INDIAN AND NORTHERN AFFAIRS CANADA

GRANULAR BORROW AND FILL QUALITY AT SELECTED LOCATIONS CANADIAN BEAUFORT SEA

June 1997

KLOHN-CRIPPEN

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June 18, 1997

Indian and Northern Affairs Canada
Les Terrases de la Chaudiere
Ottawa, Ontario
K1A 0H4

Mr. Bob Gowan

Dear Mr. Gowan:

Granular Borrow And Fill Quality
Canadian Beaufort Sea

We are pleased to submit our report on the Granular Borrow and Fill Quality of Artificial Islands in the Canadian Beaufort Sea. Information on the potential granular resources available in the abandoned islands is also documented in a database which forms part of the BeauFILL software package. The CD Rom containing the database and a set of installation instructions are enclosed with this letter.

If you have any questions on the report, or on the database included in the BeauFILL CD Rom, please do not hesitate to call.

Yours truly,

KLOHN-CRIPPEN CONSULTANTS LTD.

Brian T. Rogers, P.Eng.
Director, Geotechnical Division

BTR/je
Enclosure

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Klohn-Crippen

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS
(continued)

FIGURES

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

1. OVERVIEW

1.1 Background

Since the early 1970's, approximately 40 million cubic metres of granular material have been dredged within the Canadian Beaufort continental shelf to create artificial islands or subsea berms for caisson retained islands and drilling barges. These islands were constructed to provide temporary drilling structures for hydrocarbon exploration. Upon completion of exploratory drilling and after removal of equipment and consumables, these islands have generally been abandoned to natural erosion, or partially scalped and reused at other exploration sites.

The purpose of this report is to document the available sources of good quality granular material in the abandoned islands located in the Canadian Beaufort Sea. The report documents the sea bed borrow locations which were the original source of the fill material and presents more detailed information on the islands in which the coarser fill material was placed. The gradation of the material in the islands is detailed when quality assurance test data is available. The data suggests that there is a gradual loss of the fines compared to the original borrow source when the material is reused. This can be expected due to the dredging and submarine deposition process.

This database was prepared under Contract A7134-5-0015/001/SS on behalf of the Department of Indian and Northern Affairs, Canada, as part of the Northern Granular Resources Program. Mr. Bob Gowan was the scientific officer for the project.

1.2 Information Search

The Klohn-Crippen report titled "Granular Resource Potential of Beaufort Artificial Islands" dated March 1995 was reviewed to assess which of the abandoned islands were most suitable for a more detailed review of the granular materials used in construction, in

terms of information collected at the borrow source(s), during construction, and during post construction investigations.

The 1995 report documented 37 islands in the Canadian Beaufort Shelf which were believed to represent the total number of offshore islands constructed in the area. A tabular listing of the as-built quantities required for each island, the borrow source and a description of the fill material is included in Table 1.1.

Table 1.1 - As-Built Quantities of Beaufort Artificial Islands

No	Island Name	Island Type	Fill Quantity (m^3)	Borrow Site	Primary Fill Material	Secondary Fill Material
1	Immerk B-48	Sacrificial Beach Island	180 000	Local	sand	gravel
2	Adgo F-28	Sandbag Retained Island	46 000	Local, Immerk area	silt	gravel cap
3	Pullen E-17	Gravel Fill Island	65 000	Onshore, Yaya Lakes	gravel	
4	Unark L-24	Gravel Fill Island	44 000	Onshore, Yaya Lakes	gravel	
5	Pelly B-35	Barge Cored Island	35 000	Local, Yaya Lakes	silt	gravel cap
6	Netserk B-44	Sandbag Retained Island	306 000	Pelly Island	sand	
7	Adgo P-25	Sandbag Retained Island	27 000	Local	silt	gravel cap
8	Adgo C-15	Gravel Fill Island	70 000	Onshore, Yaya Lakes	gravel	
9	Netserk F-40	Sandbag Retained Island	291 000	Pelly Pit, Garry Harbour and Spit	sand	
10	Sarpik B-35	Gravel Fill Island	118 000	Onshore, Adgo C-15 area	gravel	
11	Ikkatok J-17	Sandbag Retained Island	38 000	Local	sand	
12	Kugmallit H-59	Sandbag Retained Island	236 000	Tufts Point	sand	
13	Adgo J-27	Sandbag Retained Island	69 000	Local, Netserk B-44 area	silt	gravel cap
14	Arnak L-30	Sacrificial Beach Island	1 150 000	Local	sand	
15	Kannerk G-42	Sacrificial Beach Island	1 150 000	Local	sand	
16	Isserk E-27	Sacrificial Beach Island	1 908 000	Local, Tufts Point	sand	
17	Issungnak O-61	Sacrificial Beach Island	4 100 000	Local, Tufts Point	sand	
18	Issungnak 2-O-61	Sacrificial Beach Island	4 900 000	Issungnak 0-61	sand	
19	Alerk P-23	Sacrificial Beach Island	2 670 000	Local	sand	
20	North Protection Island	Sacrificial Beach Island	2 000 000	Local	sand	
21	West Atkinson L-17	Sacrificial Beach Island	1 000 000	Local	sand	
22	Tarsiut N-44	Caisson Retained Island	1 800 000	Ukalerk, Issigak, Isserk, Herschel	sand	gravel

Table 1.1 - As-Built Quantities of Beaufort Artificial Islands

No	Island Name	Island Type	Fill Quantity (m^3)	Borrow Site	Primary Fill Material	Secondary Fill Material
23	Uviluk P-66	Single Steel Drilling Caisson	1 900 000	Local, Ukalerk, Isserk, Kagluk, Issigak	sand	gravel cap
24	Itiyok I-27	Sacrificial Beach Island	1 943 000	Local, Ukalerk	sand	
25	Nerlerk B-67	Single Steel Drilling Caisson	4 000 000	Ukalerk, Local	sand	
26	Kogyuk N-67	Single Steel Drilling Caisson	1 450 000	Ukalerk, Uviluk P-66, Banks Island, Rufus	sand	gravel cap
27	Kadluk O-07	Caisson Retained Island	450 000	Ukalerk	sand	
28	Amerk Q-09	Caisson Retained Island	1 700 000	Ukalerk	sand	
29	Adgo H-29	Sandbag Retained Island	75 000	Adgo J-27, Sarpik B-35, Kadiuk O-07	sand	gravel cap
30	Nipterk L-19	Sacrificial Beach Island	1 500 000	Issigak, Ukalerk	gravel	sand
31	Tarsiut P-45	Molikpaq	350 000	Ukalerk, Tarsiut N-44, Kogyuk N-67	sand	gravel
32	Minuk I-53	Sacrificial Beach Island	2 000 000	Ukalerk, Issigak, Isserk, Kadluk O-07	gravel	sand
33	Amauligak I-65	Molikpaq	1 410 000	Ukalerk, Kogyuk N-67, Amerk O-09,	sand	gravel toe
34	Arnak K-06	Sacrificial Beach Island	700 000	Local	sand	
35	Kaubvik I-43	Caisson Retained Island	565 000	Ukalerk, Isserk, Issigak	sand	gravel toe
36	Amauligak F-24	Molikpaq	2 000 000	Ukalerk, Amauligak I-65, Minuk I-53	sand	gravel toe
37	Isserk I-15	Molikpaq	72 000	Amauligak I-65	sand	

The 1995 report provided a summary of the approximate quantity of fill material still remaining in the offshore islands after abandonment following completion of drilling activities. This included approximately fourteen (14) million cubic metres of finer gradation sandfill (D_{50} less than about 280 μm) in place in sandbag retained and sacrificial beach abandoned islands. This material was typically obtained from local borrow sources immediately adjacent to the island site, and is not likely to be transported for use in construction of islands at new exploration or development sites. However the sandfill does represent a valuable base resource for potential development at the site specific exploration site.

The higher quality fill material (D_{50} greater than about 280 μm) identified included over four (4) million cubic metres of a mixture of sands and gravel available as a resource in the abandoned offshore islands, Tarsiut N-44, Nipterk I-19 and Minuk I-53, and close to seven (7) million cubic metres of Ukalerk type sand available in the abandoned berms that were used for the CRI, Molikpaq and SSDC deployments.

These islands, which are listed in Table 1.2 and located as shown on Figure 1.1, represent a delineated source of high quality sand and gravel that can be readily used for future construction activities related to exploration or development in the Canadian Beaufort Shelf. These islands have been documented in this report.

An additional 200,000 m^3 of gravel was used in four older gravel filled islands constructed in the 1970's. Due to the limited size of these individual deposits, this resource has not been included in this database.

Table 1.2 - Canadian Beaufort Artificial Islands with Higher Quality Fill

Island Name	Island Type	Latitude	Longitude	Water Depth (m)	Fill Quantity m^3	Construction Date
Tarsiut N-44	Caisson Retained Island	69.896139	136.193470	21.0	1 800 000	1981-82
Uviluk P-66	Single Steel Drilling Caisson	70.263444	132.313280	29.7	1 900 000	1981-82
Kogyuk N-67	Single Steel Drilling Caisson	70.113722	133.328220	28.1	1 450 000	1982-83
Kadluk O-07	Caisson Retained Island	69.780083	136.021250	14.0	450 000	1989
Amerk P-09	Caisson Retained Island	69.982333	133.514778	27.0	1 700 000	1983-84
Nipterk L-19	Sacrificial Beach Island	69.810583	135.298094	11.7	1 500 000	1983-84
Tarsiut P-45	Molikpaq	69.915444	136.418000	25.5	350 000	1984
Minuk I-53	Sacrificial Beach Island	69.709639	136.458860	14.7	2 000 000	1982-85
Amauligak I-65	Molikpaq	70.077694	133.804556	31.0	1 410 000	1985
Kaubvik I-43	Caisson Retained Island	69.875833	135.422028	17.9	565 000	1983-86
Amauligak F-24	Molikpaq	70.054833	133.630250	32.0	2 000 000	1985-87

Data gathering for this project included accessing the following reports from industry and government sources, to provide the granular borrow source and fill quality data.

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- Lewis Geophysical Consultants 1994, "Review of Granular Resource Potential - South-Central Beaufort Targets".

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- Sean Williams FitzPatrick 1986, Insitu State of Beaufort Sea Sandfill Structures, (M.Eng. Thesis 1986) University of Alberta.

Information from the public domain was also reviewed, these sources included the following references:

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- Boone, D.J. 1980. The construction of an artificial drilling island in intermediate water depths in the Beaufort Sea. Proceedings 12th Annual Offshore Technology Conference. Houston, Texas, Paper OTC 3873 pp. 187-195.

- Bruce, J., and Harrington, G. 1982. Design aspects of a mobile arctic caisson. Proceedings, Proceedings, 14th Annual Offshore Technology Conference, Houston, Texas, vol. 3, Paper OTC 4333, pp 405-416.

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2. BORROW AREAS

2.1 General

As discussed in Section 1.2, borrow material was typically obtained for initial island construction from local materials dredged from the seabed immediately adjacent to an island location. The grain size of material from these borrow sources is in the D_{50} = 200 μm range. This severely limits the value of the material for use in future developments, so we have not included information on this resource in this report.

Two major borrow areas have been used for the majority of the construction of the Beaufort Sea artificial islands that contain coarser fill material. These are the Issigak and Ukalerk borrow areas. The latter borrow area has also been called Erksak. The gradation of material at Issigak contains cobble, gravel and sand sizes, which is substantially coarser than that at Ukalerk which generally contains fine to medium sand with a D_{50} of 300 μm. Some fill material was also obtained from the Isserk borrow area. However the material at Isserk is substantially finer than at Ukalerk, with a D_{50} in the range of 200 μm to 250 μm, so this area is not considered a resource for obtaining higher quality fill.

The location of the Isserk and Ukalerk borrow areas are shown on Figure 1.1. The Isserk borrow area is not shown on Figure 1.1, but is located approximately 20 km north of Pullen Island, at about 69°57'N, 134°20'W.

2.2 Ukalerk Borrow Source

The Ukalerk, or Erksak, borrow area has been used as the exclusive source of fill for several islands and has also been used in conjunction with fill from abandoned islands for several others.

Figure 2.1 presents the plan of the area, and includes representative drill holes that show the D_{50} and the percentage of silt in the samples at different depths. However, it should be recognized that the bathymetry shown in Figure 2.1 is that which existed in September 1985 and that, subsequently two million cubic metres of sand were removed from Ukalerk for construction of Amauligak F-24.

In general, the fine grained sand in this location is homogeneous, although local variations in texture were observed. Particle size analyses for the material generally indicated a fines content (less than 75 μm) of less than 7 percent and a median D_{50} of typically between 200 μm and 350 μm. The overall grading envelope for the borehole samples is presented in Figure 2.2. The gradation and fines content of the various samples is given on Figure 2.3.

Some investigations were carried out in 1982 to determine if a northern extension of the pit would provide suitable sand but the material gradation was substantially finer with a D_{50} in the range of 100 μm and 300 μm. The location of the boreholes and the overall gradation envelope for the northern extension are shown on Figure 2.4.

Figure 2.5 shows the histograms of D_{50} and percentage fines obtained from dredge samples taken during fill transportation from the Ukalerk borrow area to Tarsiut P-45 and Amauligak I-65. The preponderance of the samples had D_{50} in the 250 μm to 370 μm range with a fines content between 0.5% and 2.0%. A summary of the typical limits of Ukalerk sand borrow material used in island construction is shown on Figure 2.6 as a plot of D_{50} against fines content. For reference, the typical limits for the Isserk sand borrow material is included in Figure 2.6. A review of the silt percentages for the in-situ Ukalerk borrow area samples shown on Figure 2.3 with the dredge test data suggests a drop in the percentage of silt due to the dredging operation. This is consistent with the visible evidence of silt suspended in the sea during the dredging operation.

2.3 Issigak Borrow Source

The Issigak borrow site is situated on the eastern flank of the Mackenzie Delta on a minor topographic high (Pelly Plain) that was not extensively eroded during sea level fluctuations. The bathymetric contours for the site are given in Figure 2.7.

A geotechnical investigation (EBA 1983) to delineate potential granular borrow material was performed at the site for Esso Resources Canada Ltd. during the summer of 1983. The investigation comprised 125 sampled boreholes and 460 seabed gravity cores. The location of some of the boreholes and typical gradation of the samples are also shown on Figure 2.7.

The general stratigraphy of the area is shown in Figure 2.8. In the Issigak area sporadic surficial deposits of re-worked sand and gravel have been observed overlying the clay and silt. Gravel thickness is as much as two metres. The grading envelopes for all the samples are provided in Figure 2.9.

The amount and maximum size of cobbles has not been accurately measured. EBA personnel who provided quality control monitoring on dredges (EBA, 1983) report that 500 mm (20 inch) boulders have been observed and cobbles up to about 130 mm were most common. The cobbles and boulders in some dredge loads comprised an estimated 5 to 10 percent of the total by weight. Loads that were picked-up at the south end of the deposit generally had a higher ratio of gravel to sand and contained more cobbles, than loads from the northern and eastern parts of the deposit. The fact that the south end of the deposit is coarser is confirmed by the gradation of samples from the borehole logs.

As a result of the investigation the area was divided into Proven, Probable and Prospective resources as shown on Figure 2.10. The proven resources were subdivided into eight

areas, which are also shown on Figure 2.10. These subdivisions were based on the differing percentages of gravel and sand present in the areas.

Between 1983 and 1986, 3.2 million cubic metres of material were excavated from the Issigak borrow area and deposited at Amerk, Nipterk, Minuk or Kaubvik. This had the effect of exhausting the proven reserves in Zones 2, 3 and 4, such that after the 1986 season the proven and probable resources were as shown in Table 2.3.1. Of the proven resources, 37% is estimated to be gravel. The remaining 63% and all probable and prospective resources are sand. The variation in the ratios of gravel to sand from zone to zone based on the 1983 investigation, is shown on Figure 2.10.

For the area lying outside of the Proven Resources, four of nine boreholes showed granular sediments and none encountered gravel. The geological interpretation of this part of the deposit is that most of this material is re-mobilized sand that was washed out of the main deposit during the marine transgression and hence little gravel should be expected in the Probable and Prospective Resource areas.

In years past, several dredging contractors have actively worked this area, to the extent that very little worthwhile borrow remains outside the 9 metre bathymetric contour. Ample evidence of previous dredging activities were noted on sidescan sonar records reviewed during the field program.

Table 2.3.1 Post 1986 Borrow Resource Quantities

Zone	Proven Resources (m^3)	Additional Probable Resources (m^3)	Proven & Probable Resources (m^3)	Additional Prospective Resource (m^3)	Total-Resources All Categories (m^3)
1	364,900	339,200	704,100		
2	-				
3	-	653,000	653,000		
4	-				
5	933,800	361,600	1,295,400		
6	109,900	-	109,900		
7	1,184,700		1,552,300		
8	681,400		870,000		
Totals	3,274,700		5,184,700	702,800	5,887,500

3. ARTIFICIAL ISLANDS

3.1 General

For the purpose of this report, the selected islands have been divided into two categories, those consisting almost entirely of Ukalerk size sand obtained either directly from the borrow source or from other islands and those constructed mainly of gravel and sand from Issigak.

The islands listed in Table 3.1.1, which represent the sources of good quality granular material, are those for which data is given in subsequent subsections of this report.

Table 3.1.1 Selected Beaufort Sea Artificial Islands

Island Name	Island Type	Latitude	Longitude	Water Depth (m)	As-Built Quantity (m^3)	Construction Date
Sand Islands						
Uviluk P-66	Single Steel Drilling Caisson	70.263444	132.313280	29.7	1 900 000	1981-82
Kogyuk N-67	Single Steel Drilling Caisson	70.113722	133.328220	28.1	1 450 000	1982-83
Kadluk O-07	Caisson Retained Island	69.780083	136.021250	14.0	450 000	1989
Amerk P-09	Caisson Retained Island	69.982333	133.514778	27.0	1 700 000	1983-84
Tarsiut P-45	Molikpaq	69.915444	136.418000	25.5	350 000	1984
Amauligak I-65	Molikpaq	70.077694	133.804556	31.0	1 410 000	1985
Amauligak F-24	Molikpaq	70.054833	133.630250	32.0	2 000 000	1985-87
Sand and Gravel Islands						
Tarsiut N-44	Caisson Retained Island	69.896139	136.193470	21.0	1 800 000	1981-82
Nipterk L-19	Sacrificial Beach Island	69.810583	135.298094	11.7	1 500 000	1983-84
Minuk I-53	Sacrificial Beach Island	69.709639	136.458860	14.7	2 000 000	1982-85
Kaubvik I-43	Caisson Retained Island	69.875833	135.422028	17.9	565 000	1983-86

The location of these islands is shown on Figure 1.1.

3.2 Sand Islands

3.2.1 Uviluk P-66

Dome Petroleum constructed an underwater berm at Uviluk P-66 to accommodate a single steel drilling caisson (SSDC) during the 1981-82 open water season. The berm was built in 29.7 m of water on a sandy seabed. Sand was dredged from local borrow sources, as well as from Isserk, Kaglulik South and the Ukalerk borrow and hydraulically placed to create a berm 103 m x 212 m. The SSDC was placed on the berm, and under-filled with sand and gravel for erosion protection. Gravel hauled from Issigak, Banks Island, and Herschel Island was used as a cap on the berm, which rose to 8.0 m below sea level. A total of 1.9 million m^3 of fill was used to construct the berm. Drilling activities continued over the winter, and following completion, the SSDC was released and the island abandoned.

Ukalerk sand used in the construction was reported as having a D_{50} varying between 330 μm and 370 μm. A cross-section through the island is shown on Figure 3.1.

3.2.2 Kogyuk N-67

The Kogyuk N-67 berm was initially constructed in 1982 by Gulf to support the Molikpaq. The seabed, which consisted of a surficial clay overlying sand was excavated to a depth of 1.5 m over an area, 180 m x 180 m. Approximately 643 000 m^3 of sand for Ukalerk were then placed, primarily through the drag-arms of the Geopotes IX.

In 1983, the berm was raised by Canmar to support the SSDC by the addition of a further 805 000 m^3 of fill material largely from Ukalerk and the abandoned Uviluk island. Most of this material was placed by bottom-dumping but some 66 000 m^3 were placed by the Canmor Constructor around the perimeter to produce 5H:1V slopes. The final berm elevation was -9 m, as shown on a typical cross-section of the island on Figure 3.2.

A bathymetric survey conducted on 29 August 1985 after abandonment of the island is shown on Figure 3.3. This survey was taken after material was removed for construction activities at Tarsiut P-45. It should be noted that subsequent to this survey, approximately 280 000 m^3 was removed for the construction of Amauligak I-65.

The gradation and fines content of the material from Ukalerk which was deposited at the island in 1982 is shown on Figure 3.4. This material filled the sub-cut and raised the island to Elevation -20 m.

During 1983, as the island was raised to Elevation -9 m to accommodate the SSDC, material was obtained from the Abandoned Uvikluk P-66 berm in addition to the Ukalerk borrow area. Toe protection was imported from Banks Island and the South Tarsiut (Issigak) borrow area. Figure 3.5 shows the volumes and the gradation of the materials from each source obtained from dredge samples in 1983. Similar information is also provided on Figure 3.6 for the D_{50} and the fines content from each source and indicates how material quality varies from one dredge to another and from dredge sampling location.

After completion of the island, instrumentation was installed from the deck of the SSDC. During the drilling which took place, samples were taken and their gradation and fines content determined. The results of this testing are shown on Figure 3.7 where they are compared with the overall results from the quality assurance conducted on the dredges during the 1983 construction program.

Despite the visual evidence from the plume of discloured water, that fine material is lost at every dredging and deposition activity, the evidence from the plots on Figure 3.7 shows an apparent increase in fines content. This is explained as being caused by drilling mud

contamination. The samples from the instrumentation holes show a tighter envelope for the D_{50}, with less than 10% of the material having a D_{50} of less than 300 μm.

In 1984 and 1985, material from Kogyuk was used in the construction of Tarsiut P-45 and Amauligak I-65, respectively. Figures 3.8 and 3.9 show the gradation and fines content of material obtained from samples taken on the dredges. Comparison of the information on Figures 3.6 and 3.8 indicates an increase in mean D_{50} from 320 μm to 335 μm as a result of deposition at Kogyuk N-67 and the subsequent dredging for transportation to Tarsiut P-45. Similarly a decrease in the mean fines value from 1.4% to 0.9% can be seen from a comparison of Figures 3.4 and 3.8. A similar increase in D_{50} and decrease in fines content can be seen on Figure 3.9 for the material enroute to Amauligak I-65.

3.2.3 Kadluk O-07

Kadluk O-07 was constructed by Esso in the 1983 open water season in 14.0 m of water, on 2 m thick soft clay overlying firm clay in the Ikit Trough. A sand berm was built to within 9 m of the waterline, and Esso's CRI was placed on the berm and in-filled with sand. The sand berm had an average slope of 1V:24H. The placement of this berm was accomplished exclusively by bottom dumping using the trailer suction hopper dredge, the W.D. Gateway. The berm required 450 000 m^3 of sand fill which was dredged from the Ukalerk borrow pit and hopper placed on the site. Drilling activities took place over the winter of 1983-84 and the island was subsequently abandoned, with the removal of the CRI.

The material in the island varied between a D_{50} of 290 μm and 360 μm, generally being in excess of 300 μm. The silt content varied between 2% and 4%. It should be noted that the information is based on a limited quality assurance program. A typical cross-section of the island is shown on Figure 3.10. The as-built survey is shown on Figure 3.11.

3.2.4 Amerk P-09

The Amerk well site was located 40 km offshore in the Kugmallit Channel in a water depth of approximately 27 m. The seabed at Amerk consists of a 6 m thick soft clay layer underlain by a further 12 m of unfrozen soft to firm clay. Below this 18 m depth, the foundation soils are competent and frozen.

The original design, prepared by Hardy & Associates (1982), required the removal of the top 18 m of material over an area approximately 150 m x 150 m centrally located directly beneath the island surface. This excavation was commenced in 1983 but only advanced to an average depth of 6 m, with local excavations to 9 m, as the dredging equipment could not excavate the firm clays beyond that depth.

Construction of the berm took place over the 1983-84 open water seasons, during which 1.5 million m^3 of sand fill was excavated from the Ukalerk borrow area transported and placed on the site by hopper suction dredge. The berm rose to within 9 m of sea level and had a top surface 128 m in diameter. The CRI was placed on the berm, and the centre was filled with sand. After drilling over the 1984-85 winter season, the rig was released in March 1985, and the island was subsequently abandoned with the removal of the CRI.

Sampling of the material on board the dredges was extensive and resulted in the histogram of D_{50} shown on Figure 3.12. The bulk of the D_{50} fell between 250μm and 320 μm. Unfortunately fines content information is not available.

Figure 3.13 shows a typical cross-section through the island. The most recent, 1985 survey of the location is shown on Figure 3.14.

The histogram presented in Figure 3.15 was developed from testing of samples on dredges as material was salvaged from Amerk P-09 for transportation to Amauligak I-65. A comparison of Figures 3.12 and 3.15 demonstrates the improvement to be expected in D50 values occurred by placement in an island and subsequent redredging.

3.2.5 Tarsiut P-45

Tarsiut P-45 was the first deployment site for Gulf's Molikpaq drilling structure. The Molikpaq, a reusable 110 m octagonal steel caisson, was in-filled with sand on a pre-constructed berm The berm was built in 1984 on the Kringalik Plateau in a water depth of 25.5 m. The original seabed conditions consisted of stiff clay and silt overlain by soft clay. A total of 113 830 m^3 of the soft clay was subcut from the foundation area by trailer suction hopper dredges. A total of 400 000 m^3 of sandfill was bottom discharged to fill the subcut, to create the 140 m square berm and to in-fill the Molikpaq core. The berm surface was 19.5 m below sea level and had side slopes ranging from 7H:1V to 15H:1V. Ukalerk and North Ukalerk borrow areas and the abandoned islands, Tarsiut N-44 and Kogyuk N-67, were dredged for sand fill. The island was used for drilling over the 1984 winter, and was abandoned in September 1985 when the Molikpaq was removed and towed to the newly constructed berm at Amauligak I-65.

Figure 3.16 shows a typical cross-section of the island after construction. Figure 3.17 shows the bathymetric survey of the berm prior to setting down the Molikpaq in September 1984.

The gradation and fines content of samples taken on the dredges from the two borrow sources are shown on Figure 3.18 and those from abandoned islands on Figure 3.19.

Figure 3.20 summarizes data on fill material from the dredges from all sources. The data is divided into two categories which separate material deposited in the berm from that deposited for in-filling the core of the Molikpaq. Core fill did not include material from Tarsiut N-44.

3.2.6 Amauligak I-65

The berm at Amauligak I-65 was built by Gulf in the 1985 open water season to support the Molikpaq drilling structure. The island was built in 31.0 m of water in the Kugmallit Channel physiographic region. Site conditions consisted of surficial soft clay overlying fine sand. A total of 440 000 m^3 of soft clay was subcut from the foundation area using trailer suction hopper dredges. A total of 1 408 000 m^3 of fill was used to fill the subcut, build the berm and in-fill the core. Sand was dredged from the Ukalerk borrow area and the abandoned Kogyuk N-67 and Amerk P-09 islands. The sand contained 1% to 1.5% fines with an average D_{50} of 320 μm. The completed berm had a 140 m square surface 19.5 m below the waterline sloping away at about 7H:1V to the seabed. The Molikpaq was placed on the berm and the core in-filled with sand to 1.5 m above sea level. Gravel excavated from the Issigak borrow area was used as toe protection. Due to adverse ice conditions and accelerated schedule, four dredges, the Geopotes X, IX, WD Gateway, and Cornelis Zanen were used. Several wells were drilled and tested from this platform in 1985 and 1986 before abandonment. The Molikpaq was released from Amauligak I-65 in September 1986. The abandoned Amauligak I-65 berm was used as a borrow source for Molikpaq core fill at Amauligak F-24 and Isserk I-15.

A typical cross-section of the Amauligak I-65 island is shown on Figure 3.21. The most recent bathymetric survey of the island made in 1989 prior to construction operations for Isserk I-15 is shown on Figure 3.22. During the course of construction, samples were taken on the dredges. The volumes of fill taken from the Ukalerk borrow source and from

the Kogyuk and Amerk abandoned islands together with the gradation and fines content from those sources is shown on Figure 3.23. The same gradation data is shown on Figure 3.24, presented in two categories as berm fill and core fill.

Figure 3.25 shows the D_{50} and fines content of the same fill material based on sampling in the dredge while enroute in 1987 to Amauligak F-24 for use as fill for the core. The mean D_{50} of this material is 360 μm, with a mean fines content of 0.5%.

Figure 3.26 presents gradation envelopes for the same in-situ Amauligak I-65 material as it was I-15 being transported to Isserk I-15. The medium D_{50} of material sampled from the dredge hopper during transport is 330 pm, with a mean fines content of 0.3%. The medium D_{50} samples from the borehole on the Molikpaq is 450 pm, with a fines content of 1.7%. The higher D_{50} is consistent with the borehole location which is adjacent to the discharge point at the centre of the core. The coarser material is likely to remain in the vicinity of this location. The slightly higher fines content is attributed to drilling mud contamination.

3.2.7 Amauligak F-24

The berm at Amauligak F-24 was built in 32.0 m of water to support the Molikpaq structure. Located in the Kugmallit Channel, foundation conditions consisted of soft clay overlying fine sand. A 12 m deep subcut with 5H:1V side slopes was required to remove 806 605 m^3 of soft clay from the foundation area which was subsequently in-filled with sand from the Ukalerk borrow area in 1987 and the berm was built using material from Ukalerk and the abandoned Minuk Island. The Molikpaq was placed on the berm at a draft of 15.8 m and in-filled with sand dredged from the Amauligak I-65 abandoned island. The sand in the core was 4.8 m above sea level after fill densification. Two million cubic metres of sand was required for the subcut, berm and core. The sand fill in the berm

contained 1.7% fines and had a D_{50} of 310 μm, while the core had sand fill with 0.5% fines and a D_{50} of 360 μm. Gravel from Minuk I-53 was used in the shoulders of the berm and as toe protection. The rig was released in September 1988 and the island was abandoned by removing sand from the core and refloating the Molikpaq. A survey on August 17, 1989 indicated that the abandoned berm surface was at 10.2 m below sea level.

A typical cross-section of the island is shown on Figure 3.27. The 1989 bathymetric survey is given on Figure 3.28.

The sand fill from Ukalerk, for deposition in the subcut and berm and from Amauligak I-65 for filling the core of the Molikpaq was sampled during operations. The results of the testing and the volumes obtained from each source are shown on Figure 3.29. Similar information for the gravel from Minuk I-53 which was used in the crest of the berm and around the toe of the structure is given on Figure 3.30.

3.3 Sand and Gravel Islands

3.3.1 Tarsiut N-44

Tarsiut N-44 was the first sub-sea berm in the Beaufort Sea, built by Dome Petroleum Ltd. in 1981. The berm was built in 21.0 m of water on Kringalik Plateau. The local seabed consisted of soft clay overlying stiff clay and silt. A three metre subcut was required to remove the soft clay from the foundation area prior to fill placement. The berm was constructed using 1.8 million cubic metres of both sand and gravel excavated from the Issigak (South Tarsiut) borrow area and sand from the Ukalerk borrow pit, bottom dumped on the site. Gravel from Herschel Island was placed on the 170 m diameter berm crest as a one metre cap. The finished berm was 6.5 m below sea level. Concrete caissons were placed on the berm to retain a core zone of sand and provide erosion protection and a working surface for drilling operations. The caissons were in-

filled with sand hauled from the Ukalerk borrow pit, creating the working surface. The berm was upgraded in 1982, by adding 10 000 m^3 of riprap scour rock with an average size of 1 m diameter around the berm to protect it from wave action. The island was abandoned in 1984.

A typical cross-section is shown on Figure 3.31 and the bathymetric survey from 1984 is given on Figure 3.32. A typical gradation of the sand used for construction of the island is given on Figure 3.33. The berm was reported to contain 5% clay ball contamination.

When the island was abandoned, an exploration of the northern side of the island was undertaken to determine the quality of the material for use at Tarsiut P-45. The location of the boreholes is on Figure 3.32. The gradation and fines content from the borehole samples is presented on Figure 3.34.

During transport of this fill material to Tarsiut P-45, samples were taken and tested on the dredge and the results of these tests form a portion of Figure 3.19 which is included under the Tarsiut P-45 subcut.

3.3.2 Nipterk L-19

Nipterk L-19 was a sacrificial beach island built by Esso in the 1983 and 1984 open water seasons. Located in 11.7 m of water in the Ikit Trough, the seabed consisted of soft clay overlying firm clay. A total of 1.5 million m^3 of Ukalerk sand and Issigak sand and gravel was hopper placed to create an island with a 110 m diameter working surface at a 5 m freeboard. Island dimensions included a 170 m diameter at waterline and 370 m diameter base area. The material was bottom dumped in 1983 to an elevation of 8 m below mean sea level using material from Ukalerk and Issigak. In 1984, a bow spreader method was used to bring the island to sea level and a nozzle was used to complete construction using

mainly Issigak gravel. Slopes of 3H:1V were maintained above waterline, while the beach and base had 8H:1V and 4H:1V slopes, respectively. Two wells were drilled from this platform over the 1984-85 winter and spring seasons. The island was originally names Nipterk I-19, but was renamed to L-19 based on re-evaluated seismic data.

The Ukalerk material sampled on the dredge had a D_{50} of 300 μm and a 2% fines content. The D_{50} from Issigak was 1500 μm with a fines content of 0.5%. A typical cross-section of the constructed island is shown on Figure 3.35. The latest bathymetric survey from July 1990 is shown on Figure 3.36.

3.3.3 Minuk I-53

When construction at Minuk I-53 started in September 1982, it was Esso's intention to use it as the foundation for the first use of its steel caisson retained island (CRI) and, during 1982 and 1983, Ukalerk sand was bottom-dumped to produce a sand berm to Elevation -9 m. When the CRI was subsequently located at Kadluk O-07, Minuk I-53 was converted to a sacrificial beach island. In 1984, 914 500 m^3 of material was placed on the island to bring it to Elevation +1 m. The majority (71%) of this material was obtained from Issigak. The abandoned Kadluk O-07 provided 11% of the material; 9% came direct from Ukalerk and 9% from Isserk. The island was topped off in 1985 using nozzle discharge of Issigak gravel. However, the island was severely damaged by a major storm in the latter part of that open water season, resulting in the loss of the drilling rig and associated equipment. Repair was effected in 1985 and the drilling operations were carried out over the ensuing winter season.

Minuk I-53, in 14.7 m of water, is founded on a soft clay overlying a firm clay on the Kringalik Plateau. Construction of the island required approximately 2 million m^3 of fill.

It had a 110 m diameter working surface at a 5 m freeboard. The freeboard slope was 2H:1V with a surrounding gravel beach at 15H:1V.

Median D_{50} and fines contents as measured in the dredges for material from the various sources in 1984 are given below.

Source	D_{50} (μm)	Fines (%)
Issigak	3129	0.7
Ukalerk	310	1.2
Isserk	243	2.2
Kadluk O-07	351	2.4

A typical cross-section of Minuk I-53 is shown on Figure 3.37. The most recent bathymetric survey from July 1990 is shown on Figure 3.38.

3.3.4 Kaubvik I-43

Esso constructed the caisson retained island at Kaubvik I-43 during the 1983 to 1986 open water seasons in 17.9 m of water. Located in the Ikit Trough, the local seabed consists of soft, silty clay overlying firm clay. A glory hole was excavated in the seabed prior to berm construction. Sand and gravel totaling 566 000 m3 was dredged from the Ukalerk, Issigak and Isserk borrow pits using trailing suction hopper dredges and bottom dumped on the site. The berm was built to within 9 m of the waterline with a top surface 90 m in diameter. Slopes of 12H:1V were maintained. The caisson toe protection material was pipeline placed Issigak material.

The location was hit by a summer storm when the geotechnical instrumentation program was underway. No ponding of water was observed due to wave overtopping indicating free draining nature of the fill material in the core of the CRI. The storm lasted for approximately 10 hours. The island was used for drilling over the fall of 1986, and

abandoned in 1987. During deballasting, the sand core was partially removed, leaving a berm 1 m below the waterline.

The majority of the material used in the construction was obtained from the Issigak pit, though some material was obtained from Ukalerk, Isserk and the abandoned Kadluk O-07 berm. Given that the majority of the material was from Issigak, and based on previous experience with the other sources, no quality assurance was undertaken. A typical cross-section of the island is shown on Figure 3.39. The latest bathymetric survey from July 1990 is shown on Figure 3.40.

4. RESOURCE POTENTIAL OF BORROW SOURCES AND ARTIFICIAL ISLANDS

4.1 Material Quantities in Ukalerk and Issigak Borrow Areas

The Issigak pit is considered to have a minimum 1.2 million cubic metres of gravel and 4 million cubic metres of sand still available for future offshore construction. However, some restrictions exist in its exploitation as the reserves are generally located in water depths less than nine metres.

The most recent survey of the Ukalerk borrow source was conducted on September 27, 1985 prior to the removal of 2 million cubic metres of fill material for the construction of Amauligak F-24. None of the reports reviewed for this study give an indication of the reserves of granular material available at Ukalerk. However, it is anticipated that a considerable quantity of sandfill is still available from the borrow area.

4.2 Material Quantities in Abandoned Islands

A summary of the approximate quantities of sand and gravel material remaining in each of the abandoned artificial islands covered by the study is presented in Table 4.1.1. This data is based on the most recently available bathymetric surveys. Shown on the table are the date of the latest survey, the water depths, the average fill gradation and notes on constraints which may limit the usefulness of these islands as sources of borrow material.

As noted earlier, the quality of material varied from site to site, therefore the islands with similar material types have been grouped together. Fill quality in the sand islands is very consistent, with a D_{50} in the range of 310 μm to 360 μm, and typically less than 1.5% fines. Fill gradation in the sand and gravel islands varies considerably due to the different borrow sources used, but typically includes fill with a D_{50} between 300 μm and 3000 μm, with less than 2.5% fines.

Table 4.1.1 Material in Abandoned Islands

Island Name	Island Type	Water Depth (m)	Date of Survey	Depth to Island (m)	Approximate Fill Quantity (m)	Fill Gradation		Constraints to Utilization
						D_{50} µm	Fines %	
Sand Islands								
Uviluk P-66	Single Steel Drilling Caisson	29.7	-	>9	1 500 000	330 - 370	(a)	Minimal
Kogyuk N-67	Single Steel Drilling Caisson	28.1	08/29/85	8.0	1 000 000	320	1.4	Minimal
Kadluk O-07	Caisson Retained Island	14.0	-	?	300 000	290 - 360	2.4	Minor Drilling Debris
Amerk P-09	Caisson Retained Island	27.0	19/10/85	9.0	1 000 000	315	(a)	Minor Drilling Debris
Tarsiut P-45	Molikpaq	25.5	1985	>10	300 000	315 - 400	1 - 1.5	Minimal
Amauligak I-65	Molikpaq	31.0	18/17/89	16.0	900 000	310 - 350	1 - 1.5	Minimal
Amauligak F-24	Molikpaq	32.0	08/17/90	10	1 600 000	310 - 360	0.5 - 1.5	Minimal
TOTAL					6 600 000			
Sand and Gravel Islands								
Tarsiut N-44	Caisson Retained Island	21.0	09/14/84	6.5	1 500 000	300 - 780	1 - 5	Piles/Clay and Rock Content
Nipterk L-19	Sacrificial Beach Island	11.7	07/90	2.0	1 000 000	300 - 1500	0.5 - 2	Minor Drilling Debris
Minuk I-53	Sacrificial Beach Island	14.7	07/90	awash	1 500 000	240 - 3100	0.7 - 2.4	Drilling Debris and Potential Contaminants
Kaubvik I-43	Caisson Retained Island	17.9	07/90	4.5	400 000	(a)	(a)	Minor Drilling Debris
TOTAL					4 400 000			

(a) No records found.

4.3 Constraints to Resource Utilization

There are various constraints to accessing the granular materials remaining in place in abandoned artificial islands. Key constraints include the following:

Water Depth: Dependent on the construction equipment available, islands in very shallow water and also those in deeper water may not be accessible. Most of the dredges used in the Beaufort Sea area in the 1980's had a water depth range between 8 m to 40 m. For sites shallower than 8 m, vessels were unable to fully load their hoppers. For sand deposits at depths greater than 40 m, the drag arms were too short. In addition, the smaller islands in shallow water have a greater proportion of material contaminated by local seabed soils.

Obstructions: In the case of sacrificial beach islands particularly, a considerable amount of drilling debris remains on, or close to, the abandoned island surface. This represents a major hazard to equipment used to retrieve the granular material. In other cases, rock filled gabions, sandbags or other erosion protection measures may result in a hazard to equipment accessing to the granular material.

Contaminants: The islands were used as drilling platforms and near surface material may have been in contact with drilling fluid tanks, oil storage tanks and other drilling chemicals. A concern with retrieving granular material from old islands is that the dredging process may release contaminants into the ocean. The extent of this issue will vary considerably from site to site. It is not expected to be an issue at the Molikpaq or SSDC sites where drilling rigs were self-contained on the structure. However, for islands such as Minuk I-53, which suffered storm damage, the potential for contaminants is higher.

4.4 Environmental Factors Causing Island Erosion

Several environmental processes active in the Beaufort Sea are responsible for causing ongoing island erosion. These include:

- extreme storm events
- winds and near bottom currents

- ice scouring, and
- sediment slumping

Extreme storm events are widely regarded as being the process most influential in island erosion. Wind is the driving force behind waves and near bottom (non tidal) currents. The dominant wind directions in the open water season are easterly and north-westerly. The stronger north-westerly winds are most often associated with storm events. The dominant island accretion direction is toward the southeast, indicating the north-westerly storm winds appear to be generating bottom currents which erode sediment from the northwest inclined face and island top and deposit it along the southeast face. In the absence of significant winds, however, currents are low, reducing the potential for sediment transport.

The most important mode of sediment transport appears to be bedload transport associated with storm-driven winds and currents. Bedforms occur on top of the islands, along the island margins and on the surrounding seafloor. They range in scale from centimetres to several metres in wavelength; and are best developed on sand and gravel islands. During extreme storms, where wave heights become limited by water depth, the erosion effects increase with depth. This is reflected in the increased rate of submergence observed with water depth. Most submergence occurs within the first few years of abandonment, hence an extreme storm immediately after abandonment would have a much greater impact on the erosion of the island than an extreme storm event several years later.

Sediment slumping has occurred on two islands in zones of sediment depletion. It appears to play a very minor role in sediment transport.

A local ice scour regime can be observed at a number of the abandoned islands, with several sites displaying intense scouring on the north side, which abruptly terminates on

the island margin. In contrast, scouring is absent or light along the south margin. The islands appear to have altered the scouring pattern and have produced a shadow zone relatively protected from scours. Ice scouring appears to plow the surficial veneer of coarse material on the berm face, thus exposing the underlying sand which is more prone to transport. Despite this, ice scouring appears to be only a minor factor affecting island degradation.

The submerged islands are, and will continue to be, a major granular borrow resource. Comparison of the resource potential of the oldest islands indicates that the volume of material erosion decreases from about 10% of the island volume in the first five years to 5% in the second five years, stabilising once the island surface is at least 5 metres below sea level.

Large areas of the islands are undergoing sediment depletion, but the sediment is deposited in specific directions resulting in a gradual migration and elongation of the islands rather than sediment loss from the island site. However, some sediment continues to be lost from the island as sediment is transported in suspension beyond the limits of an island and deposited in a thin blanket on the seafloor.

5. CLOSURE

This report archives information on the main borrow areas, Ukalerk and Issigak used in the Canadian Beaufort Sea, and identifies that approximately 11 million cubic metres of delineated sand and gravel are available as a granular resource in 11 abandoned island sites. The mean D_{50} for this resources is 300 micron or coarser, with fines contents in the range of 0.5% to 2%. This report documents the expected gradation for the fill available in each of the eleven (11) abandoned islands selected.

Constraints to utilization of this potential resource have been identified, together with comments on possible losses to the abandoned island fill quantities due to sediment transport. These losses will be small on an annual basis once the island surfaces have eroded to depth of about 4 metres to 5 metres below mean sea level.

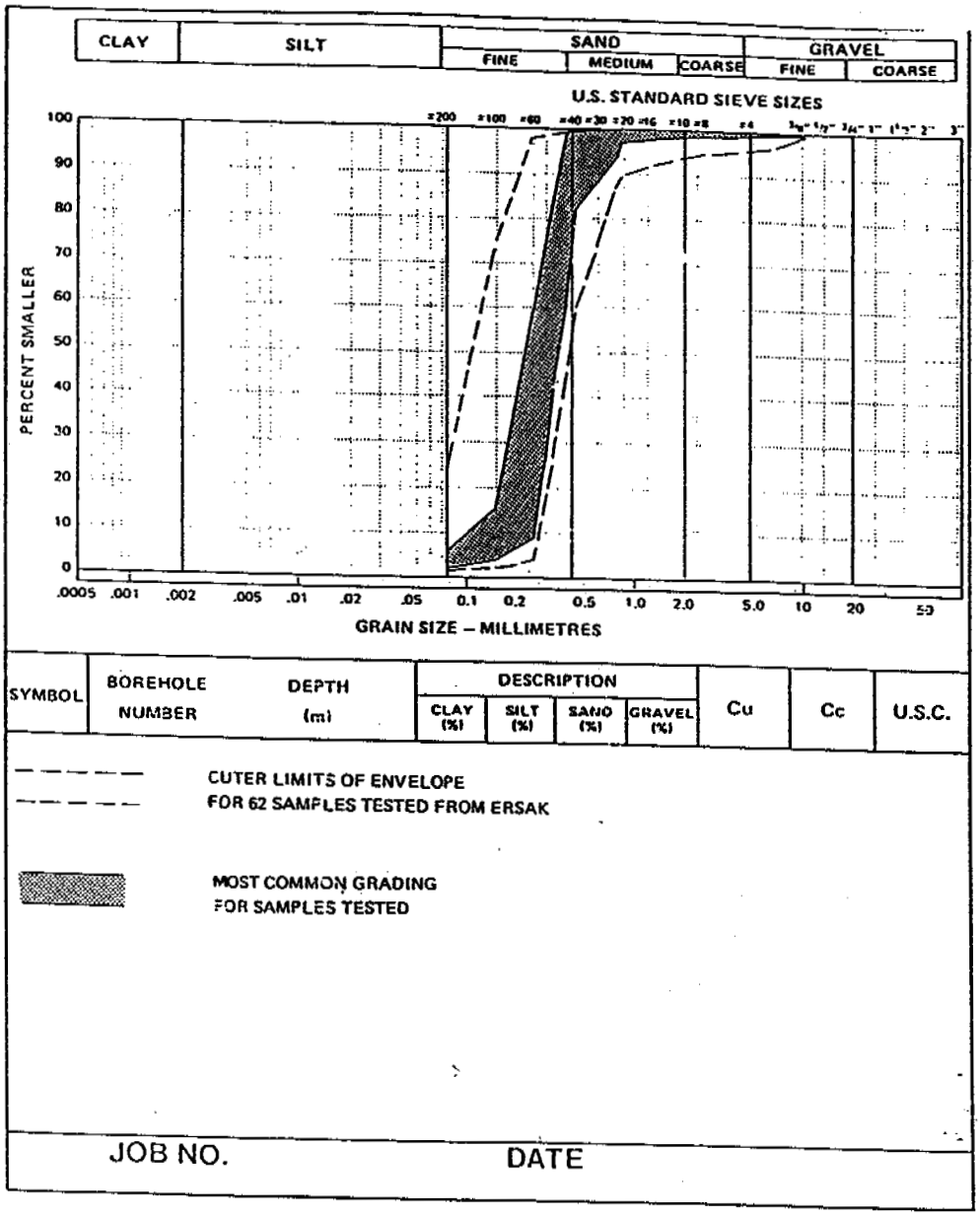
Respectfully submitted,

David James, P.Eng.
Civil Engineer

Brian T. Rogers, P.Eng.
Project Manager

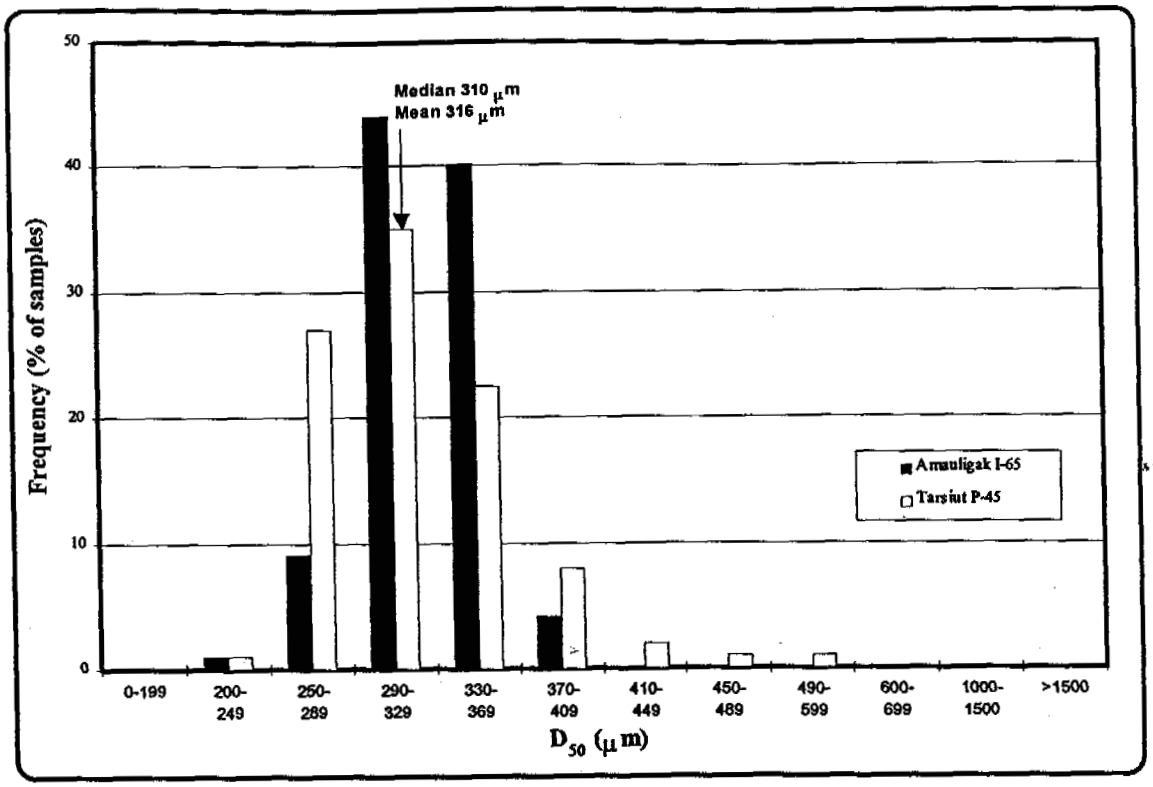
DJ/BTR/je
attachments

FIGURES



KLOHN-CRIPPEN

Figure 2.2: Grading Envelope - Ukalerk Borrow Area



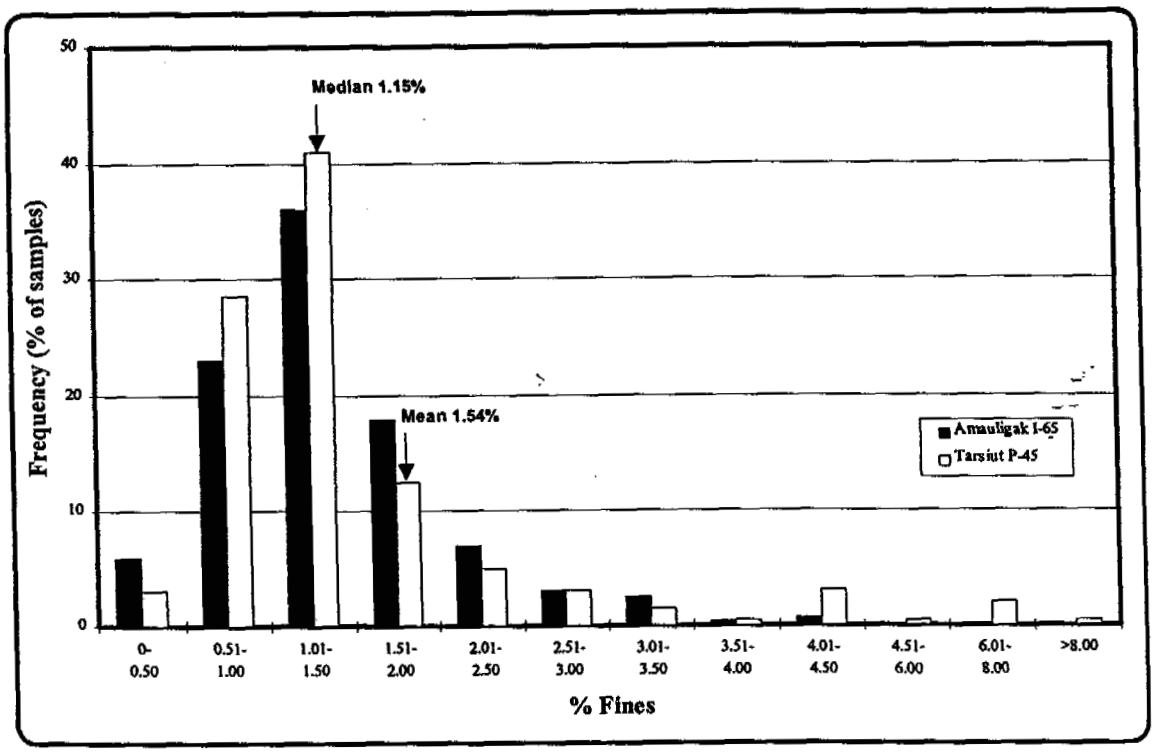


Figure 2.5: Histogram of D_{50} and % Fines for Ukalerk Borrow Area en route to Tarsiut P-45 and Amauligak I-65

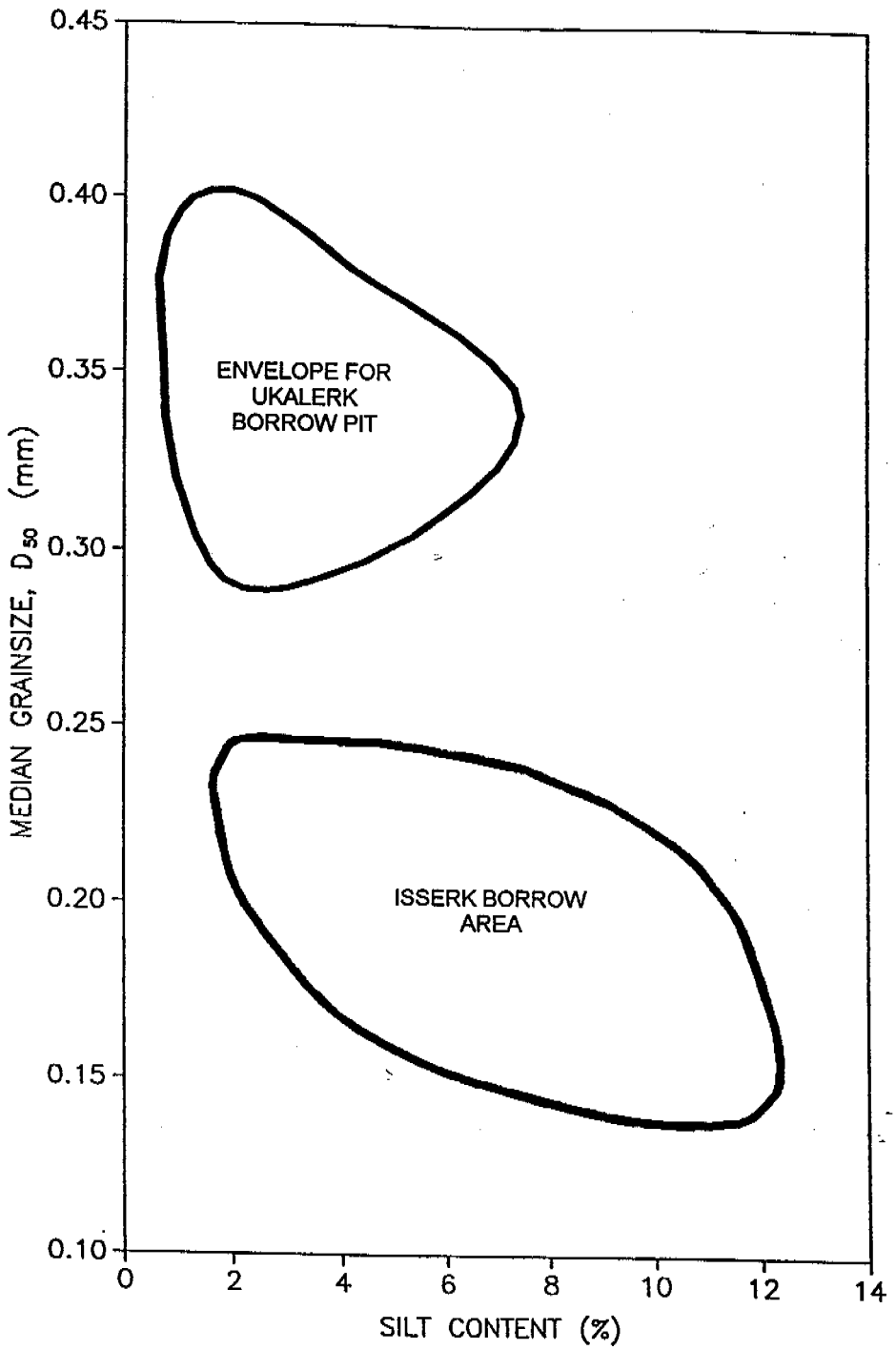
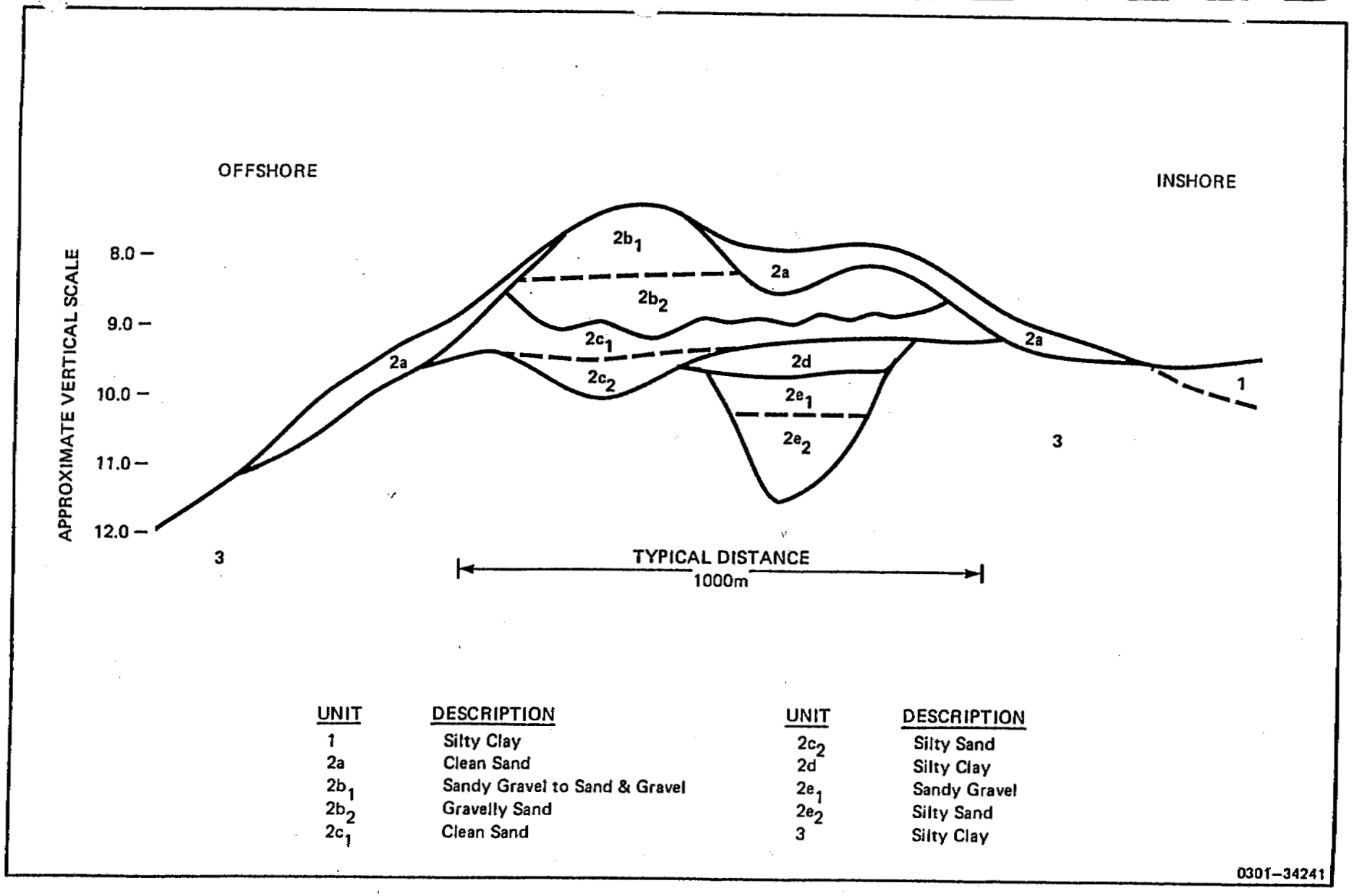


Figure 2.6: Summary of Gradation for Ukalerk and Isserk Borrow



UNIT	DESCRIPTION	UNIT	DESCRIPTION
1	Silty Clay	$2c_2$	Silty Sand
2a	Clean Sand	2d	Silty Clay
$2b_1$	Sandy Gravel to Sand & Gravel	$2e_1$	Sandy Gravel
$2b_2$	Gravelly Sand	$2e_2$	Silty Sand
$2c_1$	Clean Sand	3	Silty Clay

0301-34241

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Figure 2.8: Generalized Stratigraphy of the Issigak Deposit

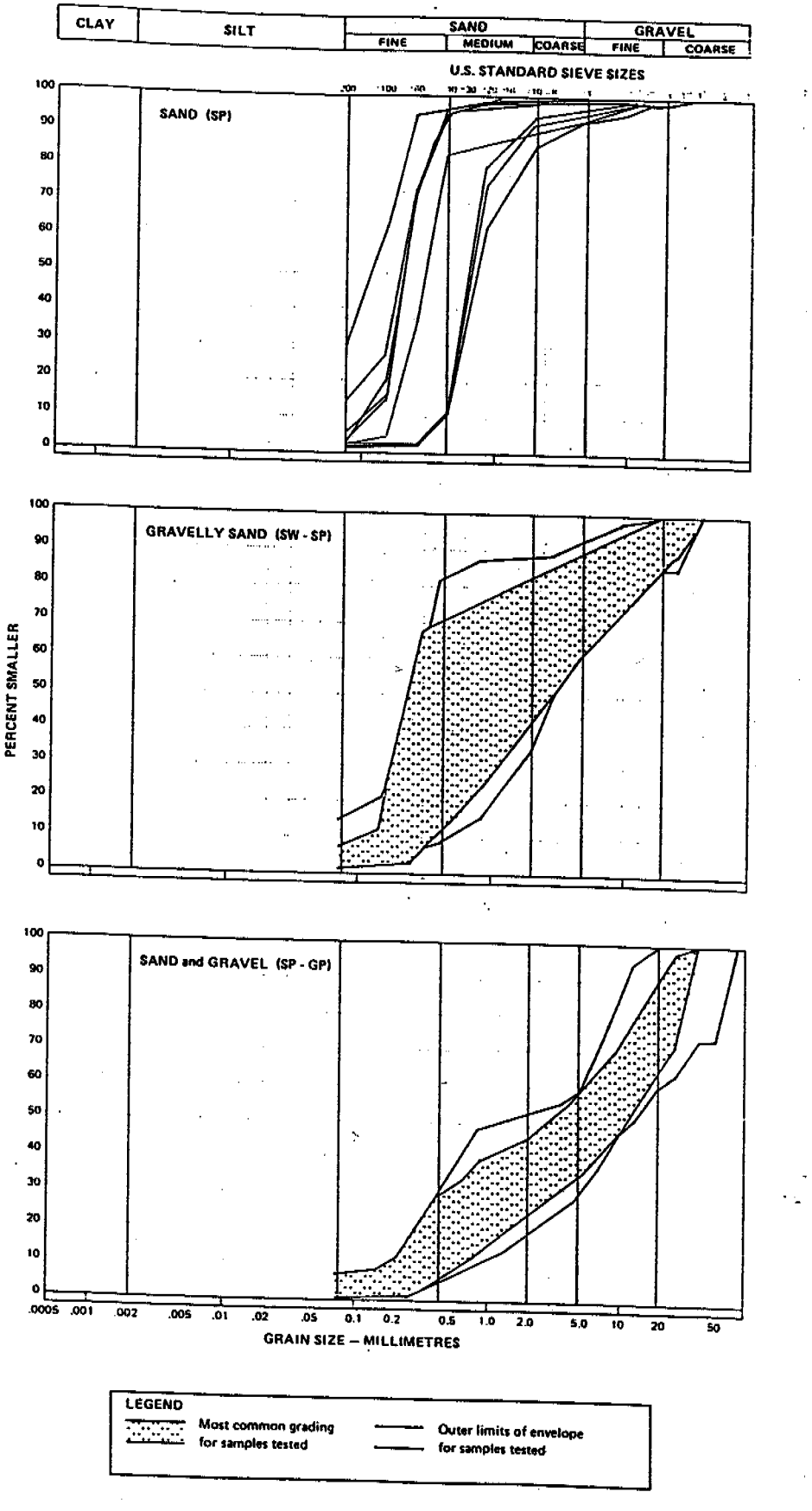

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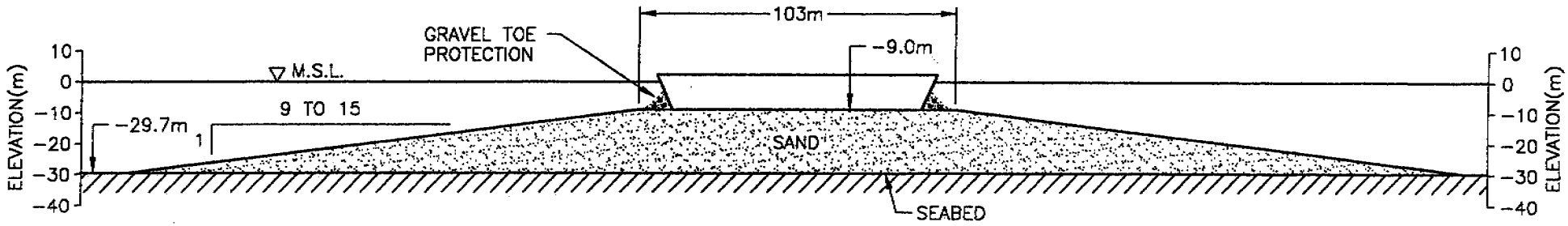
Figure 2.9: Grading Envelope for Issigak Borrow Materials



UVILUK P-66 – SINGLE STEEL DRILLING CAISSON

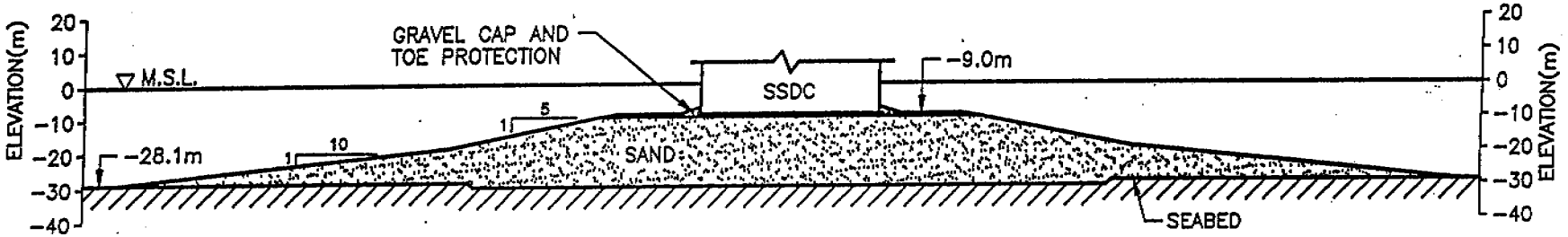
OPERATOR: DOME

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.1: Uviluk P-66 - Cross-Section



KOGYUK N−67 − SINGLE STEEL DRILLING CAISSON

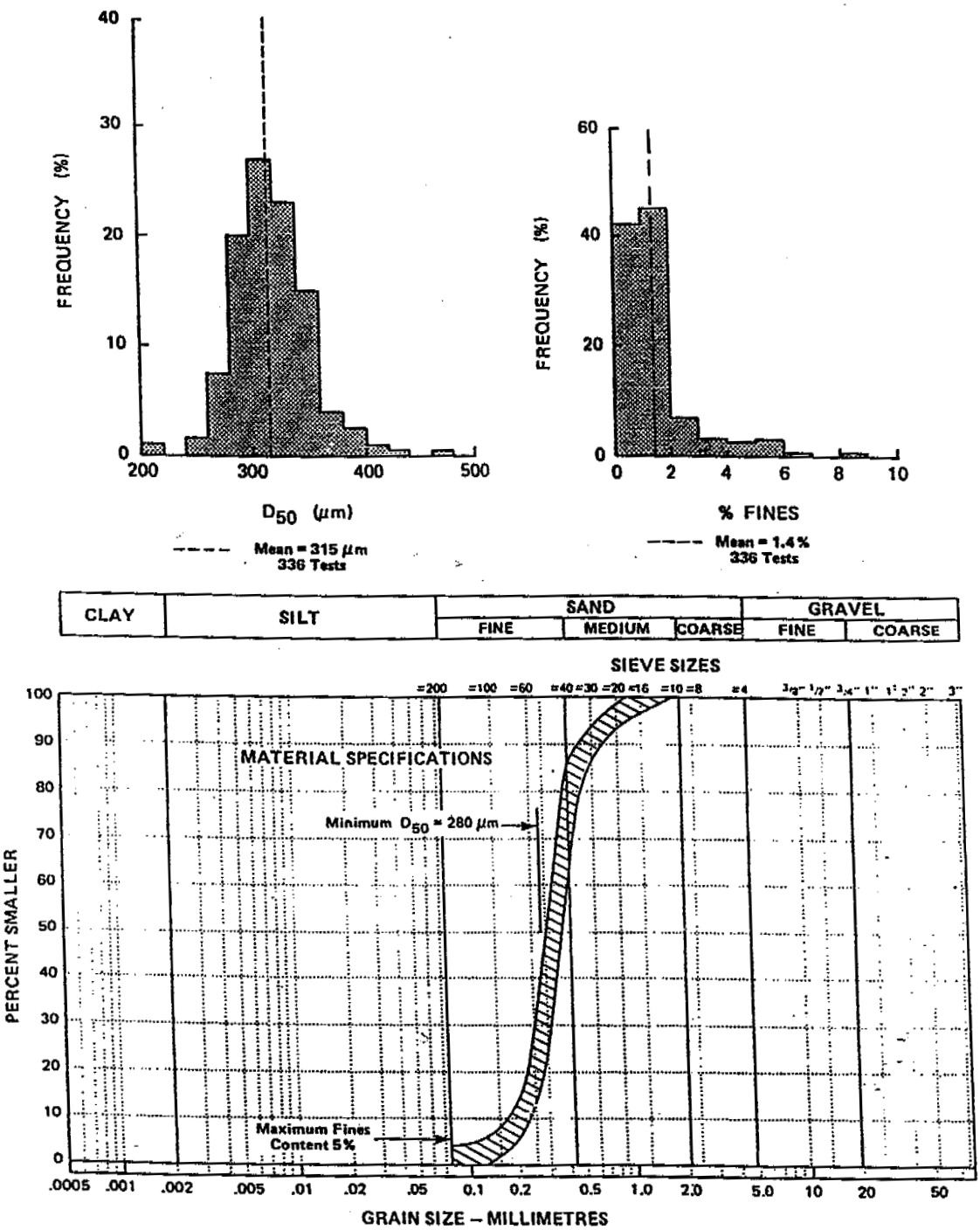
OPERATOR: GULF

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.2: Kogyuk N-67 - Cross-Section



NOTE: Based on EBA and McClelland (1982 b).

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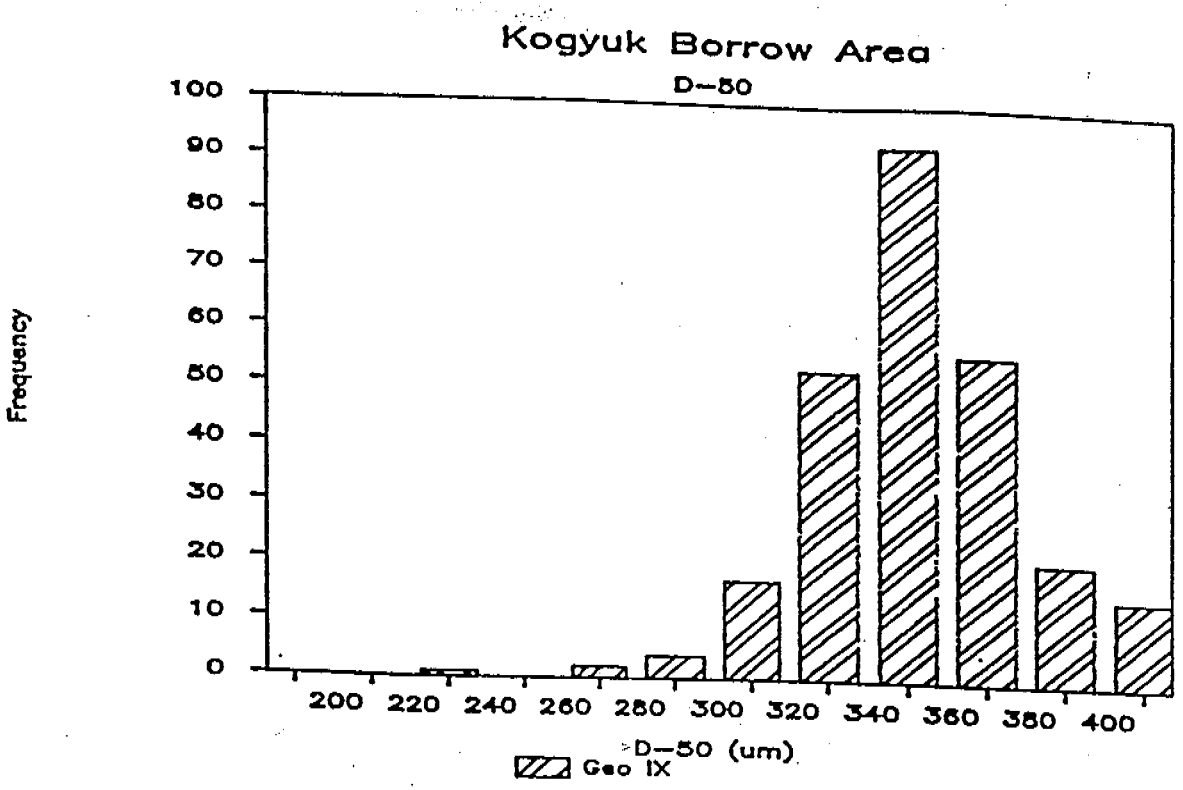
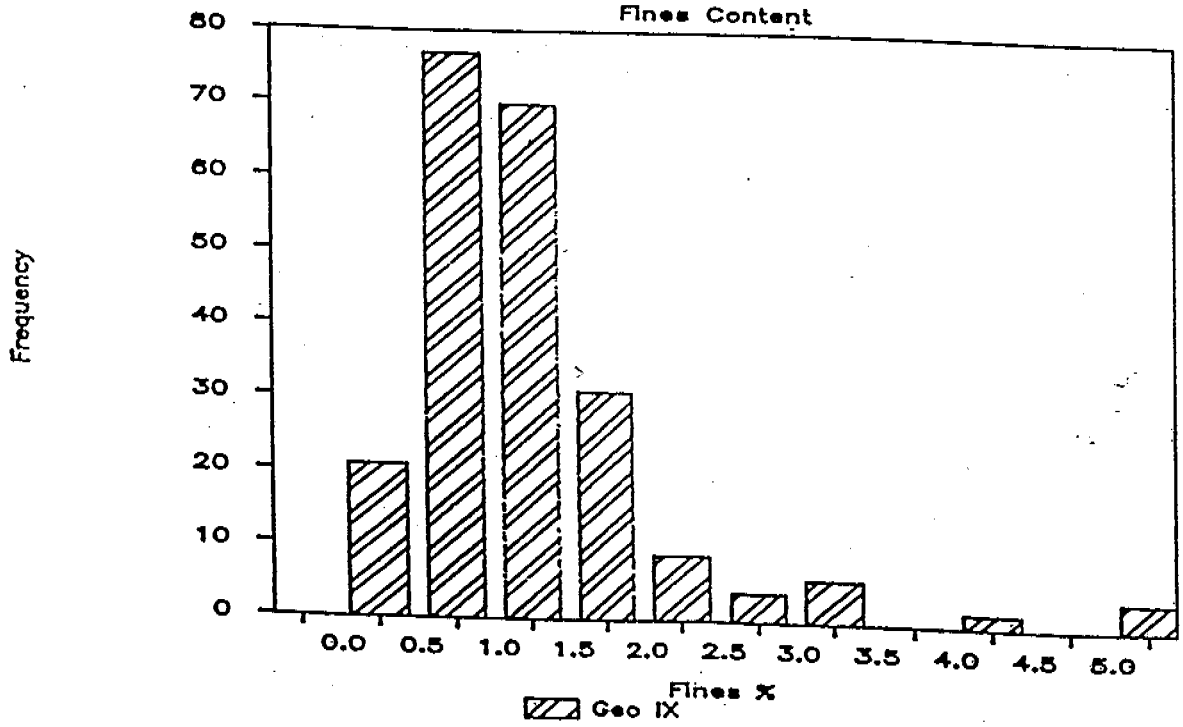
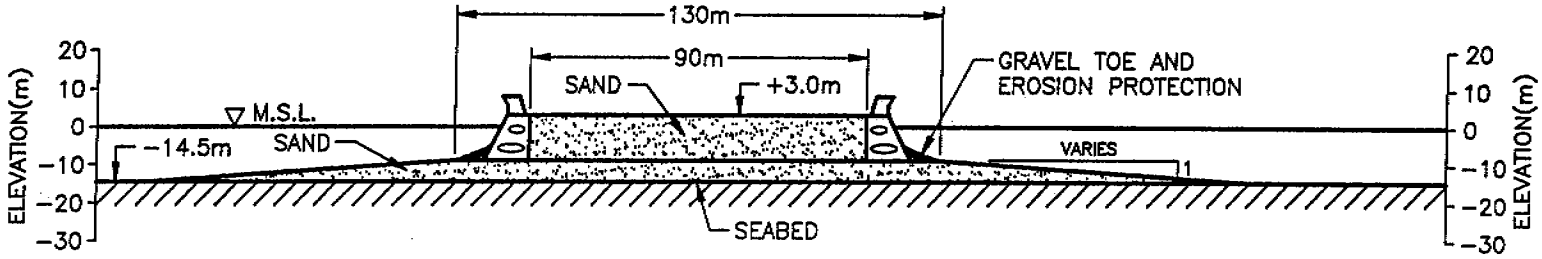
Figure 3.4: Gradation and Fines Content of Dredge Samples from Ukalerk en route to Kogyuk N-67, 1982





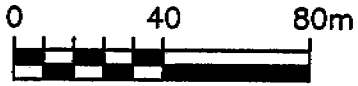
KLOHN-CRIPPEN

Figure 3.9: Gradation and Fines Content of Dredge Samples en route to Amauligak I-65 from Kogyuk N-67, 1985



KADLUK O-07 – CAISSON RETAINED ISLAND

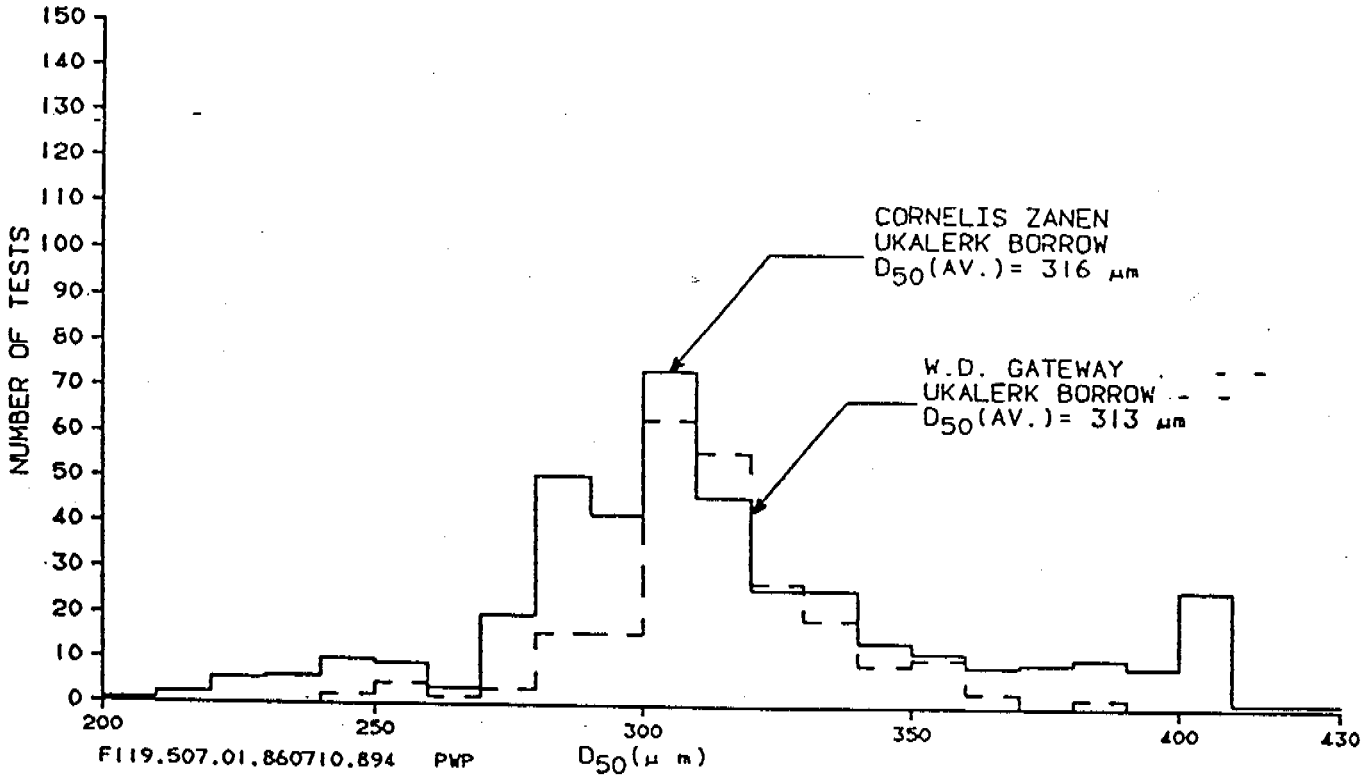
OPERATOR: ESSO



(1:2000)

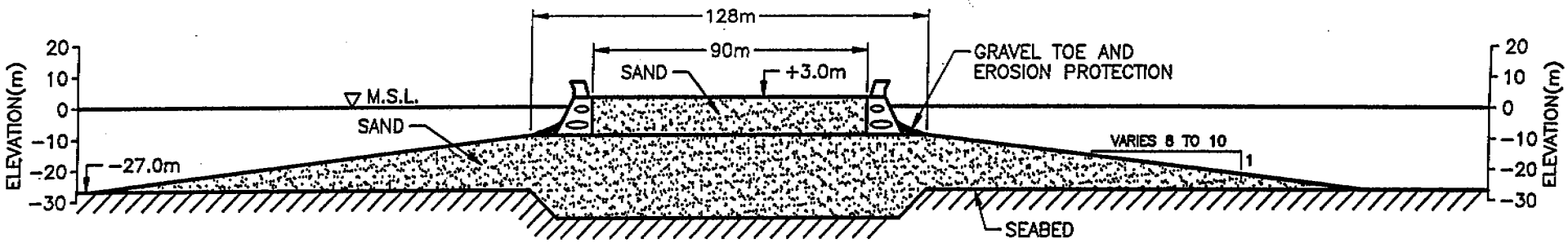
KLOHN-CRIPPEN

Figure 3.10: Kadluk O-07 - Cross-Section



KLOHN-CRIPPEN

Figure 3.12: Histogram of D_{50} of Ukalerk Borrow for Amerk Berm (Golder, 1984d)



AMERK O-09 - CAISSON RETAINED ISLAND

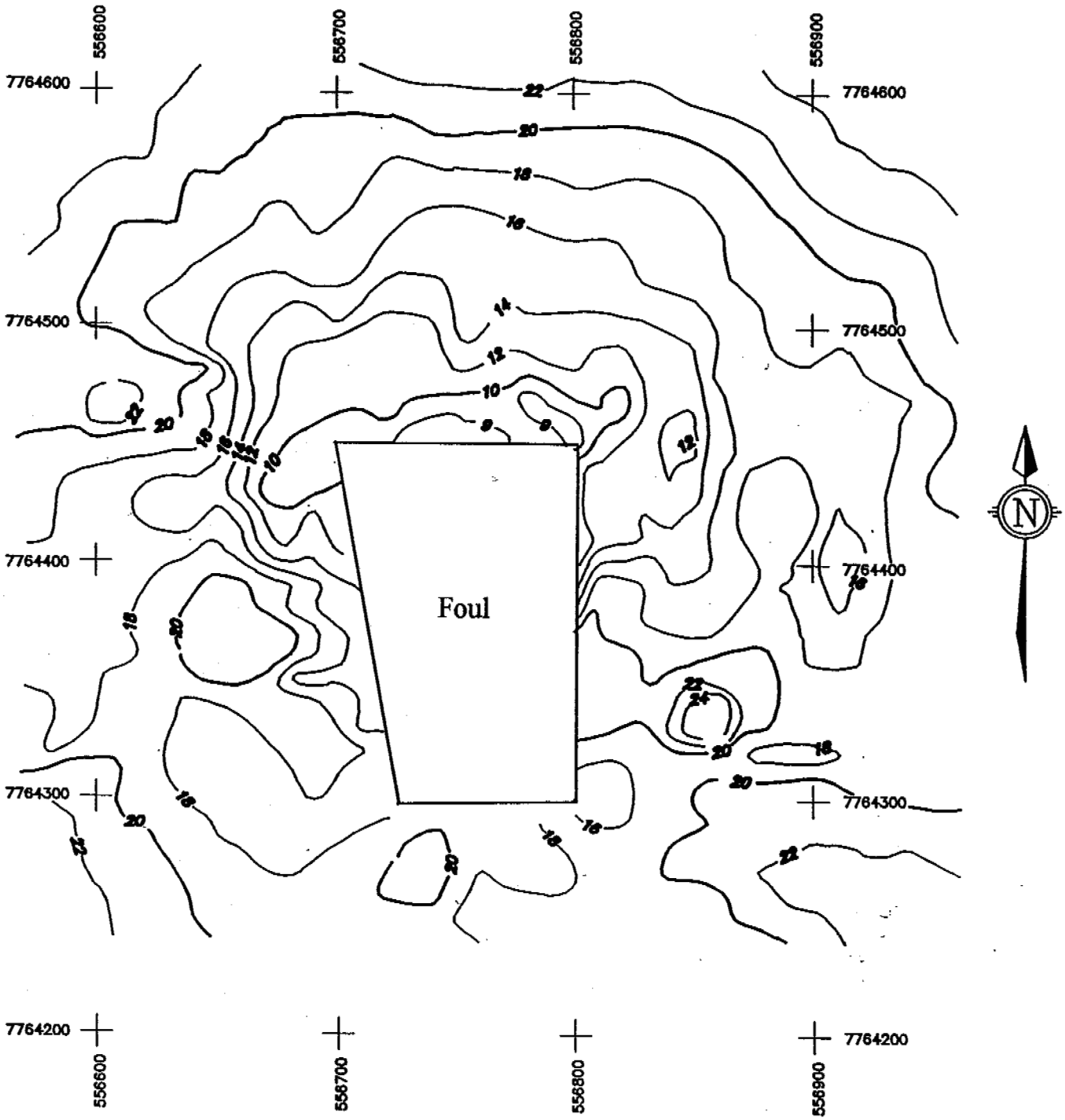
OPERATOR: ESSO

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.13: Amerk P-09 - Cross-Section



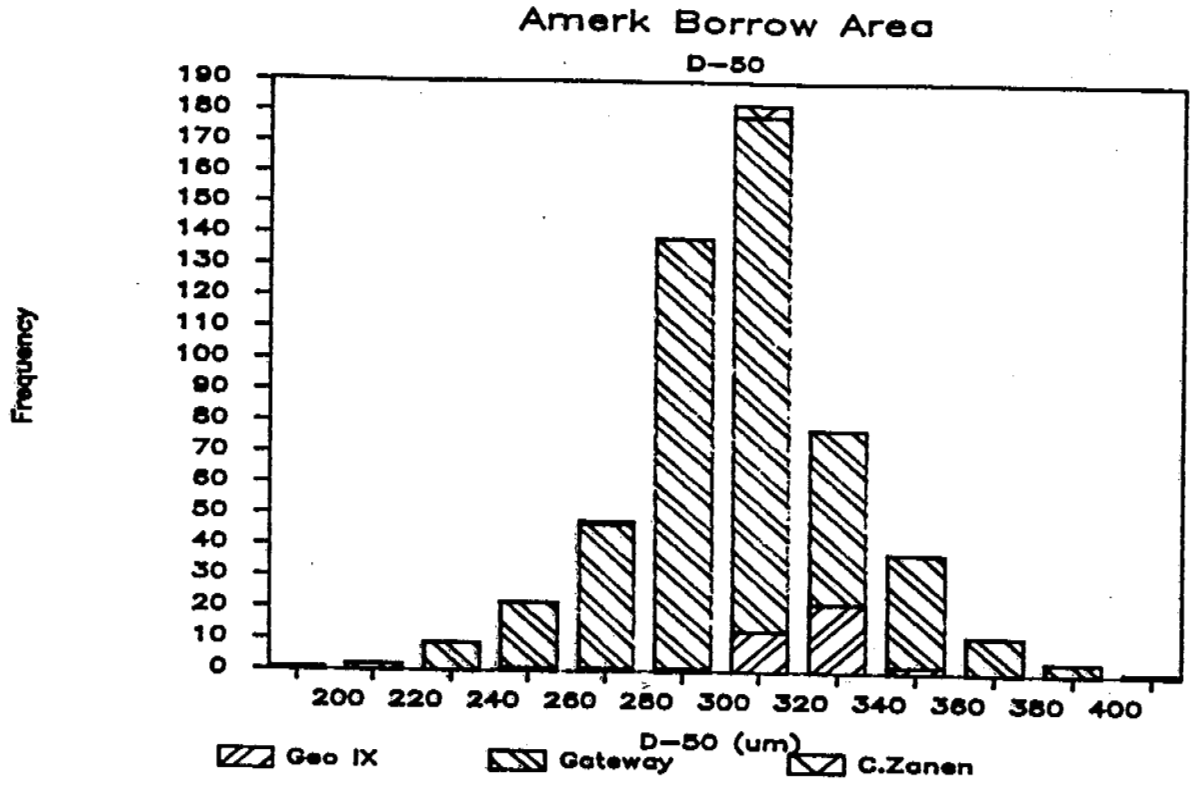
ORIGINAL SEABED : 27.0m BELOW MSL.

DATE OF SURVEY : SEPTEMBER 1985, CANADIAN ENGINEERING SURVEYS CO. LTD.

SCALE 1: 2000

KLOHN-CRIPPEN

Figure 3.14: Amerk P-09 (Sept. 1985)



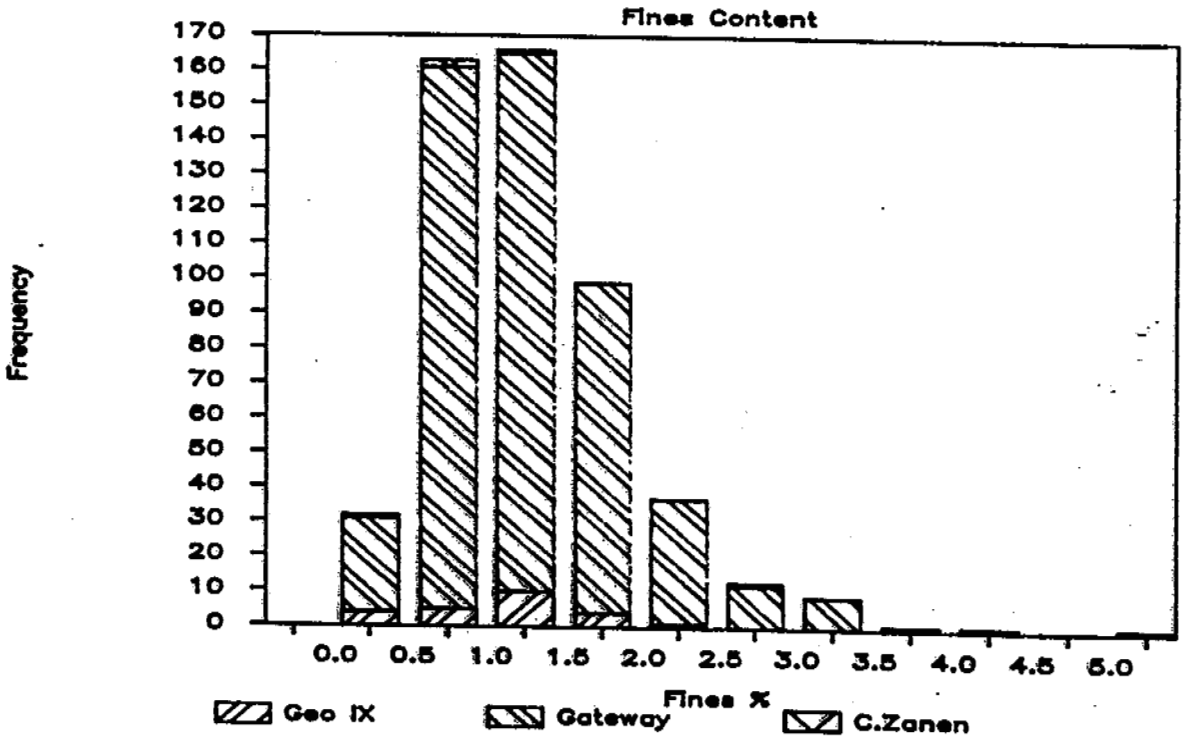
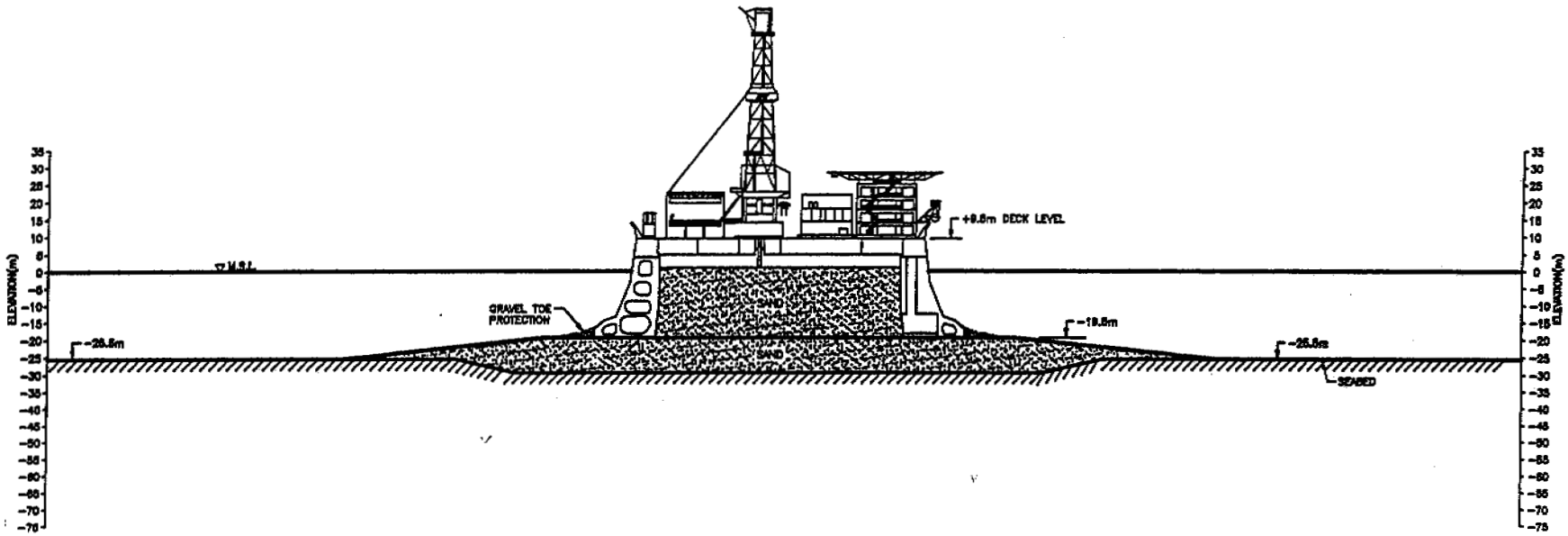


Figure 3.15: Histograms for Ukalerk Material Redredged from Amerk P-09 for Construction of Amauligak I-65



TARSIUT P-45 – MOLIKPAQ

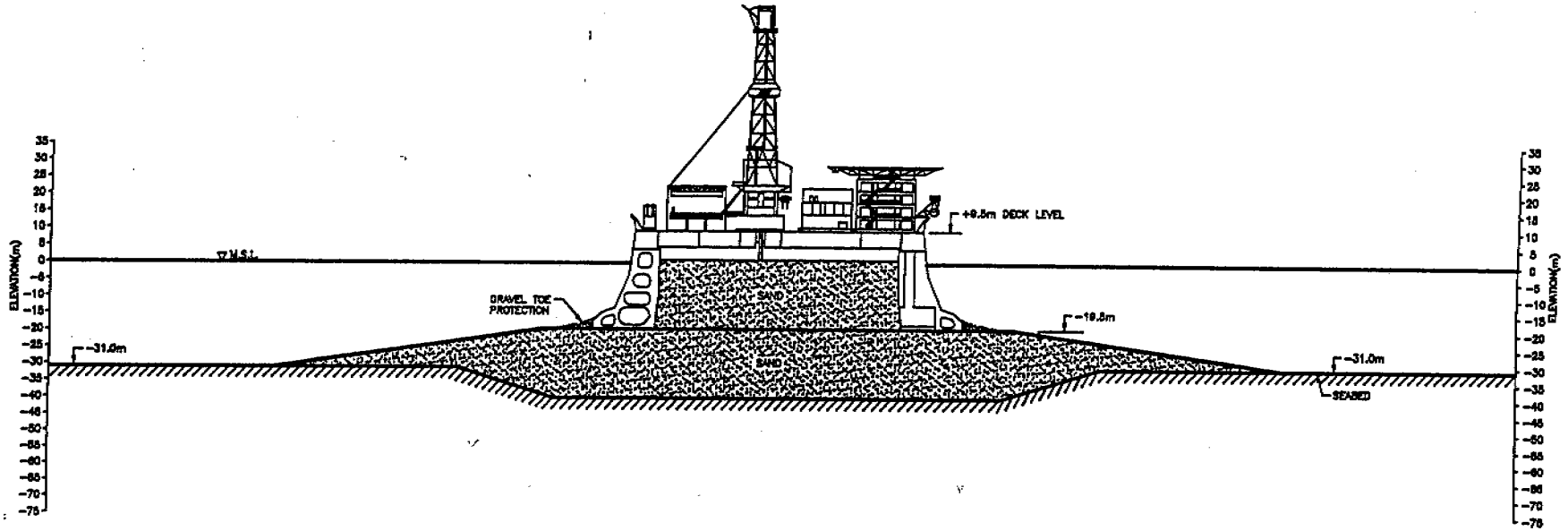
OPERATOR: GULF

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.16: Tarsiut P-45 - Cross-Section



AMAULIGAK I–65 – MOLIKPAQ

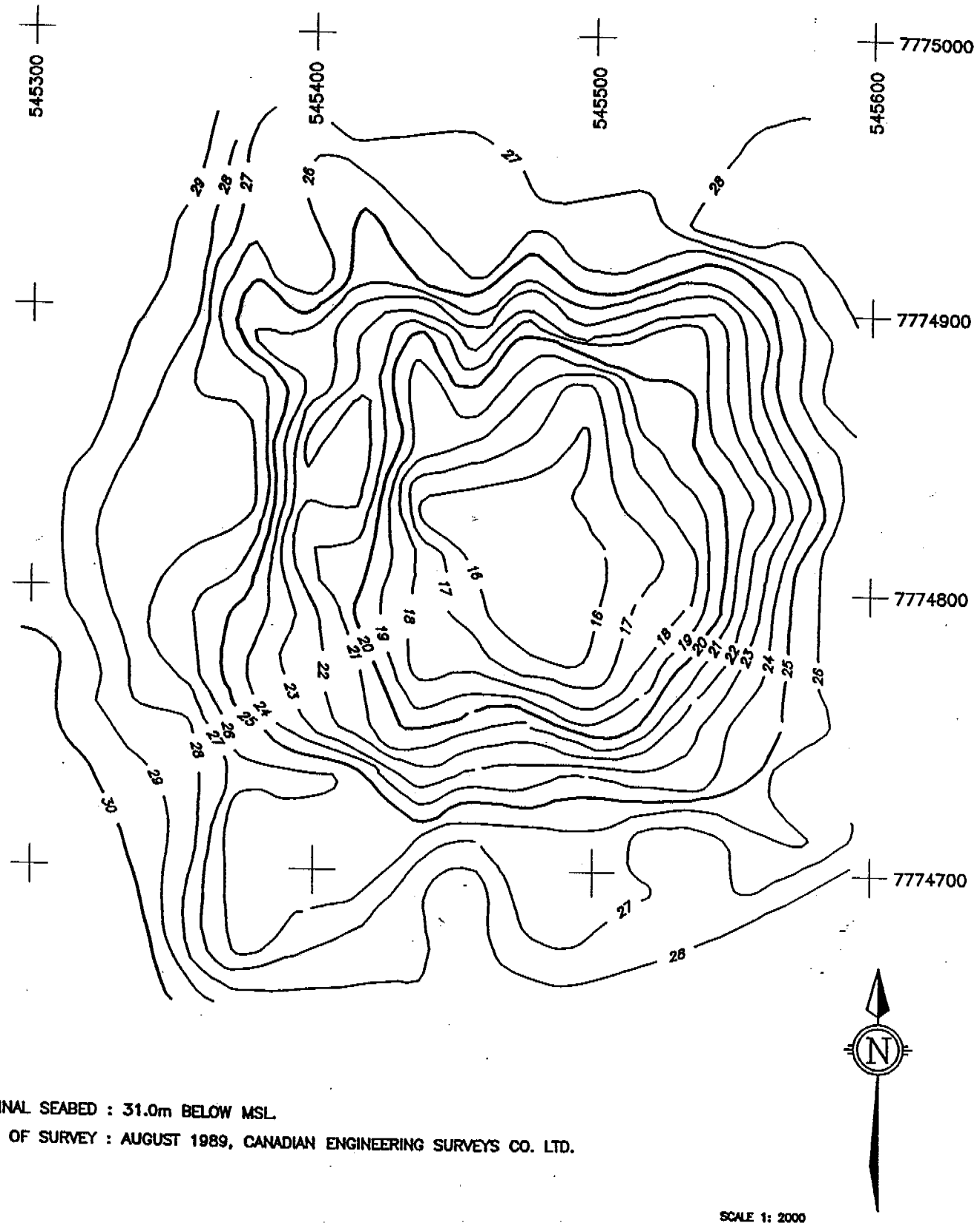
OPERATOR: GULF

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.21: Amauligak I-65 - Cross-Section



ORIGINAL SEABED : 31.0m BELOW MSL.

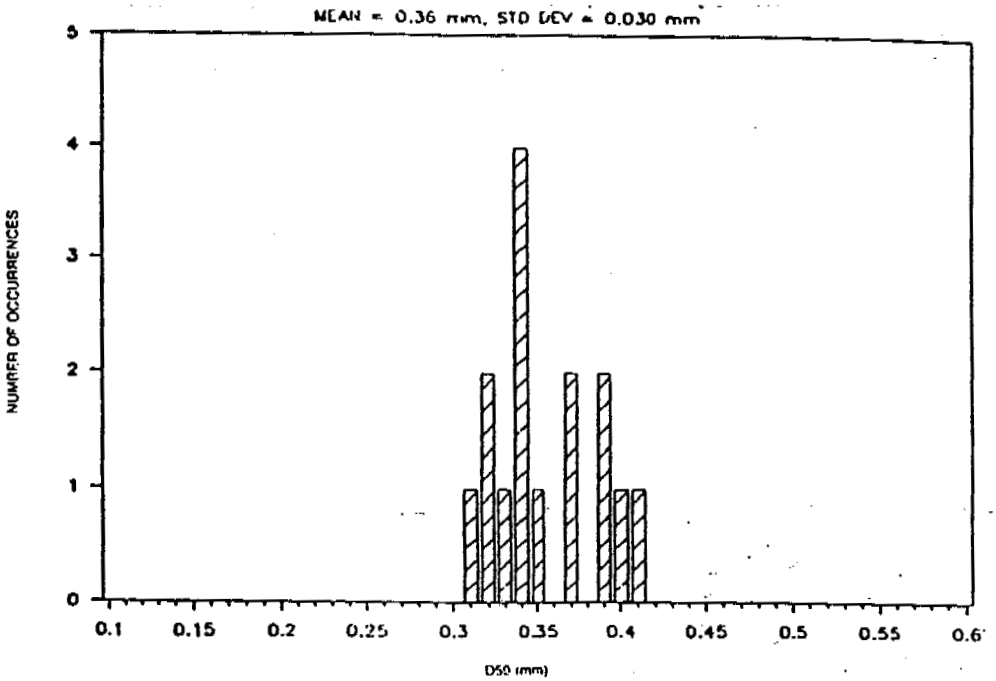
DATE OF SURVEY : AUGUST 1989, CANADIAN ENGINEERING SURVEYS CO. LTD.

SCALE 1: 2000

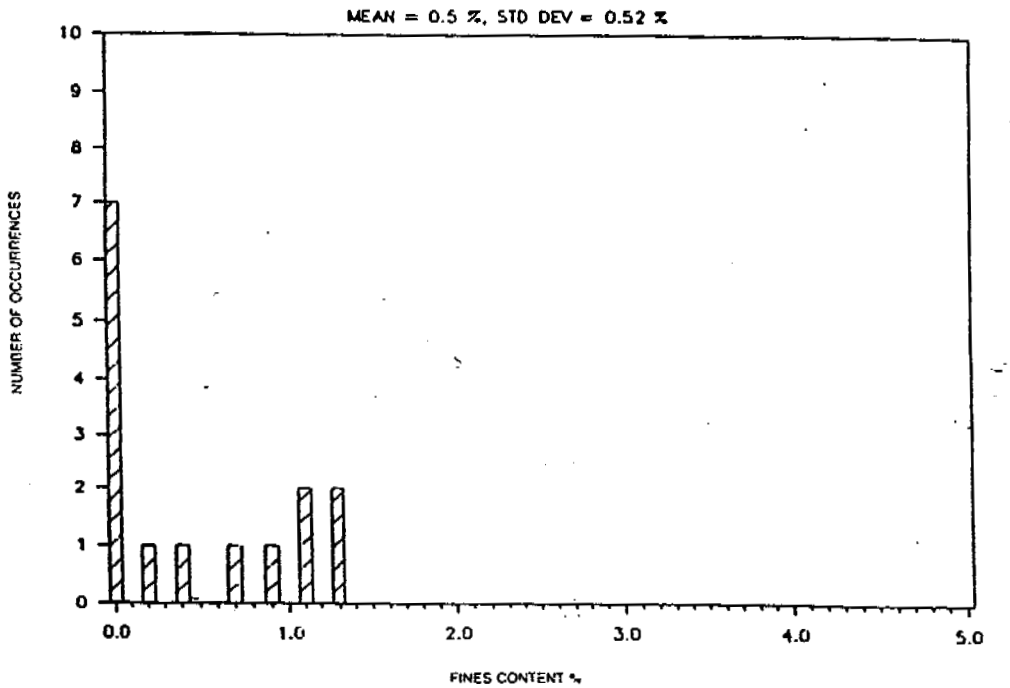
KLOHN-CRIPPEN

Figure 3.22: Amauligak I-65 (Aug. 17, 1989)

Amauligak F-24 - D_{50} of Core Sand : Fill from Amauligak I-65



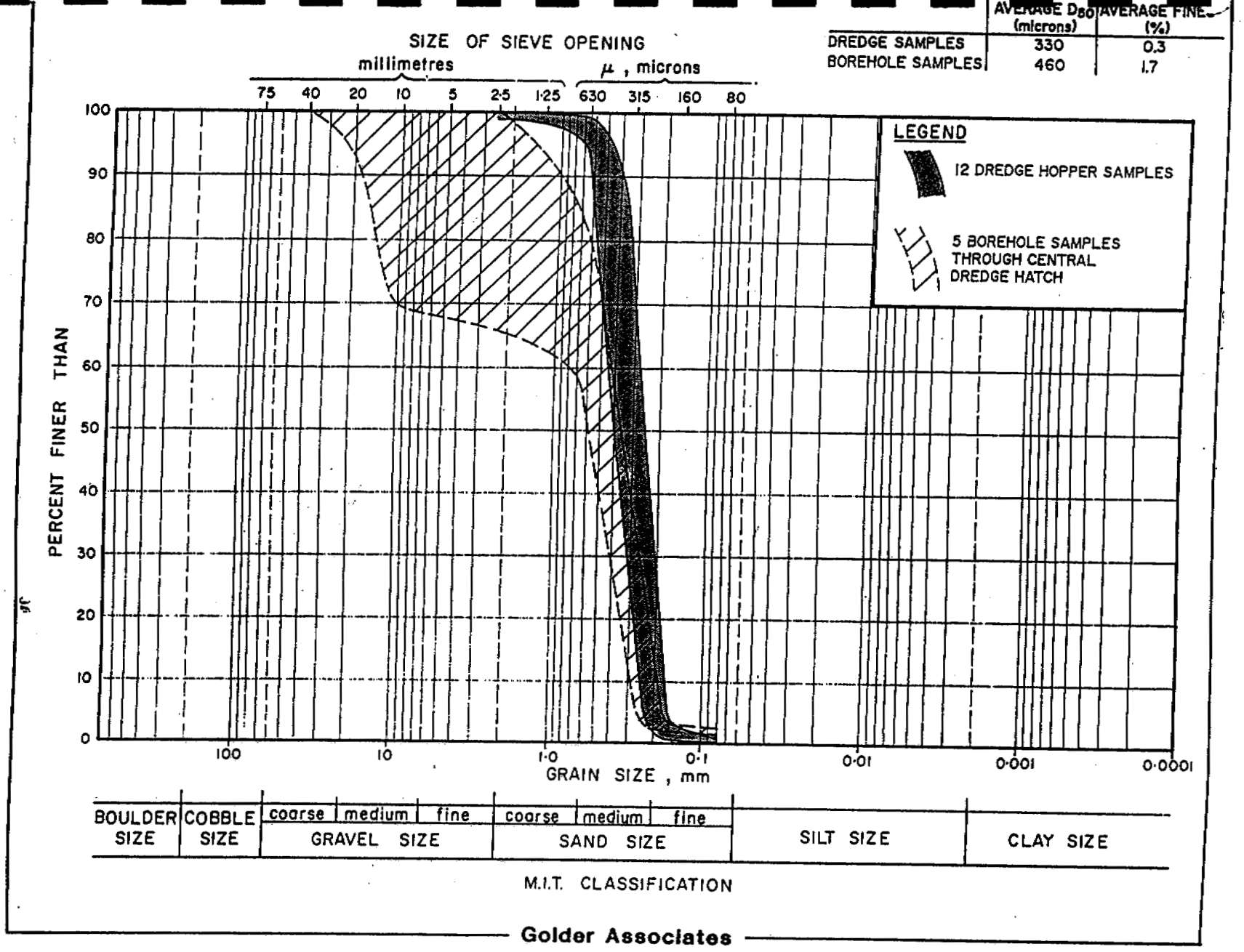
FINES OF CORE SAND: 15 TESTS



Note: ① All sand dredged at Amauligak I-65.

Figure 3.25: Histograms of Sand Quality in Core

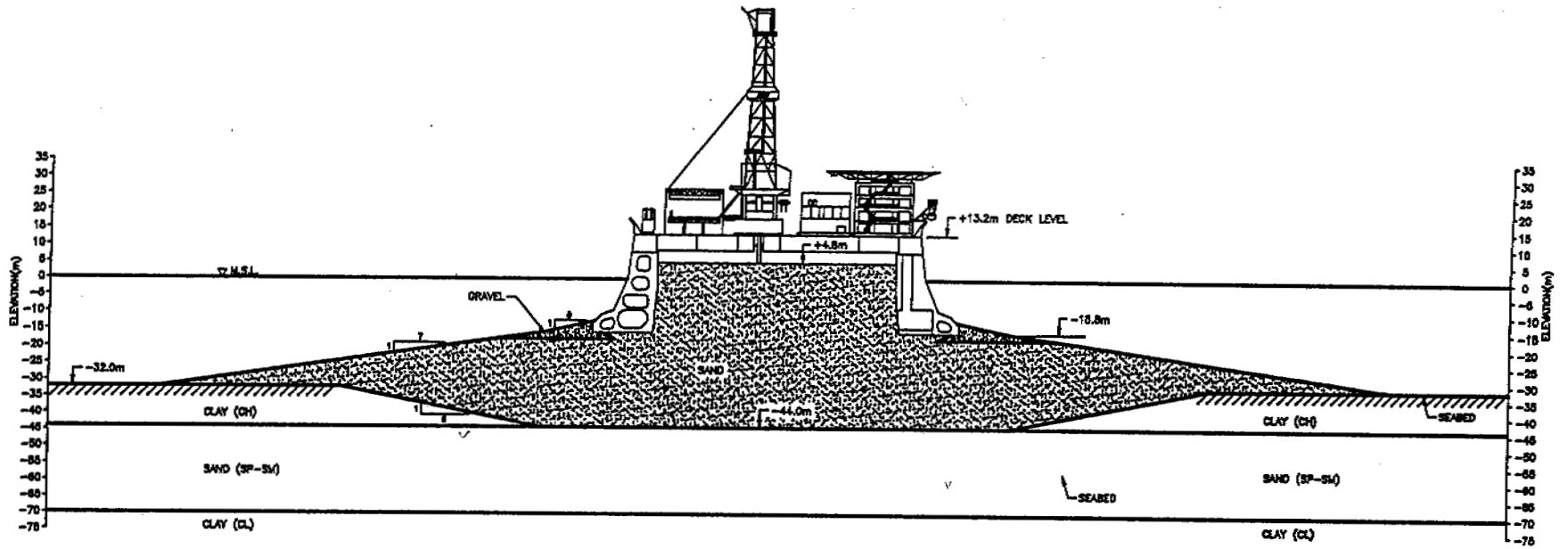
	AVERAGE D_{50} (microns)	AVERAGE FINES (%)
DREDGE SAMPLES	330	0.3
BOREHOLE SAMPLES	460	1.7



Golder Associates

KLOHN-CRIPPEN

Figure 3.26: Isserk I-15 - Grain Size Distribution Core Sand Fill from Amauligak I-65



AMAULIGAK F-24 – MOLIKPAQ

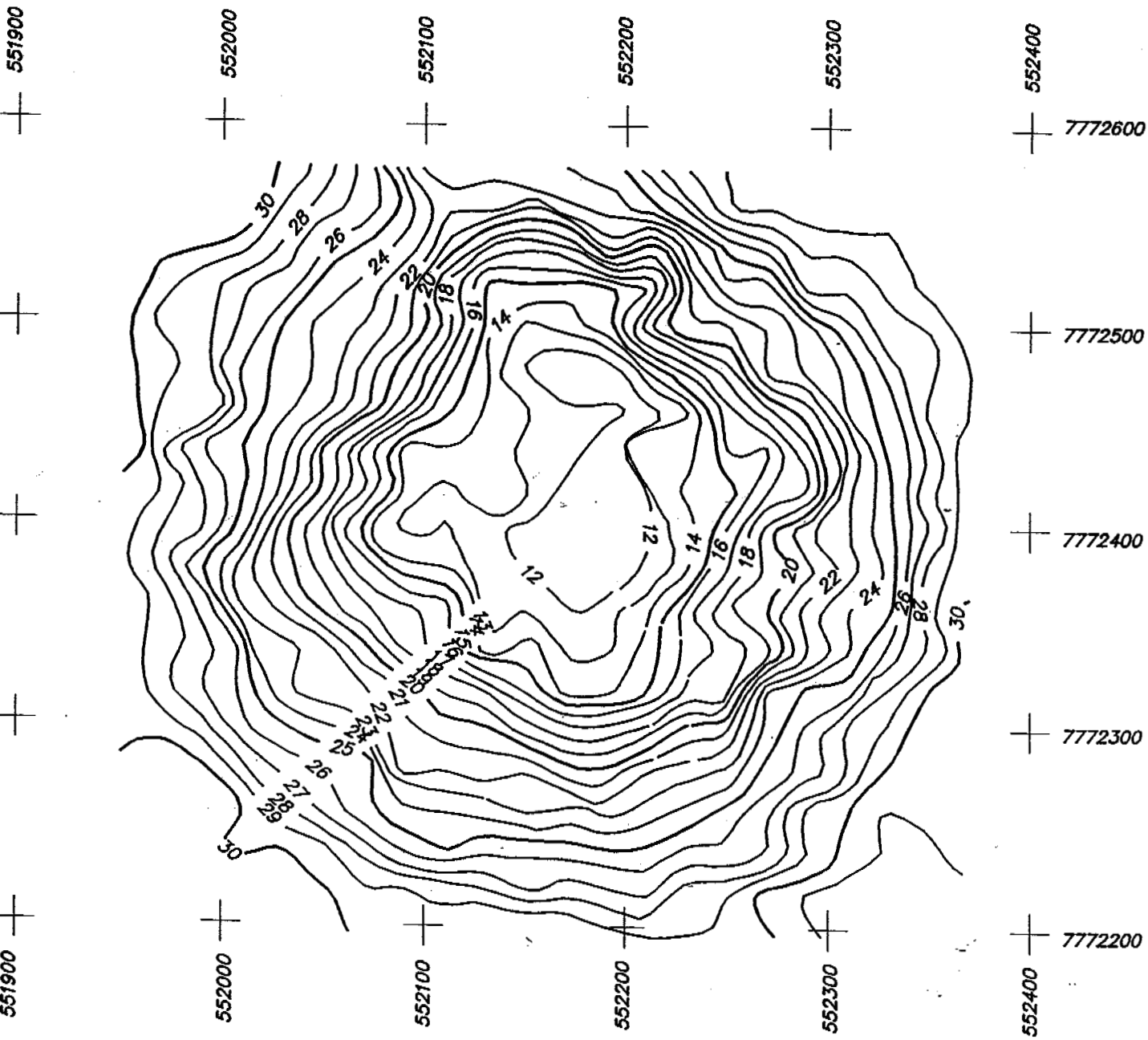
OPERATOR: GULF

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.27: Amauligak F-24 - Cross-Section



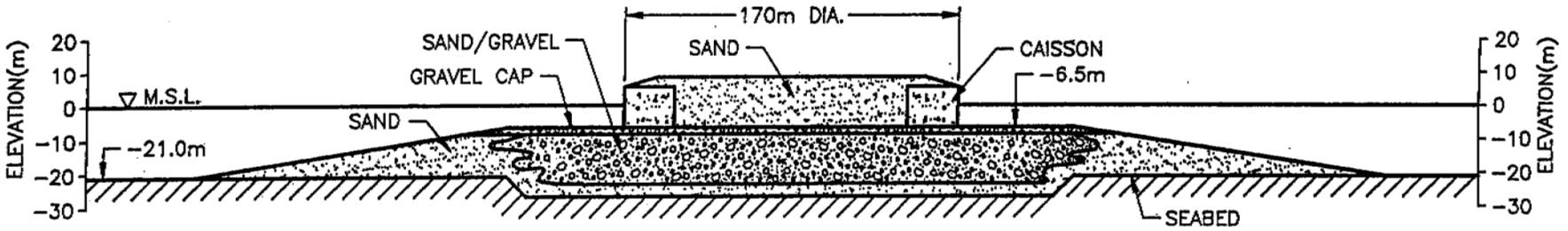
ORIGINAL SEABED : 32.0m BELOW MSL.

DATE OF SURVEY : AUGUST 1989, CANADIAN ENGINEERING SERVICES CO. LTD.

SCALE 1: 3000

KLOHN-CRIPPEN

Figure 3.28: Amauligak F-24 (Aug. 1989)



TARSIUT N-44 - CAISSON RETAINED ISLAND

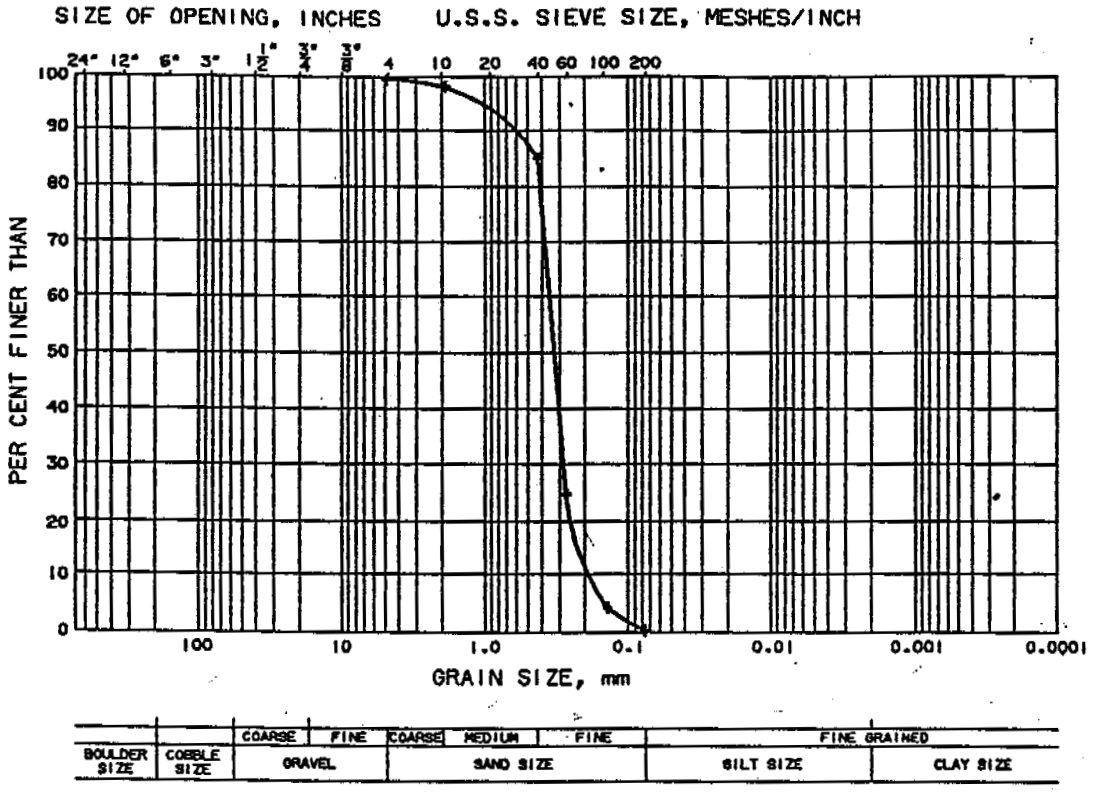
OPERATOR: GULF

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.31: Tarsiut N-44 - Caisson Retained Island



PROJECT: TARSIUT IS. RESEARCH PROGRAM
BOREHOLE NO: TARSIUT N-44
SAMPLE NO.: _____
DEPTH (m) _____

DESCRIPTION			
% CLAY	% SILT	% SAND	% GRAVEL
-	1	99	-

U.S.C. SP
D_{50} 0.3 mm
CU 2.0

CONSULTANT: E.B.A.
TECHNICIAN: -
TEST METHOD: ASTM D-422
DATE TESTED: 81-10-15

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FRONTIER DEVELOPMENT DIVISION

83F066 [173,241CH036

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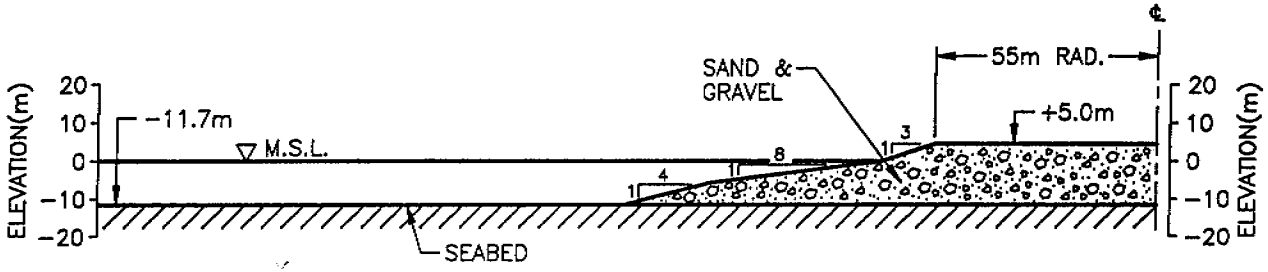
Figure 3.33: Particle Size Distribution of Tarsiut N-44 Sand



NIPTERK L-19 – SACRIFICIAL BEACH ISLAND

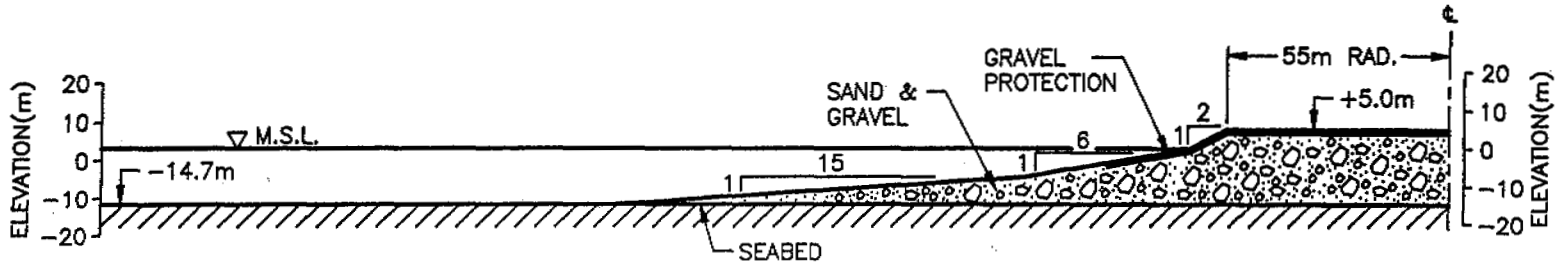
OPERATOR: ESSO

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.35: Nipterk L-19



MINUK I–53 – SACRIFICIAL BEACH ISLAND

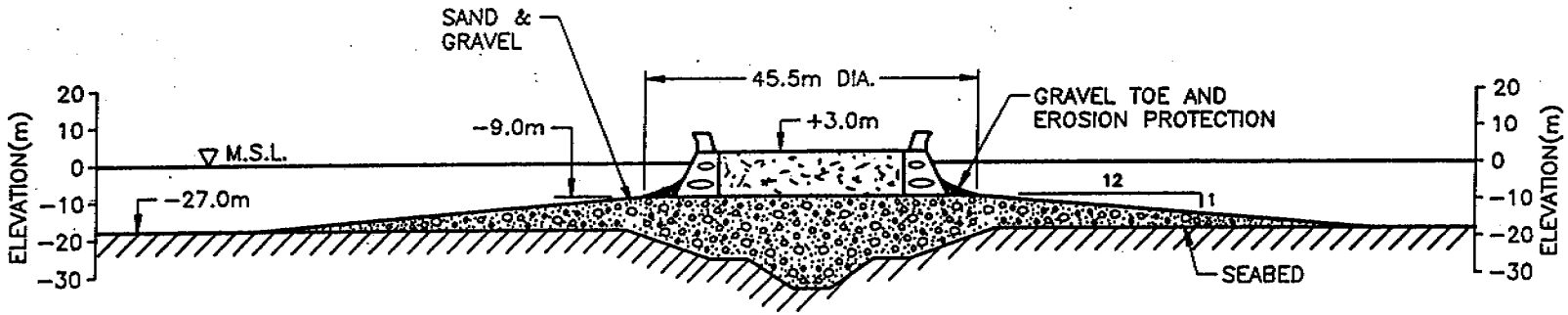
OPERATOR: ESSO

0 40 80m

(1:2000)

KLOHN-CRIPPEN

Figure 3.37: Minuk I-53 -Cross-Section



KAUBVIK I-43 – CAISSON RETAINED ISLAND

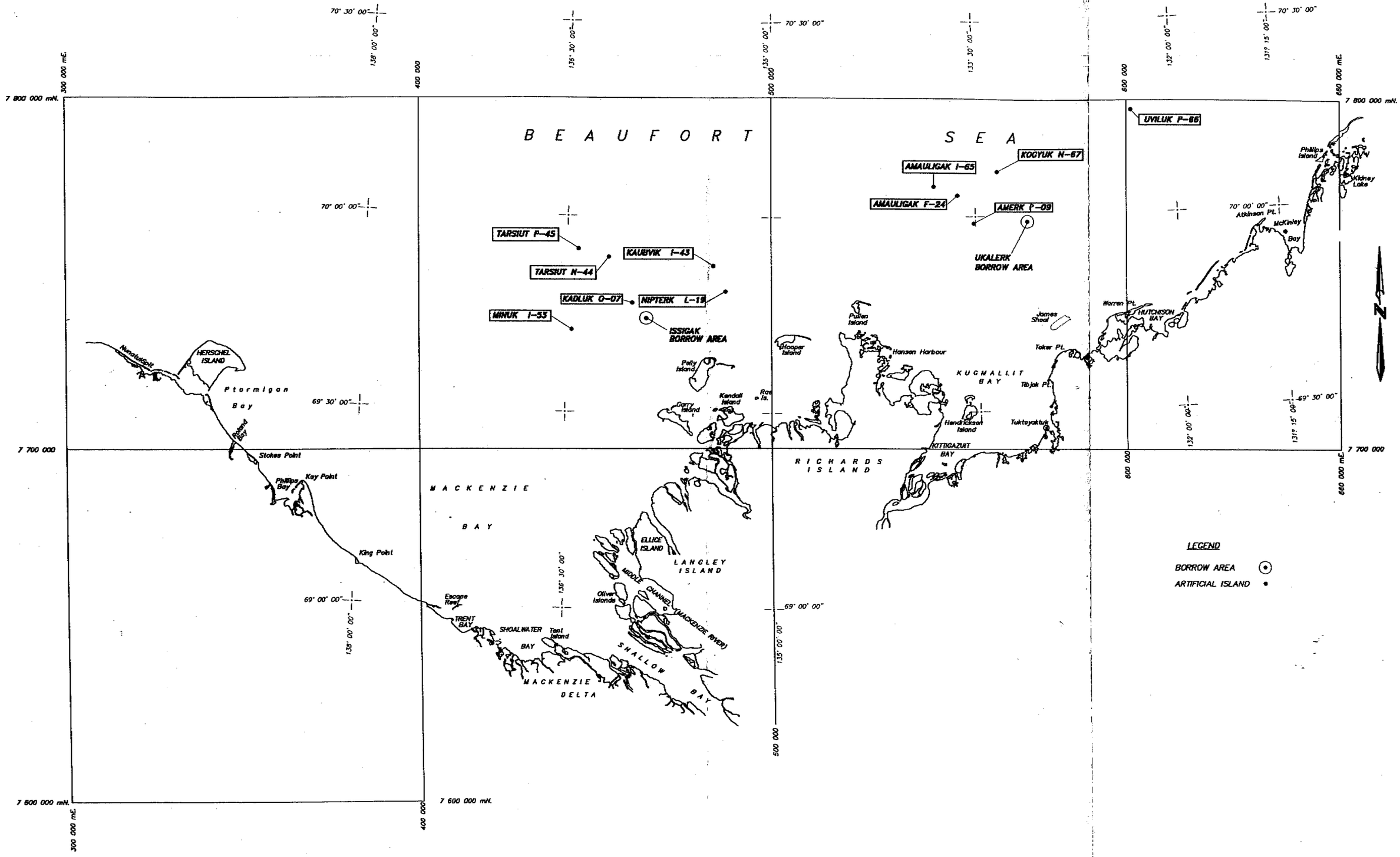
OPERATOR: ESSO

0 40 80m

(1:2000)

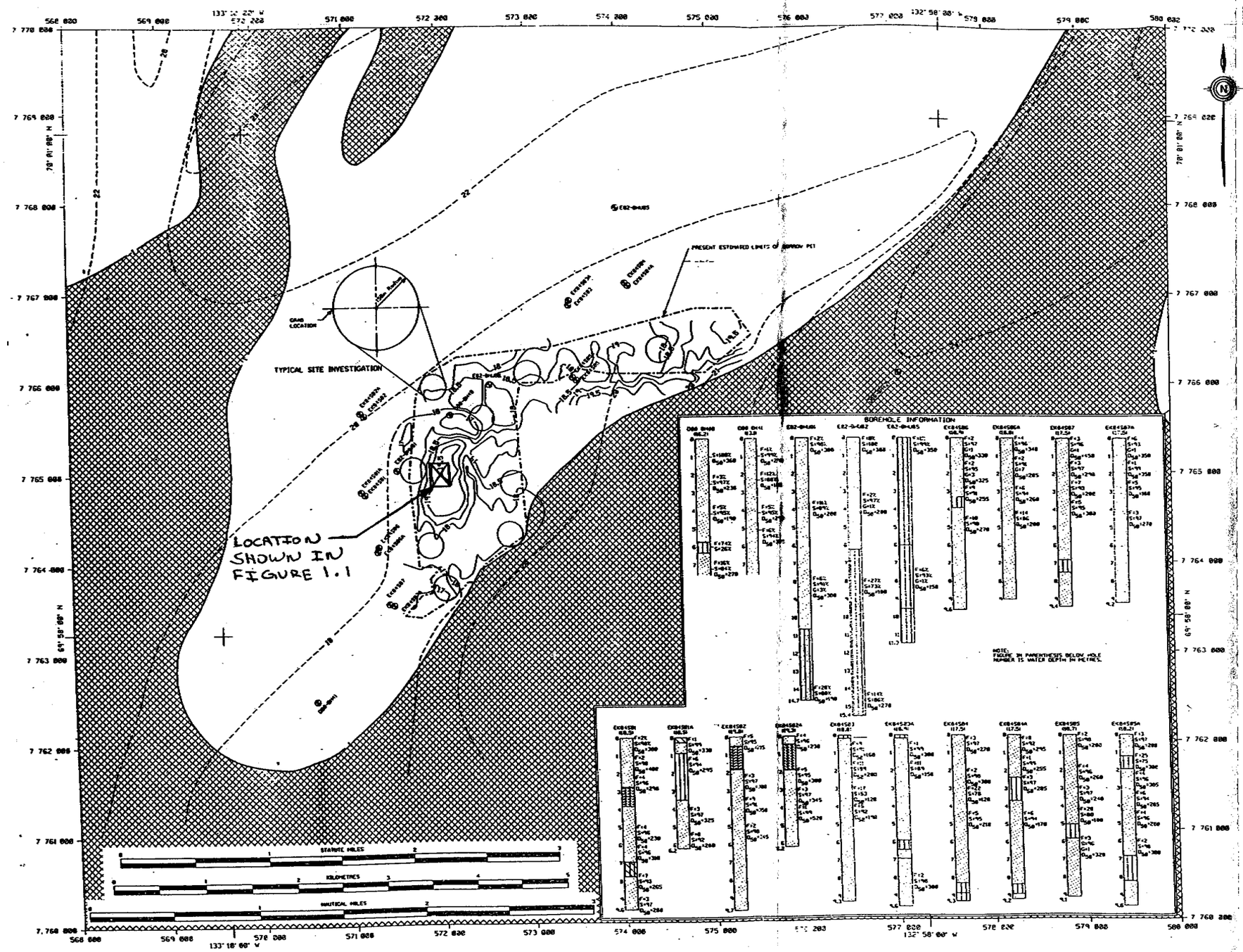
KLOHN-CRIPPEN

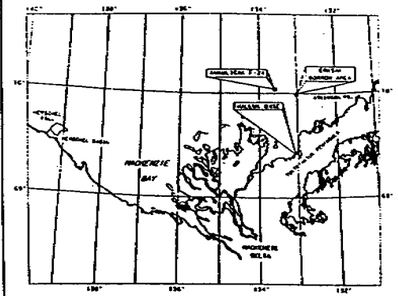
Figure 3.39: Kaubvik I-43 - Cross-Section



KLOHN-CRIPPEN

Figure 1.1: Location Plan





NOTES:

1. WATER DEPTHS NOT CORRECTED FOR EFFECTS OF WIND OR TIDE. POSSIBLE SEA LEVEL FLUCTUATIONS OF ±½ METRE.
2. BERM CENTRE COORDINATES:
   GEOGRAPHIC: 70° 03' 17.4" N 133° 37' 48.5" W
   MTM (ZONE 8): 7 772 466 N 552 150 E
3. ALL COORDINATES ARE REFERRED TO NAD 1927 DATUM WESTERN AEROJUST 1972 ADJUSTMENTS (CNS) MAY 1973)
   COORDINATES SHOWN ARE MTM ZONE 8, CENTRAL MERIDIAN 135° W LONG.
4. BATHYMETRIC SURVEY METHOD: ACTUAL BORROW AREA PERFORMED SEPTEMBER 27, 1986 BY ARCTIC SYSTEMS (CESL). ALL OTHER CONTOURS ARE APPROXIMATE.
5. CIRCULAR AREAS SHOW SITE INVESTIGATION FOR 1987, IF REQUIRED.

LEGEND

- GRAVEL, SAND, SILT, CLAY, ORGANICS — DEPTH BELOW MEDIAN SEA LEVEL IN METRES
  - F=PERCENTAGE FINES CONTENT
  - S=PERCENTAGE SAND CONTENT
  - G=PERCENTAGE GRAVEL CONTENT
  - D_{50} IN MICRONS
- EXISTING GEOTECHNICAL BOREHOLE
- 22 — BATHYMETRY CONTOURS IN METRES
- MUD THICKNESS GREATER THAN 1 METRE

87/07/07	1	ISSUED FOR CONSTRUCTION
87/04/15	0	ISSUED FOR PRICE INQUIRIES
DATE	REV.	ISSUED

DRAWING RECORD

ACCEPTED FOR CONSTRUCTION

GENERAL PROJECT MANAGER — DATE

	BY	DATE		BY	DATE
DESIGNED	BTR	87/07/07	CHECKED		
DRAWN	JLM	86/08/03	APPROVED		

GULF CANADA RESOURCES
FRONTIER DEVELOPMENT

TITLE
AMAULIGAK SEASONAL PRODUCTION
MOLIKPAQ AT F24
1987 CONSTRUCTION SEASON

PLAN OF ERIKSAK BORROW AREA

DATE: 87/03/23 | DRAWING No. AF-87-006

KLOHN-CRIPPEN

Figure 2.1: Plan of Ukalerk Borrow Area

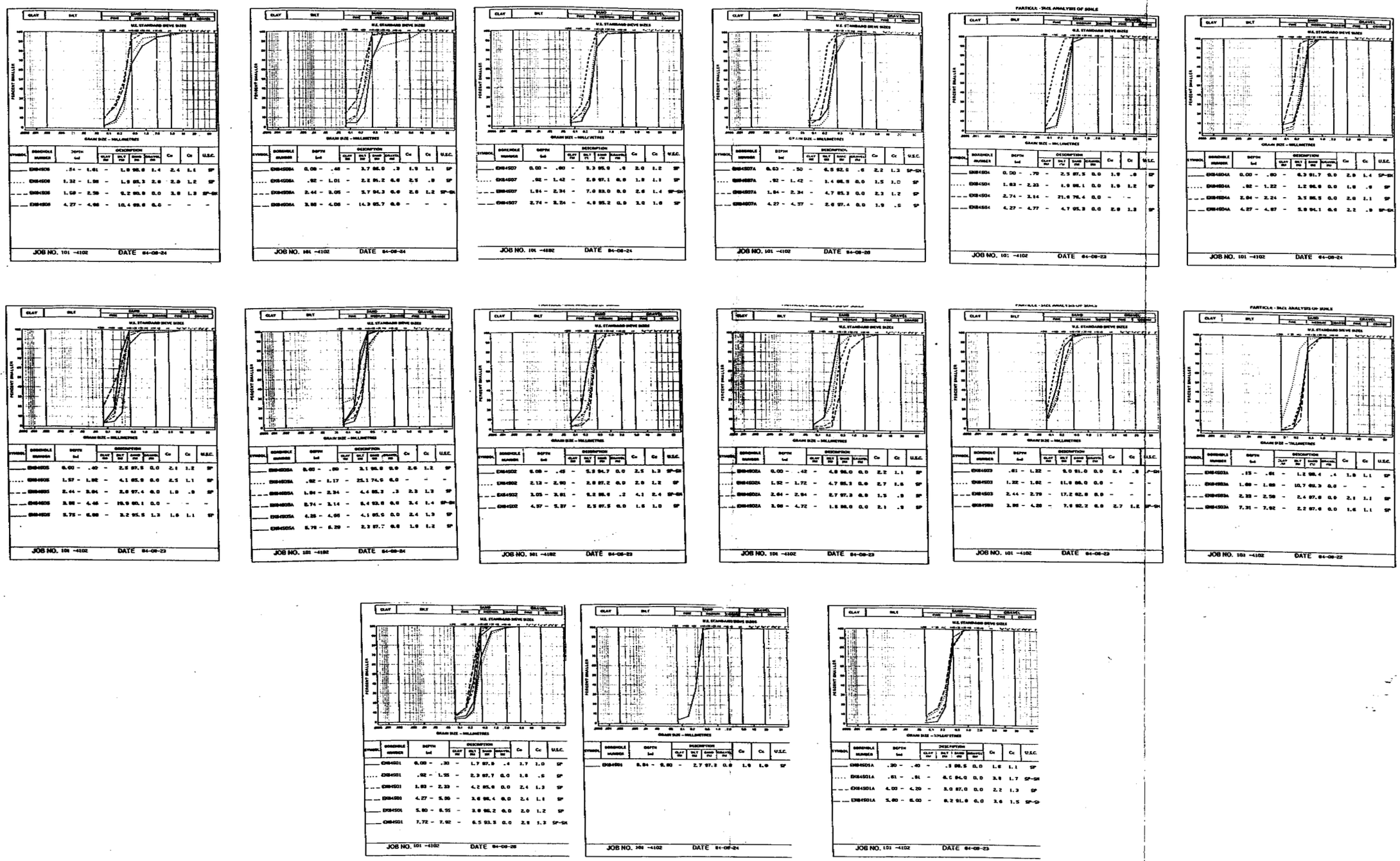


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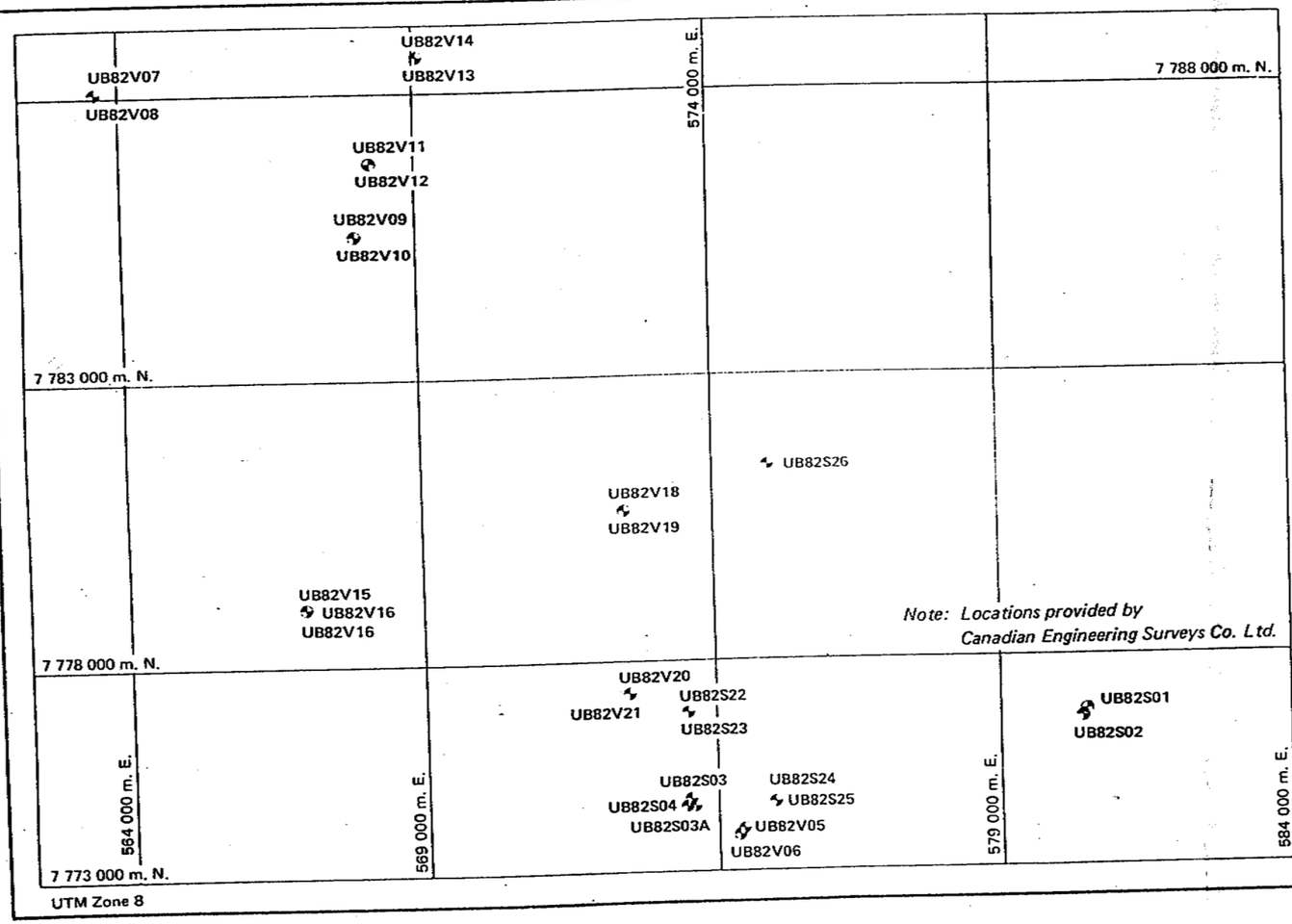
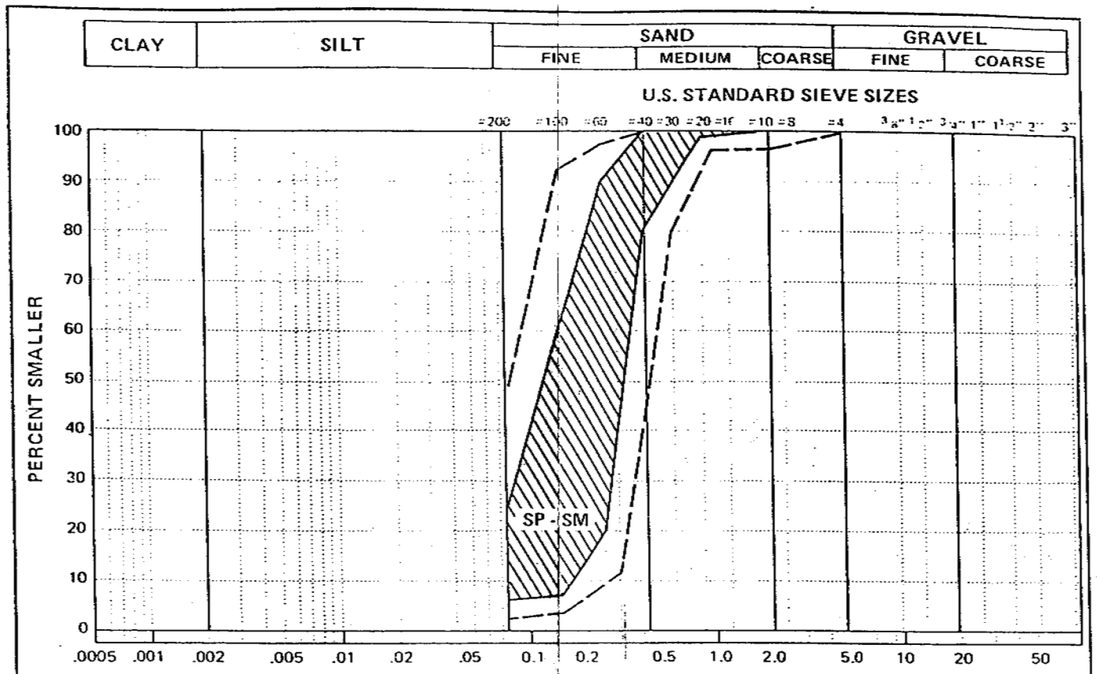
Figure 2.3: Grain Size Curves for Samples from Ukalerk Borrow Investigation



Borehole Location Map



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION				Cu	Cc	U.S.C.
			CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)			
- - - -		OUTER LIMITS OF ENVELOPE FOR SAMPLES TESTED							
▨		MOST COMMON GRADING FOR SAMPLES TESTED							

Grading Envelope Borrow Material

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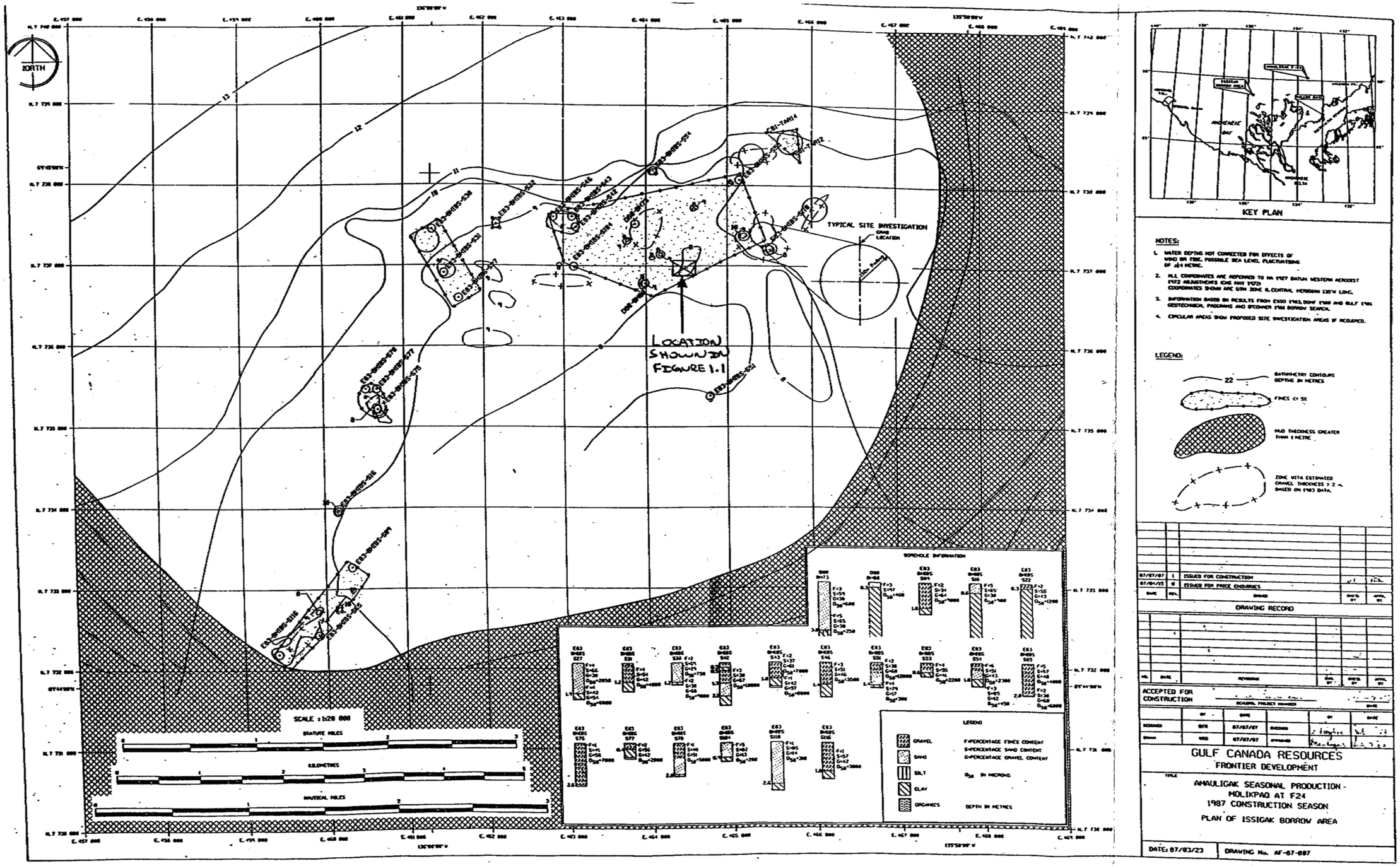
Figure 2.4: North Ukalerk Borrow Area



NOTES:

1. WATER DEPTHS NOT CORRECTED FOR EFFECTS OF WIND OR TIDE. POSSIBLE SEA LEVEL FLUCTUATIONS OF ±1 METRE.
2. ALL COORDINATES ARE REFERRED TO NAD 1927 DATUM WESTERN ARCTIC EXTENT 1972 ADJUSTMENTS (CAS NAD 1972) COORDINATES SHOWN ARE UTM ZONE 8, CENTRAL MERIDIAN 138°W LONG.
3. INFORMATION BASED ON RESULTS FROM ESSO 1983, DOME 1988 AND GULF 1986 GEOTECHNICAL PROGRAMS AND BEDMINER 1984 BOREHOLE SEARCH.
4. CIRCULAR AREAS SHOW PROPOSED SITE INVESTIGATION AREAS IF REQUIRED.

LEGEND:

22 — BATHYMETRY CONTOURS DEPTHS IN METRES

FINES (+ SX)

MUD THICKNESS GREATER THAN 1 METRE

ZONE WITH ESTIMATED GRAVEL THICKNESS > 2 m BASED ON 1983 DATA

DATE	No.	REVISIONS	BY	APPD. BY
87/07/07	1	ISSUED FOR CONSTRUCTION		
87/04/15	0	ISSUED FOR PRICE ENQUIRIES		

DRAWING RECORD

ACCEPTED FOR CONSTRUCTION

	BY	DATE		BY	DATE
DESIGNED	GTR	87/07/07	CHECKED		
DRAWN	VRD	87/07/07	APPROVED		

GULF CANADA RESOURCES
FRONTIER DEVELOPMENT

TITLE
AHAULIGAK SEASONAL PRODUCTION - MOLIKPAQ AT F24
1987 CONSTRUCTION SEASON
PLAN OF ISSIGAK BORROW AREA

DATE: 87/03/23 | DRAWING No. AF-87-887

Figure 2.7: Plan of Issigak Borrow Area

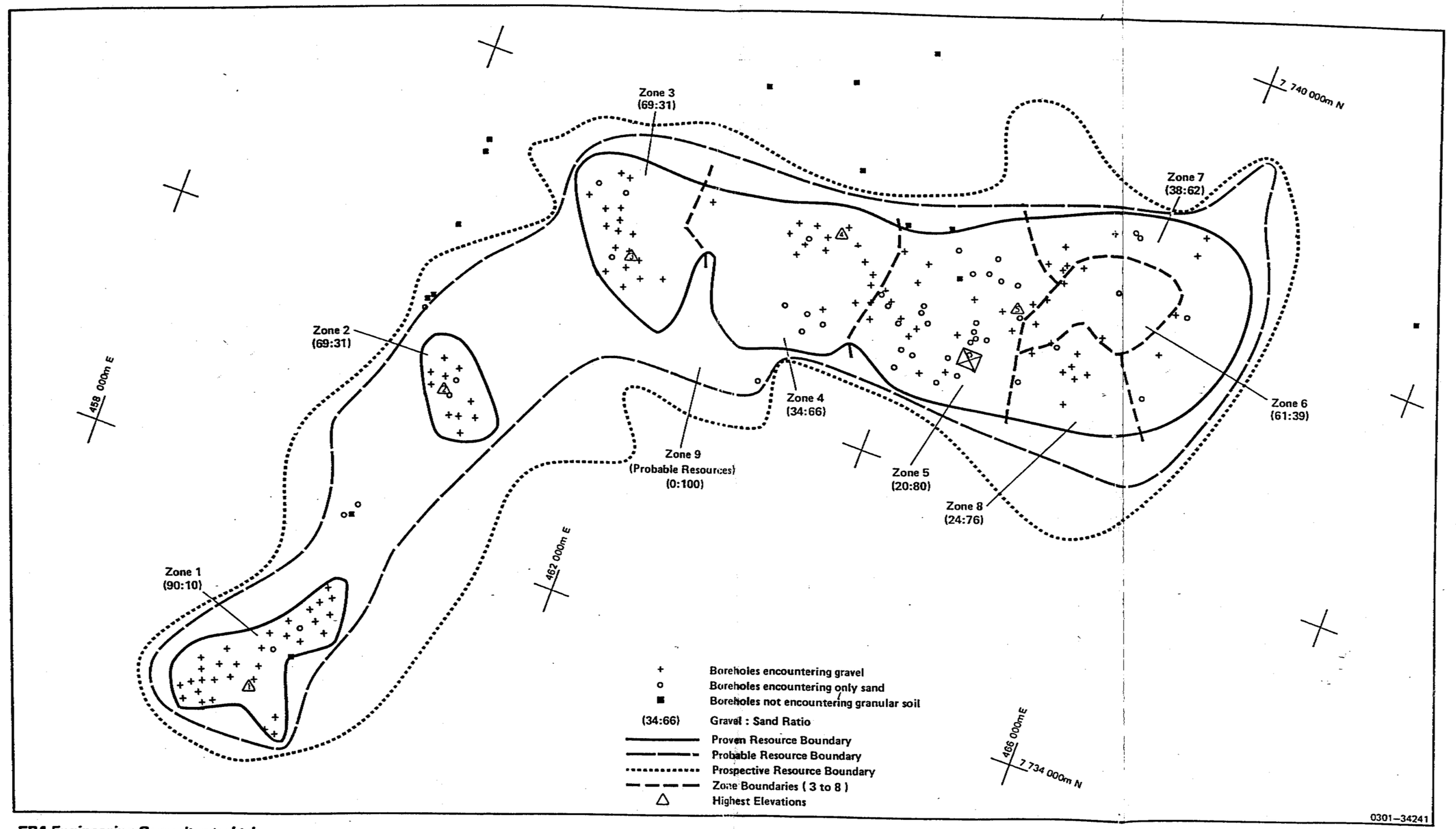


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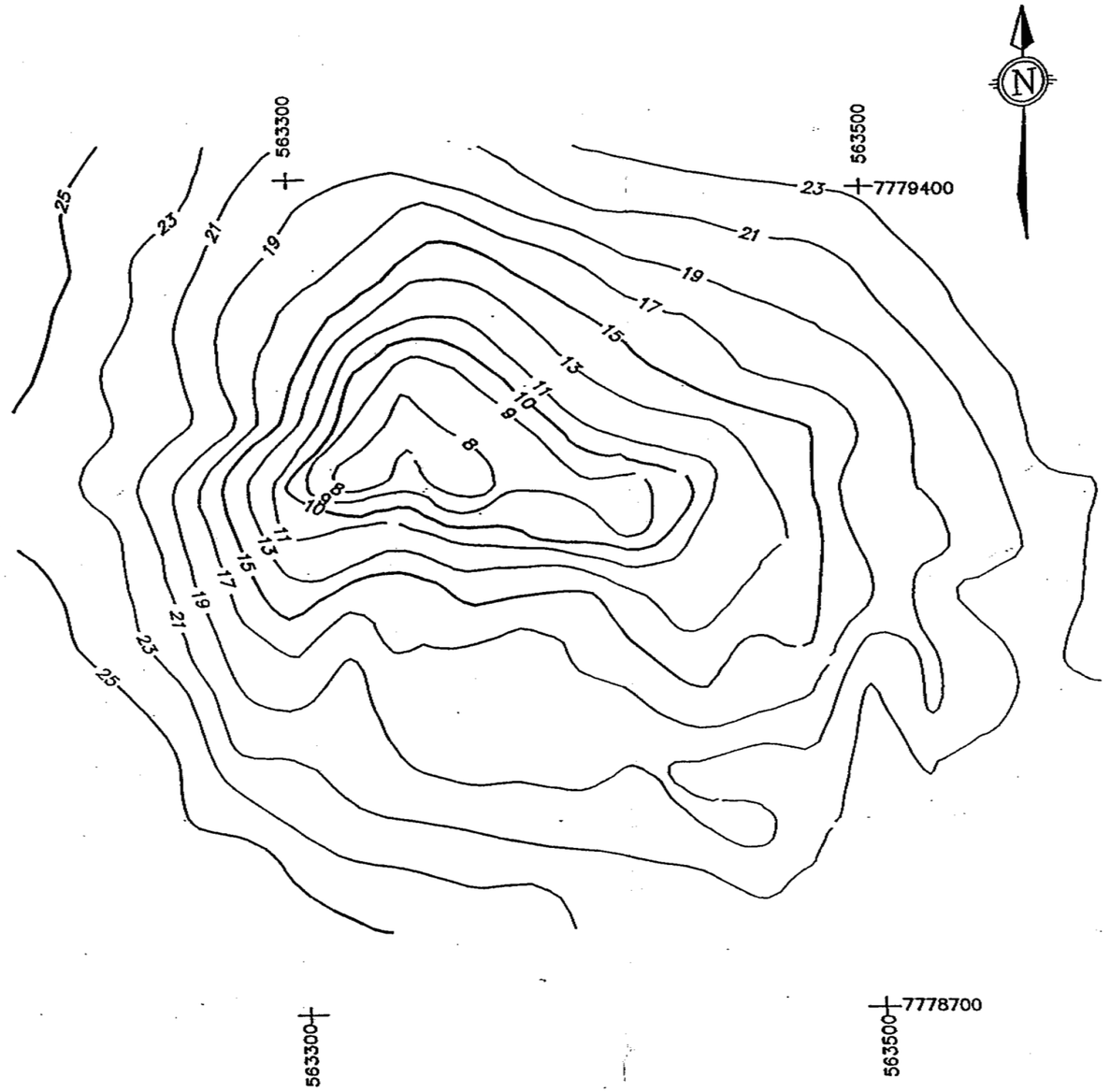
Figure 2.10: Issigak Borrow - Resource and Zone Boundaries



ORIGINAL SEABED : 28.1m BELOW MSL.
DATE OF SURVEY : AUGUST 1985, CANADIAN ENGINEERING SURVEYS CO. LTD.

SCALE 1 : 2000

KLOHN-CRIPPEN

Figure 3.3: Kogyuk N-67 (August, 1985)

KOGYUK ISLAND MATERIAL DISTRIBUTION
PER VESSEL (m^3)
VOLUMES MEASURED IN HOPPERS

	Source										
	Ukalerk				Uviluk				Banks Is.	S. Tarsiut	
Vessel	Geo X	Geo IX	WD Gwy	C.Z.	Geo X	Geo IX	WD Gwy	C.Z.	C.Z.	C.Z.	TOTAL
Bund **	65,70<	4,078			42,689						112,472
Berm Fill	174,937	166,394	59,958		22,997	55,935	86,691				566,912
Spur	8,078	4,932				15,349	5,961				34,320
Rejected	16,113	5,269	39,701			4,500 (7553) Nerlerk					(73,136)
Pads	8,273				8,300						16,573
Sand U. Fill				5,756	11,334			9,055			26,145
Toe Protection				8,090	5,000	9,836		16,123	5,200	4,000	48,249
TOTAL IN ISLAND	256,993	175,404	59,958	13,846	90,320	81,120	92,652	25,178	5,200	4,000	804,671 *
TOTAL PER BORROW	506,201				289,270				5,200	4,000	

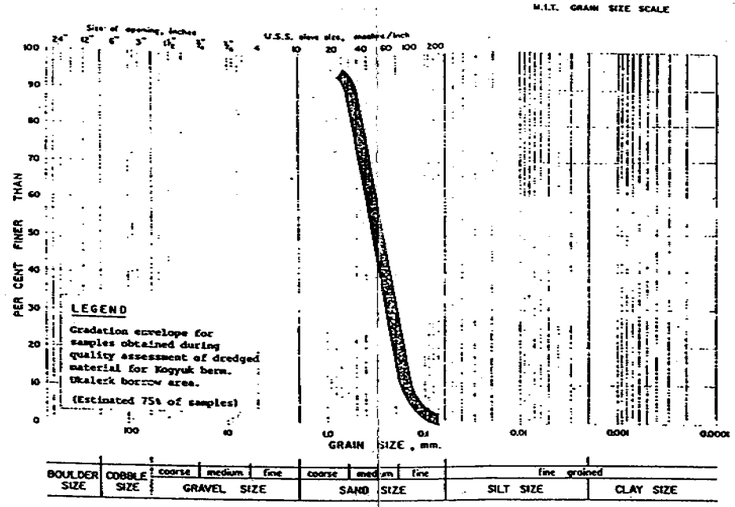
Total Island Volume Per Dredge
Geo X = 347,313 m^3
Geo IX = 256,524 m^3
WD Gwy = 152,610 m^3
C.Z. = 48,224 m^3
804,671 m^3

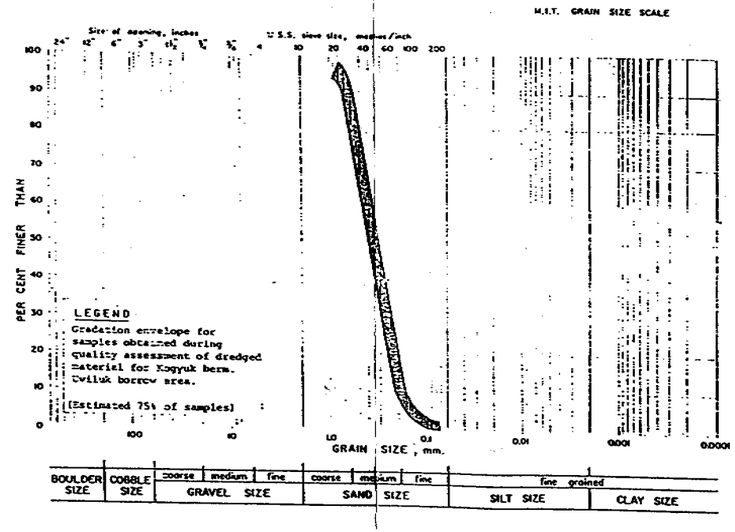
1982 Volume placed by Gulf (Geo IX) = 643,000 m^3
1,447,671 m^3

*Does not include rejected volumes
**Includes loads discharged via suction pipe

QUALITY OF THE BORROWS USED FOR KOGYUK ISLAND 1983

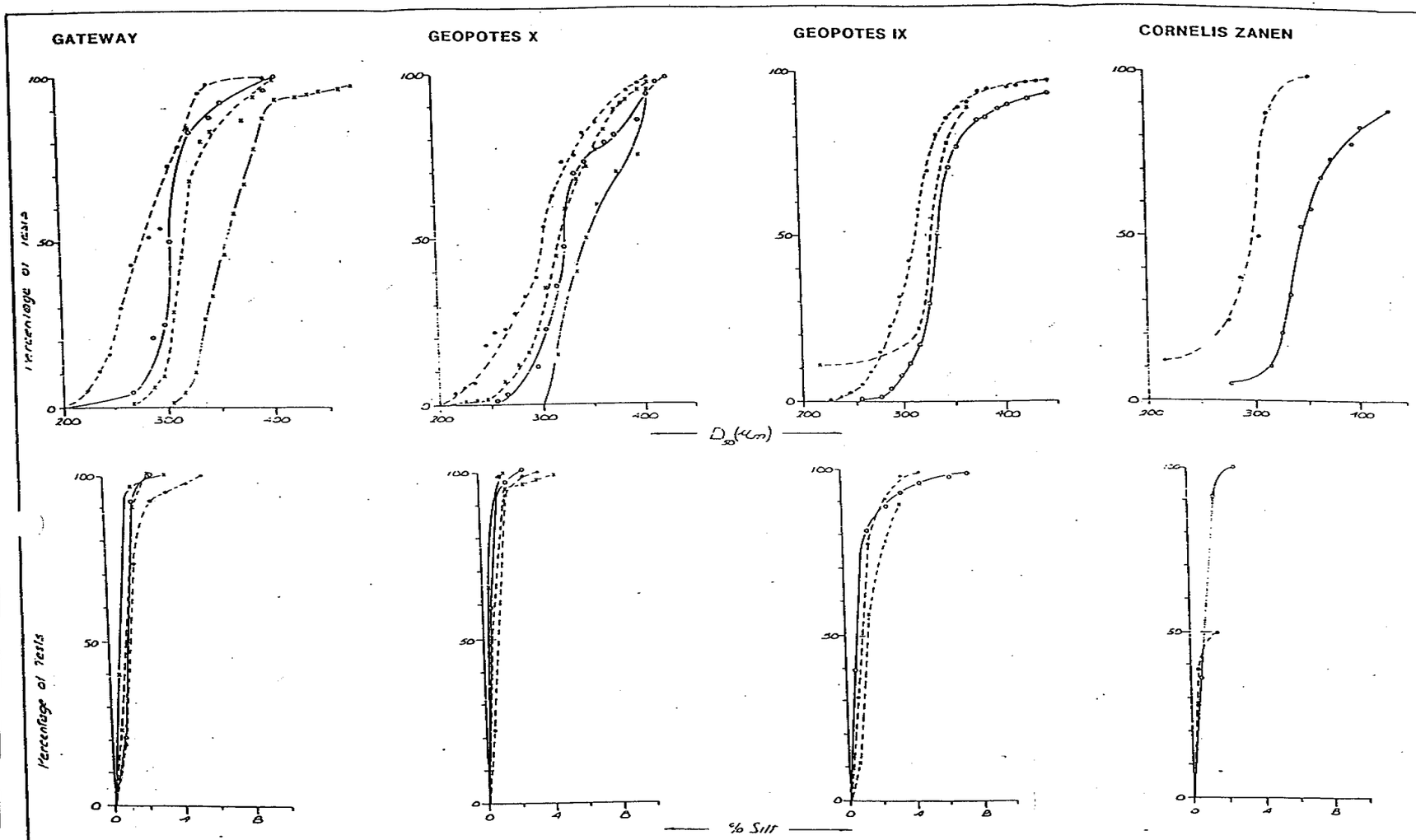
BORROW	VESSEL	VOLUME	# OF LOADS	# OF LOADS SAMPLED	D50 * BEST	D50 * MEAN	D50 * WORST	% FINES * BEST	% FINES * MEAN	% FINES * WORST
UKALERK	GEO X	256993	32	32	395	325	274	0.8	1.12	2.2
	GEO IX	175404	33	28	373	328	286	0.8	1.8	2.4
	WD GWY	59958	11	11	403	323	300	0.9	1.5	1.8
	C. Zanen	13846	2	1		297			3.2	
UVILUK	GEO X	90320	11	11	389	339	317	0.8	.95	1.2
	GEO IX	81120	16	16	487	342	316	0.9	1.9	2.6
	WD GWY	92652	16	16	373	360	327	0.8	1.1	1.7
	C. Zanen	25178	4	3	604	457	366	0.6	1.06	1.6





NOTE: DOES NOT INCLUDE REJECTED LOADS
* AVERAGE VALUES PER LOAD

Figure 3.5: Source and Gradation of Materials Sampled on Dredges en route to Kogyuk from Uviluk P-66 and Ukalerk, 1983



CUMULATIVE FREQUENCY CURVES OF 1983 QA SAMPLES

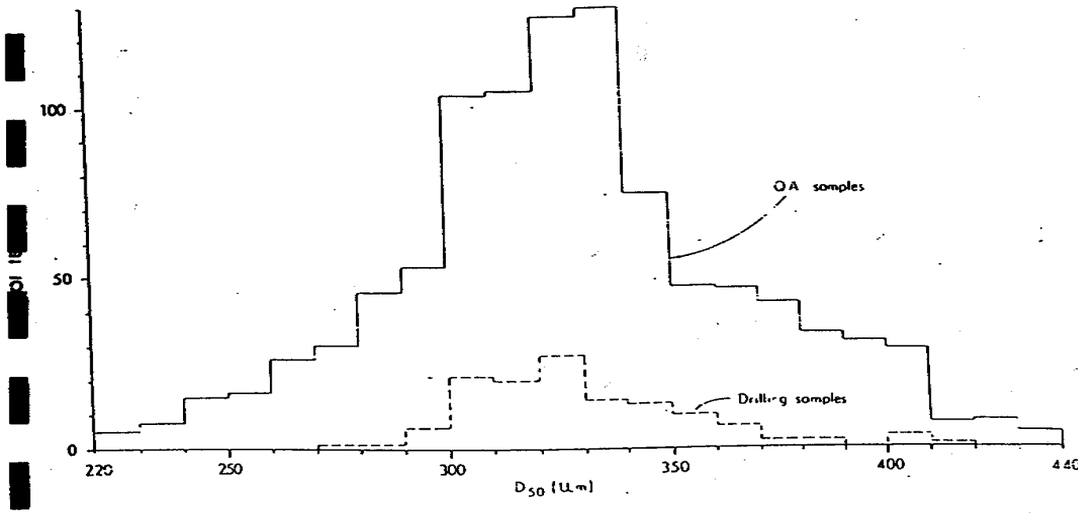
LEGEND

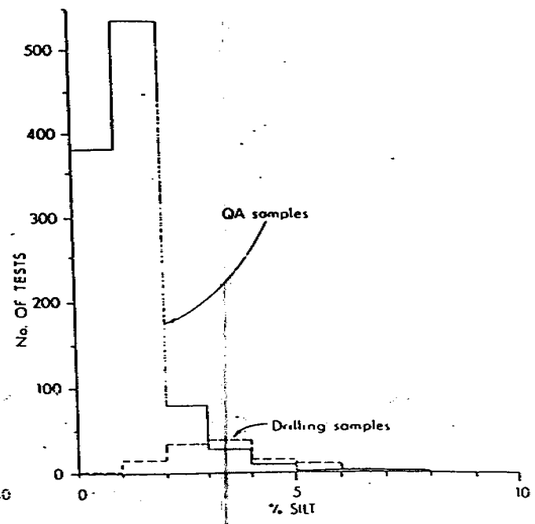
- Sounding Tube Samples Uviluk Borrow
- Sounding Tube Samples Ukalerk Borrow
- Slurry Pipe Samples Uviluk Borrow
- Slurry Pipe Samples Ukalerk Borrow

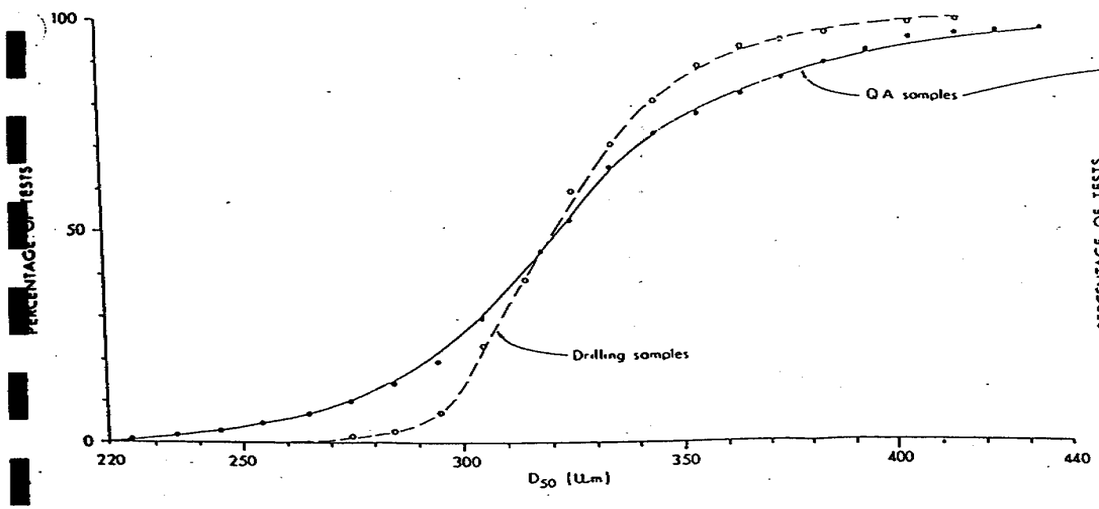
Golder Associates			
PROJECT: 832-2060	DRAWN BY: GP	DATE: Jan '84	REVIEWED:

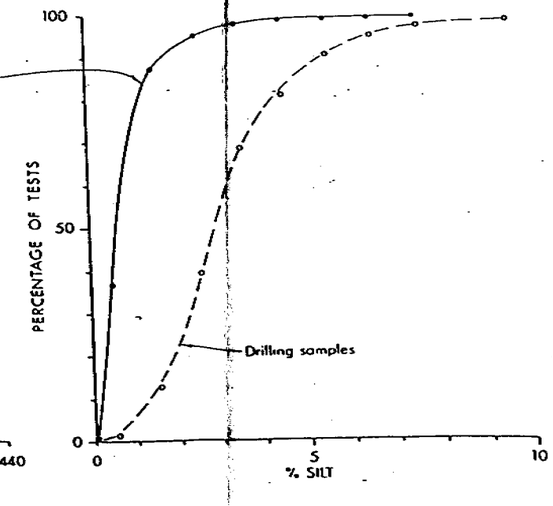
KLOHN-CRIPPEN

Figure 3.6: Gradation and Fines Content from Dredges Transporting Sand from Uviluk and Ukalerk to Kogyuk N-67, 1983







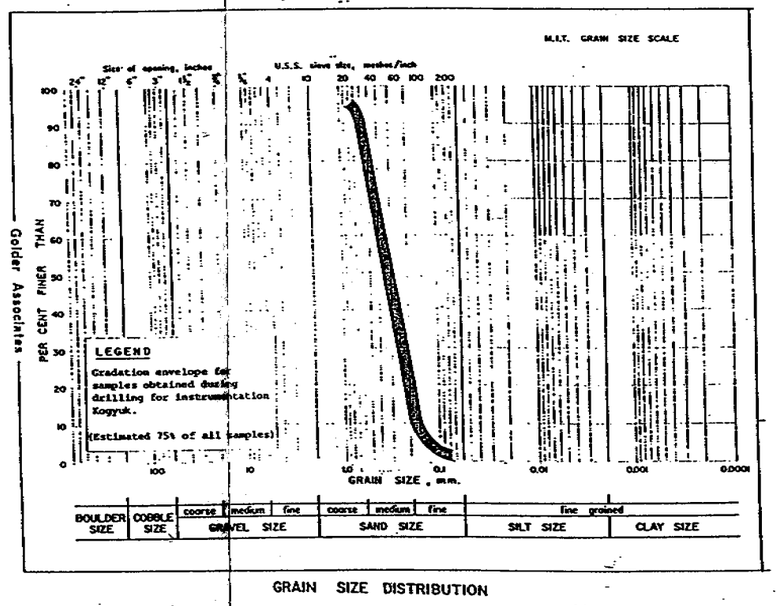


SIEVE ANALYSIS RESULTS
DRILLING / Q.A.

(All Samples)

SUMMARY OF ALL SAMPLES TAKEN DURING QUALITY ASSURANCE OF DREDGING ——
(For 1983 Construction Season Only)

SUMMARY OF SAMPLES TAKEN DURING DRILLING FOR INSTRUMENTATION INSTALLATION - - - - -

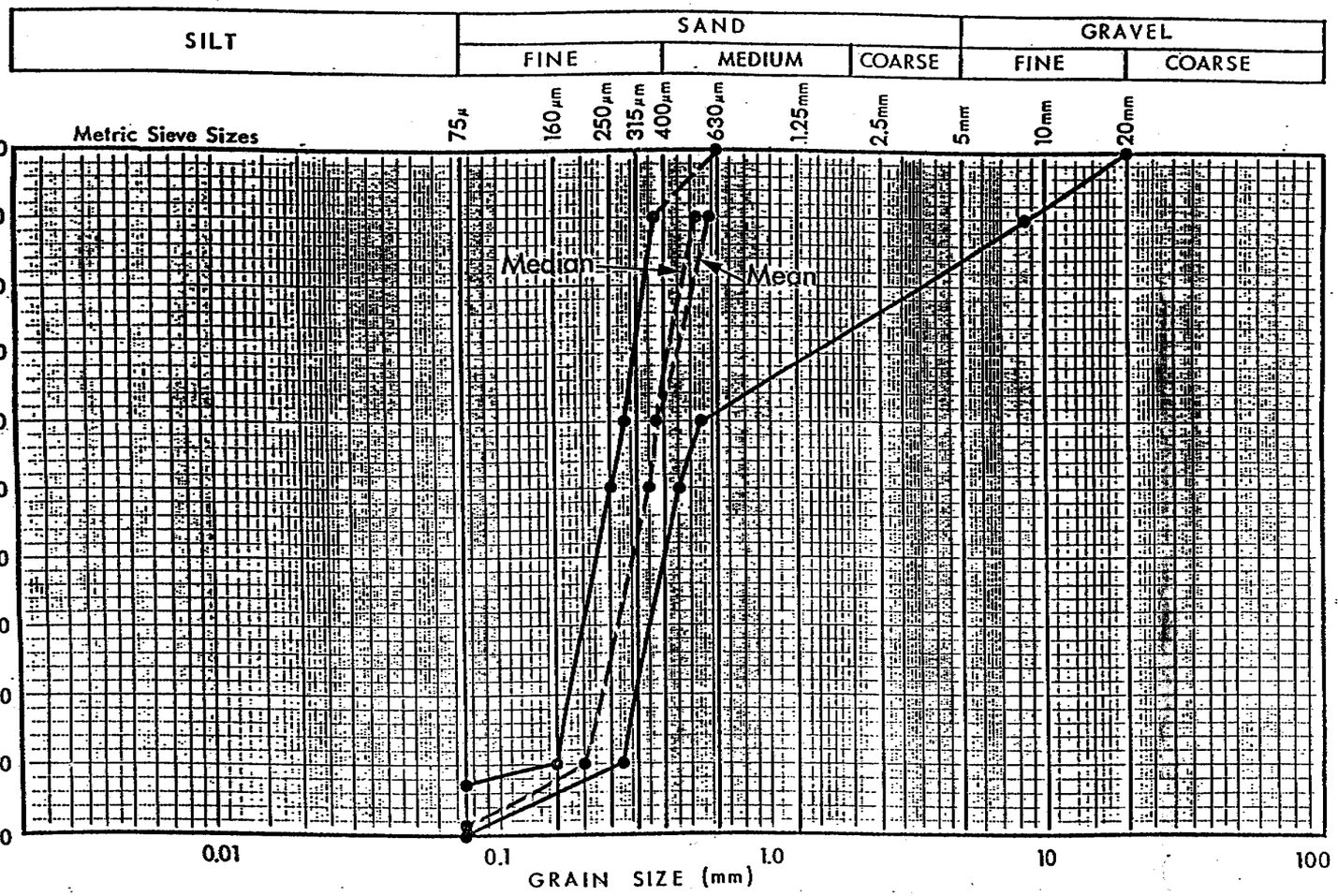


GRAIN SIZE DISTRIBUTION

Golder Associates			
PROJECT: 832-2060	DRAWN BY: GP	DATE: DEC '83	REVIEWED: DF

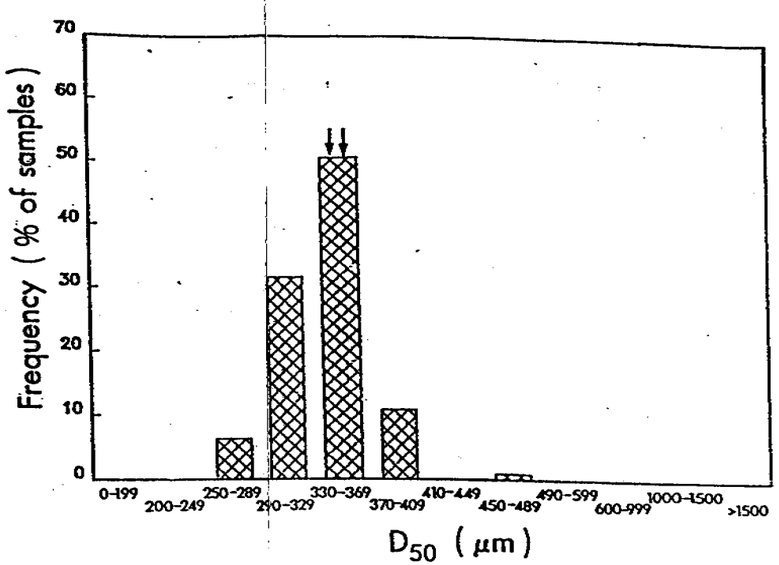
KLOHN-CRIPPEN

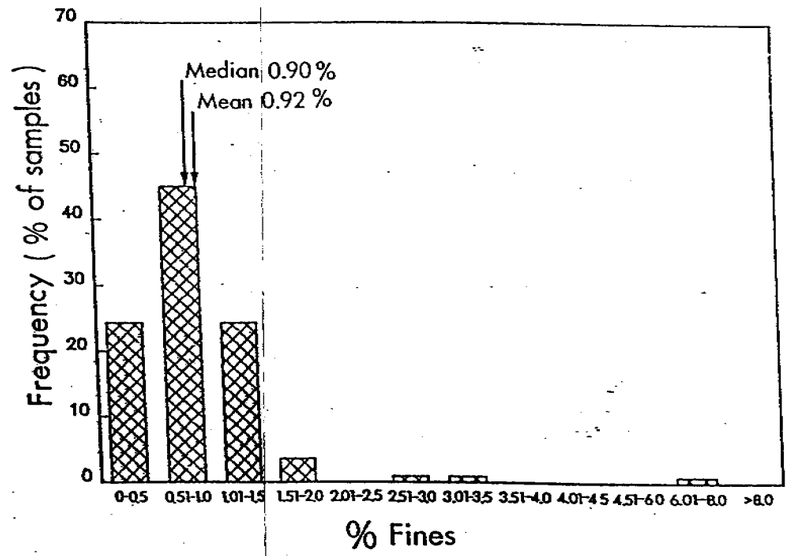
Figure 3.7: Comparison of Dredge Samples with Drill Samples from Instrument Installation at Kogyuk N-67, 1983



Grain Size Envelope
for Kogyuk N67 Borrow
Site

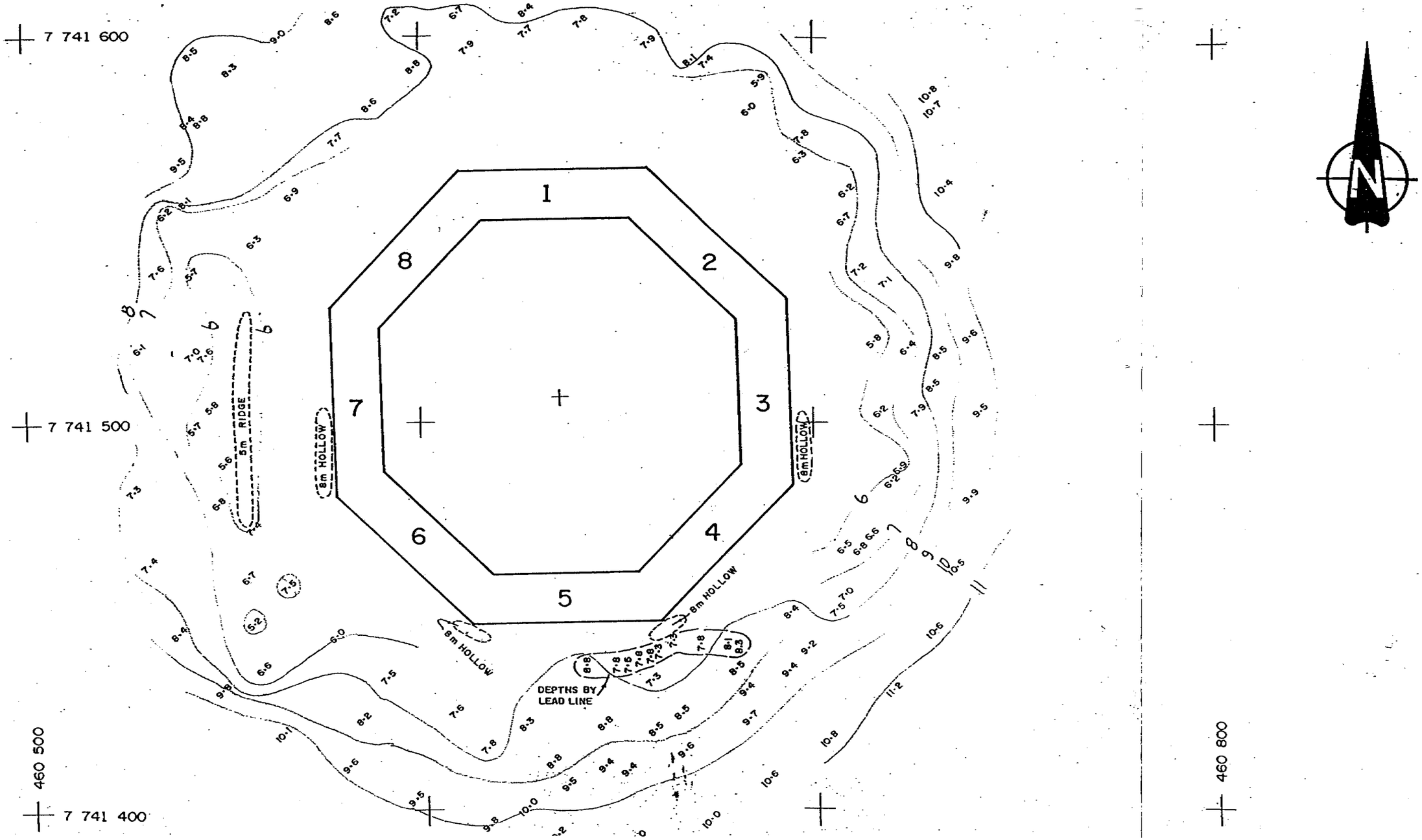
DATA FROM TARSIUT P-45 PROJECT





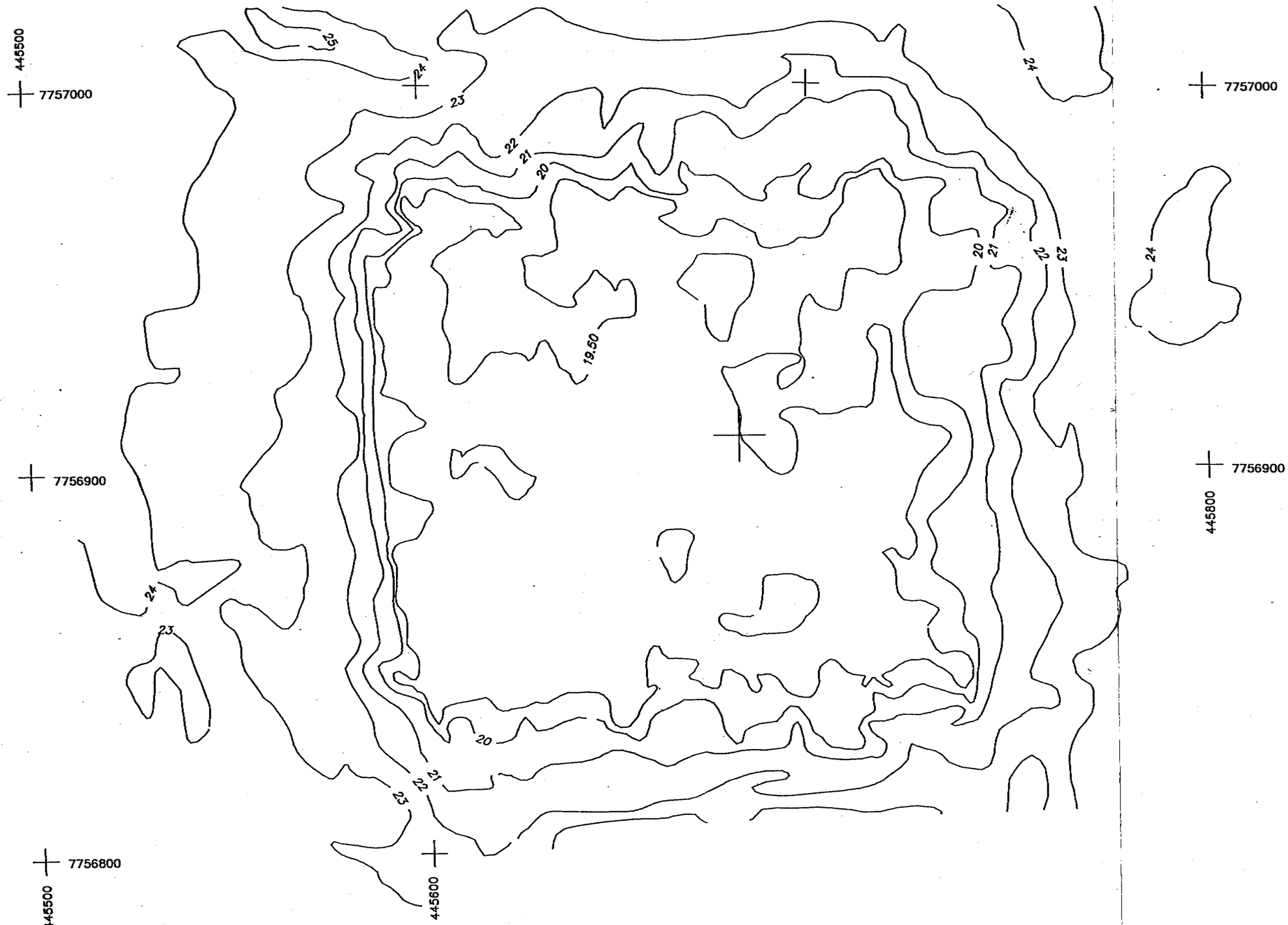
Histogram of D_{50} and % Fines for
Kogyuk N67 Borrow Site
(111 Samples)

Figure 3.8: Gradation and Fines Content of Dredge Samples en route to Tarsiut P-45 from Kogyuk N-67, 1984



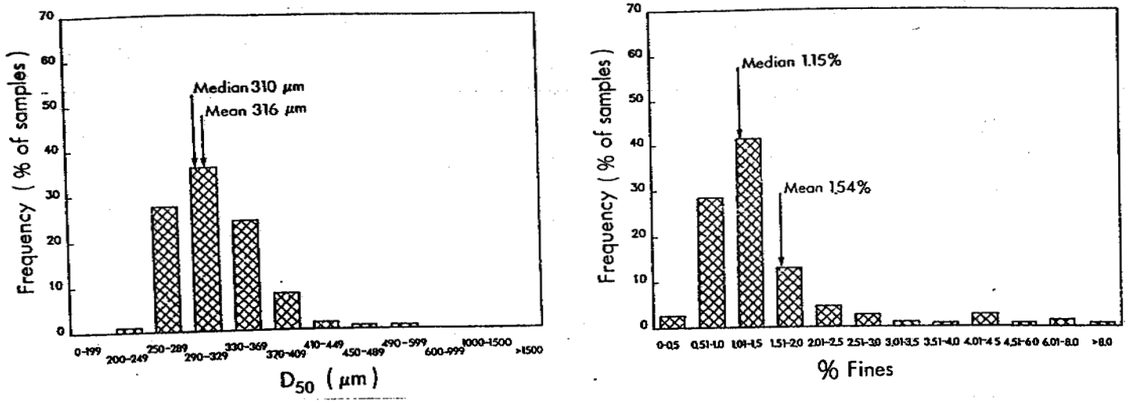
KLOHN-CRIPPEN

Figure 3.11: Kadluk O-07 (August, 1983)

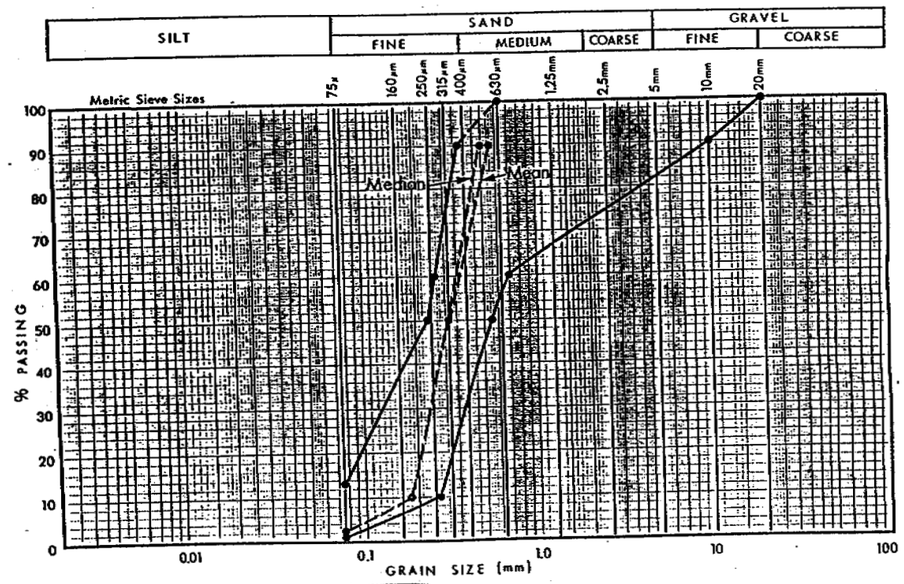


KLOHN-CRIPPEN

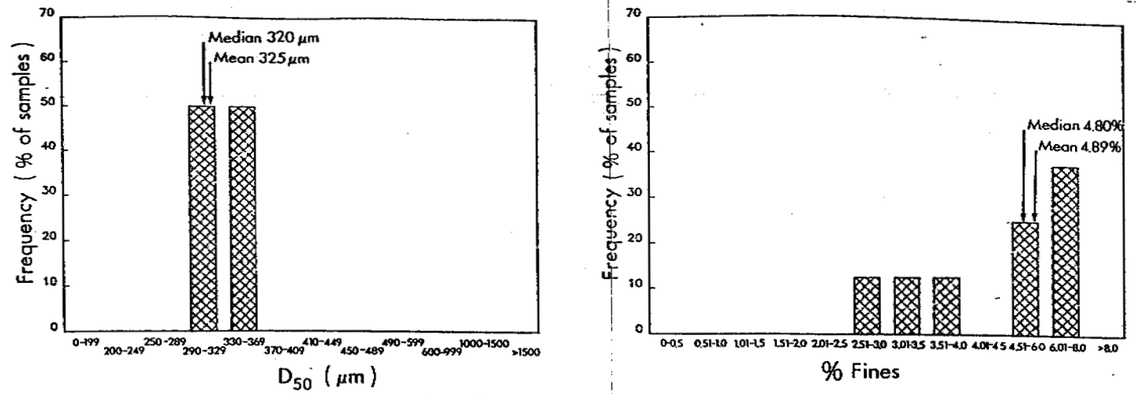
Figure 3.17: Tarsiut P-45 (September 18, 1984)



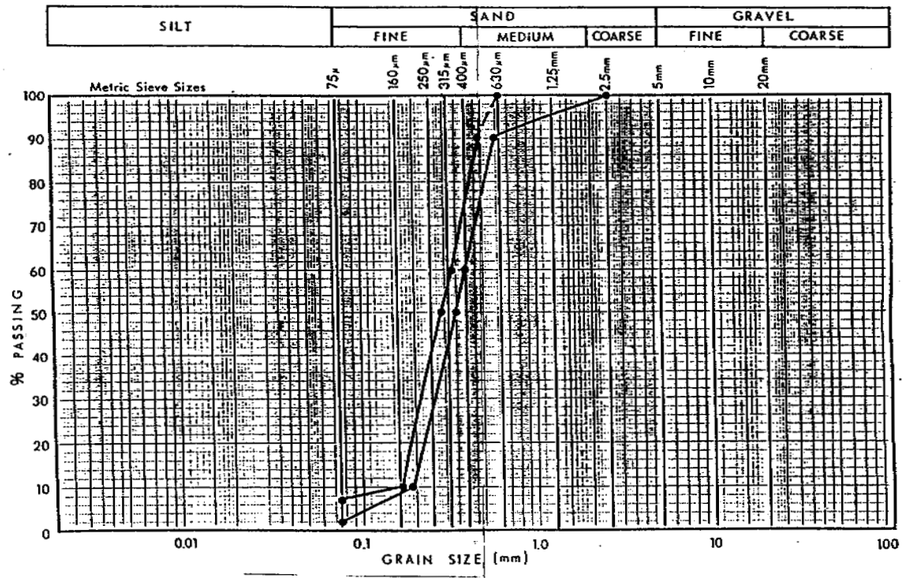
Histogram of D_{50} and % Fines for Ukalerk Borrow Site (261 Samples)



Grain Size Envelope for Ukalerk Borrow Site



Histogram of D_{50} and % Fines for N.Ukalerk Borrow Site (8 Samples)



Grain Size Envelope for N.Ukalerk Borrow Site

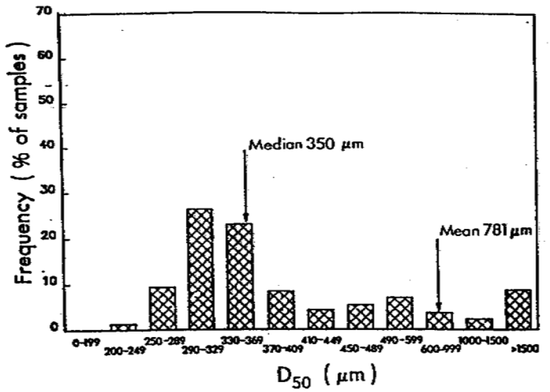
FILL MATERIAL DISTRIBUTION

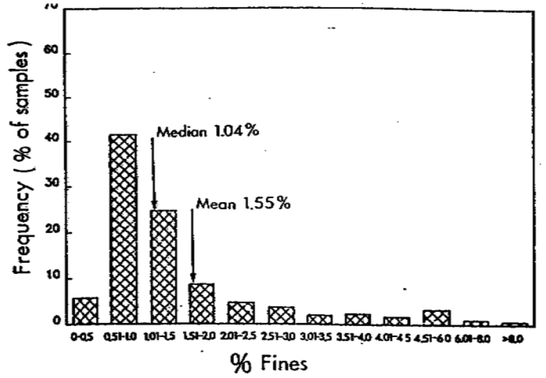
SOURCE / OPERATION	UKALERK GEO IX	UKALERK GEO X	KOGYUK N-67 GEO IX	KOGYUK N-67 GEO X	TARSIUT N-44 GEO IX	N. UKALERK GEO X	TOTAL PER OPERATION ($)
SUBCUT FILL	15,318	96,272	-	-	12,008	-	123,598 (27$)
BERM FILL	-	84,758	-	-	128,778	-	213,536 (46$)
CORE FILL	-	14,097	4,547	87,815	-	6,179	112,638 (25$)
TOE PROTECTION	-	-	-	-	9,500	-	9,500 (2$)
$ OF LOADS WASTED	50$	8$	-	-	7$	50$	9$
TOTAL	15,318	195,127	4,547	87,815	150,286	6,179	-
TOTAL PER SOURCE	210,445		92,362		150,286	6,179	459,272
$ OF TOTAL	(45$)		(20$)		(33$)	(2$)	(100$)

NOTE: 1) VOLUMES QUOTED ARE ADJUSTED HOPPER MEASURE.
TOTAL ISLAND VOLUME PER DREDGE: GEO IX = 170,151 (38$)
GEO X = 289,121 (62$)
459,272 (100$)

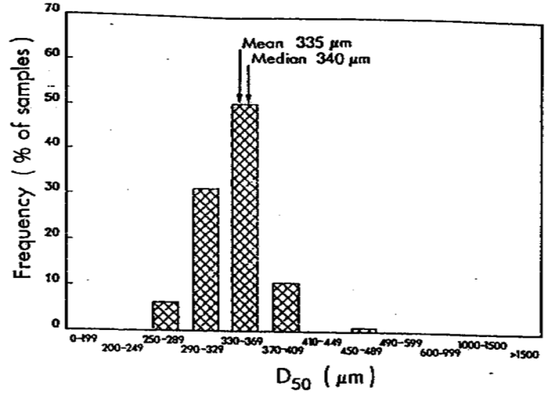
KLOHN-CRIPPEN

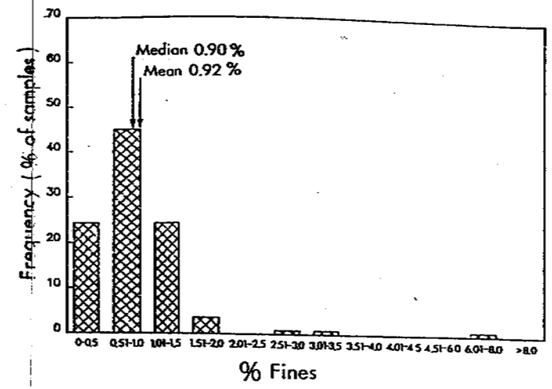
Figure 3.18: Fill Material used for Construction at Tarsiut P-45 (Sheet 1)



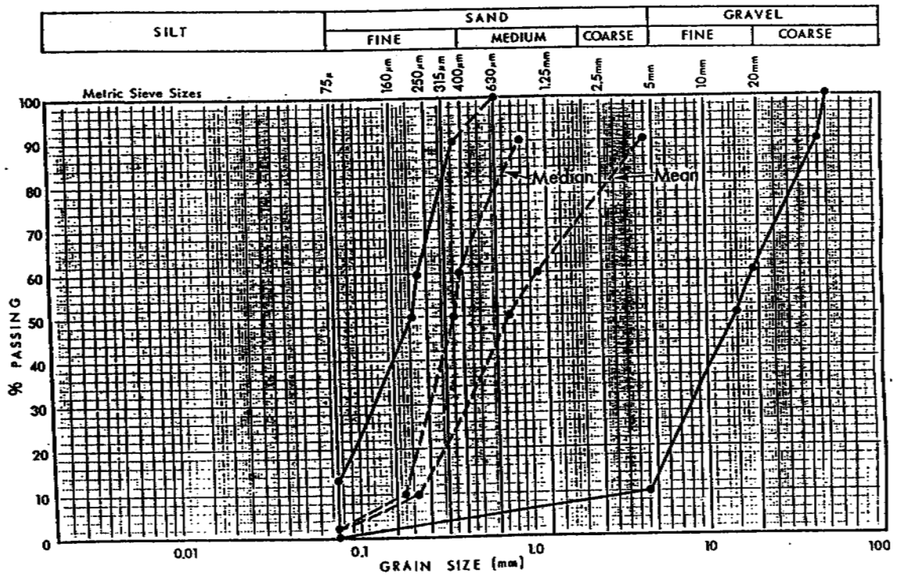


Histogram of D_{50} and % Fines for Tarsiut N-44 Borrow Site (302 Samples)

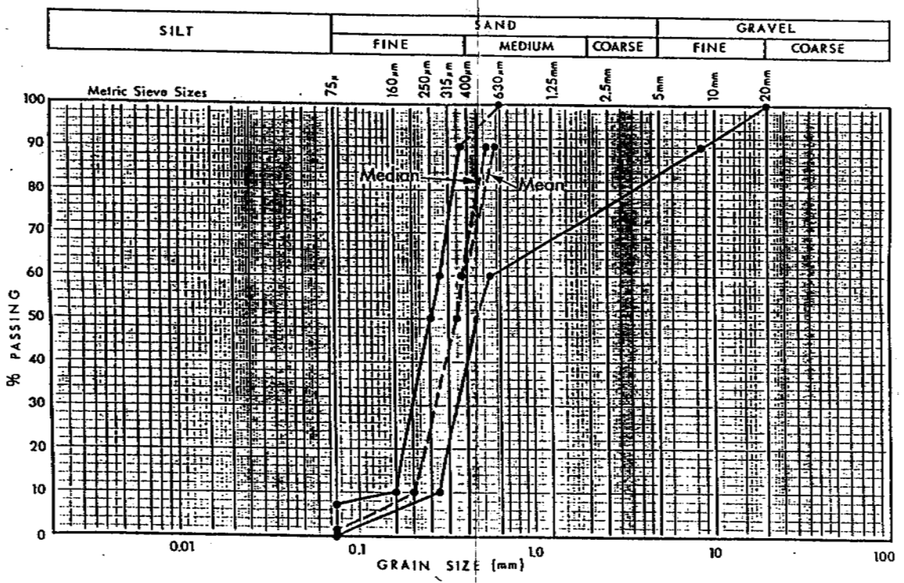




Histogram of D_{50} and % Fines for Kogyuk N-67 Borrow Site (111 Samples)



Grain Size Envelope for Tarsiut N-44 Borrow Site



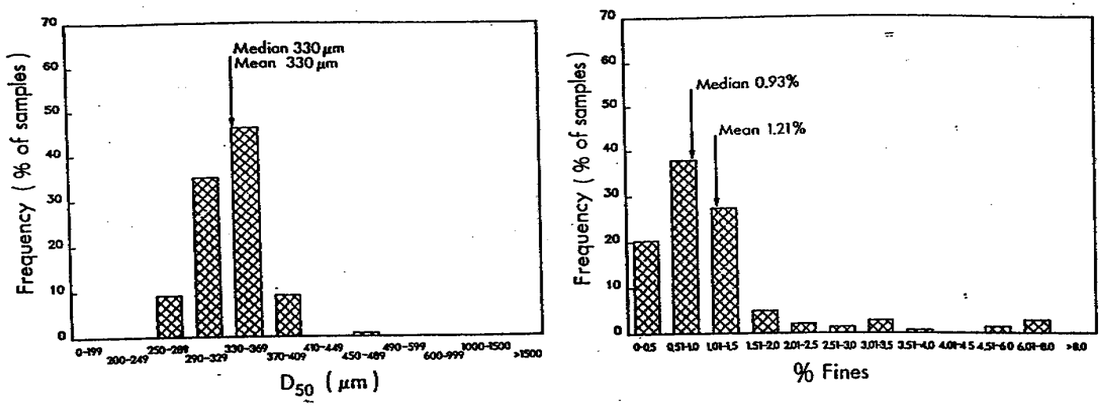
Grain Size Envelope for Kogyuk N-67 Borrow Site

FILL MATERIAL DISTRIBUTION

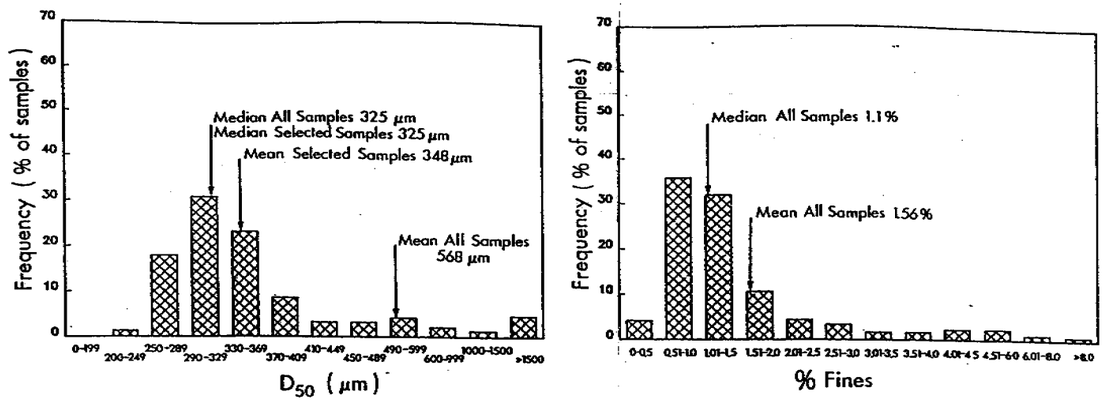
SOURCE / OPERATION	UKALERK		KOGYUK N-67		TARSIUT N-44	N. UKALERK	TOTAL PER OPERATION ($)
	GEO IX	GEO X	GEO IX	GEO X	GEO IX	GEO X	
SUBCUT FILL	15,318	96,272	-	-	12,008	-	123,598 (27$)
BERM FILL	-	84,758	-	-	128,778	-	213,536 (46$)
CORE FILL	-	14,097	4,547	87,815	-	6,179	112,638 (25$)
TOE PROTECTION	-	-	-	-	9,500	-	9,500 (2$)
$ OF LOADS WASTED	50$	0$	-	-	7$	50$	9$
TOTAL	15,318	195,127	4,547	87,815	150,286	6,179	-
TOTAL PER SOURCE	210,445		92,362		150,286	6,179	459,272
$ OF TOTAL	(45$)		(20$)		(33$)	(2$)	(100$)

NOTE: 1) VOLUMES QUOTED ARE ADJUSTED HOPPER MEASURE.
TOTAL ISLAND VOLUME PER DREDGE: GEO IX = 170,151 (38$)
GEO X = 289,121 (62$)
459,272 (100$)

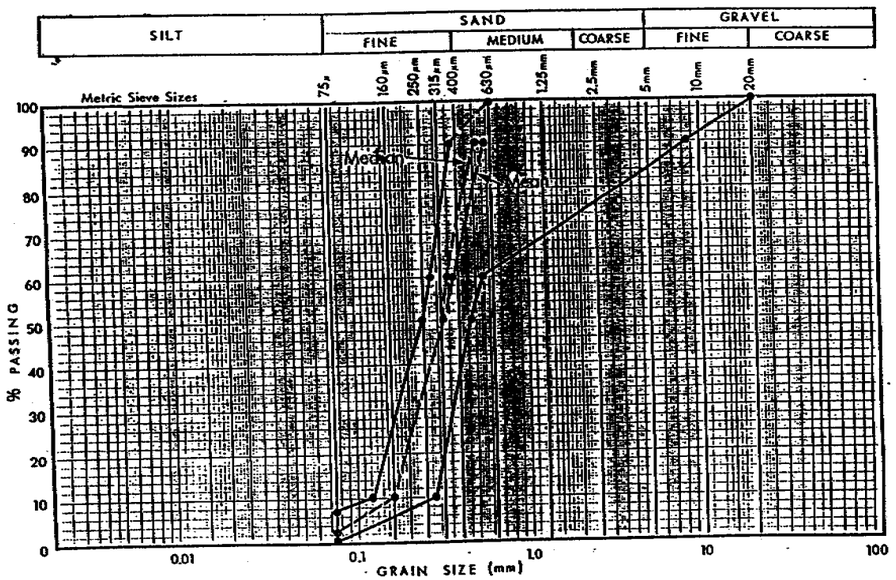
Figure 3.19: Fill Material used for Construction at Tarsiut P-45 (Sheet 2)



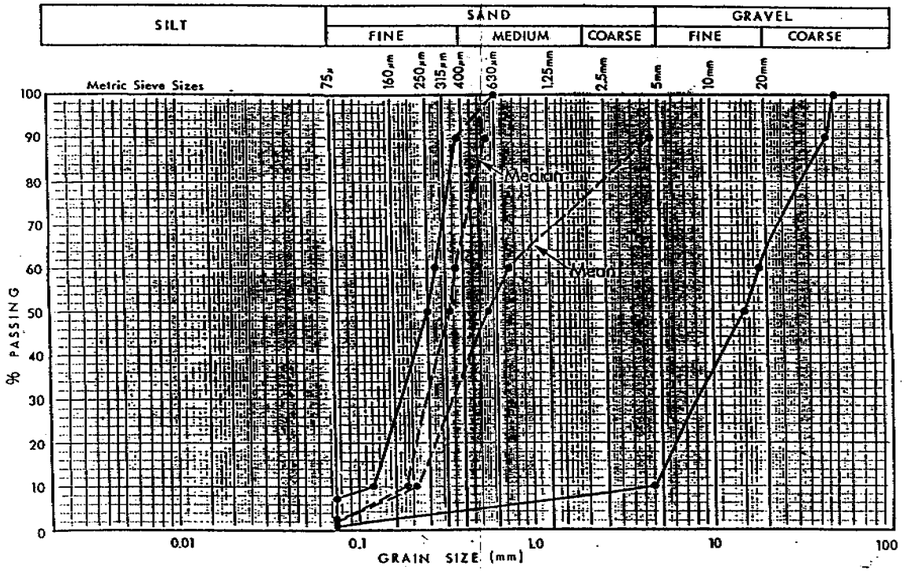
Histogram of D_{50} and % Fines for Tarsiut P-45 Core (143 Samples)



Histogram of D_{50} and % Fines for Tarsiut P-45 Berm (530 Samples)



Grain Size Envelope for Tarsiut P-45 Core

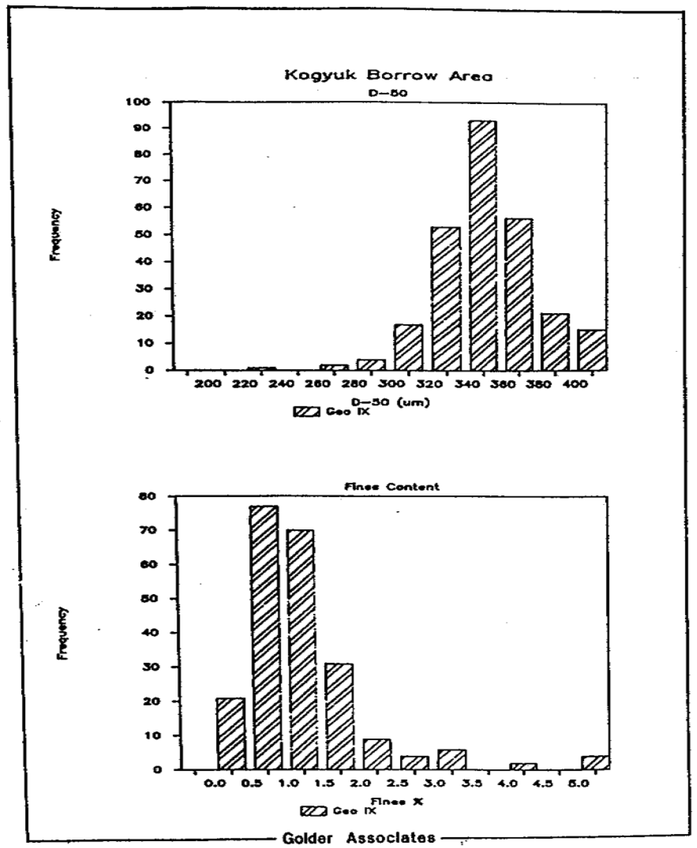


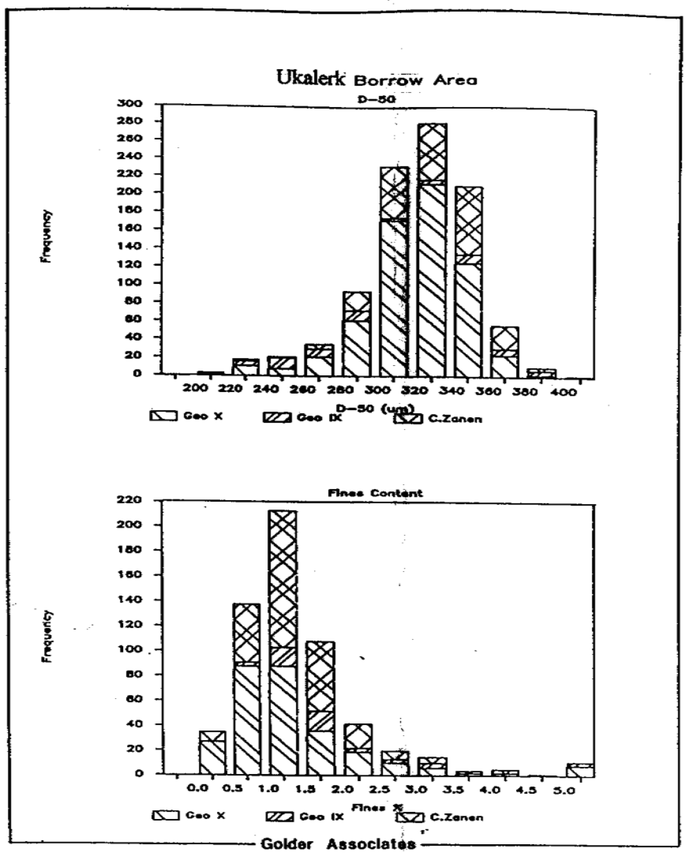
Grain Size Envelope for Tarsiut P-45 Berm

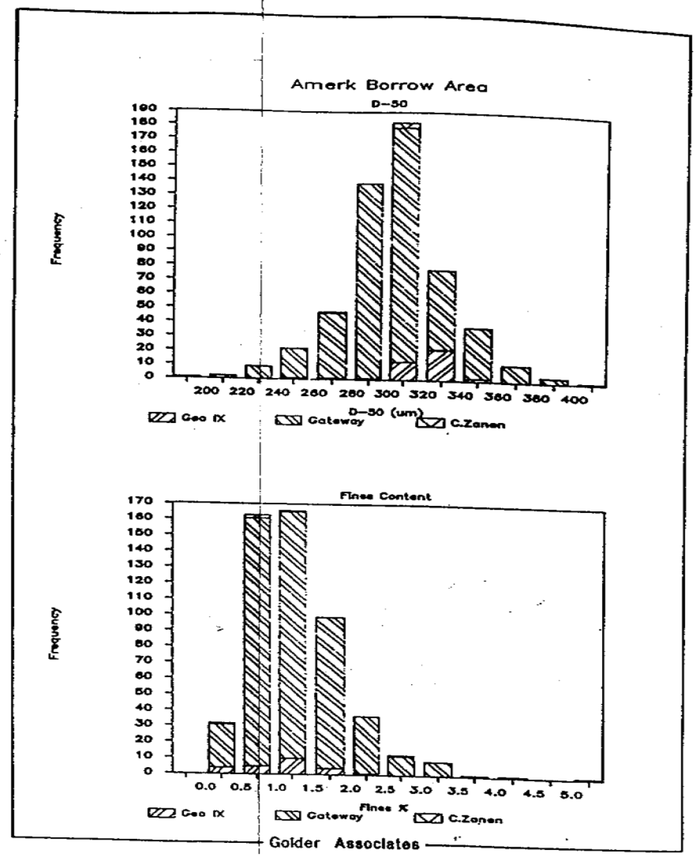
Borrow Sources: Ukalerk (210,455m^3)
Tarsiut N-44 (140,786m^3)
Kogyuk N-67 Berm (93,362m^3)
N.Ukalerk (6,179m^3)

- Vibracore & Sounding tube used to sample hopper.
- Statistics calculated only with samples with D_{50} < 1000μm.
- These diagrams are a mixture of on board grain size analysis from all borrow sites.

Figure 3.20: Gradation Envelopes for Tarsiut P-45







FILL MATERIAL DISTRIBUTION

TABLE 12.4

SOURCE	ISSIGAK	KOGYUK N-67	UKALERK			AMERK A-09			
OPERATION	C. ZAHEN	GEO IX	GEO IX	GEO X	C. ZAKEN	GATEWAY	C. ZANEN	GEO IX	TOTAL PER OPERATION ($)
Subcut Fill	4350	61,534	19,741	182,655	31,027	114,644	5278	15,947	435,176 (30.7)
Berm Fill	-	149,566	-	222,911	239,847	209,069	-	10,794	832,187 (58.6)
Core Fill	-	57,471	-	72,506	-	-	-	10,885	140,862 (9.9)
Toe Protection	-	10,716	-	-	-	-	-	-	10,716 (0.8)
% of Loads Wasted:	0	0	33% (2 Rejected)	0	0	0	0	0	0.8%
TOTAL VOLUME TOTAL NO. LOADS	4350 1	279,287 55	19,741 4	478,072 67	270,874 51	323,713 64	5278 1	37,626 7	1,418,941 250
TOTAL PER SOURCE	4350	279,287	768,687				366,617		1,418,941
% of Total	0.3	19.7	54.2				25.8		100.0

Note: 1) Volumes Quoted are Adjusted Hopper Measure
2) Total Island Volume per Dredge: Geo X = 478,072 (33.7%)
Geo IX = 336,654 (23.7%)
Gateway = 323,713 (22.8%)
C. Zanen = 280,502 (19.8%)

TOTAL = 1,418,941 (100%)

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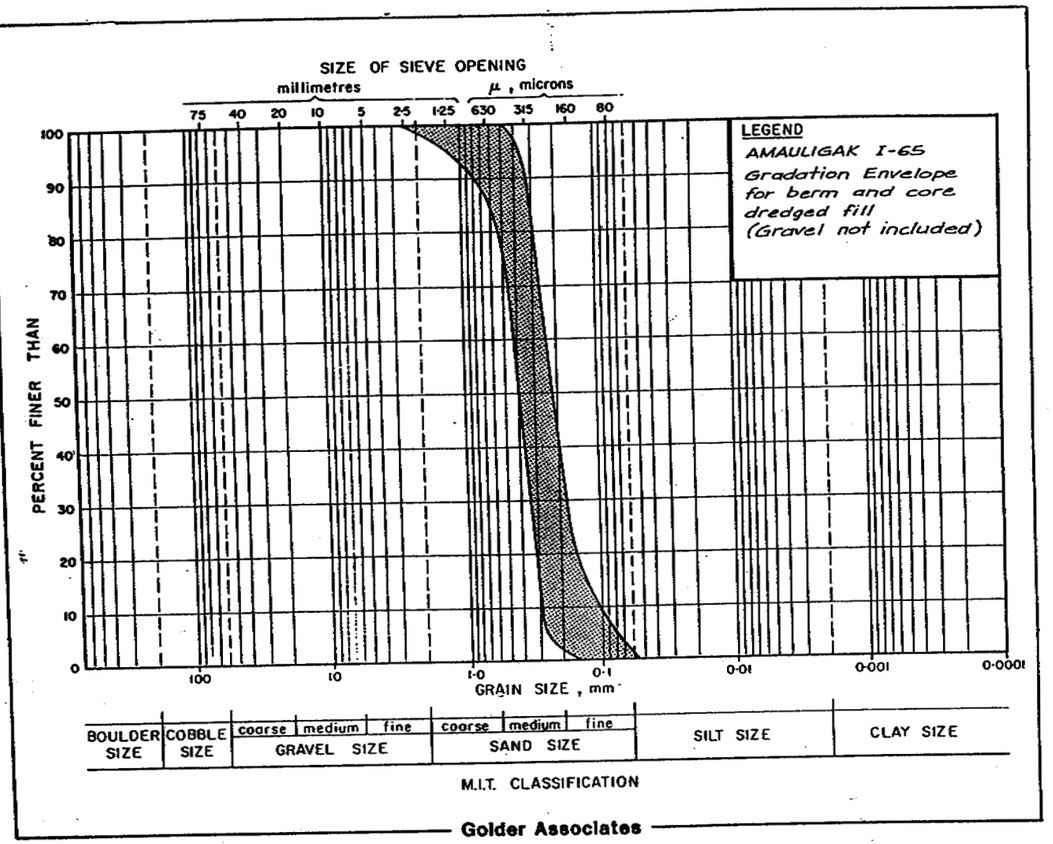
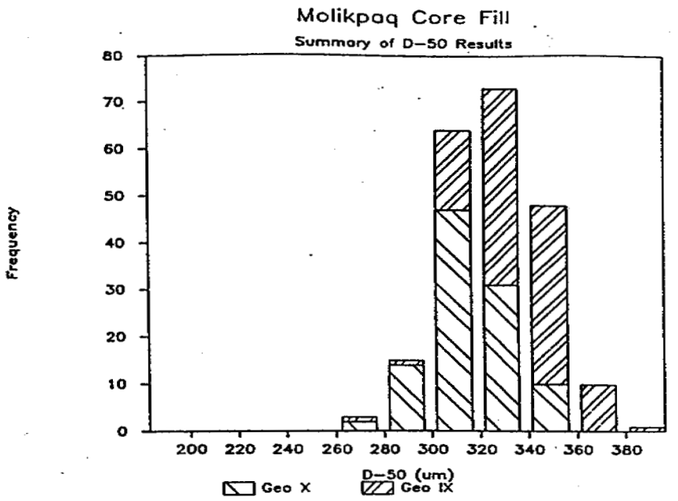
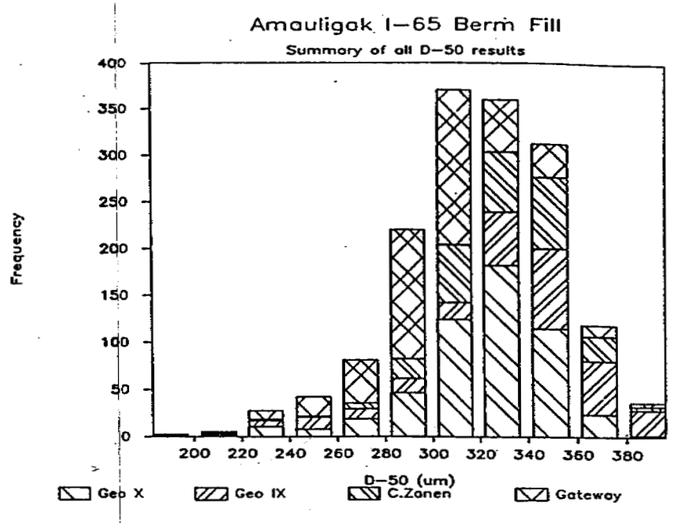
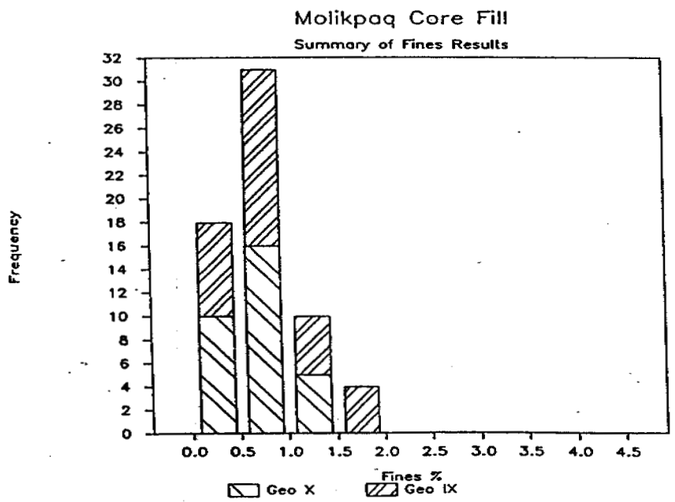
Figure 3.23: Dredge Samples by Source - Amauligak I-65









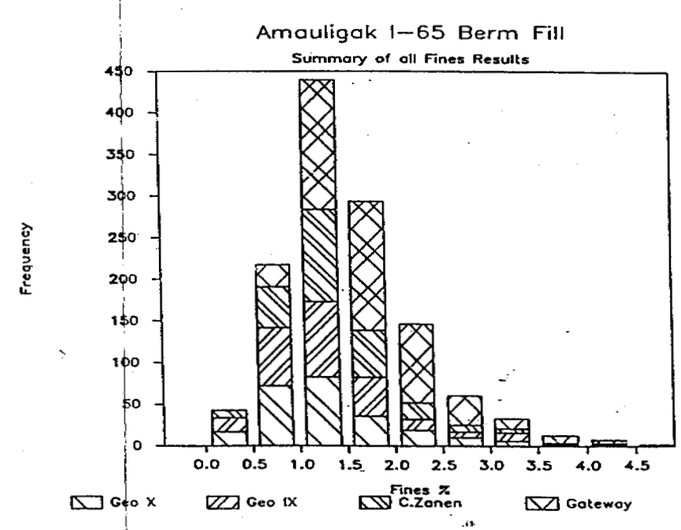
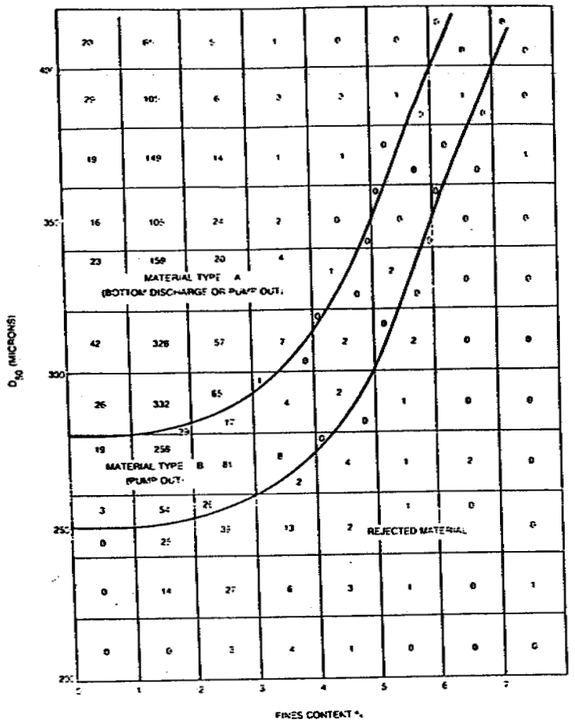


Figure 3.24: Dredge Samples by Location within Island - Amauligak I-65



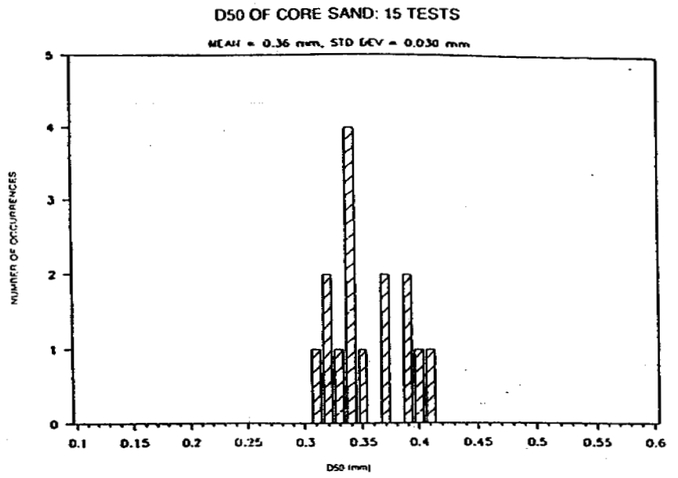
DISTRIBUTION OF SAND QUALITY IN SUBCUT AND BERM

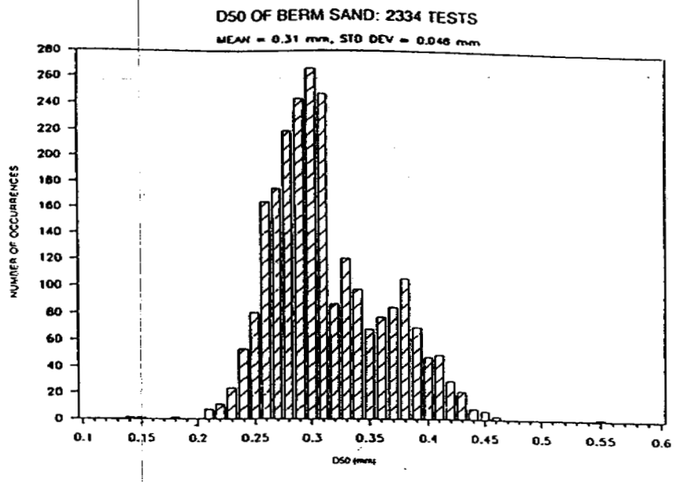
TABLE 2.2 SOURCES AND VOLUMES OF SAND AND GRAVEL

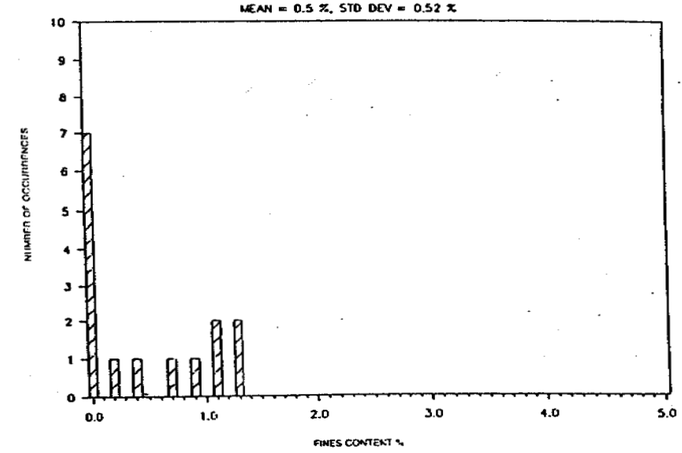
Source / F24 Location	UKALERK LOAD NO.	UKALERK VOLUME (m^3)	AMAULIGAK I-65 LOAD NO.	AMAULIGAK I-65 VOLUME (m^3)	MINUK ISLAND LOAD NO.	MINUK ISLAND VOLUME (m^3)	TOTAL VOLUME (m^3)
Berm Fill	1-303, 305 306, 308	1,994,750	316, 317, 319	19,702	-	-	2,014,452
Gravel Bund	-	-	-	-	304, 307, 309-315, 318	43,858	43,858
Core Fill	-	-	320 - 338	125,255	-	-	125,255
Gravel Toe Protection	-	-	-	-	339 - 343	20,702	20,702
TOTALS	306	1,994,750	21	144,957	14	64,560	2,204,267

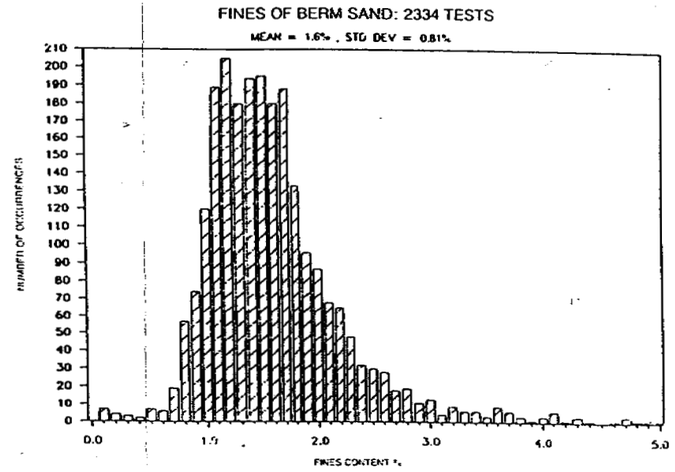
Part of Load 338 - 3859 m^3 dredged at I-65 but not placed in Molikpaq core.

NOTES: All material used from Erksak was Class A or B material.
All materials used from Amauligak I65 was Class A material.
All material used from Minuk I53 was Class C material.





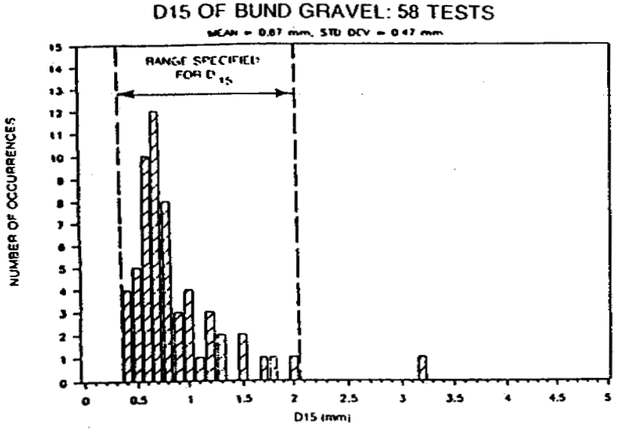


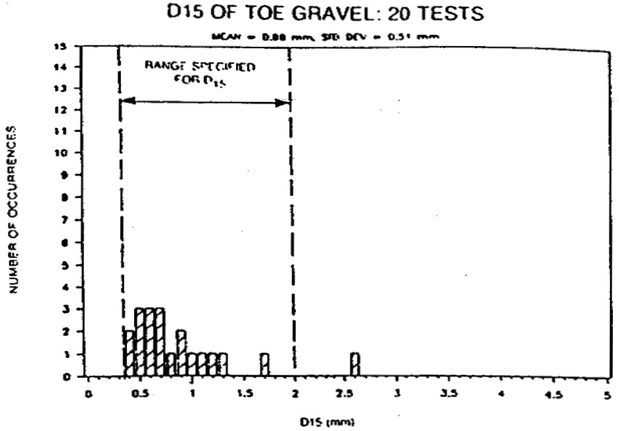


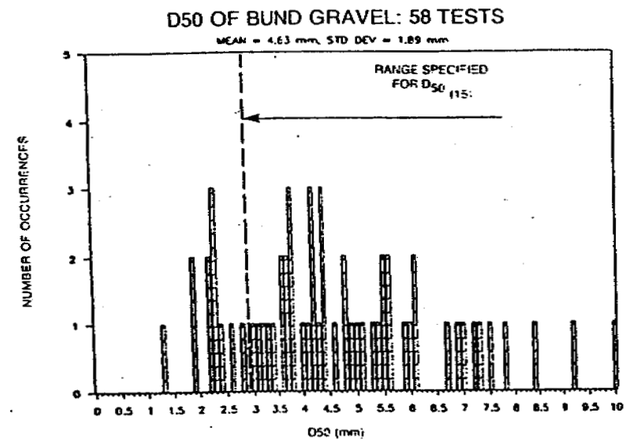
HISTOGRAMS OF SAND QUALITY IN CORE

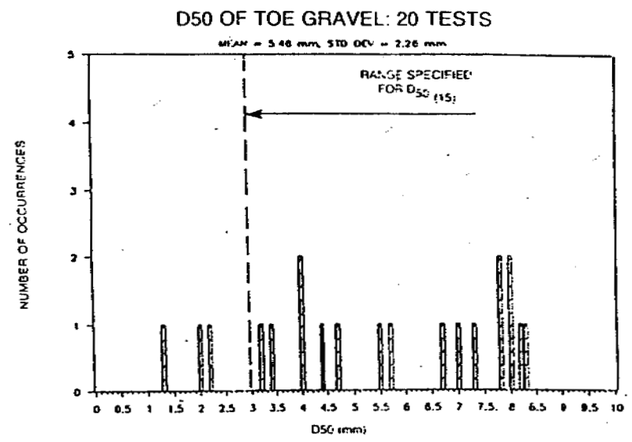
HISTOGRAMS OF SAND QUALITY IN SUBCUT AND BERM

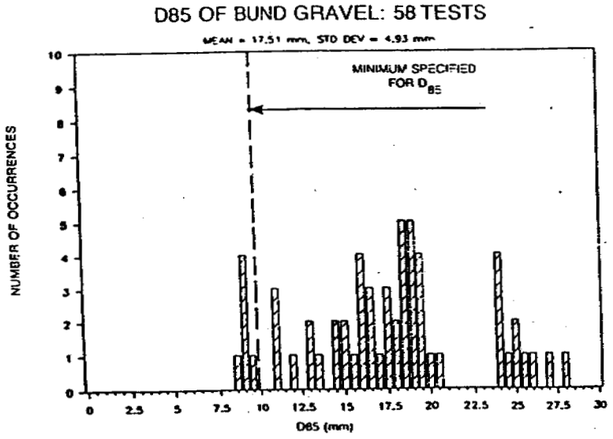
Figure 3.29: Sand Quality in Dredge - Amauligak F-24

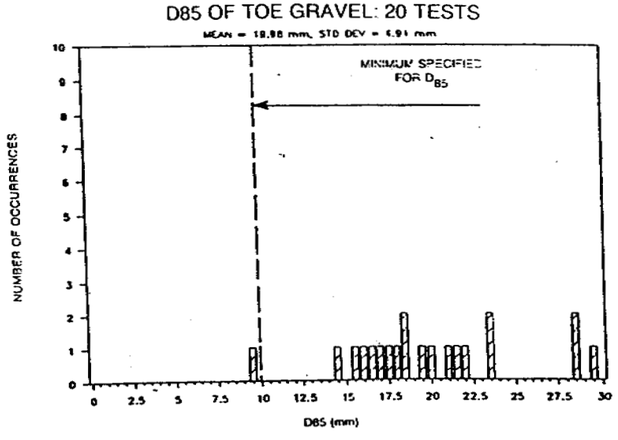






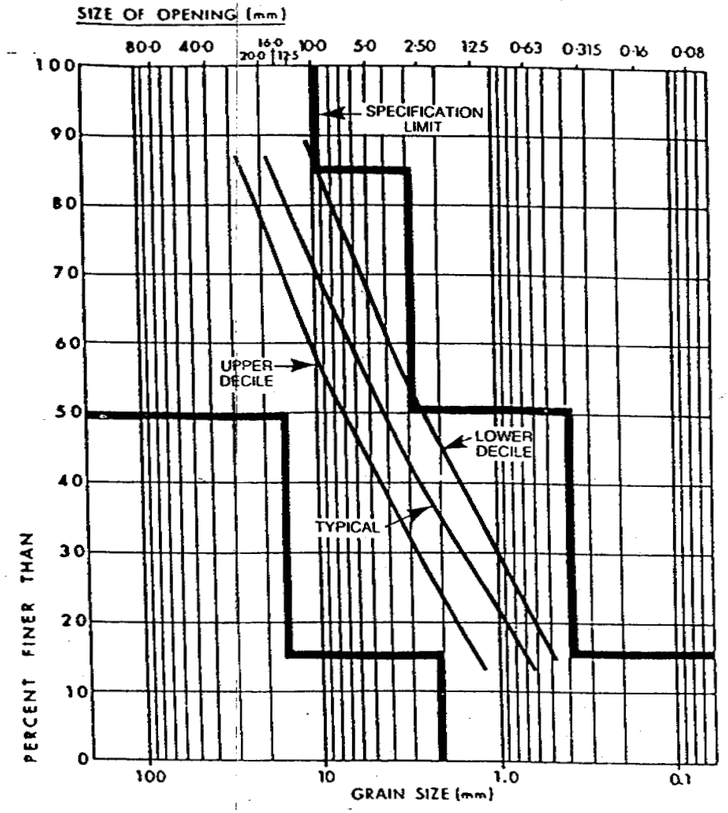






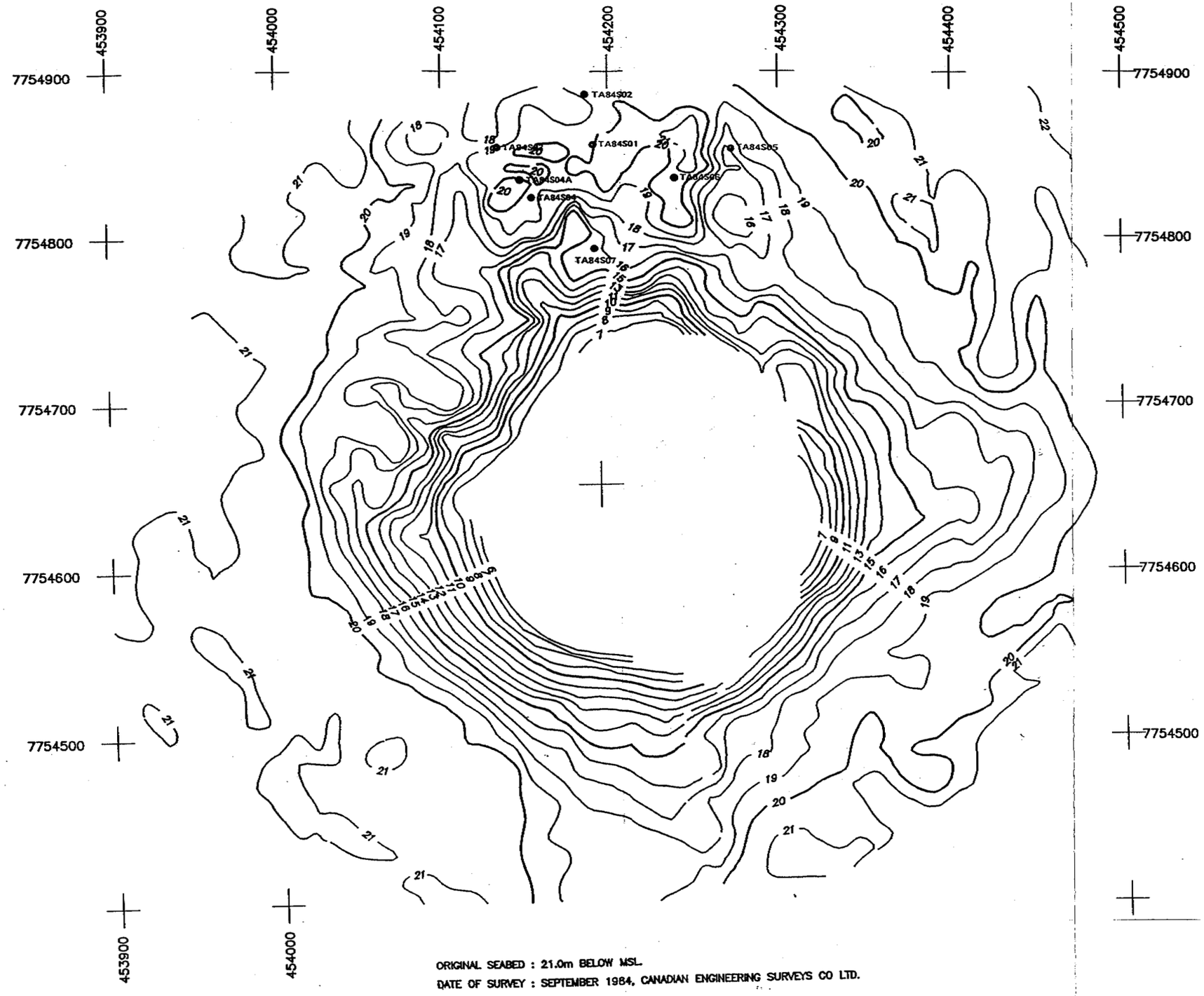
HISTOGRAMS OF BUND GRAVEL QUALITY

HISTOGRAMS OF TOE PROTECTION GRAVEL



GRAIN SIZE DISTRIBUTION OF BUND GRAVEL

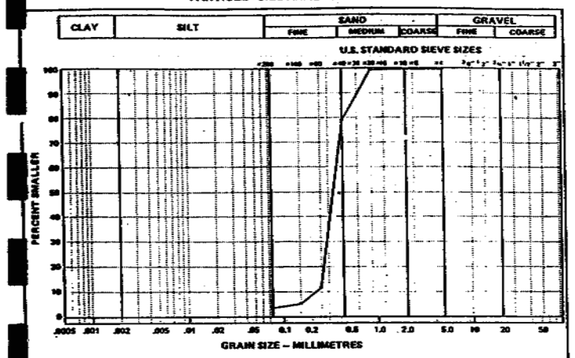
Figure 3.30: Arnauligak F-24 : Gravel Grading in Dredge from Minuk I-53



KLOHN-CRIPPEN

Figure 3.32: Tarsiut N-44 (September, 1984)

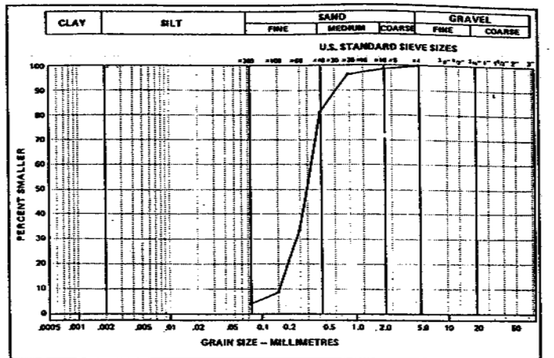
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	TA84S01	7.92 – 8.22	– 2.4	97.6	0.0		1.5	1.0	SP

JOB NO. 101 -4102 DATE 84-08-24

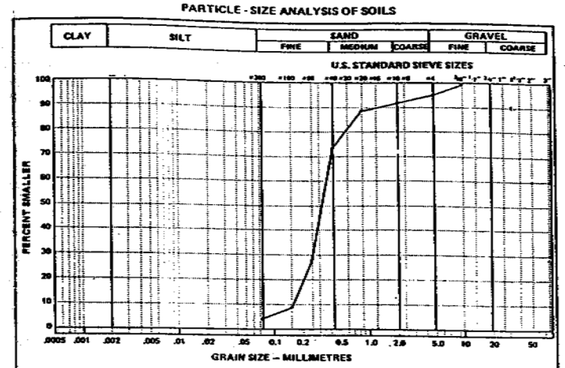
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	TA84S02	0.00 – .45	– 3.0	97.0	0.0		2.1	1.1	SP

JOB NO. 101 -4102 DATE 84-08-28

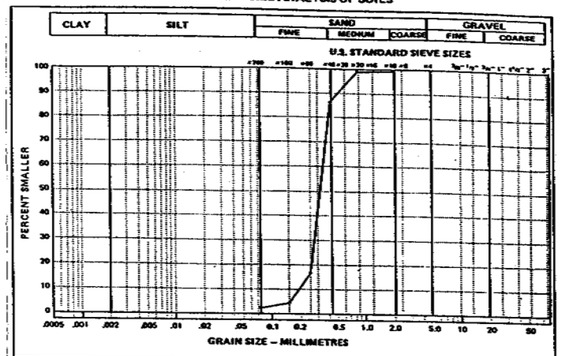
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	TA84S03	1.22 – 1.52	– 3.7	92.2	4.1		2.3	1.2	SP

JOB NO. 101 -4102 DATE 84-08-26

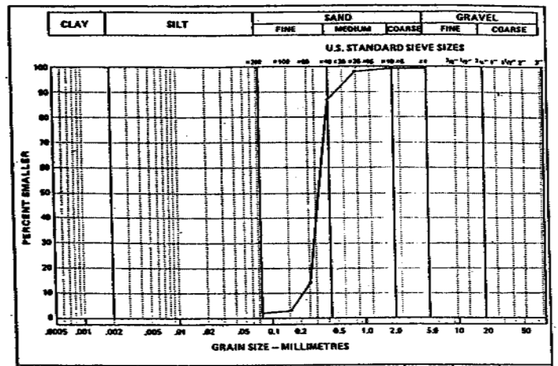
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	TA84S04A	7.92 – 8.22	– 2.1	97.9	0.0		1.8	1.2	SP

JOB NO. 101 -4102 DATE 84-08-29

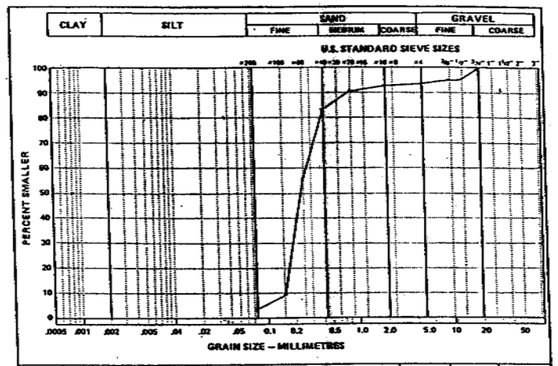
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	TA84S05	4.11 – 4.57	– 1.9	98.1	0.0		1.7	1.1	SP

JOB NO. 101 -4102 DATE 84-08-29

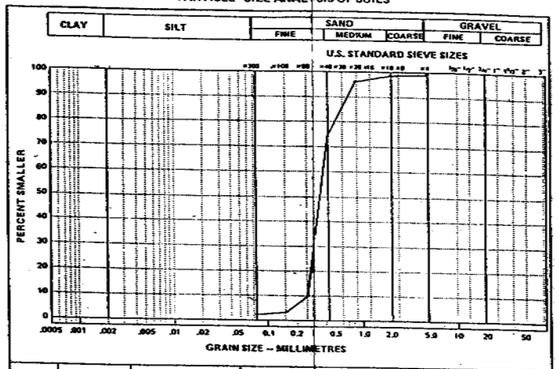
PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	TA84S06	2.44 – 2.58	– 3.4	90.7	5.9		1.8	.9	SP

JOB NO. 101 -4102 DATE 84-08-29

PARTICLE - SIZE ANALYSIS OF SOILS



SYMBOL	BOREHOLE NUMBER	DEPTH (m)	DESCRIPTION CLAY (%)	SILT (%)	SAND (%)	GRAVEL (%)	Cu	Cc	U.S.C.
	TA84S07	13.56 – 13.86	– 2.6	97.4	0.0		1.5	.9	SP

JOB NO. 101 -4102 DATE 84-08-29

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Figure 3.34: Tarsiut N-44 : Gradation of Material from Borehole Samples

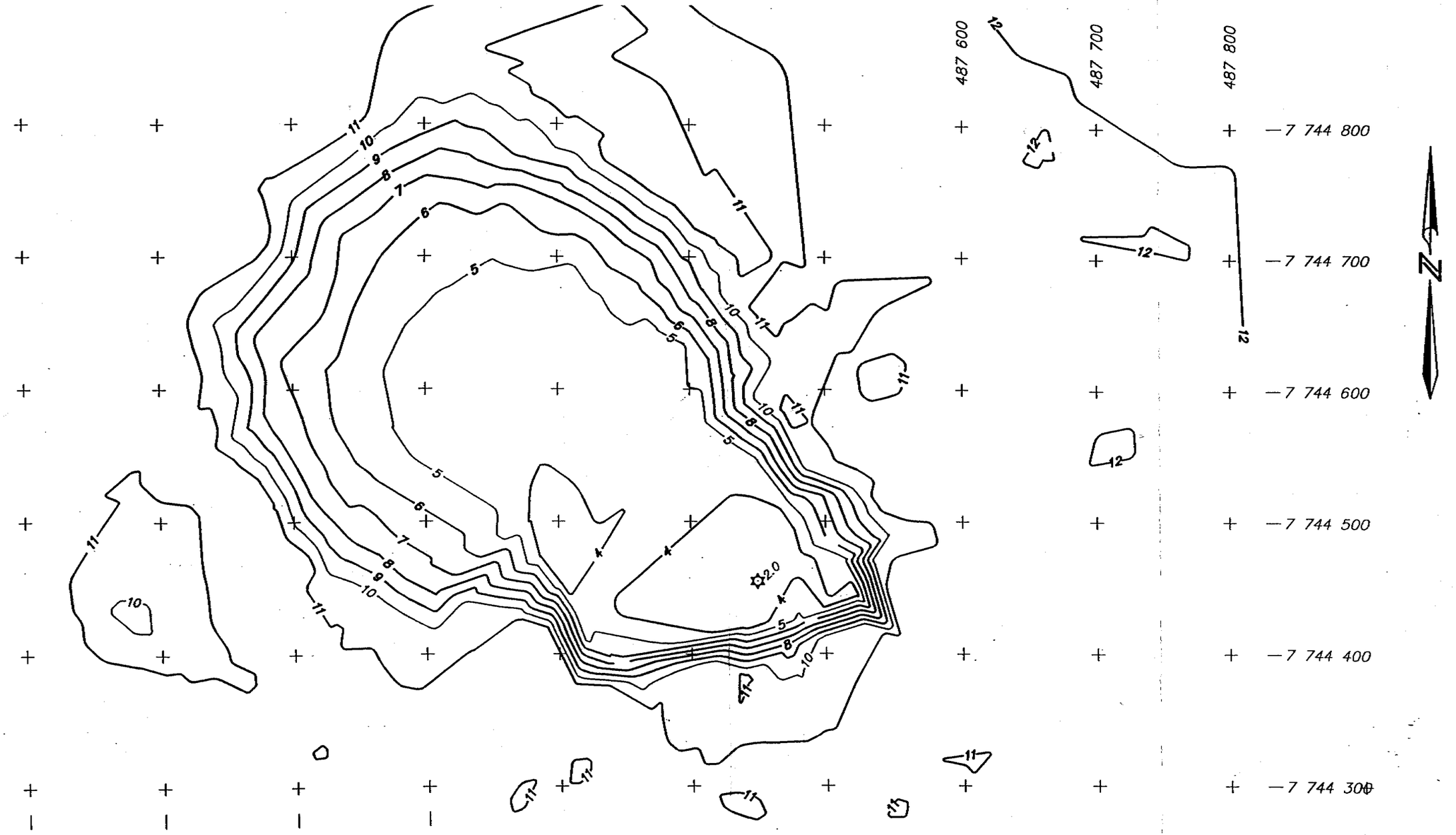

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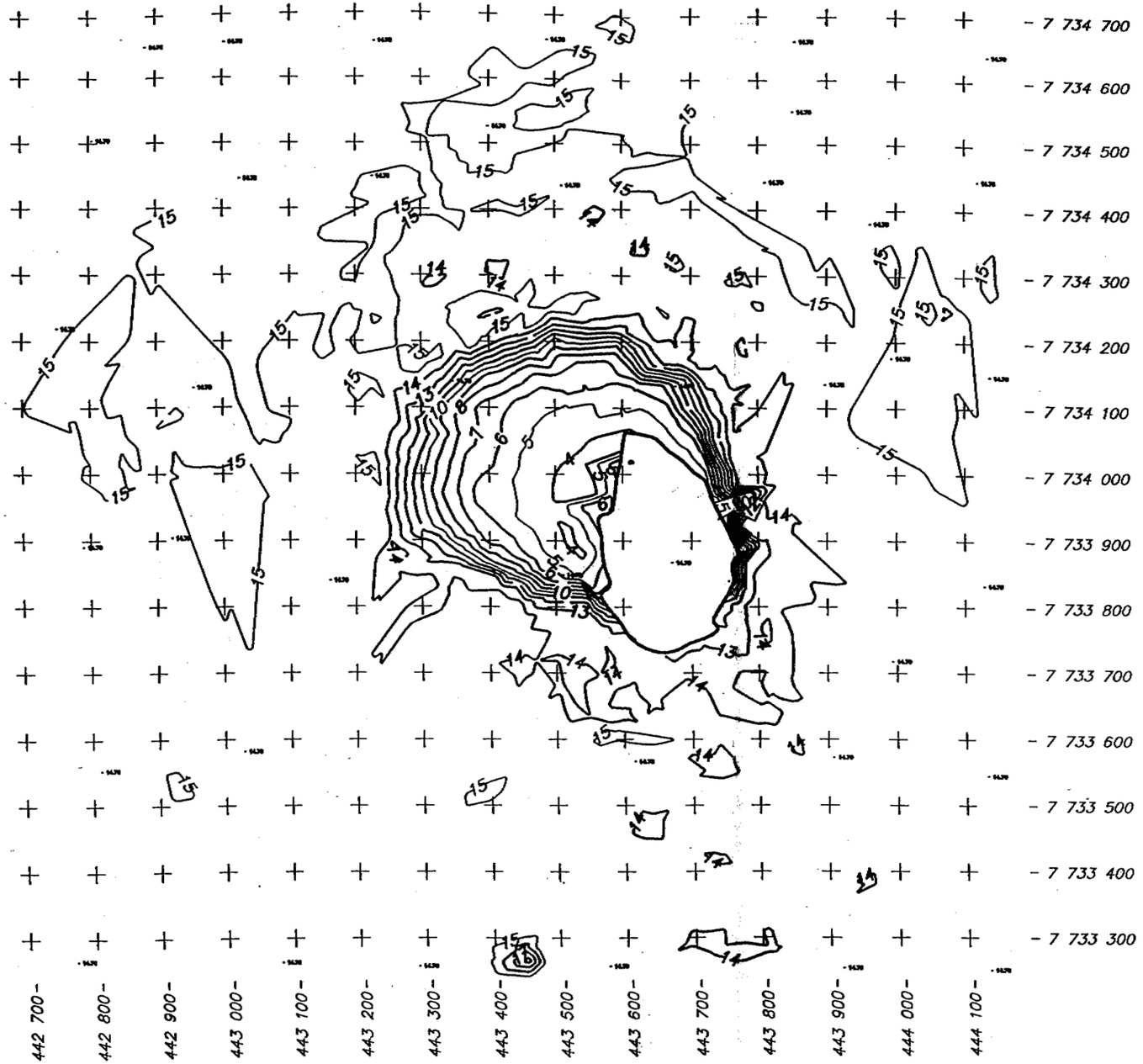
Figure 3.36: Nipterk L-19 (July, 1990)



ORIGINAL SEABED : 14.7m BELOW MSL.
DATE OF SURVEY : JULY 1990, CHALLENGER SURVEYS AND SERVICES LTD.

SCALE 1 : 7500

KLOHN-CRIPPEN

Figure 3.38: Minuk I-53 (July, 1990)

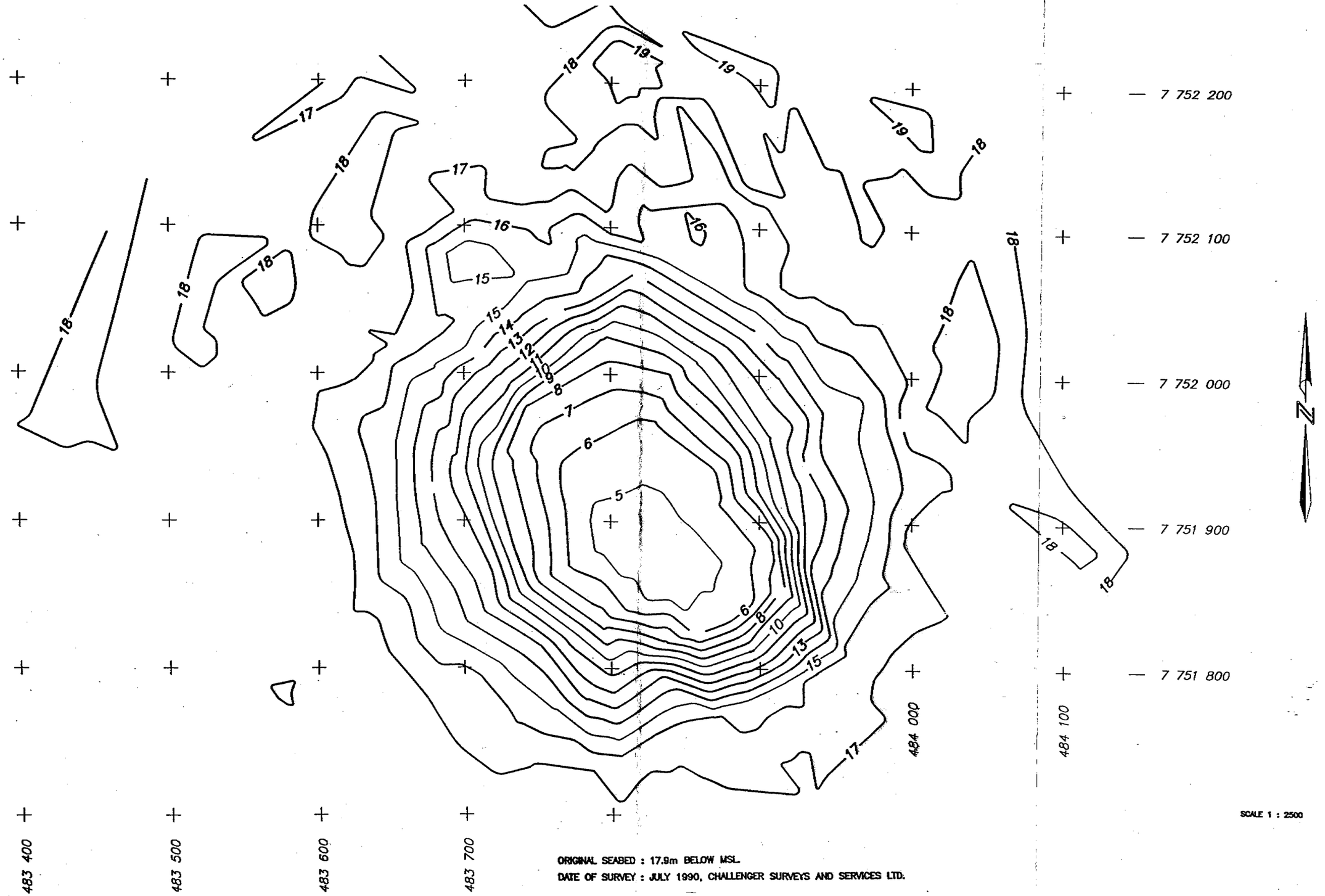


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Figure 3.40: Kaubvik I-43 (July, 1990)