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**ENGINEERING GEOLOGY AND
GEOTECHNICAL ASSESSMENT
TENAS PIT AND WASTE DUMPS**

PREPARED FOR:

MANALTA COAL LTD.

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TABLE OF CONTENTS

	<u>Page No.</u>
EXECUTIVE SUMMARY	i
1. INTRODUCTION.....	1
2. DESCRIPTION OF THE INVESTIGATION	2
2.1 COMPILATION AND REVIEW OF AVAILABLE DATA.....	2
2.2 FIELD STUDIES	2
2.2.1 OPEN PIT SLOPES	2
2.2.2 WASTE DUMPS	3
2.3 OFFICE STUDIES	3
3. ENGINEERING GEOLOGY	5
3.1 SETTING AND PHYSIOGRAPHY	5
3.2 REGIONAL AND LOCAL GEOLOGY.....	5
3.3 SURFICIAL GEOLOGY	6
3.4 STRUCTURAL GEOLOGY	7
3.4.1 FAULTS.....	8
3.4.2 BEDDING	8
3.4.3 JOINT SETS	9
3.5 ROCK STRENGTH AND COMPETENCY	9
3.5.1 UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK.....	10
3.5.2 SHEAR STRENGTH OF DISCONTINUITIES	10
3.5.3 ROCK MASS CLASSIFICATION.....	10
3.5.4 ROCK MASS STRENGTH.....	12
3.6 HYDROGEOLOGY	12
4. PIT SLOPE STABILITY ANALYSIS AND SLOPE DESIGN.....	14
4.1 BASIC SLOPE DESIGN CONSIDERATIONS	14
4.2 PROPOSED SLOPE DESIGN.....	15
4.3 APPROACH TO SLOPE DESIGN	16
4.4 ASSESSMENT OF DEEP SEATED FAILURE OF THE OVERALL SLOPES	16

TABLE OF CONTENTS (Cont'd)

Page No.

4.5 PRELIMINARY SLOPE STABILITY ANALYSES AND DESIGN OF UNBENCHED FOOTWALL SLOPES (DESIGN SECTORS T-1 AND TW-1)	17
4.6 PRELIMINARY SLOPE STABILITY ANALYSES AND DESIGN OF BENCHED FOOTWALL SLOPES (DESIGN SECTOR T-2)	18
4.7 PRELIMINARY SLOPE STABILITY ANALYSES AND DESIGN OF HIGHWALL SLOPES (DESIGN SECTORS T-4 AND TW-2)	20
4.8 PRELIMINARY SLOPE STABILITY ANALYSES AND DESIGN OF END WALL SLOPES (DESIGN SECTORS T-3 AND T-5)	21
4.9 STABILITY ASSESSMENT AND DESIGN OF OVERBURDEN SLOPES	22
5. WASTE DUMP FOUNDATIONS	23
5.1 GEOTECHNICAL PROPERTIES	23
5.2 DUMP STABILITY	24
5.3 SOIL LINER	24
6. GENERAL RECOMMENDATIONS	26
6.1 PIT SLOPES	26
6.2 WASTE DUMPS	27
7. ACKNOWLEDGMENTS	28
8. REFERENCES	29

LIST OF TABLES

TABLE 1	SUMMARY OF ROCK MASS PROPERTIES AND STRENGTHS
TABLE 2	SUMMARY OF RECOMMENDED SLOPE DESIGNS
TABLE 3	SUMMARY OF LABORATORY TEST DATA

LIST OF FIGURES

FIGURE 1	LOCATION PLAN
FIGURE 2	SITE PLAN
FIGURE 3	SECTION 2
FIGURE 4	SECTION 6
FIGURE 5	SECTION 9
FIGURE 6	SECTION 13
FIGURE 7	LOWER HEMISPHERE EQUAL AREA PROJECTION OF AVERAGE JOINT SET ORIENTATIONS MAPPED IN THE PIT 3 AREA (FROM KLOHN LEONOFF, 1985)
FIGURE 8	ESTIMATED ROCK MASS STRENGTHS
FIGURE 9	DISTRIBUTION OF DESIGN SECTORS ON ULTIMATE PIT WALLS
FIGURE 10	RESULTS OF DEEP SEATED ROTATIONAL FAILURE ANALYSES
FIGURE 11	RESULTS OF COMBINED PLANAR/ROTATIONAL FAILURE ANALYSES
FIGURE 12	RESULTS OF BILINEAR SLAB FAILURE ANALYSES
FIGURE 13	MOISTURE CONTENT VS DEPTH (TILL) - WASTE DUMPS
FIGURE 14	PLASTICITY INDEX VS LIQUID LIMIT (TILL) - WASTE DUMPS
FIGURE 15	SPT VS DEPTH (TILL) - WASTE DUMPS
FIGURE 16	COMPRESSIVE STRENGTH VS DEPTH (TILL) - WASTE DUMPS

LIST OF APPENDICES

APPENDIX I	BOREHOLE LOGS
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EXECUTIVE SUMMARY

Introduction

The engineering geology and geotechnical conditions pertaining to open pit and waste dump development in the Telkwa Project have been defined in a series of programs as follows:

- | | |
|-----------------------------|---------|
| • Pit 3 | 1983-85 |
| • Pits 7 and 8 | 1990-93 |
| • Tenas West and Tenas Pits | 1996 |

This Executive Summary describes the results of geotechnical/rock mechanics/pit slope design studies carried out in support of the Pit 7, Pit 8, and Tenas Creek portions of the Telkwa Coal Project near Telkwa, B.C. Studies for the Pit 7 and Pit 8 areas were conducted in 1993 and summarized in the Piteau Engineering Ltd. (PEL, 1994a) report entitled "Engineering Geology and Geotechnical Assessment for the Pit 7 & Pit 8 Areas". The Tenas Creek area was investigated in 1996, with results of these studies being summarized in the PEL report entitled "Engineering Geology and Geotechnical Assessment of the Tenas Pits and Waste Dumps."

Description of the Investigations

Investigations for the two studies were initiated by compiling and reviewing available data. Specifically, geologic maps and cross-sections, core photographs, drillhole logs and old reports (particularly a Klohn Leonoff (March, 1985) report prepared for Crows Nest Resources Ltd. for the proposed Pit 3 area) were reviewed. Subsequent to this, field studies were carried out, including geotechnical core logging, Point Load Index strength testing and limited geologic mapping.

Office studies initially involved preparation of a surficial geology map based on air photo interpretation and with regard to pit slope stability analysis, compilation of the field data. Mapping, core logging and Point Load testing data were processed and core logs were prepared, following which rock mass competency assessments for the various geotechnical units were carried out. Based on this, the structural and lithologic characteristics of the various portions of the rock mass were defined and a geotechnical model for the various pit walls was prepared. Kinematically possible failure modes and other possible failure mechanisms, including deep seated failure, were evaluated for each wall. Subsequently, relevant stability assessments were carried out for the various slopes in the pits, and preliminary slope design recommendations were prepared.

Engineering Geology

The project area is located within the northeast/southwest trending Skeena Arch, which separates the Jurassic age sedimentary rocks of the Bowser Basin in the north and the Nechako Basin to the south. Major valleys, such as the Bulkley River valley, are interpreted to lie along fault zones. The Telkwa coal lease is underlain by a coal-bearing sedimentary sequence comprising siltstone, sandstone, mudstone and shale strata known as the Skeena Group (Red Rose Formation) of Lower Cretaceous age. The coal-bearing Lower Cretaceous Skeena Group can be subdivided into four upper units (*i.e.*, Units 1 through 4) and a unit of undivided sediments. The economic

coal seams in the Tenas Creek area are located within Unit 1, an approximate 120 mm thick sequence of interbedded coal and sedimentary rocks. This unit is overlain by Unit 2 sedimentary rocks and Telkwa Formation volcanic rocks. The economic Seams in the Pit 7 and Pit 8 areas (seams #2 through 11) are located within Unit 3, which lies about 100 m stratigraphically above Unit 1.

Soil overburden is dominated by an extensive deposit of glacial till which ranges gradationally from a sandy silt to a silty clay, with minor gravel. The till is low plastic and of stiff to very stiff consistency. The till ranges in thickness from less than 3-4 m to more than 10 m. On the north side of the Tenas Pit, towards and beyond Tenas Creek, the bedrock surface forms a depression which is overlain by a thick (exceeding 100 m) deposit of highly permeable sand and gravel outwash. A buried channel is present in the northwest corner of the Tenas Pit waste dump sites. Channel fill materials range from clays to sands and gravels.

On the north side of the Telkwa River, the area around Pits 7 and 8 is underlain by till which lies directly on either sedimentary or volcanic bedrock.

A thin veneer (<200 mm) of organic topsoil covers most of the waste dump foundation areas. Its presence is not expected to adversely affect dump stability.

Pit Slopes

Structural Geology

The sedimentary sequence in the Tenas Pit area is folded into an upright syncline in which the gently northeastward dipping (typically 10 to 20°) western limb of the syncline subcrops on the western side of the pit area, while the moderately southwestward dipping (40 to 45°) eastern limb subcrops on the eastern side of the pit. In the Pit 7 and Pit 8 areas, the sedimentary sequence generally dips to the east and northeast at between about 10 and 30°, subcropping on the western side of the pit areas.

Faulting in the region is generally near vertical, and can be subdivided into two main groups, one which strikes approximately northwest/southeast and the other which strikes approximately northeast/southwest. A few east/west striking faults have also been interpreted. While no sedimentary bedrock exposures were available in the Pit 7, Pit 8 and Tenas Pit areas, it is expected that a similar spatial relationship between bedding joints and cross-joints exists in these pit areas as was found in the Pit 3 area, and which has been observed in many other sedimentary rock masses. That is, it is anticipated that one main set of cross-joints will strike essentially parallel to bedding and dip normal to bedding, while a second main set of cross-joints will strike approximately perpendicular to bedding and dip subvertically. Other weakly developed minor joint sets may occur locally. In the intrusive rocks in the Pit 7 and Pit 8 areas, up to four joint sets were identified, all but one of which dip near vertical.

Rock Strength

With respect to strength, the intrusive rocks in the Pit 7 and Pit 8 areas are by far the strongest rocks that will be exposed in any of the pits. In this regard, the Unconfined Compressive Strength (UCS) of the intrusives is in the order of 200 MPa, while most of the sedimentary rocks have a UCS of less than about 40 MPa. Rock mass classification confirms that the intrusives are

the most competent rocks that will be exposed in the pits, with these rocks generally classified as being of very good rock quality (relatively high rock mass strength), as opposed to the sedimentary rocks, which are considered to be of a fair to good rock quality.

Groundwater

Based on recent hydrogeological studies, the groundwater table configuration in the various pit areas generally appears to mirror the topography (PEL, 1997b). Field testing indicates that the hydraulic conductivity of the sedimentary rocks is in the order of 2.1×10^{-8} - 6×10^{-6} m/s. It is also estimated that a linear horizontal flow velocity of about 10 to 250 m/year can be expected.

Slope Stability Analysis and Slope Design

The proposed slope designs for the pit walls in the Pit 7, Pit 8 and Tenas Pit areas are comprised of unbentched footwalls on the western sides of the pits (along the base of the lowest economic coal seam) and footwalls, highwalls and endwalls on the remaining slopes. To arrive at preliminary slope design recommendations for the various slopes, assessments were carried out for both deep seated failure, as well as bench scale failure to evaluate the optimum geometry required to control failure and ravelling of individual benches on the slopes.

Preliminary assessments of deep seated failure of the sedimentary rocks were conducted using the rock mass strengths. These analyses were carried out based on a two-dimensional, limit equilibrium analysis using the Bishop Simplified Method of Slices. Numerous slip surfaces were examined for each of the slopes analyzed to arrive at a critical slip surface with a minimum factor of safety. Analyses results for overall slopes excavated in sedimentary rocks indicate that within the range of slope heights and slope angles proposed for the pits, the Factor of Safety is expected to be in excess of 1.2. As the rock mass strength of the intrusive rock is considerably higher than that of the sedimentary rocks, deep seated failure of this rock unit does not appear to be possible for the range of slope heights that are envisioned in Pit 7 and Pit 8.

With respect to the proposed unbentched footwalls on the western side of the pits, because the footwall rocks in the pit areas appear to be moderately competent, it does not appear that there are any critical failure modes that are likely to compromise the overall stability of these slopes. Thus, the proposed unbentched slope designs are considered acceptable. Notwithstanding this, it is possible that some faults, local rolls or undulations in the bedding will lead to bedding being undercut and to some failures on the footwalls. The footwall slopes should be excavated by ripping or by other non-explosive techniques next to the final wall. While groundwater conditions behind the footwall are not expected to create a stability concern in most areas, it is recommended that groundwater pressures be monitored on an ongoing basis and that depressurization measures (likely in the form of pressure relief wells or horizontal drainholes) be carried out if required.

On the eastern side of the southern portion of the Tenas Pit, where an unbentched footwall slope has been proposed, bilinear slab failure analyses indicate that such a slope would be stable. However, as there are a number of uncertainties associated with the analyses (such as the presence of coal stringers and bentonite, waviness of the bedding, etc.), it is recommended that the proposed slope be excavated as a bentched footwall. The recommended slope design criteria

are summarized in Table 2 of the Tenas Pit report. It is likely that depressurization measures, in the form of horizontal drainholes, will be required.

For the highwall and end wall slopes in sedimentary rocks, it would appear that bench scale plane and wedge failures on cross-joints will control the slope design. Similarly, for the slopes that will be excavated in intrusive rocks in the Pit 7 and Pit 8 areas, bench scale planar and wedge failures are expected to control slope design. Slope design criteria for all of these slopes are summarized in Table 5 of the Pit 7 and Pit 8 report and in Table 2 of the Tenas Pit report. Controlled blasting techniques should be utilized when mining these final wall slopes.

With respect to the Pit 3 mining area, recommendations contained in Klohn Leonoff (1985) indicate that overall highwall and end wall slope angles of up to 60° may be feasible. While such slope angles may be achievable from a deep seated stability standpoint, it is unlikely that it would be feasible to develop 60° overall slope angles within practical bench design criteria. Considering this, it is recommended that the slope design criteria summarized for the highwalls and end walls in the Pit 7 and 8 areas be used for preliminary slope design purposes in the Pit 3 area. As bedding dips in the Pit 3 area are understood to be in the 10 to 20° range, unbenched footwall slopes should be used in this pit as well.

Soil overburden in the vicinity of the pit walls is estimated to range up to 25 m in thickness. Excavated slopes in soil should not exceed 1.5 horizontal to 1 vertical.

Waste Dumps

Waste dump sites were investigated by a combination of test pits (Pits 7 and 8 area) and boreholes (Pit 3 and Tenas Pit area) and field mapping of soil exposures. At all sites, the foundations of the proposed dumps were determined to be underlain by glacial till. The foundations are generally suitable for supporting the waste dumps, subject to normal operational constraints, such as limiting the height of individual platforms and rate of dump advance.

Waste dump materials will consist of a mixture of broken sandstone, mudstone and shale, and morainal soils from the open-pit excavations. The waste rock is expected to comprise a variety of material sizes and strengths, with a significant percentage of the material being relatively weak shales and mudstones. As no test data are directly available for the dumped waste rock, predicted behavior is based on corehole samples collected during investigation of the coal deposit and on experience gained from mine waste dumps comprising similar materials. The waste rock is estimated to have a friction angle of approximately 37° with no cohesion.

Each waste dump will be constructed as a series of wraparound platforms at successively higher or lower lifts, forming an overall slope of 2:1 (H:V), the maximum slope generally planned for abandonment. The waste dumps are expected to behave as free-draining, loose to moderately dense rock fills. As such, each dump face will tend to assume the angle of repose, which is estimated to be approximately 37 degrees.

The factors of safety of individual dump platforms will be determined during the detailed engineering phase of pit and dump design. At this stage, the risk and extent of large scale instability will be assessed. However, based on the favourable foundation conditions, the ability

to control the dump geometry and loading rate (to minimize pore pressure generation), and to restrict entry of surface water into the dump, large scale instability is not anticipated to be a problem at any of the dump sites.

Portions of the waste dumps may contain rock types which have the potential to generate acidic runoff. In such areas, it is planned to construct a soil sealing layer of sufficiently low permeability beneath the dump to serve as a liner to minimize infiltration into the underlying ground. The sealing layer would be shaped and graded to collect water penetrating through the dump and direct it via channels to one or more runoff retention ponds.

Eventually, as mining is completed in individual pits, wherever practical, the available space will be utilized for backfilling waste rock mined from adjacent pits.

1. INTRODUCTION

Piteau Engineering Ltd. (PEL) was retained by Manalta Coal Ltd (Manalta) to conduct a series of geotechnical and hydrogeological investigations in support of the proposed Telkwa Coal Project near Telkwa, B.C. This report summarizes the geotechnical/rock mechanics studies carried out in 1996 and addresses pit slope design and waste dump siting aspects. The report parallels additional geotechnical and hydrogeological studies by Piteau Engineering Ltd. (PEL) for the tailings pond (PEL, 1997a), and baseline hydrogeological conditions in Tenas Pit, the waste dumps, and Pit #3 areas (PEL, 1997b). The scope of work was based on meetings and discussions with Manalta Coal Ltd. (Manalta) staff, and was outlined in a proposal submitted to Manalta on July 5, 1996.

The report provides general engineering geology and geotechnical parameters for two mining areas located on the south side of the Telkwa River, namely the Tenas Pit and the Tenas West Pit areas, as defined by Manalta and shown on the location plan in Figure 1.

The field work was conducted in late July and August, 1996. Office studies, analyses and report preparation were ongoing from September, 1996 to January, 1997.

2. DESCRIPTION OF THE INVESTIGATION

2.1 COMPILATION AND REVIEW OF AVAILABLE DATA

As some engineering geology information was available for the project area in general, a review of all such data was conducted prior to carrying out the field work. This information included old reports, a general geologic map, a surficial geology map and geologic cross-sections. Of particular interest and relevance were a Klohn Leonoff (March, 1985) report prepared for Crows Nest Resources Ltd. for the Pit 3 area, entitled "Stage II Geotechnical, Hydrological, and Hydrogeological Design Report", and the PEL (January, 1994) report for the Pit 7 and Pit 8 areas, entitled "Engineering Geology and Geotechnical Assessment for the Pit 7 and Pit 8 Areas". Relevant data from these reports, including rock strength testing results, rock competency assessments, stability analyses, results, etc. were reviewed. Discussions regarding geotechnical requirements for the 1996 coring program were also held between PEL and Manalta.

2.2 FIELD STUDIES

2.2.1 OPEN PIT SLOPES

Field studies for the program, consisting of geotechnical core logging and sampling, were conducted by Mr. A. Stewart, P.Eng. and Mr. C. Bisailon of PEL between July 29 and August 2, 1996 and between August 19 and 21, 1996. With respect to geologic structural mapping, a very limited amount of such mapping was carried out at one small outcrop of volcanic rock to the south of the proposed mine area. The presence of deep overburden across the site prevented geologic structural mapping of any of the sedimentary rock.

Geotechnical core logging was conducted on 450 m of 75 mm diameter core from four coreholes in the 1996 drilling program (see Figure 2 for corehole locations) that collectively penetrated all of the portions of the rock mass that are anticipated to be exposed on the pit walls. Geotechnical parameters that were recorded include core recovery; Rock Quality Designation (RQD); rock hardness; degree of breakage; frequency of natural bedding joints; frequency of natural cross-joints; joint condition; degree of weathering; and dip of bedding (where possible).

To provide additional data concerning the strength of intact rock, representative samples of the drill core were returned to our laboratory, where a limited amount of Point Load Index testing was conducted.

2.2.2 WASTE DUMPS

An investigation program was conducted at potential waste dump sites around the perimeter of the Tenas Pit. A total of nine holes (Figure 2 - denoted by the prefix TOB96) were drilled under the supervision of PEL personnel. These borehole logs are presented in Appendix I. Three additional sites (denoted by the prefix T96R) were also drilled without PEL involvement as exploration holes. Driller's logs for those boreholes provide approximate information on overburden lithology.

Soil samples were obtained from the boreholes at selected intervals using both split spoon and Shelby tube sampling techniques. Where split spoon samples were obtained, a standard penetration test was also conducted. The unconfined compressive strength of split spoon samples was measured in the field using a pocket penetrometer. Shelby tube samples were sealed in the field and used for laboratory permeability tests.

2.3 OFFICE STUDIES

Geotechnical core logging data were compiled and processed, and core logs were prepared (Appendix I). These data, along with the results of the Point Load Index testing, were used as the foundation for rock mass competency assessments. Based on the above, and on an assumed spatial relationship between bedding and cross-joints, the structural and lithologic characteristics of the rock mass were defined. This information, along with other available information, was then used to prepare a geotechnical model for the various pit walls. As it became apparent by the completion of the field studies that it was extremely unlikely that the volcanic rocks in the area would be exposed on any of the pit walls, or would otherwise influence the pit walls in any way, compilation and processing of the mapping data from the volcanic outcrop were not conducted.

Kinematically possible failure modes and other possible failure mechanisms, including deep seated failure and bilinear slab failure, were evaluated for each wall. Subsequently, relevant stability assessments were carried out for the various slopes in both the Tenas and Tenas West Pits, and preliminary pit slope design recommendations were developed.

3. ENGINEERING GEOLOGY

3.1 SETTING AND PHYSIOGRAPHY

The proposed Tenas and Tenas West Pits are located approximately 14 km southwest of Telkwa and 6 km south of the Telkwa River, between Tenas Creek and Four Creek (Figures 1 and 2). Natural topography in the pit areas ranges from approximately 850 - 1075 metres above sea level (masl). Most of the terrain in the area is gentle to moderate, typically sloping to the north and northeast at about 5 to 10°, with occasional flatter and steeper areas. Vegetation cover is moderate to heavy, and the above noted creeks appear to be the only streams of any significance in the area.

3.2 REGIONAL AND LOCAL GEOLOGY

The regional and local geology in the project area has been assessed and described by others. The following is based on information previously provided by Manalta.

The project area is located within the northeast/southwest trending Skeena Arch, which separates the Jurassic age sedimentary rocks of the Bowser Basin in the north and the Nechako Basin to the south. Major valleys, such as the Bulkley River valley, are interpreted to lie along fault zones. The Telkwa coal lease is underlain by a coal-bearing sedimentary sequence comprising siltstone, sandstone, mudstone and shale strata known as the Skeena Group (Red Rose Formation) of Lower Cretaceous age. The sedimentary rocks are underlain by an undifferentiated group of Lower Jurassic volcanic rocks, (*i.e.*, including andesite, trachyte, and basalt with associated tuffs and breccias) of the Hazelton Group (Telkwa Formation). Both the Skeena Group and the Hazelton Group have been intruded by a quartz feldspar porphyry of Late Cretaceous age.

The coal-bearing Lower Cretaceous Skeena Group can be subdivided into four upper units (*i.e.*, Units 1 through 4) and a unit of undivided sediments. The economic coal seams in the Tenas and Tenas West Pit areas (*i.e.*, essentially coal seam C and coal seam #1 packages, as illustrated in Figures 3 to 6) are located within Unit 1, an approximately 120 m thick sequence of interbedded coal, sandstone, siltstone, conglomerate and mudstone.

This unit is overlain and underlain by Unit 2 and the Telkwa Formation volcanic rocks, respectively, with Unit 2 being comprised primarily of marine mudstones and siltstones. It is noteworthy that 5 to 16 cm thick seams of bentonite have been identified, either within coal seam #1 or within about 5 m above or below this coal seam. Furthermore, a number of thin seams or stringers of coal have been observed in core and/or detected in geophysical logs below the footwall of coal seam #1 (the lowest of the economic coal seams), with the zone containing the stringers having a stratigraphic thickness of about 20 to 25 m. Based on a review of a limited number of core logs, and discussions with Manalta personnel, it would appear that these coal stringers vary considerably in thickness and continuity over the proposed pit areas.

3.3 SURFICIAL GEOLOGY

At surface, a sandy to silty clay glacial till appears to form a continuous unit. The till is predominantly a silty till, but ranges from a sandy till to a silty clay till with minor to some gravel and a trace of sand. Colour changes from medium brown near surface to dark grey-brown at depth. The till is stiff to very stiff and is estimated to have a very low plasticity.

The surficial geology beneath the proposed pits and waste dumps sites was determined from airphoto interpretation and borehole drilling and is described in detail in PEL (1997b). The overburden is highly variable over the lateral extent, but is dependent on the depth to bedrock, which generally increases to the north.

The waste dump sites are underlain by glacial till which ranges in thickness from 3.75 m at TOB96-12, to 13.5 m at T96R-83. The till blanket is thinnest where it is deposited directly on the bedrock surface (e.g., TOB96-01 (4.6 m), TOB96-12 (3.75 m)) and generally thickest where it overlies outwash sediments. On the east side of Tenas Pit, a relatively thin till blanket of 6.2 m (TOB96-02) and 6.0 m (TOB96-18) overlies more permeable sands and gravels.

Where the overburden is more than approximately 10 m thick, bedrock is overlain by high permeability sand and gravel outwash deposits. The thickest accumulation (106 m) of outwash sediments was encountered within the northwest corner of the Tenas Pit waste dump sites at TOB96-04 (Figure 2). A buried channel was encountered at this location where the depth to

bedrock exceeds 117 m. Channel fill material ranges from clays to sands and gravels. Other significant accumulations of outwash sand and gravel deposits overlying bedrock were encountered at boreholes TOB96-02, TOB96-03, TOB96-11 and TOB96-18 (Figure 2).

Bedrock was encountered at depths of between 4.6 m and 117 m below grade. Bedrock consists of either volcanic ash or siltstone/mudstone. The volcanic ash is purplish red and white coloured and exhibits fine sandy coatings. The siltstone is blue gray coloured, soft to hard in consistency and massive in structure, while the mudstone is dark red brown coloured, rhyolitic, fine grained, very hard in consistency and highly weathered.

The geotechnical properties of the surficial materials are described in Section 5.1.

3.4 STRUCTURAL GEOLOGY

The sedimentary sequence in the main Tenas Pit area is folded into an upright syncline that plunges to the northwest at about 3 to 4°. As can be seen from the sections in Figures 3 to 5, the gently northeastward dipping western limb of the syncline subcrops on the western side of the pit area, while the moderately southwestward dipping eastern limb of the syncline subcrops on the eastern side of the pit area. In the Tenas West Pit area, where the gently northeastward dipping footwall also subcrops on the western side of the pit area (see Figure 6), the coal seams have been cut off at depth by what is assumed to be a near-vertical fault.

The footwall slopes within the pit areas will be formed along the base of coal seam #1. The eastern slope of the Tenas West Pit and the northern portion of the east wall of the main Tenas Pit will be excavated in gently northeastward dipping sedimentary rocks that lie stratigraphically above coal seam #1.

Prediction of geologic structural conditions likely to be encountered in the vicinity of the final walls of the pits requires that structural data be obtained and assessed. For the sedimentary rock, no exposures of bedrock were available in either the Tenas Pit or Tenas West Pit areas. Hence, determination of bedding dip was based on interpretation of exploration drilling results,

extrapolation of structural data reported by Klohn Leonoff (1985) for the Pit 3 area, and assessment of anticipated spatial relationships between bedding and related joint sets.

3.4.1 FAULTS

Current information indicates very little evidence of the presence of faults in the Tenas Pit portion of the project area. Other than an apparent near-vertical northwest/southeast striking fault that cuts off the coal seams in the Tenas West Pit area, and the possibility of a second fault in the southern portion of the main Tenas Pit area, the only information available is from regional mapping and from previous geologic investigations of the Pit 3, Pit 7 and Pit 8 areas. In this regard, faulting in the area can generally be subdivided into two main groups, one which strikes approximately northwest/southeast and the other which strikes approximately northeast/southwest. A few east/west striking faults have also been interpreted. Although the offset on the faults is not known, offsets of at least 50m are not uncommon in other parts of the project area.

3.4.2 BEDDING

Geologic interpretation of exploration drilling results indicates that in the main Tenas Pit area, bedding typically dips between about 10 and 20° to the northeast, with locally steeper and flatter areas (see Figures 3 to 5), on the western limb of the syncline. Toward the south end of the west wall, bedding dips of between about 25 and 40° also appear to be present in the upper reaches of the slope. Structural contours of the base of coal seam #1 indicate that bedding is likely to be wavy, both along strike and down dip. On the eastern limb of the syncline in the southern portion of the pit, bedding has been interpreted to typically dip approximately 40 to 45° to the southwest.

In the Tenas West Pit area, it would appear that bedding dips 10 to 20° toward the northeast (see Figure 6), similar to that expected over much of the western limb of the syncline in the main Tenas Pit. Some warping of the bedding, both along strike and down dip, is also expected in this pit.

3.4.3 JOINT SETS

Results of geologic mapping carried out in a test pit in the Pit 3 area were summarized in Klohn Leonoff (1985) and are illustrated in the lower hemisphere equal area projection in Figure 7. In this projection, where bedding dips an average of 14° toward 050° , it can be seen that bedding and the other two joint sets are approximately orthogonal. In this regard, Joint Set A, which has an average dip direction/dip of $212/62$, strikes approximately parallel to bedding and dips moderately steeply to the southwest, while Joint Set B, which has an average dip direction/dip of $122/84$, strikes almost perpendicular to bedding and dips near vertical.

While no bedrock exposures were available in the Tenas and Tenas West areas, it is expected that a similar spatial relationship between bedding joints and cross-joints exists in these pit areas as was described above for the Pit 3 area, and which has been observed in many other sedimentary rock masses. That is, it is anticipated that one main set of cross-joints will strike essentially parallel to bedding and dip normal to bedding, while a second main set of cross-joints will strike approximately perpendicular to bedding and dip sub-vertically. As has been observed in similar geologic environments, other weakly developed minor joint sets may occur locally. However, any such joint sets are not expected to be sufficiently continuous or well developed to have a controlling influence on wall stability.

3.5 ROCK STRENGTH AND COMPETENCY

In addition to the structural geology aspects described above, a rational prediction of the likely behaviour of a rock mass also requires an assessment of the general physical and mechanical properties of the rock mass. Such parameters as unconfined compressive strength, rock mass strength, susceptibility to mechanical deterioration, alteration, etc., may be of key importance in evaluating rock mass behaviour. In this regard, a preliminary rock mass quality/competency assessment was conducted based on simple index tests, field observations of drill core, and an initial assessment that the rock mass could be subdivided into two main lithologic/geotechnical units; all rock stratigraphically above the footwall of coal seam #1, and all rock below the footwall of coal seam #1. While the rock types that comprise each of the geotechnical units range from fine sandstone to siltstone and mudstone, the differences between these rock types is

often subtle, with contacts being indistinct and gradational. Results of this assessment are discussed in the following.

3.5.1 UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK

Point Load Index testing was carried out on representative cores of mudstone, siltstone and fine sandstone to obtain a preliminary estimate of the unconfined compressive strength (UCS) of the rock within the proposed mine areas. Results of the testing are summarized on Table 1, and indicate that the portions of the rock mass above and below coal seam #1 have essentially the same diametral strength (16 to 22 MPa) and axial strength (36.4 to 36.8 MPa). The strength anisotropy index (defined as the ratio of the strength perpendicular to bedding (axial strength) to the strength parallel to bedding (diametral strength)) is also similar for both lithologic/geotechnical units, being in the order of 2. It is noteworthy that the gradational nature of the various rock types within each of the two geotechnical units resulted in their being very little difference in the unconfined compressive strength between rock types. As such, there was no justification for subdividing each geotechnical unit by rock type.

3.5.2 SHEAR STRENGTH OF DISCONTINUITIES

Preliminary estimates of shear strength along discontinuities were determined based on the results of limited laboratory testing conducted by Klohn Leonoff (1985) and on visual observations. Based on this, it would appear that bedding joints in the sedimentary rocks will have little or no cohesion and a lower bound residual friction angle of about 23°. It is noteworthy that this friction angle is the same as has been determined for carbonaceous bedding joints for numerous other similar environments. Natural cross-joints are expected to have zero cohesion and a lower bound residual friction angle of at least 30°.

3.5.3 ROCK MASS CLASSIFICATION

Several rock mass classification systems are available for estimating rock competency and rock mass strength based on a number of geotechnical parameters related to material strength, fracture frequency, joint condition, in-situ stress and groundwater conditions. A range of values is

assigned to each of these parameters, the rock mass is classified according to the estimated value of each parameter, and a rating is determined by applying a specific formula incorporating the parameters. For this study, the CSIR Geomechanics Classification System, or Rock Mass Rating (Bieniawski, 1976) was utilized. We have found this classification system to be the most applicable to open pit slope design.

Analysis of the overall strength and mechanical characteristics of the rock mass is based largely on an assessment of the geotechnical parameters recorded on the core logs in Appendix I. Assessment of the rock mass using the Geomechanics Classification System was carried out for the two geotechnical units discussed above. Weighted average values for estimated Rock Mass Rating (RMR), UCS, and RQD were calculated for each of the two units for the four coreholes that were geotechnically logged. RMR was calculated according to the Geomechanics classification as recommended by Hoek and Brown (1988), and a groundwater rating of 10, equivalent to completely dry conditions, was used for all observations.

The results of rock mass rating and strength estimates are summarized in Table 1, and indicate that the RMR, UCS and RQD for the two geotechnical units are almost identical. As such, it was concluded that there is no significant difference between the two geotechnical units, and an assessment of these parameters for a single, combined geotechnical unit (for all rock above and below coal seam #1) was conducted (see Table 1). Subsequent assessments and analyses were conducted assuming rock mass parameters for the combined geotechnical unit.

As a final step in the determination of average rock mass “design” parameters that could be used to determine the design strength of the rock mass, the results of the Point Load Index testing were considered. These “design” parameters, representing the range of strengths defined by both axial and diametral Point Load Testing, are also summarized in Table 1. It is noteworthy that the UCS as determined from axial Point Load testing is in very close agreement with the UCS as determined from core logging.

3.5.4 ROCK MASS STRENGTH

The strength parameters used for slope design depend on the strength of discontinuities and intact rock, the scale of the slope, the stability analysis method and the design technique used. If the intact rock strength is sufficiently low or the slope is sufficiently high or steep, it is possible that stress conditions may induce failure through the rock mass. Failure through the rock mass would be along a surface developed by a combination of sliding along discontinuities and failure through intact rock.

A rock mass is defined as an isotropic, discontinuous and heterogeneous medium made up of interlocking blocks of intact material separated by discontinuities. Rock mass strengths have been estimated using the criteria developed from Hoek and Brown (1988). This method employs a set of empirical equations from which Mohr failure envelopes can be developed over the range of stresses expected in the slope. Selection of the equation used to model the strength of the rock mass is based principally on assessments of rock mass quality, rock type and unconfined compressive strength. Rock mass quality has been related to the Rock Mass Rating (RMR) system discussed above.

Mohr envelopes for the range of design values of UCS are illustrated in Figure 8, where, as expected, it can be seen that the axial rock mass strength is greater than the diametral rock mass strength. Estimated Mohr-Coulomb strength parameters for normal stress in the range of 1.9 to 2.5 MPa are summarized in Table 1; this range of normal stresses approximates a maximum depth to possible failure surface of 75 to 100 m, and is considered reasonable for possible failure of the slope heights being evaluated.

3.6 HYDROGEOLOGY

Groundwater surface elevations in coal seam #1 range between 893.6 - 1011.2 masl, with groundwater flow interpreted to be in a northeasterly direction (mirroring the slope of the topography) under a horizontal hydraulic gradient of 0.1 (PEL, 1997b). Static water levels in four of seven piezometers completed in coal seam #1 around the proposed pit areas are above the ground surface (flowing artesian conditions exist).

Hydraulic conductivities for the various coal seams that were tested in the proposed pit areas range between 2.1×10^{-8} - 6.0×10^{-6} m/s. This is compatible with the range of hydraulic conductivity values reported in the Pit 7 and Pit 8 areas (PEL, 1994b).

The average linear horizontal flow velocity in the #1 Seam is estimated to be 115m/year, which is comparable to velocities estimated in the Pit 7 and Pit 8 areas. However, if the effects of local fault and fracture zones are taken into account, groundwater flow velocities in the range of 10 to 250 m/year may be expected.

Taking into consideration results from the hydraulic conductivity testing conducted as part of the 1996 investigation program (PEL, 1997b), potential groundwater inflows to the Tenas Pit previously estimated by PEL (1996) generally remain valid, but may be somewhat conservative.

Based on data from a double piezometer nest in one drillhole, it would appear that vertical hydraulic gradients between coal seam #1 and an underlying seam are very low. This may indicate that these two coal seams are hydraulically connected at this location.

4. PIT SLOPE STABILITY ANALYSIS AND SLOPE DESIGN

4.1 BASIC SLOPE DESIGN CONSIDERATIONS

In rock slopes, instability may result from failure along structural discontinuities such as bedding, joints, geological contacts, faults, etc. In high slopes or slopes in relatively weak rock, instability may also develop as a result of failure through intact rock or along a deep seated failure surface consisting of a combination of discontinuities and intact rock. In these cases, an assessment of the rock mass strength is required.

When assessing failure mechanisms related to structural discontinuities, the most important factors in slope stability analyses and design are the orientation, geometry, and spatial distribution of discontinuities in the slope. In terms of kinematic assessments, it is important to evaluate these discontinuities with respect to both orientation and alternative possible angles of the proposed pit slope. It is following these basic principles that slope stability analyses were carried out.

Slope control can be basically accomplished in two ways:

- a) by designing the slope so that no failures occur; or
- b) by excavating the pit slope under controlled conditions and designing the slope with adequate access so that failures can be caught on berms and removed, if necessary.

The first solution is often too conservative to be economically feasible. The second solution requires consideration of slope geometry so that failures are contained on berms and safe access is available to the berms to allow removal of debris, if required. This solution is one that provides adequate safety at minimal cost, although special design or remedial measures may be required in specific areas.

Careful consideration must be given to bench design. It is often the case that deep seated failure does not control the overall slope angle. In these cases, the slope angle may be controlled by the optimum geometry of the benches that are effectively used to catch rockfalls and/or to control ravelling on the slope.

Berm width should be controlled by the amount of access required to the slope in question. It must be accepted that even with careful perimeter or control blasting techniques, a certain amount of breakback will occur due to the effects of minor failures, deterioration of the rock, general ravelling and frost action in the slope. In general, slopes should have berms wide enough that falling debris will be trapped and that equipment will have adequate access to selected berms to keep them clean and effective as catchments.

4.2 PROPOSED SLOPE DESIGN

The slope designs proposed by Manalta for the Tenas and Tenas West Pits, including the general shape of the pits, height and orientation of the walls, etc., are illustrated in section on Figures 3 to 6 and in plan on Figure 9, and are based on the geologic interpretation that was available prior to the 1996 exploration program. In the main Tenas Pit, the western side (*i.e.*, floor) of the pit is proposed to be an unbenched footwall up to about 225 m high, excavated along the base of coal seam #1. A benched highwall slope up to about 80 m high is proposed for the northern end of the eastern side of the pit. A second benched slope, in the order of 70 to 100 m high, trending approximately east-west in the typical arrangement of an end wall slope (in that the slope orientation is normal to oblique to the strike of bedding), is proposed for the central area of the east wall of the pit, with a much shorter 20 to 30 m high benched end wall being planned for the northern end of the pit. All of these walls will be excavated in sedimentary rocks above coal seam #1 and have been planned to be comprised of 24 m high double benches, with 60° bench face angles and 8 m wide safety berms, yielding an interramp slope angle of 48°. The southern portion of the east wall, which will be up to about 120 m high, has been proposed to be an unbenched footwall slope along the base of coal seam #1 on the eastern limb of the syncline.

The western wall of the Tenas West Pit is proposed to be an unbenched footwall slope; however, the height of the slope is much less, being only up to about 50 m. It is assumed that the eastern

wall of the pit has been designed as a benched highwall slope, similar to the northern portion of the eastern wall of the main Tenas Pit.

4.3 APPROACH TO SLOPE DESIGN

Stability assessment and design of the pit slopes requires determination and consideration of not only geologic conditions (*i.e.*, rock strength, orientation of joints, faults, etc.) and structural controls on the final pit wall, but also the overall orientation of the wall itself. Different wall orientations require basically different design considerations. Thus, the general approach to slope design is to define zones which contain essentially one general set of structural conditions and one general slope orientation (*i.e.*, end walls, highwalls, footwalls for each pit). These zones have been referred to as design sectors. As can be seen in Figure 9, five and two design sectors have been identified for the main Tenas Pit and the Tenas West Pit areas, respectively.

To arrive at preliminary slope design recommendations in these areas, assessments were carried out for deep seated failure as well as for bench scale failure, to evaluate the optimum geometry required to control failure and ravelling of individual benches on the slope. Assessment of relevant failure mechanisms and recommended design criteria with respect to the different design sectors is discussed in the following and summarized in Table 2.

4.4 ASSESSMENT OF DEEP SEATED FAILURE OF THE OVERALL SLOPES

Preliminary assessments of deep seated failure of the sedimentary rocks were conducted using primarily the rock mass strengths discussed in Section 3.5.4, with some analyses taking into account the potential for at least a portion of the failure surface being along the base of the 25m thick zone (with numerous coal stringers) below the #1 seam footwall. Analyses were carried out based on a two-dimensional, limit equilibrium analysis using the Bishop Simplified Method of Slices, and assuming that the slopes were well drained. Two modes of failure were assumed: purely rotational failure for the end wall, highwall and steeper footwall slopes in Design Sectors T-2, T-3, T-4, T-5 and TW-2; and a combination of rotational failure at the toe and planar failure over the remainder of the slope for the steeper footwall slope in Design Sector T-2. Numerous

Considering the shallow bedding dip over most of the pit areas and because the coal seam #1 footwall rock appears to be moderately competent, it does not appear that there are any critical failure modes that are likely to significantly compromise the overall stability of these footwall slopes. In addition, the presence of bentonite beneath the #1 seam does not appear to be widespread. Thus, the proposed unbenched slope design in Design Sectors T-1 and TW-1 is considered acceptable. Notwithstanding this, it is possible that some faults, local rolls or undulations in the bedding will lead to bedding being undercut and to some failures on the footwall, particularly at the extreme southern end of Design Sector T-1, where bedding is steepest. However, as this area of the slope is relatively limited in extent compared to the entire footwall, and would not likely be part of the initial area to be mined, there should be sufficient time to evaluate the need for either remedial measures or a modified slope design (likely a benched footwall design, as discussed below for Design Sector T-2) prior to the onset of mining in this area.

The footwall slopes should be excavated by ripping or by other non-explosive techniques next to the final wall. Where the slope angle is steeper than about 25° , the footwall should be scaled to reduce the potential for movement of loose material on the slope. While groundwater conditions behind the footwall are not expected to create a stability concern in most areas of these design sectors, it is recommended that groundwater pressures be monitored on an ongoing basis and that depressurization measures (*i.e.*, vertical pressure relief wells or horizontal drainholes) be carried out if required.

4.6 PRELIMINARY SLOPE STABILITY ANALYSES AND DESIGN OF BENCHED FOOTWALL SLOPES (DESIGN SECTOR T-2)

As illustrated in Figures 4, 5 and 9, the southern portion of the eastern wall of the main Tenas Pit (Design Sector T-2) will be between about 100 and 120 m high. Bedding in this slope is interpreted to dip approximately 45° to the southwest, and it has been proposed that this wall be developed as an unbenched footwall along the base of coal seam #1.

Based on a review of the structural geology, there are two failure modes that are most likely to control the stability of the slope in this design sector; deep seated failure, and bilinear slab

failure. As discussed above, the results of deep seated stability analyses are summarized in Figures 10 and 11, and indicate that the Factor of Safety for such a failure mode is expected to be at least 2.0.

With respect to bilinear slab failure, it is assumed in this failure mode that the majority of the slab fails along a bedding joint, with the toe of the failure shearing through the rock mass. Not unexpectedly, initial analysis results indicated that the Factor of Safety increases with slab thickness for any given slope height. Review of the geotechnical logs for the four coreholes that were drilled as part of this study indicates that the stratigraphic depth to the numerous coal stringers beneath coal seam #1, and thus the thickness of any potential slabs, is variable. However, the stratigraphic depth to the first coal stringer beneath coal seam #1 appears to range from about 2.9 to 5.25 m. As such, subsequent stability analyses were conducted assuming a 3m thick slab. Both axial and diametral rock mass strengths were applied at the toe, where the failure plane would be expected to shear through the slab. Results of the analyses conducted for a drained slope condition are summarized in Figure 12, where it can be seen that for the weaker diametral rock mass strength, the Factor of Safety for the 100 to 120 m high unbenched wall that is proposed is in the order of 1.2.

While the stability analyses described above indicate that an unbenched footwall along the base of the #1 seam would be stable, there are a number of uncertainties associated with these analyses, all of which could adversely effect the stability of the slope. For example, besides the coal stringers that are present in the footwall rocks, an 8 cm thick seam of bentonite was observed in one corehole, approximately 4 m below the coal seam #1 footwall. In addition, the degree of waviness of the bedding, and the possible presence of continuous cross-bedding joints, are both uncertain. Should a continuous bedding discontinuity daylight on the slope, planar failure along such a structure would almost certainly occur, possibly involving the entire slope height above the daylighted structure.

Considering the above, and for preliminary design purposes, it is recommended that the proposed unbenched footwall slope be excavated as a benched footwall. At this stage, it is suggested that either 24 m high double benches with 10m wide safety berms, or 36 m high triple benches with

12 m wide safety berms, should be developed within the approximately 25 m thick zone that immediately underlies coal seam #1. Bench faces should be excavated parallel to bedding (bedding should not be undercut). Once the pit wall is behind this zone with coal stringers, it is suggested that the remainder of the slope be developed as an unbenched slope to surface. In any event, where significant coal stringers/seams are located within about 2 m of the toe of a bench, the berm width should be increased such that the bench face can be excavated along the base of the coal seam or stringer. In this manner, a more competent bench face will result.

As groundwater pressures could have a significant destabilizing effect on the slope in this design sector, and it is anticipated that this slope may be very slow to naturally drain, it is likely that depressurization measures, in the form of horizontal drainholes, will be required. To monitor groundwater pressures behind the slope, and the effectiveness of any drainholes, piezometers could be installed behind the crest in selected locations.

4.7 PRELIMINARY SLOPE STABILITY ANALYSES AND DESIGN OF HIGHWALL SLOPES (DESIGN SECTORS T-4 AND TW-2)

As illustrated in Figures 3, 6 and 9, proposed slope heights are between about 30 and 80 m in Design Sector T-4, and up to about 40 m in Design Sector TW-2. For the most part, bedding in these design sectors is expected to dip about 10 to 20° into the slope although, as noted previously, the strike of bedding may vary from the trend of the pit slope in some areas. Based on the bedding orientation and the apparent spatial relationship between bedding and cross-joints discussed above, it is also expected that cross-joints of Set A will dip about 70 to 80° to the southwest (*i.e.*, directly or obliquely out of the slope).

Considering the above, and the results of the deep seated analyses, it would appear that planar sliding on cross-joints of Set A will control the stability of the individual benches, and thus are expected to exhibit the most control over design of the whole slope. Even though the spatial relationship between the wall orientation and the cross-joints may vary slightly in some parts of these design sectors, there does not appear to be any potential for significant instability if the bench face angles are not excavated any steeper than about 70° and provided slopes are excavated using controlled blasting techniques. Based on this, and provided the slopes are

adequately depressurized, which is expected to occur naturally, the recommended slope design for Design Sectors T-4 and TW-2 is (see Table 2):

Bench height	= 24m high double benches
Berm Width	= 11m
Bench Face Angle	= 70°
Interramp slope angle	= 50.5°

If long term degradation of the bench faces, or constraints of the mining equipment, reduces the bench face angles from 70 to 65°, the 11 m wide berms will be reduced to about 8.5 m wide, which should still be acceptable and sufficient to control and retain any small scale failures, rockfalls, ravelling, etc., that may occur.

4.8 PRELIMINARY SLOPE STABILITY ANALYSES AND DESIGN OF END WALL SLOPES (DESIGN SECTORS T-3 AND T-5)

As illustrated on Figure 9, the proposed end wall configurations in the main Tenas Pit will be in the order of 70 to 100 m high in Design Sector T-3 and 20 to 30 m high in Design Sector T-5. As for the highwalls, these slopes will be excavated in rocks stratigraphically above coal seam #1. While the spatial relationship between the orientation of these slopes and the three main sets of discontinuities is significantly different than for the highwalls, in that bedding will essentially dip directly or obliquely along the slope rather than into the slope, the kinematic controls on stability appear to be at least as favourable as those in the highwalls discussed above. Thus, for preliminary design purposes, it is recommended that the same design criteria as those discussed above for the highwalls be used for the end walls. That is, the recommended slope design for Design Sectors T-3 and T-5 is:

Bench height	= 24 m high double benches
Berm width	= 11 m
Bench face angle	= 70°
Interramp slope angle	= 50.5°

It is not expected that artificial dewatering of the end wall slopes will be required.

4.9 STABILITY ASSESSMENT AND DESIGN OF OVERBURDEN SLOPES

Based on a series of cross-sections through the proposed pit areas, soil overburden in the vicinity of the pit walls appears to range from near 0 to about 25 m thick. Slopes in the overburden should be excavated in maximum 10 m high benches, with an overall slope angle not exceeding 1.5 horizontal to 1 vertical.

5. WASTE DUMP FOUNDATIONS

5.1 GEOTECHNICAL PROPERTIES

Foundation conditions are presented on borehole logs provided in Appendix II. These logs were prepared based on soil samples and were classified using the Unified Soil Classification (USC) system. Moisture contents, Atterberg Limits, grain size analyses and permeability were determined on selected samples. Laboratory test results are summarized in Table 3. Shear strength values obtained from pocket penetrometer measurements were used in assessing the stiffness of the deposit.

As noted in Section 3.3, the soil profile consists of glacial till (sand and silt) underlain by a coarse grained deposit consisting of sand, silt and gravel, and mudstone/siltstone bedrock. In several boreholes the coarse grained deposits are cross-bedded by layers of silty clay.

The glacial till is medium brown coloured and varies in thickness from 4.3 to 18.2 m. The till is low plastic, well graded, stiff to hard in consistency, and contains a little clay and gravel. Encountered in the till deposit are occasional sand stringers, areas of iron oxide staining, carbonaceous material in the form of core fragments, occasional pebbles and calcareous deposits. Moisture content values range from 8 to 16 percent with an average of 12 percent (Figure 13). The till is classified as a CL-ML or CL, which is typical of a low plastic silt or clay (Figure 14).

As indicated in Figure 15, SPT blow count values range between 8 and > 50, with the higher values of SPT observed at greater depths. This range of SPT values is indicative of a stiff to hard deposit (Terzaghi and Peck, 1996). Corresponding compressive strength values shown in Figure 16, determined by the pocket penetrometer, range from less than 1 kg/cm² at a depth of 0.5 m up to 3.5 kg/cm² at a depth of 4 m below grade.

In boreholes TOB96-02, 96-04, 96-11 and 96-18 the glacial till deposit is underlain by a coarse grain deposit consisting of various combinations of sands, silts and gravels.

Fine, medium and coarse grained sand layers varied in thickness from 2 to 30 m depending upon the borehole location. In general, the sands are poor to well sorted, loose, calcareous, olive-brown in colour and contain a trace of fines. Moisture contents values are in the range of 2 to 8 percent.

In addition to the sand layers, layers of gravels, sands and gravels, silts and gravels and clays and gravels were encountered. The gravel layers vary in thickness from 2 to 30 m. The gravels are multicoloured igneous, siltstone or coal clasts, sub-angular in shape and small in size (<1cm). As noted earlier the coarse grained deposits are cross-bedded by silty clay layers. The silty clay deposits are dark gray in colour, medium to high plastic, stiff to hard in consistency, laminated in structure and contain a trace of gravel.

5.2 DUMP STABILITY

Foundation conditions are satisfactory for supporting the proposed waste dumps, which are presently planned to a maximum height of 70 m. Both the glacial till and underlying sand and gravel deposits are generally dense, with low moisture contents, except in localized areas of poor drainage where the near surface till material may be relatively soft. In such localized areas of softened till, provision may be needed to limit the rate of dump advance to allow for any excess pore pressures generated by the dump to dissipate. To protect against potential foundation instability, the height of individual dumplifts may also need to be restricted.

5.3 SOIL LINER

Portions of the waste dump may contain rock types which have the potential to generate acidic runoff. In such areas, it is planned to construct a soil sealing layer of sufficiently low permeability beneath the dump to serve as a liner to minimize infiltration into the underlying ground. The sealing layer would be shaped and graded to collect water penetrating through the dump and direct it via channels to a runoff retention pond(s).

Because of weathering effects, including the presence of fissures, and localized sandy lenses, the native soil may not suffice as a natural liner. However, the glacial till material which covers the

dump site is of sufficiently low permeability to be suitable for use in a liner, providing that it is adequately conditioned and compacted. To this end, the following placement procedure is recommended:

- a) individual lifts no thicker than approximately 200 mm;
- b) lifts to be compacted to at least 95 percent of the Standard Proctor density, within ± 2 percent of the optimum moisture content;
- c) final thickness of liner to be at least 1.0 m; and
- d) final surface to be graded for effective drainage and sealed with several passes of a smooth drum roller.

A low lift of waste material approximately 3 m thick should be placed directly onto the till liner to protect it from impact effects of subsequent dump lifts.

6. GENERAL RECOMMENDATIONS

6.1 PIT SLOPES

In addition to the preliminary design recommendations in Section 4, the following general recommendations are also made:

Geologic Data Collection and Slope Documentation

While the above slope design recommendations for the pit slopes are felt to be realistic and suitable for a feasibility study, they are based largely on the existing geologic structural interpretations for the pit areas (which do not include the results of the 1996 exploration drilling) and on no specific mapping data. Thus, it is recommended that the slope designs be reviewed once data from the latest exploration program and any future geologic programs have been compiled and a revised geological interpretation has been prepared. All changes to the lithologic and geologic structural interpretation from those assumed herein should be assessed as to their impact on slope stability. Once mining begins, mapping of all pit slopes should be carried out on an ongoing basis for purposes of estimating bench breakback angle, and reevaluating the geologic structure and engineering geology.

Surface Runoff

Surface drainage should be diverted away from the slopes wherever possible, using ditches and other means as required.

Blasting

To prevent undue blast damage, preserve the benches in as tight and as competent a state as possible, and to minimize the lengthening of joints along which failures can occur, it is recommended that control blasting techniques, such as cushion blasting, trim blasting or pre-splitting, be used on all final wall blasts. If bench breakback can be reduced and steeper bench face angles maintained, steeper interramp angles may be feasible in some areas.

Scaling and Cleaning

Final walls should be carefully scaled and cleaned, as required, during development to limit rockfall and ravelling hazards.

Monitoring

To assist in the ongoing assessment of the behaviour of the highwalls and end walls, a general array of prisms should be installed and monitored on a regular basis. Regular visual inspections of the pit walls should also be conducted.

6.2 WASTE DUMPS

The proposed waste dump sites are satisfactory from the standpoint of foundation stability, although some restrictions may need to be applied on the height of individual lifts and rate of dumping to ensure that potential localized areas of saturated till do not develop excess pore pressures to the extent that shear failures are induced.

In areas where acid generating rock is present, it may be necessary to construct a liner beneath the dump. The till material available from within and adjacent to the dump site is suitable for constructing a soil liner. Recommendations for liner construction are provided in Section 5.3.

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Respectfully Submitted,

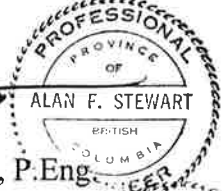
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8. REFERENCES

- B.C. Ministry of Energy, Mines and Petroleum Resources, 1993. Open File Report 1993-21, Geology of the Telkwa Coalfield.
- Bieniawski, Z.T., 1976. *Rock Mass Classification in Rock Engineering*. Proceedings of the Symposium of Rock Engineering (Vol. I). Johannesburg, S.A. November. pp. 92-106.
- Hoek, E & Brown, E.T., 1988. *The Hoek-Brown Failure Criterion - A 1988 Update*. Proceedings of 15th Canadian Rock Mechanics Symposium, University of Toronto.
- Klohn Leonoff, March 1985. *Telkwa Coal Project - Geotechnical, Hydrogeological & Hydrological Design Report*. Report to Crows Nest Resources Ltd.
- Piteau Engineering Ltd., 1997a. *Geotechnical and Hydrogeological Assessment Proposed Tailings Pond Area*. KI97-3773-12. Unpublished report to Manalta Coal Ltd. January, 1997.
- Piteau Engineering Ltd., 1997b. *Baseline Hydrogeological Investigations in Tenas Pit, the Waste Dumps, and Pit 3*. KI97-3773-12. Unpublished report to Manalta Coal Ltd. January, 1997.
- Piteau Engineering Ltd., 1996. *Preliminary Assessment of Potential Groundwater Inflows and Dewatering Requirements in the Tenas Creek Region, Telkwa Coal Project, British Columbia*. Unpublished report prepared for Manalta Coal Ltd., KI93-3773-10. January, 1996.
- Piteau Engineering Ltd., 1994. *Engineering Geology and Geotechnical Assessment for the Pit 7 and Pit 8 Areas*. Unpublished report prepared for Manalta Coal Ltd. KI94-3773-4. January, 1994.
- Piteau Engineering Ltd., 1994a. *Engineering Geology and Geotechnical Assessment for the Pit 7 and Pit 8 Areas*. Unpublished report prepared for Manalta Coal Ltd. KI94-3773-4. January, 1994.
- Piteau Engineering Ltd., 1994b. *Baseline Data Surface Water and Groundwater Telkwa Coal Project*. Unpublished Report prepared for Manalta Coal Limited. KI93-3773-1. June, 1994.
- Terzaghi K., Peck, R.B. and Mesri, G. 1996. *Soil Mechanics in Engineering Practice*. 3rd Edition, J. Wiley & Sons.

TABLE 1
SUMMARY OF ROCK MASS PROPERTIES AND STRENGTHS

LITHOLOGY	WEIGHTED MEAN VALUES BASED ON CORE LOGGING ¹				BASED ON POINT LOAD TESTING				DESIGN VALUES ⁶		ROCK MASS STRENGTH PARAMETERS BASED ON UPDATED HOEK-BROWN FAILURE CRITERION (1988)		
	LENGTH LOGGED (m)	RMR ²	UCS ³ (MPa)	RQD (%)	AXIAL ⁴		DIAMETRAL ⁴		RMR	UCS (MPa)	m _i	MOHR-COULOMB STRENGTH ⁷	
					NO. OF TESTS	UCS ⁵ (MPa)	NO. OF TESTS	UCS ⁵ (MPa)				c (kPa)	φ (°)
Above Seam #1: Primarily mudstones and siltstones, with interbedded sandstone and coal splits	301.6	73.3	36.6	92.8	51	36.4	60	16.0	-	-	-	-	-
Below Seam #1: Primarily mudstones and siltstones, with interbedded sandstone, coal seams, and splits	147.4	73.0	35.3	92.7	39	36.8	50	22.0	-	-	-	-	-
Combined: Interbedded mudstones, siltstones, sandstones, coal seams, and splits	449.9	73.1	36.2	92.8	90	36.6	110	18.7	73	36	10	1040 to 1190	40.6 to 38.2
									73	19	10	770 to 910	35.0 to 32.5

G:\PROJECT\1558\FIGSTABS\TABLE1.XLS

- NOTES: 1. Weighted mean values are based on core logging from coreholes T96R-05c, -28c, -42c and -65c.
2. RMR calculated as per Bieniawski (1976).
3. Unconfined compressive strengths based on core logging are estimated from field hardness as per ISRM (1981) standards.
4. Axial tests represent strengths perpendicular to bedding; diametral tests represent strengths parallel to bedding.
5. Unconfined compressive strengths based on point load testing are calculated as per ISRM (1985) standards, and using a UCS / PLI correlation factor of 20. Coal was not tested.
6. Design values of RMR and UCS, and of m_i, are based on core logging, point load testing, field observations, and engineering judgement.
7. Mohr-Coulomb strengths are given for a range of normal stresses from 1.9 to 2.5 MPa, approximating a depth to failure surface of 75 to 100m.
8. Prepared solely for the use of our client and no representation of any kind is made to other parties with which Piteau Associates Engineering Ltd. has not entered into a contract.

TABLE 2
SUMMARY OF RECOMMENDED SLOPE DESIGNS

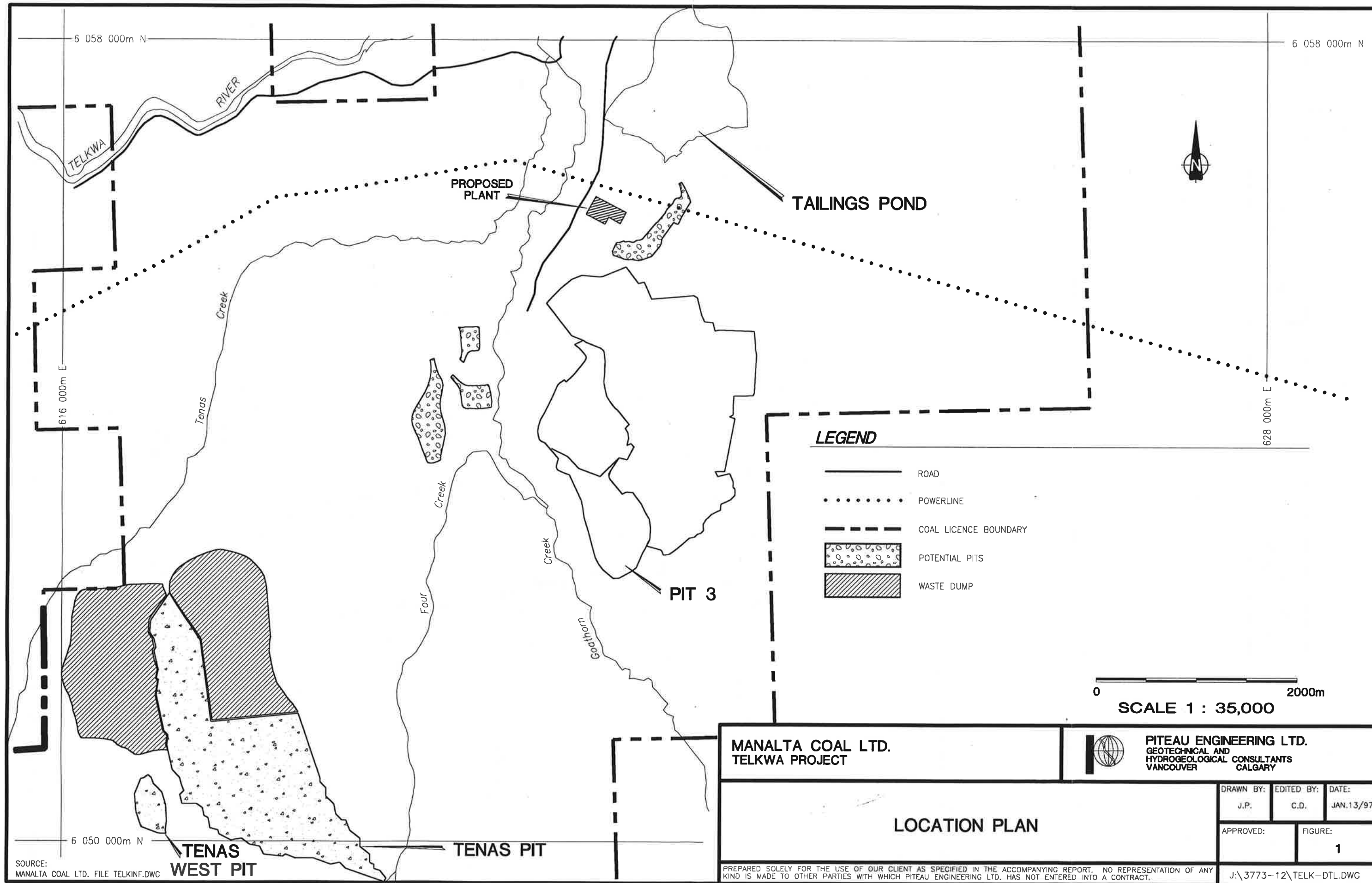
PIT	DESIGN SECTOR	BENCH HEIGHT (m)	BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTERRAMP SLOPE ANGLE (°)
TENAS	T-1	UNBENCHED	PARALLEL TO BEDDING	-	VARIABLE
	T-2	24 OR 36	PARALLEL TO BEDDING	10 OR 12	VARIABLE
	T-3	24	70	11	50.5
	T-4	24	70	11	50.5
	T-5	24	70	11	50.5
TENAS WEST	TW-1	UNBENCHED	PARALLEL TO BEDDING	-	VARIABLE
	TW-2	24	70	11	50.5

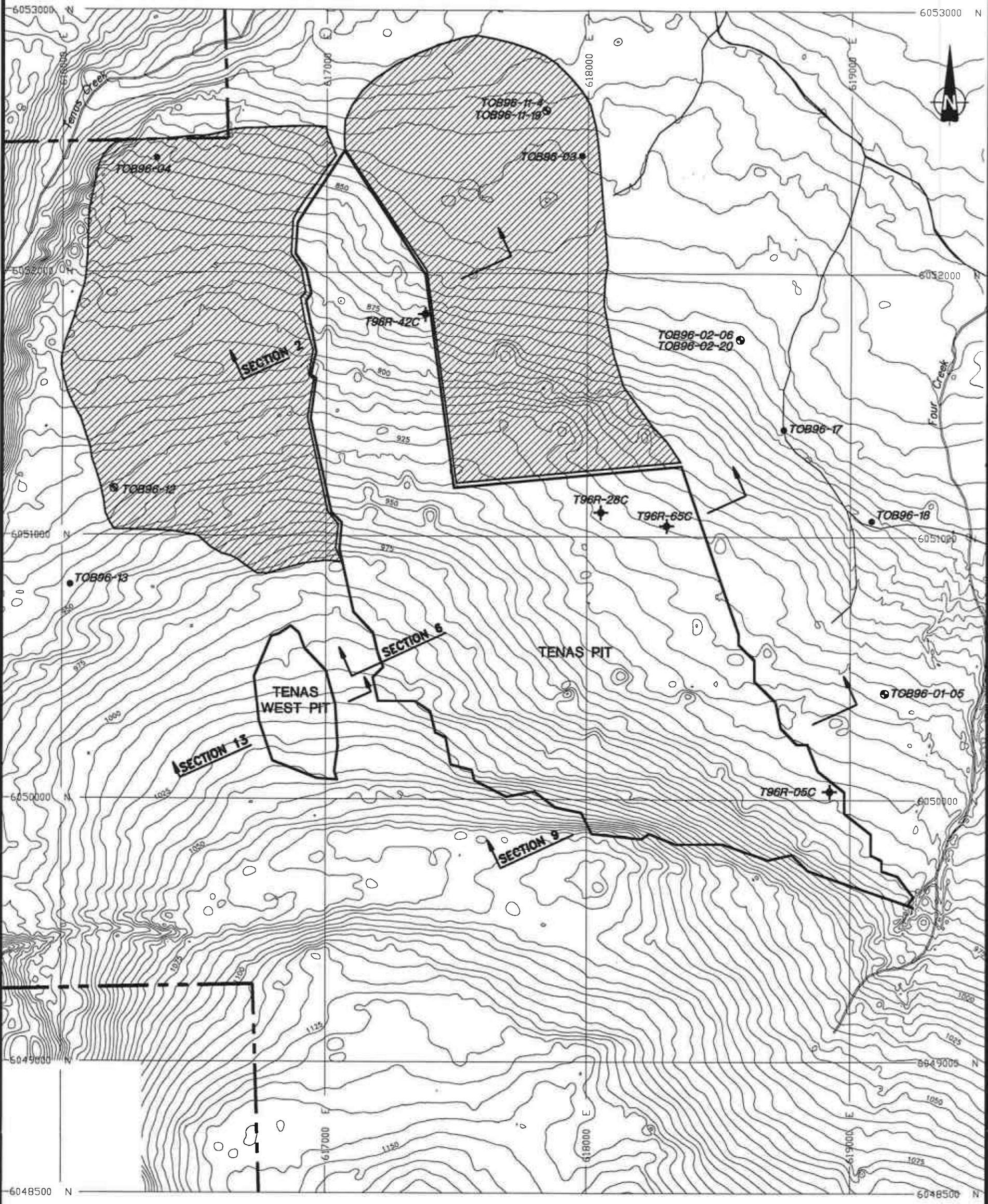
TABLE 3
SUMMARY OF LABORATORY TEST DATA

Borehole	Depth (m)	Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Grain Size Distribution				Activity P.I./% Clay
						Gravel	Sand	Silt	Clay (%)	
TOB96-11	2.85-3.30	11.3	28.6	20.3	8.3	19.7	37.2	27.5	15.0	0.53
TOB96-11	5.5-5.40	11.0	32.2	22.0	10.2	12.0	28.1	35.6	24.3	0.42
TOB96-11	10.1-10.5	15.7	23.7	19.1	4.6	12.8	24.0	49.0	14.2	0.32
TOB96-13	3.0-3.45	12.5	39.0	22.4	16.6	12.7	31.0	32.5	23.8	0.70
TOB96-13	7.0-7.45	10.0	26.8	20.7	6.1	N/A	N/A	N/A	N/A	N/A
TOB96-13	10.0-10.45	10.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOB96-17	3.0-3.45	14.1	32.7	17.3	15.4	15.3	30.9	30.3	23.5	0.66
TOB96-18	3.0-3.45	13.0	32.2	20.5	11.7	16.6	29.0	32.5	21.9	0.53

Notes:

1. Permeability tests conducted on remoulded samples consolidated to present overburden stress.
2. N/A - not analyzed.





LEGEND

- COAL LICENCE BOUNDARY
- PROPOSED PIT OUTLINE
- ROAD
- T96R-05C + GEOTECHNICAL COREHOLE LOCATION
- TOB96-03 • 1996 BOREHOLE LOCATION
- TOB96-01-05 • 1996 PIEZOMETER LOCATION
- SECTION 13 SECTION LOCATION
- WASTE DUMPS
- 5m CONTOUR INTERVAL (metres above sea level)

0 250 500 750m
SCALE 1 : 15,000

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TELKWA PROJECT



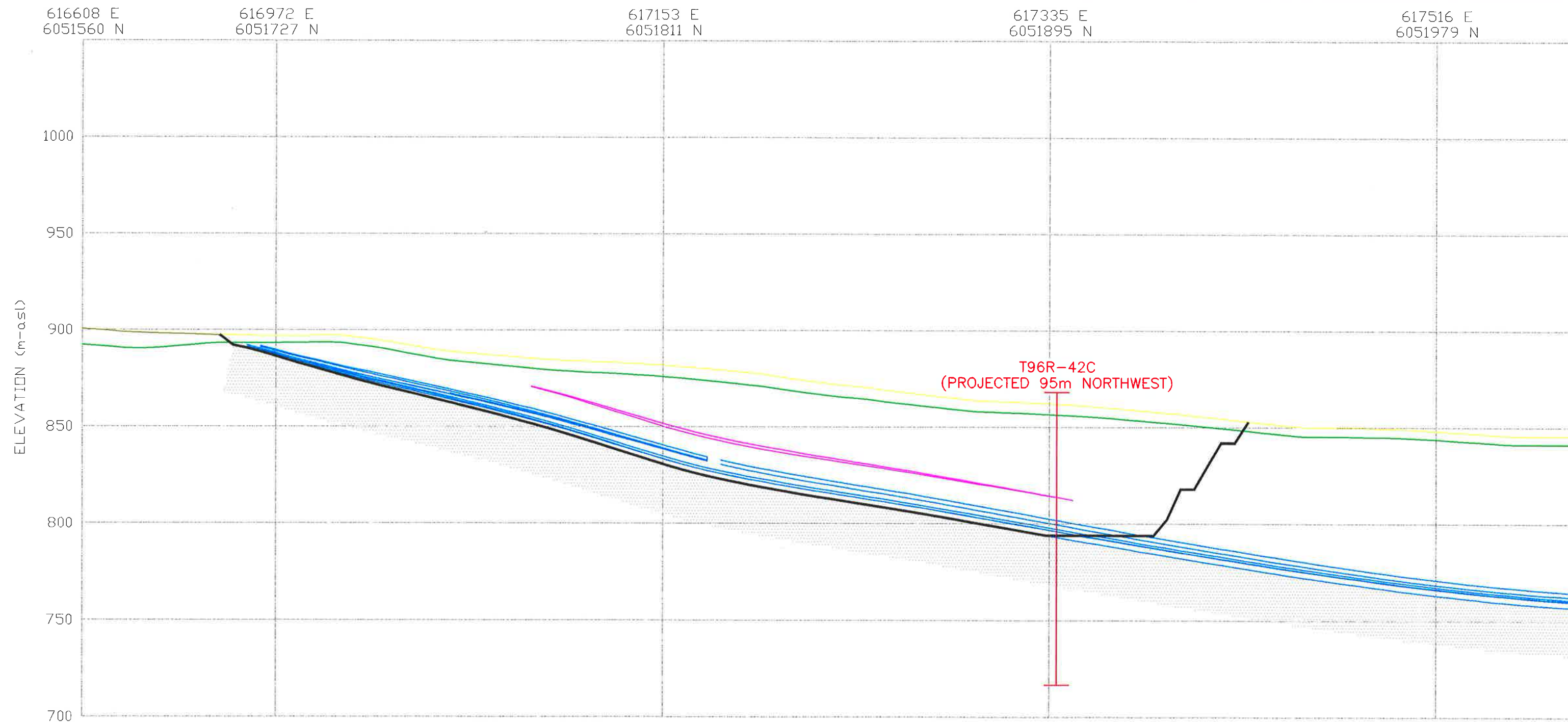
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GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS
VANCOUVER CALGARY

SITE PLAN

DRAWN BY:	EDITED BY:	DATE:
A.S./A.B.	C.D.	JAN.13/97
APPROVED:	FIGURE:	
	2	

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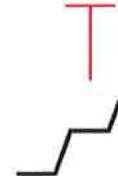
FILE: J:\3773-12\TENASPIT.dwg



LEGEND

- GROUND SURFACE
- OVERBURDEN/BEDROCK CONTACT
- C SEAM PACKAGE
- #1 SEAM PACKAGE
- UNNAMED COAL SEAM
- ZONE WITH NUMEROUS COAL STRINGERS

T96R-42C

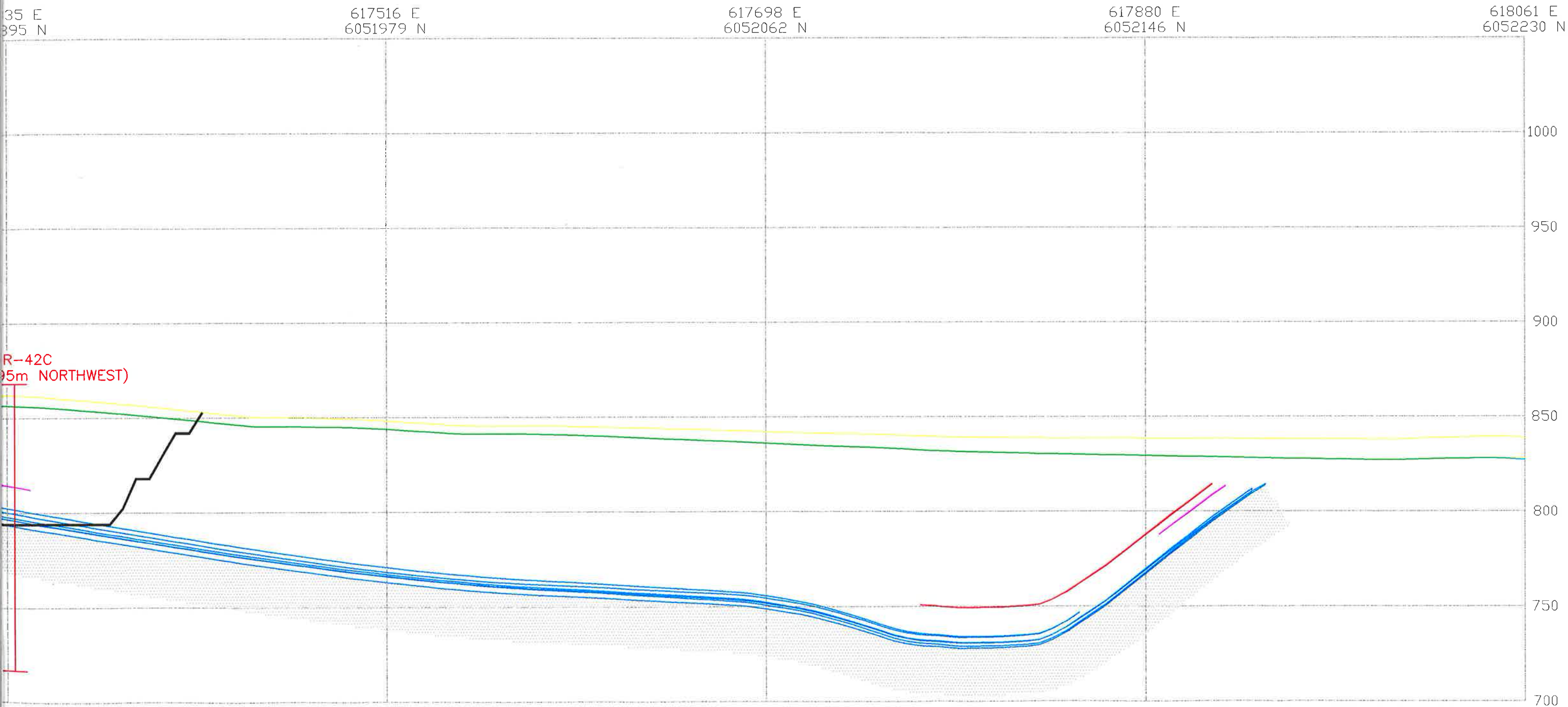


GEOTECHNICAL COREHOLE LOCATION

PROPOSED PIT DESIGN

NOTES

1. BASED ON GEOLOGICAL INTERPRETATION THAT WAS AVAILABLE PRIOR TO 1996 EXPLORATION PROGRAM.
2. SEE FIGS. 2 AND 9 FOR LOCATION OF SECTION.



IN GEOLOGICAL INTERPRETATION THAT WAS AVAILABLE
D 1996 EXPLORATION PROGRAM.
S. 2 AND 9 FOR LOCATION OF SECTION.

0 20 40 60 80 100m
SCALE 1 : 2000

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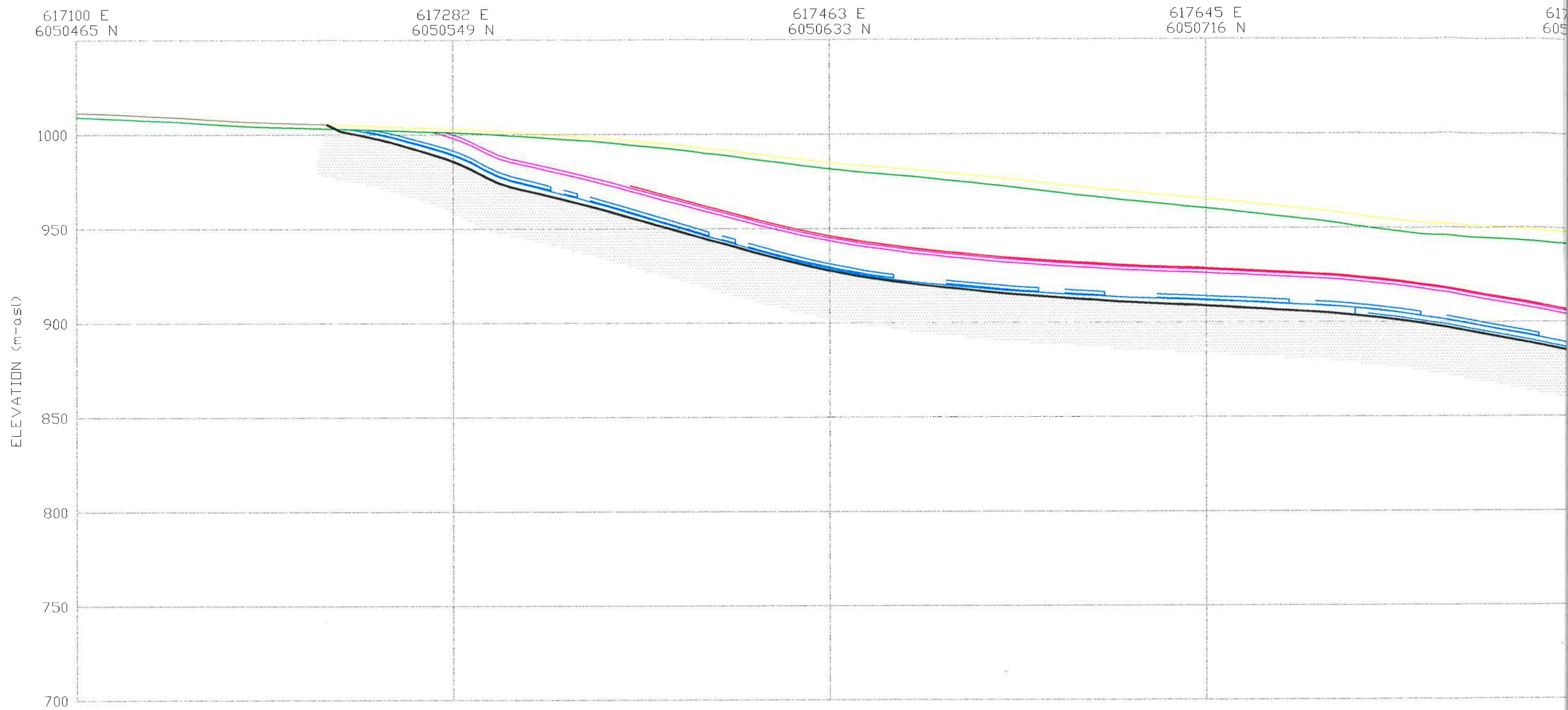
SECTION 2

DRAWN BY: A.F.S./A.B.	EDITED BY: C.D.	DATE: FEB.19/97
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APPROVED:	FIGURE: 3
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FILE: J:\3773-12\XSEC-2.dwg



NOTE

1. SEE FIG. 3 FOR LEGEND AND ADDITIONAL NOTES.

617463 E
6050633 N

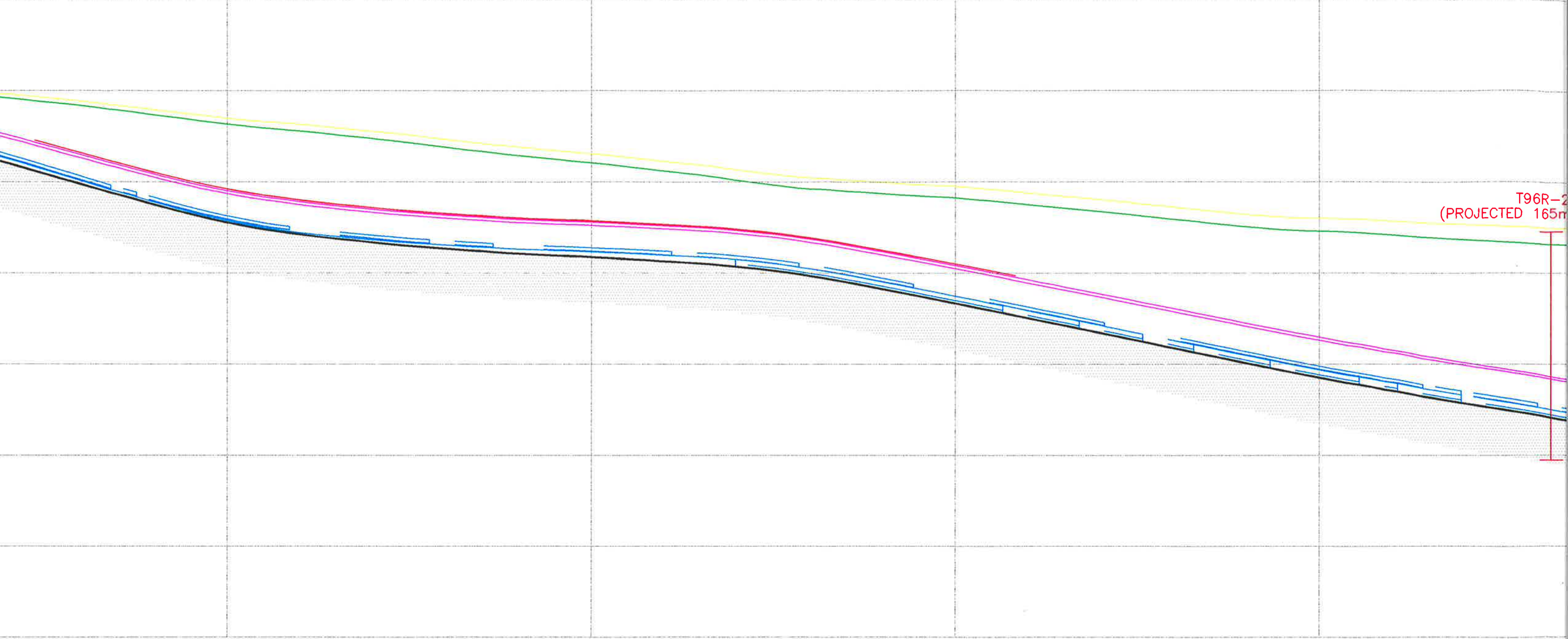
617645 E
6050716 N

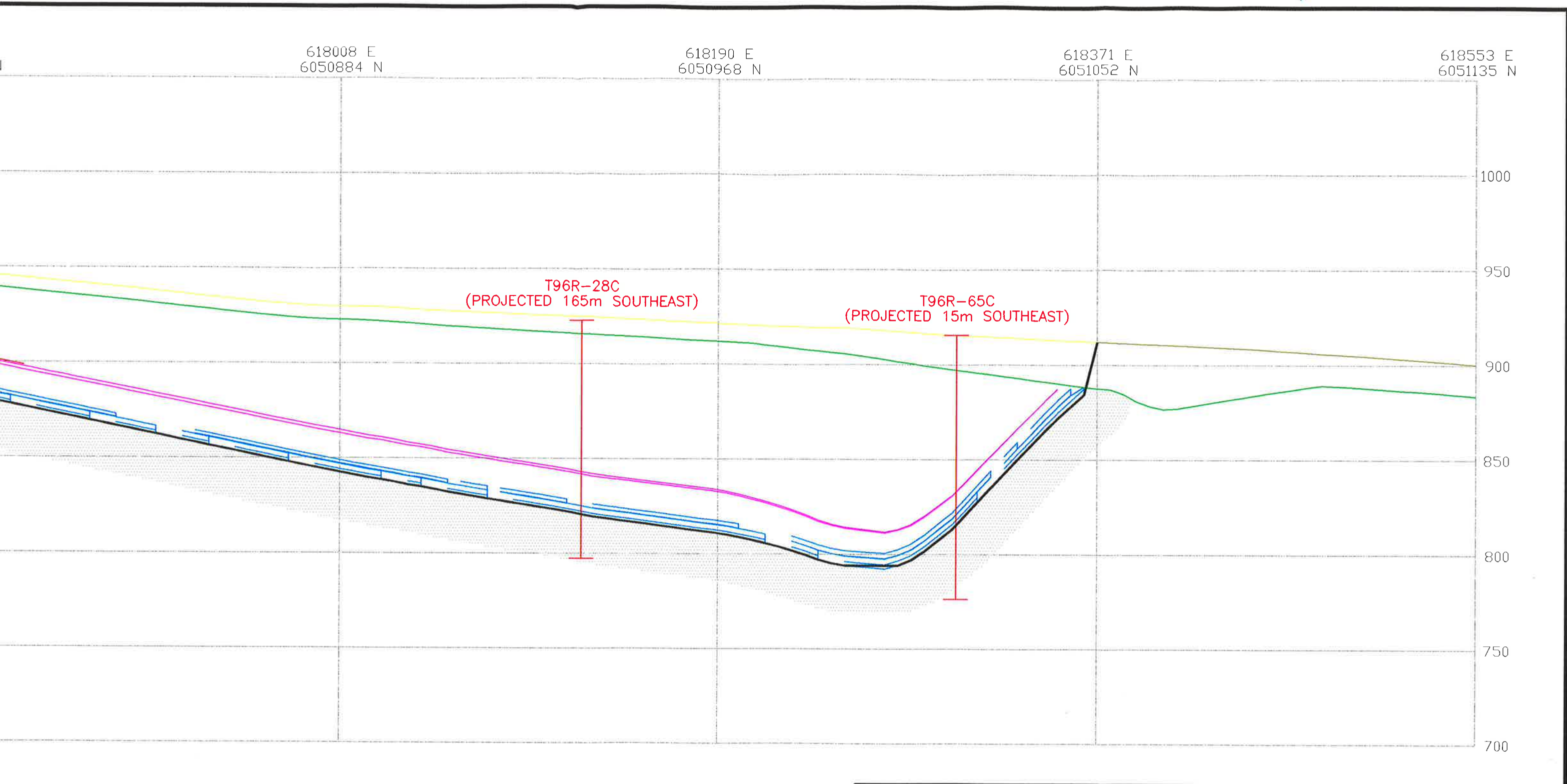
617826 E
6050800 N

618008 E
6050884 N

T96R-2
(PROJECTED 165m)

0 20 40 60
SCALE 1 : 200





0 20 40 60 80 100m
SCALE 1 : 2000

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TELKWA PROJECT



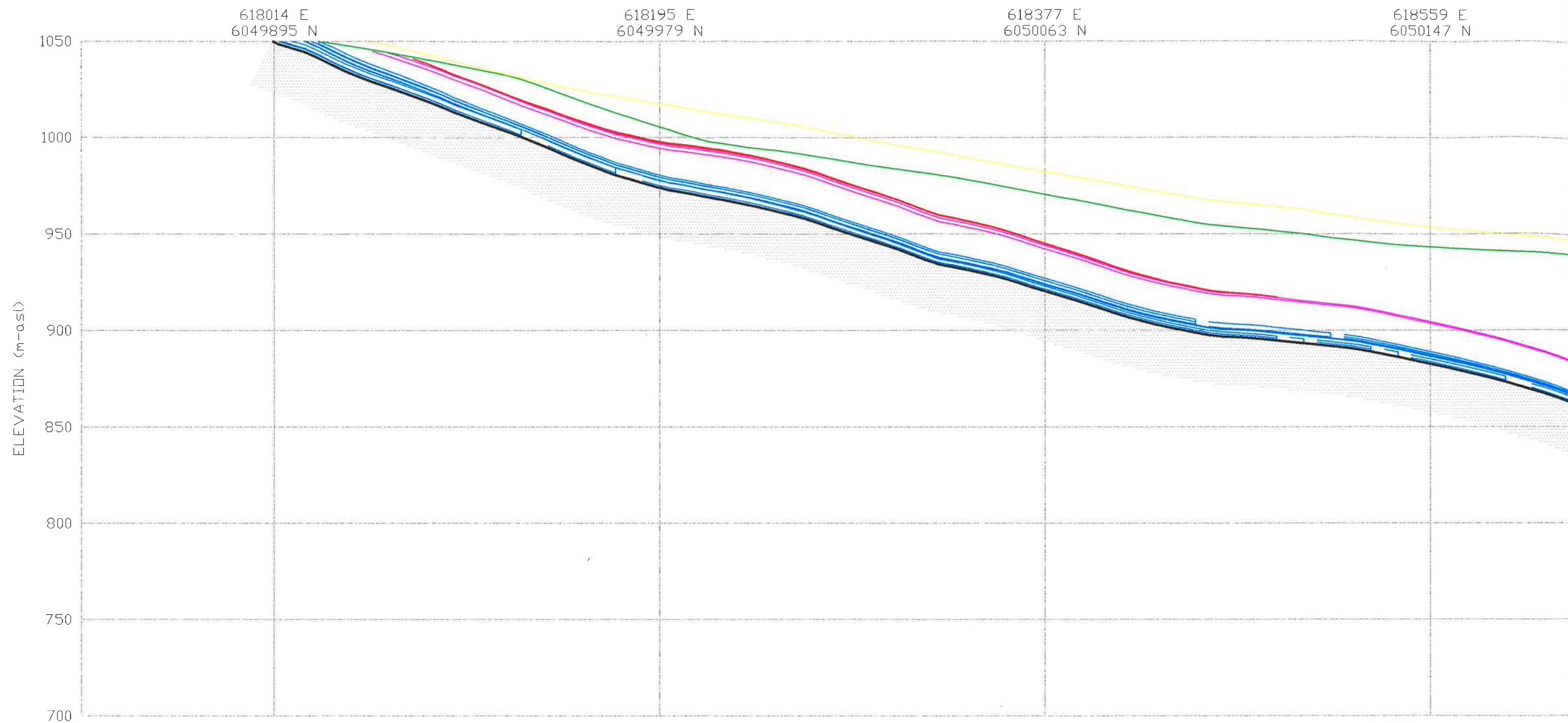
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SECTION 6

DRAWN BY: A.F.S./A.B.	EDITED BY: C.D.	DATE: JAN.14/97
APPROVED:		FIGURE: 4

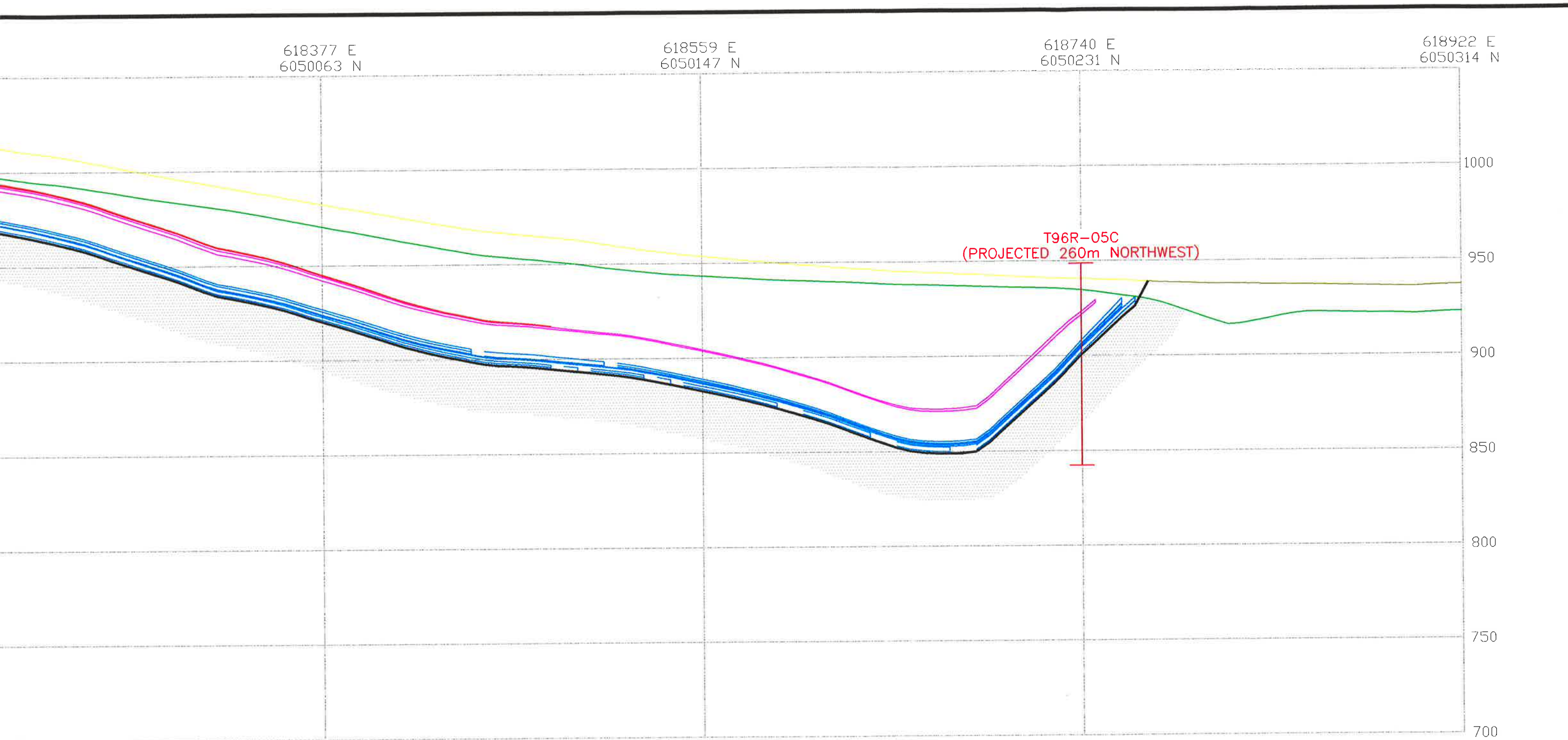
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FILE: J:\3773-12\XSEC-6.dwg



NOTE

1. SEE FIG. 3 FOR LEGEND AND ADDITIONAL NOTES.



0 20 40 60 80 100m
SCALE 1 : 2000

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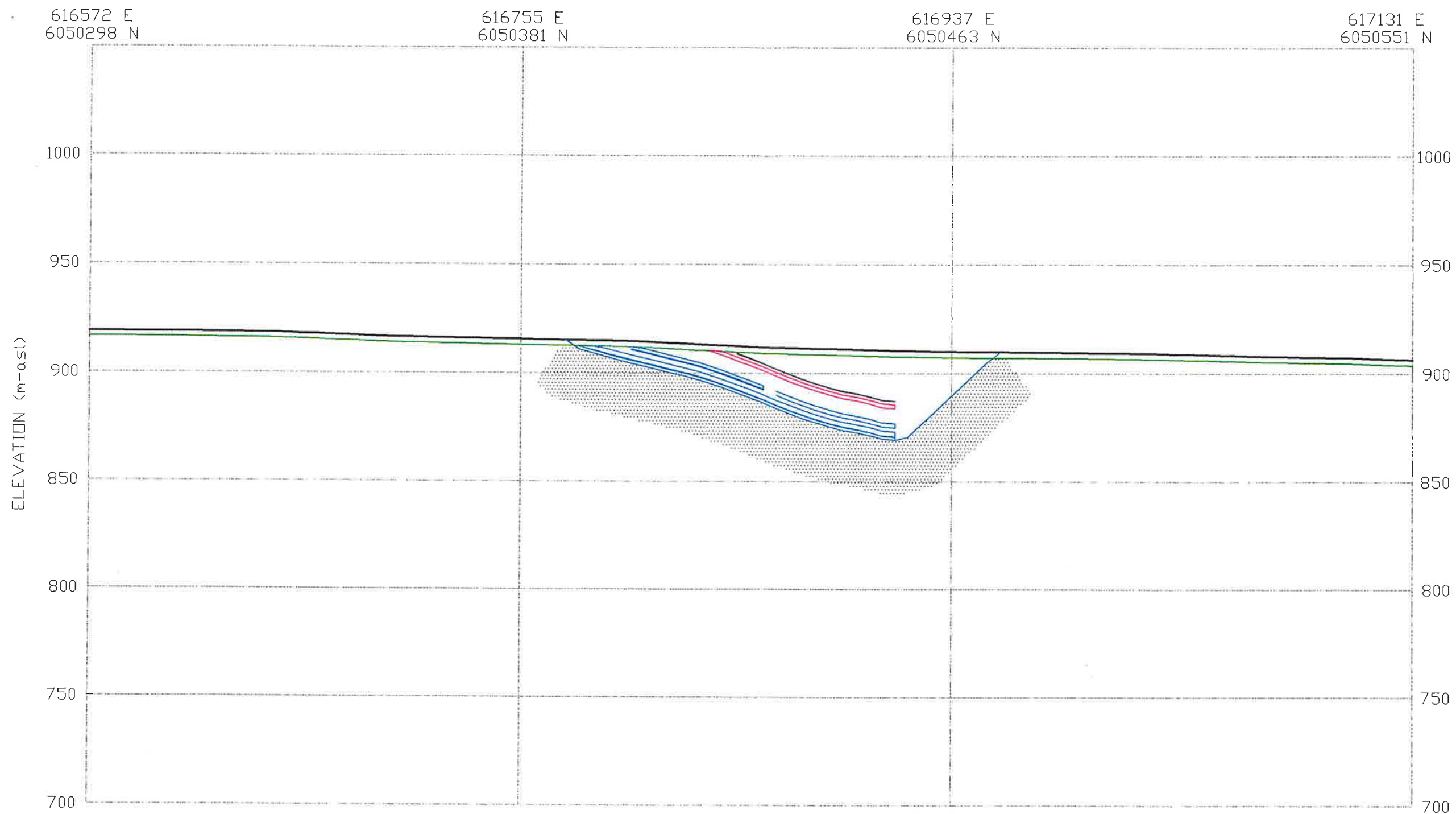
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SECTION 9

DRAWN BY:	EDITED BY:	DATE:
A.F.S./A.B.	C.D.	JAN.14/97
APPROVED:	FIGURE:	
	5	

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FILE: J:\3773-12\XSEC-9.dwg



NOTE

1. SEE FIG. 3 FOR LEGEND AND ADDITIONAL NOTES.

0 20 40 60 80 100m
SCALE 1 : 2000

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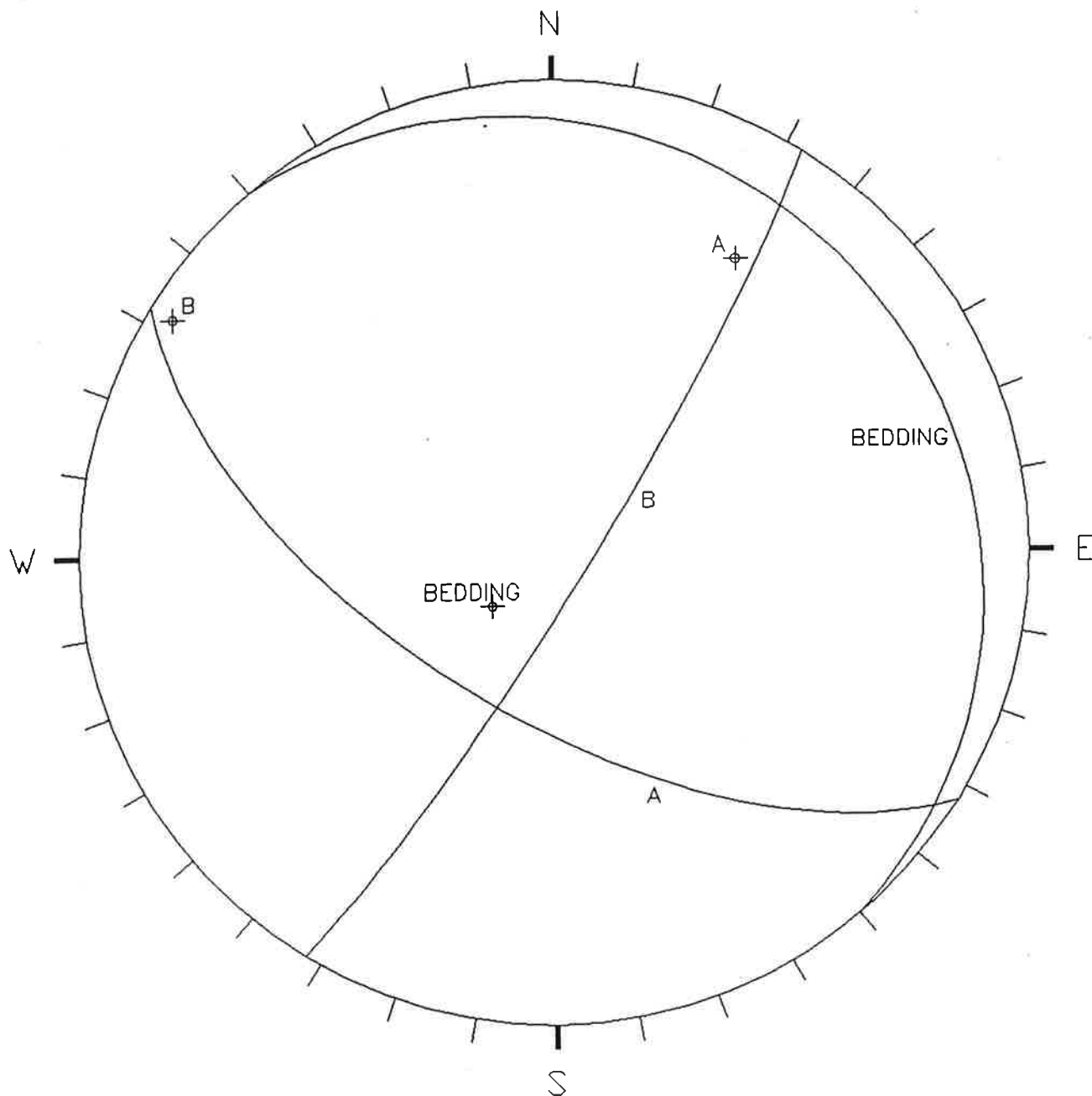
SECTION 13

DRAWN BY: A.F.S./A.B.	EDITED BY: C.D.	DATE: JAN.14/97
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APPROVED:	FIGURE: 6
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FILE: J:\3773-12\XSEC-13.dwg



SET	DIP/DIR.
BEDDING	14/050
JOINT SET A	62/212
JOINT SET B	84/122

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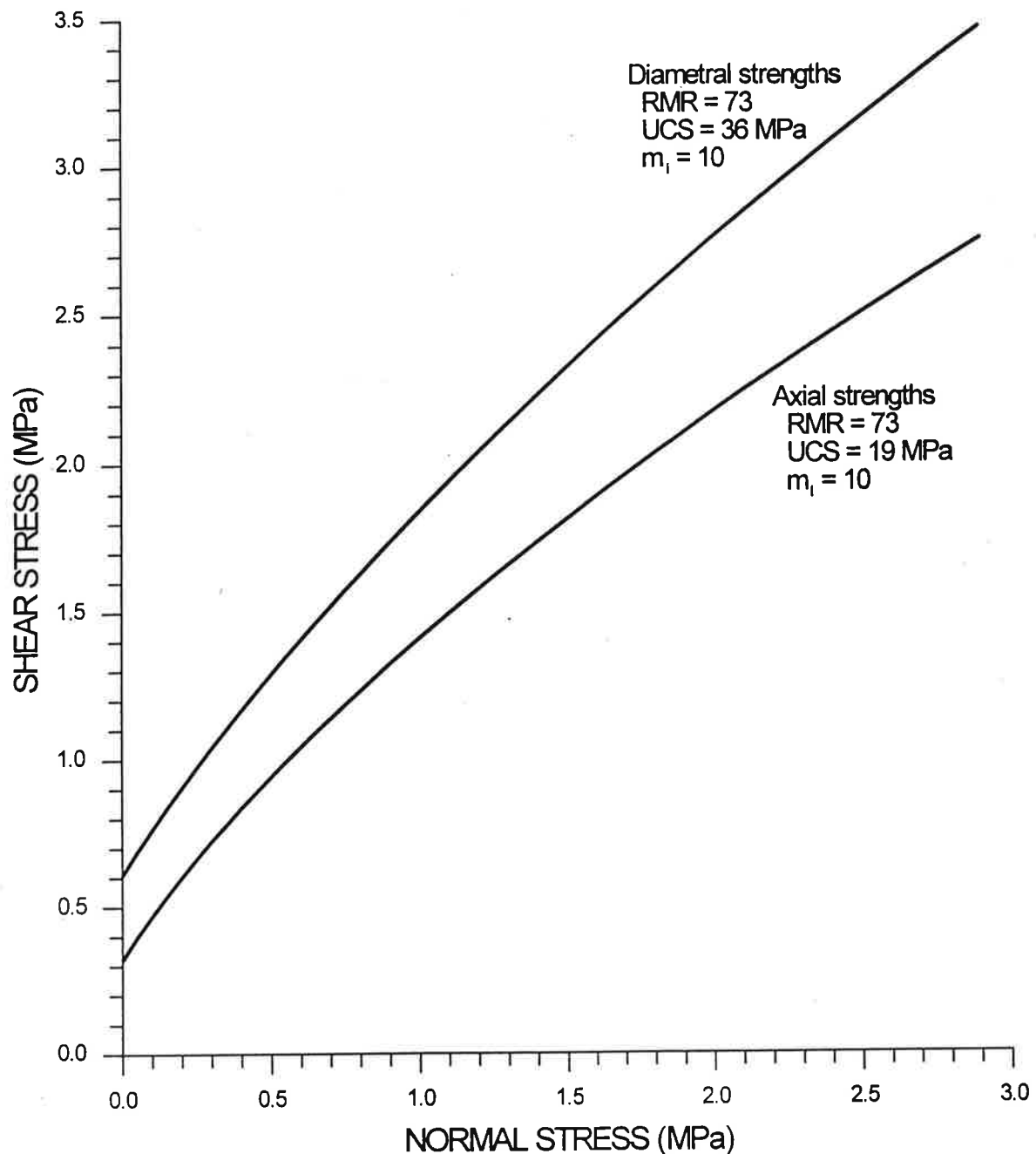
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**LOWER HEMISPHERE EQUAL AREA
PROJECTION OF AVERAGE JOINT SET
ORIENTATIONS MAPPED IN THE PIT 3 AREA
(FROM KLOHN LEONOFF, 1985)**

DRAWN BY: B.W.G.	EDITED BY: C.D.	DATE: JAN.13/97
APPROVED:	FIGURE: 7	

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JOB NO. 3773-12



- NOTES: 1. Estimates of rock mass strengths are based on the updated Hoek-Brown Failure Criterion (1988).
 2. Axial strengths are based on Point Load Index testing perpendicular to bedding; diametral strengths are based on testing parallel to bedding.

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TELKWA PROJECT



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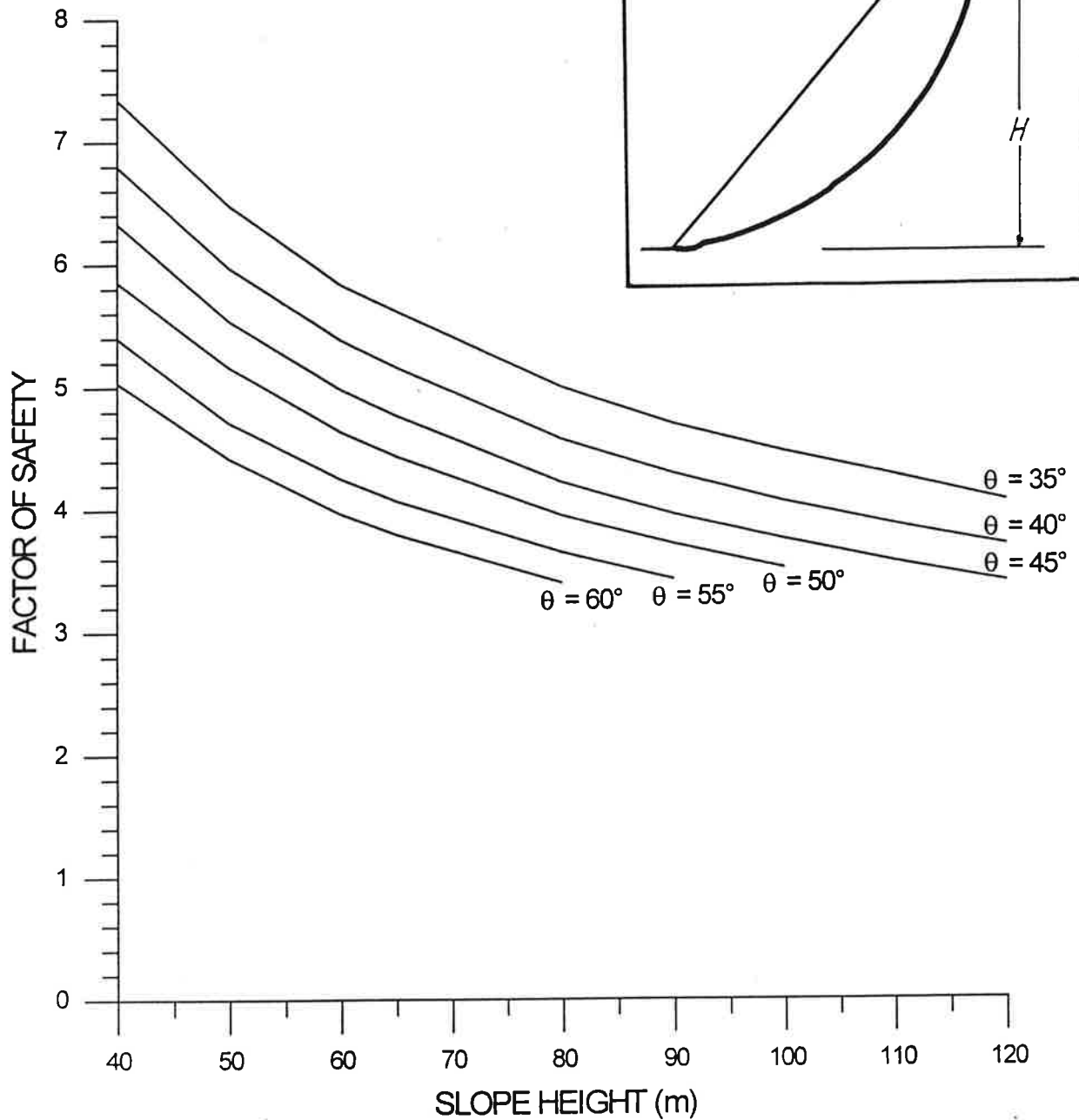
ESTIMATED ROCK MASS STRENGTHS

DRAWN BY: C.B./B.W.G.	EDITED BY: C.D.	DATE: JAN.13/97
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APPROVED:	FIGURE: 8
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JOB NO. 3773-12



- NOTES: 1. Assumptions: dry slope; non-linear rock mass strengths: RMR = 73, UCS = 36 MPa, $m_i = 10$.
 2. Analyses were conducted using the CLARA Stability Analysis program and Bishop's Method of Slices.

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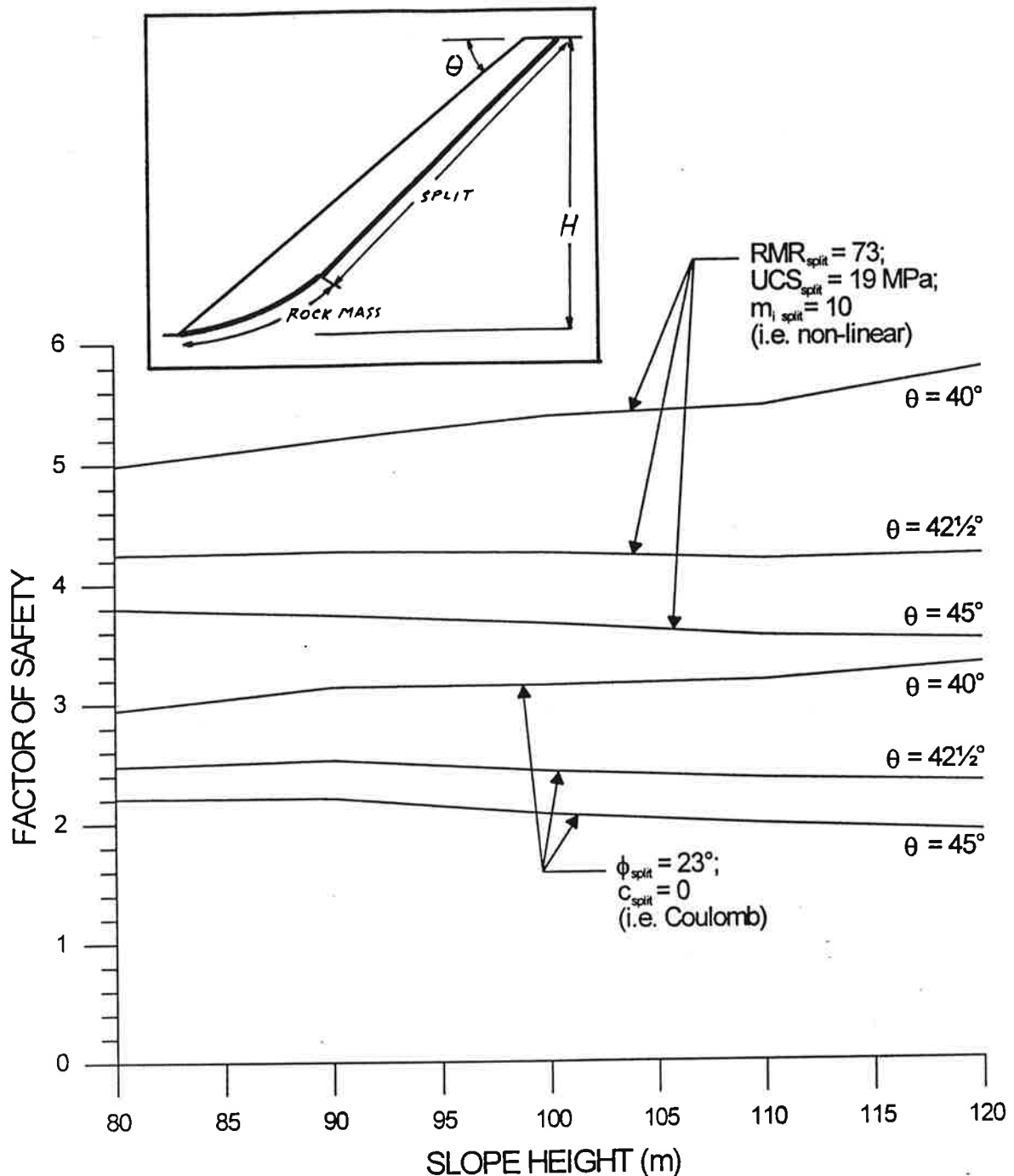
RESULTS OF DEEP SEATED ROTATIONAL ANALYSES

DRAWN BY: B.W.G.	EDITED BY: C.D.	DATE: JAN. 13/97
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APPROVED:	FIGURE: 10
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JOB NO. 3773-12



- NOTES: 1. Assumptions: dry slope; coal split at 45° ; non-linear rock mass strengths for failure through toe: $RMR = 73$, $UCS = 36 \text{ MPa}$, $m_1 = 10$.
2. Analyses were conducted using the CLARA Stability Analyses program and Bishop's Method of Slices.

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RESULTS OF COMBINED PLANAR/ ROTATIONAL FAILURE ANALYSES

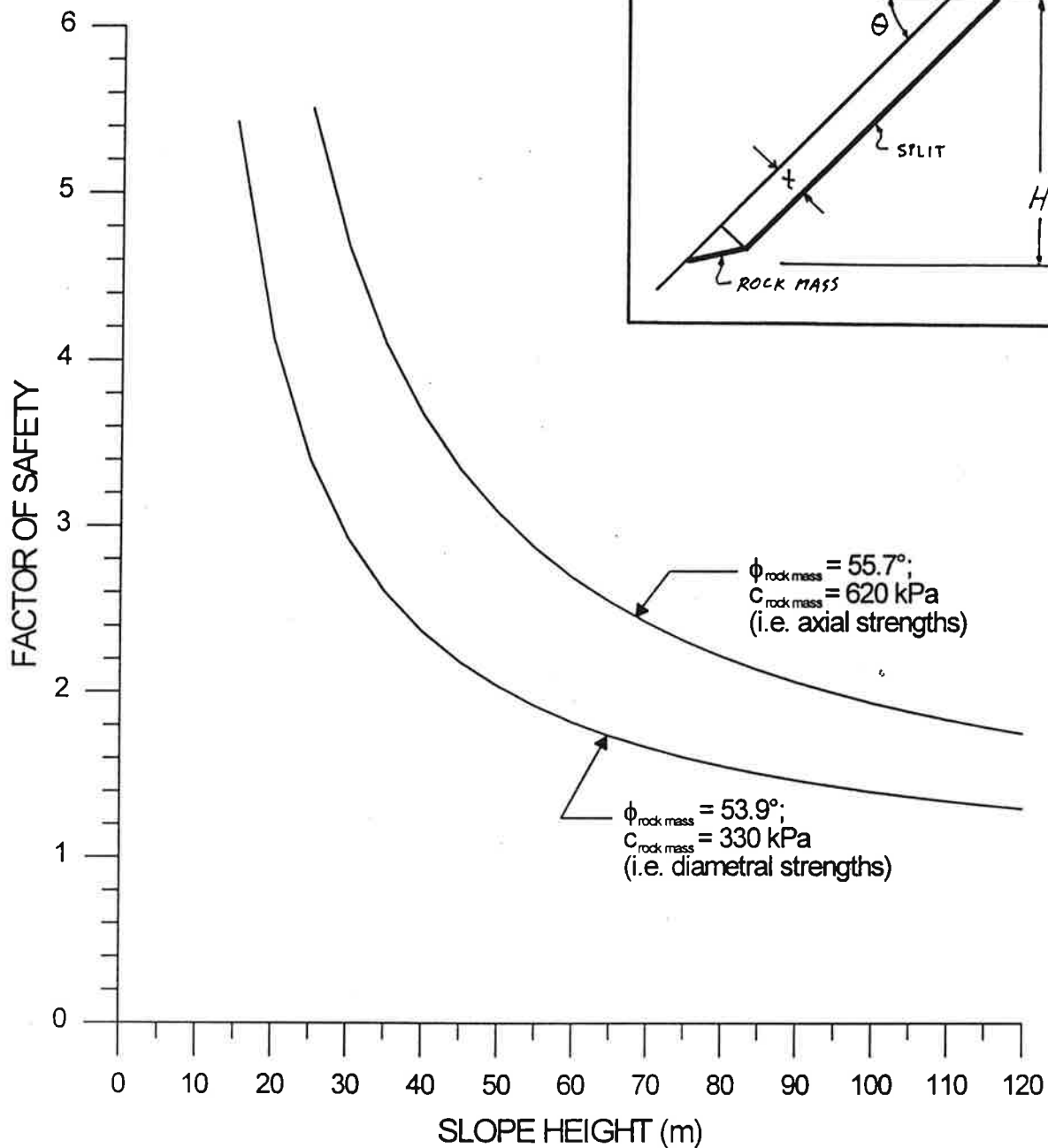
DRAWN BY: B.W.G. EDITED BY: C.D. DATE: JAN. 13/97

APPROVED: FIGURE:

11

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JOB NO. 3773-12



NOTES: 1. Assumptions: dry slope; $\theta = 45^\circ$; $t = 3 \text{ m}$; $\phi_{\text{split}} = 23^\circ$; $c_{\text{split}} = 0$.

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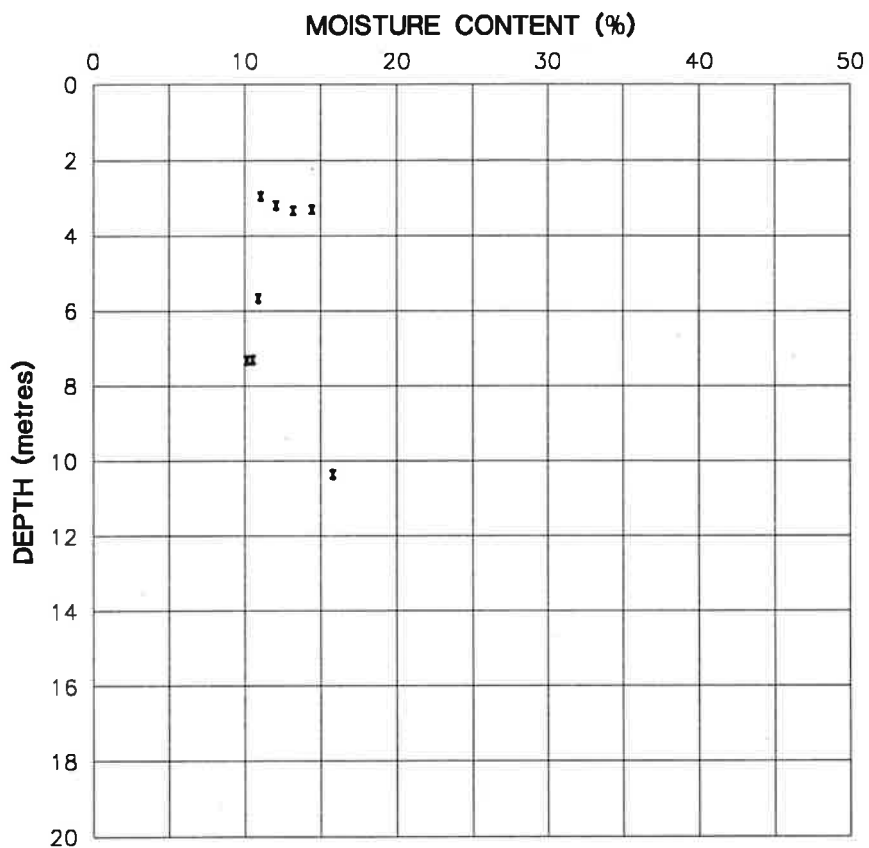
RESULTS OF BILINEAR SLAB FAILURE ANALYSES

DRAWN BY: B.W.G.	EDITED BY: C.D.	DATE: JAN.13/97
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APPROVED:	FIGURE: 12
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ENVIRONMENTAL AND ENGINEERING CONSULTANTS

**MOISTURE CONTENT vs DEPTH (TILL) -
WASTE DUMPS**

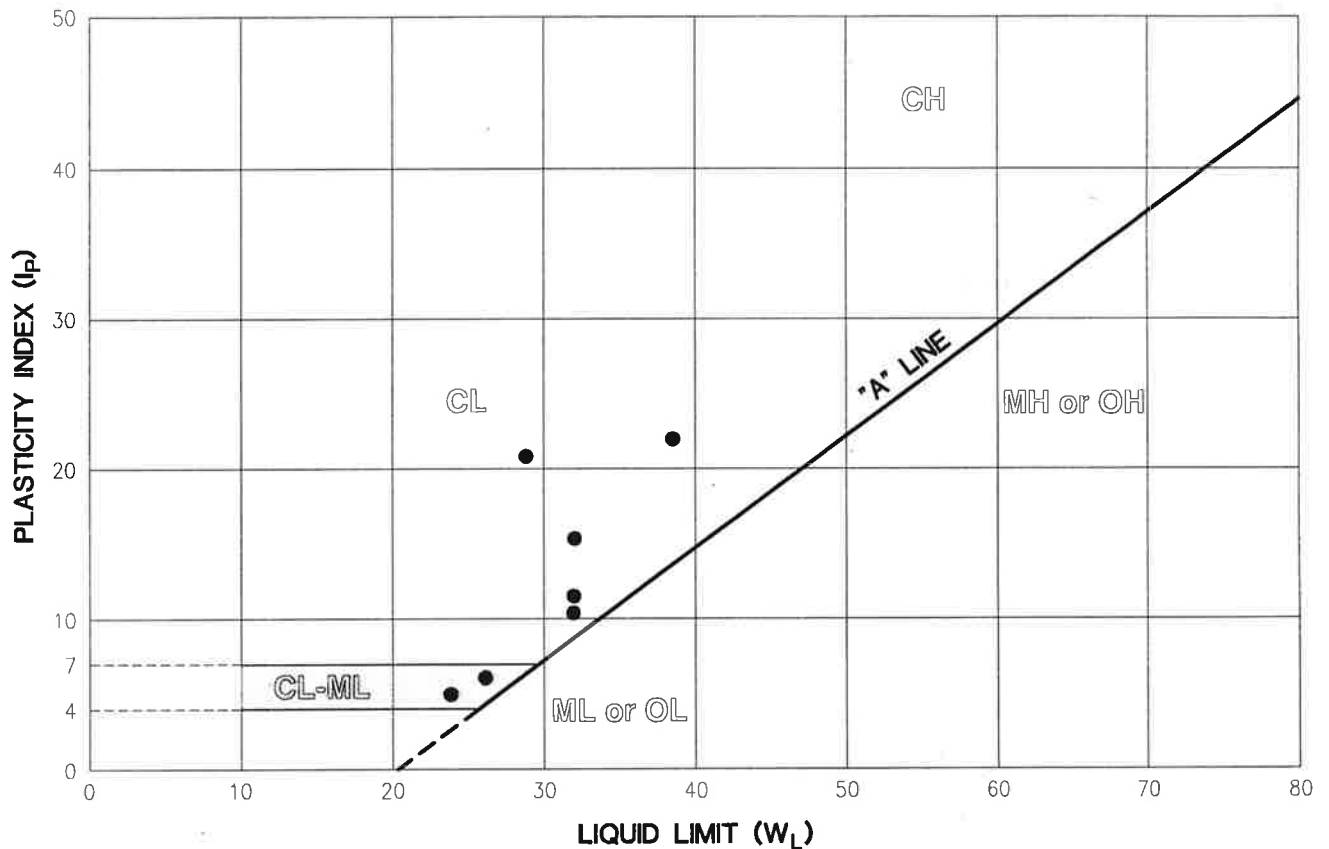
DRAWN BY: M.Z.	EDITED BY: C.D.	DATE: JAN.13/97
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APPROVED:	FIGURE:
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13

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FILE: J:\3773-12T2\MOIST-D.dwg



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ENVIRONMENTAL AND ENGINEERING CONSULTANTS

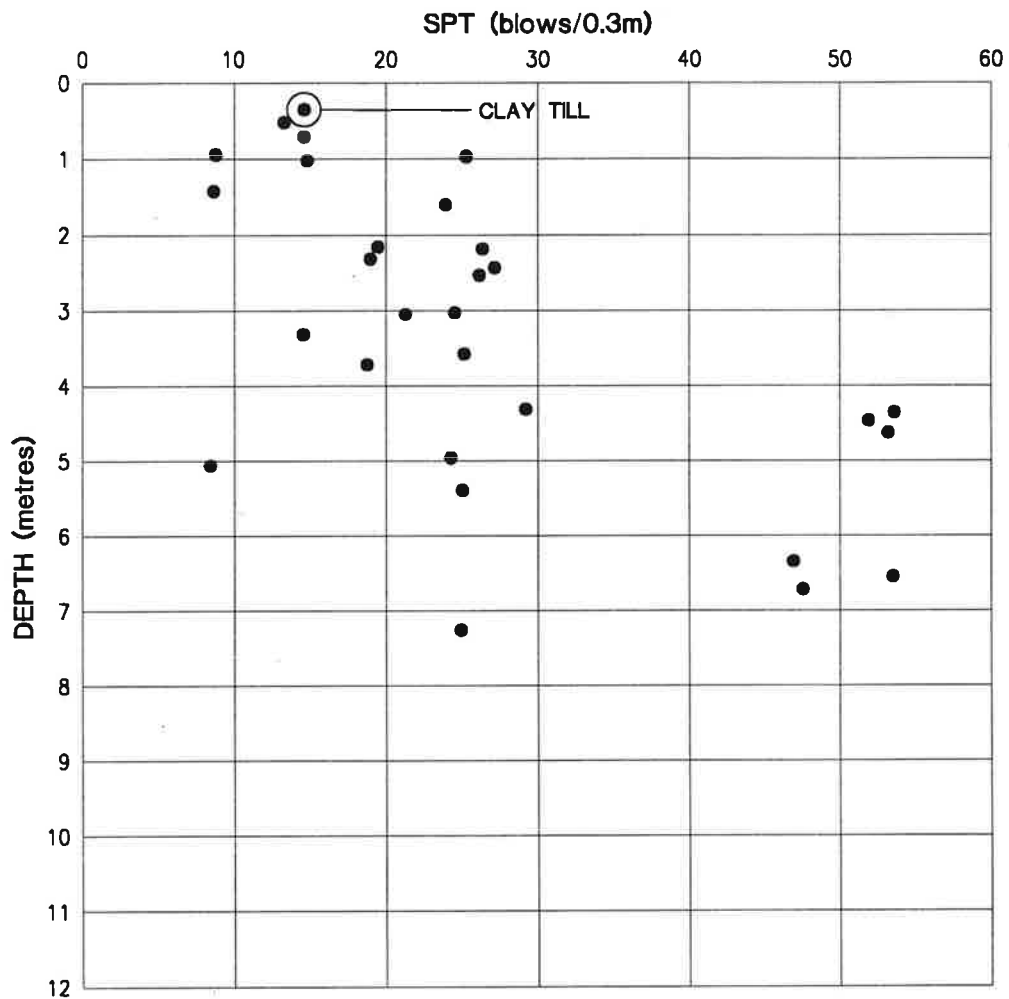
PLASTICITY INDEX vs LIQUID LIMIT (TILL) - WASTE DUMPS

DRAWN BY: M.Z.	EDITED BY: C.D.	DATE: JAN.13/97
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APPROVED:	FIGURE: 14
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FILE: J:\3773-12T2\PLAST-D.dwg



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TELKWA PROJECT



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SPT vs DEPTH (TILL) - WASTE DUMPS

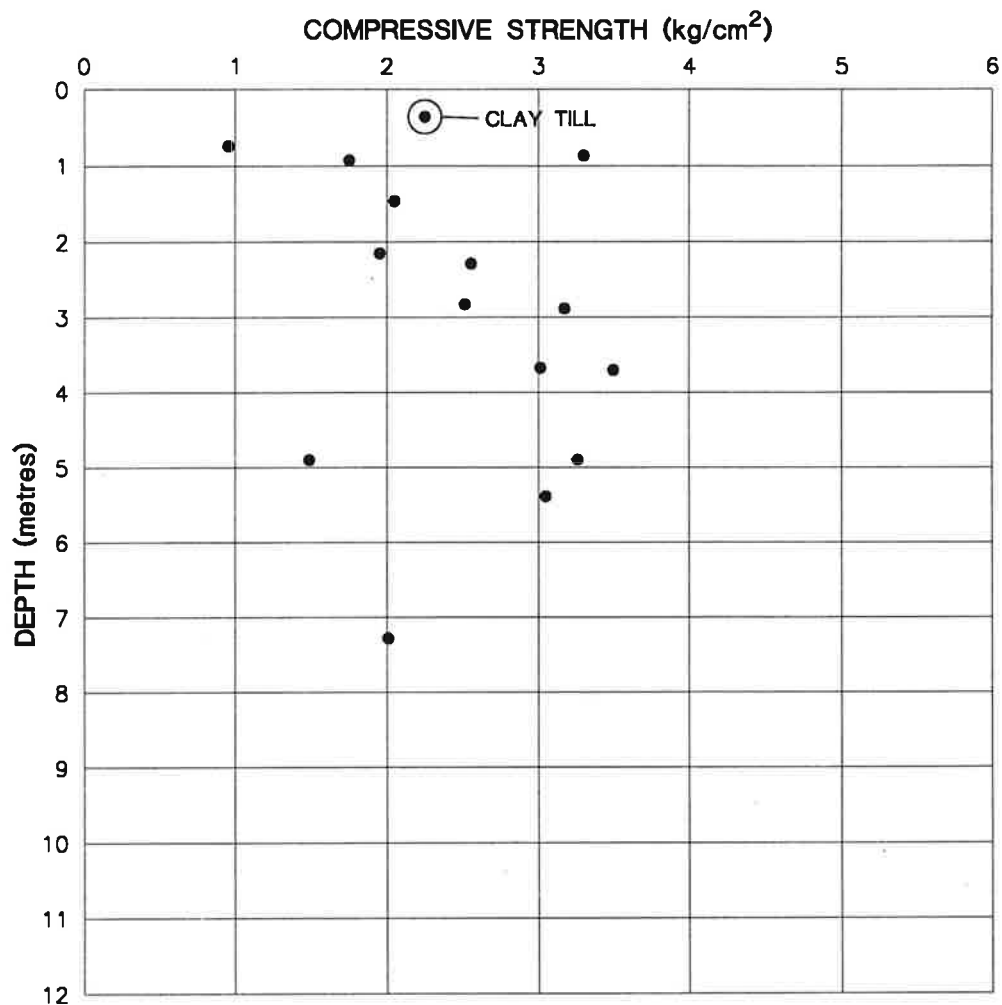
DRAWN BY:	EDITED BY:	DATE:
M.Z.	C.D.	JAN.13/97

APPROVED:	FIGURE:
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15

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FILE: J:\3773-12T2\SPT-0.dwg



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**COMPRESSIVE STRENGTH vs DEPTH (TILL) -
WASTE DUMPS**

DRAWN BY:	EDITED BY:	DATE:
M.Z.	C.D.	JAN.13/97

APPROVED:	FIGURE:
	16

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FILE: J:\3773-12T2\PENETR-D.dwg

APPENDIX I

BOREHOLE LOGS

A. WASTE DUMP SITES

B. GEOTECHNICAL COREHOLES

A. WASTE DUMP SITES (TOB96 SERIES)

CONTRACT NO 3773-12-2

COMPILED BY: M Brewster

BORING DATE July 27, 1996

BORING NO : TOB96-02 (-6, -20)

LOCATION: Tenas Waste Dumps (404)

CONTRACTOR: Cora Lynn Drilling

NORTHING 6051748 6

EASTING: 618580 69

ELEVATION: 853 41 m

SAMPLE TYPES

B BULK SAMPLE
A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRRRL BARREL
S SPLIT SPOON

T SHELBY TUBE

O THIN WALL OPEN

P THIN WALL PISTON

▽ STATIC WATER LEVEL

▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION

⊞ DISTURBED
⊞ FAIR
⊞ GOOD
⊞ LOST

TEST INFORMATION

● PENETROMETER kg/cm²

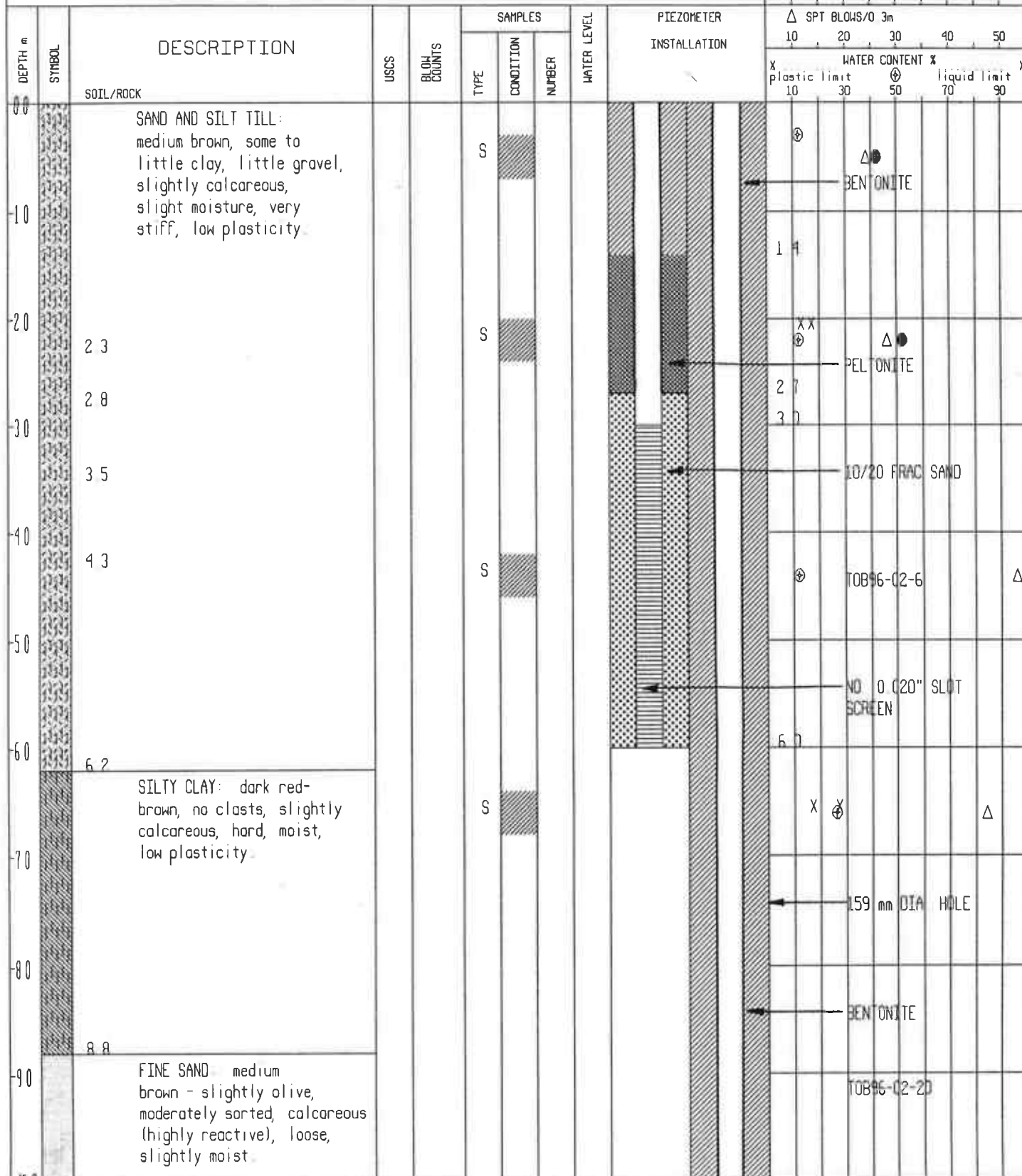
1 2 3 4

Δ SPT BLOWS/0 3m

10 20 30 40 50

X plastic limit WATER CONTENT % liquid limit X

10 30 50 70 90



CONTRACT NO 3773-12-2

COMPILED BY: M. Brewster

BORING DATE July 27, 1996

BORING NO TOB96-02 (-6, -20)

LOCATION: Texas Waste Dumps (404)

CONTRACTOR: Cora Lynn Drilling

NORTHING 6051748 6

EASTING: 618580 69

ELEVATION: 853.41 m

SAMPLE TYPES

B BULK SAMPLE
A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

T SHELBY TUBE

O THIN WALL OPEN

P THIN WALL PISTON

Σ STATIC WATER LEVEL

▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION

 DISTURBED
 FAIR
 GOOD
 LOST

TEST INFORMATION

● PENETROMETER kg/cm²

1 2 3 4

Δ SPT BLOWS/0.3m

10 20 30 40 50

WATER CONTENT %
X plastic limit 10 30 50 70 90
liquid limit

DEPTH m	SYMBOL	DESCRIPTION	USCS	BLOW COUNTS	SAMPLES			WATER LEVEL	PIEZOMETER INSTALLATION					
					TYPE	CONDITION	NUMBER							
10.0		SOIL/ROCK												
11.0		FINE SAND: as above												
11.5		Texture change to medium sand												
12.0					W									
13.0														
14.0														
15.0														
15.5														
16.0														
16.5														
16.7														
17.0														
17.5														
18.0		COARSE SAND AND GRAVEL loose, poorly sorted												
19.0														
20.0														

BENTONITE

159 mm DIA. HOLE

15.5

PELTONITE

16.7

17.0

10/20 FRAC SAND

NO. 0 (20" SLOT
SCREEN

TOB96-02-20

CONTRACT NO : 3773-12-2
BORING NO : TOB96-03
NORTHING: 6052447.9

COMPILED BY: M. Brewster
LOCATION: Tenas Waste Dumps (406)
EASTING: 617976 69

BORING DATE: July 27, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 834.49 m

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

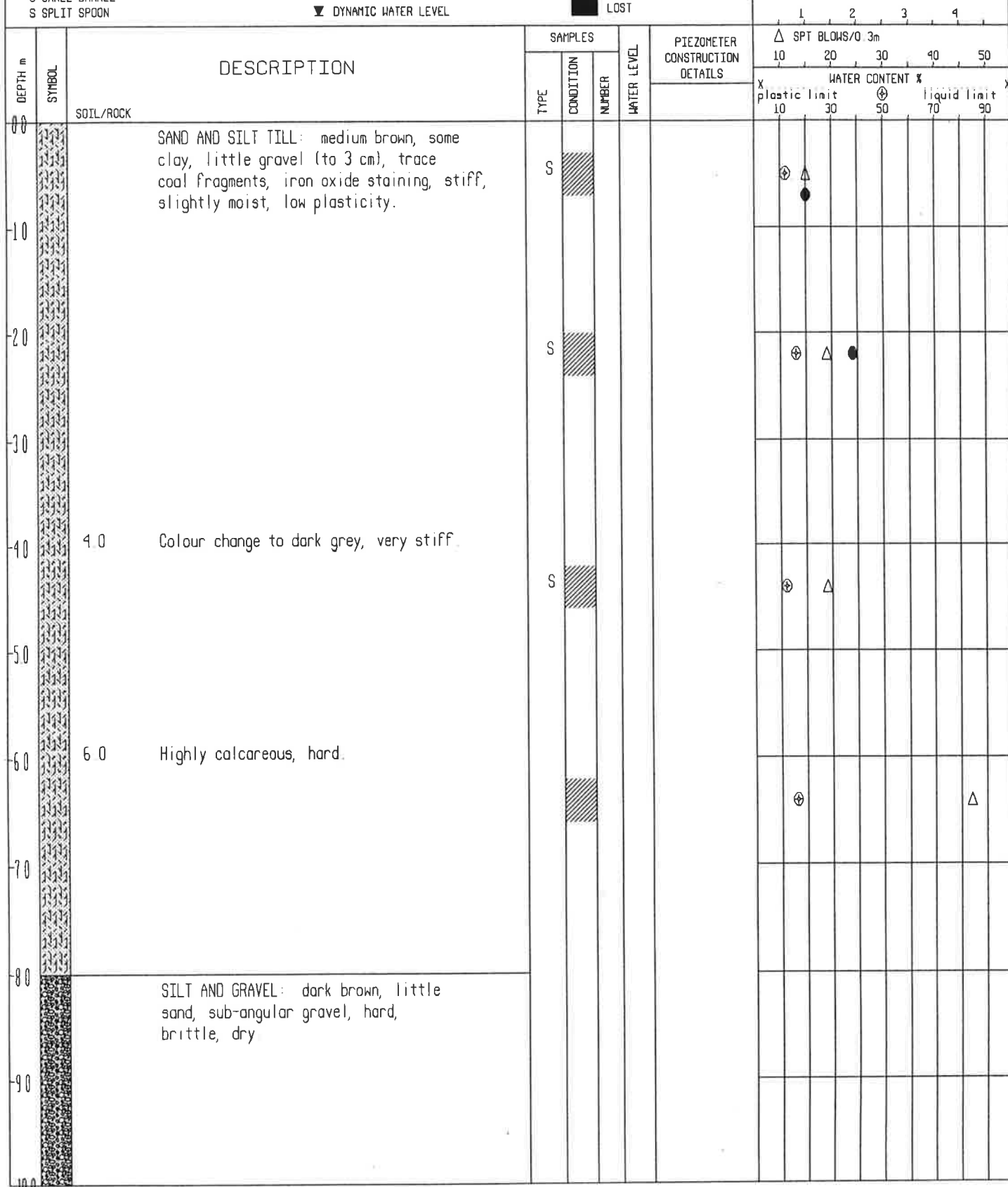
T SHELBY TUBE

☐ THIN WALL OPEN
☐ THIN WALL PISTON
☒ STATIC WATER LEVEL
☐ DYNAMIC WATER LEVEL

SAMPLE CONDITION

DISTURBED
FAIR
GOOD
LOST

TEST INFORMATION

PENETROMETER kg/cm²

CONTRACT NO. 3773-12-2
BORING NO. : T0896-03
NORTHING: 6052447.09

COMPILED BY: M. Brewster
LOCATION: Tenas Waste Dumps (406)
EASTING: 617976 69

BORING DATE: July 27, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 834.49 m

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

T SHELBY TUBE

O THIN WALL OPEN
 P THIN WALL PISTON
 ▽ STATIC WATER LEVEL
 ▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION

TEST INFORMATION

PENETROMETER kg/cm²

1	2	3	4
---	---	---	---

△ SPT BLOWS/0.3m

10 20 30 40 50

WATER CONTENT %				
X plastic limit		⊕	liquid limit	
10	30	50	70	90

[illegible]

BORING DATE: July 29-30, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 853.13 m

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

● PENETROMETER kg/cm²

[illegible]

BORING DATE: July 29-30, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 853.13

SAMPLE TYPES		T SHELBY TUBE		SAMPLE CONDITION		TEST INFORMATION		
A AUGER SAMPLE		O THIN WALL OPEN			DISTURBED	PENETROMETER kg/cm2		
W WASH SAMPLE		P THIN WALL PISTON			FAIR	1 2 3 4		
R ROCK CORE		▽ STATIC WATER LEVEL			GOOD	10 20 30 40 50		
C CORREL BARREL		▼ DYNAMIC WATER LEVEL			LOST	X plastic limit 10 30 50 70 90		
S SPLIT SPOON						WATER CONTENT %		
						Δ SPT BLOWS/0.3m		
DEPTH m	SYMBOL	DESCRIPTION	SAMPLES			PIEZOMETER CONSTRUCTION DETAILS		
			TYPE	CONDITION	NUMBER		WATER LEVEL	
60.0		SOIL/ROCK						
61.0		SILTY CLAY: dark brown, stiff, dry.						
62.0	62.0	FINE SAND: medium brown, well sorted, minor gravel.						
63.0		63.5						
64.0		64.2 SILTY CLAY: dark grey, hard, slow penetration rate, (cuttings heavily contaminated with sand from above). Interbedded gravels in silty clay, approx. 10 cm thick layers.						
65.0								
66.0								
67.0								
68.0								
69.0								
70.0								

BORING DATE: July 29-30, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 853.13

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

 PENETROMETER kg/cm²

A horizontal number line with four tick marks. The tick marks are labeled 1, 2, 3, and 4 from left to right.

△ SPT BLOWS/0.3m

10 20 30 40 50

WATER CONTENT %				
plastic limit				liquid limit
10	30	50	70	90

[illegible]

BORING DATE: July 29-30, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 853.13

TEST INFORMATION

PENETROMETER kg/cm²[illegible]

CONTRACT NO 3773-12-2
 BORING NO TOB96-11 (-5, -20)
 NORTHING: 6052619 09

COMPILED BY: M Brewster
 LOCATION Tenas Waste Dumps (407)
 EASTING 617839 70

BORING DATE Sept 13, 1996
 CONTRACTOR: Cora Lynn Drilling
 ELEVATION: 827 36 m

SAMPLE TYPES

B BULK SAMPLE
 A AUGER SAMPLE
 W WASH SAMPLE
 R ROCK CORE
 C CORREL BARREL
 S SPLIT SPOON

T SHELBY TUBE
 O THIN WALL OPEN
 P THIN WALL PISTON
 □ STATIC WATER LEVEL
 ▼ DYNAMIC WATER LEVEL

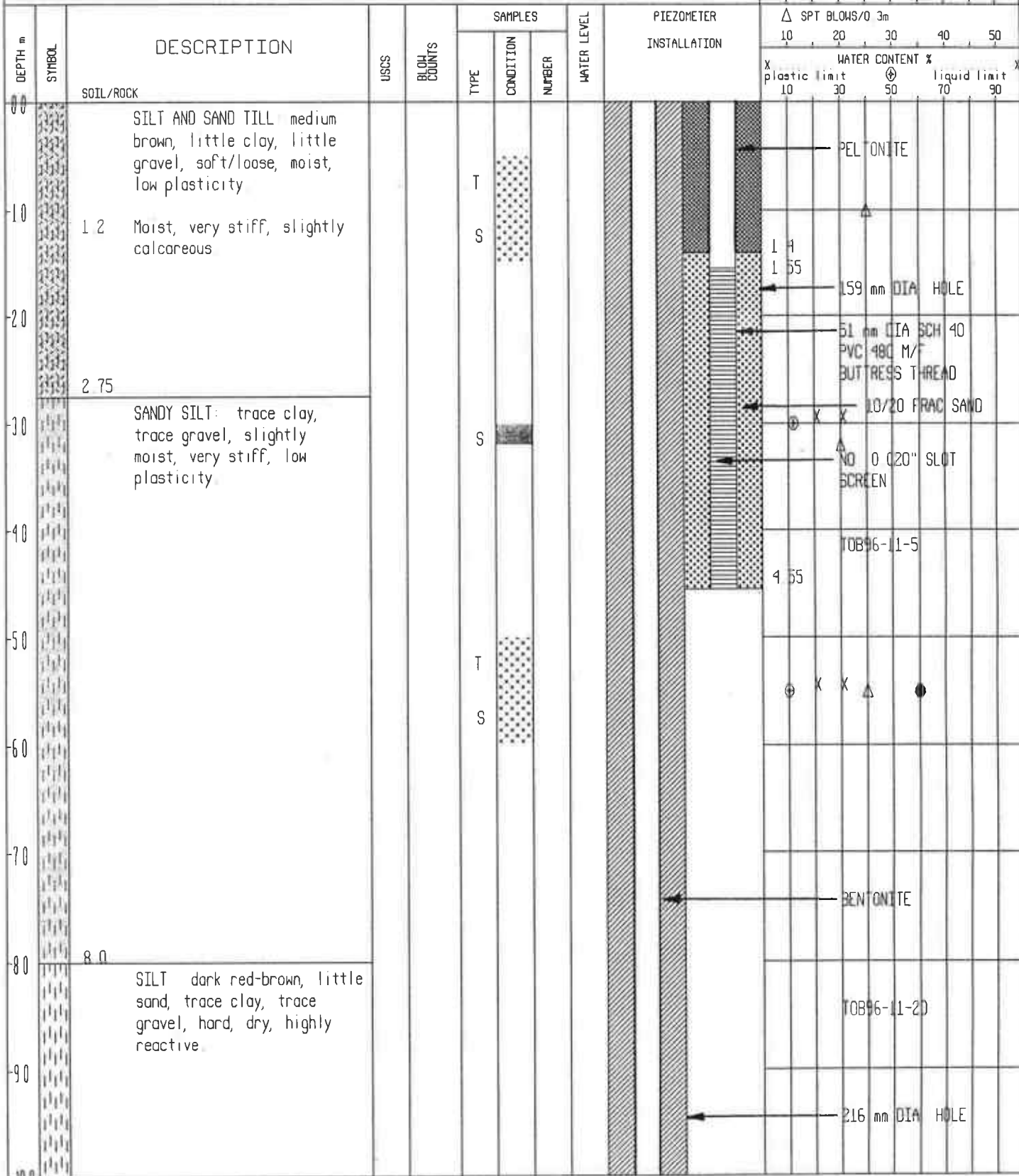
SAMPLE CONDITION

 DISTURBED
 FAIR
 GOOD
 LOST

TEST INFORMATION

● PENETROMETER kg/cm²

1 2 3 4
 Δ SPT BLOWS/0 3m
 10 20 30 40 50
 X plastic limit WATER CONTENT % liquid limit X
 10 30 50 70 90



CONTRACT NO 3773-12-2

COMPILED BY: M. Brewster

BORING DATE Sept 13, 1996

BORING NO : TOB96-11 (-5, -20)

LOCATION: Tenas Waste Dumps (407)

CONTRACTOR: Cora Lynn Drilling

NORTHING: 6052619 09

EASTING: 617839 70

ELEVATION: 827.36 m

SAMPLE TYPES

B BULK SAMPLE
A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CORREL BARREL
S SPLIT SPOON

T SHELBY TUBE
O THIN WALL OPEN
P THIN WALL PISTON
▽ STATIC WATER LEVEL
▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION

 DISTURBED
 FAIR
 GOOD
 LOST

TEST INFORMATION

● PENETROMETER kg/cm²

1 2 3 4
 △ SPT BLOWS/0.3m
 10 20 30 40 50

X plastic limit 10 30 50 70 90
 WATER CONTENT %
 liquid limit

DEPTH m	SYMBOL	DESCRIPTION	USCS	BLOW COUNTS	SAMPLES			WATER LEVEL	PIEZOMETER INSTALLATION					
					TYPE	CONDITION	NUMBER							
		SOIL/ROCK												
10.0		SILT dark red-brown, hard, dry, highly reactive			T									
11.0		11.0 Increasing gravel content			S									
12.0														
13.0														
14.0														
15.0														
16.0														
17.0														
18.0														
18.2														
19.0		FINE SAND: medium red-brown, little silt, well sorted, highly calcareous, loose, dry												
19.5		Gravel												
20.0		TOTAL DEPTH = 20.2 m												

BENTONITE

216 mm DIA HOLE

 51 mm DIA SCH 40
 PVC 480 M/F
 BUTTRESS THREAD

TOB96-11-20

17.6

PELTONITE

18.2

18.7 10/20 FRAC SAND

NO. 0 020" SLOT SCREEN

CONTRACT NO 3773-12-2
BORING NO 10B96-12 (-4)
NORTHING 6051178 81

COMPILED BY: M. Brewster
LOCATION: Tenas Waste Dump (410)
EASTING: 616196 41

BORING DATE: Sept 13, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 926.02 m

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

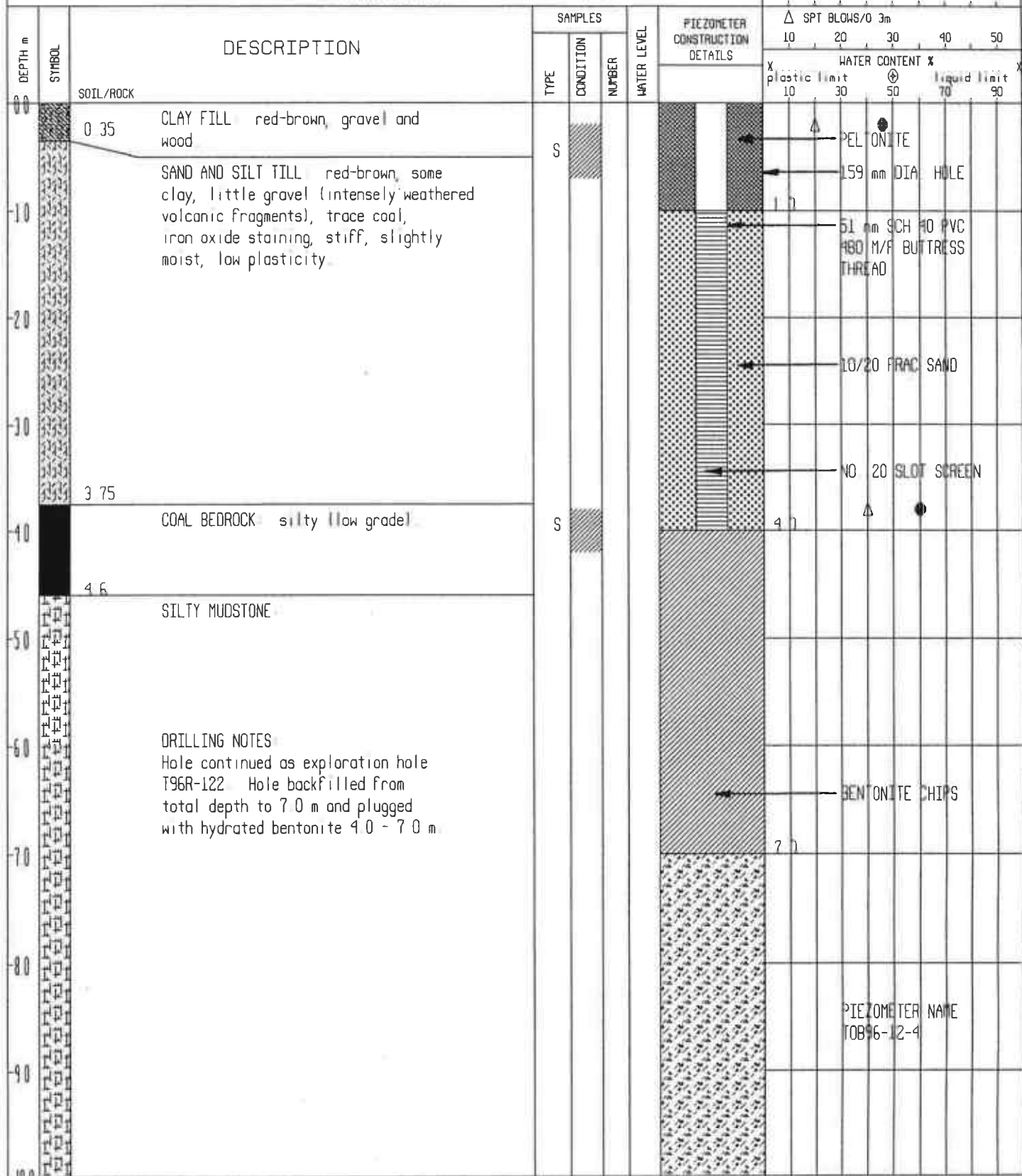
- T SHELBY TUBE
- O THIN WALL OPEN
- P THIN WALL PISTON
- ▽ STATIC WATER LEVEL
- ▼ DYNAMIC WATER LEVEL

SAMPLE	CONDITION
1	DISTURBED
	FAIR
	GOOD
	LOST

TEST INFORMATION

PENETROMETER kg/cm²

Figure 1 is a graph showing the relationship between SPT Blows/0.3m (X-axis) and Water Content (%) (Y-axis). The X-axis is labeled "SPT BLOWS/0.3m" and has values 1, 2, 3, 4. The Y-axis is labeled "WATER CONTENT %" and has values 10, 20, 30, 40, 50. A curve is plotted, showing that as SPT Blows/0.3m increases, the Water Content (%) decreases. The curve starts at approximately (1, 45) and ends at approximately (4, 15). The curve is labeled "Liquid Limit" at the right end.



CONTRACT NO 3773-12-2
BORING NO TOB96-13
NORTHING: 6050812 67

COMPILED BY: M. Brewster
LOCATION: Tenas Waste Dump (411)
EASTING: 616031.90

BORING DATE: Sept. 14, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 942.91 m

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

T SHELBY TUBE

O THIN WALL OPEN
P THIN WALL PISTON
▽ STATIC WATER LEVEL
▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION

TEST INFORMATION

● PENETROMETER kg/cm²

1 2 3 4
Δ SPT BLOWS/0 3m
10 20 30 40 50

WATER CONTENT %				
X				
plastic limit		⊕		liquid limit
10	30	50	70	90

[illegible]

CONTRACT NO 3773-12-2
BORING NO : T0896-17
NORTHING: 6051407.72

COMPILED BY: M. Brewster
LOCATION: Tenas Waste Dump (403)
EASTING: 618747.18

BORING DATE: Sept. 17, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 859.65 m

[illegible]

CONTRACT NO 3773-12-2
BORING NO : T0896-18
NORTHING 6051061 61

COMPILED BY: M. Brewster
LOCATION: Tenas Waste Dump (402)
EASTING: 619079 89

BORING DATE: Sept 17, 1996
CONTRACTOR: Cora Lynn Drilling
ELEVATION: 872.70 m

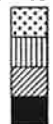
SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRRCL BARREL
S SPLIT SPOON

T SHELBY TUBE

O THIN WALL OPEN
P THIN WALL PISTON
▽ STATIC WATER LEVEL
▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION



DISTURBED
FAIR
GOOD
LOST

TEST INFORMATION

● PENETROMETER kg/cm2

1 2 3 4
△ SPT BLOWS/0.3m
10 20 30 40 50
X plastic limit WATER CONTENT % liquid limit X
10 30 50 70 90

DEPTH m	SYMBOL	DESCRIPTION	SAMPLES			PIEZOMETER CONSTRUCTION DETAILS					
			TYPE	CONDITION	NUMBER						
		SOIL/ROCK									
0.0		ROAD FILL, SILT, GRAVEL, SAND AND WOOD									
1.0		SAND AND SILT TILL: medium brown, little to some clay, little gravel, trace coal, iron oxide nodules, slightly calcareous, medium stiff, moist, low plasticity.	S								
2.0		Colour change to dark brown.									
3.0			S								
4.0											
5.0											
6.0		SAND: light to medium brown, some gravel, loose, dry.									
7.0											
8.0		GRAVEL: mustard yellow to ochre coloured fluid with medium sand and silt, moderately reactive.									
9.0											
10.0											

▼
7.0

KOMEX INTERNATIONAL LTD.		OFFICE REPORT ON SITE INVESTIGATION		SHEET 2 OF 2	
CONTRACT NO : 3773-12-2		COMPILED BY: M. Brewster		BORING DATE: Sept. 17, 1996	
BORING NO : TOB96-18		LOCATION: Tenas Waste Dump (402)		CONTRACTOR: Cora Lynn Drilling	
NORTHING: 6051061 61		EASTING: 619079.89		ELEVATION: 872.70 m	

SAMPLE TYPES A AUGER SAMPLE W WASH SAMPLE R ROCK CORE C CRRRL BARREL S SPLIT SPOON		T SHELBY TUBE O THIN WALL OPEN P THIN WALL PISTON ▽ STATIC WATER LEVEL ▼ DYNAMIC WATER LEVEL		SAMPLE CONDITION DISTURBED FAIR GOOD LOST		TEST INFORMATION ● PENETROMETER kg/cm2 1234	
--	--	---	--	---	--	---	--

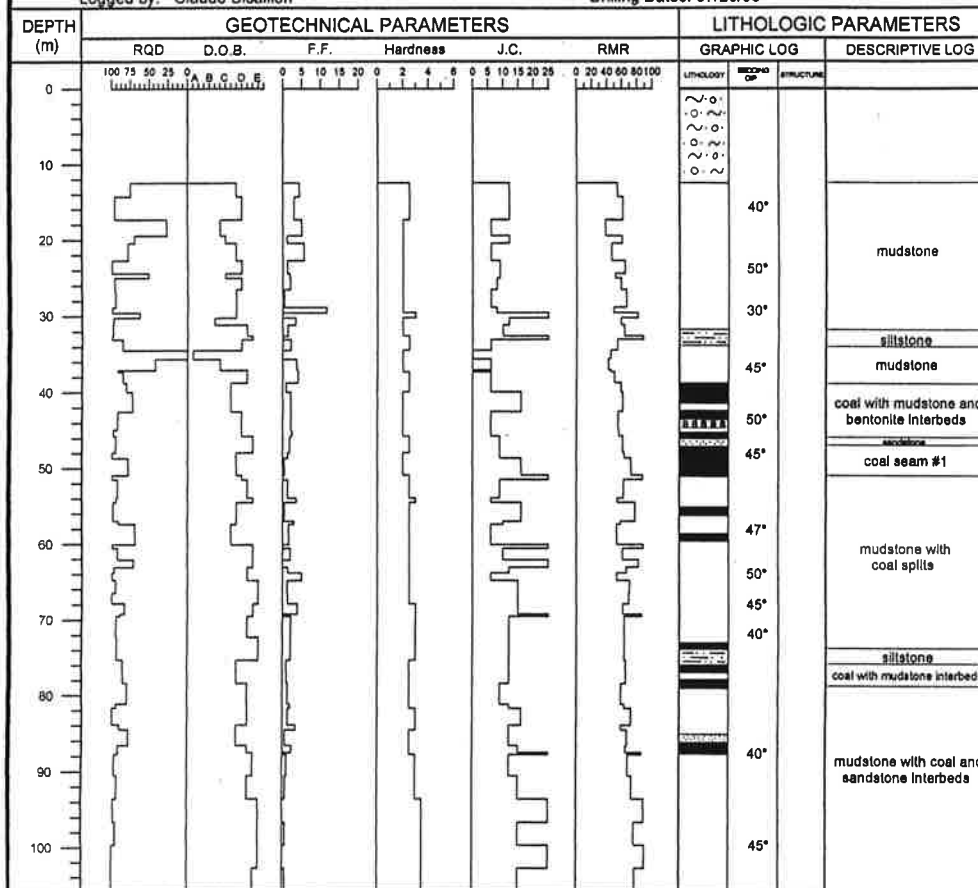
DEPTH m	SYMBOL	DESCRIPTION	SAMPLES				PIEZOMETER CONSTRUCTION DETAILS	TEST INFORMATION										
			TYPE	CONDITION	NUMBER	WATER LEVEL		Δ SPT BLOWS/0.3m	WATER CONTENT %									
									X plastic limit	X liquid limit	X	X						
10.0		SOIL/ROCK						10	20	30	40	50						
		GRAVEL: mustard yellow to ochre coloured fluid with medium sand and silt, moderately reactive.																
11.0																		
12.0																		
12.5		Lighter colour very pale yellow.																
13.0																		
14.0																		
15.0		15.0																
		MUDSTONE BEDROCK: grey-brown with black carbonaceous stringers and dirty coal lenses.																
16.0																		
17.0																		
		TOTAL DEPTH = 17.0 m.																
18.0																		
19.0																		
20.0																		

B. GEOTECHNICAL COREHOLES (T96R-05C, T96R-28C, T96R-42C, AND T96R-65C)

GEOTECHNICAL LOG T96R-05C

Location: TELKWA B.C.
Coordinates: N=6050031.11 E=618923.21
Depth: 105.77 m Collar Elev.= 948.40 m Dip: -90°
Logged by: Claude Bisailon

Drilling Contractor: Cora Lynn Drilling
Drilling Method: Diamond Drill
Hole Diam.= Core Diam.= 75 mm
Drilling Dates: 07/28/96



SCALE 1:1000

LEGEND

GEOTECHNICAL PARAMETERS

RQD = Rock Quality Designation (%)
D.O.B. = Degree of Brecciation
F.F. = Fracture Frequency (joints/m)
Hardness = (as per ISRM, 1961)
J.C. = Joint Condition (as per Bieniawski, 1978)
RMR = Rock Mass Rating (as per Bieniawski, 1978)

LITHOLOGY

OVERBURDEN

SANDSTONE

MUDSTONE

SILTSTONE

BENTONITE

COALLY MUDSTONE

MUDDY COAL

COAL

GEOLOGIC CONTACT

MANALTA COAL LTD.
TELKWA PROJECT



PITEAU ENGINEERING LTD.
GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL CORELOG: COREHOLE T96R-05C

DRAWN BY: C.B./B.L. EDITED BY: C.D. DATE: JAN.13/97

APPROVED: FIGURE:

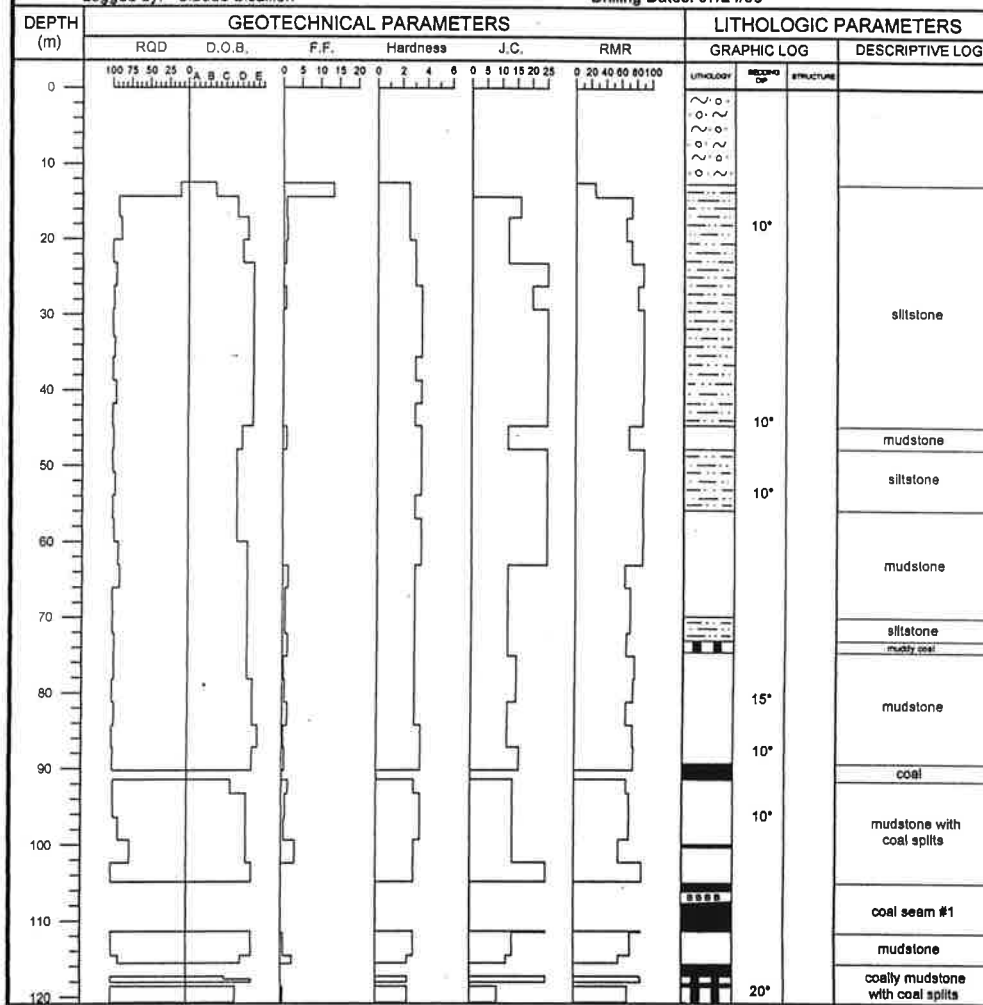
PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

JOB NO. 3773-12

GEOTECHNICAL LOG T96R-28C

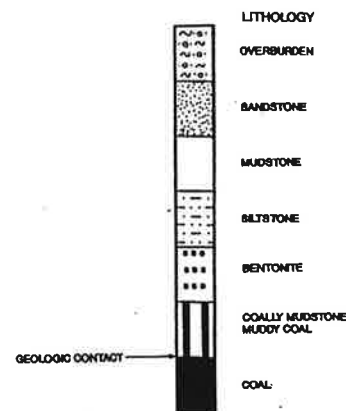
Location: TELKWA B.C.
 Coordinates: N=6051092.00 E=618052.76
 Depth: 120.7 m Collar Elev.= 919.11 m Dip: -90°
 Logged by: Claude Bisailon

Drilling Contractor: Cora Lynn Drilling
 Drilling Method: Diamond Drill
 Hole Diam.= Core Diam.= 75 mm
 Drilling Dates: 07/24/96



SCALE 1:1000

LEGEND



GEOTECHNICAL PARAMETERS

RQD - Rock Quality Designation (%)
 D.O.B. - Degree of Breakage
 F.F. - Fracture Frequency (joints/m)
 Hardness - (as per ISRM, 1981)
 J.C. - Joint Condition (as per Bieniawski, 1976)
 RMR - Rock Mass Rating (as per Bieniawski, 1976)

MANALTA COAL LTD.
 TELKWA PROJECT



PITEAU ENGINEERING LTD.
 GEOTECHNICAL AND
 HYDROGEOLOGICAL CONSULTANTS
 VANCOUVER CALGARY

GEOTECHNICAL CORELOG: COREHOLE T96R-28C

DRAWN BY:	EDITED BY:	DATE:
B.W.G.	C.D.	JAN.13/97
APPROVED:	FIGURE:	

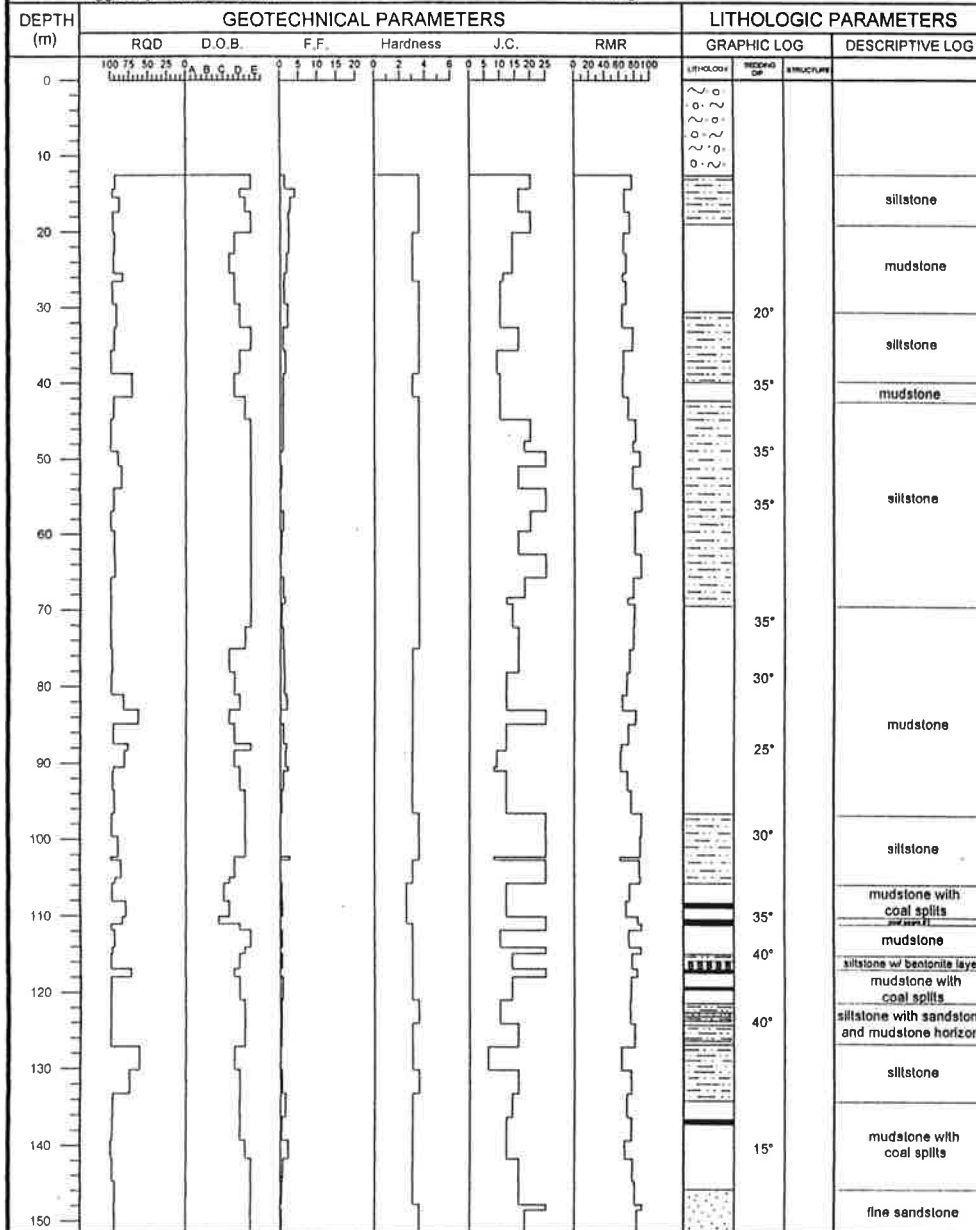
PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

JOB NO. 3773-12

GEOTECHNICAL LOG T96R-42C

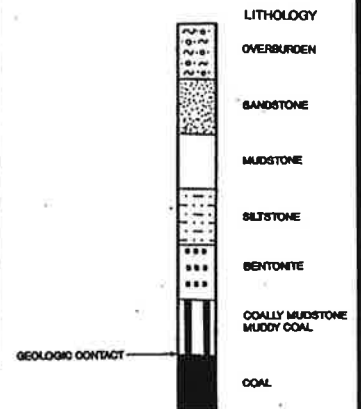
Location: TELKWA B.C.
 Coordinates: N=6051844.22 E=617377.88
 Depth: 151.57 m Collar Elev.= 868.23 m Dip: -90°
 Logged by: Claude Bisailon

Drilling Contractor: Cora Lynn Drilling
 Drilling Method: Diamond Drill
 Hole Diam.= Core Diam.= 75 mm
 Drilling Dates: 07/29/96



SCALE 1:1000

LEGEND



GEOTECHNICAL PARAMETERS

RQD - Rock Quality Designation (%)
 D.O.B. - Degree of Breakage
 F.F. - Fracture Frequency (joints/m)
 Hardness - (as per ISRM, 1981)
 J.C. - Joint Condition (as per Bieniawski, 1978)
 RMR - Rock Mass Rating (as per Bieniawski, 1978)

MANALTA COAL LTD.
 TELKWA PROJECT



PITEAU ENGINEERING LTD.
 GEOTECHNICAL AND
 HYDROGEOLOGICAL CONSULTANTS
 VANCOUVER CALGARY

GEOTECHNICAL CORELOG: COREHOLE T96R-42C

DRAWN BY: C.B./B.L. EDITED BY: C.D. DATE: JAN.13/97
 APPROVED: FIGURE:

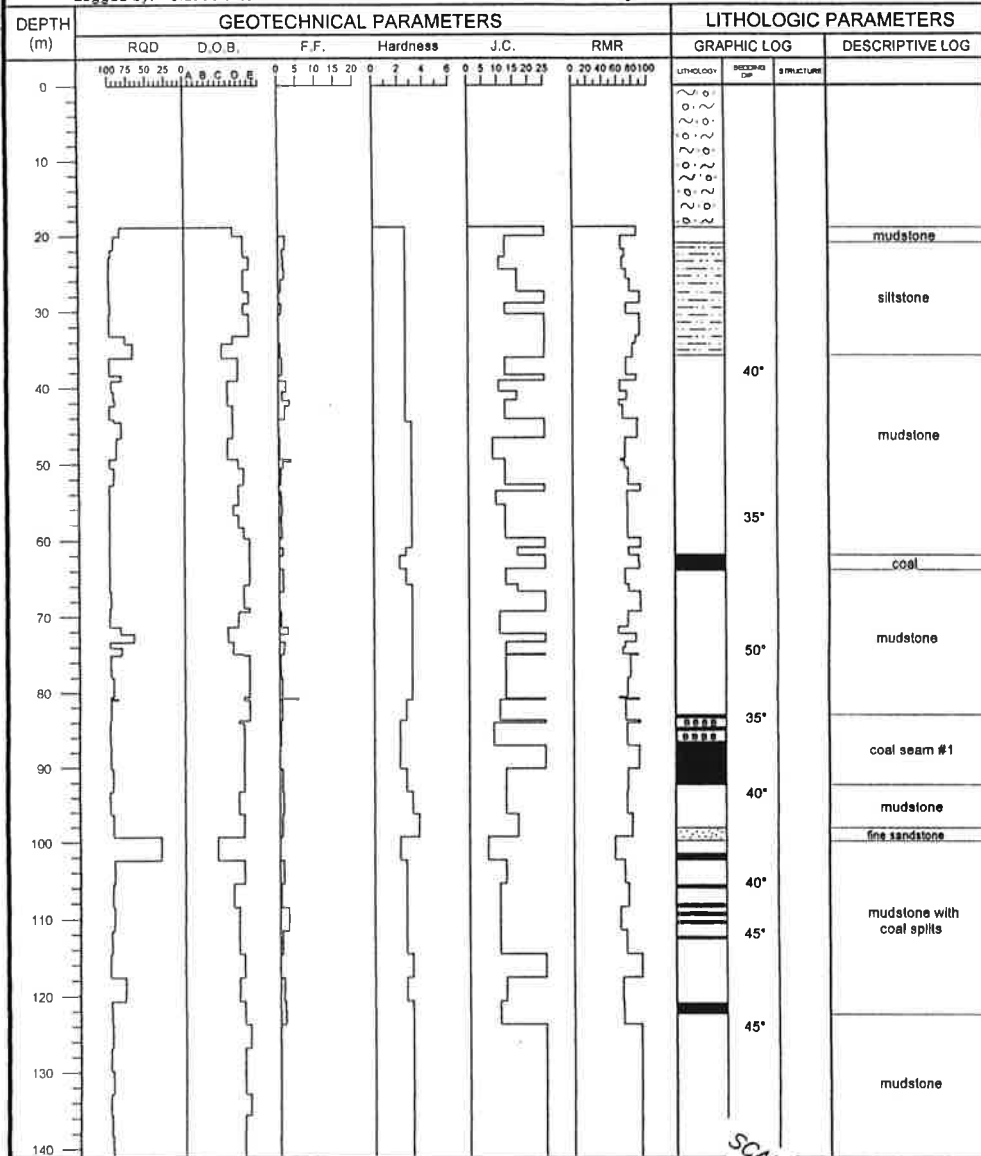
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JOB NO. 3773-12

GEOTECHNICAL LOG T96R-65C

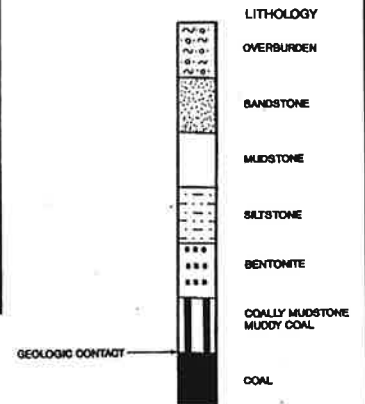
Location: TELKWA B.C.
Coordinates: N=6051041.34 E=618304.61
Depth: 141.0 m Collar Elev.= 914.54 m Dip: -90°
Logged by: Claude Bisailon

Drilling Contractor: Cora Lynn Drilling
Drilling Method: Diamond Drill
Hole Diam.= Core Diam.= 75 mm
Drilling Dates: 08/15/96



SCALE 1:1000

LEGEND



GEOTECHNICAL PARAMETERS

RQD = Rock Quality Designation (%)
D.O.B. = Degree of Breakage
F.F. = Fracture Frequency (joints/m)
Hardness = (as per ISRM, 1981)
J.C. = Joint Condition (as per Bieniawski, 1976)
RMR = Rock Mass Rating (as per Bieniawski, 1976)

MANALTA COAL LTD.
TELKWA PROJECT



PITEAU ENGINEERING LTD.
GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL CORELOG: COREHOLE T96R-65C

DRAWN BY: C.B./B.L. EDITED BY: C.D. DATE: JAN. 13/97

APPROVED: FIGURE:

PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH PITEAU ENGINEERING LTD. HAS NOT ENTERED INTO A CONTRACT.

JOB NO. 3773-12



PITEAU ENGINEERING LTD.

HYDROGEOLOGICAL AND GEOTECHNICAL CONSULTANTS

SUITE 100, 4500 - 16TH AVENUE N.W.
CALGARY, ALBERTA
CANADA T3B 0M6
TELEPHONE (403) 286-2522
FAX (403) 247-4811 or 247-0779
e-mail: komex@komex.com

**GEOTECHNICAL ASSESSMENT FOR
COAL HAUL ROADS, TAILINGS POND
AND PLANT SITE
TELKWA COAL PROJECT**

PREPARED FOR:

MANALTA COAL LTD.

TABLE OF CONTENTS

	<u>Page No.</u>
1. INTRODUCTION.....	1
1.1 REGULATORY TERMS OF REFERENCE.....	1
2. REGIONAL GEOLOGY	3
2.1 SETTING AND PHYSIOGRAPHY	3
2.2 BEDROCK GEOLOGY.....	3
2.3 OVERBURDEN GEOLOGY	3
3. COAL HAUL ROADS.....	4
3.1 FOUNDATION CONDITIONS.....	4
4. TAILINGS POND.....	5
4.1 SITE CONDITIONS	5
4.2 FOUNDATION CONDITIONS.....	5
4.3 CONSTRUCTION MATERIALS	5
5. PLANT SITE.....	6
5.1 SITE CONDITIONS	6
5.2 FOUNDATION CONDITIONS.....	6
5.3 CUT AND FILL RECOMMENDATIONS	7
5.4 FOUNDATION DESIGNS AND RECOMMENDATIONS.....	7
5.4.1 FOUNDATION TYPE.....	7
5.4.2 BEARING PRESSURE AND SETTLEMENT	7
5.4.3 SURFACE DRAINAGE	8
5.5 RAIL LOADOUT	8
6. CLOSURE	9
7. REFERENCES.....	10
8. DISCLAIMER.....	11

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

TABLE 1	SUMMARY OF GEOTECHNICAL LABORATORY TEST DATA FOR THE 1998 TEST PITS
TABLE 2	PRELIMINARY FOUNDATION LOADING

LIST OF FIGURES

FIGURE 1	SITE LOCATION
FIGURE 2	COAL HAUL ROADS
FIGURE 3	PLANT SITE AND TAILINGS POND
FIGURE 4	DRY DENSITY VS MOISTURE CONTENT, SAMPLE: SILT-CLAY TILL COMPOSITE

LIST OF APPENDICES

APPENDIX I	1998 TEST PIT LOGS
APPENDIX II	GRAIN SIZE CURVES

1. INTRODUCTION

Piteau Engineering Ltd. (Piteau) was retained by Manalta Coal Ltd. (Manalta) to conduct a geotechnical investigation in support of the proposed Telkwa Coal Project near Telkwa, B.C. (Figure 1). This report presents the results of the geotechnical investigation performed for the Coal Haul Roads, the Coal Processing Plant, and the Tailings Pond area. The scope of work was based on meetings and discussions with Manalta staff, and was outlined in a letter submitted to Manalta on March 10, 1998 (Piteau, 1998a). The CBR tests that were planned for this phase will be performed during the summer program. This report parallels baseline hydrogeologic (Piteau, 1998b) and hydrologic (Piteau, 1998d) investigations carried out for this area. Previous results of geotechnical and hydrogeological investigations have been reported for the Pit 3 and Tenas Pit Waste Dumps, Coal Processing Plant and Proposed Tailings Pond Area (Piteau, 1997a and 1998c), Tenas Pit (Piteau, 1997b and Piteau, 1997c) and for Pit 7 and 8 Areas (Piteau, 1994a and Piteau, 1994b).

The test pit program was conducted in April, 1998. Figures 2 and 3 show the location of the test pits, numbered TRC98-1 to 32. The track mounted hoe, supplied and operated by Bruce Kerr, had a maximum reach of approximately 5 m. Disturbed samples were field logged and taken to the Piteau laboratory for classification tests (Table 1). The soils were classified using the Unified Soil Classification (USC) system. Pocket penetrometer results, measuring unconfined compressive strength, are included in the test pit logs (Appendix I). Grain size curves are provided in Appendix II. Office studies, laboratory analyses, and report preparation were ongoing from April to May, 1998.

This report provides supplementary geotechnical data for the Coal Haul Roads, the Coal Processing Plant, and the Tailings Pond in support of other referenced documents intended to satisfy the requirements stated below. The general engineering geology and geotechnical parameters will provide a basis for the cost estimate for construction.

1.1 REGULATORY TERMS OF REFERENCE

Under the British Columbia Environmental Assessment Act, an environmental baseline, impact assessment and mitigation report is to be prepared. The Terms of Reference for the report were outlined in the Final Telkwa Coal Project Report Specification dated August 28, 1997. With respect to geotechnical assessments, the following project specifications apply:

B.1.5: conduct and provide sufficient geotechnical site investigations prior to project report submission to ensure that proposed facilities will not require future relocation based on geotechnical concerns and to provide satisfactory assurance that facilities will function as proposed. This is particularly important for all proposed structures for ARD prevention, such as flooded tailings impoundment and flooded pits. Sufficient geotechnical site investigation and

design work, as determined by a professional engineer, must be undertaken to demonstrate that structures can maintain sufficient water cover (according to criteria to be developed by the ARD Focus Working Group) and to address concerns regarding exfiltration;

B.1.6: present preliminary design work for the tailings impoundment in the project report, in conjunction with results of the geotechnical site investigations. Design of pits, dumps, and the tailings impoundment must demonstrate adequate stability for the site conditions, material properties and loading conditions. The construction specifications for plant facilities need to be based on the ultimate reclamation treatment. A flooded impoundment must be designed to ensure its operation in perpetuity; and,

C.3.37: characterize the waste material to be used for infrastructure construction, (roads, tailings impoundment, berms, etc.). Include ARD/ML testwork, material volumes and sourcing, and the impact that the removal of this material will have on the ability to achieve the characteristics of the blended dumps as proposed.

2. REGIONAL GEOLOGY

2.1 SETTING AND PHYSIOGRAPHY

The portion of the Coal Haul Roads investigated is approximately 10 km long, stretching from west of Goathorn Creek to Lawson Road (Figure 2). The Processing Plant and Tailings Pond are located approximately 5 to 10 km southwest of Telkwa, respectively, south of the Telkwa River and east of Goathorn Creek (Figure 3). Natural topography in the area ranges from approximately 520 - 700 metres above sea level (masl). Most of the terrain in the area is gentle to moderately rolling, typically sloping to the north and northeast at less than about 10 degrees, with occasional flat lying and steeper areas. The only steep terrain is where the Coal Haul Road crosses Goathorn Creek (Figure 2). The above noted creeks are the only significant water courses in the area.

2.2 BEDROCK GEOLOGY

The following summary of the regional bedrock geology in the project area is based on Piteau (1997b).

The project area is located within the northeast/southwest trending Skeena Arch, which separates the Jurassic age sedimentary rocks of the Bowser Basin in the north and the Nechako Basin to the south. Major valleys, such as the Bulkley River valley, are interpreted to lie along fault zones. The Telkwa coal lease is underlain by a coal-bearing sedimentary sequence comprising siltstone, sandstone, mudstone and shale strata known as the Skeena Group (Red Rose Formation) of Lower Cretaceous age. The sedimentary rocks are underlain by an undifferentiated group of Lower Jurassic volcanic rocks, (*i.e.*, including andesite, trachyte, and basalt with associated tuffs and breccias) of the Hazelton Group (Telkwa Formation).

2.3 OVERBURDEN GEOLOGY

The surficial geology for the proposed mine site was determined from airphoto interpretation and borehole drilling, as described in detail in Piteau (1996) and Piteau (1997b). Most of the soil overburden comprises glacial till, although a localized lacustrine silt and clay and sand and gravel deposits may be present in the vicinity of the Tailings Pond and Plant Site areas and along several sections of the Coal Haul Roads. The surficial geology and the geotechnical properties, based on previous work and supplemented by the 1998 test pit and laboratory program, are described for the Coal Haul Roads, the Coal Processing Plant, and the Tailings Pond in Sections 3, 4, and 5, respectively.

3. COAL HAUL ROADS

The purpose of this investigation was to determine the lithology and basic soil properties of the road foundation. Of primary interest is the potential for bedrock to be present along cut sections of the road. The road alignment investigation started from the Raw Coal Haul Road, 1 km west of the Goathorn Creek crossing, stretching to the northeast to Lawson Road (Figure 2). Twenty two test pits, TRC98-7 to 28, were excavated along the alignment of the road (Figure 2).

3.1 FOUNDATION CONDITIONS

The shallow surficial soils along most of the proposed Coal Haul Roads comprise silt-clay/clay till (CL) (hereafter referred to as silt-clay till) that is common over much of the mine area. The till is present in two units, an upper unit weathered brown and a lower dark grey unit. The till is low plastic, well graded, and contains significant amounts of fine sand as well as trace amounts of gravel and cobbles. The till is medium stiff in the upper few meters but quickly increases with depth to very stiff or hard. The silt-clay till will provide a suitable foundation for the road. Bedrock was not encountered in any of the test pits, which were generally excavated to a depth of 5 m, along the road alignment.

Along the Raw Coal Haul Road (Figure 2) there are some areas (TRC98-14, 17 and 27) with shallow silt and clay or fine sand. At TRC98-14 and 27, the soft sediments will be excavated as part of the cut operations for the road construction. At TRC98-17 however, the crossing of Goathorn Creek, the silt and clay is present in the foundation of the proposed culvert. The design of the proposed culvert should accommodate potential settlement due to this layer.

The Clean Coal Haul Road east of the plant site has not yet been investigated. General site conditions as indicated by Piteau (1998c) and in the Tailings Pond investigation suggest that the foundation will be predominantly silt-clay till. A further investigation will be required to assess the geotechnical conditions in this area.

Further to the northeast, including the loadout area (Figure 2), the foundation is predominantly silt-clay till. One exception is a thin clay silt layer, 3.5 m deep, at TRC98-13.

Other than the above mentioned road crossing, the only significant area of concern for foundation conditions is at the northeast end of the Clean Coal Haul Road, where the road enters the Hubert Creek valley. The bottom of the valley contains a minimum thickness of 3 to 4 m of clayey silt and loose fine sand (TRC98-20 to 22). Construction over these soft soils may require the use of geotextiles, granular materials and a large scale compaction effort, or possibly removal of the soft soils.

4. TAILINGS POND

This investigation was designed to characterize the shallow soil conditions in the Tailings Dam and Pond area. Four test pits, TRC98-2 to 5, were excavated at the Tailings Dam location and two, TRC98-1 and 6, over the proposed upstream coal pits (Figure 3) that will provide the construction materials for the dam. Previous information at the site is limited to coal exploration holes (Figure 3).

4.1 SITE CONDITIONS

The site is on gently rolling terrain, partially tree covered and partially farmland (Figure 3). Drainage is generally to the north, however, there are some localized areas of poor drainage and seasonal ponding. A major gravel road is located to the west and a lesser one to the south. A major powerline is present to the south of the site.

4.2 FOUNDATION CONDITIONS

The shallow surficial soils beneath the proposed Tailings Dam consist of the above described silt-clay till (CL). The till is low plastic, stiff and contains significant amounts of fine sand as well as trace amounts of gravel and cobbles. The upper weathered till, typically 1 to 1.5 m thick, has a medium brown colour. The lower unweathered till has a dark grey colour and increasing stiffness with depth.

The silt-clay till will generally provide an adequate foundation for the Tailings Dam.

4.3 CONSTRUCTION MATERIALS

Two test pits were excavated over the proposed two small Coal Pits located upstream of the Tailings Dam (Figure 3). The surficial geology is similar to that of the dam site, i.e., silt-clay till, although a sand and gravel layer was encountered at TRC98-6. The clay till, with proper conditioning and compaction will be suitable for construction of the impervious core of the Tailings Dam. Figure 4 shows the results of a standard Proctor density and permeability test for the till. The till should be placed in lifts not to exceed 150 mm and compacted to a minimum of 95 percent standard Proctor density (SPD). Optimum compaction can be obtained if the moisture content of the fill is slightly higher than the plastic limit. The plasticity value of the silt and clay till unit ranges between 13.4 to 24.6 percent. Moisture content values of the upper till unit within the plant site area range from 14.9 to 18 percent, averaging 16.7 percent. Therefore, the desired level of compaction should be achievable with four to six passes of a sheepsfoot roller. Bedrock is shallow in the area, siltstone being present at a depth of 2.8 m at TRC98-6. Suitable waste rock from the two pits can be used in the outer shell of the Tailings Dam.

5. PLANT SITE

The investigation was designed to characterize the foundation conditions for spread footings for the plant structures. Figure 3 shows the proposed layout for the plant along with the locations of test pits TRC98-29 to 32, as well as the location of previous test pit and borehole programs. In addition to the plant site there is also the rail loadout site (Figure 2) that will have similar foundation issues as the plant, and therefore the following discussion is applicable to it as well. A brief description of the geology of the rail loadout site is in Section 5.5.

5.1 SITE CONDITIONS

The site is on the east rim of the Goathorn Creek valley (Figure 3). The site is flat to gently rolling terrain, partially tree covered and partially farmland. Drainage is generally to the northeast and west. A major gravel road is located to the west and a lesser farm road to the north. A major powerline is present to the north of the site.

5.2 FOUNDATION CONDITIONS

The soil profile is laterally and vertically variable. Deposits of fine sand, sand and gravel, stratified silt to silt-clay, and silt-clay to clay till are all present. The predominant soil overburden is silt-clay till (CL), characterized by low to medium plasticity, very stiff to hard, and containing some sand and little gravel and cobbles. The sand and gravel deposit, which contains a trace of silt and the occasional cobble, is variable with respect to both gradation and density. At TRC98-31 and 32, the sand and gravel was encountered beneath silt-clay till, at depths of 4.2 and 4.6 m, respectively. This lower sand and gravel unit is loose and wet.

The silt and silt-clay (ML, ML-CL, CL) material which was identified in a previous investigation at test pit TRC97-8, is of slight to low plasticity, soft to stiff, and contains occasional sand, pebbles and coal fragments. One objective of the 1998 investigation was to delineate the extent of the soft silt and clay in the plant site area. None was found in the four test pits excavated during the 1998 program.

Depth to bedrock across the area is highly variable. The two boreholes to the south of the plant site, T97R053 and T97R063, encountered bedrock at depths of 48.5 and 102 m, respectively. Although bedrock was not encountered in any of the 1998 test pits at the plant site, it was previously encountered in two test pits several hundred meters to the east of the site (TRC97-9 and 11), at depths of less than 5 m.

The water table in test pits TRC97-8 and TRC98-29 to 32 varies between 3 and 4 m deep. It will likely be seasonally higher, particularly after a wet spring or prolonged inclement period.

Compressive strength values for the lacustrine silt and silt-clay mixtures were highly variable, ranging as high as 2.5 kg/cm^2 (TRC97-6). However, some samples had negligible strength, being too soft to be measured by a pocket penetrometer (TRC97-8). The compressive strength of the silt-clay till generally measured $>3.5 \text{ kg/cm}^2$. Although no soft silt and/or clay was encountered during the 1998 investigation, it is recommended that further investigation, including test pits and boreholes, be performed at each of the proposed plant facilities.

5.3 CUT AND FILL RECOMMENDATIONS

Organic topsoil should be removed in areas of buildings, gravel pads and access roads. We recommend that areas to be cut and filled be compacted prior to the placement of and compaction of fill. Fill should be placed in lifts not to exceed 150 mm and compacted to a minimum of 95 percent standard Proctor density (SPD). Optimum compaction can be obtained if the moisture content of the fill is slightly higher than the plastic limit. The plasticity value of the silt and clay till unit ranges between 13.4 to 24.6 percent. Moisture content values of the upper till unit within the plant site area range from 14.9 to 18 percent, averaging 16.7 percent. Therefore, the desired level of compaction should be achievable with four to six passes of a sheepfoot roller.

5.4 FOUNDATION DESIGNS AND RECOMMENDATIONS

The proposed plant site will consist of a number of facilities including a crusher, load outs, wash plant, water distribution pumphouse and substation, coal piles and a shop/office. Preliminary shallow foundation types and loading and settlement conditions for each facility were provided by Kilborn Engineering Pacific Ltd. (Table 2).

5.4.1 FOUNDATION TYPE

Recommended shallow foundations consisting of mat and spread footings, with or without grade beam, and slab on grade are appropriate for the different facilities, assuming pile foundations are not being considered. In addition, we recommend a gravel pad for support of tanks within fuel storage area.

5.4.2 BEARING PRESSURE AND SETTLEMENT

Required bearing pressure values of between 200 and 300 kPa are consistent with recommended values for very stiff to hard tills. Also, provided differential settlement values appear to be consistent with compressive characteristics of native soils. However, it should be noted that a soft silt layer was encountered near the area of the plant (TRC97-8) which, if extensive, may affect the capacity of the foundation soils. A geotechnical investigation program is required to confirm the engineering properties of the foundation soils underlying the individual facilities and provide appropriate foundation designs.

Based upon a mean freezing index value of 1250 degree days for Smithers, B.C., a frost penetration depth of 2 m would be a conservative estimate. Therefore, all shallow footings should be founded at a minimum depth of 2 m below grade.

5.4.3 SURFACE DRAINAGE

In high traffic areas, such as truck shops and load out areas, where there is the potential for generation of muddy conditions, we recommend that the working surface foundation be constructed using a 1 m thick layer of gravel. The gravel layer will prevent mixing of the underlying native soils, will ensure surface water drainage, and will minimize the potential for frost heave.

The area surrounding the various facilities should be graded to promote drainage away from the facility.

5.5 RAIL LOADOUT

The rail loadout site is located at the overlap of the Clean Coal Haul Road and the Rail Spur (Figure 2). Test pits TRC98 23 and 24 provide coverage of that site. As for most of the haul road, the soil profile consists of a thin layer of silt, < 1 m, overlying the two units of silt-clay till. No free water was encountered in either of the test pits. Compressive strength values for the silt unit ranged from 1.75 to 2.5 kg/cm³.

The cut and fill and foundation design recommendations for the plant site also apply to the rail loadout site.

6. CLOSURE

This report covers the results of the test pit investigation for the Coal Haul Roads, the Coal Processing Plant, and the Tailings Pond Area. The purpose of the investigation was to provide geotechnical data and preliminary foundation designs for the purpose of performing a cost estimate. Further geotechnical investigations, including borehole drilling, will be required before completing the final design.

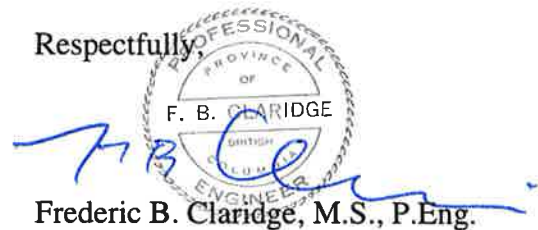


Rob Armstrong, M.Sc.



David Taplin, Ph.D., P.Eng.

Respectfully,



Frederic B. Claridge, M.S., P.Eng.

7. REFERENCES

- Piteau Engineering Ltd., 1994a. Engineering Geology and Geotechnical Assessment for the Pit 7 and Pit 8 Areas. Prepared for Manalta Coal Ltd., File No. 3773-4. January, 1994.
- Piteau Engineering Ltd., 1994b. Telkwa Coal Project Water Management of Tailings Pond and Pits 7 and 8. Prepared for Manalta Coal Ltd., 3773-3. June, 1994.
- Piteau Engineering Ltd., 1996. Preliminary Surficial Geology Map of the Telkwa Property. Prepared for Manalta Coal Ltd., File No. 3773-11. April, 1996.
- Piteau Engineering Ltd., 1997a. Geotechnical and Hydrogeological Assessment Proposed Tailings Pond Area Telkwa Coal Project. Prepared for Manalta Coal Ltd., File No. 3773-12. January, 1997.
- Piteau Engineering Ltd., 1997b. Engineering Geology and Geotechnical Assessment Tenas Pit and Waste Dumps. Prepared for Manalta Coal Ltd., File No. 3773-12. January, 1997.
- Piteau Engineering Ltd., 1997c. Baseline Hydrogeological Investigations in Tenas Pit, the Waste Dumps, and Pit 3. Prepared for Manalta Coal Ltd., File No. 3773-12. January, 1997.
- Piteau Engineering Ltd., 1997d. Geotechnical and Hydrogeological Services - 1997 Program, Tenas Creek Area, British Columbia. Letter to Manalta Coal Ltd., File No. 3773-13. July 15, 1997.
- Piteau Engineering Ltd., 1998a. Geotechnical Services - Clean Coal Haul Road and Tailings Dam Telkwa Coal Project, British Columbia. Letter to Manalta Coal Ltd., File No. 3773-13, March 10, 1998.
- Piteau Engineering Ltd., 1998b. Baseline Hydrogeologic Conditions in the Telkwa Coal Project Area. Prepared for Manalta Coal Ltd., File No. 3773-13. April, 1998.
- Piteau Engineering Ltd., 1998c. Geotechnical Assessment for Pit 3 and Tenas Waste Dumps, Coal Processing Plant and Tailings Pond Telkwa Coal Project. Prepared for Manalta Coal Ltd., File No. 3773-13. April, 1998.
- Piteau Engineering Ltd., 1998d. Water Management for the Telkwa Coal Project. Prepared for Manalta Coal Ltd., File No. 3773-13. May, 1998.

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The pertinent information reviewed by Piteau has been included in this report. The information provided by others is believed to be accurate but cannot be guaranteed. Any questions concerning the information or its interpretation should be directed to Fred Claridge.

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Table 1
Summary of Geotechnical Laboratory Test Data
for the 1998 Test Pits

Test Pit	Lithology	Depth	Moisture	Liquid	Plastic	Plasticity	Grain Size Distribution			
		(m)	Content (%)	Limit	Limit	Index	Gravel	Sand	Silt	Clay
TRC-98-1	Clay Till	3.90	13.0	--	--	--	--	--	--	--
TRC-98-2	Clay Till	2.90	11.7	--	--	--	--	--	--	--
TRC-98-3	Clay Till	2.10	11.2	--	--	--	--	--	--	--
TRC-98-4	Clay Till	0.75	20.0	--	--	--	--	--	--	--
	Clay Till	4.75	11.7	--	--	--	--	--	--	--
TRC-98-5	Clay Till	1.00	22.3	--	--	--	--	--	--	--
	Clay Till	4.90	10.2	--	--	--	--	--	--	--
TRC-98-6	Clay Till	1.00	17.8	59.2	25.4	33.8	3	28	44	25
	Sand and Gravel	2.50	11.9	--	--	--	63	27	F=10	
	Siltstone	3.00	6.8	--	--	--	--	--	--	--
TRC-98-7	Clay Till	2.50	10.9	--	--	--	--	--	--	--
TRC-98-8	Clay Till	1.20	17.0	--	--	--	--	--	--	--
	Clay Till	4.00	5.3	--	--	--	--	--	--	--
TRC-98-9	Clay Till	2.60	12.5	--	--	--	--	--	--	--
TRC-98-10	Clay Till	4.00	15.1	--	--	--	--	--	--	--
TRC-98-11	Clay Till	1.00	23.6	--	--	--	--	--	--	--
	Clay Till	2.95	12.5	--	--	--	--	--	--	--
TRC-98-12	Clay Till	1.00	15.9	--	--	--	--	--	--	--
TRC-98-13	Clay Till	2.60	11.3	--	--	--	--	--	--	--
	Clay Till	3.40	29.4	--	--	--	--	--	--	--
	Clay Till	4.00	17.9	--	--	--	--	--	--	--

Table 1
Summary of Geotechnical Laboratory Test Data
for the 1998 Test Pits

Test Pit	Lithology	Depth	Moisture	Liquid	Plastic	Plasticity	Grain Size Distribution			
		(m)	Content (%)	Limit	Limit	Index	Gravel	Sand	Silt	Clay
TRC-98-14	Sand and Gravel	0.50	20.6	--	--	--	62	33	F=5	
	Fine Sand	3.60	8.0	--	--	--	5	85	F=10	
TRC-98-15	Clay Till	1.00	16.8	--	--	--	--	--	--	--
	Clay Till	3.00	15.3	--	--	--	--	--	--	--
TRC-98-16	Sand and Gravel	0.90	7.0	--	--	--	--	--	--	--
	Siltstone	3.00	7.9	--	--	--	--	--	--	--
TRC-98-17	Clay Till	3.40	40.8	30.5	18.5	12.0	--	--	--	--
	Clay Till	4.20	8.7	--	--	--	--	--	--	--
TRC-98-18	Fine Sandy Silt	1.00	44.0	--	--	--	0	48	F=52	
	Clay Till	4.60	15.6	--	--	--	--	--	--	--
TRC-98-19	Clayey Silty Till	1.00	25.6	Non Plastic			--	--	--	--
	Clay Till	2.55	32.2	--	--	--	--	--	--	--
TRC-98-20	Clayey Silt	1.00	28.7	--	--	--	--	--	--	--
	Fine Sand	3.00	31.4	--	--	--	0	71	F=29	
TRC-98-21	Clayey Silt	1.10	28.8	32.2	24.6	7.5	--	--	--	--
	Clayey Silt	2.00	11.0	--	--	--	--	--	--	--
	Silt and Clay Till	3.40	9.4	21.8	13.4	8.4	--	--	--	--
TRC-98-22	Clay Till	1.00	22.9	--	--	--	--	--	--	--
	Fine Sand	2.00	12.0	--	--	--	--	--	--	--
	Clay Till	3.10	2.6	--	--	--	--	--	--	--
TRC-98-23	Silt	0.50	24.6	--	--	--	--	--	--	--
TRC-98-24	Silt	0.25	27.9	--	--	--	--	--	--	--
	Clay Till	3.50	11.6	--	--	--	--	--	--	--

Table 1
Summary of Geotechnical Laboratory Test Data
for the 1998 Test Pits

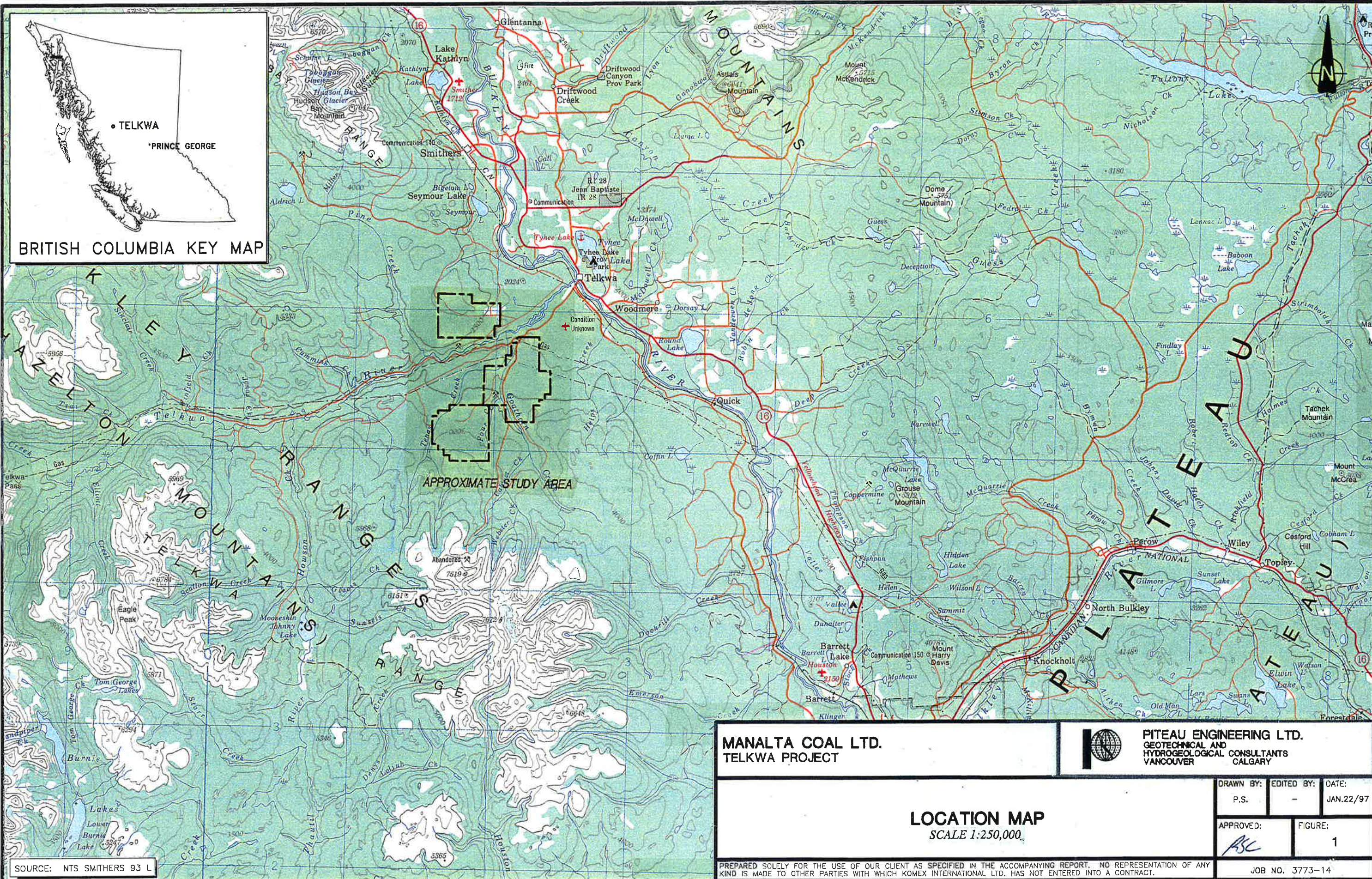
Test Pit	Lithology	Depth (m)	Moisture Content (%)	Liquid Limit	Plastic Limit	Plasticity Index	Grain Size Distribution			
							Gravel	Sand	Silt	Clay
TRC-98-25	Clay Till	1.00	14.3	--	--	--	--	--	--	--
	Clay Till	2.00	9.1	--	--	--	--	--	--	--
TRC-98-26	Clay Till	1.50	11.3	23.5	14.4	9.1	--	--	--	--
	Clay Till	2.55	12.0	--	--	--	--	--	--	--
TRC-98-27	Silt	1.10	25.9	--	--	--	--	--	--	--
	Clay Till	2.20	17.2	--	--	--	--	--	--	--
TRC-98-28	Clay Till	0.90	17.9	--	--	--	--	--	--	--
	Clay Till	2.00	13.0	--	--	--	--	--	--	--
TRC-98-29	Clay Till	0.60	17.3	--	--	--	--	--	--	--
	Clay Till	2.80	18.0	--	--	--	--	--	--	--
TRC-98-30	Sandy Silt	0.30	29.1	--	--	--	--	--	F=58	
	Clay Till	2.10	14.9	--	--	--	--	--	--	--
	Clay Till	4.00	4.7	--	--	--	--	--	--	--
TRC-98-31	Sand and Gravel	0.50	8.8	--	--	--	--	--	--	--
	Clay Till	3.10	7.0	--	--	--	55	37	F=8	
	Sand and Gravel	4.30	12.1	--	--	--	--	--	--	--
TRC-98-32	Clay Till	2.00	10.4	--	--	--	30	60	F=10	
	Sand and Gravel	4.80	13.2	--	--	--	--	--	--	--

Notes: *F= Fines (silt and clay fractions, no hydrometer conducted).*
-- denotes not analysed.

TABLE 2
PRELIMINARY FOUNDATION LOADING

Area / Facility	Foundation Type (Suggested)	Primary Loading	Maximum Allowable Differential Settlement
Crushing	Mat.	Vibrating 300 kPa	12 mm in 7.5 m
Loadout	Mat. & Spread Ftgs.	250 kPa	12 mm in 7.5 m
Wash Plant Building	Mat. & Spread Ftgs. with Grade Beam Slab- on-grade	Vibrating 250-300 kPa	10mm between bays* 12 mm between crane rails
Load-Out (100 T Coal Haul Truck)	Mat. & Spread Ftgs.	250 kPa	10 mm between bays*
Truck Shops	Spread Ftgs. With Grade Beams Slab-on Grade	250 kPa	10mm between bays* 12 mm between crane rails
Retaining Walls (Approx. 12m High Hilfiker)	Suitable native material for backfill	Surcharge CAT 785 Truck & 994 Loader	
Ancillary Buildings	Spread Ftgs. With Grade Beams Slab-on Grade	200 kPa	10mm between bays* 12mm between crane rails
Conveyors	Spread Ftg.	200 kPa	10 mm

* Differential settlement based on 7.5m spacing



SOURCE: NTS SMITHERS 93 L

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TELKWA PROJECT



PITEAU ENGINEERING LTD.
GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS
VANCOUVER

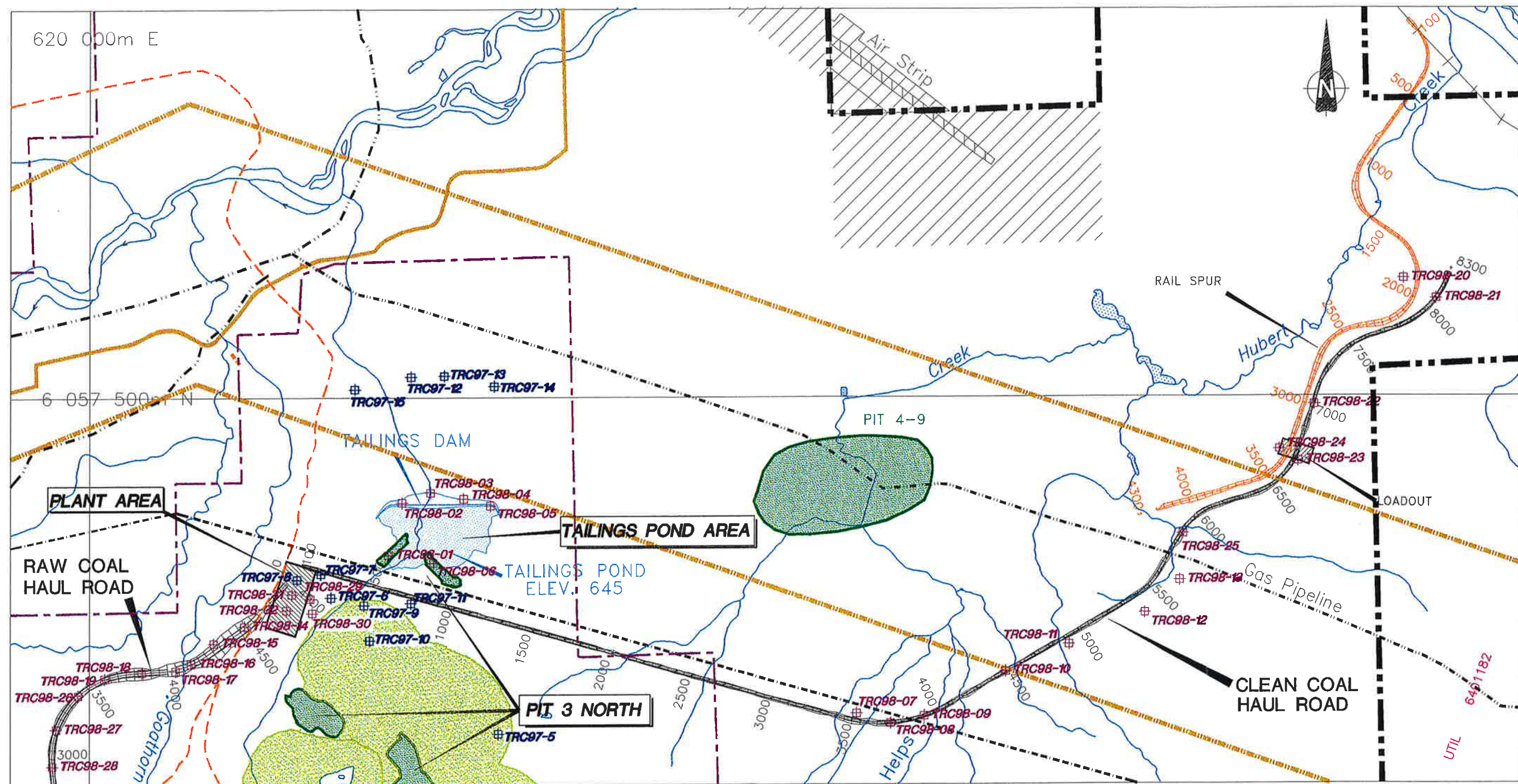
LOCATION MAP
SCALE 1:250,000

DRAWN BY:	EDITED BY:	DATE:
P.S.	-	JAN.22/97

APPROVED:	FIGURE:
<i>ASC</i>	1

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JOB NO. 3773-14



LEGEND:

- COAL LICENCE BOUNDARY
- PROJECT BOUNDARY
- UTILITY RIGHT OF WAY
- POWERLINE
- GAS PIPELINE
- PROPOSED PIT
- PROPOSED DUMP
- ⊕ 1997 TESTPIT LOCATION
- ⊕ 1998 TESTPIT LOCATION

0 250 500 750 1000m
SCALE 1 : 25,000

SOURCE: MANALTA COAL LTD. DWG. #24715 A

MANALTA COAL LTD.
TELKWA PROJECT

SITE PLAN COAL HAUL ROADS

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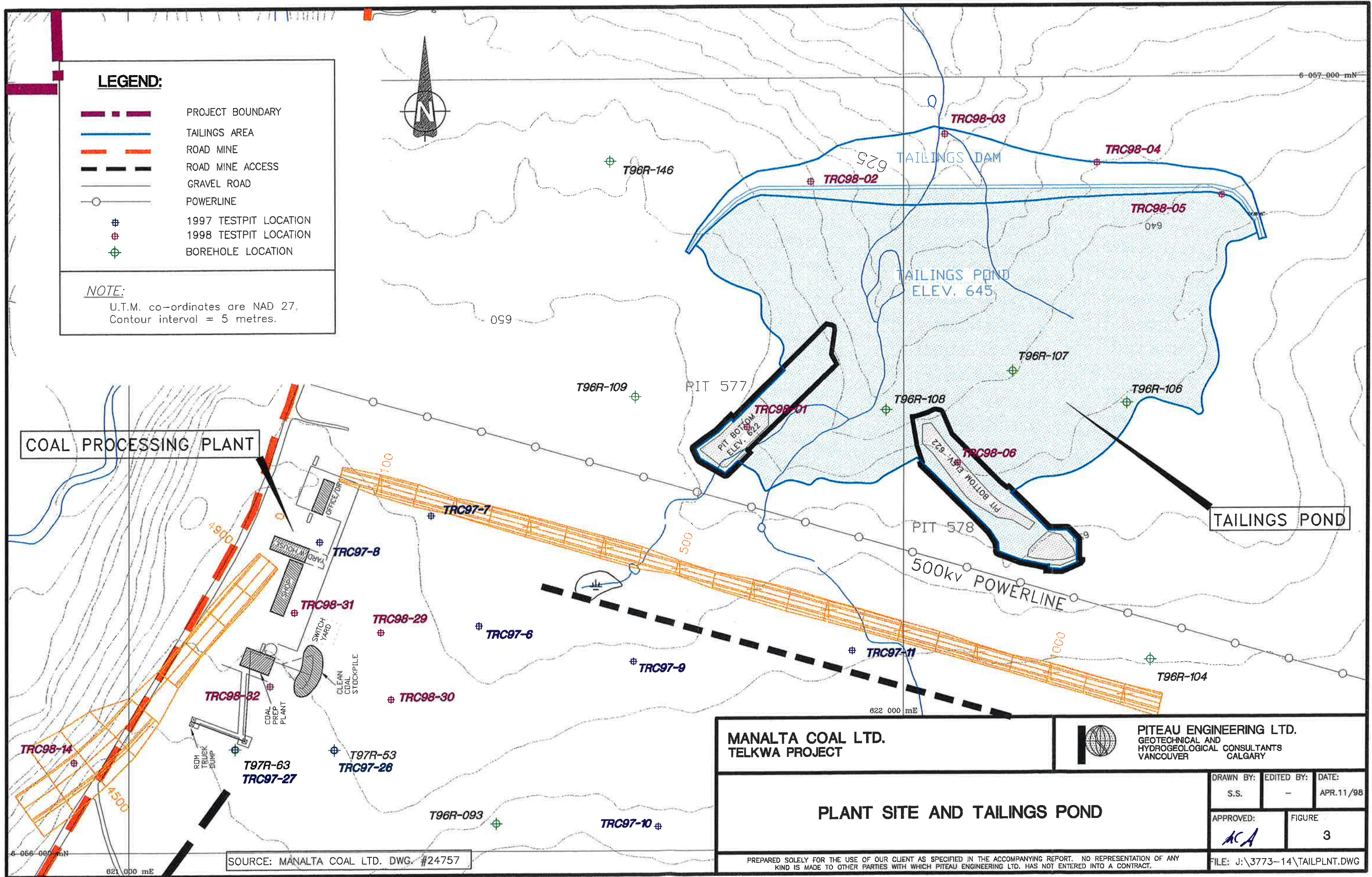
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VANCOUVER CALGARY

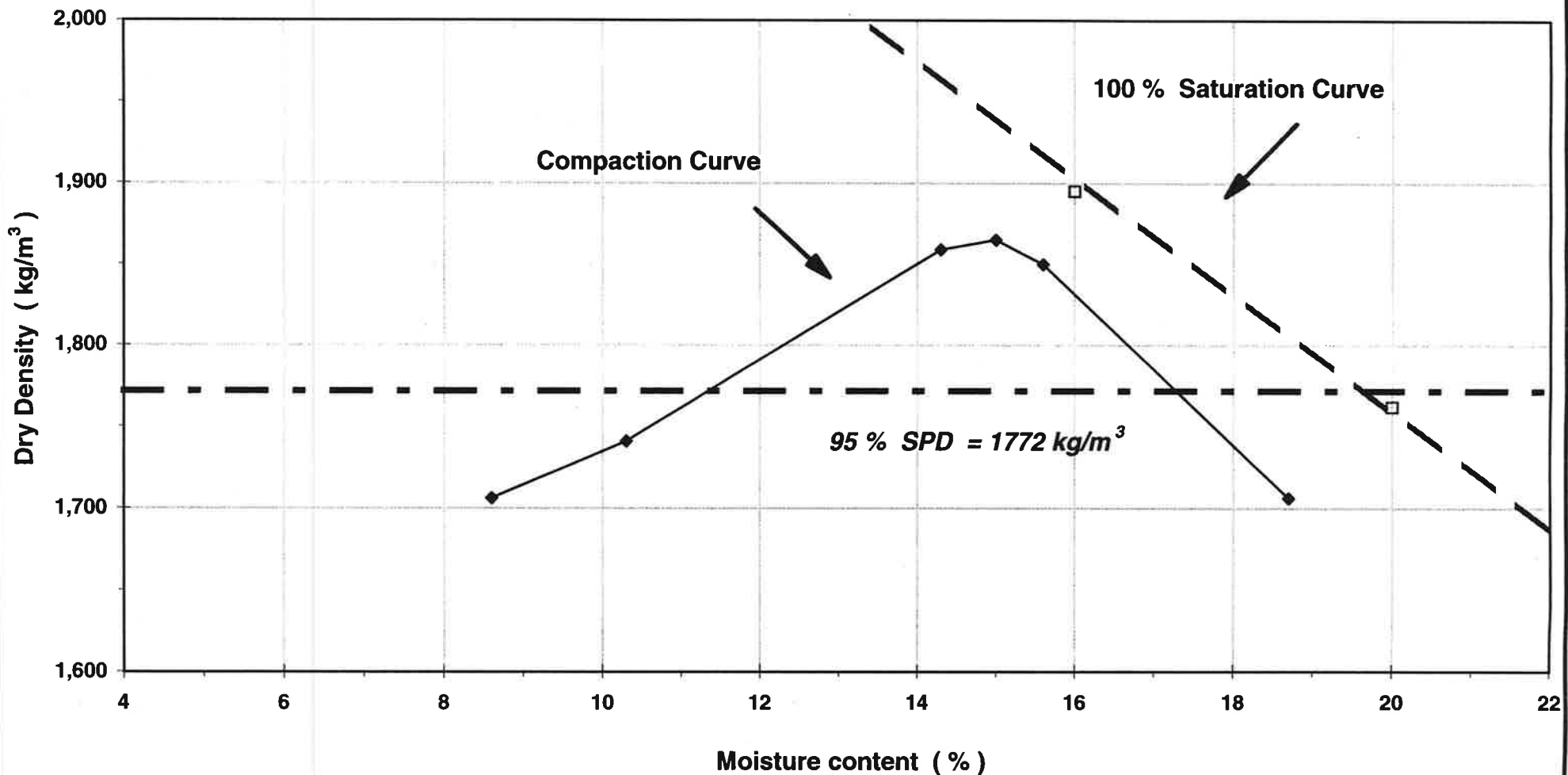
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APPROVED: *ACA* FIGURE: 2

FILE: J:\3773-14\COALHAUL.DWG

NOTE: UTM COORDINATES ARE NAD27





Maximum Dry Density = 1865 kg/m³
 Optimum Moisture Content = 15 %
 Permeability = 4.34×10^{-7} cm/s

Manalta Coal Telkwa		 PITEAU ENGINEERING LTD. GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS VANCOUVER CALGARY	
Dry Density vs. Moisture Content Sample: Silt-Clay Till Composite			
DRAWN BY: VA		EDITED BY: DATE: May, 1998	
APPROVED: 		FIGURE: 4	
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APPENDIX I

1998 TEST PIT LOGS

CONTRACT NO. 3773-14

COMPILED BY: B. Strachan

BORING DATE: April 5, 1998

BORING NO.: TRC-98-1 (*18)

LOCATION: Telkwa

CONTRACTOR: Bruce Kerr

NORTHING: 6056548.001

EASTING: 621797.164

ELEVATION:

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

T SHELBY TUBE

0 THIN WALL OPEN

P THON WALL PISTON

 ∇ STATIC WATER LEVEL

▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION



TEST INFORMATION

● PENETROMETER kg/cm²

1. 2. 3. 4.

△ SPT BLOWS/0.3m

WATER CONTENT %				
plastic limit		⊕		liquid limit
10	30	50	70	90

[illegible]

CONTRACT NO.: 3773-14
BORING NO.: TRC-98-2 (*16)
NORTHING: 6056865.894

COMPILED BY: B. Strachan
LOCATION: Telkwa
EASTING: 621879.536

BORING DATE: April 5, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

T SHELBY TUBE

O THEN WALL OPEN
 P THEN WALL PISTON
 ▽ STATIC WATER LEVEL
 ▼ DYNAMIC WATER LEVEL

SAMPLE CONDITION



DISTURBED
FAIR
GOOD
LOST

TEST INFORMATION

PENETROMETER kg/cm²

1 2 3 4

△ SPT BLOWS/0.3m

WATER CONTENT %				
X	plastic limit	⊕	liquid limit	X
	10	30	50	70

[illegible]

BORING DATE: April 5, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

 DISTURBED
 FAIR
 GOOD
 LOST

● PENETROMETER kg/cm²

Δ SPT BLOWS/0.3m

WATER CONTENT %				
X	plastic limit	⊕	liquid limit	X
	10	30	50	70
				90

[illegible]

BORING DATE: April 5, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

● PENETROMETER kg/cm²

1 2 3 4
Δ SPT BLOWS/0.3m

WATER CONTENT %

plastic limit		liquid limit
10	30 50 70 90	

[illegible]

BORING DATE: April 5, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

● PENETROMETER kg/cm²

1 2 3 4
Δ SPT BLOWS/0.3m

WATER CONTENT %				
X	plastic limit	ϕ	liquid limit	
	10	30	50	70
				90

[illegible]

BORING DATE: April 5, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

● PENETROMETER kg/cm²

[illegible]

BORING DATE: April 5, 1998
 CONTRACTOR: Bruce Kerr
 ELEVATION:

TEST INFORMATION

PENETROMETER kg/cm²[illegible]

BORING DATE: April 5, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

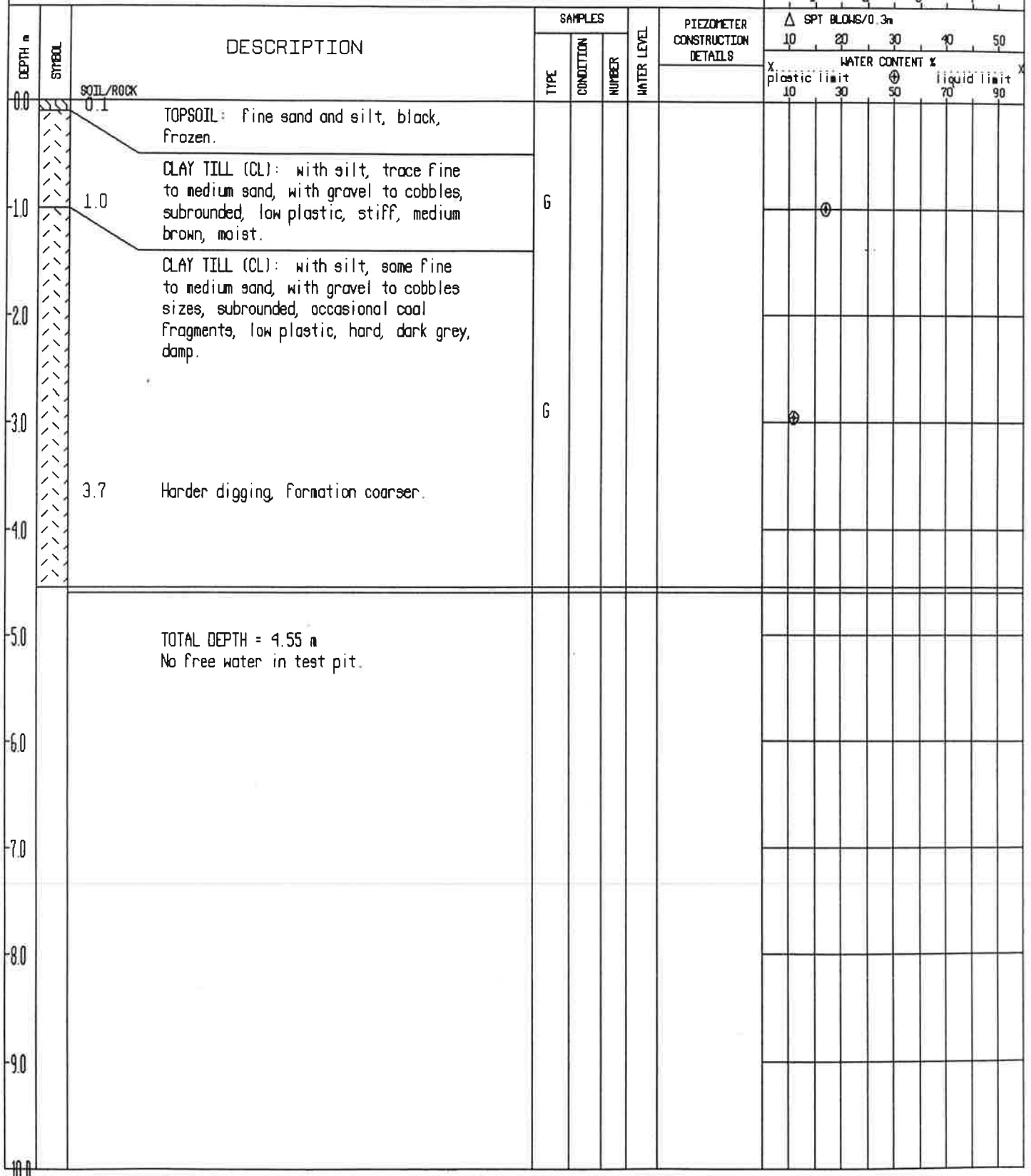
[illegible]

BORING DATE: April 6, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

● PENETROMETER kg/cm²



BORING DATE: April 6, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

WHEEL CONDITION	
	DISTURBED
	FAIR
	GOOD
	LOST

● PENETROMETER kg/cm2

[illegible]

BORING DATE: April 6, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

DISTURBED

FAIR

GOOD

LOST

● PENETROMETER kg/cm²

[illegible]

BORING DATE: April 6, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

● PENETROMETER kg/cm²

[illegible]

BORING DATE: April 6, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION



DISTURBED
FAIR
GOOD
LOST

● PENETROMETER kg/cm²

1 2 3 4
Δ SPT BLOWS/0.3m
10 20 30 40 50

WATER CONTENT %				
plastic limit		⊕		liquid limit
10	30	50	70	90

[illegible]

BORING DATE: April 6, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

PENETROMETER kg/cm²

Figure 1 is a graph showing the relationship between SPT Blows/0.3m (top x-axis) and Water Content % (bottom x-axis). The top x-axis ranges from 1 to 4, and the bottom x-axis ranges from 10 to 90. A curve is plotted, showing that as SPT Blows/0.3m increases, Water Content % decreases. The curve passes through points approximately at (1, 85), (2, 70), (3, 55), and (4, 45). The plastic limit is marked at 10% water content, and the liquid limit is marked at 90% water content. A vertical line is drawn at 50% water content.

[illegible]

BORING DATE: April 7, 1998
CONTRACTOR: Wittwer
ELEVATION:

TEST INFORMATION



	DISTURBED
	FAIR
	GOOD
	LOST

PENETROMETER kg/cm²

1 2 3 4
Δ SPT BLOWS/0.3m

WATER CONTENT %				
x				x
plastic limit		⊕		liquid limit
10	30	50	70	90

[illegible]

CONTRACT NO.: 3773-14
BORING NO.: TRC-98-21 (*2)
NORTHING: 6058085.834

COMPILED BY: B. Strachan
LOCATION: Telkwa
EASTING: 628111.878

BORING DATE: April 7, 1998
CONTRACTOR: Wittner
ELEVATION:

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

T SHELBY TUBE

O THIN WALL OPEN
 P THIN WALL PISTON
☒ STATIC WATER LEVEL
☒ DYNAMIC WATER LEVEL

SAMPLE CONDITION



DISTURBED
FAIR
GOOD
LOST

TEST INFORMATION

● PENETROMETER kg/cm²

1	2	3	4
---	---	---	---

Δ SPT BLOWS/0.3m

PIEZOMETER CONSTRUCTION DETAILS

WATER CONTENT %				
X				X
plastic limit		⊕		liquid limit
10	30	50	70	90

[illegible]

BORING DATE: April 7, 1998
CONTRACTOR: Wittwer
ELEVATION:

TEST INFORMATION

Condition	Visual Representation
DISTURBED	White with 'x' marks
FAIR	White
GOOD	Diagonally striped
LOST	Solid black

● PENETROMETER kg/cm²

1 2 3 4
△ SPT BLOWS/0.3m
10 20 30 40 50

WATER CONTENT %				
X	plastic limit	⊕	liquid limit	X
	10	30	50	70
				90

[illegible]

BORING DATE: April 7, 1998
CONTRACTOR: Wittwer
ELEVATION:

TEST INFORMATION

X	X	X		DISTURBED
				FAIR
\	\	\		GOOD
				LOST

PENETROMETER kg/cm²

1 2 3 4

△ SPT BLOWS/0.3m

10 20 30 40 50

WATER CONTENT %				
x	plastic limit	⊕	liquid limit	x
	10	30	50	70
				90

[illegible]

BORING DATE: April 7, 1998
CONTRACTOR: Wittwer
ELEVATION:

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

PENETROMETER kg/cm^2

1 2 3 4
Δ SPT BLOWS/0.3m
10 20 30 40 50

WATER CONTENT %				
plastic limit		⊕	liquid limit	
10	30	50	70	90

[illegible]

BORING DATE: April 7, 1998
CONTRACTOR: Wittwer
ELEVATION:

TEST INFORMATION

PENETROMETER kg/cm²

1 2 3 4
△ SPT BLOWS/0.3m
10 20 30 40 50

WATER CONTENT %				
plastic limit		⊕		liquid limit
10	30	50	70	90

DEPTH m	SYMBOL	DESCRIPTION	SAMPLES			WATER LEVEL	PIEZOMETER CONSTRUCTION DETAILS	SPT BLOWS/0.3m				
			TYPE	CONDITION	NUMBER			X	WATER CONTENT %			X
									plastic limit	liquid limit		
0.0	SOIL/ROCK 0.06	TOPSOIL: fine sand and silt, black, moist.						10	20	30	40	50
1.1		CLAY TILL (CL): with silt, some fine to medium sand, with gravel to cobble sizes, subrounded, low plastic, stiff, medium brown, moist.	G					10	20	30	40	50
2.0		CLAY TILL (CL): with silt, trace fine sand, with gravel to cobble sizes, subrounded to rounded, occasional coal fragments, low plastic, hard, dark grey, moist.	G					10	20	30	40	50
3.1		Formation coarser, harder digging.						10	20	30	40	50
4.25		TOTAL DEPTH = 4.25 m No free water in test pit.						10	20	30	40	50

BORING DATE: April 7, 1998
 CONTRACTOR: Bruce Kerr
 ELEVATION:

TEST INFORMATION

● PENETROMETER kg/cm²

Δ SPT BLOWS/0.3m

10 20 30 40 50

WATER CONTENT %				
x				x
plastic limit		⊕		liquid limit
10	30	50	70	90

[illegible]

BORING DATE: April 7, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

Land Use Type	Percentage
DISTURBED	10%
FAIR	20%
GOOD	40%
LOST	30%

PENETROMETER kg/cm²

1 2 3 4
Δ SPT BLOWS/0.3m
10 20 30 40 50
WATER CONTENT %
plastic limit 30 40 liquid limit 70 90

[illegible]

BORING DATE: April 7, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

PENETROMETER kg/cm²

1 2 3 4
△ SPT BLOWS/0.3m
10 20 30 40 50

WATER CONTENT %

plastic limit		liquid limit
10	30 50 70 90	

[illegible]

BORING DATE: April 8, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

DISTURBED
FAIR
GOOD
LOST

PENETROMETER kg/cm^2

1 2 3 4

△ SPT BLOWS/0.3m

10 20 30 40 50

WATER CONTENT %

X	plastic limit	50	liquid limit	X
10	30	50	70	90

[illegible]

BORING DATE: April 8, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

TEST INFORMATION

● PENETROMETER kg/cm²

[illegible]

CONTRACT NO.: 3773-14
BORING NO.: TRC-98-31 (*30)
NORTHING: 6056310.348

COMPILED BY: B. Strachan
LOCATION: Telkwa
EASTING: 621214 607

BORING DATE: April 8, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

SAMPLE TYPES

A AUGER SAMPLE
W WASH SAMPLE
R ROCK CORE
C CRREL BARREL
S SPLIT SPOON

T SHELBY TUBE

☐ THIN WALL OPEN
☐ THIN WALL PISTON
☒ STATIC WATER LEVEL
☐ DYNAMIC WATER LEVEL

SAMPLE CONDITION

DISTURBED
FAIR
GOOD
LOSE

TEST INFORMATION

● PENETROMETER kg/cm²

[illegible]

BORING DATE: April 8, 1998
CONTRACTOR: Bruce Kerr
ELEVATION:

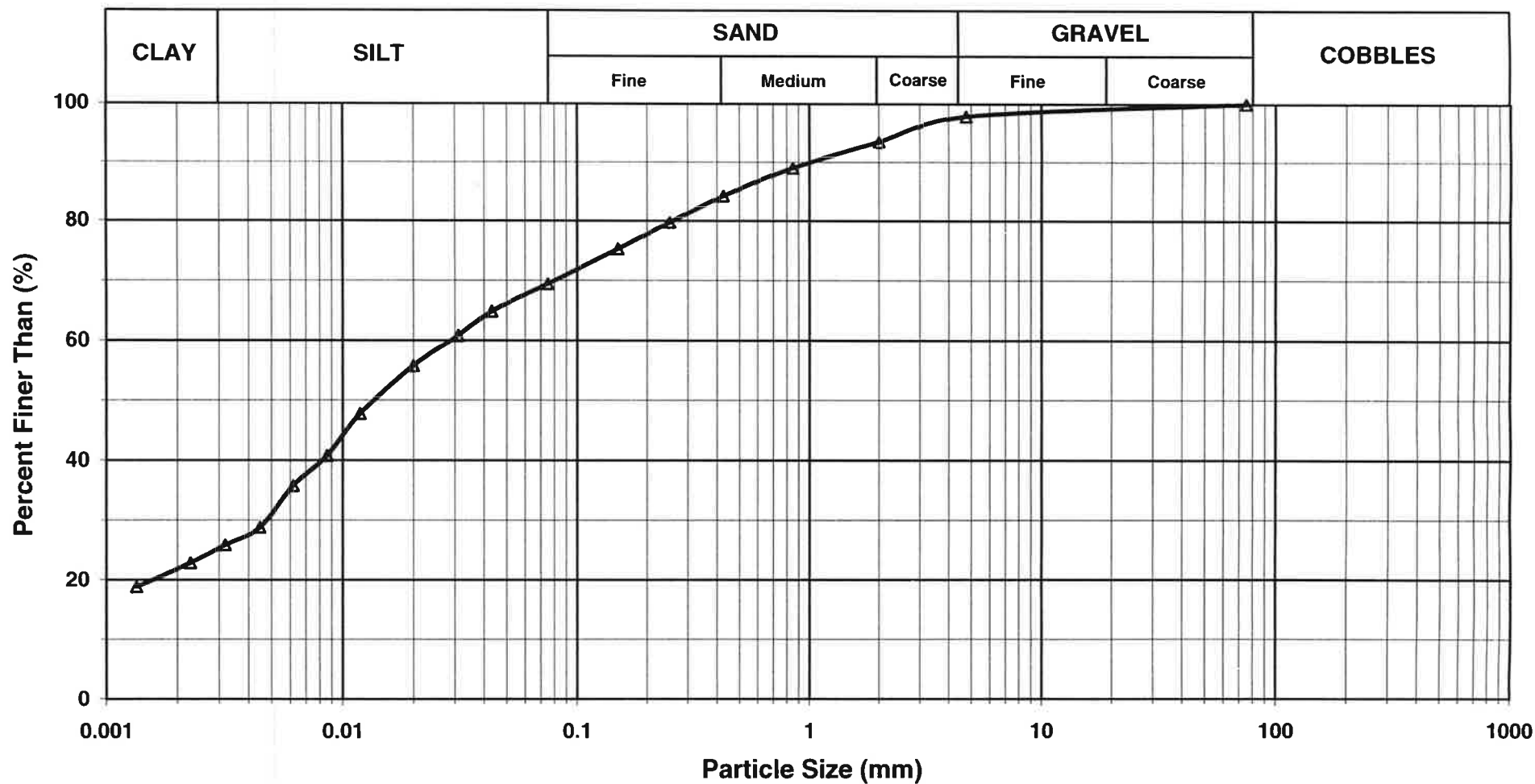
TEST INFORMATION

PILE CONDITION	PERCENTAGE OF PILES
 DISTURBED	10
 FAIR	10
 GOOD	60
 LOST	20

● PENETROMETER kg/cm²

[illegible]

APPENDIX II
GRAIN SIZE CURVES



Manalta Coal
Telkwa Test Pits



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GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS
VANCOUVER CALGARY

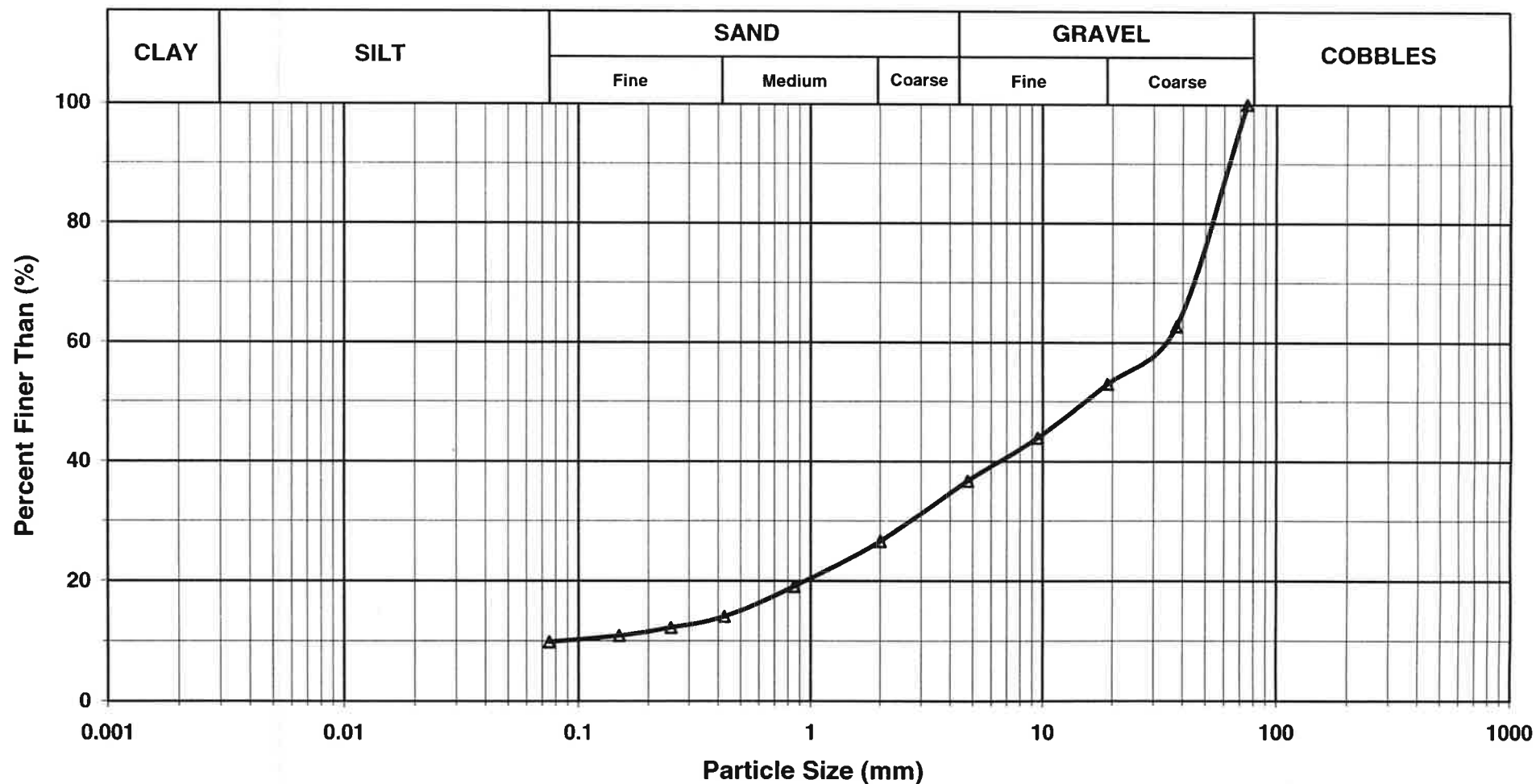
GRAIN SIZE ANALYSIS

Sample : TP-6 @ 1 m

DRAWN BY: DS/SC EDITED BY: DATE: Apr/98

APPROVED: FIGURE:

PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.



Manalta Coal
Telkwa Test Pits



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HYDROGEOLOGICAL CONSULTANTS
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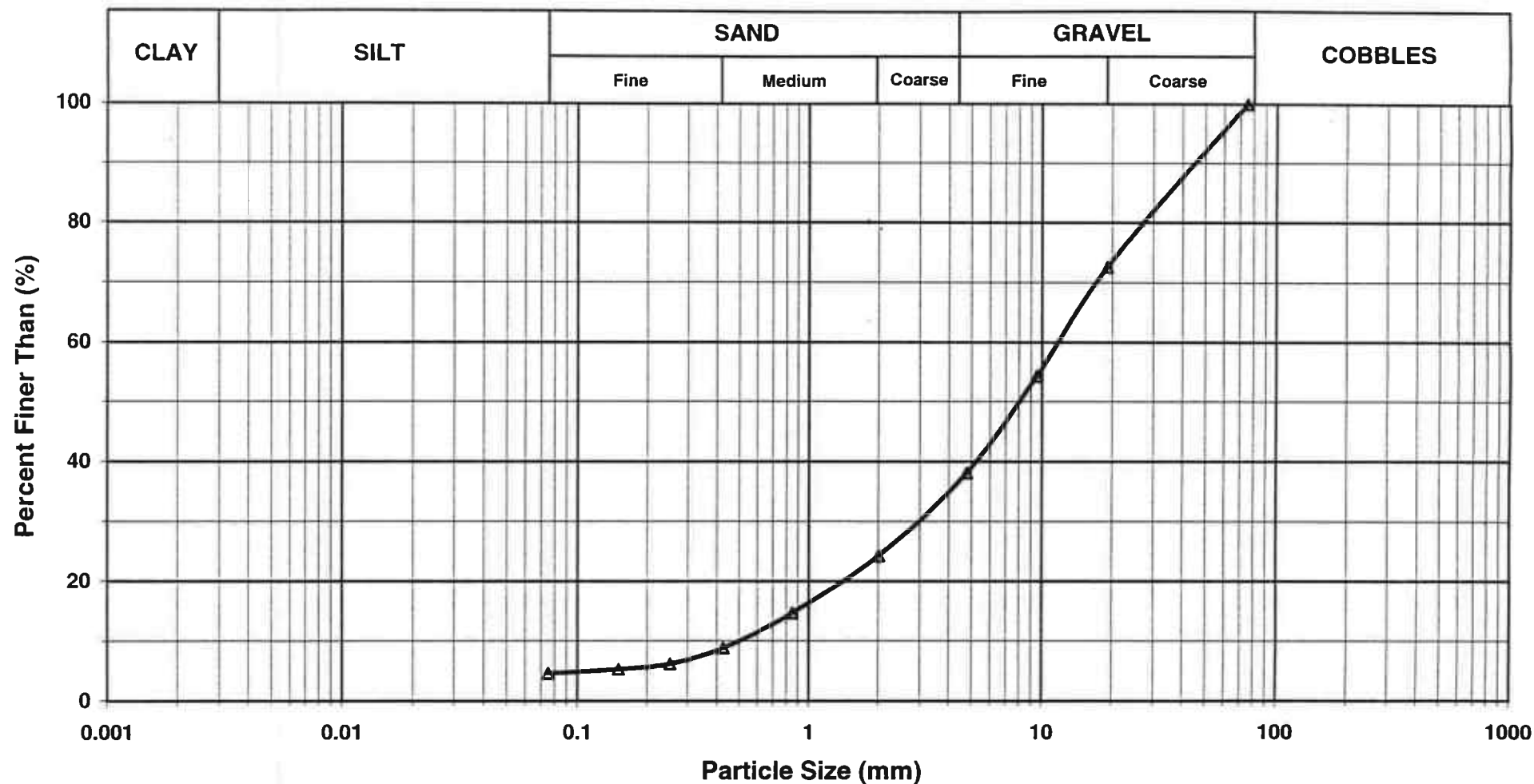
GRAIN SIZE ANALYSIS

Sample : TP-6 @ 2.5 m

DRAWN BY: SC EDITED BY: DATE: Apr/98

APPROVED: FIGURE:

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Telkwa Test Pits



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HYDROGEOLOGICAL CONSULTANTS
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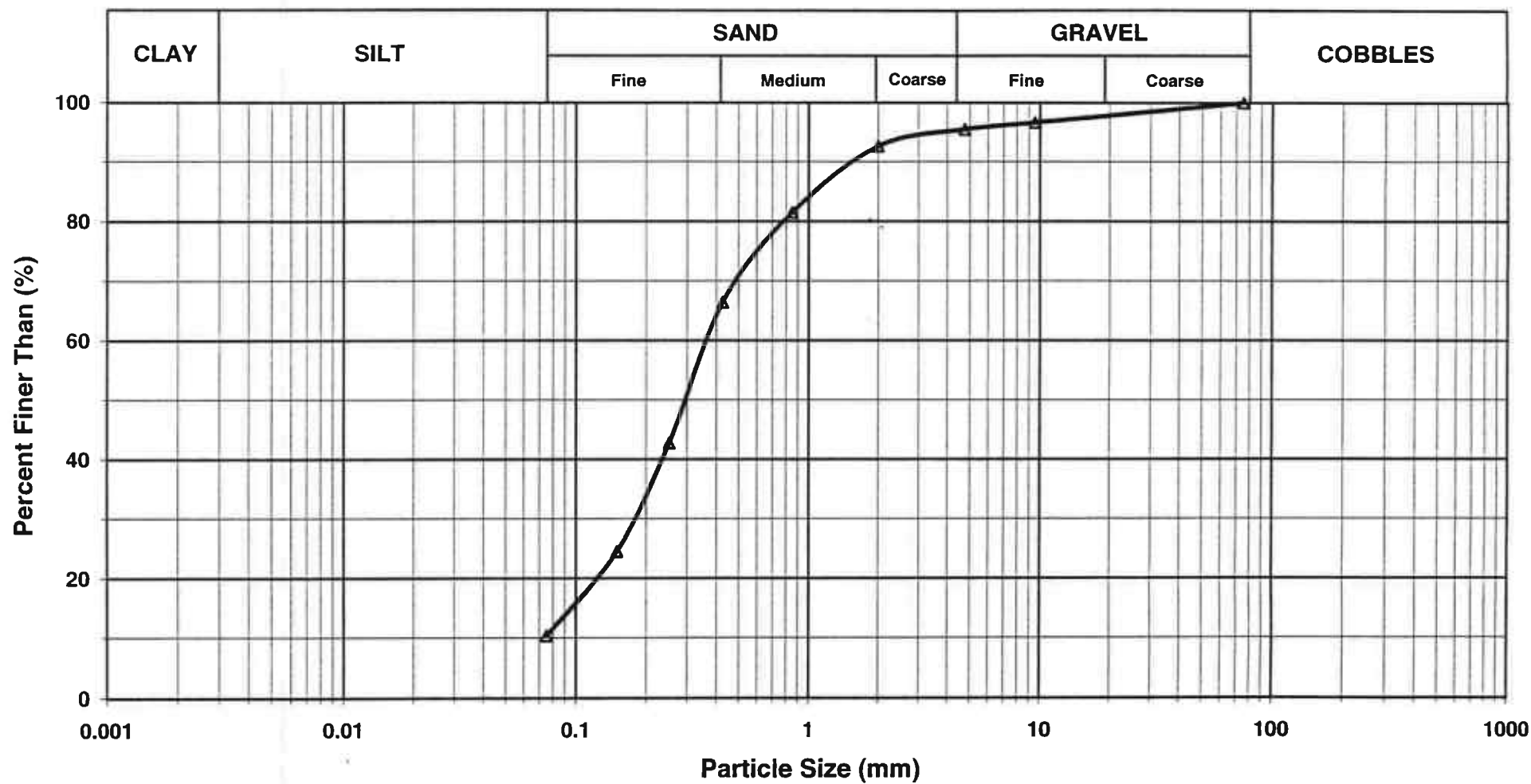
GRAIN SIZE ANALYSIS

Sample : TP-14 @ 0.5 m

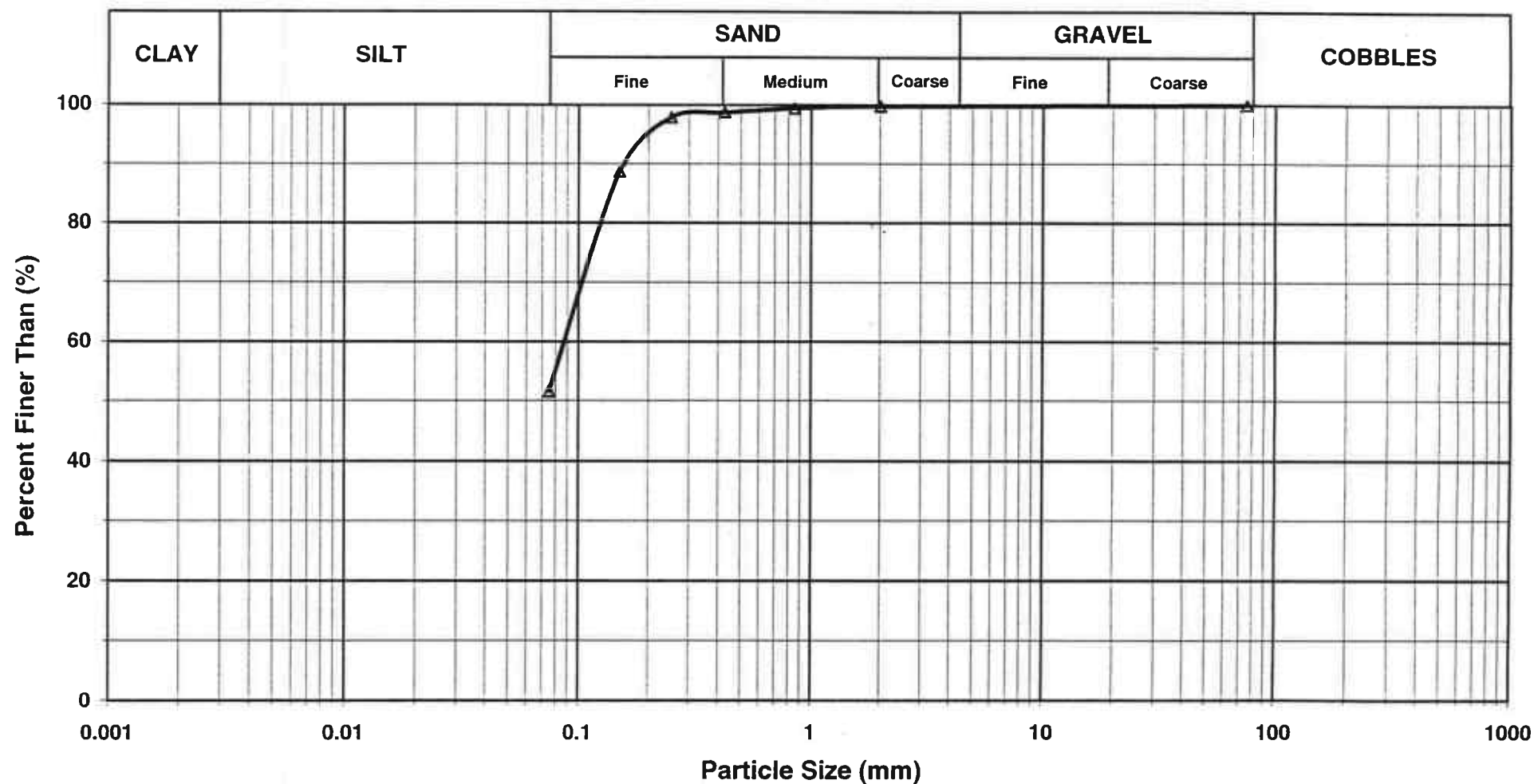
DRAWN BY: DS/SC	EDITED BY:	DATE: Apr/98
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APPROVED:	FIGURE:
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PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.



Manalta Coal Telkwa Test Pits		PITEAU ENGINEERING LTD. GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS VANCOUVER CALGARY
GRAIN SIZE ANALYSIS Sample : TP-14 @ 3.6 m		
DRAWN BY: DS/SC EDITED BY: DATE: Apr/98		APPROVED: FIGURE:
PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.		



Manalta Coal
Telkwa Test Pits



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GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS
VANCOUVER CALGARY

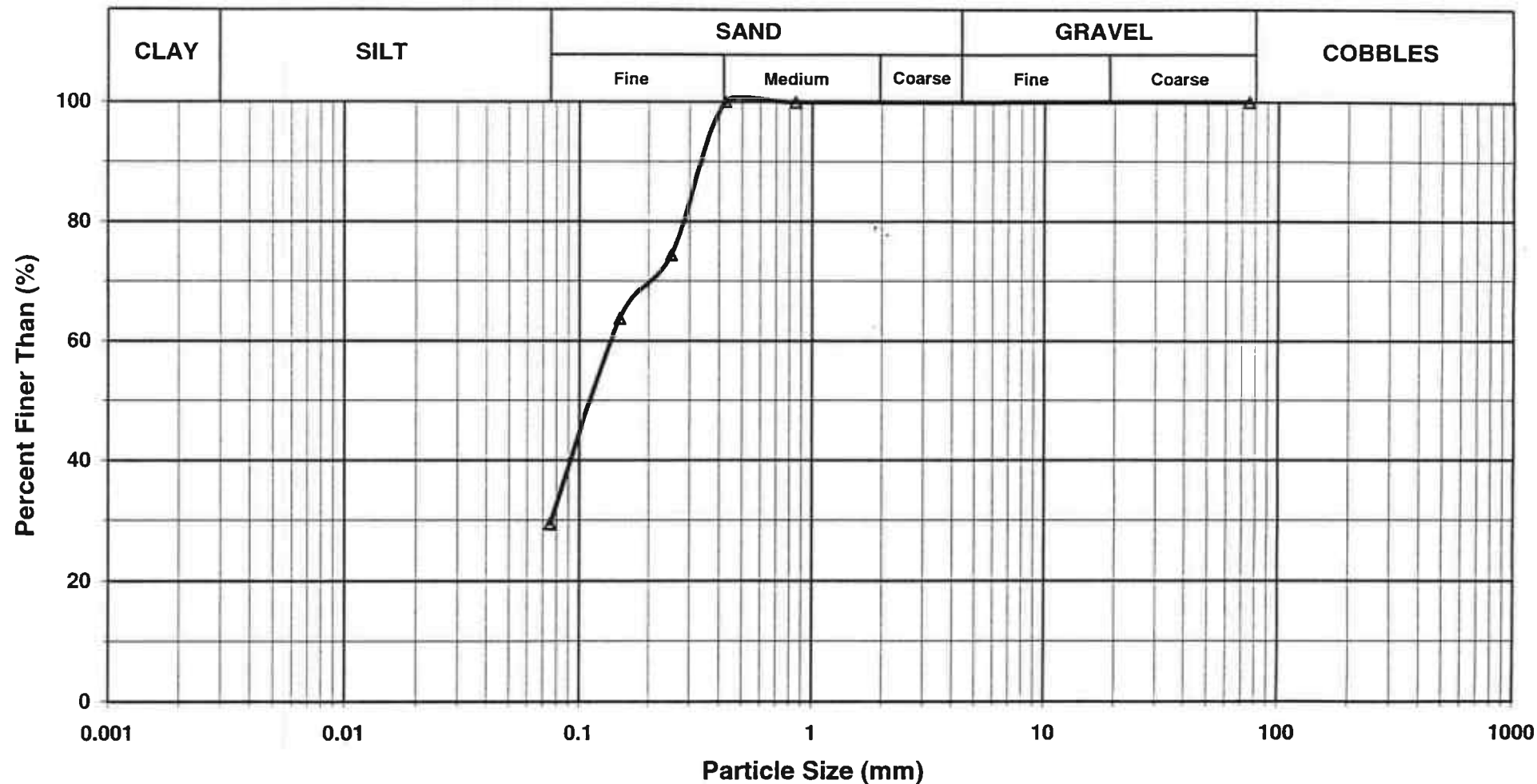
GRAIN SIZE ANALYSIS

Sample : TP-18 @ 1.0 m

DRAWN BY: DS/SC EDITED BY: DATE: Apr/98

APPROVED: FIGURE:

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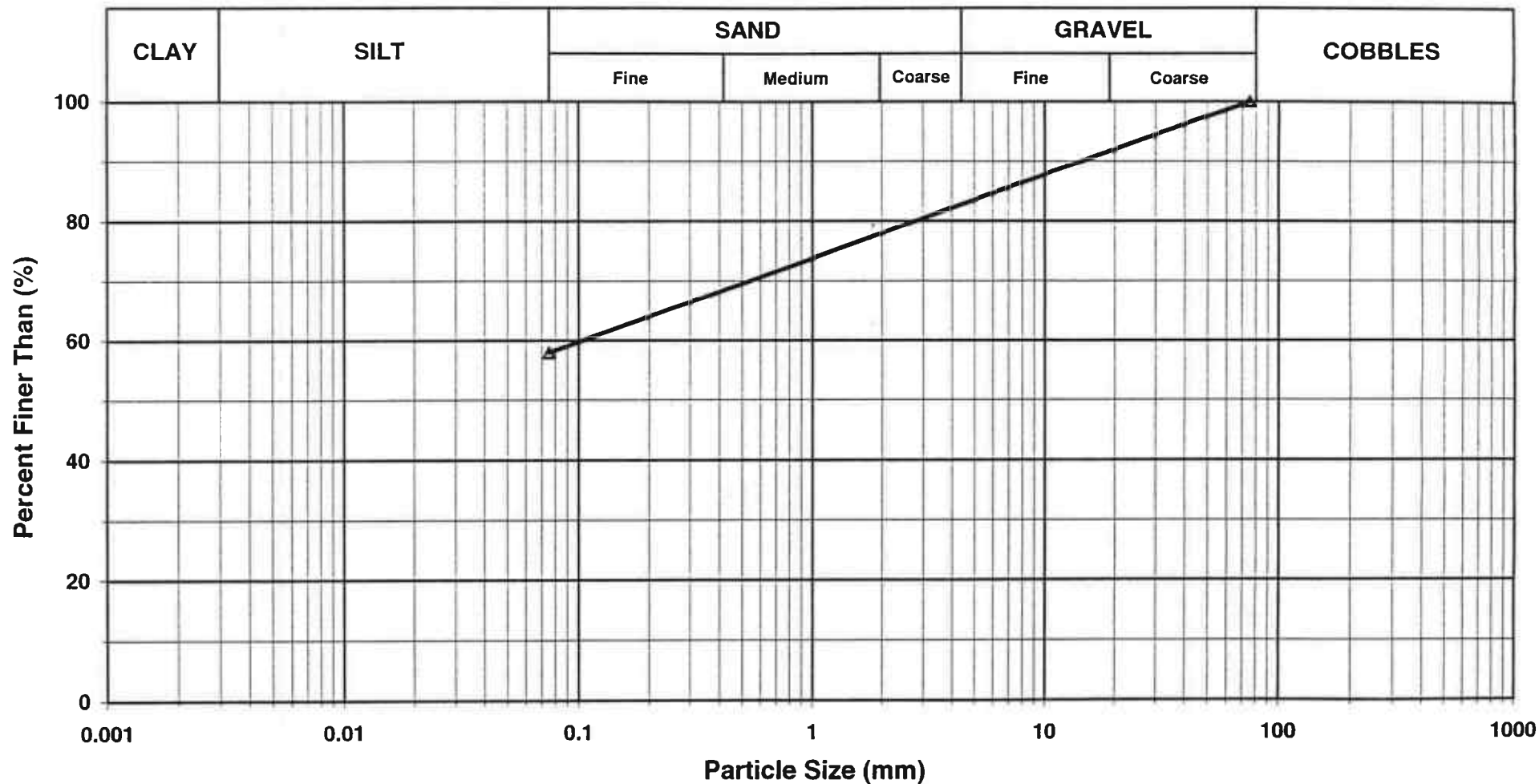
GRAIN SIZE ANALYSIS

Sample : TP-20 @ 3.0 m

DRAWN BY: DS/SC	EDITED BY:	DATE: Apr/98
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APPROVED:	FIGURE:
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NOTE: This sample was passed through the No. 200 sieve only.

Manalta Coal
Telkwa Test Pits



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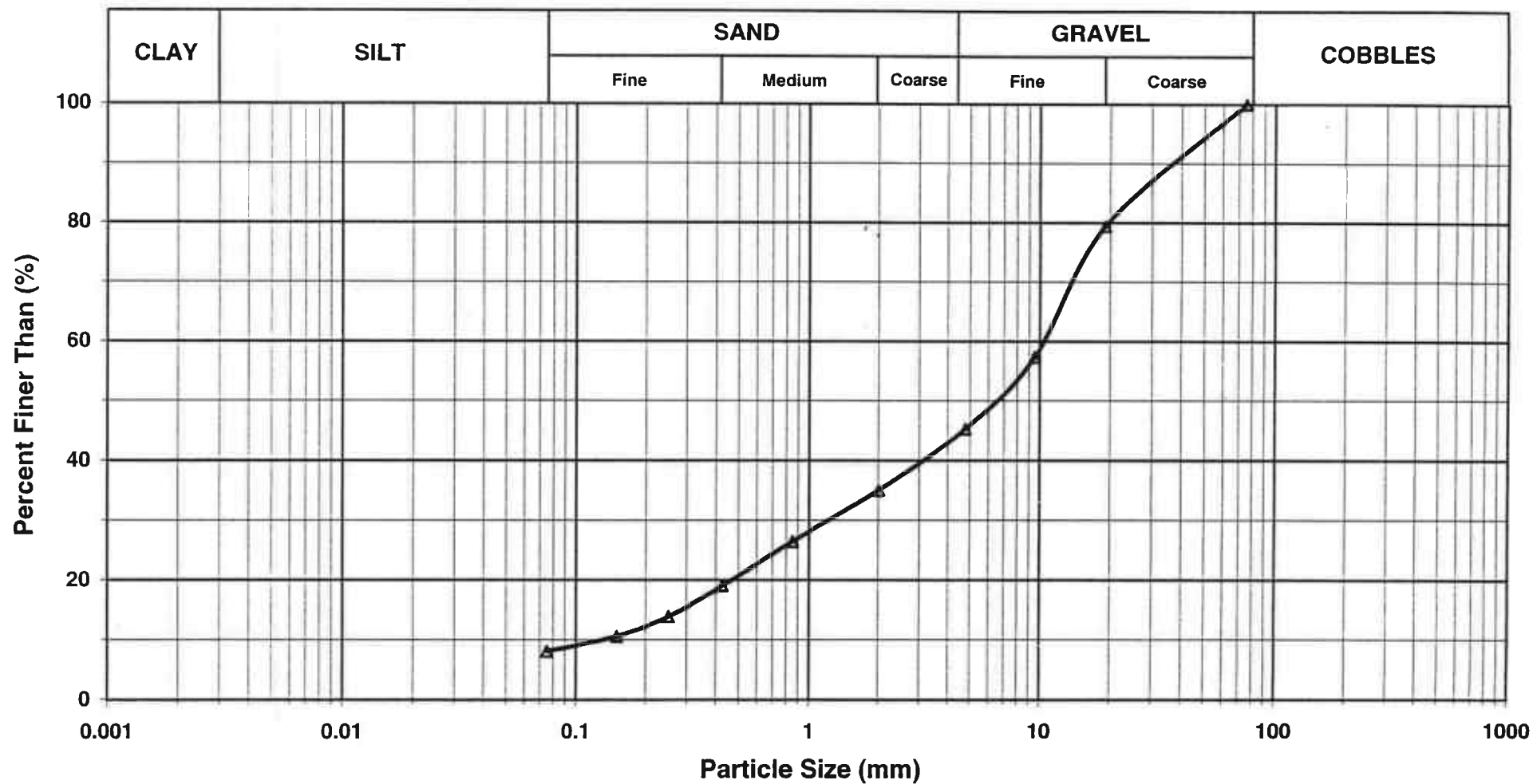
GRAIN SIZE ANALYSIS

Sample : TP-30 @ 0.3 m

DRAWN BY: DS/SC EDITED BY: DATE: Apr/98

APPROVED: FIGURE:

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Manalta Coal
Telkwa Test Pits



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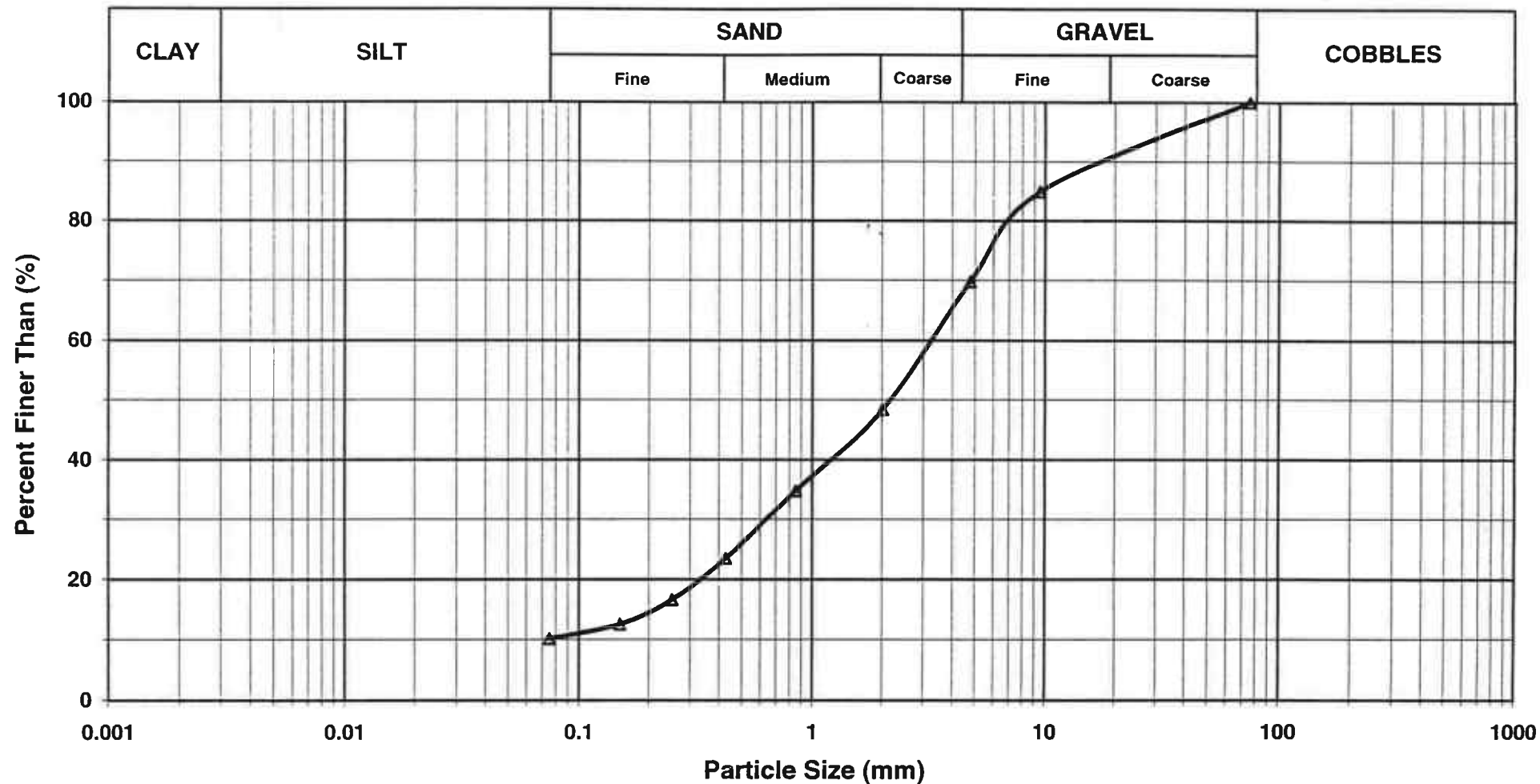
GRAIN SIZE ANALYSIS

Sample : TP-31 @ 0.5 m

DRAWN BY: DS/SC	EDITED BY:	DATE: Apr/98
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APPROVED:	FIGURE:
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<i>Manalta Coal</i> Telkwa Test Pits		 PITEAU ENGINEERING LTD. GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS VANCOUVER CALGARY	
GRAIN SIZE ANALYSIS Sample : TP-31 @ 4.3 m			
DRAWN BY: DS/SC		EDITED BY: DATE: Apr/98	
APPROVED:		FIGURE:	
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