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MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

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MONTANA PROJECT
SANDERS AND LINCOLN COUNTIES, MONTANA
GEOTECHNICAL REPORT

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Montana Project
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P.O. Box A.L.
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by:
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February 1989

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Attention: Mr. Joe Scheuering
Project Manager

Subject: Montana Project
Sanders and Lincoln Counties, Montana
Geotechnical Report

Gentlemen:

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

The purpose of this report is to provide geotechnical background to select sites for plant facilities, a mine portal, a tailings impoundment and an evaluation adit. The following sites were investigated:

- Tailings Impoundment Sites
  - Little Cherry
  - Poorman
  - Midas
- Plant Sites and Mine Portals
  - Libby Creek
  - Ramsey Creek
- Evaluation Adit Sites
  - Heidelberg Tunnel
  - South end of Rock Lake
  - Upper Heidelberg Road

The geotechnical investigations consisted of (1) geologic mapping, (2) seismic refraction surveys, (3) drilling, (4) test pit excavations and (5) laboratory testing. The results of the exploration and laboratory testing programs are presented, and site and subsurface conditions are described. Seismic design criteria are also presented in this report.

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

Sincerely,

M. P. Forrest

M. P. Forrest
Project Manager

MONTANA PROJECT
GEOTECHNICAL REPORT

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CHAPTER 1
SUMMARY AND CONCLUSIONS

Noranda Minerals Corp. is planning the development of the Montana Project in Sanders and Lincoln Counties, Montana, for mining and milling copper-silver ore. The project involves surface facilities consisting of a plant, mine adits, evaluation adits and a tailings impoundment. Morrison-Knudsen Engineers, Inc. (MKE) performed geotechnical investigations to select sites for these facilities.

This report presents the results of the field investigation program and includes discussions of (1) geologic setting, (2) seismicity, including seismic design criteria, (3) field exploration and laboratory testing programs and (4) site and subsurface conditions. The following sites were investigated:

- o Tailings Impoundment Sites
  - Little Cherry
  - Poorman
  - Midas

- o Plant Sites and Mine Portals
  - Libby Creek
  - Ramsey Creek

- o Evaluation Adit Sites
  - Heidelberg Tunnel
  - South end of Rock Lake
  - Upper Heidelberg Road

The plant, mine portal and tailings impoundment sites are located on the east side of the Cabinet Mountains and the evaluation adit sites are located on the west side. The impoundment sites are characterized by glaciofluvial and lacustrine deposits that are as thick as 200 or 300 feet. The plant sites are covered by colluvial and glaciofluvial deposits, generally on the order of 30 to 60 feet thick. Bedrock consists of Precambrian meta-sedimentary argillite, quartzite and siltite. The evaluation adit sites are located in extensive exposures of the meta-sedimentary rocks.

A seismicity study was performed to determine appropriate seismic design criteria. To assess earthquake sources, regional and local seismicity were evaluated and research of fault activity was performed. The results of our studies indicate that the design earthquake would be a magnitude 7 event originating on the Bull Lake fault, 20 kilometers to the west of the project site. The peak ground acceleration was estimated to be 0.22g.

The field investigation program in the plant, mine portal, evaluation adit and tailings impoundment sites consisted of (1) geologic mapping, (2) 50 seismic refraction survey lines, (3) 1,400 linear feet of drilling and (4) 42 test pit excavations. Field permeability tests were performed during the drilling work. Monitoring wells were constructed in selected borings. The results of the exploration at the Little Cherry and Poorman impoundment sites conducted by Chen-Northern of Helena, Montana, were also used in this study.

Soil samples collected from the borings and test pits were submitted for index and compaction laboratory testing. Unconfined compressive strengths were determined for undisturbed samples from the Midas site. At this stage of the project, triaxial compression tests were not performed. Such tests would be performed during a subsequent design development phase for use in final stability analyses.

The Little Cherry impoundment site is in a valley that drains into Libby Creek. Highly weathered rock was found at a depth of 27 feet in the north abutment. Borings were not drilled in the south abutment due to access limitations. However, bedrock was found at a depth of 50 feet in a stream channel just south of the south abutment. Geophysical results (seismic refraction and Chen-Northern's resistivity surveys) indicate that 200 to 300 feet of glaciofluvial silty sandy gravels and lacustrine silty clay cover the valley bottom. The results of permeability tests indicate that bedrock in the north abutment and site soils have low to moderate permeabilities.

Soils found in the Poorman site are similar to those found in the Little Cherry site. The Poorman site is a relatively flat area on the east side of Cable Mountain. Bedrock outcrops were found on the north side of the impoundment site. From the results of geophysical surveys, bedrock in the south and east sides of the site was estimated to be more than 200 feet deep. The soils were measured to have low to moderate permeabilities.

Artesian groundwater conditions were found in both sites. The artesian conditions result from confinement of the glaciofluvial materials by the less pervious silty clayey lacustrine sediments. However, higher artesian heads were found at the Poorman site. A groundwater level (piezometric surface) in a monitoring well installed by Chen-Northern at the east side of the Poorman site was found to be 17 feet above the ground surface. The effect of artesian groundwater conditions on impoundment design is that uplift water pressures could develop in the foundation of an impoundment dam that would have to be controlled by the use of pressure relief wells.

The Midas site is located in a valley that drains into Libby Creek. Many weathered rock outcrops were observed on the east side of the valley. The results of seismic refraction surveys indicate that bedrock is less than 50 feet thick at potential abutment locations on the west side of the valley. In the valley bottom, lacustrine deposits consisting of silty and clayey soils with some gravels were found to be more than 100 feet thick. More fine grained low-permeability soils were found at this site than at the other two impoundment sites.

Conditions at both the Libby and Ramsey plant sites are similar. Dense silty sandy gravelly soils with cobbles and boulders cover both sites. Bedrock was probably penetrated by one boring in the Libby site at a depth of about 30 feet. From the results of seismic refraction surveys, the depth to bedrock could be between 30 and 65 feet at the portal site. At the Ramsey plant site, it is unclear whether bedrock or very dense bouldery ground was found at a depth of 41 feet in one boring. Bedrock outcrops were observed in the Ramsey mine portal vicinity. Groundwater was measured at depths of 12 and 16 feet at the Libby plant site; at Ramsey, groundwater was measured at a depth of 22 feet. There is more evidence of avalanches at the Libby site than at Ramsey. Depending on planned excavation depths at the plant sites, very dense bouldery ground and bedrock may be encountered. In addition, groundwater could be encountered at either site.

Three evaluation adit sites were explored. All three sites are located in hard meta-sedimentary rock. The existing 720-foot long Heidelberg Tunnel is more than 18 years old and remains stable. Groundwater emerging primarily from foliation planes amounts to an estimated 80 gpm.

The adit location at the south end of Rock Lake would require some talus excavation to expose bedrock. The tunnel on the upper Heidelberg road is located in hard but weathered rock. Timber supports in the tunnel are in bad repair, and about 30 feet into the tunnel, the roof has caved. Rock conditions farther from the entrance could not be observed, but would be expected to improve.

The preliminary investigations described in this report were sufficient for preliminary design and site selection. However, further field investigations and laboratory testing will be needed to better define foundation conditions at the selected sites and to develop the tailings impoundment design.

CHAPTER 2
INTRODUCTION

2.1 PURPOSE AND SCOPE

Noranda Minerals Corp. is currently planning the development of the Montana Project located in Sanders and Lincoln Counties, Montana, for mining and milling copper-silver ore. The project area is located in the Kootenai and Kaniksu National Forests (Figure 1). As part of this project, Morrison-Knudsen Engineers, Inc. (MKE) performed geotechnical investigations to select the preferred sites for plant facilities, mine portal, tailings impoundment and evaluation adit portal. The following sites were investigated (Figure 2):

- o Tailings Impoundment Sites
  - Little Cherry
  - Poorman
  - Midas
- o Plant Sites and Mine Portals
  - Libby Creek
  - Ramsey Creek
- o Evaluation Adit Sites
  - Heidelberg Tunnel
  - South end of Rock Lake
  - Upper Heidelberg Road

The goal of the engineering work and geotechnical investigation is to select the preferred sites, from an engineering standpoint, for plant facilities, mine portal, tailings impoundment and evaluation adit. To accomplish this goal, the scope of work outlined below has been developed to define geotechnical conditions at the sites. The approach to the project study is described in the Design Basis Memorandum, in Appendix A.

The scope of work for site selection and preliminary design consists of the following tasks:

- o Conduct a field investigation that includes the following activities:
  - Data review
  - Reconnaissance
  - Geologic mapping
  - Seismicity evaluation
  - Seismic refraction survey
  - Test pit excavations
  - Exploratory drilling
  - Laboratory testing

- o Perform site evaluations that include the following:
  - Tailings impoundments (including seepage, design floods and stability)
  - Plant sites and mine portals
  - Evaluation sites

- o Prepare the following technical reports:
  - Geotechnical Report
  - Geotechnical Site Evaluation Report
  - Tailings Impoundment Preliminary Engineering Report

- o Attend meetings with Noranda and regulatory agencies.

This geotechnical report presents the results of the field investigation program. The Geotechnical Site Evaluation Report presents recommendations for selection of the (1) plant site, (2) mine portal location, (3) tailings impoundment site and (4) evaluation adit site. The Tailings Impoundment Preliminary Engineering Report presents the results of preliminary engineering analyses and design for the selected tailings impoundment site.

2.2 AUTHORIZATION

United States Borax & Chemical Corporation initially authorized the work for this project on 9 May 1988. On 6 September 1988, U. S. Borax transferred its interest to Noranda Minerals Corp.

CHAPTER 3
GEOLOGIC SETTING

The focus of the Montana Project is an area near Rock Lake in the Cabinet Mountains Wilderness which consists of mineral bearing quartz veins adjacent to the Rock Lake Fault. 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 and the colluvium consists of slope wash boulders and soils. The glaciofluvial deposits consist of sands and gravel overlain in places by poorly sorted till-like deposits. The glaciolacustrine deposits consist primarily of gravelly silt with some varved clays.

CHAPTER 4
SEISMICITY

4.1 GENERAL

This chapter provides background information on seismicity of the region surrounding the Montana Project area and describes procedures used to derive the project design earthquake and ground motion 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 and also in the site area, the predominant type of faulting is normal, along north to northwest oriented faults.

Table 4.1 summarizes significant earthquakes in the region and it includes the two largest events known to have occurred in the ISB, the M7.5 Hebgen Lake earthquake of 1959 and the M7.3 Borah Peak, Idaho, earthquake of 1983. These earthquakes were both 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) estimated magnitudes of 5-1/2 for earthquakes in 1945 and 1952 based on unusually large areas where ground motions were felt.

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.

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).

4.3 LOCAL SEISMICITY

The area extending from the 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 M4.7 earthquake in 1964 located 21 miles east of the project site. The closest event was small and occurred about 14 miles east of the site in 1971. No earthquakes exceeding M4-1/2 have occurred in northwest Montana in the last five years (M.C. Stickney, personal communication).

There has been a notable lack of seismicity 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 lead Algermissen et al. (1982) to select a maximum earthquake of M6.5 for the area, which is greater than the largest observed event (M5.0). This earthquake is not attributed to any specific fault.

4.4 FAULTS

Witkind (1975) identified and classified faults in the region that have 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 displacing Pleistocene deposits. This places the age of fault movement as younger than 1.5 to 2 million years. Orientations and locations of the faults are indicated on Figure 3.

o 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.

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

o 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 were not considered as potential earthquake sources in the present study.

o 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

Maximum Credible Earthquakes (MCE) were determined for potentially active earthquake sources: the Bull Lake and Rainy Creek faults, the Flathead Lake seismic

zone, and a random local earthquake. The MCE is defined as the largest rationally conceivable event that could occur in the tectonic environment in which the project is located (Seed, 1982). MCE magnitudes 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 earthquakes 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 on page 4-7.

4.6 SEISMIC DESIGN CRITERIA

A. Peak Ground Acceleration

Peak ground accelerations 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 site accelerations. As shown in Table 4.2, the random local earthquake gives the largest estimate of peak acceleration. However, the MCE on the Bull Lake fault gives an acceleration that is 5% less and, because of its larger magnitude, it could produce a longer duration of shaking (more significant stress cycles). In view of the uncertainties in the process of calculating maximum magnitude from fault length, it is considered appropriate to round up the Bull Lake MCE to magnitude 7. Thus, the design earthquake likely to produce the most severe ground motion at the site is as follows:

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

The design earthquake peak ground acceleration was used in liquefaction analyses of the tailings impoundment site (MKE, 1989).

B. Seismic Coefficient

The project site is located close to Seismic Zone 2 for which a seismic coefficient of 0.05g is recommended (Corps of Engineers, 1977). However, this coefficient is incompatible with a nearby magnitude 7 MCE. Since the boundaries of Seismic Zones 1, 2, and 3 are relatively close together in this region, it is appropriate to apply the coefficient for Seismic Zone 3, which is 0.10g. This coefficient was used in seismic stability analyses of the tailings dam (MKE, 1989).

TABLE 4.2

PEAK GROUND ACCELERATION FOR

VARIOUS SOURCE MAXIMUM CREDIBLE EARTHQUAKES

Earthquake Source	Site Distance (km)	Fault Length[1] (km)	MCE Magnitude	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 were 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 and Poorman tailings impoundment sites, the Ramsey and Libby Creek plant and mine portal sites, and at the Rock Lake evaluation adit sites. In November 1988, field exploration was performed at two potential dam locations in the Midas tailings impoundment site. The field exploration program consisted of geologic mapping seismic refraction surveys, drilling, and test pit excavation. A summary of the field exploration program is presented in Table 5.1 at the end of this chapter.

In July 1988, Chen-Northern drilled 9 wells totaling 539 linear feet in the Little Cherry and Poorman impoundment sites. Aquifer testing was performed in the wells and the test results are presented in Chen-Northern's 1989 report. Also, Chen-Northern conducted 39 resistivity surveys in both impoundment sites. Chen-Northern's exploratory work supplements MKE's field exploration of the Little Cherry and Poorman impoundment sites. The locations of the wells and resistivity surveys are shown on Figures 4 and 7.

B. Geologic Mapping

Geologic mapping was performed at the plant sites, impoundment sites and adit sites. The mapping was done to identify bedrock outcrops, rockslide areas, snowslide areas, springs, faults, and landslides. To determine the potential for rockslides into portal cuts; the orientation of major discontinuities were noted. The geologic data are shown on the exploration plans and geologic maps. In addition, a geologic map was prepared of the Heidelberg Tunnel and is presented in Appendix B, Figure B-1.

C. Seismic Refraction Surveys

In July and November 1988, 50 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. The line designations, number of seismic lines and total footage at each of the tailings impoundment, plant, and portal sites are presented in Table 5.1.

Forty-seven seismic lines were each 325 feet long with geophone spacings of 25 feet. The seismic line at the Rock Lake adit site and two lines at the Midas site had a 10-foot geophone spacing.

A twelve-channel signal-enhancement seismograph was used to record seismic 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 Figures 4, 7, 11, 16, 18 and 20, and a summary of the results of the seismic refraction surveys is presented in Appendix C.

D. Drilling

In July, August and November 1988, twenty-four borings ranging in depth from 18 to 100 feet and totalling 1402 linear feet were drilled in the project area. The boring designations, number of borings and total footage drilled for each of the tailings impoundment and plant sites are presented in Table 5.1. To minimize ground disturbance, preliminary exploration borings were located in readily accessible areas as shown on Figures 4, 7, 11, 16 and 18.

The borings were drilled by Northern Engineering and Testing, Inc., of Great Falls, Montana, using a Mobile B-53, Mobile B-50 and CME-75 rotary drilling rigs. Borings were drilled to determine depth to bedrock, bedrock characteristics, the characteristics of the overburden, and the depth to groundwater. The borings were generally drilled with a 2-15/16-inch tricone bit and casing in the overburden. Bedrock was cored by using NX or 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 with the exception of Midas site, their number was limited due to the gravelly nature of the overburden. At the Little Cherry and Poorman sites, Shelby tube 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, the borings were cased with 1-inch I.D. PVC pipe with the bottom sections slotted. Boring logs and monitoring well construction details are presented in Appendix D. Water level data are presented in Table D.1, Appendix D.

Field permeability tests were performed at the Little Cherry, Poorman, and Midas tailings impoundment sites. The tests were performed to determine permeability coefficients of foundation materials for seepage analyses. The tests were performed in the overburden 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 D.2, Appendix D.

E. Test Pits

Forty-two test pits ranging in depth from 3.5 to 16 feet were excavated at the impoundment and plant sites to characterize the soil materials and to estimate the amount of boulders in the soil matrix. Test pits were located in readily accessible areas (Figures 4, 7, 11, 16 and 18). The test pits were excavated in July, August and November by Sorlie Excavating of Trout Creek, Montana, using a Case 580D backhoe with a 1.5-foot wide bucket. Soil samples were taken from the test pits and transported to Northern Engineering and Testing for laboratory testing. Approximate unconfined compressive strengths of cohesive soils were measured with a pocket penetrometer. Test pit designations and the number of test pits at each of the tailings impoundment and plant sites are presented in Table 5.1. The test pit logs are presented in Appendix E.

5.2 LABORATORY TESTING

Laboratory tests were performed to obtain preliminary engineering parameters of the soils at the plant and tailings impoundment sites. 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. In addition, unconfined compressive strengths (ASTM D2166) were determined on undisturbed samples from the Midas site. The types and number of tests at the plant and tailings impoundment sites are summarized in Table 5.2. Laboratory test results are presented in Appendix F.

TABLE 5.1. SUMMARY OF FIELD EXPLORATION

Site	SEISMIC LINES			BORINGS			TEST PITS	
	Designation	Number of Lines	Total Coverage (Ft.)	Designation	Number of Borings	Total Footage	Designation	Number of Test Pits
Little Cherry Tailings Impoundment	TI 9-15	7	4,525	USB 1-5	5	307	TP 101-110	10
Poorman Tailings Impoundment	TI 1-8, TI 16-22	15	7,300	USA 1,1A,2-4	5	334	TP 201-210	10
Midas Tailings Impoundment	MCI-4, MCH-16	15	4,485	MCDH 2A,2-4,6-9	8	482	TP 500-501,503-512	12
Ramsey Creek Plant	RC 1-2, RC 4-5	4	1,300	RCDH 1-3	3	145	TP 301-305	5
Ramsey Creek Portal	RL 1-2	2	650					
Libby Creek Plant	LC 3-6	4	1,300	LCDH 1-3	3	134	TP 401-405	5
Libby Creek Portal	LC 1-2	2	650					
Rock Lake Evaluation Adit	RL	1	300					
TOTAL		50	20,510		24	1,402		42

TABLE 5.2. SUMMARY OF LABORATORY TESTS

Site	Sample Source	Moisture Content ASTM D 2216	Dry Density	Sieve Analysis ASTM D 422	Sieve and Hydrometer ASTM D 422	Atterberg Limits ASTM D 4318	Compaction ASTM D 698	Specific Gravity ASTM D 854	Unconfined Compression ASTM D 2166
Little Cherry Tailings Impoundment	Test Pit	5		5	1	4	2	2	
	Boring	3	1	7		1			
Poorman Tailings Impoundment	Test Pit	5		5	1	4	2	2	
	Boring	9	8	4		1			
Midas Tailings Impoundment	Test Pit	9		9		3	4	4	
	Boring	7	7	9	4	8			6
Ramsey Creek Plant	Test Pit	2		2					
Libby Creek Plant	Test Pit	2		2					
TOTAL		42	16	43	6	21	8	8	6

CHAPTER 6
SITE AND SUBSURFACE CONDITIONS

6.1 IMPOUNDMENT SITES

A. Little Cherry Site

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.

Isolated outcrops of highly weathered, fractured and jointed meta-sedimentary rock were observed on ridges on the north side of Little Cherry Creek (Figure 4). Elsewhere, the ridges are covered with colluvium and glacial outwash.

At the proposed damsite, the valley slopes and creek channel are covered with colluvium, glacial outwash and lakebed sediments to a depth of 200 to 300 feet. The colluvium overlies the higher slopes of the valley and consists of coarse slopewash material. The glacial outwash material is gravelly and contains a major silt fraction. The lakebed sediments are mostly fine grained silt and varved clays with some gravel. These surficial materials appear to interfinger below about EL 3,550, which is the highest level that lakebed sediments have been reported (Chen-Northern, 1989). Within the impoundment, colluvium and glacial outwash may overlie the sediments indicating a later period of deposition.

Little Cherry Creek is situated well above bedrock. The present channel location approximates the pre-glacial channel location, but the stream has not eroded the surficial materials to the pre-existing level.

Groundwater is transmitted through the more pervious layers of colluvial and glacial outwash materials and also through fractures in bedrock. Where groundwater is confined by the relatively impervious lakebed sediments, aquifers under artesian pressure result. A seepage area was observed, as shown on Figure 4.

2. Subsurface Conditions - The results of the exploration indicate that bedrock occurs at shallow depths in both abutments. However, in the valley bottom, bedrock was not found in the borings or wells, the deepest of which was 140 feet (LCTM-8). The seismic refraction and resistivity survey results indicate that bedrock is between 200 and 300 feet below the ground surface (see Figures 5 and 6).

Highly weathered quartzite, siltite and argillite were found at a depth of 27 feet in Boring USB-3, in the north abutment. The fracture spacing in the core varied from 1 to 6 inches and the core was soft. Core recoveries ranged from 40 to 96% and Rock Quality Designation (RQD, see Appendix D) values varied from 0 to 30%, indicating poor rock conditions. Bedrock was also reported at a depth of 65 feet in Well LCM-9, 2,400 feet east of USB-3.

Borings were not drilled in the south abutment because of access limitations. However, bedrock was found at a depth of 50 feet in Well PLCM-6, located in a stream channel just south of the south abutment.

Dense to very dense silty sandy and silty gravelly soils (lowest SPT value was 36), with lesser amounts of hard silty clayey soils, were primarily observed in the borings and test pits. Boulders and cobbles were also found in the borings, especially in Borings USB-2 and USB-4 and in Wells LCTM-8 and LCM-11. The amount of boulders in the test pits was visually estimated to range from about 5 to 10 % of the soil volume.

The laboratory test results indicate that the fines content generally ranges widely from 25 to 77% (see Figure F-1, Appendix F). Sandy gravel with 7% silt was found in Test Pit TP-105. The test pit was probably located in a fluvial outwash deposit, similar to that found in a gravel pit at the southeast side of the Poorman site (see Subsection 6.1.B.1). The soils have low plasticity with liquid limits ranging from 20 to 25 and plasticity indices ranging from 1 to 6 (see Figure F-4, Appendix F). The dry density of one undisturbed sample from USB-1 was 109 pounds per cubic foot (pcf). Natural moisture contents vary widely, between 2 and 18%. The results of the moisture-density tests (ASTM D698) show maximum dry densities of about 125 and 126 pcf; the optimum moisture content is about 9.5%. These data indicate that, due to the wide range of natural moisture contents, moisture conditioning of the soils will be required for embankment construction.

The results of field permeability tests are summarized in Table 6.1. The results show that the permeabilities of the silty sandy gravelly soils generally range from 1×10^{-5} to 1×10^{-4} cm/sec, indicating these soils are moderately pervious. In Well PLCM-6, south of the impoundment site, permeabilities range from 2×10^{-3} to 7×10^{-3} cm/sec. As expected, the silty clayey soils were found to have lower permeability values, ranging from 3×10^{-6} to 7×10^{-6} cm/sec (see Boring USB-5, Table 6.1). The results of packer tests in Boring USB-3 show that the weathered rock in the north abutment has low permeability values, ranging from less than 1×10^{-6} to 3×10^{-5} cm/sec.

Groundwater depths were measured between 22 and 34 feet in Borings USB-1, 3 and 5. Groundwater levels in the wells were reported to range between about 10 and 14 feet in August 1988 (Chen-Northern, 1988). In the valley bottom near Little Cherry Creek, the groundwater depth was measured at 2 to 3 feet in Boring USB-2. A spring was also found in the creek downstream of the damsite (Figure 4). The shallow groundwater levels in the valley bottom indicate that groundwater is discharging into Little Cherry Creek in the impoundment site.

Seepage was observed in four test pits: TP-101, 102, 104 and 110. In Test Pits TP-101 and 102, which are located in drainages, seepage was observed at depths of 6 and 8 feet, respectively. Heavy seepage was noted at 4.5 feet in TP-104, which is located about 400 feet south of Boring USB-2 where shallow groundwater was also measured. Seepage in gravelly sand at a depth of 11 feet was reported in TP-110. This seepage depth corresponds with water levels measured in Well LCM-11 (depths of 11 feet in July and 14 feet in August 1988). This well is located about 400 feet north of TP-110.

The results of the seismic refraction surveys show that soils have compressional wave (P-wave) velocities ranging from about 2,000 to 8,000 feet per second (fps). The lower velocities were measured near the ground surface; higher velocities were measured at greater depths indicating increasing soil density with depth. Bedrock on the north abutment was found to have a P-wave velocity greater than 12,300 fps.

TABLE 6.1

LITTLE CHERRY SITE

SUMMARY OF FIELD PERMEABILITY TEST RESULTS

Boring or Well	Material	Type of Test	Permeability (cm/sec)
USB-3	Highly weathered rock	Packer Test	$<1 \times 10^{-6}$ to 3×10^{-5}
USB-4	Silty sandy gravel, cobbles and boulders	Constant Head	1×10^{-4} to 2×10^{-3}
USB-5	Gravelly silty sand Silty clay-clayey silt	Constant Head Constant Head	1×10^{-5} to 7×10^{-5} 3×10^{-6} to 7×10^{-6}
LCTM-8[a]	Silty sandy gravel, cobbles and boulders	Pump Test	1×10^{-4}
LCM-9[a]	Silty gravel with boulders	Slug Test	8×10^{-5}
LCM-10[a]	Gravel, silt and sand	Slug Test	2×10^{-6}
LCM-11[a]	Silty sandy gravel, cobbles and boulders	Slug Test	2×10^{-5}
PLCM-6[a,b] (shallow)	Silty sandy gravel	Slug Test	2×10^{-3}
PLCM-6[a,b] (deep)	Silty sandy gravel	Flow Test (Constant Drawdown)	5×10^{-3} to 7×10^{-3}

Notes:

a. From Chen-Northern (1989)

b. South of impoundment site, in small creek channel.

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B. Poorman Site

1. Site Conditions - The site occupies a relatively flat area east of Cable Mountain. Portions of the site have been clear-cut. The highest point in the watershed is at El. 4,160. Access to the site is via Forest Service roads, about 10 miles from U.S. Route 2.

Highly weathered and fractured meta-sedimentary rock outcrops were mapped near the north side of the impoundment (Figure 7). On the south and east sides of the impoundment area, rock is covered to depths of more than 200 feet by colluvium, glacial outwash and lakebed sediments. The colluvium consists of coarse slopewash derived from rocky slopes. The glacial outwash is mostly gravel with a major silt fraction. Lakebed sediments consist of gravelly silt and some varved clays. The surficial material appears to interfinger below about El. 3,550, which is the highest level lakebed sediments are reported. Interfingering of a silty sandy gravel deposit was observed in a gravel pit at the southeast corner of the impoundment at El. 3,450 (Figure 7), which is well below the highest level of lakebed sediments.

Surface water runoff quantities are small and occur in numerous small streams. Surface water accumulates in an area on the south side of the impoundment, between Test Pits TP-204 and TP-206 (Figure 7), causing swampy conditions. Groundwater accumulates in the more pervious layers, as it does in the Little Cherry Creek area. Aquifers that are confined by lakebed sediments result in artesian conditions downstream (east) of the impoundment site.

2. Subsurface Conditions - Highly weathered bedrock was mapped in road cuts at the north end of the impoundment site (see Figure 7). Except for Well PLCM-6, rock was not found in the borings in the Poorman site.

Site soils are similar to those found in the Little Cherry site and consist of dense to very dense silty sand and silty gravels (lowest SPT value was 19) with lesser amounts of very stiff to hard silty clayey soils. Boulders and cobbles were noted intermittently in Boring USA-3, Well PM-2 and the test pits.

The results of laboratory testing show that the fines content generally ranges widely from about 32 to 75% (Figure F-2, Appendix F). The soils have low plasticity: liquid limits were measured between 20 and 38 and plasticity indices vary from 6 to 17 (see Figure F-5, Appendix F). The data show that the Poorman site soils have a somewhat higher plasticity than do soils at the Little Cherry site (see Figures F-4 and F-5, Appendix F). Dry densities were measured between 108 and 120 pcf. Natural moisture contents were found to range from 2 to 21%, which are comparable with the data from the Little Cherry site. Results of two moisture-density tests (ASTM D698) show maximum dry density values of 109 and 116 pcf; optimum moisture contents are 13 and 15%. As for the Little Cherry site, these data indicate that moisture conditioning of the soils will be needed for embankment construction.

The results of field permeability tests are summarized in Table 6.2. The results show that soil permeabilities are variable, ranging from less than 1×10^{-6} to 7×10^{-3} cm/sec. These values indicate that the soils have low to moderate permeabilities.

Groundwater depths were measured in Borings USA-2, 3 and 4 between 25 and 58 feet. The results of the exploration show that in the southeast and northeast corners of the impoundment site, artesian conditions exist and groundwater levels are shallow. The depth to groundwater in Boring USA-1, at the southeast corner of the impoundment site, was found at a depth of 7 feet. In Boring PM-3, also in the southeast corner of the impoundment site, the groundwater level was measured at a depth of about 13 feet. In Well PM-5, near the northeast corner of the impoundment site, groundwater (peizometric surface) was measured in August 1988 to be about 17 feet above ground level. Springs were found east of the impoundment, north and south of PM-5 (Figure 7). In Test Pit TP-207, located about 1,400 feet east and 150 feet lower in elevation than PM-5, seepage at a depth of 8 feet was observed to be perched on a lakebed deposit of varved clayey silt.

Seismic refraction results show that the soils have P-wave velocities in the range of about 2,000 to 9,000 fps. The velocities increase with depth indicating increasing densities. Bedrock at the north end of the impoundment was found to have a velocity of about 10,500 fps. Velocities greater than this value may indicate bedrock. Based on

TABLE 6.2

POORMAN SITE

SUMMARY OF FIELD PERMEABILITY TEST RESULTS

Boring or Well	Material	Type of Test	Permeability (cm/sec)
USA-1	Silty sand	Constant Head	$<1 \times 10^{-6}$
USA-2	Gravelly silty sand	Constant Head	3×10^{-4}
USB-4	Gravelly silty sand	Constant Head	$<1 \times 10^{-6}$ to 7×10^{-4}
	Sandy silty gravel	Constant Head	2×10^{-6} to 5×10^{-6}
PM-2[a] and	Silty gravel with	Pump Test	2×10^{-3} to 4×10^{-3}
PM-2OB[a]	cobbles and boulders		
PM-3[a]	Silty gravel and silt	Slug Test	5×10^{-4}
PM-5[a]	Interlayered gravel and silt	Flow Test (Constant Drawdown)	1×10^{-5}
PLCM-6[a,b] (shallow)	Silty sandy gravel	Slug Test	2×10^{-3}
PLCM-6[a,b] (deep)	Silty sandy gravel	Flow Test (Constant Drawdown)	5×10^{-3} to 7×10^{-3}

Notes:

a. From Chen-Northern (1989)

b. North of impoundment site, in small creek channel.

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the results of Chen-Northern's resistivity data and MKE's seismic refraction surveys, bedrock could be more than 200 feet deep in the eastern part of the site (see Figures 8, 9 and 10).

C. Midas Site

1. Site Conditions - The site is located in a northerly trending valley that drains into Libby Creek. The valley lies along the edge of the glacial flood plain that originated along the eastern slope of the Cabinet Mountain Range. The valley therefore does not contain as much glacial debris as the easterly oriented valleys.

The highest point in the watershed is at El. 5,660. Portions of the site are clear cut and others are heavily timbered. Access to the site is via Forest Service roads, about 7 miles west of U.S. Route 2.

Weathered rock outcrops were observed on the east side of the valley and in the stream channel downstream of the site. The left abutment consists of gravelly silt at the surface. Lakebed sediments occur as terraces on both sides of the actively eroding stream. The lakebed sediments are mostly fine grained silt and varved clay with some gravel.

Two suspected landslides were mapped in clearcut areas on both abutments at the lower impoundment site (Figure 11). These suspected slides were located in clearcut areas on both abutments. No evidence of recent movement was observed. Avalanche chutes were not observed in the Midas site.

2. Subsurface Conditions - Bedrock outcrops were mapped along a road cut on the east side of the valley and a few outcrops were mapped near the valley bottom near the lower dam axis (see Figure 11). Shallow bedrock was found near the valley bottom at boring location MCDH-4, where a stream eroded the soil materials. Outcrops were also mapped along Libby Creek, west of the west abutment. The results of seismic refraction surveys indicate that the bedrock surface is less than 50 feet deep in the west abutments of both axis locations (see Figures 12 and 13). Due to access limitations, borings could not be drilled on the west side of the valley.

Bedrock at the east abutment locations (in Borings MCDH-3 and 7) and valley bottom (Boring MCDH-4) consists of highly weathered to slightly weathered argillite. The fracture spacing in the core generally ranged from 1 to 6 inches. Core recoveries varied from 60 to 100% and RQD values ranged from 0 to 67%; these RQD values indicate that zones of poor rock conditions are present. The degree of weathering was least pronounced at Boring MCDH-7.

Lacustrine deposits at the Midas site, consisting of silty and clayey soils with some gravels, were found to be more than 100 feet thick (see Figure 14). Several samples were varved or were interbedded clayey, silty or fine sandy soils. Unconfined compression test results on six undisturbed Shelby tube samples show undrained shear strength values ranging from 1,000 to 4,000 pounds per square foot (psf). These values indicate that the soils are generally stiff to very stiff.

The results of the exploration program show that more fine grained soils exist at the Midas site than at either the Little Cherry site or Poorman site. The lowest SPT value was 15, and because of the predominantly fine grained soils at the Midas site, the boring logs show that the blow counts are generally less than those at the other two impoundment sites.

The laboratory test results show that fines content generally ranges from 21 to 100% (see Figure F-3, Appendix F). The soils have low plasticity; liquid limits range from 23 to 44 and plasticity indices range from 3 to 19 (Figure F-6, Appendix F). These plasticity test values are similar to those found at the Poorman site, but are somewhat greater than those found at the Little Cherry site. Dry densities of soil samples vary from 93 to 115 pcf. Natural moisture contents range from 10 to 31%, which, because of the finer material gradation, are higher than those measured at the other two sites. Moisture-density test (ASTM D698) results on four test pit samples show maximum dry densities between 103 and 123 pcf; the optimum moisture contents range from 10 to 21%. The test results show that the natural water contents of the soils exceed the optimum moisture content by 3 to 6%, indicating that the soils will need to be dried for embankment construction.

The results of field permeability tests are summarized in Table 6.3. Due to the fine-grained composition of the lacustrine soils, the permeability values are low; measured permeabilities range from less than 1×10^{-6} to 4×10^{-6} cm/sec. The

TABLE 6.3

MIDAS SITE

SUMMARY OF FIELD PERMEABILITY TEST RESULTS

Boring	Material	Type of Test	Permeability (cm/sec)
MCDH-2	Silty sand	Constant Head	6×10^{-5}
	Silty sand	Constant Head	2×10^{-6} to 3×10^{-6}
MCDH-3	Moderately to highly weathered rock	Packer Test	2×10^{-6} to 3×10^{-4}
MCDH-4	Slightly to moderately weathered rock	Packer Test	$<1 \times 10^{-6}$
MCDH-6	Sandy silt	Constant Head	$<1 \times 10^{-6}$
	Sandy silty clay-clayey silt	Constant Head	$<1 \times 10^{-6}$ to 4×10^{-6}
MCDH-7	Slightly weathered rock	Packer Test	2×10^{-6} to 4×10^{-6}
MCDH-8	Sandy silty gravel	Constant Head	$<1 \times 10^{-6}$
	Sandy silty clay	Constant Head	$<1 \times 10^{-6}$

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permeability of silty sand in Boring MCDH-2 is about one or two orders of magnitude higher (6×10^{-5} cm/sec). Because of the predominantly fine soils at the Midas site, the soils are generally less pervious than those at the other two impoundment sites. The results of packer tests show that the rock generally has low permeability values, ranging from less than 1×10^{-6} to 4×10^{-6} cm/sec. In the upper part of Boring MCDH-3, the permeability was measured to be 3×10^{-4} cm/sec, indicating moderately pervious bedrock.

In November 1988, groundwater depths were measured between 20 and 84 feet in the borings. Local seepage at a depth of 7.5 feet was observed in Test Pit TP-508. Measurements in Borings MCDH-2, 6 and 8 show that the water levels were at or below the stream level in November. These data suggest that the stream is discharging into the groundwater system during the autumn months.

The seismic refraction survey results show that soils have compressional wave velocities ranging from 1,000 to 6,000 fps. These velocities are lower than those measured at the other two sites. Bedrock was found to have velocities ranging from 9,400 to 13,800 fps, which are similar to the velocities measured at the two other sites.

6.2 PLANT AND MINE PORTAL SITES

A. Libby Creek

1. Site Conditions - The Libby Creek valley in the area of the plant and portal sites is characterized by steep rock slopes to within about 200 feet of the valley floor where increasing thicknesses of colluvium and glacial gravels mantle the lower valley slopes. Rock outcrops were observed in the stream channel. The rock on the slopes and in the channel consists of slightly weathered, hard, widely fractured meta-sedimentary rock with a steep westerly dip.

The plant site can be located in a triangular clear-cut area on the south side of Libby Creek at about El. 4,250. Foundation conditions may be a combination of bedrock or glacial outwash and talus overlying bedrock. No landslides or unstable slopes were

observed in this area. Several snow chutes with lengths between 1,000 and 2,000 feet exist on the southwest side of the plant area (Figure 15); these chutes should be avoided. Also, several long avalanche chutes (about 5,000 feet long) exist on the north side of the valley that will affect access roads in this area. The elevation differences between the tops of these chutes and the plant site are sufficiently great (about 2,400 feet) that avalanches originating in them could possibly override Libby Creek and move uphill into the plant site.

The portal could be located in a stand of timber on the north side of the valley and about 300 feet from the wilderness boundary. Bedrock was not found in the portal area, although one large rock exposure (possibly a boulder) was found near the site. Slopes above the portal appear stable and no snow avalanche chutes are locally present.

Surface water follows well defined channels on both sides of the plant site. In the valley bottom, some marshy areas exist where bedrock is shallow. Occasional seeps were noted on the slopes along the north side of the valley.

2. Subsurface Conditions - The Libby site exploration plan and geologic sections are shown on Figures 16 and 17, respectively. The results of the exploration indicate that the Libby plant site is covered with dense silty sandy gravelly soils with cobbles and boulders. The results of grain size tests show that two soil samples contain 17 and 18% silty fines. Boulders were observed in the test pits to be as large as 3 feet and based on visual estimates, account for as much as 15 to 20% of the soil volume. In addition, large (approximately 6 feet) boulders were observed at the surface between Test Pits TP-402 and TP-404.

Boring LCDH-2 may have penetrated bedrock at a depth of about 30 feet. The rock was drilled to a depth of about 7 feet before coring started. About 6 feet of core drilling was done. The rock quality was good: 100% of the core was recovered and the RQD was 78% and 100% for the two core runs. The seismic refraction results show that velocities in the range of 16,000 to 19,000 fps, which suggest bedrock, were measured for depths typically ranging from 30 to 70 feet. These depths correspond to the suspected bedrock depth indicated in Boring LCDH-2.

Due to lack of access, drilling was not done at the portal site. However, two seismic refraction surveys were conducted at the portal site. The results indicate that a 13,000 to 15,000 fps refractive layer, probably indicating bedrock, was found at depths ranging from approximately 30 to 65 feet.

The depths to groundwater in Borings LCDH-2 and 3 were measured at 12 and 16 feet, respectively. Groundwater was not found in the test pits. Groundwater measurements have not yet been made in LCDH-1.

B. Ramsey Creek

1. Site Conditions - The Ramsey Creek valley at the plant location resembles Libby Creek plant site except that the avalanche danger at this site is significantly less (Figure 15).

On the north slope of the valley, rock outcrops were observed several hundred feet above the valley floor, and on the south slope, rock is probably shallow. The rock on the slopes and in the channel consists of hard, widely jointed meta-sedimentary rock similar to that at Libby Creek. The lower portions of the slopes are covered with colluvium, talus and glacial outwash, and the slopes are heavily wooded. The valley floor is marshy below the portal and plant sites where glacial outwash and alluvium overlie bedrock at shallow depth.

The plant site is located in an elevated area on the north side of the valley at about El. 4,440. The area is mostly clear-cut and no snow avalanche chutes were observed above the site. Colluvium and glacial outwash cover the site to shallow depths and southeast of the site, bedrock outcrops were found in the creek channel.

At the portal location, the rock is exposed in a steep face that can be adapted for a portal. Talus that exists at the portal will need to be graded to make a tunnel entrance and working area. Several short snow chutes are present near the portal that will need to be avoided when the portal location is finally selected. Access roads may be affected by the snow chutes for short distances on the south side of the valley.

Surface water is confined to well defined channels. Marshy areas exist in the Ramsey Creek channel, especially below the portal site.

2. Subsurface Conditions - The Ramsey site exploration plan and geologic sections are shown on Figures 18 and 19, respectively. Subsurface conditions at Ramsey are similar to those at the Libby site. The exploration results show that dense silty sandy gravelly soils with cobbles and boulders cover the site. Grain size tests show that two soil samples contain 19 and 25% silty fines. Boulders found in the test pits were observed to be as large as 3 feet and, by visual estimates, account for as much as 25% of the soil volume.

Three borings were drilled at the plant site. Bedrock may have been found in Boring RCDH-1 at a depth of 41 feet; bedrock was not found in the two other borings. The core recoveries were 78 and 79%, except between 49 and 53 feet, where the recovery was 23%. RQD's were low and range from 0 to 56%, indicating poor rock quality. It was not definitely determined if bedrock or boulders were found. The seismic velocities are lower at Ramsey than they are at Libby: the velocities range from 9,000 to 14,000 fps below depths of 24 to 70 feet. These velocities may indicate bedrock or very dense bouldery ground.

Bedrock is exposed in the Ramsey portal site. Seismic refraction surveys were performed in the talus slope below the bedrock face. High velocities (about 20,000 fps) indicating bedrock were estimated at the portal site below depths of 40 to 60 feet. Drilling was not done at this site due to inadequate access.

Groundwater was measured in Boring RCDH-1 at a depth of 22 feet. Groundwater was not encountered in Boring RCDH-3 or in the test pits. Groundwater measurements could not be made in RCDH-2 because the hole caved.

6.3 EVALUATION ADIT SITES

A. Heidelberg Tunnel

The portal for the proposed evaluation adit could be located at the head of Rock Creek Meadow at about El. 4,100 and adjacent to a steep waterfall section of Rock Creek

(Figure 20). The portal site is about 900 feet lower in elevation than Rock Lake. Access to the portal is by a recently improved 4-wheel drive road. An adit about 700 feet long exists at this location. A dump exists for muck disposal immediately downstream of the existing portal.

The entire area is underlain by meta-sedimentary rock of the Belt Supergroup (mostly argillite and siltite). Fill has been placed at the portal approach to facilitate tunnel access. Except for local small talus slopes and some vegetation, bare rock is exposed at the surface. The rock at the portal is unweathered, hard, sound, widely jointed and foliated at steep angles striking to the northwest. The joint and foliation planes strike both normal and parallel to the existing adit (which is N58° E), and dip at steep angles (74° to 87° W). A third joint set may be a near-surface stress relief feature. This set strikes subparallel to the slope and dips at low angles to the south (10° to 30°). Other random sets also exist.

An important geologic feature affecting evaluation adit construction is the Rock Lake fault zone (Figure 20). The fault is not a distinct break but instead may be fracture zones several tens of feet wide. The zone is near vertical and is oriented NW-SE. Its effect on the evaluation adit is twofold: badly fractured zones could require special support (probably steel sets) and groundwater under pressure could be encountered that will need to be handled either by draining to relieve pressures or by grouting. To lessen the effect of groundwater in the excavation, the adit can be driven at an inclined grade to facilitate gravity drainage. Initial flush flows of large volume should be anticipated but steady flows should be less and are a function of fracture permeability and hydraulic head. Once the fault zone is crossed, the rock would be expected to again resemble the rock near the portal of the existing adit.

A geotechnical inspection of the Heidelberg tunnel was conducted on 9 August 1988. Features that were noted and mapped included general rock conditions, major joint sets, shear zones, and locations of water inflows. The tunnel has a rough modified horseshoe cross section, approximately 4 to 6 feet wide by 7 to 8 feet high. Debris left over from mining activity remains in the tunnel, particularly near the face at Station 7+00.

Reference for mapping was made by stringing a 100 foot cloth tape along the southeast wall beginning at Station 0+00 just inside the portal. The geologic map is presented on Figure B-1, Appendix B.

Both the adit and portal appear stable. At the time of this inspection, there were very few fallen rocks and the standup time appeared to be indefinite even at Station 3+77, where the span was about 10 feet. Short side drifts at Station 3+77 follow a major shear zone. Other similar shear zones could be encountered along the adit route. Several large rock blocks and small collapses had occurred in the southern drift. There are a few other localized unstable areas such as at Stations 6+10 and 6+87. There is minor timber in the tunnel but no significant roof support.

The rock is hard, dark gray, foliated argillite, little weathered with occasional iron oxide staining and alteration concentrated along some of the joints of the most abundant joint set. The orientation of this set is NNW, similar to that of the foliation. Typical spacing of joints and fractures is moderate at 6 to 12 inches and the Terzaghi rock condition generally varies from 3 (hard stratified or schistose) to 4 (moderately blocky and seamy, firm ground). A stereographic plot of discontinuities in the adit is shown on Figure B-2, Appendix B.

Water flowed into the adit as minor seeps and drips downstream of Station 5+00. Leaks became more frequent upstream of Station 5+00 and flows primarily emerged from open joints of the NNW-oriented set (joints parallel to the foliation). Most of the water in the tunnel entered at Station 6+87 where an estimated 50 gpm was flowing from an old horizontal drill pipe in the left rib. This drill hole was reportedly 130 feet long and originally flowed at 200 to 250 gpm. There is no available record of the location in the drill hole at which water was encountered. An additional 20 gpm flowed from an open joint at the base of the right wall at Station 6+87. The total flow of water in the tunnel was estimated to be about 80 gpm.

B. South End of Rock Lake

The portal for the proposed evaluation adit could be located at the southeast end of Rock Lake at about El. 4,975 in a steep area between two coalescing talus slopes (Figure 20). An access road would need to be constructed down to the portal from the

existing 4-wheel drive trail above. Both the new and existing access road would be subjected to avalanche danger. Two avalanche chutes were also observed in the portal area (Figure 20).

The bedrock consists of meta-sedimentary Belt Supergroup series and generally is exposed, except locally, where it is covered by talus. The rock is somewhat weathered, but is hard, sound, widely jointed and foliated. On the east side of Rock Lake the general trend of the rock mass is parallel to the lake and dipping toward the lake at variable angles from steep to vertical. This orientation tends to promote instability of the slope, and rock slides and resulting talus are common.

The portal could be located between two talus slopes in an area slightly above the level of the lake that is mostly protected from rock falls and snow slides. The seismic refraction survey results indicate that as much as 50 feet of talus would need to be removed to reach a rock face for the portal, and side slopes along the approach would need to be stabilized. Permanent protection of the adit portal would also be needed.

The hardness and widely spaced fracturing of the rock should result in good tunneling conditions with minimal support. No known faults would be intersected by an evaluation adit driven from this location but some groundwater could be expected in the joint system especially as the adit is driven down-dip below lake level.

A disposal and working area could be developed in the relatively flat ground at the tip of the lake. This area is underlain by bedrock, with talus slopes to the south.

C. Upper Heidelberg Road

The portal for the proposed evaluation adit could be located along the existing access road to Rock Lake at about El. 5,125 in an area where a short tunnel already exists (Figure 20). This location is about 170 feet higher than Rock Lake.

The bedrock consists of meta-sedimentary Belt Supergroup series of rock mostly exposed at the surface. The near surface rock at this location is badly weathered and jointed and the existing adit was supported with timbers that are now in bad repair.

The tunnel would begin at a portal adjacent to the Rock Lake fault but on the easterly side so that the alignment would not cross the fault. Groundwater will probably be present in the tunnel in small quantities but should not present unusual difficulties even though the tunnel will need to be constructed down-dip.

Some talus boulders occur on the slope above the existing adit portal but overall stability of the slope is good. Avalanche danger does not appear to be a problem at the portal, but several avalanche chutes are present along the access road (Figure 20).

REFERENCES

1. Algermissen, S.T., Perkins, D.M., Thenhaus, P.C., Hanson, S.L., and Bender, B.L., Probabilistic Estimates of Maximum Acceleration and Velocity in Rock in the Contiguous United States: U.S. Geological Survey Open-File Report 82-1033, 1982.

2. Campbell, K.W., Near-source Attenuation of Peak Horizontal Acceleration: Bulletin of the Seismological Society of America, Vol. 71, No. 6, pp. 2039-2070, 1981.

3. Camp, Dresser & McKee, Inc., Technical Review of Preliminary Tailings Dam Design, Asarco Rock Creek Project: Consultant's Report to Asarco, Inc, 1988.

4. Chen-Northern, Montana Project, Hydrology Investigation Report, 1989.

5. Idriss, I.M., Evaluating Seismic Risk in Engineering Practice: Proceedings of the 11th International Conference on Soil Mechanics and Foundation Engineering, San Francisco, Vol. 1, pp. 255-320, 1985.

6. Joyner, W.B., and Boore, D.M., Prediction of Earthquake Response Spectra: U.S. Geological Survey Open-File Report 82-977, 1982.

7. Montana Bureau of Mines and Geology, Montana in the Geologic Past, Bulletin 26, 1962.

8. Morrison-Knudsen Engineers Inc. (MKE), Montana Project, Tailings Impoundment Preliminary Engineering Report, 1989.

9. Qamar, A.I. and Stickney, M.C., Montana Earthquakes, 1869-1979: Montana Bureau of Mines and Geology Memoir 51, 1983.

10. Seed, H.B., "The Selection of Design Earthquakes for Critical Structures," Bulletin of the Seismological Society of America, Vol. 72, No. 6, December 1982.

11. Slemmons, D.B., Determination of Design Earthquake Magnitudes for Microzonation: Proceedings of the Third International Earthquake Microzonation Conference, Vol. 1, pp. 255-320, 1982.

12. Stickney, M.C., Montana Bureau of Mines and Geology, telephone conversation with F. C. Kintzer, Morrison-Knudsen Engineers, Inc., June 15, 1988.

13. Stover, C.W., The Borah Peak, Idaho Earthquake of October 28, 1983 - Isoseismal Map and Intensity Distribution: Earthquake Spectra, Vol. 2, No. 1, pp. 11-16, 1985.

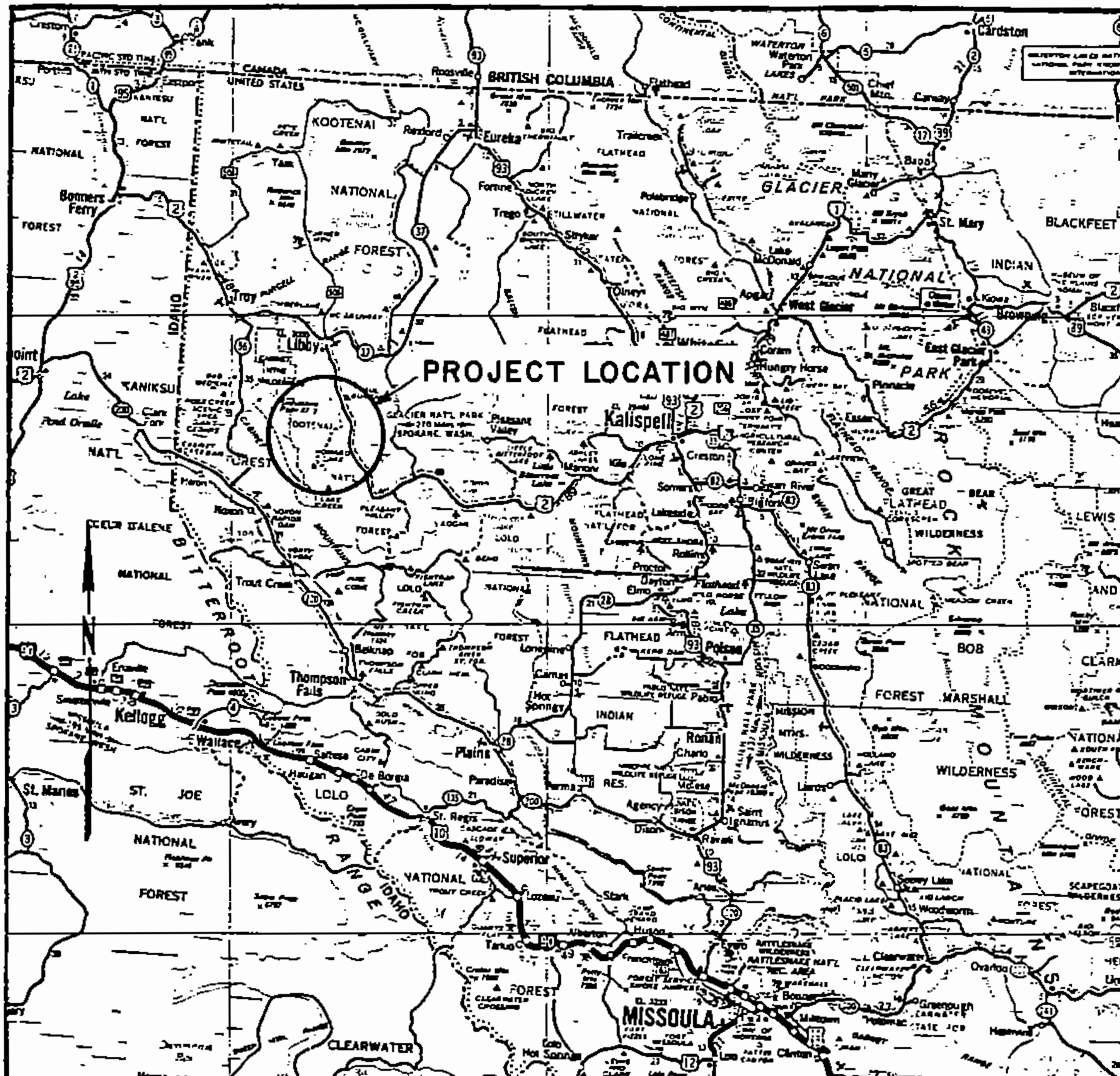
14. U. S. Bureau of Reclamation, Earth Manual, second edition, 1974.

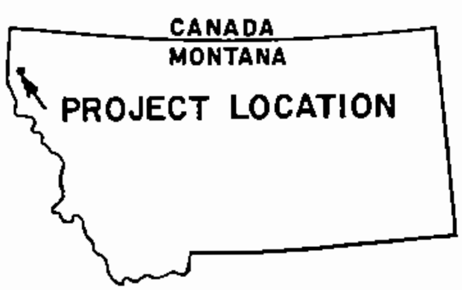
15. U. S. Corps of Engineers, Office of the Chief of Engineers, Earthquake Design and Analysis for Corps of Engineers Dams: Regulation No. ER1110-2-1806, 1977 (Rev. Spring 1982).

16. U. S. Geological Survey and U. S. Bureau of Mines, Mineral Resources of the Cabinet Mountain Wilderness, Lincoln and Sanders Counties, Montana, Geological Survey Bulletin 1501, 1981.

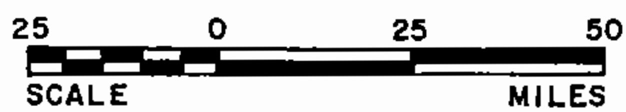
17. Witkind, I.J., Preliminary Map Showing Known and Suspected Active Faults in Western Montana: U.S. Geological Survey Open-File Report 75-285, 1975.

18. Witkind, I.J., Major Active Faults and Seismicity, Northwestern Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF-923, 1977.





KEY PLAN



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DATE OCTOBER 1988			APPROVED

MONTANA PROJECT

PROJECT LOCATION MAP

FIGURE 1

LITTLE CHERRY IMPOUNDMENT SITE (FIGURE 4)

MIDAS IMPOUNDMENT SITE (FIGURE 11)

POORMAN IMPOUNDMENT SITE (FIGURE 7)

LIBBY PLANT SITE (FIGURE 16)

RAMSEY PLANT SITE (FIGURE 18)

LIBBY AND RAMSEY SITES (FIGURE 15)

SOUTH END OF ROCK LAKE ADIT SITE

UPPER HEIDEBERG ROAD ADIT SITE

LOWER HEIDEBERG ADIT SITE

EVALUATION ADIT SITES (FIGURE 20)

REFERENCES:

U.S. GEOLOGICAL SURVEY, 7.5 MINUTE TOPOGRAPHICAL QUADRANGLES:

- HOWARD LAKE
- CABLE MOUNTAIN
- ELEPHANT PEAK
- SNOWSHOE PEAK

2000 0 2000 4000
SCALE FEET

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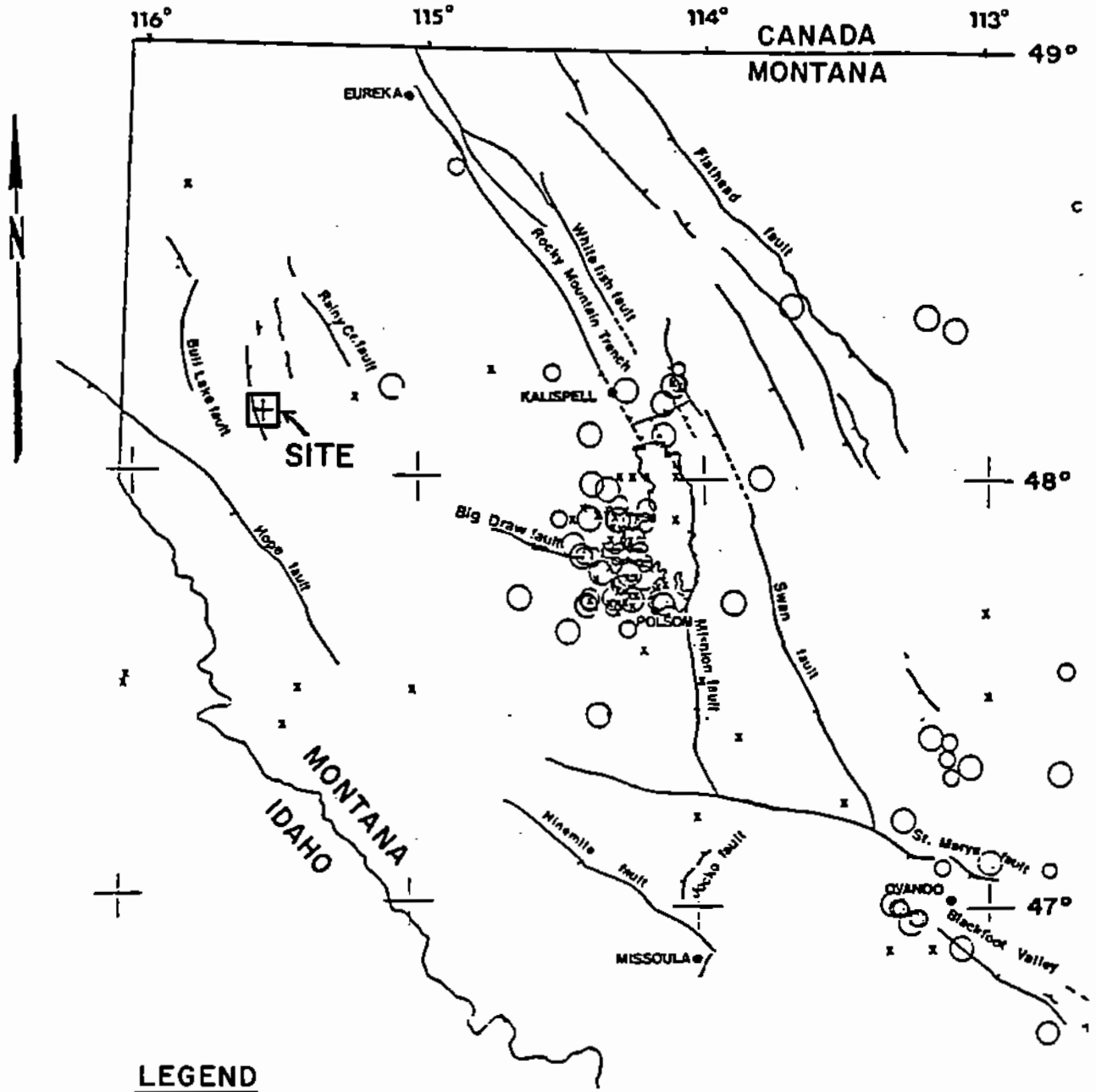
MONTANA PROJECT

VICINITY PLAN

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—barb 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

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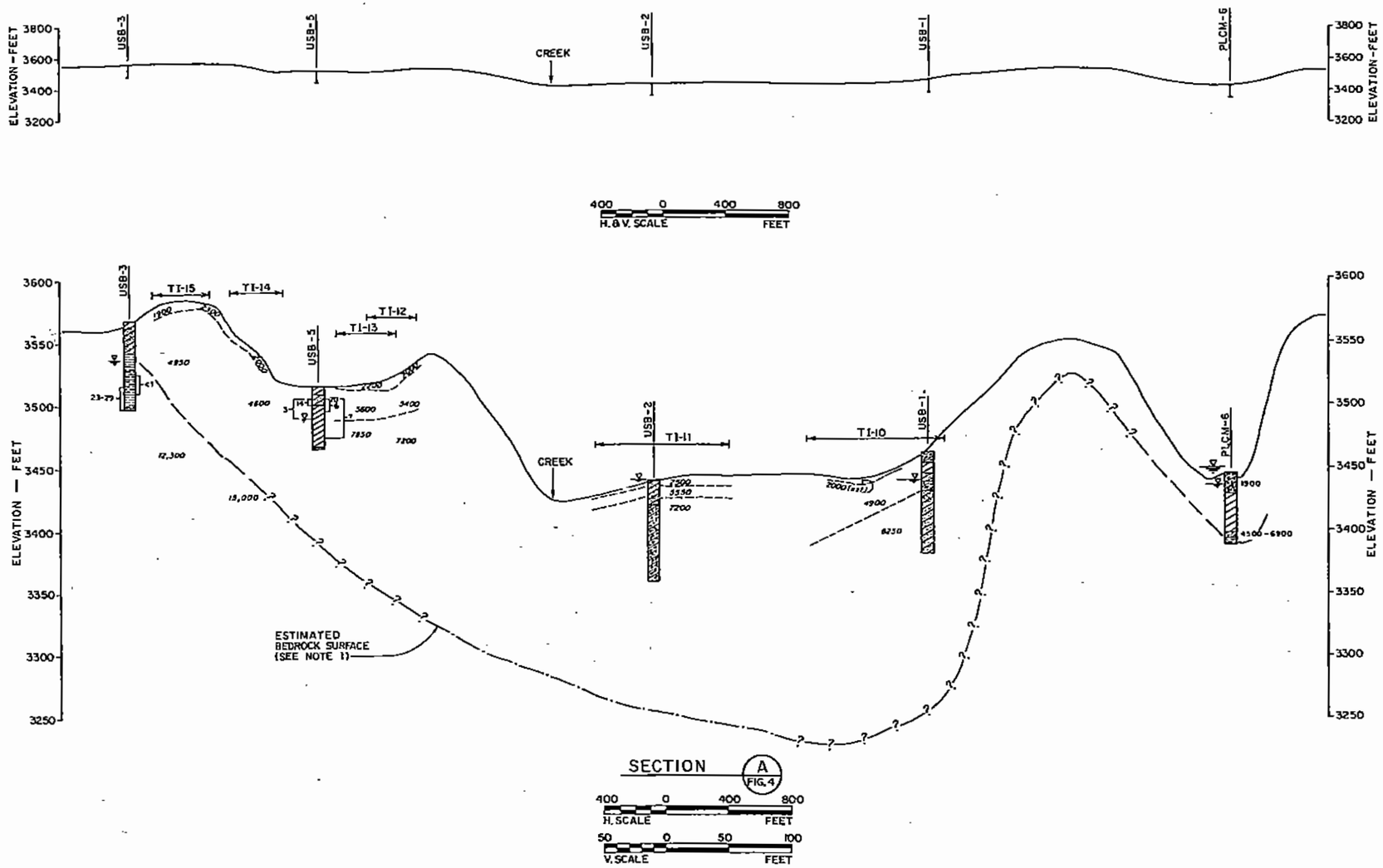
MONTANA PROJECT

HISTORICAL EARTHQUAKES IN MONTANA, 1869-1979

FIGURE 3



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 C FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX D FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX E FOR TEST PIT LOGS.

LEGEND:

- USB-1 — BORING
- ML, ML-CL* — PIEZOMETRIC SURFACE
- SW, SP* — PERMEABILITY VALUES (x 10^{-4} CM/SEC)
- SM*
- GM, GM-GP*
- ARGILLITE
- WEATHERED BEDROCK
- QUARTZITE
- 2300/4000 — SEISMIC VELOCITY (FT./SEC.) SHOWING APPROX. VELOCITY INTERFACES
- TI-16 — SEISMIC LINE
- TI-12 — SEISMIC LINE TRANSVERSE TO SECTION
- TP — TEST PIT
- ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA
- ESTIMATED BEDROCK PROFILE FROM NORTHERN ENGINEERING & TESTING (INTERPRETED FROM APPARENT RESISTIVITY)

*UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (SEE APPENDICES)

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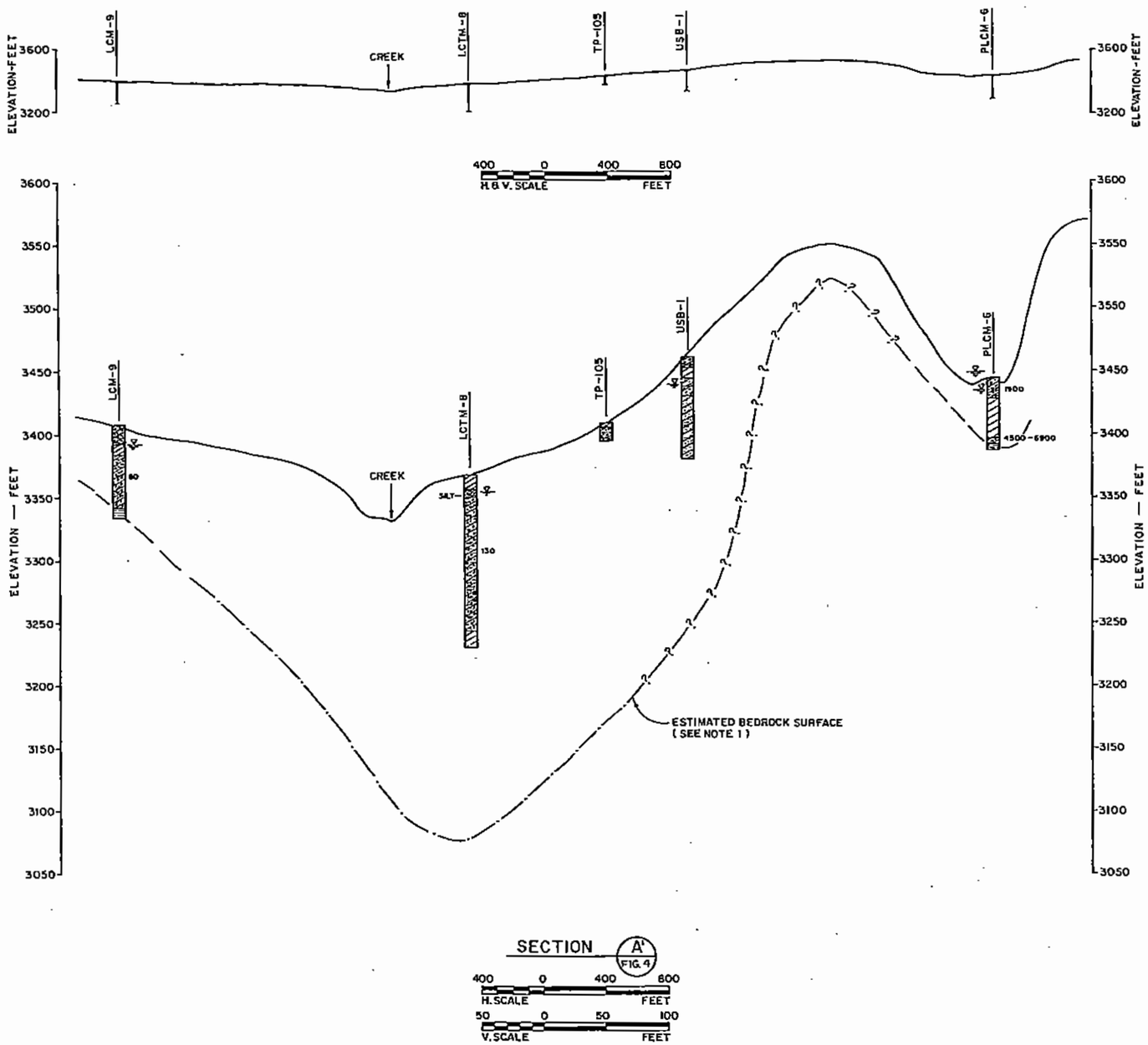
MONTANA PROJECT
LITTLE CHERRY SITE
GEOLOGIC SECTION A

MKE NO.
SHEET 1 OF 2 REV.
FIGURE 5



SECTION A¹ (FIG. 4)

400 0 400 800
H. SCALE FEET

50 0 50 100
V. SCALE FEET

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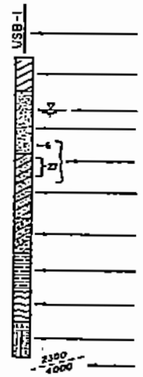
LEGEND:



BORING

ML, ML-CL*

PIEZOMETRIC SURFACE

SW, SP*

PERMEABILITY VALUES (x 10^{-4} CM/SEC)

SM*

GM, GM-GP*

ARGILLITE

WEATHERED BEDROCK

QUARTZITE

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

SEISMIC LINE

SEISMIC LINE TRANSVERSE TO SECTION

TEST PIT

ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA

ESTIMATED BEDROCK PROFILE FROM NORTHERN ENGINEERING & TESTING (INTERPRETED FROM APPARENT RESISTIVITY)

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (SEE APPENDICES)

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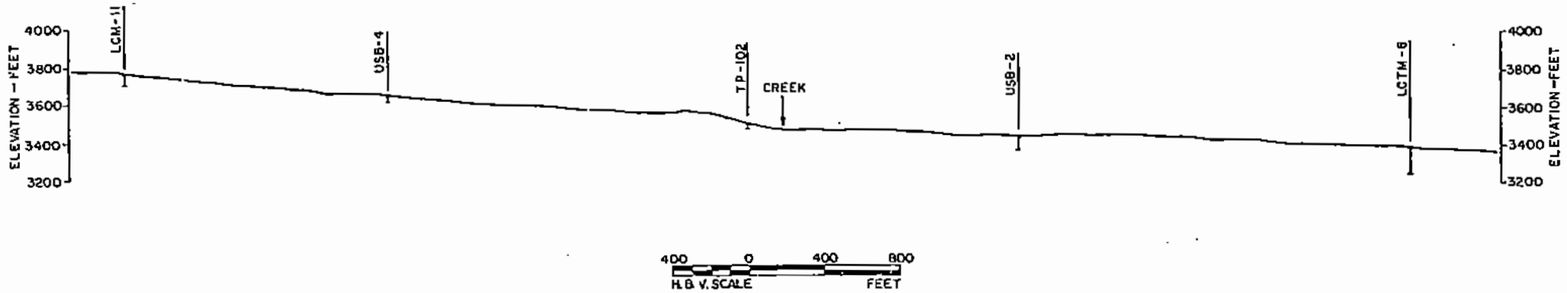
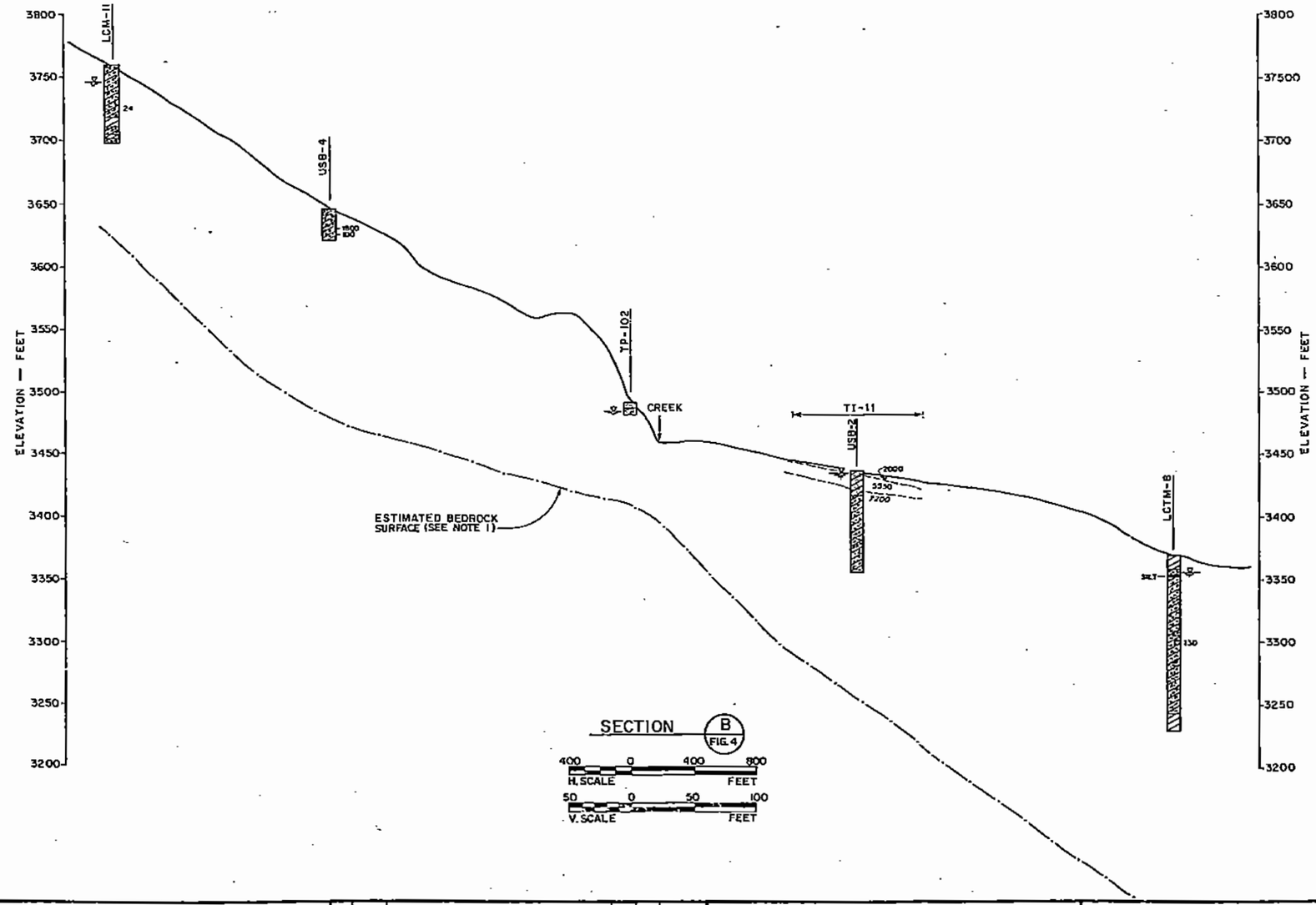
MONTANA PROJECT

LITTLE CHERRY SITE GEOLOGIC SECTION A¹

MKE NO.
SHEET 2 OF 2 REV.
FIGURE 5





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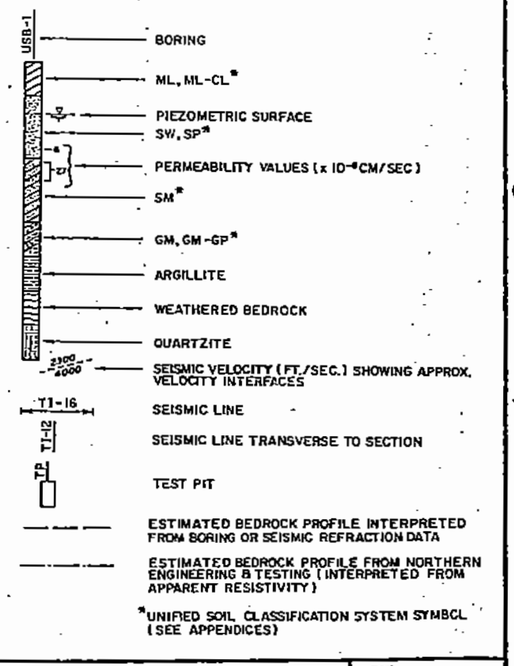

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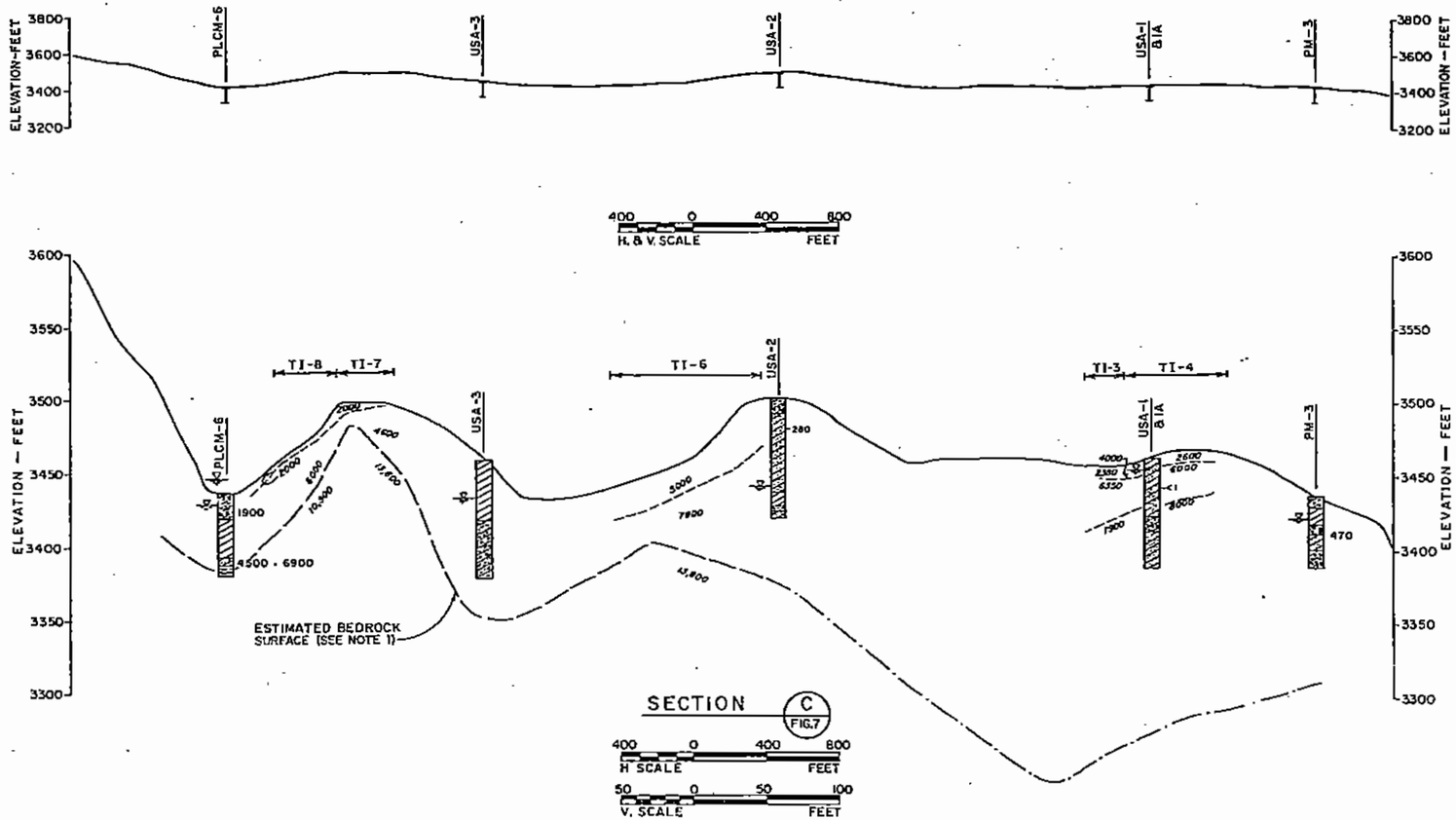
MONTANA PROJECT

LITTLE CHERRY SITE GEOLOGIC SECTION B

MKE NO.
SHEET OF REV.
FIGURE 6



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LEGEND:

- BORING
- ML, ML-CL*
- PIEZOMETRIC SURFACE
- SW, SP*
- PERMEABILITY VALUES (x 10^{-6} CM/SEC)
- SM*
- GM, GM-GP*
- ARGILLITE
- WEATHERED BEDROCK
- QUARTZITE
- SEISMIC VELOCITY (FT./SEC.) SHOWING APPROX. VELOCITY INTERFACES
- SEISMIC LINE
- SEISMIC LINE TRANSVERSE TO SECTION
- TEST PIT
- ESTIMATED BEDROCK PROFILE INTERPRETED FROM BORING OR SEISMIC REFRACTION DATA
- ESTIMATED BEDROCK PROFILE FROM NORTHERN ENGINEERING & TESTING (INTERPRETED FROM APPARENT RESISTIVITY)

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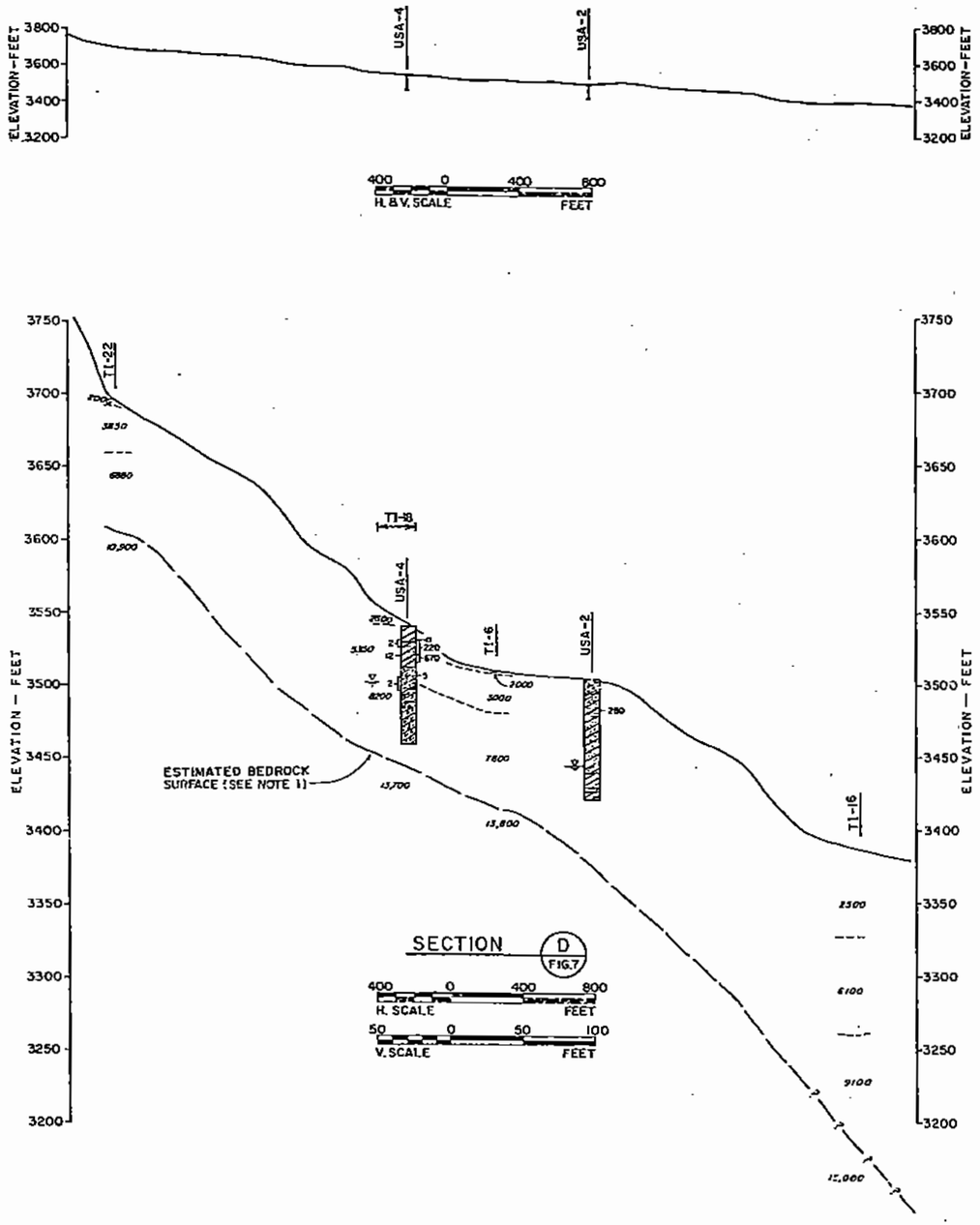
MONTANA PROJECT
POORMAN SITE
GEOLOGIC SECTION C

JOB NO
SHEET OF REV.
FIGURE 8



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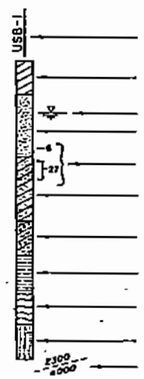

- BORING
- ML, ML-CL*
- PIEZOMETRIC SURFACE
- SW, SP*
- PERMEABILITY VALUES (x 10^{-4} CM/SEC)
- SM*
- GM, GM-GP*
- ARGILLITE
- WEATHERED BEDROCK
- QUARTZITE
- 2300 / 4000 — SEISMIC VELOCITY (FT./SEC.) SHOWING APPROX. VELOCITY INTERFACES
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* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (SEE APPENDICES)

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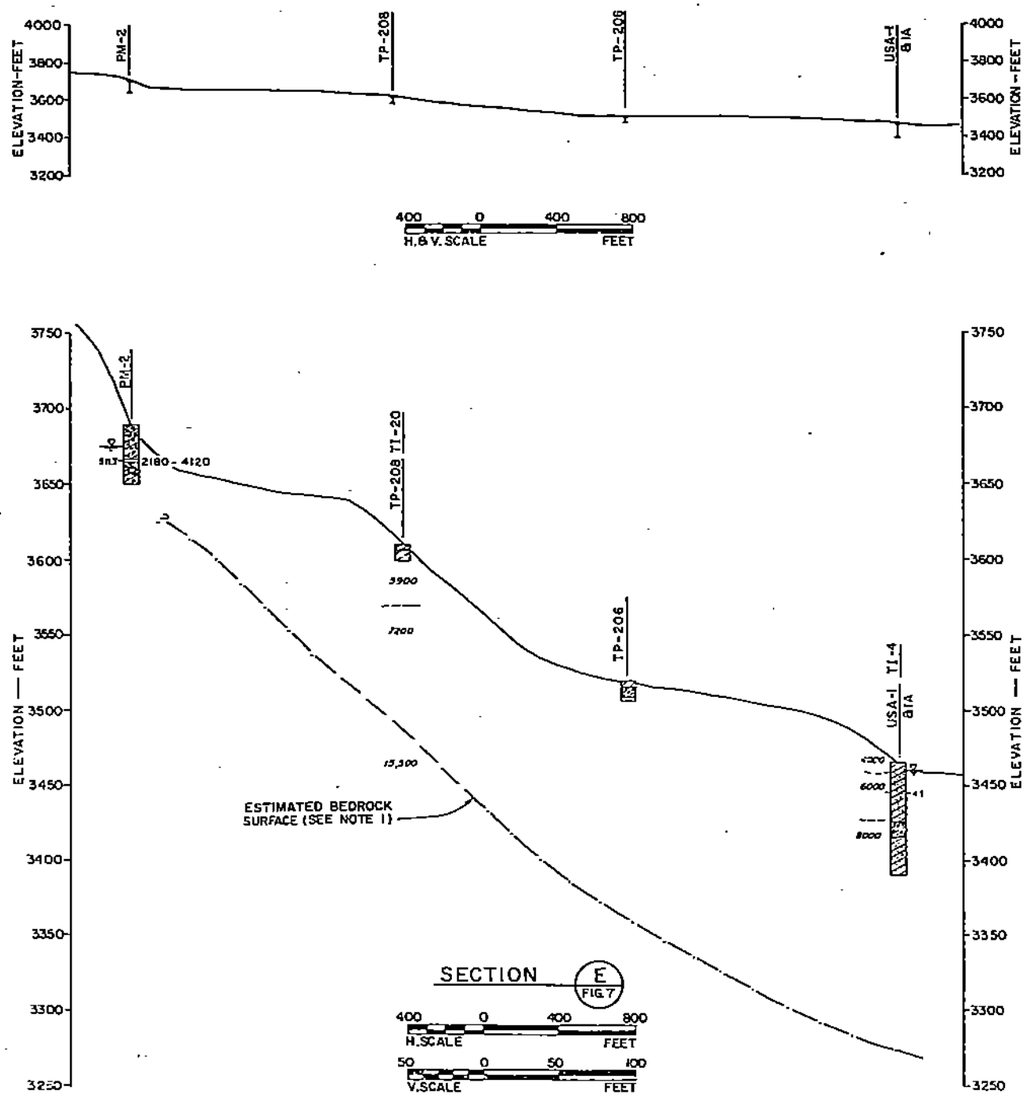
MONTANA PROJECT
POORMAN SITE
GEOLOGIC SECTION D

MKE NO
SHEET OF REV.
FIGURE 9



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LEGEND:

- BORING
- ML, ML-CL*
- PIEZOMETRIC SURFACE
- SW, SP*
- PERMEABILITY VALUES (x 10^{-4} CM/SEC)
- SM*
- GM, GM-GP*
- ARGILLITE
- WEATHERED BEDROCK
- QUARTZITE
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*UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (SEE APPENDICES)

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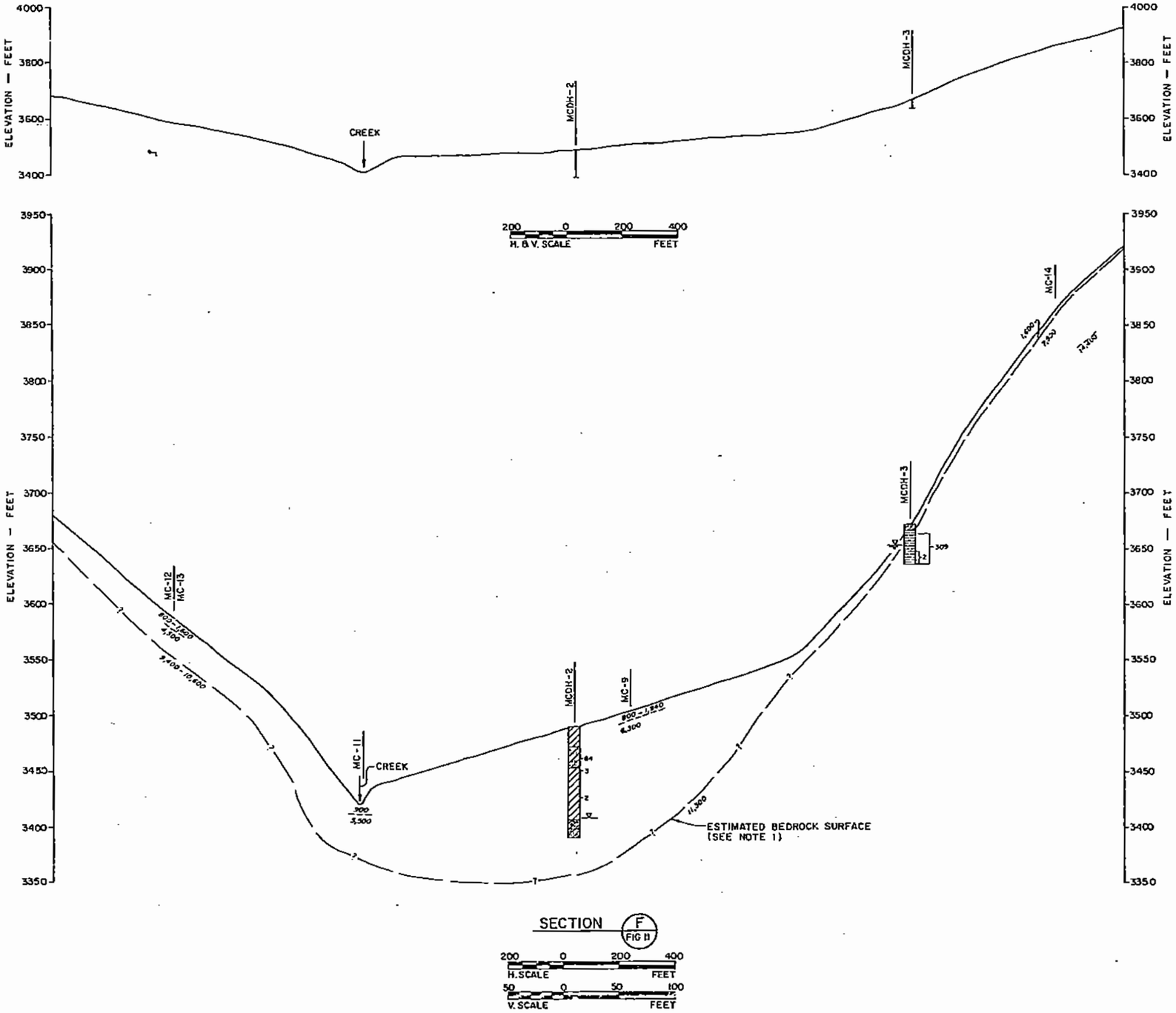
MONTANA PROJECT

POORMAN SITE GEOLOGIC SECTION E

KCO NO.
SHEET OF REV.
FIGURE 10



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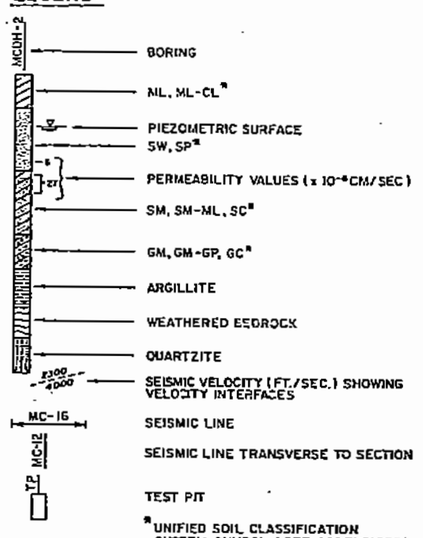
LEGEND:



*UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (SEE APPENDICES)

NO.	DATE	REVISIONS	BY	CHK.	APP'D.

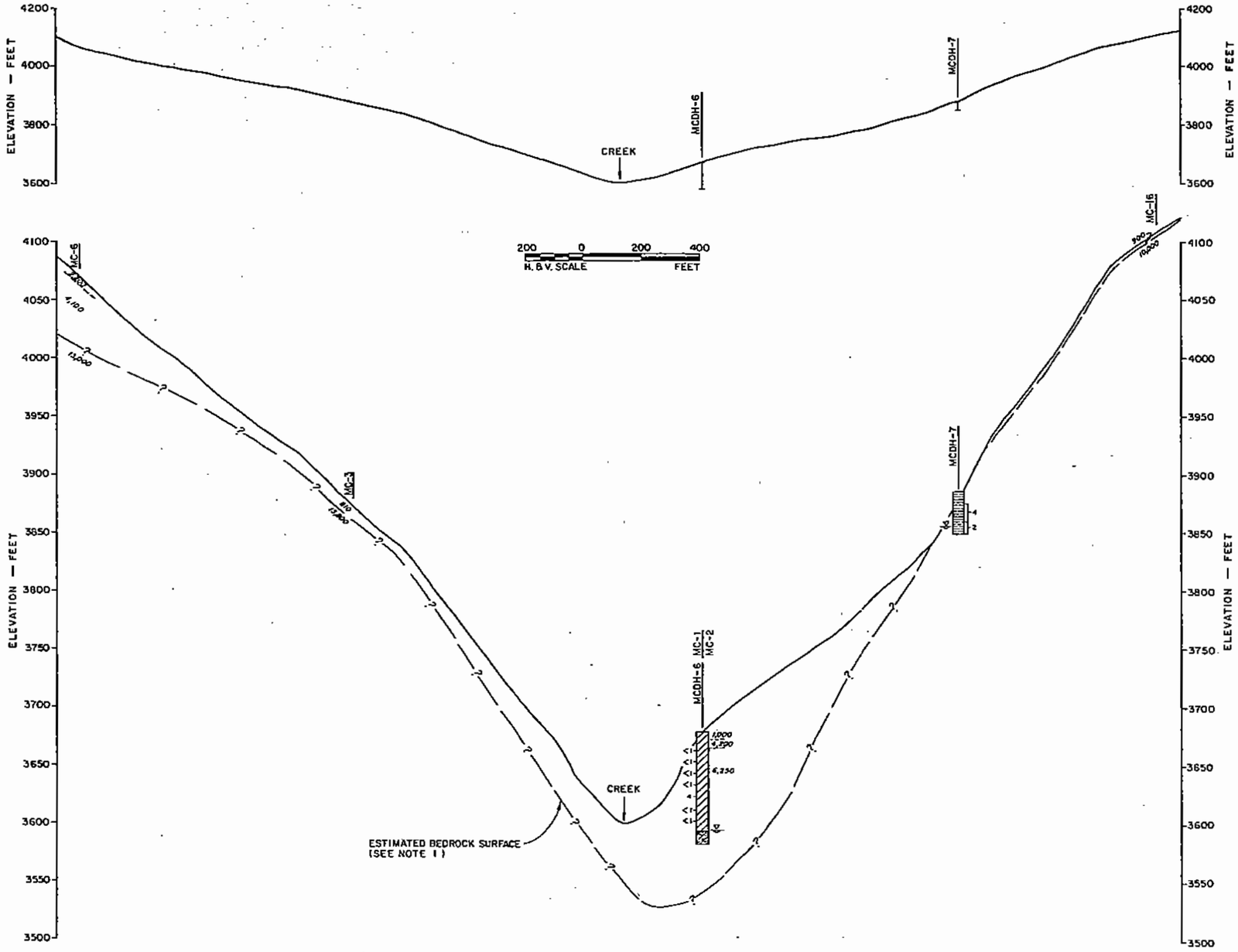
MORRISON-KNUDSEN ENGINEERS, INC.
180 HOWARD STREET, SAN FRANCISCO CALIFORNIA 94105

DESIGNED DAB	DRAWN RBC	CHECKED MFF	RECOMMENDED
DATE DECEMBER 1988			APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT
MIDAS SITE
GEOLOGIC SECTION F

MKE NO.
SHEET OF REV.
FIGURE 12



SECTION G (FIG. 11)

200 0 200 400
H. SCALE FEET

50 0 50 100
V. 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 C FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX D FOR DRILL LOGS, WATER LEVEL DATA AND PERMEABILITY TEST DATA; AND APPENDIX E FOR TEST PIT LOGS.

LEGEND:

- BORING
- ML, ML-CL*
- PIEZOMETRIC SURFACE
- SW, SP*
- PERMEABILITY VALUES (x 10^{-4} CM/SEC)
- SM, SM-ML, SC*
- GM, GM-GP, GC*
- ARGILLITE
- WEATHERED BEDROCK
- QUARTZITE
- SEISMIC VELOCITY (FT./SEC.) SHOWING VELOCITY INTERFACES
- SEISMIC LINE
- SEISMIC LINE TRANSVERSE TO SECTION
- TEST PIT

*UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (SEE APPENDICES)

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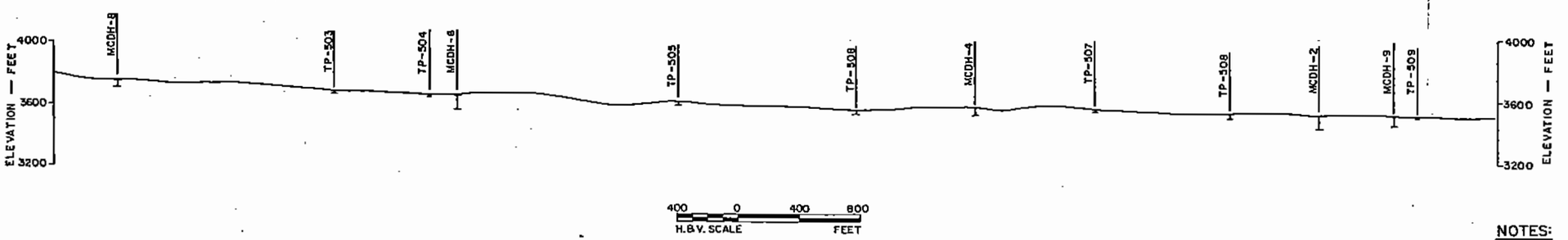
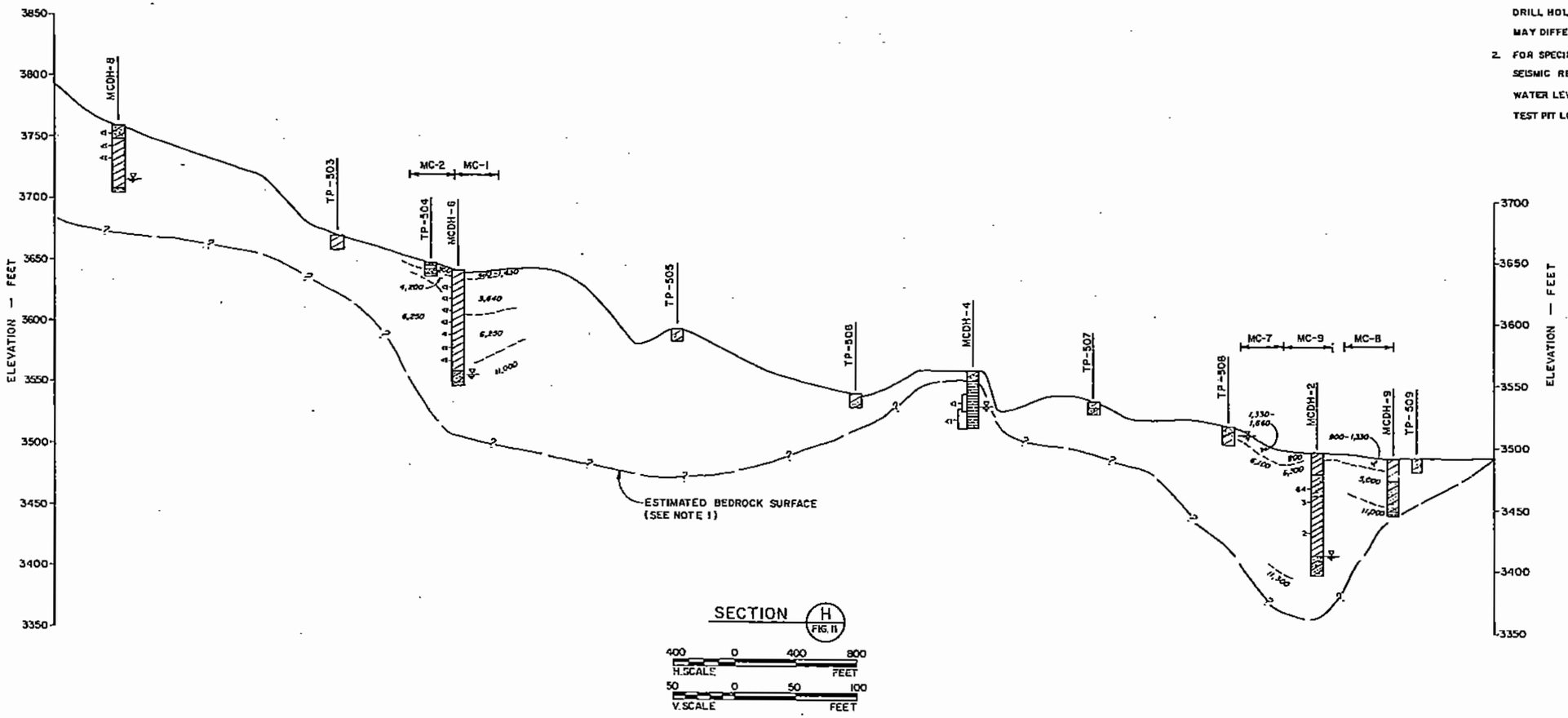
NORANDA MINERALS CORPORATION

MONTANA PROJECT
MIDAS SITE
GEOLOGIC SECTION G

JOB NO.
SHEET OF REV.
FIGURE 13





NOTES:

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LEGEND:

- BORING
- ML, ML-CL*
- PIEZOMETRIC SURFACE
- SW, SP*
- PERMEABILITY VALUES (x 10^{-6} CM/SEC)
- SM, SM-ML, SC*
- GM, GM-GP, GC*
- ARGILLITE
- WEATHERED BEDROCK
- QUARTZITE
- SEISMIC VELOCITY (FT./SEC.) SHOWING VELOCITY INTERFACES
- SEISMIC LINE
- SEISMIC LINE TRANSVERSE TO SECTION
- TEST PIT

* UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (SEE APPENDICES)

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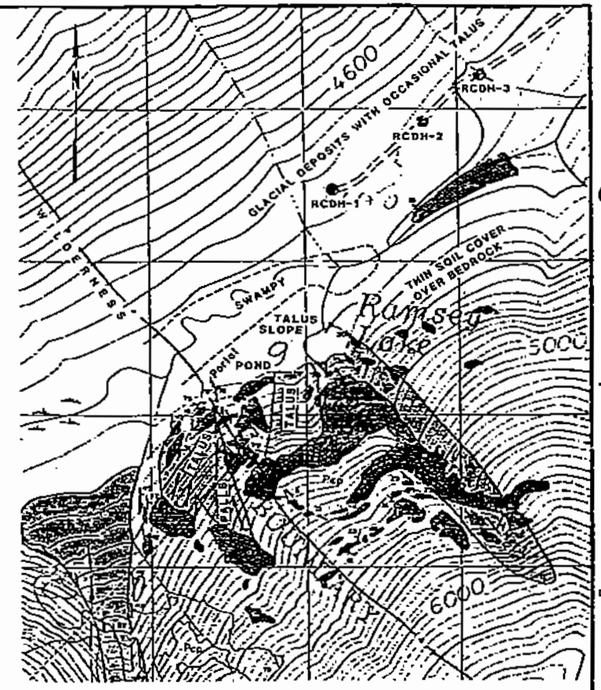
NORANDA MINERALS CORPORATION

MONTANA PROJECT
MIDAS SITE
GEOLOGIC SECTION H

MAP NO.
SHEET OF REV.
FIGURE 14



INSET

500 0 500 1000
SCALE FEET

REFERENCE DRAWINGS:

U.S. GEOLOGICAL SURVEY, 7.5 MINUTE TOPOGRAPHICAL QUADRANGLES:
- HOWARD LAKE
- ELEPHANT PEAK

INSET BASE MAP FROM U.S. BORAX DWG. NO. SP-NP-22-00-17E

LEGEND:

- ROCK OUTCROPS
- SNOW/AVALANCHE CHUTES
- BORING LOCATION (SEE APPENDIX D FOR LOGS)

1000 0 1000 2000
SCALE FEET

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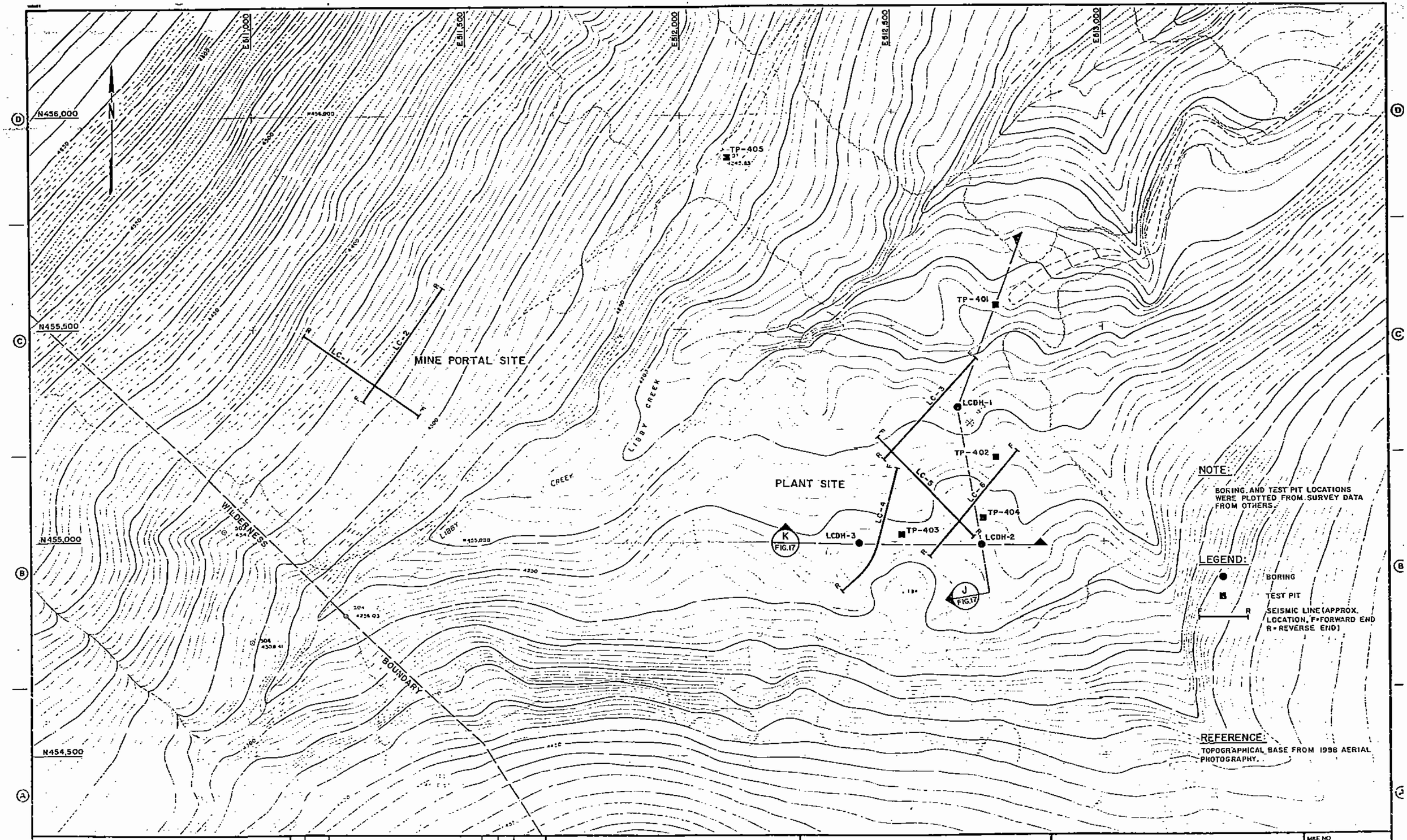
MONTANA PROJECT
LIBBY AND RAMSEY SITES GEOLOGIC MAP

LMKE NO.
SHEET OF REV.
FIGURE 15

DIETZGEN-POST MORDEN NO. 91138

(4) (3) (2) (1)



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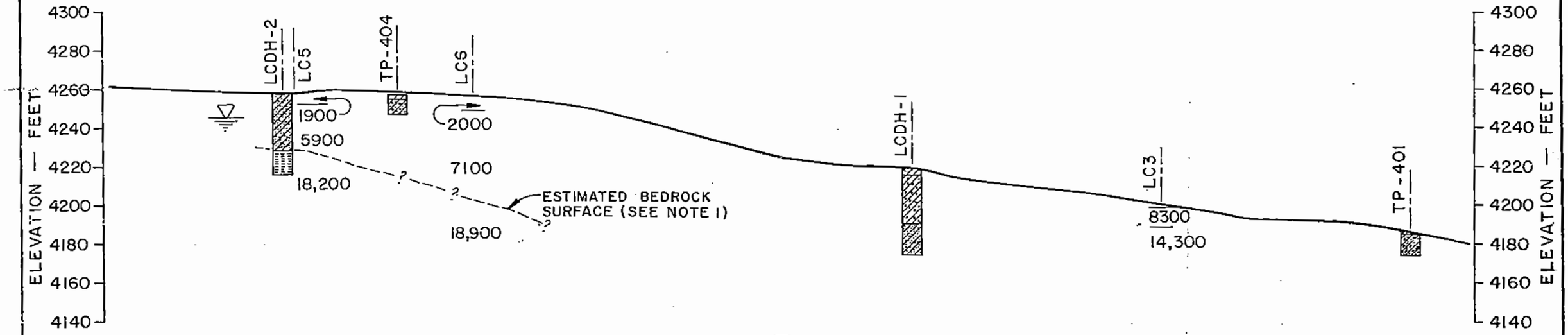
DATE NOVEMBER 1988			APPROVED

NORANDA MINERALS CORPORATION

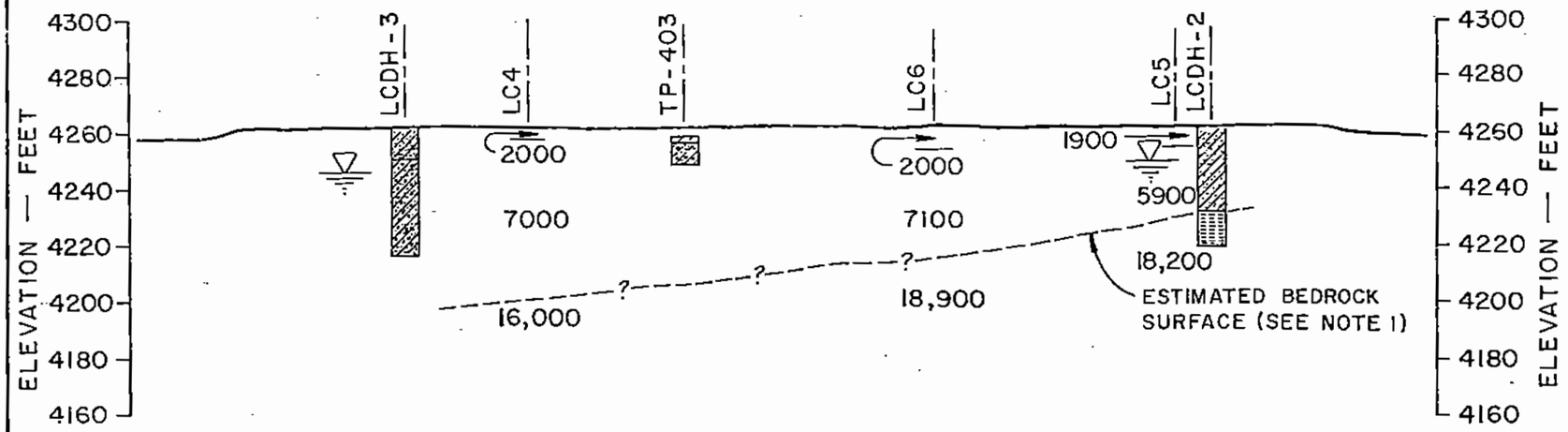
MONTANA PROJECT
LIBBY SITE
EXPLORATION PLAN

MKE NO		
SHEET	OF	REV.

FIGURE 16



SECTION J
FIG.16

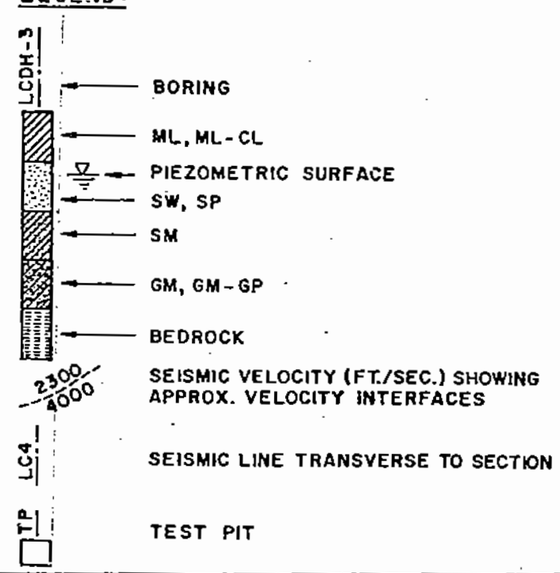


SECTION K
FIG.16

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 C FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX D FOR DRILL LOGS AND WATER LEVEL DATA; AND APPENDIX E FOR TEST PIT LOGS.

LEGEND:



50 0 50
H. & V. SCALE FEET

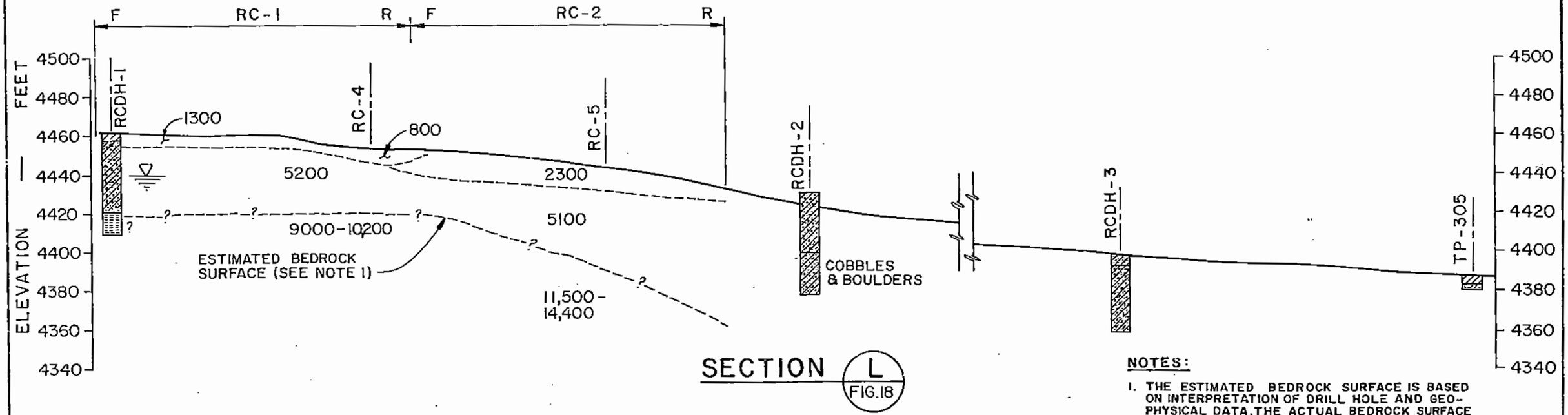
CONSULTING ENGINEERS
MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON-KNUDSEN COMPANY
180 HOWARD STREET, SAN FRANCISCO, CALIFORNIA 94105

DESIGNED	DAB	DRAWN	AMC	CHECKED	MPF	RECOMMENDED
DATE	NOVEMBER 1968					APPROVED

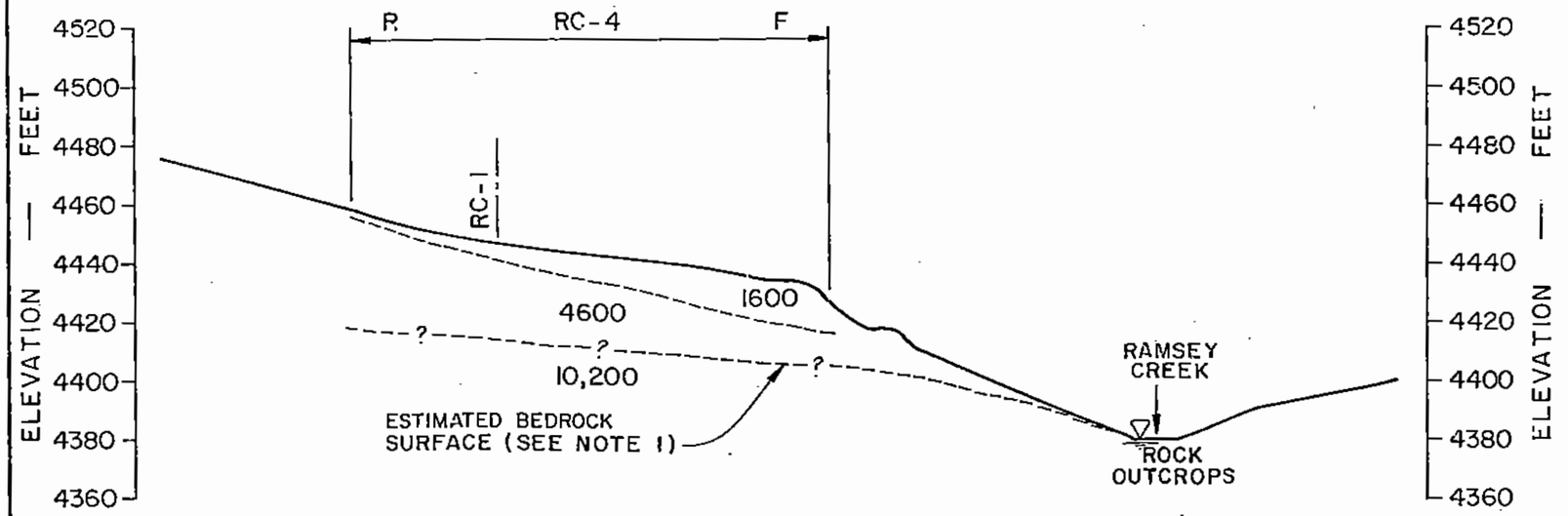
NORANDA
MINERALS CORPORATION

MONTANA PROJECT
LIBBY SITE
GEOLOGIC SECTIONS

FIGURE 17



SECTION L
FIG. 18

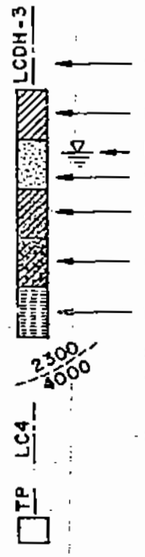


SECTION M
FIG. 18

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 C FOR SEISMIC REFRACTION SURVEY RESULTS; APPENDIX D FOR DRILL LOGS AND WATER LEVEL DATA; AND APPENDIX E FOR TEST PIT LOGS.

LEGEND:



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

CONSULTING ENGINEERS
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A MORRISON-KNUDSEN COMPANY
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NORANDA
MINERALS CORPORATION

MONTANA PROJECT
RAMSEY SITE
GEOLOGIC SECTIONS

FIGURE 19

N 448,000

N 447,000

N 445,000

E 504,000

E 503,000

E 502,000

UPPER HEIDELBERG ROAD ADIT

SEE NOTE 1

TALUS

TALUS COVERED WITH LOW BRUSH

ROCK LAKE ADIT

RL

SEE NOTE 3

TALUS

POND

ROCK LAKE

HEIDELBERG TUNNEL (SEE NOTE 2)

TO DUMP SITE

NOTES:

1. ROCK AT ADIT IS MODERATELY WEATHERED; BLOCKY; JOINTED; THIN SOIL COVER ABOVE ADIT; TALUS AND MUCK ROCK BELOW.
2. SEE APPENDIX B FOR HEIDELBERG TUNNEL GEOLOGIC DATA.
3. ROCK WITH THIN SOIL COVER; FLAT TO GENTLE SLOPE.

REFERENCE DRAWINGS:

U.S. BORAX DWG. NO. SP-NP-22-0001F, ROCK LAKE DEPOSIT GEOLOGY MAP.

LEGEND:

- ROCK OUTCROP
- CONTACT
- FAULT
- THRUST FAULT (TEETH ON UPTHROWN BLOCK)
- BEDDING, SHOWING STRIKE AND DIP
- OVERTURNED BEDDING, SHOWING STRIKE AND DIP
- FOLIATION, SHOWING STRIKE AND DIP
- JOINTS, SHOWING STRIKE AND DIP
- MONOCLINE
- SYNCLINE
- SEISMIC LINE
- SNOW/AVALANCHE CHUTE
- TALUS

SCALE 200 0 200 400 FEET

NO	DATE	REVISIONS	BY	CHK	APPD

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

DESIGNED DJU | DRAWN AMC | CHECKED MPF | RECOMMENDED

DATE NOVEMBER 1980 | APPROVED

NORANDA MINERALS CORPORATION

MONTANA PROJECT

EVALUATION ADIT SITES
GEOLOGIC MAP

JOB NO

SHEET OF REV.

FIGURE 20

APPENDIX A
DESIGN BASIS MEMORANDUM

APPENDIX A
DESIGN BASIS MEMORANDUM

Noranda Minerals Corporation
Montana Project
Design Basis Memorandum No. 8029-101-R2
General Preliminary Design Criteria

CONTENTS

1.0 Introduction
2.0 Project Goal
3.0 Scope of Work
4.0 Design Criteria
  4.1 Design Flood Criteria
    A. Tailings Impoundments
    B. Plant Sites and Portals
  4.2 Tailings Production and Tailings Effluent
  4.3 Stability
5.0 Approach
  5.1 General
  5.2 Field Investigation
    A. General
    B. Data Review
    C. Reconnaissance and Geologic Mapping
    D. Seismicity Evaluation
    E. Seismic Refraction Survey
    F. Test Pits
    G. Drilling
    H. Summary of Field Investigation
    I. Laboratory Testing
  5.3 Site Evaluation and Preliminary Design
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    B. Tailings Impoundments
      (1) Hydrologic Studies
      (2) Embankment Design and Impoundment Capacity
      (3) Stability Analyses
      (4) Seepage and Contaminant Transport
      (5) Reclamation
    C. Plant Sites, Mine Portals and Evaluation Adits
  5.4 Technical Reports
  5.5 Meetings
6.0 References

Figure 1
Attachments 1 and 2

Revision Number	Reviewed	Submitted Proj. Mgr.	Approved Ch. Eng.	Issue Date
2	V. Paseveci 1-19-89 1-19-89	M. Forest	E.S.S.H.	1/18/89

Approved by Noranda Minerals Corporation (Name/Date) 2/9/89

1.0 INTRODUCTION

On 6 September 1988, U. S. Borax & Chemical Corporation transferred its interest in the Montana Project to Noranda Minerals Corporation. Revision No. 2 of the Design Basis Memorandum follows the completion of the field investigation work.

Noranda Minerals Corporation is currently planning the further development of the Montana Project located between Libby and Noxon in Sanders and Lincoln Counties, Montana, for mining and milling copper-silver ore. The project area is located in the Kootenai and Kaniksu National Forests. As part of this project, geotechnical investigations are required to select the preferred sites for plant facilities, mine portal, tailings impoundment and evaluation adit portal. The following sites will be studied:

- Plant Sites and Mine Portals (Howard Lake Quadrangle):
  - Ramsey Creek
  - Libby Creek

- Tailings Impoundment Sites (Cable Mountain Quadrangle):
  - Little Cherry
  - Poorman
  - Midas

- Evaluation Adit (Elephant Peak Quadrangle):
  - South End Rock Lake
  - Heidelberg Tunnel
  - Upper Heidelberg Road

This Design Basis Memorandum describes preliminary design criteria, procedures and approach for site selection and preliminary design evaluation. Other considerations in the selection of surface facility sites, such as the proximity to the mineral deposit and environmental factors, are not part of this Design Basis Memorandum.

2.0 PROJECT GOAL

The goal of the engineering work and geotechnical investigation outlined in this Design Basis Memorandum is to select the preferred sites, from an engineering standpoint, for plant facilities, mine portal, tailings impoundment and evaluation adit. To accomplish this goal, the scope of work described in Section 3.0 has been developed to define geotechnical conditions at the sites. In addition, preliminary engineering evaluations will be conducted to define basic design of the selected tailings impoundment.

3.0 SCOPE OF WORK

The scope of work for site selection and preliminary design consists of the following tasks:

- Conduct a field investigation that includes the following activities:
  - Data review
  - Reconnaissance
  - Geologic mapping
  - Seismicity evaluation
  - Seismic refraction survey
  - Test pit excavations
  - Exploratory drilling
  - Laboratory testing
- Perform site evaluations that include the following:
  - Tailings impoundments (including seepage, hydrology and stability of the selected impoundment)
  - Plant sites and mine portals
  - Evaluation adits

- o Prepare the following technical reports:

  - Geotechnical Report
  - Geotechnical Site Evaluation Report
  - Tailings Impoundment Preliminary Engineering Report

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

The scope of work is sufficient for (1) site selection, (2) preliminary design, and (3) an application for Plan of Operations for mine development with the U.S. Forest Service and Montana Department of State Lands. Additional evaluations will be needed for final design consisting of the following tasks:

- o Further drilling and test pit excavations at the selected plant and impoundment sites
- o Additional laboratory testing, including triaxial compression tests, to determine strength parameters of foundation and embankment materials
- o Final stability analyses of the tailings dam
- o Optimization of tailings impoundment design.

4.0 DESIGN CRITERIA

4.1 Design Flood Criteria

A. Tailings Impoundments - 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 distances, in river miles, to the nearest dwelling and U.S. Highway 2 from the three alternative impoundment sites are shown below:

Site	Nearest Dwelling	U.S. Highway 2
Little Cherry	5.4	5.7
Poorman	6.0	6.3
Midas	6.9	7.2

The U.S. Forest Service and Department of State Lands consider the impoundment sites to have moderate to high hazard potentials (Attachment 1).

Based on dam stage size and hazard potential classifications, the agencies designated the following design flood criteria (Attachment 1):

- 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) will also be considered for diversion. The more critical of the two diversion floods will 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.

B. Plant Sites and Portals - Plant sites, mine portals and evaluation adit portals will be located above the 100-year flood level. The 100-year flood peak discharges will be determined by another consultant by using methods based on regression analyses as described in Ref. 1. The flood stage calculations will be based on available topographic maps.

4.2 Tailings Production and Tailings Effluent

A tailings slurry of 30% solids will be conveyed in a pipeline from the mill to the impoundment site. Based on the results of bench-scale flotation tests, the tailings feed will consist of silt and sand particles with 52% finer than the No. 200 sieve (0.074mm). The anticipated tailings gradation from the flotation tests follows:

Tyler Sieve No.	Particle Size (Microns)	Cumulative % Passing
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 is 20,000 tons per day, totaling 120,000,000 tons. The dry unit weight of tailings deposited in the impoundment will be based on published correlations with the anticipated tailings gradation.

Storage will also be required for tailings effluent for 20 days at 8,000 gpm (about 700 acre-feet).

4.3 Stability

The maximum sections of the starter and final embankment dam stages will be checked for static and seismic conditions. The tailings in the impoundment will be conservatively assumed to behave as a dense fluid and therefore will be assigned zero shear strength. In addition, the stability of the starter dam will be checked for the end-of-construction condition before tailings are deposited. This condition will be the most critical static case for the upstream slope since subsequent deposition of tailings into the pond will stabilize the slope.

The following minimum acceptable factors of safety will be used in design. The criteria for long-term, end-of-construction and seismic conditions are as recommended by the Corps of Engineers (Ref. 2).

Load Condition	Embankment Stage	Slope	Minimum Acceptable Factor of Safety
End-of-Construction (before tailings deposition)	Starter Dam	Upstream and Downstream	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). The results of a seismicity evaluation (Subsection 5.2.D) indicated that the seismic coefficient for use in the seismic stability computations using the "pseudo-static" method should be 0.10g as recommended by the Corps of Engineers for Seismic Zone 3 (Ref. 2).

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 (0.22g, see Subsection 5.2.D) 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. 3) and the recommended seismic coefficient of 0.10g should be used.

The material properties for use in the preliminary stability analyses will be based on the results of the field and laboratory testing programs. Foundation strengths will be obtained from correlations with Standard Penetration Test (SPT) data. Where field or laboratory test results are unavailable, appropriate properties will be selected based on a review of published data on similar materials and on correlations with index properties.

5.0 APPROACH

5.1 General

This section presents the approach for site selection and preliminary engineering. The section is divided into the following tasks as outlined in Section 3.0:

- Field Investigation
- Site Evaluation and Preliminary Design
- Technical Reports
- Meetings

5.2 Field Investigation

A. General

For purposes of preliminary site appraisal, it is appropriate to limit the scope of the field investigations to the work necessary to make a reasonably accurate determination of depths to a suitable foundation and to assess the potential hazards such as rockslides, avalanches, flooding and unfavorable groundwater conditions.

B. Data Review

Available data including previous reports, maps and aerial photographs were reviewed prior to the initial field reconnaissance. Available U.S. Forest Service soils maps were

reviewed (Ref. 4). Potential geotechnical problems at each site were identified as much as possible from the information available, and a checklist of items to be investigated during the field reconnaissance were prepared.

C. Reconnaissance and Geologic Mapping

A helicopter and ground reconnaissance was performed for planning of exploration activities and overall evaluation of the geotechnical factors that can be expected to have a significant influence on site suitability.

Geologic mapping was performed during the course of the field investigations. Geologic data by others were also confirmed during this task. The geological maps show bedrock outcrops, rockslide areas, snowslide areas and springs, faulting, landslides or other evidence of surface instability. To determine the potential for rockslides into portal cuts, the orientation of rock discontinuities were noted. In addition, a geologic map was prepared of the existing Heidelberg Tunnel. Geologic data and locations of seismic lines, drill holes and test pits are shown on the exploration plans.

D. Seismicity Evaluation

A seismicity evaluation was performed to establish suitable seismic criteria for preliminary design of the tailings impoundments. The study utilized historical seismicity data available from National Oceanic and Atmospheric Administration (NOAA), reports on potentially active faulting in the region, and previous studies for other projects in the site area.

A Maximum Credible Earthquake (MCE) for use in tailings dam engineering 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. 5). Appropriate attenuation formulas were used to calculate a range of maximum ground accelerations at the site. The design earthquake was determined to be a magnitude 7 event originating on the Bull Lake fault, 20 kilometers to the west of the project site. The peak ground acceleration was estimated to be 0.22g.

The project site is located close to Seismic Zone 2 for which a seismic coefficient of 0.05g is recommended (Ref. 2). However, this coefficient is incompatible with a nearby magnitude 7 MCE. Since the boundaries of Seismic Zones 1, 2 and 3 are relatively close together in this region, it is appropriate to apply the coefficient for Seismic Zone 3, which is 0.10g.

E. Seismic Refraction Survey

The subsurface investigation began with a seismic refraction survey of each site. The results of this work provided an indication of subsurface conditions, rippability and bedrock depth. The results of the seismic refraction survey, together with reconnaissance observations and aerial photographic interpretation, were used to select drill hole and test pit locations and to estimate required drill footage per site.

F. Test Pits

Test pits were used in conjunction with drill holes to obtain representative samples and to enable observation of conditions to be expected in excavations. The depths of the pits ranged from 3.5 to 16 feet. Test pits were backfilled and covered with topsoil. All sites will be restored as required by the U.S. Forest Service.

G. Drilling

Drilling was limited at this stage to the amount necessary for determining depth to bedrock, and to provide an understanding of bedrock characteristics, the nature of the overburden and the location of groundwater. The results of drilling performed by the consultant for groundwater investigations were also used. Perforated PVC pipes (1-inch diameter) were installed in selected drill holes at each site for groundwater level measurements. All drill sites will be restored as required by the U.S. Forest Service.

Drive samples were taken by using 2-inch O.D. Standard Penetration Test (SPT) samplers (ASTM D1586) and 2.5-inch O.D. samplers. Undisturbed samples of fine grained soils were obtained by using Shelby tube samplers (ASTM D1587).

Field tests were performed to determine permeability coefficients of foundation materials for seepage analyses. Permeability test methods conformed to procedures in the U.S. Bureau of Reclamation's "Earth Manual," Method E-18 (Ref. 6). Open-end casing constant head tests were performed at selected locations in soils. In bedrock, water pressure tests were performed by using single pneumatic packers.

H. Summary of Subsurface Investigations

A summary of the subsurface investigations is given in Table 5-1.

TABLE 5-1
SUMMARY OF SUBSURFACE INVESTIGATIONS

Site	Seismic Lines (Number/Feet)	Drill Holes (Number/Feet)	Test Pits
Plant Sites and Portals			
Ramsey Creek	6/1950	3/145	5
Libby Creek	6/1950	3/134	5
Tailings Disposal			
Little Cherry	7/4525	5/307	10
Poorman	15/7300	5/334	10
Midas (2 dam axes)	15/4485	8/482	12
Eval. Adit/Decline			
South End Rock Lake	1/300		
Heidelberg Tunnel			
Upper Heidelberg Road			
TOTALS	50/20,510	24/1402	42

I. Laboratory Testing

A limited laboratory testing program was performed to obtain preliminary engineering parameters of the soils at the plant and tailings impoundment sites. The tests followed American Society for Testing and Materials (ASTM) procedures and included the following:

- o Grain size analyses - ASTM D422
- o Natural moisture contents - ASTM D2216
- o Plasticity indices - ASTM D4318
- o Dry density
- o Moisture - density relationships - ASTM D698
- o Unconfined compression - ASTM D2166

The results of these tests were used to characterize foundation soils and potential borrow materials. Triaxial compression tests will be performed during a subsequent design development phase to establish strength parameters.

5.3 Site Evaluation and Preliminary Design

A. Site Ranking System

A tabular ranking system will be used to assist the geotechnical evaluation of the various sites for the plant, tailings impoundment and evaluation adit. The following will be included in site evaluations:

- o Topographical conditions
- o Potential for slides and avalanches
- o Flooding potential at portal and plant sites
- o Flood magnitude at the tailings impoundment sites
- o Diversion requirements
- o Foundation conditions for dams and heavy plant machinery, and depth to bedrock
- o Seepage potential at the impoundment sites
- o Availability of embankment dam construction materials and, in particular, the availability of clayey soils
- o Volume of required impoundment construction materials
- o Economic considerations
- o Impoundment capacity
- o Seismicity
- o Site access
- o Vegetative cover

The results of the studies will be used to recommend the preferred sites (from an engineering standpoint) for the mine portal, plant, tailings impoundment and evaluation adit.

B. Tailings Impoundments

(1) Hydrologic Studies - The development of the tailings impoundment design flood criteria is described in Subsection 4.1.A. The Corps of Engineers Hydrologic Engineering Center's HEC-1 Flood Hydrograph Package will be used for the impoundment design flood studies.

"Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northwest States" (Hydromet 43) developed by NOAA (Ref. 7) will be used as the basis for estimating the local storm and general storm Probable Maximum Precipitation (PMP).

The general storm PMF plus snowmelt and the local storm PMF will be considered. The following precipitation events will be used to derive these design floods:

Purpose	Tailings Dam Stage Height	Design Flood	Precipitation Event
Containment	≥100 feet	General Storm PMF	24-hour PMP plus snowmelt as described below
Containment	<100 feet	General Storm 1/2 PMF	24-hour 1/2 PMP plus snowmelt as described below
Diversion	All Stages	Local Storm PMF	6-hour PMP
Diversion	All Stages	General Storm PMF	72-hour PMP plus snowmelt as described below

Unit hydrographs will be developed following the Soil Conservation Service (SCS) method, as described in the "Design of Small Dams" (Ref. 8). Infiltration and retention losses also will be estimated following SCS curve number (CN) procedures. These estimates will be based on soil conditions and vegetal cover as determined from field observations and from a review of available reports and aerial photographs. The antecedent-moisture conditions (AMC) for the PMF estimates will be AMC III (i.e., soil is nearly saturated).

Snowmelt will be assumed to occur during both the 24-hour and 72-hour PMP's. The snowmelt potential during the PMP will be assumed to be unrestricted by snowpack depth. Snowmelt calculations will be based on the Corps of Engineers' "Runoff from Snowmelt" (Ref. 9). Depending upon forest cover, the appropriate snowmelt equation will be used. Dew point temperature and wind speed information during the PMP will be computed by using procedures described in Hydromet 43 (Ref. 7).

Required heights of diversion dams and sizes of diversion channels will be based on the results of routing the local storm PMF and the 72-hour general storm PMF. Routing will be performed by using HEC-1 procedures.

(2) Embankment Design and Impoundment Capacity - The topographical conditions and the results of the field investigation will be used to locate the tailings dam. The dam will be located so that flood waters on adjacent stream channels will not encroach on the embankment.

The ultimate impoundment will be sized to store 120 million tons of tailings. The starter impoundment will be sized to store at least 7 million tons (1 year of production). For capacity calculations, the tailings density will be based on experience with similar tailings materials. Impoundment area and capacity curves will be prepared. These curves, together with expected tailings production rates, will be used to determine the tailings level and dam crest elevation versus time.

The required impoundment storage for the design flood will be determined from the results of studies described in Subsection 5.3.B.(1). Embankment slopes will be determined from the results of stability analyses described in Subsection 5.3.B.(3).

The embankment dam stages will be constructed of (1) materials excavated from the impoundment, (2) evaluation adit and mine waste rock and (3) tailings sands. Based on an in-place rockfill density of 140 pcf, preliminary estimates indicate that approximately 831,000 cubic yards of rockfill will be available at the time of mill start-up. Subsequently, an estimated 74,000 cubic yards of rockfill will be available annually.

The operating stages after the initial stage of the impoundment will be constructed by the downstream method by using cycloned tailings sands. A seepage control dam downstream of the tailings dam will be required. An embankment drain system will be designed to control seepage and prevent piping.

Plans and typical sections of the initial and final tailings impoundment at the selected site will be prepared. Construction quantities will also be estimated.

(3) Stability Analyses - Preliminary stability analyses will be performed for the initial and final dam stages by using the Modified Bishop and infinite slope methods of analysis. The computer program STABL (Ref. 10) or other program will be used to determine the factor of safety for circular sliding surfaces. Hand calculations 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 4.3. Stability will be evaluated for a wide range of phreatic surface conditions. Final stability analyses will be performed during a subsequent design development phase.

Liquefaction potential of sandy foundation soils due to the MCE event (see Subsection 5.2.D) will be evaluated by methods outlined in Refs. 11 and 12. Liquefaction is defined as the rapid build-up of pore-water pressures and the resulting loss of soil strength caused by seismic shaking (Ref. 13). Soil deposits that are particularly susceptible to liquefaction consist of loose, saturated sands.

In the proposed approach to evaluate liquefaction potential, the induced shear stresses caused by the MCE acceleration will be compared to the stresses required to cause liquefaction. Stresses to cause liquefaction will be estimated from SPT data (see Subsection 5.2.G) and MCE magnitude.

(4) Seepage and Contaminant Transport - For control of seepage from the impoundments, the Montana regulations for non-degradation of water quality will be followed (Ref. 14). Seepage potential from the impoundment site will be evaluated

from the results of the field exploration and laboratory testing of foundation and embankment construction materials. Permeabilities of the foundation materials will be obtained from the results of field tests, including pump tests. The permeability of the fine tailings will be estimated from correlations with grain size data. For preliminary studies, simplified calculations will be performed to estimate seepage rates from the tailings impoundment for varying pond elevations.

The potential migration of tailings effluent from the selected impoundment will be evaluated. Seepage and contaminant transport analyses will be performed by using simplified analytical methods. The computed concentration of chemical constituents at a predetermined point of compliance will be compared with background chemistry data and State maximum contaminant levels. The chemical assay of the effluent for the Montana Project is shown in Attachment 2.

(5) Reclamation - A conceptual impoundment reclamation scheme will be presented. Montana regulations require that the land be returned to comparable utility that existed prior to impoundment construction (Ref. 15). The reclamation plan will basically consist of (1) subsoil stripping and stockpiling at the beginning of each impoundment construction stage, (2) capping the final tailings surface with soil, including the stockpiled subsoil, and (3) seeding the cap. Provisions to minimize erosion and promote surface drainage will also be included in the reclamation scheme.

C. Plant Sites, Mine Portals and Evaluation Adits

Evaluation studies for plant sites, mine portals and evaluation adits will concentrate on rating relative suitability of (1) access, (2) slope stability, (3) exposure to rockslides and avalanches, (4) depth to suitable rock for establishing portals, (5) potential for developing adequate working area, and (6) availability of suitable waste rock disposal areas. For plant sites, foundations will be evaluated for suitability for machine foundations. Mine portal sites will be located at least 300 feet from the wilderness boundary and plant crushers will be located at least 1,000 feet from the boundary.

5.4 Technical Reports

The following reports will be prepared:

- Geotechnical Report
- Geotechnical Site Evaluation Report
- Tailings Impoundment Preliminary 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
- Geologic sections
- Seismicity evaluation
- Results of seismic refraction surveys
- Drill hole and test pit logs
- Laboratory test results

The report will be organized on an individual site basis.

The Geotechnical Site Evaluation Report will present recommendations for selection of the (1) plant site, (2) mine portal location, (3) tailings impoundment site and (4) evaluation adit site. Each site will be evaluated in a separate section of the report. Also, recommendations will be included for further investigation of the recommended sites.

The Tailings Impoundment Preliminary Engineering Report will present the results of the preliminary design studies for the selected tailings impoundment. The report will include results of seepage, hydrology, stability and reclamation studies. Plans and sections of the conceptual design will be presented.

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 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.

6.0 REFERENCES

1. Omang, R. J., Parrett, C. and Hull, J. A., "Methods for Estimating Magnitude and Frequency of Floods in Montana, Based on Data Through 1983," U. S. Geological Survey, Water Resources Investigative Report 86-4027, Helena, Montana, 1986.

2. 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.

3. Seed, H.B. and Martin, G.R., "The Seismic Coefficient in Earth Dam Design," Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, Vol. 92, SM3.

4. U.S. Department of Agriculture, U.S. Forest Service, Kootenai National Forest, Libby, MT, Kootenai National Forest Area, Land System Inventory, 1984.

5. Seed, H.B., "The Selection of Design Earthquakes for Critical Structures," Bulletin of the Seismological Society of America, Vol. 72, No. 6, December 1982.

6. U.S. Department of the Interior, Bureau of Reclamation, "Earth Manual," Second Ed., 1974.

7. U.S. Department of Commerce, Weather Bureau, "Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northwest States," 1966.

8. U.S. Department of the Interior, Bureau of Reclamation, "Design of Small Dams," 1977.

9. U.S. Corps of Engineers, Manual EM-1110-2-1406, "Runoff from Snowmelt," 1960.

10. Siegel, R.A., "STABL User Manual," Joint Highway Research Project, Report JHRP-75-9, June 1988.

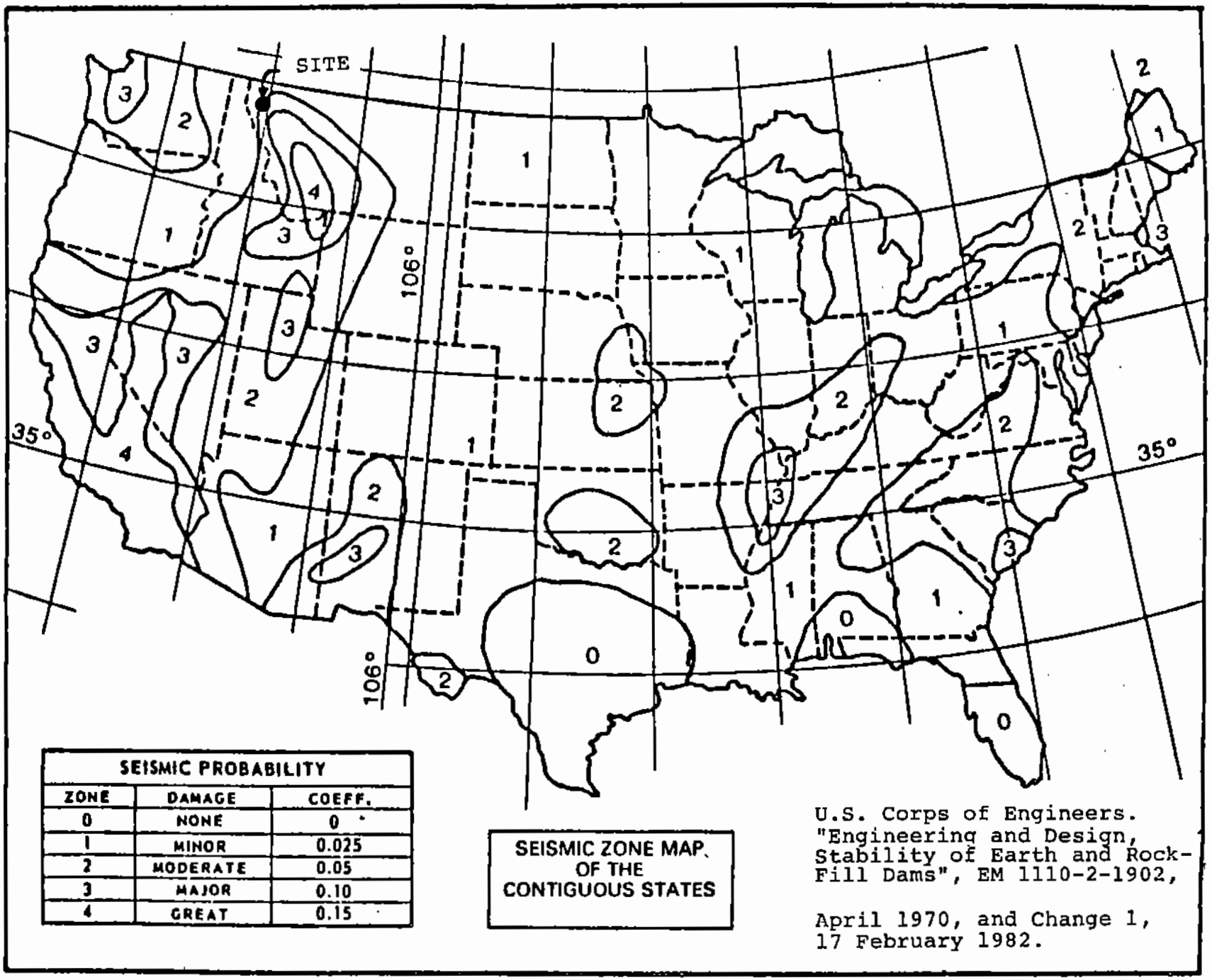
11. Seed, H.B., and Idriss, I.M., "Ground Motions and Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, 1982.

12. "Liquefaction of Soils During Earthquakes," Committee on Earthquake Engineering, National Academy of Sciences, 1985.

13. Seed, H.B., "Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground During Earthquakes," Journal of the Geotechnical Engineering Division, ASCE, Vol. 105, GT2, February 1979.

14. Administrative Rules of Montana, Department of Health and Environmental Sciences, Water Quality, Sub-Chapter 7, Non-degradation of Water Quality, 31 December 1984 and Sub-Chapter 10, Montana Groundwater Pollution Control System, 31 December 1982.

15. Administrative Rules of Montana, Chapter 4, Reclamation, Part 3 - Metal Mine Reclamation and Sub-Chapter 1, Rules and Regulations Governing the Montana Metal Mine Reclamation Act, 1 July 1980.



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

ATTACHMENT 1

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

HEADQUARTERS OFFICE
180 HOWARD STREET
SAN FRANCISCO, CALIFORNIA U.S.A. 94105
TELEX. (WUI) 677058, (ITT) 470040, (RCA) 278382, (WUD) 34378
PHONE. (415) 442-7300

8029-810

19 October 1988

U. S. Forest Service
Kootenai National Forest
506 U.S. Highway 2 West
Libby, MT 59923

Attention: Mr. Ron Erickson
FS Project Coordinator

Subject: Montana Silver Venture Project
Response to Comments on Design Basis Memorandum

Gentlemen:

In the attached 15 September 1988 letter, the Forest Service and Department of State Lands submitted their comments on the Design Basis Memorandum (Revision 0) for the Montana Silver Venture project. Morrison-Knudsen Engineers' (MKE) response to those comments follows.

Comment 1: Impoundment design flood criteria. We understand that the agencies consider the site to have moderate to high hazard potential. Based on the ultimate large size of the tailings impoundment and on this hazard potential rating, the agencies have 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)

We will use these criteria for tailings impoundment design. In addition, because thunderstorm events should also be considered for small watersheds, the local storm PMF (resulting from the 6-hour PMP) will also be computed for diversion. The more critical of the two diversion floods will be used for diversion system design.

As discussed with the Forest Service regional office in Missoula, for short-term (about 5 years) interim stages less than 100 feet high, the containment flood will be calculated from the 24-hour general storm 1/2 PMP.

Comment 2: Comparison of design floods with measured flows. The agencies have asked that the results of our studies be compared with analyses based on measured flows. The PMF is such a large and infrequent event that it cannot be compared with historical streamflow data. The return period of a PMF may be on the order of tens of thousands of years for which comparison with extrapolations of streamflow data would not be meaningful.

Computations of PMP magnitudes were based on procedures described in Hydrometeorological Report No. 43. Unit hydrographs were developed following methods developed by the Soil Conservation Service (SCS). Infiltration and retention losses were estimated following SCS curve number procedures for forested areas. Snowmelt during both the 24 and 72-hour general storm PMP's were computed. Flood hydrographs are currently being developed by using the Corps of Engineers HEC-1 procedures.

Comment 3: Method of calculation of the 100-year flood peak discharge. In the plant sites, the 100-year flood was determined by using equations derived from regression analysis of watershed characteristics as reported in R. J. Omang et al., "Methods for Estimating Magnitudes and Frequency of Floods in Montana," U. S. Geological Survey, 1986.

Comment 4: Fracture and joint data. We have measured joint attitudes and spacing on the west side of the Cabinet Mountains, where good exposures of meta-sedimentary rocks occur. These data will be used in the evaluation of adit portal stability. Rock exposures in the east side sites are much less prevalent and joint data were not measured. However, joint data are noted on the drill logs where rock coring was done. We will also obtain joint data available from Noranda's baseline work.

Comment 5: Phreatic conditions in dam stability analyses. MKE will examine stability of the dam for a range of phreatic surface conditions during preliminary design studies.

Comment 6: Monitor well drilling and completion. We acknowledge that new rules are proposed by the Department of Natural Resources and Conservation for monitor well drilling and completion. We would appreciate information on how we can obtain the rules.

Based in part on the 15 September letter, MKE is preparing Revision No. 1 of the Design Basis Memorandum (DBM). The revised DBM will be resubmitted to the agencies for their review.

If there are any further questions, please call me at (415) 442-7593.

Sincerely,

M. P. Forrest

M. P. Forrest
Project Manager

Attachment: U. S. Forest Service letter, 15 September 1988

cc: K. Walther, Department of State Lands
R. White, Regional Office, U.S. Forest Service
J. Scheuering, Noranda
B. Bailey, Noranda
G. Fletcher

7415G

United States Department of Agriculture | Forest Service | Kootenai NF | 506 US Highway 2 West Libby, MT 59923

Reply to: 2810

Date: 9/15/88

Ken Reis
U.S. Borax
3075 Wilshire Blvd.
Los Angeles, CA 90010

Dear Ken,

On July 5, 1988, Borax submitted a Design Basis Memorandum prepared by Morrison-Knudsen Engineers, for the preliminary geotechnical investigation work for the Montana Silver Venture. The following are comments on the design memo from both the Forest Service and Department of State Lands.

1. Based on the attached criteria (FSM 7511.1-.2, Amendment 12, and FSM 7531.2, Amendment 10), the agencies consider the impoundment to be a Class A structure (the highest rating) of moderate to high hazard potential. Consequently, it is recommended that the acceptable criteria for flood hydrology design of the tailings area are:

   a. 24 hour, general storm, PMP for containment
   b. 72 hour, general storm, PMF for diversion

2. In section 5.3 B (1), Hydrologic Studies, three methods of calculating the design flood and precipitation events are documented. The agencies would like these results compared with analyses based on measured flows. It is recommended that MKE share their numbers and procedures early in the design process with the agencies so that all parties are in agreement on the actual design event figures.

3. On page 5, Section 4.1 B, it states that another consultant will determine peak discharges. What method(s) will the consultant use?

4. The geologic mapping and field investigation, described on page 7 does not include a fracture/joint density study. However, the geologic baseline data Borax is collecting should include fracture and joint data. This information should be shared with MKE.

5. An analysis of the embankment stability to a variety of phreatic conditions should be included at some point in the study. This may not be necessary at the preliminary design phase, but will definitely be needed for final design.

6. For your awareness, the State Department of Natural Resources and Conservation is proposing new rules and accreditation procedures for monitoring well drilling and completion.

At Borax's request the agencies can meet to clarify the above concerns. If you have questions, please contact either Kit Walther @ 444-2074 or me @ 293-3171.

Sincerely,

Ron Erickson

Ron Erickson
ES Project Coordinator

Encl.

cc: Kit Walther, DSL
Mike Forrest, MKE

TITLE 7500 - WATER STORAGE AND TRANSMISSION

CHAPTER 7510 - ADMINISTRATION

7511 - PROJECT CLASSIFICATION. The potential effect of a water-control structure on the safety and economy of downstream areas varies with the size of the structure and probable consequences of its failure. The required scope of investigations, precision of design, quality and capacity of components, and subsequent cost vary with the acceptable degree of design risk.

Minimum acceptable criteria for design, operation, maintenance, and monitoring should be based on the size and hazard classifications established for the structure in order to keep requirements in line with structure importance.

In designing or reviewing the design of a project, the individual responsible shall investigate and evaluate all factors that may influence the potential hazard classification of the dam. The hazard rating must be consistent with the degree of downstream development that reasonably can be expected during the life of the dam. See FSH 7509.11 for details on hazard potential assessment.

7511.1 - Administrative Classification. For administrative purposes, projects are classified as follows:

1. Class A Projects

a. Dams that are 100 feet or more high or impound 50,000 acre-feet or more of water.

b. Channels, flumes, and tunnels that have a design capacity of 1,000 cubic feet or more per second (cfs).

2. Class B Projects

a. Dams that are 40 feet or more, but less than 100 feet high or impound 1,000 or more, but less than 50,000, acre-feet of water.

b. Channels, flumes, and tunnels that have a design capacity of 100 cfs or more, but less than 1,000 cfs.

3. Class C Projects

a. Dams that are 25 feet or more, but less than 40 feet high or impound 50 or more, but less than 1,000 acre-feet of water.

b. Channels, flumes, and tunnels that have a design capacity of 10 cfs or more, but less than 100 cfs.

4. Class D Projects

a. Dams that are less than 25 feet high and impound less than 50 acre-feet of water.

b. Channels, flumes and pipes that have a design capacity less than 10 cfs.

7511.2 - Hazard-Potential Classification. Dams are also classified according to hazard potential based on the loss of life or property damage that could occur if the structure failed.

1. Low Hazard. Dams built in undeveloped areas where failure would result in minor economic loss, damage would be limited to undeveloped or agricultural lands, and improvements are not planned in the foreseeable future. Loss of life would be unlikely.

2. Moderate Hazard. Dams built in areas where failure would result in serious environmental damage or appreciable economic loss with damage to improvements, such as commercial and industrial structures, public utilities and transportation systems. No urban development and no more than a small number of habitable structures are involved. Loss of life would be unlikely.

3. High Hazard. Dams built in areas where failure would likely result in loss of life or excessive economic loss. Generally this would involve urban or community development with more than a small number of habitable structures.

Where a spillway design flood range is given, select the magnitude commensurate with the involved risk.

It is recognized that failure of some dams with a relatively small reservoir capacity may have little influence on the potential damage anticipated during the spillway design flood event.

Exceptions to the recommended spillway design flood magnitude may be permissible for some structures. Requests for an exception must include sufficient documentation to demonstrate that economic loss and/or the potential for loss of life resulting from dam failure during occurence of the proposed spillway design flood would be essentially the same as would occur without a dam failure. The Regional Director of Engineering must approve exceptions to the recommended spillway design flood. When documentation is not available to support an exception, use the recommended spillway design flood criteria shown in table 1.

Table 1

RECOMMENDED SPILLWAY DESIGN FLOOD

Hazard potential	Size class	Spillway design flood
High	A	PMF
	B	PMF
	C	1/2 PMF to PMF
	D	100 yr. to 1/2 PMF
Moderate	A	PMF
	B	1/2 PMF to PMF
	C	100 yr. to 1/2 PMF
Low	A	1/2 PMF to PMF
	B	100 yr. to 1/2 PMF
	C	50 yr. to 100 yr.

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1197 SOUTH BROADWAY • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325
800-873-5227

ATTACHMENT 2

LABORATORY REPORT

TO: Noranda, Inc.
ADDRESS: P.O. Box 15638
Denver, Colorado 80215
Attn: Brent Bailey

LAB NO.: 88-16886
DATE: 01/05/89 pjf

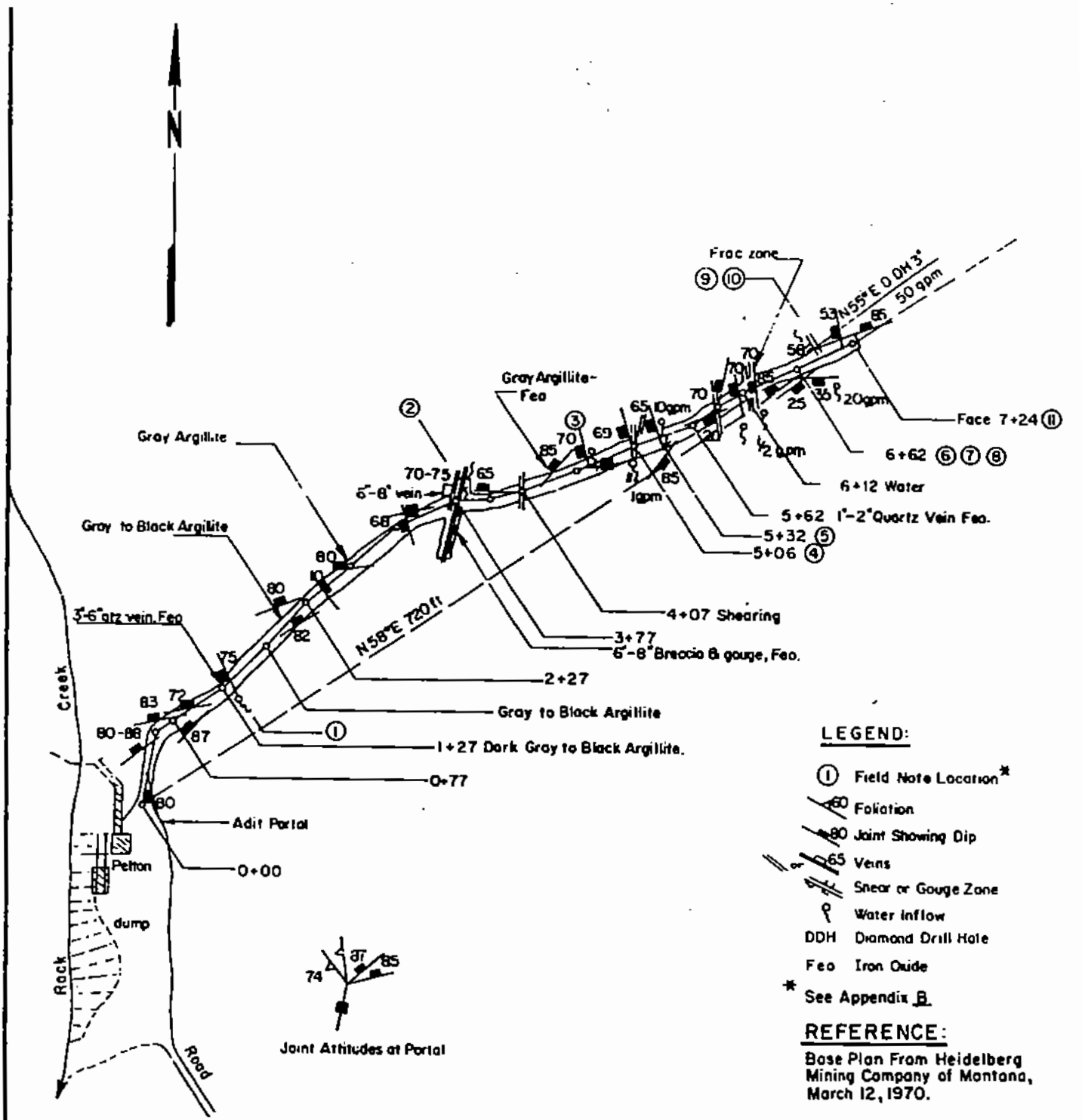
WATER ANALYSIS

Final Tailings Solution
Cycle 5
Submitted 12/20/88

CONSTITUENT	mg/l
Potassium	24
Sodium	13
Calcium	12
Magnesium	3

	mg/l	
Dissolved Metals:	DISSOLVED	TOTAL
Arsenic	<0.005	<0.005
Aluminum	0.1	0.1
Barium	<0.1	<0.1
Beryllium	<0.005	<0.005
Cadmium	<0.001	<0.001
Chromium	<0.02	<0.02
Copper	<0.01	0.02
Cobalt	<0.01	<0.01
Iron	0.05	0.08
Lead	<0.01	<0.01
Manganese	0.06	0.09
Mercury	<0.001	<0.001
Molybdenum	0.010	0.010
Nickel	<0.03	<0.03
Selenium	<0.005	<0.005
Silver	<0.005	<0.005
Antimony	0.01	0.01
Zinc	<0.01	0.05

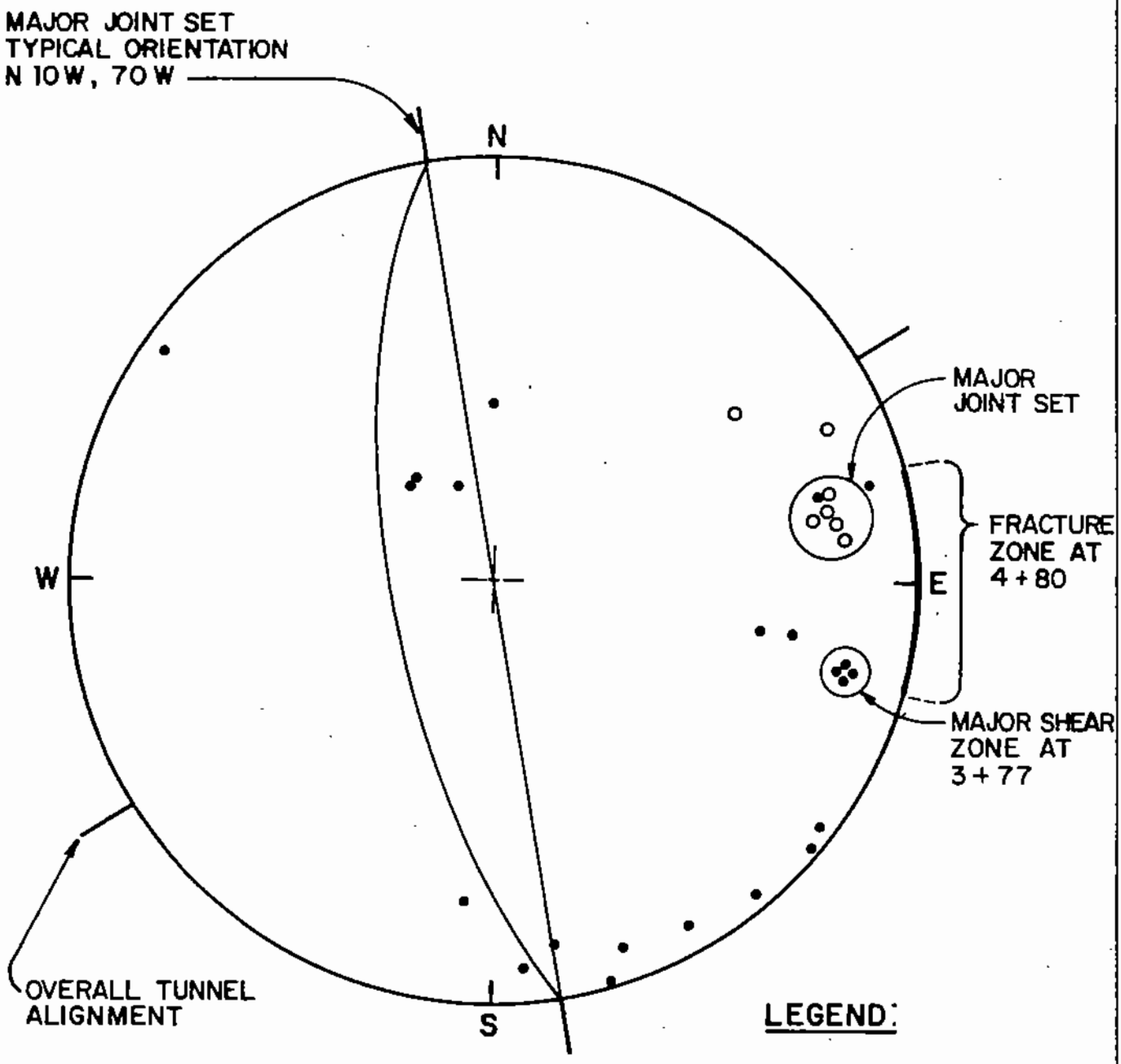
APPENDIX B
HEIDELBERG TUNNEL GEOLOGIC DATA



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

DESIGNED FK	DRAWN VB	CHECKED MPF	RECOMMENDED
DATE OCTOBER 1988			APPROVED

MONTANA SILVER VENTURE
LOWER HEIDELBERG ADIT GEOLOGIC MAP
FIGURE B-1



EQUAL AREA PROJECTION
(LOWER HEMISPHERE)

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

DESIGNED FK	DRAWN VHP	CHECKED MPF	RECOMMENDED
DATE OCTOBER 1988			APPROVED

MONTANA SILVER VENTURE
LOWER HEIDELBERG ADIT STEREOGRAPHIC
PLOT OF DISCONTINUITY DATA
FIGURE B-2

LOWER HEIDELBERG ADIT INSPECTION

Field Notes (9 August 1988)

Station	Joint Attitude (Strike, Dip)	Comments
0+10	N15W, 80W	FeO stains
0+70 to 0+90	N80E, 70-80N	Major joint set, tight, no filling
0+95	N40E, 87W	
1+35	N25W, 75W	Map Location 1: Open 0.2" aperture, seeping
0+00 to 0+80		Dry walls
0+80 to 2+00		Generally moist walls
2+10	N60E, 82N	Tight
2+25	N70E, 80N	Spacing 2 ft., 3 in joint set, many short joints, dry, tight
2+70	N85E, 80N	Minor FeO stain, tight, crown breaks subhorizontal
2+75 to 3+00		Many short random joints
3+30	N15W, 68W	Dry, filled joint, 1/10", altered
3+40	N80E, Vertical	Wet joint, FeO stain, open 1mm
3+70 to 3+77	N15E, 70-75W	4 major parallel joints, 50 to 70 ft. long in cross-chamber

Station	Joint Attitude (Strike, Dip)	Comments
3+77		Map Location 2, shear zone: 3/4" clayey seam, within fractured brecciated zone 2" to 10" wide; alcoves 5 feet wide and mined out along shear zone, several drips and light dripping overall, total ±1gpm
3+90	N85W, 65N	Major joint, FeO stains, tight
4+00 to 5+00		Walls generally moist except at 4+65-69 wet; generally Terzaghi Class 3 to 4
4+39	N37E, 85W	Several major joints, tight, dry
4+67	N15W, 70W	Map Location 3: Open joint leaking 2-4 gpm
4+80	N15E to N15W, Vertical	Previously mapped, 5 foot wide zone of closely spaced fracturing (2-1/2" spacing)
4+85	N80E, Vertical	In crown, tight, dry
5+06	N12W, 69W	Map Location 4: Cross joint, open 1/10", leaking 1 gpm; 1/2 hour after hammering on southwall, 5 gpm+ emerged and continued to shoot across to the other wall dropping 2 feet over a distance of 6-1/2 feet.
5+30	N10-12W, 65W	Map Location 5: Open joint 0.3" aperture leaking 5 gpm, 1" zone of parallel veins
5+40	N35E, 85E	

Station	Joint Attitude (Strike, Dip)	Comments
5+40 to 5+85		Few joints, walls generally moist, Terzaghi Class 2 to 3
5+80	N70E, 20S	Subhorizontal joint in crown
5+89	N10E, 70W	Map Location 6: Many short (1-foot) joints, dripping
6+10 to 6+34		Numerous small leaks
6+10	N10W, 70W	Map Location 7: Largest inflow at 6+10, 2 gpm, open 1/2" to 1"
	N50E, 25SE	One timber support
6+28	N05W, 72W	Map Location 8: Closed leaky fracture zone, FeO, 6" to 24" wide zone, 1 gpm
6+34 to 6+75		Walls moist, few joints
6+58	N50E, 85W EW 35S	2 dry, tight, major sets
6+75	N52E, 25SE	Map Location 9: Subhorizontal joints, spacing 3"-6", seeping 1/2 gpm
6+87		Map Location 10: 50+ gpm flows from drill hole in left rib; shear zone in lower right ± 20 gpm
	N35W, 55-58W	Leaky fracture zone 2 ft. across, intense fracturing in seam 2" to 4" across
7+10	N10E, 53W	Foliation

Station	Joint Attitude (Strike, Dip)	Comments
7+15	N73E, Vertical to 85N	Joints parallel to tunnel
7+24		Map Location 11: Drill hole at face making 3 to 5 gpm

APPENDIX C
SEISMIC REFRACTION SURVEY

APPENDIX C
SEISMIC REFRACTION SURVEY

C.1 PURPOSE

The purpose of the seismic refraction survey was to provide information on the depths to soil layers, the approximate depth to bedrock, and the rippability of near surface material. Seismic refraction surveys were performed at the Little Cherry and Poorman tailings impoundment sites, at the Ramsey Creek and Libby Creek plant and portal sites, and at the south end of Rock Lake evaluation adit site. The locations of the seismic lines are shown on the exploration plans.

C.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 placed at intervals of 25 feet (10 feet for the Rock Lake seismic line) 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.

C.3 SEISMIC REFRACTION PROGRAM AND RESULTS

Fifty seismic refraction lines were surveyed to determine velocity layers, and depth to bedrock. 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 up to 500 feet from the nearest geophone.

Tables C.1 and C.2 summarize the results of the seismic refraction investigation at the impoundment sites and at the plant and portal sites, respectively. The tables list the seismic velocity values and depths to the velocity interface. Seismic velocities ranged from 800 feet per second to approximately 20,000 feet per second. In general, three subsurface horizons were found based on seismic velocity ranges at the plant sites and portal areas; at the tailings impoundment sites, two to four subsurface horizons were found.

Seismic velocities below 2,500 feet per second correspond to surface materials consisting of loose silt, sand, or gravel. Velocities in the 3,500 to 9,000 feet per second range probably correspond to increasingly denser or compacted gravels, sands or silts. Velocities above 10,000 feet per second correspond to rock or possibly very dense gravel, cobbles and boulders.

In some cases, as noted in the table, estimates were made to determine the minimum depth to an assumed 12,000 foot per second velocity layer. This layer was not observed on the seismic record but the assumed value was used to estimate a minimum depth to rock. Depths noted in the tables are to the closest refracting interface and are not necessarily vertically below the seismic line.

EXPLANATION OF SEISMIC REFRACTION TABLES

Vl_F : Velocity of surficial deposits from forward seismic shot.

Vl_R : Velocity of surficial deposits from reverse seismic shot.

V2, V3, V4 : Average velocity of intermediate layers.

Di_F : Depth to bottom of layer i at forward end of seismic line.

Di_R : Depth to bottom of layer i at reverse end of seismic line.

* : Estimated velocity.

** : Minimum depth to assumed 12,000 fps velocity layer

*** : Velocity and corresponding depth obtained at offset shot point.

NOTE: Not all layers are present at each location.

TABLE C.1. SEISMIC REFRACTION RESULTS TAILINGS IMPOUNDMENT SITES

		Layer 1				Layer 2			Layer 3			Layer 4
		Seismic Velocity (feet/second)		Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)	Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)	Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)
Site	Line No.	$V1_F$	$V1_R$	$D1_F$	$D1_R$	V2	$D2_F$	$D2_R$	V3	$D3_F$	$D3_R$	V4
PC	TI-1	2500	2060	6	6	4200	38	25	7600	93**	99**	---
PC	TI-2	1540	2140	10	9	5900	42	41	8300	174**	135**	---
PC	TI-3	2380	2860	8	8	6350	45	31	7900	97**	92**	---
PC	TI-4	4000	2600	12	8	6000	31	35	8000	105**	159**	---
PC	TI-5	2340	1900	8	12	5500	67	47	8400	109**	106**	---
PC	TI-6	2000*	2000*	2	2	5000	28	21	7800	93	45	13,800
PC	TI-7	2000*	2000	3	8	4600	40	14	---	---	---	13,600
PC	TI-8	1700	2000*	9	1	6000	35	48	---	---	---	10,500
LCC	TI-9	2000*	2000*	18	1	5600	62	70	---	---	---	10,400
								140				15,000***
LCC	TI-10	2000*	2000*	4	4	4900	32	54	6250	186**	206**	---
LCC	TI-11	2500	2000*	8	2	5550	16	10	7200	148**	156**	---
LCC	TI-12	2000*	2000*	4	6	5400	12	31	7200	83**	153**	---
LCC	TI-13	2200	2000*	8	1	5600	27	26	7850	138**	---	---
LCC	TI-14	2500	2000*	7	7	4600	94	80	---	---	---	15,000
LCC	TI-15	3300	1900	21	13	4950	135***	88	---	---	---	12,320
PC	TI-16	2700	2200	63	60	6100	161	92	9100	---	170	15,000***
PC	TI-17	2200	2000*	8	2	5350	12	4	8700	57	32	14,000
PC	TI-18	2700	2500	7	7	5350	57	35	8200	111	82	13,700
PC	TI-19	2300	2000*	9	3	6000	38	31	8200	109	69	14,000
PC	TI-20	2000*	2200	2	8	5900	49	24	7200	123	---	15,500***
PC	TI-21	2000*	2000*	8	2	4600	10	20	6050	87	96	14,100
PC	TI-22	2000*	2000*	2	9	3850	41	27	6800	98	81	10,900

PC - Poorman Creek tailings impoundment

LCC - Little Cherry Creek tailings impoundment

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TABLE C.1. SEISMIC REFRACTION RESULTS TAILINGS IMPOUNDMENT SITES

(CONTINUED)

		Layer 1				Layer 2			Layer 3			Layer 4
		Seismic Velocity (feet/second)		Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)	Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)	Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)
Site	Line No.	$V1_F$	$V1_R$	$D1_F$	$D1_R$	V2	$D2_F$	$D2_R$	V3	$D3_F$	$D3_R$	V4
MC	MC-1	980	1430	4	7	3640	35	40	6250	61	74	11,000
MC	MC-2	950	600	4	6	4200	13	11	6250	80**	93**	---
MC	MC-3	810	2130	7	10	---	---	---	---	---	---	13,800
MC	MC-4	1390	1150	9	7	---	---	---	---	---	---	13,300
MC	MC-6	2200	2200	7	4	4100	---	---	---	56	50	13,000
MC	MC-7	1660	1330	12	8	6100	---	---	---	95**	91**	---
MC	MC-8	1330	900	9	6	5000	---	---	---	38	31	11,100
MC	MC-9	800	1940	5	12	6300	---	---	---	---	97	11,300
MC	MC-10	890	890	4	4	4640	---	---	---	41**	42**	---
MC	MC-11	910	2000	4	11	5500	---	---	---	39**	46**	---
MC	MC-12	1550	---	10	0	4200	---	---	---	31	27	10,600
MC	MC-13	830	830	10	6	4300	---	---	---	70	28	9,400
MC	MC-14	1610	1610	2	3	---	---	---	7900	40	47	14,400
MC	MC-15	870	1820	6	4	---	---	---	---	---	---	10,200
MC	MC-16	890	900*	6	3	---	---	---	---	---	---	10,000

MC - Midas Creek tailings impoundment

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TABLE C.2. SEISMIC REFRACTION RESULTS PLANT AND PORTAL SITES

		Layer 1				Layer 2			Layer 3
		Seismic Velocity (feet/second)		Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)	Depth to Bottom of Layer (feet)		Estimated Seismic Velocity (feet/second)
Site	Line No.	$V1_F$	$V1_R$	$D1_F$	$D1_R$	V2	$D2_F$	$D2_R$	V3
LCP	LC1	4000	---	19	0	6500	42	27	15,000
LCP	LC2	2000	1600	12	10	7000	54	65	13,400
LC	LC3	2000*	2400	1	17	8300	12	30	14,300
LC	LC4	2000*	2000*	9	1	7000	45	62	16,000
LC	LC5	2700	1900	17	5	5900	68	40	18,200
LC	LC6	2000	2000	9	9	7100	58	49	18,900
RCP	RL1	1300	1300*	10	11	5700	46	56	20,000*
RCP	RL2	---	1250	0	8	2900	42	53	20,000*
RC	RC1	1300	800	9	10	5200	32	24	9,000
RC	RC2	2300	2300	15	7	5100	48	69	11,500
RC	RC4	1600	---	14	0	4600	22	39	10,200
RC	RC5	3200	2800	17	31	6250	39	60	14,400
RL	RL	690	1850	3	2	2000	28	45	10,000

LCP - Libby Creek Portal Site
LC - Libby Creek Plant Site
RCP - Ramsey Creek Portal Site
RC - Ramsey Creek Plant Site
RL - Rock Lake Adit

APPENDIX D
DRILL LOGS

APPENDIX D
DRILL LOGS

D.1 DRILLING

Drilling equipment consisted of a CME 75, a Mobile B53, and a Mobile B50 drill rig. Drilling was performed by using a continuous hollow stem flight auger or tricone rotary bit in soil, and a diamond rotary bit in rock. An engineering geologist or geotechnical engineer of Morrison-Knudsen Engineers (MKE) observed the drilling progress and kept a log of soil and rock encountered.

Where soil conditions permitted, hollow stem augers with OD.'s ranging from approximately 7 to 9 inches were initially used to advance the boring. 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 was used to advance the boring. Three inch I.D. (NW) flush joint casing was used to keep the borings open. Each casing was either reamed or driven to the bottom of the boring. Descriptions of the auger cuttings and drill water return were entered on the boring logs included in this appendix.

Core drilling in bedrock was done with a 2.98 inch O.D. (NQ) diamond drill bit and double tube core barrel. Coring commenced as soon as coreable rock was encountered and continued 10 to 55 feet into bedrock. 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 included percent recovery, 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 the Midas site borings, which were visually located by the MKE geologist.

Water levels measured in the borings are presented in Table D.1.

D.2 SAMPLING

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

Disturbed soil samples were obtained using a standard 2-inch O.D. split barrel sampler, driven by a 140 pound hammer with a 30-inch free-fall drop, as described in ASTM D1586. The boring was cleaned of all loose material. The sampler was inserted and measurements were made to verify that the sampler reached the drilled depth 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 then 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 D-1). Samples were double sealed in plastic bags that were labeled with sample number, boring number, project number and sample depth interval.

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 O.D. sampler, 30 inches in length, was advanced 2 feet, or until refusal, by hydraulically pushing in one continuous movement 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 then identified 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 O.D. ring samples were obtained in non-gravelly soils that were too dense to use Shelby samplers. The equipment used for taking ring samples is similar to that used for taking SPT samples except that the split tube is lined with 1/2-inch long metal rings. The sampler was pushed or driven into the soil to a maximum distance of 18 inches to obtain a relatively undisturbed sample. The recovered sample was divided into 6-inch sections and placed in plastic tubes. The tubes were identified by project name and number, boring number, depth interval and sample number.

D.3 PERMEABILITY TESTS

Field permeability tests consisted of constant head tests in soil and packer tests in bedrock. Tests were performed by using procedures outlined in the U.S. Bureau of Reclamation's "Earth Manual," Method E-18.

The constant head tests were taken in casing or drill rod. At the Midas site, drill rod was used to obtain permeability values in the augered holes because the inside diameter of the augers precluded the use of the NW casing for the tests. The casing or rod was lowered to the bottom of the boring. The casing was carefully cleaned out to the bottom. 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 or rod was refilled at intervals to the original water level. The rate of flow into the hole was then determined from the total water drop.

The permeability is obtained from the following formula:

$$k = Q/(5.5\ r\ H)$$

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

Some constant head tests were performed in an uncased section at the bottom of the boring. After the casing was driven to the bottom of the boring and a constant head

test performed as described above, the hole was advanced (without advancing the casing) and additional constant head tests were performed. Permeability was 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, since there is no applied pressure. The results of the constant head tests are shown in Table D.2.

Water pressure tests in the bedrock were performed by using a single pneumatic 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. 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 a duration of 5 minutes. The flow meters were calibrated periodically.

The permeability is obtained from the following formula:

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

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

The results of the packer tests are shown in Table D.2.

D.4 PIEZOMETER INSTALLATION

Piezometers were installed in selected borings immediately after drilling was completed and extended to the bottom of the open boring. Piezometers consisted of 1-inch I.D. Schedule 80 PVC pipe, with 20 feet of 0.02-inch width machine slotted 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. A steel protective casing with a lockable lid was set in concrete at each piezometer. Construction details of the piezometers are presented on Figure D-2.

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 D-1. The relative proportions of the various soil types 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 sampler types are indicated on the boring logs as follows:

   - o SPT: 2-inch O.D. Standard Penetration Sampler (ASTM D 1586)
   - o S: 2-1/2-inch O.D. Split Spoon Sampler
   - o ST: Shelby Tube Sampler
   - o R: Ring Sampler

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

5. Groundwater level data are shown in Table D.1.

6. Piezometer construction details are shown on Figure D-2.

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

8. Borings were drilled by a Mobile B-53 or CME-75 rotary drilling rig.

9. 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.

TABLE D.1

DEPTH TO WATER (FEET)

	POORMAN SITE				LITTLE CHERRY SITE				RAMSEY SITE	LIBBY SITE			MIDAS SITE					
Boring:	USA-1*	USA-2	USA-3	USA-4	USB-1	USB-2	USB-3*	USB-5	RCDH-1	LCDH-1	LCDH-2	LCDH-3*	MCDH-2	MCDH-3	MCDH-4	MCDH-6	MCDH-7	MCDH-8
Date Completed:	8/15/88	8/14/88	8/6/88	8/18/88	8/13/88	8/1/88	7/29/88	8/24/88	7/28/88	8/26/88	8/5/88	8/4/88	11/11/88	11/11/88	11/13/88	11/15/88	11/13/88	11/15/88
7/27/88									37.5									
7/28/88							31.5/		23.0									
							34.3											
7/29/88									21.5									
7/30/88									21.8									
7/31/88									21.6									
8/2/88									21.7									
8/4/88												16.3						
8/6/88			25.0		21.6	2.8												
8/12/88			25.6		23.4	2.9												
8/14/88		14.4																
8/15/88	16.0																	
8/16/88	7.0																	
8/17/88				11														
8/18/88		57.4	24.4	37	22.9				22.0									
8/26/88		58.2	24.9	37.8	22.9	2.1		27.1			12.0							
11/13/88													83.1	17.1			14.0	
11/16/88													83.2	20.0	28.4		28.6	
11/17/88															29.0	84.4		44.3

*Note: Piezometers were not installed in these borings. Groundwater depths were measured at time of drilling.

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TABLE D.2
SUMMARY OF FIELD PERMEABILITY TESTS

Site	Boring	Depth of Casing or Packer (ft)	Depth of Boring (ft)	Gravity Head (ft)	Water Loss (gpm)	Applied Pressure (psi)	Permeability (cm/sec x 10^{-6})
Poorman	USA-1	20	20	20	0	0	<1
	USA-2	20	20	20	0.056	0	280
	USA-4	10	10	10	0	0	<1
		10	15	12.5	0.002	0	2
		10	20	15	0.7	0	220
		20	20	20	0.003	0	12
		20	25	22.5	1.9	0	670
		35	35	35	0.002	0	5
		35	45	38	0.012	0	2
Little Cherry	USB-3*	38.8	55	34.3	0	20	<1
		38.8	55	34.3	0	40	<1
		38.8	55	34.3	0	20	<1
		50.3	70	34.3	0.76	25	26
		50.3	70	34.3	1.36	50	29
		50.3	70	34.3	0.68	25	23
	USB-4	15	15	15	0.28	0	1800
		20	20	20	0.02	0	100
	USB-5	10	10	10	0.007	0	70
		10	15	12.5	0.022	0	14
		10	20	15	0.019	0	6
		10	25	17.5	0.013	0	3
		10	40	25	0.064	0	7

*Packer test in rock

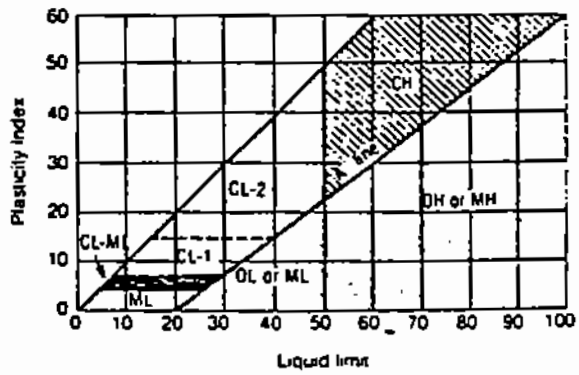
TABLE D.2
SUMMARY OF FIELD PERMEABILITY TESTS
(CONTINUED)

Site	Boring	Depth of Casing or Packer (ft)	Depth of Boring (ft)	Gravity Head (ft)	Water Loss (gpm)	Applied Pressure (psi)	Permeability (cm/sec x 10^{-6})
Midas	MCDH-2	30	30	30	0.019	0	64
		40	40	40	0.001	0	3
		65	65	65	0.001	0	2
	MCDH-3*	10	35	23	3.59	5	238
		10	35	23	6.21	10	309
		25	35	23	0	15	<1
		25	35	23	0.04	30	2
	MCDH-4*	18	32.4	27.5	0	10	<1
		18	32.4	27.5	0	20	<1
		31	46	31	0	15	<1
		31	46	31	0	25	<1
	MCDH-6	15	15	15	0	0	<1
		23.5	23.5	23.5	0	0	<1
		34	34	34	0	0	<1
		43.5	43.5	43.5	0	0	<1
		53.5	53.5	53.5	0.002	0	4
		65	65	65	0	0	<1
		75	75	75	0	0	<1
	MCDH-7*	10	26	20.5	0.06	13	4
		26	36	31.1	0	15	<1
		26	36	31.1	0.04	30	2
	MCDH-8	7	7	7	0	0	<1
		16	16	16	0	0	<1
		27	27	27	0.0002	0	<1

* Packer test in rock

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	Silty gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits below "A" line, or PI less than 4
				u			Atterberg limits above "A" line, or PI greater than 7
			GC		Clayey gravels, poorly graded gravel-sand-clay mixtures		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	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line, or PI less than 4
				u			Atterberg limits above "A" line, or PI greater than 7
			SC		Clayey sands, poorly graded sand-clay mixtures		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	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
				2			
			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		

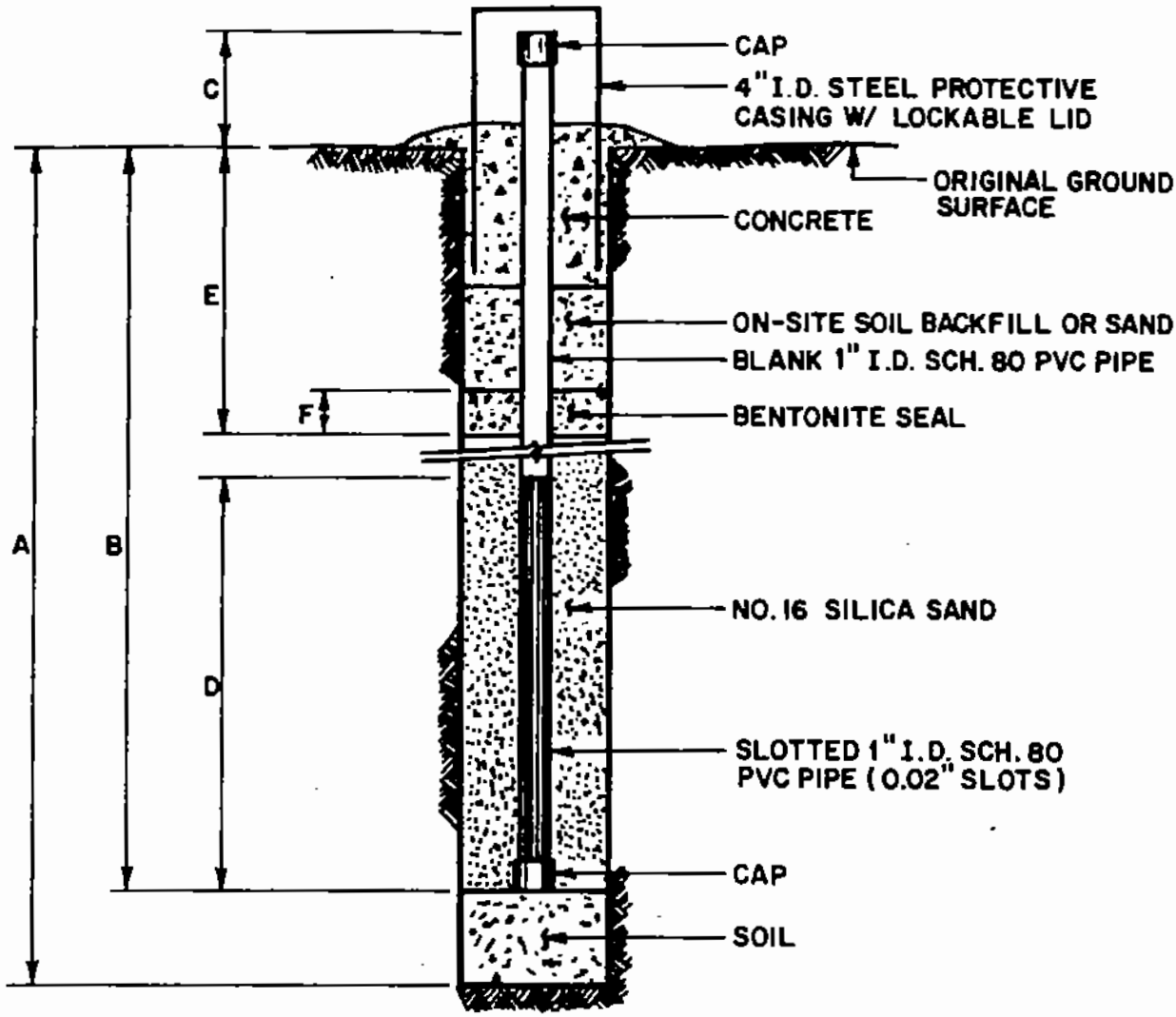


Plasticity Chart
For laboratory classification of fine-grained soils

*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



SITE	BORING NO.	DIMENSIONS (FT.)					
		A	B	C	D	E	F
POORMAN	USA-2	80.5	80.4	1.1	20	54	5
	USA-3	80.1	80.1	1.2	50	25	0
	USA-4	80.2	80.2	1.3	20	54	4
LITTLE CHERRY	USB-1	80.8	80.8	0.9	20	49	0
	USB-2	80.8	80.8	1.0	20	55	0
	USB-5	50.3	50.2	1.0	20	25	3
LIBBY	LCDH-1	45.0	24.9	1.0	20	5	0
	LCDH-2	42.8	42.8	1.0	20	18	0
RAMSEY	RCDH-1	53.0	53.0	1.7	20	28	0
MIDAS	MCDH-2	100.0	100.0	1.6	30	60	3
	MCDH-3	35.0	34.0	2.4	20	7	5
	MCDH-4	46.0	46.0	2.8	20	21	2.5
	MCDH-6	96.5	94.0	0.5	20	70	3
	MCDH-7	36.0	35.0	1.9	20	14	6
	MCDH-8	55.5	53.2	2.4	20	31	2

PIEZOMETER CONSTRUCTION

FIGURE D-2

LITTLE CHERRY SITE

Borings USB 1-5

PROJECT: MONTANA SILVER VENTURE			JOB NO. 8029		HOLE NO. USB-1
SITE: Little Cherry Tailings	DATE - STARTED AUG 2 88 FINISHED 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)	SAMPLER NUMBER	CASING	SPT / RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION	WATER DATA	REMARKS
									Road fill at surface		Started drilling (8/2/88, 9:00 AM) Temperature 40-50 deg.F, overcast, calm
3460	5	SPT-1		14 16 20	0				**SILTY SANDY GRAVEL (GM),** fine to coarse, brown, wet, dense, maximum gravel size 1-3/8"; sand is fine to medium.		Rotary drilled to 5.0', used 4" tricone bit, drilling fluid return light brown, loss 0% Recovered 20% with basket catcher Spun casing to 5.0' (NWFJ, 3-1/2"OD, 3"ID)
	10	SPT-2		7 9 12	93				**SANDY SILTY CLAY - SANDY CLAYEY SILT (CL-ML),** orangish brown, low plasticity, wet, medium stiff.		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 27 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'* Hard drilling at 17.5'-18.5'*
	20	SPT-4		28 41 50	73				**SILTY SAND (SM),** light gray to orangish brown, non plastic, wet, very dense; some gravel, fine to coarse, angular, quartsite, maximum size 1". Light gray sones are often hard but can be broken by hand (looks like soft rock). Orangish brown sones have some very fine, rounded to subrounded gravel.	▼	
3440	25	SPT-5		50/.4	100						
	30								**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).		
3430	35	SPT-6		29 18 31	100				**SILTY SAND (SM),** fine, orangish brown, non plastic, dense, wet; some gravel, fine, rounded to subrounded.		
	40										
3420	45	SPT-7		18 30 50	100				Very dense, trace medium to coarse sand; some gravel, fine to coarse, rounded to subrounded, occasionally angular.		

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

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 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) Resumed drilling at 55.0' (8/3/88, 7:00 AM) Temperature 40 deg.F, clear, calm Water level - dry (hole caved at 13.0') Rotary drilled 55.0'-65.0'
3400	60										
	65	SPT-9		27 50/.3	88				Some coarse gravel, rounded to subrounded		Spun casing 5.0'-20.0' Rotary drilled 65.0'-80.0'
3390	70										
	75	SPT-10 SPT-11		50/.3 50/.3	67 100				Some fine gravel, rounded to subrounded		
	80	SPT-12		22 50/.3	75				GRAVELLY SILTY SAND (SM), fine to coarse, orangish brown, wet, very dense; gravel is fine, rounded to subrounded. BOTTOM OF HOLE AT 80.8'		Stopped drilling (8/3/88, 1:00 PM)
3380	85										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') Removed all casing Set steel protective surface casing in concrete,.9' stickup above ground surface)
	90										
3370	95										8/6/88 - Water level 21.6 * Reported by driller 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
	100										
3360	105										

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SHEET 2 OF 2 | HOLE NO. USB-1

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: 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
3440											Started drilling (7/29/88, 12:30 PM) Temperature 95-100 deg.F, clear, slight wind Augered to 18.5' with hollow stem auger (9"OD, 3-3/8"ID)
		SPT-1		17 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". Boulder at 4.5'-5.5'*		
	5										
		SPT-2		25/0	0				Boulder at 8.0'-10.5'*		
	10										
3430											
		SPT-3		49 50/.2	100				Orangish brown to light brown, damp, sample looks like decomposed rock. Boulder at 13.2'-14.5'* Boulder at 16.0'-17.5'* light brown, damp, sample looks like decomposed rock. Boulder at 17.9'-18.5', 18.5'-18.8'*		
	15										
		SPT-4		50/.4	100						
	20	SPT-5		50/.3	100						Stopped drilling at 18.5'(7/29/88, 2:30 PM) Resumed work (7/30/88, 8:00 AM) Temperature 65 deg.F, clear, calm Removed augers Drove casing to 18' (NWFJ, 3-1/2"OD, 3"ID) Rotary drilled 18.5'-44.5', using 2-15/16" tricone bit, drilling fluid water, return light brown, no loss
3420									**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.		
	25	SPT-6		50/.3	83						
									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									**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.		Bit keeps blocking off due to silty/clayey matrix at 41.0'-44.5'*
	45	SPT-8		50/.3	100						Hole caved in when pulled tricone to do SPT test at 44.5' Drove casing 18'-40' Stopped work (7/30/88, 3:15 PM) Resumed work (7/31/88, 9:00 AM) Temperature 65 deg.F, clear, calm 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
3390									Gravel with silty/clayey lumps at 44.9'-54.5'*		Rotary drilled 44.5'-64.5'
	55	SPT-9		50/.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 50/.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'*		Hole caved in when pulled tricone to do SPT test at 74.5'
									light brown		
	80	SPT-11		22 50/.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											
	95										WATER LEVEL 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)	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
3580									Road fill at surface		Started drilling (7/26/88, 11:30 AM)
		SPT-1		13 21 23	93				**SILTY SAND (SM),** orangish brown, nonplastic, dry, dense; gravelly, fine to coarse, subangular, maximum size 2".		Temperature 95 deg.F, clear, calm Augered to 35.0' with hollow stem auger (9"OD, 3-3/8"ID)
	5										
		SPT-2		17 21 25	93				Gravel at 7.0'-7.5'* damp		
	10										
3570									Gravel at 11.0'*		
		SPT-3		18 41 43	93						
	15										
		SPT-4		18 41 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											Hard drilling at 21.5' *
		SPT-5		41 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".		
	25										
		SPT-6		25/0	0				**† TOP OF BEDROCK AT 27.0' †** Cuttings include coarse, subangular, gravel size pieces of white to gray quartzite, siltite, and argillite.		Drilling very hard 27.0'-35.0'* Probably have been in coreable rock
	30										Stopped drilling at 35.0' (7/26/88, 3:00 PM)
3550										▽	Resumed drilling at 35.0' (7/27/88, 7:00 AM) Temperature 65 deg.F., clear, calm, water level - dry
		SPT-7		50/.1	0					▼	
	35										Cored 35.0'-55.0' (NQ, hole diameter 2.98", core diameter 1.875") using augers as casing. Used diamond impregnated coring bit Drilling fluid water, return light orangish brown, loss 0%, 10.0' long double tube core barrel.
		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.		
	40										Drilling rate 3 min/ft 35.0'-40.0'
3540		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 40-50 degrees. Fracture spacing 1" to 6". Fractures are generally parallel to bedding, planar, rough to smooth, closed, occasionally with thin.		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)	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
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)
											Resumed work (7/28/88, 7:00 AM)
											Temperature 50-60 deg.F, broken clouds, slight wind
									Very soft at 50.0' to 65.0', completely weathered, highly fractured core pieces. (length < 2-1/2").		Water Pressure Test 1: 58.8'-65.0'
	60	C-6		0	50						Stopped work (7/28/88, 9:30 AM)
3520											Resumed drilling at 55.0' (7/29/88, 6:30 AM)
											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'
											Stopped drilling at 70.0' (7/29/88, 8:15 AM)
											Water Pressure Test 2: 50.3'-70.0'
	70										
3510									BOTTOM OF HOLE AT 70.0'		
											No piezometer installed
									Average RQD of bedrock = 12%		Removed all casing
	75								Average recovery = 66%		
									Average drilling rate = 2 min/ft		
	80										
3500											WATER LEVEL
											date time level
											7/28/88 7:00 AM 31.5'
	85										7/29/88 6:30 AM 34.3'
	90										
3490											
	95										
	100										
3480											
	105										

PROJECT	MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. USB-4	
SITE	Little Cherry Tailings	DATE - STARTED AUG 20 88 FINISHED 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)	SAMPLER NUMBER	CASING	SPT / RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION	WATER DATA	REMARKS
3640	5	SPT-2		49 47 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) Rotary drilled with water using a 2-15/16" tricone bit Cobbles on surface to approximately 1.0' Brown water return, 100% return Reamed casing to 5.0' (NWFJ 3"ID, 3-1/2"OD)
											Reamed casing to 10.0'
	10	SPT-3		50/.3	40				gray, subrounded to subangular, hard, fine grained quartsite.		Constant head water test at 10.0', water leaking at surface hard to seal casing in gravel 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) Remove casing, put on driving shoe (8/23/88, 9:45 AM) Casing driven to 15.0' 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.		Casing driven to 20.0' Constant head water test at 20.0'
3620	25								Boulder at 21.5' to 23.0', white and gray siltite, hard.		Hole keeps caving after drill rods removed
									BOTTOM OF HOLE AT 25.0'		Stopped drilling (8/23/88, 3:00 PM)
	30										
3610	35										
	40										
3600	45										

PROJECT		JOB NO.	HOLE NO.
MONTANA SILVER VENTURE		8029	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) 2-16/16" tricone bit and water Cobbles and boulders at surface Ream casing to 5.0' (NWFJ 3"ID, 3-1/2"OD) Orange brown water return
3510	5	SPT-1		21 50 50/.2	100						
	10	SPT-2		50/.45	86				**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. Cobbles 11.0' to 19.0'		Ream casing to 10.0' Constant head water test at 10.0' .007 GPM Return water alternates orangish brown and gray, silty sand and cobbles
3500	15										Constant head water test at 15.0', casing at 10.0'
	20	SPT-3		16 19 50	80				**SILTY CLAY - CLAYEY SILT (CL-ML),** hard, trace to some fine gravel, gray, fine grained, completely weathered.		
3490	25	SPT-4		32 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' Cobble at 33.0'		
3480	35	SPT-5		50/.26	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) Installed piesometer 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-7		80/.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'		
3460	55										
	60										
3450	65										
	70										
3440	75										
	80										
3430	85										
	90										
3420	95										
	100										
	105										

POORMAN SITE

Borings USA 1, 1A, 2 -4

PROJECT: MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. USA-1
SITE: Poorman Creek Tailings	DATE - STARTED FINISHED: AUG 15 88 - AUG 15 88	HOLE SIZE: 3"	ORIENTATION: vertical
LOCATION: Libby, Montana	ELEVATION(FT): 3480	DEPTH TO WATER(FT): 7.0	DEPTH TO ROCK (FT):
DRILLING CONTRACTOR: Northern Eng.& Test.	SAMPLES: 11	CORE BOXES: 0	DEPTH OF HOLE (FT): 75.3
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)
3480											
									SILTY SAND (SM), fine, orangish brown, nonplastic to slightly plastic, medium dense, moist; trace gravel, fine, gray and orangish brown, subrounded.		Started drilling (8/15/88, 8:30 AM) Rotary drilled with water and 2-15/16" tricone bit
	5	SPT-1		8 8 11	70						Brown water return
3470	10	SPT-2		5 9 18	66				Nonplastic, moist		
									Seams of gravel, 10' to 15', gravel layer, 12.0' to 12.5'.		
	15	ST-1									Shelby tube sample 15.0' to 15.5'
		SPT-3		12 22 40	60				light grey and orangish brown, nonplastic, very dense, damp.		
											Reamed casing to 20.0' (NWFJ 3-1/2"OD, 3"ID)
3460	20	SPT-4		34 50/.35	68				fine to medium sand; with inclusions of silty sand, fine, gray, max. size 1" (completely weathered gravel?).		Constant head water test at 20.0', no water take
											Gray water return at 25.0' to 24.5' and 26.5' to 27.0'
	25	SPT-5		50/.3	100				Layers of gray, fine grained sand and silt 20' to 30'.		No water loss
3450	30										
	35	SPT-6		50/.25	100						Brown-gray water return 30.0' to 40.0' Hard drilling
3440	40								**SILTY SANDY GRAVEL (GM),** gray, white, and orangish brown, siltite cuttings with orangish brown fine sand and silt.		
	45	SPT-7		50/.1	0						
3430											

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. USA-1

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
3430											
	55	SPT-8		22 50/.1	70				**SILTY SAND (SM),** fine, orangish brown, nonplastic, very dense, wet; with inclusions of silty sand, fine, gray, max. size 2", trace gravel (inclusions may be weathered gravel?).		Return water brown, with brownish-gray intervals
									Layers of sandy gravel 55' to 65'.		
3420	60										
	65	SPT-9		50/.25	100						
3410	70								Gravel is fine, gray, subrounded to rounded.		
	75	SPT-10		50/.3	66						Stopped drilling (8/15/88 4:00 PM)
									BOTTOM OF HOLE AT 75.3'		
3400	80										Constant head water test at 4:05 PM. Hole filled with water, top 20' cased. No water take in 15 minutes. Water level at 16.0'before test
	85										Water level 7.0' (8/16/88)
3390	90										
	95										
3380	100										
	105										

PROJECT: MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. USA-1A
SITE: Poorman Creek Tailings	DATE - STARTED FINISHED: AUG 16 88 - AUG 16 88	HOLE SIZE: 3"	ORIENTATION: vertical
LOCATION: Libby, Montana	ELEVATION(FT): 3480	DEPTH TO WATER(FT):	DEPTH TO ROCK (FT):
DRILLING CONTRACTOR: Northern Eng.& Test.	SAMPLES: 4	CORE BOXES: 0	DEPTH OF HOLE (FT): 17.8
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	WATER DATA	REMARKS
3480											Started drilling (8/16/88, 7:05 AM) Hole approximately 10' from USA-1 Hollow stem auger
		ST-1			25				**SILTY SAND (SM),** fine, orangish brown, non plastic to slightly plastic, medium dense, moist; trace gravel, fine, gray, and orangish brown, subrounded.		ST-1, 2-3/4"ID Shelby tube, sample recovery 1.2', bent end of tube and creased 1/4" to 1/2" depth along length
	5										
		ST-2			60						ST-2, 2-1/4"ID Shelby tube sample, recovery .6', bend end of tube and creased 1/4" to 1/2" depth along length
3470	10										
		R-1									R-1, 2-1/2" Ring sample, 13.5' to 13.7', recovered 11", one 6" sample and one 5" sample
	15										
		R-2									R-2, 2-1/2" Ring sample, 17.5' to 17.8', pushed 4" then attempted to drive but refusal. No sample recovered for testing.
									BOTTOM OF HOLE AT 17.8'		
3460	20										
	25										
3450	30										
	35										
3440	40										
	45										
3430											

PROJECT: MONTANA SILVER VENTURE				JOB NO. 8029	HOLE NO. USA-2
SITE: Poorman Creek Tailings	DATE - STARTED FINISHED: AUG 13 88 - AUG 14 88			HOLE SIZE 3"	ORIENTATION vertical
LOCATION: Libby, Montana	ELEVATION(FT) 3517	DEPTH TO WATER(FT) 58.2		DEPTH TO ROCK (FT)	
DRILLING CONTRACTOR: Northern Eng.& Test.	SAMPLES 13	CORE BOXES 0		DEPTH OF HOLE (FT) 80.5	
DRILL MAKE - MODEL: Mobile B-53	LOGGED BY D. A. Baskin			REVIEWED BY M. P. Forrest	

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)
									Road fill at surface		
									SANDY GRAVEL (GM), orangish brown, medium dense, fine to coarse, subangular to angular with some silt; sand is orangish brown and gray, medium to coarse.	▽	Started drilling (8/13/88, 11:00 AM) Rotary drilled with water and a 2-15/16" tricone bit
	5	SPT-1		21 10 11	0						Casing reamed to 5.0' (NWFJ 3-1/2"OD, 3"ID) Water loss approx. 50% SPT-1: 15% recovered using core sample retainer 75% water return at 7.5'
3510											
	10	SPT-2		8 11 17	55				**GRAVELLY SILTY SAND (SM),** fine, orangish brown, slightly plastic, medium dense, with some clay.		
	15	SPT-3		7 11 13	45						Casing reamed to 15.0'
3500		ST-1			90						Shelby tube sample 17.0' to 17.9', bent tube
									Layer of gravel, 18.5' to 19'		
	20	SPT-4		7 17 17	60				Gravel to 1", subrounded to subangular		Casing reamed to 20.0' Constant head test at 20.0'
	25	SPT-5		9 11 20	37						
3490											
	30										
	35	SPT-6		7 14 16	33				Layer of gravel, 35' to 35.1', fine to coarse, gray and orangish brown, subrounded, slightly to moderately weathered, quartzite/siltite		When drilling completed to 45.0', water continued flowing back up hole, flow slowed and stopped in approx. 45 min. Casing reamed to 45.0, water flowed from ground surface approx 10.0' from hole. Stopped drilling at 45.0' (8/13/88, 5:15 PM) Water flow from hole stopped approx. 45 minutes after drilling stopped
3480											
	40										
	45	SPT-7		15 21 33	85				Very dense, wet; gravel is fine, gray and greenish gray siltite, maximum size 0.8"		Started drilling at 45' (8/14/88, 8:20 AM)
3470		ST-2			100						Shelby tube sample 47.0'-47.7'

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

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)
	55	SPT-8		23 34 48	72				**SILTY SAND (SM),** fine, orangish brown, non plastic, very dense, moist to wet; seams of fine gravel, subrounded.		Water stopped flowing from surface when drilling at approx. 50.0
3460	60										
	65	SPT-9		10 10 15	45				**SILTY CLAY - CLAYEY SILT (ML-CL),** orangish brown, plastic to slightly plastic, very stiff, seams of silty sand and gravel.		
3450	70										
	75	SPT-10		50/.15	100				**GRAVEL**		
3440									**SILTY SAND (SM),** orangish brown, non plastic, very dense, moist to wet, seams and layers of sandy gravel		Stopped drilling (8/14/88, 1:55 PM)
	80	SPT-11		50/.45	60						
									BOTTOM OF HOLE AT 80.5'		Installed piezometer to 80.4' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with no.16 silica sand to 54' and covered with 5' of bentonite slurry) Removed all casing Set steel protective casing at surface in concrete,1.1' stickup above ground surface WATER LEVEL: date time level 8/14 8:15 AM 2.8' 8/14 1:00 PM 14.4' 8/18 8:05 AM 57.4' 8/26 7:40 AM 58.2'
	85										
3430	90										
	95										
3420	100										
	105										

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SHEET 2 OF 2 | HOLE NO. USA-2

PROJECT	MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO.	USA-3
SITE	Poorman Creek Tailings	DATE - STARTED FINISHED AUG 4 88 - AUG 6 88	HOLE SIZE	ORIENTATION	vertical
LOCATION	Libby, Montana	ELEVATION(FT) 3478	DEPTH TO WATER(FT) 25.0	DEPTH TO ROCK (FT)	
DRILLING CONTRACTOR	Northern Eng.& Test.	SAMPLES 12	CORE BOXES 0	DEPTH OF HOLE (FT)	80.1
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY M. I. Schauer		REVIEWED BY	D. A. Baskin

ELEV. (FT)	DEPTH (FT)	SAMPLE/R 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
									Road fill at surface		
		SPT-1		15 14 17	100				**SANDY SILTY CLAY (CL),** gravelly, orangish brown to light gray, dry, very stiff, gravel is fine to coarse, angular to subangular.		Started drilling (8/4/88, 7 AM) Temperature 45-50 deg.F, clear, calm Augured to 15.5' with hollow stem auger (9"OD, 3-3/8"ID)
	5										
3470		ST-1			100						Shelby tube sample at 7.5' to 8.2', bottom of tube buckled, pocket penetrometer on bottom of sample: UC=3.0-3.25 tsf
		SPT-2		14 18 20	100						
	10										
		SPT-3		49 50/.3	100						
	15								Boulder at 15.5'* Gravel at 16.0'-19.0'*		Removed augers Spun casing to 15.5' (NWFJ, 3-1/2"OD, 3"ID), drilling fluid water, return light brown, loss 0%
3460										▽	Tried to rotary drill with 2-15/16" tricone bit and to spin casing, but could not and had to remove casing
	20	SPT-4		14 17 16	80				orangish brown, wet		Rotary drilled 15.5' to 19.0' with a 4" tricone bit Drove casing to 15.5', tried to drive further, but ruined shoe and had to remove casing
	25	SPT-5		15 50/.3	75				Boulders at 25.8'-33.5'*	▼	Accidentally dropped pipe wrench down hole and could not retrieve Drilled new hole 3.5' offset Rotary drilled to 5.0' using 4" tricone bit, drilling fluid water, return light brown, no loss Drove casing to 5.0' (NWFJ, 3-1/2"OD, 3"ID) Rotary drilled 5.0' to 20.0' using 2-15/16" tricone bit Drove casing 5.0' to 20.0' Rotary drilled 20.0'-35.0'
3450											
	30										
	35	SPT-6		41 50/.2	71						Stopped drilling at 35.0' (8/4/88, 6:45 PM) Resumed drilling at 35.0' (8/5/88, 7:45 AM) Temperature 50-60 deg F, clear, calm Rotary drilled 35'-55.4' Drove casing 20'-55' Rotary drilled 55.4'-80' Return orangish brown
3440									**SANDY CLAYEY SILT (ML),** orangish brown, nonplastic to slightly plastic, hard, wet; gravel is fine to coarse, angular to subrounded.		
	40										
									SILTY SAND - SILTY GRAVEL (SM-GM), orangish brown, nonplastic, wet, dense; sand is fine to coarse; gravel is angular to subangular; fines are nonplastic. Gravel at 45.5'-55.4'*		
	45	SPT-7		25/.5	40						
3430											* Reported by driller

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

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
	55	SPT-8		14 26 30	0						
3420	60										
	65	SPT-9		60/.2	100						
3410	70										
	75	STP-10		26 50/.1	0						
3400	80										Stopped drilling (8/5/88, 6:45 PM)
	80	SPT-11		50/.01	0				**BOTTOM OF HOLE AT 80.1'**		Resumed work (8/6/88, 8 AM) Installed piezometer to 80.1' (1"ID Schedule 80 PVC pipe, bottom 50' machine slotted 0.02" width, backfilled with No.16 silica sand to 25.0') Removed all casing Set steel protective surface casing in concrete (2"ID, 5' long, 1.2' stickup above ground surface) Stopped work (8/6/88, 12:30 PM)
3390	85										
	90										
3380	95										
	100										
	105										

WATER LEVEL

Date	Time	Level
8/4/88	6:45 AM	18.5'
8/6/88	8:00 AM	25.0'

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SHEET 2 OF 2 | HOLE NO. USA-3

PROJECT: MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. USA-4
SITE: Poorman Creek Tailings	DATE - STARTED FINISHED: AUG 16 88 - AUG 18 88	HOLE SIZE: 3"	ORIENTATION: vertical
LOCATION: Libby, Montana	ELEVATION(FT): 3543	DEPTH TO WATER(FT): 37.8	DEPTH TO ROCK (FT):
DRILLING CONTRACTOR: Northern Eng.& Test.	SAMPLES: 11	CORE BOXES: 0	DEPTH OF HOLE (FT): 80.2
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
3540	5	SPT-1		12 21 28	80				**GRAVELLY SILTY SAND – CLAYEY SILT (SM-ML),** fine, orangish brown, slightly plastic, dense, damp to moist; gravel is fine to coarse, gray, rounded to subrounded, maximum size 2".		Started drilling (8/16/88, 12:45 PM) Rotary drilled with water and 2-15/16" tricone bit Boulders at surface Brown water return Reamed casing to 5.0' (NWFJ 3-1/2"OD, 3"ID)
	10	SPT-2		13 19 21	83				**GRAVELLY SILTY SAND (SM),** fine to coarse, orangish brown, dense, moist to wet, rounded to subrounded; interlayered with fine silty sand, orangish brown, non plastic.	▽	Reamed casing to 10.0' Constant head water test at 10.0', no water take in 15 minutes
3530	15	SPT-3		17 15 15	78						Constant head water test at 15.0', casing at 10.0'
	20	SPT-4		40 32 50/.3	0				Very dense		Constant head water test at 20.0', casing at 10.0' Reamed casing to 20.0' Constant head water test at 20.0', .003 GPM
3520	25	SPT-5		23 33 34	70				**SILTY SAND (SM), trace gravel,** reddish brown, non plastic, very dense, moist; gravel is fine grained, red, highly weathered sandstone and gray quartzite.		Stopped drilling at 25.0' (8/16/88, 4:30 PM) Constant head water test at 25.0', casing at 20.0' 8/17/88, 7:30 AM) Started drilling (8/17/88, 8:10 AM)
	30								**SANDY SILTY GRAVEL (GM),** fine to coarse, gray and orangish brown, very dense, wet, rounded to subrounded, moderately to highly weathered quartzite/siltite; sand is fine.		
3510	35	SPT-6		50/.4	100					▼	Casing reamed to 35.0' Constant head water test at 35.0', casing at 35.0'
	40										
3500	45	SPT-7		50/.25	80						Constant head water test at 45.0', casing at 35.0'

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. USA-4

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
3490	55	SPT-8		50/.35	0						Reinserted split tube with core catcher to recover some sample
	60	SPT-9		50/.4	75						
3480	65										
	70	SPT-10		50/.4	25						Stopped drilling at 70.0' (8/17/88, 2:50 PM) Started drilling at 70' (8/18/88, 10:30 AM)
3470	75										
	80	SPT-11		50/.2	75				BOTTOM OF HOLE AT 80.2'		Stopped drilling at 80' (8/18/88, 10:50 AM)
3460	85										Installed piezometer to 80.2' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with number 16 silica sand to 54', bentonite chips to 50') Removed all casing
	90										Set steel protective casing at surface in concrete
3450	95										WATER LEVEL date time level 8/17/88 7:05 AM 11' 8/18/88 8:30 AM 37' 8/26/88 7:45 AM 37.8'
	100										
3440	105										

RAMSEY SITE

Borings RCDH 1 - 3

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. RCDH-1
SITE	Ramsey Creek Plant	DATE - STARTED FINISHED JUL 26 88 - JUL 28 88	HOLE SIZE 3"	ORIENTATION vertical
LOCATION	Libby, Montana	ELEVATION(FT) 4462	DEPTH TO WATER(FT) 22.0	DEPTH TO ROCK (FT) 41.0
DRILLING CONTRACTOR	Northern Eng.& Test.	SAMPLES 7	CORE BOXES 1	DEPTH OF HOLE (FT) 53.0
DRILL MAKE - MODEL	CME 75	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	WATER DATA	REMARKS
4460	0								**SANDY SILT (ML),** brown, non plastic, dense, dry; some gravel, fine to coarse, gray, subangular, siltite.		Started drilling (7/26/88, 4:45 PM) 7-1/4"OD Hollow Stem Auger Cobbles and boulders on surface
	5	S-1		40 22 19	33				**GRAVEL (GP-GM),** coarse, gray, subrounded, slightly weathered, fine grained, quartzite; some fine sand and silt.		Stopped drilling at 4.0' (5:00 PM) Started drilling at 4.0' (7/27/88, 8:30 AM)
	10	S-2		40 50/.3	100				**SANDY SILTY GRAVEL (GM),** fine to coarse, gray, subrounded to subangular, slightly weathered, quartzite, maximum size 1-1/2"; fines are light brown, non plastic, dry to damp. Boulder at 11.0'		
4450	15	S-3		18 28 26	86				Gravel subrounded, 1/2" to 1-1/2"		
	20	S-4		48 50/.3	63				Boulder at 24.0'		
4440	25	S-5		50/.4	0						Very hard drilling at 29.0'
	30	S-6		50/.1	0						Easier drilling at 37.0'
4430	35										Flowing gravel/sand at 39.0'
	40	S-7		20 50/.1	100						Auger refusal at 41.0' Stop augering (12:15 PM) Start coring at 41.0' (7/28/88) NQ rotary with water C-1, 41.0'-46.0' Return water gray-green
4420	45	C-1		56	78				**QUARTZITE (Bedrock?),** gray, slightly weathered, hard, fine grained, FeO staining on joint surfaces, Core surfaces slightly pitted; longest core length C-1 (.7'), C-2 (.3'), C-3 (.6'); C-1 core breaks at 80 deg. to 90 deg., C-2 at 30 deg., parallel to foliation? 30 deg. foliation (relic bedding?) is apparant in all core runs. C-2 fracture spacing 1" to 3".		C-2, 46.0'-49.2', start 11:40 AM, stop 12:05 PM
		C-2		0	79						
		C-3		13	23						

SAMPLING / DRILL ACTION / WATER LOSS / CORE LOSS

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

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. RCDH-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
4410											C-3, 49.2'-53.0', start 12:45 PM, stop 2:30 PM
									BOTTOM OF HOLE AT 53.0'		Coarse sand/fine gravel washing out with cuttings Installed piesometer to 53.0' (1"ID Schedule 80 PVC, bottom 20' machine slotted .02" width, backfilled with silica sand to 28.0', backfilled to 2' with cuttings)
4400	55										
	60										
	65										
4390	70										
	75										
4380	80										
	85										
4370	90										
	95										
4360	100										
	105										

WATER LEVEL

date	time	level
7/27/88	11:00 AM	37.5'
7/28/88	9:20 AM	23.0'
7/29/88	9:00 AM	21.5'
7/30/88	1:20 PM	21.8'
8/2/88	11:10 AM	21.7'
8/18/88	9:10 AM	22.0'

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. RCDH-2
SITE	Ramsey Creek Plant	DATE - STARTED AUG 29 88 FINISHED AUG 31 88	HOLE SIZE 3"	ORIENTATION vertical
LOCATION	Libby, Montana	ELEVATION(FT) 4430.0	DEPTH TO WATER(FT)	DEPTH TO ROCK (FT)
DRILLING CONTRACTOR	Northern Eng.& Test.	SAMPLES 6	CORE BOXES 1	DEPTH OF HOLE (FT) 52.7
DRILL MAKE - MODEL	CME 75	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	WATER DATA	REMARKS
4430											Started drilling (7/29/88, 9:30 AM)
											7-1/4" Hollow Stem Auger
	5	S-1		50/.1	100				**SILTY SANDY GRAVEL (GM),** coarse, with trace cobbles, subrounded, slightly weathered, quartsite; sand is fine; fines are light brown, non plastic.		
									Cobble at 5.0'		
4420	10	S-2		50/.4	50				Cobble at 11.0'		
	15	S-3		50/.3	0						
4410	20	S-4		50/.3	60						
	25	S-5		50/.1	0				Cobble at 25.0'		Auger refusal at 25.0'
											Started rotary drilling (3:30 PM) drilled with water and 2-15/16" tricone
											Driller reported possible clay seams 27.0'-27.3', and 30.0'-30.3'
4400	30	SPT-1		50/.3	0						
		C-1		10	18				**GRAVEL? (GM),** cobbles and boulders, gray, fine grained, slightly weathered to moderately weathered, hard; longest core (C-1) 0.4'; remaining core .05' to .1'; highly broken, FeO stains on surfaces, surfaces slightly pitted; coarse sand (in return water), gray, white, brown, subrounded; quarsite, siltite.		Casing driven to 31.0' approx 1' past hole depth (NWFJ, 3"ID, 3-1/2"OD)
											Started NQ coring (7/30/88, 8:10 AM)
											Drilling alternates hard and soft, brown water return
											Some water loss 35.0'-39.0'
											C-1, 31.0'-35.0'
	35	C-2		0	14						C-2, 35.0'-39.0'
											C-3, 45.0'-48.0'
											C-4, 48.0'-52.7'
4390	40								(C-2) longest core .3', near vertical fracture, FeO stained.		
											Casing driven to 41.0'
											Tricone 2-15/16" 41.0'-45.0'
											Hard drilling at 44.0'
	45	C-3		0	33				(C-3) longest core .2', highly broken, most pieces .05' to .1', subangular, moderately weathered, FeO stained surfaces.		Casing driven to 45.5'
											Gray water return at 45.5'
		C-4		0	16						Core plugged drill bit on runs C-3 and C-4, poor recovery
4380											

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. RCDH-2

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
4380											NOTE: Possibly rock at 45.0', more likely gravel (rock would have to be intensely fractured)
									BOTTOM OF HOLE AT 52.7'		
	55										
4370	60										
	65										
4360	70										
	75										
4350	80										
	85										
4340	90										
	95										
4330	100										
	105										

PROJECT	MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. RCDH-3	
SITE	Ramsey Creek Plant	DATE - STARTED FINISHED JUL 31 88 - AUG 2 88	HOLE SIZE 3"	ORIENTATION vertical	
LOCATION	Libby, Montana	ELEVATION(FT) 4413	DEPTH TO WATER(FT)	DEPTH TO ROCK (FT)	
DRILLING CONTRACTOR	Northern Eng.& Test.	SAMPLES 4	CORE BOXES 1	DEPTH OF HOLE (FT) 39.4	
DRILL MAKE - MODEL	CME 75	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)
4410									**GRAVELLY SILTY SAND (SM),** brown, non plastic, dry to damp; gravel is coarse, gray, subrounded, slightly weathered, quartzite.		Started drilling (7/31/88, 3:30 PM) 7-1/4" Hollow Stem Auger Brown water return
	5	S-1		11 16 29	95				**SILTY SANDY GRAVEL (GM),** coarse, gray, dry to damp, subrounded, slightly weathered, quartzite; fines are non plastic.		
	10	S-2		6 10 50/.4	35				Cobbles at 10.0', fines are slightly plastic Cobbles at 12.0'		
4400	15										Auger refusal at 13.3' Started drilling at 13.3' (8/1/88, 8:45 AM) Rotary drilled with water and 2-15/16" tricone bit
	20	S-3		60 20 50/.4	33				fine sand to coarse gravel, white, gray, and brown, subrounded to rounded, some stratification by size. Boulder at 22.0'-24.0'		
4390	25										
	30	S-4		50/.4	0						Casing driven to 33.0' (NWFJ, 3"ID, 3-1/2"OD)
4380									Boulder at 33.0'-35.0'		Green gray water return 33.0'-35.0'
	35	C-1		0	12				Cobbles, gray, hard, slightly weathered, quartzite, recovered core .05' to .15' gravel sizes.		Started drilling at 35.0' (8/2/88) 2-15/16" tricone Loss of drill water at 35.0' Started NQ rotary core drilling at 37.0' with water Cannot drive casing past 33.0', casing shoe collapsed.
		C-2		0	50						C-1, 37.0'-38.8' C-2, 38.8'-39.4'
	40								**BOTTOM OF HOLE AT 39.4'**		
4370	45										Stopped drilling at 39.4' (8/2/88) Sand and gravel fills hole to 35.0', no water in hole

LIBBY SITE

Borings LCDH 1 - 3

PROJECT: MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. LCDH-1
SITE: Libby Creek Plant	DATE - STARTED FINISHED: AUG 25 88 - AUG 26 88	HOLE SIZE: 3"	ORIENTATION: vertical
LOCATION: Libby, Montana	ELEVATION(FT): 4219	DEPTH TO WATER(FT):	DEPTH TO ROCK (FT):
DRILLING CONTRACTOR: Northern Eng.& Test.	SAMPLES: 4	CORE BOXES: 0	DEPTH OF HOLE (FT): 45.0
DRILL MAKE - MODEL: Mobile B-53	LOGGED BY: D. A. Baskin	REVIEWED BY: M. P. Forrest	

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
									GRAVELLY SILTY SAND (SM), light brown, non plastic; cobbles are gray, hard, slightly weathered, quartzite.		Started drilling (8/25/88, 10:45 AM) Rotary drilled with water and a 2-15/16" tricone bit
	5	SPT-1		50/.1	50				**SANDY GRAVEL (GP-GM),** gray and orangish brown, fine grained, slightly weathered, quartzite; sand is coarse, brown, some non- plastic fines. Cobble at 6.0', light gray, black specked, fine grained, siltite Cobbles and boulders 6' to 28'		Ream casing to 5.0' Brown water return, 100% return Drill to 15.0'
4210	10	SPT-2		50/.35	57						Ream casing to 10.0'
	15	SPT-3		50/.3	40				Silty, moist to wet, very dense Cobble at 18.0'-18.7'		Return water alternates green brown (sandy gravel) and green gray (cobbles)
4200	20	SPT-4		50/.5	40				Cobble at 19.5'-20.5'		Drill to 30.0' Ream casing to 15.0' Pull casing
	25								Boulder 26.5'-27.5' Cobble 28.0'-28.7'		Started drilling (8/20/88, 7:00 AM) 4" tricone bit and water Drill to 20.0' Drive casing to 20.0'
4190	30								**SILTY SAND (SM),** fine to medium, green brown, dense, non-plastic fines, some gravel.		Tricone bit 2-15/16" start at 20.0' Drilling rate approx. 0.1 ft/min
	35										
4180	40								Cobbles at 41'-41.5' Very dense 41.5'-45'		Drilling rate approx. 4 ft/hour, 41.5' to 45.0'
	45								Cobbles 43.5'-43.9'		Stopped drilling (8/26/88, 7:30 PM)
4170									**BOTTOM OF HOLE AT 45'**		Installed piezometer to 24.9' (1"ID Schedule 80 PVC pipe, bottom20' machine slotted, .02" width, backfilled with no. 16 silica sand to 5', backfilled to surface with bentonite chips)

PROJECT: MONTANA SILVER VENTURE				JOB NO. 8029	HOLE NO. LCDH-2
SITE: Libby Creek Plant	DATE - STARTED AUG 5 88 FINISHED AUG 5 88			HOLE SIZE 3"	ORIENTATION vertical
LOCATION: Libby, Montana	ELEVATION(FT) 4260.0	DEPTH TO WATER(FT) 12.0		DEPTH TO ROCK (FT) 30.0	
DRILLING CONTRACTOR: Northern Eng.& Test.	SAMPLES 4	CORE BOXES 1		DEPTH OF HOLE (FT) 42.8	
DRILL MAKE - MODEL: Mobile B-53	LOGGED BY D. A. Baskin			REVIEWED BY M. P. Forrest	

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
4260											
	5	SPT-1		42 43 50/.4	85				**GRAVELLY SAND (SM-SP),** fine to medium, some nonplastic fines, dry; cobbles are gray, hard, slightly to moderately weathered, fine grained quartzite. dry to damp, dense		Started drilling (8/5/88, 9:20 AM) 7-1/4" Hollow Stem Auger Slow augering in cobbles
4250	10	SPT-2		50/.4	25						
	15								Cobble 13.7'-14.2', 15.0'-15.2'		Auger refusal 13.7' Started rotary drilling at 13.7' (11:40 AM) Drilled with water and 2-15/16" tricone bit Drilling alternates easy/hard, cobbles/gravelly sand Reamed casing to 17.0'
4240	20	SPT-3		50/.5	25				greenish brown, damp, fine to medium, dense		Green brown water return at 17.0' Gray water return at 18.0' Green gray water return at 18.5' Reamed casing to 19.0' Green brown water return at 19.0' Faster drilling 19.0'-21.0' and 22.5'-25.0'
	25	SPT-4		50/.2	0				Cobbles 29.0'-30.0'		
4230	30								**QUARTZITE/SILTITE (Bedrock?),** gray, slightly weathered to fresh, some FeO staining on fractures, hard, fine grained to aphanitic; foliation (relic bedding) approx. 25 deg., laminated to 1/2", most fractures parallel to foliation, some zones highly broken, -shaley, foliation alternates white/gray.		Gray water return at 29.5' Slow drilling approx. 4 ft/hour at 30.0'
	35	C-1		78	100						Start NQ coring at 37.0' Run C-1, 37.0'-42.0' (4:20 PM to 4:35 PM)
4220	40	C-2		100	100						Run C-2, 42.0'-42.8 Stop drilling (8/5/88, 5:20 PM)
									BOTTOM OF HOLE AT 42.8'		
	45										Installed piezometer to 42.8' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with no. 16 silica sand to 18', backfilled to 2' with cuttings, 1' stickup
4210											

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SHEET 1 OF 1 | HOLE NO. LCDH-2

PROJECT: MONTANA SILVER VENTURE				JOB NO. 8029	HOLE NO. LCDH-3
SITE: Libby Creek Plantsite	DATE - STARTED FINISHED: AUG 3 88 - AUG 3 88			HOLE SIZE 3"	ORIENTATION vertical
LOCATION: Libby, Montana	ELEVATION(FT) 4261	DEPTH TO WATER(FT) 16.3			DEPTH TO ROCK (FT)
DRILLING CONTRACTOR: Northern Eng.& Test.	SAMPLES 4	CORE BOXES 0			DEPTH OF HOLE (FT) 46.0
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
4260											Started drilling (8/3/88, 12:00 PM)
											7-1/4" hollow stem auger
	5	S-1		50/.5	70				**GRAVELLY SAND (SP-SM),** fine to medium, brown, some nonplastic fines, dry to damp; gravel consists of cobbles and boulders, gray, hard, slightly to moderately weathered, fine grained, quartsite. Cobbles at 5.0'		
											Auger refusal at 6.5'
											Started drilling (8/4/88, 8:40 AM)
											Rotary drilled with a 2-15/16" tricone bit and water
	10										Greenish brown water return at 6.5', fine to medium sand in return water, gray, white, brown, and green
4250									Cobbles at 11.5' to 12.0'		
		SPT-3		50	25				**SILTY SANDY GRAVEL (GM),**		
				50/.2					Cobbles and boulders, gray, hard, slightly weathered, fine grained quartsite; sand is fine to medium, brown, non plastic.		Easy drilling at 12.0'
	15								Silty seam, slightly plastic at 13.0'		
									Cobbles at 13.5'-14.0'		
									Cobbles at 16.5'-18.5'		Dark brown water return at 16.0', easier drilling, fine sand in return water
	20								Cobbles at 20.0'-21.5'		
4240											Slow drilling 13.5'-25.0'
									Cobbles at 22.0'-25.0'		
	25	SPT-4		50/.2	75				1" layer of fine sand and silt, dark reddish-brown, slightly plastic at 25.0'		Alternates harder/softer (fast/slow drilling) 25.0'-46.0', alternating gravelly layers with more sandy/silty layers
									Cobbles at 27.5'-28.0'		
	30										
4230											
	35										
	40	S-2		50/.2	50				Coarse gravel and cobbles, green gray, slightly to moderately weathered siltite		
4220									Cobble at 42.5'-42.75'		
	45								Cobble at 45.0'-45.5'		Stop drilling (8/4/88, 5:15 PM) at 46.0'
									BOTTOM OF HOLE AT 46'		WATER LEVEL 8/4/88 - 16.3'

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SHEET 1 OF 1 | HOLE NO. LCDH-3

MIDAS SITE

Borings MCDH-2, 2A, 3-4, 6-9

PROJECT: MONTANA SILVER VENTURE			JOB NO. 8029		HOLE NO. MCDH-2
SITE: Midas Creek	DATE - STARTED FINISHED: NOV 9 88 - NOV 11 88		HOLE SIZE: 3"		ORIENTATION: vertical
LOCATION: Libby, Montana	ELEVATION(FT)	DEPTH TO WATER(FT): 83.2		DEPTH TO ROCK (FT)	
DRILLING CONTRACTOR: Northrn Eng. & Test.	SAMPLES: 12	CORE BOXES: 0		DEPTH OF HOLE (FT): 100.0	
DRILL MAKE - MODEL: Mobile B-53	LOGGED BY: E. S. Hayes		REVIEWED BY: M. P. Forrest		

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
	0								**GRAVELLY SANDY SILT (ML),** orange-brown, slightly plastic, damp, dense; gravel is fine to coarse, grey, subrounded to subangular, max. 1-1/2"; sand is fine with finer grey/tan lenses.		Start drilling (11/9/88, 1:30 pm) Weather: cold, clear Augered: Hollow stem, 8" O.D., 3-3/8" I.D.
		SPT-1		11 17 16	90						
	5										
		ST-1			70						ST-1, recover 1.1' of 1.6', end of Shelby tube is bent
	10								Boulder at 10.0' Thin layer of gravels, fine to coarse, grey, subrounded.		
		SPT-2		9 13 14	90				**GRAVELLY SANDY CLAY (CL),** orange brown, slightly plastic, damp, stiff to very stiff; gravel is fine to coarse, max. 1", subangular to subrounded.		
	15										
		SPT-3		16 30 38	95				**SILTY SAND (SM),** fine, yellow brown, non plastic, damp, dense to very dense.		uc = 2.5 tsf Water at 21.5' (possibly perched water, see remarks at 80')
	20										
		SPT-4		13 20 18	95				some gravel, slightly plastic, moist to wet; gravel is fine, rounded to subrounded with fine to coarse sand.		uc = 3.75 tsf Gravels may have fallen from above
	25										
		SPT-5		18 30 37	70				sand is slightly coarser.		Constant head water test at 30.0'
	30										
	35								grading to:		
		SPT-6		6 13 19	80				**SILTY CLAY (CL),** yellow brown, plastic, damp, stiff to very stiff.		uc = 3.5 tsf Stopped drilling at 40.0' (11/9/88, 4:00 pm) Start drilling (11/10/88, 8:30 am) Weather: cold, snowing Flushed out hole Constant head water test at 40.0'
	40										
		ST-2			100						ST-2, recover 1.6' of 1.6'
	45										

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

ELEV. (FT)	DEPTH (FT)	SAMPLE NUMBER	CASING	SPT / RQD	RECOV.	DISCONTINUITIES TYPE	DISCONTINUITIES DIP	SYMBOL	MATERIAL DESCRIPTION	WATER DATA	REMARKS
	55	SPT-7		7 12 14	100				**SILTY CLAY (CL),** blue-yellow, moist, plastic, stiff to very stiff.		uc = 1.5 - 3.0 tsf
	60										
	65	SPT-8		7 8 10	100				some gravel lenses in matrix; gravel is fine, subangular to angular, dark grey with sand; sand is coarse to fine, sample breaks along silt seams.		uc = 1.75 tsf Change from auger to casing (11:00 am) Casing 3-1/2" O.D., 3" I.D. Start rotary drill (12:30 pm) Constant head water test at 65.8'
	70								grading to:		
	75	SPT-9		23 31 39	33				**GRAVELLY CLAY (CL),** some sand, orange, moist, plastic; gravel is fine, max.1", subrounded to angular; sand is coarse to fine.		At 73.0' drill water return changes to orange
	80								Cobble (approx. 6") at 81.0'.		Stop drilling at 80.0' (11/10/88, 4:00 pm) Started drilling (11/11/88, 10:00 am) Weather: partly cloudy with some snow
	85	SPT-10		25 29 40	60				**CLAYEY GRAVEL (GC),** clay is orange-brown, non plastic, moist; gravel is fine, highly weathered, max. 3/4", subrounded to angular, grey and dark red.	▼	No water in hole at time of drilling Drill rattle at 83.0', appear to be in gravels judging from multicolored drill cuttings Constant head water test at 85.0' uc = 2.0 - 2.5 tsf Installed piezometer to 100.0' (1" I.D. Schedule 80 PVC pipe, bottom 30' machine slotted .02" width, backfilled with number 16 silica sand to 60', bentonite pellets to 57')
	90										
	95										WATER LEVEL date level 11/16/88 83.2'
	100								**BOTTOM OF HOLE AT 100.0'**		
	105										

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SHEET 2 OF 2 | HOLE NO. MCDH-2

PROJECT	MONTANA SILVER VENTURE			JOB NO. 8029	HOLE NO. MCDH-2A
SITE	Midas Creek	DATE - STARTED NOV 18 88 FINISHED NOV 18 88		HOLE SIZE 3"	ORIENTATION vertical
LOCATION	Libby, Montana	ELEVATION(FT)	DEPTH TO WATER(FT)		DEPTH TO ROCK (FT)
DRILLING CONTRACTOR	Northrn Eng. & Test.	SAMPLES 5	CORE BOXES		DEPTH OF HOLE (FT) 65.5
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
	5								SEE HOLE NO. MCDH-2 FOR MATERIAL DESCRIPTIONS		Start drilling (11/18/88, 11:45 AM) 8" HSA, about 50' from MCDH-2 downstream
	10										
	15										
	20										
	25										
	30										
	35	ST-3			75						ST-3, recover 1.5' of 2.0', 2-3/4"ID
	40	ST-4			90						ST-4, recover 1.8' of 2.0', 2-3/4"ID
	45	ST-5			100						ST-5, recover 2.0' of 2.0', 2-3/4"ID

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. MCDH-2A

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
	55	ST-6			100						ST-6, recover 2.0' of 2.0'
	60										
	65	ST-7			100						ST-7, recover 2.0' of 2.0', bottom .7' of tube bent
									BOTTOM OF HOLE AT 65.5'		
	70										
	75										
	80										
	85										
	90										
	95										
	100										
	105										

PROJECT	MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. MCDH-3	
SITE	Midas Creek	DATE - STARTED FINISHED NOV 10 88 - NOV 11 88	HOLE SIZE 3"	ORIENTATION vertical	
LOCATION	Libby, Montana	ELEVATION(FT)	DEPTH TO WATER(FT) 20.0	DEPTH TO ROCK (FT) 5.0	
DRILLING CONTRACTOR	Northrn Eng. & Test.	SAMPLES 1	CORE BOXES 3	DEPTH OF HOLE (FT) 35.0	
DRILL MAKE - MODEL	Mobile B-50	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
	5	SPT-1		50/.2'	0				**SILTY SANDY GRAVEL (GM),** sand is fine, non plastic; gravel is shaley, brown and reddish brown, moderately weathered, argillite, (talus).		Started drilling (11/10/88, 10:05 am) Weather: 30 deg F, cloudy Advance HQ casing (3-1/16" I.D., 3-1/2" O.D.) using casing advancer, (tricone) and water, 0' to 6.5' Started NQ coring with water (11/10/88, 2:30 pm) C1, 6.5' to 10.0'
		C-1		10	90				**ARGILLITE,** tan and reddish brown, moderately to highly weathered, moderately hard, shaley in places, fractures 10-20 degrees, fracture surfaces moderately weathered and FeO stained, some fracture surfaces clay coated, fracture spacing from less than 1" to 3"; core is vuggy, some vugs filled with reddish brown mineral (hematite?), max. size approx. 1/8", generally less than 1/32". Core highly broken 10.2' to 10.6', 15.0' to 16.6', 21.2' to 22.2', 33.0' to 35.0'.		
	10	C-2		18	92						C2, 10.0' to 15.0'
	15	C-3		0	60						Stopped drilling at 15.0' (11/10/88, 4:30 pm) Started drilling (11/11/88, 8:30 am) C3, 15.0' to 20.0'
	20	C-4		0	100					▼	C4, 20.0' to 25.0'
	25	C-5		0	80						C5, 25.0' to 30.0'
	30	C-6		0	100						C6, 30.0' to 35.0' Water pressure tests 10.0' to 35.0' and 25.0' to 35.0' Stopped drilling (11/11/88, 3:30 pm)
	35								**BOTTOM OF HOLE AT 35.0'**		Installed piezometer to 34.0' (1" I.D. Schedule 80 PVC pipe, bottom 20.0' machine slotted .02" width, backfilled to 7' with no. 16 silica sand, backfilled to 2' with bentonite pellets)
	40								Core Box 1: 6.5' to 15.0' Core Box 2: 15.0' to 26.0' Core Box 3: 26.0' to 35.0'		
	45										WATER LEVEL date level 11/16/88 20.0'

PROJECT	MONTANA SILVER VENTURE		JOB NO. 8029		HOLE NO. MCDH-4
SITE	Midas Creek	DATE - STARTED NOV 11 88 FINISHED NOV 13 88	HOLE SIZE 3"		ORIENTATION vertical
LOCATION	Libby, Montana	ELEVATION(FT)	DEPTH TO WATER(FT) 29.0		DEPTH TO ROCK (FT) 9.0
DRILLING CONTRACTOR	Northrn Eng. & Test.	SAMPLES 2	CORE BOXES 3		DEPTH OF HOLE (FT) 46.0
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY E. S. Hayes			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
									SANDY SILTY GRAVEL (GM), dark orange brown, damp, non plastic; gravel is rounded to subrounded, max. size 4".		Started drilling (11/11/88, 4:45 pm) Auger 8" O.D., 3-3/8" I.D.
		SPT-1		55/.5	83						
	5								gravels are moderately to highly weathered, angular to subangular, damp.		
		SPT-2		41 50/.5	64						Stop drilling 8.5' (11/11/88, 5:00 pm) Started drilling (11/12/88, 8:45 am) Weather: cold, snowing
	10								**SILTITE/ARGILLITE,** orange brown with some tan lenses, orange brown is silt size particles, tan is clay size. Highly weathered at surface. Slightly to moderately weathered, hard Banding (relic bedding?) 55 - 75 degrees. Fracture spacing approx. 2" along banding, surface moderately weathered with oxidation - red/brown. C2: increase in tan and dark gray banding, slightly weathered, more obvious banding, fractures 60 degrees with oxides.		Auger refusal at 12.0' Change to rock drilling Reamed with casing shoe approx. 1' (10:00 am) tricone with 2-5/16" with water at 12.0' casing to 14.5' Start coring 14.9' (12:40 pm) with NX inner tube using set diamond bit Drill water return yellow/orange C1, 14.9' to 16.3' (blockoff) Drill speed 12 min/ft. C2, 16.3' to 17.7' (blockoff) C3, 17.7' to 18.7' (blockoff) C4, 18.7' to 19.9' (blockoff) C5, 19.9' to 21.0' (blockoff) C6, 21.0' to 22.0' (blockoff) Drill speed 10 min/ft. C7, 22.0' to 24.5' (blockoff) Stopped drilling (11/12/88, 4:30 pm)
	15	C-1		0	100						
		C-2		29	100						
		C-3		0	92						
		C-4		0	83						
	20	C-5		0	100						
		C-6		-	100						
		C-7		-	70						
	25	C-8		44	91						
		C-9		32	83				C9: fractures contain grey/tan clay.		Started drilling (11/13/88, 9:30 am) Weather: cool, sunny Drill speed 6 min/ft. C8, 24.5' to 26.8' (blockoff) C9, 26.8' to 29.3' (blockoff)
	30	C-10		0	69						C10, 29.3' to 30.5' (blockoff)
		C-11		57	100						C11, 30.5' to 31.1' (blockoff)
		C-12		20	100						C12, 31.1' to 32.4' (blockoff)
		C-13		0	100						C13, 32.4' to 34.1' (blockoff)
	35	C-14		-	91						C14, 34.1' to 35.2' (blockoff)
		C-15		-							C15, 35.2' to 37.2' (blockoff) C16, 37.2' to 40.5' (blockoff)
		C-16		0	71				C16: extremely fractured, difficult to measure recovery.		C17, 40.5' to 42.7' (blockoff) Water pressure test at 32.4' to 46.0'
	40	C-17		0	76						C18, 42.7' to 44.4' (blockoff) C19, 44.4' to 46.0' (blockoff) Installed piezometer to 46' (1"ID Schedule 80 PVC pipe, bottom 20' machine slotted .02"width, backfilled with no.16 silica sand to 21', bentonite pellets to 18.5')
		C-18		19	100				C18: rock quality improving, few fractures - blue grey, oxide stains on fractures.		
	45	C-19		67	94						
									BOTTOM OF HOLE AT 46.0'		Stopped drilling (11/13/88, 4:15 pm) WATER LEVEL 11/17/88 - 29.0'

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SHEET 1 OF 1 | HOLE NO. MCDH-4

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. MCDH-6
SITE	Midas Creek	DATE - STARTED NOV 14 88 FINISHED NOV 15 88	HOLE SIZE 3"	ORIENTATION vertical
LOCATION	Libby, Montana	ELEVATION(FT)	DEPTH TO WATER(FT) 84.4	DEPTH TO ROCK (FT)
DRILLING CONTRACTOR	Northrn Eng. & Test.	SAMPLES 14	CORE BOXES 0	DEPTH OF HOLE (FT) 96.5
DRILL MAKE - MODEL	Mobile B-53	LOGGED BY E. S. Hayes	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
	5	SPT-1		12 22 26	100				**SANDY SILT (ML),** some gravel, yellow, damp to dry, non plastic, grey clay lenses; gravel is fine to coarse, max. size 3", subrounded.		Started drilling (11/14/88, 12:30 pm) Weather: cool, sunny Auger 8" O.D., 3-3/8" I.D. uc = 2.5 tsf Auger rattle at 5.0'
	10	ST-1			100				dry, trace gravel, fine, max. size 1/2", subrounded.		ST-1, recover .3' of .3', Shelby tube is bent uc > 4.5 tsf
	15	ST-2 SPT-2		29 50/.5'	100 100				few gravels, subangular		ST-2, recover .3' of .3', Shelby tube is bent Constant head water test at 15.0' Drilling difficult
	20	SPT-3		29 50/.2'	100						SPT-3 plugged by large piece of gravel (quartz?)
	25	SPT-4		23 36 49	50				clay at top of SPT-4, with a few fine gravels and coarse sand, moist.		Constant head water test at 23.5' uc > 4.5 tsf
	30	R-1			100				**SANDY SILTY CLAY - CLAYEY SILT (CL-ML),** very stiff to hard, slightly plastic; trace to some angular gravel.		R-1, recover .6' of .6'
	35	R-2			100						R-2, recover .4' of .4' Constant head water test at 34.0'
	40	SPT-5		8 15 23					stiff, trace gravels, wet.		uc = 1.25 tsf
	45	R-3			77				SILT, damp.		Constant head water test at 43.5' Stopped drilling (11/14/88, 4:00 pm) broken hydraulic hose at 43.5' Started drilling (11/15/88, 8:50 am) Weather: cold, sunny R-3, recover 1.3' of 1.7' uc > 4.5 tsf

PROJECT: MONTANA SILVER VENTURE | JOB NO. 8029 | HOLE NO. MCDH-6

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)
	55										Constant head water test at 53.5'
		SPT-6		15 24 37	78				yellow, moist, plastic, trace to some fine sand, very stiff.		uc = 2.0 - 2.25 tsf
	60										
	65										Constant head water test at 65.0' Change from auger to rotary drill through auger at 65.0'
	70										
	75	SPT-7		10 16 24	100				Interlayered lenses of clay and sandy silt; clay is moist, plastic; silty sand is moist; sand is fine, sample breaks along sand layers.		Constant head water test at 75.0' uc = 3.25 tsf on sand, and uc = 2.75 tsf on clay
	80								grading to:		
	85	SPT-8		29 34 36	61				SANDY SILTY GRAVEL (GM), orange, wet, very dense; gravel is fine to coarse, angular to rounded, max. size 1"; sand is fine to coarse.	▼	Drill rattle at 83.0', hitting gravels. Chips in drill water Installed piezometer to 94' (1" I.D. Schedule 80 PVC pipe, bottom 20' machine slotted .02" width, backfilled with no. 16 silica sand to 70', bentonite pellets to 67')
	90										
	95	SPT-9		14 32 36							Stopped drilling 96.5' (11/15/88, 4:15 pm)
	100								BOTTOM OF HOLE AT 96.5'		WATER LEVEL date level 11/17/88 84.4'
	105										

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SHEET 2 OF 2 | HOLE NO. MCDH-6

PROJECT	MONTANA SILVER VENTURE		JOB NO. 8029		HOLE NO. MCDH-7
SITE	Midas Creek	DATE - STARTED FINISHED NOV 12 88 - NOV 13 88	HOLE SIZE 3"		ORIENTATION vertical
LOCATION	Libby, Montana	ELEVATION(FT) 3880.0	DEPTH TO WATER(FT) 28.6		DEPTH TO ROCK (FT) 0.0
DRILLING CONTRACTOR	Northrn Eng. & Test.	SAMPLES 0	CORE BOXES 3		DEPTH OF HOLE (FT) 36.0
DRILL MAKE - MODEL	Mobile B-50	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
3880											
	5								**ARGILLITE/SILTITE,** banded tan and greenish grey, slightly weathered, hard, banding (relic bedding?) at 30 - 40 degrees, rock fractures along banding surface, fracture surfaces are moderately weathered, FeO stained orangish brown, color banding is from less than 1/8" to approx. 1 to 2", many incipient fractures evident on banding surfaces either slightly open or FeO stained, greenish gray bands more silty to fine sand sizes, tan bands more fine grained, fracture spacing 1" to 3". 6.7' to 9.0' shaley. 12.1', banding is greenish grey, reddish brown, and tan.		Started drilling (11/12/88, 12:00 pm) Weather: 30 deg F, snow and hail Advance HQ casing from 0 to 6.0' with casing advancer Casing 3-1/2" O.D., 3-1/16" I.D. Drilling in drainage ditch between road and cut slope. Rock exposed on slope Start NX coring with water at 6.0' (1:00 pm) C1, 6.5' to 11.0'
		C-1		27	93						
3870	10										
		C-2		20	100						C2, 11.0' to 16.0'
	15										
		C-3		68	100				C3, C4: fracture spacing 2" to 6", longest core 10". 18.0' to 18.4', vertical fracture.		C3, 16.0' to 21.0'
3860	20										
		C-4		32	100						C4, 21.0' to 26.0' Stop drilling at 26.0' (11/12/88, 4:30 pm) Start water pressure test 10' to 26' (11/13/88, 8:15 am) Temp: 20 deg F Start NX coring at 26.0'
	25										
		C-5		44	100				C5, C6, fracture spacing 1/2" to 4", longest core .5', broken rock zone 33.5' to 35.0'.	▼	C5, 26.0' to 31.0', start 9:35, stop 10:00
3850	30										
		C-6		34	100						C6, 31.0' to 36.0', start 10:15, stop 10:45 Start water pressure test (11:00 am). Packer at 26.0', bottom of hole at 36.0'
	35										
									BOTTOM OF HOLE AT 36.0'		Stopped drilling (11/13/88, 11:15 am)
3840	40								Core Box 1: 6.5' to 16.0' Core Box 2: 16.0' to 26.0' Core Box 3: 26.0' to 36.0'		Installed piesometer to 35.0' (1"I.D. Schedule 80 PVC pipe, bottom 20' machine slotted 02" width, backfilled with no.16 silica sand to 14', bentonite to 8', set steel protective casing at surface)
	45										WATER LEVEL date 11/16/88 level 28.6'
3870											

PROJECT: MONTANA SILVER VENTURE		JOB NO. 8029	HOLE NO. MCDH-8
SITE: Midas Creek	DATE - STARTED NOV 13 88 - FINISHED NOV 15 88	HOLE SIZE 3"	ORIENTATION vertical
LOCATION: Libby, Montana	ELEVATION(FT)	DEPTH TO WATER(FT) 44.3	DEPTH TO ROCK (FT)
DRILLING CONTRACTOR: Northrn Eng. & Test.	SAMPLES 11	CORE BOXES 0	DEPTH OF HOLE (FT) 55.5
DRILL MAKE - MODEL: Mobile B-50	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
									SANDY SILTY GRAVEL (GM), fine to coarse, brown, subrounded to subangular, slightly weathered, argillite.		Start drilling (11/13/88, 3:00 pm) Advance NQ casing (3-1/2" O.D., 3-1/16" I.D.) Tricone casing advancer with water
5		SPT-1		13 12 9	0				orangish brown, wet, medium dense; fines are slightly plastic; gravel is grey and reddish brown.		
		SPT-2		6 12 18	45						Constant head water test at 7.0' Used catcher on SPT-2 Stop drilling (11/13/88, 4:45 pm) Start drilling (11/14/88, 9:05 am) Advance NQ casing
10		SPT-3		6 15 13	60				grading to: **SANDY CLAYEY GRAVEL (GC)**		
		ST-1			73				**SANDY SILTY CLAY (CL),** some gravel, brown, slightly plastic to plastic, very stiff, moist; gravel is 1/2" to 1", subangular to subrounded, slightly to moderately weathered, fine grained, hard.		
15		SPT-4		7 12 16	66						Constant head water test at 16.0' ST-1, recover 1.1' of 1.5' SPT-4, uc = 2.5 - 3.5 tsf
20		ST-2			100						Stop drilling (11/14/88, 12:00 noon) at 21.0' Start drilling (11/15/88, 9:30 am) Water standing at 5.0' in boring Hollow stem auger (8-1/2" O.D., 3-1/2" I.D.) ST-2, recover 1.5' of 1.5'
25									gravel is fine.		
		SPT-5		6 14 19	72						Constant head water test at 27.0' SPT-5, uc > 3.75 tsf
30		ST-3			85						ST-3, recover 1.7' of 2.0'
35											
40									trace sand and gravel, hard		
		SPT-6		6 12 14	50						SPT-6, uc > 4 tsf
45									grading to: **GRAVELLY CLAYEY SAND (SC),** brown, moist, medium dense.	▼	

PROJECT: MONTANA SILVER VENTURE | JOB NO. 8029 | HOLE NO. MCDH-8

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
											Hollow stem auger to 52.0'
		ST-4			80						ST-4, recover 1.6' of 2.0', end of Shelby tube bent
	55	SPT-7		7 10 14	80						SPT-7, uc = 2.5 - 4.0 tsf
									BOTTOM OF HOLE AT 55.5'		Installed piezometer to 53.2' (1" I.D. Schedule 80 PVC pipe, bottom 20.0' machine slotted .02" width, backfilled with no.16 silica sand to 31', bentonite to 29')
	60										
	65										**WATER LEVEL** date level 11/17/88 44.3'
	70										
	75										
	80										
	85										
	90										
	95										
	100										
	105										

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SHEET 2 OF 2 | HOLE NO. MCDH-8

PROJECT	MONTANA SILVER VENTURE	JOB NO. 8029	HOLE NO. MCDH-9
SITE	Midas Creek	DATE - STARTED NOV 17 88 FINISHED NOV 18 88	HOLE SIZE 3"	ORIENTATION vertical
LOCATION	Libby, Montana	ELEVATION(FT)	DEPTH TO WATER(FT)	DEPTH TO ROCK (FT) 44.0
DRILLING CONTRACTOR	Northrn Eng. & Test.	SAMPLES 6	CORE BOXES 0	DEPTH OF HOLE (FT) 47.9
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	WATER DATA	REMARKS
									GRAVELLY SANDY SILT (ML), brown, non plastic, damp; gravel is coarse, subangular to subrounded, slightly weathered, argillite.		Start drilling (11/17/88, 1:15 pm) Hollow stem auger (3-1/2" I.D., 8" O.D.)
	5										
		SPT-1		8 13	60				medium dense		
	10			9							
									SANDY CLAYEY SILT - SILTY CLAY (ML-CL), stiff, brown, slightly plastic, damp; sand is fine.		
		ST-1			90						ST-1, recover 1.8' of 2.0'
	15								moist, slightly plastic to plastic.		
									GRAVELLY CLAYEY SAND - SILTY SAND (SC-SM), slightly plastic, moist to wet, medium dense; gravel is fine to coarse.		
		SPT-2		4 4	65						
	20			11							
	25										Very hard to auger at 27.0'
		SPT-3		25 45					very dense, silt is laminated, non plastic.		
	30			60							
	35										
		SPT-4		~~50/.4~~	~~100~~						
	40										
	45								**ARGILLITE,** brown, highly weathered, 44' to 47', 47' moderately weathered, hard, FeO stained fracture surface, highly broken, banding (relic bedding) approx. 80 deg, high angle fractures along banding surfaces.		Very slow and very hard to auger at 44.0' Auger refusal at 47.0' Stop drilling (11/17/88, 3:30 pm) Start drilling (11/18/88, 9:30 am)
		SPT-5		50/.1	100						
		C-1		0	100						NQ core with water Stop drilling (11/18/88, 10:30 am)
									BOTTOM OF HOLE AT 47.9'		

APPENDIX E
TEST PIT LOGS

APPENDIX E
TEST PIT LOGS

The exploration test pits were excavated by using a Case 580D backhoe having an extendable boom with a maximum reach of 16 feet. 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 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, with the exception of the Midas site test pits, which were visually located by the MKE engineer.

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 E-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 were modified to reflect those data.

2. Classifications of soils are based on the Unified Soil Classification System, Figure E-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%

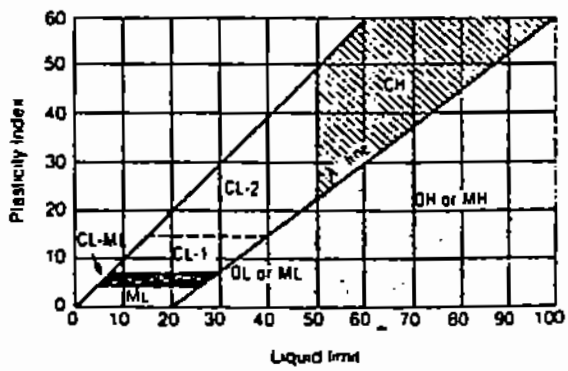
3. The relative proportions of gravels, cobbles and boulders were made visually in the field are are therefore approximate.

4. All test pits were excavated by a Case 850D backhoe equipped with a 1.5-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.**
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines	
		Gravels with fines (Appreciable amount of fines)	GM d / u	Silty gravels, poorly graded gravel-sand-clay mixtures	
			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	
			SP	Poorly graded sands, gravelly sands, little or no fines.	
		Sands with fines (Appreciable amount of fines)	SM d / u	Silty sands, poorly graded sand-silt mixtures	
			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	
			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	

$C_U = \frac{D_{60}}{D_{10}}$	Greater than 4	
$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$	Between 1 and 3	
Not meeting all gradation requirements for GW		
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
Atterberg limits above "A" line, or *PI* greater than 7		
$C_U = \frac{D_{60}}{D_{10}}$	Greater than 6	
$C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$	Between 1 and 3	
Not meeting all gradation requirements for SW		
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
Atterberg limits above "A" line, or *PI* greater than 7		



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 classifications. 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

LITTLE CHERRY SITE

Test Pits TP 101 - 110

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					Difficult digging below 4.0'
5			SILTY SAND (SM), orange, brown, and gray mottled, fissured 3"-15". Looks like decomposed rock.		
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					

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 grayish brown, damp, with some gravel and cobbles (5-10%), and trace silt; cobbles and gravel are subrounded to subangular.		
3					
4	S-2				
5			**SILTY SAND (SM),** orange, brown, and gray with oxidized fissure surfaces, moist. Looks like decomposed rock.		
6					
7					
8				▼	Slight seepage at 8.0'
9					
10					Refusal at 10.0'
			BOTTOM OF TEST PIT AT 10.0'		
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

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					
12			BOTTOM OF TEST PIT AT 11.0'		
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

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'
13			BOTTOM OF TEST PIT AT 12.0'		
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

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			SILT (ML), buff, non plastic, dry, with trace sand and trace gravel; gravel is fine to coarse, subrounded. Roots extend to 6" depth.		
2					
3					
4			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.		
5					
6					
7					
8	S-1				Easy excavating Sides of excavation are very unstable in sand layer
9					
10					
11					
12					
13					
14			BOTTOM OF TEST PIT AT 14.0'		
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

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. Borlie	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					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

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'
			BOTTOM OF TEST PIT AT 9.0'		
10					
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

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
1			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.		
3					
4					uc > 4.5 tsf
5					
6					
7					
8	S-1				
9					
10					
11					
12			BOTTOM OF TEST PIT AT 12.0'		
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET 1 OF 1

TEST PIT NO. 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			**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.		
2					
3			**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.		
4					
5					
6	S-1				
7					
8					
9					
10					
11	S-2		**GRAVELLY SAND (GP),** gray brown, non plastic, wet, with cobbles (5-10%), subrounded to rounded.	▼	Seepage at 11.0'
12					
13					
14					
15					
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

POORMAN SITE

Test Pits TP 201 - 210

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-201

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	13x15x3	7/29/88	7/29/88	3538	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1–6	S-1		SILT (ML), buff, dry to damp, with some sand, some gravel, and cobbles (5-10%) up to 12"; cobbles and gravels are subangular. Roots extend to 2.0'-3.0' depth.		
6–13			CLAYEY SILT (ML), brown, slightly plastic, very stiff, moist, with trace sand and trace fine gravel; gravel is subangular.		uc = 2.5 to 3.0 tsf Wall of pit remains stable
13			BOTTOM OF TEST PIT AT 13.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-201

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-202

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	12x15x3	7/29/88	7/29/88	3547.0	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), buff, dry, non plastic, with some gravel, trace sand, and cobbles (10-15%) up to 8"; cobbles and gravel are subangular to subrounded.		
3			SILTY CLAY (CL), brown, low plasticity, hard, moist, with trace gravel, and trace sand; gravel is subangular.		uc > 4.5 tsf
7					As stockpile dried out, material took lighter color (grey/buff)
8	S-1				
10					Difficult digging below 10.0'
12			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-202

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-203

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	14x16x3	7/29/88	7/29/88	3503.0	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), brown, non plastic, dry to damp. Roots extend to 9" depth.		
2			CLAYEY SILT (ML), orange brown with gray, very stiff, with some sand, some gravel, and cobbles (5%); gravel is subrounded to subangular. Difficult to break by hand.		
3					
4					uc = 3.0 to 3.5 tsf
5					
6	S-1				
7					
8					
9					
10	S-2		SANDY CLAYEY GRAVEL (GC), reddish brown, low plasticity, moist, with some gravel and cobbles (5%); cobbles and gravels are subrounded to subangular.		
11					uc = 1.0 to 1.5 tsf
12					
13			CLAYEY SILTY SAND (SM-SC), reddish, brown, non plastic, damp, with some gravel and some boulders.		Refusal on boulder at 14.0'
14			BOTTOM OF TEST PIT AT 14.0'		
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-203

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-204

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	12x17x3	7/30/88	7/30/88	3502	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, trace gravel, and cobbles (5%) up to 6"; cobbles and gravel are subangular to subrounded. Roots extend to 6" depth.		
6			CLAYEY SILT - SILTY CLAY (CL-ML), buff, dry, hard, with some sand, trace gravel, and cobbles (5%) up to 9"; gravel and cobbles are subangular to subrounded.		uc > 4.5 tsf Walls are stable
9	S-1				
12			BOTTOM OF HOLE AT 12.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-204

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-205

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	16x19x3.5	8/1/88	8/1/88	3437.0	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1–2			GRAVELLY SAND (SP), buff, dry, with trace silt and cobbles (5%) up to 6"; cobbles and gravels are subrounded. Roots extend to 3" depth.		Test pit located in abandoned gravel pit; estimate original ground level is 10.0' above test pit.
3–15	S-1		SILTY CLAY (CL), light brown, slightly plastic to plastic, moist, hard, with trace sand.		uc > 4.5 tsf Walls remain stable
16			BOTTOM OF TEST PIT AT 16.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET	TEST PIT NO.
1 OF 1	TP-205

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-206

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	13x22x35	7/30/88	7/30/88	3518	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1–3			SILT (ML), buff, dry, with trace sand, trace gravel, and cobbles (5%) up to 6"; gravel and cobbles are subrounded to subangular.		NOTE: Test pit is in cut of road.
4–10	S-1		SILTY SANDY GRAVEL (GM), orange brown (rust), non plastic, with cobbles (5-10%) up to 6"; gravel and cobbles are subrounded to subangular. Can break by hand with difficulty.		
11–12	S-2		GRAVELLY SAND (SW), greyish brown, moist, with some angular to subangular cobbles up to 8".		
13			BOTTOM OF TEST PIT AT 13.0'		
14–16					

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET	TEST PIT NO.
1 OF 1	TP-206

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-207

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	16x19x4.5	8/1/88	8/1/88	3224	See Below	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			**SILT (ML)**, dark brown, damp. Roots extend from 2.0′ to 5.0′ depth.		
2			**GRAVELLY SAND (SP)**, grey brown, damp, with cobbles (10-15%) up to 6" and trace silt; gravels and cobbles are subrounded.		uc = 2.0 to 2.5 tsf
3			**SILT (ML)**, orange brown, very stiff, moist, with some sand.		
4			**SILTY SAND (SM)**, greyish brown, non plastic, wet, with some gravel, cobbles (10-15%), and boulders (5%) to 15".		
5	S-1				
6					
7					
8	S-2		**CLAYEY SILT (ML)**, light brown, slightly plastic, very stiff, moist to wet, with some fine sand (20-25%) in interbedded layers (4" apart). Noticeable horizontal bedding planes.	▼	Inflow of water at 8.0′
9					uc = 3.0 tsf
10					
11					
12			**GRAVELLY SAND (SM)** greyish brown, non plastic, moist to wet, with some silt; gravel is subrounded to rounded.		
13					
14	S-3				Walls of test pit are unstable
15					
16			BOTTOM OF TEST PIT AT 16.0′		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-207

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-208

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	11x18x3.5	8/1/88	8/1/88	3614	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), Buff, dry, with trace sand, trace gravel, and cobbles (5%); cobbles and gravels are subrounded to subangular. Roots extend to 1.0' depth.		
4			SILTY CLAY (CL), orange brown, slightly plastic, hard, moist, with some sand, trace gravels, and cobbles (5%); gravel and cobbles are subrounded to subangular.		Walls remain vertical and stable uc > 4.5 tsf
9	S-1				Sample S-1 taken after thundershowers (duration 15 minutes)
11			BOTTOM OF TEST PIT AT 11.0'		Difficult digging
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-208

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-209

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	11x17x3	8/1/88	8/1/88	3666	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), buff, damp, with trace sand, trace gravel, and cobbles (5%); gravels and cobbles are subrounded to subangular. Roots extend to 1.0' depth.		
3			SANDY CLAYEY SILT (ML) orange brown, slightly plastic, hard, damp, some gravel; gravel is subrounded to subangular.		
6					uc > 4.5 tsf
8	S-1				Sample S-1 taken after rainfall
10					Difficult digging
11			BOTTOM OF TEST PIT AT 11.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-209

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Poorman Creek	MONTANA	8029	TP-210

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	14x18x3	8/1/88	8/1/88	3458	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SANDY SILT (ML), buff, dry, with trace gravel and trace cobbles. Roots extend to 1.0' depth.		
2			CLAYEY SILT - SILTY CLAY (CL-ML), brown, slightly plastic to plastic, hard, damp, with some sand, trace gravel, and cobbles (5%) up to 6"; gravels and cobbles are subrounded.		
3					
4					uc > 4.5 tsf
5					
6					Walls remain stable
7					
8					
9					
10					
11	S-1				
12					
13					
14			BOTTOM OF TEST PIT AT 14.0'		
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-210

RAMSEY SITE

Test Pits TP 301 - 305

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Ramsey Creek	MONTANA	8029	TP-301

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	9x15x3	7/30/88	7/30/88	4431	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			**SILT (ML)** dark brown, dry to damp, with roots and organic matter. Roots extend to 1.5' depth.		
2			**GRAVELLY SAND (SM)**, olive brown, non plastic; damp, with some silt, cobbles (5-10%), and boulders (5-10%); boulders, cobbles, and gravel are subrounded to subangular up to 18".		
3					
4	S-1				
5					
6					
7					
8					
9					Refusal on boulder at 9.0'
			BOTTOM OF TEST PIT AT 9.0'		
10					
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-301

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Ramsey Creek	MONTANA	8029	TP-302

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	8x18x3	7/30/88	7/30/88	4410	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML) dark brown, dry to damp, with roots and organic matter. Roots extend to 1.5' depth.		
2			SILTY SANDY GRAVEL - GRAVELLY SILTY SAND (SM-GM) greyish brown, dry to damp, with cobbles (5-10%) and boulders (10-15%) up to 24".		
3					
4					
5					
6	S-1				Difficult digging (boulders)
7					
8					Refusal on boulder at 8.0'
			BOTTOM OF TEST PIT AT 8.0'		
9					
10					
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-302

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Ramsey Creek	MONTANA	8029	TP-303

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	9x14x2.5	7/30/88	7/30/88	4406.0	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), dark brown, damp, with some organic fibre and trace cobbles (5%); cobbles are subangular. Roots extend to 1.5' depth.		
2			GRAVELLY SAND (SM/SP), brown, damp, with boulders (25%), cobbles (10-15%), and some silt; cobbles, boulders, and gravels are subangular.		
3					
4					
5					Pit walls are unstable
6	S-1				
7					
8					
9					Refusal on boulder at 9.0'
10			BOTTOM OF TEST PIT AT 9.0'		
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-303

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Ramsey Creek	MONTANA	8029	TP-304

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	11x14x3	7/30/88	7/30/88	4410	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, damp. Roots extend to 2.0' depth.		
2			SILTY SANDY GRAVEL (GM), olive brown, moist, with cobbles (10-15%) and boulders (5%) up to 24"; gravel, cobbles, and boulders are subrounded to subangular; trace of organic fibre until 6.0'-8.0'.		
3					
4					
5					
6					
7					
8	S-1				
9					
10					
11			BOTTOM OF TEST PIT AT 11.0'		
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-304

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Ramsey Creek	MONTANA	8029	TP-305

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	Backhoe	7x12x3	7/30/88	7/30/88	4387	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1–4			SILT (ML), dark brown, dry to damp, with cobbles (10%) and boulders (10%); cobbles and boulders are subrounded to subangular.		
4–7	S-1		GRAVELLY SAND (SP), brown, dry to damp, with cobbles (10-15%), and boulders (15-20%) to 36"; Gravel, cobbles, and boulders are subrounded to subangular.		Pit walls are unstable Refusal on boulder at 7.0'
7			BOTTOM OF TEST PIT AT 7.0'		
8–16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-305

LIBBY SITE

Test Pits TP 401 - 405

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Libby Creek	MONTANA	8029	TP-401

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	12x18x3.5	8/3/88	8/3/88	4187.0	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			**GRAVELLY SILT (ML),** olive brown, non plastic, moist, with some sand, some gravel, cobbles (5-10%), and boulders (20%) up to 36"; gravel, cobbles, and boulders are subrounded to subangular. Roots extend to 1.0' depth.		
2			**SILTY SANDY GRAVEL (GM),** greyish brown, moist, with trace silt, cobbles (5-10%), and boulders (15%-20%) up to 36"; gravel to boulder sizes are subrounded to subangular.		
3					
4					
5					
6					Sides of test pit tend to slough
7					
8					
9					
10					
11	S-1				
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-401

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Libby Creek	MONTANA	8029	TP-402

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	13x16x4	8/3/88	8/3/88	4240	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			**SILT (ML),** olive dark brown, non plastic, damp, with some sand and boulders (10-15%); boulders are subrounded to subangular. Roots extend to 1.0' depth.		
2			**SILTY SANDY GRAVEL (GM),** grey-greyish brown, non plastic, damp, with cobbles (5%-10%) and boulders (5%-10%) to 18"; gravels, cobbles, boulders, are subrounded to subangular.		
3					
4					
5					Easy digging
6					
7	S-1				
8					
9					
10					
11					
12					At 12.0'-13.0' material becomes wetter (moist - wet)
13			BOTTOM OF TEST PIT AT 13.0'		
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-402

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Libby Creek	MONTANA	8029	TP-403

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	10x14x4	8/3/88	8/3/88	4255	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILT (ML), dark brown, moist, with some organics (to depth 1.0'), cobbles (5-10%), and boulders (5-10%); cobbles and boulders are subrounded to subangular. Roots extend to 1.0' depth.		
2			SILTY SANDY GRAVEL (GM), greyish brown, non plastic, damp to moist, with cobbles (10-15%) and boulders (10-15%) up to 36"; gravel to boulder sizes are subrounded to subangular.		
3					
4					
5					
6					Difficult digging, many boulders
7					
8					
9	S-1				
10			BOTTOM OF TEST PIT AT 10.0'		
11					
12					
13					
14					
15					
16					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-403

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Libby Creek	MONTANA	8029	TP-404

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	10x19x4	8/3/88	8/3/88	4257	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			**SANDY SILT (ML),** olive brown, damp, with organic fibre, trace gravel, cobbles (5-10%), and boulders (10-15%); gravels, cobbles and boulders are subrounded to subangular. Roots extend to 1.5' depth.		
3			**SILTY SANDY GRAVEL (GM),** greyish brown, damp, with cobbles (10%-15%) and boulders (10%-15%); gravel sizes are subrounded to subangular.		
6	S-1				Large boulder at 6.0'-7.0'
10					Refusal on boulder at 10.0'
			BOTTOM OF TEST PIT AT 10.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-404

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Libby Creek	MONTANA	8029	TP-405

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	14x17x3.5	8/3/88	8/3/88	4244	not encountered	N. Smith

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			**SILT (ML),** olive brown, damp, with cobbles (15%), boulders (15%), up to 18"; cobbles and boulders are subrounded to subangular. Roots extend to 1.0' depth.		
3			**SILTY SAND (SM),** olive brown, non plastic, moist, with some gravel, cobbles (10-15%), and boulders (10-15%) up to 24"; gravels, cobbles, and boulders are subrounded to subangular.		Easy digging
9	S-1				Walls are unstable; tend to slough
14			BOTTOM OF TEST PIT AT 14.0'		

MORRISON-KNUDSEN ENGINEERS, INC.
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SHEET	TEST PIT NO.
1 OF 1	TP-405

MIDAS SITE

Test Pits 500-501, 503-512

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-500

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	9.5x8x3	11/16/88	11/16/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SANDY SILT (ML), topsoil, dark brown, very moist, roots extend to 1.0' depth.		Test pit on uphill side of road
2			SANDY SILTY GRAVEL (GM), light brown, moist, dense to very dense, slightly plastic silt, angular to subrounded gravel, 10-20% subangular to subrounded cobbles to 10" size.		
3					
4					
5	S-1				
6					
7					
8					
9					
10			BOTTOM OF TEST PIT AT 9.5'		
11					
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-500

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-501

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	7.5x8x2.5	11/16/88	11/16/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), topsoil, dark brown, very moist.		Test pit on uphill side of road
1			SANDY SILTY GRAVEL (GM), light brown, moist, dense to very dense, non to slightly plastic silt, fine to coarse subangular to subrounded gravel, 10% subangular cobbles to 6" size.		
2					
3	S-1				
4					
5					
6					
7			BEDROCK - fractured		Difficult digging at 7.0'
			BOTTOM OF TEST PIT AT 7.5'		
8					
9					
10					
11					
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-501

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-503

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	13x16x2.5	11/16/88	11/16/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), topsoil, dark brown, very moist, organics to 1.0' depth.		Test pit on downhill side of road
1			SANDY CLAYEY SILT (ML), grayish brown, moist, stiff, non to slightly plastic.		
2	S-1				
3					
4					At 4.0', uc > 4.5 tsf
5					
6			CLAYEY SILT (ML), yellowish brown, moist, stiff, non to slightly plastic.		
7					
8					
9			some sand at 9.0'.		
10	S-2				
11					
12					
13			BOTTOM OF TEST PIT AT 13.0'		
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-503

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-504

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	11.5x13x2.5	11/16/88	11/16/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1–3			**SILTY SANDY GRAVEL (GM) (road fill),** reddish brown, moist, dense, fine to coarse, subangular gravel, buried wood and organics.		Test pit in turn-out on downhill side of road
3–6			**SILTY GRAVELLY SAND (SM),** grayish brown, moist, dense, 5% subrounded cobbles.		
6–9	S-1		**SILTY SANDY GRAVEL (GM),** grayish brown, moist, very dense, non plastic silt, fine to coarse, subangular to subrounded gravel, 10% subangular to subrounded cobbles to 8" size.		
9–11	S-2		**SILTY SAND (SM),** light brown, moist, very dense, non plastic silt, some subrounded gravel.		
12			**BOTTOM OF TEST PIT AT 11.5'**		

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-504

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-505

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	11x12x2.5	11/17/88	11/17/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SILTY SAND ~ SANDY SILT (SM-ML), fine, light brown, moist, medium dense to dense, non plastic silt.		Excavated in cut slope
2					
3			silty		
4					
5					
6					
7	S-1		very moist interbedded lenses of gray sandy silt and silty sand.		
8					
9			GRAVELLY SILTY SAND (SM), fine, light brown, moist, dense to very dense, coarse subrounded gravel.		Boulder at 8.5'
10					
11			BOTTOM OF TEST PIT AT 11.0'		
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-505

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-506

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	11x13x2.5	11/17/88	11/17/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			SANDY SILT (ML), topsoil, dark brown, moist to very moist, organics to 1.5' depth.		
2			SILTY SAND - SANDY SILT (SM-ML), fine, light grayish brown, damp, very dense, some subrounded to rounded gravel.		
3					At 3.0', uc > 4.5 tsf
4	S-1				
5					
6			grayish brown		
7			2-5% rounded cobbles to 6" size.		Difficult digging at 7.0'
8					
9	S-2		brown, moist, non plastic, fine to coarse subangular to subrounded sand, fine to medium subrounded to rounded gravel.		
10					
11			BOTTOM OF TEST PIT AT 11.0'		
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-506

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-507

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	9x14.5x2.5	11/17/88	11/17/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
1			**GRAVELLY SILTY SAND (SM),** fine, grayish brown, moist, very dense, non to slightly plastic silt, cobbles (2-5%) to 8" size.		Excavated in turn-out
2					
3					At 3.0', uc > 4.5 tsf
4					Difficult digging at 3.5'
5	S-1		**SANDY GRAVELLY SILT - SILTY SANDY GRAVEL (ML-GM),** light brown, moist, very dense, non to slightly plastic silt, fine to coarse subangular to subrounded gravel, fine to coarse subrounded sand, subrounded cobbles (5-15%) to 8" size, occasional boulder to 12" size.		
6					Oxidized surfaces within soil chunks
7					
8					
9					Difficult digging at 8.5'
10			**BOTTOM OF TEST PIT AT 9.0'**		
11					
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-507

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-508

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	14x19x2.5	11/17/88	11/17/88		See Below	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), topsoil, dark brown, moist.		Excavated in turn-out
1			SILTY GRAVELLY SAND (SM), light brown, moist, dense, fine to coarse subrounded sand, fine subrounded gravel.		
2					
3	S-1				At 2.5', uc > 4.5 tsf
4			Interbedded sands and gravels.		
5					
6					
7				▼	Seepage at 7.5'
8			SILTY SAND - SANDY SILT (SM-ML), fine, very moist, dense, trace fine to medium gravel, subrounded cobbles (2-5%) to 10" size.		
9					
10	S-2				
11					
12					
13					Bottom of test pit wet (no standing water) after 5 min.
14			BOTTOM OF TEST PIT AT 14.0'		
15					

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-509

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	11x16x2.5	11/17/88	11/17/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			**SANDY SILT (ML), topsoil,** brown, moist, roots extend to 1.0' depth.		
1			**SILTY SAND - SANDY SILT (SM-ML),** fine, grayish brown, damp, dense, subrounded cobbles (2-5%) to 7" size, and subrounded boulders (2-5%) to 15" size.		
2					
3					
4					
5					At 4.5', uc > 4.5 tsf
6	S-1		**GRAVELLY SILTY SAND - SANDY SILT (SM-ML),** moist, very dense, fine to medium sand, coarse subrounded gravel.		
7					
8					
9			fine to coarse sand.		
10	S-2				Difficult digging
11			**BOTTOM OF TEST PIT AT 11.0'**		
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	OF	TEST PIT NO.
1	1	TP-509

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-510

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	8x15x2.5	11/18/88	11/18/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), topsoil, brown, moist, roots to 1.0' depth.		Test pit excavated on uphill side of road
1			SILTY SANDY GRAVEL (GM), light grayish brown, moist, dense to very dense, fine to coarse subangular gravel, fine to coarse subangular sand, subangular cobbles (5-10%) to 5" size.		
2					
3					
4	S-1				
5					
6					
7			BEDROCK - fractured slightly weathered, oxidized surfaces, pieces 3"-4" long by 1"-2" wide.		Difficult digging
8			BOTTOM OF TEST PIT AT 8.0'		
9					
10					
11					
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-510

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-511

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	8x17x2.5	11/18/88	11/18/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			SANDY SILT (ML), topsoil, brown, moist, roots extend to 1.0' depth.		Test pit excavated on uphill side of road
1			GRAVELLY SILTY SAND - SILTY SANDY GRAVEL (SM-GM), yellowish brown, moist, dense to very dense, slightly plastic silt, fine to coarse sand, fine to medium subangular to subrounded gravel.		
2					
3	S-1				
4					At 3.5', uc > 4.5 tsf
5			fine to coarse subangular to subrounded gravel, subangular cobbles (5-10%).		Possibly old slide debris, mixture of weathered and unweathered cobbles and boulders
6					Difficult digging Hard boulder (16"x6") at 6.0'
7					
8					Refusal at 8.0'
			BOTTOM OF TEST PIT AT 8.0'		
9					
10					
11					
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-511

TEST PIT LOG

PROJECT	SITE	LOCATION	JOB NO.	TEST PIT NO.
MONTANA SILVER VENTURE	Midas Creek	MONTANA	8029	TP-512

CONTRACTOR	EXCAVATION METHOD	SIZE (FT)	BEGUN	COMPLETED	GROUND ELEV.	GROUND WATER DEPTH (FT)	LOGGED BY:
O. Sorlie	backhoe	11x3.5x2.5	11/18/88	11/18/88		not encountered	V. N. Pascucci

DEPTH (FT)	SAMPLE NO.	GRAPHIC LOG	MATERIAL DESCRIPTION AND CLASSIFICATION	WATER DATA	REMARKS PHOTOGRAPH
0			GRAVELLY SANDY SILT (ML), topsoil, brown, moist, organics to 1.0' depth.		Test pit excavated on uphill side of road
1			SANDY SILTY GRAVEL (GM), yellowish brown, moist, very dense, non to slightly plastic silt, fine to coarse subangular to subrounded gravel, fine to medium sand.		Rock outcrop near test pit
2	S-1				
3			BOTTOM OF TEST PIT AT 3.5'		Refusal at 3.5'
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

SHEET	TEST PIT NO.
1 OF 1	TP-512

APPENDIX F
LABORATORY TEST DATA

APPENDIX F
LABORATORY TEST DATA

Laboratory testing of soils was performed by 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 included dry density, grain size distribution (ASTM D422), Atterberg limits (ASTM D4318), moisture content (ASTM D2216), unconfined compressive strength (ASTM D2166), compaction (ASTM D698) and specific gravity (ASTM D854). Visual classification of samples was made in conformance with the Unified Soil Classification System. Undisturbed samples were photographed. For the Midas site, photographs were also obtained at various stages of sample preparation and testing. 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 8029 Project Name MONTANA SILVER VENTURE Feature LITTLE CHERRY SITE Date SEPT. 1988

Hole or Trench Number	Sample Number	Depth (Feet) From	Depth (Feet) To	Laboratory Classification	Mechanical Analysis Gravel	Mechanical Analysis Sand	Mechanical Analysis Fines	Atterberg Limits LL	Atterberg Limits PI	Specific Gravity G	Natural w %	Natural γ pcf	Compaction Test	Compaction Optimum w	Compaction Optimum γ pcf	Shear Strength Test	Shear Strength Initial w	Shear Strength Initial γ	Shear Strength C	Shear Strength φ	Permeability γ	Permeability k	Consolidation C_c	Consolidation C_r	Consolidation $\bar{R}$	Notes
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	125.5											
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															
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																	Interlayered silty sand and clayey silt-silty clay
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															
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																			
				ASTM:	← D422 →			D4318		D854	D2216			← D698 →												

* Visual Classification

SP : Standard Proctor
MP : Modified Proctor
S : Special - Test Text

TC : Triaxial Compression
UC : Unconfined Compression
DS : Direct Shear

UU : Unconsolidated Undrained
CU : Consolidated Undrained
CD : Consolidated Drained

SUMMARY OF SOIL TEST RESULTS

Job No 8029 Project Name MONTANA SILVER VENTURE Feature POORMAN SITE Date SEPT. 1988

Hole or Trench Number	Sample Number	Depth (Feet) From	Depth (Feet) To	Laboratory Classification	Mechanical Analysis Gravel	Mechanical Analysis Sand	Mechanical Analysis Fines	Atterberg Limits LL	Atterberg Limits PI	Specific Gravity G	Natural w %	Natural γd pcf	Compaction Test	Compaction Optimum w	Compaction Optimum γd pcf	Shear Strength Test	Shear Strength Initial w	Shear Strength Initial γd	Shear Strength C	Shear Strength φ	Permeability γd	Permeability k	Consolidation Cc	Consolidation Cr	Consolidation R	Notes
TP-202	S-1	8	10	CL	18	25	57	38	17	2.71	8		SP	10.0	108.5											
TP-203	S-2	10	14	GC	34	26	40	30	12	2.69			SP	12.7	115.8											
TP-204	S-1	9	10	CL-ML	6	19	75				5															
TP-206	S-1	7	9	GM	45	23	32																			
TP-208	S-1	9	11	CL	14	21	65	23	7		2															
TP-210	S-1	11	13	CL-ML	9	19	72	20	6		7															
USA-1A	ST-1	2.5	4.5	SM*							15	117														
USA-1A	R-1	12.5	13.7	SM*							11	119														
USA-1	ST-1	15	15.5	SM*							21	114														
USA-1A	ST-2	7.5	9.5	SM*							16	118														
USA-1A	R-1	12.5	13.7	SM*							17	108														
USA-2	ST-1	17	17.9	SM*							17	115														
USA-2	ST-2	47.0	47.7	SM*							15	120														
USA-3	ST-1	7.5	8.2	CL*							11	113														
USA-3	SPT-2	8.3	9.7	CL	17	28	55	26	9		13															
USA-3	SPT-4	20	21.5	CL	24	29	47																			
USA-4	SPT-3	15	16.5	SM	26	40	34																			
USA-4	SPT-5	25	26.5	SM	2	49	49																			
				ASTM:	← D422 →			D4318		D854	D216		← D698 →													

* Visual Classification

SP : Standard Proctor MP : Modified Proctor S : Speed - Bar Test

TR : Triaxial Compression UC : Unconfined Compression DS : Direct Shear

UU : Unconsolidated Undrained CU : Consolidated Undrained CD : Consolidated Drained

SUMMARY OF SOIL TEST RESULTS

Job No 8029 Project Name MONTANA SILVER VENTURE Feature PLANT SITES Date SEPT. 1988

Hole or Trench Number	Sample Number	Depth (Feet) From	Depth (Feet) To	Laboratory Classification	Mechanical Analysis: Gravel	Sand	Fines	Atterberg Limits: LL	PI	Specific Gravity G	Natural: w %	γd	Compaction: Test	Optimum w	Optimum γd	Shear Strength: Test	Initial w	Initial γd	C	φ	Permeability: γs	k	Consolidation: Cc	Cc	R	Notes
RAMSEY SITE:																										
TP-302	S-1	6	8	SM	39	42	19				2															
TP-309	S-1	8	10	GM	44	31	25				13															
LIBBY SITE:																										
TP-401	S-1	11	12	GM	46	36	18				8															
TP-403	S-1	9	10	GM	47	36	17				10															
				ASTM:	←	D422	→				D2216															

* Visual Classification

SP : Standard Proctor
MP : Modified Proctor
S : Speedy - Sieve Test

TC : Triaxial Compression
UC : Unconfined Compression
DS : Direct Shear

UU : Unconsolidated Undrained
CU : Consolidated Undrained
CD : Consolidated Drained

SUMMARY OF SOIL TEST RESULTS

Job No 8029 Project Name MONTANA SILVER VENTURE Feature MIDAS SITE Date DEC. 1988

Hole or Trench Number	Sample Number	Depth (Feet) From	Depth (Feet) To	Laboratory Classification	Mechanical Analysis Gravel	Mechanical Analysis Sand	Mechanical Analysis Fines	Atterberg Limits LL	Atterberg Limits PI	Specific Gravity G	Natural w %	Natural γd pcf	Compaction Test	Compaction Optimum w	Compaction Optimum γd pcf	Shear Strength Test	Shear Strength Initial w	Shear Strength Initial γd	Shear Strength C kgf	Shear Strength φ	Permeability γd	Permeability k	Consolidation C_v	Consolidation C_c	Consolidation R	Notes
TP-503	S-2	10	11	ML	0	2	98	23	3	2.71	25		SP	20.5	102.5											
TP-504	S-1	7	8	SM	42	33	25				10															
TP-505	S-1	7	8.5	ML	1	5	94			2.72	23		SP	16.8	106.5											interbedded lenses of ML and SM
TP-506	S-1	4	5	ML	12	21	67	Non	Plastic		12															
TP-506	S-2	9	10	ML	10	31	59			2.75	16		SP	12.8	117.1											
TP-507	S-1	5	6	ML	23	20	57			2.74	12		SP	10.4	122.7											
TP-508	S-2	10	11	ML	1	4	95	Non	Plastic		23															
TP-509	S-1	6	7	ML	12	18	70				16															
TP-511	S-1	3	4	SM	34	35	31				11															
MCDH-2	ST-1	8.5	10	ML	29	15	56																			
MCDH-2	ST-2	43.5	45	CL				30	12		24	98				UC	24	98	0.99							varved
MCDH-2	SPT-2	13.5	15	CL	14	22	64	26	11																	
MCDH-2	SPT-6	38.5	40	CL				36	16																	
MCDH-2	SPT-8	63.5	65	CL	11	5	84	41	18																	
MCDH-2A	ST-4	38.5	40.5	CL	0	0	100				27	97				UC	27	97	1.30							with silt pockets
MCDH-2A	ST-6	53.5	55.5	CL*							31	93				UC	31	93	4.00							varved
MCDH-6	R-1	28.5	29.1	ML-CL	0	18	82				17	115														
MCDH-6	R-3	48.5	50	ML	0	0	100	44	17		26	104				UC	26	104	3.35							with silt lenses
MCDH-6	SPT-7	75	76.5	CL	0	3	97	39	19																	interbedded lenses of clay and sandy silt
MCDH-8	ST-2	22	23.5	CL	12	13	75				20	110				UC	20	110	2.80							
MCDH-8	SPT-3	11	12.5	GC	39	17	44	37	15																	
MCDH-8	SPT-6	42	43.5	CL	2	4	94	34	14																	
MCDH-8	SPT-7	54	55.5	SC	30	49	21																			
				ASTM:	—	D422	—	D4318		D854	D2216		—	D698	—	—	D2166	—								

* Visual Classification

SP = Standard Proctor
MP = Modified Proctor
S = Swell - Sieve Test

TC = Triaxial Compression
UC = Unconfined Compression
DS = Direct Shear

UU = Unconsolidated Undrained
CU = Consolidated Undrained
CD = Consolidated Drained

SUMMARY OF SOIL TEST RESULTS

Job No 8029 Project Name MONTANA SILVER VENTURE Feature MIDAS SITE (CONT'D) Date DEC. 1988

Hole or Trench Number	Sample Number	Depth (Feet) From	Depth (Feet) To	Laboratory Classification	Mechanical Analysis Gravel	Mechanical Analysis Sand	Mechanical Analysis Fines	Atterberg Limits LL	Atterberg Limits PI	Specific Gravity G	Natural w %	Natural γd pcf	Compaction Test	Compaction Optimum w	Compaction Optimum γd	Shear Strength Test	Shear Strength Initial w	Shear Strength Initial γd	Shear Strength C kgf	Shear Strength φ	Permeability γd	Permeability k	Consolidation C_c	Consolidation C_v	Consolidation ε	Notes
MCDH-9	ST-1	13.5	15.5	CL-ML	15	33	52				23	105				UC	23	105	1.59							
MCDH-9	ST-2	18.5	20	SC-SM	31	43	26																			
ASTM:					← D422 →			D4318		D854	D2216		← D698 →			← D2166 →										

* Visual Classification

SP = Standard Proctor; MP = Modified Proctor; S = Special - See Text; TC = Triaxial Compression; UC = Unconfined Compression; DS = Direct Shear; UU = Unconsolidated Undrained; CU = Consolidated Undrained; CD = Consolidated Drained

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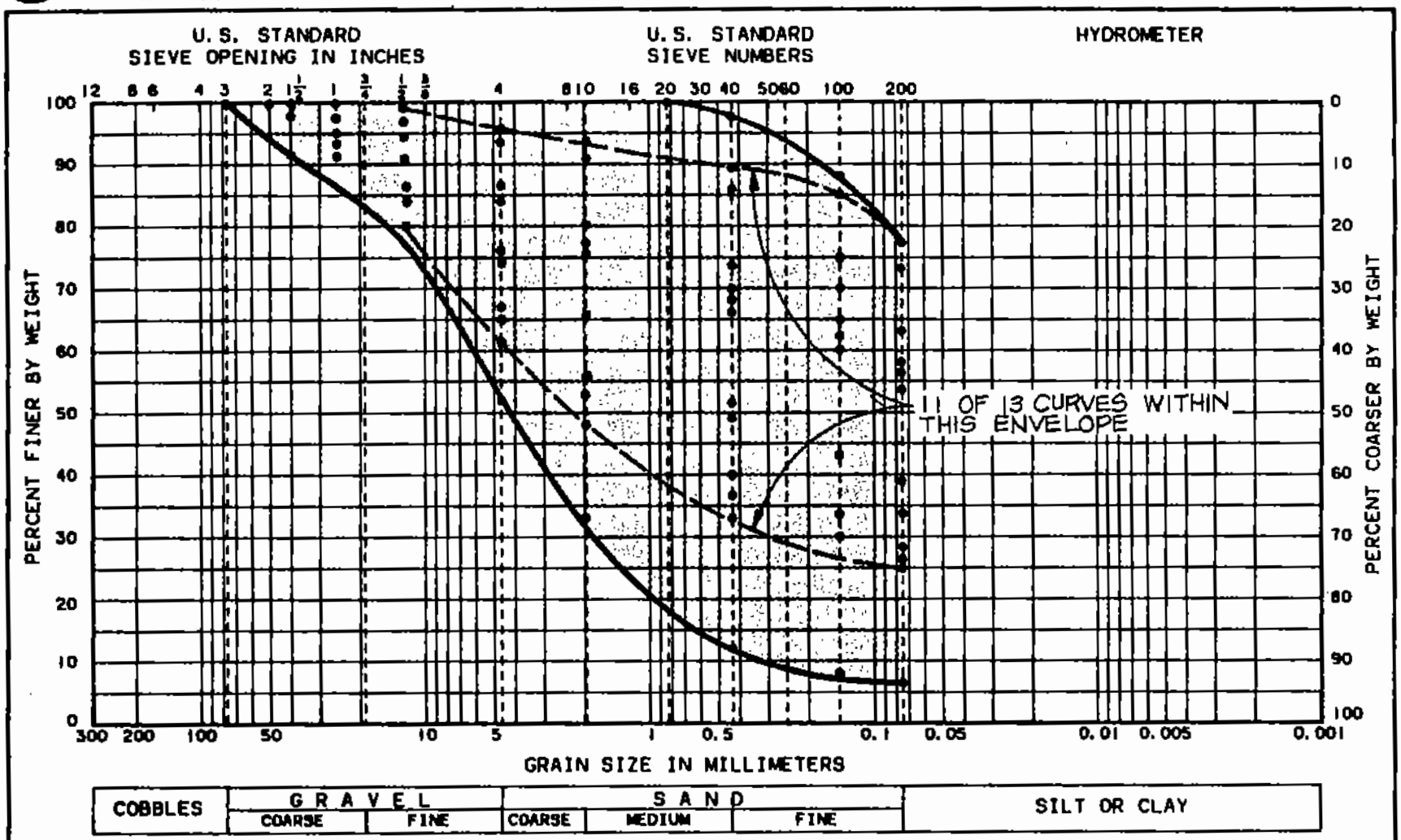

GRAIN SIZE ANALYSIS

SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT WX	LL	PL	PI
	(13 GRAIN	SIZE CURVES)				

PROJECT	MONTANA SILVER VENTURE
JOB NO.	8029
AREA	LITTLE CHERRY SITE
	GRAIN SIZE ENVELOPE
DATE	NOV. 1988 — FIGURE F-1

CAS110

MORRISON-KNUDSEN ENGINEERS, INC.
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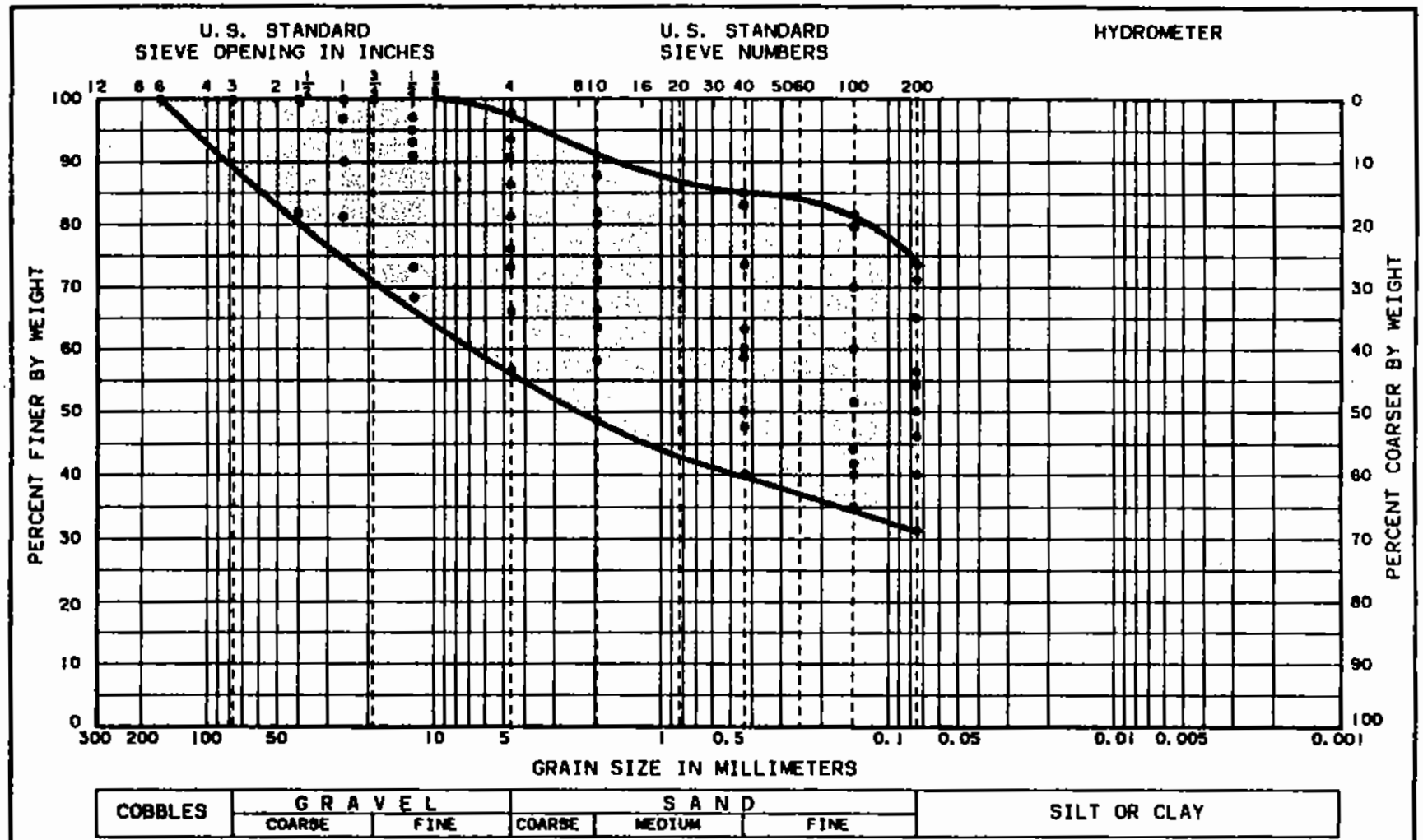


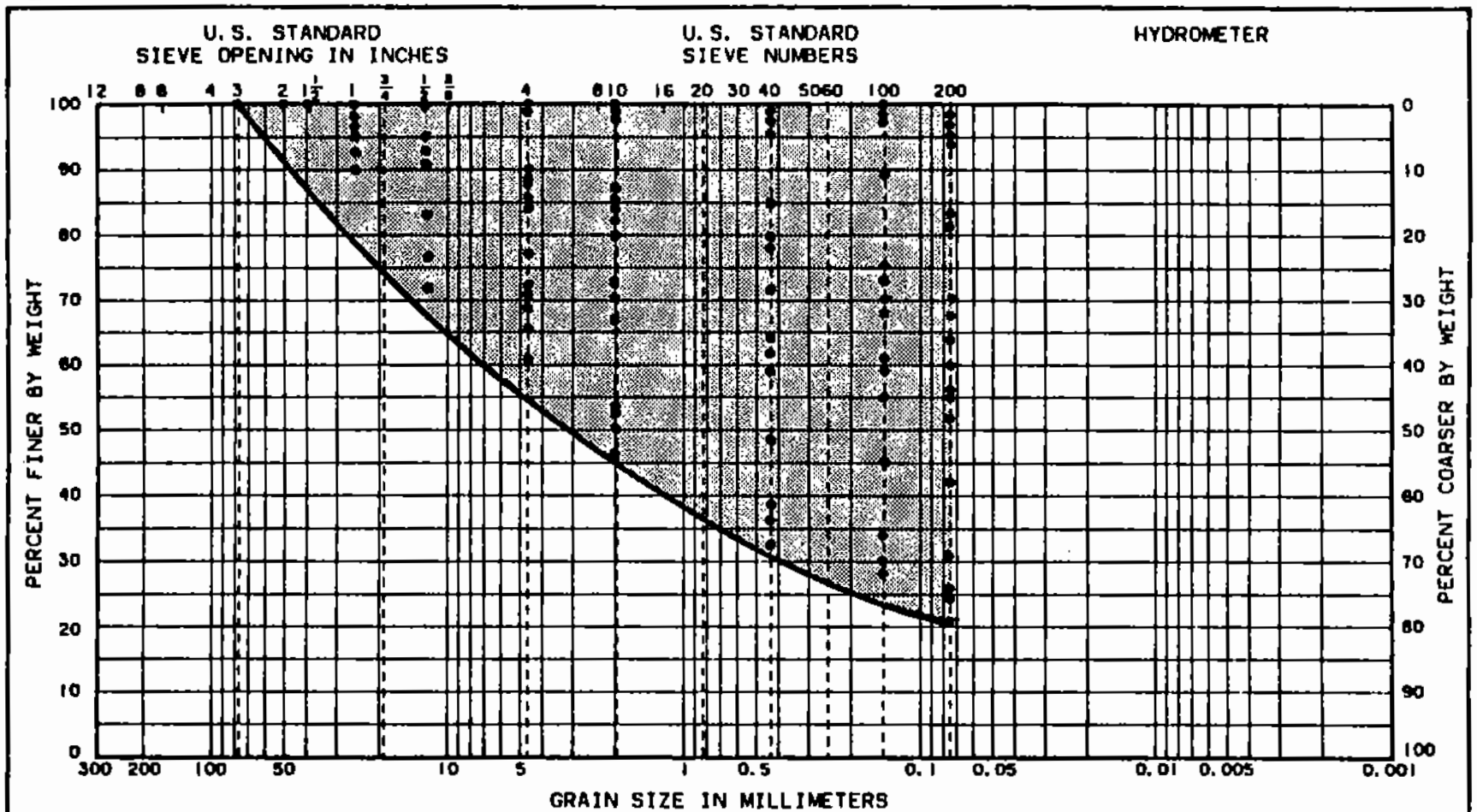
GRAIN SIZE ANALYSIS

SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT WX	LL	PL	PI
	(10 GRAIN	SIZE CURVES)				

PROJECT	MONTANA SILVER VENTURE
JOB NO.	8029
AREA	POORMAN SITE
	GRAIN SIZE ENVELOPE
DATE	NOV. 1988 — FIGURE F-2

CAB110

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON-KNUDSEN COMPANY

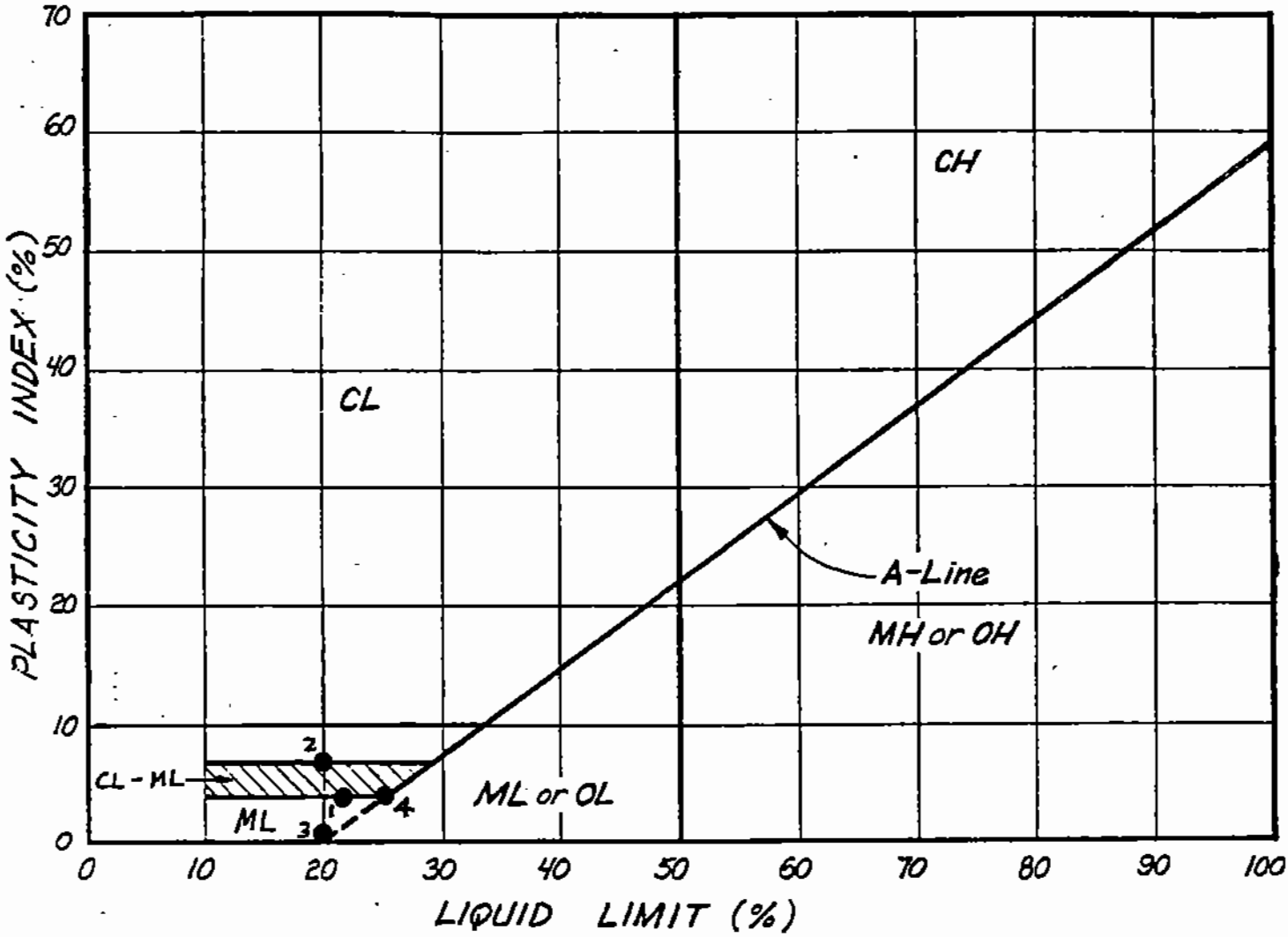


GRAIN SIZE ANALYSIS

SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
	(22 GRAIN	SIZE CURVES)				

PROJECT	MONTANA SILVER VENTURE
JOB NO.	8029
AREA	MIDAS CREEK SITE
	GRAIN SIZE ENVELOPE
DATE	JAN. 1984 — FIGURE F-3

CAB110

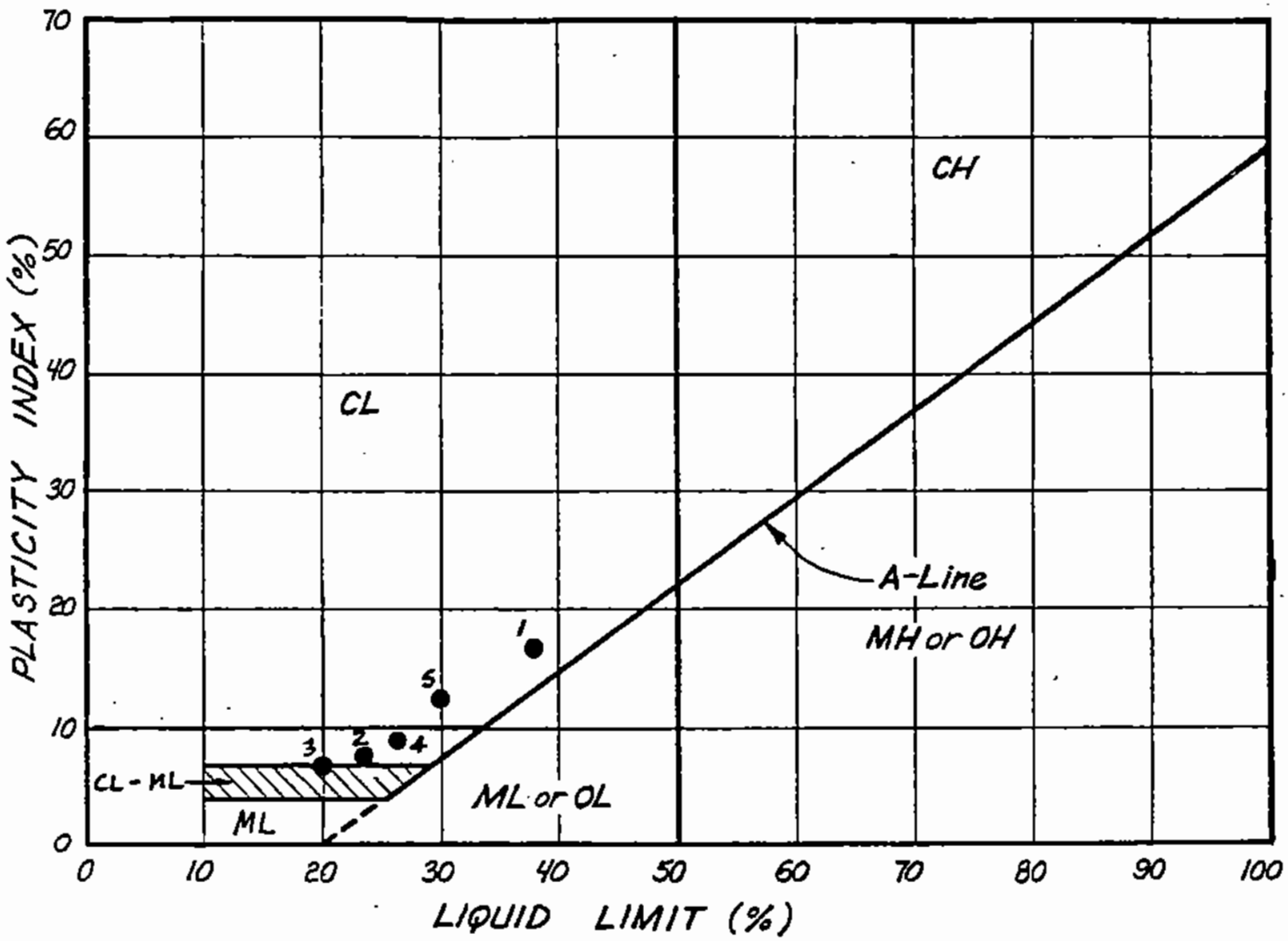


SYMBOL	CLASSIFICATION AND SOURCE	LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)	% PASSING #200 SIEVE
1	TP-103 S-1 4'-11' (CL-ML)	21	17	4	64
2	TP-107 S-1 8'-9' (CL-ML)	20	14	6	57
3	TP-109 S-1 8'-10' (ML)	20	19	1	54
4	USB-1 SPT-3 15'-16.5' (CL-ML)	25	21	4	58

LITTLE CHERRY SITE

PLASTICITY CHART

FIGURE F-4

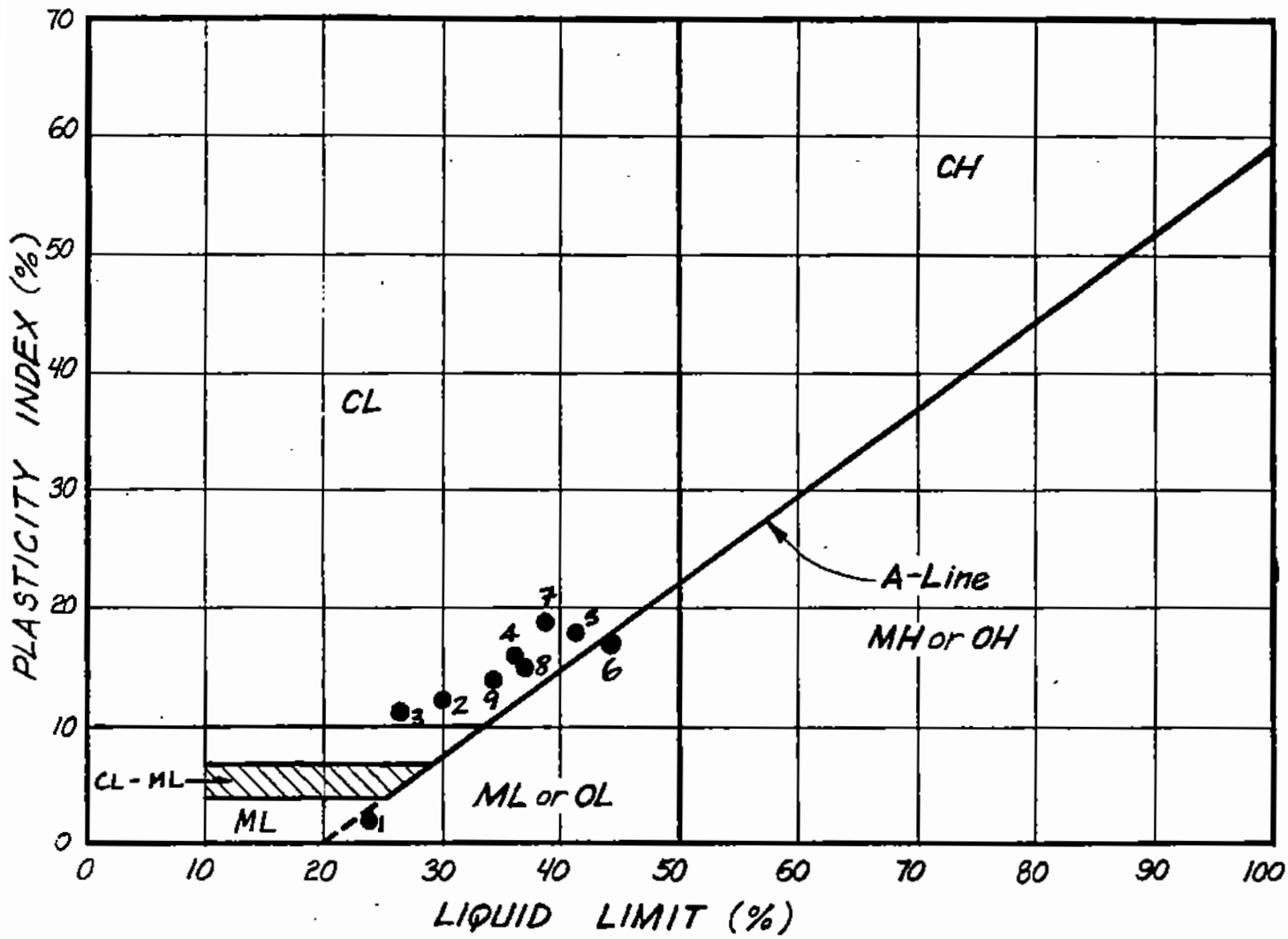


SYMBOL	CLASSIFICATION AND SOURCE	LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)	% PASSING #200 SIEVE
1	TP-202 S-1 8'-10' (CL)	38	21	17	57
2	TP-208 S-1 9'-11' (CL)	23	16	7	65
3	TP-210 S-1 11'-13' (CL-ML)	20	14	6	72
4	USA-3 SPT-2 8.3'-9.7' (CL)	26	17	9	55
5	TP-203 S-2 10'-14' (GC)	30	18	12	40

POORMAN SITE

PLASTICITY CHART

FIGURE F-5



SYMBOL	CLASSIFICATION AND SOURCE	LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)	% PASSING #200 SIEVE
1	TP-503 S-2 10'-11' (ML)	23	20	3	98
2	DH-2 ST-2 43.5'-45' (CL)	30	18	12	–
3	DH-2 SPT-2 13.5'-15' (CL)	26	15	11	64
4	DH-2 SPT-6 38.5'-40' (CL)	36	20	16	–
5	DH-2 SPT-8 63.5'-65 (CL)	41	23	18	84
6	DH-6 R-3 48.5'-50' (ML)	44	27	17	100
7	DH-6 SPT-7 75'-76.5' (CL)	39	20	19	97
8	DH-8 SPT-3 11'-12.5' (GC)	37	22	15	44
9	DH-8 SPT-6 42'-43.5' (CL)	34	20	14	94

MIDAS SITE

PLASTICITY CHART

FIGURE F-6

LITTLE CHERRY SITE

Northern
Engineering and Testing, Inc.

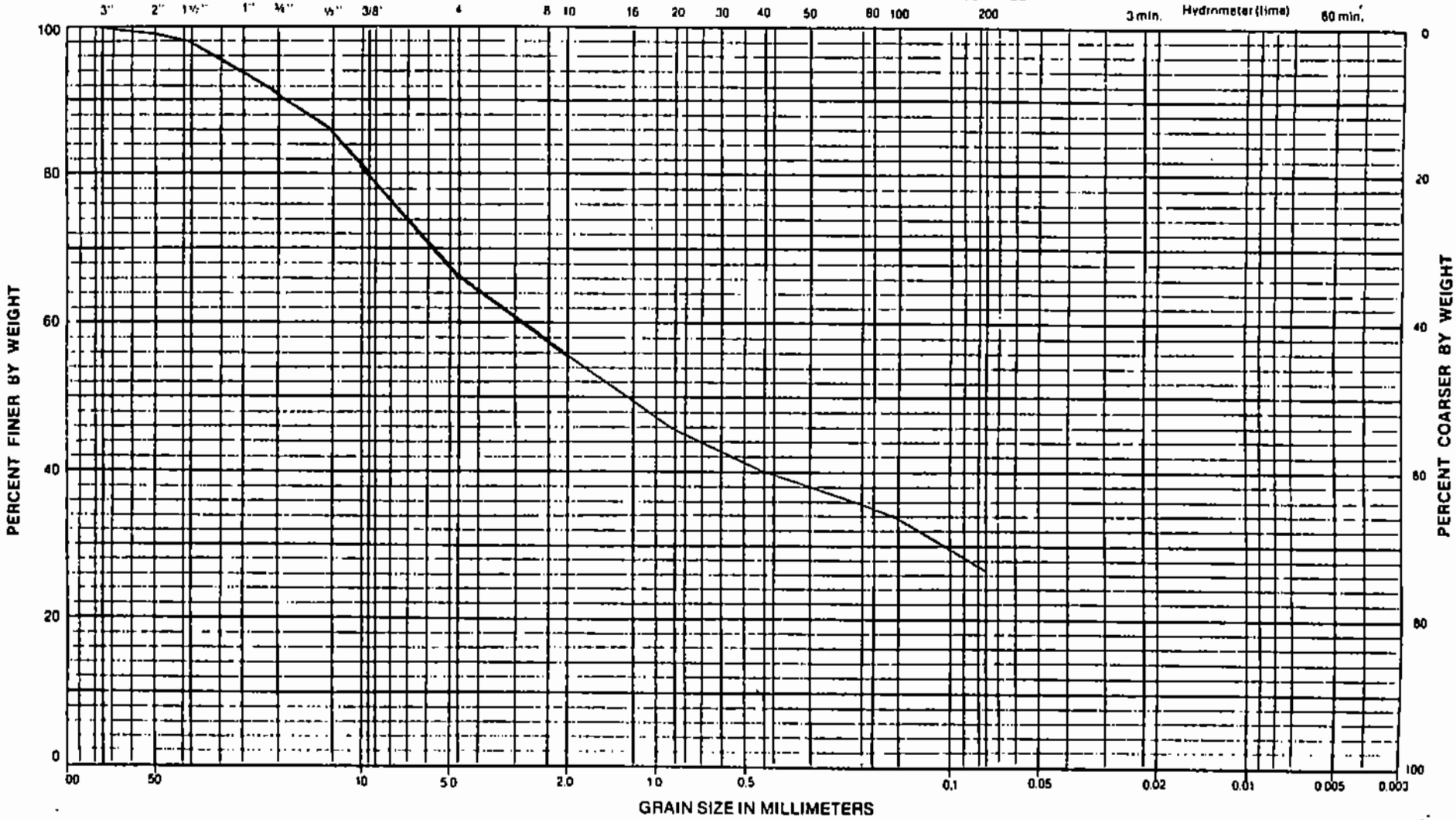
GRAIN SIZE DISTRIBUTION CURVE

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.

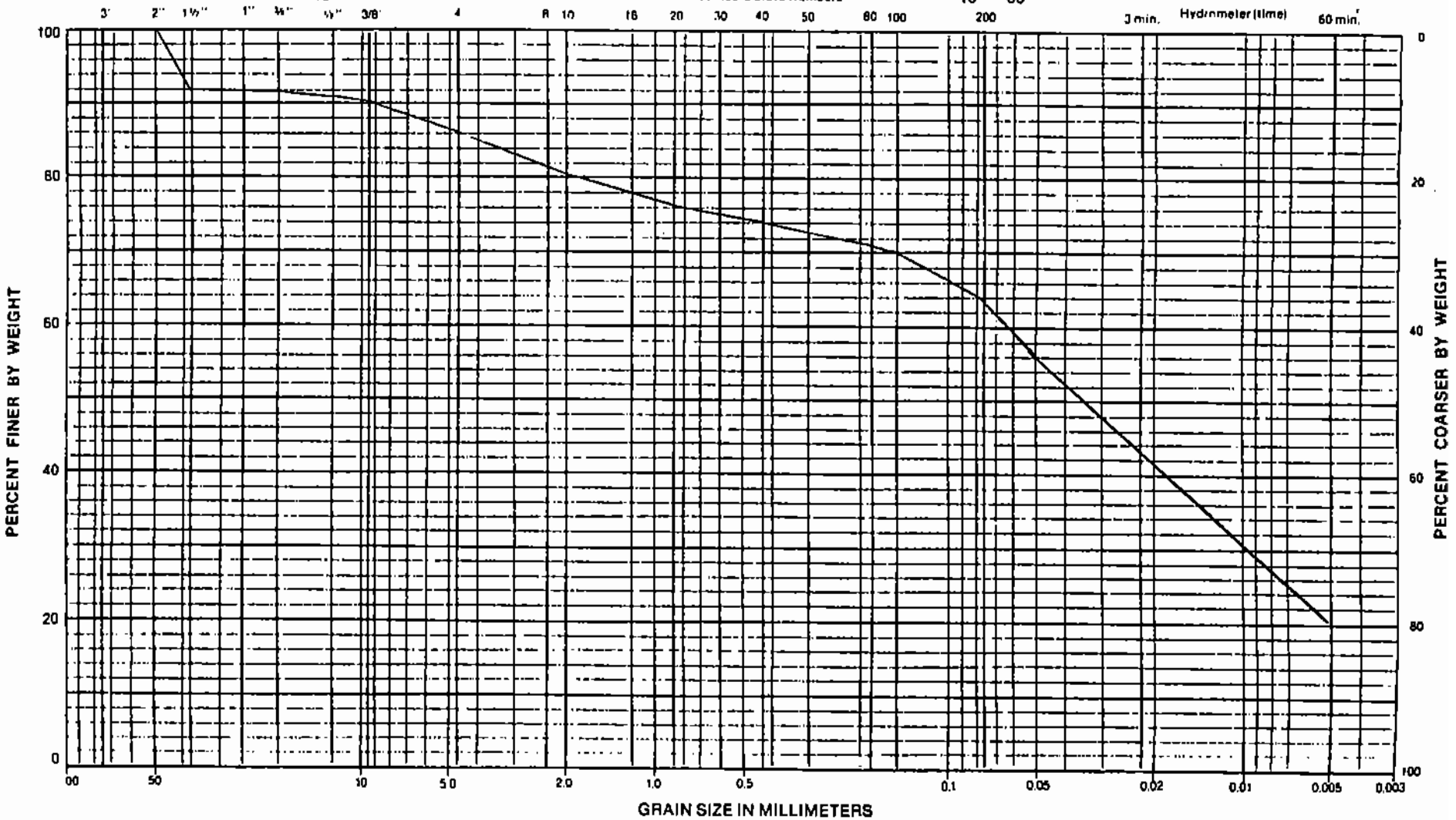
GRAIN SIZE DISTRIBUTION CURVE

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

Sample No. 32286

Location: TP-105, S-1, 8.0'-14.0'

Job No. 88-152

Classification Poorly-Graded SAND w/Silt & Gravel (SP-SM)

Date August 1988

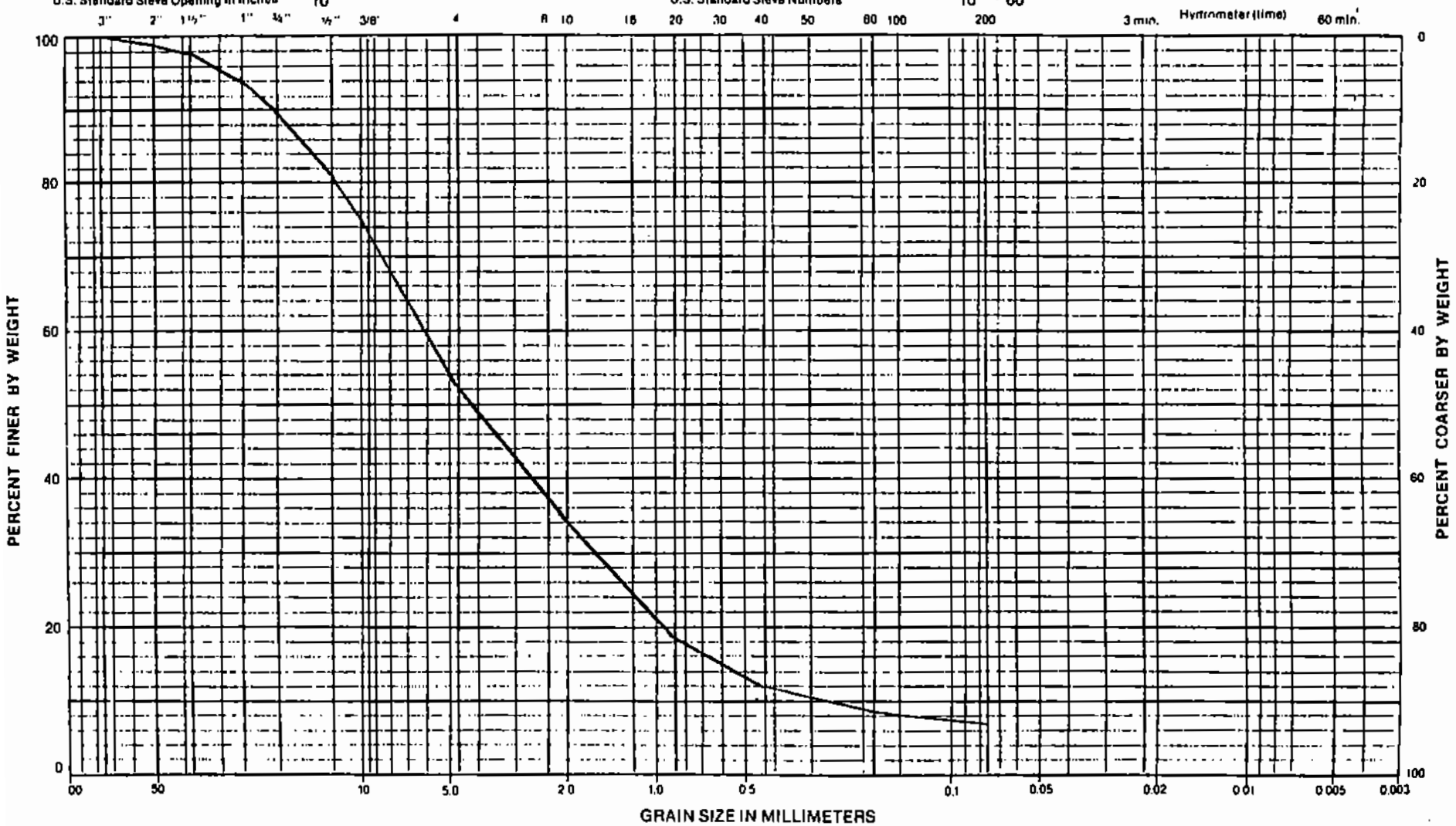
Moisture Content -- %

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

Sample No. 32287

Location: TP-106, S-1, 6.0'-8.0'

Job No. 88-152

Classification Sandy Lean CLAY (CL)

Date August 1988

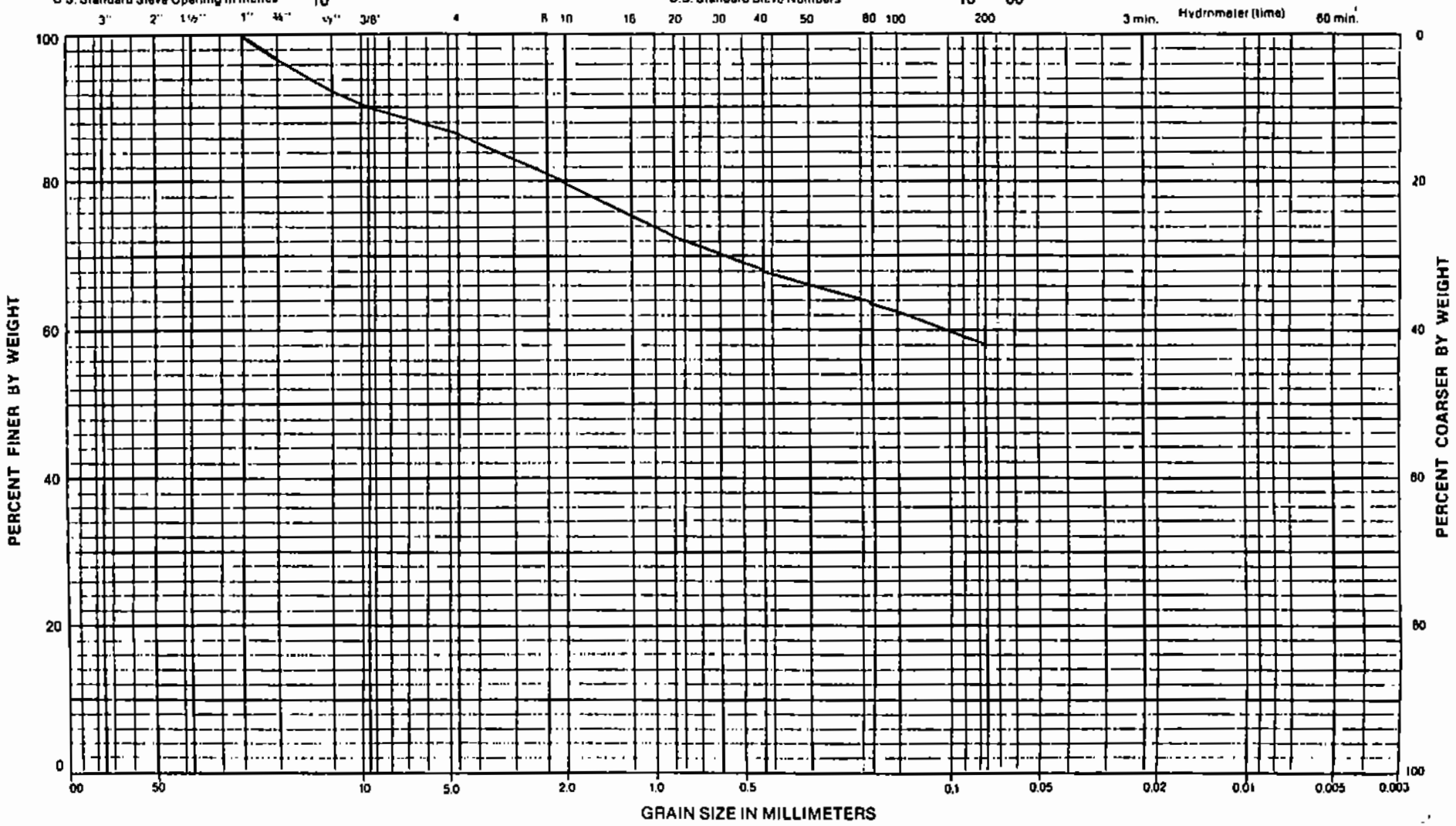
Moisture Content 11 %

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

Sample No. 32288

Location: TP-107, S-1, 8.0'-9.0'

Job No. 88-152

Classification Sandy Silty CLAY w/Gravel (CL-ML)

Date August 1988

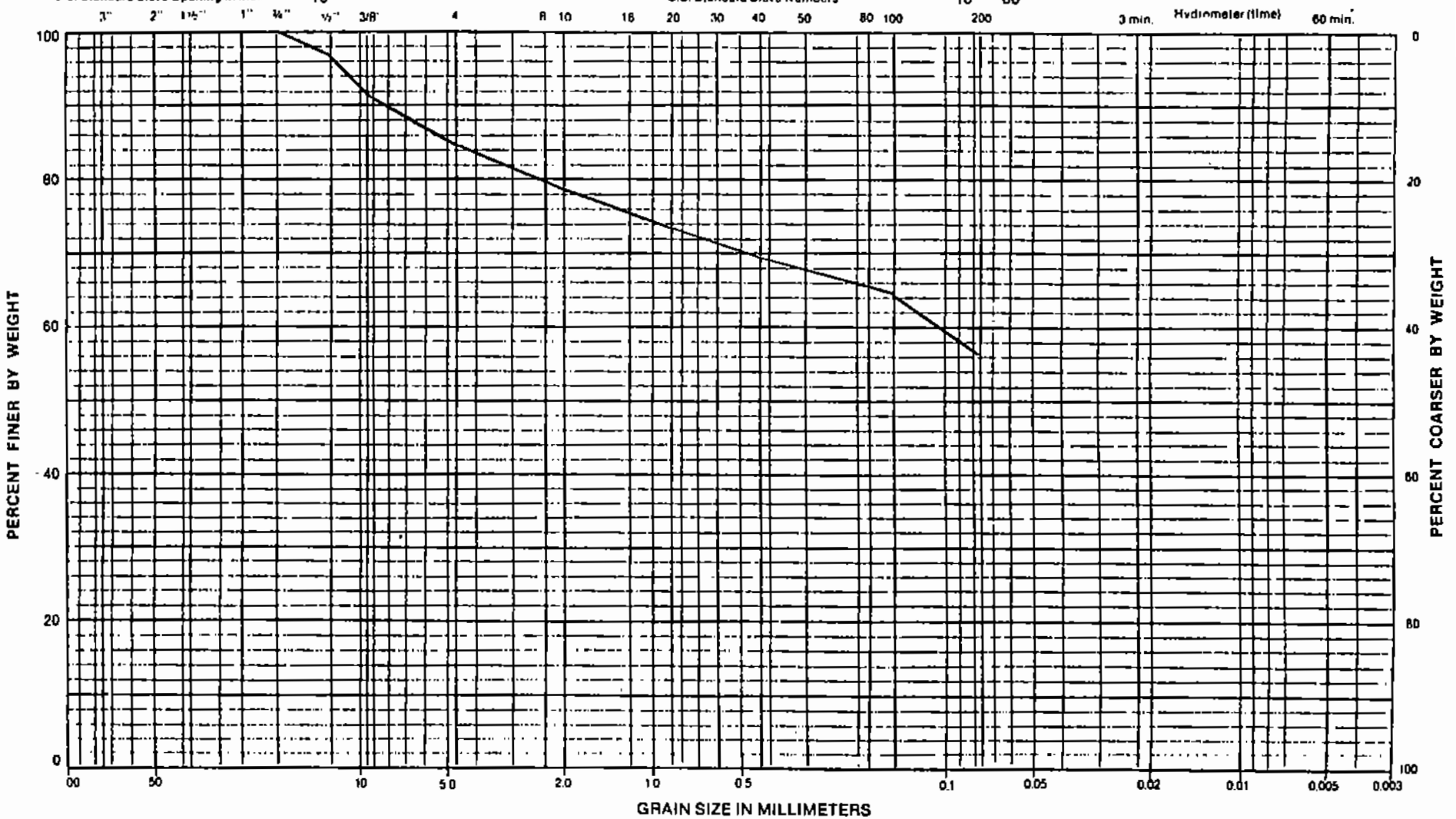
Moisture Content 6 %

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

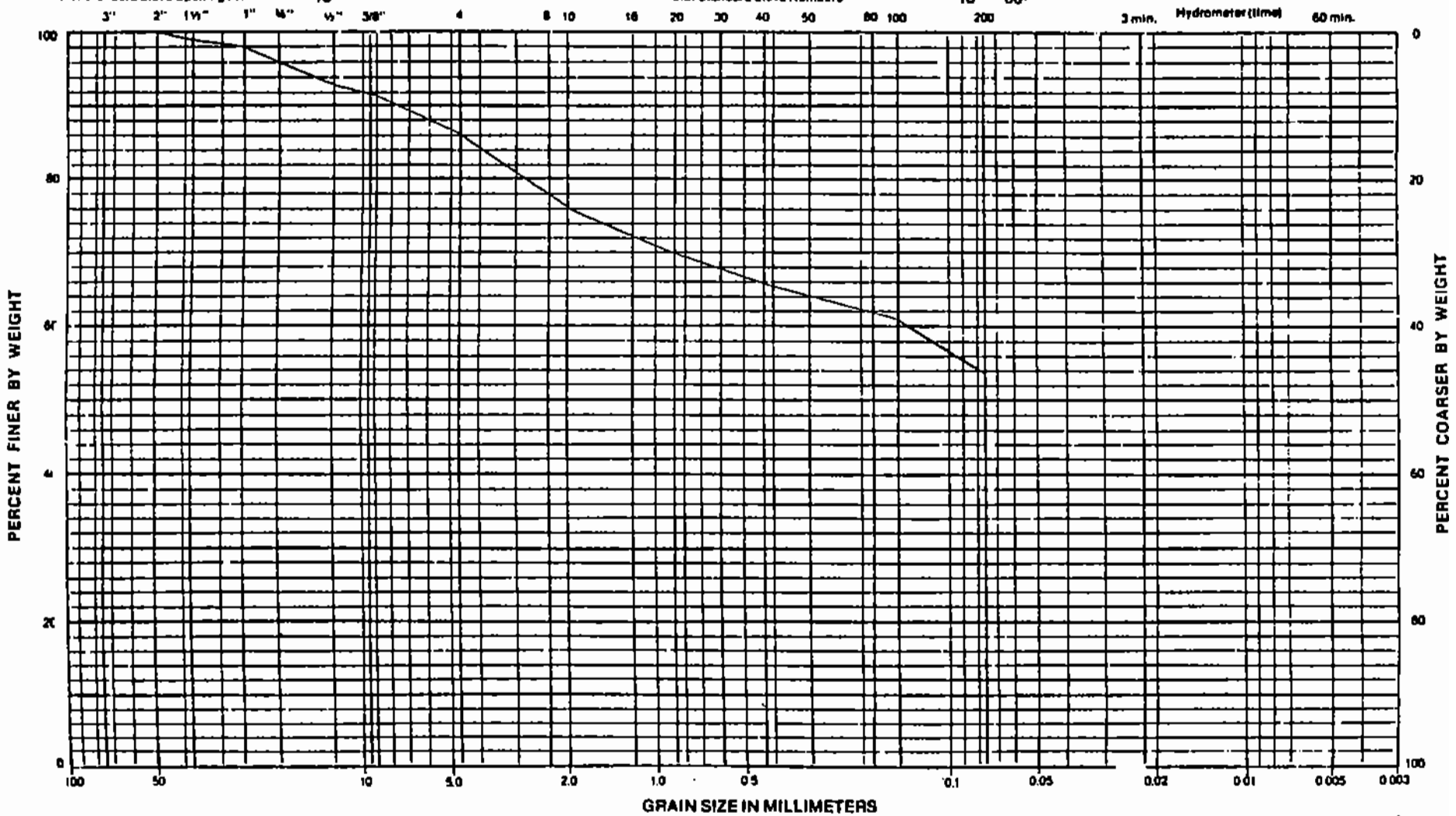
Location: Little Cherry Site, TP-109, 8.0'-10.0', S-1 Job No. 88-152

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

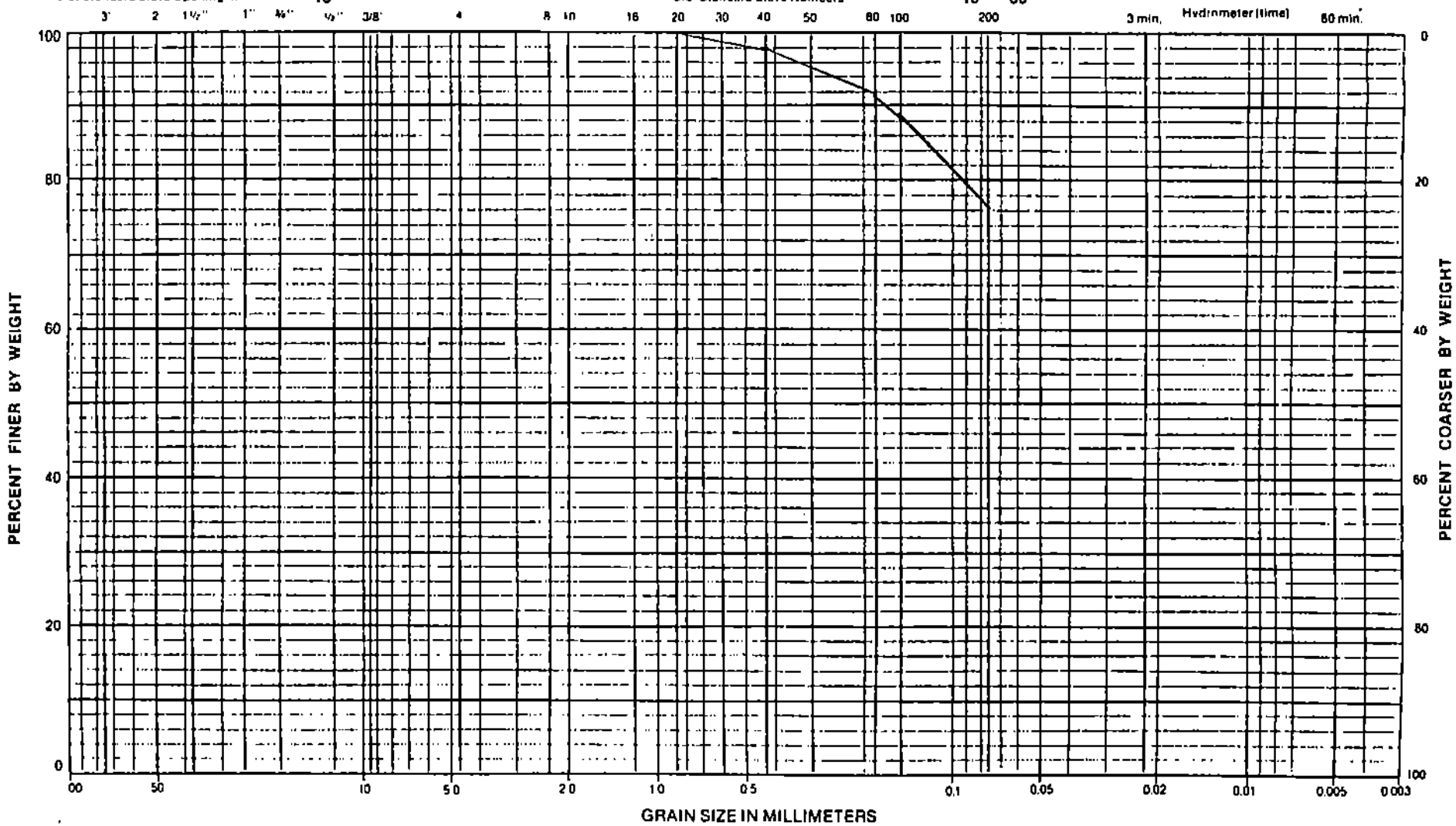
Moisture Content -- %

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

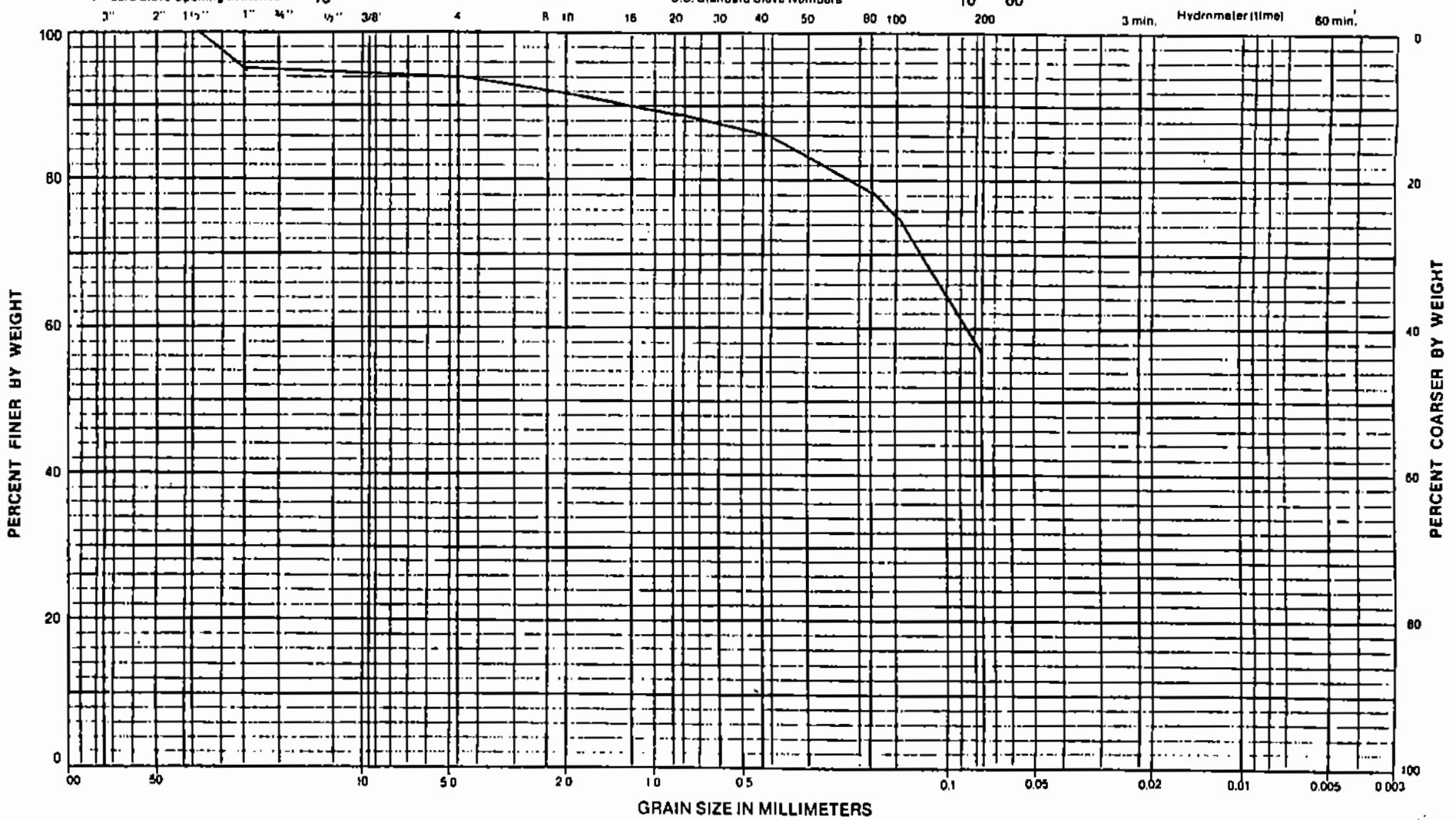
Moisture Content -- %

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

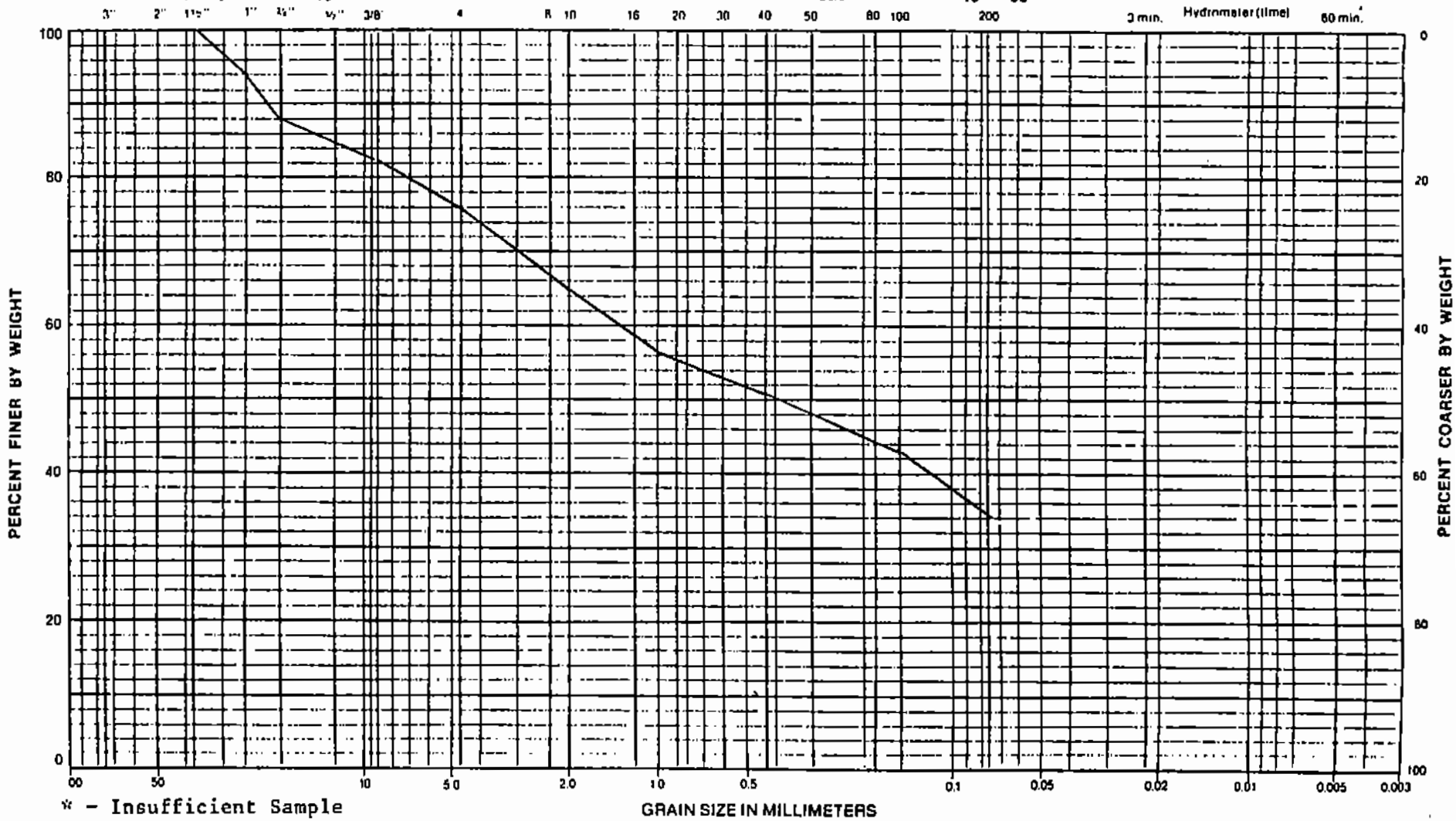
Moisture Content -- %

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.

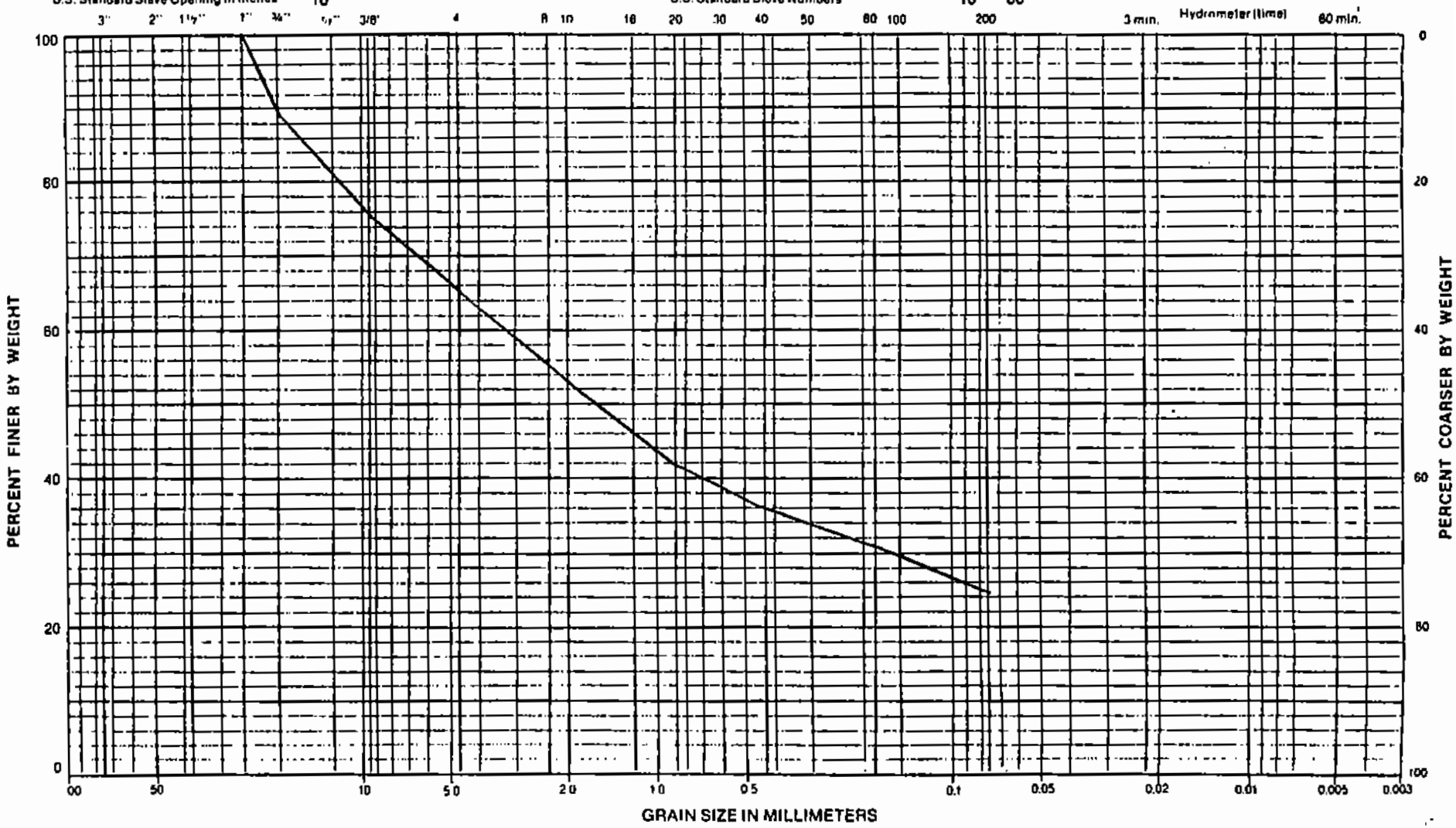
GRAIN SIZE DISTRIBUTION CURVE

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)
Moisture Content 4 %

Sample No. 32329
Job No. 88-152
Date August 1988
Liquid Limit -- %
Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



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

Sample No. 32338

Job No. 88-152

Date October 1988

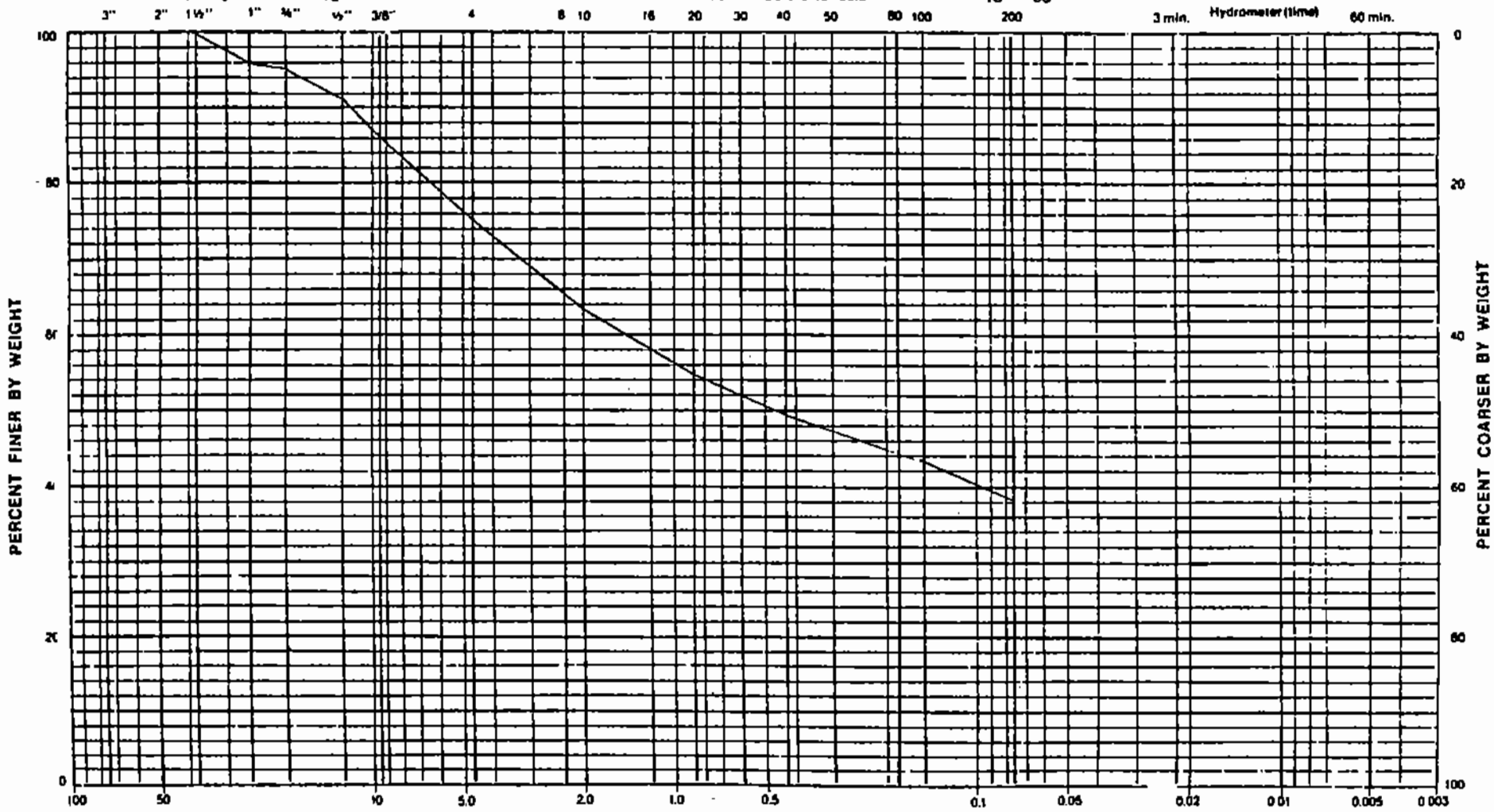
Moisture Content 15 %

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. 32971

Location: Little Cherry Site, USB-4, SPT-2, 5.0'-6.5'

Job No. 88-152

Classification: Clayey GRAVEL with Sand

Date: October 1988

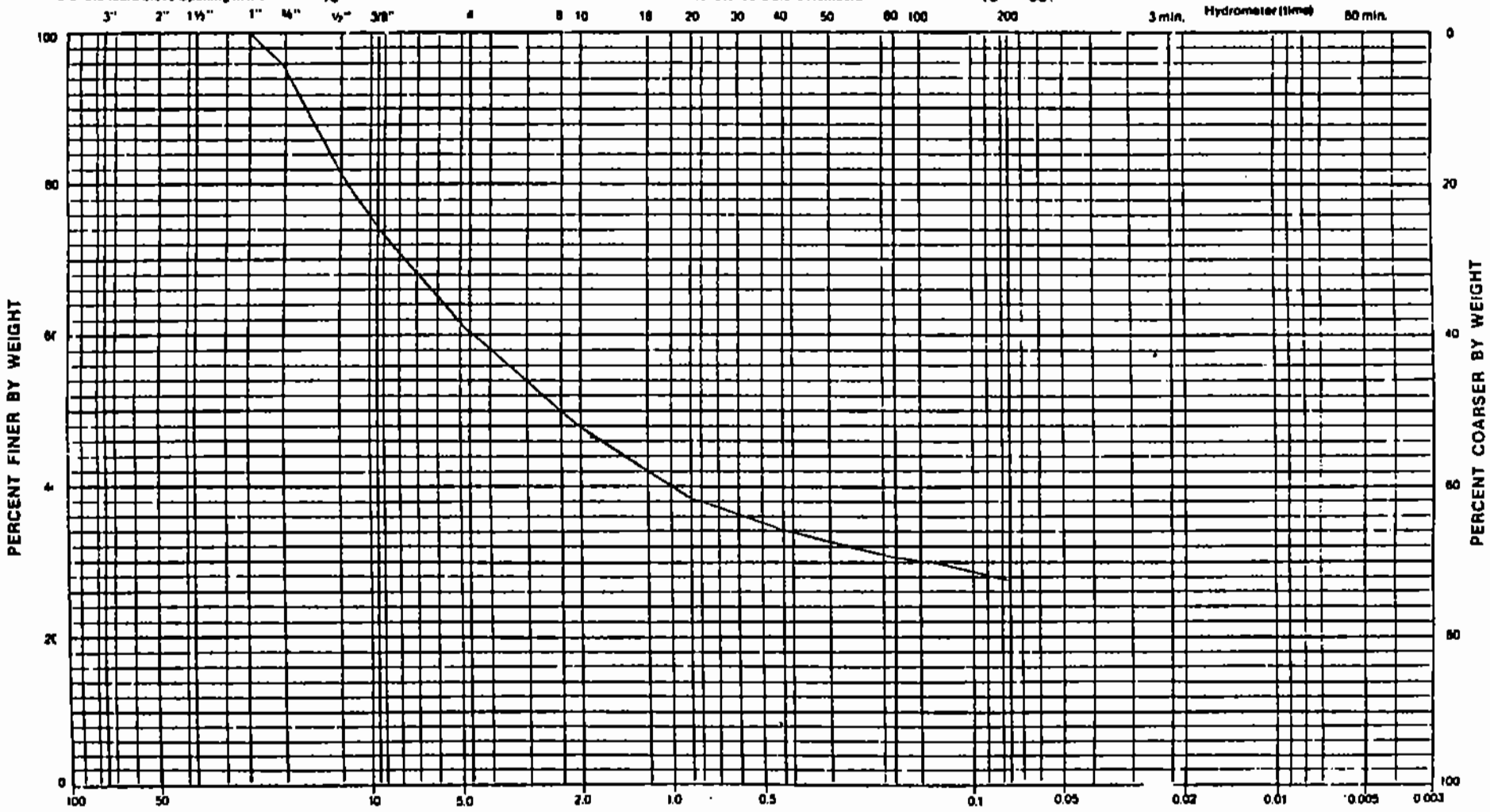
Moisture Content: -- %

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

Northern

Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine Sample No. 32976

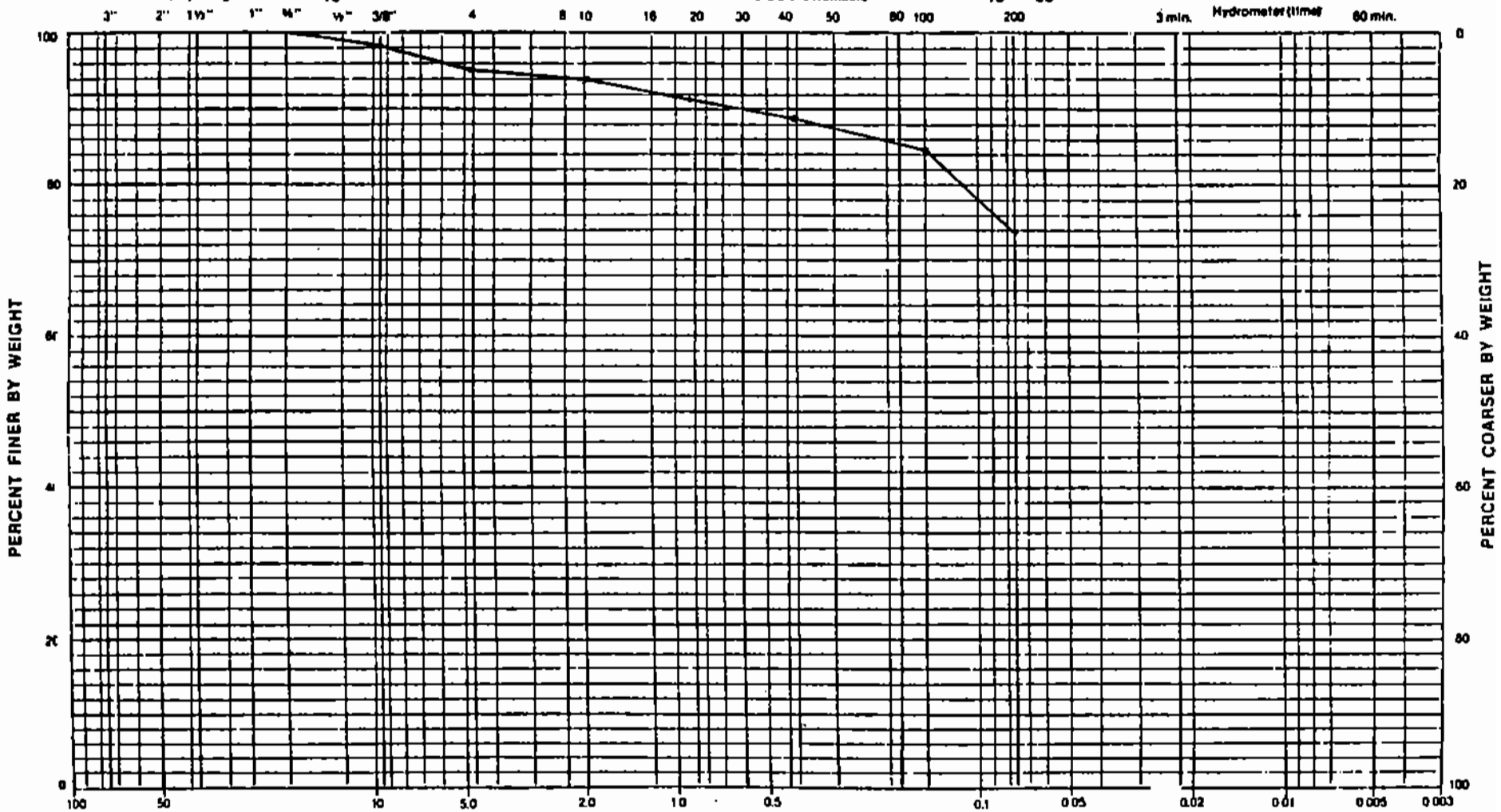
Location: Little Cherry Site, USB-5, SPT-3, 20.0'-21.5' Job No. 88-152

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

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

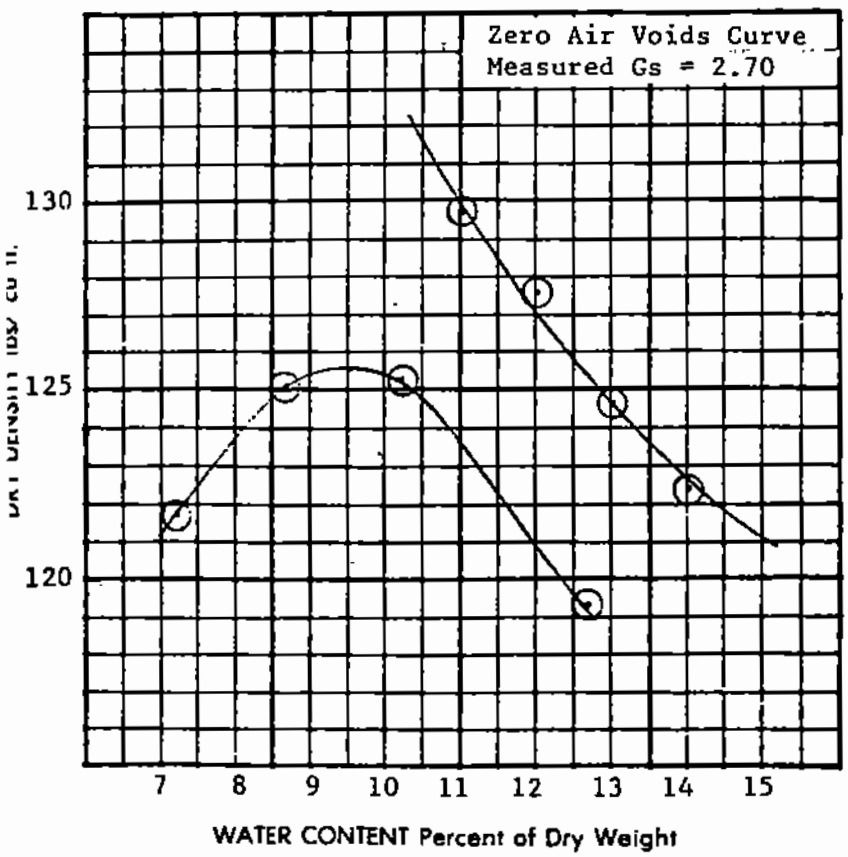
DATE: 10/07/88
JOB NUMBER: 88-152
SHEET: 1 OF 1
INVOICE NO.: 63946
LAB NO.: 32287
DATE SAMPLED: N/R
DATE RECEIVED: August 1988
SAMPLED BY: Morrison-Knudsen

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:

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 Engineering Inc.
San Francisco, California

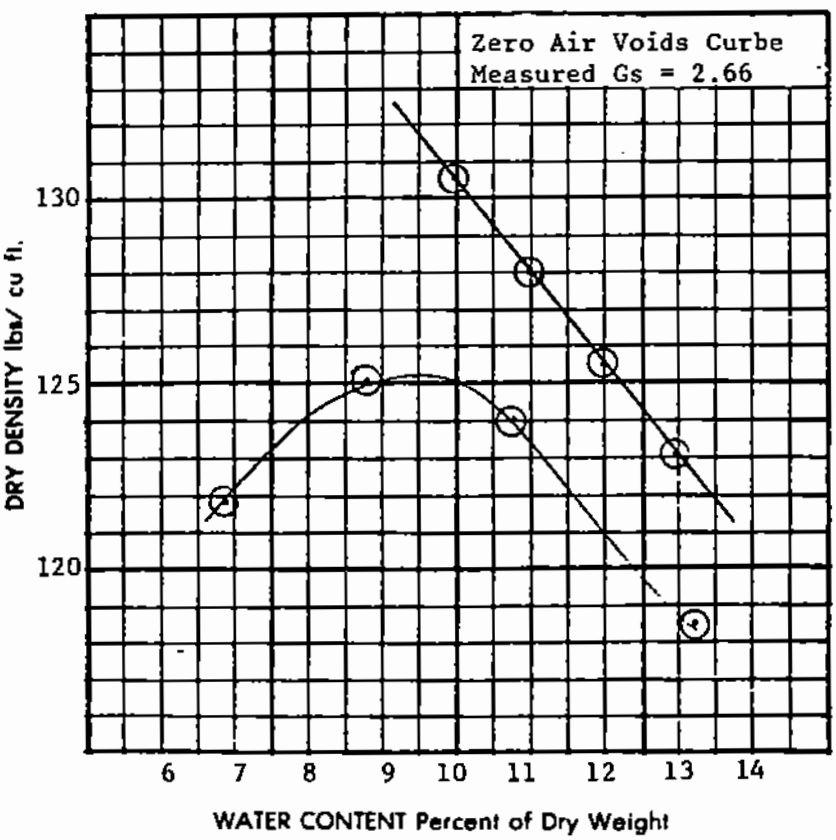
DATE: 10/07/88
JOB NUMBER: 88-152
SHEET: 1 OF 1
INVOICE NO.: 63946
LAB NO.: 32288
DATE SAMPLED: N/R
DATE RECEIVED: August 1988
SAMPLED BY: Morrison-Knudsen

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

DISTRIBUTION:

POORMAN SITE

Northern
Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine — Sample No. 32295

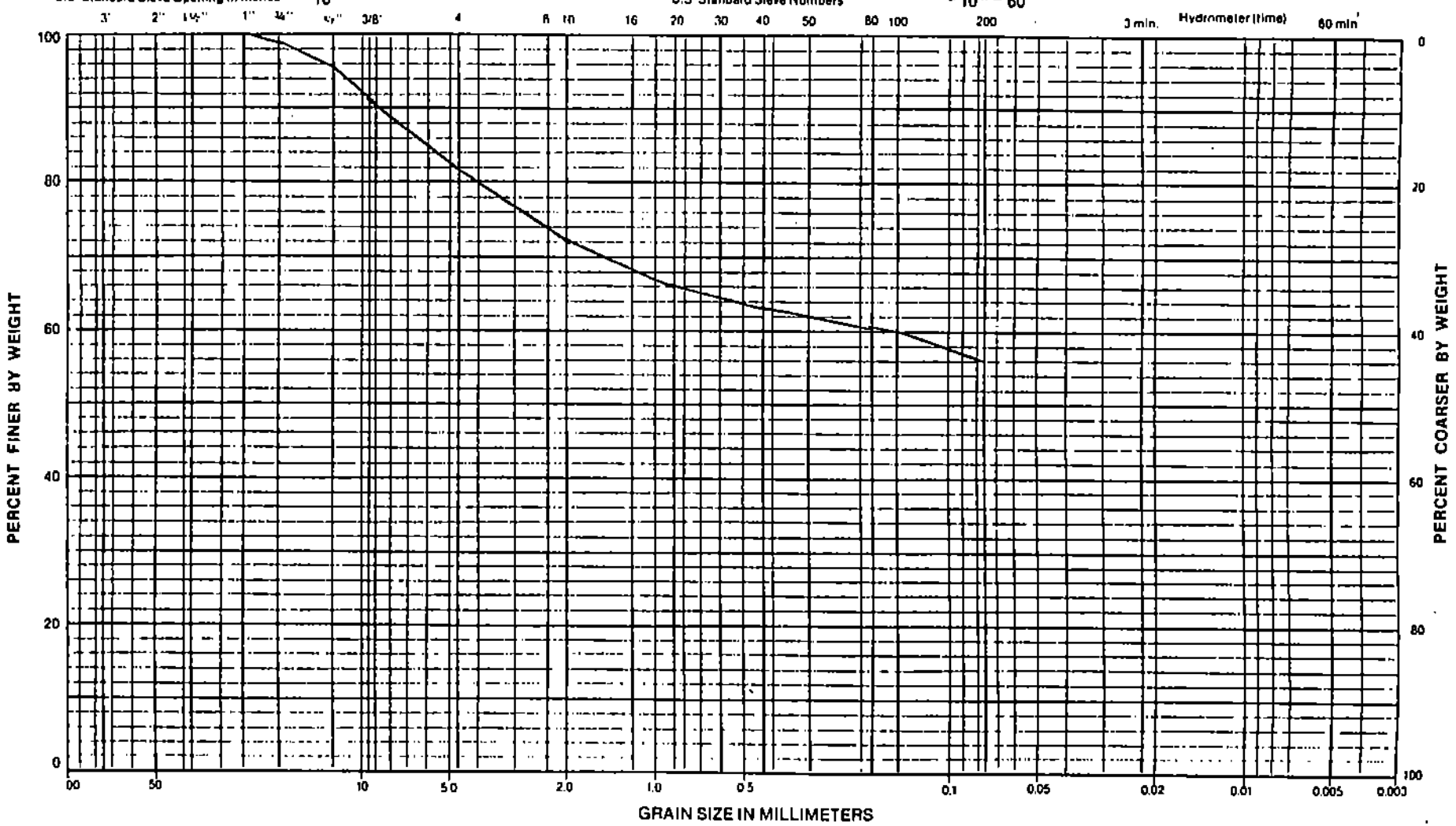
Location: Poorman Site TP-202, S-1, 8.0'-10.0' — Job No. 88-152

Classification Sandy Lean CLAY w/Gravel (CL) — Date August 1988

Moisture Content 8 % — Liquid Limit 38 % — Plasticity Index 17 %

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. 32296

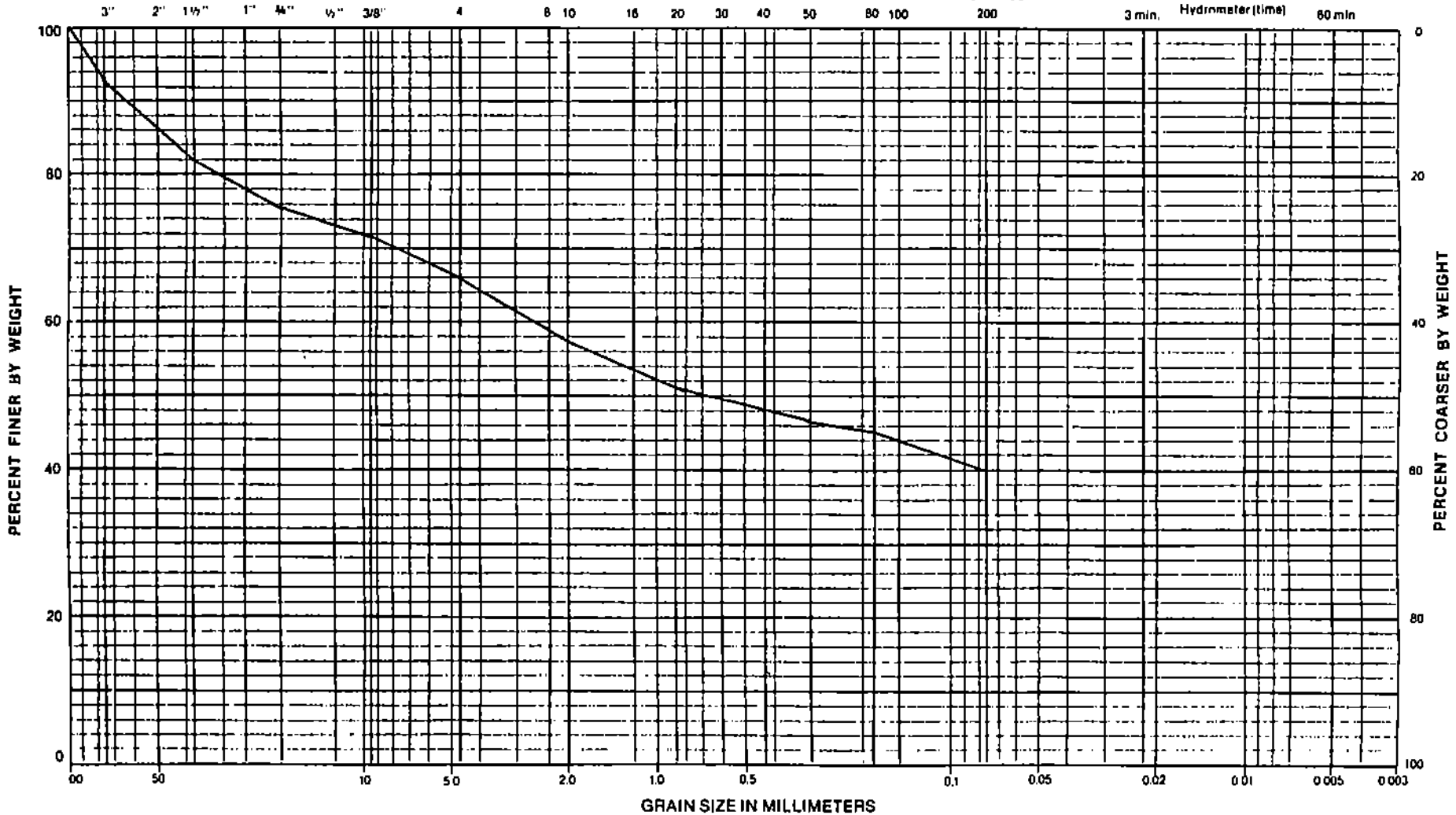
Location: Poorman Site TP-203, 10.0' - 14.0', S-2 — Job No. 88-152

Classification Clayey GRAVEL with Sand — Date October 1988

Moisture Content -- % — Liquid Limit 30 % — Plasticity Index 12 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Poorman Site

Sample No. 32297

Location: TP-204, S-1, 9.0'-10.0'

Job No. 88-152

Classification Lean CLAY w/Sand (CL)

Date August 1988

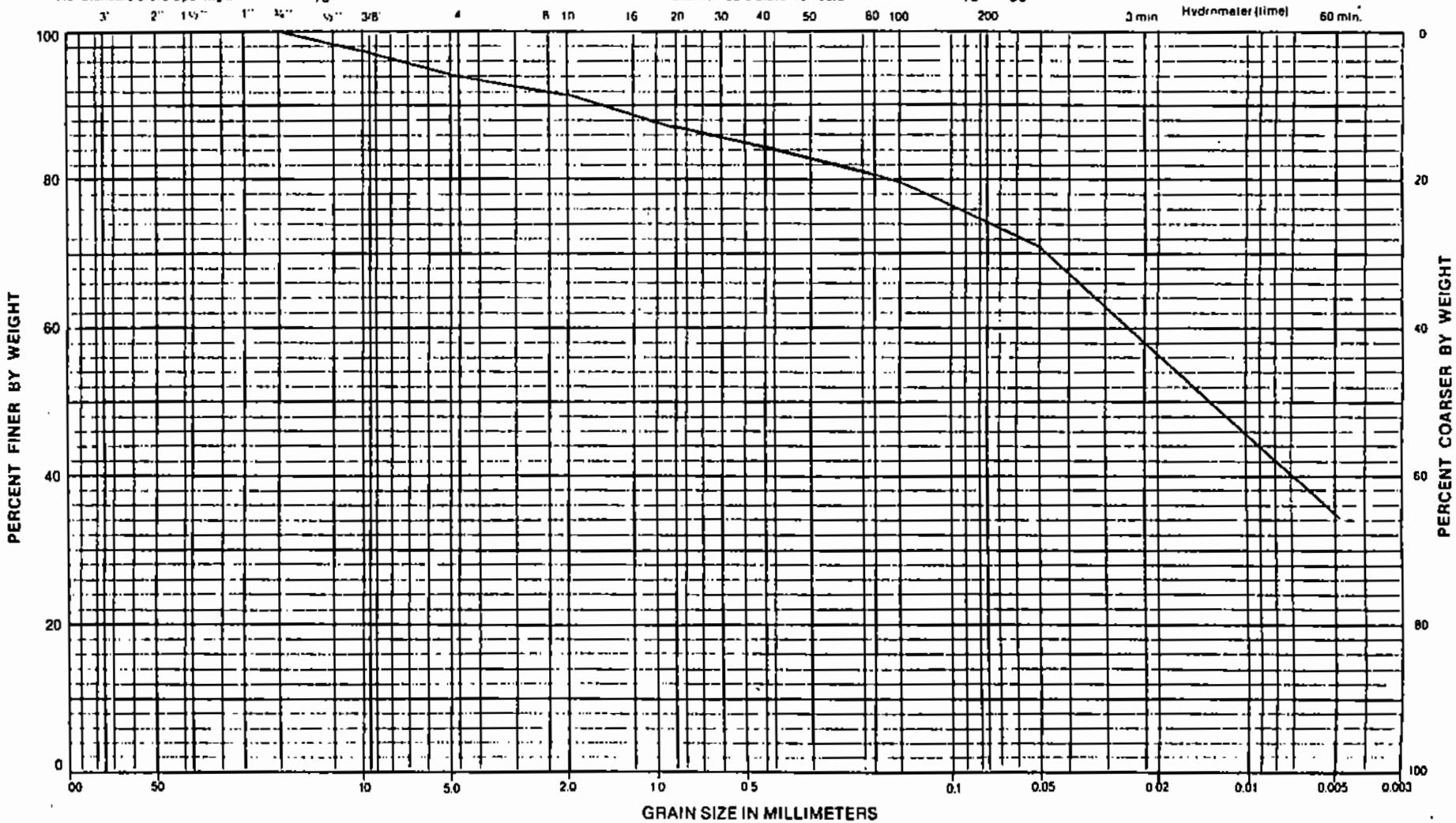
Moisture Content 5 %

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
Poorman Site

Location: TP-206, S-1, 7.0'-9.0'

Sample No. 32299

Job No. 88-152

Classification Silty Clayey GRAVEL w/Sand (GC-GM)

Date August 1988

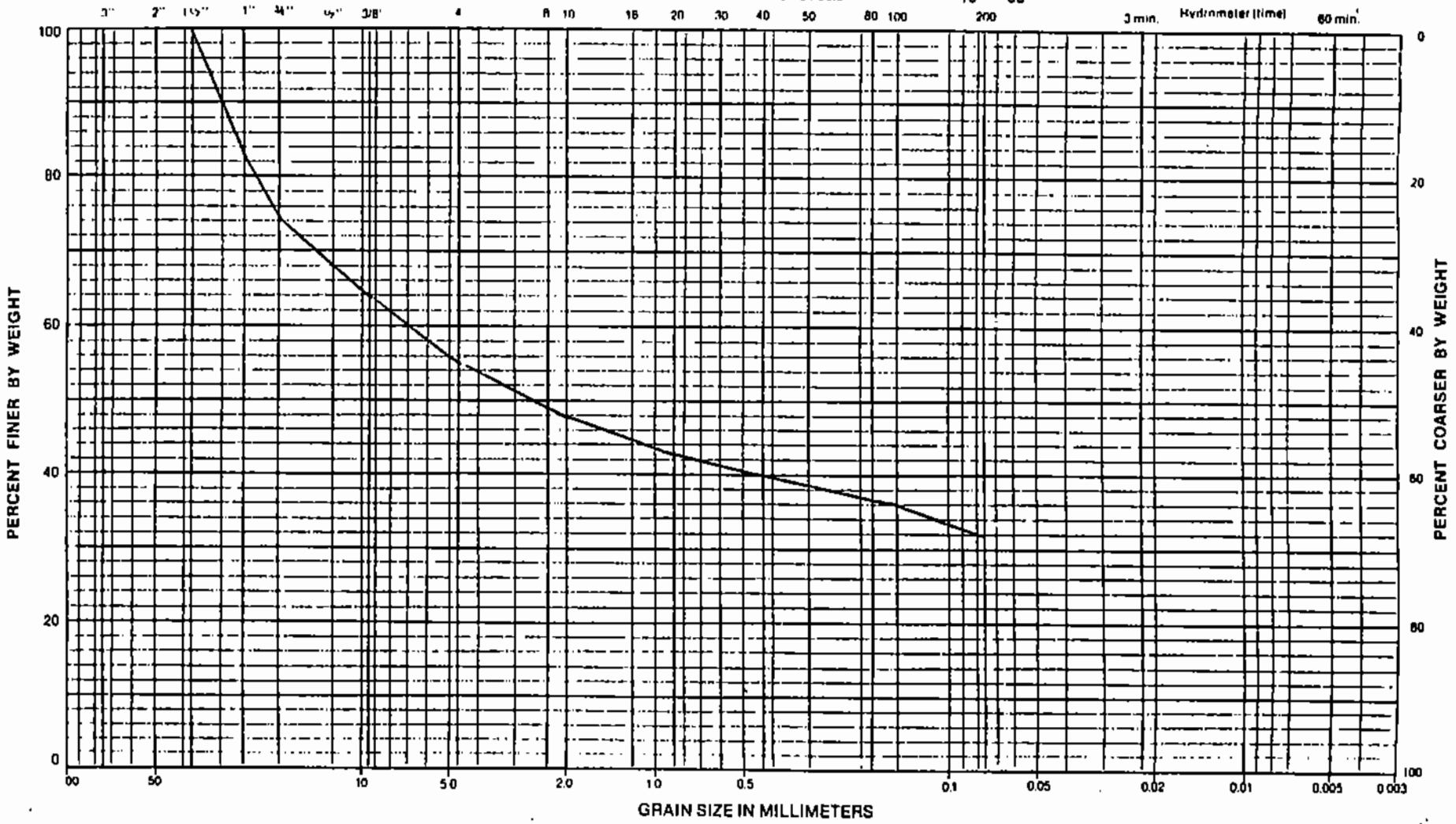
Moisture Content -- %

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
Poorman Site

Sample No. 32304

Location: TP-208, S-1, 9.0'-11.0'

Job No. 88-152

Classification Sandy Silty CLAY (CL-ML)

Date August 1988

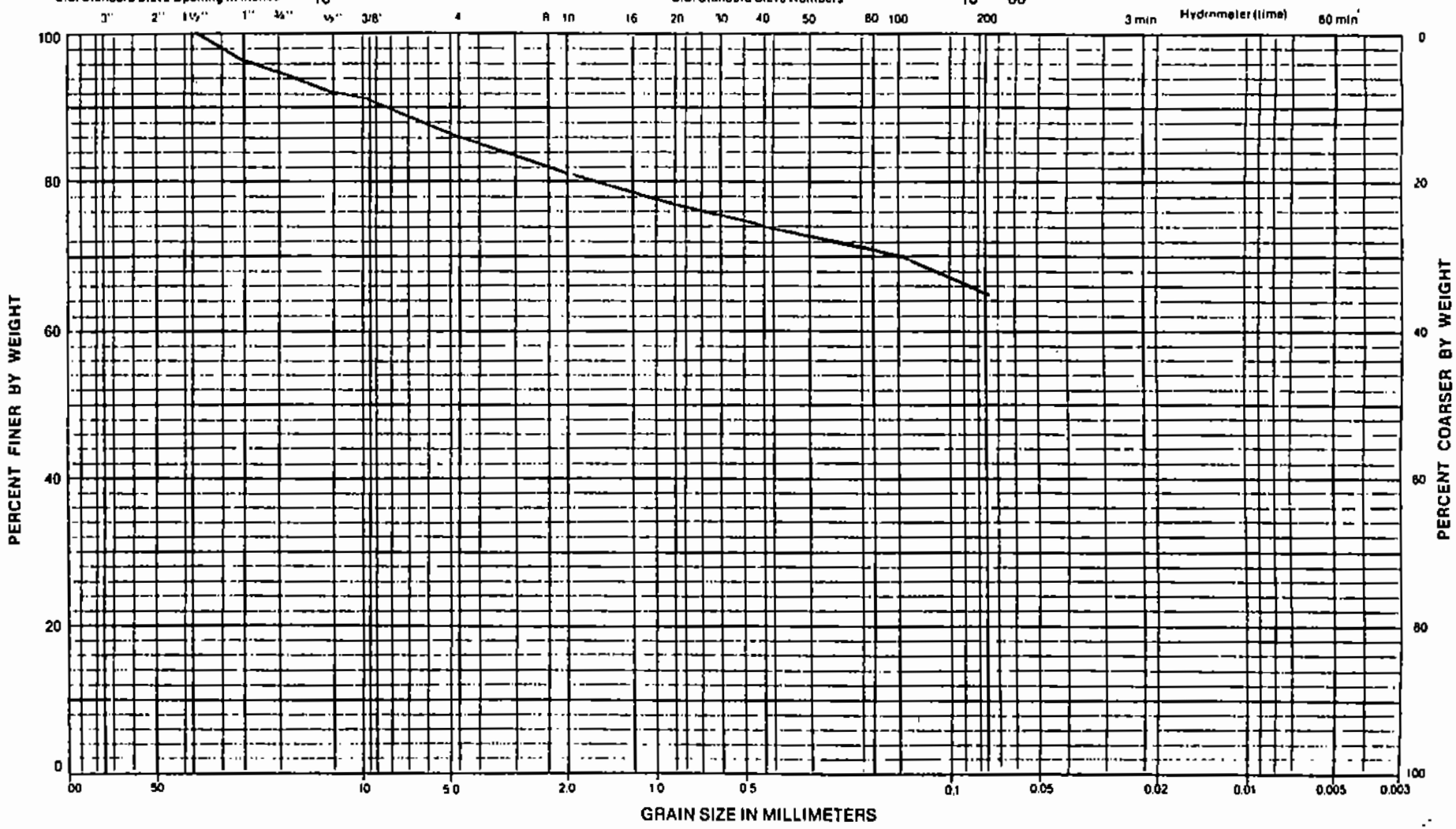
Moisture Content 2 %

Liquid Limit 23 %

Plasticity Index 7 %

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
Poorman Site

Sample No. 32306

Location: TP-210, S-1, 11.0'-13.0'

Job No. 88-152

Classification Silty CLAY w/Sand (CL)

Date August 1988

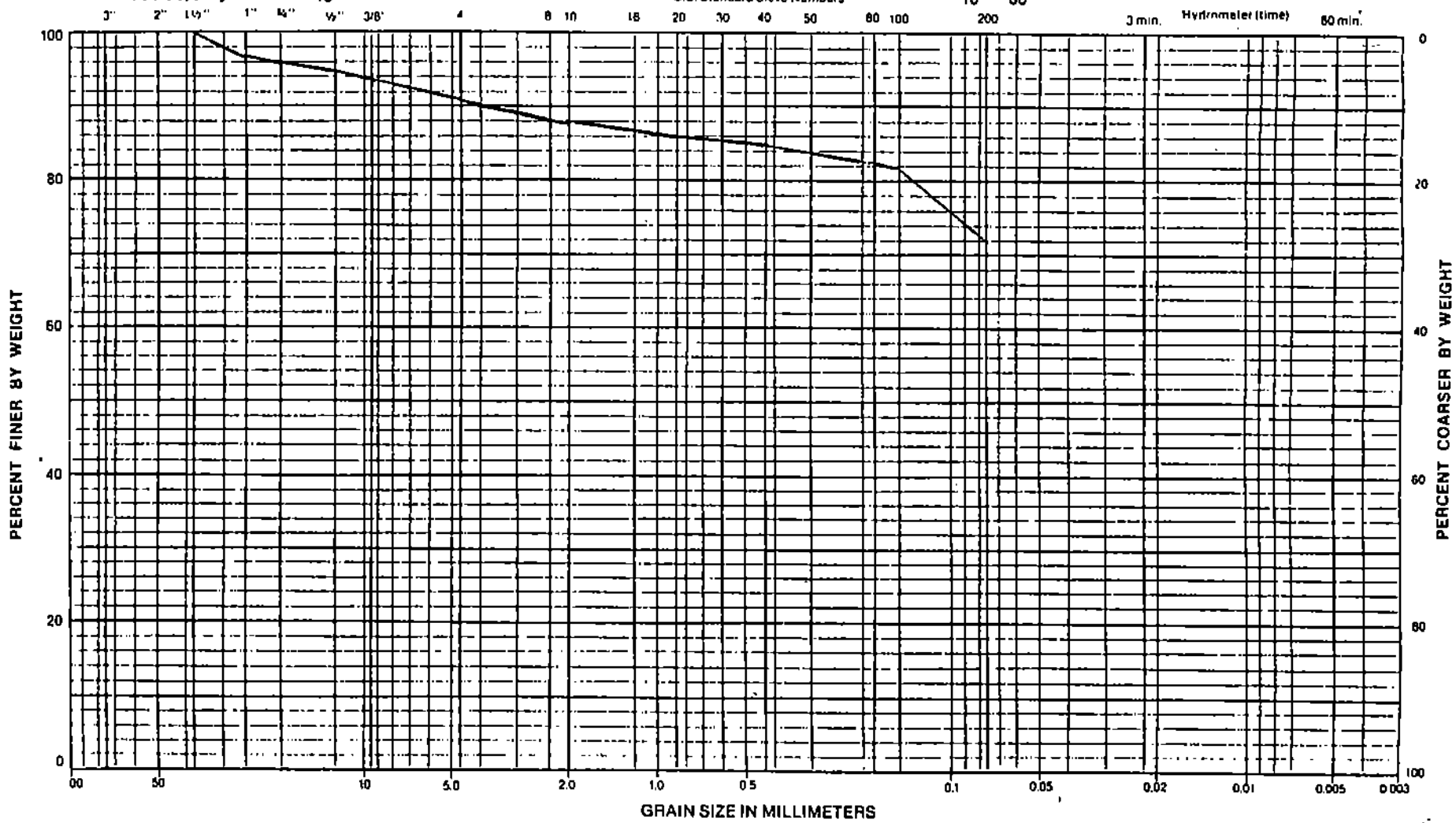
Moisture Content 7 %

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
Poorman Site

Sample No. 32342

Location: USA-3, SPT-2, 8.3'-9.7'

Job No. 88-152

Classification Sandy Lean CLAY w/Gravel (CL)

Date August 1988

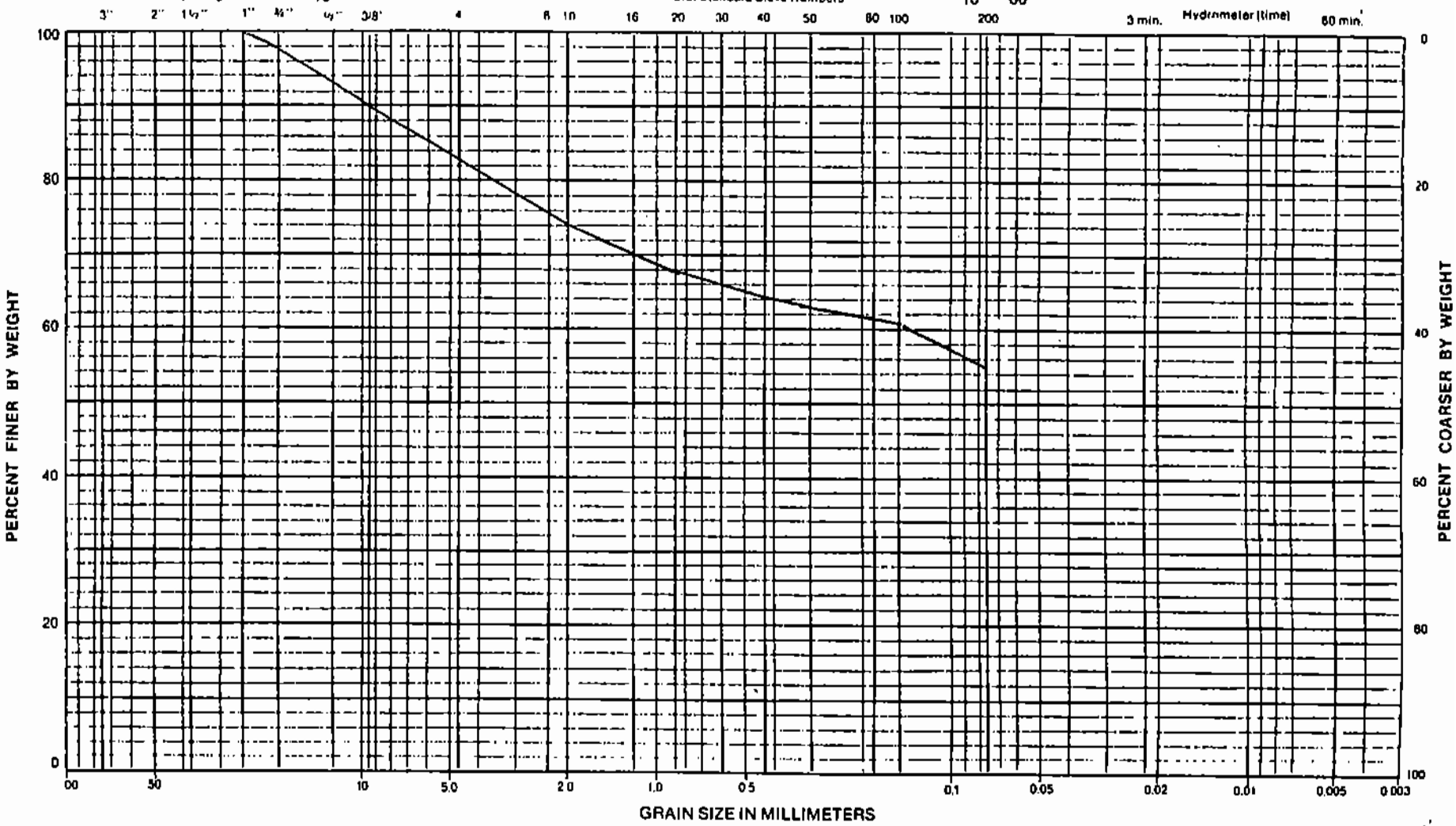
Moisture Content 13 %

Liquid Limit 26 %

Plasticity Index 9 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Poorman Site

Location: USA-3, SPT-4, 20.0'-21.5'

Classification: Sandy Lean CLAY w/Gravel (CL)

Sample No. 32344

Job No. 88-152

Date August 1988

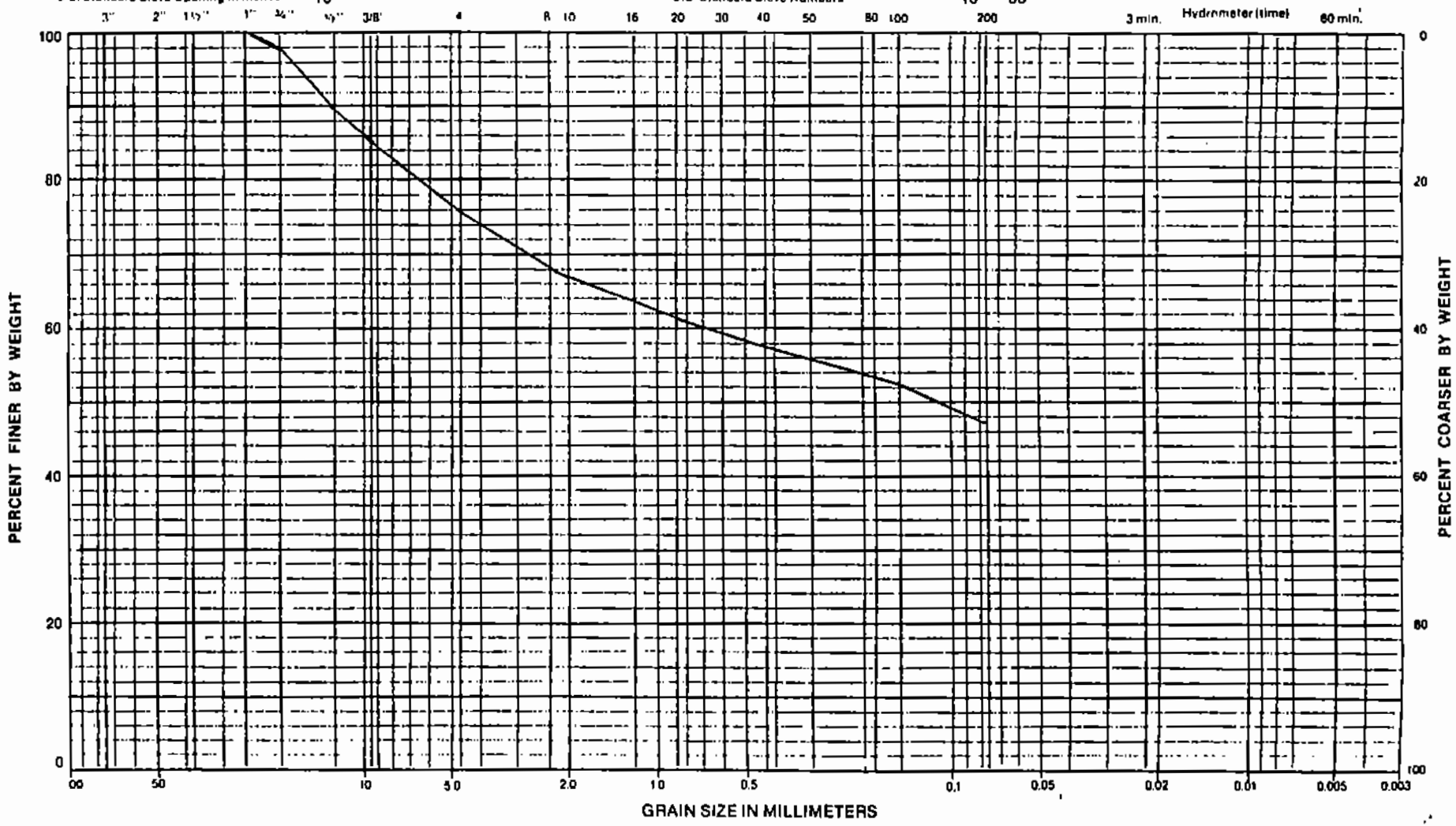
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



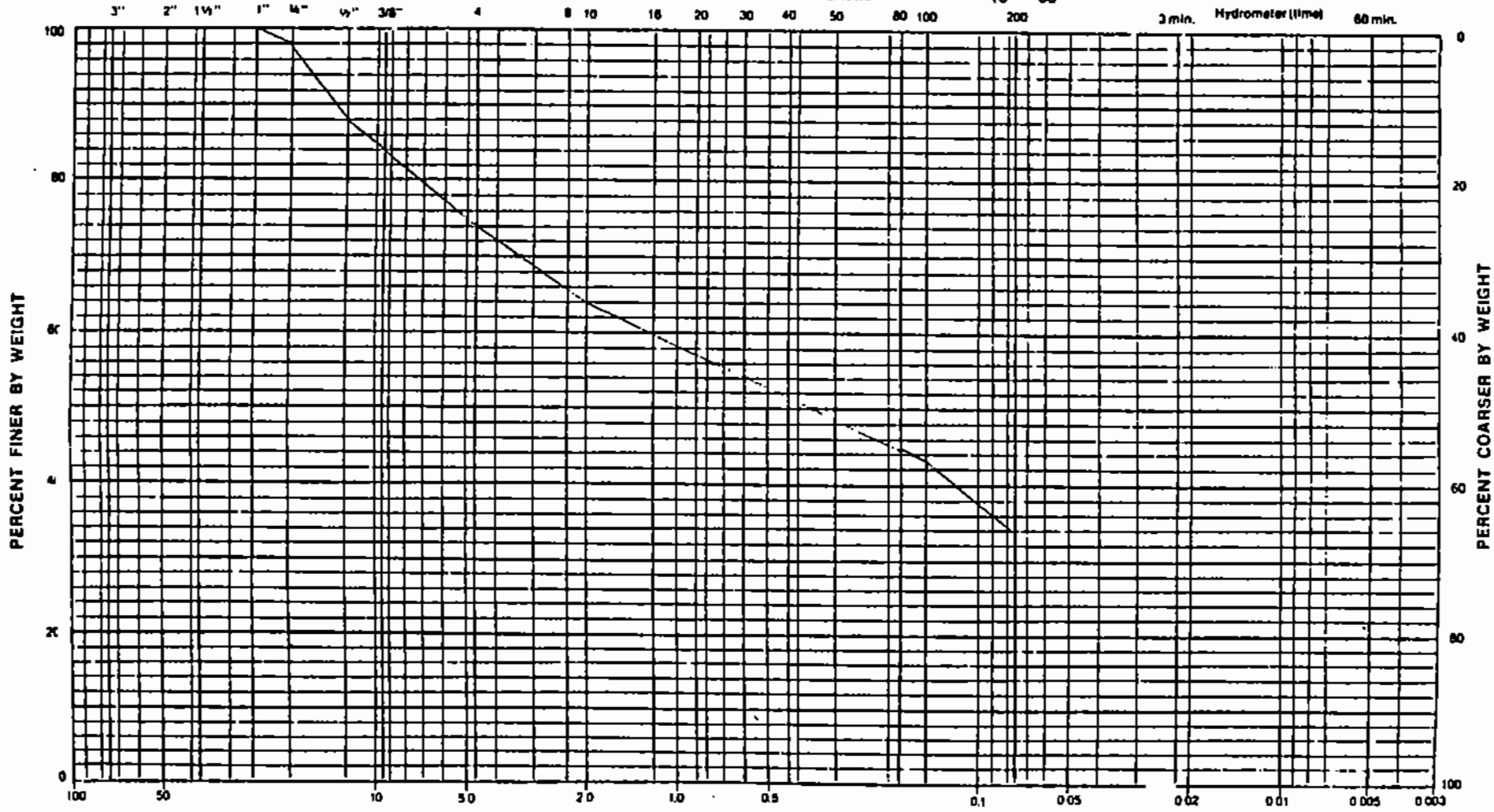
Northern
Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Sample No. 32964
Location: Poorman Site, USA-4, 15.0'-16.5', SPT 3
Job No. 88-152
Classification: Silty SAND with Gravel
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

Location: Poorman Site, USA-4, 25.0'-26.5', SPT-5

Classification: Clayey SAND

Moisture Content: -- %

Sample No.: 32965

Job No.: 88-152

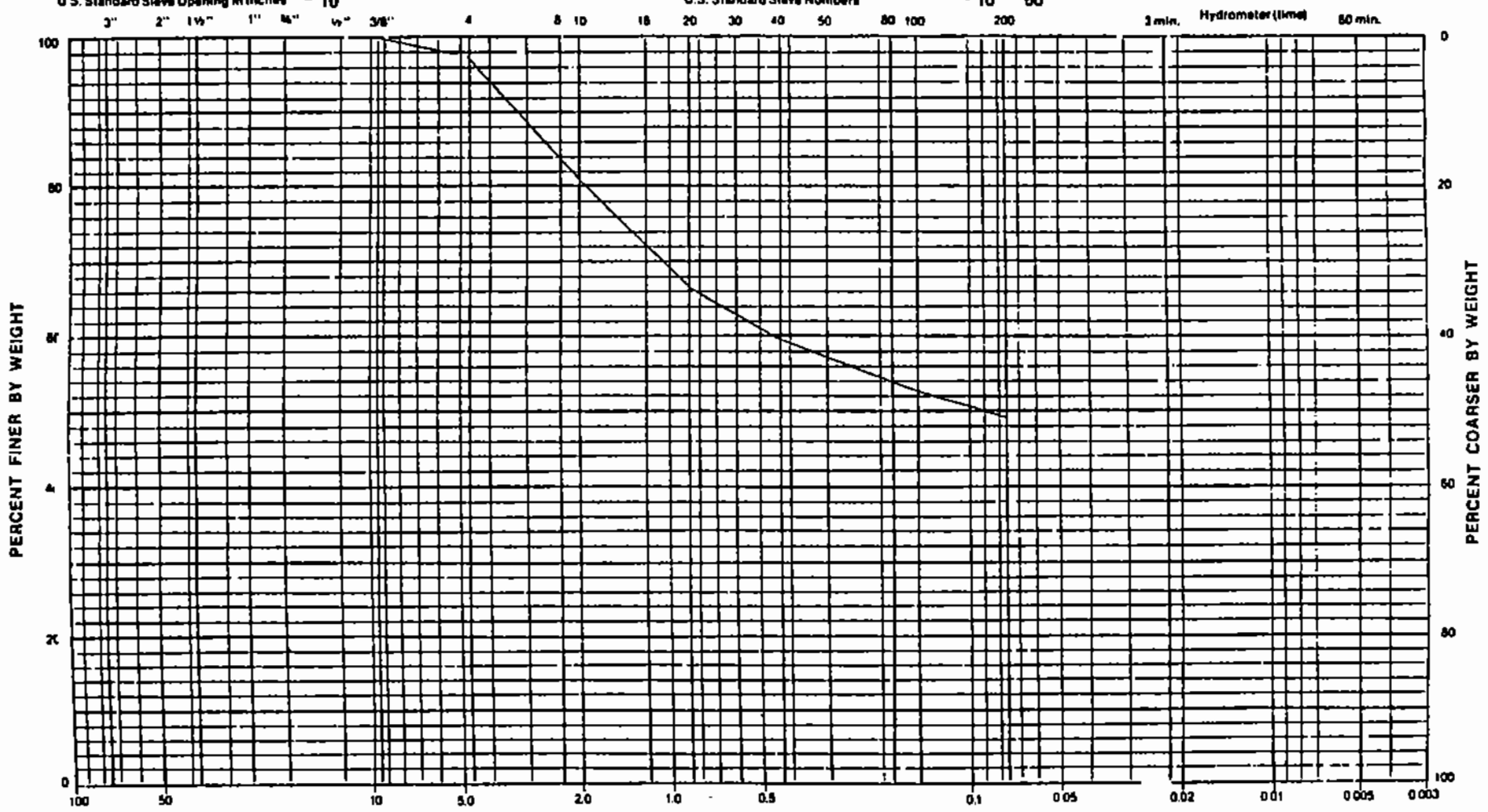
Date: October 1988

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

Chen-Northern, Inc.

528 Smelter Avenue
P.O. Box 951
Great Falls, MT 59403
(406) 453-1641
FAX (406) 727-2070

MOISTURE-DENSITY RELATIONSHIP DATA SHEET

REPORT TO: Morrison-Knudsen Engineers, Inc.
180 Howard Street
San Francisco, California

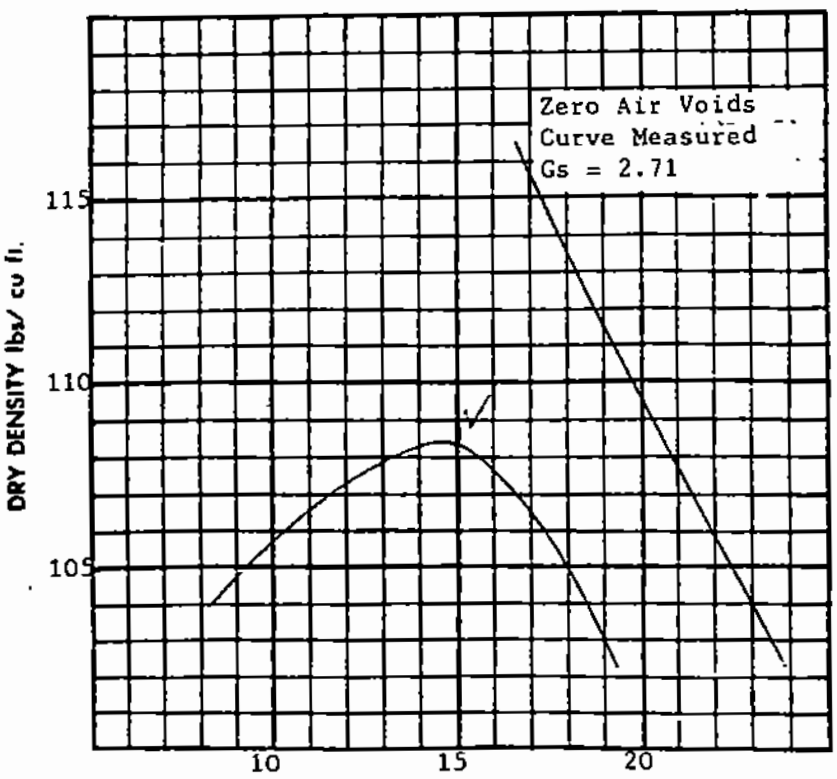
DATE: 9/22/88
JOB NUMBER: 88-152-1
SHEET: 1 OF 1
INVOICE NO.:
LAB NO.: 32295
DATE SAMPLED: N/R
DATE RECEIVED: 8/08/88
SAMPLED BY: M-K

PROJECT: Montana Silver Venture Mine
CONTRACTOR: Poorman Site
SAMPLE LOCATION: TP-202, 8.0'-10.0'
S-1
MATERIAL USE:

MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.

MOISTURE-DENSITY RELATIONSHIP



Visual CLASSIFICATION
Sandy Lean CLAY

Specific Gravity: Fine Aggregate 2.7
Specific Gravity: Coarse Aggrega

TEST PROCEDURE: ASTM D698, Method A
MAX. DENSITY: 108.5
OPT. MOIST.: 14.6
RAMMER TYPE: 5.5
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

REMARKS:

DISTRIBUTION:

Reviewed By: _____

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

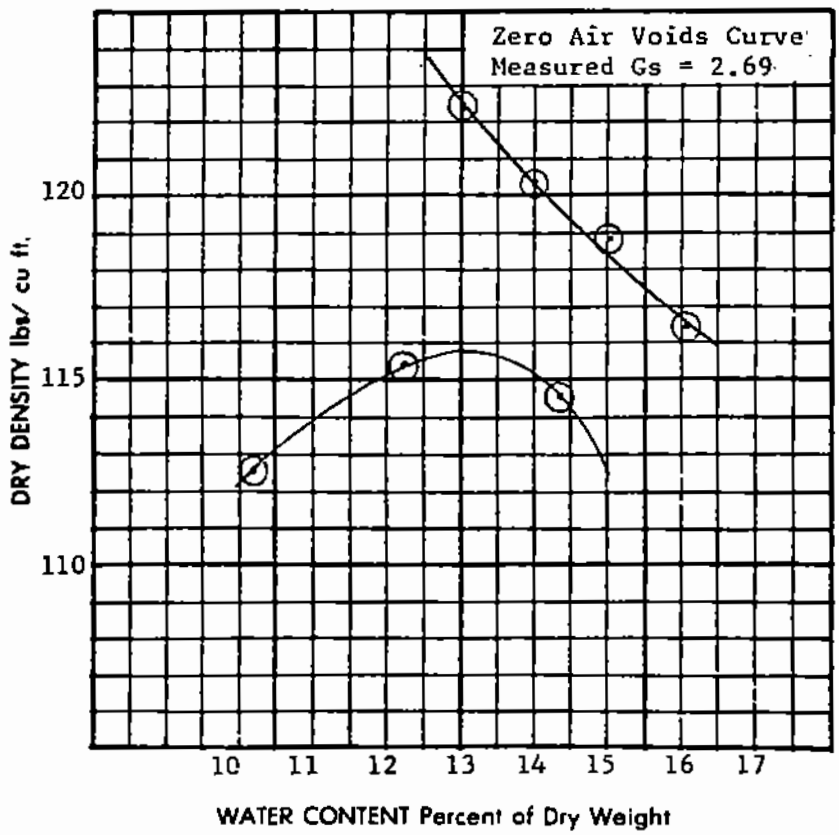
DATE: 10/07/88
JOB NUMBER: 88-152
SHEET: 1 OF 1
INVOICE NO.: 63946
LAB NO.: 32296
DATE SAMPLED: N/R
DATE RECEIVED: August 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Poorman Site
SAMPLE LOCATION: TP-203, 10.0'-14.0', S-2

MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
N/A		

MOISTURE-DENSITY RELATIONSHIP



VISUAL CLASSIFICATION
Clayey GRAVEL with Sand
SPECIFIC GRAVITY: Fine aggregate-2.66
SPECIFIC GRAVITY: Coarse aggregate-2

TEST PROCEDURE ASTM D698, Method D
MAX. DENSITY: 115.8
OPT. MOIST.: 12.7
RAMMER TYPE: 5.5
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

DISTRIBUTION:

RAMSEY SITE

Northern Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Ramsey Site

Location: TP-302, S-1, 6.0'-8.0'

Classification Silty Clayey SAND w/Gravel (SC-SM)

Sample No. 32308

Job No. 88-152

Date August 1988

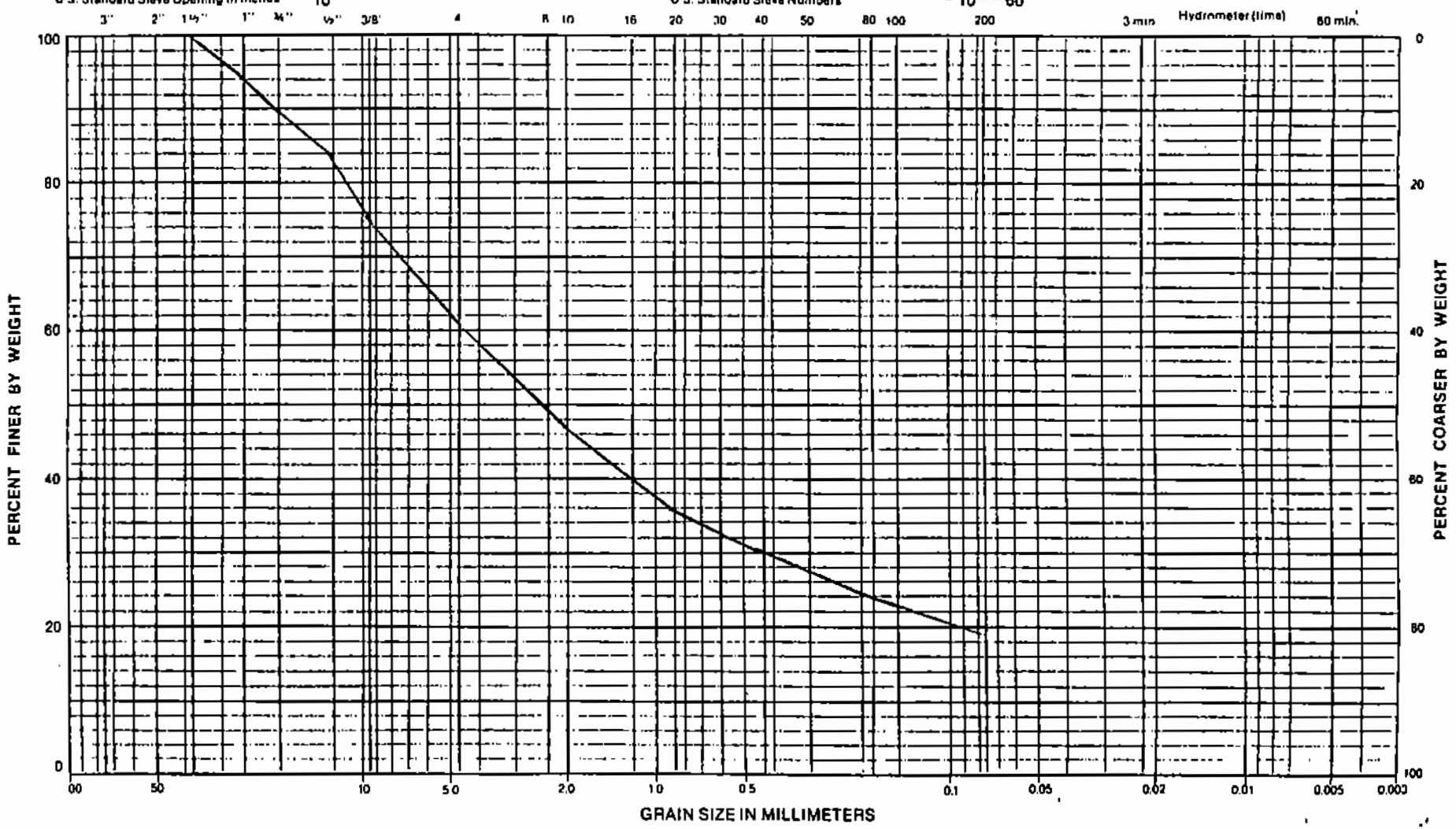
Moisture Content -- %

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
Ramsey Site

Location: TP-304, S-1, 8.1'-10.1'

Classification Silty Clayey GRAVEL w/Sand (GC-GM)

Sample No. 32310

Job No. 88-152

Date August 1988

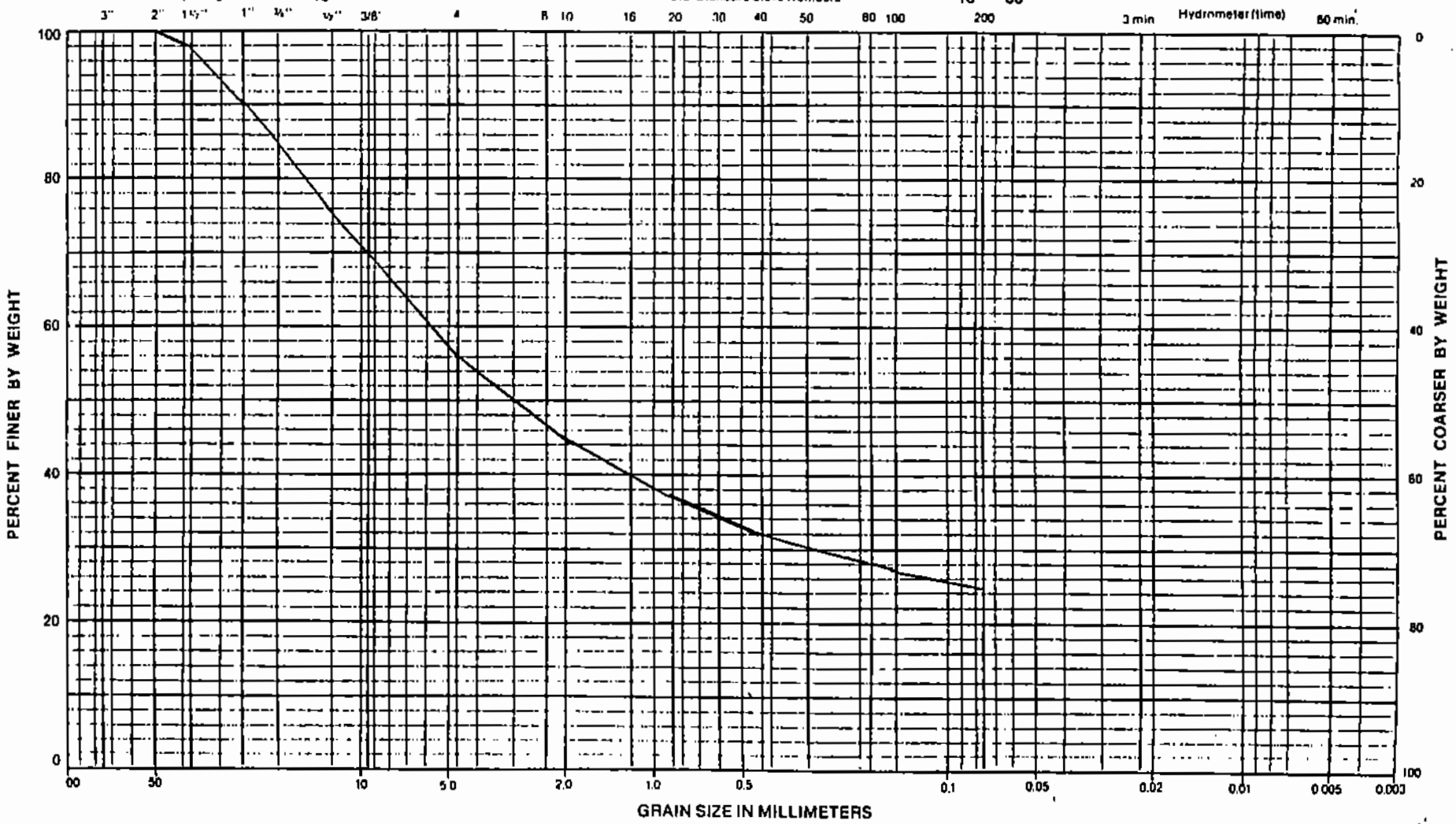
Moisture Content 13 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



LIBBY SITE

Northern
Engineering and Testing, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Libby Site

Sample No. 32312

Location: TP-401, S-1, 11.0'-12.0'

Job No. 88-152

Classification Silty Clayey GRAVEL w/Sand (GC-GM)

Date August 1988

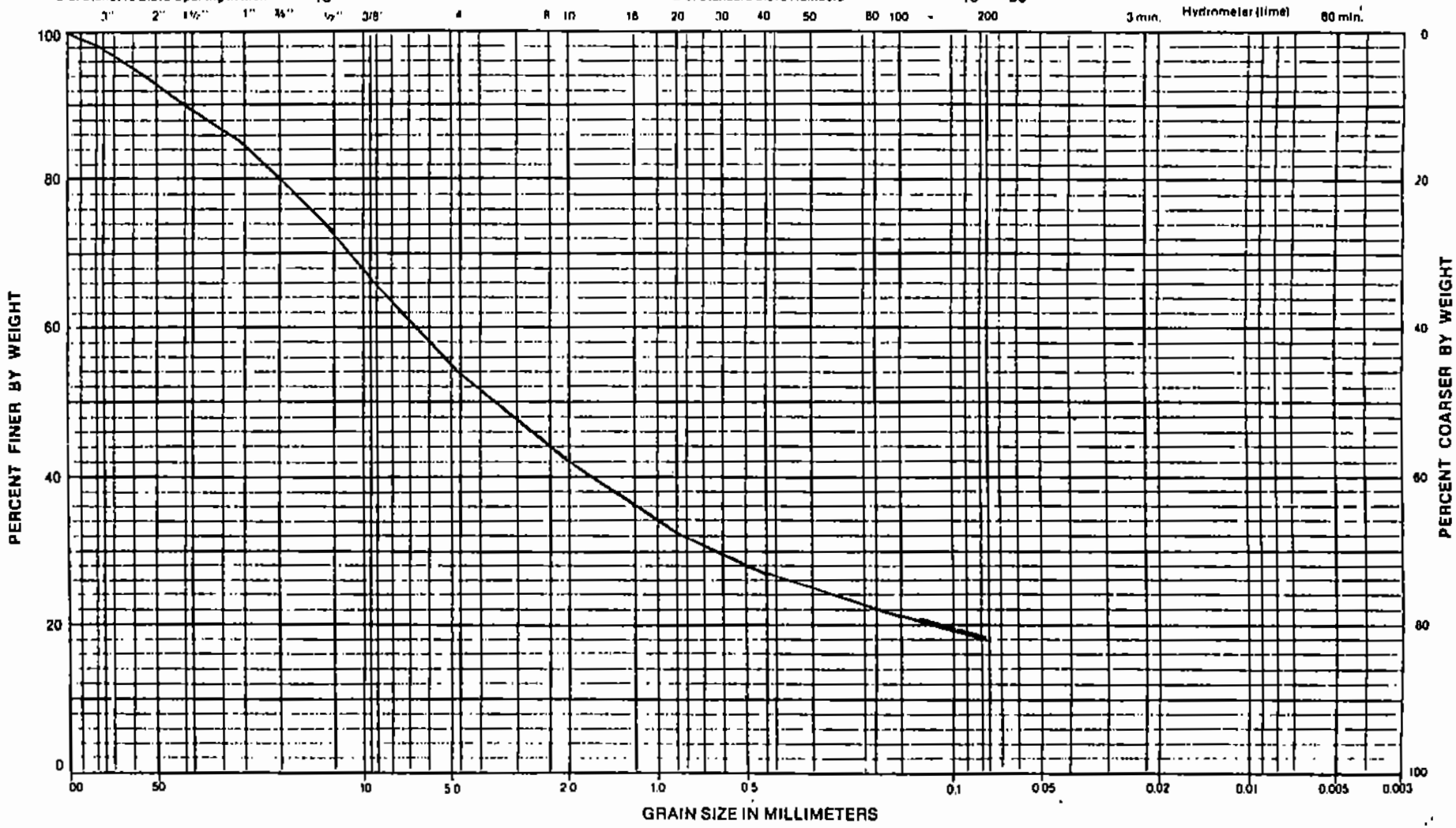
Moisture Content 8 %

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
Libby Site

Location: TP-403, S-1, 9.0'-10.0'

Classification Silty Clayey GRAVEL W/Sand (GC-GM)

Sample No. 32314

Job No. 88-152

Date August 1988

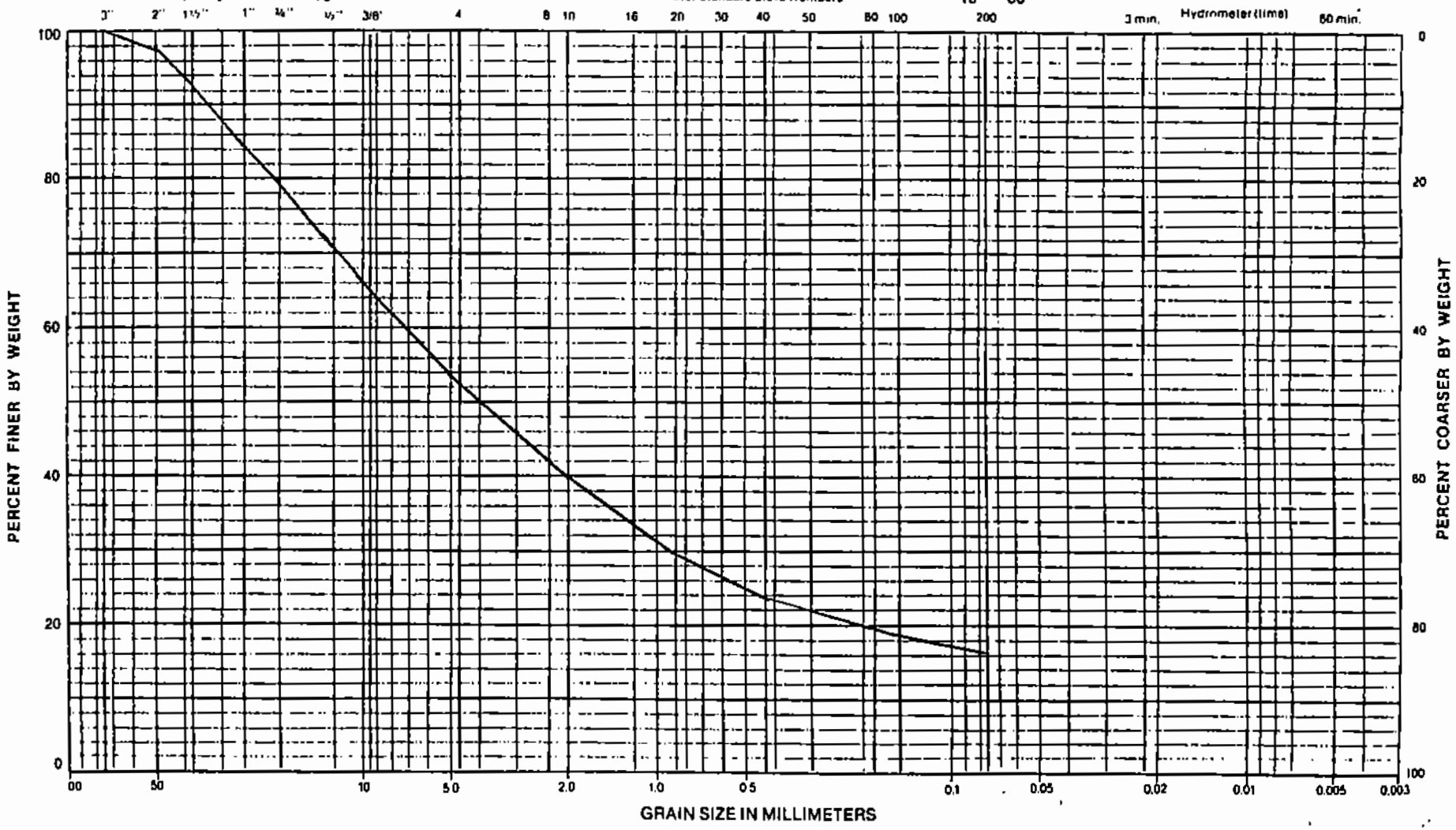
Moisture Content 10 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



MIDAS SITE

8021G

Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Sample No. 35028

Location: TP-503, S-2, 10.0' - 11.0'

Job No. 88-152-1

Classification SILT

Date December 1988

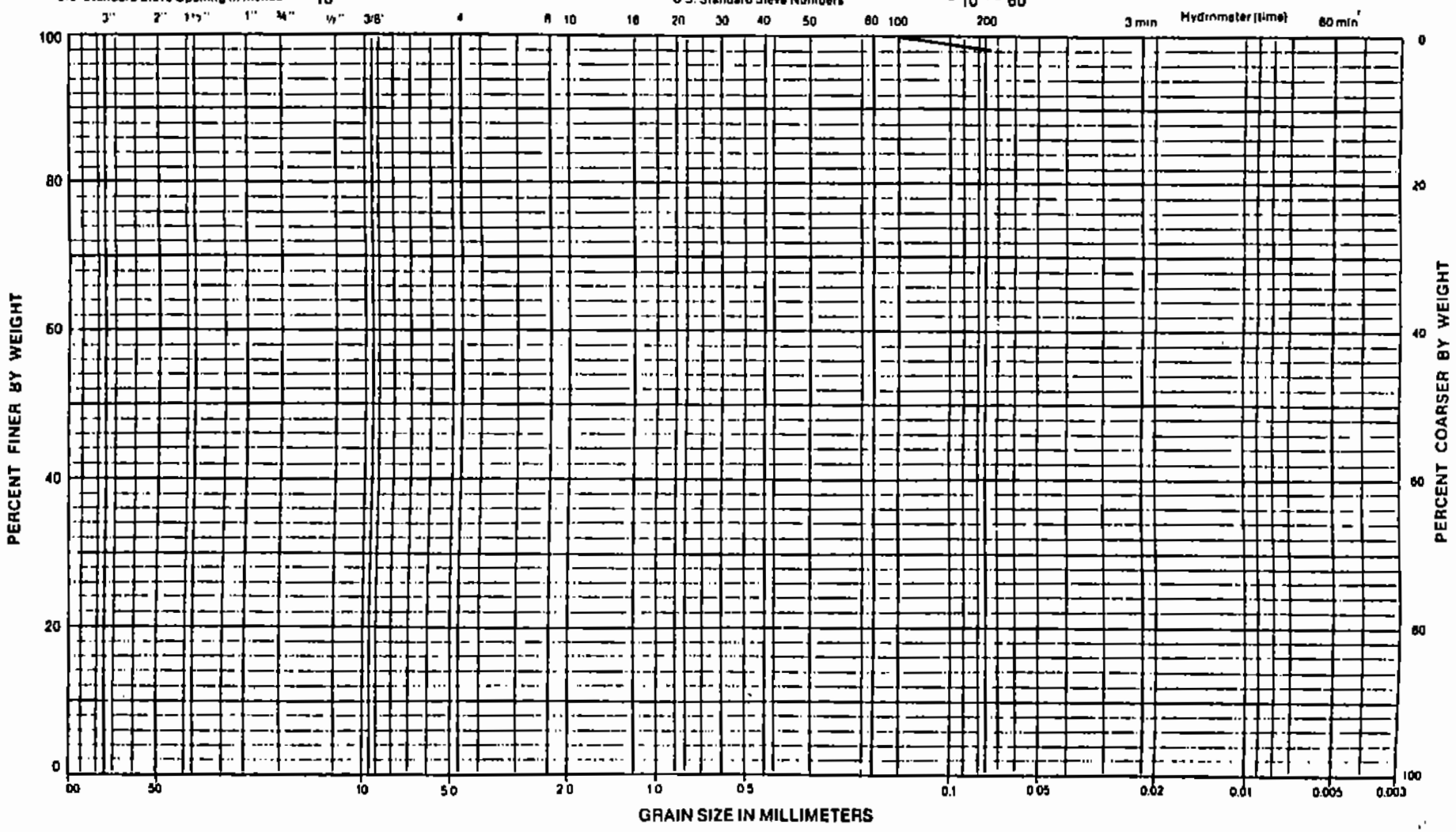
Moisture Content 25 %

Liquid Limit 23 %

Plasticity Index 3 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site
Location: TP-504, S-1, 7.0' - 8.0'

Sample No. 35029

Job No. 88-152-1

Classification Silty Clayey GRAVEL with Sand

Date December 1988

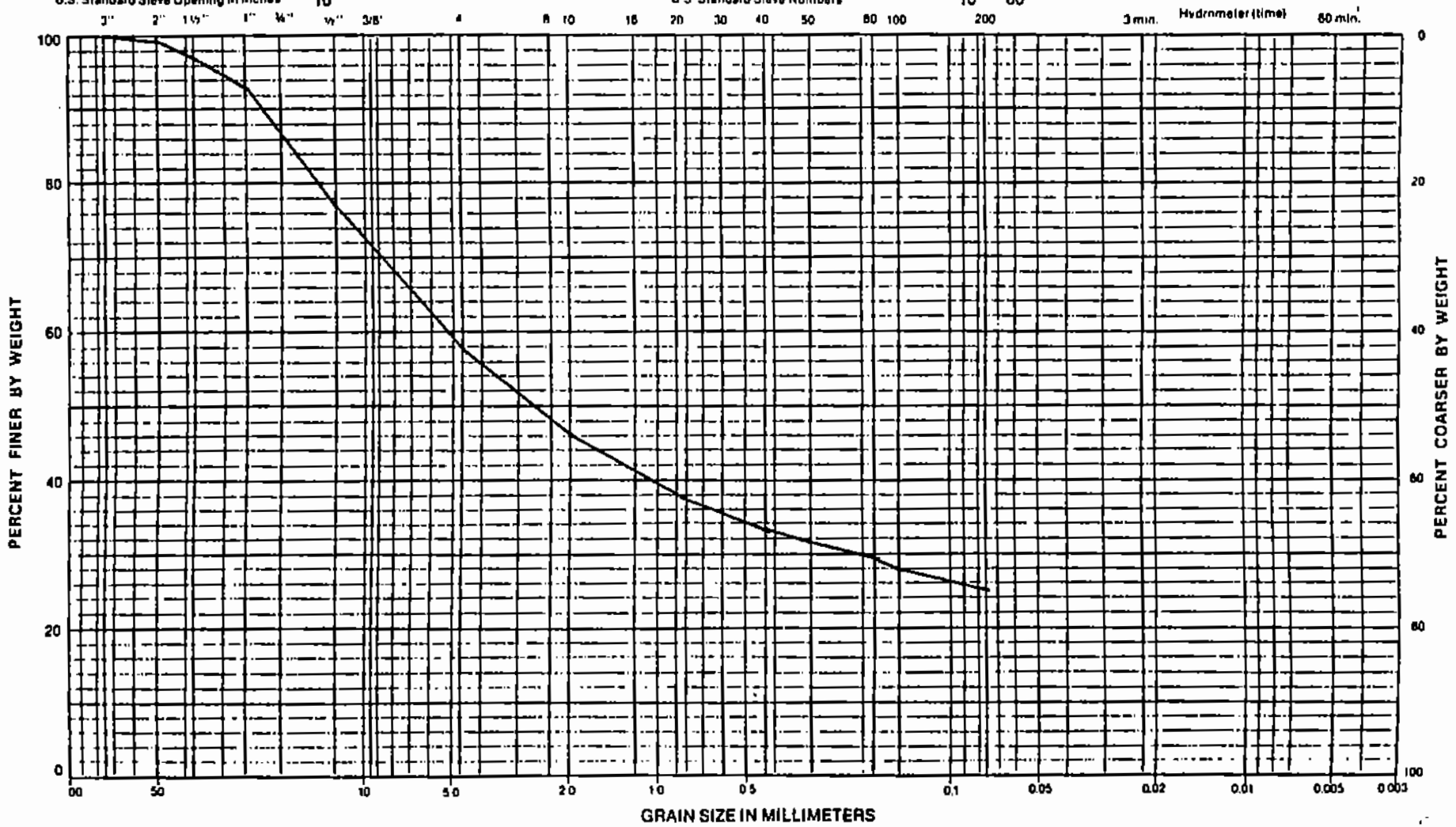
Moisture Content 10 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

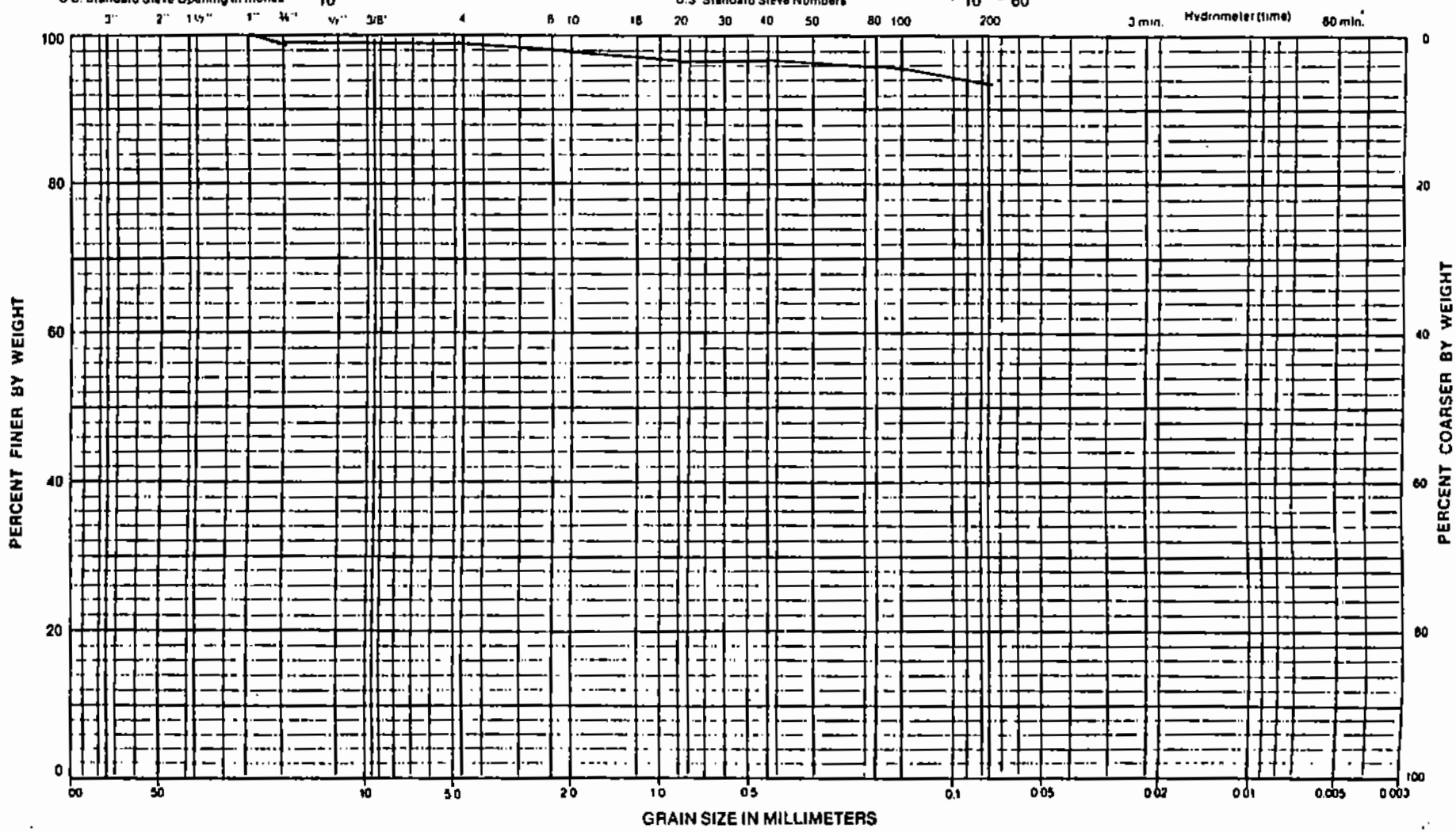
GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Location: Midas Creek Site, TP-505, S-1, 7.0' - 8.5'
Classification SILT
Moisture Content 23 %

Sample No. 35031
Job No. 88-152-1
Date December 1988
Liquid Limit -- %
Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Location: TP-506, S-1, 4.0' - 5.0'

Classification Sandy SILT

Sample No. 35032

Job No. 88-152-1

Date December 1988

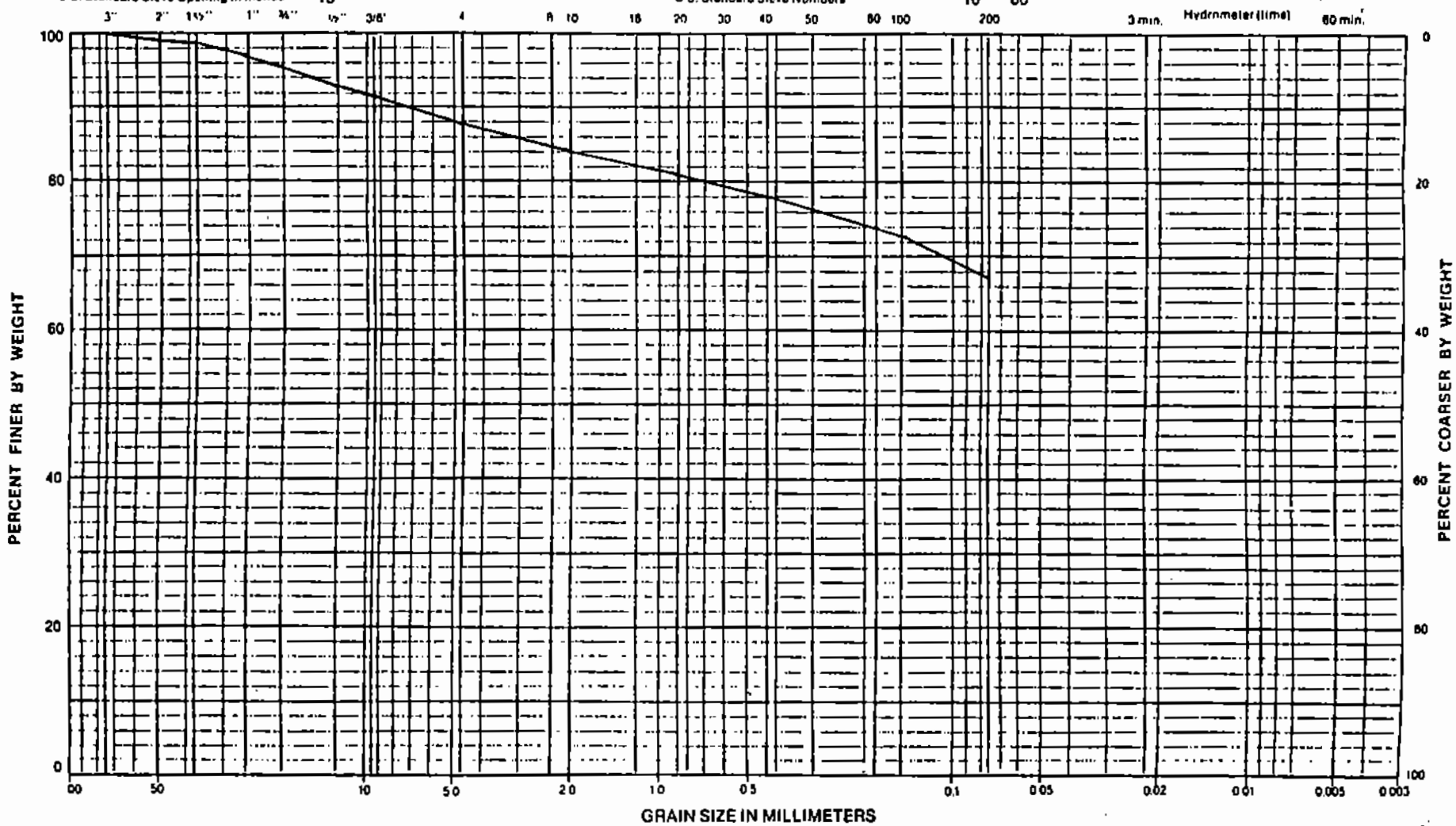
Moisture Content 12 %

Liquid Limit Granular %

Plasticity Index Non-Plastic %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site
Location: TP-506, S-2, 9.0' - 10.0'

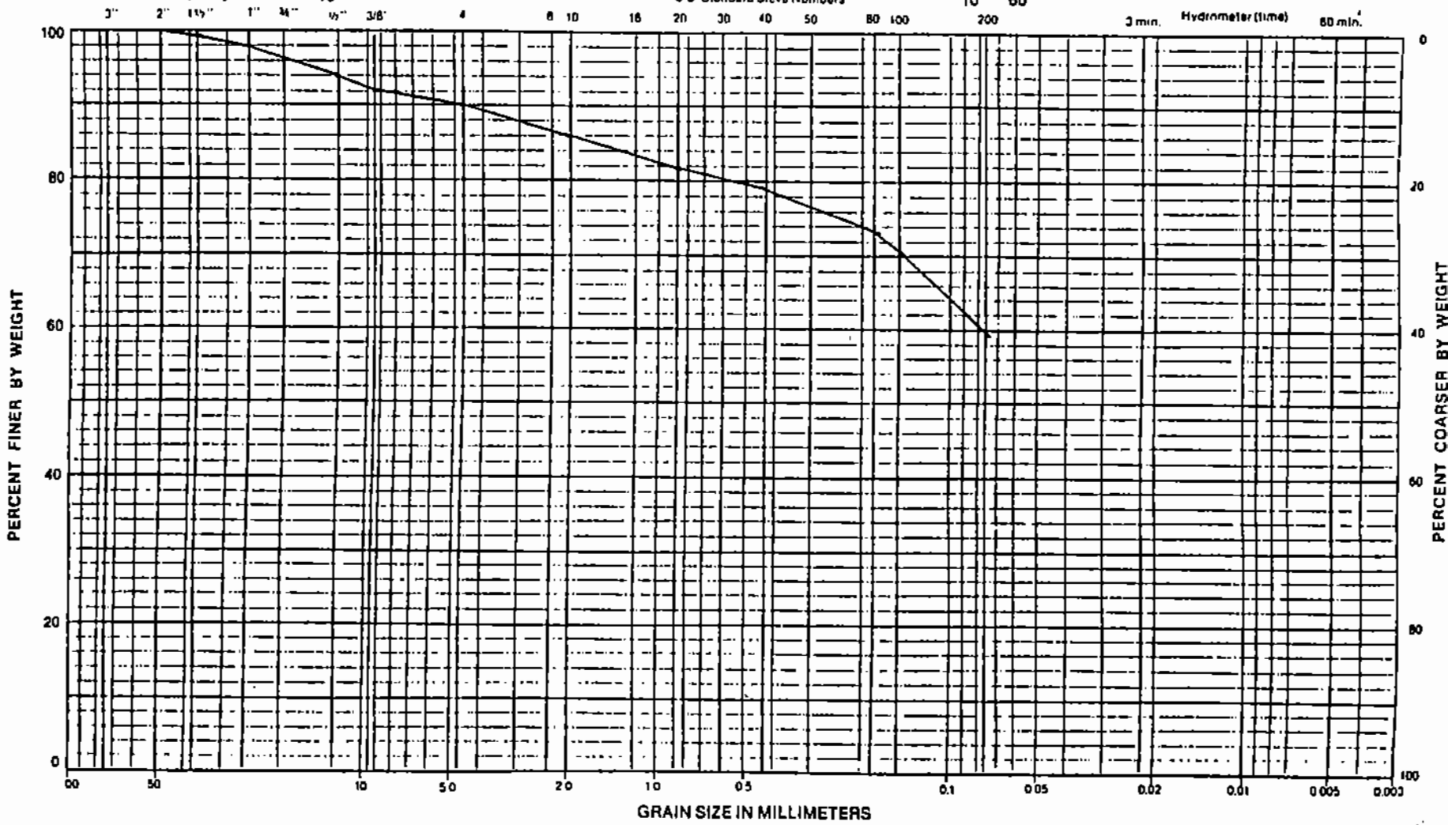
Sample No. 35033
Job No. 88-152-1
Date December 1988

Classification Sandy SILT

Moisture Content 16 %
Liquid Limit -- %
Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site
Location: TP-507, S-1, 5.0' - 6.0'

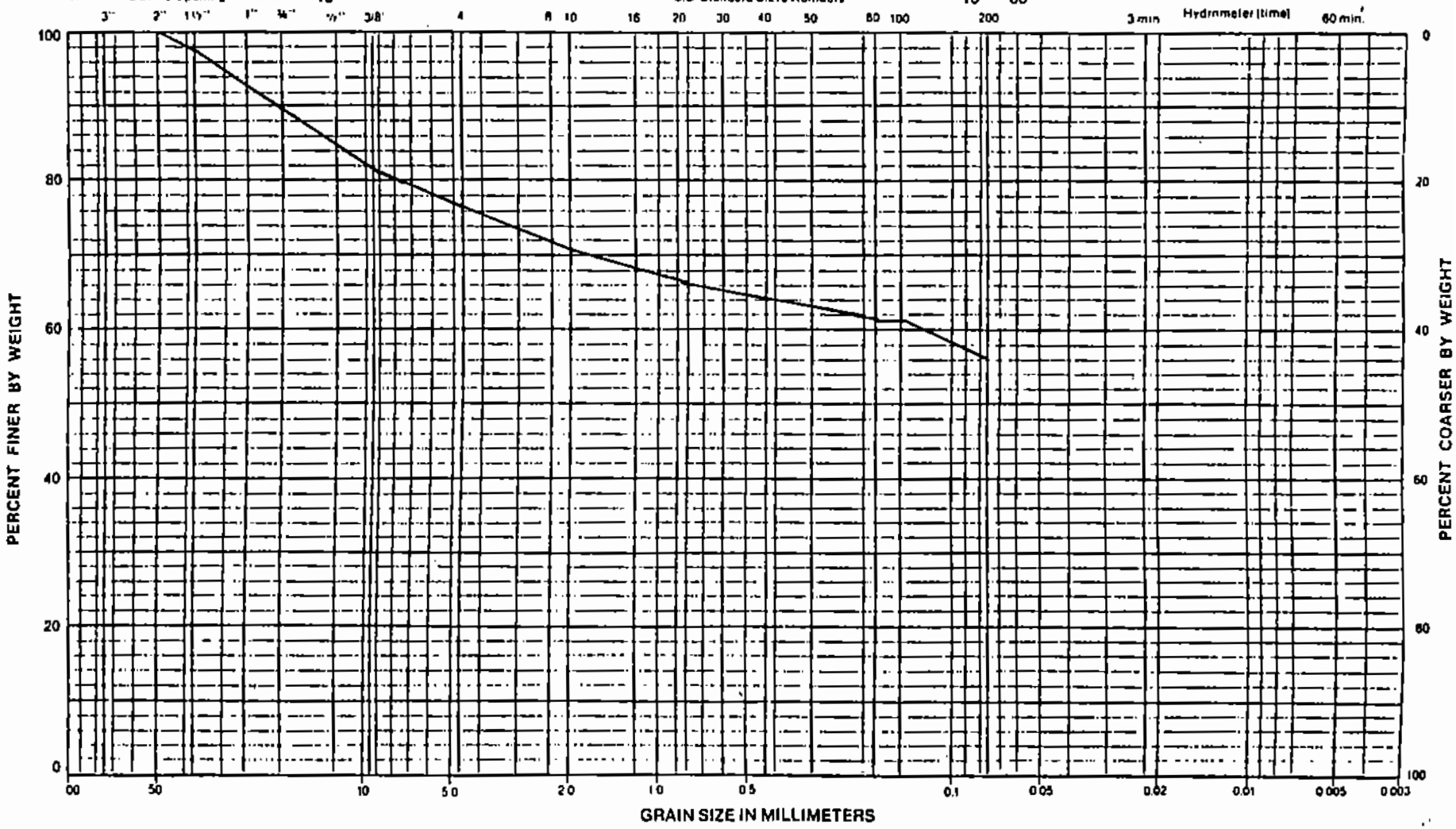
Sample No. 35034
Job No. 88-152-1
Date December 1988

Classification Gravelly SILT with Sand

Moisture Content 12 %
Liquid Limit -- %
Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Location: TP-508, S-2, 10.0' - 11.0'

Classification SILT

Sample No. 35036

Job No. 88-152-1

Date December 1988

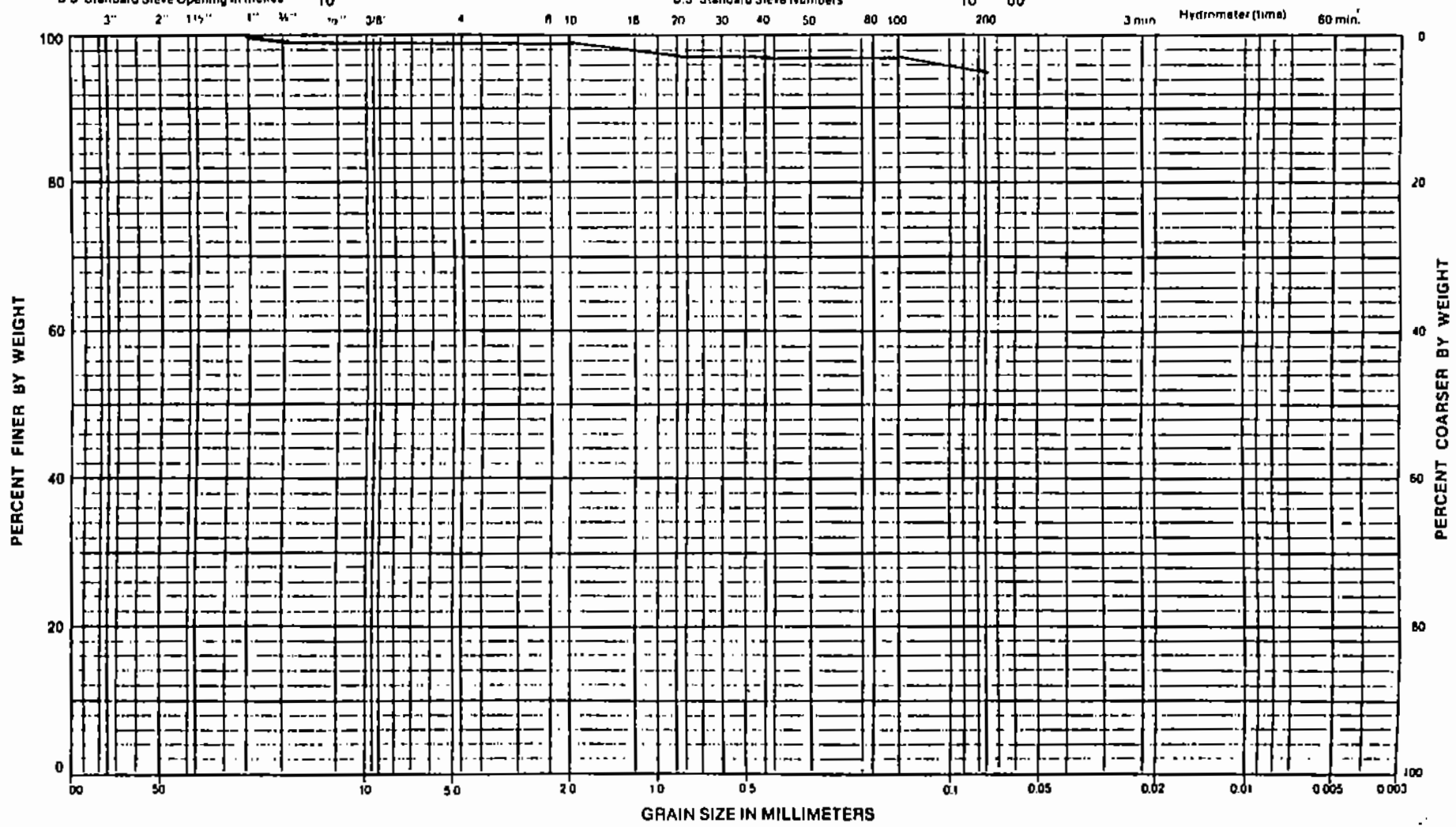
Moisture Content 23 %

Liquid Limit Granular %

Plasticity Index Non-Plastic %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Chen-Northern, Inc.

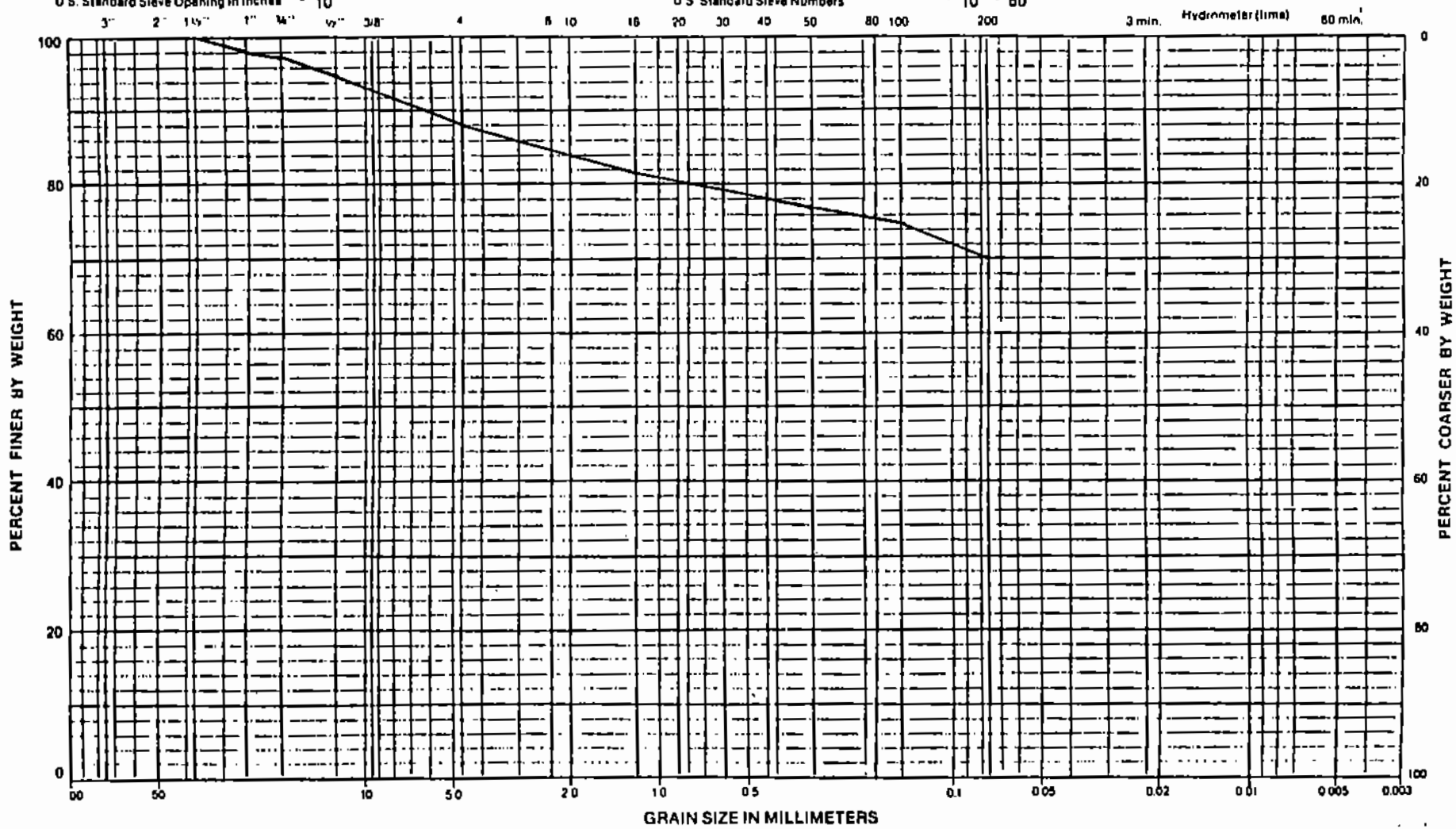
GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Location: Midas Creek Site TP-509, S-1, 6.0' - 7.0'
Classification Sandy SILT
Moisture Content 16 %

Sample No. 35037
Job No. 88-152-1
Date December 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}} = $ _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Sample No. 35040

Location: TP-511, S-1, 3.0' - 4.0'

Job No. 88-152-1

Classification Silty SAND with Gravel

Date December 1988

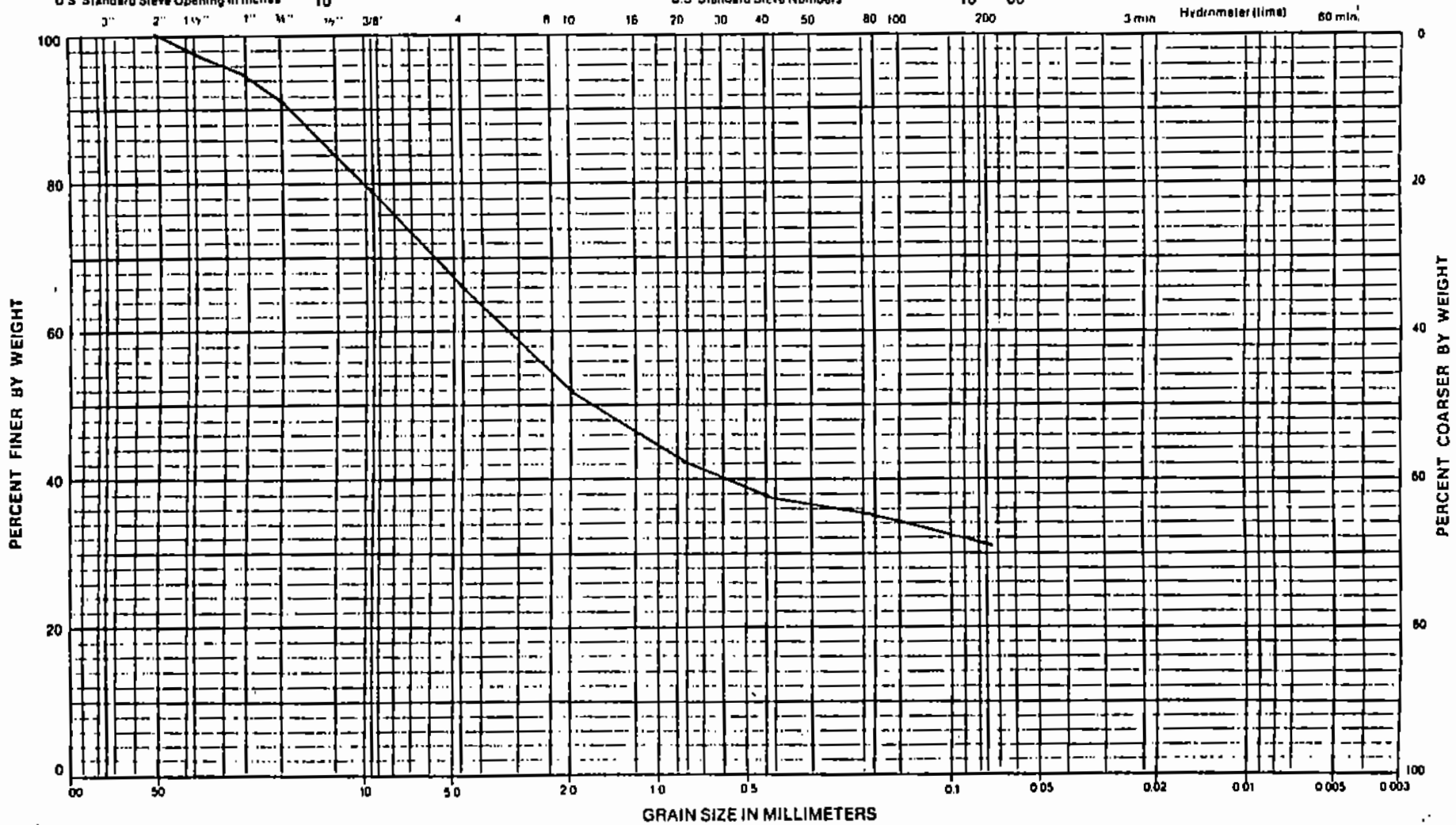
Moisture Content 11 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site
Location: DH-2, ST-1, 8.5' - 10.0'

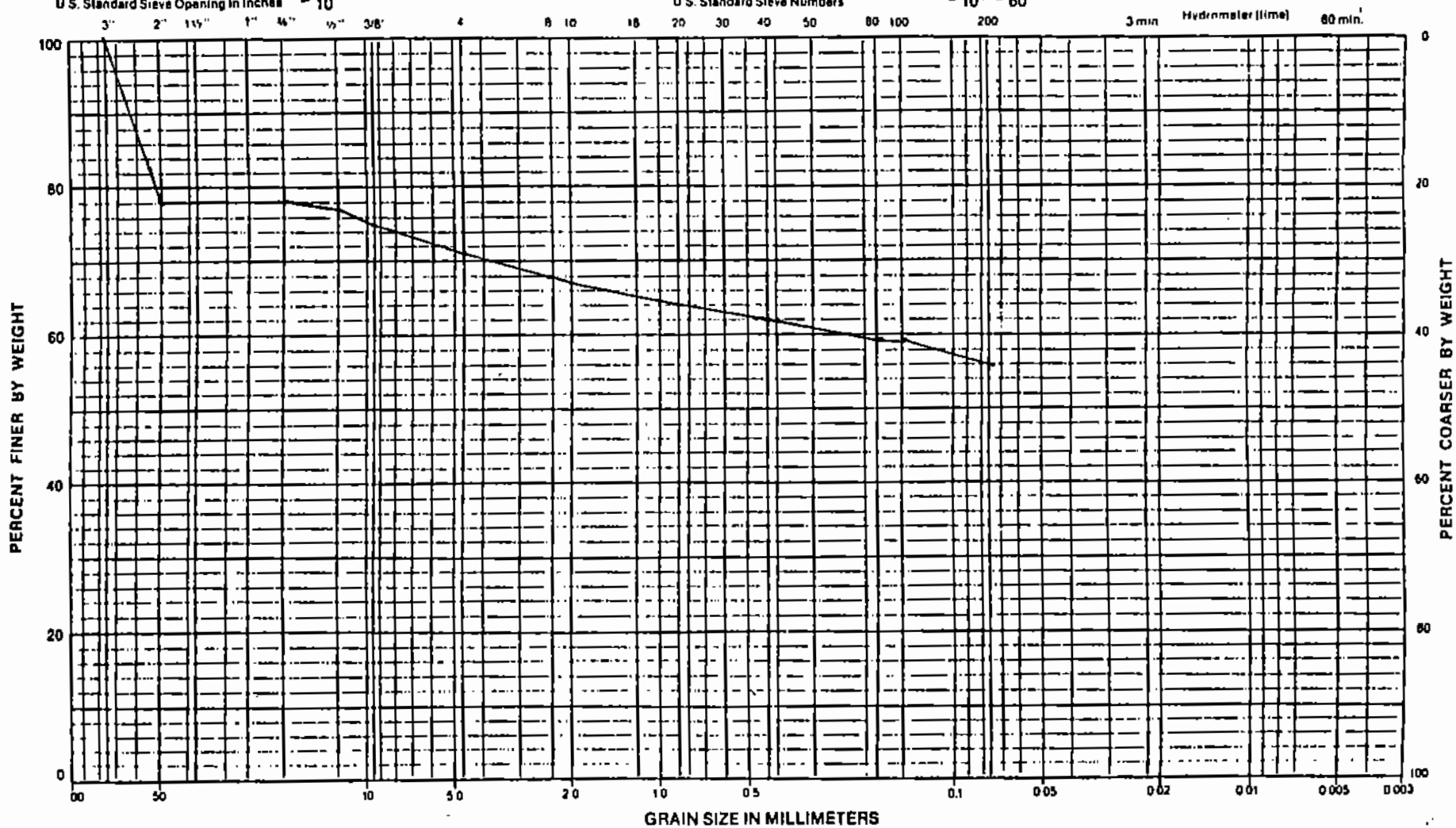
Sample No. 34987
Job No. 88-152-1
Date December 1988

Classification Gravelly SILT with Sand

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}} = $ _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Location: DH-2, SPT-2, 13.5' - 15.0'

Sample No. 34990

Job No. 88-152-1

Classification Sandy Lean CLAY

Date December 1988

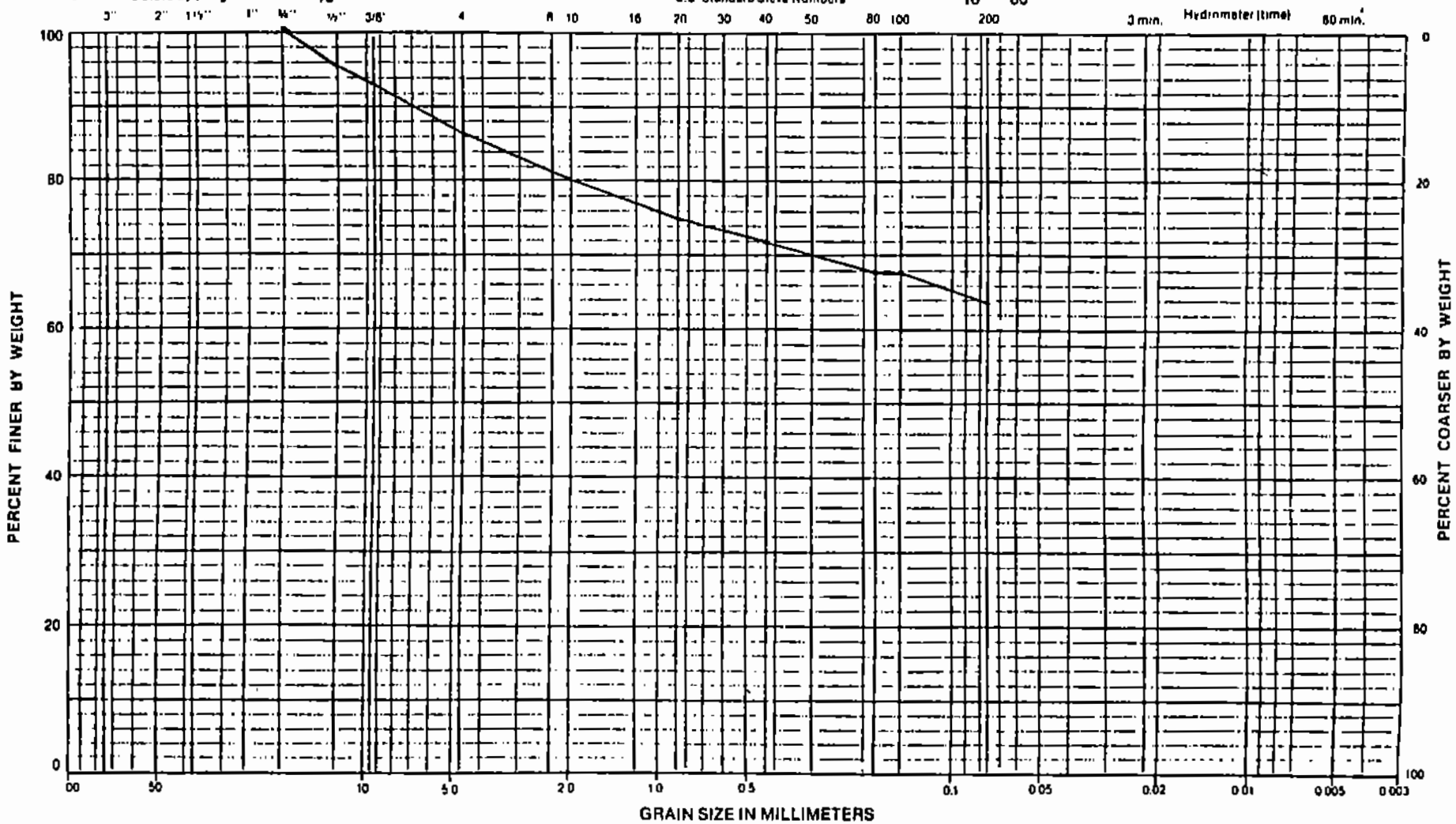
Moisture Content -- %

Liquid Limit 26 %

Plasticity Index 11 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Sample No. 34996

Location: DH-2, SPT-8, 63.5' - 65.0'

Job No. 88-152-1

Classification Lean CLAY with Gravel

Date December 1988

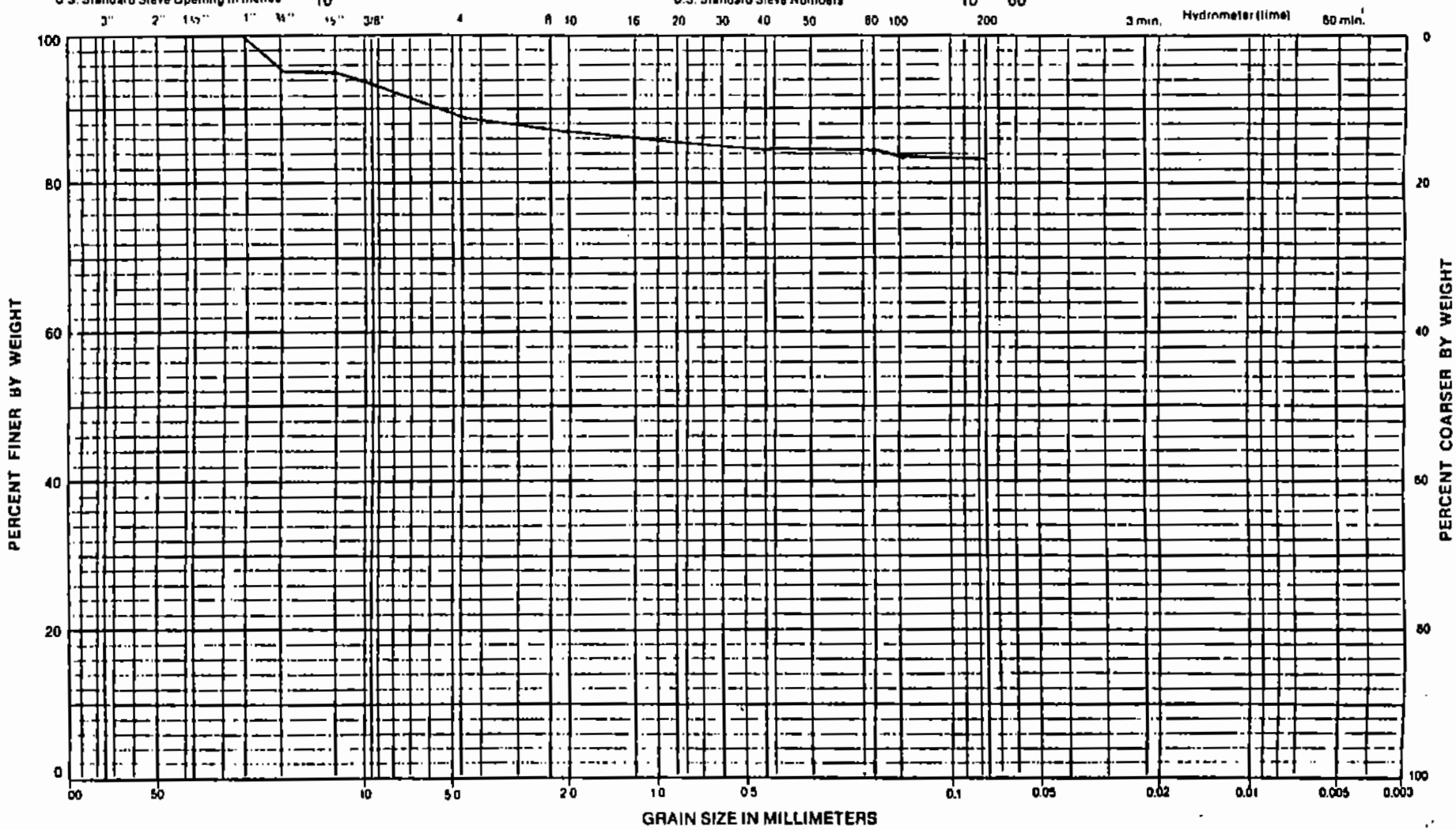
Moisture Content -- %

Liquid Limit 41 %

Plasticity Index 18 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Sample No. 34998

Location: DH-2A, ST-4, 38.5' - 40.5'

Job No. 88-152-1

Classification Lean CLAY

Date December 1988

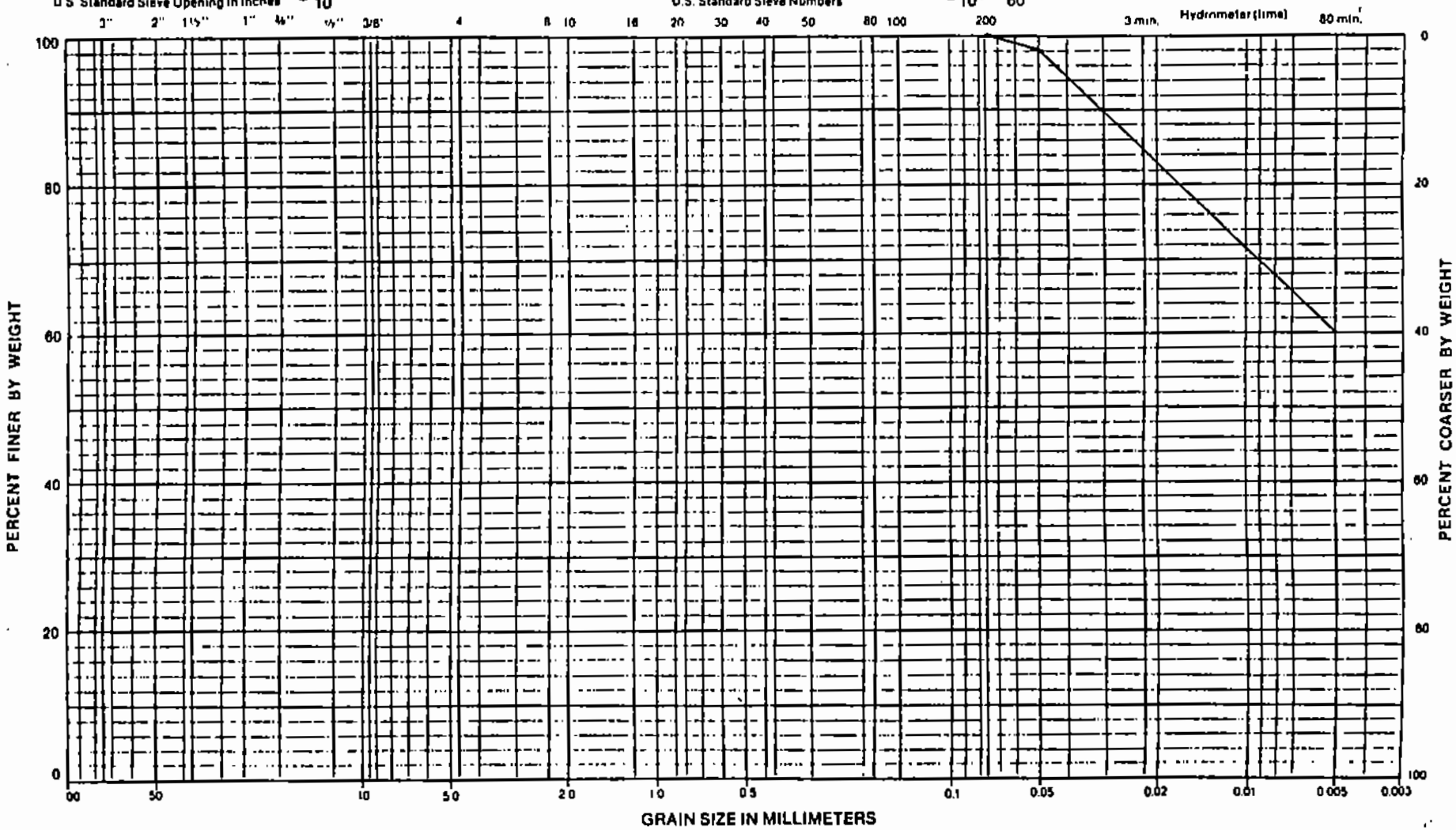
Moisture Content 27 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Location: DH-6, R-1, 28.5' - 30.0'

Classification: Silty CLAY with Sand

Sample No. 35002

Job No. 88-152-1

Date December 1988

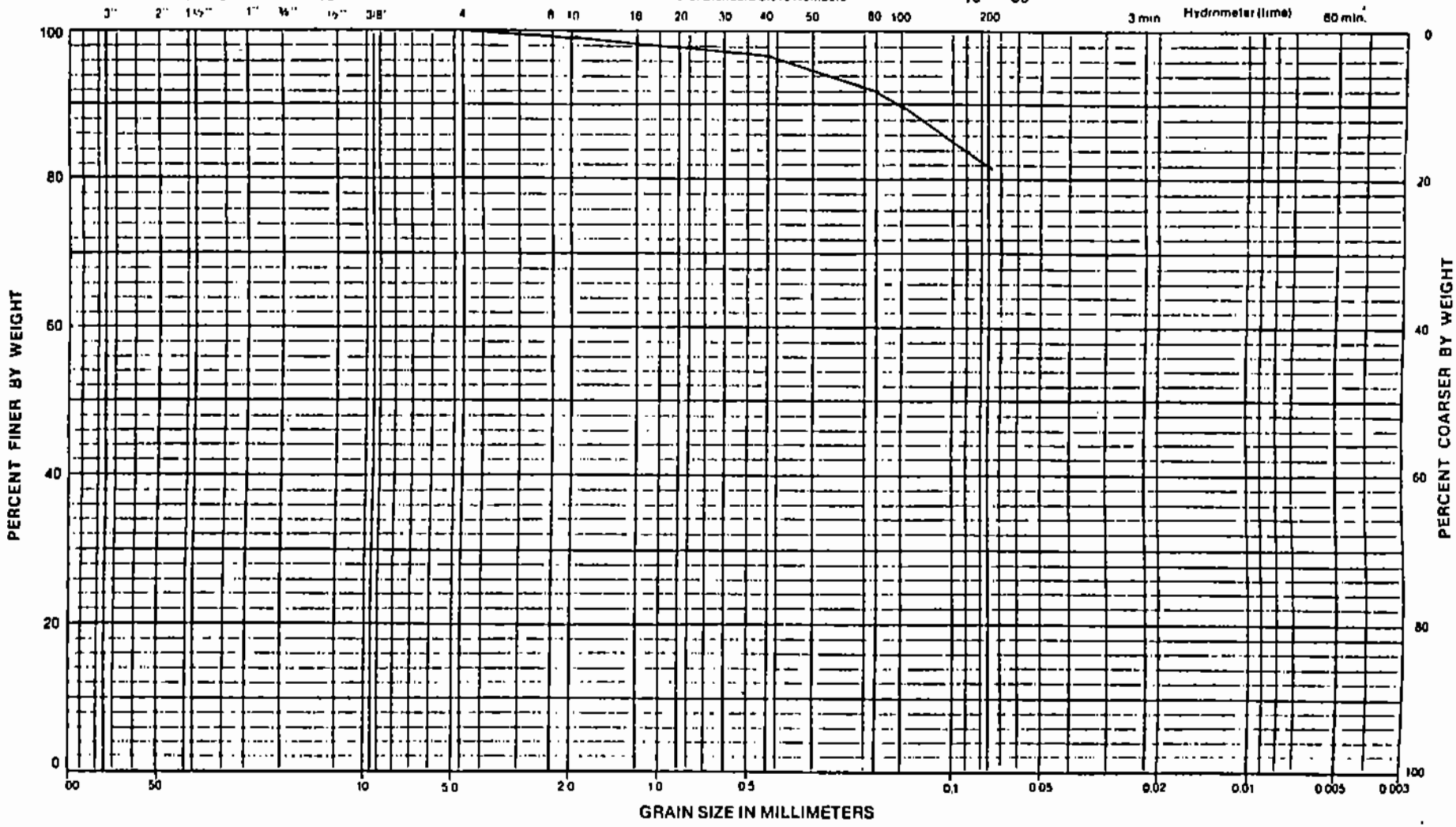
Moisture Content 17 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Location: DH-6, R-3, 48.5' - 50.0'

Sample No. 35004

Job No. 88-152-1

Classification Lean CLAY

Date December 1988

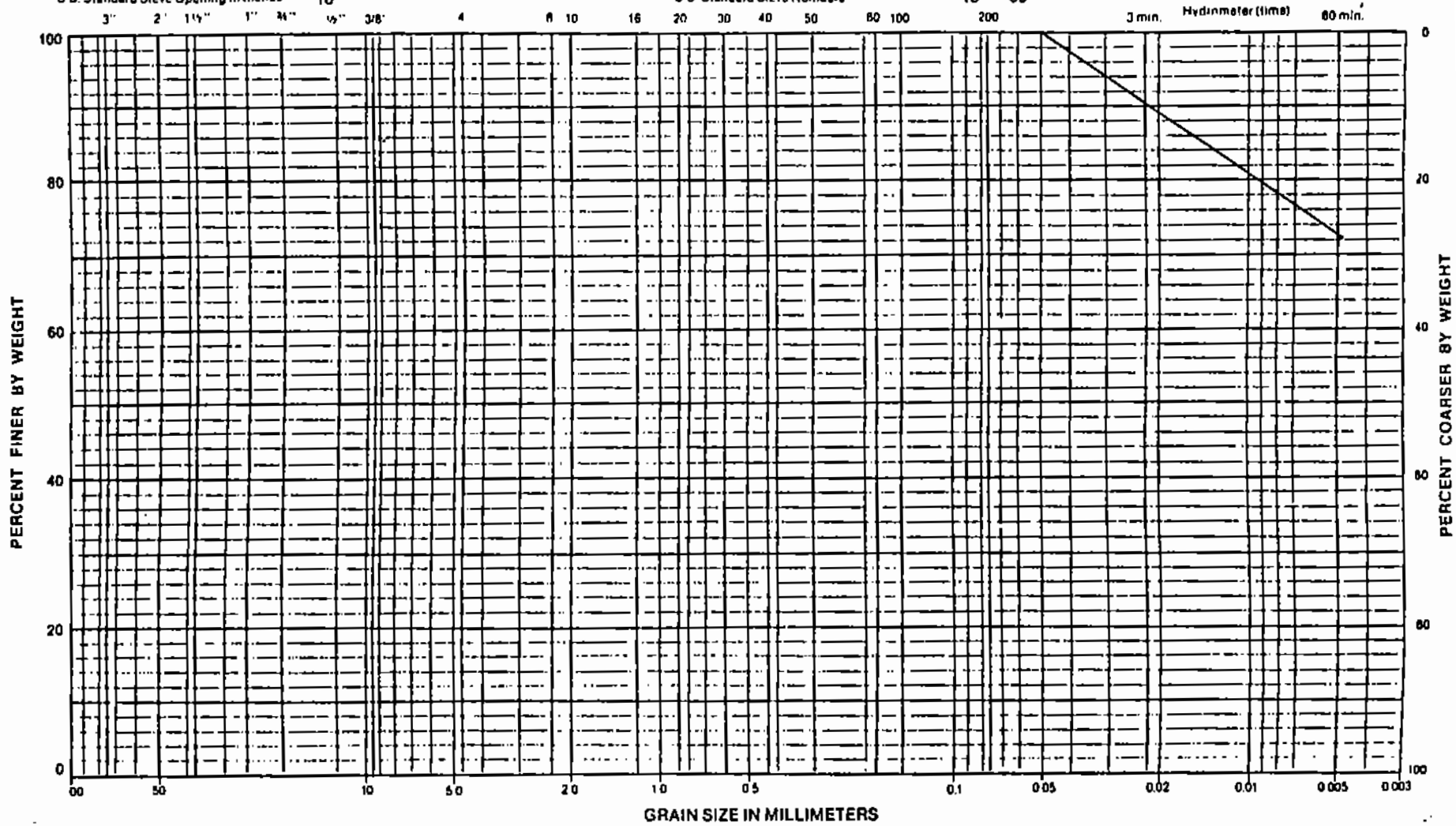
Moisture Content 26 %

Liquid Limit 44 %

Plasticity Index 17 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Chen-Northern, Inc.

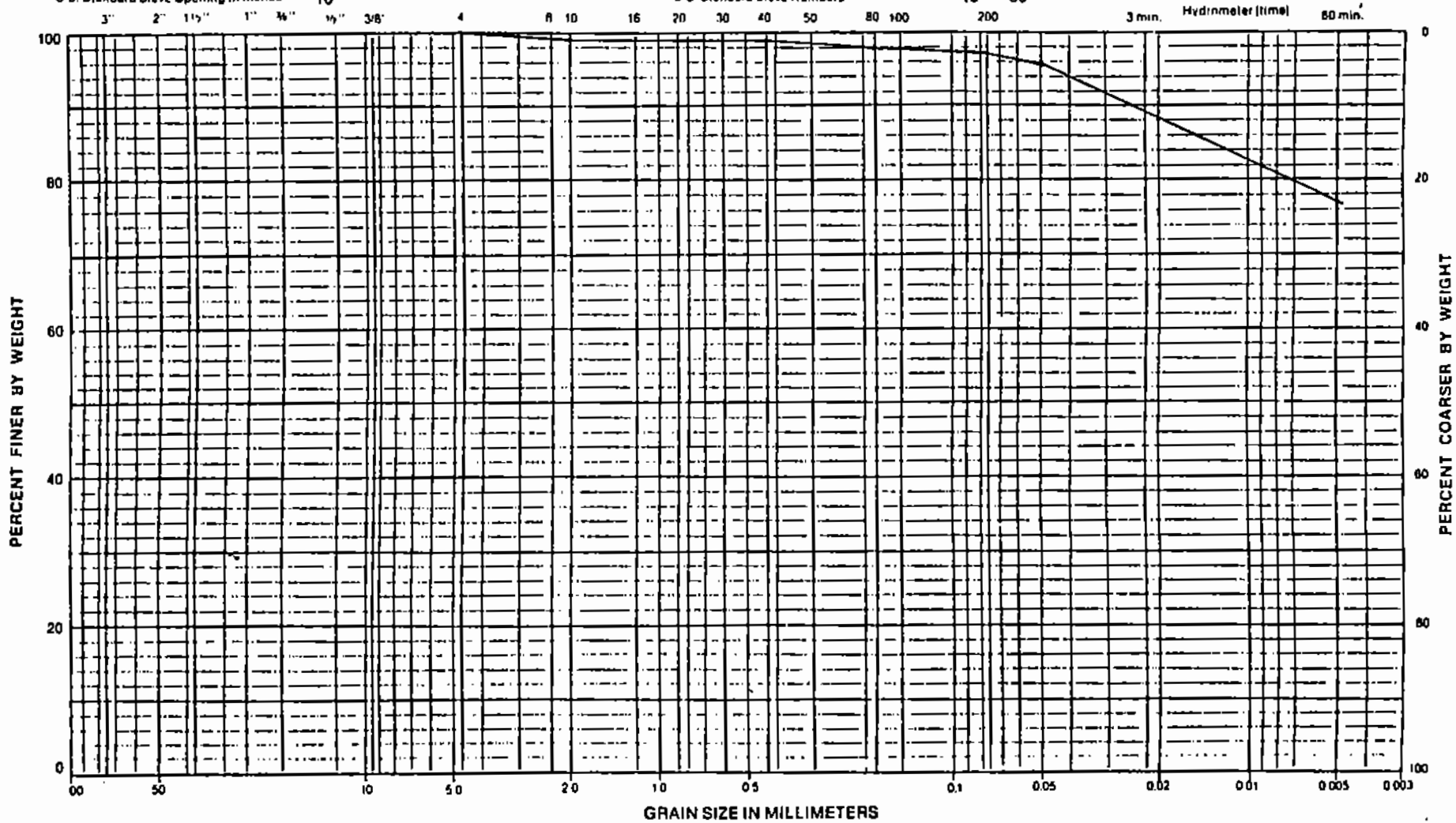
GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Location: Midas Creek Site DH-6, SPT-7, 75.0' - 76.5'
Classification: Lean CLAY
Moisture Content: -- %

Sample No. 35006
Job No. 88-152-1
Date December 1988
Liquid Limit 39 %
Plasticity Index 19 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site
Location: DH-8, ST-2, 22.0' - 23.5'

Sample No. 35010

Job No. 88-152-1

Classification Lean CLAY with Sand

Date December 1988

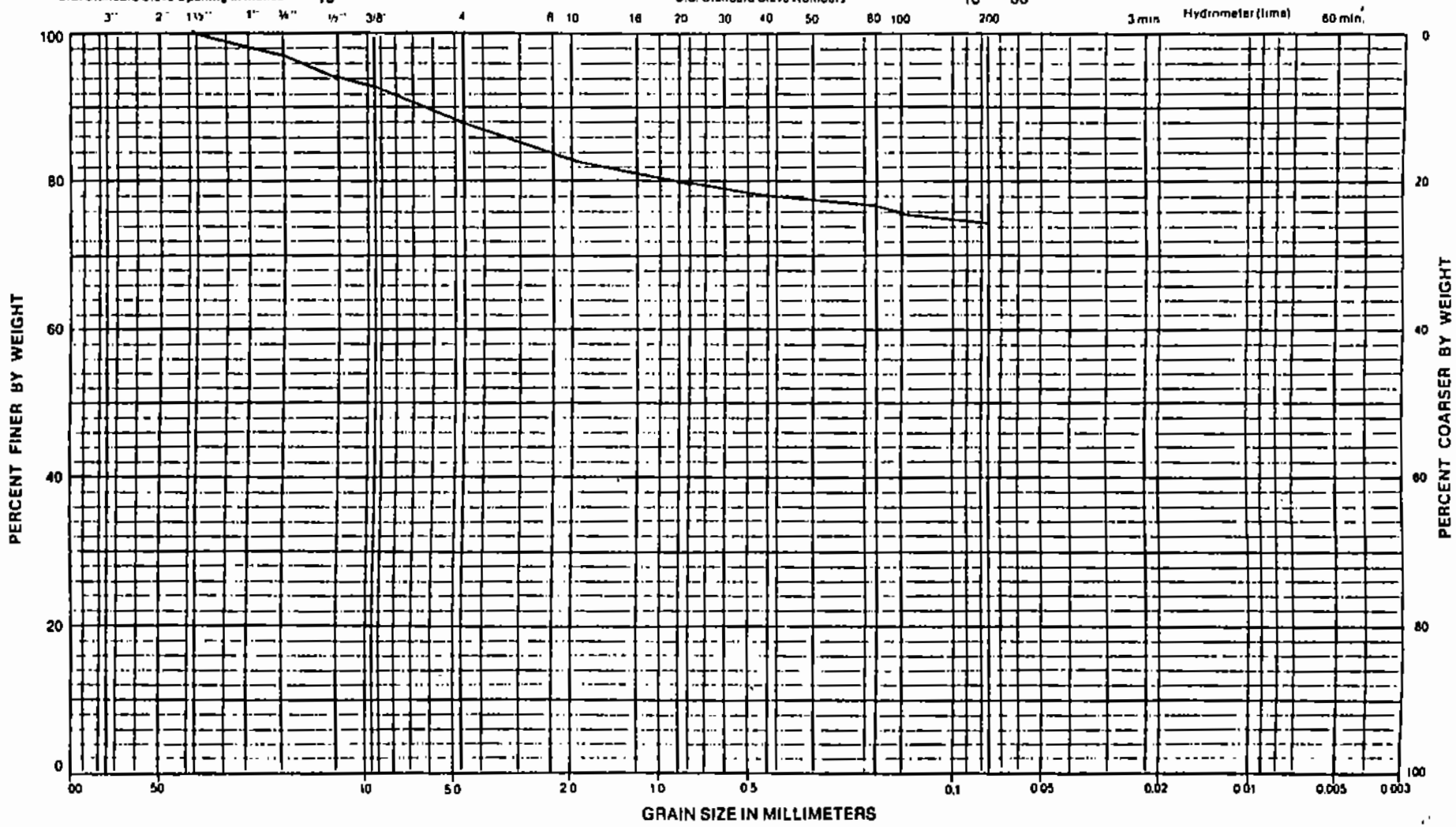
Moisture Content 20 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Location: DH-8, ST-3, 11.0' - 12.5'

Classification Clayey GRAVEL with Sand

Moisture Content -- %

Sample No. 35014

Job No. 88-152-1

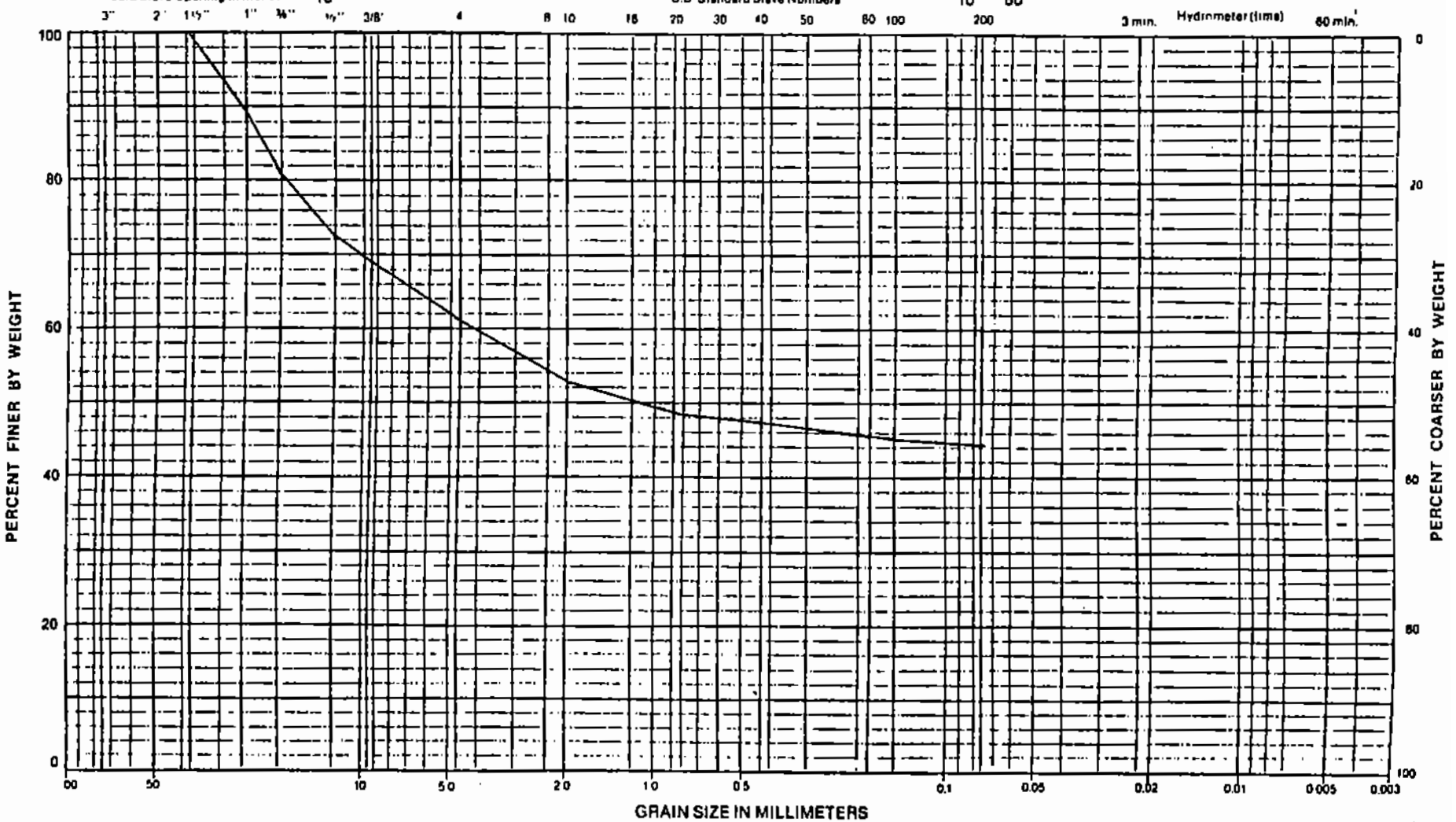
Date December 1988

Liquid Limit 37 %

Plasticity Index 15 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}} =$ _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}} =$ _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Location: Midas Creek Site
DH-8, SPT-6, 42.0' - 43.5'

Sample No. 35017
Job No. 88-152-1
Date December 1988

Classification Lean CLAY

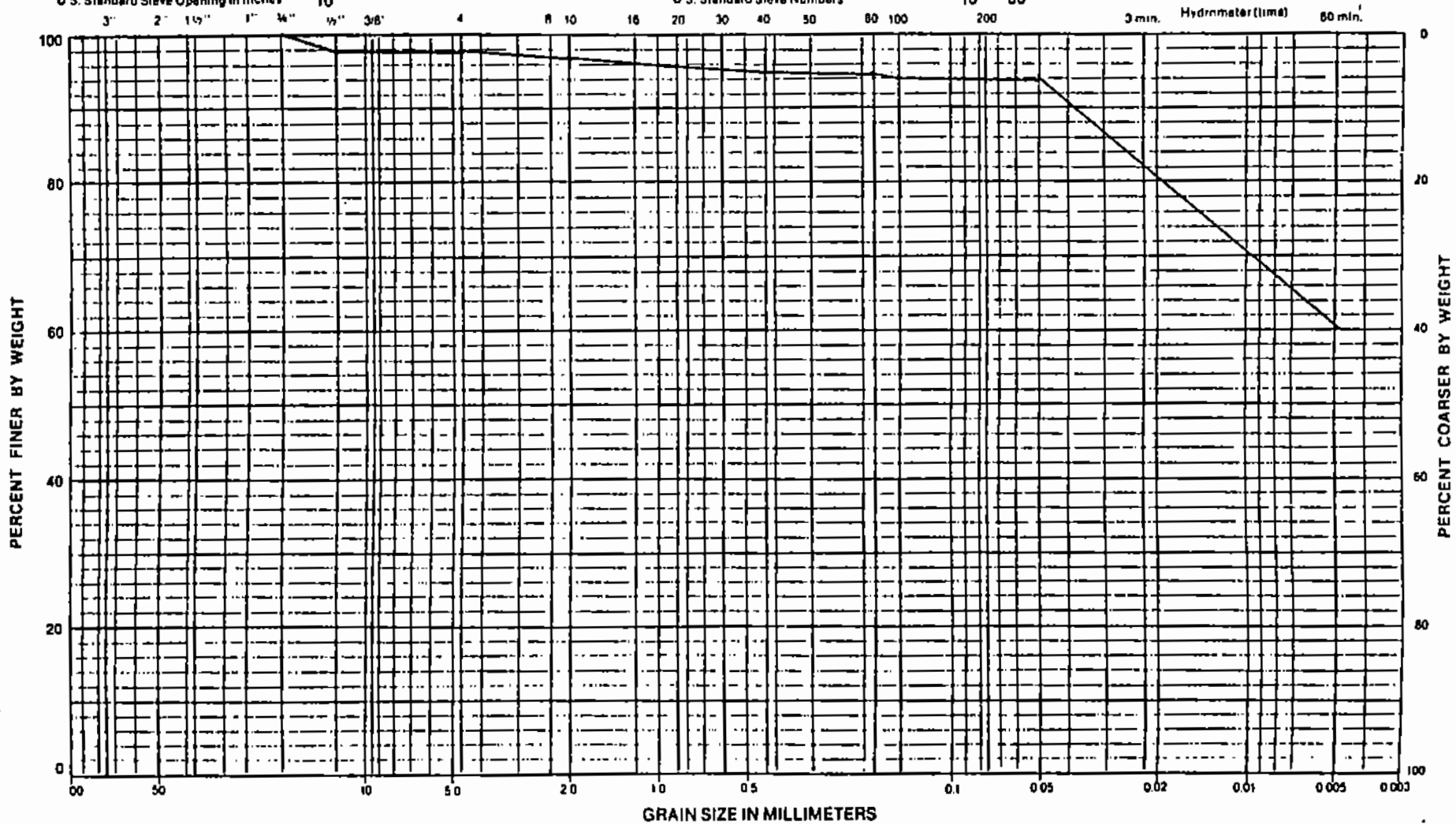
Moisture Content -- %

Liquid Limit 34 %

Plasticity Index 14 %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

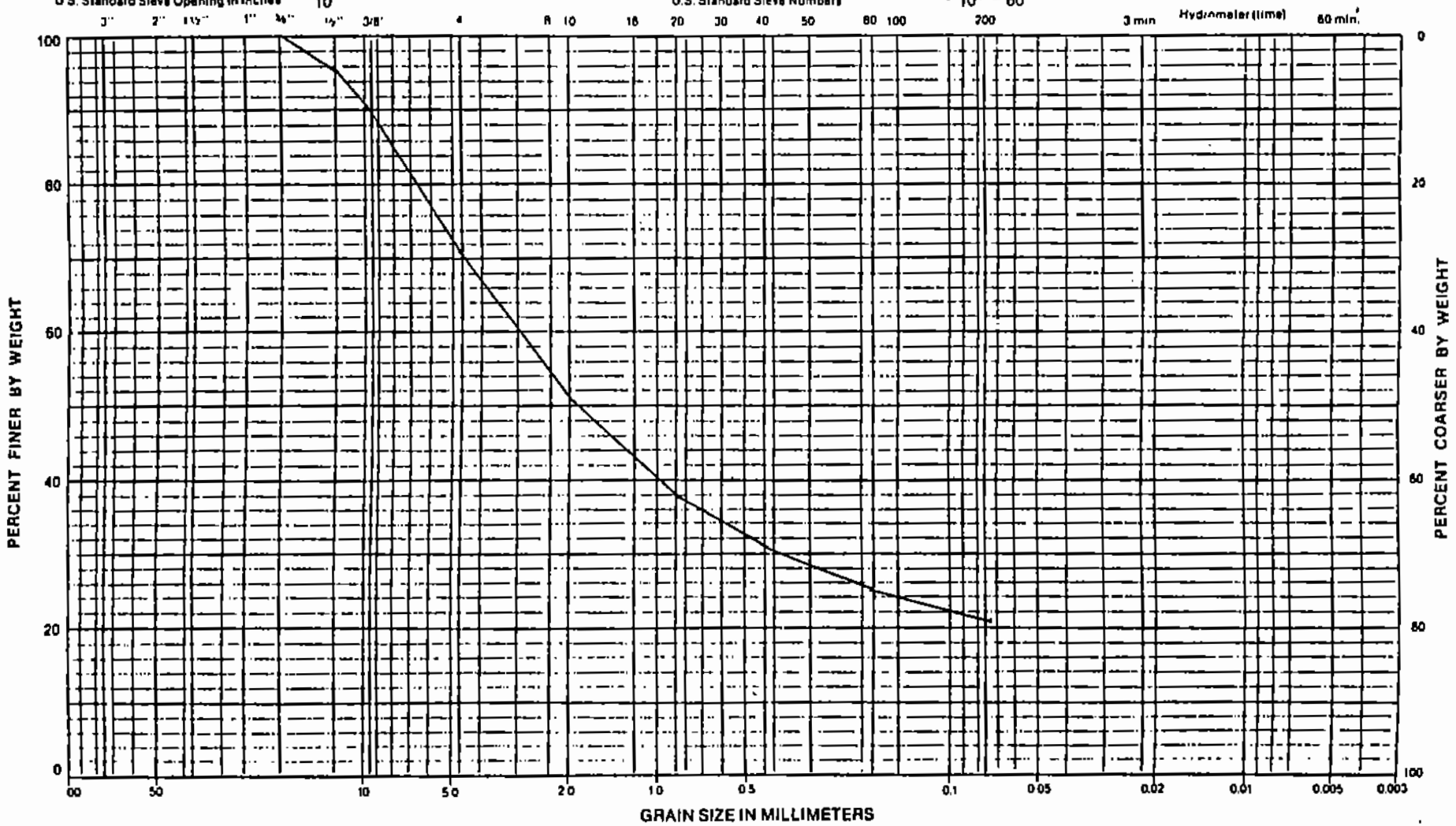
GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Location: Midas Creek Site DR-8, SPT-7, 54.0' - 55.5'
Classification: Clayey SAND with Gravel
Moisture Content: -- %

Sample No. 35018
Job No. 88-152-1
Date December 1988
Liquid Limit -- %
Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Minc.
Midas Creek Site
Location: DH-9, ST-1, 13.5' - 15.5'

Sample No. 35019

Job No. 88-152-1

Classification Sandy Lean CLAY with Gravel

Date December 1988

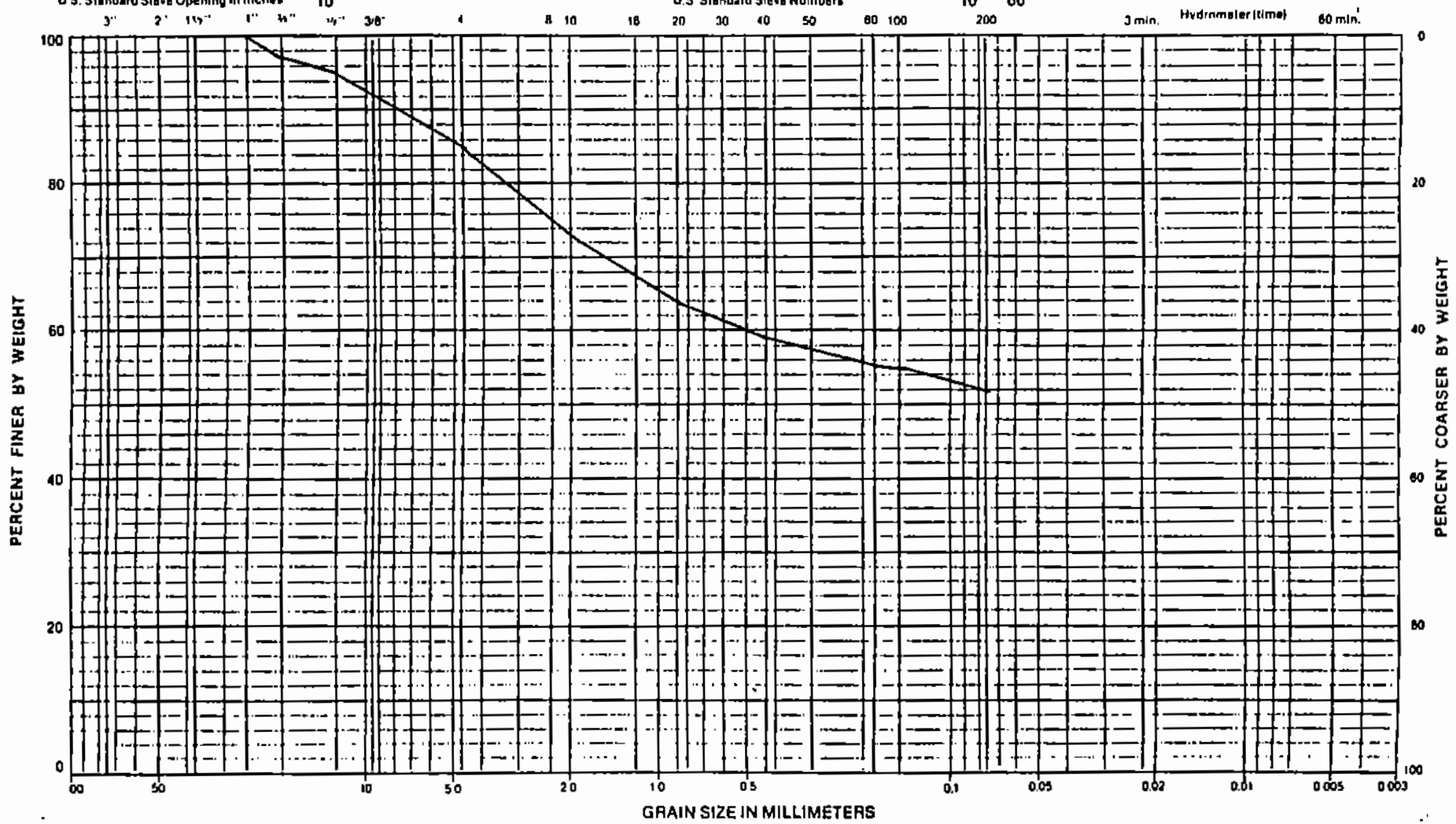
Moisture Content 23 %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

GRAIN SIZE DISTRIBUTION CURVE

Project: Montana Silver Venture Mine
Midas Creek Site

Location: DH-9, SPT-2, 18.5' - 20.0'

Sample No. 35021

Job No. 88-152-1

Classification Silty Clayey SAND with Gravel

Date December 1988

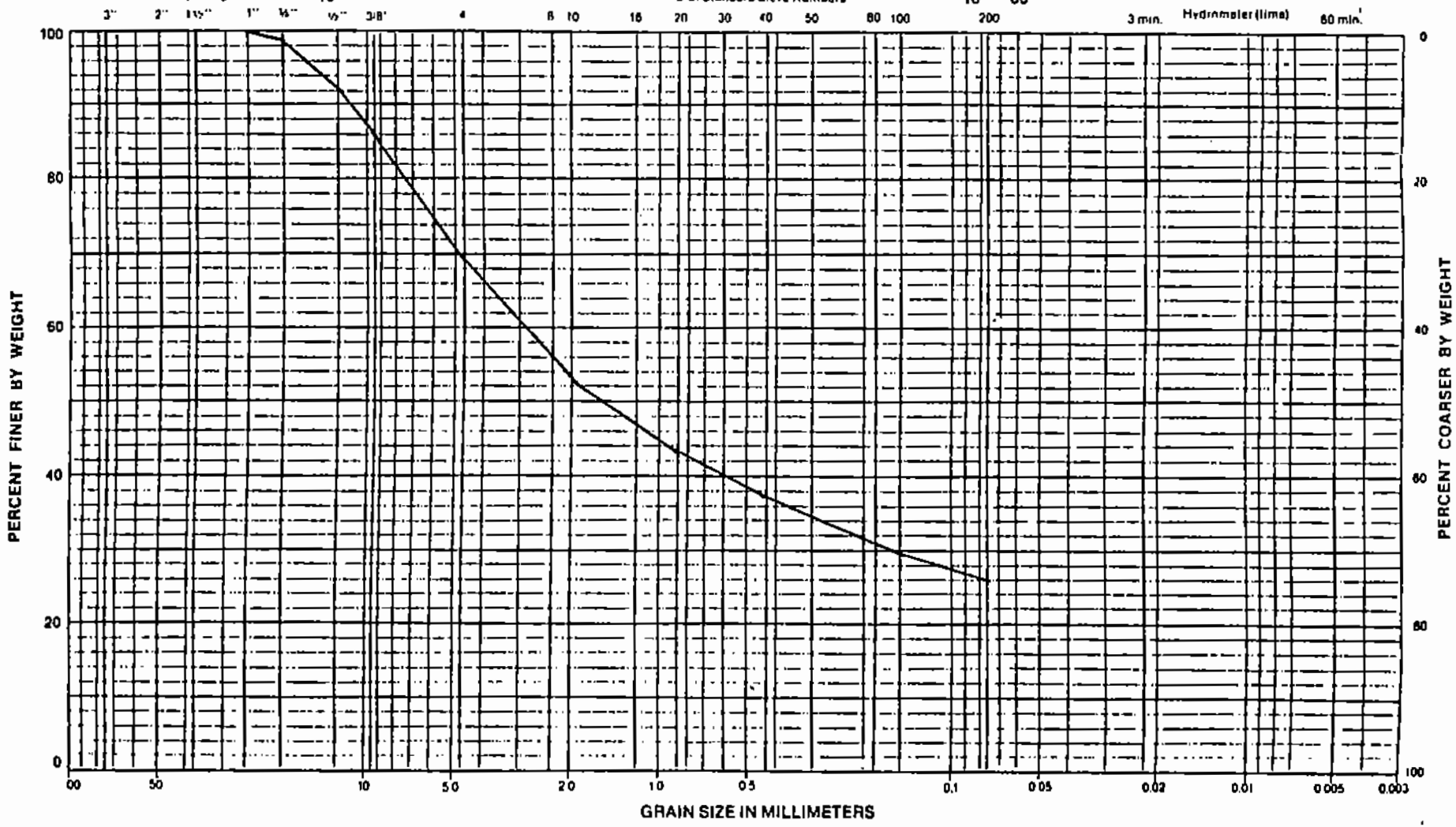
Moisture Content -- %

Liquid Limit -- %

Plasticity Index -- %

Coefficient of Uniformity = $C_U = \frac{D_{60}}{D_{10}}$ = _____

Coefficient of Curvature = $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ = _____



Chen-Northern, Inc.

528 Smelter Avenue
P.O. Box 951
Great Falls, MT 59403
(406) 453-1641
FAX (406) 727-2070

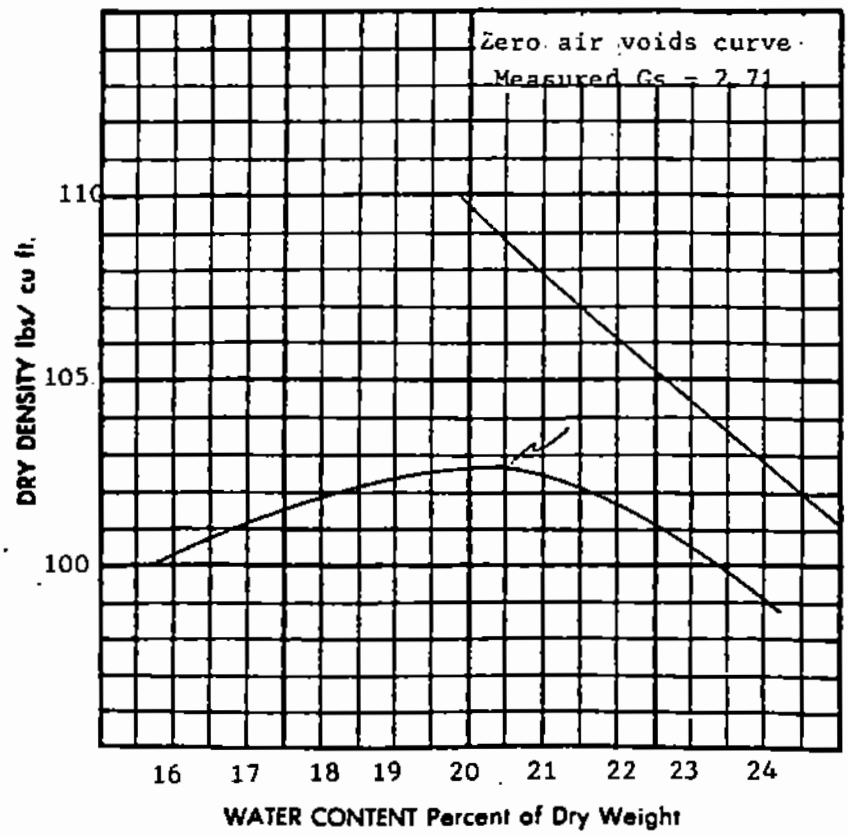
MOISTURE-DENSITY RELATIONSHIP DATA SHEET

REPORT TO:
MORRISON-KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

PROJECT: Montana Silver Venture Mine
Midas Creek Site
SAMPLE LOCATION: TP-503, S-2, 10.0' - 11.0'

DATE: December, 1988
JOB NUMBER: 88-152-1
SHEET: 1 **OF** 1
INVOICE NO.: 69307
LAB NO.: 35028
DATE SAMPLED: N/R
DATE RECEIVED: December, 1988
SAMPLED BY: Morrison-Knudsen

MOISTURE-DENSITY RELATIONSHIP



MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
No. 10	100	
No. 20	100	
No. 40	100	
No. 80	100	
No. 100	100	
No. 200 (wash)	98.1	

UNIFIED CLASSIFICATION (ASTM D2487)
SILT
SPECIFIC GRAVITY: 2.71
LIQUID LIMIT: 23
PLASTICITY INDEX: 3

TEST PROCEDURE ASTM D698, Method A
MAX. DENSITY: 102.5
OPT. MOIST.: 20.5
RAMMER TYPE: 5.5 pounds
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

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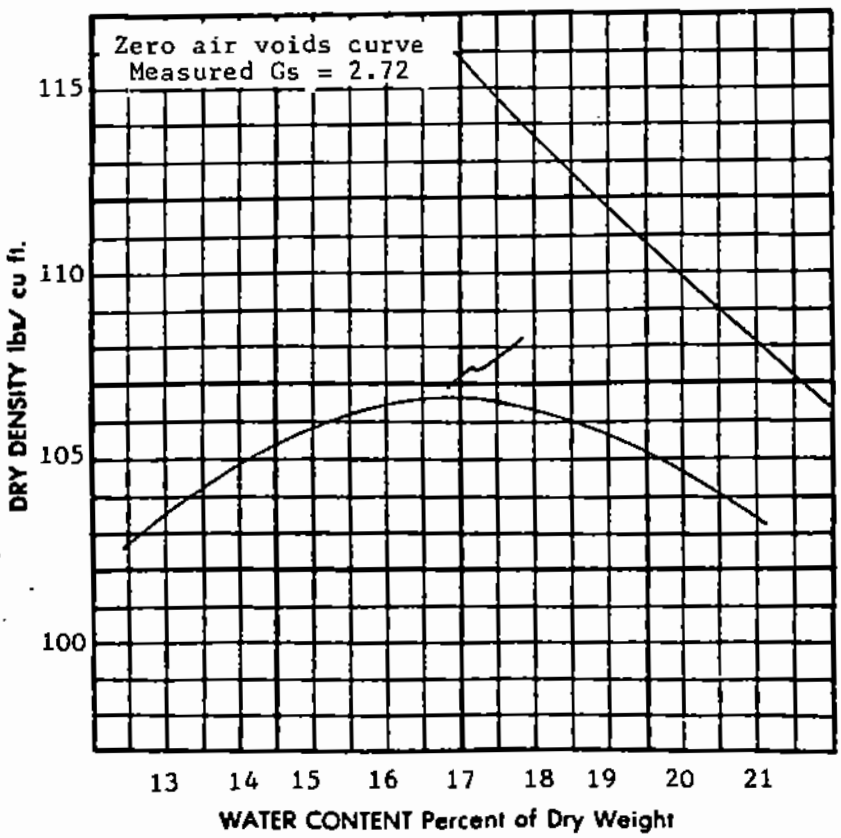
MOISTURE-DENSITY RELATIONSHIP DATA SHEET

REPORT TO:
MORRISON-KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

DATE: December 1988
JOB NUMBER: 88-152-1
SHEET: 1 OF 1
INVOICE NO.: 69307
LAB NO.: 35031
DATE SAMPLED: N/R
DATE RECEIVED: December 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Midas Creek Site
SAMPLE LOCATION: TP-505, S-1, 7.0' - 8.5'

MOISTURE-DENSITY RELATIONSHIP



MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
1"	100	
3/4"	99	
1/2"	99	
3/8"	99	
No. 4	99	
No. 10	98	
No. 20	97	
No. 40	97	
No. 80	96	
No. 100	96	
No. 200(wash)	93.8	

VISUAL CLASSIFICATION
SILT
SPECIFIC GRAVITY: 2.72
LIQUID LIMIT: N/R
PLASTICITY INDEX: N/R

TEST PROCEDURE ASTM D698, Method A
MAX. DENSITY: 106.5
OPT. MOIST.: 16.8
RAMMER TYPE: 5.5 pounds
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

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MOISTURE-DENSITY RELATIONSHIP DATA SHEET

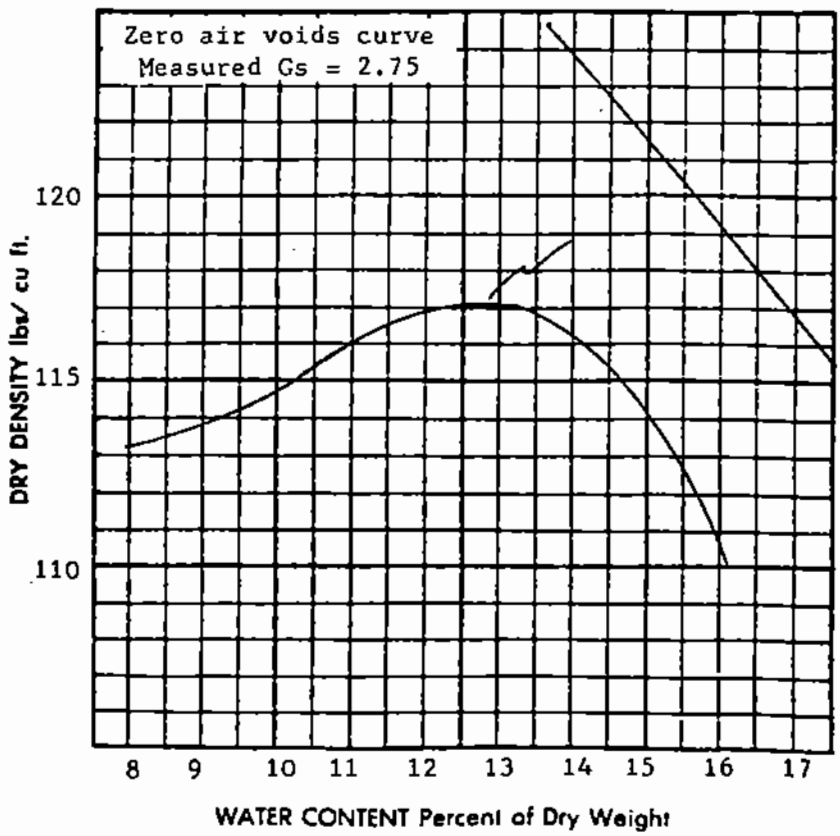
REPORT TO:

MORRISON-KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

DATE: December 1988
JOB NUMBER: 88-152-1
SHEET: 1 OF 1
INVOICE NO.: 69307
LAB NO.: 35033
DATE SAMPLED: N/R
DATE RECEIVED: December 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Midas Creek Site
SAMPLE LOCATION: TP-506, S-2, 9.0' - 10.0'

MOISTURE-DENSITY RELATIONSHIP



MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
2"	100	
1-1/2"	99	
1"	98	
3/4"	96	
1/2"	94	
3/8"	92	
No. 4	90	
No. 10	86	
No. 20	82	
No. 40	79	
No. 80	73	
No. 100	71	
No. 200(wash)	59.3	

VISUAL CLASSIFICATION
Sandy SILT
SPECIFIC GRAVITY: 2.75
LIQUID LIMIT: N/R
PLASTICITY INDEX: N/R

TEST PROCEDURE ASTM D698, Method C
MAX. DENSITY: 117.1
OPT. MOIST.: 12.8
RAMMER TYPE: 5.5 pounds
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

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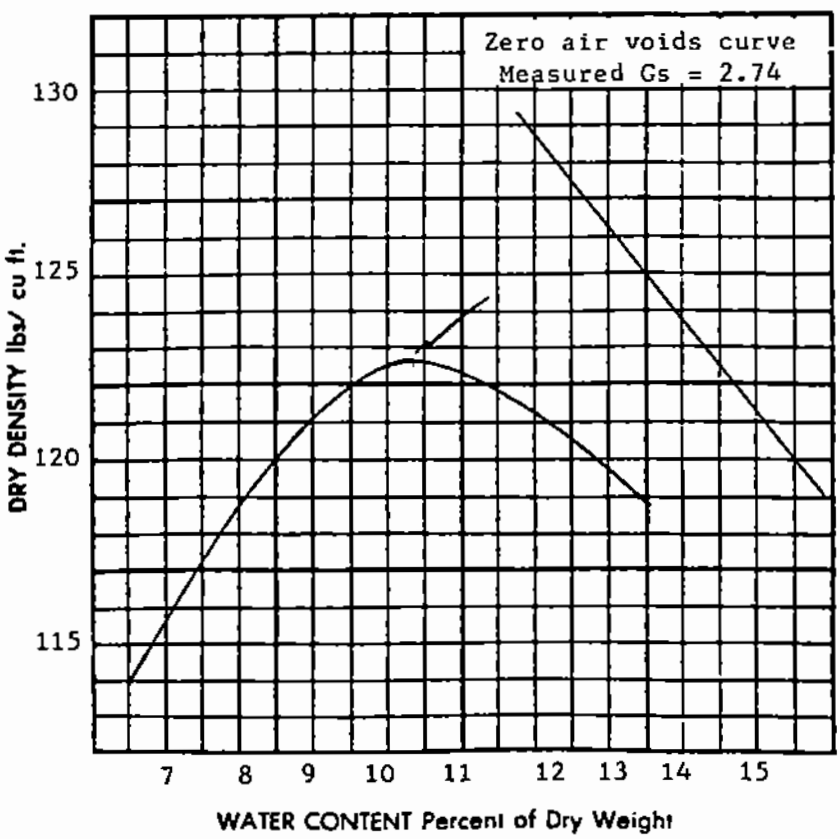
MOISTURE-DENSITY RELATIONSHIP DATA SHEET

REPORT TO:
MORRISON-KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

DATE: December 1988
JOB NUMBER: 88-152-1
SHEET: 1 OF 1
INVOICE NO.: 69307
LAB NO.: 35034
DATE SAMPLED: N/R
DATE RECEIVED: December 1988
SAMPLED BY: Morrison-Knudsen

PROJECT: Montana Silver Venture Mine
Midas Creek Site
SAMPLE LOCATION: TP-507, S-1, 5.0' - 6.0'

MOISTURE-DENSITY RELATIONSHIP



MECHANICAL ANALYSIS

SIZE	% PASS	SPECS.
2"	100	
1-1/2"	97	
1"	93	
3/4"	90	
1/2"	85	
3/8"	81	
No. 4	77	
No. 10	71	
No. 20	67	
No. 40	65	
No. 80	62	
No. 100	62	
No. 200(wash)	57.5	

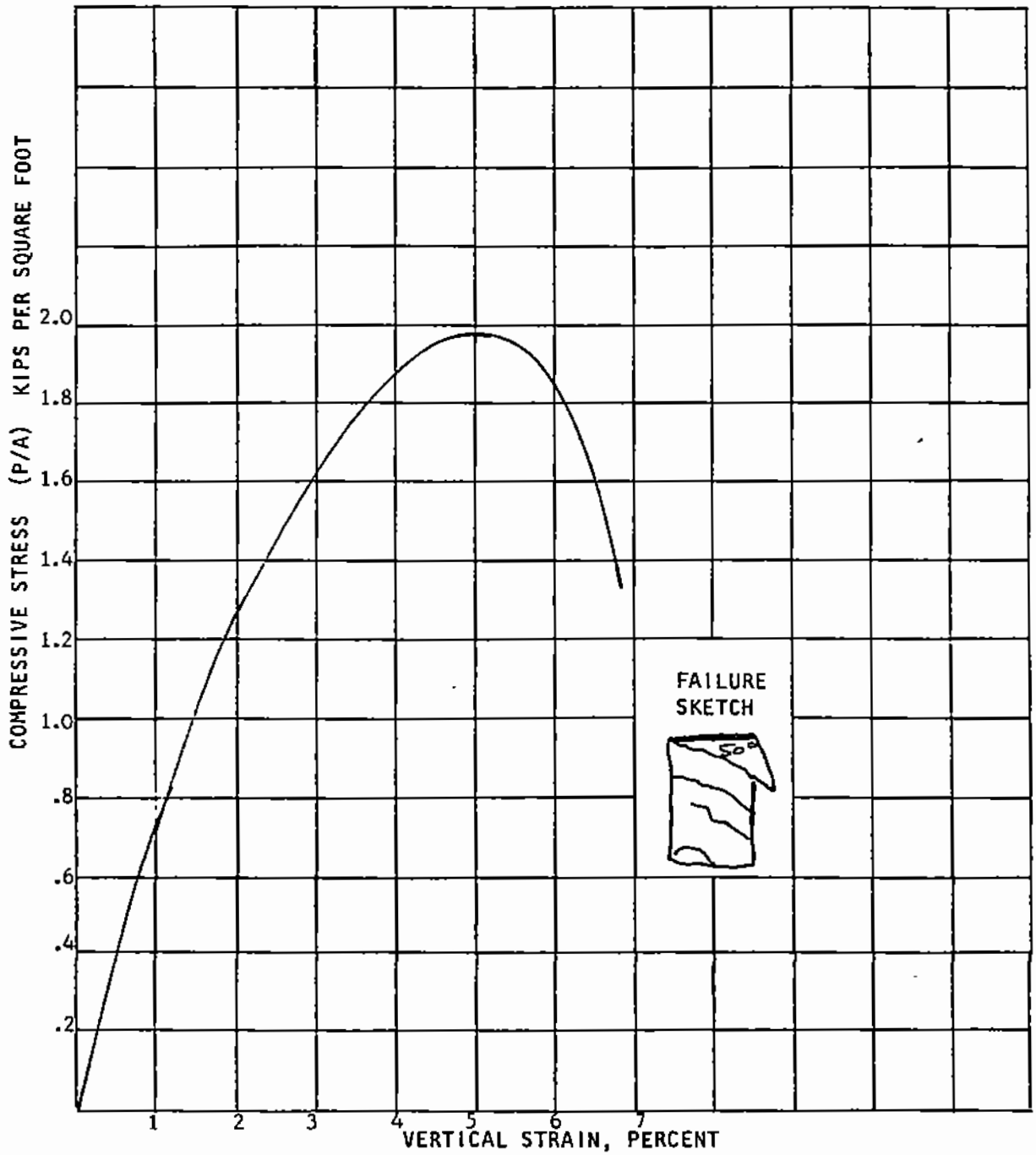
VISUAL CLASSIFICATION
Gravelly SILT with Sand
SPECIFIC GRAVITY: 2.74
LIQUID LIMIT: N/R
PLASTICITY INDEX: N/R

TEST PROCEDURE ASTM D698, Method C
MAX. DENSITY: 122.7
OPT. MOIST.: 10.4
RAMMER TYPE: 5.5 pounds
PREPARATION PROCEDURE: Moist
PENETRATION RESIS.: N/R

UNCONFINED COMPRESSION TEST

MC DRILL HOLE No. 2
DEPTH 43.5' - 45.0'
SAMPLE NO. 34988

MOIST UNIT WEIGHT: 122 pcf
DRY UNIT WEIGHT : 98 pcf
MOISTURE CONTENT : 24 %
CLASSIFICATION : Lean CLAY (varved)
HEIGHT TO DIAMETER RATIO: 2:1
RATE OF STRAIN: 1%/minute



NET 156

MONTANA SILVER VENTURE MINE
MIDAS CREEK SITE

MORRISON KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

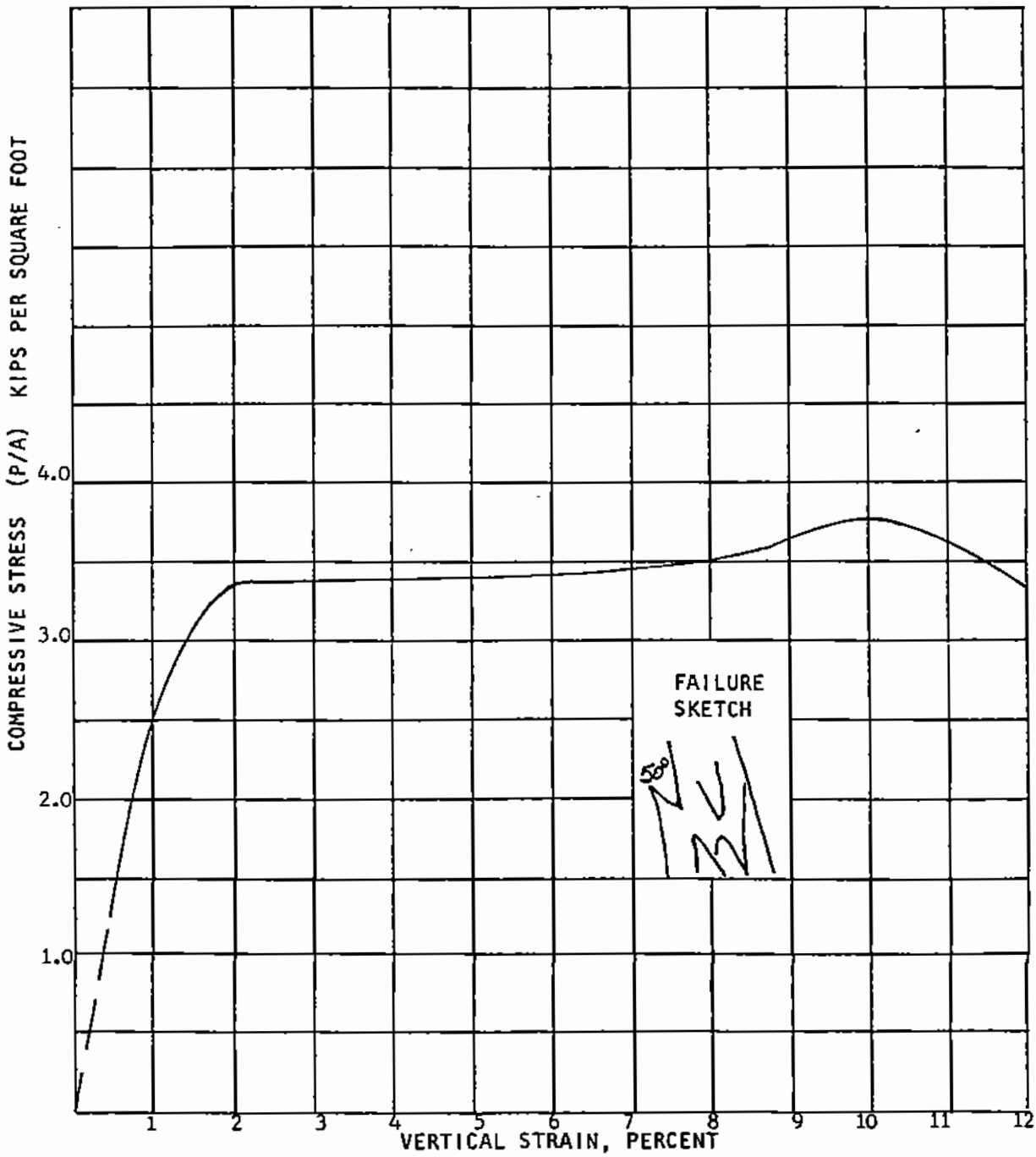
Chen-Northern, Inc.
Great Falls, Montana

JOB NO. 88-152-1

UNCONFINED COMPRESSION TEST

MC DRILL HOLE No. 2A
DEPTH 38.5' – 40.5'
SAMPLE NO. 34998

MOIST UNIT WEIGHT: 123 pcf
DRY UNIT WEIGHT : 97 pcf
MOISTURE CONTENT : 27 %
CLASSIFICATION : Lean CLAY (marbled wit silt pockets
HEIGHT TO DIAMETER RATIO: 2:1
RATE OF STRAIN: 1%/minute



MONTANA SILVER VENTURE MINE
MIDAS CREEK SITE

MORRISON KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

Chen-Northern, Inc.
Great Falls, Montana

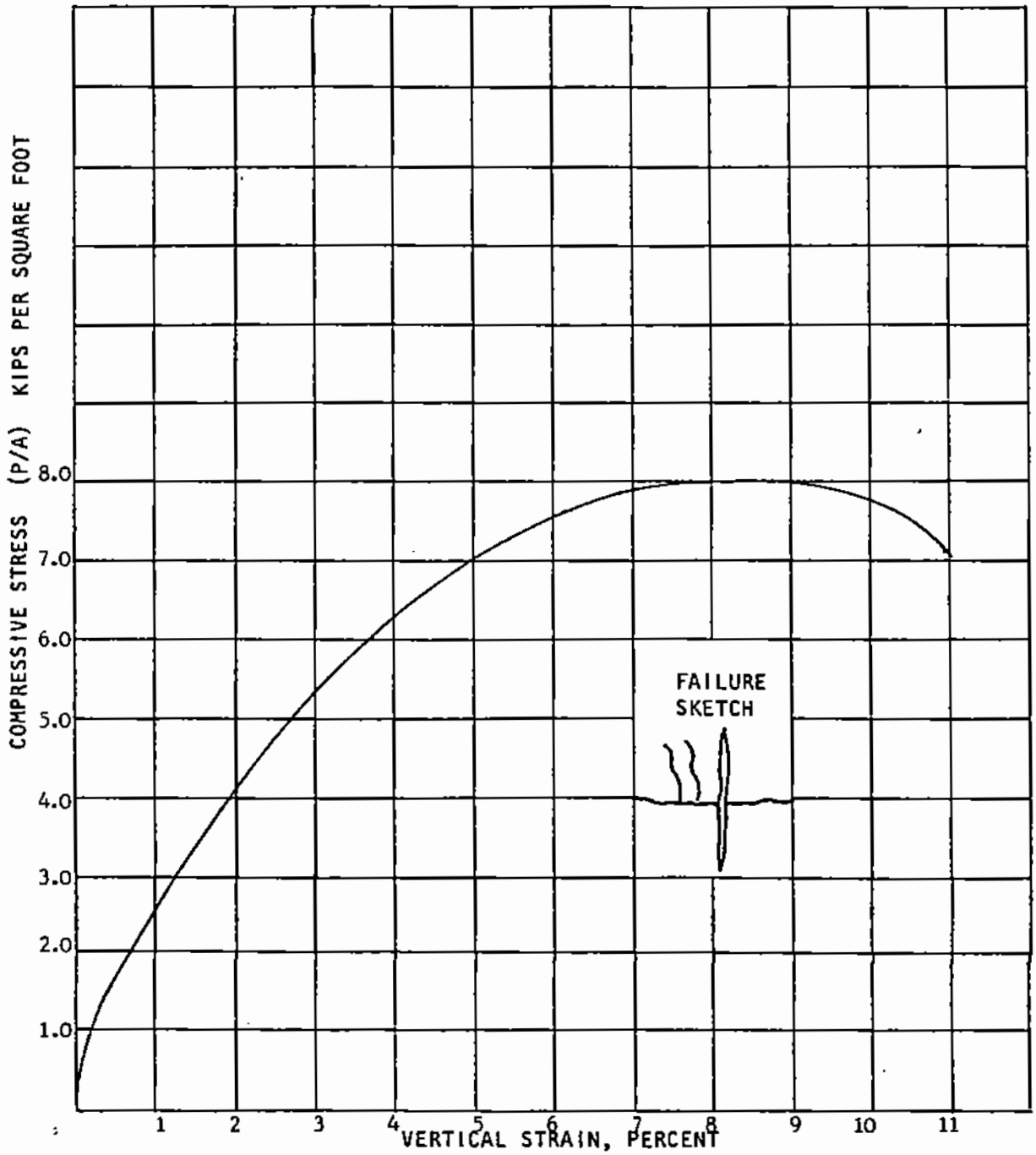
JOB NO.88-152-1

NET 158

UNCONFINED COMPRESSION TEST

MC DRILL HOLE No. 2A
DEPTH 53.5' - 55.5'
SAMPLE NO. 35000

MOIST UNIT WEIGHT: 121 pcf
DRY UNIT WEIGHT : 93 pcf
MOISTURE CONTENT : 31 %
CLASSIFICATION : Lean CLAY (varved)
HEIGHT TO DIAMETER RATIO: 1.91:1
RATE OF STRAIN: 1%/minute



MONTANA SILVER VENTURE MINE
MIDAS CREEK SITE

MORRISON KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

Chen-Northern, Inc.
Great Falls, Montana

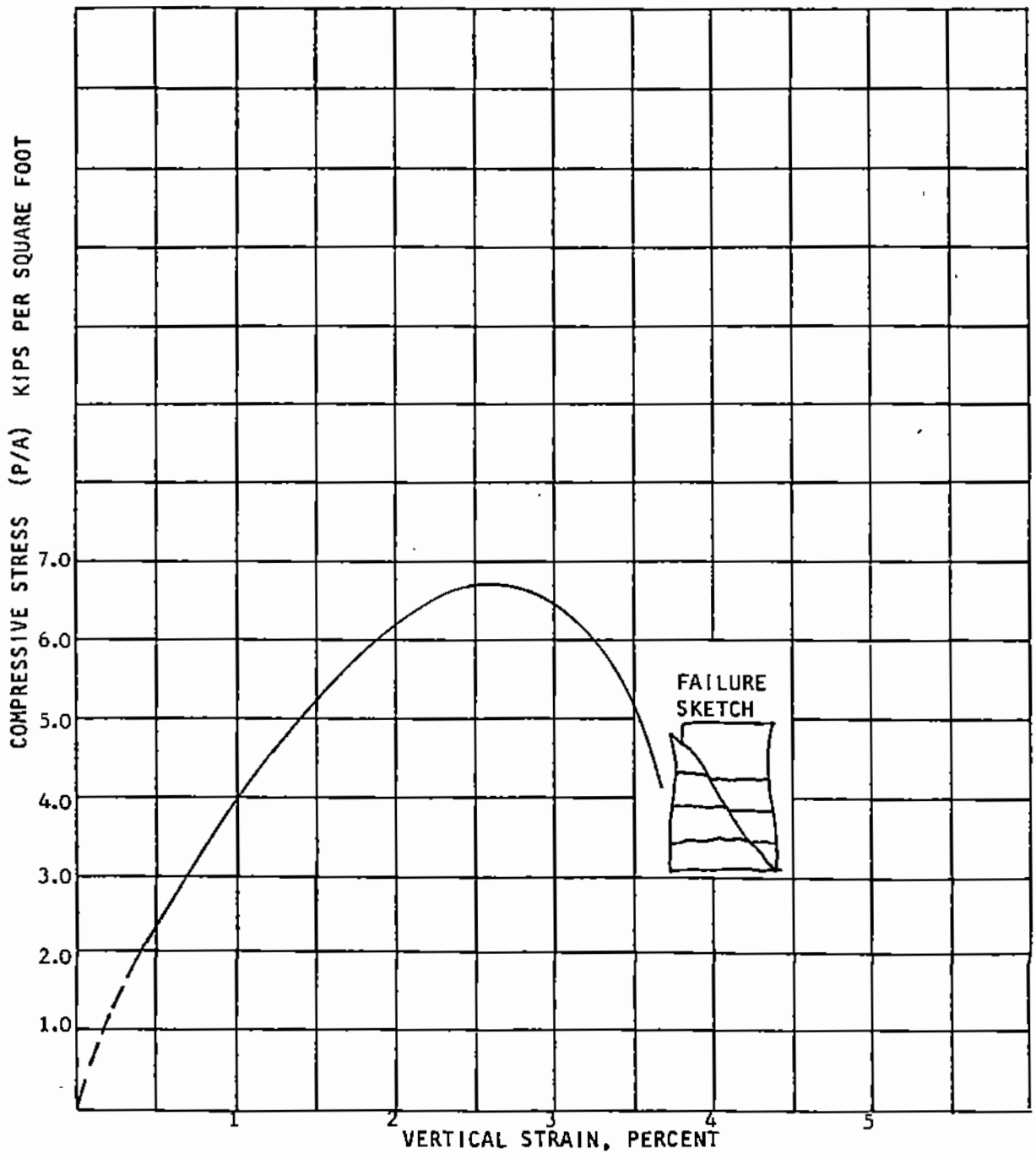
JOB NO. 88-152-1

NET 158

UNCONFINED COMPRESSION TEST

MC DRILL HOLE No. 6
DEPTH 48.5' - 50.0'
SAMPLE NO. 35004

MOIST UNIT WEIGHT: 130 pcf
DRY UNIT WEIGHT : 104 pcf
MOISTURE CONTENT : 26%
CLASSIFICATION : Lean CLAY (with silt lenses
HEIGHT TO DIAMETER RATIO: 1.73:1
RATE OF STRAIN: 1%/minute



MONTANA SILVER VENTURE MINE
MIDAS CREEK SITE

MORRISON KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

Chen-Northern, Inc.
Great Falls, Montana

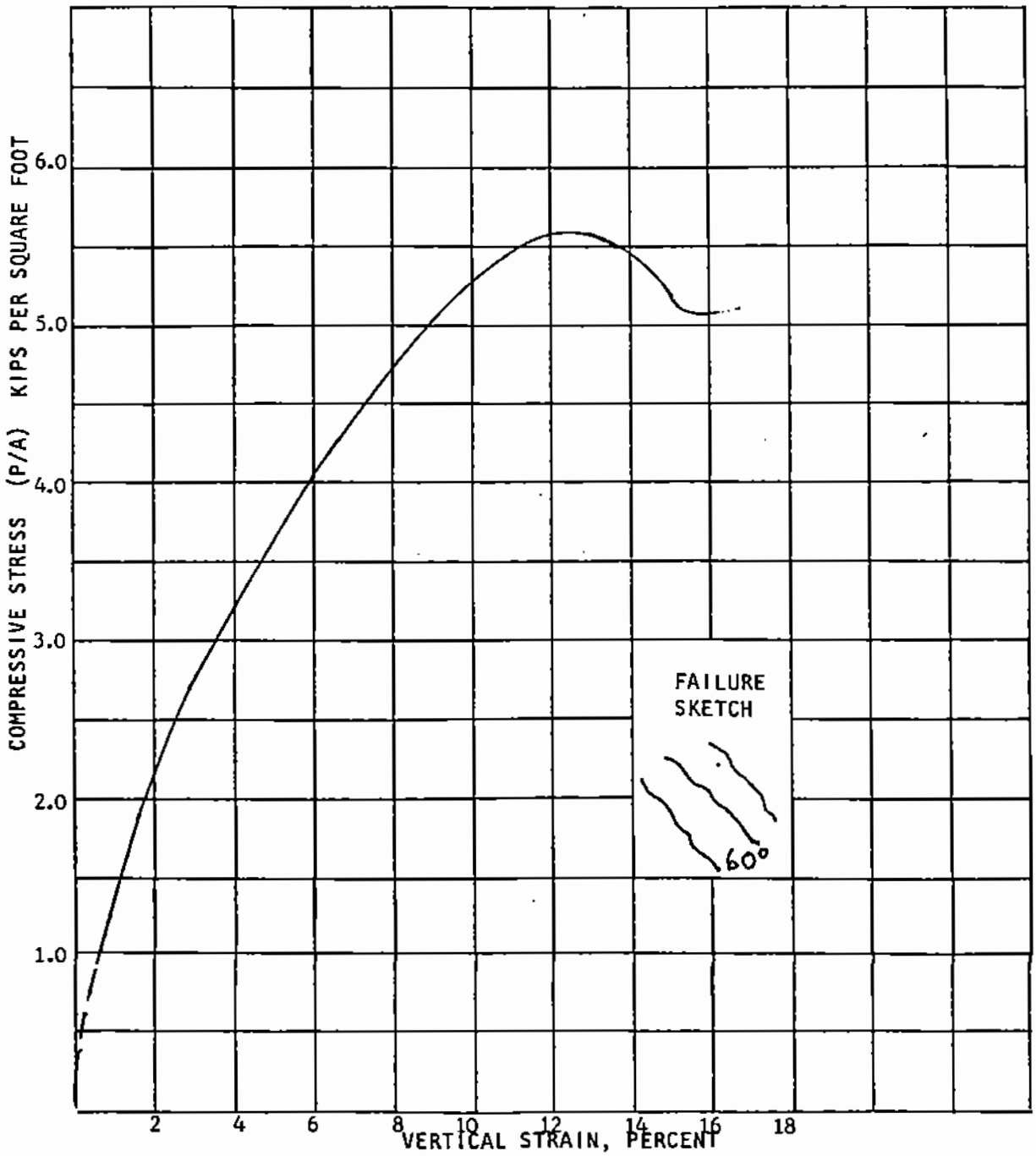
JOB NO. 88-152-1

NET 158

UNCONFINED COMPRESSION TEST

MC DRILL HOLE No. 8
DEPTH 22.0' - 23.5'
SAMPLE NO. 35010

MOIST UNIT WEIGHT: 132 pcf
DRY UNIT WEIGHT : 110 pcf
MOISTURE CONTENT : 20 %
CLASSIFICATION : Lean CLAY with Sand
HEIGHT TO DIAMETER RATIO: 1.74:1
RATE OF STRAIN: 1%/minute



MONTANA SILVER VENTURE MINE
MIDAS CREEK SITE

MORRISON KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

Chen-Northern, Inc.
Great Falls, Montana

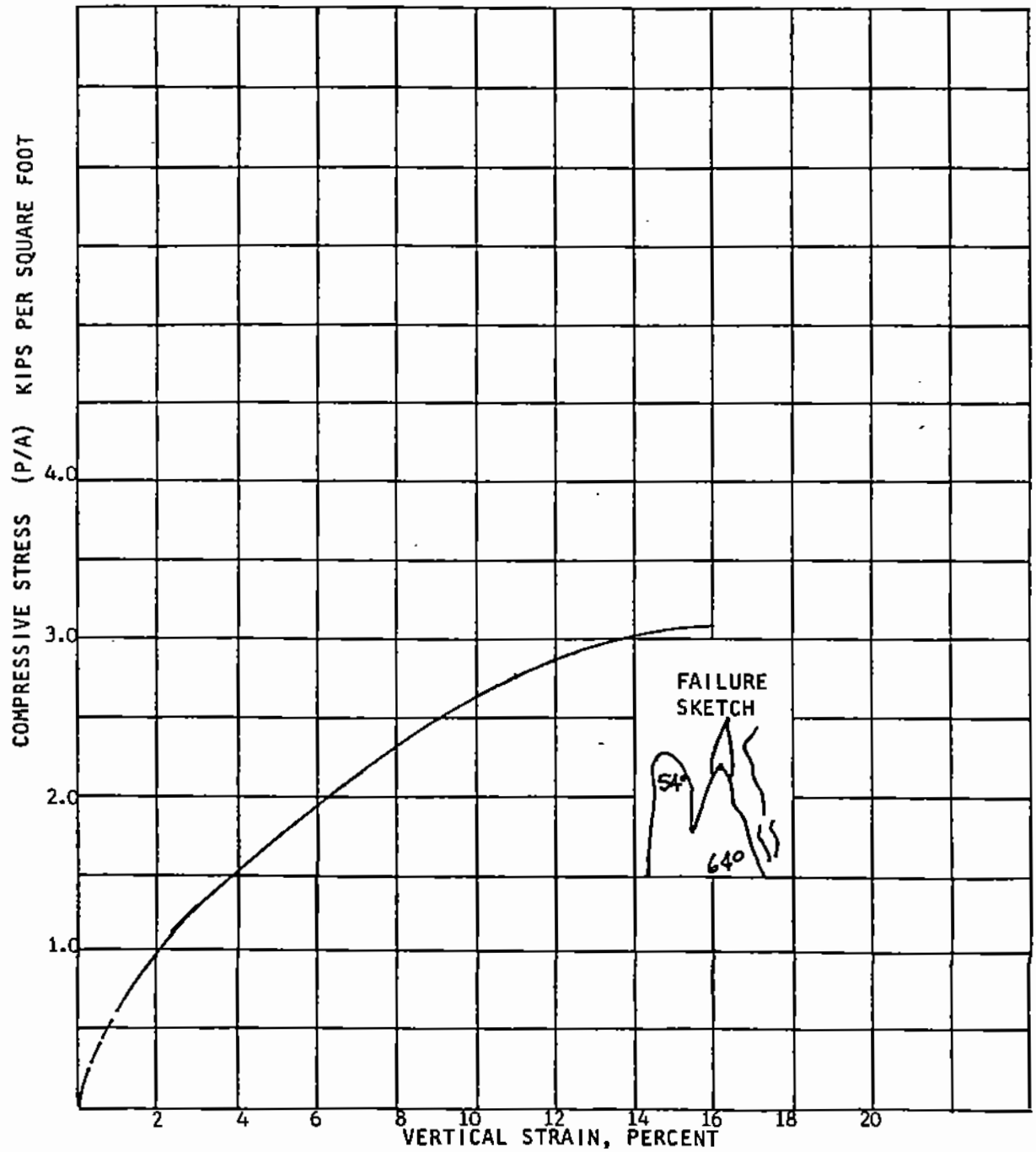
JOB NO. 88-152-1

NEI 158

UNCONFINED COMPRESSION TEST

MC DRILL HOLE No. 9
DEPTH 13.5' - 15.5'
SAMPLE NO. 35019

MOIST UNIT WEIGHT: 128 pcf
DRY UNIT WEIGHT : 105 pcf
MOISTURE CONTENT : 23%
CLASSIFICATION :Sandy Lean CLAY w/Grave
HEIGHT TO DIAMETER RATIO:2:1
RATE OF STRAIN: 1%/minute



MONTANA SILVER VENTURE MINE
MIDAS CREEK SITE

MORRISON KNUDSEN ENGINEERS
SAN FRANCISCO, CALIFORNIA

Chen-Northern, Inc.
Great Falls, Montana

JOB NO.88-152-1

NEI 158