REPORT

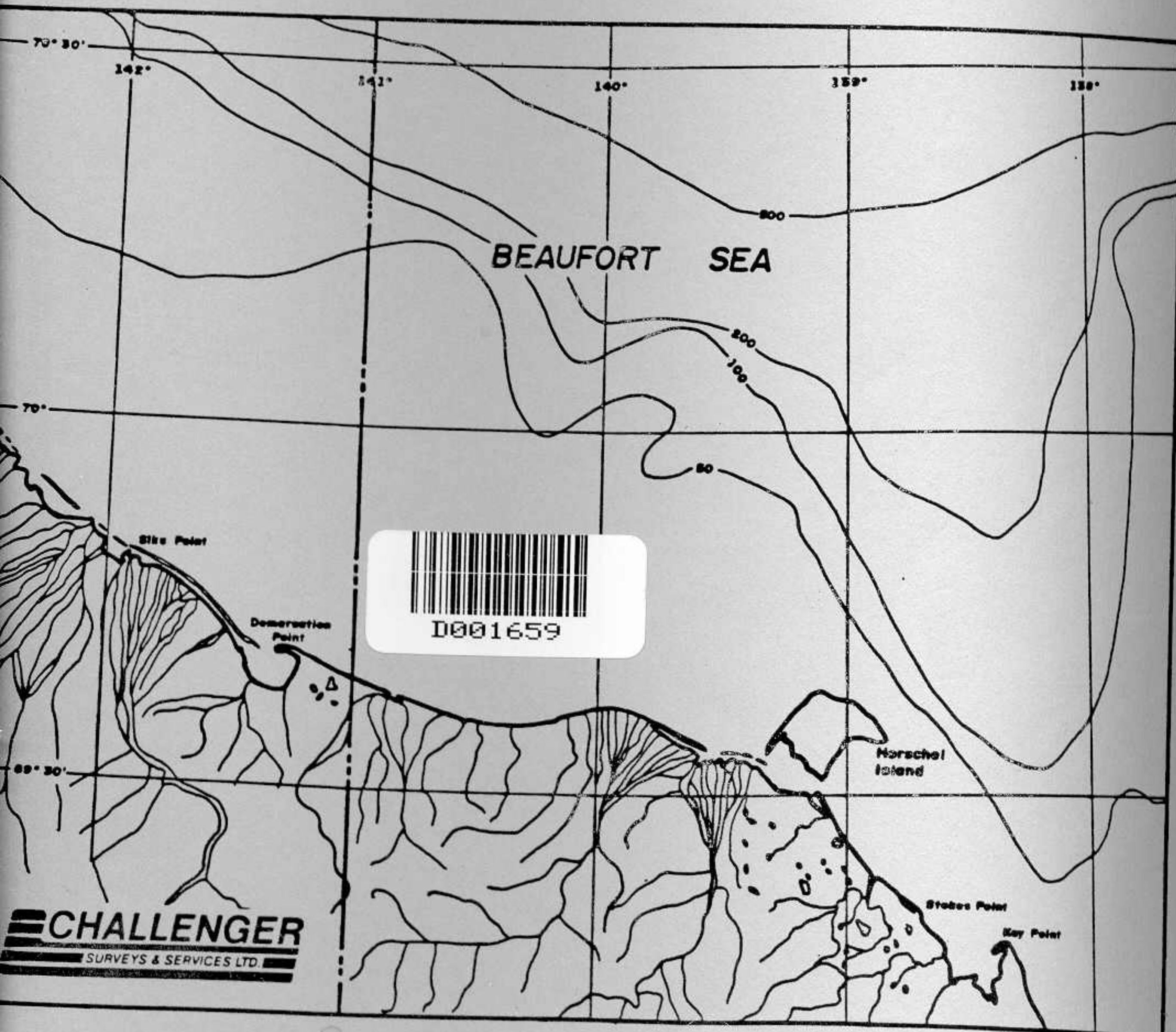
ON THE

ANALYSIS OF BATHYMETRIC DATA

WESTERN BEAUFORT (YUKON) CONTINENTAL SHELF

FOR

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT



CHALLENGER SURVEYS & SERVICES LTD.

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ANALYSIS OF BATHYMETRIC DATA

WESTERN BEAUFORT (YUKON) CONTINENTAL SHELF

for

DEPARTMENT OF INDIAN AFFAIRS

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by

CHALLENGER SURVEYS & SERVICES LTD.

1986

Edmonton, Alberta

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1.0 INTRODUCTION

On behalf of the Department of Indian Affairs and Northern Development (DIAND), Challenger Surveys & Services Ltd. was contracted to undertake a computer based analysis of bathymetric data collected in the western Canadian Beaufort Sea. The purpose of the analysis was to develop, test and implement a method of detecting subtle bathymetric anomalies and provide a description of the regional bathymetry.
The following background information to the study was provided by DIAND:

> "As part of the development of a granular resources management plan, DIAND is systematically undertaking an inventory of sand and gravel deposits in the Beaufort Sea Region. A substantial body of information on the characteristics of granular deposits has been collected in conjunction with hydrocarbon exploration activities in the eastern portions of the Canadian Beaufort. In preparation for possible developments on the western part of the Beaufort Sea, DIAND initiated the preliminary work required to evaluate the granular resource potential for this area.
>
> Analysis of the available granular resource data for the Beaufort Sea has demonstrated that almost all of the gravel deposits identified are located on subtle bathymetric highs, within a relatively narrow range of water depths. It has been speculated that this situation arises due to the historical geology of the

area: high energy environments suitable for the accumulation of coarser grained lag deposits may have existed during periods of slow sea level rise. Analysis of seabed morphology and bathymetry may, therefore, help to establish any bathymetric control of the geological framework, as related to granular resources, of the western Canadian Beaufort Sea."

Presently covering the western Canadian Beaufort Sea there exists bathymetric charts from the published natural resource series and the Canadian Hydrographic Service. Bathymetric information on these charts is depicted through the use of contour lines, spot depths and color shading. Subtle bathymetric highs, gradual changes in slope and trends in a rolling seabed cannot be readily identified on these charts.

An improved method of depicting subtle bathymetric anomalies is through the use of perspective mesh drawings of the seafloor. By developing a digital terrain model of the study area, the bottom may be viewed in perspective giving the effect of a three dimensional(3D) image of the bottom. By exaggerating the vertical component, the image may be enhanced to accentuate subtle rises and changes in slope on an otherwise flat bottom.

This report outlines the work performed under Department of Supply and Services (DSS) contract file number 25 ST-A7134-5 -0033, serial number 0ST85 - 00383. The Scientific Authority for the project was Mr. Robert J. Gowan, P. Geol., Geotechnical Advisor, Land Management Division.

2.0 DIGITAL TERRAIN MODELLING

A three dimensional continuous surface may be represented on a two dimensional medium in many ways. Contour lines, spot heights, shading or coloring are examples. In the hydrographic chart, the sea bottom is generally represented by spot depths supplemented by contour lines and color shading. This serves as a useful tool for the mariner who must navigate vessels of different size and draft safely through channels but is not adequate for an engineer/geologist who is attempting to analyze the seabed topography. Through the use of digital terrain modelling techniques, more suitable methods of representing seabed topography are possible.

A Digital Terrain Model (DTM) is a digital representation of a three dimensional continuous surface. Cartesian X,Y,Z coordinates are used to represent the surface. Generally a DTM is comprised of an elevation value located at the nodes of a regularly spaced X,Y grid covering the surface. In most cases, this grid of elevation data is interpolated from randomly spaced X,Y,Z source data.

Elevation data is derived from a variety of sources. For topographic mapping purposes X,Y,Z coordinates are generally derived from aerial photography. Stereo photographs of a continuous three dimensional surface can be reproduced and X,Y,Z ground coordinates of the model may be measured. In the case of mapping the seafloor, continuous photographic images are not available. Therefore in order to map the seabed a series of spot depths or soundings are measured and a surface is interpolated from these points.

Digital Terrain Products

A digital terrain model has many uses. As a result of the surface being represented digitally, computers may be used to process the data and portray the information in several ways. For example, using a digital data base a computer may prepare contour maps, cross sectional drawings and isometric plots of the surface. Numerical calculations may also be performed on the model to determine volumes between surfaces or the maximum slope in an area. Usually the large volume of source data which must be manipulated makes it impractical if not impossible to perform these tasks manually. With the help of computers more data may be processed and graphic products may be developed in far less time compared to manual methods.

Bathymetric Data Sources

The primary source of hydrographic data in Canada is the Canadian Hydrographic Service (CHS). The CHS has a mandate to chart the navigable waters of Canada for shipping purposes. Thus the primary interest of the CHS is not necessarily to portray sea bottom topography accurately but rather to insure that no hazard to shipping goes uncharted. In insuring that navigation hazards are avoided the CHS creates some inaccuracies in the charts they produce. Depth information portrayed on charts is said to be "shoal biased", meaning that the emphasis is placed on areas of shallow water rather than deeper areas.

There are 3 types of bathymetric data available from the CHS; charts, field sheets and raw source data. Charts, as mentioned earlier, are edited final compilation of bathymetric surveys and are intended for navigational purposes. In addition to bathymetric information a chart would depict additional information relating to vessel navigation such as navigational aids, tidal data, sailing instructions and vessel traffic patterns. Bathymetric information is shown in detail only in areas where depth is a critical concern to navigation.

A field sheet is an edited compilation of a field survey. It is intended to be used as a transcript for the production of a chart. The field sheet can be considered as a digital representation of the seafloor. Selected soundings are typically plotted at a spacing greater than that appearing on a chart usually every centimetre at chart scale. The field sheet also shows areas of dense sounding patterns where shoals were examined and where bottom samples were taken. The sounding data is also contoured at five metre intervals to a depth of 30 metres, 10 metre intervals to a depth of 100 metres, 20 metre intervals to a depth of 200 metres and 50 metre intervals for depths beyond 200 metres. The field sheet offers far more information relating to the sea bottom topography than charts, however soundings are shoal biased, thus deeper soundings in a local area are not necessarily shown.

Raw source data offers the densest data base from which to analyze bathymetry. The amount of bathymetric data that is portrayed on a chart is only a small portion of the data actually collected. Sounding data may be collected as fast as sound propagation in water will allow, appearing as a continuous trace on a chart. The recording of digital data is at a somewhat slower rate due to the added workload on the computer (computing position and navigation information).

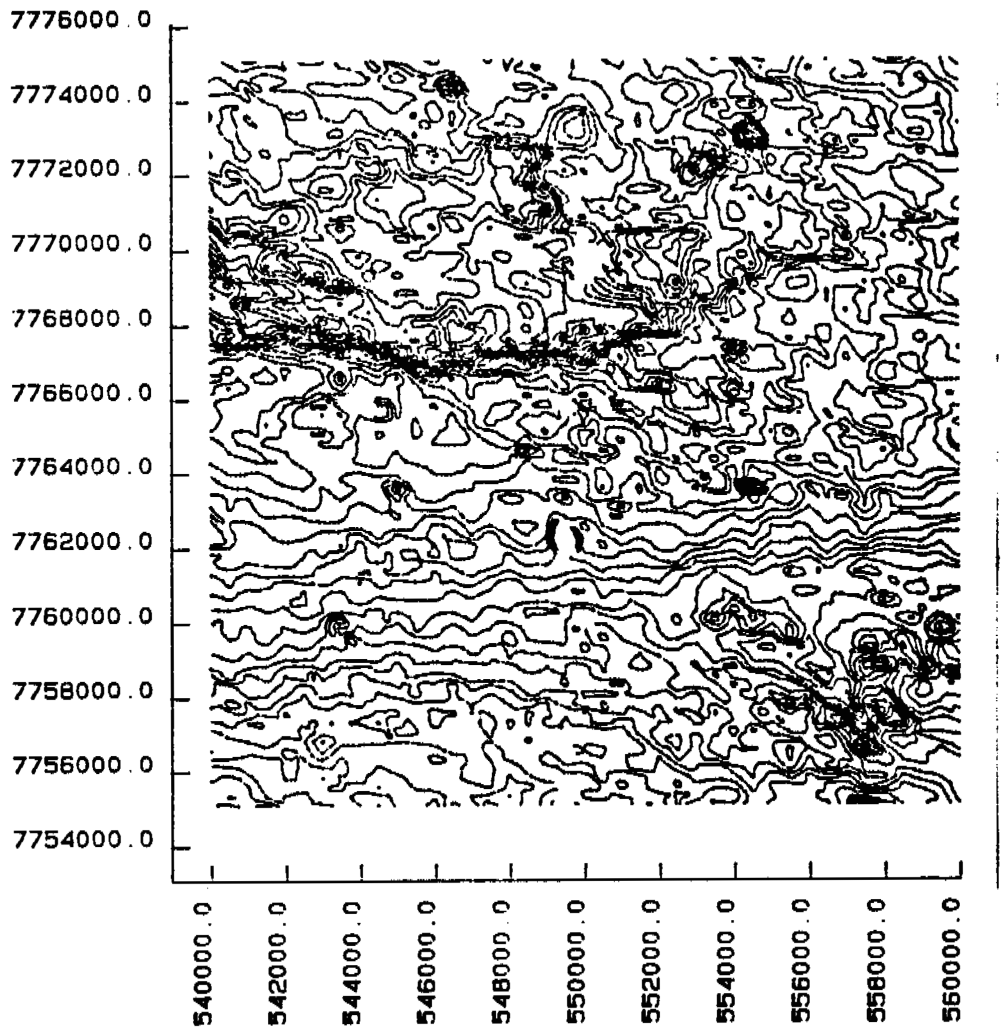
Most automated systems are capable of recording one sounding every two seconds. If a vessel is moving at 10 knots this would translate to a depth being recorded every 10 metres along a sounding line. This is considerably more dense than the soundings represented on a field sheet which would be spaced at 500 metre intervals at a scale of 1:100,000 .

Imaging

To assist in detecting and characterizing small bathymetric anomalies it is necessary to create an effective visual image of the surface. Field sheets offer better resolution than charts but are difficult to visualize and are sometimes inaccurate due to shoal biasing characteristics of the selected soundings. The solution seems to be to develop an effective image with resolution exceeding that offered by the field sheet. This may be accomplished by developing a three dimensional image using source data that has been reduced for tide and sounder variations.

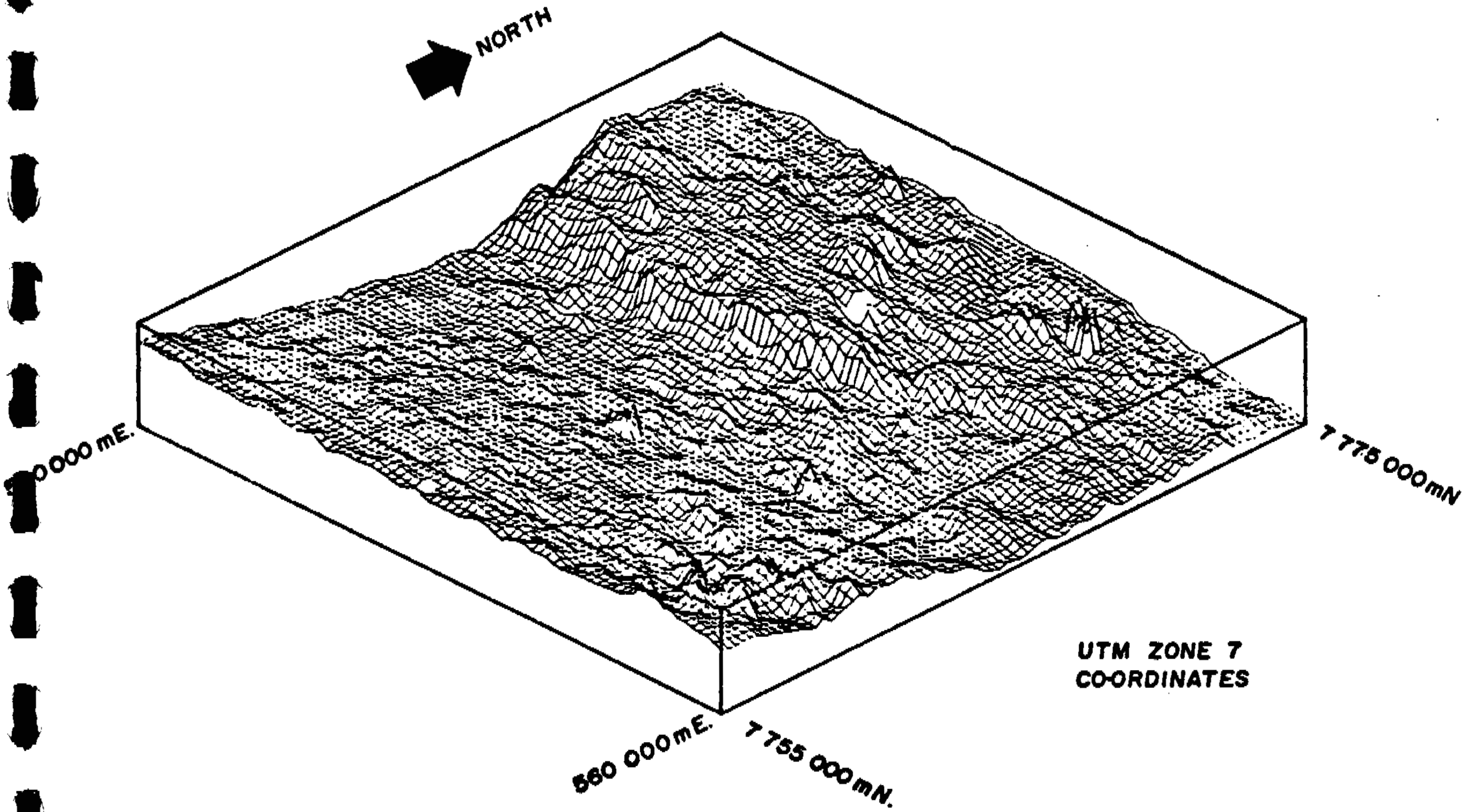
To create an enhanced visual image which is easily interpreted with the human eye the digital model can be used to generate an axonometric projection or mesh grid plot of the seabed. This model in effect portrays a three dimensional image of a digital terrain model on a two dimensional medium. The computer allows the user to view the model at varying degrees of rotation and tilt thus effectively viewing the model from any number of vantage points. As a result of the model being digital, subtle depth anomalies on a relatively smooth surface may be enhanced by exaggerating the vertical component (depth value).

Figure 1 shows an area of 20Km X 20Km with seabed elevations represented at a one metre interval. A depression extending from east to west through the centre of the plot is bounded by a steep ridge to the north and a gradual rise in the south. Figure 2 shows an axonometric projection plot of the same area, viewed from the south-east at an elevation of 30°. The vertical component is shown with a 100X vertical exaggeration. The axonometric projection presents a clearer visual image of the seabed.



CONTOUR PLOT AT 1 METRE INTERVALS

Figure 1



AXONOMETRIC PROJECTION
Vertical exaggeration 100 X

Figure 2

3.0 APPLICATION

The analysis of bathymetric data on the Western Beaufort (Yukon) continental shelf was performed in three phases. Phase one involved obtaining and visually inspecting the source data to determine if it was suitable for processing. The second phase of the project involved processing a sample area and determining whether the methodology being proposed would yield the required information concerning the seabed topography. The third phase of the project was to process all the data in the study area and analyze the resulting bathymetry.

This section of the report describes the work undertaken for each phase of the project.

SOURCE DATA EVALUATION

The objective of Phase I was to evaluate the source data and determine its suitability for processing. This phase was subdivided into five tasks as follows ;

a) Obtain source data from CHS.

b) Visually inspect the data to determine if line and point spacing is suitable for processing.

c) Determine the number and scale of map sheets required, and the minimum size of feature likely to be detected.

d) Identify areas where coverage may be inadequate for the detection of anomalies.

e) Review the results with the Scientific Authority so that a decision on whether or not to proceed can be made.

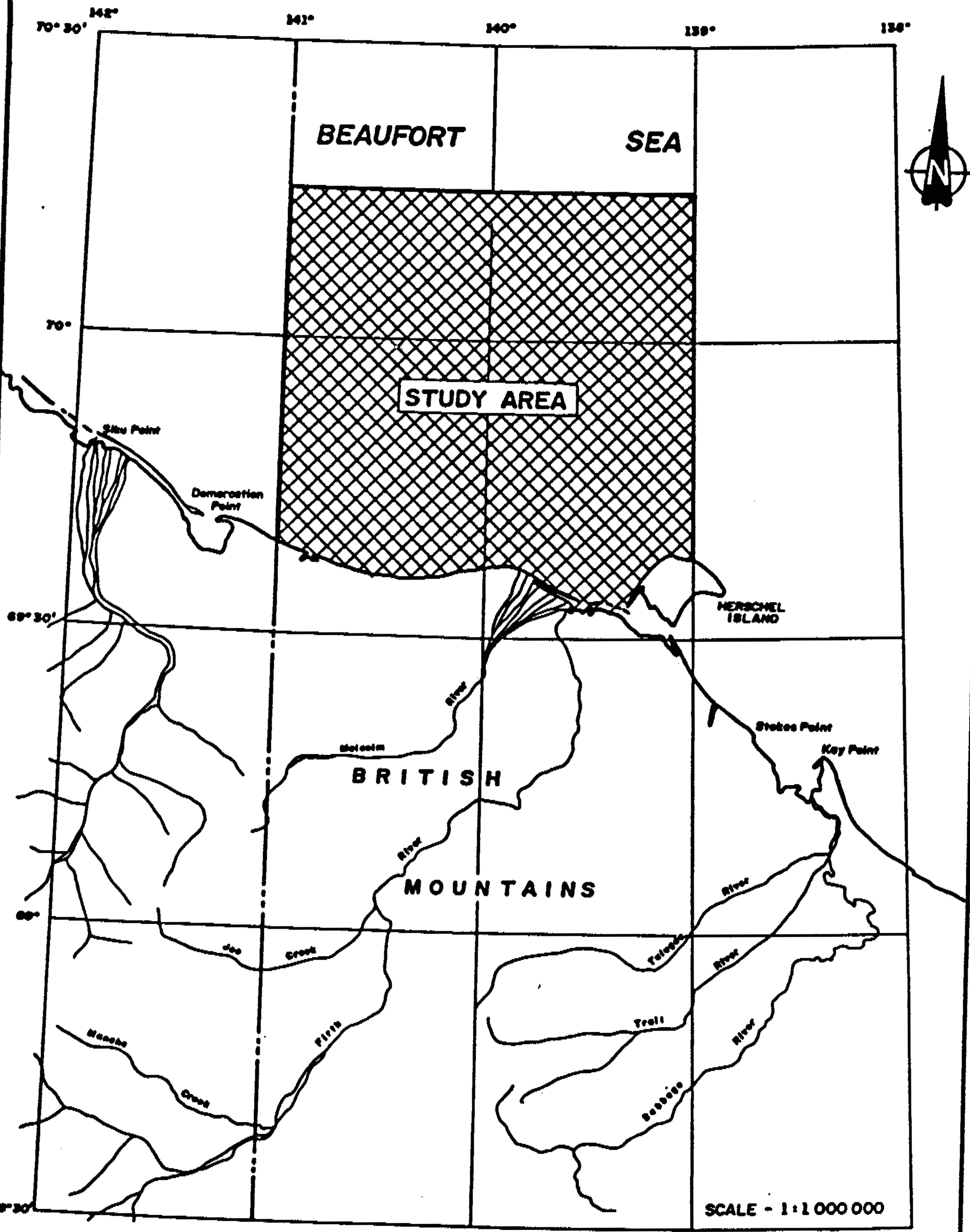
Data Acquisition

Prior to the awarding of the contract, personnel of the Canadian Hydrographic Service in Sydney B.C. were contacted by Challenger Surveys in order to determine information on the bathymetric survey off the Yukon coast. It was learned that the survey was performed by Cansite Surveys under contract to the CHS during the summer months of 1984. Field sheets of the survey were available as well as the source data recorded digitally on 9 track magnetic tapes. Field sheet WA 10167, and the 9 track tapes along with a sample data printout and format structure description were subsequently obtained from the CHS.

Visual Inspection

Field sheet WA 10167 covered the Yukon continental shelf, from the Yukon coast line, north to latitude 70° 15' N, bounded by Demarcation Point to the west (longitude 141° 00' W) and Herschel Island to the east (longitude 139° 00' W) (Figure 3). The survey covered an area of approximately 6400 km^2. Soundings were plotted at a scale of 1:100,000. The survey comprised 166 survey lines (10 east-west, 156 north-south) totaling a distance of approximately 13,280 line kilometres. Line spacing was 500 metres for the north-south lines and east-west tie lines were spaced at a 7500 metre interval. Soundings were recorded every 20 seconds along the survey line. This corresponded to a depth recording interval of approximately 100 metres along line as the survey vessel was sailing at about 10 knots. There were estimated to be approximately 132,800 soundings on the two 9 track tapes, recorded to a resolution of 0.1 of a metre. Depths were plotted every centimetre on the field sheet which would correspond to 500 metres at scale. There were 125 shoal examinations performed throughout the survey area and numerous bottom samples taken.

An examination of the sample 9 track data printout revealed that the sounding data was not recorded in a consistent format. It was noted that carriage returns occurred randomly throughout the records and occasionally in the centre of a number. This problem necessitated additional programming to reconstruct the data records properly. At the time, this was not expected to cause any significant delays in processing



STUDY AREA LOCATION

FIGURE : 3

the data.

Given the size of the study area and the high number of data points it was suggested that 16 sheets be used to cover the area. Each sheet would cover an area 20 km by 20 km at a scale of approximately 1:25,000.

Resolution

Factors which determine the size of features capable of being detected are line direction, point spacing, depth resolution, feature shape and direction. In the case of this study, north-south survey lines were spaced at 500 metre intervals with a point spacing of about 100 metres. Depths were recorded to 0.1 of a metre. Given these parameters it was expected that an anomaly of 0.1 metres depth over 100 metres could be detected provided that the feature lie in an east-west direction. This would correspond to a detectable volume of 5000 cubic metres. It was expected that the resolution in the north-south direction would not be as great due to the line spacing interval, therefore features lying in this direction may not even be detected if a sounding line did not pass over it.

Phase I Summary

The visual review of the data in phase I indicated that the data coverage throughout the study area was adequate to interpolate an accurate digital terrain model. No outstanding gaps were detected in the data at this stage. It was however realized that small features lying between sounding lines may go undetected if there was no data collected on the feature. Given the line spacing used during the survey it was thought that any anomaly small enough to fall between the survey lines would more than likely be too small to be of interest. The results were reviewed with the scientific authority and it was decided to proceed with phase II of the project.

DATA INTEGRATION AND SOURCE EVALUATION

The objective of phase II was to integrate the CHS data into the Challenger processing system and process a sample area to test the proposed methodology. The phase was subdivided into the following tasks;

a) Formulate an integration program to allow direct entry of CHS data into the contractor's computer and to permit processing.

b) Develop a digital terrain model by interpolating water depths at evenly spaced grid intervals from the randomly spaced bathymetric data.

c) Select a sample area comprising of approximately 5% of the study area to test the methodology and source data.

d) Process data from sample area and plot on a large size sheet.

e) Verify or revise minimum size of features identified.

f) Review results with the Scientific Authority to decide whether or not to proceed.

Data Integration

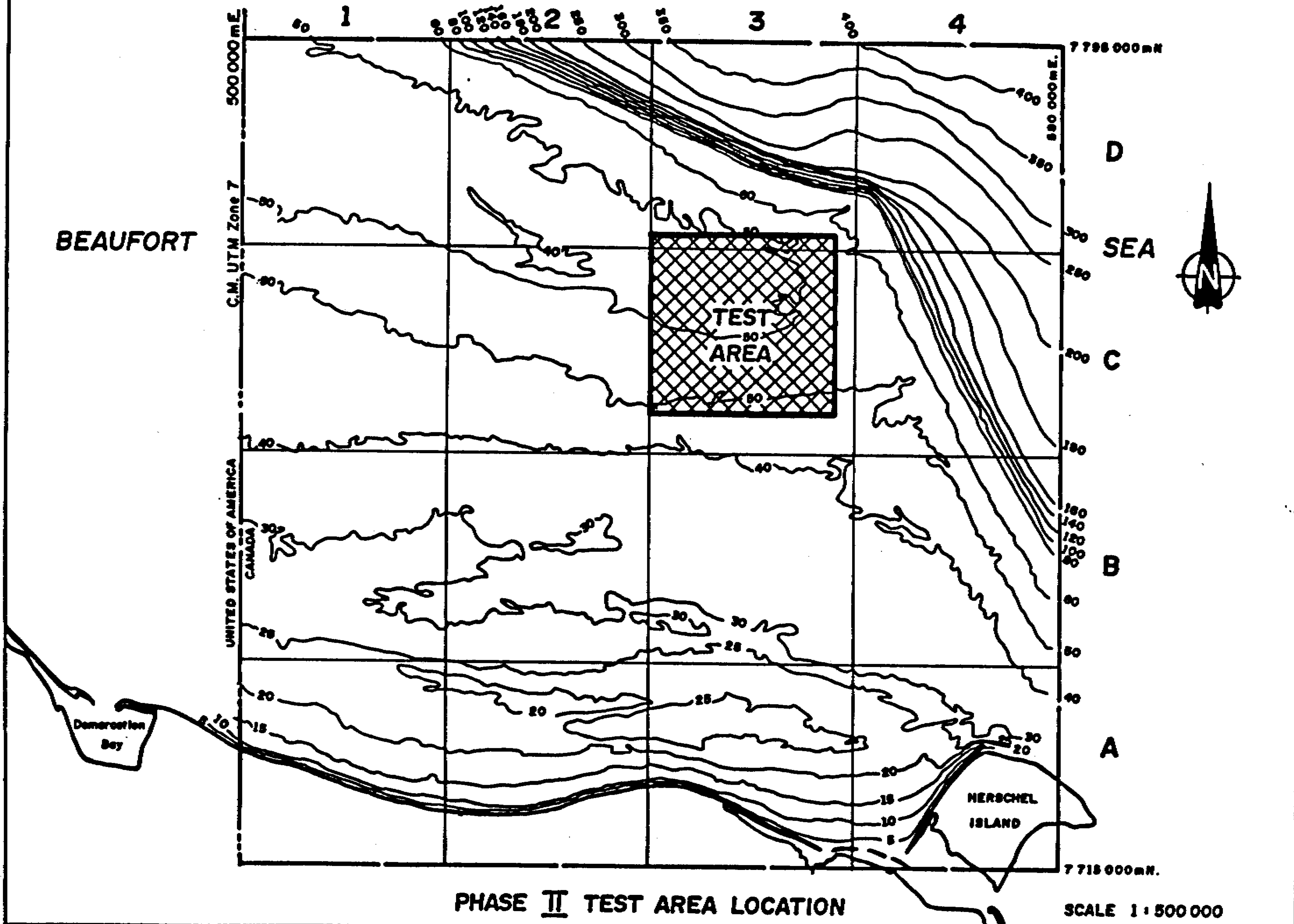
It was necessary to transfer the CHS 9 track tape data into Hewlett Packard compatible format as the digital modeling software was installed on a HP series 200 computer. A VAX

11/750 was used to read the data tapes and subsequently transfer the data to the HP machine.

Considerable problems were encountered while attempting to read the source data off of the 9 track tapes. The data structure was not consistent throughout the tape and varied within a file as well as from file to file. To compound this problem random carriage return/line feed (CR/LF) characters occurred throughout the data. These occurred not only between numbers but often in the center of numbers essentially splitting a single number into two. For example a 7 digit number representing a northing would be split up into 2 numbers of 3 and 4 digits. To over come this problem a decoding program was written to search for the erroneous characters and restructure the data into a readable format. This required a considerable amount of extra computing time due to the large volume of data being processed. There were an estimated 1,000,000 erroneous CR/LF's that needed to be separated from 700,000 correct ones.

The problem was discussed with personnel at the Canadian Hydrographic Service, Pacific Branch. It was learned that the digital data was recorded in the field on Hewlett Packard 3.5 inch floppy disks and then transferred to 9 track tape by the CHS in Sydney. Although they understood the problem they were unable to assist any further as they no longer had the original data discs. It is noted that the CHS did not expect that the digital data would be used again therefore no great effort was made to ensure that the data was properly stored to tape.

The poor quality of the digital data on 9 track resulted in alot of extra time being spent on decoding the data. Once the data base was plotted it was realized that approximately 46%



PHASE II TEST AREA LOCATION

SCALE 1 : 500 000

FIGURE: 4

of the data was not recorded on 9 track. Prior to the plotting of the data base there was no way of determining if all the data was on the 9 track tapes. These large gaps in the data primarily occurred in areas of greatest interest to the study, that is, at water depths where dredging would be practical. The original survey data disks were obtained from Cansite in an attempt to complete the data base. This data was plotted and found to be far more complete than that available on 9 track.

Test Area

An area of 18 x 18 kilometres square was selected as a test basin (Figure 4). The test area was selected because data coverage was sufficiently dense to form a meaningful digital terrain model. The area also contained significant relief on the bathymetric field sheet. A sample area in more shallow water could not be processed due to the significant lack of data stored on 9 track tape in these areas.

The test model was processed using the following parameters;

Coordinates = minimum 7758500 N. 540000 E.
maximum 7776500 N. 558000 E.
Cell size = 250 metres
Number of raw data points = 2230
Number of interpolated grid points = 5400
Minimum depth = -38.9 metres
Maximum depth = -63.3 metres

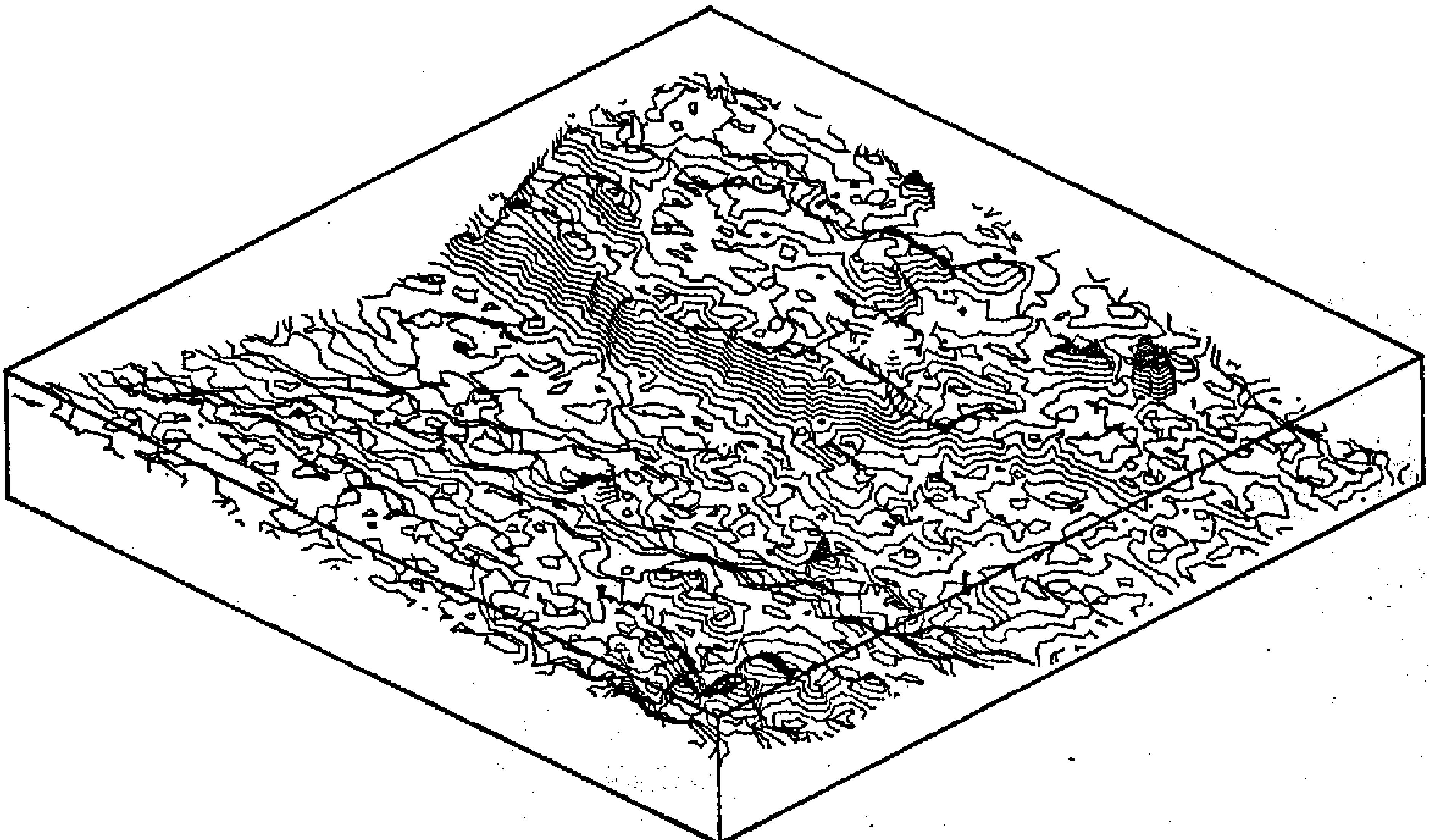
A digital terrain model was interpolated for the sample area and meshed grids were plotted from several different viewing points. The vertical exaggeration was varied in order to determine the most useful viewing parameters.

Selection of the optimum viewing point is largely a function of the orientation of the feature being examined. After preparing several plots from different viewing angles it was decided that a counter-clockwise rotation of 45 degrees was ideal because it would leave the north at the top of the sheet and would allow small bathymetric anomalies lying in an east-west direction,parallel to the coast, to be detected. This was later changed to a viewing azimuth of 225 degrees so the shallow water would appear at the top of the plot. A tilt of 35 degrees was selected because this resulted in a viewing angle where the relief was still detected yet the drawing would not become too cluttered with hidden lines. A vertical multiplier of 100 was used in this area. There is a significant difference of depth in the sample area (from 38.9 metres to 63.3 metres) therefore a 100 times multiplier was as large as could be used without the drawing becoming cluttered.

A sample plot showing contour lines viewed in perspective was generated then overlaid on a meshed grid. This gave the viewer the added capability of measuring the magnitude of detected features. Figure 6 shows a mesh plot of a section of the study area. Although a rise is clearly detectable it's magnitude cannot be determined. After overlaying Figure 6 with the contours of Figure 5, a measurement of the size of the rise can be determined. This capability may prove useful when examining features in detail.

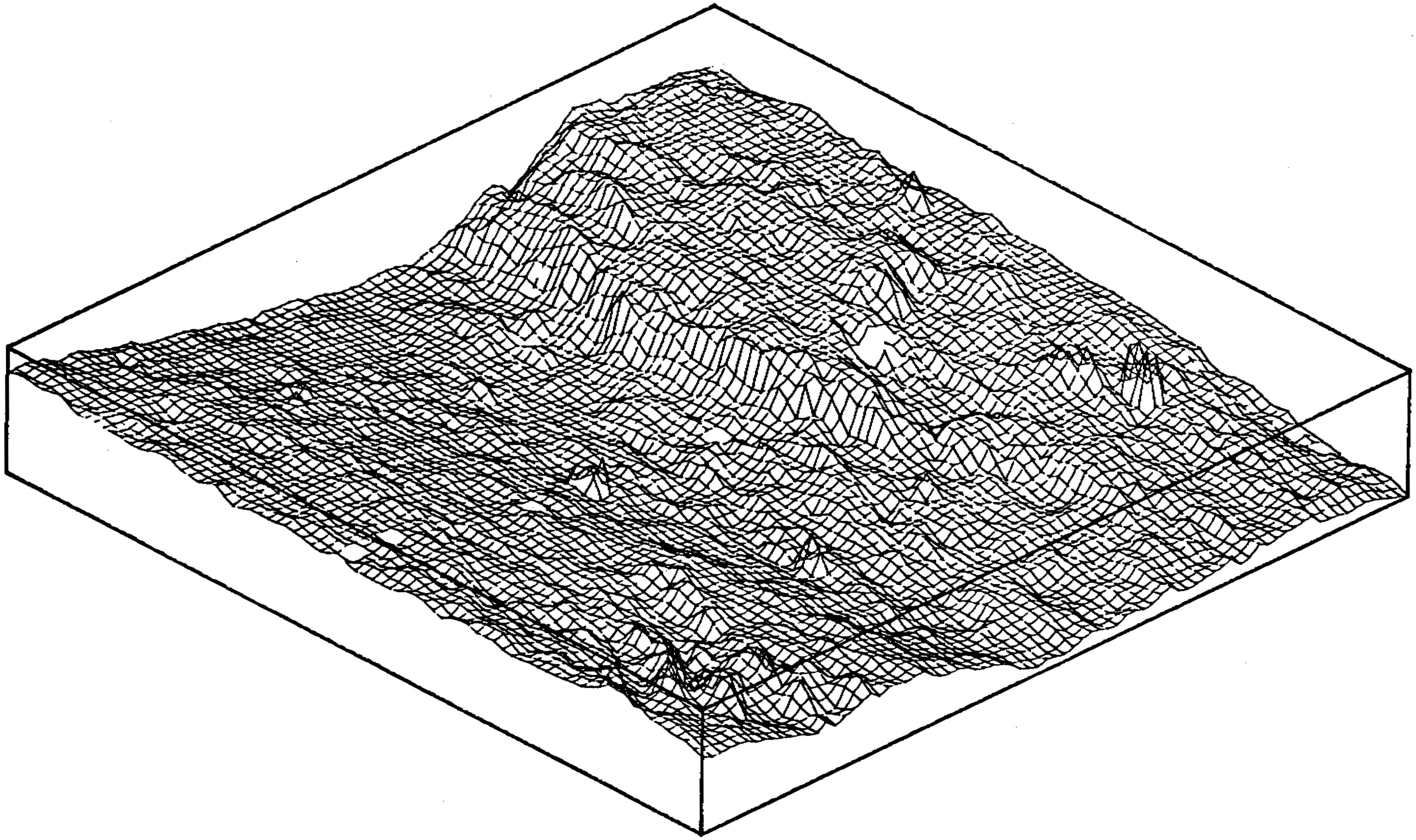
Resolution

Given the point spacing of 100 metres and the line spacing of 500 metres, a grid size of 1/2 the line spacing (250 metres) was selected. The grid interpolation algorithm uses a linear interpolation technique based on the closest 3 of 8 points forming a triangle around the grid node. Tests showed that a grid size of less than 1/2 the point spacing did not yield any improved resolution.



PERSPECTIVE VIEW OF 1 METRE CONTOURS

Figure 5



PERSPECTIVE VIEW MESH

Figure 6

Phase II Summary

Phase II illustrated that mesh grids, plotted in perspective with an exaggerated vertical scale, provide a useful means of visualizing sea bottom relief. With contour lines overlaid on the mesh a quantitative measurement of the magnitude of the relief could be determined. Small features which would be difficult to detect are made visible by exaggerating the vertical component. Depth data is also recorded to 0.1 of a meter throughout the survey on tape thus plots based on the digital data would offer better resolution than that available on the field sheet on which depths greater than 30 metres are recorded to the nearest metre.

After analyzing the sample plot it was estimated that a minimum depth anomaly of 1 metre should be detectable over a length of 500 metres. This would correspond to a volume of 250000 cubic metres if the length of the anomaly was 1 kilometre.

Given the results of the plots from the test area it was apparent that the bottom relief is easier to visualize using a 3-D grid mesh. With contour lines overlaid on the mesh a quantitative measurement of the magnitude of the relief could be determined.

Considering the extent of the missing data from the 9 track tapes, it was recommended in phase II that the data received from Cansite be used for any further processing and that the 9 track data received from the CHS be discarded completely.

ANALYSIS OF STUDY AREA

The objective of phase III was to process all data from the study area, prepare a mosaic of the study area and identify and characterize features in the area. This phase was subdivided into the following 6 tasks;

a) Process the large volume of data for the entire study area and plot on large size (approximately 24" x 36") mylar sheets.

b) Identify and characterize all significant bathymetric highs.

c) Prepare cross-sections of typical bathymetric anomalies.

d) Tabulate the results of the analysis, including the geographical coordinates, size (area and height), water depth at the base and shape of each feature identified in task b) above.

e) Prepare a large size (approximately 24" x 36") mosaic of the study area, at an appropriate scale, which identifies the location of the features included in task d) above.

f) Prepare a report which includes maps, cross sections and tables, describing the techniques and procedures utilized, the regional bathymetry, and the types of bathymetric anomalies identified in the western Beaufort (Yukon) continental shelf.

Data Processing

The bathymetric data used for the phase III of study was obtained from Cansite Surveys on March 10. This data was the original data recorded in the field and reduced for tidal and draft variations. The data was stored on 120 micro floppy discs (HP 9121 compatible) each capable of storing 250 kilobytes. Each disc consisted of several files containing the following information;

Information	Record
- Line identification	HEADER 96 BYTES
- Line start and end coordinates	
- Start and end fix numbers	
- Survey offset information	
- Date and time of fix	FIX RECORD 192 BYTES/ea
- Gyro and heading information	
- Depth	
- Antenna and offset coordinates	
- Accuracy and filtering information	
- unprocessed positioning information	

Data from a single survey line was divided into several files and disks. This lack of an organized data base require that the data be sorted prior to processing. A program was written to first break the data protect code then read only the data necessary for processing. For each fix the coordinates and depth were read then sorted according to location.

In reading all 120 discs only two READ/WRITE errors were encountered. Several attempts were made to bypass the bad portion of the disks errors but, the efforts proved unsuccessful. The entire data from one disk and half the data from the second was unreadable. This resulted in a gap, approximately one kilometre wide by 10 kilometres long, in the data base.

The source data was sorted by location into 9 grid zones. Each zone would contain approximately 8200 to 19400 points. Each fix record was 32 bytes long and consisted of a reference number, northing and easting coordinates and the depth of water.

Data processing was performed on a Hewlett Packard model 9816 computer with 1.5 megabytes of random access memory. Gridded data was stored to disc on a HP 9122 micro floppy disc drive capable of storing 640 kilobytes of data on each disk.

The study area was modelled in 16 subsections. This was necessary in order to reduce the overall processing time. Each section covered an area 20 x 20 kilometres square. Each model was bounded by the coordinates shown in Figure 8 . The number of source data points used to interpolate each grid is shown in Table 1.

Every third point along the survey line was used to interpolate the grid nodes. The grid interpolation algorithm causes the computer to search for the three closest points which form a triangle around a grid node. If the points are spaced too closely along a line, the computer searchs for data points along a single line rather than forming a triangle around the grid node. Processing each model would takes about 5 to 8 hours, depending on the number of source points used.

NORTH

500,000 520,000 540,000 560,000 580,000

7,795,000					
	12045 source pts.	10119 source pts.	10812 source pts.	10215 source pts.	D
7,775,000					
	14427 source pts.	11555 source pts.	12526 source pts.	10117 source pts.	C
7,755,000					
	10741 source pts.	11013 source pts.	11226 source pts.	9320 source pts.	B
7,735,000					
	6469 source pts.	7695 source pts.	9408 source pts.	6116 source pts.	A
7,715,000					
	1	2	3	4	

SOURCE DATA DISTRIBUTION
Table 1

After the digital modelling was completed, perspective grid plots were produced on a HP model 7580A drafting plotter. A number of spikes caused by erroneous depth values had to be interactively edited from each model. the range of depth was limited to 80 metres, in order to fit the model onto a single sheet in areas where there was a large difference in depth. This occurred around the steeply sloping edge of the continental shelf so did not affect the results of the study. Two draft mosaics were assembled, one being viewed from an azimuth of 45 degrees and the other being viewed from a azimuth of 225 degrees and a tilt of 30 degrees and a vertical exaggeration of 100 times. The latter mosaic provided a better image of the seafloor topography therefore it was selected for the final plots.

After editing was completed a final meshed grid was plotted of each model. A total of 16 grids were plotted on 24" x 36" mylar sheets. The mosaic was assembled by splicing together smaller plots of each model. A flowchart illustrating the steps involved in the data processing is included as Table 7.

Analysis

EBA Engineering Consultants were subcontracted to identify and characterize all the significant bathymetric highs in the study area. Their report is included in section 3 of this report.

DATA PROCESSING FUNCTIONAL FLOW CHART

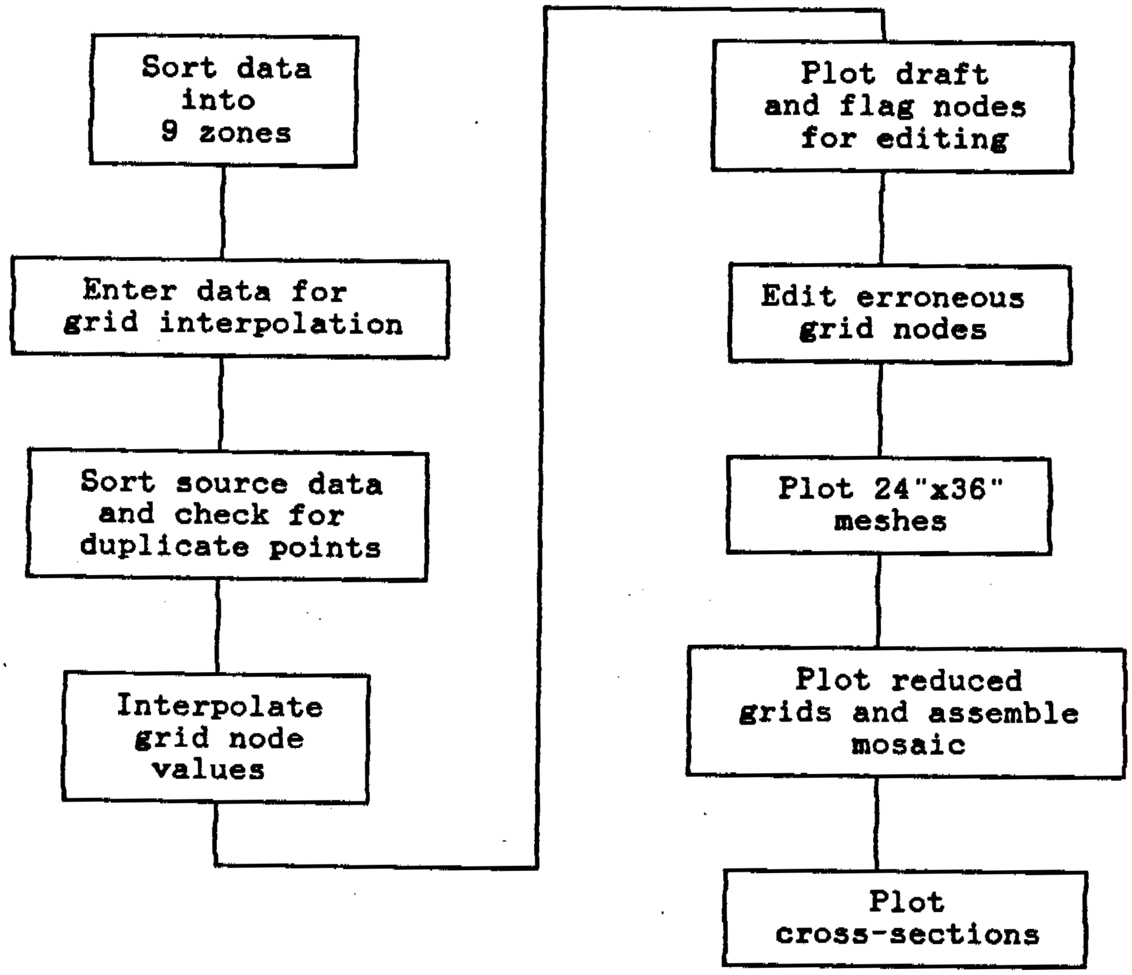


Table 2

4.0 BATHYMETRIC FEATURES OF THE YUKON SHELF

Introduction

This portion of the report describes the bathymetric features of the Yukon Shelf with reference to the possible occurrence of borrow deposits. The postulated recent geologic history of the shelf is described and related to the the features observed. "Recent" geological history comprises the period from the early Pleistocene to present.

This portion of the report has been completed under contract to Challenger Surveys by EBA Engineering Consultants Ltd..

Geological history of the Yukon Shelf

The recent geological history of the Yukon shelf is dominated by a series of sea level transgressions and regressions in response to global glacial events. Three major ice advances have been postulated for the region: in the Illinoian Stage of the middle Pleistocene (Mason River Glaciation), the early Wisconsinan Stage of late Pleistocene (Buckland Glaciation), and the late Wisconsinan Stage. These advances have been well documented on land, but very little has been published about the offshore region. It is thought that the limits of advance for the glaciers were as shown in Figure 9, although as noted above, the offshore limits are speculative.

Since the late Wisconsinan glaciation, sea level has risen and isostatic rebound of the Yukon shelf has taken place. Major delta development has occurred at the mouths of the

Malcolm and Firth rivers, with associated development of distributary mouth bars. Little active deposition from these rivers is thought to be taken place at present.

Ground truthing

Ground truthing information for the study area is understood to comprise:

- High resolution geophysical data collected by GSC in 1984/85
- Grab and gravity-core sampling of the surface during this study
- Geotechnical borehole completed by GSC in 1985
- Geotechnical borehole completed for Dome at the Netserk location
- Several proprietary geotechnical studies, including boreholes and high resolution seismic profiles, of sites to the west of the international border

This study will not access these sources of data, although data available to EBA at the time of report preparation was used to develop the conceptual bathymetric model.

Seabed features

It is important to recognize the degree of distortion created by the isometric grid mosaic in the vertical dimension. Several areas, for example B1, and D2 through D3, appear to display marked bathymetric features which, on closer examination of the records, only rise up to 1 metre above the the surrounding seafloor. Also, in several areas, the density of data changes and in consequence a feature appears. A good example of this is the boundary B4 to B3 wher matching of the data across the boundary is not perfect and a linear hollow appears.

As can be seen in Figure 7 and 8, the study area is a gently sloping shelf bounded in the north and east by a very steep continental margin. The shelf can be split (Table 3), for the purposes of discussion, into six feature areas:

- The eastern margin of the shelf to longitude 140° (orange-shaded area - Zones B4 and C4)

- The inshore ridge running parallel to the coast 10 km offshore between 139°15' and 140°45' (Red-shaded area - Zones A1 to A4)

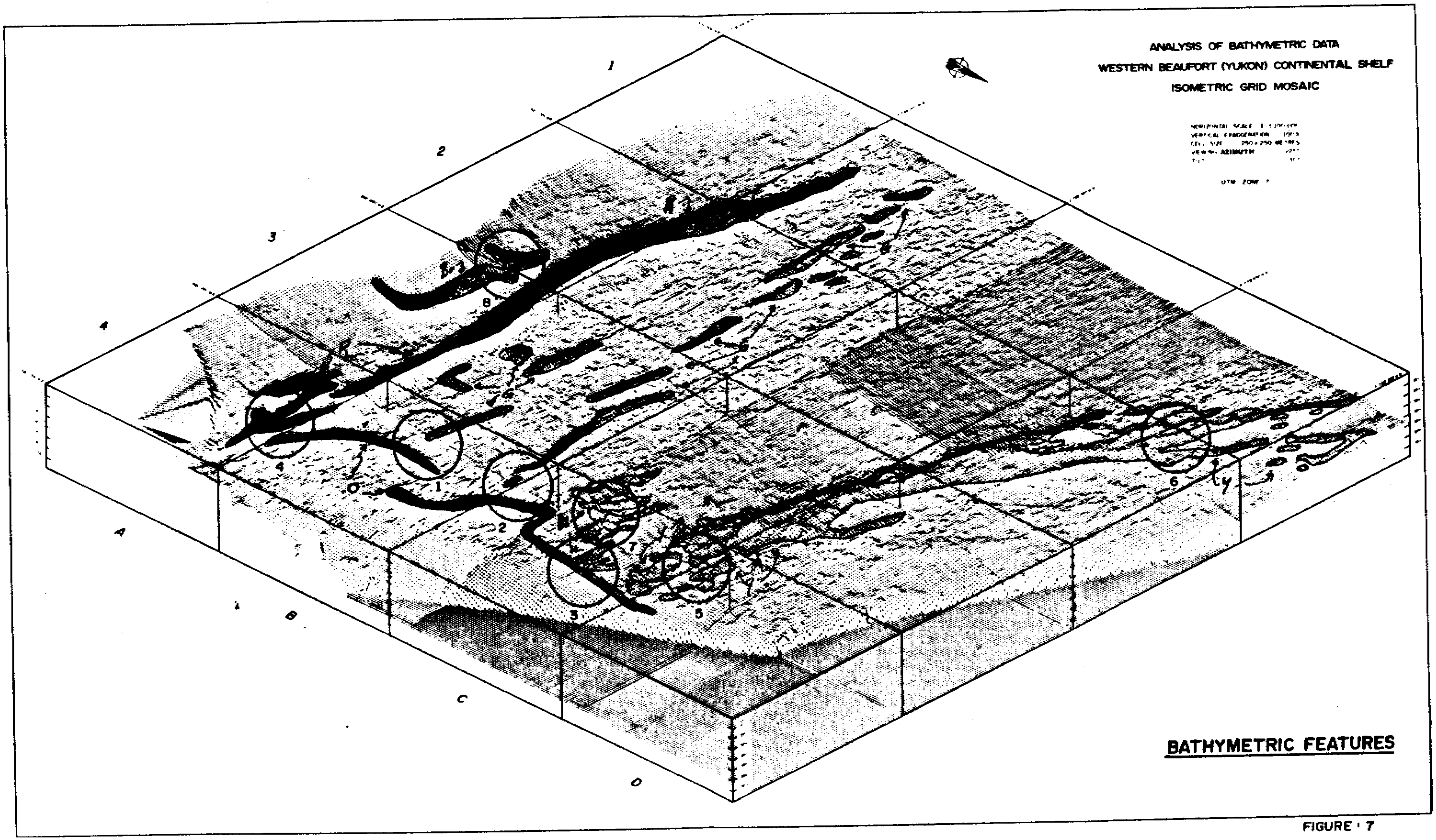
- The ridge running parallel to the coast 45 km offshore between 139°45' and 140°45' (Yellow-shaded area - Zones C3,C2,D2 and D1)

- A series of low subparallel ridges between 139°30' and 140°45'Long., and 69°45' and 69°50'Lat. within the central part of the shelf (Green-shaded area - Zones B3,B2 and B1)

- A series of parallel interfingering ridges (Blue-shaded areas - Zone C3/C4)

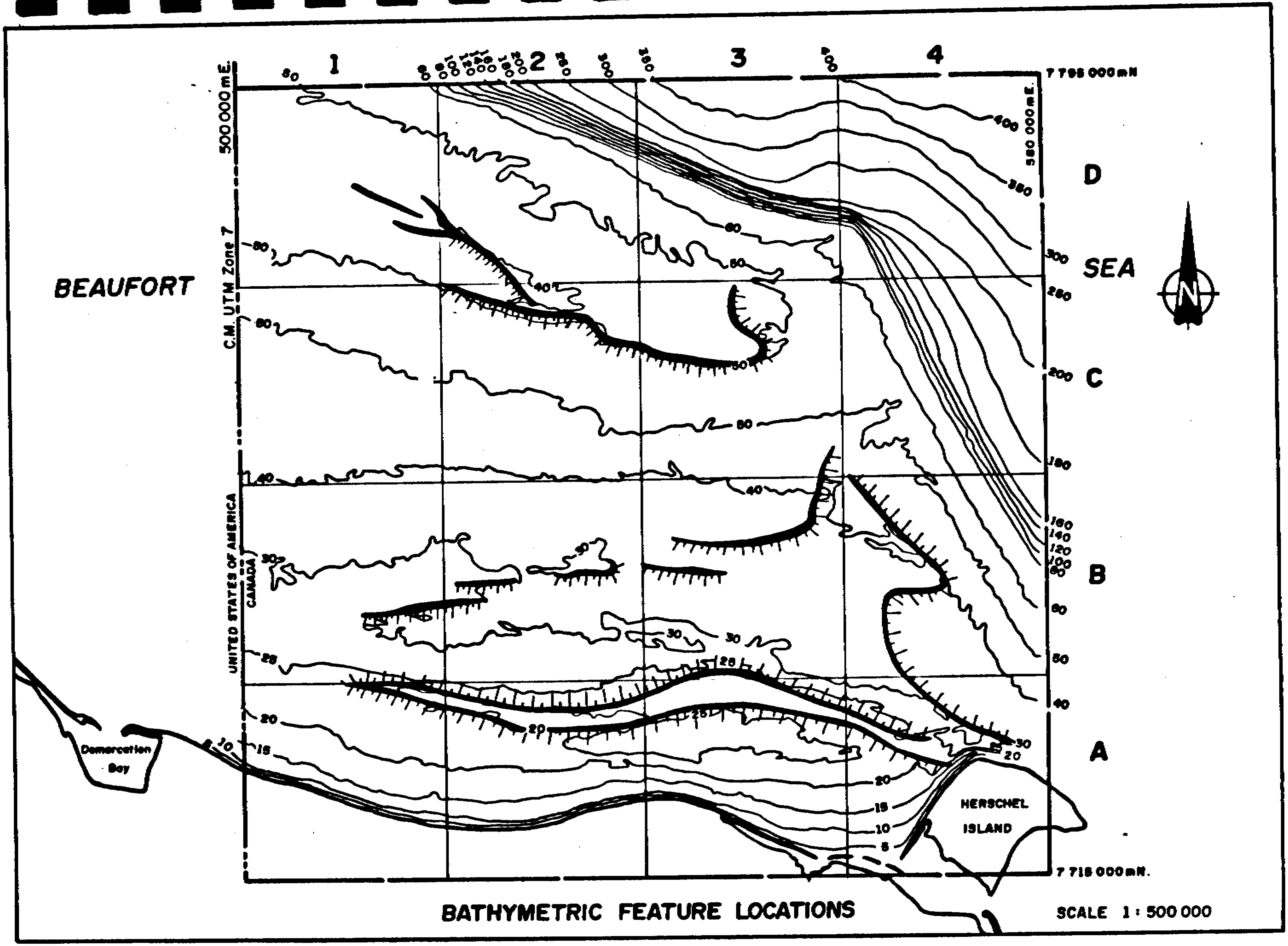
- A broad curve inshore feature at the mouth of the Malcolm River (Brown-shaded area - Zones A2/A4)

The eastern margin of the Yukon shelf is marked by a distinct bathymetric low feature or valley, extending from Herschel Island in the south to the shelf break at 70°. The hollow is approximately rectangular in plan, with its long axis



ANALYSIS OF BATHYMETRIC DATA
WESTERN BEAUFORT (YUKON) CONTINENTAL SHELF
ISOMETRIC GRID MOSAIC
BATHYMETRIC FEATURES

FIGURE 7



BEAUFORT
SEA
N
1
2
3
4
A
B
C
D
7 795 000 mN
7 715 000 mN.
500 000 mE.
580 000 mE.
C.M. UTM Zone 7
UNITED STATES OF AMERICA
CANADA
Demarcation Bay
HERSCHEL ISLAND
BATHYMETRIC FEATURE LOCATIONS
SCALE 1 : 500 000

FIGURE 8

trending north south. This feature truncates several east-west trending features, for example in zone B4, details 1 ,2 and 3. The margin of the valley in the northeast is bounded by distinct hummocky features with relief of up to 4 metres from the surrounding seafloor.

The inshore ridge, which is approximately 60 km in length,is not truncated in the east by the previous feature. At the westerly extent, the ridge appears to diminish into broad hummocky features close to the international border. The ridge appears asymmetric, with the steeper face to the south. At its maximum height, the ridge is 10 metres from the surrounding seafloor.

The offshore ridge, which is approximately 50 km in length, dies out in the east into rough hummocky features (detail 5). To the west the ridge ridge bifurcates several times to form a series of dendritic ridges. The ridge appears asymmetric, with the steeper face to the south. At its maximum height, the ridge is 15 metres from the surrounding seafloor.

The low ridges of the central area extend up to 5 metres from the seafloor. They extend from approximately 139°30' to 140° 45' along the portion of the shelf. They are symmetric and of low relief, reaching a maximum height of 5 metres above the seafloor.

The parallel symmetric interfingering ridges (detail 7) are truncated by the eastern valley (detail 3). These ridges are isolated from both the offshore ridge and the low subparallel ridges by a relatively flat area.

The broad inshore feature curves around the shoreward extent of the Malcolm River delta. It features a steep offshore slope with several curved features with an offshore trend (detail 8).

Implications of the features

It is likely that the majority of the large bathymetric features of the shelf are related to the glacial processes, modified by a small amount of modern day deposition related to the major rivers such as the Malcolm and Firth. This means that the depositional features observed are likely to be of granular texture, being either moraines or near shore deltaic deposits.

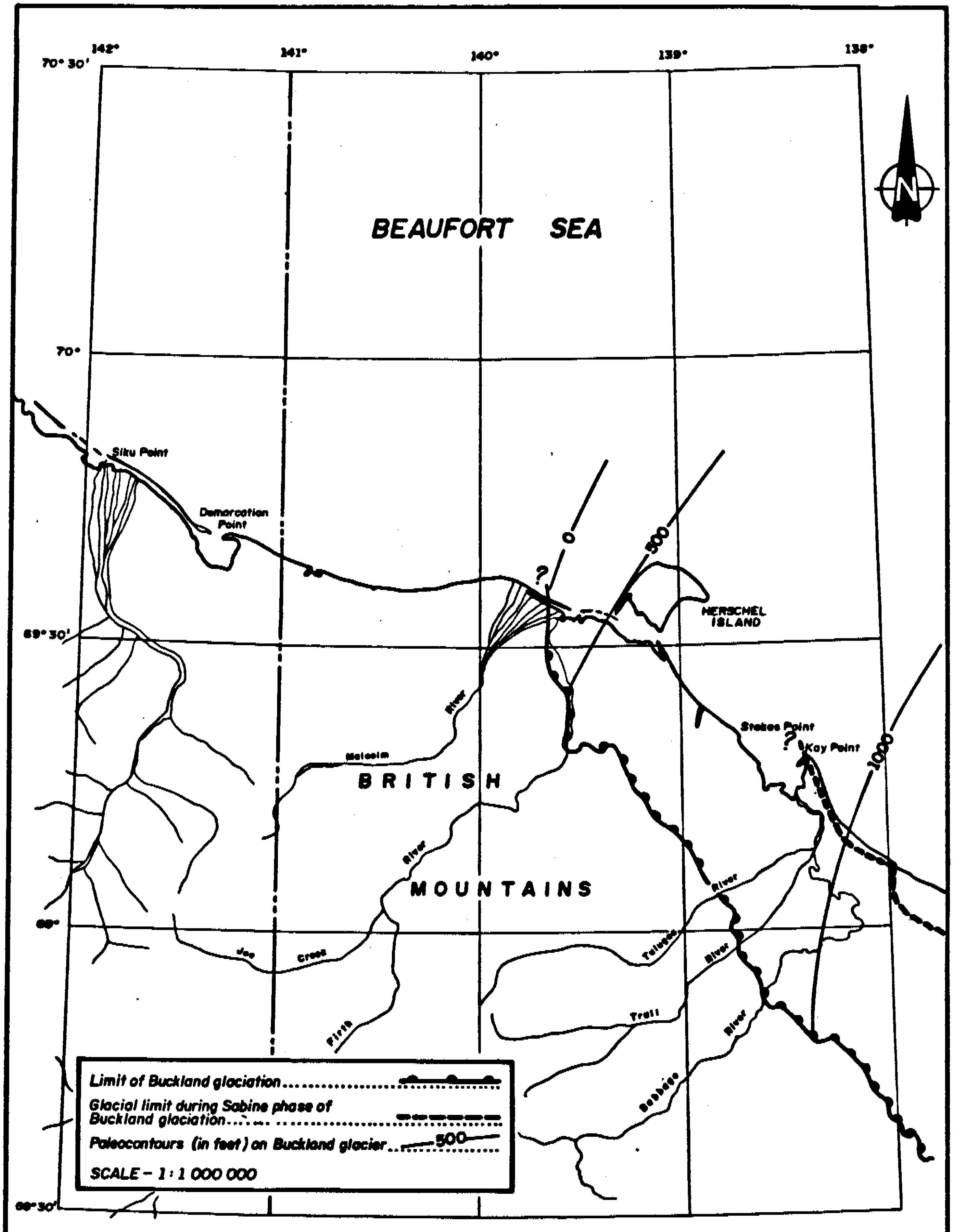
The highest probability of occurrence of a granular deposit target is the northerly offshore ridge feature. This body displays the morphology of a glacial depositional feature, such as an esker or a terminal moraine. Several grab samples derived from the body were observed to be granular texture (L.Meagher, Earth and Oceans Ltd., Personnel Communication). This feature may well be related to the Illinoian Glaciation, on the basis that the limits of this glacial ice area is thought to have been close to the shelf break in this region (Fulton,1984).

The GSC borehole was situated off the crest of the ridge, and no granular deposits were observed at the surface at this location. The water depth measured at this also indicates that the borehole is not situated on the ridge. Sample Ages derived from the surficial sediments collected at this site would be a useful indicator of the maximum possible age for this feature.
The next highest probability of the occurrence of granular deposits are the low linear features of the central region.

These features bear a strong resemblance to distributary mouth deposits and could be related to deposition from the major rivers at lower sea levels. A problem with this hypothesis is that deposits of this type are typically removed during transgression of the sea over the land surface. The low linear features appear to have steep offshore slopes and flat onshore slopes and are thus unlikely to be remnant strand lines. However, this bathymetric form could well be a stamukhi shoal from a period of lower sea levels. Ground truthing is required to determine the true nature of the feature.

The lower probability of the occurrence of granular is assigned to the inshore ridge feature. Although there is similarity between the two ridge features of the area, this feature occurs at the likely depth for the foundation of the present day stamukhi ice zone and is thus likely related to this process. The fact that this feature crosses the erosional hollow feature at the south-eastern extent of the area of interest gives further credence to formation after the last glaciation in the area.

The valley feature itself is of passing interest only. The northern limit of the Buckland glaciation has been postulated by several authors, most notably Rampton (1982), to be somewhere north of Herschel Island, with a western margin close to the present day Firth river. The limit of this valley appears to be very close to the postulated ice limit and could be imagined as evidence of the offshore extent of the ice sheet.



GLACIAL LIMITS & PALEOCONTOURS ON GLACIAL SURFACES

FIGURE : 9

RAMPTON, 1984, GSC BULL. 317

BATHYMETRIC FEATURES

Refer to Figure 7 for color coded locations.

LOCATION	SHAPE
Eastern Margin Orange	Bathymetric Valley
Inshore Ridge Red	Asymmetric Ridge
Offshore Ridge Yellow	Asymmetric Bifircating Ridge
Central Ridge System Green	Low subparallel asymmetric ridges
Northeasterly Ridge Feature Blue	Parallel symmetric interfingering ridges
Malcolm River Brown	Curved offshore slope

Table 3

5.0 CONCLUSIONS

The application of digital terrain modelling techniques to sea bottom mapping is an improved method of dealing with bathymetric data. Computer assisted processing allows large volumes of data to be analyzed in detail and in a relatively short period of time. By accessing the source data, information which may have been edited in the compilation stage of chart or field sheet production, is made available for analysis. This detailed data base allows the seabed topography to be mapped with better resolution than that available on charts, without the inaccuracies of shoal biasing.

The development of a digital terrain model allows depth data to be portrayed in many forms useful in analyzing seabed topography. Graphic products such as axonometric projections of meshed grids, allows the viewer to easily develop a three dimensional image of the sea bottom. By exaggerating the depth component, subtle bathymetric features are enhanced, thus are easier to detect.

Although the mesh grid plots are useful in developing an image of the seafloor, they are not practical for determining the magnitude and location of detected features. This may be improved somewhat by projecting contour lines on to the grid, thus allowing the viewer to measure the magnitude of a feature, however the location is still difficult to determine. Contour plots seem the most appropriate mechanism presently available for detailed delineation of features which have been detected on a mesh grid plot.

Recommendations

Although this report illustrated that the methodology used to detect bathymetric anomalies was successful, the following recommendations should be considered with future projects of this nature.

Improved Interpolation Algorithm

The interpolation algorithm is the single most important function in digital modelling. It is the bases from which all other products are derived. The algorithm used for this project proved to be lacking in speed, data capacity and ability to process all points along a line. It is recommended that an improved algorithm be employed in the future. The algorithm should be capable of processing 10,000 points an hour and have the ability to handle a larger volume of source data, possibly 50,000 points in one batch. Ideally there should be no limit on the volume of data capable of being processed at one time. The improved algorithm should also be capable of exploiting the parallel nature of sounding lines. By doing this and using every data point along a line digital models of higher resolution should result.

Data Bases

Developing a useable data base proved to be the most troublesome portion of the project. Clearly the digital data of the Yukon Shelf bathymetric survey, received from the CHS, was not useable. This however does not reflect the current state of digital data base development at the CHS. Currently the CHS is committed to the development of digital data bases: the Qualified Digital Data Base (Q.D.D.B.) is one example. The Q.D.D.B was developed to fulfill the following requirements:

- to handle large volumes of input data into the data base
- to accept new digital data into the data base
- to convert the backlog of existing data to digital form
- to facilitate metric conversion
- to provide an adequate subset of digital information to support the production of the present nautical chart, as well as, the electronic chart
- to provide digital data to expedite computer assisted chart production
- to restructure the database to facilitate external access

It is recommended that the Q.D.D.B. be looked into further in order to determine whether it would a suitable source of bathymetric data for future projects.

Ground Truthing

The availability of seismic and borehole data would assist in developing a more comprehensive bathymetric model. It is therefore suggested that all available ground truth information be made available when assessing the regional bathymetry of an area.

Re-evaluation of the regional bathymetry of the Yukon shelf should be undertaken when substantial ground truth data becomes available.

Alternate Analysis Methods

Further analysis of the data should be considered. This could include:

1) Determination of volumes of material above certain datums.

2) Slope shading to give a different visual interpretation.

3) Slope determinations using profiles.

ACKNOWLEDGEMENTS

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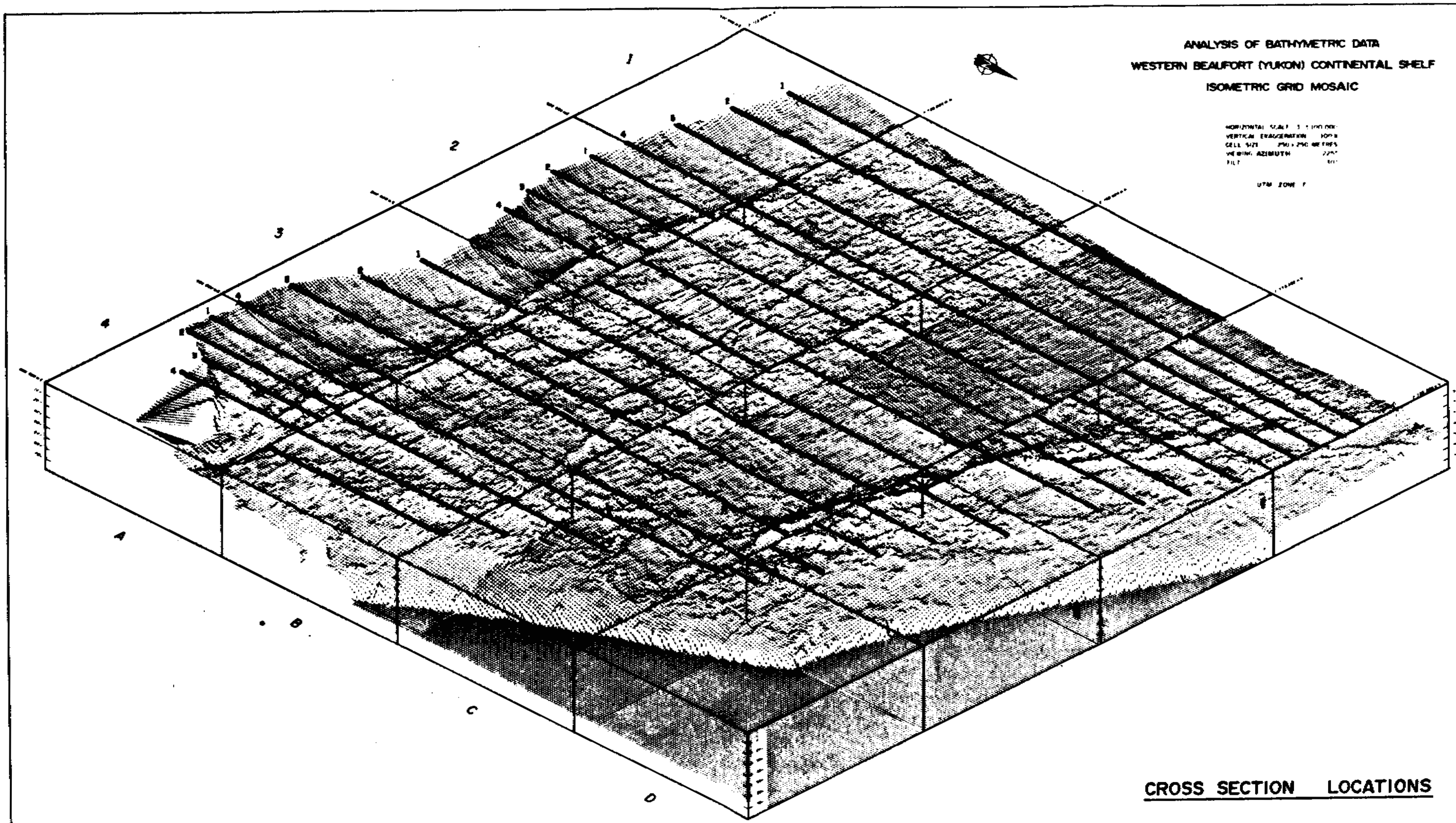
paper 84-10 pp. 69-83.

APPENDIX A

This appendix contains 64 cross sections covering the survey area encompassed by the report. A cross section location map with a numbering system for the profiles is included. As described in the report the data bases were broken into 16 areas. The data was separated in this way because of the volume of information that had to manipulated. For this reason profiles were plotted section by section with the intent being to cross as many anomalies in that area as possible. Consequently profiles from one section do not necessarily join with profiles of another.

The following cross section location map shows, in plan view, the location of each of the profiles. A numbering system for use in locating certain profiles on the mesh is implemented. On the mesh, profiles in each section are numbered from right to left from 1 to 4. This corresponds to a 1 to 4 numbering system from top to bottom on the profile plots. For example to find, in profile view, the 3rd profile in section C2 one would look under drawing no. S372-XSEC-C2 and count 3 from the top.



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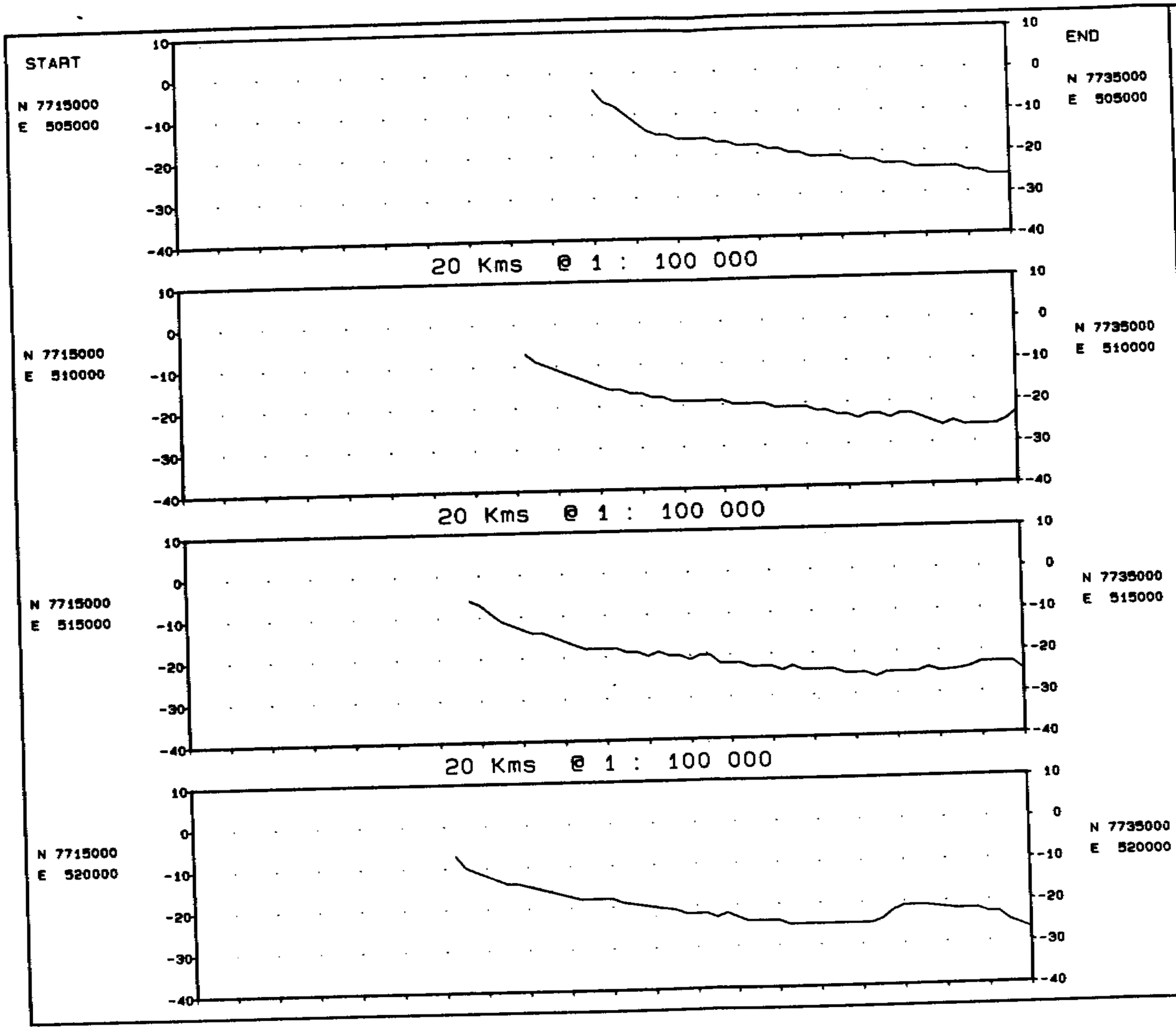


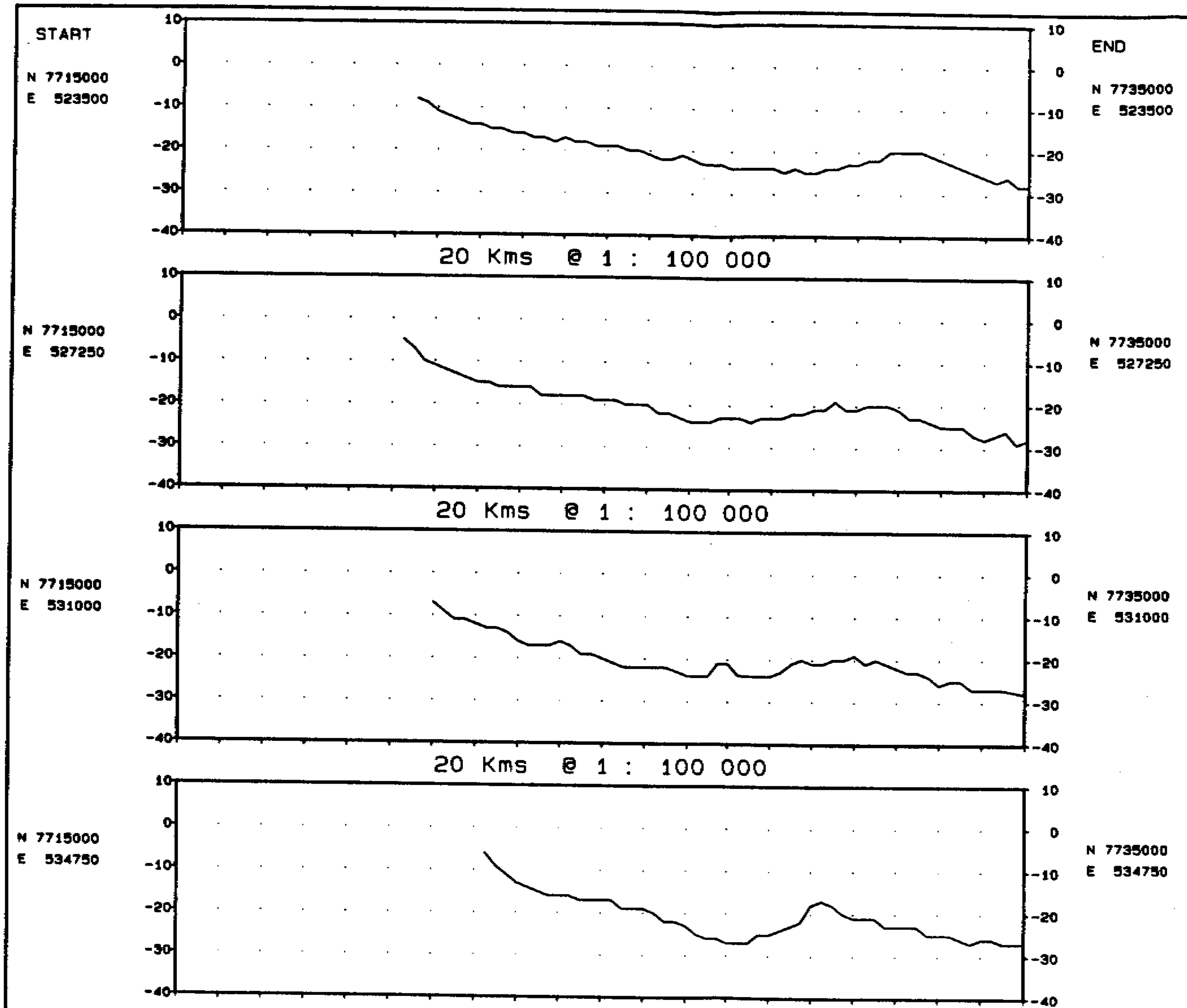
ANALYSIS OF BATHYMETRIC DATA
WESTERN BEAUFORT (YUKON)
CONTINENTAL SHELF

CROSS SECTION PLOTS

HORIZONTAL SCALE 1: 100 000
VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees
UTM ZONE 7 COORDINATES

DSS CONTRACT S/N	SHEET
0ST85-00383	1 OF 16
CSS JOB NO. S-372	DRAWING NO. S372-XSEC-A1

CHALLENGER SURVEYS & SERVICES LTD.
EDMONTON - ALBERTA



ANALYSIS OF BATHYMETRIC DATA
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CONTINENTAL SHELF

CROSS SECTION PLOTS

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VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees

UTM ZONE 7 COORDINATES

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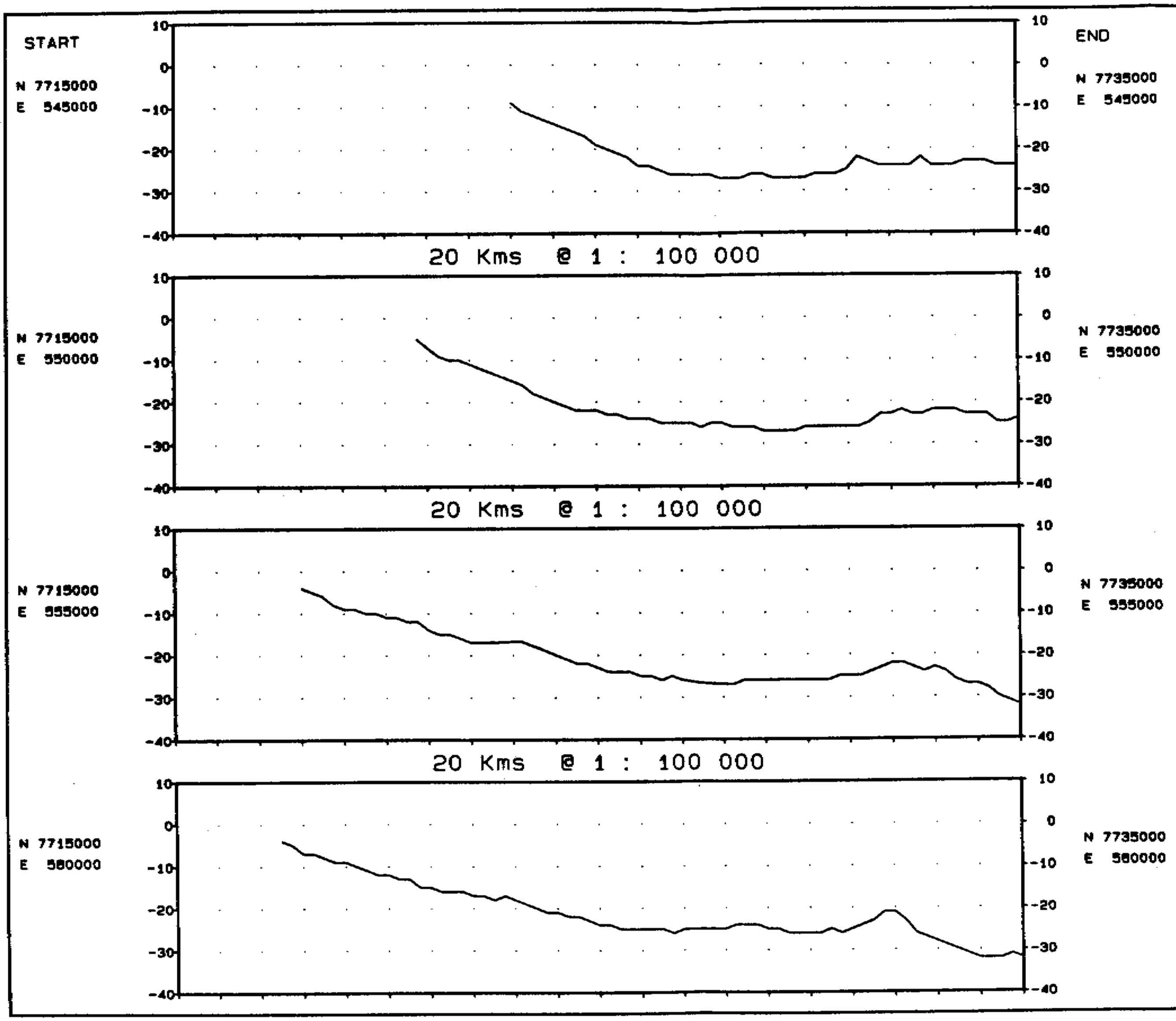

ANALYSIS OF BATHYMETRIC DATA

WESTERN BEAUFORT (YUKON)

CONTINENTAL SHELF

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ORIENTATION 0 Degrees

UTM ZONE 7 COORDINATES

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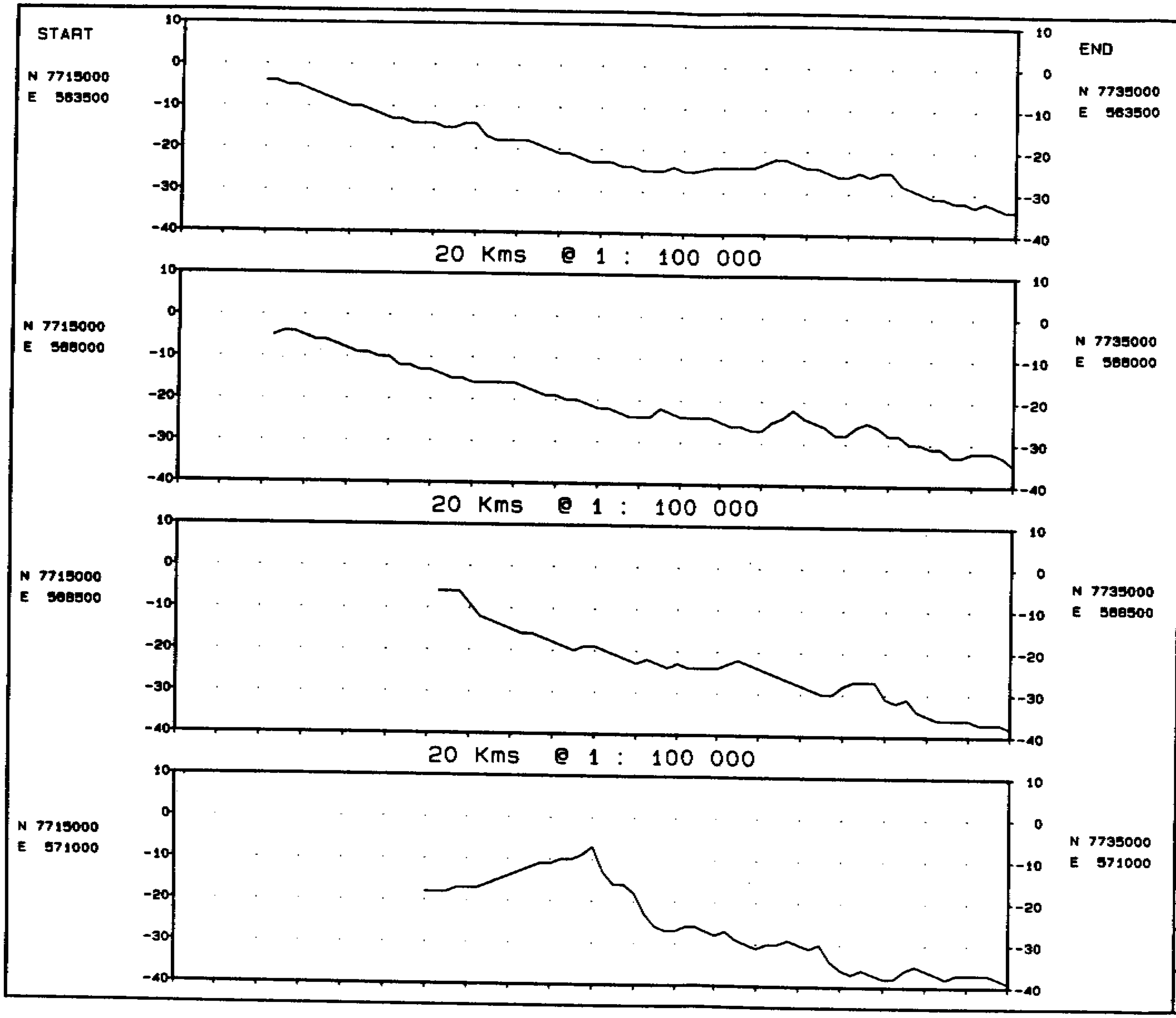

ANALYSIS OF BATHYMETRIC DATA
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CONTINENTAL SHELF

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VERTICAL SCALE 1: 1000
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UTM ZONE 7 COORDINATES

DSS CONTRACT S/N	SHEET
0ST85-00383	4 OF 16
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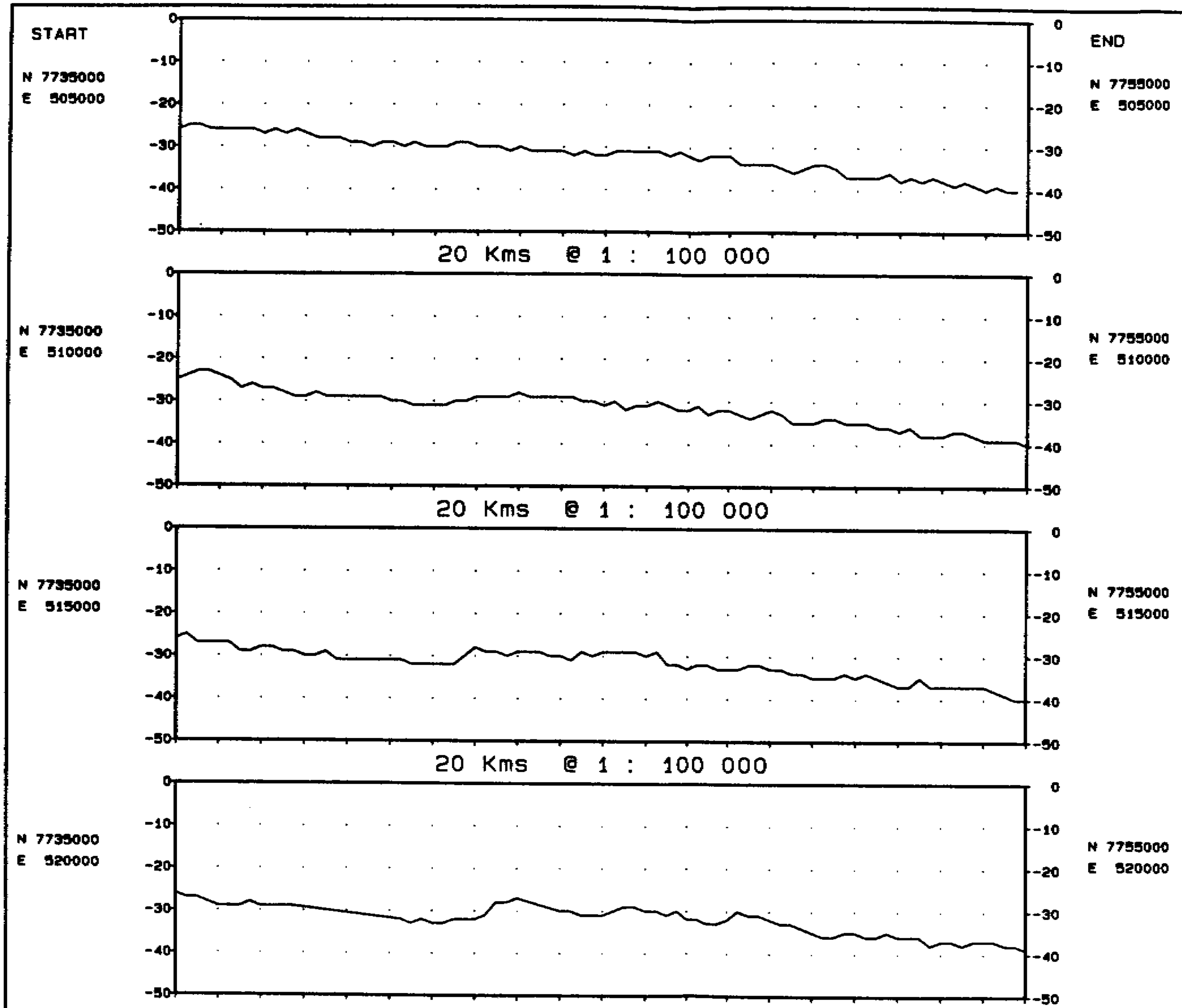

ANALYSIS OF BATHYMETRIC DATA

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CONTINENTAL SHELF

CROSS SECTION PLOTS

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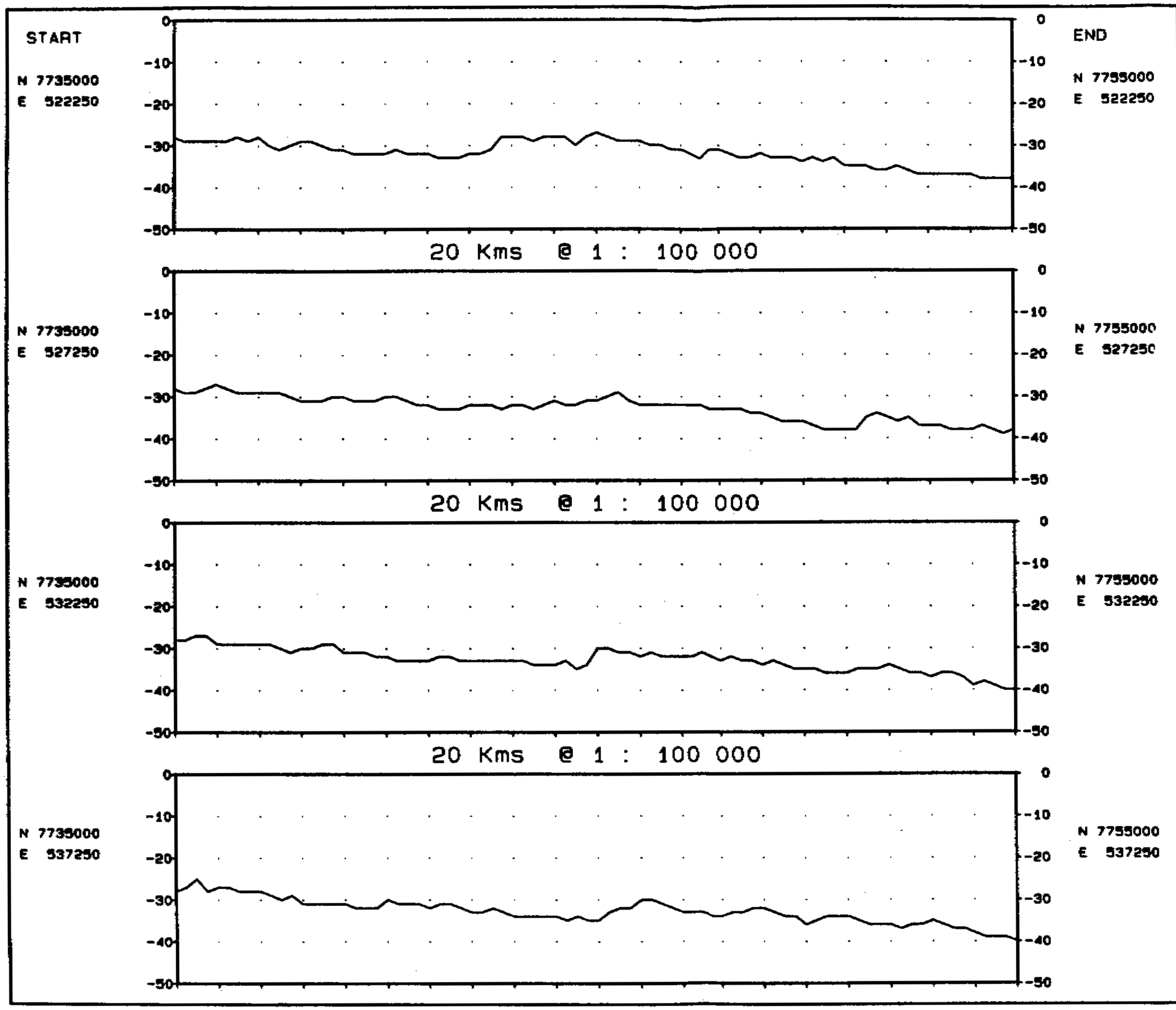

ANALYSIS OF BATHYMETRIC DATA

WESTERN BEAUFORT (YUKON)

CONTINENTAL SHELF

CROSS SECTION PLOTS

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VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees

UTM ZONE 7 COORDINATES

DSS CONTRACT S/N	SHEET
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CSS JOB NO. S-372	DRAWING NO. S372-XSEC-B2

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EDMONTON - ALBERTA

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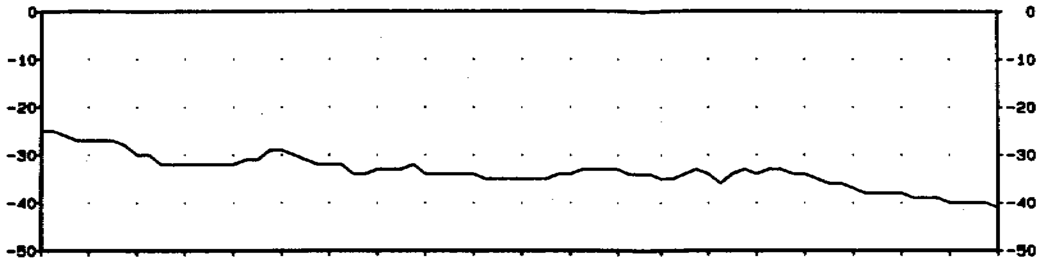
E 543500



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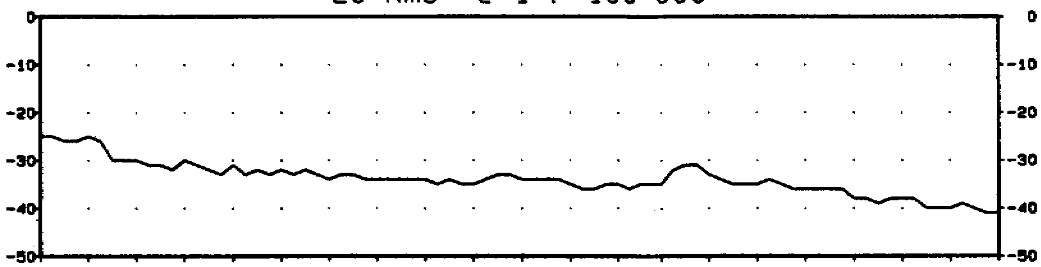

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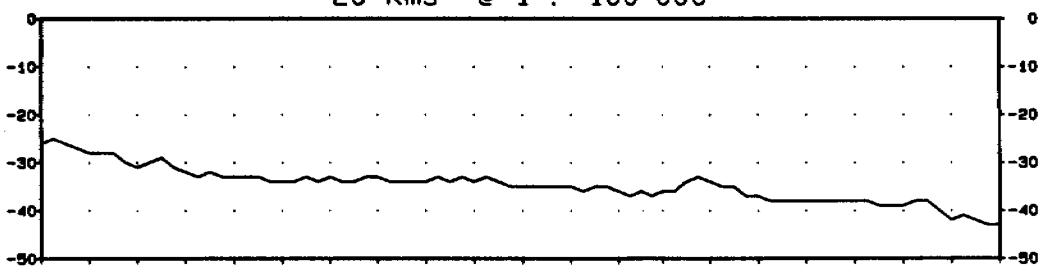
N 7735000
E 551000



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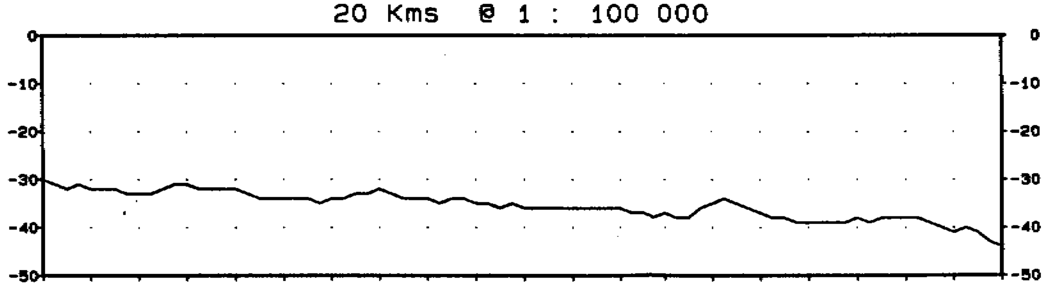

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ANALYSIS OF BATHYMETRIC DATA
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CONTINENTAL SHELF

CROSS SECTION PLOTS

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VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees

UTM ZONE 7 COORDINATES

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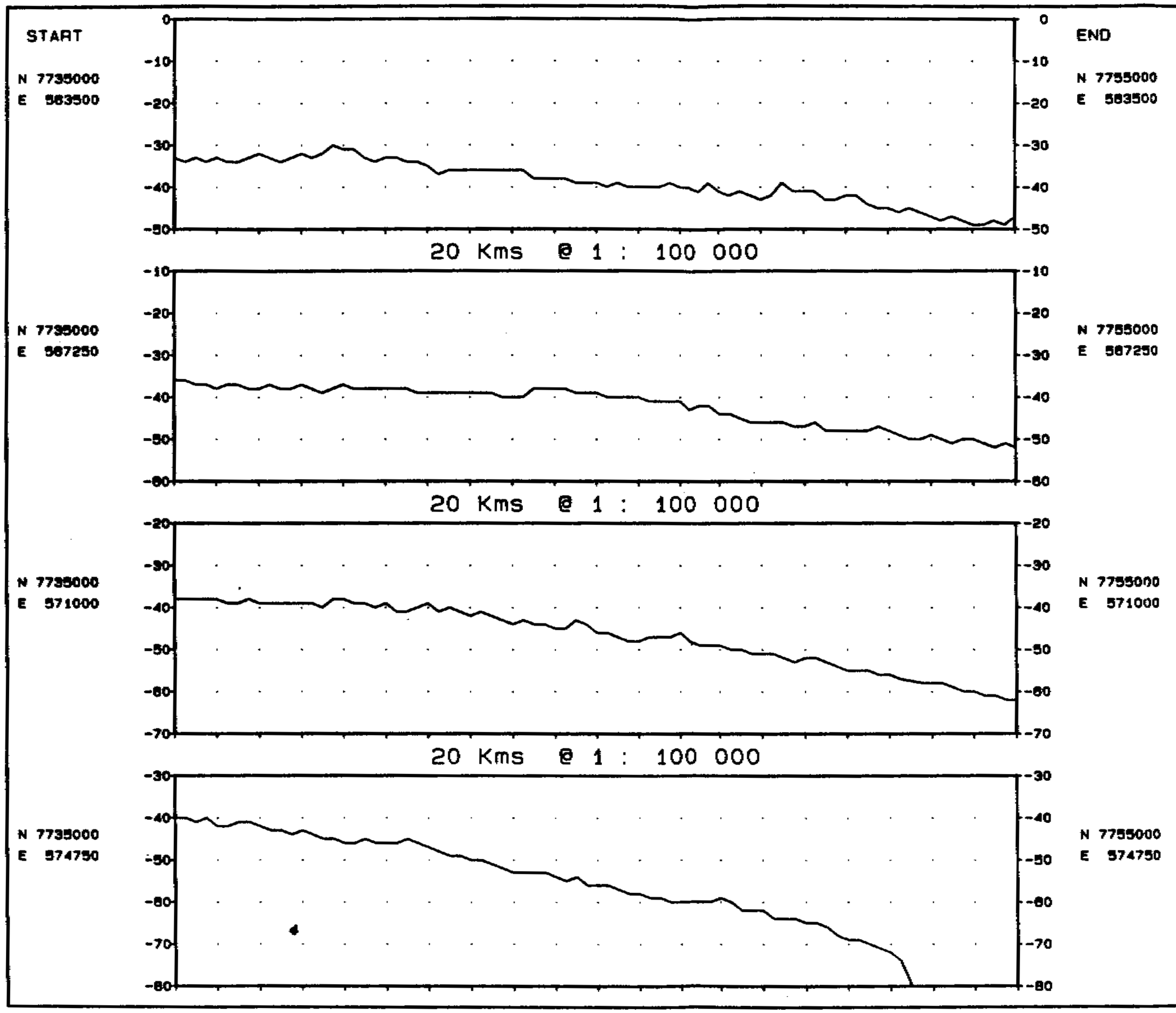

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VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees

UTM ZONE 7 COORDINATES

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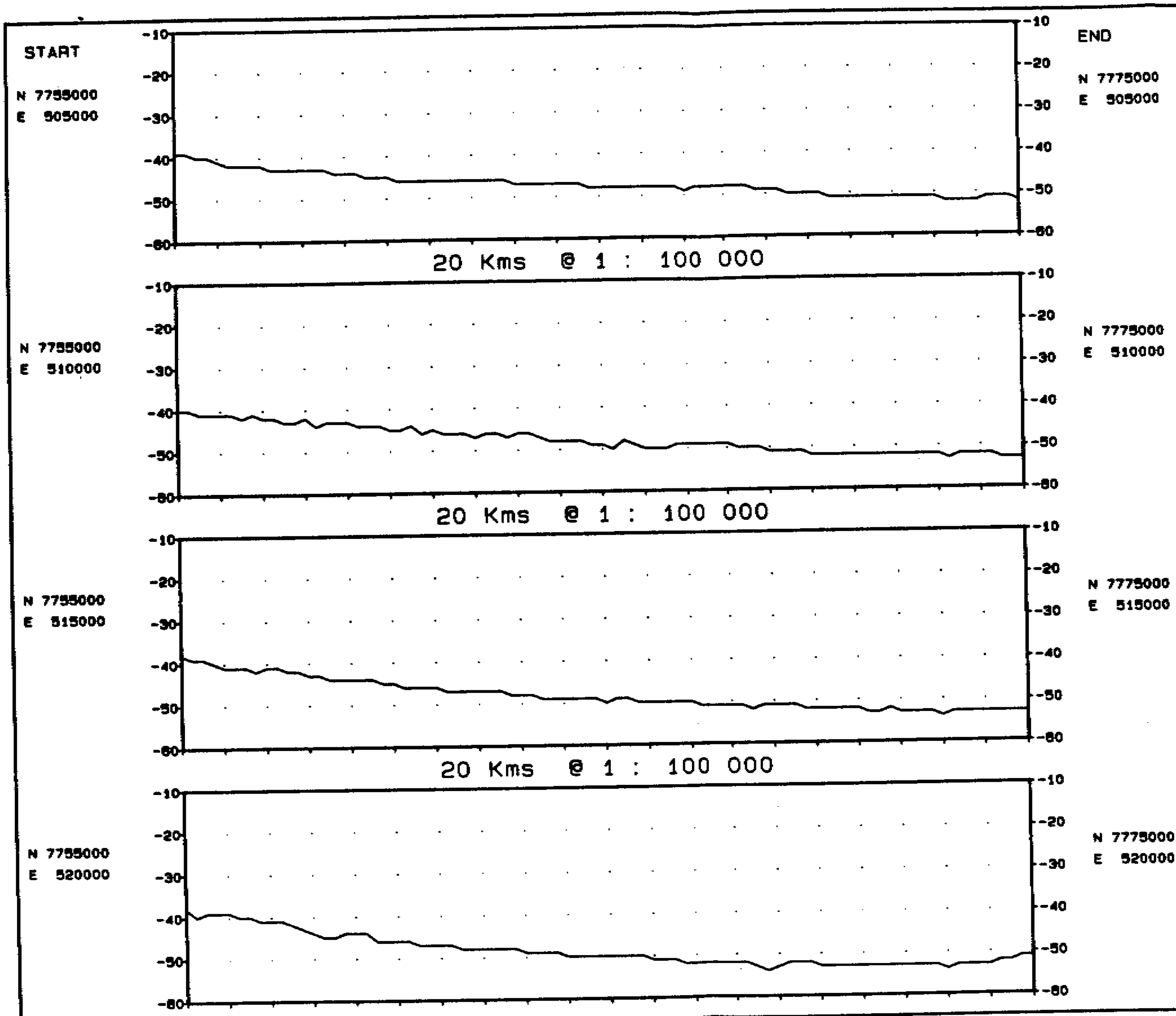

ANALYSIS OF BATHYMETRIC DATA
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UTM ZONE 7 COORDINATES

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0ST85-00383	9 OF 16
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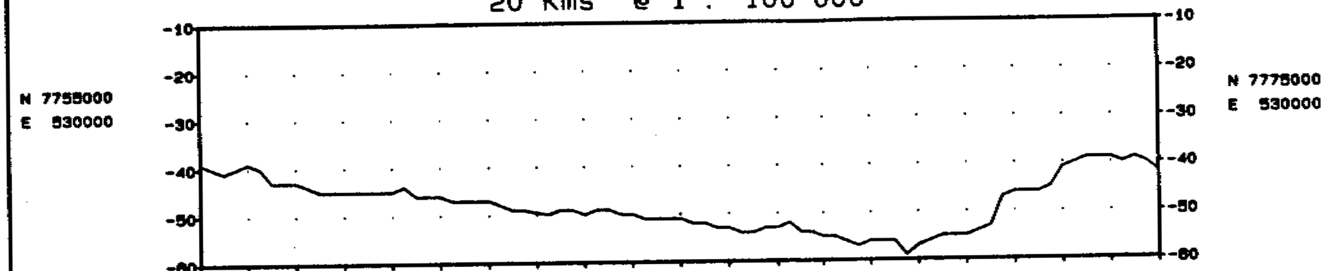

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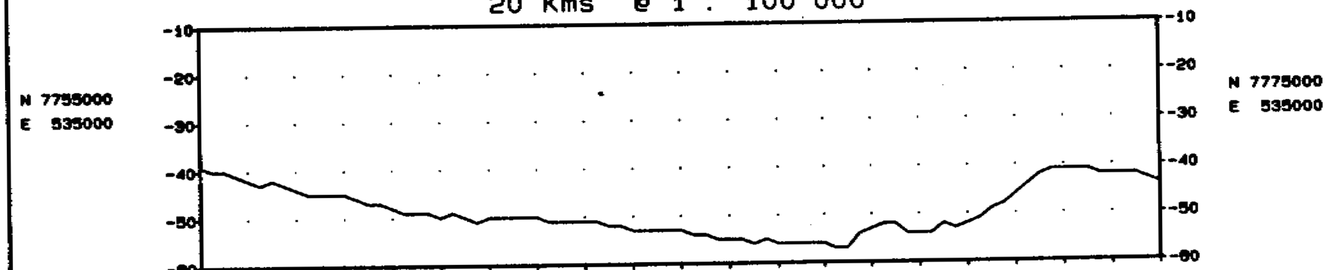

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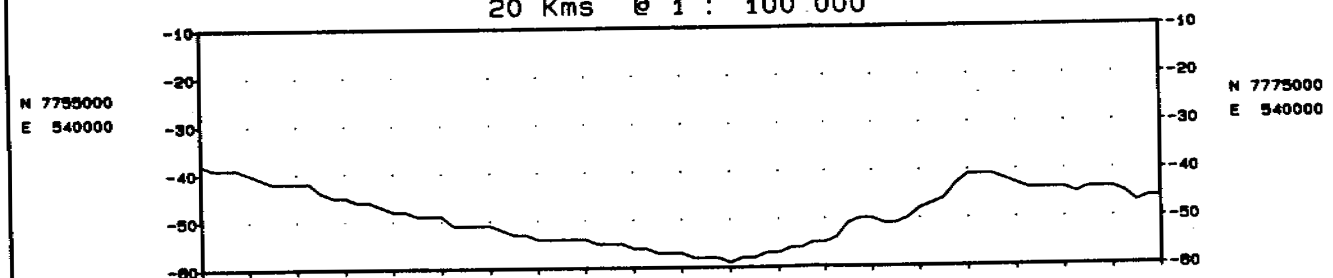

ANALYSIS OF BATHYMETRIC DATA

WESTERN BEAUFORT (YUKON)

CONTINENTAL SHELF

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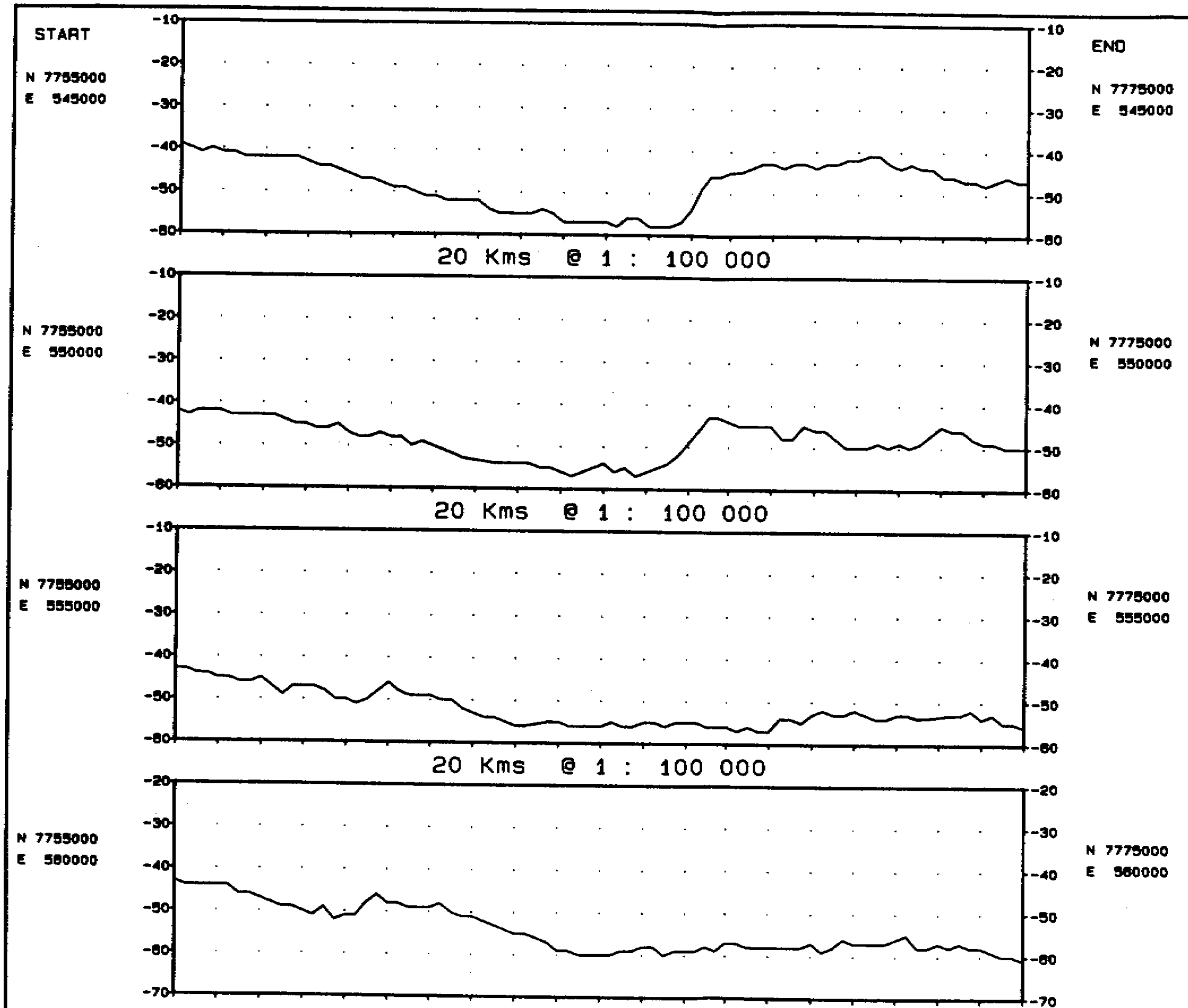

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CONTINENTAL SHELF

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UTM ZONE 7 COORDINATES

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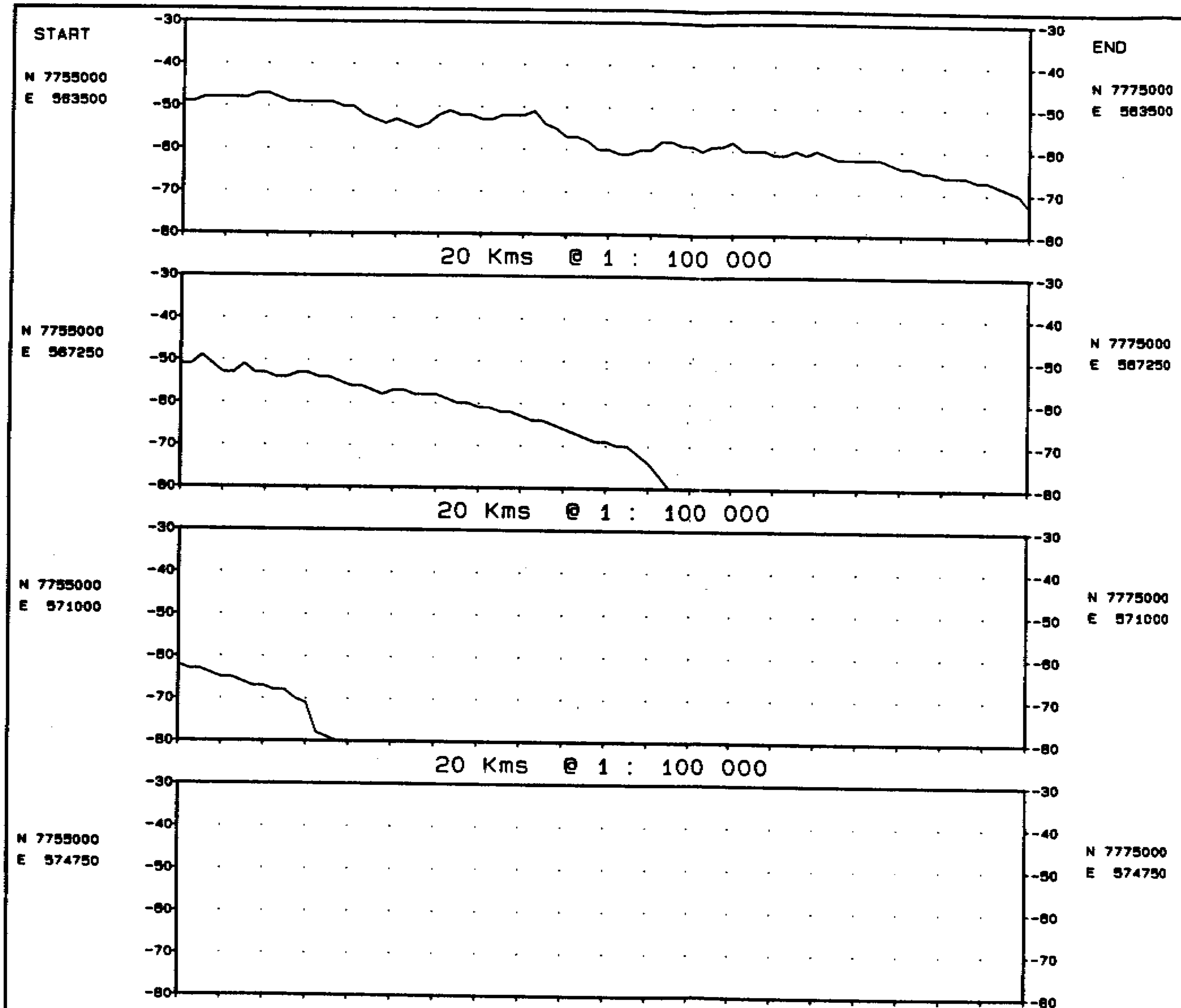

ANALYSIS OF BATHYMETRIC DATA
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CONTINENTAL SHELF

CROSS SECTION PLOTS

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UTM ZONE 7 COORDINATES

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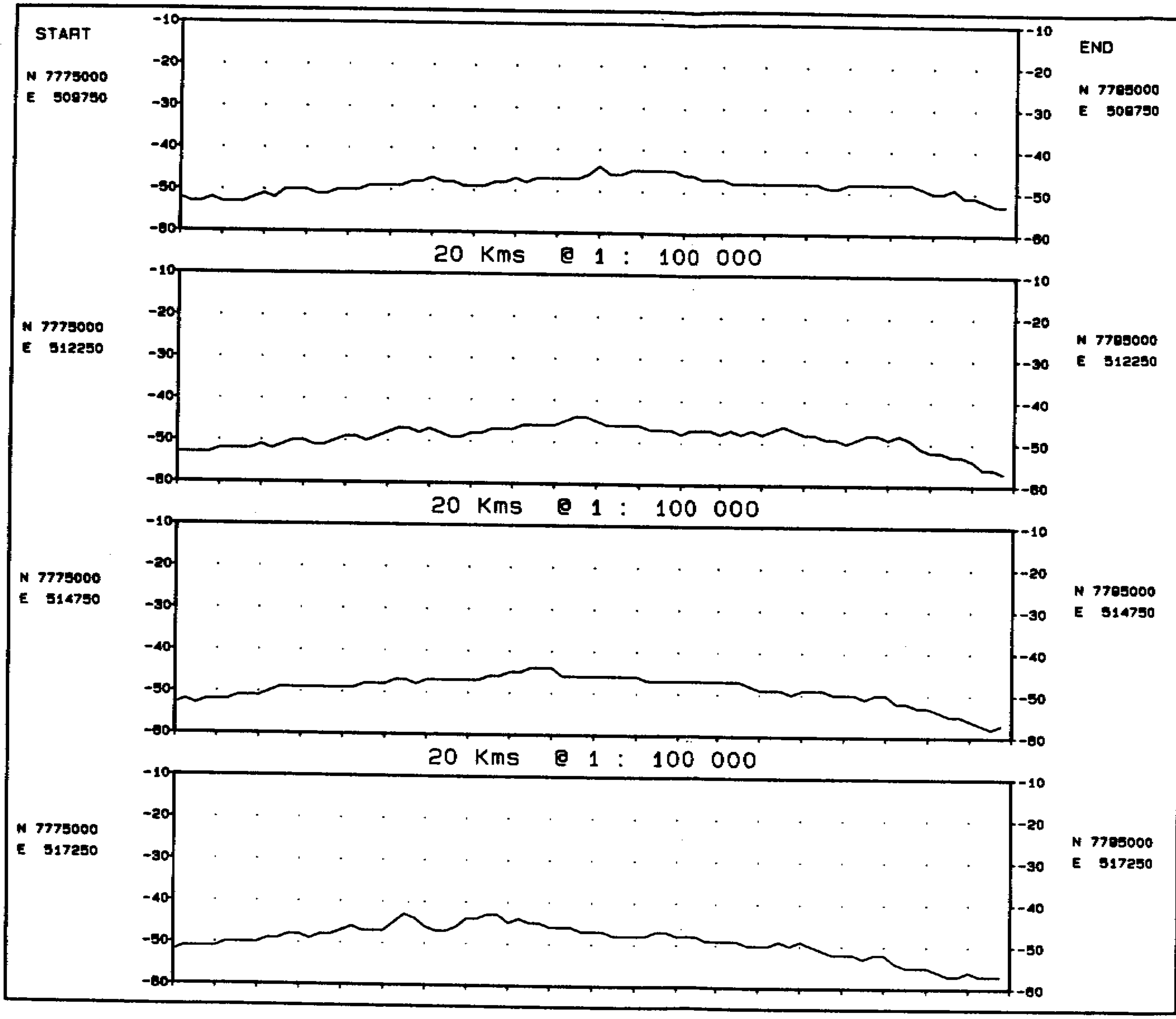

ANALYSIS OF BATHYMETRIC DATA
WESTERN BEAUFORT (YUKON)
CONTINENTAL SHELF

CROSS SECTION PLOTS

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UTM ZONE 7 COORDINATES

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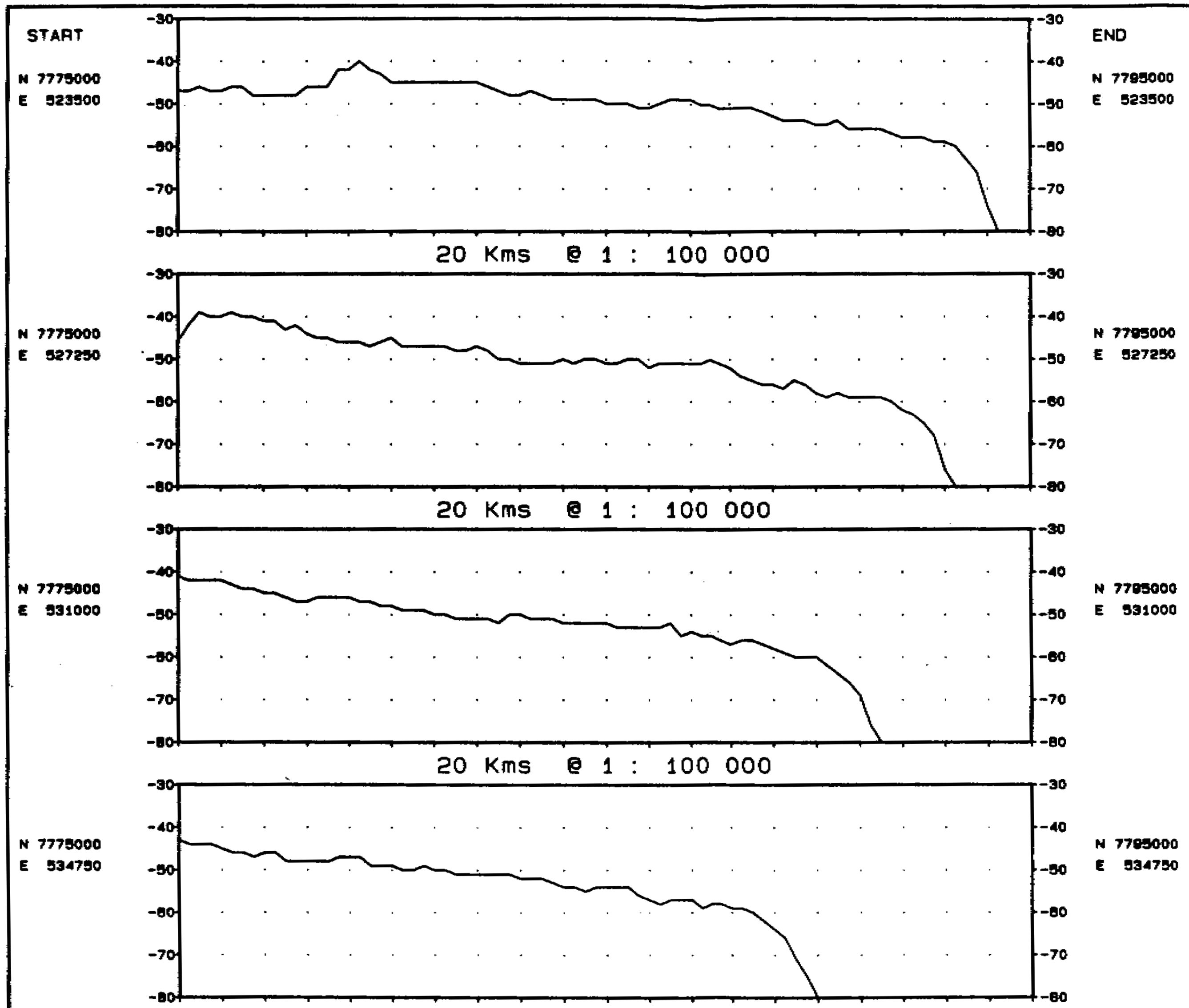

ANALYSIS OF BATHYMETRIC DATA

WESTERN BEAUFORT (YUKON)

CONTINENTAL SHELF

CROSS SECTION PLOTS

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VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees

UTM ZONE 7 COORDINATES

DSS CONTRACT S/N	SHEET
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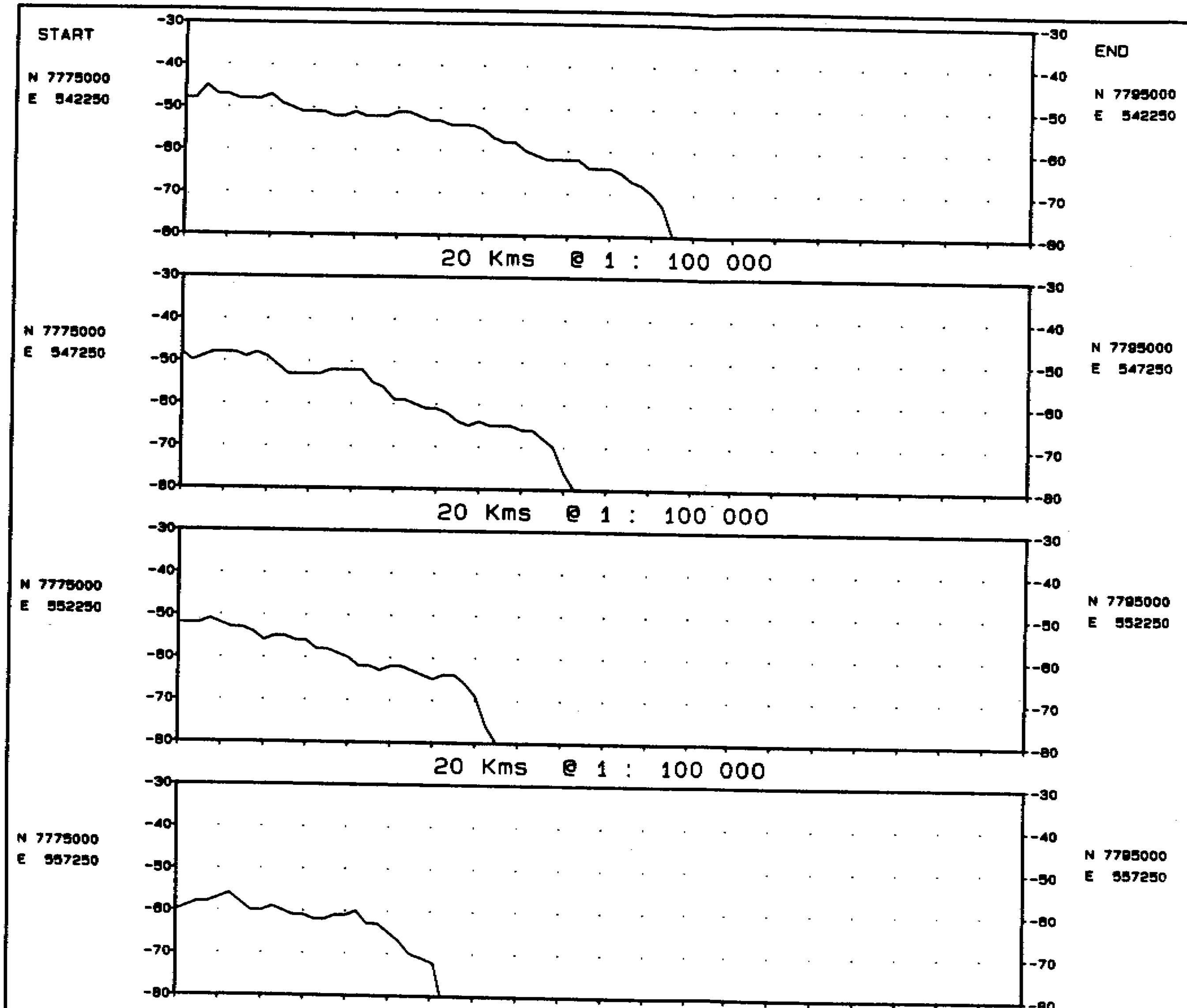

ANALYSIS OF BATHYMETRIC DATA

WESTERN BEAUFORT (YUKON)

CONTINENTAL SHELF

CROSS SECTION PLOTS

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VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees

UTM ZONE 7 COORDINATES

DSS CONTRACT S/N	SHEET
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S-372	S372-XSEC-D3

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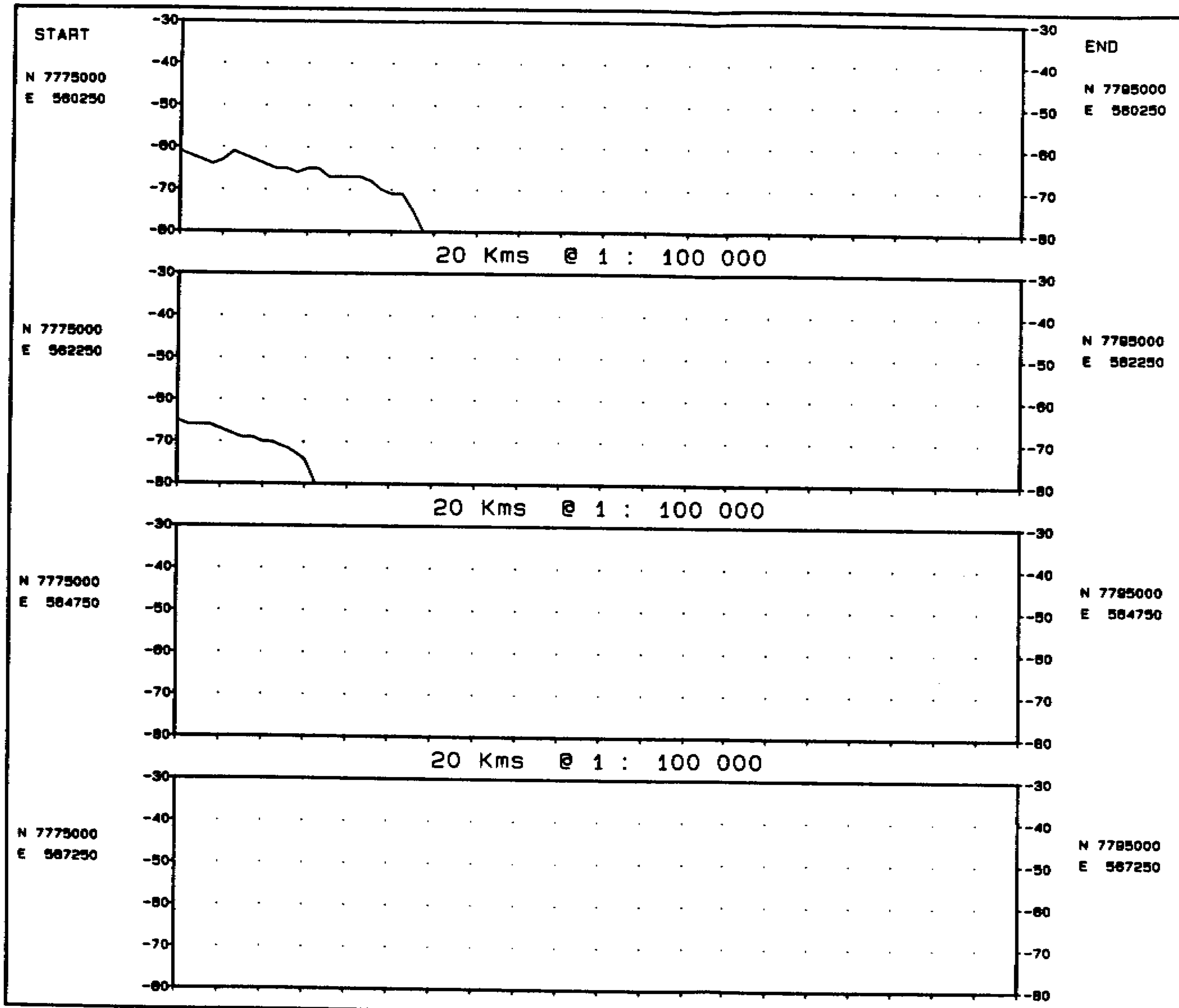

ANALYSIS OF BATHYMETRIC DATA
WESTERN BEAUFORT (YUKON)
CONTINENTAL SHELF

CROSS SECTION PLOTS

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VERTICAL SCALE 1: 1000
ORIENTATION 0 Degrees
UTM ZONE 7 COORDINATES

DSS CONTRACT S/N 0ST85-00383	SHEET 16 OF 16
CSS JOB NO. S-372	DRAWING NO. S372-XSEC-D4
CHALLENGER	SURVEYS & SERVICES LTD. EDMONTON - ALBERTA