COASTAL MARINE SCIENCE LABORATORY

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A STUDY OF SEDIMENT DISTRIBUTION IN ESQUIMALT HARBOUR

by

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INTRODUCTION

Descriptive literature dealing with Esquimalt Harbour has always listed it as having a "first-class holding bottom for anchorage" (Forde[9], 1925). The harbour is also the site of an important Canadian Naval Base. The harbour bottom therefore seemed a logical place to focus attention for an initial study by a group from this College with its new emphasis on oceanography. No scientific study, to our knowledge, has been made of the harbour sediments. Comparing bathymetric charts dating back to 1848 indicates the sedimentation is reducing the harbour volume substantially, especially in the upper reaches of the harbour.

PURPOSE

The purpose is to relate the observed sediment distribution and characteristics to source areas and to the flow regime in Esquimalt Harbour.

STATUS

This is the final report on this project. The stated purpose of this project has been taken over on a broader scale by various aspects of CMSL block grant for RRMC.

PROCEDURE

Bottom samples were obtained from the diving establishment to permit an evaluation to be made of different methods of grain size analysis of sediments.

Three methods were employed:

a) Andreasen Pipette method

b) Hydrometer method

c) Two meter settling tube method

As soon as the research vessel Tayut was equipped with the bottom profiler, test runs were made across the harbour to obtain sub-bottom profiles.

PROGRESS

All three methods of sediment grain size analysis have been employed, using grab samples from Esquimalt Harbour bottom.

The sub-bottom profiling was interrupted when the Tayut had to go in for maintenance and refit. But some very recent and interesting profiles have been obtained.

TEST

The Pipette and Hydrometer test procedures followed the British Standard: BS 1377:1975; Methods of Tests for Soils for Civil Engineering Purposes. The only deviations from that procedure was the optional use of the high speed dispersing stirrer in place of the time consuming end-over-end shaking apparatus which was not available, and the use of the closest available US Standard sieve sizes to the sieve sizes in the British Standard, which is again an option in the Standards.

The settling tube procedure is outlined here in some detail, since it is not standardized.

Introduction

The particle size distribution of sand to silt size material can be determined either directly by microscopic measurement, indirectly by sieving, sedimentation techniques or other methods. Routine size analysis by microscopic measurement is time consuming but can yield valuable information as to grain shape. Sieve analysis is extensively used to determine the size frequency distribution of sediment. However, this method is also rather time consuming and less convenient than sedimentation techniques.

Since most sediments are deposited by fluid media, sedimentation analysis is desirable because it most nearly approaches the hydro-dynamic conditions of deposition. Poole[1] showed that single grain terminal settling velocities can be used as suitable approximations for fall rates of bulk samples for thinly distributed samples. In a comparative study he found that the same sample run through a settling tube generally gave slightly coarser values than sieve diameter but finer values than microscopically measured diameters. Size distributions are routinely determined as part of research programs to study the physical characteristics of the sea bottom. The absolute calibration of size is still a major problem with all methods. For a review of the methods of size analysis see Muller[2] and Swift[3] et al.

Size analysis using a settling tube is not a new technique. The principal contribution of the present report is the development of a real-time data acquisition, reduction and display system.

Analysis System for Coarse (>50 micron) Sediment

A sediment sample is introduced to 2. meter settling tube by a pneumatically damped removable pan assembly which, upon sediment release, trips a microswitch to initiate recording. The sediment is sorted hydraulically and the sensing transducer, a semi-conductor strain gauge, measures the cumulative sediment weight on a scale pan. Sample weight is 2 grams and the resolution of this system is about 3 milligrams. Original design of this system by Van Andel and complete documentation can be found in the report by Theide[4] et al for a similar system using analogue recording.

The Royal Roads system uses a digital voltmeter to measure output from the strain gauge amplifier. The voltmeter is connected via the Hewlett Packard data bus to a programmable calculator. Since the time of fall determines the settling velocity a crystal controlled digital clock is used to give an accurate time base. This clock is also on the data bus.

The Apparatus

The experimental apparatus (see Fig. 1) consists of a 2 meter long section of 8" PVC drain pipe standing vertically

SETTLING TUBE APPARATUS

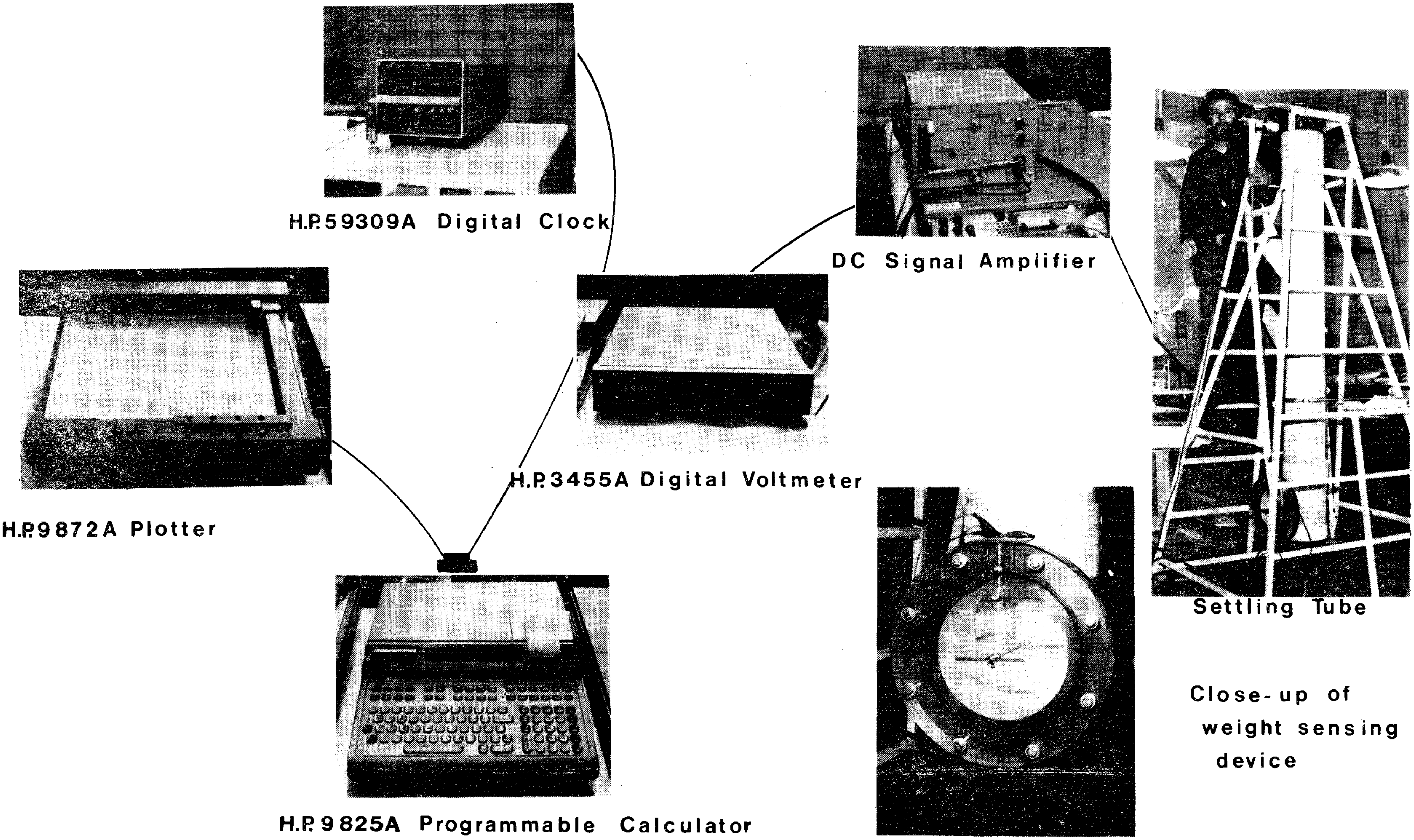

Fig. 1

with a "tee" section on the bottom. The supporting framework can be easily taken apart for increased portability and was designed by Mr. Phillip Redgrave. At the top of the column is the sample introduction system and start-timing light. This mechanism consists of a vertical shaft which allows the sample holder to rotate in the horizontal plane as well as to slide vertically. The holder may rest in one of three positions to facilitate sample loading. The sample is introduced by placing it on a removable pan and placing the inverted pan into the holder. The holder is later moved from the ready position into the run position where it settles on a pneumatic damper. As it reaches the end of its travel, the pan trips a microswitch which simultaneously de-activates the start-signal light and initiates the signal to the analog recorder. The sample tray is thus slowly and evenly immersed in the water of the column, releasing the sediment and starting the experiment.

The material then falls through the water column and in time settles on a low density polyethylene pan mounted in the "tee" portion of the tube at the bottom. This tray is mounted via three-point suspension to a 20.8 cm. long stainless steel arm transmitting the weight of settled sample to a Kistler-Morse semi-conductor strain gauge mounted in the face plate. Typical resolution for this instrument is about 3 mg. It, however, is very sensitive to seismic disturbances in the order of normal footfalls within 5 meters of the apparatus. The signal is then amplified and fed to both a chart recorder and to a Hewlett-Packard 3455A digital voltmeter. The weight of accumulated sediment on the pan is thus measured as a voltage, and is coordinated with a time signal from an H P digital clock by an H P 9825A programmable calculator which later reduces this data and plots the results. Data collection, reduction and plotting for the experiment is executed by a model 9825A Hewlett-Packard programmable calculator and peripheral devices (see Flow Chart, Appendix A). The software for these operations consists of a series of automatically linked programs recorded on magnetic tape (see Appendix B).

The programs are divided into four sections:

A) The first program which runs prior to the experiment

B) The second program which runs in real time and collects raw data from the settling tube.

C) The third through sixth programs reduce this raw data

D) The last three programs concern the presentation, preservation, and analysis of the data.

The program "Gibbstime" calculates the theoretical time-of-fall through the water column of ideal quartz spheres in the range of -2ϕ to 4ϕ in increments of $.05\phi$. The phi (ϕ) unit is a logarithmic measure of particle size used to describe geologic objects from boulders (-12ϕ) to clay particles ($+12\phi$). It is defined as minus the base two logarithm of the diameter in millimeters: i.e. $\phi = -\log_2$ (diam.mm.). Thus the settling tube range is from 4 mm. to 1/16 mm. particles.

The settling velocity as proposed by Gibbs[5] et al to be used as a basis of standardization is:

$$V = \frac{3N + \sqrt{9N^2 + GR^2P_f(P_s - P_f)(0.015476 - 0.19841R)}}{P_f(0.011607 + 9.14881R)}$$

Where:

V = velocity in cm/sec

N = dynamic viscosity of fluid (a function of temperature)

G = acceleration of gravity (= 980.96 cm/sec^2 locally)

R = sphere radius in cm

P_f = density of fluid in g/cm^3 (a function of temperature)

P_s = density of spheres (assumed quartz density of 2.65 g/cm^3)

The program asks the operator to input the temperature of the water as read by him from a thermometer suspended in the column. This information is needed to allow for density and viscosity variations of the fluid.

Times-of-fall through the 198 cm. long settling tube for each size class in the range are calculated using this equation. These values are recorded in a tape file for later use and the next program is loaded and run.

The next program, "Realtime", uses four different timing regimes. At first all available voltage readings are taken (a rate of about 5 per second). The next series of data points are weighted averages of 5 voltage values each. This yields approximately one datum each second. The last two regimes use similar averaging techniques to give data at rates of one per 5 and 10 seconds respectively. This raw data is recorded and the next program loaded and run.

The program, "Smoothing", submits the raw data to a smoothing routine utilizing a moving weighted average over eleven points. It also rejects data that are obviously false such as decreasing weights and extraneous spikes due to electrical or mechanical noise. The system is quite sensitive to seismic disturbances.

The function of the program, "Percent Weight" is to associate the smoothed voltages to the theoretical time-of-fall data. It recalls the smoothed voltage, theoretical time-of-fall and system time delays which were determined empirically. It then interpolates the experiment time base voltages to the 0.5ϕinterval classes of particles. After this is accomplished all values are scaled as percentages of the last (maximum) value. The resultant file contains the percentage of total accumulated weight for each phi size class of sediment.

"Frequency", this program differentiates the percent weight accumulated curve by means of the Gregory-Newton method. This method gives the slope of the straight line connecting two neighbouring points. The program yields the frequency percentages in each .05 phi size class.

The distribution of a particular sediment sample can be characterized and identified by the calculation of several statistical parameters showing its deviation from a gaussian or normal bell shaped curve. This is done by the program, "Statistics". The statistical arithmetic used follows the paper by Inman.[6] The mean and standard deviation (which completely characterize the normal symmetrical gaussian); skewness, a measure of assymetry; and kurtosis, which describes the peakedness of real curves are all calculated in two ways.

These statistics have been used by several researchers to individually characterize sediment samples and have been found fine enough to differentiate different sections of the same sand bar to study sediment deposition. See Folk and Ward,[7] and Friedman.[8]

These last three programs concern the presentation and preservation of data and several housekeeping chores:

"Plot": This program uses the calculator printer to output the percentile and frequency data in numerical form if desired. It also plots these on the HP 9872A Plotter.

"Savefile": This program assigns permanent files for any data set.

"Average": In order to refine the analysis and decrease error this program is run to calculate average values for each point in the frequency data set over several separate runs.

RESULTS

The results of the three methods of grain size analysis are included as Appendices: Appendix C, Pipette Analysis; Appendix D, Hydrometer Analysis; and Appendix E, the results from the 2-meter settling tube. Appendix F is a representative profile of the sub-bottom. Appendix G is a map of Esquimalt Harbour on which are shown the location from which the grab samples were taken and also the track of the Tayut for the profile included in Appendix F.

The harbour bottom, based on this brief study of sediment grain size, can be divided into three zones.

a) Entrance zone, (samples A, B, and C), predominantly (over 50%) coarse silt.

b) Central zone, (samples D, E, and F), 37% to 40% fine and medium silt.

c) Inner zone (sample G), the north end of harbour, where fine sand predominates (approximately 60%).

The profile of the harbour sub-bottom will be the subject of another report from the Coastal Marine Science Laboratory group effort at this College. Suffice to say here that the profiler has proved to be an excellent means of rapidly obtaining a plot of the sub-bottom. It remains to prove out what comprises the reflective layers. This can in part be solved by test holes around the shore of the harbour, and where possible comparing the profile to available bore-hole logs.

The settling tube together with the Hewlett-Packard calculator and peripheral equipment has been used to measure the size distribution of several samples of normally distributed glass spheres obtained from the Marine Geology Department at Oregon State University. Only one sample from Esquimalt Harbour had sediments in the size range of this instrument. This plot (Fig. 2) is for sample G in the upper regions of the Harbour. Further samples are planned in the upper region of the Harbour.

DISCUSSION

The Pipette method is generally accepted as the more accurate method of grain size analysis, however as the grain size distribution in Appendices A and B show, there is very good agreement between the Pipette and Hydrometer methods. Since the latter is somewhat quicker to run and has the advantage of permitting re-running the test if necessary, it is the chosen method for future tests. If more accurate results are ever required, the Pipette method can be employed. The settling tube has a limitation in that it is good only down to about the medium silt sizes, however the developed system is much quicker once pre-treatments are completed, and results are in final plotted form.

The samples contained an increasing percentage of fine wood fibre as the samples approached the booming grounds near Cole Island.

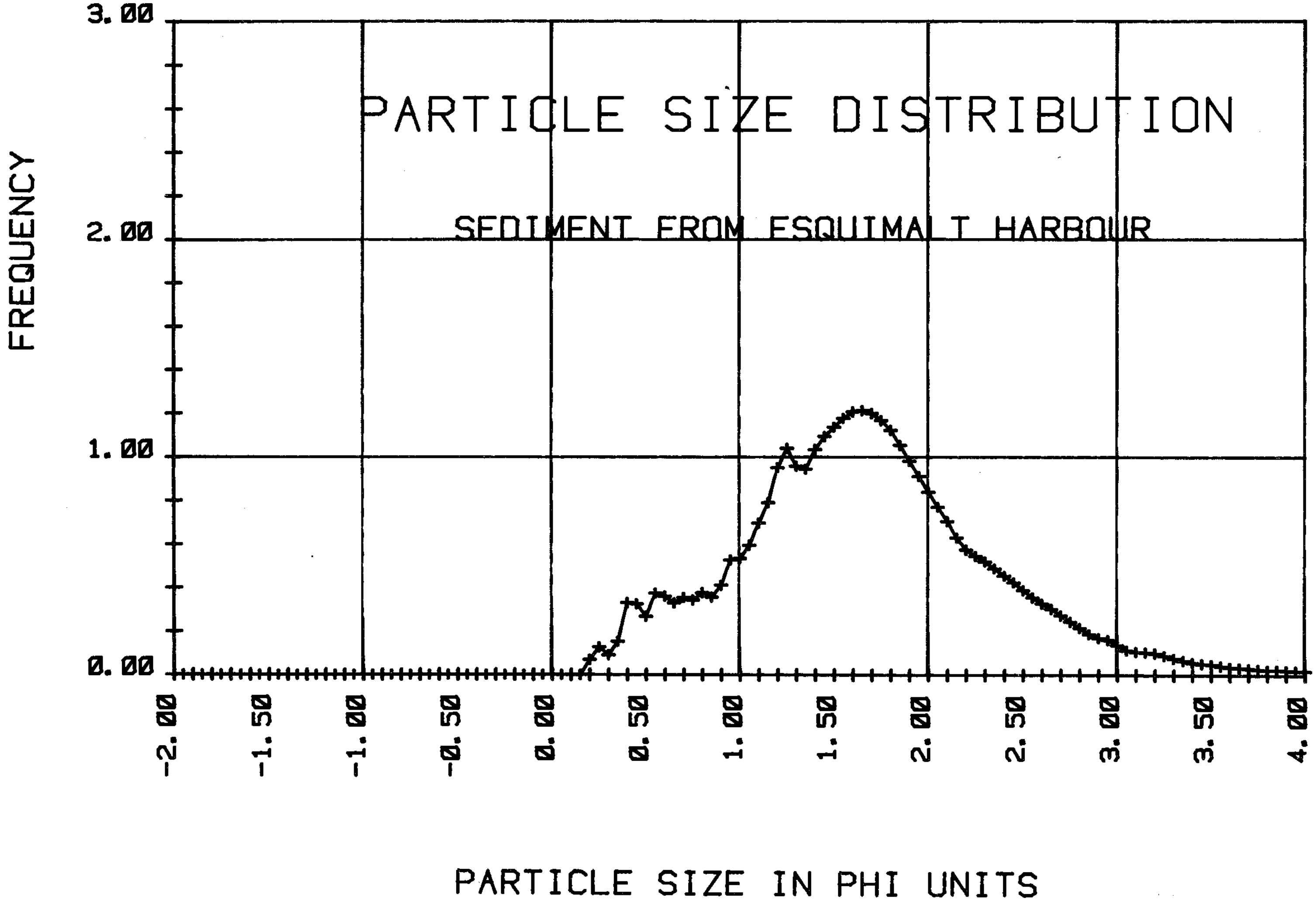
PARTICLE SIZE DISTRIBUTION
SEDIMENT FROM ESQUIMALT HARBOUR
FREQUENCY
3.00
2.00
1.00
0.00
-2.00
-1.50
-1.00
-0.50
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
PARTICLE SIZE IN PHI UNITS

FIG. 2

The coarser material at the head and entrance of the harbour with finer material in the center, suggests that the bottom sediments sampled have separate sources. Those near the head coming obviously from Mill Stream, while those near the entrance coming from longshore and tidal currents depositing sediments from further west along the coast.

SUMMARY

The predominating grain size of the upper layer of Esquimalt Harbour bottom is in the silt size range, with an increasing proportion of fine wood fibre toward the log booming ground.

The sub-bottom is composed of at least two principal layers with very conspicuous flat-topped anomolies.

CONCLUSIONS

At this time no conclusions can be made concerning the sedimentation regime of the harbour. The comprehensive studies that are now in progress will add to our understanding of this problem and is expected to lead to a solution in the near future.

This study has served well to initiate the study of the harbour sediments, and lay part of the foundation from which future studies can grow. An important part of this initial work has been the soft ware developed for the Hewlett-Packard 9825A programmable calculator which allows rapid analysis and output of results for sand sized aggregates. The success with this work indicates the obvious next step should be the interface with the computer system of similar equipment to cover the fine grain sized fraction.

ACKNOWLEDGEMENTS

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Appendix A

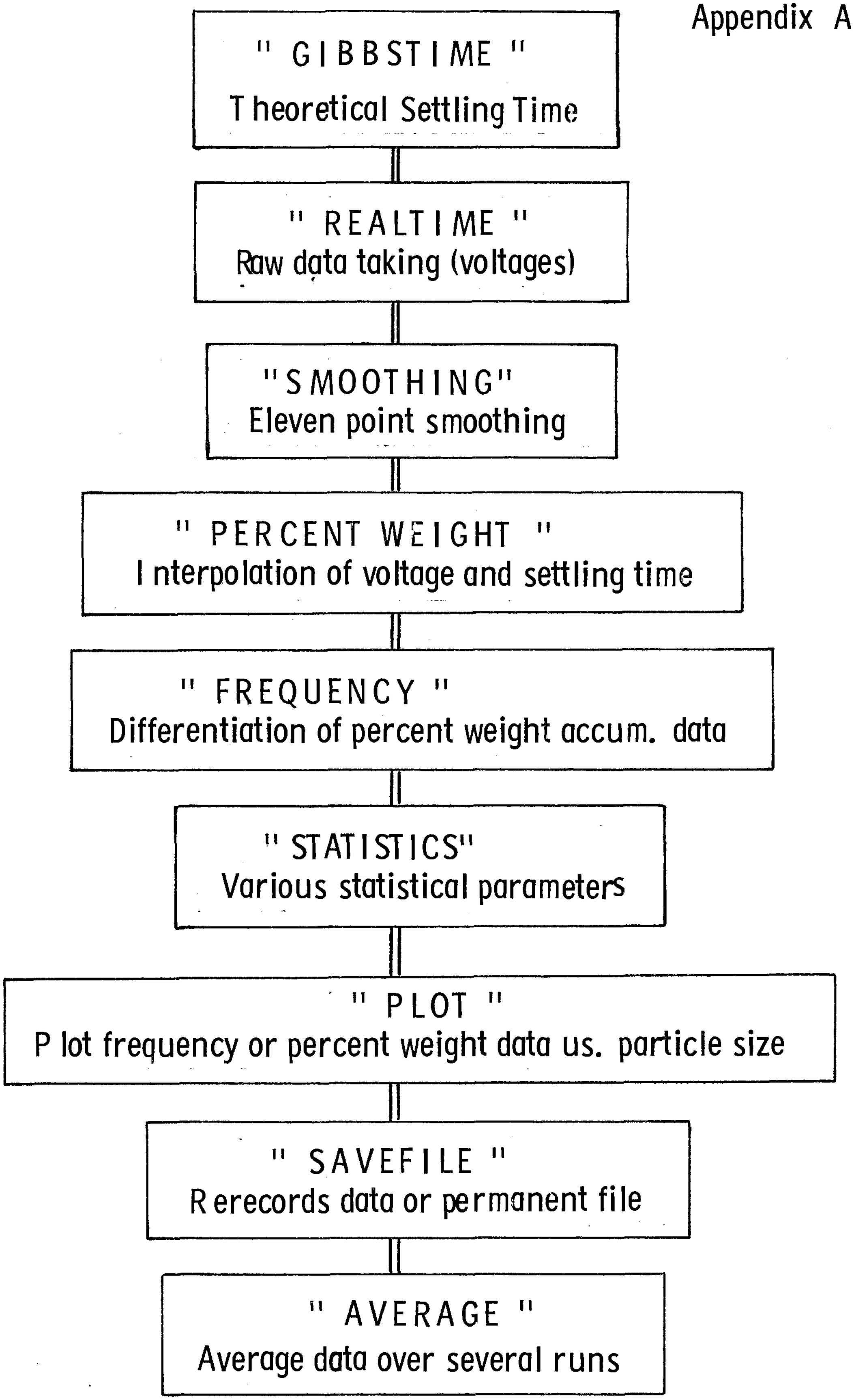


Figure PROGRAM FLOW CHART

(Programs are written in the Hewlett Packard Language (HPL)

Appendix B

```
0: dim P$[121,4],Q$[121,4],T$[121,4],R[10:30],N[10:30]
1: "GIBBSTIME":fts (-2)→P$[1];1→K
2: enp "Temperature to nearest degree?",E
3: if E>30;enp "Temp. too high. Temperature?",E;enp E;jmp 0
4: if E<10;ent "Temp. too low. Temperature?",E;enp E;jmp -1
5: .9997281→R[10];.9996336→R[11];.9995261→R[12];.9994059→R[13]
6: .9992732→R[14];.9991286→R[15];.9989721→R[16]
7: .9988041→R[17];.9986248→R[18];.9984346→R[19];.9982336→R[20]
8: .9980221→R[21];.9978003→R[22];.9975684→R[23];.9973266→R[24]
9: .9970751→R[25];.9968141→R[26];.9965437→R[27]
10: .9962642→R[28];.9959757→R[29];.9956783→R[30]
11: .01307→N[10];.01271→N[11];.01235→N[12];.01202→N[13];.01169→N[14]
12: .01139→N[15];.01109→N[16];.01081→N[17];.01053→N[18]
13: .01027→N[19];.01002→N[20];.009779→N[21];.009548→N[22];.009325→N[23
14: .009111→N[24];.008904→N[25];.008705→N[26]
15: .008513→N[27];.008327→N[28];.008148→N[29];.007975→N[30]
16: 980.96085→G;198→D
17: -3*N[E]→A
18: G*R[E](2.65-R[E])*.015476→B
19: G*R[E](2.65-R[E])*.19841→C
20: R[E]*.011607→F
21: R[E]*.14881→H
22: for K=1 to 121
23: fts (2^(-stf(P$[K])))→Q$[K]
24: stf(Q$[K])/20→O
25: fts ((F+H*O)D/(A+√(A^2+B*O^2+C*O^3)))→T$[K]
26: if K=121;jmp 2
27: fts (stf(P$[K])+.05)→P$[K+1]
28: next K
29: rcf 15,T$
30: "GIBBSTIMES IN FILE#15":ldp 1
31: end
*31860
```

```
0: "REAL TIME":dim I$[375,4],V$[375,2],A[5],B[5],C[2]
1: dev "DVM",722,"CLOCK",716,"PRINTER",701
2: dsp "Pull handle/press""CONTINUE"""
3: stp
4: red "CLOCK",r19;prt "The start time:",r19
5: wrt "DVM","F1R7T1M3"
6: wait 4000
7: "Fast data":for J=1 to 150
8: red "CLOCK",I;red "DVM",V
9: fts (frc(I*1e-6)1e6)→I$[J]
10: fti (V*1000)→V$[J]
11: next J
12: "1/sec":for J=151 to 300
13: for K=1 to 5
14: red "DVM",A[K];next K
15: red "CLOCK",I
16: fts (frc(I*1e-6)*1e6)→I$[J]
17: (A[1]+2*A[2]+3*A[3]+5*A[4]+9*A[5])/20→V
18: fti (V*1000)→V$[J]
19: next J
20: "1/5sec":for J=301 to 336
21: for L=1 to 5
22: for K=1 to 5
23: red "DVM",A[K];next K
24: (A[1]+2*A[2]+3*A[3]+5*A[4]+9*A[5])/20→B[L]
25: next L
26: red "CLOCK",I
27: fts (frc(I*1e-6)*1e6)→I$[J]
28: (B[1]+2*B[2]+3*B[3]+5*B[4]+9*B[5])/20→V
29: fti (V*1000)→V$[J]
30: next J
31: "1/10sec.":for J=337 to 372
32: for M=1 to 5
33: for L=1 to 2
34: for K=1 to 5
35: red "DVM",A[K];next K
36: (A[1]+2*A[2]+3*A[3]+5*A[4]+9*A[5])/20→C[L]
37: next L
38: (C[1]+2*C[2])/3→B[M];next M
39: red "CLOCK",I
40: fts (frc(I*1e-6)*1e6)→I$[J]
41: (B[1]+2*B[2]+3*B[3]+5*B[4]+9*B[5])/20→V
42: fti (V*1000)→V$[J]
43: next J
44: rcf 17,V$
45: prt "RAW VOLTAGES (V$) IN FILE#17"
46: ldp 2
47: end
*28453
```

```
0: "SMOOTHING":dim V$[375,2],W$[375,2],W[275]
1: ldf 17,V$
2: for I=1 to 5;V$[I]→W$[I];next I
3: for I=6 to 367
4: "SMOOTH":12*itf(V$[I])+9(itf(W$[I-1])+itf(V$[I+1]))→r40
5: r40+5(itf(W$[I-2])+itf(V$[I+2]))+3(itf(W$[I-3])+itf(V$[I+3]))→r41
6: (r41+2(itf(W$[I-4])+itf(V$[I+4]))+itf(W$[I-5])+itf(V$[I+5]))/52→r42
7: fti (r42)→W$[I]
8: next I
9: for I=368 to 372;V$[I]→W$[I];next I
10: for K=100 to 372
11: itf(W$[K])→W[K-99];next K
12: max(W[*])→r75
13: for K=1 to 372
14: if itf(W$[K])<r75;next K
15: K→I
16: for K=I to 372
17: fti (r75)→W$[K];next K
18: for K=1 to 275
19: if itf(W$[K])<=.005*r75;fti (0)→W$[K]
20: next K
21: rcf 18,W$
22: prt "SMOOTHED DATA (W$) IN FILE #18";ldp 3
23: ldp 3
24: end
*11899
```

```
0: "PERCENT WEIGHT ACCUM":dim J$[375,4],W$[375,2],T$[121,4],M$[121,4]
1: ldf 18,W$;ldf 16,J$;ldf 15,T$
2: 1→r12
3: for K=1 to 121
4: for I=r12 to 372
5: if stf(J$[I])<stf(T$[K]);next I
6: (stf(T$[K])-stf(J$[I-1]))*(itf(W$[I])-itf(W$[I-1]))→r13
7: fts (r13/(stf(J$[I])-stf(J$[I-1]))+itf(W$[I-1]))→M$[K]
8: I→r12
9: next K
10: for K=1 to 121
11: fts (stf(M$[K])*100/stf(M$[121]))→M$[K]
12: next K
13: rcf 19,M$
14: prt "% WEIGHT ACCUM. (M$) IN FILE #17"
15: ldp 4
16: end
*23338
```

Appendix B (cont'd)

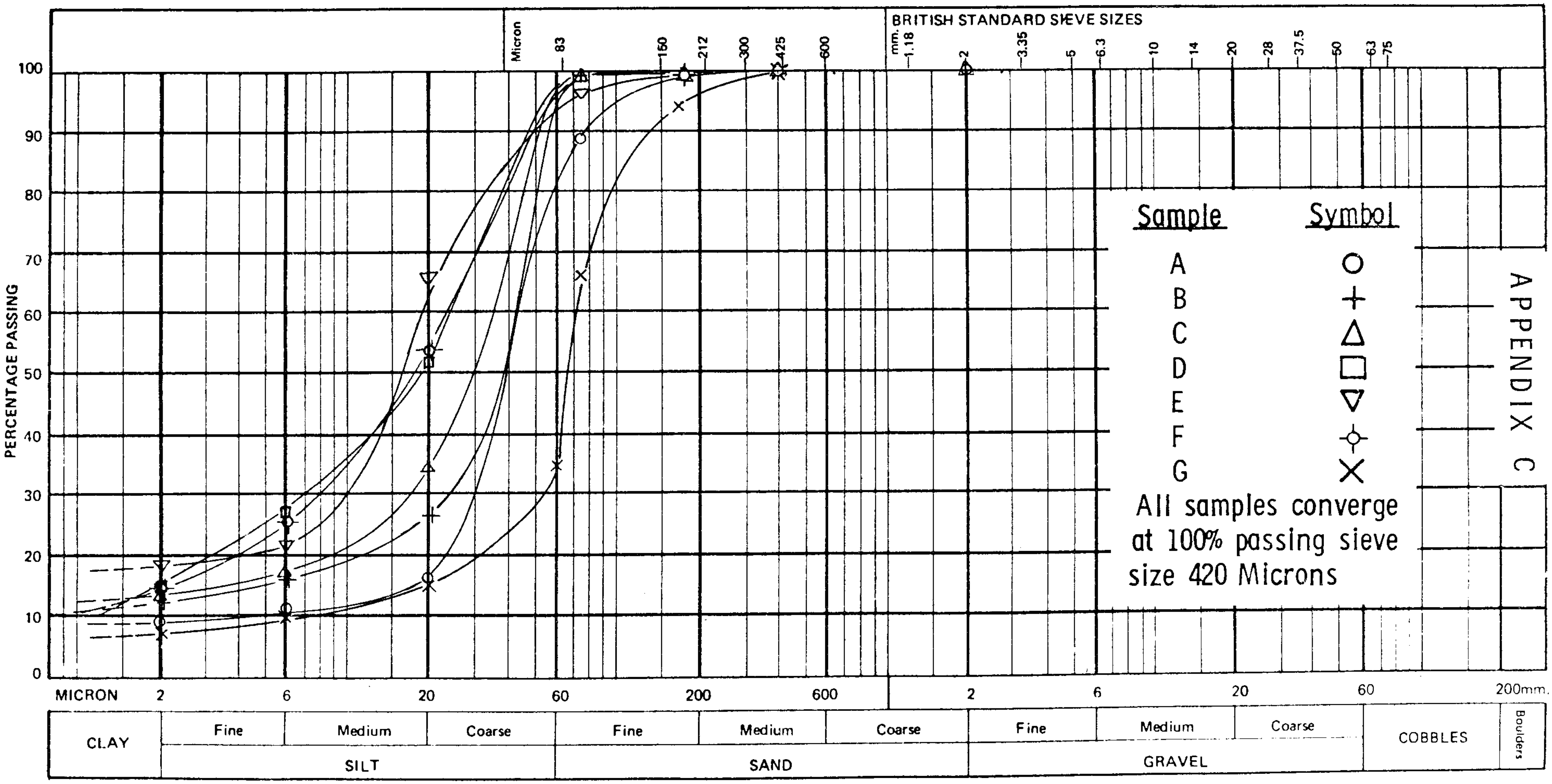
```
0: "FREQUENCY":dim T$[121,4],M$[121,4],S$[121,4]
1: ldf 15,T$;ldf 19,M$
2: for K=2 to 120
3: fts ((stf(M$[K+1])-stf(M$[K-1]))/(stf(T$[K+1])-stf(T$[K-1])))→S$[K]
4: next K
5: fts ((stf(M$[2])-stf(M$[1]))/(stf(T$[2])-stf(T$[1])))→S$[1]
6: fts ((stf(M$[121])-stf(M$[120]))/(stf(T$[121])-stf(T$[120])))→S$[121]
7: rcf 20,S$
8: prt "FREQUENCIES (S$) IN FILE#20"
9: ldp 5
10: end
*31782
 0: "STATISTICS":dim S$[121,4],S[121],M$[121,4],P[122]
 1: 0→r10→r100→r20→r30→r40
 2: ldf 20,S$;ldf 19,M$
 3: -2→P[1]
 4: for K=1 to 121
 5: stf(S$[K])→S[K]
 6: P[K]+.05→P[K+1]
 7: next K
 8: for K=1 to 121
 9: S[K]+r100→r100
 10: S[K]*P[K]+r10→r10
 11: next K
 12: dim A[5],B[5]
 13: 5→A[1];16→A[2];50→A[3];84→A[4];95→A[5
 14: 1→C
 15: for I=1 to 5
 16: for K=C to 121
 17: if stf(M$[K])<A[I];next K
 18: .05((A[I]-stf(M$[K-1]))/(stf(M$[K])-stf(M$[K-1])))+P[K-1]→B[I]
 19: K→C
 20: next I
 21: for I=1 to 5
 22: prt "%ILE:",A[I],"     @ Phi",B[I]
 23: next I
 24: prt "PHI DEV.:",(B[4]-B[2])/2
 25: prt "PHI SKEW:",2((B[2]+B[4])/2-B[3])/(B[4]-B[2])
 26: prt "2nd SKEW:",2((B[1]+B[5])/2-B[3])/(B[4]-B[2])
 27: prt "PHI KURT.:",(B[2]-B[1]+B[5]-B[4])/(B[4]-B[2])
 28: r10/r100→r1
 29: for K=1 to 121
 30: S[K](P[K]-r1)^2+r20→r20
 31: S[K](P[K]-r1)^3+r30→r30
 32: S[K](P[K]-r1)^4+r40→r40
 33: next K
 34: r20/r100→r2
 35: r30/r100→r3
 36: r40/r100→r4
 37: √r2→r12
 38: r3/r2^(3/2)→r13
 39: r4/r2^2→r14
 40: prt "Mean:",r1
 41: prt "2nd Moment:",r2
 42: prt "ST. DEV.:",r12
 43: prt "3rd Moment:",r3
 44: prt "SKEWNESS:",r13
 45: prt "4th Moment:",r4
 46: prt "KURTOSIS:",r14
 47: ldp 6
 48: end
*27224
```

```
0: "PLOT":dim M$[121,4],S$[121,4],P[122]
1: ldf 19,M$;ldf 20,S$;-2→P[1]
2: ent "Print out? 0or1",C
3: if C=0;gto "PLOTT"
4: prt "SEDIMENTATION TUBE OUTPUT"
5: for K=1 to 121
6: prt "Phi",P[K];P[K]+.05→P[K+1]
7: prt " %wt.",stf(M$[K])
8: prt "  Freq.",stf(S$[K])
9: next K
10: "PLOTT":pclr
11: ent "VERTICAL SCALE MAX?",S
12: scl -3,5,-1,S+1
13: pen# 1
14: xax 0,.1,-2,4,5
15: yax -2,.2,0,S,5
16: pen# 2
17: for K=-1 to 4
18: yax K,0,0,S
19: next K
20: for K=1 to S
21: xax K,0,-2,4
22: next K
23: pen# 3
24: -2→P[1];-1.95→P[2]
25: plt P[1],stf(S$[1]),1
26: for K=2 to 121
27: plt P[K],stf(S$[K]),2
28: pen
29: cplt -.33,-.25
30: lbl "+"
31: cplt -.67,.25
32: P[K]+.05→P[K+1]
33: next K
34: pen# 4
35: plt -1,S-.5,1
36: csiz 3;lbl "PARTICLE SIZE DISTRIBUTION"
37: plt -.5,S-1,1
38: csiz 2;lbl "SEDIMENT FROM ESQUIMALT HARBOUR"
39: plt -2.75,1.5,1
40: csiz 2,2,1,90;lbl "FREQUENCY"
41: plt -.5,-1,1
42: csiz 2;lbl "PARTICLE SIZE IN PHI UNITS"
43: pen
44: ent "Cumulative chart?",Z
45: if Z=0;ldp 7
46: "CUMULATIVE % CHART":pclr
47: scl -3,5,-10,110
48: pen# 1
49: xax 0,.1,-2,4,5
50: yax -2,5,0,100,2
51: pen# 2
52: for K=-1 to 4
53: yax K,0,0,100
54: next K
55: for K=10 to 100 by 10
56: xax K,0,-2,4
57: next K
58: pen# 3
59: -2→P[1];-1.95→P[2]
60: plt P[1],stf(M$[1]),1
```

```
0: "SAVEFILE":dim V$[375,2],T$[121,4],F$[121,4]
1: ent "SAVE?(0 or 1)",A
2: if A=0;ldp 8
3: ent "OK  WHICH FILE? ",B
4: ldf 17,V$;ldf 15,T$;ldf 20,F$
5: rcf B,V$;rcf B+1,T$;rcf B+2,F$
6: ldp 8
7: end
*11634
```

```
0: "AVERAGE":dim S$[847,4],F$[121,4]
1: enp "# OF RUNS? <8",R
2: for K=1 to R
3: enp "File #",N
4: ldf N,F$
5: for I=1 to 121
6: fts (stf(F$[I]))→S$[K*121+I-121]
7: next I
8: next K
9: for I=1 to 121;fts (0)→F$[I];next I
10: for I=1 to 121
11: for K=1 to R
12: fts (stf(S$[K*121+I-121])+stf(F$[I]))→F$[I]
13: next K
14: next I
15: for I=1 to 121
16: fts (stf(F$[I])/R)→F$[I]
17: next I
18: rcf 21,F$
19: end
*5318
```

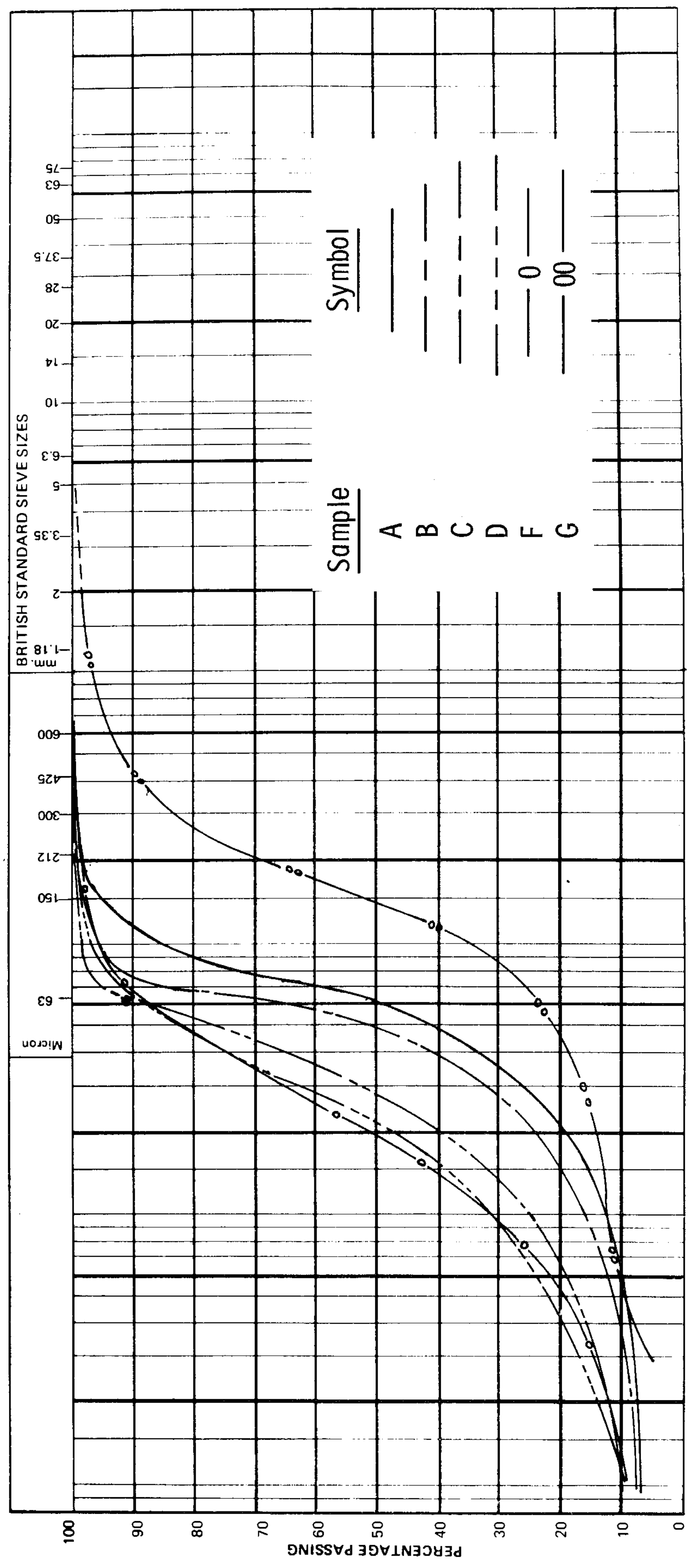
APPENDIX C



All samples converge at 100% passing sieve size 420 Microns

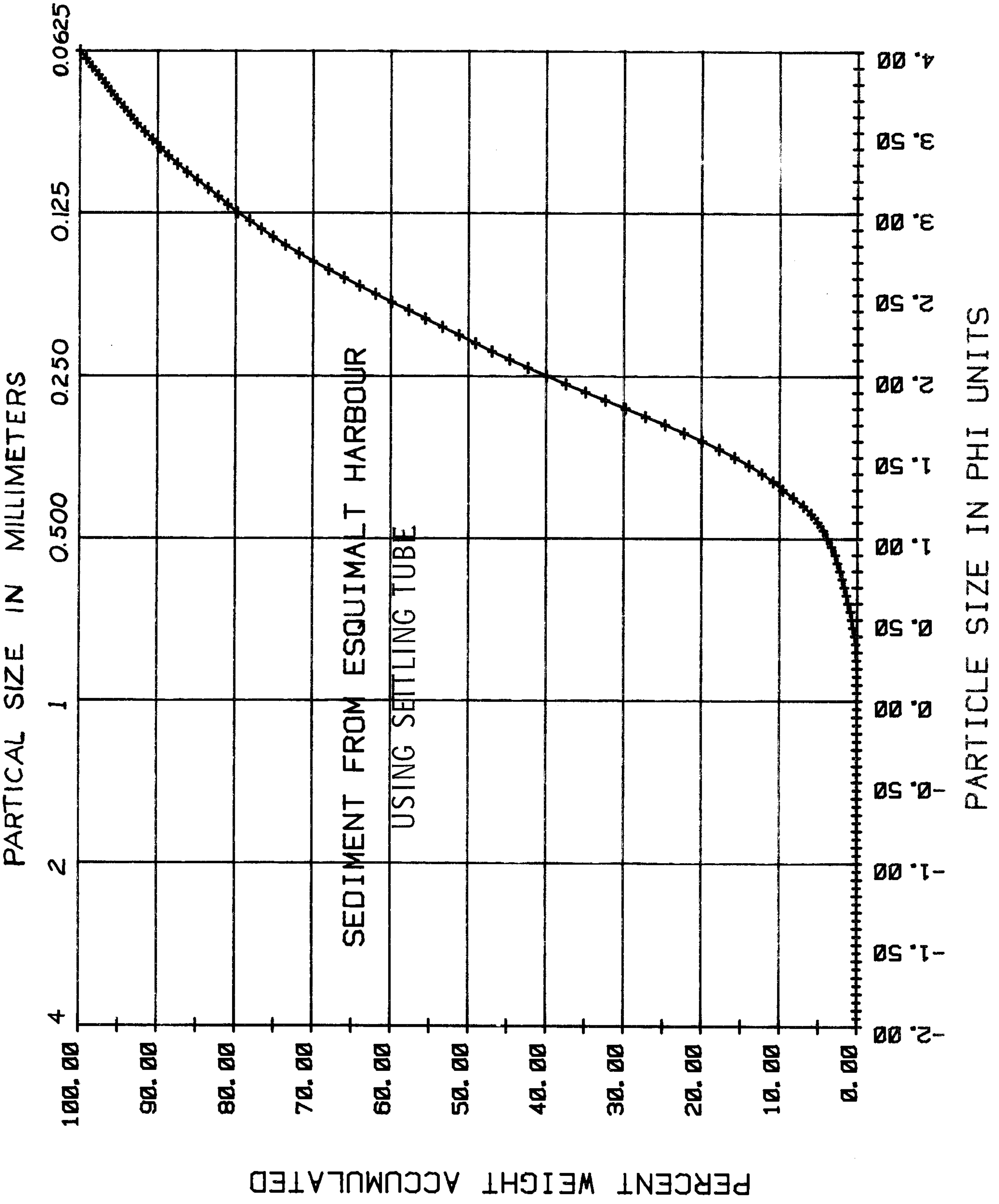
RESULTS OF PIPETTE ANALYSIS

Appendix D

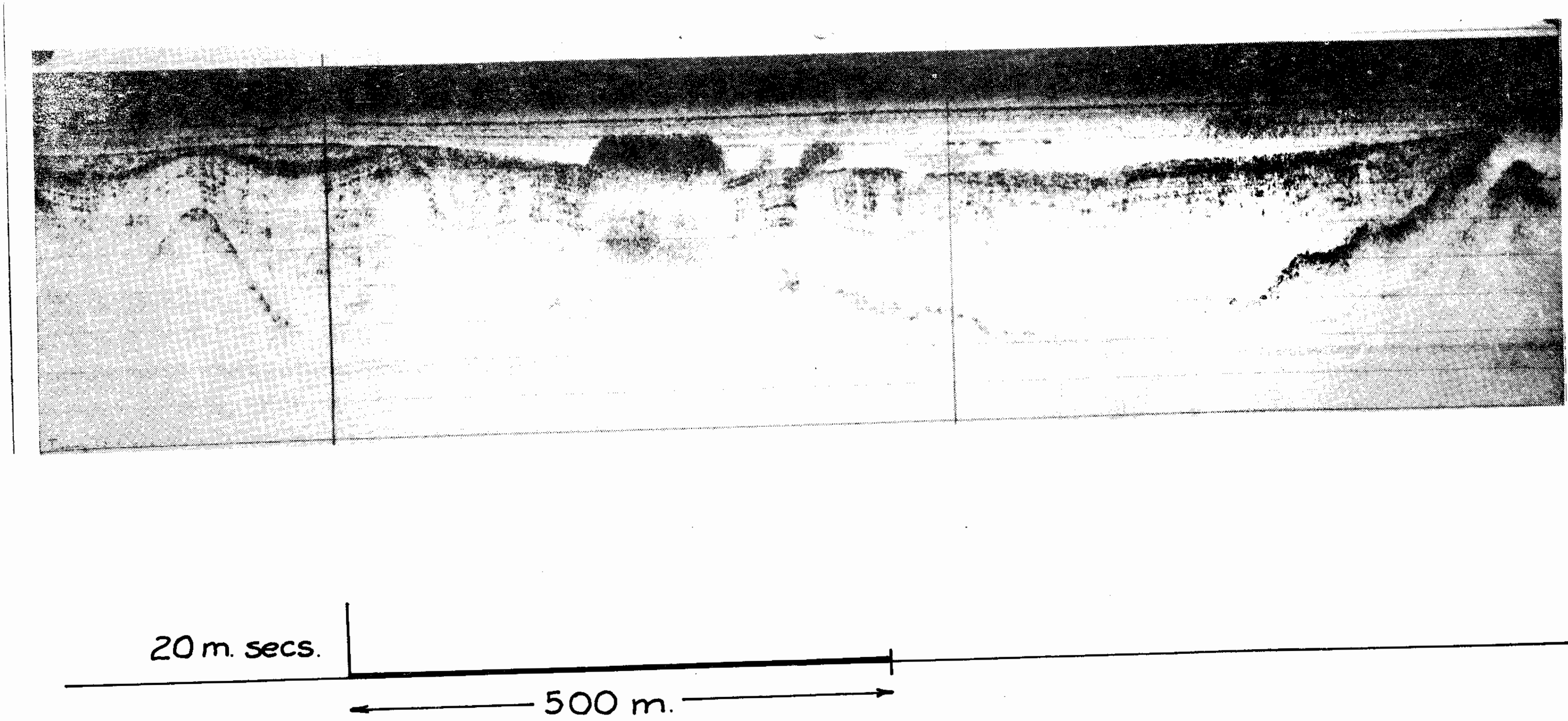


RESULTS OF HYDROMETER ANALYSIS

Appendix E

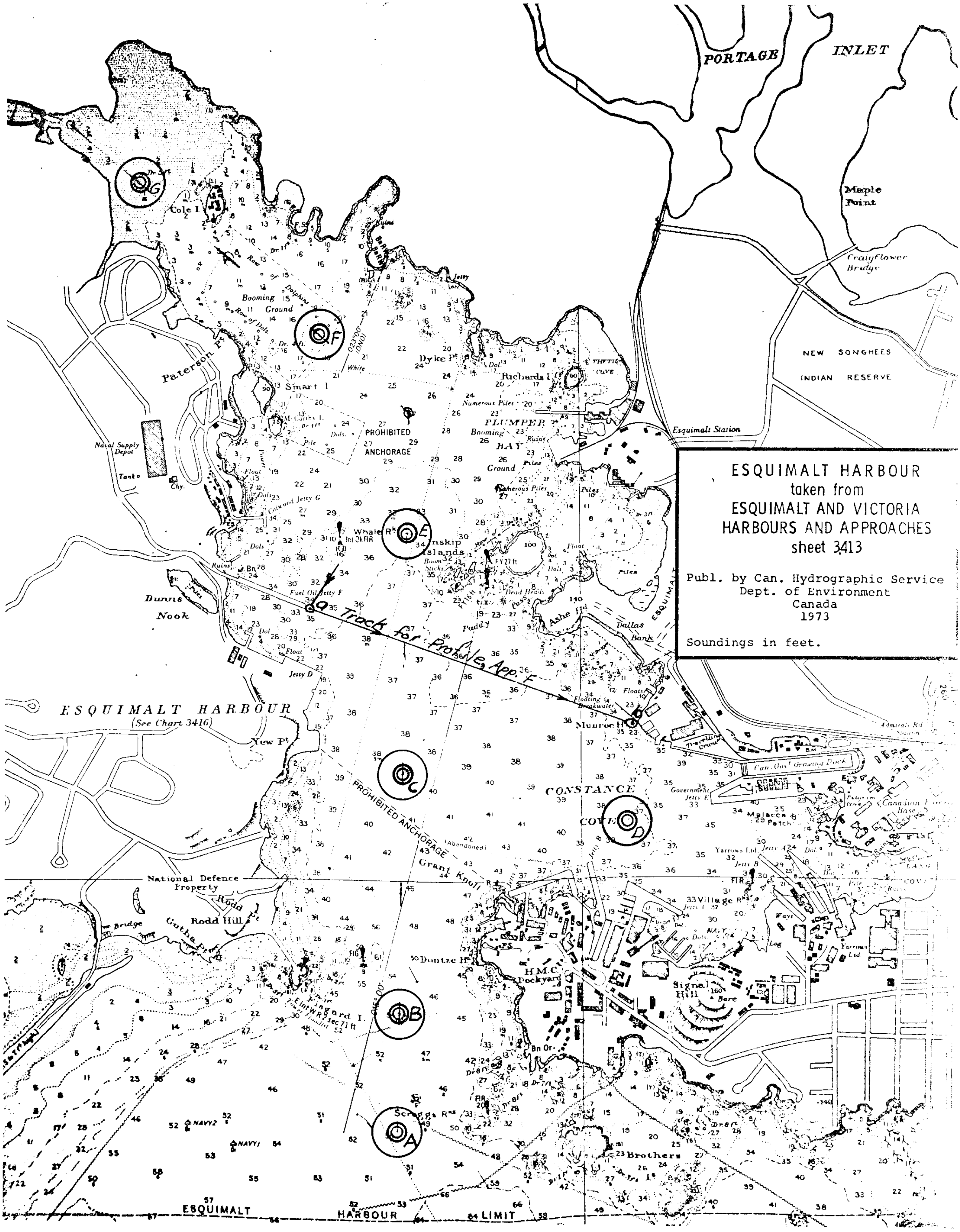

SEDIMENT FROM ESQUIMALT HARBOUR
USING SETTLING TUBE
PARTICAL SIZE IN MILLIMETERS
0.0625
0.125
0.250
0.500
1
2
4
PARTICLE SIZE IN PHI UNITS
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
PERCENT WEIGHT ACCUMULATED
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00

APPENDIX F



Profile of Sub-bottom of Esquimalt Harbour From F Jetty to Munroe Head

APPENDIX G



ESQUIMALT HARBOUR
taken from
ESQUIMALT AND VICTORIA
HARBOURS AND APPROACHES
sheet 3413

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Dept. of Environment
Canada
1973

Soundings in feet.