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Public Beach Assessment Report Aqua-PO Stafford county, Virginia

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PUBLIC BEACH ASSESMENT REPORT
AQUA-PO
Stafford County, Virginia

Technical Report Obtained Under Contract With
The Virginia Department of
Conservation and Recreation
via the
Joint Commonwealth Programs Addressing
Shore Erosion in Virginia

Prepared by

Deborah Linden
Donna Radcliffe
Scott Hardaway
Suzette Kimball

September 1991

PREFACE

The Aqua-Po Public Beach report is the first in a series of reports on the public beaches in the Commonwealth of Virginia. There are 14 localities with public beaches totalling about 23 miles of shoreline. The public beach reports are an assessment of the history of each public beach and their current status in terms of loss of beach fill and maintence needed. This is measured by the beach monitoring program sponsored by the Virginia Board on the Conservation and Development of Public Beaches.

The public beach monitoring program was initiated in 1982 shortly after the creation of the Public Beach Board. Each project funded by the Board requires the locality to monitor the beach by periodic surveys in the form of beach profiles or transects. These surveys are sent to VIMS where they are entered and stored on computer. Analysis of the beach profile data show where and how fast changes in beach form and volume occur. This data then allows the locality to determine if, when and how much addtional sand is required to maintain their public beach.

Funds for beach projects come in the form of matching grants from the Public Beach Board. There is a fifty/fifty match with the locality. The total cost of the project at the Aqua-Po Public Beach was $370,000.

Any questions or comments on the data or contents of this report should be addressed to the Advisor to the Public Beach Board P.O. Box 1024, Gloucester Point, Virginia 23062.

PUBLIC BEACH ASSESSMENT REPORT FOR AQUA-PO, STAFFORD COUNTY, VIRGINIA

by

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INTRODUCTION

Aqua-Po Public Beach is located in Stafford County, Virginia on the southern shore of the Potomac River (Figure 1). It is an important public beach site, as well as a valuable natural resource for Stafford County.

Before 1987, Aqua-Po Public Beach was one of the many stretches of Chesapeake Bay shoreline undergoing severe erosion. The shoreline was rapidly retreating to the west through overwash processes and cross-shore transport. In the late 1960's, a groin field was constructed in an attempt to maintain the beach. Continued erosion, however, left four previously attached groins over 100 feet offshore. Sediment transport at the site, predominantly to the south, resulted in a narrow beach zone along the southern section of the shore. Groins at the southern end of the beach trapped some of the material eroded from further up the shore.

Early in 1987, a major beach restoration project took place at Aqua-Po in order to halt the continued severe shoreline erosion and create a stable recreational beach for Stafford County. The project included 700 feet of stone revetment, 20,000 cubic yds of beach fill material, and four 100-foot long offshore attached breakwaters (Hardaway *et al.*, 1989).

The design of the offshore attached or headland breakwaters was based on procedures outlined in an equilibrium bay model by Silvester (1978). Embayments between headland breakwaters will reach an equilibrium or stable state over time as a function of the wave climate at the site. An explanation of this concept is given in Appendix III.

The purpose of this report is to provide information about present beach conditions at Aqua-Po relative to the 1987 restoration project. All data for this report were analyzed at the College of William and Mary, Virginia Institute of Marine Science (VIMS) and cover a time span from August 1986 through April 1990. Periodic updates of the beach surveys will be added as addendums to this report.

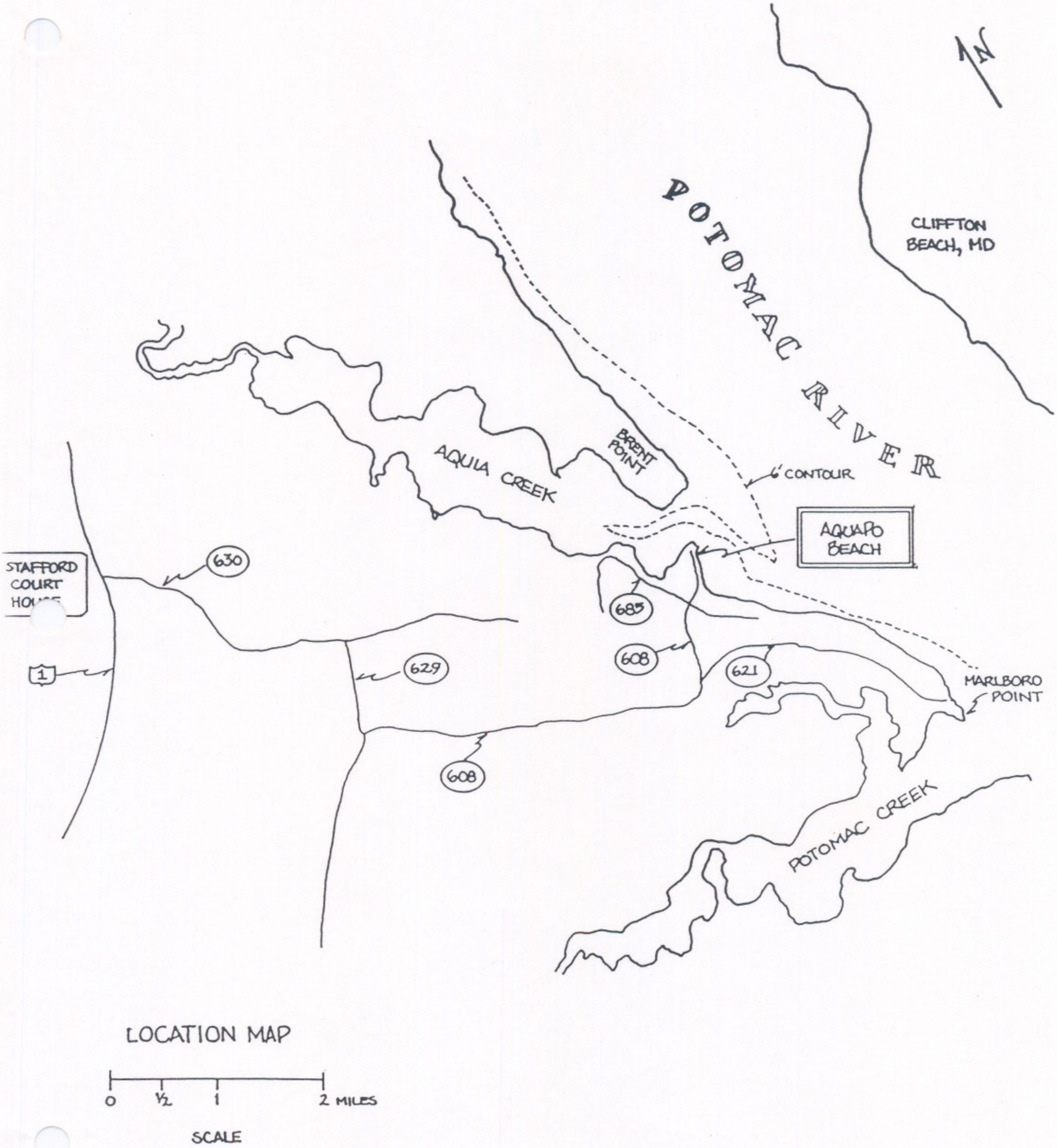
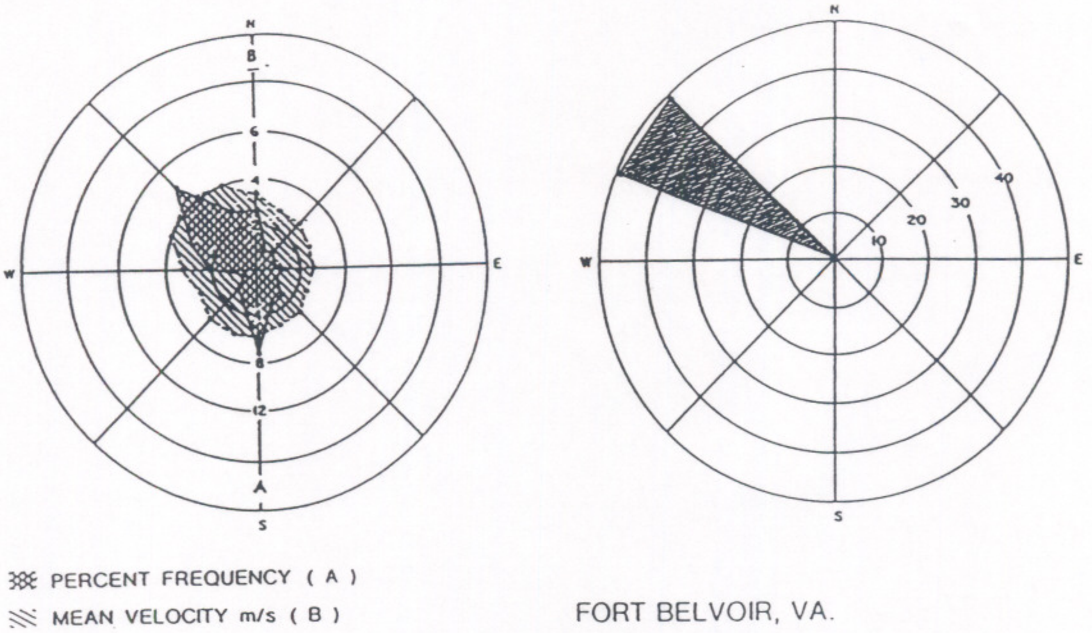


Figure 1. Aqua-Po location map (Espey, Huston & Associates, Inc., 1985-1986 proposal by Stafford County, Virginia).

SETTING

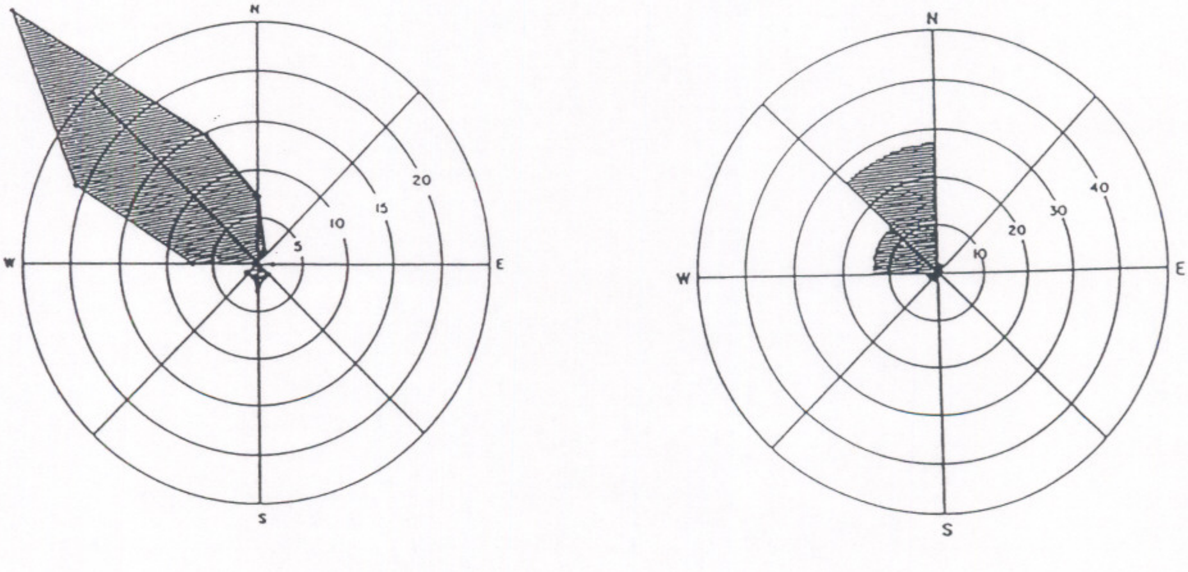
The Aqua-Po beach site is bordered on the north by Aquia Creek and on the east by the Potomac River (Figure 1). It exists on a low, broad, marshy peninsula. The shoreline faces east and is fetch-limited. A fetch refers to an area of the sea surface over which waves are generated by a wind of constant speed and direction. The fetch is particularly important in limiting wave periods and wave heights (Komar, 1976). The greater the area over which a wind may blow, the larger the waves that may be generated. In a fetch-limited situation such as Aqua-Po, the sea surface area over which the wind may blow is restricted; thus, the waves that develop remain somewhat small. The average fetch at Aqua-Po is 7.2 km (Hardaway *et al.*, 1989).

Not much information exists pertaining to wave conditions at Aqua-Po. The use of local wind data, however, enables an assessment of some effects of the wave climate. Figure 2 contains wind roses for wind data obtained at Fort Belvoir, Virginia representing the period 1957-1970. Data are shown as a total annual wind rose, frequency of winds greater than 5 m/s and 11 m/s, and annual peak-gust frequency (Rosen, 1976). From Figure 2, it is evident that the northwest wind component is dominant in this region. Hardaway *et al.* (1989), through analysis of the wind data from nearby Quantico Marine Base, found strong northeast and southeast winds to dominate that portion of the river. They determined the net direction of wave approach at Aqua-Po to be approximately shore-normal (~85° true N), perhaps reflecting a balance between the northeast and southeast winds. Because of the storm surge associated with Northeasters, waves generated from northeast winds would have more effect on the shoreline and on net sediment transport. The response of this wave process is evidenced in Aqua-Po's shoreline by the previously eroding fastland at the north and the accumulation of eroded material along the southern end of the shore.



FORT BELVOIR, VA.
ANNUAL WIND ROSE

FORT BELVOIR, VA.
WINDS > 11 M/S
PERCENT FREQUENCY



FORT BELVOIR, VA.
WINDS > 5 M/S
PERCENT FREQUENCY

FORT BELVOIR, VA.
MONTHLY PEAK GUSTS
PERCENT FREQUENCY

Figure 2. Fort Belvoir, Virginia Wind Station roses (modified from Rosen, 1976, Ph.D. Dissertation).

METHODS

The data available for analysis in this report included aerial photographs, beach profile data, and sediment samples. Three aerial photographs of the Aqua-Po site were traced and overlain so that changes in the position of the shoreline could be assessed (Figure 3). The three years used in the aerial photographic analysis correspond to a pre-project condition (February, 1985), a post-project condition (December, 1987), and a near-present condition (March, 1989).

Beach profiles have been surveyed quarterly since the restoration project by the design firm of Espey, Huston & Associates, Inc. and by Stafford County personnel. Beach profile transects were positioned along the shore in order to best determine volume changes around the breakwaters and embayments (Figure 3). Five dates were chosen to demonstrate how individual profiles of the beach have changed over time. These dates were plotted together for each of the 21 profiles (Appendix I). Profile data is summarized in terms of relative shoreline positions, average beach elevations, and annual rates of change (Table 1). Beach widths were measured on plotted profiles from the back of the beach to mean high water (MHW), and beach elevations were measured at mid-beach (half-way between the back of the beach and present MHW). Plotted profiles were also used to calculate beach volumetric changes over time, with respect to both embayment and breakwater portions of the shore (Figure 4 and Table 2).

Sediment data were analyzed for grain size and statistical parameters were calculated. Sediment data were available for only one date (March, 1987); however, samples were collected along 21 different profiles alongshore. A standard sieving technique was used to separate samples into gravel, sand, and silt and clay fractions. Weight percents of each fraction were determined for each sample. The sand portion of samples was further analyzed using the

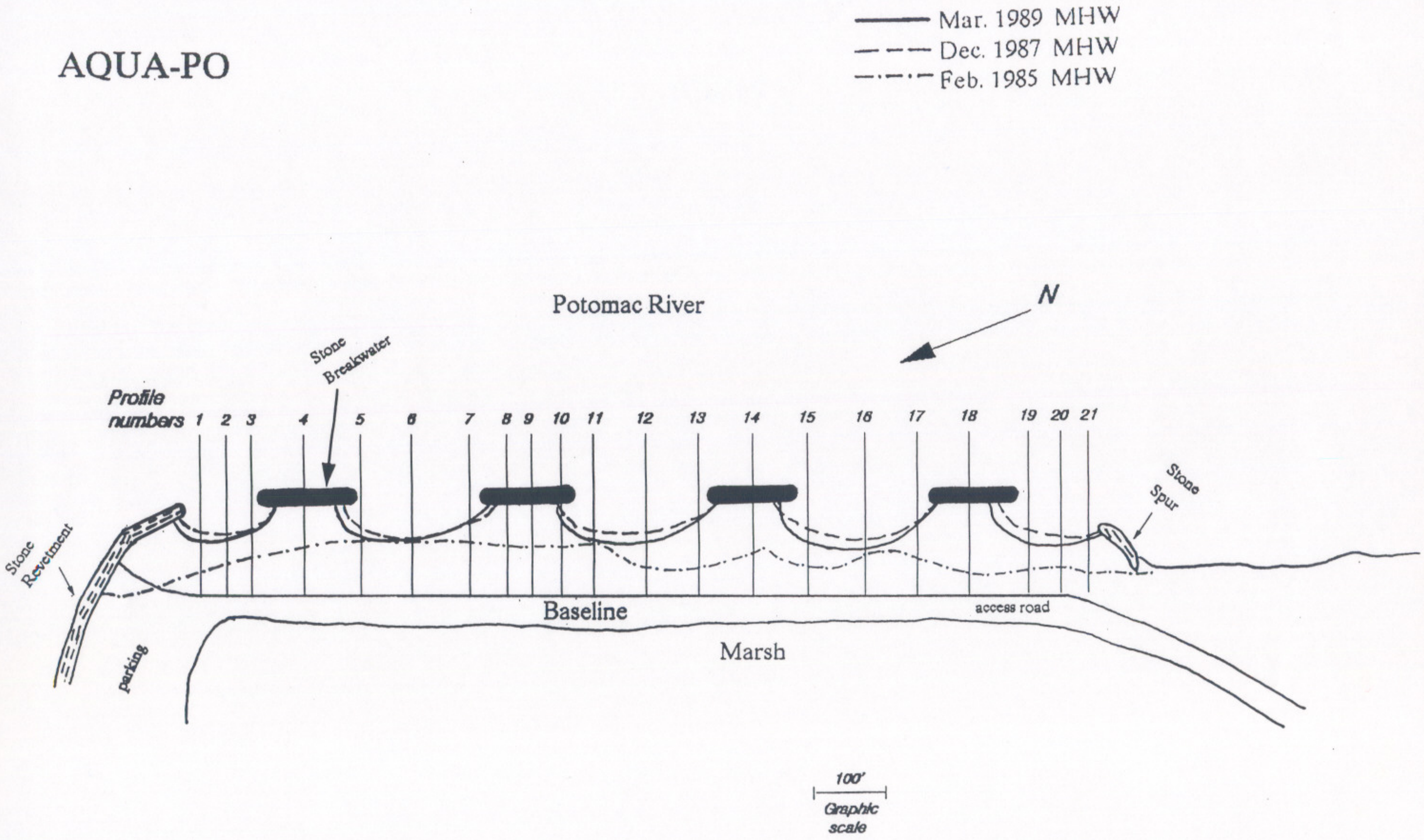
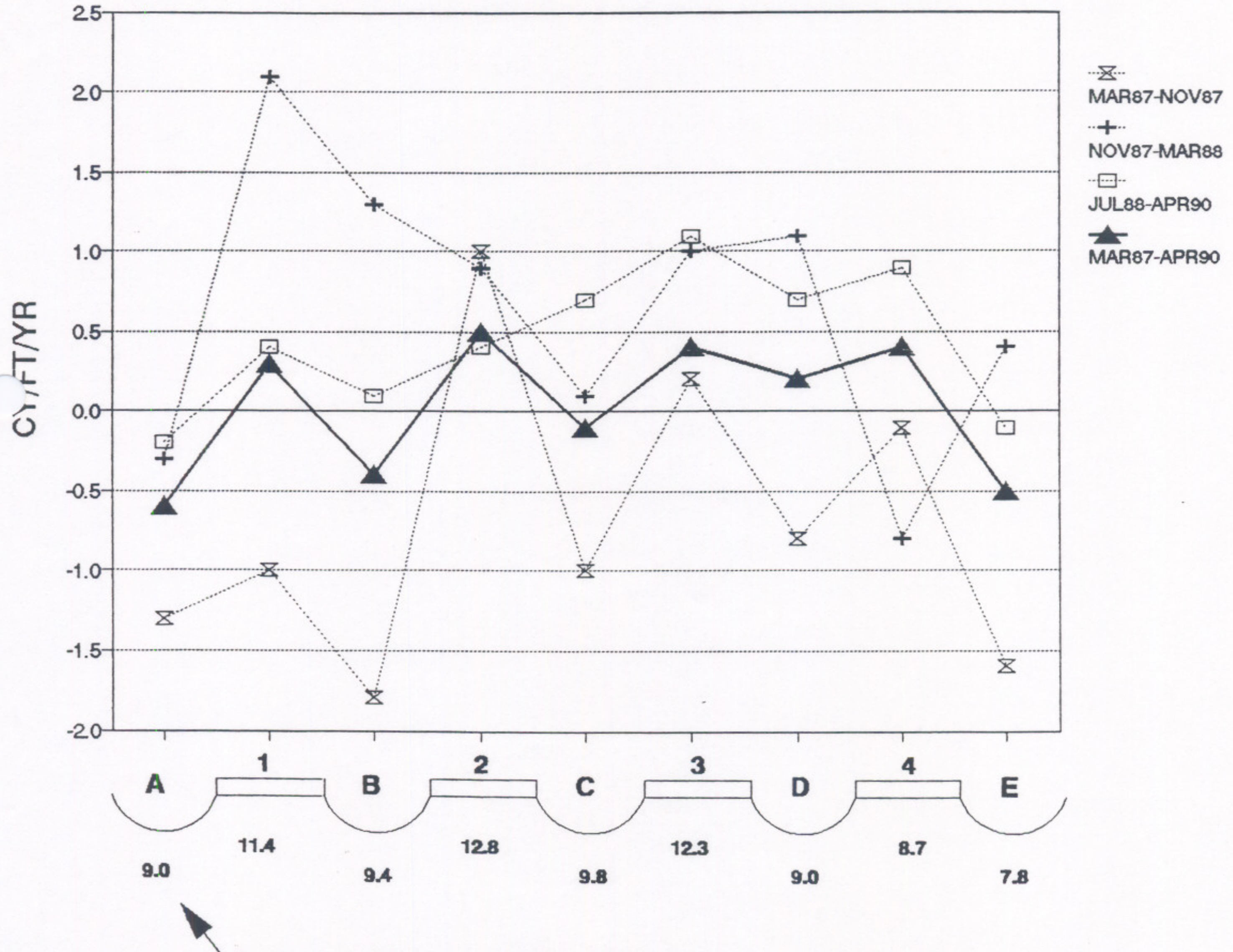


Figure 3. Aqua-Po Public Beach basemap.

Table 1. AQUA-PO PROFILE SUMMARY DATA

	BEACH WIDTH				AVERAGE ELEVATION		
Profile Number	pre to post	pre to present	post to present	Ave. rate of change	pre to post	pre to present	post to present
1	+50	+45	-5	-1.7'/yr	+3.5	+3.5	0.0
2(MB)	+55	+45	-10	-3.3'/yr	+3.5	+3.5	0.0
3	+75	+60	-15	-5.0'/yr	+3.0	+3.0	0.0
4(BW)	+80	+85	+5	+1.7'/yr	+3.5	+3.5	0.0
5	+50	+45	-5	-1.7'/yr	+3.5	+3.5	0.0
6(MB)	+45	+40	-5	-1.7'/yr	+3.5	+3.5	0.0
7	+80	+75	-5	-1.7'/yr	+4.0	+3.5	-0.5
8(BW)	+75	+85	+10	+3.3'/yr	+4.0	+3.5	-0.5
9(BW)	+70	+85	+15	+5.0'/yr	+3.5	+3.5	0.0
10(BW)	+75	+85	+10	+3.3'/yr	+3.0	+3.5	+0.5
11	+60	+50	-10	-3.3'/yr	+3.0	+4.0	+1.0
12(MB)	+45	+45	0	0.0'/yr	+3.5	+3.5	0.0
13	+80	+80	0	0.0'/yr	+3.5	+3.5	0.0
14(BW)	+75	+85	+10	+3.3'/yr	+3.5	+4.0	+0.5
15	+60	+50	-10	-3.3'/yr	+3.5	+4.0	+0.5
16(MB)	+45	+45	0	0.0'/yr	+3.5	+4.0	+0.5
17	+60	+65	-5	-1.7'/yr	+3.5	+4.0	+0.5
18(BW)	+70	+75	+5	+1.7'/yr	+4.0	+3.5	-0.5
19	+55	+45	-10	-3.3'/yr	+3.0	+3.0	0.0
20(MB)	+45	+40	-5	-1.7'/yr	+3.0	+3.0	0.0
21	+55	+45	-10	-3.3'/yr	+3.0	+3.0	0.0

All measurements are in feet. "Pre" designates pre-project conditions of 08/86, "post" designates immediate post-project conditions of 03/87, and "present" designates most recent survey data of 04/90. "MB" refers to mid-bay profile stations and "BW" refers to breakwater profile stations. Negative values indicate erosion/deflation, and positive values indicate accretion.



Numbers indicate the volume of sand added behind each embayment (A-E) and each breakwater (1-4) in 1987 (CY/FT).

Figure 4. Aqua-Po volume changes.

Table 2 . BEACH VOLUMETRIC RATE OF CHANGE RELATIVE TO BREAKWATER UNITS 1 THRU 4 AND THEIR ADJACENT BAYS A THRU E.

	MAR87-NOV87 CY/FT/YR	NOV87-MAR88 CY/FT/YR	JUL88-APR90 CY/FT/YR	MAR87-APR90 CY/FT/YR
Bay A	-1.3	-0.3	-0.2	-0.6
BW #1	-1.0	2.1	0.4	0.3
Bay B	-1.8	1.3	0.1	-0.4
BW #2	1.0	0.9	0.4	0.5
Bay C	-1.0	0.1	0.7	-0.1
BW #3	0.2	1.0	1.1	0.4
Bay D	-0.8	1.1	0.7	0.2
BW #4	-0.1	-0.8	0.9	0.4
Bay E	-1.6	0.4	-0.1	-0.5

VIMS Rapid Sediment Analyzer (RSA) in order to determine specific sand size fractions. Appendix II contains the raw sediment data. Summary plots of the sediment data were constructed in order to demonstrate changes in the mean grain size and sorting characteristics of sediments with respect to backshore, mid-shore, and foreshore profile positions. Four different mid-bay profiles were used as comparisons in these plots (Figures 5 and 6, and Tables 3A and 3B).

RESULTS

Aerial Photographic Analysis

Three sets of aerial photographs corresponding to a pre-project condition (February, 1985), a post-project condition (December, 1987), and a present condition (March, 1989), were traced and overlain in order to compare changes in the position of the shoreline over the three year monitoring period (Figure 3). The positions of the 21 profile transects are also shown on Figure 3 allowing for comparison with the individual profile plots contained in Appendix I. From Figure 3, the narrow beach can be seen that existed at Aqua-Po prior to the 1987 project - in some cases reaching almost back to the access road. Figure 3 also demonstrates the substantial increase in overall beach width from the 1985 shoreline to the 1987 shoreline created by the restoration project. In some sections of the beach, this increase is as much as 100 feet. Between 1987 and 1989, especially in the embayments, the shoreline receded slightly. However, in all cases the beach width remained greater than in the pre-project condition. Small changes in the position of the shoreline (on the order of 1 - 5 ft) cannot be evidenced on this sketch due to the scale of the drawing. Thus, the photographic analysis provides a quick visual summary of broad shoreline changes prior to and since the restoration project.

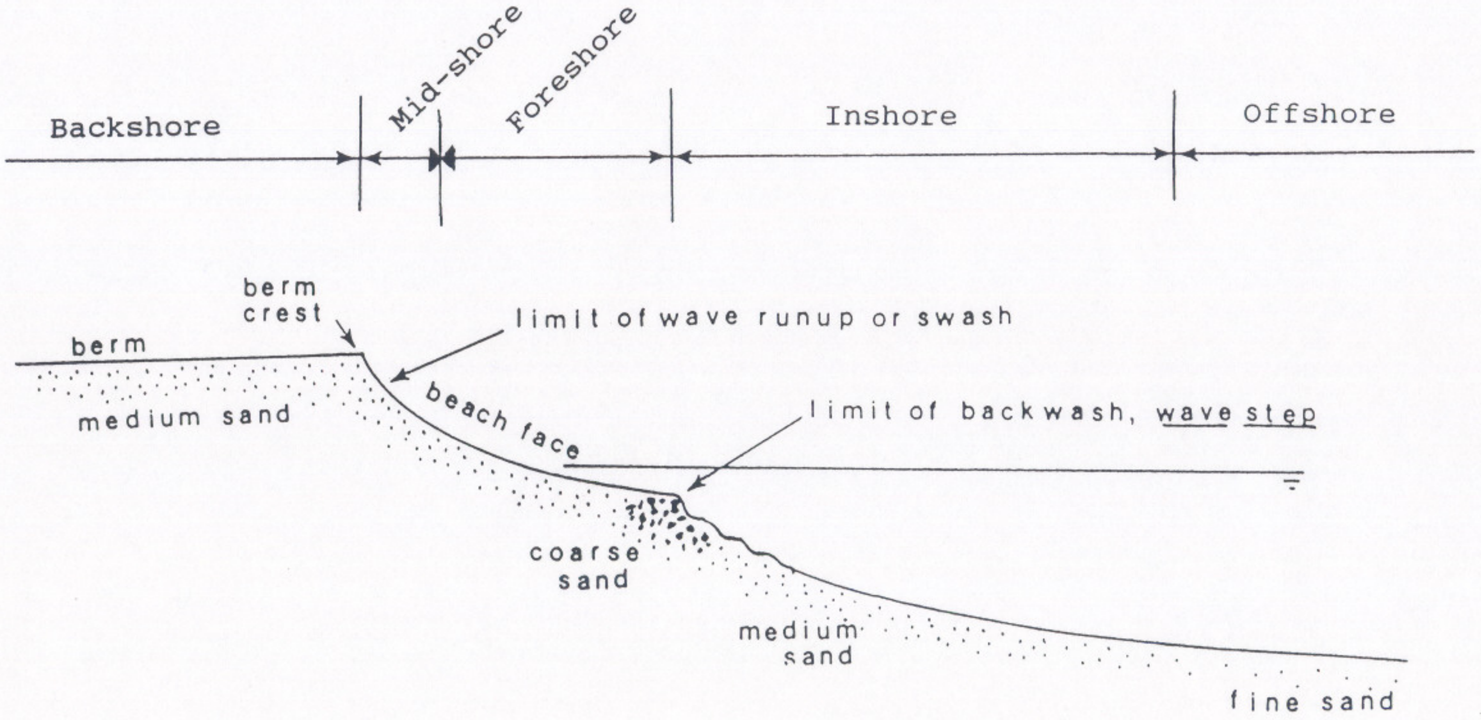


Figure 5. Features and terminology of the beach profile.

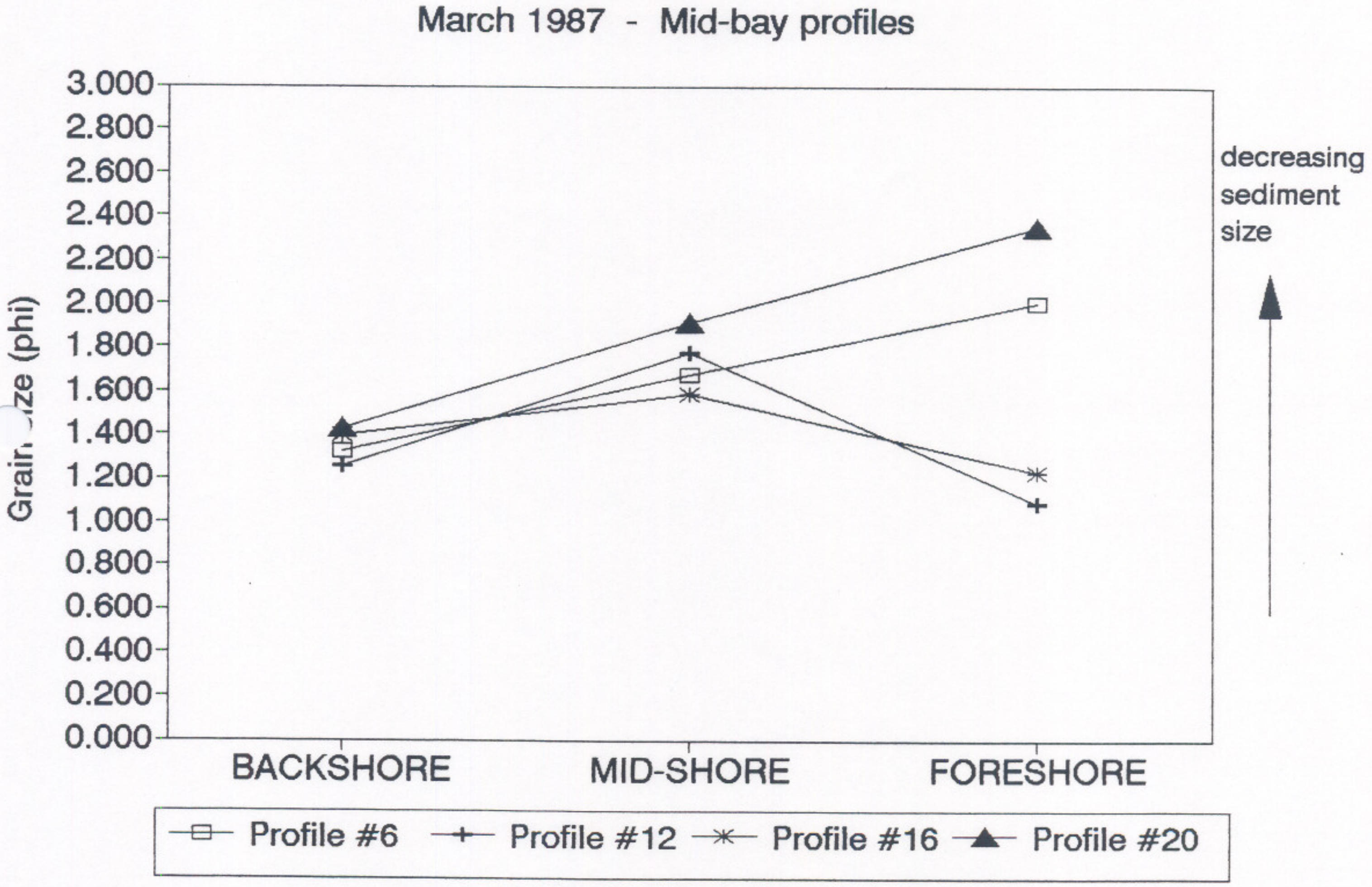


Figure 6. Mean sediment grain size for the Aqua-Po Beach profiles.

TABLE 3A – SEDIMENT SIZE CONVERSION TABLE

Millimeters (1 Kilometer)	Microns	Phi (ϕ)	Wentworth Size Class	
		-20		
4096		-12		
1024		-10	Boulder (-8 to -12ϕ)	
256		-8		GRAVEL
64		-6	Cobble (-6 to -8ϕ)	
16		-4	Pebble (-2 to -6ϕ)	
4		-2		
3.36		-1.75		
2.83		-1.5	Granule	
2.38		-1.25		
2.00		-1.0		
1.68		-0.75		
1.41		-0.5	Very coarse sand	
1.19		-0.25		
1.00		0.0		
0.84		0.25		
0.71		0.5	Coarse sand	
0.59		0.75		
0.50	500	1.0		
0.42	420	1.25		
0.35	350	1.5	Medium sand	SAND
0.30	300	1.75		
0.25	250	2.0		
0.210	210	2.25		
0.177	177	2.5	Fine sand	
0.149	149	2.75		
0.125	125	3.0		
0.105	105	3.25		
0.088	88	3.5	Very fine sand	
0.074	74	3.75		
0.0625	62.5	4.0		

(Modified from Folk, 1980; Petrology of Sedimentary Rocks)

TABLE 3B – SORTING CLASSES AND CORRESPONDING SORTING VALUES

Sorting Value	Sorting Class
< 0.35	Very well sorted
0.35–0.50	Well sorted
0.50–0.80	Moderately well sorted
0.80–1.40	Moderately sorted
1.40–2.00	Poorly sorted
2.00–2.60	Very poorly sorted
> 2.60	Extremely poorly sorted

(Modified from Friedman and Sanders, 1978; Principles of Sedimentology)

Beach Profile Analysis

Appendix I contains the individual profile plots with five chosen dates plotted together for each of the 21 profiles spanning the beach. Table 1 summarizes the profile data in terms of relative shoreline positions, average beach elevations, and average annual rates of change. Here, "pre" designates the profile survey of August, 1986, "post" designates the immediate post-project survey of March, 1987, and "present" designates the most recent survey data of April, 1990. All measurements in the table are in feet, with positive values indicating accretion and negative values indicating erosion or deflation.

Many important observations may be derived from the summary data. At all places along the shore, the beach is significantly wider than the pre-project condition. Of the width created by the 1987 project, however, the beach has narrowed in varying degrees alongshore - largely with respect to embayment or breakwater areas of the shoreline. The three central embayments (profiles 5 - 7, 11 - 13, 15 - 17) show relatively stable portions of the shoreline (profiles 12, 13, 16), as well as portions which have receded between 5 feet and 10 feet (profiles 5, 6, 7, 11, 15, 17). The two embayments at the northern-most and southern-most stretches of the site (profiles 1 - 3, 19 - 21, respectively) show that the shoreline there has receded between 5 feet and 15 feet over the three year monitoring period. In contrast, breakwater areas of the shoreline (profiles 4, 8 - 10, 14, 18) consistently show accretion between 5 feet and 15 feet, with the largest increases behind the center two breakwaters (profiles 8 - 10, 14). Because fill material placed on the beach in 1987 was added out to the breakwaters, the increases noted in beach width indicate a filling-in of material immediately behind the breakwaters. The filling-in of material yields a local increase in elevation moving the position of MHW to the breakwater position. The pattern of shoreline adjustment occurring at Aqua-Po is expected when a breakwater system has been implemented in order to maintain a recreational beach. The breakwater system at Aqua-Po was designed and constructed based on a net southerly transport of sediment, and thus intended to help trap material which would otherwise be lost to the system.

With respect to beach elevation, data indicate that the subaerial beach at Aqua-Po has remained relatively stable since the 1987 project. All profile stations show an increase in subaerial beach elevation behind each breakwater over the pre-project condition. Generally, beach embayments show no net change in elevation since the restoration project (profiles 1 - 3, 5, 6, 12, 13, 19 - 21). Exceptions to this include profile 7 which has lost 0.5 foot in elevation, and profiles 15 - 17 and 11 which have gained 1 foot and 0.5 foot, respectively, over the post-project elevation. The pattern of beach elevation change behind the breakwaters is more varied. Breakwater profile stations 4 and 9 show no change in elevation, 8 and 18 have lost 0.5 foot in elevation, and 10 and 14 have gained 0.5 foot in subaerial beach elevation.

During the three year monitoring period, net rates of shoreline recession varied between 1.7 ft/yr and 5 ft/yr among the profile stations. Net rates of shoreline accretion also varied between 1.7 ft/yr and 5 ft/yr. Because much of the shoreline adjustment typically takes place during the first few months following project implementation, the calculated net rates of change are poor estimators of actual annual changes. Typically, annual rates of change begin to slow after the first year of monitoring. Based on the 21 profiles spanning the shore, some portions of the Aqua-Po shoreline may have stabilized (profiles 12, 13, 16), while others may be very near equilibrium. Long term monitoring will provide data needed for further evaluation of beach adjustment and stabilization.

In general, beach slopes have changed very little as the shoreline has adjusted. In the embayments, shore slopes have steepened slightly as beach elevations have remained stable or increased and beach widths have decreased. In breakwater areas, shore slopes have flattened as material has accumulated behind breakwaters.

Beach Volumetric Changes

Figure 4 and corresponding Table 2 represent beach volumetric rates of change at Aqua-Po over time, with respect to both embayment and breakwater portions of the shore. In Figure 4, A - E represent embayments along the shore, with A corresponding to profiles 1 - 3 at the northern-most part of the shore. The numbers (1 - 4) represent breakwater units, with 1 being the northern-most breakwater. Volume changes were calculated in cubic yards per foot per year (cy/ft/yr). The initial fill volume within the monitoring area (between profiles 1 - 21) included approximately 13,000 cy of sand.

During the first eight months following project implementation (March, 1987 - November, 1987) negative volume changes were greatest. That is, of the fill material placed on the beach during the restoration project, the largest losses of this material overall occurred during the immediate post-project time period. This is consistent with the earlier statement that most shoreline adjustment typically takes place during the first few months following project implementation. During the next four months (November, 1987 - March, 1988), rates of change were predominantly positive along the shore. The pattern of change observed indicates that the beach was continuing to adjust.

During the next time period (July, 1988 - April, 1990) there were again predominantly positive volume changes for both embayment and breakwater units, with the exception of the two end embayments A and E. The last set of dates plotted represent rates of change over the total three year monitoring period

(March, 1987 - April, 1990). The indication is that the beach is approaching an equilibrium state as rates of change are decreasing over time.

The fastland bank along Aquia Creek, which in the past provided material to the beach site, was stabilized in the 1987 project with stone revetment. With the revetment halting the erosion of upland material, new sediment is no longer available to the system. Thus, the pattern of gain and loss observed alongshore involves mainly the movement of nourishment material placed on the beach in 1987. Over the three year period, the pattern is such that the largest volume losses are in the northern embayments A and B (-0.6 cy/ft/yr and -0.4 cy/ft/yr), smallest in embayment C (-0.1 cy/ft/yr), and volume has been increasing in the southern embayment D (0.2 cy/ft/yr) as well as behind all the breakwaters. In general, the sediment within the system is being transported from the northern embayments, bypassing the central embayment, and accumulating behind the breakwaters as well as being transported around the breakwaters and accumulating in the southern embayment. This pattern reinforces that the predominant direction of sediment transport at Aqua-Po is to the south. Embayment E is the one anomaly and has lost material at a rate of -0.5 cy/ft/yr.

Sediment Analysis

Figures 6 and 7 and Table 4 contain summarized sediment data relating changes in mean grain size and sorting characteristics of sediments to backshore, mid-shore, and foreshore profile positions. Data are for four different mid-bay profiles: 6 (embayment B), 12 (embayment C), 16 (embayment D), and 20 (embayment E). Figure 5 indicates which portions of a typical profile correspond to backshore, mid-shore, and foreshore positions. Because sediment data were available for only one date (March, 1987 - immediate post-project), we can only report on the conditions which existed at that particular time. There is no basis for a comparison with pre-project or present beach sediment characteristics.

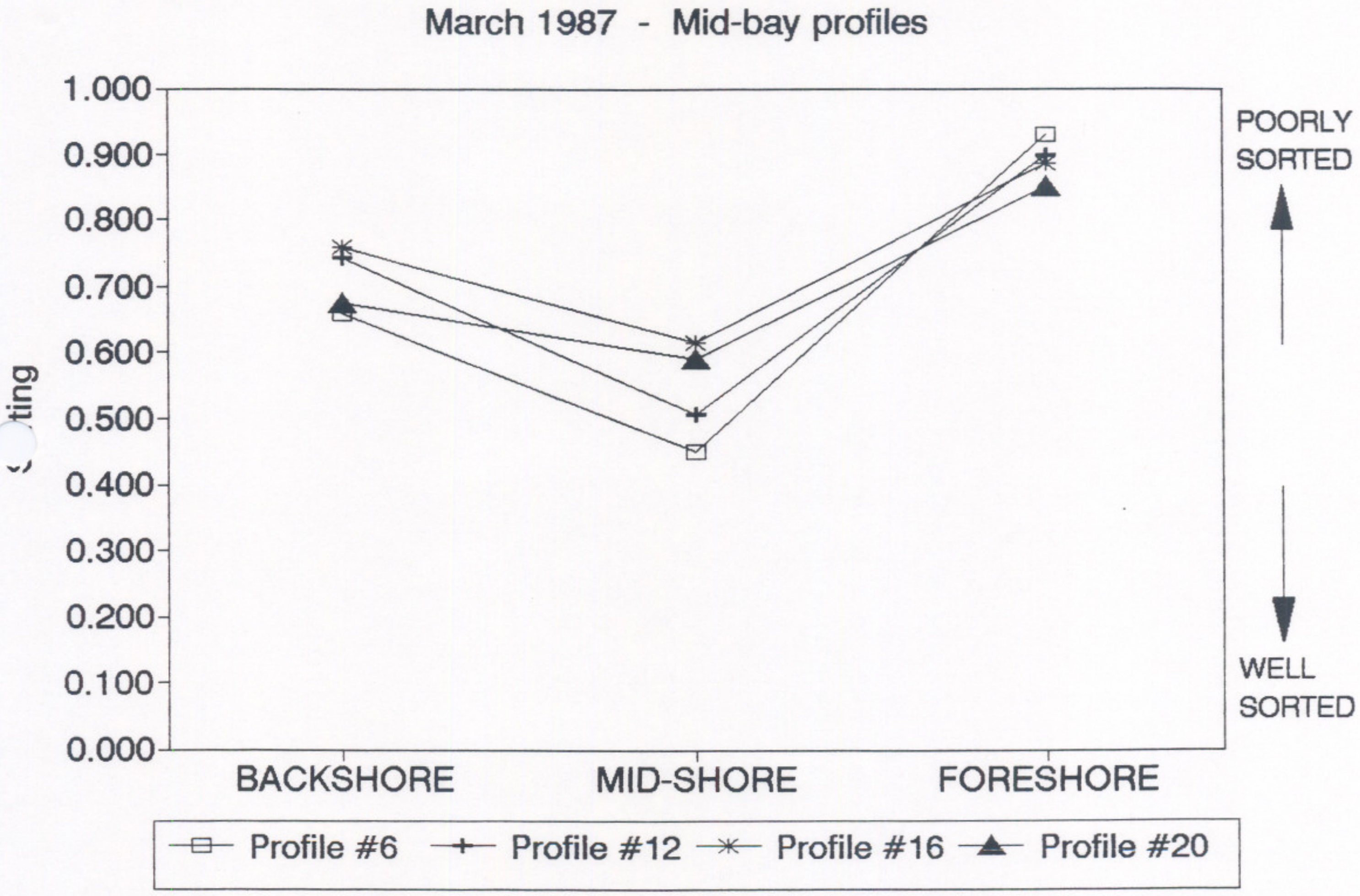


Figure 7. Sediment sorting along the Aqua-Po Beach profiles.

Table 4. SEDIMENT DATA

Mean Phi Size for Mid-Bay Profiles

Profiles	6	12	16	20
Backshore	1.329	1.254	1.394	1.429
Mid-shore	1.677	1.776	1.588	1.914
Foreshore	2.003	1.084	1.232	2.351

Sorting - Mid-Bay Profiles

Profiles	6	12	16	20
Backshore	0.66	0.744	0.758	0.675
Mid-shore	0.45	0.505	0.616	0.589
Foreshore	0.93	0.897	0.886	0.852

In Figure 6, changes in mean grain size along profiles are shown in phi. The phi scale is a common unit used to designate grain diameter that is designed to simplify calculations. A phi/mm conversion table is presented in Table 3A. Note that as phi values increase, mm values decrease. In Figure 6, mean phi size increases along the y-axis, thus corresponding to decreasing sediment size.

For profiles 6 and 20, sediments are largest in the backshore with decreasing sediment size towards the foreshore. Profiles 12 and 16 show roughly the same size sediments in the backshore and mid-shore as do profiles 6 and 20, however the foreshore sediments are significantly larger than those of profiles 6 and 20. One possible explanation for this is that smaller-grained sediments are entrained and removed from the northern part of the shore (embayment B, profile 6) and readily bypass the breakwaters as they are transported south. The larger sediments are left within the system as lag deposits and thus are observed more in the central embayments (C and D) and less at the southern end of the shore. Because the data represent immediate post-fill conditions at the site, the observed sediment characteristics are reflective of an adjusting beach.

In Figure 7, changes in sediment sorting characteristics along profiles are shown. Sorting refers to the selection of sediment particles during transport according to their sizes, specific gravities, and shapes (Friedman and Sanders, 1978). It is represented by a statistical parameter which describes the spread of a population distribution about its mean. Well-sorted sediments have a very narrow spread indicating a more homogeneous population. Table 3B shows various sorting classes and their corresponding statistical sorting values. Well-sorted sediments have values less than 0.50, while poorly-sorted sediments have values greater than 1.40. From Figure 7, sorting values for the March, 1987 data range from 0.45 to 0.93 and are thus within the moderately sorted to well-sorted range.

Typically, hydraulic sorting of sediments by wave action is most efficient in the intertidal swash zone. This zone corresponds to the mid-shore region of profiles at Aqua-Po. As Figure 7 indicates, the mid-shore contains the most well-sorted sediments for all four profiles. The backshore region in all cases contains sediments intermediate in sorting characteristic. Sorting values for the backshore are similar between profiles (0.66 to 0.76), reflective of the fill material placed on the beach which has not been affected by wave action. The most poorly-sorted sediments are observed in foreshore regions of the profiles. The poor sorting is reflected in the discrepancies in mean grain size of foreshore sediments between the profiles, and is further indicative of an adjusting beach.

CONCLUSIONS

All data analyzed over the three year period of this report indicate that the restoration project implemented in 1987 has thus far been successful. Aerial photographs clearly show the substantial increase in beach width created by the restoration project, and the small loss of this width in embayments along the shore. Beach profile analysis also indicates that the present beach at Aqua-Po is wider in all cases than in its pre-project condition. Rates of shoreline recession in embayments are small - between 1.7 ft/yr and 3.3 ft/yr, with a larger recession rate of 5 ft/yr occurring in the northern-most embayment. Rates of shoreline increase are similar, between 1.7 ft/yr and 3.3 ft/yr. Beach elevations have remained relatively constant - 12 of the profile stations show no change in elevation since the 1987 project, three profile stations show a small loss of 0.5 feet in subaerial beach elevation, and the remaining stations show an increase in beach elevation over that created by the restoration project. Beach volumetric rates of change are also small and indicate that the beach seems to be approaching an equilibrium condition as rates of volume change have decreased over time. Due to a net southerly drift, volume loss rates are greatest at the northern-most part of the shore, however, data indicate that much of this material is accumulating behind breakwaters and within embayment D. Between the time of the restoration project in 1987 and April 1990, the overall volume of beach material within the monitoring area has not changed. Though sand has moved within the system, there has been no net loss of material. These data indicate that the 1987 restoration project has succeeded in halting the previous severe shoreline erosion and in creating a stable recreational beach for Stafford County.

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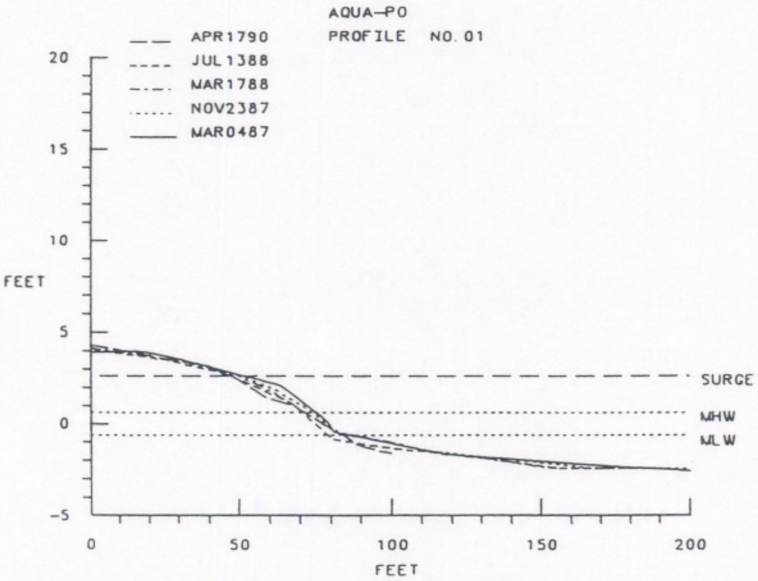
APPENDIX I

PROFILE DATA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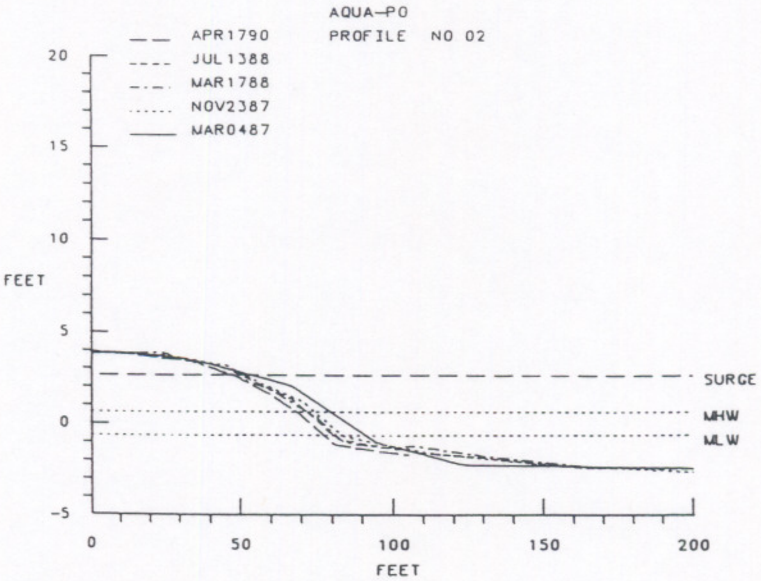
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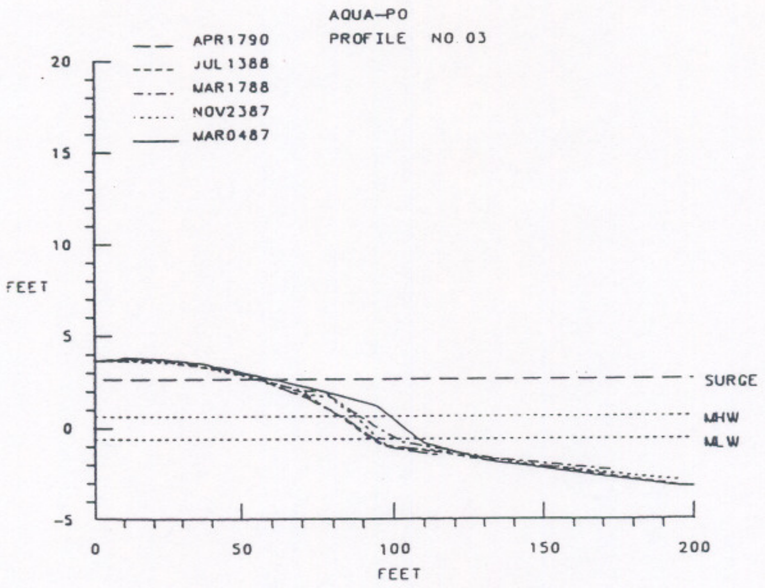
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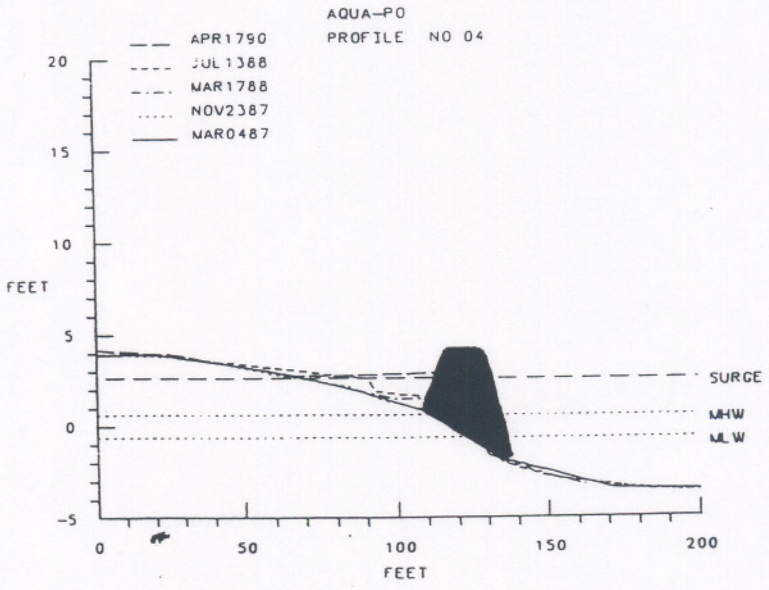
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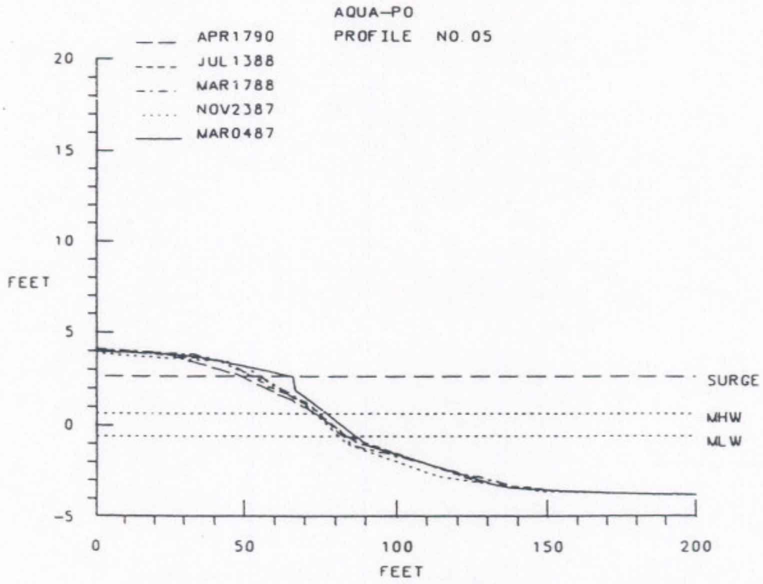
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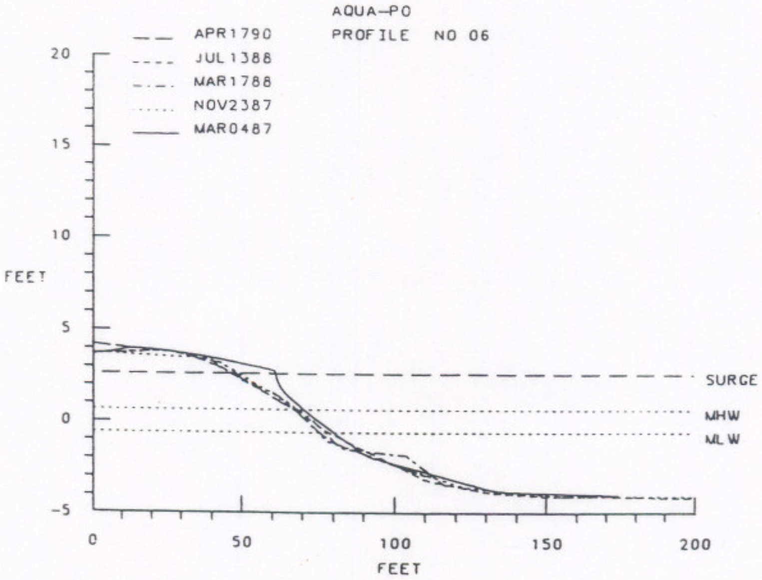
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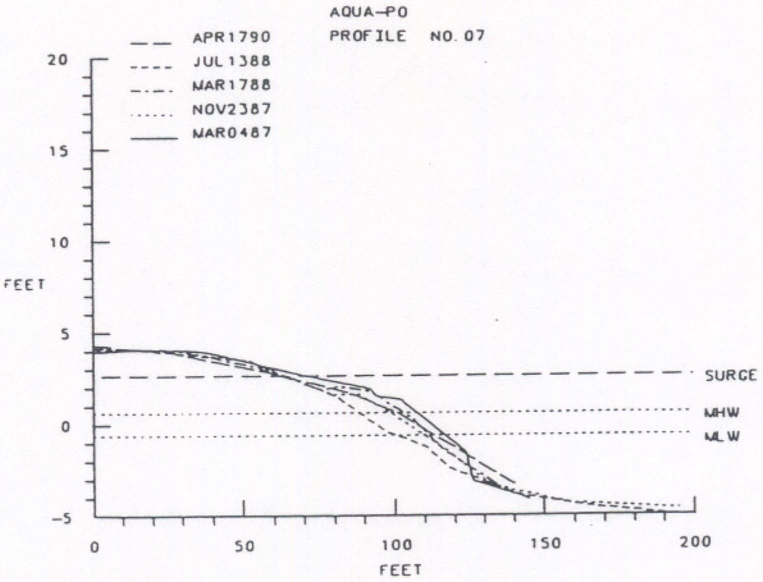
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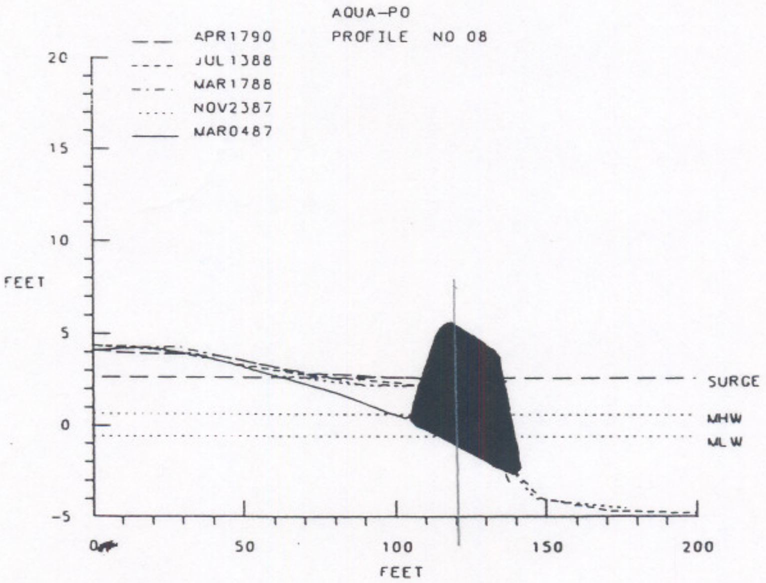
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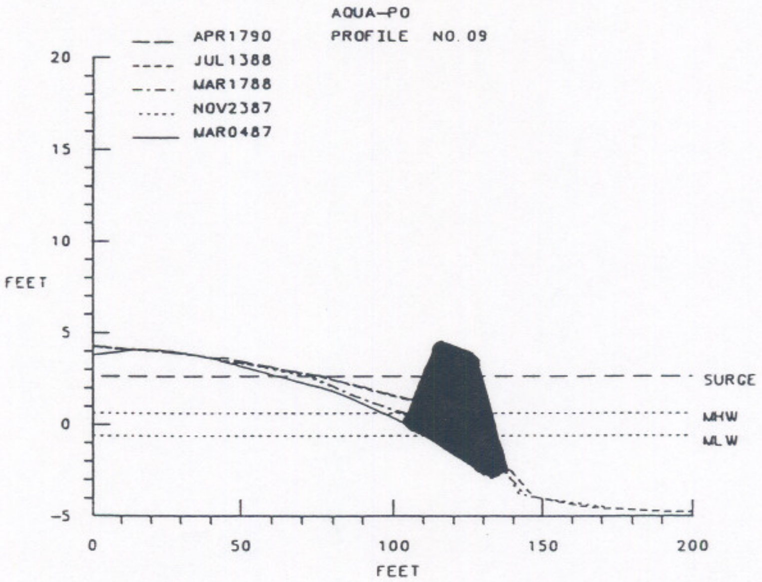
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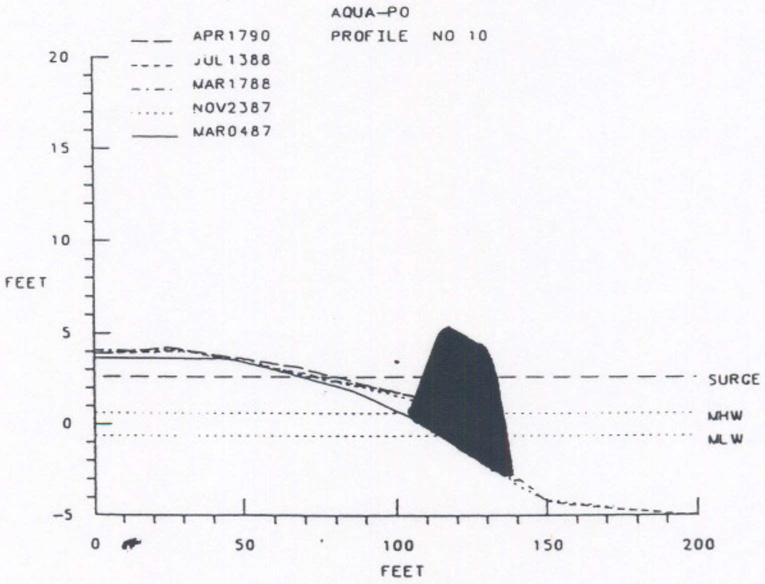
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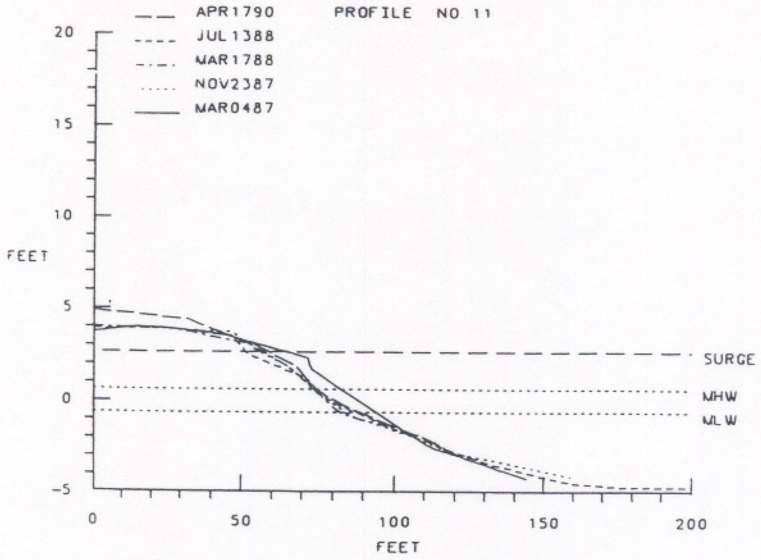
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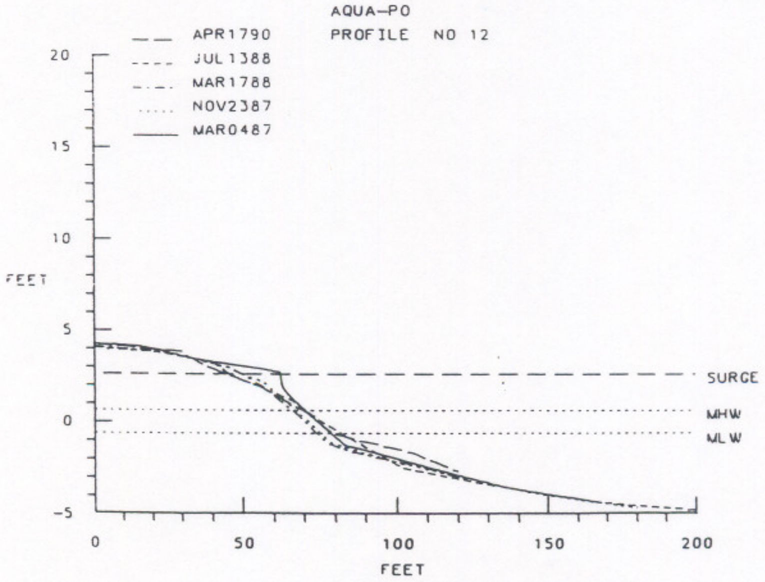
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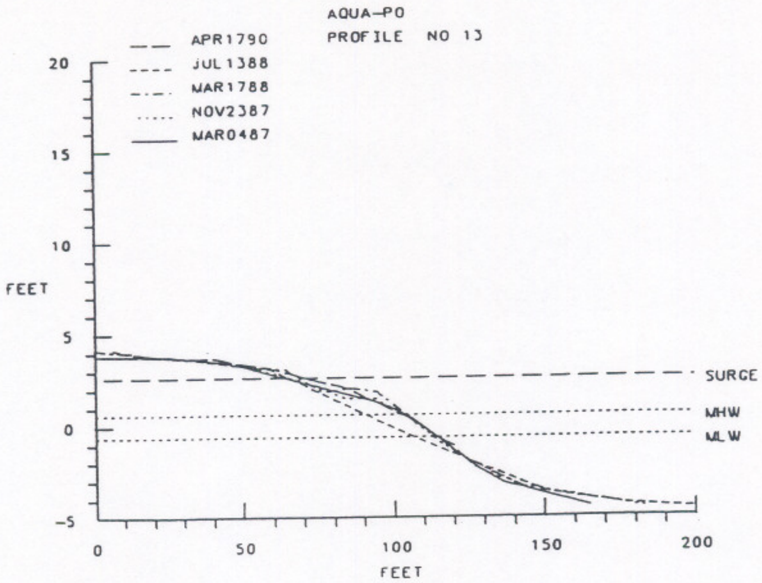
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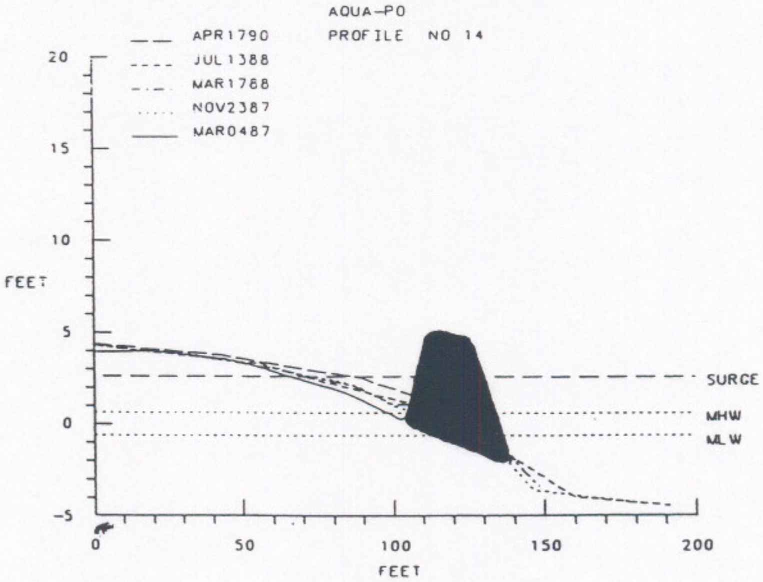
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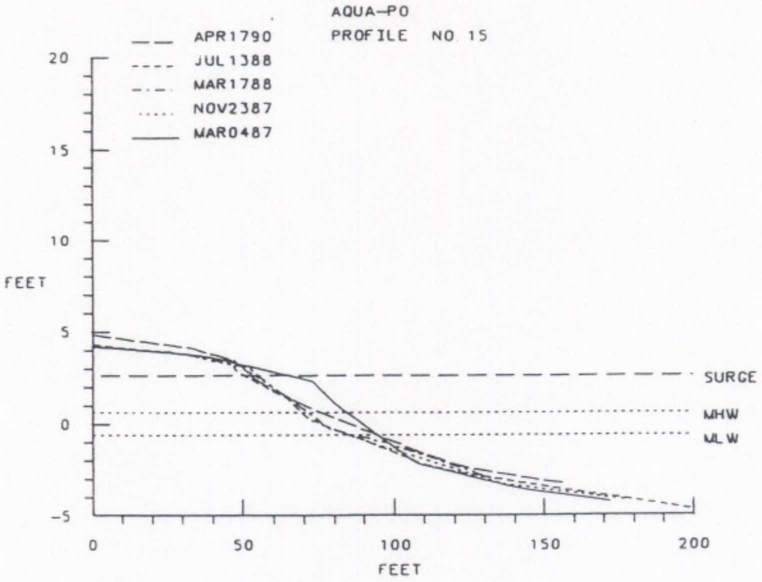
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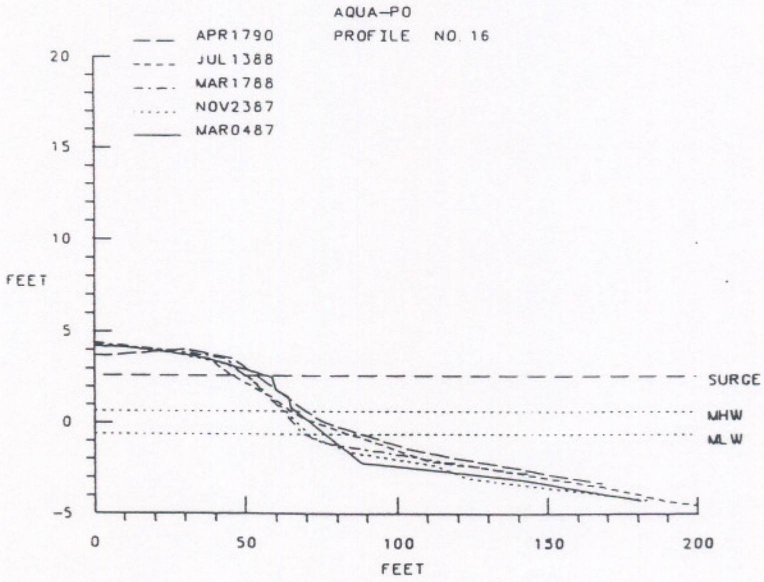
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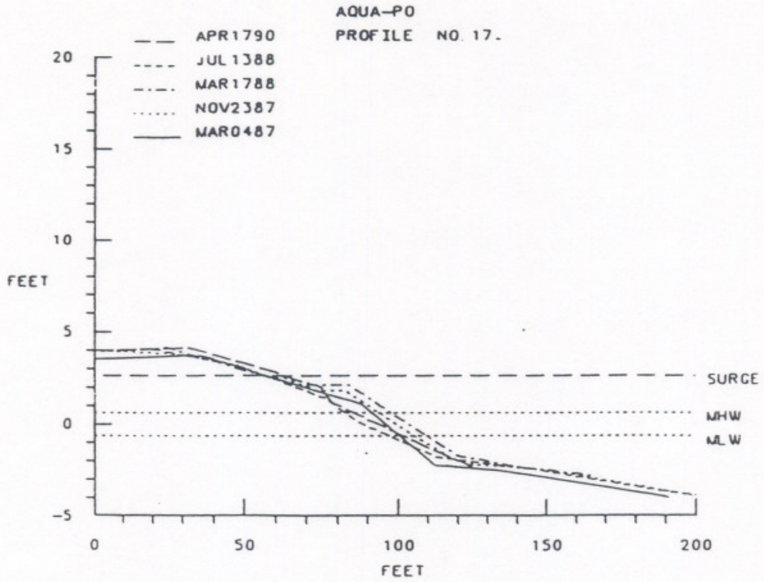
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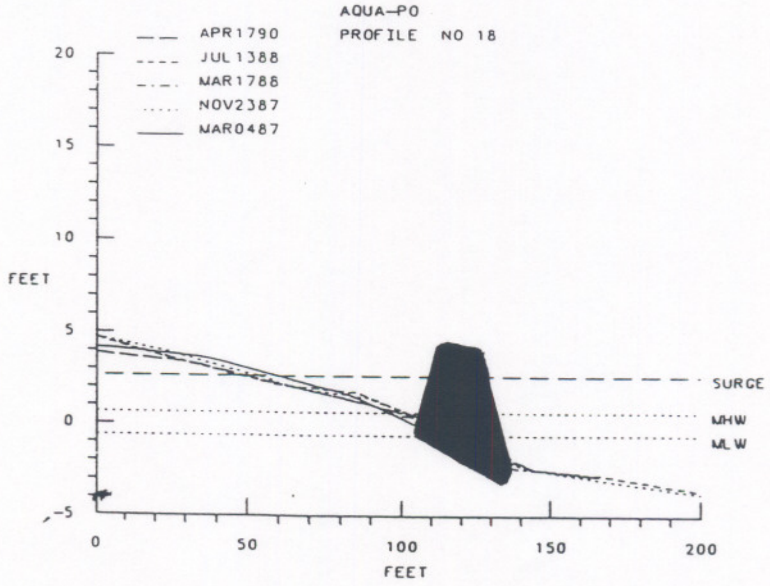
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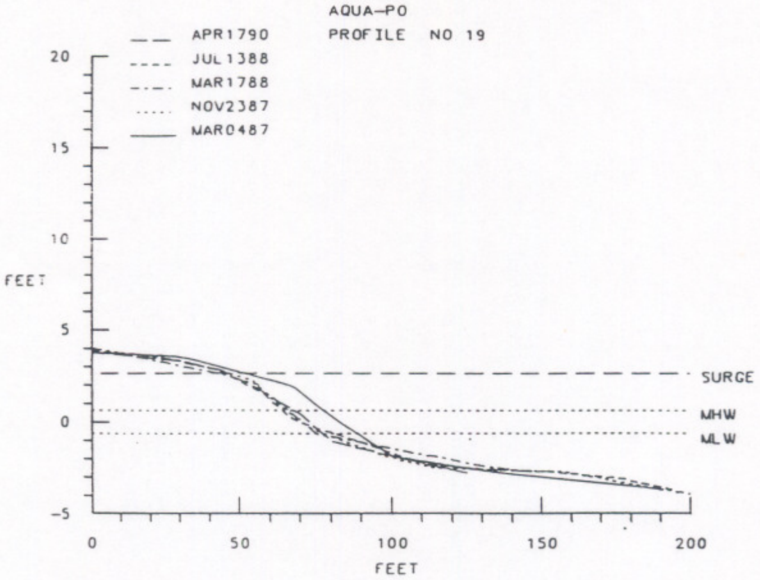
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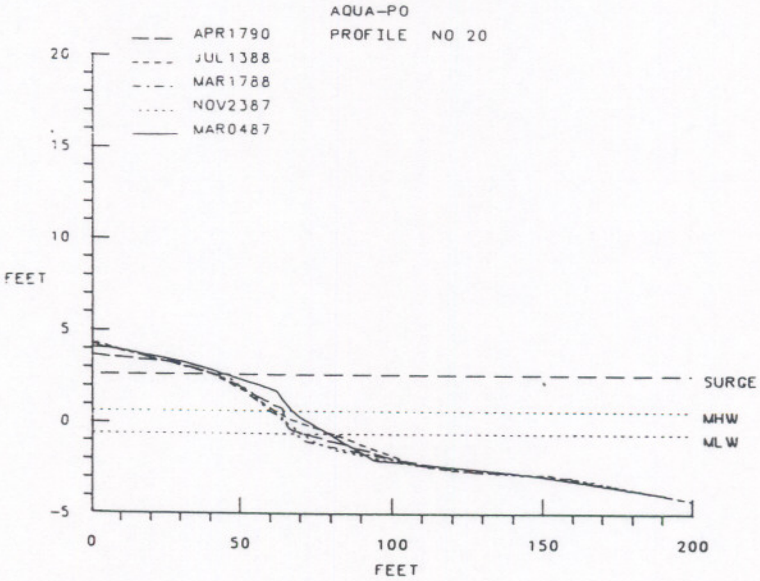
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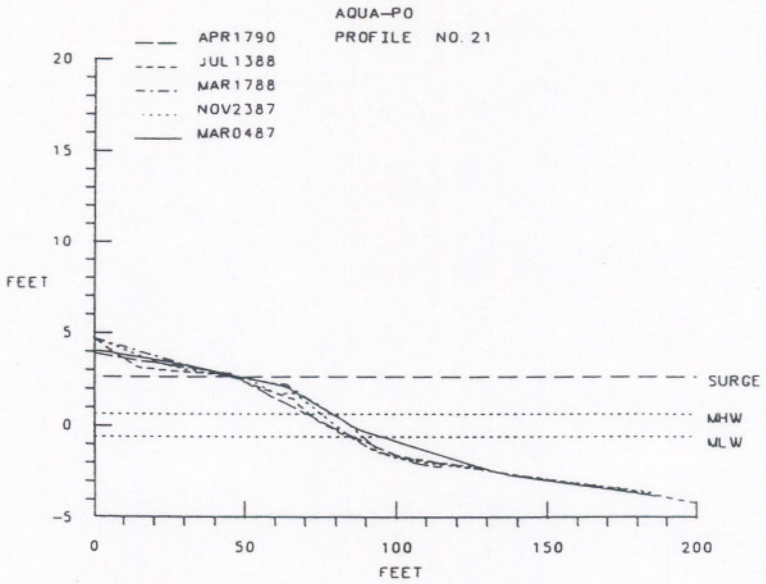
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APPENDIX II

RAW SEDIMENT DATA

Mz = Mean grain size

Md = Median grain size

SI = Standard deviation

SKI= Skewness

KG = Kurtosis

```
AQPOP6_1        (backshore - BS)
AQUA PO P6-1

     0.0        0.0        0.00  Lat  Lon  Depth(m)  Operator: CF
   724.7537  Dry Sand Fraction Weight (mg)
  2.65       Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.3534  0.6792  0.4507  3.5540  M1 M2 M3 M4 (phi)
  1.3288  1.3033  0.6601  0.0868  0.6781  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)* Im.Wt(mg) Im.Wt(%)  Cm.Wt(mg)  Cm.Wt(%)
 -1.0000    2.0000   20.1167    0.0000   0.0000    0.0000    0.0000
 -0.8750    1.8340   18.9156    0.0000   0.0000    0.0000    0.0000
 -0.7500    1.6818   17.7631    0.0000   0.0000    0.0000    0.0000
 -0.6250    1.5422   16.6582    0.0000   0.0000    0.0000    0.0000
 -0.5000    1.4142   15.6003    0.7556   0.1690    0.7556    0.1690
 -0.3750    1.2968   14.5884    0.1804   0.0403    0.9360    0.2093
 -0.2500    1.1892   13.6217    0.2615   0.0585    1.1975    0.2678
 -0.1250    1.0905   12.6995    1.7213   0.3850    2.9188    0.6528
  0.0000    1.0000   11.8208    2.8469   0.6367    5.7656    1.2895
  0.1250    0.9170   10.9848    7.5473   1.6879   13.3129    2.9774
  0.2500    0.8409   10.1905    4.4986   1.0061   17.8115    3.9835
  0.3750    0.7711    9.4370   11.2944   2.5260   29.1059    6.5095
   .5000    0.7071    8.7233   11.7714   2.6326   40.8773    9.1421
  0.6250    0.6484    8.0484   18.5988   4.1596   59.4761   13.3017
  0.7500    0.5946    7.4111   18.4075   4.1168   77.8836   17.4185
  0.8750    0.5453    6.8104   23.7573   5.3133  101.6409   22.7318
  1.0000    0.5000    6.2452   31.3369   7.0084  132.9778   29.7403
  1.1250    0.4585    5.7143   36.3950   8.1397  169.3728   37.8799
  1.2500    0.4204    5.2167   39.4223   8.8167  208.7951   46.6967
  1.3750    0.3856    4.7510   34.6459   7.7485  243.4410   54.4452
  1.5000    0.3536    4.3163   32.6395   7.2998  276.0805   61.7449
  1.6250    0.3242    3.9113   29.7172   6.6462  305.7976   68.3911
  1.7500    0.2973    3.5349   31.3505   7.0115  337.1481   75.4026
  1.8750    0.2726    3.1860   22.9493   5.1326  360.0974   80.5352
  2.0000    0.2500    2.8634   19.1656   4.2864  379.2631   84.8215
  2.1250    0.2293    2.5660   15.4815   3.4624  394.7445   88.2839
  2.2500    0.2102    2.2927   11.1765   2.4996  405.9211   90.7836
  2.3750    0.1928    2.0423   10.1961   2.2803  416.1172   93.0639
  2.5000    0.1768    1.8137    5.9549   1.3318  422.0721   94.3957
  2.6250    0.1621    1.6058    5.3560   1.1979  427.4281   95.5936
  2.7500    0.1487    1.4175    3.6208   0.8098  431.0489   96.4034
  2.8750    0.1363    1.2476    2.6507   0.5928  433.6996   96.9962
  3.0000    0.1250    1.0949    2.2560   0.5045  435.9556   97.5007
  3.1250    0.1146    0.9582    4.6489   1.0397  440.6046   98.5405
  3.2500    0.1051    0.8364    0.6445   0.1441  441.2490   98.6846
   .3750    0.0964    0.7282    1.6815   0.3761  442.9305   99.0606
  3.5000    0.0884    0.6326    3.1796   0.7111  446.1101   99.7717
  3.6250    0.0811    0.5484    0.5103   0.1141  446.6204   99.8859
   .7500    0.0743    0.4744    0.5103   0.1141  447.1306  100.0000
  3.8750    0.0682    0.4098    0.0000   0.0000  447.1306  100.0000
  4.0000    0.0625    0.3533    0.0000   0.0000  447.1306  100.0000
  4.1250    0.0573    0.3043    0.0000   0.0000  447.1306  100.0000
  4.2500    0.0526    0.2617    0.0000   0.0000  447.1306  100.0000
  4.3750    0.0482    0.2248    0.0000   0.0000  447.1306  100.0000
  4.5000    0.0442    0.1930    0.0000   0.0000  447.1306  100.0000
```

* - fall velocity of natural grains in fresh water at 20oC

```
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   I---------------------------------------------I
30 I                                             I
   I                                             I
   I                                             I
   I                                             I
   I                                             I
20 I                                             I
   I                                             I
   I                                             I
   I                                             I
   I                                             I
10 I                                             I
   I                 **                          I
   I                *******                      I
   I             ************                    I
   I           *****************                 I
   I---------------------------------------------I
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
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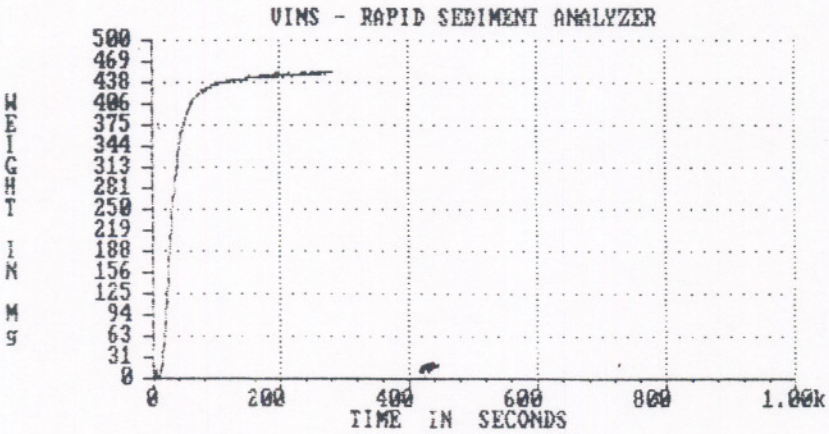

```
AQPOP6_3      (mid-shore - MS)
AQUA PO P6-3

    0.0       0.0       0.00   Lat  Lon  Depth(m)  Operator: CF
  565.6997  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.6816   0.4807 -0.0772   4.7921   M1 M2 M3 M4 (phi)
  1.6769   1.6802  0.4497   0.0039   0.4469   Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)   Wn(cm/s)* Im.Wt(mg) Im.Wt(%)  Cm.Wt(mg)  Cm.Wt(%)
 -1.0000    2.0000    20.1167    0.0935   0.0271    0.0935     0.0271
 -0.8750    1.8340    18.9156    0.2857   0.0829    0.3792     0.1100
 -0.7500    1.6818    17.7631    0.0000   0.0000    0.3792     0.1100
 -0.6250    1.5422    16.6582    0.0000   0.0000    0.3792     0.1100
 -0.5000    1.4142    15.6003    0.0000   0.0000    0.3792     0.1100
 -0.3750    1.2968    14.5884    0.0000   0.0000    0.3792     0.1100
 -0.2500    1.1892    13.6217    0.0000   0.0000    0.3792     0.1100
 -0.1250    1.0905    12.6995    0.1999   0.0580    0.5792     0.1679
  0.0000    1.0000    11.8208    0.5138   0.1490    1.0929     0.3169
  0.1250    0.9170    10.9848    0.0264   0.0077    1.1193     0.3246
  0.2500    0.8409    10.1905    0.0264   0.0077    1.1458     0.3323
  0.3750    0.7711     9.4370    1.0125   0.2936    2.1582     0.6259
   .5000    0.7071     8.7233    1.0173   0.2950    3.1756     0.9209
  0.6250    0.6484     8.0484    3.2023   0.9286    6.3779     1.8495
  0.7500    0.5946     7.4111    4.2536   1.2335   10.6314     3.0830
  0.8750    0.5453     6.8104    2.2746   0.6596   12.9061     3.7426
  1.0000    0.5000     6.2452    9.7261   2.8205   22.6321     6.5631
  1.1250    0.4585     5.7143   15.8245   4.5889   38.4566    11.1520
  1.2500    0.4204     5.2167   18.3517   5.3218   56.8083    16.4738
  1.3750    0.3856     4.7510   23.4670   6.8052   80.2753    23.2790
  1.5000    0.3536     4.3163   33.0296   9.5783  113.3049    32.8573
  1.6250    0.3242     3.9113   41.1207  11.9246  154.4257    44.7819
  1.7500    0.2973     3.5349   40.7607  11.8202  195.1863    56.6020
  1.8750    0.2726     3.1860   37.6093  10.9063  232.7956    67.5083
  2.0000    0.2500     2.8634   32.5660   9.4438  265.3616    76.9521
  2.1250    0.2293     2.5660   27.2386   7.8989  292.6002    84.8511
  2.2500    0.2102     2.2927   17.6203   5.1097  310.2205    89.9608
  2.3750    0.1928     2.0423   12.2533   3.5533  322.4738    93.5141
  2.5000    0.1768     1.8137    7.6231   2.2106  330.0970    95.7247
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  3.2500    0.1051     0.8364    0.5497   0.1594  343.5584    99.6284
   .3750    0.0964     0.7282    0.4271   0.1239  343.9855    99.7523
  3.5000    0.0884     0.6326    0.4271   0.1239  344.4126    99.8761
  3.6250    0.0811     0.5484    0.4271   0.1239  344.8397   100.0000
  3.7500    0.0743     0.4744    0.0000   0.0000  344.8397   100.0000
  3.8750    0.0682     0.4098    0.0000   0.0000  344.8397   100.0000
  4.0000    0.0625     0.3533    0.0000   0.0000  344.8397   100.0000
  4.1250    0.0573     0.3043    0.0000   0.0000  344.8397   100.0000
  4.2500    0.0526     0.2617    0.0000   0.0000  344.8397   100.0000
  4.3750    0.0482     0.2248    0.0000   0.0000  344.8397   100.0000
  4.5000    0.0442     0.1930    0.0000   0.0000  344.8397   100.0000
```

```
* - fall velocity of natural grains in fresh water at 20oC
```

```
 AQPOP6_3            1.6816  0.4807 -0.0772  4.7921
    |----------------------------------------------|
30  |                                              |
    |                                              |
    |                                              |
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20  |                                              |
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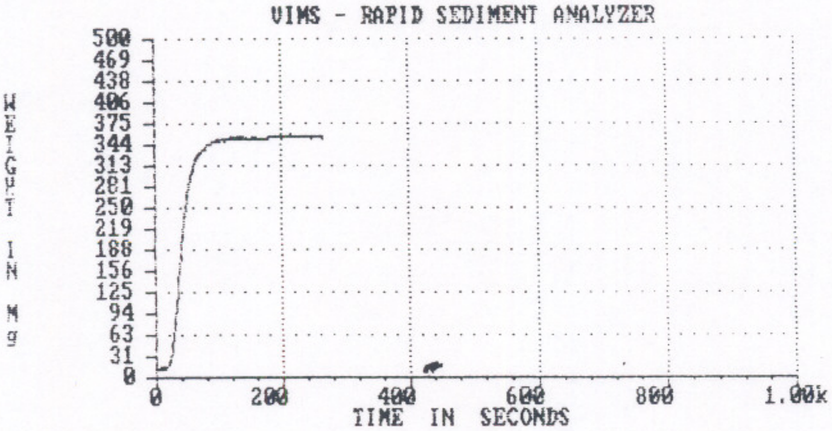
10  |                     ***                      |
    |                    *****                     |
    |                   *******                    |
    |                 **********                   |
    |                ***************               |
    |----------------------------------------------|
     ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
   -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



```
AQPOP6_4        (foreshore - FS)
AQUA PO P6-4

    0.0       0.0       0.00  Lat  Lon  Depth(m)  Operator: CF
   676.1756  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  2.0060  0.9005 -0.2924  2.5624  M1 M2 M3 M4 (phi)
  2.0032  2.0872  0.9300 -0.1381  0.5578  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)* Im.Wt(mg) Im.Wt(%) Cm.Wt(mg) Cm.Wt(%)
 -1.0000    2.0000   20.1167    0.0000  0.0000    0.0000    0.0000
 -0.8750    1.8340   18.9156    0.5222  0.1261    0.5222    0.1261
 -0.7500    1.6818   17.7631    0.5222  0.1261    1.0444    0.2522
 -0.6250    1.5422   16.6582    0.1026  0.0248    1.1470    0.2770
 -0.5000    1.4142   15.6003    0.1026  0.0248    1.2496    0.3018
 -0.3750    1.2968   14.5884    0.2291  0.0553    1.4787    0.3571
 -0.2500    1.1892   13.6217    0.1654  0.0399    1.6441    0.3970
 -0.1250    1.0905   12.6995    0.9325  0.2252    2.5766    0.6222
  0.0000    1.0000   11.8208    2.8780  0.6950    5.4546    1.3172
  0.1250    0.9170   10.9848    0.7859  0.1898    6.2405    1.5070
  0.2500    0.8409   10.1905    3.2911  0.7947    9.5317    2.3017
  0.3750    0.7711    9.4370    8.8991  2.1489   18.4308    4.4506
  0.5000    0.7071    8.7233    4.8884  1.1804   23.3191    5.6311
   .6250    0.6484    8.0484    8.1449  1.9668   31.4641    7.5979
  0.7500    0.5946    7.4111   13.8669  3.3486   45.3310   10.9465
  0.8750    0.5453    6.8104    9.0769  2.1919   54.4078   13.1383
  1.0000    0.5000    6.2452   14.9621  3.6130   69.3699   16.7514
  1.1250    0.4585    5.7143   10.9244  2.6380   80.2943   19.3894
  1.2500    0.4204    5.2167    9.9416  2.4007   90.2358   21.7901
  1.3750    0.3856    4.7510   12.8406  3.1007  103.0764   24.8908
  1.5000    0.3536    4.3163   12.8476  3.1024  115.9240   27.9932
  1.6250    0.3242    3.9113   14.8423  3.5841  130.7664   31.5773
  1.7500    0.2973    3.5349   17.5499  4.2379  148.3163   35.8153
  1.8750    0.2726    3.1860   21.6062  5.2174  169.9224   41.0327
  2.0000    0.2500    2.8634   21.7272  5.2467  191.6496   46.2793
  2.1250    0.2293    2.5660   22.0801  5.3319  213.7297   51.6112
  2.2500    0.2102    2.2927   24.0726  5.8130  237.8022   57.4242
  2.3750    0.1928    2.0423   24.3099  5.8703  262.1121   63.2946
  2.5000    0.1768    1.8137   20.9699  5.0638  283.0821   68.3584
  2.6250    0.1621    1.6058   19.5151  4.7125  302.5971   73.0708
  2.7500    0.1487    1.4175   17.7603  4.2887  320.3574   77.3596
  2.8750    0.1363    1.2476   16.5877  4.0056  336.9452   81.3652
  3.0000    0.1250    1.0949   18.5591  4.4816  355.5043   85.8468
  3.1250    0.1146    0.9582   17.9763  4.3409  373.4806   90.1877
  3.2500    0.1051    0.8364   15.0085  3.6242  388.4891   93.8119
  3.3750    0.0964    0.7282    9.7373  2.3514  398.2264   96.1633
  3.5000    0.0884    0.6326    1.3870  0.3349  399.6134   96.4982
  3.6250    0.0811    0.5484    4.1202  0.9949  403.7337   97.4932
  3.7500    0.0743    0.4744    4.1202  0.9949  407.8539   98.4881
   .8750    0.0682    0.4098    5.1541  1.2446  413.0080   99.7327
  4.0000    0.0625    0.3533    0.0767  0.0185  413.0847   99.7512
  4.1250    0.0573    0.3043    1.0301  0.2488  414.1148  100.0000
  4.2500    0.0526    0.2617    0.0000  0.0000  414.1148  100.0000
  4.3750    0.0482    0.2248    0.0000  0.0000  414.1148  100.0000
  4.5000    0.0442    0.1930    0.0000  0.0000  414.1148  100.0000
```

* - fall velocity of natural grains in fresh water at 20oC

```
AQPOP6_4           2.0060   0.9005 -0.2924   2.5624
   |----------------------------------------------|
30 |                                              |
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20 |                                              |
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10 |                                              |
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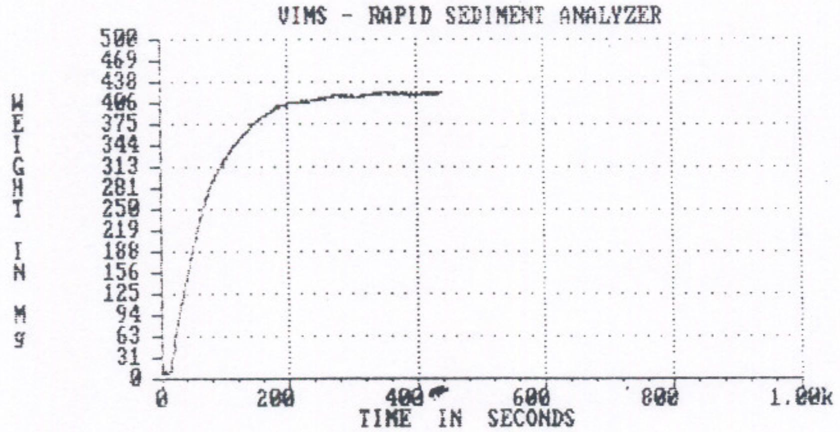
   |                       ************           |
   |           *  **********************          |
   |----------------------------------------------|
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
  -1.0     0.0     1.0     2.0      3.0     4.0   PHI
```



```
AQPO12_1          BS
AQUA PO P12-1

     0.0       0.0       0.00  Lat  Lon  Depth(m)  Operator: CF
   578.6277  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.2859  0.7850  0.3329  3.5194  M1 M2 M3 M4 (phi)
  1.2541  1.2191  0.7441  0.1317  0.7632  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)*  Im.Wt(mg)  Im.Wt(%)  Cm.Wt(mg)  Cm.Wt(%)
 -1.0000    2.0000   20.1167     0.0000    0.0000     0.0000     0.0000
 -0.8750    1.8340   18.9156     0.0000    0.0000     0.0000     0.0000
 -0.7500    1.6818   17.7631     3.8244    1.0735     3.8244     1.0735
 -0.6250    1.5422   16.6582     1.4184    0.3981     5.2428     1.4716
 -0.5000    1.4142   15.6003     0.2310    0.0648     5.4738     1.5365
 -0.3750    1.2968   14.5884     0.8699    0.2442     6.3437     1.7807
 -0.2500    1.1892   13.6217     1.8584    0.5216     8.2021     2.3023
 -0.1250    1.0905   12.6995     2.3304    0.6541    10.5325     2.9564
  0.0000    1.0000   11.8208     2.4095    0.6763    12.9420     3.6328
  0.1250    0.9170   10.9848     2.1844    0.6131    15.1264     4.2459
  0.2500    0.8409   10.1905     6.5572    1.8406    21.6836     6.0865
  0.3750    0.7711    9.4370    15.0880    4.2351    36.7716    10.3216
  0.5000    0.7071    8.7233    12.7645    3.5829    49.5361    13.9045
    6250    0.6484    8.0484    14.7836    4.1497    64.3197    18.0542
  0.7500    0.5946    7.4111    16.9807    4.7664    81.3005    22.8206
  0.8750    0.5453    6.8104    23.3298    6.5485   104.6302    29.3691
  1.0000    0.5000    6.2452    25.7090    7.2164   130.3392    36.5855
  1.1250    0.4585    5.7143    24.0705    6.7564   154.4097    43.3419
  1.2500    0.4204    5.2167    31.5187    8.8471   185.9284    52.1890
  1.3750    0.3856    4.7510    21.1575    5.9388   207.0859    58.1278
  1.5000    0.3536    4.3163    22.8680    6.4189   229.9539    64.5467
  1.6250    0.3242    3.9113    22.3894    6.2846   252.3433    70.8313
  1.7500    0.2973    3.5349    22.8881    6.4246   275.2314    77.2558
  1.8750    0.2726    3.1860    12.1157    3.4008   287.3471    80.6566
  2.0000    0.2500    2.8634    14.1671    3.9766   301.5142    84.6333
  2.1250    0.2293    2.5660    10.2772    2.8847   311.7914    87.5180
  2.2500    0.2102    2.2927     6.9232    1.9433   318.7146    89.4613
  2.3750    0.1928    2.0423     5.5773    1.5655   324.2919    91.0268
  2.5000    0.1768    1.8137     3.0040    0.8432   327.2959    91.8700
  2.6250    0.1621    1.6058     3.0040    0.8432   330.2999    92.7132
  2.7500    0.1487    1.4175     8.2104    2.3046   338.5103    95.0178
  2.8750    0.1363    1.2476     1.3418    0.3766   339.8521    95.3945
  3.0000    0.1250    1.0949     2.0143    0.5654   341.8664    95.9599
  3.1250    0.1146    0.9582     3.1830    0.8935   345.0495    96.8534
  3.2500    0.1051    0.8364     5.3279    1.4955   350.3774    98.3489
  3.3750    0.0964    0.7282     3.6894    1.0356   354.0667    99.3845
    5000    0.0884    0.6326     2.1930    0.6155   356.2597   100.0000
  3.6250    0.0811    0.5484     0.0000    0.0000   356.2597   100.0000
    7500    0.0743    0.4744     0.0000    0.0000   356.2597   100.0000
   .8750    0.0682    0.4098     0.0000    0.0000   356.2597   100.0000
  4.0000    0.0625    0.3533     0.0000    0.0000   356.2597   100.0000
  4.1250    0.0573    0.3043     0.0000    0.0000   356.2597   100.0000
  4.2500    0.0526    0.2617     0.0000    0.0000   356.2597   100.0000
  4.3750    0.0482    0.2248     0.0000    0.0000   356.2597   100.0000
  4.5000    0.0442    0.1930     0.0000    0.0000   356.2597   100.0000
```

* - fall velocity of natural grains in fresh water at 20oC

```
 AQP012_1           1.2859  0.7850  0.3329  3.5194
   |---------------------------------------------|
30 |                                             |
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   |                                             |
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20 |                                             |
   |                                             |
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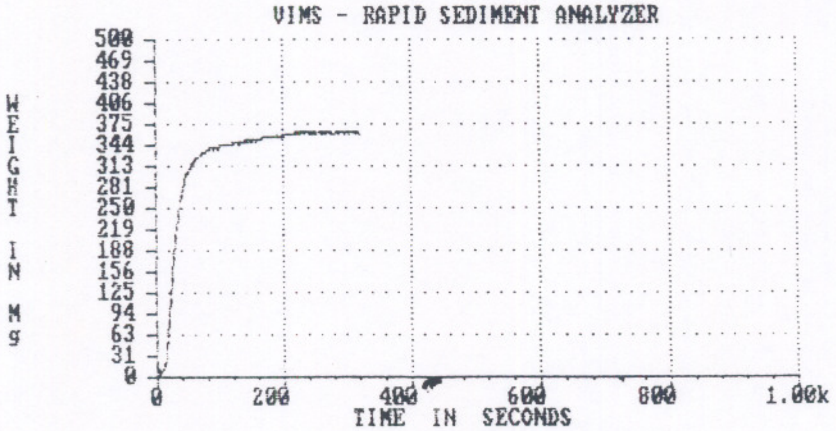
   |                                             |
   |                                             |
10 |                                             |
   |                  *                          |
   |               **** ***                      |
   |           * **********                      |
   |           ***************    *              |
   |---------------------------------------------|
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
  -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



```
AQP012_3          MS
AQUA PO P12-3

    0.0       0.0      0.00  Lat  Lon  Depth(m)  Operator: CF
  714.1762  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.7691  0.5443 -0.1007  4.1531  M1 M2 M3 M4 (phi)
  1.7764  1.7622  0.5051  0.0294  0.4865  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)* Im.Wt(mg) Im.Wt(%) Cm.Wt(mg) Cm.Wt(%)
 -1.0000    2.0000   20.1167    0.0000   0.0000    0.0000    0.0000
 -0.8750    1.8340   18.9156    0.0000   0.0000    0.0000    0.0000
 -0.7500    1.6818   17.7631    0.0380   0.0087    0.0380    0.0087
 -0.6250    1.5422   16.6582    0.0000   0.0000    0.0380    0.0087
 -0.5000    1.4142   15.6003    0.0000   0.0000    0.0380    0.0087
 -0.3750    1.2968   14.5884    0.0000   0.0000    0.0380    0.0087
 -0.2500    1.1892   13.6217    0.0477   0.0109    0.0857    0.0197
 -0.1250    1.0905   12.6995    0.0477   0.0109    0.1334    0.0306
  0.0000    1.0000   11.8208    2.5465   0.5840    2.6799    0.6146
  0.1250    0.9170   10.9848    0.7876   0.1806    3.4675    0.7952
  0.2500    0.8409   10.1905    0.8173   0.1874    4.2848    0.9826
  0.3750    0.7711    9.4370    2.2031   0.5052    6.4879    1.4878
  0.5000    0.7071    8.7233    4.1939   0.9618   10.6818    2.4496
   .6250    0.6484    8.0484    0.6833   0.1567   11.3651    2.6063
  0.7500    0.5946    7.4111    2.9734   0.6819   14.3385    3.2882
  0.8750    0.5453    6.8104    6.2965   1.4440   20.6350    4.7321
  1.0000    0.5000    6.2452    9.4175   2.1597   30.0526    6.8918
  1.1250    0.4585    5.7143   11.5949   2.6590   41.6475    9.5508
  1.2500    0.4204    5.2167   17.3429   3.9772   58.9903   13.5280
  1.3750    0.3856    4.7510   22.8830   5.2477   81.8733   18.7757
  1.5000    0.3536    4.3163   40.5673   9.3031  122.4406   28.0788
  1.6250    0.3242    3.9113   42.7643   9.8070  165.2049   37.8858
  1.7500    0.2973    3.5349   48.1159  11.0342  213.3208   48.9200
  1.8750    0.2726    3.1860   48.4299  11.1062  261.7507   60.0262
  2.0000    0.2500    2.8634   41.4230   9.4994  303.1737   69.5256
  2.1250    0.2293    2.5660   34.2691   7.8588  337.4428   77.3844
  2.2500    0.2102    2.2927   27.5740   6.3234  365.0168   83.7078
  2.3750    0.1928    2.0423   19.6660   4.5099  384.6828   88.2177
  2.5000    0.1768    1.8137   16.6794   3.8250  401.3622   92.0428
  2.6250    0.1621    1.6058   11.1325   2.5530  412.4947   94.5957
  2.7500    0.1487    1.4175    6.6344   1.5214  419.1291   96.1172
  2.8750    0.1363    1.2476    5.4872   1.2583  424.6163   97.3755
  3.0000    0.1250    1.0949    3.6051   0.8267  428.2213   98.2023
  3.1250    0.1146    0.9582    0.8283   0.1900  429.0496   98.3922
  3.2500    0.1051    0.8364    0.9682   0.2220  430.0178   98.6142
  3.3750    0.0964    0.7282    5.3795   1.2337  435.3973   99.8479
   .5000    0.0884    0.6326    0.6632   0.1521  436.0606  100.0000
  3.6250    0.0811    0.5484    0.0000   0.0000  436.0606  100.0000
   .7500    0.0743    0.4744    0.0000   0.0000  436.0606  100.0000
  3.8750    0.0682    0.4098    0.0000   0.0000  436.0606  100.0000
  4.0000    0.0625    0.3533    0.0000   0.0000  436.0606  100.0000
  4.1250    0.0573    0.3043    0.0000   0.0000  436.0606  100.0000
  4.2500    0.0526    0.2617    0.0000   0.0000  436.0606  100.0000
  4.3750    0.0482    0.2248    0.0000   0.0000  436.0606  100.0000
  4.5000    0.0442    0.1930    0.0000   0.0000  436.0606  100.0000
```

```
* - fall velocity of natural grains in fresh water at 20oC
```

```
 AQP012_3           1.7691  0.5443 -0.1007  4.1531
   |---------------------------------------------|
30 |                                             |
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   |                                             |
10 |                      **                     |
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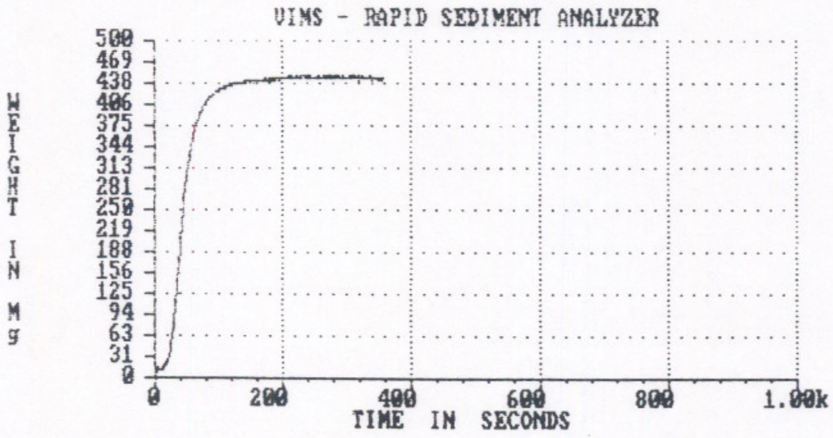
   |                   *********                 |
   |                ***************              |
   |---------------------------------------------|
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
  -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



```
AQPO12_4         FS
AQUA PO P12-4

     0.0       0.0       0.00  Lat  Lon  Depth(m)  Operator: CF
   567.2667  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.0969  0.9157  0.9650  3.4130  M1 M2 M3 M4 (phi)
  1.0841  0.8621  0.8973  0.4058  0.9333  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)* Im.Wt(mg) Im.Wt(%)  Cm.Wt(mg)  Cm.Wt(%)
 -1.0000    2.0000   20.1167    0.0000  0.0000     0.0000    0.0000
 -0.8750    1.8340   18.9156    0.0000  0.0000     0.0000    0.0000
 -0.7500    1.6818   17.7631    0.0000  0.0000     0.0000    0.0000
 -0.6250    1.5422   16.6582    0.3331  0.0957     0.3331    0.0957
 -0.5000    1.4142   15.6003    1.8054  0.5187     2.1385    0.6144
 -0.3750    1.2968   14.5884    2.4091  0.6922     4.5476    1.3066
 -0.2500    1.1892   13.6217    5.1294  1.4738     9.6770    2.7804
 -0.1250    1.0905   12.6995    2.1669  0.6226    11.8439    3.4030
  0.0000    1.0000   11.8208    4.8092  1.3818    16.6531    4.7847
  0.1250    0.9170   10.9848   14.8405  4.2640    31.4937    9.0487
  0.2500    0.8409   10.1905   12.2635  3.5235    43.7571   12.5722
  0.3750    0.7711    9.4370   22.8197  6.5565    66.5769   19.1287
  0.5000    0.7071    8.7233   30.9038  8.8792    97.4806   28.0079
   .6250    0.6484    8.0484   28.8052  8.2762   126.2858   36.2842
  0.7500    0.5946    7.4111   21.8542  6.2791   148.1401   42.5633
  0.8750    0.5453    6.8104   28.8577  8.2913   176.9978   50.8546
  1.0000    0.5000    6.2452   19.6309  5.6403   196.6287   56.4949
  1.1250    0.4585    5.7143   25.5558  7.3426   222.1845   63.8376
  1.2500    0.4204    5.2167   14.9815  4.3044   237.1659   68.1420
  1.3750    0.3856    4.7510   11.4774  3.2977   248.6434   71.4397
  1.5000    0.3536    4.3163   11.4983  3.3037   260.1416   74.7433
  1.6250    0.3242    3.9113    8.5261  2.4497   268.6678   77.1931
  1.7500    0.2973    3.5349    7.5037  2.1560   276.1715   79.3490
  1.8750    0.2726    3.1860    6.0407  1.7356   282.2123   81.0846
  2.0000    0.2500    2.8634    7.4342  2.1360   289.6465   83.2206
  2.1250    0.2293    2.5660    4.5232  1.2996   294.1697   84.5202
  2.2500    0.2102    2.2927    4.8950  1.4064   299.0647   85.9266
  2.3750    0.1928    2.0423    6.9681  2.0021   306.0329   87.9287
  2.5000    0.1768    1.8137    4.0894  1.1749   310.1222   89.1037
  2.6250    0.1621    1.6058    5.4870  1.5765   315.6092   90.6802
  2.7500    0.1487    1.4175    4.6390  1.3329   320.2482   92.0130
  2.8750    0.1363    1.2476    3.4569  0.9932   323.7051   93.0062
  3.0000    0.1250    1.0949    5.8752  1.6881   329.5803   94.6943
  3.1250    0.1146    0.9582    5.3507  1.5373   334.9310   96.2316
  3.2500    0.1051    0.8364    4.9320  1.4171   339.8630   97.6487
  3.3750    0.0964    0.7282    0.9165  0.2633   340.7795   97.9120
   .5000    0.0884    0.6326    1.2279  0.3528   342.0073   98.2648
  3.6250    0.0811    0.5484    1.2279  0.3528   343.2352   98.6176
   .7500    0.0743    0.4744    1.2279  0.3528   344.4631   98.9704
  3.8750    0.0682    0.4098    3.5835  1.0296   348.0466  100.0000
  4.0000    0.0625    0.3533    0.0000  0.0000   348.0466  100.0000
  4.1250    0.0573    0.3043    0.0000  0.0000   348.0466  100.0000
  4.2500    0.0526    0.2617    0.0000  0.0000   348.0466  100.0000
  4.3750    0.0482    0.2248    0.0000  0.0000   348.0466  100.0000
  4.5000    0.0442    0.1930    0.0000  0.0000   348.0466  100.0000
```

* - fall velocity of natural grains in fresh water at 20oC

```
  AQP012_4          1.0969  0.9157  0.9650  3.4130
    |--------------------------------------------|
 30 |                                            |
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 20 |                                            |
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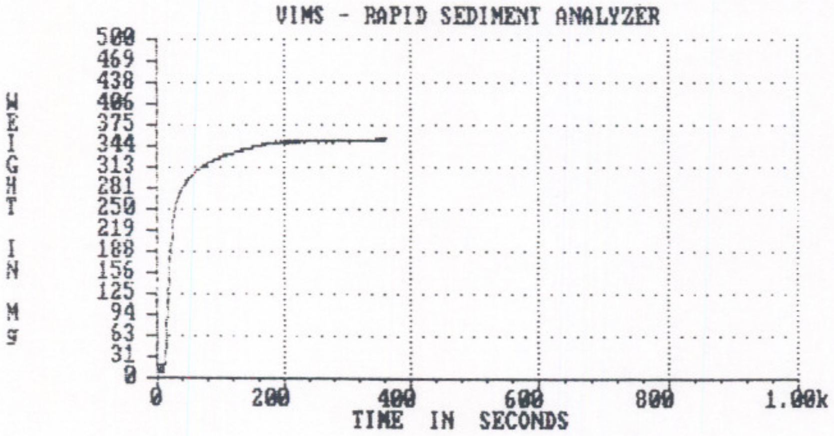
    |                                            |
    |                                            |
 10 |                                            |
    |            ** *                            |
    |           ***** *                          |
    |         * ********                         |
    |         ************** *  *                |
    |--------------------------------------------|
     ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
   -1.0     0.0     1.0     2.0     3.0     4.0  PHI
```



```
AQP016_1          BS
AQUA PO P16-1

    0.0       0.0      0.00  Lat  Lon  Depth(m)  Operator: CF
  661.6806  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.4180  0.7647  0.5144  3.3119  M1 M2 M3 M4 (phi)
  1.3940  1.3437  0.7575  0.1525  0.7255  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)* Im.Wt(mg) Im.Wt(%) Cm.Wt(mg) Cm.Wt(%)
 -1.0000    2.0000   20.1167    0.0000   0.0000    0.0000    0.0000
 -0.8750    1.8340   18.9156    0.0000   0.0000    0.0000    0.0000
 -0.7500    1.6818   17.7631    0.3867   0.0959    0.3867    0.0959
 -0.6250    1.5422   16.6582    0.0000   0.0000    0.3867    0.0959
 -0.5000    1.4142   15.6003    0.0000   0.0000    0.3867    0.0959
 -0.3750    1.2968   14.5884    0.0000   0.0000    0.3867    0.0959
 -0.2500    1.1892   13.6217    0.0000   0.0000    0.3867    0.0959
 -0.1250    1.0905   12.6995    4.8511   1.2035    5.2379    1.2994
  0.0000    1.0000   11.8208    3.8625   0.9582    9.1003    2.2576
  0.1250    0.9170   10.9848    5.5374   1.3737   14.6377    3.6314
  0.2500    0.8409   10.1905    2.6168   0.6492   17.2546    4.2806
  0.3750    0.7711    9.4370    8.2884   2.0562   25.5430    6.3368
  0.5000    0.7071    8.7233   10.8616   2.6946   36.4045    9.0313
   .6250    0.6484    8.0484   15.1027   3.7467   51.5072   12.7781
  0.7500    0.5946    7.4111   21.7181   5.3879   73.2253   18.1659
  0.8750    0.5453    6.8104   21.3877   5.3059   94.6130   23.4719
  1.0000    0.5000    6.2452   28.8788   7.1643  123.4918   30.6362
  1.1250    0.4585    5.7143   28.3150   7.0245  151.8068   37.6607
  1.2500    0.4204    5.2167   27.7169   6.8761  179.5236   44.5368
  1.3750    0.3856    4.7510   29.3719   7.2867  208.8956   51.8234
  1.5000    0.3536    4.3163   28.8242   7.1508  237.7198   58.9742
  1.6250    0.3242    3.9113   26.8959   6.6724  264.6157   65.6466
  1.7500    0.2973    3.5349   22.3016   5.5326  286.9173   71.1793
  1.8750    0.2726    3.1860   18.7393   4.6489  305.6565   75.8282
  2.0000    0.2500    2.8634   16.4476   4.0804  322.1042   79.9086
  2.1250    0.2293    2.5660   15.4627   3.8360  337.5669   83.7446
  2.2500    0.2102    2.2927    9.5754   2.3755  347.1423   86.1201
  2.3750    0.1928    2.0423   11.2210   2.7837  358.3633   88.9038
  2.5000    0.1768    1.8137    7.9610   1.9750  366.3243   90.8788
  2.6250    0.1621    1.6058    6.3503   1.5754  372.6746   92.4542
  2.7500    0.1487    1.4175    6.1446   1.5244  378.8192   93.9786
  2.8750    0.1363    1.2476    3.0065   0.7459  381.8257   94.7245
  3.0000    0.1250    1.0949    3.1236   0.7749  384.9494   95.4994
  3.1250    0.1146    0.9582    3.1236   0.7749  388.0730   96.2743
  3.2500    0.1051    0.8364    7.2497   1.7985  395.3226   98.0728
  3.3750    0.0964    0.7282    3.6240   0.8991  398.9467   98.9719
   .5000    0.0884    0.6326    0.7618   0.1890  399.7085   99.1609
  3.6250    0.0811    0.5484    0.7269   0.1803  400.4354   99.3412
   .7500    0.0743    0.4744    0.7269   0.1803  401.1623   99.5215
  3.8750    0.0682    0.4098    1.9286   0.4785  403.0909  100.0000
  4.0000    0.0625    0.3533    0.0000   0.0000  403.0909  100.0000
  4.1250    0.0573    0.3043    0.0000   0.0000  403.0909  100.0000
  4.2500    0.0526    0.2617    0.0000   0.0000  403.0909  100.0000
  4.3750    0.0482    0.2248    0.0000   0.0000  403.0909  100.0000
  4.5000    0.0442    0.1930    0.0000   0.0000  403.0909  100.0000
```

```
* - fall velocity of natural grains in fresh water at 20oC
```

```
  AQP016_1           1.4180  0.7647  0.5144  3.3119
    |---------------------------------------------|
 30 |                                             |
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 10 |                                             |
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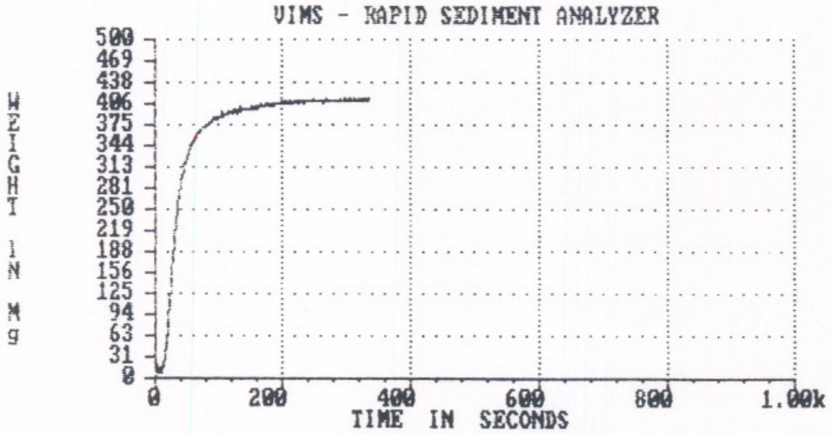
    |                ******                       |
    |              ***********                    |
    |           *****************                 |
    |---------------------------------------------|
     ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
   -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



```
AQP016_3        MS
AQUA PO P16_3

    0.0       0.0       0.00  Lat  Lon  Depth(m)  Operator: CF
  609.5767  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.6149  0.6571  0.4789  4.1733  M1 M2 M3 M4 (phi)
  1.5880  1.5897  0.6156  0.0457  0.6131  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)*  Im.Wt(mg)  Im.Wt(%)  Cm.Wt(mg)  Cm.Wt(%)
 -1.0000    2.0000   20.1167     0.0000    0.0000     0.0000    0.0000
 -0.8750    1.8340   18.9156     0.0000    0.0000     0.0000    0.0000
 -0.7500    1.6818   17.7631     0.0000    0.0000     0.0000    0.0000
 -0.6250    1.5422   16.6582     0.0000    0.0000     0.0000    0.0000
 -0.5000    1.4142   15.6003     0.0000    0.0000     0.0000    0.0000
 -0.3750    1.2968   14.5884     0.0000    0.0000     0.0000    0.0000
 -0.2500    1.1892   13.6217     1.8127    0.4800     1.8127    0.4800
 -0.1250    1.0905   12.6995     0.1093    0.0290     1.9220    0.5090
  0.0000    1.0000   11.8208     0.5245    0.1389     2.4466    0.6479
  0.1250    0.9170   10.9848     0.5245    0.1389     2.9711    0.7868
  0.2500    0.8409   10.1905     1.9156    0.5073     4.8867    1.2940
  0.3750    0.7711    9.4370     5.5854    1.4791    10.4721    2.7731
  0.5000    0.7071    8.7233     2.5835    0.6841    13.0556    3.4573
   .6250    0.6484    8.0484     7.1139    1.8838    20.1695    5.3411
  0.7500    0.5946    7.4111     9.6137    2.5458    29.7833    7.8869
  0.8750    0.5453    6.8104    12.0844    3.2001    41.8677   11.0869
  1.0000    0.5000    6.2452    15.7223    4.1634    57.5900   15.2503
  1.1250    0.4585    5.7143    19.8207    5.2487    77.4107   20.4990
  1.2500    0.4204    5.2167    25.4951    6.7513   102.9058   27.2504
  1.3750    0.3856    4.7510    26.1003    6.9116   129.0061   34.1620
  1.5000    0.3536    4.3163    33.6807    8.9189   162.6868   43.0809
  1.6250    0.3242    3.9113    36.4051    9.6404   199.0919   52.7213
  1.7500    0.2973    3.5349    34.5144    9.1397   233.6063   61.8610
  1.8750    0.2726    3.1860    33.5005    8.8712   267.1069   70.7323
  2.0000    0.2500    2.8634    25.1647    6.6638   292.2716   77.3961
  2.1250    0.2293    2.5660    21.0539    5.5753   313.3255   82.9714
  2.2500    0.2102    2.2927    15.3909    4.0756   328.7164   87.0470
  2.3750    0.1928    2.0423    10.2071    2.7029   338.9234   89.7499
  2.5000    0.1768    1.8137     7.2751    1.9265   346.1986   91.6764
  2.6250    0.1621    1.6058     7.0048    1.8549   353.2033   93.5314
  2.7500    0.1487    1.4175     4.8038    1.2721   358.0071   94.8034
  2.8750    0.1363    1.2476     2.5586    0.6775   360.5657   95.4810
  3.0000    0.1250    1.0949     2.5586    0.6775   363.1244   96.1585
  3.1250    0.1146    0.9582     2.8418    0.7525   365.9661   96.9111
  3.2500    0.1051    0.8364     2.2679    0.6006   368.2340   97.5116
  3.3750    0.0964    0.7282     2.2679    0.6006   370.5019   98.1122
  3.5000    0.0884    0.6326     2.2679    0.6006   372.7698   98.7127
  3.6250    0.0811    0.5484     0.9358    0.2478   373.7056   98.9606
  3.7500    0.0743    0.4744     0.9358    0.2478   374.6414   99.2084
  3.8750    0.0682    0.4098     2.9895    0.7916   377.6309  100.0000
  4.0000    0.0625    0.3533     0.0000    0.0000   377.6309  100.0000
  4.1250    0.0573    0.3043     0.0000    0.0000   377.6309  100.0000
  4.2500    0.0526    0.2617     0.0000    0.0000   377.6309  100.0000
  4.3750    0.0482    0.2248     0.0000    0.0000   377.6309  100.0000
  4.5000    0.0442    0.1930     0.0000    0.0000   377.6309  100.0000
```

```
AQPO16_4          FS
AQUA PO P16-4

    0.0       0.0      0.00  Lat  Lon  Depth(m)  Operator: CF
  707.1246  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.2391  0.8934  0.7782  3.2112  M1 M2 M3 M4 (phi)
  1.2324  1.0299  0.8861  0.3408  0.8183  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)* Im.Wt(mg) Im.Wt(%) Cm.Wt(mg) Cm.Wt(%)
 -1.0000    2.0000   20.1167    0.0000   0.0000    0.0000    0.0000
 -0.8750    1.8340   18.9156    0.3119   0.0718    0.3119    0.0718
 -0.7500    1.6818   17.7631    0.3119   0.0718    0.6239    0.1435
 -0.6250    1.5422   16.6582    1.3944   0.3208    2.0182    0.4643
 -0.5000    1.4142   15.6003    0.5714   0.1315    2.5897    0.5958
 -0.3750    1.2968   14.5884    0.5714   0.1315    3.1611    0.7272
 -0.2500    1.1892   13.6217    4.5437   1.0453    7.7047    1.7726
 -0.1250    1.0905   12.6995    3.4129   0.7852   11.1177    2.5578
  0.0000    1.0000   11.8208    3.4129   0.7852   14.5306    3.3430
  0.1250    0.9170   10.9848   14.2652   3.2819   28.7958    6.6249
  0.2500    0.8409   10.1905   12.2720   2.8234   41.0679    9.4482
  0.3750    0.7711    9.4370   16.9009   3.8883   57.9688   13.3365
   .5000    0.7071    8.7233   19.9540   4.5907   77.9228   17.9272
  0.6250    0.6484    8.0484   26.3213   6.0556  104.2441   23.9828
  0.7500    0.5946    7.4111   35.8342   8.2442  140.0783   32.2270
  0.8750    0.5453    6.8104   28.5087   6.5588  168.5870   38.7858
  1.0000    0.5000    6.2452   40.5749   9.3348  209.1619   48.1206
  1.1250    0.4585    5.7143   34.1439   7.8553  243.3058   55.9759
  1.2500    0.4204    5.2167   24.6154   5.6631  267.9212   61.6390
  1.3750    0.3856    4.7510   20.2203   4.6520  288.1415   66.2910
  1.5000    0.3536    4.3163   14.5358   3.3442  302.6773   69.6352
  1.6250    0.3242    3.9113   13.6000   3.1289  316.2773   72.7640
  1.7500    0.2973    3.5349   11.9130   2.7408  328.1904   75.5048
  1.8750    0.2726    3.1860   10.4336   2.4004  338.6239   77.9052
  2.0000    0.2500    2.8634    8.4113   1.9351  347.0352   79.8403
  2.1250    0.2293    2.5660    9.7529   2.2438  356.7881   82.0841
  2.2500    0.2102    2.2927   10.9697   2.5237  367.7578   84.6078
  2.3750    0.1928    2.0423   10.2252   2.3524  377.9830   86.9603
  2.5000    0.1768    1.8137    8.8258   2.0305  386.8088   88.9908
  2.6250    0.1621    1.6058    5.6256   1.2942  392.4344   90.2850
  2.7500    0.1487    1.4175    5.9440   1.3675  398.3784   91.6525
  2.8750    0.1363    1.2476    7.5535   1.7378  405.9319   93.3903
  3.0000    0.1250    1.0949    7.7937   1.7931  413.7256   95.1834
  3.1250    0.1146    0.9582    1.7157   0.3947  415.4413   95.5781
  3.2500    0.1051    0.8364    6.5938   1.5170  422.0351   97.0951
   .3750    0.0964    0.7282    1.3077   0.3009  423.3429   97.3960
  3.5000    0.0884    0.6326    1.9530   0.4493  425.2959   97.8453
  3.6250    0.0811    0.5484    2.7723   0.6378  428.0683   98.4831
   .7500    0.0743    0.4744    4.4228   1.0175  432.4910   99.5006
  3.8750    0.0682    0.4098    2.0348   0.4681  434.5258   99.9688
  4.0000    0.0625    0.3533    0.1358   0.0312  434.6617  100.0000
  4.1250    0.0573    0.3043    0.0000   0.0000  434.6617  100.0000
  4.2500    0.0526    0.2617    0.0000   0.0000  434.6617  100.0000
  4.3750    0.0482    0.2248    0.0000   0.0000  434.6617  100.0000
  4.5000    0.0442    0.1930    0.0000   0.0000  434.6617  100.0000
```

* - fall velocity of natural grains in fresh water at 20oC

```
 AQP016_4           1.2391  0.8934  0.7782  3.2112
   |---------------------------------------------|
30 |                                             |
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20 |                                             |
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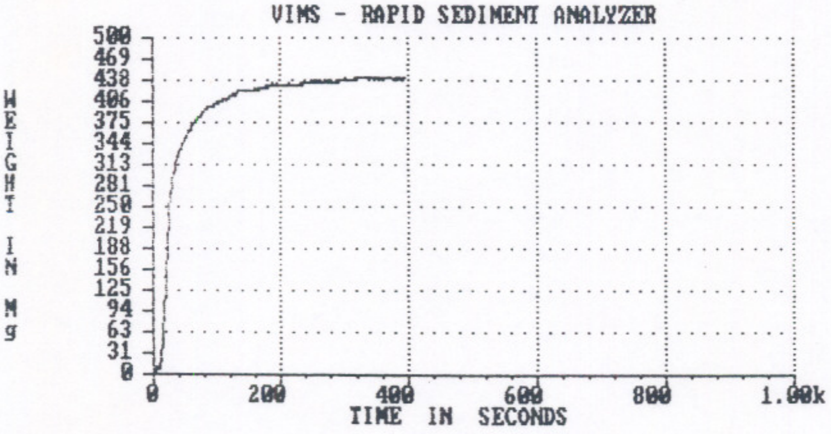
   |                                             |
   |                                             |
10 |                                             |
   |              * *                            |
   |             *****                           |
   |            ********                         |
   |         *************** ****                |
   |---------------------------------------------|
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
  -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



```
AQP020_1          BS
AQUA PO P20-1

    0.0       0.0      0.00  Lat  Lon  Depth(m)  Operator: CF
   623.6800  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.4369  0.6777  0.3929  3.2958  M1 M2 M3 M4 (phi)
  1.4285  1.3736  0.6747  0.1621  0.6920  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)* Im.Wt(mg) Im.Wt(%) Cm.Wt(mg) Cm.Wt(%)
 -1.0000    2.0000   20.1167    0.0000   0.0000    0.0000    0.0000
 -0.8750    1.8340   18.9156    0.0000   0.0000    0.0000    0.0000
 -0.7500    1.6818   17.7631    0.0000   0.0000    0.0000    0.0000
 -0.6250    1.5422   16.6582    0.1969   0.0511    0.1969    0.0511
 -0.5000    1.4142   15.6003    0.1969   0.0511    0.3937    0.1022
 -0.3750    1.2968   14.5884    0.3017   0.0783    0.6955    0.1805
 -0.2500    1.1892   13.6217    1.2329   0.3200    1.9284    0.5005
 -0.1250    1.0905   12.6995    0.8034   0.2085    2.7318    0.7090
  0.0000    1.0000   11.8208    3.5212   0.9139    6.2529    1.6228
  0.1250    0.9170   10.9848    0.7913   0.2054    7.0443    1.8282
  0.2500    0.8409   10.1905    5.5815   1.4486   12.6258    3.2768
  0.3750    0.7711    9.4370    4.1938   1.0884   16.8195    4.3652
  0.5000    0.7071    8.7233    6.3140   1.6387   23.1335    6.0039
  0.6250    0.6484    8.0484   12.1229   3.1463   35.2564    9.1501
  0.7500    0.5946    7.4111   15.1897   3.9422   50.4461   13.0923
  0.8750    0.5453    6.8104   19.6510   5.1000   70.0971   18.1924
  1.0000    0.5000    6.2452   27.3334   7.0939   97.4305   25.2862
  1.1250    0.4585    5.7143   28.6824   7.4440  126.1129   32.7302
  1.2500    0.4204    5.2167   34.2548   8.8902  160.3677   41.6204
  1.3750    0.3856    4.7510   32.6588   8.4760  193.0264   50.0963
  1.5000    0.3536    4.3163   32.6292   8.4683  225.6557   58.5646
  1.6250    0.3242    3.9113   30.5058   7.9172  256.1615   66.4818
  1.7500    0.2973    3.5349   23.9248   6.2092  280.0863   72.6911
  1.8750    0.2726    3.1860   20.3195   5.2735  300.4058   77.9646
  2.0000    0.2500    2.8634   13.9295   3.6151  314.3353   81.5798
  2.1250    0.2293    2.5660   12.8555   3.3364  327.1908   84.9161
  2.2500    0.2102    2.2927   10.9610   2.8447  338.1517   87.7609
  2.3750    0.1928    2.0423    7.1341   1.8515  345.2858   89.6124
  2.5000    0.1768    1.8137    9.8456   2.5552  355.1314   92.1676
  2.6250    0.1621    1.6058    6.1915   1.6069  361.3230   93.7745
  2.7500    0.1487    1.4175    3.8214   0.9918  365.1444   94.7663
  2.8750    0.1363    1.2476    3.5014   0.9087  368.6458   95.6750
  3.0000    0.1250    1.0949    8.9968   2.3350  377.6426   98.0100
  3.1250    0.1146    0.9582    1.5629   0.4056  379.2054   98.4156
  3.2500    0.1051    0.8364    4.2879   1.1128  383.4933   99.5284
  3.3750    0.0964    0.7282    1.3224   0.3432  384.8158   99.8716
  3.5000    0.0884    0.6326    0.2839   0.0737  385.0997   99.9453
  3.6250    0.0811    0.5484    0.1054   0.0274  385.2051   99.9726
  3.7500    0.0743    0.4744    0.1054   0.0274  385.3104  100.0000
  3.8750    0.0682    0.4098    0.0000   0.0000  385.3104  100.0000
  4.0000    0.0625    0.3533    0.0000   0.0000  385.3104  100.0000
  4.1250    0.0573    0.3043    0.0000   0.0000  385.3104  100.0000
  4.2500    0.0526    0.2617    0.0000   0.0000  385.3104  100.0000
  4.3750    0.0482    0.2248    0.0000   0.0000  385.3104  100.0000
```

```
* - fall velocity of natural grains in fresh water at 20oC
```

```
 AQP016_3           1.6149  0.6571  0.4789  4.1733
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10 |                                             |
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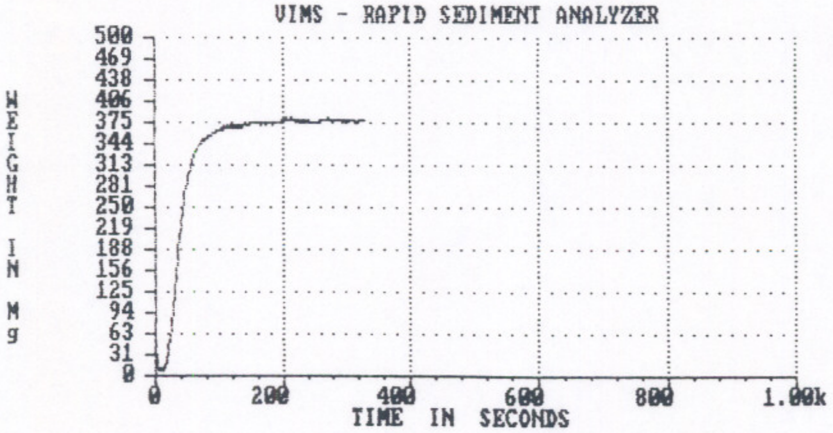
   |              **************                 |
   |---------------------------------------------|
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
  -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



* - fall velocity of natural grains in fresh water at 20oC

```
   AQPO20_1           1.4369  0.6777  0.3929  3.2958
     |---------------------------------------------|
  30 |                                             |
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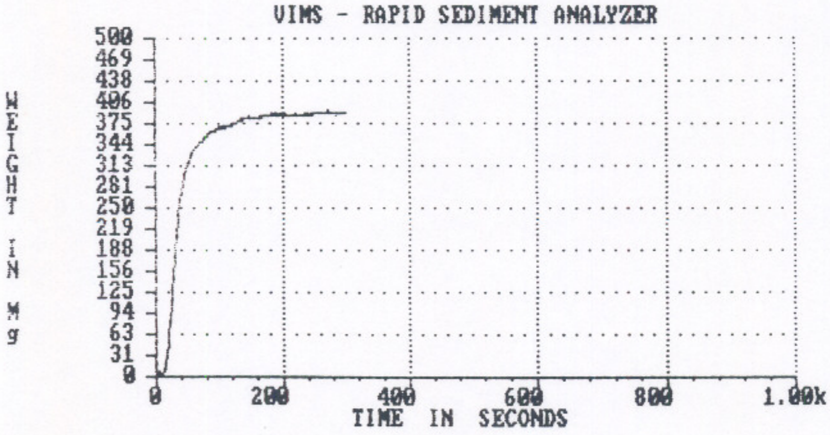
  10 |                                             |
     |                  ***                        |
     |                *******                      |
     |               *********                     |
     |             ************** *   *            |
     |---------------------------------------------|
      ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
    -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



```
AQPO20_3          MS
AQUA PO P20-3

    0.0       0.0       0.00  Lat  Lon  Depth(m)  Operator: CF
  622.5047  Dry Sand Fraction Weight (mg)
  2.65      Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
  1.9230  0.5931  0.2415  3.3963  M1 M2 M3 M4 (phi)
  1.9141  1.8721  0.5887  0.1367  0.5062  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)   Wn(cm/s)* Im.Wt(mg) Im.Wt(%)  Cm.Wt(mg) Cm.Wt(%)
 -1.0000    2.0000    20.1167    0.0000   0.0000    0.0000    0.0000
 -0.8750    1.8340    18.9156    0.0000   0.0000    0.0000    0.0000
 -0.7500    1.6818    17.7631    0.0860   0.0226    0.0860    0.0226
 -0.6250    1.5422    16.6582    0.0860   0.0226    0.1720    0.0451
 -0.5000    1.4142    15.6003    0.0860   0.0226    0.2580    0.0677
 -0.3750    1.2968    14.5884    0.0199   0.0052    0.2779    0.0729
 -0.2500    1.1892    13.6217    0.0000   0.0000    0.2779    0.0729
 -0.1250    1.0905    12.6995    0.0000   0.0000    0.2779    0.0729
  0.0000    1.0000    11.8208    0.0000   0.0000    0.2779    0.0729
  0.1250    0.9170    10.9848    0.4457   0.1169    0.7236    0.1898
  0.2500    0.8409    10.1905    0.4457   0.1169    1.1694    0.3067
  0.3750    0.7711     9.4370    0.4457   0.1169    1.6151    0.4236
   .5000    0.7071     8.7233    1.4305   0.3752    3.0456    0.7987
  0.6250    0.6484     8.0484    1.5650   0.4104    4.6106    1.2092
  0.7500    0.5946     7.4111    1.9553   0.5128    6.5658    1.7220
  0.8750    0.5453     6.8104    4.0091   1.0515   10.5750    2.7734
  1.0000    0.5000     6.2452    5.8599   1.5369   16.4349    4.3103
  1.1250    0.4585     5.7143   12.8960   3.3822   29.3309    7.6925
  1.2500    0.4204     5.2167   10.5706   2.7723   39.9014   10.4648
  1.3750    0.3856     4.7510   22.0041   5.7709   61.9055   16.2357
  1.5000    0.3536     4.3163   21.8851   5.7397   83.7907   21.9754
  1.6250    0.3242     3.9113   35.3943   9.2827  119.1850   31.2581
  1.7500    0.2973     3.5349   32.6288   8.5574  151.8138   39.8155
  1.8750    0.2726     3.1860   39.7439  10.4234  191.5577   50.2389
  2.0000    0.2500     2.8634   33.7003   8.8384  225.2580   59.0773
  2.1250    0.2293     2.5660   32.5045   8.5248  257.7625   67.6021
  2.2500    0.2102     2.2927   25.4588   6.6770  283.2213   74.2791
  2.3750    0.1928     2.0423   19.9280   5.2264  303.1493   79.5055
  2.5000    0.1768     1.8137   17.1017   4.4852  320.2511   83.9907
  2.6250    0.1621     1.6058   14.6207   3.8345  334.8718   87.8252
  2.7500    0.1487     1.4175    9.3342   2.4480  344.2060   90.2733
  2.8750    0.1363     1.2476    9.1881   2.4097  353.3941   92.6830
  3.0000    0.1250     1.0949    6.1582   1.6151  359.5523   94.2981
  3.1250    0.1146     0.9582    7.2794   1.9091  366.8317   96.2072
  3.2500    0.1051     0.8364    7.8453   2.0576  374.6770   98.2648
   .3750    0.0964     0.7282    0.9690   0.2541  375.6460   98.5189
  3.5000    0.0884     0.6326    3.6299   0.9520  379.2759   99.4709
  3.6250    0.0811     0.5484    1.1562   0.3032  380.4321   99.7741
   .7500    0.0743     0.4744    0.8613   0.2259  381.2934  100.0000
  3.8750    0.0682     0.4098    0.0000   0.0000  381.2934  100.0000
  4.0000    0.0625     0.3533    0.0000   0.0000  381.2934  100.0000
  4.1250    0.0573     0.3043    0.0000   0.0000  381.2934  100.0000
  4.2500    0.0526     0.2617    0.0000   0.0000  381.2934  100.0000
  4.3750    0.0482     0.2248    0.0000   0.0000  381.2934  100.0000
  4.5000    0.0442     0.1930    0.0000   0.0000  381.2934  100.0000
```

* - fall velocity of natural grains in fresh water at 20oC

```
 AQPO20_3           1.9230  0.5931  0.2415  3.3963
   |---------------------------------------------|
30 |                                             |
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10 |                       *                     |
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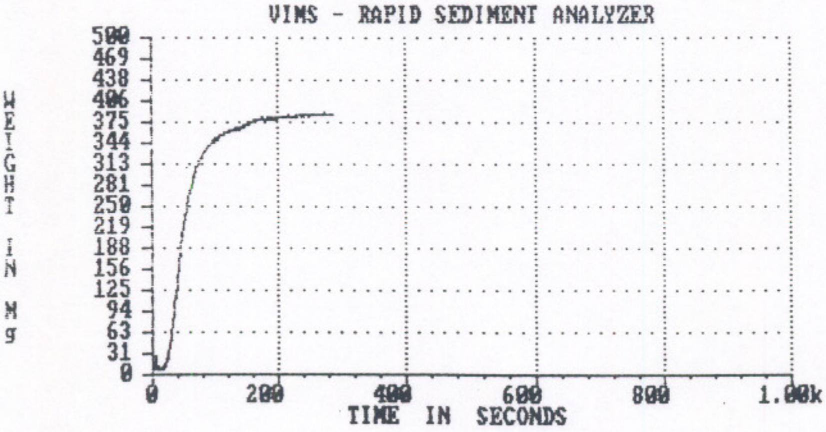
   |                     ******                  |
   |                   **********                |
   |                 ***************  *          |
   |---------------------------------------------|
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
  -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



```
AQPO20_4          FS
AQUA PO P20-4

     0.0      0.0      0.00  Lat  Lon  Depth(m)  Operator: CF
   555.1222  Dry Sand Fraction Weight (mg)
   2.65     Grain density /Natural Grain Fall Time using Wn=0.977Ws^0.913
   2.2918  0.8502 -0.4826  3.2761  M1 M2 M3 M4 (phi)
   2.3505  2.2684  0.8521  0.0152  0.5484  Mz,Md,SI,SKI,KG

Size(phi)  Size(mm)  Wn(cm/s)*  Im.Wt(mg)  Im.Wt(%)  Cm.Wt(mg)  Cm.Wt(%)
 -1.0000    2.0000   20.1167     0.3645    0.1039     0.3645     0.1039
 -0.8750    1.8340   18.9156     0.0000    0.0000     0.3645     0.1039
 -0.7500    1.6818   17.7631     0.0000    0.0000     0.3645     0.1039
 -0.6250    1.5422   16.6582     0.0000    0.0000     0.3645     0.1039
 -0.5000    1.4142   15.6003     0.0000    0.0000     0.3645     0.1039
 -0.3750    1.2968   14.5884     0.4163    0.1187     0.7808     0.2227
 -0.2500    1.1892   13.6217     0.0000    0.0000     0.7808     0.2227
 -0.1250    1.0905   12.6995     0.0000    0.0000     0.7808     0.2227
  0.0000    1.0000   11.8208     0.0000    0.0000     0.7808     0.2227
  0.1250    0.9170   10.9848     5.6317    1.6060     6.4125     1.8287
  0.2500    0.8409   10.1905     3.9161    1.1168    10.3286     2.9454
  0.3750    0.7711    9.4370     3.9161    1.1168    14.2447     4.0622
   .5000    0.7071    8.7233     1.8458    0.5264    16.0905     4.5885
  0.6250    0.6484    8.0484     1.8458    0.5264    17.9364     5.1149
  0.7500    0.5946    7.4111     2.1051    0.6003    20.0415     5.7152
  0.8750    0.5453    6.8104     0.2356    0.0672    20.2771     5.7824
  1.0000    0.5000    6.2452     4.8202    1.3746    25.0973     7.1570
  1.1250    0.4585    5.7143     3.4361    0.9799    28.5334     8.1369
  1.2500    0.4204    5.2167     4.1545    1.1847    32.6879     9.3216
  1.3750    0.3856    4.7510     5.1650    1.4729    37.8529    10.7945
  1.5000    0.3536    4.3163     9.2741    2.6447    47.1270    13.4392
  1.6250    0.3242    3.9113    12.6223    3.5995    59.7493    17.0387
  1.7500    0.2973    3.5349    18.7171    5.3376    78.4664    22.3763
  1.8750    0.2726    3.1860    24.0941    6.8709   102.5605    29.2472
  2.0000    0.2500    2.8634    24.4347    6.9681   126.9952    36.2152
  2.1250    0.2293    2.5660    24.8249    7.0793   151.8201    43.2945
  2.2500    0.2102    2.2927    20.8259    5.9389   172.6459    49.2335
  2.3750    0.1928    2.0423    18.2250    5.1972   190.8709    54.4307
  2.5000    0.1768    1.8137    18.1609    5.1789   209.0318    59.6096
  2.6250    0.1621    1.6058    15.2569    4.3508   224.2887    63.9604
  2.7500    0.1487    1.4175    13.6106    3.8813   237.8993    67.8418
  2.8750    0.1363    1.2476    16.1909    4.6172   254.0902    72.4589
  3.0000    0.1250    1.0949    13.0709    3.7274   267.1611    76.1864
  3.1250    0.1146    0.9582    17.0412    4.8596   284.2024    81.0460
  3.2500    0.1051    0.8364    18.6942    5.3310   302.8966    86.3770
   .3750    0.0964    0.7282    15.6974    4.4764   318.5940    90.8535
  3.5000    0.0884    0.6326     9.9749    2.8445   328.5689    93.6980
  3.6250    0.0811    0.5484     7.8330    2.2337   336.4019    95.9318
  3.7500    0.0743    0.4744     8.0051    2.2828   344.4070    98.2146
  3.8750    0.0682    0.4098     2.2760    0.6490   346.6830    98.8636
  4.0000    0.0625    0.3533     1.7947    0.5118   348.4776    99.3754
  4.1250    0.0573    0.3043     2.1903    0.6246   350.6679   100.0000
  4.2500    0.0526    0.2617     0.0000    0.0000   350.6679   100.0000
  4.3750    0.0482    0.2248     0.0000    0.0000   350.6679   100.0000
  4.5000    0.0442    0.1930     0.0000    0.0000   350.6679   100.0000
```

* - fall velocity of natural grains in fresh water at 20oC

```
 AQP020_4           2.2918  0.8502 -0.4826  3.2761
   |---------------------------------------------|
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10 |                                             |
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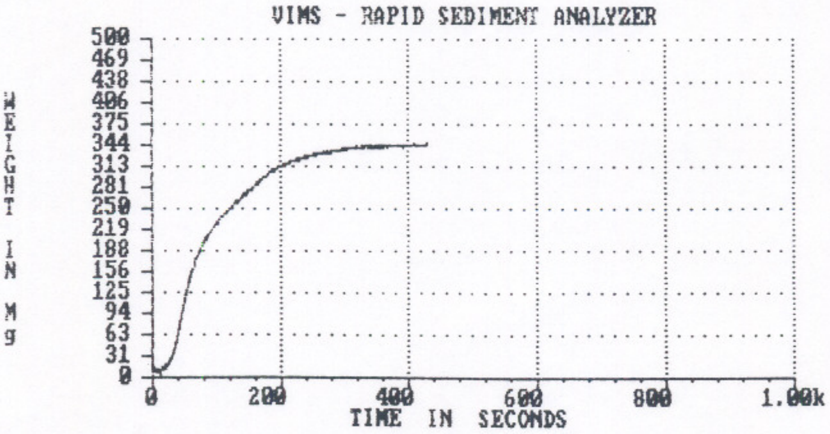
   |                       ***                   |
   |                      ******** * ***         |
   |                    *******************      |
   |---------------------------------------------|
    ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^   ^
  -1.0     0.0     1.0     2.0     3.0     4.0   PHI
```



APPENDIX III

EQUILIBRIUM BAYS

Silvester (1974) considered at least two fixed breakwaters or headlands in his definition of equilibrium shore for the embayed pocket beach. From numerous investigations of natural crenulate or log-spiral bays and physical scale models, Silvester (1974) developed a model to determine maximum bay indentation while knowing the incident wave angle, to the center line of two headland breakwaters.

Oblique incident waves approaching widely spaced breakwaters may cause an effect in the adjacent embayment. Natural headlands and their embayments have been studied by Yasso (1965), Silvester (1974), and others. The planform of the headland-bay beaches is dependent on the predominant direction of wave attack (Yasso, 1965; Silvester, 1974). Headland-bay beaches often are referred to as the aforementioned crenulate or log-spiral bay beaches.

Because of the decreasing radius of plan curvature that characteristically occurs toward the headland and because the rate of decrease in radius curvature appears to be non-linear, Yasso (1965) tested the equiangular (logarithmic) spiral,

$$R_2/R_1 = e^{\theta \cot \alpha}$$

for goodness of fit to the plan shape of headland-bay beaches. In the equation above, R_2/R_1 is the ratio of two radius vectors from a log-spiral center; α is the angle between a radius vector and tangent to the wave at that point and is a constant for a given log-spiral; θ = the angle between radius vectors; and the constant e is the base of Naperian logarithms. A diagram of log-spiral nomenclature is shown in Figure III-1.

Silvester (1976) recognized the difficulty in defining the equilibrium beach to the log-spiral formula. Extensive research on crenulate bays resulted in relating the equilibrium beach planform to maximum bay indentation and incident wave angle (Figure 2). Silvester divided the bay into the updrift shadow reach or logarithmic spiral and the tangential reach. The logarithmic spiral reach is affected most by wave diffraction. The tangential reach, which is slightly convex seaward or straight, is affected mostly by wave refraction.

Rea and Komar (1975), in studying log-spiral bays through numerical modeling, indicated that the shoreline will always attempt to achieve an equilibrium configuration which is governed by the patterns of offshore wave refraction and diffraction and by the distribution of wave energy flux. If the system is closed, then a true equilibrium is achieved wherein the shoreline everywhere takes on the shape of the wave crests (i.e. breaker angles are everywhere zero). If the system is not closed and sediment continues to be transported to the downdrift end of the model and further, then equilibrium occurs where the breaker angles are precisely those required to transport the sediment eroded from the updrift section of beach. Under this definition of equilibrium the shoreline continues to erode but retains its overall shape (Rea and Komar, 1975).

The breakwater system at Aqua-Po initially was overfilled to provide a wide backshore. The bays would adjust with time to a stable planform. According to Silvester's equilibrium bay model (1974), the maximum bay indentation within range of wave directions from shore-normal to 45° would be less than 24 m (80 ft). This was an important design consideration because the maximum bay indentation could not encroach on the road behind the beach. The costs and objective of a recreational beach were also critical factors and limited the dimensions of the project.

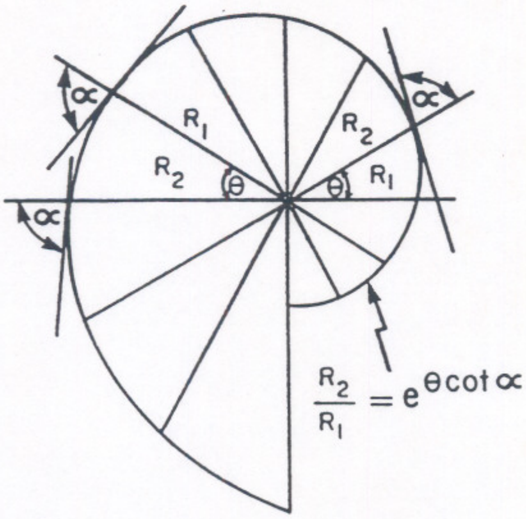


Figure III-1. Definition sketch of logarithmic spiral (after Yasso, 1965).

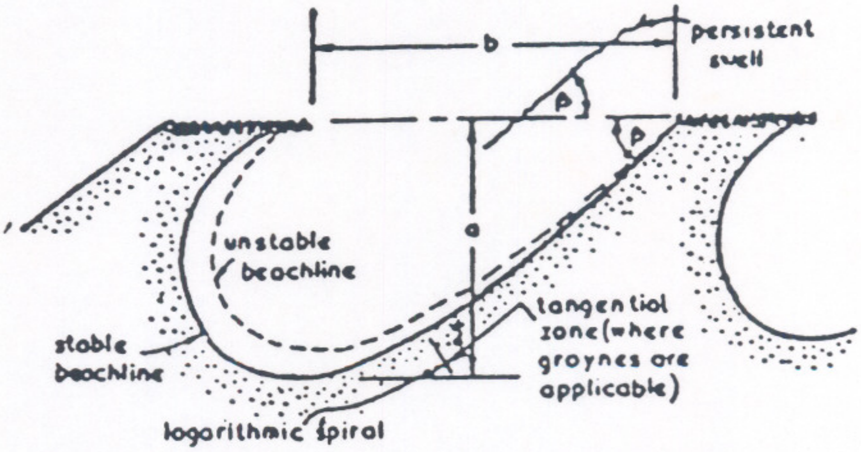


Figure III-2. Crenulate shaped bay in stable and unstable conditions (after Silvester, 1976).

APPENDIX III REFERENCES

Rea, C.C. and P.D. Komar, 1975. Computer simulation modes of a hooked beach shoreline configuration. Jour. Sedimentary Petrology 45:866-877.

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Silvester, R., 1976. Headland defense of coasts. Proc. 15th Conf. Coastal Engineering, American Society of Civil Engineers 2:1394-1406.

Yasso, W.E., 1965. Plan geometry of headland bay beaches. Jour. Geology 78:703-714.