Ripley, Klohn & Leonoff International Ltd.

CONSULTING ENGINEERS | SOIL MECHANICS & FOUNDATIONS

VANCOUVER EDMONTON CALGARY WINNIPEG
CANADA

REPORT

Title: RICHMOND DYKES-REMEDIAL TREATMENT

Location: CORPORATION OF THE TOWNSHIP OF RICHMOND, BRITISH COLUMBIA

Client: FRASER RIVER JOINT PROGRAM COMMITTEE
THE PROVINCE OF BRITISH COLUMBIA
MINISTER OF LANDS, FORESTS & WATER RESOURCES

Our File: VA1346 OCTOBER 17, 1969

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CONSULTING ENGINEERS | SOIL MECHANICS & FOUNDATIONS
1930 WEST BROADWAY • VANCOUVER 9, BRITISH COLUMBIA • CANADA
TELEPHONE: 731-5781 AREA CODE: 604 CABLE ADDRESS: "RIPSOIL"

Our File VA1346

October 17, 1969

Fraser River Joint Program Committee,
#2 - 628 Carnarvon Street,
New Westminster, British Columbia.

Mr. R.J. Talbot

Richmond Dykes

Dear Sirs:

We are pleased to submit herewith our report entitled "Richmond Dykes - Remedial Treatment" in accordance with the agreement dated July 23, 1969.

As requested by you in our discussions on September 25, 1969 we have outlined in the report our thoughts on the type of program necessary to isolate areas in which underseepage, boils and piping might be expected and to recommend remedial treatment to control that undesirable condition.

Another matter, which was not discussed at our last meeting concerns the treatment of areas where peat and organic silts were encountered in the dyke foundation areas. As discussed in the report, these materials should be removed if possible, but this may not be as simple in the Richmond area as at points upstream owing to the tides and to the considerable depths of such materials in the Lulu Island deposits.

Accordingly a program of investigations has also been included for the peat areas, to provide information on which to base designs for embankment cross sections that can be founded on the weak organic materials.

Although these specialized investigations could be carried out by others acting for the Civil Engineering Consultant, we feel it could be to your

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Ripley, Klohn & Leonoff International Ltd.
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Our File VA1346

October 17, 1969

Title: RICHMOND DYKES - REMEDIAL TREATMENT

Location: CORPORATION OF THE TOWNSHIP OF RICHMOND, B.C.

Client: FRASER RIVER JOINT PROGRAM COMMITTEE
THE PROVINCE OF BRITISH COLUMBIA
MINISTER OF LANDS, FORESTS AND WATER RESOURCES

I INTRODUCTION

This report presents field information and recommendations on general soils criteria for the guidance of the Joint Program Committee in respect of the soils and soil mechanics requirements for rehabilitation of dykes in Richmond, British Columbia, comprising all of Lulu Island west of Boundary Road, Sea Island, Twigg Island and Mitchell Island. The material presented is based on: a study of available reports on earlier investigations; a program of field examination and exploratory drilling conducted during September 1969; a limited program of laboratory testing on samples from the drilling program; and office analyses of typical and special situations observed.

Our earlier report dated July 2, 1969, commented on basic dyke design criteria used in the Fraser River Board Report dated September 1963, and recommended the field work program for the present stage of investigations. Reports by earlier investigators and other pertinent material referred to in the preparation of this report are listed in Appendix C.

Authority for the present stage of the work was given by an agreement executed by Mr. V. Raudsepp dated July 23, 1969. A copy of that agreement is contained in Appendix D.

The following extract from the agreement relates to the scope of the present assignment:

"H. The consultant shall provide the following services:

a. Carry out the investigations outlined in Ripley, Klohn & Leonoff International Ltd's Phase I report, dated July 2, 1969

b. Use the results of these investigations to establish general design criteria and typical design sections for the dykes

c. Confirm that an adequate supply of suitable dyke construction material is available."

II CONCLUSIONS AND RECOMMENDATIONS

For clarity the conclusions and recommendations which follow are presented with a minimum of detailed explanation and qualifications. The reader is referred to Section IV for clarification where required, for cautionary remarks, and for areas or points requiring more detailed investigation. The appended drawings will be of interest and assistance in the reading of this Section.

A. General Assessment

Foundation soils for the Richmond dykes fall into two broad categories. Most of the dykes are founded on a shallow layer of silt (0 to 20 ft) underlain by a deep zone of fine to medium sand (60 to 100 ft). Below the sands are even deeper beds of poorly consolidated clays, although these latter are not of particular significance to the present investigations. Some of the dykes at the east end of Lulu Island are founded on deep beds of compressible organic silt and peat which are underlain by varying depths of silt, sand and clay.

The original dykes were apparently constructed from local surface materials excavated from the ditches that exist adjacent to the downstream or landside toe in most areas. Subsequent additions appear to have been made either with further applications of local surface soil or with material dredged from the nearby river. Thus the surfaces of the slopes and the crests comprise materials ranging from silt to medium sand, whereas the central sections or cores appear predominantly as silt, the central silt core being usually indistinguishable from the foundation silts.

Quite apart from probable inadequacies in crest heights, which were not determined in the present investigations, considerable portions of the dykes are considered to be below acceptable standards for various reasons, the more important of which are discussed below.

B. Specific Problems

1. Embankment Slopes - Embankment slopes are in general too steep for adequate safety against the maximum hydraulic loading proposed for the present design.

2. Pervious Foundations - The deep sand layer was encountered under most of the sections investigated. This layer is relatively pervious and readings from piezometers installed at a typical section demonstrated that pore pressures in the sand layer follow the hydraulic head variations quite closely and with relatively little time lag. Thus, in areas where the overlying silt layer is thin or non-existant, and there is little or no silt layer on the riverside to hinder access by water to the sand strata, a potential exists for strong underseepage, boils and piping. Appendix B contains a description of the piezometer tests.

3. Weak Foundations - This condition is more prevalent on the easterly end of Lulu Island where sections of the dykes have been constructed on compressible organic silts and peat. However, there are localized sections in other areas where obviously sagging crest levels indicate excessive subsidence probably due to higher than average organic content in the top foundation layer together with greater silt depths in those areas.

It should be noted that consolidation of the deep clays, which apparently underly the entire area at depth, is no doubt contributing to a general subsidence of the dykes. However, this is usually of a more uniform nature compared to settlements in the surface materials. Also much of the deep settlement due to the dyke loadings will have developed by now and the continuing settlement from this source should be minor.

4. Drainage Ditches - As mentioned above, material used for constructing the original dykes was apparently obtained by excavating natural soils from the landside toe area. The resulting trenches were then utilized as drainage and storage ditches in the overall land drainage system. The ditches are steep-sided and often quite deep. In many areas they are immediately adjacent to the dyke toe with bank slopes as steep or steeper than the dyke slope above, and thus contribute to the inadequacy of the overall landside slope. They also tend to steepen the hydraulic gradient through the dykes beyond that which would prevail if the landside toe were at natural ground level, and the water in them masks the indications of seepage flows through or under the dykes. In places the ditches have been excavated completely through the surface silt layer to expose the underlying sand; in other areas the depth of silt remaining below the ditch is less than the acceptable minimum for safety against development of boils and piping. Appendix B describes two locations where evidence of piping was found in the ditches.

5. Rip-Rapped Slopes - It is understood that present construction standards in the municipality for rip-rapped slopes call for a 1.5 horizontal to 1 vertical embankment slope and a two foot minimum layer of rip-rap placed essentially at the same slope. It is apparent that such slopes have a very low factor of safety as evidenced by observations of slumping and general subsidence. A few areas were noted where closely spaced piles have been used to permit deepening of the river channel at the riverside toe of the dyke, with rip-rap placed on the slope above and supported at the bottom by the piles. The piles are in relatively poor condition and permit slumping of the rip-rap and the slope they were intended to support.

A two block long section in Steveston has a pile supported timber wall extending to the top of the dyke at a slope of about 1 horizontal to 4 vertical. This old and dilapidated structure is in effect the riverside slope of the dyke as shown by Section 1026 on Dwg D-1346-6.

6. Erosion - Dyke erosion is primarily a problem only along the river

channels as the sea dykes are well protected from wind generated waves by the broad shallows of Sturgeon Bank. Erosion on the river dykes is caused by waves from ships and by river current. Wave erosion will be limited generally to the upper portions of the riverside slopes between high and low water. On the other hand, current erosion extends to all levels of the slopes and can result in dangerous undercutting of the banks below the dykes. The present investigation did not include river soundings but a perusal of the Department of Public Works' hydrographic charts indicates several areas where soundings close to the banks reach 40 to 50 ft, and where a careful review will be necessary to detect and avoid the possibilities of major bank failures that could remove the dykes, foundations and all.

It is suspected that there may be areas where undermining of the dykes, similar to that due to current erosion, may have occurred through indiscriminate dredging operations.

7. Roads - Extensive sections of the Lulu Island dykes along the north and south arms have roads either on the crest or at the landside toe. Many are relatively narrow, without adequate shoulders and suffer constantly from embankment instability and subsidence. Considerable lengths are paved. Many of the most restricted areas have the added complication of a road on or adjacent to the dykes. Where the road is at the landside toe, particularily along River Road, the road surface is in very bad condition due in part to a lack of sufficient granular base material under the pavement and in part to weakening of the foundation materials by upward flowing seepage water emerging from the pervious sand strata below.

8. Built-Up Areas - Problems from this source are concentrated mainly on Lulu Island along the north and middle arms and in the Steveston area. They usually combine most of all of the foregoing problems with the added complications of high value property and structures.

9. Vegetation - The dykes have become heavily overgrown in many areas. Large sections are extensively treed. This cover hinders inspection and invites ground burrowing animals whose burrows have been reported in other dyking areas as the direct causes of piping failures.

C. Recommended Cross-Sections

Drawing D-1346-10 illustrates various riverside and landside slopes that can be used for rehabilitation of the majority of the Richmond dykes, depending on the construction materials used, existing conditions, and space limitations. It is believed that at least one of the solutions shown can be applied to most situations in the project area. The one specific exception is in areas where dykes are presently founded on peat or organic silt, which problem is discussed separately below.

Each of the cases shown on Dwg D-1346-10 is discussed below. Generally, the physical situations and the methods of treatment of landside and riverside slopes are independent; hence the two sides are dealt with separately. In the discussion which follows, and on the drawing, the solutions are identified as being riverside or landside by the abbreviations R.S. and L.S. respectively.

1. Riverside Slopes

a) Case 1 - R.S.

Basic Slope - 3 horizontal to 1 vertical

Materials - Existing dyke materials trimmed to suit and with compacted sand fill as required. Add rip-rap if required.

Use - In areas where ample space is available.

b) Case 2 - R.S.

Basic Slope - 2.5 horizontal to 1 vertical

Materials - Compacted free-draining gravel in a triangular riverward zone. Trim the existing silt slope if required to provide a contact with slope of 1.5 horizontal to 1 vertical as shown. Add rip-rap if required.

c) Case 3 - R.S.

Basic Slope - 2.0 minimum horizontal to 1 vertical

Material - Rip-rap only

Use - In areas where rip-rap is already in service, and where economics indicate the desirability of adding additional rip-rap to stabilize the slope rather than removal of the rip-rap and adoption of Case 2 R.S. Note that each application of this case should be the subject of a special stability analysis based on actual geometry of the dyke and river bank and actual soil properties in the dyke determined by detailed field investigations.

2. Landside Slopes

a) Case 1 - L.S.

Basic Slope - 2.5 horizontal to 1 vertical

Materials - Compacted sand in new embankment, horizontal compacted blanket drain, compacted silt or silty sand fill in drainage ditch

Use - Where new fill is predominantly on the landside and there is sufficient space for a horizontal drainage layer.

b) Case 2 - L.S.

Basic Slope - 2.5 horizontal to 1 vertical

Materials - Existing dyke materials trimmed to suit and with compacted sand fill as required, wedge shaped toe drain of free draining gravel, compacted silt or silty sand fill in drainage ditch

Use - Where insufficient new fill is to be placed on the landside to permit use of a horizontal drainage layer.

c) Case 3 - L.S.

Basic Slope - 2.0 horizontal to 1 vertical

Materials - Compacted clean sand, compacted blanket drain, compacted silt or silty sand in drainage ditch

Use - In areas with limited space and where a road or other construction requires a widened crest, such that the toe lies beyond the theoretical toe location for a basic dyke with 3.0 horizontal to 1 vertical slope.

d) Case 4 - L.S.

Basic Slope - 4.0 horizontal to 1 vertical

Materials - Compacted sand fill only in embankment, compacted silt or silty sand in the drainage ditch

Use - Where built-in toe drains are not desired or economical. It should be noted that localized areas of toe seepage could be encountered with this design, requiring addition at a later date of a drainage blanket as shown.

3. Crests - The clear width of crest should be not less than 12 ft exclusive of rip-rap and its bedding gravel.

In areas where the dykes are relocated such as is possible along Sturgeon Bank as a means of reclaiming additional land, the crest should be made wider so that they can be raised as required to accommodate future settlement. Section IV discusses this point further and gives recommendations for determining the necessary allowances.

D. Underseepage

As a general guide, seepage through the more pervious underlying sand strata can be ignored where the depth of the silt layer at the toe and inland from the dyke is equal to or greater than the design hydraulic head as measured between the water surface and the ground surface inside the dyke.

With silt layers of thickness less than the design hydraulic head as defined above, the potential for development of boils and piping exists, particularly where erosion or dredging has removed the silt layer riverward of the dyke. It is recommended that such areas be the subject of a further investigation, details of which are outlined in Section IV, Discussion.

E. Drainage Ditches

The foregoing recommendations all assume that the deep drainage ditches adjacent to the landside toe are to be filled in. The materials to be used for infilling the ditches should resemble as closely as possible the materials originally removed, particularly in respect of permeability. Usually the materials should be silts if such can be used practicably, otherwise they should be fine silty sands.

It is realized that the loss of water storage capacity from infilling the drainage ditches could necessitate either construction of new ditches elsewhere or provision of additional pumping capacity. Nevertheless, preliminary trial sections based on the above slope recommendations indicate that a large portion of the existing ditches will have to be filled to provide room for the greater base width of the rehabilitated dykes. Where that is the case, new ditches if provided should be located a minimum of 200 feet from the toe of the reconstructed dyke, at which distance the uplift pressures within the underlying sands should be low enough to obviate the possibility of boils developing within the new ditches.

Where a drainage ditch must be retained at the toe of the dyke, special measures may be required. The measures will depend upon such factors as depth of the silt layer below the ditch, extent of the unbroken silt blanket riverward of the dyke, depth and permeability of the sand layer, and permeability of the silt layer. It is therefore recommended that when the sections have been defined where the drainage ditches must be retained, a detailed investigation program be undertaken as outlined in Section IV, Discussion.

F. Roads

Roads constructed on the crests of the rehabilitated dykes will be of good quality provided that reasonable road building standards are adopted. Shoulders should be at least four feet wide and due consideration should be taken of the underlying dyke materials when specifying base courses, to ensure against failures due to frost action.

Preliminary trial sections in areas where the roads are presently at the downstream toe of the dykes, using the slopes recommended above for dyke rehabilitation, have indicated that the most efficient use of available space, and probably the most economical, will result from raising such roads to crest level.

Where a road must be constructed at or near the toe of a dyke, design of the subgrade should include provision for the upward flow of water from the pervious sand strata below. That action, which is akin to that found in quicksands, can result in a serious reduction in bearing strength of the soil, and maintains a constant supply of water that must be drained away. It is not possible to give useful generalized solutions to this problem and it is recommended that when such areas have been delineated a detailed soils investigation program be carried out to provide satisfactory designs for the specific locations.

G. Peat and Organic Silts

Peat and highly organic silts were encountered in some of the sections investigated at the east end of Lulu Island. These materials were encountered in the foundations at three locations and also within the dyke section at one. While such materials are very impervious, they are also highly compressible, have low unit weights and are generally very weak. Frequently the organic silts beneath the peat are the weakest materials, with extremely low shear strengths. The peat bogs in this section of Lulu Island range from 10 to 40 ft in depth although indications are that depths under or adjacent to the dykes will be more in the order of 5 to 10 ft. However, the underlying weak organic silts can extend down a further 10 to 15 ft.

The preferred treatment would be removal of these undesireable materials from the dykes and their foundations. However, this is probably not practical in the Richmond area owing to the considerable depth involved, and also to the need for maintaining adequate protection of the land at all times against the daily tidal fluctuations. Accordingly, it is recommended that a program of detailed investigations be carried out to delineate the problem and to obtain specific data on depths, compressibility and shear strengths for use in design of new dyke sections to be founded on these materials. This subject and recommended program are discussed in Section IV, Discussion.

H. Underwater Scour

A careful investigation by soundings is recommended to detect all areas where current action or dredging may have brought the deep channel too close to the dykes. As a general guide, a line of slope 3.0 horizontal to 1.0 vertical projected riverward from the riverside toe should remain in the soil and not intersect the river channel. Marginal cases should be examined critically to assess the affects of the underwater profile on overall bank stability. Departures from this general rule should only be permitted when so justified by further field explorations and detailed soil analyses.

I. Guides for Specifications

1. Surface Preparation - All vegetation and highly organic topsoil should be stripped from areas to be covered by fill. Coarse sands and gravels, and pavement materials should be stripped from crests that are to be raised. Pavements and coarse grade-materials of roads adjacent to the dyke that will be covered by fill must be removed. Particular care should be taken not to leave layers of gravel or broken pavement under areas to be covered by drainage blankets.

Treatment of rip-rapped riverside slopes will depend on the design section adopted. Where the rip-rap is not steeper than 1.5 horizontal to 1 vertical, it may be left in place and the treatment given above for Case 3 R.S. may be used. Rip-rap on steeper slopes and any timber works used against or below rip-rapped slopes should be removed.

Soft muck, reeds and other vegetation should be removed from ditches but care should be taken not to disturb the firmer materials below.

Slopes should be trimmed as required to suit the new cross-section and to eliminate abrupt discontinuities.

New land surfaces to be covered by fill, except water filled ditches, should be proof rolled with two passes of a D8 Cat or equivalent. Soft spots detected by the proof rolling should be cleaned out and backfilled with compacted silty sand.

An effective soil sterilant should be applied to those areas to be covered by fill where fill is to be less than 3 ft deep.

During surface preparation constant vigilance should be maintained for unusual situations such as:

a) Improperly constructed embankments, particularly in areas where dykes cross old sloughs and water courses and where pervious or poor quality materials may have been used.

b) Pervious zones or signs of seepage or piping along pipes and conduits through or under the dykes.

c) Peat or highly organic silts in the dyke and foundations. These areas will require further investigation as discussed in Section IV.

2. Backfilling of Ditches - This work should be scheduled for periods of low tide, and water levels in the ditches should be maintained as low as possible. The initial course will, of necessity, be deep enough to provide a firm base for equipment operation, but should not be excessively deep. This course can be end dumped from trucks which should be so routed that all portions of the course receive at least three passes of the loaded vehicles. The work should proceed so that water is displaced along the ditch to the outlets and not trapped between sections of fill.

Succeeding courses should be placed in 12 inch layers, and compacted to 90 percent of Modified Proctor density, ASTM Test D1557.

3. Fill Materials - Table 1 following describes the various materials recommended by gradation limits.

TABLE 1

GRADATION LIMITS

Material	U.S. Standard Sieve Size	Percent Passing
Silt	#200	100
Silty Sand	#200	15 - 50
Sand Fill	#100 #200	0 - 10 0 - 3
Free Draining Gravel		See Grading Curve in Appendix E
Drainage Blanket Material		See Grading Curve in Appendix E

Compaction of these materials should be carried out under close supervision. Silts, silty sands and clean sands should be compacted 90 percent of Modified Proctor density, ASTM Test D1557. The gravels will have to be compacted to a performance standard and it is recommended that they be compacted in lifts not exceeding 12 inches by 3 passes of a D8 Cat or equivalent. Application of water to these materials will be necessary before compaction.

Placement and compaction of the materials in horizontal layers is preferable. However placement in sloping layers is acceptable provided suitable arrangements can be made for compaction to the required density.

Use of frozen materials should not be permitted.

J. Protection of Slopes

All slopes not covered by rip-rap should be seeded following construction to provide a heavy cover of coarse grass.

K. Inspection and Maintenance

Routine inspection should include a detailed examination of the dykes at least once per month. The inspections should be scheduled for periods of low tide. Where flood conditions prevail, the inspections should be on a daily basis. The inspectors should report on all unusual conditions noted, including specifically the following:

1. Saturation of, or seepage from, the landside slopes.

2. Seepage from, or boils appearing on the ground surface at the landside toe or anywhere up to at least 200 ft inland.

3. Slumping of slopes or other signs of slope instability such as cracks in road surfaces or sliding of rip-rap on the river side slope. Where sliding of rip-rap occurs, the river should also be sounded to determine whether scour or dredging has undermined the dyke slope.

4. Evidence of ground burrowing animals.

5. Local subsidence of the dykes due to settlement of weak foundation materials.

6. Indications of seepage or leaks along pipes and conduits passing through or under the dykes.

Routine maintenance should include removal of trees and brush, trimming of grass and shrubs to permit effective inspection, discouragement of burrowing animals, and cleaning of ditches where such have been retained close to the dykes.

Special maintenance will involve:

1. Temporary treatment of boils by means of sand bag subdykes or enclosures, see Dwg D-1346-10.

2. Permanent treatment of troublesome underseepage, as evidenced by boils. This could involve either weighting of the area with sandfill, or installation of special drainage facilities to reduce the uplift pressures in the pervious sand zone, depending upon suitability of the remedy relative to land use and economics. This subject is discussed further in Section IV, Discussion.

3. Remedial measures for slope instability as specified by a competent soils engineer following an investigation of the specific situation.

4. Infilling of animal burrows in the dykes by injection of bentonite, clay or weak concrete in slurry form.

L. Borrow Materials

Recommended source areas for borrow materials are:

- Sand dredged from the Fraser River adjacent to the dykes.
- Gravel barged to the area from pits further upstream or in the Howe Sound and Georgia Straits areas.
- Silts and silty sands from local surface areas and from the Sturgeon Bank area.

1. Dredged Sand - Sieve analyses of samples from 5 dredged sand stockpiles on Lulu and Sea Islands show that the dredged material consists of medium to fine sand with little or no silt. Samples from different parts of the Fraser River in the Richmond area show quite similar grain size characteristics.

Those tests indicate that the general sand fill required can be obtained by selective dredging from the Fraser River. However, it will be necessary to carry out a pre-sampling program to avoid areas with excessive silt which material would probably be too wet to handle conveniently.

Coarser sands encountered in the dredging program may be suitable for use in the horizontal drainage blankets. It is believed that sands coarse enough for such service are obtainable from sections of the river in the New Westminster area and farther upstream.

2. Gravel - As pointed out in the "Construction Materials Survey" by E.M. Clark in 1963, all gravels will have to be imported by barge or truck. Enquiries were directed during the current investigations to four of the larger suppliers of gravel operating in the area regarding the supply of gravel as a construction material. Two of these suppliers obtain gravel from a pit near Langley. The third offered limestone and granite quarry waste from Texada Island, and the fourth can supply from pits in Howe Sound near Britannia. The material best suited as a free-draining gravel was found to be that from Texada Island with the plus 3 inch removed by scalping; the other materials although better graded would not be sufficiently permeable when compacted.

If enough coarse sand for the horizontal drainage blankets is not obtained from the dredging program, it is understood from discussions with one supplier using the Langley pit that an ample supply of medium sand is available from that location. As a further alternative, the finer fractions of the gravel from both the Langley and the Britannia pits will be suitable when split on a 3/4 inch mesh sieve.

Copies of the related correspondence are included in Appendix D, grain size curves are shown on Appendix E.

3. Silts and Silty Sands - There are ample quantities of silts and silty sands in the Richmond area. Such material can be obtained from almost any point within the dyked area, although for sources inside the dykes it will normally be necessary to replace the borrowed material with dredged sand so as to maintain the general land levels.

Outside the dykes, the main source area is Sturgeon Bank, although the same problem of replacing the material with sand could apply if the area is to be reclaimed during the dyke construction program.

Should it be found necessary to excavate new drainage ditches inland from the dykes; to replace those filled during the dyke construction, the materials from the new ditches could be suitable for filling the old ditches provided the materials are not too wet. Similarly material trimmed from the existing dykes to meet the new slope criteria may be suitable.

In the selection of borrow areas for silts and silty sands, it is recommended that these be not closer to the dykes than 200 ft, whether they be from an inside or an outside area. This requirement is to avoid any action that would shorten the seepage path through the pervious sand strata underlying the dykes.

III FIELD AND LABORATORY INVESTIGATIONS

A. Field Investigations

1. Inspection of Dykes and Borrow Areas - On June 8, 1969, E.J. Klohn and M.T. Olsen of Ripley, Klohn & Leonoff International Ltd made an inspection of all the readily accessible dykes in the Richmond area, to obtain a general impression of the state of the dykes.

On September 4, 1969, a program of more detailed inspection was initiated. This program entailed making a close examination of the dykes and determining positions where detailed cross-section and subsurface soil data should be obtained. Drilling was completed by September 26, 1969.

Several stockpiles of dredged river material were located during the dyke investigation. These stockpiles were in various states of depletion at the time of the investigation. Representative samples of sand were taken from 5 of these stockpiles and sieve analyses made.

2. Drilling - The subsurface explorations were carried out using the Ripley, Klohn & Leonoff penetration drill, a piston sampler and hand augers. Twenty-seven sections were investigated at each of which a penetration hole and a piston sampling hole were driven from the crest to various depths, up

to 38 ft. Shallower auger holes were drilled at and near the toes to correlate with the deeper holes from the tops of the dykes.

Two auger holes were drilled on Sturgeon Bank at the west end of Lulu Island to determine the suitability of the deltaic deposits for use as fill in rehabilitating the dykes.

Positions of the sections investigated are on Dwg D-1346-1.

3. Surveying - Each section was profiled by tape and clinometer at the time of drilling. A 2 inch square wooden peg was set alongside each drill hole, with a flagged stake as a marker, to enable the drill hole locations to be tied into the detailed surveys to be undertaken by the Civil Consultant. Photographs of the dyke were taken at each section.

Cross-sections and drill hole information are presented on Dwgs D-1346-2 to -7 inclusive. Selected photographs are presented in Appendix A.

4. Piezometers - Two locations were selected for installation of piezometers to obtain information on the relationship between tidal levels and groundwater levels. A detailed account of the piezometer installation and water level measurements is given in Appendix B.

B. Laboratory Investigations

All piston samples taken in the field were brought to the laboratory where classification and water content tests were carried out.

Sieve analyses were performed on samples taken from the dredged sand stockpiles, and from the two auger holes drilled in the Sturgeon Bank area.

Water contents are presented alongside the drill hole logs on Dwgs D-1346-2 to -7 inclusive. Results of the sieve analyses made are presented in Appendix E.

IV DISCUSSION

A. General Soil Information

The outline of the general soil profile presented in Section II is based on experience obtained by this company and its staff on numerous other projects in the Richmond area, including detailed results from a number of deep drill holes on file in this office. That experience together with shared information received from other investigators has contributed to the general picture of the soil formations in the area. However, it should be realized that the actual formations are more complex than might be assumed from the generalized discussion in Section II, and in areas where deep soil conditions are of concern to the dykes or adjacent structures some deep explorations at the specific problem areas will be essential.

Similarly, although the recent investigations described herein might indicate certain trends and relative uniformity of soil conditions from point to point, it is essential that vigilance be maintained throughout the design and construction periods for indications of inconsistancies and unusual conditions in localized areas. It is essential that all new information obtained by the Civil Consultant during the design period be made available to this company, and that periodic inspections be made by members of this firm during the construction period.

B. Design Sections

In the Richmond area the daily relief afforded by the tides will result in a lower phreatic line within the dykes than in areas further upstream where design water levels can be sustained for many days. This relatively favourable condition has been taken into consideration in the setting of the embankment slopes recommended in Section II, and the reader is cautioned that the criteria set out herein for the Richmond dykes cannot necessarily be used for dykes further upriver. This caution applies in particular to Cases 2 - R.S., 3 - R.S., 1 - L.S. and 2 - L.S., in each of which the lowered phreatic line has permitted use of steeper slopes than would be possible where the dyke is exposed to longer periods of steady seepage.

For purposes of additional stability analyses to be conducted by the Civil Consultant, it is recommended that a minimum factor of safety equal to 1.5 be used for all cases except rapid drawdown on riverside slopes where a value of 1.1 will be acceptable. The lower value for the rapid drawdown condition takes account of the relatively conservative drainage assumptions normal to such calculations.

In any portion of the project area where a relocation of the dykes is planned, long term settlements must be anticipated due to consolidation of both the surface materials and the deeper clays. Where the relocation is of considerable length, one or more deep drill holes will be in order to investigate the various soil strata, including the underlying clay. For short sections, it may be assumed that the long range settlement will be equal to about 10 percent of the depth of new material added. Provision should be made at the time of construction for the short term settlements and an increase in crest width equal to the sum of the slope cotangents times the anticipated long term settlement will permit future raises by addition of material to the crests only.

C. Underseepage

The subject of the underseepage, boils and piping has been studied extensively by the U.S. Army Corps of Engineers in connection with the Mississippi levees. That organization has gone to considerable expense and pains to understand the problem and to control it.

The initial mode of failure associated with foundation piping is the development of cracks and crevasses in the embankment as the base and upper foundation materials gradually collapse into the void below. With the formation of crevasses in the embankment from this cause, complete failure can follow quite rapidly due to erosion by direct flow through the crevasses, or by overtopping. It should be noted that the formation of crevasses in the embankment can actually commence long before a pipe has been formed all the way through the foundations to the point of entry, particularly if a natural impervious blanket exists for some distance riverward of the dyke.

It is understood that the two areas described in Appendix B, where boils were observed during this investigation, have been active for a number of years but that nothing is done about the matter. In both areas there was only a limited amount of discharged material noted in the vicinity; however, it is probable that the discharged material is removed from time to time by flow in the ditches.

Although boils and piping have not been the cause of a dyke failure in the Richmond area, it will nevertheless be prudent to take steps to prevent such a catastrophe in future.

It is generally acknowledged that local treatment of a spring or boil is not the solution to the problem, although good temporary control can be obtained by applying hydraulic back pressure from a pond created by a secondary dyke or encirclement as shown on Dwg D-1346-10. Attempts to apply gravel or filter materials directly to the boil are generally ineffective.

The Corps of Engineers use a variety of solutions to the problem involving generally one or more of the following:

1. Impervious blanketting on the riverward side to increase the length of seepage path. This can involve a complete blanket or simply repairing of scars cut by drainage channels and old borrow pits.

2. Application of a weighting zone on the landward side to increase the load on the semipervious surface layer and to reduce the effective head.

3. Drainage wells along the landside toe.

4. Drainage trenches along the landside toe.

Where blankets are used, on either side, these must be quite extensive, 100 ft or more in width.

Drainage wells are quite effective but are also costly and involve constant maintenance. To be reasonably effective the wells must extend to at least half the depth of the pervious layer and are normally installed at 50 to 100 ft centres. The wells are usually drilled at least 12 inches in diameter with a six inch or larger central pipe, suitably perforated, and packed in a graded filter material throughout the entire permeable range of the soils. Provision is required for surging and back flushing.

Drainage trenches to be effective must generally be quite wide, widths in the order of 15 to 25 ft being anticipated for the Richmond situation. The trenches must extend down to the sand level and be filled with suitably graded filter material.

It may thus be seen that measures to control seepage are costly and should not be applied indiscriminately. An extensive program of investigations can be justified to ensure against unnecessary expenditure on such control measures.

It is therefore recommended that the following two stage program be undertaken. authorized by Committee at 17th Meeting

1. Investigation of the depth of silt layer landward of the dyke by means of a series of hand auger holes at 500 to 1000 ft centres on each of two lines, staggered, one line at the dyke toe and one line 100 ft inland. These holes would be infilled with impervious material to ensure against piping, where appropriate.

2. In areas where the first stage investigation indicates that the silt layer is non-existant or shallower than the design head from the water surface down to ground level, deeper drilling will be required to explore the depth and permeability of the sand layer. together with a series of piezometric measurements similar to that described in Appendix B. This will of course include areas where it is found expedient to retain the existing drainage ditches at the toe of the dykes. It is probable that only about 10 such sections would need to be studied in this second stage of the work.

With the information from the foregoing two stage program, supplemented by details of intended land use in the area, survey information, surficial soil information in the area (both sides of the dykes), detailed cost studies can be undertaken on the various solutions possible, and firm recommendations provided.

A by-product of such an investigation program will be information to assist owners of property and buildings adjacent to the dykes in overcoming problems occasioned by variations in ground levels due to the fluctuating tidal pressures in the foundation soils, and weakening of the soils by the upward flowing seepage. This will be particularly valuable for roads to be placed along the toes of the dykes.

Authorized by Committee at 17th Meeting

D. Investigation Program for Peat and Organic Silt Areas

Although the removal of peat and organic silts from the dyke sections and their foundations is desirable, there are practical limitations in the Richmond area to that approach and it will probably be necessary to develop dyke sections that can be safely founded on these weak materials. The slopes for such sections will have to be quite flat as a safeguard against shear failures in the underlying soils due to the weight of fill above. In addition very large settlements will result, in the order of 50 percent or greater of the original depth of peat for fills with any appreciable height above the original grade. The settlements will continue over a long period of time and additional crest width should be provided to permit periodic addition of material to maintain freeboard.

The parameters for use in design of dyke sections to be constructed on the compressible organic materials are depth, compressibility and shear strength. Detailed field investigations will be required to determine these values and the range of variations of the values over the area. The investigations would take the following general form:

1. A series of piston sampler holes along the dyke close to the landside toe to delineate the peat areas, and to determine depths in that relatively critical area. These holes would be at about 200 ft centres.

2. Detailed investigation on profile across the dyke at locations selected from a study of the initial drilling, probably about every 1000 ft. This program would entail three or four holes including at least one through the existing dyke to determine variations of

depth, water content and shear strength under the existing dyke and in areas to be covered by new fill. Depth and water content would be provided by the piston samples. Shear strength would be determined by field vane shear tests.

3. Office stability calculations to determine fill placing procedures and safe embankment slopes.

RIPLEY, KLOHN & LEONOFF INTERNATIONAL LTD.

WG Harper

T. G. HARPER

CH Maartman

C.H. MAARTMAN, P.Eng.

Mark T. Olsen

M.T. OLSEN, P.Eng.

TGH/CHM/sm
Copies: 9 - Mr. R.J. Talbot
1 - Mr. E.J. Klohn(RKL)

APPENDIX A

SELECTED PHOTOGRAPHS

APPENDIX A

LULU ISLAND WEST
AT SECTION 1002

DYKE AND
STURGEON BANK
WEST END OF
FRANCIS ROAD
LOOKING NORTH

DITCH AND
LANDSIDE OF DYKE
LOOKING NORTH

SEA ISLAND - NORTH ARM
DYKE OPPOSITE RICHMOND ISLAND

LULU ISLAND - MIDDLE ARM
RIVER ROAD AT SECTION 1001

LULU ISLAND - SOUTH ARM
BOILS IN DITCH AT SECTION 1018
PENCIL 6" LONG. FOR SCALE

APPENDIX B

SEEPAGE MEASUREMENTS

Our File VA1346

October 17, 1969

SEEPAGE MEASUREMENTS

Piezometers were installed at two locations to measure ground water levels in relation to tide water levels. Both locations have similar subsoil profiles consisting of a thin silt layer overlying deep sands, a typical situation in west Lulu Island.

Dwgs D-1346-8 and -9 show the details of piezometer positions and levels. The piezometers used were of 1 inch diameter steel pipe perforated for 3 ft at the bottom end. The pipes were washed into place.

Regular measurements of piezometer water levels were made on September 22, 24, and 26, 1969 using an electrical depth measuring apparatus. All measurements of piezometer, ditch and river water levels have been plotted relative to ground level at piezometer Number 1.

A. Section 1002

On September 22nd, the sea at Section 1002 was several hundred feet from the dyke and no variation in piezometer levels was evident except for a slight drop following a drop in ditch water level. For this reason, measurements at this set of piezometers were discontinued after one day. Piezometer 3 responded quickly to changing ditch water level, but Piezometer 2 showed less response to the change. Piezometer 1 showed no appreciable response to change in ditch water level.

B. Section 1009

Piezometers 2 and 3 at Section 1009 showed very active response to changes in river level but Piezometer 1 showed a response that was much less than that in the other two piezometers. Reaction in the piezometers to changes in river level was almost instantaneous indicating that transfer of seepage pressure through the underlying sand takes place quite rapidly. No change in ditch water level was observed.

Water levels in Piezometers 2 and 3 were practically equal indicating that there is little reduction in head with distance back from the dyke. This suggests that horizontal seepage in the sand layer carries some distance back on the landside of the dyke.

C. Seepage Evidence

Two areas where underseepage was evident were located during a visual inspection of the dykes.

The most active area was on Lulu Island near Drill Hole 1018 where numerous small boils were visible along the ditch invert on the landside of the dyke. Size of these boils ranged from a few inches to 2 ft in diameter. Two photos in Appendix A show some of the boils in the area. At the time, the boils were noted, water levels in both the ditch and the river were low, but seepage was noted escaping from most of the boils.

The second area of seepage noted was on Lulu Island north, between No. 6 and Savage roads. Small boils were found in the heavily overgrown ditch on the landside of the road. A gravel stockpile lies between the road and the river. Evidence of slight house movements related to tidal cycles was reported by the owner of a house on the landside of the ditch at this location. This would indicate that uplift blanket on the landside of the ditch is occurring at high river levels.

APPENDIX C

LIST OF PERTINENT REFERENCE MATERIAL

APPENDIX C

LIST OF PERTINENT REFERENCE MATERIAL

MATERIAL RECIEVED FROM FRASER RIVER BOARD

1.	Plan No. 873	Department of Energy, Mines & Resources Inland Water Branch, Vancouver River and Dyke Profiles - Lower Fraser Valley Lulu Island North
2.	Plan No. 873	Department of Energy Mines & Resources Inland Waters Branch, Vancouver River and Dyke Profiles - Lower Fraser Valley Lulu Island South
3.	Dwg 4346-AA-A File No. 0174613	Department of Lands, Forests & Water Resources Water Rights Branch Lower Fraser Dykes, Richmond Lulu Island North Dyke Drill Hole
4.	Dwg 4346-BB-A	Department of Lands, Forests & Water Resources Water Rights Branch Lower Fraser Dykes, Richmond Lulu Island South Dyke Drill Holes
5.	Plan No. 1599	Department of Northern Affairs and Natural Resources Water Resources Branch, Vancouver Lower Fraser Valley Dyke Studies Drill Hole Locations
6.	Drill Hole 1) Drill Hole 2) Drill Hole 3)	Department of Highways, Drill Hole Logs
7.		Department of Lands, Forests & Water Resources Water Rights Branch "Water Resources Investigations, Lower Fraser Dykes Richmond, Lulu Island"
	Dwg 4346-L	a) Index Map
	Dwg 4346-BB	b) Profile & Sections Sheets 1 to 12 Lulu Island South
	Dwg 4346-AA	c) Profile & Sections Sheets 1 to 6 Lulu Island North
8.	Dwg VI-G-321	Canada Department of Transportation - Vancouver Airport Master Plan for Proposed Dyke Road around Sea Island
9.	Dwg VI-G-624	Canada Department of Transportation - Vancouver Airport Cross Sections of Proposed Dyke Road
10.	Dwg VI-G-624	Canada Department of Transportation Air Services Construction Branch - Vancouver Airport
11.	Report	"Stability of the Lower Fraser Valley Dykes" - by W.C. Jones Department of Mines & Petroleum Resources, Victoria June 18, 1963

12. Report — "Shear Strength Tests for Materials from Pit No. 1 Pit Polder, Lulu Island" to Fraser River Board, Victoria from Soil Mechanics Services Ltd., Vancouver March 12/63

13. Report — "Test Program No. 2, Shear Strength Tests for Materials from Matzic, Matsqui, Delta, Harrison Mills to Fraser River Board, Victoria from Soil Mechanics Services Ltd., April 30, 1963

14. Report — "Canada Department of Northern Affairs & National Resources Water Resources Branch, Lower Fraser Valley Dyke Studies Construction Materials Survey" by E.M. Clark, Vancouver August 1963

15. Report — Stereo Air Photographs of the Richmond Area

16. Plan No. 903 — Department of Energy, Mines & Resources Engineering Division - Pacific Region "Richmond Dykes - Cross Sections at Various Locations"

OTHER REFERENCES

17. Report — "Delta Dyke Investigations" by Ripley, Klohn & Leonoff International Ltd for Associated Engineering Services Ltd March 22, 1967

18. Report — "Final Report of the Fraser River Board on Flood Control and Hydro-Electric Power in the Fraser River Basin" September 1963, Two Volumes, Report and Appendices

19. Paper — "Investigation of Underseepage - Mississippi Levees" by W.J. Turnbull and C.I. Mansur, ASCE Transactions, Vol 126, 1961 pp 1429

20. Report — "Rehabilitation of Mitchell and Twigg Island Dykes" by C.B.A. Engineering Ltd., December 1967

APPENDIX D

CORRESPONDENCE

A G R E E M E N T

BETWEEN - The Province of British Columbia represented by the Minister of Lands, Forests and Water Resources.

AND - Ripley, Klohn & Leonoff International Ltd., 1930 West Broadway, Vancouver, British Columbia.

RE - Provision of Consultant Service.

Service - General soils consultant service for the Fraser River Joint Program Committee formed under the Agreement covering a plan for flood control in the Fraser Valley, British Columbia, dated 24 May 1968, between Canada and the Province of British Columbia.

Area - For dykes on Lulu Island and Sea Island in the Corporation of the Township of Richmond.

Scope - The consultant shall provide the following services:

a. Carry out the investigations outlined in Ripley, Klohn & Leonoff International Ltd's Phase I report, dated July 2, 1969.
b. Use the results of these investigations to establish general design criteria and typical design sections for the dykes.
c. Confirm that an adequate supply of suitable dyke construction material is available.
d. Report to the Fraser River Joint Program Committee by 30 September 1969 on the results of this work.

Personnel - Work shall be done by Mr. M.T. Olsen under the general direction of Mr. E.J. Klohn.

Fees - Services shall be in accordance with the attached schedule of fees. Services will be paid for by the Province of British Columbia on submission of an invoice.

Duration - This Agreement shall terminate when the Fraser River Joint Program Committee receives the general soils consultant's report contracted for under the terms of this Agreement, or upon written notice to the consultant.

Earle J Klohn

E. J. Klohn,
Ripley, Klohn & Leonoff International Ltd.,

1930 West Broadway,
Vancouver, B. C.

Date: ____________________

V. Raudsepp,
Deputy Minister of Water Resources,
Department of Lands, Forests and Water Resources,
Victoria, B. B.

Date: July 23 1969

CANADA — BRITISH COLUMBIA

#2 - 628 Carnarvon St.,
New Westminster,
B. C.

CANADA
E. M. CLARK
H. B. ROSENBERG
L. EDGEWORTH

BRITISH COLUMBIA
B. E. MARR
W. R. MEIGHEN
J. D. WATTS

19 August 1969

Ripley, Klohn & Leonoff International Ltd.,
1930 West Broadway,
Vancouver 9, B.C.

Attention: Mr. Mark Olsen

Dear Sir:

In Item V on page 5 of your Phase I Soil Review of the dykes of Richmond, you raised several questions in which you wished further clarification. On behalf of the Committee I shall try to answer these for you.

1. Large drainage ditches at the toes of many dykes.

To date I have not been able to determine if any of these ditches can in fact be removed or filled without interfering with the proper drainage of the Municipality. This problem could be resolved by the Civil Design Engineer. You might suggest two alternatives here:

a. Where the ditch must be retained,
b. Where the ditch can be filled.

2. Industrial and residential development near and on dykes.

In your report a general design criteria would be proposed. This could include normal typical sections and typical sections for use in confined spaces. The design engineer will prepare the design for dykes where special conditions exist, such as where they pass through industrial structures. The Municipality will obtain any rights of way required by the final design.

3. Use of dykes as roadways.

Where dykes are now used as roadways, the design will allow the roadway to remain on or adjacent to the dyke.

.....2

A minimum crest width of 12 feet will be used. Under special conditions will the Committee consider increasing the crest width.

The Committee agreed that existing works such as roads and ditches which are destroyed by the reconstruction of works under the 1968 Federal-Provincial Agreement, would be replaced. Special structures will be considered on their merits in each case.

4. Crest elevation of existing dykes.

As you will recall, I left with you two copies of the plot of a very recent survey of four locations on the dykes. If more limited information of this sort would be useful, please show me where and I will have it obtained.

It is wondered if you might wish to drill some holes to more than 20 feet of depth. The Committee agreed that holes could be drilled to depths greater than 20 feet in the Phase II Soils Review work for Richmond at the discretion of the Work Group.

I trust that the information herein will allow you to complete your Phase II report.

Yours truly,

R. J. Talbot, P.Eng.
Program Director.

RJT/fg

LAFARGE CANADA LTD. LAFARGE CONCRETE LTD.

1051 MAIN STREET, VANCOUVER 4, B.C. • TELEPHONE 685-9155 • TELEX NO. 04-5928 • CABLE: LAFARGE

WESTERN REGION

September 29 1969

Ripley, Klohn & Leonoff International Ltd.
1930 West Broadway
Vancouver, B.C.

Dear Sirs:

RE: 30,000 YDS - 6" MINUS DYCKING FOR RICHMOND DYCKS

As per your telephone call, we are submitting a sample of dycking from our quarry on Texada Island.

Screen analysis figures are as follows:-

oen Size:	9"	6"	3"	1½"	3/4"	3/8"	#4	#8	#16	#30	Pan
etained	0.0	8.5	37.5	24.5	10.1	4.8	3.3	1.8	1.9	2.6	5.0
assing	100.0	91.5	54.0	29.5	19.4	14.6	11.3	9.5	7.6	4.0	0.0

The approximate apparent density is 108 lbs. per cubic foot.

We thank you for your enquiry, and please do not hesitate to call if further information is required.

Yours very truly,

LAFARGE CONCRETE LTD.

C. Bower
Sales Manager
Ready-Mix and Sand & Gravel

CB/d

MAIN OFFICE:
1990 KENT STREET
VANCOUVER 15, B. C.
325-8231
TELEX 04-5199

RIVTOW MARINE LTD.

FORT LANGLEY AGGREGATES DIVISION
P. O. BOX 266
FORT LANGLEY, B. C.

September 30, 1969.

Ripley, Klohn, & Leonoff,
1930 West Broadway,
Vancouver, B. C.

Dear Sir:

Enclosed you will find aggregate sieve analysis of three test holes, that should give you an indication of what our material is like.

An approximate price to Lulu Island aboard 2000 ton scows, at the rate of 2,000 tons per day would be $1.00 to $1.15 per ton, depending on the tow boat rates at the time of delivery.

Thank you for calling us and I hope we can be of service to you in the future.

Yours truly,

Wayne H. Sager.

WHS/bms
Encl.

RIVTOW

LOG BARGING
LOG TOWING
SCOW TOWING
COASTAL AND INLAND WATERS

HOPE HARRISON PRINCE RUPERT TERRACE KITIMAT

VANCOUVER YARD 253-7037
NORTH SHORE YARD 929-3510
DUCK ISLAND YARD 278-6020

ROUTLEDGE GRAVEL LTD.

P.O. DRAWER 100
NEW WESTMINSTER, B.C.
TELEPHONE: 524-3651

October 2, 1969

Ripley Klohn & Leonoff International Ltd.,
1930 West Broadway,
Vancouver, B. C.

Attention: Mr. Harper

Dear Sir:

In reply to your inquiry with respect to availability of pit run and/or road minus materials in the Richmond area, we wish to confirm that processed minus materials are available in quantities suggested, and stockpiled in our Duck Island location at the north end of No. Three Road, Richmond. Although present stockpiled materials have been processed and supplied from our Britannia Beach plant, in the immediate future, supplies will come from our Furry Creek operations. We do not anticipate significant changes in gradation, as the pits are similar and in the same area.

I understand your inquiry to be a feasibility study and therefore, with regard to prices of materials and delivery of same, can only offer our present prices as a guide. Processed minus materials f.o.b. our yards list at $1.25 per ton, and present delivery rates of about .55¢ per ton. As many of our union contracts expire at the year end, it will be necessary that prices be revised at that time.

Should you require material samples or any further information, please do not hesitate to call. Find enclosed Seive analysis of road base materials.

Thank you.

Yours very truly,

ROUTLEDGE GRAVEL LTD.

[illegible] B. Reilly

[illegible]:RW
encl.

APPENDIX E

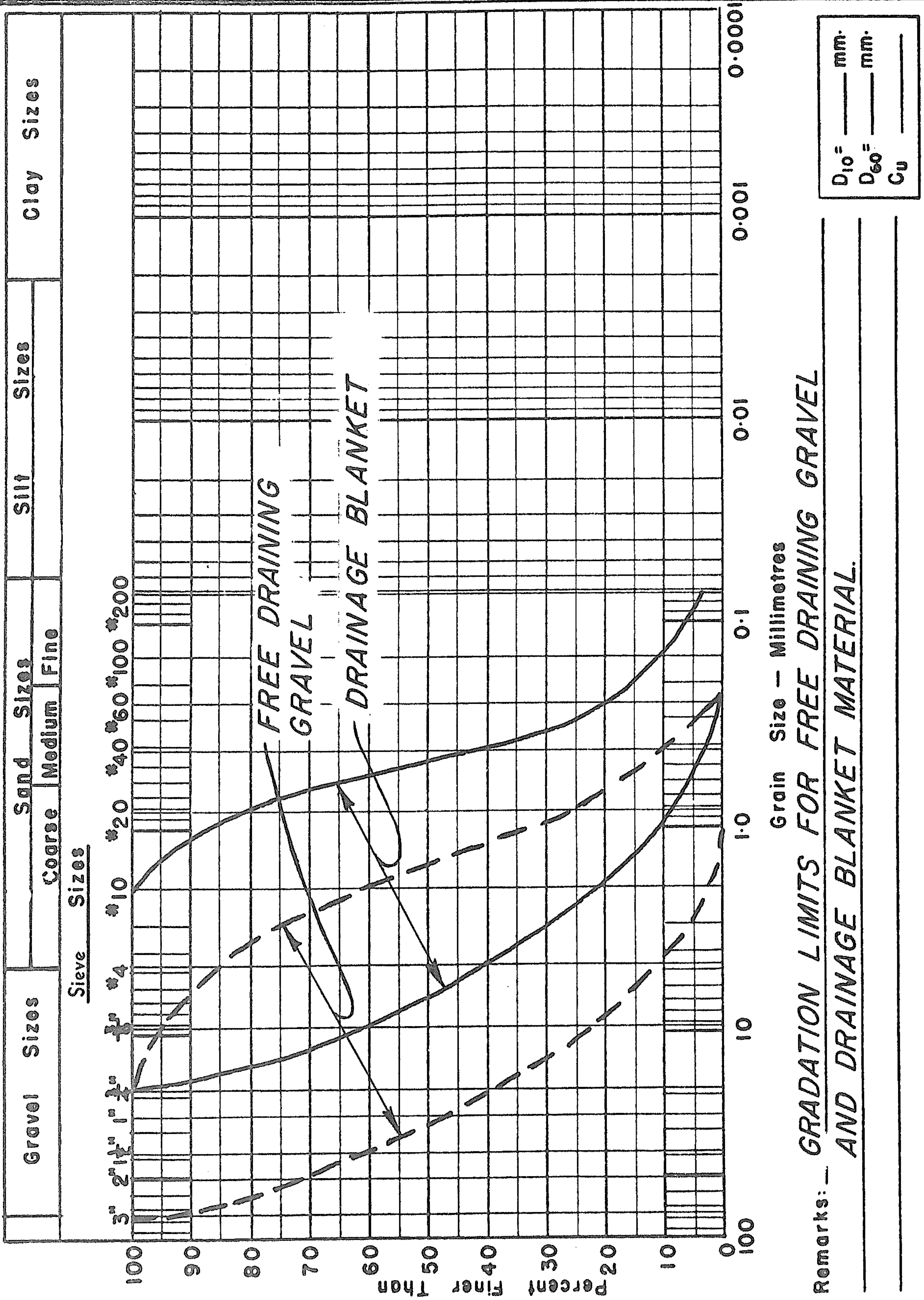
GRAIN SIZE CURVES

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

PROJECT VA 1346 - RICHMOND DYKES	
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE OCT 17,/69.



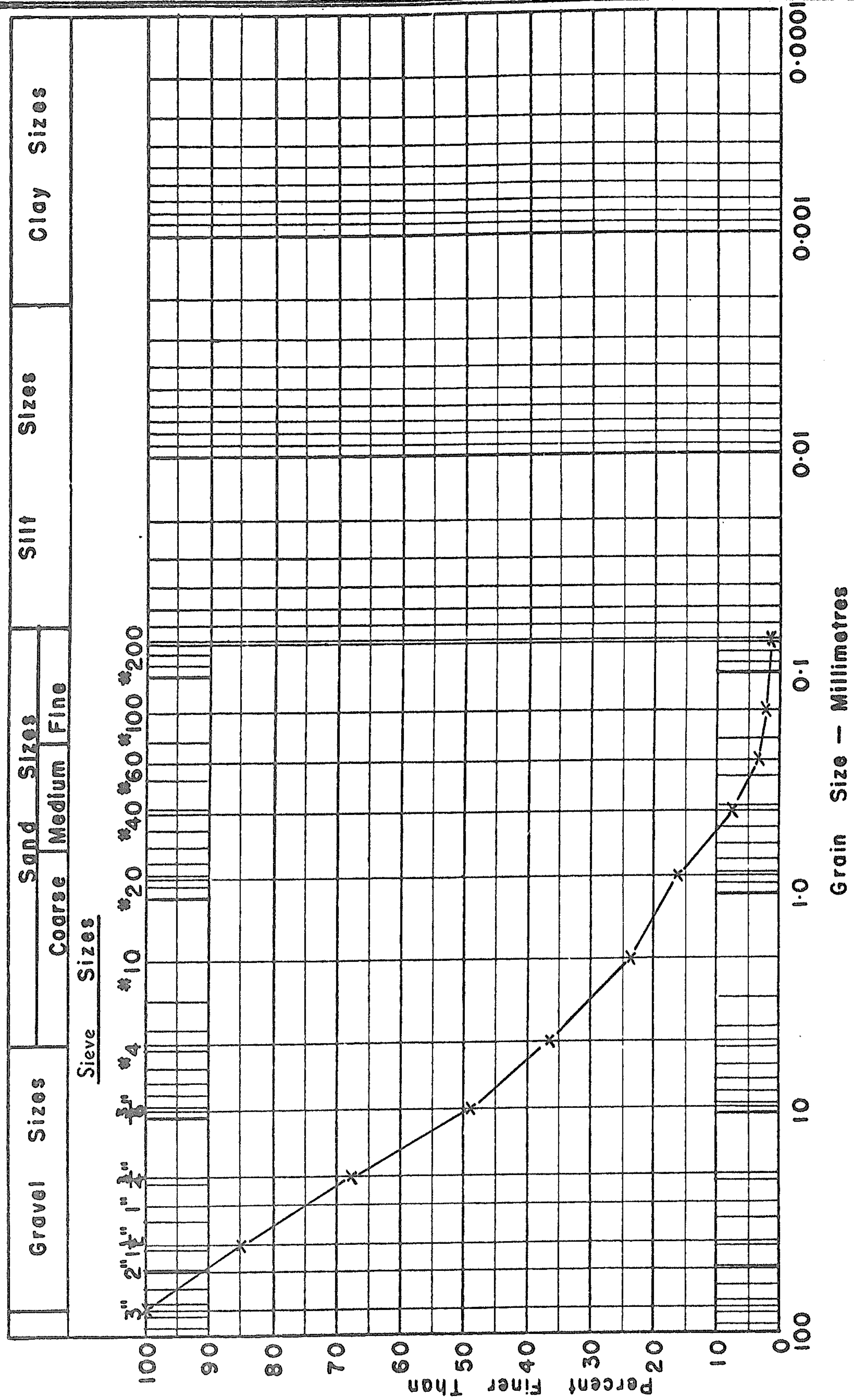
Remarks: GRADATION LIMITS FOR FREE DRAINING GRAVEL AND DRAINAGE BLANKET MATERIAL.

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT VA 1346- RICHMOND DYKES	
SAMPLE BULK	
LOCATION DUCK ISLAND STOCKPILE	
HOLE —	DEPTH —
TECHNICIAN B.C.	DATE OCT 3, 1969



Remarks: SAMPLES TAKEN FROM ROUTLEDGE GRAVEL LTD. PIT-RUN STOCK PILE ON DUCK ISLAND.

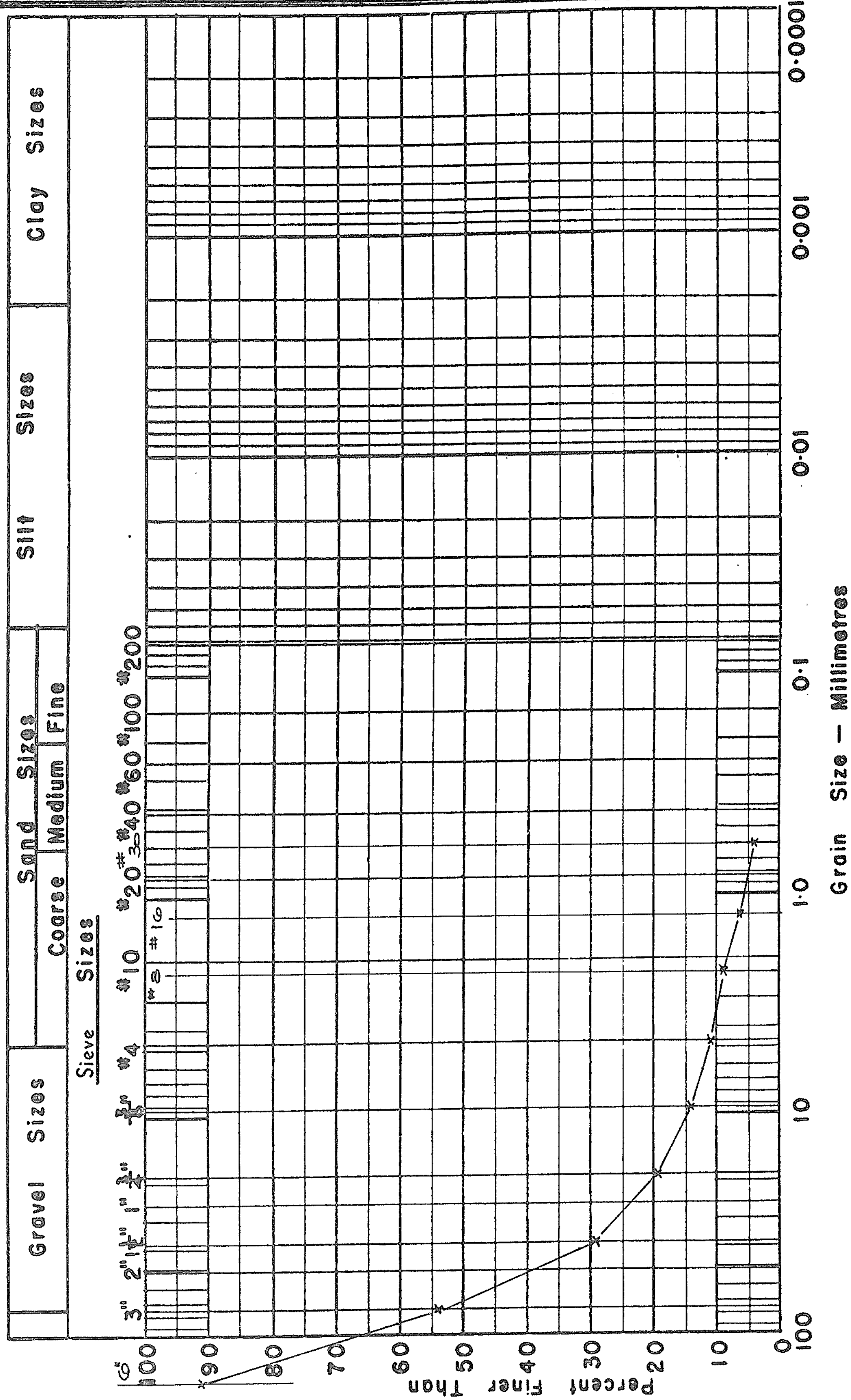
SAMPLE WASHED ON #200 SIEVE.

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT	VA 1346 - RICHMOND DYKES
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE



Remarks: 6" MINUS MATERIAL FROM LAFARGE CANADA LTD. QUARRY ON TEXADA ISLAND.

SCREEN ANALYSIS FIGURES SUPPLIED BY LAFARGE.

terials Testing Laboratories Ltd.

CALGARY EDMONTON REGINA LETHBRIDGE RED DEER VANCOUVER

ıGGREGATE ANALYSIS REPORT

W. S. Underwood,
4552 - 192 St.,
R.R. #3,
CLOVERDALE, B.C.

Lab. Order No. U2-1
Type of Sample Pit Run
Project -
Source Hole #1
Sampled by Client
Date Sampled -
Date Received 19-1-67
Date Tested 23-1-67
Date Reported 25-1-67
Laboratory Vancouver

Copies to:

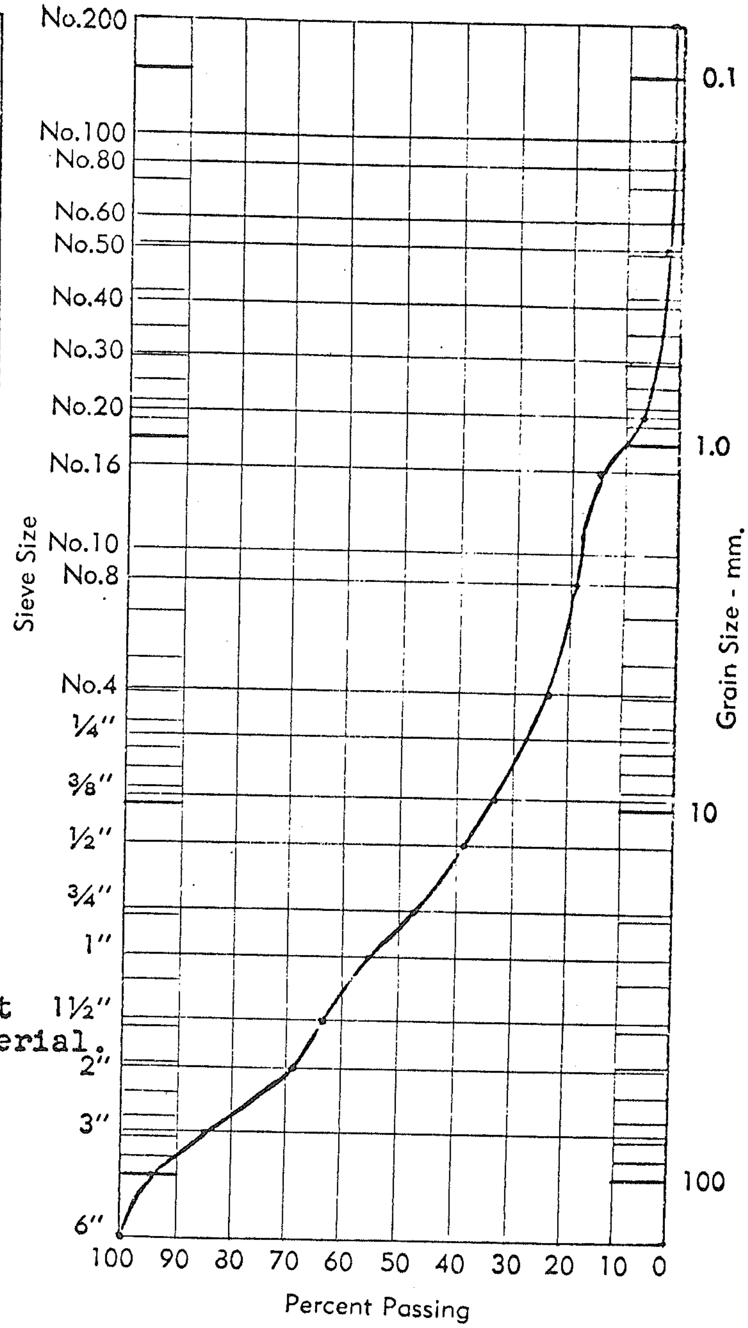
LO 51

Sieve Size	Weight Retained	Weight Passing	Percent Passing	Percent Passing Total Sample
6"	-	23690		100
4"	1610	22080		94.0
3"	2060	20020		85.2
2"	3950	16070		68.4
1½"	1260	14810		63.0
1"	1720	13090		55.7
¾"	1880	11210		47.7
½"	2010	9200		38.8
⅜"	1320	7880		33.3
¼"	-	-		-
No. 4	2390	5490		23.2
Pas'g 4	5490			
Total	23690			
No. 10				
No. 8	84.7	415.3	83.1	19.2
No. 16	113.3	302.0	60.4	14.0
No. 20	156.1	145.9	29.2	6.8
No. 50	102.2	43.7	8.7	2.0
No. 100	16.9	26.8	5.4	1.3
No. 200	4.4	22.4	4.5	1.0
Pas'g 200	22.4			
Total	500.0			

Weights in

Remarks

Some unsound mica-quartz present in 2". Also some organic material.
Shape - mostly rounded.
Hard silt particles in passing #4 material.



MTL C5.66

R.K.L. NOTE:

aterials Testing Laboratories Ltd.

CALGARY — LETHBRIDGE
EDMONTON — RED DEER
REGINA — VANCOUVER

AGGREGATE ANALYSIS REPORT

W.S. Underwood,
4552 192 St.,
R.R. #3,
CLOVERDALE, B.C.

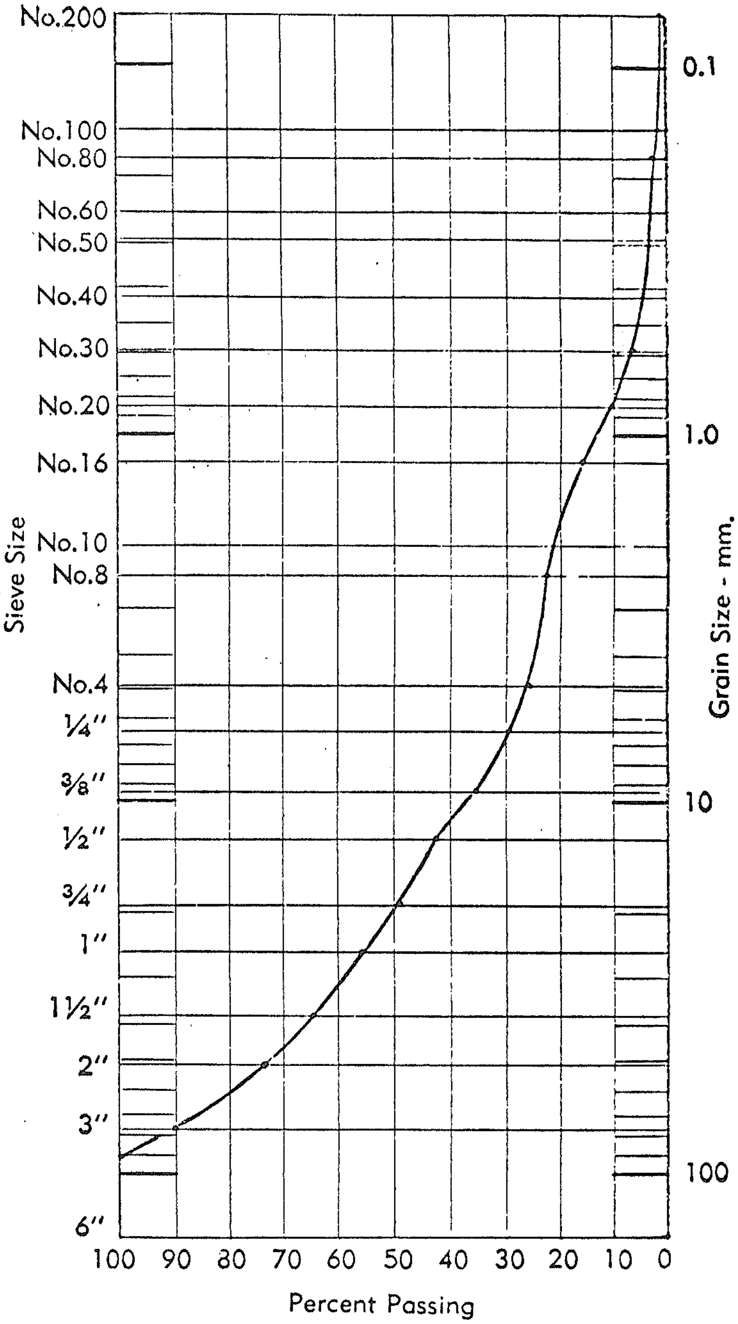
Lab. Order No. U2-2
Type of Sample Pit Run
Project -
Source Hole #2
Sampled by Client
Date Sampled -
Date Received 19-1-67
Date Tested 23-1-67
Date Reported 25-1-67
Laboratory Vancouver

Copies to:

LO 51

Sieve Size	Weight Retained	Weight Passing	Percent Passing	Percent Passing Total Sample
4"	-	13710	100.0	100.0
3"	1370	12340	90.2	90.2
2"	2280	10060	73.4	73.4
1½"	1160	8900	64.9	64.9
1"	1130	7770	56.7	56.7
¾"	1040	6730	49.1	49.1
½"	900	5830	42.5	42.5
⅜"	950	4880	35.6	35.6
¼"	-			
No. 4	1260	3620	26.4	26.4
Pas'g 4	3620			
Total	13710			
No. 10XX4	-	500.0	100.0	
No. 20XX8	70.2	429.8	85.9	22.6
No. 40XX16	114.2	315.6	63.1	16.6
No. 60XX30	189.7	125.9	25.2	6.7
No. 80	90.3	35.6	7.1	1.9
No. 100	12.8	22.8	4.6	1.2
No. 200	3.4	19.4	2.9	0.8
Pas'g 200	19.4	-	-	
Total	500.0			

Weights in



Remarks

Some unsound mica-quartz and organic material.
Shape - mostly rounded.
Hard silt particles in passing #4 material.

R.K.L. NOTE:

MTL C5-66

Data Supplied by Rivtow Marine Ltd.

Materials Testing Laboratories Ltd.

CALGARY · EDMONTON · REGINA · LETHBRIDGE · RED DEER · VANCOUVER

AGGREGATE ANALYSIS REPORT

To: W.S. Underwood,
4552 - 192 St.,
R.R. #3,
CLOVERDALE, B.C.

Lab. Order No. U2-3
Type of Sample Pit Run
Project -
Source Hole #3
Sampled by Client
Date Sampled -
Date Received 19-1-67
Date Tested 23-1-67
Date Reported 25-1-67
Laboratory Vancouver

Copies to:

LO 51

COARSE FRACTION

Sieve Size	Weight Retained	Weight Passing	Percent Passing	Percent Passing Total Sample
4"	-	16600		100
3"	1410	15190		91.5
2"	3740	11450		69.0
1½"	400	11050		66.6
1"	1320	9730		58.6
¾"	1260	8470		51.0
½"	1350	7120		42.9
⅜"	950	6170		38.2
¼"	-			
No. 4	2000	4170		25.1
Pas'g 4	4170			
Total	16600			

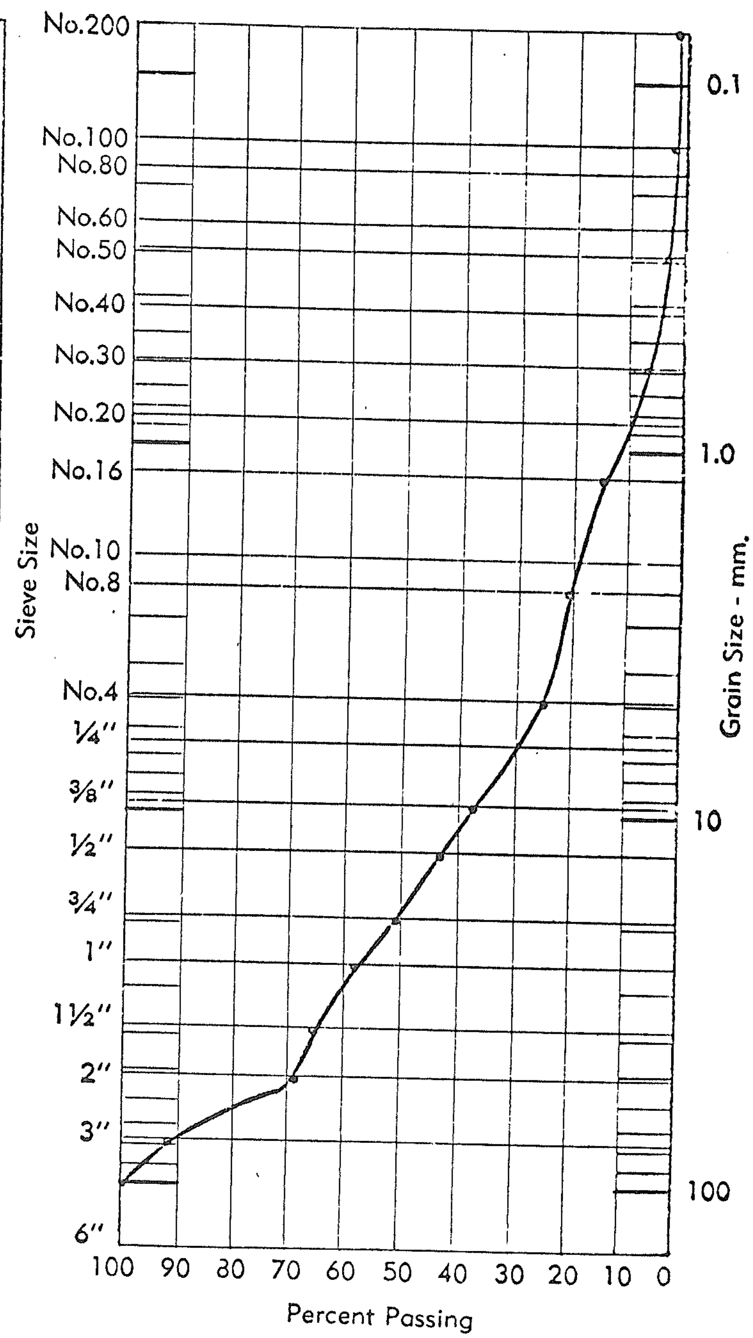
FINE FRACTION

Sieve Size	Weight Retained	Weight Passing	Percent Passing	Percent Passing Total Sample
No. 4	0.3	499.7	99.9	25.1
No. 8	83.5	416.2	83.2	20.9
No. 16	120.2	292.0	58.4	14.7
No. 30	154.7	141.3	28.3	7.1
No. 50	90.5	50.8	10.2	2.6
No. 100	23.5	27.3	5.5	1.4
No. 200	5.0	22.3	4.5	1.1
Pas'g 200	22.3			
Total	500.0			

Weights in

Remarks

Mostly rounded aggregate.
Some organic material present.
Hard silt particles in passing
#4 material.



MTL C5-66

R.K.L. NOTE:

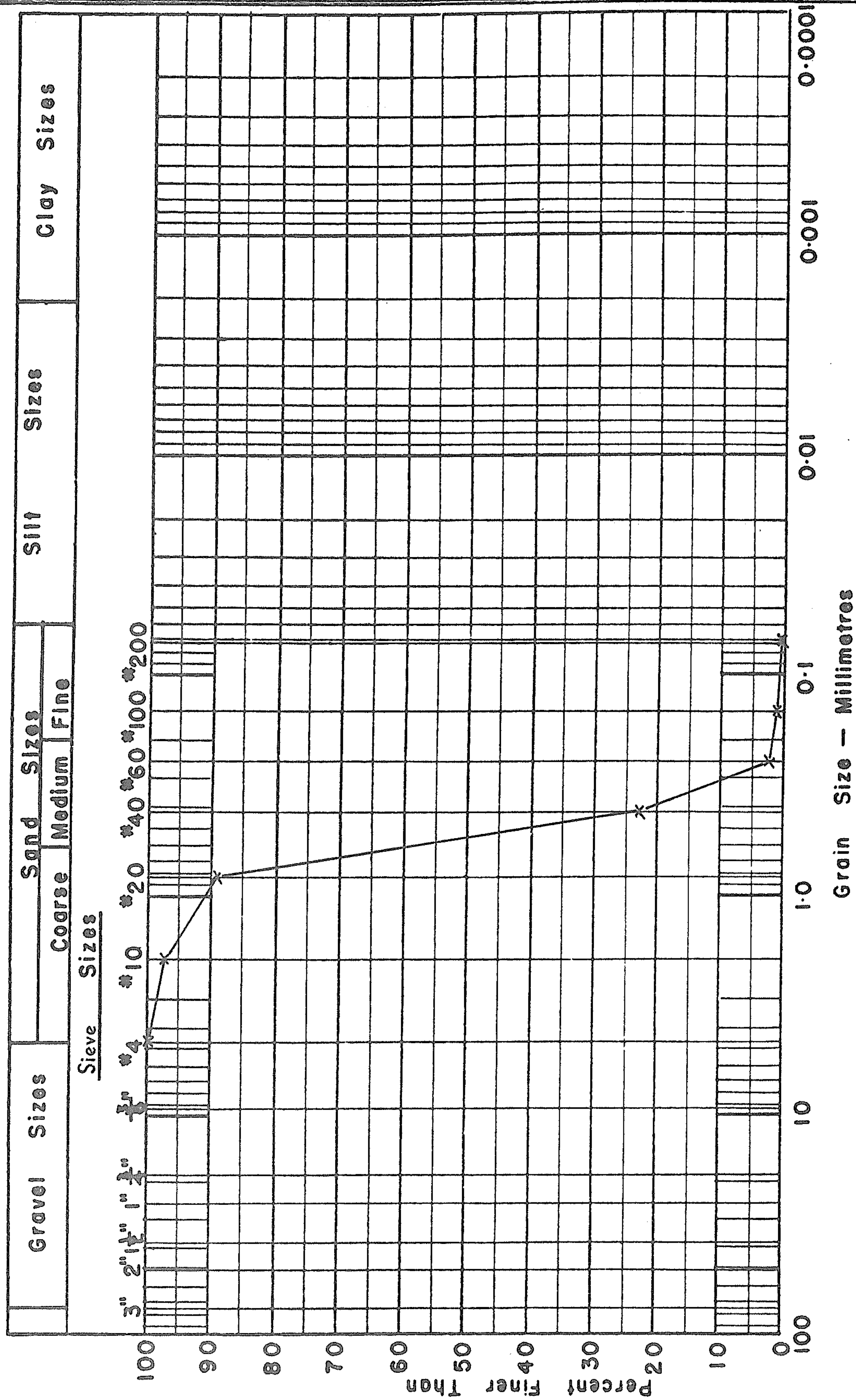
Data Supplied by Rivtow Marine Ltd.

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT	VA1346 - RICHMOND DYKE
SAMPLE	DREDGED SAND STOCKPILE
LOCATION	LULU IS. - KNIGHT ST. BRIDGE
HOLE	DEPTH —
TECHNICIAN B.C.	DATE SEPT 30, 1969



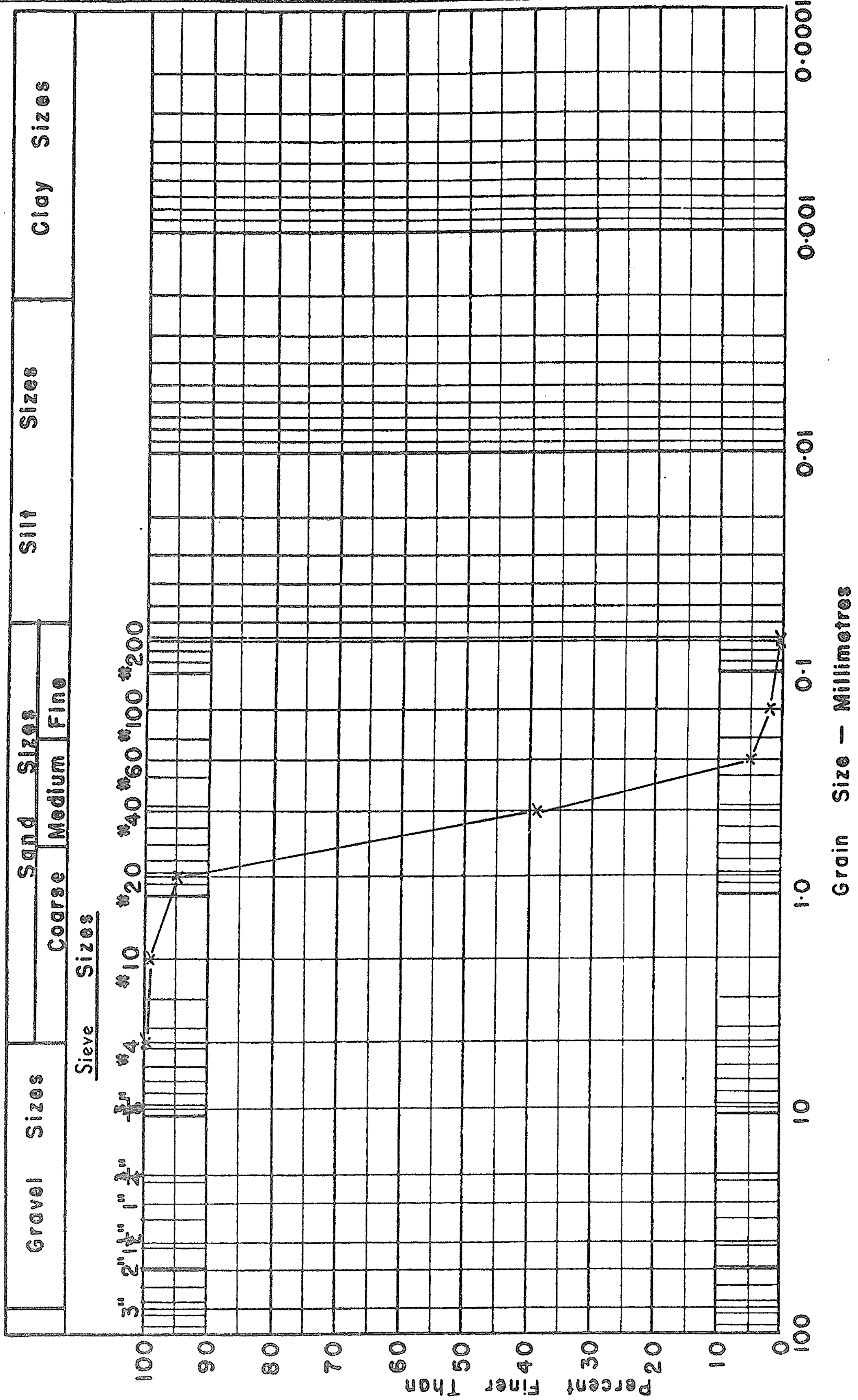
Remarks: SAMPLE SIEVED DRY.

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT	VA 1346- RICHMOND DYKES
SAMPLE	DREDGED SAND STOCKPILE.
LOCATION	SEA ISLAND-McDONALD RD. NORTH
HOLE	DEPTH
TECHNICIAN B.C.	DATE SEPT. 30, 1969



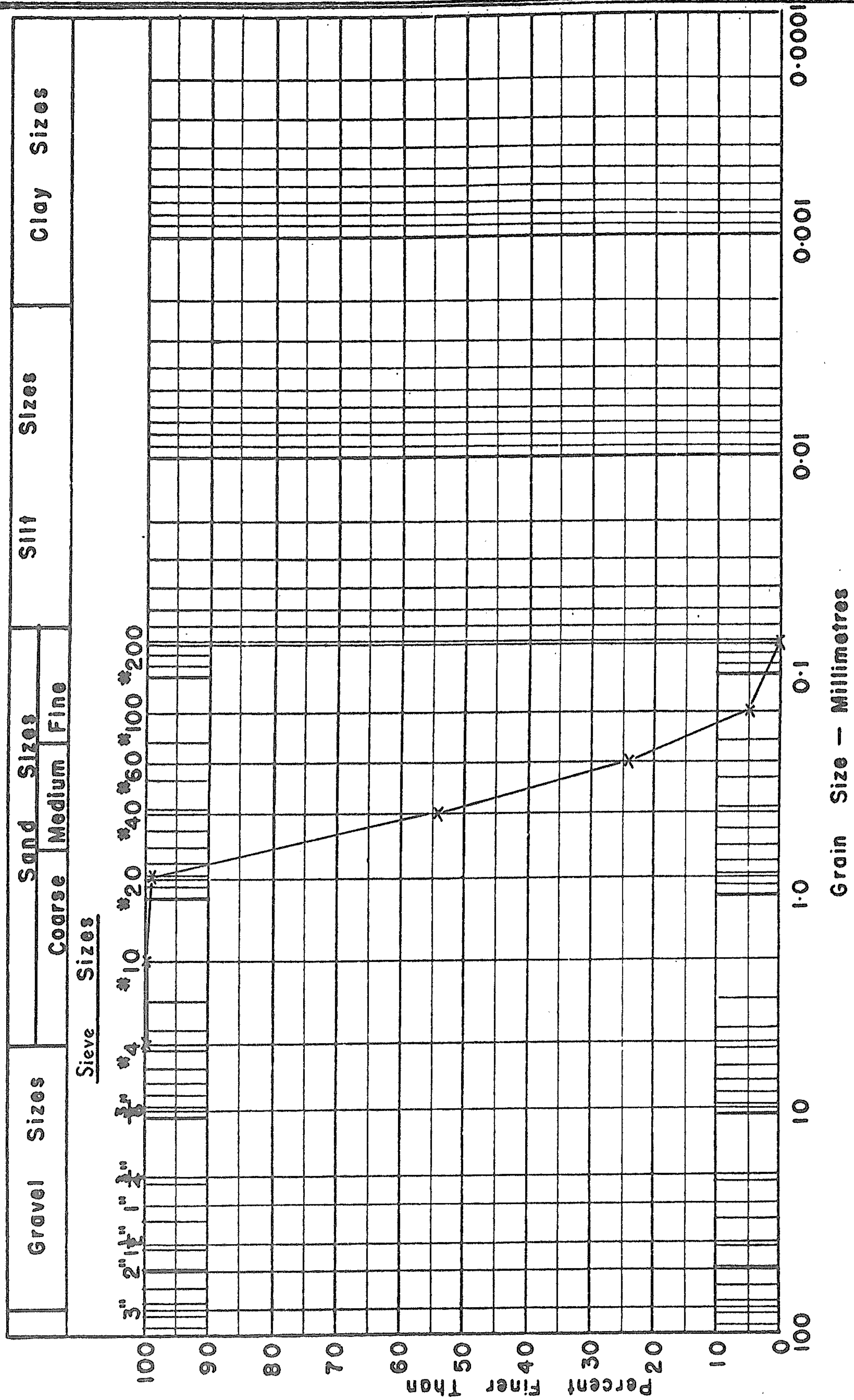
Remarks: SAMPLE SIEVED DRY.

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT	VA1346 - RICHMOND DYKES
SAMPLE	DREDGED SAND STOCKPILE
LOCATION	LULU IS. - CAMBIE RD. WEST
HOLE	DEPTH —
TECHNICIAN B.C.	DATE SEPT. 30, 1969



Remarks: SAMPLE SIEVED DRY.

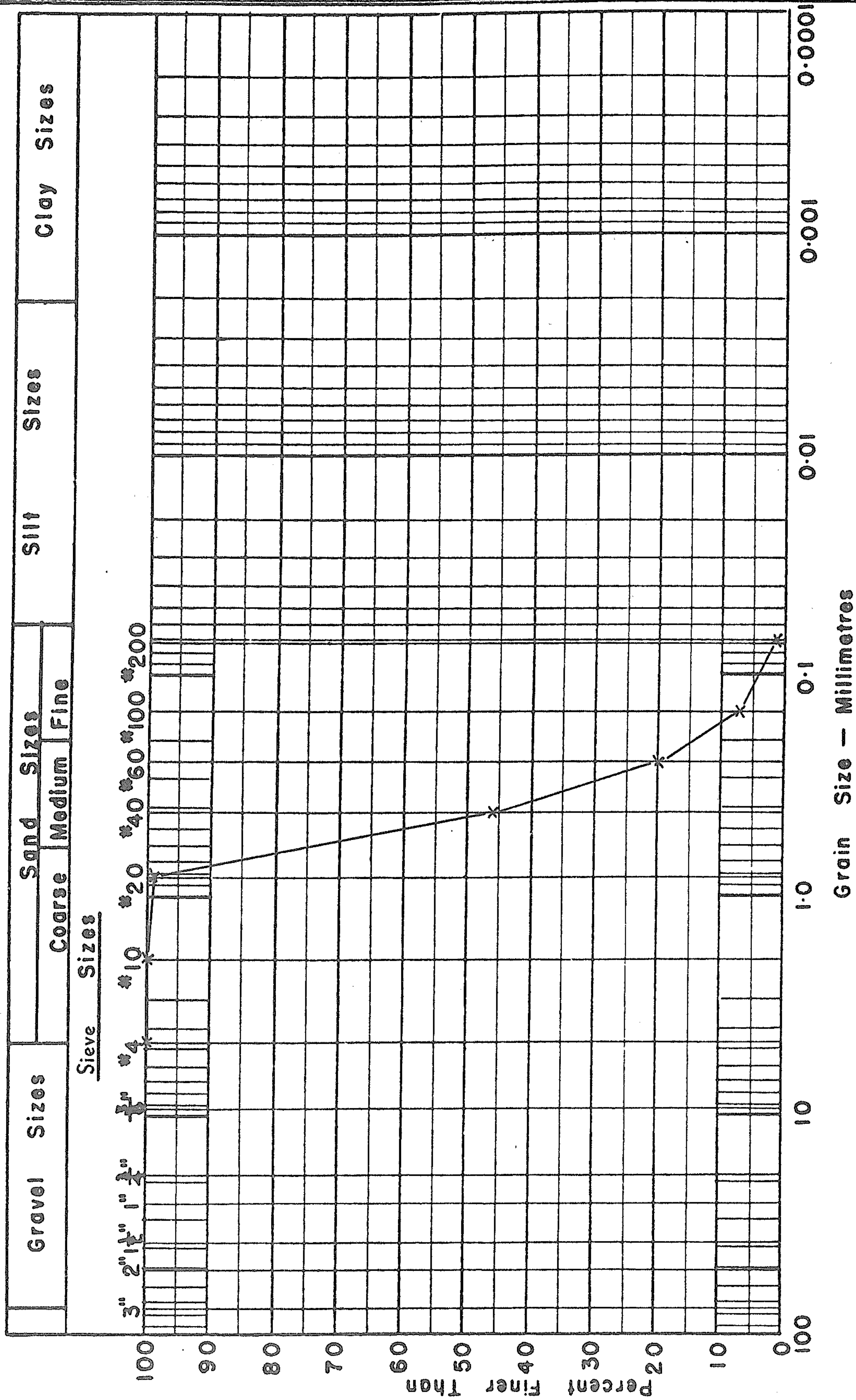
HE4 - MW

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT	VA 1346 - RICHMOND DYKES
SAMPLE	DREDGED SAND STOCKPILE
LOCATION	SEA IS. AT DINSMORE BRIDGE
HOLE	DEPTH —
TECHNICIAN	B.C. DATE SEPT. 30 1969

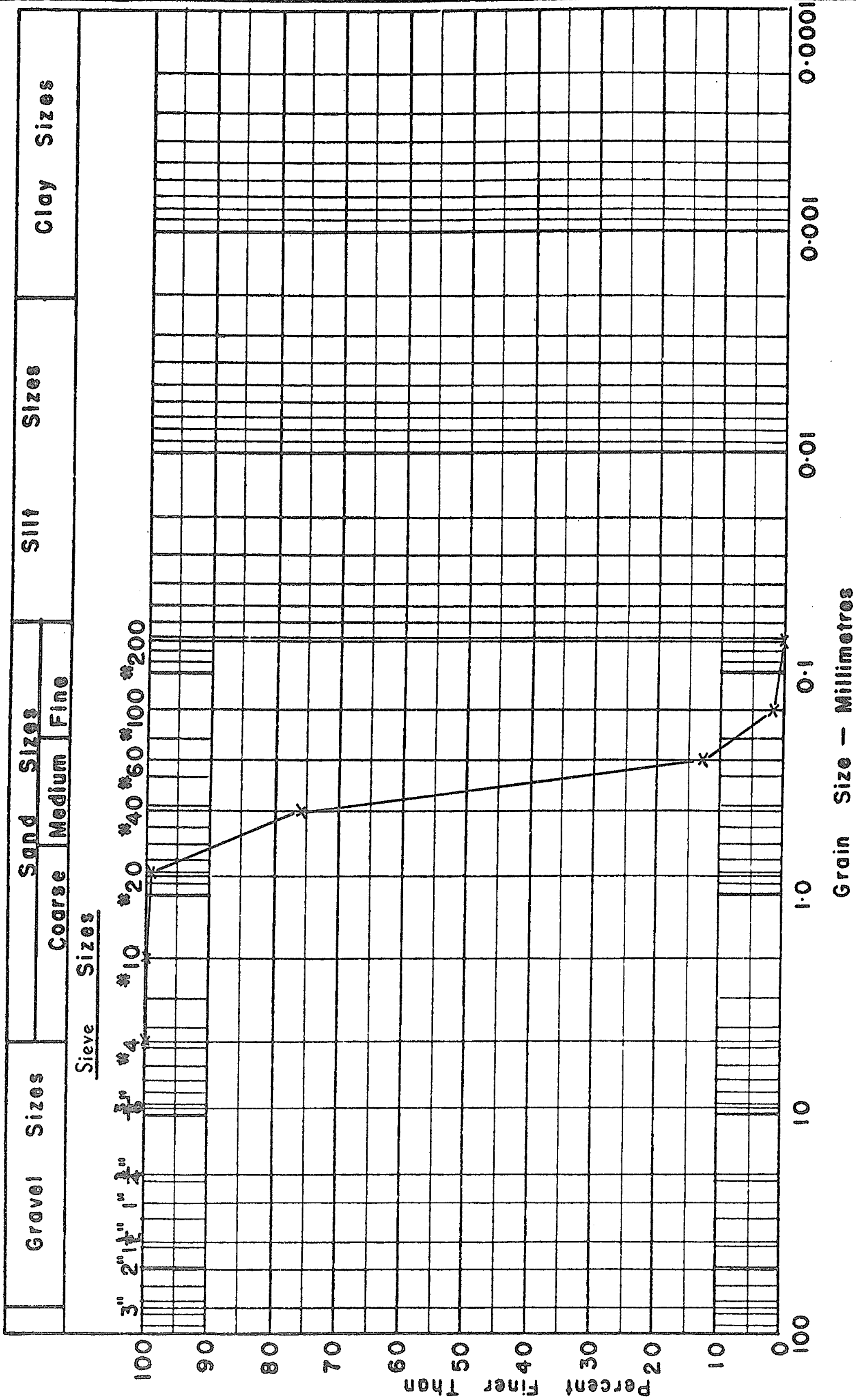


Remarks: SAMPLE SIEVED DRY

Ripley, Klohn & Leonoff International Ltd.
1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT	VA 1346 - RICHMOND DYKES
SAMPLE	DREDGED SAND STOCKPILE
LOCATION	LULU IS. - GILBERT RD. - SOUTH
HOLE	DEPTH —
TECHNICIAN B.C.	DATE SEPT. 30, 1969



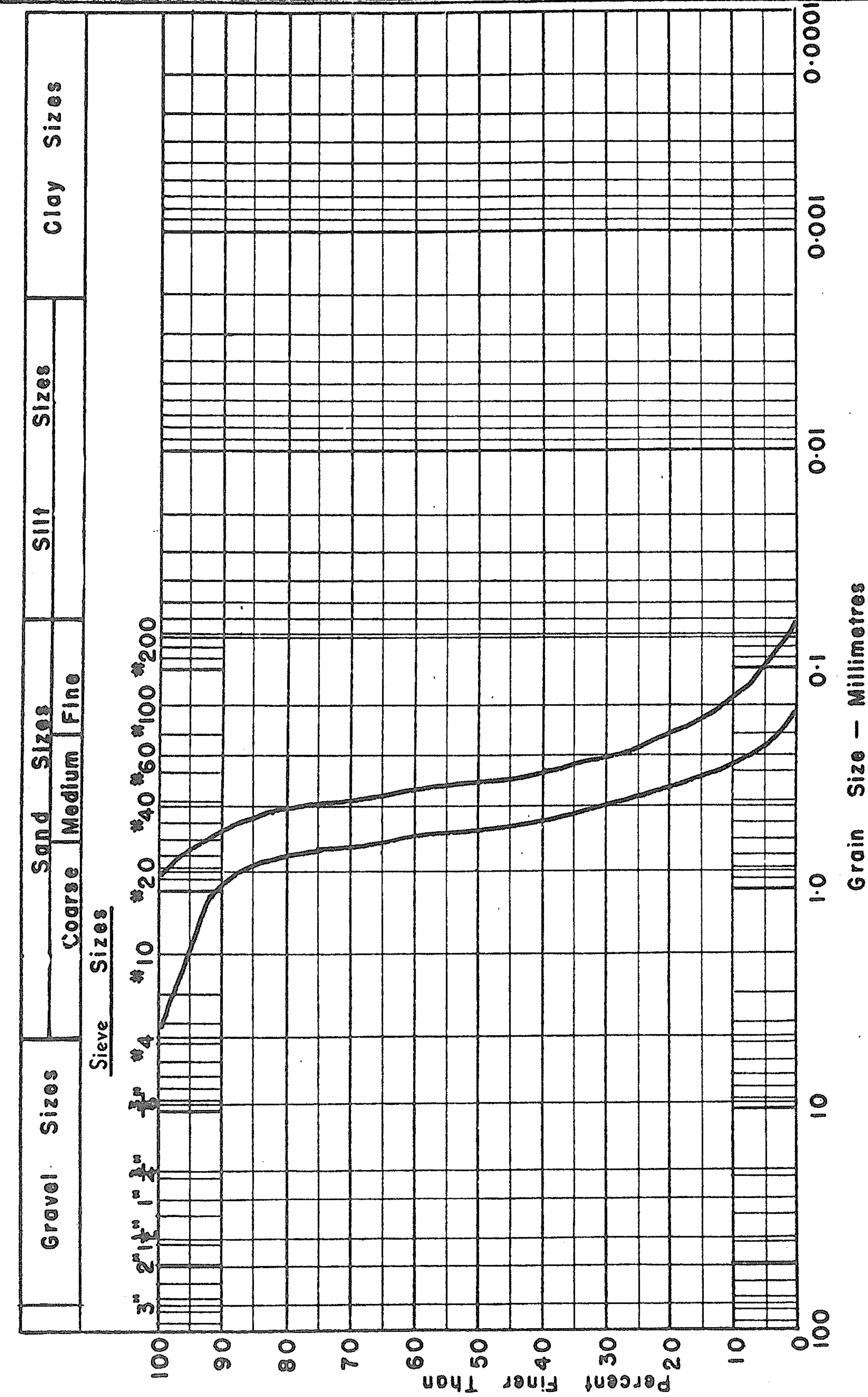
Remarks: SAMPLE SIEVED DRY

Ripley, Klohn & Leonoff International Ltd.

1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

PROJECT VA 1346 RICHMOND-DYKES	
SITE	
SAMPLE	
LOCATION	
HOLE	DEPTH
TECHNICIAN	DATE OCT. 17/69

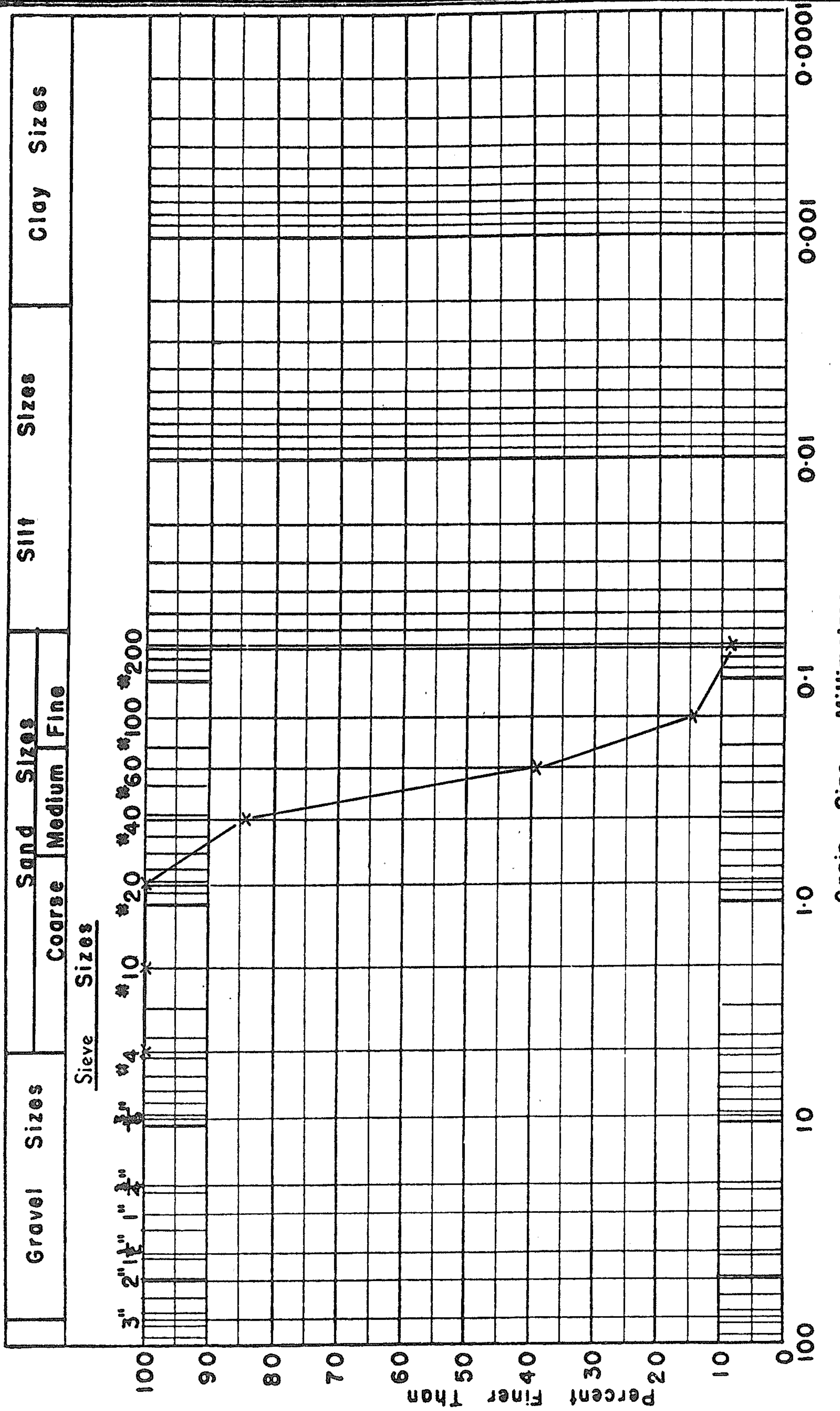


D_{10} = ____ mm.
D_{60} = ____ mm.
C_u = ____

Remarks: RANGE IN GRAIN SIZE OF DREDGED SAND SAMPLES

CHECKED.

Ripley, Klohn & Leonoff International Ltd. 1930 WEST BROADWAY, VANCOUVER 9, CANADA	LAB. ORDER
	PROJECT VA 1346 - RICHMOND DYKES
	SAMPLE 3 500' NORTHWEST OF
	LOCATION SECTION 1013 - STURGEON BANKS
	HOLE H.A. 2. DEPTH 4'-5'
GRAIN SIZE CURVE	TECHNICIAN B.C. DATE OCT 2, 1969

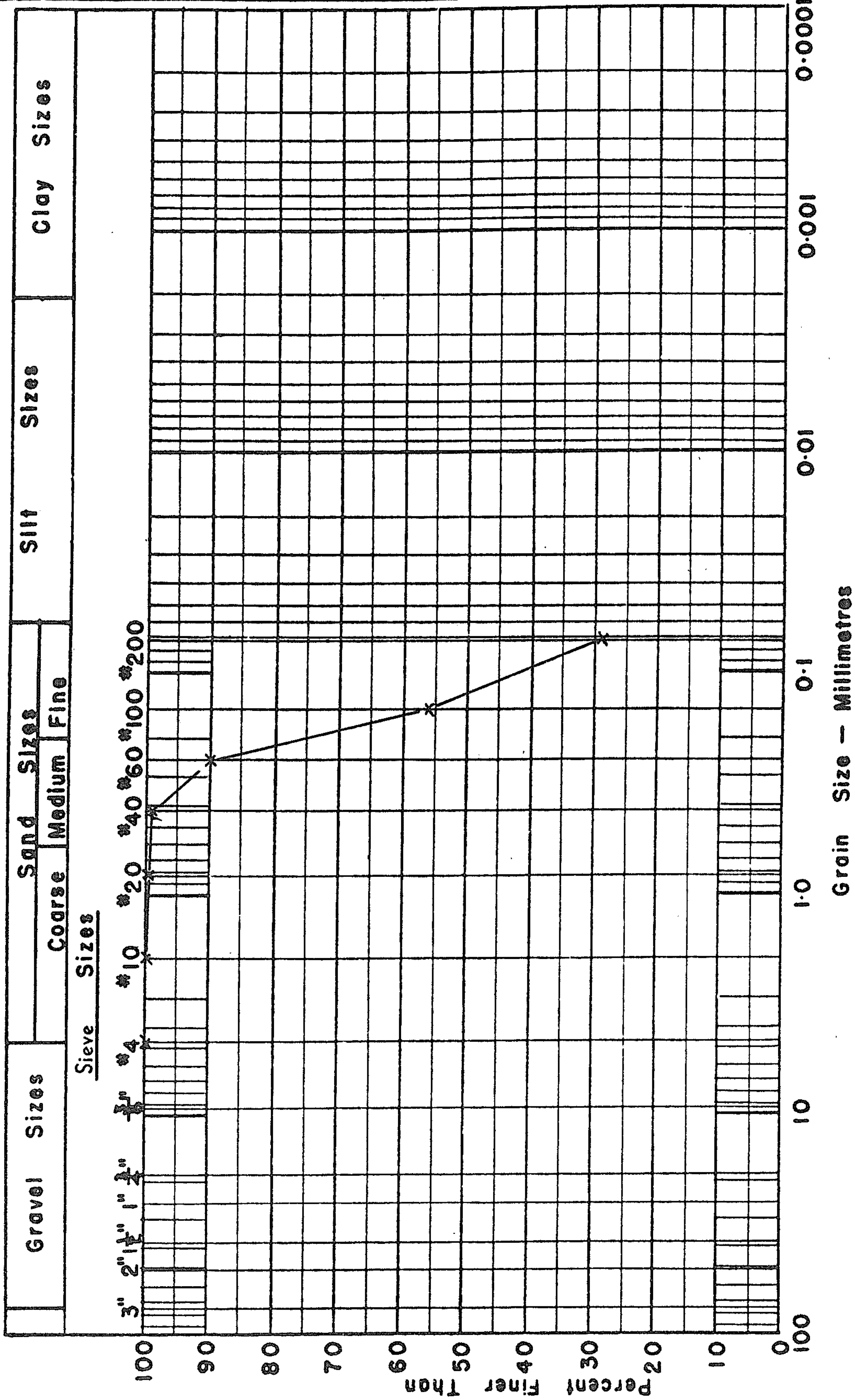


Remarks: SAMPLE WASHED THROUGH #200 SIEVE.

Ripley, Klohn & Leonoff International Ltd.
1930 WEST BROADWAY, VANCOUVER 9, CANADA

GRAIN SIZE CURVE

LAB. ORDER	
PROJECT	VA 1346 - RICHMOND DYKES
SAMPLE	3 1200' WEST OF
LOCATION	SECTION 1002 - STURGEON BANKS
HOLE	H. A. 1. DEPTH 8'-9'
TECHNICIAN	B.C. DATE OCT. 2/69

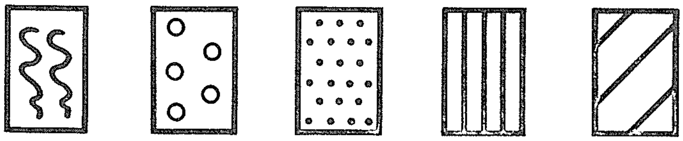


Remarks: SAMPLE WASHED THROUGH #200 SIEVE.
PORTION RETAINED ON SIEVE #10 AND #20 WAS SEA SHELLS.

SYMBOLS AND TERMS USED IN THE REPORT

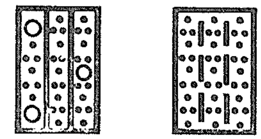
SYMBOLS

Organic Gravel Sand Silt Clay



The symbols may be combined to denote various soil combinations, the predominant soil being heavier.

Glacial Till Sand-silty



CLASSIFICATION BY PARTICLE SIZE

Boulders—larger than 8 inches
Cobbles—3 inches to 8 inches
Gravel—#4 sieve to 3 inches
Sand—#200 sieve to #4 sieve
Silt—0.002 mm. to #200 sieve
Clay—finer than 0.002 mm.

DENSITY OF SANDS AND GRAVELS

Descriptive Term	Relative Density	Standard Penetration Test
Very loose	0 - 20%	0 - 4 blows per ft.
Loose	20 - 40%	4 - 10 blows per ft.
Medium dense	40 - 70%	10 - 30 blows per ft.
Dense	70 - 90%	30 - 50 blows per ft.
Very dense	90 - 100%	Over 50 blows per ft.

NOTES

1. Relative density determined by laboratory tests.
2. Standard Penetration Test uses 140 lb. weight, 30 inch drop, 2" O.D. sampler.
3. The "R.K.L." Penetration Test uses 50 lb. weight, 30 inch drop, 1¼" O.D. drive cone attached to a single line of 1" diameter rods. The penetration diagram is a measure of skin friction plus point resistance. An approximate relationship between the Standard Penetration Test and the "R.K.L." Penetration Test exists for sands. This is shown in the following table.

Depth—Ft.	0 - 20	20 - 40	40 - 60
Std. Pen. Test / "R.K.L." Test	0.7	0.5	0.3

CONSISTENCY OF CLAYS AND SILTS

Descriptive Term	Unconfined Compressive Strength—Tons Sq. Ft.	Remarks
Very soft	less than 0.25	Can penetrate with fist
Soft	0.25 to 0.50	Can indent with fist
Firm	0.50 to 1.0	Can penetrate with thumb
Stiff	1.0 to 2.0	Can indent with thumb
Very stiff	2.0 to 4.0	Can indent with thumb-nail
Hard	4.0 and greater	Cannot indent with thumb-nail

DESCRIPTIVE SOIL TERMS

Well graded . . . . having wide range of grain sizes and substantial amounts of all intermediate sizes.

Poorly graded . . . predominantly of one grain size.

Slickensided . . . . refers to a clay that has planes that are slick and glossy in appearance; slickensides are caused by shear movements.

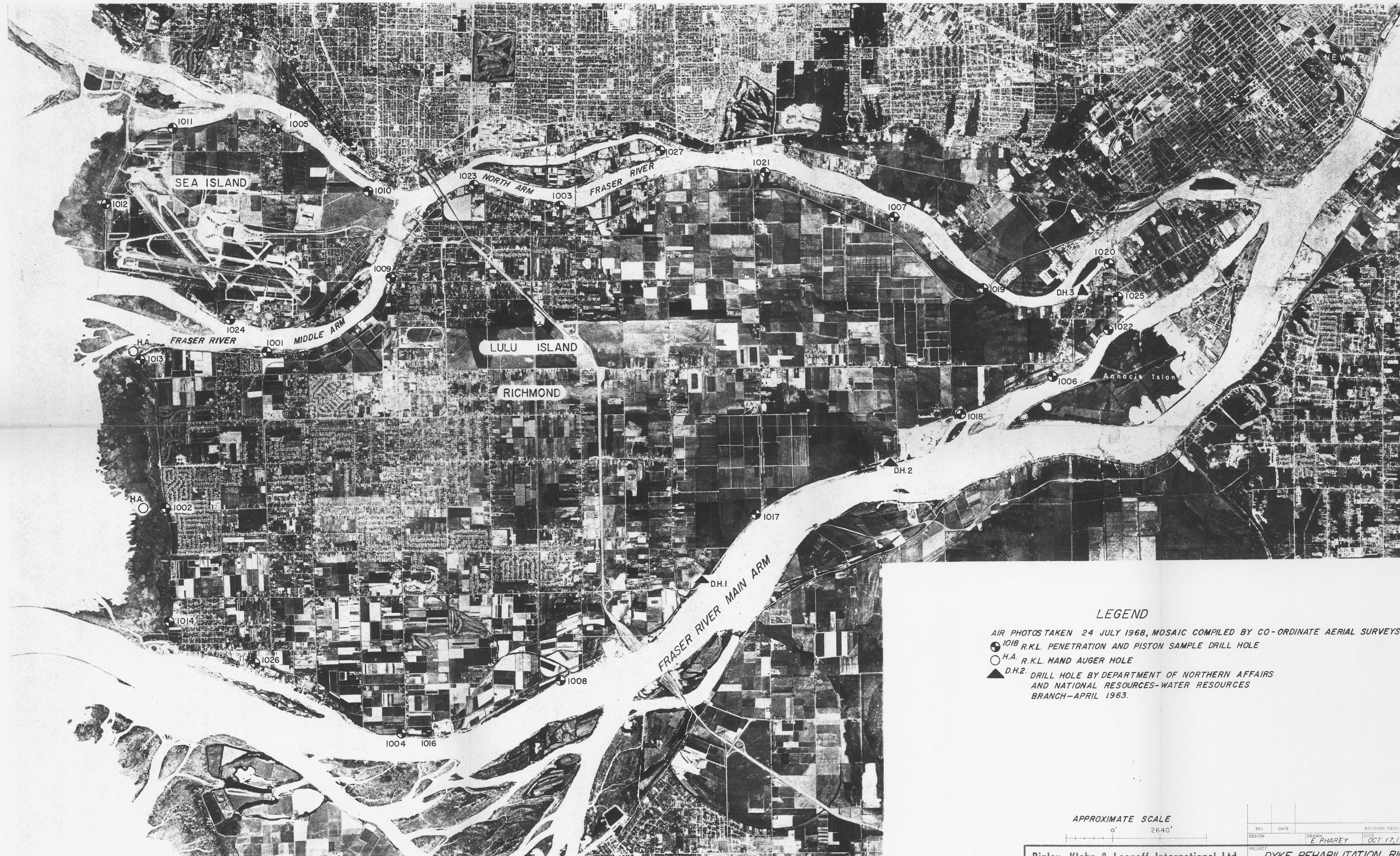
Sensitive . . . . . . exhibiting loss of strength on remolding.

Fissured . . . . . . containing cracks, usually attributable to shrinkage. Fissured clays are sometimes described as having a nugget structure.

Stratified . . . . . . containing layers of different soil types.

Organic . . . . . . containing organic matter; may be decomposed or fibrous.

Peat . . . . a fibrous mass of organic matter in various stages of decomposition. Generally dark brown to black in color and of spongy consistency.



LEGEND

AIR PHOTOS TAKEN 24 JULY 1968, MOSAIC COMPILED BY CO-ORDINATE AERIAL SURVEYS LTD.

1018 R.K.L. PENETRATION AND PISTON SAMPLE DRILL HOLE

H.A. R.K.L. HAND AUGER HOLE

D.H.2. DRILL HOLE BY DEPARTMENT OF NORTHERN AFFAIRS AND NATIONAL RESOURCES-WATER RESOURCES BRANCH-APRIL 1963.

APPROXIMATE SCALE

0' 2640'

REV.	DATE	REVISION DETAILS	
DESIGN	DRAWN E. PHAREY	DATE OCT. 17, 1969.	SCALES 1"=2640' APPROX.

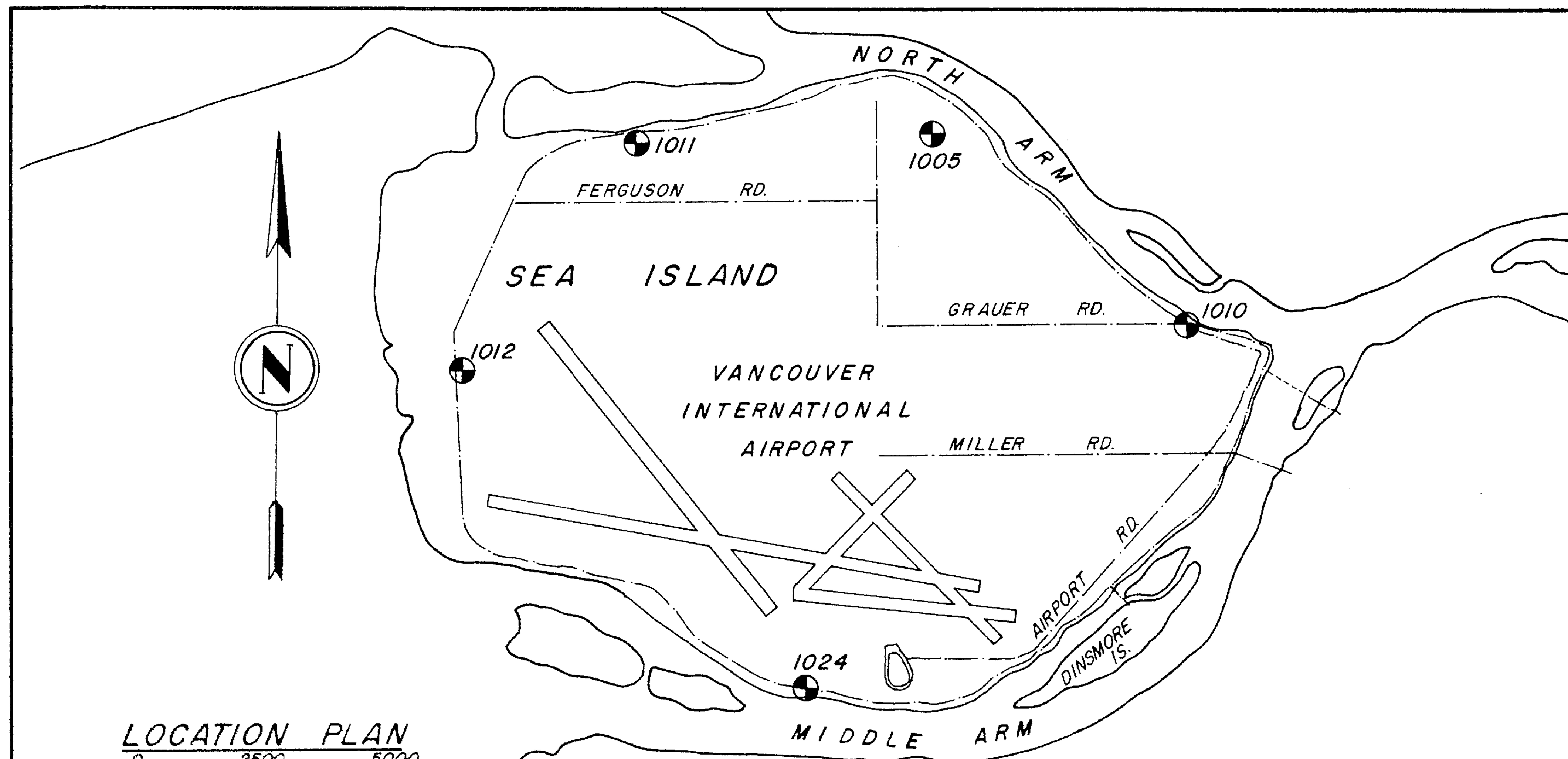
Ripley, Klohn & Leonoff International Ltd.
CONSULTING ENGINEERS
CANADA
VANCOUVER - EDMONTON - CALGARY - WINNIPEG

CLIENT: FRASER RIVER JOINT PROGRAM COMMITTEE

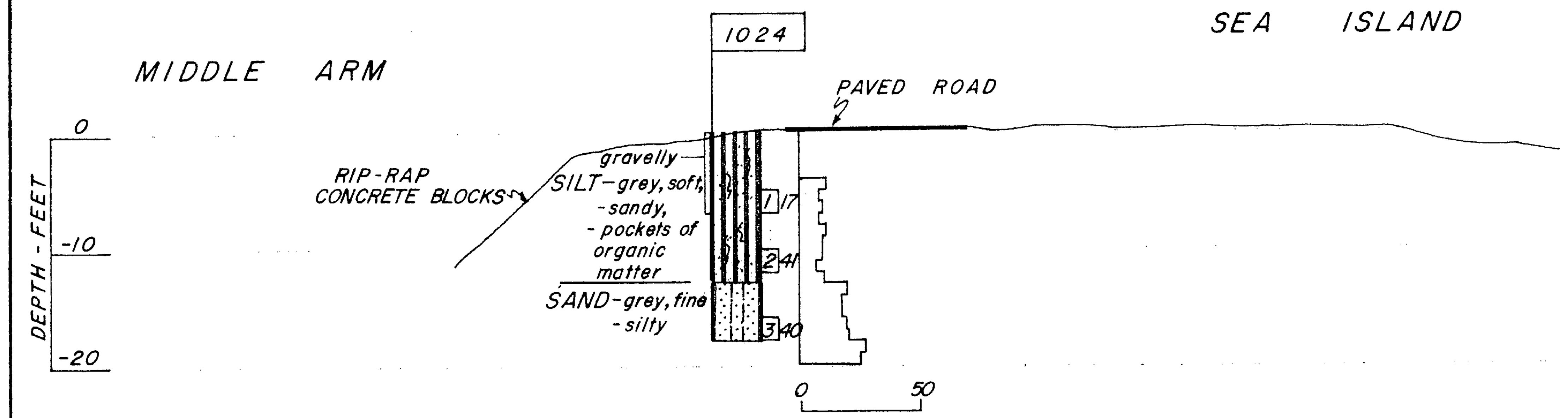
PROJECT: DYKE REHABILITATION RICHMOND B.C.

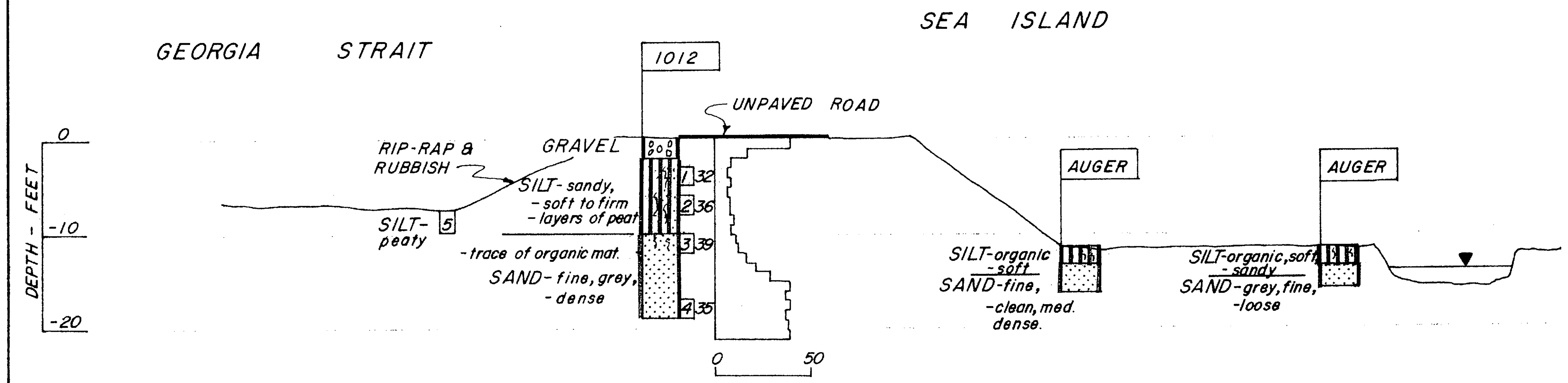
TITLE: AIR PHOTO PLAN SHOWING DRILL HOLE LOCATIONS

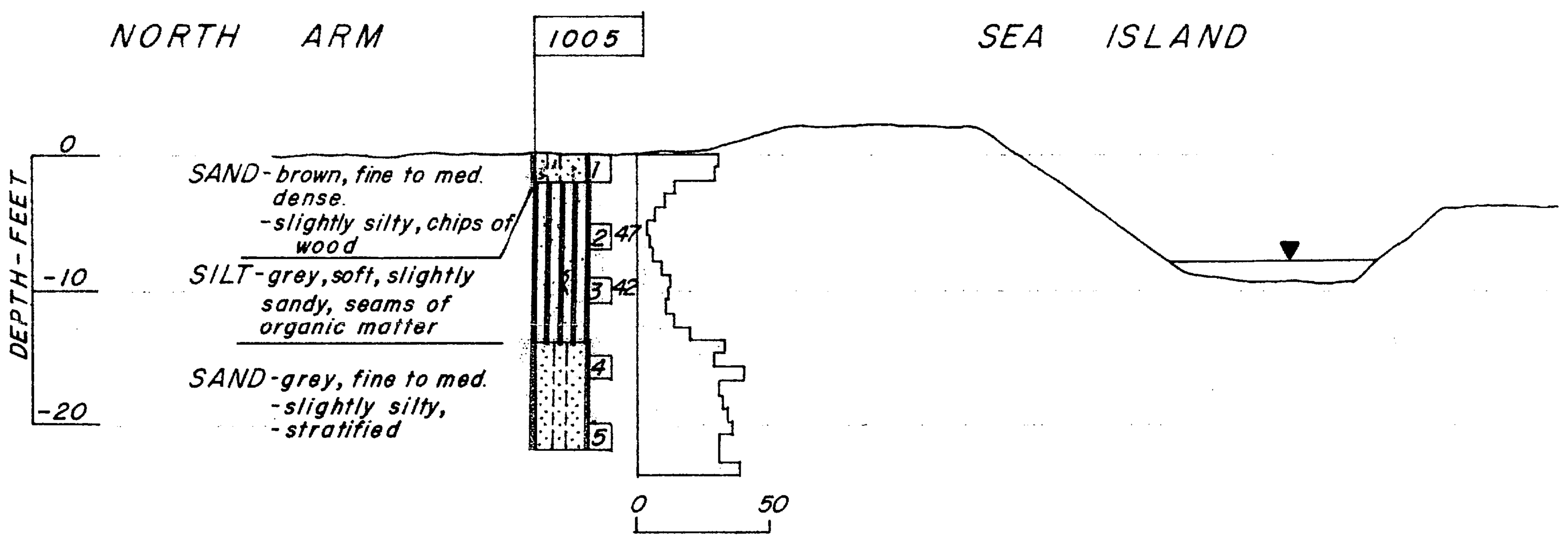
DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
OCTOBER 17, 1969. APPROVED	VA1346	D-1346-1	

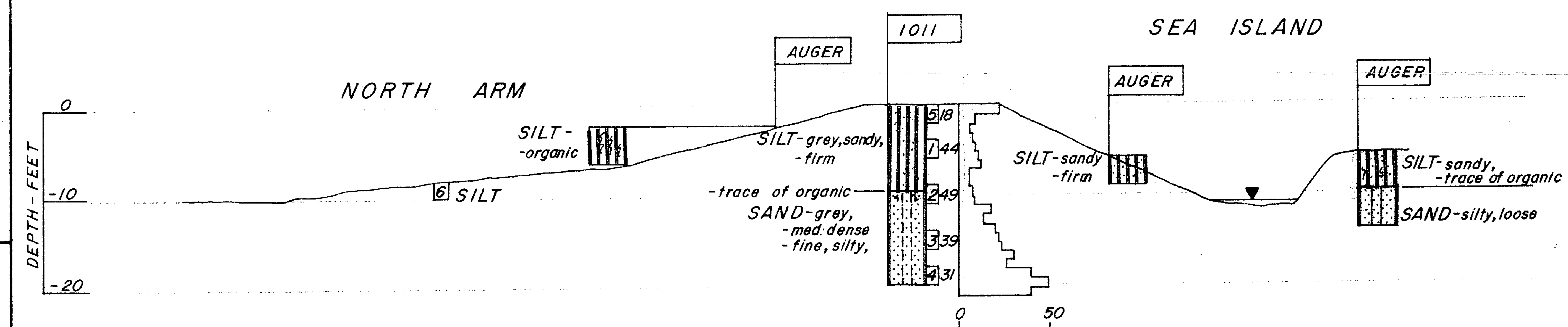


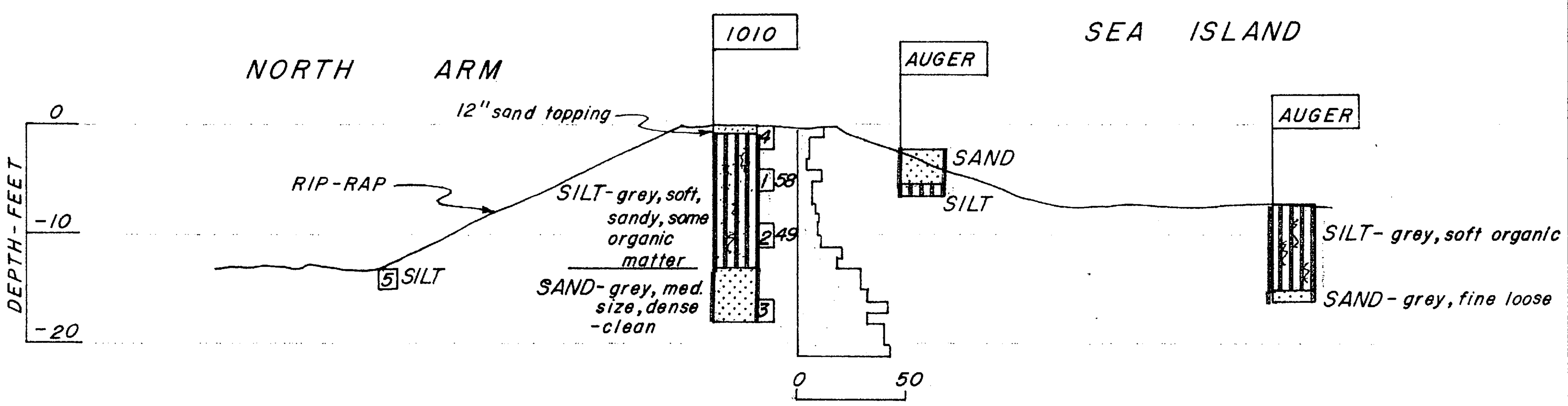
LOCATION PLAN

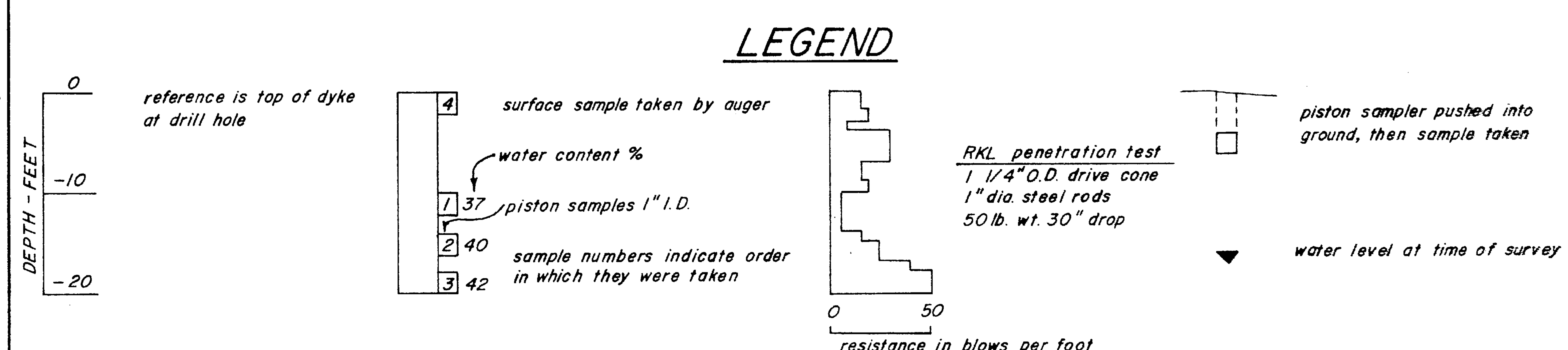












DRAWING SHOWS SECTIONS - 1005
1010
1011
1012
1024

DRAWN	E. PHAREY
DATE	OCT. 17, 1969
SCALES	1" = 10'
PROJECT	DYKE REHABILITATION - RICHMOND B.C.
TITLE	DRILL HOLE DATA AND DYKE SECTIONS SEA ISLAND
DATE OF ISSUE	OCTOBER 17, 1969
PROJECT No.	VA1346
DWG. No.	D-1346-2

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CONSULTING ENGINEERS
CANADA
VANCOUVER · EDMONTON · CALGARY · WINNIPEG

CLIENT: FRASER RIVER JOINT PROGRAM COMMITTEE

DRAWING SHOWS SECTIONS - 1003
1007
1021
1023
1027

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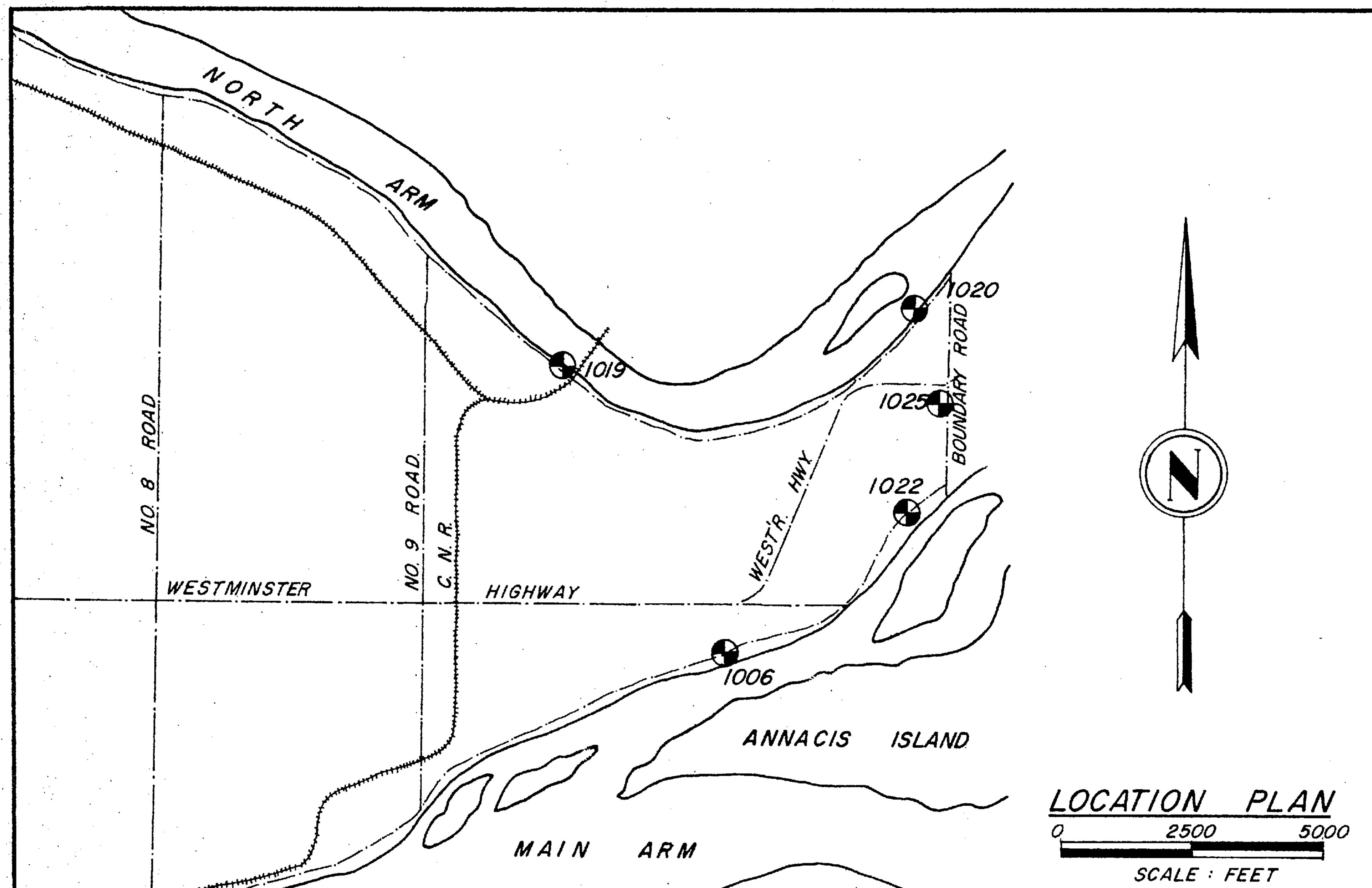
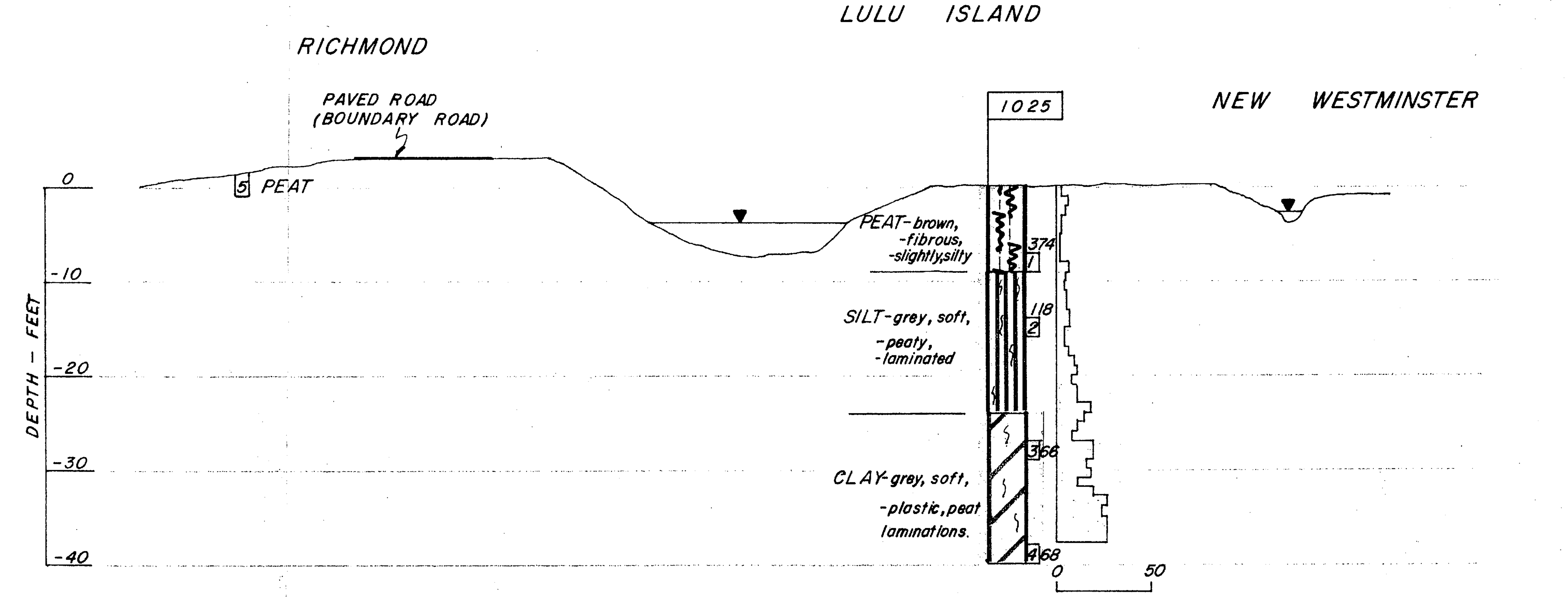
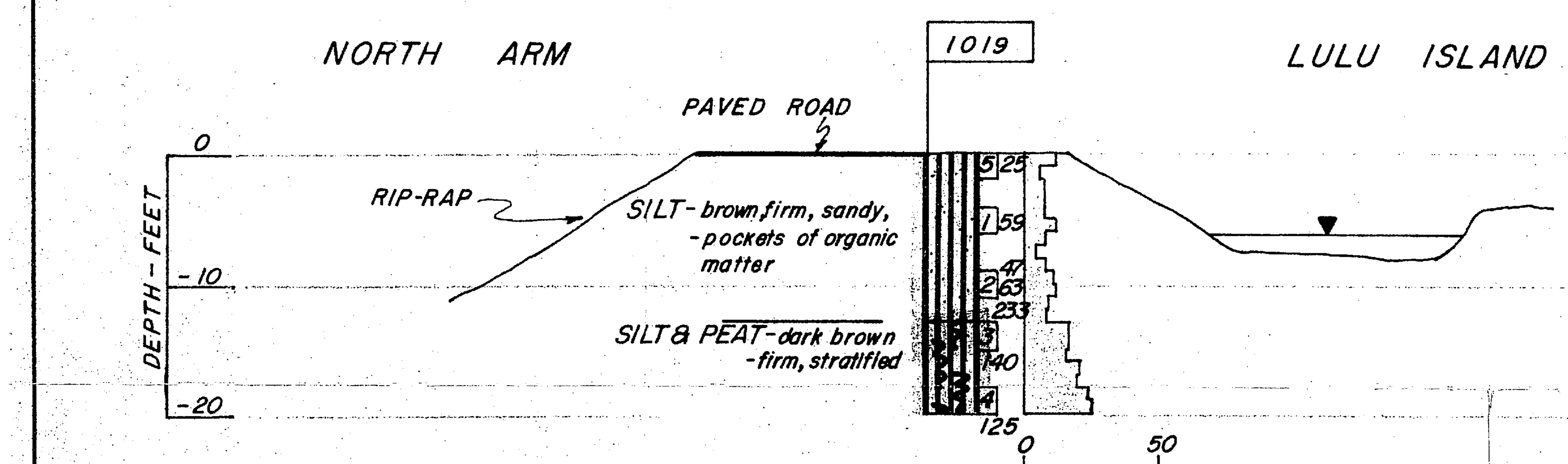
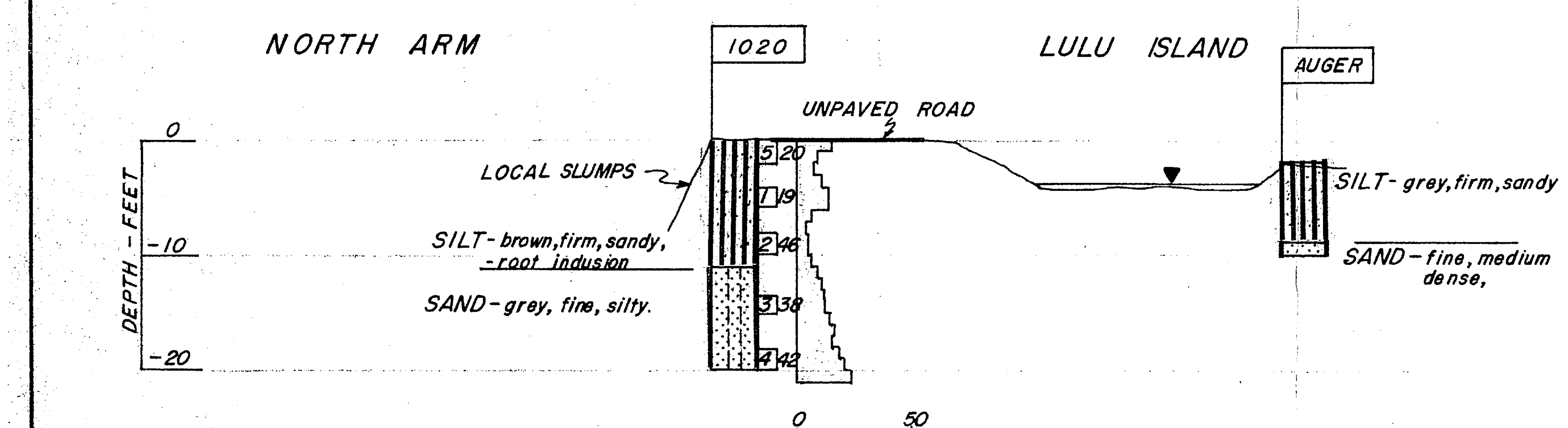
CONSULTING ENGINEERS
CANADA
VANCOUVER - EDMONTON - CALGARY - WINNIPEG

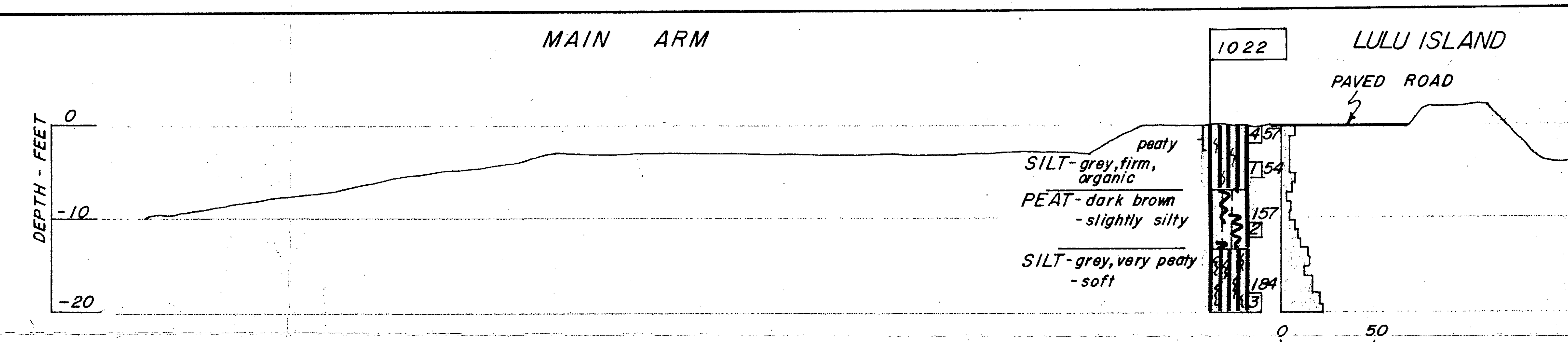
CLIENT:	FRASER RIVER JOINT PROGRAM COMMITTEE
DESIGN	
DRAWN	E. PHAREY
DATE	OCTOBER 17, 1969
SCALES	1" = 10'
PROJECT	DYKE REHABILITATION - RICHMOND B.C.
TITLE	DRILL HOLE DATA AND DYKE SECTIONS LULU ISLAND NORTH
DATE OF ISSUE	OCTOBER 17, 1969
PROJECT No.	VA1346
DWG. No.	D-1346-3
REV.	

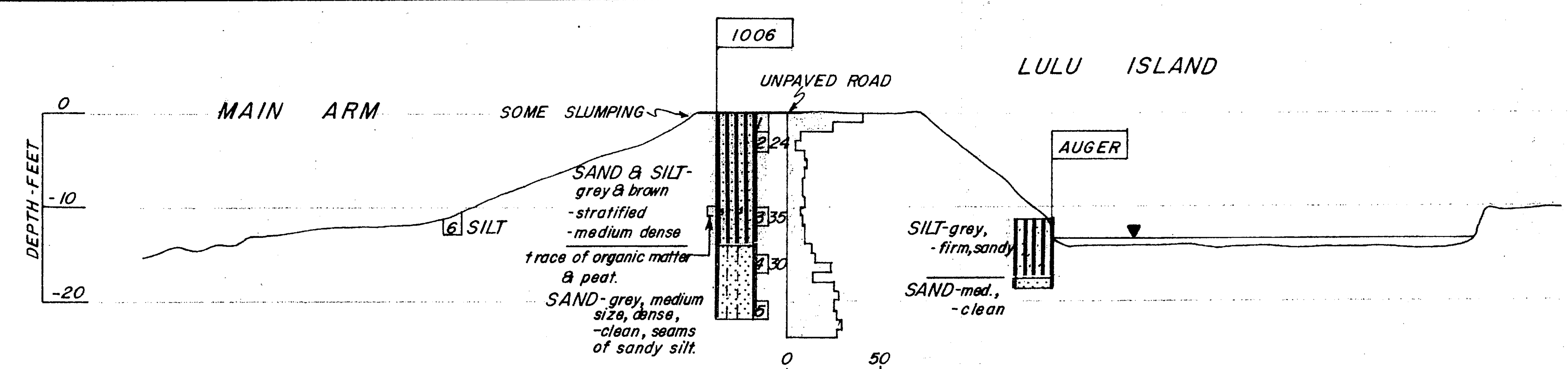












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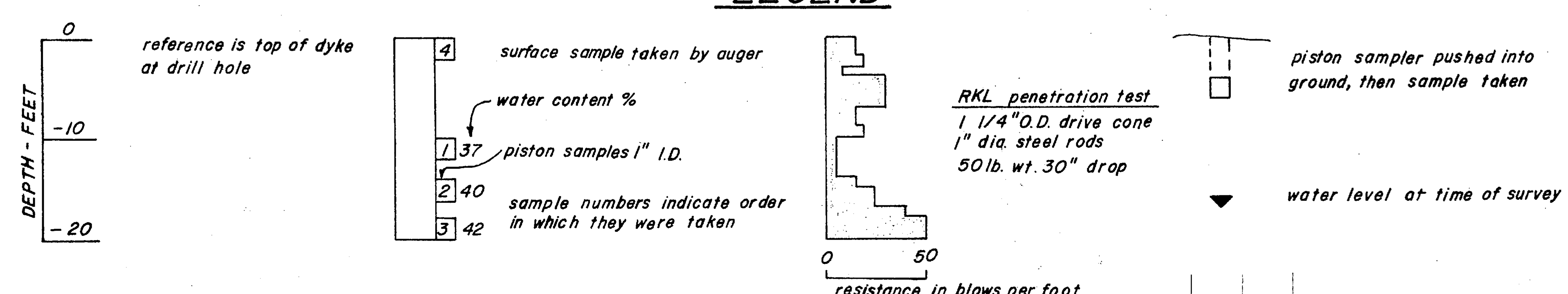

DRAWING SHOWS SECTIONS- 1006
1019
1020
1022
1025

REV.	DATE	REVISION DETAILS

DESIGN | DRAWN E. PHAREY | DATE OCT. 17, 1969 | SCALES 1" = 10'

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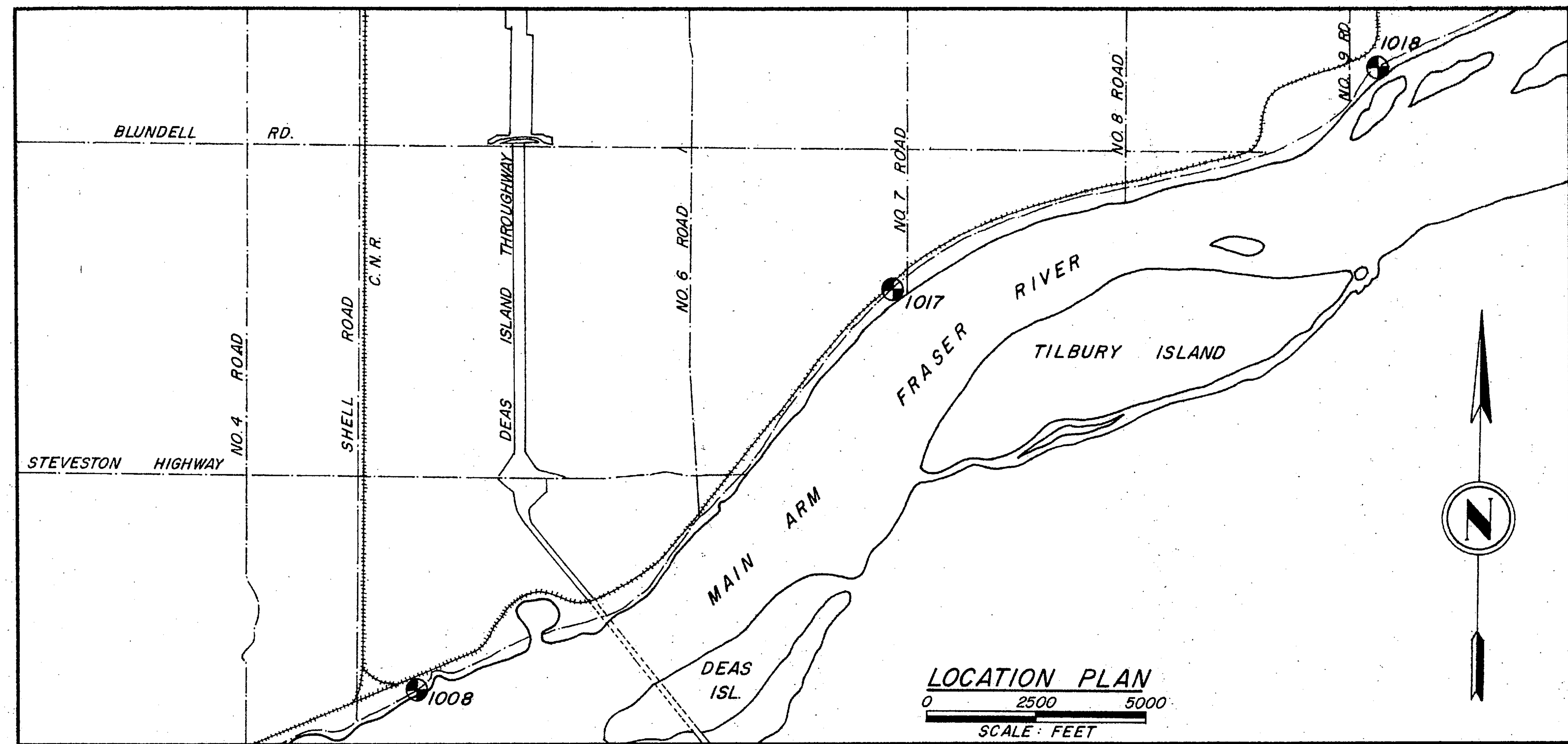
CANADA
VANCOUVER - EDMONTON - CALGARY - WINNIPEG

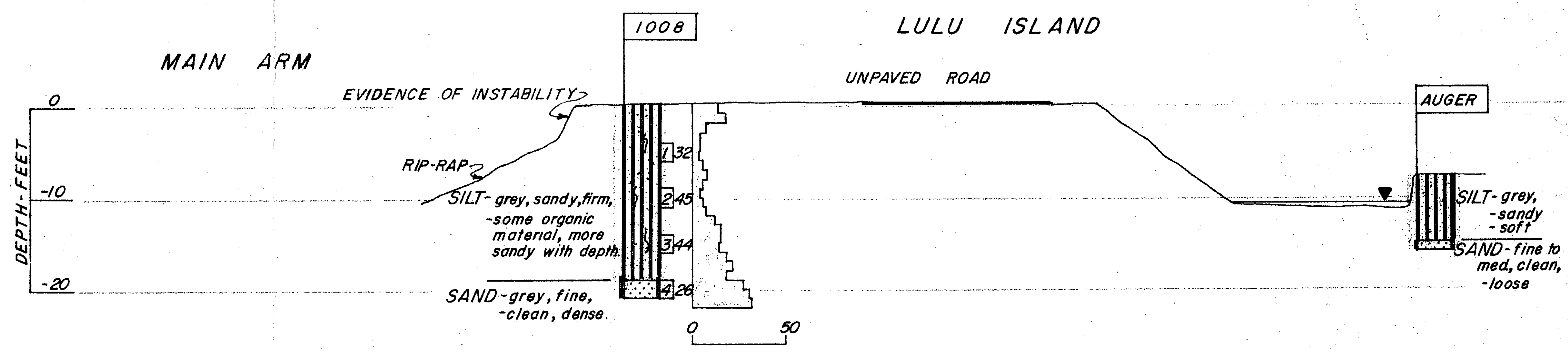
CLIENT: FRASER RIVER
JOINT PROGRAM COMMITTEE

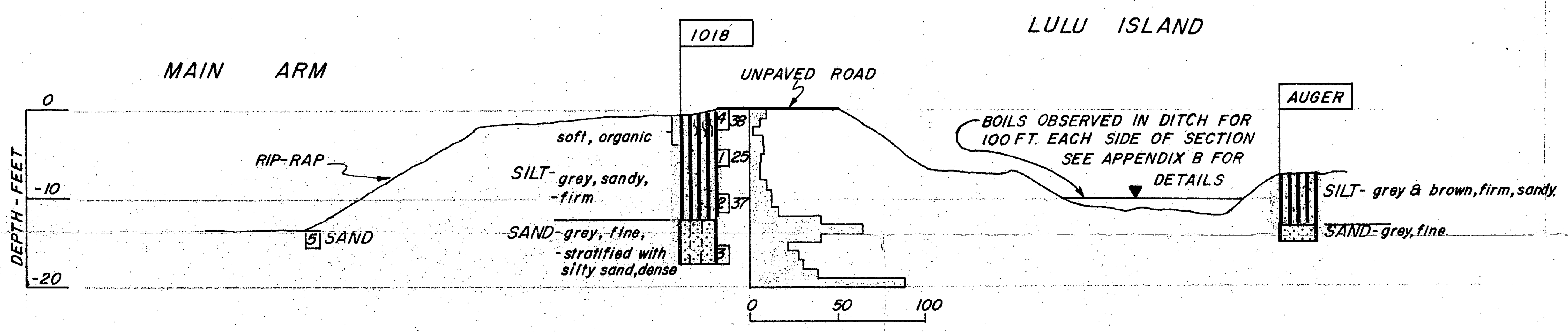
PROJECT: DYKE REHABILITATION- RICHMOND B.C.

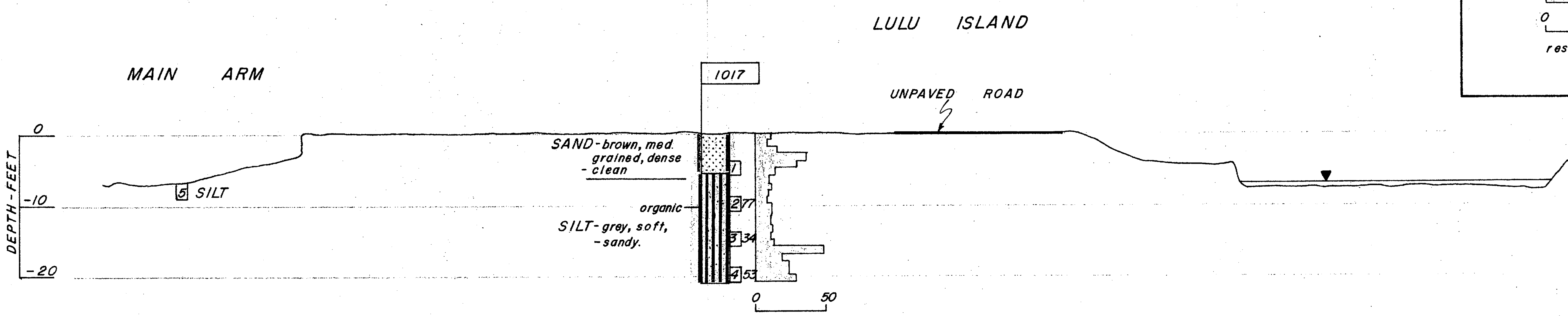
TITLE: DRILL HOLE DATA AND DYKE SECTIONS
LULU ISLAND NORTHEAST

DATE OF ISSUE OCTOBER 17, 1969 | APPROVED | PROJECT No. VA1346 | DWG. No. D-1346-4 | REV.









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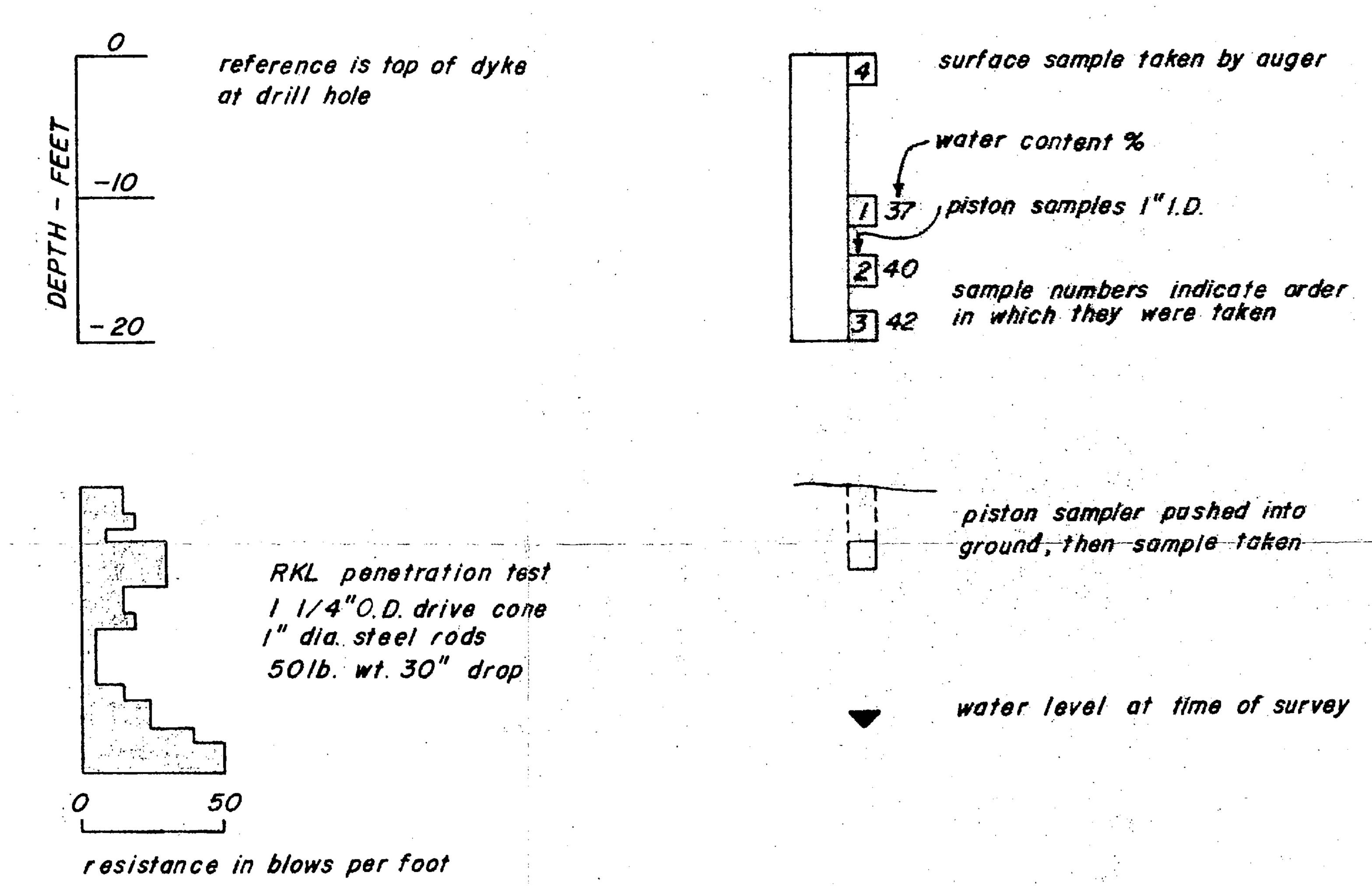


DRAWING SHOWS SECTIONS- 1008
1017
1018

REV.	DATE	REVISION DETAILS	
DESIGN	DRAWN E. PHAREY	DATE OCT. 17, 1969.	SCALES 1" = 10'

Ripley, Klohn & Leonoff International Ltd.
CONSULTING ENGINEERS
CANADA
VANCOUVER - EDMONTON - CALGARY - WINNIPEG

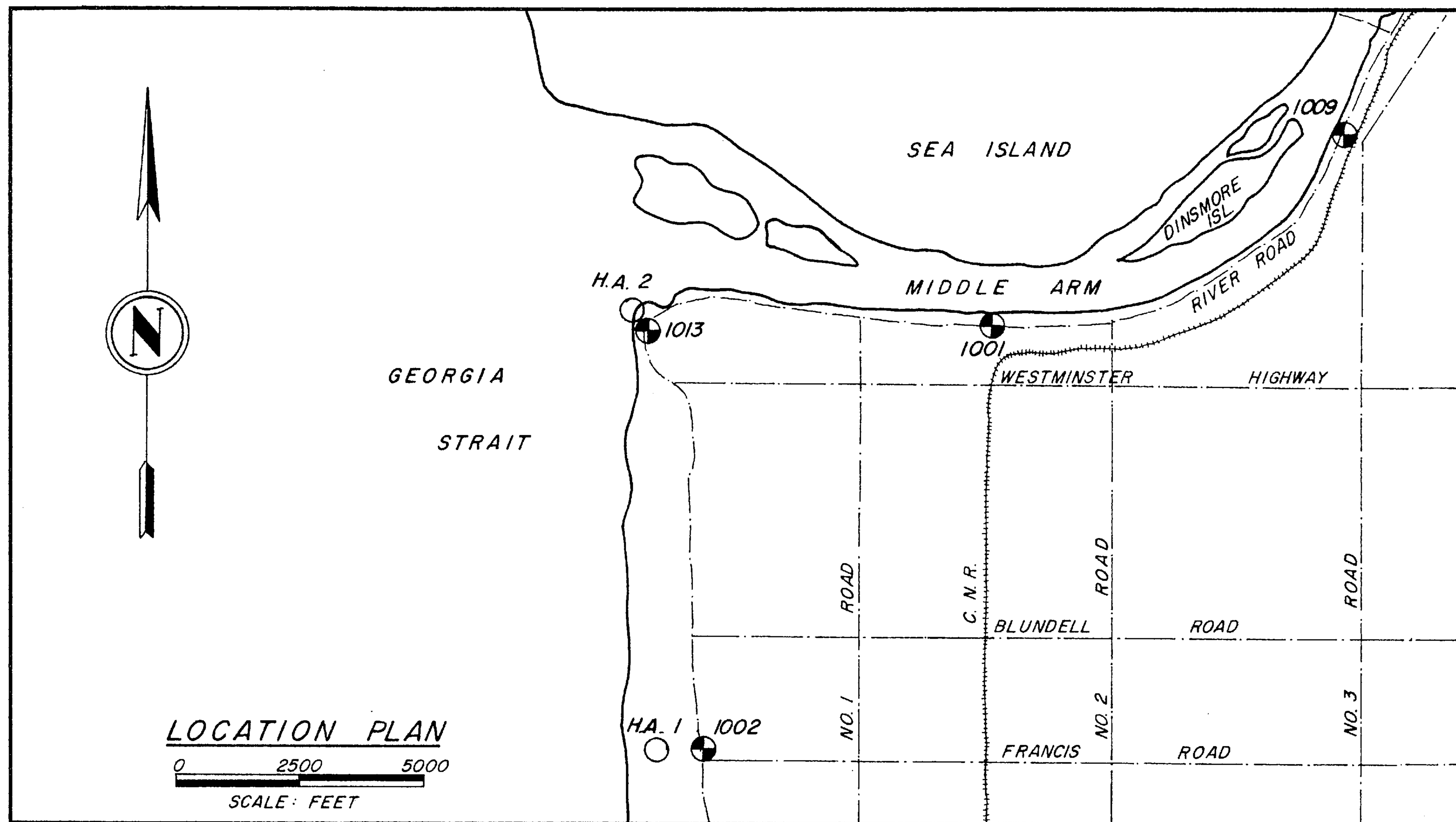
CLIENT: FRASER RIVER JOINT PROGRAM COMMITTEE

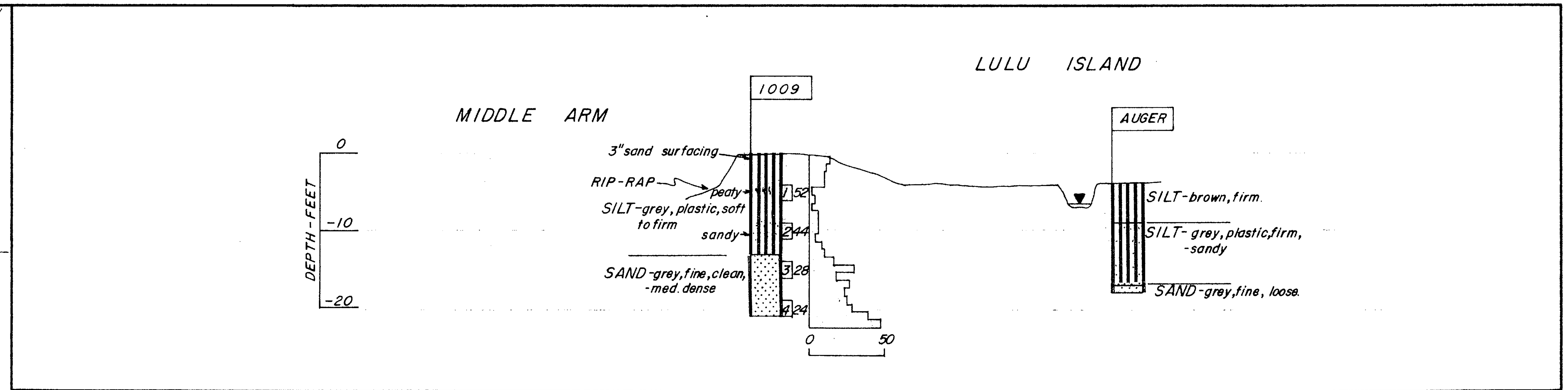
PROJECT: DYKE REHABILITATION - RICHMOND B.C.

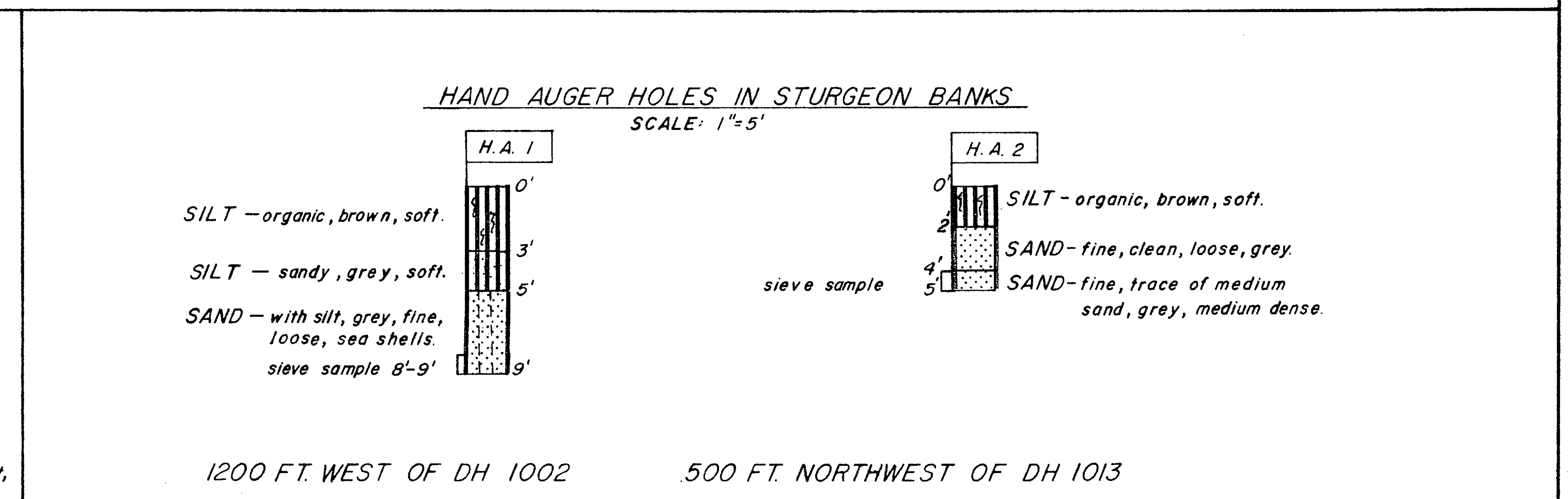
TITLE: DRILL HOLE DATA AND DYKE SECTIONS LULU ISLAND EAST

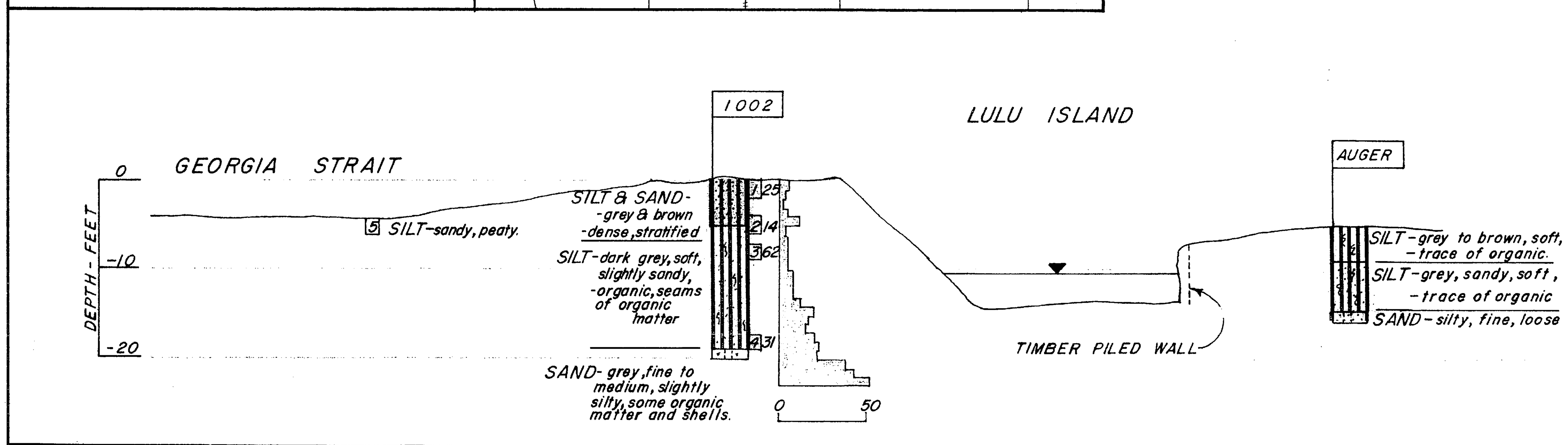
DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
OCTOBER 17, 1969.	VA1346	D-1346-5	

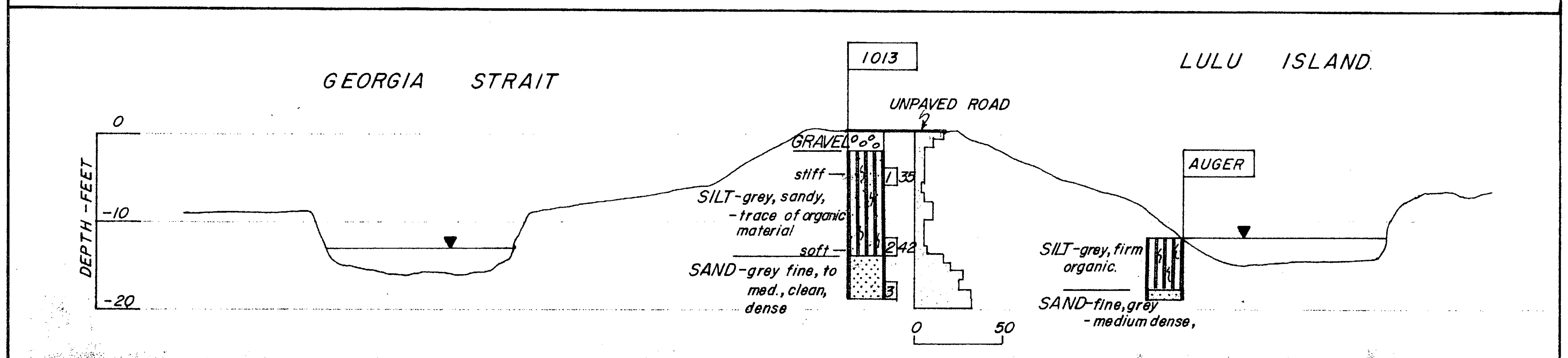
GEORGIA STRAIT
STEVESTON JETTY
NO. 1 RD
NO 2 RD
STEVESTON HIGHWAY
MONCTON ST
GILBERT RD
NO. 3 RD
C.N.R.
1014
1026
1015
1004
1016
MAIN ARM
N
LOCATION PLAN
0 2500 5000
SCALE: FEET
SOUTH ARM
LULU ISLAND
ROCK PLACED BETWEEN DYKES AND PILES
1026
UNPAVED ROAD
BUILDINGS OUTSIDE DYKES SUPPORTED ON PILES.
WOODEN PILE AND PLANK WALL
SILT-grey, -soft -slightly sandy
SAND-grey, fine, -clean, -pockets of silty sand
DRY DITCH
AUGER
SILT-grey, sandy, soft.
SAND-fine to medium
DEPTH-FEET
0
-10
-20
50
GEORGIA STRAIT
LULU ISLAND
1014
piece of wood
SILT-grey, slightly sandy, organic
SAND-grey, fine, -silty, medium dense.
6 PEAT
AUGER
SILT-grey, firm, sandy.
SAND-grey, fine.
MAIN ARM
LULU ISLAND.
1016
RIP-RAP
4 SILT
firm
SILT-grey & brown -sandy, organic soft
SAND-grey, very fine, silty, -dense.
MAIN ARM
LULU ISLAND
1004
RIP-RAP (ROCK & CONCRETE BLOCKS)
sandy, firm
SILT-grey, organic, soft to very soft, pockets of peat.
SILT-grey, sandy, soft increasing to stiff with depth, trace of organic matter
GRAVEL ROADWAY
MAIN ARM (BOAT HARBOUR)
LULU ISLAND
1015
UNPAVED ROAD
SAND & GRAVEL
SILT-brown, soft, slightly sandy, organic
SAND-grey, fine, - med. dense -slightly silty
SCOUR
5 SILT-grey, -very sandy -firm
AUGER
SILT-grey, organic, -soft
PEAT
SILT-grey, soft.
SAND-grey, fine, loose.
LEGEND
reference is top of dyke at drill hole
surface sample taken by auger
water content %
piston samples 1" I.D.
sample numbers indicate order in which they were taken
RKL penetration test
1 1/4" O.D. drive cone
1" dia. steel rods
50 lb. wt. 30" drop
resistance in blows per foot
piston sampler pushed into ground then sample taken
water level at time of survey
DRAWING SHOWS SECTIONS
- 1004
1014
1015
1016
1026
Ripley, Klohn & Leonoff International Ltd.
CONSULTING ENGINEERS
CANADA
VANCOUVER - EDMONTON - CALGARY - WINNIPEG
CLIENT
FRASER RIVER JOINT PROGRAM COMMITTEE
PROJECT
DYKE REHABILITATION - RICHMOND B.C.
TITLE
DRILL HOLE DATA AND DYKE SECTIONS
LULU ISLAND SOUTH
DRAWN E. PHAREY
DATE OCT. 17, 1969
SCALES 1"=10'
DATE OF ISSUE OCTOBER 17, 1969
PROJECT No. VA1346
DWG. No. D-1346-6

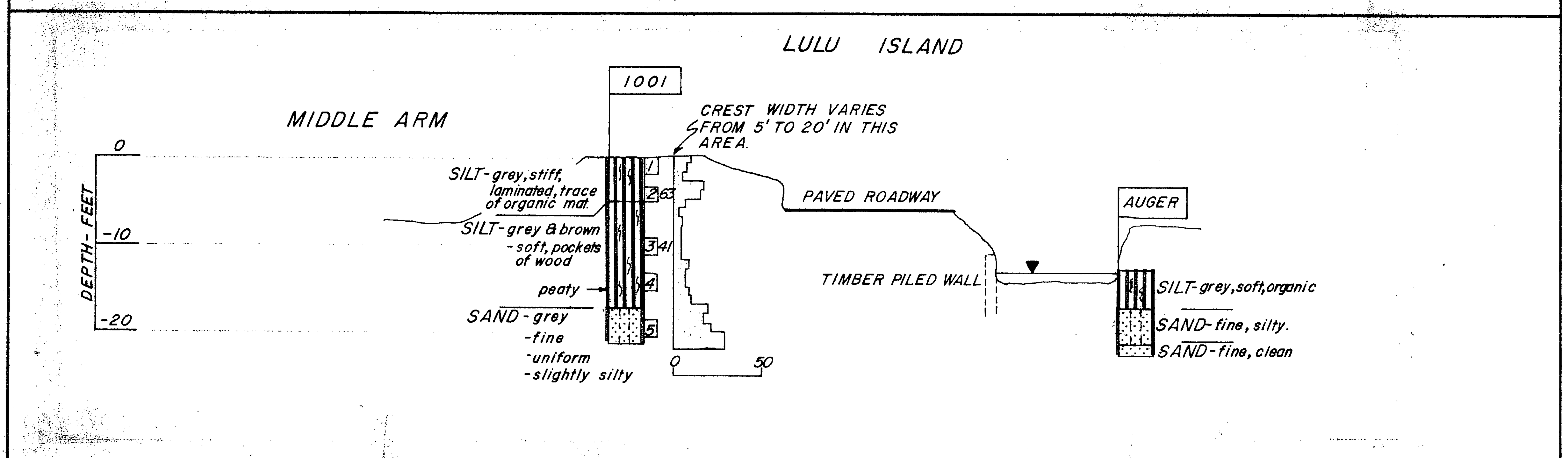


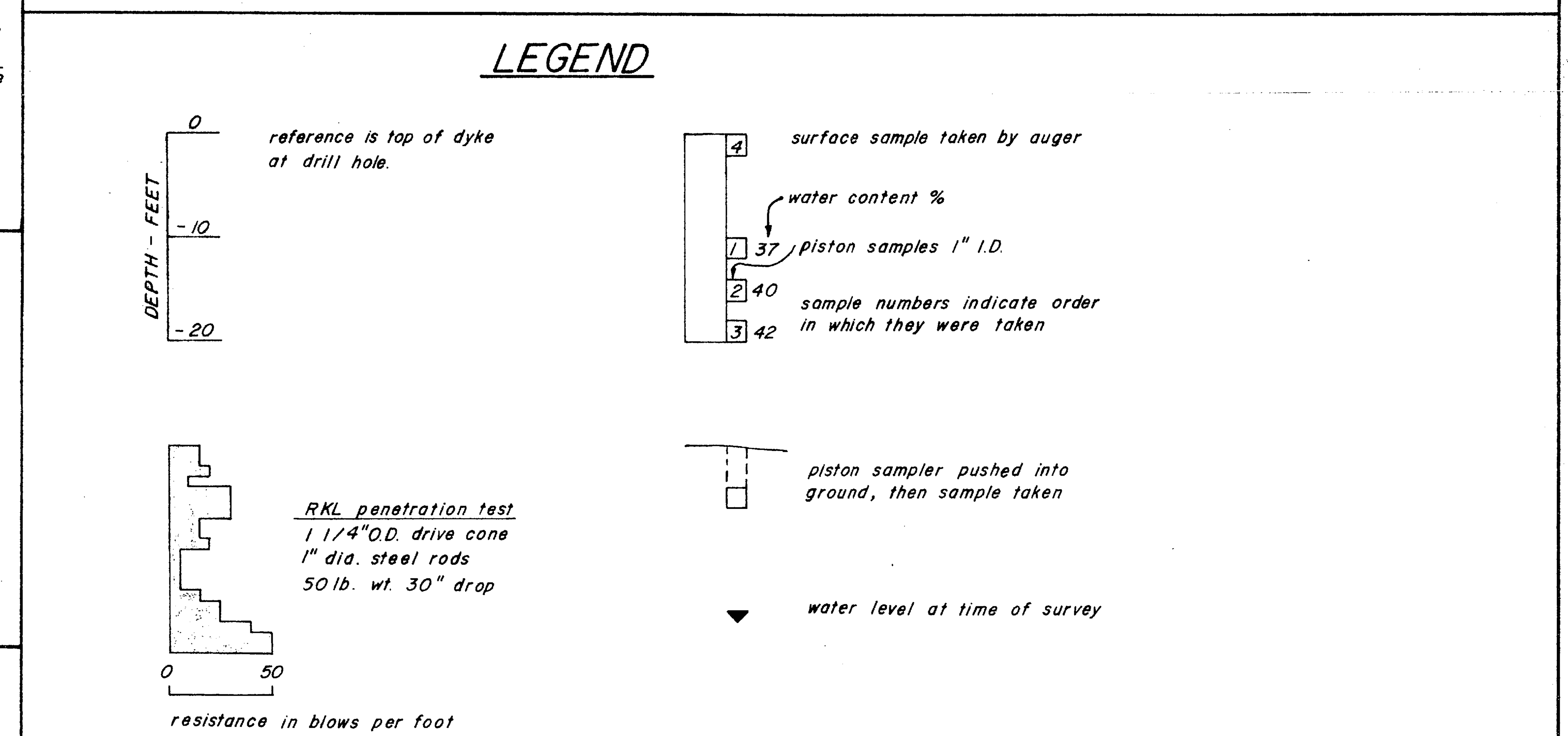












DRAWING SHOWS SECTIONS - 1001
1002
1009
1013
2 AUGER HOLES

REV.	DATE	REVISION DETAILS
DESIGN	DRAWN E. PHAREY	DATE OCT. 17, 1969 SCALES 1"=10'

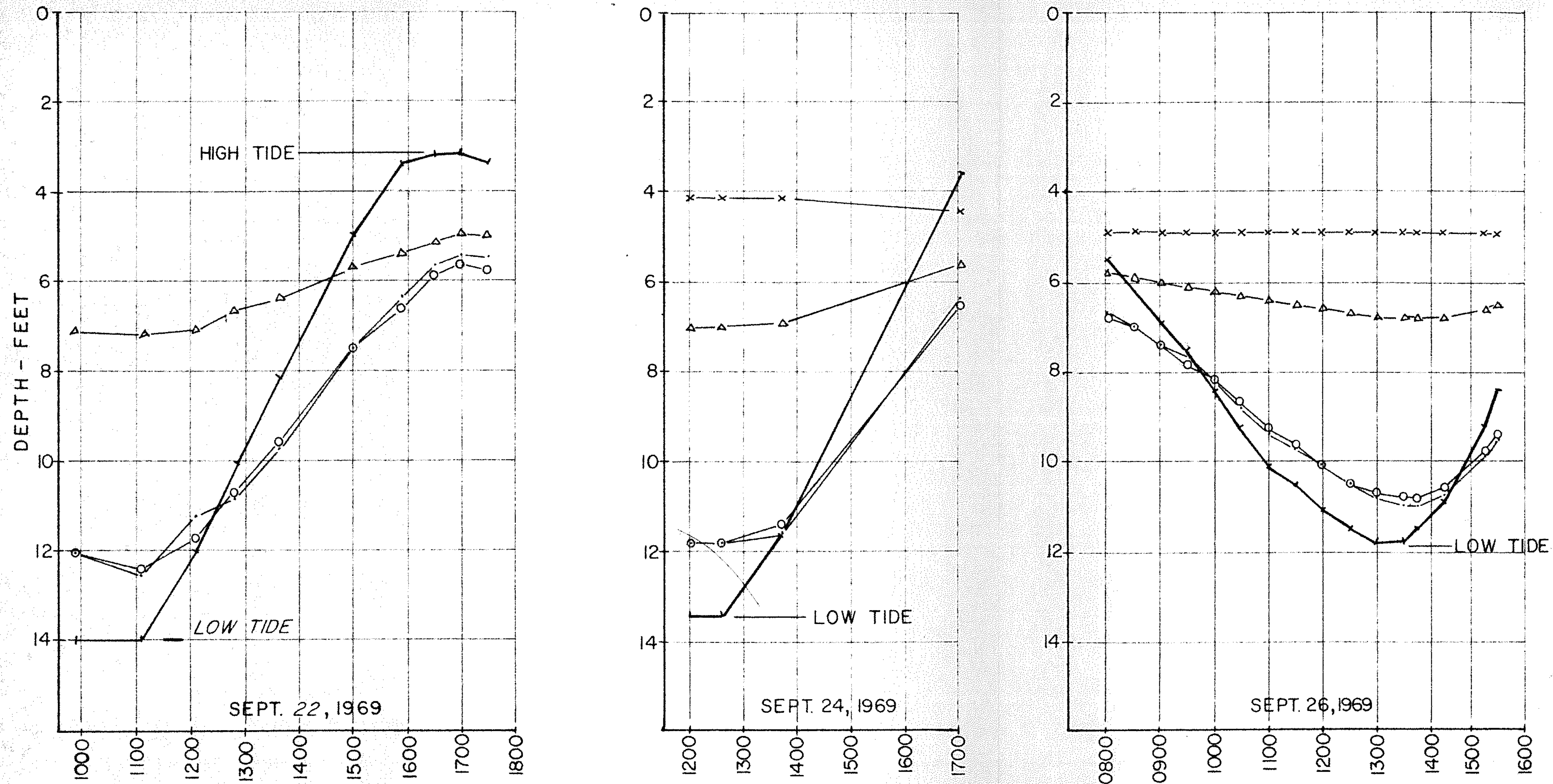
Ripley, Klohn & Leonoff International Ltd.
CONSULTING ENGINEERS
CANADA
VANCOUVER - EDMONTON - CALGARY - WINNIPEG

CLIENT: FRASER RIVER JOINT PROGRAM COMMITTEE

PROJECT: DYKE REHABILITATION - RICHMOND B.C.

TITLE: DRILL HOLE DATA AND DYKE SECTIONS LULU ISLAND NORTHWEST

DATE OF ISSUE: OCTOBER 17, 1969 — APPROVED — PROJECT No. VA1346 — DWG. No. D-1346-7 — REV.



TIME - PACIFIC DAYLIGHT TIME

GRAPHS SHOWING RELATIONSHIP BETWEEN RIVER LEVEL (TIDAL) AND GROUND WATER LEVELS.

TOP OF DYKE

GROUND LEVEL AT DITCH

DITCH WATER LEVEL (CONSTANT DURING OBSERVATIONS)

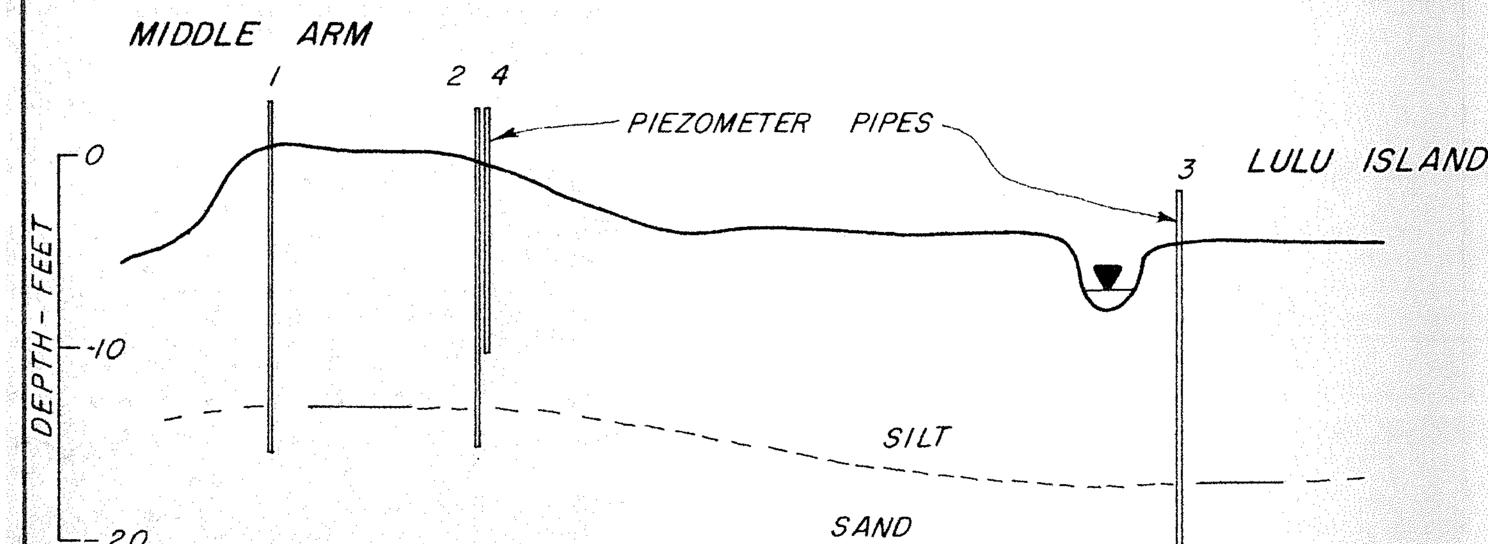
INVERT OF DITCH

SAND-SILT CONTACT BENEATH DYKE

SAND-SILT CONTACT BENEATH DITCH

LEGEND

———	RIVER LEVEL
△—△—△	PIEZOMETER 1 WATER LEVEL
•—•—•	PIEZOMETER 2 WATER LEVEL
o—o—o	PIEZOMETER 3 WATER LEVEL
×—×—×	PIEZOMETER 4 WATER LEVEL



SECTION 1009

SCALE: 1" = 10'. SEE DWG. D-1346-7 FOR COMPLETE DETAILS OF SECTION

PIEZOMETER DETAILS

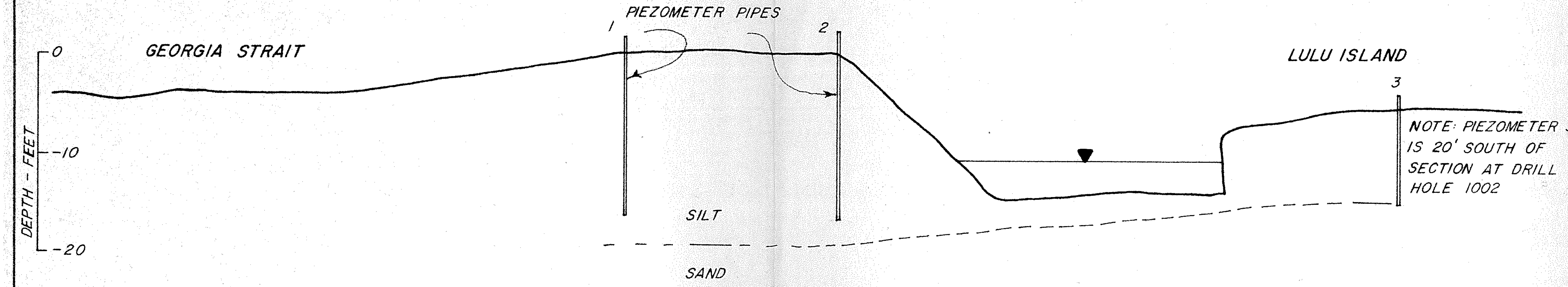
EACH PIEZOMETER CONSISTS OF A 3' SECTION OF PERFORATED 1" DIA. STEEL PIPE WITH A 1" DIA. STEEL RISER. PIPES WERE WASH BORED INTO POSITION.

WATER LEVELS MEASURED USING AN ELECTRICAL CONTACT APPARATUS ACCURATE TO ± 0.01 FT.

ALL WATER LEVEL MEASUREMENTS IN FEET BELOW DYKE CREST AT PIEZOMETER 1.

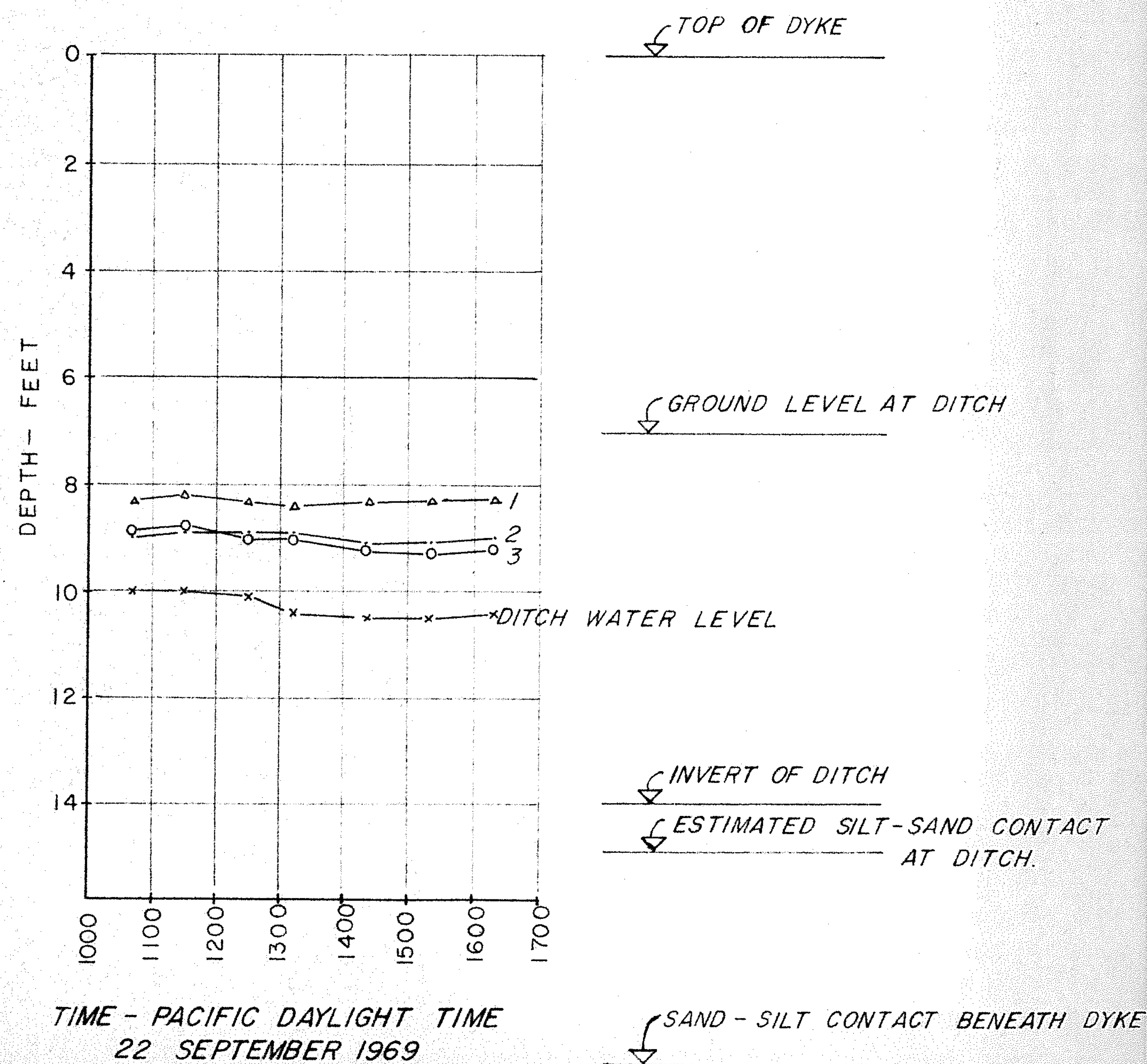
SCALE AS SHOWN

Ripley, Klohn & Leonoff International Ltd. CONSULTING ENGINEERS VANCOUVER — EDMONTON — CALGARY — WINNIPEG — CANADA	DETAILS OF PIEZOMETER INSTALLATION AND WATER LEVEL OBSERVATIONS AT SECTION 1009
CLIENT: FRASER RIVER JOINT PROGRAM COMMITTEE	APPROVED [signature] DATE OCT. 17, 1969 B-1346-8



SECTION 1002

SCALE: 1" = 10'. SEE DWG. D-1346-7 FOR COMPLETE DETAILS OF SECTION



TIME - PACIFIC DAYLIGHT TIME
22 SEPTEMBER 1969

LEGEND

△—△—△ PIEZOMETER 1 WATER LEVEL
·—·—· PIEZOMETER 2 WATER LEVEL
o—o—o PIEZOMETER 3 WATER LEVEL
×—×—× DITCH WATER LEVEL

PIEZOMETER DETAILS

EACH PIEZOMETER CONSISTS OF A 3' SECTION OF PERFORATED 1" DIA. STEEL PIPE WITH A 1" DIA. STEEL RISER. PIPES WERE WASH BORED INTO POSITION.

WATER LEVELS MEASURED USING AN ELECTRICAL CONTACT APPARATUS ACCURATE TO ± 0.01 FT.

ALL WATER LEVEL MEASUREMENTS IN FEET BELOW DYKE CREST AT PIEZOMETER 1.

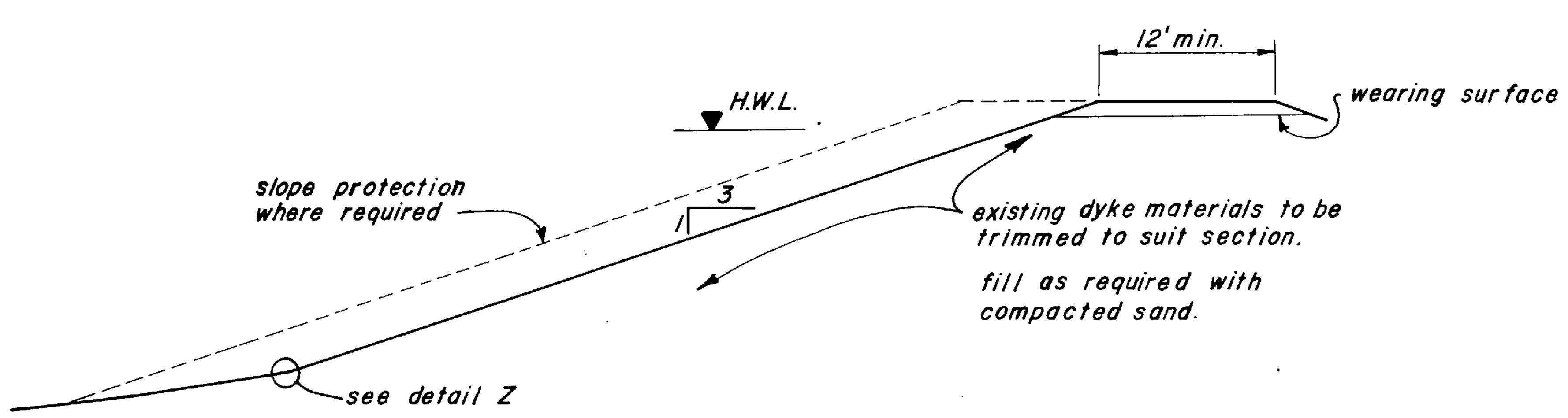
NOTE:

GRAPH SHOWING CHANGE IN PIEZOMETRIC WATER LEVEL IN THE DYKE AT THE WEST END OF FRANCIS ROAD AS A RESULT OF A CHANGE IN DITCH WATER. TIDE LEVELS IN THE STRAIT OF GEORGIA ROSE 11 FEET DURING THE PERIOD OF OBSERVATION BUT DID NOT COME WITHIN 1500 FEET OF THE DYKE.

SCALE AS SHOWN

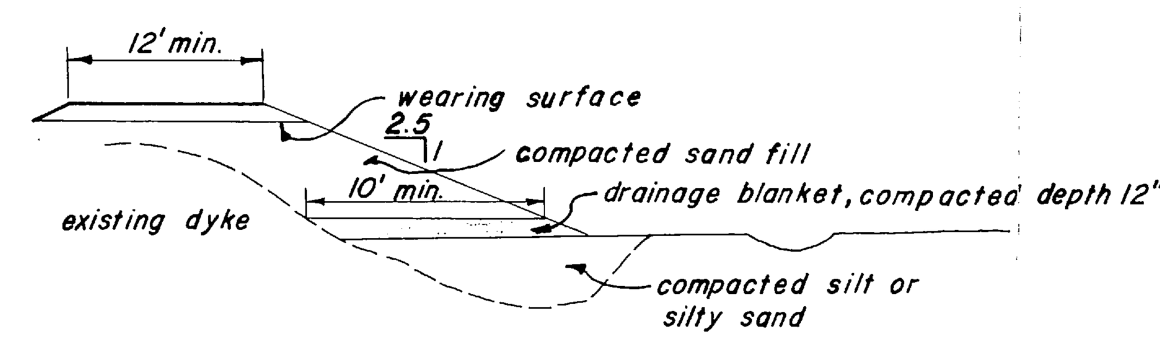
Ripley, Klohn & Leonoff International Ltd. CONSULTING ENGINEERS VANCOUVER — EDMONTON — CALGARY — WINNIPEG CANADA	DETAILS OF PIEZOMETER INSTALLATION AND WATER LEVEL OBSERVATIONS AT SECTION 1002
CLIENT: FRASER RIVER JOINT PROGRAM COMMITTEE	APPROVED: [signature] · DATE: OCT 17, 1969 · B-1346-9

RIVER SIDE

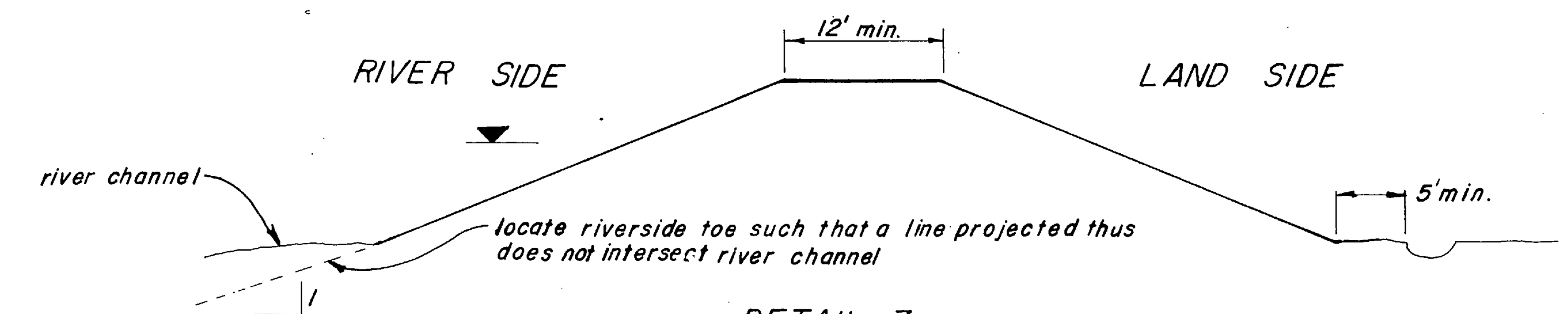


CASE 1 R.S.
use where space is ample

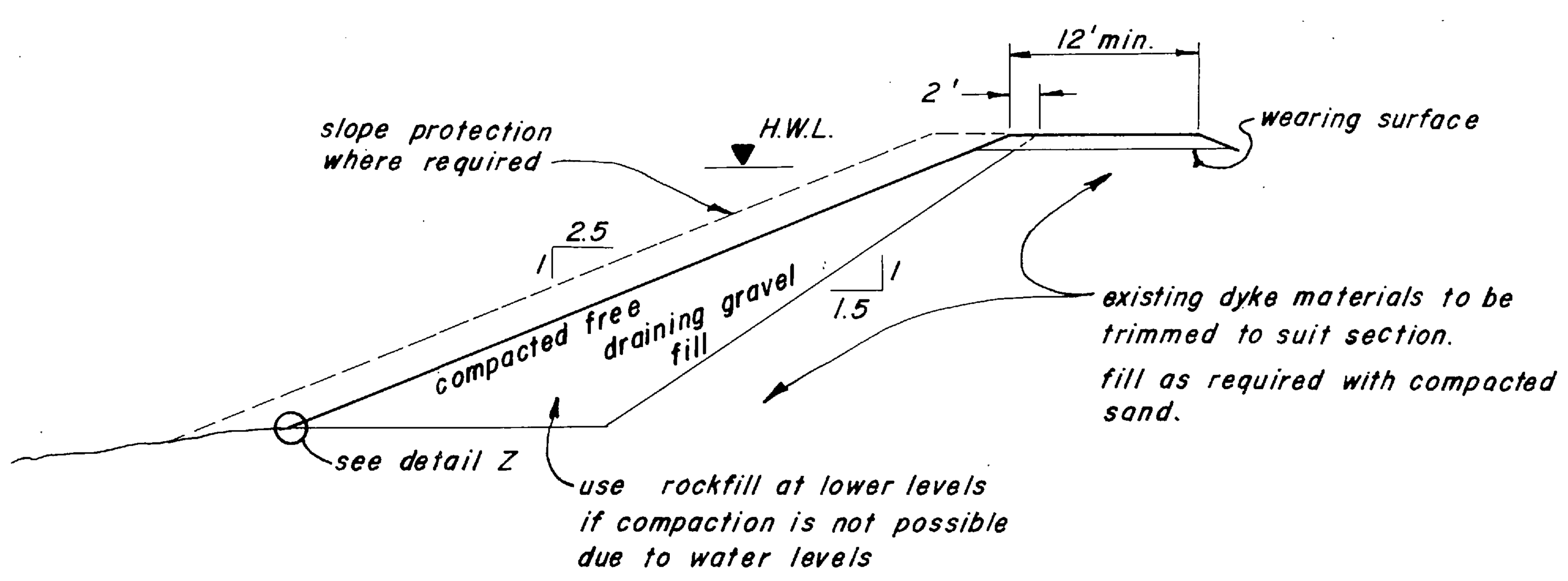
LAND SIDE



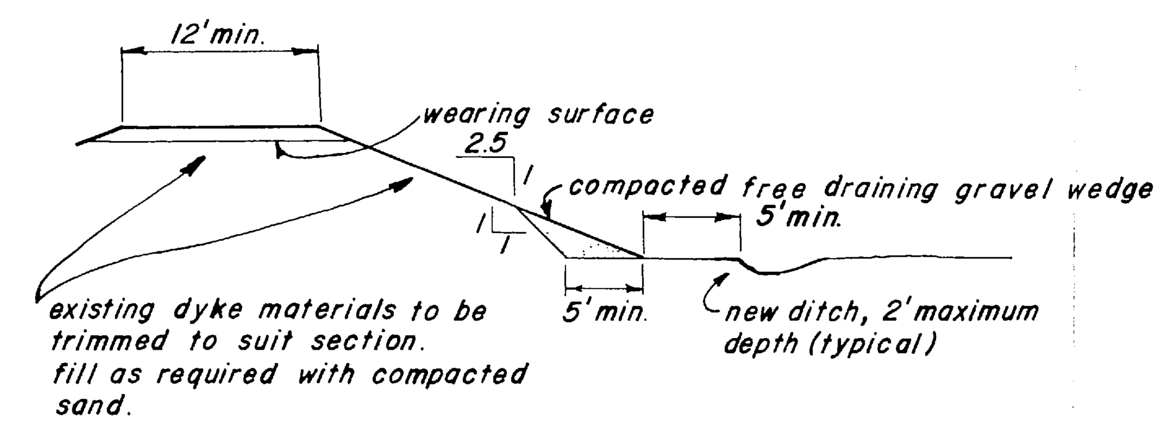
CASE 1 L.S.
use where space is ample
for horizontal toe drain



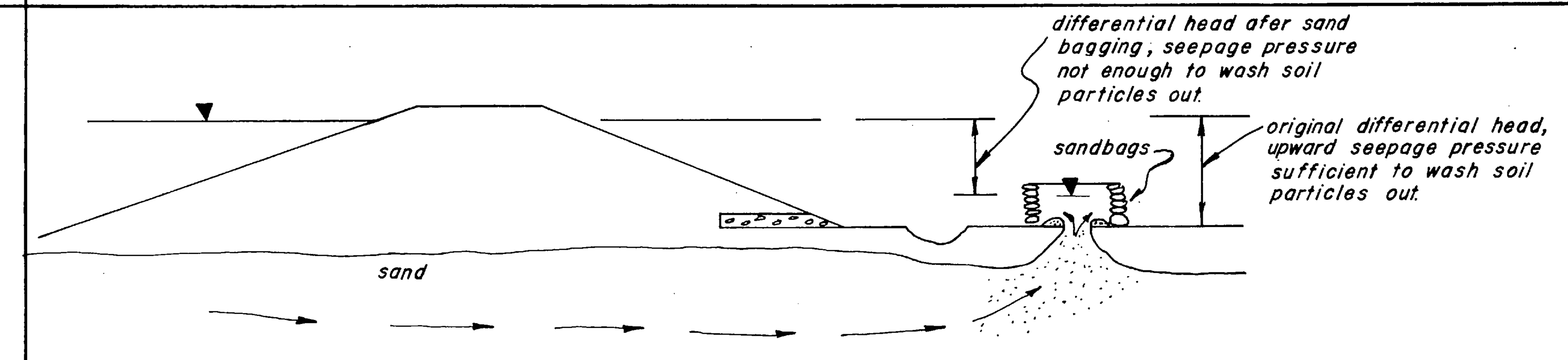
DETAIL Z



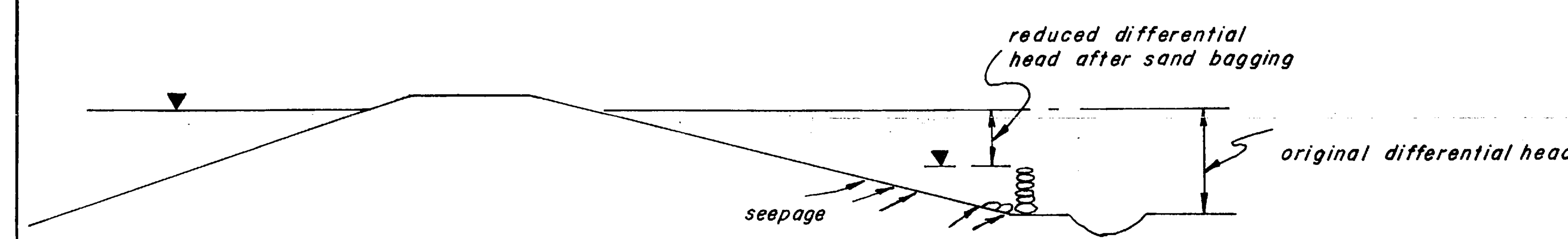
CASE 2 R.S.
used where space is limited



CASE 2 L.S.
use where space is limited
for horizontal toe drain

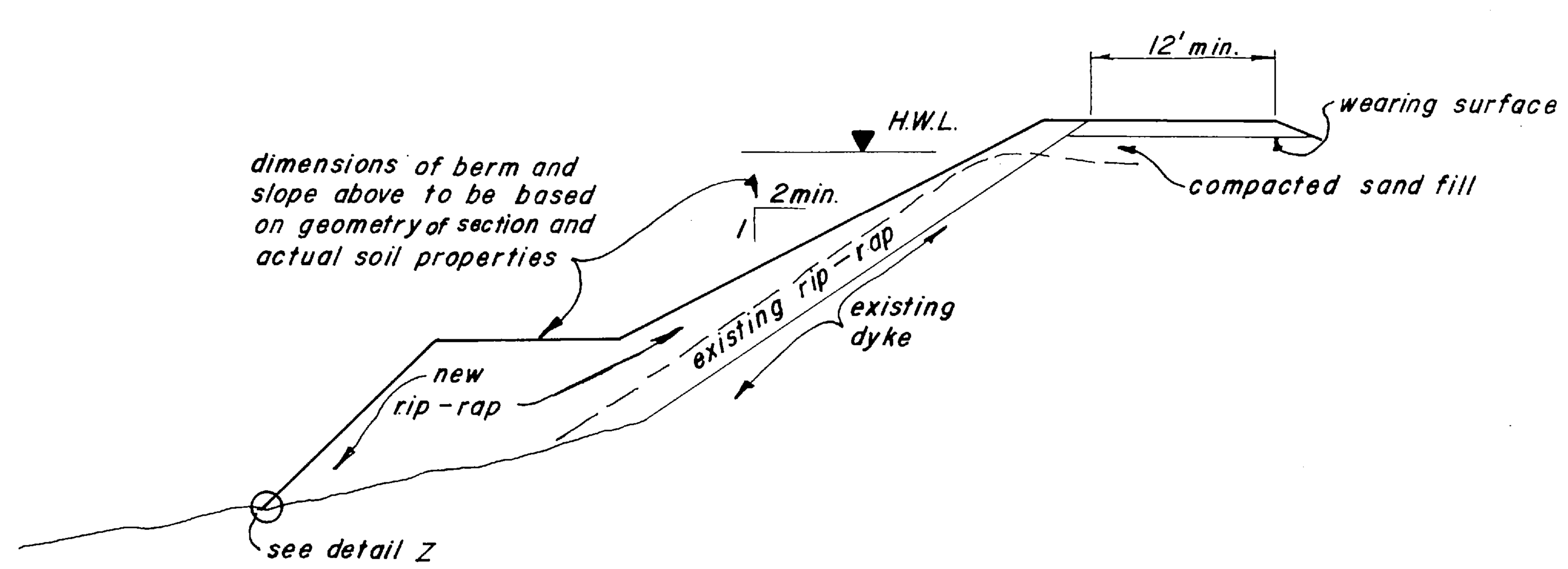


BOIL SURFACE BEYOND DYKE

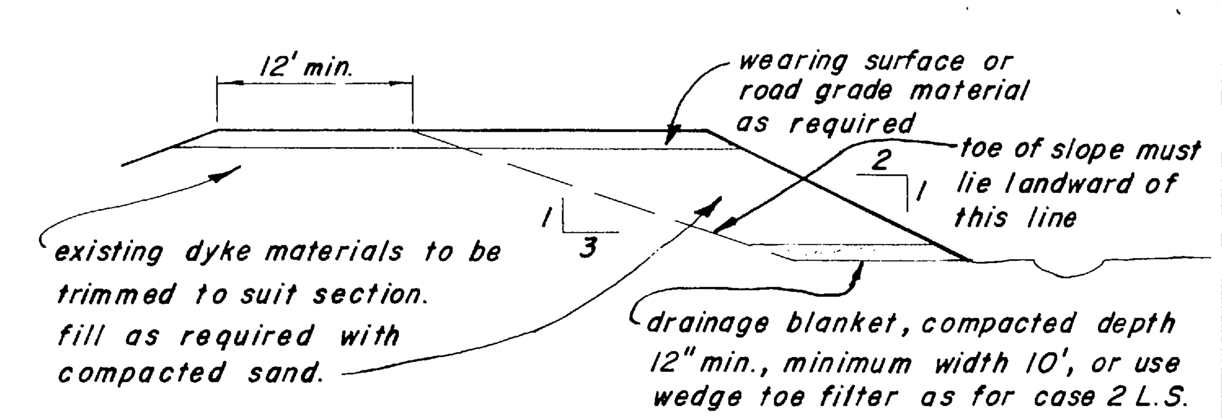


SEEPAGE FROM DYKE TOE

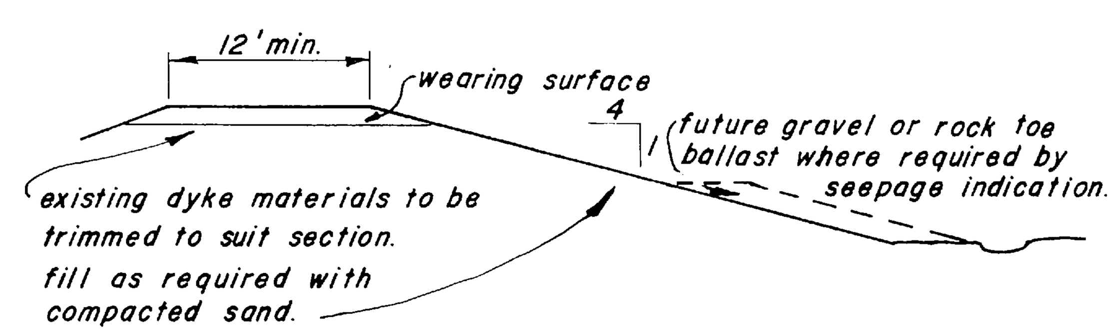
METHODS OF TEMPORARY SEEPAGE CONTROL



CASE 3 R.S.
alternate to case 2 R.S. where rip-rap
is already in place (usually at about
1.5 :1 slope.)



CASE 3 L.S.
use where widened crest required



CASE 4 L.S.
use where space ample

NOTE:
SECTIONS SHOWN ON THIS DRAWING ARE NOT FOR USE ON PEAT OR HIGHLY ORGANIC SILT FOUNDATIONS.

REV. / DATE	REVISION DETAILS
DESIGN	DRAWN E. PHAREY / DATE OCTOBER 17, 1969 / SCALES 1" = 10'
Ripley, Klohn & Leonoff International Ltd. CONSULTING ENGINEERS CANADA VANCOUVER - EDMONTON - CALGARY - WINNIPEG	PROJECT: DYKE REHABILITATION - RICHMOND B.C.
	TITLE: RECOMMENDED DESIGN DYKE SECTIONS
CLIENT: FRASER RIVER JOINT PROGRAM COMMITTEE	DATE OF ISSUE OCTOBER 17, 1969 / PROJECT No. VA1346 / DWG. No. D-1346-10 / REV.