# MONTANORE PROJECT
# INTERIM GEOTECHNICAL REPORT
# TAILINGS IMPOUNDMENT SITE

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Montanore Project
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by:
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December 1989

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Attention: Mr. Joe Scheuering
Project Manager

Subject: Montanore Project
Interim Geotechnical Report
Tailings Impoundment Site

Gentlemen:

Morrison-Knudsen Engineers, Inc. (MKE) is pleased to submit this interim geotechnical report for the Montanore Project.

The purpose of this report is to provide the results of both the 1988 and 1989 geotechnical investigations for the proposed tailings impoundment at the Little Cherry site.

The geotechnical investigations consisted of (1) geologic mapping, (2) seismic refraction surveys, (3) drilling, (4) test pit excavations, (5) in-situ field density testing, and (6) laboratory testing. Seismic design criteria and a description of subsurface conditions are presented in this report. The results of the completed laboratory tests are also presented; however some test results are still pending. The completed laboratory testing program will be used to finalize the evaluation of soil conditions. A final geotechnical report will be issued once the laboratory testing has been completed and the data analyzed.

If you have any questions about this geotechnical report, please call me at (415) 442-7593.

Sincerely,

M.P. Forrest
Project Manager

MPF/vc

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MONTANORE PROJECT

INTERIM TAILINGS IMPOUNDMENT GEOTECHNICAL REPORT

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# CHAPTER 1
# SUMMARY AND CONCLUSIONS

Noranda Minerals Corp. is currently planning the development of the Montanore Project located between Libby and Noxon in Sanders and Lincoln Counties, Montana, for mining and milling copper-silver ore. As part of this project, an impoundment located in the Little Cherry Creek valley will be required to store tailings resulting from milling operations. Morrison-Knudsen Engineers, Inc. (MKE) has been authorized to perform a geotechnical investigation at the proposed tailings impoundment site.

This interim geotechnical report presents the results of MKE's studies to date. Evaluations of soils, bedrock and groundwater are included. Laboratory soils testing is currently in progress. A description of the planned laboratory testing program is included in the Design Basis Memorandum in Appendix A of this report. The laboratory test results will be included in the final geotechnical report. The results of the laboratory testing program will be used to finalize the evaluation of soil materials present in the impoundment site.

Surficial deposits at the lower elevations of the eastern slopes in the project area include alluvial flood plain deposits, colluvium and glaciolacustrine and glaciofluvial deposits. The glaciofluvial deposits consist of sands and gravels; glaciolacustrine deposits consist primarily of gravelly clayey silt with some varved clays.

The bedrock at the site is Precambrian meta-sedimentary rock of the Belt Supergroup that consists primarily of weathered and fractured argillite, siltite and quartzite. Surficial glacial soils cover much of project area at the lower elevations. After the uplift of the Cabinet Mountains, an extensive period of glaciation and erosion followed. Though continental glaciers may not have extended to the project area, ice sheets moving south from Canada during the glacial stages dammed north flowing rivers, creating huge lakes. Sediments from one of these lakes reached the project site (Chen-Northern, 1989).

The site is in the northernmost end of the Intermountain Seismic Belt, which is characterized by moderate to large magnitude earthquakes with shallow focal depths. The largest events known to have occurred in the belt are the magnitude 7.5 Hebgen Lake, Montana, and the magnitude 7.3 Borah Peak, Idaho, earthquakes, both approximately 300 miles from the site. Although there have been no large historic earthquakes in the site region, the frequency of small to moderate events and the presence of long faults of undetermined activity suggest the potential for a large earthquake. Algermissen et al. (1982) assigned a maximum earthquake of magnitude 6.5 to the area, but it is not applied to a specific fault.

Maximum credible earthquakes (MCE) were established for potentially active seismic sources: the Rainy Creek and Bull Lake faults, the Flathead Lake seismic zone, and a random local earthquake. The most significant event for impoundment design is a magnitude 7 earthquake located on the Bull Lake fault, 22 km from the site. At the project site, the anticipated peak rock acceleration is 0.22g. and duration of strong motion is 27 seconds for this earthquake.

In the summers of 1988 and 1989, field explorations were performed to determine depths to bedrock, characteristics of the bedrock and soil, and groundwater conditions. Exploration included geologic mapping, seismic refraction surveys, drilling, test pit excavations, permeability tests and field density tests. A total of 42 seismic lines, totaling 16,445 linear feet, were surveyed to provide data on depth to bedrock and soil conditions. Piezometers were installed in 21 of the 25 borings to monitor groundwater. A total of 43 test pits were excavated to depths ranging from 5 to 17 feet. Selected test pit and boring samples were tested for moisture content, dry density, grain size, Atterberg limits, compaction and specific gravity. Laboratory testing is currently in progress.

Results of the field exploration show that bedrock generally consists of low-grade metamorphosed siltstone (siltite) and argillite, with some interbedded quartzite. Bedrock cores are generally moderately to highly weathered and fractured.

The bedrock surface is generally reflected by the topography. In the southeastern part of the site, a buried bedrock channel deeper than 367 feet extends through the proposed damsite. The results of the exploration indicate that bedrock is less than 50 feet deep in both abutments of the proposed tailings retention dam. In the excavation for the proposed diversion channel, depths to bedrock range from 3 to 41 feet.

Soil thicknesses are estimated to generally be less than 100 to 150 feet thick. The site soils primarily consist of dense mixtures of clay, silt, sand, gravel and cobbles. Boulders and cobbles were encountered in several borings and test pits in the impoundment site.

Groundwater in the impoundment site is both confined and perched. Artesian flow was noted in several borings in the proposed dam foundation. Pressure heads as high as 22 feet above the ground surface were measured. In the proposed diversion channel, the highest reported water level was 73 feet below the ground surface.

Permeabilities of soils and bedrock vary widely. Sand and gravel with low fines content typically have permeabilities on the order of $10^{-5}$ to $10^{-4}$ cm/sec. Weathered rock have permeabilities ranging from about $10^{-6}$ to $10^{-4}$ cm/sec. Low permeability silts act as confining zones where they overlie more pervious soils or rock.

Groundwater data indicate that artesian conditions exist in the proposed dam foundation. In order to prevent excessive pressures from developing in the foundation and thereby decrease stability, a pressure relief well system will be required. This relief well system will be installed during the operational life of the impoundment. Foundation piezometric pressures will be measured during operations. If pressure heads increase during the expansion of the impoundment, additional wells will be installed. The well system will be designed during the engineering phase of work.

The diversion channel will be excavated in weathered rock and soil materials. The results of seismic refraction surveys and drilling indicate that these materials generally can be excavated by ripping; however, some limited blasting will probably be needed in hard, unweathered rock, such as in quartzite zones. Groundwater levels measured in the channel area indicate that the channel invert should be above groundwater. Therefore, the excavation would generally be in dry conditions, but local seepages from perched water can be expected. For preliminary layouts, slopes in weathered rock will be 1:1; in soils, the slopes will be 2(H):1(V). These slopes will be confirmed by performing stability analyses during final design studies.

On-site materials for construction of the tailings retention dam will consist of soil and weathered rock removed from the diversion channel and other required excavations. Materials will also be obtained from a borrow area located in the western portion of the impoundment.

Clayey soil layers in the proposed dam foundation will be considered in stability analyses. Triaxial compression tests on undisturbed samples of clayey soil foundation samples are currently in progress. The results of these tests will be used in stability analyses to be performed during final engineering studies.

During the summer of 1990, a further exploration program is planned to confirm groundwater conditions for design of the relief well system. Pumping tests are planned for that field program.

# CHAPTER 2
# INTRODUCTION

## 2.1 BACKGROUND

Noranda Minerals Corp. is developing the Montanore Project, a copper-silver mining and milling operation. The project is in Sanders and Lincoln Counties, Montana as shown on Figure 1. As a part of this project, a tailings impoundment is proposed on Little Cherry Creek, in the Kootenai National Forest, and is shown on Figure 2.

In 1988, a preliminary field investigation was conducted for preparation of an operations permit application. Further field exploration was conducted in 1989 for final design.

## 2.2 PURPOSE AND SCOPE

The purpose of this interim report is to present the results of the 1988 and 1989 geotechnical investigations conducted by MKE. Laboratory soils testing is in progress. A final report will be issued when the laboratory tests have been completed and analyzed. The report provides support for engineering studies and design of the proposed tailings impoundment.

The scope of work for the geotechnical investigations includes the following tasks:

- Conduct field investigations consisting of:
  - Data review
  - Reconnaissance
  - Geologic mapping
  - Seismicity evaluation
  - Seismic refraction survey
  - Test pit excavations

- Exploratory drilling
- Field density testing
- Laboratory testing

o Provide seismic design ground motion parameters.
o Evaluate subsurface conditions

The approach to the work is discussed in a Design Basis Memorandum in Appendix A.

## 2.3 AUTHORIZATION

Noranda Minerals Corp. authorized the work for this phase of the project in April 1989.

# CHAPTER 3
# GEOLOGIC SETTING

The focus of the Montanore Project is an area near Rock Lake in the Cabinet Mountains Wilderness. The primary geological feature of the area is the Cabinet Mountains, a rugged range with altitudes of more than 7,000 feet. Cirques with high walls at the heads of the valleys were formed during the last Pleistocene glaciation. Many of the cirque basins contain lakes that are fed by snowmelt.

The project area is underlain by Precambrian meta-sedimentary rocks of the Belt Supergroup. The rocks form a north-trending structure bounded on the east and west by high-angle faults. The rock structure in general is tilted northward. The bedrock consists primarily of argillite, siltite and quartzite, with some carbonate horizons. Bedrock is exposed over most of the wilderness area except for talus and rock slides that cover many of the steep slopes. Surficial soils related to glaciation cover much of project area at the lower elevations (U.S. Geological Survey and U.S. Bureau of Mines, 1981).

An extensive period of glaciation and erosion during the Pleistocene Epoch followed uplift of the Cabinet Mountains. Glacial striations on ridges indicate that ice (probably alpine or mountain glaciers) once covered all but the highest peaks of the range. Continental glaciers may not have covered the project area. However, the effect of the ice sheets moving south from Canada during the Pleistocene glacial stages was to dam the north flowing rivers, creating huge lakes. Glacial Lake Missoula formed in this manner in the Clark Fork drainage west of the Cabinet Mountains. The water backed up into southern Montana some 250 miles, reached depths of over 2,000 feet, and rose to an elevation of 4,150 feet (Montana Bureau of Mines and Geology, 1962). Ice also blocked the north flowing Kootenai and other local rivers, creating lakes along the eastern side of the Cabinet Mountains. Sediments from one of these lakes reach an elevation of 3,550 feet in the project area, which appears to be slightly lower than that of Glacial Lake Missoula (Chen-Northern, 1989).

Surficial deposits at the lower elevations of the eastern slopes in the project area include alluvial flood plain deposits, colluvium, and glaciolacustrine and glaciofluvial deposits. The floodplain deposits consist primarily of silts, sands, gravel and cobbles. The colluvium consists of slope wash boulders and soils. The glaciofluvial deposits are composed of sands and gravel. The glaciolacustrine deposits consist primarily of gravelly clayey silt with some varved clays.

# CHAPTER 4
# SEISMICITY

## 4.1 GENERAL

This chapter provides background information on seismicity of the region surrounding the Montanore Project. The chapter also includes data used to define a project design earthquake, including ground motions expected at the site, along with the procedures used to obtain these parameters.

## 4.2 REGIONAL SEISMICITY

The site region lies near the northernmost end of the Intermountain Seismic Belt (ISB), a north-south oriented zone of seismic activity that includes the Wasatch Front in central Utah, the Teton-Yellowstone area of Wyoming and parts of the northern Rockies in western Montana. The ISB is characterized by moderate to large magnitude earthquakes with shallow focal depths. Throughout the ISB, including the project site, the predominant type of faulting is normal, along north to northwest oriented faults.

Table 4.1 summarizes significant earthquakes in the region and includes the two largest events known to have occurred in the ISB: the magnitude (M) 7.5 Hebgen Lake, Montana, earthquake of 1959 and the M 7.3 Borah Peak, Idaho, earthquake of 1983. Both these earthquakes were approximately 300 miles from the site so that ground motions felt in the site region were mild. No significant damage occurred in Libby during either earthquake (Stover, 1985).

Swarms of moderate to small earthquakes have occurred repeatedly near Flathead Lake, as shown on Figure 3. Despite the long history of intense activity, magnitudes reported by the National Oceanic and Atmospheric Administration (NOAA) have never exceeded 5.0. However, Qamar and Stickney (1983) estimate magnitudes of 5.5 for earthquakes in 1945 and 1952 based on unusually large areas where ground motions were felt.

TABLE 4.1

SIGNIFICANT EARTHQUAKES IN SITE REGION[1]

| Date | Location | Magnitude[2] | Maximum Intensity[3] | Approx. Distance to Project Site (miles) |
|---|---|---|---|---|
| 2-25-71 | S.E. of Libby, MT | --- | IV | 14 |
| 6-26-64 | Marion, MT | 4.7 | IV | 21 |
| 3-12-18 | Lake Pend Oreille, ID | --- | IV | 27 |
| 4-15-52 | Whitepine, MT | --- | IV | 30 |
| 8-16-60 | Sandpoint, ID | --- | IV | 47 |
| 7-10-30 | Missoula, MT | --- | V | 48 |
| 12-19-57 | Wallace, ID | 5.0 | VI | 48 |
| 11-28-26 | Wallace, ID | --- | V | 48 |
| 5- 9-44 | Wallace, ID | --- | IV | 48 |
| 6- 8-54 | Wallace, ID | --- | V | 50 |
| 9-23-61 | Wallace, ID | --- | IV | 51 |
| 11-01-42 | WA/ID border | --- | VI | 52 |
| 9-23-45 | Flathead Lake, MT | 5.5[5] | VII | 65 |
| 2- 4-75 | Creston/Kalispell, MT[8] | 4.6 | VI | 66 |
| 3-31-52 | Big Fork, MT | 5.5[5] | VII | 70 |
| 7-31-69 to 10-30-70 | Canada (9 events)[4] | 5.0 to 5.3 | VI | 116 to 128 |
| 12-20-72 | Canada | 5.1 | VI | 116 |
| 7-16-36 | Milton-Freewater, OR | 5.75[5] | VII | 205 |
| 8-17-59 | Hebgen Lake, MT | 7.5[6] | X, V[7] | 293 |
| 10-28-83 | Borah Peak, ID | 7.3[6] | IX, V[7] | 310 |

Notes:

(1) Sources of data: NOAA data file and Qamar and Stickney (1983). Earthquakes with M less than 5 and more than 50 miles from the site are not included.
(2) Magnitudes are body wave magnitudes ($m_b$) except as otherwise noted.
(3) Epicentral Modified Mercalli Intensity.
(4) Swarm of 9 earthquakes with M greater than 5.
(5) Estimated magnitude.
(6) Surface wave magnitude ($M_s$).
(7) Reported local intensity at Libby, Montana.
(8) Representative event; numerous other earthquakes with M less than 5 have occurred near Flathead Lake.

Other clusters of earthquakes have occurred near Wallace, Idaho, 50 miles south of the site, and in Canada, more than 115 miles to the north. In both areas, the maximum magnitudes have not exceeded 5.3. Many of the events originating from the Wallace area are rock bursts related to mining operations in the Coeur d'Alene mining district (Qamar and Stickney, 1983).

Although there have been no large historic earthquakes in the site region, the frequency of small to moderate events and the presence of long faults of undetermined activity indicate that a large earthquake is possible. Algermissen et al. (1982) attributed a maximum magnitude of 7.3 to the Flathead Lake zone and areas to the southeast.

## 4.3 LOCAL SEISMICITY

The area from Bitterroot Valley north into Canada and from Flathead Lake west to the Washington-Idaho border is characterized by low seismicity. There is no record of a moderate earthquake in the area. However, there have been scattered small earthquakes in the Idaho panhandle in the vicinity of Lake Pend Oreille and a few small earthquakes between Libby and Kalispell. As shown in Table 4.1, the largest and most significant of these was a M 4.7 earthquake in 1964, 21 miles east of the project site. The closest event occurred about 14 miles east of the site in 1971, but was small. No earthquakes exceeding magnitude 4.5 have occurred in northwest Montana in the last five years (M.C. Stickney, personal communication, 1988).

A notable lack of seismicity has been associated with geologic structures such as the Hope, Bull Lake, and Rainy Creek faults (Figure 3). Nevertheless, uncertainties in knowledge of fault activity and a rather short historical earthquake record led Algermissen et al. (1982) to select a maximum earthquake of magnitude 6.5 for the area, which is greater than the largest observed event (M = 5.0). This earthquake is not assigned to any specific fault.

## 4.4 FAULTS

Witkind (1975) identified and classified faults in the region that show evidence of movement in the last 20 million years. Of those faults, only two in the site area, the Rainy Creek and Bull Lake faults, show evidence of displacing Pleistocene deposits. This places the age of fault movement as less than 1.5 to 2 million years. Orientations and locations of the faults are indicated on Figure 3.

- Rainy Creek Fault: Witkind (1975) classified this fault as active, based on a report that it ruptured the ground surface during an earthquake in 1964. However, the Corps of Engineers performed further field investigations of the Rainy Creek fault in a study for Libby Reregulating dam (Corps of Engineers, 1978, cited in Camp, Dresser & McKee, Inc., 1988). A conclusion of this study was that the reported fault scarp was not tectonic in origin and that it was related to slumping of poorly compacted tailings and overburden. There is now doubt whether this fault should be considered potentially active.

- Bull Lake Fault: Witkind (1975) classified this fault as late Quaternary, less than about 700,000 years old, and therefore potentially active.

- Faults Bounding Libby Valley: Witkind (1975) evaluated these possible faults as late Cenozoic (older than several million years) and questioned their existence. Since there is little evidence for their activity, these faults are not considered as potential earthquake sources in the present study.

- Hope Fault: This fault is about 70 miles long and extends southeastward from Lake Pend Oreille, along the Clark Fork River past Thompson Falls. Witkind (1975) found it to be older than Pleistocene, more than 1.5 to 2 million years old. Therefore, it is not considered as a potential earthquake source.

- o Flathead Lake Seismic Zone: Earthquake activity near Flathead Lake is treated here as a seismic zone in which epicenters do not clearly coincide with known faults. There are numerous candidate faults in the area, both normal and strike slip, but their behavior and individual potential have not been resolved. A conservative distance of 40 miles from the site has been assumed to account for possible branching faults, such as the Big Draw fault, shown on Figure 3.

## 4.5 MAXIMUM CREDIBLE EARTHQUAKES

The maximum credible earthquake (MCE) is defined as the largest rationally conceivable seismic event that could occur in the tectonic environment in which the project is located (Seed, 1982). MCE's were established for three potential sources: the Rainy Creek and Bull Lake faults, the Flathead Lake seismic zone, and a random local earthquake. MCE magnitudes for Bull Lake and Rainy Creek faults were calculated using the formula of Slemmons (1982) for normal faults:

$$M_s = 0.809 + 1.341 \log L$$

where L is the entire length of the longest fault segment in meters. Maximum earthquake magnitudes for the Flathead Lake zone and for random local earthquakes were adopted from Algermissen et al. (1982). MCE magnitudes are shown in Table 4.2.

## 4.6 SEISMIC DESIGN CRITERIA

Peak rock accelerations at the project site were calculated for each of the four potential seismic sources using current attenuation functions (Campbell, 1981; Joyner and Boore, 1982; and Idriss, 1985). Table 4.2 summarizes the MCE magnitudes, source distances, and resulting rock accelerations. As shown in Table 4.2, a random, local earthquake gives the largest estimate of peak acceleration. However, although the MCE on the Bull Lake fault yields an

acceleration 5% lower than that from a local source, because of its larger magnitude, it could produce shaking of longer duration (i.e., more significant number of stress cycles). For purposes of the design earthquake, rounding up the Bull Lake MCE to magnitude 7.0 is appropriate. Thus, the design mean peak rock acceleration produced by an MCE of magnitude 7.0 is 0.22g.

The maximum duration of significant shaking for the design earthquake was based on Bolt's (1973) relation of duration and magnitude within a 25 km radius of an earthquake. The duration is taken as the time elapsed between the first and last acceleration pulses that exceed 0.05g and 1 hz. The duration of shaking for design is 27 seconds.

The predominant period of the earthquake motion at the project site was determined by procedures described in Seed, Idriss and Kiefer (1969). From their relations of observed predominant period, distance and magnitude, an average expected value was determined. For sites within 40 km of the seismic source, the predominant period is not sensitive to distance. The predominant period of the design earthquake at the site is 0.32-second.

The design earthquake ground motion parameters are summarized below:

- Source: Bull Lake Fault
- Magnitude: 7.0
- Distance from site: 20 km
- Mean Peak Rock Acceleration: 0.22g
- Duration: 27 seconds
- Predominant Period: 0.32-second

TABLE 4.2

PEAK GROUND ACCELERATION FOR

VARIOUS SOURCE MAXIMUM CREDIBLE EARTHQUAKES

| Earthquake Source | Site Distance (km) | Fault Length[1] (km) | MCE Magnitude | Mean Peak Ground Acceleration (g) | | | |
|---|---|---|---|---|---|---|---|
| | | | | C[2] | J + B[3] | I[4] | Average |
| Bull Lake Fault | 20 | 30.6 | 6.8 | 0.18 | 0.19 | 0.21 | 0.20 |
| Rainy Creek Fault | 24 | 23.3 | 6.7 | 0.15 | 0.15 | 0.17 | 0.16 |
| Flathead Zone | 65 | --- | 7.3[5] | 0.09 | 0.06 | 0.09 | 0.08 |
| Random Local | 15 | --- | 6.5[5] | 0.19 | 0.21 | 0.23 | 0.21 |

Notes:

[1] Fault lengths are scaled from map shown in Witkind (1977).

[2] Campbell (1981) attenuation.

[3] Joyner and Boore (1982) attenuation

[4] Idriss (1985) attenuation

[5] Algermissen et al. (1982)

# CHAPTER 5
# FIELD EXPLORATION AND LABORATORY TESTING

## 5.1 FIELD EXPLORATION

### A. General

In July and August 1988, field exploration was performed at the Little Cherry tailings impoundment site. Additional exploration was conducted between August and October 1989. The field exploration programs consisted of geologic mapping, seismic refraction surveys, drilling, test pit excavations and in-situ density tests. A summary of the field exploration programs is presented in Table 5.1 at the end of this chapter.

In July 1988, Chen-Northern drilled 5 wells, totaling 370 linear feet, in the Little Cherry impoundment site. Aquifer testing was performed in the wells and the test results are presented in Chen-Northern's 1989 report. Also, Chen-Northern conducted 25 resistivity surveys at the impoundment site. Chen-Northern's exploratory work supplements MKE's field exploration of the Little Cherry impoundment site. The locations of the wells and resistivity surveys are shown on Figure 4.

### B. Geologic Mapping

Geologic mapping was performed at the impoundment site. The mapping was done to identify bedrock outcrops, landslides, rockslide areas, snowslide areas and springs. The geologic data are shown on the exploration plan, Figure 4.

### C. Seismic Refraction Surveys

In July 1988, 7 seismic refraction lines were surveyed in the project area to obtain information on depth to bedrock, depths to soil layers, and rippability of site materials. In July and August 1989, 35 additional seismic refraction lines were surveyed in the impoundment area. The line designations, number of seismic lines and total footage are presented in Table 5.1.

Seismic lines were each 325 feet long with geophone spacings of 25 feet; occasionally additional offset shotpoints were used to increase the depth of information obtained. A twelve-channel signal-enhancement seismograph was used to record compressional wave (P-wave) velocities, and explosives or a 10-pound sledge hammer was used as an energy source. The approximate seismic line locations are shown on Figure 4 and a summary of the results of the seismic refraction surveys is presented in Appendix B.

## D. Drilling

In July and August 1988, five borings (USB-1 to USB-5) ranging in depth from 25 to 81 feet and totalling 307 linear feet were drilled under the direction of MKE. The boring designations, number of borings and total footage drilled for the tailings impoundment site are presented in Table 5.1. To minimize ground disturbance, preliminary exploration borings were located in readily accessible areas as shown on Figure 4.

The borings were drilled by Chen-Northern of Great Falls, Montana, using a Mobile B-53 rotary drill rig. Borings were drilled to determine depth to bedrock, characteristics of bedrock and soils, and the depth to groundwater. The borings were generally drilled with a 2-15/16-inch tricone bit and casing in the soils. Bedrock was cored by using NQ diamond bits and double-tube core barrels. Standard Penetration Test samplers (2-inch O.D., ASTM D1586) and 2.5-inch O.D. samplers were used to obtain soil samples where soil conditions permitted. Shelby tubes were used to obtain undisturbed soil samples, but sample recovery was poor and the tubes were generally bent and creased. Approximate unconfined compressive strengths of cohesive soil samples were measured with a pocket penetrometer. To monitor groundwater levels, Borings USB-1, 2 and 5 were cased with 1-inch I.D. PVC pipes (bottom sections of the pipes are slotted).

Between August and October 1989, twenty additional borings (DH-1 to DH-20) were drilled at the impoundment site. The borings range in depth from 25 to 367 feet, and total 2265 linear feet. These borings, except DH-15, were drilled by J.D. Welsh and Associates of Boise, Idaho, using an Acker ADII truck-mounted drill rig and a skid-mounted Longyear 28 drill rig. Borings were drilled to provide supplemental data on depth to bedrock, characteristics of the bedrock and the soils and the depth to groundwater. Where possible, the borings were started by using a hollow stem auger. Where auger drilling was not possible or when auger refusal occurred, the soil was cored with HQ or NQ diamond bits and triple-tube core barrels. Standard Penetration Test samplers and 2.5-inch O.D. samplers were used to obtain samples where soil conditions permitted. Since the Longyear 28 drill rig is not equipped with a hammer or cathead, drive samples could not be obtained from Borings DH-9 and DH-10. Shelby tubes were used to obtain undisturbed clayey soil samples, but they were limited to the south part of the proposed main dam foundation due to the gravelly soils found in the remainder of the site.

To monitor groundwater levels, all borings, except DH-3A, DH-5 and DH-15, were cased with 1-inch I.D. PVC pipe. DH-15 was cased with 2-inch I.D. PVC pipe. This boring was drilled by Ruen Drilling, of Clark Fork, Idaho, using a truck-mounted Schramm air rotary drill rig.

Boring logs and monitoring well construction details are presented in Appendix C. Water level data is presented in Table C.1, Appendix C. Locations of all borings, except DH-3A, were surveyed by others.

Field permeability tests were performed in the tailings impoundment site. The tests were performed to determine permeability values of foundation materials for seepage analyses. The tests were performed in the soils using constant head open-end casing tests conforming to procedures in the U.S. Bureau of Reclamation's "Earth Manual" (1974), Method E-18. Water pressure tests were performed in bedrock using a single pneumatic packer. Results of the permeability tests are presented in Table C.2, Appendix C.

## E. Test Pits

In July and August 1988, 10 test pits (TP-101 to TP-110), ranging in depth from 9 to 16 feet, were excavated in the impoundment to characterize the soil materials and to estimate the amount of boulders in the soil matrix. Test pits were located in readily accessible areas (Figure 4). Sorlie Excavating of Trout Creek, Montana, excavated the test pits with a Case 580D backhoe equipped with a 2.0-foot wide bucket. Soil samples were taken from the test pits and transported to Chen-Northern in Great Falls for laboratory testing. Approximate unconfined compressive strengths of cohesive soils were measured with a pocket penetrometer.

In July 1989, 27 additional test pits (TP-121 to TP-147), ranging in depth from 5 to 17 feet, were excavated in the impoundment site to evaluate borrow materials and impoundment excavation conditions. The test pits were excavated by Sorlie Excavating using a Cat 215 track-mounted backhoe with a 3.5-foot wide bucket. Soil samples taken from the test pits were transported to Chen-Northern in Great Falls, Montana, for laboratory testing. Approximate unconfined compressive strengths of cohesive soils were measured with a pocket penetrometer.

Test pit logs are presented in Appendix D.

## F. Density Tests

Density tests were performed in six 5- to 6-foot deep test pits (DT-1 to DT-6) excavated in the proposed tailings dam foundation. These tests were performed by using the sand-cone method conforming to ASTM D1556 and the nuclear densometer method conforming to ASTM D2922. This work was performed concurrently with the test pit excavation program. A summary of test results is presented in Appendix E.

## 5.2 LABORATORY TESTING

Laboratory tests were performed to obtain engineering parameters of the soils at the tailings impoundment site. Moisture content (ASTM D2216), dry density, grain size (ASTM D422), Atterberg limits (ASTM D4318), compaction (ASTM D698), and specific gravity (ASTM D854) were determined for selected test pit and boring samples obtained during both the 1988 and 1989 explorations. The types and number of tests at the tailings impoundment site are summarized in Table 5.2. Available laboratory test results are presented in Appendix F. Laboratory testing is currently in progress.

TABLE 5.1. SUMMARY OF FIELD EXPLORATION

| Year | SEISMIC LINES | | | BORINGS | | | TEST PITS | |
|---|---|---|---|---|---|---|---|---|
| | Designation | Number of Lines | Total Coverage (ft.) | Designation | Number of Borings | Total Footage | Designation | Number of Test Pits |
| 1988 | TI-9 to 15 | 7 | 4,525 | USB-1 to 5 | 5 | 307 | TP-101 to 110 | 10 |
| 1989 | 89-1 to 35 | 35 | 11,920 | DH-1 to 20 | 20* | 2,265 | TP-121 to 147, DT-1 to 6 | 33 |
| | | 42 | 16,445 | | 25 | 2,572 | | 43 |

*DH-16 was not drilled, DH-3A was added during exploration.

TABLE 5.2. SUMMARY OF LABORATORY TESTS

| Year | Sample Source | Moisture Content ASTM D 2216 | Dry Density | Sieve Analysis ASTM D422 | Sieve and Hydrometer ASTM D422 | Atterberg Limits ASTM D4318 | Compaction ASTM D698 | Specific Gravity ASTM D854 |
|---|---|---|---|---|---|---|---|---|
| 1988 | Test Pit | 5 | | 5 | 1 | 4 | 2 | 2 |
| | Boring | 3 | 1 | 7 | | 1 | | |
| 1989 | Test Pit | 12 | | 16 | 4 | 10 | | |
| Total | | 20 | 1 | 28 | 5 | 15 | 2 | 2 |

# CHAPTER 6
# SITE AND SUBSURFACE CONDITIONS

## 6.1 SITE CONDITIONS

The site is located in a valley that drains northeast into Libby Creek. The highest point in the watershed is at El. 5,400. Portions of the site are clear-cut and others are heavily timbered. Access to the site is via Forest Service roads, about 12 miles from U. S. Route 2. In August 1989, a 1-mile road was cleared in the south portion of the tailings retention damsite, just above the proposed diversion channel.

Isolated outcrops of highly weathered, fractured and jointed meta-sedimentary rock are mapped on the north faces of ridges, north and south of Little Cherry Creek, as shown on Figure 4. Elsewhere, the ridges are covered with colluvium and glacial outwash. Most of Little Cherry Creek is 50 feet or more above bedrock. Near the proposed seepage collection damsite, the creek has cut through the surficial material, exposing less weathered meta-sedimentary rock.

At the proposed damsite, the valley walls and creek channel are covered with colluvium, glacial outwash and lake bed sediments. The colluvium overlies the higher slopes of the valley and consists of coarse slopewash material. The glacial outwash is gravelly and contains a major clay and silt fraction. The lake bed sediments are mostly fine-grained clayey silt and varved clays with some gravel. These surficial materials appear to interfinger below about El. 3,550, which is the highest level that lake-bed sediments have been reported (Chen-Northern, 1989). Within the impoundment, colluvium and glacial outwash may overlie these sediments, indicating a later period of deposition.

Groundwater is transmitted through the more pervious layers of colluvial and glacial outwash and also through fractures in bedrock. Where groundwater is

confined by the relatively impervious lake bed sediments, aquifers under artesian pressure result. Springs were observed during the 1989 field investigation and occur in the proposed areas of the main dam and west of the north saddle dam, as shown on Figure 4.

## 6.2 SUBSURFACE CONDITIONS

### A. General

The exploration plan showing both the 1988 and 1989 field programs is presented on Figure 4. Contour maps of the bedrock surface, soil isopachs and piezometric surface are presented on Figure 5, 6 and 7, respectively. Geologic sections are shown on Figures 8 through 15. The sections show generalized soil types, bedrock profiles, permeability data, groundwater levels and seismic velocities. The information shown on the contour maps and geologic sections (Figures 5 through 15) was interpreted from the results of the exploration. Actual locations of bedrock and piezometric levels could vary from those indicated on the figures.

### B. Bedrock

Bedrock observed in the borings generally consists of low-grade metamorphosed siltite and argillite. In Borings DH-4, DH-10 and DH-13, the bedrock also contains interbedded quartzite. In general, the quartzite is very hard, the siltite varies from hard to soft, and the argillite from soft to very soft. The siltite and argillite are easily broken along thin, brown and black laminae. Bedrock cores obtained from the borings are generally moderately to highly weathered, to a soil-like texture in places; a few cores are only slightly weathered. The weathered and fractured upper section of the bedrock in many cores did not exhibit a clear contact with the overlying dense, bouldery soils.

The rock is iron- and manganese-oxide stained. Between the proposed diversion dam and right abutment of the main dam, occasional vugs, generally less than 1/3 inch, though as large as 1-1/2 inches, were noted in Borings DH-6, DH-7 and DH-8.

Planar fractures with smooth to slightly rough surfaces occur throughout the meta-sedimentary rock. Fracturing observed in the cores was usually moderate (3 to 5 fractures per foot), but some zones were slightly fractured (less than 1 fracture per foot) or intensely fractured (more than 10 fractures per foot). The intensely fractured zones are less than 2 feet thick. Fractures are both parallel and oblique to bedding. However, within the siltite and argillite, fractures most commonly occur along laminae. Some fractures intermittently contain thin talc, chlorite or soft clay filling, and some fractures are slickensided. Core recovery, frequently at 100%, was good. The rock quality is very poor to fair (generally with Rock Quality Designations of 0% to 30%), reflecting the weathered and soft condition of the rock.

With borehole, test pit, and outcrop data as controls, an approximate bedrock surface was estimated, as shown on the bedrock contour map (Figure 5). The bedrock surface tends to be reflected in the topography, with the creek location in the west approximating the pre-glacial channel. However, in the eastern part of the site, a deep bedrock channel extends through the proposed damsite. Its existence, first suspected based on the results of seismic refraction survey line TI-10, was confirmed by Boring DH-3, where bedrock is greater than 367 feet deep. Boring DH-20 further delineated the channel by reaching bedrock in the northern flank of the channel at 205 feet below ground level.

The results of the field explorations indicate that bedrock occurs at shallow depths (less than 50 feet) beneath both abutments of the proposed tailings retention dam. Except in Well LCM-9, bedrock was not reported in the borings drilled in the valley bottom during the 1988 field investigation, although bedrock may have been reached in Well LCTM-8 at about 114 feet. In the 1989 exploration, in the main dam area, bedrock was encountered in all borings, except in DH-3. Bedrock was found in the proposed diversion channel location at depths varying from 3 to 41 feet. Rock was noted at greater depths just northwest of the diversion damsite (180 feet in DH-11) and west of the north saddle dam (145 feet in DH-5). Rock conditions in these areas resemble those in other boreholes: poor to fair quality, moderately to intensely fractured and weathered.

## C. Soils

Primarily dense silty sandy and silty gravelly soils (lowest SPT value was 36) were observed in the borings and test pits over most of the site. In the tailings retention dam foundation, zones of sandy clayey silty materials were also found. Boulders and cobbles were encountered, such as in Borings USB-2, USB-4, DH-3 and DH-20, and in Wells LCTM-8 and LCM-11. The amount of boulders in the test pits was visually estimated to generally range from about 5 to 10% of the soil volume.

The estimated soil thicknesses in the site are shown on the isopach map (Figure 6). Over most of the impoundment site, the soil is less than 100 to 150 feet thick. In the bedrock channel, however, the soil thickness is estimated to be greater than 367 feet. Soils in the channel consist of clayey sandy silt with cobbles and boulders. The results of the exploration indicate that along most of the proposed diversion channel and main dam abutments, soils are generally less than 50 feet thick. Through part of the proposed seepage collection damsite, bedrock is exposed in Little Cherry Creek.

At the proposed damsite, six 5- to 6-foot deep density test pits (DT-1 to DT-6) were excavated to determine the in-situ density of the foundation material. Soils encountered in these test pits consisted of gravelly sandy clayey silt. Seven field density tests were performed by nuclear densometer (ASTM D2922) and sand cone method (ASTM D1556). Results of these tests show moisture contents and dry densities range from 12 to 24% and 95 to 124 pcf, averaging 16% and 113 pcf, respectively.

The results of the seismic refraction surveys show that soils have compressional wave (P-wave) velocities ranging from about 1,200 to 7,500 feet per second (fps). Near surface soils have lower velocities; higher velocities of deeper materials indicate increasing soil densities. Measured rock velocities range from about 7,000 to 15,000 fps, and reflect the degree of weathering. Highly weathered, soft rock would have velocities at the low end of this range.

## D. Groundwater

Groundwater in the Little Cherry site is recharged primarily from the hillside in the west. The general flow direction in the impoundment site is from west to east, corresponding approximately to the site topography. Portions of this groundwater, which flow beneath the impoundment site, emerge as springs around the proposed tailings damsite and downstream near of the confluence of Little Cherry and Libby Creeks (Chen-Northern, 1988; MKE, 1989).

A summary of 1989 piezometer readings is presented in Table 6.1. The piezometric levels in the damsite ranged from 34 feet below ground level (GL) to 9 feet (4 psi) above GL, except in Borings DH-4 and DH-13 in the right abutment, where groundwater was not observed. In the proposed diversion channel, the water level was 73 feet below GL in Boring DH-9 and 85 feet below GL in DH-10; water was not encountered in Borings DH-7 and DH-8. The water level was 142 feet below GL in Boring DH-5, near the proposed north saddle dam. In the impoundment site, the piezometric levels ranged from 50 feet below GL to 24 feet above GL (10.4 psi). In the left abutment of the proposed diversion dam, groundwater was measured at a depth of 107 feet in DH-11. Seepage was observed at depths of 4.5 to 11 feet in six test pits during excavation: TP-101,-102,-104,-110,-137 and-144.

Based on the results of field investigations, groundwater at the proposed impoundment site occurs (1) as perched water in the soil deposits, and (2) as a more extensive aquifer in bedrock and the overlying soils, which is subject to varying degrees of confinement. Figure 7 shows the piezometric surface contours derived from water level measurements from the piezometers.

The results of the field permeability tests are summarized in Table 6.2. As indicated in the table, the highest permeabilities occur in the sand and gravel with low fines content. Permeability values typically were measured to range from $2x10^{-6}$ to $2x10^{-3}$ cm/sec and average about $10^{-5}$ to $10^{-4}$ cm/sec. The permeabilities in the weathered rock generally were measured to be less than $10^{-6}$ to $3x10^{-4}$ cm/sec. Both of these materials are water bearing. In the clayey sandy silty soils, which have high fines content, measured permeabilities range from less than $10^{-6}$ to $4x10^{-5}$ cm/sec. These silty soils act as confining zones

where they overlie more pervious soils or rock. Where silty soils underlie more pervious soils, perched conditions exists.

In the north abutment and in the southern portion of the Little Cherry impoundment site, where surficial deposits are thin and bedrock is near the ground surface, the piezometric levels are below the soil-bedrock contact. The piezometric levels in Borings DH-9, DH-10 and USB-3 are below this contact; groundwater was not encountered in the piezometers installed in bedrock at DH-4, 7, 8 and 13.

The main aquifer is generally confined. Artesian flow conditions were observed in some of the piezometers in the valley bottom, as in Borings DH-6 and DH-15, downstream from the diversion channel at PLCM-6, and in the proposed dam foundation at DH-2, DH-3, DH-12 and DH-19. Pressure heads as high as 21 to 25 feet above GL (9.25 to 9.5 psi) were measured in DH-6 (diversion dam area) and DH-15 (impoundment area) as reported by Noranda, November 1989. In the tailings retention dam area, pressure heads range from less than 1 foot (DH-3 and DH-12) to 8 feet above GL (DH-2 and DH-19).

Perched water occurs throughout the soils of the Little Cherry site, as indicated by decreasing water levels during drilling, as occurred in DH-11 and DH-12. Perched water conditions are attributed to the interfingering of the relatively impervious lacustrine clayey silt within the more pervious outwash sediments.

TABLE 6.1

SUMMARY OF BORING AND WELL DATA[a]

| Boring No. | Auger Depth (ft) | Total Depth (ft) | Depth to Bedrock (ft) | Depth to Static Water (ft)[b] | Screen Interval (ft) | Sensing Zone (ft)[c] | Sensing Zone in Soil (S) or Rock (R) | Elevation of Ground Surface |
|---|---|---|---|---|---|---|---|---|
| DH-1 | 10 | 100 | 77 | 20 | 80 - 100 | 75 to BH | R | 3445.6 |
| DH-2 | 10 | 110 | 54 | 9.5 AGL | 90 - 110 | 78 to BH | R | 3414.4 |
| DH-3 | 0 | 367 | - | 2 AGL | 140 - 160<br>223 - 243 | 130 to 180 | S | 3435.4 |
| DH-3A | 25 | 25 | - | Dry | - | - | | 3435 |
| DH-4 | 0 | 40 | 9 | Dry | 20 - 40 | 21 to BH | R | 3609.5 |
| DH-5 | 5 | 197 | 145 | 140 | - | - | | 3674.4 |
| DH-6 | 5 | 60 | 40 | 22 AGL | 40 - 60 | 36 to BH | R | 3593.7 |
| DH-7 | 44 | 73 | 34 | Dry | 53 - 73 | 47 to BH | R | 3769.3 |
| DH-8 | 15 | 98 | 15 | Dry | 78 - 98 | 73 to BH | R | 3745.9 |
| DH-9 | 0 | 82 | 41 | 73 | 62 - 82 | 51 to BH | R | 3677.7 |
| DH-10 | 0 | 87 | 18 | 85 | 67 - 87 | 57 to BH | R | 3657.5 |
| DH-11 | 15 | 192 | 180 | 105 | 170 - 190 | 165 to BH | R/S | 3760.4 |
| DH-12 | 5 | 110 | 65 | 2 AGL | 90 - 110 | 84 to BH | R | 3393.2 |

[a] All depth are measured from ground level.

[b] AGL = above ground level; water levels were measured between Sept. and Nov. 1989, except water levels in USB-3 and USB-4, which were measured at the time of drilling.

[c] BH = Bottom of Hole.

TABLE 6.1

SUMMARY OF BORING AND WELL DATA[a]

(Continued)

| Boring No. | Auger Depth (ft) | Total Depth (ft) | Depth to Bedrock (ft) | Depth to Static Water (ft)[b] | Screen Interval (ft) | Sensing Zone (ft)[c] | Sensing Zone in Soil (S) or Rock (R) | Elevation of Ground Surface |
|---|---|---|---|---|---|---|---|---|
| DH-11 | 15 | 192 | 180 | 105 | 170 - 190 | 165 to BH | R/S | 3760.4 |
| DH-12 | 5 | 110 | 65 | 2 AGL | 90 - 110 | 84 to BH | R | 3393.2 |
| DH-13 | 6.5 | 80 | 15.7 | Dry | 60 - 80 | 56 to BH | R | 3682.5 |
| DH-14 | 0 | 60 | 30 | 17 | 40 - 60 | 35.5 to BH | R | 3574.7 |
| DH-15 | 0 | 120 | - | 24 AGL | 93 - 113 | 80 to BH | S | 3440.5 |
| DH-17 | 26 | 80 | 65 | 23 | 60 - 80 | 59 to BH | R/S | 3541.8 |
| DH-18 | 4.5 | 65 | - | 50 | 45 - 65 | 40 to BH | S | 3659.2 |
| DH-19 | 0 | 105 | 60 | 10.5 AGL | 85 - 105 | 76 to BH | R | 3413.4 |
| DH-20 | 25 | 214 | 205 | 9 | 144 - 154 | 136 to BH | S | 3428.4 |
| USB-1 | 0 | 81 | - | 22 | 61 - 81 | 49 to BH | S | 3462.6 |
| USB-2 | 18.5 | 81 | - | 0 | 161 - 181 | 55 to BH | S | 3440.9 |
| USB-3 | 35 | 70 | 27 | 34 | - | - | - | 3580.7 |
| USB-4 | 0 | 25 | - | Dry | - | - | - | 3646.6 |
| USB-5 | 0 | 50 | - | 26 | 30 - 50 | 25 to BH | S | 3516.0 |
| LCTM-8 | 0 | 140 | (?) | 11 | 33 - 93 | 26 to 94 | S | 3380.5 |
| LCM-9 | 0 | 72 | 65 | 8 | 57 - 67 | 56 to 64 | S | 3420.6 |

TABLE 6.2

SUMMARY OF FIELD PERMEABILITY TEST RESULTS

| Boring or Well | Material | Type of Test | Permeability ($10^{-6}$ cm/sec) |
|---|---|---|---|
| USB-3 | Highly weathered rock | Packer Test | <1 to 30 |
| USB-4 | Silty sandy gravel, cobbles and boulders | Constant Head | 100 to 2000 |
| USB-5 | Gravelly silty sand | Constant Head | 10 to 70 |
| | Silty clay-clayey silt | Constant Head | 3 to 7 |
| LCTM-8* | Silty sandy gravel, cobbles and boulders | Pump Test | 100 |
| LCM-9* | Silty gravel with boulders | Slug Test | 80 |
| LCM-10* | Gravel, silt and sand | Slug Test | 2 |
| LCM-11* | Silty sandy gravel, cobbles and boulders | Slug Test | 20 |
| PLCM-6* (shallow) | Silty sandy gravel | Slug Test | 2000 |
| PLCM-6* (deep) | Silty sandy gravel | Flow Test (Constant Drawdown) | 5000 to 7000 |
| DH-1 | Gravelly sandy silt | Constant Head | <1 to 6 |
| | Highly weathered rock | Packer Test | 2 |
| DH-2 | Highly weathered rock | Packer Test | 16 to 234 |
| DH-4 | Weathered rock | Packer Test | 17 |
| DH-5 | Clayey sandy silt, cobbles and boulders | Constant Head | <1 to 28 |
| | Weathered rock | Packer Test | <1 to 2 |

**Notes:**

* From Chen-Northern (1989)

TABLE 6.2

SUMMARY OF FIELD PERMEABILITY TEST RESULTS
(CONTINUED)

| Boring or Well | Material | Type of Test | Permeability ($10^{-5}$ cm/sec) |
|---|---|---|---|
| DH-6 | Clayey sandy silt, cobbles and boulders | Constant Head | 39 |
| DH-7 | Weathered rock | Packer Test | <1 to 80 |
| DH-8 | Weathered rock | Packer Test | 5 |
| DH-9 | Highly weathered rock | Packer Test | 72 to 115 |
| DH-10 | Weathered rock | Packer Test | 130 to 720 |
| DH-11 | Gravel, sand, silt, and clay | Packer Test | 7 |
| | Highly weathered rock | Packer Test | 2 |
| DH-13 | Weathered rock | Packer Test | 2 to 145 |
| DH-14 | Highly weathered rock | Packer Test | 12 to 46 |
| DH-17 | Cobbles, gravel, and clayey sandy silt | Constant Head | <1 |
| | Weathered rock | Packer Test | <1 |
| DH-18 | Clayey sandy silt | Constant Head | <1 to 2 |
| DH-19 | Weathered rock | Packer Test | 87 to 195 |
| DH-20 | Clayey sandy silt matrix in gravels, cobbles and boulders | Constant Head | <1 to 2 |
| | Weathered rock | Packer Test | <1 to 2 |

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KEY PLAN

25 0 25 50
SCALE MILES

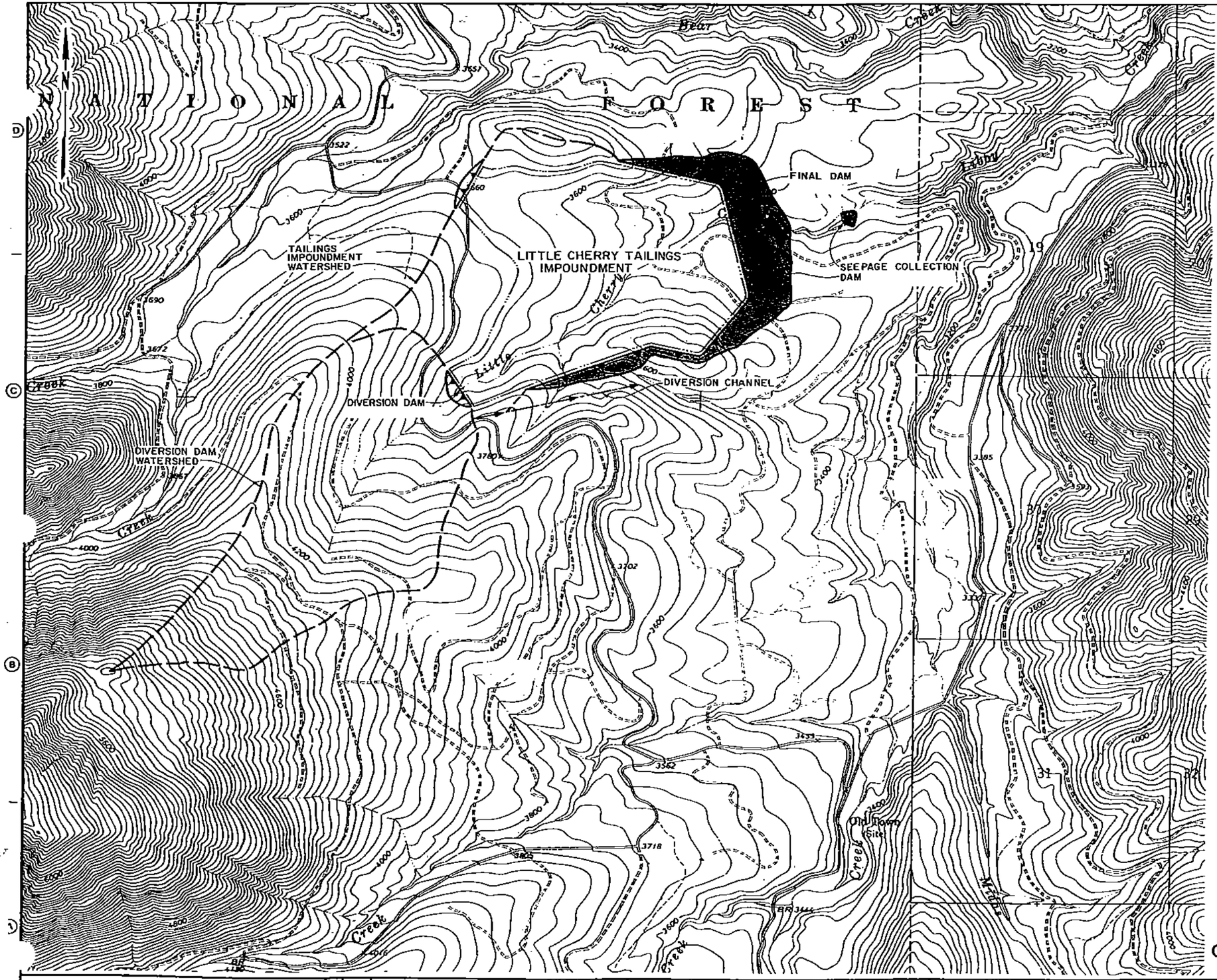
MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

| DESIGNED RB | DRAWN RB | CHECKED MPF | RECOMMENDED |
|---|---|---|---|
| DATE OCTOBER 1988 | | | APPROVED |

MONTANA PROJECT

PROJECT LOCATION MAP

FIGURE 1




REFERENCE:

U.S. GEOLOGICAL SURVEY, 7.5 MINUTE CABLE MOUNTAIN TOPOGRAPHICAL QUADRANGLE

**CONCEPTUAL-NOT FOR CONSTRUCTION**

1000 0 1000 2000
SCALE FEET

| NO | DATE | REVISIONS | BY | CHK | APPD |
|---|---|---|---|---|---|

MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

| DESIGNED CFS | DRAWN AMC | CHECKED MPF | RECOMMENDED |
|---|---|---|---|
| DATE DECEMBER 1989 | | | APPROVED |

NORANDA MINERALS CORPORATION

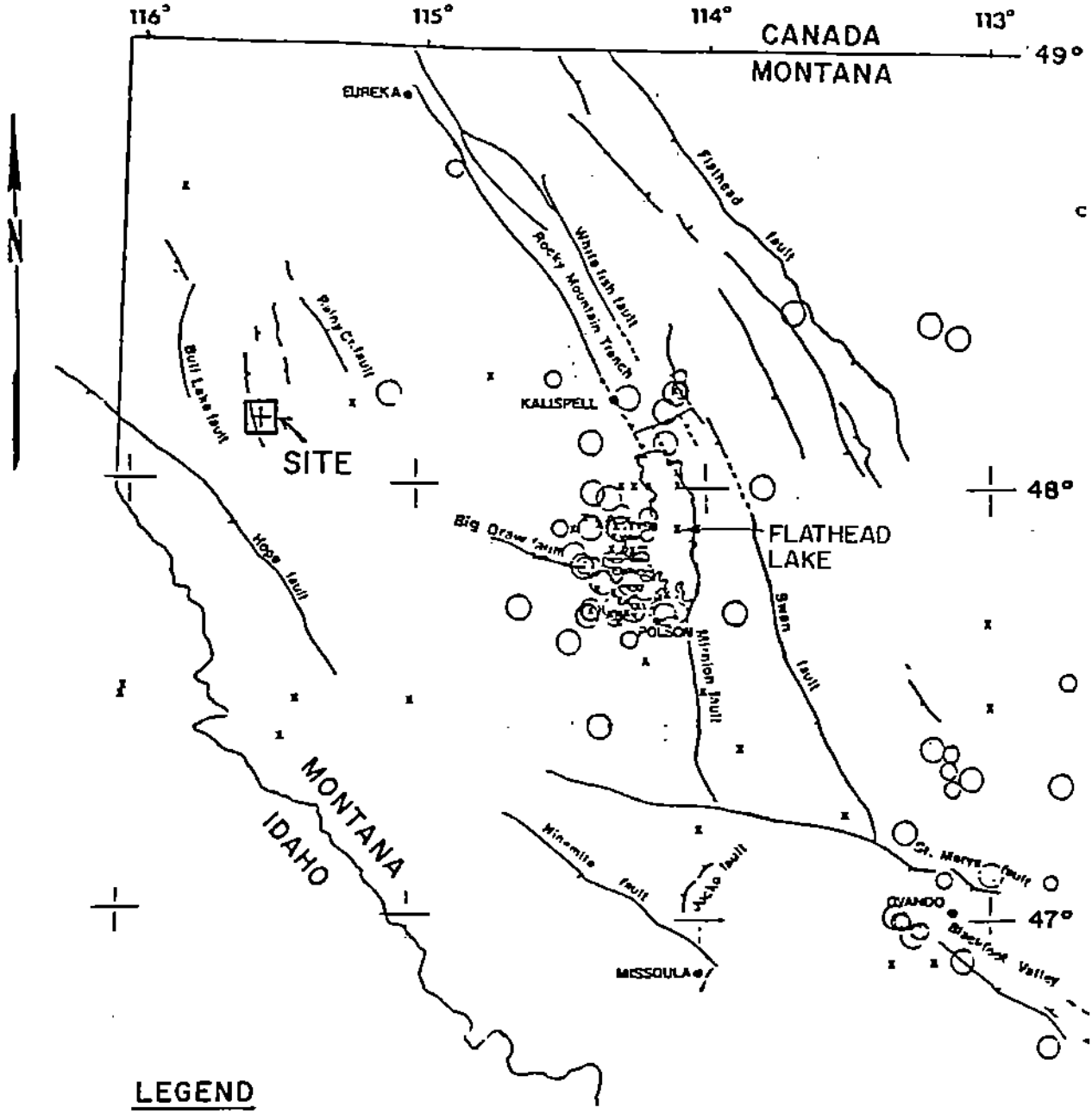
MONTANA PROJECT

# VICINITY PLAN & WATERSHED AREAS

MKE NO

SHEET OF REV.

FIGURE 2




## LEGEND

(Earthquake epicenters shown are from NOAA hypocenter data file.)

| Epicenter | Magnitude |
|---|---|
| ◯ | 7 |
| ◯ | 5 |
| ○ | 3 |
| X | not computed |

Normal fault—bars on downthrown side; dashed where inferred.

Strike-slip fault.

Sources: Qamar and Stickney (1983) and Witkind (1977)

10 0 10 20 30 40
SCALE MILES

MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

| | | |
|---|---|---|
| DESIGNED FCK | DRAWN | CHECKED HPF |
| DATE OCTOBER 1988 | | APPROVED |

MONTANA PROJECT

# HISTORICAL EARTHQUAKES IN MONTANA, 1869-1979

FIGURE 3

N490,000 N488,000 N486,000 N484,000

E519,000 E521,000 E523,000 E525,000 E527,000 E529,000 E531,000

MSV-8 MSV-31 MSV-32 MSV-29 MSV-28 MSV-26 MSV-27 MSV-10 MSV-11 MSV-40 MSV-33 MSV-30 MSV-39 MSV-6 MSV-7 MSV-38 MSV-37 MSV-36 MSV-35 MSV-34 MSV-5 MSV-4 MSV-3 MSV-25

DT-1 DT-2 DT-3 DT-4 DT-5 DT-6

DH-1 DH-2 DH-3 DH-4 DH-5 DH-6 DH-7 DH-8 DH-9 DH-10 DH-11 DH-12 DH-13 DH-14 DH-15 DH-17 DH-18 DH-19 DH-20

USB-1 USB-2 USB-3 USB-4 USB-5

LCM-9 LCM-10 LCM-11 CTM-8 PLCM-6

TP-101 TP-102 TP-103 TP-104 TP-105 TP-106 TP-107 TP-108 TP-109 TP-110 TP-120 TP-121 TP-122 TP-123 TP-124 TP-125 TP-126 TP-127 TP-128 TP-129 TP-130 TP-131 TP-132 TP-133 TP-134 TP-135 TP-136 TP-137 TP-138 TP-139 TP-140 TP-141 TP-142 TP-143 TP-144 TP-145 TP-146 TP-147

TI-9 TI-10 TI-11 TI-12 TI-13 TI-14 TI-15

89-1 89-2 89-3 89-4 89-5 89-6 89-7 89-8 89-9 89-10 89-11 89-12 89-13 89-14 89-15 89-16 89-17 89-18 89-19 89-20 89-21 89-22 89-23 89-24 89-25 89-26 89-27 89-28 89-29 89-30 89-31 89-32 89-33 89-34 89-35

APPROX. OUTLINE OF BORROW AREA

OUTLINE OF TAILINGS RETENTION DAM

LITTLE CHERRY CREEK

DIVERSION DAM

OUTLINE OF DIVERSION CHANNEL

SEEPAGE COLLECTION DAM

42° 52° 38° 35° 85°

NOTE:

BORING, MONITOR WELL AND 1988 TEST PIT LOCATIONS WERE PLOTTED FROM SURVEY DATA PROVIDED BY OTHERS. 1989 TEST PITS AND DENSITY TEST PITS ARE VISUALLY LOCATED.

REFERENCE:

TOPOGRAPHICAL BASE FROM 1988 AERIAL PHOTOGRAPHY.

LEGEND:

- BORING
- TEST PIT
- MONITOR WELL (BY NORTHERN ENGINEERING & TESTING)
- SEISMIC LINE (APPROX. LOCATION, F = FORWARD END R = REVERSE END)
- ROCK OUTCROP (HIGHLY WEATHERED)
- GRAVEL PIT
- ROCK OUTCROP (SLIGHTLY WEATHERED)
- APPROX. LOCATION, RESISTIVITY SOUNDING STATION (BY NORTHERN ENGINEERING & TESTING)
- DENSITY TEST SITE
- SPRING (INVENTORIED JULY 1989)
- STRIKE AND DIP OF BEDDING
- STRIKE AND DIP OF JOINTING

SCALE 400 0 400 800 FEET

| NO. | DATE | REVISIONS | BY | CHK | APPD. |
|---|---|---|---|---|---|

MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

DESIGNED CFS | DRAWN RBC | CHECKED BPF, JTK | RECOMMENDED
DATE NOVEMBER 1989 | APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
EXPLORATION PLAN

WKE NO
SHEET OF REV.

FIGURE 4

NOTE:

THE ESTIMATED ROCK SURFACE CONTOURS ARE BASED ON INTERPRETATION OF SURFACE, DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE CONTOURS MAY DIFFER FROM THOSE SHOWN ON THE MAP.

LEGEND:

- 3545' — BORING, WITH ELEVATION OF BEDROCK
- TEST PIT (WITH ELEVATION OF BEDROCK IF ENCOUNTERED)
- MONITOR WELL (BY NORTHERN ENGINEERING & TESTING)
- F — R — SEISMIC LINE (APPROX. LOCATION, F = FORWARD END R = REVERSE END)
- ROCK OUTCROP (HIGHLY WEATHERED)
- GRAVEL PIT
- ROCK OUTCROP (SLIGHTLY WEATHERED)
- X — APPROX. LOCATION, RESISTIVITY SOUNDING STATION (BY NORTHERN ENGINEERING & TESTING)
- DENSITY TEST SITE
- SPRING (INVENTORIED JULY 1989)
- BEDROCK CONTOUR LINE
- INTERMEDIATE CONTOUR LINE

REFERENCE:

TOPOGRAPHICAL BASE FROM 1988 AERIAL PHOTOGRAPHY

SCALE 400 0 400 800 FEET

| NO. | DATE | REVISIONS | BY | CHK | APPD. |
|---|---|---|---|---|---|

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180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

| DESIGNED CFS | DRAWN RBC | CHECKED PTL | RECOMMENDED |
|---|---|---|---|
| DATE NOVEMBER 1989 | | | APPROVED |

NORANDA MINERALS CORPORATION

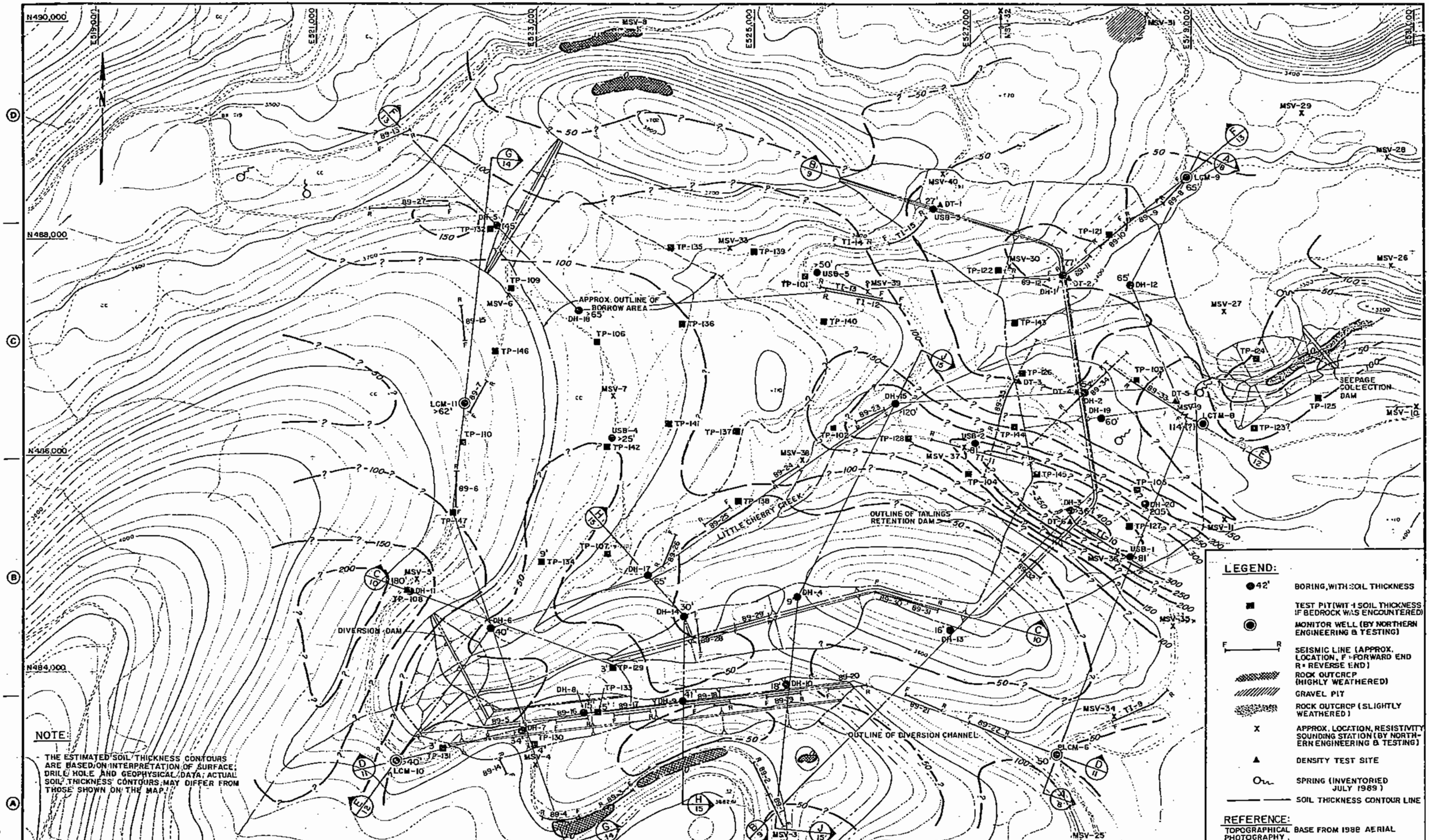
MONTANA PROJECT

# LITTLE CHERRY SITE BEDROCK CONTOUR MAP

JOB NO.

SHEET OF REV.

FIGURE 5

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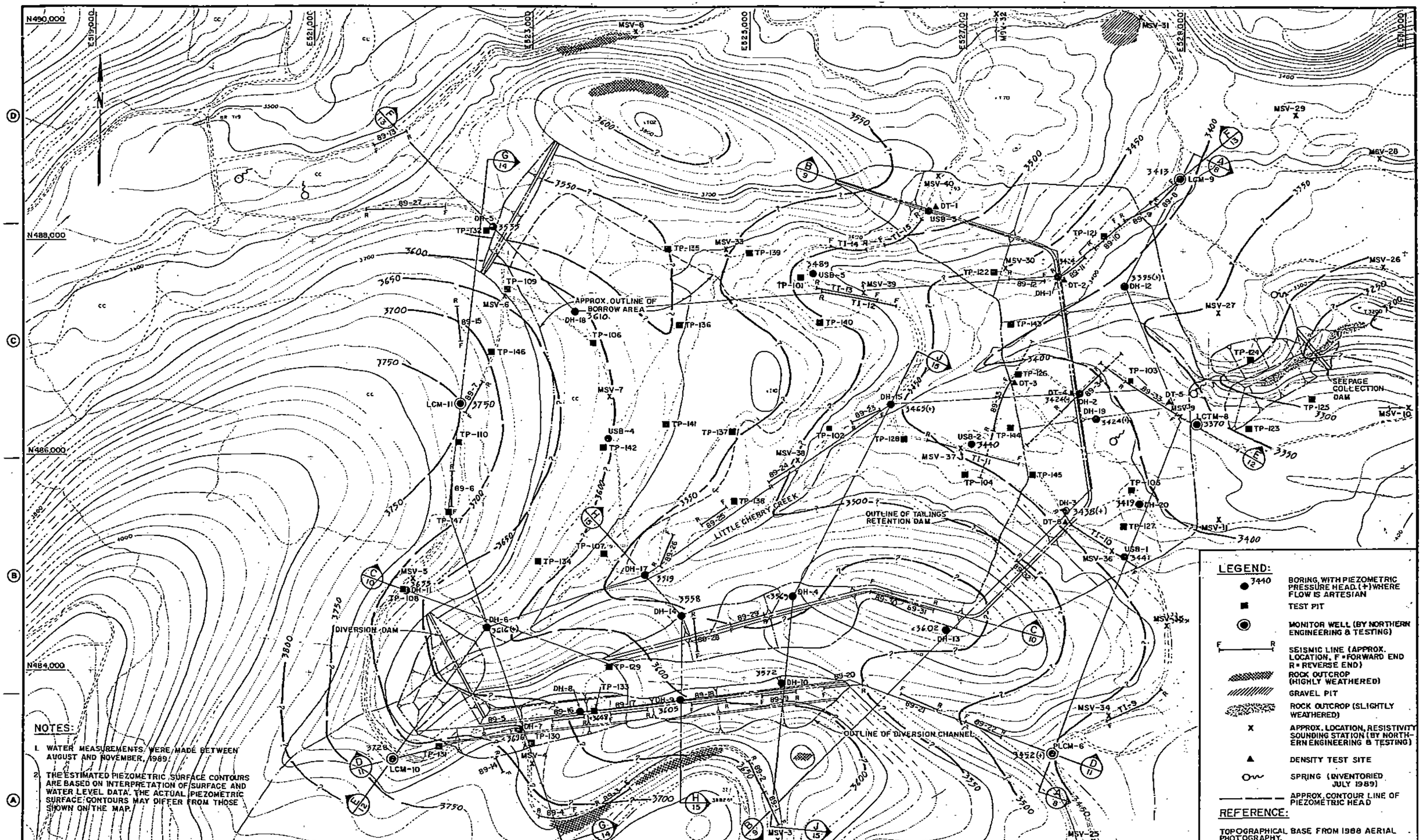
DATE NOVEMBER 1989 | APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
SOILS ISOPACH MAP

MKE NO
SHEET OF REV.

FIGURE 6

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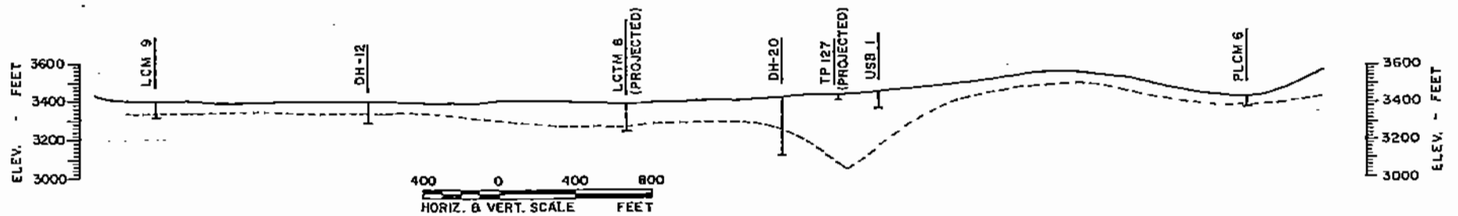
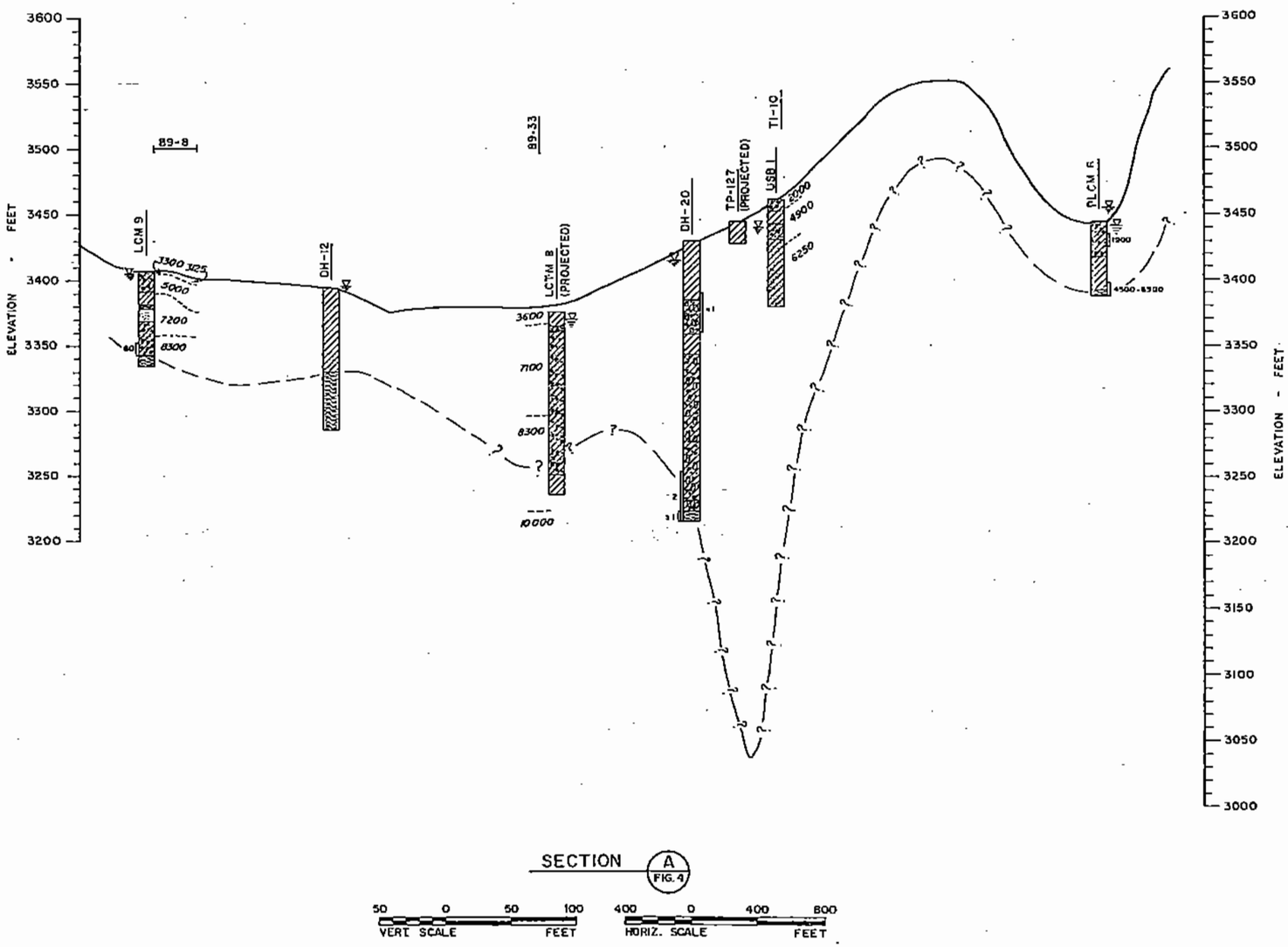
NORANDA MINERALS CORPORATION

MONTANA PROJECT

LITTLE CHERRY SITE
PIEZOMETRIC SURFACE MAP

FIGURE 7







SECTION A (FIG. 4)

50 0 50 100 VERT SCALE FEET

400 0 400 800 HORIZ. SCALE FEET

## NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCM-6 AND DH-3.

## LEGEND:

- 89-10 — SEISMIC LINE LONGITUDINAL TO SECTION
- 89-11 — SEISMIC LINE TRANSVERSE TO SECTION
- DH-1 — BORING
- ML, ML-CL* — SILT, SILT-CLAY
- PIEZOMETRIC SURFACE
- SW, SP, GW, GP* — SAND, GRAVEL
- 121 — PERMEABILITY VALUES (NORMALIZED TO 10-6 CM/SEC)
- ML-SM, SM* — SILT-SAND
- GM, GM-GP* — GRAVEL-SILT
- COBBLES AND/OR BOULDERS (IN COMBINATION WITH ANY OF THE SOILS DESIGNATED ABOVE)
- WEATHERED BEDROCK
- 2300 / 6000 — SEISMIC VELOCITY (FT/SEC) SHOWING APPROX. VELOCITY INTERFACES)
- TP-101 — TEST PIT
- ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA, QUERIED WHERE INFERRED

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

| NO. | DATE | REVISIONS | BY | CHK | APPD. |
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180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

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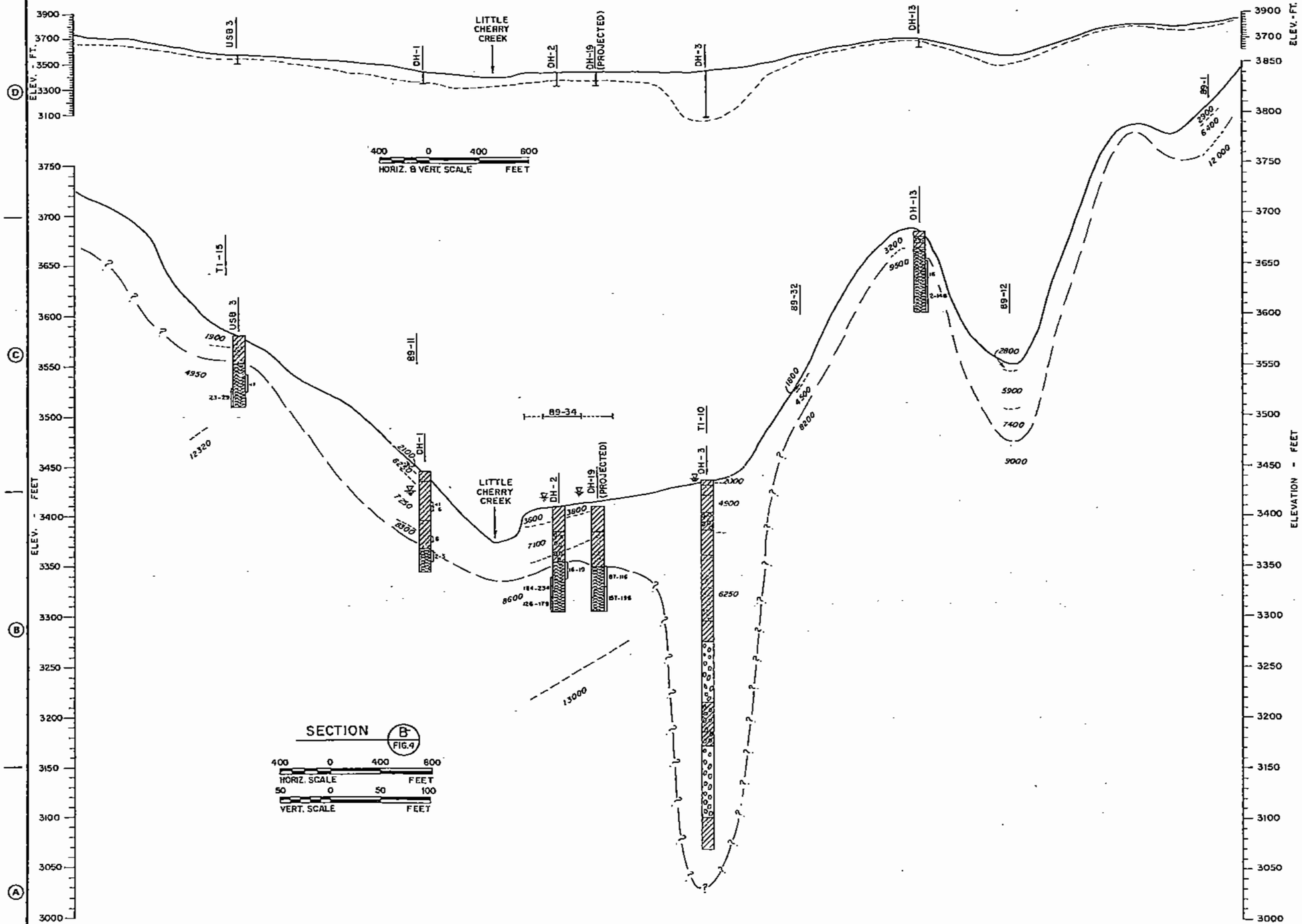
DATE NOV. 1989 | APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION A

MKE NO
SHEET OF REV.
FIGURE 8

DHTEACH-POST BEDROCK MO 111 19




## NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCM-6 AND DH-3.

## LEGEND:

- 89-10 — SEISMIC LINE LONGITUDINAL TO SECTION
- 89-11 — SEISMIC LINE TRANSVERSE TO SECTION
- DH-1 — BORING
- ML, ML-CL*
- PIEZOMETRIC SURFACE
- SW, SP, GW, GP*
- 27 — PERMEABILITY VALUES (NORMALIZED TO 10-6 CM/SEC)
- ML-SM, SM*
- GM, GM-GP*
- COBBLES AND/OR BOULDERS (IN COMBINATION WITH ANY OF THE SOILS DESIGNATED ABOVE)
- WEATHERED BEDROCK
- 2300 / 4000 — SEISMIC VELOCITY (FT/SEC) SHOWING APPROX. VELOCITY INTERFACES)
- TP-101 — TEST PIT
- ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA, QUERIED WHERE INFERRED

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX. MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

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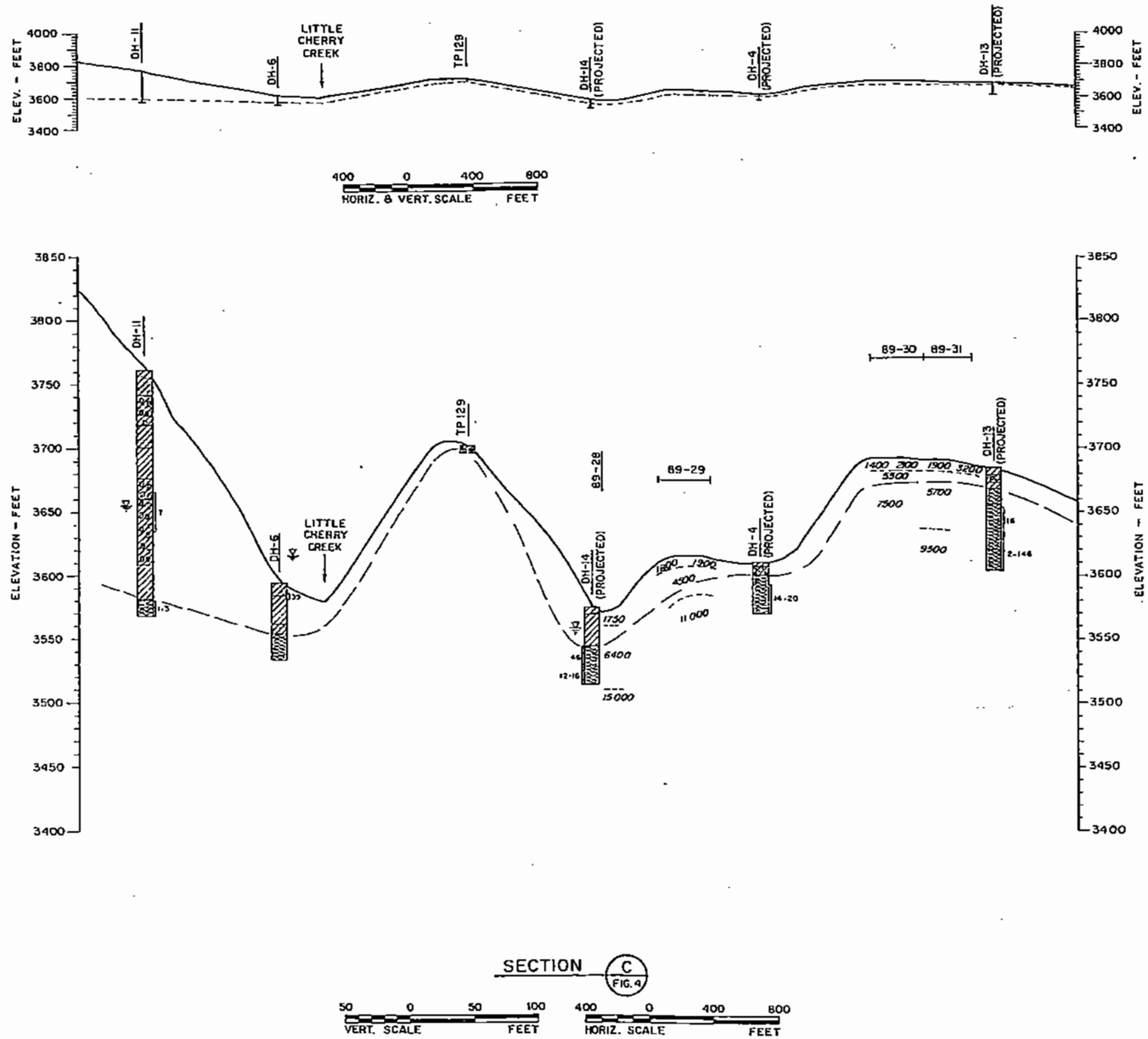
DATE NOV. 1989 | APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION B

MKE NO. | SHEET OF | REV.

FIGURE 9




## NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCM-6 AND DH-3.

## LEGEND:

- 89-10 — SEISMIC LINE LONGITUDINAL TO SECTION
- 89-11 — SEISMIC LINE TRANSVERSE TO SECTION
- DH-1 — BORING
- ML, ML-CL*
- PIEZOMETRIC SURFACE
- SW, SP, GW, GP*
- 27 — PERMEABILITY VALUES (NORMALIZED TO $10^{-6}$ CM/SEC)
- ML-SM, SM*
- GM, GM-GP*
- COBBLES AND/OR BOULDERS (IN COMBINATION WITH ANY OF THE SOILS DESIGNATED ABOVE)
- WEATHERED BEDROCK
- 7300 / 4000 — SEISMIC VELOCITY (FT/SEC) SHOWING APPROX. VELOCITY INTERFACES)
- TP-101 — TEST PIT
- ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA, QUERIED WHERE INFERRED

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX. MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

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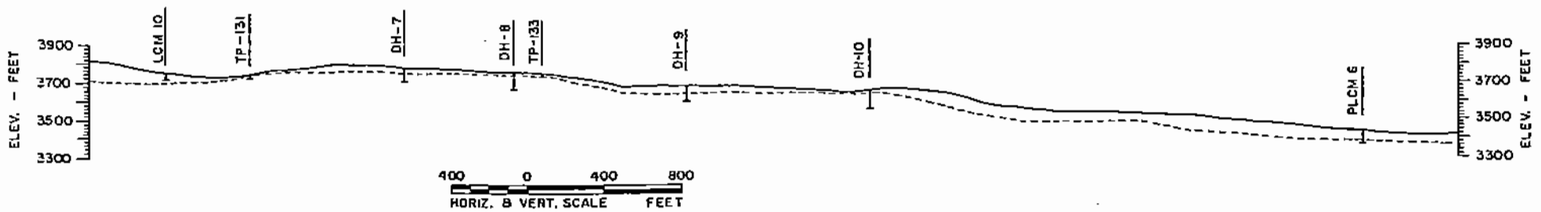
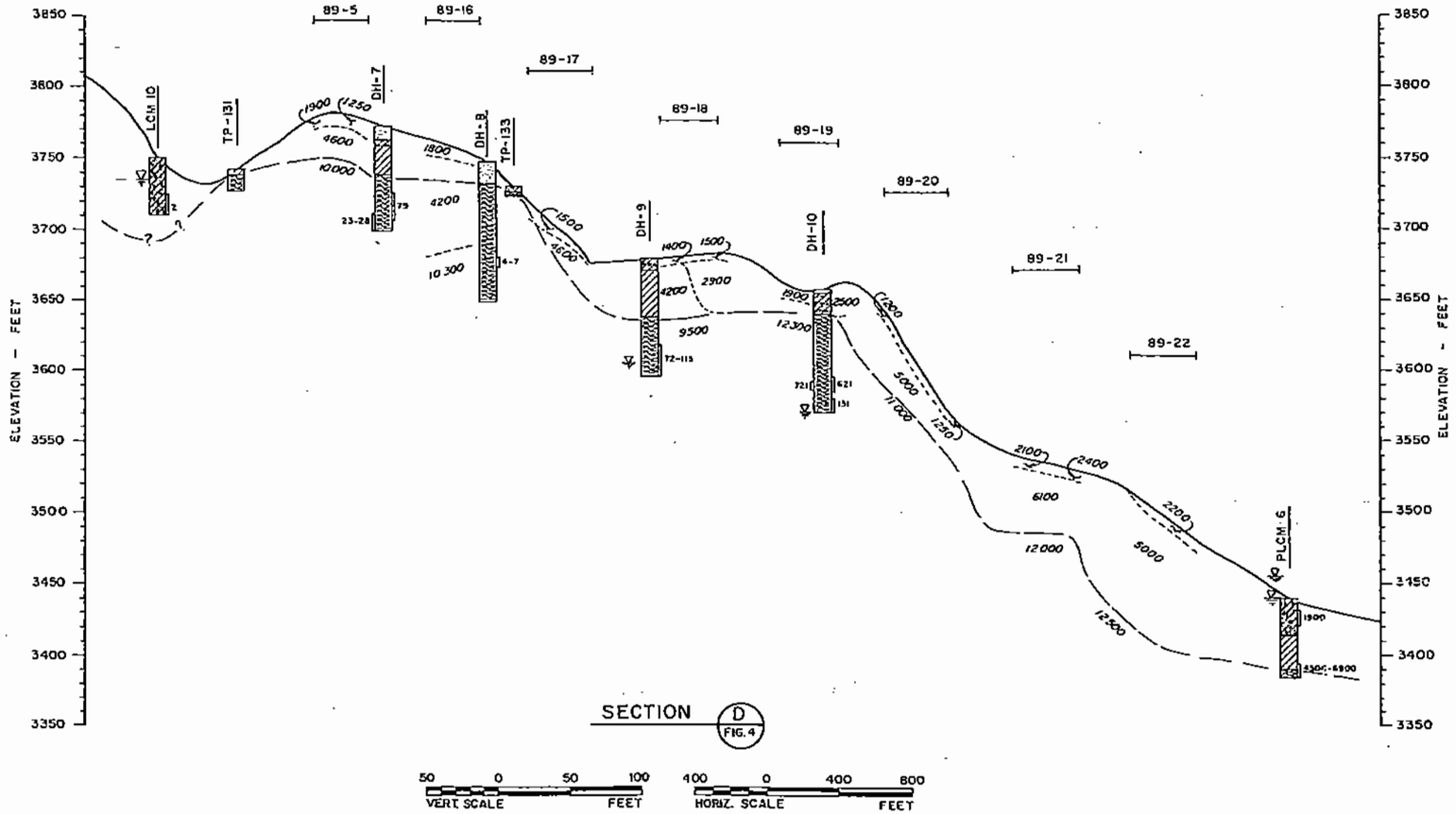
NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION C

MKE NO.
SHEET OF REV.
FIGURE 10

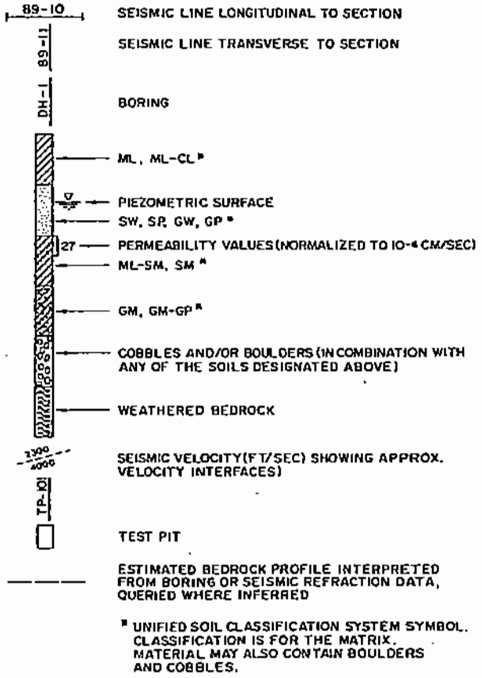



## NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCM-6 AND DH-3.

## LEGEND:




* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX. MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

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NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION D

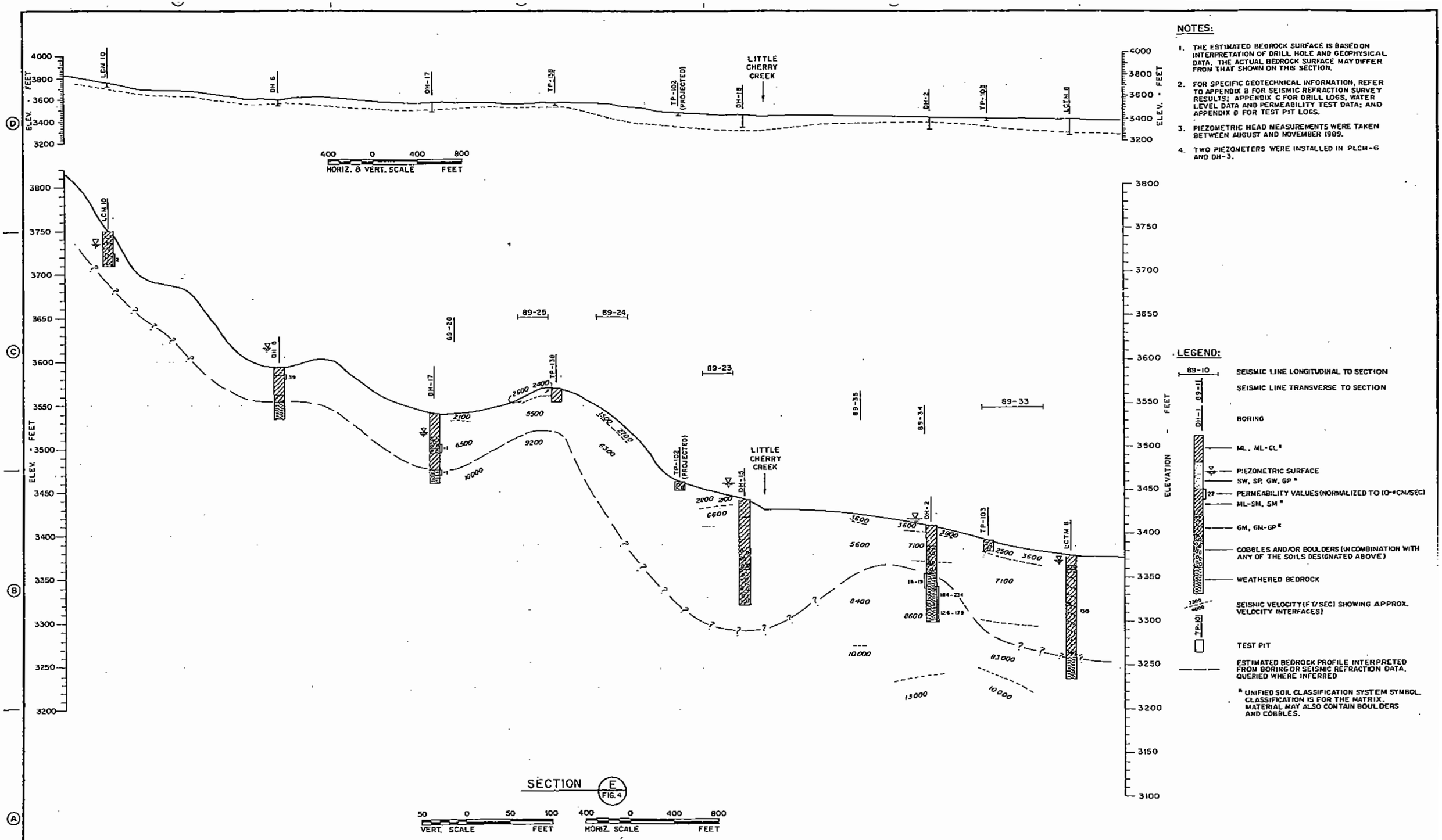
MKE NO.
SHEET OF REV.
FIGURE 11

DIETZGEN PRINT RECORDER NO. 11120

④ ③ ② ①

## NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCM-6 AND DH-3.




## LEGEND:

- 89-10 — SEISMIC LINE LONGITUDINAL TO SECTION
- 89-11 — SEISMIC LINE TRANSVERSE TO SECTION
- DH-1 — BORING
- ML, ML-CL* — PIEZOMETRIC SURFACE
- SW, SP, GW, GP*
- 27 — PERMEABILITY VALUES (NORMALIZED TO 10⁻⁴ CM/SEC)
- ML-SM, SM*
- GM, GM-GP*
- COBBLES AND/OR BOULDERS (IN COMBINATION WITH ANY OF THE SOILS DESIGNATED ABOVE)
- WEATHERED BEDROCK
- 2360 4000 — SEISMIC VELOCITY (FT/SEC) SHOWING APPROX. VELOCITY INTERFACES)
- TP-10 — TEST PIT
- ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA, QUERIED WHERE INFERRED

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX. MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

SECTION E (FIG. 4)

50 0 50 100 VERT. SCALE FEET

400 0 400 800 HORIZ. SCALE FEET

| NO. | DATE | REVISIONS | BY | CHK. | APP'D. |
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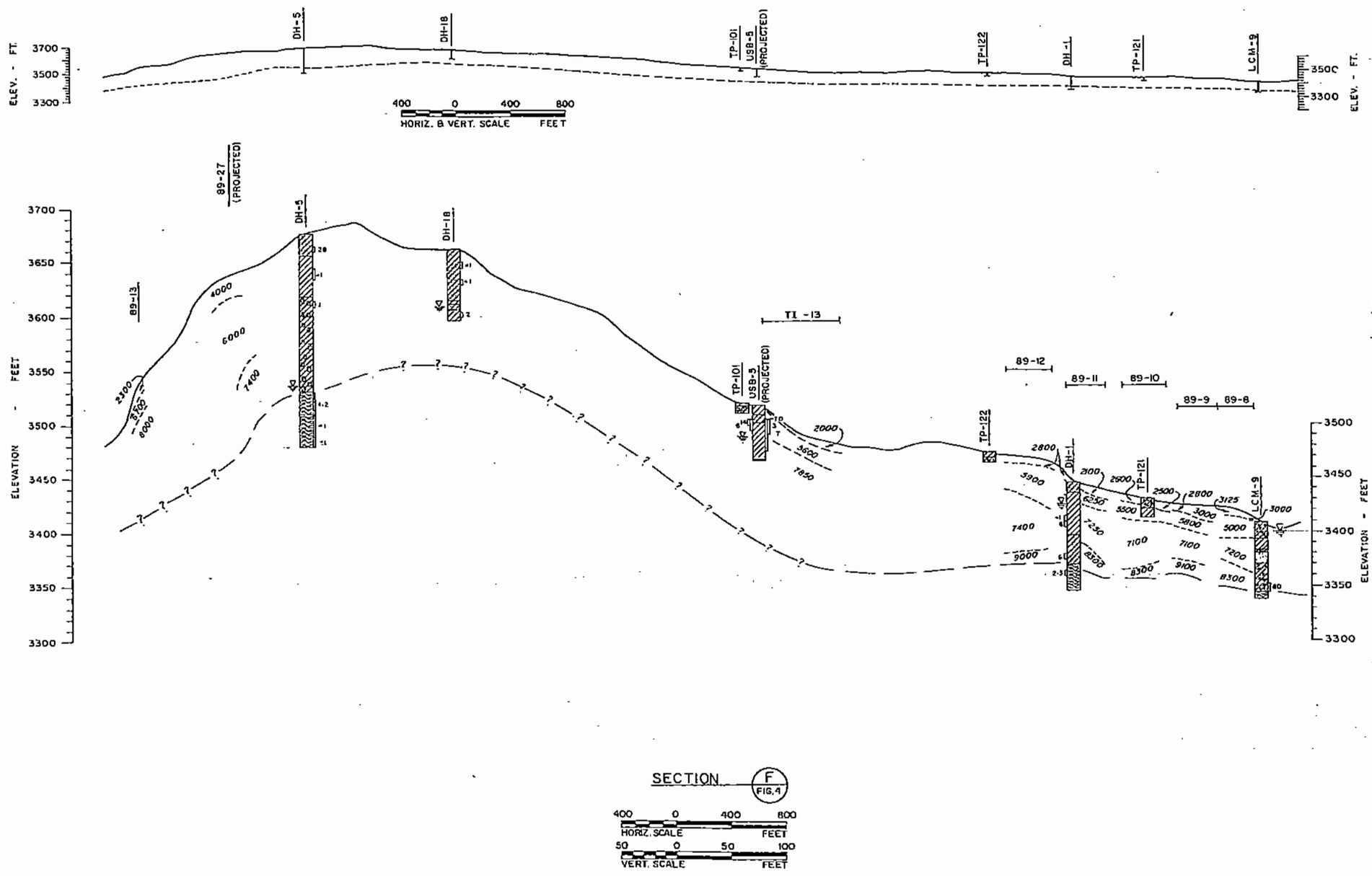
NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION E

JOB NO.
SHEET OF REV.
FIGURE 12

NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCM-6 AND DH-3.




SECTION F (FIG. 4)

400 0 400 800
HORIZ. SCALE FEET
50 0 50 100
VERT. SCALE FEET

LEGEND:

- 89-10 — SEISMIC LINE LONGITUDINAL TO SECTION
- 89-11 — SEISMIC LINE TRANSVERSE TO SECTION
- DH-1 — BORING
- ML, ML-CL* — PIEZOMETRIC SURFACE
- SW, SP, GW, GP* — PERMEABILITY VALUES (NORMALIZED TO 10-6CM/SEC)
- 27 — ML-SM, SM*
- GM, GM-GP*
- COBBLES AND/OR BOULDERS (IN COMBINATION WITH ANY OF THE SOILS DESIGNATED ABOVE)
- WEATHERED BEDROCK
- 2300 / 4000 — SEISMIC VELOCITY (FT/SEC) SHOWING APPROX. VELOCITY INTERFACES)
- TP-101 — TEST PIT
- ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA, QUERIED WHERE INFERRED

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX. MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

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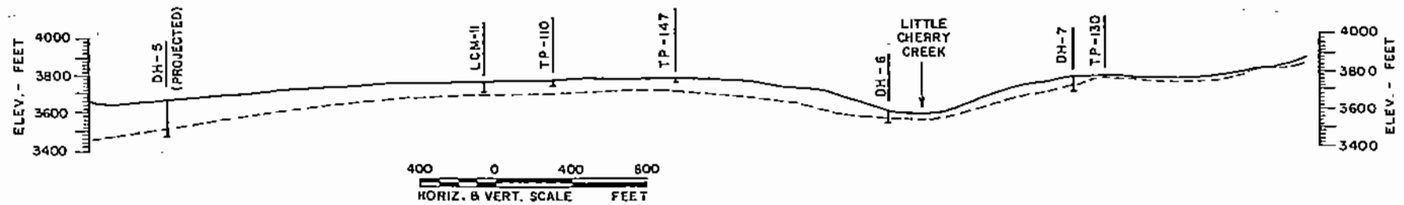
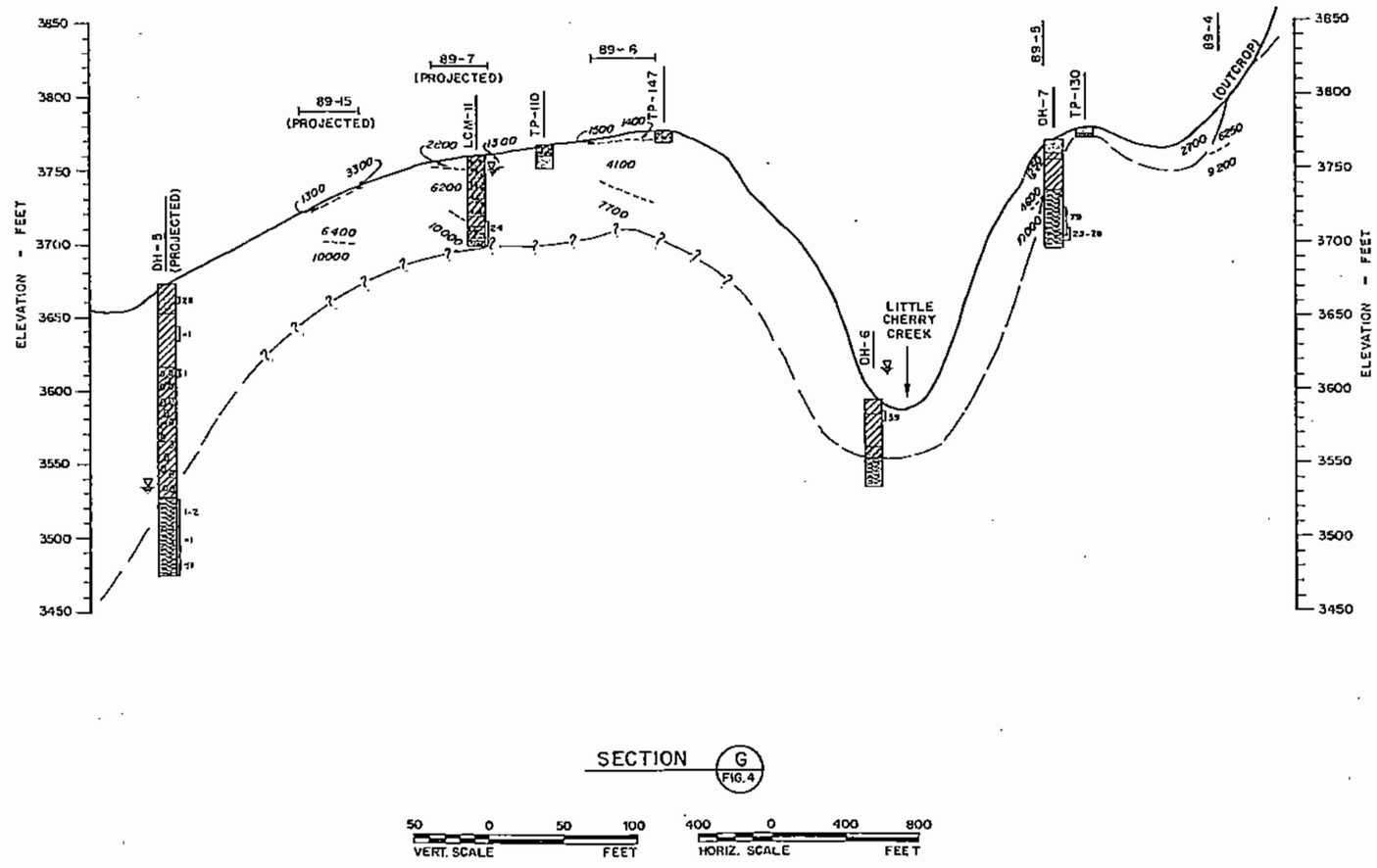
NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION F

MKE NO.
SHEET OF REV.
FIGURE 13

DIETZGEN-POST RECORD NO. 81139

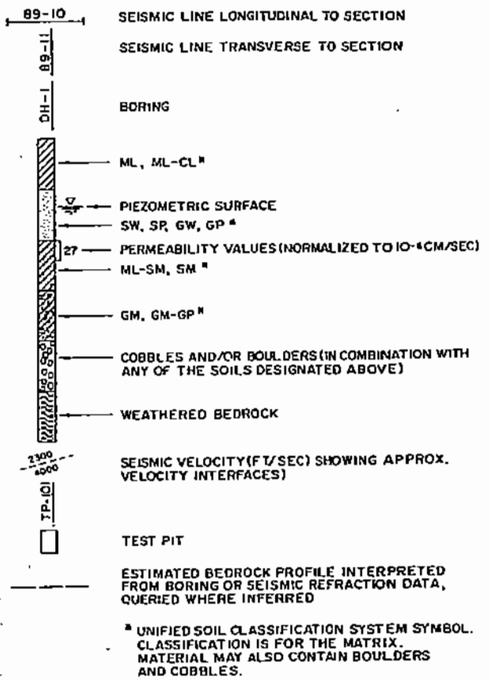



## NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCM-6 AND DH-3.

## LEGEND:




* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX. MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

| NO. | DATE | REVISIONS | BY | CHK. | APPD |
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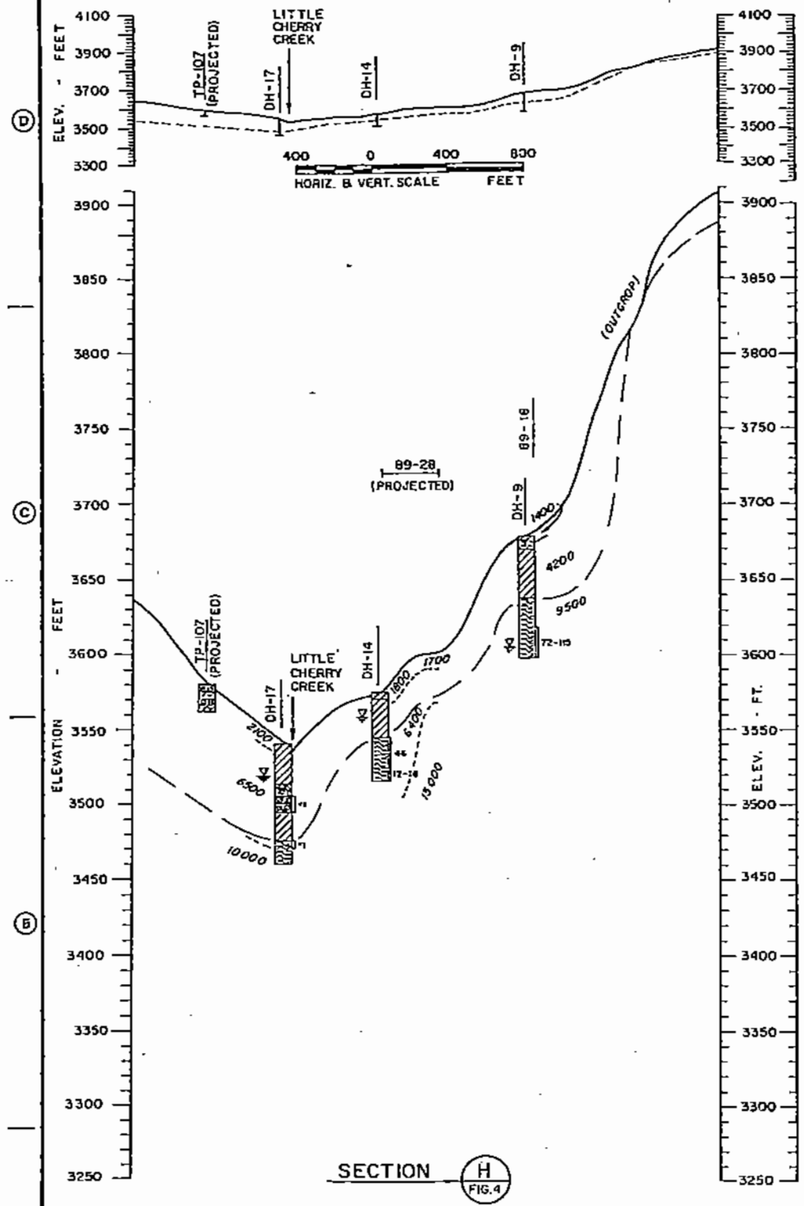
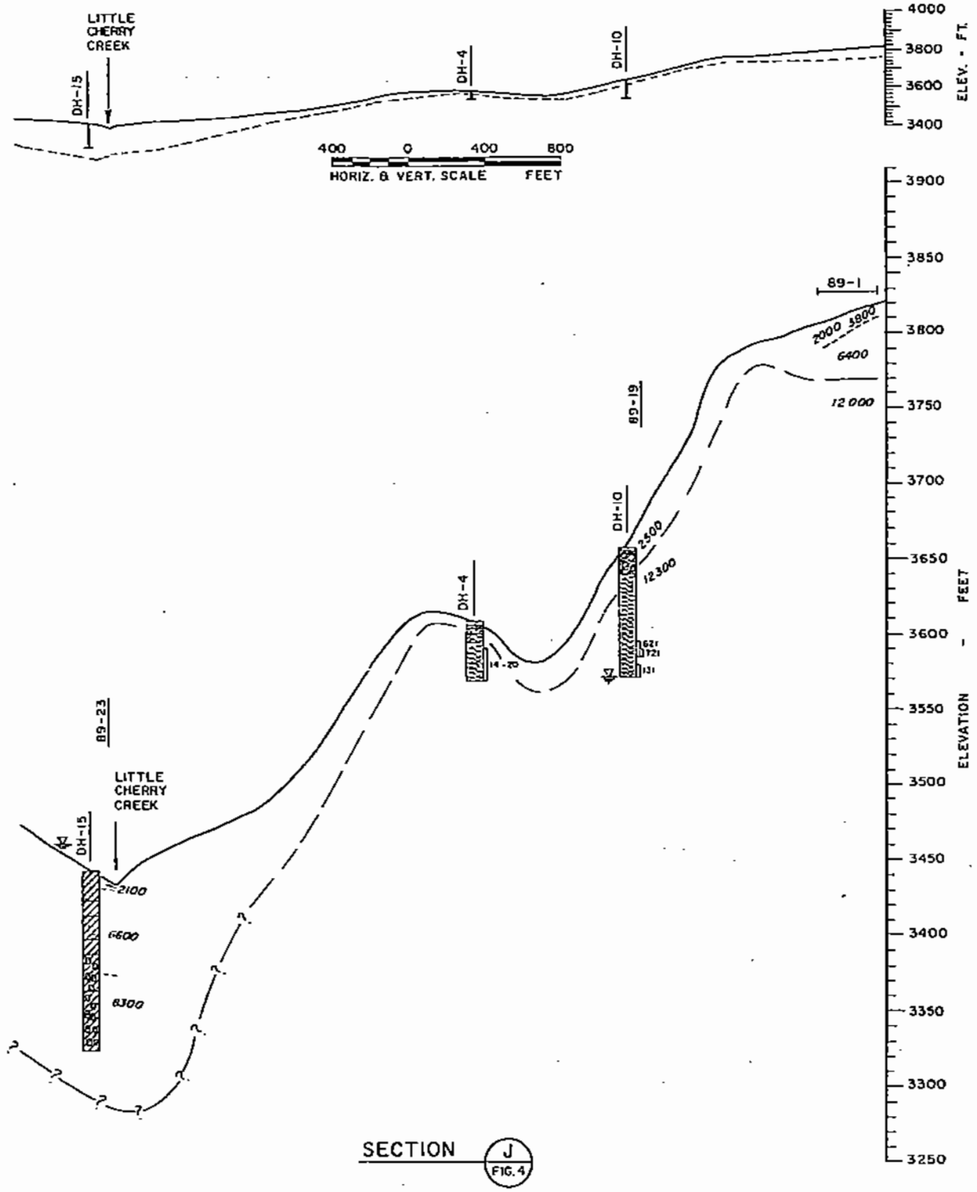
NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION G

MKE NO.
SHEET OF REV.
FIGURE 14




SECTION H FIG. 4




SECTION J FIG. 4

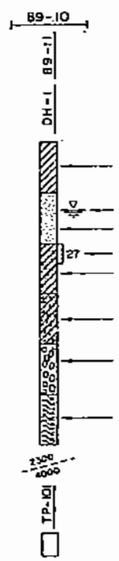
400 0 400 800
HORIZ. SCALE FEET

50 0 50 100
VERT. SCALE FEET

NOTES:

1. THE ESTIMATED BEDROCK SURFACE IS BASED ON INTERPRETATION OF DRILL HOLE AND GEOPHYSICAL DATA. THE ACTUAL BEDROCK SURFACE MAY DIFFER FROM THAT SHOWN ON THIS SECTION.
2. FOR SPECIFIC GEOTECHNICAL INFORMATION, REFER TO APPENDIX B FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX C FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX D FOR TEST PIT LOGS.
3. PIEZOMETRIC HEAD MEASUREMENTS WERE TAKEN BETWEEN AUGUST AND NOVEMBER 1989.
4. TWO PIEZOMETERS WERE INSTALLED IN PLCN-6 AND DH-3.

LEGEND:




SEISMIC LINE LONGITUDINAL TO SECTION

SEISMIC LINE TRANSVERSE TO SECTION

BORING

PERMEABILITY VALUES (NORMALIZED TO $10^{-4}$ CM/SEC)

COBBLES AND/OR BOULDERS (IN COMBINATION WITH ANY OF THE SOILS DESIGNATED ABOVE)

WEATHERED BEDROCK

SEISMIC VELOCITY (FT/SEC) SHOWING APPROX. VELOCITY INTERFACES)

TEST PIT

ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA, QUERIED WHERE INFERRED

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL. CLASSIFICATION IS FOR THE MATRIX. MATERIAL MAY ALSO CONTAIN BOULDERS AND COBBLES.

| NO. | DATE | REVISIONS | BY | CHK | APPD |
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MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105
DESIGNED CFS | DRAWN VZB | CHECKED JTK | RECOMMENDED
DATE NOV. 1989 | APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTIONS H & J

MKE NO
SHEET OF REV.
FIGURE 15

# APPENDIX A
# DESIGN BASIS MEMORANDUM

Noranda Minerals Corp.
Montanore Project
Design Basis Memorandum No. 8029-201-R0
General Final Design Criteria

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## 1.0 INTRODUCTION

Noranda Minerals Corporation is currently planning the further development of the Montanore Project located between Libby and Noxon in Sanders and Lincoln Counties, Montana, for mining and milling copper - silver ore. This Design Basis Memorandum describes the scope of work, design criteria and work approach for final design of the Little Cherry impoundment, to store tailings resulting from milling operations.

Structures required for tailings impoundment development include the following:

- o Tailings dam, consisting of starter dam and toe dike.
- o Two saddle dams
- o Diversion dam
- o Diversion channel
- o Seepage collection dam

A geotechnical investigation is part of the final design and the investigation supplements the 1988 geotechnical data base developed during the preliminary design stage.

## 2.0 PROJECT GOAL

The goal of the engineering work and geotechnical investigation outlined in this Design Basis Memorandum is to finalize the design for the Little Cherry tailings impoundment. To accomplish this goal, the scope of work described in Section 3.0 has been developed to (1) better define geotechnical conditions at the impoundment site, (2) prepare a final design and (3) provide construction cost estimates. The design will form the basis for which contract plans and specifications can subsequently be prepared.

## 3.0 SCOPE OF WORK

The scope of work for final design consists of the following tasks:

- o Conduct a field investigation that includes the following activities:
  - Seismic refraction surveys
  - Exploratory drilling
  - Test pit excavations
  - Laboratory testing

- o Perform the following final design studies:
  - Stability analyses
  - Tailings settlement analysis
  - Diversion channel design
  - Dam and dike design
  - Reclamation plan
  - Construction cost estimates

- o Prepare the following technical reports:
  - Geotechnical Report
  - Tailings Impoundment Final Engineering Report

- o Attend meetings with Noranda Minerals Corporation and regulatory agencies.

## 4.0 DESIGN CRITERIA

### 4.1 Tailings Production

During the operational stages of the impoundment, the embankment dam will be constructed by the downstream method using cycloned tailings sand. A two-stage cycloning process will be required to produce a sand having about 10 percent passing the No. 200 Sieve. The amount of fines should not be greater than about 10 percent in order to promote drainage within the embankment dam. The anticipated gradation of the tailings feed (based on flotation test results) is shown in Table 4-1 below:

TABLE 4-1
TAILINGS FEED GRADATION

| Tyler Sieve No. | Particle Size (Microns) | Cumulative % Passing Sieve |
|---|---|---|
| 65 | 208 | 99.5 |
| 100 | 147 | 90.2 |
| 150 | 104 | 69.4 |
| 200 | 74 | 52.1 |
| 270 | 52 | 35.9 |
| 400 | 37 | 25.0 |

For tailings impoundment sizing, the tailings production rate will be as shown in Table 4-2 below:

TABLE 4-2
TAILINGS PRODUCTION

| Year | Tailings Production (tons per day) |
|---|---|
| 1 | 11,000 |
| 2 | 15,000 |
| 3 | 15,000 |
| ≥4 | 20,000 |

The cyclone overflow (fine tailings) will be stored in the impoundment. The total required storage for both fine and coarse tailings will be about 120,000,000 tons. Coarse and fine tailings production curves and impoundment staging curves will be developed. A cyclone analysis will be done to determine the percent split of coarse and fine tailings. Dry unit weights of tailings will be determined by laboratory testing of flotation test samples (Subsection 5.2.E). For preliminary planning, the dry unit weight of the coarse tailings will be 100 pcf and for the fine tailings, 70 pcf will be used.

## 4.2 Stability

The following stability analyses will be performed:

- o Conventional static and seismic stability analyses
- o Dynamic response and deformation analyses
- o Liquefaction analyses.

Conventional stability analyses will be performed for the starter and final stages of the tailings dam. The starter dam will be evaluated for the end-of-construction, steady-state seepage and seismic conditions. The final dam will be evaluated for steady-state seepage, seismic and flood conditions. The analyses will be performed by using the strength parameters determined from the results of the laboratory testing program (Subsection 5.2.E). The tailings in the impoundment will be conservatively assumed to behave as a dense fluid and, therefore, will be assigned zero shear strength.

The minimum acceptable factors of safety for use in design are shown in Table 4-3. The criteria for long-term, end-of-construction and seismic conditions are as recommended by the Corps of Engineers (Ref. 1).

TABLE 4-3
STABILITY CRITERIA

| Load Condition | Embankment Stage | Slope | Minimum Acceptable Factor of Safety |
|---|---|---|---|
| End-of-Construction (before tailings deposition) | Starter Dam & Downstream | Upstream | 1.3 |
| Long-term (full tailings pond) | Starter and Final Dams | Downstream | 1.5 |
| Flood Condition | Final Dam | Downstream | 1.4 |
| Seismic | Starter and Final Dams | Downstream | 1.0 |

The project site is located close to the boundaries of Seismic Zones 1, 2 and 3 (see Figure 1). Based on a review of site seismicity during preliminary design, a seismic coefficient of 0.10g will be used in the seismic stability computations as recommended by the Corps of Engineers for Seismic Zone 3 (Ref. 1).

In the "pseudo-static" method of stability analysis, the effects of an earthquake on a potential slide mass are represented by an equivalent static horizontal force determined as the product of a seismic coefficient and the weight of the potential slide mass. The use of the maximum ground acceleration as the seismic coefficient would produce an equivalent static horizontal force equal to the maximum transient inertia force developed on the mass during the design earthquake. However, the length of time for which the force acts is an important factor in the development of deformations. Therefore, the use of the maximum transient force as an equivalent static force would be unduly conservative (Ref. 2) and the recommended seismic coefficient of 0.10g should be used.

An MCE event for use in both seismic deformation and liquefaction analyses was determined based on magnitudes of historical earthquakes and correlations between magnitude and length of active faults (potential activity during Pleistocene or Holocene). The MCE is defined as the largest rationally conceivable event that could occur in the tectonic environment in which the project is located (Ref. 3). For impoundment design, the MCE was determined to be as follows (Ref. 4):

- Source: Bull Lake Fault
- Distance: 20 km
- Magnitude: 7.0
- Peak Bedrock Acceleration: 0.22g

Due to the large size of the ultimate dam (nearly 400 feet high) and the potential for a strong nearby earthquake, an analysis will be conducted to confirm that embankment deformations resulting from the design earthquake will be acceptable. Of particular concern is that there should not be an excessive reduction of embankment freeboard due to seismically-induced deformations. The analysis approach is described (Subsection 5.3.A.2).

Foundation liquefaction analyses will be performed. Liquefaction is defined as the rapid build-up of pore-water pressures and the resulting loss of soil strength caused by seismic shaking (Ref. 5). Soil deposits that are particularly susceptible to liquefaction consist of loose, saturated sands. Liquefaction potential of sandy foundation soils due to the Maximum Credible Earthquake (MCE) event will be evaluated by methods outlined in Refs. 6 and 7.

## 4.3 Design Flood

The designation of the tailings impoundment design flood is based on size and hazard potential classifications. The tailings retention dam will be raised incrementally to increase impoundment storage capacity. Size classification is determined by either impoundment storage or dam stage height, whichever gives the larger size category. For this project, dam stage heights control size classification.

The distance, in river miles, to the nearest dwelling and to U.S. Highway 2 from the Little Cherry impoundment site is 5.4 and 5.7, respectively. The review agencies consider the impoundment site to have moderate to high hazard potential.

Based on dam stage size and hazard potential classifications, the agencies designated the following design flood criteria:

- For containment: 24-hour general storm Probable Maximum Precipitation (PMP)
- For diversion: 72-hour general storm Probable Maximum Flood (PMF)

Because thunderstorm events should also be considered for small watersheds, the local storm PMF (resulting from the 6-hour PMP) was also considered for diversion. This flood is the more critical of the two diversion floods and will therefore be used for diversion system design.

For interim stages less than 100 feet high that would be present for short term (less than 5 years), the containment flood will be calculated from the 24-hour general storm 1/2 PMP.

The minimum embankment dam freeboard (above the peak flood water surface) will be 3 feet.

## 4.4 Channel Design

The 6-hour local storm PMF will be used to develop the channel design flow rate. The design flow rate will be calculated by routing the inflow flood hydrograph

through the diversion pond and the diversion channel. The U.S. Army Corps of Engineers HEC-1 computer program will be used for this purpose. The peak flood inflow was computed to be 5230 cfs. (Ref. 8).

The diversion channel will have adequate longitudinal slope and cross-sectional area to pass the design flow with a minimum of 2 feet of freeboard to the top of the riprap. Velocities will be sufficiently high to flush out sediments. The channel will have a trapezoidal cross-section. The bottom width, side slopes and channel gradient will be designed to promote stability and minimize erosion potential.

To protect against erosion, portions of the channel in soil will be lined with rock riprap. The Safety Factors Method (Ref. 9) will be used to design the median (D50-min) rock size. Rock properties, including specific gravity, friction angle and porosity, will be estimated from published values that are typical for riprap. Manning's roughness coefficient will be calculated using the U.S. Army Corps of Engineers method (Ref. 10).

Gradation and thickness of the riprap lining will be designed based on the Corps of Engineers method (Ref. 10). Bedding layers beneath the riprap will be provided to prevent the migration of finer subgrade materials through riprap materials. Filter criteria for the bedding will be as indicated in Ref. 11.

The outlet will be designed to reduce flow velocities to a level that will not erode the natural material in the receiving drainage channel. This design concept could be accomplished by providing for a gradually divergent outlet and reduction of the channel slope. A rockfill toe will be provided to protect the channel outlet against potential headward erosion.

Initially, erosion protection is not planned for the stream channel downstream of the diversion channel. Erosion protection will be constructed if erosion is observed during operations. Such protection would consist of rockfill check dams to dissipate flow energy. The stream channel erosion protection would be based on the 100-year flood. If needed, check dams will be constructed of well-graded, durable rockfill that will retain sediment. The rockfill gradation will be designed to be stable under the design flood. The check dams will be keyed into the stream channel.

The spacing of the rockfill check dams will be based on check dam height, channel gradient and the expected final slope of the channel after sediment has accumulated behind the dams. For a final sediment deposit slope, the height and spacing of the check dams will be calculated to minimize the total required rockfill volume.

The check dams will be considered as broad-crested weirs and the discharge relationship will be based on weir flow formulas. Rockfill aprons will be constructed, if necessary, to dissipate energy of the flow over the check dams. The lengths of the aprons will be based on the heights of the check dams and channel slope.

4.5 Waste Rock Production

The mine waste rock available for dam construction is shown in Table 4-4 below:

TABLE 4-4
MINE WASTE ROCK SCHEDULE

| Year | Project Stage | In-Place Tons (X1000) | Cum. Tons (X1000) | Rock Designation |
|---|---|---|---|---|
| 1 | Evaluation | 192 | 192 | Crushed |
| 2 | | 187 | 379 | Crushed |
| 3 | Preproduction Development | 587 | 966 | Run of Mine |
| 4 | | 535 | 1501 | Run of Mine |
| 5 | Initial Production | 0 | 1501 | -- |
| 6 | | 664 | 2165 | Run of Mine |
| 7 | | 1091 | 3256 | Run of Mine |
| 8 | Full Production | 537 | 3793 | Gobbed in Mine |
| 9 | | 485 | 4278 | Gobbed in Mine |
| 10 | | 75 | 4353 | Gobbed in Mine |
| 11-17 | | 75/yr. | 4878 | Gobbed in Mine |
| ≥18 | | 0 | 4878 | Gobbed in Mine |

Table 4-5 shows the anticipated gradations of both crushed and run of mine waste rock. If gobbed rock is needed for construction, it will have to be crushed for transportation to a loading area via conveyor.

TABLE 4-5
WASTE ROCK GRADATIONS

| Crushed Rock | | Run of Mine Rock | |
|---|---|---|---|
| Size (in.) | % Passing | Size (in.) | % Passing |
| 10 | 100 | 24 | 100 |
| 8 | 90 | 16 | 90 |
| 7 | 80 | 13 | 80 |
| 6 | 70 | 10 | 70 |
| 5 | 60 | 9 | 60 |
| 4 | 50 | 7 | 50 |
| 3 | 40 | 5 | 40 |
| 2 | 30 | 3 | 30 |
| 1 1/2 | 20 | 2 | 20 |
| 3/4 | 10 | 1 | 10 |

The dry unit weight of all mine waste rockfill placed and compacted in embankments will be 140 pcf.

## 5.0 APPROACH

### 5.1 General

This section presents the approach for final design of the Little Cherry Tailings impoundment site. The section is divided into the following tasks as outlined in Section 3.0:

- Geotechnical Investigation
- Final Design Engineering
- Technical Reports
- Review Meetings

## 5.2 Geotechnical Investigation

A. General - A field investigation program was undertaken during the summer of 1989 to supplement the 1988 geotechnical data base developed for the permit application. The program consisted of seismic refraction surveys, drilling and test pit excavations. The locations of the 1988 and 1989 seismic lines, drill holes and test pits are shown on the Exploration Plan, Figure 2.

Due to access limitations during the initial investigation program in July and August 1988, drilling could not be performed along the diversion channel alignment. Therefore, a large part of the 1989 investigation was focused on the diversion channel.

Existing tracks and roads were used for site access to the maximum possible extent. However, since the investigation plan involved access track construction in timbered areas for drill sites, close coordination with the Forest Service was required for timber cutting and construction activities. All tracks and sites for drilling and test pits will be restored as required by the Forest Service.

B. Seismic Refraction Surveys - The subsurface investigation began with a seismic survey of the impoundment site. Seismic refraction surveys were performed along the diversion channel alignment to (1) estimate depths to bedrock, (2) confirm boring locations and (3) estimate rippability of the materials to be excavated. Seismic velocities also will be useful to contractors to estimate excavation equipment requirements. Seismic refraction surveys also were performed in the dam foundation to provide supplemental data on depths to bedrock. Thirty-five surveys were performed in the impoundment site.

C. Drilling - Drilling was done in the impoundment site to explore dam foundation conditions and materials to be excavated from the diversion channel. For the 1989 investigations, 20 borings totaling 2265 linear feet were drilled. A summary of the drilling program is shown in Table 5-1 below.

TABLE 5-1

SUMMARY OF DRILLING PROGRAM

| Area | Boring No. | Total Depth (feet) |
|---|---|---|
| Tailings Dam | DH-1 | 100 |
| | DH-2 | 110 |
| | DH-3 | 367 |
| | DH-3A | 25 |
| South Saddle Dam | DH-4 | 40 |
| North Saddle Dam | DH-5 | 197 |
| Tailings Impoundment | DH-6 | 60 |
| Diversion Channel | DH-7 | 73 |
| | DH-8 | 98 |
| | DH-9 | 82 |
| | DH-10 | 87 |
| Diversion Dam Abutment | DH-11 | 192 |
| Tailing Dam | DH-12 | 110 |
| South Saddle Dam | DH-13 | 80 |
| | DH-14 | 60 |
| Tailings Impoundment | DH-15 | 120 |
| | DH-17 | 80 |
| | DH-18 | 65 |
| Tailings Dam | DH-19 | 105 |
| | DH-20 | 214 |
| | TOTAL = | 2265 |

Eighteen borings were cased with PVC pipe to monitor groundwater levels in the dam foundation, proposed diversion channel excavation and tailings impoundment. Field permeability tests were performed in borings to supplement permeability values measured previously. Tests in overburden were performed by using constant head open-end casing tests conforming to procedures in the U.S. Bureau of Reclamation's "Earth Manual", Method E-18 (Ref. 12). Water pressure tests in bedrock were conducted by using a single pneumatic packer. Permeability tests also were performed in borings drilled in the diversion channel site. The results of these tests will indicate the magnitude of anticipated groundwater flow into the channel excavation. This information will be used to estimate groundwater control measures.

Standard Penetration Tests (SPT's) were performed in the borings at approximately 5-foot intervals to a depth of about 25 feet and at selected depths below 25 feet. The results of the SPT's will be used to characterize foundation materials for use in stability and liquefaction analyses (Subsection 5.3. A.).

Undisturbed samples were collected during the drilling program. Shelby tube samplers were used to obtain undisturbed samples of clayey soils. These samples will be used for strength testing as described in Subsection 5.2.E below.

D. Test Pits - Twenty-five backhoe test pits were excavated in the proposed borrow area and diversion channel excavation to confirm the suitability and condition of the soils for use as construction materials. Also, test pits were excavated in the impoundment site to identify any areas of permeable materials that may need to be blanketed with clayey soils. Samples from the test pits were taken for laboratory testing.

A backhoe with a 20-foot reach was used for final design exploration. All test pit sites will be restored as required by the U.S. Forest Service.

Field density tests to measure soil densities were performed in 6 shallow test pits excavated in the proposed dam foundation. The results of these tests will be used to prepare samples for strength testing as described in Subsection 5.2.E below.

E. Laboratory Testing - A laboratory testing program will be performed to obtain engineering parameters of the soil at the tailings impoundment site. The test data will be evaluated for use in dam design and stability analyses.

Testing of soil samples collected from the drilling and test pit excavation program will follow American Society for Testing and Materials (ASTM) procedures and consist of the following:

- Grain size analyses - ASTM D422
- Natural moisture contents - ASTM D2216
- Plasticity index characteristics - ASTM D4318
- In-situ dry densities - ASTM D2937

- o Moisture/density characteristics - ASTM D698
- o Relative Density - ASTM D4254
- o Triaxial compression - ASTM D2850
  (for unconsolidated-undrained tests)
- o Consolidation - ASTM D2435

Grain size and plasticity index tests will be performed to classify foundation soils and potential borrow materials. Natural moisture contents will be measured to determine requirements for construction moisture content conditioning of borrow materials. Dry densities of undisturbed soil samples will be measured for use in stability analyses. Moisture/density tests will be performed to determine maximum densities and optimum water contents for embankment construction. A relative density determination will be performed on a sand tailings sample for use in liquefaction and stability analyses (Subsection 5.3.A).

Strength parameters will be used in final design stability analyses. Unconsolidated-undrained (UU) triaxial compression tests will be performed on undisturbed samples of clayey foundation soils. Consolidated-undrained (CU) triaxial compression tests with pore pressure measurements will be performed on both foundation and embankment soil samples. Samples of granular soils from the foundation will be prepared for CU testing by compacting them to the densities and moisture contents determined from the results of field and laboratory tests. Samples from test pits excavated in borrow areas will be compacted to densities and moisture contents that are representative of those expected in the earthfill dams (i.e., 95% of the maximum dry density and at optimum moisture content as determined by ASTM D698).

Since the dam will be constructed primarily of sand tailings, CU triaxial compression test will be performed on tailings samples obtained from Noranda's flotation tests. The sand tailings sample gradation will be based on the results of cyclone analyses. Sample density will be based on research of densities reported for tailings dams.

To estimate settlement of the fine tailings (Subsection 5.3.B), consolidation tests will be performed on fine tailings samples obtained from the flotation tests. The fine tailings gradation will be based on the results of cyclone

analyses.

5.3 Final Design Engineering

A. Stability Analyses - The following analyses will be performed:

- o Limit equilibrium static and seismic stability analyses
- o Dynamic response and deformation analyses
- o Liquefaction analyses

A.1 Limit Equilibrium Analyses - Static and seismic stability analyses will be performed for the initial and final dam stages by using the Bishop and infinite slope methods of analysis. The computer program STABL (Ref. 13) or other program will be used to determine the factor of safety for circular sliding surfaces. For cohesionless materials, calculations also will be performed using the infinite slope method. The minimum factor of safety calculated for each loading condition will be compared to the minimum acceptable values given in Section 4.2. Stability will be evaluated for a wide range of phreatic surface conditions. In addition, factors of safety will be computed for various foundation piezometric surfaces. The stability analyses will be coordinated with relief well system design (Subsection 5.3.D.2).

A.2 Dynamic Response and Deformation Analyses - The peak bedrock acceleration (0.22g) determined for permit application studies (Ref. 4) will be used in the dynamic response and deformation analysis. The predominant period of the site due to design earthquake motion will be estimated from Seed, Idriss and Kiefer (Ref. 14). The duration of significant ground shaking at the site will be estimated by procedures described in Bolt (Ref. I5).

An earthquake acceleration time-history record will be selected based on peak acceleration, predominant period and site conditions that are similar to those for the project site. To compute dynamic response of the dam, the record will be scaled to the peak ground acceleration determined for this project. Response spectra will be computed to verify that the record is appropriately conservative.

The dynamic response of the dam (maximum crest acceleration) due to the design ground motion will be computed by using the computer program SHAKE (Ref. 16) for a one-dimensional seismic wave propagation analysis. Shear modulus parameters of tailings and foundation materials for use in the analysis will be obtained from published literature. Earthquake induced deformations will be estimated from the procedures developed by Makdisi and Seed (Ref. 17).

A.3 Liquefaction Analyses - Foundation liquefaction analyses will be performed. Shear stresses caused by seismic shaking (MCE acceleration) will be computed during the dynamic response analysis described in Subsection 5.3.A.2 above. The resistance of soils to liquefaction will be obtained from published correlations with Standard Penetration Test data obtained during drilling (Ref. 18). The effect of silt content in soils on liquefaction potential will be evaluated (Ref. 7). Factors of safety against potential liquefaction (resistance to liquefaction/seismic shear stress) will be computed.

B. Tailings Settlement Analysis - Settlement of the fine pond tailings will be calculated by using one-dimensional finite strain consolidation of fine-grained material. Void ratio-effective stress and void ratio-permeability relationships from one-dimensional consolidation testing will be used to estimate settlement. Estimates of settlement with time will be obtained from the results of laboratory consolidation tests and procedures that relate percent consolidation to time (Ref. 19). Procedures have been developed for different void ratio distributions within the consolidating material and different drainage boundary conditions. Consolidation of soft layers will be calculated by use of the computer program CSLFS (Consolidation of Soft Layers, Finite Strain) (Ref. 20). This information will be used for designing the final reclaimed pond surface configuration and estimating the amount of required earthwork.

C. Diversion Channel Design - The design of the diversion channel will be based on the results of the geotechnical investigation. The results of the investigation may indicate the need to revise the channel location or modify the channel invert profile.

To determine the size of the channel and diversion dam height, the design flood produced by the 6-hour local storm PMP event will be routed through the diversion pond by using HEC-1 procedures. A peak discharge of 5230 cfs produced by the 6-hour PMF (Ref. 8) will be used as the design flood to calculate flow depths and velocities in the diversion channel.

The location of bedrock will be a major consideration in channel design. Ideally, the lower portion of the channel will be in sound bedrock, thus eliminating the need for riprap. If the channel
invert will be in soil or soft rock, riprap protection will be designed to resist erosion from the routed design flood flows. The required thickness and gradation of the riprap layer will be determined from the results of hydraulic analyses. Filter requirements between the riprap and foundation soils will be determined. Flow energy dissipation measures at the downstream end of the channel will be designed to minimize potential scour. Channel side slopes will be analyzed to confirm that they will have adequate stability.

The following diversion channel drawings will be prepared:

- o Plan and Profile
- o Channel Sections and Details
- o Inlet and Outlet Plans, Sections and Details

D. Dam and Dike Design

D.1 Embankments - The earthfill embankment structures required for the Little Cherry tailings impoundment will consist of the following:

- o Tailings dam, consisting of starter dam and toe dike
- o Two saddle dams
- o Diversion dam
- o Seepage collection dam

The design of the structures developed during the preliminary stage will be used as a starting point for final design. Final construction

quantities and material availability will be estimated. Construction quantities will be used to compute mass-balance relationships.

The embankment dams will be constructed of (1) required excavation material, e.g. diversion channel, (2) materials excavated from the impoundment, (3) evaluation adit and mine waste rock and (4) tailings sands. The embankment dam zone configurations will be designed to take economical advantage of material availability.

A major effort of this work item will be directed towards designing the filter and drain system of the dam. Mine waste rock will be processed to provide materials for filters and drains. To prevent piping (internal erosion) of embankment materials the gradations of filters and drains will be designed on the basis of established filter criteria (Ref. 11). Drains will be designed to conduct estimated seepage through the dam and from the foundation to the downstream toe. Required thickness of the drain will be based on seepage volume and permeability of the drain. Permeability of the drain material will be based on the D15 size of the drain rock material (Ref. 21).

Construction requirements for the embankment zones, including material gradations, placement and compaction will be determined. These requirements will form the basis for preparing construction specifications.

The ultimate impoundment will be sized to store 120 million tons of tailings. The starter impoundment will be sized to store tailings resulting from at least the first year of production. For capacity calculations, the tailings density will be based on results of the laboratory soil testing plus experience with similar tailings materials. Area- capacity curves and tailings production rates will be used to develop construction staging curves.

Final design of the tailings dam will include an instrumentation plan to measure piezometric pressures and seepage. A plan showing the seepage measurement weir and piezometer installation details will be prepared.

The following drawings will be produced:

- o Impoundment Site Plan - Starter Stage
- o Impoundment Site Plan - Final Stage
- o Dam Sections and Details - Starter Stage
- o Dam Sections and Details - Final Stage
- o Instrumentation Plan and Installation Details
- o Construction Staging Curves

Survey control will be shown on the plans. This arrangement of drawings will expedite future preparation of construction drawings for the starter stage.

D.2 Pressure Relief Well System - The groundwater levels levels measured in borings in the dam foundation indicate that artesian pressures exist in the foundation. The highest pressure measured was 21 feet above the ground surface at Boring DH-15. In order to prevent excessive pressures from developing in the foundation during impoundment operations, a pressure relief well system will be required.

Designing the pressure relief well system requires determination of the most cost-effective spacing, depth and diameter of the wells. Procedures described in Ref. 22 and solutions of well drawdown analysis will be used to design the system. Parameters required for the analysis are foundation permeability, thickness of soil strata and hydraulic head. Permeability parameters will be obtained from the results of constant head tests and pump tests.

The maximum allowable head between relief wells will be based on the results of stability analyses (Subsection 5.3.A.1). As described in Subsection 5.3.A.1, various foundation pressure heads will be used in stability analysis calculations. Factors of safety will be compared with pressure heads to determine the maximum allowable pressure head in the foundation.

The relief well system will be installed during the life of the impoundment. As heads increase during the expansion of the tailings impoundment, additional wells will be installed.

Typical well details will be prepared. The wells will have screens or filters to prevent piping of the foundation soils. Filter criteria are specified in Ref. 22.

E. Reclamation Plan - A final impoundment reclamation scheme will be presented. Montana regulations require that the land be returned to comparable utility that existed prior to impoundment construction (Ref. 23). The reclamation plan will basically consist of (1) soil stripping and stockpiling at the beginning of each impoundment construction stage, (2) placing geofabric and waste rock in depression areas, (3) deposition of coarse tailings along the upstream side of the crest during the final year of operation, (4) capping the final tailings surface and downstream slope of the tailing dam with soil, including the stockpiled soil, and (5) seeding the cap and downstream slope of the dam. The crest of the tailings dam will be built up to prevent runoff from draining over the downstream slope of the dam. The north saddle dam will be removed so runoff from the tailings surface will flow through the north saddle into Bear Creek.

The following drawings will be produced:

- o Impoundment Reclamation Plan
- o Impoundment Reclamation Sections and Details

F. Construction Cost Estimates

F.1 Initial Estimate - For planning purposes, an initial construction cost estimate of the starter, operation and reclamation stages of the impoundment has been prepared. Quantities were estimated from preliminary drawings prepared for the permit application. Standard unit costs adjusted for the project area were used for most line items. Preliminary estimates were made for major cost items such as the diversion channel excavation. For minor items, where design details have not yet been developed to permit quantity

estimation, lump sum allowances were included in the estimate. Unit costs and subtotals of each impoundment structure were presented in the estimate.

Only civil construction items were included in the cost estimates; mechanical equipment (e.g., cyclones and pumps) and pipelines were not included. A construction materials flow diagram was included to show the source and placement of earth and rock material. A conceptual impoundment construction schedule for the life of the project was included in the estimate. To assist Noranda in their planning, a cash flow forecast table was also presented.

F.2. Final Estimate - After design studies have been completed, construction cost estimates will be prepared for the (1) starter stage, (2) civil work during operation and (3) reclamation of the tailings impoundment. Costs will be estimated by assuming that the work will be performed by an independent contractor. As Noranda directed, only civil construction items will be estimated; mechanical equipment (e.g., cyclones and pumps) and pipelines will not be included in the estimate. Also, operational costs for raising the dam by cycloning tailings will be excluded.

Supporting documentation will show the estimated quantity and labor, material construction equipment and subcontract cost, if applicable, for each line item in the estimate. Unit cost details will be shown where appropriate. The estimate will be accompanied by a narrative describing basic assumptions and criteria used in the development of estimated costs. Studies will be performed to establish crew composition, productivity and schedules for all significant construction activities.

Hourly construction craft labor rates (union or non-union) will be agreed on with Noranda prior to preparation of the estimate. Material and permanent equipment costs will be based on vendor quotations or experience from prior projects, as appropriate.

Allowances for material loss, damage and waste will be identified. Standard construction equipment rental and operating costs will be adjusted for project location and working conditions for use in the estimates.

Contractor mark-up including administration and overhead costs, contingency and profit will be calculated separately and distributed to the various estimate line items in proportion to direct labor costs.

Contingency allowances and inflation rates to be included in the estimate will be discussed and agreed upon with Noranda to ensure conformance with established policy.

Estimates will be prepared using the computerized estimating package (CAES). Estimated costs will be sorted and presented in an easy readable format.

A construction schedule will be prepared for the starter stage based on the final design and cost estimate, and will identify all relevant procurement and construction tasks. Schedule tasks will be selected that have easily identifiable start and finish events to enable objective monitoring of progress. Cash flow tables will be produced from cost estimates and task activities.

## 5.4 Technical Reports

The following reports will be prepared:

- Geotechnical Report
- Tailings Impoundment Final Engineering Report

The Geotechnical Report will contain the following:

- Site exploration plans, showing geologic data and locations of drill holes, test pits and seismic refraction lines
- Maps showing bedrock contours, soil depth contours and potentiometric surface contours

- o Geologic sections
- o Results of seismic refraction surveys
- o Drill hole and test pit logs
- o Laboratory test results

The geotechnical report will include field and laboratory test results from the 1988 preliminary engineering study.

The final engineering report will present the results of the tailings impoundment engineering studies. The report will include results of stability and settlement analyses. For completeness, the results of hydrologic studies performed for the preliminary report will also be included in the final report. Drawings (plans and sections) will be presented showing the impoundment features. Analysis back-up will be presented in readily accessible appendices.

The technical reports will be organized in formats agreed upon with Noranda Minerals Corporation. Each report will begin with a summary section that gives a complete overview of the work completed and results. All support information and data will be contained in readily referenced appendices.

## 5.5 Review Meetings

As the work progresses, periodic meetings will be held with Noranda Minerals Corporation, the Montana Department of State Lands and the U.S. Forest Service. The meetings will be used to discuss results of investigations and any critical project decisions.

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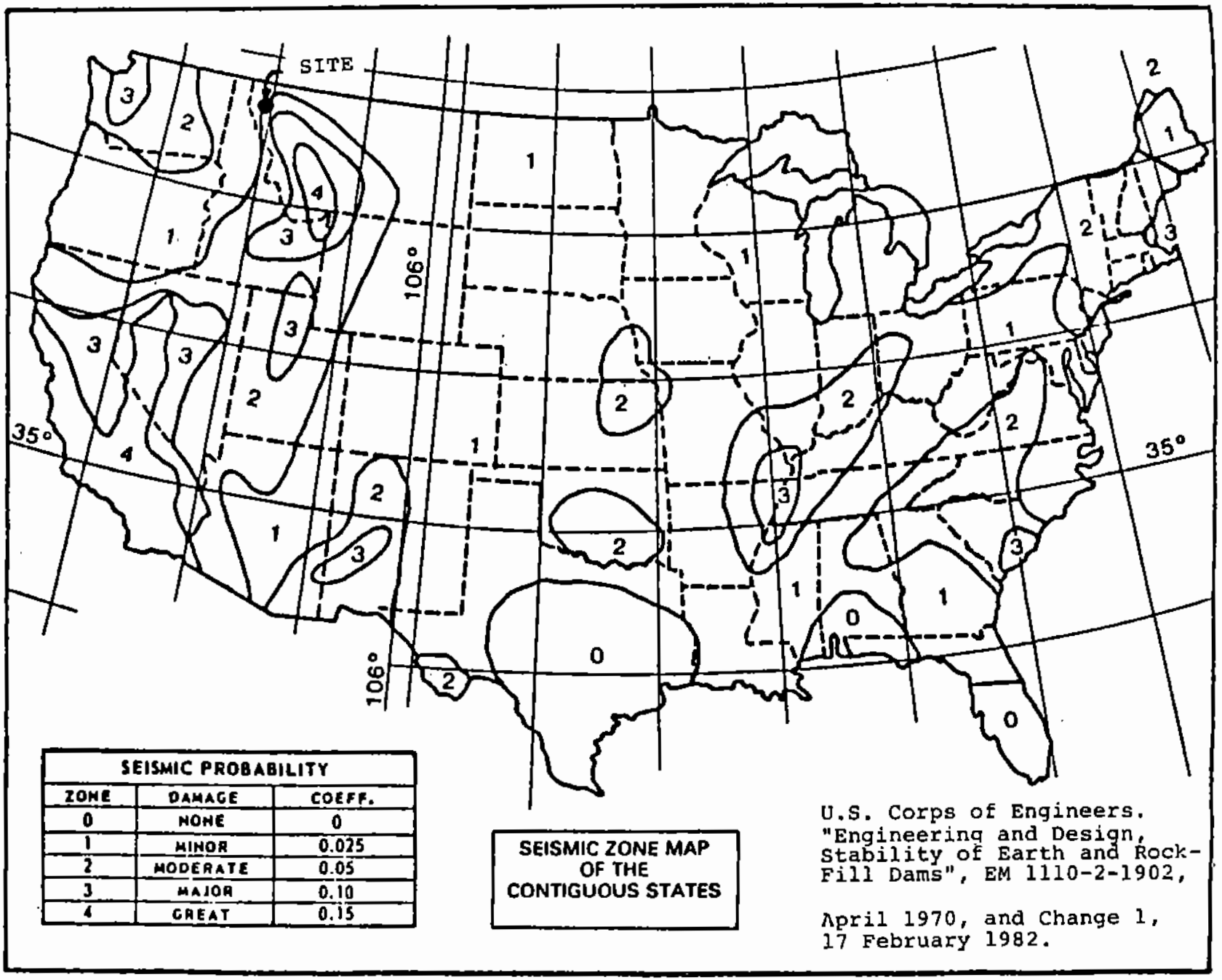
SITE
106°
35°
106°
35°
SEISMIC PROBABILITY
ZONE | DAMAGE | COEFF.
0 | NONE | 0
1 | MINOR | 0.025
2 | MODERATE | 0.05
3 | MAJOR | 0.10
4 | GREAT | 0.15
SEISMIC ZONE MAP OF THE CONTIGUOUS STATES
U.S. Corps of Engineers. "Engineering and Design, Stability of Earth and Rock-Fill Dams", EM 1110-2-1902, April 1970, and Change 1, 17 February 1982.

FIGURE 1

N490,000
N488,000
N486,000
N484,000
E819,000
E821,000
E823,000
E825,000
E827,000
E829,000
E831,000
N
MSV-6
MSV-31
MSV-32
MSV-29
MSV-28
MSV-26
MSV-27
MSV-40
MSV-30
MSV-39
MSV-33
MSV-7
MSV-38
MSV-37
MSV-5
MSV-4
MSV-3
MSV-35
MSV-34
MSV-25
MSV-10
MSV-11
MSV-36
DT-1
DT-2
DT-3
DT-4
DT-5
DH-1
DH-2
DH-3
DH-4
DH-5
DH-6
DH-7
DH-8
DH-9
DH-10
DH-11
DH-12
DH-13
DH-14
DH-15
DH-17
DH-18
DH-19
DH-20
USB-1
USB-2
USB-3
USB-4
USB-5
LCM-9
LCM-8
LCM-11
LCM-10
PLCM-6
TP-101
TP-102
TP-103
TP-104
TP-105
TP-106
TP-107
TP-108
TP-109
TP-110
TP-121
TP-122
TP-123
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TP-136
TP-137
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TP-140
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TP-142
TP-143
TP-144
TP-145
TP-146
TP-147
89-1
89-2
89-3
89-4
89-5
89-6
89-7
89-8
89-9
89-10
89-11
89-12
89-13
89-14
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89-19
89-20
89-21
89-22
89-23
89-24
89-25
89-26
89-27
89-28
89-29
89-30
89-31
89-32
89-33
89-34
TI-9
TI-10
TI-11
TI-12
TI-13
TI-14
TI-15
APPROX. OUTLINE OF BORROW AREA
OUTLINE OF TAILINGS RETENTION DAM
OUTLINE OF DIVERSION CHANNEL
DIVERSION DAM
SEEPAGE COLLECTION DAM
LITTLE CHERRY CREEK

NOTE:

CROSS-SECTION LOCATIONS WILL BE USED IN THE GEOTECHNICAL EVALUATION

NOTE:

BORING, MONITOR WELL AND TEST PIT LOCATIONS WERE PLOTTED FROM SURVEY DATA PROVIDED BY OTHERS.

LEGEND:

- BORING
- TEST PIT
- MONITOR WELL (BY NORTHERN ENGINEERING & TESTING)
- SEISMIC LINE (APPROX. LOCATION, F = FORWARD END R = REVERSE END)
- ROCK OUTCROP (HIGHLY WEATHERED)
- GRAVEL PIT
- ROCK OUTCROP (SLIGHTLY WEATHERED)
- APPROX. LOCATION, RESISTIVITY SOUNDING STATION (BY NORTHERN ENGINEERING & TESTING)
- DENSITY TEST SITE
- SPRING, JULY '89

REFERENCE:

TOPOGRAPHICAL BASE FROM 1988 AERIAL PHOTOGRAPHY

SCALE 400 0 400 800 FEET

| NO. | DATE | REVISIONS | BY | CHK | APPD |
|---|---|---|---|---|---|

MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

| DESIGNED DJU | DRAWN RBC | CHECKED MPC | RECOMMENDED |
|---|---|---|---|
| DATE OCTOBER 1988 | | | APPROVED |

NORANDA MINERALS CORPORATION

MONTANA PROJECT

# LITTLE CHERRY SITE EXPLORATION PLAN

WORK NO.
SHEET OF REV.

FIGURE 2

# APPENDIX B
# SEISMIC REFRACTION SURVEY

# APPENDIX B
# SEISMIC REFRACTION SURVEY

## B.1 PURPOSE

The purpose of the seismic refraction survey is to provide information on the depths to soil layers, the approximate depth to bedrock, and the rippability of near surface material. The locations of the seismic lines are shown on the exploration plan in Figure 4.

## B.2 SEISMIC REFRACTION METHOD

The seismic refraction method permits calculation of seismic velocity versus depth of near-surface soil and rock layers. A seismic survey is performed by producing a seismic wave and measuring the time of arrival of the waves at varying distances from the source. In this survey, seismic waves were generated by exploding one-third pound explosive charges in shallow holes or striking an aluminum plate with a 10-pound sledge hammer.

Arrivals of resulting compressional seismic waves were detected by 12 geophones generally placed at 25-foot intervals along a straight line from the shot point. Electric signals generated at the geophones were transmitted through a coaxial cable to a signal enhancement seismograph (Nimbus 1225 or 1210F). The seismograph contains amplifying and timing circuits and an electric writing oscillograph which provides a permanent record of seismic waves received.

On a time-distance graph plotted from the data, each subsurface layer is represented by a straight line segment of constant velocity. Compressional wave velocities of these layers are equal to the inverse slopes of the line segments. Depths to increasingly higher velocity material can be calculated from the locations of the changes in slope of the plotted data on the graph. The maximum depth that can be determined is approximately 1/3 to 1/4 of the total distance from either shot point to the farthest geophone.

The interpretation of seismic data is generally well established and straightforward. A potential problem inherent in the method, however, is that of velocity reversals. The reversal problem exists when lower seismic velocity material underlies higher velocity material. Refraction data analysis is based on the assumption that seismic velocity increases with depth.

## B.3 SEISMIC REFRACTION PROGRAM AND RESULTS

Forty-two seismic refraction lines were surveyed to determine velocity layers at the Little Cherry tailings impoundment site. Shot points were generally located 25 feet from the nearest geophone. For some lines, in order to evaluate subsurface horizons to a greater depth, the shot points were offset by as much as 500 feet from the nearest geophone.

Table B.1 summarizes the results of the seismic refraction investigation at the site. The table lists the seismic velocity values and depths to the velocity interfaces. Seismic velocities ranged from 1200 feet per second to approximately 15,000 feet per second. Three to four subsurface horizons were defined based on seismic velocity ranges.

Seismic velocities below 2,500 feet per second correspond to surface materials consisting of silt, sand, or gravel. Velocities in the 4,500 to 9,000 feet per second range probably correspond to increasingly denser or compacted gravels, sands or silts. Velocities greater than 7,000 feet per second correspond to weathered rock or possibly very dense gravel, cobbles and boulders.

In some cases, as noted in the table, the minimum depth to a layer with an assumed velocity was calculated. This layer was not observed on the seismic record, but assuming a value for velocity enabled the minimum depth to rock to be estimated.

## EXPLANATION OF SEISMIC REFRACTION TABLES

| | | |
|---|---|---|
| V1F | : | Velocity of surficial deposits from forward seismic shot. |
| V1R | : | Velocity of surficial deposits from reverse seismic shot. |
| V2, V3, V4 | : | Average velocity of intermediate layers. |
| DiF | : | Depth to bottom of layer i at forward end of seismic line. |
| DiR | : | Depth to bottom of layer i at reverse end of seismic line. |
| * | : | Assumed velocity. |
| ** | : | Minimum depth to layer with assumed velocity |
| *** | : | Velocity and corresponding depth obtained at offset shot point. |

NOTE: Not all layers are present at each location.

TABLE 8.1 SEISMIC REFRACTION RESULTS

| Line No. | Layer 1 Seismic Velocity (feet/second) V1F | Layer 1 Seismic Velocity (feet/second) V1R | Layer 1 Depth to Bottom of Layer (feet) D1F | Layer 1 Depth to Bottom of Layer (feet) D1R | Layer 2 Estimated Seismic Velocity (feet/second) V2 | Layer 2 Depth to Bottom of Layer (feet) D2F | Layer 2 Depth to Bottom of Layer (feet) D2R | Layer 3 Estimated Seismic Velocity (feet/second) V3 | Layer 3 Depth to Bottom of Layer (feet) D3F | Layer 3 Depth to Bottom of Layer (feet) D3R | Layer 4 Estimated Seismic Velocity (feet/second) V4 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TI-9 | 2000* | 2000* | 18 | 1 | 5600 | 62 | 70 | - | - | - | 10,400 |
| | | | | | | | 140 | | | | 15,000*** |
| TI-10 | 2000* | 2000* | 4 | 4 | 4900 | 32 | 54 | 6250 | 186** | 206** | 12,000* |
| TI-11 | 2500* | 2000* | 8 | 2 | 5550 | 16 | 10 | 7200 | 148** | 156** | 12,000* |
| TI-12 | 2000* | 2000* | 4 | 6 | 5400 | 12 | 31 | 7200 | 83** | 153** | 12,000* |
| TI-13 | 2200 | 2000* | 8 | 1 | 5600 | 27 | 26 | 7850 | 138** | - | 12,000* |
| TI-14 | 2500 | 2000* | 7 | 7 | 4600 | 94 | 80 | - | - | - | 15,000 |
| TI-15 | 3300 | 1900 | 21 | 13 | 4950 | 135 | 88 | - | - | - | 12,320*** |
| 89-1 | 3800 | 2000 | 9 | 18 | | | | 6400 | 51 | 38 | 12,000 |
| 89-2 | 1500 | 4200 | 14 | 16 | | | | 6400 | 34 | 46 | 12,200 |
| 89-3 | - | - | - | - | | | | 5300 | 21 | 13 | 11,000 |
| 89-4 | - | 2700 | 0 | 20 | | | | 6250 | 29 | 22 | 9,200 |
| 89-5 | 1250 | 1900 | 12 | 9 | | | | 4600 | 34 | 31 | 10,000 |
| 89-6 | 1400 | 1500 | 4 | 3 | | | | 4100 | 52 | 27 | 7,700 |
| 89-7 | 2800 | 1300 | 12 | 4 | | | | 6200 | 57 | 28 | 10,000 |
| 89-8 | 3000 | 3125 | 4 | 6 | 5000 | 18 | 28 | 7200 | 51 | 46 | 8,300 |
| 89-9 | 3000 | 2800 | 16 | 7 | 5800 | - | 21 | 7100 | 57 | 52 | 9,100 |
| 89-10 | 2500 | 2600 | 8 | 7 | 5500 | 19 | 25 | 7100 | 51 | 70 | 8,300 |
| 89-11 | 2100 | 2800 | 9 | 7 | 6250 | 20 | 16 | 7250 | 74 | 44 | 8,300 |
| 89-12 | 2800 | - | 7 | 7 | 5900 | 45 | 31 | 7400 | 79 | 90 | 9,000 |
| 89-13 | 2500 | 2300 | 8 | 11 | | | | 6700 | 32 | 28 | 8,000 |
| 89-14 | 1400 | 1600 | 8 | - | | | | 5000 | - | 13 | 10,000 |
| 89-15 | 3300 | 1300 | 3 | 4 | | | | 6500 | 23 | 43 | 10,000 |
| 89-16 | 1800 | - | 12 | 0 | | | | 4200 | 82 | 49 | 10,300 |
| 89-17 | 1500 | 1500 | 11 | 4 | | | | 4600 | 51** | 34** | 10,000* |
| 89-18 | 1400 | 1800 | 7 | 3 | | | | 4200 | 46 | 41 | 9,500 |
| 89-19 | 1900 | 2500 | 9 | 25 | | | | | - | - | 12,300 |
| 89-20 | 1200 | 1250 | 8 | 6 | | | | 5000 | 49 | 18 | 11,000 |
| 89-21 | 2100 | 2400 | 9 | 8 | | | | 6100 | 55 | 45 | 12,000 |
| 89-22 | 2200 | 2200 | 1 | 9 | | | | 5000 | 64 | 76 | 12,500 |
| 89-23 | 2100 | 2800 | 8 | 21 | | | | 6600 | 66** | 44** | 8,300* |
| 89-24 | 2700 | 1500 | 12 | 10 | | | | 6300 | 65** | 63** | 8,300* |
| 89-25 | 2400 | 2600 | 8 | 7 | | | | 5500 | 50 | 42 | 9,300 |
| 89-26 | 2500 | 2100 | 8 | 9 | | | | 6500 | 35 | 68 | 10,000 |
| 89-27 | 4000 | 3600 | 22 | 20 | | | | 6000 | 77 | 154 | 7,400 |
| 89-28 | 1700 | 1800 | 11 | 10 | | | | 6400 | 40 | 85 | 15,000 |
| 89-29 | 1800 | 1900 | 10 | 8 | | | | 4500 | 42 | 30 | 11,000 |
| 89-30 | 1400 | 2100 | 10 | 10 | | | | 5500 | 18 | 18 | 7,500 |
| 89-31 | 1900 | 3200 | 8 | 10 | | | | 5700 | 55 | - | 9,500 |
| 89-32 | 2000 | 1800 | 12 | 7 | | | | 4500 | 46 | 38 | 8,200 |
| 89-33 | 3600 | 2500 | 14 | 17 | 7100 | 83 | 91 | 8300 | 160 | 143 | 10,000*** |
| 89-34 | 3600 | 3800 | 13 | 8 | 7100 | 51 | 31 | 8600 | 190 | 150 | 13,000*** |
| 89-35 | 3600 | - | 12 | - | 5600 | 75 | 23 | 8400 | 167 | 126 | 10,000*** |

# APPENDIX C
# DRILL LOGS

# APPENDIX C
# DRILL LOGS

## C.1 DRILLING

During the 1988 and 1989 field explorations, drilling equipment consisted of a Mobile B-53, an Acker AD II, a Schramm Rotadrill and a skid mounted Longyear 28 drill rig. One hole, DH-15, was drilled as a monitor well, using the Schramm Rotadrill rig and air-rotary drilling method. All other holes were drilled with a continuous hollow stem flight auger, tricone rotary bit or diamond bit in soil and a diamond bit in rock. An engineering geologist or geotechnical engineer of Morrison-Knudsen Engineers (MKE) observed the drilling progress and kept a log of soil, rock and water encountered.

Where soil conditions permitted, hollow stem augers with outside diameters (O.D.) of 7 to 9 inches were initially used to advance the borings. In dense or gravelly soils or where the auger could not be advanced, rotary drilling with a 2-15/16 inch tricone drill bit and clean water or an NQ or HQ diamond drill bit and triple-tube core barrel were used to advance the hole. Three inch I.D. (NW) flush joint casing were used when drilling with tricone drill bits. Descriptions of the auger and tricone drill cuttings, core recovery, and drill water return were entered on the boring logs.

Bedrock was cored with a 2.98 inch O.D. (NQ) diamond drill bit and double or triple-tube core barrel, or with a 3.78 inch O.D. (HQ) diamond drill bit and triple-tube core barrel. Each piece of core was withdrawn from the core barrel and placed in proper sequence in the core box. Core boxes were labeled with project name and number, boring number, coring interval, core box number and date. Photographs were taken of the cores.

Rock information entered on the drill logs includes percent recovery, Rock Quality Designation (RQD), rock type, color, weathering, hardness, texture, structure and any other notable features. RQD is the ratio of the cumulative length of the core pieces greater than 4 inches to the total length of the core run. Mechanical core breaks caused by drilling or handling are disregarded.

Other conditions recorded on the drill logs included color of the return water, areas of water loss, penetration rates and drill action. The boring locations were surveyed by others, with the exception of DH-3A which was located by the MKE geotechnical engineer.

Water levels measured in the borings during and after drilling are presented in Table C.1

## C.2 SAMPLING

Soil samples were generally taken at 5-foot intervals to a depth of 25 feet; below 25 feet, samples were generally taken at 10- to 40- foot intervals where possible. Both undisturbed and Standard Penetration Test (SPT) samples were obtained. The number of undisturbed samples was limited due to the absence of cohesive non-gravelly soils.

Disturbed soil samples were obtained using standard 2-inch and 2.5-inch O.D. split barrel samplers, driven by a 140 pound hammer with a 30-inch free-fall drop, as described in ASTM D1586. After a boring was cleaned of all loose material, the sampler was inserted and measurements made to verify that the sampler reached the bottom of the boring. The sampler was driven 18 inches or until refusal (more than 50 blows to penetrate 6 inches). The number of blows required to drive each 6 inches of penetration was recorded. The sampler was removed from the boring and opened. The length of material recovered from the sampler was measured and recorded. A pocket penetrometer was used to obtain an approximate unconfined compressive strength in sections of the recovered sample that appeared cohesive. A complete material description was entered on the boring log including soil type, particle shape, color, moisture, density or consistency and plasticity. Visual classification of the samples was made in conformance with the Unified Soil Classification System (Figure C-1). Samples were double sealed in plastic bags labeled with sample number, boring number, project number and sample depth interval. Drive samples were not taken from DH-9, 10 or 15 because the skid mounted Longyear 28 and Schramm Rotadrill drill rigs were not equipped with a hammer or cathead.

Undisturbed Shelby tube samples were obtained in cohesive soil in conformance with ASTM D1587. The boring was cleaned of all loose material and the sampler inserted to the bottom of the hole. A thin walled 3-inch or 2-inch diameter sampler, 30 inches long was advanced 2 feet, or until refusal, by hydraulically pushing in one continuous motion with the drill rig. Upon retrieval, the length of the sample was measured and recorded. Any space at the end of the tubes was filled with plastic bags, the ends sealed with plastic caps, and the caps sealed with duct tape. The sample tubes were labelled with project number, boring number, sample number and sample depth interval. The tubes were also marked "Top" and "Bottom" to show sample orientation. Care was taken during handling and transport to maintain the tubes in a vertical position and to minimize soil disturbance.

Two and one-half inch diameter brass tube samples were obtained in non-gravelly soils that were too dense for Shelby samplers. The equipment used for taking ring samples was similar to that used for SPT samples, except that the split tube was lined with three 6-inch long brass tubes. The sampler was pushed or driven into the soil to a maximum distance of 18 inches to obtain a relatively undisturbed sample. The tubes with sample recovery were sealed as described for the Shelby tubes. The brass tubes were identified by project name and number, boring number, depth interval and sample number.

## C.3 PERMEABILITY TESTS

Field permeability tests consisted of constant head tests in soil and packer tests in bedrock. Tests were performed by using method E-18 procedures outlined in the U.S. Bureau of Reclamations "Earth Manual" (1974).

Constant head tests were performed in an uncased section at the bottom of the boring. After advancing the hole and pulling up the core barrel to the top of the test section (typically 10 to 30 foot length), the uncased section was cleaned out with water. A single pneumatic wireline packer was used to seal

the hole below the core barrel to minimize leakage from the uncased section. No pressure was applied using this method, except in Boring DH-11 where 10 psi was applied due to artesian conditions at the time of testing.

Water inflow was measured by two methods. A flow metering system was used to measure flow at constant head. When flow was not sufficient for the flow meter to operate accurately, the water level was allowed to drop a minimal measured amount (approximately 0.1 foot) and the casing was refilled at intervals to the original water level. The rate of flow into the hole was then determined from the total water drop.

Permeability values of tests performed in uncased sections were determined from the formula described below for water pressure tests in bedrock. For this type of constant head test, the differential head of water equals the gravity head only (except in Boring DH-11) since there is no applied pressure.

During the 1988 field exploration, some constant head tests were performed in casings. The casing was lowered to the bottom of the boring and carefully cleaned out. The water inflow was measured by the two methods described above. In these tests, permeabilities were computed from the following formula:

$$K = Q/(5.5rH)$$

where: $K$ = permeability
$Q$ = constant rate of flow into the hole
$r$ = internal radius of casing
$H$ = differential head of water

Water pressure tests in bedrock were performed by using a single pneumatic wireline packer. Prior to testing, the holes were flushed with clean water until the water return was clear. The maximum applied water pressure was approximately 1 psi per foot of depth above the packer. However, due to equipment limitations,

the total maximum applied pressure was 75 psi. Each packer test was generally run in three segments of water pressure: the first at one-half of the maximum water pressure determined for the test interval, the second at the maximum water pressure, and the third at one-half of the maximum pressure. Tests were run at a constant pressure and a generally constant flow rate for 5 minutes. The flow meters were calibrated periodically.

The permeability was calculated from the following formula:

$$k = Q \ln(L/r)/2\pi LH$$

where: k= permeability
Q= constant rate of flow into the hole
L= test section length
H= differential head of water (gravity head plus applied pressure head)
r= radius of hole tested

The results of the constant head and packer tests are shown in Table C.2.

## C.4 PIEZOMETER INSTALLATION

Piezometers were installed in selected borings immediately after drilling was completed. A Piezometer typically consisted of 1-inch I.D., Schedule 80 PVC pipe, with 20 feet of 0.02-inch width machine slotted screen section at the bottom. Number 16 silica sand was used as backfill around the bottom of the piezometer. The sand extended to at least 5 feet above the slotted section. In borings where artesian conditions were encountered, holes were sealed by grouting, from above the slotted portion to ground level, in accordance with Montana state well installation regulations. A steel protective casing with a lockable lid was set in concrete at each piezometer. Construction details of the piezometers are presented on Figure C-2 and C-3.

TABLE C.1
DEPTH TO WATER FROM GROUND SURFACE (FEET)

| BORING | USB-1 | USB-2 | USB-3 (1) | USB-5 | PLCM-6 (2) A | PLCM-6 (2) B | LCTM-8 | LCM-9 | LCM-10 | LCM-11 | DH-1 | DH-2 | DH-3 (2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE COMPLETED | 8-3-88 | 8-1-88 | 7-29-88 | 8-24-88 | 7-21-88 | | 7-27-88 | 7-20-88 | 7-25-88 | 7-22-88 | 8-14-89 | 9-20-89 | 9-18-89 |
| HOLE DEPTH (FT) | 80.8 | 80.8 | 70.0 | 50.3 | 56.0 | | 140.0 | 72.0 | 40.0 | 62.5 | 100.0 | 110.0 | 367.0 |
| 7-28-88 (3) | | | 31.5/34.3 | | 7.2 | 3.7 psi | | 9.2 | 12.9 | 11.3 | | | |
| 8- 6-88 | 21.6 | 2.8 | | | | | | | | | | | |
| 8-12-88 | 23.4 | 2.9 | | | | | | | | | | | |
| 8-18-88 (3) | 22.9 | | | | 7.4 | 3.6 psi | 12.4 | 9.8 | 12.9 | 13.8 | | | |
| 8-26-88 | 22.9 | 2.1 | | 27.1 | | | | | | | | | |
| 10- -88 (3) | | | | | 7.6 | 3.5 psi | 13.6 | 10.9 | 13.2 | 12.8 | | | |
| 1- -89 (3) | | | | | 5.8 | | 10.4 | 8.5 | 5.5 | 4.7 | | | |
| 3- -89 (3) | | | | | 4.0 | 3.5 psi | 9.9 | 7.8 | 5.2 | 4.5 | | | |
| 4- -89 (3) | | | | | | 4.1 psi | | | | | | | |
| 7- -89 (3) | 21.0 | 0.2 | | 22.1 | | | 10.7 | 7.7 | 12.2 | 13.6 | | | |
| 8-11-89 | | | | | | | | | | | | | |
| 8-12-89 | | | | | | | | | | | | | |
| 8-14-89 | | | | | | | | | | | | | |
| 8-18-89 | | | | | | | | | | | | | |
| 8-21-89 | | | | | | | | | | | | | |
| 8-22-89 | | | | | | | | | | | | | |
| 8-23-89 | | | | | | | | | | | 21.0 | | |
| 8-26-89 | | | | | | | | | | | | | |
| 8-29-89 | | | | | | | | | | | 21.0 | | |
| 9- 6-89 | | | | | | | | | | | | | |
| 9- 7-89 | | | | | | | | | | | | | |
| 9-11-89 | | | | | | | | | | | | | GRD. LVL |
| 9-12-89 | | | | | | | | | | | 21.6 | | AF |
| 9-13-89 | | | | | | | | | | | | | AF |
| 9-14-89 | | | | | | | | | | | | | AF |
| 9-15-89 | | | | | | | | | | | | | AF |
| 9-19-89 | | | | | | | | | | | | 6.0 | |
| 9-24-89 | | | | | | | | | | | 21.5 | | |
| 9-25-89 | | | | | | | | | | | | | |
| 9-26-89 | | | | | | | | | | | | | |
| 9-27-89 | | | | | | | | | | | | | |
| 9-28-89 | | | | | | | | | | | | | |
| 9-29-89 | | | | | | | | | | | 21.3 | | |
| 10- 1-89 | | | | | | | | | | | | | |
| 10- 2-89 | | | | | | | | | | | | | |
| 10- 3-89 | | | | | | | | | | | | | |
| 10- 4-89 | | | | | | | | | | | | | |
| 10- 5-89 | | | | | | | | | | | | | |
| 10- 6-89 | | | | | | | | | | | | | |
| 10- 8-89 | | | | | | | | | | | | | |
| 10- 9-89 | | | | | | | | | | | | | |
| 10-10-89 | | | | | | | | | | | | | |
| 11-10-89 (3) | 21.6 GRD. LVL. | | | 25.7 | | | 11.3 | 8.5 | 12.1 | | 19.6 | 4.1 psi | .80 psi |
| 11-16-89 (3) | | | | | 2.0 | 3.0 psi | 10.5 | 8.0 | | 6.1 | | | |
| 11-19-89 (3) | | | | | | | | | 6.6 | | | | |

| BORING | DH-4 | DH-5 (1) | DH-6 | DH-7 | DH-8 | DH-9 | DH-10 | DH-11 |
|---|---|---|---|---|---|---|---|---|
| DATE COMPLETED | 9-8-89 | 8-25-89 | 8-21-89 | 8-11-89 | 8-12-89 | 9-25-89 | 9-29-89 | 10-10-89 |
| HOLE DEPTH (FT) | 40.0 | 197.0 | 60.0 | 73.0 | 98.0 | 82.0 | 87.0 | 192.0 |
| 7-28-88 (3) | | | | | | | | |
| 8- 6-88 | | | | | | | | |
| 8-12-88 | | | | | | | | |
| 8-18-88 (3) | | | | | | | | |
| 8-26-88 | | | | | | | | |
| 10- -88 (3) | | | | | | | | |
| 1- -89 (3) | | | | | | | | |
| 3- -89 (3) | | | | | | | | |
| 4- -89 (3) | | | | | | | | |
| 7- -89 (3) | | | | | | | | |
| 8-11-89 | | | | 49.0 | | | | |
| 8-12-89 | | | | | DRY | | | |
| 8-14-89 | | | | 35.5 | 62.0 | | | |
| 8-18-89 | | | | | | | | |
| 8-21-89 | | | AF | | | | | |
| 8-22-89 | | 11.0 | | | | | | |
| 8-23-89 | | 49.6 | | DRY | | | | |
| 8-26-89 | | 125.0 | | | | | | |
| 8-29-89 | | | AF | | | | | |
| 9- 6-89 | | | | | | | | |
| 9- 7-89 | | | | | | | | |
| 9-11-89 | | | | | | | | |
| 9-12-89 | DRY | | | | DRY | | | |
| 9-13-89 | | | | | | | | |
| 9-14-89 | | | | | | | | |
| 9-15-89 | | | | | | | | |
| 9-19-89 | | | | | | | | |
| 9-24-89 | | 141.7 | | | | DRY | | |
| 9-25-89 | | | | | | 69.0 | | |
| 9-26-89 | | | | | | | | |
| 9-27-89 | | | | | | | | |
| 9-28-89 | | | | | | | | |
| 9-29-89 | | 139.6 | | | | | | |
| 10- 1-89 | | | | | | | | |
| 10- 2-89 | DRY | | | | DRY | | | |
| 10- 3-89 | | | | | | DRY | | |
| 10- 4-89 | | | | | | | | |
| 10- 5-89 | | | | | | | | |
| 10- 6-89 | | | | | | | | |
| 10- 8-89 | | | | | | | | 15.0 |
| 10- 9-89 | | | | | | | | 4.0 |
| 10-10-89 | | | | | | | | 125.0 |
| 11-10-89 (3) | DRY | | 9.5 psi | | | 72.6 | 85.2 | 189.1 |
| 11-16-89 (3) | | | | DRY | DRY | | | |
| 11-19-89 (3) | | | | DRY | DRY | | | 105.2 |

| BORING | DH-12 | DH-13 | DH-14 | DH-15 | DH-17 | DH-18 | DH-19 | DH-20 |
|---|---|---|---|---|---|---|---|---|
| DATE COMPLETED | 9-28-89 | 9-8-89 | 9-9-89 | 9-7-89 | 8-18-89 | 8-19-89 | 10-4-89 | 10-8-89 |
| HOLE DEPTH (FT) | 110.0 | 80.0 | 60.0 | 120.0 | 80.0 | 65.0 | 105.0 | 214.0 |
| 7-28-88 (3) | | | | | | | | |
| 8- 6-88 | | | | | | | | |
| 8-12-88 | | | | | | | | |
| 8-18-88 (3) | | | | | | | | |
| 8-26-88 | | | | | | | | |
| 10- -88 (3) | | | | | | | | |
| 1- -89 (3) | | | | | | | | |
| 3- -89 (3) | | | | | | | | |
| 4- -89 (3) | | | | | | | | |
| 7- -89 (3) | | | | | | | | |
| 8-11-89 | | | | | | | | |
| 8-12-89 | | | | | | | | |
| 8-14-89 | | | | | | | | |
| 8-18-89 | | | | | 2.5 | | | |
| 8-21-89 | | | | | | | | |
| 8-22-89 | | | | | | | | |
| 8-23-89 | | | | | | DRY | | |
| 8-26-89 | | | | | | | | |
| 8-29-89 | | | | | | | | |
| 9- 6-89 | | | | 110.0 | | | | |
| 9- 7-89 | | | | 12 psi | | | | |
| 9-11-89 | | | | | | | | |
| 9-12-89 | | DRY | 13.9 | | | | | |
| 9-13-89 | | | | | | | | |
| 9-14-89 | | | | | | | | |
| 9-15-89 | | | | | 23.0 | DRY | | |
| 9-19-89 | | | | | | | | |
| 9-24-89 | | | | | | | | |
| 9-25-89 | | | | | | | | |
| 9-26-89 | 4 | | | | | | | |
| 9-27-89 | 3 | | | | | | | |
| 9-28-89 | 1 | | | | | | | |
| 9-29-89 | AF | | | | 23.2 | DRY | | |
| 10- 1-89 | | | | | | | 2.0 | |
| 10- 2-89 | | DRY | 15.0 | | | | AF | |
| 10- 3-89 | | | | | | | 1.3 psi | |
| 10- 4-89 | | | | | | | 1.7 psi | |
| 10- 5-89 | | | | | | | | 6.5 |
| 10- 6-89 | | | | | | | | 17.0 |
| 10- 8-89 | | | | | | | | |
| 10- 9-89 | | | | | | | | |
| 10-10-89 | | | | | | | | |
| 11-10-89 (3) | .80 psi | DRY | 16.9 | 10.4 psi | 60.7 | DRY | 4.6 psi | |
| 11-16-89 (3) | | | | 6.8 psi | | | | 8.8 |
| 11-19-89 (3) | | | | | | 50.3 | | |

NOTES:
(1) Piezometers were not installed in these borings.
(2) Two piezometers were installed in these borings. In DH-3 water level readings were equal.
In PLCM-6, A is shallow well, B is deep well.
(3) Water levels on this date were measured and reported by Noranda and/or Chen-Northern.
(4) AF = Artesian Flow

TABLE C.2
FIELD PERMEABILITY TEST RESULTS
page 1 of 2

| HOLE | DEPTH TO BEDROCK (FT) | TOP SECTION (FT) | BOTTOM SECTION (FT) | LENGTH (FT) | Q (GPM) | APPLIED PRESSURE (PSI) | WATER TABLE (FT) | k (10-6 CM/SEC) |
|---|---|---|---|---|---|---|---|---|
| USB-3 | 27.0 | 38.8 | 55.0 | 16.2 | 0.000 | 20 | 34.3 | <1 |
| | 27.0 | 38.8 | 55.0 | 16.2 | 0.000 | 40 | 34.3 | <1 |
| | 27.0 | 38.8 | 55.0 | 16.2 | 0.000 | 20 | 34.3 | <1 |
| | 27.0 | 50.3 | 70.0 | 19.7 | 0.760 | 25 | 34.3 | 26 |
| | 27.0 | 50.3 | 70.0 | 19.7 | 1.360 | 50 | 34.3 | 29 |
| | 27.0 | 50.3 | 70.0 | 19.7 | 0.680 | 25 | 34.3 | 23 |
| USB-4 | NE | 15.0 | 15.0 | 0.0 | 0.280 | 0 | NE | 1800 |
| | NE | 20.0 | 20.0 | 0.0 | 0.020 | 0 | NE | 100 |
| USB-5 | NE | 10.0 | 10.0 | 0.0 | 0.007 | 0 | NE | 70 |
| | NE | 10.0 | 15.0 | 5.0 | 0.022 | 0 | NE | 14 |
| | NE | 10.0 | 20.0 | 10.0 | 0.019 | 0 | NE | 6 |
| | NE | 10.0 | 25.0 | 15.0 | 0.013 | 0 | NE | 3 |
| | NE | 10.0 | 40.0 | 30.0 | 0.064 | 0 | NE | 7 |
| DH1 | 77.0 | 30.0 | 35.0 | 5.0 | 0.000 | 0 | 21 | <1 |
| | 77.0 | 35.0 | 40.0 | 5.0 | 0.020 | 0 | 21 | 6 |
| | 77.0 | 65.5 | 70.0 | 4.5 | 0.020 | 0 | 21 | 6 |
| | 77.0 | 80.0 | 90.0 | 10.0 | 0.040 | 42 | 21 | 2 |
| | 77.0 | 80.0 | 90.0 | 10.0 | 0.100 | 75 | 21 | 2 |
| | 77.0 | 80.0 | 90.0 | 10.0 | 0.080 | 41 | 21 | 3 |
| DH2 | 54.0 | 55.0 | 74.0 | 19.0 | 0.460 | 25 | 6 | 18 |
| | 54.0 | 55.0 | 74.0 | 19.0 | 0.720 | 40 | 6 | 19 |
| | 54.0 | 55.0 | 74.0 | 19.0 | 0.400 | 25 | 6 | 16 |
| | 54.0 | 70.0 | 90.0 | 20.0 | 8.500 | 38 | 6 | 234 |
| | 54.0 | 70.0 | 90.0 | 20.0 | 10.100 | 50 | 6 | 215 |
| | 54.0 | 70.0 | 90.0 | 20.0 | 6.200 | 35 | 6 | 184 |
| | 54.0 | 90.0 | 110.0 | 20.0 | 6.600 | 40 | 6 | 173 |
| | 54.0 | 90.0 | 110.0 | 20.0 | 10.800 | 65 | 6 | 179 |
| | 54.0 | 90.0 | 110.0 | 20.0 | 4.800 | 40 | 6 | 126 |
| DH4 | 9.0 | 18.0 | 40.0 | 22.0 | 0.300 | 10 | NE | 14 |
| | 9.0 | 18.0 | 40.0 | 22.0 | 0.620 | 20 | NE | 20 |
| | 9.0 | 18.0 | 40.0 | 22.0 | 0.400 | 10 | NE | 18 |
| DH5 | 145.0 | 8.0 | 15.0 | 7.0 | 0.067 | 0 | 140 | 28 |
| | 145.0 | 30.0 | 40.0 | 10.0 | 0.001 | 0 | 140 | <1 |
| | 145.0 | 60.0 | 65.0 | 5.0 | 0.010 | 0 | 140 | 1 |
| | 145.0 | 147.0 | 167.0 | 20.0 | 0.140 | 20 | 140 | 2 |
| | 145.0 | 147.0 | 167.0 | 20.0 | 0.140 | 40 | 140 | 2 |
| | 145.0 | 147.0 | 167.0 | 20.0 | 0.100 | 20 | 140 | 1 |
| | 145.0 | 167.0 | 187.0 | 20.0 | 0.000 | 20 | 140 | <1 |
| | 145.0 | 167.0 | 187.0 | 20.0 | 0.000 | 40 | 140 | <1 |
| | 145.0 | 167.0 | 187.0 | 20.0 | 0.000 | 20 | 140 | <1 |
| | 145.0 | 187.0 | 197.0 | 10.0 | 0.040 | 15 | 140 | 1 |
| | 145.0 | 187.0 | 197.0 | 10.0 | 0.040 | 50 | 140 | 1 |
| | 145.0 | 187.0 | 197.0 | 10.0 | 0.000 | 15 | 140 | <1 |

NE = Not Encountered

TABLE C.2
FIELD PERMEABILITY TEST RESULTS
page 2 of 2

| HOLE | DEPTH TO BEDROCK (FT) | TOP SECTION (FT) | BOTTOM SECTION (FT) | LENGTH (FT) | Q (GPM) | APPLIED PRESSURE (PSI) | WATER TABLE (FT) | k (10-6 CM/SEC) |
|---|---|---|---|---|---|---|---|---|
| DH6 | 40.0 | 8.0 | 15.0 | 7.0 | 0.020 | 0 | 0 | 39 |
| DH7 | 34.0 | 47.0 | 64.0 | 17.0 | 2.900 | 23 | NE | 79 |
| | 34.0 | 61.0 | 73.0 | 12.0 | 0.820 | 30 | NE | 23 |
| | 34.0 | 61.0 | 73.0 | 12.0 | 1.500 | 60 | NE | 28 |
| | 34.0 | 61.0 | 73.0 | 12.0 | 0.000 | 30 | NE | <1 |
| DH8 | 15.0 | 65.0 | 73.0 | 8.0 | 0.120 | 32 | NE | 4 |
| | 15.0 | 65.0 | 73.0 | 8.0 | 0.280 | 64 | NE | 7 |
| | 15.0 | 65.0 | 73.0 | 8.0 | 0.100 | 32 | NE | 4 |
| DH9 | 41.0 | 60.0 | 82.0 | 22.0 | 4.000 | 30 | NE | 72 |
| | 41.0 | 60.0 | 82.0 | 22.0 | 9.300 | 58 | NE | 115 |
| | 41.0 | 60.0 | 82.0 | 22.0 | 6.400 | 30 | NE | 115 |
| DH10 | 18.0 | 63.0 | 73.0 | 10.0 | 9.170 | 0 | 86 | 621 |
| | 18.0 | 68.0 | 73.0 | 5.0 | 9.150 | 12 | 86 | 721 |
| | 18.0 | 78.0 | 87.0 | 9.0 | 4.500 | 40 | 86 | 131 |
| DH11 | 180.0 | 97.0 | 125.0 | 28.0 | 0.500 | 10 | 125 | 7 |
| | 180.0 | 180.0 | 192.0 | 12.0 | 0.060 | 50 | 125 | 1 |
| | 180.0 | 180.0 | 192.0 | 12.0 | 0.200 | 70 | 125 | 3 |
| | 180.0 | 180.0 | 192.0 | 12.0 | 0.100 | 50 | 125 | 2 |
| DH13 | 16.0 | 29.5 | 80.0 | 50.5 | 1.240 | 15 | NE | 17 |
| | 16.0 | 55.0 | 80.0 | 25.0 | 0.070 | 15 | NE | 2 |
| | 16.0 | 55.0 | 80.0 | 25.0 | 0.210 | 30 | NE | 3 |
| | 16.0 | 55.0 | 80.0 | 25.0 | 13.700 | 60 | NE | 146 |
| | 16.0 | 55.0 | 80.0 | 25.0 | 5.800 | 30 | NE | 93 |
| | 16.0 | 55.0 | 80.0 | 25.0 | 1.500 | 15 | NE | 32 |
| DH14 | 30.0 | 30.0 | 50.0 | 20.0 | 0.880 | 15 | 14 | 46 |
| | 30.0 | 50.0 | 60.0 | 10.0 | 0.180 | 15 | 14 | 16 |
| | 30.0 | 50.0 | 60.0 | 10.0 | 0.300 | 30 | 14 | 16 |
| | 30.0 | 50.0 | 60.0 | 10.0 | 0.140 | 15 | 14 | 12 |
| DH17 | 65.0 | 34.5 | 45.0 | 10.5 | 0.000 | 0 | 23 | <1 |
| | 65.0 | 64.5 | 70.0 | 5.5 | 0.000 | 10 | 23 | <1 |
| | 65.0 | 64.5 | 70.0 | 5.5 | 0.000 | 30 | 23 | <1 |
| | 65.0 | 64.5 | 70.0 | 5.5 | 0.000 | 40 | 23 | <1 |
| DH18 | NE | 8.0 | 15.0 | 7.0 | 0.000 | 0 | NE | <1 |
| | NE | 25.0 | 30.0 | 5.0 | 0.000 | 0 | NE | <1 |
| | NE | 55.0 | 60.0 | 5.0 | 0.020 | 0 | NE | 2 |
| DH19 | 60.0 | 59.5 | 80.0 | 20.5 | 3.200 | 30 | 0 | 116 |
| | 60.0 | 59.5 | 80.0 | 20.5 | 5.500 | 60 | 0 | 101 |
| | 60.0 | 59.5 | 80.0 | 20.5 | 2.400 | 30 | 0 | 87 |
| | 60.0 | 79.0 | 105.0 | 26.0 | 8.700 | 40 | 0 | 196 |
| | 60.0 | 79.0 | 105.0 | 26.0 | 13.000 | 70 | 0 | 169 |
| | 60.0 | 79.0 | 105.0 | 26.0 | 7.000 | 40 | 0 | 157 |
| DH20 | 205.0 | 38.0 | 68.0 | 30.0 | 0.005 | 0 | 17 | <1 |
| | 205.0 | 177.0 | 214.0 | 37.0 | 0.025 | 0 | 17 | 2 |
| | 205.0 | 205.0 | 214.0 | 9.0 | 0.040 | 50 | 17 | 1 |
| | 205.0 | 205.0 | 214.0 | 9.0 | 0.020 | 70 | 17 | 1 |
| | 205.0 | 205.0 | 214.0 | 9.0 | 0.000 | 50 | 17 | <1 |

NE = Not Encountered

TABLE C-3
LITTLE CHERRY CREEK IMPOUNDMENT SITE
DRILLHOLE LOCATIONS

| DRILLHOLE | NORTHING | EASTING | ELEVATION AT COLLAR | GROUND ELEVATION |
|---|---|---|---|---|
| DH-1 | 487758.694 | 527863.995 | 3446.3 | 3445.6 |
| DH-2 | 486677.992 | 528074.238 | 3415.9 | 3414.4 |
| DH-3 | 485575.782 | 527949.715 | 3437.6 | 3435.4 |
| DH-4 | 484764.905 | 525439.967 | 3612.3 | 3609.5 |
| DH-5 | 488154.584 | 522665.375 | | *3674.36 |
| DH-6 | 484440.829 | 522630.763 | 3594.2 | 3593.7 |
| DH-7 | 483509.749 | 522930.633 | 3769.5 | 3769.3 |
| DH-8 | 483675.677 | 523498.066 | 3746.3 | 3745.9 |
| DH-9 | 483792.201 | 524412.699 | 3678.3 | 3677.7 |
| DH-10 | 483951.939 | 525350.672 | 3658.3 | 3657.5 |
| DH-11** | 484783 | 521863 | 3761.9 | 3760.4 |
| DH-12 | 487651.28 | 528476.99 | 3394.6 | 3393.2 |
| DH-13 | 484474.478 | 526856.254 | 3684.0 | 3682.5 |
| DH-14 | 484568.628 | 524408.593 | 3575.6 | 3574.7 |
| DH-15 | 486561.096 | 526331.806 | 3443.1 | 3440.5 |
| DH-16 | DRILLHOLE | DELETED | FROM | PROGRAM |
| DH-17 | 484957.903 | 524076.336 | 3542.0 | 3541.8 |
| DH-18 | 487382.832 | 523415.049 | 3660.7 | 3659.2 |
| DH-19 | 486436.632 | 528220.918 | 3415.4 | 3413.4 |
| DH-20 | 485644.762 | 528624.176 | 3429.0 | 3428.4 |
| LCTM-8 | 486397.755 | 529138.762 | 3383.1 | 3380.5 |
| LCM-9 | 488681.850 | 528960.135 | 3423.7 | 3420.6 |
| LCM-10 | 483218.556 | 521784.337 | 3743.2 | 3740.2 |
| LCM-11 | 486511.636 | 522369.022 | 3758.9 | 3756.2 |
| PLCM-6 | 483342.261 | 527855.229 | 3447.6 | 3445.1 |
| USB-1 | 485165.718 | 528493.950 | 3463.4 | 3462.6 |
| USB-2 | 486208.367 | 527088.738 | 3441.9 | 3440.9 |
| USB-3 | 488365.499 | 526659.469 | | *3580.7 |
| USB-4 | 486220.404 | 523741.162 | | *3646.6 |
| USB-5 | 487654.050 | 525610.845 | 3517.0 | 3516.0 |

* Depth at ground surface only, no casing installed
** Location approximate; surveyed before hole was drilled

# EXPLANATION OF BORING LOGS

1. Descriptions of materials in the logs are based on visual classifications made in the field and the descriptions are therefore approximate. Where laboratory data are available, the visual classifications were modified to reflect those data.

2. Classifications of soils are based on the Unified Soil Classification System, Figure C-1. The relative proportions of the various soil types in a soil sample are defined by the following terms:

| fine-grained | coarse-grained |
|---|---|
| o trace: less than or equal 5% | o few: less than or equal 10% |
| o some: 5% to 12% | o little: 10% to 20% |
| o suffix "y" (e.g., silty): 12% to 50% | |

3. Blow count values shown on the logs were influenced by the presence of gravels, cobbles and boulders.

4. The description of weathering is based on the following:

| | decomposition | disintegration | discolorization | fracture condition |
|---|---|---|---|---|
| highly or intensely | moderate to complete | extensive | extensive | extensively coated with mud, oxides, or carbonates |
| moderately | slight change | little | moderate | moderately coated |
| slightly | no megascopic decomposition | little or no affect on cement | slight | few stains on fractured surface |
| fresh | unaffected | unaffected | none | fractures less numerous than joints |

5. Rock Quality Designation (RQD) is defined as the sum of the lengths of rock core pieces greater than 4 inches divided by the length of core run.

6. Groundwater level data are shown in Table C.1.

7. Field permeability test data are summarized in Table C.2.

8. Piezometer construction details are shown on Figures C-2 and C-3.

9. Boring locations were surveyed by others. Coordinates, boring collar elevations and ground elevations are presented in Table C.3.

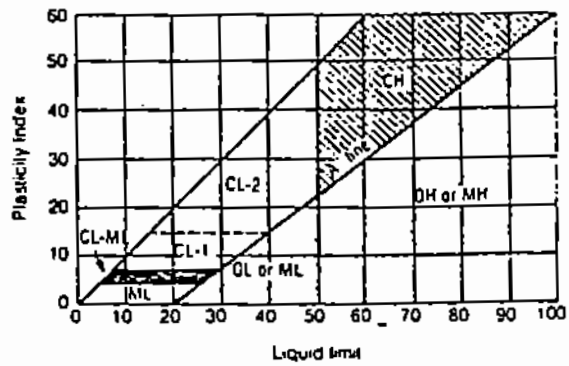
10. Borings were drilled by a Mobile B-53, Acker AD II, Shramm Rotadrill or skid mounted Longyear 28 drill rig.

11. The sampler types indicated on the boring logs are as follows:
    - o SPT: 2-inch O.D. Standard Penetration Test Sampler (ASTM D1586)
    - o S: 2-1/2-inch Split Spoon Sampler
    - o SH: Shelby Tube Sampler
    - o BR: Brass Ring Sampler

# Unified Soil Classification System

| Major Divisions | | | Group Symbols | Typical Names | Laboratory Classification Criteria |
|---|---|---|---|---|---|
| Coarse-grained Soils: More than half of material is larger than No. 200 sieve | Gravels: More than half of coarse fraction is larger than No. 4 sieve size | Clean Gravels (Little or no fines) | GW | Well graded gravels, gravel-sand mixtures, little or no fines. | $C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 |
| | | | GP | Poorly graded gravels, gravel-sand mixtures, little or no fines | Not meeting all gradation requirements for GW |
| | | Gravels with fines (Appreciable amount of fines) | GM d / u | Silty gravels, poorly graded gravel-sand-clay mixtures | Atterberg limits below "A" line, or PI less than 4 / Above "A" line with PI between 4 and 7 are *borderline* cases requiring uses of dual symbols |
| | | | GC | Clayey gravels, poorly graded gravel-sand-clay mixtures | Atterberg limits above "A" line, or PI greater than 7 / Above "A" line with PI between 4 and 7 are *borderline* cases requiring uses of dual symbols |
| | Sands: More than half of coarse fraction is smaller than No. 4 sieve size | Clean Sands (Little or no fines) | SW | Well graded sands, gravelly sands, little or no fines | $C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 |
| | | | SP | Poorly graded sands, gravelly sands, little or no fines. | Not meeting all gradation requirements for SW |
| | | Sands with fines (Appreciable amount of fines) | SM d / u | Silty sands, poorly graded sand-silt mixtures | Atterberg limits below "A" line, or PI less than 4 / Above "A" line with PI between 4 and 7 are *borderline* cases requiring uses of dual symbols |
| | | | SC | Clayey sands, poorly graded sand-clay mixtures | Atterberg limits above "A" line, or PI greater than 7 / Above "A" line with PI between 4 and 7 are *borderline* cases requiring uses of dual symbols |
| Fine-grained Soils: More than half of material is smaller than No. 200 sieve | Silts and Clays: Liquid limit less than 50 | | ML | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity | |
| | | | CL 1 / 2 | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | |
| | | | OL | Organic silts and organic silt-clays of low plasticity | |
| | Silts and Clays: Liquid limit greater than 50 | | MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts | |
| | | | CH | Inorganic clays of high plasticity, fat clays | |
| | | | OH | Organic clays of medium to high plasticity, organic silts | |
| Highly Organic Soils | | | Pt | Peat and other highly organic soils | |

Determine percentage of gravel and sand from grain size curve.
Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:
Less than 5% ..... GW, GP, SW, SP
More than 12% ..... GM, GC, SM, SC
5% to 12% ..... *Borderline* cases requiring use of dual symbols*

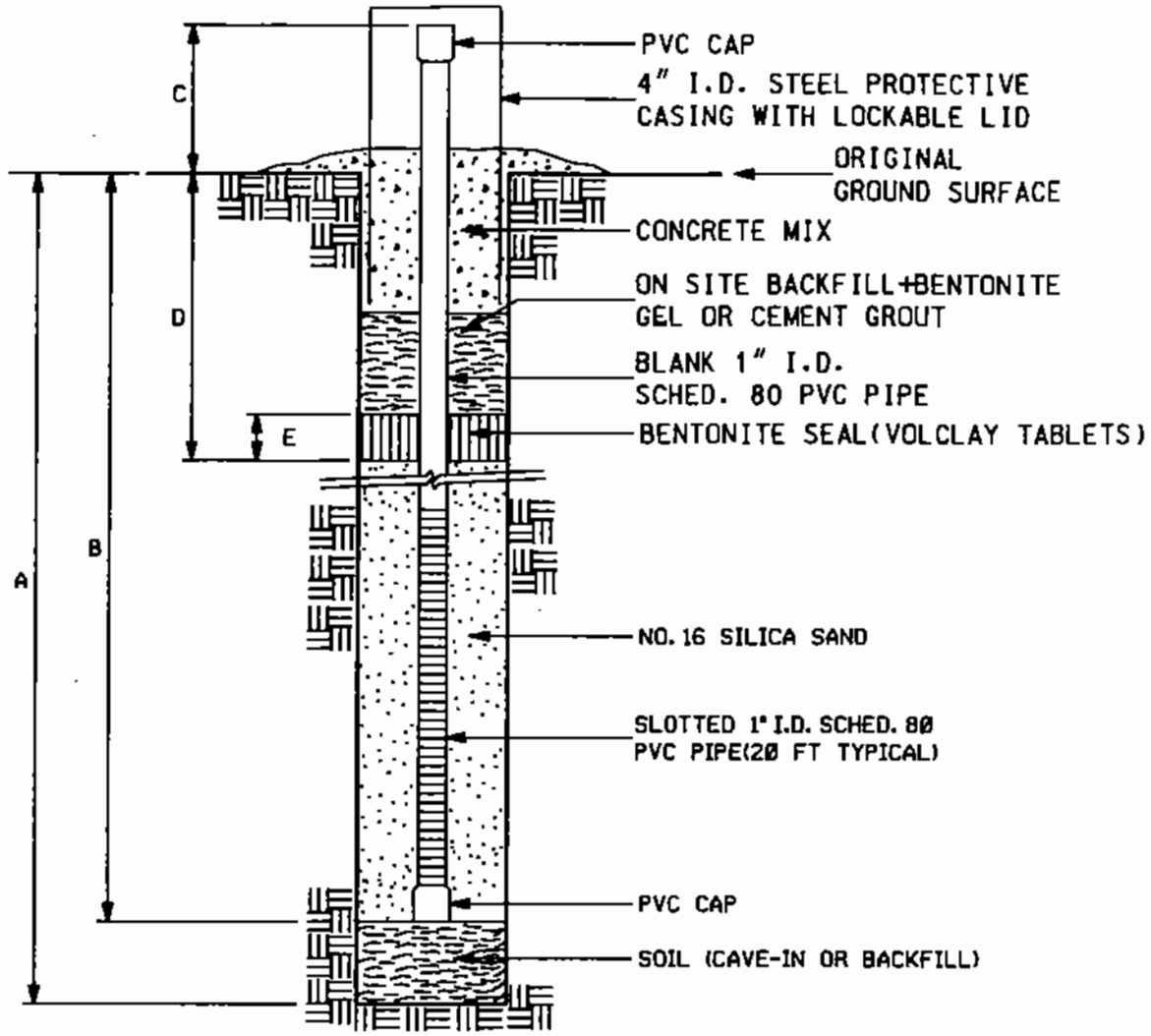



**Plasticity Chart**
For laboratory classification of fine-grained soils

*Division of GM and SM groups into subdivisions of d and u for roads and airfields only. Subdivision is based on Atterberg limits, suffix d used when liquid limit is 28 or less and the PI is 6 or less; the suffix u used when liquid limit is greater than 28.

**Borderline classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.

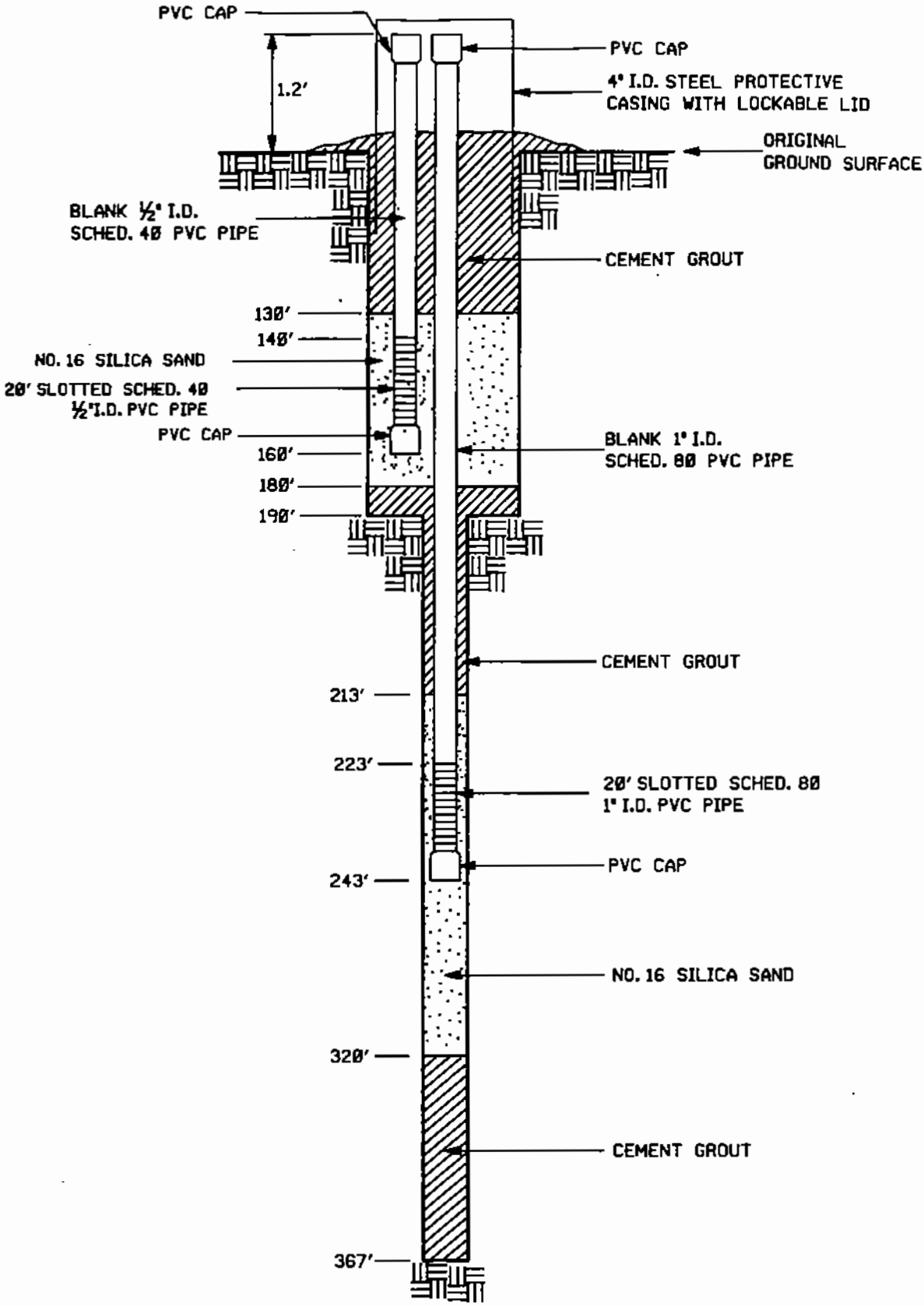
Figure No C-1




| BORING NO. | DIMENSIONS(FT.) | | | | | NOTES |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | |
| USB-1 | 81 | 81 | 0.9 | 49 | 0.0 | |
| USB-2 | 81 | 81 | 1.0 | 55 | 0.0 | |
| USB-5 | 50 | 50 | 1.0 | 49 | 3.0 | |
| DH-1 | 100 | 100 | 0.6 | 75 | 1.0 | |
| DH-2 | 110 | 110 | 1.3 | 78 | 1.0 | CEMENT GROUT TO 77 FT. |
| DH-3 | 367 | 160 | 1.2 | - | - | SEE FIGURE C-3 FOR DETAILS |
| | - | 243 | 1.2 | - | - | |
| DH-4 | 40 | 40 | 2.7 | 21 | 6.0 | |
| DH-5 | - | - | - | - | - | |
| DH-6 | 60 | 60 | 0.5 | 36 | 4.0 | PUT ABOUT 4 FT. CEMENT MIXTURE+CONCRETE |
| DH-7 | 73 | 73 | 0.2 | 47 | 2.5 | AT TOP TO SEAL OFF ARTESIAN FLOW |
| DH-8 | 98 | 98 | 0.4 | 73 | 2.5 | |
| DH-9 | 82 | 82 | 0.5 | 51 | 6.0 | |
| DH-10 | 87 | 87 | 0.8 | 57 | 6.0 | |
| DH-11 | 192 | 190 | 1.5 | 165 | 5.0 | |
| DH-12 | 110 | 110 | 1.3 | 84 | 1.5 | |
| DH-13 | 80 | 80 | 1.0 | 56 | 11.0 | |
| DH-14 | 60 | 60 | 0.7 | 35.5 | 5.5 | |
| DH-15 | 120 | 113 | 2.1 | 80 | 8.0 | INSTALLED 2" SCHED.40 PVC PIPE +20 FT OF 6" |
| - | - | - | - | - | - | CASING AS STEEL PROTECTION, CEMENT GROUT |
| DH-17 | 80 | 80 | 0.2 | 59 | 6.0 | TO 72 FT. |
| DH-18 | 65 | 65 | 1.1 | 40 | 5.0 | |
| DH-19 | 105 | 105 | 1.8 | 76 | - | CEMENT GROUT TO 76 FT. |
| DH-20 | 214 | 154 | 0.7 | 136 | 5.0 | USED 10 FT. SCREEN IN DH20 |

# PIEZOMETER CONSTRUCTION

FIGURE C-2 (Not to scale)




# PIEZOMETER CONSTRUCTION FOR DH-3

FIGURE C-3 (Not to scale)

BORING LOGS
(1988)

| | | | | | |
|---|---|---|---|---|---|
| PROJECT | MONTANA SILVER VENTURE | | | JOB NO. 8029 | HOLE NO. USB-1 |
| SITE | Little Cherry Tailings | DATE - STARTED FINISHED | AUG 2 88 - AUG 3 88 | HOLE SIZE 3" | ORIENTATION vertical |
| LOCATION | Libby, Montana | ELEVATION(FT) 3463 | DEPTH TO WATER(FT) 21.6 | | DEPTH TO ROCK (FT) |
| DRILLING CONTRACTOR | Northern Eng.& Test. | SAMPLES 12 | CORE BOXES 0 | | DEPTH OF HOLE (FT) 80.8 |
| DRILL MAKE - MODEL | Mobile B-53 | LOGGED BY M.I. Schauer | | REVIEWED BY D.A. Baskin | |

| ELEV. (FT) | DEPTH (FT) | SAMPLE NUMBER | CASING | SPT/RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3460 | 5 | SPT-1 | | 14<br>16<br>20 | 0 | | | | Road fill at surface<br>**SILTY SANDY GRAVEL (GM),** fine to coarse, brown, wet, dense, maximum gravel size 1-3/8"; sand is fine to medium. | | Started drilling (8/2/88, 9:00 AM)<br>Temperature 40-50 deg.F, overcast, calm |
| | 10 | SPT-2 | | 7<br>9<br>12 | 93 | | | | **SANDY SILTY CLAY - SANDY CLAYEY SILT (CL-ML),** orangish brown, low plasticity, wet, medium stiff. | | Rotary drilled to 5.0', used 4" tricone bit, drilling fluid return light brown, loss 0%<br>Recovered 20% with basket catcher<br>Spun casing to 5.0' (NWFJ, 3-1/2"OD, 3"ID)<br>Rotary drilled 5.0'-55.0', used 2-15/16" tricone bit 5.0'-10.0' and 17.5'-55.0', and finger bit 10'-17.5' |
| 3450 | 15 | SPT-3 | | 14<br>27<br>33 | 73 | | | | **SILTY SAND - CLAYEY SILT -SILTY CLAY (CL-ML),** wet, very dense, hard, interlayered. Silty sand layers are light gray, 2" to 3" thick, nonplastic, recovered one coarse gravel-size piece (looks like decomposed rock). Clayey silt layers are orangish brown, 1" to 2" thick, slightly plastic, with some fine, rounded to subrounded gravel. | | Sandy cuttings and white fluid return at 16.5'-19.8'*<br>Hard drilling at 17.5'-18.5'* |
| | 20 | SPT-4 | | 28<br>41<br>50 | 73 | | | | **SILTY SAND (SM),** light gray to orangish brown, non plastic, wet, very dense; some gravel, fine to coarse, angular, quartzite, maximum size 1". Light gray zones are often hard but can be broken by hand (looks like soft rock). Orangish brown zones have some very fine, rounded to subrounded gravel. | | |
| 3440 | 25 | SPT-5 | | 50/.4 | 100 | | | | **SILTY SANDY GRAVEL (GM),** orangish brown, wet, very dense, rounded to subrounded; sand is fine; fines are non plastic. Contains occasional light gray, hard, silty sand pieces (looks like decomposed rock). | | |
| | 30 | | | | | | | | | | |
| 3430 | 35 | SPT-6 | | 29<br>18<br>31 | 100 | | | | **SILTY SAND (SM),** fine, orangish brown, non plastic, dense, wet; some gravel, fine, rounded to subrounded. | | |
| | 40 | | | | | | | | | | |
| 3420 | 45 | SPT-7 | | 18<br>30<br>50 | 100 | | | | Very dense, trace medium to coarse sand; some gravel, fine to coarse, rounded to subrounded, occasionally angular. | | |

| PROJECT | MONTANA SILVER VENTURE | JOB NO. 8029 | HOLE NO. USB-1 |
|---|---|---|---|

| ELEV. (FT) | DEPTH (FT) | SAMPLE NUMBER | CASING | SPT/ RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3410 | 55 | SPT-8 | | 32<br>50/.4 | 100 | | | | Gravelly, dark orangish brown to light gray, very dense; gravel is coarse, rounded to subrounded. | | Stopped drilling at 55.0' (8/2/88, 3:00 PM)<br>Resumed drilling at 55.0' (8/3/88, 7:00 AM)<br>Temperature 40 deg.F, clear, calm<br>Water level - dry (hole caved at 13.0')<br>Rotary drilled 55.0'-65.0' |
| | 60 | | | | | | | | | | |
| 3400 | 65 | SPT-9 | | 27<br>50/.3 | 88 | | | | Some coarse gravel, rounded to subrounded | | Spun casing 5.0'-20.0'<br>Rotary drilled 65.0'-80.0' |
| | 70 | | | | | | | | | | |
| 3390 | 75 | SPT-10 | | 50/.3 | 67 | | | | Some fine gravel, rounded to subrounded | | |
| | | SPT-11 | | 50/.3 | 100 | | | | | | |
| | 80 | SPT-12 | | 22<br>50/.3 | 75 | | | | GRAVELLY SILTY SAND (SM), fine to coarse, orangish brown, wet, very dense; gravel is fine, rounded to subrounded.<br>**BOTTOM OF HOLE AT 80.8'** | | Stopped drilling (8/3/88, 1:00 PM)<br>Installed piezometer to 80.8' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with no. 16 silica sand to 49.0')<br>Removed all casing<br>Set steel protective surface casing in concrete, .9' stickup above ground surface)<br>8/6/88 - Water level 21.6<br>* Reported by driller<br>NOTE: Drilled new hole USB-1A 4.5' SE along road, augered to 10', pushed Shelby tube 10'-11.8' (1.8'), used pocket penetrometer on bottom of sample: UC=3.5-3.75 tsf |
| 3380 | 85 | | | | | | | | | | |
| | 90 | | | | | | | | | | |
| 3370 | 95 | | | | | | | | | | |
| | 100 | | | | | | | | | | |
| 3360 | 105 | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| PROJECT | MONTANA SILVER VENTURE | | | JOB NO. 8029 | HOLE NO. USB-2 |
| SITE | Little Cherry Tailings | DATE - STARTED FINISHED | JUL 29 88 - AUG 1 88 | HOLE SIZE 3" | ORIENTATION vertical |
| LOCATION | Libby, Montana | ELEVATION(FT) | 3441 | DEPTH TO WATER(FT) 2.8 | DEPTH TO ROCK (FT) |
| DRILLING CONTRACTOR | Northern Eng.& Test. | SAMPLES | 11 | CORE BOXES 0 | DEPTH OF HOLE (FT) 80.8 |
| DRILL MAKE - MODEL | Mobile B-53 | LOGGED BY | M. I. Schauer | REVIEWED BY | D. A. Baskin |

| ELEV. (FT) | DEPTH (FT) | SAMPLE NUMBER | CASING | SPT/RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3440 | | | | | | | | | | | Started drilling (7/29/88, 12:30 PM) |
| | | SPT-1 | | 17<br>50/.2 | 100 | | | | **GRAVELLY SILTY SAND (SM),** orangish brown, non plastic, dry, very dense; gravel is fine to coarse, angular to subangular, maximum size 1-1/2". | ▼ | Temperature 95-100 deg.F, clear, slight wind |
| | 5 | | | | | | | | Boulder at 4.5'-5.5'* | | Augered to 18.5' with hollow stem auger (9"OD, 3-3/8"ID) |
| | | SPT-2 | | 25/0 | 0 | | | | Boulder at 8.0'-10.5'* | | |
| | 10 | | | | | | | | | | |
| 3430 | | SPT-3 | | 49<br>50/.2 | 100 | | | | Orangish brown to light brown, damp, sample looks like decomposed rock. | ▽ | |
| | 15 | | | | | | | | Boulder at 13.2'-14.5'* | | |
| | | SPT-4 | | 50/.4 | 100 | | | | Boulder at 16.0'-17.5'*<br>light brown, damp, sample looks like decomposed rock. | | |
| | | | | | | | | | Boulder at 17.9'-18.5', 18.5'-18.8'* | | |
| | 20 | | | | | | | | | | Stopped drilling at 18.5'(7/29/88, 2:30 PM) |
| 3420 | | SPT-5 | | 50/.3 | 100 | | | | **SILTY SANDY GRAVEL (GM),** fine to coarse, orangish brown, wet, very dense, angular to subangular, quartzite, maximum size 1-1/2"; sand is fine; fines are non plastic. | | Resumed work (7/30/88, 8:00 AM)<br>Temperature 65 deg.F, clear, calm<br>Removed augers<br>Drove casing to 18' (NWFJ, 3-1/2"OD, 3"ID) |
| | 25 | SPT-6 | | 50/.3 | 83 | | | | | | Rotary drilled 18.5'-44.5', using 2-15/16" tricone bit, drilling fluid water, return light brown, no loss |
| | | | | | | | | | Hard gravel/boulders at 27.5'-30.2'* | | |
| | 30 | | | | | | | | | | |
| 3410 | | | | | | | | | Boulders at 31.0'-33.2' | | |
| | 35 | SPT-7 | | 50/.2 | 0 | | | | Sand, gravel, and boulders at 34.7'-41.0'* | | |
| | 40 | | | | | | | | | | |
| 3400 | | | | | | | | | | | Bit keeps blocking off due to silty/clayey matrix at 41.0'-44.5'* |
| | | | | | | | | | **SANDY SILTY GRAVEL (GM),** fine, orangish brown to whitish gray, wet, very dense, maximum size 3/4"; sand is fine; fines are non plastic to slightly plastic. | | |
| | 45 | SPT-8 | | 50/.3 | 100 | | | | | | Hole caved in when pulled tricone to do SPT test at 44.5'<br>Drove casing 18'-40'<br>Stopped work (7/30/88, 3:15 PM)<br>Resumed work (7/31/88, 9:00 AM)<br>Temperature 65 deg.F, clear, calm<br>Drove casing 40.0'-44.6' |

PROJECT: MONTANA SILVER VENTURE | JOB NO. 8029 | HOLE NO. USB-2

| ELEV. (FT) | DEPTH (FT) | SAMPLE NUMBER | CASING | SPT/RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| 3390 | | | | | | | | | Gravel with silty/clayey lumps at 44.9'-54.5'* | | Rotary drilled 44.5'-64.5' |
| | 55 | SPT-9 | | 60/.3 | 100 | | | | **SILTY SANDY GRAVEL (GM),** fine to coarse, orangish brown, wet, very dense, angular to subangular, maximum size 1-1/2"; sand is fine; fines are non plastic to slightly plastic. Gravel at 54.8'-64.5'* | | |
| | 60 | | | | | | | | | | |
| 3380 | | | | | | | | | | | |
| | 65 | SPT-10 | | 9 / 60/.2 | 0 | | | | | | Stopped drilling at 64.5' (7/31/88, 3:30 PM) Resumed drilling at 64.5' (8/1/88, 7:00 AM) Temperature 50-60 deg.F, clear, calm |
| | 70 | | | | | | | | | | |
| 3370 | | | | | | | | | | | |
| | 75 | | | | | | | | Gravel at 74.5'-80.0'* light brown | | Hole caved in when pulled tricone to do SPT test at 74.5' |
| | 80 | SPT-11 | | 22 / 60/.3 | 100 | | | | | | Stopped drilling (8/1/88, 12 NOON) |
| 3360 | | | | | | | | | **BOTTOM OF HOLE AT 80.8'** | | Installed peisometer to 80.8' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with no. 16 silica sand to 55') Removed all casing Set steel protective surface casing in concrete (2"ID, 5' long, 1' stickup above ground surface) |
| | 85 | | | | | | | | | | |
| | 90 | | | | | | | | | | |
| 3350 | | | | | | | | | | | **WATER LEVEL** |
| | 95 | | | | | | | | | | date / level: 7/30/88 13.5'; 7/31/88 2.4'; 8/1/88 2.4'; 8/6/88 2.8' |
| | 100 | | | | | | | | | | |
| 3340 | | | | | | | | | | | |
| | 105 | | | | | | | | | | * Reported by driller |

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SHEET 2 OF 2 | HOLE NO. USB-2

| | | | | | |
|---|---|---|---|---|---|
| PROJECT | MONTANA SILVER VENTURE | | JOB NO. 8029 | HOLE NO. | USB-3 |
| SITE | Little Cherry Tailings | DATE - STARTED FINISHED JUL 26 88 - JUL 29 88 | HOLE SIZE 3" | ORIENTATION | vertical |
| LOCATION | Libby, Montana | ELEVATION(FT) 3581 | DEPTH TO WATER(FT) 34.3 | DEPTH TO ROCK (FT) | 27.0 |
| DRILLING CONTRACTOR | Northern Eng.& Test. | SAMPLES 7 | CORE BOXES 3 | DEPTH OF HOLE (FT) | 70.0 |
| DRILL MAKE - MODEL | Mobile B-53 | LOGGED BY M. I. Schauer | REVIEWED BY | D. A. Baskin | |

| ELEV. (FT) | DEPTH (FT) | SAMPLER NUMBER | CASING | SPT/RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3580 | | | | | | | | | Road fill at surface | | Started drilling (7/26/88, 11:30 AM) |
| | | SPT-1 | | 13<br>21<br>25 | 93 | | | | **SILTY SAND (SM),** orangish brown, nonplastic, dry, dense; gravelly, fine to coarse, subangular, maximum size 2". | | Temperature 95 deg.F, clear, calm<br>Augered to 35.0' with hollow stem auger (9"OD, 3-3/8"ID) |
| | 5 | | | | | | | | | | |
| | | SPT-2 | | 17<br>21<br>26 | 93 | | | | Gravel at 7.0'-7.5'*<br>damp | | |
| | 10 | | | | | | | | | | |
| 3570 | | | | | | | | | Gravel at 11.0'* | | |
| | | SPT-3 | | 18<br>41<br>43 | 93 | | | | | | |
| | 15 | | | | | | | | | | |
| | | SPT-4 | | 18<br>41-<br>40/.1 | 100 | | | | **SILTY SAND-SANDY SILT (SM-ML),** fine, orangish brown, non plastic, very dense, damp; some gravel, fine, gray, angular to subangular, siltite, maximum size 1/2". | | |
| | 20 | | | | | | | | | | |
| 3560 | | SPT-5 | | 41<br>50/.1 | 100 | | | | **SILTY SAND (SM),** fine, orangish brown, non plastic, very dense, damp; some gravel, angular, white and buff quartzite and gray and white siltite, maximum size 1/2". | | Hard drilling at 21.5' * |
| | 25 | | | | | | | | | | |
| | | SPT-6 | | 25/0 | 0 | | | | ? TOP OF BEDROCK AT 27.0' ?<br>Cuttings include coarse, subangular, gravel size pieces of white to gray quartzite, siltite, and argillite. | | Drilling very hard 27.0'-35.0'*<br>Probably have been in coreable rock |
| | 30 | | | | | | | | | | |
| 3550 | | SPT-7 | | 50/.1 | 0 | | | | | ▽ | Stopped drilling at 35.0' (7/26/88, 3:00 PM)<br>Resumed drilling at 35.0' (7/27/88. 7:00 AM)<br>Temperature 65 deg.F., clear, calm, water level - dry |
| | 35 | C-1 | | 30 | 70 | | | | **QUARTZITE** at 35.0' to 37.0', white with some iron oxide staining, wet, moderately weathered, fine grained. Contains large square, darkened glassy crystals, possibly andalusite, almandine, or garnet. Gradational contact with underlying rock. | ▼ | Cored 35.0'-55.0' (NQ, hole diameter 2.98", core diameter 1.875") using augers as casing.<br>Used diamond impregnated coring bit Drilling fluid water, return light orangish brown, loss 0%, 10.0' long double tube core barrel. |
| | 40 | C-2 | | 28 | 96 | | | | **SILTITE/ARGILLITE** at 37.0', orangish brown and light to medium gray, silt-size grains, occasionally clay-size, wet, soft, highly weathered, sometimes vuggy. Bedding spacing 1/4" to 1-1/2", to laminated in places, dip angle 40-60 degrees. Fracture spacing 1" to 6". Fractures are generally parallel to bedding, planar, rough to smooth, closed, occasionally with thin. | | Drilling rate 3 min/ft 35.0'-40.0' |
| 3540 | | | | | | | | | | | Drilling rate 2 min/ft 40.0'-50.0' |
| | 45 | C-3 | | 16 | 72 | | | | | | * Reported by driller |

| PROJECT | MONTANA SILVER VENTURE | JOB NO. 8029 | HOLE NO. USB-3 |
|---|---|---|---|

| ELEV. (FT) | DEPTH (FT) | SAMPLER NUMBER | CASING | SPT/RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3530 | | C-4 | | 0 | 42 | | | | smooth, closed, slightly slickensided, clay filling. Other fractures are irregular, rough, open, vuggy, with iron-and manganese-oxide staining. | | Drilling rate 1 min/ft 50.0'-55.0' |
| | 55 | C-5 | | 0 | 40 | | | | | | Stopped drilling at 55.0'(7/28/88, 4:15 PM)<br>Resumed work (7/28/88, 7:00 AM)<br>Temperature 50-60 deg.F, broken clouds, slight wind<br>Water Pressure Test 1: 38.8'-55.0' |
| 3520 | 60 | C-6 | | 0 | 50 | | | | Very soft at 50.0' to 65.0', completely weathered, highly fractured core pieces. (length < 2-1/2"). | | Stopped work (7/28/88, 9:30 AM)<br>Resumed drilling at 55.0' (7/29/88, 6:30 AM)<br>Temperature 50-55 deg.F, clear, calm |
| | 65 | C-7 | | 10 | 92 | | | | Fracture spacing to 2-1/2", 65.0'-70.0' | | Cored 55.0'-70.0'<br>Stopped drilling at 70.0' (7/29/88, 8:15 AM)<br>Water Pressure Test 2: 50.3'-70.0' |
| 3510 | 70 | | | | | | | | **BOTTOM OF HOLE AT 70.0'** | | No piezometer installed<br>Removed all casing |
| | 75 | | | | | | | | Average RQD of bedrock = 12%<br>Average recovery = 66%<br>Average drilling rate = 2 min/ft | | |
| 3500 | 80 | | | | | | | | | | WATER LEVEL<br>date time level<br>7/28/88 7:00 AM 31.5'<br>7/29/88 6:30 AM 34.3' |
| | 85 | | | | | | | | | | |
| 3490 | 90 | | | | | | | | | | |
| | 95 | | | | | | | | | | |
| 3480 | 100 | | | | | | | | | | |
| | 105 | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| PROJECT | MONTANA SILVER VENTURE | | JOB NO. 8029 | HOLE NO. USB-4 | |
| SITE | Little Cherry Tailings | DATE - STARTED FINISHED AUG 20 88 - AUG 23 88 | HOLE SIZE 3" | ORIENTATION vertical | |
| LOCATION | Libby, Montana | ELEVATION(FT) 3645 ± | DEPTH TO WATER(FT) not encount | DEPTH TO ROCK (FT) | |
| DRILLING CONTRACTOR | Northern Eng & Test. | SAMPLES 4 | CORE BOXES 0 | DEPTH OF HOLE (FT) 25.0 | |
| DRILL MAKE - MODEL | Mobile B-53 | LOGGED BY D. A. Baskin | REVIEWED BY M. P. Forrest | | |

| ELEV. (FT) | DEPTH (FT) | SAMPLE NUMBER | CASING | SPT / RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3640 | 5 | SPT-2 | | 49<br>47<br>50/.4 | 33 | | | | **SILTY SANDY GRAVEL (GM),** orangish brown and gray, nonplastic, very dense, damp; gravel is fine, gray, slightly weathered, hard, fine grained quartsite. | | Started drilling (8/20/88, 7:55 AM)<br>Rotary drilled with water using a 2-15/16" tricone bit<br>Cobbles on surface to approximately 1.0'<br>Brown water return, 100% return<br>Reamed casing to 5.0' (NWFJ 3"ID, 3-1/2"OD) |
| | 10 | SPT-3 | | 50/.3 | 40 | | | | gray, subrounded to subangular, hard, fine grained quartsite. | | Reamed casing to 10.0'<br>Constant head water test at 10.0', water leaking at surface hard to seal casing in gravel<br>Alternates brown and brownish gray water return |
| 3630 | 15 | S-1 | | 50/.1 | 0 | | | | Cobbles and boulders 10.0' to 25.0', gray and white, quartsite and siltite, alternating with layers of silty sand. | | Stopped drilling at 15.0' (8/20/88, 11:45 AM)<br>Remove casing, put on driving shoe (8/23/88, 9:45 AM)<br>Casing driven to 15.0'<br>Constant head water test at 15.0' |
| | 20 | SPT-4 | | 50/.5 | 70 | | | | Silty sand, brown, non plastic, wet; some gravel, fine, gray, hard, fine grained quartsite.<br>Boulder at 21.5' to 23.0', white and gray siltite, hard. | | Casing driven to 20.0'<br>Constant head water test at 20.0'<br>Hole keeps caving after drill rods removed |
| 3620 | 25 | | | | | | | | **BOTTOM OF HOLE AT 25.0'** | | Stopped drilling (8/23/88, 3:00 PM) |
| | 30 | | | | | | | | | | |
| 3610 | 35 | | | | | | | | | | |
| | 40 | | | | | | | | | | |
| 3600 | 45 | | | | | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| PROJECT | MONTANA SILVER VENTURE | | | JOB NO. 8029 | HOLE NO. USB-5 |
| SITE | Little Cherry Tailings | DATE - STARTED FINISHED | AUG 24 88 - AUG 24 88 | HOLE SIZE 3" | ORIENTATION vertical |
| LOCATION | Libby, Montana | ELEVATION(FT) 3516 | DEPTH TO WATER(FT) 27.1 | | DEPTH TO ROCK (FT) |
| DRILLING CONTRACTOR | Northern Eng & Test. | SAMPLES 7 | CORE BOXES 0 | | DEPTH OF HOLE (FT) 50.3 |
| DRILL MAKE - MODEL | Mobile B-53 | LOGGED BY D. A. Baskin | | REVIEWED BY M. P. Forrest | |

| ELEV. (FT) | DEPTH (FT) | SAMPLE NUMBER | CASING | SPT / RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | **GRAVELLY SANDY SILT (ML),** orangish brown, non plastic, very dense, moist to wet; sand is fine; gravel is fine to coarse, gray and white, slightly weathered to completely weathered, fine grained. | | Started drilling (8/24/88, 9:20 AM)<br>2-15/16" tricone bit and water<br>Cobbles and boulders at surface<br>Ream casing to 5.0' (NWFJ 3"ID, 3-1/2"OD)<br>Orange brown water return |
| 3510 | 5 | SPT-1 | | 21<br>30<br>60/.2 | 100 | | | | | | |
| | 10 | SPT-2 | | 50/.45 | 85 | | | | **GRAVELLY SILTY SAND (SM),** orangish brown, non plastic, very dense, moist; gravel is fine to coarse, orangish brown, gray, and white, fine grained to aphanitic.<br>Cobbles 11.0' to 19.0' | | Ream casing to 10.0'<br>Constant head water test at 10.0'<br>.007 GPM<br>Return water alternates orangish brown and gray, silty sand and cobbles |
| 3500 | 15 | | | | | | | | **SILTY CLAY - CLAYEY SILT (CL-ML),** hard, trace to some fine gravel, gray, fine grained, completely weathered. | | Constant head water test at 15.0', casing at 10.0' |
| | 20 | SPT-3 | | 16<br>19<br>50 | 80 | | | | | | |
| 3490 | 25 | SPT-4 | | 32<br>50/.4 | 88 | | | | Some coarse gravel, gray, slightly weathered | ▼ | Constant head water test at 25.0', casing at 10.0' |
| | 30 | | | | | | | | Cobble at 31.0'<br>Cobble at 33.0' | | |
| 3480 | 35 | SPT-5 | | 50/.25 | 0 | | | | | | |
| | 40 | SPT-6 | | 50/.2 | 90 | | | | Cobbles 41.0' to 50.0' | | Constant head water test at 40.0', casing at 10.0' |
| 3470 | 45 | | | | | | | | | | Stop drilling at 50.0' (8/24/88, 4:15 PM)<br>Installed piezometer to 50.2' (1"ID Schedule 80 PVC pipe, bottom 20' slotted .02" width, backfilled to 25' with no. 16 silica sand, backfilled to 3' with bentonite pellets) |

| PROJECT | MONTANA SILVER VENTURE | JOB NO. 8029 | HOLE NO. USB-5 |
|---|---|---|---|

| ELEV. (FT) | DEPTH (FT) | SAMPLE NUMBER | CASING | SPT/RQD | RECOV. | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SPT-1 | | 50/.3 | 20 | | | | **SANDY GRAVEL (GM)** gray, white, and orangish brown, slightly weathered, subrounded to rounded, maximum size 1/2". | | Depth to water 27.1' (8/26/88, 7:10 AM) |
| | | | | | | | | | **BOTTOM OF HOLE AT 50.3'** | | |

55
3460
60
65
3450
70
75
3440
80
85
3430
90
95
3420
100
105

BORING LOGS
(1989)

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-1 |
| SITE: Near north abotment of tailings dam | DATE - STARTED 08-12-89 FINISHED 08-14-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION N 3435' | DEPTH TO WATER 21' | DEPTH TO ROCK 77' |
| DRILLING CONTRACTOR: J.D. Welsh | SAMPLES 5 | CORE BOXES 3 | DEPTH OF HOLE 100' |
| DRILL MAKE - MODEL: ACKER AD II | LOGGED BY A.M. SILVA | | REVIEWED BY U.J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY % | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3435' | 0 | | | | | | | | | GRAVELLY SANDY SILT - SILTY SAND (ML-SM) - dry, brn., non-pl., m. dense. | | Advanced hole with hollow-stem auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | SPT #1 | | 10<br>17<br>21 | 100% | | | | | GRAVELLY, SANDY, SILTY CLAY (CL-ML) brn., dry, non-plastic, m. dense-dense; gravels < 1" ϕ, subangular. | | Advanced hole with standard split-spoon sampler |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | (4.5 ton/ft² pressure makes ¼" indentation in ML) |
| 3425' | 10 | | | | | | | | | ML - clayey w/ few cobbles; cobble fragments consist of metasandstone and metaquartzite. | | Began HQ coring<br>-Lost drilling water return (10' @ 16.5')<br>-Noticed water coming out in test pit DT-2 across road. |
| | 11 | | | | | | | | | | | |
| | 12 | | | | | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | | | |
| | 15 | | | | | | | | | | | |
| | 16 | | | | | | | | | | | |
| | 17 | SPT #2 | | 22<br>35<br>31 | 100% | | | | | CLAYEY, SANDY SILT (ML) - with gravels; brn., dry, sl. pl., v. stiff | | |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3415' | 20 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-1 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3415' | 20 | | | | | | | | | CLAYEY, SANDY SILT (ML) - with gravels; brn., dry, sl. pl., v. stiff | | |
| | 21 | | | | | | | | | | ▼ 11' | Encountered water at 21' (8-23-89) |
| | 22 | | | | | | | | | | | |
| | 23 | SPT #3 | | 19 / 29 / 26 | 100% | | | | | SANDY, SILTY CLAY (CL) with some gravel | | |
| | 24 | | | | | | | | | | | |
| | 25 | | | | | | | | | | | |
| | 26 | | | | | | | | | | | |
| | 27 | | | | | | | | | ↓ some cobbles of metaquartzite & metasandstone. | | |
| | 28 | | | | | | | | | Occ. gravelly sections | | |
| | 29 | | | | | | | | | | | |
| 3405' | 30 | | | | | | | | | | | |
| | 31 | | | | | | | | | | | |
| | 32 | | | | | | | | | | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | | | | | ML - as above, dry - damp, v. stiff. Gravels & cobbles sub-angular, hard | | |
| | 35 | | | | | | | | | | | Conducted permeability test # 1 at 35' (30-35') |
| | 36 | | | | | | | | | | | |
| | 37 | | | | | | | | | | | |
| | 38 | | | | | | | | | | | |
| | 39 | | | | | | | | | | | |
| 3375' | 40 | | | | | | | | | | | Conducted permeability test #2 at 40' (35-40') |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-1 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3395' | 40 | SS | | 50" | 60% | | | | | CLAYEY, SANDY SILT (ML) - brn, dry-damp, v. stiff, non-plastic, with some gravels & cobbles (metaquartzite & metasandstone) | | Refusal after 5" penetration |
| | 41 | | | | | | | | | | | |
| | 42 | | | | | | | | | | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | | | |
| | 45 | | | | | | | | | | | |
| | 46 | | | | | | | | | | | |
| | 47 | | | | | | | | | | | |
| | 48 | | | | | | | | | | | |
| | 49 | | | | | | | | | | | |
| 3385' | 50 | | | | | | | | | Material becomes gravelly ML | | |
| | 51 | | | | | | | | | | | |
| | 52 | | | | | | | | | | | |
| | 53 | | | | | | | | | | | |
| | 54 | SS | | 50" | 60% | | | | | GRAVELLY, SANDY SILT (ML), brn, dry, non-plastic, tr. clay, v. stiff; possibly SM | | Refusal after 5" penetration |
| | 55 | | | | | | | | | Cobbles subrounded, consist of siltstone, argillite, metasandstone + metaquartzite | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | | | | | | | | |
| | 59 | | | | | | | | | | | |
| 3375' | 60 | | | | | | | | | | | |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-1 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | Box # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| 3375' | 60 | | | | | | | | | GRAVELLY SANDY SILT (ML) - SILTY SAND (SM) - brn., dry, non-plastic, v. stiff (dense SM), subrounded gravel & cobbles | | |
| | 61 | | | | | | | | | | | |
| | 62 | | | | | | | | | | | |
| | 63 | | | | | | | | | | | |
| | 64 | | | | | | | | | } soft, siltstone - argillite frag. | | Rough drilling |
| | 65 | | | | | | | | | | | Some vibrations |
| | 66 | | | | | | | | | Metasediment cobbles | | |
| | 67 | | | | | | | | | | | |
| | 68 | | | | | | | | | | | |
| | 69 | | | | | | | | | | | |
| 3365' | 70 | | | | | | | | | | | Performed permeability test #3 at 70' (65.5 - 70') |
| | 71 | | | | | | | | | | | |
| | 72 | | | | | | | | | | | |
| | 73 | | | | | | | | | | | |
| | 74 | | | | | | | | | | | |
| | 75 | | | | | | | | | | | |
| | 76 | | | | | | | | | | | |
| | 77 | | | | | | | | | BEDROCK AT 77' (METASEDIMENTS) | | |
| | 78 | | | 51% | 100% | 1 | | | | SILTSTONE, ARGILLITE, SOME METASANDSTONE - interbedded, org. brn., mod-int. fractured & weathered, soft-hard. | | Smooth drilling |
| | 79 | | | | | | | | | | | |
| 3355' | 80 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-1 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3355' | 80 | | | | | | | | | **SILTSTONE, ARGILLITE, SOME METASANDSTONE** -interbedded, org. brn., dry, mod.-int. fractured and weathered, soft-hard. | | |
| | 81 | | | 0 | 85% | | | | | | | |
| | 82 | | | | | | | | | | | |
| | 83 | | | 31% | 93% | 1 | | | | Fractures along Laminae at ∠ 45°-60°; surfaces are sl. rough, some smooth, few slickensides. Fe-oxide stains in some fract. | | Smooth drilling |
| | 84 | | | | | | | | | | | |
| | 85 | | | | | | | | | | | |
| | 86 | | | | | | | | | | | |
| | 87 | | | 28% | 100% | | | | | ← grey, metasandstone, hard but fractured | | |
| | 88 | | | | | 2 | | | | | | |
| | 89 | | | | | | | | | } int. fractured | | |
| 3345' | 90 | | | | | | | | | | | Conducted packer test #4 at 90' (80-90') |
| | 91 | | | 62% | 100% | | | | | ← hard but m. fractured siltstone; (fr. > 6 fr/ft. at ∠ 60°) along Laminae | | |
| | 92 | | | | | | | | | | | |
| | 93 | | | | | | | | | | | |
| | 94 | | | 21% | 100% | | | | | | | |
| | 95 | | | | | | | | | | | |
| | 96 | | | | | | | | | | | |
| | 97 | | | | | | | | | grey, hard, fractured metasedi-ments. | | |
| | 98 | | | 33% | 95% | 3 | | | | | | |
| | 99 | | | | | | | | | | | |
| 3335' | 100 | | | | | | | | | } int. fractured | | |
| | | | | | | | | | | BOH AT 100' | | Installed PVC pipe |

MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| | | | |
|---|---|---|---|
| PROJECT NORANDA | | JOB NO. 8029 | HOLE NO. DH-2 |
| SITE Near center of tailings dam | DATE STARTED 9-19-89 FINISHED 9-20-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION Libby, Montana | ELEVATION 3410' | DEPTH TO WATER 6' | DEPTH TO ROCK 54' |
| DRILLING CONTRACTOR Chen-Northern/J. D. Welsh | SAMPLES 3 | CORE BOXES 8 | DEPTH OF HOLE 110' |
| DRILL MAKE - MODEL ACKER AD II | LOGGED BY A.M. SILVA | | REVIEWED BY U. J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3410' | 0 | | | | % | | | | | SANDY SILT (ML) w/ clay - brn., dry, soft, sl. plastic | | Advanced hole with hollow-stem auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | SPT #1 | | 3<br>4<br>8 | | | | | | GRAVELLY, SANDY SILT (ML) - brn., dry, sl. plastic, soft | | Advanced hole w/ standard split-spoon sampler |
| | 6 | | | | | | | | | | ▼ | Encountered water at 6' (9-19-89) |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| | 9 | SH-1 | | | 0 | | | | | | | Pushed Shelby 9" w/ 500 lbs pressure — NO RECOVERY |
| 3400' | 10 | | | | | | | | | | | Began HQ coring |
| | 11 | | | | 100% | | | | | CLAYEY SANDY SILT (ML) - damp, as above | | No unconfined strength |
| | 12 | | | | | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | CLAYEY, SANDY SILT (ML) with gravels and cobbles | | |
| | 15 | | | 50" | | | | | | ML as above<br>Gravels & cobbles subrounded, m. hard, fract. metasediments. | | Attempted SPT #2; REFUSAL at 1"<br>Good drill water return |
| | 16 | | | | | | | | | | | |
| | 17 | | | | 88% | 1 | | | | | | |
| | 18 | | | | | | | | | grey siltstone, m. hard, fractured | | |
| | 19 | | | | | | | | | | | |
| 3390' | 20 | | | 50" | | | | | | | | Attempted SPT #3; REFUSAL at 1" |

WATER DATA: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS

REMARKS: STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-2 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | RQD % | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3390' | 20 | | | | | | | | | CLAYEY SANDY SILT (ML) with gravels & cobbles; brn., damp, sl. pl. | |
| | 21 | | | | | | | | | | |
| | 22 | | | | 62 % | | | | | | |
| | 23 | | | | | | | | | ↓ Increasing gr. & cobble content | |
| | 24 | | | | | | | | | | |
| | 25 | | | | | | | | | COBBLES & GRAVELS in a sandy silt matrix. | |
| | 26 | | | | 60 % | | | | | | |
| | 27 | | | | | | | | | Cobbles are metasediments (mostly argillite, siltstone, occ. metaqtzite and meta sandstone); int. fract. | |
| | 28 | | | | | | | | | } int. fractured argillite | |
| | 29 | | | | | | | | | | |
| 3380' | 30 | | | | 62 % | 2 | | | | ← ML | |
| | 31 | | | | | | | | | ← fract. metaquartzite | |
| | 32 | | | | | | | | | ← ML w/ gr. | |
| | 33 | | | | | | | | | | |
| | 34 | | | | 62 % | | | | | | |
| | 35 | | | | | | | | | } fract. metasandstone boulder (interbedded boulder - ML - boulder) (or boulder - siltstone - boulder) | |
| | 36 | | | | | | | | | | |
| | 37 | | | | | | | | | | |
| | 38 | | | | 75 % | 3 | | | | ← v. hard metaquartzite, Lt. grey, fract. | |
| | 39 | | | | | | | | | | |
| 3370' | 40 | | | | | | | | | | |

REMARKS

SAMPLING — STANDARD PENETRATION
DRILL ACTION — WATER PRESSURE TEST
WATER LOSS — LAB CLASSIFICATION
CORE LOSS — PIEZOMETERS

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-2 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3370' | 40 | | | | | | | | | METASEDIMENT COBBLES & BOULDERS in sandy silt (ML) matrix. Rock fragments/core is mainly metaquartzite w/ occ. siltstone, argillite, & meta-sandstone. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 41 | | | | 33 % | | | | | | | |
| | 42 | | | | | | | | | | | |
| | 43 | | | | | | | | | Rock core is m. hard, fract., sub-round. ML matrix is generally lost by washing during drilling | | |
| | 44 | | | | | | | | | | | |
| | 45 | | | | | | | | | | | |
| | 46 | | | | 57 % | 3 | | | | | | |
| | 47 | | | | | | | | | | | |
| | 48 | | | | | | | | | | | |
| | 49 | | | | | | | | | | | |
| 3360' | 50 | | | | | | | | | Typical sequence: ← ML, brn., damp, sl. stiff, sl. pl. | | |
| | 51 | | | | 71 % | | | | | | | |
| | 52 | | | | | | | | | ← metasandstone, fract., m. hard | | |
| | 53 | | | | | | | | | ← metaquartzite, v. hard, fract | | |
| | 54 | | | | | | | | | BEDROCK AT 54' | | |
| | 55 | | | 0 | 45% | 4 | | | | SILTSTONE, ARGILLITE, METASANDSTONE - interbedded org-brn., friable (sections are int. fract.), highly weathered. | | Org. brn. drill water return |
| | 56 | | | | | | | | | | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | | | | | | Fracturing occurs along thin laminae at ≤ 45°; some silt in fract. surfaces; occ. fract. near vertical; few slickensides | | |
| | 59 | | | | | | | | | | | |
| 3350' | 60' | | | | | | | | | V. poor quality rock | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-2 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3350' | 60 | | | | | | | | | SILTSTONE, ARGILLITE, META-SANDSTONE - interbedded; org. brn., friable (breaks along laminae), h. weathered, soft. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 61 | | | 0 | 83 % | | | | | | | |
| | 62 | | | | | | | | | | | |
| | 63 | | | | | | | | | | | |
| | 64 | | | | | | | | | | | |
| | 65 | | | | | | | | | | | |
| | 66 | | | 0 | 64 % | 4 | | | | | | |
| | 67 | | | | | | | | | Friable rock (easily broken by hand) | | |
| | 68 | | | | | | | | | | | |
| | 69 | | | | | | | | | White, talc coating on fract. surface | | |
| 3340' | 70 | | | | | | | | | | | |
| | 71 | | | | | | | | | | | |
| | 72 | | | 0 | 78 % | | | | | V. poor quality rock | | |
| | 73 | | | | | 5 | | | | | | |
| | 74 | | | | | | | | | | | Conducted packer test #1 at 74' (55' to 74') |
| | 75 | | | 0 | 70 % | | | | | Rock becomes harder | | |
| | 76 | | | | | | | | | | | |
| | 77 | | | | | | | | | | | |
| | 78 | | | 27 % | 100 % | | | | | Occ. metaquartzite interbeds; dk-gm. | | |
| | 79 | | | | | | | | | Occ. vugs (< .5cm ϕ) | | |
| 3330' | 80 | | | | | | | | | Tr. silt in fracture surfaces | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-2 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | Bot/# | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3330' | 80 | | | | | | | | | SILTSTONE, ARGILLITE w/ METAQUARTZITE & METASANDSTONE INTERBEDS – friable (soft-hard), mod.–int. fractured, h. weathered. | | |
| | 81 | | | 30% | 100% | | | | | | | |
| | 82 | | | | | | | | | | | |
| | 83 | | | | | 6 | | | | Fracture frequency: >6 fr./ft.; rock is not friable in most sections | | |
| | 84 | | | | | | | | | | | |
| | 85 | | | 35% | 90% | | | | | tr. ML (weathered argillite?) | | |
| | 86 | | | | | | | | | Poor quality rock | | |
| | 87 | | | | | | | | | | | |
| | 88 | | | | | | | | | Brn., sl. hard, fract. (>3 fr/ft.) siltstone & argillite | | |
| | 89 | | | 90% | 92% | | | | | grey, m. hard siltstone | | |
| 3320' | 90 | | | | | | | | | | | Conducted permeability test #2 at 90' (70' to 90') |
| | 91 | | | | | | | | | Fractures in siltstone & argillite are straight – sl. rough to smooth, some filled w/ silty clay & Fe-oxide stains; traces of slickensides. Most fract. are at ∠ 40°–60° and occ. near vertical. | | |
| | 92 | | | | | 7 | | | | | | |
| | 93 | | | | | | | | | | | |
| | 94 | | | 0 | 44% | | | | | | | |
| | 95 | | | | | | | | | int. fractured siltstone | | Slow drilling |
| | 96 | | | | | | | | | | | |
| | 97 | | | | | | | | | | | |
| | 98 | | | | | | | | | | | |
| | 99 | | | | | | | | | hard m. qtzite | | |
| 3310' | 100 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-2 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3310' | 100 | | | | | | | | | SILTSTONE, ARGILLITE w/ occ. metasandstone & metaquartzite interbeds; – brn., mod.-int. fract., h. weathered. int. fractured | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 101 | | | | | | | | | | | |
| | 102 | | | 0 | 26 % | 7 | | | | | | |
| | 103 | | | | | | | | | | | |
| | 104 | | | | | | | | | – m. qtzite | | |
| | 105 | | | | | | | | | Siltstone not friable but fractured at ∠ 30° – 50°; clean fract. surfaces | | |
| | 106 | | | | | | | | | | | |
| | 107 | | | 52 % | 76 % | 8 | | | | | | |
| | 108 | | | | | | | | | | | |
| | 109 | | | | | | | | | | | Conducted permeability test #3 at 110' (90' to 110') |
| 3300' | 110' | | | | | | | | | BOH AT 110' | | Installed PVC pipe |

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A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 | HOLE NO. DH-2

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-3 |
| SITE: Near center of tailings dam | DATE - STARTED 09-9-89 FINISHED 09-18-89 | HOLE SIZE 3.782" 2.986" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION N 3435' | DEPTH TO WATER ARTESIAN | DEPTH TO ROCK NE |
| DRILLING CONTRACTOR: Chen-Northern / J.D. Welsh | SAMPLES 9 | CORE BOXES 25 | DEPTH OF HOLE 367' |
| DRILL MAKE - MODEL: ACKER AD II | LOGGED BY A.M. SILVA | REVIEWED BY D.J. CORDON | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3435' | 0 | | | | | | | | | CLAYEY, SANDY SILT (ML) w/ gravels; reddish-brn., dry-damp, sl. plastic, | | Advanced hole w/ HQ coring bit |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | High unconfined strength |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | |
| | 6 | SPT #1 | | 7, 12, 12 | 100% | | | | | SANDY, SILTY CLAY (CL-ML) - brn., dry-damp, sl. plastic, sandier at 5.8'-6.5', some gravels, sl. stiff | | Set casing at 5' |
| | 7 | | | | | | | | | Gravels are subrounded, hard meta-quartzite, metasandstone, siltstone. | | Advanced hole w/ standard split-spoon sampler |
| | 8 | | | | 17% | | | | | | | |
| | 9 | | | | | | | | | | | |
| 3425' | 10 | SPT #2 | | 7, 8, 11 | 83% | 1 | | | | CLAYEY, SANDY SILT (ML-SM) (as above) - m. soft | | |
| | 11 | | | | | | | | | | | Using polymer drilling fluid |
| | 12 | | | | 90% | | | | | Occ. areas as MH-SC | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | few gravels | | |
| | 15 | SPT #3 | | 3, 6, 7 | 66% | | | | | SANDY, SILTY CLAY (CL) - brn., dry-damp, sl. pl.-plastic, soft, tr. gravels | | |
| | 16 | | | | | | | | | | | |
| | 17 | | | | 70% | 2 | | | | | | |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3415' | 20 | | | | | | | | | | | |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS



REVISED

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-3 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT. INJ-ITIES TYPE | DISCONT. INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3415' | 20 | SPT #4 | | 3 | 44 % | | | | | SANDY CLAYEY SILT (MH) - brn.-grey, moist, pl. - sl.pl., soft, some gravels & occ. cobbles; some sections are CH | |
| | 21 | | | 6 | | | | | | | |
| | | | | 7 | | | | | | | |
| | 22 | | | | | | | | | | |
| | 23 | | | | 80 % | | | | | | |
| | 24 | | | | | 2 | | | | | |
| | 25 | | | | | | | | | CLAYEY SANDY SILT (ML-MH) - brn., damp, sl. pl., m. stiff, w/ some gravel & cobbles | |
| | | SPT #5 | | 47 | 44 % | | | | | | |
| | 26 | | | 19 | | | | | | | |
| | | | | 17 | | | | | | | |
| | 27 | | | | | | | | | | |
| | 28 | | | | 80 % | | | | | | |
| | 29 | | | | | | | | | | |
| 3405' | 30 | | | | | | | | | | |
| | 31 | | | | | | | | | GRAVELS & COBBLES w/ clayey sandy silt. Subrounded, hard, metaquartzite, siltstone, metasandstone. Soil is org.-brn., damp, sl. plastic. | |
| | 32 | | | | 56 % | 3 | | | | | |
| | 33 | | | | | | | | | Cobbles at times soft, fractured, weathered | |
| | 34 | | | | | | | | | | |
| | 35 | | | | | | | | | Increasing cobble content | |
| | 36 | | | | | | | | | | |
| | 37 | | | | 62 % | | | | | | |
| | 38 | | | | | | | | | | |
| | 39 | | | | | | | | | | |
| 3395' | 40 | | | | | | | | | | |

| REMARKS | |
|---|---|
| SAMPLING | STANDARD PENETRATION |
| DRILL ACTION | WATER PRESSURE TEST |
| WATER LOSS | LAB CLASSIFICATION |
| CORE LOSS | PIEZOMETERS |

Good drill water return

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-3 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

DTE: CHANGE IN SCALE

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3395' | 40 | | | | 77 % | 3 | | | | GRAVELS & COBBLES w/ sandy silt, some clay | | |
| | 50 | | | | 73 % | 4 | | | | SANDY SILT (ML) w/ gravels & cobbles; some clay, brn., damp, Loose–stiff, sl. pl. | | |
| | | | | | 100 % | | | | | – friable siltstone, argillite cobbles, & occ. boulders | | |
| | 60 | | | | 100% | 5 | | | | | | |
| | | | | | 100% | | | | | | | |
| | | | | | 80 % | | | | | Gravels can be removed easily | | |
| | 70 | | | | 100 % | 6 | | | | | | |
| | | #6 | | | | | | | | SANDY SILT (ML) – v. stiff V. dense (ML) (SM) w/ few gravels | | Attempted SPT #6; advanced 11" before refusal; n = 25/50+ Recovery 4" |
| | 80 | | | | 100% | 7 | | | | Soil matrix well cemented, brn. | | |
| | | | | | 100% | | | | | | | Good drilling water return |
| | | | | | 60% | | | | | | | |
| 3345' | 90 | | | | 100 % | 8 | | | | | | |
| | | | | | 100 % | 9 | | | | | | |
| | 100 | | | | 100% | | | | | | | |
| | | | | | 100% | | | | | Occ. siltstone & argillite boulders | | |
| | 110 | | | | 80% | 10 | | | | | | |
| | | | | | 100% | | | | | | | |
| | | | | | 100% | 11 | | | | | | |
| | 120 | #7 | | | | | | | | | | Attempted SPT #7; advanced only 5" before refusal. NO RECOVERY |
| | | | | | 68 % | | | | | Increasing content of cobbles & boulders (grey metasandstones & siltstones), fract., weathered. | | |
| | | | | | 72 % | | | | | | | |
| | 130 | | | | 88 % | 12 | | | | | | |
| | | #8 | | | | | | | | Loose/soft sandy silt (ML-SM) | | Attempted SPT #8; advanced only 2"; RECOVERED 100% |
| 3295' | 140 | | | | 70% | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-3 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3225' | 140 | | | | 100% | 13 | | | | SANDY SILT (ML) w/ gravels & cobbles; org. brn., damp, sl. pl., v. dense. Subrounded gravels | | Attempted SPT #9; advanced only 1.5" (100% RECOVERY) |
| | | | | | | | | | | friable | | |
| | 150 | | | | 100% | | | | | | | Drilling rate ≈ .3 ft/min. |
| | | | | | 70% | 14 | | | | ← gravels | | |
| | | | | | 68% | | | | | | | Conducted permeability test at 160' (120' to 160') |
| | 160 | | | | 64% | | | | | | | Drilling becomes more difficult |
| | | | | | 100% | | | | | COBBLES & BOULDERS – subrounded, hard, few gravels, fr. ML. Metaquartzite, metasandstone, argillite, siltstone, fractured & weathered | | |
| | | | | | 82% | 15 | | | | | | |
| | 170 | | | | 80% | | | | | } int. fract. | | |
| | | | | | 88% | | | | | | | |
| | 180 | | | | 86% | 16 | | | | ← friable siltstone, argillite | | |
| | | | | | 62% | | | | | | | |
| 3245' | 190 | | | | 29% | 17 | | | | | | Drilling rate: .16 ft/min. |
| | | | | | 35% | 18 | | | | | | |
| | 200 | | | | 50% | | | | | Few fines – none recovered (washed) | | |
| | | | | | 11% | | | | | ] | | |
| | 210 | | | | | | | | | | | |
| | | | | | 9% | | | | | Only cobbles & boulders recovered | | Drilling rate: .4 ft/min. |
| | 220 | | | | | | | | | | | |
| | | | | | 21% | | | | | | | |
| | 230 | | | | 47% | | | | | } Int. fract. | | Water seeping out of casing |
| | | | | | 60% | 19 | | | | ML recovered ↓ | | Unconfined strength ≈ 1.5-2.0 tons/ft² |
| 3195' | 240 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-3 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3195' | 240 | | | | 50% | | | | | COBBLES & BOULDERS IN ML MATRIX (as above) | | Drilling rate: .16 ft/min |
| | | | | | | 19 | | | | Increasing ML content | | |
| | 250 | | | | 27 % | | | | | | | |
| | | | | | 50 % | 20 | | | | Decreasing content of ML<br>BOULDERS & COBBLES<br>- Hard, siltstone, metas.s. (2-5 ft/ft) | | Smoother drilling |
| | 260 | | | | 67% | | | | | | | |
| | 270 | | | | ? | | | | | | | |
| | | | | | 46 % | 21 | | | | - conglomerate | | |
| | 280 | | | | 44% | | | | | } int. fractured | | |
| | | | | | 58 % | | | | | Trace ML, mostly boulders<br>- conglomerate | | |
| 3145' | 290 | | | | | | | | | Fract. ∠ 45°, rough surface | | |
| | | | | | 38 % | 22 | | | | | | |
| | 300 | | | | 65% | | | | | Hard metasediments, occ. Loose gravels, at times boulders are intensely fractured, few slickensides | | |
| | | | | | 35% | | | | | | | |
| | 310 | | | | 58 % | | | | | - gravels, subrounded, ∠ 5cm ϕ | | |
| | | | | | 22% | 23 | | | | ← fractured | | |
| | 320 | | | | | | | | | | | |
| | | | | | 31 % | | | | | | | |
| | 330 | | | | | | | | | | | |
| | | | | | 25 % | 24 | | | | | | |
| 3095' | 340 | | | | | | | | | | | |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-3 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3095' | 340 | | | | 97% | | | | | BOULDERS (metasediments) mainly metaquartzite & metasandstone w/ cobbles, occ. gravels, and ML soil matrix; fractured, at times soft. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | | | | | | 24 | | | | | | |
| | 350 | | | | 29% | | | | | ← Hard metass. | | |
| | | | | | 87% | | | | | ← Some clayey silt in fractured boulders | | Harder drilling |
| | | | | | 60% | 25 | | | | — greenish color | | |
| | 360 | | | | 98% | | | | | — conglomerate wedge on metasandstone boulder | | |
| | | | | | 452 | | | | | | | |
| 3068' | 367' | | | | | | | | | BOH AT 367' | | Installed 1" PVC pipe to 260' and a ½" PVC pipe to 160'<br>NOTE: Water is flowing from well at a rate of .15 gpm |

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SHEET 6 OF 6 | HOLE NO. DH-3

| | | | | | |
|---|---|---|---|---|---|
| PROJECT: NORALDA | | | JOB NO. 8029 | HOLE NO. DH 3A | |
| SITE: TAILINGS IMPOUNDMENT | DATE - STARTED 9/15/89 FINISHED 9/15/89 | | HOLE SIZE (AUGER) | ORIENTATION | |
| LOCATION: UBBN, N.M. | ELEVATION | DEPTH TO WATER NE | DEPTH TO ROCK NE | | |
| DRILLING CONTRACTOR: JOHN-NORTHERN / J.D. WELSH | SAMPLES 9 | CORE BOXES — | DEPTH OF HOLE 25' | | |
| DRILL MAKE - MODEL: AUGER ADII | LOGGED BY: AILEEN M. SILVA | | REVIEWED BY | | |

| ELEV. | DEPTH | SAMPLER | CASING | SPT/ROD | RECOVERY | "N" | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | | | | |
| | | BR 1 | | | 18" | 5<br>20<br>26 | | | | SANDY SILTY SOIL (SM) w/ gravels, sl. pl. | |
| | 5 | | | | | | | | | | |
| | | BR 2 | | | 6" | 6<br>13<br>9/3" | | | | SILTY CLAY to CLAYEY SILT (CL-M) some sands and gravels | |
| | 10 | SH 1 | | | 17" | 500 psi | | | | | |
| | | SH 2 | | | 21.5" | 500 psi | | | | | |
| | 15 | SH 3 | | | 18.5" | 250 psi | | | | | |
| | | SH 4 | | | 20" | 500 psi | | | | | |
| | 20 | SH 5 | | | 24" | 250 psi | | | | | |
| | | SH 6 | | | 24" | 450 psi | | | | | |
| | | SH 7 | | | 20" | 500 psi | | | | | |
| | 25 | | | | | | | | | BOTTOM OF HOLE @ 25' | |

**REMARKS**

SAMPLING — STANDARD PENETRATION
DRILL ACTION — WATER PRESSURE TEST
WATER LOSS — LAB CLASSIFICATION
CORE LOSS — PIEZOMETERS

augered to 25' as a offset to DH-3 to obtain undisturbed samples in surface zone.

BRASS RINGS=BR
SHELBY'S = SH

quit for the day @ 25' - filled hole back in.

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SHEET 1 OF 1 | HOLE NO. DH 3A

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-4 |
| SITE: South Saddle Dam | DATE - STARTED 9-8-89 FINISHED 9-8-89 | HOLE SIZE 3,782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ≈ 3590' | DEPTH TO WATER N.E. | DEPTH TO ROCK 9' |
| DRILLING CONTRACTOR: J.D. Welsh | SAMPLES 1 | CORE BOXES 3 | DEPTH OF HOLE 40' |
| DRILL MAKE - MODEL: ACKER AD II | LOGGED BY M.I. SCHAUER | | REVIEWED BY U.J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3590' | 0 | | ← HWFJ (4" I.D.) → | | % | | | | | SANDY SILT (ML) - Lt. brn., dry-moist, soft, some organics, non-plastic. Approx. 60% n-pl. fines 40% f. sand | | |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | ? Increasing gravel content, ML → GM | | Lt. brn. water return |
| | 4 | | | | | | | | | | | |
| | 5 | SPT #1 | | 25 / 25+ | 43 | | | | | SANDY SILTY GRAVEL (GM) - Lt. brn., wet, v. dense, quartzite gravels < 4cm ϕ | | SPT #1: Second set of blows 25+ only advanced hole .2' |
| | 6 | | | | | | | | | Approx. 65% coarse, ang. gravels 20% non-pl. fines 15% fine sand | | Advanced hole w/ HQ-size diamond bit & split-tube core barrel |
| | 7 | | | | 27 % | | | | | | | |
| | 8 | | | | | 1 | | | | | | |
| | 9 | | | | | | | | | BEDROCK AT 9' | | |
| 3580' | 10 | | | | | | | | | SILTSTONE, ARGILLITE, META-SANDSTONE/QUARTZITE - interbedded, Lt. brn., wet, m. hard, mod. weathered. | | |
| | 11 | | | 18 % | 53 % | | | | | | | Drilling rate. .33 ft/min. |
| | 12 | | | | | | | | | — Siltstone & argillite break easily (friable) along laminae at ∢ 45°; Some areas are v. soft - soft; fracture surfaces occ. have soft clay filling or chlorite / talc. | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | | | |
| | 15 | | | | | | | | | — Metasandstone/metaquartzite is generally m. hard but fractured | | |
| | 16 | | | | | | | | | | | |
| | 17 | | | 38 % | 86 % | | | | | Poor - fair quality rock | | |
| | 18 | | | | | | | | | Fracture frequency: 2-5 fr/ft Fractures are straight, sl. rough, w/ Fe & manganese oxide stains or clay, few exhibit slickenside surf. Few fract. near vertical | | |
| | 19 | | | | | | | | | | | |
| 3570' | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-4 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | NAME. COLOR. CONSISTENCY. GRAIN SIZE. PLASTICITY. CLASSIFICATION. WEATHERING. HARDNESS. STRUCTURE | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| 3570' | 20 | | | | | | | | | SILTSTONE, ARGILLITE, META-SANDSTONE/QUARTZITE - interbedded, Lt. brn - brn-white, wet, m. hard, mod. weathered | | Smooth drilling |
| | 21 | | | | | | | | | | | |
| | 22 | | | 14% | 66% | | | | | crushed | | |
| | 23 | | | | | | | | | | | |
| | 24 | | | | | 2 | | | | | | |
| | 25 | | | | | | | | | | | |
| | 26 | | | | | | | | | | | |
| | 27 | | | 40% | 90% | | | | | | | |
| | 28 | | | | | | | | | | | |
| | 29 | | | | | | | | | | | |
| 3560' | 30 | | | | | | | | | | | |
| | 31 | | | | | | | | | | | |
| | 32 | | | 12% | 76% | | | | | Mod. fractured, m. weathered, soft - m. hard rock. Poor - fair quality | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | | | | | | | |
| | 35 | | | | | 3 | | | | intensely fractured | | |
| | 36 | | | | | | | | | | | |
| | 37 | | | 14% | 50% | | | | | | | |
| | 38 | | | | | | | | | - Fe-oxide stains & clay in fracture | | Ran packer test #1 (18-40') |
| | 39 | | | | | | | | | int. fract. | | |
| 3550' | 40 | | | | | | | | | BOH AT 40' | | Installed PVC pipe |

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SHEET 2 OF 2 | HOLE NO. DH-4

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-5 |
| SITE: North Saddle Dam | DATE STARTED 8/21/89 FINISHED 8/25/89 | HOLE SIZE 3.78" 2.98" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ~3670' | DEPTH TO WATER 49.6' (?) | DEPTH TO ROCK 145' |
| DRILLING CONTRACTOR: Chen-Northern / J.D. Welsh | SAMPLES 2 | CORE BOXES 17 | DEPTH OF HOLE 197' |
| DRILL MAKE - MODEL: ACKER AD II | LOGGED BY A.M. SILVA | | REVIEWED BY U.J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | RQD % | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3670 | 0 | | | | | | | | | SILTY SAND - SANDY SILT (ML-SM) brn., dry, non plastic, loose, some clay, w/ occ. cobbles & boulders, few gravels | | Advanced hole w/ hollow-stem auger to 5' |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | SPT | | 3" | | | | | | Grey, aphanitic, v. hard metaquartzite boulder, fractured | | Attempted SPT #1, advanced 3" before refusal. |
| | 5 | | | | | | | | | | | Began HQ coring |
| | 6 | | | | | | | | | | | Unconfined strength > 4.5 tons/ft² |
| | 7 | | | | 100% | | | | | | | |
| | 8 | | | | | | | | | - appears as conglomerate but some sections are loose, friable | | |
| | 9 | | | | | | | | | | | |
| 3660 | 10 | | | | | | | | | | | |
| | 11 | | | | | | | | | | ▽ = | Encountered water at 11' (8-22-89) |
| | 12 | | | | ? | | | | | - int. weathered | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | | | |
| | 15 | | | | | | | | | | | Conducted permeability test at 15' (8' to 15') |
| | 16 | SPT #2 | | 8 / 29 / 22 | 88% | | | | | GRAVELLY, SANDY, SILTY CLAY (CL-ML) brn., dry, sl. plastic, stiff, w/ few gravels | | |
| | 17 | | | | | | | | | | | |
| | 18 | | | | 0 | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3650' | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-5 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

NOTE: CHANGE IN SCALE

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3650' | 20 | | | | | | | | | SANDY CLAYEY SILT (ML-MH) brn., dry, sl. pl., v. stiff, w/gravels (conglomeratic appearance) | | |
| | 22 | | | | 100% | | | | | -yellow-brn. at 23' | | |
| | 24 | | | | | 2 | | | | -white-grey, mod. hard metasandstone | | |
| | 26 | | | | | | | | | ML with metasandstone, siltstone, argillite & metaquartzite. | | |
| | 28 | | | | 100% | | | | | | | |
| | 30 | | | | | | | | | | | |
| | 32 | | | | 100% | | | | | | | |
| | 34 | | | | | 3 | | | | | | |
| | 36 | | | | 100% | | | | | | | |
| | 38 | | | | | | | | | Fe-ox stains on fract. surfaces | | |
| 3630 | 40 | | | | | | | | | | | Conducted permeability test at 40' (30' to 40') |
| | 42 | | | | 50% | | | | | Fractured boulders | | |
| | 44 | | | | | 4 | | | | | | |
| | 46 | | | | 78% | | | | | | | |
| | 48 | | | | | | | | | | | Encountered water at 49.6 on 08/25/89 |
| | 50 | | | | | | | | | | ▽ | Unconfined strength ≈ 3 tons/ft² |
| | 52 | | | | 100% | | | | | | | |
| | 54 | | | | | 5 | | | | | | |
| | 56 | | | | | | | | | org-brn. siltstone, argillite, laminated | | |
| | 58 | | | | 100% | | | | | | | |
| 3610 | 60 | | | | | | | | | -gravels & cobbles in ML matrix | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-5 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY % | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL |
|---|---|---|---|---|---|---|---|---|---|
| 3610 | 60 | | | | | | | | |
| | 62 | | | | 34% | | | | |
| | 64 | | | | | 6 | | | |
| | 66 | | | | 100% | | | | |
| | 68 | | | | | | | | |
| | 70 | | | | | | | | |
| | 72 | | | | 100% | | | | |
| | 74 | | | | | 7 | | | |
| | 76 | | | | 100% | | | | |
| | 78 | | | | | | | | |
| 3590 | 80 | | | | | | | | |
| | 82 | | | | 70% | | | | ? |
| | 84 | | | | | | | | |
| | 86 | | | | 0 | | | | |
| | 88 | | | | | | | | |
| | 90 | | | | 38% | | | | |
| | 92 | | | | | 8 | | | |
| | 94 | | | | 42% | | | | |
| | 96 | | | | | | | | |
| | 98 | | | | | | | | |
| 3570 | 100 | | | | 64% | | | | |

## MATERIAL DESCRIPTION

NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE

SANDY SILT (ML) & COBBLES & BOULDERS, w/ gravels, clay.
ML matrix is brn., damp, sl.pl.-non pl., stiff - v. stiff
Cobbles are subrounded metasediments, hard (mixed w/ gravels)
Boulders are fractured, soft-hard, weathered, w/ Fe-ox on fract.

Core boxes possibly mislabeled
Field notes describe run from 80'-85' and 85'-88'

Metasandstone, metaquartzite, siltstone, argillite, ML, — interlayered boulders & fines

WATER DATA

## REMARKS

SAMPLING — STANDARD PENETRATION
DRILL ACTION — WATER PRESSURE TEST
WATER LOSS — LAB CLASSIFICATION
CORE LOSS — PIEZOMETERS

Conducted permeability test at 65'

Core box #7 ends at 80'
Core box #8 begins at 88'
(8' of core missing)

Began NQ coring at 85'

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-5 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3570 | 100 | | | | | | | | | BOULDERS (METASEDIMENTS) w/ SANDY SILT & GRAVELS (occ.), COBBLES. Some conglomerate | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 102 | | | | | | | | | | | |
| | 104 | | | | 50% | 8 | | | | ML is brn., clayey, coarse sandgr., (Loose sand at times) soft-stiff, conglomeratic in some intervals. | | |
| | 106 | | | | | | | | | Boulders are fractured, hard, sl. weathered. | | |
| | 108 | | | | 100% | | | | | - metasandstone | | |
| | 110 | | | | | 9 | | | | - conglomerate | | |
| | 112 | | | | 62% | | | | | - metasandstone | | |
| | 114 | | | | | | | | | - metaquartzite | | |
| | 116 | | | | 38% | | | | | - ML w/gravels, Loose | | |
| | 118 | | | | | | | | | | | |
| 3550 | 120 | | | | 38% | | | | | } fract. metas.s. | | |
| | 122 | | | | | | | | | few gravels & ML | | |
| | 124 | | | | 67% | | | | | | | |
| | 126 | | | | 40% | 10 | | | | | | |
| | 128 | | | | ? | | | | | - conglomerate (well cemented ML + gravels) | | |
| | 130 | | | | | | | | | metaquartzite, hard, fract. | | |
| | 132 | | | | 33% | | | | | Few to no soil matrix (washed?) | | |
| | 134 | | | | | | | | | Possibly upper bedrock (?); ML or argillite washed out metasandstone, sl. fract., appears fresh | | |
| | 136 | | | | 52% | | | | | | | |
| | 138 | | | | | | | | | | | |
| | | | | | 24% | | | | | } int. fract. | | |
| 3530 | 140 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-5 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3530 | 140 | | | | | | | | | METASEDIMENTS (BOULDERS?) – possibly weathered bedrock – org.-brn. soft-hard, fract., weathered, argillite is friable. | | |
| | 142 | | | 36% | | 10 | | | | | | |
| | 144 | | | | | | | | | BEDROCK AT 145' | | |
| | 146 | | | ? | ? | | | | | (METASEDIMENTS) SILTSTONE, ARGILLITE, METASANDSTONE, interbedded, hard-friable, mod. fractured, org.-brn., mod. weathered | | Water return changes to orange color |
| | 148 | | | | | | | | | | | |
| | 150 | | | 7% | 40% | 11 | | | | | | |
| | 152 | | | | | | | | | | | |
| | 154 | | | | | | | | | poor quality rock | | |
| | 156 | | | | | | | | | | | |
| | 158 | | | 17% | 70% | | | | | | | |
| 3510 | 160 | | | | | | | | | | | |
| | 162 | | | | | | | | | | | |
| | 164 | | | 98% | 66% | | | | | – brn. siltstone | | |
| | 166 | | | | | | | | | } int. fract. siltstone, argillite<br>– white-brn, hard, metasandstone | | Conducted permeability at 167' (147' to 167') |
| | 168 | | | | | | | | | | | |
| | 170 | | | 13% | ? | | | | | | | |
| | 172 | | | | | | | | | – talc filling on ∠45° fract. | | |
| | 174 | | | 28% | 68% | 12 | | | | | | |
| | 176 | | | | | | | | | | | |
| | 178 | | | 28% | 59% | | | | | friable argillite – mod. fractured; fractures along thin laminae at ∠ 45° | | |
| 3490 | 180 | | | | | | | | | | | |

SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS
STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-5 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3490 | 180 | | | | | 12 | | | | METASEDIMENTS (as above) | | |
| | 182 | | | | | | | | | | | |
| | 184 | | | 20% | 70% | | | | | | | |
| | 186 | | | | | | | | | | | Conducted permeability test at 187' (167' to 187') |
| | 188 | | | | | 13 | | | | } friable, brn. argillite | | |
| | 190 | | | 7% | 32% | | | | | | | |
| | 192 | | | | | | | | | | | |
| | 194 | | | 77% | 100% | | | | | - metaquartzite, hard, white | | |
| | 196 | | | | | 14 | | | | - siltstone, fract. w/ Fe-Ox. stains | | Conducted permeability test at 197' (187' to 197') |
| 3473' | 197 | | | | | | | | | BOH AT 197' | | |

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-6 |
| SITE: Near toe of TAILINGS Impoundment Little Cherry CK. diversion dam | DATE - STARTED 08-20-89 FINISHED 08-21-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ~ 3620' | DEPTH TO WATER ARTESIAN | DEPTH TO ROCK 40' |
| DRILLING CONTRACTOR: J.D. Welsh | SAMPLES 2 | CORE BOXES 6 | DEPTH OF HOLE 60' |
| DRILL MAKE - MODEL: ACKER AD II | LOGGED BY A.M. SILVA | | REVIEWED BY U.J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3620' | 0 | | | | % | | | | | COBBLES & GRAVELS - in a clayey, sandy silt (ML-SM) matrix. ML - brn., dry, sl. plastic, m. dense. Cobbles & gr. are metasediments (metaquartzite & siltstone), hard, subrounded. | | Advanced hole w/ auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | Began coring w/ HQ bit |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| 3610' | 10 | SPT #1 | | 40 | 100 % | | | | | GRAVELLY, SILTY SAND (SM-SC) brn., dry, sl. plastic, dense - v. dense. | | Advanced hole w/ standard split-spoon sampler |
| | 11 | | | 42 | | | | | | | | |
| | 12 | | | 49 | | | | | | | | |
| | 13 | | | | 75 % | 1 | | | | ML (as above); lt. yellowish brn. | | |
| | 14 | | | | | | | | | | | |
| | 15 | | | | | | | | | ↓ increasing cobble & gravel content. Matrix is ML as above | | Performed permeability test #1 at 15' (8' to 15') |
| | 16 | | | | | | | | | | | Unconfined strength of ML > 4.5 tons/ft² |
| | 17 | | | | 100 % | 2 | | | | Cobbles & gravels are grey, subrounded, ~ < 3" ϕ | | |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3600' | 20 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-6 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3600' | 20 | | | | | | | | | CLAYEY, SANDY SILT (ML) with cobbles & gravels. - as above | | |
| | 21 | | | | | | | | | | | |
| | 22 | | | | | 2 | | | | | | |
| | 23 | | | | | | | | | | | |
| | 24 | | | | | | | | | | | |
| | 25 | SPT#2 | | 13 | | | | | | CLAYEY SILT (ML) w/ sand; - brn., dry, sl.pl.-pl., stiff, tr. gravel | | |
| | 26 | | | 15 22 | 100% | | | | | | | |
| | 27 | | | | | | | | | Fewer cobbles & gravels; brn. argillite, fract. (friable), boulder | | (High unconfined strength) |
| | 28 | | | | | | | | | | | |
| | 29 | | | | | 3 | | | | | | |
| 3590' | 30 | | | | | | | | | | | Conducted permeability test #2 at 30' (22' to 30') |
| | 31 | | | | | | | | | | | |
| | 32 | | | | | | | | | CONGLOMERATE - well cemented coarse gr. sands, gravels, silt. Gravels vary in size & shape, most ∠1" ϕ and subrounded. | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | | | | | Mod. fractured; } Some sections poorly cemented | | |
| | 35 | | | | | | | | | | | |
| | 36 | | | | | | | | | | | |
| | 37 | | | | | 4 | | | | | | |
| | 38 | | | | | | | | | | | |
| | 39 | | | | | | | | | | | |
| 3580' | 40 | | | | | | | | | BEDROCK AT 40' (METASEDIMENTS) | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-6 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3580' | 40' | | | | | | | | | SILTSTONE, ARGILLITE, METASANDSTONE -interbedded, brn. - yellow, mod - int. fractured, mod. weathered, soft - hard. | | SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
| | 41 | | | | | | | | | | | |
| | 42 | | | 0 | 60% | 4 | | | | Fractures easily along thin Laminae at ∠ 20°-30° | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | Fracture frequency: > 5 fr/ft. | | |
| | 45 | | | | | | | | | | | |
| | 46 | | | | | | | | | | | |
| | 47 | | | 0 | 90% | 5 | | | | | | |
| | 48 | | | | | | | | | | | |
| | 49 | | | | | | | | | | | |
| 3570' | 50 | | | | | | | | | } occ. vugs < .5cm ϕ | | |
| | 51 | | | | | | | | | Friable, brn. argillite | | |
| | 52 | | | 12% | 100% | | | | | | | |
| | 53 | | | | | | | | | } hard, white-grey, metasandstone. | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | | | | | | | | | |
| | 56 | | | | | | | | | Poor quality rock | | |
| | 57 | | | 30% | 90% | 6 | | | | | | |
| | 58 | | | | | | | | | Some clay, silt on fracture surfaces | | |
| | 59 | | | | | | | | | | | Water flows out of hole at rate of ~ .5 gpm |
| 3560' | 60' | | | | | | | | | BOH AT 60' | | Installed PVC pipe |

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SHEET 3 OF 3 | HOLE NO. DH-6

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-7 |
| SITE: Near inlet of diversion channel | DATE - STARTED 8-10-89 FINISHED 8-11-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ~ 3770' | DEPTH TO WATER 35.5 ft. | DEPTH TO ROCK 34' |
| DRILLING CONTRACTOR: J. D. Welsh | SAMPLES 7 | CORE BOXES 3 | DEPTH OF HOLE 73' |
| DRILL MAKE - MODEL: ACKER ADII | LOGGED BY A.M. SILVA | | REVIEWED BY U.J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3770' | 0 | | | | % | | | | | SANDY GRAVEL (GW) - GRAVELLY SAND (SW) - Lt. brn - orange brn., dry, non-plastic, little - some silt, | | Advanced hole using 6" auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | SPT #1 | | 6<br>31<br>70 | 78 | | | | | SANDY GRAVEL (GW), Lt. brn., dry, non-plastic, v. dense, some silt, angular to sub-angular gravels | | Used standard 2" O.D. split-spoon sampler. |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | decreasing gravel content<br>Transition from GW to ML ↓ | | Ran permeability test at 9' (8.9' to 9') |
| | 9 | | | | | | | | | | | |
| 3760' | 10 | SPT #2 | | 20<br>49<br>50+ | 66 | | | | | GRAVELLY SANDY SILT (ML) to SILTY SAND (SM) - org.-brn, dry, non-plastic, v. dense, appears as weathered rock. | | 50+ blows for 4.5" advance |
| | 11 | | | | | | | | | | | |
| | 12 | | | | | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | SPT #3 | | 33<br>50+ | 39 | | | | | SANDY SILT (ML) - org. brn., dry, non-plastic to sl. plastic, v. dense | | 50+ blows for 4" advance |
| | 15 | | | | | | | | | | | |
| | 16 | | | | | | | | | | | |
| | 17 | | | | | | | | | | | |
| | 18 | | | | | | | | | | | Ran permeability test at 19' (casing at 19') |
| | 19 | SPT #4 | | 50+ | 28 | | | | | SANDY SILT (ML) - org. brn., damp to moist, sl. plastic, v. dense, fr. gravels, at times appears as weathered rock. | | Advanced hole only 6" w/ 50+ blows |
| 3750' | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-7 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY % | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3750' | 20 | | | | | | | | SANDY SILT (ML) - org brn., damp to moist, sl. plastic, v. dense, tr. gravels, indurated but friable | | Advanced hole using 6" auger and 2" ϕ split-spoon sampler for SPTs. |
| | 21 | | | | | | | | | | |
| | 22 | | | | | | | | | | |
| | 23 | | | | | | | | | | |
| | 24 | SPT 24S | | 33 / 50+ | 50 | | | | SANDY SILT (ML) - as above; well indurated but friable | | |
| | 25 | | | | | | | | | | |
| | 26 | | | | | | | | | | |
| | 27 | | | | | | | | | | Smooth augering |
| | 28 | | | | | | | | | | |
| | 29 | | | | | | | | | | |
| 3740' | 30 | | | | | | | | | | |
| | 31 | | | | | | | | | | |
| | 32 | | | | | | | | | | |
| | 33 | | | | | | | | | | |
| 3736' | 34 | | | | | | | | BEDROCK AT 34' | | |
| | 34 | SPT 34S | | 12 / 50+ | 61 | | | | (METASEDIMENTS) METASANDSTONE, SILTSTONE, ARGILLITE, interbedded, lt. brn., wet, m. hard, some Fe-oxide stains; m. fractured | | (8-14-89) → Encountered water at 35.5' but hole was dry 9 days later (8-23-89) |
| | 35 | | | | | | | | | ▼ | |
| | 36 | | | | | | | | | | |
| | 37 | | | | | | | | (Rock exhibits low-grade metamorphism but sedimentary texture is generally preserved) - Lt. brn. to Blk. Laminae Mod. weathered | | Augered borehole (no core obtained to 44') |
| | 38 | | | | | | | | | | |
| | 39 | | | | | | | | Fractures occur along laminae of the siltstone & argillite (at ≤ 20°-30°) | | |
| 3730' | 40 | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-7 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | | SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
| 3730' | 40 | | | | % | | | | | METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, lt. brn., wet, m. hard, mod. fract., some Fe-oxide stains along fracture surfaces. Moderately weathered (at times intensely weathered) | | Ran permeability test at 44' (casing at 44') |
| | 41 | | | | | | | | | | | |
| | 42 | | | | | | | | | | | Attempted SPT# 7 at 44' - refusal |
| | 43 | | | | | | | | | Poor - v. poor quality rock | | Auger refusal. |
| | 44 | | | | | | | | | | | Began coring w/ HQ bit & (3.782" ID) core barrel |
| | 45 | | | | | | | | | | | |
| | 46 | | | 6 % | 100 % | | | | | Approx. 5 fract./ft. | | |
| | 47 | | | | | | | | | Fract. along Laminae at ∠ 20°-30° | | |
| | 48 | | | | | | | | | Siltstone & argillite are friable but metasandstone is m. hard. | | |
| | 49 | | | | | 1 | | | | | ▽ | Water at 49' in a.m. 8-11-89. |
| 3220' | 50 | | | | | | | | | Fractures generally straight, sl. rough surface, sometimes polished w/ layer of chlorite, talc, Fe-oxide. (Few slickensides on surfaces) | | Rough drilling |
| | 51 | | | 0 | 60 % | | | | | | | Rods vibrating |
| | 52 | | | | | | | | | } intensely fractured | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | | | | | | } moderately to intensely fract. (>15 fr/ft.) | | |
| | 55 | | | | | | | | | | | Org. brn water return |
| | 56 | | | 0 | 40 % | | | | | | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | | | | | | Occasional near-vertical fract. (sl. rough, closed, w/ occasional clayey filling & Fe-oxide stains) | | |
| | 59 | | | | | 2 | | | | | | |
| 3710' | 60 | | | | | | | | | | | |

| PROJECT | | JOB NO. | HOLE NO. DH-7 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3710' | 60 | | | | | | | | | **METASANDSTONE, SILTSTONE, ARGILLITE** - interbedded, Lt. brn - whitish brn., wet, m. hard to friable, mod. weathered, mod. to intensely fractured. | | Rough drilling |
| | 61 | | | | | | | | | | | |
| | 62 | | | 26% | 100% | | | | | | | |
| | 63 | | | | | | | | | - 1½" vug at 63' (Occasional vugs throughout core) | | |
| | 64 | | | | | 2 | | | | | | Performed packer test #1 from 47' - 64' |
| | 65 | | | | | | | | | Fractures at ∠30° along Laminae Approx. 5-8 fract./ft. | | |
| | 66 | | | 0 | 100% | | | | | | | |
| | 67 | | | | | | | | | Rock is friable when dry. Harder and Less fractured rock is generally metasandstone | | |
| | 68 | | | | | | | | | | | |
| | 69 | | | | | 3 | | | | | | |
| 3700' | 70 | | | 0 | 45% | | | | | Poor quality rock (RQD=0) | | |
| | 71 | | | | | | | | | | | |
| | 72 | | | | | | | | | | | Performed packer test #2 from 61' - 73' |
| 3697' | 73 | | | | | | | | | BOH at 73' | | INSTALLED PVC PIPE |

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SHEET 4 OF 4 | HOLE NO. DH-7

REVISED

| | | | | | |
|---|---|---|---|---|---|
| PROJECT: NORANDA | | | | JOB NO. 8029 | HOLE NO. DH-8 |
| SITE: Near inlet of diversion channel | DATE - STARTED 8-11-89 FINISHED 8-12-89 | | | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ≈3743' | DEPTH TO WATER 62' | | DEPTH TO ROCK 15' | |
| DRILLING CONTRACTOR: J.D. Welsh / Chen-Northern | SAMPLES 3 | CORE BOXES 8 | | DEPTH OF HOLE 98' | |
| DRILL MAKE - MODEL: ACKER ADII | LOGGED BY A.M. SILVA | | | REVIEWED BY U.J. CORDON | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3743' | 0 | | | | % | | | | | SAND (SP), org. brn - brn., dry, non-pl., w/ some rock fragments | | Advanced hole with 6" auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | SPT #1 | | 12 / 22 / 23 | 33 | | | | | SAND (SP), brn., dry, non-pl., w/ occasional angular weathered rock fragments | | Advanced hole w/ standard 2" ϕ O.D. split-spoon sampler |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | SPT #2 | | 19 / 34 / 32 | 66 | | | | | SANDY GRAVEL (GW), brn., dry, non-pl., w/ some-few rock fragments, some silt | | |
| 3733' | 10 | | | | | | | | | | | |
| | 11 | | | | | | | | | | | |
| | 12 | | | | | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | SP - as above | | Attempted SPT #3 at 13.5' Refusal (only advanced 2") Rec. = 11% |
| 3728' | 15 | | | | | | | | | BEDROCK AT 15' | | |
| | 16 | | | 0 | 100% | 1 | | | | (METASEDIMENTS) METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn. to whitish-brn (metasandstone), wet, m. hard to friable, mod. fractured & weathered. Siltstone & argillite - brn., friable fract. along laminae M. Sandstone generally hard & less weathered | | Began coring w/ HQ bit & 3.782" D. ECKE BARREL |
| | 17 | | | | | | | | | | | |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3723' | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-8 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. | DEPTH | SAMPLER | CASING | SPT/RQD | RECOVERY % | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3723' | 20 | | | | | | | | | METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn. to whitish-brn, hard to friable, mod. weathered & fractured. | | |
| | 21 | | | 24 % | 100 % | 1 | | | | | | |
| | 22 | | | | | | | | | | | |
| | 23 | | | | | | | | | Fracturing along Laminae & 45°-30° generally in siltstone & argillite | | Org.-brn - beige water return |
| | 24 | | | | | | | | | Fract. w/ talc-like filling | | |
| | 25 | | | | | | | | | Poor quality rock (RQD = 0) | | |
| | 26 | | | 0 | 86 % | | | | | Occasional sections of intensely weathered & friable rock | | |
| | 27 | | | | | | | | | | | |
| | 28 | | | | | 2 | | | | | | |
| | 29 | | | | | | | | | | | |
| 3713' | 30 | | | 12 % | 100 % | | | | | } Intensely fractured | | |
| | 31 | | | | | | | | | | | Smooth to rough drilling |
| | 32 | | | | | | | | | Fractures ≈ & 20°-30° (few near-vertical) | | |
| | 33 | | | | | | | | | Fracturing: ∪ > 10 fr./ft. | | |
| | 34 | | | | | | | | | Fracture surfaces are straight, sl. rough to smooth, closed, some contain chloritic and talc-like filling (few slickensides) | | |
| | 35 | | | 0 | 50 % | | | | | | | |
| | 36 | | | | | | | | | | | |
| | 37 | | | | | | | | | | | |
| | 38 | | | | | | | | | | | |
| | 39 | | | 0 | 100 % | 3 | | | | | | |
| 3703' | 40 | | | | | | | | | | | |

MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE

WATER DATA

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-8 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3703' | 40 | | | | | | | | | METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn, wet, mod. - highly weathered & fractured (metasandstone is m. hard) | | SAMPLING: STANDARD PENETRATION<br>DRILL ACTION: WATER PRESSURE TEST<br>WATER LOSS: LAB CLASSIFICATION<br>CORE LOSS: PIEZOMETERS |
| | 41 | | | | | | | | | | | |
| | 42 | | | | | | | | | intensely fractured/friable; brn. siltstone & argillite (soft) | | |
| | 43 | | | | | 3 | | | | | | Smooth - rough drilling |
| | 44 | | | | | | | | | | | |
| | 45 | | | 32% | 100% | | | | | Fair to poor quality rock | | |
| | 46 | | | | | | | | | Brn to blk. fine Laminae in siltstone & argillite | | |
| | 47 | | | | | | | | | | | |
| | 48 | | | | | | | | | | | |
| | 49 | | | | | | | | | | | |
| 3693' | 50 | | | 16% | 100% | | | | | fractures along Laminae at 20°∠ | | |
| | 51 | | | | | 4 | | | | | | |
| | 52 | | | | | | | | | | | |
| | 53 | | | | | | | | | Rock at times vuggy (< ½" vugs) | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | 6% | 100% | | | | | | | |
| | 56 | | | | | | | | | ←56' - whitish, powdery coating in fracture | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | | 5 | | | | | | |
| | 59 | | | 0 | 100% | | | | | | | |
| 3683' | 60 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-8 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION<br>NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS<br>SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS<br>STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3683' | 60 | | | | % | | | | | METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., wet, mod.-intensely weathered, friable, at times siltstone & argillite are soft (as in section from 60'-61') (Metasandstone is generally m. hard) | | Encountered water at 62' (8-14-89) |
| | 61 | | | | | | | | | | | |
| | 62 | | | | | | | | | | | |
| | 63 | | | | | 5 | | | | | | |
| | 64 | | | | | | | | | | | |
| | 65 | | | 7% | 100% | | | | | 63'-68' occ. vugs present (< 1cm ϕ) | | Drilling rate ≈ .25 ft/min. |
| | 66 | | | | | | | | | Int. fractured | | |
| | 67 | | | | | | | | | | | |
| | 68 | | | | | | | | | — Siltstone & argillite are brn., friable (along laminae) | | |
| | 69 | | | | | | | | | | | |
| | 70 | | | 0 | 80% | | | | | | | Good water return |
| 3673' | 71 | | | | | | | | | — Metasandstone is brownish-white, m. hard, not friable but at times m. fractured | | |
| | 72 | | | | | 6 | | | | Intensely weathered siltstone; v. soft | | |
| | 73 | | | | | | | | | hard metasandstone & siltstone | | Performed packer test #1 at 73' (65-73') |
| | 74 | | | | | | | | | | | |
| | 75 | | | 8% | 94% | | | | | Mod. fractured section Fractures at ∢ 30° along laminae; surface is straight, sl. rough to smooth, occ. talc & chloritic filling | | |
| | 76 | | | | | | | | | | | |
| | 77 | | | | | | | | | | | |
| | 78 | | | | | | | | | Possible fracture filling (.5cm ϕ subrounded gravel fragments) | | |
| | 79 | | | | | | | | | Poor quality rock | | Intermittent loss of water return |
| 3663' | 80 | | | | | 7 | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-8 |
|---|---|---|---|
| SITE | DATE – STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE – MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3663' | 80 | | | | | | | | | METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., wet., mod. fractured, m.-highly weathered. | | |
| | 81 | | | 19% | 72% | | | | | | | |
| | 82 | | | | | | | | | | | |
| | 83 | | | | | 7 | | | | | | |
| | 84 | | | | | | | | | | | |
| | 85 | | | 44% | 100% | | | | | | | Intermittent loss of water return |
| | 86 | | | | | | | | | – most fractures occur along the laminations in the siltstone & argillite | | |
| | 87 | | | | | | | | | | | |
| | 88 | | | | | | | | | | | |
| | 89 | | | | | | | | | – Metasandstone mod. hard; breaks along contacts w/ siltstone & argillite | | |
| 3653' | 90 | | | 26% | 100% | 8 | | | | – Fractures @ 30° along laminae Fracture frequency: ~ 3-6 fr./ft. | | |
| | 91 | | | | | | | | | | | |
| | 92 | | | | | | | | | | | |
| | 93 | | | | | | | | | } vuggy interval (sl. vesicular) | | |
| | 94 | | | | | | | | | | | |
| | 95 | | | 10% | 60% | | | | | | | |
| | 96 | | | | | | | | | } Soft siltstone & argillite section (Int. fractured) | | |
| | 97 | | | | | | | | | | | |
| 3645' | 98 | | | | | | | | | BOH at 98' | | Installed PVC pipe |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 5 OF 5 | HOLE NO. DH-8

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-9 |
| SITE: Near middle of diversion channel | DATE - STARTED 9-22-89 FINISHED 9-25-89 | HOLE SIZE 2.986" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ≈ 3688' | DEPTH TO WATER 69' | DEPTH TO ROCK 41' |
| DRILLING CONTRACTOR: Chen-Northern / J.D. Welsh | SAMPLES — | CORE BOXES 3 | DEPTH OF HOLE 82' |
| DRILL MAKE - MODEL: Longyear 28 (skid rig) | LOGGED BY A.M. SILVA | | REVIEWED BY V.J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3688' | 0 | | | | % | | | | | SILTY, SANDY GRAVEL (GM) - org.-brn., subangular gr., w/ roots. Gravel fragments consist of whitish-grey quartzite & siltstone | |
| | 1 | | | | | | | | | | |
| | 2 | | | | | | | | | | |
| | 3 | | | | | | | | | | |
| | 4 | | | | | | | | | | |
| | 5 | | | | | | | | | | |
| | 6 | | | | 12% | | | | | | |
| | 7 | | | | | | | | | | |
| | 8 | | | | | | | | | GRAVELLY SANDY SILT (ML) - brn., damp, sl. plastic, w/ some clay in matrix, v. dense, few cobble fragments. Soil matrix (ML) ≈ 70% Gravels ≈ 30% (sub ang. to subround) | |
| | 9 | | | | | 1 | | | | | |
| 3678' | 10 | | | | 10% | | | | | | |
| | 11 | | | | | | | | | | |
| | 12 | | | | | | | | | | |
| | 13 | | | | | | | | | Clay content varies, at times may be CL | |
| | 14 | | | | | | | | | | |
| | 15 | | | | 8% | | | | | From 13' to 42' Little to no core recovery | |
| | 16 | | | | | | | | | | |
| | 17 | | | | | | | | | | |
| | 18 | | | | | | | | | | |
| | 19 | | | | | | | | | | |
| 3668' | 20 | | | | | | | | | | |

REMARKS

SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS — STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS

Advanced hole using NQ-size core barrel

Attempted to push Shelby at 5' L (crushed)

Cased hole to 5'

Easy drilling

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-9 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3668' | 20 | | | | 8% | | | | | GRAVELLY, CLAYEY, SANDY SILT (ML-CL), brn., damp, sl.pl.-pl., well cemented, w/ cobbles & grey gravels | | |
| | 21 | | | | | | | | | | | |
| | 22 | | | | | | | | | | | |
| | 23 | | | | | | | | | | | |
| | 24 | | | | | | | | | | | |
| | 25 | | | | 8% | | | | | | | Smooth drilling |
| | 26 | | | | | | | | | | | |
| | 27 | | | | | | | | | | | |
| | 28 | | | | | | | | | | | |
| | 29 | | | | | 1 | | | | | | |
| 3658' | 30 | | | | 0 | | | | | | | |
| | 31 | | | | | | | | | | | |
| | 32 | | | | | | | | | | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | | | | | ML-CL (as above) | | |
| | 35 | | | | 10% | | | | | | | |
| | 36 | | | | | | | | | | | Lost water return at 37'-38' |
| | 37 | | | | | | | | | | | |
| | 38 | | | | | | | | | 38' | | |
| | 39 | | | | 73% | | | | | Appears to contain weathered siltstone & argillite (bedrock?) fragments | | |
| 3648' | 40 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-9 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3648' | 40 | | | | | | | | | ML-CL (as above) w/ siltstone frag. | | Very slow drilling. Hole taking in lots of water |
| | 41 | | | | 90% | | | | | TOP OF BEDROCK AT 41' (METASEDIMENTS) METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, org.-brn., mod.-highly weathered, m. fract., (metasandstone generally m. hard). | | |
| | 42 | | | 0 | 50% | | | | | | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | Siltstone & argillite fracture easily along laminae (friable rock) | | |
| | 45 | | | 0 | 90% | 1 | | | | | | |
| | 46 | | | | | | | | | | | |
| | 47 | | | | | | | | | Fract. @ 10°-20° | | |
| | 48 | | | | | | | | | Poor quality rock (RQD = 0-7%) | | |
| | 49 | | | | | | | | | | | |
| 3638' | 50 | | | 7% | 70% | | | | | | | Water return at 50' Began drilling w/ mud |
| | 51 | | | | | | | | | | | |
| | 52 | | | | | | | | | Laminae consist of alternating layers of brn. & black clayey silt, indurated but friable | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | 29% | 50% | | | | | | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | | | 2 | | | | | | |
| | 58 | | | | | | | | | Mod.-int. weathered siltstone & argillite | | |
| | 59 | | | | | | | | | | | |
| 3628' | 60 | | | 0 | 0 | | | | | No core recovered 58'-63' (possibly intensely fragmented siltstone & argillite that washed out) | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-9 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | Bor # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3628' | 60 | | | | | | | | | METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn., damp, mod.-highly weathered, mod.-intensely fractured, (metasandstone generally m. hard) v. poor - fair quality rock | | |
| | 61 | | | 0 | 0 | | | | | | | |
| | 62 | | | | | | | | | | | |
| | 63 | | | | | | | | | brn., friable siltstone & argillite | | |
| | 64 | | | | | | | | | | | |
| | 65 | | | 0 | 38% | | | | | | | |
| | 66 | | | | | 2 | | | | | | |
| | 67 | | | | | | | | | | | |
| | 68 | | | | | | | | | | | |
| | 69 | | | | | | | | | | ▼ | Encountered water at 69' (9-25-89 a.m.) |
| 3618' | 70 | | | 13% | 44% | | | | | Fragmented, soft siltstone & argillite wash out during drilling | | |
| | 71 | | | | | | | | | | | |
| | 72 | | | | | | | | | | | |
| | 73 | | | | | | | | | | | |
| | 74 | | | | | | | | | | | |
| | 75 | | | | | | | | | | | |
| | 76 | | | 0 | 62% | | | | | | | |
| | 77 | | | | | 3 | | | | Metasandstone easily scratched w/ knife but not friable; may be broken w/ hands (mod. hard) | | |
| | 78 | | | | | | | | | | | |
| | 79 | | | 0 | 52% | | | | | poor quality rock | | |
| 3608' | 80 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-9 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. | DEPTH | SAMPLER | CASING | SPT/ROD | RECOVERY | Bor.# | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3608' | 80 | | | | | | | | | METASANDSTONE, SILTSTONE, ARGILLITE - interbedded, brn, damp, mod. - highly weathered, m. - int. fractured. (as above) | | Ran packer test #1 (60'-82') |
| | 81 | | | | | 3 | | | | | | |
| 3606' | 82 | | | | | | | | | BOH AT 82' | | Installed PVC pipe |

| | | | | | |
|---|---|---|---|---|---|
| PROJECT: NORANDA | | | | JOB NO. 8029 | HOLE NO. DH-10 |
| SITE: Diversion channel | | DATE - STARTED 9-27-89 FINISHED 9-29-89 | | HOLE SIZE 2.98" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | | ELEVATION ~3670' | DEPTH TO WATER 73' | | DEPTH TO ROCK 18' |
| DRILLING CONTRACTOR: J.D. Welsh | | SAMPLES — | CORE BOXES 8 | | DEPTH OF HOLE 87' |
| DRILL MAKE - MODEL: Longyear 28 (skid rig) | | LOGGED BY M. I. SCHAUER | | REVIEWED BY U.J. CORDON | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY % | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3670' | 0 | | | | % | | | | | SANDY SILT (ML), rd-brn. dry, soft, some organics, sl. pl., few gravels (subang.-subrounded) < 5cm ϕ | | Advanced hole using NQ-size diamond bit. |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | Drilling fluid is water & polymer (FLuidril Fluid-Vis) |
| | 3 | | | | | | | | | Increasing gravel & cobble content to GM - Lt.-brn, wet, dense, sl. weathered gravels w/ sand & cobble fragm. (qtzite) | | |
| | 4 | | | | 31% | | | | | | | |
| | 5 | | | | | | | | | | | Drilling rate ~ .25 ft/min (Some chatter) |
| | 6 | | | | | 1 | | | | | | |
| | 7 | | | | | | | | | | | Lost water return 7'-8' but returned; Lt. brn. to grey water |
| | 8 | | | | | | | | | | | |
| | 9 | | | | 92% | | | | | Lg. cobble fragments (>1'); most of soil matrix is washed out | | |
| 3660' | 10 | | | | | | | | | | | Bit blocked at 10.5' & 15.5' |
| | 11 | | | | | | | | | | | |
| | 12 | | | | 76% | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | 52% | | | | | | | |
| | 15 | | | | | | | | | | | |
| | 16 | | | | | | | | | | | |
| | 17 | | | | 64% | | | | | | | |
| | 18 | | | | | | | | | BEDROCK AT 18' (METASEDIMENTS) | | |
| | 19 | | | 78% | 100% | 2 | | | | METAQUARTZITE, ARGILLITE, METASANDSTONE - interbedded Lt.-grey, wet, m. hard-hard, sl. weathered | | |
| 3650' | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-10 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3650' | 20 | | | | % | | | | | METAQUARTZITE - METASANDSTONE, ARGILLITE - interbedded, lt.-grey, wet, med. hard - hard, sl. weathered, sl. fract. - mod. fractured | | Bit blocked at 22' |
| | 21 | | | | | | | | | | | |
| | 22 | | | 40% | 100% | 2 | | | | | | |
| | 23 | | | | | | | | | Some Ca & Qtz stringers | | |
| | 24 | | | | | | | | | Fracturing: ~ 3-5 fr/ft. | | |
| | 25 | | | 44% | 76% | | | | | Fractures are horiz. to 20° (if in argillite fract. are along thin Laminae) | | Rough drilling |
| | 26 | | | | | | | | | Some fract. surfaces have clay coating, Fe-oxide stains, Ca. | | |
| | 27 | | | | | 3 | | | | Most fract. are straight, rough to smooth, closed. | | |
| | 28 | | | | | | | | | | | Drilling rate: .11 ft/min. |
| | 29 | | | | | | | | | V. Hard but fractured metaqtzite Mod. weathered | | |
| 3640' | 30 | | | 0 | 45% | | | | | | | |
| | 31 | | | | | | | | | | | |
| | 32 | | | 0 | 40% | | | | | Rock is hard w/ fair quality (poor quality zones common) | | Bit blocked at 32' & 40' |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | | | | | | | |
| | 35 | | | 0 | 28% | | | | | | | |
| | 36 | | | | | | | | | | | |
| | 37 | | | | | | | | | | | |
| | 38 | | | | | | | | | | | |
| | 39 | | | 0 | 100% | | | | | Some near-vertical fractures throughout (most filled w/ Manganese or Fe-oxide stains) | | |
| 3630' | 40 | | | | | | | | | | | |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-10 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3630' | 40 | | | | | | | | | METAQUARTZITE - METASANDSTONE, ARGILLITE - interbedded, Lt. grey, wet, m. hard - v. hard, sl. weathered & fractured. | | Rough drilling |
| | 41 | | | 10% | 47% | 3 | | | | | | |
| | 42 | | | | | | | | | | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | v. hard metaqtzite | | |
| | 45 | | | 66% | 100% | | | | | Fair-good quality rock | | |
| | 46 | | | | | | | | | | | |
| | 47 | | | | | 4 | | | | | | |
| | 48 | | | | | | | | | Fract. irreg. smooth-sl. rough, w/ occ. Ca. filling, Fe-oxide stains, & Manganese oxide stains | | Lt. grey water return |
| | 49 | | | 37% | 100% | | | | | } intensely fractured | | |
| 3620' | 50 | | | | | | | | | Smooth fract. surfaces contain grn. chlorite (appear polished) | | Rough drilling Rate ≈ .11 ft/min. |
| | 51 | | | | | | | | | | | |
| | 52 | | | 20% | 100% | | | | | | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | | | | | | | | Drilling rate .25 ft./min. |
| | 55 | | | 60% | 100% | 5 | | | | Fracture frequency ≈ 2-4 fr./ft. | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | | | | | | | | |
| | 59 | | | 20% | 100% | | | | | | | |
| 3610' | 60 | | | | | | | | | | | |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-10 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3610' | 60 | | | | % | | | | | METAQUARTZITE - METASANDSTONE | | |
| | 61 | | | 20% | 100% | | | | | ARGILLITE - interbedded | | |
| | 62 | | | | | | | | | (as above) | | Rough drilling |
| | 63 | | | | | | | | | | | Drilling rate ≈ .17 ft/min |
| | 64 | | | 17% | 100% | | | | | Near vertical fract. w/ soft clay fill and fragmented rock | | |
| | 65 | | | | | | | | | | | |
| | 66 | | | | | 6 | | | | | | Bit blocked at 66' |
| | 67 | | | 90% | 100% | | | | | | | |
| | 68 | | | | | | | | | | | |
| | 69 | | | | | | | | | | | |
| 3600' | 70 | | | 26% | 100% | | | | | Some brn. coloring (Fe-oxide?) | | |
| | 71 | | | | | | | | | | | |
| | 72 | | | | | | | | | } crushed | | (BOH) 7' |
| | 73 | | | 0% | 9% | 7 | | | | 73'-78' - Mod. fract., org.-brn. (Fe-oxide stained?), mod. weathered; some fract. coated w/ silt clay (near 75') | ▼ | Encountered water at 73' but hole was dry next day |
| | 74 | | | | | | | | | | | Ran packer test #1 (63'-73') |
| | 75 | | | | | | | | | ← | | Ran packer test #2 (68'-73') |
| | 76 | | | | | | | | | Fracture freq. > 5 fr./ft. | | |
| | 77 | | | | | | | | | Fair quality rock (v. hard but m. fractured) | | Lost water return (73'-78') |
| | 78 | | | | | | | | | qtz. stringer | | |
| | 79 | | | | | | | | | | | |
| 3590' | 80 | | | | | | | | | | | Water return 50%, lt. grey |

REMARKS: SAMPLING · DRILL ACTION · WATER LOSS · CORE LOSS · STANDARD PENETRATION · WATER PRESSURE TEST · LAB CLASSIFICATION · PIEZOMETERS

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-10 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION<br>NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS<br>SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS<br>STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3590' | 80 | | | | | | | | | METAQUARTZITE - METASANDSTONE, ARGILLITE - interbedded (as above) | | Drilling rate: .17 ft/min. |
| | 81 | | | 54% | 100% | 7 | | | | Fract. ∠ 0-20°, straight, sl. rough | | |
| | 82 | | | | | | | | | Mod. weathered, org. brn., m. fract. V. hard metasite | | |
| | 83 | | | 45% | 100% | 8 | | | | | | |
| | 84 | | | | | | | | | | | |
| | 85 | | | | | | | | | | | Bit blocked at 85' & 87' |
| | 86 | | | 20% | 100% | | | | | | | Ran packer test #3 (78'-87') |
| 3583' | 87 | | | | | | | | | BOH AT 87' | | Installed PVC pipe (Bottom 20' slotted) |

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-11 |
| SITE: Diversion dam abutment | DATE STARTED 10/9/89 FINISHED 10/10/89 | HOLE SIZE 3.782" 2.98" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION N 3760 | DEPTH TO WATER 15' | DEPTH TO ROCK 180' |
| DRILLING CONTRACTOR: Chen-Northern / J.D. Welsh | SAMPLES 4 | CORE BOXES 11 | DEPTH OF HOLE 192' |
| DRILL MAKE - MODEL: ACKER AD II | LOGGED BY A.M. SILVA | | REVIEWED BY V.J. CORDON |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | Bar # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3760 | 0 | | | | % | | | | | CLAYEY SANDY SILT – SILTY SAND (ML-SM) – brn., dry, sl. plastic, stiff, tr. gravels. | | Advanced hole by means of a hollow-stem auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | Difficult augering |
| | 3 | | | | | | | | | | | |
| | 4 | SPT #1 | | 6<br>20<br>21 | 72% | | | | | CLAYEY SANDY SILT (ML-SM) – brn.-grey, dry, sl. plastic, stiff, tr. gravels & rock fragments | | Advanced hole w/ standard split-spoon sampler |
| | 5 | | | | | | | | | | | |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | SPT #2 | | 12<br>28<br>19 | 83% | | | | | ML-SM – as above, few gravels | | |
| 3750 | 10 | | | | | | | | | | | |
| | 11 | | | | | | | | | | | |
| | 12 | | | | | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | SPT #3 | | 14<br>27<br>20 | 28% | | | | | ML-SM (as above) damp | | |
| | 15 | | | | | | | | | | ▼ | Encountered water at 15' |
| | 16 | | | | | | | | | CLAYEY, SANDY SILT (ML-SM) w/ cobbles & gravels; ML is brn., damp, sl. plastic, stiff; cobbles+gr. are subangular-subrounded, grey, sl. hard | | Began HQ coring |
| | 17 | | | | 28% | 1 | | | | | | |
| | 18 | | | | | | | | | ML washed out; most of core consists of gravels + cobbles – metaquartzite, metasandstone, siltstone. | | |
| | 19 | | | | | | | | | | | |
| 3740 | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-11 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

NOTE: CHANGE IN SCALE

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3740' | 20 | | | | | | | | | COBBLES & GRAVELS in clayey silt (ML) matrix; mainly meta-sediments, grey-white, mod. hard, fractured. | | |
| | 22 | | | | 10% | | | | | | | |
| | 24 | | | | | | | | | | | |
| | 26 | | | | | | | | | | | |
| | 28 | | | | 40% | 1 | | | | | | Drilling rate: .25 ft/min. |
| | 30 | | | | | | | | | | | Grey water return |
| | 32 | | | | 47% | | | | | | | |
| | 34 | | | | | | | | | Little soil matrix recovered | | |
| | 36 | | | | 34% | | | | | | | |
| | 38 | | | | | | | | | | | |
| 3720 | 40 | | | | | | | | | | | |
| | 42 | | | | 40% | | | | | | | |
| | 44 | | | | | | | | | CLAYEY SANDY SILT (ML)-(SM) brn., damp, sl.pl., stiff, with gravels & cobbles | | Began using drilling mud to recover soil matrix |
| | 46 | | | | 75% | | | | | | | Unconfined strength > 4.5 tons/ft² |
| | 48 | | | | | 2 | | | | | | |
| | 50 | | | | | | | | | | | |
| | 52 | | | | 65% | | | | | - hard metasandstone | | Grey water return |
| | 54 | | | | | | | | | | | |
| | 56 | | | | | | | | | | | |
| | 58 | | | | 30% | | | | | | | |
| 3700 | 60 | | | | 100% | 3 | | | | | | Attempted SPT #4 at 59' - REFUSAL after 2" advance; recovered 1.5" |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-11 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3700 | 60 | | | | | | | | | BOULDERS and SANDY SILT (ML) w/ cobbles & gravels; hard-soft but fractured metasediments; brn. ML, interbedded, clayey, sl. pl, damp. | | |
| | 62 | | | | | 3 | | | | – hard siltstone | | |
| | 64 | | | | 15% | | | | | | | |
| | 66 | | | | | | | | | friable siltstone, argillite. fractures along laminae at ∢ 20°–45° | | |
| | 68 | | | | 65% | | | | | | | |
| | 70 | | | | | | | | | | | |
| | 72 | | | | 20% | | | | | | | |
| | 74 | | | | | | | | | | | |
| | 76 | | | | 55% | | | | | – fract. metaquartzite | | |
| | 78 | | | | 20% | | | | | | | |
| 3680 | 80 | | | | | | | | | gravels + ML (stiff) | | |
| | 82 | | | | 22% | | | | | | | |
| | 84 | | | | | 4 | | | | increasing content of cobbles | | |
| | 86 | | | | 64% | | | | | COBBLES & GRAVELS in sandy silt matrix (ML-SM) w/ some clay. | | |
| | 88 | | | | | | | | | | | |
| | 90 | | | | | | | | | cobbles are subrounded, mod. hard, fract., mainly metasediments. | | |
| | 92 | | | | 20% | | | | | | | |
| | 94 | | | | | | | | | | | |
| | 96 | | | | | | | | | | | |
| | 98 | | | | 30% | | | | | | | Changed bit |
| 3660 | 100 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-11 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3660 | 100 | | | | | | | | | COBBLES & GRAVELS in stiff SANDY SILT (ML) matrix, brn, reddish-brn., damp, sl. pl. (some clay) | | |
| | 102 | | | | 32 % | 4 | | | | | | |
| | 104 | | | | | | | | | Composition varies: 30% fines 70% cobbles + | | |
| | 106 | | | | 54 % | | | | | | | |
| | 108 | | | | | | | | | Occ. boulders | | |
| | 110 | | | | | 5 | | | | | | |
| | 112 | | | | 60 % | | | | | weathered rock fragments throughout | | |
| | 114 | | | | | | | | | ← gravels | | |
| | 116 | | | | | | | | | | | |
| | 118 | | | | 40 % | | | | | | | |
| 3640 | 120 | | | | | | | | | soft siltstone, argillite w/ gravels | | |
| | 122 | | | | 40 % | | | | | | | |
| | 124 | | | | | | | | | ← sandy silty gravels | | Conducted permeability test (97'-125') |
| | 126 | | | | 54 % | | | | | lg. boulders | | |
| | 128 | | | | | | | | | | | |
| | 130 | | | | | | | | | | | |
| | 132 | | | | 100 % | 6 | | | | Friable, grey, soft argillite (∡20°) | | |
| | 134 | | | | | | | | | clay filling in fract. | | |
| | 136 | | | | | | | | | | | |
| | 138 | | | | 60 % | | | | | | | |
| 3620 | 140 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-11 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INF-ITIES TYPE | DISCONT INF-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3620 | 140 | | | | | | | | | BOULDERS (metasediments) w/ cobbles & gravels in sandy silt matrix (ML) – brn, stiff, non pl. | | |
| | 142 | | | | 56 % | | | | | | | |
| | 144 | | | | | 7 | | | | | | |
| | 146 | | | | 56 % | | | | | Boulders are mod. – int. fractured, subrounded, hard – m. hard. | | |
| | 148 | | | | | | | | | | | |
| | 150 | | | | | | | | | | | |
| | 152 | | | | 72 % | | | | | | | |
| | 154 | | | | | | | | | | | |
| | 156 | | | | | | | | | hard metasandstone, siltstone | | |
| | 158 | | | | 50 % | | | | | Few to no gravels; core appears as weathered, fractured rock. | | |
| 3600 | 160 | | | | | 8 | | | | | | Difficult drilling |
| | 162 | | | | 92 % | | | | | | | |
| | 164 | | | | 58% | | | | | } int. fract. | | Changed bit to NQ-size at 164' |
| | 166 | | | | | | | | | | | |
| | 168 | | | | 53 % | | | | | } int. fract. | | |
| | 170 | | | | | | | | | | | |
| | 172 | | | | 52 % | 9 | | | | No gravels, possibly upper weathered bedrock (?); no continuous core – Loss of core may be due to: washing of ML matrix or soft argillite | | |
| | 174 | | | | | | | | | | | |
| | 176 | | | | 70% | | | | | | | |
| | 178 | | | | | | | | | | | |
| 3580 | 180 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-11 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3580 | 180 | | | | | | | | | BEDROCK AT 180' | | |
| | | | | 0 | 88% | | | | | SILTSTONE, ARGILLITE; - brn., mod-int. fractured (along Laminae at ± 50°); highly weathered, friable | | Org.-yellow water return |
| | 182 | | | | | | | | | | | |
| | 184 | | | | | | | | | | | |
| | | | | 8% | 69% | 10 | | | | | | |
| | 186 | | | | | | | | | v. poor rock quality | | |
| | 188 | | | | | | | | | | | |
| | | | | 19% | 85% | | | | | | | |
| | 190 | | | | | | | | | | | Conducted packer test (180'–192') |
| 3568 | 192 | | | | | | | | | BOH AT 192' | | Installed PVC pipe |

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A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 | HOLE NO. DH-11

REVISED

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-12 |
| SITE: Tailings dam near Little Cherry Ck. | DATE - STARTED 09/26/89 FINISHED 09/28/89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ~ 3385 | DEPTH TO WATER 4' | DEPTH TO ROCK 65' |
| DRILLING CONTRACTOR: Chen Northern / J.D. Welsh | SAMPLES 5 | CORE BOXES 7 | DEPTH OF HOLE 110' |
| DRILL MAKE - MODEL: ACKER ADII | LOGGED BY A.M. SILVA | | REVIEWED BY V.J. CORDON |

| ELEV. (ft) | DEPTH (ft) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3385 | 0 | | | | | | | | | | | Advanced hole w/ hollow-stem auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | ▼ | Encountered water at 4' |
| | 5 | SPT#1 | | 6<br>8<br>10 | 72% | | | | | SANDY GRAVEL (GP) brn., damp, sl. plastic, rounded sand gr., tr. silt & cobbles | | Advanced hole w/ standard split-spoon sampler<br>Auger refusal at 5.5' |
| | 6 | | | | | | | | | COBBLES & GRAVELS in clayey sandy silt (ML) matrix<br>rocks are metaquartzite & siltstone, grey-brn, hard, subrounded.<br>Cobbles & gravels ~ 80%<br>Clayey sandy silt ~ 20% | | Advanced hole w/ HQ coring bit |
| | 7 | | | | 27% | 1 | | | | | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| 3375 | 10 | | | | | | | | | SANDY CLAYEY SILT (ML) - w/ gravels & cobbles; brn., dry-damp, sl. pl., stiff.<br>Gravels are rounded<br>Fines ~ 80%<br>Rocks ~ 20% | | |
| | 11 | | | | | | | | | | | |
| | 12 | | | | 64% | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | | | |
| | 15 | | | | | | | | | | | |
| | 16 | SPT#2 | | 12<br>20<br>50/4 | 77% | | | | | SANDY CLAYEY SILT (ML) - brn., damp, sl. plastic, v. stiff, tr. gravels | | |
| | 17 | | | | | | | | | | | |
| | 18 | | | | 52% | | | | | Softer ML | | |
| | 19 | | | | | | | | | | | Quit for the day at 20'! Resumed drilling 9-27-89, water level 3' |
| 3365 | 20 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-12 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3365 | 20 | | | 50/4" | 0 | | | | | CLAYEY SANDY SILT (ML)-olg-brn., damp, sl.pl.-non pl. (SM), some gravels, occ. cobbles. | | Attempted SPT #3; REFUSAL at 5" penetration |
| | 21 | | | | | | | | | | | |
| | 22 | | | | 71% | 1 | | | | | | |
| | 23 | | | | | | | | | | | |
| | 24 | | | | | | | | | | | |
| | 25 | | | | | | | | | Gravels & cobbles are metasedi-ments (mainly metaquartzite, siltstone), subrounded, hard | | |
| | 26 | | | | | | | | | | | |
| | 27 | | | | 91% | 2 | | | | | | |
| | 28 | | | | | | | | | | | |
| | 29 | | | | | | | | | | | |
| 3355' | 30 | | | | | | | | | | | |
| | 31 | | | | | | | | | | | |
| | 32 | | | | 70% | | | | | | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | | | | | | | |
| | 35 | | | | | | | | | ML (as above) | | |
| | 36 | | | | 93% | | | | | | | |
| | 37 | | | | | | | | | | | |
| | 38 | | | | | | | | | | | |
| | 39 | | | | | 3 | | | | | | |
| 3345' | 40 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-12 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | Box # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3345' | 40 | | | | | | | | | CLAYEY SANDY SILT (ML) w/ gravels & cobbles, grey-brn., damp to moist, sl. plastic, stiff. | | |
| | 41 | | | | 80 % | | | | | Gravels & cobbles are subround-round, hard, mostly metasediments | | |
| | 42 | | | | | | | | | | | |
| | 43 | SPT #4 | | 50+ | 6" | | | | | SANDY SILT (ML) - (SILTSTONE?) brn., moist, v. stiff | | Attempted SPT #4 - REFUSAL at 6" |
| | 44 | | | | | 3 | | | | | | Beige color water return |
| | 45 | | | | 60 % | | | | | | | |
| | 46 | | | | | | | | | | | |
| | 47 | | | | | | | | | | | |
| | 48 | | | | 50 % | | | | | | | |
| | 49 | | | | | | | | | | | |
| 3335' | 50 | | | | | | | | | Occ. boulders | | |
| | 51 | | | | | | | | | | | |
| | 52 | | | | 46 % | | | | | | | |
| | 53 | | | | | | | | | Yellowish-brn ML w/ gravels (< 3cm ϕ) | | |
| | 54 | | | | | | | | | (Coarse sand gr. in matrix are subangular; ML appears well cemented) | | Org. brn. water return |
| | 55 | | | | | | | | | | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | | 59 % | 4 | | | | | | |
| | 58 | | | | | | | | | | | |
| | 59 | | | | | | | | | | | |
| 3325' | 60 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-12 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3325' | 60 | | | | | | | | | CLAYEY SANDY SILT (ML) w/ gravels & cobbles; brn., damp, sl. pl., stiff - v. stiff. | | |
| | 61 | | | | | | | | | | | |
| | 62 | | | | 80% | 4 | | | | | | |
| | 63 | | | | | | | | | | | |
| | 64 | | | | | | | | | | | |
| | 65 | | | | | | | | | BEDROCK AT 65' | | |
| | 66 | SPT#5 | | 11 / 21 / 50/4" | 88% | | | | | (METASEDIMENTS) SILTSTONE, ARGILLITE, w/ occ. meta-sandstone - interbedded, white-brn, dry, soft - m. hard, mod-int. fract, highly weathered | | Conducted SPT#5 in soft bedrock; REFUSAL on last 6" |
| | 67 | | | | | | | | | | | |
| | 68 | | | 0 | 30% | | | | | Siltstone & argillite friable; breaks easily along thin brn - blk. laminae | | |
| | 69 | | | | | | | | | } reddish color | | |
| 3315' | 70 | | | | | 5 | | | | | | |
| | 71 | | | | | | | | | | | |
| | 72 | | | 0 | (≥50%) | | | | | Occ. near vertical fractures, sl. rough to smooth surfaces, some silt & Fe-oxide | | |
| | 73 | | | | | | | | | | | |
| | 74 | | | | | | | | | | | |
| | 75 | | | | | | | | | | | |
| | 76 | | | | | | | | | | | |
| | 77 | | | 0 | 92% | | | | | V. poor quality rock | | |
| | 78 | | | | | | | | | | | |
| | 79 | | | | | | | | | | | |
| 3305 | 80 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-12 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3305 | 80 | | | | | | | | | SILTSTONE, ARGILLITE -w/ metasandstone interbeds; brn., dry, soft, → friable, breaks easily along laminae at ∠30°-45° | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 81 | | | | | | | | | | | |
| | 82 | | | 0 | 70% | | | | | | | |
| | 83 | | | | | 5 | | | | ARGILLITE - SILTSTONE | | |
| | 84 | | | | | | | | | | | |
| | 85 | | | | | | | | | Some silt in fractures; traces of few slickensides | | |
| | 86 | | | 25% | | | | | | | | |
| | 87 | | | | 70% | | | | | | | Easy, smooth drilling |
| | 88 | | | | | | | | | | | |
| | 89 | | | | | | | | | Friable V. poor quality rock | | |
| 3295 | 90 | | | | | 6 | | | | | | |
| | 91 | | | | | | | | | | | |
| | 92 | | | 8% | | | | | | | | |
| | 93 | | | | 70% | | | | | | | |
| | 94 | | | | | | | | | | | |
| | 95 | | | | | | | | | } reddish color | | |
| | 96 | | | | | | | | | | | |
| | 97 | | | 0 | 57% | 7 | | | | Int. fractured & highly weathered; at some intervals appears like soil (soft). | | |
| | 98 | | | | | | | | | - at 98' siltstone & argillite turn tan in color | | |
| | 99 | | | | | | | | | | | |
| 3285' | 100 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-12 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION<br>NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS<br>SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS<br>STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3285' | 100 | | | | | | | | | ARGILLITE, SILTSTONE - brn., occ. reddish-brn., soft, friable, m.-highly weathered. | | Stopped drilling at 100'. Resumed 9-28-89, water level 1' below ground. |
| | 101 | | | | | | | | | | | |
| | 102 | | | 16 % | 58 % | | | | | | | |
| | 103 | | | | | | | | | | | |
| | 104 | | | | | | | | | Some silt & talc-like coating on fracture surfaces | | |
| | 105 | | | | | | | | | | | |
| | 106 | | | | | | | | | | | |
| | 107 | | | 19 % | 72 % | | | | | | | |
| | 108 | | | | | | | | | | | |
| | 109 | | | | | | | | | | | Conducted packer tests (67.5'-110') (100'-110') |
| 3275' | 110 | | | | | | | | | BOH AT 110' | | Installed PVC pipe |

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SHEET 6 OF 6 | HOLE NO. DH-12

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-13 |
| SITE: South Saddle Dam | DATE - STARTED 09-7-89 FINISHED 09-8-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ~3665' | DEPTH TO WATER 45.5' | DEPTH TO ROCK 15.7' |
| DRILLING CONTRACTOR: J.D. Welsh | SAMPLES 4 | CORE BOXES 6 | DEPTH OF HOLE 80' |
| DRILL MAKE - MODEL: ACKER AD II | LOGGED BY M. I. SCHAUER | | REVIEWED BY V. J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BAR | DISCONT. INJ-ITIES TYPE | DISCONT. INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3665 | 0 | | HWFJ | | | | | | | SANDY SILT (ML) - Lt. brn., dry to moist, soft, some organics, non pl.<br>~60% silt & fines<br>~40% fine sand | | Advanced casing to 5' |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | Some gravels | | |
| | 3 | | | | | | | | | | | Lt. brn. water return |
| | 4 | | | | | | | | | | | |
| | 5 | SPT#1 | | 9 | 73% | | | | | SANDY SILTY GRAVEL (GM) Lt. brn., wet, dense, subangular | | Advanced hole w/ standard split-spoon sampler |
| | 6 | | | 18 | | | | | | Gravel fragments < 5cm.ϕ | | |
| | 7 | | | 22 | | | | | | | | Advanced hole w/ HQ core |
| | 8 | | | | 77% | 1 | | | | Gravels consist of metaquartzite and siltstone | | |
| | 9 | | | | | | | | | | | |
| 3655' | 10 | SPT#2 | | 8 | 87% | | | | | CLAYEY, SILTY, GRAVELLY SAND (SM-SP)<br>Lt. brn., wet, mod. dense, non pl.<br>~55% gravels<br>~45% fines | | Drilling rate: .3 ft/min |
| | 11 | | | 17 | | | | | | | | |
| | 12 | | | 17 | | | | | | | | |
| | 13 | | | | 63% | 1 | | | | GRAVELLY SILT (ML) - as above | | |
| | 14 | | | | | | | | | | | |
| | 15 | SPT#3 | | SPT | 100% | | | | | ML<br>BEDROCK AT 15.7' | | Advanced hole only 6" - REFUSAL. |
| | 16 | | | | | | | | | (METASEDIMENTS) | | |
| | 17 | | | 40% | 72% | 1 | | | | SILTSTONE, ARGILLITE, META-QUARTZITE - interbedded; brn, soft-hard, friable (not easily broken by hand), metaquartzite is hard. Sl. fractured & weathered. Siltstone & argillite have Lt. brn, brn., dark Laminations at ∠ of 20°-50° | | |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3645' | 20 | | | | | | | | | | | Attempted SPT #4 at 20'; REFUSAL. Recovered only 2" |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-13 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3645' | 20 | | | | | | | | | | | |
| | 21 | | | | | 1 | | | | SILTSTONE, ARGILLITE, META-QUARTZITE - grey-brn., interbedded, wet, soft-hard, mod. fract. (at times intensely fract.), sl. weathered Thinly Laminated at ∠ 45° | | |
| | 22 | | | 17% | 58% | | | | | | | |
| | 23 | | | | | | | | | } int. fract. | | |
| | 24 | | | | | | | | | Clay-silt grains, some sand grains (possibly weathered metasandstone) | | Sl. rough drilling |
| | 25 | | | | | | | | | } int. fract. | | |
| | 26 | | | | | 2 | | | | Occ. Fe-oxide staining along straight, sl. rough-smooth surfaces; tr. clay, tr. slickensides | | |
| | 27 | | | 0 | 56% | | | | | | | |
| | 28 | | | | | | | | | ← Hard, fract. metaquartzite | | |
| | 29 | | | | | | | | | | | |
| 3635' | 30 | | | | | | | | | | | |
| | 31 | | | | | | | | | Poor quality rock | | |
| | 32 | | | 16% | 72% | | | | | | | |
| | 33 | | | | | | | | | } int. fract. | | |
| | 34 | | | | | | | | | | | |
| | 35 | | | | | | | | | | | |
| | 36 | | | | | | | | | Most fractures are along Laminae at ∠ 45° | | |
| | 37 | | | 6% | 68% | | | | | | | |
| | 38 | | | | | 3 | | | | | | |
| | 39 | | | | | | | | | | | |
| 3625' | 40 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-13 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3625 | 40 | | | | | | | | | SILTSTONE, ARGILLITE, META-QUARTZITE - interbedded; lt. brn. to grey, soft-hard, wet, mod. frac. and weathered. Some areas v. soft (generally in weathered siltstone & argillite) Metaquartzite is hard but fract. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 41 | | | | | | | | | | | |
| | 42 | | | 22% | 100% | 3 | | | | | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | | | |
| | 45 | | | | | | | | | | ▼ | Encountered water at 45.5' (9-8-89 a.m.) |
| | 46 | | | | | | | | | | | |
| | 47 | | | 28% | 76% | | | | | Highly weathered & fractured | | |
| | 48 | | | | | | | | | | | |
| | 49 | | | | | | | | | | | |
| 3615' | 50 | | | | | 4 | | | | | | |
| | 51 | | | | | | | | | | | |
| | 52 | | | 14% | 76% | | | | | | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | | | | | | | Increasing sections with v. soft (soil-like) argillite & siltstone | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | 6% | 74% | | | | | | | |
| | 58 | | | | | | | | | | | |
| | 59 | | | | | 5 | | | | | | |
| 3605' | 60 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-13 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | RQD % | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3605 | 60 | | | | | | | | | SILTSTONE, ARGILLITE, METAQUARTZITE - interbedded; Lt. brn, grey, wet, v. soft - occ. hard., mod. fractured, mod. to extr. weathered. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 61 | | | | | | | | | | | |
| | 62 | | | 16% | 100% | | | | | | | |
| | 63 | | | | | | | | | Siltstone & argillite v. soft (at times soil-like); friable, breaks easily along 30-50° laminations | | |
| | 64 | | | | | | | | | | | |
| | 65 | | | | | | | | | Occ. metaquartzite is hard | | |
| | 66 | | | | | | | | | Most of core is siltstone & argillite | | |
| | 67 | | | 6% | 56% | 5 | | | | | | |
| | 68 | | | | | | | | | | | |
| | 69 | | | | | | | | | | | Lt. brn. water return |
| 3595 | 70 | | | | | | | | | | | |
| | 71 | | | | | | | | | | | |
| | 72 | | | 12% | 100% | | | | | Friable, m. soft | | |
| | 73 | | | | | | | | | V. poor quality rock | | |
| | 74 | | | | | | | | | | | Drilling rate: .3 ft/min. |
| | 75 | | | | | 6 | | | | | | |
| | 76 | | | | | | | | | | | |
| | 77 | | | 16% | 94% | | | | | | | |
| | 78 | | | | | | | | | | | Conducted packer test #1 (29.5'—80') |
| | 79 | | | | | | | | | | | Conducted packer test #2 (55'—80') |
| 3585' | 80 | | | | | | | | | BOH AT 80' | | Installed PVC pipe |

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SHEET 4 OF 4 | HOLE NO. DH-13

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-14 |
| SITE: South Saddle Dam | DATE – STARTED 9-9-89 FINISHED 9-9-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ~ 3600' | DEPTH TO WATER 13.9' | DEPTH TO ROCK 30' |
| DRILLING CONTRACTOR: Chen-Northern / J.D. Welsh | SAMPLES 2 | CORE BOXES 3 | DEPTH OF HOLE 60' |
| DRILL MAKE – MODEL: ACKER AD II | LOGGED BY A.M. SILVA | | REVIEWED BY V.J. CORDON |

| ELEV. (ft) | DEPTH (ft) | SAMPLER | CASING | SPT/ROD | RECOVERY % | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3600' | 0 | | | | % | | | | | CLAYEY, SANDY SILT (ML) – (SM) – with gravels and cobbles brn., damp – dry, sl. plastic, v. dense | | Advanced hole with HQ-size diamond bit & wireline core barrel |
| | 1 | | | | 0 | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | 95 % | | | | | | | |
| | 5 | | | | | | | | | | | Cased hole to 5' |
| | 6 | SPT #1 | | 12<br>22<br>25 | | | | | | CLAYEY, SANDY SILT (ML) – w/ gravels and cobbles, brn., damp, sl. pl., m. dense – dense. Gravels are angular to subangular | | Advanced hole using standard 2" ϕ split-spoon sampler |
| | 7 | | | | | | | | | – siltstone boulder fragment | | |
| | 8 | | | | 64 % | | | | | | | Smooth drilling |
| | 9 | | | | | 1 | | | | – ML w/ gravels & cobbles | | Uncontined strength = 4.5 tons/ft² (using pocket penetrometer) |
| 3590' | 10 | | | | | | | | | CLAYEY SANDY SILT (ML) – brn., damp-dry, sl. plastic, w/ gravel and cobbles, med. dense – dense | | Advanced hole w/ split-spoon sampler |
| | 11 | SPT #2 | | 9<br>16<br>22 | | | | | | | | |
| | 12 | | | | | | | | | – grey, m. hard, siltstone fragment | | |
| | 13 | | | | 52 % | | | | | | | |
| | 14 | | | | | | | | | – CLAYEY, SANDY SILT (ML) w/ gravels, cobbles & boulder frag.; matrix is brn., damp-moist, sl. pl., dense. Rock fragments are grey, some metaquartzite, siltstone and argillite. | ▼ | Encountered water at 13.9' on 9-12-89 |
| | 15 | | | | | | | | | | | |
| | 16 | | | | | | | | | | | |
| | 17 | | | | 80 % | | | | | – Boulder fragments weathered; easily broken by hand | | Good water return; beige color |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3580' | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-14 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3580' | 20 | | | | | | | | | CLAYEY, SANDY SILT (ML) - w/ gravels and cobbles, org.-brn., damp, sl.pl., dense. Cobble-boulders may be upper bedrock matl - siltstone | | Smooth drilling |
| | 21 | | | | | | | | | | | |
| | 22 | | | | | | | | | | | |
| | 23 | | | | | | | | | | | |
| | 24 | | | | | | | | | ← siltstone fragments in a sandy silt (ML) matrix | | |
| | 25 | | | | | | | | | | | |
| | 26 | | | | | | | | | - argillite, brn., friable, fract. @ 45° | | |
| | 27 | | | | | | | | | | | |
| | 28 | | | | | 2 | | | | | | |
| | 29 | | | | | | | | | - metasandstone fragments | | |
| 3570' | 30 | | | | | | | | | BEDROCK AT 30' (METASEDIMENTS) SILTSTONE, METASANDSTONE, ARGILLITE - interbedded brn.-Lt.brn, friable, m. weathered and fractured. | | Good water return, org.-brn. color |
| | 31 | | | | | | | | | | | |
| | 32 | | | 10% | 34% | | | | | | | |
| | 33 | | | | | | | | | V. poor quality rock. | | |
| | 34 | | | | | | | | | 31'-35': intensely fractured (pieces <1" Ø) | | |
| | 35 | | | | | | | | | - few metaquartzite intervals | | |
| | 36 | | | | | | | | | | | |
| | 37 | | | 8% | 70% | | | | | | | Drilling rate: .28 ft/min. |
| | 38 | | | | | | | | | | | |
| | 39 | | | | | | | | | | | |
| 3560' | 40 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-14 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3560' | 40 | | | | | | | | | SILTSTONE, ARGILLITE, METASANDSTONE - interbedded, Lt. brn - brn., soft - m. hard, (friable), m. - int. fractured and weathered. | | SL. rough drilling |
| | 41 | | | | | | | | | | | |
| | 42 | | | 17% | 48% | | | | | | | |
| | 43 | | | | | | | | | Poor quality rock (friable; RQD < 17%) | | |
| | 44 | | | | | | | | | | | |
| | 45 | | | | | | | | | Fractures along Lamination ∠ 45°, fract. surfaces are straight to wavy, Sl. rough - some smooth & filled w/ silt, Fe-oxide stains, very friable rock. | | |
| | 46 | | | | | | | | | | | |
| | 47 | | | 8% | 40% | | | | | | | |
| | 48 | | | | | 3 | | | | | | |
| | 49 | | | | | | | | | | | |
| 3550' | 50 | | | | | | | | | | | Performed permeability test #1 (30' to 50') |
| | 51 | | | | | | | | | | | |
| | 52 | | | 0 | 32% | | | | | intensely fractured | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | | | | | | | | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | 0 | 46% | | | | | | | |
| | 58 | | | | | | | | | int. fract. | | |
| | 59 | | | | | | | | | | | Performed permeability test #2 (50' to 60') |
| 3540' | 60 | | | | | | | | | BOH AT 60' | | Installed PVC pipe |

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SHEET 3 OF 3 | HOLE NO. DH-14

| | | | | |
|---|---|---|---|---|
| PROJECT: NORANDA – MONTANORE | | | JOB NO. 8029 | HOLE NO. MW DH 15 |
| SITE: TAILINGS IMPOUNDMENT | | DATE – STARTED FINISHED: 9-6-89 — 9-7-89 | HOLE SIZE: 6" | ORIENTATION |
| LOCATION: LIBBY, MT. | | ELEVATION | DEPTH TO WATER (ARTESIAN): 70-110' | DEPTH TO ROCK: NE |
| DRILLING CONTRACTOR: CHEN-NORTHERN / RUEN DRILLING | | SAMPLES: — | CORE BOXES: — | DEPTH OF HOLE: 120' |
| DRILL MAKE – MODEL: SCHRAMM ROTADRILL | | LOGGED BY: AILEEN M. SILVA | | REVIEWED BY |

| ELEV. | DEPTH | SAMPLER | CASING | SPT/RQD | RECOVERY | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | | | |
| | 5 | | | | | | | | | |
| | 10 | | | | | | | | 0-20' SAMPLES ARE SILTY SAND-(SM) W/ CHIPS FROM COBBLES – brown, dry, non plastic. Gravels are round to subround. | |
| | 15 | | | | | | | | | |
| | 20 | | | | | | | | MORE FINES – SANDY SILT W/ TRACE OF CLAY – brown, dry, non plastic, poorly graded (ML) | |
| | 25 | | | | | | | | SILT – grey/white, dry, non plastic, poorly graded (ML) | |
| | 30 | | | | | | | | SILTY SAND TO SANDY SILT – (SM-ML) poorly graded – brown/beige, dry, non plastic, angular to subangular gravel & cobble pieces, sands up to ¼" size – round. | |
| | 35 | | | | | | | | | |
| | 40 | | | | | | | | | |
| | 45 | | | | | | | | SANDY SILT W/ TRACE OF CLAY (ML) – brown, dry, slightly plastic to non plastic. | |
| | 50 | | | | | | | | | |

**REMARKS**

SAMPLING / STANDARD PENETRATION
DRILL ACTION / WATER PRESSURE TEST
WATER LOSS / LAB CLASSIFICATION
CORE LOSS / PIEZOMETERS

USING AIR ROTARY TYPE DRILLING – CATCHING BUCKET SAMPLES EVERY 5' – NO SPLIT SPOONS OR $H_2O$ TESTS.

CASED HOLE TO 15' – ROCK @ 15', COULDN'T DRIVE CASING FURTHER.

average drilling speed is 5' in 5-10 min.

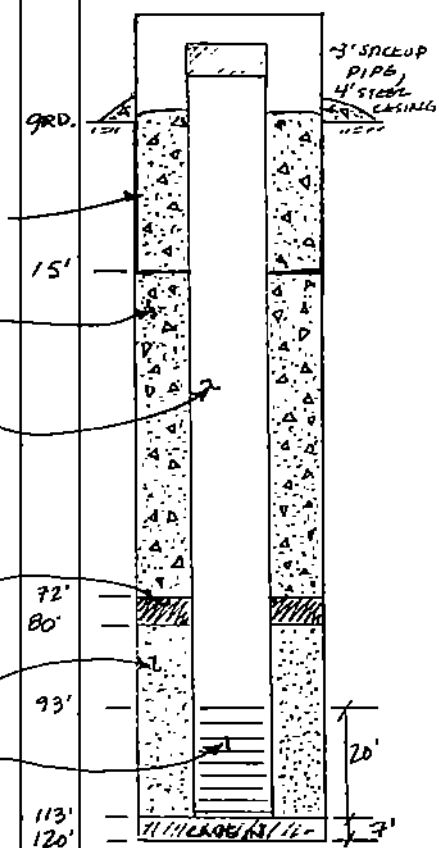
| PROJECT | | JOB NO. 9024 | HOLE NO. MW DH 15 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. | DEPTH | SAMPLER | CASING | SPT/RQD | RECOVERY | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 90 | | | | | | | | SANDY SILT W/ TRACE OF CLAY (ML) - brown, dry, slightly to non plastic | | |
| | 95 | | | | | | | | COBBLES IN SANDY SILT TO SILTY SAND (ML-SM) - brown, dry, non plastic, poorly graded | | drilling speed averages ~1'/min |
| | 60 | | | | | | | | | | |
| | 65 | | | | | | | | | | |
| | 70 | | | | | | | | COBBLES IN SANDY SILT TO SILTY SAND (ML-SM) - brown to beige w/ trace of orange, dry to damp in spots, non-plastic | | |
| | 75 | | | | | | | | | | |
| | 80 | | | | | | | | COBBLES (POSSIBLY BOULDERS) SILTY SAND W/ TRACE OF CLAY (ML) - brown, dry to damp in spots (clumps of damp cohesive soil come out of hole in return), slightly to non plastic. DOES NOT LOOK LIKE BEDROCK - FOUND IN OTHER DRILL HOLES - MORE like soil matrix, ang. cobble / boulder / gravel chips. Sands are rounded. | | soil is more damp past 80' - due to drilling speed - can not determine exactly where water is encountered. |
| | 85 | | | | | | | | | | |
| | 90 | | | | | | | | | | |
| | 95 | | | | | | | | | | |
| | 100 | | | | | | | | | | |

| PROJECT | | JOB NO. 9009 | HOLE NO. MW DH 15 |
|---|---|---|---|
| SITE | DATE – STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE – MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. | DEPTH | SAMPLER | CASING | SPT/RQD | RECOVERY | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100 | | | | | | | | COBBLES / BOULDERS / GRAVELS IN SILTY SAND TO SANDY SILT W/TRACE OF CLAY – (ML) – orangish brown, dry to damp, slightly to non plastic. | | |
| | 105 | | | | | | | | | | |
| | 110 | | | | | | | | GRAVELS / COBBLES / BOULDERS IN CLAYEY SILTY SAND (ML) – Orangish brown, slightly plastic to plastic, damp to dry. DOES NOT LOOK LIKE BEDROCK – SOME ROUND SANDS. | ▼ | HIT SUBSTANTIAL FLOW OF $H_2O$ @ 110' – ARTESIAN – $H_2O$ SEEPING OUT OF HOLE @ ~4-5 gpm ESTIMATED BY DRILLER.* PULLED RODS AND QUIT FOR THE DAY @ 120'. INSTALLED PVC 9-7-89 AM. SEE WELL INSTALLATION DIAGRAM. |
| | 115 | | | | | | | | MATR. is more coarse, porous past 115' – Could be fall in – | | |
| | 120 | | | | | | | | BOTTOM OF HOLE = 120' | | |

WELL INSTALLATION DIAGRAM – NOT TO SCALE –




*HEAD = 12psi – measured 9-8-89, Q = 2.5 gpm.

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|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| PROJECT: NORANDA | | | | JOB NO. 8029 | HOLE NO. DH-17 |
| SITE: Tailings Impoundment | | DATE - STARTED 08-17-89 FINISHED 08-18-89 | | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | | ELEVATION ~3560' | DEPTH TO WATER 23.2' | | DEPTH TO ROCK 65' |
| DRILLING CONTRACTOR: J.D. Welsh | | SAMPLES 5 | CORE BOXES 4 | | DEPTH OF HOLE 80' |
| DRILL MAKE - MODEL: ACKER ADII | | LOGGED BY A.M. SILVA | | | REVIEWED BY U.J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3560' | 0 | | | | % | | | | | COBBLES - of metasedimentary rocks in a clayey sandy silt soil | | Advanced hole with hollow-stem auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | ▽ | water at 2.5' 8-18-89, a.m. |
| | 4 | | | | | | | | | | | |
| | 5 | SPT #1 | | 12<br>17<br>34 | 100 % | | | | | GRAVELLY, SANDY, SILTY CLAY (CL) brn., dry, sl. plastic, v. stiff. | | Advanced hole with standard 2"ϕ split-spoon sampler |
| | 6 | | | | | | | | | Gravels & few rock fragments are metasediments (siltstone, meta-quartzite, metasandstone); gr. are subrounded | | |
| | 7 | | | | | | | | | | | Difficult augering Some vibrations |
| | 8 | | | | | | | | | | | |
| | 9 | | | | | | | | | | | |
| 3550' | 10 | SPT #2 | | 21<br>20<br>31 | 72 % | | | | | CLAYEY SANDY SILT (ML) - as above | | |
| | 11 | | | | | | | | | | | |
| | 12 | | | | | | | | | | | |
| | 13 | | | | | | | | | | | |
| | 14 | | | | | | | | | | | |
| | 15 | SPT #3 | | 27<br>50/4" | 44% | | | | | ML - as above | | Second set of blows only advanced sampler 3.5" REFUSAL - possibly cobble |
| | 16 | | | | | | | | | Increasing gravel content ↓ | | |
| | 17 | | | | | | | | | | | |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3540' | 20 | SPT #5 | | 17 | | | | | | ML - as above | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-17 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3540' | 20 | Spt #5 | | 29 / 49 | 88% | | | | | CLAYEY SANDY SILT (ML) - with gravels; brn., dry, sl. plastic, v. stiff | | Advanced hole w/ standard 2" ϕ split-spoon sampler |
| | 21 | | | | | | | | | | | |
| | 22 | | | | | | | | | Occ. rock fragments & gravels are metaquartzite & siltstone (hard) | | Resumed augering |
| | 23 | | | | | | | | | | ▼ | Encountered water at 23.2' (9-15-89) However, during drilling - water was found at 25' below surface 8-18-89 am. |
| | 24 | | | | | | | | | ML - damp | | |
| | 25 | SPT #6 | | 9 / 31 / 42 | 83% | | | | | ML - as above - with meta-quartzite rock fragments (boulder?) | | |
| | 26 | | | | | | | | | BOULDERS - of metaquartzite and siltstone, grey, hard, mod. fractured, sl. weathered, in a clayey, sandy silt (ML) matrix, brn., damp, sl. plastic, stiff | | Began HQ coring Good water return; beige color |
| | 27 | | | | | | | | | | | |
| | 28 | | | | 24% | | | | | | | |
| | 29 | | | | | | | | | Some gravels & cobbles | | |
| 3530' | 30 | | | | | | | | | | | |
| | 31 | | | | | | | | | | | |
| | 32 | | | | 42% | | | | | | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | 1 | | | | | | |
| | 35 | | | | | | | | | COBBLES & GRAVELS - grey-white, hard, subrounded, in a clayey, sandy silt (ML) matrix, brn., damp, v. dense (SM) - v. stiff (ML) | | Unconfined strength: over 4.5 tons/ft² |
| | 36 | | | | 100% | | | | | | | |
| | 37 | | | | | | | | | | | |
| | 38 | | | | | | | | | | | |
| | 39 | | | | | | | | | | | |
| 3520' | 40 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-17 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3520' | 40 | | | | | | | | | COBBLES & GRAVELS - grey, white, hard, subrounded, in a clayey, sandy silt (ML) matrix — brn., damp., v. stiff | | |
| | 41 | | | | | 1 | | | | | | |
| | 42 | | | | 20% | | | | | | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | ↓ fewer cobbles | | |
| | 45 | | | | | | | | | GRAVELLY SANDY SILT (ML) with clay, org. brn., damp, sl. plastic, v. stiff, with gravels - subrounded, grey-white-brn. metasediments, some conglomerate | | Conducted permeability test #1 at 45' (34.5' to 45') |
| | 46 | | | | | | | | | | | Org. brn. water return |
| | 47 | | | | | | | | | | | |
| | 48 | | | | 100% | | | | | ↓ | | |
| | 49 | | | | | | | | | | | |
| 3510' | 50 | | | | | | | | | - gravels ∠ 4 cm. ϕ | | Intermittent Loss of drilling water return |
| | 51 | | | | | | | | | | | |
| | 52 | | | | 60% | 2 | | | | | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | | | | | | | | | Slow drilling |
| | 56 | | | | | | | | | | | |
| | 57 | | | | 10% | | | | | | | |
| | 58 | | | | | | | | | ← occ. weathered rock fragments (siltstone, argillite, meta-sandstone) | | |
| | 59 | | | | | | | | | | | |
| 3500' | 60 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-17 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY % | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3500' | 60 | | | | | | | | | GRAVELLY, SANDY SILT (ML) with clay, org. brn. to tan, damp, sl. plastic, v. stiff | | |
| | 61 | | | | | | | | | | | |
| | 62 | | | | 45 % | | | | | (as above) | | |
| | 63 | | | | | 3 | | | | | | |
| | 64 | | | | | | | | | | | |
| | 65 | | | | | | | | | BEDROCK AT 65' (METASEDIMENTS) | | |
| | 66 | | | | | | | | | METASANDSTONE -w/ occ. siltstone + argillite interbeds; Lt. brn., wet, soft-m. hard, mod. weathered and fractured. | | |
| | 67 | | | 0 | 60 % | | | | | } int. fract. interval | | |
| | 68 | | | | | | | | | Some Fe-oxide staining throughout, along rough fracture surfaces | | |
| | 69 | | | | | | | | | | | |
| 3490' | 70 | | | | | | | | | | | Performed permeability test #2 at 70' (64.5' to 70') |
| | 71 | | | | | | | | | ← fract. w/ whitish talc filling. (Fractures ∢ 30°, some near vertical, rough surface, closed, straight.) | | |
| | 72 | | | 0 | 40 % | | | | | | | |
| | 73 | | | | | | | | | | | |
| | 74 | | | | | 4 | | | | Poor quality rock | | |
| | 75 | | | | | | | | | ← siltstone & argillite interbeds; soft-m. hard; Laminae at ∢ 10°-20° | | |
| | 76 | | | | | | | | | | | |
| | 77 | | | 93 % | 100 % | | | | | ← hard metasandstone | | |
| | 78 | | | | | | | | | | | |
| | 79 | | | | | | | | | | | |
| 3480' | 80 | | | | | | | | | BOH AT 80' | | Installed PVC pipe |

| | | | |
|---|---|---|---|
| PROJECT NORANDA | | JOB NO. 8029 | HOLE NO. DH-18 |
| SITE Tailings Impoundment | DATE - STARTED 08-19-89 FINISHED 08-19-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION Libby, Montana | ELEVATION ~ 3660' | DEPTH TO WATER NE | DEPTH TO ROCK NE |
| DRILLING CONTRACTOR J.D. Welsh | SAMPLES 4 | CORE BOXES 7 | DEPTH OF HOLE 65' |
| DRILL MAKE - MODEL ACKER AD II | LOGGED BY A.M. SILVA | REVIEWED BY U. J. CORDON | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3660' | 0 | | | | | | | | | GRAVELLY, SANDY SILT - SILTY SAND (ML-SM) - brn., dry, non-plastic, dense. | | Advanced hole to 4.5' by means of hollow-stem auger. |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | SPT #1 | | 17 / 26 / 26 | 100% | | | | | SANDY SILT (ML-SM) with gravel; brn., dry, non-plastic, stiff (v. dense SM) | | Began HQ coring |
| | 6 | | | | | | | | | | | |
| | 7 | | | | | | | | | | | |
| | 8 | | | | 100% | 1 | | | | Gravels are subrounded, consist of metaquartzite and siltstone, fragments ~ < 5cm φ, hard | | Beige water return |
| | 9 | | | | | | | | | | | |
| 3650' | 10 | SPT #2 | | 50+ | 100% | | | | | SILTY SAND - SANDY SILT (SM-ML) as above | | Attempted SPT#2; only advanced 3" before refusal |
| | 11 | | | | | | | | | | | |
| | 12 | | | | 76% | 1 | | | | Conglomerate fragments in ML matrix. | | |
| | 13 | | | | | | | | | Increasing clay content | | |
| | 14 | | | | | | | | | | | |
| | 15 | | | | | | | | | | | Performed permeability test #1 at 15' (8' to 15') |
| | 16 | | | | | | | | | | | |
| | 17 | | | | 100% | 2 | | | | | | |
| | 18 | | | | | | | | | | | |
| | 19 | | | | | | | | | | | |
| 3640' | 20 | | | | | | | | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 4 HOLE NO. DH-18

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-18 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3640 | 20 | SPT #3 | | 28 / 30 / 42 | 100 % | | | | | CLAYEY, SANDY SILT (ML) - (SM) w/ some gravels; brn, dry, sl. pl., stiff. | | |
| | 21 | | | | | | | | | | | |
| | 22 | | | | | | | | | | | |
| | 23 | | | | 100 % | 2 | | | | Increasing content of cobbles | | Unconfined strength of ML is ≈ 3.5 tons/ft² |
| | 24 | | | | | | | | | | | |
| | 25 | | | | | | | | | | | |
| | 26 | | | | | | | | | | | |
| | 27 | | | | 100 % | 3 | | | | | | |
| | 28 | | | | | | | | | | | |
| | 29 | | | | | | | | | | | |
| 3630 | 30 | | | | | | | | | | | Conducted permeability test # 2 at 30' (25' to 30') |
| | 31 | | | | | | | | | | | |
| | 32 | | | | 100 % | | | | | ML-SM with gravels and cobbles tan - Lt. brn., dry, sl. pl., stiff | | |
| | 33 | | | | | | | | | Cobbles are subrounded, hard, mainly metaquartzite and siltstone. | | |
| | 34 | | | | | | | | | | | |
| | 35 | | | | | | | | | | | Unconfined strength of soil matrix > 4.5 tons/ft² |
| | 36 | | | | | | | | | ← Traces of conglomerate fragments | | |
| | 37 | | | | 100 % | 4 | | | | | | |
| | 38 | | | | | | | | | | | |
| | 39 | | | | | | | | | | | |
| 3620 | 40 | | | | | | | | | ↓ Increasing conglomerate fragments | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-18 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INUITIES TYPE | DISCONT INUITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3620 | 40 | | | | | | | | | CLAYEY SANDY SILT (ML-SM) with cobbles and gravels; tan-lt. brn., dry, sl. pl., stiff | | |
| | 41 | | | | | | | | | | | |
| | 42 | | | | 100% | 4 | | | | | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | Metaquartzite cobble | | |
| | 45 | SPT #4 | | 42 | 0 | | | | | Fractured conglomerate | | Attempted SPT #4 at 45' NO RECOVERY Refusal after 7" penetration |
| | 46 | | | | | | | | | | | |
| | 47 | | | | | | | | | CLAYEY SILT (MH) w/ some fine sand and gravel; red-brn., dry, sl. pl-pl., stiff. | | |
| | 48 | | | | 100% | 5 | | | | | | |
| | 49 | | | | | | | | | | | |
| 3610 | 50 | | | | | | | | | Conglomerate - v. dense (m. hard) - silt & gravels consolidated into rock | | |
| | 51 | | | | | | | | | | | |
| | 52 | | | | | | | | | | | |
| | 53 | | | | 100% | | | | | Occasionally conglomerate is loose gravels and sandy silt | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | | | | | | | Becoming loose | | |
| | 56 | | | | | | | | | CLAYEY, SANDY SILT (ML-MH) org.-brn., dry, loose, sl. pl.-pl. with gravels | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | 100% | 6 | | | | | | Unconfined strength of soil matrix is ~ 2 tons/ft² |
| | 59 | | | | | | | | | Traces of weathered metasandstone | | |
| 3600 | 60 | | | | | | | | | | | Conducted permeability test #3 at 60' (55' to 60') |

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SHEET 3 OF 4 | HOLE NO. DH-18

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-18 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3600 | 60 | | | | | | | | | CLAYEY, SANDY SILT (ML-MH) w/gravels - org. brn., dry, Loose, sl. pl., some dense (stiff) sections. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 61 | | | | | | | | | | | |
| | 62 | | | | 100% | 6 | | | | | | |
| | 63 | | | | | | | | | | | |
| | 64 | | | | | 7 | | | | ← traces of metasandstone fragments | | |
| 3595' | 65 | | | | | | | | | BOH AT 65' | | Installed PVC pipe |

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SHEET 4 OF 4 | HOLE NO. DH-18

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-19 |
| SITE: Near center of tailings dam | DATE - STARTED 09-30-89 FINISHED 10-4-89 | HOLE SIZE 3.782" | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION ~ 3410' | DEPTH TO WATER ARTESIAN | DEPTH TO ROCK 60' |
| DRILLING CONTRACTOR: Chen-Northern / J.D. Welsh | SAMPLES 4 | CORE BOXES 7 | DEPTH OF HOLE 105' |
| DRILL MAKE - MODEL: ACKER ADII | LOGGED BY A.M. SILVA | | REVIEWED BY U.J. CORDON |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | Bar # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3410' | 0 | | | | | | | | | CLAYEY SILT (ML) w/ gravels, brn., moist-damp, sl.pl.-non pl., subrounded gravels, some sand. | | Advanced hole w/ HQ coring bit |
| | 1 | | | | | | | | | | | |
| | 2 | | 9" ø | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | | | | | | | | | | | Cased hole at 5'; pushed Shelby easy - Last 6" took ~ 100 Lbs pressure |
| | 6 | SH-1 | | | 100% | | | | | SANDY CLAYEY SILT (ML) w/gravel, brn., damp, sl. plastic., soft. | | |
| | 7 | | | | | | | | | Gravels are hard, subrounded. | | |
| | 8 | | | | | | | | | | | |
| | 9 | | | | 12% | | | | | | | |
| 3400' | 10 | | | | | | | | | | | |
| | 11 | | | | | | | | | | | |
| | 12 | SH-2 | | | 55% | | | | | | | |
| | 13 | | | | | 1 | | | | | | |
| | 14 | | | | | | | | | | | |
| | 15 | SH-3 | | | 0 | | | | | | | Attempted to push Shelby at 15' - REFUSAL |
| | 16 | | | | | | | | | | | |
| | 17 | | | | | | | | | | | |
| | 18 | | | | 30% | | | | | | | |
| | 19 | | | | | | | | | Org.-brn. color, non plastic, sl. stiff | | |
| 3390' | 20 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-19 |
|---|---|---|---|
| SITE | DATE – STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE – MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BAR | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS, STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3390' | 20 | SPT#1 | | 22 | | | | | | SANDY, SILTY GRAVEL (GM) – brn., non pl., stiff, damp. | | |
| | 21 | | | 50/4 | 66% | | | | | Gravels are subrounded, hard, most < 5 cm ϕ. | | |
| | 22 | | | | 98% | | | | | | | |
| | 23 | | | | | | | | | | | |
| | 24 | | | | 76% | | | | | | | |
| | 25 | | | | | | | | | Some cobbles (2"-3" ϕ), meta-quartzite, siltstone, gm-white, subrounded. | | |
| | 26 | | | | | | | | | | | |
| | 27 | | | | 67% | 1 | | | | Matrix is ML-SM | | |
| | 28 | | | | | | | | | | | |
| | 29 | | | | 67% | | | | | | | |
| 3380' | 30 | | | | | | | | | | | |
| | 31 | | | | | | | | | } gravels w/ ML matrix | | Changed bit at 31' |
| | 32 | | | | 50% | | | | | | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | 69% | 2 | | | | Occ. Lg. boulders<br>Approx. 50% ML-SM<br>50% Gravels, cobbles & boulders | | |
| | 35 | | | | | | | | | | | |
| | 36 | | | | | | | | | | | |
| | 37 | | | | | | | | | | | |
| | 38 | | | | 83% | | | | | | | |
| | 39 | | | | | | | | | | | |
| 3370' | 40 | | | | | | | | | | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-19 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONTINUITIES TYPE | DISCONTINUITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3370' | 40 | | | | | | | | | CONGLOMERATE - Fine-med size gr. in a cemented clayey sandy silt (ML). Gravel is subrounded, hard. ML is brn, dry-damp, stiff matrix. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| | 41 | | | | 83% | 2 | | | | | | |
| | 42 | | | | | | | | | SANDY SILT - SILTY SAND (CML-SM) w/ gravels & cobbles, occ. boulders; org.-brn., damp, non plastic, stiff. | | |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | | | | | Gravels & cobbles are hard, sub-rounded, mainly metaquartzite | | Good water return |
| | 45 | | | | 56% | | | | | | | |
| | 46 | | | | | 3 | | | | | | Rods hard to turn during drilling operations. |
| | 47 | | | | | | | | | | | |
| | 48 | | | | | | | | | | | |
| | 49 | | | | 90% | | | | | | | |
| 3360' | 50 | | | | | | | | | | | |
| | 51 | | | | | | | | | | | |
| | 52 | | | | 83% | | | | | | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | | | | | | | | |
| | 55 | | | | 65% | | | | | | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | 52% | | | | | | | |
| | 59 | | | | | | | | | | | |
| 3350' | 60 | | | | | | | | | BEDROCK AT 60' (METASEDIMENTS) | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-19 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION: NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE | WATER DATA | REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3360' | 60 | | | | | | | | | SILTSTONE, ARGILLITE, METASANDSTONE - interbedded, org.-brn., friable, mod. weathered, (easily fractures along laminae at ∠ 45°-60°) | | |
| | 61 | | | | | | | | | | | |
| | 62 | | | 27 % | 65 % | | | | | | | |
| | 63 | | | | | | | | | Some Fe-oxidation along fract. surfaces, few slickensides. | | |
| | 64 | | | | | | | | | Fractures are sl. rough-smooth, straight; some near vertical; occ. vuggy sections | | |
| | 65 | | | | | | | | | | | |
| | 66 | | | | | 4 | | | | | | |
| | 67 | | | 14 % | 67 % | | | | | | | |
| | 68 | | | | | | | | | } intensely fractured argillite, siltstone at ∠ 45° | | |
| | 69 | | | | | | | | | | | |
| 3340 | 70 | | | | | | | | | | | |
| | 71 | | | | | | | | | | | |
| | 72 | | | 23 % | 100% | | | | | | | |
| | 73 | | | | | | | | | | | |
| | 74 | | | | | | | | | } int. fractured | | |
| | 75 | | | | | | | | | | | |
| | 76 | | | | | | | | | | | |
| | 77 | | | 20 % | 80 % | | | | | | | |
| | 78 | | | | | 5 | | | | | | |
| | 79 | | | | | | | | | | | |
| 3330' | 80 | | | | | | | | | | | Conducted permeability test (59.5-80') |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-19 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3330' | 80 | | | | | | | | | SILTSTONE, ARGILLITE, META-SANDSTONE - interbedded; brn.-occ white metass., friable (easily broken along thin laminations), few slickensides. Metasandstone generally hard | | SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS |
| | 81 | | | | | | | | | | | |
| | 82 | | | 22% | 56% | 5 | | | | | | |
| | 83 | | | | | | | | | Lamination & fractures at 50°-75° | | |
| | 84 | | | | | | | | | | | |
| | 85 | | | | | | | | | extremely friable | | Water level in rods above ground level 33' |
| | 86 | | | | | | | | | ← talc filling in fracture at ∠75° | | |
| | 87 | | | 20% | 86% | 6 | | | | | | |
| | 88 | | | | | | | | | | | |
| | 89 | | | | | | | | | | | |
| 3320' | 90 | | | | | | | | | fract. along 60° ∠ Laminae | | |
| | 91 | | | | | | | | | | | |
| | 92 | | | 32% | 84% | | | | | v. hard metas.s. | | |
| | 93 | | | | | | | | | - friable argillite | | |
| | 94 | | | | | | | | | | | |
| | 95 | | | | | | | | | ↓ Rock becomes slightly harder, better induration in metasediments | | |
| | 96 | | | | | | | | | | | |
| | 97 | | | 67% | 100% | 7 | | | | | | |
| | 98 | | | | | | | | | | | |
| | 99 | | | | | | | | | | | |
| 3310' | 100 | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-19 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3310' | 100 | | | | | | | | | SILTSTONE, ARGILLITE, META-SANDSTONE - interbedded. (as above) | | |
| | 101 | | | | | | | | | | | |
| | 102 | | | 37% | | | | | | | | |
| | 103 | | | | 78% | 7 | | | | | | |
| | 104 | | | | | | | | | | | Conducted packer test (79'–105') |
| 3305' | 105 | | | | | | | | | BOH AT 105' | | Installed PVC pipe |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

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SHEET 6 OF 6 | HOLE NO. DH-19

REVISED

| | | | |
|---|---|---|---|
| PROJECT: NORANDA | | JOB NO. 8029 | HOLE NO. DH-20 |
| SITE: Tailings dam | DATE - STARTED 10-04-89 FINISHED 10-08-89 | HOLE SIZE | ORIENTATION VERTICAL |
| LOCATION: Libby, Montana | ELEVATION N 3410 | DEPTH TO WATER ~25'-40' (caved) | DEPTH TO ROCK 205' |
| DRILLING CONTRACTOR: Chen-Northern / J.D. Welsh | SAMPLES 12 | CORE BOXES 15 | DEPTH OF HOLE 214' |
| DRILL MAKE - MODEL: ACKER ADII | LOGGED BY A.M. SILVA | | REVIEWED BY V. J. CORDON |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | % RECOVERY | BOX # | DISCONT INF-ITIES TYPE | DISCONT INF-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3410 | 0 | | | | % | | | | | SANDY, CLAYEY SILT (ML-MH) brn., sl.pl.-pl., m.soft-stiff, traces gravel | | Advanced hole w/ hollow-stem auger |
| | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| | 4 | | | | | | | | | | | |
| | 5 | SH-1 | P=200psi | | 70% | | | | | | | Advanced hole by pushing Shelby tube |
| | 6 | | | | | | | | | | | P= pressure exerted by rig to push Shelby tube |
| | 7 | SH-2 | P=75 psi | | 60% | | | | | | ▽ | 10/5/89 |
| | 8 | | | | | | | | | | | |
| | 9 | SH-3 | P=50psi | | 70% | | | | | | | |
| 3400 | 10 | | | | | | | | | | | |
| | 11 | SH-4 | P=100psi | | 75% | | | | | Silt at bottom of tube | | |
| | 12 | | | | | | | | | | | |
| | 13 | SH-5 | P=50psi | | 100% | | | | | | | |
| | 14 | | | | | | | | | | | |
| | 15 | SH-6 | P=100psi | | 80% | | | | | Silty clay mat'l at bottom of tube | | |
| | 16 | | | | | | | | | | | |
| | 17 | SH-7 | P=100 psi | | 100% | | | | | | ▼ | 10/6/89 |
| | 18 | | | | | | | | | | | |
| | 19 | SH-8 | P=100psi | | 85% | | | | | Clay & sands at bottom of tube | | |
| 3390' | 20' | | | | | | | | | | | |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-20 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3390 | 20 | | | | | | | | | | | |
| | 21 | SH-9 | P=400 psi | | 50% | | | | | SANDY, CLAYEY SILT (ML-MH), lt. brn., sl. pl.-pl., soft-stiff, tr. gravels | | Pushed Shelby to 22' |
| | 22 | | | | | | | | | | | Augered to 25' |
| | 23 | | | | | | | | | | | |
| | 24 | | | | | | | | | | | |
| | 25 | | | | | | | | | | | |
| | 26 | SPT#1 | | 10<br>14<br>12 | 72% | | | | | SANDY, SILTY CLAY (CL-ML) dry; sl. pl.- to non-plastic, some gravels | | Advanced hole w/ standard split-spoon sampler |
| | 27 | | | | | | | | | Increasing content of gravels & cobbles | | Advanced hole w/ HQ coring bit |
| | 28 | | | | 46% | | | | | | | |
| | 29 | | | | | | | | | | | |
| 3380' | 30 | | | | | 1 | | | | ML-CL w/ gravels & cobbles, v. soft - soft (occ. dense), sl. pl. to plastic, gravels are hard, subrounded | | |
| | 31 | | | | | | | | | | | |
| | 32 | | | | 10% | | | | | | | |
| | 33 | | | | | | | | | | | |
| | 34 | | | | | | | | | | | |
| | 35 | | | | | | | | | | | |
| | 36 | SPT#2 | | 3<br>6<br>9 | 0 | | | | | NO RECOVERY<br>V. soft mat'l. | | |
| | 37 | | | | | | | | | | | |
| | 38 | | | | 28% | | | | | | | |
| | 39 | | | | | | | | | | | |
| 3370' | 40 | | | | | | | | | | | Conducted permeability test #1 (29'-40') |

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-20 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INJ-ITIES TYPE | DISCONT INJ-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3370' | 40 | | | | | | | | | CLAYEY SILT (ML-CL) w/ tr. fine sand and gravels, org. brn., dry, non pl. | | (H2O seeps out of hole during perm. test - may be confined between 25' and 40') |
| | 41 | | | | | | | | | | | |
| | 42 | | | | 42 % | | | | | CL-ML - pl., wet | | Losing drill water |
| | 43 | | | | | | | | | | | |
| | 44 | | | | | 1 | | | | | | |
| | 45 | | | | | | | | | | | Difficult drilling |
| | 46 | | | | | | | | | COBBLES & GRAVELS in sandy silt (ML) matrix. Rocks are siltstone & metaquartzite, grey, subrounded Soil is brn., damp, non pl.-sl. pl., soft. | | |
| | 47 | | | | 52 % | | | | | | | |
| | 48 | | | | | | | | | | | |
| | 49 | | | | | | | | | | | |
| 3360' | 50 | | | | | | | | | | | |
| | 51 | | | | 76 % | | | | | | | |
| | 52 | | | | | 2 | | | | | | |
| | 53 | | | | | | | | | | | |
| | 54 | | | | 80 % | | | | | | | |
| | 55 | | | | | | | | | | | |
| | 56 | | | | | | | | | | | |
| | 57 | | | | | | | | | | | |
| | 58 | | | | 58 % | | | | | conglomerate | | |
| | 59 | | | | | | | | | | | |
| 3350' | 60 | | | | | | | | | | | |

REMARKS

SAMPLING — STANDARD PENETRATION
DRILL ACTION — WATER PRESSURE TEST
WATER LOSS — LAB CLASSIFICATION
CORE LOSS — PIEZOMETERS

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-20 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOR # | DISCONT INF- ITIES TYPE | DISCONT INF- ITIES DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3350' | 60 | | | | | | | | | COBBLES & GRAVELS in a Sandy clayey silt matrix (as above) | | |
| | 61 | | | | | | | | | ↑ metaquartzite cobble (hard) | | |
| | 62 | | | | 51 % | 2 | | | | | | |
| | 63 | | | | | | | | | | | |
| | 64 | | | | | | | | | | | |
| | 65 | | | | | | | | | Soil becomes clayey silt (ML) w/ some sand and gravels & cobbles. | | |
| | 66 | | | | 57 % | | | | | | | |
| | 67 | | | | | | | | | | | |
| | 68 | | | | 100 % | 3 | | | | | | Conducted permeability test #2 (38'-68') |
| | 69 | | | | | | | | | | | |
| 3340' | 70 | | | | | | | | | Occ. metaquartzite cobbles-boulders | | |
| | 71 | | | | 73 % | | | | | | | |
| | 72 | | | | | | | | | | | |
| | 73 | | | | | | | | | | | |
| | 74 | | | | | | | | | | | |
| | 75 | | | | | | | | | | | |
| | 76 | | | | 93% | 4 | | | | | | |
| | 77 | | | | | | | | | | | |
| | 78 | | | | | | | | | | | |
| | 79 | | | | | | | | | | | |
| 3330' | 80 | | | | | | | | | | | |

REMARKS: SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS

| PROJECT | | JOB NO. 8029 | HOLE NO. DH-20 |
|---|---|---|---|
| SITE | DATE - STARTED FINISHED | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION / DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES / CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | REVIEWED BY | |

| ELEV. (ft.) | DEPTH (ft.) | SAMPLER | CASING | SPT/RQD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DIP | SYMBOL | MATERIAL DESCRIPTION | WATER DATA | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3330 | 80 | | | | 40% | | | | | BOULDERS & GRAVELS IN SANDY SILT MATRIX. – brn, damp, sl. pl. – non pl., loose to stiff. Rock is subrounded, metasediments (metasandstone, metaquartzite), fractured, few slickensides on long rock sections. | | SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS; STANDARD PENETRATION / WATER PRESSURE TEST / LAB CLASSIFICATION / PIEZOMETERS |
| CHANGE IN SCALE | | | | | 70% | 4 | | | | | | |
| | 90 | | | | 95% | | | | | | | |
| | | | | | 88% | | | | | | | Attempted SPT#3 at 94' REFUSAL at 1" penetration |
| | 100 | | | | 66% | 5 | | | | ML & BOULDERS | | Drilling rate ≈ .13 ft/min. |
| | | | | | 0 | | | | | ~60% ML ~40% BOULDERS, COBBLES, GRAVELS | | |
| | 110 | | | | 63% | 6 | | | | | | |
| | | | | | 45% | | | | | Interlayered sequence of soil (ML) & boulders w/ gr. | | |
| | 120 | | | | 58% | 7 | | | | | | |
| | | | | | 100% | | | | | ← conglomerate w/ clay | | |
| 3280 | 130 | | | | 72% | 8 | | | | Fractures on boulders have Fe-oxidation, tr. clay, few slickensides | | |
| | | | | | 57% | 9 | | | | ← gravels in a clayey silt matrix, sl. pl., damp., loose | | |
| | 150 | | | | 72% | | | | | | | |
| | | | | | 70% | | | | | | | |
| | 160 | | | | 44% | | | | | | | |
| | | | | | 51% | | | | | | | |
| | 170 | | | | 69% | 10 | | | | Larger cobbles & boulders separated by clayey silt (ML) matrix w/ gravels & sand. | | |
| | | | | | 42% | | | | | ← conglomerate | | |
| 3230 | 180 | | | | | | | | | Occ. gravels | | |

| PROJECT | | | JOB NO. 8029 | HOLE NO. DH-20 |
|---|---|---|---|---|
| SITE | DATE - STARTED FINISHED | | HOLE SIZE | ORIENTATION |
| LOCATION | ELEVATION | DEPTH TO WATER | | DEPTH TO ROCK |
| DRILLING CONTRACTOR | SAMPLES | CORE BOXES | | DEPTH OF HOLE |
| DRILL MAKE - MODEL | LOGGED BY | | REVIEWED BY | |

| ELEV. (Ft.) | DEPTH (Ft.) | SAMPLER | CASING | SPT/ROD | RECOVERY | BOX # | DISCONT INU-ITIES TYPE | DISCONT INU-ITIES DIP | SYMBOL | MATERIAL DESCRIPTION (NAME, COLOR, CONSISTENCY, GRAIN SIZE, PLASTICITY, CLASSIFICATION, WEATHERING, HARDNESS, STRUCTURE) | WATER DATA | REMARKS (SAMPLING, DRILL ACTION, WATER LOSS, CORE LOSS; STANDARD PENETRATION, WATER PRESSURE TEST, LAB CLASSIFICATION, PIEZOMETERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3230' | 180 | | | | 58% | | | | | CLAYEY SILT (ML) w/ BOULDERS and gravels. | | |
| | | | | | 42% | | | | | ← gravels in ML matrix | | |
| | 190 | | | | 70% | | | | | | | |
| | | | | | 72% | | | | | | | |
| | 200 | | | | 94% | | | | | int. fract. boulder, grey, hard | | |
| | | | | | | | | | | BEDROCK AT 205' | | |
| | | | | 38% | 100% | | | | | SILTSTONE, ARGILLITE - Lt. brn., friable, easily broken along laminations at ∠ 45° (> 10 ft./ft.) | | Conducted packer tests #3, 4 (205'-214') (177'-214') |
| | 210 | | | 76% | 60% | | | | | | | |
| 3196' | 214' | | | | | | | | | BOH AT 214' | | Installed PVC pipe to 154' |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 6 OF 6 | HOLE NO. DH-20

WELL LOGS
(1988)

(By Chen - Northern)

Northern Engineering and Testing, Inc.

# WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: PLCH-6

Legal Location: T ____ R ____ Sec ____ Tract ____ Descriptive Location: Little Ch. Ck. Loop Rd., (Between Poorman & L.Ch. Sites)

Recorded By: H. Corbett Hole Started: Time: 1000 Date: 07/21/88 Hole Completed: Time: 1500 Date: 07/21/88 Driller: B & B

Drill Method: air rotary Drilling Fluids Used: water in silty sections Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 56' Total Depth Reamed: ____ Total Depth Cased Below G.S.: 45.5-55.5 56 ft (deep) Diameter and Type of Casing: 2" PVC tube + screen

Weight or Gage of Casing: ____ Interval Perforated or Screened Below G.S.: ____ Target Aquifer: Bedrock & shallow gravel zone Packer Type and Depth Below G.S.: ____

| DURING INSTALLATION WAS: | YES | NO |
|---|---|---|
| Well Developed? | ____ | X |
| Well Test Pumped? | ____ | X |
| Water Samples Taken? | ____ | X |
| Material Samples Taken? | X | ____ |
| E-Logs? | ____ | X |

Bedrock

Method Perforated or Screened

____ No casing in hole
____ Open bottom
____ Slotted with Hill's Knife
____ Slotted with a torch
____ Screened by pulling casing
____ Field saw cut
X Mechanical slots
Dual Completion
5 ft. 0.03 cont slot deep
10 ft. 0.01 cont slot, shallow
____ Other (specify) ____

Static Fluid Level Measured shallow SWL as 9.9' below MP (above ground-waiting to measure later) 07/23/88 0845
Below Measuring Point: Approx. 9.5' above ground before flow slows much on deep Date/Time Measured: 07/23/88 1000

Measuring Point Description/Elevation: north side steel casing, top MP Height Above (+/-) or Below G.S.: +2.5'

Well Annulus Completion Description: 56' to 52'8" Colorado 10/20 sand; 52'8" to 47'8" PVC .03 cont. slot screen with Colorado 10/20 sand filter pack; 47'8" to 46'4" Colorado 10/20 sand; 46'4" to 45'10" bentonite pellets; 45'10" to 44'10" Colorado 10/20 sand; 44'10" to 32'8" volclay grout; 32'8" to 19'6" cement sand; 19'6" to 7'. Silica sand Colorado 10/20; 18' to 8' PVC .01 cont. slot screen; 7' to 6.5' bentonite pellets; 6.5' to 6' cement sand; neat cement inside and outside surface casing from 6' to ground level (3 sacks)

Well Development Description: ____

Remarks: Use 5' 0.03 screen for bottom interval (approx. 48-57'); use 10' 0.01 screen for top (approx. 8-18) Put 10/20 sand over pellets to keep tremie pipe away -- pump 75 gal. Volclay grout include 2-3 quarts bentonite mixed in to thicken -- probe will not stabilize at a given depth -- water displaced up but void present and volclay grout remains fluid. Shut down at 1700 to let set overnite (Don't wish to have grout invade zone for upper screen

*Note: Lower screen moved up 4" on 1st pipe jacking -- then stablized

Northern Engineering and Testing, Inc.

ORILLING AND LITHOLOGIC LOG PCLH-6

| (Depth Below G.S.) From | To | DRILLING LOG | Geological, Drilling, and Water Conditions and Sampling |
|---|---|---|---|
| ground | 4 | Soil layer | |
| 4 | 7 | Gravelly colluvium | |
| 7 | 9 | Silty, some pebbles | |
| 9 | 13 | Clean gravel, medium coarse gravel. Water at 9.5' | |
| 13 | 17 | Dirty, silty gravel, fine-medium, tan-brown colors | |
| 17 | 45.5 | Silt, minor gravel in upper portion, Clean silt below 20', Buff to light yellow-orange browns | |
| 45.5 | 49 | Silty-clayey gravel, dark gray, medium coarse. Drilled a boulder at top. Let sit few minutes -- air blew water at 45.5' | |
| 49 | 50 | Very coarse sand-fine gravel, dark gray with coaser buff subrounded fragments | |
| 50 | 52 | Highly fractured coarse chips - bedrock. Dark gray argillite with | |
| 52 | 55.5 | fracture fillings (?). Changes to pinkish or brown. Making lots of water. Cleaning fast. | |

Northern Engineering and Testing, Inc.

# WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCTM-8

Legal Location: T ____ R ___ Sec ___ Tract ___ Descriptive (Champion property) Location: east side L. Ch. site, south of L. Ch. Ck

Recorded By: M. Corbett Hole Started: Time: 1035 Date: 07/26/88 Hole Completed: Time: 1730 Date: 07/27/88 Driller: B & B

Drill Method: Air Rotary Drilling Fluids Used: water as needed Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 140 ft. Total Depth Reamed: ____ Total Depth Cased Below G.S.: 93' Diameter and Type of Casing: 6" steel with 4" PVC liner

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 33-93; etc. for 48'-43' and 58'-53' and 88'-93'; total 45' screened Target Aquifer: __ Packer Type and Depth Below G.S.: __

| DURING INSTALLATION WAS: | YES | NO |
|---|---|---|
| Well Developed? | ____ | X |
| Well Test Pumped? | ____ | X |
| Water Samples Taken? | ____ | X |
| Material Samples Taken? | ____ | X |
| E-Logs? | ____ | X |

Method Perforated or Screened

- ____ No casing in hole
- ____ Open bottom
- X Slotted with Mill's Knife outside steel casing
- ____ Slotted with a torch
- ____ Screened by pulling casing
- ____ Field saw cut
- X Mechanical slots .016 (size) exc. .03; bet. 48'-53'. Total 45'.
- ____ Other (specify) ____

Static Fluid Level Below Measuring Point: ____ Date/Time Measured: +2.5'

Measuring Point Description/Elevation: Top well protector MP Height Above (+/-) or Below G.S.: ____

Well Annulus Completion Description: Backfilled with cement sand 140' to 94'; set screen column between 88' and 33', filter packed with Colo 10.20 sand from 94' to 26'; volclay grout from 25' to 6' (on top 1' cement sand); cemented 6' to surface

Well Development Description: ____

Remarks: Screen column = 88' to 33' w 10s, 5t, 5s, 5t, 30s (top dn); Steel casing could not be jacked. Effort resulted in lift and removal of 7' casing plus bending of upper above ground (?) segment. Slotting made of steel casing 2/ft. over total screened segments, 33-88 ft.

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG LCTM-8

| (Depth to G.S.) From | To | DRILLING LOG Geological, Drilling, and Water Conditions and Sampling |
|---|---|---|
| surface | 4 | Silt rich soil. |
| 4 | 5 | Boulder? minor gravel pebbles mixed with silt |
| 5 | 11 | Mostly silt with occasional cobbles or gravel pebbles. Drilling boulder at 6'-9'; switched to hammer. |
| 11 | 13 | Pea gravel, relatively clean |
| 13 | 15.5 | Silty gravel, medium size clasts, very clayey/silty |
| 15.5 | 16 | Silt, slight chocolate brown colors, dry |
| 16 | 18 | Clean gravel pea size, slt water |
| 18 | 20 | Very silty gravel (?). Still with hammer |
| 20 | -- | Very silty gravel; switch to tricone |
| -- | 23 | Chocolate brown silts followed by coarse gravel; cobbles silty gravels with yellow/orange brown colors |
| 23 | -- | Large boulder followed by more silty gravel with chocolate color and cobbles. Continued gray, dark gray, cobbles, boulders etc., with brown, orange brown, buff, silty/clayey matrix; medium/coarse grained, small clasts are brown, buff to orange and orange brown; coarse material gray-dark gray |
| -- | 30 | Change to yellow brown matrix material |
| 30 | 35 | More of same |
| 35 | 38 | Cleaner more rounded/subrounded gravels, medium coarse grained with multi color clasts (gray, red, brown, tan) fluvial gravel; making fair amount water at 37'. Not much silt matrix. |
| 38 | 50 | Back to coarse gravel with silty matrix. Boulders |
| 50 | 51 | Clean well rounded pebble gravel -- make slt. water |
| 51 | 54 | Silty gravel? Pebble gravel with silt matrix - making more water?? |
| 54 | 58 | Boulders, silty gravel. Water dec. to nothing |
| 58 | 59 | Clean gravel -- some water (well rouned to subangular) |
| 59 | 67 | Coarse cobbles and boulders. Tough drilling |
| 67 | 68 | Small pea gravel - dirty. No visible water |
| 68 | 74 | Silty gravel, coarse, boulders |

DRILLING AND LITHOLOGIC LOG LCTM-8

| (Depth to G.S.) From | To | DRILLING LOG Geological, Drilling, and Water Conditions and Sampling |
|---|---|---|
| 74 | 75 | Clean gravel, minor water |
| 75 | 79 | Silty gravel as above |
| 79 | 80 | Clean gravel, small-medium brownish clasts |
| 80 | 84 | Silty gravel |
| 84 | 85 | Pea gravel (added more water) |
| 85 | 92 | Silty gravel, boulders, etc. Drilled large quartzite boulder |
| 92 | 94 | Cleaner medium gray gravel with some pea size clasts. No obvious water addit. |
| 94 | 96 | Drilling quartzite boulder |
| 96 | 98 | Pea gravel change to clasts 1" or more. No water |
| 98 | 99 | Drilling boulder |
| 99 | 110 | Back into gravel, boulders etc. Clean without silt matrix but not making much water (if any); highly variable clast compositions and colors (quartz, quartzite, argillite, and carbonate) |
| 110 | 114 | Some silty gravel for short distance |
| 114 | 116 | More gravel, boulders? bedrock? |
| 116 | -- | Tripped out and in with hammer bit |
| 116 | 120 | Tough rock (bedrock?) Hole drilled ahead |
| 120 | 125 | Real dirty silty pea gravel -- made water? hole drilled ahead |
| 125 | 140 TD | Very silty with pea gravel, with minor water, still open hole, silty content increasing. |

Note: Driller added heavy amounts water to drill clean thru very silty gravel. Silty very much like lacustrine silts elsewhere. Gravel mostly all fine gravel sub to well rounded. Very low permeability due to silt.

Also, driller notes same mixture silt and fine pea gravel in Libby valley (recent well) down to 615' to bedrock

Northern Engineering and Testing, Inc.

# WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCH-9

Legal Location: T ____ R ____ Sec ____ Tract ____ Descriptive Location: L. Ch. - Bear Creek area (on Champion northline)

Recorded By: M. Corbett Hole Started: Time: 1033 Date: 07/20/88 Hole Completed: Time: 1645 Date: 07/20/88 Driller : B & B

Drill Method: air rotary Drilling Fluids Used: mix or water Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 65.5 Total Depth Reamed: ____ Total Depth Cased Below G.S.: 72 Diameter and Type of Casing: 2" PVC, flush joint threaded

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 57'-67' Target Aquifer: ____ Packer Type and Depth Below G.S.: ____

| DURING INSTALLATION WAS: | YES | NO | |
|---|---|---|---|
| Well Developed? | ____ | X | |
| Well Test Pumped? | ____ | X | |
| Water Samples Taken? | ____ | X | |
| Material Samples Taken? | X | ____ | Bedrock |
| E-Logs? | ____ | X | |

Method Perforated or Screened

- ____ No casing in hole
- ____ Open bottom
- ____ Slotted with Hill's Knife
- ____ Slotted with a torch
- ____ Screened by pulling casing
- ____ Field saw cut
- X Mechanical slots .010 (size)
- ____ Other (specify) ____

Static Fluid Level Below Measuring Point: 15.3' BGS Date/Time Measured: 0900; 07/21/88

Measuring Point Description/Elevation: Top of steel, northside MP Height Above (+/-) or Below G.S.: +3.1

Well Annulus Completion Description: 72-64', concrete sand; 64'-56', 10/20 Colorado Silica Sand; 56'-55.5', bentonite pellets 55.5'-45', volclay grout; 45'-7', concrete sand; 1'-0' concrete surface seal; 6" steel from 10' to +3.1'

Well Development Description: ____

Remarks: Started completion at 1100 hours; 07/21/88, finished completion at 1530 hours

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG LCN-9

| (Depth Below G.S.) From | To | DRILLING LOG Geological, Drilling, and Water Conditions and Sampling |
|---|---|---|
| ground | 5 | Residual soil |
| 5 | 10 | Dirty clay-silt rich gravel; yellow brown to red-orange brown |
| 10 | 11 | Medium-coarse gravel, gray-tan |
| 11 | 15 | Dirty clay/silt rich gravelly material; buff to orange-brown (colluvium); pebbles light-dark gray, clays/silts more orange yellow browns |
| 15 | 19 | Orange-brown silt (medium dark tones rather than lighter buff of other wells to south. Very dry; very little clay or sand |
| 19 | 25 | More yellow brown silt with more clay sticky and damp. Slight light gray mottling, water added by driller at 23 ft. in silt; silt getting richer in clays; medium yellow brown |
| 25 | 28 | Mit boulder -- gravel and clay/silt mixed |
| 28 | 34 | Clean medium gravel light-medium gray; drilling easy |
| 34 | 38 | Coarse gravel (boulders) drilling slow. Had very light water show at 32 ft. |
| 38 | 43 | Dirty gravel, clayey |
| 43 | 48 | Silty, dry, orange brown (drilled light gray boulder 44-45') |
| 48 | 51 | Silty -- buff, minor rocks |
| 51 | 58 | Gravelly, with silts light gray rock chips alternating with silt (buff to orange brown) |
| 58 | 59 | Silt, buff, damp? clayey |
| 59 | 61 | Clean pea gravel - gray to dark gray. Damp; shut down for added drill stem and casing. Back in 2 ft. water (57 ft) |
| 61 | 64 | Silt, minor gravel. Dry. Driller adding water. |
| 64 | 65 | More gravel, dirty |
| 65 | 65.5 | Bedrock -- casing not driving. No water noted. |
| 65.5 | 72 | Drilled ahead for sample. Still no water. |
| | | Note: Completion with 10 ft. screen on bedrock + up? |

Northern Engineering and Testing, Inc.

# WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCH-10

Legal Location: T ____ R ____ Sec ____ Tract ____ Descriptive Location: ____

Recorded By: D. Hazen Hole Started: Time: 0900 Date: 07/24/88 Hole Completed: Time: 1400 Date: 07/25/88 Driller : B & B Drilling

Drill Method: air rotary Drilling Fluids Used: minor water Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 40' Total Depth Reamed: ____ Total Depth Cased Below G.S.: ____ Diameter and Type of Casing: 2" PVC flush joint threaded

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 25'-40' Target Aquifer: ____ Packer Type and Depth Below G.S.: ____

| DURING INSTALLATION WAS: | YES | NO |
|---|---|---|
| Well Developed? | ____ | X |
| Well Test Pumped? | ____ | X |
| Water Samples Taken? | ____ | X |
| Material Samples Taken? | X | ____ |
| E-Logs? | ____ | X |

Method Perforated or Screened

- ____ No casing in hole
- ____ Open bottom
- ____ Slotted with Mill's Knife
- ____ Slotted with a torch
- ____ Screened by pulling casing
- ____ Field saw cut
- X Mechanical slots 0.010 (size)
- ____ Other (specify) ____

Static Fluid Level Below Measuring Point: ____ Date/Time Measured: ____

Measuring Point Description/Elevation: Top of steel well protector MP Height Above (+/-) or Below G.S.: +3.0

Well Annulus Completion Description: 40'-23', 10/20 Colorado Silica Sand; 23-19', bentonite pellets; 19'-3', cement sand; 3'-surface, concrete surface seal

Well Development Description: ____

Remarks: 1' piece of rebar left in sand pack

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG LCN-10

| (Depth Below G.S.) From | To | DRILLING LOG | Geological, Drilling, and Water Conditions and Sampling |
|---|---|---|---|
| 0 | 1 | Top soil, organic material | |
| 1 | 20 | Gravel, silty, sandy, light brown, slightly moist, subangular to subrounded gravel clasts to 1"; occasional cobbles and boulders of gray argilite; 40% gravel, 30% sand, 30% silt; boulders at 6', 8', 15' | |
| 20 | 27 | Gravel, silty, sandy, light brown, moist at 20', slight moist below | |
| 27 | 32 | Gravel, bouldery, sandy, some gray-brown silt. Predominantly gray argillite clasts with minor yellow and green clasts. Approximately 0.5 gpm water at 32' | |
| 32 | 39 | Gravel, silty sandy, light gray brown. Mostly gray clasts with some orange-yellow, green, and light brown clasts. Making approximately 1 gpm at 36' | |
| 39 | 40 | Gravel, silty, sandy, orange silt, gray gravel clasts | |

Northern Engineering and Testing, Inc.

# WELL COMPLETION LOG

State: Montana County: Lincoln Project: Montana Silver Venture Hole Name or Number: LCH-11

Legal Location: T ____ R ____ Sec ____ Tract ____ Descriptive Location: Upper Little Cherry Creek site, northend

Recorded By: M. Corbett & D. Hazen Hole Started: Time: 0930 Date: 07/22/88 Hole Completed: Time: 1600 Date: 07/22/88 Driller : B & B

Drill Method: air rotary Drilling Fluids Used: minor water Pilot Hole Diameter: 6" Reamed Hole Diameter: ____

Total Depth Drilled: 62.5' Total Depth Reamed: ____ Total Depth Cased Below G.S.: ____ Diameter and Type of Casing: 2" PVC with 5' of 0.03 screen

Weight or Gage of Casing: Sch 40 Interval Perforated or Screened Below G.S.: 57-62' Target Aquifer: ____ Packer Type and Depth Below G.S.: ____

| DURING INSTALLATION WAS: | YES | NO |
|---|---|---|
| Well Developed? | ____ | X |
| Well Test Pumped? | ____ | X |
| Water Samples Taken? | ____ | X |
| Material Samples Taken? | ____ | X |
| E-Logs? | ____ | X |

Method Perforated or Screened

____ No casing in hole
____ Open bottom
____ Slotted with Mill's Knife
____ Slotted with a torch
____ Screened by pulling casing
____ Field saw cut
X Mechanical slots 0.03 (size) 1-5 ft. 2" sect.
____ Other (specify) ____

Static Fluid Level Below Measuring Point: 46.6' BGS Date/Time Measured: 07/24/88 1115

Measuring Point Description/Elevation: north side steel casing MP Height Above (+/-) or Below G.S.: +2.7'

Well Annulus Completion Description: 62'6" to 62', Colorado 10/20 silica Sand; Base screen at 62' with top at 57', filter pack Colorado 10/20 sand from base to 54'7"; 54'7" to 53'7" volclay pellets; 53'7" to 27' cement sand; 44'7" to 27' caved; 27' to 20' volclay grout; 20' to surface cement sand; Neat Portland cement surface casing outside (sack)

Well Development Description: ____

Remarks: Some caving of hole after 10 ft. cement sand placed above Volclay pellet seal. Steel jacked at 10 ft. increments (20 ft. sections)

Northern Engineering and Testing, Inc.

DRILLING AND LITHOLOGIC LOG LCM-11

| (Depth Below G.S.) From | To | DRILLING LOG | Geological, Drilling, and Water Conditions and Sampling |
|---|---|---|---|
| surface | 1 | Soil (brown) | |
| 1 | 2 | Boulder | |
| 2 | 9 | Gravel with silt (tan) | |
| 9 | 13 | Gravel water; small-medium size | |
| 13 | 16 | Gravel + silt; light brown | |
| 16 | 28 | Gravel, cobbles, water | |
| 28 | 31 | Silty, gravel; | |
| 31 | 34 | boulders (clay filling) dark gray to black argillites with yellow brown (acts as if very coarse talus mat. with 2-3 feet rocks | |
| 34 | 41 | Boulders (clay filling) clays filling, boulders. Lost water 28-41 ft. | |
| 41 | 48 | Orange-brown silt with angular gravel clasts; some sand; gravel is dark gray argillite with some light gray mottling | |
| 48 | 55 | Silty gravel with minor clay, gravel is angular, gray argillite with light brown friable sandstone, orange brown silt | |
| 55 | 57 | As above with orange silt | |
| 57 | 58 | Silt with minor gravel + sand, orange | |
| 58 | 60.5 | Sandy gravel with silt, light gray brown, subangular; subrounded gravel clasts, to 1", making water approximately 1 gpm gravel is light gray argillite and sandstone | |
| 60.5 | 62.5 | Light gray (boulder?), argillite, very hard drilling with tricone | |
| | TD | 62.5' | |
| | | 6" casing to 62.5' (pulled) | |

# APPENDIX D
# TEST PIT LOGS

# APPENDIX D
# TEST PIT LOGS

The exploration test pits were excavated by using Case 580D and Cat 215 backhoes. The pits were 3 to 3-1/2 feet wide and 10 to 22 feet long. The pits were at least 8 feet deep unless refusal on boulders or bedrock occurred. Test pit logs were kept and representative soil samples taken. Generally, 50 to 60 pounds of samples were taken from the piles of excavated materials and placed in bags. Approximately 1 pound of sample was also collected in plastic bags for moisture content determination. All pits were backfilled with the deeper soils first and topsoil last. The ground was then smoothed and compacted by backhoe. Test pit locations were surveyed by others, or were visually located.

Information entered on the test pit logs included soil type, color, moisture, density or consistency and plasticity. Zones of water inflow were also noted. Visual classification of the samples was made in conformance with the Unified Soil Classification System (Figure D-1).

## EXPLANATION OF TEST PIT LOGS

1. Descriptions of materials in the logs are based on visual classifications made in the field and the descriptions are therefore approximate. Where laboratory data are available, the visual classifications are modified to reflect those data.

2. Classifications of soils are based on the Unified Soil Classification System, Figure D-1. The relative proportions of the fines in a soil sample are defined by the following terms:

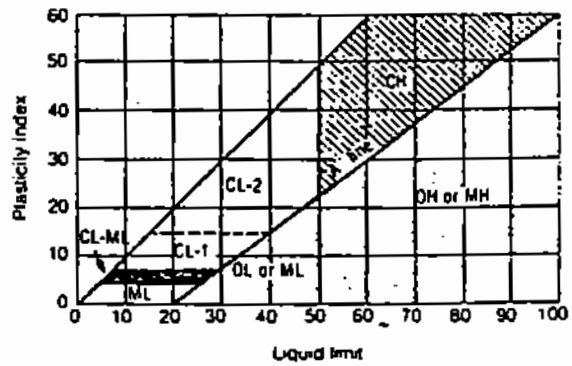
   - o trace: less than or equal to 5%
   - o some: 5% to 12%
   - o suffix "y" (e.g., silty): 12% to 50%

3. The relative proportions of gravels, cobbles and boulders were made visually in the field are therefore approximate.

4. All test pits were excavated by a Case 580D backhoe equipped with 2.0-foot wide bucket and Cat 215 backhoe equipped with 3.5-foot wide bucket.

# Unified Soil Classification System

| Major Divisions | | | Group Symbols | Typical Names | Laboratory Classification Criteria |
|---|---|---|---|---|---|
| Coarse-grained Soils: More than half of material is *larger* than No. 200 sieve | Gravels: More than half of coarse fraction is larger than No. 4 sieve size | Clean Gravels (Little or no fines) | GW | Well graded gravels, gravel-sand mixtures, little or no fines | $C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 |
| | | | GP | Poorly graded gravels, gravel-sand mixtures, little or no fines | Not meeting all gradation requirements for GW |
| | | Gravels with fines (Appreciable amount of fines) | GM d / u | Silty gravels, poorly graded gravel-sand-clay mixtures | Atterberg limits below "A" line, or *PI* less than 4 / Atterberg limits above "A" line, or *PI* greater than 7: Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring uses of dual symbols |
| | | | GC | Clayey gravels, poorly graded gravel-sand-clay mixtures | |
| | Sands: More than half of coarse fraction is smaller than No. 4 sieve size | Clean Sands (Little or no fines) | SW | Well graded sands, gravelly sands, little or no fines | $C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 |
| | | | SP | Poorly graded sands, gravelly sands, little or no fines | Not meeting all gradation requirements for SW |
| | | Sands with fines (Appreciable amount of fines) | SM d / u | Silty sands, poorly graded sand-silt mixtures | Atterberg limits below "A" line, or *PI* less than 4 / Atterberg limits above "A" line, or *PI* greater than 7: Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring uses of dual symbols |
| | | | SC | Clayey sands, poorly graded sand-clay mixtures | |
| Fine-grained Soils: More than half of material is smaller than No. 200 sieve | Silts and Clays: Liquid limit less than 50 | | ML | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity | Determine percentage of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5% ..... *GW, GP, SW, SP*; More than 12% ..... *GM, GC, SM, SC*; 5% to 12% ..... *Borderline cases requiring use of dual symbols*.** |
| | | | CL 1 / 2 | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | |
| | | | OL | Organic silts and organic silt-clays of low plasticity | |
| | Silts and Clays: Liquid limit greater than 50 | | MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts | |
| | | | CH | Inorganic clays of high plasticity, fat clays | |
| | | | OH | Organic clays of medium to high plasticity, organic silts | |
| Highly Organic Soils | | | Pt | Peat and other highly organic soils | |




**Plasticity Chart**
For laboratory classification of fine-grained soils

* Division of GM and SM groups into subdivisions of d and u for roads and airfields only. Subdivision is based on Atterberg limits; suffix d used when liquid limit is 28 or less and the *PI* is 6 or less, the suffix u used when liquid limit is greater than 28.

** *Borderline* classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.

Figure No D–1

# TEST PIT LOGS
(1988)

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-101 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 9x10x3 | 7/28/88 | 7/28/88 | 3518 | See Below | N. Smith/M. Forrest |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1 | S-1 | | **SANDY SILT (ML),** with some subrounded to subangular gravel, damp, dark brown. Roots extend to 1.0' depth. | | |
| 2 | | | **SILTY SAND (SM),** brown, slightly plastic, moist, with some gravel, cobbles (5-10%), and a trace clay; cobbles and gravel are subrounded to subangular. | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | **SILTY SAND (SM),** orange, brown, and gray mottled, fissured 3"-15". Looks like decomposed rock. | | Difficult digging below 4.0' |
| 6 | | | | ▼ | Seepage at 6.0' |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | Refusal at 9.0' |
| 10 | | | **BOTTOM OF TEST PIT AT 9.0'** | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-101 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-102 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 10x14x4 | 7/28/88 | 7/28/88 | 3488 | See Below | N. Smith/ M. Forrest |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1 | S-1 | | SANDY SILT (ML), with some subrounded to subangular gravel, damp, dark brown. Roots extend to 1.0' depth. | | |
| 2 | | | SAND (SP), light greyish brown, damp, with some gravel and cobbles (5-10%), and trace silt; cobbles and gravel are subrounded to subangular. | | |
| 3 | | | | | |
| 4 | S-2 | | | | |
| 5 | | | | | |
| 6 | | | SILTY SAND (SM), orange, brown, and gray with oxidized fissure surfaces, moist. Looks like decomposed rock. | | |
| 7 | | | | | |
| 8 | | | | ▼ | Slight seepage at 8.0' |
| 9 | | | | | |
| 10 | | | | | Refusal at 10.0' |
| 11 | | | BOTTOM OF TEST PIT AT 10.0' | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-102 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-103 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 11x16x4 | 7/28/88 | 7/28/88 | 3394 | not encountered | N. Smith/ M. Forrest |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1 | | | SILT (ML), with some organic fibre to 0.5' depth, buff, dry to damp, non plastic. | | |
| 2 | | | | | |
| 3 | | | SANDY CLAYEY SILT - SANDY SILTY CLAY (CL-ML), orange, brown, and gray, slightly plastic, damp, with trace gravel, cobbles (5%), and boulders (5%); gravel, cobbles, boulders are subrounded, maximum size 12". | | |
| 4 | S-1 | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | BOTTOM OF TEST PIT AT 11.0' | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-103 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-104 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 12x14x3 | 7/28/88 | 7/28/88 | 3449 | See Below | N. Smith/ M. Forrest |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1 | | | SANDY SILT (ML), with some organic fibre. Roots extend to 1.0' depth. Dark brown. | | |
| 2 | | | CLAYEY SILT (ML), orange, brown, and gray, iron oxide staining, slightly plastic, moist, hard, fissured, with some sand, some gravel, cobbles (5%), and boulders (5%); gravel, cobbles, and boulders are subrounded to subangular. | | |
| 3 | | | | | uc > 4.5 tsf |
| 4 | S-1 | | | ▼ | |
| 5 | | | | | Seepage observed at 4.5'. As excavation progressed, seepage became very pronounced. Bottom of excavation filled to a depth of 8.0' after approximately 20 minutes. |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | Refusal on boulder at 12.0' |
| 12 | | | BOTTOM OF TEST PIT AT 12.0' | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-104 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-105 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 14x15x4 | 7/28/88 | 7/28/88 | 3432 | not encountered | N. Smith |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1–3 | | | SILT (ML), buff, non plastic, dry, with trace sand and trace gravel; gravel is fine to coarse, subrounded. Roots extend to 6" depth. | | |
| 3–14 | S-1 (8) | | SANDY GRAVEL (GW-GM), orange brown, dry to damp, with some silt and some cobbles (5-15%) up to 6"; cobbles and gravel are subrounded. | | Easy excavating<br>Sides of excavation are very unstable in sand layer |
| 14 | | | BOTTOM OF TEST PIT AT 14.0' | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-105 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-106 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 10X16X3.5 | 8/2/88 | 8/2/88 | 3656 | not encountered | N. Smith |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1 | | | SILT (ML), buff, dry, with some sand. Roots extend to 1.0' depth. | | |
| 2 | | | CLAYEY SILT - SILTY CLAY (CL-ML), orange, brown, and gray, non plastic to slightly plastic, hard, dry to damp, with sand, trace gravel, and cobbles (5%); gravels and cobbles are subrounded to subangular. | | uc > 4.5 tsf |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | S-1 | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | BOTTOM OF TEST PIT AT 10.0' | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-106 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-107 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 9X17X6 | 8/2/88 | 8/2/88 | 3583 | not encountered | N. Smith |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1 | | | **SILT (ML),** dark brown, non plastic, dry to damp, with trace sand, trace gravel, cobbles (5%), and boulders (5%); gravel and cobbles are subrounded. Roots extend to 1.5' depth. | | |
| 2 | | | **CLAYEY SILT - SILTY CLAY (CL-ML),** orange, brown, and gray, damp, slightly plastic, hard, with some sand, some gravel, and cobbles (5%) up to. 6"; gravels and cobbles are subrounded. Looks like weathered rock. | | |
| 3 | | | | | |
| 4 | | | | | uc > 4.5 tsf |
| 5 | | | | | |
| 6 | | | | | Difficult digging |
| 7 | | | | | |
| 8 | S-1 | | | | |
| 9 | | | | | Refusal on boulder at 9.0' |
| 10 | | | BOTTOM OF TEST PIT AT 9.0' | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-107 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-108 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 12x19x3.5 | 8/1/88 | 8/1/88 | 3760 | not encountered | N. Smith |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1 | | | SILT (ML), brown, dry, traces of organic fibre. Roots extend to 1.0' depth. | | |
| 2 | | | SILTY SAND (SM), brown to grayish brown, non plastic, dry, with some gravel, cobbles (5%), and boulders (5%) to 15"; gravel, cobbles, and boulders are subrounded. | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | S-1 | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | Refusal on Boulder at 12.0' |
| | | | BOTTOM OF TEST PIT AT 12.0' | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |
| 16 | | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-108 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-109 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 12X16X3.5 | 8/2/88 | 8/2/88 | 3698 | not encountered | N. Smith |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 0 | | | SILT (ML), brown, dry, with some sand. Roots extend to 1.5' depth. | | |
| 2 | | | SANDY SILT (ML), grayish brown, non plastic, hard, damp, with some gravel, trace cobbles, and boulders (5%). Gravels, cobbles and boulders are subrounded. | | uc > 4.5 tsf |
| 8 | S-1 | | | | |
| 10 | | | | | |
| 12 | | | BOTTOM OF TEST PIT AT 12.0' | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-109 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| MONTANA SILVER VENTURE | Little Cherry Creek | MONTANA | 8029 | TP-110 |

| CONTRACTOR | EXCAVATION METHOD | SIZE (FT) | BEGUN | COMPLETED | GROUND ELEV. | GROUND WATER DEPTH (FT) | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | Backhoe | 16X16X5 | 8/2/88 | 8/2/88 | 3761.0 | See Below | N. Smith |

| DEPTH (FT) | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | WATER DATA | REMARKS PHOTOGRAPH |
|---|---|---|---|---|---|
| 1–10 | | | **SILT (ML),** brown, dry to damp, with organics, some sand, trace gravel, cobbles (5%), and boulders (5%); gravel, cobbles, and boulders are rounded to subrounded. Roots extend to 1.5' depth. | | |
| 3–10 | S-1 | | **SILTY SAND (SM),** orange, brown, and gray, slightly plastic, damp, with some gravels, cobbles (10-15%), and boulders (5%) up to 18"; gravel to boulder sizes are rounded to subrounded. | | |
| 11–16 | S-2 | | **GRAVELLY SAND (GP),** gray brown, non plastic, wet, with cobbles (5-10%), subrounded to rounded. | ▼ | Seepage at 11.0' |
| 16 | | | BOTTOM OF TEST PIT AT 16.0' | | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-110 |

TEST PIT LOGS
(1989)

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP121 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 15x4x17 | 8/7/89 | 8/7/89 | | not encountered | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SILTY SANDY GRAVEL (GM), light brown, dry, non plastic, with some cobbles (5-10%) to 8" Roots to 5'. subangular to subrounded. | Moderate digging |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | damp | Test pit stable |
| 5 | | | | |
| 6 | S-1 | | SANDY SILTY CLAYEY GRAVEL (GC) | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | S-2 | | GRAVELLY, SANDY, SILTY CLAY (CL) orangish brown, slightly plastic, very stiff, damp, with some gravel (5-10%) subangular to subrounded | Easy digging. Pocket penetrometer at 10 = 3.0-4.0 Clear layer change @ 9' |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP121 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP 12) |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 15×4×17 | 8/7/89 | 8/7/89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | | |
| 13 | | | moist, decreasing sand content with depth gravel & cobble. | Easy digging |
| 14 | | | | |
| 15 | | | | |
| 15 | S-3 | | CLAYEY SILT (ML), orangish brown, moist to wet, very stiff, medium plasticity, with trace gravel subangular to subrounded | S-3 is better sample than S-2, S-2 may have been mix of two layers. Test pit stable - walls vertical out of reach at 17' |
| 17 | | | BOTTOM OF TEST PIT AT 17' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 2 OF 2

TEST PIT NO. TP12)

HFH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP 122 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| G. Sorlie | backhoe. | 13x5x8 | 8/7/89 | 8/7/89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT (ML), Orangish brown, nonplastic, dry, with some cobbles and trace boulders (<5%) to 18" subangular to subrounded damp at 1.5' | Moderate digging |
| 1 | | | | |
| 2 | | | | |
| 3 | | | increasing cobbles/gravel/and boulders with depth. | |
| 4 | | | ... grading to ... | |
| 5 | S-1 | | GRAVELLY, SANDY, SILTY. CLAY (CL) Same as above except with 10-20 % cobbles, 5-10% boulders to 1.5 max. Subangular to subrounded. | Hard digging Test pit stable |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | Refusal at 8' |
| | | | BOTTOM OF TEST PIT AT 8.0' | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET 1 OF 1

TEST PIT NO. TP122

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 802.9 | TP123 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 16x5x16 | 8/5/89 | 8/5/89 | | not encount. | M. J. Hylton |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT (ML), brown, nonplastic, damp, with some cobbles (5-10%), occasional boulder subangular to subrounderd. roots to. 2' | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | S-1 | | | Pocket penetrometer @ 6.0 = 2.5-3.5 tsf |
| 7 | | | | |
| 8 | | | silt slightly plastic, stiff. | Easy digging Test pit stable |
| 9 | | | Boulder 3'x 2' | |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP123 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 802.9 | TP123 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 16x5x16 | 8/5/89 | 8/5/89 | | not encount. | M. A. Ilyasmp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | OUT OF REACH @ 16' |
| | | | BOTTOM OF TEST PIT AT 16.0' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 2 OF 2

TEST PIT NO. TP123

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8028 | TP124 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 13×4.5×17 | 8/8/89 | 8/8/89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SILT (ML), brown, slightly plastic, damp, with some cobbles (5-10%) to 6", roots to 2' | Surveyed location not found. Location estimate. |
| 2 | | | CLAYEY SILT (ML), yellowish brown, slightly plastic, moist, very stiff, occasional grove and cobble, sub angular to subrounded. silt is layered w/ different colors of light and dark brown, silt breaks along these alternating layers. Layers are thin - 0.5 mm - 3 mm | Penetrometer at 3' = > 4.5 tsf |
| 6 | S-1 | | SILTY CLAY (CL) | Penetrometer at 6' = 2.5-3.5 tsf. |
| 7 | | | | Penetrometer at 7' = > 4.5 tsf |
| 8 | | | | |
| 9 | | | medium plasticity, occasional boulder, cobbles and boulders, increasing quantity with depth | Easy diggin |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP124 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP124 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 13x4.5x17 | 8/8/89 | 8/8/89 | | | M.A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | | |
| 13 | | | ... grading to ... | |
| 14 | | | GRAVELLY SANDY SILT (ML), yellowish brown, slightly plastic, moist, with fine gravel (5-10%) and trace cobbles (<5%) and trace boulders (<5%) to 2' max, subrounded to subangular | |
| 15 | S-2 | | | Moderate digging |
| 16 | | | | |
| 17 | | | BOTTOM OF TEST PIT AT 17.0' | out of reach at 17' |
| 18 | | | | |
| 19 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 1 OF 2 | TEST PIT NO. TP124

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 125 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x45x17 | 8/5/89 | 8/5/89 | | none encount | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), light brown, dry, non plastic, with some cobbles (5-10%) and trace boulders (<5%) to 24", roots to 1.0', subangular to subrounded | Surveyed location not found. Location estimated, approx. 100' from treeline |
| 1 | | | | moderate digging |
| 2 | | | SANDY SILT (ML), brown, slightly plastic, moist, with some gravel (5-10%) and trace cobbles (<5%) and occasional boulder to 24". | Test pit stable |
| 3 | | | | Easy digging |
| 4 | | | | |
| 5 | | | orangish brown silt | |
| 6 | S-1 | | very stiff | Pocket penetrometer at 7' = 4.0-4.5 tsf |
| 7 | | | | |
| 8 | | | | |
| 9 | | | Slightly increasing gravel content with depth, | Test pit sides vertical and stable |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP 125 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP125 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x4.5x17 | 8/5/89 | 8/5/89 | | not encount | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | Easy digging |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | S-2 | | | |
| 16 | | | | |
| 17 | | | | Out of reach at 17' |
| | | | BOTTOM OF TEST PIT AT 17.0' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 2 OF 2 | TP125 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 126 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 13x4.5x15 | 8/5/89 | 8/5/89 | | not encount. | M. A. Hyhamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT (ML), light brown, non plastic, dry, with some cobbles (5-10%) to 8" max. occasional boulder to 18" max subrounded to subangular, organics to 0.5' | Start @ 9:30<br>Surveyed location not found, location estimated.<br><br>Test pit stable and vertical.<br>Digging easy |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | S-1 | | SANDY, SILTY CLAY (CL) with some gravel reddish brown, cobbles to 10" max. black and orangish staining, damp. | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP 126 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 80291 | TP126 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 13×4.5×15 | 8/5/89 | 8/5/89 | | not encount. | M. A Hykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | moist | |
| 13 | | | | |
| 14 | | | increasing gravel/cobble content with depth. | Digging hard. |
| 15 | | | | Out of reach at 15' |
| | | | BOTTOM OF TEST PIT AT 15' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 2 OF 2

TEST PIT NO. TP126

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP127 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x4x16 | 8/4/89 | 8/4/89 | | not encount. | M. A Hytarrip |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SANDY GRAVELLY CLAYEY SILT (ML) brown, damp, non plastic, with some cobbles (5-10%), trace boulders (<5%) subrounded to subangular. organics to 0.5', roots to 3.0'. red and black staining on fissures, | Surveyed location not found. Test pit placed approx. 250' S-SE from end of good part of road. |
| 1 | | | | |
| 2 | | | | |
| 3 | S-1 | | GRAVELLY, SANDY, SILTY CLAY (CL) | Pocket penetrometer @ 4' - 3.5-4.0 tsf |
| 4 | | | | Test pit stable. |
| 5 | | | moist, increasing gravel and cobbles with depth. occasional boulder to 15" max. | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | decreasing gravel and cobbles with depth. | |
| 11 | | | silt is slightly plastic. | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP127 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP127 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x4x16 | 8/4/89 | 8/4/89 | | not encount | M. A Hykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | decreasing gravel and cobbles with depth Some pockets of dark greenish gray sand, in a silt matrix. easily crushed with hand (see picture) | |
| 12 | | | | |
| 13 | | | | Pocket penetrometer @ 13 = 2.5, 3.0 tsf |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | out of backhoe reach |
| | | | BOTTOM OF TEST PIT AT 16' | Stop @ 4:10 pm |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 2 OF 2 | TP127 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP128 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 16x4x17 | 8/4/89 | 8/4/89 | | not encount. | M. A Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILTY CLAY – GRAVELLY SANDY CLAYEY SILT (CL-ML) yellowish brown, moist+, slightly plastic, stiff, with some cobbles (5-10%), and occasional boulder to 30" max, subrounded to subangular organic mat'l to 1.0', roots to 3' | start @ 11:30<br>Penetrometer difficult due to gravel but @ 5' = 2.0 tsf<br>Digging easy<br>Test pit stable |
| 3 | S-1 | | SANDY, GRAVELLY, SILTY CLAY (CL) | |
| 5 | | | | |
| 10 | | | ... grades to ... | |
| V | | | SILTY CLAY (CL) | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP128 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 802.9 | TP128 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | | 8/4/89 | 8/4/89 | | | M. A. Hylton |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | S-2 | | SILTY CLAY (CL), some sand, trace gravel — brown with orangish stains, wet, stiff, medium plasticity, <5% cobbles and occasional boulder (2' max), subrounded to subangular | Penetrometer at 11' = 2.5 - 3.0 tsf |
| 12 | | | | |
| 13 | | | | |
| 14 | | | increasing gravel and cobbles, boulders to 15" max. ... grading to ... | |
| 15 | | | SILTY SANDY CLAYEY GRAVEL (GM-GC), yellowish brown, fines slightly plastic, Cobbles (10-20%), trace boulders (<5%) subrounded to subangular, wet, | Hard digging |
| 16 | | | | Test pit unstable — large wedges from sides falling in |
| 17 | | | | Refusal @ 17' in gravel/cobbles |
| | | | BOTTOM OF TEST PIT AT 17.0' | Stop @ 1:40 |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 2 OF 2 | TP128 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP 129 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 10x4.5x5 | 8/9/89 | 8/9/89 | | not encount | M.A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVEL (WEATHERED ROCK), trace silt, very angular, light brown organics to 0.5' | moderate digging. |
| 1 | | | | |
| 2 | | | | |
| 3 | | | BEDROCK, bedded at 10-20° angle. rock breaks along bedding. | sides of test p.. are stable in rock. |
| 4 | | | | |
| 5 | | | | Refusal in rock |
| | | | BOTTOM OF TEST PIT AT 5.0' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP 129 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP-130 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 11x4x6.5 | 8/2/89 | 8/2/89 | | not encount. | M. A. Hylkamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0–1 | | | SILT (ML), yellowish brown, slightly plastic, damp, stiff, with organic material, roots down to 5' and trace sand | Test pit moved to west side of road. Started at 11:20 AM<br>Easy digging |
| 1–4 | | | GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), yellowish brown, fines are slightly plastic, damp, with gravel (30-50%) & cobbles (10-20%) to 6" max. subangular to angular.<br>more angular with depth | Test pit stable |
| 4–6 | S-1 | | BEDROCK<br>highly weathered, stained w/ orange & black on breaks. Can be broken with hand, siltstone, some quartzite. Large slabby pieces, angular and fissures. Black & orange stains along fissures | hard digging at 4.5 |
| 6–11 | | | BOTTOM OF TEST PIT AT 6.5' | Stopped at 12:05 AM |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-130 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP-131 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x4.5x14 | 8/2/89 | 8/2/89 | | not encount | M. A. Hykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SILT (ML) | start @ 2:30 |
| 1 | S-1 | | orangish brown, slightly plastic, damp, 5-10% sand, subrounded to subangular, fine to coarse, occasional cobble to 3" max. Patches of white silt within orangish brown silt. white silt has no sand or gravel, slightly plastic, occurs in patches on side of pit with a max size of 2 x 4. It is not a continuous layer throughout pit | 2 baggie samples included, one with orangish brown silt, the other with the white silt. |
| 2 | | | | Picture shows white patch in orangish brown silt. |
| 3 | | | BEDROCK, | Moderate digging |
| 4 | | | highly weathered, stained w/ orange & black along fissures, angular, can be broken w/ hand, siltstone | |
| 5 | | | | |
| 6 | | | Rock fragments are 6" max. size, still highly weathered | |
| 7 | | | | |
| 8 | | | Weathered bedrock, siltstone with occasional quartzite inclusions. | Hard digging |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP-131 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 131 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x45x14 | 8/2/89 | 8/2/89 | | | M. A. Ilykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | Weathered Bedrock | |
| 12 | | | | |
| 13 | | | 8" max. rock fragments | |
| 14 | | | Bottom of Test Pit at 14' | |

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SHEET 2 OF 2

TEST PIT NO. TP-131

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP13Z |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 12x4.5x14 | 8/8/89 | 8/8/89 | | not encount. | M A. Nyka |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SILT (ML), dry, reddish brown, nonplastic, with some gravel (5-10%) occasional cobble & boulder to 2' ~~s~~round. to subangular, roots to 2' | Surface boulder near pit 5'x4'x2'. |
| 1 | | | | |
| 2 | | | SANDY CLAYEY SILT TO SANDY SILTY CLAY (ML-CL), some gravel, brown, damp, slightly plastic, with some cobbles (5-10%), some boulders (5-10%) to 3'x2' max, subangular to rounded. | Hard digging. |
| 3 | S-1 | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| | | | ... grades to ... | |
| 8 | | | SILTY SANDY GRAVEL (GM) same as above, but more gravel. (40-60%), moist | Very hard digging. |
| 9 | | | | Test pit stable |
| 10 | | | | |
| 11 | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP13Z |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP-132 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 13x4.5x14 | 8/8/89 | 8/8/89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | Refusal on boulders & gravels |
| | | | BOTTOM OF TEST PIT AT 14' | |
| 15 | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 2 OF 2 | TP132 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP-133 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 10x4.5x7 | 8/9/89 | 8/9/89 | | not encount. | M. A Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SILTY, SANDY GRAVEL (GP) light brown, subangular to angular, non-plastic, dry, roots to 1' organics to 0.5' | Surveyed location not found. TP-133 located 100' East of OH-8. Digging moderate |
| 1 | S-1 | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | WEATHERED ROCK, very angular - same as TP-129. rock breaks along bedding planes in angular flat pieces | Very hard digging. |
| 6 | | | | |
| 7 | | | | Refusal in rock |
| 8 | | | BOTTOM OF TEST PIT AT 7.0' | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-133 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP-134 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 16x4x9 | 8/ /89 | 8/ /89 | | not encount. | M. A Hykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT (ML), brown, non plastic, damp, with some cobbles (5-10%), and occasional boulders to 2' max. | Start @ 10:00 AM |
| 1 | S-1 (small) | | | |
| 2 | S-2 | | GRAVELLY, SANDY, CLAYEY SILT (ML) greyish brown; non plastic, damp, with some cobbles (5-10%) and trace boulders (<5%) to 18' max. Soil matrix is stained orange and black in some places and some white silt is also visible. moisture and stiffness increasing with depth. At 4.' material is very stiff. | |
| 3 | | | | |
| 4 | | | | Hard digging penetrometer inaccurate due to gravel. |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | Test pit stable |
| 8 | S-3 (small) | | SILTY SANDY GRAVEL (GM), brown, rounded to angular, damp, with cobbles (20-40%) and trace boulders (5-10%) silt is non plastic, rock is siltstone and quartzite (white) | |
| 9 | | | BOTTOM OF TEST PIT AT 9.0' | Refusal - backhoe scraping rock Stop @ 11:10 AM |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-134 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP135 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 8x4x13 | 8/7/89 | 8/7/89 | | non encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT - GRAVELLY SILTY SAND (ML-SM), brown, non plastic, gravel subrounded to angular with some cobbles (5-10%) and trace boulders (<5%) to 2' max, damp. | Surveyed location not found, location estimated |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | S-1 | | increasing gravel and cobbles with depth<br>less sand with depth | |
| 7 | | | GRAVELLY, SANDY, SILTY CLAY (CL) | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | ... grading to ... | Hard digging in boulders |
| 11 | | | GRAVELLY SANDY SILT (ML) | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-135 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP135 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 18x4x13 | 8/7/89 | 8/7/89 | | not encountd | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11<br>12<br>13 | | | GRAVELLY SANDY SILT (ML), brown, damp to moist, non plastic, with some cobbles and occasional boulder to 1.5' max subangular to subrounded<br><br>BOTTOM OF TEST PIT AT 13' | Test pit stable<br>Moderate digging<br><br>Refusal on boulder |

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SHEET 2 OF 2

TEST PIT NO. TP135

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP136 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x3x13 | 8/3/89 | 8/3/89 | | not encount. | M. A Hyharry? |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT (ML), light brown w/ some orangish staining, nonplastic, damp, with some cobbles (5-10%) and trace boulders (<5%) to 15" max, subrounded to subangular, organic material and roots to 1.0' | Start @ 2:00 PM |
| 1 | | | | Moderate digging |
| 2 | S-1 | | GRAVELLY lean CLAY (CL) with sand | Test pit stable |
| 3 | | | large boulder in side of pit (4'x5' min) | |
| 4 | | | | |
| 5 | | | | 5' - digging harder due to boulders. |
| 6 | S-2 | | GRAVELLY SANDY SILTY CLAY (CL) very stiff reddish brown, medium plasticity, moist, with occasional cobble, subrounded to subangular | Moderate digging Test pit sides below 6' are vertical, flat and stable. |
| 7 | | | | |
| 8 | | | | Pocket penetrometer @ 8' = 3.75-4 tsf |
| 9 | | | | |
| 10 | | | | |
| 11 | | | yellow, orange and white color variations in silty clay., moist, | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP-136 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP-136 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x3x13 | 8/ /89 | 8/ /89 | | not encount | M. A Hyironymo |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | | Hard digging |
| 13 | | | | Refusal on @ 13' |
| | | | BOTTOM OF TEST PIT AT 13' | Stop @ 3:00 PM |
| 14 | | | | |

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SHEET 2 OF 2

TEST PIT NO. TP-136

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 137 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15 x 4 x 13 | 8/4/89 | 8/4/89 | | 10.0' | M. A. Hystad |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SANDY SILT (ML), brown, non plastic, damp, roots to 4.0' some gravel and cobbles, occas boulder (3' max.) | Start @ 9:00 AM |
| 1 | | | GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), brown, fine sand, nonplastic, damp, cobbles (20-40%), and trace boulders (<5%), subrounded to angular (one boulder was very square 1.5' each side w/ sharp corners) | Hard digging |
| 2 | S-1 | | | |
| 3 | | | increasing gravel/cobbles/boulders with depth | |
| 4 | | | boulders to 3' max (20-30%) | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | Very hard digging; |
| 8 | | | | sides of test pit stable |
| 9 | | | | |
| 10 | | | | Seepage @ 10.0' water enters pit @ rate of approx 1 s.f. in 10 minutes |
| 11 | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP 137 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP137 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 15x4x13 | 8/4/89 | 8/4/89 | | 10.0' | M. A. Hyhamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | | |
| 13 | | | | Refusal @ 13' on boulders & gravels |
| | | | BOTTOM OF TEST PIT @ 13.0' | |

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SHEET 2 OF 2

TEST PIT NO. TP137

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 802.91 | TP-138 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 10x4x15 | 8/3/89 | 8/3/89 | | not encount. | M. A. Hyironimp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY CLAYEY SILT (ML) | Start @ 4:20 PM |
| 1 | | | brown, non plastic, damp, with some cobbles (5-10%) and occasional boulders to 18" max, subround-subang gravel & silt is brown stained with orange and streaked with white silt organic matl to 0.5', roots to 2' | Easy digging. |
| 2 | S-1 | | | |
| 3 | | | increasing gravel/cobble content with depth. | |
| 4 | | | gravel & cobble content vary. | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | moist. occasional boulders to 18" max, | Hard digging. |
| 11 | | | | |

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP-138 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP-138 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 10x4x15 | 8/3/89 | 8/3/89 | | not encount. | M. A Hykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | silt matrix is slightly plastic, moist | test pit stable |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | out of reach at 15' |
| | | | BOTTOM OF TEST PIT AT 15' | stop @ 5:14 |

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| SHEET | TEST PIT NO. |
|---|---|
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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP139 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 10x4x8 | 8/7/89 | 8/7/89 | | not encount | M. A Hylkamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELY SANDY SILT (ML), brown, non plastic, damp, with some cobbles (5-10%), and occasional boulder to 18" max subangular to subrounded | Moderate digging |
| 1 | | | | |
| 2 | | | | |
| 3 | S-1 | | increasing gravel/cobbles with depth | |
| 4 | | | | |
| 5 | | | ... grading to ... | Hard digging |
| 6 | | | SILTY SANDY GRAVEL (GM), brown, damp, subangular to subrounded with gravel (20-40%), cobbles (10-20%) and some boulders (5-10%) to 2.5' max, fines non plastic | Very hard digging Test pit stable but pitted |
| 7 | | | | |
| 8 | | | | Refusal in gravel |
| | | | BOTTOM OF TEST PIT AT 8' | |

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SHEET 1 OF 1

TEST PIT NO. TP139

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 140 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 14x4x12 | 8/7/89 | 8/7/89 | | not encount. | M. A Ilykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SANDY SILT (ML), reddish brown, non plastic, damp, with some gravel (5-10%), trace cobbles (<5%) to 8", one boulder to 12", subangular to subrounded, organics to .1', roots to 3'. | |
| 2 | | | ...grading to... GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM), yellowish brown, damp, fines non plastic, with some cobbles (5-10%) and trace boulders (<5%) to 13" | Hard digging Test pit stable |
| 3 | S-1 | | SANDY, GRAVELLY, SILTY CLAY (CL) | |
| 4 | | | Increasing gravel/cobbles/boulders with depth. | |
| 5 | | | 5' - boulder - 3' x 1.5' x 1' | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | Some boulders (5-10%) to 2' max. | Very Hard diggin. |
| 11 | | | | |
| 12 | | | Large boulder (3x5' min) | Refusal @ 12' |

BOTTOM OF TEST PIT AT 12'.

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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP 140 |

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# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP-141 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 20x5x12.5 | 8/3/89 | 8/3/89 | | not encount. | M. A Hykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT (ML), brown, non plastic, damp with some cobbles (5-10%) and occasional boulder to 2' max, subrounded to subangular, some orangish staining in silt, organics at 1' to 0.5', roots to 3' | Start @ 11:50 |
| 1 | | | | |
| 2 | | | | Hard digging |
| 3 | | | | |
| 4 | S-1 | | trace boulders (5-10%) to 3' max. | |
| 5 | | | | |
| 6 | | | Increasing gravel / cobbles / boulders with depth | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| | | | ... grades to ... | |
| 10 | | | SILTY SANDY GRAVEL (GM), brown, subrounded to subangular, damp, fines are non plastic, cobbles (30-50%) and some boulders (5-10%) to 2' max size. | |
| 11 | | | | |

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| SHEET | TEST PIT NO. |
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HFH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 141 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 20x5x12S | 8/3/89 | 8/3/89 | | not encount | M. A Hylamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | |
| 12 | | | | Very hard digging<br>REfusal on large boulder (6'x4') min |
| 13 | | | BOTTOM OF TEST PIT AT 12.5' | Step @ 1:30 |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 2 OF 2 | TP 141 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP-142 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 13x4x6 | 8/ /89 | 8/ /89 | | not encount. | M. A Ilykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SILT (ML), reddish brown, non plastic, damp, with some sand (5-10%) and trace gravel (<5%) and occasional cobble subrounded to subangular. Organic mat'l to 0.5' and roots to 0.5' | Start @ 8:25 AM |
| 2 | S-1 | | GRAVELLY, SANDY, CLAYEY SILT (ML) grayish brown, non plastic, damp, with some cobbles (5-10%) and occasional boulder to 15" max, subrounded to angular, well graded. | Hard digging |
| 5 | | | Boulders to 24" max, increasing gravel and cobble content with depth | Refusal on large boulder (9x4 min.) |
| 6 | | | BOTTOM OF TEST PIT AT 6.0' | stop @ 9:20 AM |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-142 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP143 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 13x4x16 | 8/8/89 | 8/8/89 | | not encount | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY SILT - SILTY SANDY GRAVEL (ML-GM) light brown, dry to damp, fines are non plastic, with some cobbles (5-10%) and some boulders (5-10%) subangular to subrounded, roots to 2' | Surveyed location not found, but location estimated. moderate digging |
| 1 | | | | |
| 2 | | | | |
| 3 | | | gravel/cobble/boulder content decreasing with depth, damp | |
| 4 | | | | |
| 5 | | | | Easy digging |
| 6 | S-1 | | SANDY, SILTY CLAY (CL) with some gravel | |
| 7 | | | | |
| 8 | | | | moderate digging |
| 9 | | | | |
| 10 | | | gravel/cobble boulder content increasing with depth. moist | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP143 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8079 | TP143 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorke | backhoe | 13x4x16 | 8/8/89 | 8/8/89 | . | not encount. | M. A. Nikaido |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | | moderate digging |
| 12 | | | | Test pit stable |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | Out of reach @ 16' |
| | | | BOTTOM OF TEST PIT AT 16' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 2 OF 2

TEST PIT NO. TP143

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 802.89 | TP 144 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 14×4×16 | 8/5/89 | 8/5/89 | | 10' | M. A. Hyhnrup |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SILT (ML), dark reddish brown, damp, nonplastic, with some sand, and occasional cobble - subrounded to subangular, organics to 0.5', roots to 2'. | Start at 8:10<br>Could not find surveyed location. Location estimated. |
| 1 | | | | |
| 2 | | | | |
| 3 | S-1 | | color is grey is brown below organic mat'l.<br>GRAVELLY, SILTY CLAY (CL) with some sand<br>stiff to very stiff | |
| 4 | | | | Penetrometer at 4.0' = 4.0 - 4.5' |
| 5 | | | ... grading to ... | |
| 6 | | | SANDY SILT (ML), brown, slightly plastic, damp, very stiff, with some gravel (5-10%), trace cobbles, subrounded to subangular. | Test pit sides stable and vertical |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | ... grading to ... | Seepage at 10' at approx 1 ft²/5 min. |
| 11 | | | SILTY SANDY GRAVEL (GM), brown, subrounded to subangular, moist, fines slightly plastic, some cobbles (5-10%) and | Test pit walls pitted. |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 2 | TP144 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 144 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O' Sorlie | backhoe | 14x4x16 | 8/5/89 | 8/5/89 | | 10' | M. A. Hydeman |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 11 | | | trace boulders to 18" max. | |
| 12 | | | increasing size and quantity of cobbles and boulders with depth. | |
| 13 | | | some pockets of green silty sand | Hard digging. |
| 14 | | | | |
| 15 | | | | |
| 16 | | | boulder (4'x5' min.) | Refusal on boulder |
| | | | BOTTOM OF TEST PIT AT 16.0' | Stop @ 9:00 AM |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 2 OF 2 | TP 144 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | MONTANA | 8029 | TP 145 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O'. Sorlie | backhoe | 13x4 x11 | 8/4/89 | 8/4/89 | | not encount. | M. A. Hylton MP |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SANDY SILT (ML), brown, moist, nonplastic, with some gravel (5-10%), trace cobbles and trace boulders, (<5%) subangular to subround. 2' max. Organics to 0.5', roots to 3' some lenses of gray clayey silt - slightly plastic, some orangish staining | Start @ 2:00 PM Test pit moved to other side of road. Easy digging |
| 3 | S-1 | | | |
| 4 | | | SANDY SILTY CLAY (CL), with some gravel, light gray, medium plasticity, stiff, moist, subrounded to subangular. Thickness of layer varies throughout pit. | Pocket penetrometer at 5' = ~2.5 |
| 5 | S-2 | | | |
| 7 | | | | |
| 8 | | | SANDY GRAVELLY SILT, brown, moist, slightly plastic, some cobbles (5-10%) | Hard digging |
| 11 | | | | Refusal @ 11' in gravel |
| | | | BOTTOM OF TEST PIT AT 11.0' | Stop @ 2:50 PM |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | TP-145 |

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP 146 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 10x5x10 | 8/8/89 | 8/8/89 | | not encount | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SANDY GRAVELLY SILT (ML), reddish brown, damp, nonplastic, with some cobbles (5-10%) and trace boulders (<5%) to 4x2x1' max. rounded to subangular, | Hard digging |
| 1 | | 1' | ... grades to ... | |
| 2 | | | SILTY SANDY GRAVEL, as above with cobbles (10-20%) and some boulders (5-10%) to 3' max, silt non plastic. | No sample - too many boulders and cobbles for representative sample. |
| 3 | | | | |
| 4 | | | | Very hard digging from 3-10' |
| 5 | | | increasing boulders with depth. | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | Refusal in boulders |
| | | | BOTTOM OF TEST PIT AT 10.0' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 1 OF 1

TEST PIT NO. TP 146

HEH420

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | TP 147 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 12x4.5x7 | 8/8/89 | 8/8/89 | | not encount | M.A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SANDY, SILTY GRAVEL – SANDY, GRAVELLY SILT (GM) yellowish brown, subangular to subrounded, with cobbles (10-20%) and some boulders (5-10%) to 2.5' max, material is non plastic, damp, roots to 2'. | Hard digging. |
| 1 | S-1 | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | increasing gravel/cobbles and boulders with depth | |
| 6 | | | | |
| 7 | | | | Refusal @ 7' |
| 8 | | | BOTTOM OF TEST PIT AT 7' | |

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 1 OF 1

TEST PIT NO. TP147

# APPENDIX E
# FIELD DENSITY TEST RESULTS

# APPENDIX E
# FIELD DENSITY TEST RESULTS

In August 1989, concurrently with the test pit excavation program, six pits (DT-1 through DT-6) were excavated in the tailings dam foundation to perform field density tests in the soils. These pits were excavated to depths of 5 or 6 feet by using a Cat 215 backhoe. Water was not encountered in any of these pits. Soils in the pits consisted of gravelly sandy clayey silt. Density test pit logs are included in this appendix.

The field density tests were performed by the nuclear densometer method (ASTM D2922) and by sand cone method (ASTM D1556). Results of these field tests are included in this appendix.

## EXPLANATION OF DENSITY TEST PIT LOGS

1. Descriptions of materials in the logs are based on visual classifications made in the field and the descriptions are therefore approximate. Where laboratory data are available, the visual classifications are modified to reflect those data.

2. Classifications of soils are based on the Unified Soil Classification System, Figure D-1. The relative proportions of the fines in a soil sample are defined by the following terms:

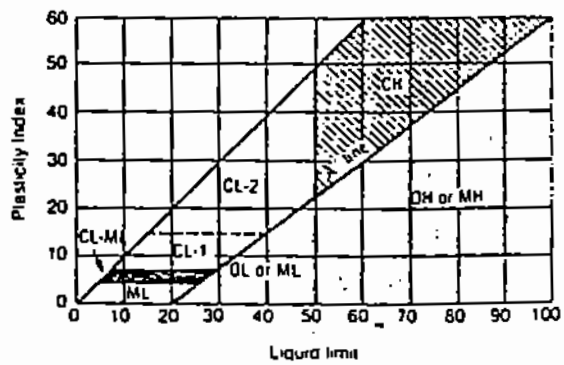
| | | |
|---|---|---|
| o | trace: | less than or equal to 5% |
| o | some: | 5% to 12% |
| o | suffix "y" (e.g., silty): | 12% to 50% |

3. The relative proportions of gravels, cobbles and boulders were made visually in the field are therefore approximate.

4. All test pits were excavated by a Cat 215 backhoe equipped with a 3.5-foot wide bucket.

# Unified Soil Classification System

| Major Divisions | | | Group Symbols | Typical Names | Laboratory Classification Criteria | |
|---|---|---|---|---|---|---|
| Coarse-grained Soils: More than half of material is larger than No. 200 sieve | Gravels: More than half of coarse fraction is larger than No. 4 sieve size | Clean Gravels (Little or no fines) | GW | Well graded gravels, gravel-sand mixtures, little or no fines | Determine percentage of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5% ..... GW, GP, SW, SP. More than 12% ..... GM, GC, SM, SC. 5% to 12% ..... Borderline cases requiring use of dual symbols** | $C_u = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 |
| | | | GP | Poorly graded gravels, gravel-sand mixtures, little or no fines | | Not meeting all gradation requirements for GW |
| | | Gravels with fines (Appreciable amount of fines) | GM d / u | Silty gravels, poorly graded gravel-sand-clay mixtures | Atterberg limits below "A" line, or PI less than 4 | Above "A" line with PI between 4 and 7 are borderline cases requiring uses of dual symbols |
| | | | GC | Clayey gravels, poorly graded gravel-sand-clay mixtures | Atterberg limits above "A" line, or PI greater than 7 | |
| | Sands: More than half of coarse fraction is smaller than No. 4 sieve size | Clean Sands (Little or no fines) | SW | Well graded sands, gravelly sands, little or no fines | $C_u = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 | |
| | | | SP | Poorly graded sands, gravelly sands, little or no fines. | Not meeting all gradation requirements for SW | |
| | | Sands with fines (Appreciable amount of fines) | SM d / u | Silty sands, poorly graded sand-silt mixtures | Atterberg limits below "A" line, or PI less than 4 | Above "A" line with PI between 4 and 7 are borderline cases requiring uses of dual symbols |
| | | | SC | Clayey sands, poorly graded sand-clay mixtures | Atterberg limits above "A" line, or PI greater than 7 | |
| Fine-grained Soils: More than half of material is smaller than No. 200 sieve | Silts and Clays: Liquid limit less than 50 | | ML | Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity | | |
| | | | CL 1 / 2 | Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays | | |
| | | | OL | Organic silts and organic silt-clays of low plasticity | | |
| | Silts and Clays: Liquid limit greater than 50 | | MH | Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts | | |
| | | | CH | Inorganic clays of high plasticity, fat clays | | |
| | | | OH | Organic clays of medium to high plasticity, organic silts | | |
| Highly Organic Soils | | | Pt | Peat and other highly organic soils | | |




**Plasticity Chart**
For laboratory classification of fine-grained soils

*Division of GM and SM groups into subdivisions of d and u for roads and airfields only. Subdivision is based on Atterberg limits; suffix d used when liquid limit is 28 or less and the PI is 6 or less, the suffix u used when liquid limit is greater than 28

**Borderline classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder

Figure No E-1

# Chen-Northern, Inc.

A member of the HIH group of companies

528 SMELTER AVENUE
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GREAT FALLS, MT 59403
(406) 453-1641
FAX (406) 727-2070


## TECHNICAL REPORT

**REPORT TO:**

MORRISON-KNUDSEN ENGINEERS, INC. (2)
ATTN: MIKE FORREST
180 HOWARD STREET
SAN FRANCISCO, CA 94105

**DATE:** August 18, 1989
**JOB NUMBER:** 88-152-1
**SHEET:** 1 OF 2
**INVOICE NO.:** 74828

**REPORT OF:** Field density tests of in-place material for density determination in natural state, Montana Project, Libby, MT

---

**SAMPLE IDENTIFICATION:**

Attached are the results of field density tests performed on the above-referenced project on the dates and at the locations shown. Unless otherwise noted, our personnel utilized the nuclear densometer method of testing in accordance with ASTM D2922. In accordance with our quality control procedures, occasional routine correlation tests are performed using sand cone methods in accordance with ASTM D1556.

Contractor: Morrison-Knudsen Engineers, Inc.

Test Locations were selected by: Contractor personnel

Minimum required in-place density: N/A

Maximum density as determined by: N/A

Remarks:

Reviewed By: Kenneth B Munday

Distribution:


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(Rev. 1/89) CNI-114A

Nuclear Density Testing
Morrison-Knudsen Engineers, Inc.
San Francisco, California

August 18, 1989
Job No. 88-152-1
Sheet: 2 of 2

NUCLEAR
TEST RESULTS:

| Test Date | Lab No. | Field Moisture Content pcf | Field Dry Density pcf |
|---|---|---|---|
| 8/10/89 | 38867A | 12.5 | 123.9 |
| Location: DT-2, 6' below ground surface. | | | |
| 8/10/89 | 38868A | 14.0 | 116.2 |
| Location: DT-1, 5' below ground surface. | | | |
| 8/10/89 | 38869A | 15.7 | 119.7 |
| Location: DT-3, 6' below ground surface. | | | |
| 8/10/89 | 38870A | 15.0 | 113.0 |
| Location: DT-4, 4.5' below ground surface. | | | |
| 8/10/89 | 38871A | 14.8 | 117.2 |
| Location: DT-5, 6' below ground surface. | | | |
| 8/10/89 | 38872A | 23.9 | 98.1 |
| Location: DT-5, 4' below ground surface. | | | |
| 8/10/89 | 38873A | 13.1 | 109.6 |
| Location: DT-6, 5' below ground surface. | | | |

# Chen-Northern, Inc.

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## TECHNICAL REPORT

REPORT TO:

MORRISON-KNUDSEN ENGINEERS, INC. (2)
ATTN: MIKE FORREST
180 HOWARD STREET
SAN FRANCISCO, CA 94105

DATE: August 18, 1989
JOB NUMBER: 88-152-1
SHEET: 1 OF 2
INVOICE NO.: 74828

REPORT OF: Field density tests of in-place material for density determination in natural state, Montana Project, Libby, MT

Sample Identification:
Summarized below are the results of field density tests performed on the above referenced project for the dates and at the locations shown. Unless otherwise noted, these tests were performed using sand-cone methods in accordance with ASTM D1556.

Test locations were selected by Chen-Northern at random locations.

~~The project specifications require a minimum in place density of 95 percent of the maximum density as determined by ASTM D1557.~~

TEST RESULTS:

| Test Date | Lab No. | Field Moisture Content pcf | Field Dry Density pcf |
|---|---|---|---|
| 8/10/89 | 38867 | 12.9 | 118.5 |
| Location: DT-2, 6' below ground surface. | | | |
| 8/10/89 | 38868 | 12.0 | 117.0 |
| Location: DT-1, 5' below ground surface. | | | |
| 8/10/89 | 38869 | 15.2 | 112.6 |
| Location: DT-3, 6' below ground surface. | | | |
| 8/10/89 | 38870 | 15.2 | 111.1 |
| Location: DT-4, 4.5' below ground surface. | | | |
| 8/10/89 | 38871 | 15.0 | 122.5 |
| Location: DT-5, 6' below ground surface. | | | |
| 8/10/89 | 38872 | 23.2 | 94.8 |
| Location: DT-5, 4' below ground surface. | | | |
| 8/10/89 | 38873 | 14.0 | 110.4 |
| Location: DT-6, 4' below ground surface. | | | |

REVIEWED BY:


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(Rev. 1/89) CNI-114

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | DT-1 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 11x5x5 | 8/10/89 | 8/10/89 | | not encount. | M.A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY CLAYEY SILT (ML-CL) brown, non plastic, dry, with some cobbles (5-10%) and trace boulders (<5%) to 14" max. subrounded to subangular. | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | S-1 | | damp | |
| 5 | | | | Density Test performed at 5' |
| | | | BOTTOM OF TEST PIT AT 5.0' | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | DT-1 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | DT-2 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 10x5x6 | 8/10/89 | 8/10/89 | | not encount. | M.A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY CLAYEY SILT (ML-CL) yellowish brown, silt non plastic, subangular to subrounded, damp, with some cobbles (5-10%) to 10" max, roots to 1' | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | S-1 | | | |
| 5 | | | | Density Test performed at 6.0' |
| 6 | D.T. | | moist | |
| | | | BOTTOM OF TEST PIT AT 6.0' | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | DT-2 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | DT-3 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | 10x5x6 | 8/10/89 | 8/10/89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0–1 | | | SANDY SILT (ML), reddish brown, damp, non plastic, with trace gravel, cobbles & boulders (<5%) to 1.5' max, subangular to subrounded, roots to 2' | |
| | | | ... grading to ... | |
| 2–4 | | | SANDY CLAYEY SILT (ML), some gravel, yellowish brown, damp, non plastic, with some cobbles (5-10%) and trace boulders (<5%) to 1.5' max, subangular to subrounded. | |
| 5 | S-1 | | moist | |
| 6 | | | | Density test performed at 6.0' |
| | | | BOTTOM OF TEST PIT AT 6.0' | |
| 7–11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | DT-3 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | DT-4 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | | 8/10/89 | 8/10/89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | SANDY SILT (ML), brown, nonplastic, damp, with some gravel (5-10%) some cobbles (5-10%) and trace boulders (<5%) to 13" | |
| 1 | | | | |
| 2 | | | ... grading to... | |
| 2 | | | GRAVELLY SANDY SILT (ML), yellowish brown, moist, nonplastic, with some cobbles and some boulders (5-10%), subangular to subrounded. | Digging easy |
| 3 | | | | |
| 4 | S-1 | | SILTY CLAYEY SAND WITH GRAVEL (SC-SM) granular, nonplastic | Density Test performed at 4' |
| 5 | | | | |
| 6 | | | Wet | Density test not poss. @ 6' due to saturation of the soil |
| 6 | | | BOTTOM OF TEST PIT AT 6.0' | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
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| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | DT-4 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | DT-5 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O Sorlie | backhoe | 10x5x6 | 8/ /89 | 8/ /89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SANDY CLAYEY SILT (ML) reddish brown, non plastic, damp, with some cobbles (5-10%) and trace boulders (<5%) to 15" max, subangular to subrounded. yellowish brown below 1' | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | moist, trace of gray silt in the sandy silt, gray silt clumps are non plastic | |
| 4 | S-1 | | | Density Test performed at 4.0' |
| 5 | | | | |
| 6 | | | wet | Density Test performed at 6.0' |
| | | | BOTTOM OF TEST PIT AT 6.0' | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | DT-5 |

# TEST PIT LOG

| PROJECT | SITE | LOCATION | JOB NO. | TEST PIT NO. |
|---|---|---|---|---|
| Montana Project | Little Cherry Creek | Montana | 8029 | DT-6 |

| CONTRACTOR | EXCAVATION METHOD | SIZE | BEGUN | COMPLETED | GROUND ELEV. | GR. WATER DEPTH | LOGGED BY: |
|---|---|---|---|---|---|---|---|
| O. Sorlie | backhoe | | 8/10/89 | 8/10/89 | | not encount. | M. A. Nykamp |

| DEPTH | SAMPLE NO. | GRAPHIC LOG | MATERIAL DESCRIPTION AND CLASSIFICATION | REMARKS PHOTOGRAPH |
|---|---|---|---|---|
| 0 | | | GRAVELLY SILTY SAND – GRAVELLY SANDY SILT (ML-SM) brown, non plastic silt, damp, with some cobbles (5-10%), subrounded to subangular, roots to to 1' | |
| 1 | | | | |
| | | | ... grades to ... | |
| 2 | | | GRAVELLY SANDY CLAYEY SILT – GRAVELLY SANDY SILTY CLAY (CL-CL) brown, slightly plastic, subrounded to subangular, moist. | Easy digging<br>Test pit Stable. |
| 3 | | | | |
| 4 | S-1 | | | |
| 5 | | | | Density test performed at 5.0' |
| | | | BOTTOM OF TEST PIT AT 5.0' | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

| SHEET | TEST PIT NO. |
|---|---|
| 1 OF 1 | DT-6 |

# APPENDIX F
# LABORATORY TEST DATA

# APPENDIX F
# LABORATORY TEST DATA

Laboratory testing of soils was performed by Chen-Northern Engineering and Testing, Inc. in Great Falls and Billings, Montana. Tests were performed on selected bag samples obtained from the test pits, and SPT, Shelby tube and ring samples obtained from the borings. Tests include dry density, grain size distribution (ASTM D422), Atterberg limits (ASTM D4318), moisture content (ASTM D2216), compaction (ASTM D698), specific gravity (ASTM D854), consolidation (ASTM D2435), and triaxial (CU and UU). Visual classification of samples was made in conformance with the Unified Soil Classification System. Material descriptions noted in the boring and test pit logs were revised based on results obtained from the laboratory tests.

# SUMMARY OF SOIL TEST RESULTS



Job No Bora Project Name Montana Project Feature Tailings Impoundment Area Date 12-17-89

| Hole or Trench Number | Sample Number | Depth (feet) From | Depth (feet) To | Laboratory Classification | ASTM D422 Mechanical Analysis: Gravel | Sand | Fines | D4318 Atterberg Limits: LL | PI | D854 Specific Gravity G | Natural ⓐ: w (%) | γd pcf | D698 Compaction: Test | Optimum w | Optimum γd | Shear Strength: Test | Initial w | Initial γd | C | φ | Permeability: γd | k | Consolidation: Cc | Cc | Cr | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USB-1 | SPT-2 | 10 | 11.5 | CL-ML | 0 | 23 | 77 | | | | | | | | | | | | | | | | | | | |
| USB-1 | SPT-3 | 15 | 16.5 | CL-ML | 6 | 36 | 58 | 25 | 4 | | | | | | | | | | | | | | | | | |
| USB-1 | SPT-4 | 20 | 21.5 | SM | 24 | 42 | 34 | | | | | | | | | | | | | | | | | | | |
| USB-1A | ST-1 | 10 | 11.8 | CL-ML* | | | | | | | 18 | 109 | | | | | | | | | | | | | | |
| USB-2 | SPT-3 | 12.5 | 13.2 | SM | 34 | 41 | 25 | | | | 4 | | | | | | | | | | | | | | | interlayered silty sand and clayey silt - silty clay |
| USB-3 | SPT-3 | 12.5 | 14 | SM | 25 | 36 | 39 | | | | 15 | | | | | | | | | | | | | | | |
| USB-4 | SPT-2 | 5 | 6.5 | GM | 39 | 33 | 28 | | | | | | | | | | | | | | | | | | | |
| USB-5 | SPT-3 | 20 | 21.5 | CL-ML | 5 | 21 | 74 | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TP-102 | S-2 | 4 | 8 | SM | 33 | 40 | 27 | Non-Plastic | | | 12 | | | | | | | | | | | | | | | |
| TP-103 | S-1 | 4 | 11 | CL-ML | 14 | 22 | 64 | 21 | 4 | | 2 | | | | | | | | | | | | | | | |
| TP-105 | S-1 | 8 | 14 | GW-GM | 48 | 45 | 7 | | | | | | | | | | | | | | | | | | | |
| TP-106 | S-1 | 6 | 8 | CL-ML | 13 | 29 | 58 | | | 2.70 | 11 | | SP | 9.5 | 126.5 | | | | | | | | | | | |
| TP-107 | S-1 | 8 | 9 | CL-ML | 15 | 28 | 57 | 20 | 6 | 2.66 | 6 | | SP | 9.4 | 125.2 | | | | | | | | | | | |
| TP-109 | S-1 | 8 | 10 | ML | 14 | 32 | 54 | 20 | 1 | | 13 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TP-121 | S-2 | 9 | 11 | CL | 17 | 20 | 63 | 24 | 11 | | 19 | | | | | | | | | | | | | | | |
| TP-127 | S-1 | 3 | 5 | CL | 17 | 19 | 64 | 26 | 10 | | 13 | | | | | | | | | | | | | | | |
| TP-128 | S-1 | 3 | 5 | CL | 15 | 14 | 71 | 26 | 10 | | 20 | | | | | | | | | | | | | | | |
| TP-128 | S-2 | 11 | 14 | CL | 3 | 7 | 90 | 41 | 19 | | 27 | | | | | | | | | | | | | | | |
| TP-131 | S-1 | 1 | 2 | ML | - | - | - | 28 | 5 | | 17% ⓑ | | | | | | | | | | | | | | | |
| TP-132 | S-2 | 3 | 7 | CL-ML | 11 | 27 | 62 | | | | 11 | | | | | | | | | | | | | | | |
| TP-134 | S-2 | 2 | 4 | ML-SM | 15 | 37 | 48 | .. | | | 6 | | | | | | | | | | | | | | | |
| TP-136 | S-2 | 6 | 8 | CL | 17 | 16 | 67 | 42 | 22 | | 22 | | | | | | | | | | | | | | | |

* Visual Classification

SP = Standard Proctor; MP = Modified Proctor; S = Consol - Swell Test; TC = Triaxial Compression; UC = Unconfined Compression; DS = Direct Shear; UU = Unconsolidated Undrained; CU = Consolidated Undrained; CD = Consolidated Drained

NOTES: ⓐ Top value by nuclear densometer method, bottom value by sand-cone method.
ⓑ Moisture content values from different parts of same sample.

# SUMMARY OF SOIL TEST RESULTS

SHEET 2 of 2

Job No 8029 Project Name Montana Project Feature Tailings Impoundment Area Date 12-12-80

| Hole or Trench Number | Sample Number | Depth (feet) From | Depth (feet) To | Laboratory Classification | ASTM D422 Mechanical Analysis Gravel | Sand | Fines | D4318 Atterberg Limits LL | PI | D854 Specific Gravity G | Natural @ Value w % | Natural @ Value γ (pcf) | D698 Compaction Test | Optimum w | Optimum γ (pcf) | Shear Strength Test | Initial w | Initial γ | C | φ | Permeability γ | k | Consolidation C | C | K | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TP-138 | S-1 | 2 | 4 | CL | 18 | 23 | 59 | 25 | 9 | | 12 | | | | | | | | | | | | | | | |
| TP-142 | S-1 | 2 | 3 | ML | 18 | 29 | 53 | | | | 10 | | | | | | | | | | | | | | | |
| TP-144 | S-1 | 3 | 5 | CL | 25 | 11 | 64 | 26 | 9 | | 16 | | | | | | | | | | | | | | | |
| TP-147 | S-1 | 1 | 3 | SM-GM | 33 | 28 | 39 | | | | 9 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DT-1 | S-1 | 4 | 5 | ML-CL | 14 | 28 | 58 | | | | 14.0<br>12.0 | 116.2<br>117.0 | | | | | | | | | | | | | | |
| DT-2 | S-1 | 4 | 5 | CL-ML | 21 | 24 | 55 | 23 | 6 | | 12.5<br>12.9 | 123.9<br>118.5 | | | | | | | | | | | | | | |
| DT-3 | S-1 | 5 | 6 | CL | 8 | 18 | 74 | | | | 15.7<br>15.2 | 119.7<br>112.6 | | | | | | | | | | | | | | |
| DT-4 | S-1 | 4 | 6 | SC-SM | 24 | 30 | 46 | Granular-Non-Plastic | | | 15.0<br>15.2 | 113.0<br>111.1 | | | | | | | | | | | | | | |
| DT-5 | S-1 | 4 | 5 | ML | 21 | 26 | 53 | | | | 23.9<br>22.2 | 98.1<br>94.8 | | | | | | | | | | | | | | |
| DT-5 | S-2 | 6 | | (Field Density Test only) | - | - | - | | | | 14.8<br>15.0 | 117.2<br>122.5 | | | | | | | | | | | | | | |
| DT-6 | S-1 | 4 | 5 | CL | 17 | 20 | 63 | 30 | 12 | | 13.1<br>14.0 | 109.6<br>110.4 | | | | | | | | | | | | | | |

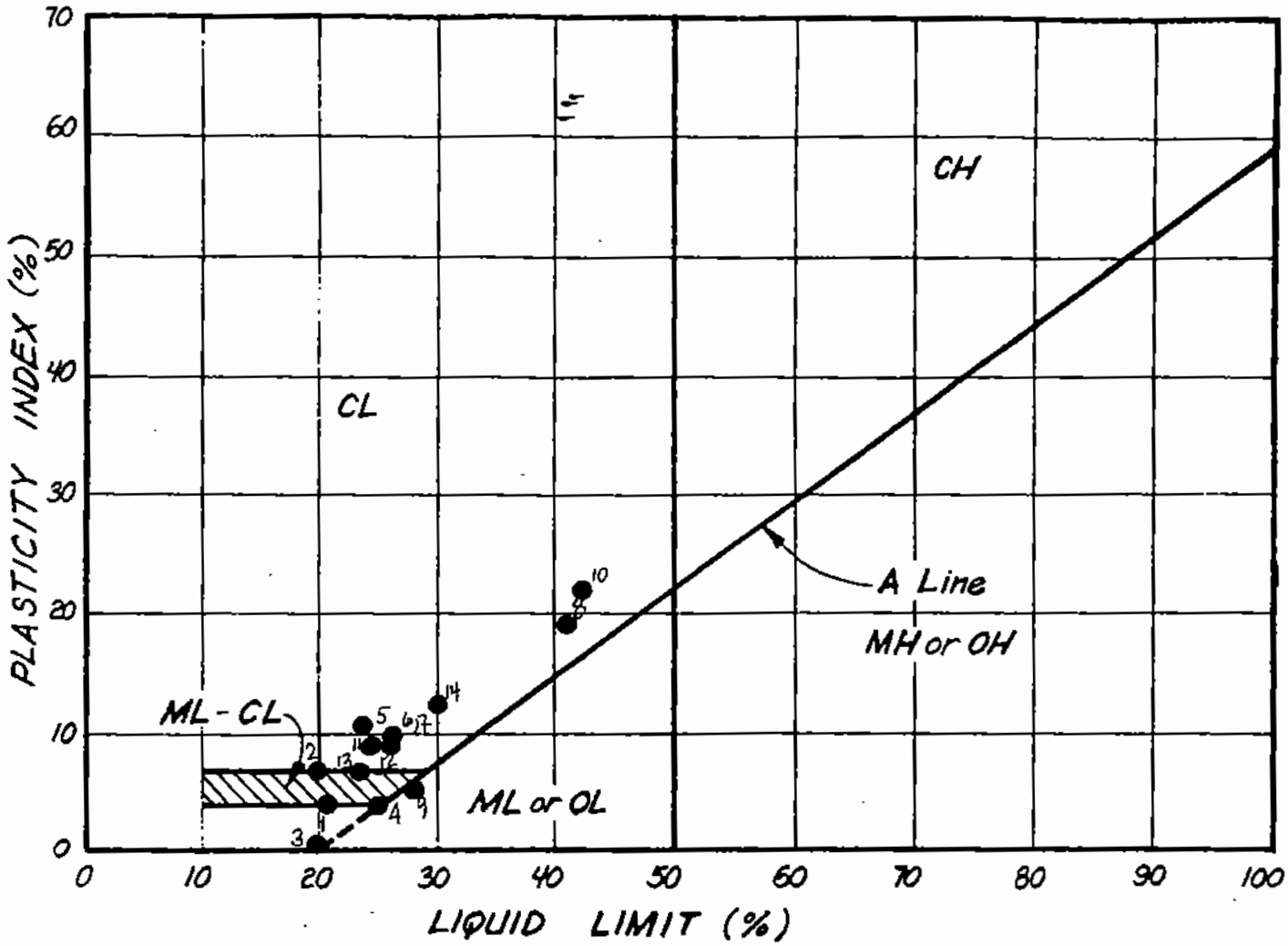
* Visual Classification

SP = Standard Proctor
MP = Modified Proctor
S = Specific - See Text

TC = Triaxial Compression
UC = Unconfined Compression
DS = Direct Shear

UU = Unconsolidated Undrained
CU = Consolidated Undrained
CD = Consolidated Drained

@ see sheet 1 of 2




| SYMBOL | CLASSIFICATION AND SOURCE | LIQUID LIMIT (%) | PLASTIC LIMIT (%) | PLASTICITY INDEX (%) | % PASSING #200 SIEVE |
|---|---|---|---|---|---|
| 1 | TP-103 4'-11' (CL-ML) | 21 | 17 | 4 | 64 |
| 2 | TP-107 8'-9' (CL-ML) | 20 | 14 | 6 | 57 |
| 3 | TP-109 8'-10' (ML) | 20 | 19 | 1 | 54 |
| 4 | USB-1 15'-16.5' (CL-ML) | 25 | 21 | 4 | 58 |
| 5 | TP-121 9'-11' (CL) | 24 | 13 | 11 | 63 |
| 6 | TP-127 3'-5' (CL) | 26 | 16 | 10 | 64 |
| 7 | TP-128 3'-5' (CL) | 26 | 16 | 10 | 71 |
| 8 | TP-128 11'-14' (CL) | 41 | 22 | 19 | 90 |
| 9 | TP-131 1'-2' (ML) | 28 | 23 | 5 | ? |
| 10 | TP-136 6'-8' (CL) | 42 | 20 | 22 | 67 |
| 11 | TP-138 2'-4' (CL) | 25 | 16 | 9 | 59 |
| 12 | TP-144 3'-5' (CL) | 26 | 17 | 9 | 64 |
| 13 | DT-2 4'-5' (ML-CL) | 23 | 17 | 6 | 55 |
| 14 | DT-6 4'-5' (CL) | 30 | 18 | 12 | 63 |

PLASTICITY CHART

FIGURE F-2

Northern
Engineering and Testing, Inc.

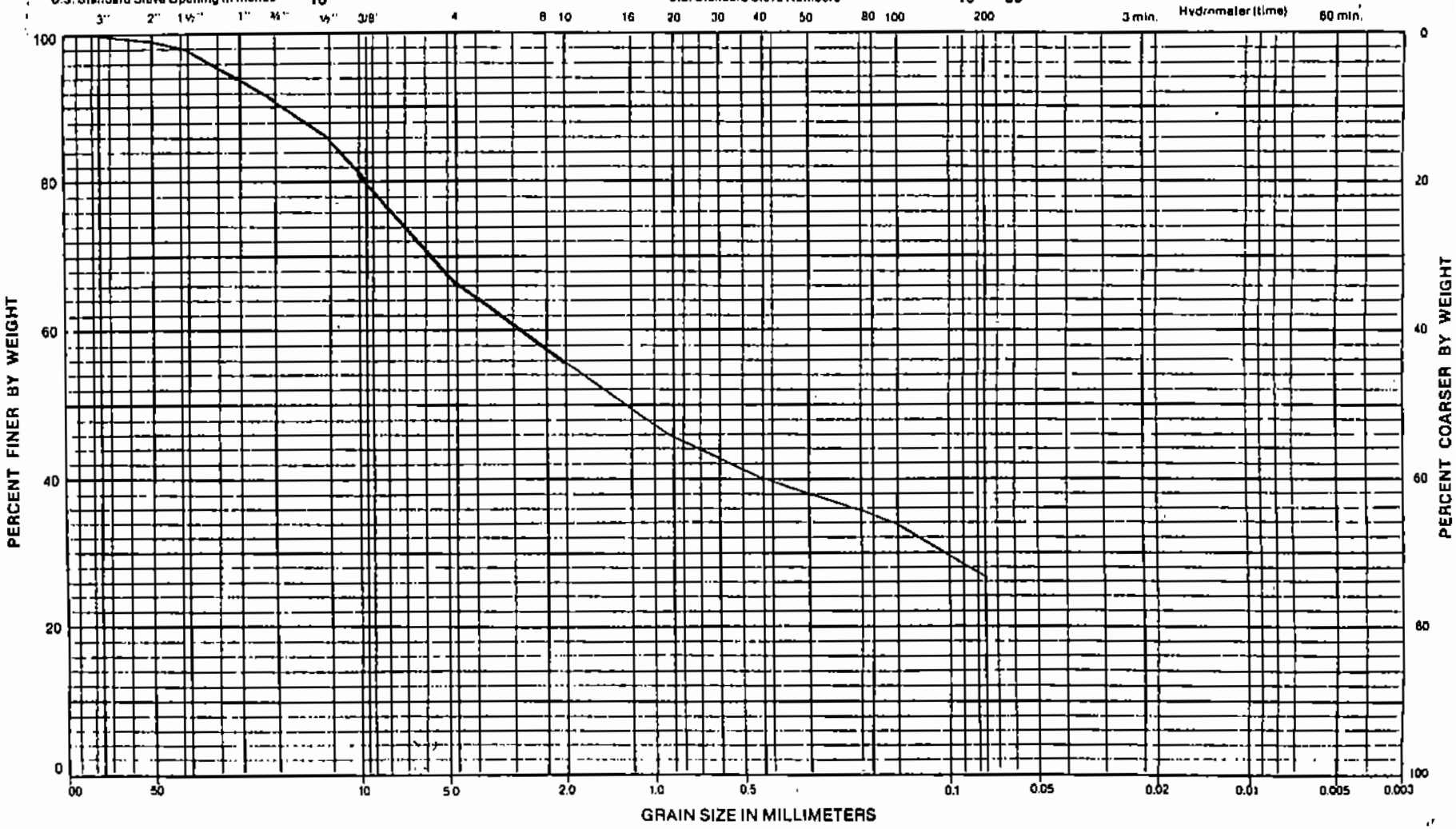
## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Location: Little Cherry Site TP-102, S-2, 4.0'-8.0'
Classification Silty SAND w/Gravel (SM)
Moisture Content 12 %

Sample No. 32284
Job No. 88-152
Date August 1988
Liquid Limit GNP %
Plasticity Index ____ %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ ____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ ____



Northern Engineering and Testing, Inc.

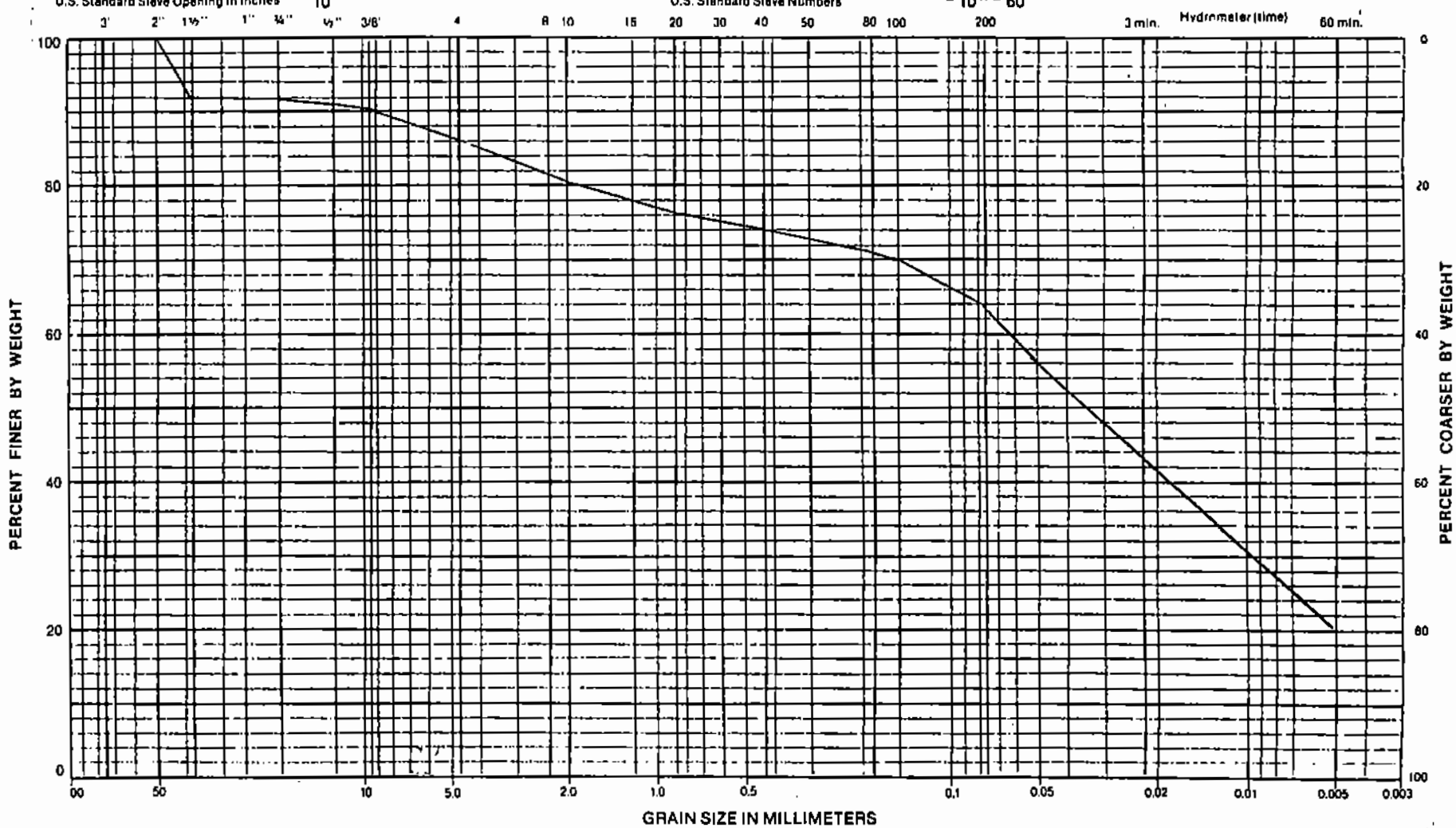
## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Location: Little Cherry Site TP-103, S-1, 4.0'-11.0'
Classification: Sandy Silty CLAY (CL-ML)
Moisture Content: 2 %

Sample No.: 32285
Job No.: 88-152
Date: August 1988
Liquid Limit: 21 %
Plasticity Index: 4 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Northern Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Location: TP-105, S-1, 8.0'-14.0'

Classification Poorly-Graded SAND w/Silt & Gravel (SP-SM)

Sample No. 32286

Job No. 88-152

Date August 1988

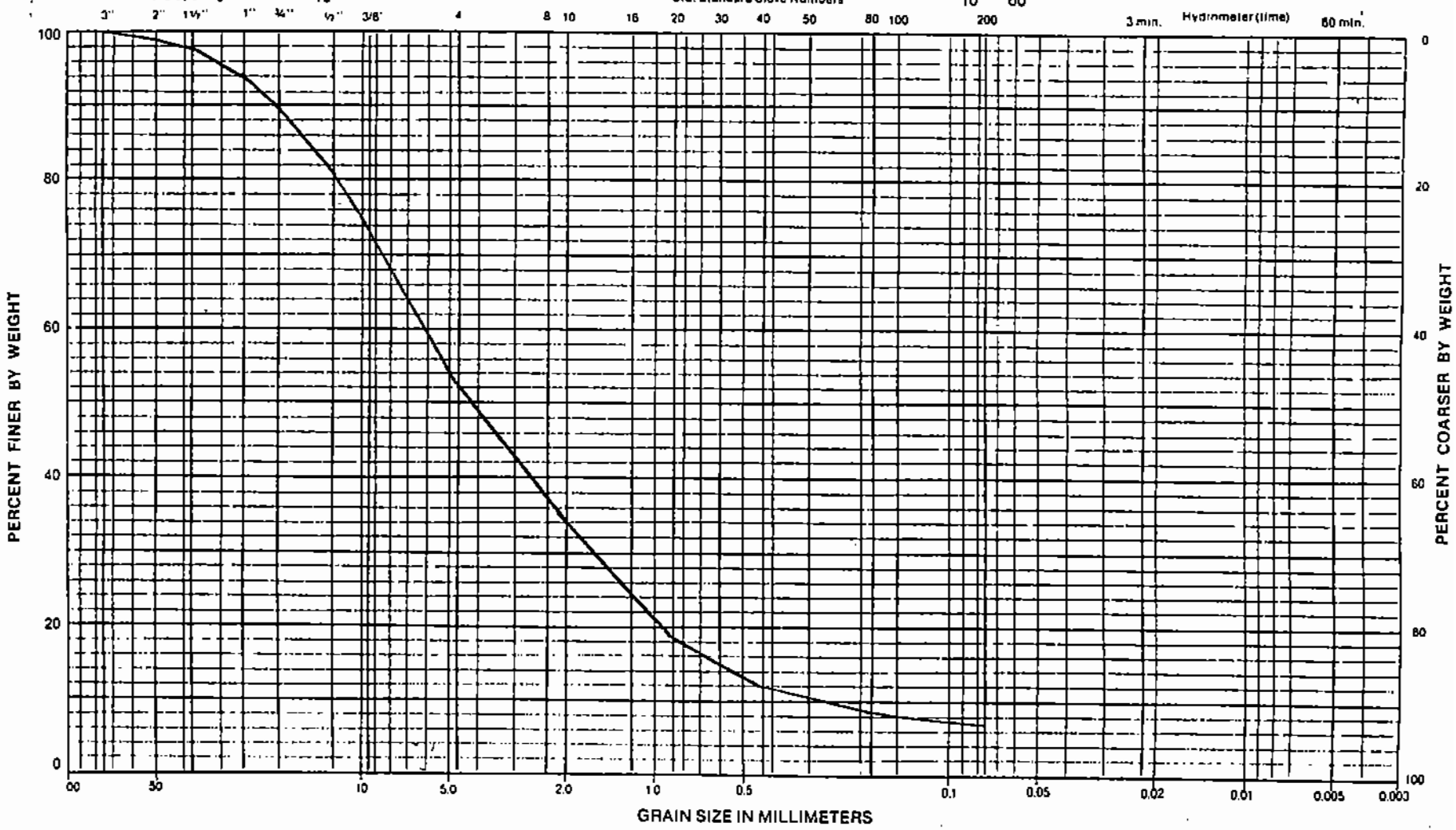
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} = 20$

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 3.83$



Northern
Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

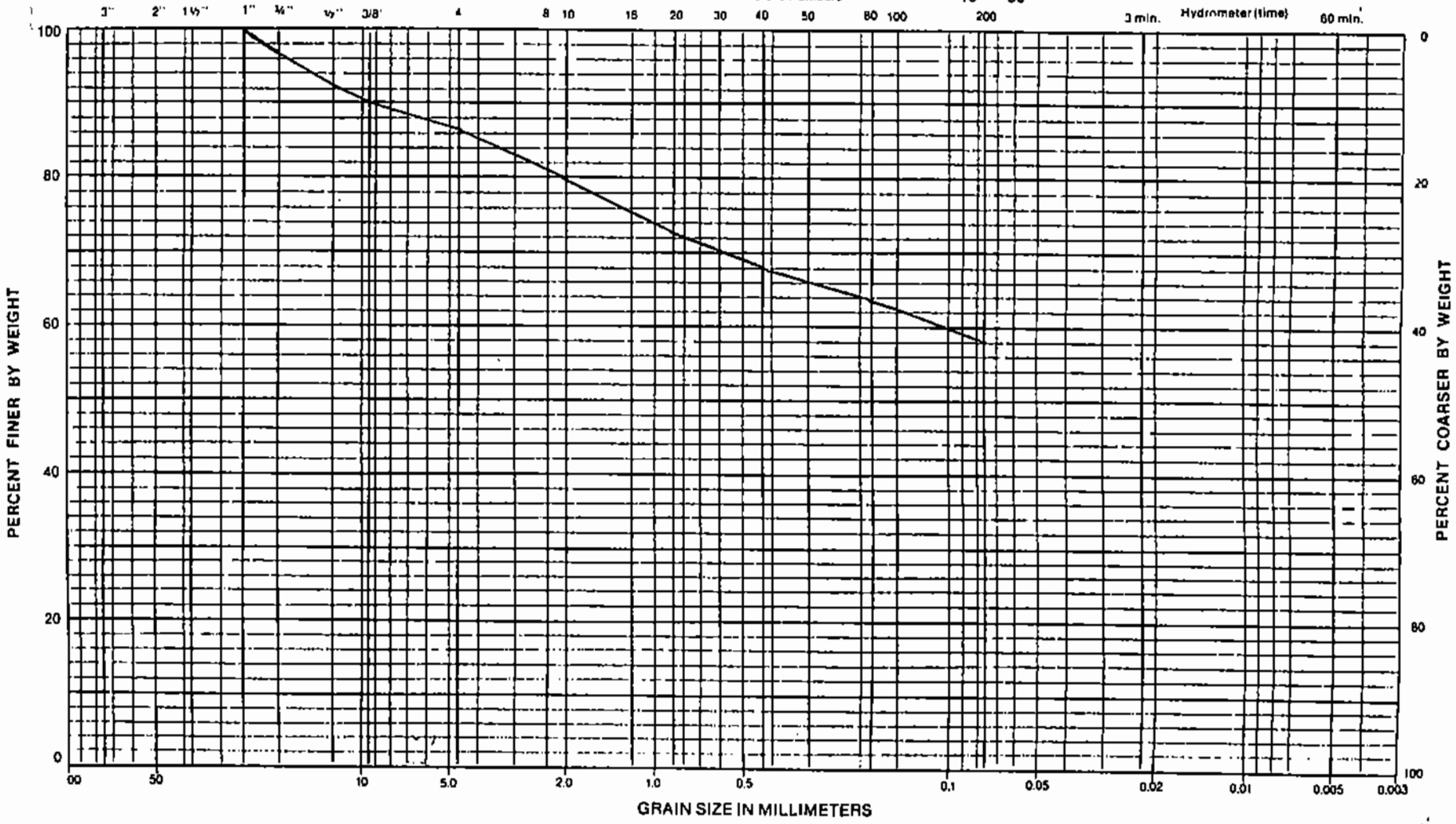
Project: Montana Silver Venture Mine
Little Cherry Site
Location: TP-106, S-1, 6.0'-8.0'
Classification Sandy Lean CLAY (CL)

Sample No. 32287
Job No. 88-152
Date August 1988

Moisture Content 11 %
Liquid Limit -- %
Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern

Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Location: TP-107, S-1, 8.0'-9.0'

Classification: Sandy Silty CLAY w/Gravel (CL-ML)

Sample No. 32288

Job No. 88-152

Date August 1988

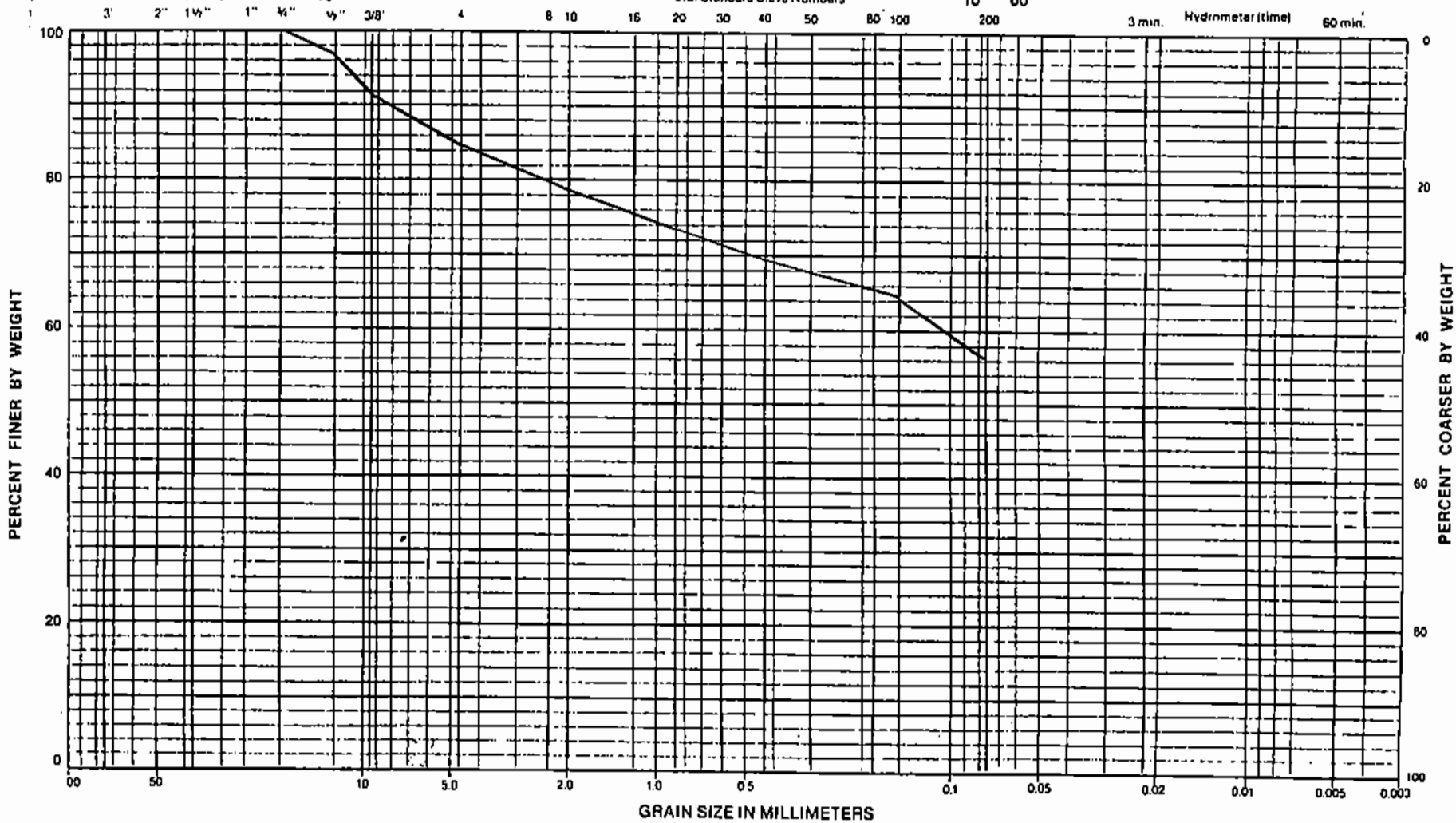
Moisture Content 6 %

Liquid Limit 20 %

Plasticity Index 6 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} = $ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} = $ _____



Northern Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine  Sample No. 32290

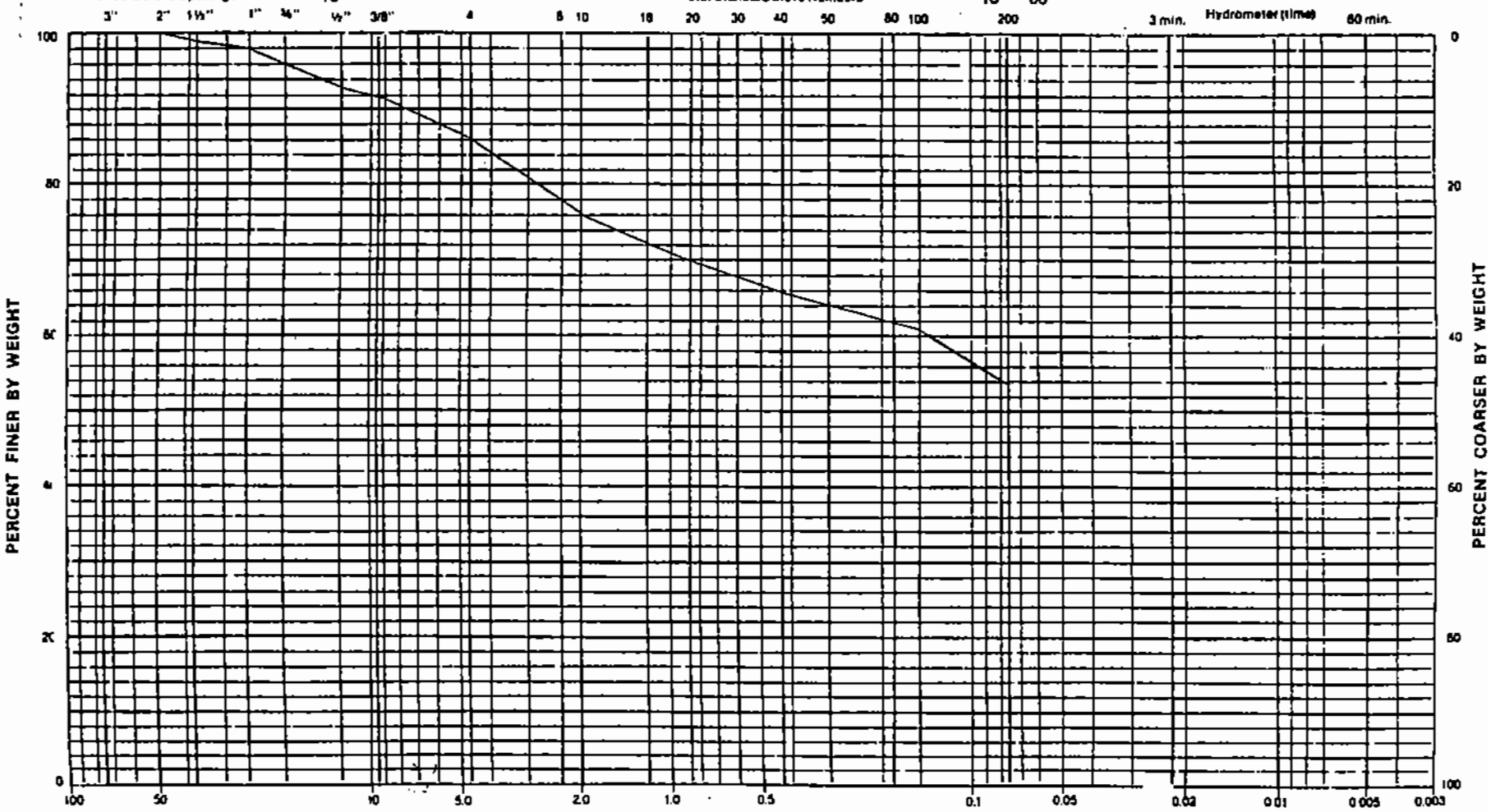
Location: Little Cherry Site, TP-109, 8.0'-10.0', S-1  Job No. 88-152

Classification Sandy SILT  Date October 1988

Moisture Content 13 %  Liquid Limit 20 %  Plasticity Index 1 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

NET-105

Northern
Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

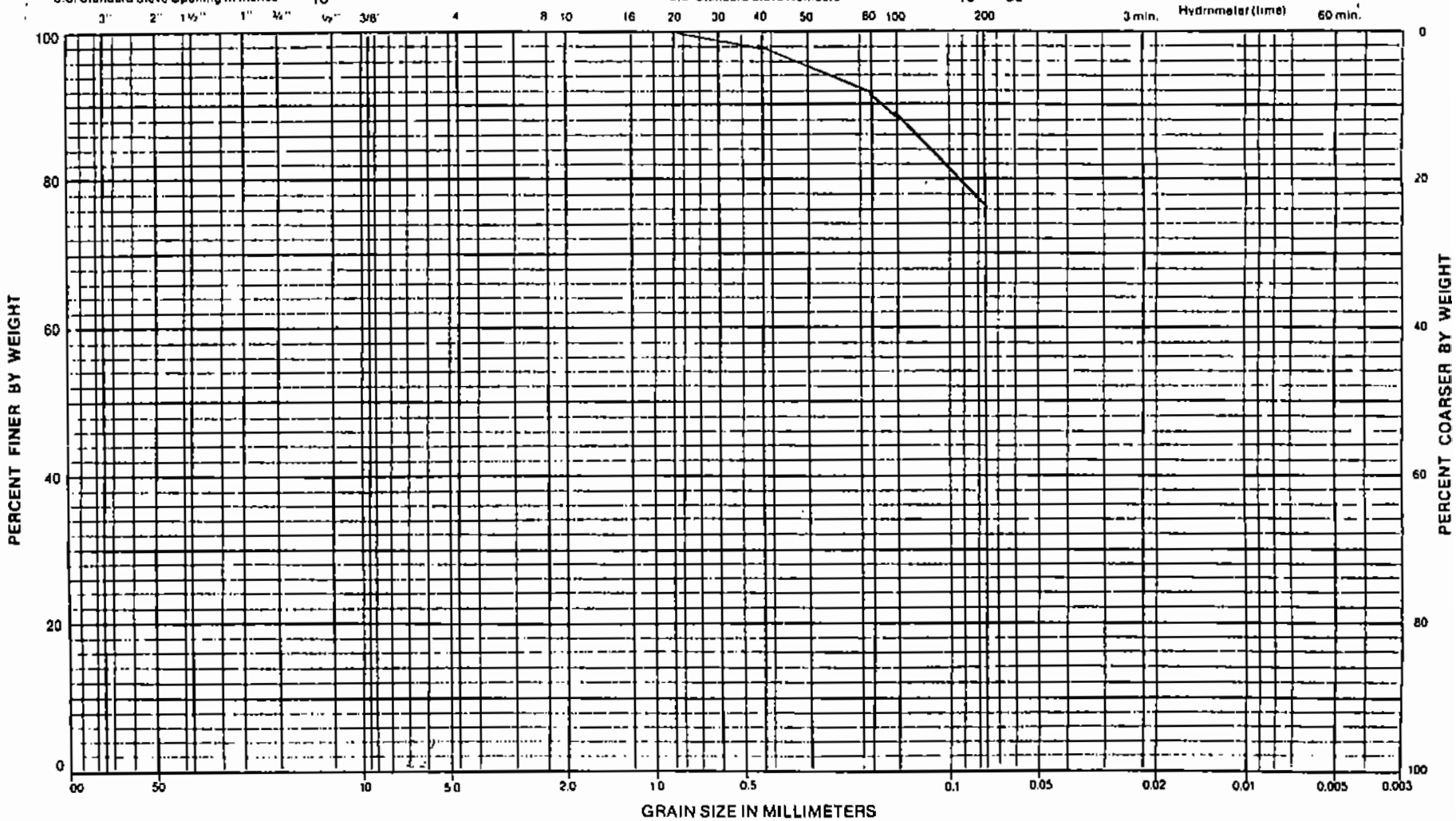
Project: Montana Silver Venture Mine
Little Cherry Site
Location: USB-1, SPT-2, 10.0'-11.5'
Classification Lean CLAY w/Sand (CL)

Sample No. 32317
Job No. 88-152
Date August 1988

Moisture Content -- %
Liquid Limit -- %
Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Northern
Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

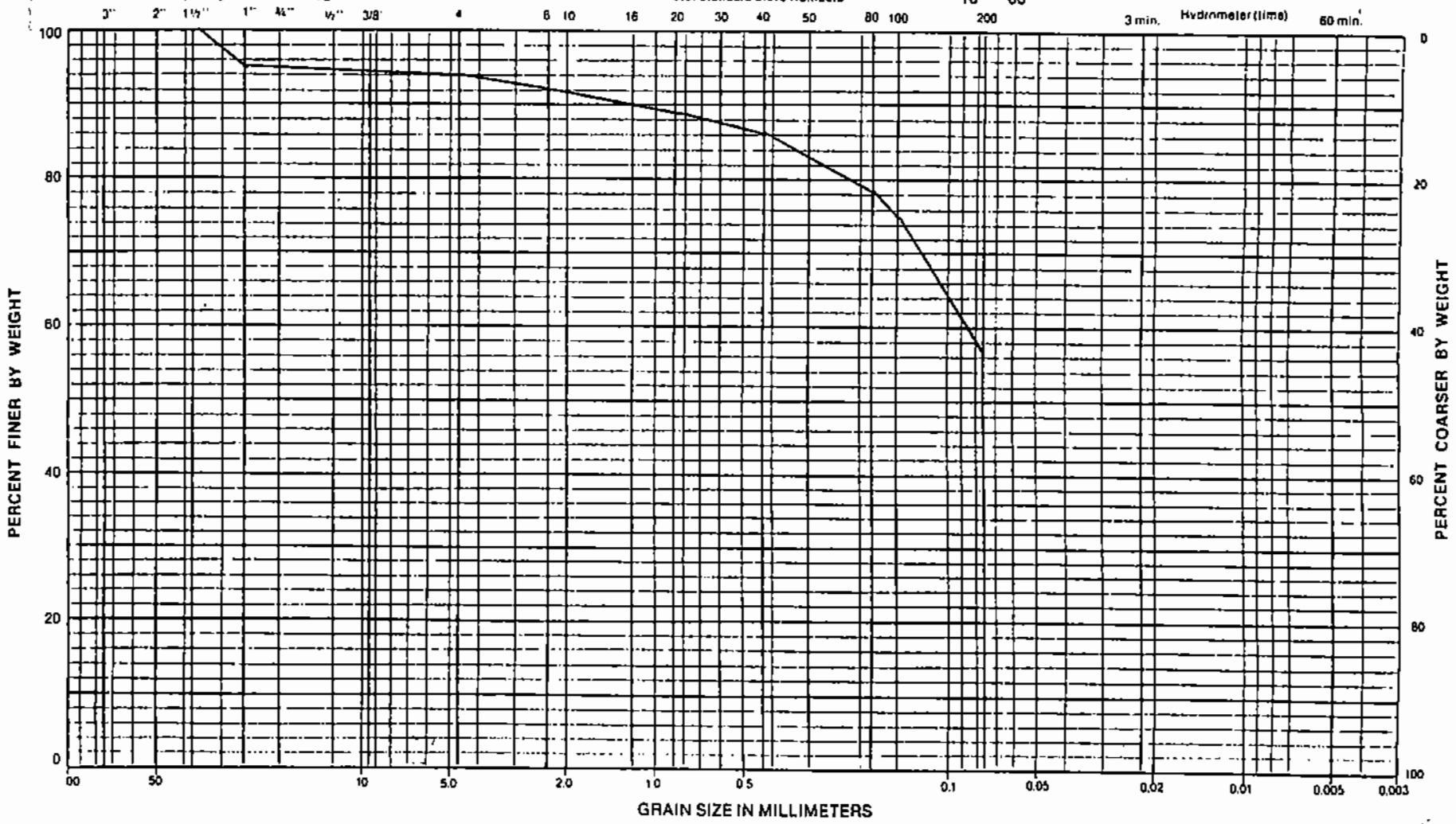
Project: Montana Silver Venture Mine
Location: Little Cherry Site USB-1, SPT-3, 15.0'-16.5'
Classification Sandy Silty CLAY (CL-ML)

Sample No. 32318
Job No. 88-152
Date August 1988

Moisture Content -- %
Liquid Limit 25 %
Plasticity Index 4 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Northern Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Sample No. 32319

Location: USB-1, SPT-4, 20.0'-21.5'

Job No. 88-152

Classification Silty Clayey SAND w/Gravel (SC-SM)

Date August 1988

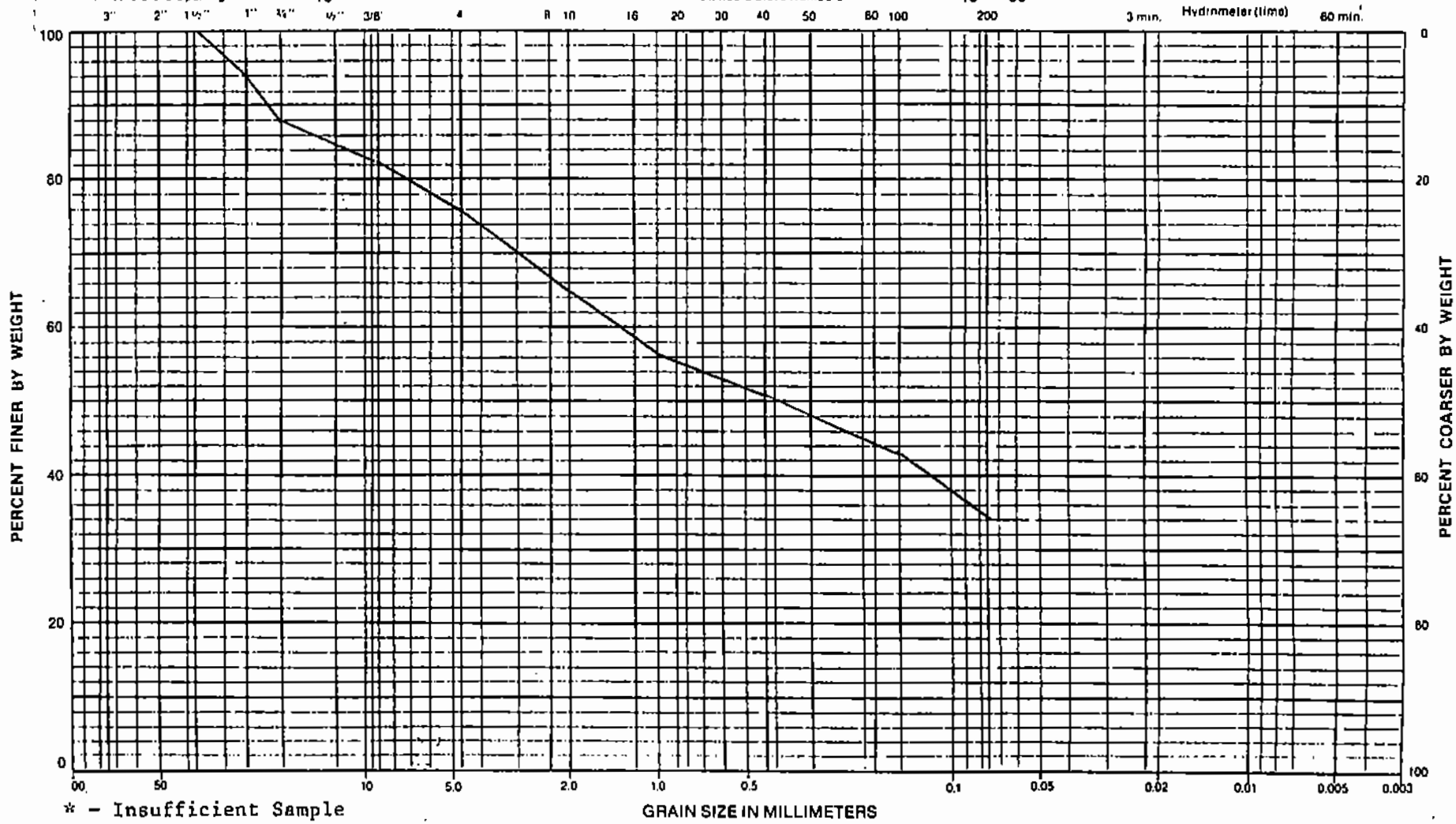
Moisture Content -- %

Liquid Limit * %

Plasticity Index * %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




* - Insufficient Sample

Northern Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Little Cherry Site

Location: USB-2, SPT-3, 12.5' - 13.2'

Classification Silty Clayey SAND w/Gravel (SC-SM)

Sample No. 32329

Job No. 88-152

Date August 1988

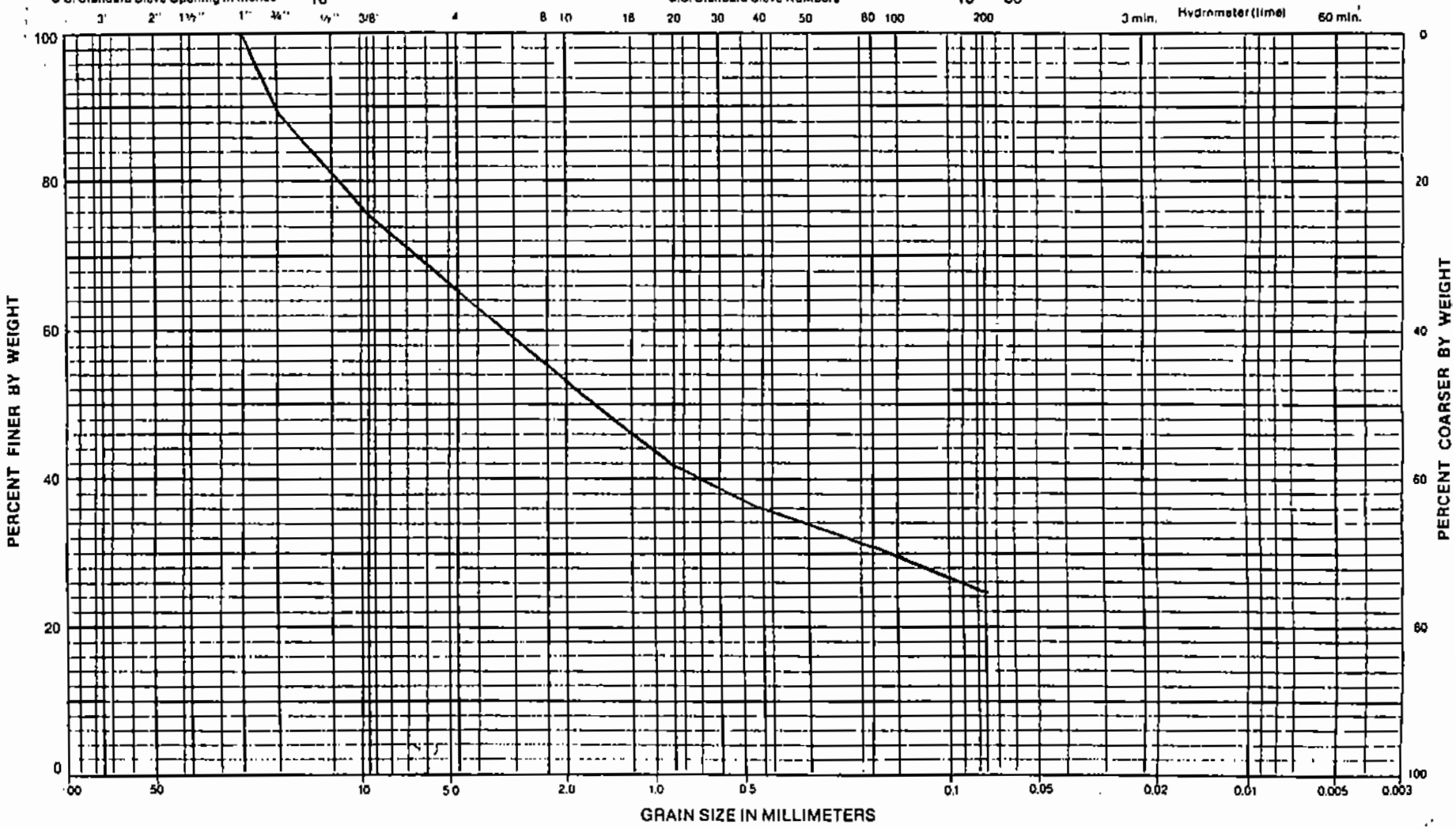
Moisture Content 4 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern

Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: Little Cherry Site, USB-3, SP-3, 12.5'-14.0'

Classification: Silty SAND with Gravel

Moisture Content: 15 %

Sample No.: 32338

Job No.: 88-152

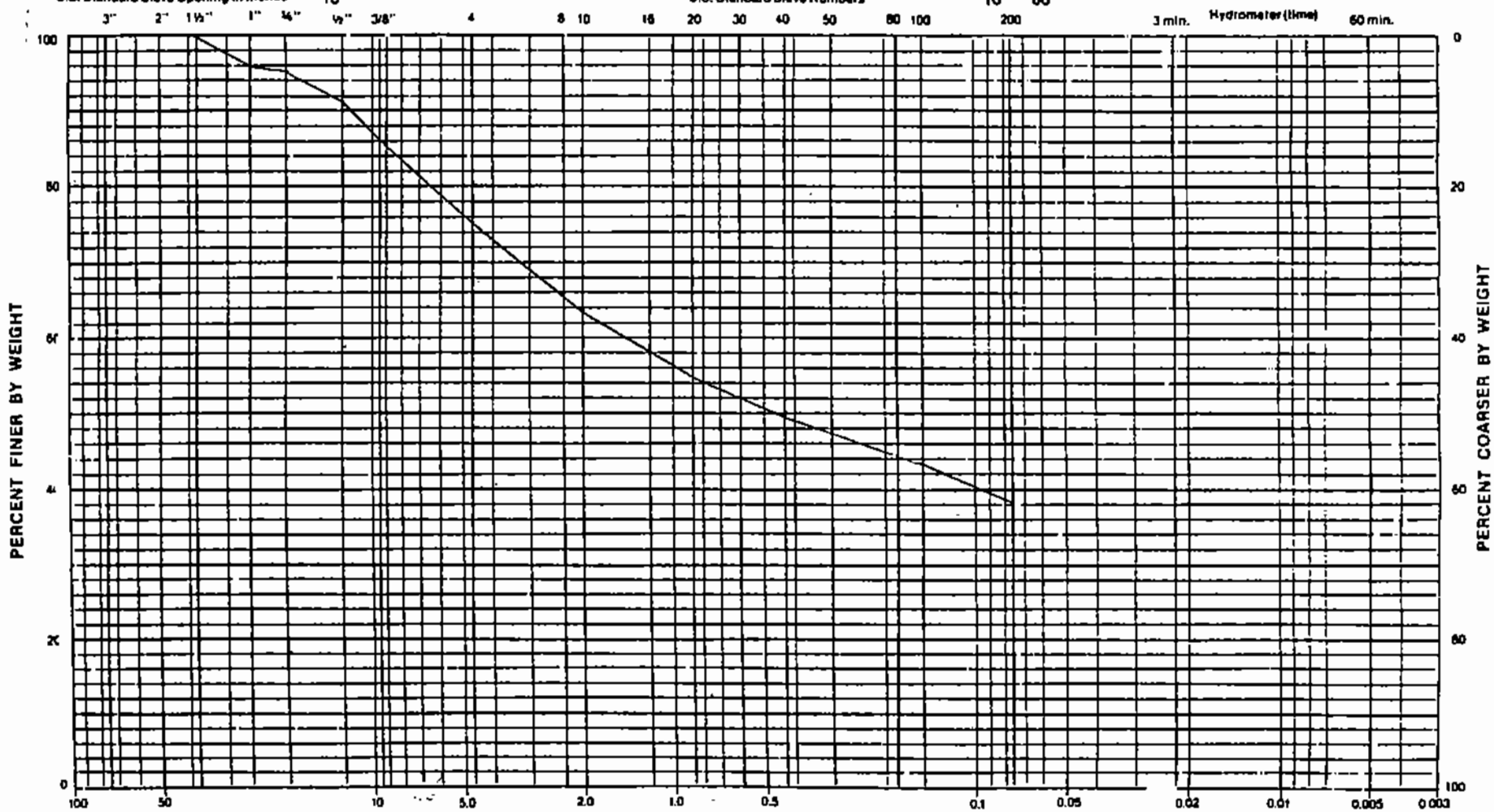
Date: October 1988

Liquid Limit: -- %

Plasticity Index: -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

NET-105

Northern

Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Location: Little Cherry Site, USB-4, SPT-2, 5.0'-5.5'

Classification: Clayey GRAVEL with Sand

Sample No. 32971

Job No. 88-152

Date October 1988

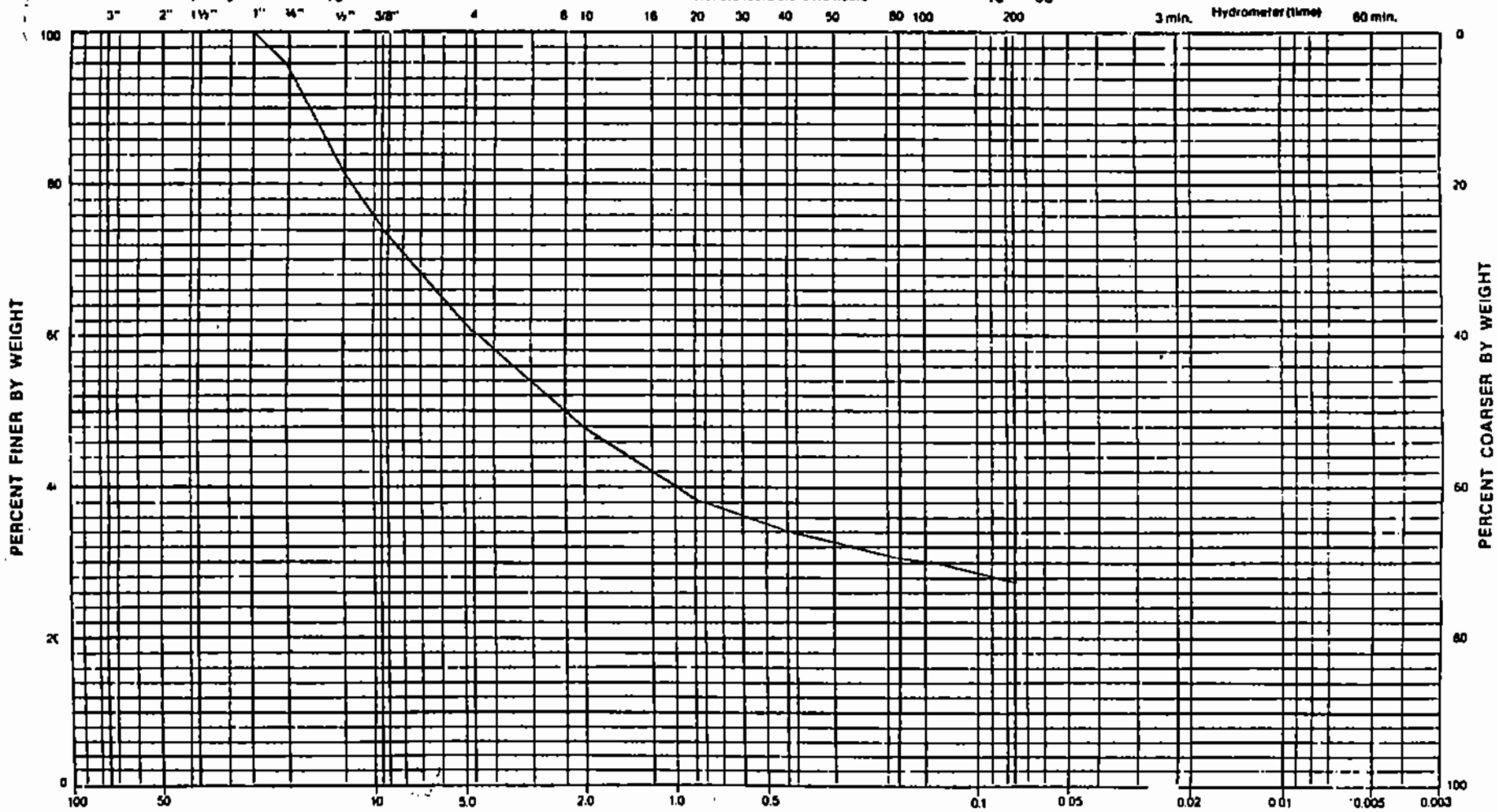
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

NET-105

Northern

Engineering and Testing, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine

Sample No. 32976

Location: Little Cherry Site, USB-5, SPT-3, 20.0'-21.5'

Job No. 88-152

Classification Lean CLAY with Sand

Date October 1988

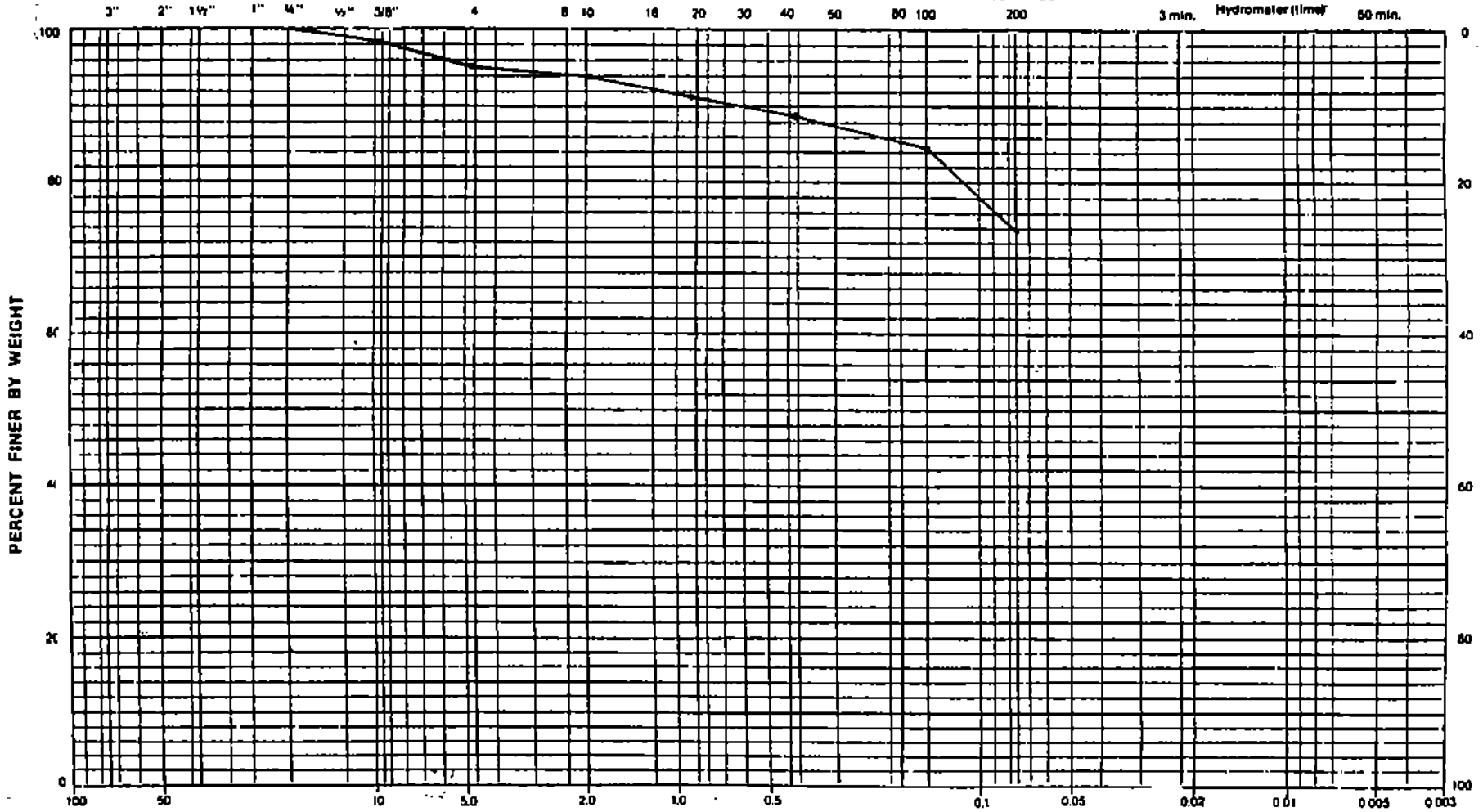
Moisture Content --- %

Liquid Limit --- %

Plasticity Index --- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

NET-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-1, S-1, 4.0' - 5.0'

Classification Sandy Lean CLAY (CL)

Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

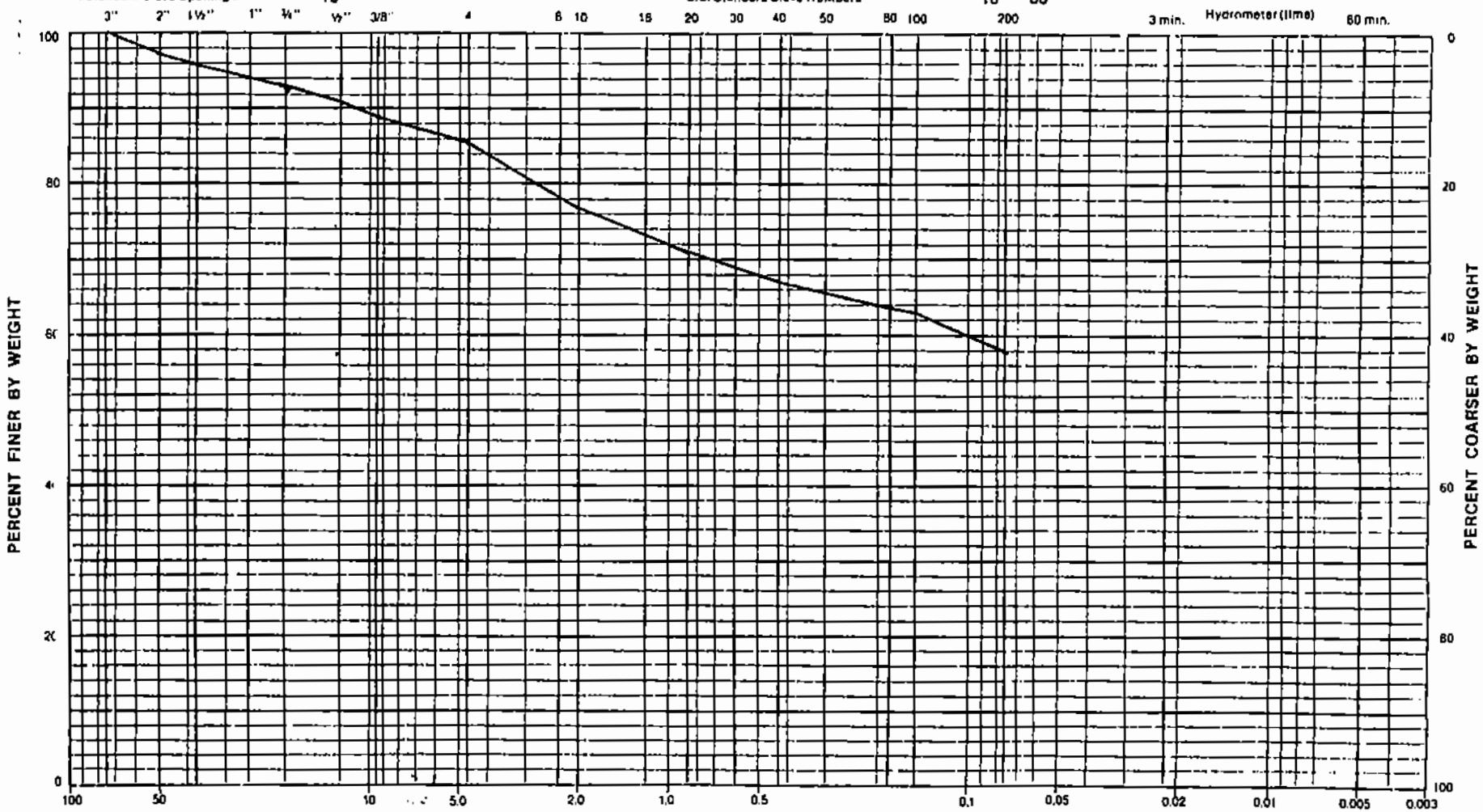
Sample No. 39441

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-2, S-1, 4.0' - 6.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content -- %

Liquid Limit 23 %

Plasticity Index 6 %

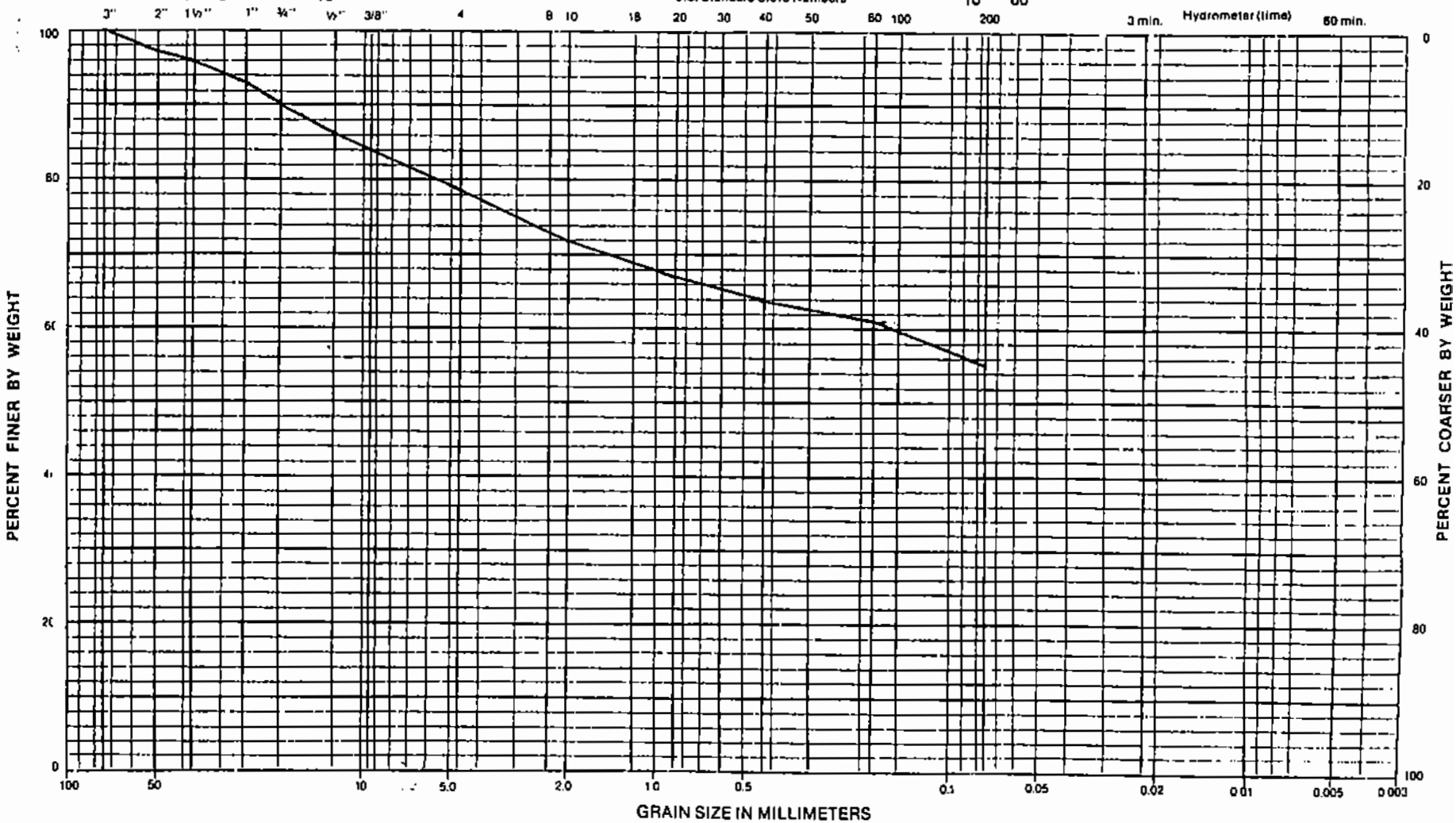
Sample No. 39442

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-3, S-1, 4.0' - 6.0'

Classification Lean CLAY with Sand (CL)

Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

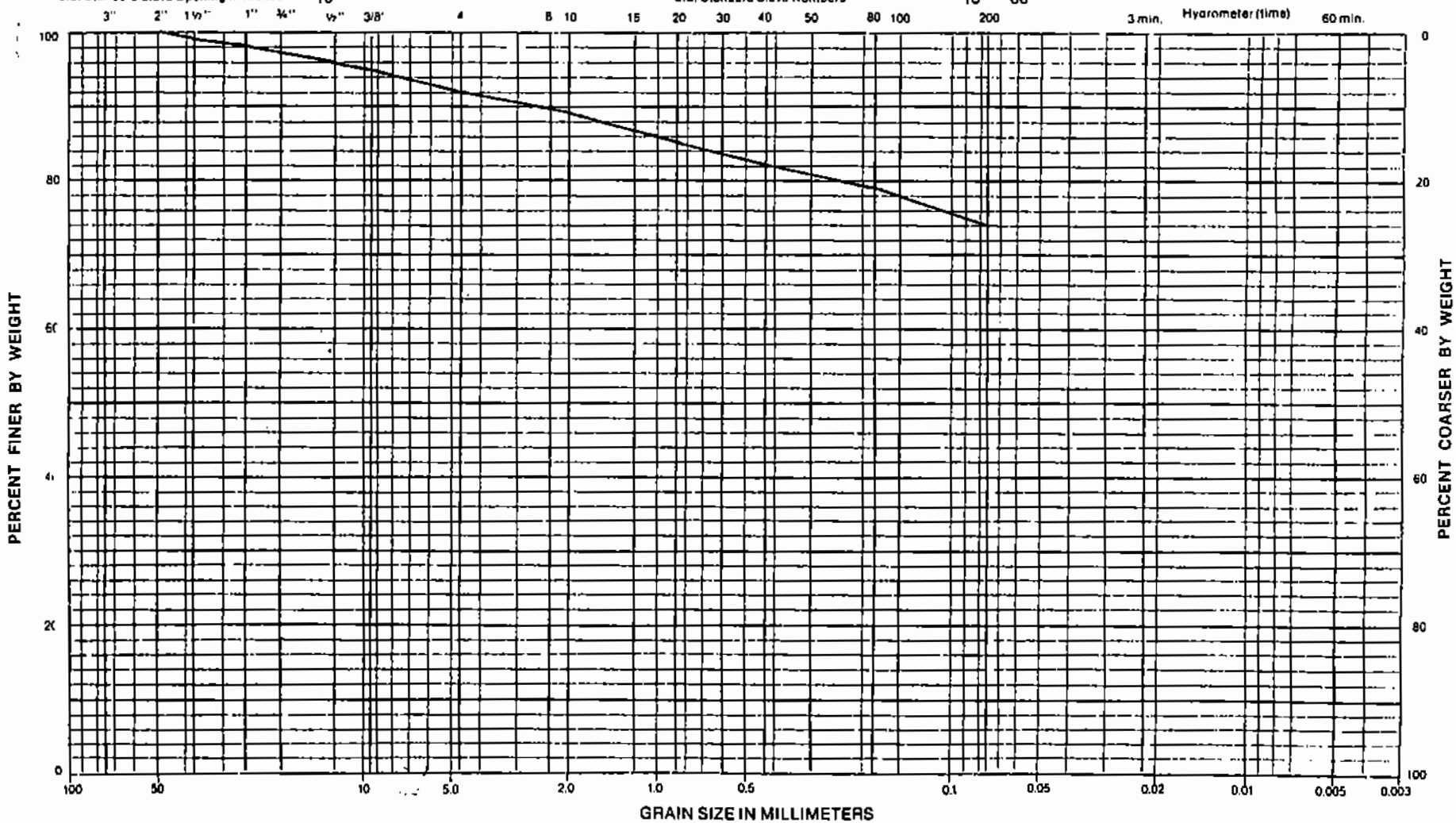
Sample No. 39443

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-4, S-1, 4.0' - 6.0'

Classification Silty Clayey SAND with Gravel (SC-SM)

Moisture Content -- %

Liquid Limit Granular %

Plasticity Index Non-Plastic %

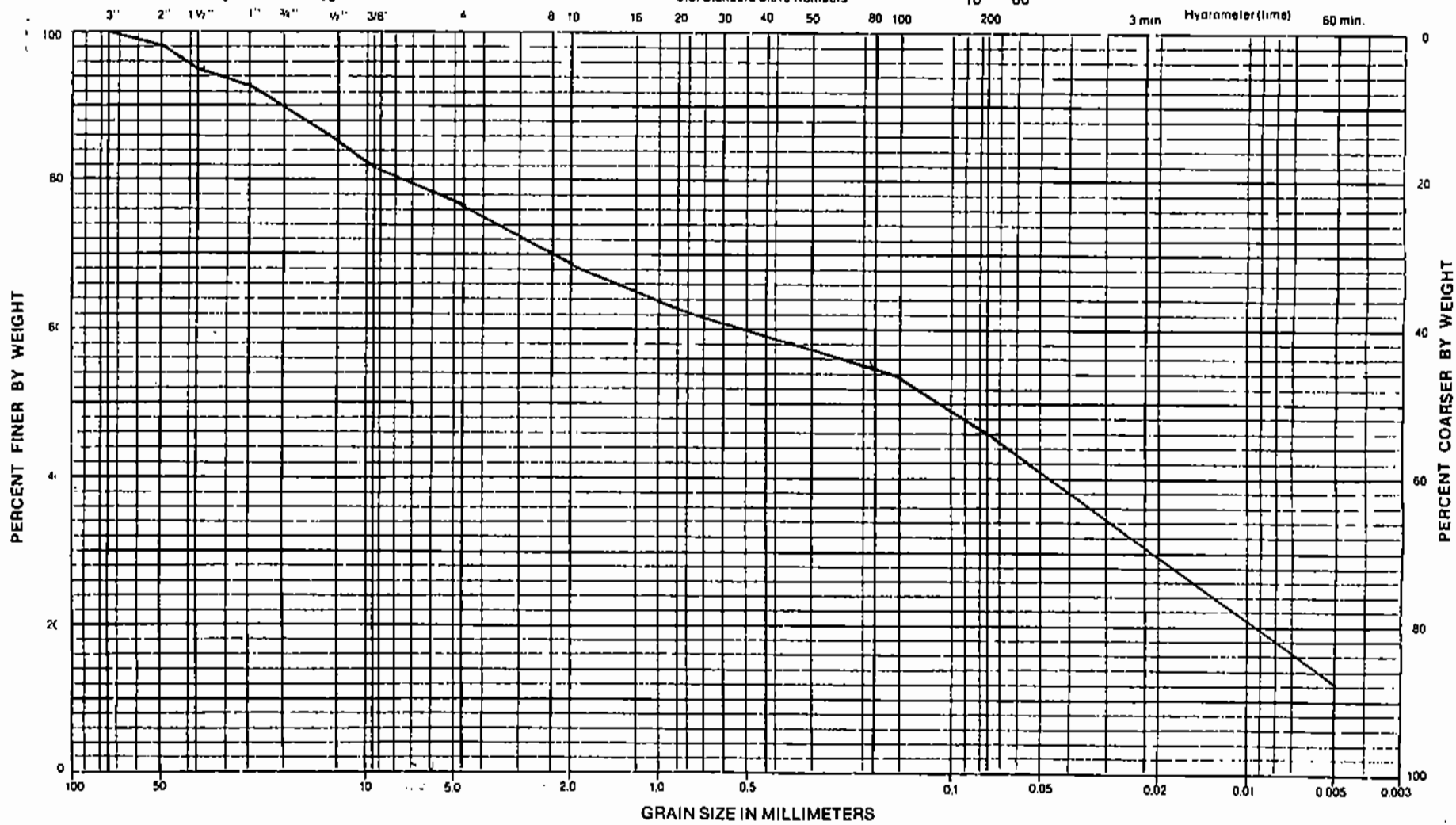
Sample No. 40716

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-5, S-1, 4.0' - 5.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

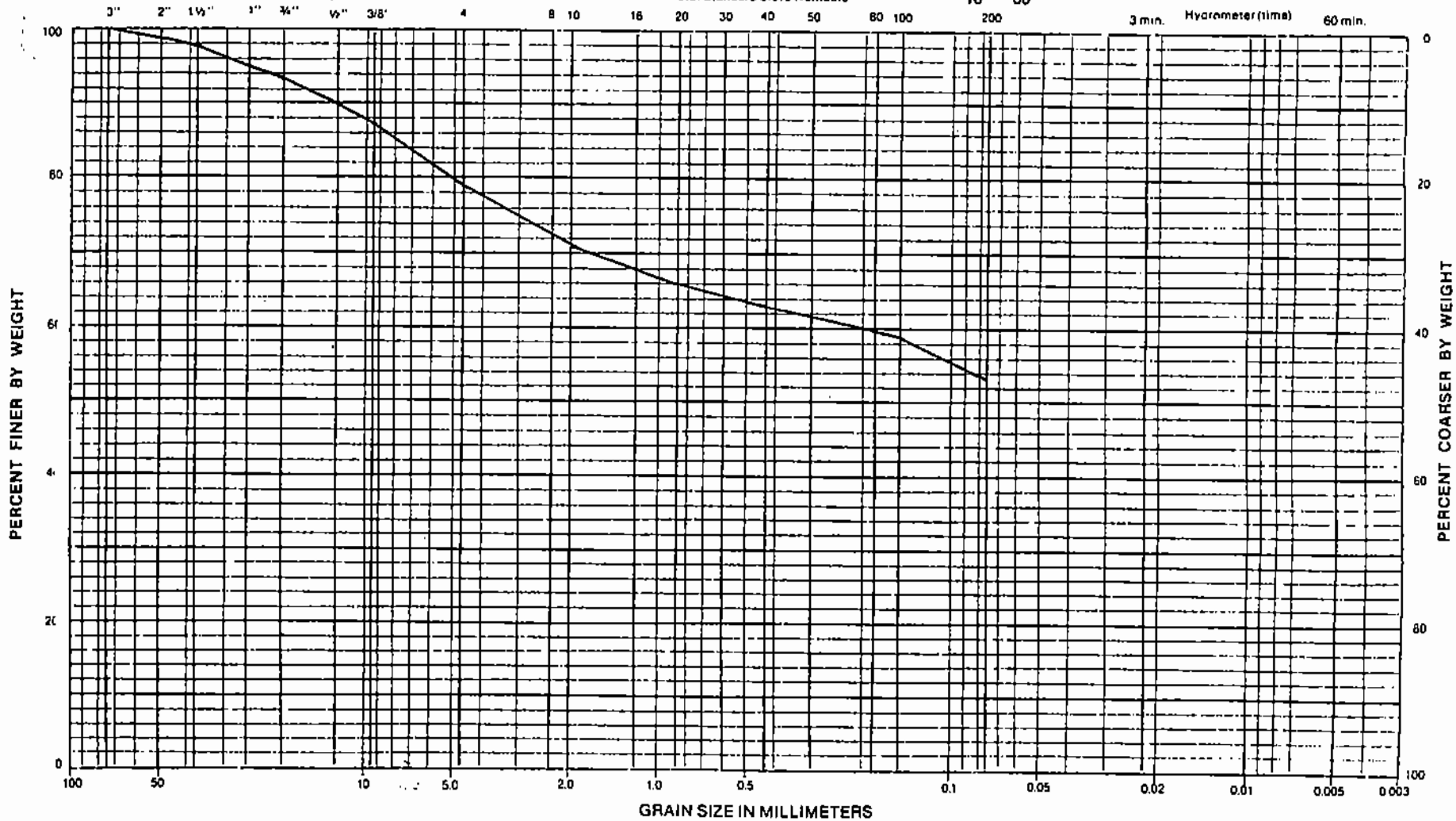
Sample No. 39444

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 1

Project: Montana Silver Venture Mine

Location: DT-6, S-1, 4.0' - 5.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content -- %

Liquid Limit 30 %

Sample No. 39445

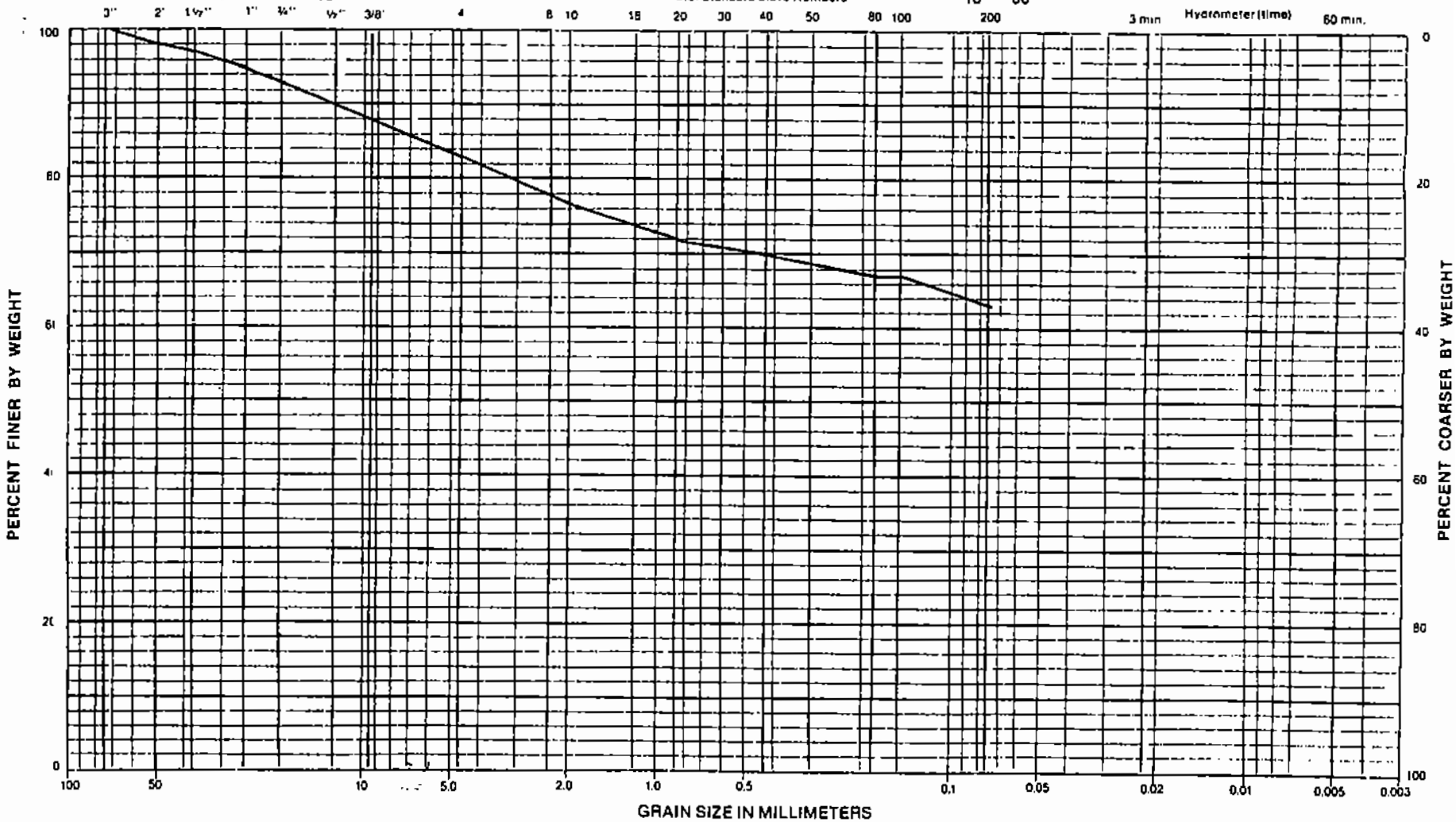
Job No. 88-152-2

Date 12/04/89

Plasticity Index 12 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-121, S-2, 9.0' - 12.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 19 %

Liquid Limit 24 %

Plasticity Index 11 %

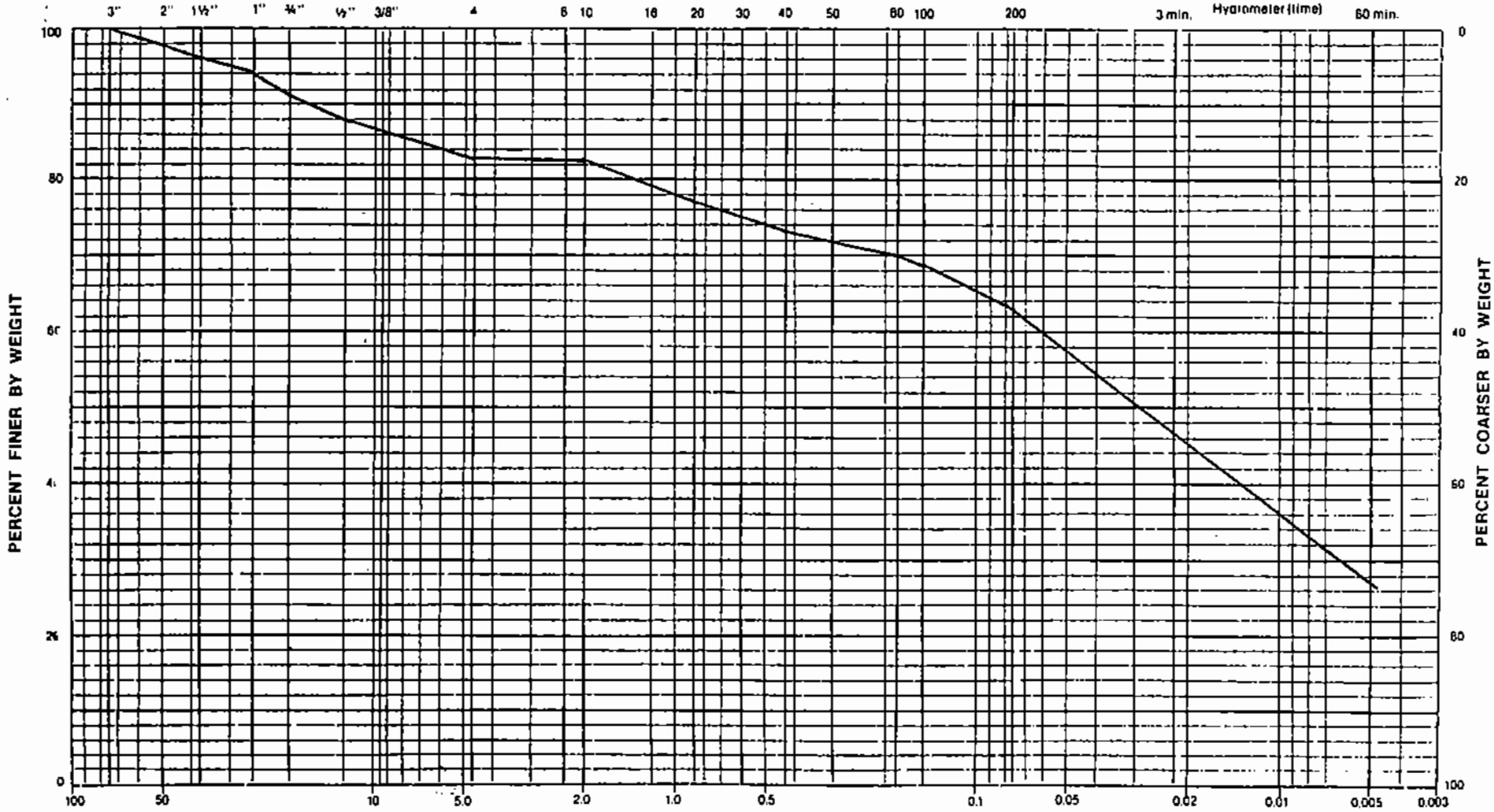
Sample No. 39452

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-127, S-1, 3.0' - 5.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 13 %

Liquid Limit 26 %

Plasticity Index 10 %

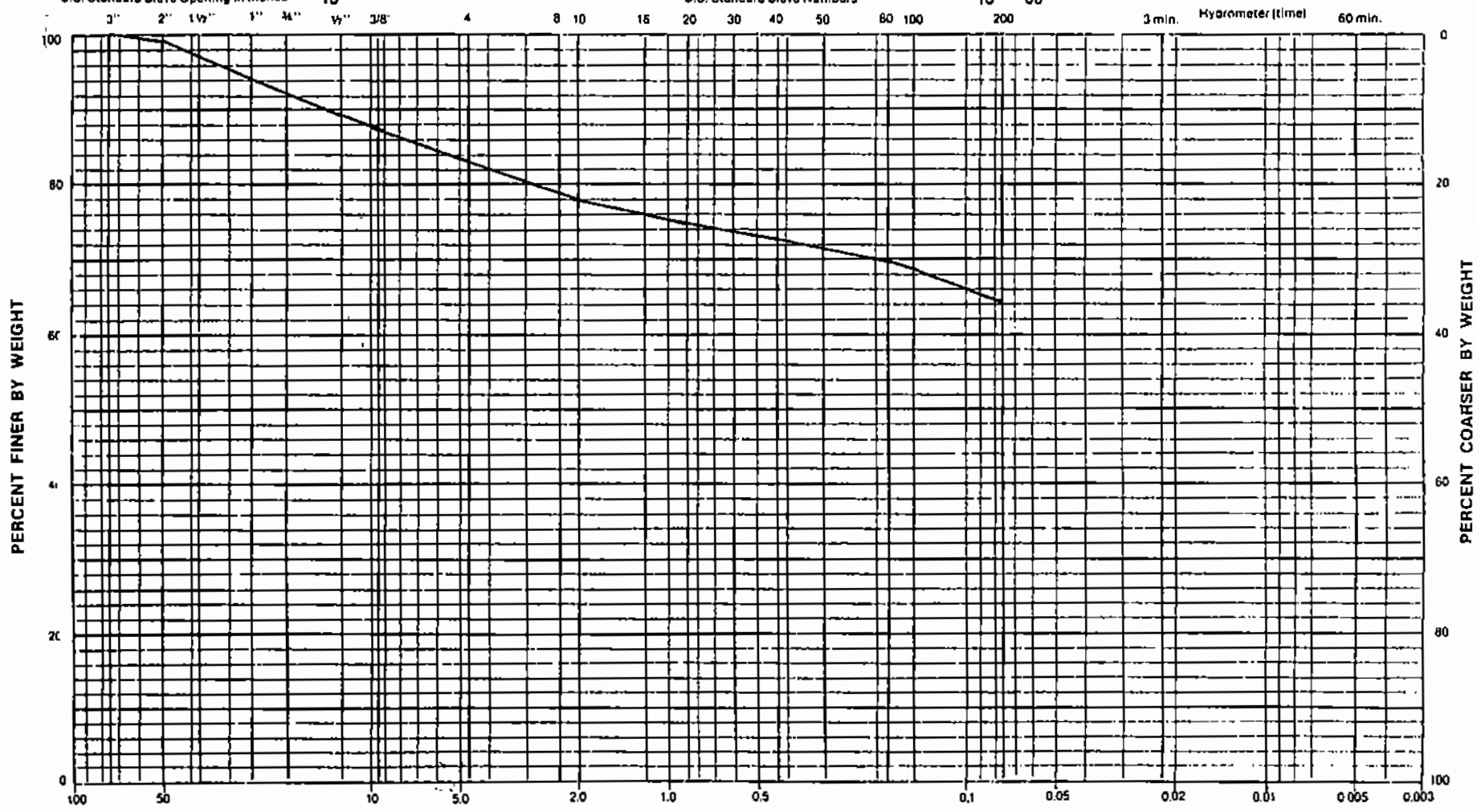
Sample No. 39454

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-128, S-1, 3.0' - 5.0'

Classification Lean CLAY with Gravel (CL)

Moisture Content 20 %

Liquid Limit 26 %

Plasticity Index 10 %

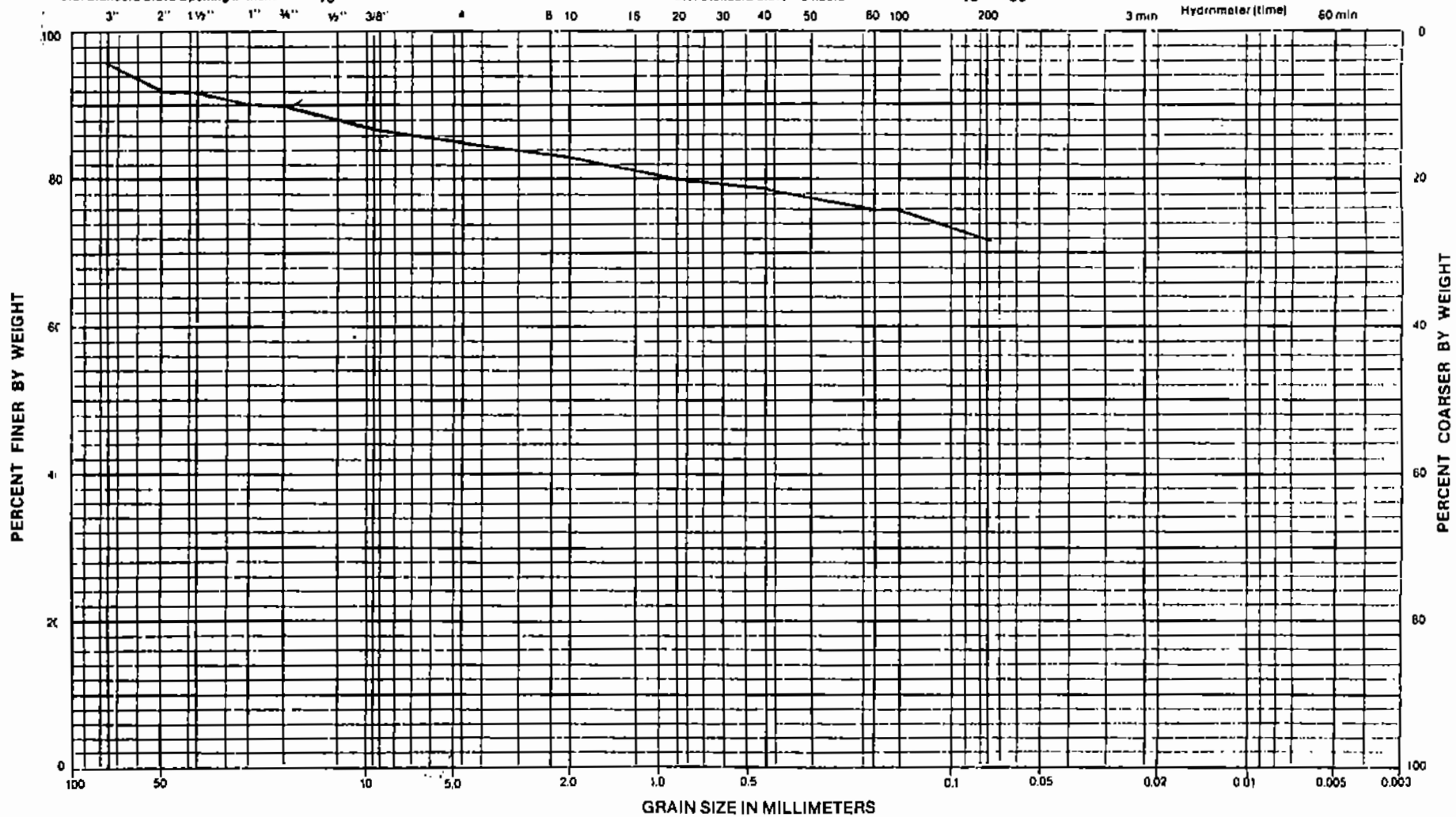
Sample No. 39455

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-128, S-2, 11.0' - 14.0'

Classification Lean CLAY (CL)

Moisture Content 27 %

Liquid Limit 41 %

Sample No. 39456

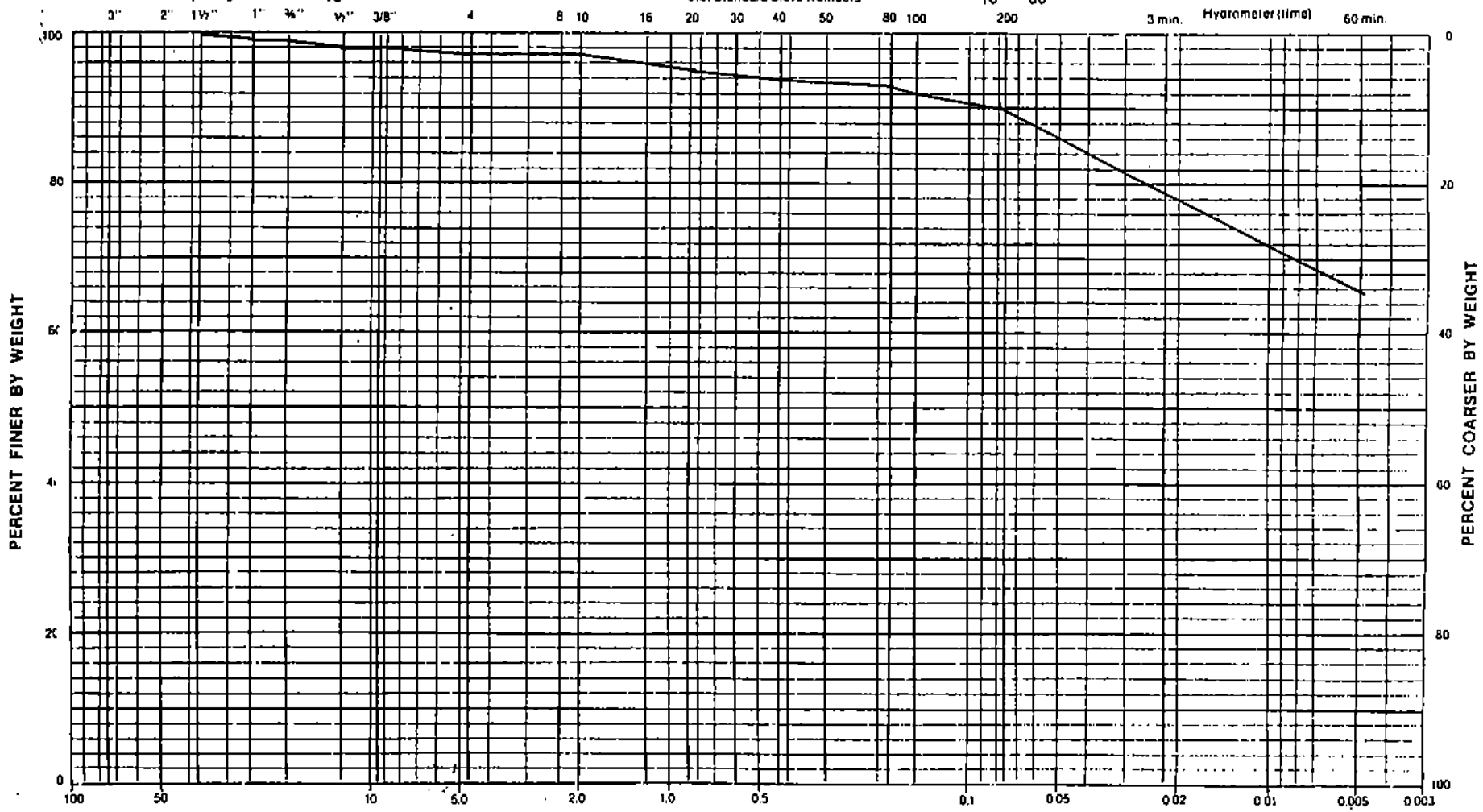
Job No. 88-152-2

Date 12/04/89

Plasticity Index 19 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-132, S-1, 3.0' - 7.0'

Classification Sandy Lean CLAY (CL)

Moisture Content 11 %

Liquid Limit -- %

Sample No. 39459

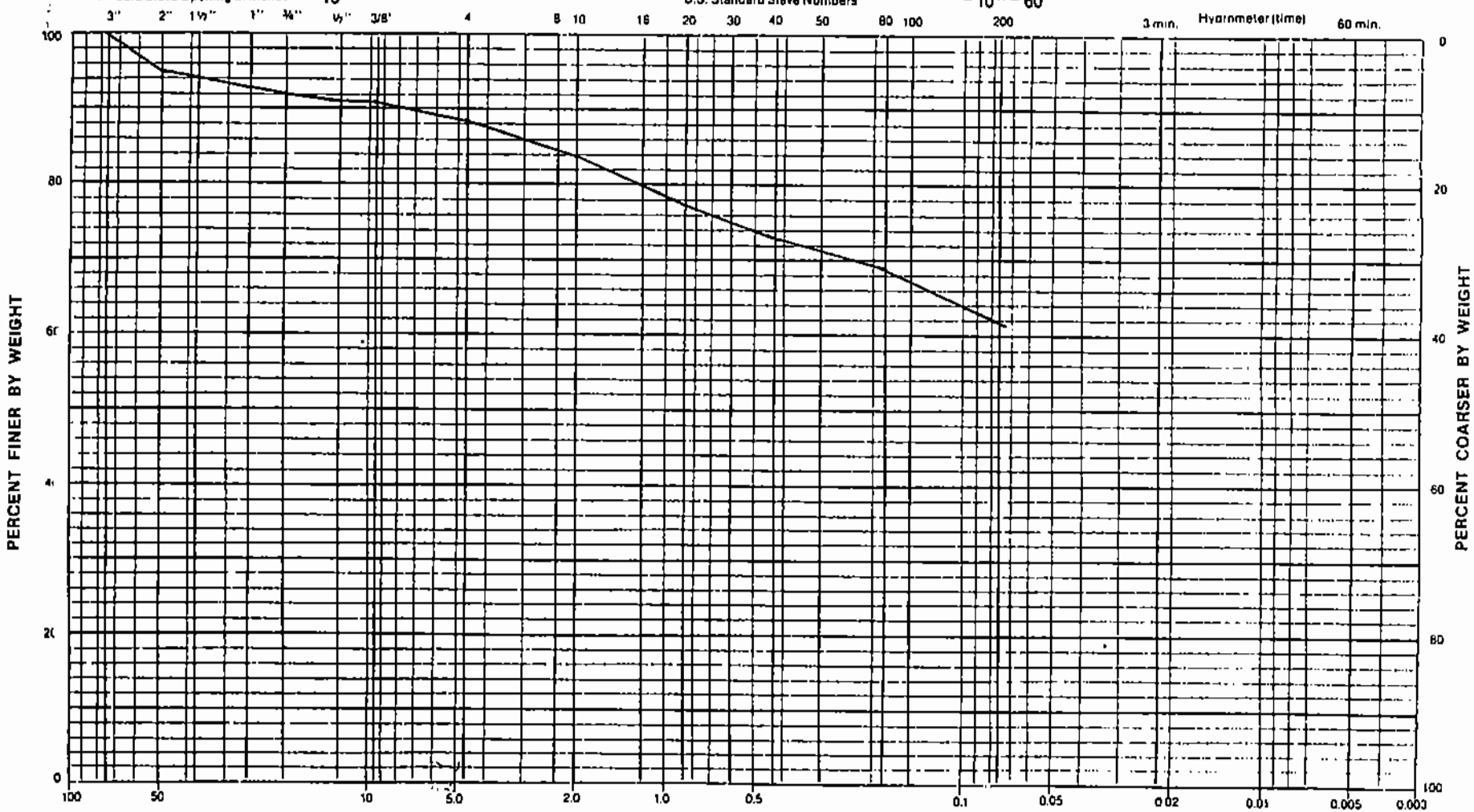
Job No. 88-152-2

Date 12/04/89

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-134, S-2, 2.0' - 4.0'

Classification Clayey SAND with Gravel

Moisture Content 6 %

Liquid Limit -- %

Plasticity Index -- %

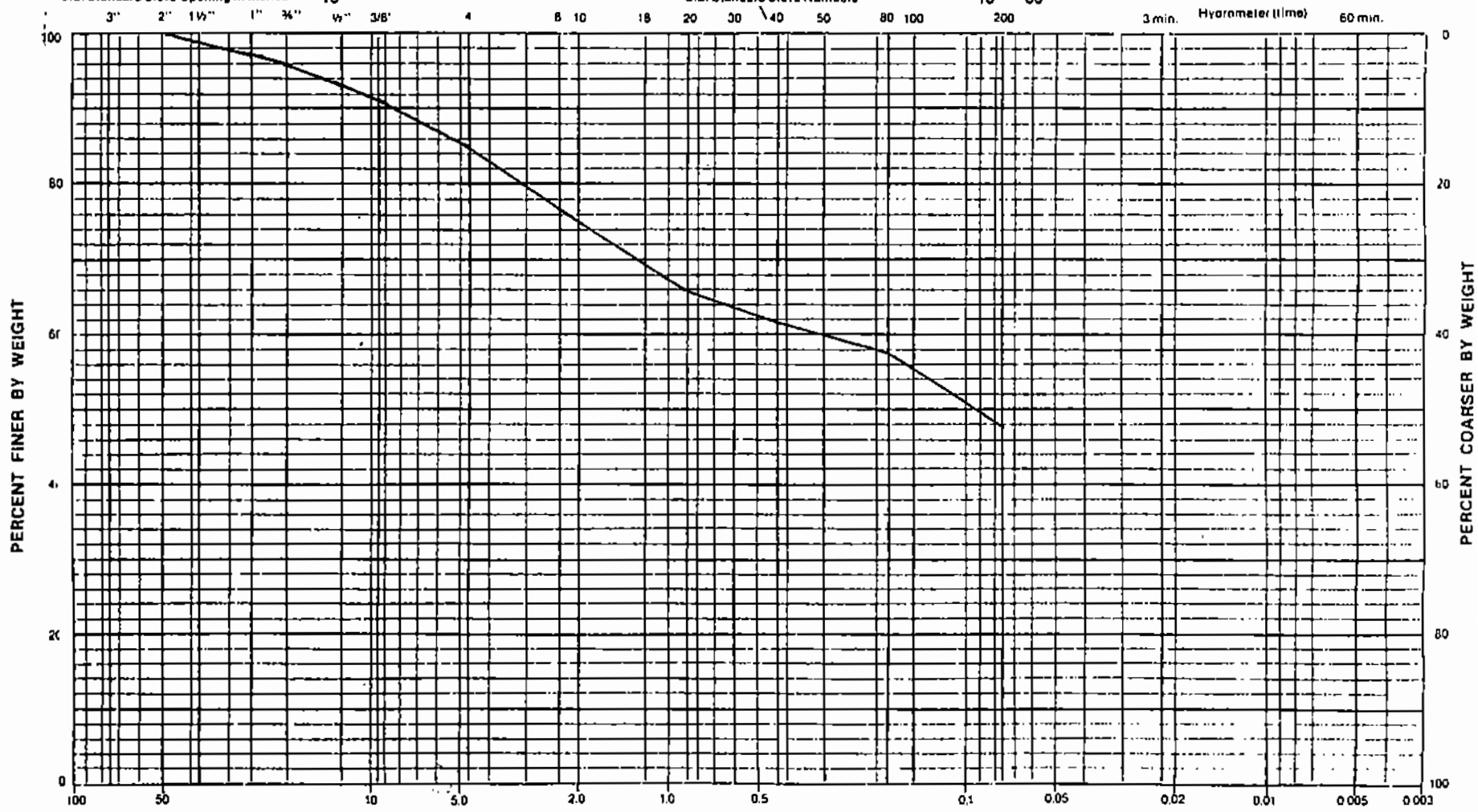
Sample No. 39461

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-136, S-1, 2.0' - 4.0'

Classification Gravelly Lean CLAY with Sand (CL)

Sample No. 39463

Job No. 88-152-2

Date 12/04/89

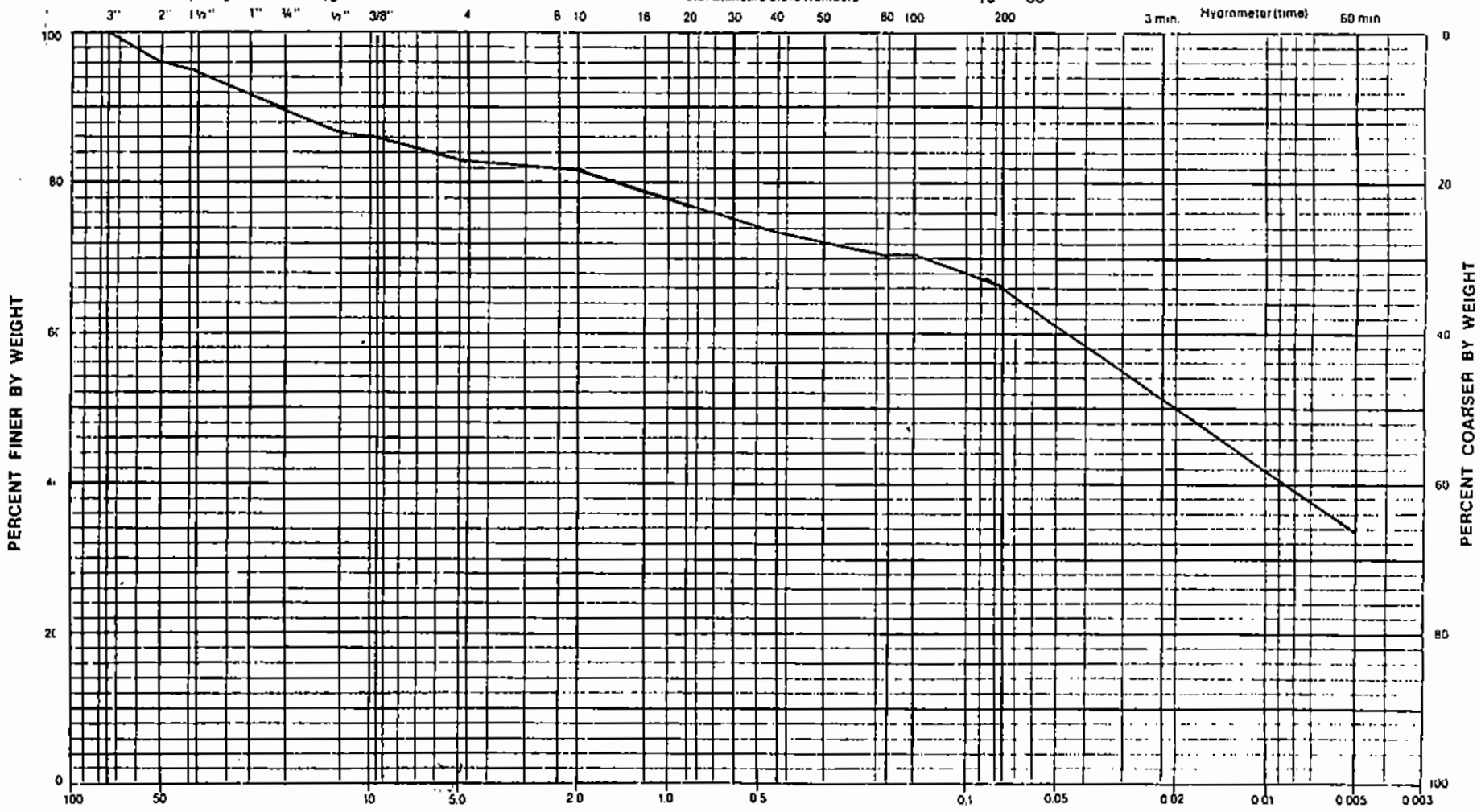
Moisture Content 22 %

Liquid Limit 42 %

Plasticity Index 22 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-138, S-1, 2.0' - 4.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 12 %

Liquid Limit 25 %

Plasticity Index 9 %

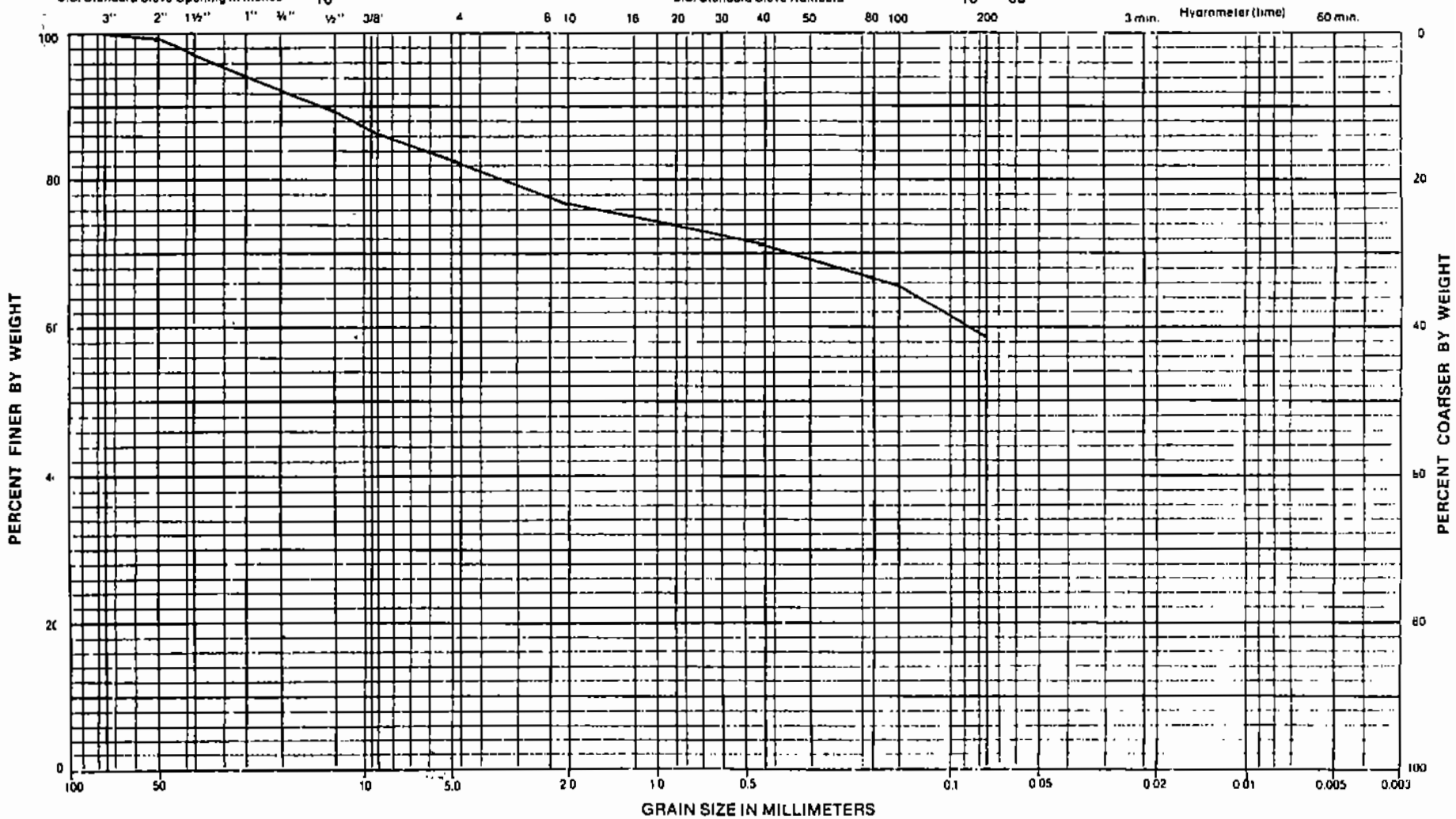
Sample No. 39464

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-142, S-1, 2.0' - 3.0'

Classification Sandy Lean CLAY with Gravel (CL)

Moisture Content 10 %

Liquid Limit -- %

Plasticity Index -- %

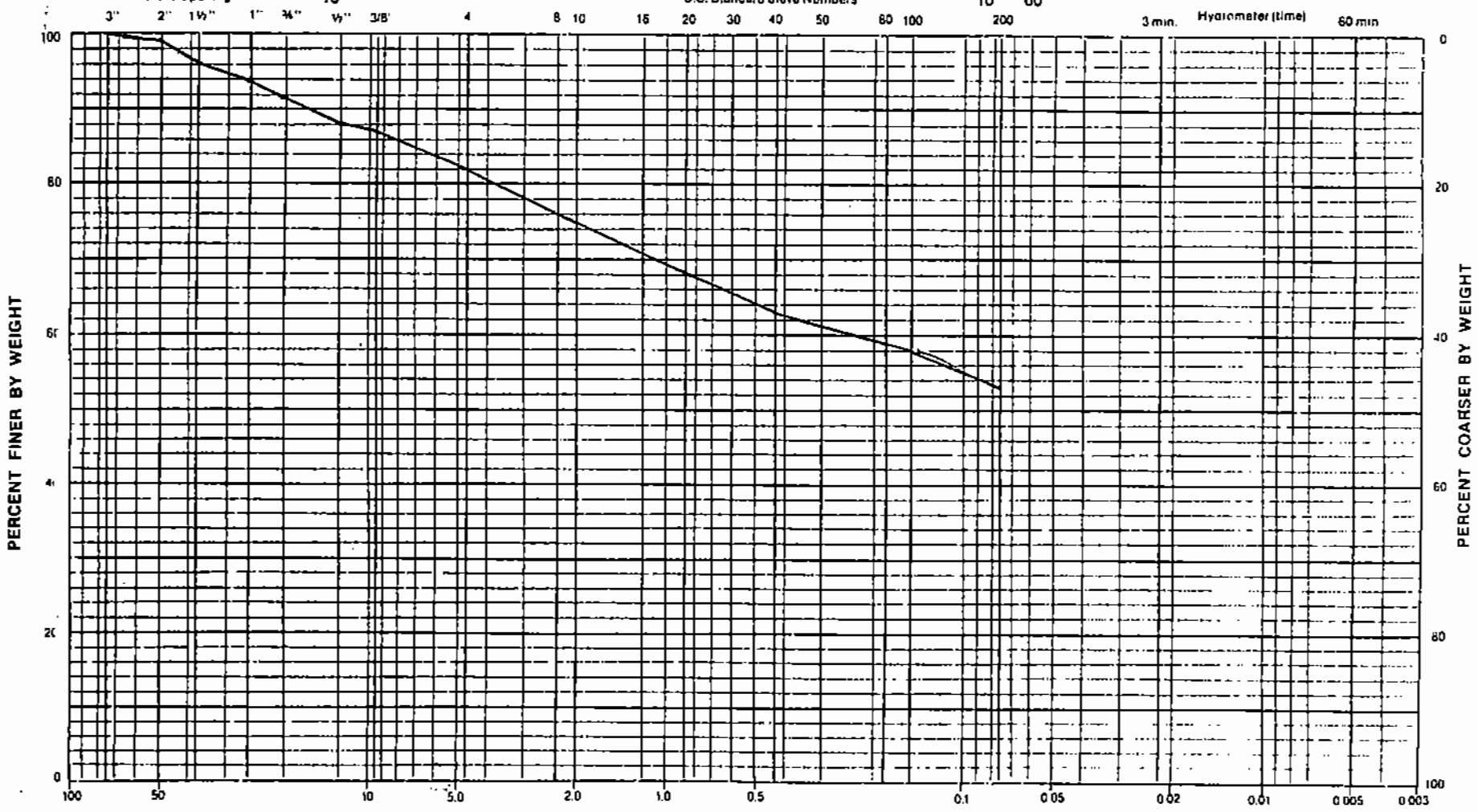
Sample No. 39466

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-144, S-1, 3.0' - 5.0'

Classification Gravelly Lean CLAY (CL)

Moisture Content 16 %

Liquid Limit 26 %

Sample No. 39467

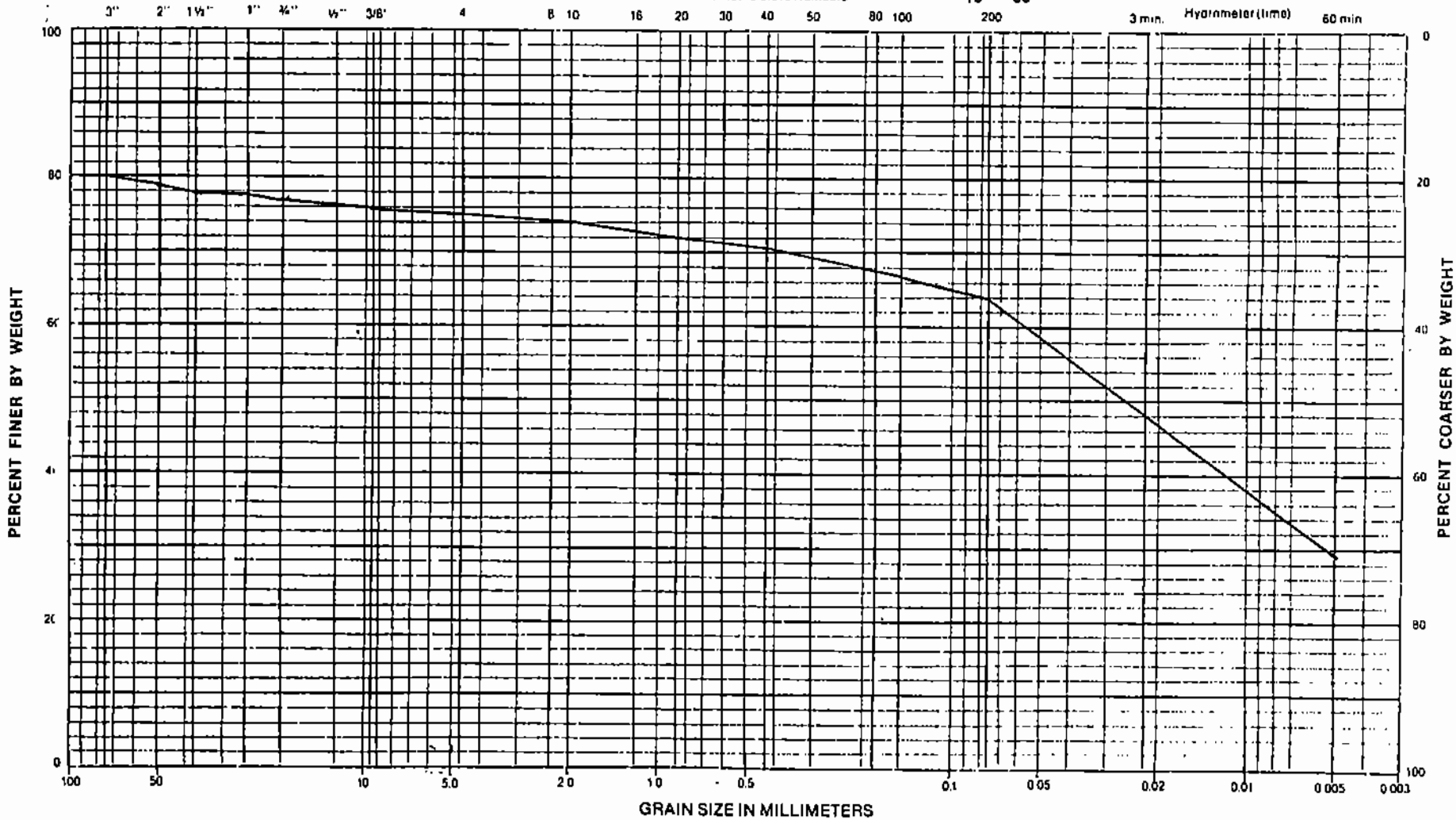
Job No. 88-152-2

Date 12/04/89

Plasticity Index 9 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

# Chen-Northern, Inc.

## GRAIN SIZE DISTRIBUTION CURVE

PROGRAM NO. 2

Project: Montana Silver Venture Mine

Location: TP-147, S-1, 1.0' - 3.0'

Classification Clayey GRAVEL with Sand (GC)

Moisture Content 9 %

Liquid Limit -- %

Plasticity Index -- %

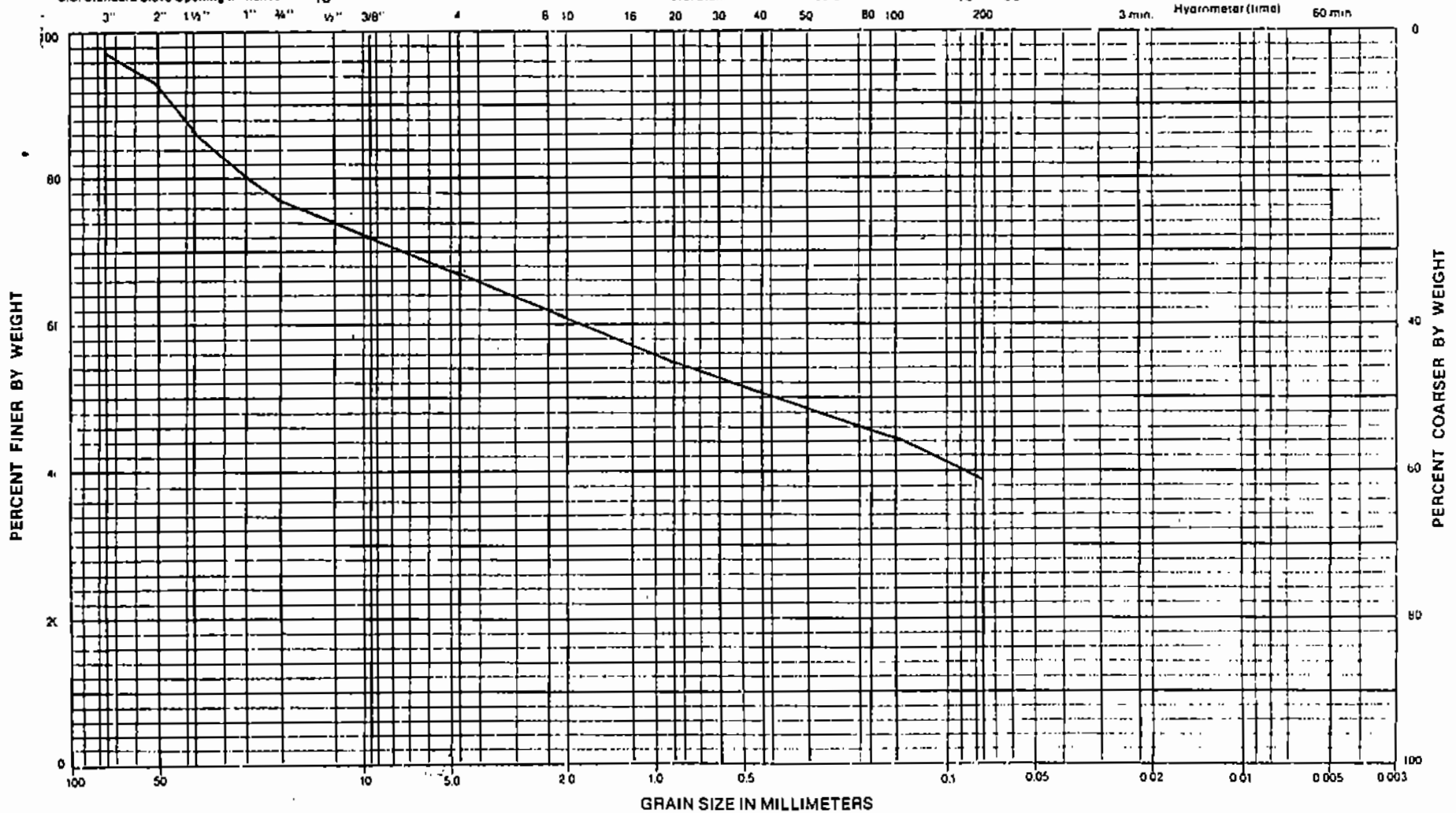
Sample No. 39468

Job No. 88-152-2

Date 12/04/89

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____




| Gravel | | Sand | | | Fines | |
|---|---|---|---|---|---|---|
| Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |

(Rev. 1/89) CNI-105

Northern
Engineering and Testing, Inc.
528 Smelter Avenue
P.O. Box 951
Great Falls, MT 59403
(406) 453-1641

# MOISTURE-DENSITY RELATIONSHIP DATA SHEET

REPORT TO: Morrison-Knudsen Engineers, Inc.
San Francisco, California

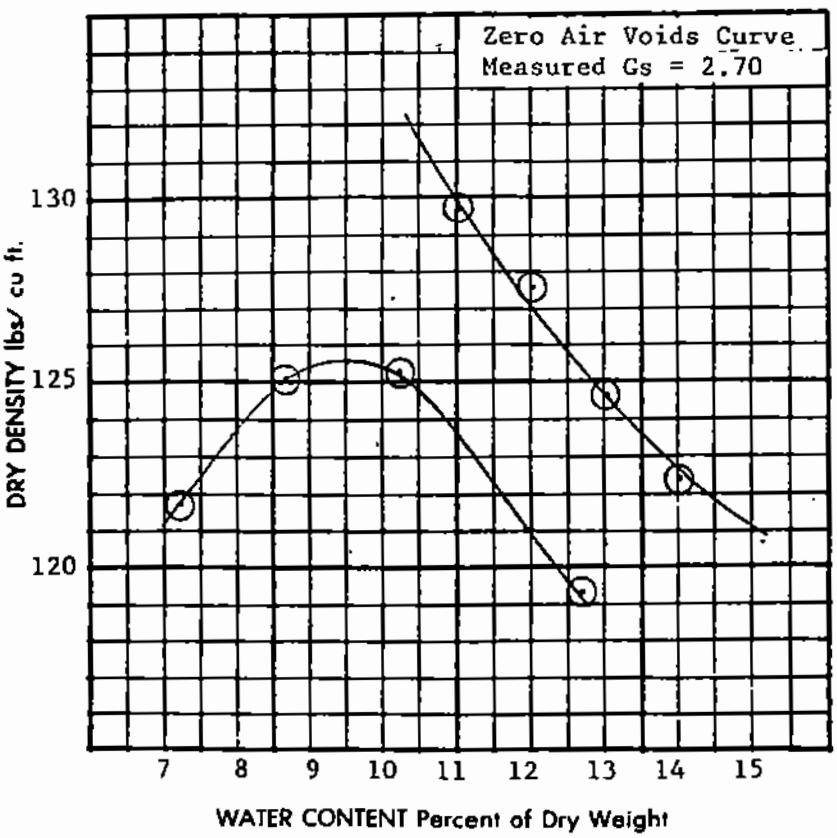
DATE: 10/07/88
JOB NUMBER: 88-152
SHEET: 1 OF 1
INVOICE NO.: 63946
LAB NO.: 32287
DATE SAMPLED: N/R
DATE RECEIVED: August 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Little Cherry Site
SAMPLE LOCATION: TP-106, 6.0'-8.0', S-1

MECHANICAL ANALYSIS

| SIZE | % PASS | SPECS. |
|---|---|---|
| N/A | | |

MOISTURE-DENSITY RELATIONSHIP




VISUAL CLASSIFICATION
Silty SAND
SPECIFIC GRAVITY: Fine Aggregate-2.70
SPECIFIC GRAVITY: Coarse Aggregate-2.69

TEST PROCEDURE ASTM D698 Method C
MAX. DENSITY: 125.5
OPT. MOIST.: 9.5
RAMMER TYPE: 5.5
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

DISTRIBUTION:

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# MOISTURE-DENSITY RELATIONSHIP DATA SHEET

REPORT TO: Morrison-Knudsen Engineering Inc.
San Francisco, California

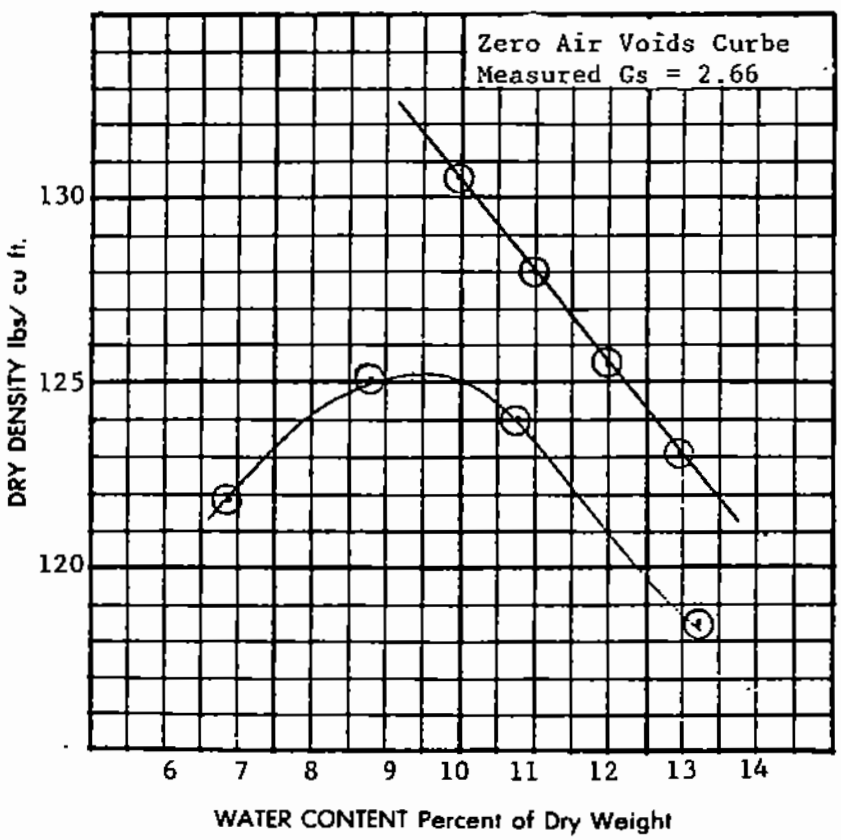
DATE: 10/07/88
JOB NUMBER: 88-152
SHEET: 1 OF 1
INVOICE NO.: 63946
LAB NO.: 32288
DATE SAMPLED: N/R
DATE RECEIVED: August 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Little Cherry Site
SAMPLE LOCATION: TP-107, 8.0'-9.0', S-1

MECHANICAL ANALYSIS

| SIZE | % PASS | SPECS. |
|---|---|---|
| N/A | | |

MOISTURE-DENSITY RELATIONSHIP




VISUAL CLASSIFICATION
Silty SAND
SPECIFIC GRAVITY: Fine aggregate-2.69
SPECIFIC GRAVITY: Coarse aggregate-2.65

TEST PROCEDURE ASTM D698, Method D
MAX. DENSITY: 125.2
OPT. MOIST.: 9.4
RAMMER TYPE: 5.5
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

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