SECTION 17

GEOLOGIC INFORMATION

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SECTION 17 GEOLOGIC INFORMATION

The Pinabete Mine Plan permit area (permit area) and adjacent areas are located on the west flank of the San Juan Structural Basin, within the Navajo Section of the Colorado Plateau in northwestern New Mexico. The Colorado Plateau, or Colorado Plateaus Province, is a physiographic region of the Intermontane Plateaus, roughly centered on the Four Corners region of the southwestern United States. The Colorado Plateau covers an area of approximately 130,000 square miles (sq mi) within western Colorado, northwestern New Mexico, southeastern Utah, and northern Arizona (Leighty 2001). Within the Colorado Plateau, the San Juan Basin covers about 7,500 sq mi across the Colorado/New Mexico border and measures approximately 100 miles long in the north-south direction and 90 miles wide. The land surface elevations within the basin range from 5,100 feet on the western side to over 8,000 feet in the northern side. This basin is an asymmetric, structural basin with a northeast-trending axis parallel to the Hogback Monocline in northwestern New Mexico. It is bounded to the north by the San Juan Uplift and to the south by the Zuni Uplift and the Chaco Slope. The western rim is formed by the Defiance Uplift and Four Corners Platform and the eastern rim is formed by the Brazos Uplift and the Nacimiento Uplift. The Continental Divide trends north to south along the east side of the San Juan Basin.

The stratigraphic section in the permit area reflects the Late Cretaceous transition of shallow marine depositional environment to a terrestrial fluvial depositional environment. The four rock sequences encompassing this depositional environment change are (in descending order): Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone (PCS), and Lewis Shale. Mining activities will occur in the Kirtland Shale and Fruitland Formation. The Fruitland Formation contains the mineable coal-bearing units.

17.1 Geologic Description

The geologic units to be mined or potentially influenced by mining include the Kirtland Shale, Fruitland Formation, and PCS. The geologic strata in the permit area outcrop along the western edge and dip approximately 2° to the east or northeast toward the center of the San Juan Basin. The surface topography in the area is described in Section 13 (Topography). The area is generally arid, rolling terrain with some incised arroyos. A generalized geologic column of the rock sequence planned to be mined is provided as Figure 17.1-1.

The Kirtland Shale is the uppermost consolidated geologic layer within or adjacent to the permit area. It conformably overlies the Fruitland Formation. The Kirtland Shale is divided into two units, the upper shale member, which includes Farmington Sandstone, and the lower shale member. Sediments in the Kirtland Shale were deposited in an upland floodplain environment where aggrading stream channels were separated by narrow, parallel floodplains. The upper shale member is composed of a series of interbedded sandstone lenses and claystone shales. The shale beds in the upper shale member of the Kirtland Shale are much more colorful than those in the lower shale member and are purple, green, white, and gray. The lower shale member is composed of gray claystone shales that contain a few thin interbeds of siltstone and sandstone. No coal beds exist in the Kirtland Shale (Fasset and Hinds 1971). A detailed discussion of ground water quantity, quality, and transport within the Kirtland Shale is provided in Section 18 (Water Resources). Several deposits of Quaternary alluvial and eolian sands occur within the permit area. These are important sources of topdressing material for reclamation and are discussed in Section 14 (Soil).

The Fruitland Formation, which conformably overlies the PCS, contains sediments deposited in fluvial delta-plain and adjoining back beach-bar depositional environments (Flores and Erpenbeck 1981). The lithologies of the rock units encountered in the Fruitland Formation include fine- to medium-grained sandstones, siltstones, sandy and silty claystones, carbonaceous claystones, bentonitic claystones, and coal. Although the rock-unit bedding is generally parallel, the units are not continuous throughout the permit area.

There are eight primary coal seams and eight corresponding overburden/interburden horizons defined by the geologic model within the permit area. Each interburden layer is referred to using the name of the coal seam directly below the interburden layer. Coal seams are numbered from deepest to shallowest. For example, the deepest coal seam to be mined is the No. 2 coal seam (S2) and the interburden above it and below the No. 3 coal seam (S3) is referred to as No. 2 interburden (I2). In situations where the coal seam splits, the coal seam number is followed by alphabetic designation (e.g., S2A and S2B). Interburden layers between splits in the No. 2 coal seam are referred to as I2A and I2B. Further, if interburden layers are composed of horizons of differing rock strata (e.g., sandstone and shale) the interburden number will be followed by numeric designation (e.g., I2-1 or I2A-1). For example, if the bottom horizon in I2 is primarily sandstone and the upper primarily shale, then the bottom horizon within this interburden would be labeled I2-1 and the next horizon above would be I2-2. An exhibit showing the Pinabete permit boundary and cross-section locations is presented as Exhibit 17.1-1. Cross-sections of the geologic model are provided in Exhibit 17.1-2, Exhibit 17.1-3, Exhibit 17.1-4, and Exhibit 17.1-5.

The production operations will remove units from the surface down to and including No. 2 coal seam. Coal seams below the No. 2 coal seam will not be extracted and the underlying PCS will not be mined. Some of the coal seams and interburdens within and adjacent to the permit area are under perched, saturated conditions due to recharge zones at the outcrops. However, the water is not of sufficient quantity to be of sustainable use or pose a challenge during mining or reclamation operations. A detailed discussion of groundwater quantity, quality, and transport within the Fruitland Formation is provided in Section 18 (Water Resources).

The PCS conformably overlies and forms overlapping layers with the Lewis Shale. This formation consists of both delta-front and barrier-beach sediments and marks the change to a littoral (near-shore) depositional environment (Flores and Erpenbeck 1981). The upper two-thirds of the PCS consists of a generally coarsening upward sequence of light gray, fine- to medium-grained sandstone while the lower one-third of the formation consists of interbedded shale and sandstone. The upper 60 feet of this sandstone is consistently massive, light gray to light brown, fine to medium grained with predominately rounded quartz grains, and has a salt-and-pepper appearance. The total thickness of the PCS is approximately 110 feet in the permit area. The PCS is the lowest potential water-bearing unit within and adjacent to the permit area that could be impacted by mining but it will not be mined. A detailed discussion of groundwater quantity, quality, and transport within the PCS is provided in Section 18 (Water Resources).

The Lewis Shale contains the last purely marine shales deposited in the Upper Cretaceous epeiric seaway. It consists of gray to black shale with some interbeds of sandy limestone, brown sandstone, and bentonite. The Lewis Shale is located below the PCS and will not be mined; however, it is included in the groundwater model discussed in Section 18 (Water Resources).

Geologic hazards within the mining area are limited to those created during the mining process, namely exposed highwalls and spoil piles. Hazards encountered during mining are managed in accordance with Mine Safety and Health Administration (MSHA) regulations. There is no history of landslide or mudslide potential within or adjacent to the permit area. No major faults cut the permit area, although minor low-angle compaction faults and slumps with up to 10 feet of displacement are not uncommon. The Colorado Plateau is considered tectonically stable. The U.S. Geological Survey National Seismic Hazard Map indicates the permit area is within a low-hazard zone for ground shaking, with a 2% chance of experiencing a seismic event that would cause ground shaking at a level of 4% to 8% of acceleration of gravity in the next 50 years (Petersen et.al. 2008). Of the nearly 1,800 seismic events with epicenters recorded in New Mexico between 1962 and 1995 approximately 10 occurred within 100 miles of the permit area (Sanford et.al. 2002). In 1976 and 1977 two deep earthquakes with moment magnitudes of 4.6 and 4.2, respectively, occurred around Crownpoint, New Mexico, approximately 75 miles south of the permit area (Wong et.al. 1984). The epicenter of these was about 26 miles below the surface at a tectonic transition zone between the Basin and Range-Rio Grande Rift and Colorado Plateau stress provinces.

17.2 Overburden Characteristics

The characteristics of in-situ overburden from eight drill holes have been evaluated. These holes were drilled as part of drilling programs conducted in 1987, 1998, and 2007 (Exhibit 17.2-1). The 1987 drilling program consisted of coring and sampling five drill holes (487-01 through 487-05) in Area 4 North; four of these drill holes (487-01 through 487-04) are located in permit area. The 1998 drilling program included coring and sampling one hole in the permit area and nine holes south of the permit area. The 2007 drilling program included coring three holes in the permit area and 13 holes south of the permit area. The core inventory logs for the 1987, 1998, and 2007 holes cored in the permit area are included in Appendix 17.A,

Appendix 17.B, and Appendix 17.C, respectively. Samples from the overburden/interburden material at defined intervals were analyzed for the physical/chemical properties outlined in Table 17.2-1. Results from the 1987, 1998, and 2007 overburden/interburden analyses are provided in Table 17.2-2, Table 17.2-3, Table 17.2-4, Table 17.2-5, Table 17.2-6, Table 17.2-7, Table 17.2-8, and Table 17.2-9.

Data collected in the 1987 drilling program were used in the initial Area 4 North overburden characterization found in the BNCC Navajo Mine Surface Mining Control and Reclamation Act (SMCRA) permit application package (Office of Surface Mining Reclamation and Enforcement [OSM] Permit No. NM-0003F) (BNCC 2009). Each geologic stratum encountered in core was sampled for analysis per OSM instruction, i.e. major strata were sampled in five foot increments. For the 1987 drilling program, BNCC did not attempt to create a statistical model to predict the overburden/interburden characteristics.

Data collected in the 1998 drilling program were used in the development of the first statistical analysis of interburden and overburden sampling in the permit area. This report was prepared by J.W. Kern, PhD, of Western EcoSystems Technology, Inc. and is included as Appendix 17.D. The objectives of this report included identifying which overburden/interburden layers contain high proportions of material unsuitable for root-zone material, and estimating the volume of root-zone material available for reclamation. Kern's report focused on an area within the southwest corner of the Pinabete permit area extending south of the permit boundary to the southwest bank of the Pinabete Arroyo.

The 2007 drilling program expanded drilling into all of the Pinabete permit area and south of the Pinabete permit area. These data, along with the 1998 and 1987 data, were used to develop a statistical analysis of the overburden/interburden sampling within the Pinabete permit area. This report was prepared by BNCC and is included as Appendix 17.E. The objectives of the statistical analysis were to estimate the total volume of root-zone suitable material in the overburden and interburden layers most likely to be used for reclamation, characterize the in-situ overburden and interburden layers, and characterize mixed material (spoil) suitability. When characterizing the suitability of in-situ overburden and interburden layers and modeled spoil material, two potential criteria limits were used: OSM Southwestern U.S. criteria limits (OSM 1999) and BNCC Navajo Mine site-specific criteria limits (BNCC 2009). These root-zone suitability criteria, provided in Table 17.2-10, were selected because of the location of the Pinabete permit area in proximity to BNCC Navajo Mine.

The recoverable suitable root-zone material will come from overburden strata above the first seam to be mined. Suitable root-zone thickness for each drill hole was determined by comparing the weighted average of analytical results to both OSM and Navajo Mine criteria. The results of suitable thickness calculations are summarized in Appendix 17.E.

Characterization of the in-situ interburden above each coal seam suggests that, in some locations, the rock strata associated with the interburden above the No. 6 coal seam (I6) in the Pinabete permit area has soluble selenium concentrations that exceed OSM suitability criteria, but are below Navajo Mine suitability criteria. In-situ acid-base potential (ABP) characterization suggests a net alkaline environment for the majority of interburden layers across the permit area. The characterization suggests that in some drill hole locations, the rock strata associated with interburden above the No. 2 coal seam (I2) has pyritic sulfur ABPs that are outside criteria limits. This layer is thin and makes up less than 6% of the total thickness of interburden to be excavated during mining (Appendix 17.E). Characterization of the in-situ interburden above each coal seam suggests that, in general, the rock strata present in I6, I4, I3, and I2 across the Pinabete permit area possess saturation percent, sodium adsorption ratio (in I4, I3, and I2 only), and pH values that are outside criteria limits established by OSM and Navajo Mine for root-zone suitability.

Spoil material quality was modeled by computing the weighted mean for each analyte within each drill hole (Appendix 17.E). These data are used to characterize spoil at each drill hole location and estimate spoil variability within permit area. The results of these computations are included in Appendix 17.E. Modeled spoil quality indicates criteria limits exceedances for saturation percent, pH, and sodium adsorption ratio (SAR) only. ABP values are greater than the root-zone suitability criteria, suggesting the modeled spoils represent alkaline or neutralizing rock strata. The Navajo Mine saturation percent suitability criterion is exceeded in five of the eight drill holes in the Pinabete permit area from 11.1% to 40.3%. SAR suitability criteria are exceeded in six of the eight drill holes in the permit area by up to 19.4, but the average SAR value is below both OSM and Navajo Mine suitability criteria. The Navajo Mine pH suitability criteria is exceeded in two of the eight drill holes in the Pinabete permit area by 0.1 standard units (s.u.).

In conclusion, there is no widespread occurrence of potentially acid- and toxic- forming materials (PATFM) within the Pinabete permit area. ABP characterization suggests a net alkaline environment for the majority of interburden layers across the permit area. One in-situ interburden layer, I2, possesses APB values that are outside criteria limits. This layer is thin compared to the total thickness of interburden to be excavated during mining, constituting less than 6% of the in-situ interburden thickness at each drill hole location. Characterization of the in-situ interburden also suggests that the rock strata present in I6, I4, I3, and I2 in the permit area possess values for saturation percent, SAR (I4, I3, and I2 only), and pH that are outside criteria limits established by OSM and Navajo Mine for root-zone suitability. These characteristics are common to alkaline subsurface environments where weathering has not altered the rock strata.

When analyzed as a composite to model mine spoil conditions, the influence of the I6, I4, I3, and I2 layer characteristics is attenuated and the overall values for physical and chemical analytes for the spoil, with the exception of pH, saturation percent, and SAR, are within suitability limits and PATFM is not a concern. Despite containing these thin layers of low pyritic sulfur ABP interburden, all modeled spoil columns have net alkaline values (Appendix 17.E). In addition, there is substantially more material present in the overburden of the uppermost coal seam to be mined to provide 4 feet of suitable root-zone. The average in-situ suitable overburden thickness over the permit area, based on drill hole information, is 30.8 feet. This thickness is greater than the required regulatory thickness. Assuming the entire disturbance area required 4 feet of suitable material, these results suggest the amount of material available in the Pinabete permit area exceeds potential requirements by 7.7 times.

17.3 Coal Characteristics

The areal extent of the Fruitland Formation coal seams varies across the permit area due to strata dip and localized pinch outs, as shown by the cross-sections in Exhibit 17.1-2, Exhibit 17.1-3, Exhibit 17.1-4, and Exhibit 17.1-5. Some of these seams split locally from "parent" seams to form "child" seams. Defined croplines are not typically expressed at the topographic surface due to deep weathering and burn areas. The general characteristics and extent of the coal are discussed in the following section.

The No. 2 coal seam is the lowest seam to be mined and lies above the PCS. In some areas, the coal seam is in contact with the PCS and in others is separated from the PCS by interburden. The cropline is located on the west side of the permit area, outside of the coal lease. The seam has two splits, No. 2A and No. 2B, with No. 2A being the lower of the two. In Area 4 South, these seams have additional splits locally, named Nos. 2A2, 2A1, 2B2, and 2B1. No significant rock partings occur in this seam.

The No. 3 coal seam lies above the No. 2 seams and is separated by the interburden above the No. 2 coal seam (I2). The cropline is located on the west side of the permit area, outside of the coal lease. This seam has two splits, No. 3A and No. 3B, with No. 3A being the lower of the two. No significant rock partings occur in this seam.

The No. 4 coal seam lies above the No. 3 seam and is separated by the interburden above the No. 3 coal seam (I3). The cropline is located on the west side of the permit area, outside of the coal lease. In Area 5 this seam splits locally into No. 4A and No. 4B, with No. 4A being the lower of the two. No significant rock partings occur in this seam.

The No. 6 coal seam lies above the No. 4 coal seam, separated by the No. 4 coal seam interburden (I4). The cropline is located on the west side of the permit area, outside of the coal lease. The No. 6 coal seam splits locally into No. 6A and No. 6B, with the No. 6A being the lower of the two. No significant rock partings occur in this seam.

The No. 7 coal seam lies above the No. 6 coal seam, separated by the No. 6 coal seam interburden (I6). Croplines can be seen along bluffs and in valley floors throughout the permit area. The seams are absent or more weathered in the western portion of the permit area in Area 4 South. The No. 7 coal seam splits locally into No. 7A and No. 7B, with No. 7A being the lower of the two. No significant rock partings occur in this seam.

The No. 8 coal seam lies above the No. 7 coal seam, separated by the No. 7 interburden (I7). Croplines can be seen along bluffs and in valley floors throughout the permit area. In Area 4 South, the outcrops can be seen within Pinabete Arroyo. The seams are absent or more weathered in the western portion of the permit area in Area 4 South. This seam has two splits, No. 8A and No. 8B, with No. 8A being the lower of the two. In Area 4 South, these seams have additional splits locally, named Nos. 8A2, 8A1, 8B2, and 8B1. No. 8B coal seam splits into 8B2 and 8B1 in only localized areas within Area 4 South but does not split in Area 5. No significant rock partings occur in this seam.

Coal seams and splits, described above, were sampled and analyzed for total sulfur and pyritic sulfur content. The average total sulfur percent and average pyritic sulfur percent of each seam are summarized in Table 17.3-1. Average thickness of each seam is summarized in Table 17.3-2 and detailed in Appendix 17.A, Appendix 17.B, and Appendix 17.C. Average total sulfur values range from 0.53% to 1.27%, with No. 2A and No. 7 coal seams showing the highest values. Weighted average total sulfur, as a function of average seam thickness, for all seams is 0.76%. Average pyritic sulfur values range from 0.10% to 0.71%, with No. 2A and No. 7 coal seams showing the highest values. Weighted average pyritic sulfur, as a function of average seam thickness, for all seams is 0.28%. Pyritic sulfur is the main contributor to acid-forming materials through oxidation processes and makes up a small percentage of both the coal seams and the overburden/interburden materials. As stated in Section 17.2, the overburden/interburden rock strata have a large positive ABP that can neutralize any acidic groundwater that may be generated by the unmined coal faces in the highwall and any waste coal that may be placed in the backfill, as described in Section 21 (Waste Disposal Structure and Facilities). In addition, baseline groundwater from coal seams is described in Section 18 (Water Resources) and does not indicate the presence of any PATFM. Therefore, the coal seams do not contain PATFM.

17.4 Geologic Information Collection and Analysis

Geologic information is collected as part of BNCC's drilling programs. The goals of the drilling programs are to enhance understanding of the coal geology for geologic modeling, collect samples for coal quality evaluation, and collect samples for overburden/interburden characterization. BNCC maintains a 3-dimensional geologic model in Vulcan software. This model is the source of cross-sections presented in this section.

Mo-Te Drilling completed five drill holes for the 1987 drilling program in Area 4 North and 10 holes for the 1998 drilling program in Area 4 South. Each hole was logged and continuous core samples were collected (Appendix 17.A and Appendix 17.B). The core log information from the 1987 and 1998 drilling programs within the permit area are provided in Appendix 17.A and Appendix 17.B, respectively. ACZ Laboratories, Inc. conducted the coal quality and overburden analysis for the 1987 drilling program. Wyoming Analytical Laboratories, Inc. conducted the coal quality and overburden analysis for the 1998 drilling program. The results from overburden analyses are provided in Table 17.2-1, Table 17.2-2, Table 17.2-3, Table 17.2-4, Table 17.2-5, Table 17.2-6, Table 17.2-7, Table 17.2-8, Table 17.2-9, and Table 17.2-10. Stewart Brothers Drilling drilled the 16 holes for the 2007 drilling program in Area 4 South and Area 5. Continuous coring was utilized for sample collection. Core log information for these data within the permit area is provided in Appendix 17.B and Appendix 17.C. SGS Labs conducted the coal quality analysis, and Green Analytical Laboratory performed the overburden analysis. Results from the overburden analyses are contained in Table 17.2-7, Table 17.2-8, and Table 17.2-9. The location of drill holes is shown on Exhibit 17.1-1 and Exhibit 17.2-1.

Subsequent drilling programs will be initiated through the life of the operation. Data collected through these drilling programs will be used to enhance understanding of the geologic model. Additional sampling and testing will also take place for further overburden characterization as mining activities advance toward the south. As applicable, this section of the permit will be updated with the additional information. Future drilling programs will focus on Area 4 North, as it will be the area to be mined first. Towards the end of the life of mining in Area 4 North, BNCC will focus drilling programs on Area 4 South. These additional drilling programs are discussed further in Section 22 (Support Facilities).

Personnel

Persons or organizations responsible for data collection, analysis, and preparation of this permit application package section:

Kent Applegate Ron Van Valkenburg Matt Owens BHP Navajo Coal Company	Mo-Te Drilling, Farmington, NM ACZ Laboratories, Inc. Steamboat Springs, CO Wyoming Analytical Laboratories, Inc., Laramie, WY Stewart Brothers Drilling, Milan, NM SGS Labs, Denver, CO

Green Analytical Laboratory, Durango, CO

References

BHP Navajo Coal Company. 2009. Navajo Mine Permit Application Package. Chapter 5 – Geology. OSM Permit No. NM0003F. On file with the Office of Surface Mining Reclamation and Enforcement-Western Region Technical Office. Denver, Colorado.

Fasset, J.E., and J.S. Hinds. 1971. Geology and Fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado: U.S. Geological Survey Professional Paper 676; U.S Geological Survey, Washington, DC..

Flores, R.M., and M.F. Erpenbeck. 1981. Differentiation of delta front and barrier lithofacies of the Upper Cretaceous Pictured Cliffs Sandstone, southwestern San Juan Basin, New Mexico. The Mountain Geologist, v. 18, no. 2, p. 23-34.

Leighty, Dr. Robert D. 2001. "Colorado Plateau Physiographic Province". Contract Report. Defense Advanced Research Projects Agency (DOD) Information Sciences Office. Leighty & Associates, Inc. Vienna, Virginia.

Petersen, M.D., 2008. 2008 United States National Seismic Hazard Maps: U.S. Geological Survey Fact Sheet 2008–3018. Published online by U.S. Geological Survey at http://pubs.usgs.gov/fs/2008/3018/pdf/FS08-3018_508.pdf (Verified March 29, 2012)

Sanford, A.R., K. Lin, I. Tsai, and L.H. Jacksha. 2002. Earthquake catalogs for New Mexico and bordering areas: 1869–1998, New Mexico Bureau of Geology and Mineral Resources Circular 210, New Mexico Institute of Mining and Technology, Socorro, New Mexico.

Wong, I.G., D.J. Cash, and L.H. Jaksha. 1984. The Crownpoint, New Mexico, Earthquakes of 1976 and 1977. Bulletin of the Seismological Society of America; v. 74, no. 6, p. 2435-2449.

Table 17.2-1 Physical and Chemical Properties Analyzed or Calculated for Overburden/Interburden Samples from 1987, 1998, and 2007 Drilling Program

pH (s.u.)
Electrical conductivity (EC) (mmhos/cm)
ESP (Exchangeable Sodium Percentage) [1]
Saturation (%)
Calcium (meq/L)
Magnesium (meq/L)
Sodium (meq/L)
Sodium adsorption ratio (SAR)
Sand (%), silt (%), clay (%) [2]
USDA soil texture
Organic carbon [1]
CaCO3 (%)
Total sulfur (%) [2]
Acid potential total sulfur (t/kt) [2]
Neutralization potential (t/kt) [2]
Acid-base potential total sulfur (t/kt)
Sulfate (%) *
Organic sulfur (%) *
Pyritic sulfur (%) *
Acid-base pyritic sulfur (t/kt) * [2]
Acid-base potential pyritic sulfur (t/kt) * [2]
Boron (ppm)
Total selenium (ppm)
Soluble selenium (ppm)

* analysis performed only if total sulfur acid-base potential is less than zero t/kt

[1] analysis performed only on samples from 1987 drilling program

[2] analysis performed only on samples from 1998 and 2007 drilling programs

CONFIDENTIAL Table 17.2-2

Characteristics for In-situ Overburden in Area 4 North from Drill Hole 487-01

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

Data in this table are summarized in Appendix 17.E.

CONFIDENTIAL Table 17.2-3

Characteristics for In-situ Overburden in Area 4 North from Drill Hole 487-02

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

Data in this table are summarized in Appendix 17.E

CONFIDENTIAL Table 17.2-4

Characteristics for In-situ Overburden in Area 4 North from Drill Hole 487-03

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

Data in this table are summarized in Appendix 17.E

CONFIDENTIAL Table 17.2-5

Characteristics for In-situ Overburden in Area 4 North from Drill Hole 487-04

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

Data in this table are summarized in Appendix 17.E

CONFIDENTIAL Table 17.2-6

Characteristics for In-situ Overburden in Area 4 South from Drill Hole 498-06

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.
Data in this table are summarized in Appendix 17.E

CONFIDENTIAL Table 17.2-7

Characteristics for In-situ Overburden in Area 4 South from Drill Hole 407-32

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

Data in this table are summarized in Appendix 17.E

CONFIDENTIAL Table 17.2-8

Characteristics for In-situ Overburden in Area 4 South from Drill Hole 407-33

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

Data in this table are summarized in Appendix 17.E

CONFIDENTIAL Table 17.2-9

Characteristics for In-situ Overburden in Area 4 South from Drill Hole 407-34

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

Data in this table are summarized in Appendix 17.E

Table 17.2-10 Potential Root-zone Suitability Criteria and PATFM Characteristic Analytes

Characteristic analytes	OSM southwestern U.S. criteria	Navajo Mine site-specific criteria[3]
Boron	≤10 ppm	na
Total selenium	≤0.8 ppm	≤2.5 ppm
Soluble selenium	≤0.15 ppm	≤0.26 ppm
pH	≥5.5 and ≤9.0	≥5.0 and ≤9.0
Acid-base account (Acid-base potential[1])	>-5 t $CaCO_3$/1000 t	≥-5 t $CaCO_3$/1000 t
Saturation	≥ 20% and ≤90%	≤85% OR ≤100% only if EC≥4 mmhos/cm
Electrical conductivity (EC)	≤12 mmhos/cm	≤16 mmhos/cm
Sodium adsorption ratio (SAR)	sandy loam ≤20 loam, clay loam ≤16 40% clay ≤14	≤18 OR ≤40 only if EC ≥4 mmhos/cm
Texture	≤45% clay	≤50% clay
$CaCO_3$	%	no criteria
Neutralization potential	t $CaCO_3$/1000 t	no criteria
Total sulfur	%	no criteria
Total sulfur acid potential	t $CaCO_3$/1000 t	no criteria
Sulfate[2]	%	no criteria
Organic sulfur[2]	%	no criteria
Pyritic sulfur[2]	%	no criteria
Acid-base pyritic sulfur[2]	t $CaCO_3$/1000 t	no criteria

[1] Total sulfur and pyritic sulfur acid-base potential are considered under this criteria.

[2] These analytes including pyritic sulfur acid-base potential are analyzed when total sulfur acid-base potential is less than zero.

[3] Navajo Mine site-specific criteria are found in Navajo Mine Permit NM-0003F (BNCC 2009).

Table 17.3-1 Chemical Characteristics for Coal Seams to be Mined

Seam identification	Average total sulfur (%)	Average pyritic sulfur* (%)
No. 8	0.66	-
No. 8B	0.79	0.21
No. 8A	0.78	0.22
No. 7	1.25	0.71
No. 7B	1.11	-
No. 7A	0.60	-
No. 6	0.61	0.10
No. 6B	0.53	0.13
No. 6A	0.63	0.20
No. 4	0.55	0.11
No. 4B	0.60	0.13
No. 4A	0.62	0.23
No. 3	0.74	0.37
No. 3B	0.97	0.29
No. 2	0.91	0.40
No. 2B	0.69	0.34
No. 2A	1.27	0.55

* Pyritic sulfur analyses were not performed on No. 8, No. 7B, and No. 7A coal seams.

CONFIDENTIAL Table 17.3-2

Average Thickness for Coal Seams to be Mined

In accordance with 30 CFR 773.6(d)(3)(i) this table is confidential and has been submitted separately from the remainder of this permit application package.

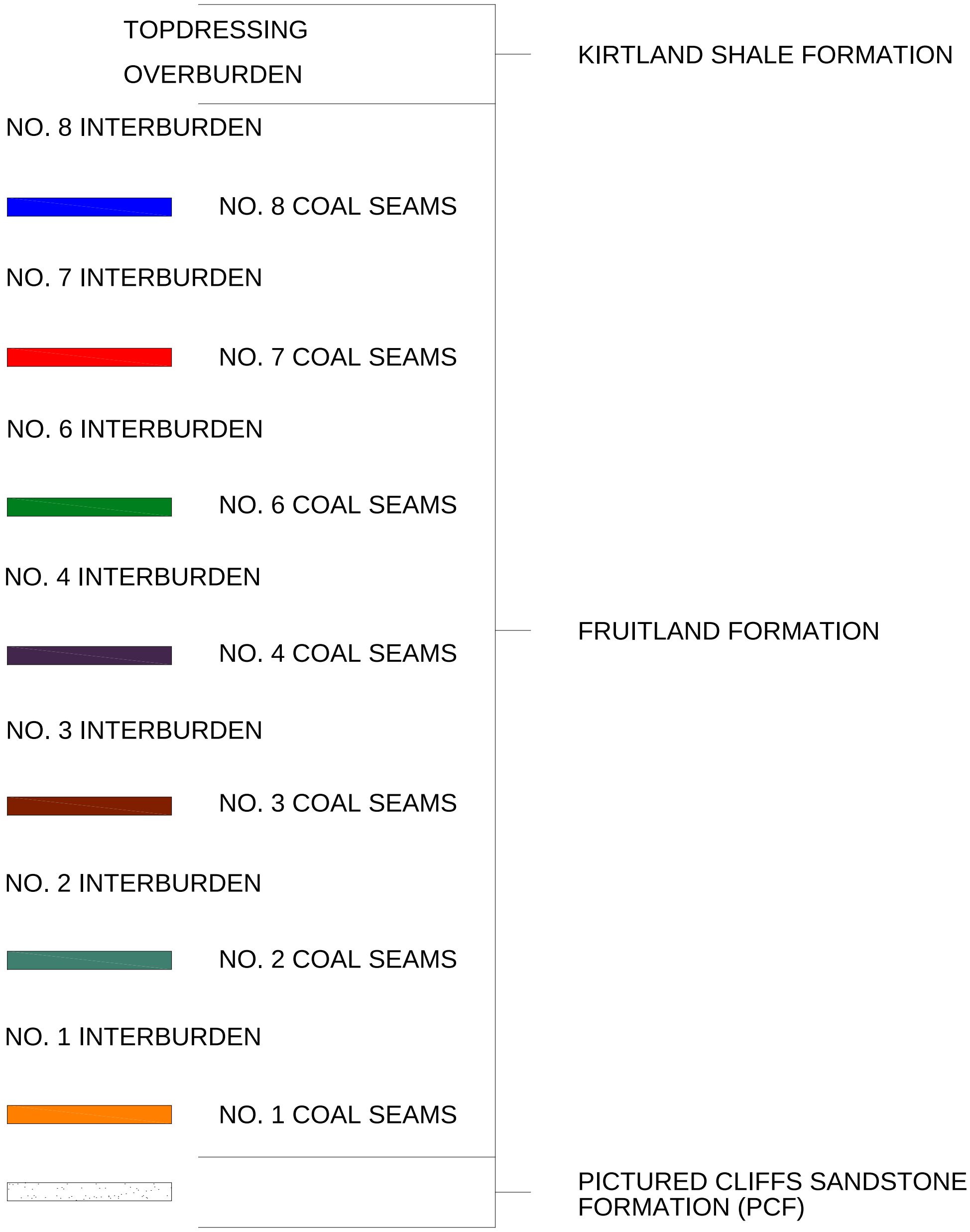
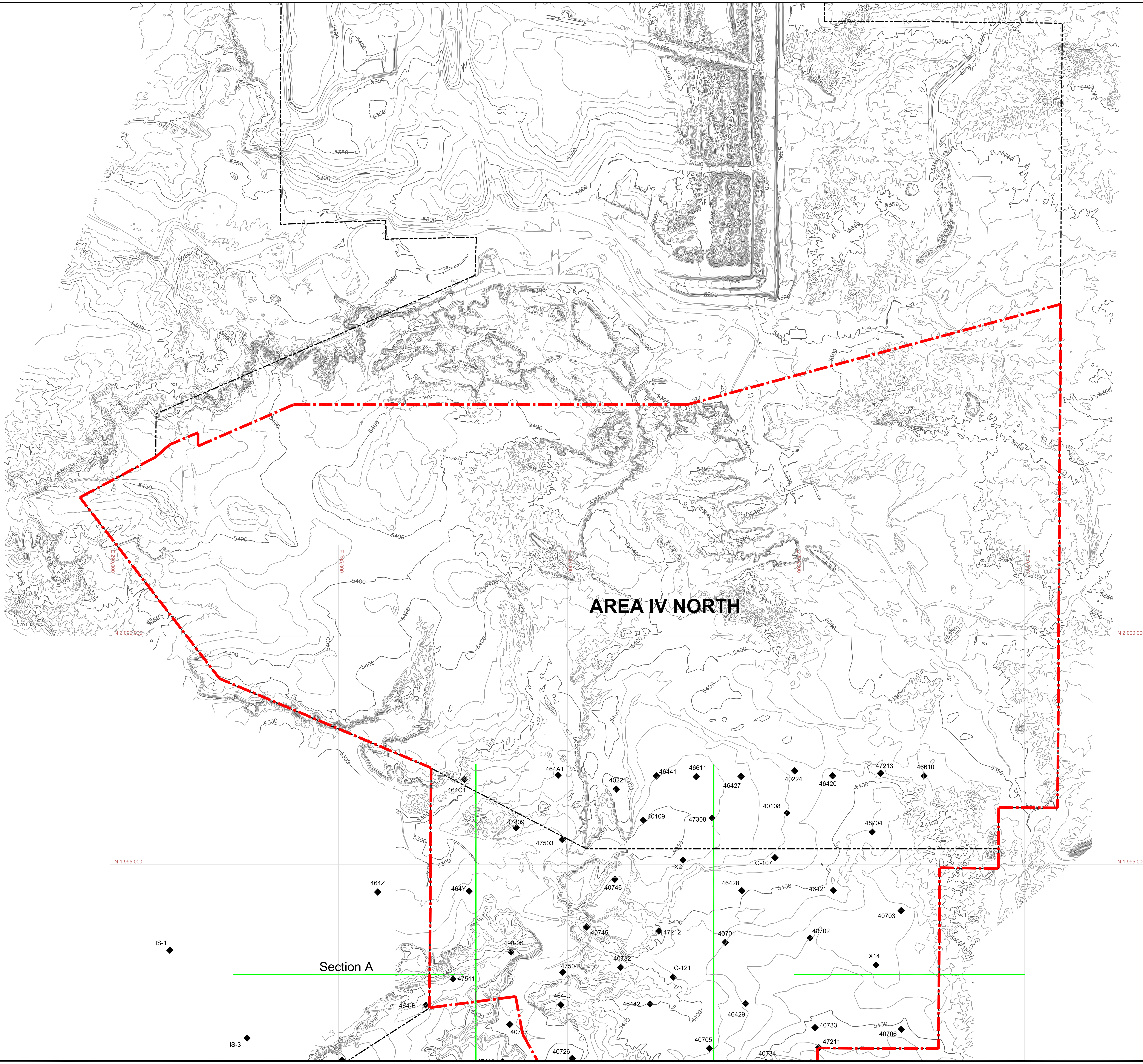
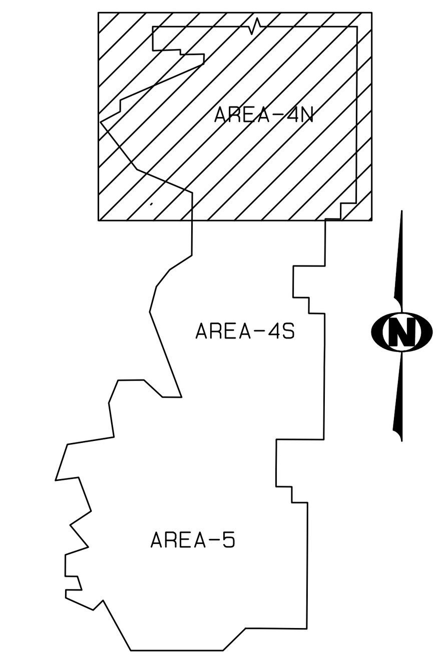


Figure 17.1-1 Generalized Stratigraphic Column Showing Overburden/Interburden, Coal Seams, and Pictured Cliffs Sandstone Formation.





1000' 0' 1000' 2000'

"NOTES"

ADDITIONAL MINE STRUCTURES, INCLUDING ROADS, RAILROAD, PONDS, IMPOUNDMENTS AND CULVERTS, ALTHOUGH PRESENT ON THIS EXHIBIT AS PART OF AERIAL BASE MAPPING, ARE NOT INTENDED TO BE CURRENT OR ACCURATE ON THIS EXHIBIT. PLEASE REFER TO THE APPROPRIATE P.A.P. TEXT SECTION FOR A MINE STRUCTURE EXHIBIT REFERENCE.

LEGEND

- PERMIT BOUNDARY
- LEASE BOUNDARY
- PINCH LINE/CROP LINE/SPLIT LINE
- 5100 TOPOGRAPHY CONTOUR
- ROAD LINE
- 40736 DRILL HOLE
- CROSS SECTION LINE

REV. No.	DATE	DRAFT. BY	REVISION DESCRIPTION	ENG.	E.Q.	P.E.	
12-A	FEB 2012	JM	PREPARED FOR SUBMITTAL TO OSM	JM	KA		
				APPROVALS			

EXHIBIT 17.1-1

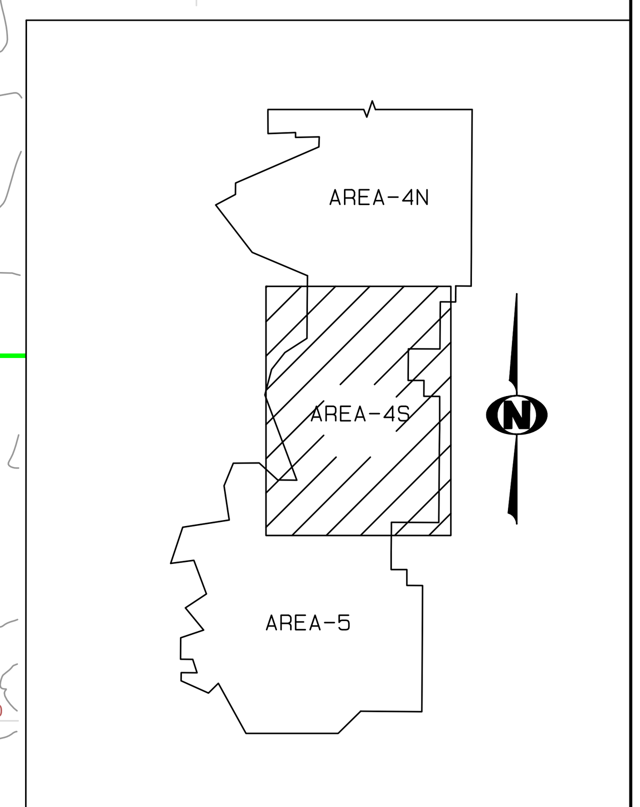
BHP Navajo Coal Company

P.O. Box 1717
Fruitland, New Mexico, 87416

Phone: 505-598-4200
Fax: 505-568-3361

AREA 4 NORTH DRILL HOLE AND CROSS-SECTION LOCATIONS

PREPARED BY JM	DRAWN BY MO	SCALE 1"= 1000'
APPROVED BY KA	DATE 2-15-2012	(SHEET 1 OF 2)



1000 0 1000 2000

"NOTES"

ADDITIONAL MINE STRUCTURES, INCLUDING ROADS, RAILROAD, PONDS, IMPOUNDMENTS AND CULVERTS, ALTHOUGH PRESENT ON THIS EXHIBIT AS PART OF AERIAL BASE MAPPING, ARE NOT INTENDED TO BE CURRENT OR ACCURATE ON THIS EXHIBIT. PLEASE REFER TO THE APPROPRIATE P.A.P. TEXT SECTION FOR A MINE STRUCTURE EXHIBIT REFERENCE.

LEGEND

- PERMIT BOUNDARY
- LEASE BOUNDARY
- PINCH LINE/CROP LINE/SPLIT LINE
- 5100 TOPOGRAPHY CONTOUR
- CROSS SECTION
- 40736 DRILL HOLE

REV. No.	DATE	DRAFT. BY	REVISION DESCRIPTION	ENG.	E.Q.	P.E.	
12-A	FEB 2012	JM	PREPARED FOR SUBMITTAL TO OSM	JM	KA		

APPROVALS

EXHIBIT 17.1-1

bhpbilliton

BHP Navajo Coal Company

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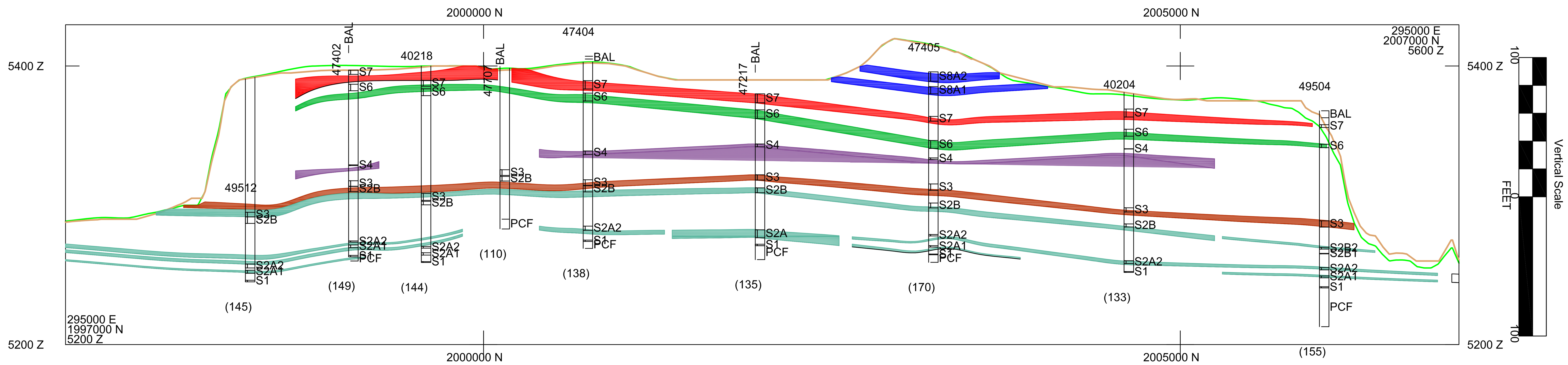
Fruitland,New Mexico,87416
Phone: 505-598-4200
Fax: 505-568-3361

AREA 4 SOUTH DRILL HOLE AND CROSS SECTION LOCATIONS

PREPARED BY JM	DRAWN BY MO	SCALE 1"= 1,000'
APPROVED BY KA	DATE 2-15-2012	(SHEET 2 OF 2)



Area 4 North - Section 1

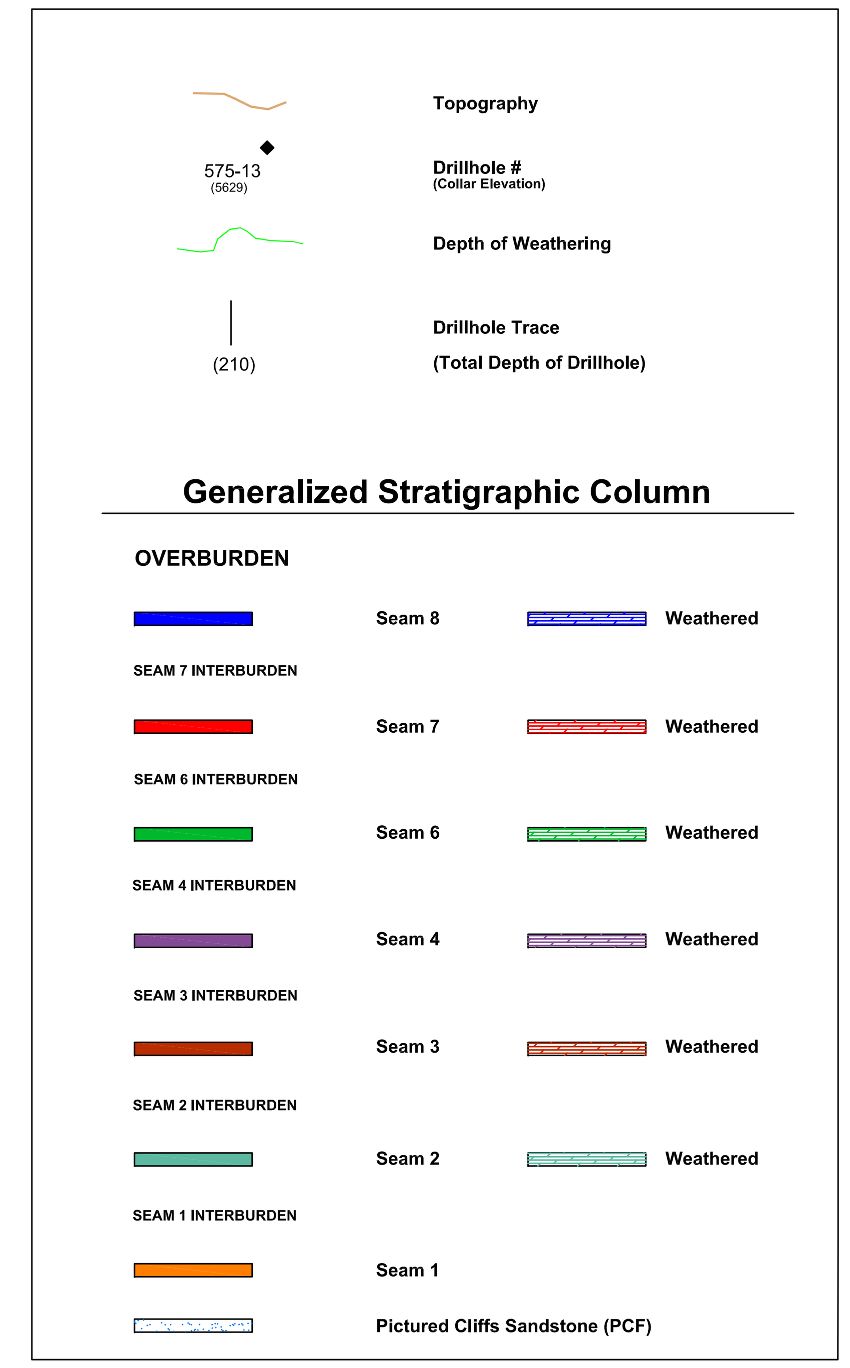
Section 295,000 East

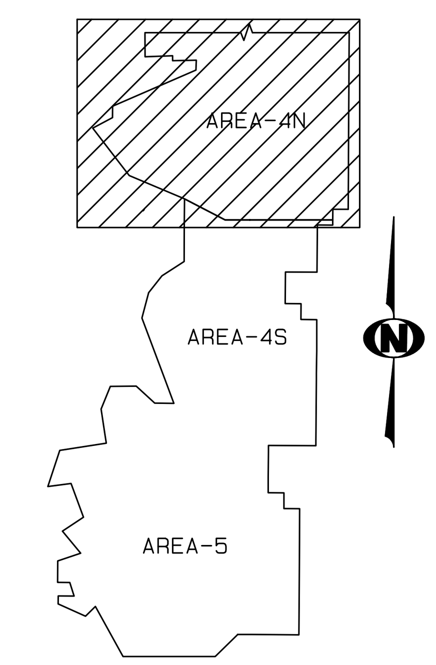
Looking West

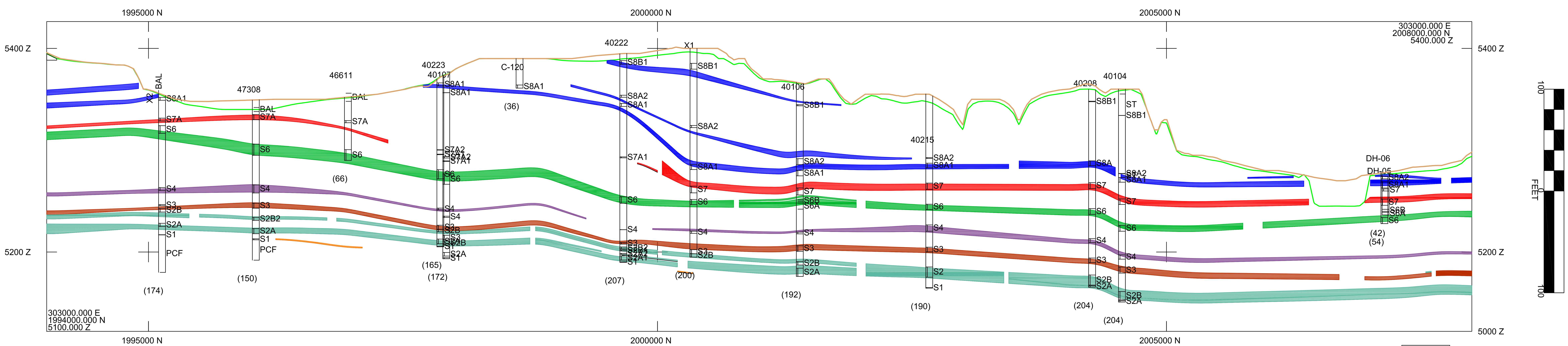
Horizontal Scale

1000 0 1000 FEET

LEGEND







Area 4 North - Section 2

Section 303,000 East

Looking West

Horizontal Scale

1000 0 1000 FEET

12-A	Feb 2012	RY	PREPARED FOR SUBMITTAL TO OSM	JM	KA	
REV. NO.	DATE	DRAFT BY	REVISION DESCRIPTION	ENG.	E.Q.	P.E.
				APPROVALS		

EXHIBIT 17.1-2

bhpbilliton

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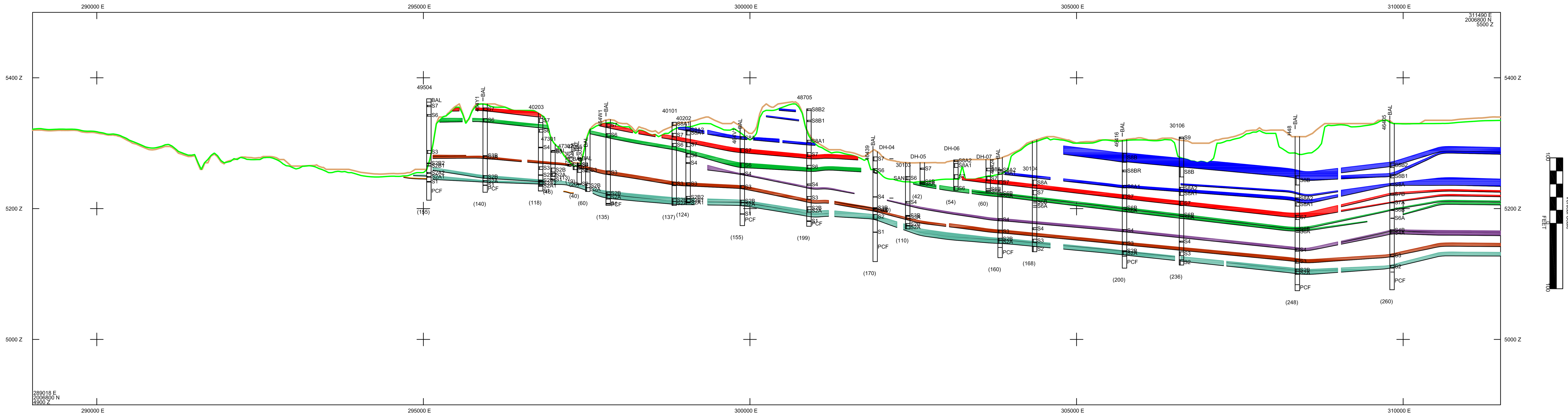
AREA 4 NORTH
NORTH - SOUTH GEOLOGIC
CROSS-SECTIONS

PREPARED BY JM	DRAWN BY MO	SCALE AS SHOWN
APPROVED BY KA	DATE 2-15-2012	(SHEET 1 OF 1)



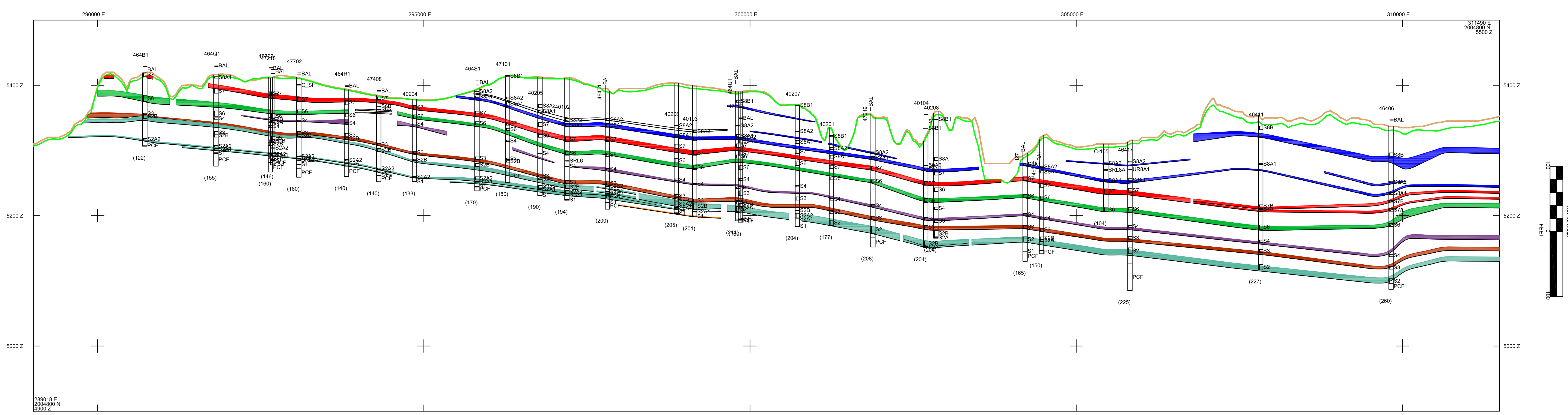
Area 4 North - Section A

Section 2,006,800 North

Looking North

Horizontal Scale

1000 FEET 1000



Area 4 North - Section B

Section 2,004,800 North

Looking North

Horizontal Scale

1000 FEET 1000

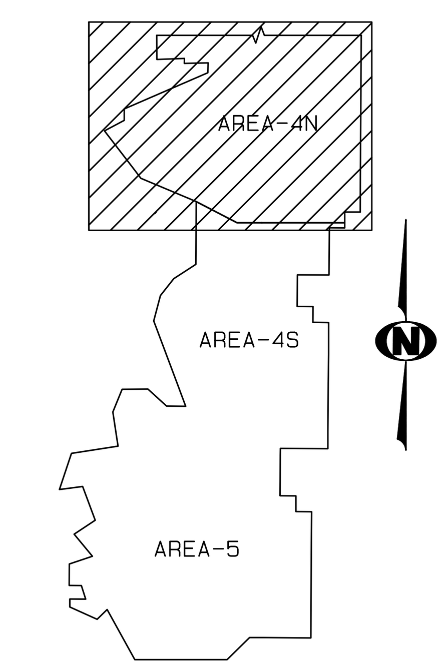
LEGEND

Topography	
575-13 (5629)	Drillhole # (Collar Elevation)
Depth of Weathering	
(210)	Drillhole Trace (Total Depth of Drillhole)

Generalized Stratigraphic Column

OVERBURDEN

	Seam 8	Weathered
SEAM 7 INTERBURDEN		
	Seam 7	Weathered
SEAM 6 INTERBURDEN		
	Seam 6	Weathered
SEAM 4 INTERBURDEN		
	Seam 4	Weathered
SEAM 3 INTERBURDEN		
	Seam 3	Weathered
SEAM 2 INTERBURDEN		
	Seam 2	Weathered
SEAM 1 INTERBURDEN		
	Seam 1	
	Pictured Cliffs Sandstone (PCF)	



REV. No.	DATE	DRAFT. BY	REVISION DESCRIPTION	ENG.	C.G.	P.E.
12-A	MAR 2012	MO	PREPARED FOR SUBMITTAL TO OSM	JM	KA	KB
				APPROVALS		

EXHIBIT 17.1-3

bhpbilliton

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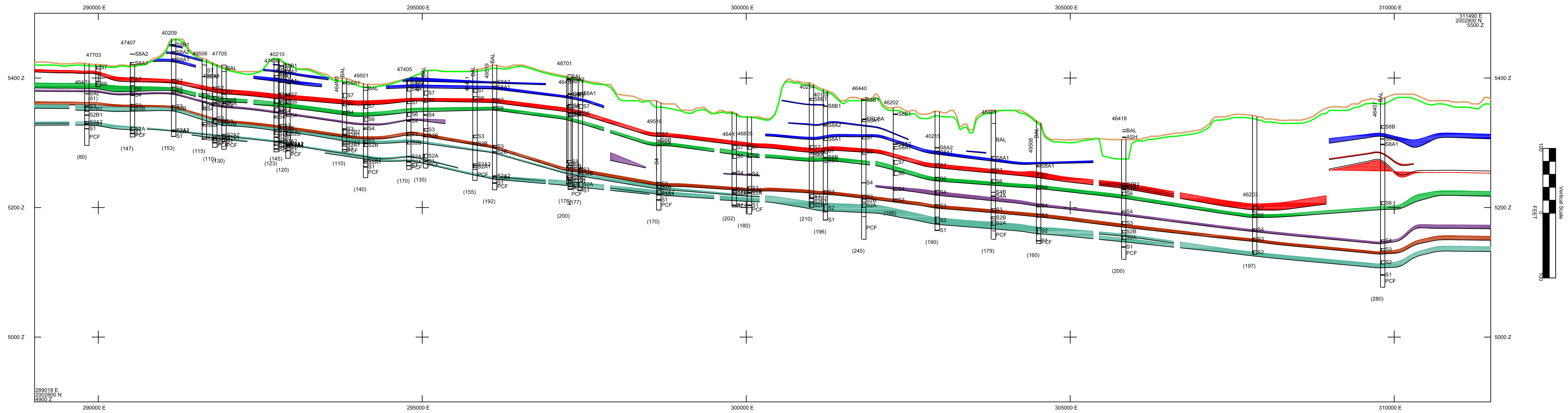
Fax: 505-598-3361

AREA 4 NORTH
EAST - WEST GEOLOGIC
CROSS-SECTIONS A - B

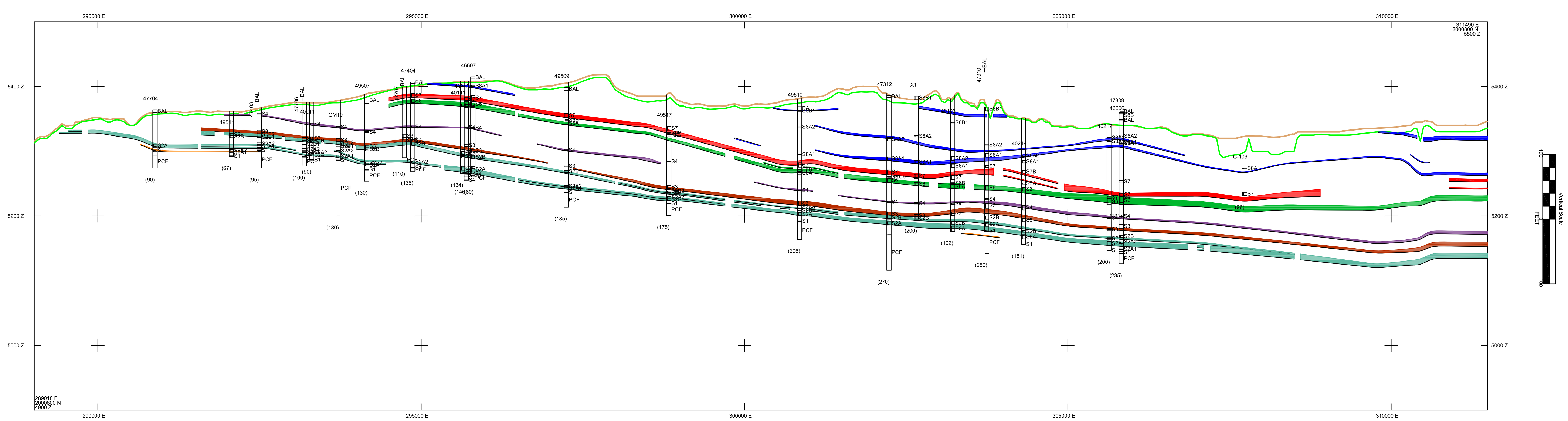
PREPARED BY JM	DRAWN BY MO	SCALE AS SHOWN
APPROVED BY CKA	DATE 3/3/2012	(SHEET 1 OF 3)



Area 4 North - Section C

Section 2,002,800 North

Looking North



Area 4 North - Section D

Section 2,000,800 North

Looking North

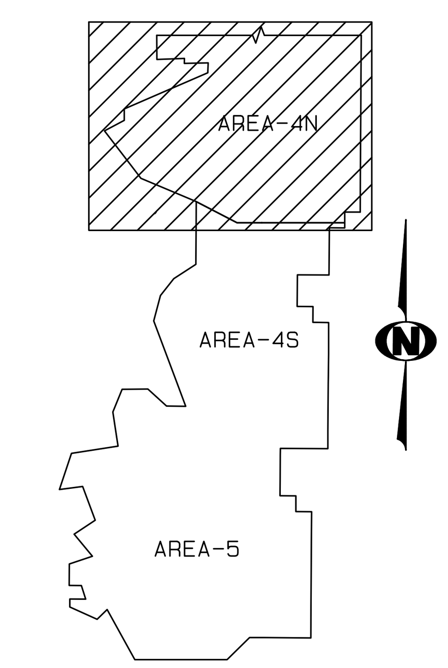
LEGEND

- Topography
- 575-13 (5629) — Drillhole # (Collar Elevation)
- Depth of Weathering
- (210) — Drillhole Trace (Total Depth of Drillhole)

Generalized Stratigraphic Column

OVERBURDEN

	Seam 8		Weathered
SEAM 7 INTERBURDEN			
	Seam 7		Weathered
SEAM 6 INTERBURDEN			
	Seam 6		Weathered
SEAM 4 INTERBURDEN			
	Seam 4		Weathered
SEAM 3 INTERBURDEN			
	Seam 3		Weathered
SEAM 2 INTERBURDEN			
	Seam 2		Weathered
SEAM 1 INTERBURDEN			
	Seam 1		
	Pictured Cliffs Sandstone (PCF)		



REV. No.	DATE	DRAFT. BY	REVISION DESCRIPTION	ENG.	E.Q.	P.E.
12-A	MAR 2012	MO	PREPARED FOR SUBMITTAL TO OSM	JM	KA	KB

APPROVALS

EXHIBIT 17.1-3

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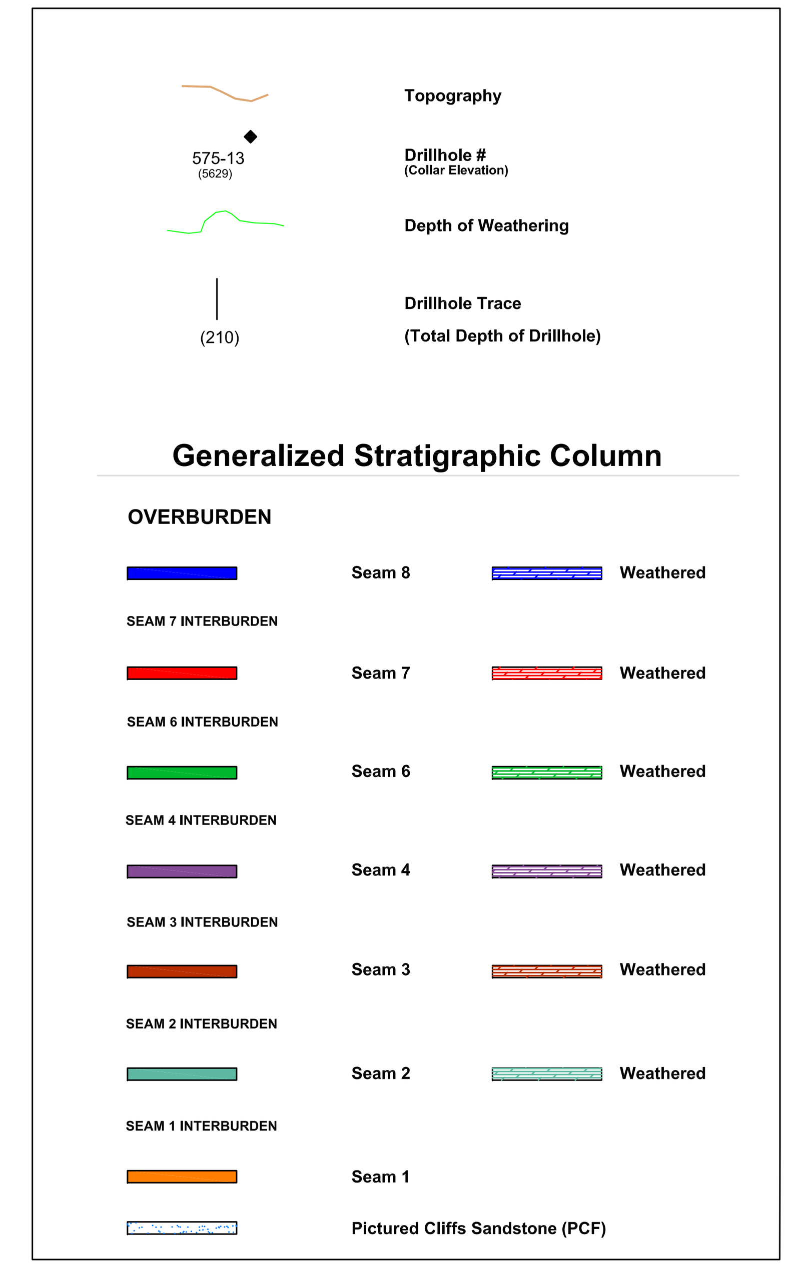
Fruitland, New Mexico, 87416

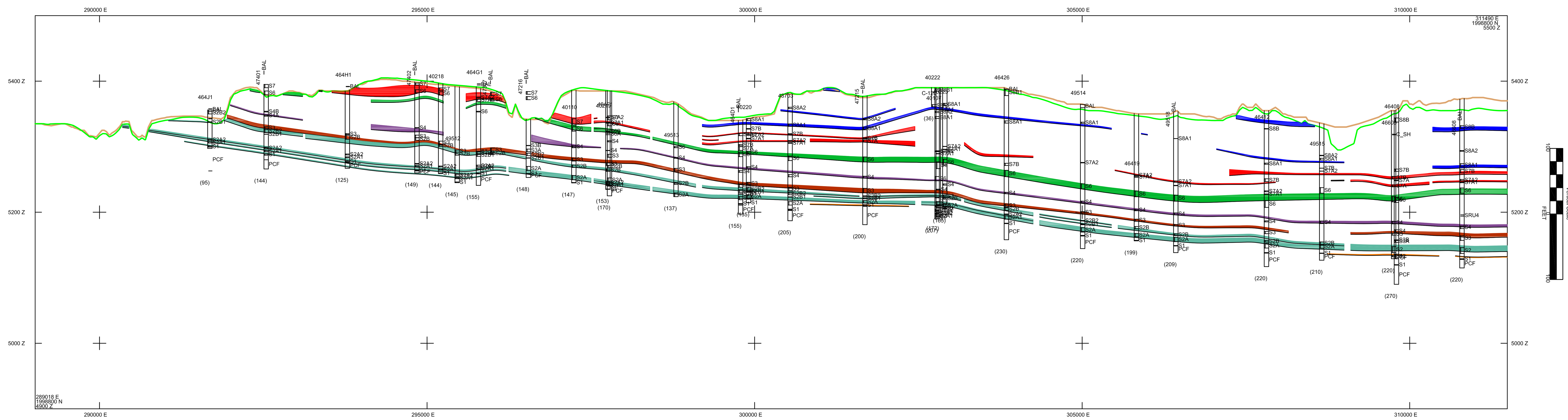
Phone: 505-598-4200
Fax: 505-568-3361

AREA 4 NORTH
EAST - WEST GEOLOGIC
CROSS-SECTIONS C - D

PREPARED BY JM	DRAWN BY MO	SCALE AS SHOWN
APPROVED BY CKA	DATE 3/3/2012	(SHEET 2 OF 3)

LEGEND

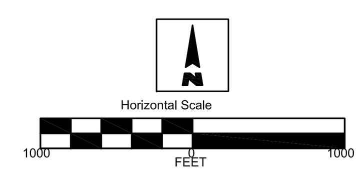


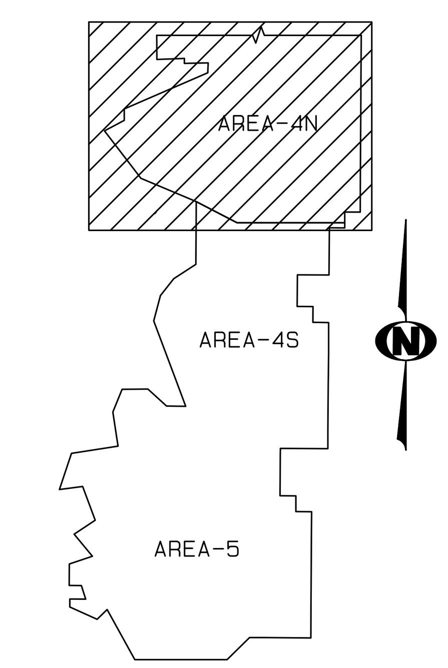


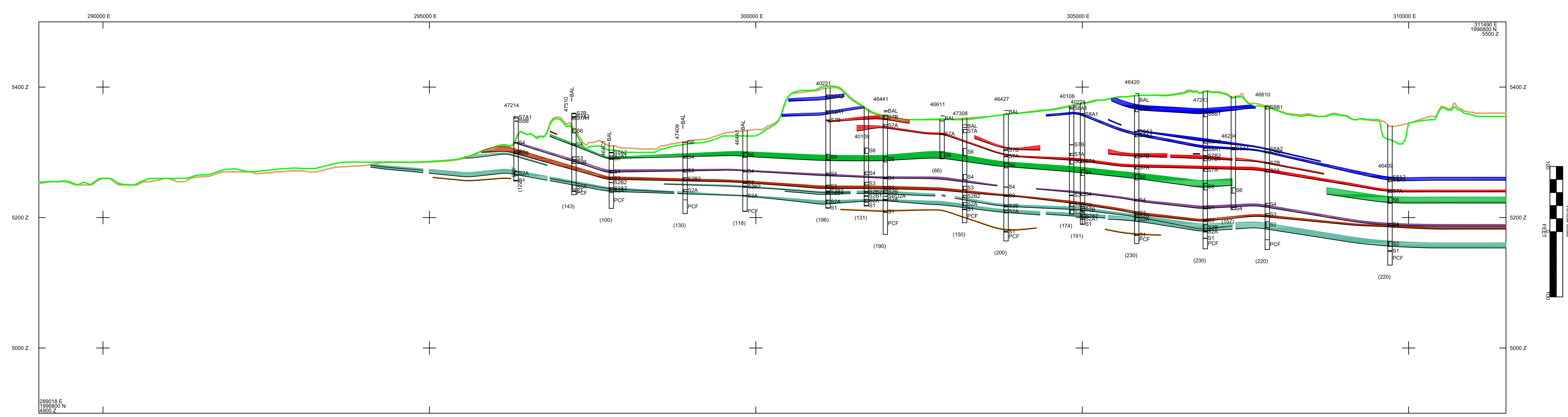
Area 4 North - Section E

Section 1,998,800 North

Looking North



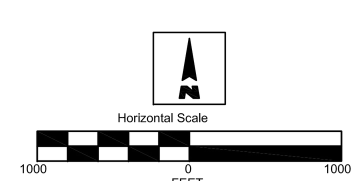




Area 4 North - Section F

Section 1,996,800 North

Looking North



REV. No.	DATE	DRAFT. BY	REVISION DESCRIPTION	ENG.	E.Q.	P.E.
12-A	MAR 2012	RY	PREPARED FOR SUBMITTAL TO OSM	JM	KA	KB

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EXHIBIT 17.1-3

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BHP Navajo Coal Company

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Fruitland, New Mexico, 87416

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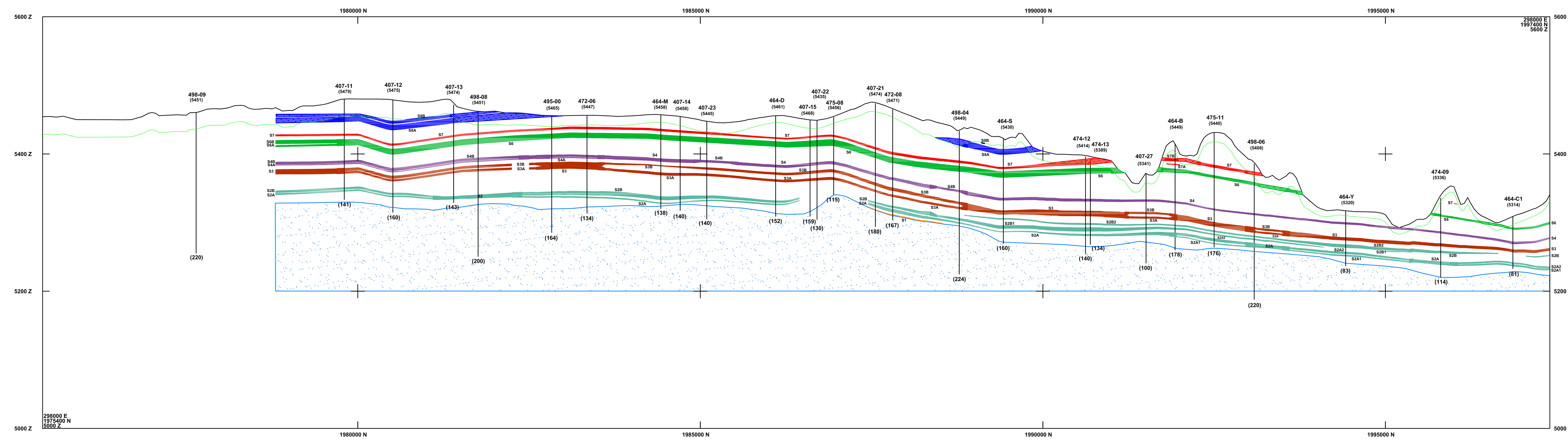
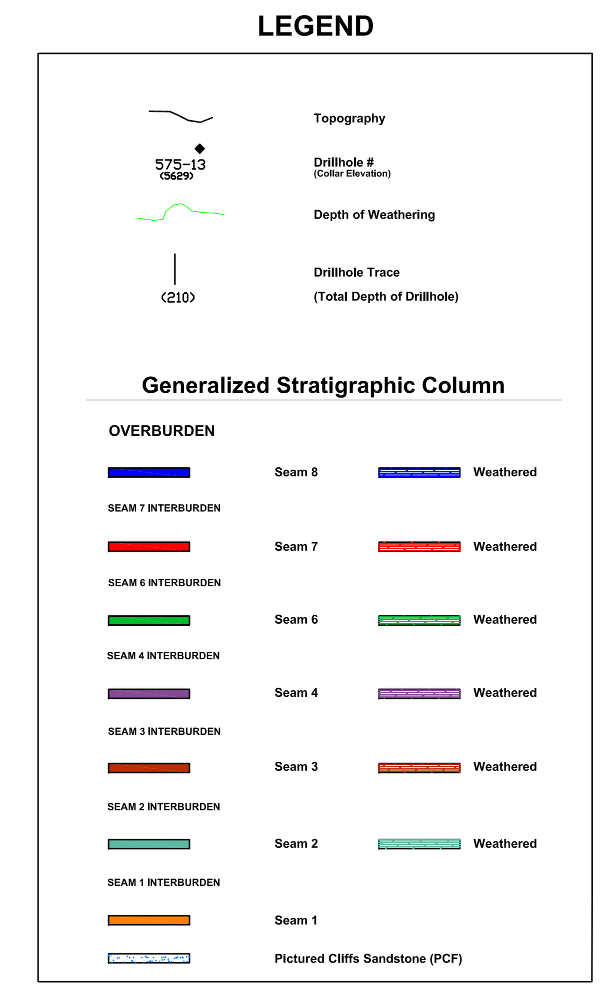
Fax: 505-568-3361

AREA 4 NORTH
EAST - WEST GEOLOGIC
CROSS-SECTIONS E - F

PREPARED BY JM	DRAWN BY MO	SCALE AS SHOWN
APPROVED BY CKA	DATE 3/3/2012	(SHEET 3 OF 3)

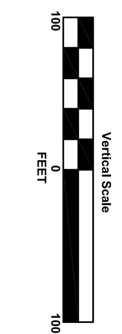


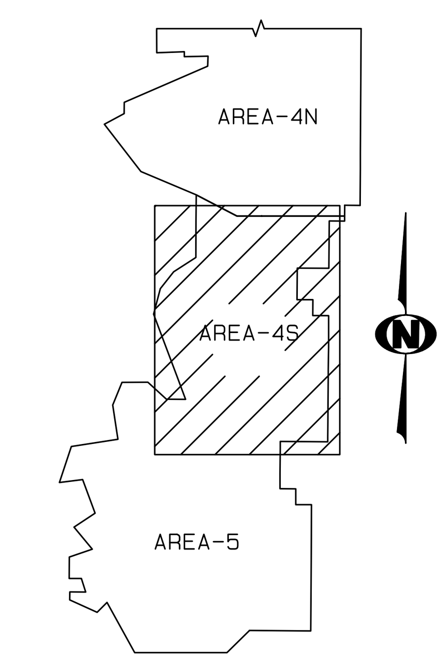


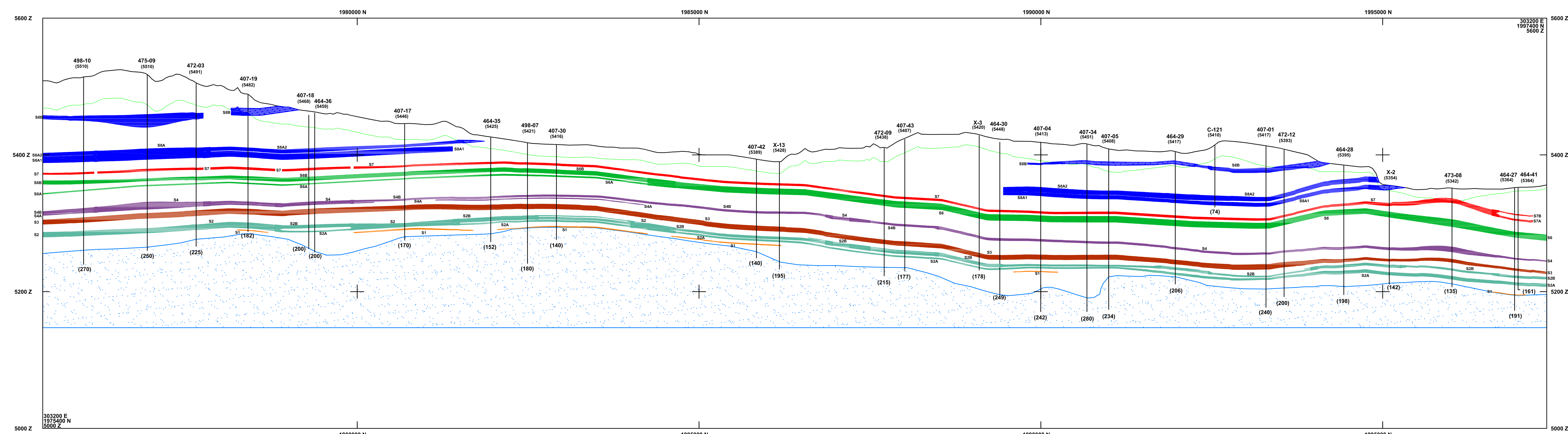
Area 4 South - Section 1

Section 298,000 East

Looking West



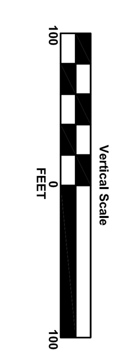




Area 4 South - Section 2

Section 303,200 East

Looking West



REV. No.	DATE	DRAFT BY	REVISION DESCRIPTION	ENG.	C.Q.	P.E.
12-A	2/29/12	MPO	PREPARED FOR SUBMITTAL TO OSM	CKA		

APPROVALS

EXHIBIT 17.1-4

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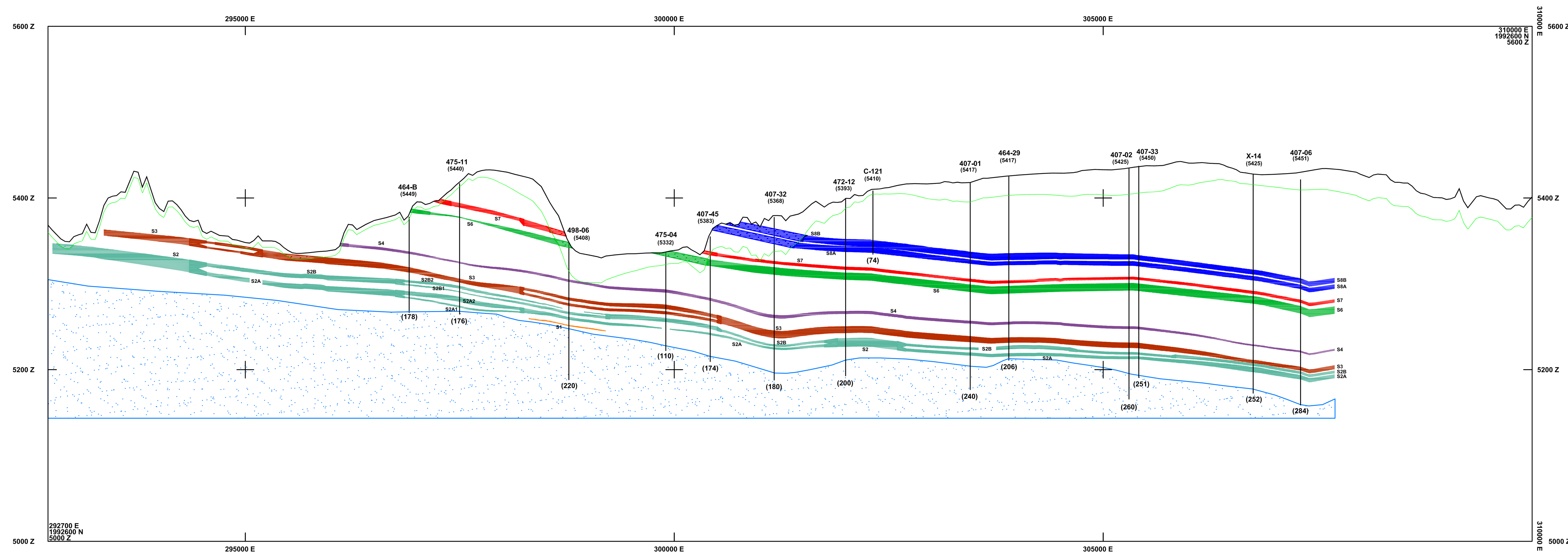
BHP Navajo Coal Company

P.O. Box 1717
Fruitland, New Mexico, 87416

Phone: 505-598-4200
Fax: 505-598-3361

AREA 4 SOUTH
NORTH - SOUTH DRILL HOLE
CORRELATION SECTIONS

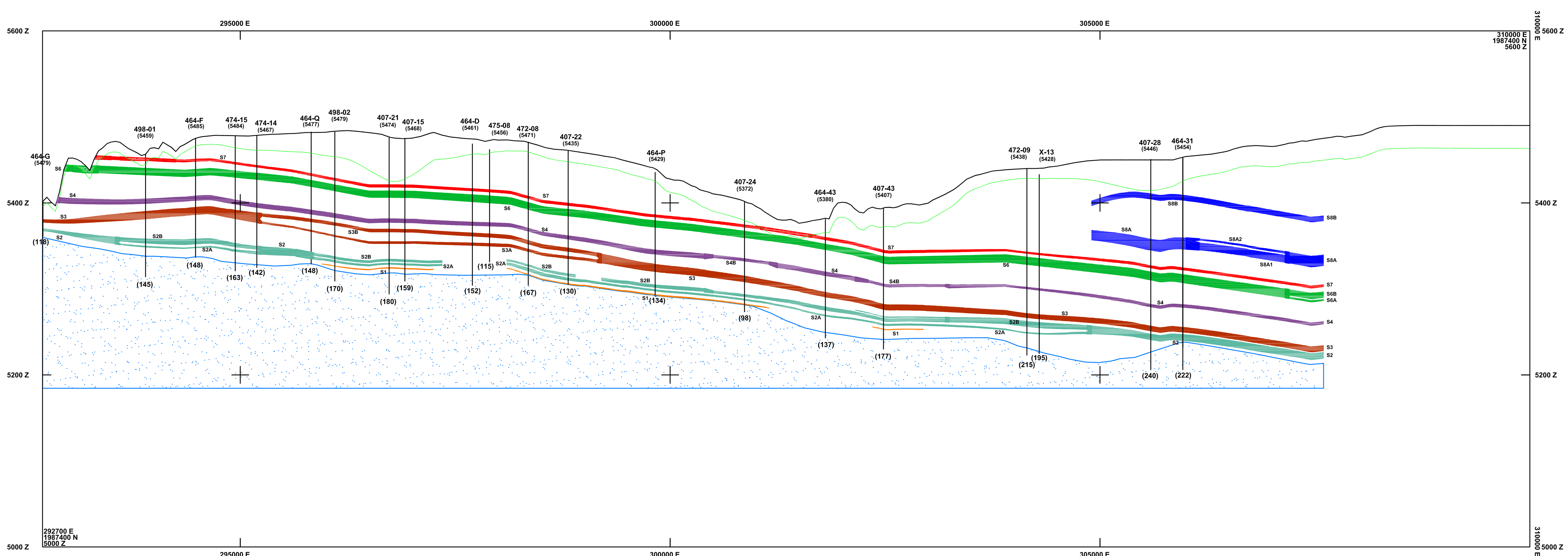
PREPARED BY JM	DRAWN BY JM	SCALE AS SHOWN
APPROVED BY KB	DATE 15-08-2011	(SHEET 1 OF 1)



Area 4 South - Section A

Section 1,992,600 North

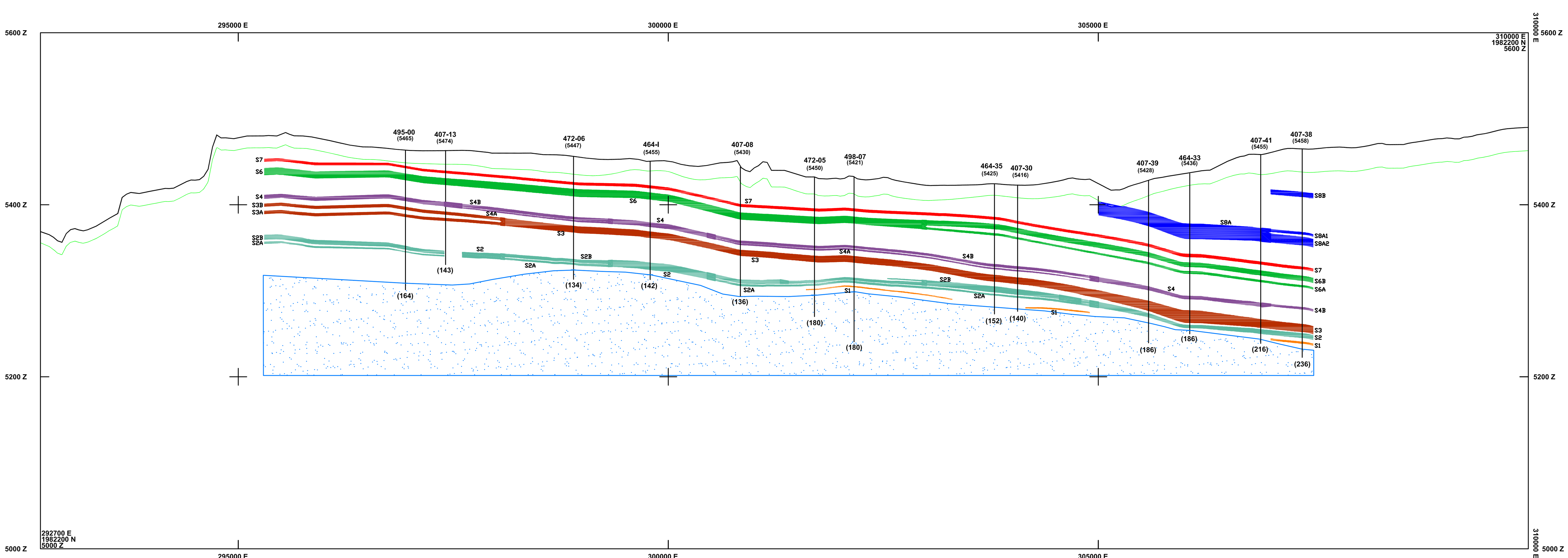
Looking North



Area 4 South - Section B

Section 1,987,400 North

Looking North

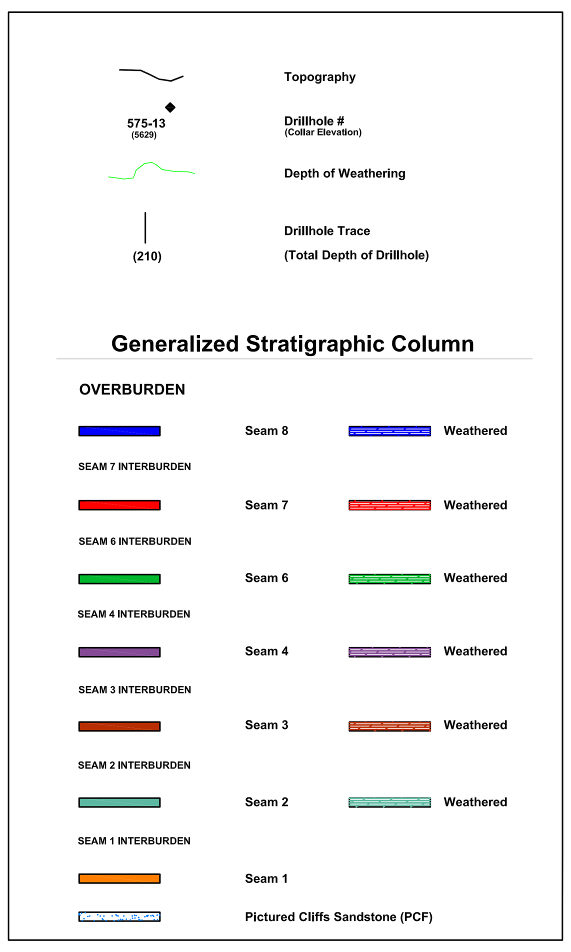


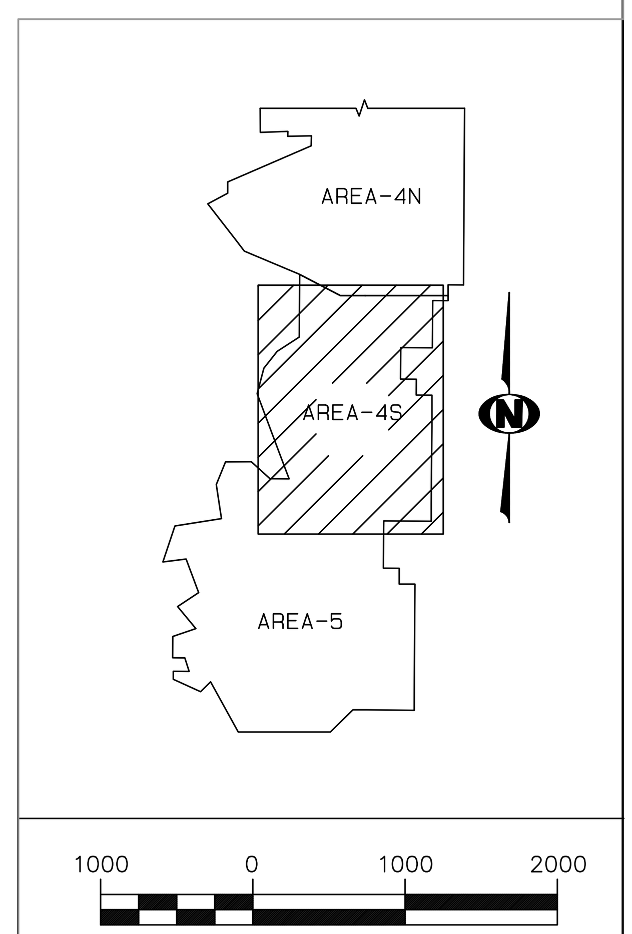
Area 4 South - Section C

Section 1,982,200 North

Looking North

LEGEND





REV. No.	DATE	DRAFT BY	REVISION DESCRIPTION	ENG.	E.Q.	P.E.
12-A	2/29/12	MO	PREPARED FOR SUBMITTAL TO OSM	KA		
				APPROVALS		

EXHIBIT 17.1-5

bhpbilliton

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P.O. Box 1717
Fruitland, New Mexico, 87416

Phone: 505-598-4200
Fax: 505-598-3361

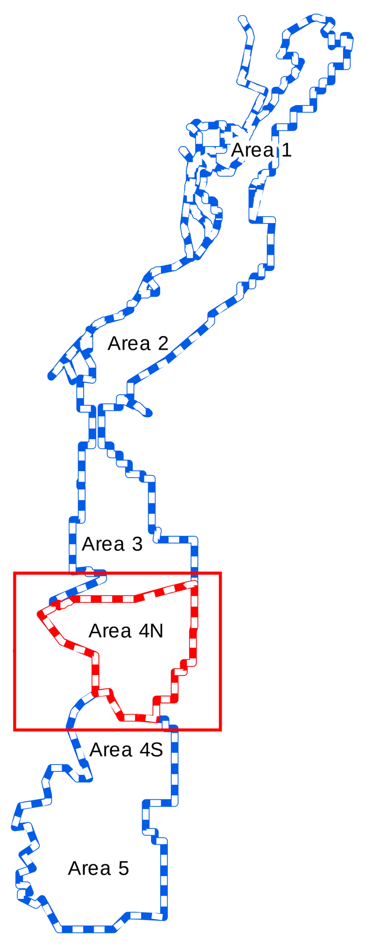
AREA 4 SOUTH
EAST - WEST DRILL HOLE
CORRELATION SECTIONS

PREPARED BY JM	DRAWN BY JM	SCALE AS SHOWN
APPROVED BY KB	DATE 15-08-2011	(SHEET 1 OF 1)

Legend

Overburden Drill Hole Locations

- 1987 Drilling Program
- 1998 Drilling Program
- 2007 Drilling Program
- Pinabete SMCRA Permit Area
- Mining Lease Area



Coordinate System:
NAD 1927 State Plane New Mexico West FIPS 3003
Projection: Transverse Mercator
Datum: North American 1927

Units: Foot US

N

0 500 1,000 2,000 3,000 Feet
1:12,000

REV. No.	DATE	DRAFT BY	REVISION DESCRIPTION	ENG.	EQ D.	PE.	
12-A	2/29/2012	MPO	Prepared for submittal to OSM		CKA		

APPROVALS

Exhibit 17.2-1

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resourcing the future

BHP NAVAJO COAL COMPANY

Overburden Drill Hole Locations

PREPARED BY: MPO	DRAWN BY: MPO	PAPER SIZE: ARCH D
APPROVED BY: CKA	DATE: 2/20/12	

CONFIDENTIAL Appendix 17.A

1987 Area 4 North Drill Hole Core Logs

In accordance with 30 CFR 773.6(d)(3)(i) this appendix is confidential and has been submitted separately from the remainder of this permit application package.
The data contained in this appendix is summarized in Appendix 17.E

CONFIDENTIAL Appendix 17.B

1998 Area 4 South Overburden Core Inventory

In accordance with 30 CFR 773.6(d)(3)(i) this appendix is confidential and has been submitted separately from the remainder of this permit application package.
The data contained in this appendix is summarized in Appendix 17.E

CONFIDENTIAL Appendix 17.C

2007 Area 4 South Overburden Core Inventory

In accordance with 30 CFR 773.6(d)(3)(i) this appendix is confidential and has been submitted separately from the remainder of this permit application package.
The data contained in this appendix is summarized in Appendix 17.E

Appendix 17.D

Statistical Analysis of Phase I Interburden Sampling – 1998

No Name Project

Statistical Analysis of Phase I Interburden Sampling

Prepared For:

Ron C. Van Valkenburg, PE

William W. Skeet

BHP Minerals
New Mexico Coal
300 West Arrington, Suite 200
Farmington, NM 87401

Prepared By:

John W. Kern Ph.D.

Western EcoSystems Technology Inc.
2003 Central Ave
Cheyenne, WY 82001

3 August, 1998

TABLE OF CONTENTS

STATISTICAL ANALYSIS OF PHASE I INTERBURDEN DATA

I. INTRODUCTION

The first phase of drilling to sample overburden at the No Name mine site consisted of 10 drill holes. Each drill hole resulted in continuous core samples through overburden, interburden and coal seams. The continuous cores were sampled at no greater than 5-foot increments for chemical assay and samples were taken at each change in lithology. The objectives of the phase I statistical analysis are to

1. Assess the adequacy of the phase I drilling program to conclude that either A) overburden is adequately sampled, or B) that further drilling is needed in order to make an adequate decision, and

2. Estimate the percent suitable material for reclamation and establishment of an adequate root zone to support vegetation,

3. Determine if particular stratigraphic layers contain high proportions of unsuitable materials,

4. Investigate spatial patterns in the proportion of suitable material and average value of analytes of interest,

5. Estimate the total volume of suitable material in the interburden layers most likely to be used for reclamation.

II. LITHOLOGY AND NAMING CONVENTIONS

The No Name mine area is composed of 8 coal seams and 8 corresponding overburden horizons with the Picture Cliffs sandstone comprising the deepest unit described in these investigations. Throughout this report, each interburden layer is referred to using the name of the coal seam directly below the layer.

Coal seams are numbered from deepest to shallowest. For example the deepest coal seam is seam 1 and the interburden above seam 1 and below seam 2 would be referred to as I1. In situations where there may be splits resulting in coal seams say 1A and 1B, then the interburden between these splits is referred to as I1A and I1B. Further if interburden layer I1A were composed of several horizons, say one horizon of primarily sandstone and the other of primarily shale, then the bottom horizon within this interburden would be labeled I1A1 and the next horizon above would be I1A2.

In general, each horizon within interburden is classified based on lithology, although some horizons may be composed of 2 or more lithologies, sandstone (SS), siltstone (SLTS) or shale (SH). Table 1 gives a list of each of the horizons and the composition of each in terms of percent of samples labeled SS, SLTS or SH. Thin (generally less than 12 inches) carbonaceous shale (CS) exists adjacent to the top or bottom of some coal seams. In most cases, the CS intervals were sent to the coal lab for BTU analysis and have to date not been analyzed by the soil lab; therefore occurrences of CS are not included with this analysis and because of the small quantities of CS, the effects will not be significant. There were 9 interburden samples labeled as carbonaceous shale that have been eliminated from the analysis.

Geologic Cross Section

The locations of two cross sections through the No Name Mine area are shown in plan view in Figure 1, and cross sections one and two are presented in Figures 2 and 3. These cross sections are lumped into interburden layers (white) and coal layers (shaded). In addition to the cross sections, the mining area limit and combined polygons of influence are plotted for the area of influence of drill holes 498-01, 498-03, 498-04, 498-05, 498-06, 498-07. These polygons were selected for investigation because mixed material was 100 percent suitable within each of these drill holes.

Table 1. Interburden horizon labels and lithologic composition.

Horizon	Percent Sandstone	Percent Shale	Percent Siltstone	Number of Observations
I1A	25	42	33	12
I2A	18	55	27	11
I2B	100	0	0	1
I2C1	0	100	0	10
I2C2	80	0	20	15
I2C3	0	91	9	23
I3A	0	100	0	1
I3A 1	100	0	0	2
I3A 2	0	0	100	2
I3B	100	0	0	1
I3C	0	72	28	16
I4A	0	100	0	2
I4C1	5	86	9	22
I4C2	70	15	15	26
I4C3	0	100	0	25
I6A	0	100	0	3
I6B	0	100	0	15
I7A 1	0	100	0	10
I7A 2	88	0	11	18
I7A 3	0	100	0	9
I7A 4	100	0	0	1
I7A 5	0	100	0	1
I8A	0	100	0	2
I8B1	0	100	0	1
I8B2	85	15	0	7
I8C1	0	80	20	5
I8C2	61	13	26	23
I8C3	0	100	0	4
I9A	0	100	0	4
I9B1	0	100	0	2
I9B2	75	25	0	4
PCSS	Picture Cliffs Sandstone			15
T7A 2	Topsoil			4
T7A 3	Topsoil			4
T8A	Topsoil			4
T8B 2	Topsoil			1
T8C 2	Topsoil			8
T9B 2	Topsoil			4

III. STATISTICAL METHODS

Proportion Suitable and Analyte Distributions

Interburden characterization data were obtained from BHP's soil lab (Inter-mountain Laboratories, Inc.) in electronic spreadsheets. The data were exported to ASCII comma delimited text files for import into SAS statistical processing software. Analyses of interest include the characterization of percentage of suitable interburden material based on 9 analytes: sodium absorption ratio (SAR), pH, electrical conductivity (EC), acid-base potential (ABPT), texture (percent clay CLA) saturation percentage (SAT), Boron (B), and total and soluble Selenium (TSE and SSE). Determination of suitability was made on a sample by sample basis using both Office of Surface Mining guidelines and site specific guidelines currently in use at Navajo Mine. Due to the proximity of the No Name mine site to the Navajo Mine, a similar site-specific standard is appropriate. Office of Surface Mining southwestern United States, and Navajo Mine suitability criteria can be found in Table 2.

Table 2. Office of Surface Mining Reclamation and Enforcement, Southwestern United States and Navajo Mine suitability criteria.

	SUITABILITY LIMITS	
Characteristic	Navajo Mine Site Specific	OSM Southwestern U. S. Criteria
1. SAR	≤18 OR ≤40 only if EC≥4 mmhos/cm	sandy loam≤20 loam, clay loam≤16 40% clay≤14
2. pH	≥5 and ≤9	≥5.5 and ≤9.0
3. EC	≤16 mmhos/cm	≤12 mmhos/cm
4. Acid-Base Account	≥-5 t $CaCO_3$/1000 t	same
5. Texture	≥50% clay	≥45% clay
6. Saturation	≤85% OR ≤100% only if EC≥4 mmhos/cm	same
7. Boron	≤10 ppm	same
8. Total Selenium	≤0.8 ppm	same
9. Soluble Selenium	≤0.15 ppm	same

Box plots (Refer to Figures 6 to 14) were constructed to display the statistical distribution of analyte values as a function of lithology and interburden layer. The box in each plot represents the 25^{th} and 75^{th} percentiles. The horizontal line in each box represents the median. The whiskers represent the range of the data up to 1.5 times the box length (interquartile range) from the box center. Observations further from the box center are plotted as ”+”symbols. Boxes that do not overlap can be thought of informally to represent differences in distribution, although this is not a rigorous statistical test.

Percent of suitable material was estimated within each interburden horizon. In general each horizon represented is composed primarily of one lithologic type (Table 1). The analysis methods followed Kern 1998, ***Draft Statistical Analysis Plan for Phase I Overburden Characterization Appendix A***. This is an analysis weighted by length of sample where each drill hole is treated as an independent experimental unit (i.e. a sample of at most 10 independent observations from each layer, with layers treated separately). The parameter estimates and precision were used to determine sample adequacy. For example, when the proportion suitable is very high or very low, low precision is acceptable and additional drilling would not be required. Conversely, if parameter estimates are marginal, then a higher level of precision is needed to make adequate decisions. The results of this analysis are presented in Figures 24 through 33 in plots of one-sided 90% confidence intervals for the percent of suitable material for each of 9 analytes.

Volume of Suitable Material

The total volume of material and total volume of suitable material in the I7A (interburden and overburden) was estimated. Information available from the 10 continuous core drill holes to estimate the percent suitable, and additional information on the total volume from 64 coal exploration drill holes was also used in the volume calculations. The analysis was applied to the mining area limit, within I7A, and to the combined polygons of influence for drill holes 498-01, 498-03, 498-04, 498-05, 498-06 and 498-07. These were the areas with the most suitable material.

In the mining process, mixing of the interburden material can be expected prior to reclamation as a result of loading, stockpiling and/or truck-dumping activities. Mixing will tend to improve the suitability of the material in that unsuitable intervals will tend to be diluted. An alternative approach is to utilize only the in-place (un-mixed) suitable materials for reclamation. Therefore, volumes of suitable material have been estimated under two conditions: 1) that the I7A interburden zone is mixed as a result of the mining process, and 2) that the in-place (un-mixed) suitable material is not mixed with intervals that are unsuitable. These conditions are evaluated because the mining and reclamation plans are likely to be different depending on whether interburden mixing is used.

Volume of in-place suitable material--Because additional coal exploration data are available, improved estimates can be constructed by estimating the total volume of an individual interburden layer independently from the continuous core data, and then multiplying by the proportion of suitable material. If V_{tot} represents the estimated total volume and $P_{suitable}$ represents the estimated proportion of suitable material, then the estimated volume of suitable material is

$$V_{suitable} = P_{suitable} V_{total}$$

and the estimated variance of the estimate is (Reed et al 1989)

$$\operatorname{var}(V_{suitabl}) = P^2{}_{suitable}\ \operatorname{var}(V_{total}) + V^2{}_{total}\ \operatorname{var}(P_{suitable}) - \operatorname{var}(P_{suitable})\ \operatorname{var}(V_{total}).$$

As described previously, the proportion of suitable material was estimated from the 10 continuous core drill holes. The total volume of material was estimated by kriging (Cressie 1991) the thickness of interburden layers using 64 additional drill holes from the exploratory drilling program. This allowed more accurate estimates of the volume of interburden layers than estimates based on the sparser continuous core data. Thickness was treated as the variable of interest and the mean thickness was estimated. When mean thickness is multiplied by total area of interest, it provides an estimate of the total volume. It should be noted that this is mathematically equivalent to developing kriged estimates of the thickness on a fine mesh grid using point kriging followed by adding the products of thickness by pixel area and summing. The advantage of this method is that variance estimates are also available for the estimated volume. In addition to estimating total volume, an isopach map showing interburden I7A over the mine site is provided in figure 5.

Volume of mixed suitable material--Although the volume of in-place suitable material can be estimated, it is of interest to consider the mixed volume of interburden and overburden which can be expected to be suitable. The continuous core data were averaged within interburden I7A and within drill hole and the resulting averages were compared to the suitability criteria to determine which areas could be expected to contain suitable interburden after mixing. The combined polygons of influence for these drill holes were used to delineate an area expected to be suitable after mixing. The total volume and a lower 90 percent confidence bound for mixed suitable material in interburden I7A was estimated using kriging.

Spatial Distribution of Suitable Interburden in I7A

The spatial distribution of suitable material was investigated in two ways;

1) The percent of suitable material on a sample by sample basis was plotted in plan view. Both OSM and Navajo criteria were investigated and results are displayed on Figure 4 as percent suitable by Navajo Mine Criteria / percent suitable by OSM criteria.

2) Under the assumption that material will be mixed in handling, data were pooled within interburden and drill hole, and the average analyte values were calculated using a weighted average with weights proportional to length of core. The weighted averages were compared to both OSM and Navajo criteria, and the results were posted in plan view showing which drill holes resulted in suitable average analyte values.

Regression Analysis for Trend in Parameters

If substantial gradients exist across the proposed mine site, one might encounter a situation where the mean parameters are suitable, while in fact there may be spatial strata which are composed of extremely poor material or extremely good material. In order to assess this question, a standard multiple regression analysis was conducted (Neter et al. 1996). The linear statistical model used was of the form

$$Analyte = \mu_0 + \mu_{litho\log y} + \beta_1 depth + \beta_2 Easting + \beta_3 Northing + Interactions + error$$

To take into account the unequal weighting inherent in the continuous core samples the regression coefficients and variance estimates were obtained using a weighted regression with weights proportional to the length of core sampled.

Statistical Quality Assurance

A set of 33 measurements was chosen for duplicate analysis following IML quality assurance procedures (QAP). To assess the relative magnitude of analytical error in the database, 95% confidence intervals were calculated for the relative difference between original measurements and duplicate measurements. Relative error was defined to be ([original value - duplicate value] / original value)**.** Reported values for boron, total and soluble selenium were occasionally zero resulting in relative errors that were not defined. For this reason the QA analysis for these analytes was reported in absolute units (ppm). Table (4) summarizes the results of this analysis.

IV. RESULTS

Analyte Distribution

Box plots of the distribution of each analyte are presented in figures 6 through 14 for all interburden layers pooled. Each analyte is broken out into separate box plots for each lithology, sandstone, shale and siltstone. It was found that interburden layer I7A was the most likely to provide adequate suitable material so box plots of analyte distributions are also presented by lithology within horizon I7A in figures 15 through 23.

Confidence Intervals for Percent Suitable

One-sided 90% confidence intervals for percent suitable material (Navajo Mine thresholds) are presented in graphical form in figures 24 through 34. Although the upper confidence limit on percent suitable is not of interest, it should be noted that the two-sided confidence interval should be interpreted as an 80% confidence interval. In general, it can be said that we are 90% confident that the true proportion of suitable material is greater than the lower confidence limit shown in the figures. These figures show that interburden I7A is the most promising target for suitable materials.

Estimated Volume of Suitable Material in Interburden I7A

All volumetric calculations are based on suitability for all analytes simultaneously. If the material is unsuitable for any analyte then it is considered unsuitable.

Volume of in-place suitable material-- Total volume of in-place suitable material in interburden I7A, and the overburden was estimated for the full mining area limit and in combined polygons of influence for drill holes 01, 03, 04, 05, 06, and 07. The results are summarized in table (3). Application of the kriging model requires estimation of a spatial correlation function. The estimated model was an isotropic spherical model with nugget effect 0.11 and range of influence 3,463 feet.

The estimated total volume of interburden I7A over the mining area limit is 91.7 Mcy. Of that, the estimated in-place volume of suitable material is 37.6 Mcy with a standard error of 12.4 Mcy. The estimated probability that there are at least 21.8 Mcy of in-place suitable material in the planned mine area in interburden I7A is 90%.

When interburden I7A is restricted to just the polygons of influence associated with drill holes 01, 03, 04, 05, 06, and 07, (those with suitable mixed material), the total volume of material is estimated to be 47.0 Mcy. The estimated volume of in-place suitable material is 36.2 Mcy with standard error 13.0 Mcy. The probability that there are at least 19.4 Mcy of in-place suitable material in this portion of the planned mine area in interburden I7A is 90%.

Table 3. Estimated volume of suitable material based on estimates of percent suitable from continuous core drilling and average thickness based on coal exploration drilling.

				Mixed Volume			In-place Volume		
Region	Surface Area $1x10^6$ ft^2	Percent Suitable	SE	Total Volume $1x10^6$ yd^3	SE Feet	Lower 90% Limit $1x10^6$ yd^3	Volume Suitable $1x10^6$ yd^3	SE $1x10^6$ yd^3	Lower 90% Limit $1x10^6$ yd^3
Mining Area Limit Overburden	153.7 ($17x10^6$ yd^2)	48%	15%	127.7	8.0	116.8	60.9	18.9	36.8
Polygons 1 3 4 5 6 7 Overburden	74.42	67%	28%	60.0 [a]	5.0	43.6 [a]	40.0	17.0	18.0
Mining Area Limit I7A Interburden	153.7 ($17x10^6$ yd^2)	41%	13%	91.7	3.6	87.1	37.6	12.4	21.8
Polygons 1 3 4 5 6 7 I7A Interburden	74.42	77%	28%	47.0 [a]	2.2	44.2 [a]	36.2	13.0	19.4
Overburden Seam 8	38.78	81%	28%	32.5 [a]	6.7	23.9 [a]	26.1	7.3	16.8

[a] Suitable material when mixing occurs.

Volume of suitable mixed interburden material in I7A—The estimated total volume of suitable mixed interburden material in interburden I7A within the combined polygons of influence for drill holes 01, 03, 04, 05, 06, and 07, is 47.0 Mcy. The probability that there are at least 44.2 Mcy of suitable mixed material in this portion of the planned mine area in interburden I7A is 90%.

Sample adequacy – There are at least two ways to demonstrate that adequate in-place suitable material exists in the permit area with 90% confidence. First, there is a 90% probability that the volume of in-place suitable material in the overburden, (material above uppermost coal seam) is at least 36.8 Mcy. Second, the total combined volume in the overburden associated with seam 8 and the material in the I7A interburden is estimated to be greater than 16.8+19.4 = 36.2 Mcy with 90% confidence. Either of these estimates indicates that the total volume is well above the 22.7 Mcy needed for successful reclamation.

Spatial Distribution of Suitable Material within Interburden I7A

Weighted averages of analyte values were computed for each drill hole. These values were compared to OSM and Navajo Mine criteria to assess the spatial distribution of suitable material after mixing, in anticipation of the mining and handling process. Drill holes were marked with a solid circle if all analytes passed the OSM southwestern United States Criteria, and drill holes were marked with a hatched circle if one or more OSM criteria were not met, while the Navajo Mine criteria were met for all analytes. The results of these investigations can be seen in figure (2). When mixing is assumed, drill holes 498-01, -03, -04, -05, and -06 contained suitable material by OSM criteria. In addition, mixed material in drill hole 498-07 was suitable by Navajo Mine Site specific criteria.

Isopach of Interburden I7A

Analysis of the interburden thickness data resulted in spatial correlations which ranged up to 3,463 feet but which included a nugget effect of 0.11. These parameters were used to krige the 74 isopach measurements to develop point estimates of the isopach on a regular grid with 200 foot spacing. The resulting isopach map can be seen in figure (5).

Regression Analysis

Regression analysis results are presented in Table 5, where R-squared statistics are listed along with variables that are statistically significant predictors of analyte values. In particular, acid base potential, percent clay, percent saturation and soluble selenium each vary with lithology. These relationships to lithology are most easily discerned by looking at the box plots. For example the distribution of acid base potential (figure 6) shows that ABP is significantly higher in sandstone and siltstone than in shale. Similarly, (and perhaps obviously) percent clay also varies across lithology (R^2 = 0.72), as one would expect with shale, siltstone and topsoil all having more clay than sandstone. In addition, there is an interaction between depth and lithology and easting and lithology. The indication of significant interactions is that percent clay may be increasing with easting for some lithologies and decreasing or not changing with easting for others. For further interpretation of these relationships one is referred to Appendix B, where full regression outputs are available. Selenium concentration is also correlated with lithology, easting and depth (R^2 = 0.61). Again for additional interpretation see Appendix B.

Statistical Quality Assurance

A summary of results of the statistical quality assurance can be found in Table 4. Average relative analytical measurement error was less than 2 percent for pH, EC, SAT, SAR, CLAY, Neut-pot, and Total Sulfur. Ninety five percent confidence intervals for the average error ranged from –4% to 6.57%. Because Boron, and total and soluble SE were often recorded as 0.00 when rounded to 2 decimals, absolute precision was calculated for these analytes. Duplicate measurements for Boron were on average within 0.015 ppm with a 95% interval of (-0.04, 0.1 ppm). Total selenium averaged $1x10^{-18}$ ppm with a 95% confidence interval of (-0.008, 0.012). Soluble selenium averaged 0.0064 (ppm) analytical error, with a 95% confidence interval of (–0.002, 0.020). IML quality standards are that duplicate analytical measurements are within 15% of original measurements.

V. CONCLUSIONS

The primary objective of these investigations is to identify interburden horizons that contain sufficient volume of material suitable for establishment of a root zone in reclamation, and to determine if the present level of drilling is adequate to characterize the volume of suitable material.

Based on the plots of percent suitable by analyte and interburden layer, I7A interburden is the most likely interburden layer to contain adequate suitable material. There may be smaller pockets of suitable material within other interburden layers such as I8 and I9 although I7A was the primary focus of these investigations. If I7A can be established as containing adequate volume, then any additional interburden layers later found to contain suitable material can simply be incorporated in the mine plan.

The 10 continuous core samples used to estimate the percentage of suitable material represent a random sample of the mining area limit. As such, statistical inferences apply to this region. To make a decision regarding drilling adequacy, some form of definition of adequacy is required. In these studies, adequacy is defined to mean sufficient number of samples to allow a decision *with 90% statistical confidence* that either yes, *there is sufficient volume of mixed suitable material, or no there is not sufficient volume of mixed suitable material* for reclamation. An inadequate number of drill holes would be characterized by a situation where neither of the above statements can be made, (i.e. 90% confidence intervals for volume of mixed suitable material overlap the minimum volume of material needed to reclaim). Based on a target of 4 feet of soil depth over all of the mining area limit (3530 acres) 22.7 Mcy of suitable material are needed.

In the mining process, mixing of the interburden material can be expected prior to reclamation as a result of loading, stockpiling and/or truck-dumping activities. Mixing will tend to improve the suitability of the material in that unsuitable intervals will tend to be diluted. An alternative approach is to utilize only the in-place (un-mixed) suitable materials for reclamation. Therefore, volumes of suitable material have been estimated under two conditions (see Table 3): 1) that the I7A interburden zone is mixed as a result of the mining process, and 2) that the in-place (un-mixed) suitable material is not mixed with intervals that are unsuitable. These conditions are evaluated because the mining and reclamation plans are likely to be different depending on whether interburden mixing is used.

Consider the total volume of mixed suitable material (i.e. material from the polygons of influence for drill holes 01, 03, 04, 05, 06, and 07). Based on the 64 drill holes from coal exploration drilling and the 10 continuous core holes (i.e. N=74 total), the estimated total volume of mixed suitable material is 47.0 Mcy. ***Based on this analysis, we can say with 90% confidence that the volume of mixed suitable material in the combined polygons of influence for holes 1,3,4,5,6,and 7 in I7A interburden (44.2 Mcy) is greater than the needed 22.7 Mcy.***

It has also been shown with 90% confidence that the volume of in-place (un-mixed) suitable material in the combined polygons of influence for holes 1, 3, 4, 5, 6 and 7 in the I7A interburden plus the I8 overburden combined is at least 36.2 Mcy. There is also a 90% probability that the volume of in-place suitable material in the overburden, (material above uppermost coal seam) is at least 36.8 Mcy

In summary, it has been demonstrated with 90% confidence that there is sufficient mixed suitable material from the I7A interburden zone to allow development of a 4-foot root zone as part of the reclamation strategy. It has also been demonstrated with 90% confidence that there is sufficient in-place (un-mixed) suitable material from the I7A interburden and I8 overburden zones to allow development of a 4-foot root zone. It can be concluded based on these studies that additional drilling to verify the presence of adequate volume of suitable material is not required in order to proceed with mine planning.

Table 4. Statistical quality assurance analysis of laboratory duplicate chemical analysis. Ninety five percent confidence intervals were developed for the relative difference between duplicates and original measurements. When upper confidence limits are positive and lower confidence limits are negative the relative error is not significantly different from zero.

	PH	EC	SAT	SAR	CLAY	Neut-pot	Total Sulphur	Boron[a] (ppm)	Total Se[a] (ppm)	Soluble Se[a] (ppm)
Mean	-0.07%	2.00%	-0.42%	0.04%	-0.32%	-1.73%	-1.73%	0.015	1.7e-18	0.0064
Variance	0.001%	0.65%	0.10%	1.01%	0.06%	0.36%	0.42%	0.023	0.0005	0.0005
Lower Confidence Limit	-0.21%	-0.91%	-1.56%	-3.58%	-1.23%	-3.90%	-4.05%	-0.039	-0.008	-0.0020
Upper Confidence Limit	0.15%	6.57%	1.36%	5.72%	1.11%	1.68%	1.92%	0.101	0.012	0.0195

[a] Boron and total and soluble selenium are reported in absolute units (ppm) because reported values were often 0.00 ppm when rounded to 2 significant digits.

Table 5. Summary of regression analysis results. The models were fit one analyte at a time and the table presents R-squared values for all models and lists variables (if any) which were statistically significant at the 10% level.

Analyte (Dependent Variable)	R^2	Significant parameters at p<0.10 Parameter	Statistical Significance
Acid Base Potential (ABP)	0.53	Lithology	0.044
Boron (BOR)	0.57	None	p>0.14
Percent Clay (CLA)	0.79	Lithology	0.001
		Easting	0.034
		Easting*Lithology	0.001
EC	0.43	None	p>0.15
PH	0.48	None	p>0.13
Sodium Absorption Ratio (SAR)	0.49	None	p>0.16
Percent Saturation (SAT)	0.51	Lithology	0.09
		Depth*Lithology	0.06
		Easting*Lithology	0.09
Soluble Selenium (SSE)	0.24	None	p>0.23
Total Selenium	0.63	Lithology	0.003
		Depth	0.001
		Easting	0.001
		Depth*Lithology	0.001
		Easting*Lithology	0.004

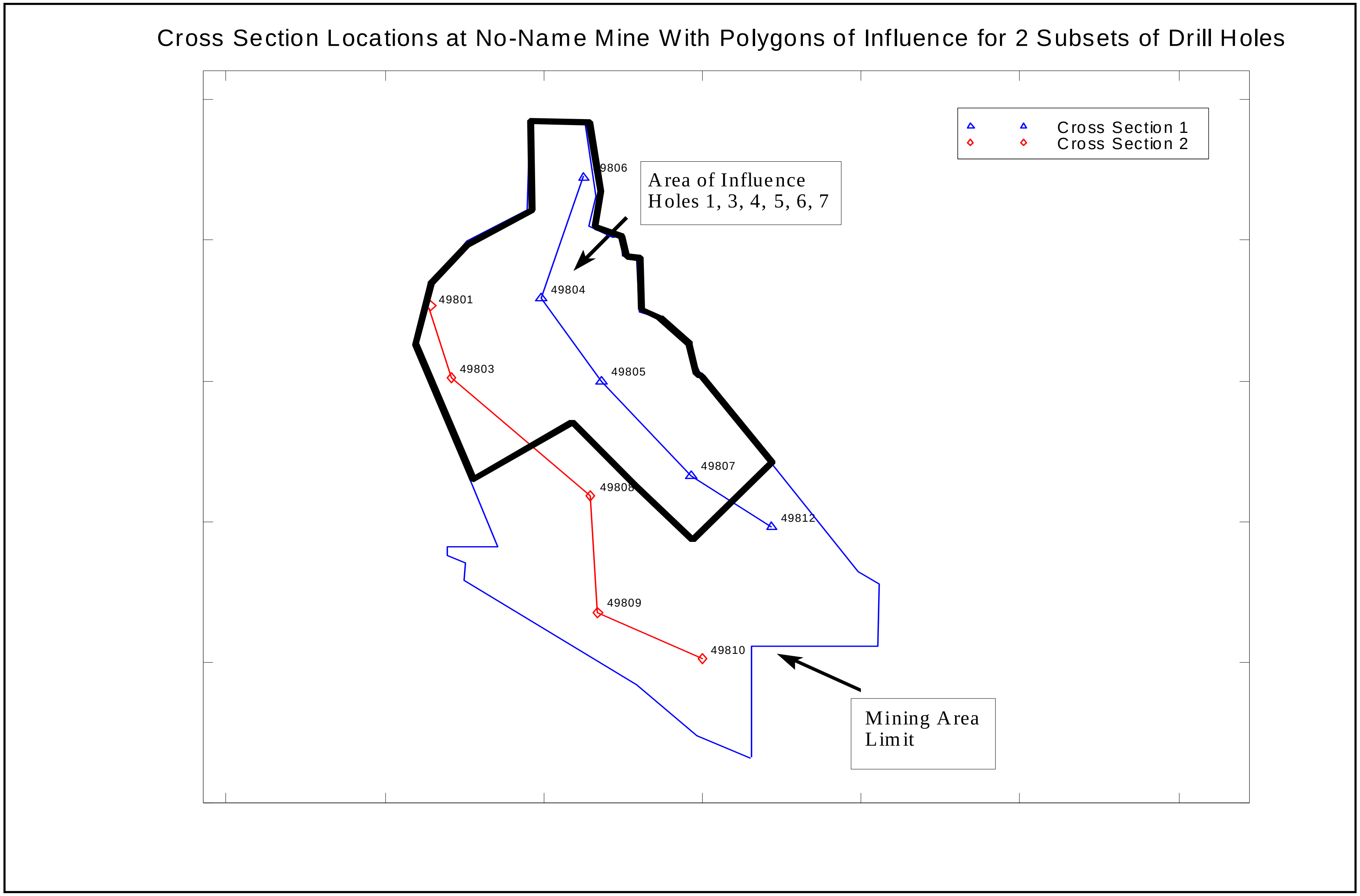


Figure 1. **Plan view of No Name mining area limit with locations of cross sections (1) and (2) and combined polygons of influence associated with continuous core samples 498-01, 498-03, 498-04, 498-05, 498-06, and 498-07. Total volume of suitable material was estimated on both polygons.**

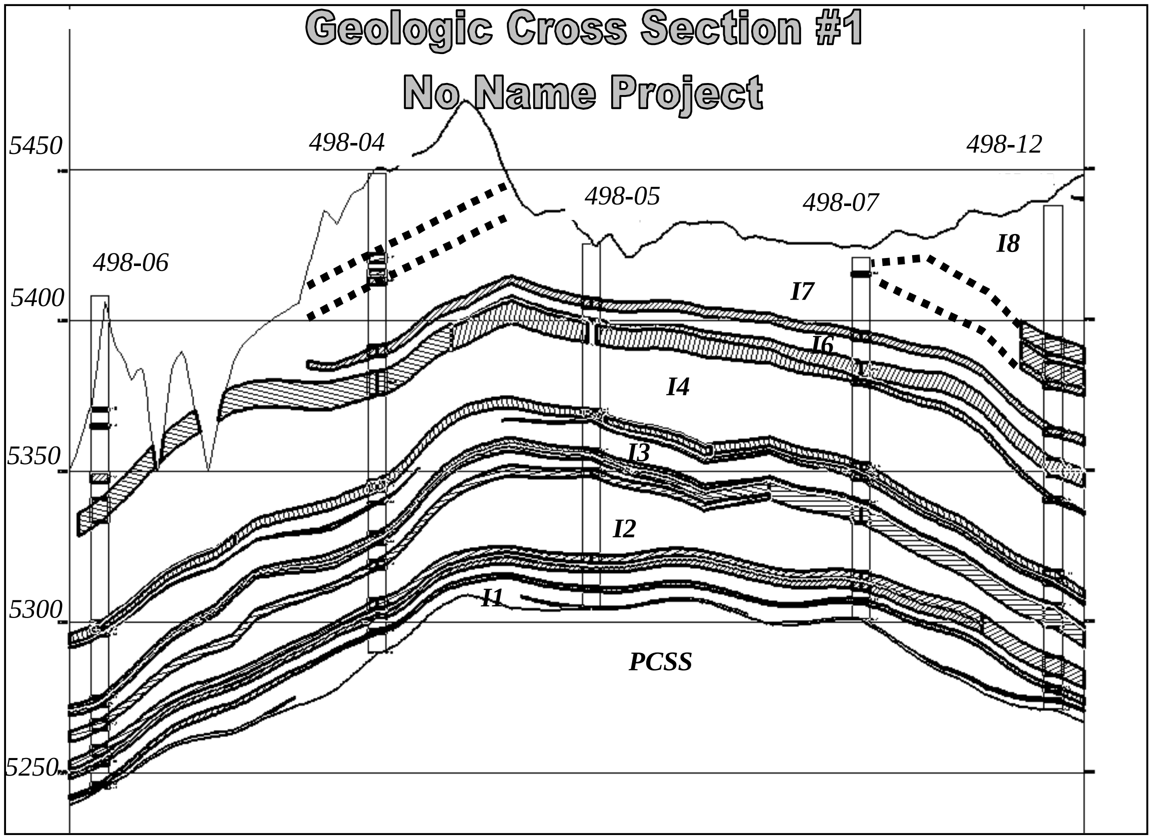


Figure 2. Geologic cross section number 1 at the No Name mine site. For a plan view, see figure (1).

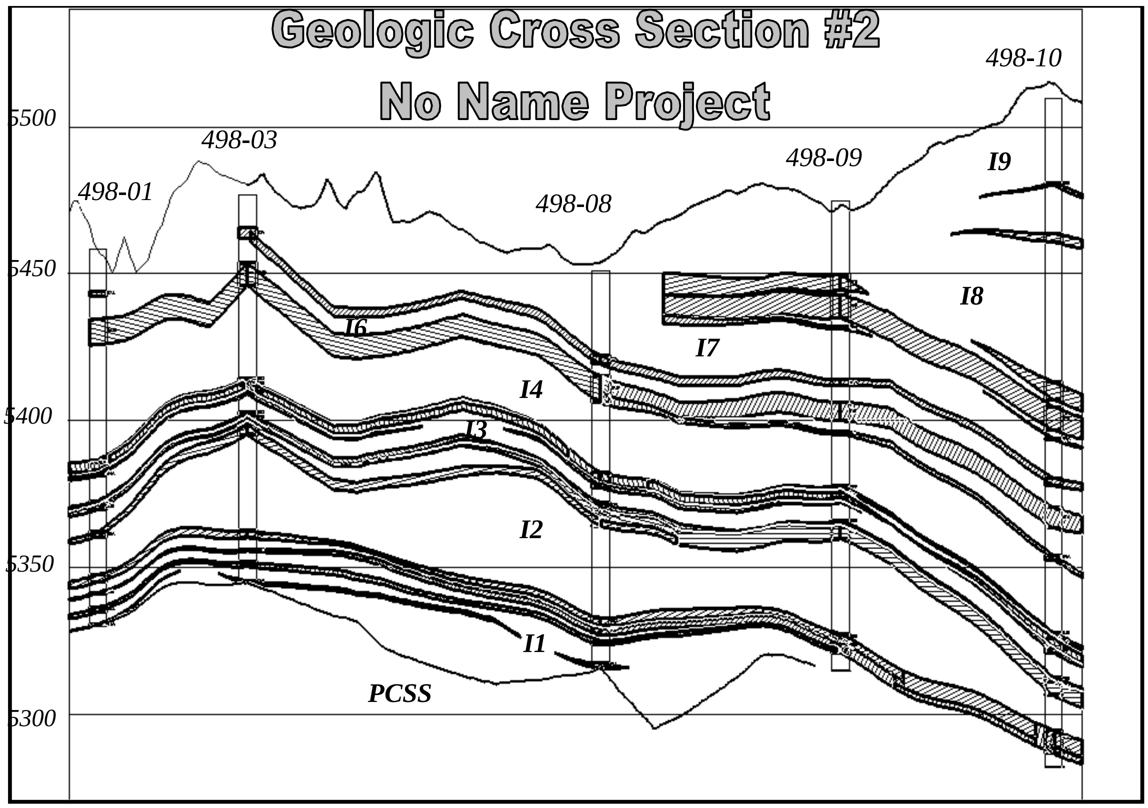


Figure 3. **Geologic cross section number 2 at the No Name mine site. For a plan view, see figure (1).**

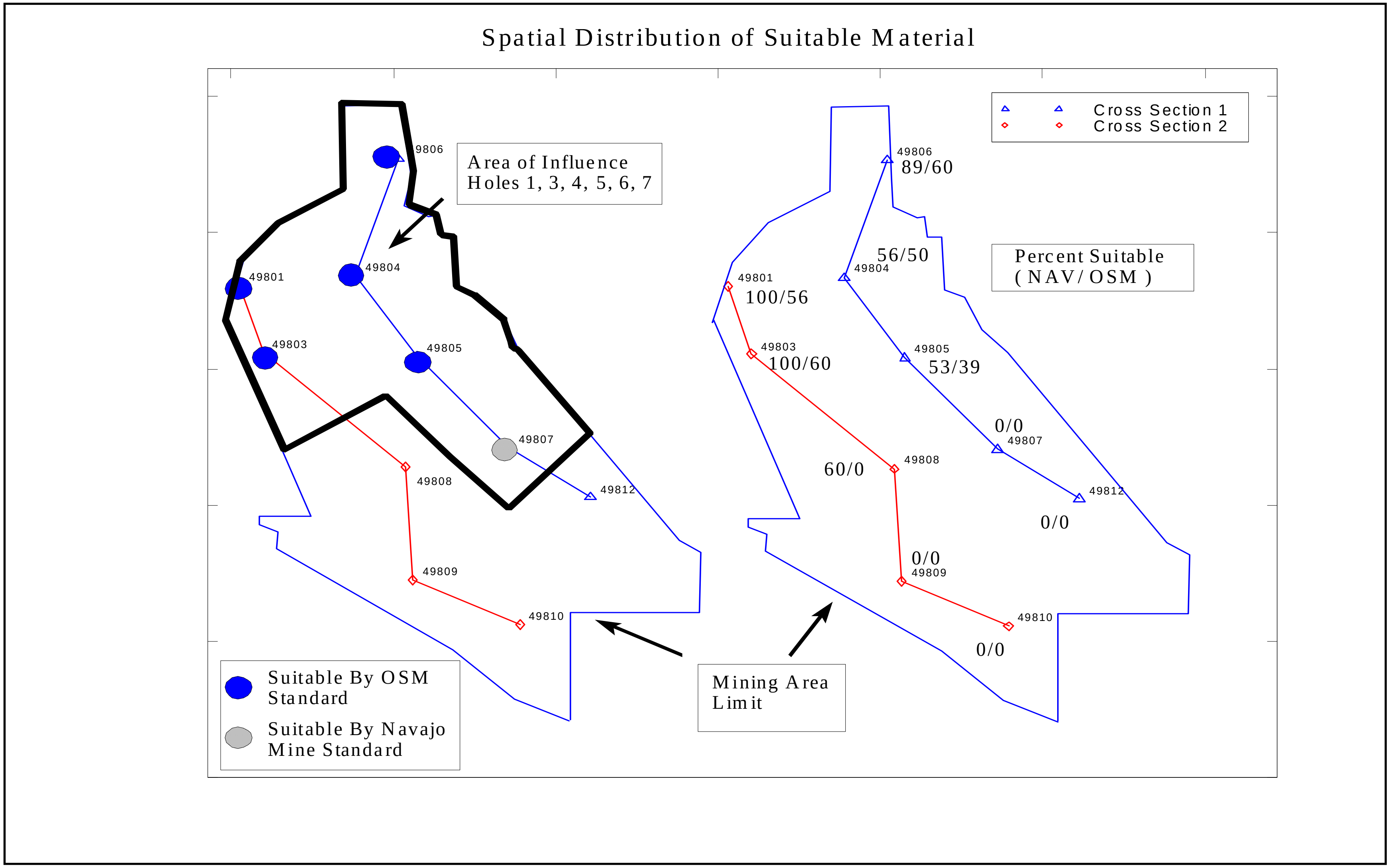


Figure 4. **Spatial distribution of Suitable material in the I7A interburden at the No Name mine site. In the left pane, filled circles indicate that the weighted average of each analyte met OSM and Navajo Mine criteria. Hatched circles indicate that the Navajo Mine criteria were met but the OSM criteria were not. In the right pane, the percentage of suitable material on a sample by sample basisi is posted at each drill hole. The percentages are listed by (Navajo Criteria/OSM Criteria). Drill hole 498-08 failed on SE=1.3ppm.**

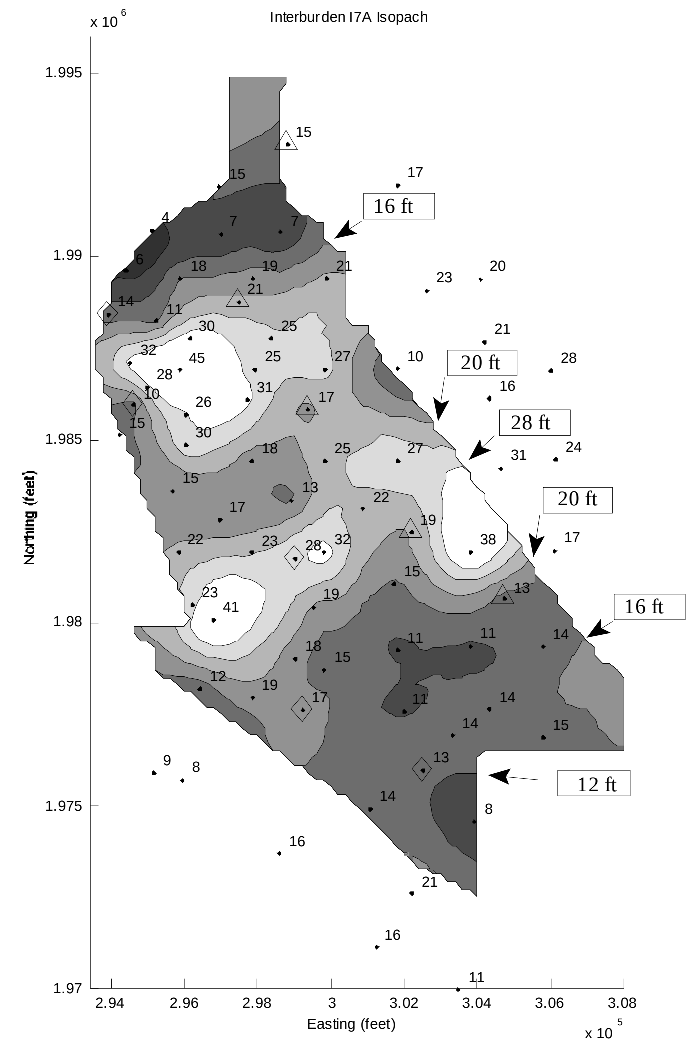


Figure 5. **Kriged isopach map of the I7A interburden at the No Name mine site. The contour interval is 4 feet and the actual data are posted. Triangles represent drill holes on cross section 1 and diamonds represent drill holes on cross section 2.**

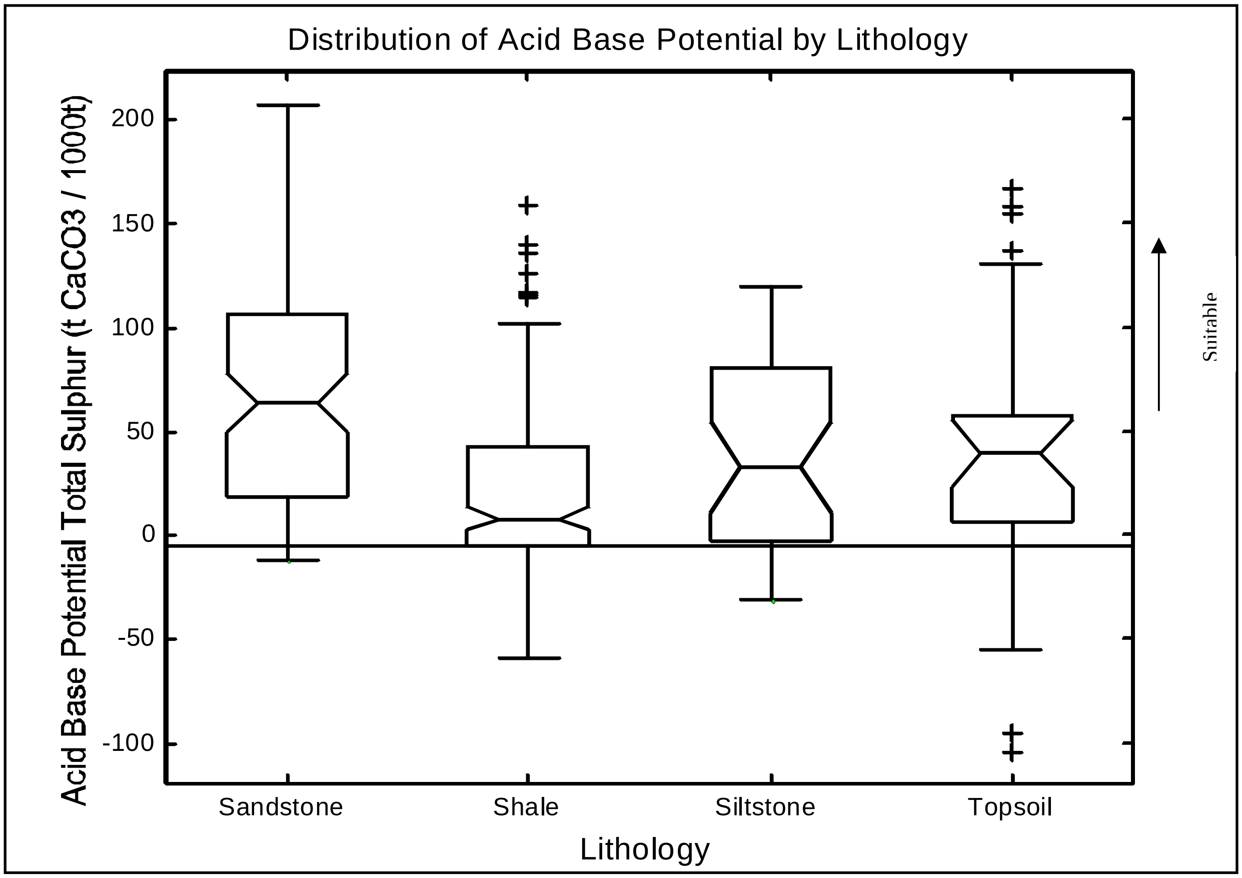


Figure 6. Box and whisker plots of Acid Base Potential stratified by lithology for all interburden layers. The box represents the 25th and 75 th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal line represents the Navajo Mine site specific standard for suitability.

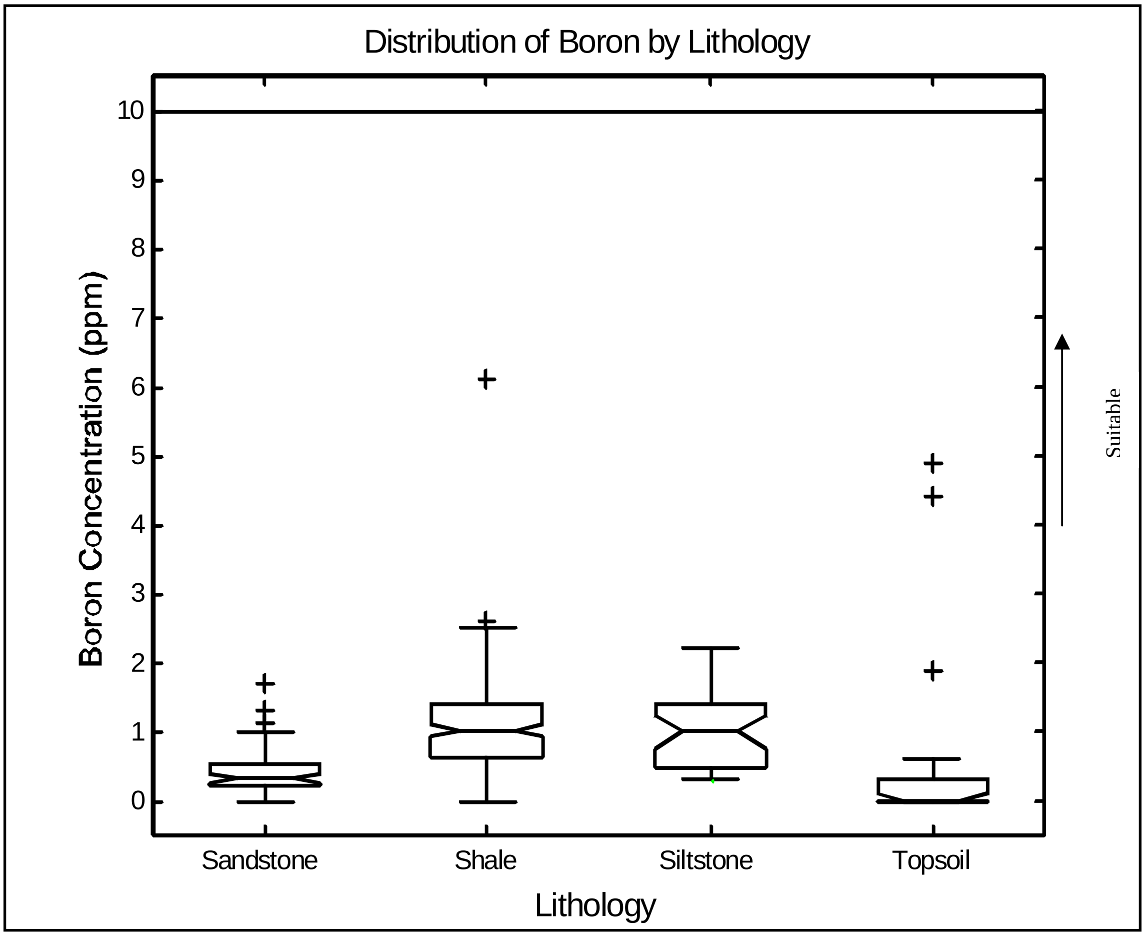


Figure 7. **Box and whisker plots of Boron concentration in parts per million stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal line represents the Navajo Mine site specific standard for suitability.**

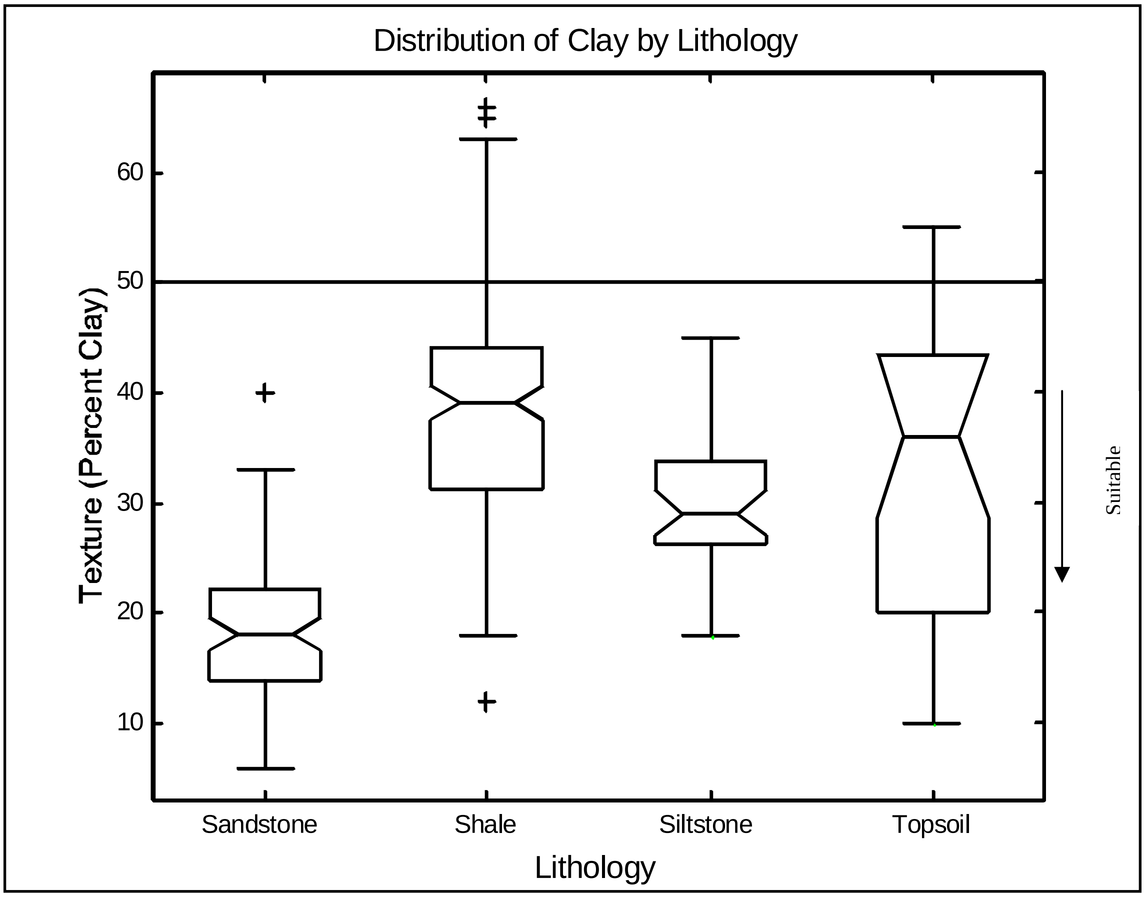


Figure 8. **Box and whisker plots of percent clay stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal line represents the Navajo Mine site specific standard for suitability.**

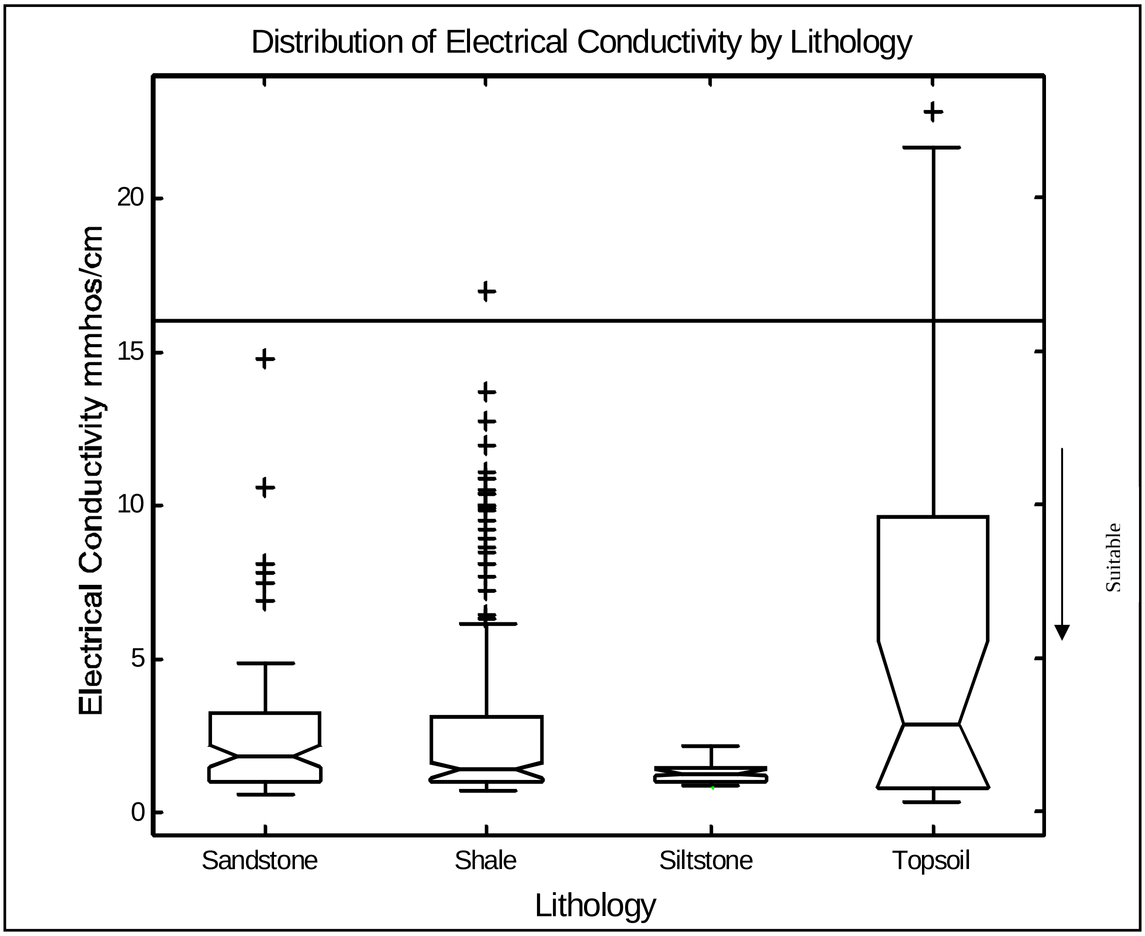


Figure 9. **Box and whisker plots of electrical conductivity stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal line represents the Navajo Mine site specific standard for suitability.**

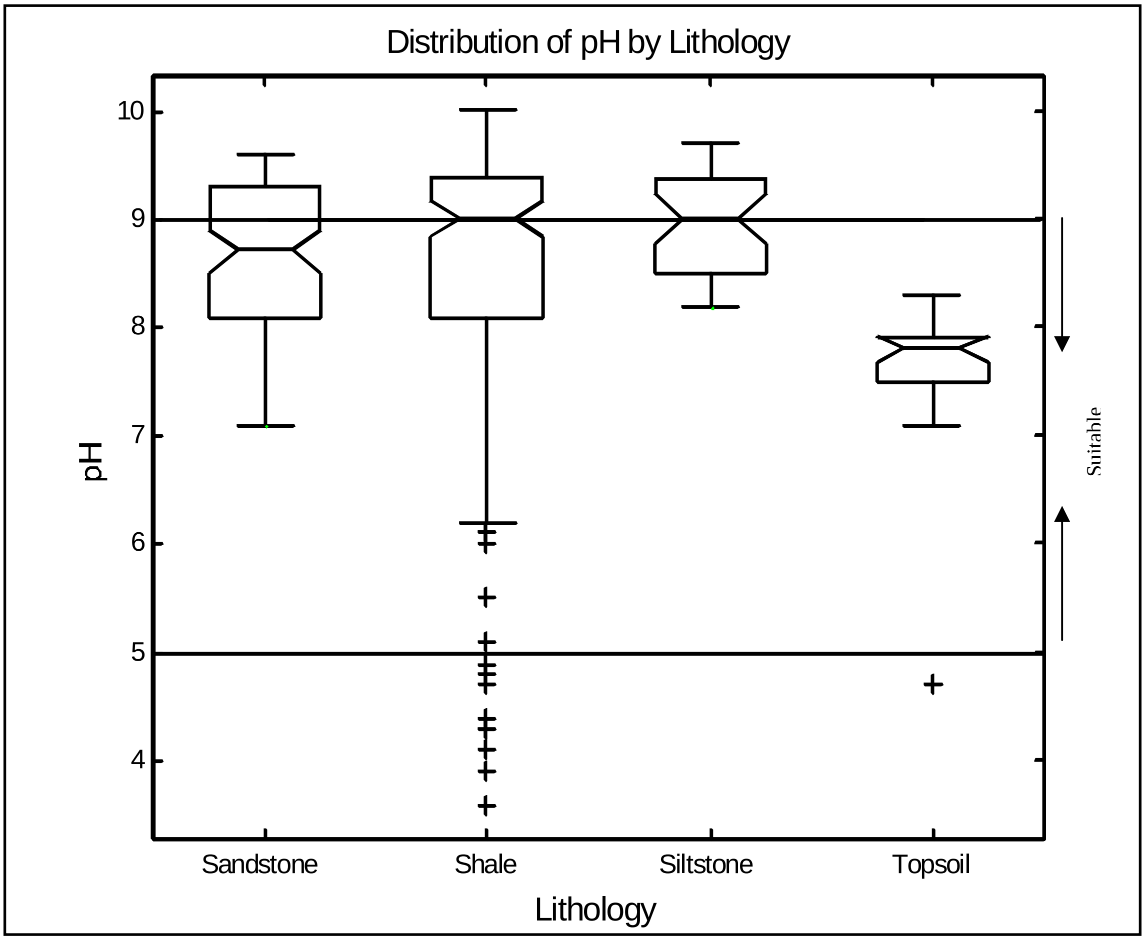


Figure 10. **Box and whisker plots of pH stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal line represents the Navajo Mine site specific standard for suitability.**

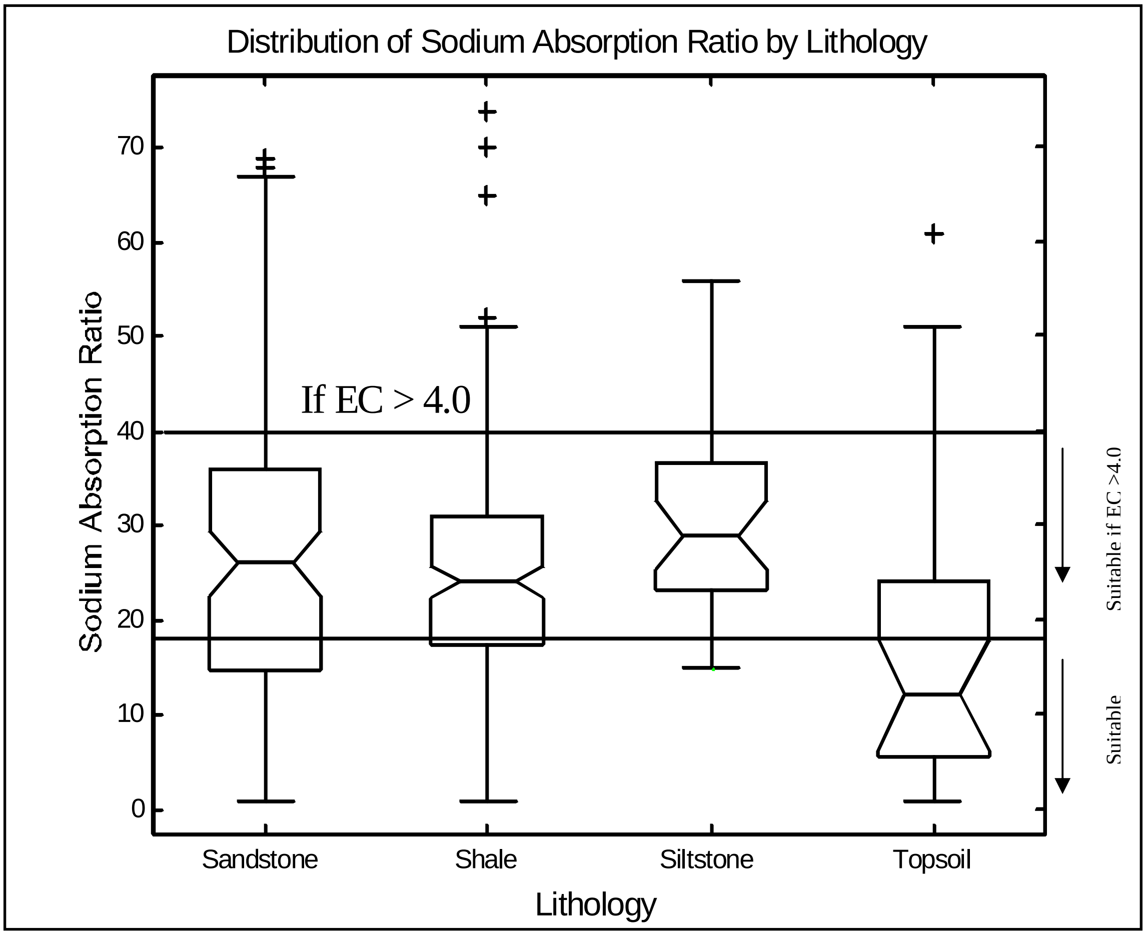


Figure 11. **Box and whisker plots of sodium absorption rate stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal lines represent the Navajo Mine site specific standard for suitability.**

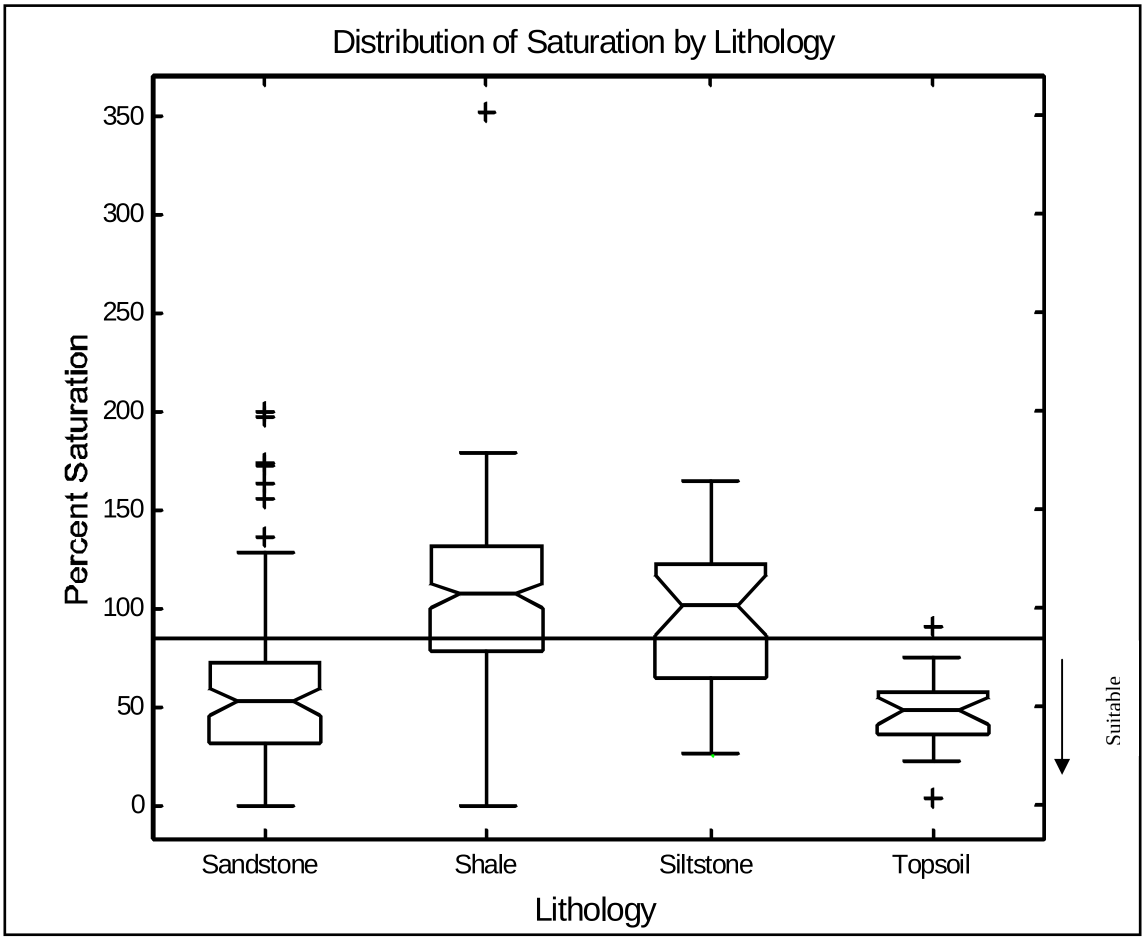


Figure 12. **Box and whisker plots of percent saturation stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal lines represent the Navajo Mine site specific standard for suitability.**

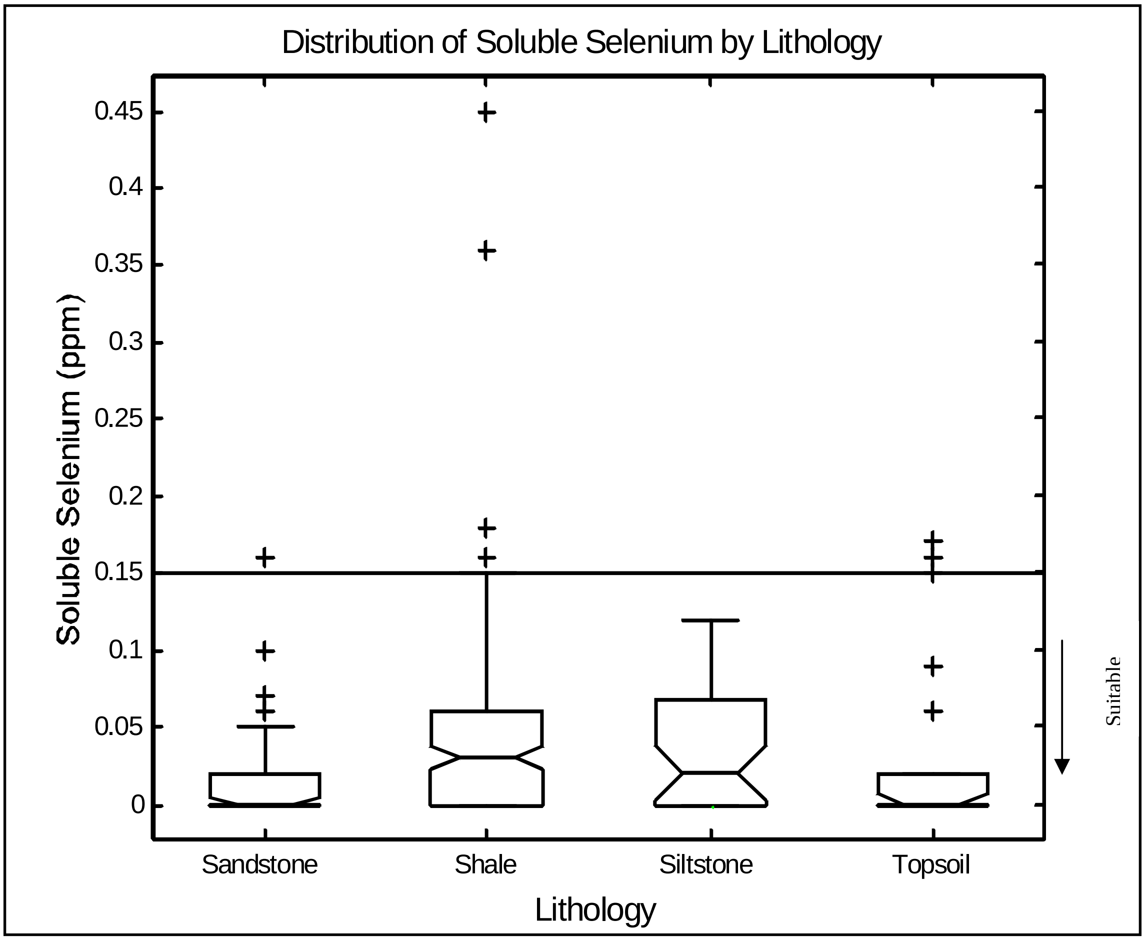


Figure 13. **Box and whisker plots of soluble selenium by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal lines represent the Navajo Mine site specific standard for suitability.**

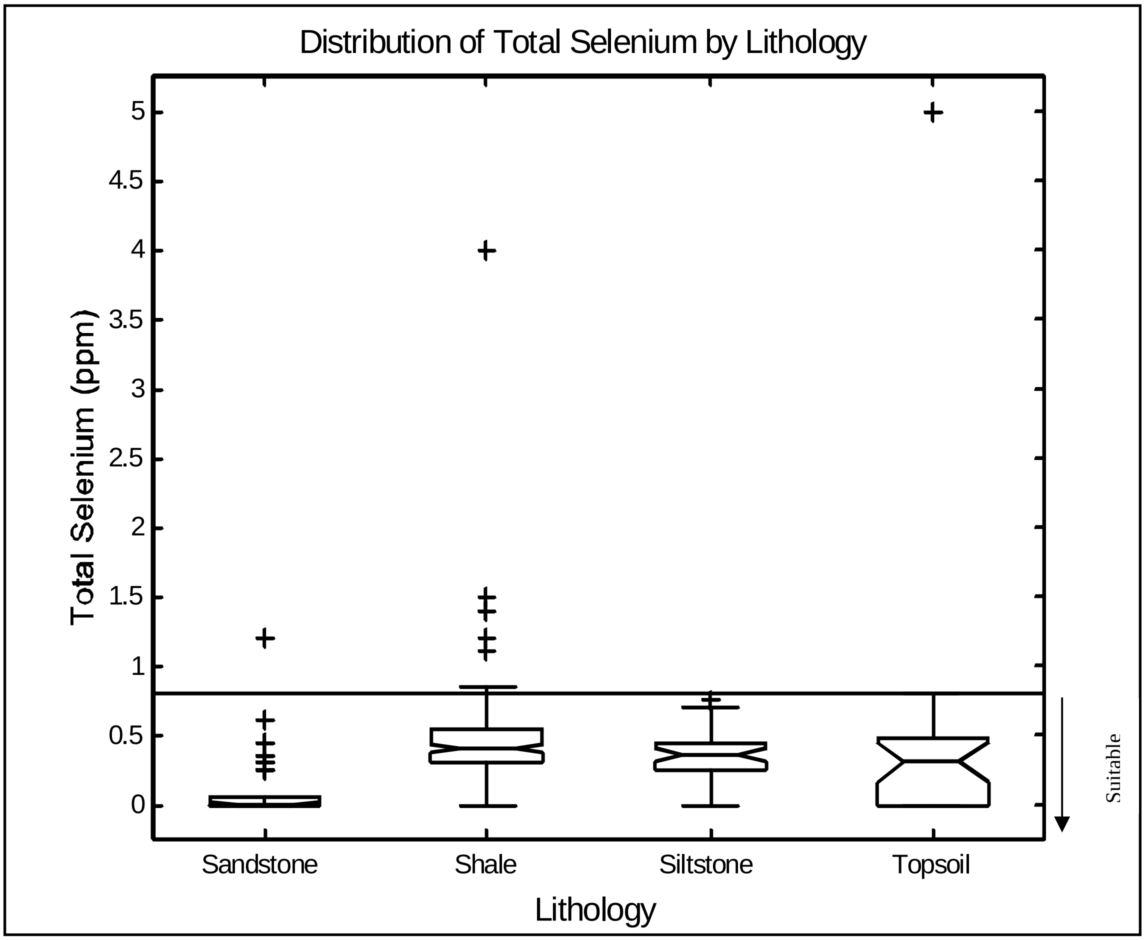


Figure 14. **Box and whisker plots of total selenium by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal lines represent the Navajo Mine site specific standard for suitability.**

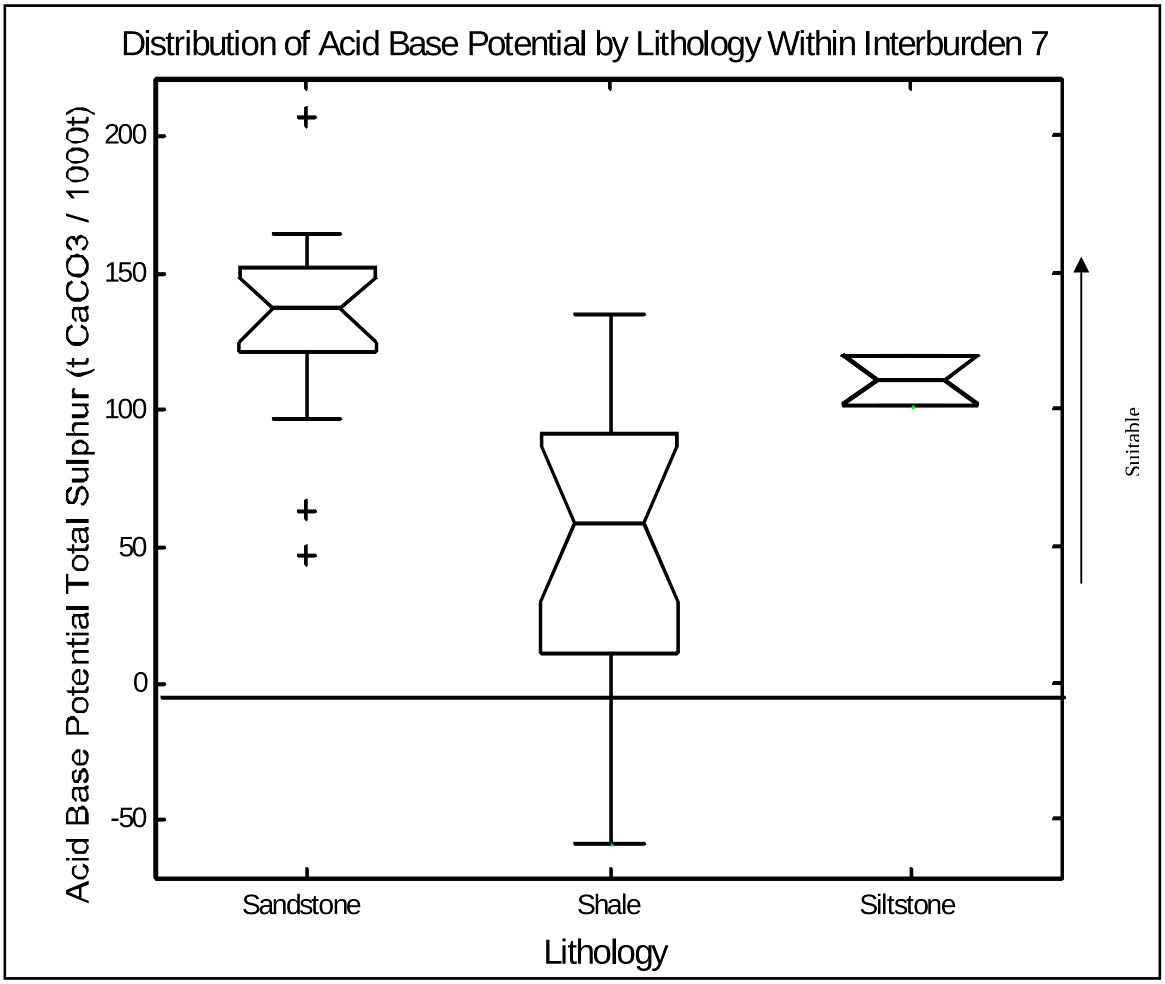
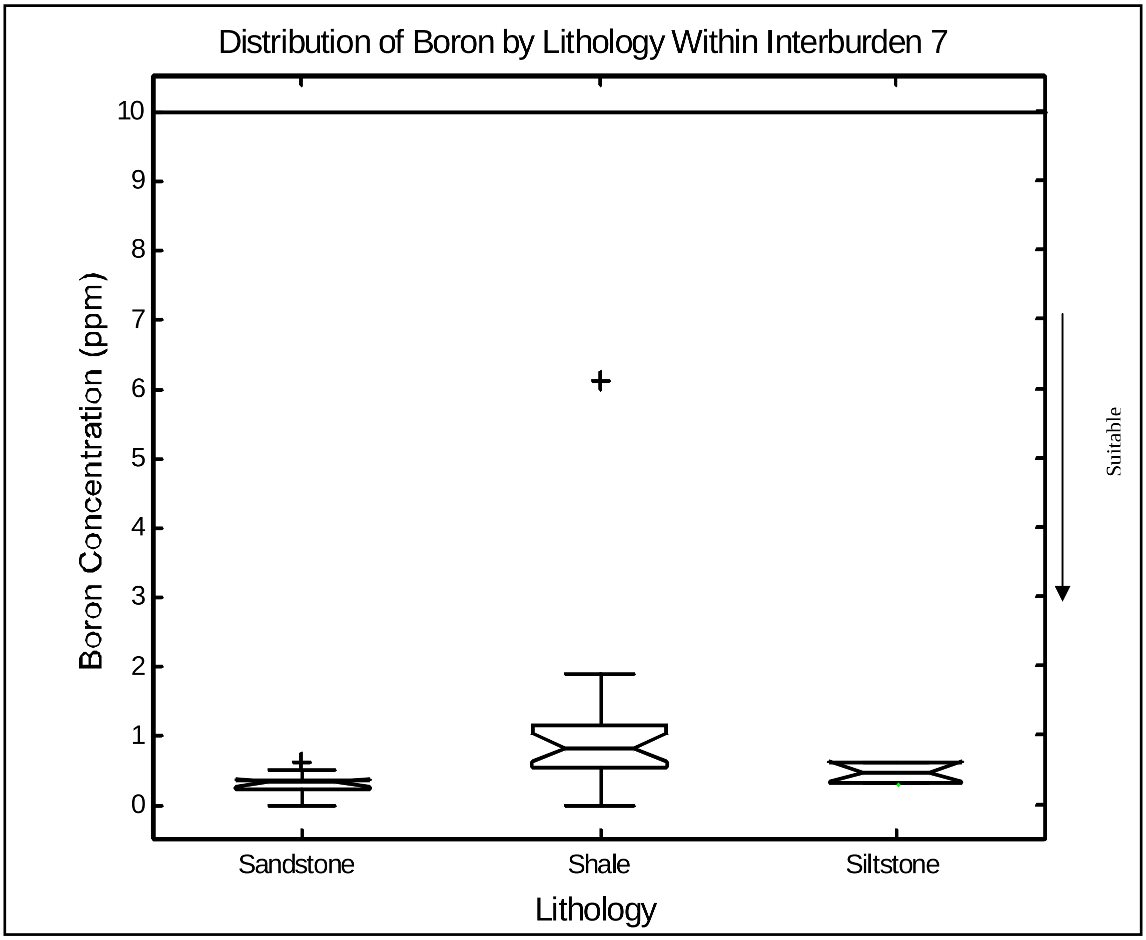


Figure 15. **Box and whisker plots of acid base potential within interburden 7 stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal lines represent the Navajo Mine site specific standard for suitability.**



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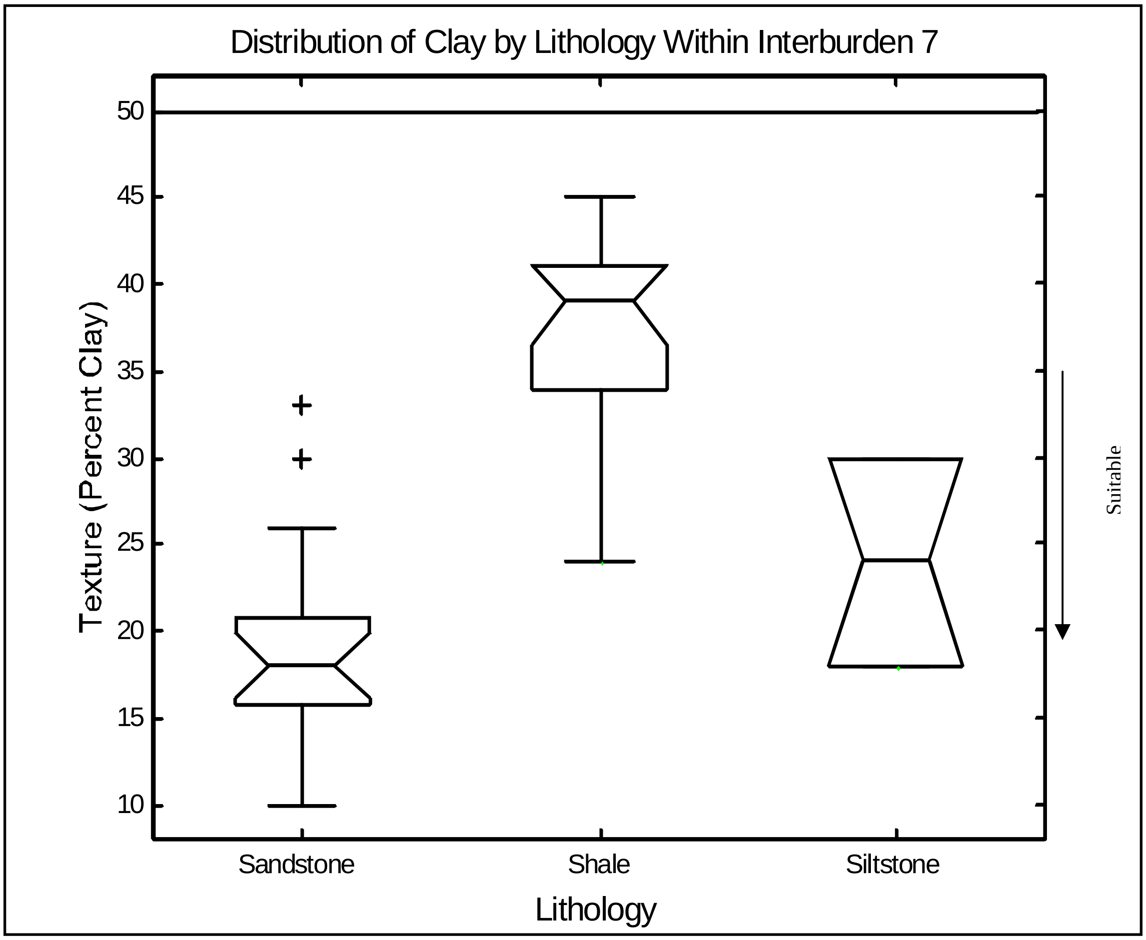

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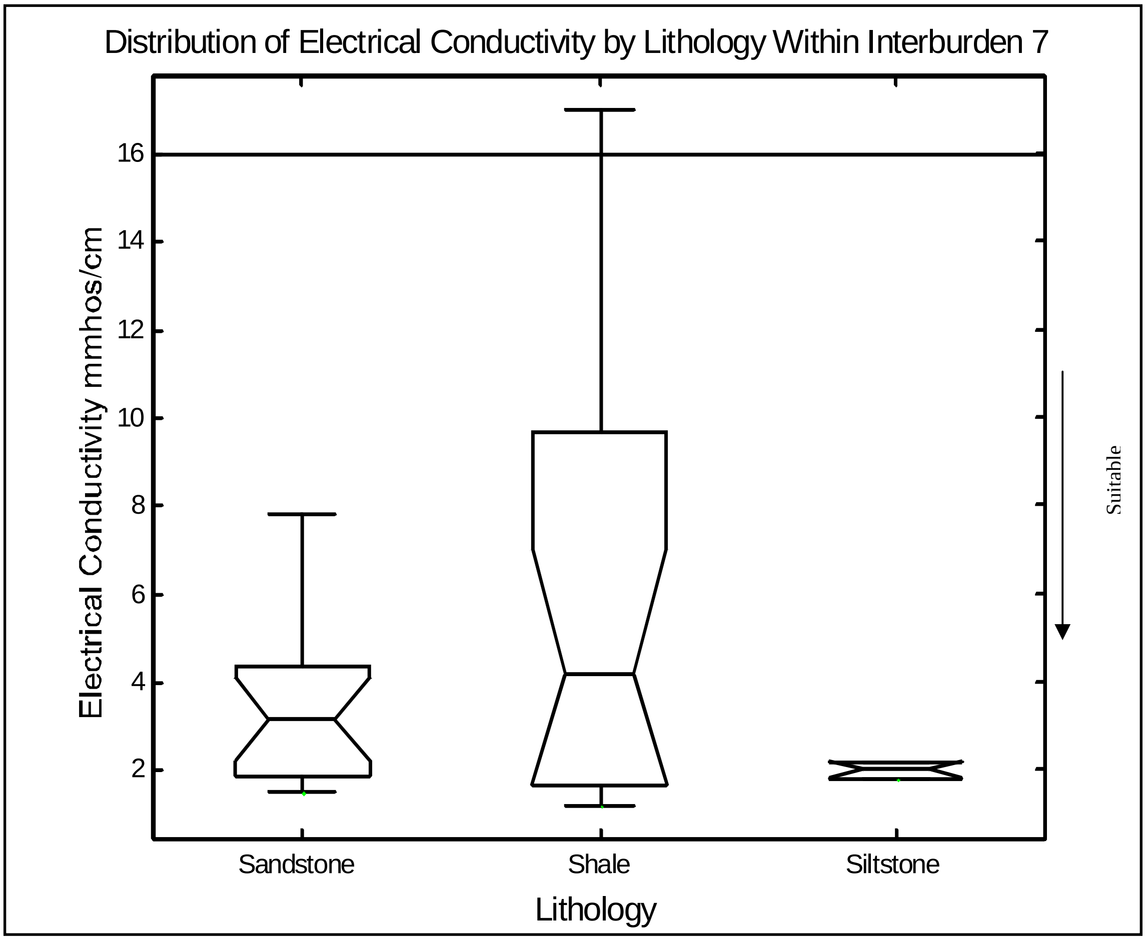

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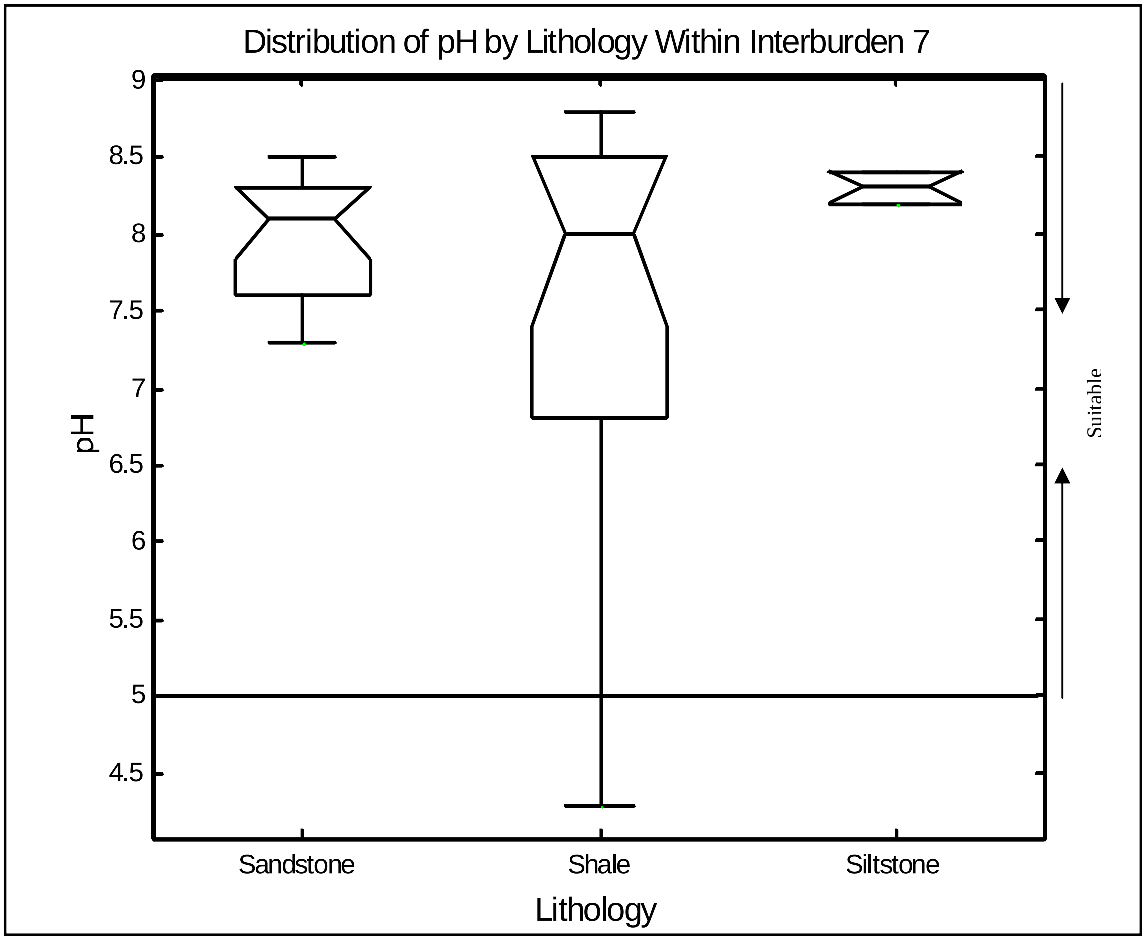
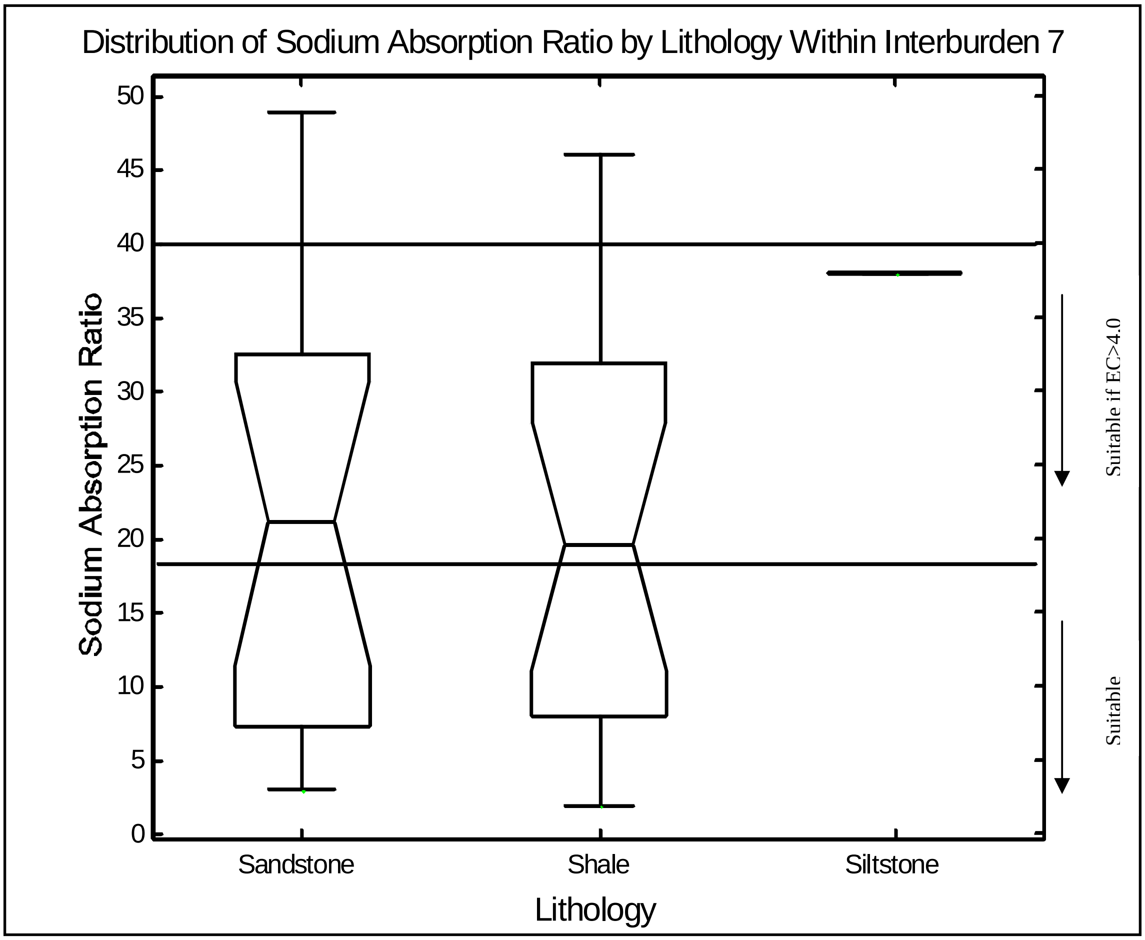


Figure 19. **Box and whisker plots of pH within interburden 7 stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal lines represent the Navajo Mine site specific standard for suitability.**



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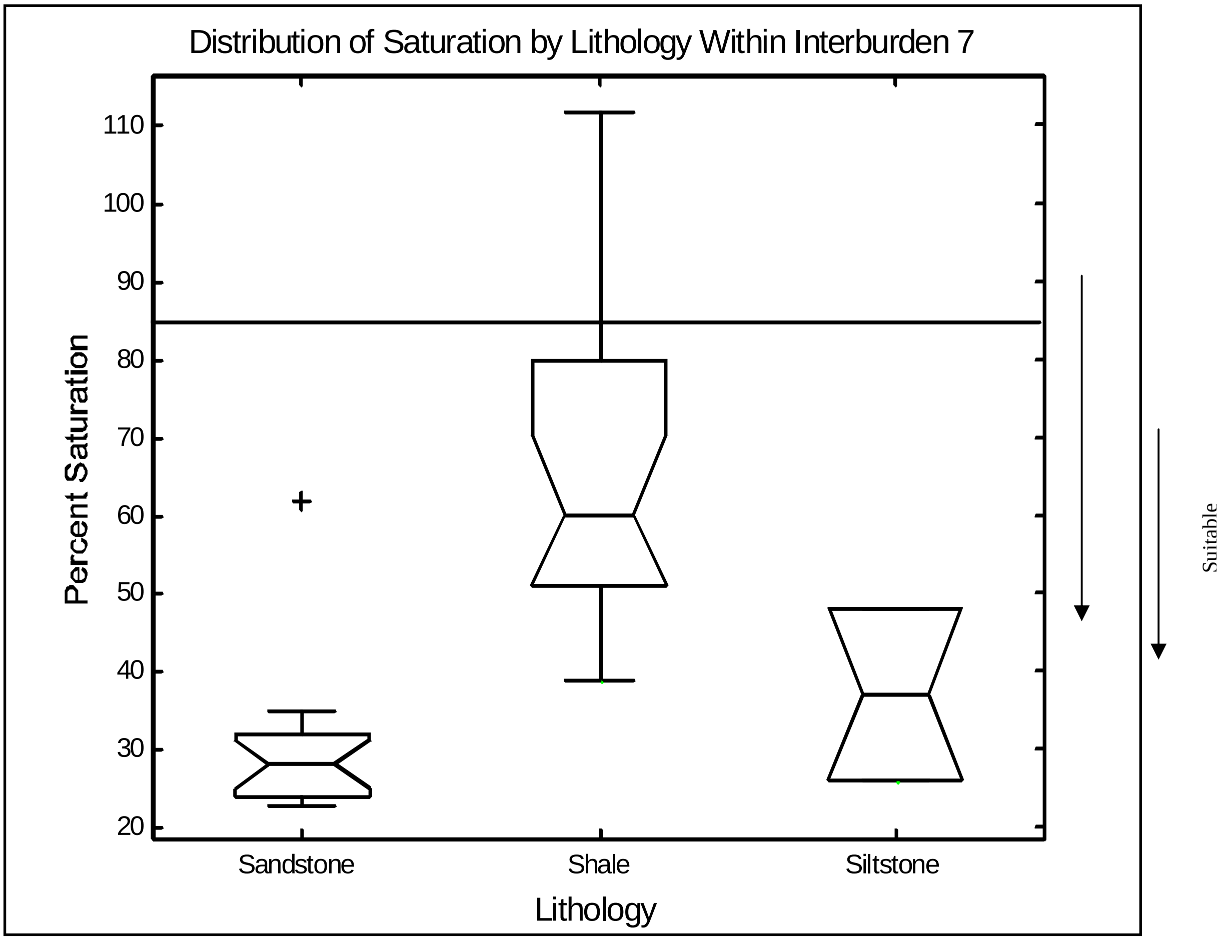

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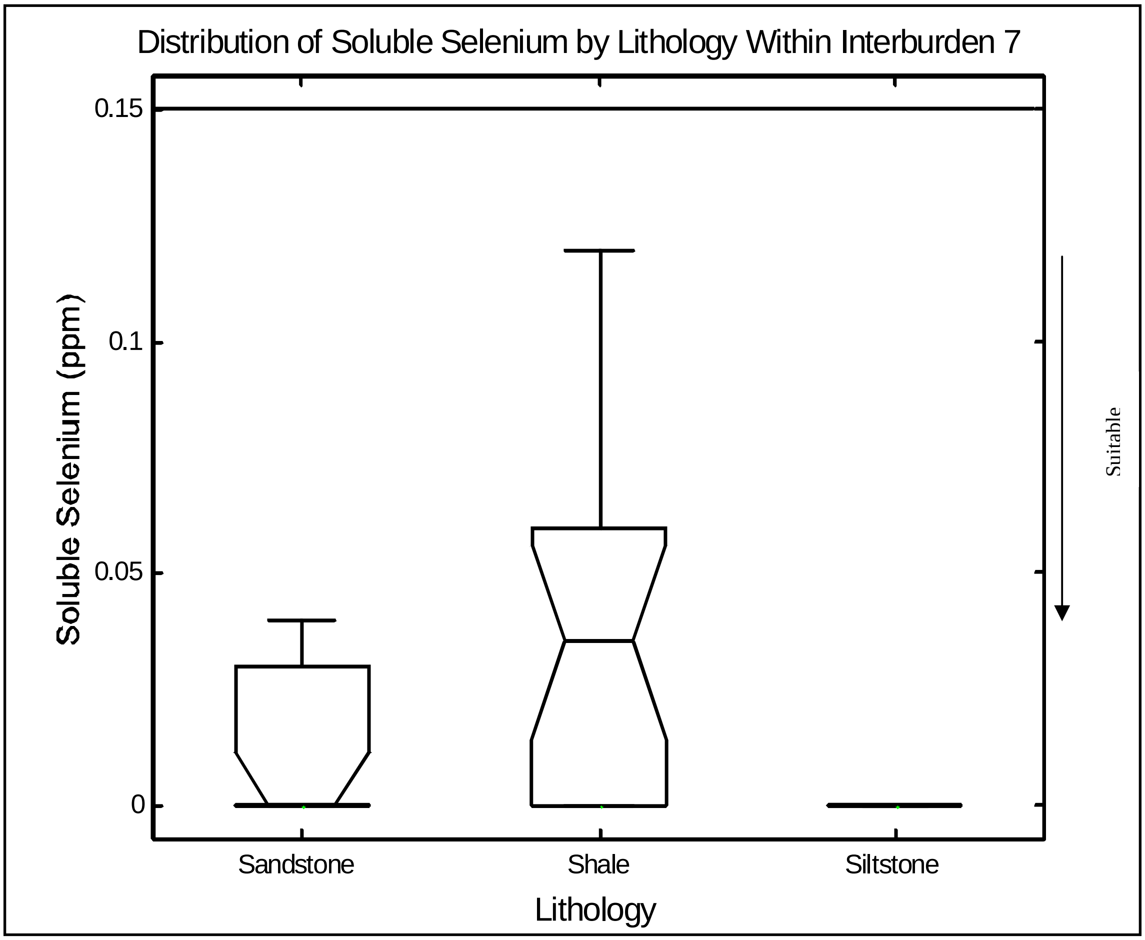

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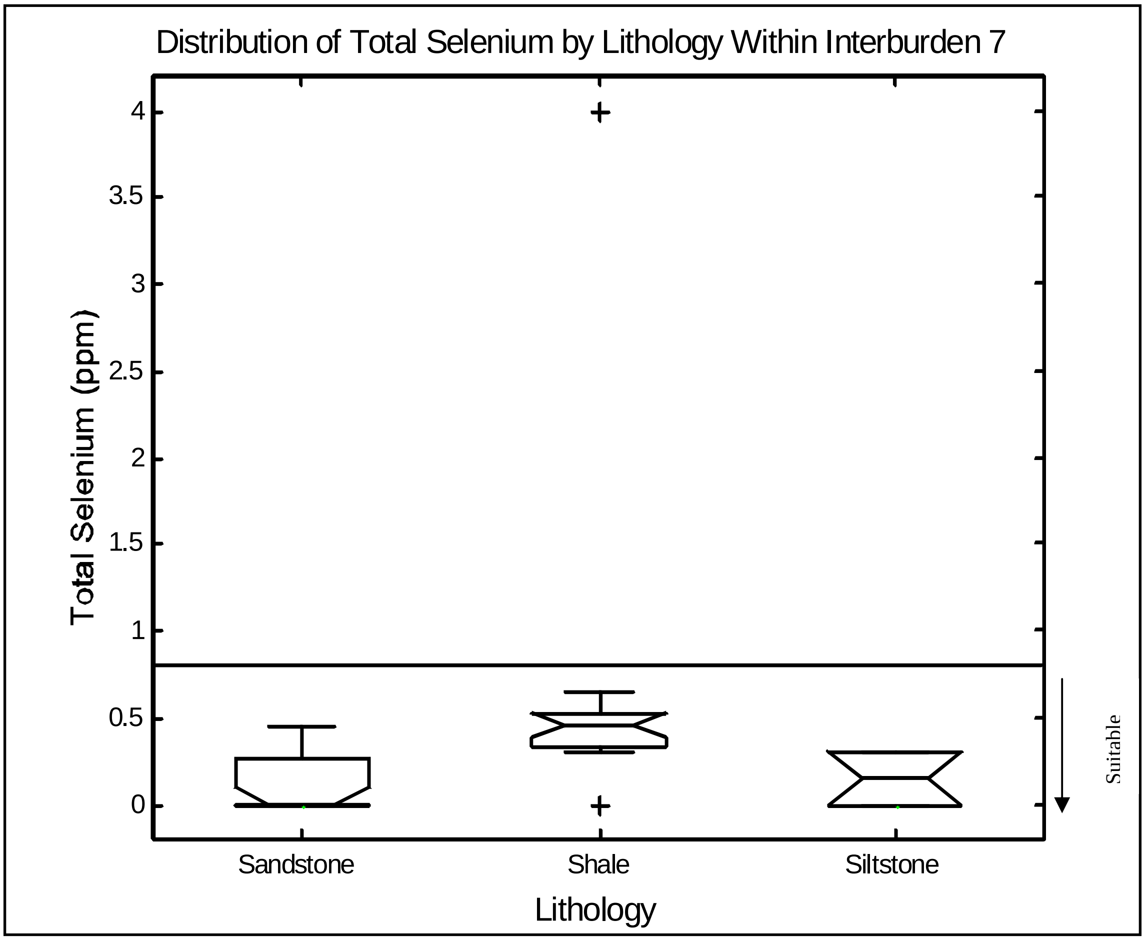
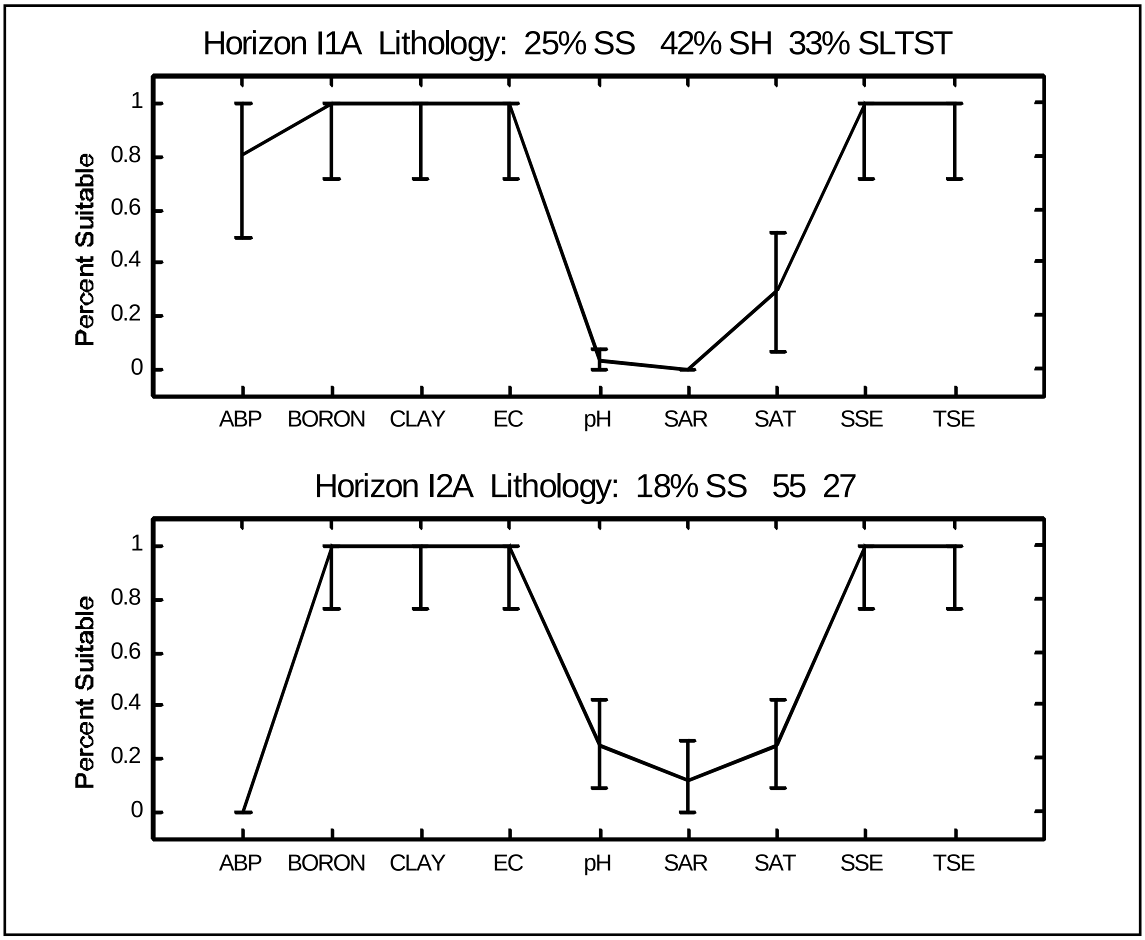


Figure 23. **Box and whisker plots of total selenium within interburden 7 stratified by lithology for all interburden layers. The box represents the 25th and 75th percentiles (1st and 3rd quartiles), the whiskers represent the range of the data up to 1.5 times the length of the box (interquartile range, IQR). Values more than the IQR from the box center are plotted as '+'. The horizontal lines represent the Navajo Mine site specific standard for suitability.**



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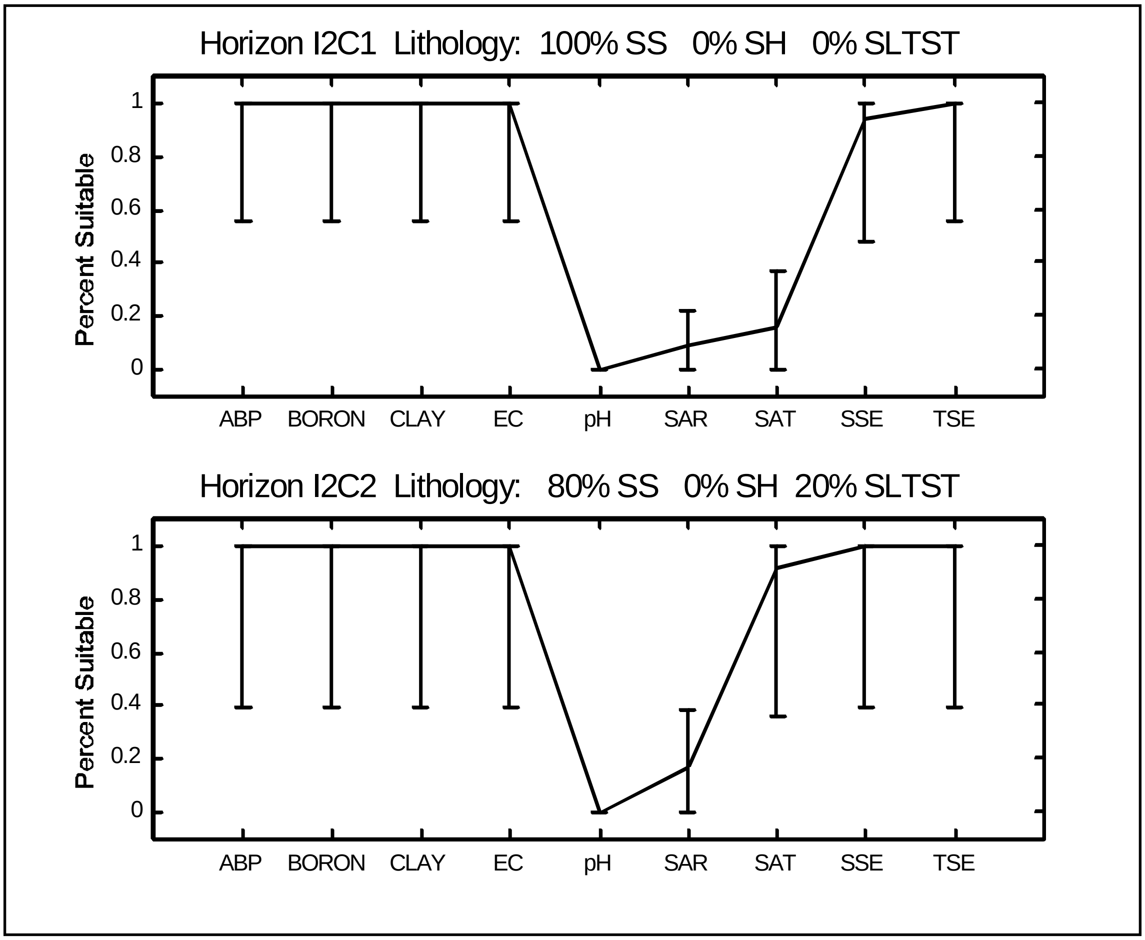
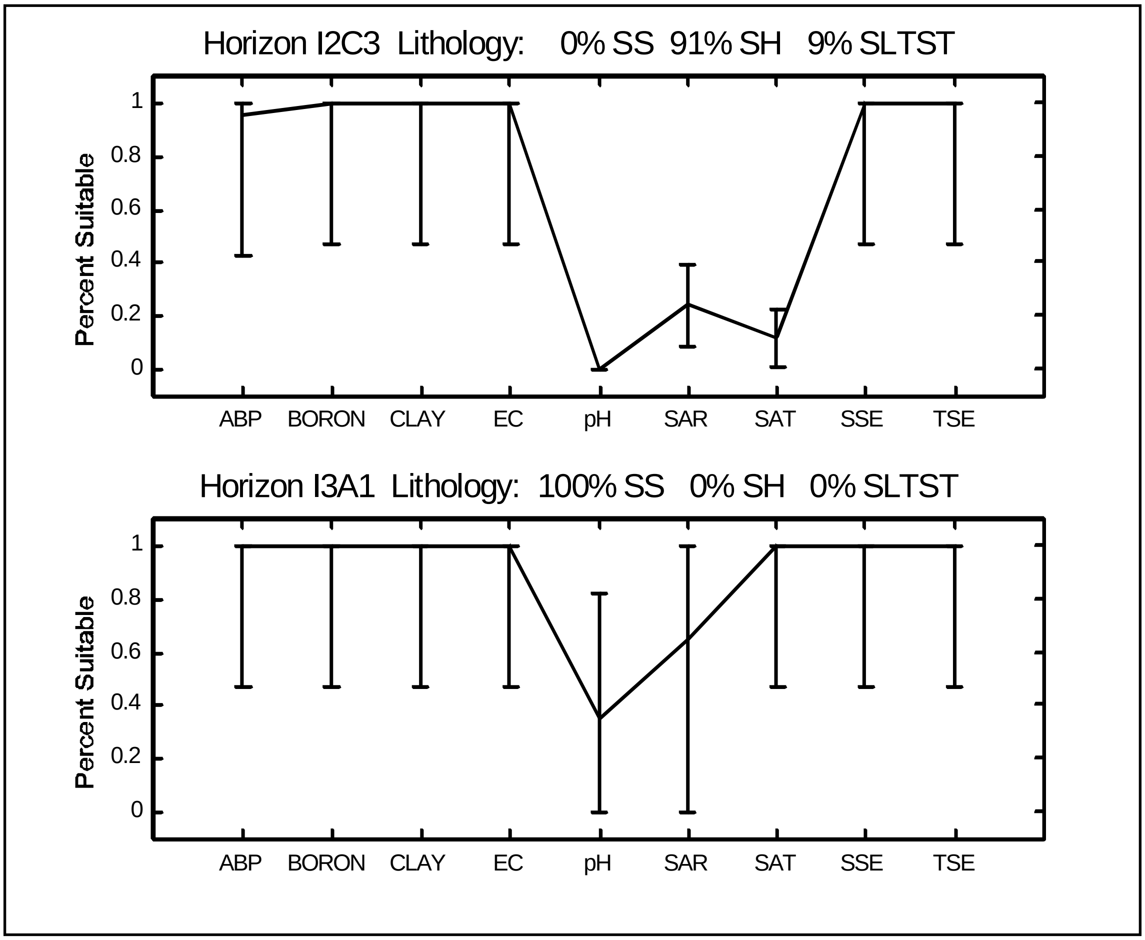


Figure 25. **One-sided 90% confidence intervals on the percent suitable material for the I2C1 and I2C2 horizons based on each analyte, acid base potential (ABP), boron concentration (BORON), texture based on percent clay (CLAY), electrical conductivity (EC), pH, sodium absorption ratio (SAR), soluble selenium (SSE), and total selenium (TSE). The lithologic composition for the horizon is given as percent sandstone (SS), percent shale (SH), and percent siltstone (SLTST). The vertical bar is the 80% confidence interval. The connecting line links estimates of percent of suitable material.**



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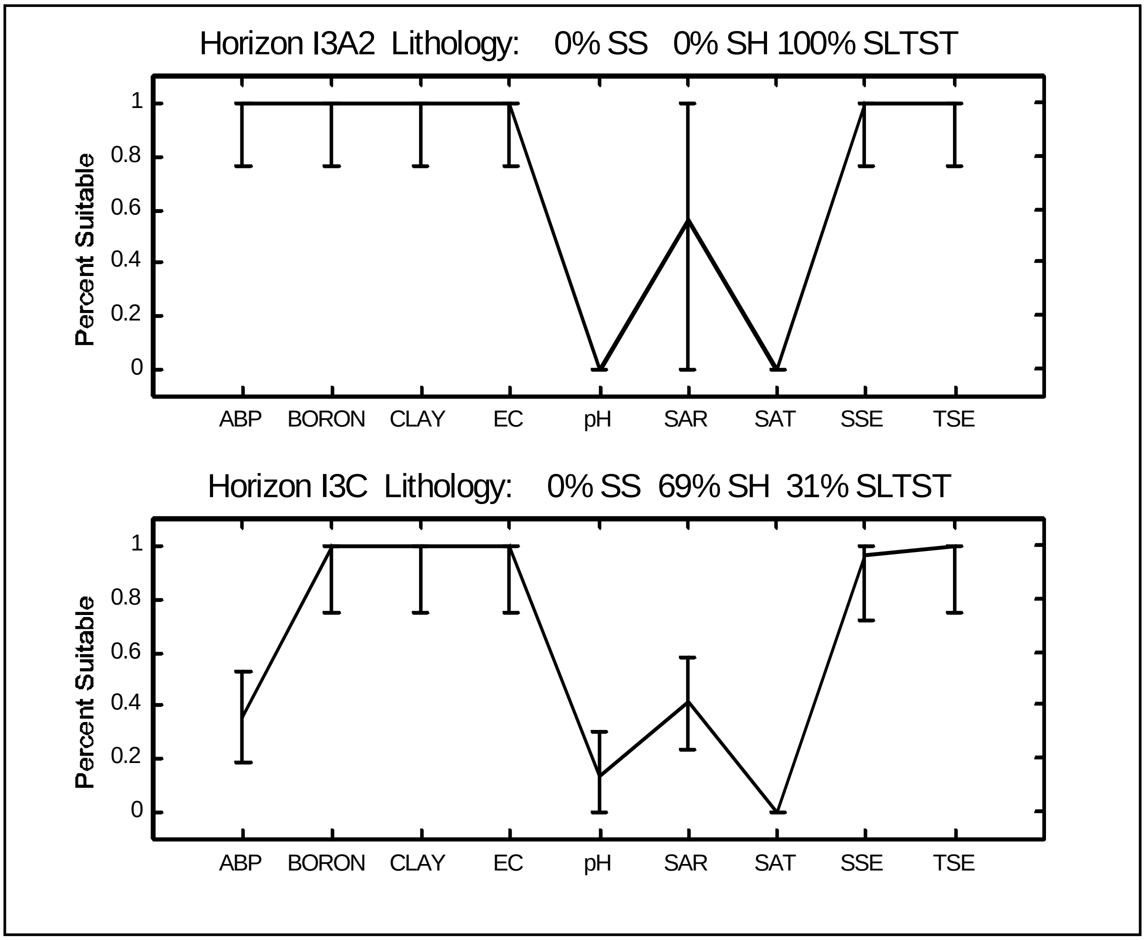

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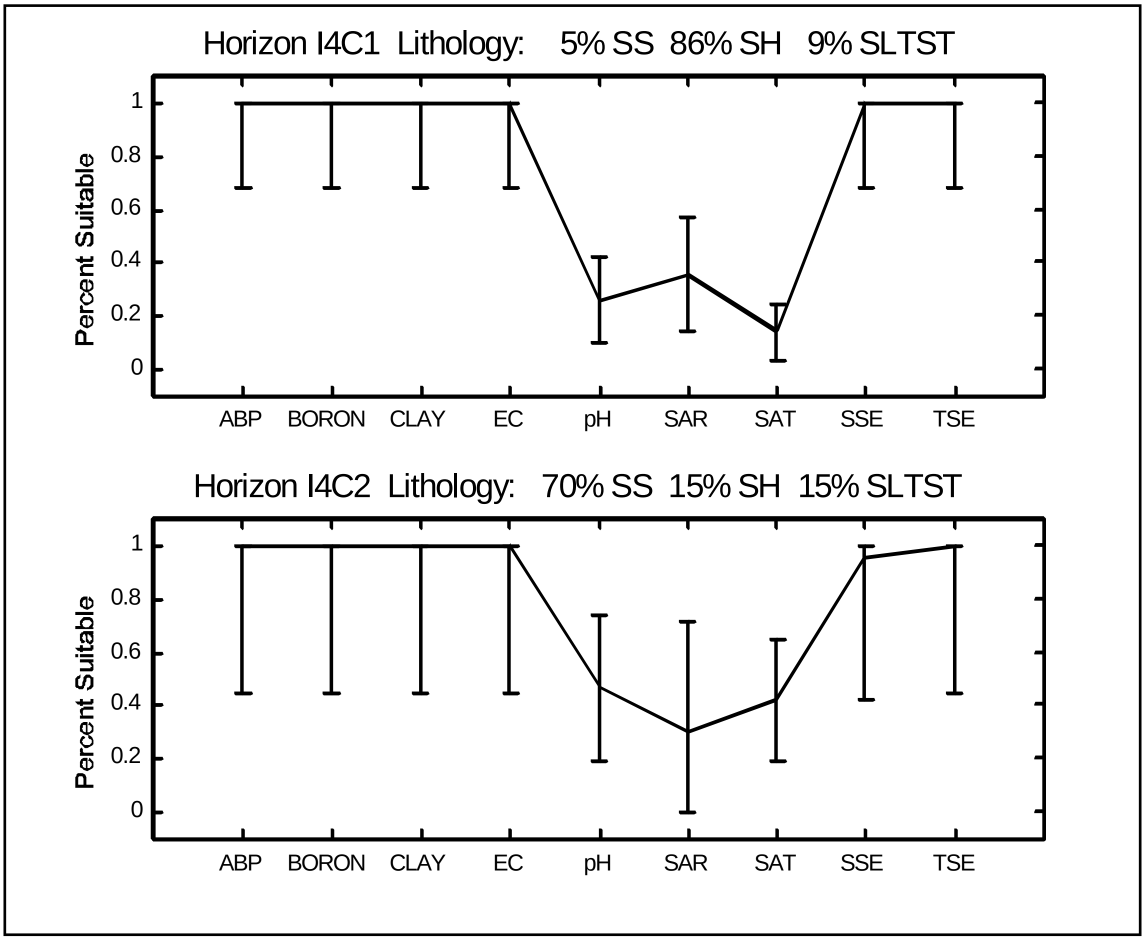

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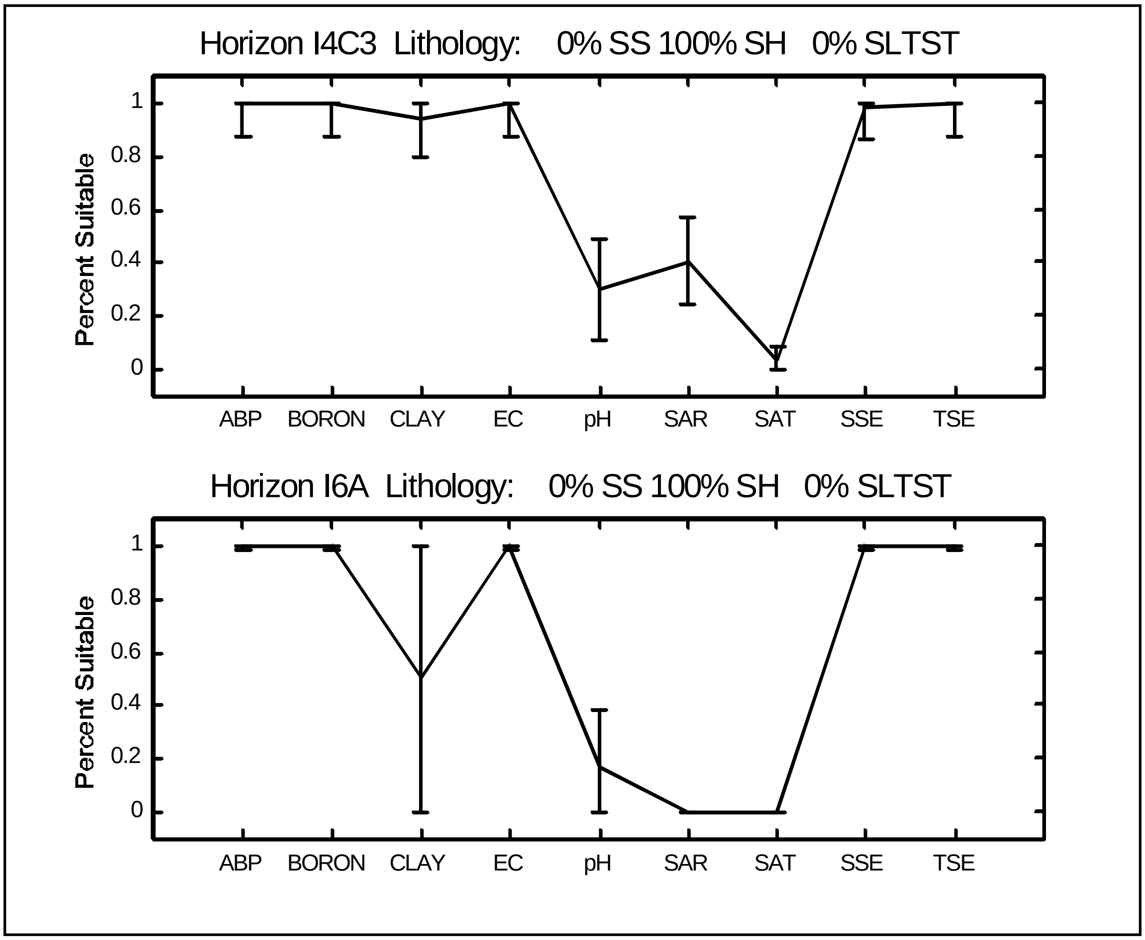

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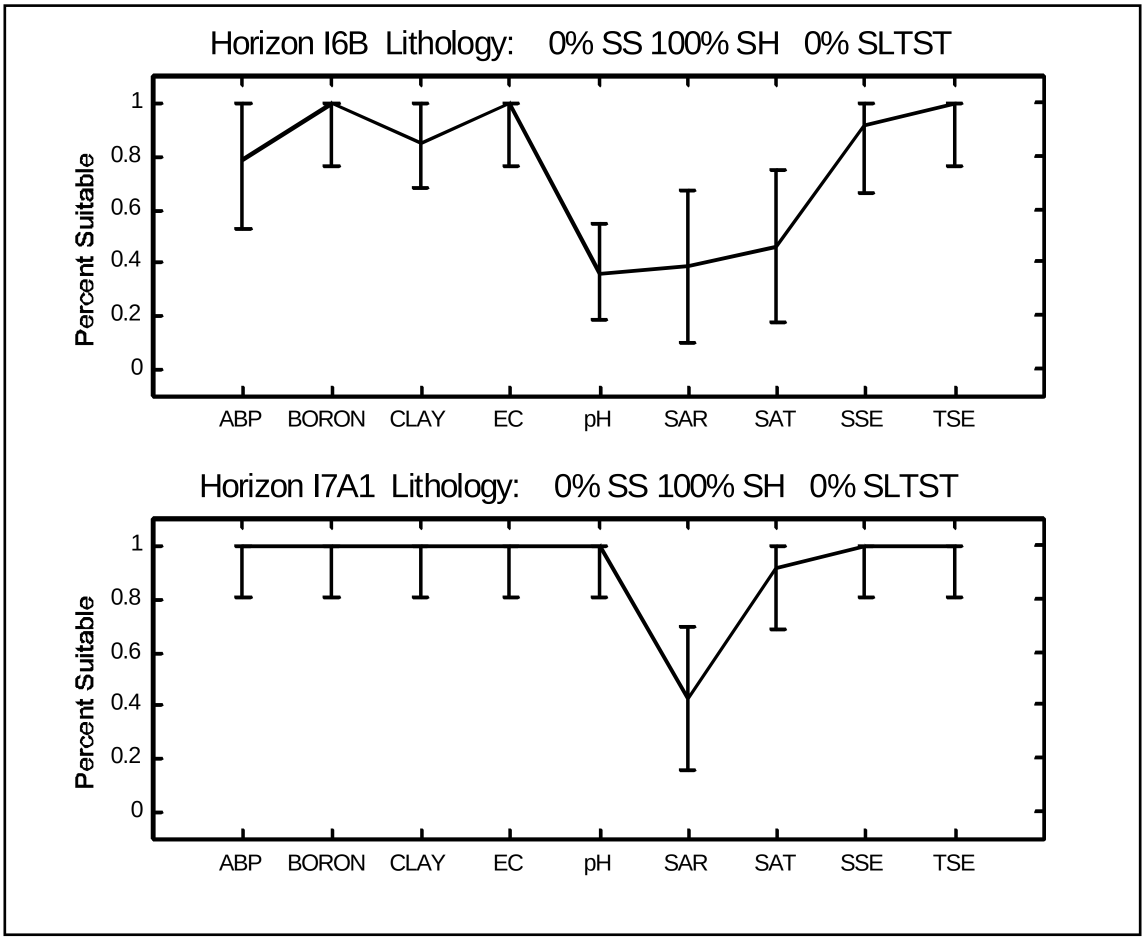

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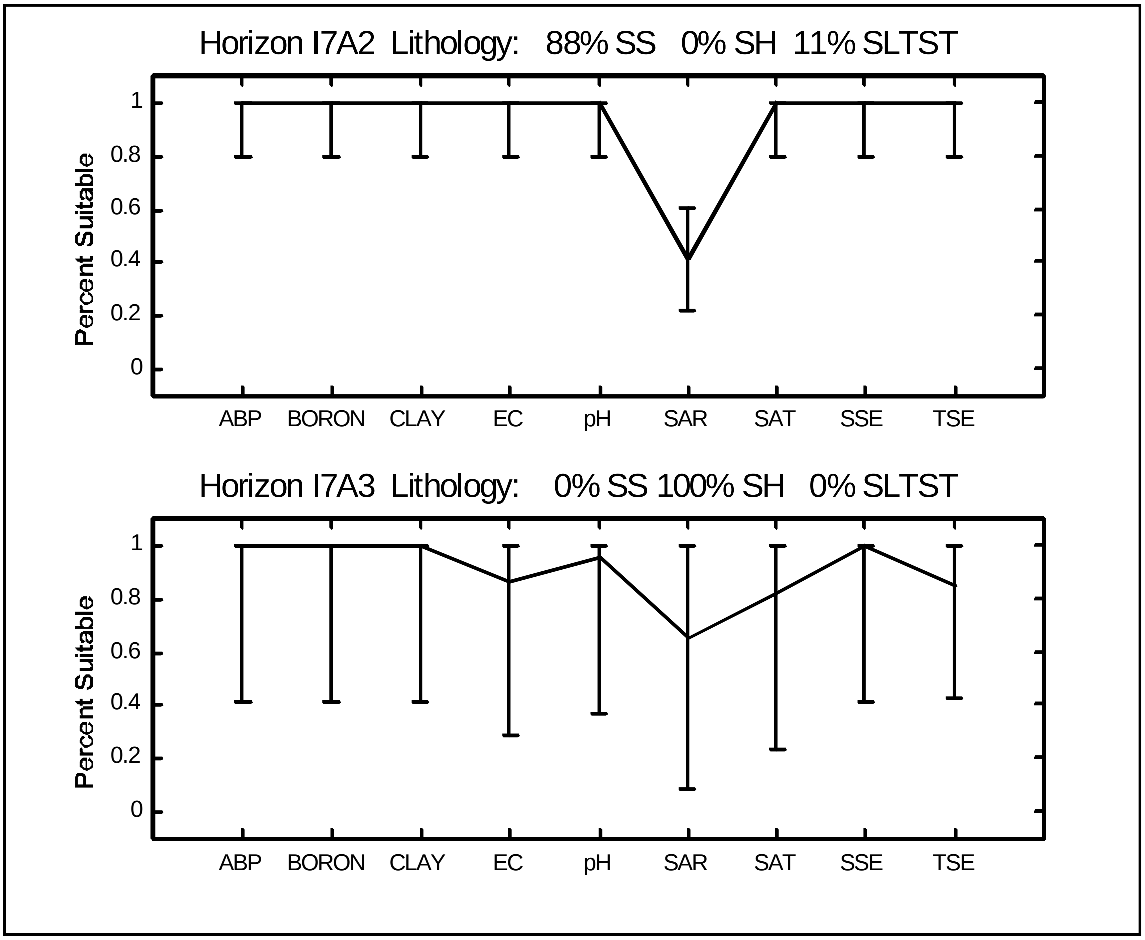

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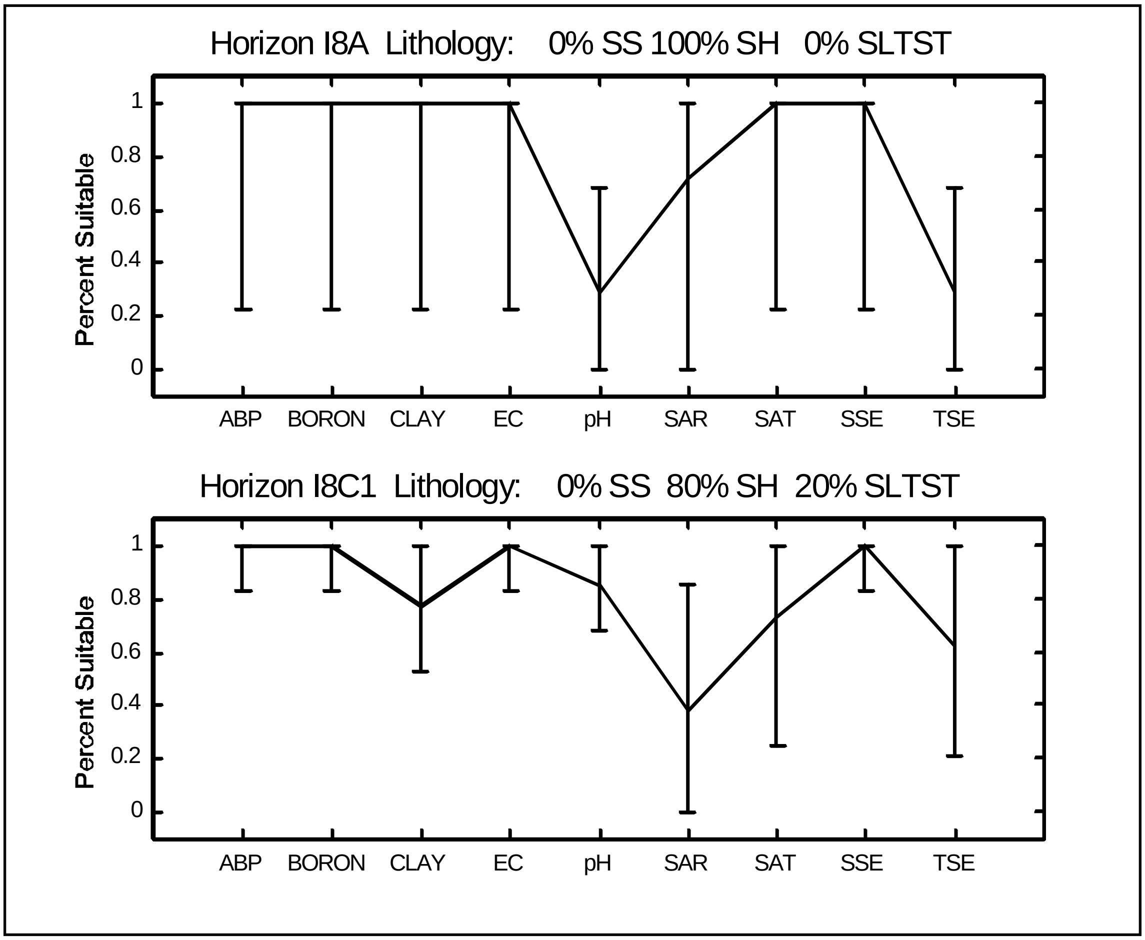

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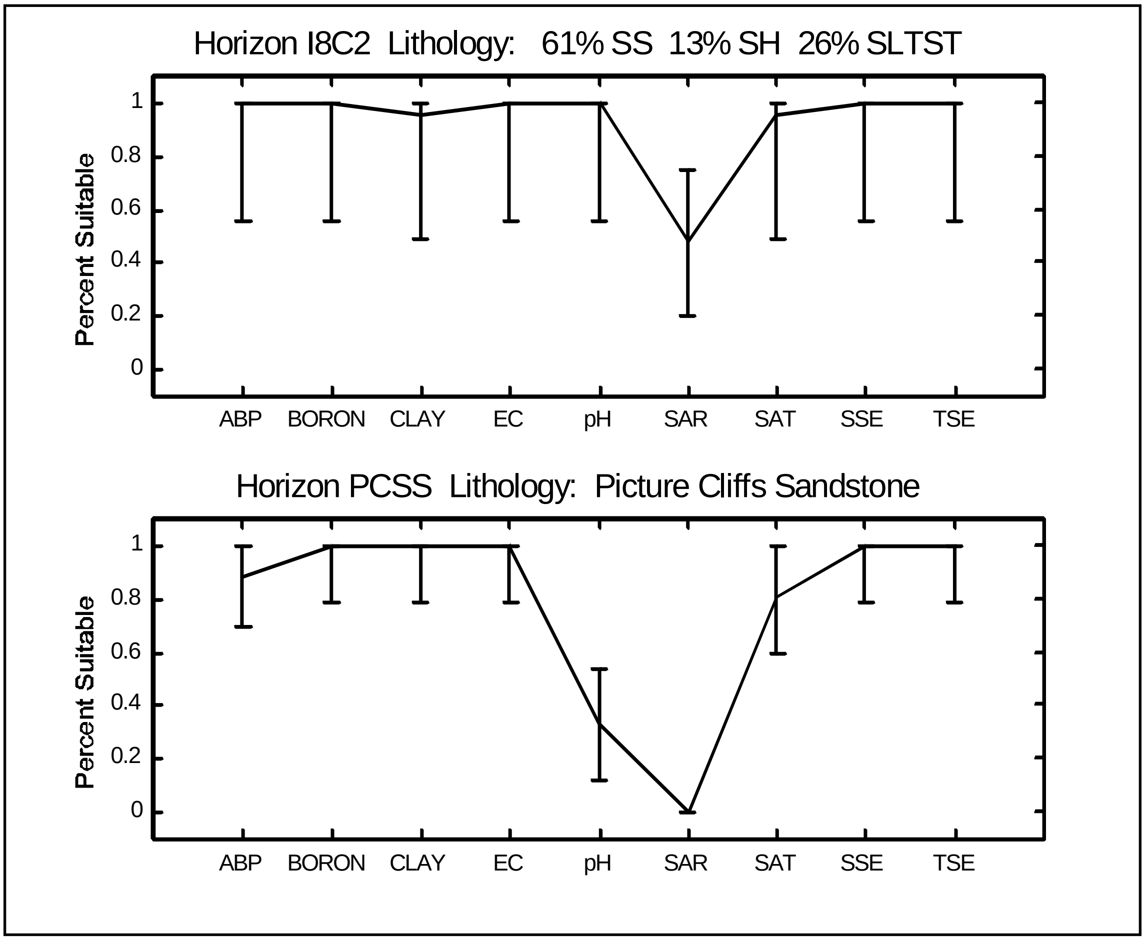

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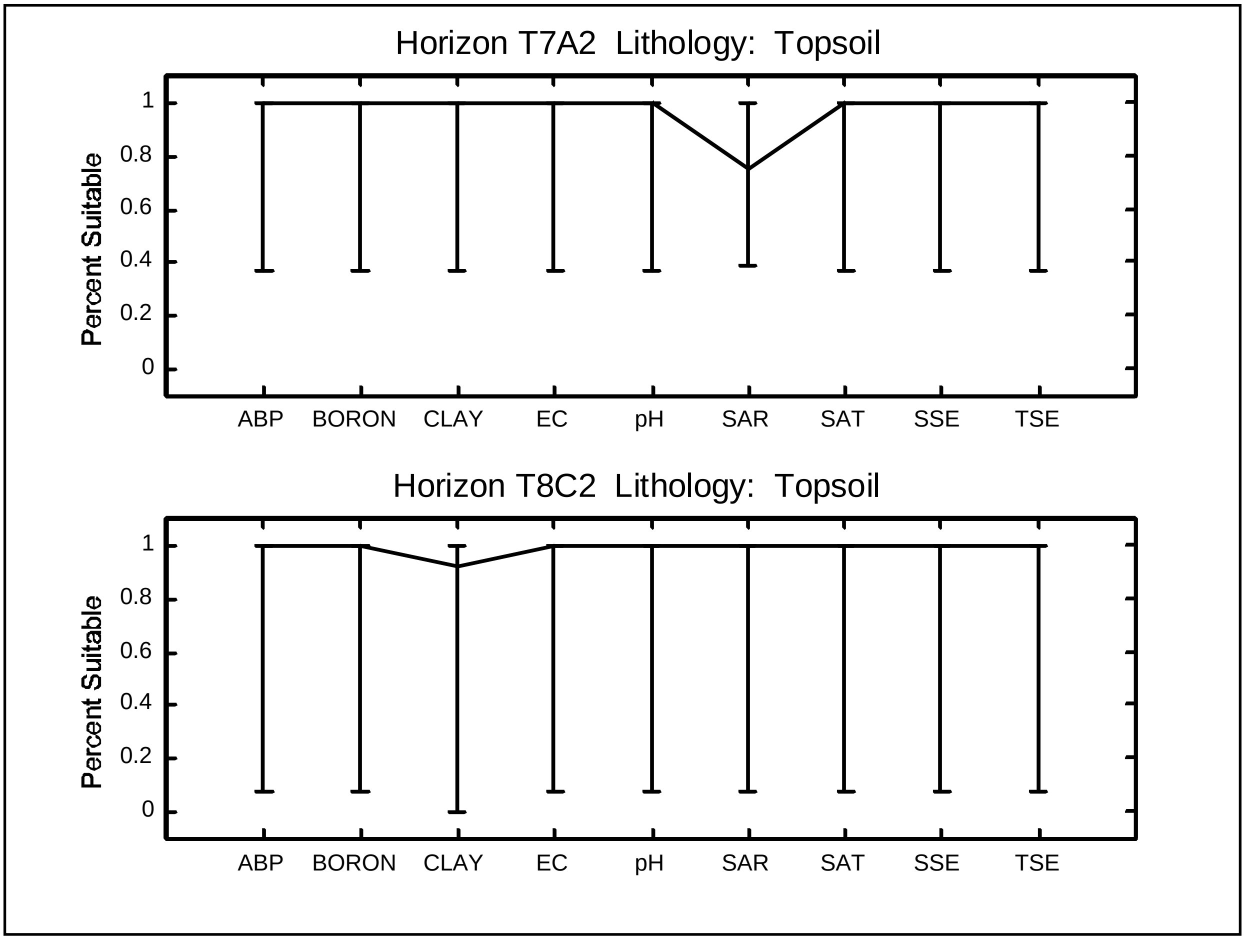

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Appendix 17.E

Statistical Analysis of Overburden/Interburden Sampling from

1987, 1998, and 2007 Drilling Programs

APPENDIX 17.E

STATISTICAL ANALYSIS OF OVERBURDEN/INTERBURDEN SAMPLING FROM 1987, 1998, AND 2007 DRILLING PROGRAMS

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APPENDIX 17.E

STATISTICAL ANALYSIS OF OVERBURDEN/INTERBURDEN SAMPLING FROM 1987, 1998, AND 2007 DRILLING PROGRAMS

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I. INTRODUCTION

BHP Navajo Coal Company (BNCC) prepared a statistical analysis study on overburden samples collected from eight drill holes within the Pinabete permit area (permit area). The first phase of drilling to sample overburden in the permit area took place in 1987 and consisted of four continuous core drill holes. The second phase of drilling in the Pinabete permit area took place in 1998 and consisted of one continuous core drill hole. The third phase of drilling in the permit area took place in 2007 and consisted of three additional continuous core drill holes. Details of the first phase are contained in the existing BNCC Navajo Mine permit application package (OSM Permit No NM-0003F) (BNCC 2009). The details of the second phase are contained in "No Name Project Statistical Analysis of Phase I Interburden Sampling" prepared by John W. Kern, Ph.D. of Western EcoSystems Technology Inc. on 3 Aug 1998. This report is included as a separate appendix to Section 17 (Geologic Information). The objective of the "Kern study" was to assess the adequacy of the drilling program, estimate the volume of suitable material available for reclamation, determine what interburden layers contain high proportions of materials not suitable for reclamation, investigate spatial patterns in material suitability, and estimate the total volume of suitable material in the overburden/interburden layers most likely to be used for reclamation. This statistical analysis of the 1987, 1998, and 2007 drilling programs builds on the findings of the "Kern study" and modifies the analysis area to the lease extents of the Pinabete permit area. The objectives of the study are to characterize the interburden layers, estimate the total volume of root zone suitable material in the interburden layers most likely to be used for reclamation, and characterize mixed material (spoil) suitability.

The in-situ physical and chemical characteristics of each overburden/interburden horizon or geologic layer have been analyzed for each of the eight drill holes within the Pinabete permit area. Each horizon was sampled at varying intervals during the core logging process and analyzed for the suite of physical parameters and chemical analytes listed in Table 17.E-1. The data for each discrete sample were averaged, as described below in the Approach and Calculation Methods section, to provide a single value for each horizon in each drill hole. This characterization was used to identify interburden layers that contain proportions of unsuitable material or potentially acid- or toxic-forming material (PATFM). In addition, the characterization of interburdens from each drill hole are mathematically composited, as described in the Approach and Calculation Methods section, to model spoil quality and to determine if there are any areas (based on drill hole location) in the mined-out pit that contain proportions of unsuitable material or PATFM. When characterizing the suitability of overburden/interburden layers and spoil material, two potential criteria limits were used: (1) Office of Surface Mining Reclamation and Enforcement (OSM) Southwestern U.S. criteria limits and (2) BNCC Navajo Mine site-specific criteria limits (Table 17.E-2).

II. LITHOLOGY AND NAMING CONVENTIONS

There are eight primary coal seams and eight corresponding overburden/interburden horizons within the permit area. The Pictured Cliffs Sandstone (PCS) is the deepest unit described in these investigations, as it conformably underlies the coal-bearing units of the Fruitland Formation. Comprehensive geologic cross-sections and a detailed geologic description of the permit area are included in Section 17 (Geologic Information). Throughout this report, each interburden layer is designated using the name of the coal seam directly below the interburden layer. Coal seams are numbered from deepest to shallowest. For example, the deepest coal seam to be mined is the No. 2 coal seam (S2) and the interburden above it and below the No. 3 coal seam (S3) is referred to as No. 2 interburden (I2). Similarly, a parting in S2 would be referred to as P2. In situations where the coal seam splits, the coal seam number is followed by an alphabetic designation (e.g., S2A and S2B). For example, interburden and parting layers between splits in the No. 2 coal seam are referred to as I2A and I2B or P2A and P2B. Further, if interburden layers are composed of horizons of differing rock strata (e.g., sandstone and shale); the interburden number will be followed by numeric designation (e.g., I2-1 or I2A-1). For example, if the bottom horizon in I2 is primarily sandstone and the upper primarily shale, then the bottom horizon within this interburden would be labeled I2-1 and the next horizon above would be I2-2. Interburden names and the number of observations during the 1987, 1998, and 2007 drilling programs are provided in Table 17.E-3. Stratigraphic columns and geologic model cross-sections are presented in Section 17 (Geologic Information).

III. APPROACH AND CALCULATION METHODS

The results from analysis of the in-situ characteristics of core samples are the basis for all discussions and calculations that follow. As noted in Table 17.E-1, percent sulfate, percent organic sulfur, percent pyritic sulfur, pyritic sulfur acid-base, and pyritic sulfur acid-base potential were determined only for samples with total sulfur acid-base potential (ABP) less than zero. A total sulfur ABP value greater than zero indicates that the pyritic sulfur ABP value is greater than zero. The criteria limit presented in Table 17.E-2 is for pyritic sulfur ABP. In this way, total sulfur ABP is used as a screening method to determine if further analysis is needed to characterize the acid-forming potential of the sample.

In-situ Overburden/Interburden Characteristics

Data resulting from the physical and chemical analysis of discrete samples from continuous core drilling provide the basis for calculations used to characterize the in-situ overburden/interburden (interburden) layers. Analysis of the in-situ interburden required simplification of the data set through the calculation of an average value for each analyte for every interburden layer identified in the drill holes. This average value is calculated as the weighted mean $(\bar{x})$. For purposes of calculation, values reported as below the detection limit were assigned values at one half the detection limit. In some cases, a core length could not be recovered during drilling, thus no analytical values were determined. The approach to fill the data gap and maintain the thickness of the interburden layer was to calculate the values for the missing core as a weighted mean of the two adjacent core samples. The weighted mean $(\bar{x})$ was calculated as a function of thickness for each core length sampled. The formula for weighted mean calculations follows:

Equation 1: $$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},$$

where $[x_1, x_2, \ldots, x_n]$ is the analyte value and $[w_1, w_{2,} \ldots, w_n]$ is the thickness weighting factor for the sample

This approach simplifies the data set for each drill hole and addresses the variations in analyte values within each set of interburden samples. The weighted mean values are representative of each interburden layer within that drill hole and are used to compare interburden layer characteristics between holes across the permit area.

When evaluating the variability of a particular interburden layer across the permit area, the arithmetic mean $(\bar{a})$ and standard deviation (σ), along with the range maximum and minimum, were computed for each parameter. The formula for $(\bar{a})$ and (σ)calculations follows:

Equation 2: $$\bar{a} = \frac{\sum_{i=1}^{n} x_i}{n}$$ and

Equation 3: $$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{a}^2\right)}{n}}$$

where $[x_1, x_2, \ldots, x_n]$ is the analyte value and n is the number of values in the data set

In this approach, each weighted mean value for the interburden layer is treated as a discrete data point across the permit area and each weighted mean value has the same influence on the calculated values. In conclusion, the weighted mean is used to calculate a representative value from analyte values for interburden samples taken within the same drill hole. Arithmetic mean and standard deviation are used to determine the variability of interburdens between drill holes across the permit area.

Suitable Root Zone Material

The volume of suitable root zone material available within each mining area was estimated using the overburden/interburden above the uppermost coal seam to be mined. This material can be practically handled and stockpiled for use in reclamation, if required. Unlike in the “Kern report”, the volume does not come from any single interburden layer. The weighted mean $(\bar{x})$ for the analytes of interest from the uppermost interburden layer from each drill hole was calculated using the formula above. In some cases, the entire thickness of the overburden was not used in the calculation if the lower samples negatively impacted material suitability. This approach of neglecting the lower, less suitable material is in line with how the material would be recovered in the field. The thickness was adjusted accordingly to reduce the potential depth of recovery from the surface and the weighted mean was recalculated. The average thickness $(\bar{a})$ of suitable root zone material, determined by drill hole data, was extrapolated to the mining area boundary to develop a volume of in-situ suitable root zone material.

The continuous core samples included material from the surface or very near the surface that could be salvaged as suitable topdressing. Consequently, the volume of suitable root zone material estimated for the mining area $[V_{estimate}]$ was adjusted to account for the volume of topdressing $[V_{topdress}]$ to be salvaged. The thickness and volume of available topdressing $[V_{topdress}]$ are discussed in Section 14 (Soil). Volume adjustments were based on the following equation:

Equation 4: $$V_{suitable} = V_{estimate} - V_{topdress}$$

Modeled Spoil Characteristics

The in-situ overburden/interburden characteristics were used to model spoil characteristics by mathematically compositing all interburden layers within each drill hole. This was done by calculating the weighted mean $(\bar{X})$ of the $(\bar{x})$ values for each interburden layer. In this manner, all core samples within the drill hole are treated as a single mixed or composite sample, resulting in eight modeled spoil samples. The weighted mean $(\bar{X})$ was calculated as a function of thickness for each interburden layer within the drill hole. The formula for weighted mean $(\bar{X})$ calculations follows:

Equation 5: $$\bar{X} = \frac{\sum_i^n W_i \bar{x}_i}{\sum_i^n W_i},$$

where $[\bar{x}_{I8}, \bar{x}_{I7}, \ldots, \bar{x}_{I2}]$ is the weighted mean for the analyte for each interburden layer and $[W_{I8}, W_{I7}, \ldots, W_{I2}]$ is the thickness weighting factor for the interburden layer

As stated above, it is difficult to predict the thickness of topdressing to be removed at each drill hole location. The topdressing material cannot be addressed in the same manner as used for determining the volume of suitable root zone material. The approach taken in this case was to neglect sample data from the top 5 ft of the uppermost core in each drill hole. This approach is appropriate because it removes the maximum depth of material that would be removed as topdressing. As stated in Section 14 (Soil), soil classification and suitability of the baseline soils survey are limited to the upper 5 ft of unconsolidated material. In addition, this approach adds a degree of conservatism since the uppermost layers of the overburden are typically suitable for use as root zone material as a result of weathering. Equation 2 and Equation 3 were used to calculate the arithmetic average $(\bar{a})$ of the weighted mean $(\bar{X})$ for each analyte for spoil and the corresponding standard deviation (σ). The range limits for the values were also determined. These descriptive statistics are used to compare the variability of the eight modeled spoil samples across the permit area.

IV. RESULTS

Characterization of In-situ Overburden/Interburden Layers

The physical and chemical characteristics of each overburden/interburden layer are compared to OSM and Navajo Mine root zone suitability criteria listed in Table 17.E-2. Results for all interburden layers above the major coal seam (e.g., S8) are presented and discussed together (e.g., I8A, I8B, etc.). The various interburden layers between major coal seams were not delineated by lithology for the purposes of this analysis since the objective was to understand average physicochemical properties by overburden/interburden layer. The weighted mean $(\bar{x})$, maximum value, and minimum value for each analyte by interburden layer along with arithmetic mean $(\bar{a})$ and standard deviation (σ) of weighted values for interburden layers I8, I7, I6, I4, I3, and I2 are shown in Table 17.E-4, Table 17.E-5, Table 17.E-6, Table 17.E-7, Table 17.E-8, and Table 17.E-9, respectively.

Interburden Above Number 8 Coal Seam

The I8 interburden in the Pinabete permit area is characterized by five layers identified in six drill holes (Table 17.E-4). Average saturation percent in the I8 interburden is within OSM and Navajo Mine suitability criteria, although five of the nine measured values exceeded the OSM suitability criteria and four of the nine measured values exceeded Navajo Mine site specific suitability criteria presented in Table 17.E-2. The average clay percent in the I8 interburden is within OSM and Navajo Mine suitability criteria, although one value measured in layer I8A exceeded OSM suitability criteria by 1%. Total sulfur ABP values within I8 are above both OSM and Navajo Mine suitability criteria, indicating that pyritic sulfur ABP is also above both suitability criterias, suggesting alkaline or neutralizing rock strata. The average soluble selenium (SSe) concentration in I8 is below OSM and Navajo Mine suitability criteria, although one measured value in I8A1 exceeded OSM suitability criteria by 0.033 parts per million (ppm). The average total selenium (TSe) concentration in I8 is below OSM and Navajo Mine suitability criteria, although one measured value in I8A1 exceeded OSM suitability criteria by 0.142 ppm. Sodium adsorption ratio (SAR) values vary widely in I8 but the average SAR value is below OSM and Navajo Mine suitability criteria. Five of the nine measured values for SAR in I8 exceeded OSM suitability criteria and four of the nine measured values exceeded Navajo Mine suitability criteria. Values for all other parameters, including pH and boron, are within the appropriate criteria for suitable root zone material.

Interburden Above Number 7 Coal Seam

The I7 interburden in the Pinabete permit area is characterized by two layers identified in eight drill holes (Table 17.E-5). Average saturation percent in the I7 interburden is within OSM and Navajo Mine suitability criteria, although two of the nine measured values exceeded OSM and Navajo Mine suitability criteria limits. The average clay percent in the I7 interburden is within OSM and Navajo Mine suitability criteria, although three measured values exceeded OSM suitability criteria by up to 14% and one measured value exceeded Navajo Mine suitability criteria by 9%. Total sulfur ABP values in I7 average well above the OSM and Navajo Mine suitability criteria, indicating that pyritic sulfur ABP is also above both suitability criterias, suggesting alkaline or neutralizing rock strata. One total sulfur ABP value was measured 0.1 t/kt below OSM and Navajo Mine suitability criteria in I7. The average SSe concentration in I7 is below OSM and Navajo Mine suitability criteria, although two measured values exceeded OSM suitability criteria and one measured value exceeded Navajo Mine suitability criteria. The average SAR value measured in I7 was within OSM and Navajo Mine suitability criteria, although five of the nine measured values exceeded both Navajo Mine and OSM criteria. Values for all other parameters, including conductivity (EC) and TSe, are within the appropriate criteria for suitable root zone material.

Interburden Above Number 6 Coal Seam

In the Pinabete permit area, I6 is characterized by three layers identified in eight drill holes (Table 17.E-6). The range of pH values in the I6 interburden is outside the OSM and Navajo Mine suitability criteria outlined in Table 17.E-2, with only four of the nine measured values falling within both suitability criterias. The majority of saturation percent values exceed Navajo Mine and OSM suitability criteria although the average saturation percent is within OSM suitability criteria. The average saturation percent in I6 is 88.5 %, which exceeds Navajo Mine site specific suitability criteria by approximately 3.5% but is within the OSM suitability criteria limit of 90%. The average clay percent in the I6 interburden is within OSM and Navajo Mine suitability criteria, although one measured value exceeded OSM suitability criteria by 10% and Navajo Mine suitability criteria by 5%. Total sulfur ABP values in I6 range from -37.8 t/kt to 152.3 t/kt, with the average value being 16.2 t/kt which is well above the OSM and Navajo Mine suitability criteria. The average total sulfur ABP in I6 indicates that the pyritic sulfur ABP is also above both the OSM and Navajo Mine suitability criterias, suggesting alkaline or neutralizing rock strata. Seven of the nine measured SAR values exceeded OSM and Navajo Mine criteria limits in I6, although the average value was within both criterias. SAR values ranged from 9.2 to 51.2 with an average value of 9.1 (calculated from the arithmetic mean values for calcium, magnesium, and sodium). The average TSe value in I6 is within both OSM and Navajo Mine suitability criteria, although three of the four measured TSe values exceeded OSM suitability criteria by up to 0.200 ppm. The average SSe value in I6 is below Navajo Mine site specific suitability criteria, but outside OSM suitability criteria. The average SSe value in I6 is approximately 0.019 ppm above the OSM suitability criteria of 0.15 ppm. Values for all other parameters, including EC and boron, are within the appropriate criteria for suitable root zone material.

Interburden Above Number 4 Coal Seam

The I4 interburden in the Pinabete permit area is characterized by one layer identified in seven drill holes (Table 17.E-7). The range of pH values in the I4 interburden is 8.1 standard units (s.u.) to 9.6 s.u. The majority of pH values are outside the OSM and Navajo Mine suitability criteria by up to 0.6 s.u. Five of the seven measured values for saturation percent in I4 exceed OSM suitability criteria and four of the seven measured values exceed Navajo Mine suitability criteria. The average saturation percent for I4 exceeds OSM suitability criteria by 15.6% and Navajo Mine suitability criteria by 20.6%. The average clay percent in the I4 interburden is within OSM and Navajo Mine suitability criterias, although one measured value exceeded Navajo Mine suitability criteria and two measured values exceeded OSM suitability criteria. Total sulfur ABP values in I4 average well above the OSM and Navajo Mine suitability criteria, indicating that pyritic sulfur ABP is also above both suitability criterias, suggesting alkaline or neutralizing rock strata. One total sulfur ABP value was measured 2.0 t/kt below OSM and Navajo Mine suitability criteria in I4. The average SSe value in I4 was within OSM and Navajo Mine suitability criteria, although one measured value exceeded OSM suitability criteria by 0.080 ppm. Every measured SAR value in I4, as well as the average value, exceeded OSM suitability criteria, although one value was within Navajo Mine suitability criteria. Values for all other parameters, including TSe and boron, are within the appropriate criteria for suitable root zone material.

Interburden Above Number 3 Coal Seam

In the Pinabete permit area, I3 is characterized by three layers identified in eight drill holes (Table 17.E-8). The majority of pH values measured in I3, including the average, exceeded OSM and Navajo Mine suitability criteria by up to 0.8 s.u. Every measured saturation percent value in I3, except for one, exceeded OSM and Navajo Mine suitability criteria. The average saturation percent in I3 is approximately 15.4% above OSM suitability criteria and 20.4% above Navajo Mine suitability criteria. The average clay percent in the I3 interburden is within OSM and Navajo Mine suitability criteria, although one measured value exceeded OSM suitability criteria by 14% and Navajo Mine suitability criteria by 9%. The average total sulfur ABP value in I3 is within OSM and Navajo Mine suitability criteria, indicating that pyritic sulfur ABP is also above both suitability criteria, although four of the 11 measured values were below both criteria. The majority of SAR values measured in I3, including the average, exceeded Navajo Mine suitability criteria. The average TSe value in I3 is within both OSM and Navajo Mine suitability criteria, although one of the 11 measured values exceeded OSM suitability criteria by approximately 0.100 ppm. Values for all other parameters, including EC and SSe, are within the appropriate criteria for suitable root zone material.

Interburden Above Number 2 Coal Seam

The I2 interburden in the Pinabete permit area is characterized by four layers identified in seven drill holes (Table 17.E-9). I2 pH values range from 8.5 s.u. to 9.8 s.u., with the majority of measured values exceeding OSM and Navajo Mine suitability criteria. Every measured saturation percent value in I2, except for one, exceeded OSM and Navajo Mine suitability criteria. The average saturation percent in I2 exceeds OSM suitability criteria by 25.6% and Navajo Mine suitability criteria by 30.6%. The average clay percent in I2 is within OSM and Navajo Mine suitability criteria, although two measured values exceed OSM suitability criteria and one value exceeds Navajo Mine suitability criteria. Total sulfur ABP values in I2 range from -43 t/kt to 50.4 t/kt. The average total sulfur ABP is 2 t/kt below the OSM and Navajo Mine suitability criteria. I2 is characterized by 16 samples in the Pinabete permit area, 13 of which contain total sulfur ABP below the suitability criteria. These 13 samples were collected among four of the eight drill holes. The pyritic sulfur ABP of two of these samples is above the suitability criteria. The pyritic sulfur ABP for the remainder of the samples ranges from -89.0 t/kt to -5.0 t/kt (Table 17.E-10). The length of core represented by the samples with pyritic sulfur ABP values less than the suitability criteria range from 0.3 feet to 4.6 feet or 0.27% to 4.14% of the in-situ interburden thickness for the respective drill holes (Table 17.E-10). The average TSe concentration in I2 is within OSM and Navajo Mine suitability criteria, although one measure value exceeded OSM suitability criteria by approximately 0.213 ppm. The average SSe concentration in I2 is within OSM and Navajo Mine suitability criteria, although four of the eight measured values exceed OSM suitability criteria by up to 0.060 ppm. Values for all other parameters, including boron and EC, are within the appropriate criteria for suitable root zone material.

Estimated Volume of Suitable Root Zone Material

If needed, suitable root zone material is available from overburden strata above the first seam to be mined. Suitable root zone thickness for each drill hole was determined by comparing the $(\bar{x})$ of analytical results to both OSM and Navajo Mine criteria. In cases where the $(\bar{x})$ of the entire core above the uppermost seam was not suitable, the thickness was mathematically reduced by removing core sample data from the lowest portion of the core until $(\bar{x})$ met the criteria limits. The results of suitable thickness calculations are summarized in Table 17.E-11. The suitable thickness ranges from 0.0 ft in drill holes 487-01 and 487-04 to 52.3 ft in drill hole 407-34 in the Pinabete permit area. The average thickness $(\bar{a})$ over the permit area, based on drill holes, is 30.8 ft. This thickness is much greater than the 4 ft. of root zone material that would be replaced during reclamation of mined areas.

The volume of suitable root zone material available, based on the average thickness over the permit area and taking into account the material removed for topdressing, is approximately 276 million bank cubic yards (Mbcy). Assuming the projected disturbance area requires 4 ft of suitable material, the Pinabete Permit Area requires 35.9 Mbcy. The results suggest the amount of suitable root zone material available in the Pinabete Permit Area exceeds potential requirements by a factor of 7.7.

Characterization of Spoil Material

Spoil material quality was modeled by computing the weighted mean $(\bar{X})$ of all layers for each analyte within each drill hole. These data are used to characterize spoil at each drill hole location and estimate spoil variability within and among each operational area. The results of these computations are included in

Table 17.E-12. The pH values in spoil material in the Pinabete permit area range from 7.5 s.u. to 9.1 s.u. The pH values in spoil material associated with drill holes 487-01 and 487-04 exceed OSM and Navajo Mine suitability criteria by 0.1 s.u. The saturation percent values in spoil material in the Pinabete permit area range from 70.7% to 125.3%, with an average value that exceeds both OSM and Navajo Mine criteria by 4.8% and 9.8%, respectively. The majority of SAR values for spoil material in the Pinabete permit area exceed OSM and Navajo Mine suitability criteria, but the average value (calculated from the arithmetic mean values of calcium, magnesium, and sodium) is below both criteria. Drill holes 407-33, 407-34, 487-01, 487-02, 487-03, and 487-04 have spoil material SAR values which exceed Navajo Mine suitability criteria. Total sulfur ABP values for the modeled spoil material in the Pinabete permit area range from 30.6 t/kt to 102.7 t/kt. The level of total sulfur ABP in the spoil material from the Pinabete permit area indicates the pyritic sulfur ABP will also be above criteria limits, suggesting the modeled spoil material represents alkaline or neutralizing rock strata. The average clay percent for all modeled spoil material in the Pinabete permit area was within OSM and Navajo Mine suitability criteria, although modeled spoil material from drill hole 487-04 indicates a clay percent value which exceeds OSM suitability criteria by 1%. Values for all other parameters, including SSe and EC, are within the appropriate criteria for suitable root zone material.

In summary, the modeled spoil material in the Pinabete permit area meets all Navajo Mine suitable root zone criteria with the exception of pH, saturation percent, and SAR.

V. CONCLUSIONS

In conclusion, there is no widespread occurrence of PATFM within the Pinabete permit area. Characterization of the in-situ interburden above each coal seam suggests that the materials present in I6 in the Pinabete permit area possess SSe values that are outside OSM suitability criteria, but below Navajo Mine suitability criteria and thus are of limited concern. Acid-base potential characterization suggests a net alkaline environment across the geologic column in the Pinabete permit area. One interburden layer in the Pinabete permit area (I2) possesses pyritic sulfur APB values that are outside criteria for several samples. This layer is thin compared to the total thickness of interburden to be excavated during mining, constituting less than 6% of the in-situ interburden thickness at each drill hole location. Characterization of the in-situ interburden also suggests that the materials present in I6, I4, I3, and I2 in the Pinabete permit area possess saturation percent (>85%) and pH (>9.0) (and SAR [>18] in I4, I3, and I2) values, that are outside criteria established by OSM and Navajo Mine for root zone suitability. These characteristics are common of alkaline subsurface environments where weathering has not altered the rock strata.

When analyzed as a composite to model mine spoil conditions, the influence of these layer characteristics is attenuated and the overall values for physical and chemical analytes, with the exception of pH, SAR, and saturation percent, for the spoil material are within suitability limits and PATFM is not a concern. Despite containing these thin layers of low pyritic sulfur ABP interburden, all modeled spoil columns have net alkaline values. In addition, there is substantially more material present in the overburden of the uppermost seam to be mined than is necessary to provide 4 ft of suitable root zone. The Pinabete Permit Area contains approximately 276 Mbcy of suitable material compared to the 35.9 Mbcy required to provide 4 ft of suitable root zone across the mined area.

VI. REFERENCES

BHP Navajo Coal Company (BNCC). 2009. Navajo Mine Permit Application Package. OSM Permit No. NM-0003F. On file at Office of Surface Mining Reclamation and Enforcement- Western Region Technical Office. Denver, Colorado.

Table 17.E-1 Physical and Chemical Properties Analyzed or Calculated for Overburden/Interburden Samples from 1987, 1998, and 2007 Drilling Program

pH (s.u.)
Conductivity (mmhos/cm)
ESP (Exchangeable Sodium Percentage) [1]
Saturation (%)
Calcium (meq/L)
Magnesium (meq/L)
Sodium (meq/L)
SAR
Sand (%), silt (%), clay (%) [2]
USDA soil texture
Organic Carbon [1]
CaCO3 (%)
Total sulfur (%) [2]
Acid potential total sulfur (t/kt) [2]
Neutralization potential (t/kt) [2g]
Acid-base potential total sulfur (t/kt)
Sulfate (%) *
Organic sulfur (%) *
Pyritic sulfur (%) *
Acid-base pyritic sulfur (t/kt) * [2]
Acid-base potential pyritic sulfur (t/kt) * [2]
Boron (ppm)
Total selenium (ppm) [2]
Soluble selenium (ppm)

* analysis performed only if total sulfur acid-base potential is less than zero t/kt

[1] analysis performed only on samples from 1987 drilling program

[2] analysis performed only on samples from 1998 and 2007 drilling programs

Table 17.E-2 Potential Root Zone Suitability Criteria and PATFM Characteristic Analytes

Characteristic Analytes	OSM Southwestern U. S. Criteria	Navajo Mine Site Specific Criteria[3]
Boron	≤10 ppm	na
Total Selenium	≤0.8 ppm	≤2.5 ppm
Soluble Selenium	≤0.15 ppm	≤0.26 ppm
pH	≥5.5 and ≤9.0	≥5.0 and ≤9.0
Acid-Base Account (Acid-Base Potential[1])	>-5 t $CaCO_3$/1000 t	≥-5 t $CaCO_3$/1000 t
Saturation	≥ 20% and ≤90%	≤85% OR ≤100% only if EC≥4 mmhos/cm
EC	≤12 mmhos/cm	≤16 mmhos/cm
SAR	sandy loam ≤20 loam, clay loam ≤16 40% clay ≤14	≤18 OR ≤40 only if EC ≥4 mmhos/cm
Texture	≤45% clay	≤50% clay
$CaCO_3$	%	No Criteria
Neutralization Potential	t $CaCO_3$/1000 t	No Criteria
Total Sulfur	%	No Criteria
Total Sulfur Acid Potential	t $CaCO_3$/1000 t	No Criteria
Sulfate[2]	%	No Criteria
Organic Sulfur[2]	%	No Criteria
Pyritic Sulfur[2]	%	No Criteria
Acid-Base Pyritic Sulfur[2]	t $CaCO_3$/1000 t	No Criteria

[1] Total sulfur and pyritic sulfur acid-base potential are considered under this criteria.
[2] These analytes including pyritic sulfur acid-base potential are analyzed when total sulfur acid-base potential is less than zero.
[3] Navajo Mine site specific criteria are found in Navajo Mine Permit NM-0003F.

Table 17.E-3 Interburden Name and Number of Layer Observations from 1987, 1998, and 2007 Drilling Programs

Interburden name	Number of observations in Area 4
I8	1
I8A	4
I8A1	1
I8A2	1
I8B	2
I7	8
I7-R	1
I6	4
I6A	1
I6B	4
I4	7
I3	4
I3A	3
I3B	4
I2	2
I2A	1
I2B	2
I2B/2A	2
I2B1	1

Table 17.E-4 Weighted Mean of Physical and Chemical Properties by Interburden Layer for I8

Area 4	Interburden layer	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)
407-33	I8A1	8.5	2.0	83.8	0.52	0.13	17.51	30.8	13	53
407-33	I8A2	8.6	2.0	72.8	0.40	0.16	16.81	31.7	24	45
407-33	I8B	8.7	2.4	98.3	2.28	0.64	19.11	15.8	32	42
407-34	I8A	8.8	1.4	95.2	0.24	0.09	13.31	32.8	16	57
407-34	I8B	7.5	5.1	96.8	5.54	2.81	45.33	22.2	24	44
487-01	I8A	7.7	4.7	119.9	17.36	4.75	48.50	17.5	12	43
487-03	I8A	8.4	0.9	39.6	1.23	1.57	6.94	6.7	17	62
487-04	I8A	9.0	2.4	112.7	1.68	0.56	24.00	36.7	8	48
498-06	I8	6.8	4.2	44.1	24.58	13.49	9.27	2.1	51	26
Minimum		6.8	0.9	39.6	0.2	0.1	6.9	2.1	7.6	26.4
Maximum		9.0	5.1	119.9	24.6	13.5	48.5	36.7	50.7	62.5
Arithmetic mean*		-	2.8	84.8	6.0	2.7	22.3	10.7	21.8	46.7
Standard dev		-	1.5	28.0	8.8	4.3	14.9	-	13.2	10.3

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-4 (Contined)

Area 4	Clay (%)	CaCO3 (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
407-33	34	7.48	0.896	28.0	74.8	46.8	2.20	0.942	0.188
407-33	30	10.11	0.627	19.6	101.1	81.6	1.80	0.653	0.116
407-33	26	8.58	0.212	6.6	85.8	79.2	1.22	0.276	0.057
407-34	28	8.39	0.377	11.8	83.9	72.1	1.19	0.423	0.083
407-34	32	4.76	0.218	6.8	47.6	40.7	1.15	0.262	0.086
487-01	45	4.58	1.053			12.9	1.36		0.136
487-03	20	23.34	0.034			232.5	0.46		0.023
487-04	46	9.45	0.215			87.7	0.73		0.127
498-06	23	6.26	0.462	14.5	64.6	50.2	0.54	0.461	0.019
Minimum	20.4	4.6	0.0	6.6	47.6	12.9	0.5	0.3	0.0
Maximum	45.6	23.3	1.1	28.0	101.1	232.5	2.2	0.9	0.2
Arithmetic mean*	31.6	9.2	0.5	14.5	76.3	78.2	1.2	0.5	0.09
Standard dev	8.9	5.6	0.3	8.2	18.6	62.6	0.6	0.3	0.1

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-5 Weighted Mean of Physical and Chemical Properties by Interburden Layer for I7

Area 4 South	Interburden layer	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)
407-32	I7	8.2	2.5	35.4	2.77	1.43	22.49	15.5	59	26
407-33	I7	9.0	2.0	61.4	0.15	0.07	17.51	52.1	31	45
407-34	I7	8.9	2.0	78.4	0.23	0.13	20.08	47.0	25	51
487-01	I7	8.1	1.8	65.1	3.90	2.63	18.62	14.2	18	46
487-02	I7	8.3	0.5	38.4	0.88	0.69	4.99	7.2	33	48
487-03	I7	9.0	1.4	177.6	0.15	0.05	13.99	38.0	5	46
487-04	I7	8.3	1.7	80.1	0.25	0.01	18.35	44.2	5	36
487-04	I7R	8.9	1.4	120.1	0.28	0.00	13.99	32.7	2	52
498-06	I7	6.9	8.3	41.3	29.36	49.91	33.48	5.3	44	28
Minimum		6.9	0.5	35.4	0.2	0.0	5.0	5.3	1.6	26.1
Maximum		9.0	8.3	177.6	29.4	49.9	33.5	52.1	59.5	52.2
Arithmetic mean*		-	2.4	77.5	4.2	6.1	18.2	8.0	24.7	42.0
Standard dev		-	2.3	45.9	9.5	16.5	7.6	-	19.6	9.6

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-5 (Continued)

Area 4 South	Clay (%)	CaCO3 (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
407-32	14	12.95	0.225	7.0	129.5	122.5	0.82	0.676	0.061
407-33	24	16.16	0.542	16.9	161.6	144.7	1.62	0.620	0.092
407-34	23	9.38	0.590	18.4	93.8	75.4	1.28	0.509	0.076
487-01	36	14.82	0.252			140.2	1.02		0.129
487-02	19	9.91	0.021			100.5	0.50		0.021
487-03	49	2.93	0.162			24.5	1.04		0.119
487-04	59	2.96	1.113			-5.1	1.40		0.285
487-04	46	3.63	0.442			21.4	0.85		0.151
498-06	28	8.32	0.424	13.1	76.6	63.4	0.54	0.227	0.066
Minimum	14.4	2.9	0.0	7.0	76.6	-5.1	0.5	0.2	0.021
Maximum	58.8	16.2	1.1	18.4	161.6	144.7	1.6	0.7	0.285
Arithmetic mean*	33.3	9.0	0.4	13.9	115.4	76.4	1.0	0.5	0.111
Standard dev	15.2	5.1	0.3	5.1	37.9	54.7	0.4	0.2	0.1

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-6 Weighted Mean of Physical and Chemical Properties by Interburden Layer for I6

Area 4 South	Interburden layer	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)
407-32	I6	9.1	1.5	95.9	0.19	0.19	18.39	42.3	8	57
407-33	I6	9.3	1.8	85.0	0.13	0.05	15.31	51.2	6	60
407-34	I6	8.9	1.2	94.9	0.20	0.12	12.22	30.6	15	55
487-01	I6B	9.1	1.0	85.6	0.69	5.66	13.78	11.8	8	58
487-02	I6B	9.2	1.0	122.5	0.13	0.17	11.89	31.9	3	73
487-03	I6B	9.0	1.4	90.8	0.11	0.00	13.78	42.9	5	55
487-04	I6B	9.0	0.9	48.7	0.14	0.00	9.84	29.1	5	66
487-04	I6A	9.0	1.3	93.0	0.10	0.00	13.10	41.4	1	44
498-06	I6	4.8	10.5	80.0	22.00	37.00	50.00	9.2	22	38
Minimum		4.8	0.9	48.7	0.1	0.0	9.8	9.2	1.0	38.0
Maximum		9.3	10.5	122.5	22.0	37.0	50.0	51.2	22.0	73.3
Arithmetic mean*		-	2.3	88.5	2.6	4.8	17.6	9.1	8.2	56.2
Standard dev		-	3.1	19.2	7.3	12.2	12.4	-	6.5	10.5

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-6 (Continued)

Area 4 South	Clay (%)	CaCO3 (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
407-32	35	0.55	0.883	27.6	5.5	-22.1	1.91	0.839	0.198
407-33	34	0.64	1.125	35.1	6.4	-28.8	1.90	1.000	0.210
407-34	30	0.66	1.423	44.5	6.6	-37.8	1.95	0.875	0.195
487-01	34	0.25	0.602			-16.5	1.29		0.134
487-02	24	3.26	0.493			17.4	0.62		0.067
487-03	40	11.63	0.265			87.3	1.06		0.087
487-04	29	20.69	0.306			152.3	0.81		0.058
487-04	55	0.30	0.820			-1.0	1.60		0.210
498-06	40	0.61	0.380	12.0	7.0	-5.3	0.90	0.450	0.360
Minimum	24.0	0.2	0.3	12.0	5.5	-37.8	0.6	0.450	0.058
Maximum	55.0	20.7	1.4	44.5	7.0	152.3	2.0	1.000	0.360
Arithmetic mean*	35.6	4.3	0.7	29.8	6.4	16.2	1.3	0.791	0.169
Standard dev	8.9	7.2	0.4	13.7	0.6	63.1	0.5	0.2	0.1

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-7 Weighted Mean of Physical and Chemical Properties by Interburden Layer for I4

Area 4 South	Interburden layer	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)
407-32	I4	9.3	1.1	79.1	0.18	0.20	11.49	26.4	50	32
407-33	I4	9.2	1.5	61.3	0.14	0.08	12.64	37.5	42	40
407-34	I4	9.0	1.1	111.8	0.14	0.07	11.11	35.0	12	55
487-02	I4	9.2	1.8	165.0	0.20	0.50	20.40	34.5	4	36
487-03	I4	9.2	1.2	105.0	0.10	0.03	12.06	38.1	5	56
487-04	I4	9.6	1.1	123.2	0.06	0.01	11.83	36.5	4	49
498-06	I4	8.1	4.7	94.0	3.16	1.51	51.21	33.5	27	39
Minimum		8.1	1.1	61.3	0.1	0.0	11.1	26.4	4.0	31.9
Maximum		9.6	4.7	165.0	3.2	1.5	51.2	38.1	50.1	55.9
Arithmetic mean*		-	1.8	105.6	0.6	0.3	18.7	27.6	20.5	43.8
Standard dev		-	1.3	33.4	1.1	0.5	14.7	-	19.3	9.5

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-7 (Continued)

Area 4 South	Clay (%)	CaCO3 (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
407-32	18	7.74	0.096	3.0	77.4	74.4	0.62	0.148	0.029
407-33	19	7.61	0.139	4.3	76.1	71.8	0.96	0.211	0.087
407-34	34	7.11	0.317	9.9	71.1	61.2	1.42	0.394	0.109
487-02	60	0.30	0.310			-7.0	1.40		0.230
487-03	40	12.02	2.453			113.8	0.89		0.072
487-04	47	7.93	0.206			68.4	1.31		0.063
498-06	34	4.50	0.091	2.9	44.8	41.9	0.26	0.198	0.049
Minimum	18.0	0.3	0.1	2.9	44.8	-7.0	0.3	0.1	0.029
Maximum	60.0	12.0	2.5	9.9	77.4	113.8	1.4	0.4	0.230
Arithmetic mean*	35.7	6.7	0.5	5.0	67.3	60.6	1.0	0.2	0.091
Standard dev	14.9	3.6	0.9	3.3	15.3	36.8	0.4	0.1	0.1

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-8 Weighted Mean of Physical and Chemical Properties by Interburden Layer for I3

Area 4 South	Interburden layer	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)
407-32	I3	9.6	0.8	109.2	0.08	0.05	9.16	35.6	19	48
407-33	I3	9.4	1.0	96.2	0.13	0.21	8.50	20.5	27	39
407-34	I3	9.4	1.1	99.8	0.12	0.10	11.28	34.1	20	49
487-01	I3B	9.6	0.9	144.6	0.35	0.53	10.99	21.2	21	46
487-01	I3A	9.8	0.7	111.0	0.10	0.10	8.60	27.2	0	41
487-02	I3B	9.5	1.6	143.0	0.14	0.06	17.24	49.7	2	61
487-03	I3B	9.5	1.3	143.5	0.10	0.03	14.15	44.7	3	56
487-03	I3A	9.2	1.2	116.0	0.10	0.10	12.50	39.5	5	50
487-04	I3	9.5	1.4	78.4	0.16	0.00	16.25	44.1	4	52
498-06	I3A	9.2	1.0	104.0	0.62	1.10	13.00	14.0	30	38
498-06	I3B	7.9	5.8	123.7	7.49	3.80	57.27	24.1	26	43
Minimum		7.9	0.7	78.4	0.1	0.0	8.5	14.0	0.0	38.0
Maximum		9.8	5.8	144.6	7.5	3.8	57.3	49.7	30.0	61.0
Arithmetic mean*		-	1.5	115.4	0.9	0.6	16.3	19.4	14.1	47.6
Standard dev		-	1.4	21.5	2.2	1.1	13.9	-	11.6	7.2

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-8 (Continued)

Area 4 South	Clay (%)	CaCO3 (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
407-32	34	3.06	1.547	48.3	30.6	-17.7	1.61	0.703	0.051
407-33	34	3.56	1.685	52.6	35.6	-17.0	1.60	0.900	0.036
407-34	31	2.62	1.540	48.1	26.2	-21.9	1.87	0.609	0.074
487-01	33	4.94	0.369			37.9	2.13		0.075
487-01	59	0.20	0.150			-3.0	2.30		0.120
487-02	31	4.44	1.073			8.4	1.19		0.097
487-03	41	4.51	1.135			9.5	1.01		0.045
487-03	45	0.10	0.360			-10.0	1.10		0.130
487-04	44	5.48	1.200			16.4	1.48	0.000	0.101
498-06	32	1.60	0.280	8.8	14.0	5.7	1.40	0.600	0.120
498-06	31	2.86	1.001	31.4	27.1	-4.2	0.60	0.299	0.010
Minimum	30.6	0.1	0.2	8.8	14.0	-21.9	0.6	0.0	0.010
Maximum	59.0	5.5	1.7	52.6	35.6	37.9	2.3	0.9	0.130
Arithmetic mean*	37.7	3.0	0.9	37.9	26.7	0.4	1.5	0.5	0.078
Standard dev	8.9	1.8	0.6	18.2	8.0	17.6	0.5	0.3	0.0

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-9 Weighted Mean of Physical and Chemical Properties by Interburden Layer for I2

Area 4 South	Interburden layer	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)
407-32	I2B1	9.3	0.9	115.6	0.08	0.05	10.67	40.7	24	42
407-33	I2	9.3	0.9	82.8	0.12	0.06	11.00	37.0	18	53
407-34	I2	9.3	1.0	95.8	0.08	0.07	9.92	36.1	10	58
487-01	I2B	9.8	0.7	122.4	0.12	0.72	9.20	20.1	2	37
487-02	I2B	9.3	1.7	138.7	0.06	0.01	17.52	54.4	9	55
487-02	I2A	8.5	2.4	134.0	0.10	0.05	23.00	72.7	14	49
487-03	I2B/2A	9.5	1.2	103.8	0.04	0.01	12.91	40.5	6	51
498-06	I2B/2A	9.3	1.4	132.0	0.38	0.41	17.00	27.0	28	24
Minimum		8.5	0.7	82.8	0.0	0.0	9.2	20.1	2.5	24.0
Maximum		9.8	2.4	138.7	0.4	0.7	23.0	72.7	28.0	57.5
Arithmetic mean*		-	1.3	115.6	0.1	0.2	13.9	36.2	13.9	46.0
Standard dev		-	0.6	20.0	0.1	0.3	4.8	-	8.8	11.2

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-9 (Continued)

Area 4 South	Clay (%)	CaCO3 (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
407-32	34	0.93	0.496	15.5	9.3	-6.2	2.33	1.013	0.189
407-33	30	0.58	0.208	6.5	5.8	-0.7	1.35	0.700	0.017
407-34	33	0.66	0.141	4.4	6.6	2.2	1.20	0.550	0.210
487-01	60	0.20	0.170			-3.5	3.00		0.166
487-02	36	0.41	1.487			-42.5	2.02		0.182
487-02	38	0.90	1.670			-43.0	1.60		0.075
487-03	42	5.72	0.219			50.4	1.28		0.123
498-06	48	1.00	0.680	21.0	8.0	-13.2	1.50	0.700	0.010
Minimum	30.0	0.2	0.1	4.4	5.8	-43.0	1.2	0.550	0.010
Maximum	60.4	5.7	1.7	21.0	9.3	50.4	3.0	1.013	0.210
Arithmetic mean*	40.1	1.3	0.6	11.8	7.4	-7.0	1.8	0.741	0.121
Standard dev	10.0	1.8	0.6	7.8	1.5	29.4	0.6	0.2	0.1

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-10 Summary of Sulfur Analysis for Interburden Samples with Total Sulfur Acid-Base Potential Values Less Than Zero t/kt.

Interburden name	Sample ID	Date sampled	Thickness (ft)	OB core thickness (ft)	Sample of OB core (%)	Rock type	pH (s.u.)	Total Sulfur (%)	Total Organic Carbon (%)	Sulfate Sulfur (%)	Pyritic Sulfur (%)	Organic Sulfur (%)
I8A	487-01		10.0	127.2	7.86%		7.5	1.73	1.2	1.7	0.05	0.03
I8A	487-04		3.4	168.5	2.02%		9.2	0.20	1.2			
I8A	487-04		1.3	168.5	0.77%		8.3	0.98	14.5	0.0	0.63	0.34
I8A	487-04		3.9	168.5	2.31%		8.1	0.82	4.4	0.1	0.50	0.18
I8A	487-04		3.4	168.5	2.02%		9.0	0.39	4.9			
Average			4.4				8.4	0.8	5.2	0.6	0.4	0.2
Minimum			1.3				7.5	0.2	1.2	0.0	0.1	0.0
Maximum			10.0				9.2	1.7	14.5	1.7	0.6	0.3
I7	487-04		1.2	168.5	0.71%		8	1.150	17.100	0.110	0.580	0.460
I7	487-04		1.3	168.5	0.77%		7.3	2.060	33.900	0.060	1.120	0.860
I7	487-04		3.7	168.5	2.20%		8.3	1.360	6.600	0.290	0.880	0.210
I7	487-04		3.7	168.5	2.20%		8.6	0.660	3.400	0.060	0.450	0.100
I7	487-04		4.0	168.5	2.37%		8	1.660	14.500	0.160	0.990	0.510
I7-R	487-04		1.1	168.5	0.65%		8.9	0.110	5.600			
I7-R	487-04		1.4	168.5	0.83%		9.3	0.230	0.500			
I7	487-01		1.3	127.2	1.02%		4	0.410	2.200	0.260	0.020	0.130
I7	487-01		0.3	127.2	0.24%		8.5	1.530	6.300	0.260	1.030	0.240
Average			2.0				7.9	1.0	10.0	0.2	0.7	0.4
Minimum			0.3				4.0	0.1	0.5	0.1	0.0	0.1
Maximum			4.0				9.3	2.1	33.9	0.3	1.1	0.9
I6B	487-03		0.6	124.9	0.48%		7	1.840	12.700	0.000	1.660	0.270
I6B	487-03		0.5	124.9	0.40%		8.4	1.780	5.500	0.140	1.460	0.180
I6B	487-03		4.4	124.9	3.52%		9	0.220	1.000	0.000	0.160	0.060
I6B	487-03		4.4	124.9	3.52%		8.8	0.430	1.600			
I6B	487-03		0.9	124.9	0.72%		8.8	0.360	2.800	0.000	0.260	0.100
I6B	487-03		4.9	124.9	3.92%		8.8	0.240	3.000			
I6B	487-04		3.8	168.5	2.26%		9	0.820	2.400			
I6A	487-04		3.3	168.5	1.96%		9	0.820	4.600	0.030	0.640	0.150
I6B	487-02		4.8	111.0	4.32%		8.7	1.050	3.100	0.110	0.800	0.140
I6B	487-02		4.5	111.0	4.05%		8.8	1.890	1.000	1.540	0.260	0.090
I6B	487-02		1.6	111.0	1.44%		8.8	0.320	1.700	0.020	0.270	0.030
I6B	487-01		3.9	127.2	3.07%		9.1	0.560	2.400	0.090	0.360	0.110
I6B	487-01		3.4	127.2	2.67%		9	0.650	4.500	0.180	0.360	0.110
I6	498-06 #14	4/17/1998	4.1	110.8	3.70%	SH	4.8	0.38				
I6	407-32 S-546	4/14/2007	0.85	113.8	0.75%	CSH	8.65	1.686				
I6	407-32 S-547	4/14/2007	3.15	113.8	2.77%	SH/ST	9.26	0.666				
I6	407-33 S-606	4/16/2007	3.9	190.3	2.05%	SH	9.29	1.125				
I6	407-34 S-669	4/18/2007	2.9	185.8	1.59%	CSH/SH	8.87	1.423				
Average			3.1				8.6	0.9	3.6	0.2	0.6	0.1
Minimum			0.5				4.8	0.2	1.0	0.0	0.2	0.0
Maximum			4.9				9.3	1.9	12.7	1.5	1.7	0.3
I4	487-02		4.5	111.0	4.05%		9.20	0.310	1.400	0.010	0.180	0.120
I4	487-03		0.7	124.9	0.56%		9.10	1.060	7.400	0.000	0.880	0.160
I4	487-03		1.0	124.9	0.80%		9.10	0.350	5.400	0.000	0.230	0.120

Table 17.E-10 (Continued)

Interburden name	Sample ID	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Sulfate (%)	Organic sulfur (%)	Pyritic sulfur (%)	Acid-base pyritic sulfur (t/kt)	Acid-base potential pyritic sulfur (t/kt)
I8A	487-01			-49	1.65	0.03	0.05		3
I8A	487-04			-58					
I8A	487-04			-29	0.01	0.34	0.63		-18
I8A	487-04			-23	0.14	0.18	0.50		-13
I8A	487-04			-2					
Average				-32.2	0.6	0.2	0.4		-9.3
Minimum				-58.0	0.0	0.0	0.1		-18.0
Maximum				-2.0	1.7	0.3	0.6		3.0
I7	487-04			-32.0	0.110	0.460	0.580		-14.0
I7	487-04			-61.0	0.060	0.860	1.120		-32.0
I7	487-04			-41.0	0.290	0.210	0.880		-25.0
I7	487-04			-5.0	0.060	0.100	0.450		0.0
I7	487-04			-48.0	0.160	0.510	0.990		-27.0
I7-R	487-04			-1.0					
I7-R	487-04			-16.0					
I7	487-01			-12.0	0.260	0.130	0.020		0.0
I7	487-01			-46.0	0.260	0.240	1.030		-30.0
Average				-29.1	0.2	0.4	0.7		-18.3
Minimum				-61.0	0.1	0.1	0.0		-32.0
Maximum				-1.0	0.3	0.9	1.1		0.0
I6B	487-03			-59.0	0.000	0.270	1.660		-51.0
I6B	487-03			-53.0	0.140	0.180	1.460		-43.0
I6B	487-03			-5.0	0.000	0.060	0.160		-3.0
I6B	487-03			-1.0					
I6B	487-03			-9.0	0.000	0.100	0.260		-6.0
I6B	487-03			-42.0					
I6B	487-04			-23.0					
I6A	487-04			-1.0	0.030	0.150	0.640		-17.0
I6B	487-02			-31.0	0.110	0.140	0.800		-23.0
I6B	487-02			-53.0	1.540	0.090	0.260		-2.0
I6B	487-02			-8.0	0.020	0.030	0.270		-6.0
I6B	487-01			-16.0	0.090	0.110	0.360		-9.0
I6B	487-01			-17.0	0.180	0.110	0.360		-8.0
I6	498-06 #14	12	7	-5.3	0.3	0.06	0.07	2.2	4.4
I6	407-32 S-546	52.7	6.38	-46.3	0.015	0.566	1.105	34.5	-28.1
I6	407-32 S-547	20.8	5.26	-15.6	<0.001	0.176	0.510	15.9	-10.7
I6	407-33 S-606	35.1	6.38	-28.8	0.101	0.192	0.832	26.0	-19.6
I6	407-34 S-669	44.5	6.63	-37.8	0.029	0.220	1.175	36.7	-30.1
Average		33.0	6.3	-25.1	0.2	0.2	0.7	23.1	-16.8
Minimum		12.0	5.3	-59.0	0.0	0.0	0.1	2.2	-51.0
Maximum		52.7	7.0	-1.0	1.5	0.6	1.7	36.7	4.4
I4	487-02			-7.00	0.010	0.120	0.180		-3.00
I4	487-03			-23.00	0.000	0.160	0.880		-18.00
I4	487-03			-9.00	0.000	0.120	0.230		-5.00

Table 17.E-10 (Continued)

Interburden name	Sample ID	Date sampled	Thickness (ft)	OB core thickness (ft)	Sample of OB core (%)	Rock type	pH (s.u.)	Total Sulfur (%)	Total Organic Carbon (%)	Sulfate Sulfur (%)	Pyritic Sulfur (%)	Organic Sulfur (%)
I4	487-04		4.6	168.5	2.73%		9.70	0.110	2.400			
Average			2.7				9.3	0.5	4.2	0.0	0.4	0.1
Minimum			0.7				9.1	0.1	1.4	0.0	0.2	0.1
Maximum			4.6				9.7	1.1	7.4	0.0	0.9	0.2
I3	487-04		1.6	168.5	0.95%		9.70	1.640	4.300	0.000	0.830	1.010
I3	487-04		3.8	168.5	2.26%		9.30	1.290	1.600	0.140	1.100	0.140
I3	487-04		3.5	168.5	2.08%		9.00	1.190	15.700	0.000	0.960	0.230
I3B	487-02		4.8	111.0	4.32%		9.50	0.670	2.200	0.140	0.420	0.110
I3B	487-02		4.5	111.0	4.05%		9.60	1.270	1.900	0.140	0.980	0.150
I3B	487-02		3.9	111.0	3.51%		8.70	2.030	5.200	0.270	1.650	0.110
I3B	487-03		2.8	124.9	2.24%		9.40	0.700	3.700			
I3B	487-03		4.0	124.9	3.20%		9.40	1.520	2.500	0.040	1.340	0.140
I3A	487-03		1.6	124.9	1.28%		9.20	0.360	3.900	0.000	0.270	0.090
I3B	487-01		3.4	127.2	2.67%		9.00	0.510	3.600	0.030	0.350	0.130
I3B	487-01		5.0	127.2	3.93%		9.30	0.600	5.400	0.080	0.370	0.150
I3B	487-01		4.6	127.2	3.62%		10.10	1.500	3.200	0.000	1.300	0.200
I3B	487-01		4.7	127.2	3.69%		9.40	1.420	2.200	0.520	0.730	0.170
I3A	487-01		4.3	122.2	3.52%		9.80	0.150	2.400			
I3	407-32 S-561	4/14/2007	2.7	113.8	2.37%	SH	9.99	1.632				
I3	407-32 S-562	4/14/2007	4	113.8	3.51%	SH	9.54	1.690				
I3	407-32 S-563	4/14/2007	2.45	113.8	2.15%	SH	9.58	1.530				
I3	407-32 S-564	4/14/2007	0.9	113.8	0.79%	CSH	8.81	2.643				
I3	407-33 S-619	4/16/2007	5.3	190.3	2.79%	SH/ASH	9.59	1.807				
I3	407-33 S-620	4/16/2007	4.8	190.3	2.52%	SH	9.39	1.793				
I3	407-33 S-623	4/16/2007	2.3	190.3	1.18%	CSH	9.10	1.961				
I3	407-34 S-676	4/18/2007	4.8	185.8	2.58%	SH/CSH	9.60	1.658				
I3	407-34 S-677	4/18/2007	3.9	185.8	2.10%	SH	9.52	1.651				
I3	407-34 S-678	4/18/2007	4.0	185.8	2.15%	SH	9.17	1.205				
I3	407-34 S-679	4/18/2007	4.4	185.8	2.37%	SH/ST	9.35	1.442				
I3	407-34 S-680	4/18/2007	1.3	185.8	0.73%	CSH	9.17	2.107				
Average			3.6				9.4	1.4	4.1	0.1	0.9	0.2
Minimum			0.9				8.7	0.2	1.6	0.0	0.3	0.1
Maximum			5.3				10.1	2.6	15.7	0.5	1.7	1.0
I2B	487-02		3.4	111.0	3.06%		9.70	0.280	3.800	0.110	0.140	0.030
I2B	487-02		0.3	111.0	0.27%		8.70	1.650	9.200	0.350	0.990	0.310
I2B	487-02		1.6	111.0	1.44%		9.80	0.290	1.700	0.040	0.119	0.060
I2B	487-02		4.6	111.0	4.14%		9.40	2.110	11.400	0.000	1.740	0.370
I2B	487-02		0.5	111.0	0.45%		8.30	3.410	25.800			
I2B	487-02		3.0	111.0	2.70%		8.50	2.200	25.700	0.160	1.650	0.390
I2A	487-02		3.0	111.0	2.70%		9.00	1.670	4.600	0.120	1.350	0.200
I2A	487-02		3.0	111.0	2.70%		8.00	1.670	3.700	0.100	1.370	0.200
I2B	487-01		2.0	127.2	1.57%		9.60	0.220	8.600	0.010	0.070	0.140
I2B	487-01		3.4	127.2	2.67%		9.90	0.150	1.400			
I2B	487-01		3.4	127.2	2.67%		9.90	0.160	4.200			
I2B/I2A	487-03		2.9	124.9	2.32%		9.30	0.420	5.200	0.000	0.300	0.120
I2B/I2A	487-03		0.8	124.9	0.64%		9.50	0.550	34.000	0.000	0.190	0.360
I2B/2A	498-06 #30	4/17/1998	1.8	110.8	1.62%	SH	9.3	0.68				
S2B2	407-32 S-567	4/14/2007	0.6	113.8	0.53%	CO	8.12	1.416				

Table 17.E-10 (Continued)

Interburden name	Sample ID	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Sulfate (%)	Organic sulfur (%)	Pyritic sulfur (%)	Acid-base pyritic sulfur (t/kt)	Acid-base potential pyritic sulfur (t/kt)
I4	487-04			-3.00					
Average				-10.5	0.0	0.1	0.4		-8.7
Minimum				-23.0	0.0	0.1	0.2		-18.0
Maximum				-3.0	0.0	0.2	0.9		-3.0
I3	487-04			-50.0	0.000	1.010	0.830		-18.0
I3	487-04			-7.0	0.140	0.140	1.100		1.0
I3	487-04			-24.0	0.000	0.230	0.960		-17.0
I3B	487-02			-7.0	0.140	0.110	0.420		1.0
I3B	487-02			-26.0	0.140	0.150	0.980		-19.0
I3B	487-02			-62.0	0.270	0.110	1.650		-51.0
I3B	487-03			-2.0					
I3B	487-03			-25.0	0.040	0.140	1.340		-19.0
I3A	487-03			-10.0	0.000	0.090	0.270		-7.0
I3B	487-01			-14.0	0.030	0.130	0.350		-9.0
I3B	487-01			-17.0	0.080	0.150	0.370		10.0
I3B	487-01			-31.0	0.000	0.200	1.300		-25.0
I3B	487-01			-33.0	0.520	0.170	0.730		-12.0
I3A	487-01			-3.0					
I3	407-32 S-561	51.0	13.1	-37.9	<0.001	0.220	1.479	46.2	-33.1
I3	407-32 S-562	52.8	19.8	-33.0	0.060	0.183	1.447	45.2	-25.4
I3	407-32 S-563	47.8	19.8	-28.0	<0.001	0.186	1.425	44.5	-24.7
I3	407-32 S-564	82.6	5.26	-77.3	<0.001	0.416	2.457	76.8	-71.5
I3	407-33 S-619	56.5	24.0	-32.5	0.108	0.183	1.516	47.4	-23.4
I3	407-33 S-620	56.0	25.1	-30.9	0.112	0.197	1.484	46.4	-21.3
I3	407-33 S-623	61.3	7.50	-53.8	0.203	0.329	1.430	44.7	-37.2
I3	407-34 S-676	51.8	32.3	-19.5	<0.001	0.227	1.486	46.4	-14.1
I3	407-34 S-677	51.6	22.2	-29.3	<0.001	0.182	1.506	47.0	-24.8
I3	407-34 S-678	37.6	29.1	-8.58	<0.001	0.167	1.131	35.3	-6.27
I3	407-34 S-679	45.0	24.6	-20.5	0.067	0.161	1.214	37.9	-13.3
I3	407-34 S-680	65.8	12.2	-53.6	<0.001	0.285	1.944	60.7	-48.5
Average		55.0	19.6	-28.3	0.1	0.2	1.2	48.2	-21.2
Minimum		37.6	5.3	-77.3	0.0	0.1	0.3	35.3	-71.5
Maximum		82.6	32.3	-2.0	0.5	1.0	2.5	76.8	10.0
I2B	487-02			-8.0	0.110	0.030	0.140		-3.0
I2B	487-02			-52.0	0.350	0.310	0.990		-31.0
I2B	487-02			-8.0	0.040	0.060	0.119		-5.0
I2B	487-02			-60.0	0.000	0.370	1.740		-48.0
I2B	487-02			-75.0					
I2B	487-02			-67.0	0.160	0.390	1.650		-89.0
I2A	487-02			-49.0	0.120	0.200	1.350		-39.0
I2A	487-02			-37.0	0.100	0.200	1.370		-26.0
I2B	487-01			-5.0	0.010	0.140	0.070		1.0
I2B	487-01			-3.0					
I2B	487-01			-3.0					
I2B/I2A	487-03			-12.0	0.000	0.120	0.300		-8.0
I2B/I2A	487-03			-16.0	0.000	0.360	0.190		-5.0
I2B/2A	498-06 #30	21	8	-13.2	0	0.11	0.58	18.1	-10.1
S2B2	407-32 S-567	44.2	6.38	-37.9	<0.001	0.761	1.354	42.3	-35.9

Table 17.E-10 (Continued)

Interburden name	Sample ID	Date sampled	Thickness (ft)	OB core thickness (ft)	Sample of OB core (%)	Rock type	pH (s.u.)	Total Sulfur (%)	Total Organic Carbon (%)	Sulfate Sulfur (%)	Pyritic Sulfur (%)	Organic Sulfur (%)
I2B1	407-32 S-568	4/14/2007	1.7	113.8	1.45%	CSH	9.30	0.870				
Average			2.2				9.1	1.1	10.7	0.1	0.8	0.2
Minimum			0.3				8.0	0.2	1.4	0.0	0.1	0.0
Maximum			4.6				9.9	3.4	34.0	0.4	1.7	0.4

Table 17.E-10 (Continued)

Interburden name	Sample ID	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Sulfate (%)	Organic sulfur (%)	Pyritic sulfur (%)	Acid-base pyritic sulfur (t/kt)	Acid-base potential pyritic sulfur (t/kt)
I2B1	407-32 S-568	27.2	17.6	-9.58	0.059	0.248	0.563	17.6	0.01
Average		30.8	10.7	-28.5	0.1	0.3	0.8	26.0	-23.0
Minimum		21.0	6.4	-75.0	0.0	0.0	0.1	17.6	-89.0
Maximum		44.2	17.6	-3.0	0.4	0.8	1.7	42.3	1.0

Table 17.E-11 Summary of Suitable Root Zone Thickness by Drill Hole for Area 4 South and Area 5

Area 4	Thickness (ft)	Interburden name	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)	Clay (%)
498-06	42.6	I8	6.92	3.86	42.1	23.0	12.6	8.8	2.1	53.9	24.9	21.2
407-32	44.6	I7	7.91	2.26	34.0	2.4	1.2	20.7	15.3	58.9	23.6	13.5
407-33	37.6	I8B	8.26	3.40	83.7	5.7	1.3	26.6	14.3	54.9	25.9	19.2
407-34	52.3	I8B	6.66	4.54	80	5.6	2.4	39.8	19.9	24.6	37.5	26.8
487-01	0.0	-	-	-	-	-	-	-	-	-	-	-
487-02	37.2	I7	8.3	0.49	39	0.60	0.61	5.27	7.9	30	51	19
487-03	31.8	I8A	8.4	0.70	39	0.96	1.64	4.95	5.6	15	65	20
487-04	0.0	-	-	-	-	-	-	-	-	-	-	-
Minimum thickness	0.0											
Maximum thickness	52.3											
Average thickness	30.8											

Table 17.E-11 (Continued)

Area 4	$CaCO_3$ (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
498-06	6.847	0.389	12.2	70.8	58.7	0.51	0.393	0.017
407-32	11.862	0.203	6.33	118.6	112	0.79	0.582	0.055
407-33	9.339	0.102	3.20	93.4	90.2	1.09	0.098	0.019
407-34	4.40	0.174	5.45	44	38.5	0.95	0.227	0.068
487-01	-	-	-	-	-	-	-	-
487-02	10.3	0.02	-	-	105	0.52	-	0.02
487-03	24.8	0.02	-	-	248	0.26	-	0.03
487-04	-	-	-	-	-	-	-	-
Minimum thickness								
Maximum thickness								
Average thickness								

Table 17.E-12 Weighted Mean of Physical and Chemical Properties by Drill Hole for Mixed Material (Spoil)

Area 4	Thickness (ft)	pH (s.u.)	Conductivity (mmhos/cm)	Saturation (%)	Calcium (meq/L)	Magnesium (meq/L)	Sodium (meq/L)	SAR	Sand (%)	Silt (%)
498-06	110.8	7.5	5.2	77.7	14.39	12.54	34.95	9.5	37	34
407-32	113.8	9.0	1.5	70.7	1.06	0.60	15.21	16.7	46	33
407-33	190.3	8.9	1.9	81.5	0.96	0.31	15.82	19.9	31	43
407-34	185.8	8.6	2.4	96.1	1.56	0.78	21.75	20.1	18	52
487-01	127.2	9.1	1.6	125.3	3.30	1.72	17.43	19.4	16	45
487-02	111.0	9.0	1.1	104.3	0.36	0.30	12.33	32.4	13	58
487-03	124.9	9.0	1.2	100.0	0.36	0.37	12.00	33.5	7	55
487-04	168.5	9.1	1.7	102.6	0.73	0.22	17.49	37.4	6	49
Minimum	110.8	7.5	1.1	70.7	0.36	0.22	12.00	9.5	6	33
Maximum	190.3	9.1	5.2	125.3	14.39	12.54	34.95	37.4	46	58
Arithmetic mean*		-	2.1	94.8	2.84	2.10	18.37	11.7	22	46
Standard dev		-	1.2	16.4	4.45	3.97	6.91	-	14	9

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.

Table 17.E-12 (Continued)

Area 4	Clay (%)	CaCO3 (%)	Total sulfur (%)	Acid potential total sulfur (t/kt)	Neutralization potential (t/kt)	Acid-base potential total sulfur (t/kt)	Boron (ppm)	Total selenium (ppm)	Soluble selenium (ppm)
498-06	29	4.91	0.439	13.7	48.6	34.9	0.52	0.33	0.047
407-32	20	8.26	0.378	11.8	82.6	70.8	0.97	0.48	0.060
407-33	27	8.33	0.483	15.1	83.3	68.2	1.38	0.46	0.082
407-34	29	6.30	0.499	15.6	63.0	47.4	1.29	0.41	0.103
487-01	39	5.19	0.450			37.8	1.91		0.102
487-02	27	5.00	0.626			30.6	0.94		0.078
487-03	37	11.80	0.614			102.7	0.91		0.073
487-04	46	8.78	0.422			69.3	1.06		0.118
Minimum	20	4.91	0.378	11.8	48.6	30.6	0.52	0.33	0.047
Maximum	46	11.80	0.626	15.6	83.3	102.7	1.91	0.48	0.118
Arithmetic mean*	32	7.32	0.489	14.1	69.4	57.7	1.12	0.42	0.083
Standard dev	8	2.26	0.083	1.5	14.5	22.9	0.38	0.06	0.022

* Arithmetic mean of the weighted mean values for parameters for each interburden layer except SAR. Arithmetic mean of SAR is calculated from the arithmetic mean values for calcium, magnesium, and sodium.