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THE FRASER RIVER DELTA:
A REVIEW OF HISTORIC SOUNDING CHARTS

PREPARED BY:
IAN STEWART
BRUNO TASSONE

MARCH 1989

Inland Waters
Pacific and Yukon Region
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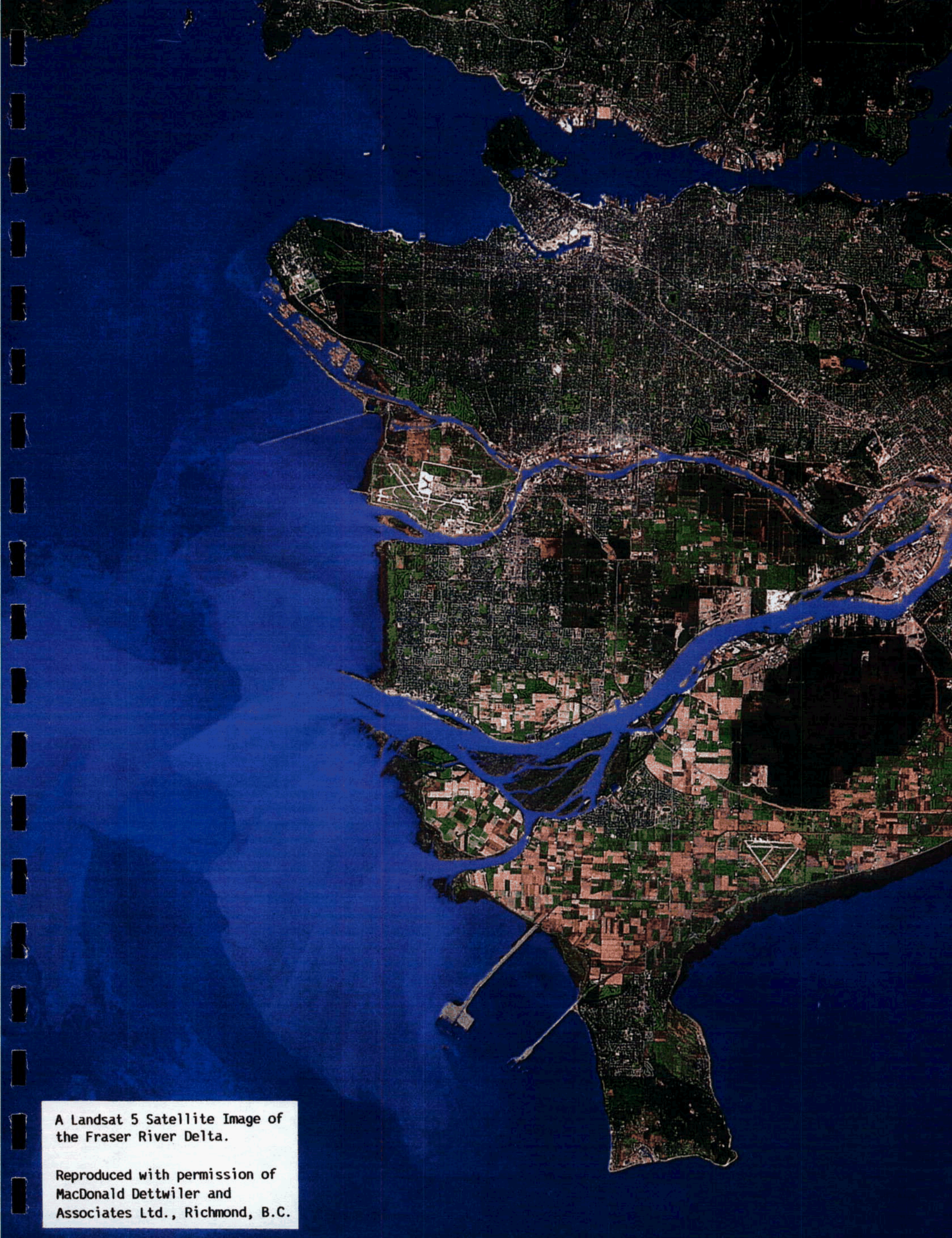

A Landsat 5 Satellite Image of the Fraser River Delta.

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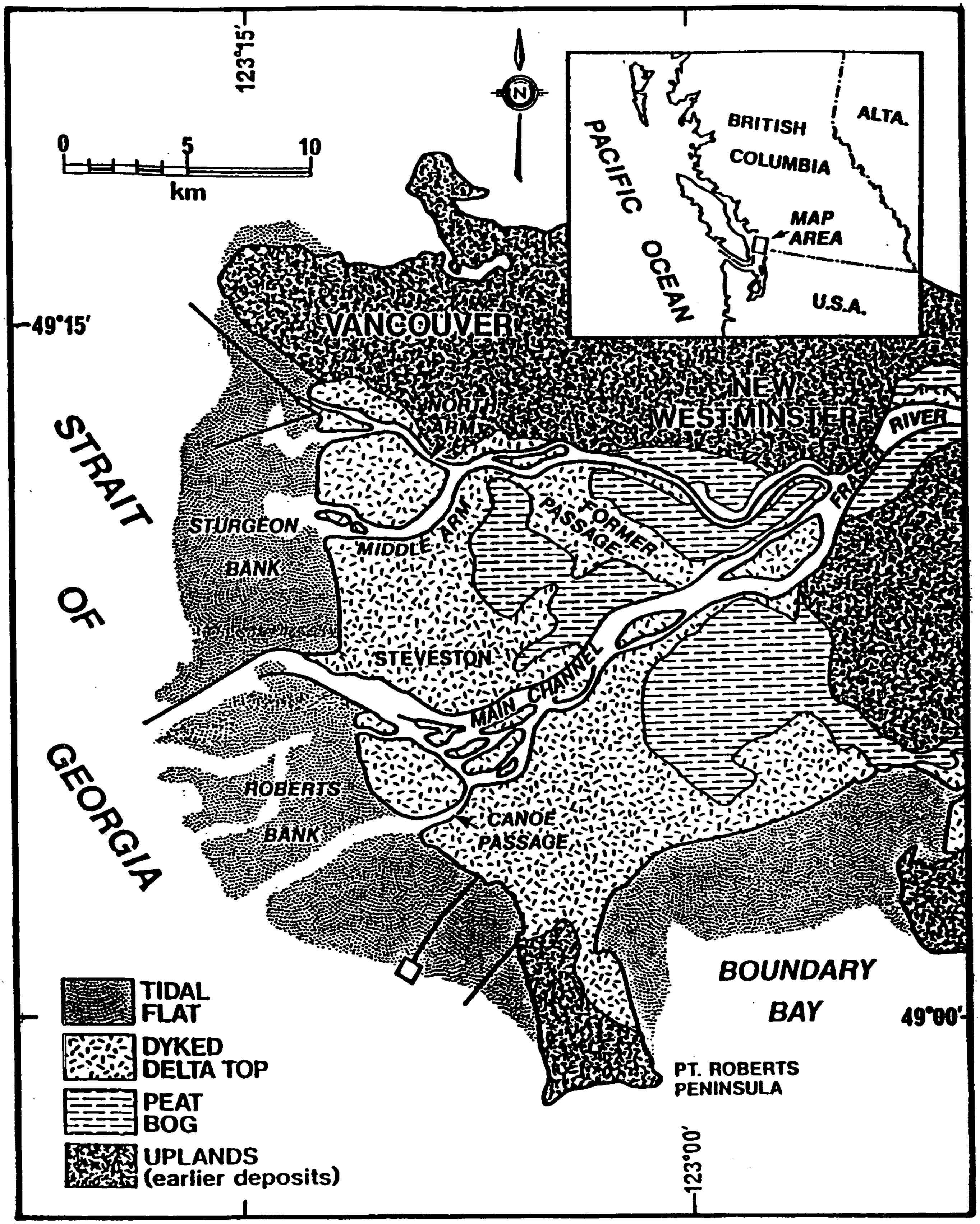

Key Map of the Fraser River Delta
(from Kostaschuk, Luternauer and Millard, 1986)

ABSTRACT

Sounding charts of the Fraser River delta are reviewed in response to concern that the dredging program carried out by Public Works Canada (PWC) is affecting delta growth. Sixteen sounding charts are adjusted to a common scale and separated into five time-series groups. The 10-metre and 90-metre below datum contours (-10m and -90m) are overlaid to provide a visual indication of delta growth. Profiles, plotted from six radial lines drawn at intervals along the delta, provide a more detailed perspective. On average, the Fraser delta -90m contour advanced 210 metres or 4.5 metres per year between 1932 and 1974, whereas the -10m contour appeared relatively stable. At the river mouth the -90m contour advanced 8.6 m/year between 1929 and 1979. This is remarkably close to the 8.5 m/year previously reported by Mathews and Shepard (1962) for the period 1929 to 1959.

PWC dredges sand-sized material (0.177 - 2.0mm) from the river bed in the navigation channel; delta growth is attributed to deposition of finer material (<0.125mm) transported as suspended wash load. The conclusions identify the need for conducting regular surveys of the Fraser delta, investigating particle-size distribution on the delta, and conducting annual bathymetric surveys to assist in determining the Fraser River's sediment budget.

RESUME

Suite à l'inquiétude que la croissance du delta du fleuve Fraser est affectée par le programme de dragage effectué par Travaux Publics Canada, (TPC) des cartes bathymétriques du delta ont été revisées. Seize de ces cartes sont ajustées à une échelle commune et separées en cinq groupes de séries chronologiques. Des courbes de niveaux de 10 mètres et de 90 mètres sous l'horizon fondamental (-10m et -90m) sont superposées pour reproduire visuellement la croissance du delta. Des profils bathymétriques, tracés de six lignes radiales espacées au long du delta, donnent un aperçu plus détaillé. La courbe de -90m du delta du Fraser s'est avancée en moyonne de 210 mètres ou de 4.5 mètres par année entre 1932 à 1974, par contre la courbe de -10m semble être relativement stable. A l'embouchure du fleuve la courbe de -90m s'est avancée de 8.6m par année de 1929 à 1979. Ceci est remarquablement proche de 8.5m par année antérieurement rapparté par Mathews et Shepard (1962) pour la période de 1929 à 1959.

TPC drague des matériaux de grosseur de sable (0.177 - 2.0mm) dans le canal de navigation du fleuve; toutefois, l'accumulation des dépots dans le delta provient du dépot de matériaux encore plus fins (< 0.125mm) transportés en suspension comme charge de ruissellement. Les conclusions soulignent les besoins de poursuivre régulièrement des levées du delta Fraser afin d'examiner la répartition granulométrique de sédiments et aussi de produire des levées annuelles bathymétriques pour aider à la détermination d'un bilan de sédiments pour le fleuve Fraser.

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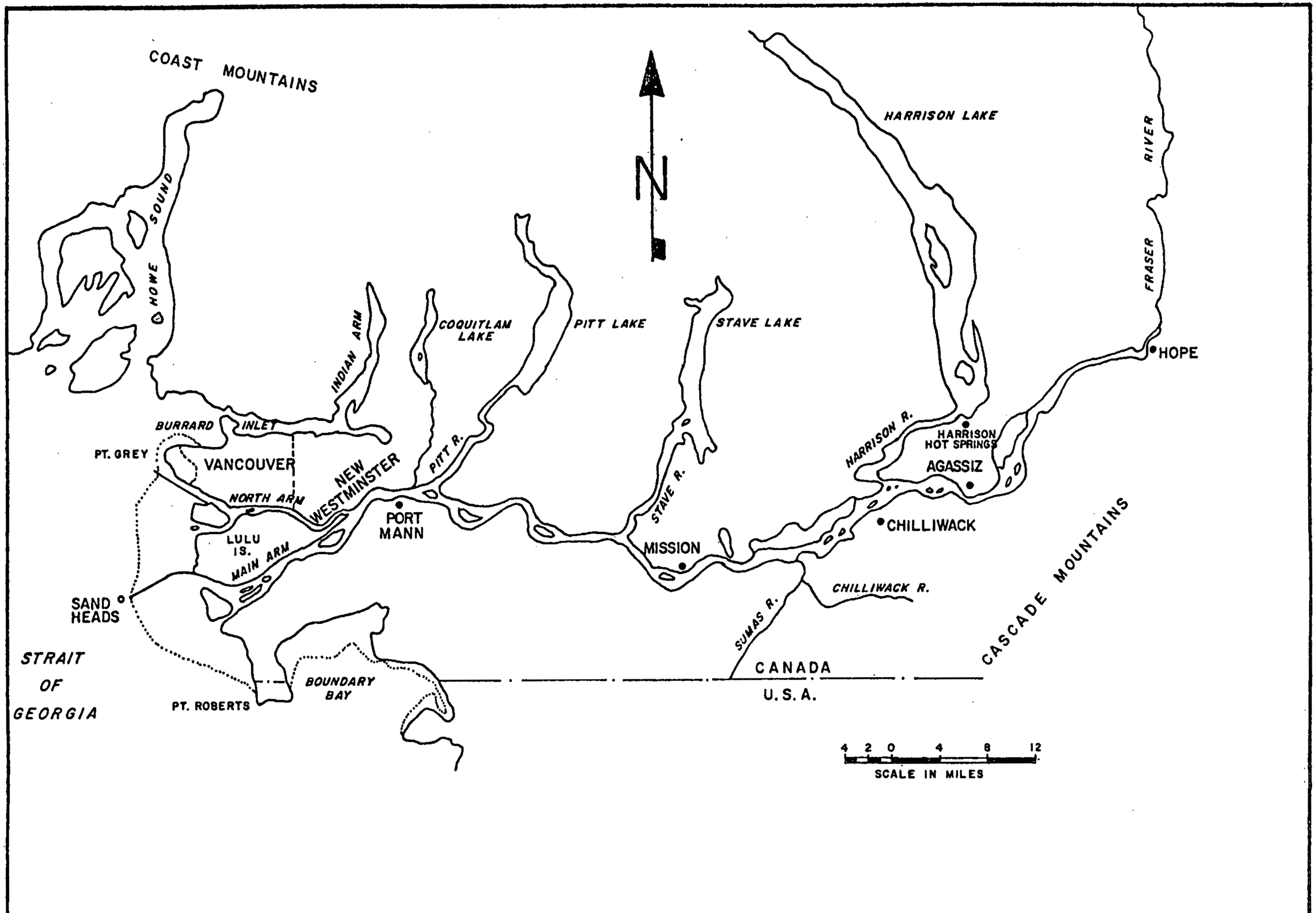


Figure 1. Map of the Lower Fraser River (from WCHL, 1978)

1. BACKGROUND

The Fraser is the largest river in British Columbia draining an area over 234 000 square kilometres and travelling approximately 1 400 kilometres from its headwaters in Mount Robson Provincial Park to its mouth near Vancouver, British Columbia. Runoff in the basin is dominated by spring snowmelt and generally produces a bell-shaped hydrograph. Peak annual flows normally occur between the first of May and the end of June. Annual peaks at Hope, since 1912, have ranged from 5 130 cubic metres per second (cms) to 15 200cms with a mean of 8 770cms.

Based on 18 years of sediment data at Mission, 84 kilometres upstream from the mouth, the mean annual total sediment load is 17.3 million tonnes/year (Environment Canada, 1988). This load is composed of approximately 35 percent sand (particles >0.063mm), 50 percent silt (0.004 - 0.063mm) and 15 percent clay (<0.004mm).

In this report, the Lower Fraser River refers to the 165-kilometre reach between Hope and Sand Heads, the navigation light at the end of Steveston North Jetty (Figure 1). Transport Canada is responsible for maintaining the navigable reaches of the Lower Fraser River; Public Works Canada (PWC) carries out much of the required dredging.

Transport Canada's objective is to maintain a 10-metre deep navigation channel from Sand Heads to New Westminster 95 percent of the time. This objective is now achieved approximately 30 percent of the time (Fakidis, 1987, pers. comm.). In recent years PWC, through a combination of dredging and training works, has been lowering the mean river bed elevation by an average of 10 centimetres per year to reach the desired depth (Wu, 1986, pers. comm.).

From a review of PWC dredging records, the average amount of material removed (net dredgate) from the Fraser between 1975 and 1985 is estimated at 4.3 million m^3/year, of that 4.0 million m^3/year is from the main channel between New Westminster and Sand Heads. Based on an average density of 1.6 tonnes/m^3, this amounts to 6.4 million tonnes/year of total dredgate between New Westminster and Sand Heads. Bed material samples taken at various locations in the navigation channel indicate that the dredgate is composed primarily of sands between 0.177mm and 2.0mm in size. The total bed material load (>0.177mm) at Mission has recently been estimated at 3.0 million tonnes/year (McLean and Tassone, 1988). Thus it appears that Public Works has been dredging at a rate exceeding the natural supply.

2. OBJECTIVE

Concern has been expressed that PWC's dredging program may be creating a sand deficit in the sediment budget of the Lower Fraser estuary (Kellerhals 1984, 1985). To obtain an overview of the situation, Inland Waters (IW) embarked on an analysis of sounding information for the delta area. This report reviews and analyzes historic sounding charts from the Canadian Hydrographic Service to determine the areal changes which have occurred on the delta front during the period 1929 to 1985.

3. METHOD

Sixteen sounding charts spanning the years 1929 to 1985 were obtained from the Canadian Hydrographic Service (Table 1). The charts were adjusted to a common scale of 1:30 000 and separated into five time-series groups.

The -10m and -90m (Geological Survey of Canada datum) contours were chosen for plotting as they correspond closely to a previous study and results could be compared (Mathews and Shepard, 1962). For each group, the -10m and -90m contours were plotted on a transparency. Overlaid on a base map, these sequential transparencies provide a visual indication of the advance or retreat of the delta. For illustrative purposes the transparencies were photographically reduced and included in this report (Figure 2). For a more detailed view, profiles were plotted along six radial lines for each group (Figures 4 - 9).

4. ACCURACY OF RESULTS

There are four major possible sources of imprecision or error in the results. Due to these imprecisions, an observed change is not considered real or significant unless the lateral movement is > ±28m or the vertical movement is > ±one metre.

a) Boat positioning accuracy
Positioning errors ranging from ±12 metres to ±18 metres are given on charts produced after 1968. Earlier charts do not indicate a positioning error, but it is unlikely to be better than later surveys.

b) Distance scaling limitations
On the 1:30 000 scale charts, distances can be determined with a precision of ±10 metres.

TABLE 1. CANADIAN HYDROGRAPHIC SERVICE SOUNDING CHARTS

GROUP	CHART NUMBER	YEAR OF SURVEY	DESCRIPTION	SCALE
1	2207-L	1929	Fraser River, Sheet 1, Entrance-Steveston	1:12,160
	1117-L	1932	Discovery Island - Point Roberts	1:72,960
	2223-L	1942	Fraser River, Sheet 1	1:12,160
2	2274-S	1962	Entrance to North Arm Fraser River	1:12,160
	2273-L	1968	Strait of Georgia (Sand Heads-Boundary Bay)	1:30,000
	2274-L	1968	Strait of Georgia (Sand Heads-Burrard Inlet)	1:30,000
	2285-L/A	1974	Fraser River and Approaches (North Arm)	1:15,000
	2286-L/A	1974	Sturgeon Bank	1:15,000
3	2287-L/A	1974	Fraser River and Approaches (Sand Heads)	1:15,000
	2288-L	1974	Fraser River and Approaches (Sand Heads)	1:30,000
	2289-L/B	1974	Fraser River and Approaches (Roberts Bank)	1:30,000
4	2285-L/C	1979	Fraser River and Approaches (North Arm)	1:15,000
	2289-L/C	1979	Fraser River and Approaches (Roberts Bank)	1:30,000
	2286-L/C	1979	Sturgeon Bank	1:15,000
5	2286-D	1985	Sturgeon Bank	1:15,000
	2289-D	1985	Southern Roberts Bank	1:30,000

c) Soundings
Sounding error and positioning error (See 4.a) are correlated over a sloping bottom. For a typical bottom slope of four degrees and positioning accuracy of ±18 metres the sounding depth error would be ±1.3m. To allow for instrument accuracy and tide adjustments soundings are considered accurate to ±1.5m.

d) Areal coverage
The available sounding charts do not provide comprehensive coverage of the delta. Group 1 only covers the delta between Sand Heads and Boundary Bay. Groups 2 and 3 provide complete coverage from Point Grey to Boundary Bay, but the short six-year interval provides limited opportunity for comparison. Groups 4 and 5 provide only spot coverage of the delta.

5. RESULTS

A. Ten-Metre and 90-Metre Below Datum Contour Overlays

From 1932 to 1968, both the -10m and -90m contours from Sand Heads midway to the International Boundary advanced approximately 100 to 240 metres, or an average of 2.4 to 5.7 metres/year (Figure 2). South to the boundary there is an alternating sequence of advance and retreat up to Westshore Terminals beyond which there is a general retreat of the delta. The 1974 survey shows the same general pattern as the 1968 survey. Between radial Lines I and K there is an advance of both the -10m and -90m contours, south of Line K both contours are retreating. The 1979 and 1985 surveys show a continuing retreat in the vicinity of Line K.

North of Sand Heads, there is complete coverage only for the 1968 and 1974 surveys. In this period, the -10m contour remained relatively constant. The -90m contour was also stable except for the portion between Lines D and F1 that shows a major advance of 200 metres. This is substantiated by the profile for Line F1 (Figure 6) which indicates a net delta advance for both contours of 130 metres over six years or 22 metres/year.

Spot surveys in 1979 and 1985 indicate that in the vicinity of Line PG1 the -10m contour is retreating and the -90m contour is advancing. Around Line D both the -10m and -90m contours are retreating.

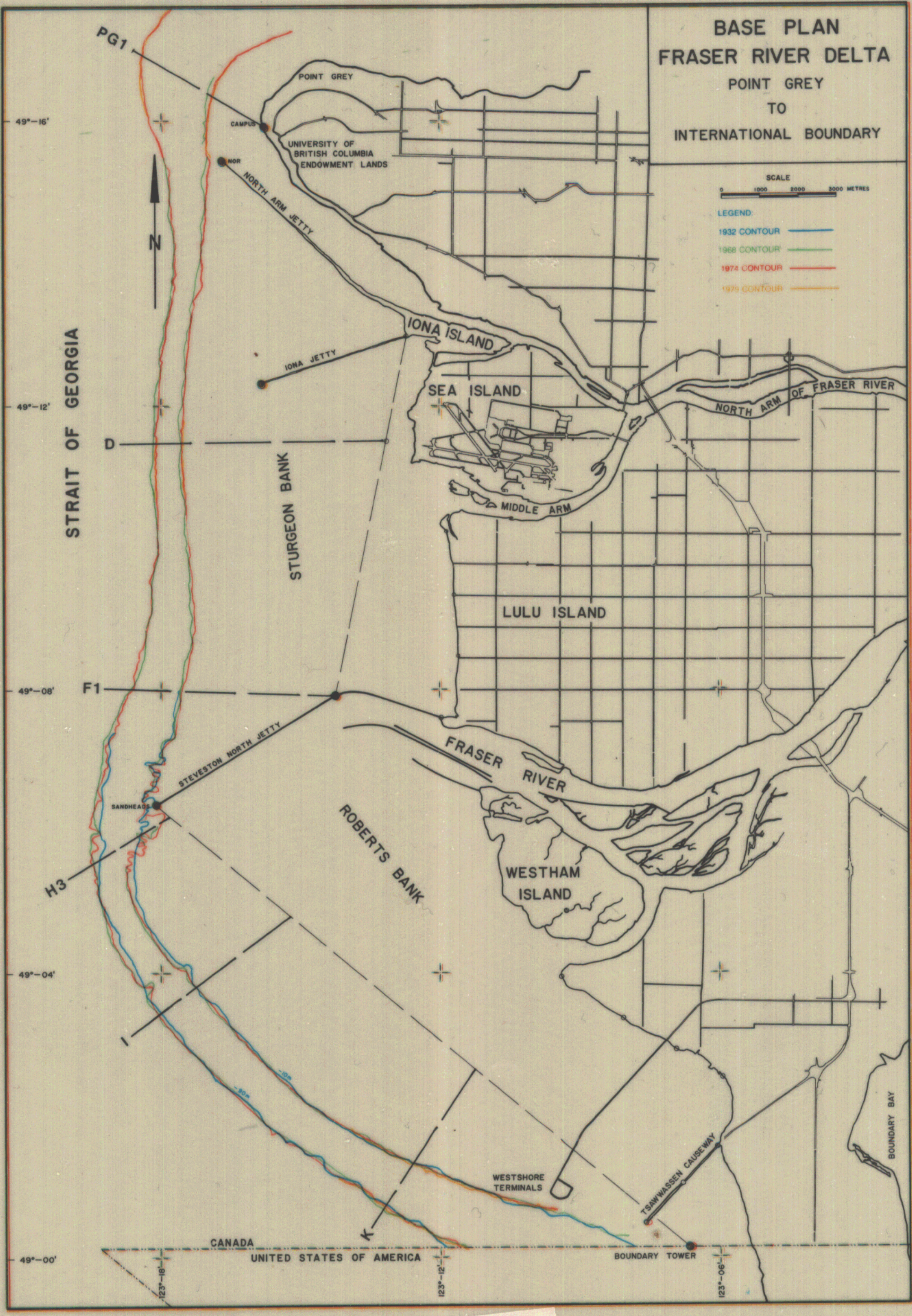


Figure 2. Overlays Showing Historical -10 metre and -90 metre Contours

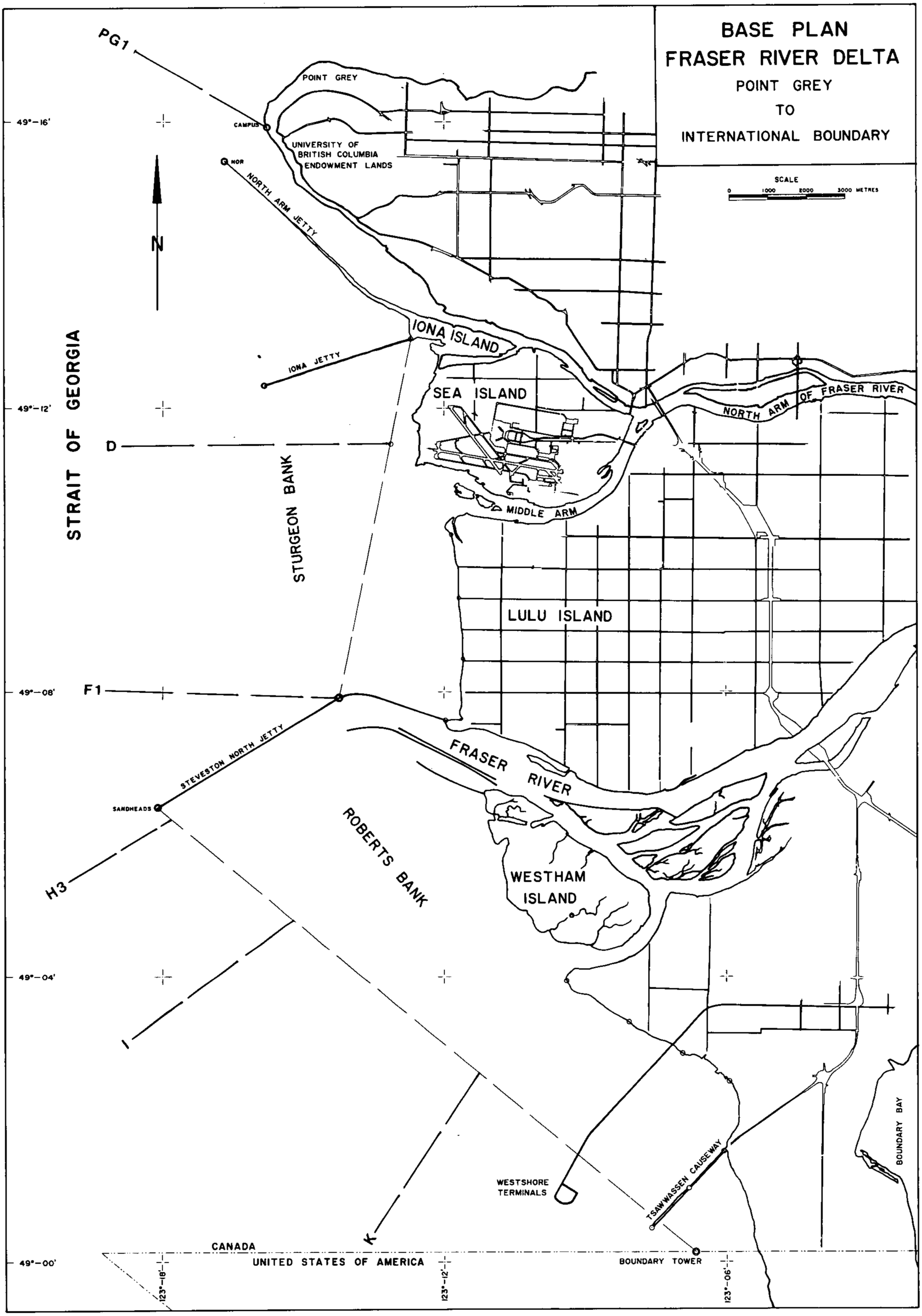


Figure 2. Overlays Showing Historical -10 metre and -90 metre Contours

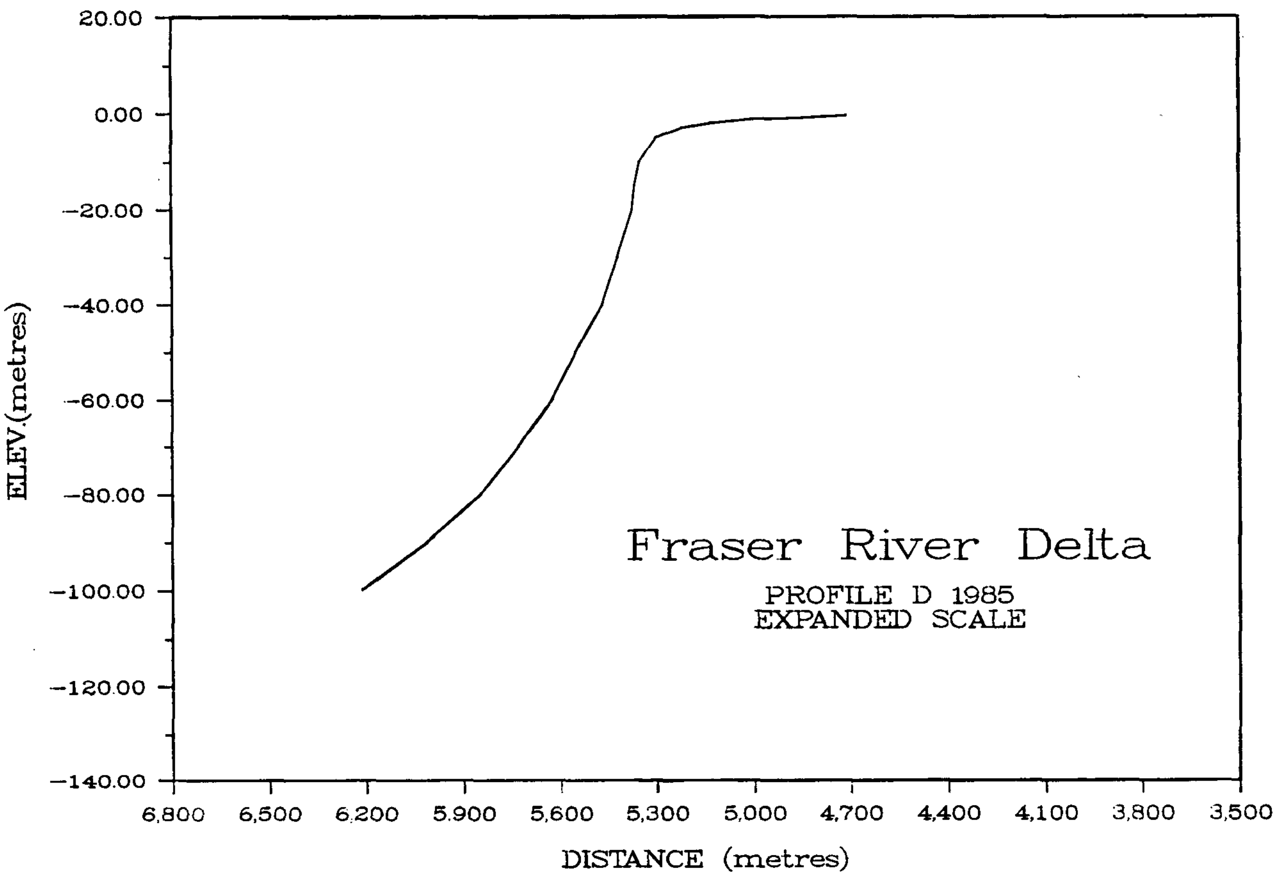
B. Profiles

B. Profiles

Six radial lines were plotted at intervals along the delta: PG1, D, F1, H3, I and K (Figure 2); corresponding profiles were drawn where data were available (Figures 4-9).

The profiles (Figures 4-9) were plotted to an exaggerated scale, horizontal to vertical of 20:1, to show the changes more clearly. Profile D (Figure 3) is shown in both exaggerated and true scale to indicate the proper perspective.

The profiles from each line are plotted to show changes between data sets, with the last profile showing the overall change between the earliest and latest data set.



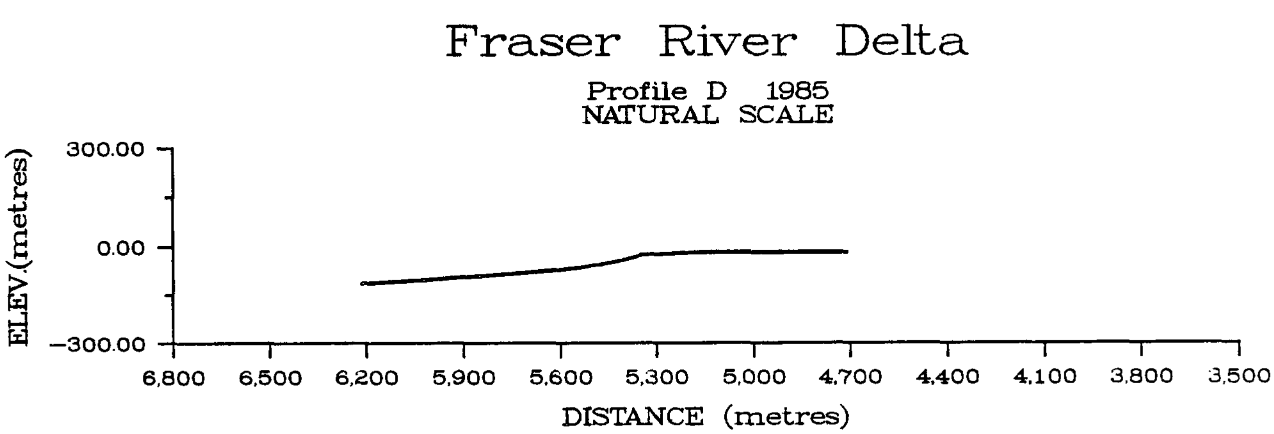


Figure 3. Typical Line Profile Comparing Expanded Scale to Natural Scale

Profile PG1

Line PG1, starting northwest of Point Grey, compares profiles from 1962 to 1974 (Figure 4a) and from 1974 to 1979 (Figure 4b). The bed elevation of the upper foreshore zone (between 1900 and 2600 metres) has risen an average of two metres between 1962 and 1979 (Figure 4c). For elevations between -10m to -30m the profile shows an average retreat of 57m between 1962 and 1974 or 3.4 metres/year. The 1974 and 1979 profiles are virtually identical in this zone. At lower elevations, -30m to -70m, the delta toe advanced 37 metres or 7.4 metres/year from 1974 to 1979 (the 1962 survey did not extend beyond -36m). The -10m to -35m zone has an average slope of 3.5 degrees and the -35m to -100m zone has an average slope of 2.9 degrees.

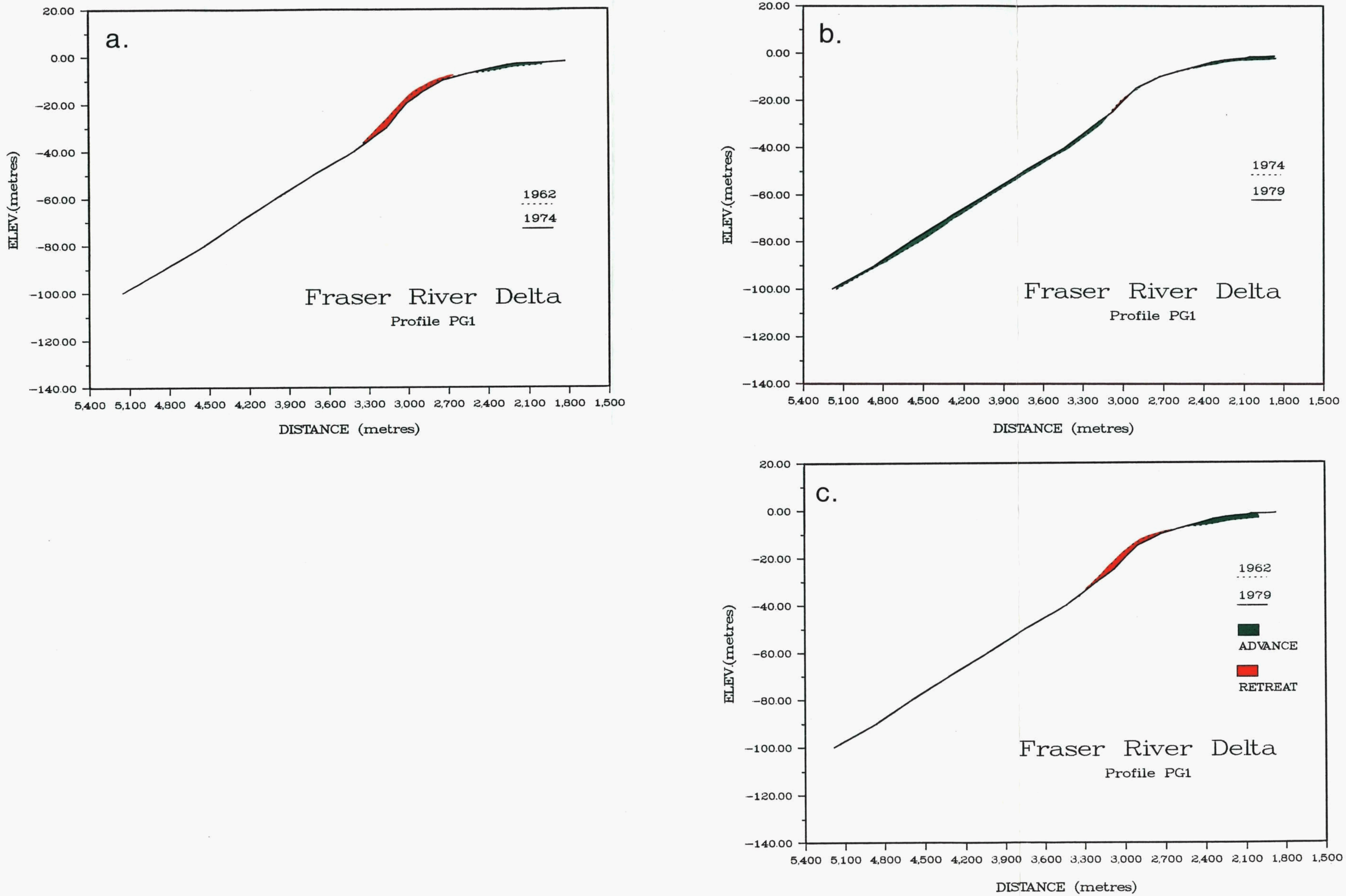


Figure 4. Line PG1 Profiles for 1962, 1974, 1979

Profile D

Line D, west of Sea Island, compares profiles from 1968 to 1974, 1974 to 1979 and 1979 to 1985 (Figure 5a, b and c).

This line shows a general retreat between 1968 and 1985 of approximately 2.4 metres/year (40m). The only exception is the zone between -45m and -55m which shows no change (Figure 5d). Slopes are much steeper for the -5m to -50m zone (13 degrees) than for the -50m to -90m zone (5 degrees).

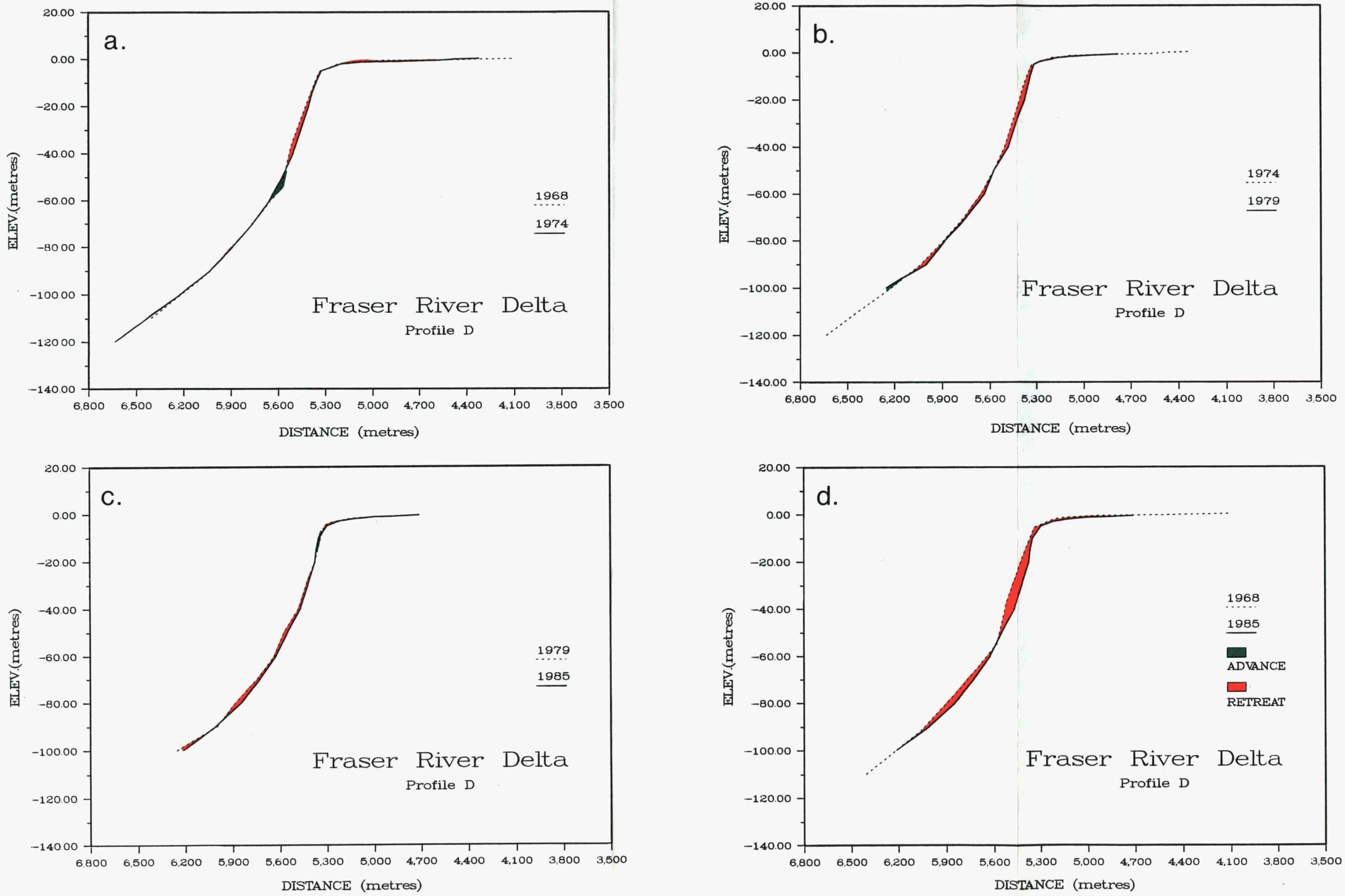


Figure 5. Line D Profiles for 1968, 1974, 1979, 1985

Profile F1

Line F1, west of the southern end of Lulu Island, compares profiles from 1968 to 1974 (Figure 6). There has been a general advance of the entire profile in this area of 22 metres/year or 130 metres in total. Slopes for the -10m to -55m zone average 8.5 degrees compared to 2.3 degrees for the -55m to -90m zone.

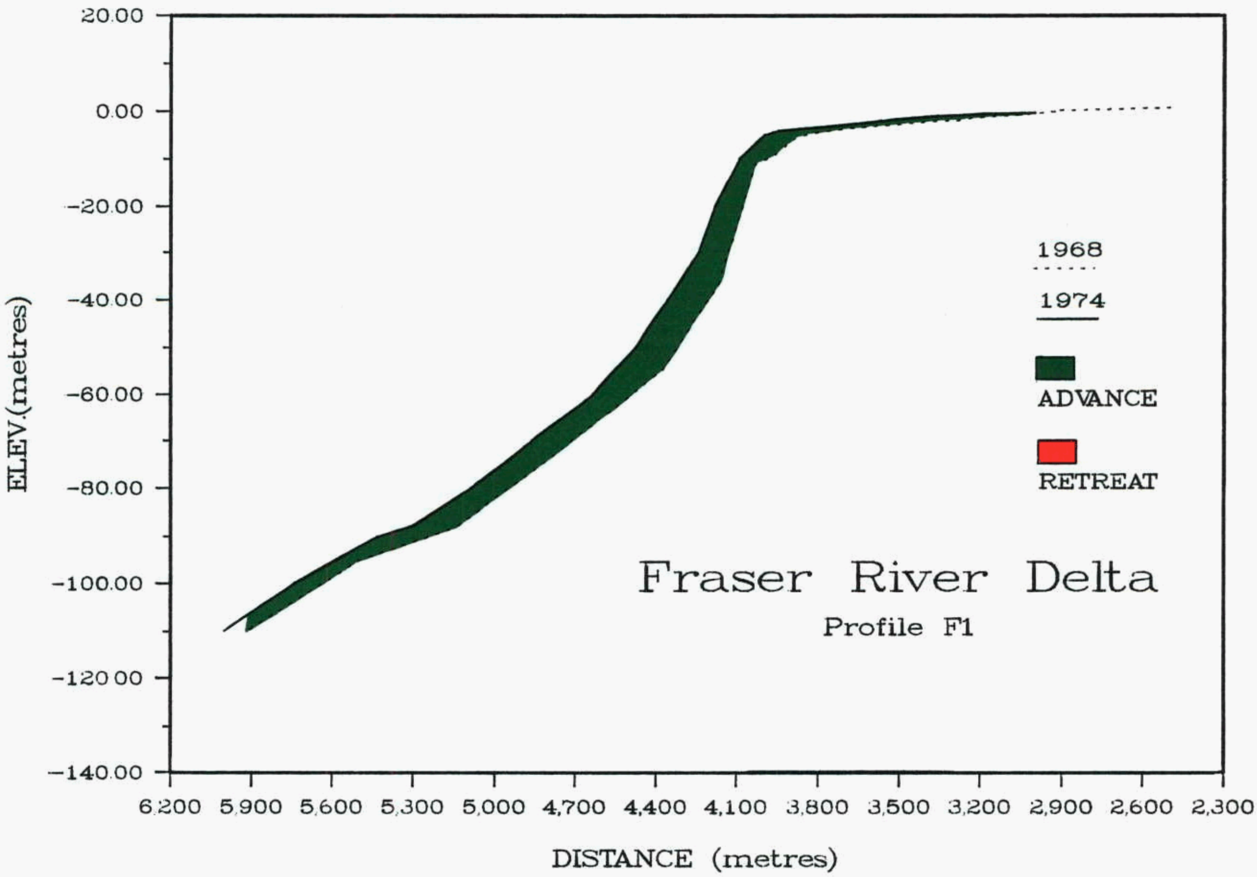


Figure 6. Line F1 Profiles for 1968, 1974

Profile H3

Line H3 lies parallel to Steveston Jetty south of the navigation channel; profiles are shown for 1929, 1942, 1968 and 1974 (Figure 7). This line lies close and parallel to the river mouth and shows the disposition of the coarser sand material which is transferred out to the Strait of Georgia by the river. The analysis of Line H3 is complicated by the presence of hill and valley structures in the 1968 and 1974 profiles. These structures are not present in the 1929 and 1942 profiles. The gully formations in the vicinity of the river mouth were also noted by Mathews and Shepard (1962) in a 1959 survey but are much less pronounced in the 1929 and 1942 surveys. The lack of gully formations in the 1929 and 1942 surveys may be due to a lower survey resolution.

Between 1929 and 1942, the foreshore aggraded an average of 3.2m and the delta, between -10m and -20m, advanced an average of 235m. In 1929 the river mouth was located approximately 200m south of its present location (Mathews and Shepard, 1962). The aggradation and advance of the delta may be partially due to the northward migration of the river mouth and its subsequent stabilization following completion of the Steveston North Jetty in 1932.

The 1968 and 1974 surveys indicate degradation of the foreshore to levels below that of 1929: an average degradation of 11m. Much of this degradation is due to a valley structure present at distance 500m (Figures 7c and 7d). If one disregards this valley structure the foreshore has degraded to the 1929 level. Line H3 is located approximately 100m south of the navigation channel; foreshore degradation may be due to dredging in the navigation channel in order to achieve the 10m design draft.

For the -20m to -50m zone there was an average advance of 210m between 1929 and 1968. The advance ranged from 0 - 340m due to the hill and valley structures. The 1974 survey indicates there was a 45m retreat of the delta from the 1968 survey.

For the -50m to -100m zone there was an advance of 275m or 7.1m/year between 1929 and 1968. A further advance of 100m or 16.8 m/year occurred between 1968 and 1974. The overall average rate of advance, 8.6 m/year, of the -90m contour compares closely with the 8.5 m/year estimated by Mathews and Shepard (1962) for a 3500-metre zone near the river mouth. The higher annual rate of advance between 1968 and 1974 may be due to the presence of a dredge spoil site in this area.

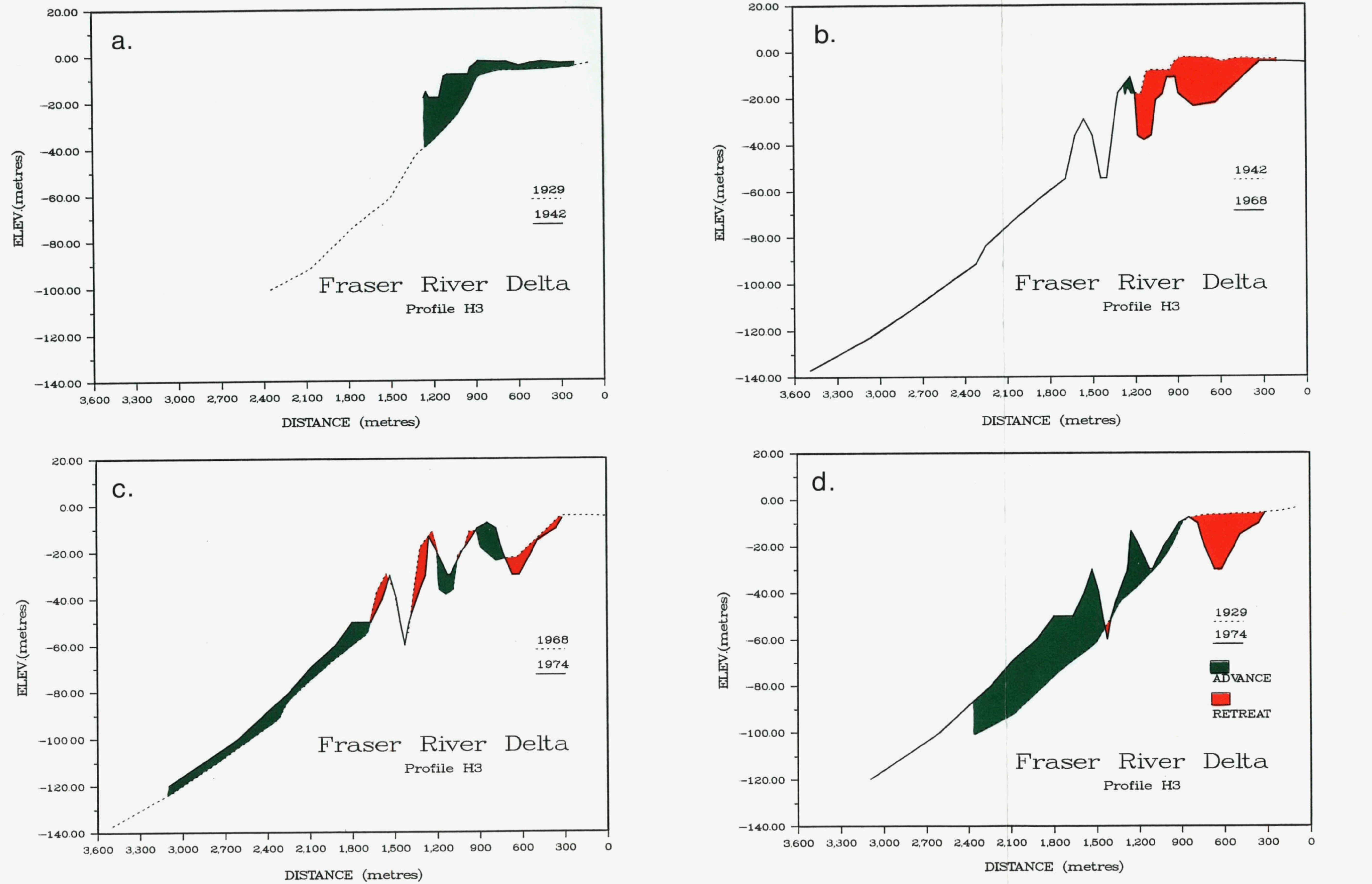


Figure 7. Line H3 Profiles for 1929, 1942, 1968, 1974

Profile I

Line I lies southwest off Westham Island between Sand Heads and the International Boundary. Profiles are plotted for 1932, 1968 and 1974 (Figure 8).

For the 0m to -20m zone the delta advanced 70m between 1932 and 1968 or 1.9m/year (Figure 8) and 24.7m between 1968 and 1974 or 4.1 m/year. In the -20m and -60m zone the delta advanced 108m between 1932 and 1974 or 2.6 m/year. There was no measurable change between the 1968 and 1974 surveys. For the -60m to -100m zone the delta advanced 110m between 1932 and 1968 or 3.0 m/year and a further 45m between 1968 and 1974 or 7.5 m/year. The average slope of the delta along this line is 3.7 degrees.

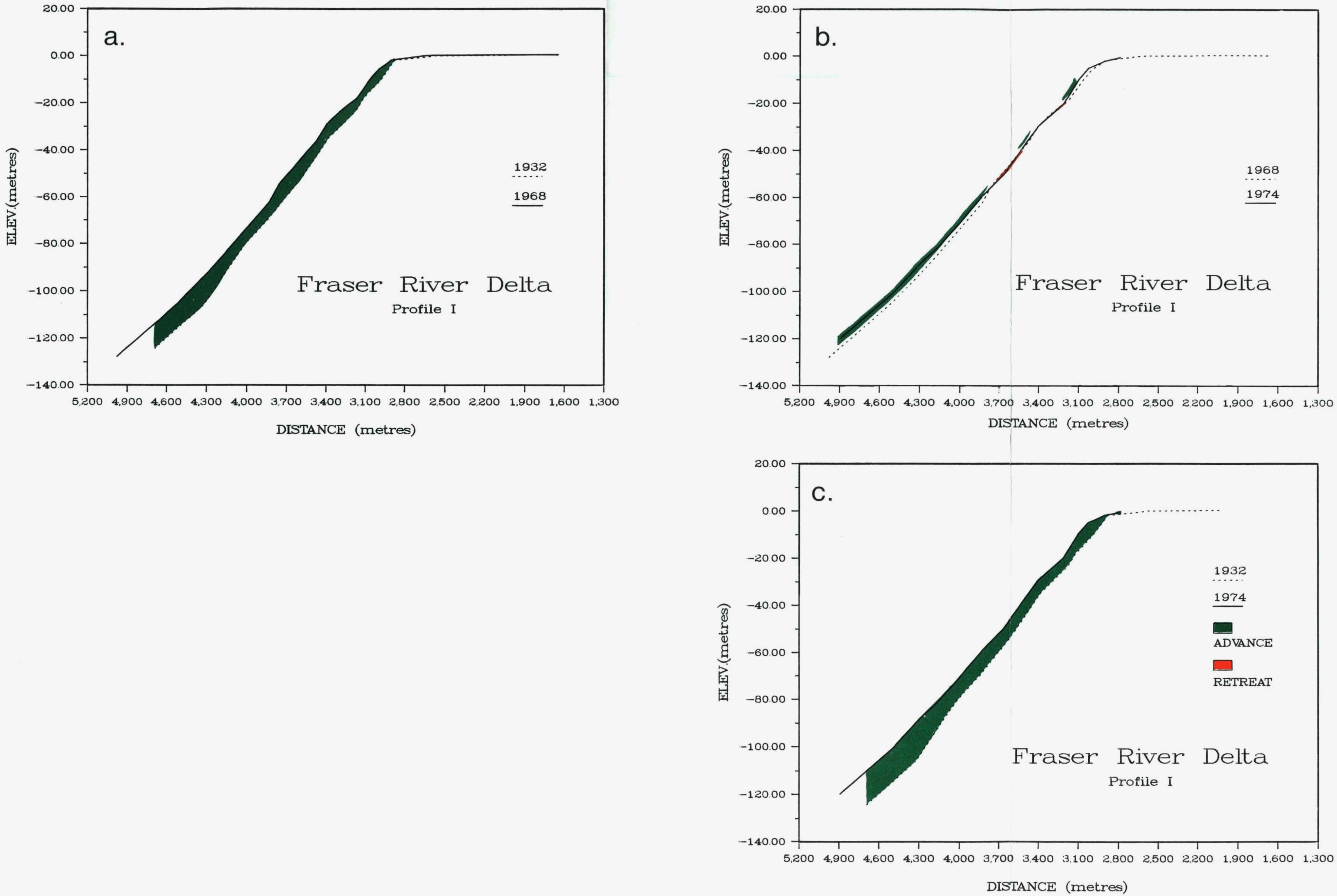


Figure 8. Line I Profiles for 1932, 1968, 1974

Profile K

Line K, parallel to Line I and further south, has good coverage with profiles for 1932, 1968, 1974, 1979 and 1985 (Figure 9).

For the -5m to -20m zone there was a 65m advance between 1932 and 1968 followed by a uniform retreat of 40m between 1968 and 1985. For the -20m and -60m zone the delta advanced 45m between 1932 and 1968 with a further 10m advance between 1968 and 1985. For the -60m and -100m zone the delta advanced 160m between 1932 and 1968 or 4.4 m/year followed by a uniform retreat of 55m between 1968 and 1985 or 3.3m/year.

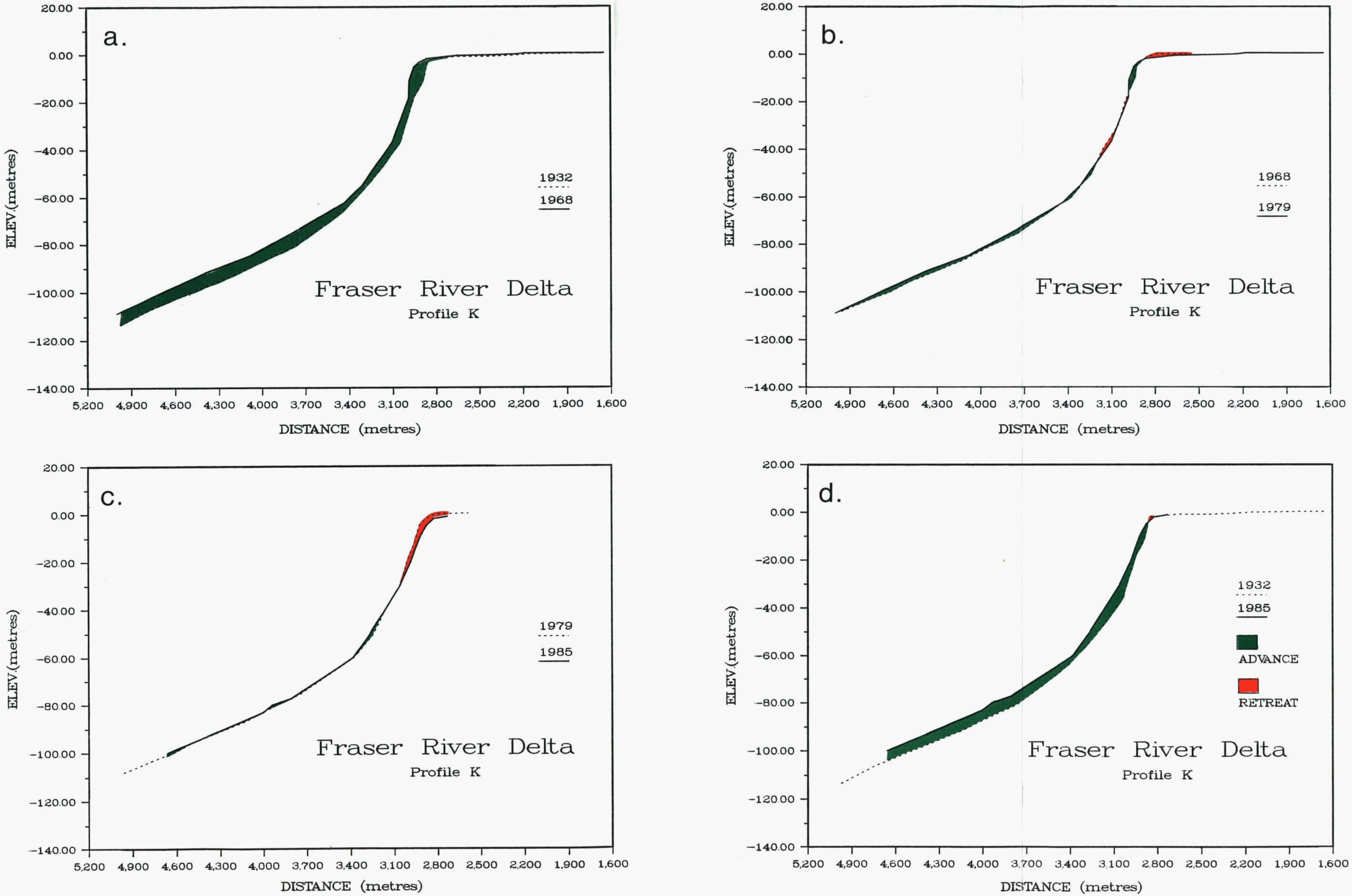


Figure 9. Line K Profiles for 1932, 1968, 1979, 1985

6. DISCUSSION

The results indicate that the Fraser delta toe advanced approximately 4.5 metres/year or 210 metres between 1932 and 1974. However, the evolution of the delta is not uniform; there are certain areas where the delta is retreating, primarily in the vicinity of Lines D and K (Figure 2).

Man-made structures like jetties, training walls and causeways have probably had a considerable impact on the patterns of growth and retreat along the delta front. These structures have affected the overall pattern of transport and deposition as seen in the Landsat photograph in the front of the report. The North Arm jetty is never submerged and thus the North Arm contributes very little material of any type to Sturgeon Bank. Also, almost no Fraser River sediments are entering the area between Westshore Terminals and the Tsawwassen Ferry Terminal.

As might be expected the greatest rate of advance of the delta is in the vicinity of the river mouth at Sand Heads where the delta toe (-90m) advanced an average of 8.6 m/year between 1929 and 1974. This is remarkably close to Mathews and Shepard's (1962) estimate of an 8.5 metre/year rate of advance or 254 metres between 1929 and 1959 for a 3500-metre frontal or shore zone near the river mouth. Higher rates of advance (16 m/year) between 1968 and 1974 are attributed to the location of a dredge spoil site in this area.

PWC generally dredges sand-sized material coarser than 0.125mm from the Fraser navigation channel. Luternauer and Murray (1973) analyzed a number of sediment samples from the delta. Material coarser than 0.125mm was generally found only on the tidal flats (0m to -9m) in the vicinity of outlet channels, such as the Middle Arm, Main Channel and Canoe Passage (Figure 10). The upper foreslope (-9m to -90m) was finer than 0.125mm except in the immediate vicinity of Sand Heads. The delta deposits become progressively finer in the seaward direction. From samples of bed sediments on the delta, Mathews and Shepard (1962) showed that the upper foreslope off Roberts Bank had a much higher sand content than the area off Sturgeon Bank.

It appears that the bed material load of the Fraser River is locally deposited in the river channel and at the river mouth. Finer-grained particles transported as washload account for most of the natural deposition on the delta. Depositional patterns are affected by river training and port structures built on the tidal flats. However, there is no indication that the areal extent of the delta foreshore has changed significantly over the period evaluated.

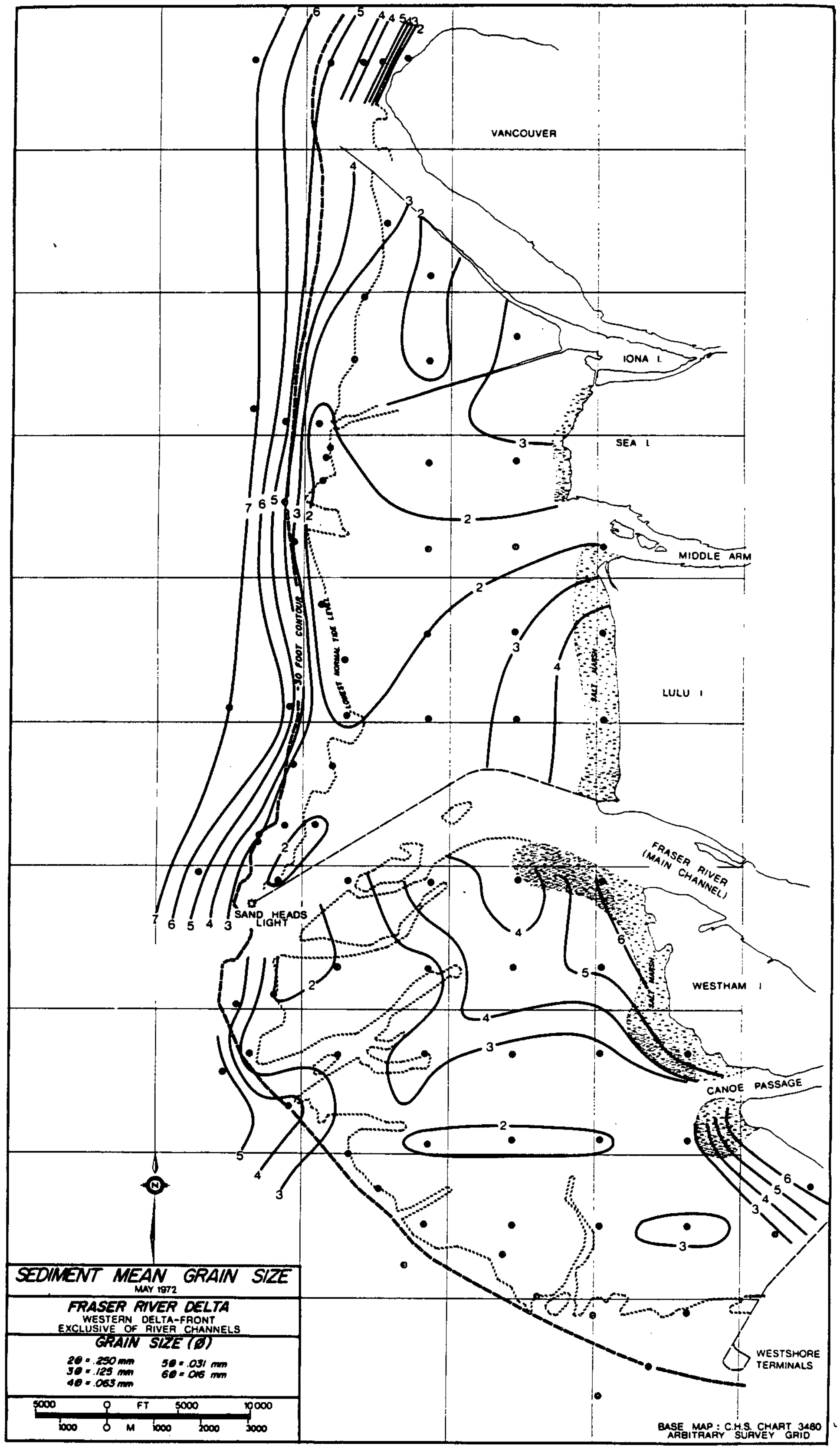


Figure 10. Mean Grain Size of Sediments on the Fraser River Delta (from Luternauer and Murray, 1973)

7. CONCLUSIONS

The technique of comparing periodic bathymetric surveys is an effective method of monitoring the advance or retreat of the Fraser River delta.

The last complete survey was done in 1974; changes noted from the sparse data available since 1974 indicate that a new survey is due now. Complete surveys should be done at least every 20 years with intermediate localized surveys on areas of maximum activity every five years or as deemed necessary.

A comprehensive core study of the delta would determine the particle-size deposition pattern. The study should review existing data and literature, show time-related particle-size deposition patterns and identify deficiencies in any particular size that may be occurring. This would show the evolutionary pattern of the Fraser River delta.

Finally, annual bathymetric surveys carried out on the river channel from the last dredging site to the toe of the slope at the river mouth would assist in the computation and verification of the total amount of coarse material being transported and deposited by the river and thus assist in determining the sediment budget of the Lower Fraser River.

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