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Final Data Summary and Analysis Report

Subsidence Drilling Investigation
Red Lodge, Montana

Prepared for:

Montana Department of Environmental Quality
Remediation Division
Abandoned Mines Lands Section
PO Box 200901, Helena, Montana 59620

Prepared by:

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May 2015

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EXECUTIVE SUMMARY

This Data Summary and Analysis Report (DSAR) describes the data collected during the Red Lodge Subsidence Drilling Investigation and presents the engineering analyses conducted based on that data. Work included survey monitoring and subsurface investigation, which involved excavation of hand auger and test pit holes, and drilling/installation of bore holes. Survey monitoring work began in January 2014 and continued quarterly throughout the year. Drilling field work began on August 15, 2014 and was originally anticipated to take 6 weeks. However, difficult subsurface conditions resulted in slower than expected progress and the work took nearly 12 weeks; consequently, drilling was completed on November 4, 2014.

The primary objective of this effort was to gather information to evaluate subsurface conditions and assess the condition of abandoned underground coal mine tunnels and pillars in the vicinity of several homes within the City of Red Lodge, Montana. As many as seven coal seams underlying this part of Red Lodge were mined in the early 20th century. The coal seams are located in sandstone and claystone bedrock, which is overlain by 14 to 111 feet of alluvial gravel and boulders. The seams vary in depth and condition, with depths below ground surface ranging from 50 feet to over 700 feet. The seams are numbered from 1 to 5: number 1 being nearest the ground surface. Eight boreholes were drilled, field logged, and sampled. The information gathered from the boreholes was utilized to assess the potential of mine-induced subsidence.

The drilling work was performed in two phases:

1. Phase I involved drilling through the upper alluvial layers of gravels and boulders to bedrock and installing a temporary steel casing.
2. Phase II involved a core drill rig which was set up over the steel casing to core the underlying bedrock. Core samples collected from this work are used to evaluate the occurrence or potential for subsidence due to collapsed mine workings. This work also verified the presence, location, and condition of mine workings or coal seams.

The locations, drilled depths, and conditions at each hole are listed in Table ES-1. The table also includes coal seams encountered at each location. The method of mining employed left pillars of coal in place next to mined-out rooms; if the coal seam encountered in drilling was intact, it means that either a pillar was found or that part of the seam was not mined. Bedrock core was collected continuously and observations were made regarding the strength and condition of this rock, especially in the region immediately above or below a coal seam.

A monitoring device (extensometer) was installed in one borehole (BH02) to detect vertical movement of the bedrock. This device will be monitored over the course of 2015. Data from this device will be used to determine if any active movement of the bedrock immediately above the mine workings is occurring. The data logger for the extensometer is set to record displacements on a daily basis and information is scheduled to be downloaded quarterly during survey point monitoring. Information from the data logger is incomplete at this stage and will be reported in an addendum to this DSAR.

Table ES- 1. Location and Depth of Bore Holes

HOLE	LOCATION	TOTAL DEPTH (FT.)	6" STEEL CASING (FT.)	DEPTH COAL SEAM ENCOUNTERED	MINE WORKINGS/VOIDS ENCOUNTERED
BH01	25 14th St W	459	119	No.4–234 ft; No.4½ –253 ft; No.5–369 ft	In the No.4 seam a 1-ft void was encountered at depth of 234 ft; other coal seams were intact or collapsed.
BH02	207 S Hauser (on Oakes Ave)	379	109	No.4–173 ft; No.4½ –195 ft; No.5– 316 ft	No voids or collapse – coal seams intact.
BH03	501 Broadway (on E 16th St)	679	99.5	No.1½ – 160 ft; No.2–243 ft; No.3–326 ft; No.4–472 ft; No.4½ – 494 ft; No.5 – 613 ft	In the No. 5 seam a 6-ft void was encountered at a depth of 622 ft; other coal seams were intact or collapsed.
BH04	505 Platt	653	54	No.1– 50 ft; No.1½ – 168 ft; No.2–248 ft; No.3–333 ft; No.4–472 ft; No.4½ –501 ft; No.5 – 609 ft	In the No.4 seam a 1-ft void was encountered at a depth of 472 ft; all other coal seams were intact or collapsed.
BH05	511 Haggin (East side of street)	679	34	No.1– 60 ft; No.1½ – 180 ft; No.2–254 ft; No.3–341 ft; No.4– 478 ft; No.4½ –503 ft; No.5 – 623 ft	In the No.4 seam a 2-ft void was encountered at a depth of 478 ft; all other coal seams were intact.
BH06	524 Broadway (on E 17th St)	744	74	No.1– 143 ft; No.1½ – 261 ft; No.2–337 ft; No.3–423 ft; No.4–566 ft; No.4½ – 583 ft; No.5 – 706 ft	In the No.2 seam a 5-ft void was encountered at a depth of 337 ft; all other coal seams were intact.
BH07	404 S Broadway (on E 15th St)	549	99	No.2–116 ft; No.3 –200 ft; No.4 –342 ft; No.4½ – 365 ft; No.5 – 493 ft	In the No.4 seam a 4-ft void was encountered at a depth of 342 ft; all other coal seams were intact.
BH08	Rodeo Rd (750 feet north of Rodeo Grounds)	269	59	No.1½ – 119 ft; No.2 – 209 ft	In the No.1½ seam a 2.5-ft void was encountered at a depth of 119 ft; No.2 seam was collapsed.
TOTALS		**4,397**	**647**		

Other exploratory work conducted included:

1. Excavation of a test pit near the intersection of Platt Avenue and 17th Street to assess surface soils in an area showing an apparent surface depression.
2. Excavation of two shallow hand auger holes to assess surface soils at 505 Platt Avenue.
3. Coring concrete and excavation of six hand auger holes to investigate floor subsidence at the Police Station shop.

Survey monitoring started in January 2014, with the goal of measuring elevations to determine if any ground movement is occurring in the vicinity of the residences in question. The area is roughly bounded by Hauser Avenue on the west, Haggin Avenue on the east, 13th Street on the north, and 17th Street to the south. Survey work included:

1. Installation of survey monitoring monuments and establishment of monitoring points to measure.
2. Installation of foundation crack gages at existing cracks on home foundations.
3. Quarterly survey of elevations and crack gage measurements.

A total of 90 survey monuments and 8 crack gages were installed on and around residences of interest. The survey work will be continued on a quarterly basis in 2015 to obtain another year of data.

Extensive research was conducted regarding the mining history, mine locations and conditions, subsidence of underground coal mines in other locales, and previous studies in the Red Lodge area. This research is incorporated throughout the report.

An engineering analysis of the data collected from the drilling investigation was performed to determine the likelihood and magnitude of past, present, and future ground surface movement caused by the underground coal mine workings. Ground surface displacements from failure of room and pillar mines can occur through the following mechanisms:

1. Pothole Subsidence; and
2. Trough Subsidence.

Pothole, or sinkhole, subsidence occurs in areas overlying underground mines which are relatively close to the surface. Pothole subsidence is fairly localized and can express as a steep-sided pothole or shallow-sided pothole formation on the surface. Steep-sided potholes are the most familiar and damaging to structures.

Trough subsidence occurs over abandoned mines when the overlying soils (or overburden) sags downward due to the failure of remnant mine pillars or by punching of the pillars into a soft mine floor. The resultant surface effect is a large, shallow, and broad depression of the ground surface.

The following items summarize principal findings and conclusions of the investigation and analyses:

1. **Structures of Interest:**
    a. 207 South Hauser Ave. – Reported observation of a subsidence feature combined with drilling observations is cause for additional investigation and continued monitoring.
    b. 501 South Broadway Ave. – No definitive evidence of mine-related subsidence was found.
    c. 505 South Platt Ave. –No definitive evidence of mine-related subsidence was found; however, the observed surface depression located parallel to Platt Avenue warrants continued monitoring and possible additional investigation.
    d. 404 South Broadway Ave. – Observation of an undocumented opening in conjunction with disruption of the bore hole casing and the resident's reported subsidence observations warrants continued monitoring and additional investigation to provide definitive causality.
    e. Police Station – No evidence was found that floor subsidence was caused by mining-related activities.

2. **Extent of Mining:**
   Historic documentation of the abandoned mines is fairly well preserved with the exception of seam No. 2. The absence of mine data for seam No. 2 greatly inhibits the interpretation of potential subsidence features in the Southeast section of the study area.
3. **Existing Mine Conditions:**
   The mine conditions were observed to range between fully open (6 feet of void in BH06) to completely converged. Mine workings that are not totally collapsed may continue to slowly deteriorate such that further collapse ensues. Based on the fact that the mining occurred over 100 years ago, any further collapse would likely occur over a long period.
4. **Overburden Materials:**
   Natural conditions within the overburden materials that are able to cause surface subsidence were not observed. Although a thin veneer of non-native fill material was observed in hand auger holes and test pits in the Finn Park area, this material, if improperly constructed on, could be responsible for structural settlements but is not likely to cause surface subsidence features.
5. **Pothole Subsidence:**
   Most of the workings are at depths where chimney failures, which can lead to pothole subsidence, are likely to self-arrest before reaching the upper limit of the bedrock. Pothole subsidence is possible in locations of the city where bedrock thicknesses are less than approximately 150 feet (Figure 8-13). Hazardous, steep-sided pothole subsidence (ie. Sinkholes) are considered highly unlikely anywhere. Shallow-sided pothole subsidence may be possible in areas of lesser bedrock thickness. The likelihood of a future pothole of this nature to affect any one resident is very low, considering only two are suspected to have developed over the past 75 years.
6. **Trough-type Subsidence:**
   Potential vertical settlement is estimated to be on the order of 3 to 7 inches, depending on the size of mine room collapse. Considering the abandoned mines below Red Lodge have likely been slowly degrading and collapsing for the past 75 years and within this time frame no significant observations regarding subsidence have been made, future trough-type subsidence are likely to remain slow and may accumulate over the next 50-100 years. Building damage resulting from this slow deterioration is estimated to be localized and structural damage may be on the order of slight to appreciable. Building size and orientation with respect to the collapse feature are key factors affecting the amount of potential structural impacts.

Figure ES-1 shows areas recommended for continued monitoring and additional investigation. The recommendations include:

1. Continued survey, crack gage, and extensometer monitoring through 2015. Add monitoring points in strategic locations, such as the Civic Center and along the west side of Platt Ave., 500 block. The area located north of 14 St. S, between Villard Ave. and Hauser Ave., encompasses the structure of interest at 207 South Hauser Ave.

2. If monitoring shows the potential for a problem, initiate additional investigative work, which may include:

   i. Install and monitor additional extensometer(s) or inclinometer(s);
   ii. Evaluate the potential effectiveness of and conduct a geophysical investigation; and
   iii. Install additional bore hole(s).

3. Evaluate the potential effectiveness of a seismic geophysical investigation to:
   i. Locate and map the No. 2 mine workings. This would include the area between Broadway and Haggin, from 17th St. South to 14th St. South and also encompass the area in the vicinity of BH03.
   ii. Investigate possible causes (both near-surface and mine-related) of the depression located at 505 South Platt Ave.
   iii. Investigate possible causes (both near-surface and mine-related) of the depression located at 207 S. Hauser Ave.

LEGEND

- PIONEER TEST PIT
- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014
- STRUCTURES OF INTEREST

RECOMMENDED WORK

- CONTINUE MONITORING. CONDUCT GEOPHYSICAL INVESTIGATION
- CONTINUE MONITORING

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY; PIONEER; CN; KIEWET

0 200 400 800
Feet

FIGURE ES-1

PIONEER TECHNICAL SERVICES, INC.

AREAS RECOMMENDED FOR CONTINUED MONITORING AND ADDITIONAL INVESTIGATION

DATE: 3/12/2015

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\Monitoring_ES.mxd

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List of Acronyms

HQ3: Wireline Triple Tube Coring System, Core/Hole Outer Diameter = 2.41/3.78 inches
PQ3: Wireline Triple Tube Coring System, Core/Hole Outer Diameter = 3.27/4.83 inches
HWT: Drill rod used in conjunction with PQ-3 coring System
DSAR: Data Summary and Analysis Report
DEQ: Montana Department of Environmental Quality
USCS: Unified Soil Classification System
RQD: Rock Quality Designation
ASTM: American Society for Testing and Materials
CO: Carbon Monoxide
LEL: Lower Explosive Limit

1 INTRODUCTION

This Data Summary and Analysis Report (DSAR) presents results and preliminary engineering assessment of field sampling activities that were completed between August 15, 2014 and November 4, 2014 by Pioneer Technical Services, Inc. (Pioneer) under contract to the Montana Department of Environmental Quality (DEQ) to support an evaluation of historic coal mines beneath the City of Red Lodge, Montana. Data presented in this DSAR are intended to be used to assess the geotechnical condition of the abandoned coal mine workings and overlying materials.

Several residents within the town expressed concern over whether collapse of underground mines could lead to surface subsidence, which may present a current or future threat to their homes and property. The purpose of this investigation was to collect data necessary to assess whether ground and structural deformations (in buildings) observed in the City of Red Lodge, Montana are related to abandoned coal mines known to exist beneath parts of the City and whether future collapse of those mines may result in damage to properties. Specific objectives were:

1. Complete a subsidence drilling investigation to identify the character of subsurface materials, the condition of the existing workings, and providing necessary data to assess subsidence potential;
2. Compile historic and new subsidence-related data into a common data base; and
3. Provide the DEQ with a data evaluation and recommendations.

Work completed under this investigation and described in this DSAR included the following:

1. Develop a drilling investigation plan to assess the subsurface conditions in the vicinity of the homes in question;
2. Complete geotechnical drilling to define:
    a. Thickness of alluvium and depth to bedrock,
    b. The location and depth to historic mine workings,
    c. The geomechanical properties of bedrock materials, and
    d. The condition of historic mine workings;
3. Collect and geotechnically describe the overburden materials; collect continuous HQ3 and PQ3 core through bedrock and mine workings for geotechnical analysis;
4. Observe in detail the drilling activities, describing the presence of voids, condition of the mine roofs and floors, and character of rock mass;
5. Conduct an investigation of the Police Station shop floor to determine whether the observed floor settlement might be associated with mining-related activities;
6. Conduct a limited geotechnical test pit and hand auger investigation of surface soils along Platt Avenue to evaluate soil conditions and types;
7. Compile recent geotechnical data with historic maps and preexisting data;
8. Conduct an assessment of subsurface data; and
9. Surface monitoring.

Preceding and occurring concurrently with the drilling investigation, a survey monitoring program has been conducted and is ongoing within the study area. The purpose of this monitoring program is to measure ground elevations and positions regularly to determine whether active movement is occurring in these areas that could be associated with the mine workings.

The following information is included in this report:

1. Objectives of the investigation;
2. Summary of mining history;
3. Police Station shop floor investigation findings;
4. Platt Avenue soils investigation findings;
5. Locations of all bore holes;
6. Field documentation;
7. Description of sampling methods;
8. Description of field monitoring devices;
9. Detailed location of historic mine workings;
10. Cross sections of subsurface overburden, bedrock, and mine workings;
11. Summary of survey monitoring data to date;
12. Data assessment and engineering analyses; and
13. Conclusions.

Appendix A contains bore hole and test pit logs; Appendix B contains photographic documentation of the field work.

2 PROJECT DESCRIPTION

2.1 Project Location

The City of Red Lodge is located in south-central Montana, approximately 60 miles southwest of Billings. The legal description of the area is Section 27 and Section 34 of Township 07 South, Range 20 East. The majority of the work was roughly bounded by Hauser Ave. on the west, Haggin Ave. on the east, 13th St. on the north, and 17th St. to the south. Figure 2-1 shows the site location.

2.2 Red Lodge Area Geology

Surface geology of Red Lodge is presented in the geologic Map of Carbon County, Montana (Lopez, D.A., 2005). Local surface geology typically consists of coarse-grained alluvium overlying the Fort Union Formation Tongue River Member. Observed alluvial gravels beneath the City of Red Lodge, within the area shown on Figure 2-1, vary between 14 to 111 feet in thickness. The alluvial gravels beneath the city are Pleistocene in age and are described as a series of glacial outwash (alluvial fan) deposits emanating from the mouth of Rock Creek. During times of deposition (Pleistocene), the alluvial fan surface was likely uniform in elevation

above the city, similar in elevation to the east and west bluff, and have since eroded to the current levels.

The Tongue River Member is generally described as fine- to medium-grained sandstone, interbedded with carbonaceous shale, siltstone, and coal beds (Lopez, D.A., 2005). The dip of the beds is 18 degrees (north to south) at Red Lodge and decreases southeastward to 9 degrees in the western part of Bear Creek and to 3 degrees a short distance further to the south (Woodruff, 1909). Specific details of the bedrock lithology are described later in this report.

2.3 Project Background and Site History

An extensive account of the historical development of mining in the Red Lodge area is provided in *Reclamation Recommendations, Red Lodge Coal Field – Red Lodge, MT, Phase I Report* by Kiewit Mining and Engineering Co. (Kiewit, 1983). For this report, the background and site history focuses on information specific to mine stability (e.g., extent of mining, mining methods, historic observations, and workings development timing). The Kiewit information is summarized in the *Report of Investigation, Red Lodge/Bear Creek Subsidence Potential Study* by Chen Northern, Inc. (Chen Northern, 1987).

Two distinct districts were developed in the City of Red Lodge: first, the Eastside Mine District (also known as the Old mine) and several years later the "Westside Mine" (also known as the "Sunset Mine") (Rowe, 1910). The Eastside mine was opened prior to 1882, but until 1889 conducted operations on a small scale. By the end of 1907 the Westside mine buildings and opening had been constructed (Woodruff, 1909).

The mines within the Eastside mine district were sequentially opened in the order of No. 4, 2, 5, and lastly the 1½ (Parsons, 1907a). Initially, a slope was sunk on the No. 4 seam; the No. 2 and No. 5 mines were worked through tunnels. The slope of the No. 4 was timbered with long stingers, posts and caps were used in parts of the entries, and props and stulls were used in the rooms (Hogan, 1891).

In 1905, the No. 4 seam was the best developed bed; five levels had been driven east and four levels driven west (Rowe, 1905). By 1907, Bed Nos. 1, 1½, 2, 4, 5, and 6 had been developed and worked, although the most extensive operation remained in the No. 4. Levels extending from beds other than the No. 4, in 1907, were described as "In Bed No 1 there are 10 rooms, in bed No 1½ 31 rooms, and in bed No. 2 four east and three west levels, but some are not being worked."(Darton, 1907).

Regarding specific mine conditions, in 1907, Parsons states, "The No. 5 seam has a bad top and bottom and as consequence many creeps have occurred entailing the loss of considerable coal. The general scheme in working this latter seam is to leave 5 feet of coal as a supporting roof and work the remaining 7 feet." He also describes the conditions of the No. 2 bed as "In the No. 2 bed the top is good while the bottom is poor. This condition necessitates leaving large pillars to prevent the bottom from heaving or the coal from sinking into the 12 foot seam of clay underlying the seam… …The miners on the No. 2 seam undercut the coal before shooting, but in

many other places the coal is shot from the solid, probably one-half of the entire output being obtained." (Parsons, 1907b)

In a 1908 report titled *Some Economic Geology of Montana* Rowe further describes the development, progress, and conditions in the Eastside mine district: "This property is worked from two main "entry ways" or "slopes" No. 2 and No. 4 slopes… Seams Nos. 1, 1½ , 2, 4, 5, and 6 are the only ones now being worked… Coal has been mined from Beds 1, 1½, 2, 3, 4, 4½, 5, 6, and 7, but the main operations have been confined to the Nos. 1, 2, and 4." (Rowe, 1908)

Rowe goes on to describe mining methods and geometry for the No. 4 seam:

> "No. 4 is the best worked seam on the mine. This seam has six east and four west levels… The sixth level east of seam No. 4 is underwater… The method of working all of the seams and levels is by room and pillar. The distance of the rooms from center to center is 70 feet. The general distance between levels is 550 feet. A good substantial pillar is left between rooms, and after the rooms are worked out the pulling of the pillars is undertaken. This latter is a thing that has not appeared to have been generally done in the Red Lodge mines, hence not a large percent of the coal has been taken from each level. During the past year and for the future this work will be done, and at least half or more coal from each level will be mined."

According to *The Engineering and Mining Journal* (1908), on November 20, 1908, a fire started in the second drift, east from the No. 2 slope, killing six miners and probably many more.

In a 1910 article titled *Red Lodge and Bear Creek Coal Mines*, Rowe describes the additional progress within the No. 4 seam, water conditions, and pillar pulling practices up to the date of authorship (Rowe, 1910):

> "The Eastside mine or Old mine has been worked for several years. The main slope on No. 4 is now in over 3,850 feet or 3,700 feet horizontal from the portal. The 5th level east of No. 4 is worked out, but was driven in over 8,900 feet. The 4th level east which has produced more coal than any other level in the mine is now worked out, but was worked for over 9,900 feet from the main slope of No. 4. This level was quite dry as were most of the levels and yielded a good grade of sub-bituminous coal. All of the levels of No. 4 bed above and including No. 5 have been worked. Some of them, however, have not had all the pillars pulled and from the way the mine was worked some four or five years ago, the pulling of these pillars would now be unprofitable and extremely dangerous. At present, when rooms are worked out the pillars are pulled. Some few years ago the pillars were left standing for a long time after the rooms were worked out, before any attempt was made to pull them. One can readily see the impracticality of this and also the danger."

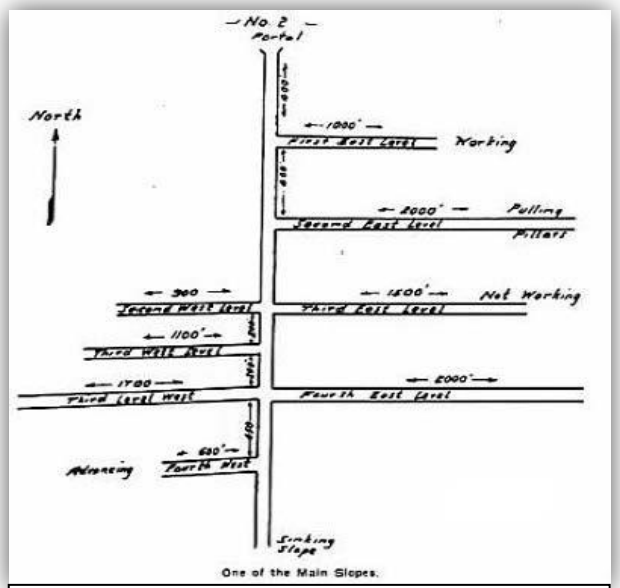
In the same article Rowe further describes a change in room and pillar mining to pillar and stall mining, mine geometries, and progress of the No. 4 mine:

"The method of working the mines is by pillar and stall practice; working the rooms in batteries of six, the rooms being 25 feet wide and 60 feet between centers, thereby leaving a pillar 35 feet wide between rooms. Between batteries a pillar ranging from 60 to 120 feet is left. The distance level is 550 ft. It may readily be seen when the pillars were not pulled and left remaining, but 41% of the coal was recovered.

The second level west of the seam No. 4 is 5700 ft. This is all old work and it is the farthest west yet worked in the mine. The 5th level west on the No. 4 seam is now being worked and is in 3200 ft. The 6th level west on No. 4 seam was recently started and is now about 700 ft. So it may be readily seen that No. 4 seam is by far the best worked bed in this district. On the east side of No 4 bed levels No's 6, 7 and 8 are being worked; and on the west side of Bed No. 4 levels 5 and 6 are being worked. However, the chief places where coal is now being mined at the Old or Eastside mine are the 5th level west on Bed No. 4 and the 6th and 7th levels east on No. 4.

The Eastside or Old mine is one of the oldest large producers in Montana… The seams being worked are Nos. 1½, 2, 4, 5, and 6."

Rowe also presents a figure of activity within the No. 2 slope and seams. The figure (reproduced to the right) shows four east levels and four west levels. The first level east is actively being worked, pillars are being pulled from the second level east, the third level east is not being worked. Based on the author's labels, the second level west is driven 900 feet, the third west level is driven 1,100 feet, the third level west is driven 1,700 feet, and the fourth west level is driven 600 feet and is being advanced.



1910 Diagram of No. 2 Slope and Seams

As mining methods progressed, according to Palmer (1914), "At the East slope, work has been changed recently so that the rooms are driven across the pitch instead of with the pitch, the rooms being turned from the latter and this simplifying the work of gathering."

According to Kiewit Mining Co. (1983), by around 1922 more economical mines were opened and coal extraction in Red Lodge was reduced. In 1932 the mines were closed.

DEQ provided digital copies of historic mine maps. **Error! Reference source not found.** presents a list of the workings maps showing the dates of creation and the last revisions. As evidenced by the above narrative, coal bed Nos. 1, 1½, 2, 3, 4, 4½, 5, and 6 were mined in the

Red Lodge Coal Mine (Rowe 1908). Beds worked within the boundaries of this study include Nos. 1½, 2, 4, and 5 (Figure 2-2).

Since the mines have closed, several studies have been conducted to address the environmental impact of the abandoned workings (Kiewit, 1983), cultural significance (GCM Services, 1983), subsidence potential (MBMG, 1961 and Chen Northern, 1987) and subsidence investigations (Dowl-HKM, 2011a, Dowl-HKM, 2011b, Gradient Geophysics, 1999).

3 POLICE STATION INVESTIGATION AND RESULTS

The Red Lodge police station is constructed of a prefabricated metal building attached to the rock masonry City Hall. A portion of the steel building houses the police department administrative offices while the other portion is used as a garage to store police cars and equipment. The police station is founded on spread footings and has a slab-on-grade floor system. A floor drain runs along the entire length of the concrete floor. The construction date of the prefabricated steel building is unknown but is thought to be in excess of 30 years old.

A portion of the slab-on-grade floor has settled 6.4 inches. Due to the settlement and subsequent negative gradient, the floor drain no longer works in this area of the police station. DEQ and Pioneer speculated that the settlement may be attributed to constructing the building on top of coal slack which was historically located in the area.

To investigate if coal slack is under the police station floor, five hand auger holes (PS-01 through PS-05) were advanced through the floor on November 18, 2014. The holes were advanced by coring a 6-inch diameter hole through the concrete floor and then using a 2-inch diameter hand auger to drill through the soils. The hand auger holes varied in depth between 1.8 feet and 5.6 feet and were advanced until auger refusal. Hand auger refusal occurred when the hand auger bit hung up on a rock particle and could not be advanced to a deeper depth.

PS-01, PS-03, and PS-04 were located in the area that had settled and each contained a void between the concrete floor and subgrade soils. PS-02 and PS-05 were located outside of the settlement area and did not have void between the concrete and subgrade soils. In the deepest hole, PS-02, a very soft silty sand layer was observed between the 3.5- and 5.0-foot depths. A summary of the hand auger holes is shown in Table 3-1 and a detailed description of the soil lithology is included in the hand auger logs in Appendix A. A brief description of observed hole conditions at each location follows:

- Hole PS-01 – Concrete (4.75"); Void (0.75"); Gravel and sand, coal and brick fragments.
- Hole PS-02 – Concrete (5"); Gravel and sand, glass, coal, brick, and plastic fragments.
- Hole PS-03 – Concrete (5.25");Void (2"); Sand and silt.
- Hole PS-04 – Concrete (5"); Void (1.5"); Sand and silt, brick and glass fragments.
- Hole PS-05 – Concrete (5.5"); Sand and silt.

A plan view of the police station floor, hand auger hole locations, and survey reference locations are displayed in Figure 3-1.

4 GEOTECHNICAL TEST PITTING AND HAND AUGER HOLES

4.1 Test Pit

One test pit (TP-01) was excavated on the northwest corner of the intersection of Platt Avenue South and 17th Street East on November 18, 2014. The test pit was excavated in the gravel-surfaced parking area between 17th Street East and a private residence located at 521 Platt Avenue South. Figure 4-1 shows the location of the test pit in plan-view. The test pit was visually aligned, in a north-south direction, with the house/front porch interface at 521 Platt Avenue South. Based on utility locate information, a City of Red Lodge water main runs in an east-west direction near the southern edge of the test pit.

The test pit was excavated to a depth of 6.0 feet using a John Deere 410D backhoe owned and operated by Mountain Excavation Inc. Two soil profiles were observed within the test pit, one on the south side of the test pit near 17th Street and one on the north side of the test pit near 521 Platt Avenue South. The southern soil profile primarily consisted of fill and was attributed to waterline backfill. The northern soil profile consisted of fill and alluvial soils and is described in more detail in the test pit log included in Appendix A.

4.2 Hand Auger

The residence at 505 Platt Avenue South is a single story, wooden framed house with a concrete foundation. There is an attached front porch and two detached out buildings near the alley. The house was reportedly constructed in the Bear Creek area and moved to its current location in the 1940s. Prior to 2014, the front porch settled and the residents jacked up the porch and rested it on timbers. Concrete steps leading to the front porch also settled and were removed. The residents suspected the settlement might be related to historic mining activities and reported the settlement in a letter to the DEQ dated March 23, 2011. Subsequently, DOWL HKM performed multiple site visits to inspect the residence in 2011. These investigations and DOWL HKM's conclusions were listed in a memorandum to the DEQ dated November 3, 2011 (DOWL HKM, 2011b). One of the conclusions of the memorandum stated "there are many reasons for the settlement of flatwork and foundations that are unrelated to mine subsidence." Some possible contributing factors to settlement listed by DOWL HKM include:

1. Age of flatwork and foundation,
2. Type of construction,
3. Foundation depth, soil, and rock type present below foundation and/or porch,
4. Depth to groundwater or groundwater fluctuations,
5. Utility related issues,
6. Extreme weather conditions, and
7. Tree roots.

The Anderson residence is located in the Finn Park neighborhood. Conversation with City officials and residents indicate that this area of Red Lodge was in a lower area of town and the

residents used fill to push Rock Creek further to the east and then construct the neighborhood. Further discussion of this is provided in Section 8.1 below.

Two hand auger holes (BH04a and BH04b) were completed in the front and back yard of the residence at 505 South Platt Avenue. The location of 505 South Platt is shown in Figure 4-1 and the location of the hand auger holes relative to the house is shown Figure 4-2. Hand auger refusal was encountered at the 3.0-foot depth in BH04a and the 4.5-foot depth in BH04b, potentially the top of the alluvial gravels. In each of the hand auger holes, the soil was considered non-native fill due to the debris observed throughout the profile. Native alluvial sands and gravels were not directly observed in either of the hand auger holes. A detailed description of the drilling and lithology for each of the holes is provided in Appendix A and summarized in Table 4-1.

5 Geotechnical Overburden and Bedrock Drilling Methods and Results

5.1 Drilling and Sampling Methods

The intent of the drilling investigation was to determine the thickness of alluvium, locate historic mine workings, identify geotechnical soil and rock properties, and assess structural conditions of historic mine workings. A total of eight bore holes were completed, field logged, and sampled during the investigation. Locations are shown in Figure 5-1. Bore hole locations were selected based on review of historic mine maps, access to the drilling location, and the site utilities, and were generally placed in the vicinity of a residence that had voiced concern to DEQ. The actual drill locations were adjusted as necessary to accommodate equipment access. Drilling was completed in two phases: surface casing installation through overburden materials and core drilling.

A field log book and drill logs were maintained during field sampling. Bore hole logs have been created for each of the drill holes and are included in Appendix A. The bore hole logs provide USCS soil classification, lithology descriptions, Rock Quality Designation (RQD), fracture data, indirect strength testing, total bore hole depth, and the presence of water (when applicable). Field log books and bore hole logs for this investigation are maintained on file at the Pioneer office in Helena, Montana.

Stratification lines shown on the bore hole logs represent the approximate boundary between soil and rock types as observed in the bore holes. The actual *in situ* transition may be either gradual or abrupt and typically changes within the limits of the investigation. Due to the depositional characteristics of natural materials, care should be taken in interpolating subsurface conditions beyond the location of the bore holes.

5.2 Phase 1: Surface Casing Installation

Phase 1 drilling work was performed by O'Keefe Drilling of Butte, Montana under contract with Pioneer. The drilling work was completed with a Foremost Dual Rotary (DR-24) drill rig which

advanced 6-inch steel casing through the overburden. The bottom of the steel casing was generally set at a depth between 5 and 15 feet into bedrock. Overburden materials, which were typically glacial outwash, are referred to as alluvial gravels for the remainder of this report. These overburden materials ranged between 14 to 111 feet in thickness.

Field data collection consisted of bore hole location; date and time; soil profile/lithology descriptions, including USCS soil classification; sample numbers; sample depth intervals; personnel present; and associated organization. Pioneer also noted the presence of water observed during the drilling.

Sampling was generally completed at 5-foot intervals or at specific depths determined by the geotechnical engineer. Due to the air-rotary drilling method, samples are disturbed and suitable only for approximate classification purposes. Pioneer visually classified all soils in accordance with ASTM D2487 (USCS). Subsurface conditions interpreted from the field observations, drill performance, and water production from the holes during the drilling process were noted on the drilling logs. Samples consisted of materials collected from the cutting shoot of the drill rig. Samples were sealed in one-gallon plastic bags and transported to the on-site storage facility.

5.3 Phase 2: Core Drilling

Phase 2 work was performed by Axis Drilling of Belgrade, Montana under contract with Pioneer. The drilling work was completed with a Christensen CS1500 core rig. The core rig set up over each of the 6-inch steel casings and installed 5.5-inch HWT casing inside the 6-inch casing to provide lateral support for the drill stem. Continuous coring was initiated with PQ-3 (3.3/4.8-inch inner/outer diameters) through the upper bedrock, typically until the first workings were encountered, at which point HQ-3 (2.4/3.8-inch inner/outer diameters) drilling was initiated. PQ-3 drilling was performed with a 5-foot core barrel and splits. Upon switching to HQ-3, the PQ-3 core barrel and drill string were removed and re-advanced with a casing shoe to allow for continued drilling through the PQ-3 drill stem. HQ-3 drilling was performed with both 5- and 10-foot core barrel and splits. All holes were completed with HQ-3 drilling methods. Drilling fluids were managed with a drill-through tank.

Core drilling field data collection consisted of date and time; sample depth intervals; rock lithology and lithologic descriptors, bedding and foliation texture, weathering, hardness/strength, contacts, discontinuities (fracture dip and mode), RQD, core recovery, and drill fluid circulation. Subsurface conditions interpreted from the field observations, drill performance, and fluids circulation during the drilling process was also noted on the bore logs. Notes also were made regarding personnel present and their associated organizations.

During core logging, select samples were tested for unconfined compressive strength by method of the Shore Scleroscope (International Society for Rock Mechanics, 1981). Correlation between Shore hardness (S_h) and unconfined compressive strength was made with the empirical relationship provided in Deere and Miller, 1966. This empirical relationship provides correlation between the two parameters and dispersion limits defined for 75% confidence.

5.4 Down-Hole Camera

A down-hole camera was used to evaluate the existing mine workings. The camera was loaned to the DEQ by the Office of Surface Mining and was able to record video footage to a depth of approximately 500 feet. The camera was lowered into bore holes BH01, BH03, BH04, BH05, BH07, and BH08. Usable video was recovered only from bore holes BH01, BH07, and BH08 due to the cloudiness of the water in the bore holes.

5.5 Extensometer

One extensometer was installed during the field investigation. An extensometer is a device designed to measure vertical subsurface movements. Extensometers are composed of an anchor, a small diameter stainless steel rod, a PVC sheath, and a displacement recording device. The anchor and rod are mechanically connected to the ground at a depth where vertical displacement measurements are desired, say 120-125 feet below the surface. The stainless steel rod extends from the anchor to the surface. The bore hole volume above the anchor is backfilled with either a neat cement or bentonite to hold the rod in place laterally. Prior to backfilling the bore hole, a PVC pipe is installed over the steel rod to isolate it from the backfill material. At this stage, a rod is mechanically attached to the subsurface at a depth of 120-125 feet; the rod is free to move vertically above 120 feet. If the materials between 120 to 125 feet move vertically, the end of the rod at the surface will move the same amount. At the surface a measuring device is installed to monitor vertical movement of the steel rod and thus measure vertical movement at the depth of the anchor.

An Extensometer was installed in bore hole (BH02), at a depth of 124 feet below the surface. A second extensometer was proposed for installation in bore hole BH07, but subsurface conditions did not allow for the installation; more detail is provided later in this report.

5.6 General Stratigraphy

Several early reports document the individual coal beds within the Red Lodge Coal Field, the earliest being J.E. Wolff presented by G.H. Eldridge in 1886. The earliest presentations of complete stratigraphic sections distinguishing the coal seams (as named by the Mines, Nos. 1, 1½, 2, 3, 4, 4½, 5, 6, 7, 8, and 9) was completed by N.H. Darton in 1907 and E.G. Woodruff in 1909. The two sections are similar but not identical; according to the authors, the difference in coal seam thickness may be explained as each section was created from different measurement points. The section by Woodruff was measured along the east bluff of Rock Creek; due to this proximity to the current site investigation, it is used as a point of reference in this report.

Figure 5-2 shows an illustration of the generalized coal beds logged in each bore hole adjacent to the stratigraphic sections presented by Darton and Woodruff. The bore hole columns are drawn by assigning the No. 4 seam to the stratigraphic depth of 362 feet reported in Woodruff; beds above and below are drawn relative. Cross-sections in Figure 5-3, Figure 5-4, and Figure 5-5 show the depth and location of beds Nos. 1 through 5; section locations are shown in plan-view in Figure 5-1. Table 5-1 presents the depth below ground surface where the roof and floor of each seam was observed.

5.7 Bore Hole Lithology Descriptions

A description of the soils/rock lithology and pertinent observations made by both the driller and the geotechnical engineer during the drilling is discussed in the following subsections. The narrative is only a brief description of the information recorded during the logging process; additional information is recorded on the bore hole logs and in a summary provided in Appendix A. Specific photographs of core samples are referenced in the discussion of bore hole BH05 and presented in Appendix B.

5.7.1 Bore Hole Rock Quality

Rock Quality Designation (RQD), a parameter describing the degree of jointing or fracture in a rock mass, was calculated for each core run. RQD was recorded during the entire drilling process and is an important indication of rock strength and stability.

RQD is determined by summing the length of core pieces longer than 4 inches and dividing this value by the length of the run, typically five or ten feet. The resulting value (RQD) is a number that is qualitatively associated with five divisions of rock mass quality as indicated in the list below (after Bieniawski, 1989):

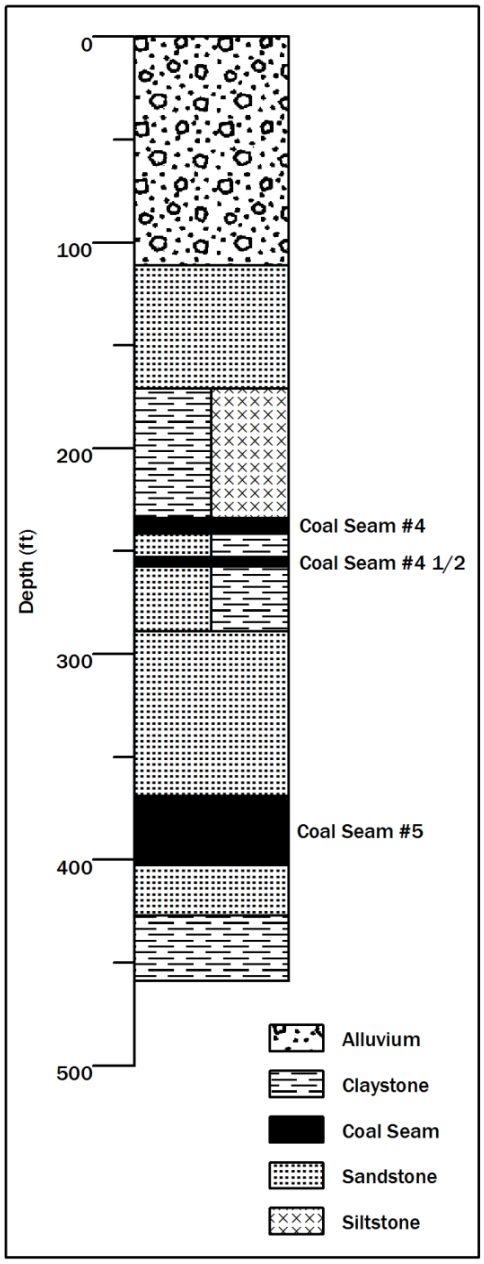
- RQD = 91-100% Excellent
- RQD = 76-90% Good
- RQD = 51-75% Fair
- RQD = 26-50% Poor
- RQD = <25% Very Poor

The RQD measured in each bore hole is shown in Figure 5-6. Bore hole depths are plotted by assigning seam No. 4 a stratigraphic depth of 362 feet, as presented by Darton and Woodruff. Some notable observations are the following:

1. Greater than approximately 75% RQD in bore holes BH03, 04, 05, and 06 between seams 2 and 3. RQD greater than 76% is assigned a rock mass quality of good. RQD is 30-55% (Poor to Fair) between the same two seams (Nos. 4 and 5) in bore hole BH07.
2. Greater than approximately 90% RQD in bore holes BH03, 04, 05, 06, and 07 between seams 3 and 4. RQD greater than 91% is assigned a rock mass quality of excellent.
3. Greater than approximately 80% RQD in boreholes BH03, 04, 05, 06, and 07 between seams 4 and 5. RQD greater than 76% is assigned a rock mass quality of good. RQD is 50-90% (Fair to Good) between the same two seams (Nos. 4 and 5) in bore holes BH01 and 02.

5.7.2 BH01

BH01 is located in the right-of-way on the north side of 14th Street, west of the alley and east of the house located at 25 14th Street West (Figure 5-1). An illustration of the bore hole cross section is shown to the right.



BH01 Log

Six-inch steel casing was installed to a depth of 119 feet. Core was drilled starting at a depth of 119 feet and continued through seams No. 4 (234 to 241.5 feet), No. 4½ (253 to 257.5 feet) and No. 5 (387 to 402.5) to the total depth of 459 feet. Drilling indicated 1 foot of void space in the No. 4 seam at a depth of 234 feet.

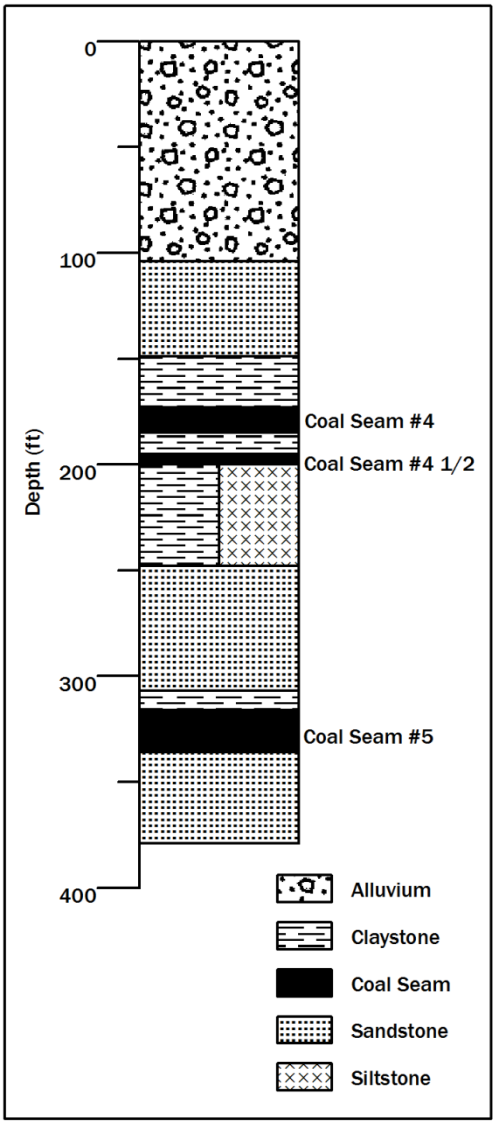
Bore hole BH01 was drilled approximately 50 feet west of bore hole DH03CN, which was installed by Chen-Northern in 1987 (Figure 5-1). The bore logs for both holes were compared to determine differences and similarities. In general, the materials and depths encountered in each hole were similar, with the major difference being the damaged thickness above Seam No. 5 observed in BH01 was 8 feet, compared to 33.5 feet in DH03CN. The difference may be explained by lateral variations in the mine collapsed geometry, or it could suggest that collapse occurred between the year drilling occurred for DH03CN (1987) until the present time.

5.7.2.1 Down-Hole Camera

After completing the drilling, a down-hole camera was lowered through the 6-inch casing and into the bedrock. Camera footage shows the top of the opening at the depth of 231 feet. Footage shows broken and possibly collapsed roof materials from the depth of 231 to 234 feet, and water circulating from the depth below 234 feet.

5.7.3 BH02

BH02 is located on Oakes Avenue approximately 15 feet west of the garage for the residence at 207 S. Hauser Avenue (Figure 5-1). An illustration of the bore hole cross section is shown to the right. The resident at 207 S. Hauser recalled that approximately 40 to 60 years ago, before the garage on the property was built, a depression had abruptly opened adjacent to the northwest corner of the house. The depression was subsequently filled with "two dump truck loads of gravel." No official report was made at the time and there has been no further investigation of the specific depression site.



BH02 Log

The six-inch steel casing was installed to a depth of 109 feet. The core was advanced starting at that depth and continued through seams No. 4 seam (173 to 185 feet); and No. 5 (316 to 336 feet). Total depth of the hole was 379 feet. No void space was encountered in either seam, though there was some evidence of damaged rock above the No. 4 seam.

5.7.3.1 Extensometer Installation

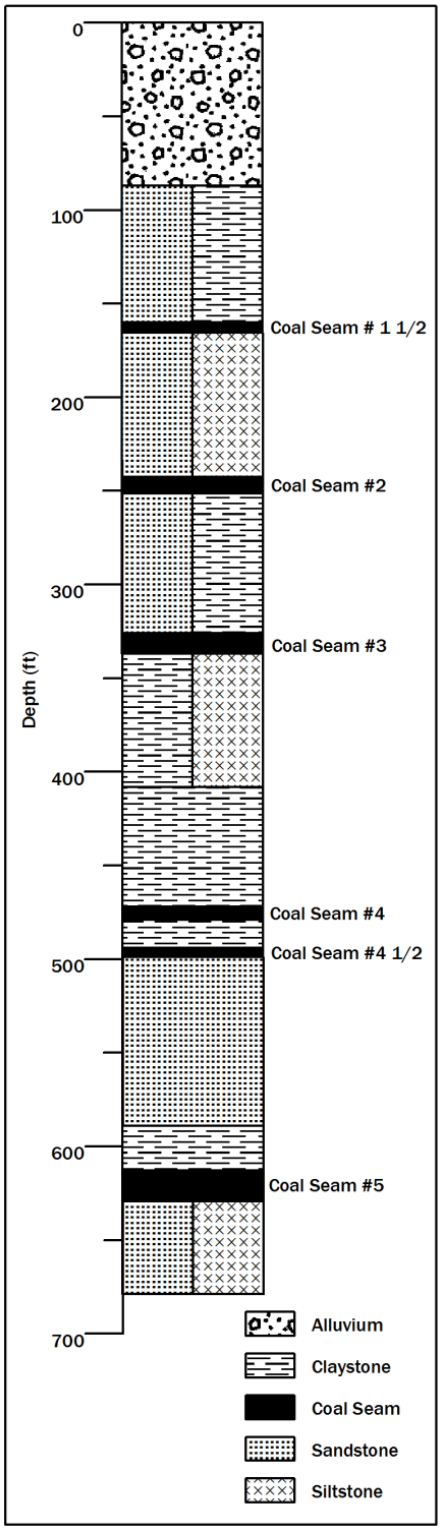
Based on the close proximity of the bore hole to relatively shallow workings of the seam No. 4, significant pinching of the drill rods near 134 feet, and the reported subsidence feature reported by the resident, a Slope Indicator rod extensometer was installed to a depth of 124 feet (19 feet below the top of bedrock). An extensometer is a device that measures and records vertical movement of subsurface materials. A VW Displacement Sensor (Slope Indicator) and VW MiniLogger (Slope Indicator) were installed below grade to monitor the movements of the extensometer. The VW MiniLogger was programmed to collect one reading every 24 hours. This data was collected as part of the survey monitoring program (Section 5.9.2) on a quarterly basis starting in December 2014 and will continue to be collected through 2015. A report of data will be prepared at a later date.

5.7.4 BH03

BH03 is located in the right-of-way on the south side of 16th Street, north of the house located at 501 Broadway (Figure 5-1). An illustration of the bore hole cross section is shown to the right.

Six-inch steel casing was installed to a depth of 99 feet. Core drilling began at that depth was drilled through seams No. 1½ (160 to 166.5 feet); No. 2 (242.5 to 251.5 feet); No. 3 seam (326 to 337 feet); No. 4 (472 to 479 feet); No. 4½ (494 to 499 feet); and No. 5 (613 to 629.5 feet). Total depth of the hole was 670 feet.

No large voids were observed, but 6 feet of very loose material, likely sand sized or smaller particles was encountered in the No. 4 seam. Within the No. 5 seam two larger (2.6 foot) voids were observed at depths of 622.5 and 627 feet. The total damaged thickness for the No. 5 seam was observed to be 16.5 feet.



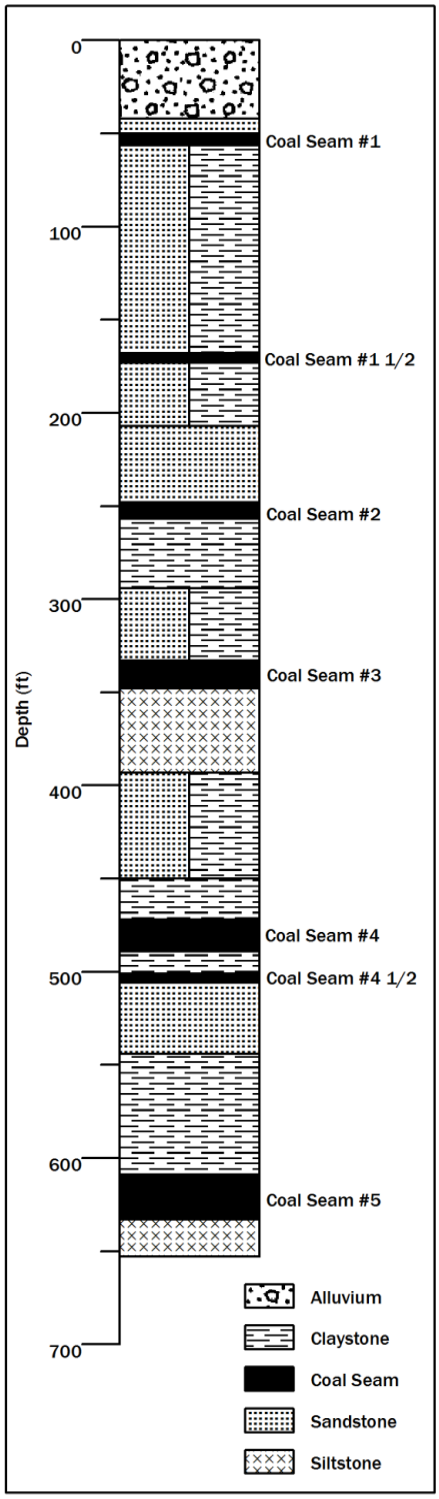
BH03 Log

5.7.5 BH04

BH04 is located in the right-of-way between Platt Ave. and the house located at 505 South Platt Ave. (Figure 5-1). An illustration of the bore hole cross section is shown to the right.

Six-inch steel casing was installed to a depth of 54 feet. Core drilling began at that depth and drilled through seams No. 1½ (168 to 173 feet); No. 2 (248 to 257 feet); No. 3 (333 to 348 feet); No. 4 (472 to 489 feet); No. 4½ (501 to 506 feet); and No. 5 (609 to 633) feet. Total hole depth was 653 feet.

A 1-foot void was observed in the No. 4 seam. No voids were found in the No. 5 seam, but very loose material was observed between depths of 625 to 629 feet. Total damaged thickness for the No. 5 seam was 33 feet.



BH04 Log

5.7.6 BH05

BH05 is located in the right-of-way east of the street in front of 511 Haggin Ave. (Figure 5-1). An illustration of the bore hole cross section is shown to the right.

The 6-inch steel casing was advanced to a depth of 19 feet. Core drilling began at this depth and drilled through seams No. 1 (59.5 to 71.5 feet); No. 1½ (180 to 186 feet); No. 2 (254 to 263 feet); No. 3 (341 to 356 feet); No. 4 (478 to 493 feet); No. 4 ½ (503 to 510 feet); No. 5 (623 to 642.5). Total hole depth was 679 feet.

Picture #14 (below and in Appendix B), includes core sample photographs of coal from seam No. 1 and the floor claystone floor.

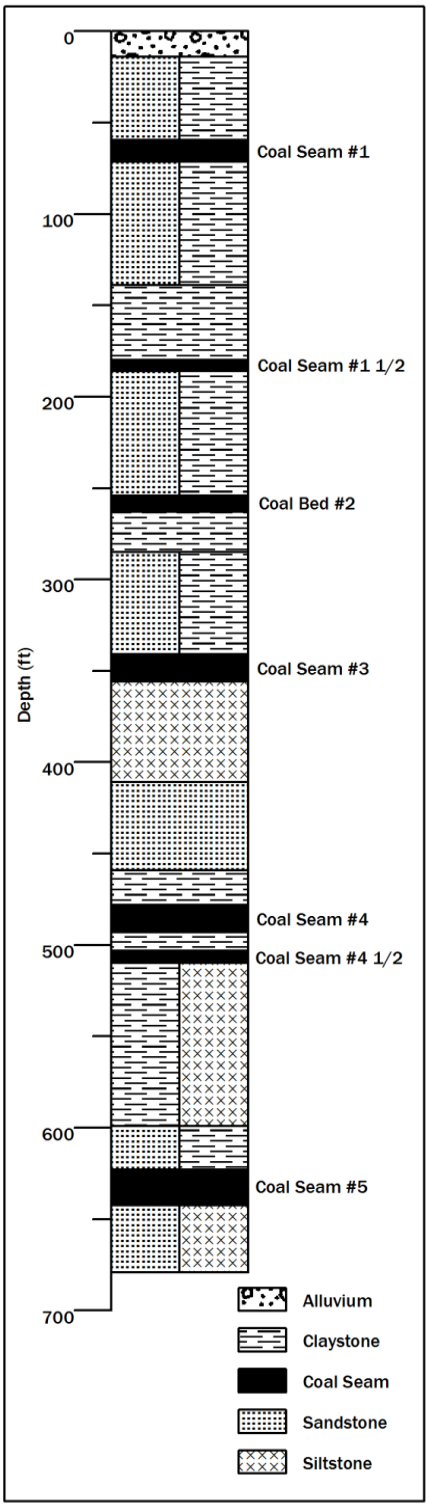
Picture #15 is an example of materials observed in the roof of seam No. 1 ½, bedding parallel and nonparallel joints. Picture #16 is an example of the interface between the claystone roof and seam No. 1 ½ and joints sets (cleats). Picture #17 is an example of the fine grained sandstone observed between seam No. 1 ½ and No. 2.

Pictures #18 and #19 are an example of the lower section of seam No. 2 immediately above the moderately hard claystone floor material.

Picture #20 shows fine grained sandstone, above moderately soft claystone immediately above the upper portion of seam No. 3.

Intermittent voids of 7, 2, 5, and 2 inches were encountered through the loose material in the No. 4 seam. Looseness of materials was also evidenced by recovered materials showing drill marks along multiple surfaces, indicating loose confinement within the seam.

Picture #21 shows the hard claystone bedrock observed immediately prior to encountering the



BH05 Log

1-foot void above seam No. 4. Caved materials beneath the void were observed as hard claystone that had caved from the roof. Picture #22 shows the materials constituting the floor of seam No. 4. The claystone was disturbed and moderately soft.

Picture #23 shows the lower extent of seam No. 4 ½ and the underlying soft claystone material.

Picture #24 is an example of the claystone roof above seam No. 5 and the upper section of coal. At this location the claystone roof was observed as hard. Picture #25 shows the lower section of seam No. 5 and the hard siltstone floor that was typically observed.

Picture #14 – BH05 Core 69-74' depth – Coal Seam 1 and Floor

Picture #15 – BH05 Core 173-178.3' depth – Seam No 1 ½ Roof

Pictures #18 & 19 – BH05 Core 259-269' depth –Seam 2 and floor beneath

Picture #20 – BH05 Core 339-34' depth –Seam 3 Upper Section

Picture #21 –BH05 Core 469-479.3' depth–Claystone bet. Seams 3 & 4

Picture #22 – BH05 Core 496-499' depth –Seam 4, claystone floor

Picture #23 – BH05 Core 509-514' depth –Seam 4 ½, claystone floor

Picture #24 – BH05 Core 619-629' depth – Claystone roof, Seam 5

Picture #25 – BH05 Core 639-649' depth – Seam 5, claystone floor

5.7.6.1 Down-Hole Camera

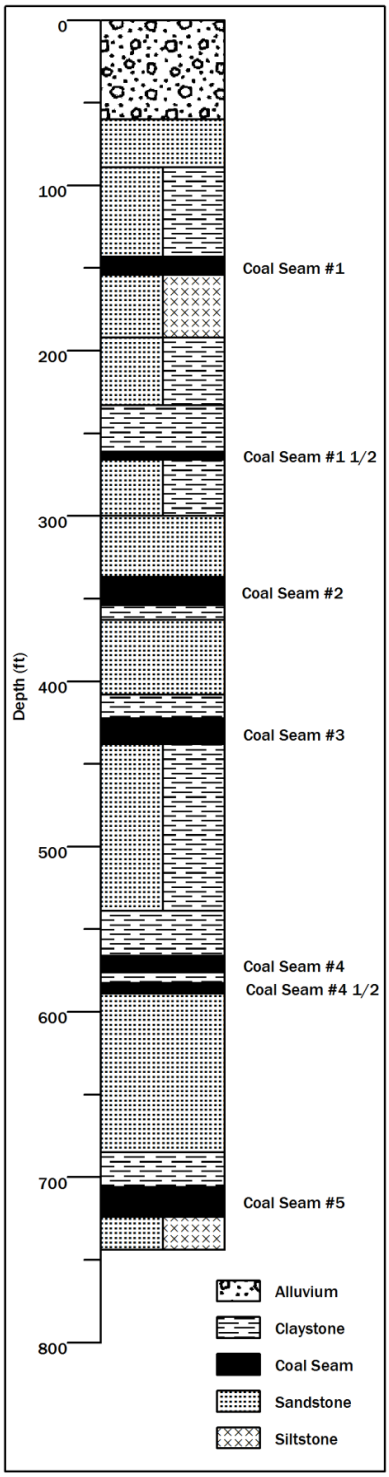
After the drilling phase was completed, a down-hole camera was lowered through the 6-inch casing into the core hole in the bedrock. The camera was lowered to the depth of 260 feet, where the No. 2 seam was observed during drilling. The water was too cloudy to view the inside of the bore hole and no observations were made.

5.7.7 BH06

Bore hole BH06 is located in the west-bound lane of 17th Street, just east of Broadway Avenue (Figure 5-1). An illustration of the bore hole cross section is shown to the right.

Six-inch steel casing was installed to a depth of 74 feet. Core drilling began at this depth and drilled through seams No. 1 (143 to154 feet); No 1½ (261 to 266 feet); No. 2 (337 to 354 feet); No. 3 (442.5 to 438 feet); No. 4 (566 to 576 feet); No. 4 ½ (583 to 589 feet); and No. 5 (706 to 724 feet). Total hole depth was 744 feet.

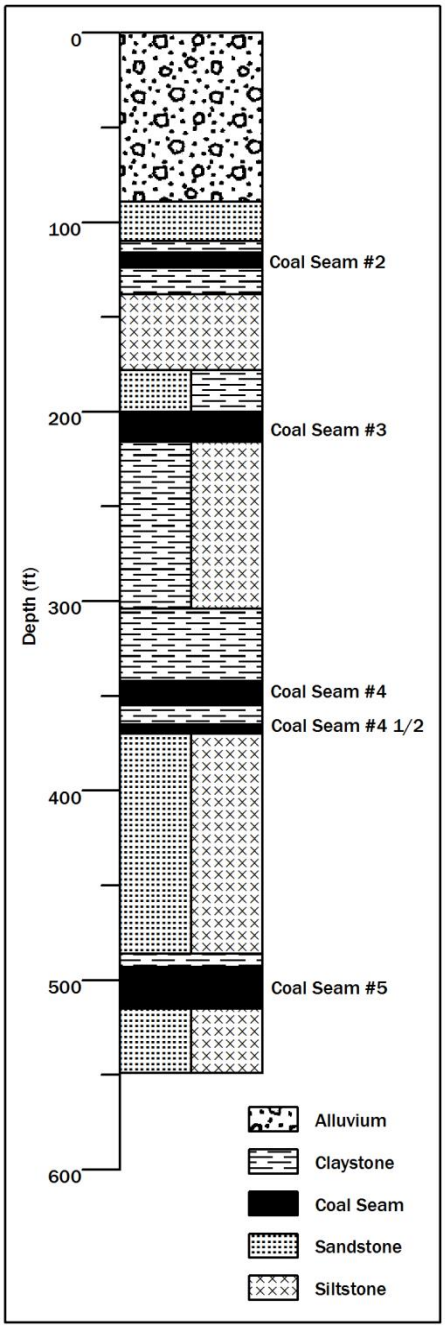
A 5-foot void was encountered in the No. 2 seam between depths of 337 and 342 feet.



BH06 Log

5.7.8 BH07

BH07 is located in the right-of-way south of 15th Street, adjacent to the residence at 404 Broadway Avenue (Figure 5-1). An illustration of the bore hole cross section is shown to the right.



BH07 Log

Six-inch steel casing was installed to a depth of 98.5 feet. Core drilling started at this depth and drilled through seams No. 2 (116 to 124 feet); No. 3 (200 to 216 feet); No. 4 (342 to 355 feet); and No. 5 (493 to 515 feet). Total hole depth was 539 feet.

No voids were encountered during drilling in this hole, but down-hole camera footage (see Section 5.7.8.1) revealed a void of approximate size of 2 to 3 feet within the No. 2 seam at a depth of 122 to 124 feet. Also, as shown in Figure 5-6, RQD in the zone between the top of bedrock and just below seam No. 3 is uncharacteristically low, ranging between 0 to 65%, a rock mass quality of Very Poor to Fair.

5.7.8.1 Down-Hole Camera

After the drilling phase was completed, a down-hole camera was lowered through the 6-inch casing and into the bore hole and into the bedrock. The camera was lowered to the depth of 123 feet, where an opening in the bedrock was observed at the No. 2 seam. The opening was not observed during drilling. Camera footage shows the top of the opening is at the depth of 122 feet. The footage shows a 360-degree view of the opening. The size and scale of the opening is difficult to interpret; however, at the location of the camera, the opening is 1 foot in height. In one horizontal direction, the opening height gets smaller and in the opposite direction, the opening height gets larger, approximately 2 to 3 feet in height. The camera location appears to be above a small rubble slope which has since covered the bore hole below the 124-foot depth. As noted above, the recovered bore hole data in this section showed the coal in the No. 2 seam had fair RQD and circulation was continuous through the coal seam. Workings in seam No. 2 at this location were not anticipated; based on the documented maps, seam No. 2 was not mined in this area. It is possible a complete map of seam No. 2 may show some degree of mining in this area. If mining was not performed at this location, the opening

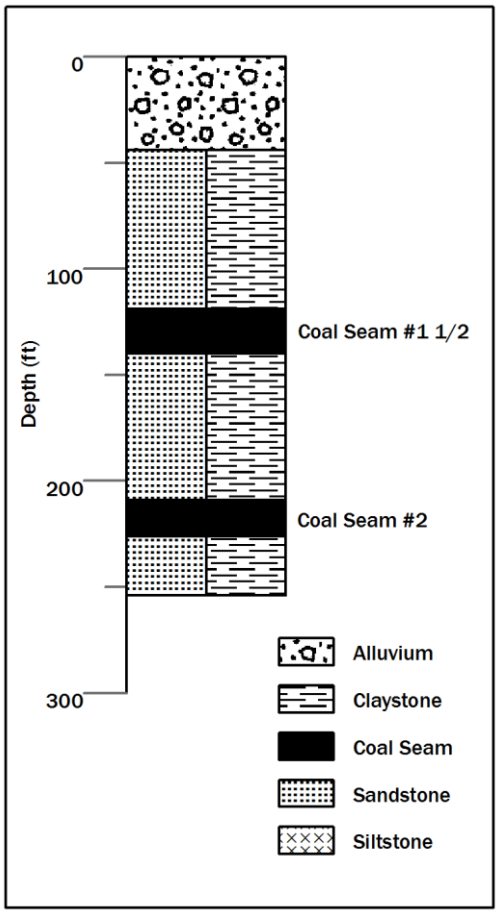
may also be the signature of collapse of seam No. 4; the map of seam No. 4 shows a large section of pillars were removed in this area and further east.

5.7.8.2 Extensometer Installation

Based on the close proximity of the observed opening below the depth of 123 feet, an attempt was made to install a Slope Indicator rod extensometer to a depth of 110 feet (13 feet above the observed opening). During the installation attempt, the 6-inch diameter steel casing appeared to have sheared at the 49-foot depth. The extensometer installation could not be completed as planned and a steel cap was welded onto the top of the casing.

5.7.9 BH08

BH08 is located northwest of the rodeo grounds along Rodeo Road (Figure 5-1). An illustration of the bore hole cross section is shown to the right.



BH08 Log

Six-inch steel casing was installed to a depth of 57 feet. Core drilling began at this depth and drilled through seams No. 1½ (117 to 140 feet) and No. 2 (209 to 226 feet). The total depth of the hole was 254 feet.

A 2.5-foot void was encountered in the No. 1½ seam between depths of 119 feet and 121.5 feet. Loose, soft materials were drilled between 121.5 and 133 feet. At 133 feet, caved materials were drilled to a depth of 141 feet.

5.7.9.1 Down-Hole Camera

After the drilling phase was completed, a down-hole camera was lowered through the 6-inch casing and into bore hole within the bedrock. The camera was lowered to the total depth of 119 feet, where an opening in the bedrock was observed in the No. 1½ seam. Camera footage shows the top of the opening is at the depth of 117.5 feet and static groundwater within the opening is near 118.5 feet. Above the opening, ground water is also observed flowing from fractures into the bore hole.

The footage shows a 360-degree view of the bore hole from 55 feet to the depth of 119 feet. The size and scale of the opening is difficult to interpret. In the location of the camera, the initial opening is 1.5 feet in height. The void appears to be the upper limit of the active roof caving process.

5.8 Water Level Data

Groundwater elevations were recorded during the drilling investigation and are presented in the borehole logs in Appendix A. The groundwater elevations represent the depth to groundwater observed in the alluvium. Accurate groundwater measurements during the Phase II coring investigation within the bedrock were not determined due to the use of water as a drilling fluid during the coring process.

The first west level of seam No. 1½, was encountered between depths of 119 to 140 feet below the ground surface in BH08. The ground elevation at BH08 is 5,732 feet, placing the first level at a minimum elevation of 5,592 feet. Groundwater was observed in both the overlying alluvial gravels at depths between 6 to 12 feet below the surface. Groundwater was also observed with the down-hole camera at a depth of 119 feet within the void of the workings.

The mine map for seam No. 1½ (Figure 8-4) shows that the westerly portion of these mine workings begins near the slope of the west bluff adjacent to 14th Street. The hydraulic connectivity of this level is not well understood, nor are water surface elevations near the east end of the west bluff; however, the abandoned workings are higher than the base of the bluff and the workings may be storing a significant volume of water.

5.9 Survey Data

5.9.1 Bore Hole Coordinates

Survey coordinates and elevations for each of the bore holes are included in the logs provided in Appendix A.

5.9.2 Subsidence Monitoring

Pioneer has established and maintained a survey grid of monitoring points around suspected areas of mine subsidence in Red Lodge. Survey monitoring started in January 2014, with the goal of measuring elevations to determine if any ground movement is occurring in the vicinity of the residences in question. The surveyed area is roughly bounded by Hauser Ave. on the west, Haggin Ave. on the east, 13th St. on the north, and 17th St. to the south. The work included the following tasks:

1. Installation of survey monitoring monuments and establishment of monitoring points to measure.
2. Installation of foundation crack gages at existing cracks on home foundations.
3. Quarterly survey of elevations and crack gage measurements.

A total of 90 monitoring points and 8 crack gages have been established as of January 2015. The monitoring points consist of a combination of two National Geodetic Survey (NGS) benchmarks, fire hydrants, 36-inch long #6 rebar pounded into the ground, bench ties installed in the house foundations, and “MAG” nails installed in concrete flat work. The monitoring points and crack gages have been surveyed on a quarterly basis. As of January 2015, five quarterly monitoring

(QM1 through QM5) trips have been performed. Three additional monitoring trips will be performed on a quarterly basis through the remainder of 2015.

Horizontal coordinates were surveyed using a RTK GPS and are in Montana State Plane NAD 83 (2011), international feet. Horizontal coordinates have been surveyed twice (QM1 and QM4). A comparison of the horizontal data has not been performed due to accuracy differences in the QM1 and QM4 survey methods. The horizontal coordinates from QM1 were initially surveyed using a 4-second shot with GPS that is intended only for mapping purposes. The horizontal coordinates from QM4 were then surveyed again using a GPS with a several-minute shot that results in higher accuracy and will allow for more precise long-term monitoring of horizontal movement. QM4 horizontal coordinates will be compared to future horizontal readings. Elevations were surveyed using level loop with a digital level. Elevations from each of the monitoring trips were compared to evaluate potential changes in elevation.

Survey data is listed in Table 5-2. For a more detailed discussion of the data, refer Appendix C. A brief summary of the data collected to date is listed below:

1. Monitoring Point 627 (a 3-foot long rebar embedded into the ground near 404 Broadway) has recorded the maximum cumulative elevation decrease of -0.024 feet (~9/32 inch).
2. Monitoring point 616 (a 3-foot long rebar embedded on Platt Avenue) recorded the maximum cumulative elevation increase of 0.064 feet (~43/64 inches). Surveyors noted that frost heave may be attributable for this elevation increase.
3. The average change in elevation for all the points from QM1 to QM5 was -0.005 feet (1/16 inch) with a standard deviation of 0.015 feet (3/16 inch).
4. Review of the data and discussions with the surveyors indicate that the differences in elevation values are primarily attributable to expected error and bias in the method and digital level accuracy limitations. The estimated accuracy of this survey configuration is ± 0.03 feet; the measured readings are within the survey accuracy and therefore do not suggest measurable surface subsidence.
5. In addition to absolute elevations, no trends between consecutive measurements have been observed, suggesting, as of QM5, that no measurable settlement at any of the monitoring points or crack gages has occurred.

6 EXTENSOMETER INSTALLATION AND SETUP

Based on review of the historic mine maps and observations made during the drilling investigation, Pioneer and DEQ decided to install two extensometers, one in BH02 and one in BH07. Review of the mine maps and drilling observations showed these two locations are areas where the No. 4 seam (BH02) and the No. 2 seam (BH07) have the thinnest layer of bedrock separating alluvial gravels from the mined openings and thus pose the greatest risk of chimney failures. In BH02, bottom of alluvium was observed at 105 feet and the No. 4 seam was observed at the depth of 173 feet, for a bedrock thickness of 68 feet. At BH07, bottom of alluvium was observed at 89 feet and the top of the No. 2 seam was observed at 116 feet, for a bedrock thickness of 27 feet.

The extensometer as-built log for BH02 is provided in Appendix A. The log presents information on the materials, equipment, and geometry of the installed extensometer. The device was installed on November 4, 2014, and the data logger was set to record once per day.

Extensometer installation in BH07 was abandoned after the six-inch casing broke. The extensometer rod was cemented into the ground between the depths of 101 to 111 feet. Upon backfilling the remaining bore hole, it was realized the 6-inch diameter steel well casing sheared at the depth of approximately 49 feet below the ground surface, subsequently failing the grout tube and presumably the quarter-inch stainless steel rod. The partial extensometer log is provided in Appendix A.

7 Site Observations

7.1 House Structural Observations

The locations of the structures of interest are shown on Figure 4-1. These residents are the ones who expressed concern to DEQ and are all part of the survey monitoring program described in Section 6. These homes, and those in their vicinity, are typically older homes, many of them in excess of 100 years old. Many of the homes have multiple foundations systems such as full height basements, crawlspaces, slab-on-grades, and concrete piers. The foundations systems were typically constructed with concrete, concrete masonry units (CMU), or cobblestone. By today's standards, many parts of the home foundations were not constructed deep enough to provide adequate freeze/thaw (frost) protection.

No governing building code existed at the time these homes were constructed; as is typical in wood structures of this age some of the structural framing likely was under-designed (by today's standards), leaving the homes susceptible to a large amount of deflection. Observation of the houses of interest through the survey monitoring program, along with some of the neighboring structures, shows some floors out of level and cracking on foundations and walls. This would indicate the homes have experienced differential movement at some point in the past. Many of the homes have multiple additions, including porches, that may have been built on varying levels of loose or poorly compacted fill materials.

8 Data Assessment

In relation to underground mining, subsidence is generally described as a gradual or sudden depression of the ground surface resulting from the extraction of minerals from the subsurface. Subsidence expressions are typically observed in two forms: pothole and trough (Karfakis, 1987a). Pothole subsidence is a localized feature which occurs due to the collapse of overburden into underground voids. Potholes can be further segregated into shallow-sided potholes and steep-sided (Singh and Dhar, 1997). Steep-sided potholes are considered the most hazardous due to the sudden onset of failure and the nature of the surface expression (Figure 8-1c). Trough subsidence is a depression covering a large area, often symmetrical about the mining geometry, with maximum vertical displacement at the mid-span of the active opening. Displacements across troughs gradually decrease outward from the center (Figure 8-1).

The objective of this assessment is to determine if subsidence related to the underground workings has occurred and to evaluate the potential for the formation of subsidence features due to the underground workings. The evaluation will address the following topics:

1. Describe the existing non-native and *in situ* materials overlying bedrock (overburden);
2. Present documented lateral extent of workings, data gaps in workings maps, and implications of these data gaps;
3. Describe the assessment of conditions necessary for shallow-sided and steep-sided potholes and trough subsidence; and
4. Provide estimates of potential structural damages resulting from potential future trough subsidence.

8.1 Overburden Materials

The overburden materials are considered the various soil layers overlaying the Fort Union bedrock formation. The overburden materials were predominately alluvial gravels with varying amounts of sand, cobbles, and boulders. Non-native fill soils, typically classified as Poorly Graded Sand or Silty Sand (SM), were also observed at some locations near the ground surface.

Alluvial gravels were logged in each of the bore holes during this investigation and in the test pit excavated on 17th Street. Alluvium thickness is listed in Table 5-1 and ranged between 14 feet in BH05 to 111 feet in BH01. Alluvium thickness increases from the southeast part of town to the northwest as shown in Figure 8-2. Pioneer personnel also observed alluvium in numerous open excavations associated with construction projects ongoing at the time of the investigation.

Non-native soils were logged near the ground surface in some of the drill and hand auger holes and test pit:

1. BH03 – 2.5 feet of non-native soil;
2. BH04 – 4.5 feet of non-native soil;
3. BH05 – 4.0 feet of non-native soil;
4. BH04a – 3.0 feet of non-native soil, refusal at 3.0 feet, interpreted as alluvial gravels;
5. BH04b – 4.5 feet of non-native soil, refusal at 4.5 feet, interpreted as alluvial gravels; and
6. TP-01 – 2.0 feet of non-native soil.

The non-native soils appear to be remnants of past construction or mining-related activities and frequently contained debris such as broken glass, metal fittings, wire, or railroad spikes. The non-native soil is considered unclassified fill indicating the methods used to place the soils (i.e. soil lift thickness or compactive effort applied during placement) are unknown.

An 1888 survey (Figure 8-3) indicates that Rock Creek (historically known as the Rocky Fork River) originally flowed through the Finn Park neighborhood, which may have been a low lying area of the valley floor. At some point in the past, likely between 1888 and 1904, Rock Creek was channeled to its current location on the eastern edge of town. Figure 8-3 displays the

historic map surveyed in 1888 by George Sheetz showing Rock Creek meandering through a portion of town. The map further indicates that the historic alignment of Rock Creek meandered diagonally in a southwest to northeast direction from 17th Street to 15th Street, between Broadway Avenue and Haggin Avenue. Non-native soils were likely used to fill the old channel bed and possibly help divert Rock Creek to its current location.

8.2 Lateral Extent and Depth of Mine Workings

As discussed in the introduction, coal seam Nos. 1, 1½, 2, 3, 4, 4½, 5, and 6 have been mined in the Red Lodge Coal Mine (Rowe, 1908). Seams that have been worked within the boundaries of this study include Nos. 1½, 2, 3, 4, and 5. DEQ provided digital copies of mine maps, and Table 8-1 presents a list of the maps showing the date of creation and the last revision.

Each of the digital mine maps were overlaid and geo-referenced into a GIS Database. The maps were located using landmarks, mine infrastructure, section corners, and common features between maps (e.g. No. 2 slope, No. 4 slope, rock tunnels, and local northing and easting coordinates). Surfaces of each of the mine workings were created from data included in the mine maps and drilling. The digital mine maps were projected to the respective bed surfaces.

The lateral extent of each of the mine workings shown on the available maps are presented as follows:

1. Figure 8-4. Mine Map No. 1½ Seam,
2. Figure 8-5. Extent of Mining No. 2 Seam, as presented by Kiewit (1983),
3. Figure 8-6. Mine Map No. 2 Seam,
4. Figure 8-7. Mine Map No. 3 Seam,
5. Figure 8-8. Mine Map No. 4 Seam,
6. Figure 8-9. Mine Map No. 5 Seam, and
7. Figure 8-10. Mine Map No. 6 Seam.

A map of the No. 2 workings, west of the main slope, was not provided and could not be located. The Kiewit report provides some information regarding the northern limit of mining within the No. 2 seam. However, observation of a significant void, potentially a room or a level entry, was observed during drilling in BH07, suggesting some undocumented mining activity may have occurred north of the reported boundary provided by Kiewit.

Some data regarding mining activities west of the No. 2 main slope can be observed on the No. 1½ and the No. 5 mine maps. Both maps show details of the main slope geometry. In particular, branches shown on the east side of the main slope can be interpolated to connect to the first and second east levels shown on Figure 8-6. Similarly, branches on the west side of the No. 2 main slope imply some level of undocumented mining activity may have taken place north of the workings limit shown in Figure 8-5. These potential connections are illustrated in Figure 8-14.

A map of seam No. 1 workings was not provided and the extent of mining is not well understood. However, seam No. 1 is not beneath the immediate areas of interest.

Three cross sections (A-A', B-B', and C-C'), were created in the north-south direction. The cross-sections, presented in Figure 5-3, Figure 5-4, and Figure 5-5, show the existing ground surface, top of bedrock, worked extent of each seam 1 ½ through 5, and east-west traversing streets.

8.3 Stability Assessment

Ground surface displacements from failure of room and pillar mines can occur through the following mechanisms:

1. Pothole Subsidence (Chimney Failure and Bedrock Fissuring); and
2. Trough Subsidence.

Depending on the location, depth, and type of subsurface failure, displacements can be expressed in both vertical and horizontal directions. This section presents an overview the subsidence mechanisms and a summary of the engineering analyses completed to evaluate subsidence risk within the study area. A complete discussion of the engineering analysis is presented in Appendix D.

8.3.1 Pothole Subsidence

8.3.1.1 Chimney Failure and Potholes

The following section presents an evaluation of chimney failure potential and subsequent development of steep-sided and shallow-sided potholes. For this discussion, chimney failures are those which form by progressive, localized caving of mine roof material through overlying strata (Figure 8-1). Chimney failures typically continue to propagate vertically through overlying strata unless arrested by formation of a stable geometry, more competent roof materials, bulking of caved debris, or when intersecting overburden materials, thereby changing the mode of propagation to one of granular flow (for the case of non-cohesive overburden). Potholes are surface expressions caused when overburden readjusts to the presence of the void space created by chimney failure below. The thickness and character of the overburden greatly influence the pothole shape.

For a pothole to form, the chimney failure has to reach the surface. For the case of Red Lodge, chimney failure must propagate through the bedrock to the base of the alluvial gravels and then propagate through the gravels to the surface. To assess the occurrence of chimney failures at the bore hole locations, floor-to-roof distance measurements and caved material thicknesses within the workings were compared to calculated maximum caving heights. In addition to calculated estimates, reference is also made to several authors' observations of chimney failure/pothole subsidence and descriptions of geometric conditions conducive to such failures.

The distance between the roof and floor was recorded in the bore hole logs. Table 8-1. Mine Map Inventory
Table 8-2 summarizes these observations for each of the bore holes and the respective beds. The data in the table also show the thickness for each of the intact coal beds when workings were not directly encountered.

Of all the mined workings observed, the greatest extent of roof caving was observed above the seam No. 2 in BH08, with a total caved up distance of 25 feet. Calculations were performed to estimate the maximum extent of a chimney failure at this location. The calculations use equations presented by Whittaker and Reddish (1989) that describe a maximum caving height above the roof. With the implied assumptions, the calculated height of potential chimney collapse is between 17 to 34 feet (Appendix D). As described above, the maximum observed caving height, approximately 25 feet, is in seam No. 2 at BH08. At this location only a very slight void was encountered, therefore available space for additional caving is minimal and further appreciable caving in this location is unlikely. Comparison of the calculated chimney height and the maximum observed (self-arrested) caved thickness shows reasonable agreement.

Similar to several other authors (as discussed in Appendix D), observations made by Karfakis (1987b) at the Hanna Mining district in Wyoming show the frequency of pothole occurrence greatly decreases at depths greater than 160 feet (Figure 8-11). The author estimates a 2% probability for chimney failures at overburden depths greater than 160 feet at this mining district. Similarly, Singh (2007) reports 90% of potholes observed at the Son-Mahanadi Master Coal Basin occurred in areas where the overburden was less than 150 feet (Figure 8-11).

The minimum bedrock and associated overburden thicknesses above each of the openings in the Red Lodge Mines are as follows:

1. Bed No. 1 ½: 274 feet of bedrock and 45 feet of alluvial gravels;
2. Bed No. 2: 27 feet of bedrock and 89 feet of alluvial gravels;
3. Bed No. 3: Not worked in study area;
4. Bed No. 4: 103 feet of bedrock and 103 feet of alluvial gravels;
5. Bed No. 4 ½: Not worked in study area;
6. Bed No. 5: 114 feet of bedrock and 53 feet of alluvial gravels; and
7. Bed No. 6: Not worked in study area.

Further discussion of pothole potential is presented in Subsection 8.3.1.3.

8.3.1.2 Bedrock Fissuring and Potholes

A second mechanism that may cause pothole formation is bedrock fissuring. For this discussion, bedrock fissures are near vertical fractures which form by progressive roof collapse and localized tensile stresses in overlying strata (Figure 8-12). As a mine roof collapses, overlying and adjacent bedrock is pulled down and towards the collapse. The stretched bedrock cracks at its surface, forming a fissure that propagates vertically downward through overlying strata, creating a vertical void. Fissuring typically will form in areas immediately adjacent to the workings, not directly above the rooms. Alluvial sands and gravels and groundwater can flow into and fill the void. Potholes are surface expressions caused when overburden readjusts and fills the void space created by the fissure.

8.3.1.3 Chimney Failure and Fissuring Pothole Potential

Excluding the shallow opening observed at BH07, the calculated maximum caving height (17 to 34 feet) suggests the likelihood of pothole formation within the study area is very low since

bedrock thicknesses are much greater than 100 feet. However, the calculated estimate makes several simplifying assumptions and the empirical evidence of pothole formation is strong and suggests a more appropriate maximum caving height is on the order of 150 feet. Observed caving heights may greatly exceed the calculated estimates in cases where the slabbed material has a very low bulking factor or no stable arch can form and groundwater ingress and/or inclined beds remove caved materials such that bulking is inhibited.

To determine areas where the greatest potential exists for pothole formation, available data from drilling and mine map elevation was input to an ArcGIS database. Since bedrock thickness above workings is a critical parameter for predicting pothole formation and, therefore, subsidence potential, for each mine level, a surface for the top of the level and top of bedrock was created. Thickness maps, or Isopachs, were created for each layer. These were then overlaid upon each other to reveal the thinnest bedrock zones. This information was used to create Figure 8-13, which shows approximate bedrock thickness associated with areas above documented mine workings. Figure 8-13 also includes Isopachs for bedrock thicknesses above seam No. 2 in the area where the extent of mining within this seam is not well understood. Bedrock thicknesses in the figure are divided into 50-foot intervals; as discussed above, thinner bedrock thicknesses are typically associated with higher potential for chimney failure and therefore are assigned a higher potential. The strength of the rock units above the workings will also influence the potential for mine collapse being manifest at the surface (i.e., higher strength rock units result in lower potential).

Zones of greater or lesser potential are inferred from these 50-foot intervals. As this shows, a strong to moderate potential for pothole formation exists near the airport due to the shallow presence of the No. 1½ workings. Within the city, a moderate potential exists between Word Ave. and Broadway Ave, from 14th St. W. extending north approximately 200 feet, due to the presence of shallow No. 4 workings, as shown in Figure 8-13. Should undocumented mining have taken place within seam No. 2, a strong to moderate potential for pothole formation would exist in the area between Broadway and Haggin, from about 16th St. W. to 15th St. W.

Within the City of Red Lodge, the minimum bedrock thickness above the seam No. 1½ is much greater than 150 feet, and that for seam Nos. 4 and 5 is slightly greater than 100 feet. Seam No. 2 was observed to have an opening to some extent in the area beneath BH07. The exact extent and geometry of this opening is unknown due to the absence of a mine map. The opening in seam No. 2 was observed at a depth of 116 feet below the ground surface, 27 feet below the bedrock surface that is overlaid with 89 feet of alluvial gravels. Due to the close proximity of this opening to the top of bedrock and the unknown lateral extent, an analysis assessing the likelihood of a steep-side pothole developing within the alluvial gravels was performed.

The steep sided pothole calculations are shown in Appendix D. The results suggest formation of a near-surface cavity and/or a steep-sided pothole is unlikely for conditions observed above seam No. 2 in BH07. For a near-surface cavity or steep-side pothole to develop, the materials through which the pothole forms, in this case the alluvial gravels, must have a semblance of tensile strength and cohesion. Based on observations of the alluvial gravels in the Red Lodge area, both through drilling, test pit, and outcrop, the materials do not show a cohesive nature and are strictly granular.

Based on this analysis, conditions observed in Red Lodge are not conducive to formation of a steep-sided pothole. However, the formation of shallow-sided potholes is possible near BH07 and possibly above shallower reaches of the Nos. 4 and 5 seams, due to the potential for granular soils to flow downward into voids caused by bedrock fissures or chimney failure.

8.3.2 Trough Subsidence Mechanisms

Mine openings and coal pillar stability in room-and-pillar mining method depend on the interaction of roof, coal pillar, and mine floor. To determine the condition of the mine workings in relation to pillar stability, two general assessments were performed for the workings: bearing failure and pillar strength. The objective of the assessments was to determine how and if the observed conditions affect roof support, which consists of the floor and pillars.

As discussed in the following two sub-sections, degradation of both mine floors and pillars have been observed in other abandoned workings and evidence of similar conditions has been observed here. Degradation of these structures in the mine directly affects the workings stability. Gradual loss of roof support will increase stresses in the mine roof and therefore the potential for convergence of the roof and floor. Based on the reasonable potential for a loss of roof support, the next section (8.3.3) will present an evaluation to assess the degree to which roof convergence may affect the ground surface and man-made structures.

8.3.2.1 Bearing Failure

The mine floor constitutes the foundation of the pillar, and the presence of weak floor strata can cause differential or excessive pillar settlement and punching of pillars into the floor, ultimately causing roof, subsurface, and surface movement. Often coal beds are underlain by claystones, which are significantly weakened by strain and moist conditions. Progressive strain and moisture softening of such materials can greatly reduce the ultimate bearing capacity of the floor (Marino G.G. and Choi 1999). In addition to the floor strength, the thickness of a soft layer in the floor is a major contributing factor to the magnitude of floor deformation. In locations with thick claystone layers, long-term floor deformation is governed by the severity and extent of floor deterioration under the pillars.

Calculations were performed to assess the available bearing capacity of generalized pillar geometries within the mine workings. Because geological material is immensely variable, parameters related to mine floor bearing capacity (e.g. material strength and thickness) were summarized from the drilling data for each of the worked coal seams (Table 8-3). Claystone floor material was observed to vary between deteriorated to non-deteriorated. Bearing capacity calculations were performed using equations for a foundation on layered soil where a weaker soil (claystone) is underlain by a significantly stronger material (sandstone) (Das, 1999). Figure 8-15 and Figure 8-16 show Safety Factor (SF) charts of bearing failure for a typical pillar (with dimensions of 35 feet by 75 feet) bearing on a non-deteriorated claystone floor. Figure 8-17 and Figure 8-18 present equivalent charts for the hypothetical case of a deteriorated claystone floor.

By assuming a range of floor strengths (deteriorated and non-deteriorated) combined with several claystone floor thicknesses, the result of this evaluation suggests the mechanism of bearing capacity failure is possible and may contribute to roof failure. The actual degree of deterioration beneath the pillars is unknown. However, to some extent, the observed claystone floor materials are probably degrading beneath any existing pillars. If the existing pillars are providing roof support, gradual degradation of the floor materials will likely contribute to roof failure as the floor bearing capacity decreases and the floor can no longer support the overburden pressures. The rate of floor degradation is a complicated problem and is very difficult to predict in an abandoned mine where access is restricted. Because of the uncertainties in the distribution of deteriorated claystone floor material, subsidence estimates in Section 8.3.3 will assume the floor materials are deteriorated.

8.3.2.2 Pillar Strength

Coal pillars are the portion of coal left in place to support the mine openings and are typically square or rectangular in shape. As discussed previously, from the initiation of mining until approximately 1912 the coal pillars, for the most part, were left in place within the Red Lodge Mines. Following 1912, historical documents, mining journal and mine maps, suggest the practice of extracting pillars was implemented.

Since pillars are left for support, long-term degradation greatly contributes to the potential for subsidence. To evaluate potential for pillar failure, SFs were calculated relative to typical extraction ratios using the methods of Pariseau (2007). Extraction ratio is the ratio of the excavated area to the total area; the larger the extraction ratio, the greater the proportion of coal removed and the smaller the pillars. Extraction ratios were calculated from the mine maps and then adjusted assuming an approximate deterioration rate.

Figure 8-19 and Figure 8-20 present charts showing extraction ratio versus SF at several depths for Total and Effective overburden unit weights. The results of this evaluation suggest that, over a 50-year period, deterioration of pillar materials may decrease pillar strengths and SFs. Depending on the mine conditions, SFs for pillar strength may be reduced to 60% of the initial values. In light of these estimates, subsidence estimates in Section 8.3.3 assume pillar failure is possible.

8.3.3 Subsidence Estimates

Conditions within the Red Lodge mine are conducive to slow degradation of the claystone floor materials and existing pillars. The effect of this degradation and loss of roof support may allow for localized roof sag and transference of stresses to adjacent pillars, further lowering the adjacent pillar support SF, and/or increase the effective roof span, thereby potentially causing roof sag. To evaluate the consequence of progressive degradation of roof support, calculations were performed to estimate surface effects due to the loss of a single pillar. The calculations use methods of the National Coal Board, adjusted for conditions of western U.S. coal fields versus U.K. coal fields as presented by Pariseau (2007). Detailed calculations describing the methods and assumptions for these calculations are provided in Appendix D. The two face-side subsidence profiles and two face-side surface strain profiles are presented in Figure 8-21 through Figure 8-24.

The analysis was performed for two generalized scenarios for the Red Lodge Mines. Due to the nature of specific coal mine depths, seam mined thicknesses, and multiple mined layers, extrapolation of this example is not reasonable to any one specific location, rather, this evaluation was performed as a preliminary assessment to provide potential order of magnitude surface deformations resulting from the observed conditions. The primary contributing variable, the mine opening height, is assumed from average values observed during drilling. The actual mining opening height could be two to three times greater or near zero, depending on the location selected, but the average opening height is 2 feet and the available collapse height is 1 foot.

The magnitude of surface displacement is proportional to the amount of available space for collapse. Void space is multiplied by a subsidence factor (s), a number less than 1.0, since subsidence experienced at the surface is less than the height of the void space, due to the breakup of and bulking of the overlying materials. The overlying material type and strength can have a tremendous influence on the amount and distribution of surface settlement. The greater the amount of hard rock, the smaller the amount and extent of surface subsidence (i.e. subsidence factor decreases). Typical values for subsidence factors for western coal mines range between 0.33 to 0.65 (Peng, 1978). The percentage of hard rock in the boreholes ranged from about 26% to 60%. To be conservative in our estimates, a subsidence factor of 0.65 was used.

For the assumed conditions (Appendix D), the calculated maximum vertical subsidence, trough width, peak compressive strain, and peak tensile strain are listed below:

1. Case 1
   i. Maximum Vertical Subsidence = -0.25 feet
   ii. Trough Width = 202 feet
   iii. Peak Compressive Strain = 0.0012
   iv. Peak Tensile Strain = 0.0004

2. Case 2
   i. Maximum Vertical Subsidence = -0.32 feet
   ii. Trough Width = 252 feet
   iii. Peak Compressive Strain = 0.0019
   iv. Peak Tensile Strain = 0.0011

These values for maximum subsidence may be considered reasonable estimates, though not necessarily the maximum possible. The limit of vertical subsidence in both cases would occur when the opening width reaches a critical value relative to the opening depth. For 1 foot of available space, the limiting vertical subsidence at ground surface (absolute maximum) is 0.65 feet.

Figure 8-25, reproduced from the National Coal Board as presented by Pariseau (2007), provides an index of structural damage resulting from surface strain. The figure compares the reciprocal length of a structure to strain and provides an estimate of structural damage.

A structure with length of 50 feet (1/L = 0.020 1/ft), approximately the longest dimension of a residential home, could experience:

- Very Slight damage if exposed to horizontal strains between 0.0004 and 0.0012 (Case 1); and
- Very Slight to Slight damage if exposed to horizontal strains between 0.0011and 0.0019 (Case 2).

A longer structure with a length of 100 feet (1/L = 0.010 1/ft), (approximately the length of the Civic Center) could experience:

- Very Slight to Slight Damage if exposed to horizontal strains between 0.0004 and 0.0012 (Case 1); and
- Slight to Appreciable damage if exposed to horizontal strains between 0.0011 and 0.0019 (Case 2).

8.4 Alternative Causes of Surface Displacements and Structural Damage

Numerous non-mining factors and conditions may cause distress to a structure or surface displacements. Many of the residences of interest may have multiple factors causing problems. These factors were previously mentioned in the Site Observations Section 7. These factors may include:

1. Insufficient structural support due to antiquated or inadequate foundation systems.
2. Structural weakening and deterioration due to age, environmental conditions, original construction practices or faulty maintenance (Day, 2010).
3. Insufficient structural connection between additions and original structures.
4. Susceptibility to frost action (cyclic freezing and thawing) due to shallow foundations.
5. Soils settlement caused by loose or poorly compacted fill (notably in the former Rock Creek alignment area described in Section 8.1), poor drainage or other factors.

Further investigation into each of these factors would be required to definitively identify any of these as causes to structural distress.

9 SUMMARY

A summary of the findings from this investigation and analysis is shown in Table 9-1. The following paragraphs summarize the results for each area of analysis.

9.1 Extent of Mining and Mine Conditions

The extent to which the coal seams beneath the city of Red Lodge have been mined is fairly well documented in the available mine maps and historic journal articles describing mine observations and activities. Observations of the mine workings are consistent with the maps except for seam No. 2. Documented locations of the workings within seam No. 2 were anticipated to be limited in the northerly direction by 17th Street, approximately. Observations of the No. 2 seam within BH07 (15th and Broadway) suggest mining may have occurred to some extent in this area, which is not documented. The void observed in the No. 2 seam at BH07 is the shallowest documented opening, with 27 feet of bedrock cover. For comparison, the next shallowest, seam No. 4. has 103 feet of bedrock cover. If mining did in fact occur, and in a similar fashion as in the east levels of the No. 2 seam, then a portion of the southeast side of town is built above room and pillar workings with bedrock thicknesses as little as 27 feet.

The mine conditions were observed to range between fully open (6 feet of void in BH06) to completely converged. The average remaining opening was calculated at 2 feet in height. The mine floor materials were observed to be sensitive to water and appeared to deteriorate when exposed to water, suggesting the possibility of active deterioration with time. Notably, ground stresses (possibly active or possibly residual) were observed in three bore holes (BH02, BH05, and BH06) when the drill rods were pinched by lateral forces exerted from the surrounding bedrock materials. Further evidence of ground stress was observed in BH07, when the 6-inch steel casing appeared to be sheared off at a depth of 49 feet during the installation of the extensometer. Based on these observations it is possible the mines are continuing to slowly deteriorate and collapse.

Consideration should be given to an investigation into the extent of mining of the No. 2 seam in the areas East of Broadway Ave. to Rock Creek and South of 14th Street to 17th Street. This may be accomplished through:

1. Continue monitoring the existing survey points and install several other points in areas possibly being affected by workings of the No. 2 seam; or
2. Evaluation of the effectiveness of a seismic geophysical investigation or additional bore holes that may detect the presence of mine workings at the known depth of the No. 2 coal seam or the presence of chimney failures near the bedrock surface.

9.2 Overburden

Overburden materials were described as a thin veneer of non-native material (fill) and *in situ* alluvial gravels. The fill materials were observed from the ground surface to depths up to 4.5 feet in the Finn Park neighborhood. Pioneer does not have any as-built documentation indicating the construction techniques used to build the residences of interest. Modern construction practices typically require compacting subgrade soils, setting the foundation depth below frost depth (building code is 48 inches in Red Lodge), and providing positive drainage away from the structure. Based on the era the houses of interest were constructed and Pioneer's site observations and survey monitoring, it appears that many features on these houses were not built using modern building standards.

If residences, additions, or other structures are constructed directly on or above the non-native materials without proper engineering, it is possible to initiate further consolidation of these materials through the addition of building loads. Due to the shallow nature and poor drainage characteristic, structures built on the non-native fine grained materials may be exposed to frost action. If residences or structures are constructed directly on or above uncompacted *in situ* alluvial gravels, small amounts of long-term consolidation may be expected. If structures have been constructed such that foundation drainage is poor and undersides of foundations are exposed to freezing temperatures or excesses of water, structural displacements may still be expected.

9.3 Subsidence Potential

9.3.1 Potholes

For this analysis pothole features have been divided into two categories, steep-sided and shallow-sided. The results suggest formation of steep-sided potholes and/or near surface cavities are unlikely due to the non-cohesive nature of the overburden materials. The combination of engineering calculations, resident observations, and case histories documenting pothole subsidence in other coal mining areas, suggests conditions for the formation of shallow-sided potholes within the study area do exist.

The formation of shallow-sided potholes resulting from chimney failure is possible in areas where the mine workings are less than 150 feet below the bedrock surface. In areas where the mines are more than 150 feet from the bedrock surface, the formation of shallow-sided potholes is much less likely. Bedrock thicknesses within this range were observed in areas where the mined extent of seams No. 4 and 5 are shallowest and the opening at BH07. The formation of shallow-sided potholes resulting from bedrock fissuring is possible in areas where the mines have not fully collapsed.

To this date, occurrences of chimney failure related pothole formation have primarily been observed in two locations close to Red Lodge:

1. On the bench east of the city, where the workings are relatively shallow, on the order of 50 feet or less below the top of bedrock (Kiewit, 1983); and
2. On the bench west of the city, near the current airport, another location of shallow workings (Kiewit, 1983).

The potential occurrence of pothole-type formation within the study area is restricted to three suspected locations, 404 S. Broadway, 207 S. Hauser, and 314 and 316 S. Platt. Continued monitoring and evaluation should be carried out in these areas.

The reported pothole at the 207 S. Hauser residence is not located directly above any workings; rather, it is located approximately 40 to 50 feet to the north of seam No. 4. The reported feature is of unknown origin, and at this time no definitive evidence ties it to the mine workings below. Historic near-surface structures, such as an abandoned water well, may also cause localized

settlement. In light of an absence of definitive evidence tying this feature to mining or historic infrastructure, continued monitoring and evaluation should be carried out before any conclusions are drawn.

The reported depression at 314 and 316 S. Platt Ave. is also not located directly above any workings; rather, it is located approximately 150 feet to the north of seam No. 4. As with the feature reported at 207 S. Hauser Ave., this feature is also of unknown origin and there is no definitive evidence tying this feature to the mine workings or historic infrastructure. Similar to the residence at 207 Hauser Ave., monitoring and evaluation of this feature is recommended.

9.3.2 Trough

Trough subsidence associated with room-and-pillar mining is difficult to predict. Difficulties arise due to the wide variability of pillar geometries, mining geometries, interaction of multiple seam excavations, limited materials data, and prediction of long-term degradation of pillar and floor materials.

Analysis of the potential for trough subsidence was conducted systematically. First, the existing mine and bedrock conditions were observed during the drilling investigation. Second, based on drilling observations, calculations were performed to evaluate the stability of the openings as encountered and then estimate the potential for present and future deterioration of the stability conditions. Lastly, the present conditions, described as incomplete collapse, active degradation of mine floor materials, observed ground stresses, and postulated weathering of pillar materials, suggested further degradation and collapse may be occurring and may continue into the future.

Typical of abandoned mine workings, limited data restricts the estimate of future subsidence to an approximate magnitude that is based on observation of the existing mine conditions. If historic subsidence measurements are available, estimates of future subsidence rates may be cautiously extrapolated. Available data is limited to observation of existing mine conditions with no data for past subsidence rates. Prediction of future trough-type subsidence is therefore difficult, but is estimated to be in the range of 0.0 feet to 0.65 feet within the study area, with a reasonable estimated maximum of 0.25 to 0.32 feet

To assess the risk of damage to infrastructure, two preliminary engineering evaluations were performed to determine if ground surface distortions resulting from a reasonable estimate of continued failure of the mine openings would be detrimental to the current infrastructure of Red Lodge. The results show future minor damage is possible to existing structures in the City of Red Lodge. Potential structural damage from trough subsidence ranges from very slight to appreciable, depending on the size and location of the structure.

To address this potential for structural damage, Pioneer recommends assessing selected infrastructure located near specific reaches of seams Nos. 4 and 5 for subsidence damages and ground movements. This can be accomplished through the installation of crack gages and monitoring points on the Civic Center. The Civic Center is one of the larger buildings, near a shallow reach of seam No. 4. This could include the installation of several additional survey

monuments at selected locations near the shallow reaches of workings within seam Nos. 2, 4, and 5 and the continued monitoring of the existing survey points in these areas.

9.4 Survey Monitoring

To date no noticeable trends suggest active settlement or subsidence in the monitoring area. A few survey monitoring points have moved more than the expected amount in a positive direction, which have been attributed to frost heave or a damaged monitoring point. All negative movements to date have been within the accuracy tolerances of the survey methods.

9.5 Site Specific

The following sections summarize site-specific findings related to each of the locations where residents expressed concerns to DEQ over the possibility of mining-related subsidence.

9.5.1 BH02 / 207 S. Hauser Ave.

This house is located near the shallow reaches of seam No. 4 but not directly above. A subsidence feature was reportedly observed and backfilled in the past. Cracking in a sidewalk adjacent to the northwest corner of the house (near the reported feature), appears to verify the prior subsidence feature. Difficult drilling conditions (pinching of drill rods) were encountered in the upper 30 feet of bedrock in the nearby bore hole BH02; because of this observation, an extensometer was installed to monitor for ground movement.

The reported subsidence feature was of unknown origin, and at this time no definitive evidence ties it to the mine workings below. Historic near-surface structures, such as an abandoned water well, have caused localized surface subsidence in other parts of town. Monitoring of the foundation crack gages over the course of the past year showed no changes. In light of an absence of definitive evidence tying this feature to mining or historic infrastructure, continued monitoring and evaluation should be carried out before any conclusions are drawn.

9.5.2 BH03 / 501 S. Broadway Ave.

This house is located above moderately deep reaches of seams No. 4 and 5. Pothole features due to chimney failures from seams No. 4 and 5 are considered a very rare possibility in this area, although trough subsidence is moderately possible. The house foundation and superstructure do show signs of past minor damage of unknown origin. Monitoring of the foundation crack gages over the course of the past year showed no changes. Should undocumented mining have taken place in seam No. 2, this residence may be affected and is therefore included in the area recommended for additional evaluation of seam No. 2.

9.5.3 BH04 / 505 S. Platt Ave.

This house is located above moderately deep reaches of seams No. 4 and 5. Pothole features due to chimney failures from seams No. 4 and 5 are considered a very slight possibility in this area, although trough subsidence is moderately possible. Should undocumented workings of the shallower seam No. 2 exist, they may contribute to ground strain. Pinching of drill rods was not observed in the immediate bore hole (BH04) but was observed in nearby bore holes BH05 and

BH06. Monitoring of the foundation crack gages over the course of the past year showed no changes. Continued monitoring of survey monuments and crack gages is recommended.

A depression located in front of the house could be the result of a number of possible factors. Therefore, consideration should be given to locating additional survey monitoring points in this area, which could be added into the continuing survey program. Further evaluation is necessary to determine potential causes of the observed depression.

9.5.4 BH07 / 404 S. Broadway Ave.

This house is located above a moderately shallow and undocumented opening in seam No. 2 and moderately deep reaches of seams No. 4 and 5. The undocumented opening may have contributed to the resident's reported ground strain and the suspected broken casing observed in the adjacent bore hole (BH07). Continued evaluation is necessary to determine the origin and extent of the observed opening and reported ground strain.

Pothole features due to chimney failures from deeper seams (No. 4 and 5) are considered a very slight possibility in this area, although trough subsidence is moderately possible.

Monitoring of the foundation crack gages over the course of the past year showed no changes. The main portion of the house appears to have been constructed on alluvial gravels; it is not clear what the additions were constructed on. Continued monitoring of survey monuments and crack gages is recommended. Should undocumented mining have taken place in seam No. 2, this residence may be affected and is therefore included in the area recommended for additional evaluation of seam No. 2.

9.5.5 Police Station

Based on the debris observed in the majority of the hand auger holes, the police station floor appears to be bearing directly on granular fill soils. No coal slack was observed in any of the hand auger holes. Pioneer's investigation was limited to the depth of the hand auger holes; however, no evidence of past mining activity was logged during the police station investigation that would suggest the settlement is attributable to historic mining activities.

10 CONCLUSIONS

The following items summarize principal findings and conclusions of the investigation and analyses:

1. Structures of Interest:
    1. 207 South Hauser Ave. – Reported observation of a subsidence feature combined with drilling observations is cause for additional investigation and continued monitoring.
    2. 501 South Broadway Ave. – No definitive evidence of mine-related subsidence was found.

3. 505 South Platt Ave. –No definitive evidence of mine-related subsidence was found, however the observed surface depression is cause for additional investigation and continued monitoring.
4. 404 South Broadway Ave. – Observation of an undocumented opening in conjunction with disruption of the bore hole casing and the resident's reported subsidence observations warrants continued monitoring and additional investigation to provide definitive causality.
5. Police Station – No evidence was found that floor subsidence was caused by mining-related activities.

2. Extent of Mining:
   Historic documentation of the abandoned mines is fairly well preserved with the exception of seam No. 2. The absence of mine data for seam No. 2 greatly inhibits the interpretation of potential subsidence features in the southeast section of the study area.
3. Existing Mine Conditions:
   The mine conditions were observed to range between fully open (6 feet of void in BH06) to completely converged. Mine workings that are not totally collapsed may continue to slowly deteriorate such that further collapse ensues. Based on the fact that the mining occurred 100 years ago, any further collapse would likely occur over a long period.
4. Overburden Materials:
   Natural conditions within the overburden materials that are able to cause surface subsidence were not observed. Although a thin veneer of non-native fill material was observed in hand auger holes and test pits in the Finn Park area, this material, if improperly constructed on, could be responsible for structural settlements but not likely to cause surface subsidence features.
5. Chimney Pothole Subsidence:
   Most of the workings are at depths where chimney failures are likely to self-arrest before reaching the upper limit of the bedrock. Chimney-type pothole subsidence is possible in locations of the city where bedrock thicknesses are less than approximately 150 feet (Figure 8-13). Hazardous, steep-sided pothole subsidence (ie. Sinkholes) are considered highly unlikely anywhere. Shallow-sided pothole subsidence may be possible in areas of lesser bedrock thickness. The likelihood of a future pothole of this nature to affect any one resident is very low, considering only two are suspected to have developed over the past 75 years.
6. Trough-type Subsidence:
   Potential maximum vertical settlement is estimated to be on the order of 0 to 7 inches, depending on the size of mine room collapse. Considering the abandoned mines below Red Lodge have likely been slowly degrading and collapsing for the past 75 years and within this time frame, no significant observations regarding subsidence have been made, future trough-type subsidence are likely to remain slow and may accumulate over the next 50 to 100 years. Building damage resulting from this slow deterioration is estimated to be localized and structural damage may be on the order of slight to appreciable, depending on the size of building.

11 RECOMMENDATIONS

Figure 10-1 shows areas recommended for continued monitoring and additional investigation. The recommendations include:

1. Continued survey, crack gage, and extensometer monitoring through 2015. Add monitoring points in strategic locations, such as the Civic Center and along the west side of Platt Ave., 500 block. The area located north of 14 St. S., between Villard Ave. and Hauser Ave., encompasses the structure of interest at 207 South Hauser Ave.
2. If monitoring shows the potential for a problem, initiate additional investigative work which may include:
   i. Install and monitor additional extensometer(s) or inclinometer(s);
   ii. Evaluate the potential effectiveness and conduct geophysical investigation; and
   iii. Install additional bore hole(s).
3. Evaluate the potential effectiveness of a seismic geophysical investigation to:
   i. Locate and map the No. 2 mine workings. This would include the area between Broadway and Haggin, from 17th St. South to 14th St. South and also encompass the area in the vicinity of BH03.
   ii. Investigate possible causes (both near surface and mine related) of the depression located at 505 South Platt Ave.
   iii. Investigate possible causes (both near surface and mine related) of the reported subsidence feature at 207 S. Hauser Ave.

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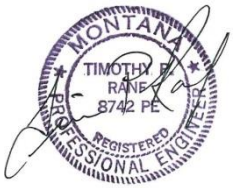
13 PROFESSIONAL CERTIFICATION

I hereby certify that this report was prepared by me and that I am a duly Licensed Professional Engineer under the laws of the State of Montana.



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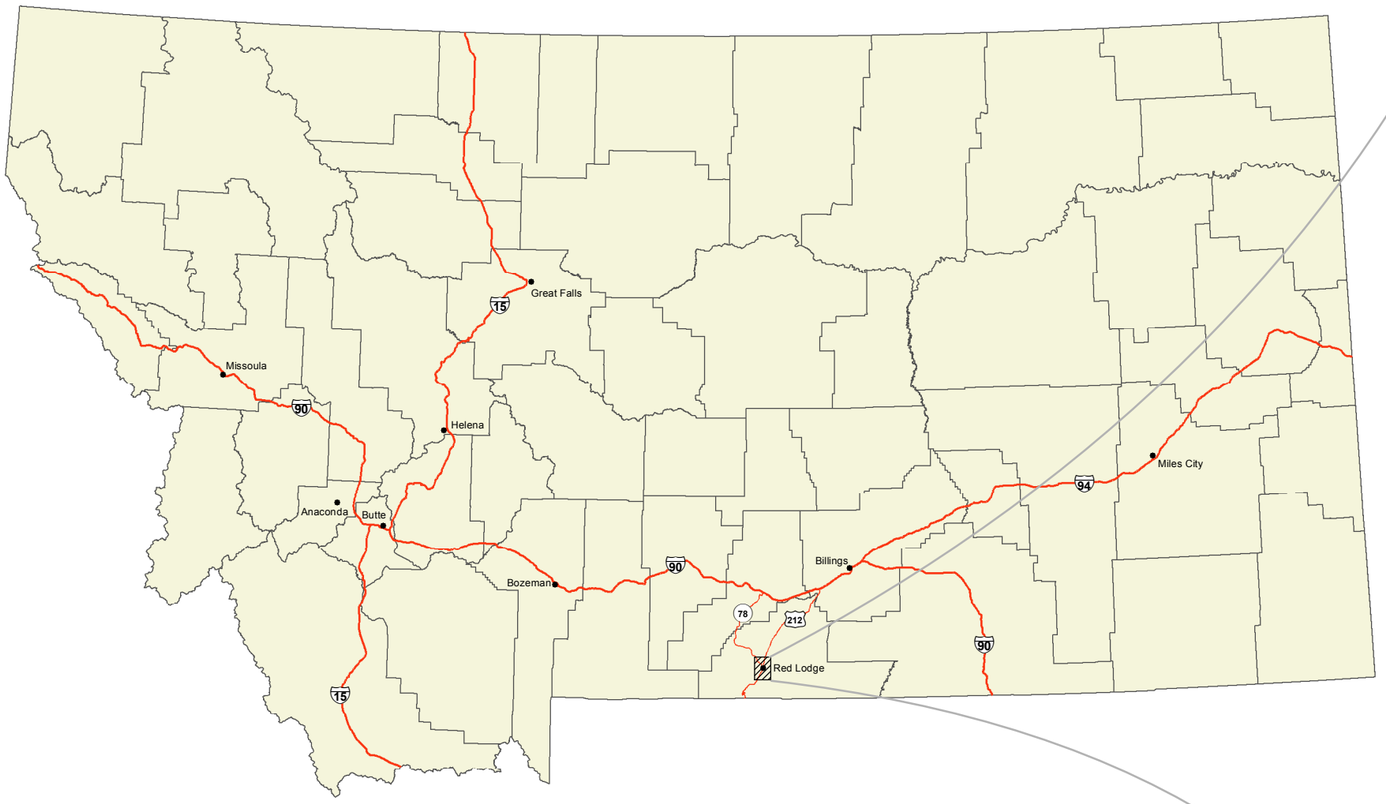
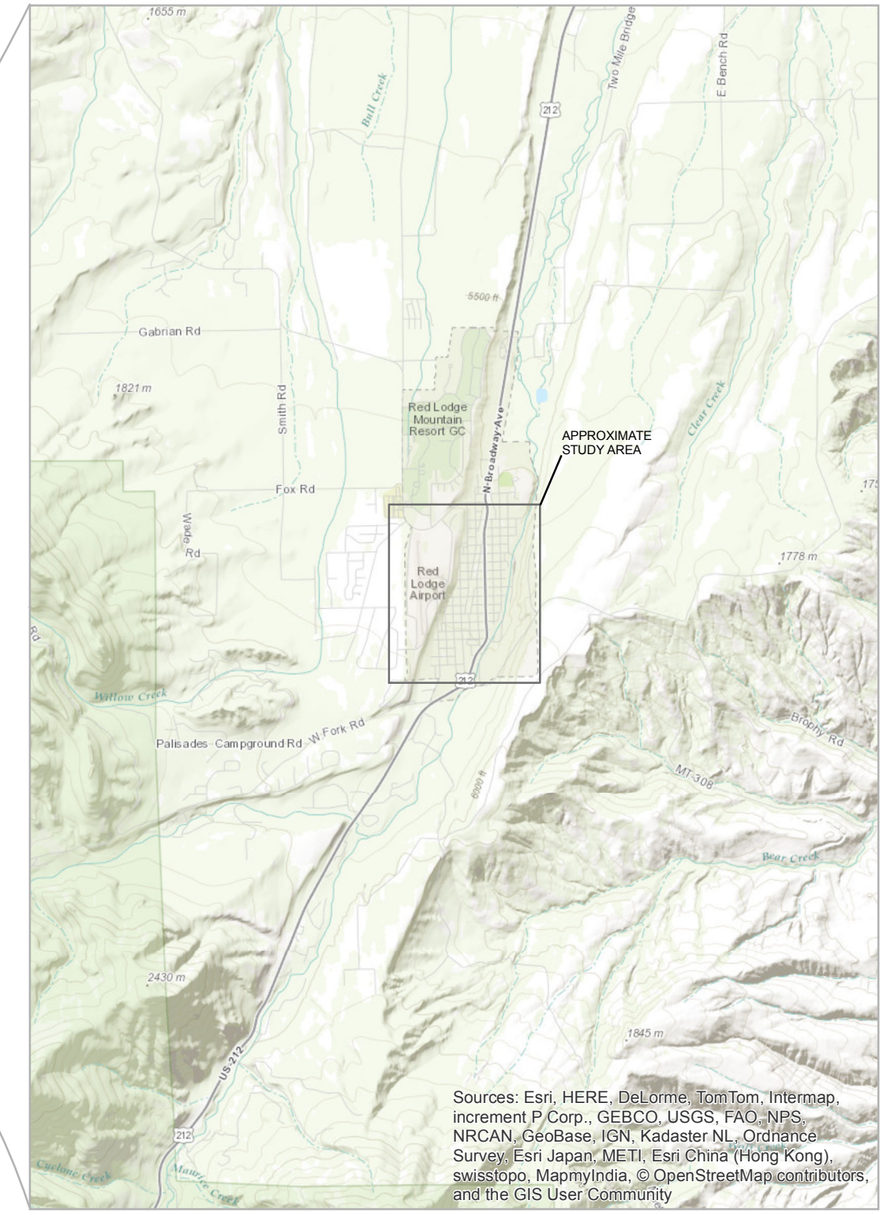
FIGURES



MONTANA



N

DISPLAYED AS:
PROJECTION/ZONE: NA
DATUM: NA
UNITS: NA
SOURCE: NA

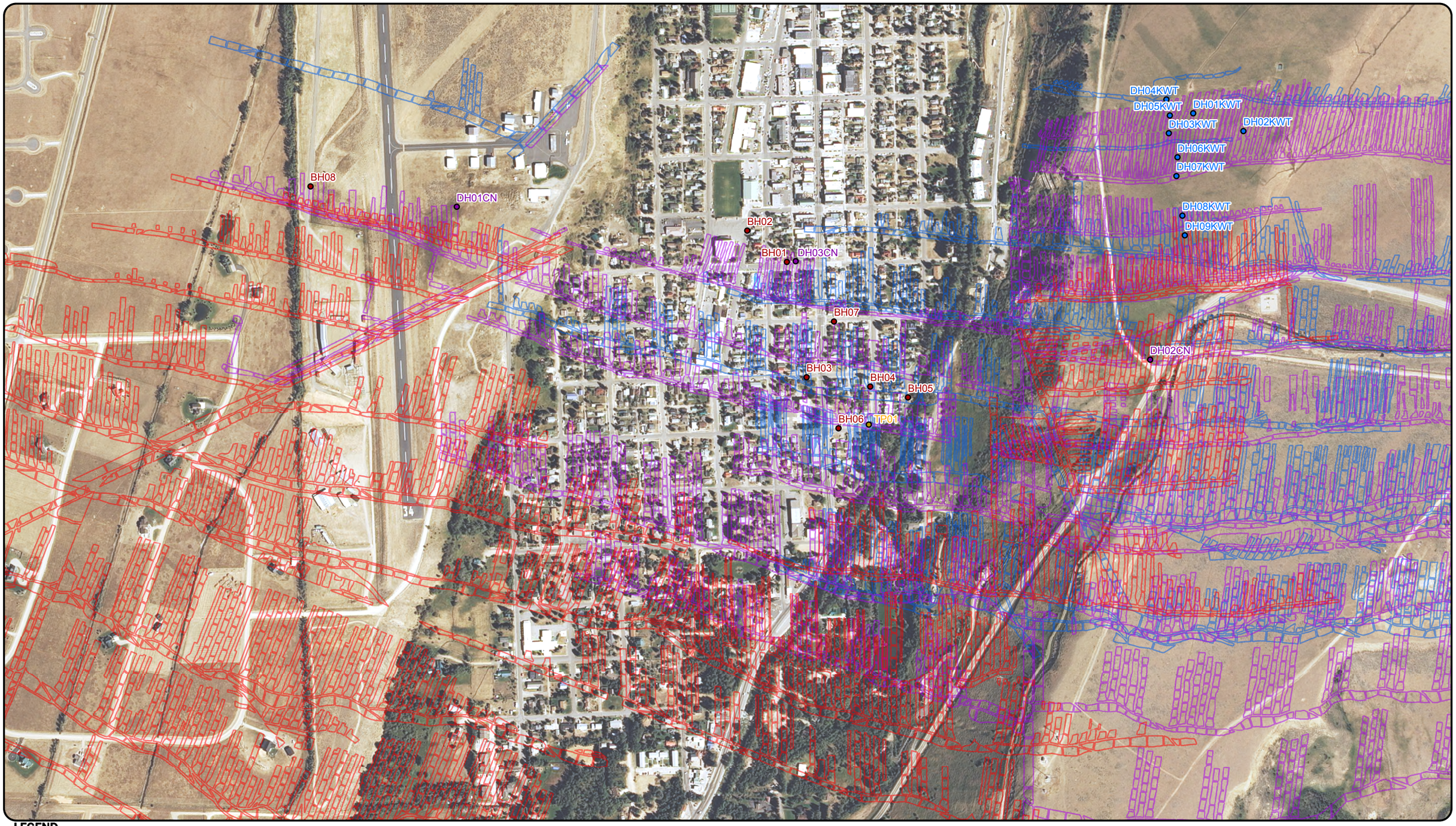
FIGURE 2-1

PIONEER TECHNICAL SERVICES, INC.

RED LODGE SUBSIDENCE DRILLING INVESTIGATION PROJECT LOCATION MAP

DATE: 1/27/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\REDLODGE_PROJ_LOC.mxd



LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014
- PIONEER TEST PIT
- MINE_1_5
- MINE_4
- MINE_5

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY; PIONEER; CN; KIEWET

0 250 500 1,000
Feet

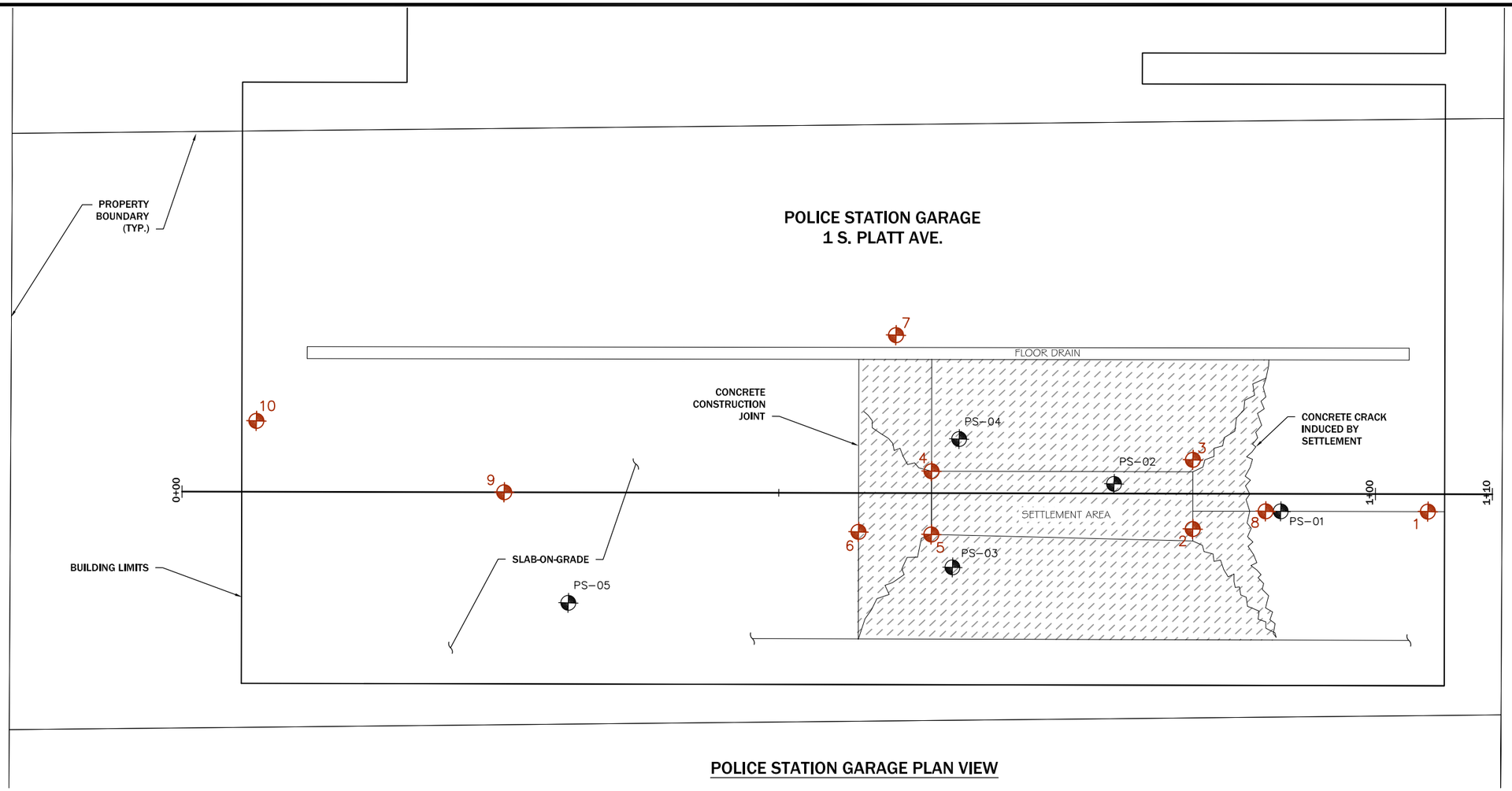
FIGURE 2-2

PIONEER TECHNICAL SERVICES, INC.

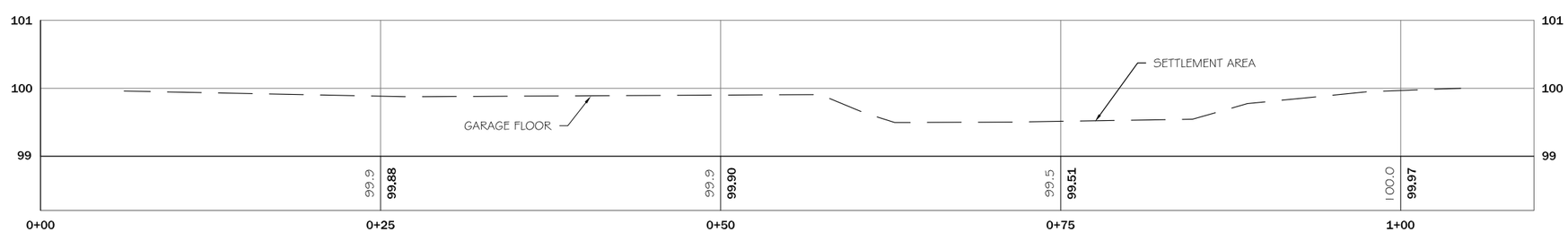
GENERAL LOCATION OF DOCUMENTED MINE WORKINGS

DATE: 5/6/2015

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\WORKINGS_OVERVIEW.mxd



POLICE STATION GARAGE PLAN VIEW



POLICE STATION GARAGE PROFILE

5 FT VERTICAL EXAGGERATION

LEGEND

= Temporary benchmark (X on concrete) for measuring subsidence

= Hand auger holes

N

	DISPLAYED AS:
COORD SYS/ZONE:	MT STATE PLANE COORDINATES
DATUM:	NAD83(2011)
UNITS:	INTERNATIONAL FEET
SOURCE:	OPUS & NGS BENCHMARK

SCALE IN FEET
0 5 10

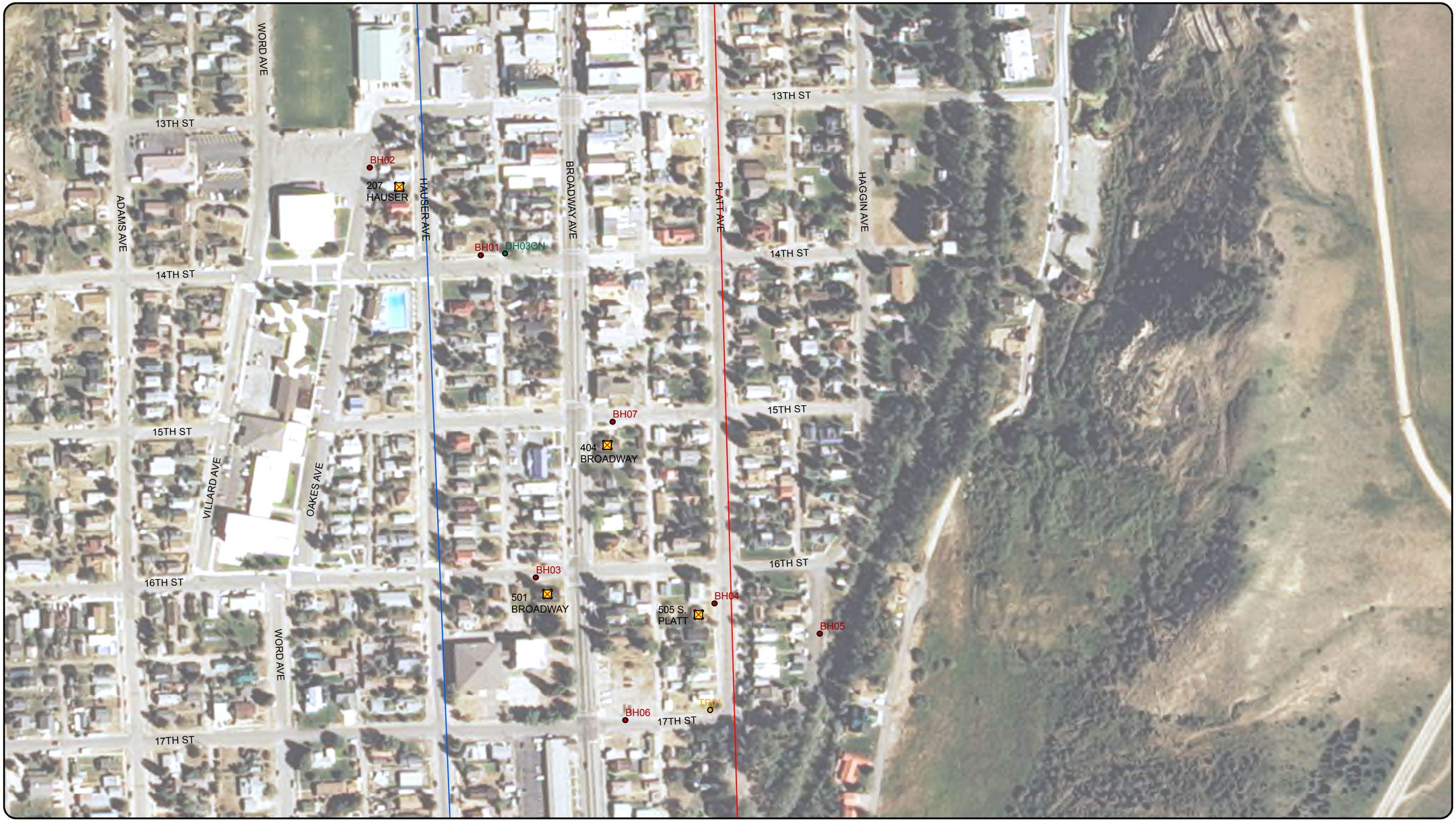
FIGURE 3-1

PIONEER TECHNICAL SERVICES, INC.
201 E. BROADWAY, SUITE C
HELENA, MT 59601
(406) 457-8252

POLICE STATION GARAGE

DATE: 01-26-15

1/28/2015 1:17:59 PM \\192.168.250.13\DATA$\LABDATA$\SURVEY-CLIENTS\MT DEQ\RED LODGE SUBSIDENCE MONITORING\2014\DRAWINGS\SURVEY\REDLODGE-BAS-SU-001-14.DWG



LEGEND

- PIONEER TECHNICAL BORE HOLE 2014
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TEST PIT
- STRUCTURES OF INTEREST
- CROSS SECTION A-A'
- CROSS SECTION B-B'

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY, PTS, CN1987

0 50 100 200
Feet

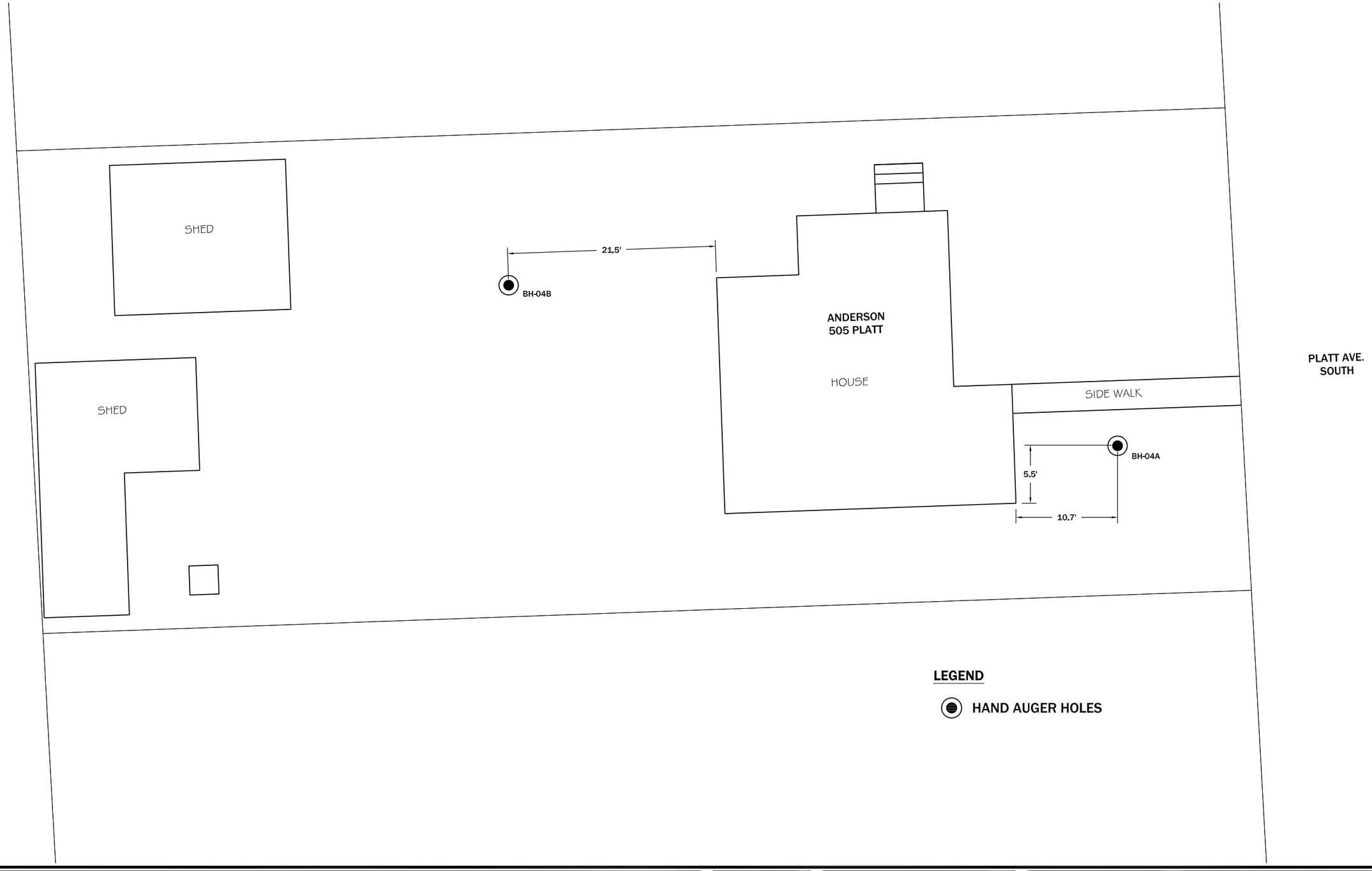
FIGURE 4-1

STRUCTURES OF INTEREST

PIONEER TECHNICAL SERVICES, INC.

DATE: 3/9/2015

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\STRUCTURES_INSPECTED_INTEREST.mxd



N

	DISPLAYED AS:
COORD SYS/ZONE:	MT STATE PLANE COORDINATES
DATUM:	NAD83(2011)
UNITS:	INTERNATIONAL FEET
SOURCE:	OPUS & NGS BENCHMARK

SCALE IN FEET
0 5 10

FIGURE 4-2

HAND AUGER LOCATIONS
505 S. PLATT
RED LODGE, MT

PIONEER TECHNICAL SERVICES, INC.
201 E. BROADWAY, SUITE C
HELENA, MT 59601
(406) 457-8252

DATE: 12/19/14

LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014
- PIONEER TEST PIT

- CROSS SECTION A-A'
- CROSS SECTION B-B'
- CROSS SECTION C-C'

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY

0 100 200 400 600
Feet

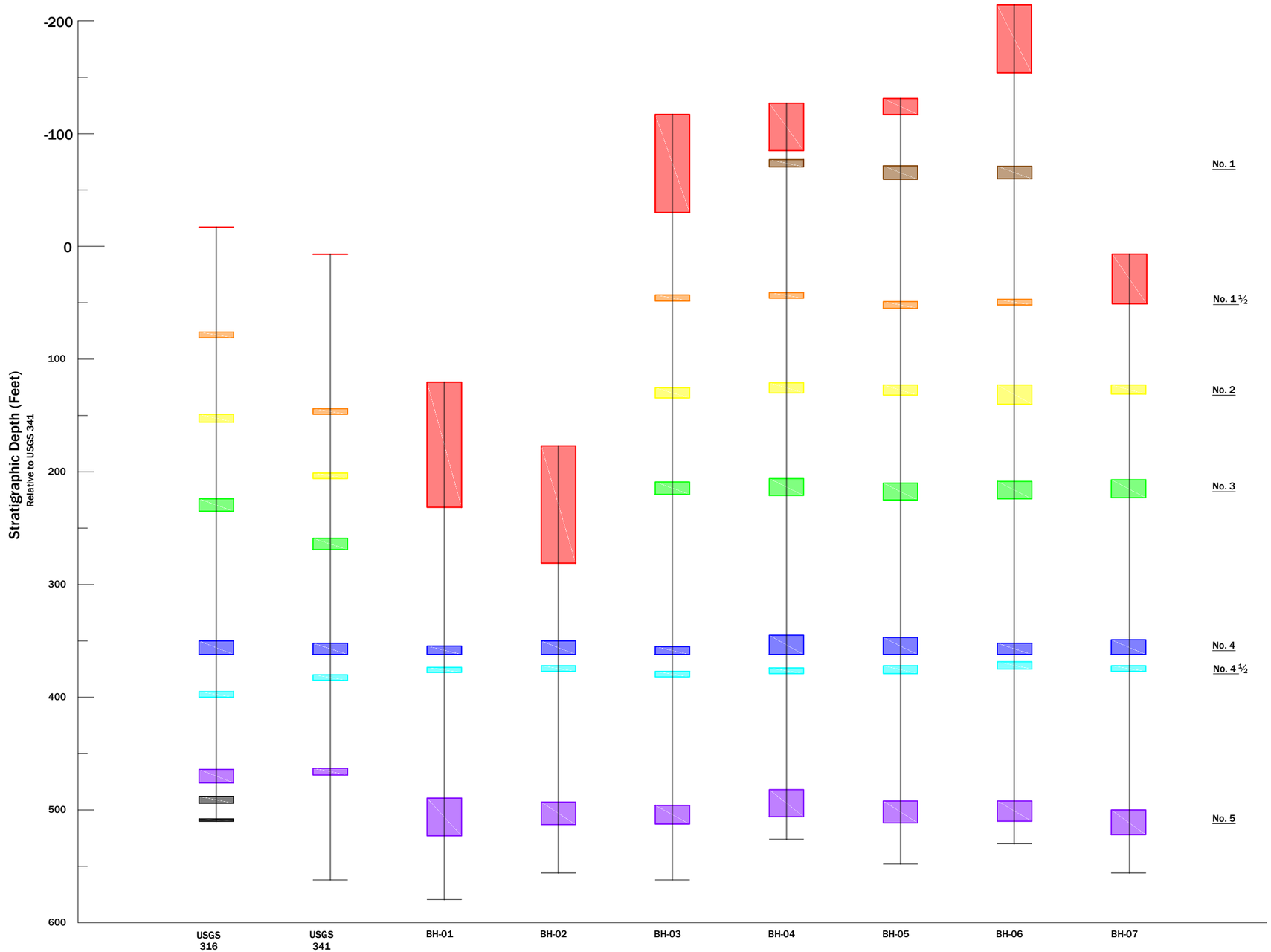
FIGURE 5-1

BORE HOLE, TEST PIT AND CROSS-SECTION LOCATIONS

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\BOREHOLE_LOCATIONS.mxd



LEGEND:

- Alluvium
- No. 1
- No 1½
- No 2
- No 3
- No 4
- No 4½
- No 5
- Total Depth

DISPLAYED AS:

COORD SYS/ZONE: NA

DATUM: NA

UNITS: FEET

SOURCE: PIONEER

SCALE IN FEET

0 NTS

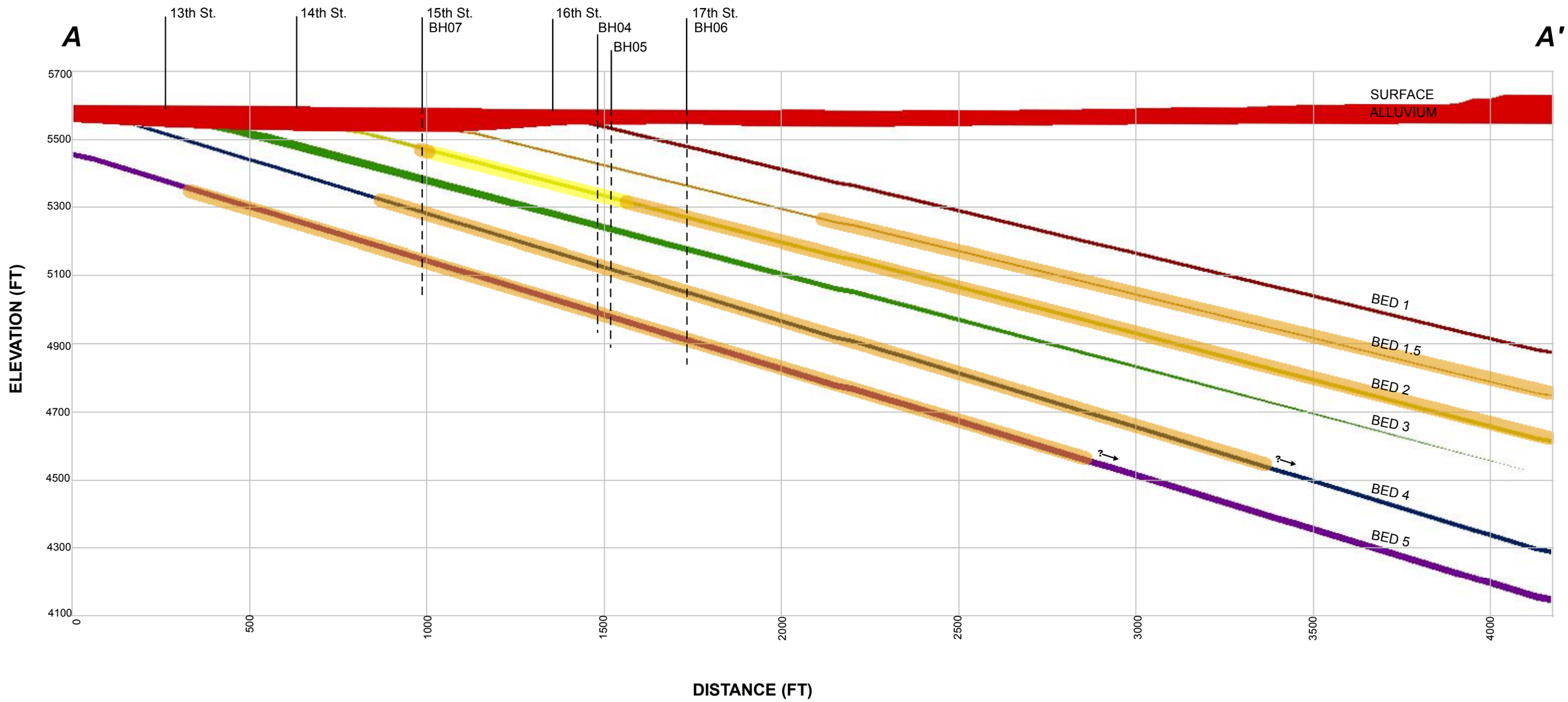
FIGURE 5-2

GENERALIZED COAL BEDS

PIONEER TECHNICAL SERVICES, INC.
106 PRONGHORN TRAIL, SUITE A
BOZEMAN, MONTANA 59718
(406) 388-8578

DATE: 01/08/15

2/6/2015 9:01:24 AM \\192.168.253.15\PROJECT$\HELENADATA\DEQ\RED LODGE SUBSIDENCE\DRAWINGS\REDLODGE-FIG5_2-001-15.DWG



LEGEND

APPROXIMATE EXTENT OF WORKINGS (WHERE DATA IS AVAILABLE)

POTENTIAL WORKED AREA

? → WORKINGS MAY EXTEND FARTHER; LOCATION IS LIMITED TO AVAILABLE MAPS

*BOREHOLE LOCATIONS ARE PROJECTED ONTO CROSS-SECTION PARALLEL TO BED STRIKE.

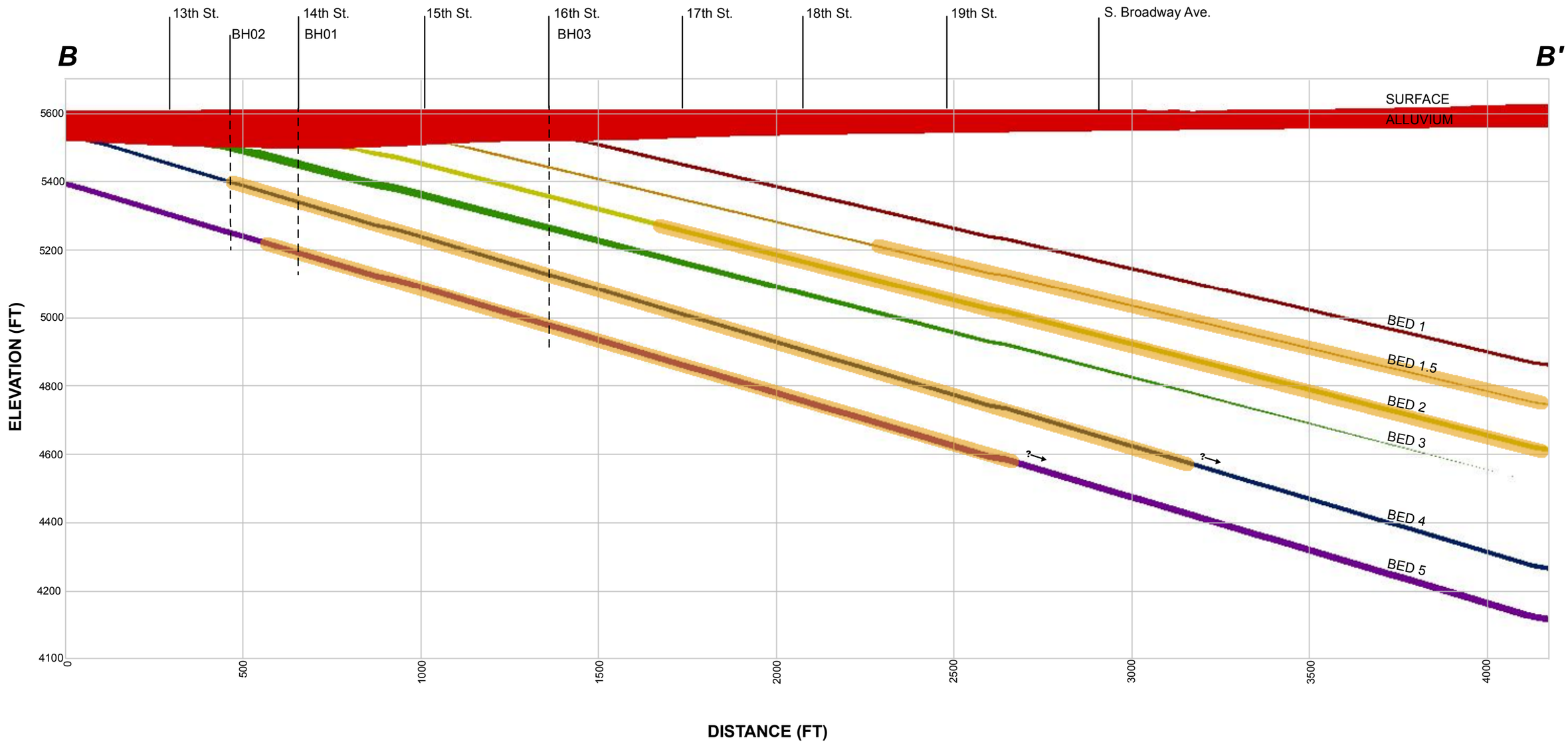
DISPLAYED AS:
PROJECTION/ZONE: NA
DATUM: NAD83
UNITS: FEET
SOURCE: PIONEER, CN, KIEWIT BH DATA & NWIC MAPS

FIGURE 5-3 CROSS SECTION A-A': PLATT AVE

PIONEER TECHNICAL SERVICES, INC.

DATE: 1/27/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\CS_A_A.mxd



LEGEND

APPROXIMATE EXTENT OF WORKINGS (WHERE DATA IS AVAILABLE)

? → WORKINGS MAY EXTEND FARTHER; LOCATION IS LIMITED TO AVAILABLE MAPS

***BOREHOLE LOCATIONS ARE PROJECTED ONTO CROSS-SECTION PARALLEL TO BED STRIKE.**

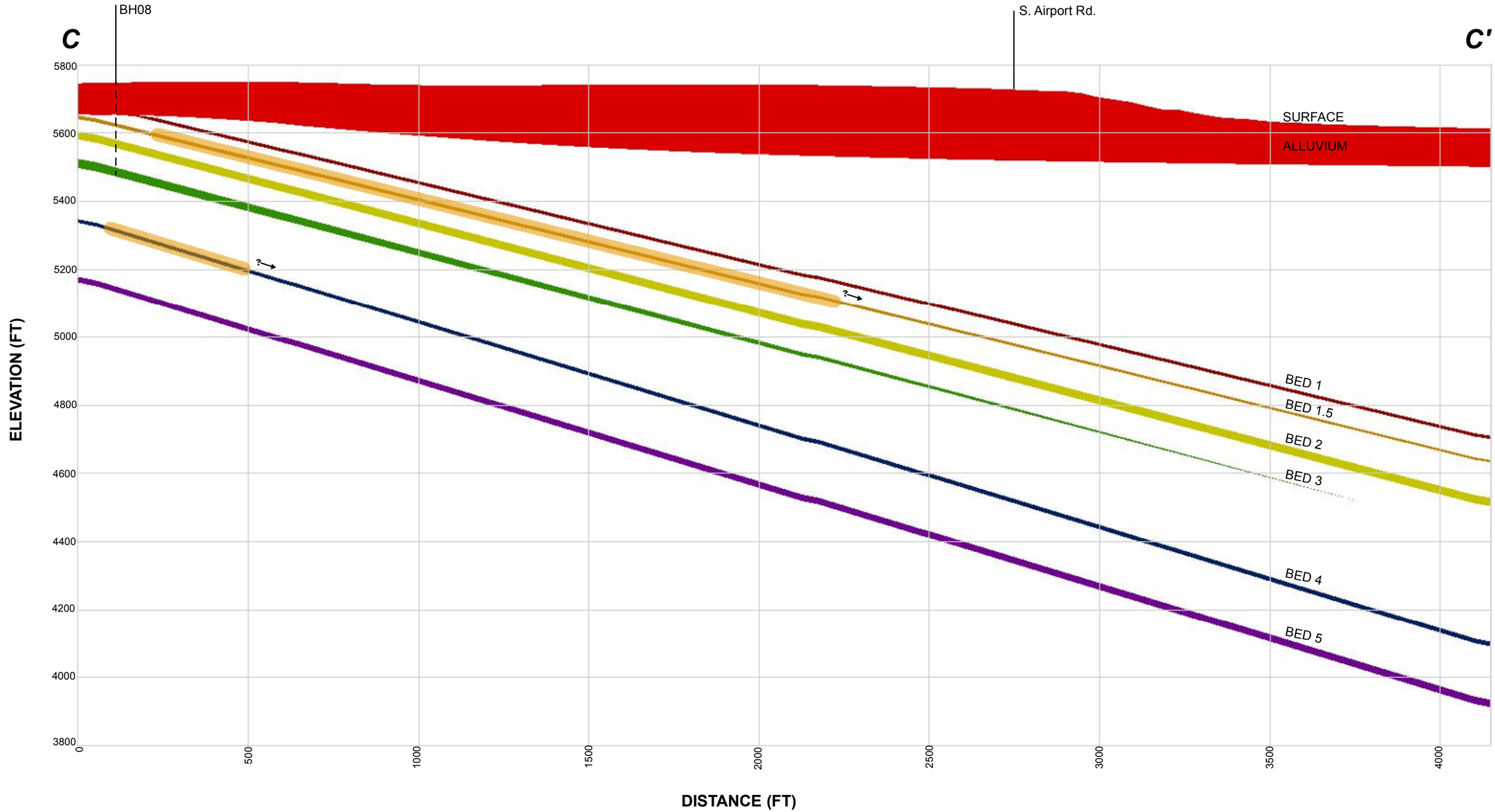
DISPLAYED AS:
PROJECTION/ZONE: NA
DATUM: NAD83
UNITS: FEET
SOURCE: PIONEER, CN, KIEWIT BH DATA & NWIC MAPS

FIGURE 5-4 CROSS SECTION B-B': HAUSER AVE

PIONEER TECHNICAL SERVICES, INC.

DATE: 1/27/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\CS_B_B.mxd



LEGEND

APPROXIMATE EXTENT OF WORKINGS (WHERE DATA IS AVAILABLE)

? → WORKINGS MAY EXTEND FARTHER; LOCATION IS LIMITED TO AVAILABLE MAPS

***BOREHOLE LOCATIONS ARE PROJECTED ONTO CROSS-SECTION PARALLEL TO BED STRIKE.**

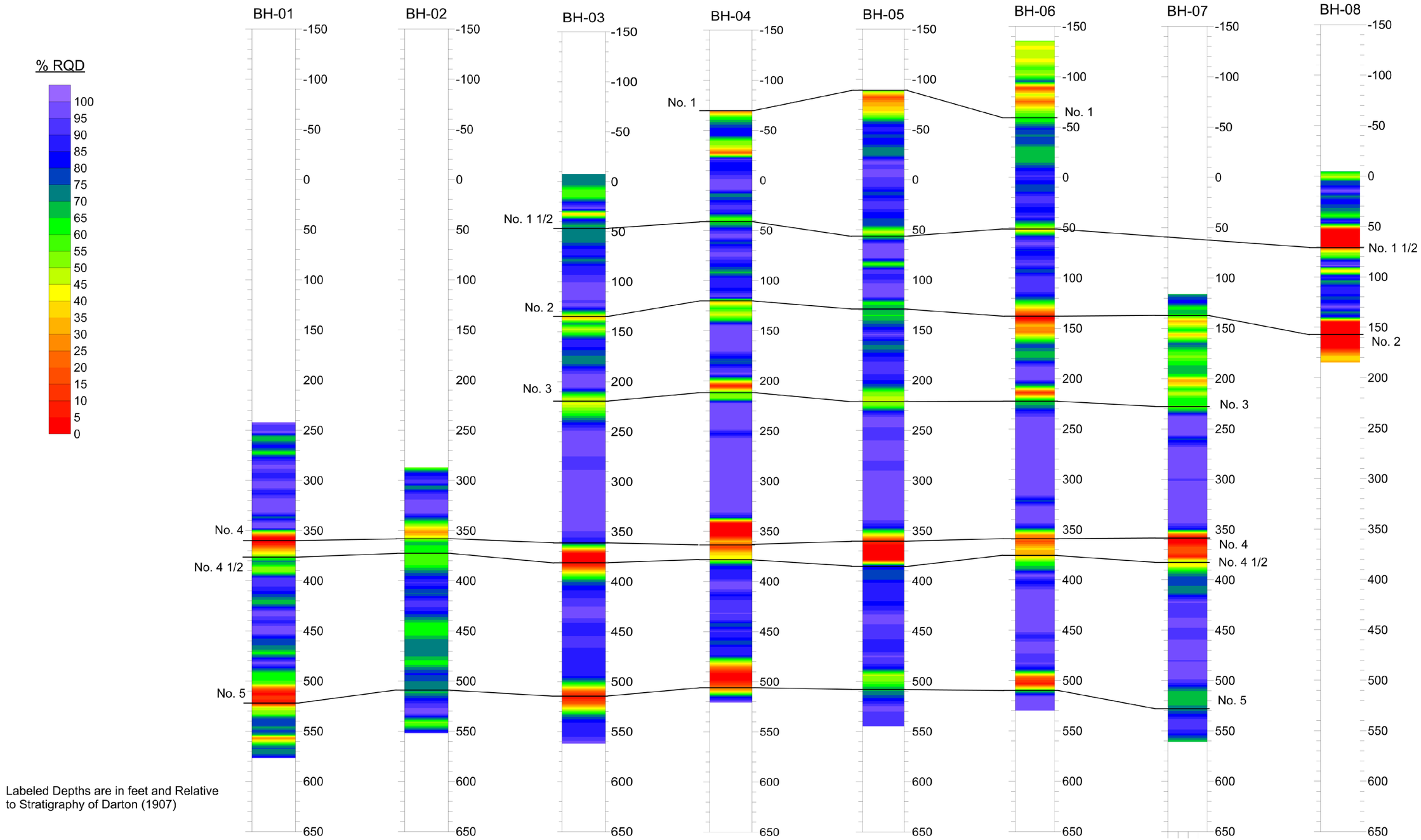
DISPLAYED AS:
PROJECTION/ZONE: NA
DATUM: NAD83
UNITS: FEET
SOURCE: PIONEER, CN, KIEWIT BH DATA & NWIC MAPS

FIGURE 5-5 CROSS SECTION C-C': AIRPORT

PIONEER TECHNICAL SERVICES, INC.

DATE: 1/27/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\CS_C_C.mxd



Labeled Depths are in feet and Relative to Stratigraphy of Darton (1907)

DISPLAYED AS:
PROJECTION/ZONE:
DATUM:
UNITS:
SOURCE:

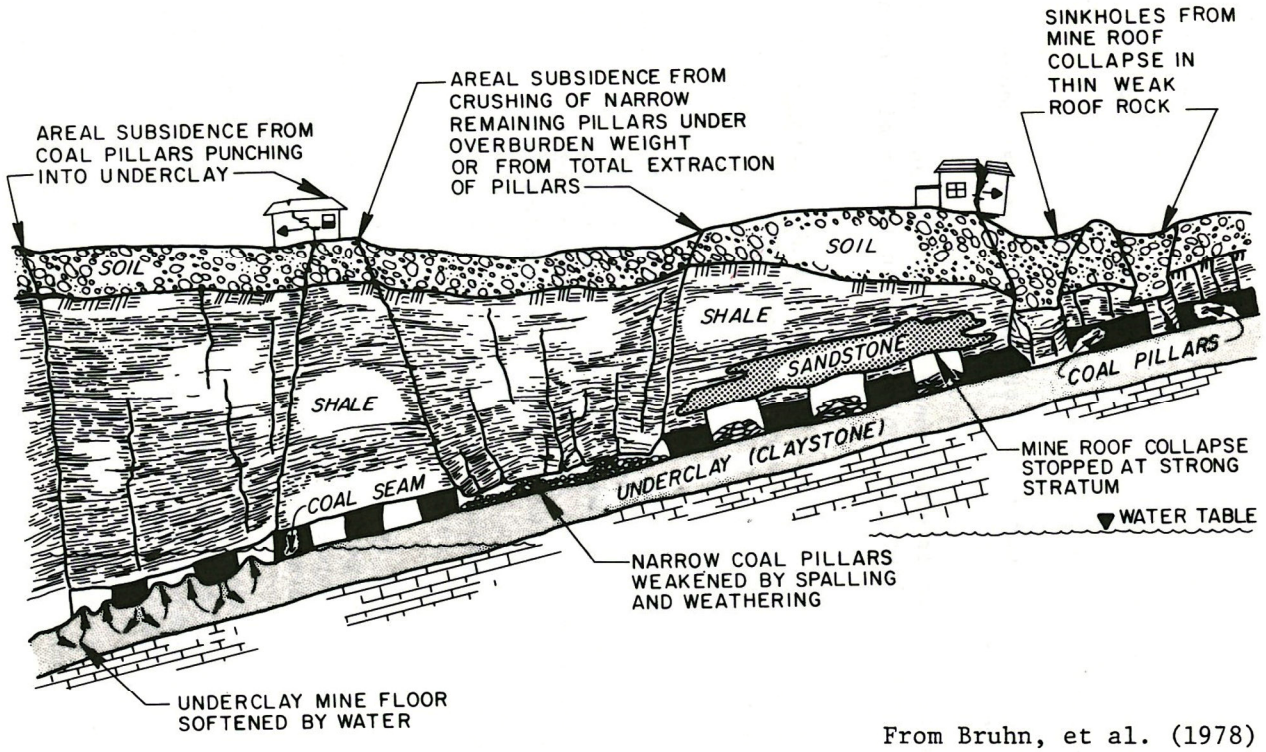
FIGURE 5-6

PIONEER TECHNICAL SERVICES, INC.

DATE: 4/20/2015

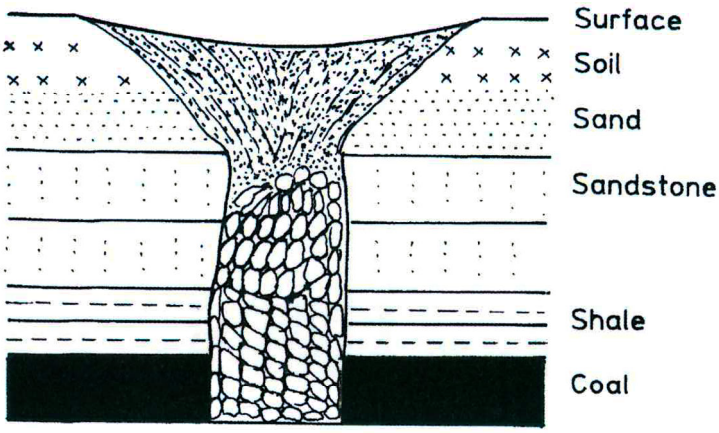
BORE HOLE ROCK QUALITY DESIGNATION

Path: P:\DEQ\RedLodge\GIS\BoreholeRock Quality.mxd

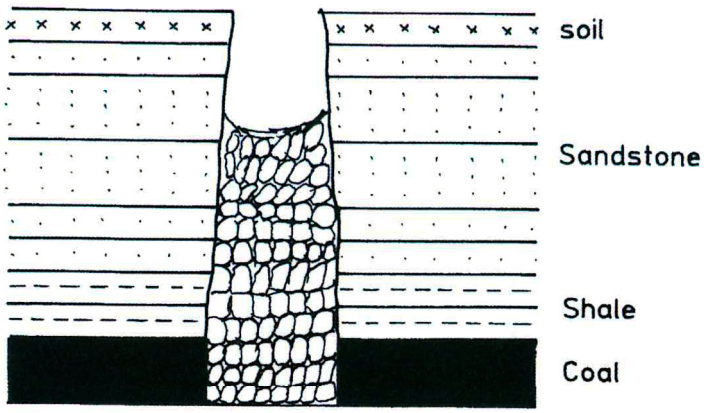


From Bruhn, et al. (1978)

A



B



C

From Singh, K.B. and Dhar, B.B (1997)

A) MODES OF SUBSIDENCE
B) SHALLOW-SIDED POTHOLE
C) STEEP-SIDED POTHOLE

FIGURE 8-1

MODES OF SUBSIDENCE TROUGH AND POTHOLE

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/3/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\MODES_OF_SUBSIDENCE_TROUGH_POTHOLE.mxd

LEGEND

- CONTOUR: THICKNESS OF ALLUVIUM
- PIONEER TECHNICAL BORE HOLE 2014

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD1983
UNITS: FEET INTERNATIONAL
SOURCE: NAIP IMAGERY, PIONEER AND CN BH DATA

0 50 100 200
Feet

FIGURE 8-2

ALLUVIUM THICKNESS

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\ALLUVIUM_THICKNESS.mxd

LEGEND

STRUCTURES OF INTEREST

- 207 HAUSER
- 404 BROADWAY
- 501 BROADWAY
- 505 PLATT

MAP OVERLAY WAS SURVEYED BY GEORGE SHEETZ, JULY 28- AUGUST 3, 1888. THE MAP IS LAYED OVER CURRENT AERIAL IMAGERY ON THE LEFT AND 1951 AERIAL IMAGERY ON THE RIGHT.

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD 83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP, USGS

0 200 400 800
Feet

FIGURE 8-3

1888 MAP OVERLAY

PIONEER TECHNICAL SERVICES, INC.

DATE: 3/9/2015

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\OVERLAY1888.mxd

LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014

***MINE MAP OVERLAY: NORTHWESTERN IMPROVEMENT COMPANY MAP OF RED LODGE & SUNSET MINES ON NO. 1.5 BED. RED LODGE, MT. JANUARY, 1910**

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD1983
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY

0 100 200 400 600
Feet

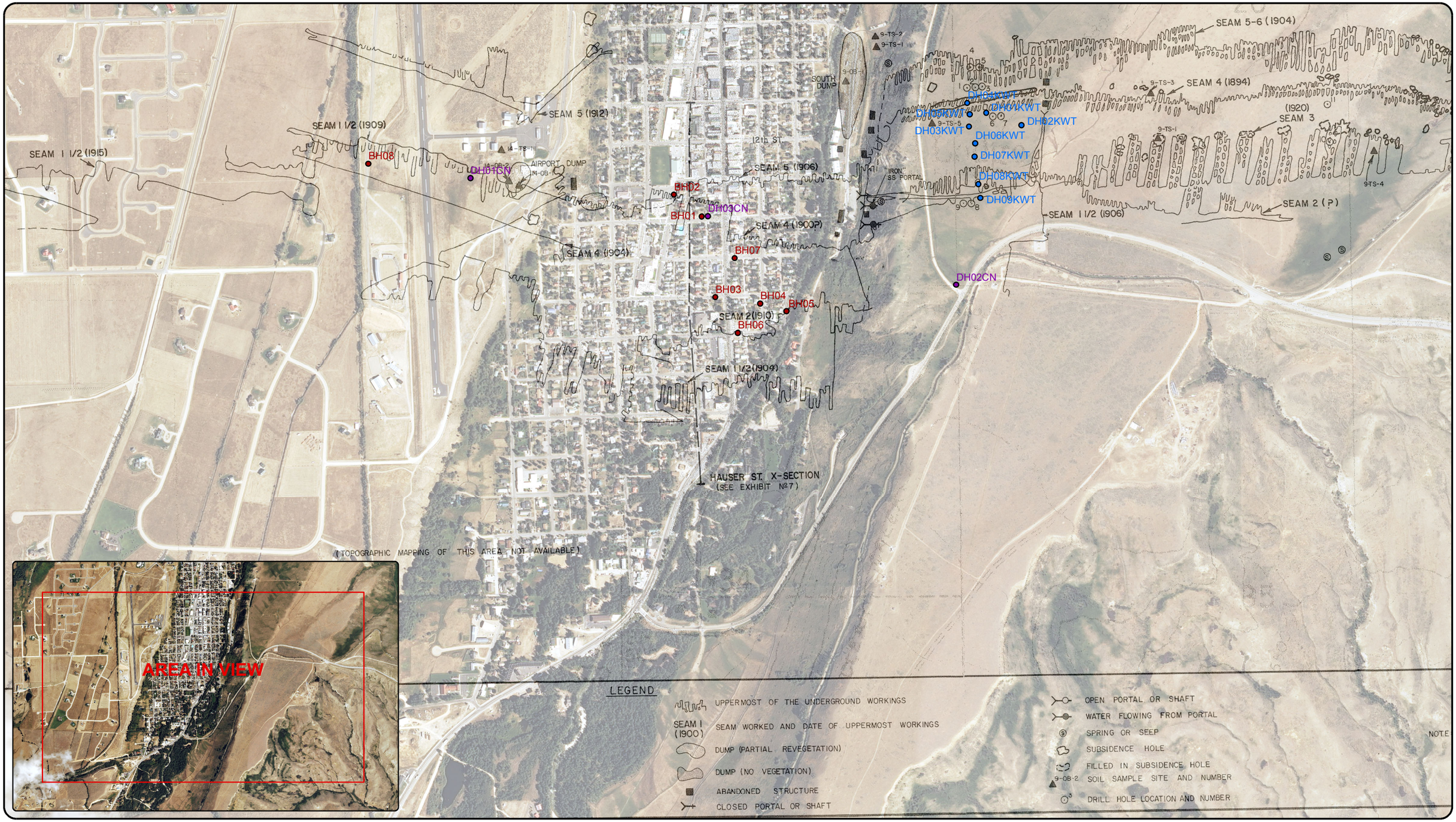
FIGURE 8-4

MINE MAP NO. 1.5 SEAM

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\EXTENT_1_5.mxd



LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014

***MAP OVERLAY: PETER KIEWET SONS' COMPANY RED LODGE AML PROJECT EXHIBIT NO. 3 (1983)**

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY; PTS; CN; KIEWET

0 200 400 800
Feet

FIGURE 8-5 EXTENT OF MINING NO. 2 SEAM AS PRESENTED BY KIEWIT 1983

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\KIEWET_OVERLAY.mxd

LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987

***MINE MAP OVERLAY: NORTHWESTERN IMPROVEMENT COMPANY MAP OF MINE NO. 2 BED. RED LODGE, MT. NOVEMBER 1923**

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY

0 100 200 400 600
Feet

FIGURE 8-6

MINE MAP NO. 2 SEAM

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\EXTENT_2.mxd

LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987

***MINE MAP OVERLAY: NORTHWESTERN IMPROVEMENT COMPANY MAP OF RED LODGE MINE NO. 3 BED. RED LODGE, MT. JANUARY 1926**

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY

0 100 200 400 600
Feet

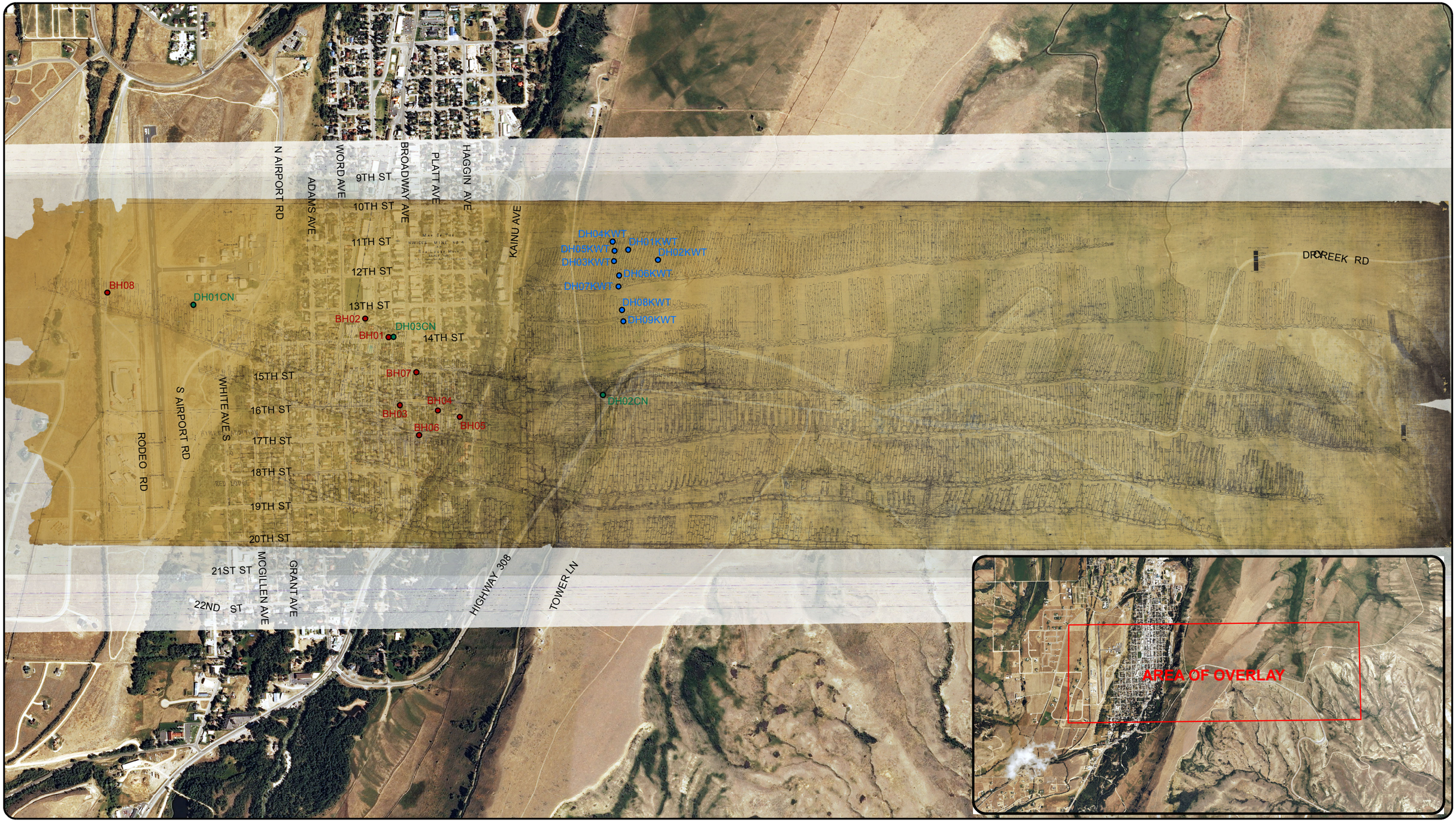
FIGURE 8-7

MINE MAP NO. 3 SEAM

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\EXTENT_3.mxd



LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014

***MINE MAP OVERLAY: NORTHWESTERN IMPROVEMENT COMPANY MAP OF MINE NO. 4 AT RED LODGE, MT. JANUARY 1907**

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY

0 150 300 600 900
Feet

FIGURE 8-8

MINE MAP NO. 4 SEAM

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\EXTENT_4.mxd

LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014

***MINE MAP OVERLAY: NORTHWESTERN IMPROVEMENT COMPANY MAP OF RED LODGE NO. 5 MINE. RED LODGE, MT. AUGUST 1912**

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY

0 100 200 400 600
Feet

FIGURE 8-9

MINE MAP NO. 5 SEAM

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\EXTENT_5.mxd

LEGEND

- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987

***MINE MAP OVERLAY: NORTHWESTERN IMPROVEMENT COMPANY MAP OF RED LODGE MINE NO. 6 BED. RED LODGE, MT. AUGUST 1926**

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY

0 100 200 400 600
Feet

FIGURE 8-10

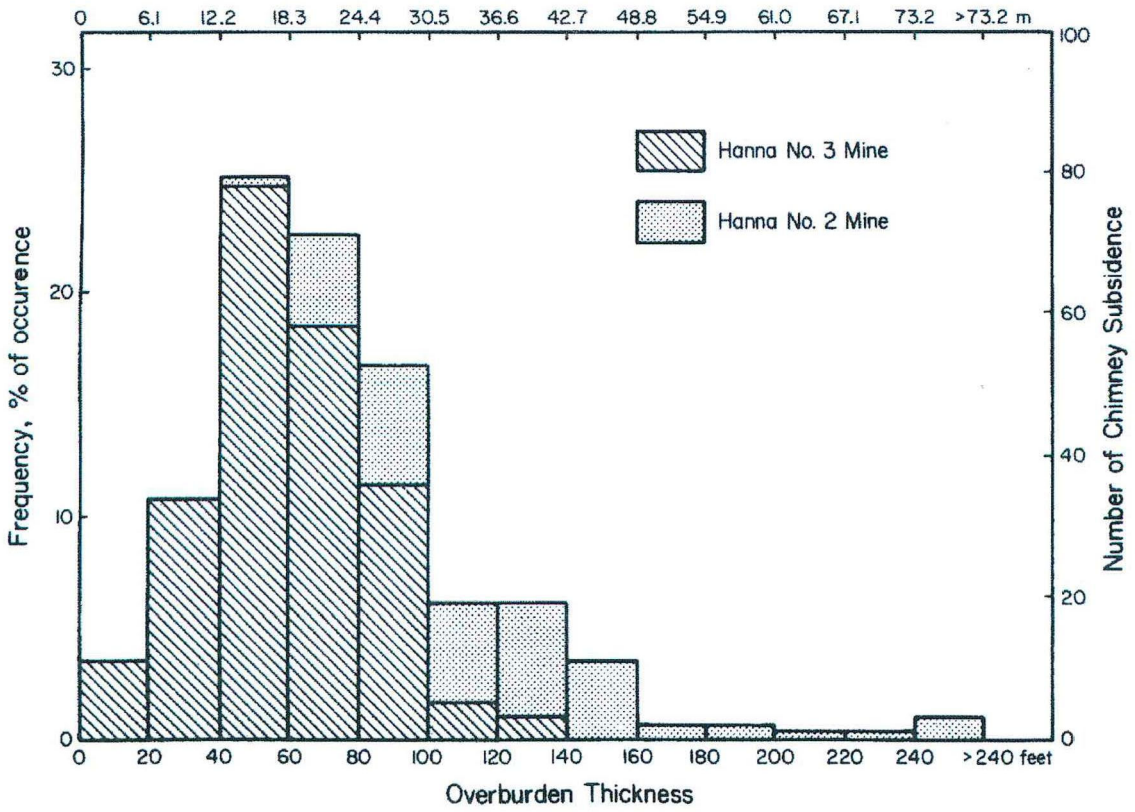
MINE MAP NO. 6 SEAM

PIONEER TECHNICAL SERVICES, INC.

DATE: 2/6/2015

Path: \\192.168.253.15\project$\HelenaData\DEQ\Red Lodge Subsidence\Documents\DSR\GIS\EXTENT_6.mxd

FROM: KARFAKIS (1987)



FROM: SINGH (2007)

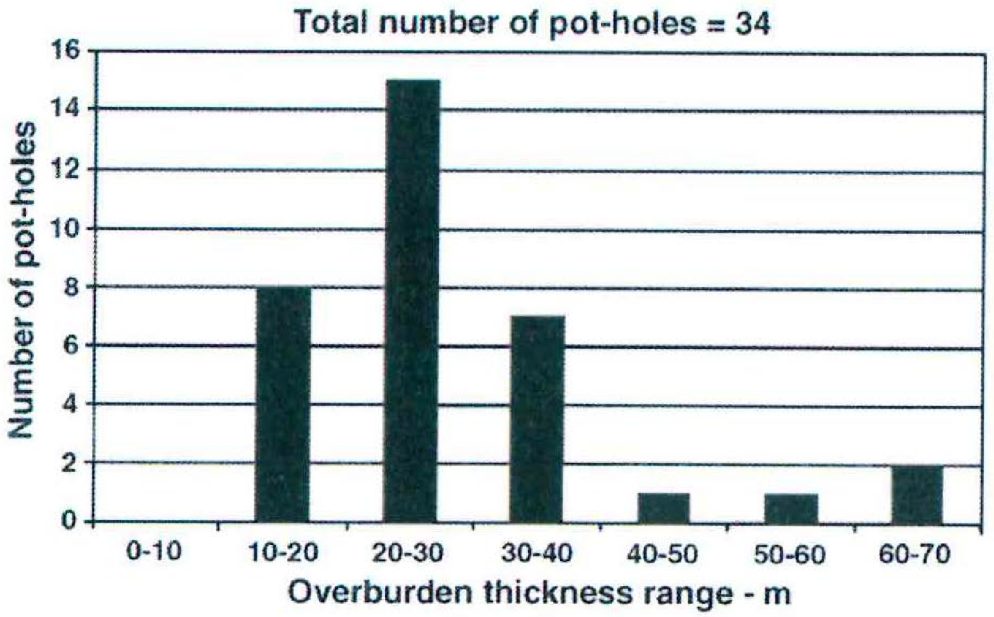


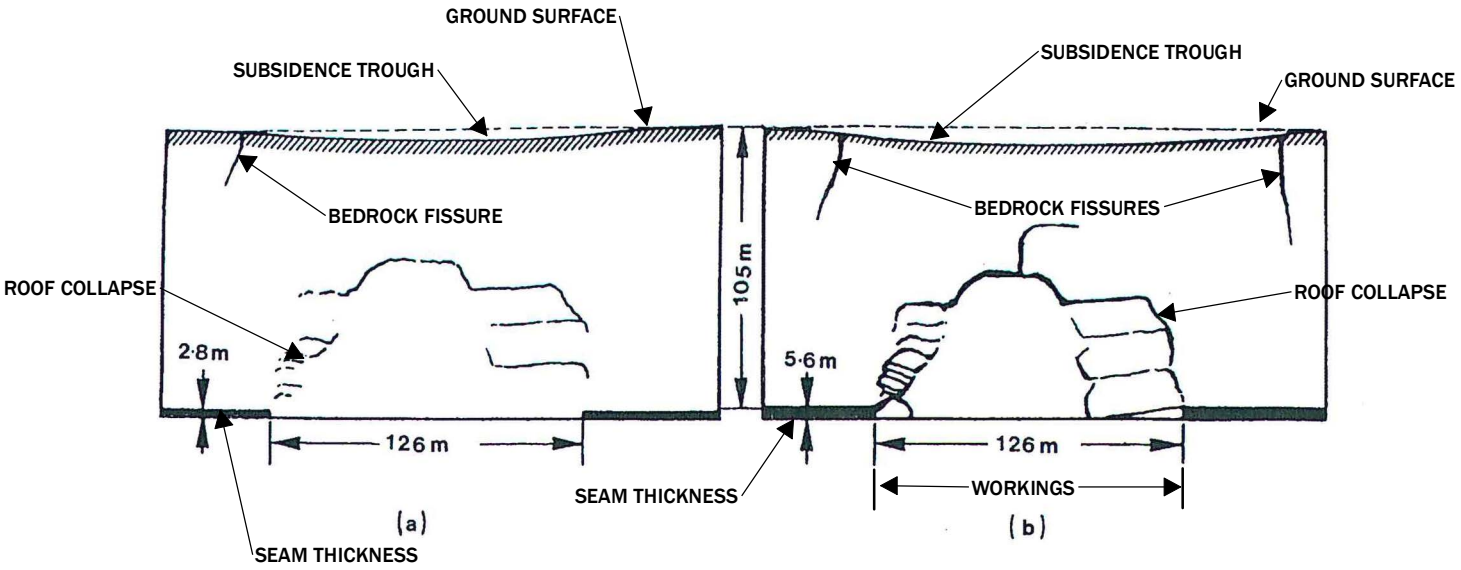
FIGURE 8-11

POTHOLE OCCURANCE, HANNAH MINING DISTRICT AND SON-MAHANADI MASTER COAL BASIN

PIONEER TECHNICAL SERVICES, INC.

DATE: 3/6/2015

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\FIG_8-11.mxd



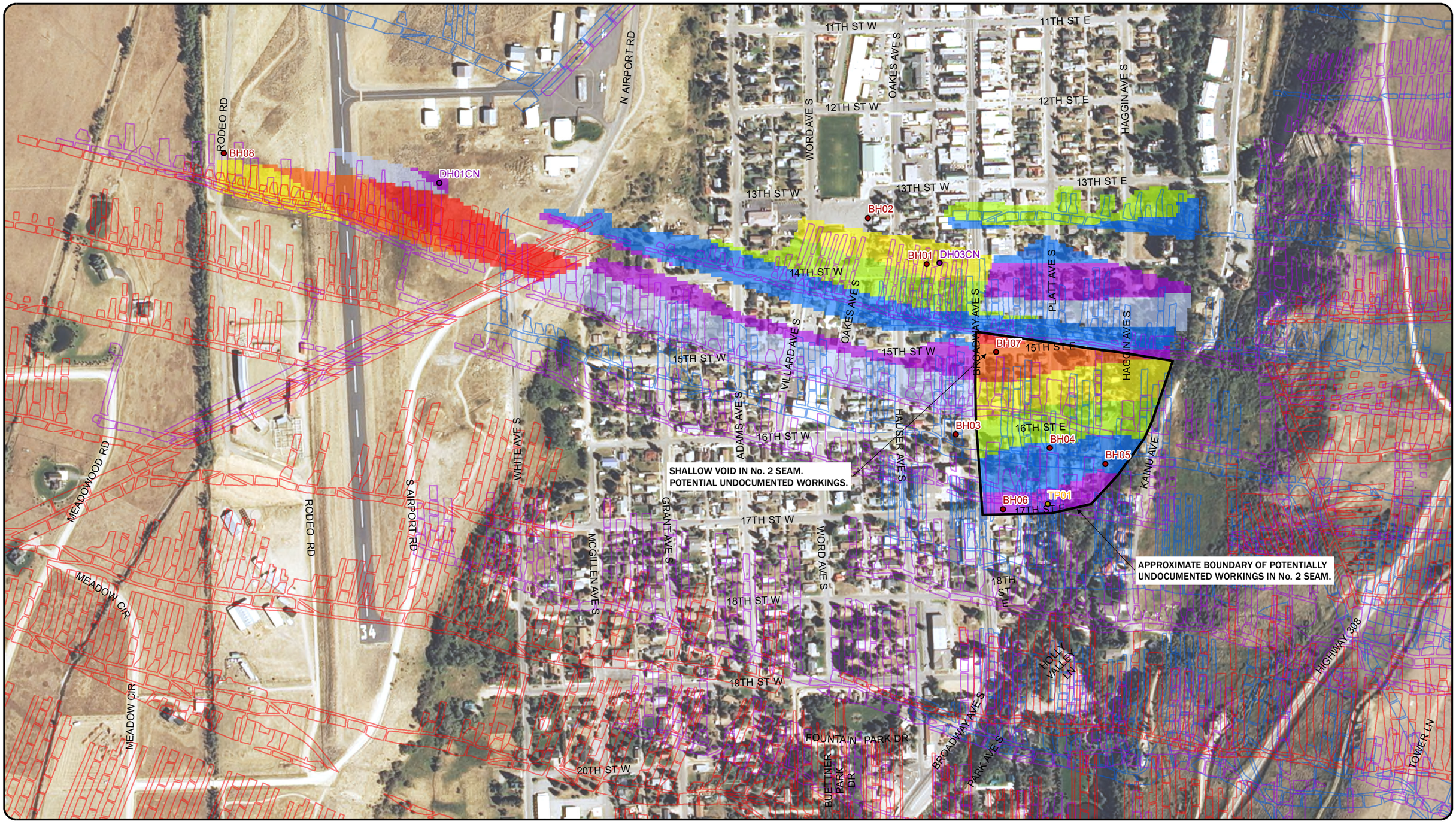
MODIFIED FROM: WHITAKER et al (1990)

FIGURE 8-12 BEDROCK FISSURING

PIONEER TECHNICAL SERVICES, INC.

DATE: 3/6/2015

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\FIG_8-12.mxd



LEGEND

- PIONEER TEST PIT
- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014

- MINE_1_5
- MINE_4
- MINE_5

BED ROCK THICKNESS ABOVE WORKINGS: POSSIBILITY OF POT HOLE SUBSIDENCE OCCURANCE

- 0 - 50' STRONG
- 50- 100' MODERATE TO STRONG
- 100 - 150' MODERATE
- 150 - 200' SLIGHT TO MODERATE
- 200 - 250' SLIGHT
- 250 - 300' VERY SLIGHT TO SLIGHT
- 300 - 350' VERY SLIGHT

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY; PIONEER; CN; KIEWET

0 200 400 800
Feet

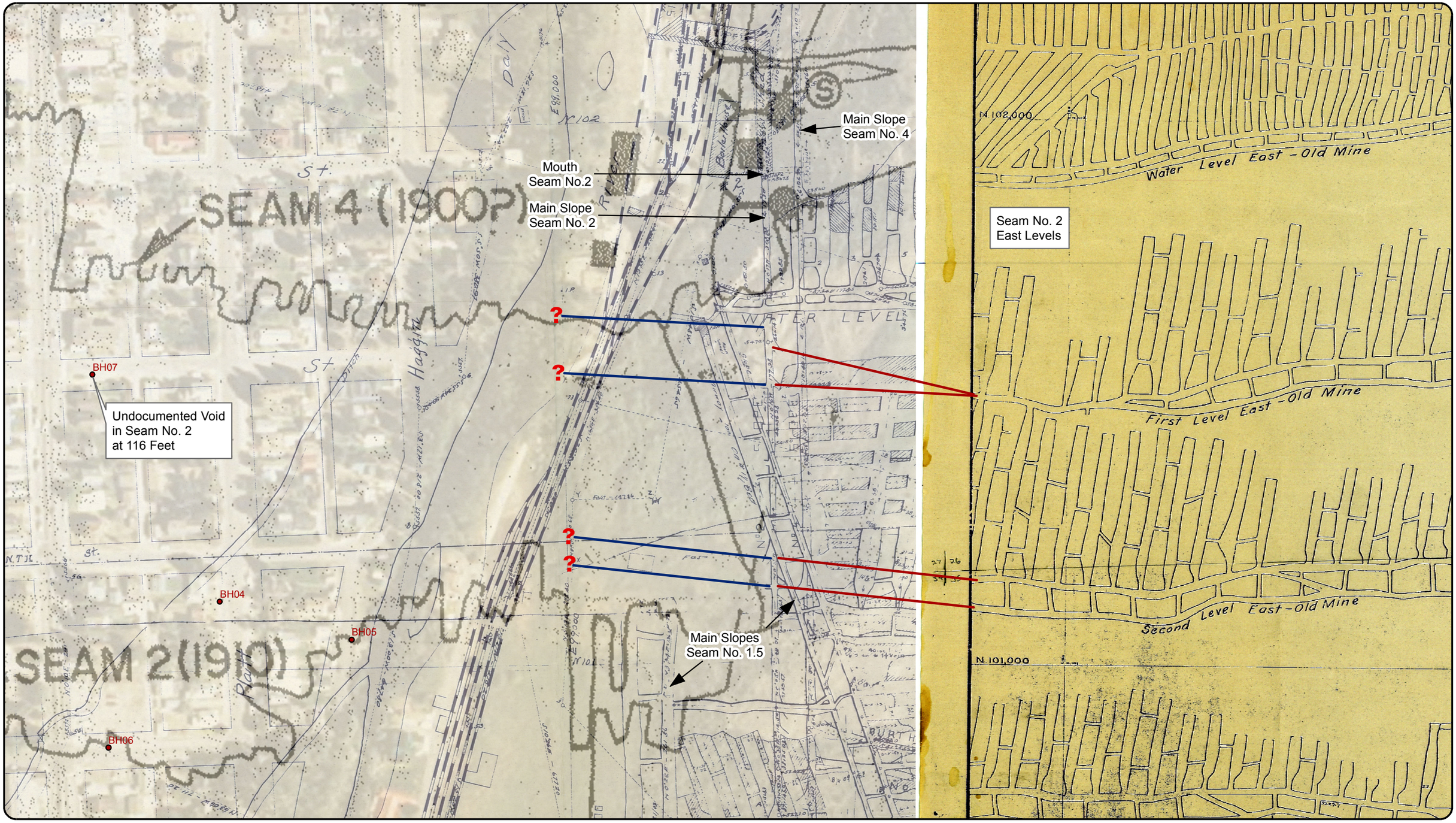
FIGURE 8-13

PIONEER TECHNICAL SERVICES, INC.

DATE: 3/10/2015

POSSIBILITY OF POT HOLE SUBSIDENCE (BEDROCK THICKNESS ABOVE WORKINGS)

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\BedrockThickness.mxd



LEGEND

- PIONEER TECHNICAL BORE HOLE 2014
- INTERPOLATED EAST WORKINGS
- EXTRAPOLATED WEST WORKINGS

***MINE MAP OVERLAYS:**
NWIC MAP OF NO. 1.5 BED. JANUARY, 1910.
NWIC MAP OF MINE NO. 2 BED. NOVEMBER 1923

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD1983
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY; PTS; MWIC

0 50 100 200
Feet

FIGURE 8-14

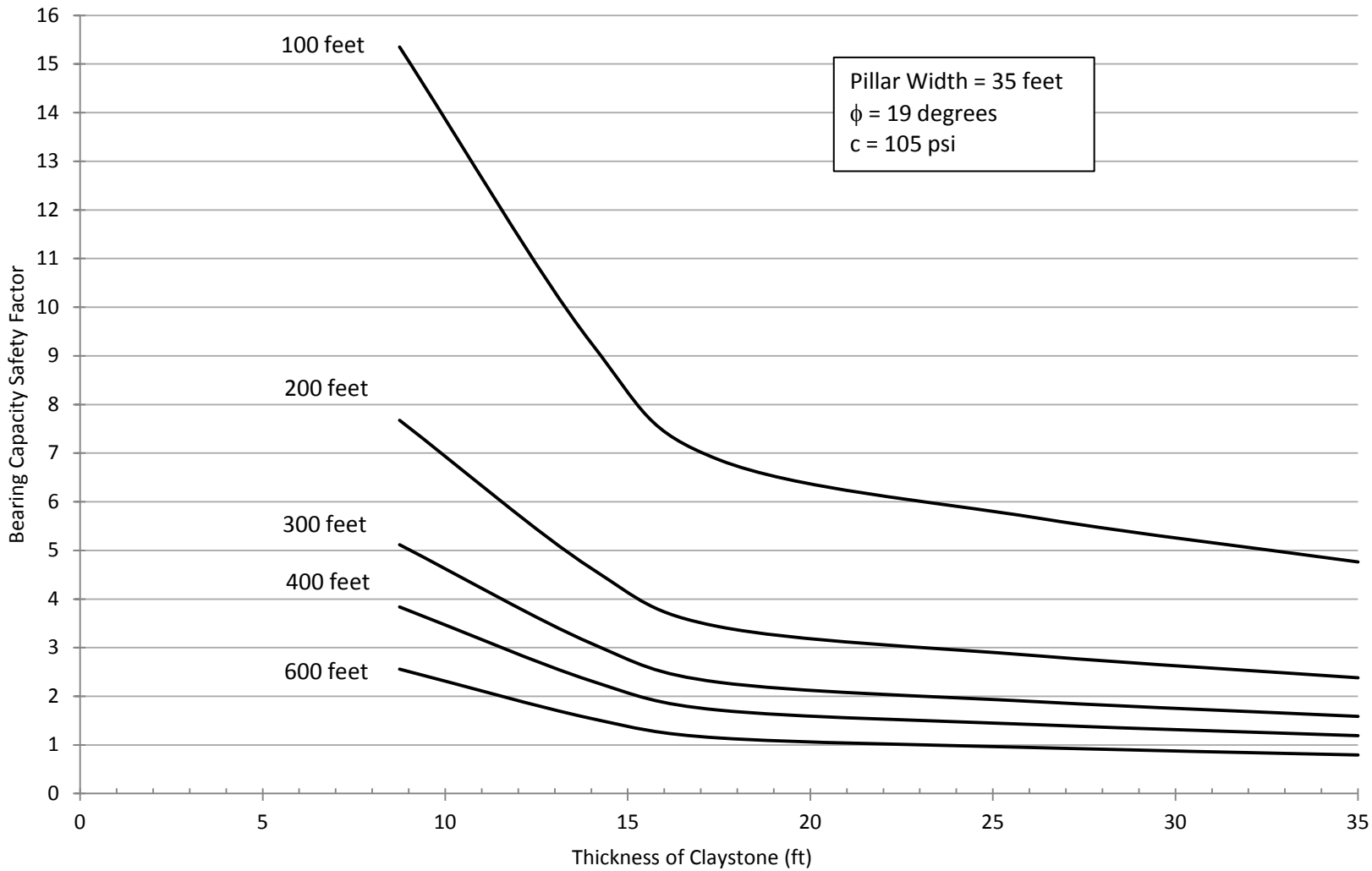
PIONEER TECHNICAL SERVICES, INC.

DATE: 3/6/2015

NO. 2 SEAM EAST AND WEST LEVELS

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\EXTENT_2_UNKNOWNS.mxd

Figure 8-15
Red Lodge Drilling Investigation
Total Stress Bearing Capacity Safety Factor
Non-deteriorated Floor



P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Drilling\Engineering Analysis\Pillar Stability\Pillar stability_2-27-15

Figure 8-16
Red Lodge Drilling Investigation
Effective Stress Bearing Capacity Safety Factor
Non-deteriorated Floor

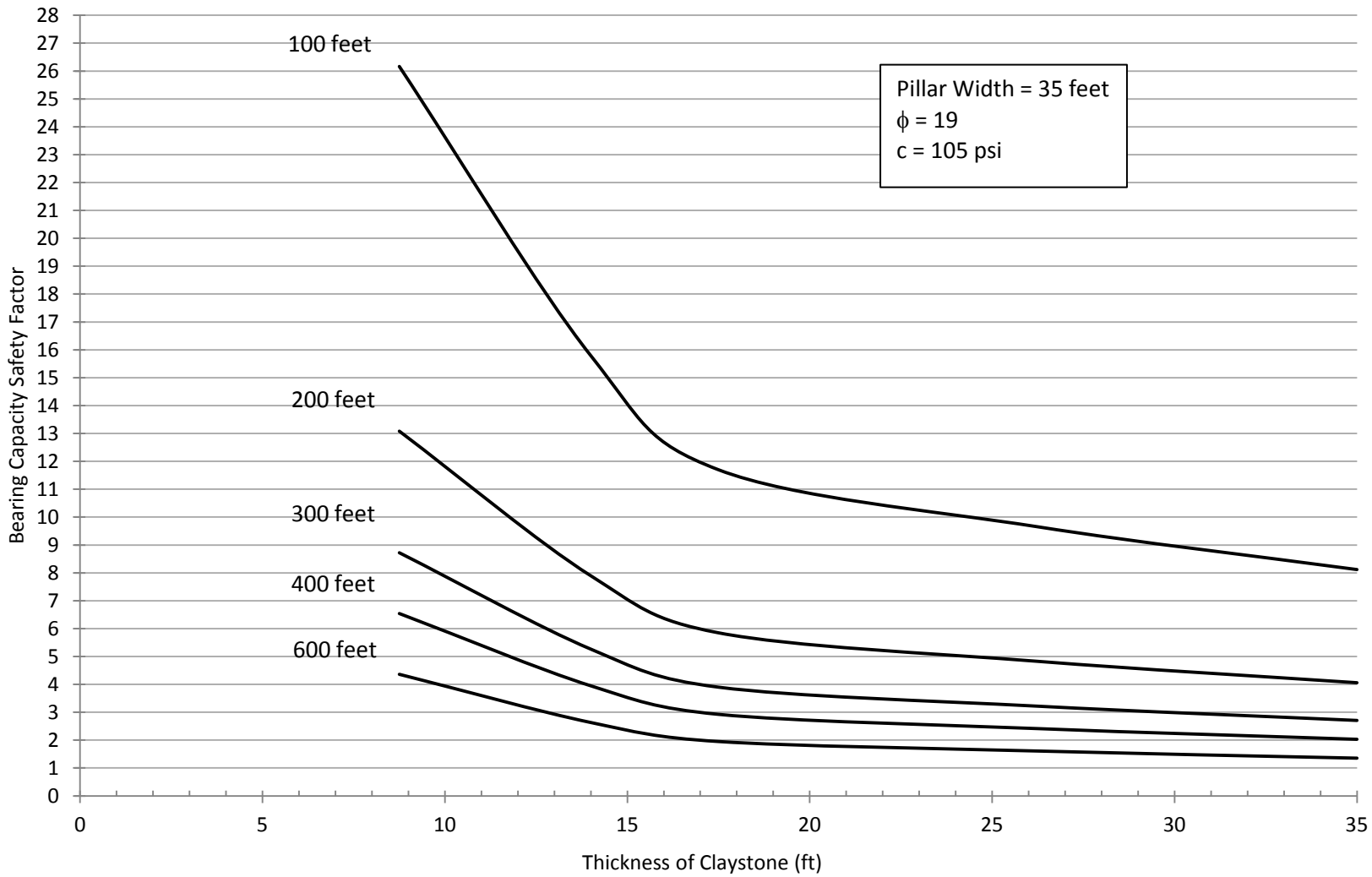


Figure 8-17
Red Lodge Drilling Investigation
Total Stress Bearing Capacity Safety Factor
Deteriorated Floor

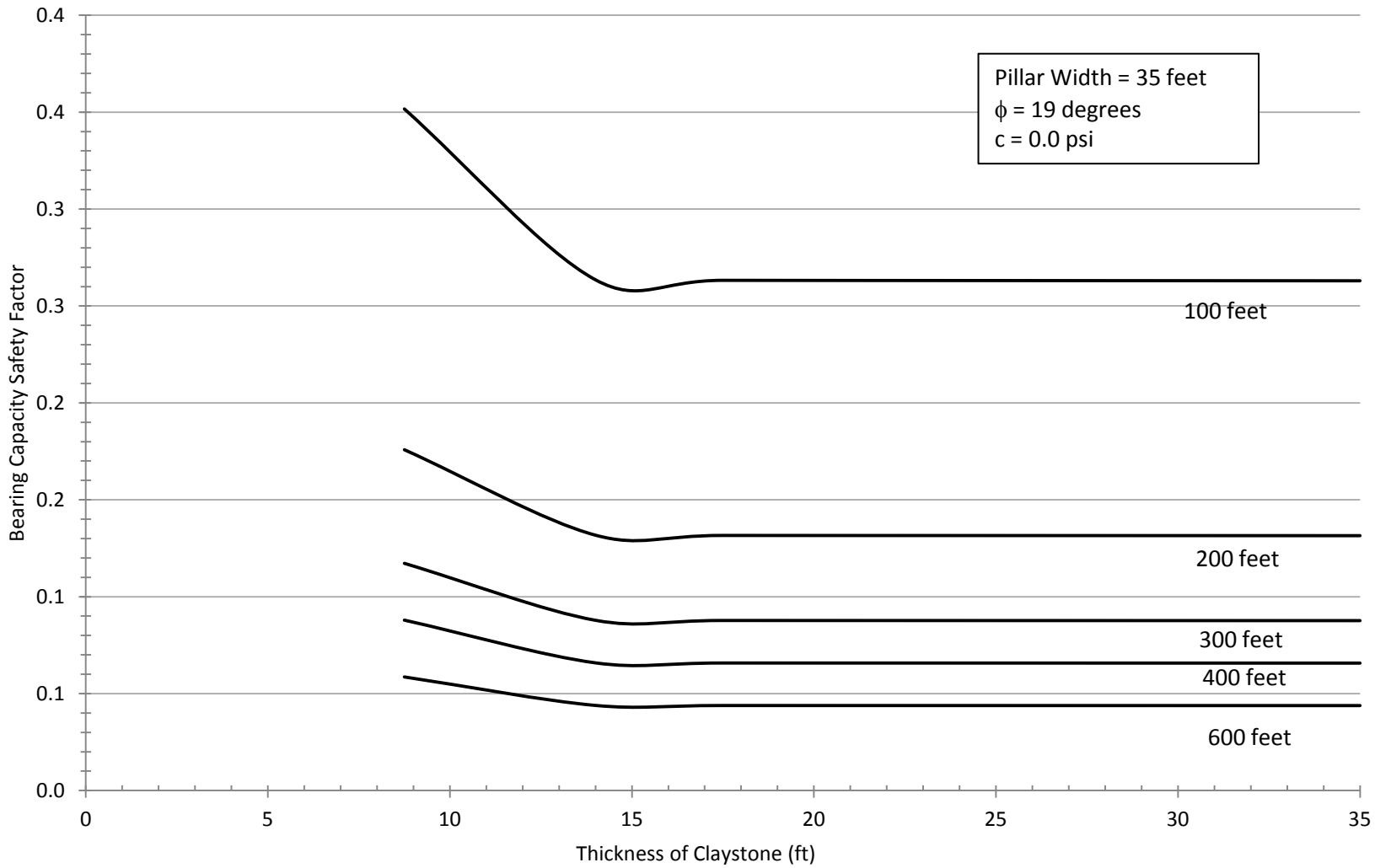


Figure 8-18
Red Lodge Drilling Investigation
Effective Stress Bearing Capacity Safety Factor
Deteriorated Floor

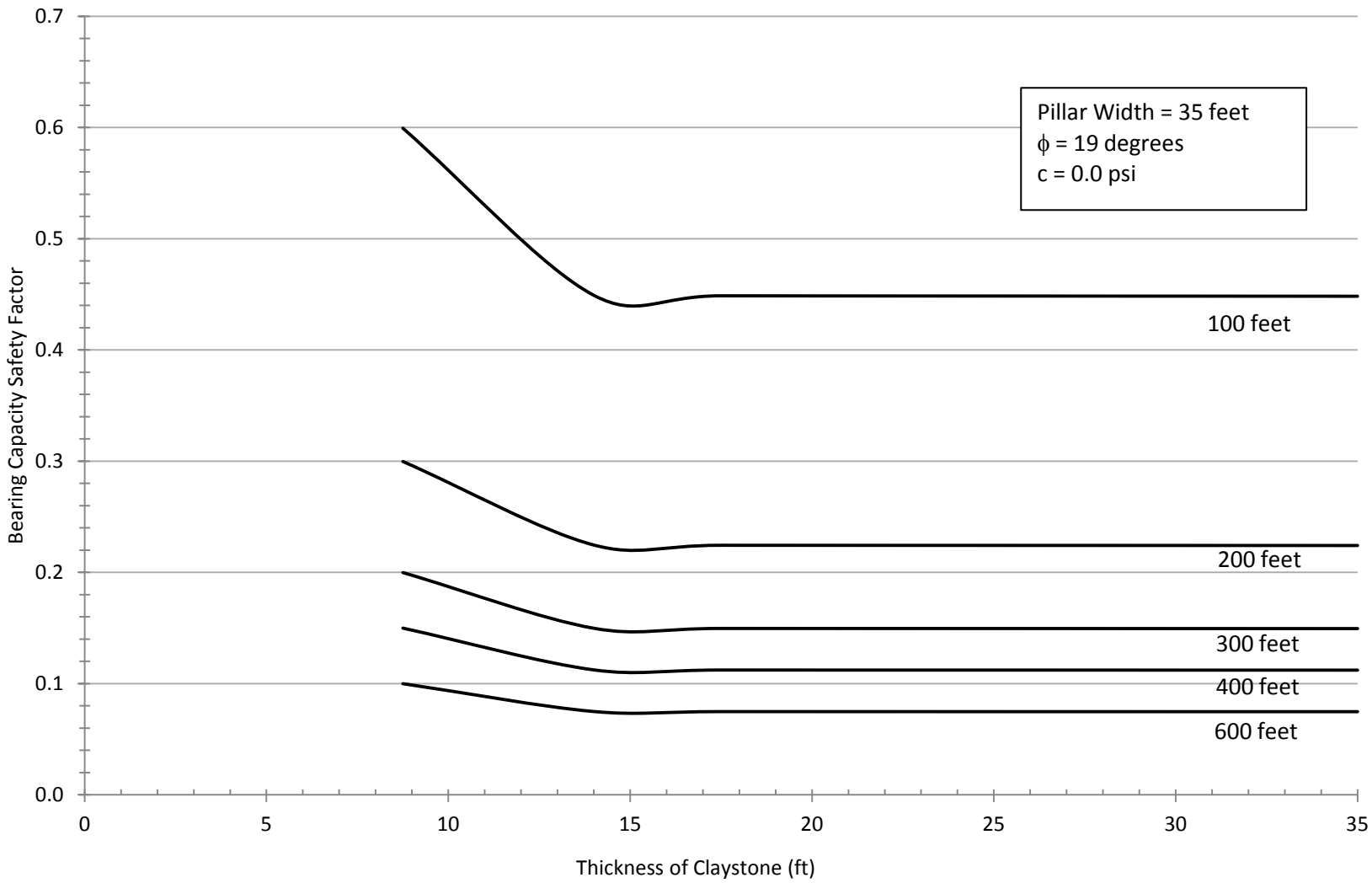


Figure 8-19
Red Lodge Drilling Investigation
Total Stress Pillar Strength Safety Factor

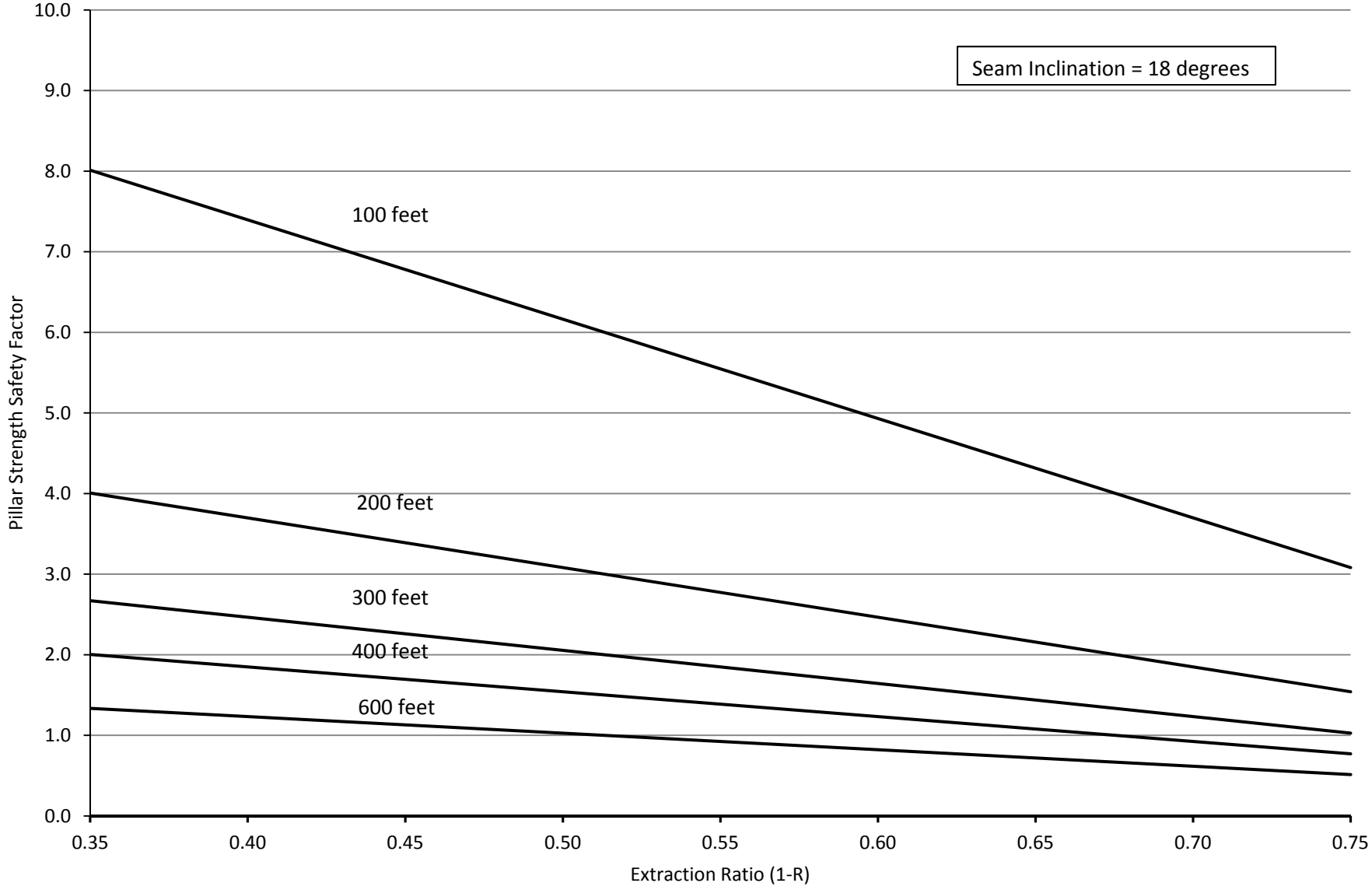


Figure 8-20
Red Lodge Drilling Investigation
Effective Stress Pillar Strength Safety Factor

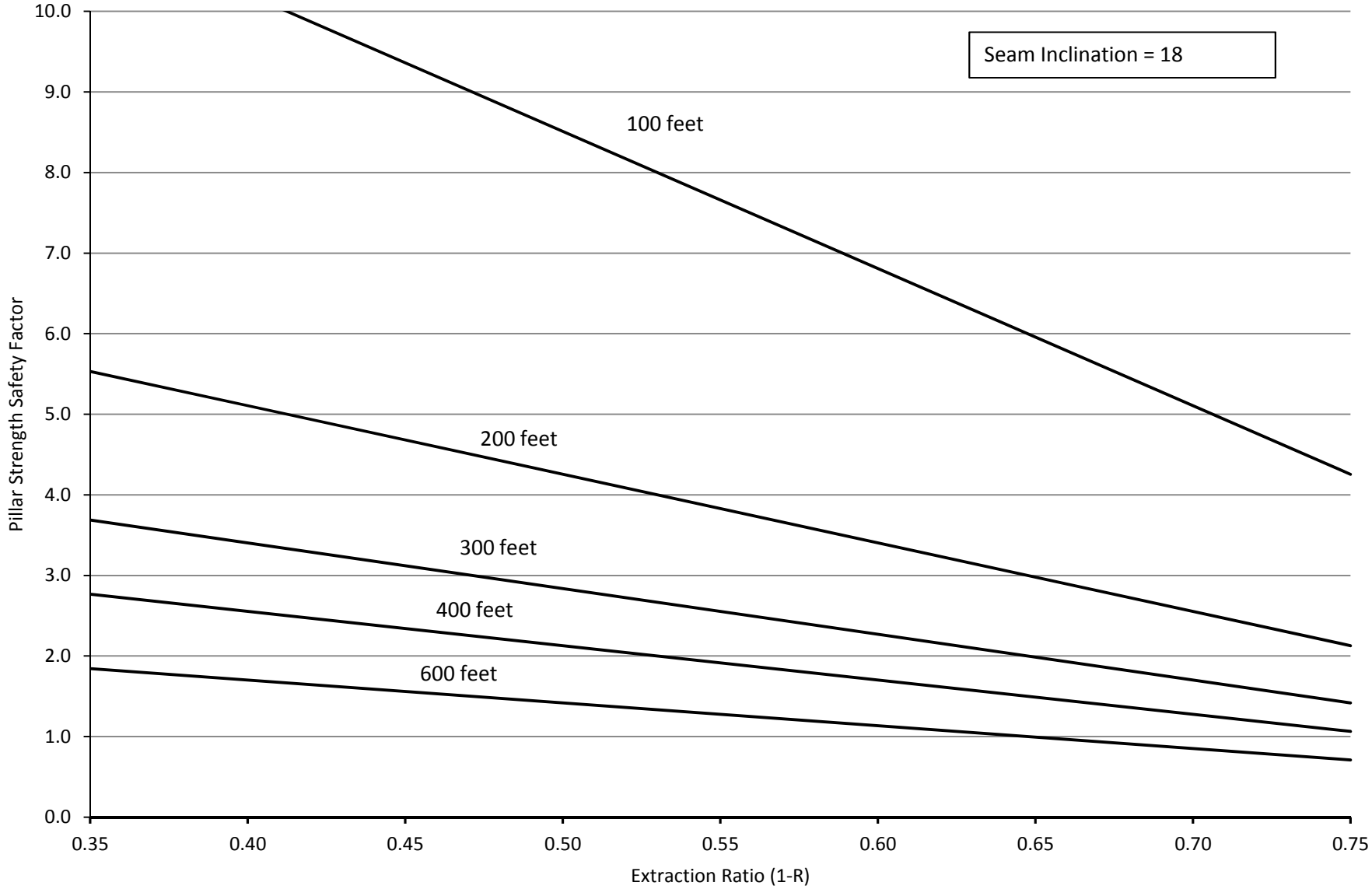


Figure 8-21
Case 1: Subsidence Profile

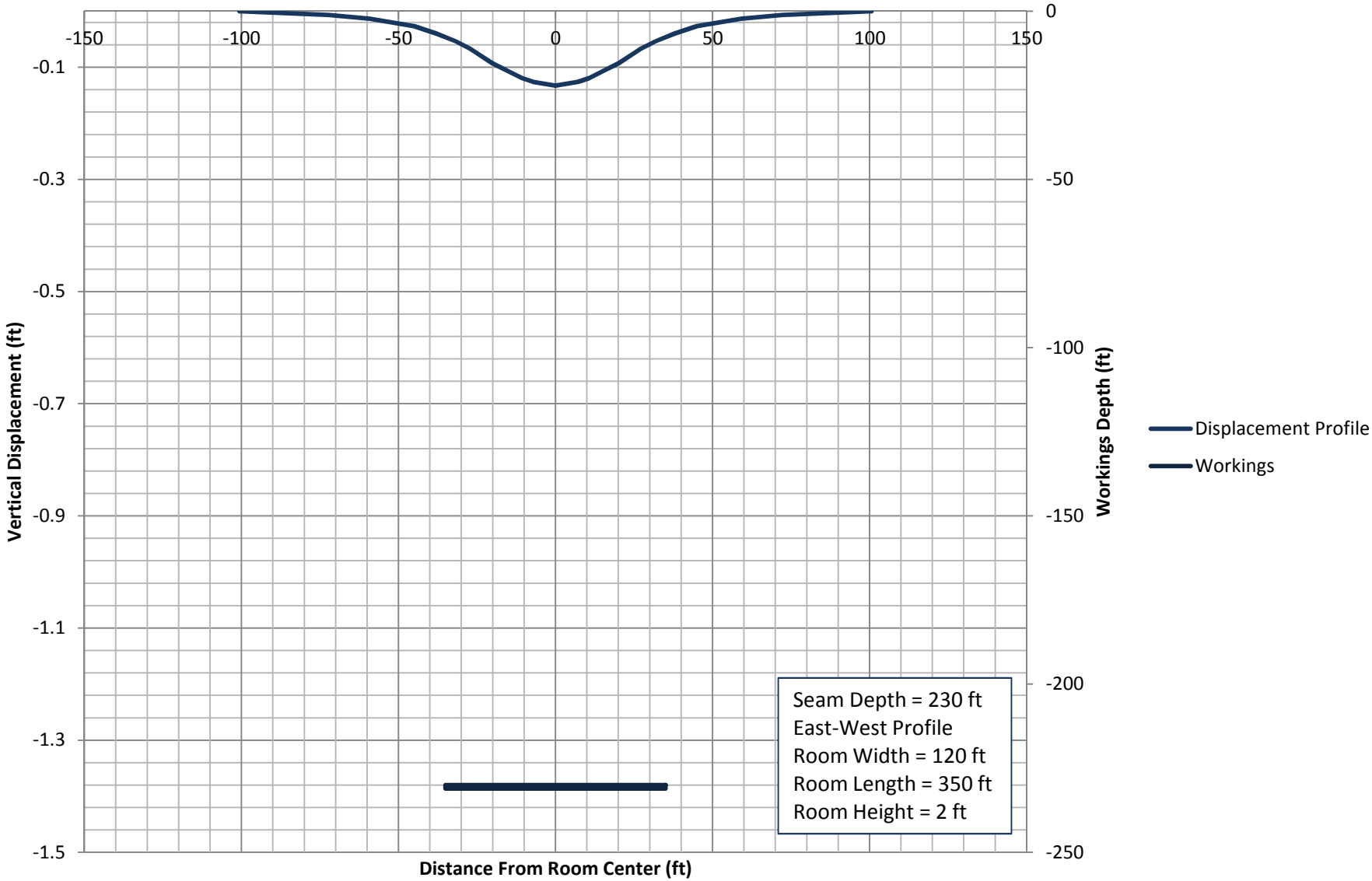


Figure 8-22
Case 1: Surface Strain Profile

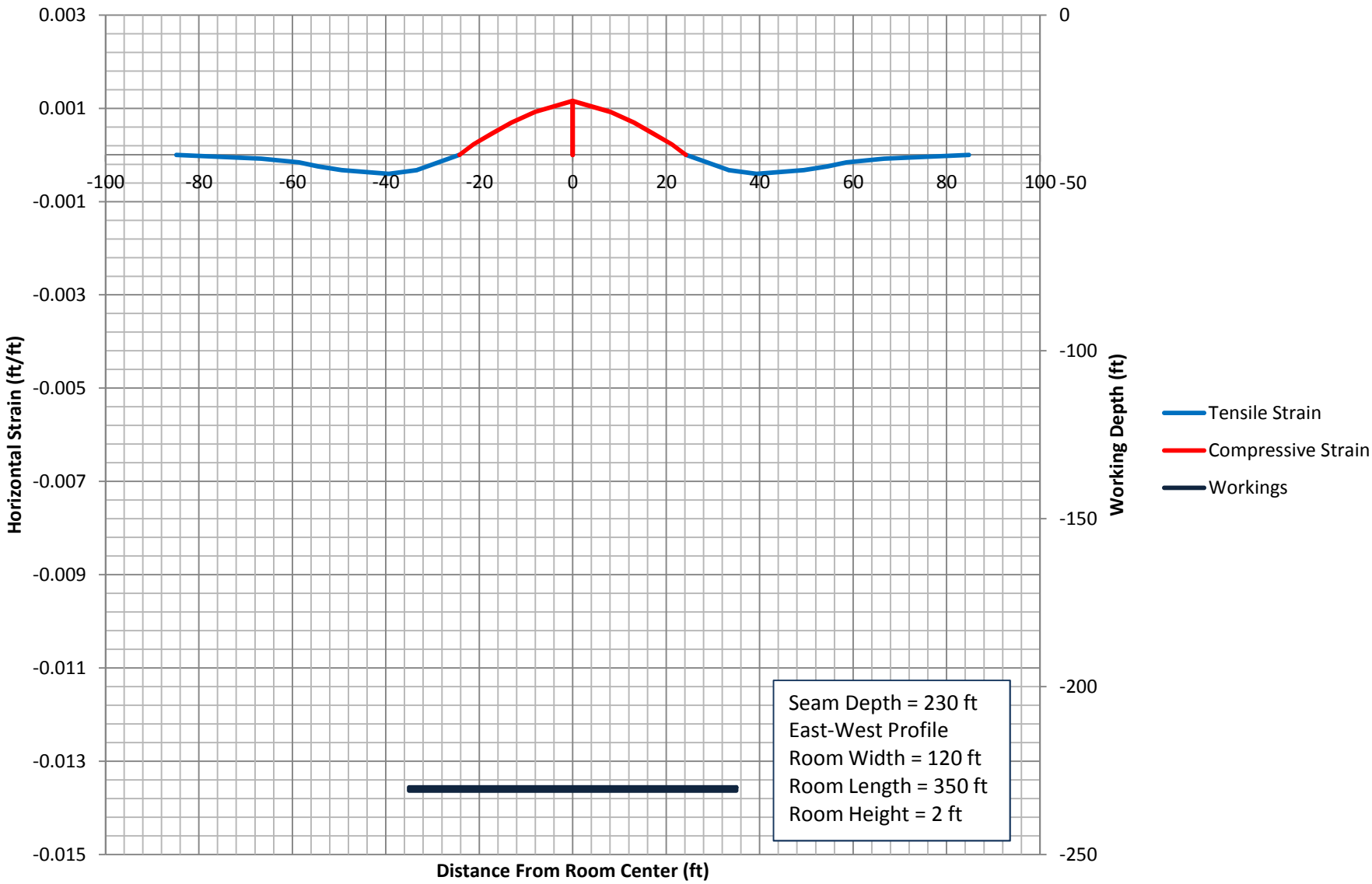


Figure 8-23
Case 2: Subsidence Profile

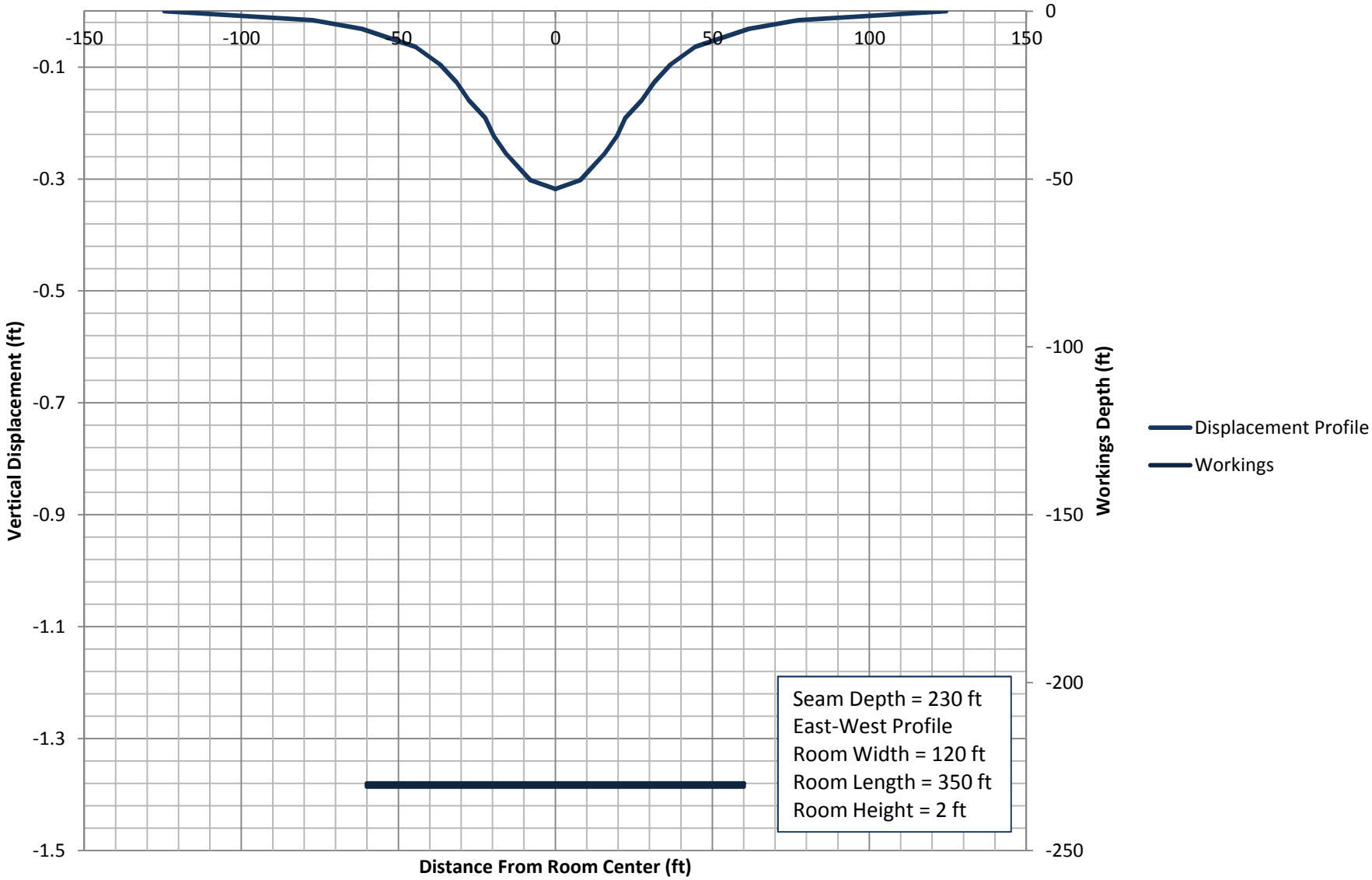


Figure 8-24
Case 2: Surface Strain Profile

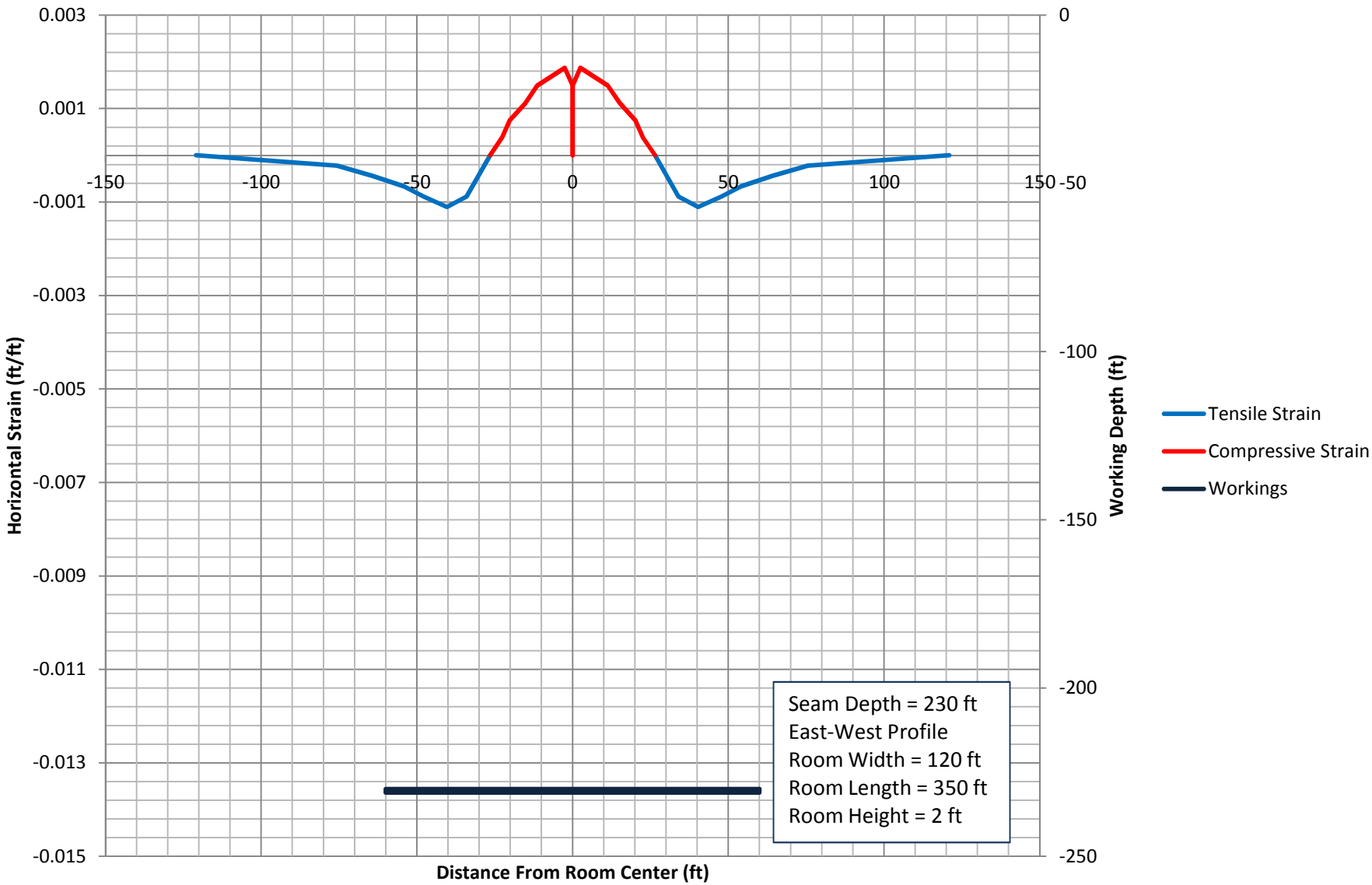
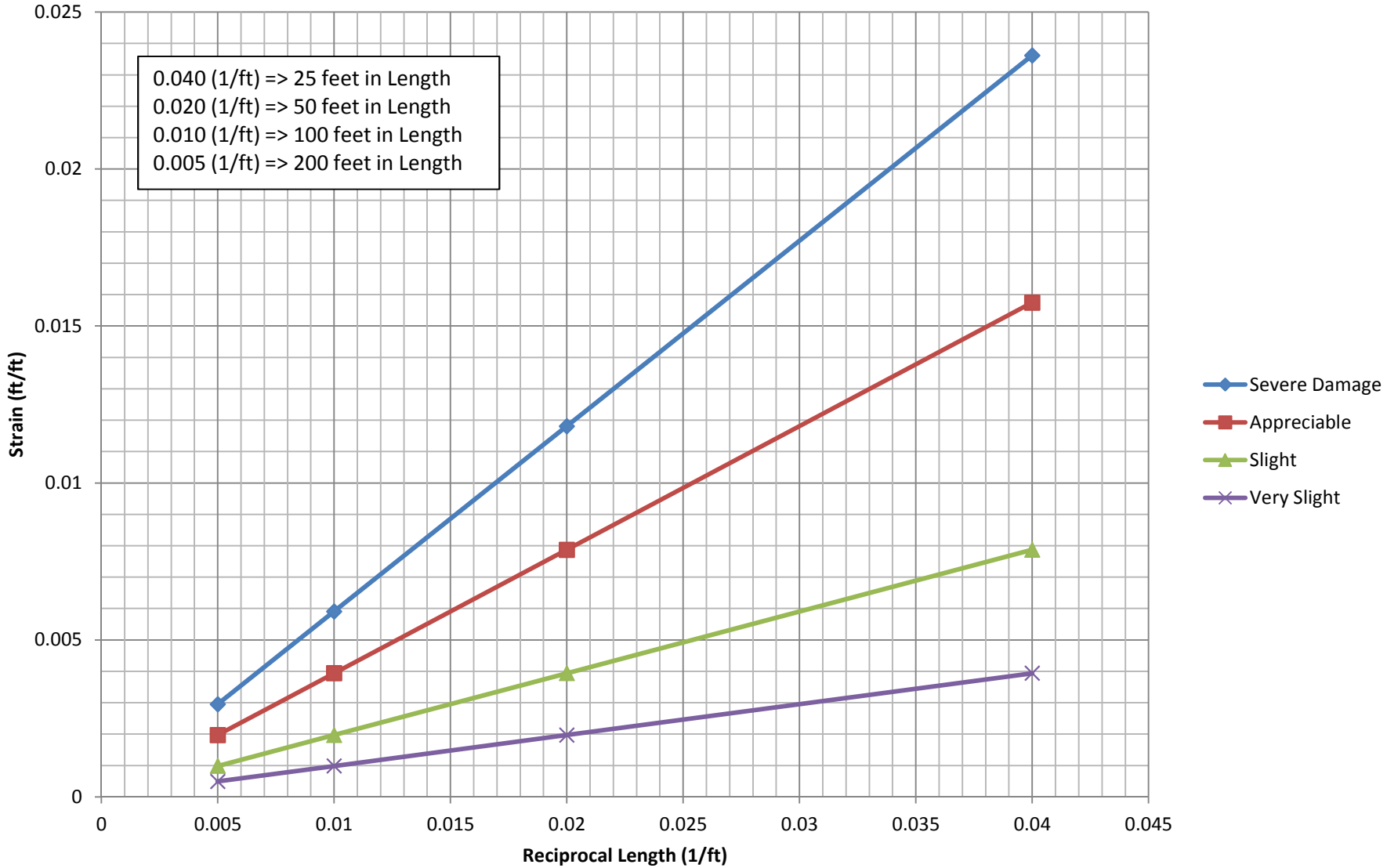


Figure 8-25
Horizontal Strain Damage Guide

(Reproduced from SHB-NCB)



LEGEND

- PIONEER TEST PIT
- KIEWIT BORE HOLE 1983
- CHEN-NORTHERN BORE HOLE 1987
- PIONEER TECHNICAL BORE HOLE 2014
- STRUCTURES OF INTEREST

RECOMMENDED WORK

- CONTINUE MONITORING. CONDUCT GEOPHYSICAL INVESTIGATION
- CONTINUE MONITORING

N

DISPLAYED AS:
PROJECTION/ZONE: MONTANA STATEPLANE
DATUM: NAD83
UNITS: FEET INTERNATIONAL
SOURCE: NAIP BASE IMAGERY; PIONEER; CN; KIEWET

0 200 400 800
Feet

FIGURE 10-1

PIONEER TECHNICAL SERVICES, INC.

AREAS RECOMMENDED FOR CONTINUED MONITORING AND ADDITIONAL INVESTIGATION

DATE: 3/12/2015

Path: P:\HelenaData\DEQ\Red Lodge Subsidence\Documents\Draft DSAR\GIS\Monitoring.mxd

TABLES

Table 3-1
Red Lodge Police Station
Summary of Hand Auger Holes

Hole ID	Concrete Thickness (in)	Void Thickness Below Concrete (in)	Subgrade Lithology	Debris Observed	Coal Slack Observed	Refusal Depth (ft)
PS-01	4.75	0.75	Poorly Graded Gravel, Poorly Graded Sand, Clayey Sand	Coal fragments, decayed brick fragments	No	3.8
PS-02	5.00	0.00	Poorly Graded Sand, Poorly Graded Gravel, Silty Sand	Glass, brick fragments, coal fragments, plastic	No	5.6
PS-03	5.25	2.00	Poorly Graded Sand, Silty Sand	No debris logged	No	1.9
PS-04	5.00	1.50	Poorly Graded Sand, Silty Sand	Brick fragments, glass fragments	No	3.0
PS-05	5.50	0.00	Poorly Graded Sand, Silty Sand	No debris logged	No	1.8

Table 4-1
505 Platt Avenue
Summary of Hand Auger Holes

Hole ID	Sod Thickness (ft)	Subgrade Lithology	Debris Observed	Coal Slack Observed	Refusal Depth (ft)
BH-04a	0.2	Silty SAND with Gravel (SM), trace Organics (grass and tree roots), trace Debris, trace Mica flakes; dry; very dark brown (7.5YR 2.5/2); minus No. 40 sieve particles have slight plasticity; no HCl reaction.	Glass, 4-in long railroad spike	No	3.0
BH-04b	0.2	Silty SAND with Gravel (SM), trace Organics (roots), trace Debris; dry; very dark brown (7.5YR 2.5/2); loose (easy auguring); non plastic; no HCl reaction.	Glass, 2-inch diameter metal object, wire fitting, coal fragments	No	4.5

Table 5-1
Red Lodge Drilling Investigation
Observed Coal Seam Depths

	BH-01		BH-02		BH-03		BH-04		BH-05		BH-06		BH-07		BH-08	
Coal Bed No.	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor	Roof	Floor
Alluvium		111		104		87		42		14		60		89		44
#1	0	0	0	0	0	0	50	56.5	59.5	71.5	143	154				
#1 1/2	0	0	0	0	160	165.5	168	173	180	186	261	266			119	140
#2	0	0	0	0	242.5	251.5	248	257	254	263	337	354	116	124	209	226
#3	0	0	0	0	326	337	333	348	341	356	422.5	438	200	216		
#4	234	241.5	173	185	472	479	472	489	478	493	566	576	342	355		
#4 1/2	253	257.5	195	200	494	499	501	506	503	510	582.5	589	365	370		
#5	369	402.5	316	336	613	629.5	609	633	623	642.5	706	724	493	515		
Total Depth		459		379		679		653		679		744		549		254

Table 5-2
Red Lodge Subsidence Monitoring
Horizontal and Vertical Survey Coordinates

	Point Number	Northing (Feet)	Easting (Feet)	Elevation QM1 January 2014 (Feet)	Elevation QM2 April 2014 (Feet)	Elevation QM3 July 2014 (Feet)	Elevation QM4 November 2014 (Feet)	Elevation QM5 January 2015 (Feet)	Elevation Change (QM1 to QM2) (Feet)	Elevation Change (QM2 to QM3) (Feet)	Elevation Change (QM3 to QM4) (Feet)	Elevation Change (QM4 to QM5) (Feet)	Elevation Change (Cumulative) (Feet)	Description
Loop 1: control points	2	338,651	2,033,227	5,603.560	5,603.560	5,603.560	5,603.560	5,603.560	0.000	0.000	0.000	0.000	0.000	Q215 - NGS benchmark
	502	339,614	2,033,402	5,590.547	5,590.547	5,590.550	5,590.542	5,590.541	0.000	0.003	-0.008	-0.001	-0.006	FH-BOLT
	510	339,730	2,033,580	5,586.508	5,586.510	5,586.508	5,586.499	5,586.501	0.002	-0.002	-0.009	0.002	-0.007	R215
	Minimum								*0.000*	*-0.002*	*-0.009*	*-0.001*	*-0.007*	
	Maximum								*0.002*	*0.003*	*0.000*	*0.002*	*0.000*	
	Average								*0.001*	*0.000*	*-0.006*	*0.000*	*-0.004*	
Loop 2	502	339,614	2,033,402	5,590.547	5,590.547	5,590.550	5,590.542	5,590.541	0.000	0.003	-0.008	-0.001	-0.006	FH-BOLT
	612	339,668	2,033,466	5,586.374	5,586.376	5,586.379	5,586.373	5,586.373	0.002	0.003	-0.006	0.000	-0.001	MP-AC
	611	339,827	2,033,453	5,584.318	5,584.316	5,584.325	5,584.315	5,584.320	-0.002	0.009	-0.010	0.005	0.002	MP-AC
	501	339,979	2,033,393	5,586.683	5,586.681	5,586.694	5,586.682	5,586.675	-0.002	0.013	-0.012	-0.007	-0.008	FH-BOLT
	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	5,580.700	-0.004	0.011	-0.015	-0.005	-0.013	FH-BOLT
	603	339,986	2,033,909	5,578.512	5,578.511	5,578.522	5,578.504	5,578.516	-0.001	0.011	-0.018	0.012	0.004	MP-AC
	604	339,960	2,034,030	5,576.211	5,576.209	5,576.219	5,576.202	5,576.201	-0.002	0.010	-0.017	-0.001	-0.010	MP-AC
	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	5,577.558	-0.002	0.011	-0.016	-0.002	-0.009	FH-BOLT
	605	339,960	2,034,128	5,574.530	5,574.523	5,574.528	5,574.504	5,574.583	-0.007	0.005	-0.024	0.079	0.053	MP-AC, hit by snow plow
	504	339,955	2,034,289	5,575.804	5,575.802	5,575.809	5,575.795	5,575.793	-0.002	0.007	-0.014	-0.002	-0.011	FH-BOLT
	617	339,861	2,034,332	5,574.577	5,574.578	5,574.584	5,574.571	5,574.569	0.001	0.006	-0.013	-0.002	-0.008	MP-AC
	618	339,741	2,034,321	5,577.027	5,577.031	5,577.036	5,577.021	5,577.013	0.004	0.005	-0.015	-0.008	-0.014	MP-AC
	610	339,596	2,034,183	5,578.723	5,578.730	5,578.727	5,578.724	5,578.720	0.007	-0.003	-0.003	-0.004	-0.003	MP-AC
	503	339,511	2,034,148	5,583.054	5,583.061	5,583.057	5,583.056	5,583.050	0.007	-0.004	-0.001	-0.006	-0.004	FH-BOLT
	509	339,637	2,034,087	5,582.797	5,582.803	5,582.797	5,582.796	5,582.795	0.006	-0.006	-0.001	-0.001	-0.002	FH-BOLT
	609	339,599	2,034,068	5,580.944	5,580.952	5,580.947	5,580.948	5,580.948	0.008	-0.005	0.001	0.000	0.004	MP-AC
	608	339,625	2,033,859	5,583.354	5,583.361	5,583.354	5,583.355	5,583.354	0.007	-0.007	0.001	-0.001	0.000	MP-AC
	508	339,641	2,033,752	5,585.951	5,585.962	5,585.956	5,585.958	5,585.954	0.011	-0.006	0.002	-0.004	0.003	FH-BOLT
	607	339,628	2,033,742	5,583.658	5,583.671	5,583.669	5,583.660	5,583.663	0.013	-0.002	-0.009	0.003	0.005	MP-AC
	606	339,623	2,033,607	5,585.333	5,585.336	5,585.350	5,585.328	5,585.335	0.003	0.014	-0.022	0.007	0.002	MP-AC
	Minimum								*-0.007*	*-0.007*	*-0.024*	*-0.008*	*-0.014*	
	Maximum								*0.013*	*0.014*	*0.002*	*0.079*	*0.053*	
	Average								*0.002*	*0.004*	*-0.010*	*0.003*	*-0.001*	
Loop 3	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	5,577.558	-0.002	0.011	-0.016	-0.002	-0.009	FH-BOLT
	615	339,855	2,034,071	5,576.592	5,576.589	5,576.597	5,576.579	5,576.581	-0.003	0.008	-0.018	0.002	-0.011	MP-AC
	616	339,743	2,034,135	5,578.083	5,578.093	5,578.084	5,578.075	5,578.147	0.010	-0.009	-0.009	0.072	0.064	MP-AC
	509	339,637	2,034,087	5,582.797	5,582.803	5,582.797	5,582.796	5,582.795	0.006	-0.006	-0.001	-0.001	-0.002	FH-BOLT
	Minimum								*-0.003*	*-0.009*	*-0.018*	*-0.002*	*-0.011*	
	Maximum								*0.010*	*0.011*	*-0.001*	*0.072*	*0.064*	
	Average								*0.003*	*0.001*	*-0.011*	*0.018*	*0.011*	
Loop 4	509	339,637	2,034,087	5,582.797	5,582.803	5,582.797	5,582.796	5,582.795	0.006	-0.006	-0.001	-0.001	-0.002	FH-BOLT
	620	339,775	2,033,949	5,581.360	5,581.365	5,581.364	5,581.356	5,581.357	0.005	-0.001	-0.008	0.001	-0.003	MP-AC
	619	339,888	2,033,944	5,579.413	5,579.415	5,579.419	5,579.412	5,579.419	0.002	0.004	-0.007	0.007	0.006	MP-AC
	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	5,577.558	-0.002	0.011	-0.016	-0.002	-0.009	FH-BOLT
	Minimum								*-0.002*	*-0.006*	*-0.016*	*-0.002*	*-0.009*	
	Maximum								*0.006*	*0.011*	*-0.001*	*0.007*	*0.006*	
	Average								*0.003*	*0.002*	*-0.008*	*0.001*	*-0.002*	
Loop 5	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	5,580.700	-0.004	0.011	-0.015	-0.005	-0.013	FH-BOLT
	613	339,880	2,033,731	5,580.291	5,580.297	5,580.302	5,580.296	5,580.290	0.006	0.005	-0.006	-0.006	-0.001	MP-AC
	614	339,755	2,033,737	5,582.152	5,582.161	5,582.156	5,582.156	5,582.145	0.009	-0.005	0.000	-0.011	-0.007	MP-AC
	508	339,641	2,033,752	5,585.951	5,585.962	5,585.956	5,585.958	5,585.954	0.011	-0.006	0.002	-0.004	0.003	FH-BOLT
	Minimum								*-0.004*	*-0.006*	*-0.015*	*-0.011*	*-0.013*	
	Maximum								*0.011*	*0.011*	*0.002*	*-0.004*	*0.003*	
	Average								*0.005*	*0.001*	*-0.005*	*-0.006*	*-0.005*	
Loop 6	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	5,580.700	-0.004	0.011	-0.015	-0.005	-0.013	FH-BOLT
	512	340,359	2,033,726	-	5,580.233	5,580.244	5,580.228	5,580.220	-	0.011	-0.016	-0.008	-0.013	FH-BOLT
	511	340,301	2,034,066	-	5,577.891	5,577.894	5,577.886	5,577.871	-	0.003	-0.008	-0.015	-0.020	FH-BOLT
	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	5,577.558	-0.002	0.011	-0.016	-0.002	-0.009	FH-BOLT
	Minimum								*-0.004*	*0.003*	*-0.016*	*-0.015*	*-0.020*	
	Maximum								*-0.002*	*0.011*	*-0.008*	*-0.002*	*-0.009*	
	Average								*-0.003*	*0.009*	*-0.014*	*-0.008*	*-0.014*	
Loop 7	501	339,979	2,033,393	5,586.683	5,586.681	5,586.694	5,586.682	5,586.675	-0.002	0.013	-0.012	-0.007	-0.008	FH-BOLT
	514	-	-	-	-	5,584.615	5,584.596	5,584.602	-	-	-0.019	0.006	-0.013	FH-BOLT
	630	340,909	2,033,368	-	-	5,578.798	5,578.768	5,578.776	-	-	-0.030	0.008	-0.022	MP-AC
	513	-	-	-	-	5,578.298	5,578.283	5,578.288	-	-	-0.015	0.005	-0.010	FH-BOLT
	501	339,979	2,033,393	5,586.683	5,586.681	5,586.694	5,586.682	5,586.675	-0.002	0.013	-0.012	-0.007	-0.008	FH-BOLT
	Minimum								*-0.002*	*0.013*	*-0.030*	*-0.007*	*-0.022*	
	Maximum								*-0.002*	*0.013*	*-0.012*	*0.008*	*-0.008*	
	Average								*-0.002*	*0.013*	*-0.019*	*0.003*	*-0.013*	
Loop 8	630	340,909	2,033,368	-	-	5,578.798	5,578.768	5,578.776	-	-	-0.030	0.008	-0.022	MP-AC
	1014	340,694	2,033,540	-	-	-	5,581.054	5,581.061	-	-	-	0.007	0.007	BH-01 center steel cap
	630	340,909	2,033,368	-	-	5,578.798	5,578.768	5,578.776	-	-	-0.030	0.008	-0.022	MP-AC
	Minimum										*-0.030*	*0.007*	*-0.022*	
	Maximum										*-0.030*	*0.008*	*0.007*	
	Average										*-0.030*	*0.007*	*-0.008*	
Loop 9	617	339,861	2,034,332	5,574.577	5,574.578	5,574.584	5,574.571	5,574.569	0.001	0.006	-0.013	-0.002	-0.008	MP-AC
	1009	339,814	2,034,328	-	-	-	5,576.051	5,576.047	-	-	-	-0.004	-0.004	BH-05 center steel cap
	618	339,741	2,034,321	5,577.027	5,577.031	5,577.036	5,577.021	5,577.013	0.004	0.005	-0.015	-0.008	-0.014	MP-AC
	Minimum								*0.001*	*0.005*	*-0.015*	*-0.008*	*-0.014*	
	Maximum								*0.004*	*0.006*	*-0.013*	*-0.002*	*-0.004*	
	Average								*0.003*	*0.005*	*-0.014*	*-0.005*	*-0.009*	
Loop 10	608	339,625	2,033,859	5,583.354	5,583.361	5,583.354	5,583.355	5,583.354	0.007	-0.007	0.001	-0.001	0.000	MP-AC
	1004	339,613	2,033,876	-	-	-	5,583.337	5,583.340	-	-	-	0.003	0.003	BH-06 center steel cap
	Minimum								*0.007*	*-0.007*	*0.001*	*-0.001*	*0.000*	
	Maximum								*0.007*	*-0.007*	*0.001*	*0.003*	*0.003*	
	Average								*0.007*	*-0.007*	*0.001*	*0.001*	*0.001*	

	Point Number	Northing (Feet)	Easting (Feet)	Elevation QM1 January 2014 (Feet)	Elevation QM2 April 2014 (Feet)	Elevation QM3 July 2014 (Feet)	Elevation QM4 November 2014 (Feet)	Elevation QM5 January 2015 (Feet)	Elevation Change (QM1 to QM2) (Feet)	Elevation Change (QM2 to QM3) (Feet)	Elevation Change (QM3 to QM4) (Feet)	Elevation Change (QM4 to QM5) (Feet)	Elevation Change (Cumulative) (Feet)	Description
Loop 11: 513 Hauser (Gebo)	630	340,909	2,033,368	-	-	5,578.798	5,578.768	5,578.776	-	-	-0.030	0.008	-0.022	MP-AC
	207-1	-	-	-	-	5,579.348	5,579.319	5,579.326	-	-	-0.029	0.007	-0.022	BENCHTIE
	207-2	-	-	-	-	5,579.305	5,579.276	5,579.283	-	-	-0.029	0.007	-0.022	BENCHTIE
	207-4	-	-	-	-	5,579.073	5,579.052	5,579.084	-	-	-0.021	0.032	0.011	BENCHTIE
	631	340,905	2,033,325	-	-	5,578.624	5,578.594	5,578.600	-	-	-0.030	0.006	-0.024	MP-AC
	207-3	-	-	-	-	5,579.452	5,579.424	5,579.431	-	-	-0.028	0.007	-0.021	BENCHTIE
	207-5	-	-	-	-	5,579.248	5,579.219	5,579.227	-	-	-0.029	0.008	-0.021	BENCHTIE
	632	340,884	2,033,297			5,579.476	5,579.446	5,579.453			-0.030	0.007	-0.023	MP-AC
	1001	340,898	2,033,282	-	-	-	5,578.701	-	-	-	-	-	-	BH-02 center steel cap
	207-6	-	-	-	-	5,579.247	5,579.232	5,579.237	-	-	-0.015	0.005	-0.010	BENCHTIE
	513	-	-	-	-	5,578.298	5,578.283	5,578.288	-	-	-0.015	0.005	-0.010	FH-BOLT
	Minimum										*-0.030*	*0.005*	*-0.024*	
	Maximum										*-0.015*	*0.032*	*0.011*	
	Average										*-0.026*	*0.009*	*-0.016*	
Loop 12: 404 Broadway (Uzelac)	511	340,301	2,034,066	-	5,577.891	5,577.894	5,577.886	5,577.871	-	0.003	-0.008	-0.015	-0.020	FH-BOLT
	404-8	-	-	-	5,575.162	5,575.168	5,575.159	5,575.152	-	0.006	-0.009	-0.007	-0.010	MAGNAIL
	404-51	-	-	-	5,574.165	5,574.171	5,574.161	5,574.146	-	0.006	-0.010	-0.015	-0.019	BENCHTIE
	404-5	340,268	2,033,897	-	5,573.987	5,573.993	5,574.000	5,574.005	-	0.006	0.007	0.005	0.018	MAGNAIL
	404-6	340,268	2,033,874	-	5,573.776	5,573.782	5,573.790	5,573.793	-	0.006	0.008	0.003	0.017	MAGNAIL
	404-7	340,255	2,033,859	-	5,574.128	5,574.136	5,574.162	5,574.182	-	0.008	0.026	0.020	0.054	MAGNAIL
	404-4	-	-	-	5,574.969	5,574.977	5,574.966	5,574.953	-	0.008	-0.011	-0.013	-0.016	BENCHTIE
	404-9	-	-	-	5,576.745	5,576.754	5,576.739	5,576.728	-	0.009	-0.015	-0.011	-0.017	BOLT ON WELL
	629	340,252	2,033,876	-	5,573.727	5,573.732	5,573.714	5,573.704	-	0.005	-0.018	-0.010	-0.023	MP-AC
	628	340,279	2,033,876	-	5,573.913	5,573.919	5,573.908	5,573.894	-	0.006	-0.011	-0.014	-0.019	MP-AC
	1010	340,307	2,033,846	-	-	-	5,574.997	5,574.989	-	-	-	-0.008	-0.008	BH-07 center steel cap
	404-3	-	-	-	5,574.923	5,574.931	5,574.922	5,574.913	-	0.008	-0.009	-0.009	-0.010	BENCHTIE
	404-2	-	-	-	5,576.056	5,576.065	5,576.055	5,576.041	-	0.009	-0.010	-0.014	-0.015	BENCHTIE
	627	340,290	2,033,797	-	5,576.327	5,576.334	5,576.312	5,576.303	-	0.007	-0.022	-0.009	-0.024	MP-AC
	626	340,253	2,033,795	-	5,576.050	5,576.055	5,576.032	5,576.030	-	0.005	-0.023	-0.002	-0.020	MP-AC
	404-1	-	-	-	5,576.578	5,576.584	5,576.564	5,576.558	-	0.006	-0.020	-0.006	-0.020	BENCHTIE
	512	340,359	2,033,726	-	5,580.233	5,580.244	5,580.228	5,580.220	-	0.011	-0.016	-0.008	-0.013	FH-BOLT
	Minimum									*0.003*	*-0.023*	*-0.015*	*-0.024*	
	Maximum									*0.011*	*0.026*	*0.020*	*0.054*	
	Average									*0.007*	*-0.009*	*-0.007*	*-0.009*	
Loop 13: 501 Broadway (Dukart)	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	5,580.700	-0.004	0.011	-0.015	-0.005	-0.013	FH-BOLT
	602	339,925	2,033,739	5,579.466	5,579.468	5,579.481	5,579.468	5,579.464	0.002	0.013	-0.013	-0.004	-0.002	LP-NE-FOOT
	501-1	-	-	5,582.609	5,582.606	5,582.619	5,582.604	5,582.606	-0.003	0.013	-0.015	0.002	-0.003	MAGNAIL
	501-2	-	-	5,581.419	5,581.418	5,581.435	5,581.419	5,581.418	-0.001	0.017	-0.016	-0.001	-0.001	BENCHTIE
	501-3	-	-	5,581.225	5,581.222	5,581.239	5,581.219	5,581.218	-0.003	0.017	-0.020	-0.001	-0.007	BENCHTIE
	501-4	-	-	5,581.344	5,581.343	5,581.359	5,581.341	5,581.338	-0.001	0.016	-0.018	-0.003	-0.006	BENCHTIE
	501-5	-	-	5,581.213	5,581.213	5,581.224	5,581.204	5,581.201	0.000	0.011	-0.020	-0.003	-0.012	BENCHTIE
	501-6	-	-	5,581.236	5,581.235	5,581.252	5,581.233	5,581.228	-0.001	0.017	-0.019	-0.005	-0.008	BENCHTIE
	622	339,931	2,033,676	5,581.838	5,581.838	5,581.850	5,581.834	5,581.829	0.000	0.012	-0.016	-0.005	-0.009	BOLT-WELLHEAD
	501-9	-	-	5,582.740	5,582.737	5,582.754	5,582.733	5,582.738	-0.003	0.017	-0.021	0.005	-0.002	HINGE-GARAGE
	601	339,934	2,033,603	5,582.807	5,582.806	5,582.823	5,582.805	5,582.801	-0.001	0.017	-0.018	-0.004	-0.006	BENCHTIE-PP
	1013	339,945	2,033,668	-	-	-	5,579.979	5,579.969	-	-	-	-0.010	-0.010	BH-03 center steel cap
	501-7	-	-	5,580.324	5,580.316	5,580.335	5,580.318	5,580.329	-0.008	0.019	-0.017	0.011	0.005	MAGNAIL (Sidewalk)
	501-8	-	-	5,580.269	5,580.262	5,580.280	5,580.261	5,580.272	-0.007	0.018	-0.019	0.011	0.003	MAGNAIL
	506	339,897	2,033,619	5,581.745	5,581.744	5,581.758	5,581.736	5,581.731	-0.001	0.014	-0.022	-0.005	-0.014	MP-AC
	501-13	-	-	5,581.933	5,581.931	5,581.946	5,581.933	5,581.927	-0.002	0.015	-0.013	-0.006	-0.006	BENCHTIE
	501-12	-	-	5,581.463	5,581.459	5,581.470	5,581.459	5,581.453	-0.004	0.011	-0.011	-0.006	-0.010	BENCHTIE
	501-11	-	-	5,581.457	5,581.454	5,581.467	5,581.453	5,581.448	-0.003	0.013	-0.014	-0.005	-0.009	BENCHTIE
	501-10	-	-	5,581.623	5,581.621	5,581.634	5,581.620	5,581.614	-0.002	0.013	-0.014	-0.006	-0.009	BENCHTIE
	623	339,871	2,033,687	5,580.785	5,580.785	5,580.794	5,580.782	5,580.775	0.000	0.009	-0.012	-0.007	-0.010	MP-AC
	613	339,880	2,033,731	5,580.291	5,580.297	5,580.302	5,580.296	5,580.290	0.006	0.005	-0.006	-0.006	-0.001	MP-AC
	Minimum								*-0.008*	*0.005*	*-0.022*	*-0.010*	*-0.014*	
	Maximum								*0.006*	*0.019*	*-0.006*	*0.011*	*0.005*	
	Average								*-0.002*	*0.014*	*-0.016*	*-0.003*	*-0.006*	
Loop 14: 505 Platt (Anderson)	615	339,855	2,034,071	5,576.592	5,576.589	5,576.597	5,576.579	5,576.581	-0.003	0.008	-0.018	0.002	-0.011	MP-AC
	505-1	-	-	5,578.550	5,578.547	5,578.551	5,578.541	5,578.549	-0.003	0.004	-0.010	0.008	-0.001	BENCHTIE
	625	339,846	2,034,007	5,578.788	5,578.786	5,578.790	5,578.777	5,578.785	-0.002	0.004	-0.013	0.008	-0.003	MP-AC
	505-7	-	-	5,581.863	5,581.855	5,581.860	5,581.854	5,581.863	-0.008	0.005	-0.006	0.009	0.000	X ON NW COR FIRE PIT
	505-6	-	-	5,580.444	5,580.443	5,580.436	5,580.426	5,580.441	-0.001	-0.007	-0.010	0.015	-0.003	BENCHTIE
	505-2	-	-	5,578.843	5,578.840	5,578.845	5,578.833	5,578.842	-0.003	0.005	-0.012	0.009	-0.001	BENCHTIE
	505-3	-	-	5,578.601	5,578.599	5,578.602	5,578.590	5,578.597	-0.002	0.003	-0.012	0.007	-0.004	BENCHTIE
	624	339,888	2,034,012	5,577.835	5,577.839	5,577.833	5,577.817	5,577.828	0.004	-0.006	-0.016	0.011	-0.007	MP-AC
	505-5	-	-	5,578.433	5,578.431	5,578.434	5,578.424	5,578.428	-0.002	0.003	-0.010	0.004	-0.005	BENCHTIE
	1006	339,884	2,034,083	-	-	-	5,576.106	-	-	-	-	-	0.000	BH-04 center steel cap
	505-4	-	-	5,578.173	5,578.171	5,578.175	-	5,578.169	-0.002	0.004	-	-	0.002	BENCHTIE
	505-8	-	-	5,578.273	5,578.270	5,578.275	5,578.265	5,578.272	-0.003	0.005	-0.010	0.007	-0.001	X ON STEPS
	Minimum								*-0.008*	*-0.007*	*-0.018*	*0.002*	*-0.011*	
	Maximum								*0.004*	*0.008*	*-0.006*	*0.015*	*0.002*	
	Average								*-0.008*	*-0.007*	*-0.018*	*0.002*	*-0.011*	
	Total Minimum								***-0.008***	***-0.009***	***-0.030***	***-0.015***	***-0.024***	
	Total Maximum								***0.013***	***0.019***	***0.026***	***0.079***	***0.064***	

Note:

1) Horizontal coordinates are in Montana State Plane NAD 83 (2011)
2) Q215 = NGS benchmark
3) 500 Series Point Numbers typicall are Fire Hydrant Bolt (FH-BOLT)
4) 600 Series Point Numbers are typically Monitoring Point with Aluminum Cap on embeded 36" long, No. 6 Rebar (MP-AC)
5) Horrizontal coordinates not surveyed for points attached to residences.
5) BH-08 not monitored on quarterly basis due to being located out of range of the survey loop system.
6) QM = Quarterly Monitoring
7) Shadded cells are borehole locations

Table 8-1
Red Lodge Drilling Investigation
Mine Map Inventory

Coal Bed	Map Title	Creation Date	Last Revision	General Description
No. 1 1/2	Northwestern Improvement Company, Map of Red Lodge and Sunset Mines of No. 1 1/2 Bed, Red Lodge Montana.	Jan - 1910	June - 1923	Map of No. 1 1/2 workings, Sunset and Eastside Mines, showing slopes for Nos. 1 1/2, 2, and 4.
No. 2	Northwestern Improvement Company, Map of Red Lodge Mine, No. 2 Bed, Red Lodge, Montana.	Nov - 1923	NA	Map of No. 2 workings east of main slope and City of Red Lodge. Main slope in within the east bluff. Main slope suggests 4 or more levels west of main slope, area not covered by map.
No. 2	Rowe, J.P. (1910). The Mining World, Red Lodge and Bear Creek Coal Mines, Montana. Figure Titled: One of the Main Slopes.	Jan - 1910	NA	Skectch of the No. 2 main slope, showing four west and east levels. Shows approximate locations and distance from main slope.
No. 3	Northwestern Improvement Company, Map of Red Lodge, No. 3 Bed, Red Lodge Montana.	Jan - 1926	Aug - 1932	Map of No. 3 workings. Workings are beneath east bluff. No hint of mining beneath City of Red Lodge in No. Bed or west of east bluff.
No. 4	Map of the N.W.I.CO'S Mine No. 4 at Red Lodge, Montana.	NA	Jan - 1907	Map of No. 4 workings west and east of main slope.
No. 4	Northwestern Improvement Company, Red Lodge No. 4 Mine, Workings east of main slope, Red Lodge, Montana.	Dec - 1909	Oct - 1923	Map of No. 4 workings east of main slope, showing slopes for Nos. 1, 1 1/2, 2, and 4.
No. 5	Northwestern Improvement Company, Map of Red Lodge No. 5 Mine, Red Lodge Montana.	Aug - 1912	NA	Map of No. 5 workings west and east of main slope, showing No. 5 slope in west bluff, No. 2 and No. 4 main slopes in east bluff.
No. 6	Northwestern Improvement Company, Map of Red Lodge No. 6 Bed, Red Lodge Montana.	NA	Apr - 1929	Map of No. 6 workings east of main slope, showing No. 4 and 7 slopes.
Nos. 1 1/2 and 4	Northwestern Improvement Company, Map of the Red Lodge and Bear Creek Coal Fields, Situate in Carbon Co. Montana.	1908	NA	Shows coutours levels, Sunset and Eastside beds Nos. 1 1/2, 4, and 5.

Table 8-2
Red Lodge Drilling Investigation
Coal Seam, Void, and Caved Thickness Summary

Coal Bed No.	Seam Thickness (ft) USGS Bulletin 341	BH-01 Observed Thickness (ft)(1)	BH-01 Void Thickness (ft)(2)	BH-01 Caved Thickness (ft)(3)	BH-02 Observed Thickness (ft)(1)	BH-02 Void Thickness (ft)(2)	BH-02 Caved Thickness (ft)(3)	BH-03 Observed Thickness (ft)(1)	BH-03 Void Thickness (ft)(2)	BH-03 Caved Thickness (ft)(3)	BH-04 Observed Thickness (ft)(1)	BH-04 Void Thickness (ft)(2)	BH-04 Caved Thickness (ft)(3)	BH-05 Observed Thickness (ft)(1)	BH-05 Void Thickness (ft)(2)	BH-05 Caved Thickness (ft)(3)	BH-06 Observed Thickness (ft)(1)	BH-06 Void Thickness (ft)(2)	BH-06 Caved Thickness (ft)(3)	BH-07 Observed Thickness (ft)(1)	BH-07 Void Thickness (ft)(2)	BH-07 Caved Thickness (ft)(3)	BH-08 Observed Thickness (ft)(1)	BH-08 Void Thickness (ft)(2)	BH-08 Caved Thickness (ft)(3)
#1	7										6.5	0	0	12	0	0	11	0	0				0		
#1 1/2	5							5.5	0	0	5	0	0	6	0	0	5	0	0				21	2.5	18.5
#2	5							9	P	P	9	P	P	9	P	P	17	5	12	8	3	5	17	0	17
#3	10							11	0	0	15	0	0	15	0	0	15.5	0	0	16	0	0			
#4	10	7.5	1	7	12	0	0	7	0	7	17	1	18	15	2.25	12.75	10	P	P	13	3.75	8.25			
#4 1/2	5	4.5	0	0	5	0	0	5	0	0	5	0	0	7	0	0	6.5	0	0	5	0	0			
#5 and 6	12	33.5	0	35	20	0	0	16.5	6	10.5	24	0	24	19.5	P	P	18	P	P	22	P	P			

Notes:

1) Observed thickness was measured from top of existing roof materials to the floor of the mine, usually denoted by competent materials or underclay.

2) Void height was recorded during drilling as distance drill rods would "fall" without turning or applied down pressure.

3) Caved height was measured during drilling as distance driller and engineer noted drill action was reprsentative of drilling through loose and block materials.

4) Shaded Beds were observed as worked.

Table 8-3
Red Lodge Drilling Investigation
Coal Seam Floor Material and Thickness Summary

	BH-01			BH-02			BH-03			BH-04			BH-05			BH-06			BH-07			BH-08		
Coal Bed No.	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)	Floor Material (ft)(1)	Hardness (2)	Floor thickness (ft)(3)
#1										Sandstone/ Claystone	H3/H3	3/5	Claystone/ Siltstone	H6/H3	0.5/9	Siltstone/ Sandstone	H3/H2	7/6				0		
#1 1/2							Claystone/ Sandstone	H7-H4/H3	7/5	Claystone/ Sandstone	H7/H3	3/20	Claystone/ Sandstone	H3/H3	9/20	Claystone/ Sandstone	H6/H4	0.5/3				Claystone /Sandstone	H6/H3	3/20
#2							Claystone	H5/H4	11/24	Claystone	H4	21	Claystone	H4	21	Claystone	H6/H5	11/5	Claystone	H6/H5/H4	5/5/4	Claystone	H7/H5	11/9
#3							Claystone/ Siltstone	H4/H4	5/20	Claystone/ Siltstone	H6/H3	1/20	Claystone/ Siltstone	H5/H4	1/20	Claystone /Siltstone	H6/H4	3/20	Claystone/ Sandstone	H4/H2	0			
#4	Claystone	H6	5.5	Claystone	H3	10	Claystone	H7/H6/H4	3/7/5	Claystone	H6/H5/H4	5/3/4	Claystone	H6	10	Claystone/ Sandstone	H6/H3	3/3	Siltstone/ Claystone	H4/H5	2/6			
#4 1/2	Claystone/ Sandstone	H3/H3	1/7	Claystone/ Siltstone	H6/H3	1/7	Claystone/ Sandstone	H4/H3	3/20	Claystone/ Sandstone	H7/H3	3/2	Claystone/ Siltstone	H6/H2	5/20	Claystone/ Sandstone	H6/H4	5/7	Claystone/ Sandstone	H5/H2	5/20			
#5	Claystone/ Sandstone	H6/H3	2/19	Siltstone/ Sandstone	H3/H3	1/20	Sandstone/ Siltstone	H3/H3	4/5	Claystone/ Siltstone	H5/H3	1/5	Siltstone	H3	20	Sandstone/ Claystone	H3/H3	7/4	Siltstone	H3	20			

Notes:
1) Floor materials are summarize from detailed drillhole logs.
2) Field Hardness Descriptor: H1 = Extremely Hard, H2 = Very Hard, H3 = Hard, H4 = Moderately Hard, H5 = Moderately Soft, H6 = Soft, H7 = Very Soft. See Refs for Qualitative Descriptions, Engineering Geology Field Manual.
3) Material thickness is summarized from detailed drillhole logs.
4) Shaded Beds were observed as worked.

Table 8-4
Red Lodge Drilling Investigation
Pillar Extraction Ratio and Aspect Ratio Summary

	BH-01		BH-02		BH-03		BH-04		BH-05		BH-06		BH-07		BH-08	
Coal Bed	(1-R)	W/H	(1-R)	W/H	(1-R)	W/H	(1-R)	W/H	(1-R)	W/H	(1-R)	W/H	(1-R)	W/H	(1-R)	W/H
No. 1 1/2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.50	5.30
No. 2*	NA	NA	NA	NA	0.45	6.30	0.45	6.30	0.45	6.30	0.45	6.80	0.49	5.60	NA	NA
No. 4	0.62	1.95	0.57	1.95	0.55	3.30	0.40	4.15	0.45	4.15	0.41	3.45	0.49	4.20	NA	NA
No .5	0.52	3.57	0.53	3.79	0.45	4.29	0.44	4.21	0.44	4.14	0.43	4.43	0.51	4.14	NA	NA

* Approximated from NWIC, Map of Red Lodge Mine, No.2 Bed, Red Lodge, Montana (East of Main Slope)

Table 9-1. Drilling Investigation Summary

FINDING	BORE HOLE ID																					
	BH-01		BH-02		BH-03			BH-04			BH-05			BH-06			BH-07			BH-08		
Seams Worked at Each Location	No. 4	No. 5	No. 4	No. 5	No. 2	No. 4	No. 5	No. 2	No. 4	No. 5	No. 2	No. 4	No. 5	No. 2	No. 4	No. 5	No. 2	No. 4	No. 5	No 1 1/2	No. 2	No. 4
Residence Voiced Mine Subsidence Concern to DEQ	No		Yes - 207 S. Hauser		Yes - 501 S. Broadway			Yes - 505 Platt Ave			No			No			Yes - 404 S. Broadway			No		
Mine Workings Based on Historical Maps	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Undocumented Workings Interpolated to be in Area	Documented		Documented		Maybe	Documented		Maybe	Documented		Documented			Documented			Yes	Documented		None	Documented	
Mine Workings Observed During Drilling	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Void-Yes?	Yes	Yes	Yes	Yes	NA
Depth of Workings (ft)	234	369	173	316	None	472	613	NA	472	609	254	472	623	337	566	706	116	342	493	NA	119	209
Workings Condition	Partial Collapse	Collapse	Pillar	Pillar	NA	Collapse	Partial Collapse	NA	Partial Collapse	Yes	Partial Collapse	Partial Collapse	Pillar	Partial Collapse	Pillar	Pillar	Partial Collapse	Partial Collapse	Pillar	Partial Collapse	Collapse	NA
Void Height (ft)	1	0	Pillar	Pillar	NA	0	6	NA	1	0	Pillar	2.25	Pillar	5	Pillar	Pillar	3	3.75	Pillar	2.5	0	NA
Pillar Crushing Safety Factor Non-Deteriorated	2.00	1.60	3.06	1.83	NA	1.18	1.11	NA	1.57	1.13	2.67	1.44	1.11	2.01	1.28	1.00	NA	1.84	1.23	5.18	NA	NA
Pillar Crushing Safety Factor Deteriorated	1.21	1.10	1.99	1.25	NA	0.78	0.80	NA	1.18	0.83	1.94	1.03	0.81	1.46	0.96	0.73	NA	1.30	0.85	3.63	NA	NA
Pillar Punching Potential	Possible	Possibly Slight	Possible	Possibly Slight	Possible	Possible	Possibly Slight	Possible	Possible	Possibly Slight	Possible	Possible	Possibly Slight	Possible	Possible	Possibly Slight	Possible	Possible	Possibly Slight	Possible	Possible	Possibly Slight
Subsidence Observed in Survey Monitoring	No		No		No			No			No			No			No			NA		
Extensometer Installed	No		Yes		No			No			No			No			No			No		
Further Action Required	Monitoring Survey		Monitoring Survey		Monitoring Survey			Monitoring Survey			Monitoring Survey			Monitoring Survey			Monitoring Survey, MASW, Drill Hole			None		

APPENDIX A. FIELD LOGS

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1 BH01

BH01 is located in the right-of-way on the north side of 14th Street, west of the alley and east of the house located at 25 14th Street West (Figure 2-1). Six-inch steel casing was installed to a depth of 119 feet. The soil profile consisted of Silty Sand with Gravel (SM) from the surface to a depth of 4 feet where it graded into Poorly Graded Gravel with Sand (GP). Several large boulders were encountered throughout the depth of the alluvium. Bedrock was encountered at 111 feet.

On August 22, 2014, the core drill set up over the six-inch steel casing and core drilling was initiated. PQ-3 core was drilled from a depth of 119 feet to 250 feet. PQ-3 was drilled through seams No. 4 (234 – 241.5 feet). At 250 feet, the drillers switched to HQ-3 core and drilled through the No. 4½ (253 – 257.5 feet) and No. 5 seam (387 - 402.5) to the total depth of 459 feet.

Evidence of the No. 4 seam was first encountered at a depth of 233 feet where drill fluid circulation was lost. At the depth of 234 feet the driller observed the rods fall by gravity for a distance of 1 foot, indicating 1 foot of void space. The roof of the No. 4 seam was observed as 24 feet of hard siltstone. Below the roof, coal was recovered in the form of Silty Gravel with Sand (GM). A section of timbers was recovered near the floor of the seam. The last bit of coal was recovered at the depth of 241.5 feet, immediately above 5.5 feet of soft claystone followed by moderately hard sandstone. The total damaged thickness for the No. 4 seam was observed to be 7.5 feet.

The No. 4½ was encountered between the depths of 253 to 257.5 feet and was underlain by 1 foot of hard claystone followed by hard, fine-grained sandstone.

Evidence of the No. 5 seam was first encountered at a depth of 369 feet where drill fluid circulation was lost. No large voids were encountered, but 14 feet of loose material was drilled from the depth of 375 to 389 feet. Rods never fell by gravity, but drilling action was observed as "bouncing through loose material and moving in and out of solid materials". The roof material, soft claystone, was encountered at the depth of 391 to 396 feet. Coal gravel was recovered from 396 to 402.5 feet; the floor was observed as 2 feet of soft claystone underlain by hard fine-grained sandstone to a depth of 427 feet. The hole was advanced an additional 56 feet past the floor to a total depth of 459 feet.

Bore hole BH01 was drilled approximately 50 feet west of bore hole DH-3, which was installed by Chen-Northern in 1987 (Figure 5-1). Comparison of the data collected in each bore hole shows similar results for seam No. 4 and different observations for seam No. 5. In BH01, a void was detected at 234 and the floor was observed at a depth of 241.5. The log for DH-3 indicated that seam No. 4 was encountered at a depth of 228 feet. The coal was described as highly fractured with an RQD of 0% and the floor was observed at a depth of 238 feet, which is similar to BH01. Seam No. 4½ was not documented in DH-3.

In BH01, damaged rock associated with seam No.5 was first detected at a depth of 369 feet followed by drilling of loose materials until the roof was drilled through at 396 feet. The floor of seam No. 5 was observed at the depth of 402.5 feet in BH01 for a damaged thickness of 33.5 feet. In DH-3, seam No. 5 was not noted in the log, but a potential indicator of this seam was first noted at a depth of 429 where the RQD dropped from 86% to 15%. Chen reported that roof strain was evident in the core below 425 feet; they also concluded that there had been roof-floor convergence in this seam due to pillar crushing or punching. The total damaged thickness observed in DH-3 was approximately 8 feet.

A sizable difference, 8 feet vs. 33.5 feet, in damaged thickness was observed between the two bore holes in seam No. 5. The difference may be explained by lateral variations in the mine collapsed geometry. Or it could suggest that collapse occurred between the year drilling occurred for DH-3 (1987) until the present time. Either scenario is feasible.

1.1 Down-Hole Camera

After completing the drilling, a down-hole camera was lowered through the 6-inch casing and into the bedrock. The camera was lowered to the depth of 234 feet where an opening in the bedrock was observed at the No. 4 seam. Camera footage shows the top of the opening at the depth of 231 feet. The camera was not able to penetrate below 234 feet, where a 1-foot void was encountered during drilling. Footage shows broken and possibly collapsed roof materials from the depth of 231 to 234 feet, and water circulating from the depth below 234 feet.

2 BH02

BH02 is located on Oakes Avenue approximately 15 feet west of the garage for the residence at 207 S. Hauser Avenue (Figure 5-1). The resident at 207 S. Hauser recalled that approximately 40 to 60 years ago, before the garage on the property was built, a depression had abruptly opened

adjacent to the northwest corner of the house. The depression was subsequently filled with "two dump truck loads of gravel". No official report was made at the time and there has been no further investigation of the specific depression site.

For this bore hole, the six-inch steel casing was installed to a depth of 109 feet. Medium- to coarse-grained Well-Graded Sand with Gravel (SW) was encountered from below the surficial asphalt pavement to a depth of 8 feet, where it graded into Poorly Graded Gravel with Sand (GP). Sandstone bedrock was encountered at a depth of 105 feet. Several large boulders were encountered throughout the depth of the alluvium. The operators of the DR-24 stated the sandstone was very tight and the decision was made to stop the hole at 109 feet instead of continuing to the planned depth of 114 feet.

The core drill set up over the six-inch steel casing and began PQ-3 coring. The PQ-3 core was advanced to a depth of 114 feet where the driller stated drilling was requiring more torque than normal. Upon reaching a depth of 134 feet, drilling was requiring 90% of the available drill rig torque. The driller pulled back on rods and the rods were nearly stuck in the ground. After working the rods loose and pulling back to 113 feet, the rods were re-advanced to 134 feet in an attempt to ream out the hole. Reaming the hole did not help to reduce the required torque. The geotechnical engineer decided to reduce to HQ-3 at the depth of 134 feet. The remainder of the hole was drilled with HQ-3; the driller noted that drilling still required more torque that normal, but not an excessive amount.

The top of the No. 4 seam was encountered at a depth of 173 feet and floor at a depth of 185 feet for a total thickness of 12 feet. The entire section of coal was recovered and the two 10-foot runs through the seam had RQD values of 26% and 70%. Two shear zones were observed, adjacent to the top coal/claystone contact, dipping from horizontal at 10 and 40 degrees.

At the depth of 239 feet, the driller needed to change the HQ-3 bit. Upon tripping the rods back into the bore hole, progress was stopped at a depth of 169 feet due to a caved hole. The drillers reamed the hole to 179 feet, where the rods again could be lowered by gravity. RQD from the No. 4 to the top of the No. 5 seam ranged between 63 to 95%. The No. 5 seam was encountered between depths of 316 to 336 feet, for a total thickness of 20 feet. Total depth of the hole was 379 feet.

2.1 Extensometer Installation

Based on the close proximity of the bore hole to shallow workings of the seam No. 4, significant pinching of the drill rods near 134 feet, and the reported subsidence feature reported by the resident, a Slope Indicator rod extensometer was installed to a depth of 124 feet (19 feet below the top of bedrock). An extensometer is a device that measures and records vertical movement of subsurface materials. To install the rod extensometer, a mechanical PQ packer (4 3/8 inch outer diameter) was lowered to the depth of 127 feet on the end of HQ rods, engaged to plug the bore hole at the depth of 125 feet, and the rods were disconnected from the packer and removed. A tremmie pipe was fastened to the bottom of the extensometer with three wraps of electrical

tape. The rod extensometer was lowered to the depth of 124 feet and suspended from the surface. Neat cement, consisting of four Quikrete No. 1124 (47 lbs each) bags mixed with 10 gals of water, was tremmied above the mechanical packer, filling approximately 10 feet of the bore hole. The tremmie pipe was left in place.

The next day the cement was setup and the remaining bore hole volume (112 linear feet) was filled with 3/8-inch bentonite chips, to 2.5 feet from the surface. A VW Displacement Sensor (Slope Indicator) and VW MiniLogger (Slope Indicator) were installed below grade to monitor the movements of the extensometer. The VW MiniLogger was programed to collect one reading every 24 hours.

3 BH03

BH03 is located in the right-of-way on the south side of 16th Street, north of the house located at 501 Broadway (Figure 5-1). Six-inch steel casing was installed to a depth of 99 feet. The soil was classified as Poorly Graded Sand with Clay and Gravel (SP-SC) from the ground surface to a depth of 2.5 feet, were it graded into Well-Graded Sand with Gravel (SW). Poorly Graded Gravel with Sand (GP) was encountered from the 9-foot depth to 87 feet where bedrock was encountered. Several large boulders were encountered throughout the depth of the alluvium.

The core drill set up over the 6-inch steel casing and drilled PQ-3 core to a depth of 275 feet. PQ-3 was drilled through seams No. 1½ (160 to 166.5 feet) and No. 2 (242.5 to 251.5 feet). Core recovery through the No. 2 seam was approximately 95%. RQD in the central section of the seam was 26%. The floor beneath the No. 2 was observed as moderately soft claystone for a distance of 11 feet and transitioning to moderately hard claystone that persisted to a depth of 296 feet.

The No. 3 seam was encountered from 326 to 337 feet. This seam was underlain by 5 feet of moderately hard claystone, then siltstone.

The top of the No. 4 seam was encountered between 472 feet and 479 feet. No large voids were observed, but 6 feet of very loose material, likely sand sized or smaller particles. Drill rods fell by gravity as circulation of drill fluids flushed out materials, with several small noticeable drops (1 to 2 inches) of free fall. Near the bottom of the seam, at a depth of 479 feet, the sampling tube was sanded in and the rods were pulled to free the tube. The floor was observed as 3 feet of very soft claystone underlain by 12 feet of soft claystone transitioning to moderately hard claystone.

The No. 4½ was encountered between depths of 494 and 499 feet and was underlain by 3 feet of moderately hard claystone followed by hard fine- and medium-grained sandstone.

Evidence of the No. 5 seam was first encountered at a depth of 613 feet, where the driller observed the rods fall by gravity 4 inches three separate times. The roof of the No. 5 was observed as 4 feet of soft claystone. Below the roof, coal was recovered in the form of Poorly Graded Gravel with Sand (GP). Two larger (2.6 foot) voids were observed at depths of 622.5

and 627 feet. Firm drilling was encountered at a depth of 629.5 feet, where the drill encountered the floor of hard, fine-grained sandstone. The total damaged thickness for the No. 5 seam was observed to be 16.5 feet. The hole was advanced an additional 40 feet past the floor into fine-grained sandstone with an RQD greater than 95%.

4 BH04

BH04 is located in the right-of-way between Platt Ave. and the house located at 505 South Platt Ave. (Figure 5-1). Six-inch steel casing was installed to a depth of 54 feet. Poorly Graded Sand with Silt (SP) was encountered from the ground surface to a depth of 4.5 feet, where it graded into Poorly Graded Gravel with Sand (GP). Bedrock was encountered at 42 feet. Several large boulders were encountered throughout the depth of the alluvium.

The core drill set up over the 6-inch steel casing and drilled PQ-3 core to a depth of 304 feet. PQ-3 was drilled through seams No. 1½ (168 to 173 feet) and No. 2 (248 to 257 feet). Core recovery through the No. 2 seam was approximately 98%. RQD in the upper section of the seam was 27% and the lower section was 72%. The floor beneath the No.2 consisted of 21 feet moderately hard claystone between 257 feet and 278 feet. Several steeply dipping joint sets were observed in the bedrock materials above seam No. 2.

The No. 3 seam was encountered between 333 and 348 feet. The No. 3 seam was underlain by 1 foot of soft claystone followed by hard siltstone that persisted for 45 feet to a depth of 393 feet. No steeply dipping joints were observed between seams No. 2 and 3.

Evidence of the No. 4 seam was encountered at 472 feet, when drilling circulation was lost and a 1-foot void was observed. Loose material was drilled between the depths of 473 and 489 feet. Rods never fell by gravity, but drilling action was observed as “bouncing through loose material and moving in and out of solid materials”. Looseness of materials was also evidenced by recovered materials showing drill marks along multiple surfaces, indicating the rock was loosely confined and pushed around during the coring process. The floor was observed as 5 feet of soft claystone underlain by 3 feet of moderately soft claystone mixed with coal (described as a Clayey Gravel), then 4 feet of moderately hard claystone. A slight number of steeply dipping joints were observed between seams No. 3 and 4.

The No. 4½ was encountered between depths of 501 and 506 feet and was underlain by 2.5 feet of moderately hard claystone followed by hard fine- and medium-grained sandstone.

Evidence of the No. 5 seam was first encountered at a depth of 609 feet, where the RQD dropped from 74% to 22%. The roof of the No. 5 was observed as 5 feet of moderately soft claystone. Below the roof, advancing through the coal required very little down pressure. Sand heaved into the tube at the depth of 624 feet; the drillers had to pull the rods to remove the splits from the barrel. Drilling from 625 to 629 feet, the drillers stated the drills would not fall by gravity but required very little down pressure to advance. Firm drilling was encountered at a depth of 633 feet where the drill encountered the floor of hard fine-grained sandstone beneath 1 foot of moderate soft claystone. RQD of the floor materials remained poor until a depth of 642 feet.

The total damaged thickness for the No. 5 seam was observed to be 33 feet. The hole was advanced to a total depth of 653 feet into fine-grained sandstone with an RQD greater than 95%. No steeply dipping joints were observed between seams No. 4 and 5

5 BH05

BH05 is located in the right-of-way east of the street in front of 511 Haggin Ave. (Figure 5-1). During the first attempt to drill BH05, drill refusal was encountered when a large metallic object was hit at a depth of 1-foot. The DR-24 drill rig was moved 5 feet to the south and a second attempt was made to advance the six-inch steel casing. The six-inch steel casing was advanced at the new location; however, the edge of the steel object was observed at a depth of 4 inches. Pioneer was unable to identify what the steel object was.

The soil profile consisted of fill from the ground surface to a depth of 9 feet; 0 to 4 feet was classified as Poorly Graded Sand (SP) and 4 to 9 feet was classified as Poorly Graded Gravel (GP) with frequent lenses of Well Graded Sand (SW). Alluvial, Poorly Graded Gravel with Sand and Silt (GP) was logged from 9 feet to 14 feet where bedrock was encountered.

The core drill set up over the 6-inch steel casing and drilled PQ-3 core to a depth of 269 feet. PQ-3 was drilled through seams No. 1 (59.5 to 71.5 feet), No 1½ (180 to 186 feet) and No. 2 (254 to 263 feet). Appendix B, Picture #14, includes core sample photographs of coal from seam No. 1 and the floor claystone floor. A narrow zone of sheared material (intermixed ground up coal and clay) was observed between the coal and the claystone. This shear zone is where the No. 1 coal seam moved laterally relative to the claystone floor material; inter-bedding shear can occur as bedrock adjusts to mine related displacements. Picture #15 is an example of materials observed in the roof of seam No. 1 ½, bedding parallel and nonparallel joints. Claystone is typically weaker than siltstone; therefore, bedding parallel joints and shear fractures prefer to form within the thin claystone layers rather than the siltstone layers. Picture #16 is an example of the interface between the claystone roof and seam No. 1 ½ and joints sets (cleats). Coal bed cleats typically form both parallel and perpendicular to bedding; the two intersecting fractures are bedding parallel and perpendicular cleats. Picture #17 is an example of the fine grained sandstone observed between seam No. 1 ½ and No. 2.

Core recovery through the No. 2 seam was approximately 90%. RQD in the upper section of the seam was 28% and the lower section was 80%. The floor beneath the No. 2 (at 263 feet) was observed as moderately hard claystone that persisted for 21 feet to a depth of 284 feet. Drilling fluid circulation was maintained through the No. 2 seam.

Upon drilling into the No. 2 seam, drilling fluid pressure increased greatly and the drill rods were squeezed tight enough to stop them from spinning. The drillers removed the water swivel from the top of the drill stem to pull the tube and noted both the smell of ‘swamp gas’ and the air quality monitor alarm sounded for carbon monoxide (CO) levels higher than 40 ppm. The gas monitor also monitored the lower explosive limit (%LEL), percent Oxygen, and Hydrogen Sulfide. Neither the %LEL nor the Hydrogen Sulfide meters recorded any changes. The CO

alarm lasted for several seconds. Work was temporarily stopped to assess the situation. Drilling resumed after the situation was assessed and the gas meter no longer recorded a CO reading.

Pictures #18 and #19 are an example of the lower section of seam No. 2 immediately above the moderately hard claystone floor material.

The No. 3 seam was encountered between depths of 341 and 356 feet. The No. 3 seam was underlain by 1 foot of moderately soft claystone followed by moderately hard siltstone that persisted for 51 feet to a depth of 406 feet.

Picture #20 shows fine grained sandstone, above moderately soft claystone immediately above the upper portion of seam No. 3. The claystone degraded to a soft condition following exposure to fluid flow through the more permeable coal seam.

Evidence of the No. 4 seam was encountered at 478 feet when drilling circulation was lost and a 1-foot void was observed. Loose material was drilled at the depth of 478 to 493 feet. Rods never fell by gravity, but drilling action was observed as bouncing through loose material and moving in and out of solid materials. Intermittent voids of 7, 2, 5, and 2 inches were encountered through the loose material. Looseness of materials was also evidenced by recovered materials showing drill marks along multiple surfaces, indicating loose confinement within the seam. The floor was observed as 10 feet of soft claystone.

Picture #21 shows the hard claystone bedrock observed immediately prior to encountering the 1-foot void above seam No. 4. Caved materials beneath the void were observed as hard claystone that had caved from the roof. Picture #22 shows the materials constituting the floor of seam No. 4. The claystone was disturbed and moderately soft.

The No. 4½ seam was encountered between the depths of 503 and 510 feet and was underlain by 5 feet of soft claystone followed by very hard siltstone. Picture #23 shows the lower extent of seam No 4 ½ and the underlying soft claystone material.

Evidence of the No. 5 seam was first encountered at a depth of 623 feet. The roof of the No. 5 seam was observed as 5 feet of hard claystone. Recovery through the seam was 98% and the RQD of the coal and was between 43% to 62%. Firm drilling was encountered at a depth of 642.5 feet, where the drill encountered the floor of hard siltstone. RQD of the floor materials remained greater than 93% from the floor to the bottom of the hole at 679 feet.

Picture #24 is an example of the claystone roof above seam No. 5 and the upper section of coal. At this location the claystone roof was observed as hard. Picture #25 shows the lower section of seam No. 5 and the hard siltstone floor that was typically observed.

5.1 Down-Hole Camera

After the drilling phase was completed, a down-hole camera was lowered through the 6-inch casing into the core hole in the bedrock. The camera was lowered to the depth of 260 feet, where the No. 2 seam was observed during drilling. The water was too cloudy to view the inside of the bore hole and no observations were made.

6 BH06

Bore hole BH06 is located in the west-bound lane of 17th Street, just east of Broadway Avenue (Figure 5-1). Six-inch steel casing was installed to a depth of 74 feet. Below the asphalt pavement, Poorly Graded Gravel with Sand (GP) was logged until bedrock was encountered at a depth of 60 feet.

The core drill set up over the 6-inch steel casing and drilled PQ-3 core to a depth of 375 feet. PQ-3 was drilled through seams No. 1 (143 to154 feet), No 1½ (261 to 266 feet) and No. 2 (337 to 354 feet). At the depth of 88 feet, 28 feet into bedrock, circulation was briefly lost and material squeezed in on the drill rods. At this depth a 1-foot thick layer of material described at Clayey Gravel (GC) was recovered. Intermittently poor RQD (less than 50%) persisted to the depth of 140 feet. At 140 feet, torque and water pressure spiked and material squeezed in on the rods. The variation in RQD can be observed in Figure 5-6 (materials above seam No. 1)

The No. 1 seam was then encountered between depths of 143 and 154 feet. The roof material was described as 2.5 feet of moderately soft claystone. Core recovery through the No. 1 seam was approximately 100%. RQD in the upper section of the seam was 28% and the lower section was 70%. The floor beneath the No.1 (at 154 feet) was observed as moderately hard siltstone thinly laminated with claystone.

The No. 1½ seam was encountered between depths of 261 and 266 feet. The No. 1½ seam was overlaid by hard claystone and underlain by 1 foot of soft claystone followed by interbedded, moderately soft, fine-grained sandstone and claystone to a depth of 274 feet.

Evidence of the No. 2 seam was encountered at 313 feet when drilling circulation was lost. RQD remained good for the next 21 feet when a 5-foot void was encountered between depths of 337 and 342 feet. From 342 to 344 feet the rods would not fall by gravity with fluid circulation off, but with fluid circulation on the rods would drop as fluids jetted out loose material. Loose material was drilled from the depth of 344 to 354 feet. Rods never fell by gravity, but drilling recovered disturbed Clayey Gravel. The floor was observed as 11 feet of soft claystone underlain by 5 feet of moderate soft claystone interbedded with moderately hard siltstone. RQD remained poor to a depth of 375 feet. The drillers reduced from PQ-3 to HQ-3 at 375 feet.

The No. 3 seam was encountered between depths of 422.5 and 438 feet. The No. 3 seam was overlaid by moderately hard claystone and underlain by moderately hard fine-grained sandstone and siltstone to a depth of 454 feet.

Evidence of the No. 4 seam was encountered at 566 feet when drilling circulation was lost and loose material was drilled from the depth of 566 to 576 feet. The drillers removed the water

swivel from the top of the drill stem to pull the tube and noted the smell of 'swamp gas, but the gas meter did not read any measurable levels. No voids or caved material was detected. Recovery through the seam was 34% for the first run and 98% for the remaining two. RQD of the coal was poor at 19%. The floor was observed as 3 feet of soft claystone underlain by 3 feet of moderately hard fine-grained sandstone.

The No. 4½ was encountered between depths of 583 and 589 feet and was underlain by 5 feet of soft claystone followed by moderately hard to very hard fine-grained sandstone.

Evidence of the No. 5 seam was first encountered at a depth of 706 feet. The roof of the No. 5 seam was observed as 19 feet of hard claystone. Recovery through the seam was 95% and the RQD of the coal was poor at between 0 to 19%. Firm drilling was encountered at a depth of 724 feet where the drill encountered the floor of hard fine-grained sandstone. RQD of the floor materials remained greater than 93% from the floor to the bottom of the hole at 744 feet.

7 BH07

BH07 is located in the right-of-way south of 15th Street, adjacent to the residence at 404 Broadway Avenue (Figure 5-1). Six-inch steel casing was installed to a depth of 98.5 feet. The DR operator stated that drilling into the bedrock was very difficult and did not want to risk breaking the casing by pulling it back the planned 2 feet. Poorly Graded Gravel with Sand (GP) was logged from the ground surface to a depth of 89 feet, where bedrock was encountered.

The core drill set up over the 6-inch steel casing and drilled PQ-3 core to a depth of 379 feet. PQ-3 was drilled through seams No. 2 (116 to 124 feet), No. 3 (200 to 216 feet) and No. 4 (342 to 355 feet).

The No. 2 seam was encountered between depths of 116 and 124 feet. The seam was overlaid with 3 feet of soft claystone. No voids or caved material were detected during drilling (see camera discussion below). Recovery through the seam was 88% for the first and second runs. RQD of the coal was fair at 52% and 82%. The seam is underlain by 14 feet of soft claystone grading to moderately hard claystone at a depth of 133 feet. Floor materials had poor to fair RQD values of 30%, 37%, and 72%. As shown in Figure 5-6, RQD from the top of bedrock until the just beyond seam No. 3 RQD is uncharacteristically low, hovering between 0 to 65%, a rock mass quality of Very Poor to Fair.

The No. 3 seam was encountered between depths of 200 and 216 feet. The No. 3 seam was overlaid by 1.5 feet of soft claystone and underlain by 1.0 feet of moderately hard claystone, followed by very hard fine-grained sandstone and hard siltstone to a depth of 233 feet.

Evidence of the No. 4 seam was encountered at 339 feet when drilling circulation was lost. A 4-foot void was encountered between 342 feet and 346 feet. Loose, soft materials were drilled from 346 to 355 feet. Recovery through the seam was 34% for the first run and 98% for the remaining two. The floor was observed as 2 feet of moderately hard to hard siltstone underlain by soft claystone. The No. 4½ was encountered at a depth of 365 to 369 feet. The seam was

overlain by 6 feet of moderately soft claystone and underlain by 6.0 feet of moderately soft claystone, followed by very hard to hard fine- grained sandstone and hard siltstone to a depth of 289 feet.

Evidence of the No. 5 seam was first encountered at a depth of 493 feet. The roof of the No. 5 was observed as 6 feet of hard to moderately hard claystone. Recovery through the seam was 100% and the RQD of the coal and was between 67% and 75%. Firm drilling was encountered at a depth of 515 feet, where the drill encountered the floor of hard to very hard siltstone. RQD of the floor materials remained greater than 89% until the bottom of the hole at 539 feet.

7.1 Down-Hole Camera

After the drilling phase was completed, a down-hole camera was lowered through the 6-inch casing and into the core hole and into the bedrock. The camera was lowered to the depth of 123 feet, where an opening in the bedrock was observed at the No. 2 seam. The opening was not observed during drilling. Camera footage shows the top of the opening is at the depth of 122 feet. The footage shows a 360-degree view of the opening. The size and scale of the opening is difficult to interpret; however, at the location of the camera, the opening is 1 foot in height. In opposite horizontal directions, the opening height gets smaller and in the other direction, the opening height gets larger, approximately 2 to 3 feet in height. The camera location appears to be above a small rubble slope which has since covered the bore hole below the 124-foot depth. As noted above, the recovered bore hole data in this section showed the coal in the No. 2 seam had fair RQD and circulation was continuous through the coal seam. Workings in seam No. 2 at this location was not anticipated; based on the documented maps, seam No. 2 was not mined in this area. It is possible a complete map of seam No. 2 may show some degree of mining in this area, if any. If mining was not performed at this location, the opening may also be the signature of collapse of seam No. 4; the map of seam No. 4 shows a large section of pillars were removed in this area and further east.

7.2 Extensometer Installation

Based on the close proximity of the observed opening below the depth of 123 feet, a Slope Indicator rod extensometer was installed to a depth of 110 feet (13 feet above the observed opening). To install the rod extensometer, a mechanical PQ packer (4 3/8 inch outer diameter) was lowered to the depth of 113 feet on the end of HQ rods, engaged to plug the bore hole at the depth of 111 feet, and the rods were disconnected from the packer and removed. A tremmie pipe was fastened to the bottom of the extensometer with three wraps of electrical tape. The rod extensometer was lowered to the depth of 110 feet and suspended from the surface. Neat cement, consisting of four Quikrete No. 1124 (47 lbs each) bags mixed with 10 gals of water, was tremmied above the mechanical packer, filling approximately 10 feet of the bore hole. The tremmie pipe was left in place.

The next day the cement was setup and the remaining bore hole volume (105 linear feet) was to be filled with 3/8-inch bentonite chips. The volume was anticipated to require approximately 30 bags of bentonite; however, the hole filled after 13 bags. Based on the discrepancy between the

calculated hole volume and volume of bentonite used to fill the hole, it was decided to push a 1½-inch diameter PVC pipe down the inside of the 6-inch casing and through the bentonite to see if the hole was bridged off with bentonite. Upon reaching the depth of 49 feet the PVC was stopped by something very stiff and the pipe could not be advanced any further. In an attempt to flush the object from the below the PVC, the pipe was connected to the water truck and water was pumped down the PVC. Water began to flow on the ground surface from the grout line left in place; indicating there was a hydraulic connection between the PVC and grout line. The grout line should have been grouted in place to a depth of 110 feet; however, when it was pulled on, it was easily removed. The end of the grout line was sheared off at a depth of 49 feet.

The 6-inch diameter steel casing appeared to have sheared at the 49-foot depth. The extensometer installation could not be completed as planned and a steel cap was welded onto the top of the casing.

8 BH08

BH08 is located northwest of the rodeo grounds along Rodeo Road (Figure 5-1). Six-inch steel casing was installed to a depth of 57 feet with the DR-24. The soil lithology was logged as alternating layers of Well-Graded Sand with Silt and Well to Poorly graded Gravel with Sand (GW & GP) from the ground surface to a depth of 44 feet, where sandstone bedrock was encountered.

The core drill set up over the 6-inch steel casing and drilled PQ-3 core to a depth of 254 feet. PQ-3 was drilled through seams No. 1½ (117 to 140 feet) and No. 2 (209 to 226 feet).

Evidence of the No. 1½ seam was encountered at 117 feet when drilling circulation was lost. A 2.5-foot void was encountered between depths of 119 feet and 121.5 feet. Loose, soft materials were drilled between 121.5 and 133 feet. At 133 feet, caved materials were drilled to a depth of 141 feet. Within this interval, siphoning of water from the drill rods (caused by materials with very high permeability and low head) vibrated the drill stem. The floor was observed as 2.0 feet of soft claystone grading to hard fine-grained sandstone. The coal bed was underlain by moderately hard fine-grained sandstone and moderately hard claystone with fair RQD, ranging between 58% and 74%.

Evidence of the No. 2 seam was encountered at 209 feet when disturbed Silty Gravel (GM) was encountered. Recovery of the silty gravels showed the gravel particles graded from sandstone to entirely coal. The last bit of coal was recovered at 226 feet. The seam was underlain by 18 feet of soft claystone grading to moderately hard claystone at a depth of 226 feet. Floor materials had poor to fair RQDs of 0%, 23%, 39%, and 32%. The total depth of the hole was 254 feet.

8.1 Down-Hole Camera

After the drilling phase was completed, a down-hole camera was lowered through the 6-inch casing and into core hole within the bedrock. The camera was lowered to the total depth of 119 feet, where an opening in the bedrock was observed in the No. 1½ seam. Camera footage shows

the top of the opening is at the depth of 117.5 feet and static groundwater within the opening is near 118.5 feet. Above the opening, ground water is also observed flowing from fractures into the bore hole.

The footage shows a 360-degree view of the bore hole from 55 feet to the depth of 119 feet. The size and scale of the opening is difficult to interpret. In the location of the camera, the initial opening is 1.5 feet in height. The void appears to be the upper limit of the active roof caving process.

Drill Hole Logs

Drill Hole No. BH-01

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/6/14 - 8/27/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5580.40 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 340693.919, E. 2033539.606	HAMMER TYPE: None

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		1, 2, 3			X	G14487		Dry, Light brownish gray [10YR 6/2], SILTY SAND with Gravel, SM, non-plastic, Alluvium, with mica flakes, no reaction to HCl.					
		4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21			X	G14488, G14489, G14490, G14491		Dry, Light brownish gray [10YR 6/2], POORLY GRADED GRAVEL, GP, non-plastic, with frequent cobbles and boulders, particles not disturbed by drilling are rounded to subrounded, no reaction to HCl.					Slow drilling through boulders 9.5-11.5' Boulder 12.5-14.5' Boulder 16-18.0' Boulder Water level measured at 20.5' on 8-25-14

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PHONE NUMBER:	

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		22						Dry, Light brownish gray [10YR 6/2], POORLY GRADED GRAVEL, GP, non-plastic, with frequent cobbles and boulders, particles not disturbed by drilling are rounded to subrounded, no reaction to HCl. *(Continued)*					
		23				G14491							
		24											24-25' Boulder
		25											
		26											
		27						Wet, Light brownish gray [10YR 6/2], POORLY GRADED GRAVEL, GP, non-plastic, with frequent cobbles and boulders, particles not disturbed by drilling are rounded to subrounded, no reaction to HCl.					Groundwater at 27' while drilling
		28											
		29											29-31' Boulder
		30				G14492							
		31											
		32											
		33											
		34											
		35											
		36											
		37											
		38				G14493							
		39											
		40											39.5-41.5' Boulder
		41											
		42				G14494							
		43											
		44											

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					X	G14494							
		45			X			Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL, GP, non-plastic, with frequent cobbles and boulders, particles not disturbed by drilling are rounded to subrounded, no reaction to HCl.					
		46			X								
		47			X	G14495							
		48			X								
		49			X								
		50			X								
		51			X								
		52			X	G14496							
		53			X								
		54			X								
		55			X								
		56			X								
		57			X	G14497							
		58			X								
		59			X								
		60			X								
		61											
		62											
		63											
		64											
		65											
		66											
		67											

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		68						Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL, GP, non-plastic, with frequent cobbles and boulders, particles not disturbed by drilling are rounded to subrounded, no reaction to HCl. *(Continued)*					
		69											
		70											
		71											
		72											
						G14498							
		73											
		74											
		75											
		76											
		77											
						G14499							
		78											
		79											
		80											
		81											
		82											
						G14500							
		83											
		84											
		85											
		86											
		87											
		88											
		89											
		90											

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								Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL, GP, non-plastic, with frequent cobbles and boulders, particles not disturbed by drilling are rounded to subrounded, no reaction to HCl. *(Continued)*					
		91											
		92				G14501							
		93											
		94											
		95											
		96											
		97				G14502							
		98											
		99											
		100											
		101											101.5-103.5' Boulder
		102				G14503							
		103											
		104											
		105											Driller noted softer drilling at 105', no change in cuttings
		106											
		107				G14504							
		108											
		109											
		110											
		111						Dry, Gray [10YR 6/1], cuttings fine grained sand, Sandstone.					No cutting return
		112				G14505							
		113											

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								Dry, Gray [10YR 6/1], cuttings fine grained sand, Sandstone. *(Continued)*					
		114				G14505							
		115											Slow drilling
		116											
		117				G14506							
		118											
		119											Bottom of steel casing at 119'
		120											Start core drilling on 8-22-14
		121											Bentonite and drill cuttings from 119.7-122.2'. Observe marking from hammer on top of core
		122											
								Greenish gray [5GY 5/1], medium to fine grained Sandstone, hard, fresh.					
		123					100		100				One Mechanical break at 123.4'
		124											124.2' 16° Joint, Fresh
		125											
		126											
							98		90				
		127											127.3' 0° Joint, Moderately to slightly weathered
		128											127.7' 3° Joint, Fresh 128.4' 3° Joint, Fresh
		129						Greenish gray [5GY 5/1], medium grained Sandstone, hard, fresh, Bedding hard to distinguish.					
		130											129.8' 24° Joint
		131											
							100		98	13	5.6		
		132											
		133											132.5' 0° Mechanical break 132.6' 0° Mechanical break
		134						Greenish gray [5GY 5/1], medium grained Sandstone, moderately hard, fresh, coal strings at 137.5'.					
		135					100		60				134.5' 20° Joint, Fresh 134.6' 10° Shear, slightly weathered to fresh 135.2' 22° Shear/Joint, Fresh
		136											

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		137		X			100	Greenish gray [5GY 5/1], medium grained Sandstone, moderately hard, fresh, coal strings at 137.5'. *(Continued)*	60				136.0' 19° Shear/Joint, Fresh 136.5' 19° Shear/Joint, Fresh 137.3' 17° Shear/Joint 137.5-137.8' Intensely fractured
		138		X									
		139		X				Greenish gray [5GY 5/1], medium grained Sandstone, Bedding 26°, hard, fresh, carbonaceous stringers.					139.4' 10° Mechanical break
		140		X									140.5' 20° Bedding joint
		141		X			94		74				141.4' Mechanical break
		142		X									142.1 2° Mechanical break
		143		X				Brown [10YR 5/3], very fine grained claystone.					142.9' 19° Bedding joint
		144		X				Greenish gray [5GY 5/1], medium grained Sandstone, Bedding 25°, moderately hard, fresh.					143.5' 26° Bedding joint
		145		X									
		146		X									145.6' 16° Shear 145.8' 23° Shear
		147		X			100	Greenish gray [5GY 5/1], coarse grained Sandstone, with trace of pebbles, coal strings approx. 1" thick.	88				146.5' Mechanical break 146.9' 31° Shear
		148		X				Greenish gray [5GY 5/1], medium grained interbedded with coarse grained Sandstone.					
		149		X				Greenish gray [5GY 5/1], fine grained Sandstone, moderately hard, fresh, carbonaceous stringers, no reaction to HCl.					
		150		X									
		151		X									
		152		X			86	Greenish gray [5GY 5/1], coarse Sandstone with 3/4" pebbles. Greenish gray [5GY 5/1], Siltstone, interbedded carbonaceous layers, clay gouge at 17°, 152-152.3' Intensely fractured, 152.5-152.6' Intensely fractured, Shear, intensely weathered.	58				151.7' 27° Shear
		153		X									Lost water
		154		X									
		155		X				Greenish gray [5GY 5/1], fine grained Sandstone.					155' 80° Shear 155.4' 35° Bedding joint
		156		X									155.8' 17° Shear
		157		X			100		84				
		158		X									
		159		X									158.6' 0° Mechanical break

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		160						Light gray [N7], Bedding 22°, thinly laminated, fine grained Sandstone with dark gray Claystone, claystone is thin like strings. *(Continued)*					160.3' 22° Bedding joint
		161					98		92				
		162											
		163											
		164						Light gray [N7], fine grained Sandstone, Bedding 27°, thinly laminated with carbonaceous stringers, Very hard, fresh.					
		165											
		166					104		98				
		167											
		168											168.5' 27° Bedding joint
		169						Light gray [N7], fine grained Sandstone, thinly laminated with carbonaceous Claystone (paper thin) hard, fresh, flow structure cross bedding approx. 1" thick.					
		170											
		171					96	Very dark gray [N3], Claystone, Bedding 22°, flow structures, hard, fresh.	90				
		172											
		173											173.0' 7° Mechanical break 173.2' 7° Joint, Shear At 173.2', broken chips with some clay
		174						Gray [N5] Very dark gray [N3], Siltstone, Bedding 23°, thinly laminated with Claystone.					
		175											175' 33° Shear, slightly rough, slightly weathered 175.2' 33° Shear, slightly rough, slightly weathered
		176					86		86				176.3' 33° Shear, slightly rough, slightly weathered
		177											
		178											
		179						Gray [N5] Very dark gray [N3], Sandstone, Bedding 26°, thinly laminated with claystone, hard, fresh.					Extra core to previous run
		180					131		98				
		181											190.4' 9° Shear, Smooth, Fresh
		182											

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		183					131	Gray [N5] Very dark gray [N3], Sandstone, Bedding 26°, thinly laminated with claystone, hard, fresh. *(Continued)*	98				
		184, 185, 186, 187, 188					100	Gray [N5] Very dark gray [N3], fine grained Sandstone, Bedding 21°, thinly laminated with Claystone stringers and carbonaceous stringers.	100				
		189, 190, 191, 192, 193					100	Gray [N5] Very dark gray [N3], Siltstone, Bedding 23°, thinly laminated with fine grained Sandstone, hard, fresh.	81				189.1' 9° Bedding joint, smooth 192.6' 14° Joint, Fresh, rough 192.8' 21° Bedding Joint/Shear, Clay filling
		194, 195, 196, 197, 198					100	Gray [N5] Very dark gray [N3], Siltstone, Bedding 27°, thinly laminated with fine grained Sandstone, hard, fresh.	96				196.1 26° Bedding joint, slightly rough, Fresh 196.6' 10° Mechanical break
		199, 200, 201, 202, 203					98	Very dark gray [N3], Siltstone, Bedding 26°, thinly laminated with gray Siltstone, hard, fresh.	96				201.9' 42° Shear, Fresh, Smooth, clean
		204, 205					100	Dark gray [N4], Dark gray Siltstone, Bedding 23°, thinly laminated with Gray Siltstone, hard, fresh.	98	25	7.3		

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		206						Dark gray [N4], Dark gray Siltstone, Bedding 23°, thinly laminated with Gray Siltstone, hard, fresh. *(Continued)*					206.3' 23° Bedding joint, Fresh, smooth, clean
		207					100		98	25	7.3		
		208											
		209						Dark gray [N4], Siltstone, Bedding 23°, Very hard, fresh.					
		210											
		211					98		100	28	7.9		
		212											
		213											
		214						Dark gray [N4], Claystone/Siltstone, Bedding 25-27°, Very hard, fresh.					
		215											
		216					98		72				Fractures 216.8' 17° Joint, smooth
		217											217.3' 24° Bedding joint, smooth
		218											217.4' 24° Shear, moderately thick 218.0' 50° JR, moderately thin, slightly rough
		219											
		220											Fracture 219.6' 7° Mechanical break
		221					100	Dark gray [N4], Claystone/Siltstone, Bedding 25°, Very hard, fresh.	100				
		222											
		223											
		224						Dark gray [N4], Claystone/Siltstone, Bedding 26°, Very hard, fresh. Trace of tan mudstone from 227.5-229.0'.					
		225											
		226					98		100				Fracture 225.8' 26° Bedding joint
		227											
		228											

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				X			98	Dark gray [N4], Claystone/Siltstone, Bedding 26°, Very hard, fresh. Trace of tan mudstone from 227.5-229.0'. *(Continued)*	100				
		229		X				Dark gray [N4], Claystone/Siltstone, Bedding 25°, Very hard, fresh. Trace of carbonaceous material at end of core.					
		230		X									Fractures 230.5' 9° Joint, clean
		231		X			54		41				231.5' 9° Joint, clean
		232		X									
		233		X									233' Lost circulation
		234		X				Void, top of Bed No. 4 cave.					Hole open from 234-235'
		235		X				Black [10YR 2/1], SILTY GRAVEL, GM, Coal, trace pyrite, wash rock? Angular, non-layered, particles range from 1" diameter to silt, Bed No. 4.					Very easy drilling from 235-239.6', advanced in 8 seconds, then at 239.6' got solid
		236		X									
		237		X			74						
		238		X									Mined up dip, let water drain down, and coal drain
		239		X									
				X				Wood Timber.					
		240		X				Black [10YR 2/1], SILTY GRAVEL, GM, Coal, wasterock, particles to 1.5" diameter, angular, Bed No. 4.					Very soft drilling, hit something then drops
				X				Wood Timber.					
		241		X				Black [N2], Coa, Bed No. 4.					
		242		X			80	Fat clay, CH.					At 241.5', possible insitu Floor
		243		X				Siltstone.					
		244		X				Gray [N6], fine grained sandstone.					
		245		X				Gray [5YR 5/1], Claystone, Bedding 22-26°, soft, fresh.					Fractures 244.7' 26° Bedding joint, soft
		246		X									245.6' 26° Bedding joint, soft
				X			65		30				
		247		X				Gray [5YR 5/1], fine grained sandstone.					247.3' 24° Bedding joint, soft to hard
		248		X									
		249		X									
				X			20						
		250		X				Gray [5YR 5/1], Claystone with carbonaceous stringers, Bedding 19°, moderately soft, fresh.					Start HQ core at 250'
				X			110						
		251		X									

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		252						Gray [5YR 5/1], Claystone with carbonaceous stringers, Bedding 19°, moderately soft, fresh. *(Continued)*					
		253					110						Mechanical break, material is too plastic, observed fractures are mechanical break on bedding 252.5' 65° slightly open, clean, very closely spaced Fractures 242-257.5' 65° slightly open, clean, very closely spaced Fractures are stepping
		254						Black [N2], Coal, Bedding 24°, Laminated, moderately hard, fresh, Bed No. 4 1/2.					
		255						Black [N2], Coal , Bedding 24°, traces of pyrite on bedding planes, fine grained nodules of 5Y 6/8 Resinite, Bed No. 4.					
		256					100		58				
		257											Strike of fractures are near parallel in bedding strike, but dip in opposite direction
		258						Claystone.					
		259						Gray [N6], fine grained Sandstone interbedded with Very dark gray [N3] Claystone, Bedding 26°, Laminated to very thinly bedded, Sandstone is hard, fresh, Claystone is hard, fresh, no reaction to HCl.					
		260											
		261					100		76	15	5.8		Fractures 260.6-263.1' 90° very closely spaced, slightly open to moderately open, very thin, moderately healed, calcite filled, strong reaction to HCl, nearly perpendicular to bedding strike
		262											
		263											
		264						Gray [N6], fine grained Sandstone interbedded with very dark gray [N3] Claystone, Bedding 24°, Laminated to very thinly bedded, hard, fresh, flow structures in some of bedding.					Fractures 264.1' 75° moderately open, very thin, moderately healed, calcite filling, strong reaction to HCl 265.4' 18° Bedding joint
		265											
		266					100	Gray [N6], Claystone, moderately soft, fresh.	50				
		267						Gray [N6], fine grained Sandstone interbedded with Very dark gray [N3] claystone laminated to very thinly bedded, hard, fresh.					
		268											
								Light brownish gray [10YR 6/2], Sandstone to light gray 10YR 7/1 fine grained Sandstone, Bedding 24°, hard, fresh.					268.3' 36° Bedding joint, Random fracture
		269						Very dark gray [N3], Siltstone, Bedding 22°, thinly laminated with Claystone, hard, fresh.					Remaining fractures are mechanical breaks, bedding planes break with easy manual pressure Fractures 269.6' 22° Bedding joint 270.5' 22° Bedding joint
		270											
		271						Very dark gray [N3], Fat Clay/Claystone, Very soft.					
								Very dark gray [N3], Claystone, moderately hard, fresh.	54	12	5.5		
		272						Siltstone.					
		273											273' 15° Random fracture
		274											

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							100	Gray [N5], fine grained Sandstone, thinly laminated with gray [N6] Claystone, Bedding 26°, moderately soft, fresh. *(Continued)*	94	14	5.7		
		275											
		276											Mechanical break from Schmidt hammer, break along bedding
							100		94	14	5.7		275.1' 7° Random fracture 276.9' 24° Bedding joint
		277											
		278											
		279						Very dark gray [N3], Claystone, Bedding 21°, moderately soft, fresh, trace of coal feathers.					Fractures 279.5' 0° Random fracture, Coal feather
		280											
		281											280.6' 7° Random fracture
							100			28	8.0		281.2' 21° Bedding joint 281.7' 22° Bedding joint
		282											
		283											283.2' 17° Shear, very intensely to intensely fractured, thin, rough
		284						Very dark gray [N3], Claystone, Bedding 26°, thinly to moderately laminated with fine grained gray [N5] Sandstone, moderately soft Claystone, hard Siltstone, fresh.					
		285											Fractures 284.7' 0° Random fracture
		286											285.7' 25° Bedding joint
							100		90	26	7.5		286.7' 25° Bedding joint
		287											
		288											
		289						Gray [N5], fine grained Sandstone, Bedding 27°, moderately laminated with Very dark gray [N3] Claystone, hard, fresh.					288.7' Random fracture
		290											Fractures 289.5' 25° Bedding joint 290.4' 0° Mechanical break
		291											
							96		82	34	9.1		
		292											292' 25° Bedding joint
		293											292.8' 29° Bedding joint
		294						Gray [N5], fine grained Sandstone, Bedding 24°, thinly to very thinly laminated with Very dark gray [N3] Siltstone. Thin coal seam at 298.8-299'. Variable Bedding, flow structures.					
		295											Fractures 294.4' 26° Bedding joint 294.3' 36° Bedding joint
							100		74				
		296											
		297											

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		298					100	Gray [N5], fine grained Sandstone, Bedding 24°, thinly to very thinly laminated with Very dark gray [N3] Siltstone. Thin coal seam at 298.8-299'. Variable Bedding, flow structures. *(Continued)*	74				297.7' Random Fracture 297.8' 16° Shear
		299						Black [N2], Coal.					
		300						Gray [N5], fine grained Sandstone, Bedding 27°, very thinly laminated with Very dark gray [N3] Siltstone, variable Bedding from flow structures, hard, fresh.					Fractures 299.8' 26° Bedding joint
		301					100		64	22	6.8		
		302											Mechanical break from 301.5-304'
		303											
		304						Gray [N6], fine grained Sandstone, Bedding 29°, very thinly laminated with Very dark gray [N3] Siltstone.					
		305											Fractures 304.7' 35° Bedding joint
		306					106		84				305.6' 60° Shear, Totally healed, tight, very thin, moderately spaced up dip side displaced 1/8"
		307											
		308											307.7' 37° Bedding joint 308.5' Random fracture
		309						Gray [N6], fine grained Sandstone, Bedding 27°, very thinly laminated with Very dark gray [N3] Siltstone, hard, fresh.					308.6' 60° Shear, totally healed, tight, very thin, moderately spaced Shears are perpendicular to breaks Fractures
		310											
		311					80		100	28	7.8		309.9' 85° Shear, totally healed, tight, very thin, disp downbed dip 311.2' 36° Shear, totally healed, tight, very thin, very closely spaced
		312											
		313											312.4' 75° Shear, totally healed, tight, very thin 312.4' 35° Shear, totally healed, tight, very thin, very closely spaced
		314						Gray [N6] Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 27°, very thinly laminated with Claystone, hard, fresh.					
		315											
		316					104		92				Fractures 316.8' 27° Bedding joint
		317											
		318											317.5' 40° Shear, totally healed, tight, very thin, moderately spaced, 30° displaced in up dip direction approx 1"
		319						Gray [N6] Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 27°, thinly laminated, hard, fresh.					
		320					96		88	25	7.4		319.6' Fractures 25° Shear, tight, moderately spaced

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		321						Gray [N6] Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 27°, thinly laminated, hard, fresh. *(Continued)*					
		322					96		88	25	7.4		
		323											
		324						Gray [N6] Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 27°, thinly laminated.					
		325											Fractures 324-328.5' 35° Shear, tight, very thin, moderately spaced 325.5' 85° Shear, tight, very thin, offset 1/4"
		326											
							104		100				
		327											
		328											
		329						Greenish gray [5GY 5/1], Sandstone, Bedding 35°, very thinly laminated with [N4] Siltstone, hard, fresh.					
		330											
		331											
							96		100				
		332											
		333											
		334						Greenish gray [5GY 5/1], Sandstone, Bedding 34°, thinly laminated with dark gray [N4] Siltstone.					Fractures 333.7' Shear, tight, very thin 333.75' Shear, tight, very thin
		335											
		336											
							104		78				
		337											
		338											Fractures 338.4' 36° Shear
		339						Greenish gray [5GY 5/1], Sandstone, Bedding 28°, hard, fresh, no reaction to HCl.					
		340											Fracture 340' 40° Shear, tight, very thin
		341					98			21	6.8		
		342											
		343											

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							98	Greenish gray [5GY 5/1], Sandstone, Bedding 28°, hard, fresh, no reaction to HCl. *(Continued)*		21	6.8		
		344						Greenish gray [5GY 5/1], Sandstone, Bedding 34°, variable flow structures, trace of very thin laminations of very dark gray [N3] Siltstone, hard, fresh, no reaction to HCl.					
		345											Fractures 345' 36° Shear, tight, very thin
		346											
							100		74	31	8.3		
		347											
		348											
		349						Greenish gray [5GY 5/1], Sandstone, Bedding 39°, variable flow structures, trace of very thin laminations of very dark gay [N3] Siltstone, hard, fresh, no reaction to HCl.					
		350											All breaks Mechanical
		351											
							96		62				
		352											
		353											
		354						Greenish gray [5GY 5/1], Sandstone, Bedding 28°, variable flow structures, hard, fresh, no reaction to HCl.				
		355											
		356											
							100						
		357											Fractures 357.3' 27° Bedding joint 357.4' 50° Shear, tight, moderately thin
		358											
		359						Greenish gray [5GY 5/1], Sandstone, Bedding, variable flow structures, no reaction to HCl, hard, fresh.					
		360											
		361											
							96		100				
		362											
		363											
		364						Greenish gray [5GY 5/1], Sandstone, Bedding, variable flow structures, no reaction to HCl, hard, fresh.					
		365					102			16	6.0		Fractures 364.5' 0° Random fracture
		366											365.8' Mechanical break

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		367		X			102	Greenish gray [5GY 5/1], Sandstone, Bedding, variable flow structures, no reaction to HCl, hard, fresh. *(Continued)*		16	6.0		
		368		X									
		369		X				Greenish gray [5GY 5/1], Sandstone, Bedding, variable flow structures, no reaction to HCl, hard, fresh.					
		370		X									
		371		X			78		62				Lost circulation, possible void
		372		X									All breaks 0° Mechanical break
		373		X									
		374		X				Greenish gray [5GY 5/1], Sandstone, hard, fresh, no reaction to HCl.					
		375		X									no return, slow drilling Drilled 10'
		376		X			44		60				Driller states bumping down, no obvious voids, but broken up feeling
		377		X									
		378		X									
		379		X				Greenish gray [5GY 5/1], Sandstone with very thinly laminated Black [N2] carbonaceous stringers, evidence of core pieces moving while drilling.					Fractures 25° Joint 15° Joint 50° Joint
		380		X									
		381		X									Driller states like drilling through slabs
		382		X									
		383		X									
		384		X				Dark greenish gray [5GY 4/1], Sandstone, variable Bedding, very thinly laminated with carbonaceous stringers, hard, fresh.					
		385		X									Fractures 384.5' 42° Bedding joint 385' 65° Bedding joint 386' 50° Bedding joint 386.3' 46° Bedding joint
		386		X			52		23	22	6.9		
		387		X				Very dark grayish brown [2.5Y 3/2], CLAYEY GRAVEL, GC, Gravels are Very soft, gravels are pieces of claystone, some coal strings in Claystone, clays are high plasticity.					
		388		X									Some movement of core pieces during drilling, gaps between rock fractures
		389		X									

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		390					28	Very dark grayish brown [2.5Y 3/2], CLAYEY GRAVEL, GC, Gravels are Very soft, gravels are pieces of claystone, some coal strings in Claystone, clays are high plasticity. *(Continued)*					
		391											Water pressure, no torque or down pressure, clayey
		392					28	Very dark gray [2.5Y 3/1], Claystone, Soft, strength greater than pocket pen.					Too broken up for fracture measurements, intensely to moderately fractured
		393											
		394						Black [N2], Coal.					
								Very dark gray [2.5Y 3/1], Claystone, Bedding 16°, Soft.					
		395											
		396					70		17				Fractures 396-399' 80° extremely closely spaced, partly healed, clean, slightly open
		397						Black [2.5Y 2.5/1], Coal, hard, fresh, but very brittle on cleat faces.					
		398											
		399											
		400						Black [2.5Y 2.5/1], POORLY GRADED GRAVEL, GP, angular gravel, gravels are coal, particles are 1/2" to 2.5" diameter, would classify as GP.					
		401					44		0				
		402											
		403						Dark greenish gray [5GY 4/1], Claystone, Soft, Claystone is decomposed to very stiff fat clay, strength is greater than the pocket pen.					
		404						Dark gray [N4], Sandstone, Bedding 24°, Shale and sandstone is moderately laminated, hard, fresh, interbedded with Shale, Soft.					
		405											Fractures 404.5' 30° Shear, very thin, tight 405' 24° Random fracture 405.5' 23° Bedding joint
		406						Claystone.					
		407					100		54				
								Dark gray [N4], Sandstone, Bedding 24°, moderately laminated with Shale soft to very soft, hard, fresh.					
		408											
		409											408.5' 26° Bedding joint
		410						Claystone.					
		411					100	Dark gray [N4] Gray [N5], Sandstone, Bedding 24°, hard, fresh, 2" Claystone layer at 418.5'.	48				Fractures 411.2' 24° Bedding joint 411.6' 0° Joint
		412											

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		413		X			100	Dark gray [N4] Gray [N5], Sandstone, Bedding 24°, hard, fresh, 2" Claystone layer at 418.5'. *(Continued)*	48				412.5' Joint 413.5' Joint
		414		X									
		415		X									Fractures 415' 23° Bedding joint
		416		X									415.7' 15° Bedding joint 415.9' 15° Bedding joint 416.2' 24° Bedding joint
				X			104		77				
		417		X									416.7' 70° very thin, tight, moderately healed, calcite filled
		418		X									417.3' 70° Shear, very thin, slightly open, calcite filled, moderately healed 417.4' 70° Shear, very thin, slightly open, calcite filled, moderately healed, closely spaced
		419		X				Greenish gray [5GY 5/1], Sandstone, Bedding 26°, thinly laminated with Claystone, hard, fresh.					418.4' 24° Bedding joint
		420		X									
		421		X			94		82				
		422		X									
		423		X									
		424		X				Gray [N5], Sandstone, variable Bedding flow structures, moderately laminated with Greenish Gray (5GY 4/1) Sandstone and Dark gray [N4] Claystone, hard, fresh.					
		425		X									Fractures 424.5' 75° Shear, clean, tight, moderately healed 425' 0-5° Mechanical break
		426		X									426.2' 17° Bedding joint 426.2' Coal feathers 426.6' 22° Bedding joint 426.7' 25° Bedding joint 427.1' Intensely to moderately fractured
				X			100		68				
		427		X				Claystone.					
		428		X				Dark gray [N4], Claystone, Bedding 19°, 9° variable, but getting shallower, thinly laminated with Gray [N6] fine grained Sandstone, moderately hard, fresh, trace coal feathers.					
		429		X									
		430		X									Fractures 430.2' 9° Bedding joint
		431		X									
				X			92		87				431.6' 17° Bedding joint 431.7' 17° Bedding joint
		432		X									432.5' 15° Bedding joint
		433		X									
		434		X									
				X			115	Black [N2], Claystone, very thinly laminated, moderately soft.	22				
		435		X									

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							115	Black [N2], Claystone, very thinly laminated, moderately soft. *(Continued)*	22				435.3' 26° Shear, very thin, tight, moderately healed
		436						Black [N2], Coal, hard, blocky.					
		437						Gray [N5], fine grained Sandstone, Bedding 17°.					
		438					104	Black [N2], Claystone, moderately soft.	60				
		439											
		440						Gray [N5], fine grained Sandstone.					
		441											Fractures 441' 7° Bedding joint
		442											442' 14° Bedding joint 442.3' 14° Bedding joint
							100	Dark gray [N4], Claystone, Bedding 16°, thinly laminated with Gray [N5] fine grained Sandstone, Claystone moderately soft, Sandstone moderately hard.	77				
		443											
		444											443.7' 15° Bedding joint
		445											
		446											Fractures
							96	Black [N2], Claystone, Bedding 22°, laminated, soft, fresh, coal particles approx. 1/6" to 1/8" in thickness.	69				446.4' 16° Bedding joint
		447											
		448						Black [N2], Coal, blocky.					
		449											
		450						Dark greenish gray [5GY 4/1], Claystone, Bedding 17°, moderately soft, moderately laminated with Greenish gray [5GY 5/1] fine grained Sandstone, very hard, fresh, Gray [N6] Shale, moderately hard, moderately laminated, trace coal feathers, trace thin coal feathers approx. 1/8" thick.					
		451											Fractures 450.3' 12° Joint 453.4' 20° Bedding joint
							92		68				
		452											
		453											
		454						Gray [N6], Claystone, Bedding 17-22°, moderately soft, Very dark gray [N3] fine grained Sandstone, Very hard, fresh, Gray [N6] Shale, moderately hard, moderately laminated, trace coal, feathers approx 1/8".					
		455											
		456					104	Sandstone.	92				Fractures 455.7' 17° Bedding joint
								Claystone.					456.7' 17° Bedding joint 456.9' 19° Bedding joint
		457						Sandstone.					457.5' 24° Bedding joint
		458											

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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
				X			104	.	92				458.2' 13° Bedding joint
		459											Total Depth= 459'
		460											
		461											
		462											
		463											
		464											
		465											
		466											
		467											
		468											
		469											
		470											
		471											
		472											
		473											
		474											
		475											
		476											
		477											
		478											
		479											
		480											
		481											

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CLIENT: Montana Department of Environmental Quality

ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-02

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/15/14 - 10/23/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5578.70 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 340899.017, E. 2033282.338	HAMMER TYPE: None

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		1, 2, 3, 4, 5, 6, 7			X	G14507, G14508		Damp, Brown [10YR 5/3], WELL GRADED SAND with Gravel, SW, non-plastic, Alluvium, medium to coarse grain, no reaction to HCl.					
		8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21			X	G14509, G14510, G14511		Moist to wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent cobbles and boulders, intact gravels are subrounded, no reaction to HCl.					11.5-12.5' Boulder Depth to water = 13.5' checked on 10/21/14

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Drill Hole No. BH-02

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								Moist to wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent cobbles and boulders, intact gravels are subrounded, no reaction to HCl. *(Continued)*					
		22											22-23.0' Boulder
		23				G14511							
		24											
		25											24.5' Water in cuttings
		26											
		27											
						G14512							
		28											28' Wet
		29											
		30											30' Cuttings stuck in casing
		31											
		32											32-34' Boulder
						G14513							
		33											
		34											
		35											
		36											
		37											
						G14514							
		38											
		39											
		40											
		41											
		42				G14515							
		43											
		44											

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					X	G14515		Moist to wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent cobbles and boulders, intact gravels are subrounded, no reaction to HCl. *(Continued)*					
		45			X								45' Frequent boulders
		46			X								
		47			X	G14516							
		48			X								
		49			X								
		50			X								
		51			X								
		52			X	G14517							
		53			X								
		54			X								
		55			X								
		56			X								
		57			X								57-58' Boulder
					X	G14518							
		58			X								
		59			X								
		60			X								
		61			X								
		62			X								
					X	G14519							
		63			X								
		64			X								
		65			X								
		66			X	G14520							
		67											

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								Moist to wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent cobbles and boulders, intact gravels are subrounded, no reaction to HCl. *(Continued)*					
		68				G14520							
		69											
		70											
		71											
		72				G14521							72-74' Boulder
		73											
		74											
		75											75' Drillers empty cuttings from casing
		76											
		77				G14522							
		78											
		79											
		80											
		81											81-83' Boulder
		82				G14523							
		83											
		84											
		85											
		86											
		87				G14524							
		88											88-90' Boulder
		89											
		90											

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								Moist to wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent cobbles and boulders, intact gravels are subrounded, no reaction to HCl. *(Continued)*					
		91											
		92											91.5-93' Boulder
						G14525							
		93											
		94											
		95											
		96											
		97											
						G14526							
		98											
		99											
		100											
		101				G14527							
		102											
		103											
						G14528							
		104											
		105						Sandstone.					
		106											
		107											
		108											107.5' Started PQ
		109											
		110											
		111						Olive gray [5Y 5/2], fine grained Sandstone, hard, slightly weathered to fresh.					
		112											112' Fracture 27° Joint, hard, moderately to slightly weathered, weather 1" into
		113		X			556		53				

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							556	Olive gray [5Y 5/2], fine grained Sandstone, hard, slightly weathered to fresh. *(Continued)*	53				fracture face
		114						Olive gray [5Y 5/2], fine grained Sandstone, Bedding 21°, hard, slightly weathered to fresh.					Fractures 114.5' 10° Joint, hard, moderately to slightly weathered
		115											115.5' 80° Joint, partly healed, slightly open, very thin
		116					108		83				116.5' 0° Joint, pyrite 116.7' 12° Joint, hard
		117											
		118											118' 48° Shear, thin, moderately to slightly weathered
		119						Olive gray [5Y 5/2], fine grained Sandstone, Bedding 16°, hard, slightly weathered to fresh.					
		120											Fractures 119.7' 20° Joint, hard
		121					100		86				120.5' 15° Joint, hard, moderately to slightly weathered
		122											120.5' 47° Shear, hard, moderately to slightly weathered
		123											122.4' 32° Shear, soft, very thin
		124						Olive gray [5Y 5/2], fine grained Sandstone, Bedding 17°, slightly weathered to fresh, No 3 bed.					
		125											
		126							96				126.3' 15° Shear, thin, moderately soft
		127											127.4' 20° Joint, very thin, moderately hard
		128											
		129						Olive gray [5Y 5/2], fine grained Sandstone thinly laminated with Carbonaceous strings, hard, Slightly weathered to fresh.					
		130											Fractures 129.9' 25° Thin, moderately hard, moderately to slightly weathered
		131					88		66				130.2' 27° Thin, moderately hard, moderately to slightly weathered
		132											131.5' 75° Shear, thin, moderately soft, displacement downstrike
		133											131.8' 13° Joint, clean, hard, fresh
		134						Olive gray [5Y 5/2], fine grained Sandstone, Bedding 21°, thinly laminated with Carbonaceous strings, hard, slightly weathered to fresh.					132.4' 80° Shear, moderately thin, moderately soft, displacement downstrike
		135					100		90				Driller states rod very tight. Rock is pinching. Drilled 90% torque to 134', decide
		136											

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		137					100	Olive gray [5Y 5/2], fine grained Sandstone, Bedding 21°, thinly laminated with Carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*	90				to reduce to HQ at 134' Fractures 134.5' 24° Shear, moderately thin, moderately hard, moderately to slightly weathered 135.5' 22° Joint/Bedding Joint, very thin, hard, slightly weathered to fresh
		138											
		139						Olive gray [5Y 5/2], fine grained Sandstone, thinly laminated w/ Olive gray (5Y 4/2) Siltstone, hard, slightly weathered to fresh, and Carbonaceous strings.					138.8' 20° Bedding joint/Shear, very thin, moderately soft, slightly weathered to fresh
		140											
		141											Fractures 141.1' 20° Shear, thin, moderately soft
		142											
		143											
		144					102		97				
		145											
		146											
		147											146.5' 21° Shear, moderately thin, moderately soft
		148											
		149						Olive gray [5Y 5/2], Claystone, Bedding 22°, Moderately laminated with fine grained Sandstone, hard, slightly weathered to fresh.					Fractures 149.7' 14° Joint, hard, slightly weathered to fresh
		150											
		151											
		152											
		153											
		154					102		98				
		155											
		156											
		157											
		158											
		159											158.9' 24° Bedding

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		160						Olive gray [5Y 5/2], Claystone, moderately laminated with fine grained sandstone, hard, slightly weathered to fresh. *(Continued)*					joint/Shear, very thin, moderately hard Fractures 160.2' 28° Joint, clean, hard, slightly weathered to fresh
		161											161.4' 25° Shear, moderately thin, moderately hard, slightly weathered to fresh
		162											161.9' 27° Joint, clean, hard, slightly weathered to fresh 162.7' 10° Joint, clean, hard, slightly weathered to fresh
		163											
		164					100						
		165											
		166											
		167											167' 80° Shear, moderately thin, soft
		168											
		169						Gray [N5], Claystone, Bedding 21°, hard, slightly weathered to fresh, 50% of fractures filled with pyrite.					
		170											Fractures 170.4' 80° Joint, clean, hard 170.5' 42° Joint, clean, hard
		171											171.4' 20° Shear, very thin, moderately soft 171.8' 30° Shear, very thin, moderately soft
		172											172.4' 75° Shear/Joint, moderately thin, soft 172.5' 40° Shear, moderately thin, soft
		173						Black [N2], Coal, very hard, slightly weathered to fresh, Bed No. 4.					
		174					100		26				172.7' 40° Shear, moderately thick, approx 1", gravel and clay 173-173.7' Intensely fractured 173.6' Shear 10° 2" thick, sand to clay size coal ground up 173.7'-177.0' 21° Bedding joint, closely spaced 174-179' 80° Joint
		175											
		176											
		177											
		178											178-179' 85-90° Joint
		179						Black [N2], Coal, very hard, slightly weathered to fresh, Bed No. 4.					
		180											Fractures 179.9' 11° Bedding joint 180.4' 15° Bedding joint
		181					105		67				
		182											

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		183						Black [N2], Coal, very hard, slightly weathered to fresh, Bed No. 4. *(Continued)*					181.9' 15° Bedding joint 183.1' 10° Bedding joint 183.6' 19° Shear, moderately thin, moderately soft
		184											184.1' 20° Bedding joint, very thin, hard
		185					105	Dark gray [5Y 4/1], Claystone, hard, slightly weathered to fresh, trace Carbonaceous feathers.	67				
		186											185.9' 16° Shear, very thin, moderately hard 186.6' 26° Shear, moderately thick, moderately soft
		187											186.9' 48° Shear, moderately thin, moderately soft
		188											187.2' 0° Joint, moderately thin, moderately soft
		189						Black [5Y 2.5/1], Claystone, Bedding 19°, hard ,slightly weathered to fresh.					188.2' 40° Shear, moderately thick, 1.5" thick, moderately soft 188.6' 15° Joint, very thin, moderately soft Fractures 189.7' 15° Shear/bedding joint, very thin, moderately hard 189.9' 15° Shear/bedding joint, very thin, moderately hard
		190											190' 15° Shear/bedding joint, very thin, moderately hard
		191											
		192											
		193											
		194					100						191.2' 18° Bedding joint, clean
		195						Black [N2], Coal, Bed No. 4 1/2.					192.4' 25° Shear, moderately thick, 1" thick, moderately soft 194' 15° Bedding joint, clean, moderately soft 194.5' 15° Shear, moderately thick, moderately soft
		196											
		197											195.4' 15° Bedding joint, clean 196.3' 35° Joint, clean 197.2' 17° Shear, thin, moderately soft
		198											197.6' 15° Bedding joint, very thin 198.3' 15° Bedding joint, very thin Fractures
		199											
		200						Very dark gray [5Y 3/1], Claystone, soft.					199.7' 21° Shear/Bedding joint 200' 20° Shear/Bedding joint
		201						Very dark gray [5Y 3/1], Siltstone, Bedding 21°, thinly laminated, Gray (5Y 5/1) Siltstone, hard, slightly weathered to fresh.					200.2' 20° Shear/Bedding joint
		202					100		55				200.6' 21° Shear/Bedding joint 201' 0° Shear/Bedding joint 202' 14° Shear, thin, moderately soft
		203											202.7' 7° Joint
		204											
		205											

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Drill Hole No. BH-02

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		206						Very dark gray [5Y 3/1], Siltstone, Bedding 21°, thinly laminated, Gray (5Y 5/1) Siltstone, hard, slightly weathered to fresh. *(Continued)*					205.4' 20° Joint 205.6' 85° Joint, very closely spaced 206' 20° Bedding joint 206.7' 26° Shear, thin, soft
		207					100		55				
		208											
		209						Very dark gray [5Y 3/1], Claystone.					
		210											Fractures 210' 12° Shear, moderately soft, 0.15" thick, clay gouge 211.1' 15° Shear, thin, soft, clay gouge
		211											
		212						Very dark gray [5Y 3/1], Siltstone, hard, slightly weathered to fresh.					212.1' 15° Shear, moderately thin, soft
		213											213' 20° Shear, moderately thin, soft
		214					103		75				213.8' 15° Shear, moderately thick, 0.15" thick, moderately soft
		215											
		216											216' 22° Shear, moderately thick, 0.2" thick, moderately soft
		217											216.7' 15° Shear, moderately thin, moderately soft
		218						Very dark gray [5Y 3/1], Claystone, Bedding 15°, Moderately hard, slightly weathered.					218' 16° Joint/Shear, very thin, moderately hard
		219											
		220											Fractures 219.8' 12° Bedding joint/Shear, moderately soft 220.3' 35° Shear, thin, moderately soft
		221											221.6' 14° Bedding joint
		222											222.3' 21° Shear, moderately thin, soft
		223											222.5' 40° Shear, thin, soft
		224					101		91				223.9' 32° Joint, clean, moderately hard 224.1' 33° Shear, thin, soft
		225											225.5' 25° Shear, moderately thick, 0.1" thick
		226											226.3' 25° Joint/Bedding joint, very thin, soft 226.9' 23° Shear, moderately thin, moderately soft
		227											
		228											

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	229					101	Very dark gray [5Y 3/1], Claystone, Bedding 15°, Moderately hard, slightly weathered. *(Continued)*	91				228.6' 23° Shear/Bedding joint Driller changed bit, hole squeezed in at 169', upon re-entering can feel rock has shifted
	230											
	231						Very dark gray [5Y 3/1], Siltstone, thinly laminated with Claystone and Carbonaceous strings, hard, slightly weathered to fresh, moderately laminated with fine grained Sandstone, hard, slightly weathered to fresh.					
	232											Fractures 230.4-231.7' 25° Shear, thin, very closely spaced, moderately soft
	233											
	234					100		73				233.9' 10° Shear, moderately thick, soft
	235											
	236											235.4' 32° Bedding joint, clean
	237											
	238											237.9' 20° Bedding joint, very thin, moderately soft
	239						Very dark gray [5Y 3/1], Siltstone, Bedding 20-30°, thinly laminated with Black (5Y 2.5/1) Siltstone, thinly laminated with Carbonaceous strings, hard, slightly weathered to fresh.					
	240											
	241											Fractures 240.9' 20° Bedding joint
	242											
	243											243.3' 15° Bedding joint
	244					100		95				
	245											
	246											246.6' 17° Bedding joint
	247											
	248						Gray [5Y 5/1], fine grained Sandstone, Bedding variable, thinly laminated with Black (5Y 2.5/1) Siltstone and Claystone.					
	249											
	250					100		83				Fractures 249.4' 29° Bedding joint, very thin, moderately soft
	251											

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Drill Hole No. BH-02

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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
		252						Gray [5Y 5/1], fine grained Sandstone, Bedding variable, thinly laminated with Black (5Y 2.5/1) Siltstone and Claystone. *(Continued)*					251.4' 20° Shear/bedding joint, thin, soft
		253											253.2' 12° Shear, thick, 0.2" thick
		254											254.2' 36° Bedding joint, very thin, moderately soft
		255					100		83				
		256											256.4' 50° Bedding joint, very thin, moderately soft
		257											
		258											
		259						Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with very dark gray (5Y 3/1) Siltstone, 95% hard, slightly weathered to fresh, 5% Moderately soft, slightly weathered.					
		260											Fractures
		261											260.7' 25° Bedding joint, clean
		262											261.6-261.9' Intensely fractured
		263											262.7' 46° Shear, moderately thin, moderately healed
		264					105		64				
		265											265.3' 15° Bedding joint
													265.5' 35° Bedding joint
		266											265.5-267.5' 85° Joint, not healed, hard
		267											
		268											267.5-268.3' Intensely fractured, very closely spaced, moderately soft
		269						Gray [5Y 5/1], fine grained Sandstone, thinly laminated with Carbonaceous strings, hard, slightly weathered to fresh.					268.5-269' 85° Joint, is 25% healed, moderately hard, intensely fractured, zones are low cohesion fine grained Sandstone Fractures
		270											269.7-270.7' Intensely fractured, moderately soft
		271					102		62				269.7' Shear 60° moderately soft
		272											271.6' 64° Shear, moderately thin, soft
		273											272.3' 63° Shear, moderately thin, moderately healed
		274											

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		275						Gray [5Y 5/1], fine grained Sandstone, thinly laminated with Carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*					275.8' 0° Mechanical break
		276					102		62				
		277											277.2' 85° Joint, not healed, moderately soft, very thin
		278											
		279						Gray [5Y 5/1], fine grained Sandstone, Bedding variable, very hard to hard, thinly laminated with Carbonaceaous strings.					Fractures 279-279.5' 85° Joint
		280											
		281											
		282											
		283											
		284					104		75				284.5' 0-10° Joint, moderately soft
		285											
		286											286' 15° Bedding joint, moderately hard 286.4' 15° Bedding joint, moderately soft 286.9' 58° Shear, very thin, partly healed
		287											287.3' 59° Shear, very thin, partly healed
		288											288' 85° Shear/Joint, moderately thin, moderately healed
		289						Gray [5Y 5/1], fine grained Sandstone, thinly laminated with Carbonaceous strings and Black (5Y 2.5/1) Siltstone, 90% hard, slightly weathered to fresh, 10% moderately soft, slightly weathered, between 290.2' and 292.0'.					289.5' 65° Joint/Shear 290-292' 0° Joint, closely spaced
		290											
		291											
		292											
		293					98		74				
		294											294.2' 25° Bedding joint, clean, hard
		295											
		296											295.5' 16° Bedding joint/Shear, moderately thin, moderately hard
		297											

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								Black [N2], Coal, Bedding 15°, very hard, slightly weathered to fresh, Bed No. 5. *(Continued)*					320' 15° Bedding joint
		321											320.8' 15° Bedding joint, thin
													321.5' 15° Bedding joint
		322											321.9' 15° Bedding joint
		323											322.7' 20° Bedding joint
		324											324' 17° Bedding joint/Shear, moderately thick
							98		73				
		325											
													325.4' 15° Bedding joint/Shear, thin
		326											326.2' 10° Bedding joint/Shear, moderately thin
		327											327' 12° Bedding joint/Shear, moderately thin
		328											
		329											
		330											Fractures 329-330.6' 15° Bedding joint, closely spaced
		331											
													331.4' 15° Bedding joint
		332											331.8' 15° Bedding joint
													332.4' 18° Bedding joint
		333											332.7' 15° Bedding joint 333-333.2' Intensely fractured, cleats
		334					101		69				333.4' 0° Bedding joint
		335											335' 10° Bedding joint
													335.7' 15° Bedding joint
		336						Dark gray [5Y 4/1], Siltstone, hard, slightly weathered to fresh.					
													336.5' Bed no. 5
		337						Dark gray [5Y 4/1], fine grained Sandstone, hard, slightly weathered to fresh, Siltstone and fine grained Sandstone are complete with out cracks.					
		338											
		339											
		340						Dark gray [5Y 4/1], fine grained Sandstone, moderately laminated with Siltstone and very dark gray (5Y 3/1) Claystone, hard, slightly weathered to fresh.					Fractures
		341					102		90				340.8' 17° Bedding joint 341.3' 17° Bedding joint/Shear
		342											
		343											

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Drill Hole No. BH-02

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		344						Dark gray [5Y 4/1], fine grained Sandstone, moderately laminated with Siltstone and very dark gray (5Y 3/1) Claystone, hard, slightly weathered to fresh. *(Continued)*					
		345											
		346					102		90				345.9' 14° Bedding joint
		347											
		348											
		349						Dark gray [5Y 4/1], fine grained Sandstone, moderately laminated with very dark gray (5Y 3/1) Siltstone, Hard, slightly weathered to fresh.					
		350											
		351											
		352											
		353											
		354					100		100				
		355											
		356											
		357											
		358						Gray [5Y 5/1], fine grained Sandstone, moderately soft, massive, very low cohesion, almost soil-like.					
		359											
		360											359-363.5' Mechanical breaks, very soft, Sandstone material eroded by drilling fluid, can break with hand pressure
		361											
		362											
		363					100		50				
		364						Gray [5Y 5/1], fine grained Sandstone, very hard, fresh, massive.					
		365											
		366											

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		298					98	Gray [5Y 5/1], fine grained Sandstone, thinly laminated with Carbonaceous strings and Black (5Y 2.5/1) Siltstone, 90% hard, slightly weathered to fresh, 10% moderately soft, slightly weathered, between 290.2' and 292.0'. *(Continued)*	74				298.4' 0° Mechanical break
		299						Gray [5Y 5/1], fine grained Sandstone, Bedding variable, moderately to thinly laminated with very dark gray (5Y 3/1) Siltstone, hard, slightly weathered to fresh.					
		300											Fractures
		301											299-302.7' 0° Joint, closely spaced
		302											302' 70° Joint/Shear, very thin, moderately hard, partly healed
		303											302.5' 72° Joint/Shear, very thin, moderately hard, partly healed
		304					103		61				303' 72° Joint/Shear, very thin, moderately hard, moderately healed
		305											
		306											306' 28° Bedding joint, clean, hard
		307						Black [2.5Y 2.5/1], Claystone, moderately hard, slightly weathered to fresh.					306.6'-307.6' Bedding joint/Shear, approx 20°, moderately hard, very closely spaced
		308											
		309											
		310											
		311											Fractures
		312											311.4' 15° Joint/Bedding joint
		313											312.8' 10° Joint/Bedding joint
		314					93		82				
		315											
		316											
		317						Black [N2], Coal, Bedding 15°, very hard, slightly weathered to fresh, Bed No. 5.					316.4' 0° Bedding joint 316.5' 45° Shear, moderately thin, moderately soft
		318											Retaining circulation 316.4-317.5' intensely to moderately fractured, 70/20 cleats
		319											317.7' 68° Shear/Joint, clean
		320					98		73				Fractures

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		367					100	Gray [5Y 5/1], fine grained Sandstone, very hard, fresh, massive. *(Continued)*	50				366.2-366.4' moderately soft, Sandstone
		368											
		369						Gray [5Y 5/1], fine grained Sandstone, very hard, fresh, massive.					
		370											
		371											Fractures
		372											371.5-372' 70° Joint, moderately healed 372-372.8' 75° Joint, not healed
		373											
		374					100		92				
		375						Dark gray [5Y 4/1], fine grained Sandstone with Carbonaceous feathers, hard, slightly weathered to fresh.					
		376											
		377											
		378											
		379											Total Depth=379.0'
		380											
		381											
		382											
		383											
		384											
		385											
		386											
		387											
		388											
		389											

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PHONE NUMBER:

Drill Hole No. BH-03

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/14/14 - 10/1/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5579.80 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 339945.629, E. 2033668.009	HAMMER TYPE: None

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		1, 2						Damp, Dark brown [10YR 3/3], POORLY GRADED SAND with Clay and Gravel, SP-SC, low plasticity, no reaction to HCl.					
		3, 4, 5, 6, 7, 8				G14529, G14530		Damp, Brown [10YR 4/3], WELL GRADED SAND with Gravel, SW, non-plastic, Alluvium, gravels are subrounded, no reaction to HCl.					
		9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21				G14531, G14532, G14533		Damp, Very dark grayish brown [10YR 3/2], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles an boulders, gravels subrounded, no reaction to HCl.					13-15.5' Boulders 18-20.0' Boulders

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		22						Moist to wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles an boulders, gravels subrounded, no reaction to HCl. *(Continued)*					
		23				G14533							23-24' Boulder
		24											
		25											25-29' Boulders
		26						Moist to wet, Dark reddish gray [5YR 4/2], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles an boulders, gravels subrounded, no reaction to HCl.					
		27				G14534							
		28											
		29											
		30											
		31						Moist to wet, Dark gray [5Y 4/1], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles an boulders, gravels subrounded, no reaction to HCl.					
		32				G14535							
		33											
		34											
		35											
		36											
		37				G14536							
		38											
		39											
		40											
		41											
		42				G14537							
		43											
		44											

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					X	G14537		Moist to wet, Dark gray [5Y 4/1], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles an boulders, gravels subrounded, no reaction to HCl. *(Continued)*					
		45			X								
		46			X								
		47			X	G14538							
		48			X								
		49			X								
		50			X								
		51			X								
		52			X	G14539							
		53			X								
		54			X								
		55			X								
		56			X								
		57			X	G14540							
		58			X								
		59			X								
		60			X								
		61			X								
		62			X	G14541							
		63			X								
		64			X								
		65			X								
		66			X	G14542							66-68.5' Boulder
		67											

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		68			X	G14542		Moist to wet, Dark gray [5Y 4/1], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles an boulders, gravels subrounded, no reaction to HCl. *(Continued)*					
		69			X								
		70			X								
		71			X								
		72			X	G14543							
		73			X								
		74			X								
		75			X								
		76			X								
		77			X	G14544							
		78			X								
		79			X								
		80			X								
		81			X								
		82			X	G14545							
		83			X								
		84			X								
		85			X								
		86			X								
		87			X			Wet, Black [10YR 2/1], Coal, no reaction to HCl, possibly Bed No. 1.					
		88			X	G14546							
		89			X			Moist, Brown [10YR 5/3] Dark grayish brown [10YR 4/2], Sandstone, intact particles are brown, composite is dark grayish brown, becoming damp at 95', strong reaction to HCl.					
		90			X	G14547							

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		91						Moist, Brown [10YR 5/3] Dark grayish brown [10YR 4/2], Sandstone, intact particles are brown, composite is dark grayish brown, becoming damp at 95', strong reaction to HCl. *(Continued)*					
		92				G14547							
		93											
		94											
		95											
		96											
		97				G14548							
		98											
		99											
		100						.					
		101											
		102											
		103											
		104											
		105						Very dark gray [5Y 3/1], Claystone, Bedding 17°, thinly laminated with N2.5 claystone, moderately soft, slightly weathered, weak reaction to HCl.					105.5' Top of first core
		106											
		107					91		72				107.6' 17° Joint, very thin, moderately soft, moderately to slightly weathered Fractures 107.1' 17° Joint, thin, soft, moderately weathered
		108											108.5' 17° Joint, thin, soft, moderately weathered
		109						Very dark gray [5Y 3/1], Claystone, Bedding 19°, thinly laminated with carbonaceous stringers, breaks easily on bedding planes, moderately soft, slightly weathered, weak reaction to HCl.					Fractures 109.8' 5° Joint, very thin, moderately soft, slightly weathered to fresh
		110											
		111					94		68	14	5.8		110.0' 10° Joint, very thin, slightly weathered to fresh 111.4' 15° Bedding joint, moderately thin, moderately weathered, soft
		112											112.6' 17° Bedding joint,
		113											

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							94		68	14	5.8		clean, slightly weathered to fresh 113.0' 12° Joint, clean, slightly weathered to fresh 113.2' 12° Joint, clean slightly weathered to fresh
		114						Very dark gray [5Y 3/1], Claystone, Bedding 42°, moderately soft, slightly weathered, weak reaction to HCl.					Fractures 114.5' 35° Bedding joint, very thin, slightly weathered 115.4' 15° Joint, very thin, slightly weathered
		115											
		116					100		76				115.9' 25° Joint, very thin, slightly weathered 117.1' 0° Joint, moderately thin, moderately weathered
		117											
		118											118.5' 21° Mechanical break
		119						Very dark gray [5Y 3/1], Claystone, Bedding 30°, moderately laminated with carbonaceous feathers, moderately soft, slightly weathered, weak reaction to HCl.					Fractures 119.5' 0° Joint, moderately thin, moderately to slightly weathered
		120											120.2' 52° Shear, thin, moderately to slightly weathered
		121					94		32				120.4' 36° Shear, thin, moderately to slightly weathered 120.7' 13° Joint 121.7' 13° Joint
		122											122.6' 0° Joint, moderately thin, moderately to slightly weathered
		123											122.9' 13° Shear, thin, moderately weathered, soft 123.3' 25° Bedding joint, moderately thin, moderately weathered, soft
		124											
		125											
		126						Dark gray [5Y 4/1], fine grained Sandstone, very thinly laminated, with carbonaceous stringers, hard, fresh, weak reaction to HCl.					
							104		75	18	6.3		
		127						Claystone [5YR 4/1].					
		128											Fractures 128.4' 10° Mechanical break
		129						Dark gray [5Y 4/1], fine grained Sandstone, very thinly laminated with carbonaceous stringers, hard, fresh, weak reaction to HCl.					
		130											
		131											
							98		86	26	7.6		
		132											Fractures 132.1' 19° Joint, very thin, hard, slightly weathered to fresh 132.8' 5° Joint, very thin, hard, fresh
		133						Claystone, variable bedding with flow structures, hard, fresh.					
		134											
		135					88		98				
		136											

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Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-03

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		137					88	Claystone, variable bedding with flow structures, hard, fresh. *(Continued)*	98				Fractures 136.1' 21° Shear, clean, slightly weathered to fresh, hard
		138											
		139						Olive gray [5Y 4/2], Claystone, hard, fresh.					Fractures 139.5' 70° Joint/Shear, moderately thin, Extremely hard
		140						Black [5Y 2.5/2], Claystone, Bedding 20°, thinly laminated with carbonaceous stringers moderately soft, moderately weathered.					
		141					100		32				141-144' 20-29° Bedding joint, thin to moderately thick, moderately spaced, Intensely to moderately weathered
		142											
		143											
		144						Black [5Y 2.5/2], Claystone, Bedding 22°, hard, fresh, moderately laminated with fine grained sandstone, hard to Extremely hard.					Fractures 144.6' 20° Bedding joint, very thin, very soft, intensely weathered
		145											
		146					100		86				145.7' 24° Joint, very thin, very soft, intensely weathered
		147											147.5' 20° Joint, clean, partly healed
		148											
		149						Black [5Y 2.5/2], Claystone, moderately hard, slightly weathered to fresh.					
		150											Fractures 150-150.5' 55° Joint, moderately spaced 150.5-151.3' 13° Shear, moderately spaced, parallel to beds
		151					94		64				
		152						Light gray [2.5Y 7/2], Siltstone, very thinly laminated with Black N2.5 Claystone and carbonaceous stringers.					
		153											
		154						Light gray [2.5Y 7/2], Siltstone, very thinly laminated with Black N2.5 Claystone and carbonaceous stringers.					
		155											
		156					104		79				Fractures 156.1' 15° Joint
		157						Black [5Y 2.5/2], Claystone, moderately hard, slightly weathered to fresh.					157.0' 17° Joint, thin, moderately soft, moderately weathered
		158											158.1' 17° Joint, very thin, moderately hard, moderately to slightly weathered
		159											

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		160						Black [5Y 2.5/2], Claystone, moderately hard, slightly weathered to fresh. *(Continued)*					158.5-160' 17° Joint, thin, moderately spaced, moderately soft, moderately weathered
		161					96	Black [2.5Y 2.5/1], Coal, Bedding 25°, Bed No. 1 1/2.	69				Fractures 161' 15° Joint
		162											162.4' 15° Joint
		163											163-167' 70° Joint, very closely spaced
		164											
		165											
		166					104	Very dark gray [5Y 3/1], Claystone, Very soft, Intensely to moderately weathered.	71				Fractures 164-165.5' 17°/72° Joint, very closely spaced 164.6-165' Intensely fractured, cletes 165-165.5' 90° Joint, very closely spaced, cletes
		167						Very dark gray [5Y 3/1], fine grained, clayey, Sandstone, hard, slightly weathered.					
		168											
		169						Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered to fresh.					
		170											
		171					92		76				
		172											
		173						Dark greenish gray [5GY 4/1], fine grained Sandstone, bedding variable, flow structures, hard, slightly weathered to fresh.					Fractures: 172.5-173.3' 29°, Joint, moderately soft to soft, moderately weathered, closely spaced
		174											
		175											
		176					94		85				
		177											
		178						Very dark gray [5Y 3/1], Claystone, Bedding 17°, moderately hard, slightly weathered to fresh.					Fractures 178.3' 17° Bedding joint 178.6' 70° Shear, moderately thick, slickens on surface, most 3/4" gravels with clay as gouge
		179											
		180					104	Very dark gray [5Y 3/1], Siltstone, Bedding 14°, thinly laminated with carbonaceous stringers and claystone, hard, slightly weathered to fresh, Trace of carbonaceous feathers, breaks easily on bed planes with carbonaceous stringers.	90				
		181											
		182											

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		183		X			104	Very dark gray [5Y 3/1], Siltstone, Bedding 14°, thinly laminated with carbonaceous stringers and claystone, hard, slightly weathered to fresh, Trace of carbonaceous feathers, breaks easily on bed planes with carbonaceous stringers. *(Continued)*	90				Fractures 183.1' 14° Bedding joint 183.4' 14° Bedding joint, thin, moderately hard, moderately weathered
		184		X				Very dark gray [5Y 3/1], Siltstone, Bedding 13° to 20°, moderately laminated with fine grained Sandstone and Claystone and carbonaceous strings, moderately hard, slightly weathered.					
		185		X									
		186		X			104		67				Fractures: 184-189' 13-20°, Bedding joint, soft, moderately thin to thin, intensely to moderately weathered, moderately spaced
		187		X									
		188		X									
		189		X				Dark gray [N4], fine grained Sandstone, massive, hard, fresh, strong reaction to HCl.					
		190		X									
		191		X			96		85				
		192		X									Fractures 192.4' 10° Joint, clean, hard, slightly weathered to fresh 192.9' 0° Bedding joint, coal feathers
		193		X									
		194		X				Dark gray [N4], fine grained Sandstone, massive, hard, fresh, strong reaction to HCl.					193.4' 20° Joint, clean, hard, slightly weathered to fresh
		195		X									Fracture 195' 35° Shear, thin, moderately soft, moderately weathered, small pea gravels and clay gouge
		196		X			104		85				196.1' 20° Bedding joint, very thin, moderately hard, slightly weathered
		197		X									197.4' 10° Joint, very thin, hard, slightly weathered
		198		X									
		199		X				Dark gray [N4], fine to medium grained Sandstone, thinly laminated with carbonaceous stringers, hard, fresh, strong reaction to HCl.					
		200		X									Fractures 200.6' 14° Shear, very thin, hard
		201		X			100		90				201-202' 90° Joint, very thin, totally healed, calcite
		202		X									
		203		X									203.4' 17° Shear, moderately thin, moderately hard, moderately to slightly weathered
		204		X			104	Gray [N5], fine to medium grained Sandstone, thinly laminated with carbonaceous strings, hard, fresh, strong reaction to HCl.	92	14	5.7		Fractures
		205		X									

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		206						Gray [N5], fine to medium grained Sandstone, thinly laminated with carbonaceous strings, hard, fresh, strong reaction to HCl. *(Continued)*					204.7' 26° Bedding joint, clean, hard, slightly weathered to fresh 205' 16° Bedding joint, clean, hard, fresh 206.4' 14° Bedding joint, very thin, hard, slightly weathered to fresh
		207					104		92	14	5.7		
		208											
		209						Gray [N5], fine grained Sandstone, thinly laminated with carbonaceous strings, hard, fresh, strong reaction to HCl.					
		210											
		211											
							100		96				
		212											
		213											
		214						Gray [N5], fine grained Sandstone, Bedding 21°, thinly laminated with carbonaceous strings between 217.5 and 219, hard, fresh, massive.					
		215											
		216											
							100		100				
		217											
		218											
		219						Gray [N5], fine grained Sandstone, bedding variable, thinly laminated with carbonaceous strings, hard, fresh, weak reaction to HCl.					
		220											
		221											
							86		100	15	6.9		
		222											
		223											
		224						Gray [N5], fine grained Sandstone, thinly laminated with carbonaceous strings, hard, fresh, weak reaction to HCl.					Fractures 224.5' 12° Bedding joint, clean, hard, fresh 225.2' 26° Joint, clean, hard, slightly weathered to fresh
		225											
		226					104		92	18	6.3		
		227											
		228											

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		229					104	Gray [N5], fine grained Sandstone, thinly laminated with carbonaceous strings, hard, fresh, weak reaction to HCl. *(Continued)*	92	18	6.3		
		230						Gray [N5], fine grained Sandstone, moderately laminated with carbonaceous strings hard, fresh, strong reaction to HCl.					
		231					100		100	16	5.9		
		232											
		233											
		234											
		235											
		236					100	Very dark gray [5Y 3/1], Siltstone, Bedding 22°, moderately hard, slightly weathered to fresh, strong reaction to HCl.	90	23	7.0		
		237											Fractures 237.2' 10° Joint 237.7' 24° Shear/Joint, clean, moderately hard, slightly weathered to fresh
		238											
		239											
		240											
		241											Fracture 241' 17° Bedding joint
		242					100	Black [2.5Y 2.5/1], Claystone, Bedding 22°, moderately hard, slightly weathered.	56	20	6.5		241-242' 17° Bedding joint, very closely spaced, moderately soft, moderately weathered 242.7' 25° Bedding joint
		243						Black [2.5Y 2.5/1], Coal, Bedding 25°, Bed No. 2.					243.3' 25° Bedding joint 242.5-244' 80°, Joint, very closely spaced
		244						Black [2.5Y 2.5/1], Coal, Bedding 14°, moderately laminated with 5Y 2.5/1 Coal, very hard, Bed No. 2.					
		245											
		246											Fractures
		247					100		26				244-249' 14° Joint, clean, Slightly weathered to fresh, very hard, moderately spaced 244-249' 60° Shear, very thin, slightly weathered to fresh, very hard, spacing .8'
		248											
		249											
		250					86		74				Fractures 249.7' 25° Bedding joint, Fresh, very hard
		251											

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								Black [5Y 2.5/1], Claystone, moderately hard, slightly weathered.					251' 21° Bedding joint, very hard, slightly weathered to fresh
		252					86	Very dark gray [5Y 3/1], Siltstone, moderately hard, slightly weathered.	74				251.5-252' 20° Bedding joint, closely spaced, moderately soft, moderately weathered
		253											
		254						Very dark gray [5Y 3/1], Claystone, moderately soft, moderately weathered, weathers to CH.					Fractures 254.5-254.9' intensely to moderately fractured 255.2-256.1' 58° Joint/Shear, soft, intensely to moderately weathered 255.2-256.1' 20° Joint, very closely spaced 256.7-257.6' 75° Joint/Shear, soft, intensely to moderately weathered
		255											
		256					104		46				
		257											
		258											258.5' 54° Random fracture
		259											
		260											Fractures 259.3' 24° Joint 259.7-260.3' intensely to moderately fractured, clay and gravel
		261					96		58				261.4'-262' 90° Clay, CH, intensely to moderately fractured, very soft, intensely to moderately weathered
		262						Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered to fresh.					
		263											
		264						Black [5Y 2.5/1], Claystone, Bedding 21°, moderately hard, slightly weathered to fresh.					
		265											
		266					104		87				
		267											Fractures 267' 21° Bedding joint, very thin, moderately to slightly weathered, moderately soft
		268											268.2' 21° Bedding Joint, very thin, moderately hard, slightly weathered
		269						Black [5Y 2.5/1], Claystone, Bedding 20°, moderately hard, slightly weathered to fresh.					
		270											270' 20° Bedding joint, very thin, moderately hard, slightly weathered to fresh
		271					86		91				
		272											271.7' 5°, Joint, very thin, moderately hard, slightly weathered to fresh
		273											272.9' 17°, Bedding joint, very thin, moderately hard, slightly weathered to fresh
		274											

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								Black [5Y 2.5/1], Claystone, Bedding 14°, moderately hard, slightly weathered to fresh. *(Continued)*					
		275											RQD PQ switch to HQ Fractures 275.6' 14° Bedding joint, moderately hard, very thin 275.9' 13° Bedding joint, moderately hard, very thin
		276											276.5' 14° Bedding joint, moderately hard, very thin
		277					105						277' 15° Bedding joint, moderately hard, very thin 278' 14° Bedding joint, moderately hard, very thin
		278											
		279						Black [5Y 2.5/1], Claystone, moderately laminated with carbonaceous strings, moderately hard, slightly weathered to fresh, breaks easily on carbonaceous strings.					278.8' 14° Bedding joint, moderately hard, very thin
		280											279.7' 15° Bedding joint, very thin, very soft, moderately weathered
		281											
		282											282.2' 15° Bedding joint, clean, moderately hard, slightly weathered to fresh
		283											
		284					99		74				284.5' 16° Bedding joint, clean, moderately hard, slightly weathered to fresh
		285											
		286											286' 16° Bedding joint, clean, moderately hard, slightly weathered to fresh 286.7' 15° Bedding joint, moderately thin, moderately soft, moderately to slightly weathered
		287											
		288											288' 15° Bedding joint, moderately thin, moderately soft, moderately to slightly weathered
		289						Black [5Y 2.5/1], Claystone, Bedding 20°, variable bedding with flow structures, moderately hard, slightly weathered to fresh, thinly laminated with fine grained Sandstone, hard, slightly weathered to fresh.					
		290											
		291											
		292											
		293					102		97	23	7.1		Fractures 292.9' Joint/Bedding joint, moderately hard, slightly weathered to fresh
		294											
		295											295.3' Joint/Bedding joint, moderately soft, moderately to slightly weathered
		296											
		297						Gray [N5], fine grained Sandstone, thinly laminated with (5Y 2.5/1) Black, Siltstone.					

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		298					102	Gray [N5], fine grained Sandstone, thinly laminated with (5Y 2.5/1) Black, Siltstone. *(Continued)*	97	23	7.1		
		299						Black [5Y 2.5/1], fine grained Sandstone, Bedding 24°, variable bedding flow structures, thinly laminated with (5Y 2.5/1) Black, Siltstone, hard, Fresh.					
		300											
		301											
		302											
		303											
		304					102		98	15	5.9		
		305											
		306											
		307						Very dark gray [5Y 3/1], Siltstone, Bedding 15°, hard, slightly weathered to fresh, thinly laminated with carbonaceous strings, moderately laminated with Claystone, moderately hard, slightly weathered.					
		308											
		309											
		310											
		311											
		312											
		313											
		314					100		99	14	5.7		
		315											
		316											
		317											
		318											
		319						Black [5Y 2.5/1], Claystone, Bedding 14°, moderately hard, slightly weathered, zones of moderately soft, moderately weathered with bedding joints on carbonaceous strings, core breaks easily on bedding.					Fractures 319-320' 14° Bedding joint, closely spaced, moderately soft, moderately weathered
		320					97		51				

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		321						Black [5Y 2.5/1], Claystone, Bedding 14°, moderately hard, slightly weathered, zones of moderately soft, moderately weathered with bedding joints on carbonaceous strings, core breaks easily on bedding. *(Continued)*					320.5-321' 14° Bedding joint, closely spaced, soft, moderately weathered
		322											
		323					97		51				322.6' Mechanical break
		324											323.7-326' 15° Bedding joint, moderately spaced
		325											
		326						Black [2.5Y 2.5/1], Coal, Bedding 17°, Bed No. 3.					
		327					83		44				Fractures 326-329' 75° Joint, partly healed, cletes, discontinuous
		328											
		329						Black [2.5Y 2.5/1], Coal, Bedding 17-22°, Bed No. 3.					Fractures 329.5' 18° Bedding joint
		330											
		331											330.9' 17° Bedding joint
		332											331.9' 15° Bedding joint 332.5' 20° Bedding joint
		333											333.1' 60° Joint dip opposite of bedding dip, spacing 0.9'
		334					102		60				333.5' 20° Bedding joint 334' 60° Joint dip opposite of bedding dip, spacing 0.9' 334.1' 20° Bedding joint
		335											334.7' 62° Joint dip opposite of dip, spacing 0.9' 335.2' 23° Bedding joint
		336											329-339' 60° Discontinuous, very thin, moderately healed, very closely spaced
		337						Black [5Y 2.5/2], Claystone, thinly laminated with carbonaceous strings, moderately laminated with coal, moderately hard, slightly weathered to fresh.					
		338											337' 20° Bedding joint, spacing 0.6-1.2'
		339											
		340											Fractures 339.7' 30° Joint 340.1' 24° Joint
		341					104		84				340.8' 20° Joint, Intensely fractured
	× × × ×	342						Dark gray [N4], grading to Dark Olive Gray (5Y 3/2) Siltstone, moderately hard, slightly weathered to fresh.					341.8' 0° Joint, Intensely fractured
	× × × ×	343											342.8' 15° Joint

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		344, 345, 346, 347, 348, 349					104	Dark gray [N4], grading to Dark Olive Gray (5Y 3/2) Siltstone, moderately hard, slightly weathered to fresh. *(Continued)*	84				
		350, 351, 352, 353, 354, 355, 356, 357, 358, 359					100	Dark gray [5Y 4/1], Siltstone, variable bedding, moderately hard, slightly weathered to fresh.	100				
		360, 361, 362, 363, 364, 365, 366					100	Dark gray [5Y 4/1], Siltstone, variable bedding, moderately laminated with Claystone bedding, core breaks on bedding planes.	99	27	7.7		Fractures 364.6' 14° moderately thin, soft, clayey zone

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		367, 368					100	Dark gray [5Y 4/1], Siltstone, variable bedding, moderately laminated with Claystone bedding, core breaks on bedding planes. *(Continued)*	99	27	7.7		
		369, 370, 371, 372, 373, 374, 375, 376, 377, 378					96	Very dark gray [N3] Dark gray [N4], Siltstone, Bedding 15° variable bedding with flow structures, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh, breaks easily on carbonaceous strings.	97	27	7.6		Fractures 371.1' 14° Bedding joint, very thin, hard, slightly weathered to fresh 374.7' 17° Bedding joint, moderately thin, moderately soft, intensely to moderately weathered 375.5' 24° Bedding joint, moderately thin, moderately soft, intensely to moderately weathered
		379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389					102	Black [5Y 2.5/1], Claystone, Bedding 23°, moderately hard, slightly weathered to fresh, strong reaction to HCl.	90				379.7' 23° Bedding joint, clean, moderately hard, slightly weathered to fresh 381' 30° Shear, moderately thin, moderately soft, moderately to slightly weathered 386.5' 17° Bedding joint, thin, moderately soft, moderately to slightly weathered 387.2' 20° Bedding joint, very thin, moderately soft, moderately to slightly weathered

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		390, 391, 392, 393, 394					101	Dark gray [5Y 4/1], Claystone, moderately laminated with Gray (5Y 6/1) Claystone, hard, slightly weathered to fresh, strong reaction to HCl. *(Continued)*	98				
		395, 396, 397, 398, 399					101	Gray [5Y 5/1], Siltstone, hard, slightly weathered to fresh, moderately laminated with Dark gray (5Y 4/1) Claystone, moderately hard, slightly weathered to fresh, strong reaction to HCl.	98				
		400, 401, 402, 403, 404, 405, 406, 407					100	Gray [5Y 5/1], Siltstone, moderately laminated with (5Y 4/1) Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh, strong reaction to HCl.	98	60	16.3		Fractures 404' 0° Joint, moderately thin, moderately hard, moderately to slightly weathered
		408, 409, 410, 411, 412					100	Gray [5Y 5/1], Claystone, moderately laminated with Dark gray (5Y 4/1) Claystone and Gray (5Y 5/1) Siltstone, hard, slightly weathered to fresh, strong reaction to HCl.	98	26	7.5		Fractures 411.7' 0° Joint, moderately thin, moderately soft, moderately weathered

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		413						Gray [5Y 5/1], Claystone, moderately laminated with Dark gray (5Y 4/1) Claystone and Gray (5Y 5/1) Siltstone, hard, slightly weathered to fresh, strong reaction to HCl. *(Continued)*					412.7' 13° Bedding joint, clean, hard, slightly weathered to fresh
		414											
		415											
		416					100		98	26	7.5		
		417											
		418											
		419						Gray [5Y 5/1], Claystone, Bedding 24°, moderately laminated with Dark gray (5Y 4/1) Claystone and (5Y 5/1) Siltstone, moderately hard, slightly weathered to fresh, trace carbonaceous strings, strong reaction to HCl.					
		420											
		421											
		422											422.5-422.8' 21° Shear, moderately thick, moderately soft, moderately to slightly weathered
		423											423' 22° Shear, very thin, moderately hard, slightly weathered
		424					100		97	23	7.0		
		425											
		426											
		427											
		428											
		429						Gray [5Y 5/1], Claystone, Bedding 24°, moderately laminated with Dark gray (5Y 4/1) Claystone and Siltstone, trace carbonaceous strings, strong reaction to HCl.					
		430											
		431											
		432					93		100				
		433											
		434											
		435											

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		436						Gray [5Y 5/1], Claystone, Bedding 24°, moderately laminated with Dark gray (5Y 4/1) Claystone and Siltstone, trace carbonaceous strings, strong reaction to HCl. *(Continued)*					
		437					93		100				
		438											
		439						Very dark gray [5Y 3/1], Claystone, Bedding 24°, hard, slightly weathered to fresh, strong reaction to HCl.					
		440											
		441											
		442											Fractures 442.1' 35° Shear, very thin, hard, displacement opposite of dip 441-442' 70° Shear, clean, hard, totally healed
		443											
		444					100		97	26	7.5		
		445											
		446											
		447											
		448											
		449						Dark olive gray [5Y 3/2], Claystone, Bedding 16°, hard, slighty weathered to fresh, strong reaction to HCl.					
		450											
		451											Fractures 450.3' 32° Shear, thin, moderately soft, moderately weathered, dip of fractures opposite of bed dip
		452											
		453											
		454					93		95				
		455											
		456											
		457											
		458											

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							93	Dark olive gray [5Y 3/2], Claystone, Bedding 16°, hard, slighty weathered to fresh, strong reaction to HCl. *(Continued)*	95				
		459						Dark olive gray [5Y 3/2], Claystone, Bedding 18°, hard, slightly weathered to fresh, strong reaction to HCl.					Fractures 459.9' 20° Joint
		460											460.6' 25° Shear, thin, moderately hard, Anatomois
		461											
		462											462.0' 46° Joint, very thin, hard
		463						Dark olive gray [5Y 3/2], Claystone, Bedding 18°, hard, slightly weathered to fresh,.					
		464					104		83	32	8.7		
		465											464.5' 37° Shear, very thin, hard, slightly weathered
		466											
		467											466.5' 15° Shear, moderately thick, hard, slightly weathered
		468											467.9' 20° Shear, very thin, hard, slightly weathered
		469						Dark olive gray [5Y 3/2], Claystone, Bedding 17°, moderately hard, slightly weathered to fresh.					
		470											
		471											470.6' 26° Joint, moderately thin, moderately soft, moderately to slightly weathered Fracture 469.3' 18° Bedding joint, very thin, moderately hard 470.2' 30° Joint, very thin, moderately hard 471.3' 17° Shear, very thin, moderately hard, moderately to slightly weathered, partly healed 471.5' 20° Joint, thin, moderately soft, moderately to slightly weathered 471.7' 25° Joint, very thin, moderately hard, slightly weathered 471.9' Clay, coal interface Driller states no large void, little spaces 1-2". Set rod on bottom, falls through with water on probably mud
		472						Coal, Bed No. 4.					
		473						caved materials.					
		474					35		57	33	8.9		
		475											
		476											
		477											
		478											
		479						Very dark gray [5Y 3/1], Claystone, very soft, Intensely weathered, trace of coal gravel at 479'.					
		480					85		0				Mislatch, splits completely sanded with coal, heave from 479'
		481											

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								Very dark gray [5Y 3/1], Claystone, very soft, Intensely weathered, trace of coal gravel at 479'. *(Continued)*					
		482						Very dark gray [5Y 3/1], Claystone, moderately hard, moderately weathered.					
		483											
								fine grained Sandstone.					
		484						Very dark gray [5Y 3/1], Claystone, Soft, moderately weathered.					Fractures 479-481' very loose, soil-like 480.7' 45° Shear, soft, intensely to moderately weathered 481' 47° Shear, soft, intensely to moderately weathered 479-783' Random fractures, very closely spaced 484.5' 45° Shear, soft, moderately weathered 486' 40° Shear, soft, moderately to slightly weathered 486.5' 70° Joint, moderately soft, moderately to slightly weathered 486.7' 20° Joint, moderately soft, moderately to slightly weathered 486.9' 70° Joint, moderately soft, moderately to slightly weathered Fractures 489-490' 15° Bedding joint, closely spaced, moderately healed 490.7' 20° Bedding joint, moderately thin, moderately soft, moderately to slightly weathered 491.6' 20° Bedding joint, moderately thin, moderately soft, moderately to slightly weathered 492.2' 15° Bedding joint, very thin, moderately soft, moderately to slightly weathered 492.7' 15° Bedding joint, very thin, moderately soft, moderately to slightly weathered 494-499' 15° Bedding joint, moderately spaced 494.5' 75° Joint
		485					85		0				
		486											
		487											
		488											
								thin lense of Coal.					
		489						Very dark gray [5Y 3/1], Claystone, Bedding 15°, moderately hard, slightly weathered, drilling fluid washes clay from side of core.					
		490											
		491											
		492											
		493											
		494					100	Coal, Bed No. 4 1/2.	50				
		495											
		496											
		497											
		498											
		499						Very dark gray [5Y 3/1], Claystone, Bedding 16°, moderately hard, Slighty weathered to fresh.					
		500											Fractures 500' 24° Shear/Joint, thin, moderately hard, slightly weathered
		501											
		502					100	Dark gray [5Y 4/1], fine grained Sandstone, hard, slightly weathered to fresh.	80				501.7' 58° Shear, hard, moderately to slightly weathered 502' 59° Shear, clean to very thin, hard, moderately to slightly weathered 502.5' 59° Shear, clean to very thin, hard, moderately
		503						Dark gray [5Y 4/1], medium grained Sandstone, hard, slightly weathered to fresh.					
		504											

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		505						Dark gray [5Y 4/1], medium grained Sandstone, hard, slightly weathered to fresh. *(Continued)*					to slightly weathered 503.6' 24° Joint, clean, hard, slightly weathered to fresh
		506					100		80				
		507											
		508											
		509						Dark gray [N4], medium grained Sandstone, Bedding 15°, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		510											
		511											
		512											
		513											
		514					104		88				
		515											
		516											
		517											
		518											
		519						Dark gray [N4], medium grained Sandstone, hard, slightly weathered, trace carbonaceous feather, massive, fractures form in soft Sandstone layers.					
		520											
		521											
		522											
		523					100		93				
		524						Claystone.					Fractures 524.3-524.7' 5° Bedding joint, moderately hard, moderately to slightly weathered, softer sandstone 525.3' 10° Joint, moderately hard, moderately to slightly weathered 526.3' 10° Joint, moderately hard, moderately to slightly
		525						Sandstone.					
		526											
		527											

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								Dark gray [N4], medium to fine grained Sandstone, Bedding 15°, moderately laminated with carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*					weathered
		528					100		93				
		529											
		530											
		531											
		532											
		533											
		534					100		100				
		535											
		536											
		537											
		538											
		539						Dark gray [N4], medium grained Sandstone, Bedding 20°, moderately laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		540											
		541											Fractures 541.5' 52° Shear, healed, hard, slightly weathered to fresh
		542											
		543											
		544											
		545											545.2' 57° Shear, healed, hard, slightly weathered to fresh
		546											545.4' 65° Shear, healed, hard, slightly weathered to fresh
		547											546.4' 52° Shear, healed, hard, slightly weathered to fresh
		548						Dark gray [N4], fine grained Sandstone, variable bedding dominant Bedding 20°, hard, slightly weathered to fresh.					546.5' 55° Shear, healed, hard, slightly weathered to fresh
		549					100		89				
		550											Fractures

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		551						Dark gray [N4], fine grained Sandstone, variable bedding dominant Bedding 20°, hard, slightly weathered to fresh. *(Continued)*					550.1' 62° Shear, very thin, moderately soft, slightly weathered 550.4' Shear, moderately thick, moderately soft, slightly weathered 550.4-551' 17° Joint, moderately thick, moderately hard, moderately weathered, closely spaced
		552											
		553											
		554											
		555					100		89				
		556											
		557											
		558											
		559						Dark gray [N4], fine grained Sandstone, variable bedding, hard, slightly weathered to fresh.					Fractures 559' 65° Shear, hard, slightly weathered to fresh
		560											
		561											
		562											
		563											
		564					100		93				
		565											
		566											
		567											566.7' 39° Bedding joint, hard, slightly weathered to fresh 566.8' 38° Bedding joint, hard, slightly weathered to fresh
		568											
		569						Dark gray [N4], fine grained Sandstone, very hard, slightly weathered to fresh, massive, trace of pieces of Siltstone floating in Sandstone matrix.					Fractures 569.4' 27° Shear, moderately thin, moderately soft, moderately weathered 569.7' 30° Joint, clean, hard, slightly weathered to fresh
		570											
		571							86				
		572											
		573											

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		574						Dark gray [N4], fine grained Sandstone, very hard, slightly weathered to fresh, massive, trace of pieces of Siltstone floating in Sandstone matrix. *(Continued)*					573.7' 14° Joint, clean, hard, slightly weathered to fresh
		575											
		576							86				
		577											
		578						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 30° but variable, moderately laminated (5Y 2.5/1) Siltstone, hard, slightly weathered to fresh.					577.7' 15° Shear, moderately thick, hard, slightly weathered to fresh
		579											579' 55° Shear, end of core
		580											Fractures 579.7' 30° Joint/Shear, thin, soft, intensely to moderately weathered 580.9' 30° Joint, clean, hard, slightly weathered to fresh 581.2' 30° Joint, clean, hard, slightly weathered to fresh
		581											
		582											
		583											583' 29° Joint, clean, hard, slightly weathered to fresh
		584					100		88				
		585											584.7' 20° Shear, moderately thin, moderately soft, slightly weathered
		586											
		587											587.1' 27° Joint, clean, hard, slightly weathered to fresh
		588											
		589						Black [5Y 2.5/1], Siltstone, variable bedding, moderately laminated with 5Y 4/1 fine grained sandstone and carbonaceous strings, breaks easily on bedding and carbonaceous strings, hard, slightly weathered to fresh.					
		590											Fractures 590.4' 29° Joint, clean, hard, slightly weathered to fresh
		591											
		592											
		593					100		91				
		594											593.5' 10° Bedding joint, clean, hard, slightly weathered to fresh
		595											595' 32° Bedding joint, clean, hard, slightly weathered to fresh
		596											595.5' 20° Shear,

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	597					100	Black [5Y 2.5/1], Siltstone, variable bedding, moderately laminated with 5Y 4/1 fine grained sandstone and carbonaceous strings, breaks easily on bedding and carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*	91				moderately thin, soft, intensely to moderately weathered 597.2' 25° Shear, moderately thin, soft, intensely to moderately weathered
	598						Black [5Y 2.5/1], Claystone, thinly laminated with carbonaceous strings, moderately hard, slightly weathered.					
	599											
	600											Fractures 599.4-599.7' 22° Bedding joint, closely spaced 600.1' 10° Bedding joint, very thin, moderately hard, slightly weathered 600.4' 25° Joint, very thin, moderately hard, slightly weathered 601.5-602.4' 20-25° Joint, moderately thin, soft, moderately weathered, closely spaced
	601											
	602											
	603											
	604					96		66				
	605											605.2' 27° Mechanical break
	606											
	607											606.9' 0° Joint, very thin, moderately hard, slightly weathered 607.5' 30° Joint, very thin, moderately hard, slightly weathered
	608											
	609						Black [5Y 2.5/2], Claystone, Soft, Intensely weathered.					
	610											Driller states, rods fell by gravity 3 times, about 4" each
	611											
	612											Fractures difficult to measure, intensely fractured, possibly out of place
	613						Black [2.5Y 2.5/1], POORLY GRADED GRAVEL with SILT AND SAND, GP, gravels and sand are coal, sizes range from 1" diameter to coarse sand, Bed No. 5.					Fractures 609-613' 35° Bedding joint, closely spaced 612' 65° Shear
	614							0				
	615											
	616											
	617											
	618											
	619					22		20				

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		620						Black [2.5Y 2.5/1], Coal and Black Shale, hard, slightly weathered to fresh, 20% of recovery is GP with evidence of movement, Bed No. 5. *(Continued)*					
		621											
		622											Rods fell by gravity 622.6-625.1'
		623						Void, Bed No. 5.					
		624											
		625					22	Likely caved material, no recovery from this section, Bed No. 5.	20				
		626											
		627						Void, Bed No. 5.					Rods fell by gravity 627-629.6'
		628											Continue drilling without pulling tube, drill to 630.3'
		629											
		630						Dark gray [N4], fine grained Sandstone, variable bedding, hard, slightly weathered, moderately laminated with dark gray (N4) Siltstone. Trace of Claystone at 630.3', moderately soft, moderately weathered. Over drill at 632.4' (core with evidence of movement).					
		631											
		632											
		633											Fractures 632.8' 16° Joint, hard, slightly weathered to fresh
		634					107	Very dark gray [N3], Siltstone, hard, slightly weathered to fresh.	67				634' 16° Bedding joint, moderately hard, slightly weathered, moderately thin
		635											
		636											635.8' 19° Bedding joint, moderately hard, slightly weathered, very thin
		637											637' 19° Bedding joint, moderately hard, slightly weathered, very thin
		638											637.2' 34° Shear, moderately soft, moderately to slightly weathered, thin
		639											637.7' 22° Bedding joint, moderately soft, moderately to slightly weathered, thin
		640					100	Dark gray [N4], fine grained Sandstone, hard, slightly weathered to fresh.	90				Fractures 640.2' 60° Shear, hard, moderately thin, partly healed
		641											640.2' 80° Shear, hard, moderately thin, partly healed
		642											

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		643						Dark gray [N4], fine grained Sandstone, hard, slightly weathered to fresh. *(Continued)*					
		644											
		645											
		646					100		90				645.3' 50° Shear, hard, moderately thin, not healed 646.2' 65° Shear, hard, moderately thin, moderately healed
		647											
		648											
		649						Gray [N5], fine grained Sandstone, thinly laminated with carbonaceous strings, Very hard, fresh, massive.					
		650											
		651											Fractures 650.3' 77° Shear, very thin, slightly weathered to fresh, partly healed 650.4' 60° Shear, very thin, slightly weathered to fresh, partly healed 651.5' 75° Shear, very thin, slightly weathered to fresh, partly healed 653.7' 60° Shear, very thin, slightly weathered to fresh, healed
		652											
		653											
		654					100		85				
		655											
		656											
		657											
		658											
		659						Gray [N5], fine grained Sandstone, Very thinly laminated with carbonaceous strings, Very hard, fresh, massive.					
		660											
		661											
		662					104		99				
		663											
		664											
		665											

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ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

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		666						Gray [N5], fine grained Sandstone, Very thinly laminated with carbonaceous strings, Very hard, fresh, massive. *(Continued)*					
		667					104		99				
		668											Fractures 668.0' 10° Bedding joint, hard, fresh
		669											
		670											
		671						Very dark gray [N3], Siltstone, Bedding 20°, moderately hard, slightly weathered to fresh, thinly laminated with Gray [N3] Claystone, moderately hard, slightly weathered to fresh, thinly laminated with carbonaceous strings, breaks easily on bedding.					
		672											
		673											
		674					100		95				
		675											
		676											
		677											
		678											Fractures 678.2' 40° Joint, clean, moderately hard, slightly weathered to fresh
		679											
		680											
		681											Total depth=679.0'
		682											
		683											
		684											
		685											
		686											
		687											
		688											

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PHONE NUMBER:

Drill Hole No. BH-04

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/12/14 - 8/15/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5575.90 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 339883.904, E. 2034082.632	HAMMER TYPE: None

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		1, 2, 3, 4			X	G14552		Damp, Very dark grayish brown [10YR 3/2], POORLY GRADED SAND with Silt, SP-SM, non-plastic, no reaction to HCl.					
		5, 6, 7, 8, 9			X	G14553		Damp, Grayish brown [10YR 5/2], POORLY GRADED GRAVEL with Sand, GP, non-plastic, gravels are subrounded to subangular, no reaction to HCl.					Wet cuttings at 8'
▼		10, 11, 12			X	G14554		Moist, Dark yellowish brown [10YR 3/4], WELL GRADED GRAVEL with Sand, SW, non-plastic, sand is medium grained, alluvium, no reaction to HCl.					Groundwater measured at 10.1' on 8-13-14
		13, 14, 15, 16, 17, 18, 19			X	G14555, G14556		Wet, Dark gray [10YR 4/1], POORLY GRADED GRAVEL, GP, non-plastic, Alluvium, gravels are subrounded to subangular, no reaction to HCl.					
		20, 21			X	G14557							

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		22			X			Wet, Dark gray [10YR 4/1], POORLY GRADED GRAVEL, GP, non-plastic, Alluvium, gravels are subrounded to subangular, no reaction to HCl. *(Continued)*					
		23			X	G14557							
		24			X			Moist, Dark yellowish brown [10YR 4/6], WELL GRADED SAND, SW, non-plastic, Alluvium, sands medium grained, no reaction to HCl.					
		25			X								
		26			X	G14558							
		27			X								
		28			X			Wet, Dark gray [10YR 4/1], POORLY GRADED GRAVEL with Sand, GP, Alluvium, with cobbles and boulders, intact gravels are subrounded, no reaction to HCl.					
		29			X								
		30			X								
		31			X								31-35', a lot of return water
		32			X	G14559							
		33			X								33-35' Boulder
		34			X								
		35			X								
		36			X								
		37			X								
		38			X	G14560							
		39			X								
		40											
		41											
		42			X			Damp, Dark gray [10YR 4/1], Sandstone, weak reaction to HCl.					Return water stopped when hit Sandstone at 42'
		43			X	G14561							Cuttings similar to silty sand at 43'
		44											

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		45						Damp, Dark gray [10YR 4/1], Sandstone, weak reaction to HCl. *(Continued)*					
		46											
		47				G14561							
		48											
		49											
		50						Damp, Black [10YR 2/1], Coal, no odor, no reaction to HCl, possibly Bed No. 1.					
		51				G14562							
		52						Damp, Very dark gray [10YR 3/1], Sandstone, weak reaction to HCl.					
		53				G14563							Set drill rods at 52.8', bentonite
		54				G14564		Damp, Very dark brown [10YR 2/2], Coal, no odor, no reaction to HCl, possibly Bed No. 1.					
		55											
		56											
		57						Gray [N5], fine grained Sandstone, hard, fresh.					
		58											
		59											
		60						Gray [N5], Claystone, Bedding 20°, hard, fresh.					Fractures 58.8' 24° Joint 59.1' Intensely fractured 59.6' 0° Joint, slightly weathered 60.4' 16°, moderately thick, slightly weathered to fresh 60.9' 28° Bedding joint, moderately thick, slightly weathered to fresh 61.9' 0° moderately thick, slightly weathered to fresh, intensely fractured
		61					94		24				
		62											
		63											
		64						Greenish gray [5GY 5/1], fine grained Sandstone, hard, fresh, discoloration extends 1-4" from fractures.					Fractures 63.6' 33° Shear, very thin, slightly weathered 63.7' 64° Shear, very thin, slightly weathered 64.7' 12° Shear, very thin, slightly weathered 64.7' 64° Shear, very thin, slightly weathered
		65					100		58				
		66											
		67											

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		68, 69		X			100	Greenish gray [5GY 5/1], fine grained Sandstone, hard, fresh, discoloration extends 1-4" from fractures. *(Continued)*	58				67.7' 70° Shear, thin, moderately to slightly weathered
		70, 71, 72, 73		X			100	Dark greenish gray [5GY 4/1], Claystone, Bedding 25°, moderately hard.	72				Fractures 70.1' 10° Shear, very thin, slightly weathered to fresh 70.4' 76° Joint 72' 27° Bedding joint 72.4' 40° Shear, thin, moderately to slightly weathered
		74		X				Very dark gray [N3], Claystone, thinly laminated, with black N2.5 Coal, moderately soft, moderately to slightly weathered.					
		75, 76, 77, 78		X			84	Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 17°, very thinly laminated with Carbonaceous, hard, fresh, moderately laminated, with Greenish gray (5GY 5/1) Claystone, hard, fresh.	71				Fractures 74.6' 17° thin, moderately hard, moderately to slightly weathered 74.8' 17° thin, moderately hard, moderately to slightly weathered 75.0' 17° moderately hard, moderately to slightly weathered
		79, 80, 81, 82, 83		X			100	Greenish gray [5GY 5/1], fine grained Sandstone, thinly laminated with Greenish gray (5GY 5/1) Claystone, very thinly laminated with Carbonaceous, Hard, fresh.	100				
		84		X				Greenish gray [5GY 5/1], thinly laminated with Claystone, cuttings, very soft, intensely weathered.					84.0' CH cuttings stuck to rods
		85, 86, 87, 88, 89		X			100	Dark greenish gray [5G 4/1], Claystone, Bedding 21° very thinly laminated with Carbonaceous thinly laminated with coal from 88.2-88.9', weak reaction to HCl.	70				Fractures 86.1' 21° Bedding joint, slightly weathered to fresh 87.7' 65° Joint, fresh 88.2' 20° Bedding joint, slightly weathered to fresh 88.5' 21° Bedding joint, slightly weathered to fresh 88.7' 22° Bedding joint, slightly weathered to fresh
		90		X			94	Greenish gray [5GY 5/1], Claystone, very thinly laminated with Carbonaceous strings and moderately laminated with fine grained Sandstone, moderately hard, fresh.	49				

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		91						Greenish gray [5GY 5/1], Claystone, very thinly laminated with Carbonaceous strings and moderately laminated with fine grained Sandstone, moderately hard, fresh. *(Continued)*					Fractures 90.0' 68° Joint 91.2' 16° Bedding joint 91.4' 17° Bedding joint
		92					94		49				92.5' 18° Bedding joint
		93											92.9' 17° Bedding joint, thin, moderately to slightly weathered
		94											93.0' 17° Bedding joint, thin, moderately to slightly weathered
		95						Greenish gray [5GY 5/1], fine grained Sandstone, moderately laminated Claystone, hard, fresh.					93.3' 17° Bedding joint, thin, weathered Fractures 94.5' 17° Bedding joint 95.0' 49° Joint
		96					104		48				95.6' 85° Joint, moderately spaced
		97											95.6' 19° Joint 97.2' 17° Shear
		98											97.7' 10° Random fracture 98.4' 46° Joint
		99						Greenish gray [5GY 5/1], fine grained Sandstone, hard, fresh.					
		100											Fractures 99-103' 90° Joint/Shear, very thin
		101					86		9				101.5' 29° Joint
		102											102.7' 28° Joint
		103											
		104						Greenish gray [5GY 5/1], Sandstone, very hard to hard, fresh.					
		105											
		106					84		95				
		107											Fractures 107.4' 25° Joint
		108						Very dark gray [N3], Claystone, Bedding 20°, very thinly laminated with fine grained Sandstone, very thinly laminated, Carbonaceous strings, hard, fresh.					
		109											
		110											
		111					114		84				Fractures 111.2' 20° Bedding joint, moderately thin, moderately soft, moderately weathered 111.4' 19° Shear/Bedding joint, moderately thin,
		112											
		113											

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							114	Very dark gray [N3], Claystone, Bedding 25°, very thinly laminated with Carbonaceous, hard, fresh.	84				moderately soft, moderately weathered 112.0' 19° Shear/Bedding joint, thin, moderately weathered 113.3' 17° Bedding joint, very thin, moderately weathered 113.4-113.7' 18° intensely fractured, thin, gouge with angular Fractures 116.8' 7° Joint 116.9' 80° Joint 117.1' 25° Joint/Bedding joint
		114											
		115											
		116					100		77				
		117											
		118											
		119						Very dark gray [N3], Claystone, very thinly laminated, with Carbonaceous, moderately hard, fresh.					118.6' 25° Bedding joint
		120											Fractures 120.2' 9° Joint 120.3' 23° Shear, moderately thin, moderately weathered
		121					100		87				
		122											121.9' 7° Joint, slightly weathered to fresh
		123											
		124											
		125						Greenish gray [5GY 5/1], fine grained Sandstone, hard, fresh.					Fractures 124.7' 21° Joint 124.8' 24° Joint
		126											
							106	Black [N2], Coal.	93				
		127						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 21°, hard, fresh, strong reaction to HCl.					
		128											
		129						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 21°, hard, fresh, strong reaction to HCl.					
		130											
		131					96		100				
		132											
		133											
		134						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 22°, moderately laminated with Greenish gray [5GY 5/1] Siltstone, grading to Claystone, strong reaction to HCl.					
		135					96		83				
		136											

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		137		X			96	Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 22°, moderately laminated with Greenish gray [5GY 5/1] Siltstone, grading to Claystone, strong reaction to HCl. *(Continued)*	83				Fractures 136.2' 58° Joint/Shear
		138		X									138' 8° Mechanical break 138.4' Mechanical break
		139		X				Very dark gray [N3], Claystone, Bedding 25°, very thinly laminated with Carbonaceous string 1/16", moderately hard, fresh, no reaction to HCl.					
		140		X			75		100				
		141		X				Very dark gray [N3], Claystone, Bedding variable, moderately hard, fresh, no reaction to HCl.					
		142		X			100		97				
		143		X									
		144		X				Very dark gray [N3], Claystone, very thinly laminated Carbonaceous, moderately hard, slightly weathered to fresh, no reaction to HCl.					Fractures 144.2' 32° Shear, moderately thin, intensely to moderately weathered 144.4' 33° Shear, moderately thin, intensely to moderately weathered 144.5' 35° Shear, moderately thin, intensely to moderately weathered 144.7' 35° Shear, thin, moderately weathered 145.7-146.0' 12° intensely fractured 146.7' 17° moderately hard, fresh
		145		X									
		146		X			98		71				
		147		X									
		148		X									
		149		X				Very dark gray [N3], Claystone, moderately hard, fresh, strong reaction to HCl.					
		150		X									
		151		X			100		86				Fractures 151.6' 20° Random fracture 151.8' 7° Random fracture 152.1' 8° Joint
		152		X									
		153		X				Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 21°, very thinly laminated Carbonaceous strings, hard, fresh, strong reaction to HCl.					153.6' 21° Mechanical break
		154		X									
		155		X									
		156		X			100	Very dark gray [N3], Claystone, variable bedding with flow structures, very thinly laminated with fine grained Sandstone, moderately hard, fresh, strong reaction to HCl.	96				
		157		X									
		158		X									Fractures 158.3' 20° Bedding joint, slightly weathered to fresh
		159		X									

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		160						Very dark gray [N3], Claystone, variable bedding with flow structures, very thinly laminated with fine grained Sandstone, moderately hard, fresh, strong reaction to HCl. *(Continued)*					
		161					74		86				
		162											
		163											
		164						Very dark gray [N3], Claystone, Bedding 21°, thinly laminated with Grayish brown [2.5Y 5/2] Claystone, hard, fresh.					
		165						Grayish brown [2.5Y 5/2], Claystone, very soft, intensely to moderately weathered.					Fractures 165.3' 0° thick, 1.75" intensely to moderately weathered
		166							54				166.7' 21° Bedding joint, clean, slightly weathered to fresh
		167											
		168						Black [N2], Coal, Bedding 16°, very hard, fresh, Bed No. 1 1/2.					Top of #1.5
		169											
		170											Joints in coal are discontinuous, cleats, perpendicular to bedding, closely spaced
		171					100		66				Fractures 169.7' 17° Bedding joint
		172											Joints in coal are discontinuous, vertical joints, closely spaced
		173											Fractures 172.0' 65° Joint
								Dark grayish brown [2.5Y 4/2], Claystone, very soft, very intensely weathered.					
		174						Dark gray [N4], fine grained Sandstone, hard, fresh.					
		175											
		176						Black [N2], Claystone, moderately hard, fresh.					
		177					100		72				Fractures 177-177.8' 0-10° Bedding joint, moderately fractured, closely spaced
		178						Black [N2], Claystone, moderately soft, moderately to slightly weathered.					
								Dark gray [N4], fine grained Sandstone, hard, fresh.					178.5' 60° Joint
		179						Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding 14°, moderately laminated with medium to fine grained Sandstone, hard, fresh, no reaction to HCl.					
		180											
		181					100		100				
		182											

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		183		X			100	Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding 14°, moderately laminated with medium to fine grained Sandstone, hard, fresh, no reaction to HCl. *(Continued)*	100				
		184		X				Greenish gray [5GY 5/1], fine grained Sandstone, bedding, no reaction to HCl.					
		185		X									
		186		X			100		100				
		187		X									
		188		X									
		189		X				Greenish gray [5GY 5/1], fine grained Sandstone, massive, very hard, fresh, weak reaction to HCl.					Fractures 189.0' 70° Joint
		190		X									
		191		X			100		76				
		192		X									
		193		X									193.5' 70° Joint
		194		X				Greenish gray [5GY 5/1], fine grained Sandstone, massive, trace carbonaceous feather.					
		195		X				Greenish gray [5GY 5/1], medium grained Sandstone, hard, fresh, trace of pebbles.					
		196		X				fine grained Sandstone.					
		197		X			100	Dark greenish gray [5GY 4/1], Claystone, Bedding 17°, thinly laminated with Siltstone, very thinly laminated with Carbonaceous strings, strong reaction to HCl.	88				Fractures 196.8' 17° Bedding joint 197.7' 12° Bedding joint 198.2' 5° Joint 198.8' 10° Bedding joint
		198		X									
		199		X									
		200		X				Very dark gray [N3], Claystone, Bedding 15°, thinly laminated with siltstone and fine grained sandstone, strong reaction to HCl.					
		201		X			96		100				
		202		X									
		203		X									
		204		X			100	Very dark grayish brown [2.5Y 3/2], Siltstone ,Bedding 16°, thinly laminated with fine grained Sandstone, strong reaction to HCl.	96				
		205											

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		206						Very dark grayish brown [2.5Y 3/2], Siltstone ,Bedding 16°, thinly laminated with fine grained Sandstone, strong reaction to HCl. *(Continued)*					
		207					100	Gray [N5], fine grained Sandstone, hard, fresh, trace of Carbonaceous string, strong reaction to HCl.	96				Fracture 206.9' 15° Bedding joint
		208											
		209						Gray [N5], fine grained Sandstone, moderately laminated with Carbonaceous strings, very hard, fresh, strong reaction to HCl.					
		210											
		211											Fracture 210.7' 70° Joint, opposite dip of beds
							96		83				
		212											
		213											
		214						Gray [N5], fine grained Sandstone, moderately laminated with Carbonaceous strings, very hard, fresh, strong reaction to HCl.					
		215											214.7' 28° Bedding joint
		216											215.4' 36° Shear, very thin, not healed, some gouge 216' 29° Joint
							100		80				
		217											
		218											217.4' 35° Shear, moderately thin, is healed or recemented
		219						Gray [N5], fine grained Sandstone, moderately laminated with Carbonaceous strings, hard, fresh, strong reaction to HCl.					
		220											Fracture 219.7' 55° Joint
		221											
							100		68				
		222											
		223											Fracture 223.0' 45° Bedding joint
		224						Gray [N5], fine grained Sandstone, Bedding 18°, hard, fresh, moderately laminated with carbonaceous strings, strong reaction to HCl.					
		225											
		226					100		86				
		227											
		228											Fractures 227.7' 18° Bedding joint

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							100	Gray [N5], fine grained Sandstone, Bedding 18°, hard, fresh, moderately laminated with carbonaceous strings, strong reaction to HCl. *(Continued)*	86				282.2' 37° Joint 228.6' 7° Mechanical break
		229						Gray [N5], fine grained Sandstone, hard, fresh, moderately laminated with Greenish gray [5GY 5/1] fine grained Sandstone, moderately laminated with Carbonaceous strings, very hard, fresh, strong reaction to HCl.					
		230											
		231					96		92				Fractures 231.2' 16° Bedding joint 231.5' 17° Shear/Bedding joint 231.7' 30° Bedding joint
		232											
		233											
		234						Greenish gray [5GY 5/1], fine grained Sandstone, very thinly laminated with Carbonaceous strings, strong reaction to HCl.					
		235											Fractures 234.5' 78° Joint, slightly weathered to fresh
		236					98		78				236.2' 36° Bedding joint
		237											
		238											
		239						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 16°, variable flow structures, very thinly laminated with Carbonaceous strings, strong reaction to HCl.					
		240											
		241					70		89				
		242											
		243						Very dark gray [5Y 3/1], Siltstone, Bedding 15°, very thinly laminated with Dark gray [N4] Siltstone and very thinly laminated with Carbonaceous strings.					
		244											
		245											
		246					138		100				
		247											
		248						Black [5Y 2.5/1], Claystone, Moderately hard.					
		249					96	Black [N2], Coal, very hard, thinly laminated with Black N2.5 Claystone, Bed No. 2.	27				Fractures 249-252.9' 64°, Joint, closely spaced, approx 0.04" Three fractures in the group, no observable shear displacement
		250											
		251											

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								Black [N2], Coal, very hard, thinly laminated with Black N2.5 Claystone, Bed No. 2. *(Continued)*					Maintaining circulation then coal and above
		252					96		27				
													Fractures 252.9-256.8' 70° Joint, closely spaced, very thin, 25% healed, calcite 252.9-256.8' 90°, discontinuous, Joint, very closely spaced
		253											
		254											
		255											
							100		72				
		256											
		257						Black [5Y 2.5/1], Claystone, Moderately hard, slightly weathered.					Fracture 257.1' 28° Joint/Shear
		258						Black [2.5Y 2.5/1], Claystone, hard to moderately hard, slightly weathered to fresh.					
		259											Fractures 258.8' 0° Joint 259.2' 0° Joint 259.8' 0° Joint 260.2-261' 9° Joint 261.2' 45° Joint
		260											
		261					64		40				
		262											
		263											Fractures 262.9' 5° Joint 263.4' 5° Joint
		264						Black [5Y 2.5/1], Claystone, moderately hard, fresh.					263.9' 12° Joint, moderately thin, slightly weathered to fresh
		265											265.5' 16° Joint, very thin, slightly weathered
		266						Black [5Y 2.5/1], Claystone, moderately hard, slightly weathered to fresh, weak reaction to HCl.					266.5' 90° Joint
		267											267' 78° Shear
		268											268' 3° Joint
							90		61				
		269											269.3' 12° Joint
		270											
		271						Black [2.5Y 2.5/1], Claystone, moderately hard, slightly weathered to fresh, thinly laminated with Dark greenish gray [5GY 4/1] Claystone, moderately hard, slightly weathered to fresh.					
		272											
							132		100				Fracture 272.5' 5° Mechanical break
		273											
		274											

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		275					90	Black [5Y 2.5/1], Claystone, moderately laminated with Greenish gray [5GY 5/1] fine grained Sandstone, very thinly laminated with Carbonaceous strings, hard, fresh. *(Continued)*	100				274.6' 10° Mechanical break
		276											
		277					90		100				
		278											
		279						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 20°, thinly laminated with Black [5Y 2.5/1] Claystone, hard, fresh.					
		280											
		281					108		100				Fracture 280.4' 20° Mechanical break/Bedding joint
		282											
		283											
		284						Black [5Y 2.5/1], Claystone, Bedding 17°, thinly laminated with Very dark gray [5Y 3/1] fine grained Sandstone, thinly laminated with Carbonaceous strings, strong reaction to HCl.					
		285											
		286					92		100				
		287											
		288											
		289						Black [5Y 2.5/1], Claystone, thinly laminated with Dark gray [5Y 4/1] fine grained Sandstone,thinly laminated with Carbonaceous strings.					
		290											
		291					102		100				
		292											
		293											
		294						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 19°, thinly laminated with Black [5Y 2.5/1] Claystone, hard, fresh.					
		295					84		100				
		296											
		297											

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		298					84	Dark gray [5Y 4/1], fine grained Sandstone, Bedding 19°, thinly laminated with Black [5Y 2.5/1] Claystone, hard, fresh. *(Continued)*	100				
		299						Black [5Y 2.5/1], Claystone, Bedding 19°, hard, fresh.					Fracture 299.6' 5° Joint
		300											
		301					104		96				
		302											
		303											
		304						Black [5Y 2.5/2], angular gravels (GC) and Claystone, soft, clays are medium plasticity.					
								Black [5Y 2.5/2], Claystone, moderately hard, fresh.					Change to HQ from PQ
		305					100						
		306											Core is possible over drill from PQ
		307											Fractures 307.4-308.2' 90° Mechanical break
		308											
		309					135	Black [N2], Coal.	70				
		310						Black [5Y 2.5/2], Claystone, Bedding 17°, moderately soft, moderately to slightly weathered.					309.5-310.5' Intensely fractured
		311						Black [5Y 2.5/2], Claystone, Bedding 17°, hard, fresh.					Fracture 310.5-311.1' 90° Mechanical break
		312						Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with Carbonaceous strings and moderately laminated with Black [5Y 2.5/1] Claystone, hard, fresh.					
		313											
		314					98		92				
		315											
		316											Fracture 315.5' 14° Bedding joint
		317						Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with Carbonaceous strings and moderately laminated with Black [5Y 2.5/2] Claystone, hard, fresh, strong reaction to HCl.					
		318					96		88				
		319											Fractures 318.7' 17° Bedding joint, fresh 319.8' 5-15° Random fracture, some clay
		320											

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		321		X			96	Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with Carbonaceous strings and moderately laminated with Black [5Y 2.5/2] Claystone, hard, fresh, strong reaction to HCl. *(Continued)*	88				
		322		X				Dark gray [5Y 4/1], fine grained Sandstone, Bedding 16°, thinly laminated with Carbonaceous strings, hard, fresh, strong reaction to HCl.					Fracture 322.9' 13° Mechanical break/Bedding joint
		323		X			100		100				
		324		X				Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with Carbonaceous strings, hard, fresh, no reaction to HCl.					324.7' 66° Joint, hard, slightly weathered to fresh
		325		X									
		326		X			104		87				
		327		X									
		328		X									Fracture 328.5' 20° Bedding joint
		329		X									
		330		X				Black [5Y 2.5/2], Claystone, moderately laminated with coal strings, soft, intensely weathered.					Most fractures are all defined-possibly from drilling of intensely weathered materials
		331		X					16				
		332		X									Fractures 332-334' 90° very closely spaced, discontinuous 332.5' 65° Shear
		333		X				Black [N2], Coal, thinly laminated with Black (N2.5) Claystone, Bed No. 3.					
		334		X									Fractures 334-339' 80° Joint, very closely spaced, cleats
		335		X									335.5' 58° Shear/Joint
		336		X				Black [N2], Coal, blocky, breaks at cleats very easily, Bed No. 3.					336' 62° Shear/Joint
		337		X									
		338		X									334-339' 20° Joint, very closely spaced
		339		X				Black [N2], Coal, Bed No. 3.					
		340		X									Fractures 339.3' 0° Random fracture/Joint 340.2' 14° Bedding joint
		341		X			86		72				340.9' 20° Joint
		342		X				Black [N2], Claystone.					341.6' 14° Bedding joint 342' 40° Shear 342.3' 17° Joint
		343		X				Black [N2], Coal, Bedding 15°, moderately laminated with Black (N2.5) Claystone, Bed No. 3.					

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		344		X			86	Black [N2], Coal, Bedding 15°, moderately laminated with Black (N2.5) Claystone, Bed No. 3. *(Continued)*	72				339-344' 60° Shear/Joint, very thin, slightly opened, calcite, very closely spaced, discontinuous
		345		X									Fractures 345.2' 16° Bedding joint 345.4' 14° Bedding joint 345.6' 12° Bedding joint
		346		X			98		51				346.1' 16° Joint 346.3' 9° Joint
		347		X									347' 9° Joint 347.2' 17° Joint 347.5-347.9' Random fracture/intensely fractured, cleats
		348		X				Black [5Y 2.5/1], Claystone, soft, intensely weathered.					
		349		X									
		350		X				Greenish gray [5GY 5/1], Siltstone, hard, fresh, bedding not distinguishable, weak reaction to HCl.					
		351		X			98		100	29	8.1		
		352		X									
		353		X									
		354		X				Greenish gray [5GY 5/1], Siltstone, variable bedding, trace of coal feathers, hard, fresh, strong reaction to HCl.					
		355		X									
		356		X									
		357		X					100	29	8.1		
		358		X									
		359		X				Greenish gray [5GY 5/1], Siltstone, bedding variable flow structure, moderately laminated with fine grained Sandstone, hard, fresh, strong reaction to HCl.					
		360		X									
		361		X									
		362		X			98		100	30	8.2		
		363		X									
		364		X				Dark gray [N4], Siltstone, Bedding 35-60° with flow structure, moderately laminated fine grained Sandstone, hard, fresh, trace Carbonaceous strings, strong reaction to HCl.					
		365		X			100		100				
		366		X									

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		367, 368		X			100	Dark gray [N4], Siltstone, Bedding 35-60° with flow structure, moderately laminated fine grained Sandstone, hard, fresh, trace Carbonaceous strings, strong reaction to HCl. *(Continued)*	100				Fracture 366.6' 0° Mechanical break
		369, 370, 371, 372, 373		X			94	Dark gray [N4], Siltstone, Bedding 21°, moderately laminated, Carbonaceous strings, moderately laminated with fine grained Sandstone, hard, fresh, strong reaction to HCl.	100				
		374, 375, 376, 377, 378		X			100	Dark gray [N4], Siltstone, thinly laminated with Carbonaceous, moderately laminated with fine grained Sandstone, hard, fresh.	100				
		379, 380, 381, 382, 383		X			100	Dark gray [N4], Siltstone, thinly laminated with Carbonaceous strings, hard, fresh.	80				Fractures 379.7' 35° Bedding joint, fresh 381.0' 35° Bedding joint, moderately to slightly weathered, moderately thin 381.7' 7° Joint, slightly weathered to fresh
		384, 385, 386, 387, 388		X			100	Dark gray [N4] Gray [N5], Siltstone, variable bedding, thinly laminated with carbonaceous strings, hard, fresh.	100				
		389		X				Dark gray [N4] Gray [N5], Siltstone, thinly laminated with fine grained Sandstone and Claystone, hard, fresh.					

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		390, 391, 392, 393					94	Dark gray [N4] Gray [N5], Siltstone, thinly laminated with fine grained Sandstone and Claystone, hard, fresh. *(Continued)*	100	30	8.3		
							94		100	30	8.3		
		394, 395, 396, 397, 398					106	Dark greenish gray [5GY 4/1], Claystone, moderately laminated with Gray [N5] Siltstone and Gray [N5] fine grained Sandstone, moderately hard, fresh, strong reaction to HCl.	100				
		399, 400, 401, 402, 403					86	Dark greenish gray [5GY 4/1], Claystone, Bedding 21-28°, thinly laminated with fine grained Sandstone and Siltstone, hard, fresh, strong reaction to HCl.	95	32	8.7		Fractures 399.7' 20° Joint, slightly weathered to fresh
		404, 405, 406, 407, 408					100	Dark greenish gray [5GY 4/1], Claystone, Bedding 20-25°, thinly laminated with fine grained Sandstone and Siltstone with trace Carbonaceous strings, hard, fresh, strong reaction to HCl.	100	30	8.3		
		409, 410, 411, 412					102	Dark greenish gray [5GY 4/1], Claystone, moderately laminated with fine grained Sandstone and Siltstone, trace Carbonaceous strings, strong reaction to HCl.	100	32	8.7		

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		413		X			102	Dark greenish gray [5GY 4/1], Claystone, moderately laminated with fine grained Sandstone and Siltstone, trace Carbonaceous strings, strong reaction to HCl. *(Continued)*	100	32	8.7		
		414		X				Dark gray [N4], fine grained Sandstone, massive, very hard, fresh, strong reaction to HCl.					
		415		X									
		416		X			109		100	31	8.4		
		417		X									
		418		X									
		419		X				Dark gray [N4], fine grained Sandstone, very hard, fresh, massive, strong reaction to HCl.					
		420		X									
		421		X			96		100				
		422		X									
		423		X									
		424		X				Dark gray [N4], fine grained Sandstone, Bedding 20°, moderately to thinly laminated with Carbonaceous strings, very hard, fresh, massive, strong reaction to HCl.					
		425		X									
		426		X			108		100				
		427		X									
		428		X									
		429		X				Dark gray [N4], fine grained Sandstone, thinly laminated with Carbonaceous strings, very hard, fresh, massive, strong reaction to HCl.					
		430		X									
		431		X			98		100				
		432		X									
		433		X									
		434		X				Gray [N5], fine grained Sandstone, Bedding 17°, moderately laminated with Very dark gray [N3] Claystone, very hard, strong reaction to HCl.					
		435		X			102		100	28	7.8		

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		436						Gray [N5], fine grained Sandstone, Bedding 17°, moderately laminated with Very dark gray [N3] Claystone, very hard, strong reaction to HCl. *(Continued)*					
		437					102		100	28	7.8		
		438											
		439						Very dark gray [N3], Claystone, Bedding 25°, variable bedding with flow structures, moderately laminated with Gray [N5] fine grained Sandstone, hard, fresh.				
		440											
		441					96		100	26	7.5		
		442											
		443											
		444						Gray [N5], fine grained Sandstone, Bedding 26°, moderately laminated with Very dark gray [N3] Claystone, hard, fresh.					
		445											Fractures 445' 20° Shear, parallel with beds, some gouge, very thin, moderately to slightly weathered 446' 30° Joint, dips into beds
		446					102		94				
		447											
		448											
		449											
		450						Very dark gray [N3], Bedding 19°, hard, fresh.					
		451					94		100	29	8.1		
		452											
		453											
		454						Very dark gray [N3], Claystone, Bedding 24°, thinly laminated with Dark gray [N4] Siltstone, hard, fresh.					
		455											
		456					100		100	31	8.5		
		457											
		458											

PIONEER TECHNICAL SERVICES, INC.

CLIENT: Montana Department of Environmental Quality

ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-04

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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
		459		X			100	Very dark gray [N3], Claystone, Bedding 24°, thinly laminated with Dark gray [N4] Siltstone, hard, fresh. *(Continued)*	100	31	8.5		
		460		X									
		461		X			92		100				
		462		X				Dark gray [N4], Claystone, Bedding 23°, hard, fresh, strong reaction to HCl.					
		463		X									
		464		X				Dark gray [N4], Claystone, very thinly laminated with fine grained Sandstone, hard, fresh.					
		465		X									
		466		X			102		96	28	7.8		
		467		X									
		468		X									Fracture 468.3' 20° Joint, slightly weathered
		469		X				Dark gray [N4], Claystone, hard, fresh.					
		470		X									470.3' 18° Bedding joint, moderately hard, moderately to slightly weathered
		471		X			106		82	29	8.1		
		472		X				Void, top of caved Bed No. 4.					Lost water at 472.3', void from 472.3-472.4' easy drilling to 474.0'
		473		X				3 pieces of gravel composed of Claystone, hard, fresh, probably caved.					
		474		X				Dark gray [N4], Claystone, hard, fresh with Gray [N5] clay. Core fragment are drilled on multiple surfaces, suggesting loose, caved material.					
		475		X									
		476		X			60		0	24	7.2		One piece is 1' in length and another piece is 0.5' Rods dont' fall, but drilling is bouncing, drilling loose material
		477		X									
		478		X									
		479		X				Dark gray [N4], Claystone, hard, slightly weathered, pieces are drilled on multiple surfaces, suggesting loose, caved material.					
		480		X			67		0	27	7.7		
		481		X									

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		482		X			67	Dark gray [N4], Claystone, hard, slightly weathered, pieces are drilled on multiple surfaces, suggesting loose, caved material. *(Continued)*	0	27	7.7		Drill popped through a rock and started another, not able to measure distance
		483		X									
		484		X				Dark gray [N4], Claystone, hard, moderately to slightly weathered, some fracture faces are weathered approx 1/8" from face, stained. Core pieces are drilled on multiple surfaces.					Two pieces of core are 0.5' in length One piece is 0.7' in length but not in place
		485		X									
		486		X			42		0				Six foot run to reach something to hold tube
		487		X									
		488		X									
		489		X				Black [5Y 2.5/2], LEAN CLAY, CL, medium plasticity, soft, intensely to moderately weathered, trace of coal feathers, stiff but can be broken by hand, too stiff for pocket pen.					
		490		X									
		491		X									Fractures 489.5-494' 30° Bedding joint, moderately spaced
		492		X			98		57				
		493		X									
		494		X				Black [5Y 2.5/2], medium plasticity, Claystone with gravel, moderately soft, moderately weathered, appears broken, maybe caved, pieces of coal mixed with the Clayey gravel, GC.					
		495		X									
		496		X			65		0				
		497		X				Black [5Y 2.5/2], Claystone, Bedding 13°, moderately hard, slightly weathered, coal feathers.					Possible bottom of Bed No. 4
		498		X									
		499		X									
		500		X									Fractures
		501		X			98	Black [N2], Coal, blocky, Bed No. 4 1/2.	38				498.6-501' 14° Bedding joint, moderately spaced
		502		X									501-503.7' 85° very thin, very closely spaced, discontinuous, calcite filled
		503		X									501-507.7' 15° Bedding joint, moderately spaced
		504		X			79		36				

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		505						Black [N2], Coal, blocky, Bed No. 4 1/2. *(Continued)*					Fractures 503.7-506.2' 80° Joint, very closely spaced, discontinuous 503.7-506.2' 20° Bedding joint, very closely spaced, partly healed 506.2-509' 0-10° Mechanical break, widely spaced
		506											
		507					79	LEAN CLAY, CL.	36				
		508											
		509						Greenish gray [5GY 5/1], fine grained Sandstone, thinly laminated with Dark greenish gray [5GY 4/1] Claystone, hard, fresh.					Fractures 510' 15° Bedding joint
		510											
		511						Dark greenish gray [5GY 4/1], Claystone, moderately soft, slightly weathered.	74				511.2' 17° Bedding joint
		512											512' 16° Bedding joint 512.1' 16° Bedding joint
		513											513-514' Bedding joint, very closely spaced
		514						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 19°, thinly laminated with Dark greenish gray [5GY 4/1] Claystone and thinly laminated with Carbonaceous strings, hard, fresh.					
		515											Fractures 515.4' 19° Bedding joint
		516					100		88				
		517											517' 9° Bedding joint, moderately soft, moderately to slightly weathered 517.6' 17° Bedding joint
		518											518.3' 17° Bedding joint, moderately soft, moderately to slightly weathered
		519						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 17°, thinly laminated with Dark greenish gray [5GY 4/1] Claystone, moderately laminated with Carbonaceous strings.					
		520											Fractures 520' 19° Bedding joint, slightly weathered, moderately thin
		521					98		88				521' 5° Joint, slightly weathered
		522											
		523											
		524						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 24°, moderately laminated Greenish gray [5GY 5/1], hard, fresh.					
		525					100		84				Fractures 524.5' 60° Joint, moderately thin, hard, fresh
		526											526.4' 30° Joint, moderately hard, slightly weathered
		527											

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		528		X			100	Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 24°, moderately laminated Greenish gray [5GY 5/1], hard, fresh. *(Continued)*	84				527.4' 70° Joint/Shear, very thin, fresh, not healed
		529		X				Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding 20°, thinly laminated with Dark greenish gray [5GY 4/1] Claystone, hard, fresh.					
		530		X									
		531		X			96		100				
		532		X									
		533		X									
		534		X				Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 19°, very thinly laminated with Dark greenish gray [5GY 4/1] Claystone, hard, fresh.					
		535		X									Fracture 535.2' 17° Joint, moderately soft, moderately weathered
		536		X			100		98				
		537		X									
		538		X									
		539		X									
		540		X									Fractures 539.7' 25° Bedding joint
		541		X									539.7-541' 75° Shear, totally healed, moderately thin, slightly open, closely spaced
				X			94		81				541' 26° Bedding joint
		542		X									
		543		X									542.7' 28° Bedding joint
		544		X				Very dark gray [5Y 3/1], Claystone, moderately laminated with Carbonaceous strings, moderately hard, slightly weathered to fresh.					
		545		X									Fractures 545.5' 15° Bedding joint, thin, moderately soft, moderately weathered
		546		X			104		88				
		547		X									547.4' 20° Bedding joint, very thin, moderately soft, moderately weathered
		548		X									
		549		X				Very dark gray [5Y 3/1], Claystone, Bedding 26°, moderately laminated with Carbonaceous strings, moderately hard, slightly weathered to fresh.					
		550		X			94		100				

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Drill Hole No. BH-04

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		551						Very dark gray [5Y 3/1], Claystone, Bedding 26°, moderately laminated with Carbonaceous strings, moderately hard, slightly weathered to fresh. *(Continued)*					
		552					94		100				
		553											
		554						Very dark gray [5Y 3/1], Claystone, Bedding 21-26°, moderately laminated with Carbonaceous strings, moderately hard, slightly weathered to fresh.					
		555											
		556											
							106		91				
		557											
		558											Fractures 557.7' 15° Shear, very thin, moderately hard, moderately weathered, not healed 558.2' 15° Joint/Bedding joint, moderately thin, moderately hard, moderately to slightly weathered 558.6' 21° Bedding joint, very thin, moderately hard, moderately to slightly weathered 558.7' 21° Bedding joint 559.9' 27° Joint, moderately thin, moderately soft, moderately weathered, not healed
		559						Very dark gray [5Y 3/1], Claystone, moderately laminated with Carbonaceous strings, moderately hard, slightly weathered to fresh.					
		560											
		561											
							94		96				
		562											
		563											
		564						Very dark gray [5Y 3/1], Claystone, moderately laminated with Carbonaceous strings, moderately hard, slightly weathered to fresh.					
		565											
		566											
							104		96				
		567											Fracture 567.5' 28° Bedding joint
		568											
		569						Very dark gray [5Y 3/1], Claystone, variable flow bedding, moderately laminated with Siltstone, moderately laminated with Carbonaceous strings, hard, fresh.					
		570											Fractures 569.5' 48° Joint, moderately thin, moderately hard, moderately to slightly weathered 569.6' 42° Joint, thin, moderately soft, moderately to slightly weathered 572.7' 42° Bedding joint, very thin, moderately hard, slightly weathered
		571					96		71				
		572											
		573											

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							96		71				572.8' 42° Bedding joint 573.2' 42° Bedding joint
		574						Very dark gray [5Y 3/1], Claystone, Bedding 40°, thinly laminated with Gray [N5] fine grained Sandstone and Carbonaceous strings.					Fractures 574.5' 38° Bedding joint
		575											
		576											575.7' 35° Bedding joint
							104		87				
		577											577' 30° Joint, thin, moderately soft, moderately to slightly weathered
		578											
		579						Very dark gray [5Y 3/1], Claystone, moderately laminated with Gray [N5] fine grained Sandstone and moderately laminated with Carbonaceous strings.					
		580											
		581											
							100		96				
		582											
		583											Fracture 582.6' 32° Joint, thin, moderately hard, moderately to slightly weathered
		584						Very dark gray [5Y 3/1], Claystone, thinly laminated with Dark gray [N4] fine grained Sandstone and moderately laminated with Carbonaceous strings.					
		585											
		586											
							104		76				
		587											
		588											
		589						Very dark gray [5Y 3/1], Claystone, Bedding 24°, thinly laminated with Dark gray [N4] fine grained Sandstone, hard, fresh.					
		590											
		591											Fractures 591' 24° Bedding joint 591.4' 24° Bedding joint 591.6' 31° Bedding joint
							100		80				
		592											
		593											
		594						Very dark gray [5Y 3/1], Claystone, Bedding 23°, thinly laminated with Dark gray [N4] fine grained Sandstone, hard, fresh.					
		595					108		89				
		596											

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		597						Very dark gray [5Y 3/1], Claystone, Bedding 23°, thinly laminated with Dark gray [N4] fine grained Sandstone, hard, fresh. *(Continued)*					Fractures 596.7' 12° Bedding joint
		598					108		89				597.5' 16° Bedding joint
		599						Gray [N5], fine grained Sandstone, 17° Bedding variable, thinly laminated with Very dark gray [5Y 3/1].					
		600											
		601					92		93				Fracture 601.2' 17° Bedding joint, thin, moderately soft, moderately weathered
		602											602.5' 17° Bedding joint, thin, moderately soft, moderately weathered
		603						Very dark gray [5Y 3/1], Claystone, moderately laminated with Gray [N5] fine grained Sandstone, moderately hard, slightly weathered to fresh, strong reaction to HCl.					
		604											
		605											Fractures 604.4' 20° Bedding joint, clean, moderately hard 604.8' 20° Bedding joint, thin, moderately soft, moderately weathered 605-605.5' 90° Joint, Intensely to moderately fractured
		606					100		74				
		607											
		608											
		609						Very dark gray [5Y 3/1], Claystone, moderately soft, slightly weathered.					608.5' 36° Shear, moderately thin, moderately hard, moderately to slightly weathered
		610											Fractures 610.5' 80° Shear, moderately thin, moderately soft, moderately to slightly weathered, not healed, moderately spaced
		611					80		28				
		612						1" thick lense of Coal.					611.0' 38° Shear, moderately thin, moderately soft, moderately to slightly weathered
		613						Claystone.					612.7' 75° Shear, very thin, moderately healed, moderately spaced
		614											
		615						Black [N2], Coal, core, Bedding approx 42°, Bed No. 5.					Driller states very soft drilling, core is intensely fractured, blocky. Fell completely apart upon sliding out of split, particles broke into coarse sand to 2" gravel size, mostly 1" gravel
		616											
		617					74		27				
		618											
		619						Black [N2], GP, Coal, not intact.	0				

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		620						Very dark gray [5Y 3/1], CLAYEY GRAVEL, GC, claystone gravels with clay.					Heaved into tube and block off water, had to pull tube. Tube recovered (GP) of coal from sand to 1.5" diameter .
								Black [N2], Coal, partial core with fractures, partial core, intensely fractured into sand sized particles, Bed No. 5.					Driller states hit a 3 small voids approx 0.5' each
		621											
		622							0				Fractures 622' 50° Shear 622' 80° Shear
		623											
		624						Black [N2], Poorly graded gravels, gravels are coal, blocky, 6" of intact coal core above claystone at 633-633.5'.					
		625											10' run to prevent sand heave and blocking off water
		626											
		627											Driller states very loose drilling from 625-629', very little down pressure needed, but rods wouldn't fall
		628											
		629											
		630						Black [N2], Coal, Bed No. 5.					
		631											
		632											
		633											
		634						Very dark gray [5Y 3/1], Claystone, moderately soft, slightly weathered.					
		635						Very dark gray [5Y 3/1], Siltstone, moderately laminated with Very dark gray [5Y 3/1] fine grained Sandstone, hard, fresh.					Fractures
		636					104		25				634-639' (20-42°) Joint, Shear, very thin, moderately hard, moderately to slightly weathered, closely spaced 637.8-638.2' Joint/Shear, thin, moderately soft
		637											
		638											638.5' 17° Joint, moderately soft, moderately to slightly weathered
		639						Very dark gray [5Y 3/1], Claystone, moderately soft, moderately weathered.					
		640						Very dark gray [5Y 3/1], Siltstone, hard, slightly weathered to fresh.					
		641					100	Very dark gray [5Y 3/1], Claystone, moderately soft, moderately to slightly weathered.	45				
		642											

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		643		X			100	Olive gray [5Y 5/2], fine grained Sandstone, hard, fresh, 1" layer of Claystone, moderately soft, moderately to slightly weathered at 643'. *(Continued)*	45				
		644		X				Dark gray [5Y 4/1], fine grained Sandstone, hard, fresh, massive.					
		645		X			100		90				
		646		X									
		647		X									Fracture 647' 20° Joint, moderately thin, moderately hard, moderately to slightly weathered
		648		X				Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with Very dark gray [5Y 3/1] Claystone, hard, fresh, no reaction to HCl.					
		649		X									
		650		X			100		100				
		651		X									
		652		X									
		653											Total depth=652.9'
		654											
		655											
		656											
		657											
		658											
		659											
		660											
		661											
		662											
		663											
		664											
		665											

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ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-04A

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/11/14 - 8/11/14	DRILLER:
LOGGED BY: M. Browne	DRILL TYPE: Hand Auger
GROUND SURFACE ELEVATION:	HOLE DIAMETER: 2"
BOREHOLE LOCATION: See Figure 4-2	HAMMER TYPE: None

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								Sod.					
		1			X	G14549		Dry, Very dark brown [7.5YR 2.5/2], SILTY SAND with Gravel, SM, low plasticity, no reaction to HCl, Fill, trace of organics, grass and tree roots, trace glass, and 4" long railroad spike, trace mica flakes, gravels are rounded.					
		2											
		3											Refusal at 3.0'
		4											
		5											
		6											
		7											
		8											
		9											
		10											
		11											
		12											
		13											
		14											
		15											
		16											
		17											
		18											
		19											
		20											
		21											

PIONEER TECHNICAL SERVICES, INC.

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ADDRESS: P.O. Box 200901 Helena, Montana 59620-0901	
PHONE NUMBER:	

Drill Hole No. BH-04B

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/11/14 - 8/11/14	DRILLER:
LOGGED BY: M. Browne	DRILL TYPE: Hand Auger
GROUND SURFACE ELEVATION:	HOLE DIAMETER: 2"
BOREHOLE LOCATION: See Figure 4-2	HAMMER TYPE: None

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		1			X	G14550		Sod. Dry, Very dark brown [7.5YR 2.5/2], SILTY SAND with Gravel, SM, non-plastic, no reaction to HCl, Fill, trace organics, roots, debris including glass, 2" diameter metal object, wire fitting, coal. Trace mica flakes.					Refusal at 4.5'
		2											
		3											
		4											
		5											
		6											
		7											
		8											
		9											
		10											
		11											
		12											
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CLIENT: Montana Department of Environmental Quality	
ADDRESS: P.O. Box 200901 Helena, Montana 59620-0901	
PHONE NUMBER:	

Drill Hole No. BH-05

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/11/14 - 10/20/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5575.50 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 339814.001, E. 2034327.129	HAMMER TYPE: None

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		1, 2, 3			X	G14565		Dry, Dark gray [2.5Y 4/1], POORLY GRADED SAND, SP, non-plastic, weak reaction to HCl.					Hit buried metal, moved 5' south, more buried metal, drill rig swivel broke
		4, 5, 6, 7, 8			X	G14571		Dry to Damp, Light brownish gray [2.5Y 6/2], POORLY GRADED GRAVEL, GP, non-plastic, with frequent well-graded sand (SW) lenses, no reaction to HCl.					Cuttings generally dry to damp, intermittent water between 8-14' in cuttings, approx. 10 gallons total
		9			X	G14566		Damp, Light brownish gray [10YR 6/2], WELL GRADED SAND with Gravel, SW, non-plastic, no reaction to HCl.					
		10, 11, 12, 13, 14			X	G14567		Damp, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL with SILT AND SAND, GP-GM, non-plastic, weak reaction to HCl.					
		15, 16, 17, 18, 19			X	G14568		Damp, Brown [10YR 4/3], Sandstone, weak reaction to HCl.					Sandstone cuttings are pulverized and have characteristics similar to silty sand
		20, 21			X	G14569		Damp, Dark yellowish brown [10YR 4/4], Sandstone.					

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		22						Damp, Dark yellowish brown [10YR 4/4], Sandstone. *(Continued)*					
		23											
		24											
		25				G14569							
		26											
		27											
		28											
		29											
		30						Damp, Dark grayish brown [10YR 4/2].					
		31											
		32				G14570							
		33											
		34						Very dark gray [5Y 3/1], Claystone, moderately soft, moderately weathered.					Drill casing to 34'
		35											Drill center bit to 35', placed bentonite chips to 32.8'
		36											
		37											36.5' Begin PQ drilling Fractures 37.3' 17° Bedding joint, moderately soft, clean 37.6' 68° Joint, moderately soft, clean 37.7' 68° Joint, moderately soft, clean
		38						Coal.					
		39					96	Claystone.					
		40											
		41											
		42						Dark gray [N4], fine grained Sandstone, Bedding 16°, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		43					100		56				Fractures 42.7' 16° Bedding joint 43.5' 0° Random fractures 44.1' 29° Bedding joint
		44											

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		45					100	Very dark gray [5Y 3/1], Claystone, thinly laminated with carbonaceous strings, moderately hard, slightly weathered. *(Continued)*	56				44.2' 85° Bedding joint, soft, moderately thin 44.4' 29° Bedding joint, partly healed 44.8' 31° Bedding joint, partly healed
		46						Very dark gray [5Y 3/1], Claystone, moderately hard, moderately weathered, trace of coal at 50.9'.					
		47											
		48					85		26				Fractures 46.0-48.0' 55° Shear, moderately soft, moderately spaced (0.8') 46.4' 30° Shear, moderately soft 48.4' 72° Joint 49.1' 25° Shear
		49											
		50											
		51						Very dark gray [5Y 3/1], Siltstone, Bedding 25°, moderately hard, slightly weathered, moderately laminated with Very dark gray [5Y 3/1] Claystone, moderately soft, moderately to slightly weathered.					
		52					113		0				Fractures
		53						Very dark gray [5Y 3/1], Claystone, Bedding variable 10-19°, moderately soft, moderately to slightly weathered, trace of coal at 54.3' approx 1/2" thick.					50.9'-54.0' 25° Shear, moderately thick, soft, closely spaced (0.2") Gouge in all Shears, CH and fine angular gravel, fractures are on bedding planes 54.2' 24° Joint, moderately soft 54.4' 14° Bedding joint 54.7' 19° Shear, moderately soft, moderately thick 55.2' 27° Joint, moderately soft, clean 55.8' 46° Shear, moderately soft, moderately thin 56.7' 21° Joint/Shear, moderately soft 57.0' 12° Bedding joint 57.7' 17° Bedding joint/Shear
		54											
		55											
		56					90		40				
		57											
		58						Dark gray [5Y 4/1], Claystone, hard, slightly weathered to fresh.					
		59											58-59' Random fractures, intensely to Moderately fractured
		60						Black [N2], Coal, hard, Bed No. 1.					
		61						Black [5Y 2.5/1], Claystone, moderately soft, moderately to slightly weathered.					Fractures 59-60.5' intensely to moderately fractured 59.5' 80° Joint 61.4' 27° Shear, thin 61.7' 10° Joint, clean, hard 62.6' 13° Joint, clean, hard 62.8' 17° Bedding joint, clean, hard 63.0' 17° Bedding joint 63.3' 10° Joint
		62					100	Black [N2], Coal, Bed No. 1.	34				
		63											
		64						Black [N2], Coal, hard, Bed No. 1.					
		65											Fractures 64.5' 13° Bedding joint 65.2' 5° Shear, thin, moderately hard 66.2' 14° Shear, moderately thin, moderately hard
		66					100		56				
		67											

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								Black [N2], Coal, hard, Bed No. 1. *(Continued)*					66.9' 6° Joint/Bedding joint
		68					100	Black [N2], Coal, broken on cleats 1/2" to sand sized, Bed No. 1.	56				67.9' 6° Joint/Bedding joint 68-69' Intensely fractured, broken on cleats
		69						Black [N2], Coal, Bed No. 1.					
		70											Fractures 69.3' 45° Shear, clean, hard
		71											70.7' 35° Shear, very thin, hard
							94	Very dark gray [5Y 3/1], Claystone with ground up coal chips (GC).	53				71.4-71.9' Shear, thick, 0.5' thick
		72						Dark olive gray [5Y 3/2], Siltstone, Bedding 17°, very hard, slightly weathered to fresh.					
		73											73.3' 17° Joint/Shear, clean, very hard
		74						Dark olive gray [5Y 3/2], Siltstone, Bedding 16°, very hard, slightly weathered to fresh.					
		75											
		76					100		90				
		77											
		78											Fractures 77.7' 17° Shear, very thin, moderately hard 77.8' 17° Shear, very thin, hard
		79						Dark gray [5Y 4/1], Siltstone, Bedding 21°, with flow structures, very hard, slightly weathered to fresh.					78.2' 16° Shear/bedding joint, moderately hard, thick
		80											
		81						Very dark gray [5Y 3/1], Claystone, Bedding 20°, hard, slightly weathered to fresh.					Fractures 80.9' 16° Joint/Shear, clean, hard
		82					92		89				81.0' 16° Joint/Shear, clean, hard
		83											
		84						Dark greenish gray [5GY 4/1], Claystone, moderately laminated with Siltstone, hard, slightly weathered to fresh.					
		85											
		86					100	Black [5Y 2.5/1], Claystone, very thinly laminated with coal strings, moderately soft, moderately to slightly weathered.	72				86-87' Shear along bedding, most deformation is between 86.6-87.0' sand to clay gouge
		87						Dark greenish gray [5GY 4/1], Claystone, Bedding 20°, hard, slightly weathered to fresh.					
		88											87-89' water remains in bedding joints as sample drys, moderately spaced
		89											
		90					100	Dark gray [5Y 4/1], fine grained Sandstone, very thinly laminated with Black N2.5 Claystone, hard, slightly weathered to fresh.	96				Fractures 90.2' 24° Joint

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		91						Dark gray [5Y 4/1], fine grained Sandstone, very thinly laminated with Black N2.5 Claystone, hard, slightly weathered to fresh. *(Continued)*					
		92					100		96				
		93											
		94											
		95						Gray [5Y 5/1], Siltstone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					Fractures 95.5' 73° Joint/Shear, not healed, moderately thin, soft
		96					100		74				
		97						Very dark gray [5Y 3/1], Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		98											
		99											
		100						Black [N2], Coal.					Fractures 99.3' 36° Shear 99.8' 17° Bedding joint 100.5' 17° Bedding joint 99.8-100.5' Coal has discontinuous cleats, very closely spaced
		101					88	Dark gray [5Y 4/1], Claystone, Bedding 16°, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.	73				
		102											
		103											
		104											
		105						Dark gray [5Y 4/1], Claystone, hard, slightly weathered to fresh.					Fractures 104.4' 44° Shear, moderately soft, moderately thin
		106					100		70				105.4' 17° Bedding joint/Shear, moderately hard, moderately thick
		107						Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					106.3' 18° Bedding joint,Shear, moderately hard, moderately thin 107.2' 8° Shear, moderately soft, thick, (0.3') 107.7' 16° Bedding joint, hard, very thin
		108											
		109						Dark gray [5Y 4/1], fine grained Sandstone, variable bedding with flow structures, very thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		110											
		111					96		94				
		112											Fractures 112.3' 5° Joint, clean, hard 112.9' 8° Joint, clean, hard
		113											

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							96	Dark gray [5Y 4/1], fine grained Sandstone, variable bedding with flow structures, very thinly laminated with carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*	94				
		114						Dark gray [5Y 4/1], fine grained Sandstone, variable bedding, very thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		115											
		116					100		100				
		117											
		118											
		119						Dark gray [5Y 4/1], Claystone, very thinly laminated with carbonaceous strings, breaks with hand pressure on carbonaceous, hard, slightly weathered to fresh.					
		120											Fractures 119.7' 14° Bedding joint 119.8' 14° Bedding joint 120.4' 15° Bedding joint, coal feather
		121											
							84		90				
		122											
		123											
		124						Dark gray [5Y 4/1], Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		125											
		126											
							92		100				
		127											
		128											
		129						Dark gray [5Y 4/1], Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		130											
		131											Fractures
							108		91				131-131.8' Mechanical break, difficulty removal of splits from barrel 132.5' 28° Shear
		132											
		133											133.4' 0° Mechanical break
		134						Dark gray [5Y 4/1], fine grained Sandstone, hard, slightly weathered to fresh.					
		135					100		0				Fractures 134-138.5' 90° Joint, very thin, 25% healed, calcite on joint face
		136											

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		137		X			100	Dark gray [5Y 4/1], fine grained Sandstone, hard, slightly weathered to fresh. *(Continued)*	0				Driller broke most of sample removing from barrel, joint is from previous fracture, most other fractures from driller
		138		X									
		139		X									
		140		X				Dark gray [5Y 4/1], Claystone, moderately laminated with fine grained sandstone, Hard, slightly weathered to fresh.					
		141		X			100		90				
		142		X									Fracture 142' 59° Shear/Joint, very thin, moderately hard
		143		X									
		144		X				Dark gray [5Y 4/1], Claystone, moderately laminated with Very dark gray [5Y 3/1] Claystone and Dark gray [5Y 4/1] Siltstone, thinly laminated with carbonaceous strings.					
		145		X									
		146		X									Fractures 145.7' 72° Joint, clean, hard
							100		72				146.5' 15° Bedding joint/Shear, very thin, soft, not healed
		147		X				Very dark gray [5Y 3/1], Claystone, thinly laminated with carbonaceous strings, moderately hard, slightly weathered.					
		148		X									Fractures
		149		X									149.0' 7° Bedding joint/Shear, thin, moderately soft 149.1' 8° Bedding joint/Shear, very thin, moderately soft 149.4' 7° Bedding joint/Shear, moderately thin, moderately soft 149.5' 40° Shear, moderately thin, soft 149.6' 15° Shear/Bedding joint, moderately thin, soft 152' 5° Mechanical break/Joint 153' 18° Bedding joint/Shear, clean, hard
		150		X									
		151		X			106		89				
		152		X									
		153		X									
		154		X				Very dark gray [5Y 3/1], Claystone, thinly laminated with carbonaceous strings, moderately hard, slightly weathered.					
		155		X									Fractures 155.5' 12° Shear, very thin, moderately soft
		156		X			92		94				
		157		X									
		158		X									158.4' 14° Bedding joint, clean, moderately hard 158.6' 7° Bedding joint,
		159		X									

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		160						Black [5Y 2.5/1], Claystone, Bedding 16°, thinly laminated with carbonaceous strings, hard, slightly weathered. *(Continued)*					clean, moderately hard
		161					98		96				Fracture 160.7' 11° Shear, clean, hard
		162											
		163											
		164						Black [5Y 2.5/1], Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered.					
		165											
		166					100		76				Fractures 165.6' 12° Shear/Joint, very thin, hard
		167											167.0' 19° Shear/Joint, thin, moderately soft
		168											167.7' 17° Shear/Joint, moderately thin, moderately soft
		169						Black [5Y 2.5/1], Claystone, thinly laminated with Pale yellow [5Y 7/3] Siltstone, hard, slighty weathered to fresh.					Remaining fractures are driller induced
		170											Fractures 169.6' 15° Bedding joint/Shear, very thin, soft
		171					80		80				171.3' 23° Shear, very thin, soft
		172											
		173											173.0' 65° Joint, clean, hard
		174						Black [5Y 2.5/1], Claystone, thinly laminated with Pale yellow [5Y 7/3] Siltstone, hard, slighty weathered to fresh.					
		175											
		176					107		93				
		177											176.7' 9° Joint, very thin, hard
		178											
		179											Fractures 179.4' 17° Bedding joint, clean, thin 179.5' 18° Bedding joint/shear, thin, soft
		180						Black [N2], Coal, hard, Bed No. 1 1/2.	27				180.8' 73° Joint, clean, hard, cleats, two step joints well developed
		181											
		182											

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		183						Black [N2], Coal, hard, Bed No. 1 1/2. *(Continued)*	27				182.5' 16° Bedding joint 182.8' 70° Joint, very thin, hard, cleats, two step joints are well developed
		184											
		185											Fracture 185.2' 15° Bedding joint
		186					100	Black [5Y 2.5/1], Claystone, hard, slightly weathered to fresh.	67				
		187											187-189' Driller induced fractures
		188											
		189											
		190											
		191					100		74				Fractures 191.7' 17° Bedding joint
		192											
		193						Dark gray [5Y 4/1], Siltstone, hard, slightly weathered to fresh.					192.5' 21° Bedding joint/Shear, 3" thick clay gouge and angular claystone 1/2" to sand
		194											
		195						Dark gray [5Y 4/1], fine to medium grained Sandstone, hard, slightly weathered to fresh, massive.					
		196					100		100				
		197											
		198											
		199						Dark gray [5Y 4/1], fine to medium grained Sandstone, hard, slightly weathered to fresh, massive.					
		200											
		201					90		100				
		202											
		203											
		204					110	Dark gray [5Y 4/1], fine to medium grained Sandstone, hard, slightly weathered to fresh, massive.	96				
		205											

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		206						Dark gray [5Y 4/1], fine to medium grained Sandstone, hard, slightly weathered to fresh, massive. *(Continued)*					
		207					110		96				
		208											
		209						Dark gray [5Y 4/1], fine to medium grained Sandstone, hard, slightly weathered to fresh, massive.					
		210											
		211											
							100		96				
		212											Fracture 212.5' 17° Joint, clean
		213											
		214						Dark gray [5Y 4/1], fine to medium grained Sandstone, Bedding 22°, hard, slightly weathered to fresh, trace pebble layer 216-217'.					Fractures 214.3' 14° Bedding joint/Shear, clean, hard 214.5-217' 85-90° Joint, hard, slightly weathered to fresh, clean, joint curves through interval
		215											
		216											
							100		48				
		217											
		218											
		219											
		220						Dark gray [5Y 4/1], fine grained Sandstone, Bedding variable, moderately laminated with Very dark gray [5Y 3/1] Siltstone, hard, slightly weathered to fresh.					Fractures 220' 12° Joint, clean, hard
		221											
							90		96				
		222											221.7' 12° Bedding joint/Shear, very thin, soft
		223											
		224						Dark gray [5Y 4/1], fine grained Sandstone, trace carbonaceous strings, hard, slightly weathered to fresh.					
		225											Fractures 225.5' 56° Shear, thin, two parallel shears
		226					106		87				
		227											226.7' 13° Joint, clean
		228											

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							106	Dark gray [5Y 4/1], fine grained Sandstone, trace carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*	87				
		229						Dark gray [5Y 4/1], fine grained Sandstone, moderately laminated with Dark gray [5Y 4/1] fine to medium grained Sandstone, moderately laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		230											
		231					98		86				Fractures 231.6' 45° Joint/Shear, clean
		232											232.2' 0° Mechanical break
		233											233.3' 72° Joint, clean, hard
		234						Dark gray [5Y 4/1], fine grained Sandstone, moderately laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		235											
		236					100		100				
		237											
		238											
		239						Dark gray [5Y 4/1], fine grained Sandstone, moderately laminated with carbonaceous strings and Black [5Y 2.5/1] Siltstone, hard, slightly weathered to fresh.					
		240											
		241					100		96				
		242											Fractures 242.2' 0° Mechanical break
		243											
		244						Very dark gray [5Y 3/1], Siltstone, Bedding 17°, thinly laminated with Black [5Y 2.5/1] Claystone.					244.3' 17° Bedding joint/Shear, very thin, soft
		245											
		246					86		100				
		247											
		248											
		249						Very dark gray [5Y 3/1], Claystone, thinly laminated with carbonaceous strings, moderately hard, slightly weathered to fresh, and Black [5Y 2.5/1] Claystone, Core breaks on carbonaceous strings.					
		250					113		98				Fractures 250.7' 3° Joint, clean,
		251											

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													moderately hard
		252					113	Black [5Y 2.5/1], Claystone, moderately hard, slightly weathered to fresh.	98				
		253											Fractures
		254						Black [N2], Coal, moderately laminated with bone. Strong odor of oil and sulfur, Bed No. 2.					254-259' 75° cleats (Joint), discontinuous, very closely spaced Has 0.0ppm
		255											
		256					83	Black [5Y 2.5/1], Claystone, bubbles of gas emmiting from area even when washed, moderately soft.	38				256.5' 10° Joint, clean
		257						Black [N2], Coal, 70% stay intact when removed from tray, the rest breaks into cleats, Bed No. 2.					257.5' 10° Joint, clean
		258											Water pressure went up a lot, something squeezed rods and stopped drill from turning Cuttings are foaming black, smells like old oil. Driller removed and CO meter alarmed at 40ppm
		259						Black [N2], Coal, Bedding 15°, hard, slightly weathered to fresh, Bed No. 2.					Fractures 259-263.2' 75° cleats, discontinuous
		260											
		261					96		79				259.5' 15° Bedding joint, clean 259.8' 18° Bedding joint, clean
		262											260.4' 80° Joint, clean 10% of cleats are filled with calcite
		263											
		264						Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered to fresh.					
		265											Fractures 265' 65° Shear, very thin, moderately hard 265.5' 60° Shear, moderately thin, moderately soft
		266					100		64				
		267											266.4' 0° Mechanical break 267.4' 60° Shear, very thin
		268											267.9' 7° Joint, clean
		269						Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered to fresh.					
		270											
		271					105		75				Fractures 270.8' 14° Bedding joint 271.0' 16° Shear, very thin, moderately soft
		272											272' 14° Bedding joint, clean 272.1' 14° Shear, thin, moderately soft
		273											272.6' 14° Shear, thin, moderately soft 273.1' 10° Joint
		274											273.3' 6° Joint

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								Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered to fresh. *(Continued)*					273.9' 5° Joint
		275											275' 0° Mechanical break
		276					105		75				
		277											
		278											
		279						Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered to fresh.					
		280											Fractures 279.5' 15° Bedding joint, clean
		281											281.2' 2° Shear/Joint, thin, moderately soft
		282						Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered to fresh, thinly laminated with Gray [5Y 5/1] Siltstone, hard, slightly weathered to fresh.					281.7' 3° Shear/Joint, moderately thin, moderately soft
		283											
		284					100		97				
		285						Gray [5Y 6/1], fine grained Sandstone, very hard, slightly weathered to fresh.					
		286											
		287											
		288											
		289						Gray [5Y 6/1], fine grained Sandstone, Bedding 13°, trace carbonaceous strings, very hard, slightly weathered to fresh.					
		290											
		291											
		292											Fractures 291.7' 17° Bedding joint, clean, very hard
		293					103		68				
		294											
		295											
		296											295-298' 85° Joint, 15° Bedding, one long joint
		297											

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		298					103	Gray [5Y 6/1], fine grained Sandstone, Bedding 13°, trace carbonaceous strings, very hard, slightly weathered to fresh. *(Continued)*	68				
		299						Black [5Y 2.5/1], Claystone, Bedding 15°, breaks with hand pressure on bedding planes, hard, slightly weathered to fresh.					
		300											299-303' 15° Bedding joint, closely spaced
		301											295.8' 24° Bedding joint, clean, hard
		302											
		303						Gray [5Y 6/1], fine grained Sandstone, variable bedding with flow structures, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					
		304					100		84				
		305											
		306											
		307											
		308											
		309						Dark gray [5Y 4/1], fine grained Sandstone, variable bedding, thinly laminated with carbonaceous strings, carbonaceous strings at 32-60°, hard, slightly weathered to fresh.					
		310											
		311											Fractures 311.5' 60° Shear/Bedding joint, very thin, soft
		312											
		313											
		314					100		94				313.5' 35° Bedding joint, clean, moderately hard 314' 34° Bedding joint
		315											315.2' 25° Bedding joint/Shear, thin, soft, joints on carbonaceous strings
		316											
		317											
		318											
		319						Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with carbonaceous strings and Black (N2.5) Siltstone.					
		320					99		90	16	6.1		

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		321						Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with carbonaceous strings and Black (N2.5) Siltstone. *(Continued)*					
		322											
		323											
		324											
							99		90	16	6.1		
		325											Fractures 325.5' 5° Bedding joint, clean
		326											
		327											
		328											328-329' 90° Joint, clean, slightly open
		329						Dark gray [5Y 4/1], fine grained Sandstone, moderately laminated, with Very dark gray [5Y 3/1] Siltstone and carbonaceous strings, hard, slightly weathered to fresh.					
		330											Fractures 329-331.5' 85° Joint, very closely spaced, same joint as 328-329' 331.5' 0° Joint, clean, hard
		331											
		332											
		333											333.3' 11° Joint, clean, hard
		334					100		80	14.5	5.8		
		335						Very dark gray [5Y 3/1], Claystone, thinly laminated with carbonaceous strings, breaks with heavy hand pressure on carbonaceous strings, hard, slightly weathered to fresh.					
		336						Very dark gray [5Y 3/1], Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					335.7' 6° Joint, clean, moderately hard
		337											336.5' 17° Bedding joint, clean, moderately hard 336.8' 50° Shear, very thin, moderately soft 337.0' 5° Shear/Joint, very thin, moderately soft
		338											
		339											338.5' 15° Shear/Bedding joint, thin, moderately soft 338.7' 15° Bedding joint/Mechanical break
		340						Very dark gray [5Y 3/1], Claystone, moderately soft, moderately to slightly weathered.					339.5' 14° Bedding joint, clean, moderately hard 340.1' 15° Bedding joint, clean, moderately soft
		341					100	Black [N2], Coal, Bedding 14°, moderately laminated with bone, Bed No. 3.	44				340.2' 15° Bedding joint, clean, moderately hard 340.5' 25° Shear, very thin, soft 340.7' 15° Bedding joint, very thin, moderately soft
		342											
		343											

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		344						Black [N2], Coal, Bedding 14°, moderately laminated with bone, Bed No. 3. *(Continued)*					340.8' 15° Bedding joint, very thin 341.4-341.6' 15°/75° Joints, cleats, very closely spaced 342' 15°/75° Joints, cleats, very closely spaced 342.9' 12° Bedding joint 343-343.7' 15°/75° Joint, cleats, very closely spaced 345-345.5' 20° Shear, moderately thin, (not cleat)
		345											
		346					100		44				
		347											347.4-349' 85-90° Joint/Shear, thin, not cleat
		348											347-349' Intensely to moderately fractured, mostly from vertical splitting
		349						Black [N2], Coal, Bedding 16°, moderately laminated with bone, Bed No. 3.					
		350											349.6' 40° Mechanical break on coal feather 350.3' 16° Bedding joint, clean, moderately hard 350.9' 15° Bedding joint, clean, hard
		351											
		352											352.0' 13° Bedding joint, clean, hard 352.4' 10° Bedding joint 352.8' 85° Joint
		353											
		354					105		53				353.6-354.5' 15°/75°, Joint, very closely spaced, cleats
		355											354.7-355.3' 15°/75°, Joint, very closely spaced, cleats
		356						Black [5Y 2.5/1], Claystone, moderately soft, slightly weathered.					
		357						Dark gray [5Y 4/1], Siltstone, moderately hard, slightly weathered to fresh.					356.5' 60° Shear, thin, moderately hard 356.5-357.3' Shear, intensely to moderately fractured, moderately hard
		358											
		359						Gray [5Y 5/1], Siltstone, moderately laminated with carbonaceous strings, moderately hard, slightly weathered to fresh.					
		360											
		361											
		362											
							102		100				
		363											363.2' 31° Mechanical break on carbonaceous strings
		364											
		365											
		366											

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		367, 368					102	Gray [5Y 5/1], Siltstone, moderately laminated with carbonaceous strings, moderately hard, slightly weathered to fresh. *(Continued)*	100				
		369, 370, 371, 372, 373, 374, 375, 376, 377, 378					100	Gray [5Y 5/1], Siltstone, moderately laminated with carbonaceous strings.	95				
		379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389					100	Dark gray [5Y 4/1], Siltstone, Bedding 16°, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.	94				Fractures 382.3' 16° Bedding joint, clean 383.6' 16° Bedding joint, clean 384.6' 16° Bedding joint/Shear, soft, moderately thin 384.7' 16° Bedding joint/Shear, soft, moderately thin 385.3' 17° Bedding joint/Shear, soft, moderately thin 384.5' 16° Bedding joint/Shear, soft, moderately thin

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		390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412					100	Dark gray [5Y 4/1], Siltstone, Bedding 17°, thinly laminated with Claystone, hard, slightly weathered to fresh, breaks on Claystone strings. *(Continued)*	96				Fractures 392.7' 17° Bedding joint, very thin
							100		96				395.5' 10° Bedding joint/Shear, very thin, soft 397.0' 5° Joint, clean 397.4' 17° Bedding joint, clean 398.5' 13° Bedding joint, very thin
								Dark gray [5Y 4/1], Siltstone, moderately laminated with Gray [5Y 5/1] fine grained Sandstone, hard, slightly weathered to fresh.					399.6' 14° Bedding joint/Shear, very thin, soft 401.0' 3° Joint, clean 402.8' 17° Bedding joint, clean
							100		96				
								Gray [5Y 5/1], fine grained Sandstone, variable bedding, very hard, slightly weathered to fresh.					
							100		94				Fractures 410.3' 46° Joint, moderately thin, soft 411.0' 44° Joint, clean 411.2' 18° Shear, moderately thin, soft
								Dark gray [5Y 4/1], Siltstone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					

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		413, 414, 415, 416					100	Dark gray [5Y 4/1], Siltstone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*	94				414.3' 10° Shear, very thin, soft 415.3' 42° Joint, clean
		417, 418, 419						Gray [5Y 5/1], fine grained Sandstone, hard, slightly weathered to fresh.					
		420, 421, 422, 423, 424, 425, 426, 427, 428					100	Gray [5Y 5/1], fine grained Sandstone, Bedding 15-25°, moderately laminated with Dark gray [5Y 4/1] Siltstone, hard, slightly weathered to fresh and thinly laminated with carbonaceous strings.	96				Fracture 421.9' 55° Joint, clean
		429, 430, 431, 432, 433, 434, 435					100	Gray [5Y 5/1], fine grained Sandstone, Bedding variable at 25°, moderately laminated with Olive [5Y 4/4] Siltstone, hard, slightly weathered to fresh, massive.	100				

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		436						Gray [5Y 5/1], fine grained Sandstone, Bedding variable at 25°, moderately laminated with Olive [5Y 4/4] Siltstone, hard, slightly weathered to fresh, massive. *(Continued)*					
		437					100		100				
		438											
		439											
		440											
		441											
		442						Gray [5Y 5/1], fine grained Sandstone, moderately laminated with Dark gray [5Y 4/1] Claystone and thinly laminated with carbonaceous strings.					Fractures 442.5' 85° Joint, clean, terminates on 442.7' Shear 442.7' 30° Shear, thin, clay gouge, same orientation as bedding 443.0' 40° Joint, clean
		443											
		444					100		95	20	6.5		
		445											
		446											
		447											
		448											
		449						Gray [5Y 5/1], fine grained Sandstone, Bedding 24°, thinly laminated with carbonaceous strings, moderately laminated with Dark gray [5Y 4/1] Claystone, hard, slightly weathered to fresh.					
		450											
		451											
		452											
		453											
		454					100		100	22	6.9		
		455											
		456											
		457											
		458											

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							100		100	22	6.9		
		459						Dark gray [5Y 4/1], Claystone, Bedding 15-20°, moderately laminated with Gray [5Y 5/1] fine grained Sandstone, hard, slightly weathered to fresh.					
		460											
		461											
		462											
		463											
		464					100		98				
		465											Fracture 464.5' 35° Joint/Shear, very thin, moderately hard
		466											
		467											
		468											
		469											
		470											Fractures 470.2' 19° Bedding joint/Shear, thin, moderately soft
		471											
		472											
		473											472.5' 24° Shear, 0.2" thick 472.7' 14° Bedding joint, very thin 473.1' 18° Shear, moderately thin, soft 473.9' 23° Joint, very thin, moderately hard
		474					100		92				
		475											
		476											475.9' 24° Shear, thin, soft
		477											476.9' 17° Joint, iron stains on face 477.5' 10° Joint, clean
		478											
								Void, top of Bed No. 4 cave.					478.5-479.3' Void
		479											
		480					57	Dark gray [5Y 4/1], Claystone, hard, slightly weathered to fresh, fractures have iron staining approx 1/4" into face. Core recovered 6' of Claystone, 1.9' Claystone, moderately soft, 1.6' of Siltstone, moderately hard, moderately to slightly weathered.	0	32	8.6		
		481											

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		482						Dark gray [5Y 4/1], Claystone, hard, slightly weathered to fresh, fractures have iron staining approx 1/4" into face. Core recovered 6' of Claystone, 1.9' Claystone, moderately soft, 1.6' of Siltstone, moderately hard, moderately to slightly weathered. *(Continued)*					
		483											
		484											
		485											
		486											
		487											
		488											
		489					57		0	32	8.6		Core rods drop, continue w/o pulling tube at 489'
		490											
		491											
		492											
		493						Black [2.5Y 2.5/1], Claystone, floor of Bed No. 4, moderately soft, moderately to slightly weathered.					493-496' Driller states material felt firm for the last 3' of run
		494											Fractures 494.0' 27° Shear, thin, clay/gravel 494.5' 0° Shear, thin, clay
		495											
		496						Black [5Y 2.5/1], Claystone, Bedding 20°, soft, moderately to slightly weathered, Claystone appears broken up, gravels floating in clay matrix.					
		497											
		498					100		0				Core recovered 6" of claystone and coal gravel, probable slaff, suggests through No. 4, gravels are subround
		499						Very dark gray [5Y 3/1], Siltstone, hard, slightly weathered to fresh.					
		500						Black [5Y 2.5/1], Claystone, Bedding 37°, soft, moderately to slightly weathered.					
		501											Highly fractured, dominate fractures are: 499-503' 37° Shear, on bedding planes, very closely spaced 499-503' 32° Shear, opposite of bedding, very closely spaced
		502					50		0				
		503						Black [N2], Coal, recovered as core, but broke into 1" to coarse sand size particles upon disturbance, Bed No. 4 1/2.					503-504' 15°/75° intensely to moderately fractured on cleats
		504											

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ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-05

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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
		505					50	Black [N2], Coal, recovered as core, but broke into 1" to coarse sand size particles upon disturbance, Bed No. 4 1/2. *(Continued)*	0				Poor recovery due to high plasticity of clay sticking to inside of tube and poor quality of coal, not strong enough to push sample into tube
		506											
		507											
		508						Black [N2], Coal, Bedding 23°, very hard, slightly weathered to fresh, Bed No. 4 1/2.					Fractures
		509											509-510' 23°/65° Joint, cleat
		510						Black [5Y 2.5/1], Claystone, soft, intensely to moderately weathered.					510-514' 27° Shear, very closely spaced
		511					100		0				
		512											
		513											
		514						Black [5Y 2.5/1], Claystone, moderately hard, slightly weathered.					
		515											
		516						Very dark gray [5Y 3/1], Siltstone, very hard, slightly weathered to fresh.					Fractures 515.5' 24° Shear, moderately thick, moderately soft
							100		84	51	13.3		
		517											517' 25° Shear, moderately thick, moderately soft 517.1' 35° Shear, moderately thick, moderately hard
		518											517.2' 60° Joint/Shear, very thin, calcite, moderately healed
		519						Very dark gray [5Y 3/1], Siltstone, thinly laminated with Gray [5Y 5/1] fine grained Sandstone and thinly laminated with carbonaceous strings, very hard, slightly weathered to fresh.					517-519' 85° Joint/Shear, very thin, calcite filled, partly healed
		520											519.4' 23° Bedding joint, clean 519.7' 59° Bedding joint, clean, coal feather
		521											520.5' 44° Bedding joint/Shear moderately thin, soft
		522											521.4' 26° Bedding joint/Shear, moderately thin, moderately hard
		523					100		73				522.5' 24° Bedding joint/Shear, moderately thin, moderately hard
		524											524.4' 21° Bedding joint/Shear, moderately thin, soft
		525											525.8' 0° Bedding joint
		526											526.4' 15° Bedding joint 527' 19° Bedding
		527											

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		528					100	Very dark gray [5Y 3/1], Siltstone, thinly laminated with Gray [5Y 5/1] fine grained Sandstone and thinly laminated with carbonaceous strings, very hard, slightly weathered to fresh. *(Continued)*	73				joint/Shear, moderately thin, soft 528.5' 24° Bedding joint, clean
		529						Very dark gray [5Y 3/1], Siltstone, thinly laminated with Dark gray [5Y 4/1] Siltstone and thinly laminated with carbonaceous strings, break with heavy hand pressure in strings, hard, slightly weathered to fresh.					
		530											
		531											Fractures 530.6' 25° Bedding joint/Shear, thin, moderately soft
		532											
		533											
		534					105		91				
		535											534.8' 14° Bedding joint/Shear, thin, moderately soft
		536											
		537											537' 16° Bedding joint, very thin, moderately soft 537.5' 14° Bedding joint, clean
		538											538.5' 30° Joint, clean
		539											
		540						Black [5Y 2.5/1], Claystone, thinly laminated with carbonaceous strings, moderately hard, slightly weathered to fresh.					540.4' 10° Bedding joint, very thin, soft
		541											541.4' 19° Bedding joint, very thin, moderately soft
		542											542.1' 15° Bedding joint, clean, moderately hard
		543											
		544					100		87				
		545											544.5' 18° Bedding joint, clean, moderately hard
		546											545.7' 15° Bedding joint, very thin, moderately hard 546' 15° Bedding joint, very thin, moderately hard
		547											
		548											
		549						Black [5Y 2.5/1], Claystone, Bedding 23°, hard, slightly weathered to fresh.					
		550					105		83				

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		551						Black [5Y 2.5/1], Claystone, Bedding 23°, hard, slightly weathered to fresh. *(Continued)*					
		552											
		553											Fractures 553.5' 14° Bedding joint
		554					105		83				554.3-555.6' 87° Joint, clean
		555											554.7' 14° Shear/Bedding joint, moderately thin, moderately soft
		556											556' 0° Joint
		557											
		558											
		559						Very dark gray [5Y 3/1], Claystone, Bedding 30°, hard, slightly weathered to fresh.					
		560											
		561											
		562											
		563											
		564					100		99				
		565											
		566											
		567											
		568						Gray [5Y 5/1], Siltstone, thinly laminated, Dark gray [5Y 4/1] Siltstone and carbonaceous strings, hard, slightly weathered to fresh.					
		569											
		570											Fractures 569.3' 40° Bedding joint, clean
		571					100		94	12	5.5		
		572											572.5' 33° Shear/Bedding joint, moderately thin, moderately soft
		573											

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		574, 575, 576, 577, 578					100	Gray [5Y 5/1], Siltstone, thinly laminated, Dark gray [5Y 4/1] Siltstone and carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*	94	12	5.5		576' 54° Shear/Bedding joint, moderately thin, moderately soft 576.8' 32° Shear/Bedding joint, moderately thin, moderately soft
		579						Gray [5Y 5/1], Siltstone, thinly laminated with Dark gray [5Y 4/1] Siltstone and carbonaceous strings, hard, slightly weathered to fresh.					Driller fought sand heave
		580, 581, 582, 583, 584, 585, 586, 587, 588					100		94				Fractures 581.4' 28° Shear, moderately thin, moderately soft 582.9' 36° Bedding joint, very thin, moderately hard 584.4' 25° Bedding joint, clean, moderately hard
		589						Gray [5Y 5/1], Siltstone, Bedding variable, thinly laminated with Dark gray [5Y 4/1] Siltstone and carbonaceous strings, hard, slightly weathered to fresh.					Fractures 589.6' 24° Bedding joint, carbonaceous strings
		590, 591, 592, 593, 594, 595, 596					100		81				594.8' 37° Bedding joint/Shear

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Drill Hole No. BH-05

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		597						Gray [5Y 5/1], Siltstone, Bedding variable, thinly laminated with Dark gray [5Y 4/1] Siltstone and carbonaceous strings, hard, slightly weathered to fresh. *(Continued)*					596.5' 32° Joint, very thin, moderately soft 596.9' 46° Joint, very thin, moderately soft
		598					100		81				598' 40° Joint/Shear, very thin, moderately soft
		599						Gray [5Y 5/1], fine grained Sandstone, moderately laminated with carbonaceous strings, very hard, slightly weathered to fresh.					
		600											Fractures 600.3' 32° Joint/Bedding joint
		601											
		602											601-602.3' 78° Joint, moderately to totally healed, moderately thin
		603											
		604							96				
		605											
		606											
		607											
		608											
		609						Gray [5Y 5/1], fine grained Sandstone, moderately laminated with Dark gray [5Y 4/1] Siltstone, very hard, slightly weathered to fresh.					
		610											
		611											
		612											
		613											
		614							92				
		615											
		616											
		617											
		618											
		619					100	Dark gray [5Y 4/1], Claystone, hard to moderately hard, grading to Very dark gray [5Y 3/1] Claystone, moderately hard.	43				

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		620						Dark gray [5Y 4/1], Claystone, hard to moderately hard, grading to Very dark gray [5Y 3/1] Claystone, moderately hard. *(Continued)*					Fractures 619-621.5' 90° Joint, very thin, moderately healed, calcite 619.6' 7° Bedding joint, clean, hard 620.6' 38° Shear, moderately thick, moderately hard 620.9' 8° Shear, thin, moderately hard 621.5' 20° Bedding joint, clean, hard 621.5' 70° Shear, moderately thick, moderately soft 622.4' 53° Shear, very thin, moderately hard, slickens 622.6' 50° Shear, moderately thin, moderately soft 623' 21° Shear, thin, moderately soft 624' 19° Bedding joint, clean 624.3' 23° Bedding joint/Shear, hard 625-626' 15°/75° cleats, very closely spaced,partly healed 626-626.7' 90° Joint, moderately healed, very thin 626.5-627.5' 17°/73°, cleats, very closely spaced, partly healed Cleats are 95°, discontinuous 627.2' 0° Bedding joint, hard 628.1' 14° Bedding joint, hard 628.2' 21° Bedding joint/Shear, moderately hard 628.4' 40° Shear, clean, hard At 619-621.5' and 626-626.7' Joints are in stiffer Sandstone and terminate on Siltstone 629.5' 15° Bedding joint, clean, very hard 629.8' 20° Bedding joint, clean, very hard 630' 5° Joint, clean, very hard 630.7' 16° Joint, clean, very hard 630.7-634' 75° Joint, very thin, moderately healed, calcite 635.7-637.6' 15°/75° Joint, cleats, closely spaced 638' 17° Bedding joint 639-640' 15°/72° Intensely fractured, cleats 641.5-642.5' 18°/72° Intensely to moderately fractured, cleats
		621											
		622											
		623						Black [N2], Coal, 19° Bedding, moderately laminated with bone, very hard, slightly weathered to fresh, Bed No. 5.					
		624					100		43				
		625											
		626											
		627											
		628											
		629											
		630						Black [N2], Coal, Bedding 14°, very hard, slightly weathered to fresh, Bed No. 5.					
		631											
		632											
		633											
		634					98		66				
		635											
		636											
		637											
		638											
		639											
		640											
		641					100						
		642											

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Drill Hole No. BH-05

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		643						Very dark gray [5Y 3/1], Siltstone, Bedding 14°, hard, slightly weathered to fresh.					
		644											
		645											
							100						
		646											645.8' 14° Bedding joint
		647											
		648											647.8' 14° Bedding joint
		649											
		650											
		651						Very dark gray [5Y 3/1], Siltstone, grading to Dark gray [5Y 4/1] Siltstone, thinly laminated with Gray [5Y 5/1] fine grained Sandstone, hard, slightly weathered to fresh.					Fractures 651' 0° Joint, clean 651.4' 7° Bedding joint, clean
		652											
		653											652.5-654' 85° Joint, very thin, moderately healed
		654					103		97				
		655											
		656											655.7' 14° Bedding joint, clean 656-657' 82° Joint, very thin, moderately healed
		657											
		658											657.5-659' 87° Joint, very thin, slightly open, partly healed, fracture face covered with pyrite
		659						Very dark gray [5Y 3/1], Siltstone, thinly laminated with Dark gray [5Y 4/1] fine grained Sandstone, hard, slightly weathered to fresh.					Fractures 659-660' 87° Joint, very thin, slightly open, 25% healed
		660											
		661											
		662					100		93				
		663											663.2' 5° Joint, very thin, moderately soft
		664											
		665											

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		666						Very dark gray [5Y 3/1], Siltstone, thinly laminated with Dark gray [5Y 4/1] fine grained Sandstone, hard, slightly weathered to fresh. *(Continued)*					665.5' 70° Joint, very thin, slightly open, moderately to totally healed
		667					100		93				667.0' 10° Joint, very thin, moderately soft
		668											
		669						Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with Very dark gray [5Y 3/1] Siltstone, hard, slightly weathered to fresh.					
		670											Fractures 670' 10° Bedding joint/Mechanical break
		671											671.3' 5° Bedding joint/Mechanical break
		672											
		673											672.6' 10° Bedding joint/Mechanical break
		674					100		90				
		675											674.4' 0° Mechanical break
		676											675.4' 25° Bedding joint/Mechanical break
		677											
		678											
		679											678.5' 25° Shear, very thin, moderately soft
		680											
		681											Total depth=679.0'
		682											
		683											
		684											
		685											
		686											
		687											
		688											

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PHONE NUMBER:

Drill Hole No. BH-06

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/29/14 - 9/9/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5583.40 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 339613.608, E. 2033874.965	HAMMER TYPE: None

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								.					
		1						Moist, Brown [10YR 4/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, occasional cobbles and boulders, intact gravel particles are subrounded, no reaction to HCl.					
		2											
		3											
		4											
		5											
		6											
		7				G14572							
		8											
		9											
		10											
		11											
		12				G14573							
		13											
		14											14-15' Boulder
		15											
		16											
		17				G14574							
		18											
		19											19-21' a lot of water in cuttings
		20											
		21				G14575							

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Drill Hole No. BH-06

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		22			X			Moist, Brown [10YR 4/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, occasional cobbles and boulders, intact gravel particles are subrounded, no reaction to HCl. *(Continued)*					
		23			X	G14575							23-24' Boulder
		24			X								
		25			X								
		26			X			Wet, Dark yellowish brown [10YR 4/4], WELL GRADED SAND with Gravel, SW, non-plastic, Alluvium, sand is well graded, and gravels are subrounded, no reaction to HCl.					
		27			X	G14576							
		28			X			Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles and boulders, intact gravels are subrounded, no reaction to HCl.					28' wet cuttings
		29			X	G14577							
		30			X								
		31			X								
		32			X	G14578							
		33			X								
		34			X								
		35			X								
		36			X								
		37			X	G14579							
		38			X								
		39			X								
		40			X								
		41			X								
		42			X	G14580							
		43			X								
		44			X								

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		45			X	G14580		Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL with SILT AND SAND, GP, non-plastic, Alluvium, frequent cobbles and boulders, intact gravels are subrounded, no reaction to HCl. *(Continued)*					
		46											
		47				G14581							
		48											
		49											
		50											
		51											
		52				G14582							
		53											
		54											
		55											
		56											
		57											
		58											
		59											
		60			X	G14583		Damp, Very dark gray [10YR 3/1], Sandstone, no reaction to HCl.					60.5' Cuttings are fine grained Silty Sand
		61											
		62											
		63				G14584							
		64											
		65											
		66				G14585							
		67											

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		68			X	G14585		Damp, Very dark gray [10YR 3/1], Sandstone, no reaction to HCl. *(Continued)*					
		69			X								
		70			X								
		71											
		72			X								
		73			X	G14586							73.3' Start core run 73.3-75.0' Bentonite chip
		74			X								
		75		X	X			Dark greenish gray [5GY 4/1], fine grained Sandstone, hard, fresh, moderately laminated with Dark greenish gray [5GY 4/1] Claystone, moderately soft, fresh, with some bentonite from previous drilling.					Bottom of Air-Rotary drilling
		76		X	X								Fractures 75.6' 16° Bedding joint
		77		X	X		62		52				
		78		X	X								
		79		X	X			Light gray [N7], Sandstone, Bedding 16°, moderately laminated with Dark greenish gray [5GY 4/1] Claystone, moderately soft, Sandstone is hard.					
		80		X	X								79.8' 50° Shear 80.0' 70° Shear 80.1' 16° Random fracture, trace of coal feathers
		81		X	X		94		34				
		82		X	X								
		83		X	X								Fractures 83.8' 75° Shear
		84		X	X			Dark greenish gray [5GY 4/1], fine grained Sandstone, Hard Bedding 19°, laminated with Dark greenish gray [5GY 4/1] Claystone, hard, moderately soft, weak reaction to HCl.					
		85		X	X								
		86		X	X		72		58				85.6' 15° Shear, moderately thick, gouge
		87		X	X								86.8' 13° Bedding joint
		88		X	X								
		89		X	X		92	Dark greenish gray [5GY 4/1], CLAYEY GRAVEL, GC.	46				Material very broken above coal seam. Driller lost water, material was squeezing in on rods
		90											

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		91						Dark greenish gray [5GY 4/1], Claystone, moderately laminated, moderately soft, with Dark greenish gray [5GY 4/1] fine grained Sandstone, moderately soft, coal seam at 89.3', trace of pyrite in coal, weak reaction to HCl. *(Continued)*					
		92					92		46				Fractures 92.5' 0° Random fracture
		93						Dark greenish gray [5GY 4/1], Claystone, variable bedding, soft, feathers of coal 1/4" thick (trace), weak reaction to HCl.					93.0' 43° Shear/Bedding joint
		94											
		95											Fractures 95.2' 60° Shear, clean, slightly open, not healed
		96					92		42				96.3' 50° Shear, thin, not healed
		97											97.1' 48° Shear, moderately thin, 25% healed
		98											
		99						Dark greenish gray [5GY 4/1], Claystone, Bedding 20°, trace 1/4" feathers of coal.					Fractures 99.5' 20° Bedding joint
		100											
		101					100		63				101.4' 23° Bedding joint
		102						Black [N2], Coal.					102.3' 25° Bedding joint in coal
		103						Dark greenish gray [5GY 4/1], Claystone.					102.4' 25° Bedding joint in coal
		104						Black [N2], Coal.					
								Dark greenish gray [5GY 4/1], Claystone, Soft.					
		105											
		106						Gray [N5], fine grained Sandstone, Bedding 21°, hard, very thinly laminated with Claystone.					Fractures 106.2' 21° Bedding joint 106.2' 49° Shear
							94		40				
		107											107.4' 50° Shear, dip opposite of bedding
		108											107.5' 22° Bedding joint 107.7' 20° Bedding joint 108.0' 73° Random fracture 108.5' 20° Bedding joint
		109											109.4' 13° Bedding joint 109.7' 17° Bedding joint 110.0' 17° Bedding joint 110.0' 65° Random Fracture 110.6' 15° Bedding joint
		110						Gray [N5], fine grained Sandstone, hard, moderately laminated with Dark greenish gray [5GY 4/1] Claystone, moderately soft.					
		111					88		55				
								Dark greenish gray [5GY 4/1], Claystone, Bedding 19°, soft, fresh.					111.4' 20° Bedding joint 111.7' 0° Mechanical break
		112											
		113											112.7-112.9' Intensely fractured

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							88	Dark greenish gray [5GY 4/1], Claystone, Bedding 19°, soft, fresh. *(Continued)*	55				
		114						Very dark gray [N3], Claystone, Bedding 24°, thinly laminated with carbonaceous materials, soft, highly plastic.					
		115											Driller states clay
		116					80		78				
		117						Very dark gray [N3], Siltstone.					
		118											
		119						Dark olive gray [5Y 3/2], Sandstone, carbonaceous layers thinly laminated and are sandy.					
		120											Drilled very fast, slight bit of loose, medium plasticity clay on bit
		121					70						
		122											Mislatch, pull drill rods. Core fell from barrel when bit removed, reassembled in photos
		123											
		124						Dark olive gray [5Y 3/2], Sandstone, Bedding 26-27°, carbonaceous layers thinly laminated, some showing coal.					Fracture 124.5-127.8' 90° Joint
		125											
		126					88		16				126.5' 12° Joint
		127											127.6' 12° Shear, very thin, slightly open, totally healed
		128											
		129						Dark olive gray [5Y 3/2], Sandstone, variable bedding, thinly laminated with carbonaceous layers, approx 20% of run carbonaceous yellowish tinge.					Fractures 129.5' 68° Joint/Shear
		130											130.4' 32° Bedding joint
		131					100		66				
		132											131.7' 31° Bedding joint
		133											132.6' 15° Bedding joint 40° Shear, very thin, slightly open, completely healed 65° Shear, very thin, slightly open, completely healed
		134						Dark olive gray [5Y 3/2], Sandstone, thinly laminated with carbonaceous yellowish tinge.					134.5-136' 85° Joint
		135					96		21				134.4' 12° Shear, very thin, slightly open, completely healed
		136											

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		137		X			96	Dark olive gray [5Y 3/2], Sandstone, thinly laminated with carbonaceous yellowish tinge. *(Continued)*	21				136.0' 79° Shear, very thin, slightly open, not healed 136.5' 70° Joint 137.0' 62° Shear
		138		X									138.0' 35° Shear, very thin, slightly open, 25% healed 138.2' 45° Shear
		139		X				Dark olive gray [5Y 3/2], Sandstone, Bedding 25°, thinly laminated with carbonaceous seams.					
		140		X									
		141		X			71	Dark greenish gray [5GY 4/1], Claystone, Bedding 22°, very thinly laminated, moderately soft.	49				Water pressure increases, torque increases, something sealing off water and squeezing in on rods
		142		X									
		143		X				Black [N2], Coal, Bedding 19°, Bed No. 1.					Fine sand pack on tube on return
		144		X									Fractures 144.5' 90° Joint
		145		X									145.4' 18° Bedding joint
		146		X			100		38				146.4' 19° Bedding joint 146.6' 19° Bedding joint 147.0' 18° Bedding joint 147.2' 19° Bedding joint
		147		X									
		148		X									148.2' -149' intensely to moderately fractured
		149		X				Black [N2], Coal, Bedding 22°, hard, fresh, Bed No. 1.					149.5'-151' 65° Joint, very closely spaced, zero ends leave the exposure, slightly open, very thin, calcite filling Coalesence of shear, perpendicular to bedding
		150		X									
		151		X			100		70				
		152		X									
		153		X									
		154		X				Light yellowish brown [2.5Y 6/3] Very dark gray [N3], Siltstone, Bedding 16 °, thinly laminated with Very dark gray [N3] Claystone, hard, fresh, 1/2" coal seam at 154.5', weak reaction to HCl.					Fractures 154.5' 27° Random fracture 154.6' Random fracture
		155		X									
		156		X			90		64				
		157		X									157.0' 16° Bedding joint 157.3' 17° Bedding joint
		158		X									
		159		X									158.9' 17° Bedding joint

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		160						Light yellowish brown [2.5Y 6/3] Very dark gray [N3], Siltstone, Bedding 16 °, thinly laminated with Very dark gray [N3] Claystone, hard, fresh, 1/2" coal seam at 154.5', weak reaction to HCl. *(Continued)*					
		161					100	Dark greenish gray [5GY 4/1], fine grained Sandstone, very hard, fresh, weak reaction to HCl.	80				160.5' 73° Shear
		162											
		163											
		164						Dark greenish gray [5GY 4/1], fine grained Sandstone, very hard, fresh, weak reaction to HCl.					
		165											Fractures 165.3' 75° Shear, very thin, calcite filling 165.3' 73° Shear, very thin, fine gouge
		166					104		83				
		167						Dark greenish gray [5GY 4/1], Siltstone/Claystone, very thinly laminated, hard, weak reaction to HCl.					
		168						Light brownish gray [2.5Y 6/2] Gray [N5], Silt and Claystone, Bedding 22°, seam of coal at 170-170.9'.					
		169											
		170						Black [N2], Coal.					Fractures 170.0' 22° Bedding joint 170.1' 65° Shear, moderately healed, tight, very thin
		171					100	Dark gray [N4], fine grained Sandstone, Bedding 17°, thinly laminated with Dark greenish gray [5GY 4/1] Claystone, hard, fresh.	70				170.4' 23° Bedding joint 170.9' 22° Bedding joint
		172											
		173											173.2' 50° Shear
		174											
		175											Fracture 175.0' 18° Bedding joint
		176					96		79				176.5' 12° Joint
		177											
		178						Gray [N6], fine grained Sandstone, hard, fresh.					178.3' 0° Mechanical break
		179											
		180					94		82				
		181											
		182											

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		183					94	Black [N2], Claystone with slight coal seam. *(Continued)*	82				
		184											Fractures 184.3-184.7' 18°, Bedding joint, intensely to moderately fractured 184.9-185.5' 80° Joint
								Black [N2], Coal, blocky.					
		185					100	Gray [N6], Siltstone, Bedding variable approx 18°, thinly laminated with Claystone, hard, fresh.	53				
		186											Sand and clay on bottom of hole upon re-inserting drill rods
		187											
		188											
		189											
							100		70				
		190											Fractures 190.2' 17° Bedding joint 190.4' 17° Bedding joint 190.5' 18° Bedding joint 190.8' 19° Bedding joint
								Black [N2], Coal.					
		191						Dark greenish gray [5GY 4/1], Claystone, thinly laminated with Siltstone, hard, fresh.					
		192											
		193						Dark greenish gray [5GY 4/1], Claystone, thinly laminated with Siltstone, hard, fresh, very thin carbonaceous strings within Claystone, Yellowish brown (2.5Y 6/3) Claystone between 196.2-196.5'.					
		194											
		195					91		62				
		196											Fractures 196.0' 85° Shear, very thin, slightly open, pyrite precipitate
		197											
		198						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding variable 23°, laminated with very thin carbonaceous strings, Yellowish brown (2.5Y 6/3) layer of Claystone from 198.0-198.3'.					Fractures 198.0' 85° Shear, pyrite, slickenside on surface
		199											
		200					94		88	21	6.7		
		201											
		202											
		203											
		204					92	Very dark gray [N3], Claystone, Bedding 25°, very thinly laminated with coal strings, hard, fresh.	79				
		205											

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		206					92	Very dark gray [N3], Claystone, Bedding 25°, very thinly laminated with coal strings, hard, fresh. *(Continued)*	79				Fractures 205.3-205.4' intensely to moderately fractured 205.9' 20° Joint 206.3' 25° Bedding joint
		207											
		208											
		209											
		210					100	Greenish gray [5GY 5/1], Siltstone/Claystone, Bedding 16°, hard, fresh, feather trace of coal, strong reaction to HCl.	92	26	7.6		
		211											
		212											
		213						Very dark gray [N3] Dark greenish gray [5GY 4/1], Claystone, Bedding 15°, thinly interbedded, very thin strong of coal, hard, fresh.					
		214											Fractures 214.0' 18° Bedding joint
		215											
		216							88				
		217											217.2' 12° Bedding joint, moderately weathered 217.8' 12° Bedding joint, moderately weathered
		218											
		219						Very dark gray [N3] Dark greenish gray [5GY 4/1], Claystone, hard, fresh, no reaction to HCl.					218.7' 10° Intensely to moderately fractured, moderately weathered 219.2' 10° Intensely to moderately fractured, moderately weathered
		220											
		221					98	Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding 14°, very thinly laminated with Black (N2.5) Claystone, no reaction to HCl.	62				
		222											
		223											
		224						Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding variable 30°, hard, fresh, weak reaction to HCl.					Fractures 224.6' 12° Joint 225.0' 27° Joint/Bedding joint
		225											
		226					95		85				
		227											
		228											

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		229						Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding difficult to see, very thinly laminated with Black (N2.5) Claystone.					
		230											Core was hard to remove from barrel, 95% of fractures are mechanical breaks
		231					96		92				
		232											
		233											
		234					100	Dark greenish gray [5GY 4/1], Claystone, Bedding 20°, very hard, fresh, strong reaction to HCl.	100				
		235											Fractures 234.7' 19° Bedding joint
		236					100			31	8.5		
		237						Light brownish gray [2.5Y 6/2], Claystone, very hard, fresh, strong reaction to HCl.					
		238						Very dark gray [N3], Claystone, Bedding 20° with coal seams, approx 1/4" thick, very hard, fresh, strong reaction to HCl.					237.7' 19° Bedding joint, slightly weathered 238-238.2' 12° Bedding joint, intensely to moderately weathered, limonite in clay 238.7-238.8' 12° Bedding joint, intensely to moderately weathered, limonite in clay
		239											
		240						Light brownish gray [2.5Y 6/2], Claystone, thinly laminated with Very dark gray [N3] Claystone, very hard, fresh, strong reaction to HCl, boney.					239.0' 12° Bedding joint, fresh
		241					89	Very dark gray [N3], Siltstone, thinly interbedded with Very dark gray [N3] Claystone, hard, fresh.	61	13	5.6		
		242						Very dark gray [N3], Claystone, Bedding 12°, trace of thin coal seams.					242.0' 12° Bedding joint, fresh 242.3' 17° Bedding joint, moderately weathered 242.4' 17° Bedding joint, moderately weathered
		243											
		244						Very dark gray [N3], Claystone, trace of thin coal seams, thinly laminated with fine grained Sandstone.					
		245											
		246							98				
		247											
		248											
		249						Very dark gray [N3], Claystone, Bedding 13°, thinly laminated with Light brownish gray [2.5Y 6/2] fine grained Sandstone, very hard, fresh.					
		250					98		90	16	6.0		Fractures 250.0' 4° Joint, moderately weathered 250.1' 5° Joint, moderately weathered
		251											

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		252					98	Very dark gray [N3], Claystone, Bedding 13°, thinly laminated with Light brownish gray [2.5Y 6/2] fine grained Sandstone, very hard, fresh. *(Continued)*	90	16	6.0		250.9' Random Fracture 251.8' 36° Shear, slightly weathered to fresh
		253											
		254					88	Very dark gray [N3], Claystone, Bedding 21°, thinly laminated with Very pale brown [10YR 7/3] fine grained Sandstone, cross bedding in Sandstone, carbonaceous material in the Very dark gray (N3) Claystone.	77	19	6.4		
		255											
		256											
		257											Fractures 257.2' 74° Joint
		258											
		259					100	Very dark gray [N3], Claystone, Bedding 19°, thinly laminated with Very pale brown [10YR 7/3] fine grained Sandstone, strong reaction to HCl.	18				259.7' 15° Joint, intensely to moderately weathered, clay on face 260.5' 80° Joint 260.5' 30° Shear, 25% healed, thin, intensely to moderately weathered 261-264' 78° Shear, not healed, slightly open, very closely spaced
		260											
		261						Black [N2], Coal, moderately laminated with Black N2.5 Shale, blocky, breaks into "cubes" when put in core box, Bed No. 1 1/2.					
		262											
		263											
		264											Fractures 264-265' 80° very closely spaced, partly healed, clean, slightly open
		265											
		266					102	Dark greenish gray [5GY 4/1], Claystone, moderately soft. Greenish gray [5G 5/1], fine grained Sandstone, hard, fresh, coal seam 1/2" thick at 269.6', no reaction to HCl.	60				265.2' -265.5' intensely to moderately fractured 265.8' 85° Joint/Shear
		267											267.2' 35° Shear, very thin, partly healed, tight Spiral fractures from twisting barrel/bit
		268											
		269											Fractures 269.6' 16° Bedding joint
		270						Very dark gray [N3], Claystone, can't see Bedding, moderately hard, fresh, no reaction to HCl.					
		271					102	Gray [N6], fine grained Sandstone, Bedding 17°, moderately hard, fresh.	88				271.7' 17° Bedding joint
		272											
		273											
		274											

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		275					100	Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding 15°, thinly laminated with Gray (N3) Claystone, very hard, fresh. *(Continued)*	100	24	7.2		
		276											
		277					100		100	24	7.2		
		278											
		279						Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding 18°, thinly laminated with Siltstone and Claystone, thin coal seam at 282.5', 1/4" thick.					
		280											
		281											
		282					72		94	24	7.2		Fractures 281.6' 17° Bedding joint 282.5' 25° Bedding joint, coal seam
		283						Very dark gray [N3], Claystone, thinly laminated with Dark greenish gray [5GY 4/1] fine grained Sandstone, Bedding 19°-22°, trace carbonaceous strings 1/16" thick, hard, fresh, strong reaction to HCl.					
		284											284.5-285.8' intensely to moderately fractured
		285											
		286					121		71				285.6' 19° Bedding joint 285.7' 19° Bedding joint
		287											
		288											287.4' 41° Shear, very thin, clay gouge
		289						Very dark gray [N3], Claystone, Bedding 19°, thinly laminated with Dark greenish gray [5GY 4/1] fine grained Sandstone, hard, fresh, weak reaction to HCl.					
		290											
		291					92		86	19	6.5		Fracture 290.5' 20° Bedding joint, carbonaceous material 291.4' 15° Bedding joint, carbonaceous material
		292											
		293											
		294						Dark grayish brown [2.5Y 4/2], Siltstone, Bedding 15°, thinly laminated with Very dark gray [N3] Claystone and carbonaceous strings, no reaction to HCl.					
		295					112		100				
		296											296.3-298' Lost some in hole
		297					270						

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		298					270	Dark grayish brown [2.5Y 4/2], Siltstone, Bedding 15°, thinly laminated with Very dark gray [N3] Claystone and carbonaceous strings, no reaction to HCl. *(Continued)*					Fractures 297.7' 20° Joint
		299											
		300						Gray [N5], fine grained Sandstone, very hard, fresh, trace carbonaceous strings 1/16" thick, weak reaction to HCl.					Fractures 300' 48° Joint/Shear 300.6' 0° Random Fracture
		301					100		82	56	15.0		301.5' 21° Bedding joint
		302											
		303											
		304						Gray [N5], fine grained Sandstone, very hard, fresh, trace carbonaceous strings, 1/16" thick, weak reaction to HCl.					Fractures 304.5' 11° Bedding joint
		305											305.4' 70° Shear, clean, tight
								Gray [N5], Sandstone.					
		306					98	Gray [N5], fine grained Sandstone, Bedding 29°, hard, fresh, trace carbonaceous strings, 1/32" thick.	69				306.3' 42° Shear 306.5' 10° Random fracture
		307											
		308											
		309											
		310											
		311					108		96				Fractures 311.7' 8° Bedding joint in coal string
		312											
		313											313' Driller lost water
		314											
		315						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 16°, trace thinly lamination of carbonaceous materials, moderately hard, fresh.					
		316					100		92	12	5.5		
		317											
		318											Fractures 318' 14° Bedding joint 318.4' 14° Bedding joint
		319					100	Greenish gray [5GY 5/1], fine grained Sandstone, Bedding variable, trace thinly laminated with carbonaceous material, hard, fresh, weak reaction to HCl.	98				
		320											

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Drill Hole No. BH-06

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		321		X				Greenish gray [5GY 5/1], fine grained Sandstone, Bedding variable, trace thinly laminated with carbonaceous material, hard, fresh, weak reaction to HCl. *(Continued)*					
		322		X			100		98				321.6' 12° Mechanical break
		323		X									
		324		X				Greenish gray [5GY 5/1], fine grained Sandstone, thinly to moderately laminated with carbonaceous strings, hard, fresh, weak reaction to HCl.					
		325		X									Fractures 325.6' 20° Bedding joint
		326		X									
				X			98		88	14	5.7		326.5' 17° Bedding joint
		327		X									
		328		X									328' Still no return
		329		X				Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 45°, thinly laminated with fine grained Sandstone w/Yellowish brown [10YR 5/4] clay in pore spaces, carbonaceous strings, very hard, fresh.					Fractures 329.7' 45° Bedding joint
		330		X				Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 55° massive, weak reaction to HCl.					
		331		X			96						
		332		X									332.2' 14° Random fracture/Shear
		333		X									
		334		X				Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 45°, thinly laminated with carbonaceous strings 1/8" thick, massive, hard, fresh, strong reaction to HCl.					
		335		X									335.4' 14° Shear, very thin
				X			100		77				335.5' 22° Shear
		336		X									336.5' 4° Joint
		337		X				Void, top of cave, Bed No. 2.					337-342' Void
		338											
		339											
		340											
		341											
		342		X				CLAYEY GRAVEL, GC, Gravels are coal and claystone, soft drilling, caved material.					Soft, rods jetted down to 344'
		343		X									

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	344		X				CLAYEY GRAVEL, GC, Gravels are coal and claystone, soft drilling, caved material. *(Continued)*					Decided to add another rod to capture slough
	345		X									
	346		X			50		40				
	347		X				Very dark gray [5Y 3/1], Claystone, soft, intensely to moderately weathered.					
	348		X									
	349		X				Very dark gray [5Y 3/1], CLAYEY GRAVEL, GC, gravels are mudstone (hard), fine grained Sandstone (hard), claystone (soft), disturbed.					
	350		X									
	351		X			48		0				
	352		X									
	353		X									
	354		X				Dark olive gray [5Y 3/2], Claystone, Bedding 15°, soft, intensely to moderately weathered to intensely weathered, thin fine grained Sandstone at 354.2', fine grained Sandstone strong reaction to HCl, Shale no reaction to HCl, looks in place bottom of Bed No. 2 at 354'.					Fractures 354.4' 15° Shear, moderately thin
	355		X									
	356		X			81		23				355.5' 14° Bedding joint
	357		X									
	358		X									
	359		X				Very dark gray [5Y 3/1], Claystone, Bedding 17°, moderately soft, thinly laminated with Very dark gray [5Y 3/1] Siltstone, moderately hard Siltstone.					Fractures 358.8' 44° Shear, clean, slightly open, 25% healed Bedding joints, moderately spaced, through core
	360		X			104		40				360.2' 14° Shear, clean, slightly open
	361		X									
	362		X									
	363		X				Dark grayish brown [2.5Y 4/2], fine grained Sandstone, very hard, Bedding 20°, laminated with very dark gray [N3] Claystone, moderately hard, moderately laminated with claystone 1/2"-1/8" thick, moderately soft, weak reaction to HCl.					
	364		X			100		22	29	8.1		
	365		X									
	366		X									

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Drill Hole No. BH-06

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		367					100	Dark grayish brown [2.5Y 4/2], fine grained Sandstone, very hard, Bedding 20°, laminated with very dark gray [N3] Claystone, moderately hard, moderately laminated with claystone 1/2"-1/8" thick, moderately soft, weak reaction to HCl. *(Continued)*	22	29	8.1		Fractures 367.0' 32° Shear, thin
		368											
		369						Dark grayish brown [2.5Y 4/2], fine grained Sandstone, Bedding 15°, very thinly laminated with Very dark gray [N3] Claystone, very hard, moderately laminated, moderately hard, Sandstone is cross bedded, moderately soft, no reaction to HCl.					369.3-372.7' Bedding joint, moderately to closely spaced
		370											
		371					85		48				
		372											
		373											
		374					121	Gray [2.5Y 5/1], fine grained Sandstone, very thinly laminated with Very dark gray [N3] Claystone.	65				Fractures 374' 16° Bedding joint 374.6' 14° Bedding joint
		375						Gray [2.5Y 5/1], fine grained Sandstone, very hard, variable cross bedding, very thinly laminated with Very dark gray [N3] Claystone, moderately hard, trace of Light olive brown [2.5Y 5/3] Claystone at 378.2'.					375' End PQ start HQ Fractures 375.9' 12° Shear, moderately thin, moderately weathered
		376											
		377											
		378					92		80				378.2' 14° Shear, Very thin, moderately weathered
		379						Gray [2.5Y 5/1], medium grained Sandstone, very hard, fresh.					379.0' 17° Shear, very thin, moderately weathered
		380						Gray [N6], fine to medium grained Sandstone, thinly laminated with Very dark gray [N3] Siltstone, moderately hard to moderately soft, slightly weathered to fresh, weak reaction to HCl.					
		381											Fractures 381.5' 3° Random fracture
		382					97		72	18	6.3		382.0' 0° Random fracture
		383											382.9' 0° Random fracture 383.1' 3° Bedding joint/Random fracture
		384						Gray [N6], fine to medium grained Sandstone, Bedding 8°, moderately hard to moderately soft, thinly laminated with Black [N2] carbonaceous strings approx 1/32", variable cross bedding, weak reaction to HCl.					
		385											384.5-384.7' Shear, Intensely to moderately fractured, intensely to moderately weathered 385.7' 0° Random fractures
		386					104		67	12	5.5		386.2' 8° Shear/Random fracture, moderately thin, intensely to moderately weathered
		387											
		388											386.5' 4° Shear/Random fracture, moderately thin, intensely to moderately weathered
		389											Fractures are in poorly

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		390					96	Gray [N6], fine to medium grained Sandstone, Bedding 8°, moderately hard to moderately soft, thinly laminated with Black [N2] carbonaceous strings approx 1/32", variable cross bedding, weak reaction to HCl. *(Continued)*	73	79	25.1		cemented zones
		391											Fractures 391.2' 75° Shear, very thin, slightly open, not healed, closely to very closely spaced
		392					96	Gray [N5], fine grained Sandstone, Bedding 22°, extremely hard, fresh, fractures go from fine grained Sandstone to medium grained Sandstone, very hard to see in fine to medium grained Sandstone, weak reaction to HCl.	73	79	25.1		392.4' 65-70° Shear, very thin, slightly open, not healed, closely to very closely spaced
		393											
		394						Gray [N6], fine to medium grained Sandstone, thinly laminated with carbonaceous strings 1/16-1/32", very hard, slightly weathered to fresh.					393' 60-70° Shear, very thin, slightly open, not healed, closely to very closely spaced
		395											Fractures
		396											395.8' 9° Joint
							98		92	13	5.5		396.2' 0° Mechanical break, ground smooth from spin
		397											397.0' 2° Mechanical break, ground smooth from spin
		398											
		399						Gray [N6], fine to medium grained Sandstone, Bedding 47°, thinly laminated with carbonaceous strings 1/8-1/16", moderately hard, slightly weathered to fresh, no reaction to HCl.					Fractures 399.4' 8° Mechanical break
		400											400.6' 0° Mechanical break
		401					98		98				
		402											401.7' 17° Bedding joint/Mechanical break 402' 6° Joint, very thin, 25% healed
		403											
		404											
		405						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 12°, very thinly laminated with Very dark gray [N3] Siltstone, hard, fresh, trace of carbonaceous coal 1/16" at 407.5'.					
		406					102		100	24	7.3		
		407											
		408											
		409						Gray [2.5Y 5/1] Gray [N5], Siltstone, Bedding 15°, thinly laminated with Dark olive gray [5Y 2.5/2] Claystone, hard, fresh, no reaction to HCl.					
		410											
		411					98		100	17	6.1		
		412											

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		413					98	Gray [2.5Y 5/1] Gray [N5], Siltstone, Bedding 15°, thinly laminated with Dark olive gray [5Y 2.5/2] Claystone, hard, fresh, no reaction to HCl. *(Continued)*	100	17	6.1		
		414											
		415						Black [N2], Coal, Bedding 17°, small resine approx 1/8" diameter.					Fractures 415.2' 8° Mechanical break
		416					94	Black [5Y 2.5/2], Claystone, thinly laminated, hard, fresh, 1/16" noncontinuous, carbonaceous strings.	80				416.4' 31° Joint, fresh
		417											
		418											418.5' 41° Joint, fresh
		419											
		420						Black [5Y 2.5/2], Claystone, Bedding 32°, thinly laminated, hard, slightly weathered to fresh, no reaction to HCl, #3 start at 422.5'.					Fractures 420.5' 47° Joint
		421					90		55				421.2' 50° Joint, fresh
		422											422.0' 32° Bedding joint 422.5' 32° Bedding joint
		423						Black [N2], Coal, Bedding 17°, moderately laminated with Black [N2} Mudstone, 1/2" diameter, bits of resin, trace pyrite on fracture faces, Bed No. 3.					
		424											424.3' 424.3-429' 82° clean to very thin, very closely spaced, moderately to totally healed, filled with calcite, strong reaction to HCl
		425											
		426											
		427					100						
		428											
		429						Black [N2], Coal, moderately laminated with Black [N2] mudstone, 1/4" diameter, bits of resin, Bed No. 3.					Fractures 429.5-434' 83° Joint, very thin, moderately to totally healed, very closely spaced 429.5' 25° Bedding joint 430.0' 23° Bedding joint 430.1' 22° Bedding joint
		430											
		431					94		64				430-434' 65° Joint, very thin, moderately to totally healed, very closely spaced 431.7' 20° Bedding joint
		432											
		433											433.2' 22° Bedding joint
		434						Black [N2], Claystone, Bedding 30°, moderately laminated with Black [N2] Coal, hard, fresh.					434-437' 82° Joint, very thin, moderately to totally healed, very closely spaced
		435					98		57				

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		436						Black [N2], Claystone, Bedding 30°, moderately laminated with Black [N2] Coal, hard, fresh. *(Continued)*					
		437					98		57				437-437.6' 69° Joint, clean, moderately healed, very closely spaced, perpendicular to bedding in coal
		438						Dark olive gray [5Y 3/2], Claystone, soft, moderately weathered.					
		439											
		440						Very dark gray [N3], Claystone, Bedding 20°, moderately hard, fresh.					
		441					100		86				
		442						Gray [N5], Siltstone, moderately hard, no reaction to HCl.					
		443						Olive gray [5Y 5/2], fine grained Sandstone, moderately hard, fresh, massive, no reaction to HCl.					
		444											
		445						Gray [5Y 5/1], Siltstone, very hard, fresh.					
		446					100	Claystone.	100	33	8.8		
		447						Siltstone.					
		448						Dark gray [5Y 4/1], fine grained Sandstone, hard, fresh.					
		449						Dark greenish gray [5GY 4/1], Siltstone, Bedding 17°, hard, fresh.					
		450											
		451					100		100				
		452											
		453											
		454						Dark greenish gray [5GY 4/1], fine grained Sandstone, variable bedding, thinly laminated with Dark gray [5Y 4/1] Siltstone, hard.					
		455											
		456					100		100				
		457											
		458											

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		459		X			100	Dark greenish gray [5GY 4/1], fine grained Sandstone, variable bedding, thinly laminated with Dark gray [5Y 4/1] Siltstone, hard. *(Continued)*	100				
		460		X				Greenish gray [5G 5/1], fine grained Sandstone, Bedding 22°, thinly laminated with Dark greenish gray [5GY 4/1] Siltstone, Bedding variable, moderately laminated with carbonaceous strings, 1/16".					
		461		X			98		100				
		462		X									
		463		X									
		464		X				Greenish gray [5GY 5/1], fine grained Sandstone, thinly laminated with Dark greenish gray [5GY 4/1] mudstone, trace carbonaceous strings.					
		465		X									
		466		X			100		100				
		467		X									
		468		X									
		469		X				Dark greenish gray [5GY 4/1], Claystone, thinly laminated with fine grained Sandstone, trace carbonaceous strings.					
		470		X									
		471		X			90	Black [2.5Y 2.5/1], Claystone, Bedding 26°, thinly laminated with carbonaceous strings, moderately hard.	100	22	6.9		
		472		X									
		473		X									
		474		X				Black [2.5Y 2.5/1], Claystone, Bedding 22°, thinly laminated with carbonaceous strings, moderately hard, fresh, no reaction to HCl.					
		475		X									
		476		X			104		100				
		477		X									
		478		X									
		479		X				Black [2.5Y 2.5/1], Claystone, thinly laminated with carbonaceous strings, 1/32", no reaction to HCl.					
		480		X			100		100	27	7.6		
		481											

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								Black [2.5Y 2.5/1], Claystone, thinly laminated with carbonaceous strings, 1/32", no reaction to HCl. *(Continued)*					
		482											
							100		100	27	7.6		
		483											
		484											
		485						Greenish gray [5GY 5/1], fine grained Sandstone, hard, fresh, thinly laminated with Dark gray [5Y 4/1] Siltstone and Mudstone, very hard, fresh, fine grained Sandstone also very thinly laminated with carbonaceous strings 1/16" thick, no reaction to HCl.					
		486											
							100	Light olive gray [5Y 6/2], Claystone, hard, fresh.	100	29	8.1		
		487						Greenish gray [5GY 5/1], fine grained Sandstone, Bedding variable 12-16°, hard, fresh, thinly laminated Dark greenish gray [5GY 4/1] Siltstone and Mudstone. Fine grained Sandstone is very thinly laminated with carbonaceous strings 1/16"-3/16", no reaction HCl.					
		488											
		489											
		490											
		491											
							94		100	28	7.8		
		492											
		493											
		494											
		495											
		496											
							100		100	67	19.0		
		497						Dark greenish gray [5GY 4/1], fine grained Sandstone, hard, fresh, massive, weak reaction to HCl.					
		498											
		499						Greenish gray [5GY 5/1], fine grained Sandstone, thinly laminated with Siltstone and Claystone and very thinly laminated with carbonaceous strings, hard, fresh.					
		500											
		501											
							100		100				
		502											
		503											
		504					94		100				

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Drill Hole No. BH-06

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		505, 506, 507, 508, 509					94	Greenish gray [5GY 5/1], fine grained Sandstone, moderately laminated with Claystone, hard, fresh, weak reaction to HCl. *(Continued)*	100				
		510, 511, 512, 513, 514					100	Dark greenish gray [5GY 4/1], Claystone and Siltstone, Bedding 13°, thinly laminated with fine grained Sandstone, weak reaction to HCl.	100				
		515, 516, 517, 518, 519					100	Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 15°, moderately laminated with Dark greenish gray [5GY 4/1] Claystone, hard, fresh, fine grained Sandstone is massive, hard, fresh.	100	26	7.6		
		520, 521, 522, 523, 524, 525					90	Greenish gray [5GY 5/1], fine grained Sandstone, Bedding 14°, moderately laminated with Dark gray [N4] Siltstone, hard, fresh.	100				
		526, 527					100	Dark gray [N4], Siltstone, Bedding 15°, moderately laminated with fine grained Sandstone, very hard, fresh.	100	33	8.9		

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		528					100	Dark gray [N4], Siltstone, Bedding 15°, moderately laminated with fine grained Sandstone, very hard, fresh. *(Continued)*	100	33	8.9		
		529						Dark gray [N4], Claystone, Bedding 15°, moderately laminated with fine grained Sandstone and Siltstone, hard, fresh.					
		530											
		531					96		67	29	8.1		Fractures 530.8' 15° Shear, moderately thin, soft, intensely to moderately weathered 531.2' 34° Joint, clean, very hard, fresh
		532											
		533											
		534											
		535						Gray [N5], fine grained Sandstone, Bedding 17°, moderately laminated with Dark gray [N4] Siltstone and Claystone, all hard, fresh and thinly laminated with carbonaceous strings.					
		536					100		100				
		537											Fractures 537.3' 65° Shear, clean, tight, moderately to totally healed 538.2' 68° Shear, clean, tight, moderately to totally healed
		538											
		539						Dark gray [N4], Claystone, Bedding 19°, hard, fresh.					
		540											Fractures 539.8' 53° Shear, clean, tight, moderately to totally healed 540.0' 55° Shear, clean, tight, moderately to totally healed
		541					96		100	34	9.0		
		542											
		543											543.5' 60° Shear, clean, tight, moderately to totally healed
		544						Dark gray [N4], Claystone, thinly laminated, hard, fresh.					
		545											
		546					100		100	30	8.3		
		547						Dark gray [N4], Claystone, Bedding 20°, moderately laminated with Greenish gray [5GY 5/1] fine grained Sandstone, hard, fresh.					
		548											
		549						Dark gray [N4], Claystone, Bedding 20°, thinly laminated with Siltstone, hard, fresh, trace bone.					
		550					100		100	30	8.3		

Drill Hole No. BH-06

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								Dark gray [N4], Claystone, Bedding 20°, thinly laminated with Siltstone, hard, fresh, trace bone. *(Continued)*					Fractures 550.5' 56° clean, tight, moderately to totally healed
		551											
		552					100		100	30	8.3		
		553											
		554						Dark gray [N4], Claystone, Bedding 19°, moderately laminated with Siltstone, both hard, fresh.					
		555											
		556					100		100				
		557											Fractures 557.5' 75° very thin, tight, moderately to totally healed
		558											
		559						Dark gray [N4], Claystone, Bedding 25°, moderately laminated with carbonaceous strings 1/16" thick, weak reaction to HCl.					
		560											
		561					96						Mechanical break on coal strings
		562											
		563											
		564						Dark gray [N4], Claystone, Bedding 16°.					
		565											
		566					34	Black [N2], Coal, Poorly graded gravel, coal subrounded, Bed No. 4.					Lost water at 566'
		567											
		568											
		569						Black [N2], LEAN CLAY, CL, medium plasticity, strong organic "swamp" smell, Bed No. 4. Black [N2], Coal, Bedding 15°, black pyrite on some faces, Bed No. 4.					Fractures 569-571' Intensely fractured, fresh, totally healed
		570											
		571					100		19				571-573' 65° Joint, very closely spaced, fresh, 25% healed, 20% Joint filled with calcite, strong reaction to HCl 573-575.7' 80° very closely spaced, fresh, 25% healed
		572											
		573											

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ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-06

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		574						Black [N2], Coal, Bedding 20°. *(Continued)*					
		575					97		19				
		576						Very dark grayish brown [2.5Y 3/2], Claystone, soft, intensely to moderately weathered to moderately hard, moderately to slightly weathered.					Fractures 576.8' 45° Shear, moderately hard, partly healed
		577											577.4' 20° Shear, moderately hard, moderately to slightly weathered
		578											577.6' 60° Shear, clean, tight, partly healed 577.7' 60° Shear, clean, tight, partly healed
		579					100		38				578.9' 52° Shear, clean, tight, partly healed 579.7' 50° Shear, moderately thin, totally healed
		580						Very dark grayish brown [2.5Y 3/2], fine grained Sandstone, Bedding 20°, hard, fresh.					
		581											580.4' 60° Shear, hard, totally healed
		582											
		583						Black [N2], Coal, Bedding 16°, moderately laminated with Black [N2] Shale, very hard, fresh, Bed No. 4 1/2.					Fractures 583.0' 17° Bedding joint 583.3' 75° Shear, fresh, 0.5' spacing 583.4' 16° Bedding joint
		584											
		585					79		26				585.2' 75° Shear, fresh, 0.5' spacing 585.6' 15° Bedding joint 584.4-587.9' intensely to moderately fractured, clean, partly healed
		586											
		587											587.1' 75° Shear, fresh, 0.5' spacing
		588						Black [N2], Claystone, very soft, intensely to moderately weathered, smells like oil.					587.9-588.4' Intensely to moderately fractured
		589						Very dark gray [5Y 3/1], Claystone, soft, moderately weathered.					
		590					84		43				589.6' 10° Random fracture 589.9' 16° Bedding joint 590.2' 16° Bedding joint
		591											590.9' 15° Bedding joint
		592											591.4' 20° Shear, moderately thin, intensely to moderately weathered, not healed
		593											592.4-594' moderately fractured, several mechanical breaks 593.3' 40° Shear, moderately hard
		594					100	Dark gray [N4], fine grained Sandstone, Bedding 19°, moderately hard, fresh.	66				593.6' 35° Shear, moderately hard
		595											595.3' 40° Shear, hard, slightly weathered
		596											

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		597		X			100	Dark gray [N4], fine grained Sandstone, Bedding 19°, moderately hard, fresh. *(Continued)*	66				
		598		X				Dark gray [5Y 4/1], fine grained Sandstone, Bedding 14°, thinly to moderately laminated with Very dark gray [N3] Siltstone, very hard, fresh.					
		599		X									
		600		X			102						
		601		X									Fractures 601.3' 14° Bedding joint
		602		X				Dark gray [5Y 4/1], fine grained Sandstone, hard, fresh, trace carbonaceous strings, less cemented zone are very soft, 1/2"-1" thickness.					
		603		X									
		604		X									604' Less cemented zones mechanical break and twisted flat
		605		X			95		100				
		606		X									
		607		X									
		608		X									
		609		X				Dark gray [5Y 4/1], fine grained Sandstone, hard, fresh, trace carbonaceous strings, no reaction to HCl.					
		610		X			100		96				Fractures 610.5' 5° Random fracture, soft zone 1/4"
		611		X									
		612		X									
		613		X									
		614		X				Dark gray [5Y 4/1], fine grained Sandstone, Bedding 20°, very thinly laminated with Very dark gray [N3]Siltstone and Claystone, hard, fresh, carbonaceous strings, no reaction to HCl.					
		615		X									615.5' 15° Shear, soft
		616		X			100		73				
		617		X									
		618		X									
		619		X			100	Dark gray [5Y 4/1], fine grained Sandstone, Bedding 16°, very thinly laminated with Very dark gray [N3] Siltstone and Claystone, hard, fresh, no reaction to HCl.	96				

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		620						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 16°, very thinly laminated with Very dark gray [N3] Siltstone and Claystone, hard, fresh, no reaction to HCl. *(Continued)*					Fractures 620.5' 16° Bedding joint
		621					100		96				
		622											
		623											622.8' 0° Mechanical break
		624						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 15°, very thinly laminated Very dark gray [N3] Siltstone and Claystone, hard, fresh, no reaction to HCl.					
		625					100		100				
		626											
		627											
		628						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 16°, very thinly laminated with Very dark gray [N3] Siltstone and Claystone, hard, fresh, no reaction to HCl.					
		629											
		630					100		100				
		631						Dark gray [5Y 4/1], fine grained Sandstone, cross bedding, very thinly laminated with carbonaceous strings, hard, fresh, no reaction to HCl.					
		632											
		633						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 17°, very thinly laminated with carbonaceous strings, moderately laminated with Very dark gray [N3] Siltstone, hard, fresh, no reaction to HCl.					
		634											
		635					100		100				
		636											
		637											
		638											
		639						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 16° with flow structures, moderately laminated with carbonaceous strings 1/4"-3/16", hard, fresh.					
		640					100		100				Fractures 640.2' 20° Mechanical break/Bedding joint 641.2' 15° Mechanical break/Bedding joint
		641											
		642											641.9' 5° Mechanical break

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Drill Hole No. BH-06

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		643		X			100	Dark gray [5Y 4/1], fine grained Sandstone, Bedding 16° with flow structures, moderately laminated with carbonaceous strings 1/4"-3/16", hard, fresh. *(Continued)*	100				
		644		X				Dark gray [5Y 4/1], fine grained Sandstone, variable Bedding, moderately laminated with carbonaceous strings 1/16" thick, hard, fresh.					Fractures 644.0' 5° Mechanical break
		645		X									645.0' 7° Mechanical break
		646		X			100		100				
		647		X									646.5' 11° Mechanical break 647.3' 65° Shear, very thin, not healed, sand gouge, very soft
		648		X									
		649		X									
		650		X									
		651		X			100	Dark gray [5Y 4/1], fine grained Sandstone, Bedding 14°, moderately laminated with carbonaceous strings, moderately hard.	98				651.1' 11° Joint
		652		X									
		653		X									
		654		X				Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with carbonaceous strings, moderately hard, some softer zones, moderately soft, 1-2" thick no reaction to HCl.					
		655		X									655.1' 0° Mechanical break, intensely to moderately fractured, soft zone
		656		X			100		100				
		657		X									656.8' 0° Mechanical break, moderately fractured, soft zone 657.0' 0° Mechanical break, intensely to moderately fractured
		658		X									
		659		X				Dark gray [5Y 4/1], fine grained Sandstone, thinly laminated with carbonaceous strings, some soft zones, moderately soft, no reaction to HCl.					658.0' 75° Shear, very thin, slightly open, totally healed, quartz filling 658.0' 85° Shear/Joint, very thin, slightly open, totally healed, quartz filling 659' 0° 14 Mechanical breaks in soft zones, closely spaced
		660		X									
		661		X			92		100				
		662		X									
		663		X									
		664		X				Gray [N5], fine grained Sandstone, Bedding 14°, thinly laminated with carbonaceous strings, some soft zones, moderately soft.					Fractures 664.5' 14° Bedding joint 664.8' 0° 7 Mechanical
		665		X			104		83				

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		666						Gray [N5], fine grained Sandstone, Bedding 14°, thinly laminated with carbonaceous strings, some soft zones, moderately soft. *(Continued)*					breaks in soft zones, moderately spaced 665.8' 75° Shear, totally healed
		667					104		83				
		668						Gray [N5], fine grained Sandstone, thinly laminated with carbonaceous strings, hard.					
		669											
		670											669.9' 10° Mechanical break
		671					92		100				
		672											
		673											
		674						Gray [N5], fine grained Sandstone, thinly laminated with carbonaceous strings, hard, fresh. Zone 675.5'-677.0', moderately soft.					
		675											
		676					98		96				Fractures 675-677.0' 0° intensely to moderately fractured 677.1' 7° Joint 677.4' 2° Joint
		677											
		678											
		679						Gray [N5], fine grained Sandstone, Bedding variable, thinly laminated with carbonaceous strings, hard, fresh, no reaction to HCl.					
		680											Fractures 680.3' 10° Joint
		681					96		100				
		682											
		683											
		684											
		685						Black [5Y 2.5/1], Claystone, Bedding 25°, hard, fresh.					
		686					100		88				Fractures 685.9' 20° Shear, gouge, very soft, very thin, not healed
		687											
		688											687.6' 20° Shear, gouge, very soft, very thin, not

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Drill Hole No. BH-06

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		689		X			100	Black [5Y 2.5/1], Claystone, Bedding 25°, hard, fresh. *(Continued)*	88				healed
								Black [5Y 2.5/1], Claystone, Bedding 19°, thinly laminated with carbonaceous strings, hard, fresh.					
		690											
		691					94		100				
		692											
		693											
		694						Black [5Y 2.5/1], Claystone, hard, fresh.					
		695											Fractures
		696					100		92				694-699' 70° very closely spaced, clean, tight, totally to moderately healed 694-699' 90° clean, tight, totally to moderately healed, not continuous
		697											
		698											
		699						Black [5Y 2.5/1], Claystone, moderately laminated with carbonaceous strings, hard, fresh.					
		700											Fractures 700.4' 17° Bedding joint
		701					94		77				700.9' 17° Bedding joint
		702											702.4' 15° Random fracture
		703											703.1' 30° Random fracture
		704						Black [5Y 2.5/1], Claystone, moderately bedded with coal, hard, fresh.					
		705											Fractures 705-706.5' 35° closely spaced, very thin, not healed
		706											706.5-708' 90° very closely spaced, clean, slightly open, partly healed
							90	Black [N2], Coal, Bedding 25°, thinly laminated with bone, Bed No. 5.	24				
		707											706.5-708' 75° very closely spaced, clean, slightly open, partly healed
		708											
		709											Fractures
		710					88		18				710.5-711.5' closely spaced, blocky bedding, joints and vertical joints 711.5-712.5' vertical joints, very closely spaced
		711											

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		712						Black [N2], Coal, Bedding 25°, thinly laminated with bone, Bed No. 5. *(Continued)*					711.5-714' intensely fractured
		713					88		18				
		714						Black [N2], Coal, Bedding 15°, thinly laminated with bone, Bed No. 5.					714-719' vertical joints, very closely spaced, totally healed 714-719' 80-90° stepping joints, very closely spaced 714-719' 75° Shear with at least 1" of displacement, closely spaced 714-719' 20-45° calcite filled fractures, intensely fractured, very thin, not healed, calate 714-719' 65° Shear, very thin, tight, totally healed, calcite filled
		715											
		716					100		0				
		717											
		718											
		719						Black [N2], Coal, Bedding 16°, moderately laminated with bone, Bed No. 5.					
		720											
		721					88		64				
		722											
		723											
		724						Dark greenish gray [5GY 4/1], fine grained Sandstone, Bedding 24°, moderately laminated with Very dark gray [N3] claystone, hard, fresh.					
		725											
		726					100		100				
		727											
		728											
		729											
		730											
		731						Very dark gray [N3], Claystone, hard, slightly weathered to hard.					
		732					94		100				
		733											
		734					104		100				

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Drill Hole No. BH-06

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		735						Very dark gray [N3], Claystone, hard, slightly weathered to hard. *(Continued)*					
								Gray [N5], fine grained Sandstone, hard, fresh.					
		736											
							104		100				
		737											
		738											
		739						Gray [N5], fine grained Sandstone, very thinly laminated with carbonaceous strings, hard, fresh.					
		740											
		741											
							96		100				
		742											
		743											
		744											Total Depth=744.0'
		745											
		746											
		747											
		748											
		749											
		750											
		751											
		752											
		753											
		754											
		755											
		756											
		757											

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PHONE NUMBER:

Drill Hole No. BH-07

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/18/14 - 10/10/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5574.70 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 340306.537, E. 2033846.346	HAMMER TYPE: None

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		1, 2, 3, 4, 5, 6, 7, 8, 9			X			Damp, Very dark grayish brown [10YR 3/2], SILTY SAND with Gravel, SM, low plasticity, Frequent cobbles and boulders, weak reaction to HCl.					
		10, 11			X			Gray [10YR 6/1], Boulder.					Glass debris washed up outside of casing when drilling near 10' depth Boulder 10-13'
		12, 13, 14, 15, 16, 17, 18, 19, 20, 21			X			Damp to Wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent boulders and cobbles, gravels are subrounded. Occasional seams of well-graded sand between 12 and 15', and at 21', no reaction to HCl.					Wet at 16'

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Drill Hole No. BH-07

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
		22						Damp to Wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent boulders and cobbles, gravels are subrounded. Occasional seams of well-graded sand between 12 and 15', and at 21', no reaction to HCl. *(Continued)*					
		23											
		24											
		25											
		26											
		27											
		28											
		29											
		30											
		31											
		32											
		33											
		34											
		35											
		36											
		37											
		38											
		39						Damp to Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent boulders and cobbles, gravels are subrounded, no reaction to HCl.					
		40											
		41											
		42											
		43											
		44											

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		45			X			Damp to Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent boulders and cobbles, gravels are subrounded, no reaction to HCl. *(Continued)*					
		46			X								
		47			X								
		48			X								
		49			X								
		50			X								
		51			X								
		52			X								
		53			X								
		54			X								
		55			X								
		56			X								
		57			X								
		58			X								
		59			X								
		60			X								
		61			X								
		62			X								
		63			X								
		64			X								
		65			X								
		66			X								
		67			X								

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		68			X			Damp to Wet, Dark grayish brown [10YR 4/2], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Alluvium, frequent boulders and cobbles, gravels are subrounded, no reaction to HCl. *(Continued)*					
		69			X								
		70			X								
		71			X								
		72			X								
		73			X								
		74			X								
		75			X								
		76			X								
		77			X								
		78			X								
		79			X								
		80			X								
		81			X								
		82			X								
		83			X								
		84			X								
		85			X								
		86											
		87											
		88											
		89						Wet, Light olive brown [2.5Y 5/3], Sandstone, strong reaction to HCl.					
		90											

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		91						Wet, Light olive brown [2.5Y 5/3], Sandstone, strong reaction to HCl. *(Continued)*					
		92						Wet, Grayish brown [2.5Y 5/2], Sandstone, weak reaction to HCl.					
		93											
		94											
		95											
		96											
		97											
		98											
		99											98.9' Started core drilling 10-2-14
		100											
		101											
		102						Dark gray [5Y 4/1], fine grained Sandstone, Bedding variable, moderately soft, moderately to slightly weathered.					
		103					110		68				
		104						Dark gray [5Y 4/1], fine grained Sandstone, moderately soft, moderately to slightly weathered.					
		105											Fractures 105.1' 24° Joint, moderately soft, moderately to slightly weathered, clean 105.5' 8° Joint, clean
		106											106.5' 64° Shear, very thin, very soft, moderately to slightly weathered 106.5' 25° Joint, clean, moderately soft, moderately to slightly weathered
		107											107.1' 19° Joint, clean, moderately soft, moderately to slightly weathered 107.5-107.9' 90° Joint
		108											108.5' 10° Joint
		109											
		110											
		111					104	Very dark gray [5Y 3/1], Siltstone, moderately soft, moderately to slightly weathered, thinly laminated with Black [5Y 2.5/1] Siltstone, moderately soft, moderately to slightly weathered.	81				111.6' 40° Joint, clean
		112											112.0' 40° Joint, clean 112.2' 48° Shear, very thin, soft, moderately to slightly weathered
		113											

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		114		X			104	Very dark gray [5Y 3/1], Claystone, soft, moderately to slightly weathered. *(Continued)*	81				114.5' 12° Joint, very thin, soft, moderately to slightly weathered 114.6' 13° Joint, very thin, soft, moderately to slightly weathered
		115		X									
		116		X			88	Black [N2], Coal, hard, slightly weathered to fresh, bed No. 2.	52				114.8' 76° Shear, very thin, soft, moderately to slightly weathered 114-115.5' 5-10° Bedding joint, moderately spaced 116.0' 12° Bedding joint, hard, slightly weathered to fresh
		117		X									
		118		X									
		119		X				Black [N2], Coal, Bedding 21°, hard, slightly weathered to fresh, bed No. 2.					117.2' 14° Bedding joint, hard, slightly weathered to fresh 116-119' 68° cleats, very closely spaced, discontinuous, none transect entire core
		120		X									
		121		X			88		82				120.0' 20° Bedding joint
		122		X									
		123		X									122.5' 24° Bedding joint
		124		X				Very dark gray [5Y 3/1], Claystone, very soft, moderately to slightly weathered.					124.6' 13° Joint
		125		X									125.0' 70°
		126		X									125.7' 13° Joint 126.0' 59° Shear, very thin
		127		X			92		30				126.6' 0° Joint
		128		X									128.0' 58° Shear, very thin 128.4' 48° Shear, very thin
		129		X				Very dark gray [5Y 3/1], Claystone, Bedding 14°, moderately soft, moderately to slightly weathered, core breaks with hand pressure on bedding planes.					128.5' 48° Shear, very thin 128.6' 47° Shear, very thin 129.5' 63° Shear, very thin
		130		X									130.0' 10° Joint, very thin
		131		X			86		37				130.5' 10° Joint 130.8-131.3' 20° Joint, ground up by drill
		132		X									132.1' 14° Bedding joint
		133		X									
		134		X				Very dark gray [5Y 3/1], Claystone, Bedding 17°, thinly laminated with carbonaceous strings, broke easily on carbonaceous strings, moderately hard, slightly weathered.					
		135		X			100		72				
		136		X									

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		137					100	Very dark gray [5Y 3/1], Claystone, Bedding 17°, thinly laminated with carbonaceous strings, broke easily on carbonaceous strings, moderately hard, slightly weathered. *(Continued)*	72				Fractures 136.5' 13° Shear, very thin, soft, intensely to moderately weathered 137.4-137.7' 14° Shear, moderately thick, soft, moderately weathered
		138						Very dark gray [5Y 3/1], Siltstone, Bedding 17°, moderately laminated with Very dark gray [5Y 3/1] Claystone and thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					138.2' 20° Bedding joint, very thin, moderately hard, slightly weathered 138.7' 24° Joint, very thin, moderately hard, slightly weathered 139.5' 17° Joint 140.0' 18° Joint 140.5' 17° Joint 141.3' 21° Bedding joint 141.5' 21° Bedding joint 142.0' 24° Bedding joint 142.7' 19° Bedding joint Mislatch core in this run 143.9-144.3' Mechanical break, over drill 144.7' 28° Shear, moderately thick, hard, slightly weathered 144.9' 28° Shear, moderately thick, moderately hard, moderately to slightly weathered 145.5' 0° Mechanical break/Joint
		139											
		140											
		141							35				
		142											
		143											
		144											
		145					158		46				
		146											
		147											
		148						Black [5Y 2.5/1], Siltstone, thinly laminated with carbonaceous strings.					148.3' 35° Bedding joint
		149											
		150					100		77				150.3' 28° Bedding joint, very thin, intensely to moderately weathered, very soft 151.0' 17° Bedding joint, very thin, intensely to moderately weathered, soft, partly healed
		151											
		152											
		153						Black [5Y 2.5/1], Siltstone, Bedding 19°, very thinly laminated with carbonaceous strings, breaks easily on carbonaceous strings.					151.2' 17° Bedding joint, clean 152.1' 10° Bedding joint, clean 152.8' 15° Joint, very thin, moderately weathered, soft 153.2' 17° Shear, moderately thick, moderately weathered, soft
		154											
		155					98		68				
		156											156.4' 17° Joint, clean
		157											157.4' 18° Joint
		158					93	Very dark gray [5Y 3/1], Siltstone, Bedding variable with flow structure, very thinly laminated with Black [5Y 2.5/1] Siltstone and carbonaceous strings, hard, slightly weathered.	54				
		159											

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		160, 161, 162, 163					93	Very dark gray [5Y 3/1], Siltstone, Bedding variable with flow structure, very thinly laminated with Black [5Y 2.5/1] Siltstone and carbonaceous strings, hard, slightly weathered. *(Continued)*	54				158.9' 29° Joint, very thin, soft, moderately weathered 159.4' 26° Bedding joint, clean 159.6' 26° Bedding joint/Shear, moderately thin, soft, moderately weathered 160.3' 35° Mechanical break/Shear, moderately thick, hard 160.6' 35° Shear, moderately thick, hard 161.1' 27° Bedding joint, clean
		164, 165, 166, 167, 168					100	Very dark gray [5Y 3/1], Siltstone, variable bedding, very thinly laminated with Black [5Y 2.5/1] Siltstone and carbonaceous strings, hard, slightly weathered.	54				162.2' 53° Joint, hard, slightly weathered 163.9' 24° Bedding joint, clean 164.4' 55° Shear, very thin, soft, intensely to moderately weathered 164.8' 25° Shear, moderately thin, soft 165.1' 25° Shear, moderately thin, soft 166.9' 50° Shear, very thin 167.4' 57° Shear, very thin 167.4' 23° Shear, very thin, soft
		169, 170, 171, 172, 173					92	Gray [N5], Siltstone, Bedding variable, variable flow structure, very thinly laminated with Black [5Y 2.5/1] Siltstone, hard, slightly weathered, thin coal seam at 169-169.5'.	68				Fractures 170.6' 23° Bedding joint, very thin, soft 171.8' 17° Joint, moderately thin, moderately hard 172.6' 72° Joint, very thin, soft 173.0' 12° Joint, very thin, soft
		174, 175, 176, 177, 178					95	Very dark gray [5Y 3/1], Siltstone, Bedding variable mostly 30° with flow structures, very thinly laminated with Black [5Y 2.5/1] Siltstone, hard, slightly weathered to fresh. Trace of carbonaceous feathers.	63				173.9' 27° Bedding joint, moderately thin, moderately soft 175.0' 35° Bedding joint, very thin, soft 176.3' 30° Bedding joint, clean, hard 176.8' 28° Bedding joint, very thin, moderately soft 176.9' 60° Joint, hard 177.6' 32° Shear/Bedding joint, very thin, soft 178.3' 30° Bedding joint, moderately thin, soft
		179, 180, 181, 182					100	Black [2.5Y 2.5/1], Claystone, Bedding 19°, moderately soft, slightly weathered, very thinly laminated with Very dark gray [5Y 3/1] Siltstone, hard, slightly weathered to fresh.	74				179.4' 15° Bedding joint 180.4-180.7' 20-30° Shear, thin, very closely spaced, soft

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		183		X			100	Black [2.5Y 2.5/1], Claystone, Bedding 19°, moderately soft, slightly weathered, very thinly laminated with Very dark gray [5Y 3/1] Siltstone, hard, slightly weathered to fresh. *(Continued)*	74				182.2' 25° Bedding joint, thin, soft 182.3' 32° Joint, clean
		184		X				Black [5Y 2.5/1], Claystone, moderately hard, slightly weathered.					183.2' Indication of loose material, overdrill mark, 1/8" or core moved in barrel 183.7-189' Entire core is moderately fractured to intensely to moderately fractured
		185		X									
		186		X			94		30				184.7' 32° Joint/Shear, moderately thin, soft 185.5' 36° Joint/Shear, thin, soft
		187		X									185.4-186.5' Shear, intensely to moderately fractured 187.1' 10° Shear, very thin, soft
		188		X									187.7' 50° Shear, clean 188.0' 38° Shear, very thin, soft
		189		X				Black [5Y 2.5/1], Claystone, moderately hard, slightly weathered, thin lense of coal from 189-189.1'.					
		190		X									189.7-190.0' 21° Bedding joint, closely spaced
		191		X			100	Dark gray [5Y 4/1], fine grained Sandstone, very thinly laminated with carbonaceous strings, very hard, slightly weathered to fresh.	40				190.7-191' 17° Bedding joint/Shear, closely spaced, moderately thick
		192		X									192-193.6' 86° Joint
		193		X									
		194		X				Black [5Y 2.5/1], Claystone, moderately hard, slightly weathered, thin (1/4") coal feather.					194-195.2' 20° Bedding joint, very closely spaced
		195		X				Dark gray [5Y 4/1], fine grained Sandstone, very thinly laminated with carbonaceous strings, very hard, slightly weathered to fresh.					
		196		X			94		64				195.8' 14° Joint, moderately thin, soft 196.4' 26° Bedding joint, very thin, soft
		197		X									
		198		X									198.1' 6° Bedding joint, clean
		199		X				Black [5Y 2.5/1], Claystone, very soft, intensely to moderately weathered.					
		200		X				Black [N2], Coal, Bedding 15°, moderately laminated with Black [N2] bone, hard, slightly weathered to fresh, breaks easily on bedding and cleats, Bed No. 3.					200.1' 15° Bedding joint
		201		X			100		40				201.0' 17° Bedding joint
		202		X									
		203		X									202.6' 20° Joint 203.3' 75° cleats, very closely spaced, discontinuous
		204		X			98	Black [N2], Coal, Bedding 15°, moderately laminated with Black [N2] bone, hard, slightly weathered to fresh, Bed No. 3.	71				204.5' 50° Joint, clean
		205		X									

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		206						Black [N2], Coal, Bedding 15°, moderately laminated with Black [N2] bone, hard, slightly weathered to fresh, Bed No. 3. *(Continued)*					
		207					98		71				206.3' 10° Joint/Shear, moderately thick, soft 207.4' 10° Joint/Bedding joint, thin, moderately soft
		208											
		209											Fractures 209.6' 5° Joint/Bedding joint, very thin, moderately soft
		210						Black [N2], Coal, Bedding 15°, moderately laminated with Black [N2] bone, hard, slightly weathered to fresh, Bed No. 3.					210.0' 5° Joint/Bedding joint, very thin, moderately soft
		211					100		58				210.5' 17° Bedding joint, moderately thin, soft 210.8' 17° Bedding joint, moderately thick, hard 211.5' 5° Joint, very thin, hard
		212											
		213											212.9-213.3' 17° Joint/Shear, intensely to moderately fractured
		214											213.7' 15° Joint, clean, hard
		215											214-219' Core stuck in tube, used hammer to remove many mechanical breaks
		216						Dark gray [5Y 4/1], Claystone, moderately hard, slightly weathered.					No RQD
		217						Dark gray [5Y 4/1], fine grained Sandstone, Bedding 18°, very hard, fresh.					
		218											
		219											
		220											
		221					94		94				
		222											
		223						Dark gray [5Y 4/1], Siltstone, Bedding 24°, moderately laminated with Gray [N5] Claystone, hard, slightly weathered to fresh.					Fractures 223.0' 71° Shear, moderately thin, partly healed
		224											223.0' 18° Bedding joint
		225											
		226					108		100				
		227											
		228											

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		229, 230					108	Dark gray [5Y 4/1], Siltstone, Bedding 24°, moderately laminated with Gray [N5] Claystone, hard, slightly weathered to fresh. *(Continued)*	100				
		231, 232					92	Gray [N5], Siltstone, moderately laminated with Gray [N5] Claystone, hard, slightly weathered to fresh, strong reaction to HCl.	100				
		233, 234, 235, 236, 237, 238						Very dark gray [5Y 3/1], Claystone, Moderately laminated with Gray [N5] Siltstone, hard, slightly weathered to fresh and Moderately laminated with carbonaceous strings.	98				Fractures 237.2' 22° Bedding joint, very thin, soft
		239, 240, 241, 242, 243					74	Very dark gray [5Y 3/1], Claystone, Moderately laminated with Dark gray [5Y 4/1] Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.	100				
		244, 245, 246, 247, 248, 249					98	Very dark gray [5Y 3/1], Claystone, Moderately laminated with Dark gray [5Y 4/1] Claystone, hard, slightly weathered to fresh.	71				Fractures 244.6' 9° Joint 245.8' 25° Shear, thin, soft 246.1' 12° Joint, clean, hard 246.5' 20° Bedding joint, clean, hard 246.9' 2° Mechanical break, clean, hard 247.1' 14° Bedding joint, clean, hard 247.6' 11° Shear, thin, soft 248.4' 15° Bedding joint, clean, hard 248.6' 12° Joint, clean, hard 248.7' 17° Bedding joint, clean, hard
		250, 251					100	Gray [5Y 5/1], Siltstone, moderately laminated with Dark gray [5Y 4/1] Claystone, hard, slightly weathered to fresh.	94				250.7' 25° Bedding joint

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		252, 253					100	Gray [5Y 5/1], Siltstone, moderately laminated with Dark gray [5Y 4/1] Claystone, hard, slightly weathered to fresh. *(Continued)*	94				
		254, 255, 256, 257, 258					100	Gray [5Y 5/1], Claystone, moderately laminated with Gray [5Y 5/1] Siltstone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.	100	27	7.7		
		259, 260, 261, 262, 263					100	Dark gray [5Y 4/1], Claystone, Bedding 18°, moderately laminated with Gray [5Y 5/1] Siltstone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.	95	27	7.7		Fractures 259.6' 16° Bedding joint, hard
		264, 265, 266, 267, 268					96	Dark gray [5Y 4/1], Claystone, moderately laminated with Gray [5Y 5/1] Siltstone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.	96				Fractures 264.0' 23° Bedding joint, hard
		269, 270, 271, 272, 273, 274					102	Gray [5Y 5/1], Siltstone, moderately laminated with Dark gray [5Y 4/1] Claystone, thinly laminated with carbonaceous strings, hard, slightly weathered to fresh.					Fractures 272.9' 18° Bedding joint/Mechanical break, hard, slightly weathered to fresh

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							100	Gray [5Y 5/1], fine grained Sandstone, moderately laminated with Gray [5Y 5/1] Siltstone and Dark gray [5Y 4/1] Claystone, all hard, slightly weathered to fresh. *(Continued)*	96				
		275											275-275.5' 85° Joint, closely spaced, discontinuous fractures in fine grained Sandstone and terminate in Claystone, clean, slightly open, not observed in other fine grained Sandstone layers
		276					100		96				
		277											
		278											
		279						Gray [5Y 5/1], fine grained Sandstone, moderately laminated with Dark gray [5Y 4/1] Claystone, hard, slightly weathered to fresh.					Fractures 279-280.4' 90° Joint, discontinuous and only in fine grained Sandstone, clean, slightly open, closely spaced
		280											
		281							100				
		282											
		283											
		284						Gray [5Y 5/1], fine grained Sandstone, moderately laminated with Dark gray [5Y 4/1 Siltstone and Claystone.					Fractures 284.3' 48° Shear, moderately thin, hard, slightly weathered to fresh 284.7' 42° Joint, moderately thin, hard, slightly weathered to fresh
		285											
		286					108		93				
		287											
		288											
		289						Gray [5Y 5/1], fine grained Sandstone, Bedding 17°, moderately laminated with Dark gray [5Y 4/1] Siltstone and Claystone.					
		290											
		291					76		100				
		292											
		293											
		294						Dark gray [5Y 4/1], Claystone, moderately laminated with Gray [5Y 5/1] fine grained Sandstone and Gray [5Y 5/1] Siltstone, hard, slightly weathered to fresh.					
		295					106		100				
		296											
		297											

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		298					106	Dark gray [5Y 4/1], Claystone, moderately laminated with Gray [5Y 5/1] fine grained Sandstone and Gray [5Y 5/1] Siltstone, hard, slightly weathered to fresh. *(Continued)*	100				
		299						Gray [5Y 5/1], Siltstone, Bedding 27°, moderately laminated with Dark gray [5Y 4/1] Claystone, thinly laminated with carbonaceous strings.					
		300											
		301					106		96				
		302											Fractures 302.6' 29° Bedding Joint/Shear, thin, moderately soft, slightly weathered, observe anatomising fractures in gouge
		303											
		304						Dark gray [5Y 4/1], Claystone, Bedding 25°, moderately laminated with Gray [5Y 5/1] Siltstone, hard, slightly weathered to fresh.					
		305											
		306											305.7' 24° Bedding Joint/Shear, thin, moderately soft, moderately to slightly weathered
							100		94				
		307											
		308											
		309						Dark gray [5Y 4/1], Claystone, Bedding 25°, thinly laminated with Gray [5Y 5/1] Claystone, hard, slightly weathered to fresh.					
		310											
		311											
							100		100				
		312											
		313											
		314											
		315						Dark gray [5Y 4/1], Claystone, Bedding 28°, thinly laminated with Gray [5Y 5/1] Claystone, hard, slightly weathered to fresh.					
		316											
							100		100				
		317											
		318											
		319						Dark gray [5Y 4/1], Claystone, Bedding 26°, thinly laminated with Gray [5Y 5/1] Claystone, hard, fresh.					
							64		100				
		320											

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		321						Dark gray [5Y 4/1], Claystone, Bedding 26°, thinly laminated with Gray [5Y 5/1] Claystone, hard, fresh. *(Continued)*					
		322					64		100				Fractures 322.5-326' 27° Joint/Shear, very closely spaced, moderately to totally healed 322.5-326' 63° Bedding joint/Shear, very closely spaced, moderately healed
		323											
		324						Dark gray [5Y 4/1], Claystone, Bedding 27°, hard, slightly weathered to fresh.					
		325											
		326					135		100				Fractures 326.5' 2° Mechanical break, hard, slightly weathered to fresh
		327											
		328						Dark gray [5Y 4/1], Claystone, Bedding 27°, hard, slightly weathered to fresh.					328.3' 30° Shear, hard, slightly weathered to fresh, clean 328.7' 57° Shear, very thin, partly healed 329.4' 30° Shear, soft, moderately to slightly weathered, thin 328-333.4' 27° Bedding joint/Shear, very closely spaced, moderately healed
		329											
		330											
		331					98		92				
		332											
		333											
		334						Dark gray [5Y 4/1], Claystone, Bedding 26°, hard, slightly weathered to fresh.					333.9' 24° Shear, thin, moderately hard
		335											
		336					100		80				
		337											337.1' 26° Shear, moderately thick, moderately soft
		338											337.6' 42° Shear, moderately thick, moderately hard
		339						Dark gray [5Y 4/1], Claystone, hard, slightly weathered to fresh.					339.3' 26° Shear, clean
		340					43						339.8' 19° Shear, very thin, moderately soft 340.2' 19° Shear, moderately thin, soft 340.7' 19° Shear, thin, soft 340.9' 18° Shear, thin, soft 341.7' 18° Shear, thin, soft
		341											
		342						Black [N2], 342-345.8 void, top of Bed No. 4 cave.					342-345.8' open space
		343											

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		344						Black [N2], 342-345.8 void, top of Bed No. 4 cave. *(Continued)*					
		345											345.8' Rods won't fall, but very soft drilling Recovered coal somewhere between 346-350.0'
		346						Black [N2], Coal, Bedding 20°, 90% broken core, 10% Poor graded gravel, GP, recovered 2' of coal, 1' is Poorly graded gravel, 1" particle to sand sized, 1' is cored piece with fractures, coals smells like swamp smell.					Drilling soft, then dropping 1-2"
		347											
		348					43						Fractures 348.0' 85° Shear, thin, very hard, closely spaced, broken gouge sand sized 348.5' 60° Shear, very thin, very hard, closely spaced
		349											
		350											
		351						Very dark gray [5Y 3/1], Siltstone, Moderately hard, moderately weathered.					Fractures
		352					111		13				351.7' 16° Shear, very hard, gouge of 1/2" gravel 352.0' 25° Bedding joint/Shear, very hard 352.4' 65° Shear, thin, hard, gravel 1/2" gouge
		353											252.8' 60° Shear, moderately thin, hard 253.0' 20° Shear, thin, moderately hard, gravel 353.8' 70° Shear, moderately thin, moderately hard
		354											
		355											
		356											Cleat joints not very prevalent, approx 10% of sample shows cleats
		357					94	Very dark gray [5Y 3/1], Claystone, Moderately hard, moderately to slightly weathered.	26				355.5' 36° Shear 355.5' 82° Shear, very thin, soft 356.7' 30° Bedding joint, very thin, moderately hard 357.2' 40° Shear, very thin, soft
		358						Very dark gray [5Y 3/1], Siltstone, hard, moderately to slightly weathered.					
		359											357.7' 50° Shear, moderately thick, moderately soft
		360						Very dark gray [5Y 3/1], Claystone, Bedding 29°, moderately soft, moderately weathered.					358.0' 64° Joint, very thin, moderately hard 358.3' 42° Shear, moderately thin, soft
		361					84		0				359-360.3' Clayey Gravel, GC, intensely fractured 361.1' 24° Joint
		362											362.0' 64° Shear, moderately thick, soft 362.0' 29° Bedding joint 362.5' 64° Shear, moderately thick, soft
		363											
		364						Very dark gray [5Y 3/1], Claystone, moderately soft, moderately weathered.					364.6' 22° Bedding joint/Shear, moderately thick, moderately soft
		365					92	Black [N2], Coal, Bedding 22°, moderately laminated with bone, Bed No. 4 1/2.	50				364.6-369' Cleats, discontinuous, very closely spaced, but intact core
		366											

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	367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389					92	Black [N2], Coal, Bedding 22°, moderately laminated with bone, Bed No. 4 1/2. *(Continued)*	50				364.6-369' 22-26° Bedding joint, closely spaced
						70	Very dark gray [5Y 3/1], Claystone, moderately soft, moderately weathered.	40				Fractures 370.0' 10° Joint, hard 370.2' 20° Bedding joint, hard/moderately soft 370.5' 20° Bedding joint/Shear, moderately soft 371.0' 20° Bedding joint/Shear, moderately soft 371.5' 30° Bedding joint/Shear, moderately soft 371.5-372.5' Shear, very closely spaced, moderately soft, partly healed 372.5' 40° Shear, moderately soft
							Very dark gray [5Y 3/1], Claystone, moderately hard, moderately weathered.					374.5' 70° Joint, clean 374.7' 72° Joint, clean
							Gray [5Y 5/1], fine grained Sandstone, variable bedding, very hard, slightly weathered to fresh, thinly laminated with Dark gray [5Y 4/1] Claystone, hard, slightly weathered to fresh.	66				375.7' 65° Shear, moderately thin 377.9' 22° Shear/Bedding joint, moderately thin, moderately soft
						104	Gray [5Y 5/1], Siltstone, thinly laminated with Dark gray [5Y 4/1] Claystone, hard, slightly weathered.	82	21	6.7		379' Switch from PQ to HQ 10-8-14 Fractures 379.5' 27° Shear, moderately soft, thin 380.0' 19° Joint, moderately soft 380.6' 14° Joint, hard 381.7' 19° Bedding joint, moderately soft 382.8' 2° Joint, hard 384.3' 14° Joint, hard 385' 12° Joint, hard 385.2-386.5' 80° Joint, hard

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							100	Gray [N5], fine grained Sandstone, very hard, fresh, moderately laminated with carbonaceous strings. *(Continued)*	68				
		390											Fractures 390.4' 44° Shear, partly healed 391.1' 27° Bedding joint, hard 391.3' 85° Joint, hard
		391											
		392											
		393											393.0' 14° Bedding joint, hard
		394					100		68				
		395											
		396											396.0' 78° Shear/Joint, moderately soft, very thin
		397											
		398											397.5' 24° Bedding joint, hard, clean
		399											
		400						Gray [N5], fine grained Sandstone, very hard, fresh.					
		401											
		402											
		403											Fractures 402.7' 30° Shear, clean, hard
		404					100		96	16	6.0		
		405											405.3' 0° Mechanical break
		406											
		407											
		408											407.6' 24° Bedding joint/Shear, moderately thin, moderately hard 408.3' 2° Joint
		409						Gray [N5], fine grained Sandstone, hard, fresh, random carbonaceous strings.					
		410											
		411					100		91				Fractures 411.6' 0° Mechanical break
		412											

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		413, 414, 415						Gray [N5], fine grained Sandstone, hard, fresh, random carbonaceous strings. *(Continued)*					413.1' 0° Mechanical break 413.6' 0° Mechanical break
		416, 417, 418, 419, 420					100	Dark gray [5Y 4/1], Siltstone, thinly laminated with Gray [5Y 5/1] Siltstone hard, fresh.	91				415.3' 5° Mechanical break 416.7' 27° Bedding joint/Shear, very thin, soft 417.0' 32° Bedding joint/Shear, very thin, soft 417.1' 32° Bedding joint/Shear, very thin, soft 417.6' 36° Bedding joint/Shear, very thin, soft 10° Joint 26° Bedding joint/Shear, thin, soft 420.1' 45° Bedding joint
		421, 422						Dark gray [5Y 4/1], Siltstone, variable bedding with flow structures, moderately laminated with Gray [N5] fine grained Sandstone, hard, slightly weathered to fresh.					
		423, 424, 425, 426, 427, 428, 429					100	Very dark gray [5Y 3/1], Siltstone, moderately laminated with Gray [N5] fine grained Sandstone, hard, slightly weathered to fresh.	97				
		430, 431, 432, 433, 434, 435					100	Very dark gray [5Y 3/1], Siltstone, moderately laminated with Gray [N5] fine grained Sandstone, hard, slightly weathered to fresh.	94	17	6.1		Fractures 429.7' 42° Bedding joint/Shear, thin, moderately hard 431.2' 29° Bedding joint/Shear, moderately thin, very hard

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		436						Very dark gray [5Y 3/1], Siltstone, moderately laminated with Gray [N5] fine grained Sandstone, hard, slightly weathered to fresh. *(Continued)*					435.4' 31° Bedding joint/Shear, moderately thin, soft
		437					100		94	17	6.1		436.6' 30° Bedding joint/Shear, thin, moderately soft
		438											
		439						Very dark gray [5Y 3/1], Siltstone, moderately laminated with Gray [N5] fine grained Sandstone, hard, slightly weathered to fresh.					
		440											
		441						Gray [N5], fine grained Sandstone, moderately laminated with Dark gray [5Y 4/1] siltstone, very thinly laminated carbonaceous strings.					Fractures 441.6' 22° Bedding joint/Shear, moderately thin, moderately soft
		442											
		443											
		444					100		94				
		445											445.2' 22° Bedding joint/Shear, moderately thin, moderately soft
		446											445.7' 25° Bedding joint/Shear, moderately thin, moderately soft, slickens
		447											446.0' 25° Bedding joint/Shear
		448											
		449						Gray [N5], fine grained Sandstone, Bedding 24°, thinly laminated with carbonaceous strings and Very dark gray [5Y 3/1] Claystone, hard, slightly weathered to fresh.					
		450											
		451											450.7' 85° Shear, moderately healed, very thin
		452											
		453											
		454					100		100				
		455											
		456											
		457											
		458											

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							100		100				
		459						Gray [N5], fine grained Sandstone, Bedding 30°, thinly laminated with carbonaceous strings and Very dark gray [5Y 3/1] Claystone, thin coal string at 467.7-467.8'.					
		460											
		461											
		462											
		463											
		464					100		94				Fractures
		465											465.0' 30° Bedding joint/shear, moderately thin, moderately soft
		466											
		467											467.2' 30° Bedding joint/Shear, very thin, moderately soft, slickens parallel to strike
		468											467.8' 30° Bedding joint
		469						Gray [N5], fine grained Sandstone, thinly laminated with Very dark gray [5Y 3/1] Claystone and carbonaceous strings.					
		470											
		471											
		472											
		473											Mechanical breaks on carbonaceous strings at 472.7 and 477.6'
		474					100		100				
		475											
		476											
		477											
		478											
		479						Gray [5Y 5/1], Siltstone, thinly laminated with Very dark gray [5Y 3/1] Claystone, hard, slightly weathered to fresh, joint on carbonaceous strings.					
		480					100		94				Fractures
		481											480.8' 30° Bedding joint,

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		482						Gray [5Y 5/1], Siltstone, thinly laminated with Very dark gray [5Y 3/1] Claystone, hard, slightly weathered to fresh, joint on carbonaceous strings. *(Continued)*					clean, hard
		483											483.0' 33° Bedding joint, clean, hard
		484											
		485					100		94				484.8' 24° Bedding joint, clean, hard
		486											
								Very dark gray [5Y 3/1], Claystone, hard, slightly weathered to fresh.					
		487											487.0' 24° Bedding joint/Shear, thick, moderately hard
		488											
		489						Very dark gray [5Y 3/1], Claystone, moderately hard, slightly weathered.					Fractures
		490											490.0' 59° Shear, clean, moderately hard
		491											
		492											492.3' 36° Shear, clean, moderately hard 492.7' 10° Bedding joint
		493						Very dark gray [5Y 3/1], Claystone, moderately soft, moderately to slightly weathered.					
		494					100	Black [N2], Coal, moderately laminated with Black [N2] bone, Bed No. 5.	67				493.5' 24° Bedding joint, clean, moderately hard 493.7' 28° Bedding joint
		495											495.0' 85° Joint, clean
		496											495-496' 70° cleats, very closely spaced 495-496' 20° cleats, very closely spaced
		497											
		498											
		499						Black [N2], Coal, Bedding 20°, moderately laminated with bone, very hard, slightly weathered to fresh, Bed No. 5.					498.5' 12° Joint/Mechanical break 499.3' 0° Joint, very hard 499.4' 0° Joint, very hard
		500											500.2' 15° Bedding joint, hard
		501					100		67				501.3' 5° Joint, hard 501.4' 5° Joint, hard 501.8' 14° Bedding joint, hard
		502											
		503											502.8' 6° Bedding joint, hard 502.9' 6° Bedding joint, hard 503.4' 15° Bedding joint 503.6' 12° Bedding joint
		504											

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		505						Black [N2], Coal, Bedding 20°, moderately laminated with bone, very hard, slightly weathered to fresh, Bed No. 5. *(Continued)*					505.3' 18° Bedding joint 505.8' 22° Bedding joint
		506					100		67				506.3' 10° Bedding joint 506.7' 10° Bedding joint
		507											
		508											Pillars appear intact. Probably near a center. Fractures in only bedding joint or joint near bedding
		509						Black [N2], Coal, Bedding 15°, thinly laminated with Black [N2] bone/shale, very hard, slightly weathered to fresh, cleats 75°, 95° of joints are bedding, 514.1-514.5' is blocky, broken on cleats, Bed No. 5.					Fractures
		510											510.1' 14° Bedding joint, hard
		511											510.9' 15° Bedding joint, hard 511.6' 9° Bedding joint/Joint, hard
		512											
		513											513' 13° Bedding joint, hard
		514					100		75				513.6' 15° Bedding joint, hard 513-513.6' 75° Closely spaced, cleats, moderately healed, discontinuous, intact 514.1-514.5' 15° Bedding joint, very closely spaced, blocky
		515						Very dark gray [5Y 3/1], Siltstone, hard, slightly weathered to fresh, grading to Very dark gray [5Y 3/1] Siltstone, hard, slightly weathered to fresh.					
		516											
		517											
		518											
		519						Gray [5Y 5/1], Siltstone, very hard, slightly weathered to fresh, moderately laminated with Very dark gray [5Y 3/1] Claystone, hard, slightly weathered to fresh.					
		520											
		521											Fractures 521.3' 8° Bedding joint, moderately hard
		522											
		523					103		96				
		524											524.0' 0° Mechanical break, hard
		525											524.9' 8° Bedding joint, moderately hard 525.3' 3° Bedding joint/Joint, moderately soft
		526											
		527											

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PHONE NUMBER:

Drill Hole No. BH-07

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		528					103	Gray [5Y 5/1], Siltstone, very hard, slightly weathered to fresh, moderately laminated with Very dark gray [5Y 3/1] Claystone, hard, slightly weathered to fresh. *(Continued)*	96				528.4' 12° Bedding joint
		529						Gray [5Y 5/1], fine grained Sandstone, moderately to thinly laminated with Very dark gray [5Y 3/1] Claystone and Siltstone, hard, slightly weathered to fresh.					
		530											
		531											Fractures 530.7' 22° Bedding joint, moderately soft, moderately weathered
		532											532' 21° Bedding joint, hard, slightly weathered to fresh 532.6' 16° Bedding joint/Shear, moderately hard, moderately to slightly weathered
		533											
		534					157		89				534.0' 12° Bedding joint, hard, slightly weathered to fresh
		535											
		536											
		537											
		538											
		539											538.5' 15° Bedding joint, hard, slightly weathered to fresh
		540						Very dark gray [5Y 3/1], Claystone, moderately laminated with coal strings and feathers, hard, slightly weathered to fresh.					539.7-541.2' Bedding joint, closely spaced, extremely hard, broken on coal
		541											
		542											
		543											543.2' 10° Bedding joint
		544					99		64				543.8' 25° Shear
		545											544.7' 15° Bedding joint 544.8' 17° Joint
		546											545.5' 75° Joint, coal feathers
		547											
		548											547.8' 65° Joint, coal feathers
		549											Total Depth = 549.0'
		550											

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PHONE NUMBER:

Drill Hole No. BH-08

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/4/14 - 8/20/14	DRILLER: O'Keefe/Axis Drilling
LOGGED BY: M. Browne/J. Riedel	DRILL TYPE: Foremost DR-24/Christensen CS1500
GROUND SURFACE ELEVATION: 5732.20 ft	HOLE DIAMETER: 6"/PQ-3/HQ-3
BOREHOLE LOCATION: N. 341185.114, E. 2030439.521	HAMMER TYPE: None

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		1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13				G14587, G14588, G14589		Damp, Dark yellowish brown [10YR 4/6], WELL GRADED SAND with Silt, SW-SC, non-plastic, Trace fine to medium coarse gravels, gravels are subrounded to subangular, no reaction to HCl.					Soil Descriptions based on classification of cuttings Irrigation ditch approx. 100' east Water level = 6.25' on 8/6/2014
		13, 14, 15, 16, 17, 18, 19				G14590		Wet, Brown [10YR 5/3], POORLY GRADED GRAVEL with Sand, GP, non-plastic, Gravel subrounded to subangular, no reaction to HCl.					Water level = 14.0' on 8/5/2014 Water in casing when drilling at approximately 15'
		19, 20, 21				G14591		Damp, Dark yellowish brown [10YR 4/6], WELL GRADED SAND with Silt and Gravel, SW-SM, non-plastic, gravels fine to medium, gravels subrounded to subangular, no reaction to HCl.					

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Drill Hole No. BH-08

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		22						Damp, Dark yellowish brown [10YR 4/6], WELL GRADED SAND with Silt and Gravel, SW-SM, non-plastic, gravels fine to medium, gravels subrounded to subangular, no reaction to HCl. *(Continued)*					
		23				G14591							
		24						Wet, Grayish brown [10YR 5/2], WELL GRADED GRAVEL, GW, non-plastic, gravels rounded to subrounded, some angular fragments, possibly fractured from drilling.					
		25											
		26											
		27											
						G14592							
		28											
		29											
		30											
		31						Wet, Yellowish brown [10YR 5/4], WELL GRADED SAND with Silt, SW-SM, non-plastic, no reaction to HCl.					
		32											
						G14593							
		33											
		34											
		35											
		36											
		37											
						G14594							
		38											
		39											
		40											
		41						Wet, Olive yellow [2.5Y 6/6], WELL GRADED SAND with Silt, SW-SM, non-plastic.					
		42				G14595							
		43											
		44											

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								Damp, Brownish yellow [10YR 6/6], SANDSTONE, fragments have weak field strength. *(Continued)*					Cuttings classify as Silty Sand with Gravel, SM
		45				G14596							
		46											Wet 46-47'
		47											
		48				G14597		Moist to wet, Dark yellowish brown [10YR 4/6], SANDY ELASTIC SILT, fragments have weak to moderate field hardness.					
		49											Slow drilling through Sandstone
		50											
		51											
		52											
		53											
		54											
		55											
		56											
		57											Finish casing drilling at 57'
		58											
		59						Gray, Claystone.					58.7' Started PQ
		60											
		61						Gray [N5], Claystone, bedding of coal at 29°, trace of fossils, moderately hard, fresh, shear fractures at 62-62.7', coal seam at 61-62', totally healed dip at 25°, different strike than bedding, intensely fractured, bedding parallels fractures in coal.					Strong reaction to HCl
		62					87		67				
		63											
		64											
		65						Light gray, Claystone, Bedding 40°, variable bedding with flow structure, moderately hard, fresh, Moderately fractured, strong reaction to HCl.					
		66					100		44				
		67											

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		68		X			100	Light gray, Claystone, Bedding 40°, variable bedding with flow structure, moderately hard, fresh, Moderately fractured, strong reaction to HCl. *(Continued)*	44				
		69		X				Black, Coal, soft, fresh, very intensely fractured.					
		70		X				Gray, Claystone, very fine grained, Bedding variable, flow structure, trace of coal feathers, soft, fresh.					
		71		X									
		72		X			98		76				
		73		X				Gray, Claystone, fracture at 73.8', Bedding 70°, slight alteration, trace limonite on surface. Remaining mechanical breaks are not measured.					
		74		X									
		75		X				Light gray, Claystone, variable bedding flow structure with thin bedding approx. 1mm ossicilate from black to gray, Moderately hard, Slightly weathered to fresh. Most of core is Moderately to slightly fractured except 77.2-78.0' is Intensely fractured.					Strong reaction to HCl
		76		X									
		77		X			96						
		78		X				Light gray, interbedded zones of fine grained sandstone that is weaker than very fine grained Claystone.					
		79		X									
		80		X				Light gray, Claystone, Bedding 28°, variable flow structure, thin bedding (1mm), moderately hard, slightly weathered to fresh, Mechanical breaks easily occur on bedding. All breaks mechanical, no measures, strong reaction to HCl.					
		81		X									
		82		X			104		100				
		83		X									
		84		X				Light gray, Claystone, very fine grained, Bedding 26°, thin bedding (1mm) thickness, mechanical breaks parallel to bedding.					Fractures 85-85.3' 26° Intensely fractured 85.8' 60° Mechanical break
		85		X									
		86		X			100		71				
		87		X				Light gray, Claystone, very fine grained, Bedding 27°, flow structure, mechanical breaks on bedding, Moderately hard, Fresh, strong reaction to HCl.					87.0' 60° Mechanical break
		88		X									88.2' 27° Mechanical break
		89		X			100		85				
		90											

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		91						Light gray, Claystone, very fine grained, Bedding 27°, flow structure, mechanical breaks on bedding, Moderately hard, Fresh, strong reaction to HCl. *(Continued)*					Fractures 90.3' 27°
		92					100		85				
		93											93.1' 26°
		94						Light gray, Claystone, very fine grained, Bedding 26°, mechanical breaks and bedding, moderately hard, fresh, fossils on fracture faces, strong reaction to HCl.					94.7' 26°
		95											95.4' 18°
		96					104		77				96.5' 26°
		97											96.9' 26°
		98						Light gray, Claystone, Bedding 30°, healed fracture with slickensides at 98.6'.					98.1' 20°
		99						Light gray, Claystone, very fine grained, Bedding 24°, thin black feathers approx 0.5mm interbedded, tan inclusion of mudstone at 101', Moderately hard, Fresh, strong reaction to HCl.					
		100											
		101					88		71				
		102											
		103											Fractures 103.0' 27° 103.5-104.0' Mechanical break, from removal of core from shoe
		104						Light gray, Claystone, very fine grained, Bedding 23°, Moderately hard, Fresh, 61° fractures have alteration on surface, probably limonite, strong reaction to HCl.					
		105											Fractures 105.3' 61° 105.5' 25° 105.6' 61°
		106					100		58				106.5' 81°
		107						Light gray to tan, fine grained Sandstone interbedded with Light gray Shale, Bedding shows flow structures, strong reaction to HCl.					107.3' 5°
		108						Light gray, very fine grained Sandstone, Bedding 27°, Moderately hard, Fresh, mechanical breaks on bedding less persistent than in Shale.					108.2' 21° Arc between bedding, 61° fractures
		109											
		110											Fractures 110.2' 10° 110.6' 27°
		111					92		93				
		112											
		113											112.5' 65° 112.6' 65°

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							92	Light gray, very fine grained Sandstone, Bedding 27°, Moderately hard, Fresh, mechanical breaks on bedding less persistent than in Shale. *(Continued)*	93				113.0' 65°
		114						Light gray, fine grained Sandstone/Siltstone, Bedding 20°, Moderately hard, Fresh, interbedded lenses of coal, 1mm thick.					Core from 114' to 117' is Moderately to slighty fractured Fractures
		115											
		116					96		48				115.8' 20° Shear 116.2' 20° Shear
		117											Core from 117' to 119' is Intensely fractured 117.2' 10°, Joint, Intensely fractured
		118						Saturated, Light gray, FAT CLAY, CH, medium to high plasticity.					118.2' 24°, Bedding joint, Slightly weathered/Moderately to slightly weathered 118.4' 24°, Bedding joint, Intensely fractured Rods dropped 2.5' at 119.0'
		119						Void, top of Bed No. 1 1/2 cave.					
		120											
		121											
		122						Light gray, fine grained Sandstone/mudstone, Bedding 36°, recovery was seven pieces of rubble, some pieces never cut by bit.					
		123											Driller states no torque, no water, very soft
		124											
		125					10		0				
		126											
		127						Very dark gray [N3], Claystone, Very soft, Slightly weathered, Intermiten with light gray [N7] fine grained sandstone, cuttings are fat clay and cmall cobbles (2" diameter).					Driller states very easy drilling, no water pressure, barely down pressure, barely torque
		128											
		129											
		130					63		0				
		131											
		132											
		133						Light gray [N7], fine grained Sandstone.					
		134							0				
		135											
		136											

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		137						Very dark gray [N3], angular Claystone with Dark gray (10YR 4/1) Clay with Sand, CL. 10% of angular faces have limonite alteration. Shear zone appearance, angular particles floating in fine grained clay matrix. *(Continued)*	0				Water getting siphoned out of rods
		138											
		139						Very dark gray [N3], very fine grained Claystone, interbedded at 3mm, flow structure, wave deposit, cross bedding.					
		140											
								Coal, Intensely fractured, Bed No. 1 1/2.					
		141					98	Dark olive brown [2.5Y 3/3], FAT CLAY, CH, high plasticity, with rust orange.	47				
		142						Dark greenish gray [5GY 4/1], LEAN CLAY, CL.					
								Dark olive brown [2.5Y 3/3], FAT CLAY, CH, high plasticity.					
		143						Greenish gray [5GY 6/1], fine grained Sandstone, thin coal lense.					
		144											Fractures
								Very dark gray, CLAYEY GRAVEL, GC.					144.4' 41°, Bedding joint
		145											145.0' 33°, Bedding joint
								Greenish gray [5GY 6/1], fine grained Sandstone, hard, fresh, no reaction to HCl.					145.4' 29°, Bedding joint 145.5' 29°, Bedding joint
		146					94		58				
		147											
		148											
		149						Gray [5Y 5/1], fine grained Sandstone, Bedding 22°, calcite inclusions react with HCl, no reaction to HCl.				
		150											
		151					96		90				
		152											
		153											
		154						Very dark gray and gray, fine grained Sandstone, Bedding 23°, interbedded with siltstone, Black (N1), Hard, lense of coal in 0.5 mm thickness (weak reaction to HCl), strong reaction to HCl.					
		155											
		156					98		98				Fractures
		157											157.2' 23°, Bedding joint
		158											
								Very dark gray [N3] Black [N2], Claystone, Bedding 24°.					158.9' 15°, Joint
		159											

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PHONE NUMBER:

PROJECT NAME: Red Lodge Drilling Investigation

Drill Hole No. BH-08

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		160					118	Very dark gray [N3] Black [N2], Claystone, Bedding 24°. *(Continued)*	47				
								CLAYEY GRAVEL, GC, angular particles.					
		161						Claystone, intensely fractured is .08" thick, weak reaction to HCl.					Fractures 160.5' 13°, Joint 160.6' 27°, Joint 161.0' 19°, Joint 161.3' 17°, Shear
		162					97	Gray [5Y 5/1], fine grained Sandstone, Bedding 23°, interbedded with think (1mm) strip of very fine grained siltstone, hard, fresh, coal lense not parallel to bedding, no reaction to HCl.	42				162.0' 31°, Joint, Plumose structure on face 162.2' 31°, Joint, Plumose structure on face
		163											
		164											163.7' 36°, Joint 163.9' 0°, Mechanical break
		165											
		166					100		94				165.8' 5°, Joint 166.1' 20°, Shear
		167											
		168						Gray [5Y 5/1], fine grained Sandstone, Bedding 24°, hard, fresh, no reaction to HCl.					
		169											
		170											Fractures 170.6' 27°, Shear
		171					96		67				
		172											172.1' 39°, Shear 172.5' 33°, Shear
		173											173.0' 33°, Shear 173.5' 21°, Joint
		174						Dark greenish gray, fine grained Sandstone, Bedding 45° (could be crossbed), hard, fresh, no reaction to HCl.					
		175											Fractures
		176					102		88				176.0' 35°, Shear 176.5' 60°, Shear
		177											177.0' 33°, Joint
		178											
		179						Gray [5Y 5/1], fine to medium grained Sandstone, variable bedding with flow structure, hard, fresh, strong reaction to HCl.					
		180					94		89				Fractures 180.5' 10°, Shear
		181											181.3' 45°, Shear
		182											

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		183					94	Dark greenish gray [5GY 4/1], fine grained Sandstone, hard, fresh, interbedded with Very dark gray siltstone stringers approximately 0.5mm thick, weak reaction to HCl.	89				
		184						Dark greenish gray [5GY 4/1], fine grained Sandstone, hard, fresh, weak reaction to HCl.					Fractures
		185											185.3' 24°, Shear
		186											186.2' 7°, Shear
							100		78				
		187											187.4' 7°, Shear 187.6' 7°, Shear 187.8' 7°, Shear 188.4' 45°, Shear
		188						Claystone.					
		189											
		190						Greenish gray [5GY 6/1], fine grained Sandstone, Bedding 53°, interbedded with carbonaceous 0.5mm thick, hard, fresh.					Fractures
		191											190.7' 19°, Shear
							100		81				
		192											
		193											
		194						Very dark gray [N3], very fine grained Sandstone/Siltstone interbedding between Siltstone and Sandstone, Bedding 33°, thin bed of vitronite, weak reaction to HCl.					
		195											
		196											
							96		100				
		197											
		198											
		199						Dark greenish gray [5GY 4/1], fine grained Sandstone/Siltstone, interbedded with carbonaceous layers.					Fractures 199.7' 27°, Bedding joint
		200											200.1' 0°, Shear, Intensely fractured 0.1' 200.2' 22°, Shear
		201											201.2' 19°, Shear
							104		71				
		202											201.7' 14°, Joint 201.7'-202.3' Intensely fractured 202' 50°, Shear 202' 13° Joint
		203											
		204						Gray [N6], fine grained Sandstone, Bedding 40° interbedded with carbonaceous materials and siltstone.					
							92		86				
		205											

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Helena, Montana 59620-0901

PHONE NUMBER:

This log is part of a report prepared by Pioneer Technical, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
		206						Gray [N6], fine grained Sandstone, Bedding 40° interbedded with carbonaceous materials and siltstone. *(Continued)*					Fractures 205.2' 40°, Bedding Joint
		207					92		86				206.4' 7°, Shear, Slightly weathered 206.5' 7°, Shear, Slightly weathered 207.2' 27°, Shear, Slightly weathered
		208											
		209						Gray [N6], SILTY GRAVEL, GM, gravels are fine grained Sandstone, fines are medium to high plasticity Silt, ML, top of Bed No. 2 cave.					Gulping water in rods
		210											
		211					30		0				
		212											
		213											
		214						Dark gray [N4], SILTY GRAVEL, GM, medium to high plasticity, silts are elastic, gravels are very soft. Gravels are floating in elastic silt matrix, split sample vertically interbedded Siltstone, very soft.					
		215											
		216					56		0				
		217											
		218											
		219						Dark greenish gray, SILTY GRAVEL, GM, medium to high plasticity, silts are elastic, gravels are very soft.					
		220						Dark greenish gray, LEAN CLAY, CL, intermixed with coal, coal is 1mm particles, not in place.					
		221					60		0				
		222											
		223											
		224											224' Driller lost water
		225											224-225.5' no torque pressure
		226					50	Black [N2], Gravel, gravels are angular coal from 3" to 1/8" diameter.	0				
		227						Dark greenish gray, Claystone, very soft, moderately to slightly weathered, thin interbedded coal strings.					
		228											

PIONEER TECHNICAL SERVICES, INC.

CLIENT: Montana Department of Environmental Quality

ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-08

This log is part of a report prepared by Pioneer Technical, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
							50	Dark greenish gray, Claystone, very soft, moderately to slightly weathered, thin interbedded coal strings. *(Continued)*	0				
		229						Dark greenish gray, Claystone, very soft, slightly weathered, intensely to moderately fractured, thin coal strings.					
		230											
		231					59		0				
		232											
		233						Dark greenish gray, Claystone, very soft, slightly weathered, thin coal strings.					
		234											
		235											Fractures 235.5' Fracture 26° Joint
		236							0				
		237											
								thin lense of Sandstone.					
		238						Gray [N6] Very dark gray [N3], Claystone/Shale, Bedding 26°, moderately soft, moderately weathered, interbedded with very dark gray [N6] Claystone, soft, slightly weathered.					
		239											
		240											Fractures 240.0' 27°, Bedding Joint 240.1' 26°, Bedding Joint 240.3' 26°, Bedding Joint
		241					100		23				241.5' 26°, Bedding Joint
		242											242.2' 27°, Bedding Joint
		243											242.7' 26°, Bedding Joint
		244						Light gray [N7] Gray [N5], fine grained Sandstone, Bedding 30°, interbedded with siltstone and trace of claystone, Hard, Fresh, no reaction to HCl.					243.8' 22°, Bedding Joint 244.1 27°, Bedding Joint 244.2' 27°, Bedding Joint 244.9' 15°, Bedding Joint 244.95' 27°, Bedding Joint
		245						Claystone.					
		246						Sandstone.					
							102	Claystone.	39				246.4' 27°, Bedding Joint
		247						Gray [N6] Dark gray [N4], fine grained sandstone, Bedding 21°, interbedded with siltstone and claystone, Sandstone is Hard, Fresh. Claystone is Moderately soft, Slightly weathered.					247.2' 27°, Shear 247.2 50°, Joint 247.4' 30°, Bedding joint 247.8' 30°, Bedding joint 248.3' 27°, Bedding joint
		248											
		249											249.3' 24°, Bedding joint
		250					96		32				250.4' 24°, Bedding joint
		251											

PIONEER TECHNICAL SERVICES, INC.

CLIENT: Montana Department of Environmental Quality

ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

PROJECT NAME: Red Lodge Drilling Investigation

Drill Hole No. BH-08

This log is part of a report prepared by Pioneer Technical, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	RQD (%)	Average Shore Hardness (Sh)	Average Unconfined Compressive Strength (psi x1000)		REMARKS / TESTING
		252		X			96	Gray [N6] Dark gray [N4], fine grained sandstone, Bedding 21°, interbedded with siltstone and claystone, Sandstone is Hard, Fresh. Claystone is Moderately soft, Slightly weathered. *(Continued)*	32				251.0' 32°, Bedding joint 251.3' 26°, Bedding joint 251.5' 26°, Bedding joint 252.0' 60°, Joint
		253		X									
		254		X				Claystone.					Total Depth =254.0'
		255											
		256											
		257											
		258											
		259											
		260											
		261											
		262											
		263											
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		266											
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		268											
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		270											
		271											
		272											
		273											
		274											

PIONEER TECHNICAL SERVICES, INC.

CLIENT: Montana Department of Environmental Quality

ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

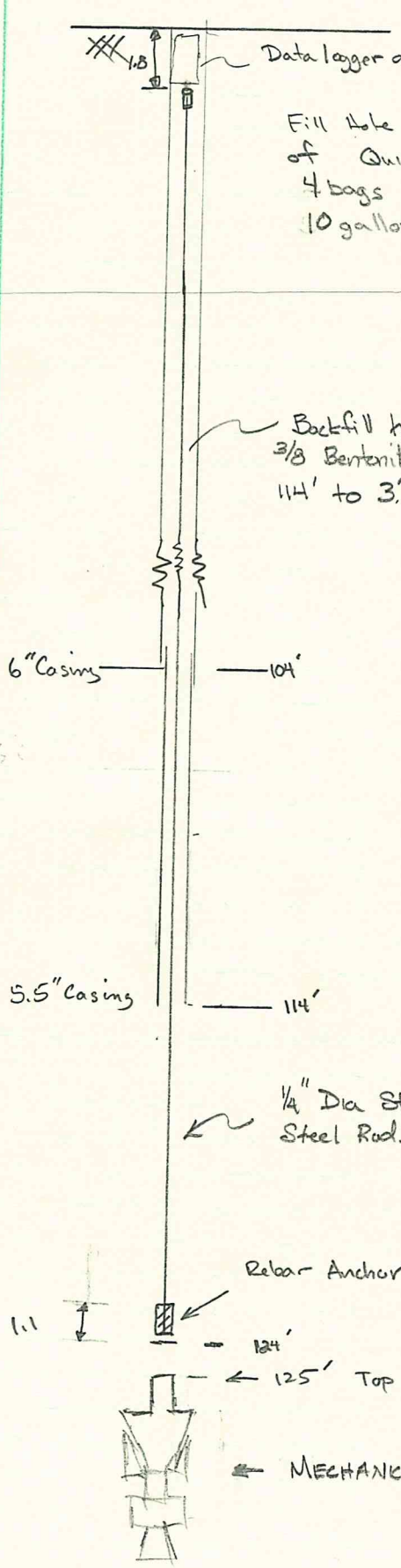
Extensometer Logs

BH-02

RED LODGE
Extensometer Install

10-24-14
10-25-14

JR
PTS



Grout Volume Hole

PG Hole Dia 4.827"

$$\text{Volume} = \pi r^2 h$$
$$= \pi\left(\left[\frac{4.827}{12}\right]/2\right)^2 \cdot 1'$$
$$= \pi(0.402/2)^2 \cdot 1$$
$$= 0.127 \text{ ft}^3/\text{ft of Hole}$$

$$1 \text{ gal} = 0.133 \text{ ft}^3$$
$$= 0.127 \text{ ft}^3/\text{ft} \cdot \frac{1 \text{ gal}}{0.133 \text{ ft}^3}$$
$$= 0.96 \text{ gal/ft}$$

Volume Grout Tube
130 ft

$$V = \pi r^2 h$$
$$V = \pi\left(1/4/12\right)^2 (130$$
$$V = 0.177 \text{ ft}^3$$
$$V = 1.33 \text{ gal}$$

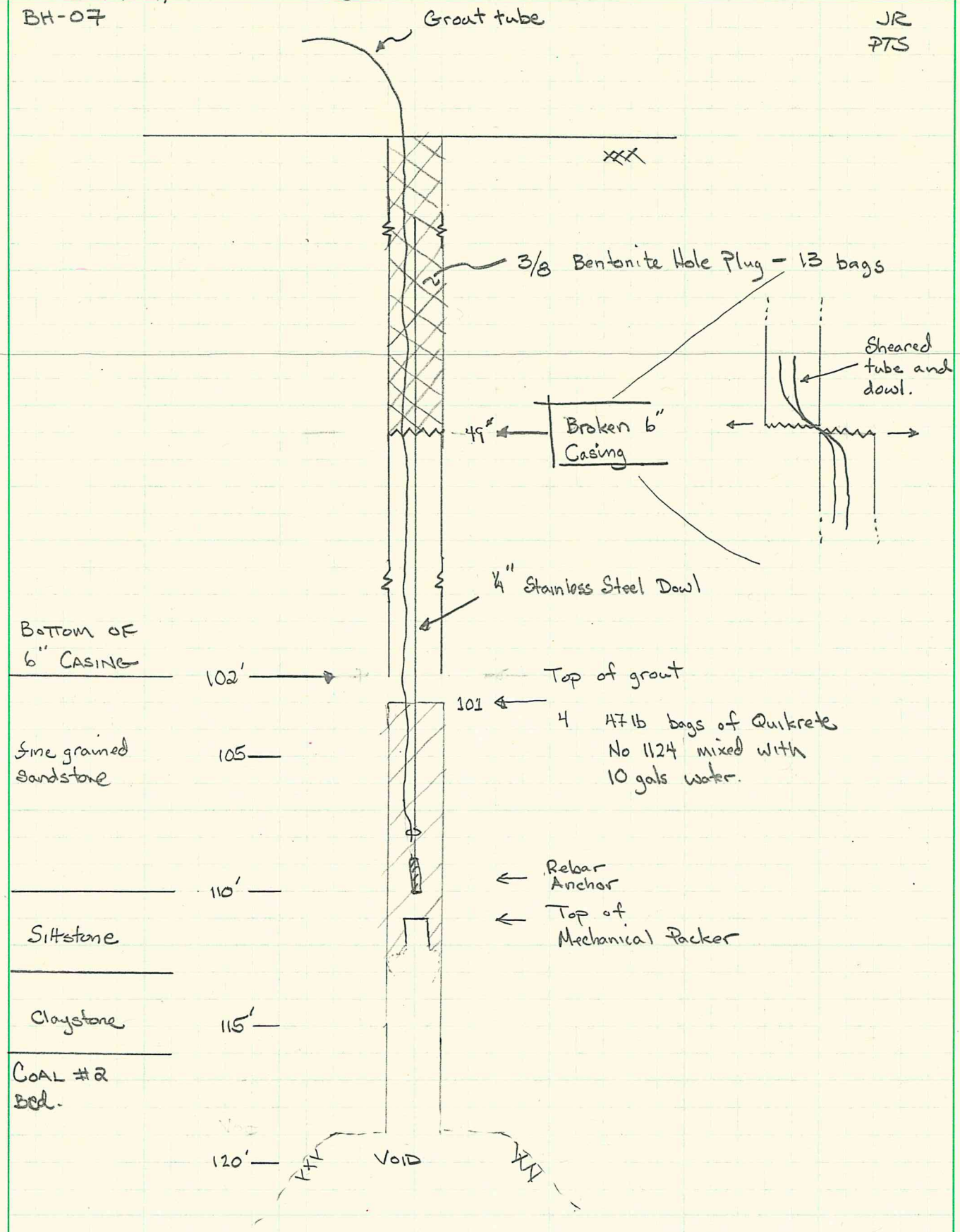
Anchor 1.15'
1.6
2.6

124
2.7
121.3' ← Steel Length

EXTENSOMETER
BH-07

Red Lodge
Extensometer Install

10-28-14
JR
PTS



Hand Auger
505 S. Platt

Drill Hole No. BH-04A

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/11/14 - 8/11/14	DRILLER:
LOGGED BY: M. Browne	DRILL TYPE: Hand Auger
GROUND SURFACE ELEVATION:	HOLE DIAMETER: 2"
BOREHOLE LOCATION: See Figure 4-2	HAMMER TYPE: None

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WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
		1			X	G14549		Sod. Dry, Very dark brown [7.5YR 2.5/2], SILTY SAND with Gravel, SM, low plasticity, no reaction to HCl, Fill, trace of organics, grass and tree roots, trace glass, and 4" long railroad spike, trace mica flakes, gravels are rounded.						
		2												
		3												Refusal at 3.0'
		4												
		5												
		6												
		7												
		8												
		9												
		10												
		11												
		12												
		13												
		14												
		15												
		16												
		17												
		18												
		19												
		20												
		21												

PIONEER TECHNICAL SERVICES, INC.

CLIENT: Montana Department of Environmental Quality

ADDRESS: P.O. Box 200901
Helena, Montana 59620-0901

PHONE NUMBER:

Drill Hole No. BH-04B

PROJECT NAME: Red Lodge Drilling Investigation	
DATE STARTED / FINISHED: 8/11/14 - 8/11/14	DRILLER:
LOGGED BY: M. Browne	DRILL TYPE: Hand Auger
GROUND SURFACE ELEVATION:	HOLE DIAMETER: 2"
BOREHOLE LOCATION: See Figure 4-2	HAMMER TYPE: None

This log is part of a report prepared by Pioneer Technical, Inc. for this project and should be read with the report. This summary applies only at the location of the boring and at the time of the drilling. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplication of actual conditions encountered.

WELL LOG	GRAPHIC LOG	DEPTH (FT)	SAMPLES: DRIVE	SAMPLES: UNDISTURBED	SAMPLES: BULK	SAMPLE ID	RECOVERY (%)	MATERIAL DESCRIPTION	LIQUID LIMIT	PLASTIC LIMIT	CORRECTED SPT	DRY DENSITY (pcf)	MOISTURE (%)	REMARKS / TESTING
		1						Sod. Dry, Very dark brown [7.5YR 2.5/2], SILTY SAND with Gravel, SM, non-plastic, no reaction to HCl, Fill, trace organics, roots, debris including glass, 2" diameter metal object, wire fitting, coal. Trace mica flakes.						
		2			X	G14550								
		3												
		4												
		5												Refusal at 4.5'
		6												
		7												
		8												
		9												
		10												
		11												
		12												
		13												
		14												
		15												
		16												
		17												
		18												
		19												
		20												
		21												

PIONEER TECHNICAL SERVICES, INC.

CLIENT: Montana Department of Environmental Quality	
ADDRESS: P.O. Box 200901 Helena, Montana 59620-0901	
PHONE NUMBER:	

Police Station Logs

201 E Broadway STE C
Helena, MT 59602
Phone: 406-457-8252
Fax: 406-442-1158

LOG OF BORING

PIONEER TECHNICAL SERVICES, INC.

Project Name: Red Lodge		Project Number:	
Borehole Location:		Borehole Number: PS-01	Sheet 1 of 1
Drilling Equipment: Hand Auger	Hammer Type:	Driller: Bushnell	Logger: Browne
Drilling Fluid: na	Borehole Diameter (in): na	Date Started: 11/18/14	Date Finished: 11/18/14

Elevation and Datum: Ground: Casing:

Notes:

DEPTH (feet)	DRILL: OPERATION	DRILL: PRESSURE (psi)	DRILL: RATE (fph)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST: SPT	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT: LL	PLASTIC LIMIT: PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS
														CONCRETE (4.75 in), wire reinforcement, soft coring.	0.4	
														VOID (0.75 in).	0.5	
														Poorly Graded GRAVEL with Sand, Clay, and Cobbles; wet (core); dark brown; subrounded to rounded; minus No. 40 sieve particles have medium plasticity; no HCl reaction.	1.3	
														Poorly Graded SAND; moist; yellowish brown; minus No. 40 sieve particles have no plasticity; no HCl reaction.	1.4	
2														Clayey SAND with Gravel; dark brown; minus No. 40 sieve particles have medium plasticity; angular particles, trace coal, brick debris (orange), trace sandstone gravels; no HCl reaction.	3.8	

Operation Types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sampler Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Penetrometer; Vane Shear; Special Samplers; Testpit

WATER LEVEL OBSERVATIONS

While Drilling ▽ ft Upon Completion of Drilling ▼ ft
Time After Drilling
Depth To Water (feet)
Remarks:

201 E Broadway STE C
Helena, MT 59602
Phone: 406-457-8252
Fax: 406-442-1158

LOG OF BORING

PIONEER TECHNICAL SERVICES, INC.

Project Name: Red Lodge		Project Number:	
Borehole Location:		Borehole Number: PS-02	Sheet 1 of 1
Drilling Equipment: Hand Auger	Hammer Type:	Driller: Bushnell	Logger: Browne
Drilling Fluid: na	Borehole Diameter (in): na	Date Started: 11/18/14	Date Finished: 11/18/14

Elevation and Datum: Ground: Casing:

Notes:

DEPTH (feet)	DRILL: OPERATION	DRILL: PRESSURE (psi)	DRILL: RATE (fph)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST: SPT	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT: LL	PLASTIC LIMIT: PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS
														CONCRETE (5 in), no void.	0.4	
														Poorly Graded SAND with Silt (SP) and Gravel; moist; yellowish brown; minus No. 40 sieve particles have no plasticity; no HCl reaction.	0.8	
														Poorly Graded GRAVEL with Sand and Clay; moist; dark brown; brick debris (orange); mica flakes; minus No. 40 sieve particles have low plasticity; no HCl reaction.	1.3	
2														Poorly Graded SAND with Silt; glass debris; moist; dark brown with thin layer of yellowish brown; minus No. 40 sieve particles have no plasticity; no HCl reaction.	1.7	
														Silty SAND with Gravel (SM); moist; dark brownish black to black; minus No. 40 sieve particles have no plasticity; no HCl reaction.		
4														Trace coal, plastic, glass, wood, and rounded gravels at 3 to 5.6 ft depth. Material soft at 3.5 to 5 ft depth.	5.6	

Operation Types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sampler Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Penetrometer; Vane Shear; Special Samplers; Testpit

WATER LEVEL OBSERVATIONS

While Drilling ____ ft Upon Completion of Drilling ____ ft
Time After Drilling ____ ____ ____ ____
Depth To Water (feet) ____ ____ ____ ____
Remarks:

201 E Broadway STE C
Helena, MT 59602
Phone: 406-457-8252
Fax: 406-442-1158

LOG OF BORING

PIONEER TECHNICAL SERVICES, INC.

Project Name: Red Lodge		Project Number:	
Borehole Location:		Borehole Number: PS-03	Sheet 1 of 1
Drilling Equipment: Hand Auger	Hammer Type:	Driller: Bushnell	Logger: Browne
Drilling Fluid: na	Borehole Diameter (in): na	Date Started: 11/18/14	Date Finished: 11/18/14

Elevation and Datum: Ground: Casing:

Notes:

DEPTH (feet)	DRILL: OPERATION	DRILL: PRESSURE (psi)	DRILL: RATE (fph)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST: SPT	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT: LL	PLASTIC LIMIT: PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS
														CONCRETE (5.25 in).	0.4	
														VOID (2 in).	0.6	
														Poorly Graded SAND with Silt (SP); moist; yellowish brown; minus No. 40 sieve particles have no plasticity; no HCl reaction.	0.8	
														Silty SAND with Gravel (increase with depth); moist; brown; gravels are subrounded; minus No. 40 sieve particles have no plasticity.; no HCl reaction Trace angular igneous rock fragments at 1.3 ft depth; thin grayish sand layer at 1.4 ft depth.	1.9	

Operation Types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sampler Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Penetrometer; Vane Shear; Special Samplers; Testpit

WATER LEVEL OBSERVATIONS

While Drilling ____ ft Upon Completion of Drilling ____ ft
Time After Drilling ____ ____ ____ ____
Depth To Water (feet) ____ ____ ____ ____
Remarks:

201 E Broadway STE C
Helena, MT 59602
Phone: 406-457-8252
Fax: 406-442-1158

LOG OF BORING

PIONEER TECHNICAL SERVICES, INC.

Project Name: Red Lodge		Project Number:	
Borehole Location:		Borehole Number: PS-04	Sheet 1 of 1
Drilling Equipment: Hand Auger	Hammer Type:	Driller: Bushnell	Logger: Browne
Drilling Fluid: na	Borehole Diameter (in): na	Date Started: 11/18/14	Date Finished: 11/18/14

Elevation and Datum: Ground: Casing:

Notes:

DEPTH (feet)	DRILL OPERATION	DRILL PRESSURE (psi)	DRILL RATE (fph)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST SPT	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS
														CONCRETE (5 in).	0.4	
														VOID (1.5 in).	0.5	
														Poorly Graded SAND with Silt; moist; yellowish brown; minus No. 40 sieve particles have no plasticity; no HCl reaction.	0.8	
2														Silty SAND with Gravel (SM); gravels are subrounded; moist; dark brown; minus No. 40 sieve particles have no plasticity; no HCl reaction. Brick debris at 1.5 ft depth; glass debris at 2 to 3 ft depth; pyrite flakes.	3.0	

Operation Types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sampler Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Penetrometer; Vane Shear; Special Samplers; Testpit

WATER LEVEL OBSERVATIONS

While Drilling ____ ft Upon Completion of Drilling ____ ft
Time After Drilling ____ ____ ____ ____
Depth To Water (feet) ____ ____ ____ ____
Remarks:

201 E Broadway STE C
Helena, MT 59602
Phone: 406-457-8252
Fax: 406-442-1158

LOG OF BORING

PIONEER TECHNICAL SERVICES, INC.

Project Name: Red Lodge		Project Number:	
Borehole Location:		Borehole Number: PS-05	Sheet 1 of 1
Drilling Equipment: Hand Auger	Hammer Type:	Driller: Bushnell	Logger: Browne
Drilling Fluid: na	Borehole Diameter (in): na	Date Started: 11/18/14	Date Finished: 11/18/14

Elevation and Datum: Ground: Casing:

Notes:

DEPTH (feet)	DRILL OPERATION	DRILL PRESSURE (psi)	DRILL RATE (fph)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST SPT	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS
														CONCRETE (5.5 in), no void.	0.5	
														Poorly Graded SAND with Silt; moist; yellowish brown; minus No. 40 sieve particles have no plasticity; no HCl reaction.	0.7	
														Silty SAND with Gravel; gravels subrounded (3 in); moist; brown; minus No. 40 sieve particles have no plasticity; no HCl reaction.	1.2	
														Silty SAND with Gravel; gravels subrounded (1 in); moist; brown; fine grain; minus No. 40 sieve particles have no plasticity; no HCl reaction.	1.8	

Operation Types: Auger, Casing Advancer, Core Barrel, Drive Casing

Sampler Types: Split Spoon, Shelby, Bulk Sample, Grab Sample, Penetrometer, Vane Shear, Special Samplers, Testpit

WATER LEVEL OBSERVATIONS

While Drilling ____ ft Upon Completion of Drilling ____ ft
Time After Drilling
Depth To Water (feet)
Remarks:

Test Pit

201 E Broadway STE C
Helena, MT 59602
Phone: 406-457-8252
Fax: 406-442-1158

LOG OF BORING

PIONEER TECHNICAL SERVICES, INC.

Project Name: Red Lodge		Project Number:	
Borehole Location:		Borehole Number: TP-01	Sheet 1 of 1
Drilling Equipment: John Deere 410G Backhoe	Hammer Type:	Driller: Mountain Excavation Co	Logger: Browne/Bushenell
Drilling Fluid: na	Borehole Diameter (in): na	Date Started: 11/18/14	Date Finished: 11/18/14

Elevation and Datum: Ground: Casing:

Notes: Near northeast corner of Platt Avenue and 17th Street Intersection; North Face of Test Pit Wall.

DEPTH (feet)	DRILL OPERATION	DRILL PRESSURE (psi)	DRILL RATE (fph)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST SPT	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS
														ROADMIX; Well Graded SAND with Gravel and Silt; frozen to moist; yellowish brown; sub rounded; minus No. 40 sieve particles have no plasticity; no HCl reaction.	0.6	
														FILL, Silty SAND with organics, trace debris (glass); moist; dark brownish; minus No. 40 sieve particles have no plasticity; no HCl reaction.	2.0	
2														ALLUVIUM, Poorly Graded SAND, fine grain; damp; light brown; roots; no HCl reaction.	2.6	
														ALLUVIUM; Poorly Graded GRAVEL with Sand and Silt, frequent Cobbles and large rounded Boulders; moist; dark brown; rounded; trace roots; [Scoria found in spoils pile]; minus No. 40 sieve particles have no to slight plasticity; no HCl reaction.		
4																
6															6.0	

Operation Types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sampler Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Penetrometer; Vane Shear; Special Samplers; Testpit

WATER LEVEL OBSERVATIONS

While Drilling ▽ ____ ft Upon Completion of Drilling ▼ ____ ft

Time After Drilling ____ ____ ____ ____

Depth To Water (feet) ____ ____ ____ ____ ▼

Remarks: Groundwater table not encountered

APPENDIX B. PHOTO DOCUMENTATION

Picture #: 1	Description: BH-01, looking northeast.

Picture #: 2	Description: BH-04, looking south down Platt Ave.

Picture #: 3	Description: BH-05, looking northeast along Haggin Ave.

Picture #: 4	Description: Typical core drilling operation shown at BH-05.

Picture #: 5	Description: BH-06, looking west along 17th St.

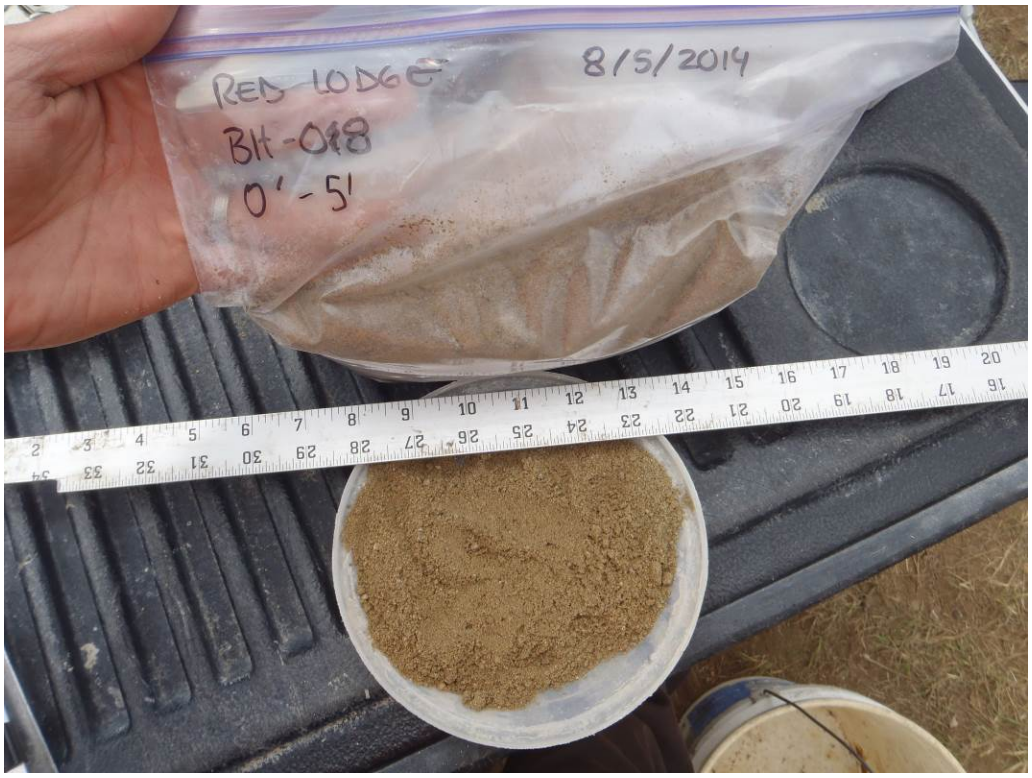
Picture #: 6	Description: BH-07, looking southwest along 15th St.

Picture #: 7	Description: BH-08, looking east.

Picture #: 8	Description: BH-05, unknown metal object encountered at 1 ft depth. Borehole subsequently moved 5 ft south.

Picture #: 9	Description: BH-04, 0-5 ft sample depth. Typical cuttings representing fill.

Picture #: 10	Description: BH-01, 95-100 ft sample depth. Typical cuttings representing alluvial gravels.



Picture #: 11	Description: BH-08, 0-5 ft sample depth. Typical cuttings representing alluvial sands.

Picture #: 12	Description: BH-04, 53.5-54 ft sample depth. Typical cuttings representing coal.

Picture #: 13	Description: BH-05, 30-35 ft sample depth. Typical cuttings representing bedrock.

Picture #: 14	Description: Lower section of seam No. 1 and floor material.

Picture #: 15	Description: Claystone above seam No. 1 1/2.

Picture #: 16	Description: Lower section of seam 1 1/2 and floor materials.

Picture #: 17	Description: Fine grained sandstone between seams No. 1 1/2 and 2.

Picture #: 18	Description: Lower section of seam No. 2.

Picture #: 19	Description: Floor immediately beneath seam No. 2.

Picture #: 20	Description: Upper section of seam No. 3.

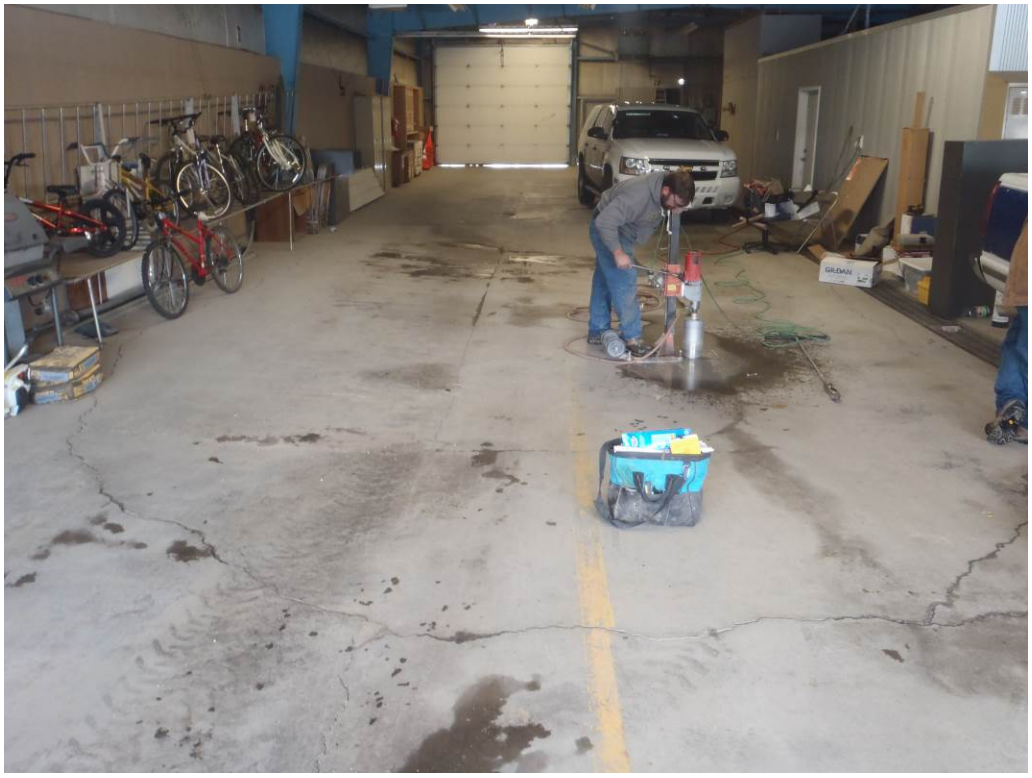
Picture #: 21	Description: Claystone between seams No. 3 and 4.

Picture #: 22	Description: Lower section of seam No. 4 and claystone floor.

Picture #: 23	Description: Lower section of seam No. 4 1/2 and claystone floor.

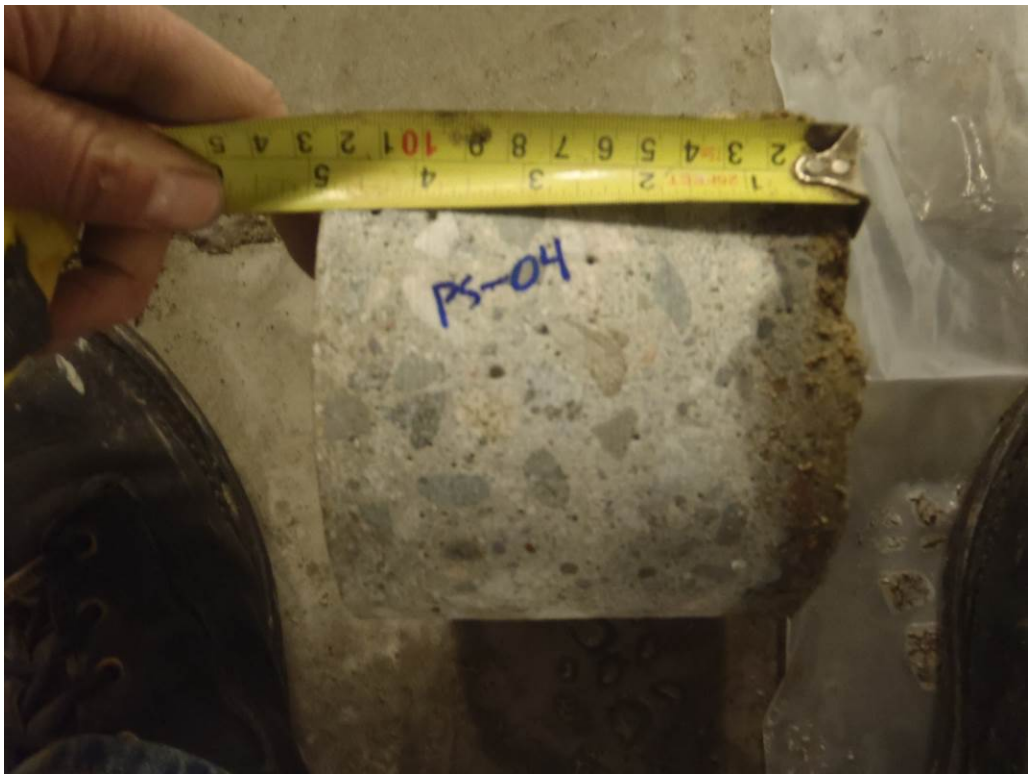
Picture #: 24	Description: Claystone between seams No. 4 1/2 and 5.

Picture #: 25	Description: Lower section of seam No. 5 and floor material.

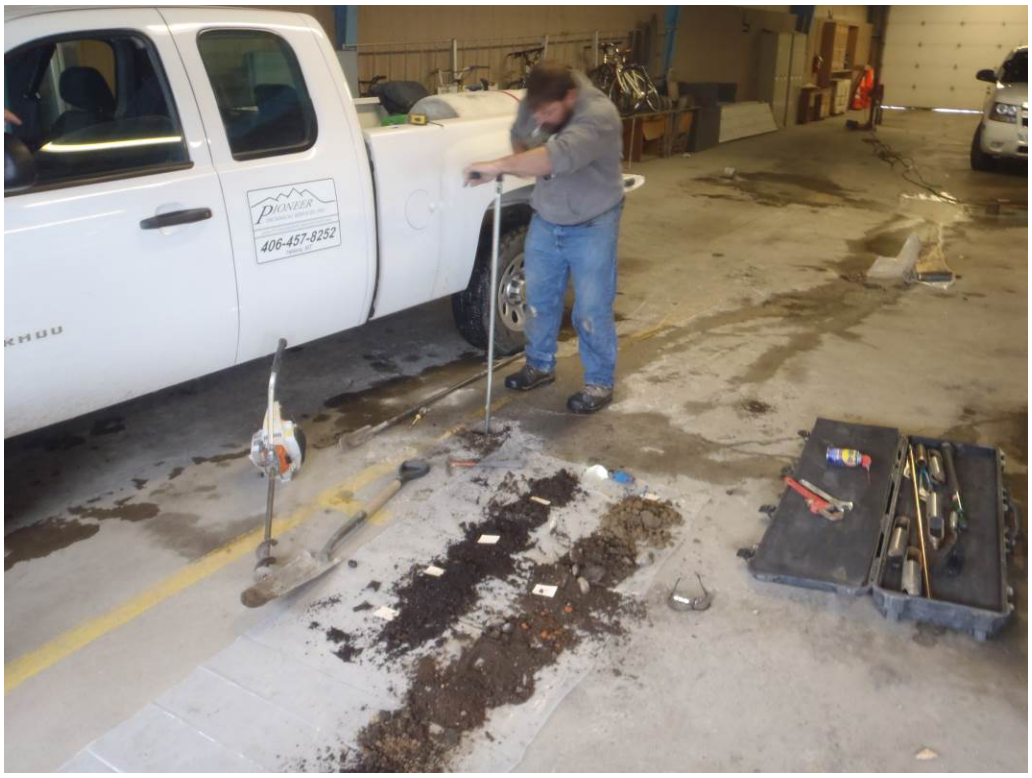


Picture #: 26	Description: Police Station, coring through concrete slab at PS-01.

Picture #: 27	Description: Police Station, void beneath concrete slab.



Picture #: 28	Description: Police Station, PS-04 concrete core.



Picture #: 29	Description: Police Station, hand augering at PS-02.

Picture #: 30	Description: Police Station, PS-01 soils at 0-4 ft sample depth.

Picture #: 31	Description: Police Station, PS-02 soils at 0-6 ft sample depth.

Picture #: 32	Description: Police Station, PS-02 debris at 3-5.6 ft sample depth.

Picture #: 33	Description: BH-04A (hand auger), looking west at 505 Platt Ave. Arrow denotes approximate hand auger hole location.

Picture #: 34	Description: BH-04B (hand auger), looking east at 505 Platt Ave.

Picture #: 35	Description: BH-04A. Soils recovered from hand auger hole.

Picture #: 36	Description: BH-04B. Soils recovered from hand auger hole.

Picture #: 37	Description: BH-04A, debris.

Picture #: 38	Description: BH-04B, debris.

Picture #: 39	Description: Test Pit, looking north at 521 Platt Ave residence.

Picture #: 40	Description: Test Pit, north side of test pit soil profile at 2 ft depth.

Picture #: 41	Description: Test Pit, , north side of test pit soil profile soil profile at 4 ft depth.

Picture #: 42	Description: Test Pit, soil profile at 6 ft depth.

Picture #: 43	Description: Test Pit, soil profile at 6 ft depth.

Picture #: 44	Description: Test Pit, spoils pile.

APPENDIX C. SUMMARY OF SURVEY MONITORING

Red Lodge Subsidence Monitoring
SUMMARY OF MONITORING REPORTS TO DATE

1 INTRODUCTION

Survey monitoring was conducted throughout 2014 to determine whether or not surface movement was occurring within the study area. Survey points and benchmarks were established and crack gauges were installed on foundation cracks, which could then be monitored regularly. Initially, the primary residences of concern are located at 501 Broadway Avenue South and 505 Platt Avenue South in Red Lodge, Montana. Two more residences were added during the course of the year – 404 Broadway Avenue South and 207 Hauser Avenue South. These residences, as well as numerous monitoring points in the general area were surveyed on a quarterly basis throughout 2014 to assess potential mine related subsidence.

2 INITIAL INSTALLATION AND QUARTERLY MONITORING EVENTS

Pioneer Technical Services Inc. (Pioneer) conducted an initial site on January 7, 2014 to meet with Town of Red Lodge officials, obtain access agreements, observe areas of possible subsidence, and determine locations to install the monitoring points and crack gauges. A secondary visit was performed during the week of January 20th to install the monitoring points, crack gauges, and survey the monitoring points. A total of 57 monitoring points and 5 crack gauges were established and surveyed/recorded during the initial site visit. This is referred to as Quarterly Monitoring Event 1 (QM1). Both horizontal and vertical coordinates were surveyed and recorded during this event.

Additional monitoring points and crack gauges were added surrounding the residence at 404 Broadway on April 28, 2014 as part of QM2. A total of 73 monitoring points and 7 crack gauges had been established and surveyed following QM2. Only vertical elevations were surveyed and recorded during this event.

Additional monitoring points and crack gauges were added surrounding the residence at 207 Hauser on July 30, 2014 as part of QM3. A total of 83 monitoring points and 8 crack gauges had been established and surveyed following QM3. Only vertical elevations were surveyed and recorded during this event.

QM4 occurred on November 19, 2014. Seven additional monitoring points were added during this event, bringing the total to 90 monitoring points and 8 crack gauges. Both horizontal and vertical coordinates were surveyed and recorded during this event.

2.1 Survey Monitoring Network

A control network of stable monitoring points consisting of two National Geodetic Survey (NGS) benchmarks, fire hydrants, 36-inch long #6 rebar pounded into the ground, bench ties installed in the house foundations, and “MAG” nails installed in concrete flat work. As shown in Figure 1, monitoring points were installed around a three block area surrounding the houses in a

grid of approximately every 150 feet. The locations for the points surrounding each of the houses are shown on Figures 2-5.

RTK GPS was used to collect horizontal coordinates of the control points in Montana State Plane NAD 83 (2011) international feet. Elevations were established using a digital level. A level loop through Primary Control using a Trimble DiNi digital level was run from NGS benchmark "Q 215" to NGS benchmark "R 215" and through all the fire hydrants closing back on "Q 215". This loop revealed a difference of 0.12 feet between the reported NGS elevation of "R 215" and Pioneer's measured difference. Differences of this magnitude are relatively common between older NGS control points, however this difference is noted and will be checked each quarter.

After the Primary Control loop, shorter loops were run through the Secondary Control stations. Each of these loops closed very well and all misclosures were adjusted. Coordinates for the monitoring points established during this first quarterly monitoring trip (QM1) are listed in Table 1.

2.2 Crack Monitoring Gauges

Three crack monitoring gauges were installed at 501 Broadway Ave; two gauges were installed at 505 Platt Ave; two were installed at 404 Broadway Ave; and one was installed at 207 Hauser. The gauges were installed at visible cracks within the foundation and were adjusted to a 'zero' reading. The gauges will be monitored during subsequent trips to record any potential movement. It should be noted that the gauges were only installed at 'cracks' within the foundations; not at construction joints (i.e., a joint within the foundation as a result of constructing an addition or stairs to a previously constructed potion of the house). Photos of the installed crack gauges are included in the attached photo log.

3 SUMMARY

The survey data is listed in Table 1 and graphically displayed in Figures 6 through 9. No alarming measurements or trends in the data were noted during the data review. A brief summary of the data is listed below:

- Monitoring point 404-7 recorded the maximum elevation increase from QM3 to QM4 at 0.026 feet (5/16 inches). Cumulatively point 404-7 has moved a total of 0.034 feet (13/32 inches). Point 404-7 is MAG nail located in the sidewalk in the back yard of 404 Broadway. The average elevation change for this survey loop (Loop 12) was -0.009 feet (7/64 inch). Pioneer speculates that frost heave may attribute to monitoring point 404-7 elevation increase.
- Monitoring point 630 recorded the maximum elevation decrease from QM3 to QM4 at -0.030 feet (23/64 inches). Cumulatively point 630 has moved a total of -0.030 feet. Point 630 is a secondary control station (36-inch long rebar with an aluminum cap) located in the front yard of 207 Hauser. The average elevation change for this survey loop (Loop 11) was -0.026 feet (5/16 inch) which indicates the elevation change can be attributed to the survey method rather than movement within the control point.

- The average change in elevation for all the points from QM3 to QM4 was 0.0130 feet (5/32 inches). The average cumulative change in elevation from QM1 to QM4 for all the points is 0.0071 feet (5/64 inches).
- Review of the data and discussions with the surveyors indicate that the differences in elevation values are primarily attributable to expected error and bias in the method and digital level accuracy limitations.

The two crack gauges installed at 501 Broadway Ave (CG 1 and CG 2) cumulatively have registered no movement. The crack gauges installed at 505 Platt, 404 Broadway, and 2017 Hauser (CG 4 through CG 8) have cumulative registered movements of 0.5 millimeters (mm) or less. No movement trends have been recorded in the crack gauge data to date. Crack gauge measurements are listed in Table 2 and displayed in the attached photo log.

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LEGEND

= Primary Control Station
Existing Fire Hydrants or NGS Benchmark

= Secondary Control Station
#6x36" rebar and 2-1/2" alum. cap

N

DISPLAYED AS:	
COORD SYS/ZONE:	MT STATE PLANE COORDINATES
DATUM:	NAD83(2011)
UNITS:	INTERNATIONAL FEET
SOURCE:	OPUS & NGS BENCHMARK

SCALE IN FEET
0 100 200

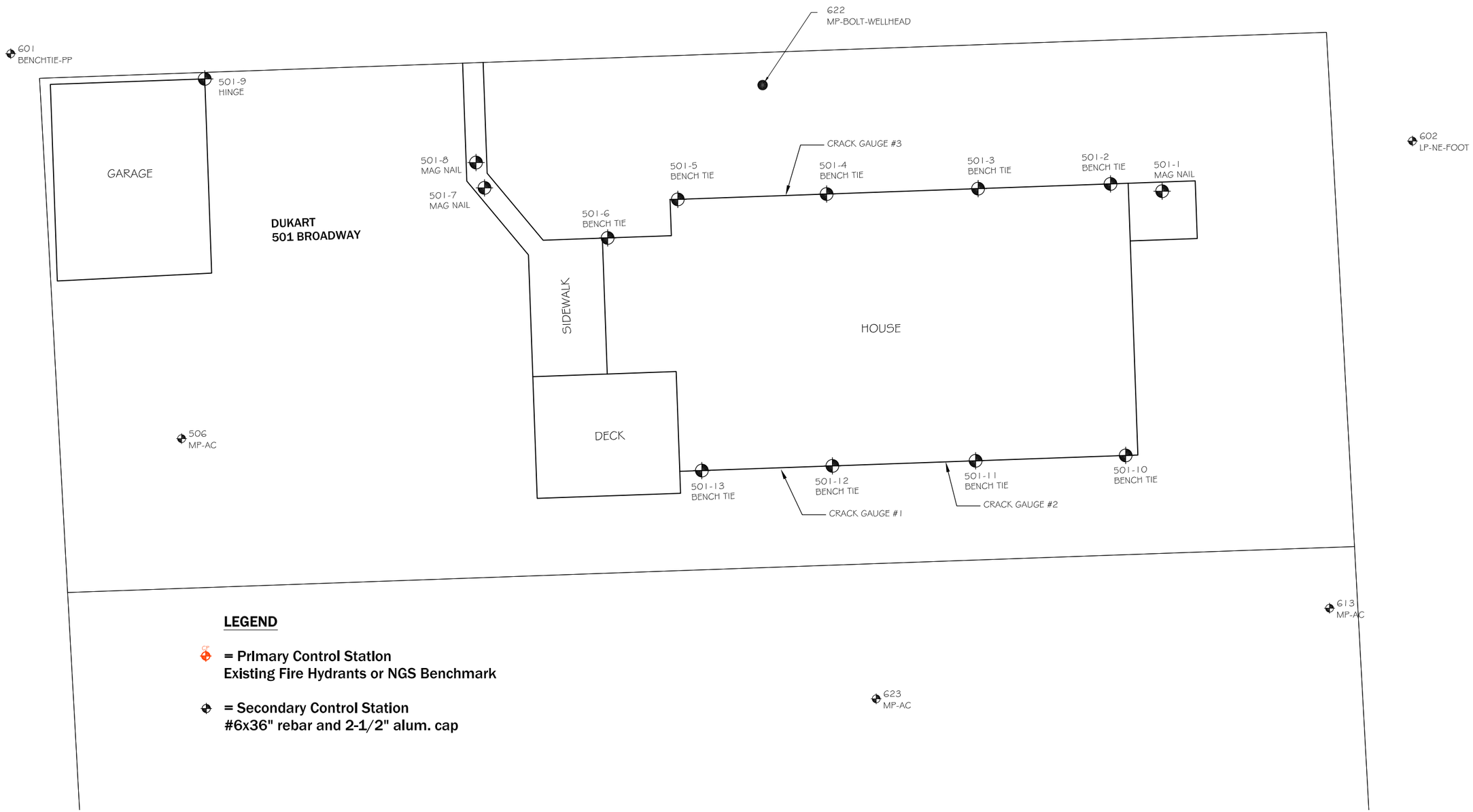
FIGURE 1

PIONEER TECHNICAL SERVICES, INC.
201 E. BROADWAY, SUITE C
HELENA, MT 59601
(406) 457-8252

MONITORING POINT LOCATIONS

DATE: 9/26/14

9/26/2014 3:12:22 PM M:\SURVEY-CLIENTS\MT DEQ\RED LODGE SUBSIDENCE MONITORING\2014\DRAWINGS\SURVEY\REDLODGE-BAS-SU-001-14.DWG



LEGEND

= Primary Control Station
Existing Fire Hydrants or NGS Benchmark

= Secondary Control Station
#6x36" rebar and 2-1/2" alum. cap

N

	DISPLAYED AS:
COORD SYS/ZONE:	MT STATE PLANE COORDINATES
DATUM:	NAD83(2011)
UNITS:	INTERNATIONAL FEET
SOURCE:	OPUS & NGS BENCHMARK

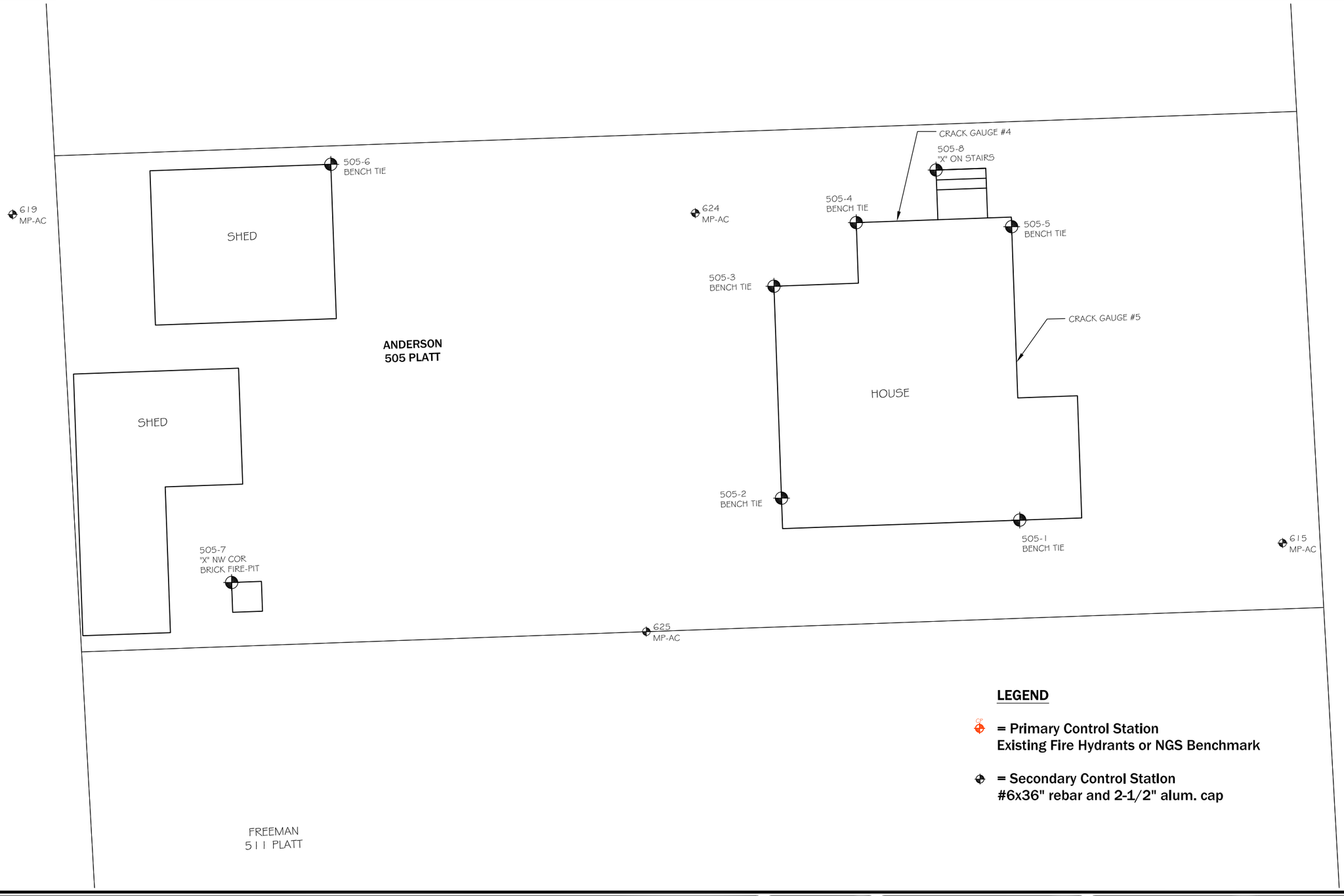
SCALE IN FEET
0 5 10

FIGURE 2

501 BROADWAY

PIONEER TECHNICAL SERVICES, INC.
201 E. BROADWAY, SUITE C
HELENA, MT 59601
(406) 457-8252

DATE: 02/04/2014



LEGEND

= Primary Control Station
Existing Fire Hydrants or NGS Benchmark

= Secondary Control Station
#6x36" rebar and 2-1/2" alum. cap

N

DISPLAYED AS:	
COORD SYS/ZONE:	MT STATE PLANE COORDINATES
DATUM:	NAD83(2011)
UNITS:	INTERNATIONAL FEET
SOURCE:	OPUS & NGS BENCHMARK

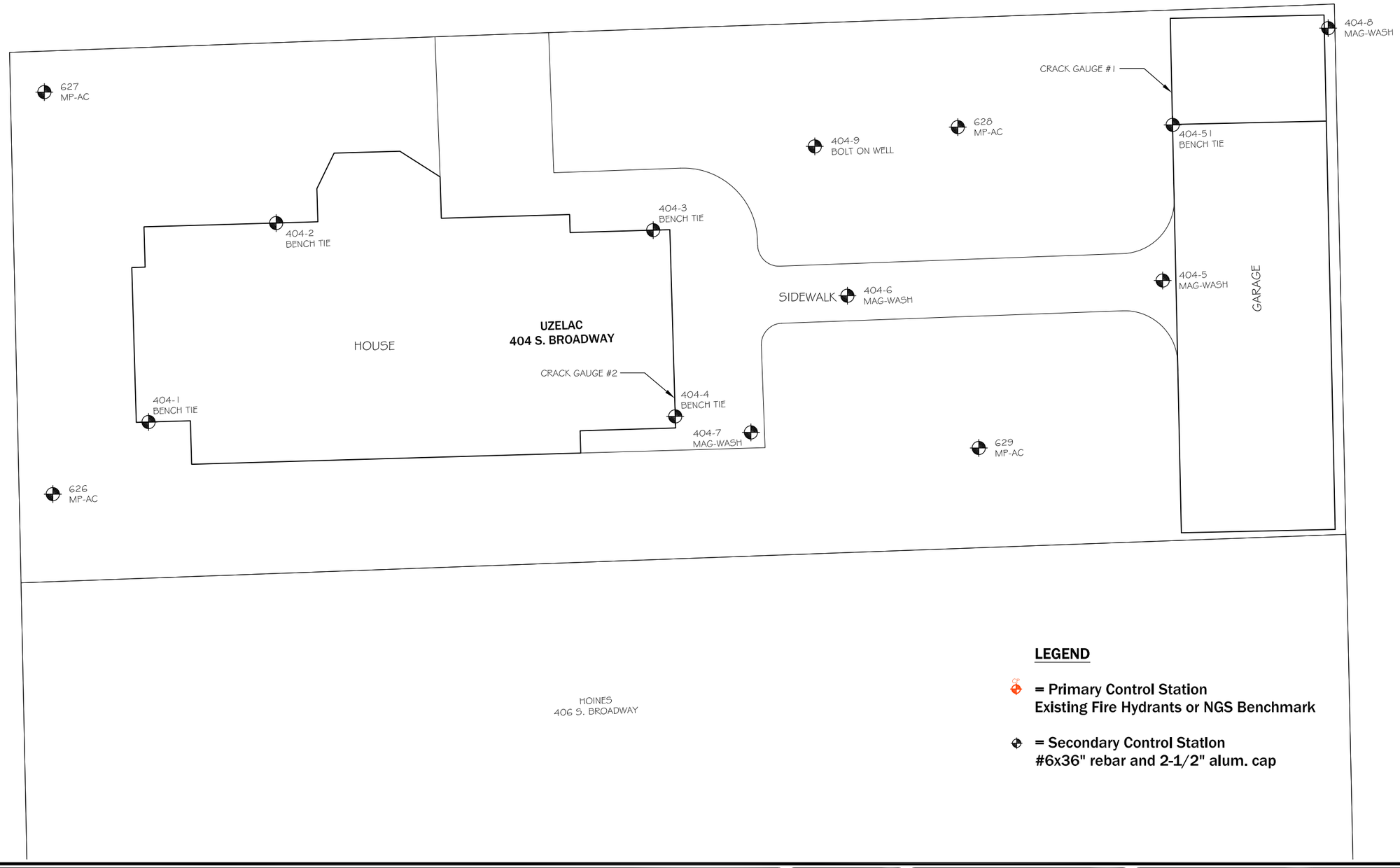
SCALE IN FEET
0 5 10

FIGURE 3

505 PLATT

PIONEER TECHNICAL SERVICES, INC.
201 E. BROADWAY, SUITE C
HELENA, MT 59601
(406) 457-8252

DATE: 02/04/2014



LEGEND

= Primary Control Station
Existing Fire Hydrants or NGS Benchmark

= Secondary Control Station
#6x36" rebar and 2-1/2" alum. cap

N

DISPLAYED AS:	
COORD SYS/ZONE:	MT STATE PLANE COORDINATES
DATUM:	NAD83(2011)
UNITS:	INTERNATIONAL FEET
SOURCE:	OPUS & NGS BENCHMARK

SCALE IN FEET
0 5 10

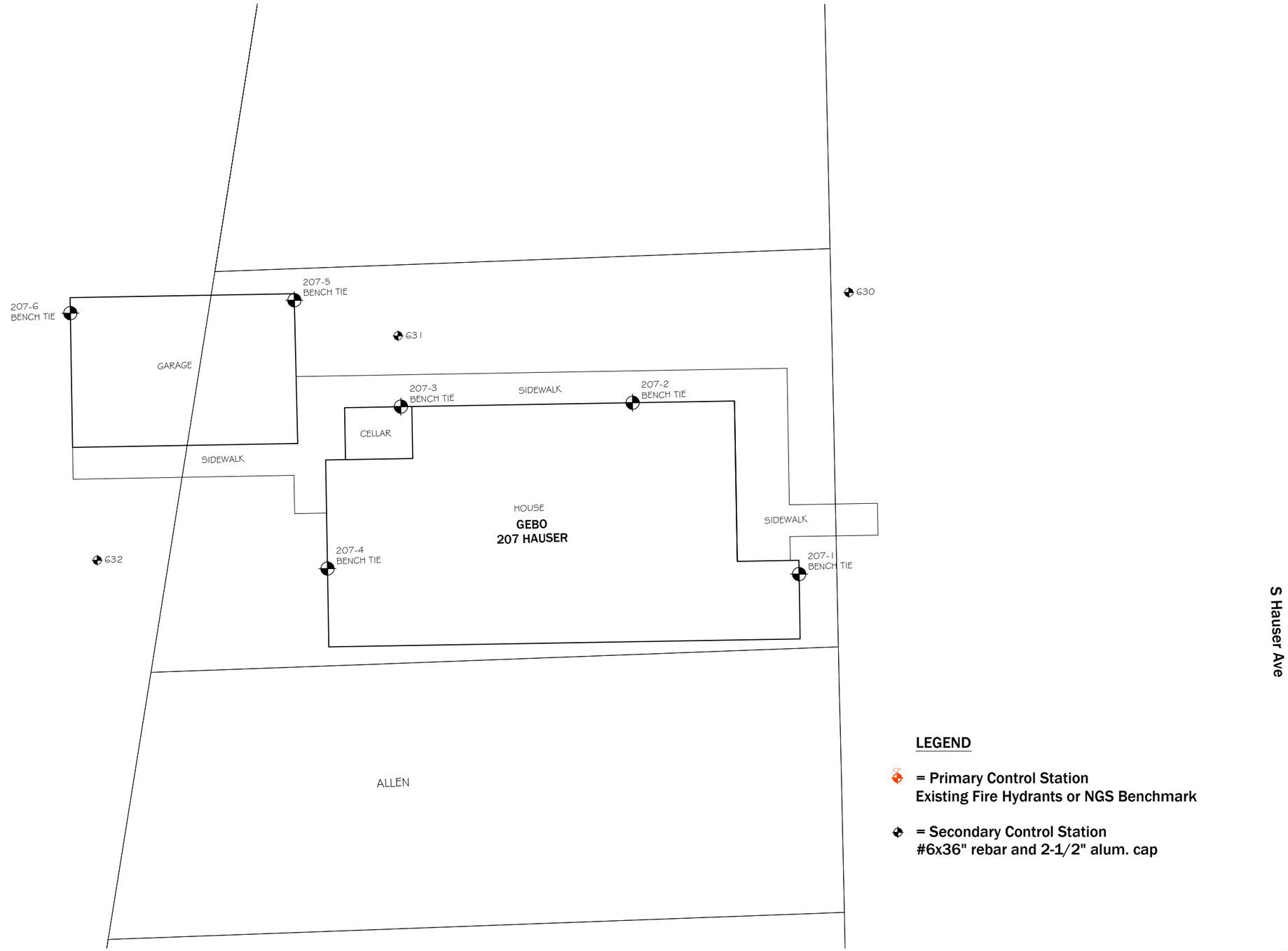
FIGURE 4

404 BROADWAY

PIONEER TECHNICAL SERVICES, INC.
201 E. BROADWAY, SUITE C
HELENA, MT 59601
(406) 457-8252

DATE: 04/28/2014

5/27/2014 9:09:21 AM \\192.168.250.13\DATA$\LABDATA$\SURVEY-CLIENTS\MT DEQ\RED LODGE SUBSIDENCE MONITORING\2014\DRAWINGS\SURVEY\REDLODGE-BAS-SU-001-14.DWG



LEGEND

= Primary Control Station
Existing Fire Hydrants or NGS Benchmark

= Secondary Control Station
#6x36" rebar and 2-1/2" alum. cap

N

DISPLAYED AS:
COORD SYS/ZONE: MT STATE PLANE COORDINATES
DATUM: NAD83(2011)
UNITS: INTERNATIONAL FEET
SOURCE: OPUS & NGS BENCHMARK

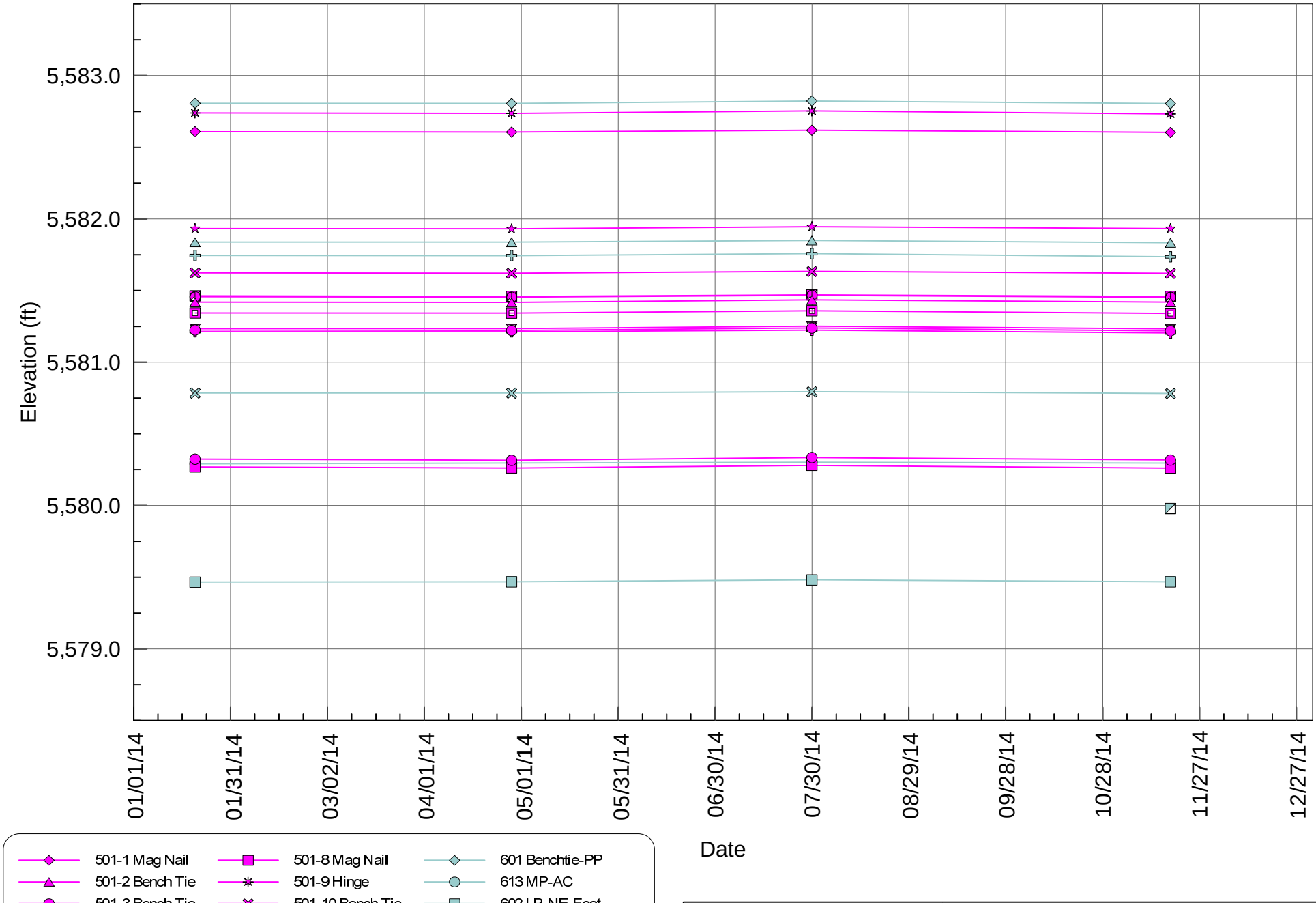
SCALE IN FEET
0 5 10

FIGURE 5

207 HAUSER

PIONEER TECHNICAL SERVICES, INC.
201 E. BROADWAY, SUITE C
HELENA, MT 59601
(406) 457-8252

DATE: 04/28/2014



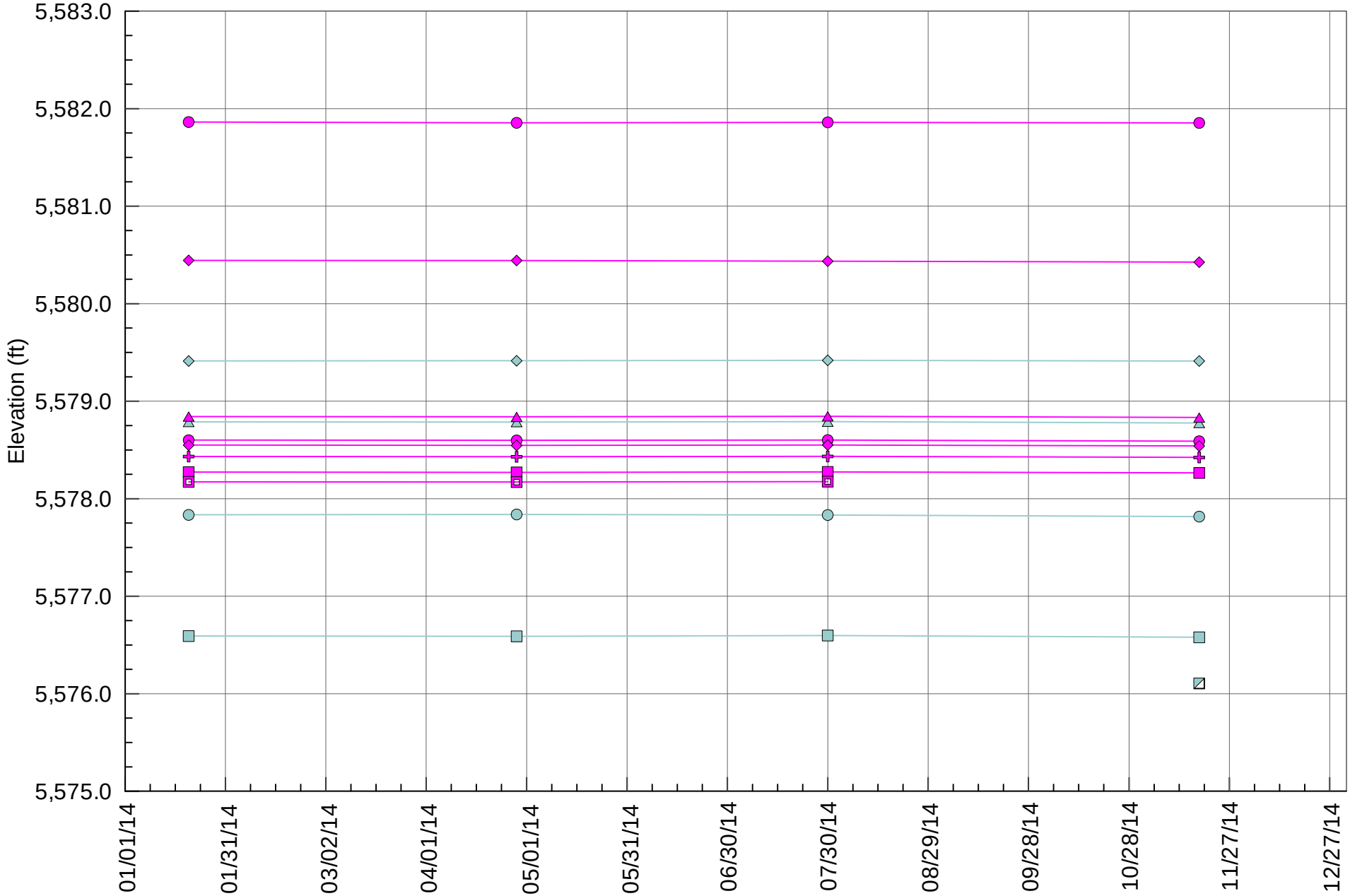
Red Lodge Subsidence Monitoring

Montana DEQ

PIONEER TECHNICAL SERVICES, INC.

Figure 6:
501 Broadway
Elevation vs Time

MaterialsLabServer/data/labData/Survey-Clients/MT DEQ/Red Lodge Subsidence Monitoring/2014/Data



Legend

- 505-1 Bench Tie
- 505-2 Bench Tie
- 505-3 Bench Tie
- 505-4 Bench Tie
- 505-5 Bench Tie
- 505-6 Bench Tie
- 505-7 X NW Cor Brick Fire-Pit
- 505-8 X on Stepsl
- 619 MP-AC
- 624 MP-AC
- 615 MP-AC
- 625 MP-AC

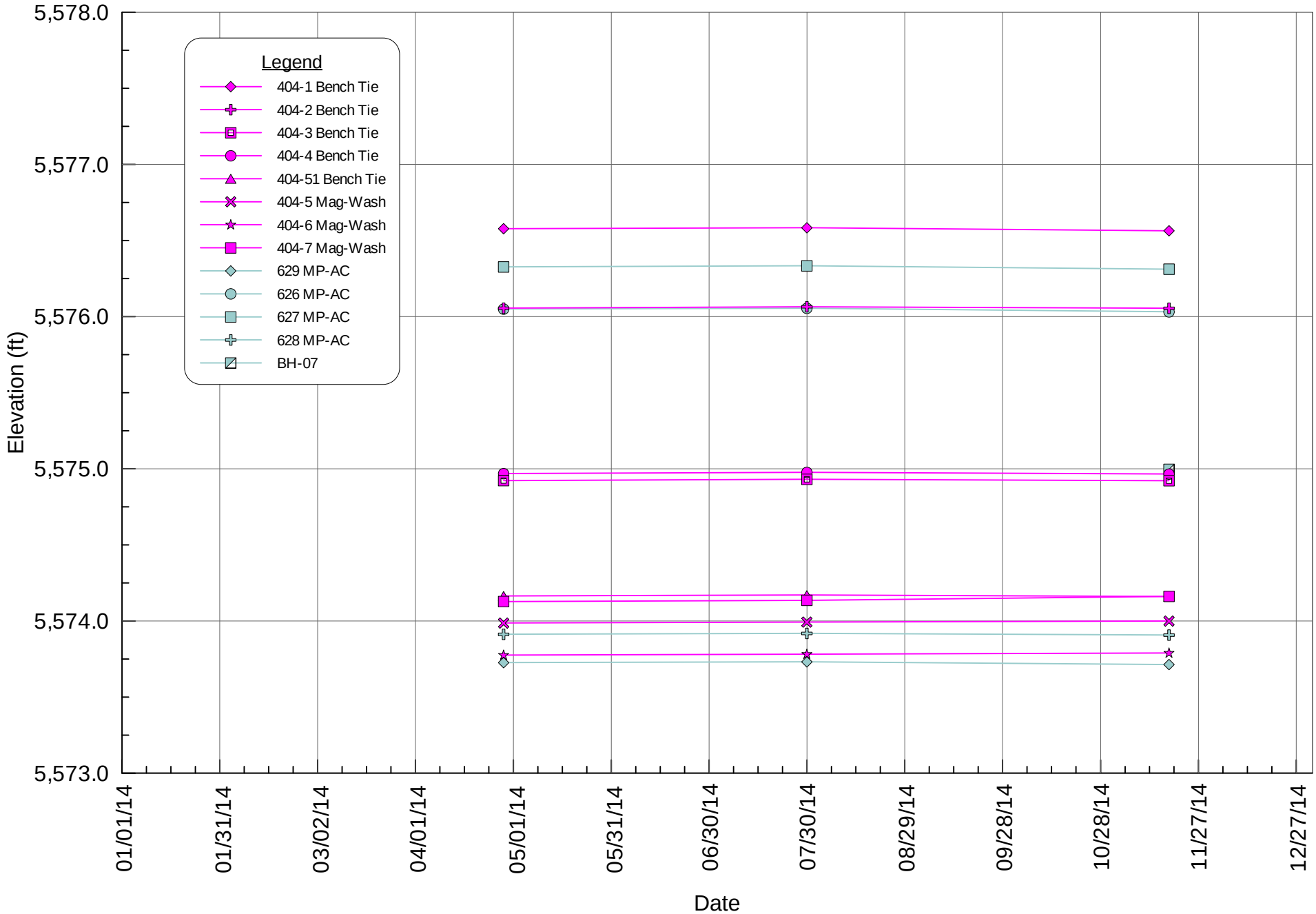
Red Lodge Subsidence Monitoring

Montana DEQ

PIONEER TECHNICAL SERVICES, INC.

Figure 7:
505 Platt
Elevation vs. Date

MaterialsLabServer/data/labData/Survey-Clients/MT DEQ/Red Lodge Subsidence Monitoring/2014/Data



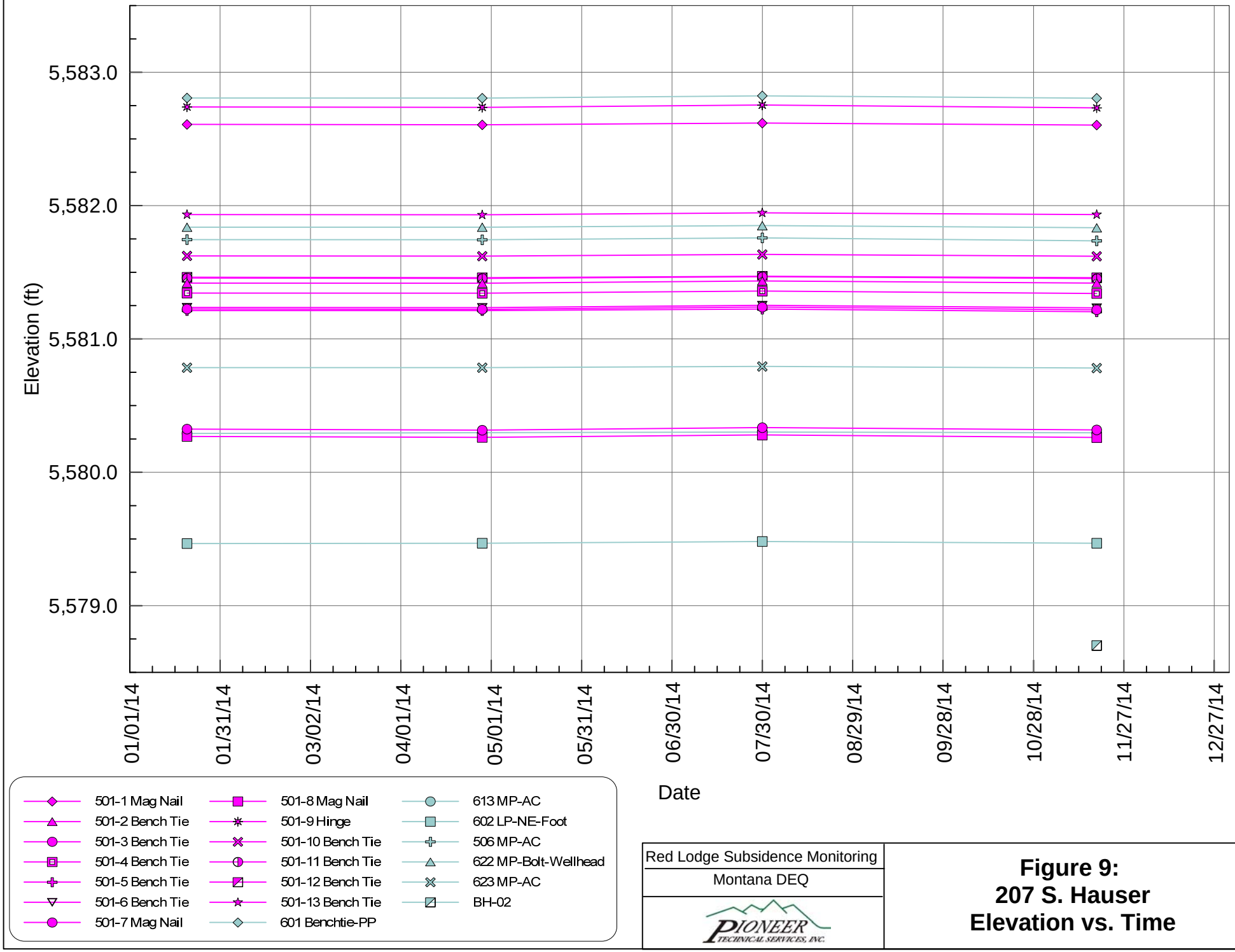
Red Lodge Subsidence Monitoring

Montana DEQ

PIONEER TECHNICAL SERVICES, INC.

Figure 8: 404 Broadway Elevation Change vs Date

MaterialsLabServer/data/labData/Survey-Clients/MT DEQ/Red Lodge Subsidence Monitoring/2014/Data



Red Lodge Subsidence Monitoring

Montana DEQ

PIONEER TECHNICAL SERVICES, INC.

Figure 9:
207 S. Hauser
Elevation vs. Time

Materials\LabServer/data/labData/Survey-Clients/MT DEQ/Red Lodge Subsidence Monitoring/2014/Data

Table 1: Survey Coordinates

	Point Number	Northing (Feet)	Easting (Feet)	Elevation QM1 (Feet)	Elevation QM2 (Feet)	Elevation QM3 (Feet)	Elevation QM4 (Feet)	Elevation Change (QM1 to QM2) (Feet)	Elevation Change (QM2 to QM3) (Feet)	Elevation Change (QM3 to QM4) (Feet)	Elevation Change (Cumulative) (Feet)	Description
Loop 1: control points	2	338,651	2,033,227	5,603.560	5,603.560	5,603.560	5,603.560	0.000	0.000	0.000	0.000	Q215 - NGS benchmark
	502	339,614	2,033,402	5,590.547	5,590.547	5,590.550	5,590.542	0.000	0.003	-0.008	-0.005	FH-BOLT
	510	339,730	2,033,580	5,586.508	5,586.510	5,586.508	5,586.499	0.002	-0.002	-0.009	-0.009	R215
	Minimum							*0.000*	*-0.002*	*-0.009*	*-0.009*	
	Maximum							*0.002*	*0.003*	*0.000*	*0.000*	
	Average							*0.001*	*0.000*	*-0.006*	*-0.005*	
Loop 2	502	339,614	2,033,402	5,590.547	5,590.547	5,590.550	5,590.542	0.000	0.003	-0.008	-0.005	FH-BOLT
	612	339,668	2,033,466	5,586.374	5,586.376	5,586.379	5,586.373	0.002	0.003	-0.006	-0.001	MP-AC
	611	339,827	2,033,453	5,584.318	5,584.316	5,584.325	5,584.315	-0.002	0.009	-0.010	-0.003	MP-AC
	501	339,979	2,033,393	5,586.683	5,586.681	5,586.694	5,586.682	-0.002	0.013	-0.012	-0.001	FH-BOLT
	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	-0.004	0.011	-0.015	-0.008	FH-BOLT
	603	339,986	2,033,909	5,578.512	5,578.511	5,578.522	5,578.504	-0.001	0.011	-0.018	-0.008	MP-AC
	604	339,960	2,034,030	5,576.211	5,576.209	5,576.219	5,576.202	-0.002	0.010	-0.017	-0.009	MP-AC
	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	-0.002	0.011	-0.016	-0.007	FH-BOLT
	605	339,960	2,034,128	5,574.530	5,574.523	5,574.528	5,574.504	-0.007	0.005	-0.024	-0.026	MP-AC
	504	339,955	2,034,289	5,575.804	5,575.802	5,575.809	5,575.795	-0.002	0.007	-0.014	-0.009	FH-BOLT
	617	339,861	2,034,332	5,574.577	5,574.578	5,574.584	5,574.571	0.001	0.006	-0.013	-0.006	MP-AC
	618	339,741	2,034,321	5,577.027	5,577.031	5,577.036	5,577.021	0.004	0.005	-0.015	-0.006	MP-AC
	610	339,596	2,034,183	5,578.723	5,578.730	5,578.727	5,578.724	0.007	-0.003	-0.003	0.001	MP-AC
	503	339,511	2,034,148	5,583.054	5,583.061	5,583.057	5,583.056	0.007	-0.004	-0.001	0.002	FH-BOLT
	509	339,637	2,034,087	5,582.797	5,582.803	5,582.797	5,582.796	0.006	-0.006	-0.001	-0.001	FH-BOLT
	609	339,599	2,034,068	5,580.944	5,580.952	5,580.947	5,580.948	0.008	-0.005	0.001	0.004	MP-AC
	608	339,625	2,033,859	5,583.354	5,583.361	5,583.354	5,583.355	0.007	-0.007	0.001	0.001	MP-AC
	508	339,641	2,033,752	5,585.951	5,585.962	5,585.956	5,585.958	0.011	-0.006	0.002	0.007	FH-BOLT
	607	339,628	2,033,742	5,583.658	5,583.671	5,583.669	5,583.660	0.013	-0.002	-0.009	0.002	MP-AC
	606	339,623	2,033,607	5,585.333	5,585.336	5,585.350	5,585.328	0.003	0.014	-0.022	-0.005	MP-AC
	Minimum							*-0.007*	*-0.007*	*-0.024*	*-0.026*	
	Maximum							*0.013*	*0.014*	*0.002*	*0.007*	
	Average							*0.002*	*0.004*	*-0.010*	*-0.004*	
Loop 3	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	-0.002	0.011	-0.016	-0.007	FH-BOLT
	615	339,855	2,034,071	5,576.592	5,576.589	5,576.597	5,576.579	-0.003	0.008	-0.018	-0.013	MP-AC
	616	339,743	2,034,135	5,578.083	5,578.093	5,578.084	5,578.075	0.010	-0.009	-0.009	-0.008	MP-AC
	509	339,637	2,034,087	5,582.797	5,582.803	5,582.797	5,582.796	0.006	-0.006	-0.001	-0.001	FH-BOLT
	Minimum							*-0.003*	*-0.009*	*-0.018*	*-0.013*	
	Maximum							*0.010*	*0.011*	*-0.001*	*-0.001*	
	Average							*0.003*	*0.001*	*-0.011*	*-0.007*	
Loop 4	509	339,637	2,034,087	5,582.797	5,582.803	5,582.797	5,582.796	0.006	-0.006	-0.001	-0.001	FH-BOLT
	620	339,775	2,033,949	5,581.360	5,581.365	5,581.364	5,581.356	0.005	-0.001	-0.008	-0.004	MP-AC
	619	339,888	2,033,944	5,579.413	5,579.415	5,579.419	5,579.412	0.002	0.004	-0.007	-0.001	MP-AC
	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	-0.002	0.011	-0.016	-0.007	FH-BOLT
	Minimum							*-0.002*	*-0.006*	*-0.016*	*-0.007*	
	Maximum							*0.006*	*0.011*	*-0.001*	*-0.001*	
	Average							*0.003*	*0.002*	*-0.008*	*-0.003*	
Loop 5	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	-0.004	0.011	-0.015	-0.008	FH-BOLT
	613	339,880	2,033,731	5,580.291	5,580.297	5,580.302	5,580.296	0.006	0.005	-0.006	0.005	MP-AC
	614	339,755	2,033,737	5,582.152	5,582.161	5,582.156	5,582.156	0.009	-0.005	0.000	0.004	MP-AC
	508	339,641	2,033,752	5,585.951	5,585.962	5,585.956	5,585.958	0.011	-0.006	0.002	0.007	FH-BOLT
	Minimum							*-0.004*	*-0.006*	*-0.015*	*-0.008*	
	Maximum							*0.011*	*0.011*	*0.002*	*0.007*	
	Average							*0.005*	*0.001*	*-0.005*	*0.002*	

Table 1: Survey Coordinates

	Point Number	Northing (Feet)	Easting (Feet)	Elevation QM1 (Feet)	Elevation QM2 (Feet)	Elevation QM3 (Feet)	Elevation QM4 (Feet)	Elevation Change (QM1 to QM2) (Feet)	Elevation Change (QM2 to QM3) (Feet)	Elevation Change (QM3 to QM4) (Feet)	Elevation Change (Cumulative) (Feet)	Description
Loop 6	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	-0.004	0.011	-0.015	-0.008	FH-BOLT
	512	340,359	2,033,726	-	5,580.233	5,580.244	5,580.228	-	0.011	-0.016	-0.005	FH-BOLT
	511	340,301	2,034,066	-	5,577.891	5,577.894	5,577.886	-	0.003	-0.008	-0.005	FH-BOLT
	505	340,002	2,034,072	5,577.567	5,577.565	5,577.576	5,577.560	-0.002	0.011	-0.016	-0.007	FH-BOLT
	Minimum							*-0.004*	*0.003*	*-0.016*	*-0.008*	
	Maximum							*-0.002*	*0.011*	*-0.008*	*-0.005*	
	Average							*-0.003*	*0.009*	*-0.014*	*-0.006*	
Loop 7	501	339,979	2,033,393	5,586.683	5,586.681	5,586.694	5,586.682	-0.002	0.013	-0.012	-0.001	FH-BOLT
	514	-	-	-	-	5,584.615	5,584.596	-	-	-0.019	-0.019	FH-BOLT
	630	340,909	2,033,368	-	-	5,578.798	5,578.768	-	-	-0.030	-0.030	MP-AC
	513	-	-	-	-	5,578.298	5,578.283	-	-	-0.015	-0.015	FH-BOLT
	501	339,979	2,033,393	5,586.683	5,586.681	5,586.694	5,586.682	-0.002	0.013	-0.012	-0.001	FH-BOLT
	Minimum							*-0.002*	*0.013*	*-0.030*	*-0.030*	
	Maximum							*-0.002*	*0.013*	*-0.012*	*-0.001*	
	Average							*-0.002*	*0.013*	*-0.019*	*-0.016*	
Loop 8	630	340,909	2,033,368	-	-	5,578.798	5,578.768	-	-	-0.030	-0.030	MP-AC
	1014	340,694	2,033,540	-	-	-	5,581.054	-	-	-	-	BH-01 center steel cap
	630	340,909	2,033,368	-	-	5,578.798	5,578.768	-	-	-0.030	-0.030	MP-AC
	Minimum									*-0.030*	*-0.030*	
	Maximum									*-0.030*	*-0.030*	
	Average									*-0.030*	*-0.030*	
Loop 9	617	339,861	2,034,332	5,574.577	5,574.578	5,574.584	5,574.571	0.001	0.006	-0.013	-0.006	MP-AC
	1009	339,814	2,034,328	-	-	-	5,576.051	-	-	-	-	BH-05 center steel cap
	618	339,741	2,034,321	5,577.027	5,577.031	5,577.036	5,577.021	0.004	0.005	-0.015	-0.006	MP-AC
	Minimum							*0.001*	*0.005*	*-0.015*	*-0.006*	
	Maximum							*0.004*	*0.006*	*-0.013*	*-0.006*	
	Average							*0.003*	*0.005*	*-0.014*	*-0.006*	
Loop 10	608	339,625	2,033,859	5,583.354	5,583.361	5,583.354	5,583.355	0.007	-0.007	0.001	0.001	MP-AC
	1004	339,613	2,033,876	-	-	-	5,583.337	-	-	-	-	BH-06 center steel cap
	Minimum							*0.007*	*-0.007*	*0.001*	*0.001*	
	Maximum							*0.007*	*-0.007*	*0.001*	*0.001*	
	Average							*0.007*	*-0.007*	*0.001*	*0.001*	
Loop 11: 513 Hauser (Gebo)	630	340,909	2,033,368	-	-	5,578.798	5,578.768	-	-	-0.030	-0.030	MP-AC
	207-1	-	-	-	-	5,579.348	5,579.319	-	-	-0.029	-0.029	BENCHTIE
	207-2	-	-	-	-	5,579.305	5,579.276	-	-	-0.029	-0.029	BENCHTIE
	207-4	-	-	-	-	5,579.073	5,579.052	-	-	-0.021	-0.021	BENCHTIE
	631	340,905	2,033,325	-	-	5,578.624	5,578.594	-	-	-0.030	-0.030	MP-AC
	207-3	-	-	-	-	5,579.452	5,579.424	-	-	-0.028	-0.028	BENCHTIE
	207-5	-	-	-	-	5,579.248	5,579.219	-	-	-0.029	-0.029	BENCHTIE
	632	340,884	2,033,297			5,579.476	5,579.446			-0.030	-0.030	MP-AC
	1001	340,898	2,033,282	-	-	-	5,578.701	-	-	-	-	BH-02 center steel cap
	207-6	-	-	-	-	5,579.247	5,579.232	-	-	-0.015	-0.015	BENCHTIE
	513	-	-	-	-	5,578.298	5,578.283	-	-	-0.015	-0.015	FH-BOLT
	Minimum									*-0.030*	*-0.030*	
	Maximum									*-0.015*	*-0.015*	
	Average									*-0.026*	*-0.026*	

Table 1: Survey Coordinates

	Point Number	Northing (Feet)	Easting (Feet)	Elevation QM1 (Feet)	Elevation QM2 (Feet)	Elevation QM3 (Feet)	Elevation QM4 (Feet)	Elevation Change (QM1 to QM2) (Feet)	Elevation Change (QM2 to QM3) (Feet)	Elevation Change (QM3 to QM4) (Feet)	Elevation Change (Cumulative) (Feet)	Description
Loop 12: 404 Broadway (Uzelac)	511	340,301	2,034,066	-	5,577.891	5,577.894	5,577.886	-	0.003	-0.008	-0.005	FH-BOLT
	404-8	-	-	-	5,575.162	5,575.168	5,575.159	-	0.006	-0.009	-0.003	MAGNAIL
	404-51	-	-	-	5,574.165	5,574.171	5,574.161	-	0.006	-0.010	-0.004	BENCHTIE
	404-5	340,268	2,033,897	-	5,573.987	5,573.993	5,574.000	-	0.006	0.007	0.013	MAGNAIL
	404-6	340,268	2,033,874	-	5,573.776	5,573.782	5,573.790	-	0.006	0.008	0.014	MAGNAIL
	404-7	340,255	2,033,859	-	5,574.128	5,574.136	5,574.162	-	0.008	0.026	0.034	MAGNAIL
	404-4	-	-	-	5,574.969	5,574.977	5,574.966	-	0.008	-0.011	-0.003	BENCHTIE
	404-9	-	-	-	5,576.745	5,576.754	5,576.739	-	0.009	-0.015	-0.006	BOLT ON WELL
	629	340,252	2,033,876	-	5,573.727	5,573.732	5,573.714	-	0.005	-0.018	-0.013	MP-AC
	628	340,279	2,033,876	-	5,573.913	5,573.919	5,573.908	-	0.006	-0.011	-0.005	MP-AC
	1010	340,307	2,033,846	-	-	-	5,574.997	-	-	-	-	BH-07 center steel cap
	404-3	-	-	-	5,574.923	5,574.931	5,574.922	-	0.008	-0.009	-0.001	BENCHTIE
	404-2	-	-	-	5,576.056	5,576.065	5,576.055	-	0.009	-0.010	-0.001	BENCHTIE
	627	340,290	2,033,797	-	5,576.327	5,576.334	5,576.312	-	0.007	-0.022	-0.015	MP-AC
	626	340,253	2,033,795	-	5,576.050	5,576.055	5,576.032	-	0.005	-0.023	-0.018	MP-AC
	404-1	-	-	-	5,576.578	5,576.584	5,576.564	-	0.006	-0.020	-0.014	BENCHTIE
	512	340,359	2,033,726	-	5,580.233	5,580.244	5,580.228	-	0.011	-0.016	-0.005	FH-BOLT
	Minimum								*0.003*	*-0.023*	*-0.018*	
	Maximum								*0.011*	*0.026*	*0.034*	
	Average								*0.007*	*-0.009*	*-0.002*	
Loop 13: 501 Broadway (Dukart)	507	340,004	2,033,735	5,580.713	5,580.709	5,580.720	5,580.705	-0.004	0.011	-0.015	-0.008	FH-BOLT
	602	339,925	2,033,739	5,579.466	5,579.468	5,579.481	5,579.468	0.002	0.013	-0.013	0.002	LP-NE-FOOT
	501-1	-	-	5,582.609	5,582.606	5,582.619	5,582.604	-0.003	0.013	-0.015	-0.005	MAGNAIL
	501-2	-	-	5,581.419	5,581.418	5,581.435	5,581.419	-0.001	0.017	-0.016	0.000	BENCHTIE
	501-3	-	-	5,581.225	5,581.222	5,581.239	5,581.219	-0.003	0.017	-0.020	-0.006	BENCHTIE
	501-4	-	-	5,581.344	5,581.343	5,581.359	5,581.341	-0.001	0.016	-0.018	-0.003	BENCHTIE
	501-5	-	-	5,581.213	5,581.213	5,581.224	5,581.204	0.000	0.011	-0.020	-0.009	BENCHTIE
	501-6	-	-	5,581.236	5,581.235	5,581.252	5,581.233	-0.001	0.017	-0.019	-0.003	BENCHTIE
	622	339,931	2,033,676	5,581.838	5,581.838	5,581.850	5,581.834	0.000	0.012	-0.016	-0.004	BOLT-WELLHEAD
	501-9	-	-	5,582.740	5,582.737	5,582.754	5,582.733	-0.003	0.017	-0.021	-0.007	HINGE-GARAGE
	601	339,934	2,033,603	5,582.807	5,582.806	5,582.823	5,582.805	-0.001	0.017	-0.018	-0.002	BENCHTIE-PP
	1013	339,945	2,033,668	-	-	-	5,579.979	-	-	-	-	BH-03 center steel cap
	501-7	-	-	5,580.324	5,580.316	5,580.335	5,580.318	-0.008	0.019	-0.017	-0.006	MAGNAIL (Sidewalk)
	501-8	-	-	5,580.269	5,580.262	5,580.280	5,580.261	-0.007	0.018	-0.019	-0.008	MAGNAIL
	506	339,897	2,033,619	5,581.745	5,581.744	5,581.758	5,581.736	-0.001	0.014	-0.022	-0.009	MP-AC
	501-13	-	-	5,581.933	5,581.931	5,581.946	5,581.933	-0.002	0.015	-0.013	0.000	BENCHTIE
	501-12	-	-	5,581.463	5,581.459	5,581.470	5,581.459	-0.004	0.011	-0.011	-0.004	BENCHTIE
	501-11	-	-	5,581.457	5,581.454	5,581.467	5,581.453	-0.003	0.013	-0.014	-0.004	BENCHTIE
	501-10	-	-	5,581.623	5,581.621	5,581.634	5,581.620	-0.002	0.013	-0.014	-0.003	BENCHTIE
	623	339,871	2,033,687	5,580.785	5,580.785	5,580.794	5,580.782	0.000	0.009	-0.012	-0.003	MP-AC
	613	339,880	2,033,731	5,580.291	5,580.297	5,580.302	5,580.296	0.006	0.005	-0.006	0.005	MP-AC
	Minimum							*-0.008*	*0.005*	*-0.022*	*-0.009*	
	Maximum							*0.006*	*0.019*	*-0.006*	*0.005*	
	Average							*-0.002*	*0.014*	*-0.016*	*-0.004*	

Table 1: Survey Coordinates

	Point Number	Northing (Feet)	Easting (Feet)	Elevation QM1 (Feet)	Elevation QM2 (Feet)	Elevation QM3 (Feet)	Elevation QM4 (Feet)	Elevation Change (QM1 to QM2) (Feet)	Elevation Change (QM2 to QM3) (Feet)	Elevation Change (QM3 to QM4) (Feet)	Elevation Change (Cumulative) (Feet)	Description
Loop 14: 505 Platt (Anderson)	615	339,855	2,034,071	5,576.592	5,576.589	5,576.597	5,576.579	-0.003	0.008	-0.018	-0.013	MP-AC
	505-1	-	-	5,578.550	5,578.547	5,578.551	5,578.541	-0.003	0.004	-0.010	-0.009	BENCHTIE
	625	339,846	2,034,007	5,578.788	5,578.786	5,578.790	5,578.777	-0.002	0.004	-0.013	-0.011	MP-AC
	505-7	-	-	5,581.863	5,581.855	5,581.860	5,581.854	-0.008	0.005	-0.006	-0.009	X ON NW COR FIRE PIT
	505-6	-	-	5,580.444	5,580.443	5,580.436	5,580.426	-0.001	-0.007	-0.010	-0.018	BENCHTIE
	505-2	-	-	5,578.843	5,578.840	5,578.845	5,578.833	-0.003	0.005	-0.012	-0.010	BENCHTIE
	505-3	-	-	5,578.601	5,578.599	5,578.602	5,578.590	-0.002	0.003	-0.012	-0.011	BENCHTIE
	624	339,888	2,034,012	5,577.835	5,577.839	5,577.833	5,577.817	0.004	-0.006	-0.016	-0.018	MP-AC
	505-5	-	-	5,578.433	5,578.431	5,578.434	5,578.424	-0.002	0.003	-0.010	-0.009	BENCHTIE
	1006	339,884	2,034,083	-	-	-	5,576.106	-	-	-	-	BH-04 center steel cap
	505-4	-	-	5,578.173	5,578.171	5,578.175	-	-0.002	0.004	-	0.002	BENCHTIE
	505-8	-	-	5,578.273	5,578.270	5,578.275	5,578.265	-0.003	0.005	-0.010	-0.008	X ON STEPS
	Minimum							*-0.008*	*-0.007*	*-0.018*	*-0.018*	
	Maximum							*0.004*	*0.008*	*-0.006*	*0.002*	
	Average							*-0.008*	*-0.007*	*-0.018*	*-0.018*	
	Total Minimum							***-0.008***	***-0.009***	***-0.030***	***-0.030***	
	Total Maximum							***0.013***	***0.019***	***0.026***	***0.034***	

Note:
1) Horizontal coordinates are in Montana State Plane NAD 83 (2011)
2) Q215 = NGS benchmark
3) FH-BOLT = Fire Hydrant Bolt
4) MP-AC = Monitoring Point with Aluminum Cap (36" rebar)
5) Horrizontal coordinates not surveyed for points attached to residences.
5) BH-08 not monitored on quarterly basis due to being located out of range of the survey loop system.

Table 2: Crack Gauge Data

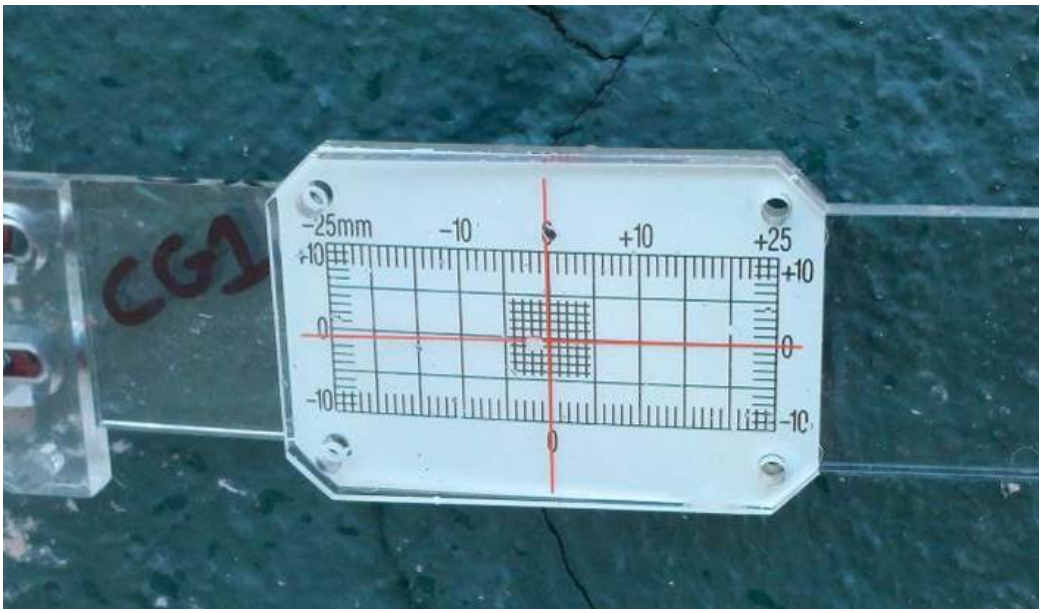
Residence	Crack Gauge	Location	Change from QM1 to QM2	Change from QM2 to QM3	Change from QM3 to QM4	Cumulative Change
501 Broadway	CG 1	South side of house	No movement	No movement	No movement	No movement
	CG 2	South side of house	0 mm horizontal, 0.5 mm down	0.5 mm left, 0 mm vertical	0 mm horizontal, 0.5 mm down	No movement
	CG 3	North side of house	1.0 mm left, 1.5 mm up	Destroyed[2]	Destroyed[2]	Destroyed[2]
505 Platt	CG 4	North side of house	2.0 mm down, rotated 4° counter clockwise	2.0 mm up, rotated 4° clockwise	0.5 mm horizontal, 0 mm vertical	0.5 mm horizontal.
	CG 5	East side of house	No movement	No movement	0.5 mm horizontal, 0 mm vertical	0.5 mm horizontal.
404 Broadway	CG 6	East side of house	na[1]	0 mm horizontal, 0.5 mm vertical	0.5 mm horizontal, 0 mm vertical	0.5 mm horizontal, 0 mm vertical
	CG 7	West side of garage	na[1]	0 mm horizontal, 0.5 mm up	No movement	0 mm horizontal, 0.5 mm up
207 Hauser	CG 8	West side of house	na[3]	na[3]	0.5 mm horizontal, 0 mm vertical	0.5 mm horizontal, 0 mm vertical

Notes:

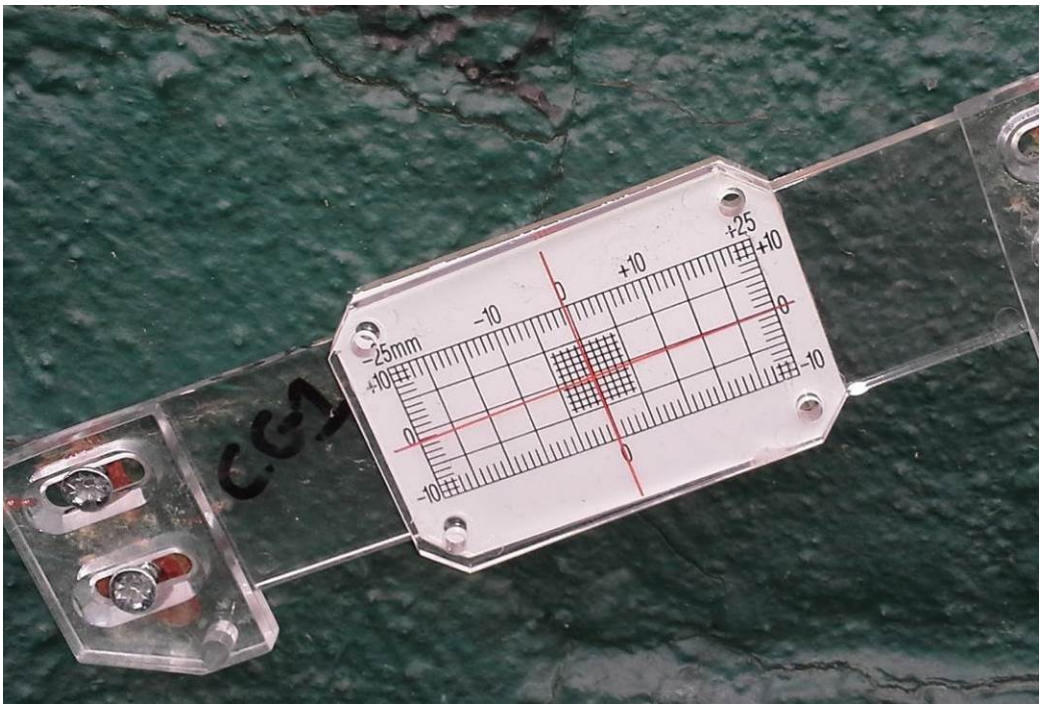
1) CG 6 and CG7 installed during the QM2 monitoring.

2) GG 3 was knocked free at some point between the QM2 and QM3 monitoring and is no longer accurate or monitored.

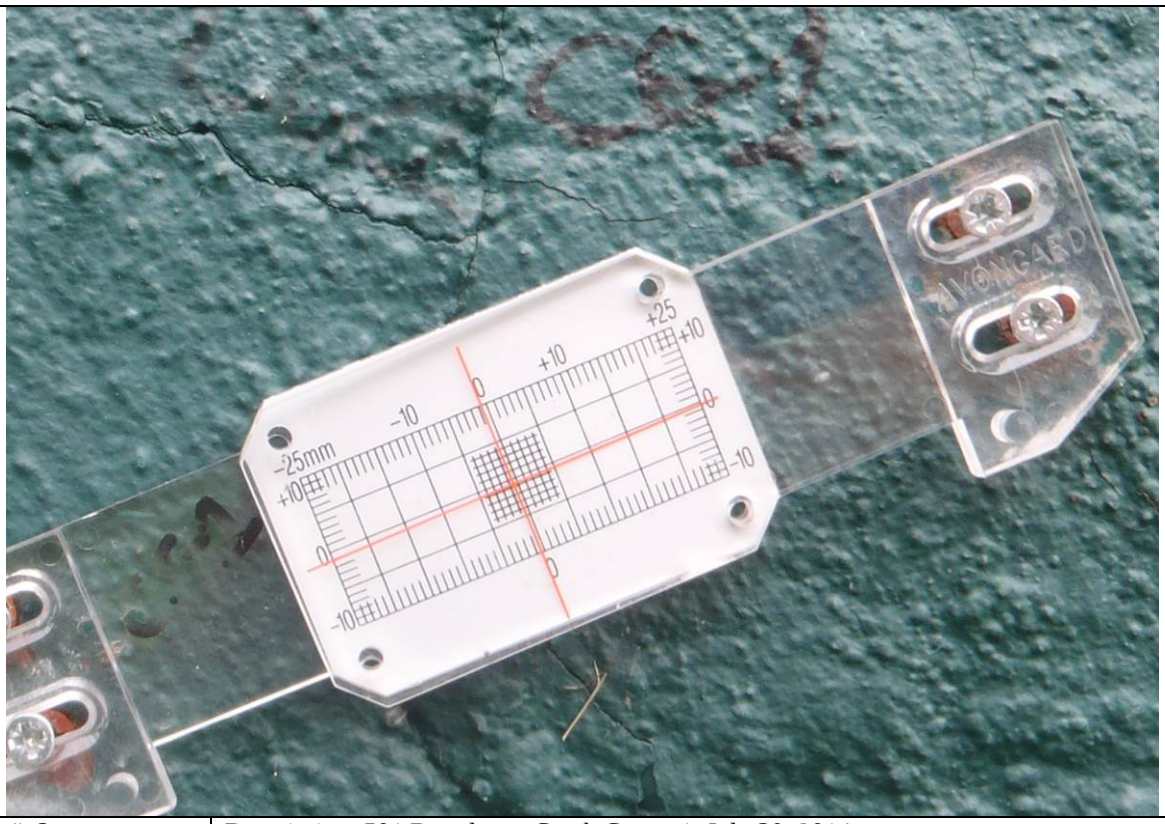
3) CG 8 installed in July 2014 during QM3 monitoring.



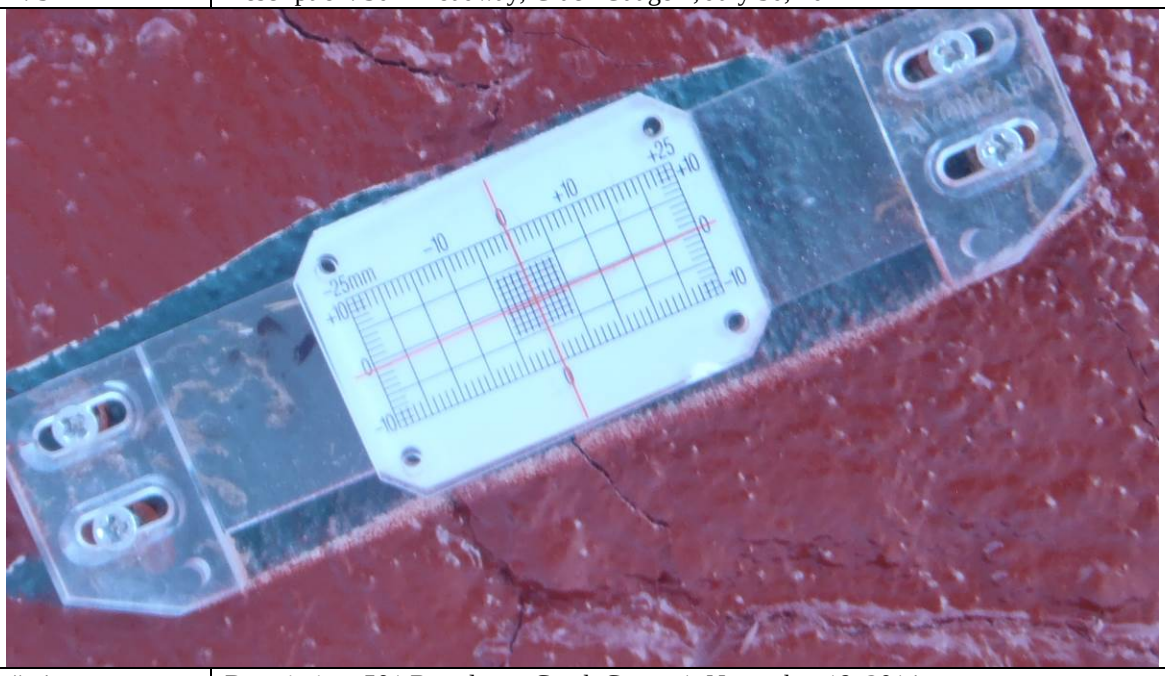
Picture #: 1	Description: 501 Broadway, Crack Gauge 1. January 20, 2014.



Picture #: 2	Description: 501 Broadway, Crack Gauge 1, April 28, 2014.

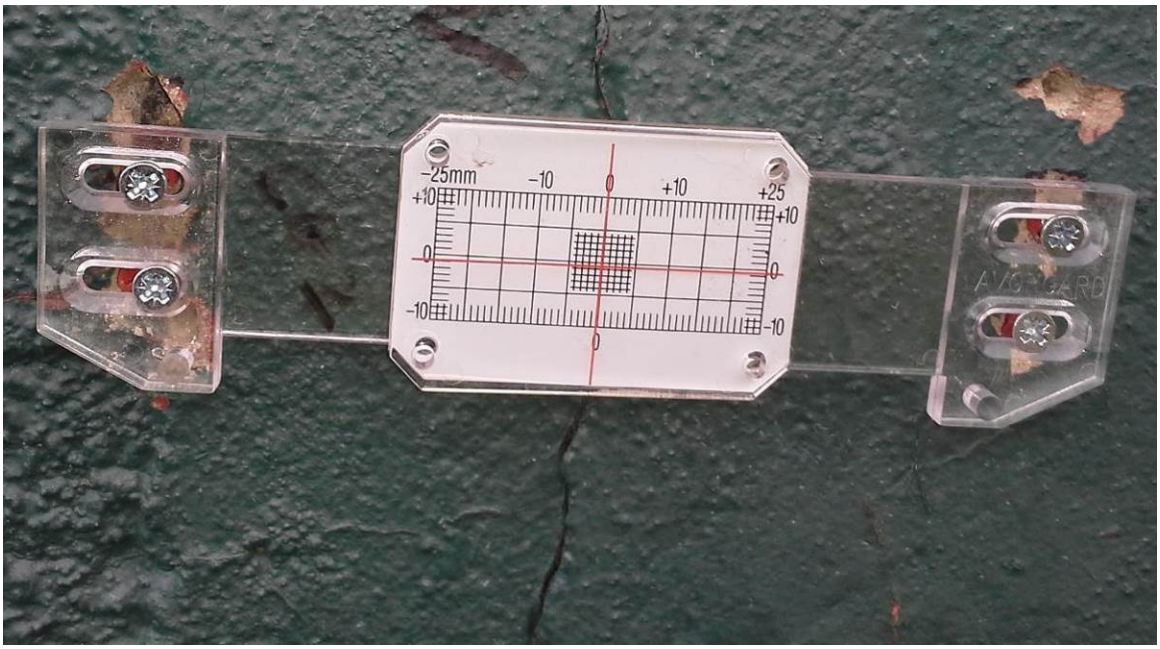


Picture #: 3	Description: 501 Broadway, Crack Gauge 1, July 30, 2014

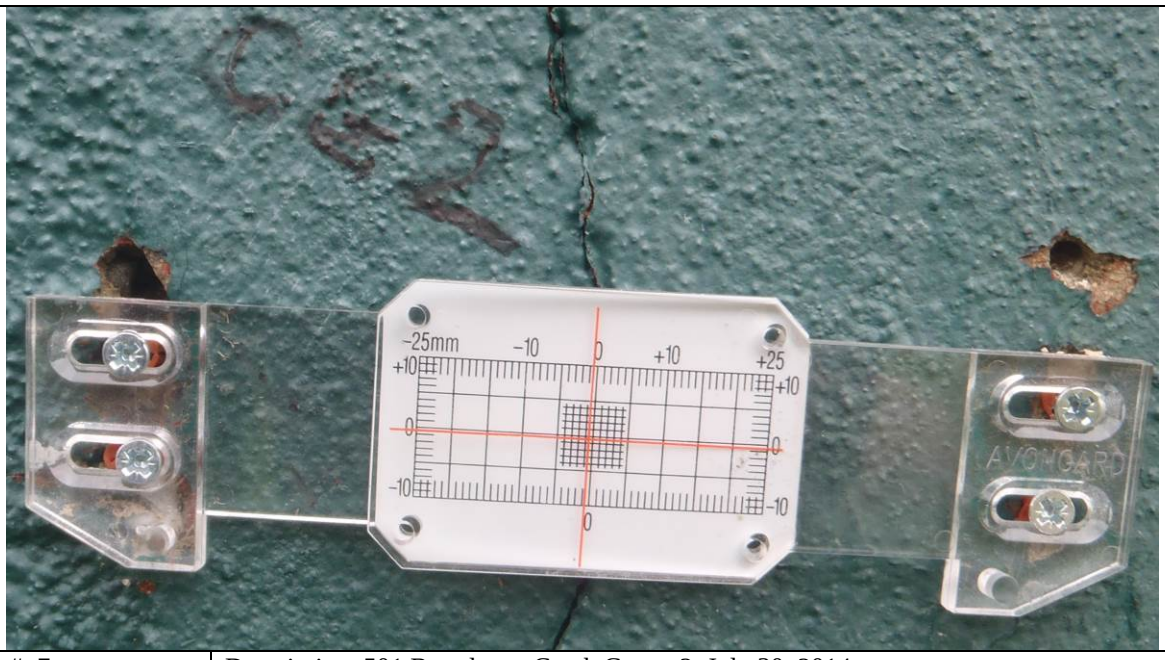


Picture #: 4	Description: 501 Broadway, Crack Gauge 1, November 19, 2014

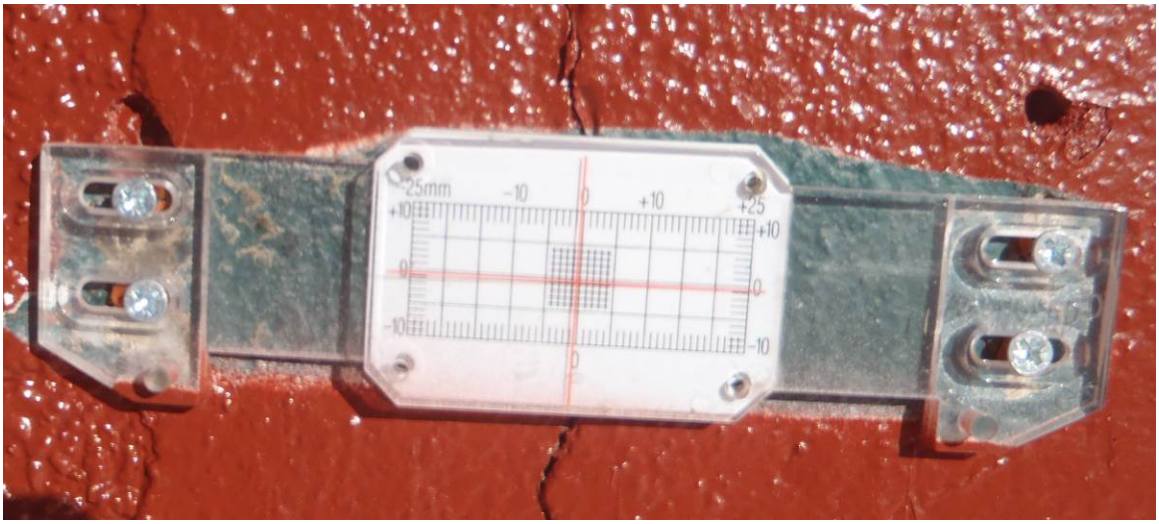
Picture #: 5	Description: 501 Broadway, Crack Gauge 2. January 20, 2014.



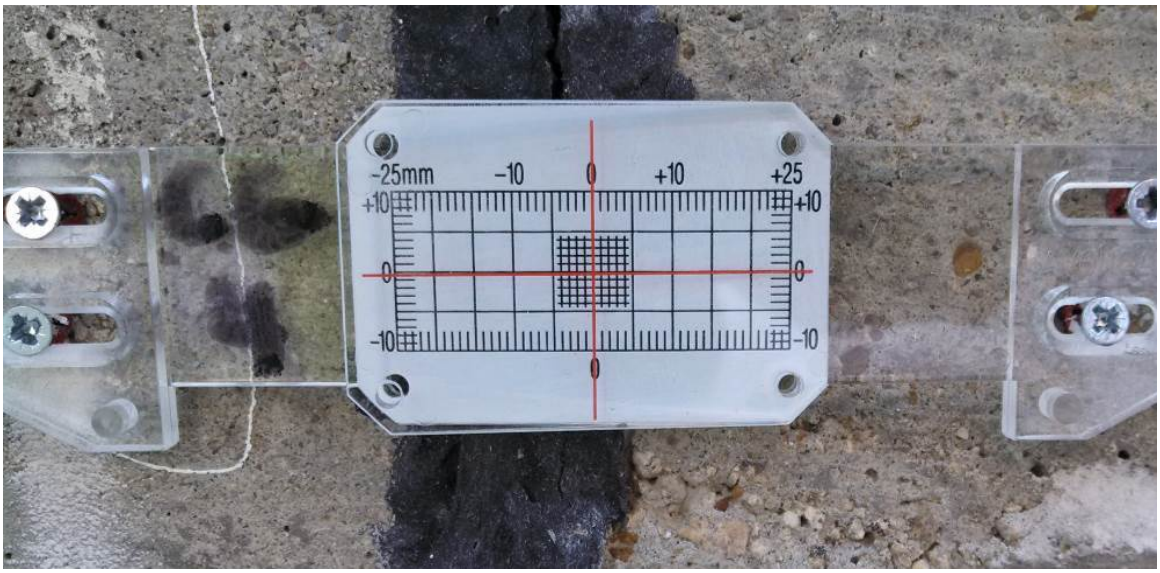
Picture #: 6	Description: 501 Broadway, Crack Gauge 2, April 28, 2014.



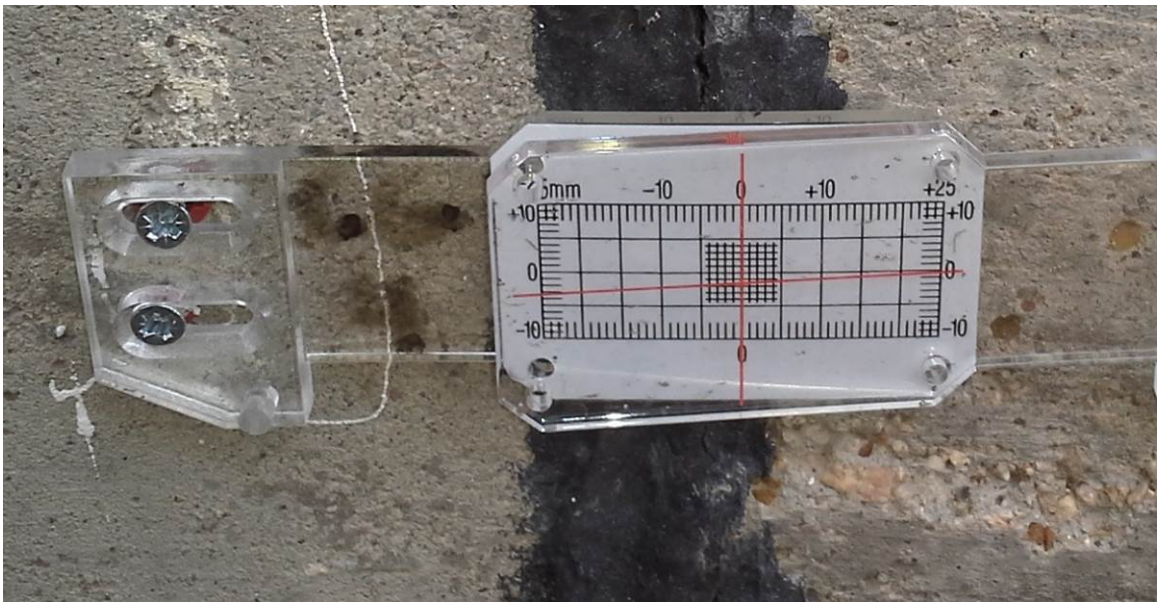
Picture #: 7	Description: 501 Broadway, Crack Gauge 2, July 30, 2014.



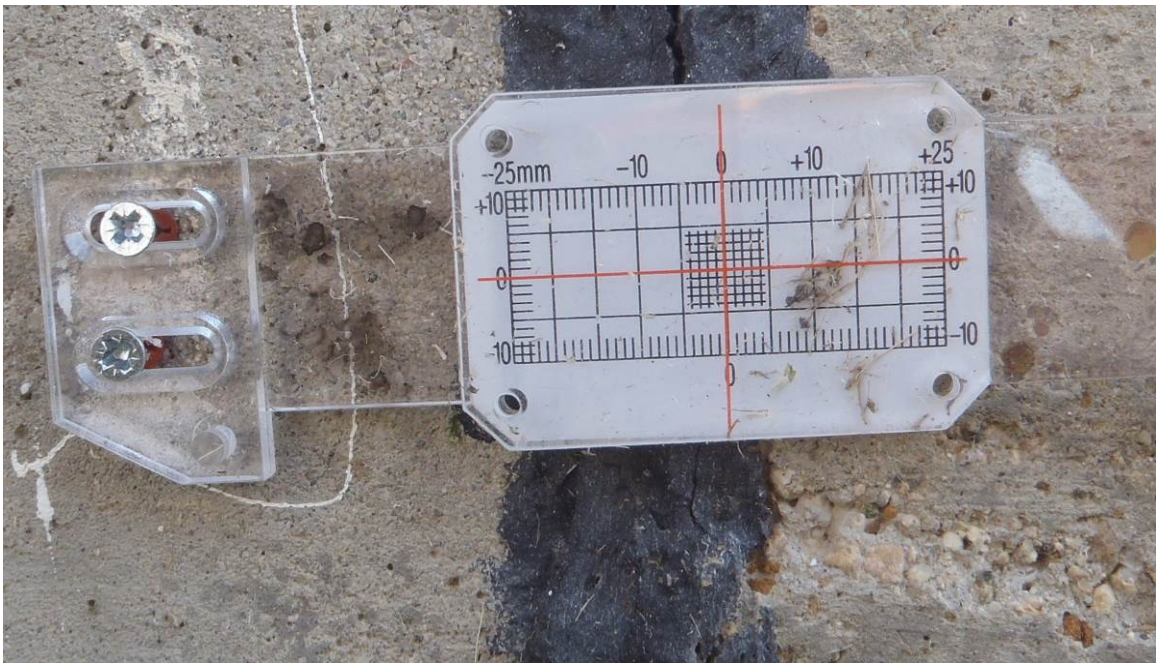
Picture #: 8	Description: 501 Broadway, Crack Gauge 2, November 19, 2014



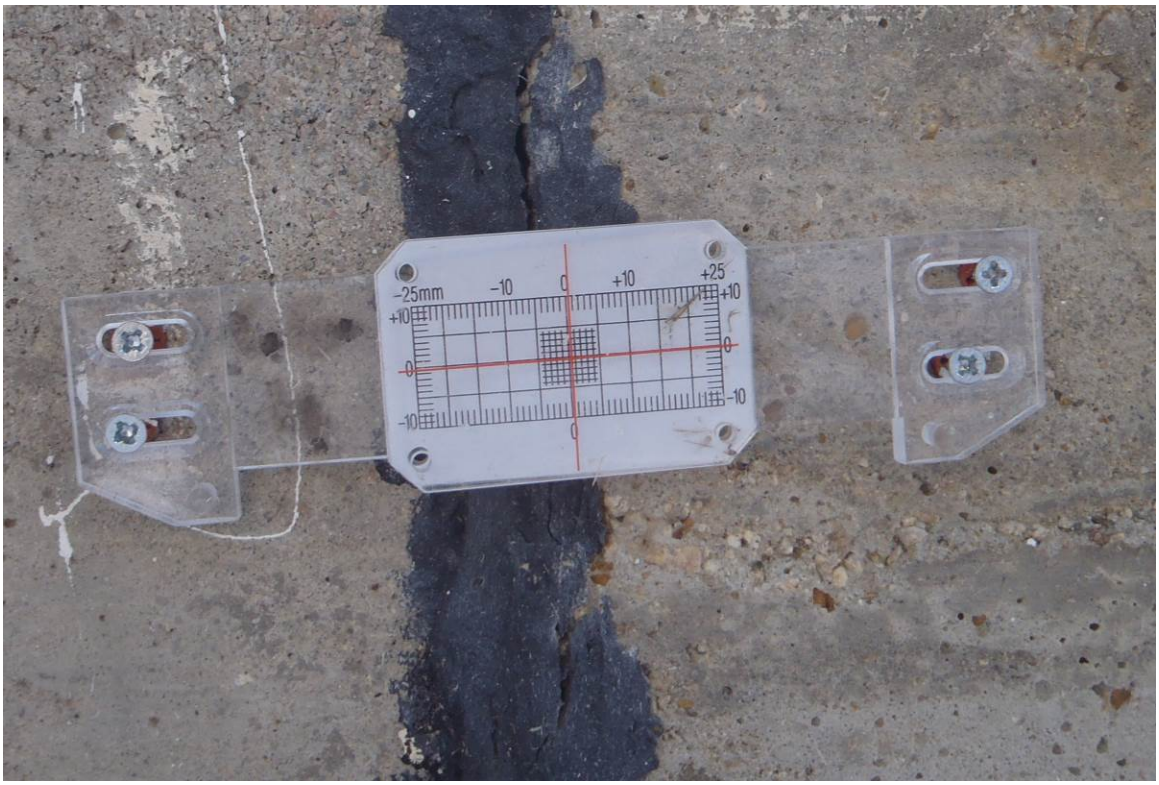
Picture #: 9	Description: 505 Platt Ave., Crack Gauge 4. January 21, 2014.



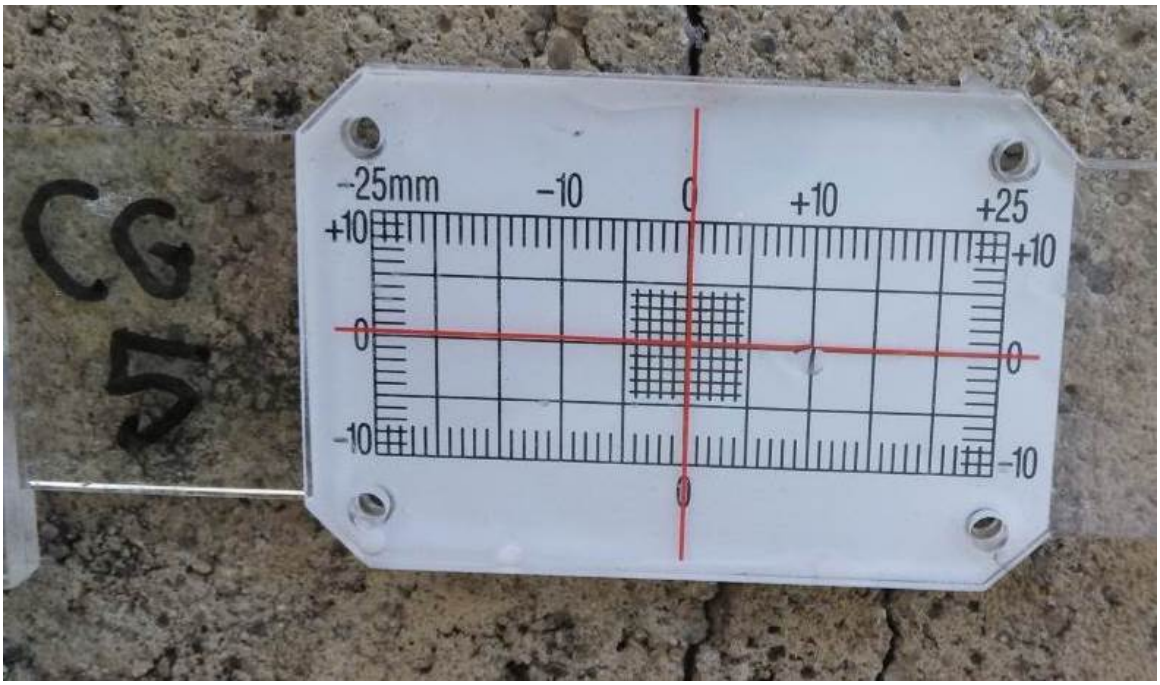
Picture #: 10	Description: 505 Platt Ave., Crack Gauge 4. April 28, 2014.



Picture #: 11	Description: 505 Platt Ave., Crack Gauge 4. July 30, 2014.

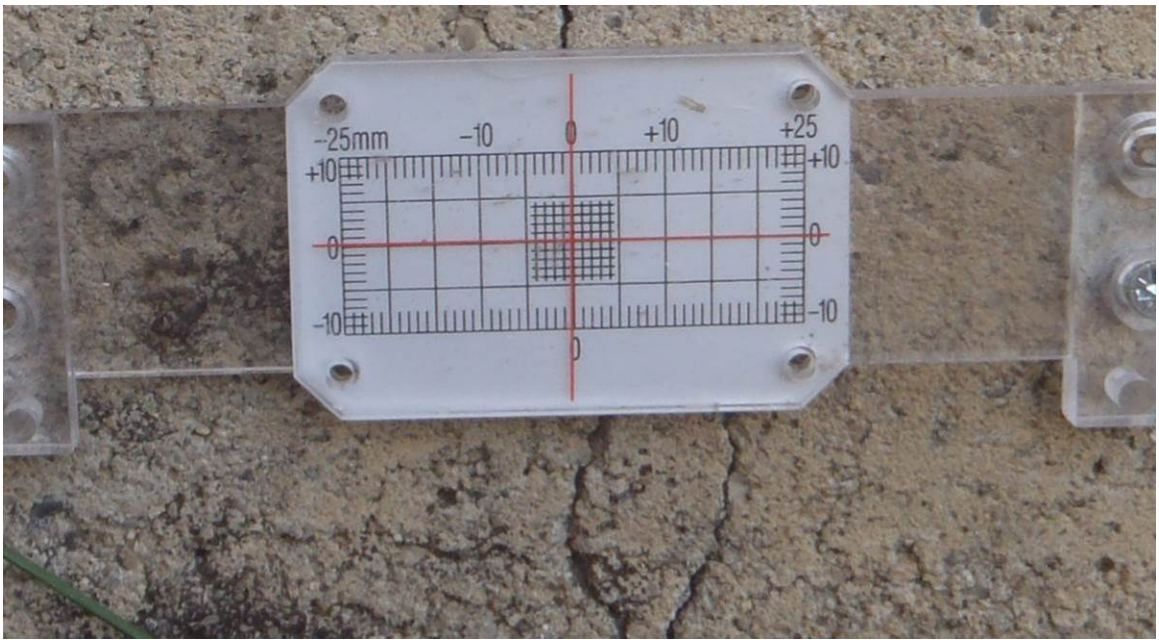


Picture #: 12	Description: 505 Platt Ave., Crack Gauge 4. November 19, 2014.

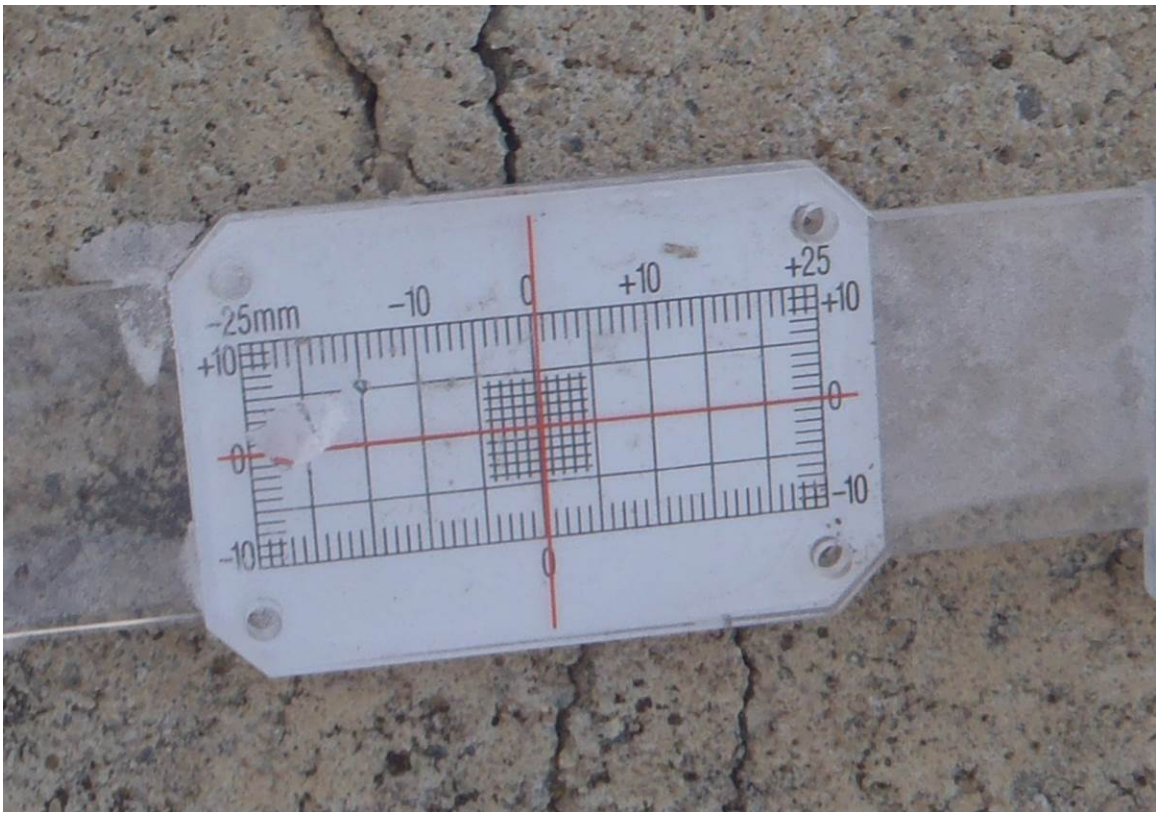


Picture #: 13	Description: 505 Platt Ave., Crack Gauge 5. January 21, 2014.

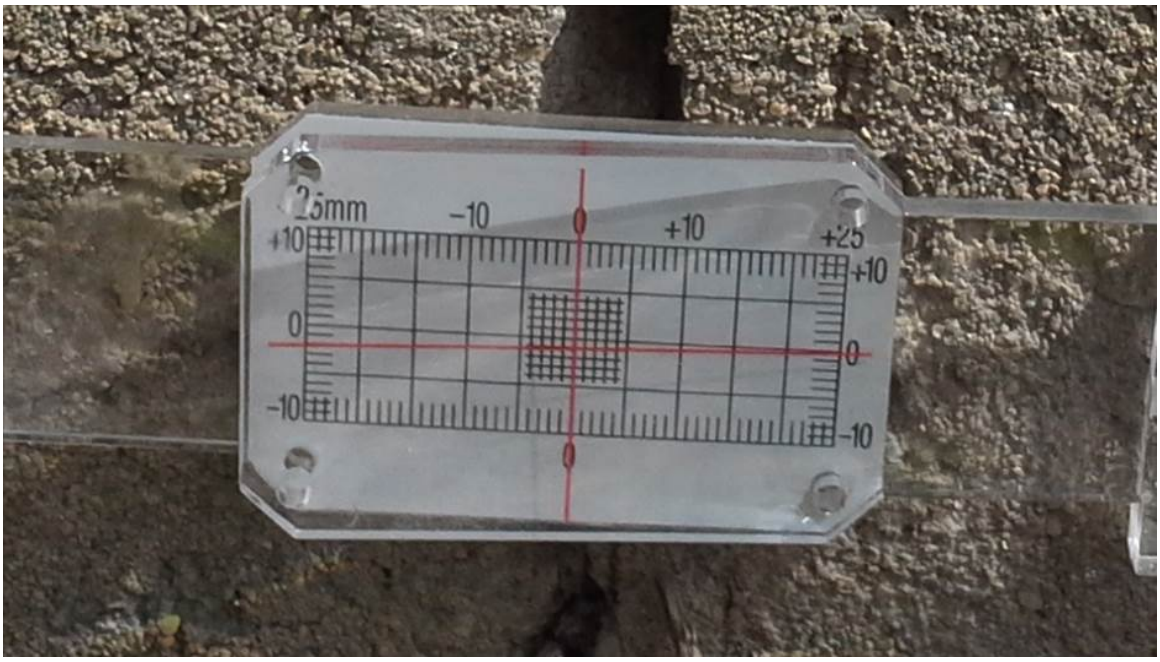
Picture #: 14	Description: 505 Platt Ave., Crack Gauge 5. April 28, 2014.



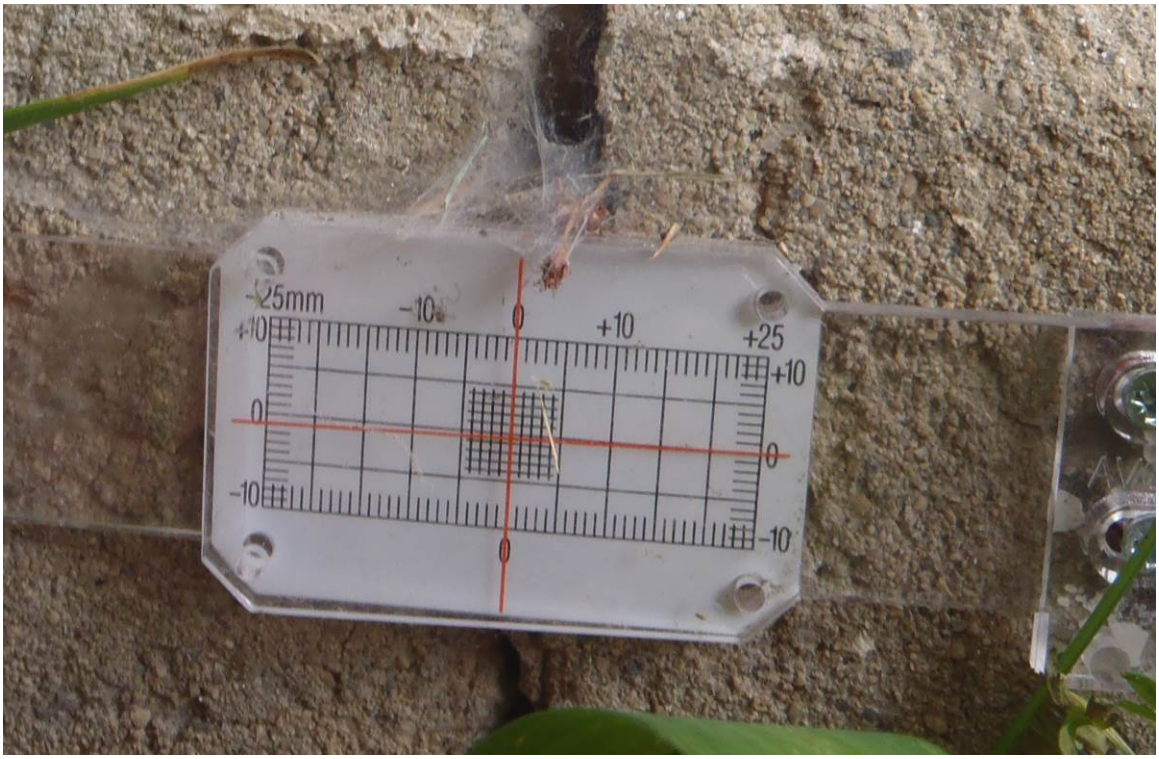
Picture #: 15	Description: 505 Platt Ave., Crack Gauge 5. July 30, 2014



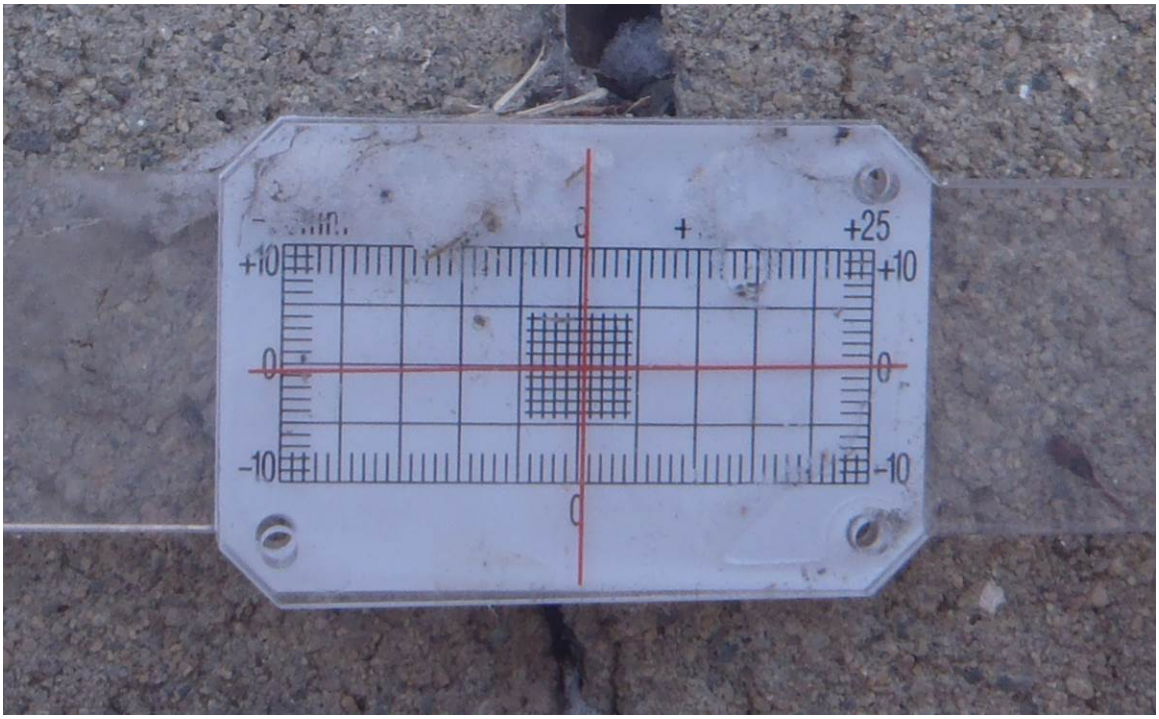
Picture #: 16	Description: 505 Platt Ave., Crack Gauge 5. November 19, 2014



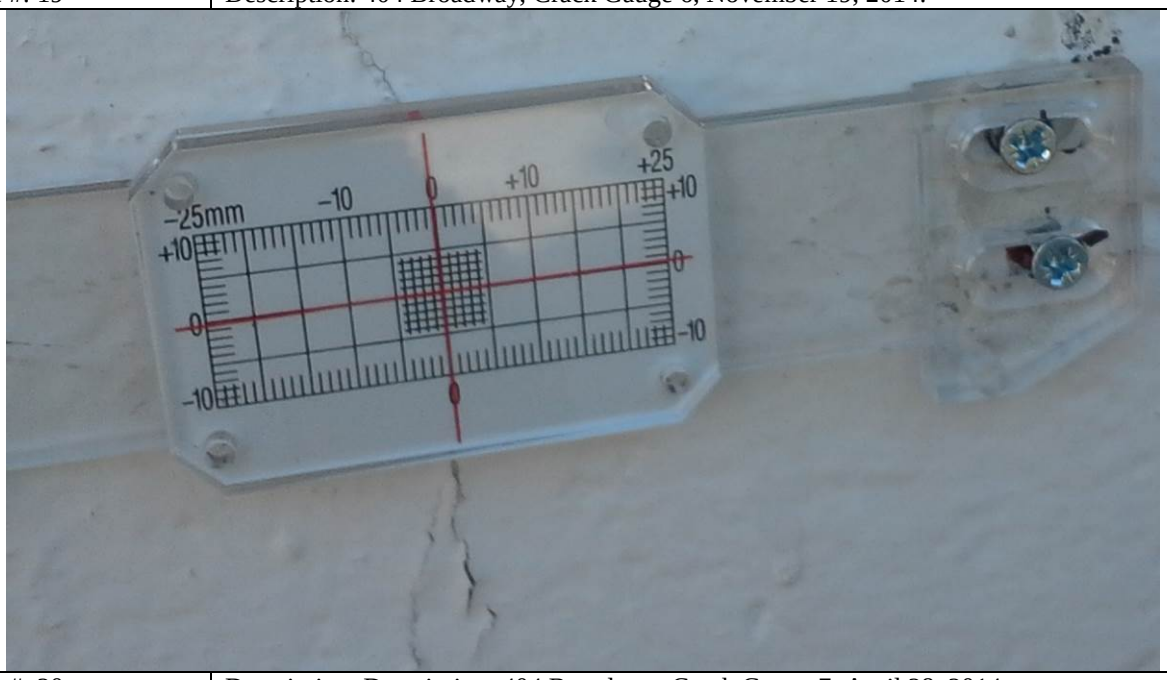
Picture #: 17	Description: 404 Broadway, Crack Gauge 6, April 28, 2014.



Picture #: 18	Description: 404 Broadway, Crack Gauge 6, July 30, 2014

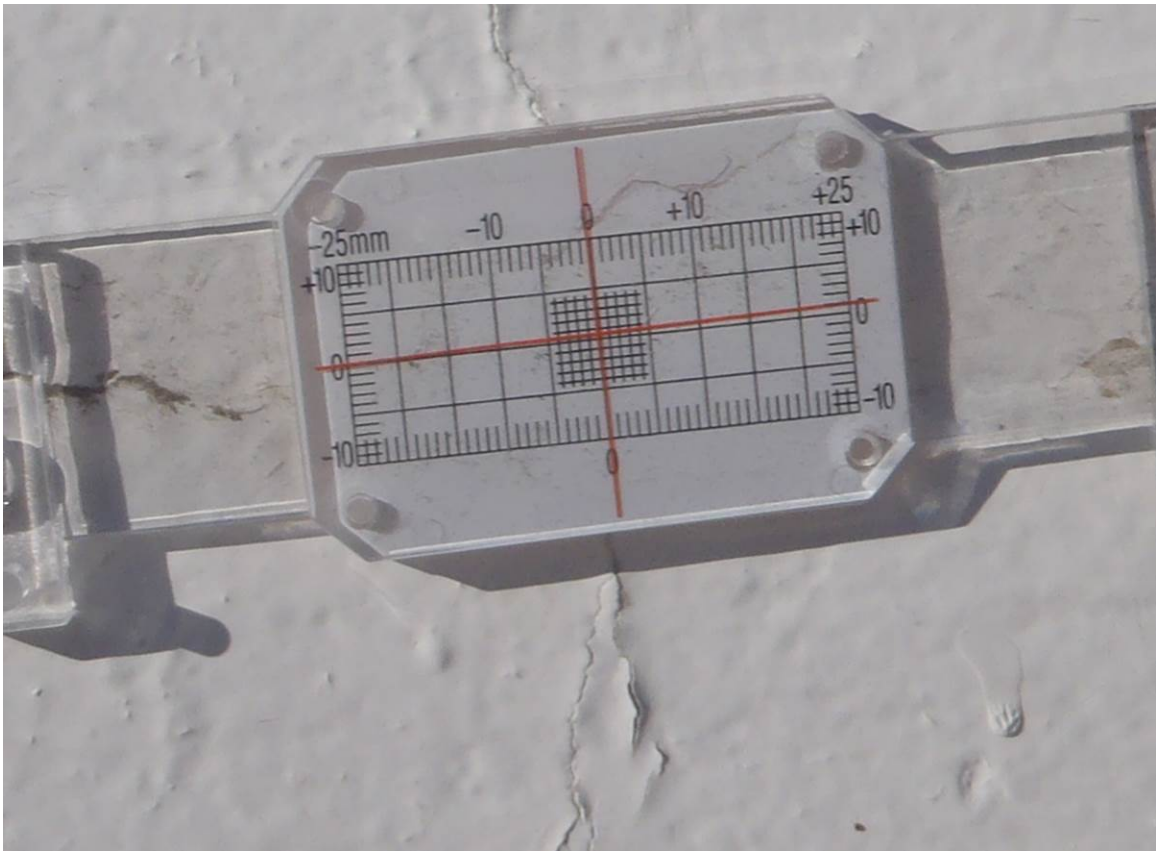


Picture #: 19	Description: 404 Broadway, Crack Gauge 6, November 19, 2014.

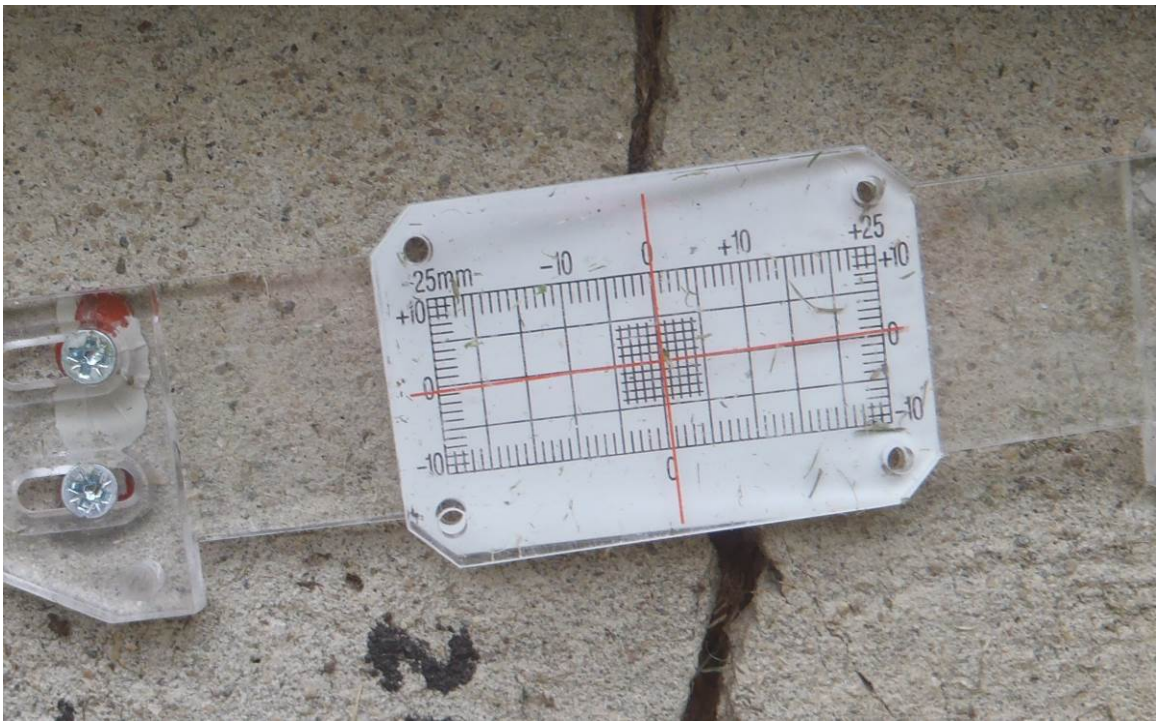


Picture #: 20	Description: Description: 404 Broadway, Crack Gauge 7, April 28, 2014.

Picture #: 21	Description: Description: 404 Broadway, Crack Gauge 7, July 30, 2014



Picture #: 22	Description: Description: 404 Broadway, Crack Gauge 7, November 19, 2014.



Picture #: 23	Description: 207 Hauser, Crack Gauge 8, July 30, 2014

Picture #: 24	Description: 207 Hauser, Crack Gauge 8, November 19, 2014.

APPENDIX D. ENGINEERING CALCULATIONS

Date:	4/13/15	Project:	Red Lodge Drilling Investigation	Prepared By:	JJR
Rev. No.	1.0	Office:	Bozeman	Checked By:	TPR
Rev. Date:	4/13/15	Calc. No.		Approved By:	JJR
Subject:	Red Lodge Abandoned Mine Subsidence Potential Assessment				

Subsidence Mechanisms – Engineering Evaluation

1 PURPOSE AND OBJECTIVES

The purpose of this calculation brief is to evaluate potential subsidence mechanism for the conditions observed. Ground surface displacements from failure of room and pillar mines can occur through the following mechanisms:

1. Pothole Subsidence (Chimney Failure and Bedrock Fissuring); and
2. Trough Subsidence.

Depending on the location, depth, and type of subsurface failure, displacements can be expressed in both vertical and horizontal directions. This document is meant to provide a more technical discussion for Section 8 of the Final Data Summary and Analysis Report. Figures and Tables referenced are included in the main document.

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2 POTHOLE SUBSIDENCE

2.1 Chimney Failure Potholes

The following section presents an evaluation of chimney failure potential and subsequent development of steep-sided and shallow-sided potholes. For this discussion, chimney failures are those which form by progressive, localized caving of mine roof material through overlying strata (Figure 8-1). Chimney failures typically continue to propagate vertically through overlying strata unless arrested by formation of a stable geometry, more competent roof materials, bulking of caved debris, or when intersecting overburden materials, thereby changing the mode of propagation to one of granular flow (for the case of non-cohesive overburden). Potholes are surface expressions caused when overburden readjusts to the presence of void space created by chimney failure below. The thickness and character of overburden greatly influence the pothole shape.

For a pothole to form, chimney failure has to reach the surface. For the case of Red Lodge, chimney failure must propagate through the bedrock to the base of the alluvial gravels and then through the gravels to the surface. To assess the occurrence of chimney failures at the bore hole

locations, floor-to-roof distance measurements and caved material thicknesses within the workings were compared to calculated maximum caving heights The calculated estimates use equations presented by Whittaker and Reddish (1989) to estimate the vertical extent of a chimney failure through bedrock for a generalized mine geometry. In addition to calculated estimates, reference is also made to several authors' observations of chimney failure/pothole subsidence and descriptions of geometric conditions conducive to such failures.

In the worked regions, it is unlikely failure modes are limited to roof caving; other modes such as pillar shortening, floor heave, floor bearing capacity failure, and roof strain have also likely affected the relative distance between the "floor" and the top of the damaged zone.
As will be shown by the comparison, most of the workings are at depths where theoretical chimney failures are likely to self-arrest before reaching the upper limit of the bedrock. However, at location BH-07, the shallow workings may be near enough to the surface to propagate to the bedrock surface, and therefore the ground surface. For this condition an additional evaluation of steep-sided pothole development, also known as channeling, through alluvial gravels is presented. This analysis makes reference to theoretical work by Drescher and Vgenopoulou (1983) and assesses the conditions necessary for channeling of a cohesive-granular material in a bin or hopper.

2.1.1 Drilling Observations

The distance between the roof and floor was recorded in the bore hole logs. The roof is defined as the location above the workings where a loss of drilling circulation, a sharp drop in RQD, or a void was first observed. The floor is defined as the location where either the last trace of coal or underclay was observed. In workings where voids were observed, the thickness is the total distance in which the drill rods fell by gravity through the workings. Thickness of caved material was also recorded, where this is the total distance in which drilling was through loose and/or blocky material. Table 8-2 summarizes these observations for each of the bore holes and the respective beds. The data in the table also show the thickness for each of the intact coal beds when workings were not directly encountered. The following subsections summarize observations of each of the coal beds that were worked in the areas drilled (note that Beds No. 1, 3, and 4½ were not worked beneath the location of the bore holes).

2.1.1.1 Bed No. 1 ½

Seam No. 1½ was encountered in five of the bore holes. One hole showed the immediate location had been worked and four showed a complete section of coal (pillar or unworked area). Based on the stratigraphy presented in Woodruff (1909) and drilling observations, the coal bed ranges between 5 to 6 feet in thickness. In the worked location (BH-08), a 2.5-foot void and 20.5 feet of caved material were encountered for a total distance of 23 feet. Assuming the floor has not heaved and the roof has not converged, the roof materials (bedrock) have caved up for a distance of 18 feet.

2.1.1.2 Bed No. 2

Seam No. 2 was encountered in six of the bore holes. Three holes showed the immediate location had been worked and three showed a complete section of coal (pillar or unworked area). Based on the stratigraphy presented in Woodruff (1909) and drilling observations, the No. 2 seam ranges between 5 to 9 feet in thickness. Within the two worked locations (BH-06 and BH-08), two thick damaged regions were observed. A 5-foot void and 12 feet of caved material were encountered for a total distance of 17 feet in BH-06, and a slight void and nearly 31 feet of caved materials were encountered in BH-08. Assuming the floor has not heaved and the roof has not converged, the roof materials have caved up for a distance of 8 feet in BH-06 and 25 feet in BH-08.

2.1.1.3 Bed No. 4

Seam No. 4 was encountered in seven of the bore holes. Six holes showed the immediate location had been worked and one showed a complete section of coal (pillar or unworked area). Based on the stratigraphy presented in Woodruff (1909) and drilling observations, the No. 4 seam ranges between 10 to 12 feet in thickness. Of the seven worked locations, the thickest damage was observed in BH-04 where a 1-foot void and 24 feet of caved material were encountered for a total distance of 25 feet. Assuming the floor has not heaved and the roof has not converged, the roof materials have caved up for a distance of 13 feet in BH-04.

2.1.1.4 Bed No. 5

Seam No. 5 was encountered in seven of the bore holes. Three holes showed the immediate location had been worked and four showed a complete section of coal (pillar or unworked area). Based on the stratigraphy presented in Woodruff (1909) and drilling observations, the No. 5 seam ranges between 12 to 20 feet in thickness. According to Parsons (1907b), due to poor roof conditions, 5 feet of coal was typically left on the roof for support and the remaining 7 feet was mined. Of the three worked locations, the thickest damage was observed in BH-04 where a void was observed and 18 feet of caved material was encountered. Assuming the floor has not heaved and the roof has not converged, the roof materials have caved up for a distance of 18 feet in BH-04. In BH-03 a 5-foot void was observed and 11.5 feet of caved material were encountered for a total distance of 16.5 feet.

2.1.2 Chimney Failure Analysis

Of all the mined workings observed, the greatest extent of roof caving was observed above the No. 2 bed in BH-08, with a total caved up distance of 25 feet. Calculations were performed to estimate the maximum extent of a chimney failure at this location. The calculations use equations presented by Whittaker and Reddish (1989) that describe a maximum caving height above the roof. The analysis equates two volumes: the volume of the space created by caving and the volume of space filled by the caved material (created space multiplied by bulking factor); when the two volumes are equal, the caving process is self-arrested. Two conditions were evaluated with the following assumptions:

1. Mined room widths of 15 and 25 feet (based on mine geometry shown on No. 2 Mine map);
2. Excavated height (coal mined) of 5 and 10 feet;
3. Angle of repose of caved rock = 40 degrees (typical for angular rock);
4. Bulking factor = 1.33 [average from Whittaker and Reddish (1989)]; and
5. Diameter of chimney = 21 and 35 feet (estimated as width x √2).

With these assumptions, the calculated height of potential chimney collapse is between 17 to 34 feet (Attachment A). As described above, the maximum observed caving height, approximately 25 feet, is in the No. 2 bed at BH-08. At this location only a very slight void was encountered, therefore available space for additional caving is minimal and further appreciable caving in this location is unlikely. Comparison of the calculated chimney height and the maximum observed (self-arrested) caved thickness shows reasonable agreement.

Singh and Dhar (1997) summarize several authors' observations in relation to the occurrence of chimney failure and pothole subsidence. According to the authors, Matheson and Eckert-Clift (1986) observed a strong possibility of pothole occurrence when the overlying bedrock thickness (h) to mining height (m) ratio is less than 5; and if the ratio is between 5 and 11, the occurrence of potholes rapidly decreases. Statham and Treharne (1991) observed 90% of total potholes occurred when the (h/m) ratio was less than 6, and none occurred when the ratio was greater than 18. Observations made by Karfakis (1987b) at the Hanna Mining district in Wyoming show similar results for room heights between 10 to 20 feet (Figure 8-11). The author reports a 2% probability for chimney failures at overburden depths greater than 160 feet. Singh (2007) reports 90% of potholes observed at the Son-Mahanadi Master Coal Basin occurred in areas where the overburden was less than 150 feet (Figure 8-11).

Typical mining heights in the Red Lodge Mines ranged between 5 to 10 feet, suggesting the following general statements:

1. For a mining height of 5 feet, areas with less than 50 feet of bedrock have a higher potential for chimney failures to extend to the bedrock alluvial gravel interface,
2. For a mining height of 10 feet, areas with less than 100 feet of bedrock have a higher potential for chimney failures to extend to the bedrock alluvial gravel interface.

In the Red Lodge mines, minimum bedrock and associated overburden thicknesses above each of the openings are as follows:

1. Seam No. 1 ½: 274 feet of bedrock and 45 feet of alluvial gravels;
2. Seam No. 2: 27 feet of bedrock and 89 feet of alluvial gravels;
3. Seam No. 3: Not worked in study area;
4. Seam No. 4: 103 feet of bedrock and 103 feet of alluvial gravels;
5. Seam No. 4 ½: Not worked in study area;
6. Seam No. 5: 114 feet of bedrock and 53 feet of alluvial gravels; and
7. Seam No. 6: Not worked in study area.

Further discussion of pothole potential and site observations is presented in Subsection 2.1.4.

2.1.3 Bedrock Fissuring Potholes

A second mechanism that may cause pothole formation is bedrock fissuring. For this discussion, bedrock fissures are near vertical fractures which form by progressive roof collapse and localized tensile stresses in overlying strata (Figure 8-13). As a mine roof collapses, overlying and adjacent bedrock is pulled down and towards the collapse. The stretched bedrock cracks at its surface forming a fissure that propagates vertically downward through overlying strata creating a vertical void. Fissuring typically will form in areas immediately adjacent to the workings, not directly above the rooms. Alluvial sands and gravels and groundwater can flow into and fill the void. Potholes are surface expressions caused when overburden readjusts and fills the void space created by the fissure.

2.1.4 Chimney Failure and Fissuring Pothole Potential

Excluding the shallow opening observed at BH-07, the calculated maximum caving height suggests the likelihood of pothole formation within the study area is very low. However, the calculated estimate makes several simplifying assumptions and the empirical evidence of pothole formation is strong and suggests a more appropriate maximum caving height is on the order of 150 feet. As observed by several authors, caving heights may greatly exceed the calculated estimates in cases where the slabbed material has a very low bulking factor or no stable arch can form and groundwater ingress and/or inclined beds remove caved materials such that bulking is inhibited.

To determine areas where the greatest potential exists for pothole formation, available data from drilling and mine map elevation was input to an ArcGIS database. Since bedrock thickness above workings is the most important parameter for predicting mine collapse and, therefore, subsidence potential, for each mine level, a surface for the top of the level and top of bedrock was created. Thickness maps, or Isopachs, were created for each layer. These were then overlaid upon each other to reveal the thinnest bedrock zones. This information was used to create Figure 8-13, which shows approximate bedrock thickness associated with areas above documented mine workings. Bedrock thicknesses in the figure are divided into 50 foot intervals; as discussed above, thinner bedrock thicknesses are typically associated with higher potential for chimney failure and therefore are assigned a higher potential.

Zones of greater or lesser potential are inferred from these 50-foot intervals. As this shows, a strong to moderate potential for pothole formation exists near the airport due to the shallow presence of the No. 1½ workings. Within town, a strong to moderate potential for pothole formation exists in the area between Broadway and Haggin, from about 16th St W to 15th St W. due to the possible presence of the No. 2 workings. A moderate potential also exists in the between Word and Broadway, from 14th St W extending north approximately 200 feet, due to the presence of shallow No. 4 workings, as shown in Figure 8-13.

Within the Town of Red Lodge, the minimum bedrock thickness for Bed No. 1½ is much greater than 150 feet, and that for the Nos. 4 and 5 beds is slightly greater than 100 feet. The No. 2 bed was observed to have an opening to some extent in the area beneath BH-07. The exact extent and geometry the No.2 opening is unknown due to the absence of a mine map. The opening in seam No. 2 was observed at a depth of 116 feet below the ground surface, 27 feet below the bedrock surface that is overlaid with 89 feet of alluvial gravels. Due to the close proximity of this opening to the top of bedrock and the unknown lateral extent, an analysis assessing the likelihood of a steep-side pothole developing within the alluvial gravels was performed.

The steep sided pothole calculations are shown in Attachment B. The results suggest formation of a near-surface cavity and/or a steep-sided pothole is unlikely for conditions observed above the No. 2 Bed in BH-07. For a near-surface cavity or steep-side pothole to develop, the materials through which the pothole forms, in this case the alluvial gravels, must have a semblance of tensile strength and cohesion. Based on observations of the alluvial gravels in the Red Lodge area, both through drilling, test pit, and outcrop, the materials do not show a cohesive nature and are strictly granular.

Based on this analysis, conditions observed in Red Lodge are not conducive to formation of a steep sided pothole. However, the formation of shallow-sided potholes is possible near BH-07 and possibly above shallower reaches of the Nos. 4 and 5 seams, due to the potential for granular soils to flow downward into voids caused by bedrock fissures or chimney failure.

Observation of residences in these areas may indicate the potential for shallow pothole subsidence. The resident at 404 Broadway South reported home damage and potential subsidence of the back yard; this home is located where the No. 2 seam has an undocumented opening at a shallow depth.

The resident at 207 S. Hauser (located approximately 50-feet north of the shallow reaches of the seam No. 4 workings) reported the development of a pothole some 50 years ago. The resident located at 314 and 316 S. Platt Ave (located immediately adjacent to the shallow reaches of the No. 4) has observed continued subsidence of a localized area within the backyard, reportedly at a rate of 2 feet per year for the last 13 years (as of 1998) (Gradient Geophysics, 1999).

The location at 314 and 316 South Platt was investigated in the past (Gradient Geophysics, 1999). Gradient Geophysics identified a solid body of material approximately beneath the ground surface that correlated to an old foundation on the site, circa 1901. The authors suggest a reflection patterns observed in the data may be explained by either a metallic plate or footing, or the pattern is also indicative of a localized downward movement of material that originates from a source 40 to 63 feet. The authors also state, “The fact that this signal pattern diminishes in strength with increasing depth in this case would be a result of an unidentified stabilizing force”. The stabilizing force was the metallic plate or footing. Review of nearby water wells data (Dowl-HKM, 2011) suggests the depth to bedrock is likely between 13 to 18 feet in this general area.

Residents have observed a shallow linear depression where there is noted settlement of the ground surface, porches, front steps, and cracked concrete. The linear depression originates near 501 S. Platt Ave. and continues in a southerly direction along the west side of Platt Ave and appears to terminate near 607 S. Platt Ave. The axis of the linear depression is similarly aligned with the long axis of rooms within Seam No. 4. The depth of these workings between 16th and 17th street are between 411 and 566 feet below the surface, respectively. The length of the rooms in this area of Seam No. 4 is approximately 290 feet in.

2.2 Trough Subsidence Mechanisms

Mine openings and coal pillar stability in room-and-pillar mining method depend on the interaction of roof, coal pillar, and mine floor. To determine the condition of the mine workings in relation to pillar stability, two general assessments were performed for the workings: bearing failure and pillar strength. The objective of the assessments was to determine how and if the observed conditions affect roof support, which consists of the floor and pillars.

Degradation of both the mine floor and pillars has been observed in other abandoned workings and evidence of similar conditions has been observed here. Degradation of these structures in the mine directly affects the workings stability. Gradual loss of roof support will increase stresses in the mine roof and therefore the potential for convergence of the roof and floor. Based on the reasonable potential for a loss of roof support, an evaluation was performed to assess the degree to which roof convergence may affect the ground surface and man-made structures.

2.2.1 Bearing Failure

The mine floor constitutes the foundation of the pillar, and the presence of weak floor strata can cause differential or excessive pillar settlement and punching of pillars into the floor, ultimately causing roof, subsurface, and surface movement. Often coal beds are underlain by claystones, which are significantly weakened by strain and moist conditions. The thickness of a soft layer in the floor is a major contributing factor to the magnitude of floor deformation. Long-term floor deformation is governed by the strength and extent of floor deterioration under the pillars. Progressive strain and moisture softening of such materials can greatly reduce the ultimate bearing capacity of the floor (Marino G.G. and Choi 1999). Evidence from active mines show deterioration of a mined roadway floor exposed to moisture (driven 15 years prior), while the under-pillars materials remained in a competent state (Vasundhara, 2001). Others suggest and have calculated bearing capacities based on “zones” of deteriorated materials extending below the floor and beneath pillars (Mario, G.G. and Osouli, A., 2012).

Calculations were performed to assess the available bearing capacity of generalized pillar geometries within the mine workings. Because geological material is immensely variable, parameters related to mine floor bearing capacity (e.g. material strength and thickness) were summarized for each of the worked coal seams (Table 8-13).

Table 8-13 summarizes lithology, field hardness (U.S. Department of the Interior, 2001), and thicknesses of the floor materials. The seams of primary interest (Nos. 1½, 2, 4, and 5) show reasonably consistent sequence of floor materials; thicknesses and hardness are less consistent. If field hardness is assumed as being an indicator for floor deterioration between like materials, hardness differences between floor materials appear to be a function of exposure. That is, observation of claystones in areas where the coal has been mined is described as soft (H6), claystones where coal was not mined, in the same unit, were described as hard (H3) (BH-02, No. 4). Similar to observations in active mines, exposed floor materials appear more deteriorated than unexposed floor materials. Prediction of deterioration is very difficult, as stated by Marino and Choi 1999; *insitu* factors can have a large effect on the rate and degree of softening:

1. Cleat and joint densities in adjacent rock units;
2. Increases in the rock mass permeability as a result of stress relief fractures; and
3. Increases in rock mass permeability as a result of swell-induced micro fracturing.

Qualitative hardness descriptions and targeted field pocket penetration tests provide a means to estimate a range of *insitu* strengths for the floor materials. Pocket penetration tests were performed on samples described as soft. The results of the penetration test showed the "soft" material was slightly above the range of the penetrometer scale; the maximum reading of the penetrometer is an undrained shear strength, S_0 = 62 psi. Marino and Choi reports consolidated-drained triaxial compression test results for intact floor rocks from beneath pillar centers (not deteriorated) and the exposed floor (deteriorated). Strength parameters (friction angle ϕ, and cohesion c), for the non-deteriorated claystones are ϕ = 19 degrees and c = 105 psi and deteriorated strengths are ϕ = 19 degrees and c = 0.0 (Marino and Osuli, 2012)

Seam No. 1½ is underlain by 0.5 feet to 9 feet of claystone with hardness ranging from very soft to moderately hard. Seam No. 2 is underlain by 5 to 20+ feet of claystone with hardness ranging from very soft to moderately soft. Seam No. 4 is underlain by 3 to 15 feet of claystone with hardness ranging from soft to hard. Seam No. 5 is underlain by 0 to 2 feet of claystone with hardness ranging from soft to moderately soft. The majority of Seam No. 5 is underlain by either hard siltstone or hard sandstone.

Bearing capacity calculations were performed using equations for a foundation on layered soil where a weaker soil (claystone) is underlain by a significantly stronger material (sandstone) (Das, 1999). The equations assume the bearing surface is horizontal, therefore likely overestimates the ultimate bearing capacity of the floor; however, as a first order evaluation, these equations were used since bearing capacity equations are generally conservative.

Figure 8-15 and Figure 8-16 show Safety Factor (SF) charts of bearing failure for a typical pillar (with dimensions of 35 feet by 75 feet) bearing on a non-deteriorated claystone floor, ϕ = 19 and c = 105 psi, for total stress and effective overburden unit weight respectively. SF is a ratio describing the strength of an object versus the applied load. A SF less than 1.0 means failure is likely. The SFs are calculated at depth intervals of 100 feet to a total depth of 600 feet. For non-deteriorated floors, the calculated SFs are greater than 1.0, with the exception of the combination of depths greater than 600 feet and claystone thicknesses greater than 25 feet. Figure 8-17 and

Figure 8-18 present equivalent charts for the hypothetical case of a fully deteriorated claystone floor, ϕ = 19 degrees and c = 0 psi. The calculations show the SFs for bearing failure on the degraded claystone floor are all less than 1.0 at any depth.

Claystone floor materials are probably degrading beneath any existing pillars to some extent. If the existing pillars are providing roof support, gradual degradation of the floor materials will likely contribute to roof failure as the floor bearing capacity decreases and the floor can no longer support the overburden pressures. The rate of floor degradation is a complicated problem and is very difficult to predict in an abandoned mine where access is restricted.

The result of this evaluation suggests the mechanism of bearing capacity failure is possible and may contribute to roof failure. Loss of roof support will be used in the subsidence estimates.

2.2.2 Pillar Strength

Coal pillars are the portion of coal left in place to support the mine openings and are typically square or rectangular in shape. As discussed previously, from the initiation of mining until approximately 1912 the coal pillars, for the most part, were left in place within the Red Lodge Mines. Following 1912, historical documents, mining journal and mine maps, suggest the practice of extracting pillars was implemented.

Since pillars are left for support, their failure greatly contributes to the potential for long-term subsidence. To evaluate potential for pillar failure, SFs were calculated relative to the extraction ratio using the methods of Pariseau (2007). Extraction ratio is the ratio of the excavated area to the total area; the larger the extraction ratio, the greater the proportion of coal removed and the smaller the pillars. The calculations assume typical strength characteristics for coal as discussed by Mark (1996), adjusted for size effect (Mark, 1999). Strength characteristics are not adjusted for time dependent degradation or creep of coal or floor materials.

Figure 8-19 and Figure 8-20 present charts showing extraction ratio versus SF at several depths for Total and Effective overburden unit weights. For comparison, Table 8-14 shows various estimated extraction ratios for pillars near each of the drilled boreholes. Extraction ratios mostly range between 0.40 and 0.62. For example, an extraction ratio of 0.5 and effective stress conditions (flooded workings), the SF for pillars at depths of 100, 200, 300, 400, and 600 feet are 8.5, 4.3, 2.8, 2.1, and 1.4 respectively.

Biswas, Mark, and Peng (1999) studied the effects of time versus coal pillar strength. For the data they evaluated, two relationships were devised describing the depth of weathering from the coal face, in coal and partings, with respect to time. Partings are thin layers of claystone found within the thicker seam of coal. To gain insight into the effects of weathering on the calculated SFs, Biswas's relationships were used to estimate a depth of weathering, and then calculate the change in extraction ratio with time and therefore calculated SF. The relationships were used to estimate the depth of weathering at which coal/parting strengths reduced to 60% of the original value after 50 years. This depth was used to calculate a revised extraction ratio by assuming the weathered materials no longer provided support. Detailed calculations for this analysis are

shown in Attachment D. Data used to determine the relationships were limited to a 50-year time span and therefore calculations in this report will not extrapolate beyond 50 years.

For an initial extraction ratio of 0.50, after 50 years of weathering the extraction ratio increases to values of 0.55 (for coal weathering) and 0.68 (for parting weathering). As a comparison to the example discussed above, an extraction ratio of 0.68 and effective stress conditions, the SF for pillars at depths of 100, 200, 300, 400, and 600 feet are 5.45, 2.72, 1.82, 1.36, and 0.91 respectively. SFs, assuming the weathered partings control pillar strength, are reduced to 64% of the original value after a 50-year time period.

Strength reduction of coal pillars is not restricted to weathering of the pillar sides; weathering of the claystone floor also likely degrades the outer pillar materials, in that, as weathering of the claystone proceeds beneath the pillar, support of the outer perimeter decreases. Perimeter materials are likely to fracture and spall and the inner parts of the pillar are required to carry more load. Fracturing and load transfer to the center of the pillar reduces the effective area of the pillar and thus increases the effective extraction ratio.

2.3 Subsidence Estimates

Conditions within the Red Lodge mine are conducive to slow degradation of the existing pillars and claystone floor materials. The effect of this degradation and loss of roof support may transfer stress to adjacent pillars, further lowering the pillar support SF, and/or increase the effective roof span, thereby potentially causing roof sag. To evaluate the consequence of progressive degradation of roof support, calculations were performed to estimate surface effects due to the loss of a single pillar. The calculations use methods of the National Coal Board, adjusted for conditions of western U.S. coal fields versus U.K. coal fields as presented by Pariseau (2007). Detailed calculations describing the methods and assumptions for these calculations are provided in Attachment E.

The analysis was performed for one generalized scenario of the Red Lodge Mines. Due to the nature of specific coal mine depths, seam mined thicknesses, and multiple mined layers, extrapolation of this example is not reasonable to any one specific location, rather, this evaluation was performed as preliminary assessment to provide potential order of magnitude surface deformations resulting from the observed conditions. The primary contributing variable, the mine opening height, is assumed from average values observed during drilling. The actual mining opening height could be two to three times greater or near zero, depending on the location selected.

Table 8-2 shows void space heights observed during the drilling investigation. At locations where pillars were not encountered, average void space height and number of (observations) for each seam are: No. 1½ = 2.5 ft (1), No. 2 = 2.6 ft (3), No. 4 = 1.6 ft (5), and No. 5 = 2 ft (3). The overall average void height is approximately 2 feet. Table 8-4 shows calculated extraction ratio near each bore hole. Extraction ratio is the ratio of excavated area to the total area. Height of the void space observed in each room combined with the extraction ratio is an approximate indication of the amount of space available for further collapse. For example, if a pillar punched

or collapsed in an area with a 0.50 extraction ratio and a 2-foot void height, half the void space would be taken up by the broken pillar material and the other half by convergence of the roof. Bulked and or caved materials were also observed beneath many of the voids; consolidation of these materials could also contribute to the available space for collapse. Since the objective of this evaluation is to estimate a generalized subsidence profile, consolidation of these materials was not considered.

Room and pillar dimensions within the Red Lodge mines varied depending on the judgment of the mining engineer relative to the specific conditions of each seam and level. An example room length of 350 feet (face side), width of 23 feet (rib side), with pillars spaced 46 feet from center to center (extraction ratio of approximately 0.50) was selected. A sketch of this general condition is shown with the calculations in Attachment D. Analyses performed included the following:

- Case 1, where support from one pillar is lost (similar to pillar removal), thus creating a room (or panel) with dimensions of 350 feet by 70 feet; and
- Case 2, where a second adjacent pillar is lost creating a room (or panel) with dimensions of 350 feet by 120 feet.

The two face-side subsidence profiles and two face-side surface strain profiles are presented in Figure 8-22 through Figure 8-25. Face-side profiles are perpendicular to the face-side and parallel to the rib-side (Attachment D). The calculations assume the panels are at a depth of 230 feet below ground surface, 2-feet of void and an extraction ratio of 0.50 (1 foot of available void space).

The magnitude of surface displacement is proportional to the amount of available space for collapse. Void space is multiplied by a subsidence factor (s), a number less than 1.0, since subsidence experienced at the surface is less than the height of the void space, due to the breakup of and bulking of the overlying materials. The overlying material type and strength can have a tremendous influence on the amount and distribution of surface settlement. The greater the amount of hard rock, the smaller the amount and extent of surface subsidence (i.e. subsidence factor decreases).

Typical subsidence factors for coal mines where overburden materials include hard rocks (sandstone and limestone) range between (0.33 – 0.65). (Peng, 1978) Data compiled by Webb (1982) and presented by Karmis (1982) shows the influence of sandstone and limestone on the subsidence factor estimated for Appalachian coal fields, Figure 8-21. Overburden materials with 30 to 60% hard rock are categorized with a subsidence factor between 0.3 to 0.4. The average percentage of sandstone calculated from bore holes in Red Lodge is 39% (Range: 26% to 60%), therefore the estimated subsidence factor of 0.65 appears reasonable for the site conditions.

The maximum vertical subsidence, trough width, peak compressive strain, and peak tensile strain are listed below:

1. Case 1
    i. Maximum Vertical Subsidence = -0.25 feet
    ii. Trough Width = 202 feet

iii. Peak Compressive Strain = 0.0012
iv. Peak Tensile Strain = 0.0004

2. Case 2
   i. Maximum Vertical Subsidence = -0.32 feet
   ii. Trough Width = 252 feet
   iii. Peak Compressive Strain = 0.0019
   iv. Peak Tensile Strain = 0.0011

From the calculated strain values, Figure 8-26, reproduced from the National Coal Board as presented by Pariseau (2007), provides an index of structural damage resulting from surface strain. The figure compares the reciprocal length of a structure to strain and provides an estimate of structural damage.

Damage severity is divided by four lines which split Figure 8-26 into five parts, Very Slight, Slight, Appreciable, Severe Damage, and Very Severe Damage. These categories are defined as:

1. Very Slight:
   i. Change in structural length up to 0.1 foot.
   ii. Hairline cracks in plaster, perhaps isolated slight fracture in the building, not visible from the outside.
2. Slight:
   i. Change in structural length between 0.1 to 0.2 feet.
   ii. Several slight fractures showing inside the building. Doors and windows may stick slightly. Repairs to decoration probably necessary.
3. Appreciable:
   i. Change in structural length between 0.2 to 0.4 feet.
   ii. Slight fractures showing on outside of building (or one main fracture). Doors and windows sticking. Service pipe may fracture.
4. Severe:
   i. Change in structural length between 0.4 to 0.6 feet.
   ii. Service pipes disrupted. Open fractures requiring re-bonding and allowing weather into the structure. Window and door frames distorted; floors sloping noticeably; walls leaning or bulging noticeably. Some loss of bearing beams. If compressive damage, overlapping of roof joints and lifting of brickwork with open horizontal fractures.
5. Very Severe:
   i. Change in structural length greater than 0.6 feet
   ii. As above, but worse and requiring partial or complete rebuilding. Roof and floor beams loose bearing and need shoring up. Windows broken with distortion. Severe slopes on floors. If compressive damage, severe buckling and bulging of the roof and walls.

A structure with length of 50 feet (1/L = 0.020 1/ft), approximately the longest dimension of a residential home, could experience:

- Very Slight damage if exposed to horizontal strains between 0.0004 and 0.0011 (Case 1); and
- Very Slight to Slight damage if exposed to horizontal strains between 0.0011and 0.0019 (Case 2).

A longer structure with a length of 100 feet (1/L = 0.010 1/ft), (approximately the length of the Civic Center) could experience:

- Very Slight to Slight Damage if exposed to horizontal strains between 0.0004 and 0.0011 (Case 1); and
- Slight to Appreciable damage if exposed to horizontal strains between 0.0011 and 0.0019 (Case 2).

3 REFERENCES

See Data Summary and Analysis Report for referenced materials.

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ATTACHMENT A

Estimate the height of a chimney collapse for the following geometry using equations by Reddish 1989.

$$Z = 4/((k-1)\pi D^2)\left[2wM^2 \cot \phi + Mw^2\right]$$

where:

V_{caved} = volume of caved rock from collapse - chimney
V_{space} = volume of available space to recieve caved rock
k = bulking factor
Z = height of collapse - chimney
D = diameter of collapse - chimney
w = width of mine rooms
M = excavated height of mine rooms
ϕ = angle of repose of caved rock within mine rooms adjoining collapse area.

The above equation assumes a 4-way junction of mine rooms.

Geometry for this calculation is estimated from a 4-way junction presented on NWIC Map of Red Lodge mine No 2 Bed, Nov 1923, First Level East Old Mine. Assume entire coal thickness of 5 ft is removed.

$w = 15$ ft
$D = w \cdot \sqrt{2} = 21.2$ ft
$M = 5$ ft
$\phi = 40°$ (Angle of repose angular rock)
$k = 1.33$ to 1.5

$$Z = 4/((1.33-1)\pi \cdot 21.2^2)\left[2 \cdot 15 \cdot 5^2 \cot 40° + 5 \cdot 15^2\right]$$

$$Z = (0.008507)\left[2018.8\right]$$

$$Z = 17.2 \text{ ft}$$

For the No 4 Seam, specifically for geometries near BH-01. Peform the same calculation for a room width of 25 ft and a mined thickness of 10 ft.

Again

$$Z = 4/((k-1)\pi D^2)\left[2wM^2 \cot\phi + Mw^2\right]$$

$k = 1.33$
$w = 25$ ft
$D = 35$ ft
$M = 10$
$\phi = 40°$

$$Z = 4/((1.33-1)\pi \cdot 35^2)\left[2 \cdot 25 \cdot 10^2 \cdot \cot 40° + 10 \cdot 25^2\right]$$

$$Z = (0.00314)\left[12208.8\right]$$

$$\underline{Z = 38 \text{ ft}}$$

TOPS

ATTACHMENT B

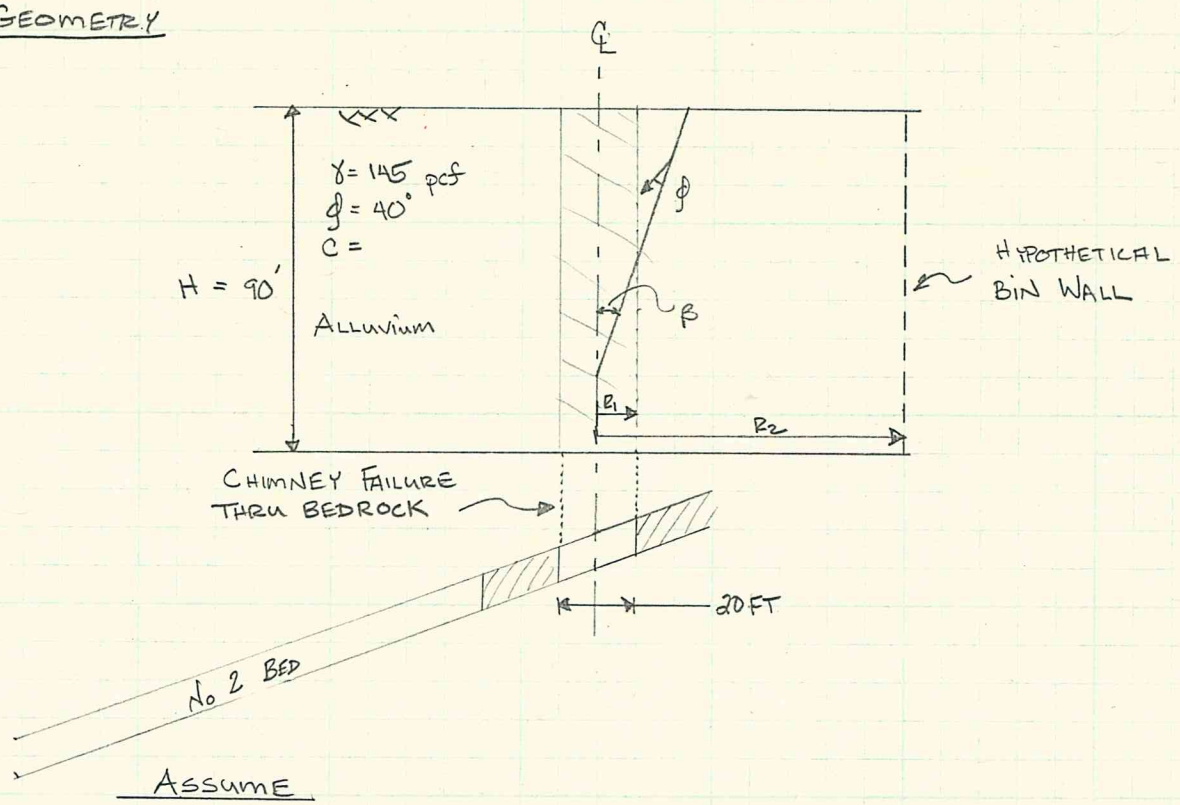
OBJECTIVE

EVALUATE THE POTENTIAL FOR THE FORMATION OF A POT-HOLE AT THE GROUND SURFACE, THRU 90 FT OF A POORLY GRADED ALLUVIAL GRAVEL.

METHOD

USE THE THEORETICAL ANALYSIS OF DRESCHER AND VGENOPOULOU TO EVALUATE THE NECESSARY CONDITIONS FOR THE FORMATION OF A CHANNEL THRU THE GRAVELS.

GEOMETRY



ASSUME

1) A CHIMNEY FAILURE PROPAGATES THRU BEDROCK TO THE ALLUVIUM WITH A DIAMETER OF 20 FT

2) ALLUVIUM WILL NOT SUFICIENTLY BULK TO SELF-ARREST

3) CYLINDRICAL BIN WITH OUTER RADIUS (R2) LARGE ENOUGH TO NOT INTESECT WITH SHEAR SURFACE.

4) ORIFICE RADIUS (R1) IS EQUAL TO CHIMNEY IN ROCK, 20 FT

5) SHEARING MODE ONLY $\delta = \phi$

CALCULATIONS

ACCORDING TO DRESCHER AND VGENOPOULOU THE RELATION BETWEEN MATERIAL PROPERTIES AND THE GEOMETRY OF THE PRISM AT COLLAPSE, WHEN SHEARING/TENSILE MODE IS EXCLUDED, IS

$$\frac{C}{\gamma H} = \frac{1}{H}\,\frac{M_1}{N_1}\,\frac{\cos(\beta+\phi)}{\cos\phi} \qquad \text{eq (11) DRESCHER}$$

H = CYLINDER HEIGHT

β = SHEAR SURFACE

ϕ = FRICTION ANGLE

γ = UNIT WEIGHT

$$M_1 = \frac{1}{3}(h)^2 \tan\beta\,(t+2s) - \frac{1}{2}(h)(2\lambda - \sin 2\lambda)R_1^2 + \frac{1}{3}\cot\beta\,(3sR_1^2 - s^3 - 3R_1^3\lambda\cos\lambda)$$

$$N_1 = \frac{(h)^2\tan\beta}{\cos\alpha} + \frac{(h)(s+t)}{\cos\beta} - \frac{R_1}{\sin\beta}(R_1\lambda - s\cos\lambda)$$

$$\lambda = \arcsin\left(\frac{s}{R_1}\right)$$

$$t_s = s - (h)\tan\alpha\tan\beta$$

THREE INDEPENDENT VARIABLES

β, s, AND h

THE AUTHORS NUMERICALLY SOLVED THE MULTIVARIABLE FUNCTION AND PROVIDED CHARTS DEFINING STABLE AND UNSTABLE CONDITIONS FOR SELECT MATERIAL PROPERTIES AND CYLINDER DIMENSIONS

FROM FIGURE 4 IN THE AUTHOR PAPER AND THE GEOMETRY OF THE ASSUMED PROBLEM, THE FOLLOW STATEMENT ARE MADE

$R_1 = 10$ FT
$\phi = 40°$
$\gamma = 145$ pcf
$H = 90$ ft.
$R_2/H = 0.4$

$R_1/H = 0.11$
$\phi = 1$

R_1	H	R_1/H	$C/\gamma H$	C (psf)	ϕ
10	90	0.11	0.0047	61	40°
10	50	0.20	0.0085	62	40°
5	90	0.05	0.0023	30	40°

FROM THE FIGURE, IN ORDER TO HAVE A CHANNEL FORM THE MATERIAL MUST HAVE A MINIMUM AMOUNT OF COHESION. FOR THE CONDITIONS EVALUATED THIS COHESION IS BETWEEN 30 - 60 PSF.

WHILE SOME VERTICAL SLOPES CAN BE MAINTAINED IN ALLUVIAL GRAVELS, THESE SLOPES ARE USUALLY MOIST AND THE MOISTURE PROVIDES A MINIMAL AMOUNT OF SURFACE TENSION AND THEREFORE COHESION. AS THE MATERIAL DRYS THE COHESION IS REDUCED AND THE SLOPES COLLAPSE.

THE ALLUVIUM ABOVE THE RED LODGE MINES ARE SATURATED AND THEREFORE WILL NOT GAIN STRENGTH FROM MOISTURE AND LIKELY HAVE A COHESIVE STRENGTH OF ZERO. THEREFORE CHANNEL FORMATION IS VERY UNLIKELY.

Drescher and Vgenopoulou Theoretical Analysis of Channeling in Bins and Hoppers.
Powder Technology 42 (1985) 181-191

hopper. The variables are the dimensions of the prism. Results were obtained numerically, and are presented below in a graphical form as lines separating the region of unstable slopes from the region where channeling may occur. The mechanisms leading to the greatest ratio $c/\gamma H$ are indicated as: broken lines for collapse within the material; solid lines for collapse partly along the wall of bin or hopper.

Figures 4 to 7 show some of the results for cylindrical bins. Two bin aspect ratios R_2/H = 0.4 and 0.2, and several values of the material parameters were selected. The broken lines in Fig. 4 pertain to the shearing mode of failure along all walls of the prism, that dissipate energy (eqn. (11)); these were obtained in [7]. The results for conical hoppers with $R_2/H = 1$ and 0.6 are depicted in Figs. 8 to 11. For collapse along the hopper wall the unknown angle δ_0 in eqn. (12) was computed by assuming the angle $\delta \geqslant \phi_i$ at the corner points E and F of the prism such that the maximum of the ratio $c/\gamma H$ was attained.

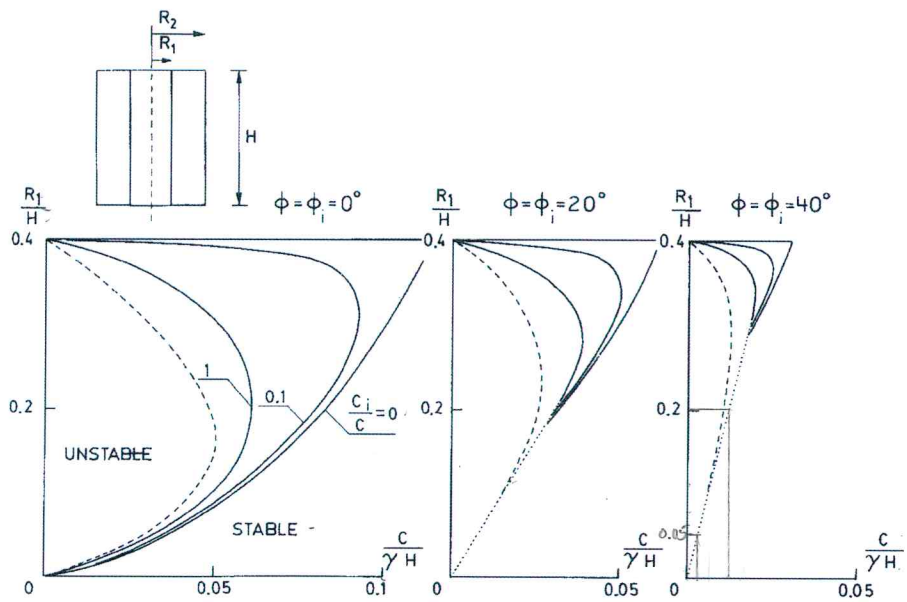


Fig. 4. Regions of stable and unstable empty channel in a cylindrical bin. $R_2/H = 0.4$; $q = q_i = 1$.

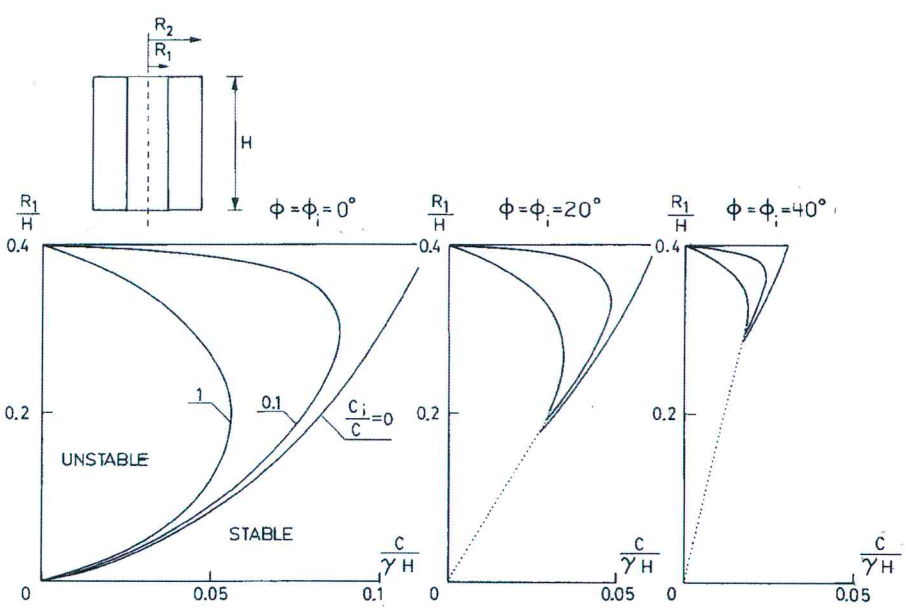
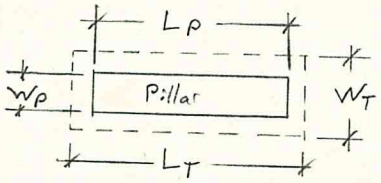


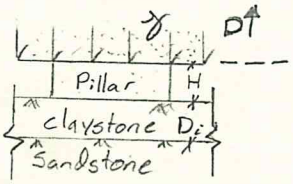
Fig. 5. Regions of stable and unstable empty channel in a cylindrical bin. $R_2/H = 0.4$; $q = q_i = 2$.

ATTACHMENT C

In-Situ coal pillars are underlain by softening claystone underlain by rigid sandstone. Softening claystone in similar conditions was found to have a friction angle (ϕ) of 19° (Marino, 2012).

<u>Given</u>: Pillar Height = $H = 10\,ft$
Pillar Width = $W_p = 35\,ft$
Pillar Length = $L_p = 150\,ft$
Tributary Width = $W_T = 60\,ft$
Tributary Length = $L_T = 175\,ft$
Depth of Pillar = $D = 300\,ft$
Depth of Claystone = $D_i = 17\,ft$
Unit weight = $\gamma = 150\,lb/ft^3$
Surcharge = $q = 0\,psf$





Applied Stress (σ)

$$\sigma = \frac{D\gamma W_T L_T}{W_p L_p} = \frac{300ft(150\,lb/ft^3)60ft(175ft)}{35ft(150ft)} = \underline{90000\,psf = \sigma}$$

Safety Factor

$$SF = \frac{q_u}{\sigma} \quad \text{where } q_u = \text{bearing capacity}$$

Bearing Capacity (q_u)

$$q_u = cN_c^* + qN_q^* + \tfrac{1}{2}\gamma_{claystone} W_p N_\gamma \quad \text{Eq. 4-1 Das (1999)}$$

where:
Cohesive strength = $c = 9000\,psf$
(from pentrometer, cohesion is atleast this strong)
N_γ^*, N_c^* = Modified Bearing Factors

Modified Bearing Factors

$D_i/W_p = 17/35 = 0.49$ By Fig 4.4 & 4.6 (Das, 1999) using $\phi = 19°$

$N_c^* = 22 \quad N_\gamma^* = 3$

$$q_u = 9000(22)psf + \tfrac{1}{2}150\,lb/ft^3(35ft)3 = 198000 + 7875 = 205875$$

$$SF = \frac{205875}{90000} = \boxed{2.3 = SF}$$

D/13

CHAPTER FOUR

SPECIAL CASES OF SHALLOW FOUNDATIONS

4.1 INTRODUCTION

The bearing capacity problems described in Chapters 2 and 3 assume that the soil supporting the foundation is homogeneous and extends to a great depth below the bottom of the foundation. They also assume that the ground surface is horizontal; however, this is not true in all cases. It is possible to encounter a rigid layer at a shallow depth, or the soil may be layered and have different shear strength parameters. It may be necessary to construct foundations on or near a slope. Bearing capacity problems related to these special cases will be described in this chapter.

4.2 FOUNDATION SUPPORTED BY A SOIL WITH A RIGID ROUGH BASE AT A LIMITED DEPTH

Figure 4.1a shows a shallow rigid rough continuous foundation supported by a soil which extends to a great depth. The ultimate bearing capacity of this foundation can be expressed (neglecting the depth factors) as (Chapter 2)

$$q_u = cN_c + qN_q + \frac{1}{2}\gamma BN_\gamma \tag{4.1}$$

The procedure for determining the bearing capacity factors N_c, N_q, and N_γ in homogeneous and isotropic soils was outlined in Chapter 2. The extent of the failure zone in soil at ultimate load q_u is equal to D. The magnitude of D obtained during the evaluation of the bearing capacity factor N_c by Prandtl [1] and N_q by Reissner [2] is given in a nondimensional form in Fig. 4.2. Similarly, the magnitude of D obtained by Lundgren and Mortensen [3] during the evaluation of N_γ is given in Fig. 4.3.

Now if a rigid rough base is located at a depth of $H < D$ below the bottom of the foundation, full development of the failure surface in soil will be restricted. In such a case, the soil failure zone and the development of slip lines at ultimate load will be as shown in Fig. 4.1b. Mandel and Salencon [4] determined the bearing capacity factors for such a case by numerical integration using the theory of plasticity. According to Mandel and Salencon's theory, the ultimate bearing capacity of a rough continuous foundation with a rigid rough base located at a shallow depth can be given by the relation

$$q_u = cN_c^* + qN_q^* + \frac{1}{2}\gamma BN_\gamma^* \tag{4.2}$$

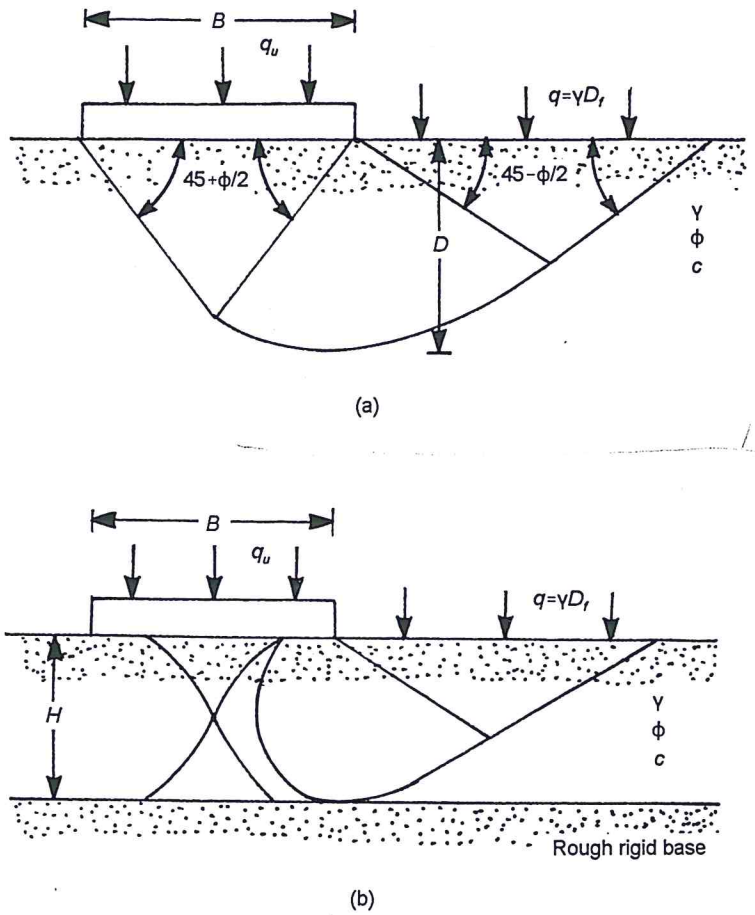


FIGURE 4.1 Failure surface under a rigid rough continuous foundation: (a) Homogeneous soil extending to a great depth; (b) With a rough rigid base located at a shallow depth

where N_c^*, N_q^*, N_γ^* = modified bearing capacity factors
B = width of foundation
γ = unit weight of soil

Note that, for $H \geq D$, $N_c^* = N_c$, $N_q^* = N_q$, and $N_\gamma^* = N_\gamma$ (Lundgren and Mortensen). The variations of N_c^*, N_q^*, and N_γ^* with H/B and soil friction angle ϕ are given in Figs. 4.4, 4.5, and 4.6, respectively.

Neglecting the depth factors, the ultimate bearing capacity of rough circular and rectangular foundations on a sand layer ($c = 0$) with a rough rigid base located at a shallow depth can be given as

D/B

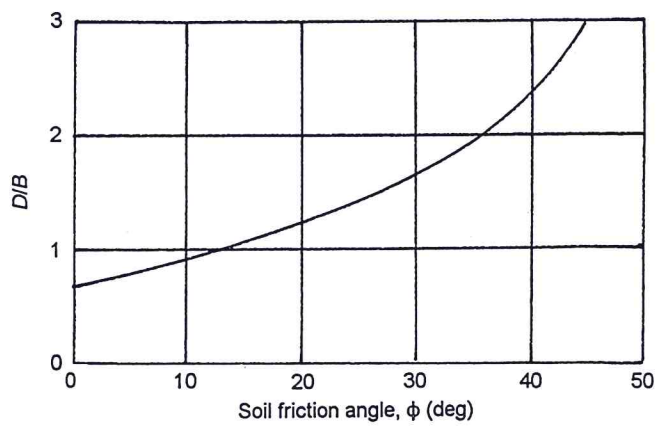


FIGURE 4.2 Variation of D/B with soil friction angle (for N_c and N_q)

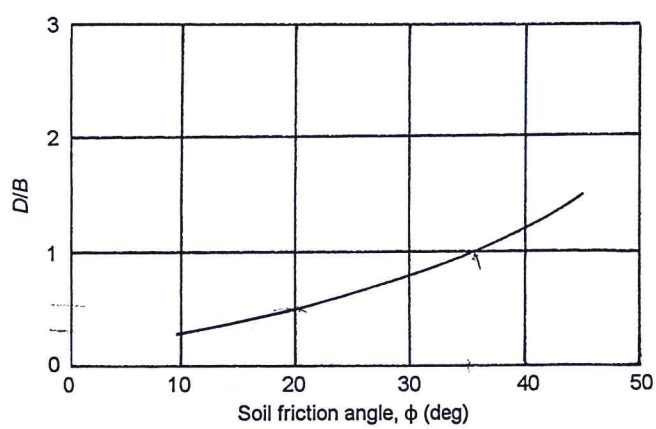


FIGURE 4.3 Variation of D/B with soil friction angle (for N_γ)

$$q_u = qN_q^*\lambda_{qs}^* + \frac{1}{2}\gamma BN_\gamma^*\lambda_{\gamma s}^* \tag{4.3}$$

where λ_{qs}^*, $\lambda_{\gamma s}^*$ = modified shape factors

The above-mentioned shape factors are functions of H/B and ϕ. Based on the work of Meyerhof and Chaplin [5] and with simplifying the assumption that, in radial planes, the stresses and shear zones are identical to those in transverse planes, Meyerhof [6] evaluated the approximate values of λ_{qs}^* and $\lambda_{\gamma s}^*$ as

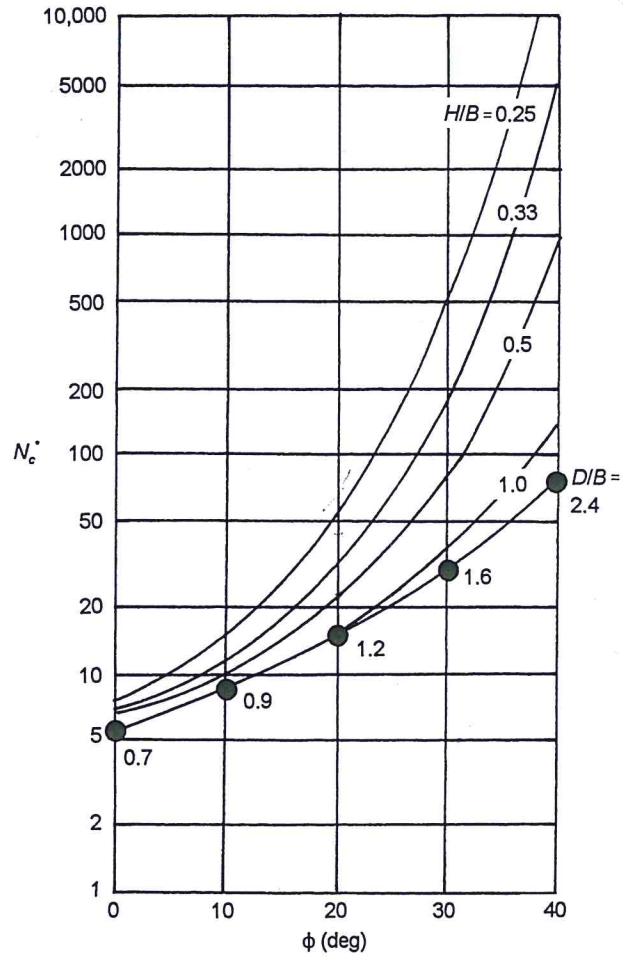


FIGURE 4.4 Mandel and Salencon's bearing capacity factor N_c^* [Eq. (4.2)]

$$\lambda_{qs}^* = 1 - m_1\left(\frac{B}{L}\right) \tag{4.4}$$

and

$$\lambda_{\gamma s}^* = 1 - m_2\left(\frac{B}{L}\right) \tag{4.5}$$

where L = length of the foundation

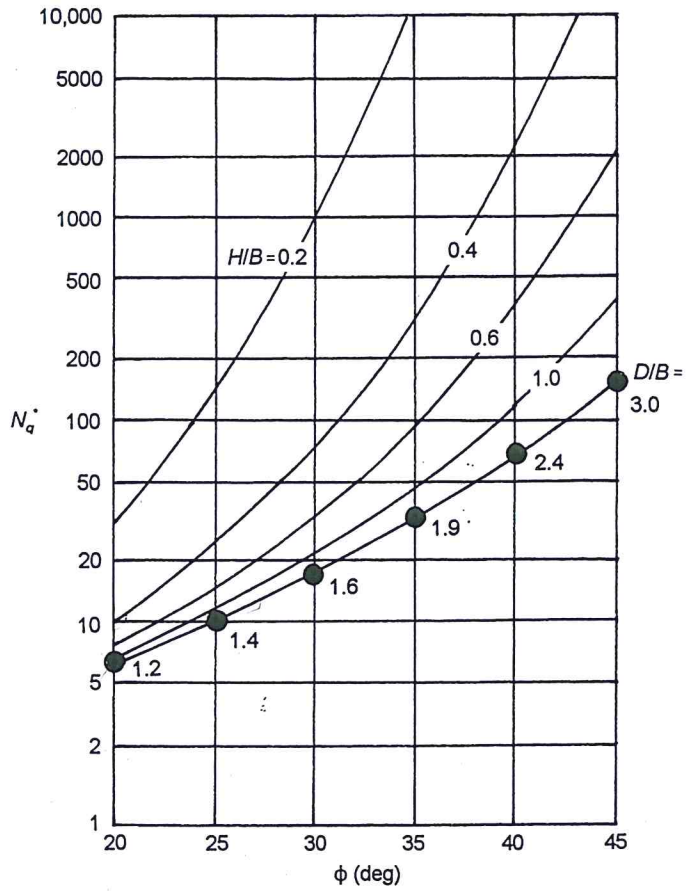


FIGURE 4.5 Mandel and Salencon's bearing capacity factor N_q^* [Eq. (4.2)]

The variations of m_1 and m_2 with H/B and ϕ are given in Figs. 4.7 and 4.8.

Milovic and Tournier [7] and Pfeifle and Das [8] conducted laboratory tests to verify the theory of Mandel and Salencon [4]. Figure 4.9 shows the comparison of the experimental evaluation of N_γ^* for a rough surface foundation ($D_f = 0$) on a sand layer with theory. The angle of friction of the sand used for these tests was 35°. From Fig. 4.9 the following conclusions can be drawn:

(4.4)

(4.5)

1 The value of N_γ^* for a given foundation increases with the decrease in H/B.

2. The magnitude of $H/B = D/B$ beyond which the presence of a rigid rough base has no influence on the N_γ^* value of a foundation is about 50-75% more than that predicted by the theory.

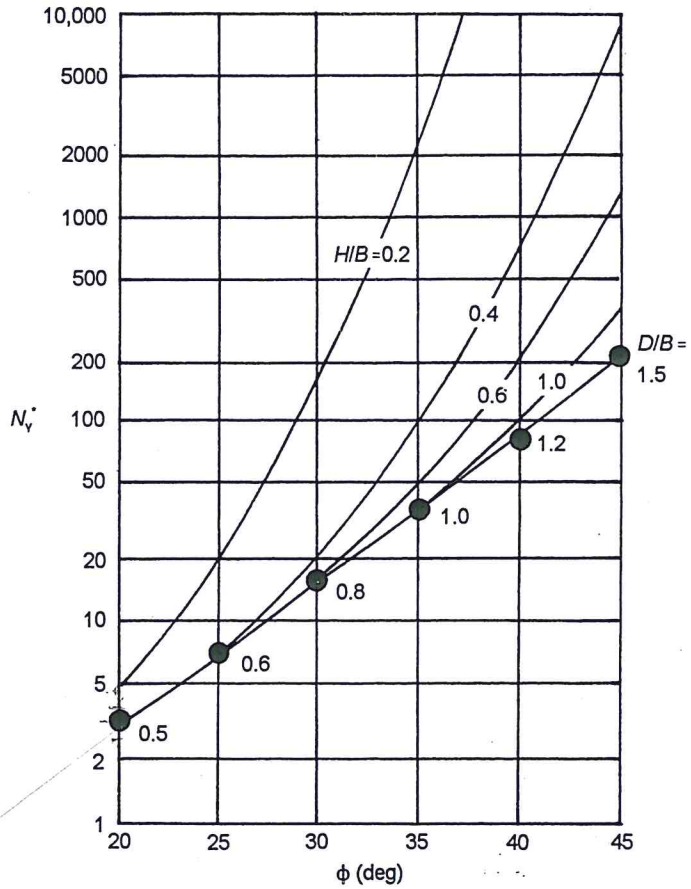


FIGURE 4.6 Mandel and Salencon's bearing capacity factor N_γ^* [Eq. (4.2)]

3. For H/B between 0.6 to about 1.9, the experimental values of N_γ^* are higher than those predicted theoretically.
4. For H/B < about 0.6, the experimental values of N_γ^* are substantially lower than those predicted by theory. This may be due to two factors: (a) the crushing of sand grains at such high values of ultimate load, and (b) the curvilinear nature of the actual failure envelope of soil at high normal stress levels.

For saturated clay (that is, $\phi = 0$), Eq. (4.2) will simplify to the form

$$q_u = c_u N_c^* + q \tag{4.6}$$

Mandel and Salencon [9] performed calculations to evaluate N_c^* for *continuous foundations*. Similarly, Buisman [10] gave the following relationship for

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ATTACHMENT D

Objective

Calculate Factor of Safety for a general pillar in the No. 4 Coal Bed using methods of Pariseau (2007)

Given

Bed dip = 18°
Pillar height = 10 ft
Room width = 25 ft and 60 ft between centers
Pillar width = 35 ft
Pillar length = 150 ft
Depth = 300 ft
$\gamma_{overburden}$ = 150 pcf

Size effect (Mark - Bieniawski) (Mark, 1999)

$$S_p = S_i\,(0.64 + 0.54\,w/h - 0.18(w^2/Lh)$$

S_i = 900 psi (Mark, 1996)
w = 25 ft
h = 10 ft
L = 150

$$S_p = 900\left(0.64 + 0.54\left(\frac{35}{10}\right) - 0.18\left(\frac{35^2}{150 \cdot 10}\right)\right)$$

$$S_p = 900\,(0.64 + 1.89 - 0.147)$$

$$\underline{S_p = 2144 \text{ psi}} = 308{,}736 \text{ psf}$$

Calculations

Pre excavation stress

$$\sigma_{zz} = \gamma \cdot h$$

$$\sigma_{zz} = 150 \cdot 300$$

$$\sigma_{zz} = 45{,}000 \text{ psf}$$

Stress on 18° Beds ($\delta = 18°$)

$$\sigma_n = \frac{\sigma_{yy} + \sigma_{zz}}{2} - \frac{\sigma_{yy} - \sigma_{zz}}{2}\cos(2\delta) - \tau_{yz}\sin(2\delta)$$

$$\tau_\delta = -\left(\frac{\sigma_{yy} - \sigma_{zz}}{2}\right)\sin(2\delta) + \tau_{yz}\cos(2\delta)$$

TOPS

Assume Pre excavation conditions

$\sigma_{yy} = K_o \sigma_{zz}$ AND $\tau_{yz} = 0$

$$\sigma_n = \frac{\sigma_{zz}(K_o+1)}{2} - \frac{\sigma_{zz}(K_o-1)}{2}\cos(2\delta)$$

$$\sigma_n = \frac{45{,}000(1/3+1)}{2} - \frac{45{,}000(\frac{1}{3}-1)}{2}\cos(2\cdot 18^\circ)$$

$$\sigma_n = 29993 + 12135$$

$$\sigma_n = 42{,}128 \text{ psf}$$

$$\tau_s = -\frac{(K_o\sigma_{zz} - \sigma_{zz})}{2}\sin 36$$

$$\tau_s = -\frac{(1/3\cdot 45{,}000 - 45{,}000)}{2}\cdot \sin 36^\circ$$

$$\tau_s = 8{,}816 \text{ psf}$$

Assume Mohr-Coulomb to Estimate ϕ & C

$$\sin\phi = \frac{C_o - T_o}{C_o + T_o} = \frac{308{,}736 - 31{,}000}{308{,}736 + 31{,}000}$$

Assume $T_o \cong \frac{1}{10} C_o$

$$\phi = \operatorname{asin}\left(\frac{277{,}736}{339{,}736}\right)$$

$$\phi = 55^\circ$$

$$C = \frac{C_o(1-\sin\phi)}{2\cos(\phi)} = \frac{308{,}736(1-\sin 55^\circ)}{2\cos(55^\circ)}$$

$$C = 48{,}672 \text{ psf} = 338 \text{ psi}$$

For the assume pillar and room dimensions calculate extraction ratio and pillar σ and τ

$$R = \frac{A_p}{A} = \frac{(35)(150)}{(35+25)(150+25)} = \frac{5250 \text{ ft}^2}{10,500 \text{ ft}^2}$$

$$\boxed{R = 0.5}$$

$$\tan(\beta) = \frac{\tau_s}{\sigma_n} = \frac{8,816}{42,128} = 0.21$$

$$\beta = 11.8^\circ$$

Calculate Safety factor

$$FS_p = \frac{R\,(\text{strength})}{R\,(\text{stress})}$$

$$R\,(\text{strength}) = \left[\frac{c\cos\phi}{1-\sin(\phi-\beta)}\right]$$

$$R\,(\text{stress}) = \left[(\sigma_p/2)^2 + (\tau_p/2)^2\right]^{1/2}$$

$$\sigma_p = \frac{\sigma_n}{1-R} \qquad \tau_p = \frac{\tau_s}{1-R}$$

$$FS_p = \frac{C\cdot\cos\phi}{1-\sin(\phi-\beta)} \Big/ \left[\left(\frac{\sigma_n}{1-R}/2\right)^2 + \left(\frac{\tau_s}{1-R}/2\right)^2\right]$$

$$FS_p = \frac{48,672\cdot\cos 55}{1-\sin(55-11.8)} \Big/ \left[\left(\frac{42,128}{1-0.5}/2\right)^2 + \left(\frac{8,816}{1-0.5}/2\right)^2\right]^{1/2}$$

$$FS_p = 88,498 / 43040$$

$$\boxed{FS_p = 2.06}$$

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ATTACHMENT E

Calculate the maximum subsidence and trough width for a single panel with the following properties.

CASE 2

Inclination: Flat
Face Width: 120 ft
Length: 350 ft
Seam Height: 2 ft
Angle of Draw: 16°
Subsidence Factor: 0.65
Depth: 230 ft

Use methods presented in Pariseau, 2007

1) Calculate Width/Depth Ratio

$$\frac{W}{H} = \frac{120}{230} = 0.52$$

2) Determine Subsidence Factor S/h

$$S/h = 0.9\left\{1 - \exp\left[-2.47(W/H)^2\right]\right\}$$

$$S/h = 0.9\left\{1 - \exp\left[-2.47(0.52)^2\right]\right\}$$

$$S/h = 0.43$$

$$S = 0.43\,(2)$$

$$S = 0.86 \text{ ft}$$

Adjust U.K. Conditions (0.9 and ∡ 35°) to given conditions

$$S' = S\left(\frac{S_f'}{S_f}\right) = 0.86\left(\frac{0.65}{0.9}\right)$$

$$S' = 0.62 \text{ ft}$$

From Table 8.1

S/S =	0	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1.0
x/H =	0.95	0.59	0.47	0.34	0.28	0.24	0.21	0.17	0.15	0.12	0.08	0.06	0.00

Thus

$S(m)$ =	0	0.031	0.062	0.124	0.186	0.248	0.31	0.372	0.434	0.496	0.558	0.589	0.62

$$x' = x\left(\frac{W'}{W_o}\right) = \left[\frac{W + 2H\tan\zeta'}{W + 2H\tan\zeta}\right] x$$

$$x' = x\left[\frac{120 + 2(230)\tan(16)}{120 + 2(230)\tan(35)}\right]$$

$$x' = x\left[\frac{251.9}{442.1}\right]$$

$$x' = x\left[0.57\right]$$

$x'(m)$ =	124.5	77.3	61.6	44.6	36.7	31.5	27.5	22.3	19.7	15.7	10.5	7.9	0

Trough Width

$$W' = W + 2H\tan(\zeta)$$

$$W' = 120 + 2(230)\tan(16°)$$

$$W' = 251.9'$$

Which agrees with $S(m) = 0$ at $x'(m) = 124.5$

Calculate the Peak tensile and compressive strain for a single panel with the properties on the previous pages detailing vertical displacement profile.

From page 1 the maximum subsidence $s' = 0.62$ ft

From Table 8.3, $W/H = 0.52$

$E+ = 0.80$

$E- = 1.35$

$$E_t = (E+)(S/H) = (0.80)(0.62/230) = \underline{0.002}$$

$$E_c = (E-)(S/H) = (1.35)(0.62/230) = \underline{0.0036}$$

For $W/H = 0.52$

$$\frac{-e}{-E} = \exp\left[-4\left(\frac{W}{H} - 0.5\right)^2\right]$$

$$= \exp\left[-4\left(0.52 - 0.5\right)^2\right]$$

$$= 0.998$$

$$e_c = 0.003 \cdot 0.998 \simeq 0.003$$

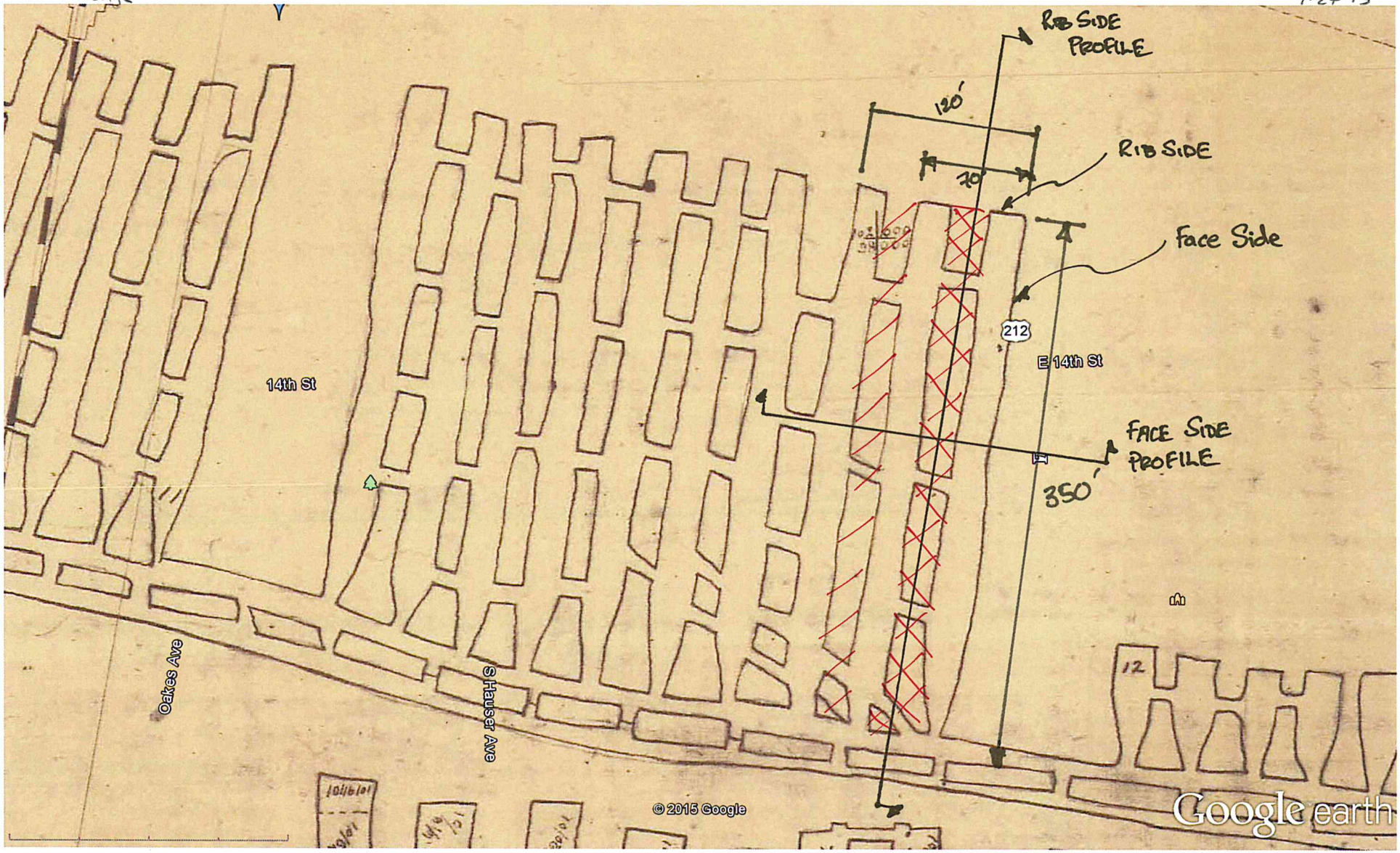
Estimate Strain Profile, from Table 8.2 for $W/H = 0.52$

			E_t									E_c					
e/E	0.0	0.2	0.4	0.6	0.8	1.0	0.8	0.0	0.2	0.4	0.6	0.8	1.0	0.8	0.6	0.4	0.2	0.0
e	0	4×10^{-4}				2×10^{-3}		0	6×10^{-4}				3×10^{-3}					0

Red Lodge

Subsidence Estimate NCB Method

JR
4/4
1-27-15



Google Earth Pro

feet 500
meters 100

Case 1

Case 2