0.2
G08020803-003	Hole #17	8-24	1.7	< 0.1	3	44	53	SIC	80.0	6.7	0.78	5.44	1.49	0.73	0.4
G08020803-004	Hole #17	24-40	1.3	< 0.1	< 1	46	54	SIC	75.8	6.8	1.25	7.52	3.76	2.02	0.8
G08020803-005	Hole #17	40-54	0.8	< 0.1	1	48	51	SIC	78.9	6.0	3.49	24.5	23.0	4.43	0.9
G08020803-006	Hole #17	54-60	0.9	< 0.1	9	46	45	SIC	75.7	4.5	3.83	23.4	30.8	4.78	0.9
G08020803-007	Hole #27	0-2	2.6	< 0.1	8	58	33	SICL	63.3	7.4	0.56	2.41	1.14	2.41	1.8
G08020803-008	Hole #27	2-17	1.3	< 0.1	4	47	49	SIC	83.5	7.0	4.60	24.2	10.3	20.0	7.0
G08020803-009	Hole #27	17-24	1.2	4.5	4	43	53	SIC	77.5	8.0	0.16	22.7	14.0	50.3	11.7
G08020803-010	Hole #27	24-39	1.0	1.8	3	47	50	SIC	84.5	7.9	5.62	22.3	13.3	43.4	10.3
G08020803-011	Hole #27	39-60	0.8	< 0.1	5	50	45	SIC	79.0	7.9	5.88	21.9	15.9	44.7	10.3
G08020803-012	Hole #36	0-2	2.1	1.9	14	54	32	SICL	68.0	8.0	0.64	2.10	0.88	3.61	3.0
G08020803-013	Hole #36	2-15	1.3	< 0.1	9	46	45	SIC	84.2	8.0	4.08	23.8	11.1	34.0	8.1
G08020803-014	Hole #36	15-26	1.1	< 0.1	9	48	45	SIC	78.6	8.0	6.15	23.3	16.2	47.7	10.7
G08020803-015	Hole #36	26-38	0.9	< 0.1	9	41	50	SIC	84.1	8.0	7.41	28.6	24.6	60.4	11.7
G08020803-016	Hole #36	38-60	0.8	< 0.1	11	39	50	C	77.4	8.0	6.22	22.7	21.3	45.8	9.8
G08020803-017	Hole #39	0-2	4.1	< 0.1	19	55	26	SIL	50.0	6.8	0.67	3.04	1.95	0.14	< 0.1
G08020803-018	Hole #39	2-15	1.9	4.3	17	46	37	SICL	63.7	7.3	0.49	2.40	1.58	0.42	0.3
G08020803-019	Hole #39	15-32	1.0	1.7	31	37	32	CL	58.4	8.0	0.83	2.67	2.76	2.60	1.6
G08020803-020	Hole #39	32-52	0.7	< 0.1	27	36	37	CL	62.0	8.0	5.14	22.0	51.2	10.7	1.8
G08020803-021	Hole #39	52-60	0.7	< 0.1	21	72	7	SIL	75.4	8.1	5.25	23.5	54.5	10.1	1.6
G08020803-022	Hole #40	0-4	4.2	< 0.1	17	50	33	SICL	71.4	6.6	0.59	3.15	1.47	0.14	0.1
G08020803-023	Hole #40	4-14	2.4	< 0.1	12	55	33	SICL	60.7	7.1	0.88	3.64	1.48	0.50	0.3
G08020803-024	Hole #40	14-27	1.6	< 0.1	7	58	35	SICL	57.8	7.8	0.76	4.25	1.64	1.95	1.1
G08020803-025	Hole #40	27-38	1.6	< 0.1	1	52	47	SIC	74.8	8.1	1.52	4.42	2.01	9.67	5.4
G08020803-026	Hole #40	38-60	1.7	< 0.1	3	51	46	SIC	75.8	7.9	4.42	24.0	11.3	25.1	6.0
G08020803-027	Hole #41	0-4	4.2	3.9	25	56	19	SI	45.5	7.7	1.03	7.70	2.69	0.25	0.1
G08020803-028	Hole #41	4-21	1.1	1.7	11	54	35	SICL	64.2	7.7	3.78	27.7	20.1	8.30	1.7
G08020803-029	Hole #41	21-36	0.6	1.2	< 1	95	5	SI	63.8	8.6	13.3	25.3	100	148	18.7
G08020803-030	Hole #41	36-45	0.8	1.8	18	64	18	SiL	42.4	8.7	16.6	27.0	122	216	25.0
G08020803-031	Hole #41	45-60	0.5	0.5	34	49	17	L	33.6	8.7	14.8	25.0	107	175	21.4
G08020803-032	Hole #42	0-6	3.4	1.5	22	62	16	SiI	44.6	7.8	7.56	28.7	54.2	37.2	6.8
G08020803-033	Hole #42	6-17	1.3	8.0	26	60	14	SiI	40.2	8.3	15.4	30.9	191	135	17.9
G08020803-034	Hole #42	17-39	0.6	< 0.1	28	62	10	SIL	35.0	8.6	14.5	31.2	187	125	12.0
G08020803-035	Hole #42	39-60	0.6	< 0.1	30	56	14	SIL	37.1	8.6	10.9	28.5	109	83.5	10.1
G08020803-036	Hole #43	0-2	11.7	1.1	24	48	28	CL	63.7	6.2	1.11	5.45	3.02	0.61	0.3
G08020803-037	Hole #43	2-14	2.1	< 0.1	22	36	42	C	68.8	7.4	0.80	5.28	3.27	0.87	0.4
G08020803-038	Hole #43	14-38	1.0	< 0.1	32	36	32	CI	43.3	8.5	0.81	1.15	1.12	4.10	3.9
G08020803-039	Hole #43	38-60	0.8	< 0.1	50	28	22	I	39.8	8.8	1.76	1.25	1.76	15.3	12.5
G08020803-040	Hole #50	0-2	2.3	2.6	44	38	18	L	30.8	8.6	0.37	1.97	1.10	0.14	0.1

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020803

Report Date: 03/28/08
Date Received: 02/28/08

		Analysis	OM	Coarse Fragments	Sand	Silt	Clay	Texture	SAT	pH-sat paste	EC-sat paste	Ca-sat paste	Mg-sat paste	Na-sat paste	SAR-sat paste
		Units	%	%	%	%	%		wt%	s_u_	mmhos/cm	meq/L	meq/L	meq/L	unitless
Sample ID	Client Sample ID	Depth	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results
G08020803-041	Hole #50	2-7	1.8	2.6	32	34	34	CL	46.9	7.4	0.58	3.72	2.03	0.29	0.2
G08020803-042	Hole #50	7-13	1.9	2.4	26	38	36	CL	66.8	8.1	0.42	2.37	1.47	0.42	0.3
G08020803-043	Hole #50	13-25	1.0	3.1	44	29	27	CL	39.1	8.3	0.48	1.53	1.52	1.62	1.3
G08020803-044	Hole #56	0-3	6.0	< 0.1	16	56	28	SiCL	74.9	7.4	0.96	7.78	1.33	0.09	< 0.1
G08020803-045	Hole #56	3-14	2.5	< 0.1	< 1	72	28	SiCL	48.0	7.7	1.07	8.69	1.92	0.29	0.1
G08020803-046	Hole #56	14-26	2.2	< 0.1	8	60	32	SiCL	50.8	7.6	3.08	32.2	8.13	1.42	0.3
G08020803-047	Hole #56	26-36	2.0	1.5	18	56	26	SiL	46.4	7.5	3.43	36.7	9.58	2.45	0.5
G08020803-048	Hole #56	36-60	1.2	3.0	34	44	22	L	39.2	7.7	3.70	36.9	12.1	2.29	0.5
G08020803-049	Hole #57	0-2	2.1	5.4	22	42	36	CL	73.1	7.6	2.49	32.1	1.11	0.23	< 0.1
G08020803-050	Hole #57	2-8	0.7	< 0.1	32	38	30	CL	64.3	7.6	2.55	30.7	3.92	0.35	< 0.1

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020803

Report Date: 03/28/08
Date Received: 02/28/08

		Analysis	B-Hot H20	Se-Hot H20
		Units	mg/kg	mg/kg
Sample ID	Client Sample ID	Depth	Results	Results
G08020803-001	Hole #17	0-3	0.3	< 0.01
G08020803-002	Hole #17	3-8	0.3	< 0.01
G08020803-003	Hole #17	8-24	0.5	< 0.01
G08020803-004	Hole #17	24-40	0.6	< 0.01
G08020803-005	Hole #17	40-54	0.8	< 0.01
G08020803-006	Hole #17	54-60	0.8	< 0.01
G08020803-007	Hole #27	0-2	0.3	< 0.01
G08020803-008	Hole #27	2-17	2.0	0.03
G08020803-009	Hole #27	17-24	2.3	0.07
G08020803-010	Hole #27	24-39	1.0	0.06
G08020803-011	Hole #27	39-60	1.1	0.08
G08020803-012	Hole #36	0-2	0.4	< 0.01
G08020803-013	Hole #36	2-15	1.7	0.02
G08020803-014	Hole #36	15-26	2.3	0.03
G08020803-015	Hole #36	26-36	2.3	0.03
G08020803-016	Hole #36	36-60	1.5	0.03
G08020803-017	Hole #39	0-2	0.2	< 0.01
G08020803-018	Hole #39	2-15	0.3	< 0.01
G08020803-019	Hole #39	15-32	0.4	< 0.01
G08020803-020	Hole #39	32-52	0.9	0.04
G08020803-021	Hole #39	52-60	2.5	0.03
G08020803-022	Hole #40	0-4	0.3	< 0.01
G08020803-023	Hole #40	4-14	0.3	< 0.01
G08020803-024	Hole #40	14-27	0.4	< 0.01
G08020803-025	Hole #40	27-38	0.6	0.02
G08020803-026	Hole #40	38-60	0.7	0.06
G08020803-027	Hole #41	0-4	0.4	< 0.01
G08020803-028	Hole #41	4-21	0.7	0.03
G08020803-029	Hole #41	21-36	7.7	0.25
G08020803-030	Hole #41	36-45	4.2	0.24
G08020803-031	Hole #41	45-60	1.5	0.22
G08020803-032	Hole #42	0-6	1.0	0.07
G08020803-033	Hole #42	6-17	1.1	0.15
G08020803-034	Hole #42	17-39	1.8	0.09
G08020803-035	Hole #42	39-60	1.2	0.04
G08020803-036	Hole #43	0-2	0.4	< 0.01
G08020803-037	Hole #43	2-14	0.2	< 0.01
G08020803-038	Hole #43	14-38	0.5	< 0.01
G08020803-039	Hole #43	38-60	0.8	0.01
G08020803-040	Hole #50	0-2	0.1	< 0.01

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020803

Report Date: 03/28/08
Date Received: 02/28/08

		Analysis	B-Hot H20	Se-Hot H20
		Units	mg/kg	mg/kg
Sample ID	Client Sample ID	Depth	Results	Results
G08020803-041	Hole #50	2-7	0.1	< 0.01
G08020803-042	Hole #50	7-13	0.3	< 0.01
G08020803-043	Hole #50	13-25	0.2	< 0.01
G08020803-044	Hole #56	0-3	0.2	< 0.01
G08020803-045	Hole #56	3-14	0.3	< 0.01
G08020803-046	Hole #56	14-26	0.3	< 0.01
G08020803-047	Hole #56	26-36	0.3	< 0.01
G08020803-048	Hole #56	36-60	0.2	< 0.01
G08020803-049	Hole #57	0-2	0.3	< 0.01
G08020803-050	Hole #57	2-8	0.3	< 0.01

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020805

Report Date: 03/31/08
Date Received: 02/28/08

		Analysis	OM	Coarse Fragments	Sand	Silt	Clay	Texture	SAT	pH-sat paste	EC-sat paste	Ca-sat paste	Mg-sat paste	Na-sat paste	SAR-sat paste
		Units	%	%	%	%	%		wt%	s_u_	mmhos/cm	meq/L	meq/L	meq/L	unitless
Sample ID	Client Sample ID	Depth	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results
G08020805-001	Hole #80	0-3	3.4	3.5	30	40	30	CL	69.2	7.5	0.75	4.69	2.03	1.47	0.8
G08020805-002	Hole #80	3-10	1.8	< 0.1	20	38	42	C	74.1	8.4	1.55	1.18	1.88	13.5	11
G08020805-003	Hole #80	10-18	1.3	4.8	24	70	6	SIL	69.5	8.2	9.21	22.1	61.0	79.7	12
G08020805-004	Hole #83	0-2	3.0	14.9	52	36	12	I	33.2	8.4	0.79	5.94	1.88	0.56	0.5
G08020805-005	Hole #83	2-8	1.9	8.8	38	38	23	I	40.1	7.3	0.92	6.85	1.88	0.34	0.2
G08020805-006	Hole #83	8-18	1.9	8.2	22	51	27	CI	40.1	7.4	2.89	30.1	9.02	5.25	1.2
G08020805-007	Hole #84	0-8	2.4	< 0.1	14	53	33	SICI	62.6	7.1	0.87	6.25	4.69	0.35	0.2
G08020805-008	Hole #84	8-17	1.7	< 0.1	8	59	33	SICI	64.7	8.1	0.67	2.87	2.96	1.74	1.0
G08020805-009	Hole #84	17-33	0.8	< 0.1	6	61	33	SICI	64.2	8.5	2.27	1.60	5.81	16.0	8.3
G08020805-010	Hole #84	33-42	0.7	< 0.1	10	61	29	SICL	48.8	8.0	8.02	27.8	61.1	50.6	7.6
G08020805-011	Hole #84	42-60	0.6	< 0.1	18	57	27	SICI	45.9	8.1	7.62	27.7	50.5	45.2	7.2
G08020805-012	Hole #72	0-3	3.3	< 0.1	17	51	32	SICL	53.4	8.3	0.52	2.98	1.09	0.32	0.2
G08020805-013	Hole #72	3-18	1.2	< 0.1	26	39	35	CI	55.3	7.6	0.49	1.74	0.51	2.86	2.7
G08020805-014	Hole #72	18-28	1.2	2.8	10	47	43	SIC	69.7	7.9	4.52	20.2	12.3	30.1	7.5
G08020805-015	Hole #72	28-43	1.0	1.7	16	69	15	SIL	69.0	8.2	8.21	23.5	50.0	69.8	12
G08020805-016	Hole #72	43-60	0.8	2.1	22	53	25	SIL	67.4	8.3	10.0	21.9	73.5	94.0	14
G08020805-017	Hole #73	0-3	3.1	< 0.1	44	35	21	L	51.1	7.4	0.99	5.59	3.21	2.31	1.1
G08020805-018	Hole #73	3-15	1.7	< 0.1	10	41	49	SIC	77.0	7.9	0.51	8.5	9.4	52.4	18
G08020805-019	Hole #73	15-23	0.9	< 0.1	2	58	40	SIC	67.4	7.8	11.2	24.7	29.4	110	22
G08020805-020	Hole #73	23-34	1.1	< 0.1	< 1	60	40	SIC	65.5	8.0	12.9	35.5	35.5	134	22
G08020805-021	Hole #73	34-38	0.9	< 0.1	0	42	52	SIC	75.1	8.0	13.8	34.0	30.9	142	24
C08020805-022	Hole #73	38-60	0.0	< 0.1	4	31	65	C	67.7	8.0	12.2	33.0	31.8	123	22
G08020805-023	Hole #74	0-3	1.6	< 0.1	58	16	26	SCL	30.0	7.8	0.73	5.47	2.04	0.79	0.4
C08020805-024	Hole #74	3-15	0.8	< 0.1	54	19	27	SCL	46.2	8.3	0.60	1.62	1.45	4.66	3.8
C08020805-025	Hole #74	15-27	0.6	< 0.1	36	35	29	CL	51.5	8.5	5.68	5.4	15.0	55.9	17
C08020805-026	Hole #74	27-38	1.3	< 0.1	40	37	23	L	37.9	8.5	13.7	28.2	95.0	162	21
G08020805-027	Hole #74	38-51	0.5	< 0.1	50	31	19	L	34.3	8.4	13.2	25.9	92.3	150	20
C08020805-028	Hole #74	51-60	0.4	< 0.1	64	17	19	SL	33.1	8.4	12.7	23.9	82.0	143	20
G08020805-029	Hole #75	0-4	2.5	< 0.1	28	45	27	CL	60.4	7.8	0.84	4.62	1.79	2.13	1.2
C08020805-030	Hole #75	4-15	2.2	< 0.1	14	53	33	SICL	63.9	7.7	1.78	7.76	2.94	8.47	3.7
G08020805-031	Hole #75	15-35	1.3	< 0.1	16	55	29	SICL	52.2	7.6	6.61	28.4	15.6	48.5	10
G08020805-032	Hole #75	35-46	1.0	< 0.1	15	58	27	SICL	53.9	7.8	8.46	28.3	24.1	74.1	14
G08020805-033	Hole #75	46-60	1.0	< 0.1	12	59	29	SICL	54.5	7.8	8.23	27.4	24.2	69.8	14
G08020805-034	Hole #76	0-2	1.9	< 0.1	48	39	13	L	31.5	5.3	1.04	3.79	2.44	2.75	1.6
G08020805-035	Hole #76	2-21	1.3	< 0.1	14	42	44	SIC	69.1	7.7	5.77	19.6	14.2	43.2	11
G08020805-036	Hole #76	21-29	0.9	2.7	20	39	41	C	67.0	6.9	6.84	23.5	16.7	53.1	12
G08020805-037	Hole #76	29-46	1.0	5.7	19	45	36	SICL	60.6	7.6	4.87	7.22	6.07	43.4	17
G08020805-038	Hole #76	46-60	0.6	< 0.1	10	58	32	SICL	53.8	7.3	4.57	3.85	3.15	44.1	24
G08020805-039	Hole #77	0-4	2.0	1.7	36	37	27	CL	52.6	7.6	0.54	4.10	1.14	0.43	0.3
G08020805-040	Hole #77	4-17	1.5	< 0.1	22	41	37	CL	58.4	7.7	1.21	6.47	3.13	4.01	1.8

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020805

Report Date: 03/31/08
Date Received: 02/28/08

		Analysis	OM	Coarse Fragments	Sand	Silt	Clay	Texture	SAT	pH-sat paste	EC-sat paste	Ca-sat paste	Mg-sat paste	Na-sat paste	SAR-sat paste
		Units	%	%	%	%	%		wt%	s_u_	mmhos/cm	meq/L	meq/L	meq/L	unitless
Sample ID	Client Sample ID	Depth	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results
G08020805-041	Hole #77	17-36	0.9	< 0.1	22	73	5	SiL	67.2	8.0	5.66	23.7	44.8	27.1	4.6
G08020805-042	Hole #77	36-48	0.8	< 0.1	24	61	15	SiL	64.9	7.8	6.62	23.8	62.6	32.0	4.9
G08020805-043	Hole #79	0-3	5.1	< 0.1	18	46	36	SiCL	58.5	6.1	0.78	1.65	1.19	4.02	3.4
G08020805-044	Hole #79	3-17	1.6	< 0.1	12	41	47	SiC	73.7	4.1	4.61	22.4	22.1	22.9	4.9
G08020805-045	Hole #79	17-30	0.9	6.8	18	33	49	C	72.4	3.6	4.75	24.7	20.4	21.9	4.6
G08020805-046	Hole #79	30-42	0.9	5.0	22	32	46	C	65.1	3.7	2.50	11.4	7.65	9.50	3.1
G08020805-047	Hole #79	42-60	0.9	9.5	16	37	47	C	61.9	3.6	2.30	10.1	6.32	7.31	2.6

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020806

Report Date: 03/31/08
Date Received: 02/28/08

Sample ID	Client Sample ID	Analysis / Units / Depth	B-Hot H20 mg/kg Results	Se-Hot H20 mg/kg Results
G08020805-001	Hole #60	0-3	0.2	< 0.01
G08020805-002	Hole #60	3-10	0.4	0.01
G08020805-003	Hole #60	10-18	1.6	0.11
G08020805-004	Hole #63	0-2	0.1	< 0.01
G08020805-005	Hole #63	2-6	< 0.1	< 0.01
G08020805-006	Hole #63	6-16	0.3	< 0.01
G08020805-007	Hole #64	0-6	< 0.1	< 0.01
G08020805-008	Hole #64	6-17	0.2	< 0.01
G08020805-009	Hole #64	17-33	1.1	0.03
G08020805-010	Hole #64	33-42	2.7	0.12
G08020805-011	Hole #64	42-60	1.5	0.06
G08020805-012	Hole #72	0-3	0.2	< 0.01
G08020805-013	Hole #72	3-18	0.2	< 0.01
G08020805-014	Hole #72	18-28	1.1	0.12
G08020805-015	Hole #72	28-43	2.0	0.27
G08020805-016	Hole #72	43-60	1.6	0.16
G08020805-017	Hole #73	0-3	0.2	< 0.01
G08020805-018	Hole #73	3-15	0.8	0.06
G08020805-019	Hole #73	15-23	2.5	0.34
G08020805-020	Hole #73	23-34	2.3	0.44
G08020805-021	Hole #73	34-38	1.7	0.42
G08020805-022	Hole #73	38-60	1.8	0.37
G08020805-023	Hole #74	0-3	0.2	< 0.01
G08020805-024	Hole #74	3-15	0.2	< 0.01
G08020805-025	Hole #74	15-27	1.1	0.08
G08020805-026	Hole #74	27-38	2.5	0.21
G08020805-027	Hole #74	38-51	1.7	0.20
G08020805-028	Hole #74	51-60	1.3	0.16
G08020805-029	Hole #75	0-4	0.3	< 0.01
G08020805-030	Hole #75	4-15	0.4	< 0.01
G08020805-031	Hole #75	15-35	0.5	< 0.01
G08020805-032	Hole #75	35-46	0.7	< 0.01
G08020805-033	Hole #75	46-60	0.0	0.01
G08020805-034	Hole #76	0-2	0.2	< 0.01
G08020805-035	Hole #76	2-21	1.2	0.02
G08020805-036	Hole #76	21-29	0.8	< 0.01
G08020805-037	Hole #76	29-48	0.6	0.04
G08020805-038	Hole #76	48-60	0.5	0.17
G08020805-039	Hole #77	0-4	0.2	< 0.01
G08020805-040	Hole #77	4-17	0.6	< 0.01

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020805

Report Date: 03/31/08
Date Received: 02/28/08

		Analysis	B-Hot H20	Se-Hot H20
		Units	mg/kg	mg/kg
Sample ID	Client Sample ID	Depth	Results	Results
G08020805-041	Hole #77	17-36	4.4	0.03
G08020805-042	Hole #77	36-48	6.3	0.04
G08020805-043	Hole #79	0-3	0.6	< 0.01
G08020805-044	Hole #79	3-17	0.9	< 0.01
G08020805-045	Hole #79	17-30	0.6	< 0.01
G08020805-046	Hole #79	30-42	0.4	< 0.01
G08020805-047	Hole #79	42-60	0.3	< 0.01

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Durdock Soils
Workorder: G08020806

Report Date: 04/07/08
Date Received: 02/26/08

Sample ID	Client Sample ID	Analysis	OM	Coarse Fragments	Sand	Silt	Clay	Texture	SAT	pH-sat paste	EC-sat paste	Ca-sat paste	Mg-sat paste	Na-sat paste	SAR-sat paste
		Units	%	%	%	%	%		wt%	s_u_	mmhos/cm	meq/L	meq/L	meq/L	unitless
		Depth	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results
G08020806-001	Hole #82	0-4	3.0	0.0	61	32	17	L	35.7	6.3	1.78	8.06	4.01	0.10	0.08
G08020806-002	Hole #82	4-12	1.9	2.0	40	27	33	CL	49.3	7.1	1.10	5.93	3.57	1.95	0.89
G08020806-003	Hole #82	12-17	1.6	< 0.1	54	24	22	SCL	40.7	7.6	0.98	5.10	3.38	1.46	0.71
G08020806-004	Hole #82	17-28	1.5	< 0.1	54	24	22	SCL	38.0	7.9	0.99	5.09	3.19	1.75	0.82
G08020806-005	Hole #82	28-43	0.7	< 0.1	58	22	20	SCL	39.2	7.9	2.98	6.88	12.5	14.1	4.56
G08020806-006	Hole #83	0-3	3.2	< 0.1	14	53	33	SICL	53.3	6.8	0.43	1.23	0.72	1.20	1.22
G08020806-007	Hole #83	3-17	1.0	< 0.1	14	43	43	SIC	52.2	4.8	0.31	0.40	0.23	1.82	3.23
G08020806-008	Hole #83	17-33	1.0	< 0.1	9	47	44	SIC	59.4	5.7	4.85	25.3	25.0	22.3	4.44
G08020806-009	Hole #83	33-42	0.6	< 0.1	6	69	25	SI	78.1	7.6	5.71	26.5	35.1	30.4	5.47
G08020806-010	Hole #83	42-52	0.5	< 0.1	8	69	23	SIL	82.3	7.9	6.61	26.0	46.3	38.3	6.37
G08020806-011	Hole #83	52-60	0.4	< 0.1	12	79	9	SIL	74.9	7.9	6.67	24.4	42.7	42.6	7.36
G08020806-012	Hole #84	0-5	8.0	< 0.1	4	59	37	SICL	87.0	7.4	1.87	1.83	6.48	12.7	6.22
G08020806-013	Hole #84	5-18	1.8	< 0.1	9	52	39	SICL	83.2	8.2	11.8	24.5	105	112	14.0
G08020806-014	Hole #84	18-37	0.8	< 0.1	12	46	42	SIC	76.8	8.4	14.0	22.8	149	148	15.9
G08020806-015	Hole #84	37-47	1.1	< 0.1	6	55	39	SICL	70.8	8.3	11.6	23.5	103	108	13.5
G08020806-016	Hole #84	47-60	0.6	< 0.1	32	37	31	CL	59.7	8.1	8.14	21.8	80.2	61.6	9.63
G08020806-017	Hole #85	0-2	4.2	< 0.1	32	48	20	L	51.5	6.3	0.43	2.37	1.44	0.23	0.16
G08020806-018	Hole #85	2-7	2.3	< 0.1	20	41	39	SICL	80.6	7.3	0.71	4.24	2.30	0.73	0.40
G08020806-019	Hole #85	7-17	1.0	< 0.1	10	46	38	SICL	68.9	7.9	0.71	2.58	1.79	2.93	1.98
G08020806-020	Hole #85	17-30	1.3	< 0.1	22	40	38	CL	65.4	8.0	1.71	4.81	4.08	9.26	4.39
G08020806-021	Hole #88	0-2	3.0	2.1	21	46	33	CL	64.7	6.7	0.54	3.27	1.99	0.43	0.26
G08020806-022	Hole #88	2-9	1.8	< 0.1	11	43	46	SIC	77.9	7.8	0.80	4.04	1.88	2.48	1.44
G08020806-023	Hole #88	9-18	1.3	< 0.1	14	82	4	SI	77.0	7.8	3.09	31.4	13.3	13.6	2.88
G08020806-024	Hole #89	0-2	4.4	3.1	12	54	34	SICL	72.4	6.4	0.80	4.78	2.40	0.32	0.17
G08020806-025	Hole #89	2-18	2.4	3.7	9	46	46	SIC	87.3	7.7	1.41	5.88	4.12	5.07	2.54
G08020806-026	Hole #89	18-31	1.5	< 0.1	6	43	51	SIC	83.7	7.8	3.75	23.8	14.0	16.3	3.75
G08020806-027	Hole #89	31-37	1.5	< 0.1	3	49	48	SIC	86.0	7.7	3.98	27.7	15.5	16.0	3.44
G08020806-028	Hole #90	0-2	2.5	< 0.1	1	48	51	SIC	84.1	6.8	0.37	2.25	0.89	0.42	0.34
G08020806-029	Hole #90	2-8	1.8	< 0.1	2	44	54	SIC	89.8	7.4	0.44	2.82	0.78	0.76	0.56
G08020806-030	Hole #90	8-20	1.5	< 0.1	6	41	53	SIC	89.0	7.7	0.70	4.84	1.35	1.86	1.06
G08020806-031	Hole #91	0-4	2.0	< 0.1	20	44	36	CL	65.3	7.0	1.21	10.9	3.22	0.65	0.24
G08020806-032	Hole #91	4-19	1.7	< 0.1	22	67	11	SI	85.5	7.8	4.65	26.5	14.5	26.5	5.89
G08020806-033	Hole #91	19-40	0.5	< 0.1	16	74	10	SIL	79.9	8.4	12.7	23.7	81.7	144	19.8
G08020806-034	Hole #91	40-48	0.8	< 0.1	19	47	34	SICL	80.9	8.4	13.7	23.4	98.1	156	20.0
G08020806-035	Hole #91	48-60	0.6	< 0.1	10	68	22	SIL	94.3	8.3	14.4	25.1	109	170	20.7
G08020806-036	Hole #92	0-7	2.3	< 0.1	10	44	36	SICL	74.9	7.5	0.79	4.99	1.50	2.09	1.15
G08020806-037	Hole #92	7-19	1.0	< 0.1	12	48	40	SIC	88.2	7.6	3.32	27.6	9.68	10.4	2.42
G08020806-038	Hole #93	0-4	2.9	< 0.1	50	36	12	L	41.8	7.2	0.77	6.13	1.94	0.22	0.11
G08020806-039	Hole #93	4-8	2.1	< 0.1	50	32	18	L	39.4	7.5	0.71	6.25	1.80	0.14	0.07
G08020806-040	Hole #94	0-2	6.3	< 0.1	8	48	44	SIC	88.7	6.9	0.92	4.64	3.22	1.06	0.54

POWERTECH (USA) INC.

ENERGY LABORATORIES, INC. * 400 W Boxelder Rd * Gillette, WY 82718-5315
Toll Free 866.686.7175 * 307.686.7175 * FAX 307.682.4625 * gillette@energylab.com

LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020806

Report Date: 04/07/08
Date Received: 02/28/08

		Analysis	OM	Coarse Fragments	Sand	Silt	Clay	Texture	SAT	pH-sat paste	EC-sat paste	Ca-sat paste	Mg-sat paste	Na-sat paste	SAR-sat paste
		Units	%	%	%	%	%		wt%	s_u_	mmhos/cm	meq/L	meq/L	meq/L	unitless
Sample ID	Client Sample ID	Depth	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results	Results
G08020806-041	Hole #94	2-8	1.8	< 0.1	8	48	44	SiC	87.8	7.6	0.66	3.55	1.58	1.61	1.00
G08020806-042	Hole #94	8-20	1.2	6.0	19	41	40	SiC	85.6	7.6	2.27	20.6	5.30	3.89	1.08
G08020806-043	Hole #94	20-32	1.0	3.1	16	45	39	SiCL	82.6	7.6	3.00	26.0	9.46	5.36	1.27
G08020806-044	Hole #94	32-44	1.2	8.9	9	49	42	SiC	87.2	7.6	3.81	26.2	18.1	13.4	2.84
G08020806-045	Hole #94	44-60	0.9	5.0	12	47	41	SiC	87.0	7.8	5.22	23.7	27.5	29.4	5.82
G08020806-046	Hole #95	0-2	3.6	< 0.1	39	43	18	L	46.4	7.1	0.70	5.33	2.36	0.10	0.06
G08020806-047	Hole #95	2-8	2.0	< 0.1	41	39	20	L	43.8	7.6	0.93	7.16	2.64	0.40	0.18
G08020806-048	Hole #95	8-17	1.2	< 0.1	40	41	19	L	39.5	7.9	0.65	3.56	2.66	0.71	0.40
G08020806-049	Hole #95	17-24	0.7	< 0.1	35	39	26	L	51.3	8.3	0.90	1.18	2.30	5.73	4.34
G08020806-050	Hole #95	24-38	1.0	< 0.1	34	33	33	CL	62.7	8.3	6.10	15.6	37.7	41.7	8.08

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020806

Report Date: 04/07/08
Date Received: 02/28/08

		Analysis	B-Hot H20	Se-Hot H20
		Units	mg/kg	mg/kg
Sample ID	Client Sample ID	Depth	Results	Results
G08020806-001	Hole #82	0-4	0.3	< 0.01
G08020806-002	Hole #82	4-12	0.3	< 0.01
G08020806-003	Hole #82	12-17	0.3	< 0.01
G08020806-004	Hole #82	17-28	0.3	< 0.01
G08020806-005	Hole #82	28-43	0.5	< 0.01
G08020806-006	Hole #83	0-3	0.3	< 0.01
G08020806-007	Hole #83	3-17	0.3	< 0.01
G08020806-008	Hole #83	17-33	1.9	< 0.01
G08020806-009	Hole #83	33-42	5.4	0.02
G08020806-010	Hole #83	42-52	8.4	0.04
G08020806-011	Hole #83	52-60	5.2	0.07
G08020806-012	Hole #84	0-5	1.0	< 0.01
G08020806-013	Hole #84	5-18	1.6	0.02
G08020806-014	Hole #84	18-37	2.8	0.06
G08020806-015	Hole #84	37-47	2.0	0.02
G08020806-016	Hole #84	47-60	1.8	< 0.01
G08020806-017	Hole #85	0-2	0.2	< 0.01
G08020806-018	Hole #85	2-7	0.2	< 0.01
G08020806-019	Hole #85	7-17	0.6	< 0.01
G08020806-020	Hole #85	17-30	0.8	< 0.01
G08020806-021	Hole #88	0-2	0.2	< 0.01
G08020806-022	Hole #88	2-9	0.4	< 0.01
G08020806-023	Hole #88	9-18	1.2	< 0.01
G08020806-024	Hole #89	0-2	0.3	< 0.01
G08020806-025	Hole #89	2-18	0.6	< 0.01
G08020806-026	Hole #89	18-31	1.3	0.02
G08020806-027	Hole #89	31-37	1.6	0.01
G08020806-028	Hole #90	0-2	0.3	< 0.01
G08020806-029	Hole #90	2-8	0.4	< 0.01
G08020806-030	Hole #90	8-20	0.8	< 0.01
G08020806-031	Hole #91	0-4	0.2	< 0.01
G08020806-032	Hole #01	4-10	0.3	0.02
G08020806-033	Hole #01	10-40	1.6	0.07
G08020806-034	Hole #91	40-48	1.0	0.08
G08020806-035	Hole #91	48-60	1.0	0.10
G08020806-036	Hole #92	0-7	0.2	< 0.01
G08020806-037	Hole #92	7-19	0.7	< 0.01
G08020806-038	Hole #03	0-4	< 0.1	< 0.01
G08020806-039	Hole #03	4-8	0.1	< 0.01
G08020806-040	Hole #94	0-2	0.6	< 0.01

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LABORATORY ANALYTICAL REPORT

Client: Knight Piesold and Company
Project: 451b Dewey-Burdock Soils
Workorder: G08020806

Report Date: 04/07/08
Date Received: 02/28/08

		Analysis	B-Hot H20	Se-Hot H20
		Units	mg/kg	mg/kg
Sample ID	Client Sample ID	Depth	Results	Results
G08020806-041	Hole #94	2-8	0.4	< 0.01
G08020806-042	Hole #94	8-20	0.5	< 0.01
G08020806-043	Hole #94	20-32	0.7	< 0.01
G08020806-044	Hole #94	32-44	1.1	< 0.01
G08020806-045	Hole #94	44-60	0.8	0.02
G08020806-046	Hole #95	0-2	0.2	< 0.01
G08020806-047	Hole #95	2-8	0.1	< 0.01
G08020806-048	Hole #95	8-17	0.1	< 0.01
G08020806-049	Hole #95	17-24	0.2	< 0.01
G08020806-050	Hole #95	24-38	1.5	0.15

APPENDIX 2.6-E

PRIME FARMLAND DESIGNATION

United States Department of Agriculture

NRCS

Natural Resources Conservation Service
200 Fourth Street SW
Huron, South Dakota 57350

Phone: (605) 352-1200
Fax: (605) 352-1270

September 5, 2008

Mr. Adam Beilke
BKS Environmental Associates, Inc.
P.O. Box 3467
Gillette, Wyoming 82717

RE: Maps for Custer and Fall River Counties, South Dakota (SD)

Dear Mr. Beilke:

Attached are the prime and important farmland maps you requested for the Sections in Township 6 and 7 North and Range 1 East in Custer and Fall River Counties in SD.

Important farmland is land, in addition to prime and unique farmlands, that is of statewide importance for the production of food, feed, fiber, forage, and oil seed crops. Criteria for defining and delineating this land are to be determined by the appropriate state agency or agencies.

Generally, additional farmlands of statewide importance include those that are nearly prime farmland and that economically produce high yields of crops when treated and managed according to acceptable farming methods. Some may produce as high a yield as prime farmlands if conditions are favorable. Below is the criteria we use in determining important farmland in South Dakota:

A map unit is "Farmland of Statewide Importance" if 50 percent or more of named Components meet the Criteria and the Land Capability Class of all named components is Class 4 or less.

Mesic or frigid temperature regime
Available Water Capacity (AWC): 5.00 or Better (high) in top 40 inches.
pH: 4.5 - 8.4 in top 24 inches
EC: less than 8 in top 24 inches
SAR: less than 15 in top 24 inches
Surface Fragments > 3 in; less than 10%
Water erosion: Kw*slope Representative Value < 3.
Wind Erosion: I*C < 60.
Flooding or Ponding: Less than Frequent
Wetness: High Water table > 6 inches.
Mapunit is not prime farmland under all conditions

If I can be a further assistance, do not hesitate to let me know.

Sincerely,

DANIEL SHURTLIFF
Acting State Soil Scientist

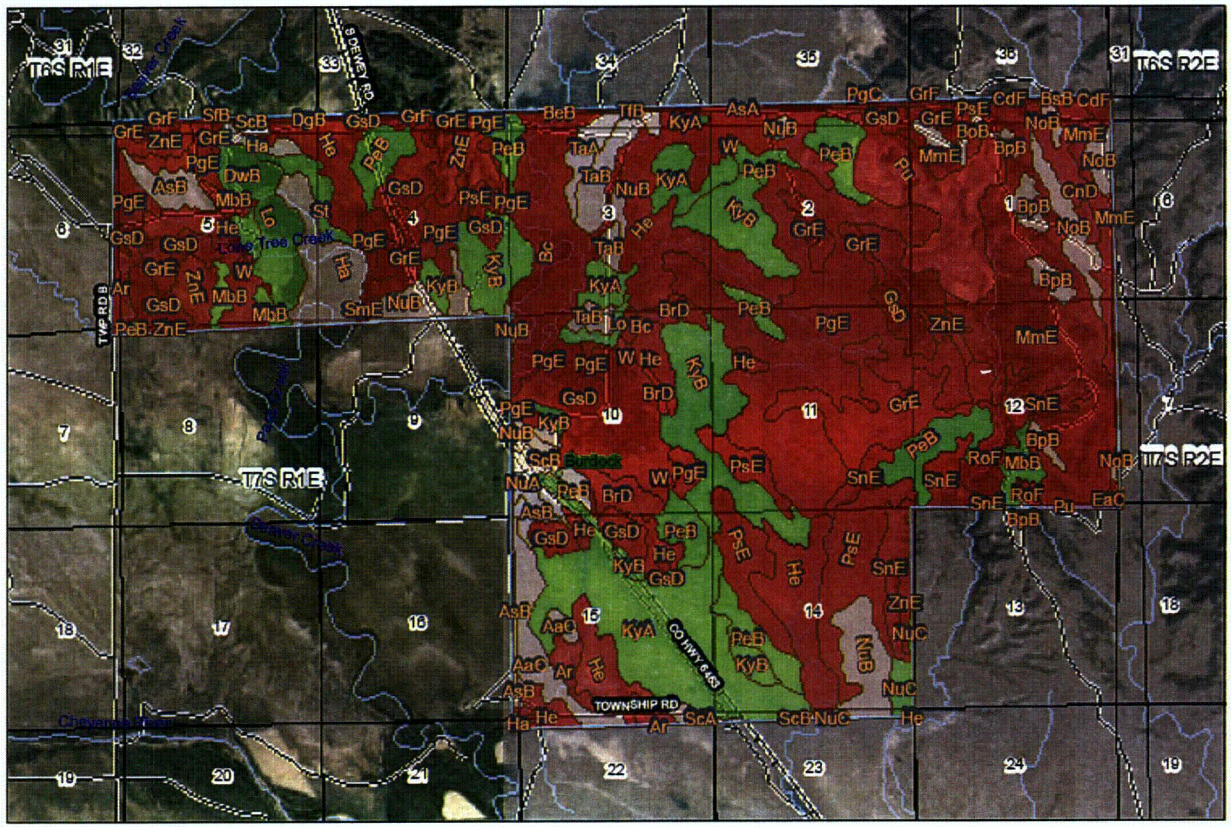
Attachments

cc: Kory Bossert, DC, NRCS, Hot Springs FO

Helping People Help the Land

An Equal Opportunity Provider and Employer

Farmland Classification–Custer and Pennington Counties, Black Hills Parts, South Dakota; and Fall River County, South Dakota
(BKS Env 7S 1E)



MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- Not prime farmland
- All areas are prime farmland
- Prime farmland if drained
- Prime farmland if protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated
- Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated and drained
- Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- Prime farmland if irrigated and reclaimed of excess salts and sodium
- Farmland of statewide importance
- Farmland of local importance
- Farmland of unique importance
- Not rated or not available

Political Features

Public Land Survey
- Township and Range
- Section

Municipalities
- Cities
- Urban Areas

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails

Roads
- Interstate Highways
- US Routes
- State Highways
- Local Roads
- Other Roads

MAP INFORMATION

Original soil survey map sheets were prepared at publication scale. Viewing scale and printing scale, however, may vary from the original. Please rely on the bar scale on each map sheet for proper map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 13N

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Custer and Pennington Counties, Black Hills Parts, South Dakota
Survey Area Data: Version 0, Feb 8, 2008

Soil Survey Area: Fall River County, South Dakota
Survey Area Data: Version 10, Feb 8, 2008

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 1991; 1994

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Farmland Classification

Farmland Classification—Summary by Map Unit — Custer and Pennington Counties, Black Hills Parts, South Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
AsA	Arvada-Stickspots complex, 0 to 3 percent slopes	Not prime farmland	11.1	0.2%
BeB	Barnum-Wheifil complex, 0 to 6 percent slopes	Not prime farmland	5.0	0.1%
BrB	Bullhat silt loam, 3 to 6 percent slopes	Not prime farmland	1.2	0.0%
BsB	Bullhat-Cordeston silt loams, 2 to 9 percent slopes	Not prime farmland	2.7	0.0%
CdF	Canyon-Rock outcrop complex, 15 to 60 percent slopes	Not prime farmland	6.7	0.1%
DgB	Demar-Grummit-Stickspots complex, 0 to 6 percent slopes	Not prime farmland	5.2	0.1%
GrD	Grummit-Rock outcrop complex, 6 to 15 percent slopes	Not prime farmland	1.5	0.0%
GrF	Grummit-Rock outcrop complex, 15 to 60 percent slopes	Not prime farmland	14.6	0.2%
HaA	Haverson loam, 0 to 2 percent slopes	Prime farmland if irrigated	0.7	0.0%
NfE	Nihill-Zigweid complex, 15 to 50 percent slopes	Not prime farmland	1.8	0.0%
PgC	Pierre-Grummit clays, 2 to 9 percent slopes	Not prime farmland	7.8	0.1%
SfB	Satanta-Arvada complex, 2 to 6 percent slopes	Not prime farmland	2.5	0.0%
TfB	Tilford silt loam, 2 to 6 percent slopes	Prime farmland if irrigated	3.5	0.1%
ZnD	Zigweid-Nihill complex, 6 to 15 percent slopes	Not prime farmland	1.5	0.0%

Farmland Classification— Summary by Map Unit — Fall River County, South Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
AaC	Alice fine sandy loam, 2 to 9 percent slopes	Prime farmland if irrigated	59.8	1.5%
Ar	Arvada loam	Not prime farmland	69.0	1.0%
AsB	Ascalon fine sandy loam, 0 to 6 percent slopes	Prime farmland if irrigated	66.4	1.0%

Farmland Classification—Summary by Map Unit—Fall River County, South Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Bc	Barnum silt loam	Not prime farmland	251.7	3.8%
BoB	Boneek silt loam, 2 to 6 percent slopes	Prime farmland if irrigated	19.1	0.3%
BpB	Boneek silt loam, bedrock substratum, 2 to 6 percent slopes	Prime farmland if irrigated	56.2	0.9%
BrD	Broadhurst clay, 2 to 15 percent slopes	Not prime farmland	66.4	1.0%
CnD	Colby-Norka silt loams, 6 to 15 percent slopes	Not prime farmland	99.5	1.5%
DwB	Dwyer loamy fine sand, 2 to 6 percent slopes	Not prime farmland	13.7	0.2%
EaC	Eckley loam, 0 to 9 percent slopes	Not prime farmland	5.0	0.1%
GrE	Grummit-Rock outcrop complex, 3 to 40 percent slopes	Not prime farmland	327.9	5.0%
GsD	Grummit-Shamo clays, 3 to 15 percent slopes	Not prime farmland	523.3	7.9%
Ha	Haverson loam	Prime farmland if irrigated	130.0	2.0%
He	Hisle-Slickspots complex	Not prime farmland	733.9	11.1%
KyA	Kyle clay, 0 to 2 percent slopes	Farmland of statewide importance	466.2	7.1%
KyB	Kyle clay, 2 to 6 percent slopes	Farmland of statewide importance	421.1	6.4%
Lo	Lohmiller silty clay loam	Farmland of statewide importance	131.5	2.0%
MbB	Manzanola silty clay loam, 2 to 6 percent slopes	Farmland of statewide importance	75.0	1.1%
MmE	Mathias-Midway-Rock outcrop complex, 15 to 30 percent slopes	Not prime farmland	512.2	7.7%
NoB	Norka silt loam, 2 to 6 percent slopes	Prime farmland if irrigated	92.5	1.4%
NuA	Nunn clay loam, 0 to 2 percent slopes	Prime farmland if irrigated	26.0	0.4%
NuB	Nunn clay loam, 2 to 6 percent slopes	Prime farmland if irrigated	160.5	2.4%
NuC	Nunn clay loam, 6 to 9 percent slopes	Farmland of statewide importance	25.3	0.4%
PeB	Pierre clay, 2 to 6 percent slopes	Farmland of statewide importance	322.0	4.9%
PgE	Pierre-Grummit clays, 6 to 25 percent slopes	Not prime farmland	747.0	11.3%
PsE	Pierre-Samsil clays, 6 to 25 percent slopes	Not prime farmland	289.6	4.4%

Farmland Classification—Summary by Map Unit — Fall River County, South Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Pu	Pits, mine	Not prime farmland	214.8	3.2%
RoF	Rock outcrop-Mathias-Butche complex, 30 to 75 percent slopes	Not prime farmland	52.7	0.8%
ScA	Satanta loam, 0 to 2 percent slopes	Prime farmland if irrigated	13.3	0.2%
ScB	Satanta loam, 2 to 6 percent slopes	Prime farmland if irrigated	38.6	0.6%
ScC	Satanta loam, 6 to 9 percent slopes	Farmland of statewide importance	0.0	0.0%
SmE	Schamber-Eckley complex, 9 to 40 percent slopes	Not prime farmland	7.1	0.1%
SnE	Shingle-Penrose-Rock outcrop complex, 15 to 40 percent slopes	Not prime farmland	158.7	2.4%
St	Stetter clay	Farmland of statewide importance	36.0	0.5%
TaA	Tilford silt loam, 0 to 2 percent slopes	Prime farmland if irrigated	42.7	0.6%
TaB	Tilford silt loam, 2 to 6 percent slopes	Prime farmland if irrigated	75.0	1.1%
W	Water	Not prime farmland	9.9	0.1%
ZnE	Zigweid-Nihill complex, 6 to 20 percent slopes	Not prime farmland	160.5	2.4%
Totals for Area of Interest (AOI)			6,609.1	100.0%

Description

Farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. It identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. NRCS policy and procedures on prime and unique farmlands are published in the "Federal Register," Vol. 43, No. 21, January 31, 1978.

Rating Options

Aggregation Method: No Aggregation Necessary

Tie-break Rule: Lower

Prime and other Important Farmlands

This table lists the map units in the survey area that are considered important farmlands. Important farmlands consist of prime farmland, unique farmland, and farmland of statewide or local importance. This list does not constitute a recommendation for a particular land use.

In an effort to identify the extent and location of important farmlands, the Natural Resources Conservation Service, in cooperation with other interested Federal, State, and local government organizations, has inventoried land that can be used for the production of the Nation's food supply.

Prime farmland is of major importance in meeting the Nation's short- and long-range needs for food and fiber. Because the supply of high-quality farmland is limited, the U.S. Department of Agriculture recognizes that responsible levels of government, as well as individuals, should encourage and facilitate the wise use of our Nation's prime farmland.

Prime farmland, as defined by the U.S. Department of Agriculture, is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. It could be cultivated land, pastureland, forestland, or other land, but it is not urban or built-up land or water areas. The soil quality, growing season, and moisture supply are those needed for the soil to economically produce sustained high yields of crops when proper management, including water management, and acceptable farming methods are applied. In general, prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, an acceptable salt and sodium content, and few or no rocks. The water supply is dependable and of adequate quality. Prime farmland is permeable to water and air. It is not excessively erodible or saturated with water for long periods, and it either is not frequently flooded during the growing season or is protected from flooding. Slope ranges mainly from 0 to 6 percent. More detailed information about the criteria for prime farmland is available at the local office of the Natural Resources Conservation Service.

For some of the soils identified in the table as prime farmland, measures that overcome a hazard or limitation, such as flooding, wetness, and droughtiness, are needed. Onsite evaluation is needed to determine whether or not the hazard or limitation has been overcome by corrective measures.

A recent trend in land use in some areas has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, droughty, and less productive and cannot be easily cultivated.

Unique farmland is land other than prime farmland that is used for the production of specific high-value food and fiber crops, such as citrus, tree nuts, olives, cranberries, and other fruits and vegetables. It has the special combination of soil quality, growing season, moisture supply, temperature, humidity, air drainage, elevation, and aspect needed for the soil to economically produce sustainable high yields of these crops when properly managed. The water supply is dependable and of adequate quality. Nearness to markets is an additional consideration. Unique farmland is not based on national criteria. It commonly is in areas where there is a special microclimate, such as the wine country in California.

In some areas, land that does not meet the criteria for prime or unique farmland is considered to be *farmland of statewide importance* for the production of food, feed, fiber, forage, and oilseed crops. The criteria for defining and delineating farmland of statewide importance are determined by the appropriate State agencies. Generally, this land includes areas of soils that nearly meet the requirements for prime farmland and that economically produce high yields of crops when treated and managed according to acceptable farming methods. Some areas may produce as high a yield as prime farmland if conditions are favorable. Farmland of statewide importance may include tracts of land that have been designated for agriculture by State law.

In some areas that are not identified as having national or statewide importance, land is considered to be *farmland of local importance* for the production of food, feed, fiber, forage, and oilseed crops. This farmland is identified by the appropriate local agencies. Farmland of local importance may include tracts of land that have been designated for agriculture by local ordinance.

Report—Prime and other Important Farmlands

Prime and other Important Farmlands--Custer and Pennington Counties, Black Hills Parts, South Dakota		
Map Symbol	Map Unit Name	Farmland Classification
AsA	Arvada-Slickspots complex, 0 to 3 percent slopes	Not prime farmland
BeB	Barnum-Winetti complex, 0 to 6 percent slopes	Not prime farmland
BrB	Bullfat silt loam, 3 to 6 percent slopes	Not prime farmland
BsB	Bullfat-Cordeston silt loams, 2 to 9 percent slopes	Not prime farmland
CdF	Canyon-Rock outcrop complex, 15 to 60 percent slopes	Not prime farmland
DgB	Demar-Grummit-Slickspots complex, 0 to 6 percent slopes	Not prime farmland
GrD	Grummit-Rock outcrop complex, 6 to 15 percent slopes	Not prime farmland
GrF	Grummit-Rock outcrop complex, 15 to 60 percent slopes	Not prime farmland
HaA	Haverson loam, 0 to 2 percent slopes	Prime farmland if irrigated
NfE	Nihill-Zigweid complex, 15 to 50 percent slopes	Not prime farmland
PgC	Pierre-Grummit clays, 2 to 9 percent slopes	Not prime farmland
SfB	Satanta-Arvada complex, 2 to 6 percent slopes	Not prime farmland
TfB	Tilford silt loam, 2 to 6 percent slopes	Prime farmland if irrigated
ZnD	Zigweid-Nihill complex, 6 to 15 percent slopes	Not prime farmland

Prime and other Important Farmlands--Fall River County, South Dakota		
Map Symbol	Map Unit Name	Farmland Classification
AaC	Alice fine sandy loam, 2 to 9 percent slopes	Prime farmland if irrigated
Ar	Arvada loam	Not prime farmland
AsB	Ascalon fine sandy loam, 0 to 6 percent slopes	Prime farmland if irrigated
Bc	Barnum silt loam	Not prime farmland
BoB	Boneek silt loam, 2 to 6 percent slopes	Prime farmland if irrigated
BpB	Boneek silt loam, bedrock substratum, 2 to 6 percent slopes	Prime farmland if irrigated

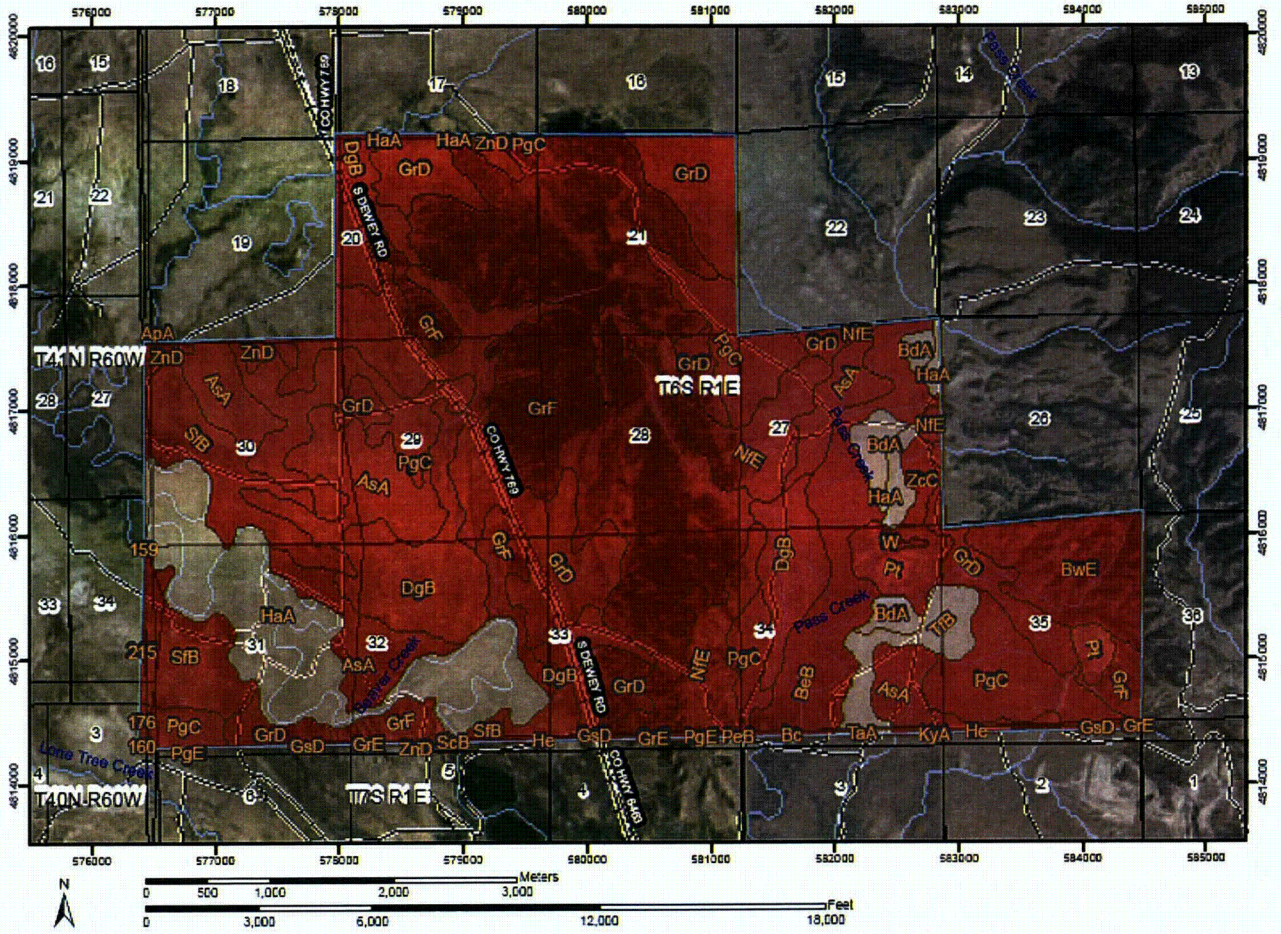
Prime and other Important Farmlands - Fall River County, South Dakota		
Map Symbol	Map Unit Name	Farmland Classification
BrD	Broadhurst clay, 2 to 15 percent slopes	Not prime farmland
CnD	Colby-Norka silt loams, 6 to 15 percent slopes	Not prime farmland
DwB	Dwyer loamy fine sand, 2 to 6 percent slopes	Not prime farmland
EaC	Eckley loam, 0 to 9 percent slopes	Not prime farmland
GrE	Grummit-Rock outcrop complex, 3 to 40 percent slopes	Not prime farmland
GsD	Grummit-Smoma clays, 3 to 15 percent slopes	Not prime farmland
Ha	Haverson loam	Prime farmland if irrigated
He	Hisle-Stickspots complex	Not prime farmland
KyA	Kyle clay, 0 to 2 percent slopes	Farmland of statewide importance
KyB	Kyle clay, 2 to 6 percent slopes	Farmland of statewide importance
Lo	Lohmiller silty clay loam	Farmland of statewide importance
MbB	Manzanola silty clay loam, 2 to 6 percent slopes	Farmland of statewide importance
MmE	Mathias-Midway-Rock outcrop complex, 15 to 30 percent slopes	Not prime farmland
NoB	Norka silt loam, 2 to 6 percent slopes	Prime farmland if irrigated
NuA	Nunn clay loam, 0 to 2 percent slopes	Prime farmland if irrigated
NuB	Nunn clay loam, 2 to 6 percent slopes	Prime farmland if irrigated
NuC	Nunn clay loam, 6 to 9 percent slopes	Farmland of statewide importance
PeB	Pierre clay, 2 to 6 percent slopes	Farmland of statewide importance
PgE	Pierre-Grummit clays, 6 to 25 percent slopes	Not prime farmland
PsE	Pierre-Samsil clays, 6 to 25 percent slopes	Not prime farmland
Pu	Pits, mine	Not prime farmland
RoF	Rock outcrop-Mathias-Sutphe complex, 30 to 75 percent slopes	Not prime farmland
ScA	Satanta loam, 0 to 2 percent slopes	Prime farmland if irrigated
ScB	Satanta loam, 2 to 6 percent slopes	Prime farmland if irrigated
ScC	Satanta loam, 6 to 9 percent slopes	Farmland of statewide importance
SmE	Schamber-Eckley complex, 9 to 40 percent slopes	Not prime farmland
SnE	Shingle-Penrose-Rock outcrop complex, 15 to 40 percent slopes	Not prime farmland
St	Stetter clay	Farmland of statewide importance
TaA	Tilford silt loam, 0 to 2 percent slopes	Prime farmland if irrigated
TaB	Tilford silt loam, 2 to 6 percent slopes	Prime farmland if irrigated
W	Water	Not prime farmland
ZnE	Zigweid-Nihill complex, 6 to 20 percent slopes	Not prime farmland

Data Source Information

Soil Survey Area: Custer and Pennington Counties, Black Hills Parts, South Dakota
Survey Area Data: Version 9, Feb 6, 2008

Soil Survey Area: Fall River County, South Dakota
Survey Area Data: Version 10, Feb 6, 2008

Farmland Classification–Custer and Pennington Counties, Black Hills Parts, South Dakota; Fall River County, South Dakota; and Niobrara County, Wyoming
(BKS_Farmland_4)



USDA Natural Resources Conservation Service

Web Soil Survey 2.0
National Cooperative Soil Survey

9/5/2008
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Farmland Classification–Custer and Pennington Counties, Black Hills Parts, South Dakota; Fall River County, South Dakota; and Niobrara County, Wyoming
(BKS_Farmland_4)

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Soil Ratings
- Not prime farmland
- All areas are prime farmland
- Prime farmland if drained
- Prime farmland if protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated
- Prime farmland if drained and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if irrigated and drained
- Prime farmland if irrigated and either protected from flooding or not frequently flooded during the growing season
- Prime farmland if subsoiled, completely removing the root inhibiting soil layer
- Prime farmland if irrigated and the product of I (soil erodibility) x C (climate factor) does not exceed 60
- Prime farmland if irrigated and reclaimed of excess salts and sodium
- Farmland of statewide importance
- Farmland of local importance
- Farmland of unique importance
- Not rated or not available

Political Features

Public Land Survey
- Township and Range
- Section

Municipalities
- Cities
- Urban Areas

Water Features
- Oceans
- Streams and Canals

Transportation
- Rails

Roads
- Interstate Highways
- US Routes
- State Highways
- Local Roads
- Other Roads

MAP INFORMATION

Original soil survey map sheets were prepared at publication scale. Viewing scale and printing scale, however, may vary from the original. Please rely on the bar scale on each map sheet for proper map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 13N

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Custer and Pennington Counties, Black Hills Parts, South Dakota
Survey Area Data: Version 10, Aug 26, 2008

Soil Survey Area: Fall River County, South Dakota
Survey Area Data: Version 10, Feb 6, 2008

Soil Survey Area: Niobrara County, Wyoming
Survey Area Data: Version 6, Mar 4, 2008

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Date(s) aerial images were photographed: 1991; 1994

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Farmland Classification

Farmland Classification—Summary by Map Unit—Custer and Pennington Counties, Black Hills Parts, South Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
AgA	Arvada variant loam, 0 to 2 percent slopes	Not prime farmland	6.8	0.1%
AsA	Arvada-Stickspots complex, 0 to 3 percent slopes	Not prime farmland	610.9	8.5%
BdA	Barnum very fine sandy loam, 0 to 3 percent slopes	Prime farmland if irrigated	87.5	1.2%
BeB	Barnum-Winetti complex, 0 to 6 percent slopes	Not prime farmland	343.7	4.8%
BwE	Butche-Rock outcrop complex, 9 to 60 percent slopes	Not prime farmland	256.0	3.6%
DgB	Demas-Grummit-Stickspots complex, 0 to 6 percent slopes	Not prime farmland	602.8	8.4%
GrD	Grummit-Rock outcrop complex, 6 to 15 percent slopes	Not prime farmland	1,116.0	15.6%
GrF	Grummit-Rock outcrop complex, 15 to 60 percent slopes	Not prime farmland	1,657.8	23.2%
HaA	Haverson loam, 0 to 2 percent slopes	Prime farmland if irrigated	635.7	8.9%
NtE	Nihill-Zigweid complex, 15 to 50 percent slopes	Not prime farmland	373.1	5.2%
PgC	Pierre-Grummit clays, 2 to 9 percent slopes	Not prime farmland	697.2	9.7%
Pt	Pits, quarries	Not prime farmland	119.5	1.7%
SfB	Satanta-Arvada complex, 2 to 6 percent slopes	Not prime farmland	379.9	5.3%
TfB	Tilford silt loam, 2 to 6 percent slopes	Prime farmland if irrigated	109.9	1.5%
W	Water	Not prime farmland	8.1	0.1%
ZcC	Zigweid-Canyon complex, 2 to 15 percent slopes	Not prime farmland	35.5	0.5%
ZnD	Zigweid-Nihill complex, 6 to 15 percent slopes	Not prime farmland	33.5	0.5%

Farmland Classification—Summary by Map Unit—Fall River County, South Dakota				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
Bc	Barnum silt loam	Not prime farmland	7.2	0.1%
GrE	Grummit-Rock outcrop complex, 3 to 40 percent slopes	Not prime farmland	10.7	0.1%
GsD	Grummit-Snomo clays, 3 to 15 percent slopes	Not prime farmland	13.3	0.2%
Ha	Haverson loam	Prime farmland if irrigated	0.5	0.0%
He	Hisle-Slickspots complex	Not prime farmland	19.7	0.3%
KyA	Kyle clay, 0 to 2 percent slopes	Farmland of statewide importance	0.1	0.0%
PeB	Pierre clay, 2 to 6 percent slopes	Farmland of statewide importance	2.0	0.0%
PgE	Pierre-Grummit clays, 6 to 25 percent slopes	Not prime farmland	4.7	0.1%
Pu	Pits, mine	Not prime farmland	0.1	0.0%
ScB	Satanta loam, 2 to 6 percent slopes	Prime farmland if irrigated	1.8	0.0%
TaA	Tilford silt loam, 0 to 2 percent slopes	Prime farmland if irrigated	4.9	0.1%
ZnE	Zigweid-Nihill complex, 6 to 20 percent slopes	Not prime farmland	1.3	0.0%

Farmland Classification—Summary by Map Unit—Niobrara County, Wyoming				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
159	Lohmiller-Haverdad complex, saline, 1 to 4 percent slopes	Not prime farmland	0.0	0.0%
160	Manzanola silty clay loam, 0 to 6 percent slopes	Not prime farmland	1.1	0.0%
176	Pierre-Grummit clays, 6 to 25 percent slopes	Not prime farmland	4.1	0.1%
185	Samday-Savageton-Bahl association, 3 to 10 percent slopes	Not prime farmland	0.4	0.0%
215	Ulm-Fortwood loams, 0 to 6 percent slopes	Not prime farmland	6.5	0.1%
Totals for Area of Interest (AOI)			7,153.3	100.0%

Description

Farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. It identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. NRCS policy and procedures on prime and unique farmlands are published in the "Federal Register," Vol. 43, No. 21, January 31, 1978.

Rating Options

Aggregation Method: No Aggregation Necessary

Tie-break Rule: Lower

Prime and other Important Farmlands

This table lists the map units in the survey area that are considered important farmlands. Important farmlands consist of prime farmland, unique farmland, and farmland of statewide or local importance. This list does not constitute a recommendation for a particular land use.

In an effort to identify the extent and location of important farmlands, the Natural Resources Conservation Service, in cooperation with other interested Federal, State, and local government organizations, has inventoried land that can be used for the production of the Nation's food supply.

Prime farmland is of major importance in meeting the Nation's short- and long-range needs for food and fiber. Because the supply of high-quality farmland is limited, the U.S. Department of Agriculture recognizes that responsible levels of government, as well as individuals, should encourage and facilitate the wise use of our Nation's prime farmland.

Prime farmland, as defined by the U.S. Department of Agriculture, is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. It could be cultivated land, pastureland, forestland, or other land, but it is not urban or built-up land or water areas. The soil quality, growing season, and moisture supply are those needed for the soil to economically produce sustained high yields of crops when proper management, including water management, and acceptable farming methods are applied. In general, prime farmland has an adequate and dependable supply of moisture from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, an acceptable salt and sodium content, and few or no rocks. The water supply is dependable and of adequate quality. Prime farmland is permeable to water and air. It is not excessively erodible or saturated with water for long periods, and it either is not frequently flooded during the growing season or is protected from flooding. Slope ranges mainly from 0 to 6 percent. More detailed information about the criteria for prime farmland is available at the local office of the Natural Resources Conservation Service.

For some of the soils identified in the table as prime farmland, measures that overcome a hazard or limitation, such as flooding, wetness, and droughtiness, are needed. Onsite evaluation is needed to determine whether or not the hazard or limitation has been overcome by corrective measures.

A recent trend in land use in some areas has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, droughty, and less productive and cannot be easily cultivated.

Unique farmland is land other than prime farmland that is used for the production of specific high-value food and fiber crops, such as citrus, tree nuts, olives, cranberries, and other fruits and vegetables. It has the special combination of soil quality, growing season, moisture supply, temperature, humidity, air drainage, elevation, and aspect needed for the soil to economically produce sustainable high yields of these crops when properly managed. The water supply is dependable and of adequate quality. Nearness to markets is an additional consideration. Unique farmland is not based on national criteria. It commonly is in areas where there is a special microclimate, such as the wine country in California.

In some areas, land that does not meet the criteria for prime or unique farmland is considered to be *farmland of statewide importance* for the production of food, feed, fiber, forage, and oilseed crops. The criteria for defining and delineating farmland of statewide importance are determined by the appropriate State agencies. Generally, this land includes areas of soils that nearly meet the requirements for prime farmland and that economically produce high yields of crops when treated and managed according to acceptable farming methods. Some areas may produce as high a yield as prime farmland if conditions are favorable. Farmland of statewide importance may include tracts of land that have been designated for agriculture by State law.

In some areas that are not identified as having national or statewide importance, land is considered to be *farmland of local importance* for the production of food, feed, fiber, forage, and oilseed crops. This farmland is identified by the appropriate local agencies. Farmland of local importance may include tracts of land that have been designated for agriculture by local ordinance.

Report—Prime and other Important Farmlands

Prime and other Important Farmlands--Custer and Pennington Counties, Black Hills Parts, South Dakota		
Map Symbol	Map Unit Name	Farmland Classification
AgA	Arvada variant loam, 0 to 2 percent slopes	Not prime farmland
AsA	Arvada-Slickspots complex, 0 to 3 percent slopes	Not prime farmland
BdA	Barnum very fine sandy loam, 0 to 3 percent slopes	Prime farmland if irrigated
BeB	Barnum-Winetti complex, 0 to 6 percent slopes	Not prime farmland
BsE	Butche-Rock outcrop complex, 9 to 60 percent slopes	Not prime farmland
DgB	Demar-Grummit-Slickspots complex, 0 to 6 percent slopes	Not prime farmland
GrD	Grummit-Rock outcrop complex, 6 to 15 percent slopes	Not prime farmland
GrF	Grummit-Rock outcrop complex, 15 to 60 percent slopes	Not prime farmland
HaA	Haverson loam, 0 to 2 percent slopes	Prime farmland if irrigated
NtE	Nihill-Zigweid complex, 15 to 50 percent slopes	Not prime farmland
PgC	Pierre-Grummit clays, 2 to 9 percent slopes	Not prime farmland
Pt	Pits, quarries	Not prime farmland
SfB	Satanta-Arvada complex, 2 to 6 percent slopes	Not prime farmland
TfB	Tilford silt loam, 2 to 6 percent slopes	Prime farmland if irrigated
W	Water	Not prime farmland
ZcC	Zigweid-Canyon complex, 2 to 15 percent slopes	Not prime farmland
ZnD	Zigweid-Nihill complex, 6 to 15 percent slopes	Not prime farmland

Prime and other Important Farmlands--Fall River County, South Dakota		
Map Symbol	Map Unit Name	Farmland Classification
Bc	Barnum silt loam	Not prime farmland
GrE	Grummit-Rock outcrop complex, 3 to 40 percent slopes	Not prime farmland
GsD	Grummit-Shomo clays, 3 to 15 percent slopes	Not prime farmland

Prime and other Important Farmlands--Fall River County, South Dakota		
Map Symbol	Map Unit Name	Farmland Classification
Ha	Haverson loam	Prime farmland if irrigated
He	Haste-Stickspots complex	Not prime farmland
KyA	Kyle clay, 0 to 2 percent slopes	Farmland of statewide importance
PeB	Pierre clay, 2 to 6 percent slopes	Farmland of statewide importance
PgE	Pierre-Grummit clays, 6 to 25 percent slopes	Not prime farmland
Pu	Pits, mine	Not prime farmland
ScB	Satanta loam, 2 to 6 percent slopes	Prime farmland if irrigated
TaA	Tilford silt loam, 0 to 2 percent slopes	Prime farmland if irrigated
ZnE	Zigweid-Nihill complex, 6 to 20 percent slopes	Not prime farmland

Prime and other Important Farmlands--Niobrara County, Wyoming		
Map Symbol	Map Unit Name	Farmland Classification
159	Lohmiller-Havesdad complex, saline, 1 to 4 percent slopes	Not prime farmland
160	Manzanola silty clay loam, 0 to 6 percent slopes	Not prime farmland
176	Pierre-Grummit clays, 6 to 25 percent slopes	Not prime farmland
185	Samday-Savageton-Bahl association, 3 to 10 percent slopes	Not prime farmland
215	Ulm-Forkwood loams, 0 to 6 percent slopes	Not prime farmland

Data Source Information

Soil Survey Area: Custer and Pennington Counties, Black Hills Parts, South Dakota
Survey Area Data: Version 10, Aug 26, 2008

Soil Survey Area: Fall River County, South Dakota
Survey Area Data: Version 10, Feb 6, 2008

Soil Survey Area: Niobrara County, Wyoming
Survey Area Data: Version 6, Mar 4, 2008

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ADDENDUM 2.6-F

SITE PHOTOGRAPHS

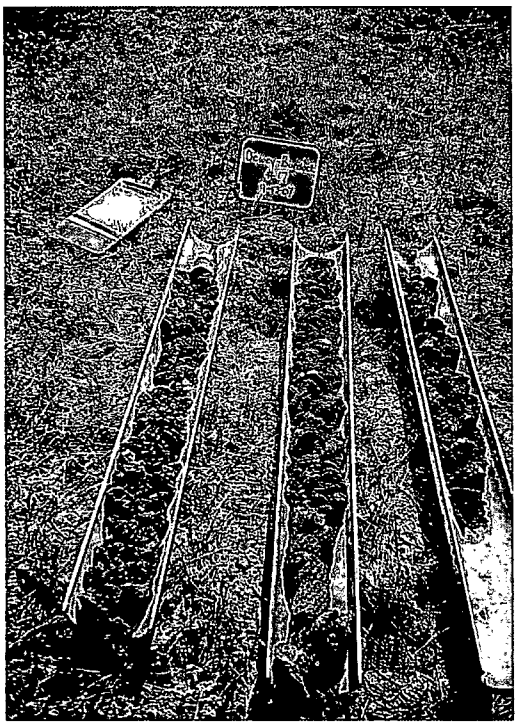

Photo 1: Hole 17 Profile

Photo 2: Hole 17 General View W

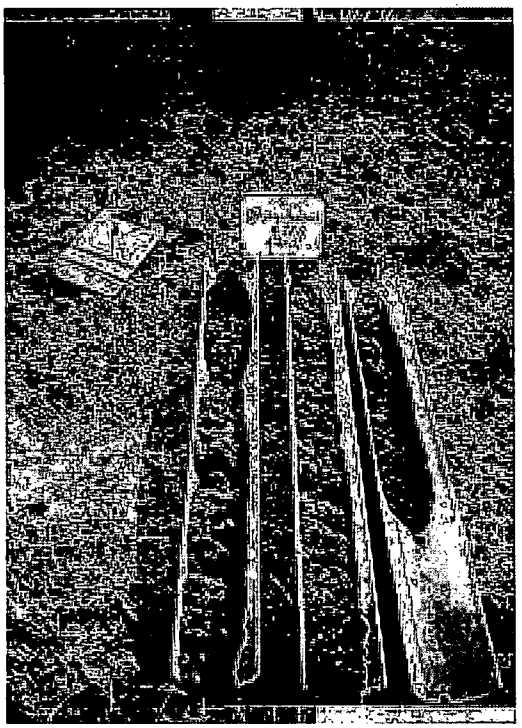

Photo 3: Hole 27 Profile

Photo 4: Hole 27 General View N

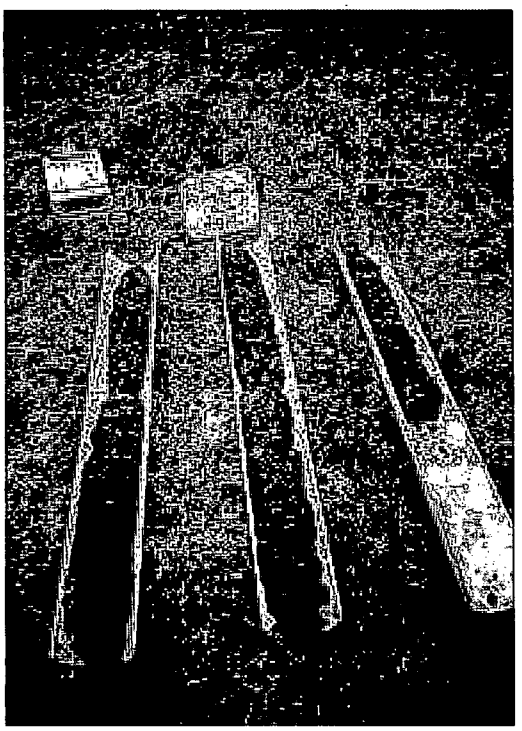

Photo 5: Hole 36 Profile

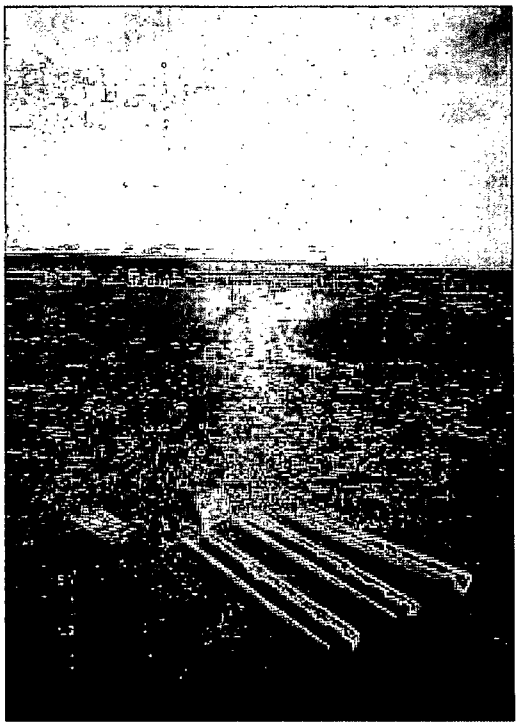

Photo 6: Hole 36 General View S

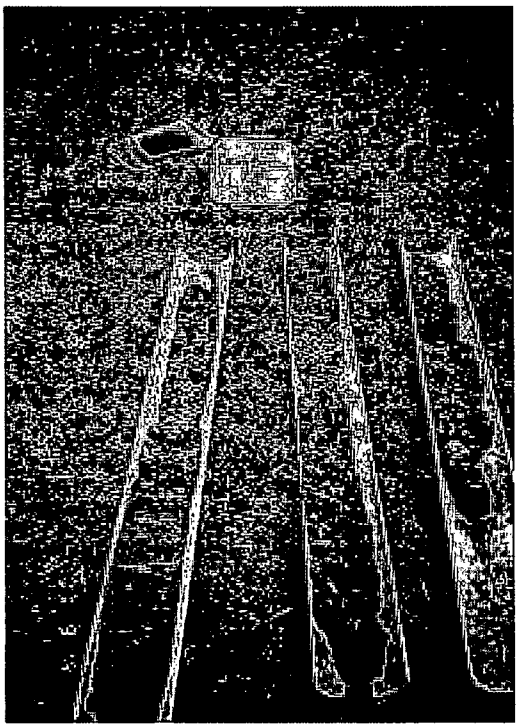

Photo 7: Hole 39 Profile

Photo 8: Hole 39 General View E

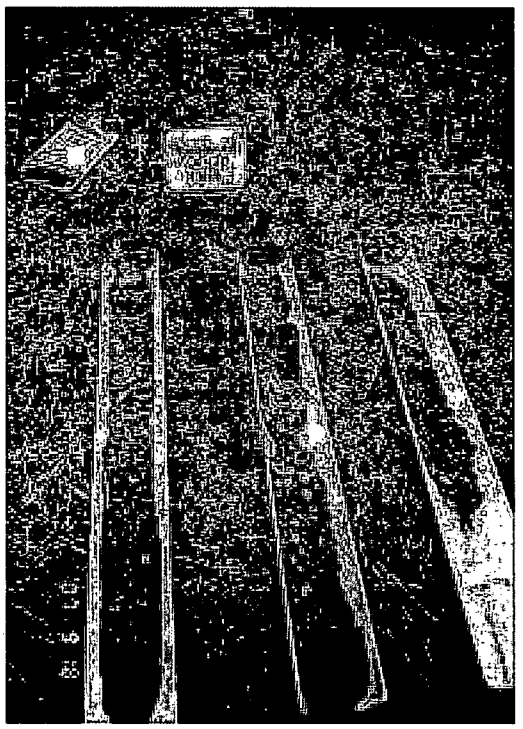

Photo 9: Hole 40 Profile

Photo 10: Hole 40 General View W

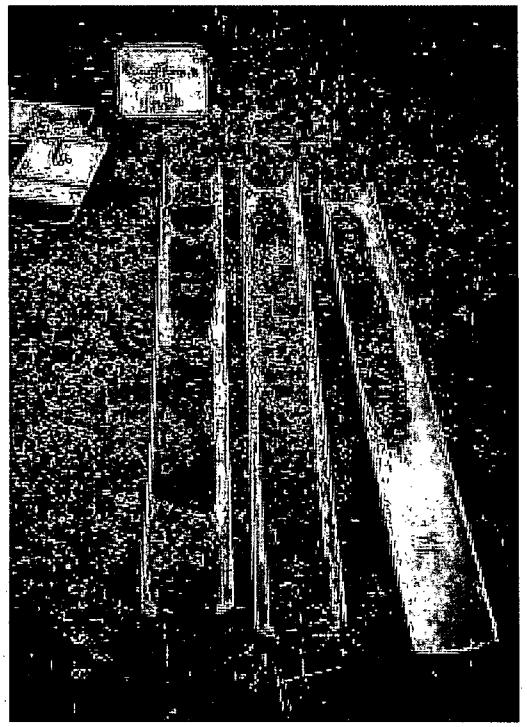

Photo 11: Hole 41 Profile

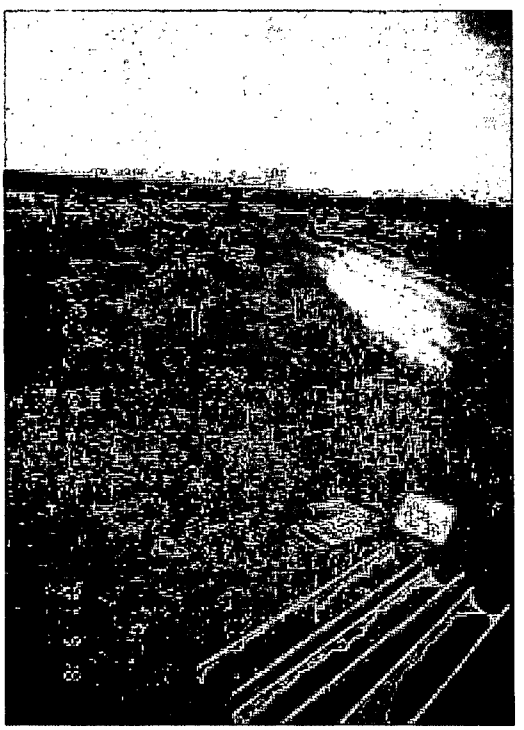

Photo 12: Hole 41 General View W

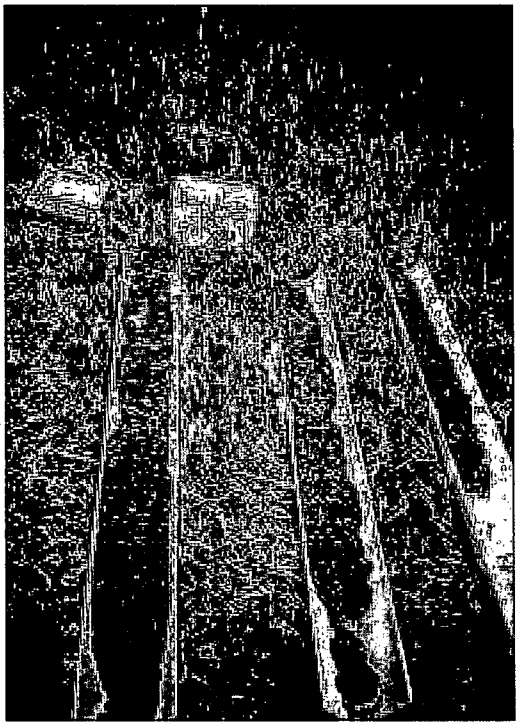

Photo 13: Hole 42 Profile

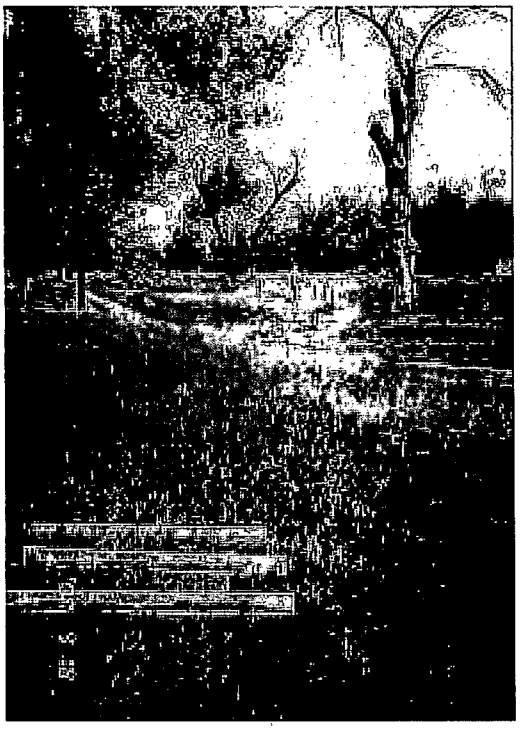

Photo 14: Hole 42 General View

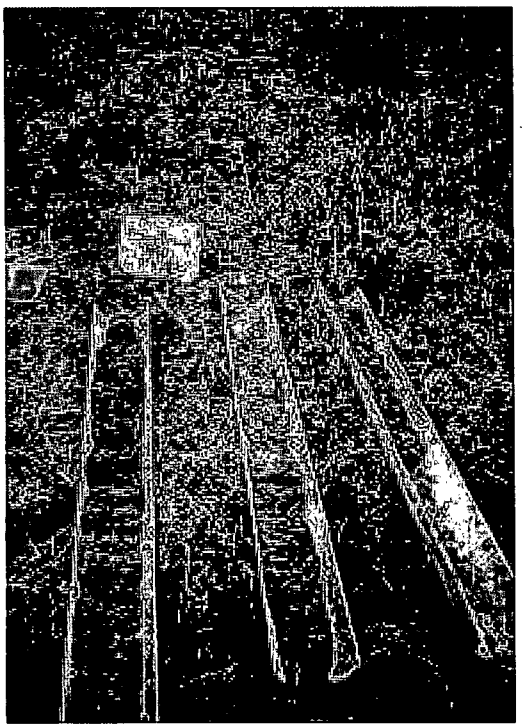

Photo 15: Hole 43 Profile

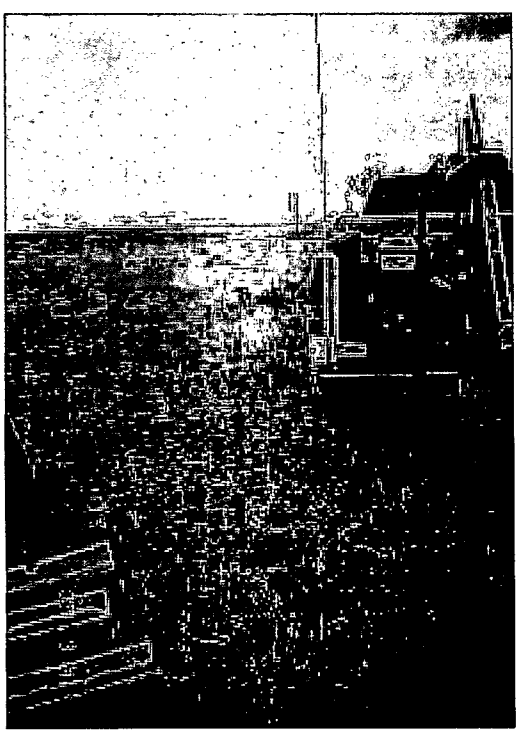

Photo 16: Hole 43 General View NW

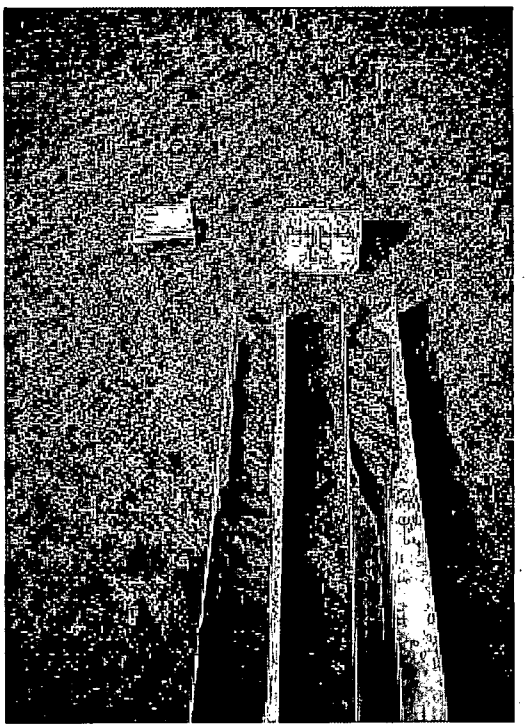

Photo 17: Hole 50 Profile

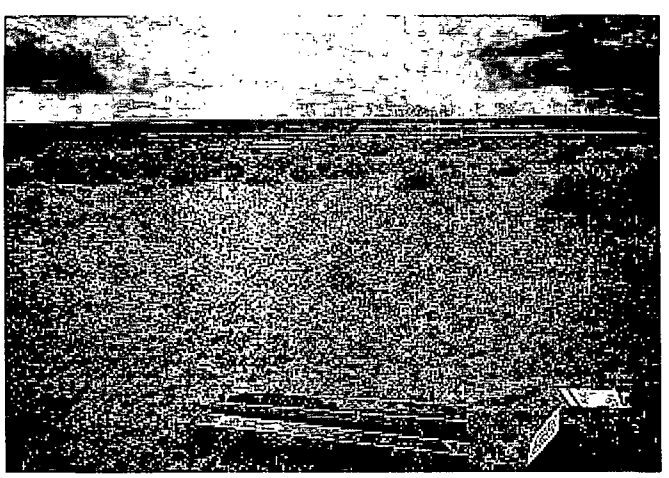

Photo 18: Hole 50 General View

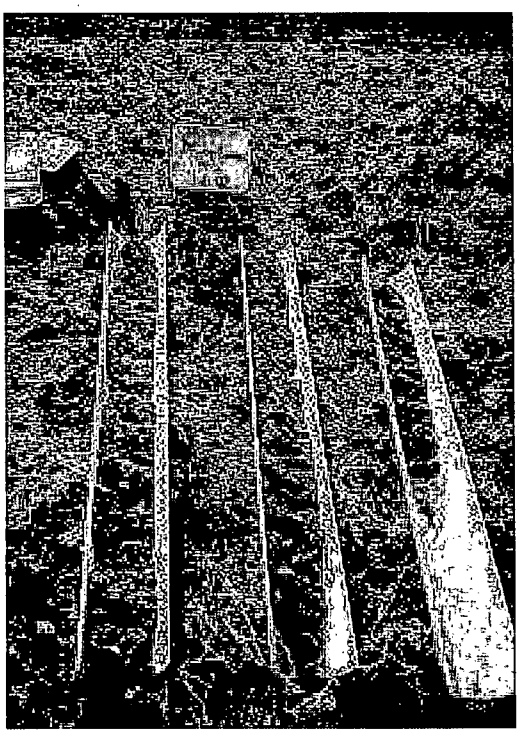

Photo 19: Hole 56 Profile

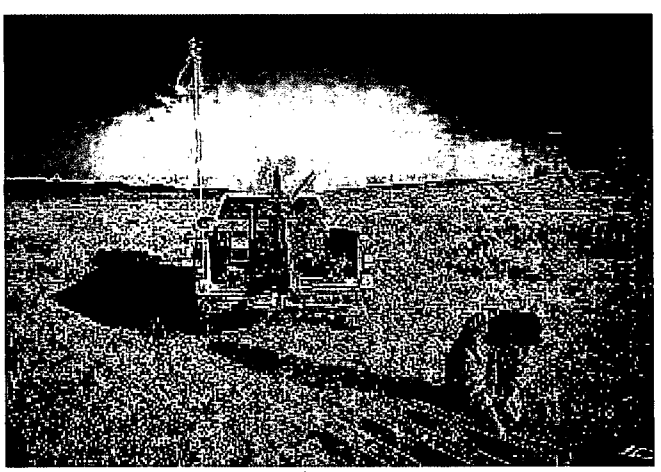

Photo 20: Hole 56 General View

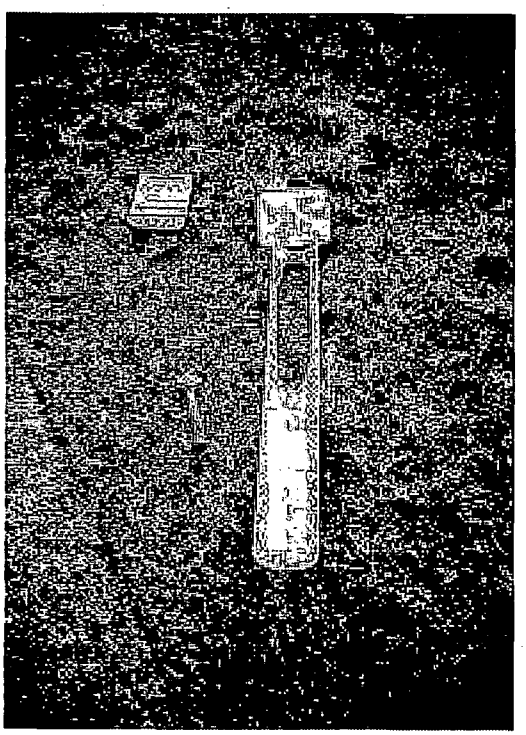

Photo 21: Hole 57 Profile

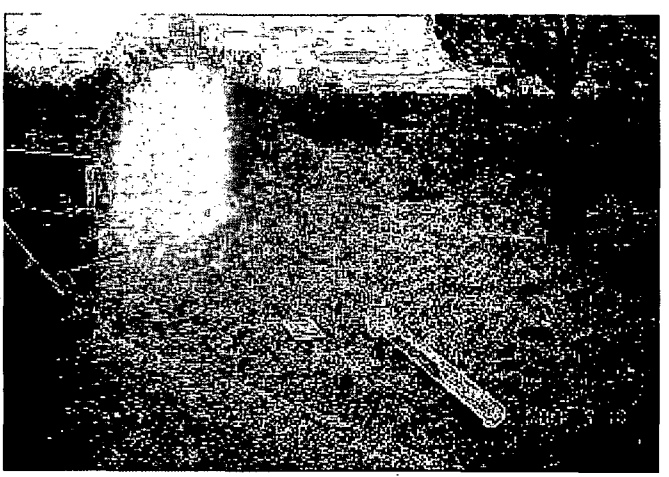

Photo 22: Hole 57 General View ESE

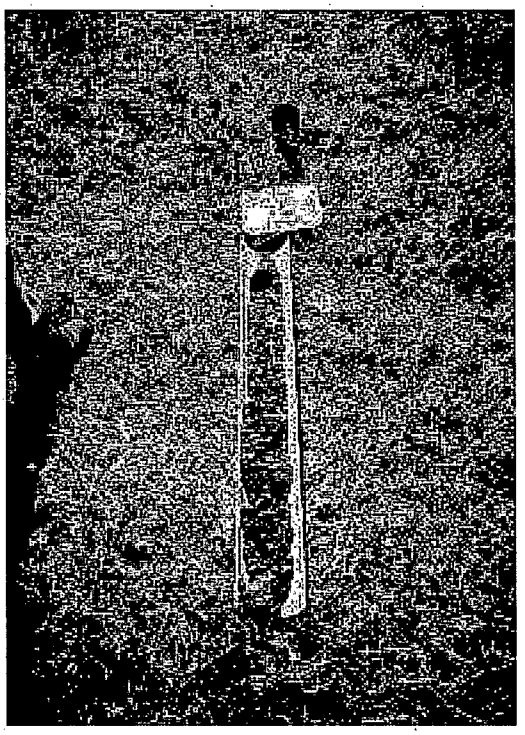

Photo 23: Hole 60 Profile

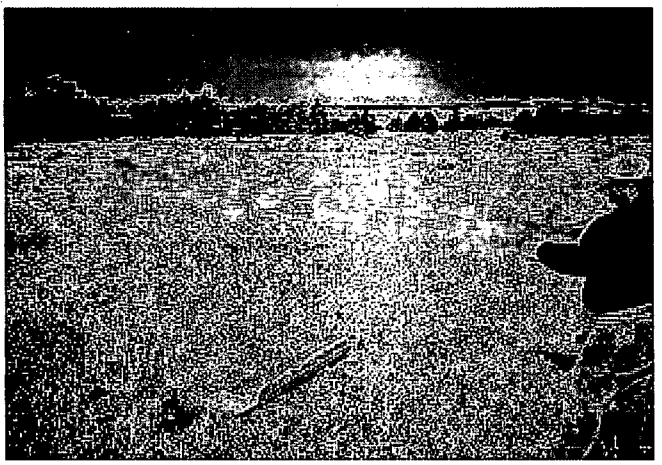

Photo 24: Hole 60 General View W

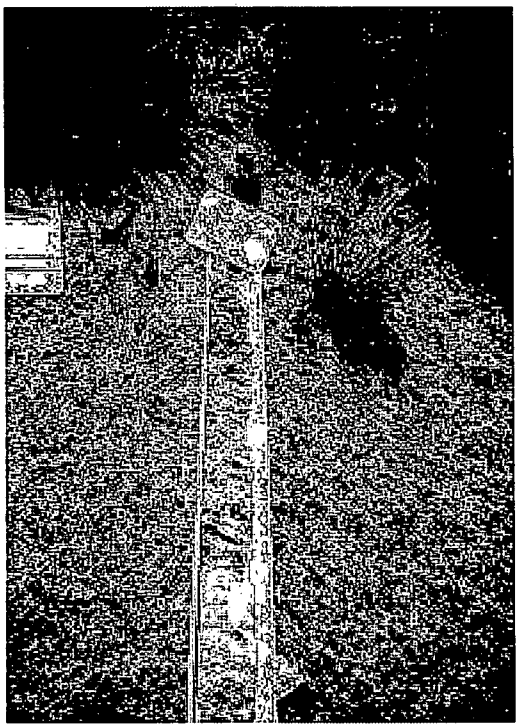

Photo 25: Hole 63 Profile

Photo 26: Hole 63 General View N

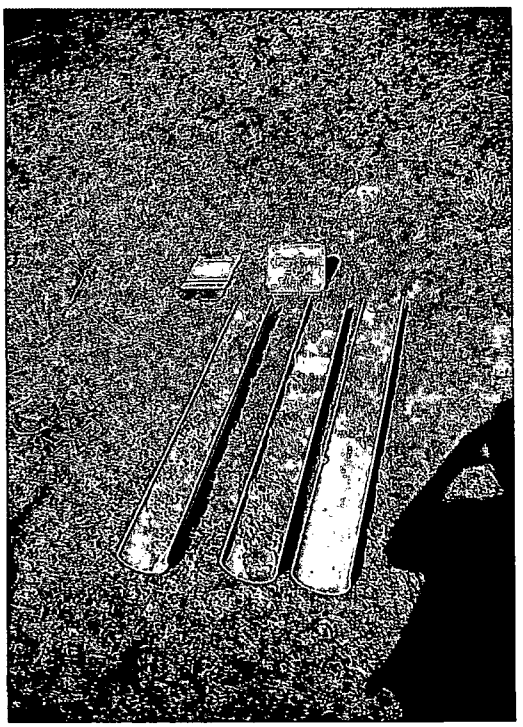

Photo 27: Hole 64 Profile

Photo 28: Hole 64 General View N

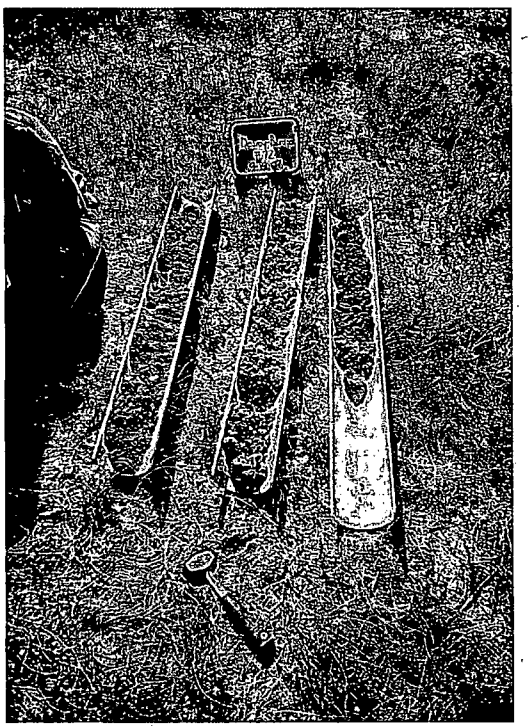

Photo 29: Hole 72 Profile

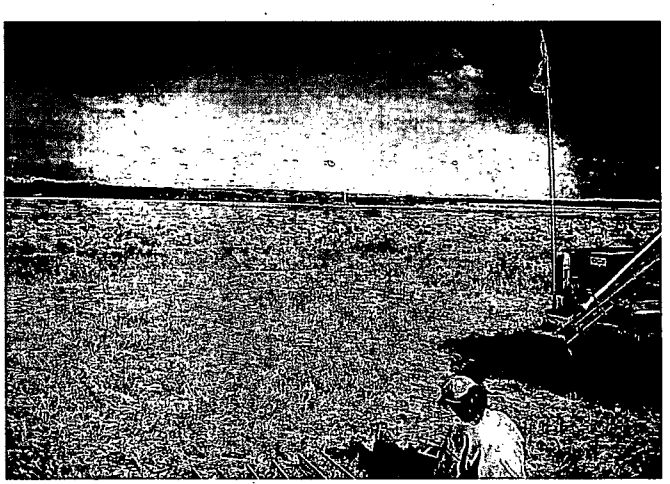

Photo 30: Hole 72 General View E

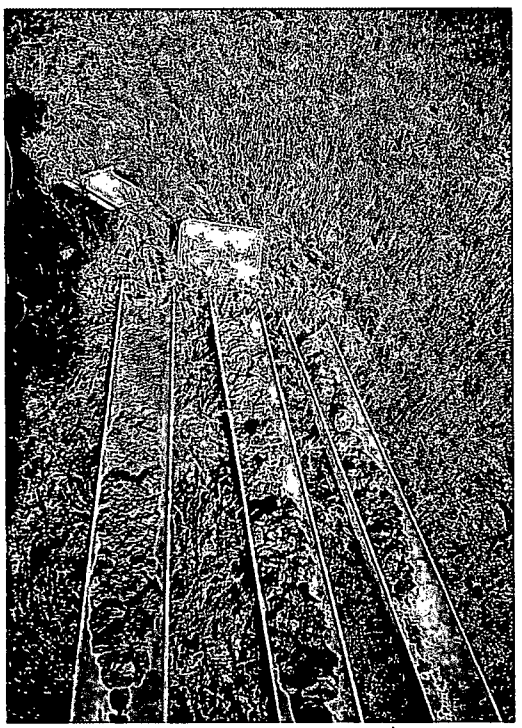

Photo 31: Hole 73 Profile

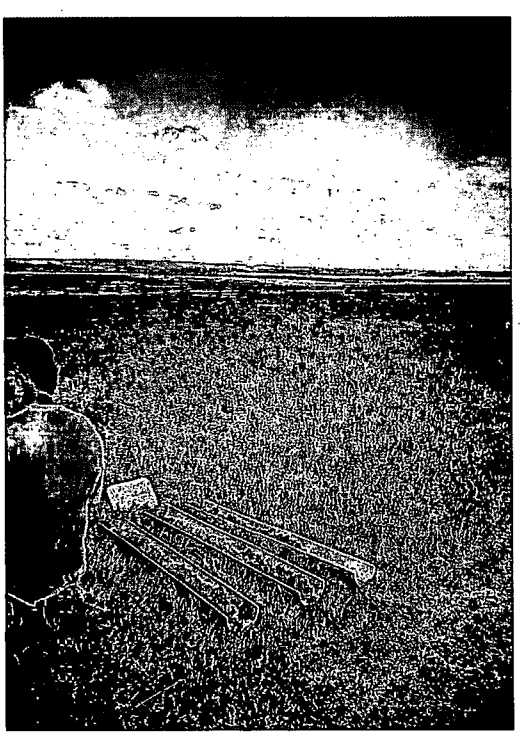

Photo 32: Hole 73 General View E

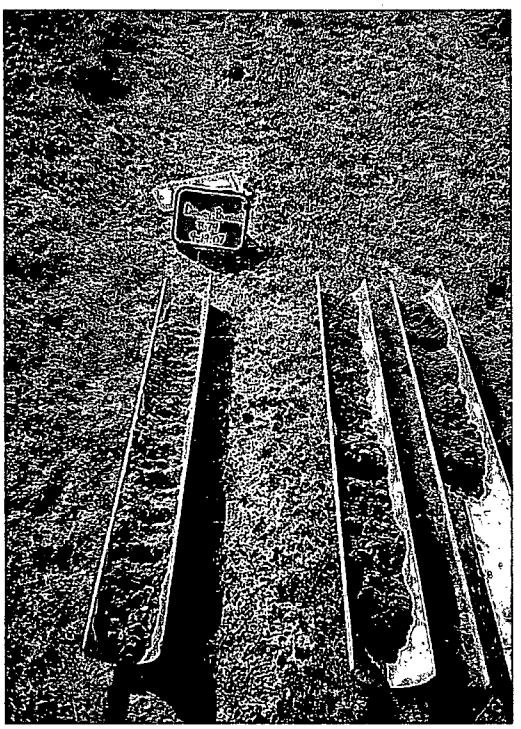

Photo 33: Hole 74 Profile

Photo 34: Hole 74 General View E

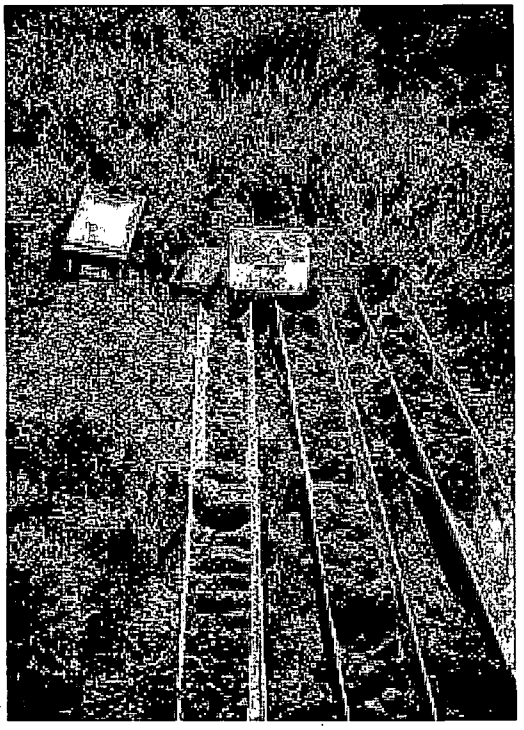

Photo 35: Hole 75 Profile

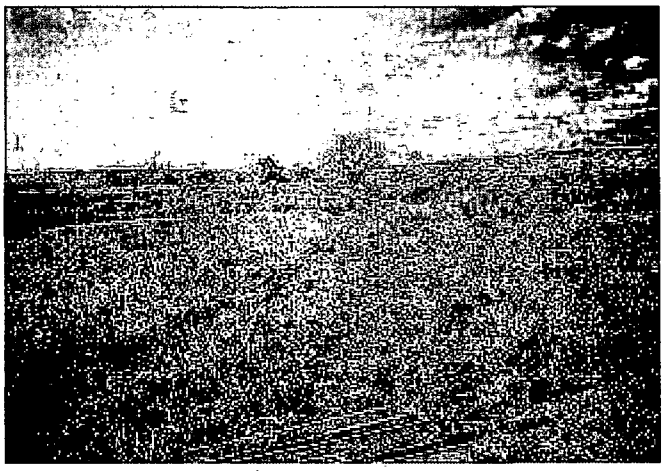

Photo 36: Hole 75 General View N

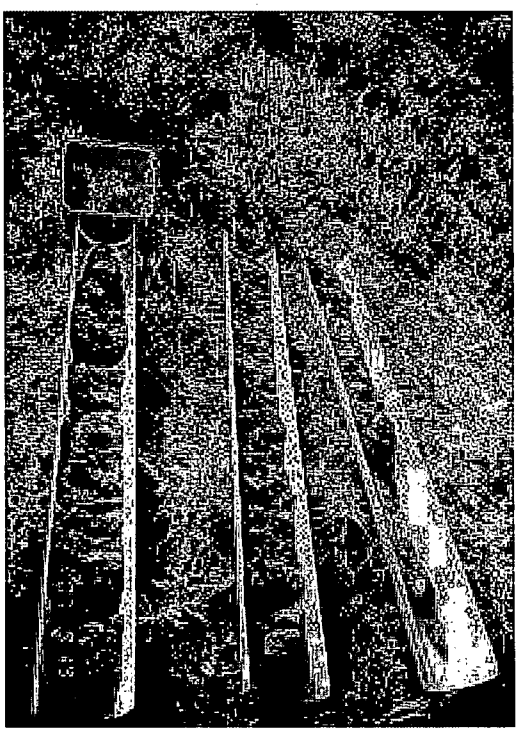

Photo 37: Hole 76 Profile

Photo 38: Hole 76 General View N

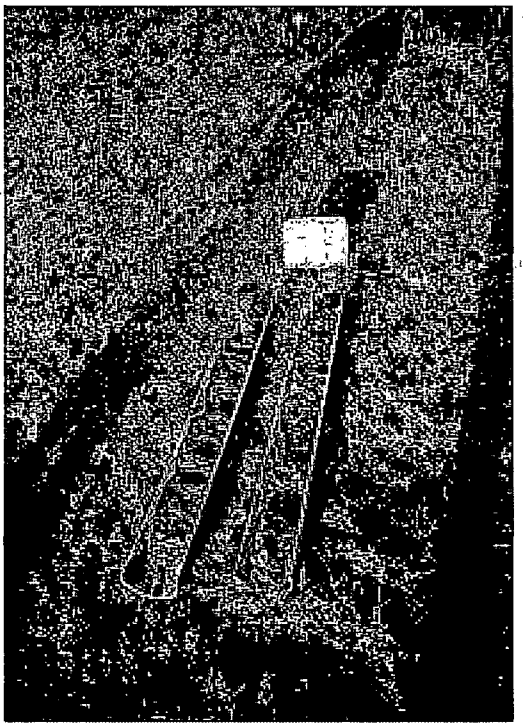

Photo 39: Hole 77 Profile

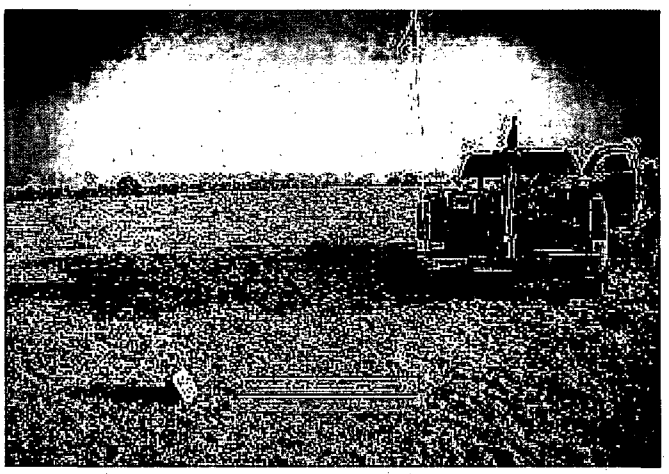

Photo 40: Hole 77 General View N

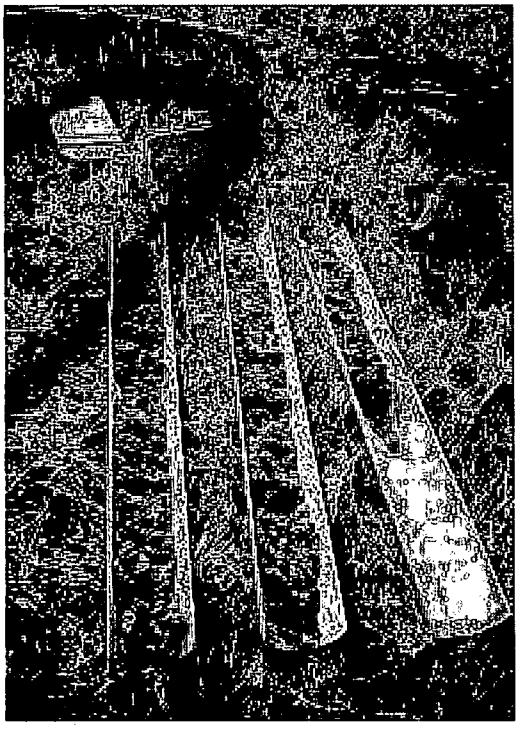

Photo 41: Hole 79 Profile

Photo 42: Hole 79 General View NE

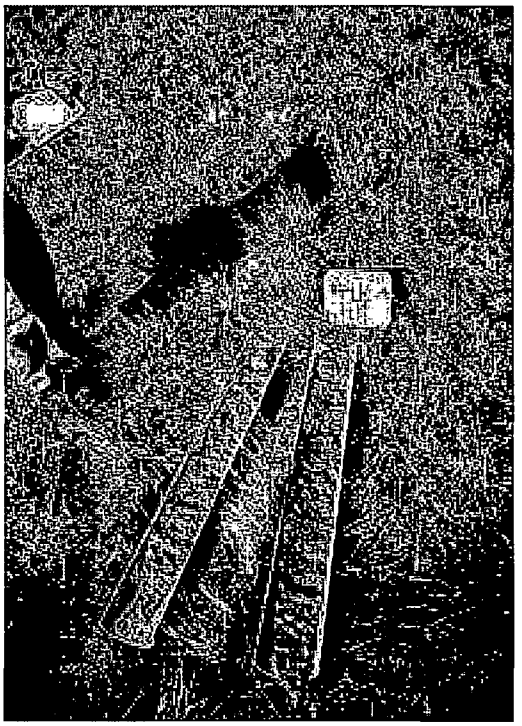

Photo 43: Hole 82 Profile

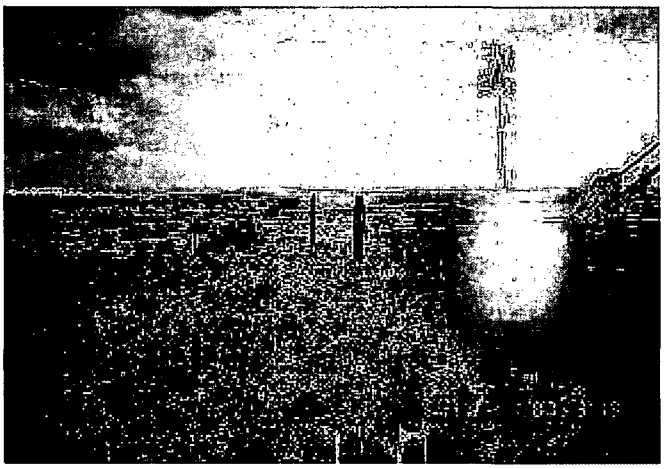

Photo 44: Hole 82 General View E

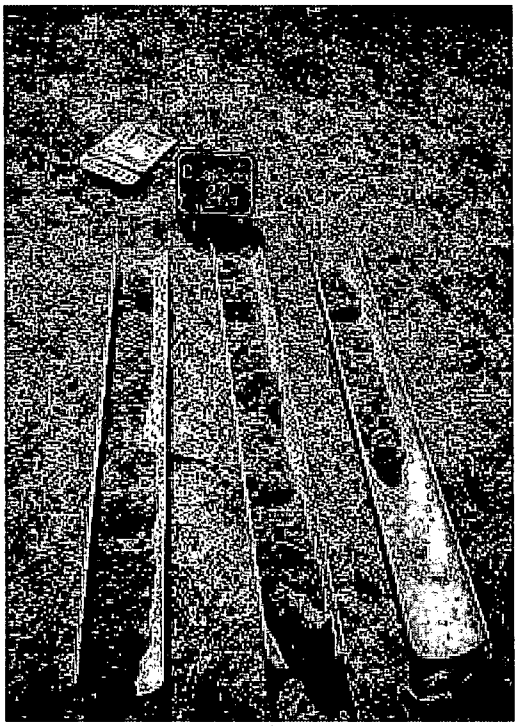

Photo 45: Hole 83 Profile

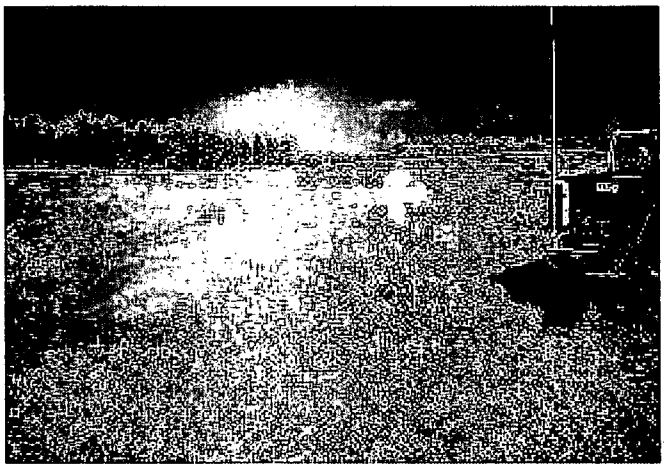

Photo 46: Hole 83 General View N

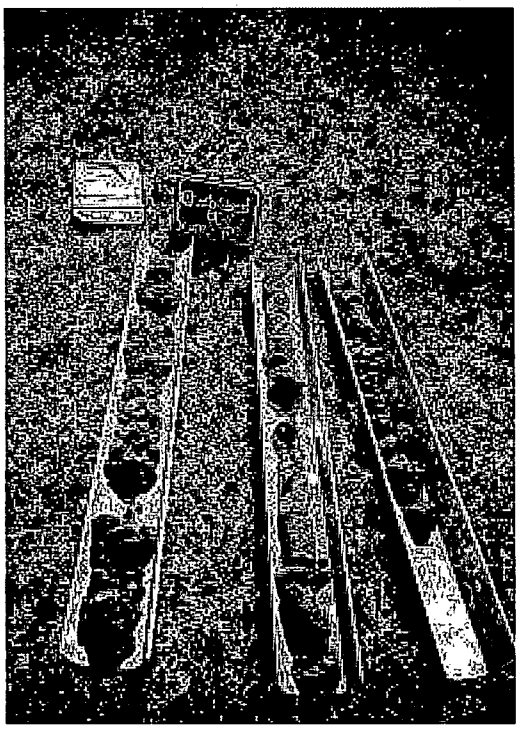

Photo 47: Hole 84 Profile

Photo 48: Hole 84 General View SE

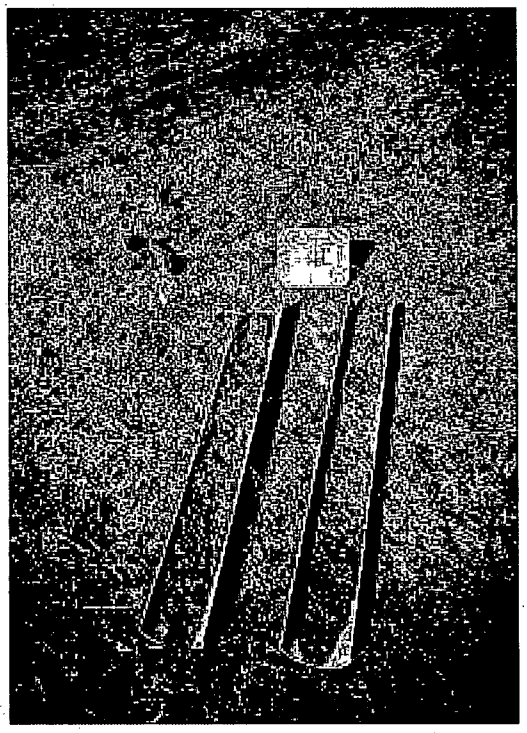

Photo 49: Hole 85 Profile

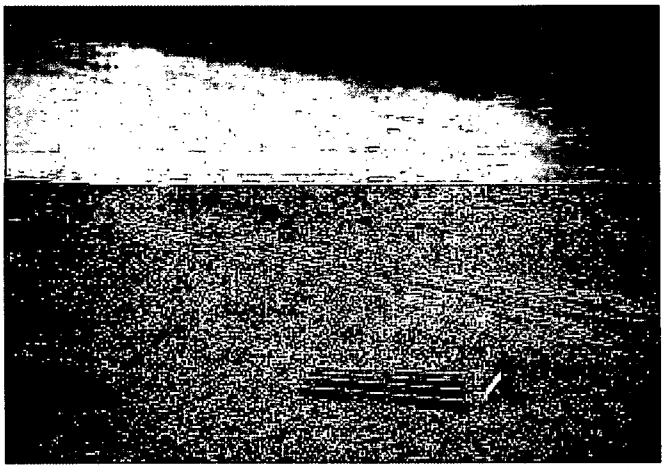

Photo 50: Hole 85 General View S

Photo 51: Hole 88 Profile

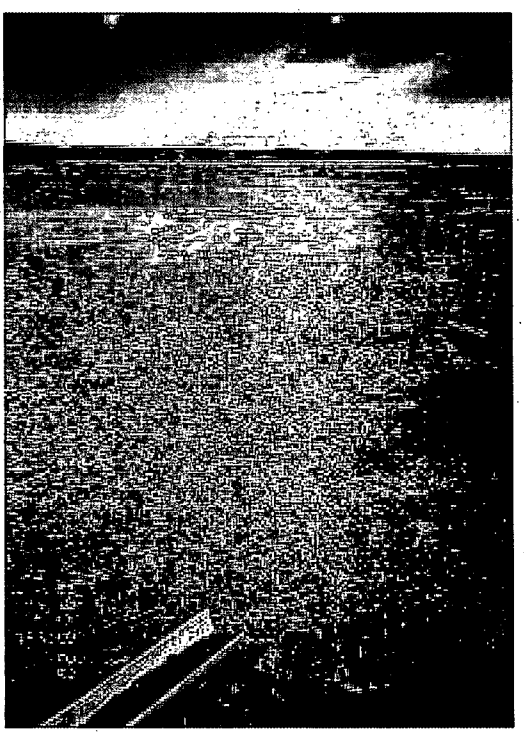

Photo 52: Hole 88 General View

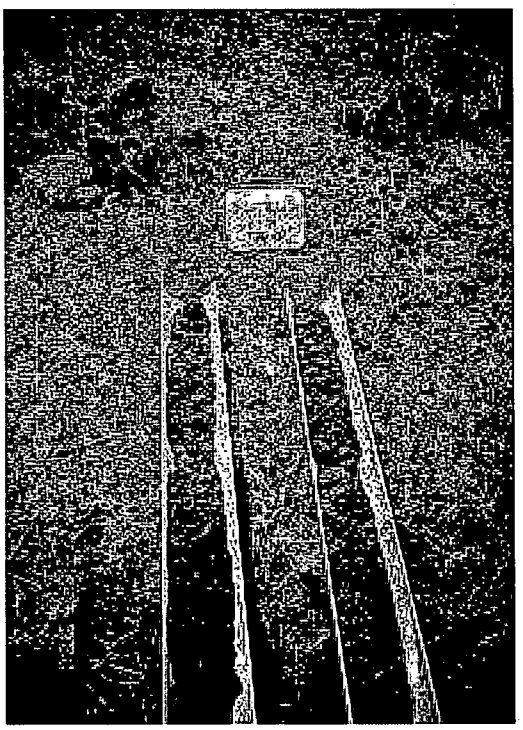

Photo 53: Hole 89 Profile

Photo 54: Hole 89 General View N

Photo 55: Hole 90 Profile

Photo 56: Hole 90 General View

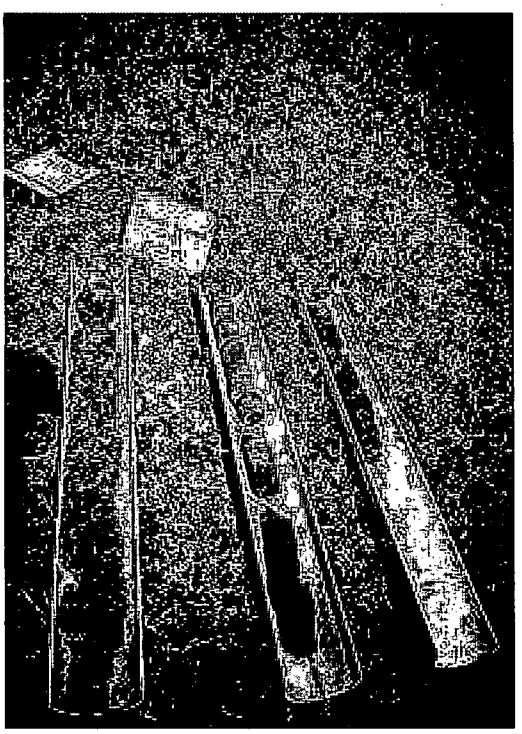

Photo 57: Hole 91 Profile

Photo 58: Hole 91 General View N

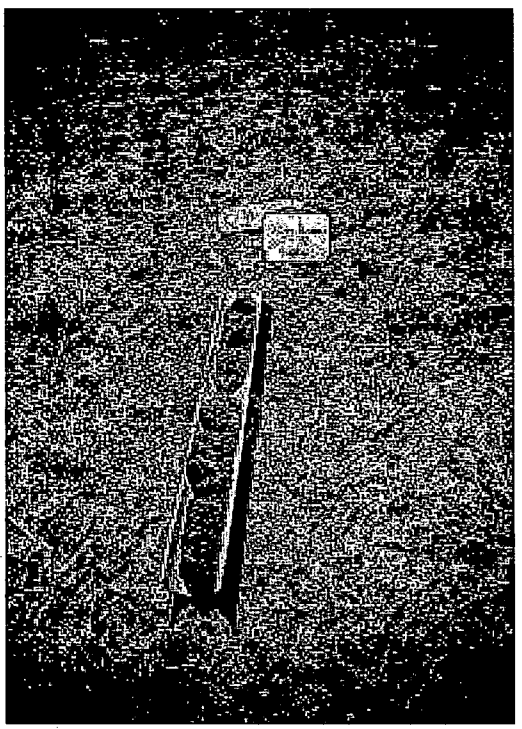

Photo 59: Hole 92 Profile

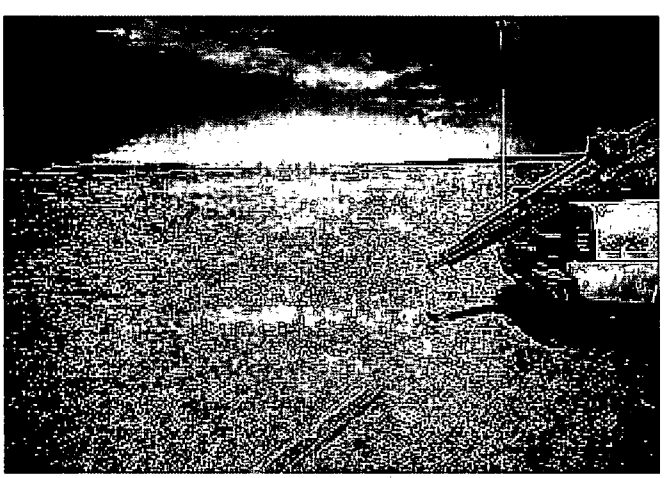

Photo 60: Hole 92 General View N

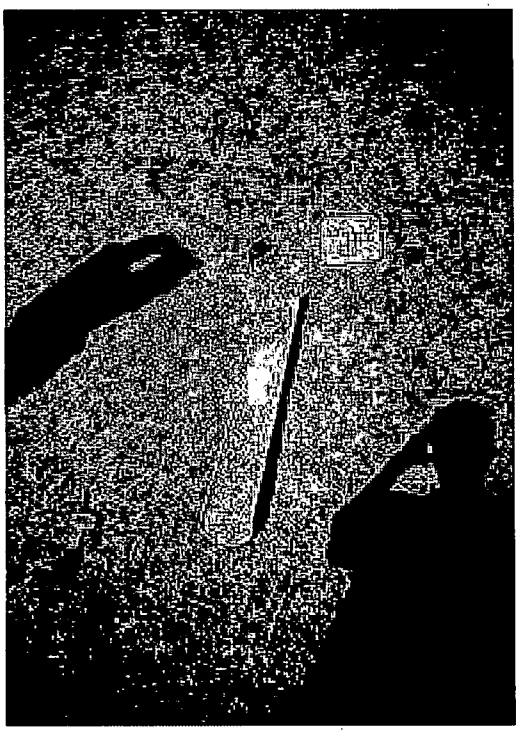

Photo 61: Hole 93 Profile

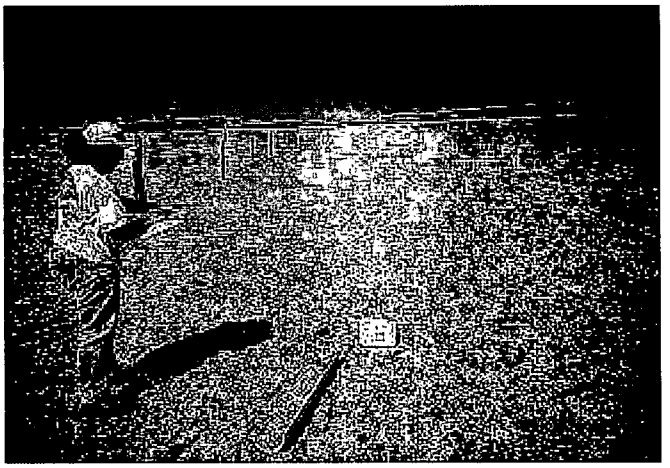

Photo 62: Hole 93 General View N

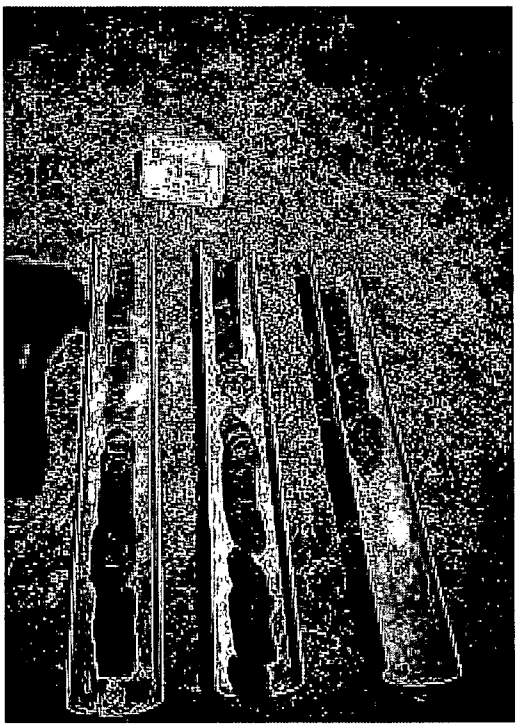

Photo 63: Hole 94 Profile

Photo 64: Hole 94 General View SSE

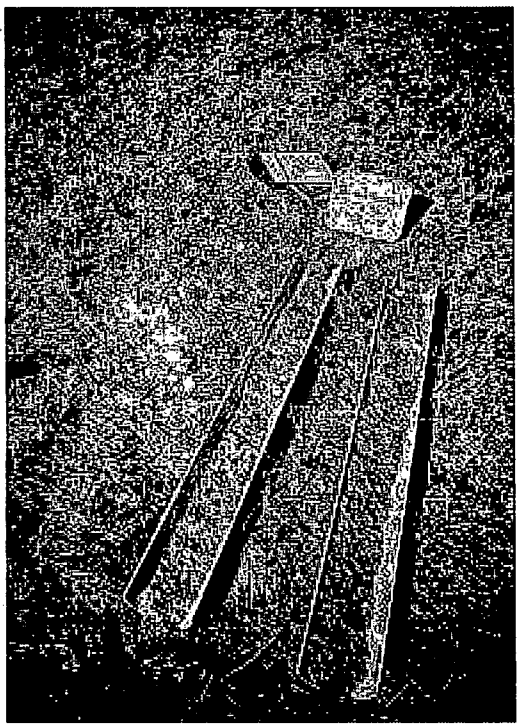

Photo 65: Hole 95 Profile

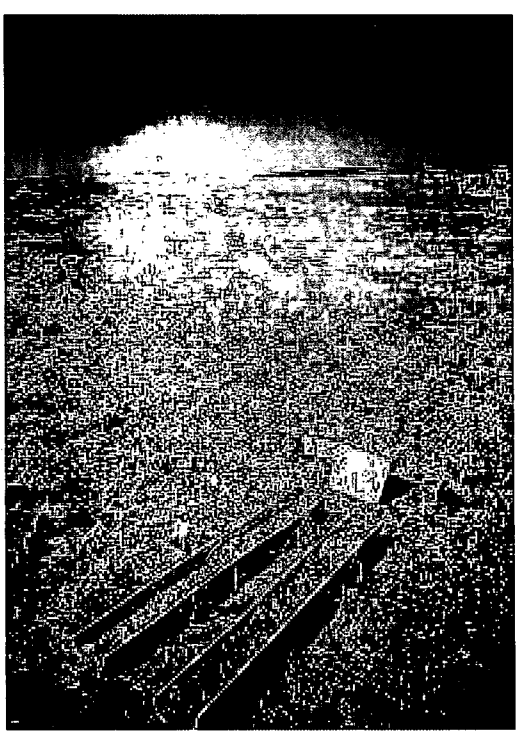

Photo 66: Hole 95 General View N

APPENDIX 2.6-G

USGS EARTHQUAKE DATABASE RESULTS

USGS science for a changing world

NEIC: Earthquake Search Results

U. S. GEOLOGICAL SURVEY

EARTHQUAKE DATA BASE

FILE CREATED: Mon Apr 7 18:18:37 2008
Circle Search Earthquakes= 10
Circle Center Point Latitude: 43.300N Longitude: 103.900W
Radius: 100.000 km
Catalog Used: PDE
Data Selection: Historical & Preliminary Data

CAT	YEAR	MO	DA	ORIG TIME	LAT	LONG	DEP	MAGNITUDE	IEFM NFPO TFS	DTSVNWG	DIST km
PDE	1975	05	16	055701.50	43.24	-103.68	5		4F	.....	19
PDE	1987	01	01	080224.07	42.79	-103.48	5	3.50 LgGS	3F	.....	66
PDE	1992	11	02	065410.34	42.74	-104.39	5	3.00 MLGS	5F	.....	73
PDE	1994	03	18	225143.15	43.40	-103.50	5	2.80 LgGS	.F	.....	34
PDE	1994	03	20	071506	43.40	-103.50	5	2.30 LgGS	.F	.....	34
PDE	1996	02	06	160836.75	43.98	-103.73	5	3.70 LgGS	5F	.....	76
PDE	1996	04	09	024808.19	43.07	-104.10	5	3.70 LgGS	3F	.....	30
PDE	1996	05	03	074751.53	43.04	-104.02	5	3.10 LgGS	..	.....	30
PDE	2004	01	05	025316.58	43.60	-104.00	5	2.80 LgGS	.F	.....	33
PDE	2004	01	24	040901.30	44.00	-103.20	5	2.50 LgGS	.F	.....	96

NEIC: Earthquake Search Results

U. S. GEOLOGICAL SURVEY

EARTHQUAKE DATA BASE

FILE CREATED: Wed Apr 16 16:32:15 2008
Circle Search. Earthquakes= 49
Circle Center Point Latitude: 43.300N Longitude: 103.900W
Radius: 200.000 km
Catalog Used: PDE
Data Selection: Historical & Preliminary Data

CAT	YEAR	MO	DA	ORIG TIME	LAT	LONG	DEP	MAGNITUDE	IEFM DTSVNWG DIST NFPO km TFS
PDE	1975	05	16	055701.50	43.24	-103.68	5		4F 19
PDE	1976	09	03	041816.20	44.04	-106.15	10	4.80 mb GS	.F 199
PDE	1978	01	16	035001.70	42.44	-105.32	5	3.00 MLGS	.F 150
PDE	1978	05	07	160619.60	42.30	-101.93	15	4.30 MLGS	5F 195
PDE	1981	09	13	221629.74	43.04	-101.85	5	3.40 LgTUL	5F 169
PDE	1983	02	13	134444.09	42.23	-105.73	5	4.00 MLGS	4F 190
PDE	1983	05	06	061446.95	42.96	-102.20	5	3.30 MLGS	 143
PDE	1983	11	15	123312.19	43.02	-105.96	5	3.00 MLGS	3F 170
PDE	1984	05	29	201832.68	44.23	-105.96	18	5.00 mb GS	5F 195
PDE	1984	10	18	153023.06	42.38	-105.72	33	5.50 MLGOL	6D M 180
PDE	1984	10	18	155737.38	42.37	-105.81	33	4.50 mb GS	.F 187
PDE	1984	10	18	173827.41	42.41	-105.77	33	3.80 MLGOL	 181
PDE	1984	10	19	162904.44	42.41	-105.77	33	3.30 MLGS	 182

```
PDE  1984  10 20 115108.63  42.40 -105.87  33 3.50 MLGS    .. . .......
189
PDE  1984  10 22 111756.30  42.40 -105.88  33 3.10 MLGS    .. . .......
190
PDE  1984  10 24 090354.78  42.32 -105.72  21 3.20 MLGS    .. . .......
184
PDE  1984  11 06 113852.51  42.31 -105.71  33 3.30 MLGS    .. . .......
184
PDE  1984  12 06 040452.33  42.44 -105.82  20 2.90 MLGS    .. . .......
183
PDE  1984  12 17 093132.24  42.36 -105.73  33 3.30 MLGS    .. . .......
182
PDE  1986  06 12 151434.03  42.40 -105.69  20 3.00 MLGS    .. . .......
177
PDE  1987  01 01 080224.07  42.79 -103.48   5 3.50 LgGS    3F. . .......
66
PDE  1989  02 09 051545.80  42.69 -101.90   5 3.80 LgGS    5F . .......
176
PDE  1990  01 28 045959.19  43.31 -102.50   5 4.00 LgTUL   5F . .......
113
PDE  1990  03 02 041527     43.30 -102.50   5 3.20 MLGS    4F . .......
113
PDE  1991  11 05 161849     44.35 -103.75   0 2.50 MLGS    .F . ....R..
117
PDE  1992  11 02 065410.34  42.74 -104.39   5 3.00 MLGS    5F .........
73
PDE  1993  02 24 235217.58  43.71 -105.29   0 3.60 MLGS    .F . ....E..
121
PDE  1993  06 30 065057.83  42.99 -105.37   5 3.00 MLGS    .. . .......
124
PDE  1993  07 23 063023.84  42.48 -105.70   5 3.70 MLGS    4F . .......
173
PDE  1993  09 05 081235.50  44.40 -103.80   5 2.70 MLGS    3F . .......
122
PDE  1993  10 10 041746.76  42.42 -105.87   5 3.70 MLGS    4F . .......
188
PDE  1993  12 13 145103.05  42.33 -105.50   5 3.50 MLGS    .. . .......
169
PDE  1994  03 18 225143.15  43.40 -103.50   5 2.80 LgGS    .F . .......
34
PDE  1994  03 20 071506     43.40 -103.50   5 2.30 LgGS    .F . .......
34
PDE  1996  02 06 160836.75  43.98 -103.73   5 3.70 LgGS    5F . .......
76
PDE  1996  04 09 024808.19  43.07 -104.10   5 3.70 LgGS    3F . .......
30
PDE  1996  05 03 074751.53  43.04 -104.02   5 3.10 LgGS    .. . .......
30
PDE  1996  10 19 132757.97  43.09 -106.06   5 4.20 MLGS    .F . .......
176
PDE  1998  06 18 162638.32  42.62 -103.00   5 3.40 LgGS    .F . .......
104
PDE  2000  04 13 181731.73  42.41 -105.81   5 3.30 MLGS    .. . .......
185
```

```
PDE  2003  02 01 184411.53  43.08 -106.18   5 3.70 MLGS    .F . .......
186
PDE  2003  05 25 073233.39  43.09 -101.79   5 4.00 LgGS    4F . .......
172
PDE  2004  01 05 025316.58  43.60 -104.00   5 2.80 LgGS    .F . .......
33
PDE  2004  01 24 040901.30  44.00 -103.20   5 2.50 LgGS    .F . .......
96
PDE  2004  02 15 031818.02  42.94 -105.40  10 3.50 MLGS    3F . .......
128
PDE  2004  08 29 184944.26  42.89 -105.49   5 3.80 MLGS    4F . .......
136
PDE  2006  09 07 062320.02  42.98 -102.24   5 2.60 LgGS    .. . .......
140
PDE  2007  02 07 103558.70  44.03 -102.58   5 3.10 LgGS    3F . .......
134
PDE  2007  04 24 093501.26  42.58 -102.94   5 2.70 LgGS    .. . .......
111
```

APPENDIX 2.7-A

WATER LEVELS IN INYAN KARA WELLS

POWERTECH (USA) INC.

Appendix 2.7-A
Water Levels in Inyan Kara Wells

Well No.	12	38	49	607	608	609	610	613	614	615	619	622	628	631
Formation	Lakota	Lakota	Fall River	Fall River	Lakota	Lakota	Fall River	Fall River	Fuson	Lakota	Lakota	Fall River	Inyan Kara	Fall River
SubSurface (SS) or Free-Flowing (FF)	FF	FF	FF	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Targeted Measurement Frequency	Quarterly	Quarterly	Quarterly	Monthly	Monthly	Monthly	Monthly	Quarterly	Quarterly	Monthly	Quarterly	Monthly	Quarterly	Quarterly
Surveyed Well Casing Elevation, ft	3641.14		3620.86	3610.55	3609.26	3700.67	3704.85	3736.93	3741.16	3741	3700.12	3753.28	3731.99	3745.37
Stick Up (Well Casing Mark), ft	-0.58			-0.07	-0.08	-0.1	-0.49	-0.45	-0.11	-0.54	0	-0.46	-0.56	-0.33
Surveyed Control Point Elevation, ft		3637.49	3618.86											
Stick Up (Control Point), ft		-2.15												
Calculated Measuring Point Elevation, ft	**3641.72**	**3639.64**	**3618.86**	**3610.62**	**3609.34**	**3700.77**	**3705.34**	**3737.38**	**3741.27**	**3741.54**	**3700.12**	**3753.74**	**3732.55**	**3745.7**
Well No.	12	38	49	607	608	609	610	613	614	615	619	622	628	631
Units	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet
9/25/2007		3644.25	3640.54			3690.47	3692.81	3701.3	3700.14	3691.6			3695.95	
9/26/2007														3715.79
9/27/2007	3653.72										3679.13		3695.72	
10/2/2007														
10/9/2007														
10/26/2007				3584.35		3690.52	3692.81							
11/9/2007	3653.26	3644.02	3641.93	3584.61							3679.19			3715.85

POWERTECH (USA) INC.

Appendix 2.7-A
Water Levels in Inyan Kara Wells

Well No.	12	38	49	607	608	609	610	613	614	615	619	622	628	631
Formation	Lakota	Lakota	Fall River	Fall River	Lakota	Lakota	Fall River	Fall River	Fuson	Lakota	Lakota	Fall River	nyan Kara	Fall River
11/14/2007						3690.27	3690.12						3694.86	3715.85
11/19/2007								3701.07	3700.07	3691.85				
11/27/2007													3696.44	
12/11/2007						3690.21	3693.83						3696.24	
1/11/2008								3701.39	3700.08	3690.42				
1/30/2008				3585.69		3689.85	3694.98							
2/3/2008														
2/5/2008												3710.04		
2/20/2008						3688.25	3694.6						3696.07	3715.68
2/21/2008			3641.52	3585.21										
3/6/2008						3689.55	3692.63	3701.08	3700.01	3691.08				3712.68
3/9/2008				3584.9										
3/24/2008														
3/30/2008														
3/31/2008														
4/1/2008										3691.03		3709.1		
4/21/2008										3690.99		3709.52		
4/22/2008														
4/29/2008				3585.21	3584.19	3689.81	3692.64							
5/8/2008														
5/12/2008														
5/19/2008						3689.45	3692.32							3713.64
5/21/2008														
5/28/2008								3701.23	3699.92	3690.47		3709.32		
5/29/2008													3695.87	
5/30/2008														
6/1/2008														
6/9/2008				3585.27	3584.45									
6/10/2008														
6/23/2008														

POWERTECH (USA) INC.

Appendix 2.7-A
Water Levels in Inyan Kara Wells

Well No.	12	38	49	607	608	609	610	613	614	615	619	622	628	631
Formation	Lakota	Lakota	Fall River	Fall River	Lakota	Lakota	Fall River	Fall River	Fuson	Lakota	Lakota	Fall River	nyan Kara	Fall River
6/24/2008														
6/25/2008								3701.18	3699.89	3690.06		3709.14		
6/30/2008	3652.22	3643.95	3639.69			3689.09	3692.45							
7/1/2008														
7/13/2008														
7/14/2008										3689.69		3709.29		
7/28/2008				3585.49	3584.47	3688.86	3692.22							
n	3	3	4	8	3	11	11	6	6	9	2	6	7	6
Average	3653.06	3644.07	3640.92	3585.09	3584.37	3689.67	3692.86	3701.21	3700.02	3690.8	3679.16	3709.4	3695.87	3714.92

Notes: Water surface elevation (WSE) calculated by subtracting depth measurement from or adding pressure measurement (converted to water head in feet) to measuring point elevation (MPE).

WSE = MPE +/- (measured depth or measured pressure)

Conversion of pressure measurement (psi) to head (ft) uses density of water at 4C

POWERTECH (USA) INC.

Appendix 2.7-A
Water Levels in Inyan Kara Wells

Well No.	650	668	680	681	685	688	689	694	695	696	697	698	3026	8002	8003
Formation	Lakota	Inyan Kara	Lakota	Fall River	Fall River	Fall River	Lakota	Fall River	Fall River	Lakota	Lakota	Fall River	Lakota	Lakota	Unknown
SubSurface (SS) or Free-Flowing (FF)	SS	FF	SS	FF	FF	SS	FF	FF	FF	FF	FF	SS	SS	FF	FF
Targeted Measurement Frequency	Quarterly	Quarterly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly	Quarterly	Quarterly
Surveyed Well Casing Elevation, ft			3701.94	3626.99	3627.85	3701.26	3627.27	3598.29	3597.8	3597.96	3597.69	3714.25	3820.48		
Stick Up (Well Casing Mark), ft			0.26	-0.15	-0.12	-0.04	-0.12	-1.71	-3.13	-1.94	-2.56	-0.23	-0.2		
Surveyed Control Point Elevation, ft	3821.06	3624.14												3543.42	3543.16
Stick Up (Control Point), ft	-0.56	-1.17												-1.43	-1.34
Calculated Measuring Point Elevation, ft	**3821.62**	**3625.31**	**3701.68**	**3627.14**	**3627.97**	**3701.3**	**3627.39**	**3600**	**3600.93**	**3599.9**	**3600.25**	**3714.48**	**3820.68**	**3544.85**	**3544.5**
Well No.	650	668	680	681	685	688	689	694	695	696	697	698	3026	8002	8003
Units	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet	Feet
9/25/2007															
9/26/2007														3574.83	
9/27/2007															
10/2/2007	3682.35														
10/9/2007		3650.68													
10/26/2007															
11/9/2007	3682.35	3650.68													

POWERTECH (USA) INC.

Appendix 2.7-A
Water Levels in Inyan Kara Wells

Well No.	650	668	680	681	685	688	689	694	695	696	697	698	3026	8002	8003
Formation	Lakota	Inyan Kara	Lakota	Fall River	Fall River	Fall River	Lakota	Fall River	Fall River	Lakota	Lakota	Fall River	Lakota	Lakota	Unknown
11/14/2007															
11/19/2007															
11/27/2007		3652.99													
12/11/2007														3579.45	
1/11/2008			3662.69												
1/30/2008			3662.68												
2/3/2008			3662.73												
2/5/2008														3578.64	3563.35
2/20/2008	3682.13														
2/21/2008															
3/6/2008															
3/9/2008		3649.88	3662.41												
3/24/2008	3681.92														
3/30/2008								3648.48	3634.12		3679.14	3680.02	3681.89		
3/31/2008			3662.33												
4/1/2008															
4/21/2008			3660.88			3662.22									
4/22/2008									3630.68		3679.85	3679.98	3681.77		
4/29/2008															
5/8/2008							3685.02								
5/12/2008				3644.75											
5/19/2008									3630.26						
5/21/2008								3648.09			3679.6		3682.13		
5/28/2008						3661.26						3679.68	3681.73		
5/29/2008															
5/30/2008	3682														
6/1/2008			3661.85												
6/9/2008															
6/10/2008			3660.56			3669.41									
6/23/2008									3631.05						

Appendix 2.7-A
Water Levels in Inyan Kara Wells

Well No.	650	668	680	681	685	688	689	694	695	696	697	698	3026	8002	8003
Formation	Lakota	Inyan Kara	Lakota	Fall River	Fall River	Fall River	Lakota	Fall River	Fall River	Lakota	Lakota	Fall River	Lakota	Lakota	Unknown
6/24/2008								3648.81			3680.8	3679.88	3681.85		
6/25/2008				3642.95		3662.45	3685.6								
6/30/2008		3649.65				3662.01									
7/1/2008				3641.99			3685.43								
7/13/2008									3631.95				3681.78		
7/14/2008				3639.89			3681.62	3648.63			3680.66	3679.87			
7/28/2008						3662.68									
n	5	5	8	4	0	6	4	4	5	0	5	5	6	3	1
Average	**3682.2**	**3650.8**	**3662**	**3642.4**		**3663.3**	**3684.4**	**3648.5**	**3631.6**		**3680**	**3679.9**	**3681.9**	**3577.6**	**3563.4**

Water surface elevation (WSE) calculated by subtracting depth measurement from or adding pressure measurement (converted to water head in feet) to measuring point elevation (MPE).

WSE = MPE +/- (measured depth or measured pressure)

Conversion of pressure measurement (psi) to head (ft) uses density of water at 4C

Head (feet of H2O) = Measured Pressure (lb / in^2) x 144 (in^2 / ft^2) x 0.01602 (ft^3 / lb)

APPENDIX 2.7-B

2008 PUMPING TESTS: RESULTS AND ANALYSIS

Knight Piésold
CONSULTING

Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests:
Results and Analysis

November 2008

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Project DV102.00279.01

Rev. No.	Date	Description	Knight Piésold	Client
0	November 2008	Final to Client	Paul Bergstrom	Powertech (USA)

Knight Piésold CONSULTING

Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests:
Results and Analysis

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Knight Piésold
CONSULTING

Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests:
Results and Analysis

1.0 Introduction

Powertech Uranium Corp. (Powertech) is submitting an application to the United States Nuclear Regulatory Commission (USNRC) for the Radioactive Source Materials License to develop and operate the Dewey-Burdock Uranium Project using in-situ recovery (ISR) methods. The project is located near Edgemont, South Dakota in Custer and Fall River Counties and will consist of injection and production well fields and a central processing plant (ion exchange resin columns and yellowcake dryer) to recover the final uranium product.

Figure 1.1 shows the project location and license boundary. The Project is located approximately 12 miles north-northwest of Edgemont, South Dakota and spans northern Fall River and southern Custer Counties. The project boundary encompasses approximately 11,000 acres of private land on either side of County Road 6463. The Dewey-Burdock project will operate uranium ISR production facilities at both the Dewey and Burdock project areas, with a central processing plant located at the Burdock site. It is anticipated that the ISR well fields at each site will operate at an estimated flow rates of between 1500 gallons per minute (gpm) to 2000 gpm. Net withdrawal of groundwater during ISR leaching operations is expected to be 0.5 to 3 percent of total flow, or 10 to 60 gpm at each site. Total production from both sites is expected to produce approximately 1,000,000 pounds of U_3O_8 per year.

1.1 Objectives

USNRC NUREG 1569 Sections 2.7.2 and 2.7.3, Hydrology, Review Procedures (3) and Acceptance Criteria (3), describe the type of information and analyses that can fulfill the requirements for a description of Site hydrogeology. Consistent with the examples provided in the NUREG sections referenced above, the objective of this report is to provide the determinations of aquifer properties obtained with two pumping tests together with the results of laboratory tests Powertech conducted on related core samples. The pumping tests are interpreted in the context of geological and hydrogeological data that are summarized here and presented authoritatively in greater detail in NRC Technical Report Sections 2.6 and 2.7. The more detailed information presented outside this report consists of: (1) geologic cross-sections, including the underlying electric log data from test pumping wells, test observation wells and

nearby exploration boreholes; (2) isopach maps of the production zone, overlying confining units and aquifers and underlying confining units and aquifers; and (3) potentiometric surface maps of the major aquifers.

Other information prescribed in NUREG 1569 Section 2.7.1, Hydrology, Areas of Review (3), notably soil survey and baseline groundwater quality information, is presented in separate reports. It is noted that the pumping tests described here are not intended to replace well field-scale pumping tests that are proposed to be conducted prior to startup of each particular mine unit. The following information is included in this report:

- Site location maps
- A summary of previous pumping test results
- A synopsis of geologic and hydrogeologic information for the Project Area relevant to the interpretation of pumping tests, including detailed conceptual stratigraphic cross-sections illustrating the test layouts relative to ore-body features
- Presentation of the pumping test results, including raw test data (drawdown graphs) that provide overall response characteristics for all wells monitored during the tests
- Interpretation of aquifer parameters using type curve matches and other methods of parameter determinations
- Interpretation, based on the communication of pumping and observation wells that it is likely feasible to conduct ISR mining within limited portions of the major aquifers
- Interpretation, based on the pumping test data and laboratory core data, that there is likely additional vertical containment between major aquitards overlying and underlying the major aquifers

1.2 Report Organization

This report includes seven sections. Section 1 (this section) is the introduction. Section 2 describes site-specific geologic and hydrogeologic conditions followed by a summary of previous aquifer tests in the period 1979 to 1982. Section 3 describes the general procedures for well installation, test equipment used, background measurements, and data processing procedures for the pumping tests. Details of the background monitoring and analysis are provided in Appendix A-1, and Appendix A-2 provides an overview of pumping test interpretation methods, theoretical considerations, and spreadsheet tools used for test analysis. Section 4 describes the results and analysis of the pumping test at the Dewey test location; Appendix B provides backup data for the Dewey Pumping Test including well completion

diagrams, processed time-drawdown data used to perform the test analysis, and the determinations of aquifer parameters with graphical methods not directly presented in the text. Similarly, Section 5 describes the results and analysis at the Burdock test location and Appendix C provides the related data for the Burdock test. Section 6 is a summary of laboratory core testing information and Appendix D provides the laboratory data report for the core testing. Section 7 is a summary describing major conclusions from the testing. Appendix E is a CD-ROM that contains the raw digital pressure transducer data in binary files.

1.3 Limitations and Disclaimer

This report entitled "Powertech (USA) Inc., Dewey-Burdock Project, 2008 Pumping Tests: Results and Analysis" has been prepared by Knight Piésold and Co. for the exclusive use of Powertech (USA) Inc. No other party is an intended beneficiary of this report or the information, opinions, and conclusions contained herein. Any use by any party other than Powertech (USA) Inc. of any of the information, opinions, or conclusions is the sole responsibility of said party. The use of this report shall be at the sole risk of the user regardless of any fault or negligence of Powertech (USA) Inc. or Knight Piésold and Co.

The information and analyses contained herein have been completed to a level of detail commensurate with the objectives of the assignment. This report and its supporting documentation have been reviewed and/or checked for conformance with industry-accepted norms and applicable government regulations. Calculations and computer simulations have been checked and verified for reasonableness, and the content of the report has been reviewed for completeness, accuracy, and appropriateness of conclusions. To the best of the information and belief of Knight Piésold and Co. the information presented in this report is accurate to within the limitations specified herein.

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2.0 Site Characterization

This section presents a synopsis of geologic and hydrogeologic information. Section 2.1 presents geologic information (see Figure 2.2) taken from Section 2.6 of the USNRC Technical Report. Section 2.2 presents hydrogeologic information presented in Section 2.7 of the Technical Report. Section 2.3 describes the history of previous aquifer testing in relation to uranium exploration and development.

2.1 Stratigraphy

The sedimentary rocks of interest that underlie the Dewey-Burdock Project range in age from Upper Jurassic to Early Cretaceous. These are the Upper Jurassic Sundance Formation, the Unkpapa Formation, and the Morrison Formation. The Early Cretaceous Lakota Formation, the Fall River Formation, the Skull Creek Shale Formation and the Mowry Shale Formation. Figure 2.1.

Underlying these, are rocks that range in age from Cambrian to Pennsylvanian in age. The sediments exposed at the Dewey-Burdock Project are of Early Cretaceous age.

2.1.1 Overlying Unit: Skull Creek Formation Shales

The combined Skull Creek Shale – Mowry Shale reaches a thickness of 400 ft (ft) in the western part of the Dewey-Burdock project.

Mowry Shale

The Mowry Shale consists of light gray marine shale with minor amounts of siltstone, fine grained sandstone, and a few thin beds of bentonite.

Newcastle Sandstone Formation

The Newcastle Sandstone, normally occurring between the Skull Creek Shale and the Mowry Shale, is composed of fine-grained sandstone interbedded with siltstones. This formation is discontinuous across the region and is absent across the project area. At the Dewey-Burdock Project the Skull Creek Shale is directly overlain by the Mowry shale.

Skull Creek Shale Formation

The Skull Creek Shale is a sequence of dark-gray to black marine shales. The Skull Creek shale consists of black shale, organic material, and some silt sized quartz grains. The Skull Creek

Shale has a thickness of approximately 200 ft. The Skull Creek Shale is eroded from the eastern parts of the project.

2.1.2 Inyan Kara Group: Fall River Formation and Lakota Formation Sandstones

Inyan Kara Group

The Early Cretaceous Inyan Kara Group consists of two formations, the Lakota and the Fall River. The Inyan Kara is composed of interbedded sandstone siltstone and shale. The depositional environment of the Inyan Kara is fluvial to marginal marine.

Fall River Formation

The Fall River formation is composed of carbonaceous interbedded siltstone and sandstone, channel sandstones, and a sequence of interbedded sandstone and shale. The lower part of the Fall River consists of dark carbonaceous siltstone interbedded with thin laminations of fine-grained sandstone. Channels were cut into this interbedded sequence by northwest flowing rivers and fluvial sandstones were deposited. These channel sandstones occur across various parts of the Dewey-Burdock Project and generally contain the uranium deposits. Overlying the channel sandstones is another sequence of alternating sandstone and shales.

Lakota Formation

The Lakota Formation consists of three members, from lower to upper is the **Chilson** Member, the **Minnewasta Limestone** Member and the **Fuson** Member.

The **Minnewasta Limestone** Member is not present in the Dewey-Burdock Project area.

The **Chilson** Member is composed largely of fluvial deposits. These deposits consist of sandstone, shale, siltstone, and shale. The unit consists of a complex of channel sandstone deposits and their fine-grained equivalents. The unit contains uranium deposits.

The **Fuson** Member is the upper most member of the Lakota Formation and the shale-siltstone portion of the Fuson has been used to divide the Lakota Formation from the Fall River Formation.

The Fuson is described as having a lower discontinuous sandstone unit at its' base and an upper discontinuous sandstone at the top of the member. If present the lower sandstone unit was

mapped as a Lakota sandstone. Similarly if the upper sandstone was present it was mapped as a Fall River sandstone. The Lakota was deposited by a northwest flowing river system.

2.1.3 Underlying Units: Morrison Formation Shale and Unkpapa/Sundance Formation Sandstone

Morrison Formation

The Upper Jurassic Morrison Formation was deposited as flood plain deposits. It is composed of waxy, unctuous, calcareous, noncarbonaceous massive shale with numerous limestone lenses and a few thin fine grained sandstones.

Unkpapa Formation

Overlying the Sundance Formation is a sandstone unit that has been called the Unkpapa formation. The Unkpapa is a massive fine grained sandstone that was deposited as sand dunes.

Sundance Formation

The Sundance Formation of Upper Jurassic age consists of marine rocks composed of red shales and sandstones. The Sundance has been subdivided into five members. In ascending order they are the **Canyon Springs** sandstone member, the **Stockade Beaver** shale member, the **Hulett** sandstone member, the **Lak** member, and the **Redwater** shale member.

2.2 Hydrogeologic Conditions: Potentiometric Surface and Hydraulic Gradient

Groundwaters within the Inyan Kara formations are under artesian conditions in much of the Dewey-Burdock area. Some wells are known to have flowed for years. Figure 2.3 is a potentiometric surface map of the Fall River Formation aquifer within the Inyan Kara group. The map is based on measurements made in 2008. Based on Figure 2.3, groundwater flow direction in the Fall River aquifer is generally to the southwest, consistent with the topography of the broad Black Hills domal uplift, with significant components either more southerly or more westerly as reflected by the curvature of the potentiometric surface equipotential lines.

Groundwater gradient in the Fall River aquifer varies significantly throughout the project area. Near the outcrop areas upgradient of both the Dewey and Burdock project portions of the Site, the gradient is about 20 to 25 ft per mile (0.0038 to 0.0047 feet per foot [ft/ft]). At the Burdock portion of the Site, the Fall River aquifer gradient flattens to about 14 ft per mile (0.0026 ft/ft) extending downgradient to the southwestern project boundary. At the Dewey portion of the Site,

however, the groundwater gradient in the Fall River aquifer increases sharply to as much as about 52 ft per mile [0.01 ft/ft] within the central portion of the project area.

Figure 2.4 is a potentiometric surface map of the Lakota Formation aquifer below the Fall River aquifer within the Inyan Kara Group, based on measurements made in 2008. Groundwater flow direction is generally to the southwest with locally more southerly component. At the Burdock portion of the site, the groundwater gradient is relatively uniform from the outcrop area to the project boundary, about 18 ft per mile (about 0.0034 ft/ft). At the Dewey portion of the site Figure 2.4 indicates a somewhat flatter overall gradient, about 16 ft per mile (0.003 ft/ft). However, within the central portion of the Dewey project area there a broad area where the potentiometric surface elevations in the Lakota are between 3,680 and 3,690 ft above mean sea level (amsl).

The variations in the potentiometric surfaces in both Inyan Kara formations produce variations in the direction of vertical gradients throughout the project area. At the Burdock portion of the Site, the potentiometric surface in the Fall River aquifer is generally close to that in underlying Lakota (Chilson) aquifer; where there are differences, the Fall River appears to be slightly higher in elevation by a few (less than five) feet. This indicates minimal overall vertical gradients with possible downward flow direction between the two formations through the intervening Fuson Member of the Lakota Formation.

By contrast, at the Dewey portion of the Site there are areas where the potentiometric surface in the Lakota Formation is 20 to 30 ft higher than in the overlying Fall River Formation, indicating a vertically upward gradient. This is consistent with the character of the intervening Fuson Member in previous pumping tests, described in Section 2.6 below, where the Fuson was described as leaky in the Burdock area but a more effective aquitard in the Dewey area. This was also noted in earlier investigations (Keene, 1973, p. 26), which stated that "pressures in the Lakota Formation appear greater than those of the Fall River aquifer in the northwestern townships of the [Fall River] county. This is reasonable when one considers the higher intake elevation of the Lakota Formation, the greater thickness of the Chilson Member than the Fall River sands, and the smaller production from the Lakota aquifer."

Figure 2.5 is a potentiometric surface map of the Unkpapa aquifer below the Inyan Kara group, based on measurements made in 2008 at four locations. The potentiometric surface in the Unkpapa Formation indicates groundwater flow direction to the southwest with locally more southerly components. Overall gradient is about 100 ft per 3 miles, which corresponds to an

average gradient of about 0.006 ft/ft. The potentiometric surface elevation is generally about 50 to 100 ft higher in both the overlying Lakota and Fall River Formation aquifers. This indicates vertical upward gradients between the Unkpapa Formation, the intervening Morrison Formation and the Inyan Kara Group. The Morrison Formation thus appears to function as an effective aquitard throughout the project area.

2.3 Summary of Previous Aquifer Testing Results

The Tennessee Valley Authority (TVA) conducted groundwater pumping tests from 1977 through 1982 as part of a uranium mine development project near the towns of Edgemont and Dewey, South Dakota. TVA produced two summary pumping test reports, "Analysis of Aquifer Tests Conducted at the Proposed Burdock Uranium Mine Site" (Boggs and Jenkins, 1980) and "Hydrogeologic Investigations at Proposed Uranium Mine Near Dewey, South Dakota" (Boggs, 1983). In addition, TVA prepared a draft Environmental Impact Statement for the proposed Edgemont Uranium Mine in 1979.

TVA first conducted two unsuccessful tests in 1977 at the Burdock test site. The results of the 1977 tests were considered inconclusive because of various problems including questionable discharge measurements, some observation wells improperly constructed, and some pressure gauges malfunctioned. No data from the 1977 tests are currently available.

TVA conducted three successful pumping tests, two in 1979 near the current Burdock Project Area, and one in 1982 about two miles north of the current Dewey Project Area. The results of these successful tests are described in separate sections below. However, no data for these tests, in particular electronic records of drawdown, are available, other than information contained in the reports.

2.3.1 Dewey Project Area

The Dewey test was conducted in 1982 northeast of the Dewey Road at the location shown on Figure 1.1. The test consisted of pumping in the Lakota formation for 11 days at an average rate of 495 gpm. The test developed the following information:

- Transmissivity of the Lakota averaged about 4,400 gallons per day per foot (gpd/ft) which is equivalent to 590 ft squared per day (ft^2/day).
- Storativity of the Lakota was about 1.0×10^{-4} (dimensionless).

- There was response between the Fall River and Lakota formations through the intervening Fuson shale-siltstone member that was manifested at relatively late time (3000 to 10000 minutes).

- The vertical hydraulic conductivity of the Fuson aquitard using the Neuman-Witherspoon ratio method (Neuman and Witherspoon, 1973) was 2 x 10^{-4} ft/day; storativity of the Fuson Member was not determined and specific storage was about 7 x 10^{-7} ft^{-1}.

- A barrier boundary, or a decrease in transmissivity due to lithologic changes with distance from the test site, or both, were observed; a possible geologic feature corresponding to a barrier was noted to be the Dewey Fault Zone, located about 1.5 miles north of the test site, where the Lakota and Fall River formations are structurally offset.

2.3.2 Burdock Project Area

The Burdock tests were conducted in 1979 near the Dewey road at the location shown on Figure 1.1. The Burdock tests consisted of separate pumping tests from the Lakota (Chilson) and Fall River Aquifer, respectively in April and July of 1979. The tests used the same pumping well with packers to alternately isolate screens open to the respective formations. Test durations were 73 hours for the Lakota test and 49 hours for the Fall River test. Pumping rates were about 200 gpm from the Lakota aquifer and 8.5 gpm from the Fall River. The reason for the unexpected low pumping rate from the Fall River aquifer was not specified in the TVA report.

The tests developed the following information:

- Interpreted transmissivity of the Lakota was based on analysis of later time data and inferred decreasing transmissivity with distance from the test site due to changes in lithology; overall transmissivity averaged about 1,400 gpd/ft (190 ft^2/day) and storativity about 1.8 x 10^{-4} (dimensionless); maximum transmissivity from early time data was about 2,300 gpd/ft (310 ft^2/day).

- Transmissivity of the Fall River averaged about 400 gpd/ft (54 ft^2/day) and storativity about 1.4 x 10^{-5} (dimensionless).

- There was communication between the Fall River and Lakota formations through the intervening Fuson shale-siltstone member; leaky behavior was observed in the Fall River Formation and believed to exist in the Lakota although "leakage effects in the Lakota drawdown data are masked by the conflicting effect of a decreasing transmissivity in site vicinity" (p. 16 in Boggs and Jenkins, 1980).

- The vertical hydraulic conductivity of the Fuson aquitard determined with the Neuman-Witherspoon ratio method (Neuman and Witherspoon, 1973) ranged from

10^{-3} to 10^{-4} ft/day; storativity was not determined, and specific storage was assumed to be about 10^{-6} ft^{-1}.

3.0 2008 Pumping Tests: Design and Procedures

In 2008 pumping tests were performed at both the Dewey and Burdock project areas. A work plan (Knight Piésold, 2008) was prepared and distributed to interested representatives of State and Federal agencies, including the South Dakota DENR and the USEPA. Individual production zones within the Inyan Kara Group will likely be on the order of 10 to 15 ft thick to target ore horizons in both the Fall River and Lakota aquifers. Uranium ore is often located at different horizons in both aquifers at the same spatial locations (Drawings 4.1, 4.2, 5.1, 5.2 and 5.3).

Powertech performed geologic interpretations, well design, well installation and mechanical integrity testing. Well completions are described in detail for the test layout at each of the Dewey and Burdock project areas (Sections 4 and 5). Field activities for the Dewey and Burdock pumping tests were jointly performed by Powertech and Knight Piésold personnel. Aquifer test analyses were performed and this aquifer testing report was written by Knight Piésold.

3.1 Well Installation, Completion and Mechanical Integrity Testing

Well bores are drilled to diameters specified in SDDENR regulations. New casing is set and 15.2 pounds per gallon (lb/gal) cement is positively displaced into the annulus. After a cement cure time not less than 24 hours, the well is pressured up with air for a minimum of 1 hour. After the mechanical integrity test has passed, the well is developed until the water runs clear, and the screen is then pushed into place. The casing is cut off to 2.5 ft above ground surface and capped. Applicable reports are filed with the State. Wells are not used under conditions that do not meet manufacturer's recommendations and specifications for its type (SDA74:02:04:42).

3.2 Pumping Test Equipment and Facilities

Powertech personnel installed the pumping and monitoring equipment prior to testing. Knight Piésold verified the performance of the pumping test equipment by conducting step-drawdown tests at each site. Thereafter, Knight Piésold performed or supervised pump operations throughout the constant rate tests together with the datalogger programming and day-to-day downloads of data.

The tests were performed using a 5-horsepower (Hp) electrical submersible pump powered by a portable generator. At each site the pump was set at 300 ft with 2-inch diameter drop pipe. Surface flow monitoring equipment were Cameron 1-inch NUFLO™ flowmeters and MP-III™ digital flow analyzer with readout of instantaneous flow and totalizer of flow. In accordance

with the temporary discharge permit received from South Dakota DENR, the pump discharge water was piped to temporary holding ponds via 1 1/4-inch diameter high density polyethylene plastic pipe. Throughout the tests, a portion of the discharge water was routed through a YSI™ flow-through cell with multi-parameter probe that read field parameters (temperature, pH, conductivity, dissolved oxygen and turbidity) that were recorded twice daily through pumping phases of the tests.

Water levels in each well were measured and recorded with vented In-Situ™ Level TROLL™ pressure transducers with built in data loggers. The pressure ratings for the transducers range from 100 to 300 pounds per square inch (psi). Transducer accuracy (in comparison to known pressure or other pressure reading devices) is stated by the manufacturer to be ±0.1 percent of full-scale reading (i.e., 100 to 300 psi), so the limit of accuracy varies from 0.1 to 0.3 psi, or about 0.2 to 0.7 ft. Transducer sensitivity is stated to be ±0.01 percent of full-scale, resulting in sensitivity limits of about 0.01 to 0.03 psi, or 0.02 to 0.07 ft.

The sequence of events before and during the 2008 pumping tests is summarized in Figures 3.1 and 3.2. Figure 3.1 illustrates background pressure transducer and site barometer measurements that are described in Section 3.3, below. Evaluation of the background monitoring data produced several methods for correcting water levels; however, after these were applied on a test data set it was concluded that necessary corrections to water level data were minimal and that the test interpretations could equally well rely on uncorrected time-drawdown data.

Figure 3.2 displays output from the discharge flow data logger that is described in Section 3.4, below.

3.3 Background Monitoring and Water Level Corrections

Pressure transducers were installed in wells at both sites by April 2, 2008 in order to obtain background groundwater level measurements. At the Burdock test site, a transducer was installed in the designated pumping well (DB07-11-11C) in the lower Lakota Formation. At the Dewey test site, a transducer was installed in observation well (DB07-32-4C), screened in the same zone as the pumping well in the lower Fall River Formation. The right hand axis of Figure 3.1 graphs hourly barometric pressure measurements in millibars obtained from the meteorological station installed at the site. The site station is maintained by South Dakota State University (SDSU) and data are available at the following URL: "http://climate.sdstate.edu/awdn/edgemont/archive3.asp".

One month of background measurements were obtained from April 8 to May 9, 2008 (Figure 3.1). Background measurements shown on Figure 3.1 fluctuate over a range of about 0.4 psi with the expected inverse relationship between site barometer readings and increases/decreases in groundwater levels. There are also smaller cyclic sinusoidal variations that occur twice daily and are attributable to Earth tide cycles. A period of two weeks (April 23 to May 8, 2008) after pump installation and initial testing produced undisturbed background water level data.

Three types of water level correction procedures were evaluated using the background monitoring data. The first procedure was manually correcting the transducer psi values with a constant barometric efficiency (BE) determined for each major aquifer (e.g., Kruseman and de Ridder, 1991). The BE is defined as the change in water level in a well versus a related change in atmospheric pressure. Gontheir (2007) describes the historical methods of determining BE, which by convention is dimensionless and ranges from zero to one.

The second type of correction that was evaluated considers additional factors, chiefly long-term seasonal trends and Earth tides (Gontheir, 2007). A spreadsheet distributed by the USGS as an open-file report (Halford, 2006) has programming that empirically factors the overall water level response into multiple synthetically generated time series with adjustments to both phase and amplitude of each component (see Appendix A.1, Figures A.1-3 and A.1-4). The USGS spreadsheet was used to determine that the Dewey background water level data from April 23 to May 8, 2008, could be closely matched as a series of four components: (1) water level increase at a linear rate [i.e., slope], (2) variation in air pressure measured with the site barometer, (3 and 4) two Earth tide components.

The third type of correction procedure evaluated was a computer method known as BETCO (Sandia Corporation, 2005; Toll and Rasmussen, 2006). This software is available at "http://www.sandia.gov/betco/". To correct data, water level, time and barometric pressure are input and BETCO calculates corrected water level values. Compared with the manual BE correction, the corrected water levels calculated in BETCO yielded similar results, generally within about ± 0.01 psi.

The manual BE method was judged to be better than the BETCO computer method for the background calibration period examined (Appendix A). Moreover, both the BETCO and USGS methods were difficult to apply with confidence to the drawdown data after the background monitoring period because wells with similar construction to the pumping test wells, but outside

the area of test influence, are not available to validate the corrections. A further difficulty with the BETCO and USGS computer methods is that they do not accommodate logarithmic measurement times as input data.

To examine the possible importance of BE corrections on water levels, the drawdown phase of the Dewey test was manually corrected with a BE of 0.48 (see Figure A.1-1 in Appendix A) relative to the site barometer over the test period. The maximum effect of the BE correction was to add about 0.2 ft to the water levels at the end of the drawdown phase due to an overall barometric pressure decline of about 15 millibars (i.e., from about 1,030 to 1,015 millibars, Figure 3.1). Test interpretations (Theis drawdown) were made with and without the BE corrections for the Dewey test. The corrections were found to have no discernable effect on the visual fits to type curves. Because the changes in barometric pressure during the 3-day constant rate tests at Burdock and Dewey were similar (Figure 3.1), the analysis determined that BE corrections would be no greater for the Burdock test compared to the Dewey test. Therefore, corrections to water level data were not further performed and the test interpretations rely on uncorrected time-drawdown data.

3.4 Test Procedures, Data Collection, Data Processing

The discharge flow data logger was set to record at hourly intervals and was downloaded at the end of the tests (Figure 3.2). The discharge flow rate was adjusted with a manual gate valve. Step-drawdown tests were performed on May 12 and 13, 2008 (Figures 3.1 and 3.2). The step-drawdown tests consisted of four steps at 10 gpm, 20 gpm, 25 gpm, and 30 gpm for a minimum of 90 minutes at each step. The step-drawdown data indicated successful performance of all equipment at both test sites. Subsequent analysis of the step-drawdown data was not performed due to the better quality (i.e., much longer time) data obtained from the constant rate tests for determining both aquifer parameters and well efficiencies.

Constant rate tests were performed on May 15 to May 18, 2008 at Dewey and from May 18 to May 21, 2008 at Burdock (Figures 3.1 and 3.2) after recovery from the step-rate tests. At both test sites the recorded hourly flow rates during the constant rate tests varied no more than 2 percent (between 30.0 and 30.7 gpm) throughout the tests and the pumping rates for the entire 3-day tests at each site averaged 30.2 gpm.

The data loggers in all wells were synchronized to the same clock-time immediately prior to start-up. To collect closely-spaced measurements during the start-up of the drawdown phase of the test, the transducers were programmed to record temperature and psi measurements at

one-second intervals for two hours, then at ten second-intervals for 70 to 72 hours. For recovery, the data loggers returned to a measurement frequency of one-second for two hours, during which time the pump was shut off, followed by ten-second measurement intervals thereafter.

The time-drawdown data output from the data loggers consisted of two hours of data at one-second intervals followed by 72 or 74 hours of data collected at ten-second intervals, with the sequence repeated for the recovery phase. The WinSitu^{TM} software produced drawdown graphs that are reproduced in Sections 4 and 5. The software exported records to text ".csv" files with approximately 60,000 to 70,000 records for each well. The time-drawdown data were processed using a custom FORTRAN program that wrote data records to an output file based on a template file specifying which date-time records would be written. The template file was prepared to produce logarithmically spaced data with 30 records per log cycle (in seconds). Due to slight variations in transducer output and the precision of the Microsoft Excel date-time format, there are some ± one-second variations in the sequences of records from well to well.

The FORTRAN program also converted transducer psi to drawdown in ft using formulas described in Appendix A. The reference value for zero drawdown was set as the average of psi readings from the start of the data log to the time just prior to test startup. Separate time-drawdown files were prepared for both drawdown and recovery phases of the tests. Tables of the processed time-drawdown data used for test interpretations are provided in Appendices B and C. Complete binary files with the raw data for each well in Win-Situ^{TM} format are also provided on a CD-ROM in Appendix E.

4.0 Dewey Project Area Pumping Test

4.1 Test Layout and Initial Potentiometric Surface Measurements

The Dewey pumping test well is located in NE ¼ NW ¼ Sec. 32, T.6S, R.1E, Custer County, South Dakota (Figure 4.1, Table 4.1). Powertech completed the pumping well (DB07-32-3C) with a fifteen-ft screen within the lower sandstone layer in the Fall River Formation near the roll front ore zones (Drawings 4.1 and 4.2). Three new observation wells were similarly screened at the same stratigraphic horizon within the lower Fall River Formation, located at radial distances of 265, 467 and 2,400 ft away from the pumped well (Figure 4.1 Table 4.1). A pre-existing stock watering well (GW-49) was also monitored. The stock well is located approximately 1,400 ft west of the pumped well and is believed (based on a recent electric log) to be an open hole for about 70 ft corresponding to about the top half of the Fall River formation.

Additional information on the design of the pumping test well layout and objectives for test analysis are provided in Appendix A.2. Well Construction diagrams and borehole electric logs for the Dewey test wells are provided, respectively, in Appendices B.1 and B.2.

Within a fifty-ft radius around the pumping well, additional observation wells were completed in a vertical nest in order to provide hydraulic data for the degree of confinement of both the test sandstone horizon and the entire Fall River Formation aquifer. Observation well DB-07-32-9C was screened in the upper Fall River aquifer at 41 ft lateral distance and 95 ft vertically above the screen in pumping well 32-3C. Observation well DB-07-32-10 was located within the underlying Lakota Formation 61 ft laterally and 130 ft vertically below the screen in the pumping well. Observation well DB-07-32-11 was located in the underlying Unkpapa Formation aquifer 50 ft laterally and 325 ft vertically below the screen in pumping well 32-3C.

Piezometric measurements (Eric Krantz, RESPEC, personal communication, May 2008) and well survey data provided by Powertech were used to calculate potentiometric surface elevations in ft above mean sea level with an estimated accuracy of ± 3 ft (Table 4.2). The potentiometric surface elevations for the Unkpapa, Lakota, and Fall River aquifers at the wells in the vertical well nest at the Dewey test site indicate artesian conditions. The three major geologic formations appear to be locally hydraulically isolated with upward vertical gradients, as follows:

- nearly 80 ft head difference upward (Table 4.2) between the Unkpapa and lower Lakota aquifers

- nearly 40 ft head difference upward between the lower Lakota and lower Fall River aquifers
- nearly 20 ft head difference upward between the wells screened in the lower Fall River and upper Fall River formation

4.2 Pumping Rate and Duration

The pumping phase of the constant-rate test at the Dewey area was started at 10:30:09 AM on May 15, 2008 and the pump was shut down at 12:30:59 PM on May 18, 2006, for a total duration of 4,440 minutes or 3.08 days (Figure 3.2). Because of the artesian condition in the pumping zone, the pumping well (32-3C) was shut-in, the pump turned on at 10:29:54 AM and the shut-in valve opened at 10:30:09 AM, the designated starting time of the test. The artesian observation wells had been left open for at least a day prior to startup to test for leakage from gaskets surrounding the transducer cables. Leakage during the constant rate test was not observed at any well except observation well 32-11 in the Unkpapa Formation, as described in Section 4.6, below.

The average pumping rate for the 3.08 day test was 30.2 gpm (Figure 3.2). During drawdown, there was a major flow rate adjustment where the gate valve was opened and throttled back; this occurred from 0.4 to 1.2 minutes and produces a discontinuity on logarithmically displayed time-drawdown data at the pumping well (Figure 4.7). Minor flow rate adjustments were also made at 21, 125, and 2777 minutes into the test that can also be seen on time-drawdown data for the pumping well (Figure 4.7). During recovery, the pumping well was initially left open to discharge water in piping and then shut-in when it was determined that the well was discharging due to artesian flow; this produces a discontinuity shown on the recovery plot for the well (Figure 4.7).

4.3 Responses at Pumping and Observation Wells

Table 4.2 summarizes the responses to pumping for the Dewey test. Figures 4.2, 4.3 and 4.4 display the transducer responses. Drawdown throughout the lower Fall River aquifer was 44.8 ft at the pumping well and ranged from 13.0 to 1.5 ft at the observation wells. Response to pumping varied progressively with distance from the pumping well throughout the lower Fall River: within 3 minutes at the two observation wells at 265 and 467 ft, and response was at 140 minutes at 2,400 ft distance. Similarly, the upper Fall River stock well (GW-49) responded at 40 minutes at 1,400 ft distance (Table 4.2).

However, it took 10.6 minutes for upper Fall River well (32-9C) to respond at 41 ft radial distance and 95 ft vertical distance (Table 4.2. The delayed response at the upper Fall River well is attributed to vertical anisotropy due to shale interbeds overlying the lower sandstone layer (Drawings 4.1 and 4.2).

The pumping and observation wells generally had symmetrical patterns of drawdown response and recovery response, except at the distant observation well 29-7 (Figure 4.3). There, the drawdown began at 140 minutes into the test, and drawdown continued to a maximum of 2.1 ft at about two days after the pump was shut down (Table 4.2). Therefore, the recovery response at well 29-7 was not further analyzed.

4.4 Determination of Aquifer Parameters

Aquifer parameters determined with the Theis drawdown, Theis recovery, Cooper-Jacob drawdown, Theis-Cooper-Jacob recovery, and distance drawdown methods are summarized in Table 4.3. Appendix A provides a definition of the well function parameters (u, u'), a complete description of the methods used, and corresponding assumptions for aquifer parameter determinations. For the straight-line methods, analyses with u or u' > 0.01 are reported but are not considered acceptable, as indicated in the table. Appendix B provides the graphical analyses that determined aquifer parameters at each well listed in Table 4.3.

The following discussion and Figures 4.5 through 4.8 illustrate the overall analysis of the pumping test and exemplify the determination of aquifer parameters with figures illustrating each of the major graphical analysis methods used. The observation well exhibiting the most diagnostic response is discussed first, followed by the drawdown at all observation wells, the drawdown at the pumping well, and finally the recovery at all wells.

4.4.1 Theis Drawdown and Recovery Analysis

Figure 4.5 displays time drawdown data and analysis on the log-log Theis plot for the closest observation well (32-5 at 265 ft distance). The data indicate a confined aquifer response fitting the Theis type curve until latest time, where there is a barrier boundary, where the drawdown increased above the theoretical rate of drawdown. The boundary was encountered at a time of about 0.6 days into the test (Table 4.2). The data at the next closest observation wells (32-4C and the stock well GW-49) also suggest a barrier boundary at times ranging from about 0.7 to 1.9 days into the test (Table 4.2).

Drawdown analyses using the Theis method for all applicable wells (i.e., 32-3C, 32-5, 32-4C, 29-7, and GW-49) are given in Appendix B.4 (Figures B.4-1 through Figure B.4-5) and summarized in Table 4.3. The Theis analyses in Appendix B use test analysis software (AquiferWin32^{TM} ESI, 2003). Input data is weighted to ignore the late-time barrier boundary using an automated curve matching procedure. The weighting for all samples is the same, as follows: time-drawdown data before the first response are ignored, and data after the earliest occurrence of the barrier boundary at any of the wells (0.6 days) are ignored. The aquifer parameters transmissivity and storativity determined with Theis analyses are summarized in Table 4.3.

Figure B.4-6 in Appendix B shows the data at observation well 32-9C, completed in the upper Fall River 41 ft radially and 95 ft vertically from the screened interval in the pumping well. Samples are weighted as described above. This data cannot be interpreted successfully with the Theis analysis because only the middle-time portion of the drawdown closely follows the type curve. The poor fit to the Theis curve for well 32-9C yields a transmissivity of 217 ft^2/d, a value within the range of other observation wells, but a high storativity value of 0.016, which is inappropriate for a confined aquifer (e.g., Freeze and Cherry, 1979, Halford and Kuniansky, 2002). The artificially high storativity is attributed to the time-delay in response. The time-delay is attributed to vertical anisotropy as described in Section 4.3, above. Therefore, aquifer parameters from this well are reported in Table 4.3 but are not considered reliable determinations and are not used in determining the overall average aquifer parameters for the test.

4.4.2 Theis-Cooper-Jacob Straight-line Analysis

Figure 4.6 displays the Theis recovery analysis at the closest observation well 32-5 using automated straight-line fitting in AquiferWin32^{TM} software. Appendix A.2 provides an overview of the theoretical basis for straight-line test analysis and definitions for the terms u', t and t'. Samples are weighted according to (1) the theoretical criterion that u' be < 0.01, which restricts the data to later-time (to the left on the t/t' axis); and (2) the portion of the recovery before the change in slope due the barrier boundary. The sample weighting restricts the matched straight-line portion of the recovery plot to the line-segment shown in Figure 4.6 and a value for the transmissivity, but not storativity, is obtained (Table 4.3).

Figure 4.7 (top) shows a Cooper-Jacob straight-line drawdown plot for the Dewey pumping well 32-3C. This USGS graphical-analysis tool is a spreadsheet that allows manual fitting of the straight-line (Halford and Kuniansky, 2002). The portion of the plot corresponding to later time

where is indicated, and this slope is used to determine transmissivity of 250 ft^2/d and well efficiency of 81 percent (Table 4.3).

The bottom portion of Figure 4.7 shows the USGS spreadsheet implementation of the Theis recovery analysis for the pumping well 32-3C, referred to as the Theis-Cooper-Jacob method (Halford and Kuniansky, 2002). Similar to Figure 4.6, the portion of the plot corresponding to later time is indicated to the left on the t/t' axis, and this slope is used to determine transmissivity of 270 ft^2/d (Table 4.3). The recovery plot at the pumping well also shows the change in slope with an increase in rate of drawdown at the latest times which is ignored in the manual fit of the straight-line.

4.4.3 Distance-Drawdown Analysis

Figure 4.8 is distance-drawdown analysis plot that determines transmissivity, storativity, and pumping well efficiency by considering all observation wells at once. The pumping well efficiency of 93 to 95 percent is determined by extending the straight line to the assumed diameter of the pumping well (0.25 ft for the 6-inch diameter well casing or possibly 0.33 ft for the 8-inch diameter borehole) relative to the actual drawdown observed at the pumping well. The aquifer parameters and the high efficiency are somewhat questionable given the relatively poor ($r^2 = 0.7$) straight-line fit through all data points. However, transmissivity and storativity values obtained are reasonable and the distance drawdown results are included in the overall average aquifer parameters for the test (Table 4.3).

The distance-drawdown analysis also gives the maximum radius of influence of the test. Based on Figure 4.8, the radius of influence was about 5,700 ft, about twice the radial distance to the most distant responding well (i.e., 29-7 at 2,400 ft). The radius of influence may be compared to the dimensions of prospective well fields in the area to evaluate whether aquifer parameters have been adequately characterized.

4.4.4 Summary of Dewey Test – Lower Fall River Formation Aquifer Parameters

The aquifer parameters determined by the techniques described above are summarized in Table 5.3. Ten accepted determinations of transmissivity (outlined) range from 180 to 330 ft^2/day and the mean and median are close at 251 to 255 ft^2/day. The five accepted storativity determinations ranged from 2.3×10^{-5} to 2.0×10^{-4}. The geometric mean and median storativity values are respectively 5.2 to 4.6×10^{-5}. The median transmissivity of 255 ft^2/day and median storativity of 4.6×10^{-5} are considered the best measures of the central tendency of the test results.

4.5 Underlying Lakota Aquifer Test Results

Observation well (DB-07-32-10, Figure 4.1, Drawing 4.2) was located within the underlying Lakota Formation 61 ft laterally and 130 ft vertically below the screen in pumping well 32-3C. Figure 4.4 illustrates that there was no response of observation well 32-10 to the drawdown or recovery phases at the pumping well 32-3C. Therefore, there was no further analysis of this observation well.

4.6 Underlying Unkpapa Aquifer Test Results

Observation well DB-07-32-11 is screened in the underlying Unkpapa Formation aquifer 50 ft radially and 325 ft vertically below the screen in pumping well 32-3C (Table 4.1). Figure 4.4 depicts a generally rising trend in transducer response with sinusoidal variations associated with Earth tides indicating the aquifer remained undisturbed when the pump was turned on and turned off. Mid-way through the recovery, a shift in the pressure response on May 20, 2008 was noted similar to when leaks in the gasket-seal were observed previously. The threaded cap and gasket were checked on May 21, 2008 and found to be moist suggesting that a temporary leak may have occurred.

Figure 4.4 illustrates that there was no response of observation well 32-11 to the drawdown or recovery phases at the pumping well 32-3C. Therefore, there was no further analysis of this observation well.

5.0 Burdock Project Area Pumping Test

5.1 Test Layout and Initial Potentiometric Surface Measurements

The Burdock pumping test well is located in NE ¼ SW ¼ Sec. 11, T.7S, R.1E, Fall River County, South Dakota (Figure 5.1, Table 5.1). Powertech completed the pumping well (DB07-11-11C) with a ten-ft screen within a lower sandstone layer in the Lakota (Chilson) formation. Hereafter, the term Lakota is used to refer to the Chilson member of the Lakota formation. The ten-ft screen was set near the horizon of the lower Lakota ore zone(s), indicated by the roll fronts on Drawings 5.1 through 5.3. Three new observation wells were similarly screened at the same stratigraphic horizon within the lower Lakota Formation, located at radial distances of 243, 250 and 1,292 ft away from the pumped well (Figure 5.1, Table 5.1).

Additional information on the design of the pumping test well layout and objectives for test analysis are provided in Appendix A.2. Well Construction diagrams and borehole electric logs for the Burdock test pumping and observation wells are provided respectively, in Appendices C.1 and C.2.

Within a fifty-ft radius around the pumping well, additional observation wells were completed in a vertical nest in order to provide hydraulic data for the degree of confinement of both the test sandstone horizon and the entire Lakota formation aquifer. Observation well DB-07-11-19 was screened in the upper Lakota aquifer at 50 ft lateral distance and 100 ft vertical distance above the screen in pumping well 11-11C. Observation well DB-07-11-19 was located within the overlying Fall River Formation 61 ft laterally and 180 ft vertically above the screen in the pumping well. Observation well DB-07-11-18 was located in the underlying Unkpapa Formation aquifer 50 ft radially and 195 ft vertically below the screen in the pumping well.

Piezometric measurements (Eric Krantz, RESPEC, personal communication, May 2008) and well survey data provided by Powertech were used to calculate potentiometric surface elevations in ft msl with an estimated accuracy of ±3 ft (Table 5.2). The potentiometric surfaces of the Lakota and Fall River aquifers at the wells in the vertical well nest at the Burdock site indicate confined and non-artesian conditions. The two major aquifers (Fall River and Lakota) appear to be locally hydraulically connected through the intervening Fuson Member with minimal vertical gradients because the water levels are similar within ± 2-3 ft (Table 5.2).

Piezometric surface information for the Unkpapa and Lakota/Fall River aquifers indicate that the Unkpapa formation aquifer is artesian and hydraulically isolated with a nearly 70 ft head difference directed vertically upward (Table 5.2).

5.2 Pumping Rate and Duration

The pumping phase of the constant-rate test at the Burdock area was started at 2:20:36 PM on May 18, 2008 and the pump was shut down at 2:30:37 PM on May 21, 2008, for a total duration of 4,320 minutes or 3.0 days. The average pumping rate was 30.2 gpm. A flow rate adjustment was made at 160 minutes into the test that can be seen on logarithmic time-drawdown data for the pumping well (Figure 5.7). The average pumping rate for the 3.0 day test was 30.2 gpm (Figure 3.2).

5.3 Responses at Pumping and Observation Wells

Table 5.2 summarizes the responses to pumping for the Burdock test. Figures 5.2, 5.3 and 5.4 display the transducer responses. Drawdown throughout the lower Lakota aquifer was 91.1 ft at the pumping well and ranged from 17.0 to 3.1 ft at the observation wells. Response to pumping varied with distance from the pumping well in the Lakota aquifer in a non-systematic manner indicating significant lateral and vertical anisotropy, as follows:

- Response was within 3.6 minutes at the observation well (11-14C) at 250 ft distance with 17 ft of ultimate drawdown (Table 5.2).
- But the other lower Lakota observation well at 243 ft distance (11-15) took 140 minutes to respond, with 10 ft of ultimate drawdown.
- Upper Lakota observation well 11-19 took 160 minutes to respond with 3.4 ft ultimate drawdown at 50 ft radial distance and 100 ft vertical distance.
- First response was at 280 minutes at the most distant well (11-2) at 1,292 ft distance.

The responses of close-in well 11-14C and the distant well 11-2 are interpreted as a typical sequence of response to pumping well in a confined aquifer with similar transmissivity connecting all three wells. The delayed response at the upper Lakota well 11-19 is attributable to vertical anisotropy due to shale interbeds overlying the lower sandstone layer (Drawings 5.1 through 5.3). The delayed response of the closest observation well 11-15 requires an explanation in addition to lateral anisotropy. Powertech geologists were contacted and have subsequently indicated that there may have been problems with the installation of well 11-15 because it was subjected to intensive efforts during development.

Figures 5.2 through 5.4 indicate symmetrical patterns of drawdown response and recovery response, such that if the drawdown response was delayed there was a generally similar time before the recovery response (e.g., wells 11-2, and 11-19 on Figure 5.3). The anomalous recovery response at observation well 11-17, screened in the overlying Fall River aquifer, is discussed in Section 5.5, below.

5.4 Determination of Aquifer Parameters

Aquifer parameters determined with the Theis drawdown, Hantush-Jacob drawdown, Cooper-Jacob drawdown, Theis-Cooper-Jacob recovery and distance drawdown methods are summarized in Table 5.3. For the straight-line methods, analyses with u or u' > 0.01 are reported but are not considered acceptable, as indicated in the table. Appendix A provides a complete description of the methods used and corresponding assumptions for aquifer parameter determinations. Appendix C provides the graphical analyses that determined aquifer parameters at each well listed in Table 5.3.

The following discussion and Figures 5.5 through 5.8 illustrate the overall analysis of the pumping test and exemplify the determination of aquifer parameters with figures illustrating each of the major graphical analysis methods used. The observation well exhibiting the most diagnostic response is discussed first, followed by the drawdown at all observation wells, the drawdown at the pumping well, and finally the recovery at all wells.

5.4.1 Theis Drawdown Analysis

Figure 5.5 displays time-drawdown data and analysis on the log-log Theis plot for close-in observation well 11-14C at 250 ft distance. The data indicate confined aquifer response fitting the Theis type curve for the first 1.1 days of the test. After 1.1 days, the drawdown indicates a recharge boundary or vertical leakage from an adjacent confining layer where the actual rate of drawdown is less than the theoretical rate of drawdown. The drawdown at the most distant observation well (11-2 at 1,292 ft distance) also fits the Theis type curve for the first 1.8 days of the test (see Appendix C, Figure C.4-5) at which time a recharge boundary is encountered. Boundary responses are summarized in Table 5.2.

Drawdown analyses using the Theis method for all applicable wells (i.e., 11-11C, 11-15, 11-14C and 11-29) are given in Appendix C.4 (Figures C.4-1 through Figure C.4-5) and summarized in Table 5.3. The Theis analyses in Appendix C use test analysis software (AquiferWin32^{TM} ESI, 2003). Input data is weighted to ignore the late-time recharge boundary using an automated curve matching procedure. The weighting for all samples is the same, as follows:

time-drawdown data before the first response are ignored, and data after the earliest occurrence of the recharge boundary at any of the wells (1.1 days) are ignored. The aquifer parameters transmissivity and storativity determined with Theis analyses are summarized in Table 5.3.

The data at the close-in Lakota observation well 11-15 at 243 ft distance are successfully fitted with the Theis curve and recharge boundary (see Appendix C, Figure C.4-2). A trial analysis of the best fit yields a transmissivity value lower than the range of other observation wells and a relatively high storativity value of 0.0013. Because this storativity value is high compared to confined aquifers in general (e.g., Freeze and Cherry, 1979, Halford and Kuniansky, 2002) and also the other Burdock test wells (Table 5.3), aquifer parameters from this well were not further considered. The high storativity is attributable to the delayed response time (140 minutes at 243 ft distance), and the cause of the delay is attributed to problems with well construction.

At observation well 11-19, completed in the upper Lakota 50 ft radially and 130 ft vertically from the screened interval in the pumping well, the drawdown data appear to be interpretable with the Theis analysis and yield a transmissivity value within the range of other observation wells (see Appendix C, Figure C.4-7). However, the very high storativity value of 0.10 is inappropriate for a confined aquifer. As described in Appendix A.2, there are a number of violations of the Theis test conditions when attempting to analyze drawdown due to pumping between partially penetrating well screens set apart 130 ft vertically. The artificially high storativity is attributed to the time-delay in response (160 minutes). The time-delay is attributed to vertical anisotropy as described in Section 5.3, above. Therefore, aquifer parameters from this well were not further considered.

5.4.2 Hantush-Jacob Drawdown Analysis

The AquiferWin32™ software implements the Hantush-Jacob (Hantush and Jacob, 1955) analytical model for drawdown analysis that follows the Theis curve in early-time and calculates a flattening recharge boundary due to vertical leakage from an assumed overlying leaky confining layer. The vertical leakage is described in the term r/B, which is implemented in this analysis as follows:

- $r/B = r/((T \cdot b')/K')^{0.5}$
- T transmissivity of confined Lakota aquifer (assume provisional value of 145 ft^2/day)
- b' thickness of Fuson member aquitard/confining layer (35 ft, based on Drawing 5.3)

- K' vertical hydraulic conductivity of Fuson (10^{-3} ft/day from the TVA test, Section 2.3.2)
- radial distance (r = 250 ft to well 11-14C and 1,292 ft to well 11-2)
- r/B well 11-14C = 0.11; r/b well 11-2 = 0.57

Figure 5.6 shows the Hantush-Jacob analysis at observation well 11-14C where r/B is input as fixed and all data after initial response are equally weighted. It is noted that automated curve-fitting in the AquiferWin32™ software can also be set to optimize to r/B, and a value of 0.11 is also obtained, indicating that this is a good match. For distant observation well 11-2 the software optimized to an r/B value of 0.77, so the calculated value of 0.57 was fixed (see Figure C.4-6 in Appendix C). Transmissivity and storativity values obtained through the curve matching at the two observation wells are entered in Table 5.3.

5.4.3 Theis-Cooper-Jacob Straight-line Analysis

Figure 5.7 (top) shows a Cooper-Jacob drawdown plot for the Burdock pumping well 11-11C. This USGS graphical-analysis tool is a spreadsheet that allows manual fitting of the straight-line (Halford and Kuniansky, 2002). Appendix A.2 provides an overview of the theoretical basis for straight-line test analysis and definitions for the terms u, u', t and t'. The portion of the plot corresponding to later time where $u < 0.01$ is indicated, and this slope is used to determine transmissivity of 150 ft^2/day and well efficiency of 65 percent (Table 5.3).

The bottom portion of Figure 5.7 shows the USGS spreadsheet implementation of the Theis recovery analysis for the pumping well 11-11C, referred to as the Theis-Cooper-Jacob method (Halford and Kuniansky, 2002). The portion of the plot corresponding to later time where $u' < 0.01$ is indicated to the left on the t/t' axis, and this slope is used to determine transmissivity of 140 ft^2/d (Table 5.3). A definite change in slope indicating a late time leakage/recharge boundary is not apparent at the pumping well, but the late-time data has a slight upward concavity indicating reduction in the rate of drawdown.

The results of Theis recovery analyses for all wells are summarized in Table 5.3, together the u' criteria on which each transmissivity determination is based. Analyses with $u' > 0.01$ are tabulated but are not considered acceptable, as indicated in the table.

5.4.4 Distance-Drawdown Analysis

Figure 5.8 is distance-drawdown analysis plot that determines transmissivity, storativity, and pumping well efficiency by considering all observation wells at once. As shown on Figure 5.8,

fitting a straight line to incorporate the close-in observation wells 11-14C and 11-15 simultaneously is not ideal because it averages the clearly anisotropic response between the close-in wells. On the other hand, convention (Driscoll, 1986 and numerous other references) dictates that a distance-drawdown analysis should be based on a minimum of three observation wells. It is noted that if a two-well solution is used ignoring the anisotropic response at well 11-14C, transmissivity is 108 ft^2/day and storativity is 2.8 x 10^{-5}. Nevertheless, the three-well solution with greater transmissivity and storativity is accepted as indicated on the figure and in Table 5.3.

The pumping well efficiency of 61 to 63 percent is determined with the three-well distance-drawdown solution by extending the straight line to the assumed diameters of the pumping well. These efficiencies agree with the 65 percent determined in the USGS spreadsheet (Table 5.3). The aquifer parameters are somewhat questionable given the relatively poor (r^2 = 0.7) straight-line fit through all data points. Based on the large u criterion (0.08) at one of the wells (11-15), the transmissivity and storativity values obtained are not included in the overall average aquifer parameters for the test (Table 5.3).

The distance-drawdown analysis also gives the maximum radius of influence of the test. Based on Figure 5.8, the radius of influence was about 2,100 ft, somewhat greater than the radial distance to the most distant responding well (i.e., 11-2 at 1,292 ft). The radius of influence may be compared to the dimensions of prospective well fields in the area to evaluate whether aquifer parameters have been adequately characterized.

5.4.5 Summary of Burdock Test – Lower Lakota (Chilson) Formation Aquifer Parameters

The aquifer parameters determined by the techniques described above are summarized in Table 5.3. Nine accepted determinations of transmissivity (outlined) range from 120 to 223 ft^2/day and the mean and median are close at 150 and 158 ft^2/day. Four accepted storativity determinations ranged from 6.8 x 10^{-5} to 1.9 x 10^{-4}. The geometric mean and median storativity values are 1.1 x 10^{-4} and 1.2 x 10^{-4}. The median transmissivity of 150 ft^2/day and median storativity of 1.2 x 10^{-4} are considered the best measures of the central tendency of the test results.

Only two wells were used to contribute to the overall storativity results because of the large anisotropy in responses exhibited between wells 11-15 and 11-14C and the anomalous results at

11-15 described above. Powertech geologists have noted that there were problems with the installation of well 11-15.

5.5 Overlying Fall River Aquifer Test Results

Observation well 11-17 is screened in the lower Fall River 50 ft laterally and about 185 ft vertically above the screen in pumping well 11-11C (Table 5.2, Drawing 5.3). Piezometric surface information for the Lakota aquifer indicates the two wells are locally hydraulically connected with similar water levels within ± 2 ft (Table 5.2).

Figure 5.3 illustrates response of observation well 11-17 to the drawdown phase of the Burdock well 11-11C pumping in the Lakota Formation. The first response was a very slight increase in pressure over a period of about 600 minutes, corresponding to a water level increase of about 0.12 ft (3.5 centimeter [cm]). The water level stopped increasing then underwent 1.1 ft of drawdown to time of pump shut-down (2:00 PM) on May 21, 2008. Drawdown continued for about a day to a maximum of 1.4 ft, then remained flat with erratic fluctuations for another 24 hours, until the evening of May 23, 2008 where a partial and sharply "spiked" recovery started.

The response of a "reverse" drawdown monitored in a zone above (or below) the pumping zone is known as the Noordbergum effect (Ohio EPA, 2006). There is uncertainty whether the water level increase at Burdock well 11-17 is the Noordbergum effect or alternatively a barometric response. In any case, the Noordbergum effect was observed in the 1979 TVA Lakota aquifer pumping test at Burdock pumping at 200 gpm where increases in water levels were monitored in the Fall River aquifer and Fuson Member observation wells for 30 to 90 minutes after the start of the test. Judging from the water level plot figures (Boggs and Jenkins, 1980), the increases were a fraction of a ft in the Fall River and up to about 1.5 ft in the Fuson.

In a 1985 pumping test in the Eastern Black Hills near Wall, South Dakota, pumping at 125 gpm, a water level rise of about 1.7 ft just after pumping started, eventually declining in an "erratic manner", was attributed to the Noordbergum effect (Rahn, 1992). There the well (Kelly Well) with the anomalous response was open to an unknown portion of the Inyan Kara aquifer; however it was considered to be somewhat hydraulically isolated from the pumping and other observation wells based on differing background water levels.

The fact that substantial Noordbergum effects were observed in pumping tests in the Fuson/Fall River and Inyan Kara (undifferentiated) monitoring wells at widely spaced locations in the Black

Hills uplift (i.e., the TVA and Wall tests) suggests the effect is a characteristic of the Inyan Kara Group. A small magnitude Noordbergum effect response observed in the 2008 test at Burdock is attributable to the much lower pumping rate and relatively short, 10-ft screened intervals of both pumping and observation wells. The Noordbergum effect of a 10 cm rise in water levels has been simulated with numerical models by the USGS (Hsieh, 1997), where three-dimensional deformation caused by groundwater withdrawal from a confined aquifer can induce positive hydraulic head changes in adjacent aquitards (and presumably in an aquifer overlying an aquitard).

An alternative explanation for the slight rise in water level in the Fall River (Burdock 11-17) is found in similar patterns of water level changes seen in the Unkpapa Formation (Burdock 11-18), underlying the Lakota Formation, at about the same time and magnitude. This will be described further in Section 5.6 below.

Referring again to Figure 5.3, an explanation for the drawdown in the Fall River aquifer at Burdock continuing for about a day past the pump shut-down and then stabilizing for another day is not apparent. It is most similar to the 1.5 days of extended drawdown and poor recovery observed at well 29-7 at the Dewey pumping test. These anomalous responses are attributed to the observation wells having been located away from the sandstone layer with the pumping well; it is possible the observation wells are monitoring localized effects in sedimentary facies separated from the pumping well by numerous shale layers,

5.6 Underlying Unkpapa Aquifer Test Results

As discussed in Section 3, observation well 11-18 is screened in the Unkpapa aquifer 35 ft laterally and 195 ft vertically below the screen in pumping well 11-11C (Table 5.1). Piezometric surface information for the Unkpapa and Lakota aquifers indicate the two wells are locally hydraulically isolated, with a nearly 70 ft head difference directed vertically upward (Table 5.1).

Figure 5.4 illustrates that there was no response of observation well 11-18 to the drawdown or recovery phases at the pumping well 11-11C. However, comparison with the Fall River observation well (Burdock 11-17, Figure 5.3) finds a similar pattern, timing and magnitude of several water level changes. In addition to the early time rise in water levels (i.e. possible Noordbergum effect described above) starting at about 2:00 PM on 5/18/08 (i.e., the time of pump shut-down and start of recovery), there are the following similarities:

- the erratic transducer readings starting at about 3:00 PM on 5/22/08

- the upward spike in transducer readings at about 7:00 PM on 5/23/08

The barometer readings for the site (Figure 3.1) were examined in detail, and there is a possible correlation with barometric fluctuations where the water level increases start at the times of temporary declines (troughs) in barometric pressure throughout an overall period of increasing atmospheric pressure (i.e., going forward in time from the start of Burdock Recovery on Figure 3.1). However, throughout several days there were equally large fluctuations in barometric pressure with no similar corresponding changes in water levels.

An explanation for the water level variations simultaneously in both wells is that the Unkpapa monitoring well 11-18 (Figure 5.4) records a barometric and tidal response while the Fall River monitoring well 11-17 (Figure 5.3) records a combination of both drawdown (without recovery) and barometric response. As noted above, the existence of the Noordbergum effect at the Fall River monitoring well is possible but uncertain.

6.0 Laboratory Core Data

6.1 Background

Selected core samples were sent to Core Laboratories by Powertech (Personal Communication, Frank Lichnovsky, February 1, 2008) for measurement of intrinsic permeability to assess the differences in the less permeable Skull Creek shale, Fuson shale, Morrison shale, and interbed units of the Dewey (Fall River) and Burdock (Lakota) sandstone units. The intrinsic permeability data were converted to hydraulic conductivity values as shown in Table 6.1.

6.2 Conversion from Intrinsic Permeability to Hydraulic Conductivity

Intrinsic permeability is a property of the core material (rock) only and does not include any fluid properties. The core intrinsic permeability was measured by moving air through the core under confining pressure in the laboratory which resulted in the measurement of both porosity (from the bulk density and particle density of the core) and intrinsic permeability in milliDarcys (mD) as shown in Table 6.1. The footnotes at the bottom of Table 6.1 show the constants assumed for the conversion from intrinsic permeability to hydraulic conductivity at the prevailing temperatures of the laboratory, assumed to be 70 °F, and the site groundwater (average of 52.8 °F from field measurements by RESPEC (Personal Communication, Crystal M. Hocking, February 4, 2008).

It is well known that the units of intrinsic permeability can be changed from mD to cm^2 by using equations shown in Table 6.1. The intrinsic permeability is multiplied by the fluid properties of water density times the gravitational constant divided by the dynamic viscosity (both temperature dependent) of the site groundwater to obtain the hydraulic conductivity.

Analyses of core data in Table 6.1 indicate that the horizontal hydraulic conductivity of the Skull Creek shale is approximately 6.0×10^{-8} centimeters per second (cm/s). The horizontal hydraulic conductivity of the Fuson Shale ranges from 8.0×10^{-7} to 3.2×10^{-8} cm/s, and for the Morrison between 7.7×10^{-7} and 3.1×10^{-9} cm/s. Vertical hydraulic conductivities of the Skull Creek and Morrison shales, and the Fuson shale from the Dewey project area, are typically one-tenth to one-twentieth the horizontal values. In terms of ft per day (ft/day) vertical hydraulic conductivities for all the above shale units range from about 2 to 6×10^{-5} ft/day.

The average vertical hydraulic conductivity for the two core samples from the Fuson shale from the Burdock project area is considerably more permeable (9.8×10^{-8} cm/sec), at roughly 25 percent the horizontal value. In terms of ft/day, vertical hydraulic conductivities for the

Burdock Fuson shale units are about 3 x 10^{-4} ft/day, about one order of magnitude less than the Fuson shale sample at the Dewey project area (2 x 10^{-5} ft/day) and also all the Skull Creek and Morrison shale samples.

In contrast, the core units of the Burdock Lakota sandstone unit have an average horizontal hydraulic conductivity of 2.6 x 10^{-3} cm/s (7.4 ft/day), ranging from 2.1 x 10^{-3} to 3.2 x 10^{-3} cm/s. Core from the Dewey Fall River sandstone unit has a horizontal hydraulic conductivity of 2.2 x 10^{-3} cm/s (6.1 ft/day). The ratio of horizontal to vertical hydraulic conductivity (K_h:K_v) for the Burdock sandstone units is 2.4:1, and for the Dewey sandstone unit it is 4.5:1, based on the core data shown in Table 6.1.

6.3 Interpretations of the Laboratory Core Data

Comparison of horizontal hydraulic conductivity of the Dewey and Burdock sandstone samples in Table 6.1 with the conductivity calculated from pumping test transmissivity (Tables 4.3 and 5.3) can be made as follows:

- Dewey Transmissivity 255 ft^2/d divided by 15 ft screen length = 17 ft/day
- Dewey Transmissivity 255 ft^2/d divided by 165 ft formation thickness = 1.5 ft/day
- Burdock Transmissivity 150 ft^2/d divided by 10 ft screen length = 15.0 ft/day
- Burdock Transmissivity 150 ft^2/d divided by 170 ft formation thickness = 0.9 ft/day

The most commonly used procedure when converting test results is to use the screen length of the pumping well as the divisor. The above analysis indicates that the pumping test data may be interpreted to yield up to two to three times greater higher hydraulic conductivity than core data.

However, the above analysis also indicates that the hydraulic conductivities calculated from the pumping test transmissivities and the overall formation thicknesses bracket the core data at the lower end of ranges in hydraulic conductivity, with the core falling in the middle of the range. The core data can be considered to be generally consistent with, and therefore independently confirming, the pumping test results. Generally, the above ranges in calculated hydraulic conductivity also indicate order-of-magnitude uncertainty (generally, about one to 17 ft/day),

Powertech reports that the laboratory would not take samples containing uranium, so sandstone core samples from outside of the ore zone were submitted. The electric logs and boring lithologic logs indicate that the core samples were taken from sandstone layers which may have

had slightly different, possibly less permeable, ideologies than the screened intervals used for the pumping tests in the ore zones.

6.4 Conclusions

The first conclusion from the core analyses is that the major shale aquitards (Fuson, Skull Creek, Morrison formations) have hydraulic conductivities several orders of magnitude lower than hydraulic conductivities of either the Fall River or Lakota sandstone units. Using the vertical hydraulic conductivities as a measure of degree of confinement, at the Burdock project area Table 6.1 indicates that the shales in the Fuson overlying the Lakota formation (K_h = 7.4 ft/day) have an average vertical permeability of about 2.7×10^{-4} ft/day and the underlying Morrison formation 6.0×10^{-5} ft/day. At the Dewey project area, shales in the Fuson formation underlying the Fall River formation (Kh = 6.6 ft/day) have an average vertical permeability of 1.8×10^{-5} ft/day, and shale in the single sample of overlying Skull Creek shale has a vertical permeability of 1.5×10^{-5} ft/day.

The second conclusion is that core data from the sandstones are within the range of hydraulic conductivities determinable from test transmissivities, specifically 1.5 to 17 ft/day at the Dewey project area and 0.9 to 15 ft/day at the Burdock project area. This is also an appropriate range of uncertainty for converting the test results to hydraulic conductivity. Using the usual procedure for determining hydraulic conductivity from pumping test transmissivity, the sandstone core results may have two to three times smaller hydraulic conductivities than those estimated from the pumping tests, perhaps due to slightly different lithologies between the core and screened intervals. Overall, there is reasonable agreement between the laboratory and field hydraulic tests considering typically order-of-magnitude differences in hydraulic conductivity determinations.

7.0 Summary and Conclusions

The following sections first summarize new facts about the Dewey and Burdock project areas based on the 2008 tests and related information. A discussion of the results in comparison to the 1979 to 1982 TVA pumping tests follows. The Burdock site is discussed first because comparison with the TVA tests is most straightforward.

7.1 Burdock Project Area

7.1.1 Summary

A summary of aquifer parameters for the 2008 Burdock pumping test and related laboratory core testing is as follows:

- Nine determinations of transmissivity (Table 5.3) ranged from 120 to 223 ft^2/day with the median value of 150 ft^2/day.
- Four storativity determinations (Table 5.3) ranged from 6.8×10^{-5} to 1.9×10^{-4} with the median value of 1.2×10^{-4}.
- The radius of influence of the pumping test determined by a distance-drawdown plot was 2,100 ft (Section 5.3.3).
- The pumping well in the lower Lakota formation was determined to be moderately efficient: 80 to 83 percent by the empirical distance-drawdown method and 65 percent the USGS (Halford and Kuniansky, 2002) theoretical method.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 6.1) were made on sandstone layers similar to that tested in the pumping test; measured horizontal hydraulic conductivity ranged from 5.9 to 9.1 ft/day, the mean value was 7.4 ft/day and the mean ratio of horizontal to vertical hydraulic conductivity in Burdock area sandstone was 2.47:1
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 6.1) were made on shale layers from the two major confining units for the Lakota formation in the pumping test area with the following results:
  - Fuson Shale: the laboratory core data indicate vertical permeabilities of about 2×10^{-7} to 1×10^{-8} cm/sec (average 2.7×10^{-4} ft/day) for shale samples from within the Fuson member overlying the Lakota formation.
  - Morrison Shale: the laboratory core data for the shales in the underlying Morrison formation indicate vertical permeabilities of 9×10^{-9} to 3×10^{-8} cm/sec (average 6.0×10^{-5} ft/day).

- The range of hydraulic conductivities determinable from test transmissivities (Section 6.3) was 0.9 to 15.0 ft/day, which is considered an appropriate range that is also verified by the sandstone core sample results falling in the middle of the range; it is noted that the lower end of the hydraulic conductivity range is probably appropriate for use with the entire formation thickness (shale layers included) and the upper end represents the most permeable sandstone layers such as the ore zone areas tested in the pumping test.

7.1.2 Conclusions

The Burdock pumping test in 2008 may be directly compared to the 1979 TVA test for the Lakota (Chilson) aquifer as the tests were nearly at the same location (Figure 1.1). The average transmissivity and storativity values determined from the TVA tests were 190 ft^2/d and 1.8×10^{-4} (Section 2.3, see p. 17 in Boggs and Jenkins, 1980). Comparing median transmissivity of 150 ft^2/d and storativity of 1.2×10^{-4}determined in the 2008 test (Section 5.4.4) to the TVA test, the new aquifer parameters for the lower Lakota are respectively about 80 and 70 percent of the 1979 results. Because transmissivity and storativity depend on aquifer thickness, comparing the results suggests that there may be some scaling effect between the tests due to the differing lengths of screened intervals.

Therefore, the 1979 TVA test is transmissivity of 190 ft^2/d is considered representative of the entire Lakota aquifer for a regional application, such as groundwater flow model where an average hydraulic conductivity of about 1 ft/day over a thickness of 170 ft could be specified. The 2008 test provides specific data at the operational-scale of a prospective ISR well field where local hydraulic conductivities of up to 15 ft/day could be specified for the most permeable ore zones horizons.

Within the Lakota formation, vertical communication throughout the entire formation is indicated by the delayed response at the upper Lakota observation well (11-19). The 160-minute delay in response at the upper Lakota observation well 11-19 is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pumping test site (Drawings 5.1, 5.2 and 5.3). The extent and continuity of the shale interbeds are unknown. Whether the shale interbeds in the Lakota aquifer are sufficiently thick and continuous to serve as vertical confinement for ISR operations will probably need to be evaluated by analyzing cores from borings as well fields are drilled.

The 2008 test indicates that the lower and upper portions of the Lakota formation behave as a single, confined, leaky aquifer. Confinement and leakage from the overlying Fuson member is

evident in the matches to the Hantush-Jacob type curves seen most clearly at observation wells 11-14C and 11-2. These results are more definitive than the 1979 TVA test where confined, leaky behavior for the Lakota was predicted but not demonstrated with curve match results. Hydraulic communication through the Fuson member between the Lakota and Fall River aquifers is evidenced by the drawdown at the Fall River observation well 11-17, indicating that leakage was established through underlying the Fuson formation.

The laboratory core data indicate an average vertical permeability of 9.3×10^{-8} (2.7×10^{-4} ft/day) for shale samples from within the Fuson member. The shale core permeability values are about one to two orders of magnitude less permeable than pumping test values determined in the 1979 TVA test at Burdock, where the vertical hydraulic conductivity of the Fuson aquitard was calculated using the Neuman-Witherspoon ratio method to be about 10^{-3} ft/day (see page i in Boggs and Jenkins, 1980).

As described in Section 5.1, the potentiometric surface in the Fall River aquifer is close to that in the Lakota aquifer at the Burdock pumping test site, indicating some local connection between the two formations through the intervening Fuson member. In other locations in the Inyan Kara, the Fuson member is known to have sandstone layers that are downcut into the Lakota member (Gott et al., 1974). Therefore, determining the degree of vertical confinement for ISR operations by the Fuson will probably need to be evaluated by analyzing cores from borings as well fields are drilled, and with well field-scale pumping tests that are proposed to be conducted prior to startup of each particular mine unit.

The aquifer tests in 1979 and 2008 indicate that the Lakota Formation is a confined aquifer with a leaky confining layer, which is demonstrably the Fuson member. The laboratory core data for the shales in the underlying Morrison formation indicate an average vertical permeability of 2.1×10^{-8} cm/sec (6×10^{-5} ft/day). Together with the pumping test data, the core data indicate that the underlying Morrison formation and overlying Fuson member can serve as aquitards for ISR operations.

For the Lakota sandstone, the laboratory core data indicate an average horizontal hydraulic conductivity of 7 ft/day, and as high as 9.1 ft/day. Interpretation of the test results calculates that horizontal permeability may be as great as 15 ft/day throughout one of the ore zones. Within the lower Lakota formation, the test results indicate transmissive response between pumping and observation wells up to 250 ft apart with 17 ft of drawdown. Response was nearly 3 ft of

drawdown at 1,290 ft distance. This indicates the aquifer was stressed to produce good quality analytical results.

7.2 Dewey Project Area

7.2.1 Summary

A summary of aquifer parameters for the 2008 Dewey pumping test and related laboratory core testing is as follows:

- Ten determinations of transmissivity (Table 4.3) ranged from 180 to 330 ft^2/day with the median value of 255 ft^2/day.
- Five storativity determinations (Table 4.3) ranged from 2.3×10^{-5} to 2.0×10^{-4} with the median value of 4.6×10^{-5}.
- The radius of influence of the pumping test determined by a distance-drawdown plot was 5,700 ft (Section 4.4.3).
- The pumping well in the Fall River formation was determined to be highly efficient: 93 to 95 percent by the empirical distance-drawdown method and 81 percent the USGS (Halford and Kuniansky, 2002) theoretical method.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 6.1) were made in a core sample from the sandstone layer similar to that tested in the pumping test; measured horizontal hydraulic conductivity was 6.1 ft/day, and the ratio of horizontal to vertical hydraulic conductivity was 4.5:1.
- Laboratory measurements of horizontal and vertical hydraulic conductivity (Table 6.1) were made on shale samples from the two major confining units overlying and underlying the pumping test area with the following results:
  - Skull Creek shale: laboratory core data for the shale sample from the overlying Skull Creek formation indicate a vertical permeability of 5.4×10^{-9} cm/sec (1.5×10^{-5} ft/day).
  - Fuson Formation: laboratory core data for the shale sample from the underlying Fuson formation indicate a vertical permeability of 6.2×10^{-9} cm/sec (1.8×10^{-5} ft/day).

7.2.2 Conclusions

The Dewey pumping test in 2008 in the Fall River aquifer is not directly comparable to the 1982 TVA test because the underlying Lakota aquifer was tested in 1982. As demonstrated above for the Lakota aquifer (Section 7.1), a scaling effect may be assumed between total formation transmissivity and storativity (i.e., regional-scale) and the 2008 operational-scale test.

However, there are several lines of evidence that the 2008 test transmissivity and storativity results are representative of the entire Fall River aquifer at the Dewey test site, as follows:

1. Thickness of the sandstone layer screened by the pumping well is about one-half the total formation thickness as shown in Drawings 4.1 and 4.2.

2. Response at the stock tank well (GW-49 at 1,400 ft distance) was within the acceptable range for a confined aquifer; this is interpreted to indicate that the effects of partial penetration (due to elevation differences between the pumping well screen and the observation well open to the upper half of the aquifer) were diminished at the 1,400 ft distance and 40 minute response time.

3. The delay in response at the upper Fall River observation well 32-9C was a relatively brief 11 minutes (Table 4.2), compared to 160 minutes in the Burdock test; together with (2) above, these responses suggest that the vertical anisotropy due to shale interbeds overlying the lower sandstone layer does not extend laterally for more than about 1,400 ft.

The 2008 test indicates that the lower and upper sandstone portions of the Fall River formation behave as a single, confined, aquifer with some form of lateral barrier due changing lithology, such as a channel boundary. The TVA test in 1982 observed a barrier boundary in the underlying Lakota formation which was attributed to either a change in lithology or the Dewey Fault zone. Apparently, both the Lakota and Fall River formations in the general Dewey project area are highly transmissive and show barrier boundaries. These test results are more definitive than the 1982 TVA test concerning the proximity of the barrier boundary, because the 2008 radius of influence was about one mile compared to greater than two to three miles distance to the fault zone.

Vertical communication throughout the entire Fall River formation is indicated by the delayed response at the upper Fall River observation well (32-9C). Within the Fall River formation, the 11-minute delay in response at the upper observation well is attributed to lateral and vertical anisotropy due to the shale interbeds seen on the conceptual stratigraphic cross-sections for the pumping test site (Drawings 4.1 and 4.2). The extent and continuity of the shale interbeds are not known. Whether the shale interbeds in the Fall River aquifer are sufficiently thick and continuous to serve as vertical confinement for ISR operations will need to be evaluated by analyzing cores from borings as well fields are drilled.

Leakage from a confining layer, presumably the Fuson member, was observed in the 1982 TVA test of the Lakota formation. However, the leakage was observed only relatively late in the TVA tests, at 3,000 to 10,000 minutes, with a much greater pumping rate (495 gpm) and radius of influence. The large-scale vertical hydraulic conductivity value of 2×10^{-4} ft/day (7.1×10^{-8} cm/sec) determined in the 1982 TVA regional test at Dewey using the Neuman-Witherspoon ratio method is sufficiently impermeable to be considered an aquitard or aquiclude.

Hydraulic communication through the Fuson member between the Fall River and underlying Lakota aquifers is not indicated by the 2008 response at observation well 32-10. The 2008 test demonstrates that vertical leakage through the Fuson may not occur over a mile-wide radius. As described in Section 4.1, the Lakota and Fall River aquifers at the Dewey test site appear to be locally hydraulically isolated by the intervening Fuson member with nearly 40 ft head difference. The laboratory core data indicate a very low vertical permeability of 6.2×10^{-9} cm/sec (1.8×10^{-5} ft/day) for the shale sample from within the Fuson shale member.

The laboratory core data for the shale sample from the Skull Creek formation, overlying the Fall River formation, indicate a very low vertical permeability of 5.4×10^{-9} cm/sec (1.5×10^{-5} ft/day), also appropriate for an aquitard or aquiclude.

For the Fall River sandstone, the laboratory core data indicate a horizontal hydraulic conductivity of 6.1 ft/day, and interpretation of the test results calculates that horizontal permeability may be as great as 17 ft/day throughout one of the ore zones. Within the lower Fall River formation, the test results indicate transmissive, rapid response (two to three minutes) between pumping and observation wells up to 467 ft apart with nearly 10 ft of drawdown. Response was nearly 9 ft of drawdown at 1,400 ft distance. This indicates the aquifer was stressed to produce good quality analytical results.

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8.0 Certification

This report "Powertech (USA) Inc., Dewey-Burdock Project, 2008 Pumping Tests: Results and Analysis" has been prepared for Powertech (USA) Inc. by Knight Piésold and Co. The material in it reflects the best judgment of Knight Piésold and Co. in light of the information available to both firms at the time of the report preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. Knight Piésold and Co. and Powertech (USA), Inc. accept no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

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Tables

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Table 4.1
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Dewey Pumping Test Completion Information

Well ID and Stratigraphic Interval	Well Type	Location	Radial Distance from pumping Well (ft)	Depth to top of Screen (ft bgs)	Depth to bottom of Screen (ft bgs)	Note
Ore Zone (lower Fall River Sandstone)						
DB 07-32-3C	Pumping Well	NWQ Sec. 32	0	585	600	
DB 07-32-05	Obs. Well #1	NWQ Sec. 32	265	593	608	
DB 07-32-4C	Obs. Well #2	NWQ Sec. 32	467	580	595	
DB 07-29-7	Obs. Well #3	SEQ Sec. 29	2,400	635	650	
Upper Fall River Sandstone						
DB 08-32-9C	Obs. Well	NWQ Sec. 32	41	490	505	
Lakota Sandstone Layer						
DB 08-32-10	Obs. Well	NWQ Sec. 32	61	715	730	
Unkpapa Formation						
DB 07-32-11	Obs Well	NWQ Sec. 32	50	910	930	
Additional Wells						
GW-49	Upper Fall River 70 ft	NEQ Sec. 29	1,433	475	540	Stock Well

Notes: Screen completion information from diagrams prepared by Powertech, Appendix B
Radial distance information provided by Powertech.

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Table 4.2
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Dewey Pumping Test Drawdown and Response Summary

Well ID and Stratigraphic Interval	Well Type	Radial Distance from pumping Well (ft)	Approximate Ground Surface Elevation (ft amsl)[1]	Approximate Groundwater Elevation (ft amsl)[2]	Note	Maximum Drawdown at 3.08 days (ft)[3]	Note	Time of First Drawdown Response (min)	Minimum Pumping Groundwater Elevation (ft amsl)	Boundary Type (days)[4]
Ore Zone (lower Fall River Sandstone)										
DB 07-32-3C	Pumping Well	0	3626.3	3643.9	A	44.8		0.0	3599.1	
DB 07-32-05	Obs. Well #1	265	3622.2	3641.0	A	13.0		1.6 to 2.4	3628.0	Barrier (0.7)
DB 07-32-4C	Obs. Well #2	467	3626.3	3644.0	A	9.8		2.8	3634.2	Barrier (0.6)
DB 07-29-7	Obs. Well #3	2,400	3662.5	3659.3		1.5	a	140 to 850	3657.8	
Upper Fall River Sandstone										
DB 08-32-9C	Obs. Well	41	3625.9	3626.3	A	10.6		11.5	3615.7	
Lakota Sandstone Layer										
DB 08-32-10	Obs. Well	61	3625.2	3682.8	A	-0.1	N	No Response	NA	
Unkpapa Formation										
DB 07-32-11	Obs Well	50	3625.2	3761.0	A	-2.0	N	No Response	NA	
Additional Wells										
GW-49	Stock Well	1,433	3628	3652	A	9.0		40	3643.0	Barrier (1.9)

Notes: Screen completion information from diagrams prepared by Powertech, Appendix A
Radial distance informationprovided by Powertech.

[1] Ground Surface Elevations from Powertech

[2] Pressure or depth to water measurements relative to ground surface, Eric Krantz, RESPEC, personal communication.

[3] From table of processed drawdown data in Appendix B, or calculated visually from WinSituTM graph and table of data in non-responding wells.

[4] Boundary time estimated based on time of deviation from Theis type curve; 0.7 days used for weighting calculations.

A Artesian pressure surface above ground level.

N N response to pumping, water level rose slightly through drawdown phase of test

[a] Drawdown continued for about 1.5 days past pump shut-down to a maximum of 2.1 ft at about 3:00 AM on May 20, 2008.

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Table 4.3
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Summary of Aquifer Hydraulic Characteristics for the Dewey Pumping Test

Dewey Test Site Pumping Test Interpretations

Well I.D.	Well Type	Radial Dist. (ft)	Interpretation Method	Transmissivity (ft^2/day)	u or u' (unitless)	Storativity (unitless)	Note
Ore zone (lower Fall River Sandstone)							
32-3C	Pumping	0.25 (0.33)	Theis DD[1]	250	--	1.2E-06[d]	--
			CJ DD [3]	250	<0.01	--	--
Pumping Well Efficiency = 80%[3]							
			CJ Recovery [3]	270	<0.01	--	--
32-5	Obs #1	243	Theis DD[1]	294	--	3.3E-05	--
			Theis Recovery[1]	260	<0.01	--	--
			CJ Recovery[3]	280	<0.01	--	--
32-4C	Obs #2	467	Theis DD[1]	333	--	5.6E-05	--
			CJ Recovery [3]	120[a]	<0.01	--	
29-7	Obs #3	2,400	Theis DD[2]	178	--	2.0E-04	
			CJ Recovery [3]	Insufficient recovery for analysis			--
Fall River Aquifer Stock Well (Screened in top half of Fall River)							
GW-49	Stock	1,400	Theis DD[1]	177	--	2.3E-05	--
			CJ Recovery [3]	110	<0.05	--	--
Upper Fall River Sandstone							
32-9C	Obs	41	Theis DD[1]	217	--	1.6E-02	--
			CJ Recovery [3]	150	<0.05	--	--

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Table 4.3
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Summary of Aquifer Hydraulic Characteristics for the Dewey Pumping Test

Dewey Test Site Pumping Test Interpretations

Well I.D.	Well Type	Radial Dist. (ft)	Interpretation Method	Transmissivity (ft^2/day)	u or u' (unitless)	Storativity (unitless)	Note
Lakota Sandstone Layer							
32-10	Obs	61	No response during pumping test.				--
Unkpapa Formation							
32-11	Obs	50	No response during pumping test.				--
Distance Drawdown (32-5, 32-4C, 29-7, GW-49)[2]				218	<0.05	4.6E-05	r^2 = 0.78 (4 point line)
Pumping Well Efficiency = 93% to 95%							--
Summary:	Median			255		4.60E-05	
	Average/Geometric Mean[4]			251		5.23E-05	

Notes/References: DD = drawdown, CJ = Cooper -Jacob, Obs = Observation Well

[1] Calculated by automated curve fitting in AquiferWin32™ software (ESI, 2003).

[2] Knight Piesold spreadsheet after methods in Driscoll (1986).

[3] Spreadsheet methods in U.S. Geol. Surv. Open File Rept. 02-197, Halford and Kuniansky (2002).

[4] Average value valculated for Transmissivity, Geometric Mean value calculated for Storativity.

[a] only slope satisfying u 'critereon occurs after intersection with barrier boundary.

[b] not accepted due to anomalous response at well, see text.

[d] storativity not valid at pumping well.

= accepted value based on conformance with theory discussed in the text.

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Table 5.1
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Burdock Pumping Test Completion Information

Well ID and Stratigraphic Interval	Well Type	Location	Radial Distance from pumping Well (ft)	Depth to top of Screen (ft bgs)	Depth to bottom of Screen (ft bgs)	Note
Ore Zone (lower Lakota Sandstone)						
DB 07-11-11C	Pumping Well	SWQ Sec. 11	0	426	436	
DB 07-11-15	Obs. Well #1	SWQ Sec. 11	243	418	428	
DB 07-11-14C	Obs. Well #2	SWQ Sec. 11	250	413	423	
DB 07-11-02	Obs. Well #3	NWQ Sec. 11	1,292	450	460	
Upper Lakota Sandstone						
DB 07-11-19	Obs. Well	SWQ Sec. 11	50	325	335	
Fall River (lower Sandstone layer)						
DB 07-11-17	Obs. Well	SWQ Sec. 11	50	245	255	
Unkpapa Formation						
DB07-11-18	Obs Well	SWQ Sec. 11	<100	621	631	
Additional Distant Wells	None					

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Table 5.2
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Burdock Pumping Test Drawdown and Response Summary

Well ID and Stratigraphic Interval	Well Type	Radial Distance from pumping Well (ft)	Approximate Ground Surface Elevation (ft amsl)[1]	Approximate Groundwater Elevation (ft amsl)[2]	Note	Maximum Drawdown at 3.0 days (ft)[3]	Note	Time of First Drawdown Response (min)	Minimum Pumping Groundwater Elevation (ft amsl)	Boundary Type (days)[4]
Ore Zone (lower Lakota Sandstone)										
DB 07-11-11C	Pumping Well	0	3700.5	NA		91.1		0.0	3529	
DB 07-11-15	Obs. Well #1	243	3691.5	3660.2		10.4		140.2	3649.8	
DB 07-11-14C	Obs. Well #2	250	3688.4	3660.9		17.0		3.6	3643.9	Recharge (1.1)
DB 07-11-02	Obs. Well #3	1,292	3717.9	3664.8		3.1		280	3661.7	Recharge (1.8)
Upper Lakota Sandstone										
DB 07-11-19	Obs. Well	50	3701.7	3662.1		3.4		160	3658.7	
Fall River (lower Sandstone layer)										
DB 07-11-17	Obs. Well	50	3700.1	3660.3		2.1	a	see note b	3657.2	
Unkpapa Formation										
DB07-11-18	Obs Well	35	3699.2	3728.4	A	-0.5	N	No Response	NA	
Additional Wells										
None										

Notes: Radial distance information from Autocad drawing provided by Powertech.

[1] Ground Surface Elevations from Powertech

[2] Pressure or depth to water measurements relative to ground surface, Eric Krantz, RESPEC, personal communication.

[3] From table of processed drawdown data in Appendix B, or calculated from WinSitu™ graph and table of data in non-responding wells.

[4] Boundary time estimated based on time of deviation from Theis type curve; shortest time used for weighting calculations.

A Artesian pressure surface above ground level.

N N response to pumping, water level rose slightly through drawdown phase of test

(a)Drawdown continued for about 1 day past pump shut-down to a maximum of 3.1 ft at about 5:00 PM, May 22, 2008.

(b)First response was a 0.23 ft rise in water levels peaking at about 12:00 AM on May 19, 2008, interpreted as a possible Noordbergum effect.

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Table 5.3
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Summary of Aquifer Hydraulic Characteristics for the Burdock Pumping Test

Burdock Project Pumping Test Interpretations

Well I.D.	Well Type	Radial Dist. (ft)	Interpretation Method	Transmissivity (ft^2/day)	u or u' (unitless)	Storativity (unitless)	Note
Ore zone (lower Lakota Sandstone)							
11-11C	Pumping	0.25 (0.33)	Theis DD[1]	145	--	2.9E-09[a]	--
			CJ DD [3]	150	<0.01	--	--
Pumping Well Efficiency = 65%[3]							
			CJ Recovery [3]	140	<0.01	--	--
11-15	Obs #1	243	Theis DD[1]	67	--	1.3E-03	--
			CJ Recovery [3]	100	<0.1	--	--
11-14C	Obs #2	250	Theis DD[1]	128	--	6.8E-05	--
			H-J DD[1]	120	--	6.9E-05	--
			Theis Recovery[1]	174	<0.01	--	--
			CJ Recovery [3]	160	<0.01	--	--
11-02	Obs #3	1,292	Theis DD[1]	223	--	1.9E-04	--
			H-J DD[1]	185	--	1.7E-04	--
			CJ Recovery [3]	260	<0.15	--	--
Upper Lakota Sandstone							
11-19	Obs	50	Theis DD[2]	260	--	1.0E-01	--
			CJ Recovery [3]	190	<0.15	--	--
Fall River (lower sandstone layer)							
11-17	Obs	50	Noordbergum Effect and response cannot be interpreted analytically				

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Table 5.3
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Summary of Aquifer Hydraulic Characteristics for the Burdock Pumping Test

Burdock Project Pumping Test Interpretations

Well I.D.	Well Type	Radial Dist. (ft)	Interpretation Method	Transmissivity (ft^2/day)	u or u' (unitless)	Storativity (unitless)	Note
Unkpapa Formation							
11-18	Obs	35	No response during pumping test.				--
Distance Drawdown (11-14C, 11-15, 11-02)[2] Pumping Well Efficiency = 61% to 63%				145	<0.08	2.2E-04	r^2 = 0.76 (3 point line)
Summary:	Median			150		1.20E-04	
	Average/Geometric Mean[5]			158		1.12E-04	
	TVA[4]			190		1.8E-04	

Notes/References: DD = drawdown, CJ = Cooper-Jacob, HJ = Hantush-Jacob, Obs = Observation Well

[1] Calculated by automated curve fitting in AquiferWin32™ software (ESI, 2003).

[2] Knight Piesold spreadsheet after methods in Driscoll (1986).

[3] Spreadsheet methods in U.S. Geol. Surv. Open File Rept. 02-197, Halford and Kuniansky (2002).

[4] Summary values from p. 17 in Boggs and Jenkins (1980).

[5] Average value valculated for Transmissivity, Geometric Mean value calculated for Storativity.

(a) storativity not valid at pumping well.

(b) based on 6 inch casing (8 inch borehole).

= accepted value based on conformance with theory discussed in the text.

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Table 6.1
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Laboratory Core Analyses for Powertech USA Inc. at Dewey-Burdock Site

Sample Number	Depth (ft)	Confining Stress (psig)	Porosity (%)	Air Intrinsic Permeability[1] k_a (mD)	Particle Density (g/cm^3)	Notes	Water Hydraulic Conductivity[2][3] K_w (cm/s)	Core K_h (ft/day)	Core K_v (ft/day)
DB 07-11-11C	**Burdock**								
1H	252.20	600	10.50	1.040	2.356	Fuson Shale	8.0073E-07		
1V	252.35	600	10.15	0.228	2.356	Fuson Shale	1.7555E-07		
4H	412.30	600	9.68	0.041	2.511	Fuson Shale	3.1567E-08		
4V	412.45	600	9.59	0.015	2.514	Fuson Shale	1.1549E-08		
DB 07-29-1C	**Dewey**								
2H	480.70	600	8.90	0.078	2.613	Skull Creek shale	6.0055E-08		
2V	480.80	600	9.30	0.007	2.610	Skull Creek shale	5.3896E-09		
3H	609.10	600	12.26	0.073	2.603	Fuson Shale	5.6205E-08		
3V	609.10	600	10.84	0.008	2.793	Fuson Shale	6.1595E-09		
DB 07-11-14C	**Burdock**								
5H	423.60	600	29.56	3,207	2.645	Lakota Sand	2.4692E-03	7.0	
5V	423.35	600	30.34	1,464	2.645	Lakota Sand	1.1272E-03		3.2
6H	430.20	600	31.90	4,161	2.640	Lakota Sand	3.2037E-03	9.1	
6V	430.35	600	30.16	939	2.646	Lakota Sand	7.2297E-04		2.1
7H	453.50	600	10.86	1.000	2.519	Morrison Shale	7.6994E-07		
7V	453.45	600	11.82	0.043	2.543	Morrison Shale	3.3107E-08		

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Table 6.1
Powertech (USA) Inc.
Dewey-Burdock Project
2008 Pumping Tests: Results and Analysis

Laboratory Core Analyses for Powertech USA Inc. at Dewey-Burdock Site

Sample Number	Depth (ft)	Confining Stress (psig)	Porosity (%)	Air Intrinsic Permeability[1] k_a (mD)	Particle Density (g/cm^3)	Notes	Water Hydraulic Conductivity[2][3] K_w (cm/s)	Core K_h (ft/day)	Core K_v (ft/day)
DB-07-11-16C	**Burdock**								
8H	420.40	600	30.50	2,697	2.643	Lakota Sand	2.0765E-03	5.9	
8V	420.10	600	30.17	1,750	2.651	Lakota Sand	1.3474E-03		3.8
9H	455.90	600	6.99	0.004	2.536	Morrison Shale	3.0797E-09		
9V	455.45	600	7.65	0.012	2.556	Morrison Shale	9.2392E-09		
10H	503.30	600	12.96	0.697	2.474	Morrison Shale	5.3665E-07		
10V	503.45	600	No data						
DB 07-32-4C	**Dewey**								
11H	573.25	600	29.15	2,802	2.641	Fall River Sand	2.1574E-03	6.1	
11V	573.40	600	29.04	619	2.645	Fall River Sand	4.7659E-04		1.4
Summary									
Average Lakota Sand K_h, K_v								7.4	3.0
Average Lakota Sand K_h/K_v								2.42	
Fall River Sand K_h, K_v								6.1	1.4
Fall River Sand K_h/K_v								4.53	
Dewey Skull Creek Shale K_h							6.01E-08	1.71E-04	
Dewey Skull Creek Shale K_v							5.39E-09		1.54E-05
Dewey Skull Creek Shale K_h/K_v							11.14		

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Table 6.1
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2008 Pumping Tests: Results and Analysis

Laboratory Core Analyses for Powertech USA Inc. at Dewey-Burdock Site

Sample Number	Depth (ft)	Confining Stress (psig)	Porosity (%)	Air Intrinsic Permeability[1] k_a (mD)	Particle Density (g/cm^3)	Notes	Water Hydraulic Conductivity[2][3] K_w (cm/s)	Core K_h (ft/day)	Core K_v (ft/day)
Average Burdock Fuson Shale K_h							4.16E-07	1.19E-03	
Average Burdock Fuson Shale K_v							9.35E-08		2.67E-04
Average Burdock Fuson Shale K_h/K_v							4.45		
Dewey Fuson Shale K_h							5.62E-08	1.60E-04	
Dewey Fuson Shale K_v							6.16E-09		1.76E-05
Dewey Fuson Shale K_h/K_v							9.13		
Average Burdock Morrison Shale K_h							4.37E-07	1.24E-03	
Average Burdock Morrison Shale K_v							2.12E-08		6.03E-05
Average Burdock Morrison Shale K_h/K_v							20.62		

Notes:

(1) Assumed air temperature = 70°F.

(2) Assumed water temperature = 52.8°F, water density = 0.999548 g/cm^3, and water dynamic viscosity = 0.012570 g/cm-s.

(3) $K_w = k_a \times (\rho_w g/\mu_w)$, and 1.0 mD = 0.987 x 10^{-11} cm^2

Constants: At 52.8 °F Water (11.5 °C)

Density = 0.999548 g/cm^3

Dynamic Viscosity = '0.01257 g/cm-s

1 mD = 9.87E-12 cm^2

gravity = 981 cm/s^2