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# Evaluation of Ventra Vacs at Pier 12 Naval Base, Norfolk, Virginia

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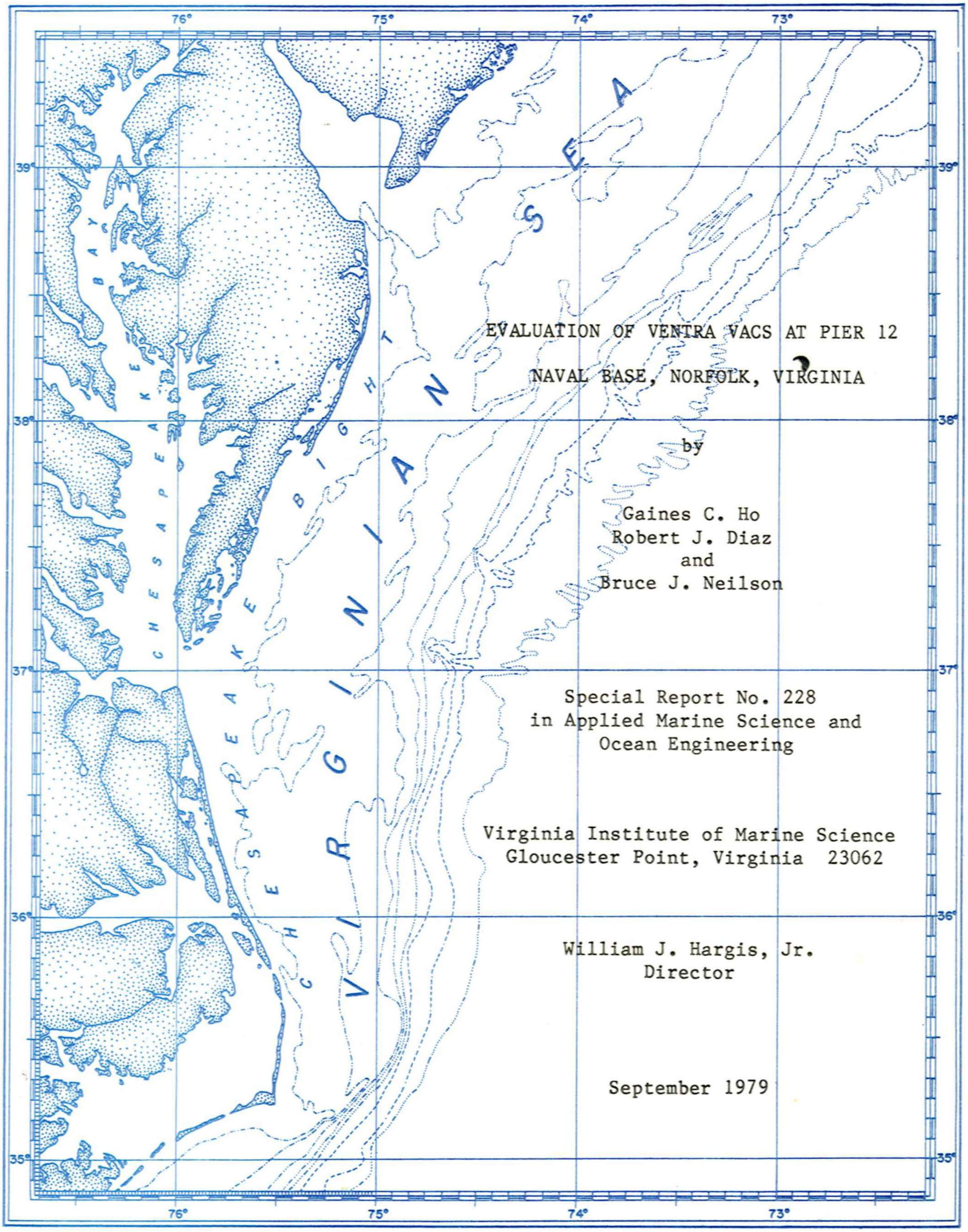


# EVALUATION OF VENTRA VACS AT PIER 12 NAVAL BASE, NORFOLK, VIRGINIA

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Special Report No. 228
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# EXECUTIVE SUMMARY

# I. Summary and Conclusions

The Virginia Institute of Marine Science (VIMS) conducted field and flume studies to determine the effectiveness of Ventra Vac units to resolve condenser fouling problems on deep-draft vessels. This situation seems to be caused at least in part by marine organisms settlings onto the bottom of the ship berths adjacent to Pier 12. Field studies included currents, water quality, bathymetry, and the distribution and entrainment of fouling organisms. A flume study was also conducted at VIMS hydraulic laboratory to determine the critical current speed at which the fouling organisms start to roll or slide along the bottom, the settling velocity vs. colony size, and the moving patterns of these organisms under different current speeds.

In general, current speeds near the bottom layer of Pier 12 were rarely higher than 8 cm/sec (0.15 knot) which is the critical speed to move the fouling organisms along a smooth bottom. In addition, our current measurements indicated for most instances, the current direction was not toward the Ventra Vacs along the bottom nor away from the Ventra Vacs at the surface. Since the directions were not towards the Ventra Vacs in the bottom layers, this suggested that natural current (tidal currents or currents induced by passing vessels in the Norfolk Reach Channel) were stronger than those induced by Ventra Vacs. All water quality data indicated there were no significant changes due to Ventra Vacs' operation. High and variable suspended solids were observed before Ventra Vac operation suggesting that "natural" variations would overshadow Ventra Vac efforts.

The field survey indicated fouling organisms were not evenly distributed at Pier 12. Instead, more of them were found in the deep berth area. No attached colonies were found during the surveys. All of the material collected was small to large fragments, about one-third of which was dead. The field entrainment study indicated that after one and one-half hours of operation the Ventra Vac did not lift any hydroids from the bottom.

All of these facts suggest that Ventra Vacs are ineffective in entraining and removing the fouling organisms from the berths and that there were no significant changes in water quality and current speed.

Flume tests indicated that hydroids sank faster than bryozoans. Also the larger the colony the faster it sank. The specific gravity of the hydroids was 1.15. We did not measure specific gravity of the bryozoans. The critical current speed needed to start both organisms rolling and/or sliding along the smooth level flume floor was slightly higher than 8 cm/sec (0.15 knot). The size of the colony had little or no effect on this critical current speed. At flume speeds as high as 25 cm/sec (0.46 knot) colonies were found to remain near the bottom and were not swept into the water column. Turbulence, created by placing rocks on the flume bottom, lifted colonies into water column only at flume speeds over 25 cm/sec (0.46 knot). Over the rough muddy bottom at Pier 12, it is anticipated that the critical current speed to start colonies moving would be higher than 8 cm/sec (0.15 knot). This suggests that effective suction of those fouling organisms by the Ventra Vac units cannot be expected.

Even if Ventra Vacs did lift colonies from the bottom because of the high settling velocity, the colonies would resettle to the berth again. A horizontal current speed of 10.2 cm/sec (0.19 knot) would be required if the settled colonies were to be resuspended by the next unit located at 100 ft. intervals. It is unlikely that current of this magnitude and flow away from the pier would be found within the Pier 12 area.

Field investigation also indicated that siltation was a big problem at Ventra Vac sites for long periods when the units were idle. We believe this is due mainly to partial removal of the earth mound during installation. These spots, deeper than the neighboring areas, facilitated siltation. An estimated 3.05 m (10 feet) of mud, silt and shellrock was found at both sites at the end of study after an idle period of 2 months and prevented us from trying increased air flow to units. Therefore a semi-continuous operation scheme is necessary to prevent burial of Ventra Vacs.

The high siltation rate and the refractory nature of the hydroid skeleton allow accumulation of hydroid material in the sediments. Navy divers have reported hydroids as deep as 0.9 m (3 feet) below the sediment surface in the Pier 12 area prior to maintenance dredging. In sedimentary areas hydroids are quickly buried. In a box core taken, for another project, from a sedimentary environment similar to the pier 12 area at 18.6 m (61 ft.) in the channel off Newport News Point on June 13, 1979, we found live hydroid colonies growing in the surface (Figure 1). Some were attached to bits of shell and some were just partly buried. Also starting at a depth of 10 cm (4 in) there was an accumulation of dead hydroid material we believe to be winter of 1978 growth (Figures 2 and 3). The amount of buried hydroids was sufficient to limit total penetration of the box core to 15 cm (6 in) in the muddy-sandy sediment that without hydroids usually produces cores 60 cm (24 in) and longer. If hydroids are buried in areas that are 13.7 m to 15.2 m (45 ft. to 50 ft.) deep, the sphere of influence of the carrier's water pumps may be sufficient to erode the unconsolidated muddy surface sediments, resuspending and entraining the hydroid material, and causing a fouling problem.

In summary, it appears that it is neither effective nor feasible to use Ventra Vacs to resolve the deep-draft vessels condenser fouling problem caused by marine organisms settling onto the bottom of the ship berths adjacent to Pier 12.

## II. Recommendations

Our recommendations are divided into three general categories relating to possible solutions to the fouling problem and clearer definition of the biological and engineering properties of the hydroids. Unfortunately there is no concrete recommendation that can be made which will solve the Navy's fouling problems. A better grasp is needed on the exact nature of the problem. The recommendations as outlined are a step in this direction.

## Possible solutions

· Use the vessels to clean the slip. By modifying operating procedures the vessels could pump water a day or two before departure and prior to departure clean out condenser boxes. This is a brute force approach where the carrier purposefully fouls its condensers prior to departure.

· Revolving screens or water filtration to prevent hydroids from entering cooling water.

· Improved raking to practices to remove accumulated hydroids. (See Appendix A for a basic rake design.)

## Hydroid Properties

· Biological - a detailed look at the life history of the hydroids in the lower James River and Hampton Roads area is needed in order to define their origin and attempt to quantify for any particular year how severe fouling problems will be.

· Engineering - laboratory tests to characterize the hydrodynamic properties of the hydroids under simulated natural conditions are needed. This will provide the necessary data to develop predictive models on the fate and movement of the hydroids.

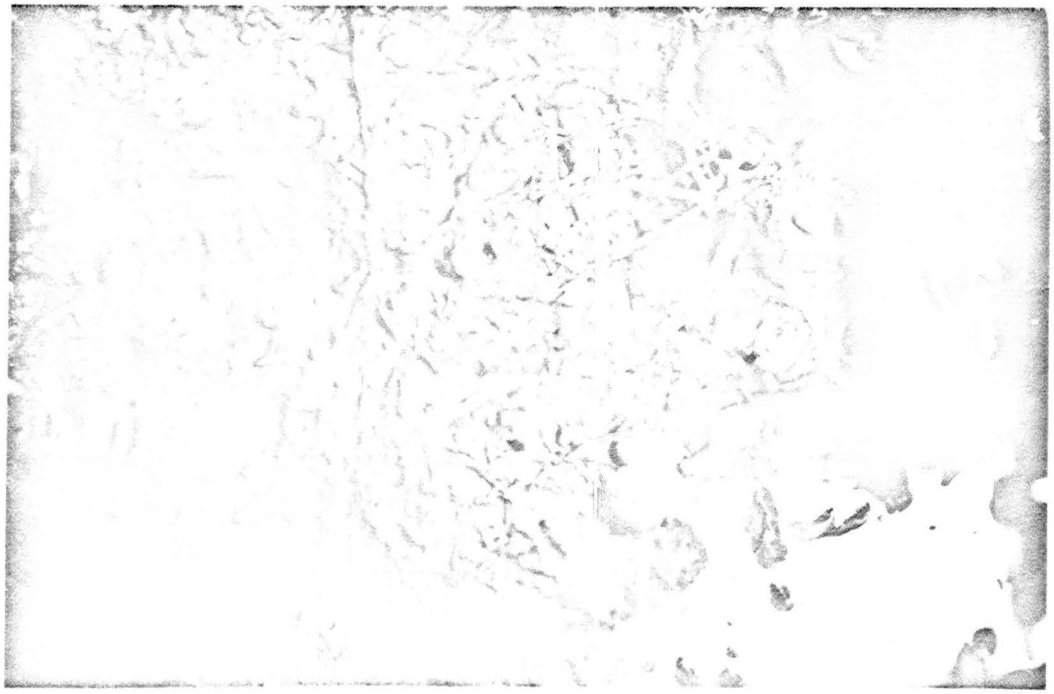

Figure 1. Live hydroids on the surface of a core taken from the channel of Newport News Point at 61 ft (actual size).

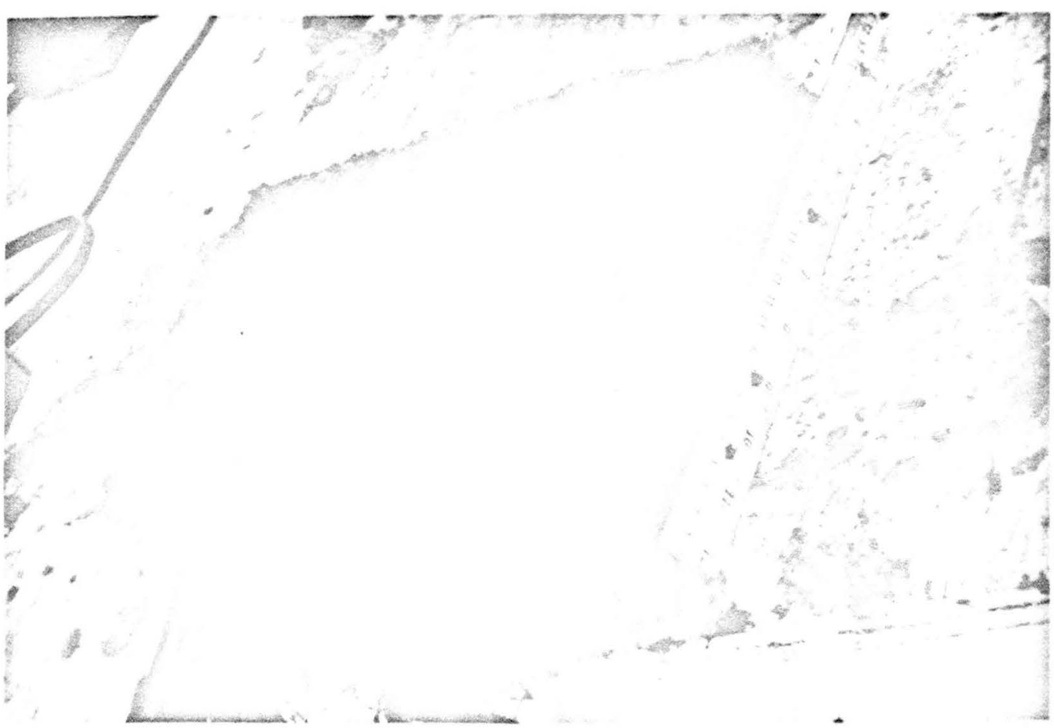

Figure 2. Oblique view of a section of the core from Figure 1. Dead hydroids can be seen hanging over the edge of the table.


Figure 3. X-Radiograph of section shown in figure 2 indicating depth and concentration of dead hydroid material below the sediment surface.

FINAL REPORT

# INTRODUCTION

Observations by U. S. Navy personnel and studies conducted by Virginia Institute of Marine Science (VIMS) in the 1960's have shown that two marine organisms, a fleshy bryozoan (Alcyonidium verrilli) and a hydroid (Sertularia argentea) are mainly responsible for condenser fouling of deep-draft vessels berthed at Pier 12. The occurrence of colonies in the berthing areas was shown to be entirely due to transport and deposition. Available data indicates that these colonial animals develop on the shoals and bars of Hampton Roads, lower Chesapeake Bay and possibly the lower James River estuary. These shallow areas are frequently subjected to sufficient wave action to break up or dislodge colonies from the substrate and permit "transport" by currents. The current velocities in the pier basins are slow enough to allow these animals to settle out. Once deposited the possibility of resuspension and transport out of the area is reduced by the bottom profile created by the dredged basin.

In September 1978, VIMS entered a contract (NS 2470-78-C-4605) with the U. S. Department of Navy, Naval Facilities Engineering Command, Norfolk, Virginia, to conduct a six-month engineering and biological evaluation of the feasibility and effectiveness of "Ventra Vac" units in eliminating the organisms from berthing area. Attention also was given to assessing the study of these units to reduce sedimentation adjacent to Pier 12.

The study included:

(a) surveying the distribution of these organisms in the Pier 12 berth and in the adjacent Norfolk Channel using trawls and dredges.

(b) flume study to determine the minimum scouring velocity and the mechanism of transport.

(c) the evaluation of the efficacy of removal.

(d) determining the fate of entrained organisms.

(e) monitoring water quality, and

(f) physical survey of the area.

## VENTRA VACS

The Ventra Vac unit is a type of air lift pump (Figure 1). Due to the cone and bell construction, it pulls from a "horizontal" (claimed by the manufacturer) direction bringing the water to the tip of the cone and the center of the venturi where air in injected. The air-water mixture is then directed into a vertical pipe and discharged. The performance specification of Ventra Vacs with a static head of 13 m (45 feet) and under dynamic tidal influence is known, but the manufacturers claimed an effective radius of 30.48 m (100 feet) was obtainable.

Two 45.7 cm x 6.70 m (18 in x 22 ft) Ventra Vacs with extensions that provided an overall length of 13 m (45 feet) were leased from Ventra Vac, Inc., Ventura, California. They were installed along Pier 12 at 30.5 m (100 feet) and 83.8 m (275 feet) marks with the base plates located at -13 m (-45 ft) MLW (mean low water). A portion of the earth mound below that pier and some fender piles were removed during installation to allow these two units to operate unobstructed at an elevation of -13 m (45 ft) MLW. The units were equipped with baffles which limited the incoming water flow to the front 150° quadrant so that water was drawn from the berthing area and not from below the pier.

After some initial difficulty, the two Ventra Vacs were properly sitting and seamed at 30.5 m (100 ft.) and 83.8 m (275 ft) marks on March 8, 1979. On March 13, the Ventra Vacs were connected to air supply and were operational (Figure 2). Air flow was maintained at 1.4 $kg/cm^2$ (20 psi) gauge pressure at 1.78 - 1.84 $m^3$/min (63-65 cfm).

## FIELD STUDY

The field study consists of four parts: a) water quality monitoring, b) current study, c) organism distribution and entrainment, and d) bathymetric study.

A. <u>Water quality monitoring</u>:

Water quality in the vicinity of Pier 12 was monitored to determine if operation of Ventra Vacs was causing any change in quality. Samples were collected near the surface and near the bottom of water column. It was anticipated that water quality impacts would be greatest when units began operation and diminished thereafter. Accordingly, water samples were collected at slack tide immediately before and after start-up, and at the end of the testing period. These samples were analyzed for dissolved oxygen, salinity, biochemical oxygen demand, total phosphorus, total Kjeldahl nitrogen, and suspended solids. Analytical methods used were those listed in "Standard Methods for the Examination of Water and Wastewater" and EPA's "Methods for Chemical Analysis of Water and Wastes".

Besides these laboratory analyses, a HIAC flow-through turbidimeter (Model NT-621) which registers in NTU (Nephelometric turbidity unit) was used to provide instant qualitative information on suspended solids concentrations.

Water quality was monitored three times. The locations of sampling stations are shown in Figure 3 and the water quality data are given in Tables 1, 2, 3, and 4. First water samples were collected on November 9, 1978 at 26 stations to provide a general picture and the rationale for designing a field sampling program in the later stages when Ventra Vacs were operating. The second monitoring was conducted on April 11, 1979 while the north side of Pier 12 was clear and Ventra Vacs were operating. The third monitoring was conducted on April 19 while the USS Independence was berthed on the north of Pier 12 and Ventra Vacs operating. An additional turbidity study under similar conditions as the third monitoring using the HIAC turbidimeter was initiated on April 24 and lasted three days.

B. Current study:

Current studies were to determine the radius of influence of Ventra Vacs' action providing a guideline for water quality monitoring and biological entrainment study. Current velocities were measured at various distances from Ventra Vacs at several depths. Current data were obtained with Marine Advisor current meters (Model S-13).

Three successful studies were conducted. The location of stations and field data are presented in Figure 4 and Tables 5, 6, and 7. The first current study was on December 9, 1978 at SBE (slack-before-ebb). Current readings were taken at stations 1-1, 1-2, and 1-3 at 1 m (3.3 ft) below the surface and 1 m (3.3 ft) above the bottom.

With the cooperation of the Navy personnel, a barge was used as a working platform for the second and third current studies. The barge was relatively stable, eliminating interference caused by bouncing of the current meter from the small boat, and resulted in more reliable current readings. On May 3, 1979, the second current study was conducted while the USS Independence was berthed alongside Pier 12 and the Ventra Vacs were operating. Current speed and direction were taken hourly at 1 m (3.3 ft) depth intervals at stations 4-1 and 4-2 for a half tidal cycle from SBF (slack-before flood) to SBE (slack-before-ebb). The third current study was conducted on May 10 with Ventra Vacs in operation and pier clear. Current speed and direction were taken at station 5-1 and 5-2 hourly at 1 m (3.3 ft) intervals for a half tidal cycle SBE to SBF.

C. Organism distribution and entrainment:

While there are a host of species involved in the fouling problem about 90% to 95% of the problem is caused by the hydroid, *Sertularia argentea*, and about 5% to 10% caused by the bryzoan, *Alcyonidium verrilli*. In light of this we have concentrated on the hydroid.

Extensive study on the source and rate of supply is beyond the scope of this project. However, the distribution of the hydroid in the Pier 12 berth and in the adjacent Norfolk Channel was included in the field study. A semi-quantitative survey of the berth area and nearby bottom using a trawl was conducted on November 9, 1978. We did not find any hydroids in the water column. All hydroids taken were from the bottom. The second survey using a dredge was conducted on March 28, 1979. No attached colonies were found during the surveys. All the material collected were small to large fragments, most of which were dead. Live fragments accounted for about one-third of the total. Our surveys were semi-quantitative and intended to note where the hydroids were concentrated within the slip. Figure 5 indicates that the greatest densities were next to the bulkhead with decreasing densities toward the mouth of the slip. There were virtually no hydroids on the shallow area adjacent to the slip.

All the hydroid fragments caught on the north side of Pier 12 were apparently on or very near to the bottom. Trawls 2.4 m to 3.1 m (8 ft to 10 ft) of the bottom along some transects as shown in Figure 5 failed to find any hydroids.

Whether the Ventra Vacs can effectively collect hydroids from the berth was determined by placing dye marked and thread tagged hydroids in the berth at various distances from the Ventra Vacs and collected at the discharge pipe with a large 6.4 mm (0.25 in) mesh bag. This field study was conducted on May 21, 1979. First, five one-quart samples of hydroids were placed at 3.1 m, 6.1 m, 9.1 m, and 12.2 m (10 ft, 20 ft, 30 ft, and 40 ft) from Ventra Vac located at the 83.8 m (275 ft) mark during low tide and slack current (Figure 6). The Ventra Vacs were then started. No hydroids, tagged or untagged, were caught in the bag after half an hour's operation. The bag was reattached to the discharge pipe and Ventra Vacs restarted. After ten minutes of operation a quart of tagged hydroids was placed on the bottom 1.5 m (5 ft) from the unit, while it was still operating. After an hour of operation there were still no hydroids found in the bag.

In summary, after one and one-half hours of operating the Ventra Vacs did not lift any hydroid, tagged or untagged, from the berth. This finding is consistent with the results of our current study and flume study.

D. Bathymetric study:

In order to detect any bottom changes near the Ventra Vacs, sounding was made using a Raytheon electronic fathometer on December 5, 1978 before the operation of the Ventra Vacs. Bottom profiles were taken in a very dense grid as shown in Figure 7. Because of the sloping bottom and submerged structures excessive "echo" interference were found near pier side. In addition there were dredging operations in late February and early March of 1979. It was decided that an additional bathymetric study be conducted which concentrated on the bottom around the Ventra Vacs. The transducer was towed 10.7 m (35 ft) below water level; 5 transects, each 15.2 m long (50 ft) and perpendicular to pier, were made. These two bathymetric surveys were overlapped and used as background. The location of transects and depth are presented in Figure 8.

The present study and field data collected previously by VIMS scientists (Ruzecki et al.) indicated that "natural" currents were higher than those inducted by the Ventra Vacs. In addition, high and variable suspended solids observed before Ventra Vacs operation suggested that "natural" variation would overshadow Ventra Vac efforts. It is anticipated that silting patterns will remain unchanged and a post-operation survey seems unnecessary.

## FLUME STUDY

The flume study served two purposes. First, to determine the minimum current speed necessary to move the fouling organisms along the bottom and the relationship between rolling speed and ambient current speed. Secondly, to determine the settling velocity of fouling organisms.

The hydraulic flume has a 14.6 m (48 ft.) (L) by 0.9 m by 0.9 m (3 ft) test section. The current speed in the test section may be adjusted from 2 cm/sec to 85 cm/sec (0.038 - 1.65 knot). The overall uniformity of current speed versus depth is within 2-3%.

Once the current speed had been properly adjusted the fouling organisms were released at the head of the test section. The moving pattern and speed were recorded. Several current speeds were tried until a general picture was gained. Settling velocities were determined in standing water. The results of flume tests are present in Table 8 and Figures 9 and 10.

All animals used in the test had been preserved in 10% formaldehyde. The only apparent disadvantage of preserved materials was that they tended to be slightly more brittle than live hydroids.

The ability of hydroids to go up a 1:4.39 incline (12.84°) and over a 20.3 cm (8 in) barrier also was tested (Figure 11). At flume speeds of 8.7 and 9.7 cm/sec (0.17 and 0.19 knot) hydroids and bryozoans went up the incline and were caught by the barrier. At a flume speed of 14.7 cm/sec (0.29 knot) some of the animals were blown over the barrier with larger colonies (>10 g) caught by the barrier. At flume speeds 25 cm/sec (0.46 knot) and higher all colonies bypassed the barrier and colonies caught by the barrier at the lower flume speeds were entrained with the flow field.

The drag coefficient of the hydroids in the flume (that is flume speed - hydroid speed) was fairly consistent at about 5 cm/sec (0.01 knot). Under field conditions drag should be influenced by type of sediment and how "sticky" it appears to the hydroids. It is expected that the initial speed to move a hydroid colony and drag coefficient would be greater in muddy sediments than in flume calculations.

## RESULTS AND DISCUSSION

### A. Efficacy of Removal:

The flume settling velocity tests indicated that the hydroids sank faster than the bryozoans (Figure 9). Also the larger the colony the faster it sank. The significance of this is that once broken free it is unlikely that colonies will remain near the surface or in the water column unless there is sufficient turbulence created by at least 0.51 knot currents to keep them in suspension. Once on the bottom, the current needed to start both animals rolling or sliding along the smooth, level flume floor was slightly higher than 8 cm/sec (0.15 knot) (Figure 10). The size of the colony had little effect on this critical rolling/sliding speed. At flume speeds as high as 25 cm/sec

(0.46 knot) colonies remained near the bottom and were not swept into the water column. When rocks were placed on the bottom of the flume to create turbulence, colonies were lifted into the water column only at flume speeds near or over 25 cm/sec (0.46 knot). Over the rough muddy bottom in the Pier 12 area it is anticipated that the critical rolling/sliding speed would be higher than 8 cm/sec (0.15 knot), but turbulent currents near 25 cm/sec (0.46 knot) should be able to lift colonies into the water column.

The horizontal velocity of colonies over the smooth level bottom was substantially lower than the flume speed measured at 51 cm (20 in) above the bottom (Figure 12). This difference is considered drag and is partly due to the attenuation of current as the bottom is approached and to the frictional resistance of the colonies to moving. The difference was greatest for flume speeds near the critical rolling/sliding speed. At the flume speed of 8.7 cm/sec (0.17 knot), the median rolling/sliding speed for the hydroids was 2.0 cm/sec (0.039 knot), and 1.5 cm/sec (0.029 knot) for the bryozoans. Drag was then 6.7 cm/sec for hydroids and 7.2 cm/sec for bryozoans. At flume speeds of 9.9 cm/sec and 14.9 cm/sec (0.19 and 0.28 knot) both animals had a drag of about 5 cm/sec (0.097 knot).

From the field and flume tests it appears that both the hydroids and the bryozoans enter the Pier 12 slip on or near the bottom. Assuming the flume data to be the idealized field situation then once in the slip these animals would settle in the areas where currents were less than 8 cm/sec (0.15 knot). In order to lift colonies from the bottom currents speeds over 25/cm sec (0.46 knot) would be required.

Current studies indicates that even at 6.1 m (20 ft) away from the Ventra Vacs, bottom current speeds rarely exceeded 7 cm/sec (0.13 knot). If, in addition, bottom roughness retards movement, it is clear that Ventra Vacs will not effectively remove the animals.

B. Water Quality:

Data on the water quality in the vicinity of Pier 12 before and after operating the Ventra Vacs are presented in Tables 1, 2, 3, and 4, and are quite comparable to those reported by previous investigators (Brehmer, et al). The five-day biochemical oxygen demand ($BOD_5$), was generally less than 2.5 mg/l, total Kjeldahl nitrogen (TKN) was about 0.5 mg/l, and dissolved oxygen was between 8 to 10 mg/l. Suspended solids (SS) concentrations show a great variation between top and bottom, sampling locations, and time. A slight variation of SS for surface samples was noticed. Concentrations of SS as high as 200 mg/l for bottom samples were observed on April 19, while Ventra Vacs were off.

The water quality did not show any significant change after the Ventra Vacs operated one-half tidal cycle. Preliminary calculations indicated the effective radius of influence (current speed equal to or greater than 5.15 cm/sec (0.1 knot)) would be less than 15.2 m (50 ft.) assuming that 30.5 cm (1 ft) of bottom layer water is drawn to the Ventra Vacs. It is believed that equilibrium will be reached

In summary, the water quality near Pier 12 was not significantly changed by operating Ventra Vacs. The current speeds during Ventra Vacs' operation were almost the same as those reported previously (Ruzecki et al.) and strongly suggested that operating of the Ventra Vacs cannot be expected to effectively retard the sediment rate or remove hydroids near Pier 12.

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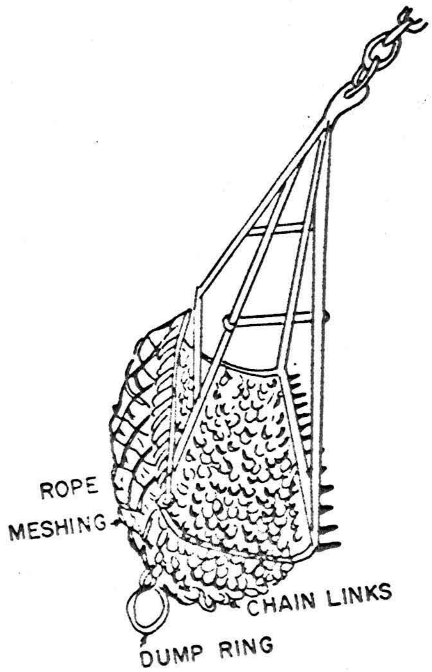
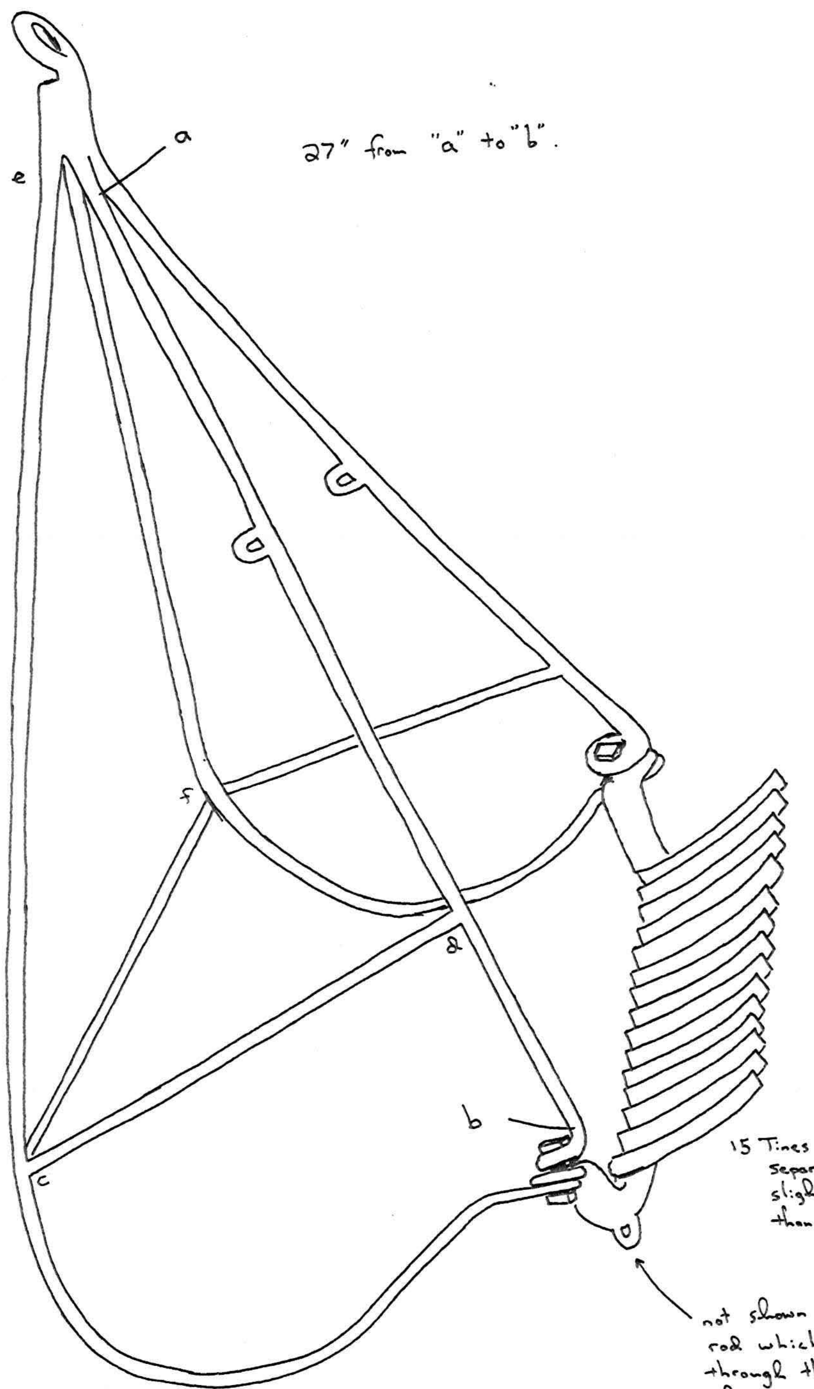
2. Ruzecki, E. P. and Ayers, R., 1974. "Suspended Sediments near Pier 12, Norfolk Navy Base on 26 June and 15 September 1973" Data Report No. 11, Va. Institute of Marine Science.

# APPENDIX A

## Basic Design for a Rake




27" from "a" to "b".

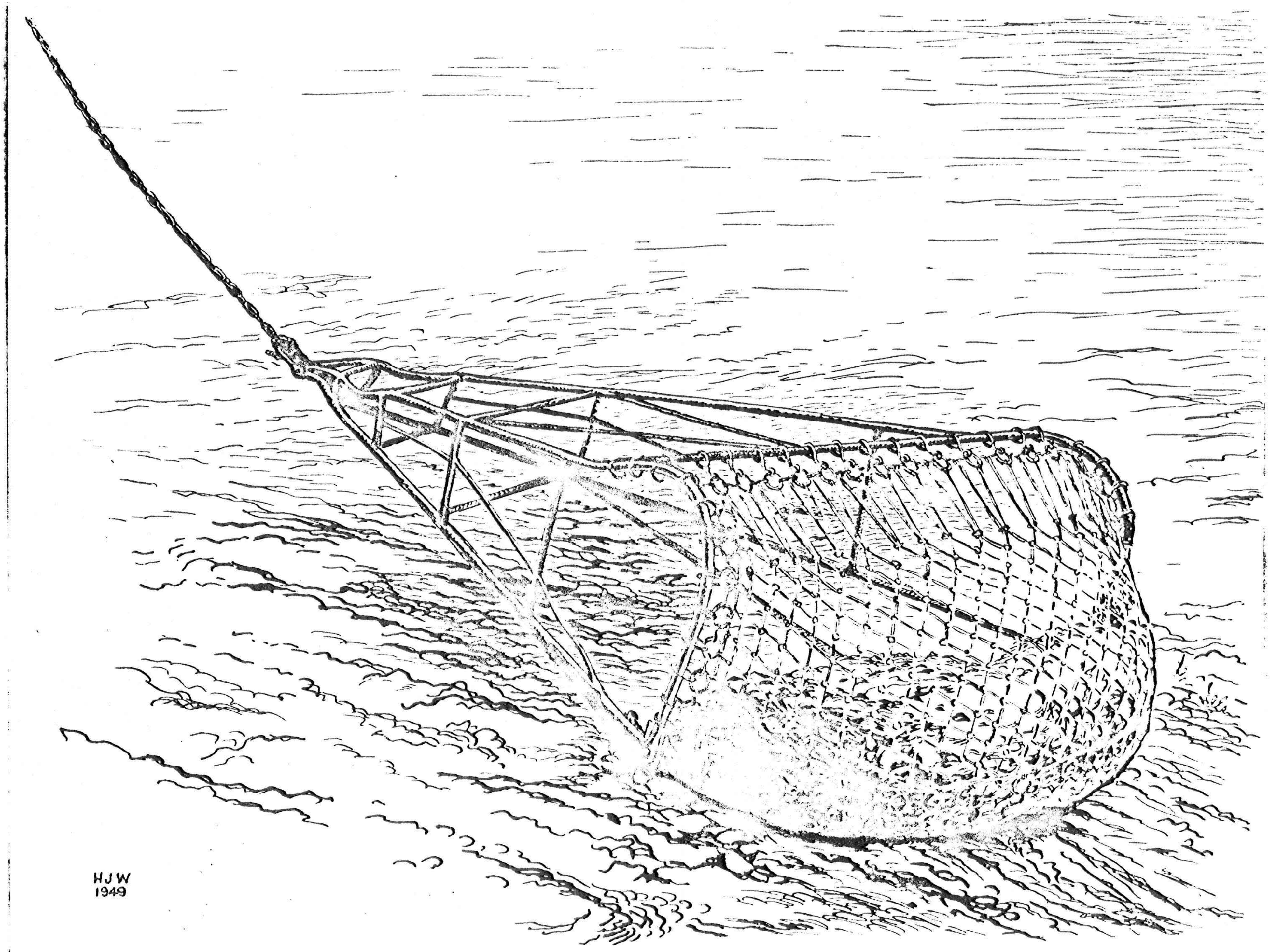
15 Tines are separated by slightly less than 1".

"c" to "d" = 12"

"c" to "e" = 25"

"c" to "f" = 21½"

not shown is a rod which fits through this and other supports under the tines carriage from which the chain bag hangs.
Tine carriage measures 21" from bolt to bolt.


HJW
1949

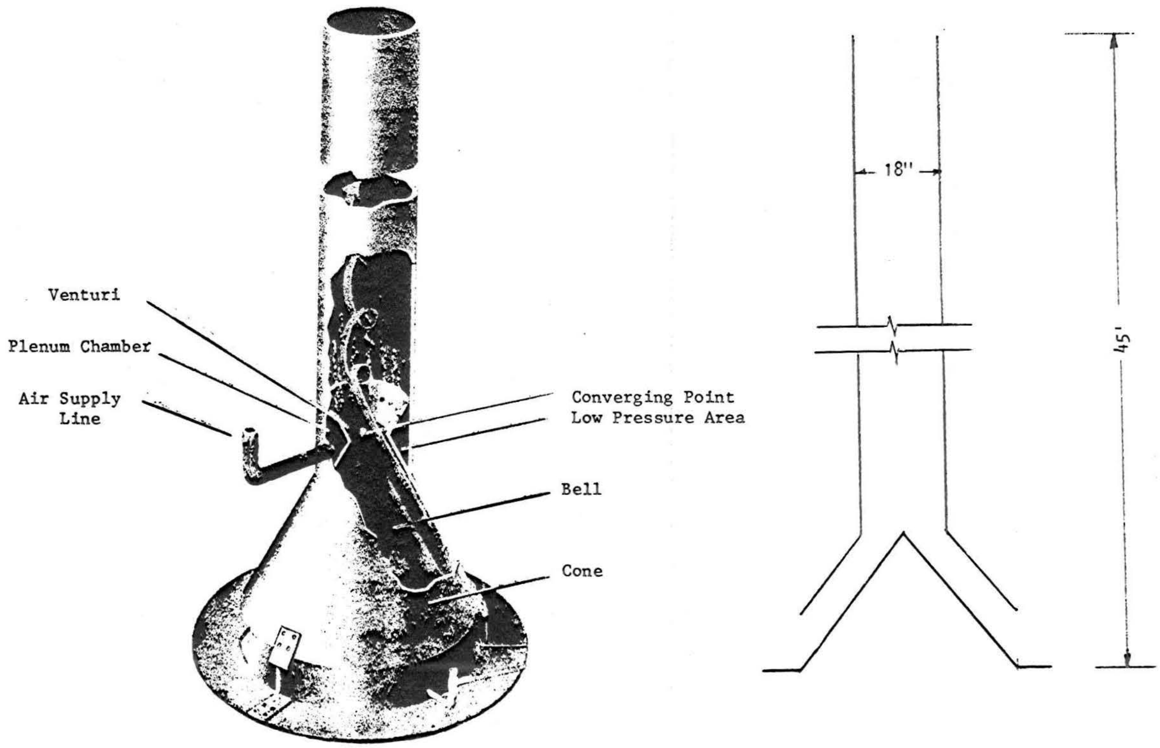



Figure 1. the Ventra Vac Unit.

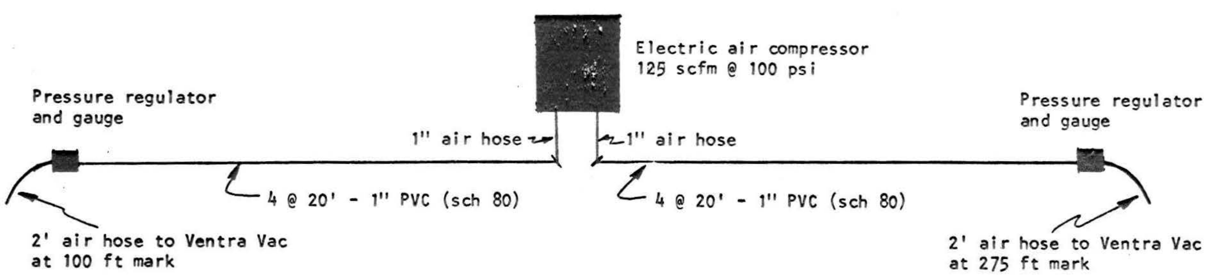



Figure 2. Schematic diagram of air supply system for Ventra Vacs.

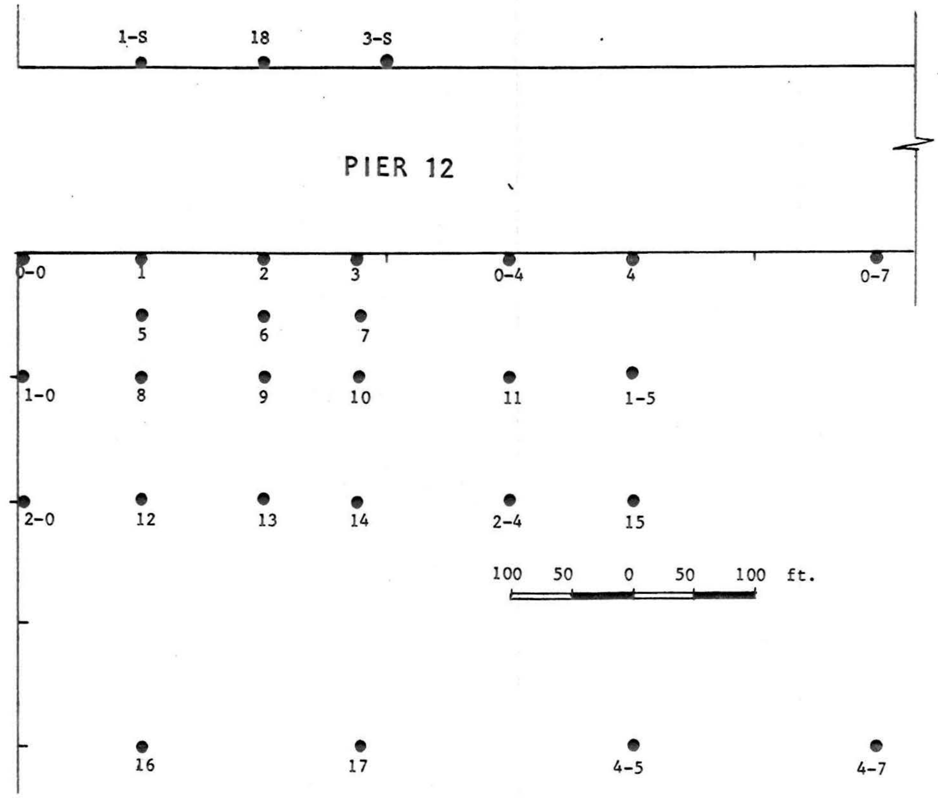



Figure 3. Location of field sampling stations.

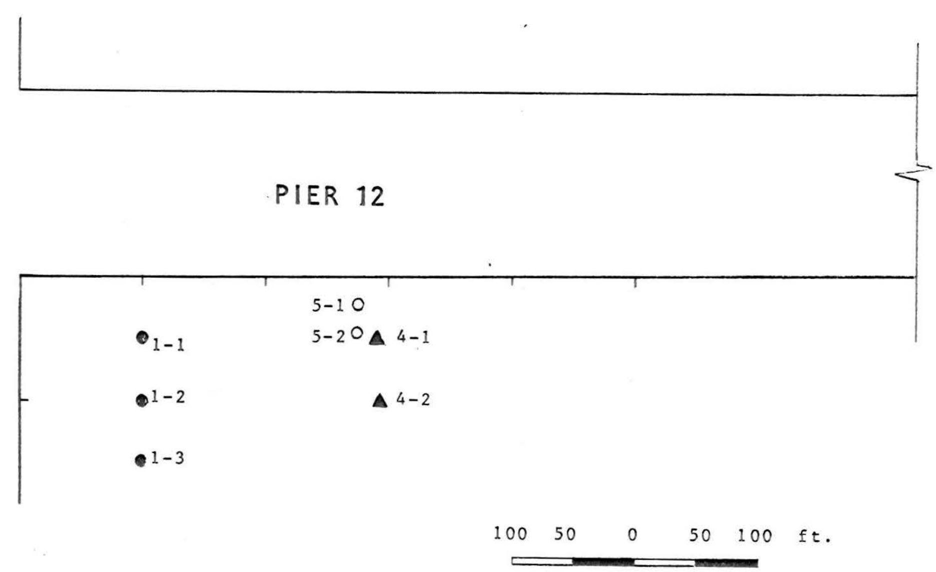



Figure 4. Location of current stations.

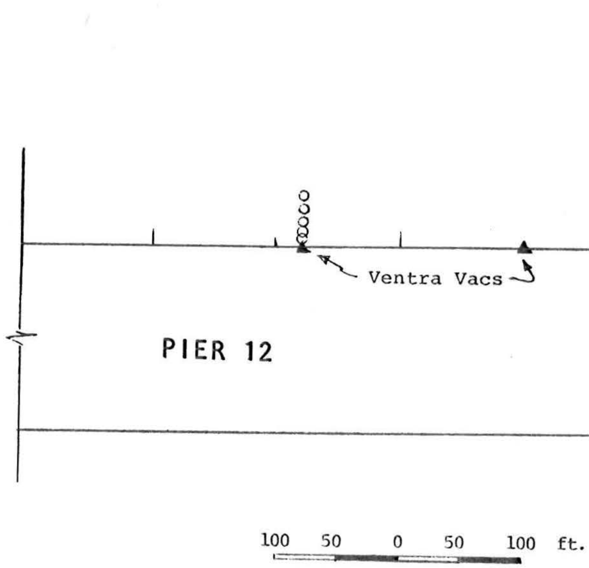



Figure 6. Placement of tagged hydroids around Ventra Vac.

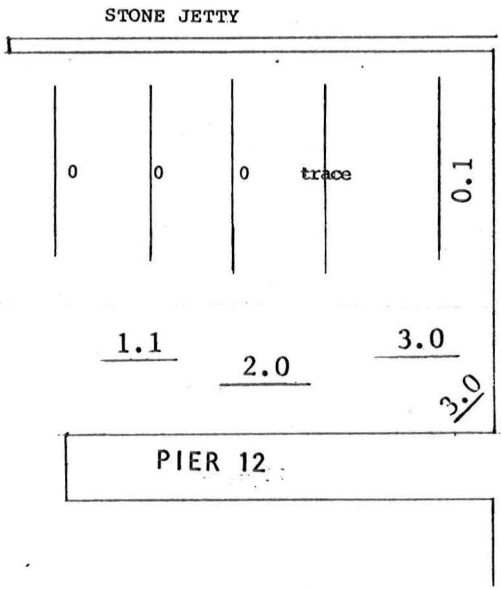



Figure 5. Transects sampled for hydroids, values are total volume of hydroids in quarts.

PIER 12

| | 50 | | 100 | | 150 | | 200 | | 250 | | 300 | | 350 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 36 | 35 | 40 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| | 40 | 41 | 45 | 45 | 45 | 45 | 45 | 45 | 44 | 44 | 45 | 44 | 45 |
| | 44 | 45 | 46 | 46 | 46 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| 50 | 44 | 46 | 47 | 47 | 47 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 |
| | 45 | 47 | 47 | 47 | 47 | 46 | 46 | 47 | 46 | 46 | 46 | 46 | 47 |
| | 45 | 47 | 47 | 47 | 47 | 47 | 46 | 46 | 46 | 47 | 47 | 47 | 47 |
| 100 | 41 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| 150 | 40 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| 200 | 37 | 46 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| 250 | 37 | 45 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| | 30 | 46 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 | 48 |
| 300 | | | | | | | | | | | | | |

* Depth in feet below mean low water

Figure 7. Bathymetric profiles of study area.

PIER 12

| | 90 | | 100 | 110 | | 260 | 270 | | 280 | 290 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 34 | 42 | 40 | 38 | 41 | 35 | 43 | 44 | 43 | 35 |
| 10 | 34 | 43 | 41 | 39 | 42 | 37 | 44 | 44 | 44 | 35 |
| | 37 | 45 | 42 | 41 | 43 | 37 | 45 | 44 | 45 | 35 |
| 20 | 43 | 46 | 44 | 43 | 44 | 41 | 45 | 45 | 46 | 38 |
| | 45 | 47 | 45 | 45 | 44 | 42 | 46 | 45 | 47 | 41 |
| 30 | 46 | 47 | 46 | 46 | 44 | 43 | 46 | 45 | 47 | 42 |
| | 47 | 47 | 47 | 46 | 45 | 44 | 47 | 46 | 47 | 44 |
| 40 | 47 | 47 | 47 | 47 | 45 | 45 | 47 | 47 | 47 | 46 |
| | 47 | 47 | 47 | 47 | 46 | 47 | 47 | 47 | 47 | 47 |
| 50 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |

* Depth in feet below mean low water

Figure 8. Bathymetric profiles around 100 ft and 275 ft marks areas.

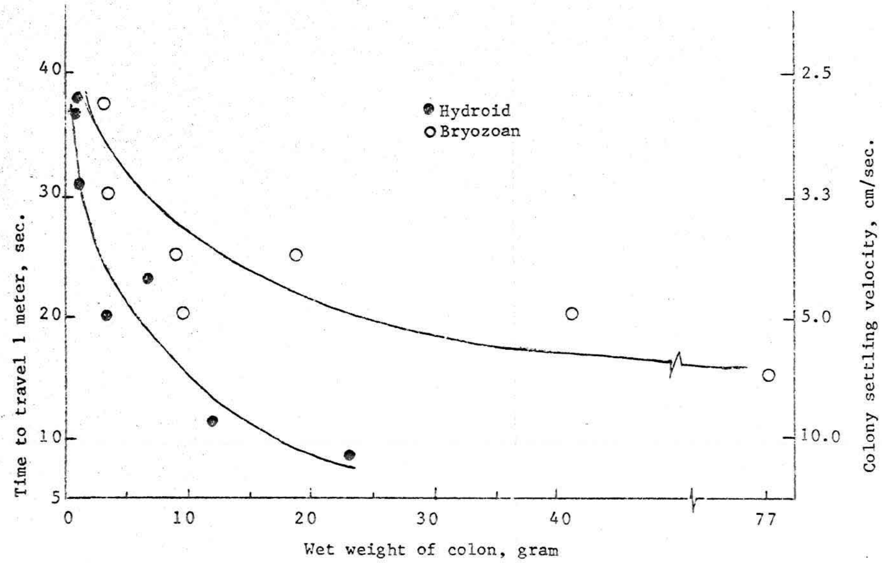



Figure 9. Settling speed vs. wet weight for both colonial animals.

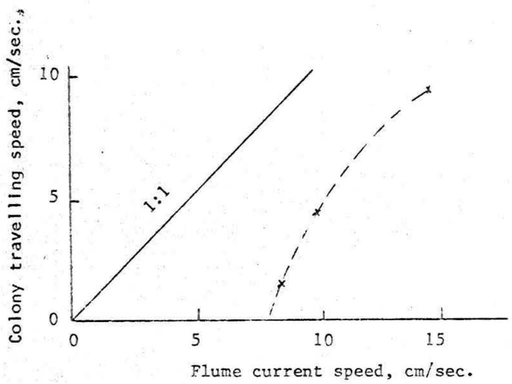



Figure 10. Ratio of animal colony speed over the bottom to the flume current speed.

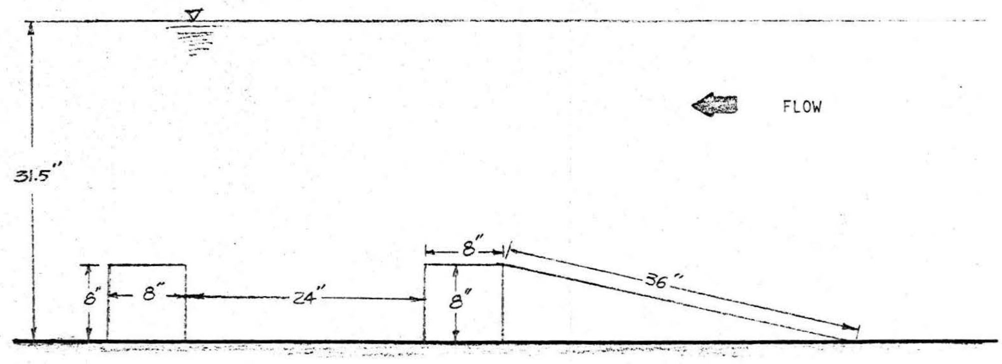



Figure 11. Schematic set up for flume incline test.

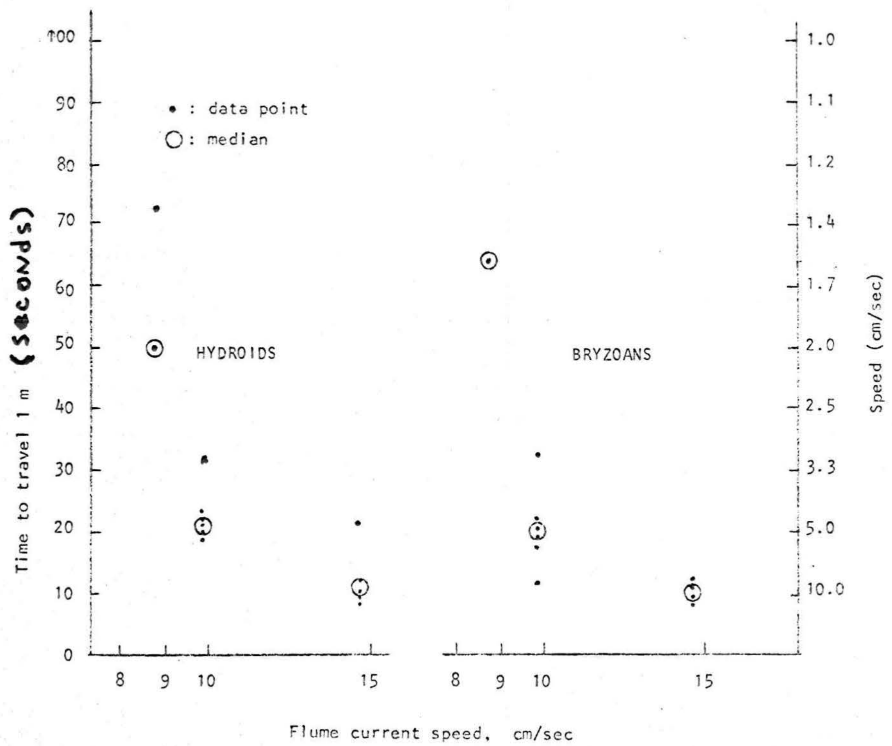



Figure 12. Horizontal speed of hydroids and bryzoans at various flume speeds.

Table 1. Water Quality Data: Samples Collected on November 9, 1978 (1200)

| Station No. | Salinity (ppt) | | Dissolved Oxygen (mg/l) | | $BOD_5$ (mg/l) | | Total Phosphorus (mg/l) | | TKN (mg/l) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | B | T | B | T | B | T | B | T | B |
| 0-0 | | | 9.41 | 8.40 | 0.55 | 0.70 | 0.059 | 0.073 | 0.250 | 0.375 |
| 1 | 22.22 | 21.60 | 8.02 | 7.58 | 0.50 | 0.80 | 0.352 | 0.059 | 0.45 | 0.475 |
| 2 | 22.26 | 21.57 | 8.20 | 7.82 | 0.85 | 1.40 | 0.225 | 0.047 | 0.350 | 0.280 |
| 3 | | | 8.20 | 8.08 | 1.20 | 0.80 | 0.082 | 0.089 | 0.025 | 0.400 |
| 0-4 | | | 8.09 | 7.80 | 0.70 | 1.35 | 0.054 | 0.103 | 0.425 | 0.525 |
| 4 | | | 8.14 | 8.06 | 0.55 | 0.80 | 0.098 | 0.105 | 0.375 | 0.60 |
| 0-7 | | | 8.14 | 8.22 | 0.60 | 1.00 | 0.054 | 0.077 | 0.411 | 0.400 |
| 1-9 | 21.44 | 21.59 | 8.00 | 8.32 | 0.90 | 0.70 | 0.094 | 0.066 | 1.32 | 0.300 |
| 1-0 | 21.46 | 21.53 | 8.10 | 9.15 | 0.50 | 0.80 | 0.077 | 0.045 | 0.34 | 0.28 |
| 8 | 21.43 | 22.10 | 8.29 | 7.74 | 0.75 | 1.50 | 0.084 | 0.080 | 0.450 | 0.46 |
| 9 | 21.55 | 21.58 | 8.07 | 7.92 | 0.80 | 0.50 | 0.112 | | - | 0.520 |
| 10 | 21.56 | 21.93 | 8.32 | 7.92 | 0.70 | 0.50 | 0.080 | 0.062 | 0.475 | 0.525 |
| 11 | 21.50 | 21.95 | 8.13 | 8.54 | 0.80 | 0.65 | | | 0.425 | 0.425 |
| 1-5 | 21.48 | 22.01 | 8.16 | 7.11 | 0.90 | 2.00 | 0.391 | 0.071 | 0.425 | 1.1 |
| 2-0 | | | 8.24 | 9.35 | 0.50 | 0.65 | 0.024 | 0.057 | 0.34 | 0.46 |
| 12 | | | 8.40 | 8.42 | 0.85 | 0.95 | 0.368 | 0.054 | 0.450 | 1.83 |
| 13 | | | 8.92 | 7.95 | 0.70 | 0.65 | 0.073 | 0.059 | 0.425 | 0.45 |
| 14 | | | 8.61 | 8.18 | 0.95 | 0.70 | | 0.061 | 0.32 | 0.350 |
| 2-4 | | | 8.46 | - | 0.70 | 0.55 | 0.073 | 0.066 | 0.300 | 0.32 |
| 15 | | | 8.22 | 8.27 | 0.65 | 0.60 | 0.091 | 0.103 | 0.320 | 0.55 |
| 16 | 21.53 | 21.44 | 8.69 | 8.36 | 0.70 | 0.75 | 0.075 | 0.068 | 0.480 | 0.25 |
| 17 | | | 8.62 | 8.26 | 0.45 | 0.75 | 0.082 | 0.054 | 0.500 | 0.624 |
| 4-5 | | | 9.35 | 8.34 | 0.75 | 0.40 | 0.064 | 0.059 | 1.32 | 0.498 |
| 4-7 | | | - | - | | 0.65 | 0.098 | - | - | 0.65 |
| 1-5 | | | 8.29 | 7.78 | 0.80 | 0.75 | 0.100 | 0.105 | 0.333 | 0.32 |
| 3-5 | | | 7.93 | 8.04 | 1.05 | 0.85 | 0.054 | 0.082 | 0.525 | 0.44 |

T = Top B = Bottom

Table 2. Water Quality Data: Sample Collected on April 11, 1979

| Time EDT | Station Number | Salinity (ppt) T | Salinity (ppt) B | Dissolved Oxygen (mg/l) T | Dissolved Oxygen (mg/l) B | $BOD_5$ (mg/l) T | $BOD_5$ (mg/l) B | Total Phosphorus (mg/l) T | Total Phosphorus (mg/l) B | TKN (mg/l) T | TKN (mg/l) B | Suspended Solids (mg/l) T | Suspended Solids (mg/l) B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 13.35 | 20.36 | 10.54 | 9.11 | | 1.50 | 0.144 | 0.095 | 0.500 | 0.425 | 8 | 21 |
| | 2 | 12.41 | 16.75 | 10.93 | 9.21 | 2.45 | 1.25 | 0.103 | 0.113 | 0.950 | 0.525 | 11 | 22 |
| | 3 | 12.44 | 23.27 | 10.85 | 9.64 | 2.20 | 4.75 | 0.137 | 0.075 | 0.800 | 0.400 | 18 | 19 |
| | 4 | 13.16 | 23.12 | 10.71 | 9.25 | 1.65 | 1.55 | 0.074 | 0.077 | 0.425 | 0.60 | 11 | 16 |
| | 5 | 12.40 | 23.20 | 11.74 | 9.17 | 6.0 | 2.45 | | | | | | |
| | 6 | 12.71 | 23.34 | 10.54 | 8.93 | 2.50 | 2.90 | | | | | | |
| | 7 | 12.62 | 23.47 | 10.79 | 9.21 | 2.75 | 1.10 | | | | | | |
| 920- | 8 | 12.60 | 23.45 | 10.85 | 8.99 | 2.25 | 1.95 | 0.121 | 0.160 | 0.575 | 0.750 | 11 | 54 |
| 1120 | 9 | 12.96 | 23.59 | 10.54 | 9.70 | 1.80 | 1.60 | 0.009 | 0.162 | 0.575 | 0.60 | 6 | 43 |
| | 10 | 12.46 | 23.52 | 11.05 | 9.37 | 2.35 | 2.30 | 0.080 | 0.126 | 0.275 | 0.450 | 12 | 25 |
| SBE | | | | | | | | | | | | | |
| | 11 | 13.19 | 23.59 | 10.36 | 9.23 | 2.05 | 2.10 | 0.121 | 0.077 | 0.450 | 0.475 | 11 | 19 |
| | 12 | 13.72 | 23.54 | 11.01 | 9.09 | 2.00 | 1.30 | 0.087 | 0.082 | 0.350 | 0.396 | 13 | 28 |
| | 13 | 13.74 | 14.63 | 10.83 | 11.55 | 2.25 | 4.20 | 0.121 | 0.095 | 0.550 | 0.700 | 19 | 14 |
| | 14 | 14.37 | 23.43 | 9.72 | 9.70 | 1.45 | 1.85 | 0.039 | 0.126 | 0.275 | 0.525 | | 39 |
| | 15 | 14.24 | 23.48 | 10.02 | 8.67 | 1.85 | 2.85 | 0.085 | 0.201 | 0.425 | 0.921 | 13 | 31 |
| | 16 | 13.65 | 22.19 | 10.22 | 8.89 | 1.30 | 1.20 | 0.064 | 0.080 | 0.400 | 0.313 | 9 | 17 |
| | 17 | 13.67 | 21.80 | 10.28 | 9.07 | 1.45 | 1.60 | 0.075 | 0.090 | 0.405 | 0.603 | 24 | 13 |
| | 1 | 14.40 | | 11.57 | | 2.35 | | 0.069 | | 0.500 | | 16 .5 | |
| | 2 | 14.25 | 15.21 | 13.27 | 10.17 | 2.20 | 1.80 | 0.090 | 0.0370 | 0.513 | 0.475 | 13 | 19 |
| | 3 | 14.10 | | 11.08 | | 2.20 | | 0.090 | | 0.575 | | 17 | |
| | 4 | 13.98 | 14.80 | 11.49 | 10.00 | 2.05 | 2.30 | 0.075 | 0.093 | 0.475 | 0.500 | 11 | 32 |
| | 5 | 13.46 | 20.21 | 11.45 | 8.73 | 2.65 | 2.55 | | | | | | |
| 1545- | 6 | 13.96 | 19.52 | 10.81 | 7.98 | 2.25 | 1.45 | | | | | | |
| 1720 | 7 | 13.92 | 20.16 | 11.35 | 8.38 | 2.80 | 2.60 | | | | | | |
| | 8 | 13.67 | 18.74 | 11.09 | 9.09 | 2.15 | 1.65 | 0.460 | 0.590 | 0.500 | 0.400 | 11 | 27 |
| | 9 | 13.07 | 17.95 | 11.41 | 9.09 | 2.15 | 2.10 | 0.075 | 0.126 | 0.475 | 0.475 | 14.5 | 25 |
| | 10 | 14.03 | 19.76 | 11.09 | 8.97 | 2.45 | 2.10 | 0.080 | 0.113 | 0.575 | 0.368 | 9 | 31 |
| SBF | | | | | | | | | | | | | |
| | 11 | 14.15 | 19.75 | 11.29 | 8.97 | 2.20 | 2.35 | 0.093 | 0.077 | 0.450 | <0.025 | 12.5 | 8.5 |
| | 12 | 14.35 | 20.05 | 10.85 | 8.87 | 2.20 | 1.90 | 0.100 | 0.077 | 0.400 | 0.475 | 5 | 20 |
| | 13 | 14.52 | 20.03 | 11.15 | 9.11 | 1.85 | 2.20 | 0.030 | 0.087 | 0.575 | 0.575 | 12.5 | |
| | 14 | 14.17 | 20.38 | 11.35 | 8.36 | 2.10 | 2.70 | 0.073 | 0.231 | 0.550 | 0.900 | 14 | 32 |
| | 15 | 14.38 | 17.82 | 11.49 | 9.09 | 2.45 | 1.90 | 0.106 | 0.121 | 0.400 | 0.500 | 16 | 20.5 |
| | 16 | 14.38 | 16.37 | 11.31 | 9.60 | 2.30 | 2.70 | 0.090 | 0.170 | 0.550 | 0.550 | 15 | 35 |
| | 17 | 14.44 | 18.25 | 11.11 | 9.37 | 2.00 | 1.60 | 0.069 | 0.080 | 0.425 | 0.538 | 12 | 10 |

T = Top B = Bottom

Table 3. Water Quality Data: Samples Collected on April 19, 1979

| Time EDT | Station Number | Salinity (ppt) T | Salinity (ppt) B | Dissolved Oxygen (mg/l) T | Dissolved Oxygen (mg/l) B | BOD5 (mg/l) T | BOD5 (mg/l) B | Total Phosphorus (mg/l) T | Total Phosphorus (mg/l) B | TKN (mg/l) T | TKN (mg/l) B | Suspended Solids (mg/l) T | Suspended Solids (mg/l) B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 12.13 | 12.51 | 10.47 | 9.53 | 1.40 | 0.85 | 0.009 | 0.059 | 0.275 | 0.450 | 16 | 12 |
| | 3 | 12.13 | 14.06 | 10.15 | 9.17 | 1.35 | 2.10 | 0.051 | | 0.400 | | 29 | 114 |
| | 5 | 12.09 | 14.17 | 10.02 | 9.53 | 1.30 | 1.40 | 0.059 | 0.007 | 0.400 | 0.325 | 10 | 32 |
| 1025- | 6 | 12.03 | 14.11 | 10.11 | 8.99 | 1.25 | 2.50 | 0.012 | 0.248 | 0.300 | 0.875 | 21 | 146 |
| | 7 | 12.02 | 13.87 | 10.03 | 9.41 | 1.40 | 1.40 | 0.051 | 0.337 | 0.400 | 1.150 | 18 | 117 |
| | 8 | 12.08 | 14.00 | 10.07 | 9.01 | 1.30 | 1.85 | 0.046 | | 0.375 | 0.725 | 17 | 24 |
| SBF | 9 | 11.99 | 13.96 | 10.18 | 9.53 | 1.15 | 1.40 | 0.051 | 0.138 | 0.325 | 0.588 | 25 | 67 |
| | 10 | 12.29 | 21.49 | 9.80 | 9.05 | 1.35 | 1.90 | 0.049 | 0.029 | 0.375 | 0.525 | 21 | 50 |
| | 12 | 11.99 | 14.24 | | 10.05 | 1.25 | 2.25 | 0.009 | 0.233 | 0.300 | 1.125 | 25 | 226 |
| | 13 | 12.03 | 14.23 | 10.05 | 9.05 | 1.20 | 1.85 | 0.068 | 0.084 | 0.425 | 0.475 | 26 | 47 |
| | 14 | 12.13 | 14.29 | 10.15 | 9.15 | 1.45 | 1.20 | 0.017 | 0.071 | 0.400 | 0.568 | 24 | 40 |
| EDT | 1 | 13.98 | 19.32 | 9.85 | 8.26 | 1.40 | 4.50 | 0.050 | 0.310 | 0.475 | 1.825 | 17 | 349 |
| | 2 | 13.33 | 19.55 | 9.29 | 8.82 | 1.20 | 1.30 | 0.039 | 0.046 | 0.450 | 0.350 | 5 | 15 |
| | 3 | 13.49 | 19.49 | 9.47 | 8.82 | 1.75 | 2.30 | 0.044 | 0.036 | 0.700 | 0.575 | 6 | 32 |
| | 5 | 13.74 | 19.57 | 9.61 | 8.40 | 1.45 | 3.40 | 0.064 | 0.130 | 0.325 | 0.750 | 12 | 67 |
| | 6 | 13.48 | 19.23 | 9.77 | 8.99 | 1.60 | 1.75 | 0.044 | 0.084 | 0.375 | 0.425 | 10 | 13 |
| 1435- | 7 | | 19.71 | 9.65 | 8.06 | 1.50 | 1.70 | 0.002 | 0.265 | 0.388 | 0.675 | 10 | 82 |
| 1527 | 8 | 13.49 | 19.65 | 9.61 | 9.21 | 1.30 | 4.80 | 0.029 | 0.347 | 0.400 | 1.225 | 15 | 205 |
| | 9 | 13.57 | 19.83 | 9.51 | 8.86 | 2.15 | 2.85 | 0.004 | 0.116 | 0.350 | 0.550 | 8 | 49 |
| SBE | 10 | 12.58 | 19.67 | 10.15 | 8.88 | 2.20 | 2.60 | 0.068 | 0.033 | 0.463 | 0.600 | 10 | 62 |
| | 12 | 13.23 | 19.63 | 9.65 | 9.65 | 1.50 | 2.70 | 0.051 | 0.136 | 0.425 | | 7 | 77 |
| | 13 | 12.72 | 19.94 | 9.63 | 8.84 | 3.05 | 2.10 | 0.014 | 0.161 | 0.575 | 0.700 | 11 | 39 |
| | 14 | 12.81 | 19.91 | 10.01 | 7.82 | 1.80 | 3.60 | 0.056 | 0.324 | 0.500 | 0.975 | 9 | 230 |

T = Top B = Bottom

Table 4. Water Quality Data: Samples Collected on April 20, 1979

| Time EDT | Station Number | Salinity | Dissolved Oxygen (mg/l) T | Dissolved Oxygen (mg/l) B | BOD5 (mg/l) T | BOD5 (mg/l) B | Total Phosphorus (mg/l) T | Total Phosphorus (mg/l) B | TKN (mg/l) T | TKN (mg/l) B | Suspended Solids (mg/l) T | Suspended Solids (mg/l) B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 9.87 | 10.87 | 1.65 | 1.70 | | | | | 13 | 13 |
| | 3 | | | 9.97 | 4.80 | 2.05 | | | | | 8.5 | 275 |
| | 5 | | 9.39 | 10.23 | 2.00 | 2.00 | | | | | 12 | 15 |
| | 6 | | | 10.00 | 6.20 | 2.05 | | | | | 10.5 | 446 |
| 1130- | 7 | | | 9.91 | 6.00 | 2.20 | | | | | 13.5 | 249 |
| 1225 | 8 | | 8.74 | 10.19 | 3.35 | 5.76 | | | | | 7 | 80.5 |
| | 9 | | 8.34 | 10.25 | 4.65 | 1.75 | | | | | 7 | 386 |
| SBF | 10 | | 8.10 | 10.17 | 4.35 | 2.00 | | | | | 15 | 435 |
| | 12 | | 7.78 | 10.78 | 6.45 | 1.90 | | | | | 11.5 | |
| | 13 | | 8.22 | 10.31 | 4.50 | 2.05 | | | | | 12.5 | 372 |
| | 14 | | 8.26 | 10.25 | 4.05 | 2.10 | | | | | 13.5 | 343 |
| | 1 | | 8.56 | 10.47 | 2.80 | 2.25 | 0.096 | 0.078 | 0.575 | 0.600 | 23 | 38 |
| | 3 | | 8.65 | 9.99 | 2.20 | 1.80 | 0.068 | 0.063 | 0.542 | 0.625 | 10 | 29.5 |
| 1545- | | | | | | | | | | | | |
| 1630 | 5 | | | 10.13 | 2.10 | 1.60 | 0.089 | 0.052 | 0.475 | 0.525 | 10.5 | 23 |
| | 6 | | 8.80 | 10.45 | | 2.10 | 0.070 | 0.063 | 0.575 | 0.475 | 8 | 22.5 |
| SBE | 7 | | 8.76 | 10.17 | 2.50 | | 0.052 | 0.052 | 0.500 | 0.500 | 11.5 | 21 |
| | 8 | | 8.70 | 10.31 | 2.20 | | 0.060 | 0.052 | 0.525 | 0.475 | 7 | 22.5 |
| | 9 | | 8.84 | 10.13 | 2.35 | 2.00 | 0.060 | 0.050 | 0.525 | 0.550 | 13 | 22 |
| | 10 | | 8.80 | 10.27 | 2.00 | 2.05 | 0.174 | 0.060 | 0.775 | 0.450 | 9 | 70.7 |
| | 12 | | 8.72 | 10.23 | 2.00 | 1.90 | 0.060 | 0.058 | 0.475 | 0.450 | 12 | 24 |
| | 13 | | 9.75 | 9.95 | 1.60 | 1.50 | 0.089 | 0.065 | 0.721 | 0.575 | 17 | 64 |
| | 14 | | 8.38 | 9.45 | 2.85 | 1.60 | 0.119 | 0.055 | 0.650 | 0.475 | 4.5 | 122.5 |

T = Top B = Bottom

Table 5. Preliminary Current Speed Measured at Stations 1-1, 1-2 and 1-3 on December 19, 1978 (1300-1345)

| Station 1-1 | | Station 1-2 | | Station 1-3 | |
|---|---|---|---|---|---|
| Depth (m) | Current Speed (cm/sec) | Depth (m) | Current Speed (cm/sec) | Depth (m) | Current Speed (cm/sec) |
| 1 | 4.0 | 1 | 4.0 | 1 | 2.7 |
| 14 | 2.0 | 14 | 2.3 | 14 | 3.2 |

Table 6-1. Current Speed and Direction Measured at Station 4-1 on May 3, 1979 (SBF to SBE)

Maximum Water Depth = 15m

| Depth (m) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) |
|---|---|---|---|---|---|---|
| 1 | 1130 | 4.6 | 110 | 1230 | 3.7 | 180 |
| 2 | | 4.6 | 150 | | 3.7 | 160 |
| 3 | | 4.6 | 310 | | 3.7 | 230 |
| 4 | | 4.6 | 360 | | 3.7 | 70 |
| 5 | | 3.7 | 340 | | 3.7 | 110 |
| 6 | | 2.8 | 280 | | 3.7 | 360 |
| 7 | | 3.7 | 100 | | 3.7 | 30 |
| 8 | | 4.6 | 260 | | 3.7 | 60 |
| 9 | | 4.6 | 200 | | 4.6 | 230 |
| 10 | | 3.7 | 80 | | 5.5 | 85 |
| 11 | | 4.6 | 170 | | 3.7 | 340 |
| 12 | | 8.0 | 350 | | 3.7 | 90 |
| 13 | | 5.5 | 340 | | 5.5 | 260 |
| 14 | | 3.7 | 45 | | 6.3 | 280 |
| 15 | | 3.7 | 45 | | 4.6 | 260 |
| 1 | 1400 | 5.5 | 180 | 1455 | 4.6 | 270 |
| 2 | | 5.5 | 80 | | 5.5 | 110 |
| 3 | | <2.8 | 180 | | 4.6 | 150 |
| 4 | | 5.5 | 320 | | 5.5 | 350 |
| 5 | | 4.6 | 270 | | 5.5 | 240 |
| 6 | | 3.7 | 320 | | 5.5 | 260 |
| 7 | | 6.3 | 320 | | 5.5 | 340 |
| 8 | | 4.6 | 270 | | 3.7 | 240 |
| 9 | | 5.5 | 270 | | 3.7 | 80 |
| 10 | | 5.5 | 280 | | 3.7 | 210 |
| 11 | | 8.9 | 110 | | 5.5 | 260 |
| 12 | | 7.2 | 220 | | 3.7 | 50 |
| 13 | | 7.2 | 190 | | 4.6 | 30 |
| 14 | | 7.2 | 290 | | 5.5 | 360 |

Table 6-2. Current Speed and Direction Measured at Station 4-2 on May 3, 1979 (SBF to SBE)

Maximum Water Depth = 15m

| Depth (m) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) |
|---|---|---|---|---|---|---|
| 1 | 1210 | 3.7 | 90 | 1300 | 4.6 | 90 |
| 2 | | 3.7 | 160 | | 3.7 | 340 |
| 3 | | 3.7 | 110 | | 3.7 | 280 |
| 4 | | 3.7 | 50 | | 4.6 | 240 |
| 5 | | 3.7 | 10 | | 4.6 | 230 |
| 6 | | <2.8 | 20 | | 4.6 | 230 |
| 7 | | 7.2 | 60 | | 3.7 | 250 |
| 8 | | 8.9 | 45 | | 4.6 | 130 |
| 9 | | 7.2 | 60 | | 5.5 | 280 |
| 10 | | 3.7 | 30 | | 4.6 | 250 |
| 11 | | 10.6 | 260 | | 4.6 | 320 |
| 12 | | 6.3 | 250 | | 4.6 | 30 |
| 13 | | 4.6 | 110 | | 6.3 | 50 |
| 14 | | 3.7 | 110 | | 10.6 | 70 |
| 15 | | | | | 10.6 | 100 |
| | | | | | | |
| 1 | | 3.7 | 180 | 1535 | 3.7 | 180 |
| 2 | | 5.5 | 250 | | 4.6 | 150 |
| 3 | | 6.3 | 360 | | 5.5 | 90 |
| 4 | | 8.0 | 40 | | 7.2 | 70 |
| 5 | | 7.2 | 10 | | 5.5 | 60 |
| 6 | | 4.6 | 10 | | 4.6 | 40 |
| 7 | | 2.8 | 210 | | 3.7 | 30 |
| 8 | | 4.6 | 90 | | 5.5 | 60 |
| 9 | | 5.5 | 260 | | 3.7 | 360 |
| 10 | | 4.6 | 260 | | 5.5 | 240 |
| 11 | | 7.2 | 230 | | 4.6 | 240 |
| 12 | | 6.3 | 50 | | 4.6 | 240 |
| 13 | | 7.2 | 360 | | 3.7 | 120 |
| 14 | | 8.0 | 45 | | 4.6 | 30 |

Table 7-1. Current Speed and Direction Measured at Station 5-1 on May 10, 1979 (SBE to SBF).

Maximum Water Depth = 15m

| Depth (m) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0945 | 9.8 | 360 | 1105 | 3.7 | 360 | 1210 | 2.8 | 320 |
| 2 | | 10.6 | 360 | | 4.6 | 360 | | 2.8 | 360 |
| 3 | | 8.0 | 10 | | 2.8 | 360 | | 2.8 | 350 |
| 4 | | 8.9 | 330 | | 3.7 | 90 | | 2.8 | 280 |
| 5 | | 10.6 | 330 | | 3.7 | 360 | | 3.7 | 255 |
| 6 | | 12.4 | 275 | | 4.6 | 30 | | 2.8 | 340 |
| 7 | | 9.8 | 265 | | 3.7 | 90 | | 2.8 | 115 |
| 8 | | 2.8 | 60 | | 3.7 | 130 | | 2.8 | 130 |
| 9 | | 2.8 | 60 | | 2.8 | 60 | | <2.8 | 250 |
| 10 | | 2.8 | 285 | | 5.5 | 70 | | 2.8 | 240 |
| 11 | 1000 | <2.8 | 30 | 1120 | 8.0 | 70 | | 2.8 | 70 |
| 12 | | 3.7 | 250 | | 4.6 | 80 | | <2.8 | 360 |
| 13 | | | | | 3.7 | 340 | | <2.8 | 15 |
| 14 | 1005 | 0.10 | 360* | | 3.7 | 135 | | 2.8 | 300 |
| 15 | 1010 | 0.10 | 360+ | | 2.8 | 180 | | | |

| Depth (m) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1300 | 2.8 | 360 | 1400 | 7.2 | 20 | 1520 | <2.8 | 0 |
| 2 | | 3.7 | 360 | | 7.2 | 10 | | 2.8 | 50 |
| 3 | | 2.8 | 20 | | 7.2 | 10 | | 3.7 | 30 |
| 4 | | <2.8 | 0 | | 3.7 | 20 | | 3.7 | 20 |
| 5 | | <2.8 | 0 | | 3.7 | 0 | | 2.8 | 70 |
| 6 | | 2.8 | 330 | | 2.8 | 30 | | 3.7 | 70 |
| 7 | | 2.8 | 180 | | 3.7 | 45 | | 2.8 | 60 |
| 8 | | 2.8 | 0 | | 2.8 | 60 | | 3.7 | 80 |
| 9 | | 2.8 | 170 | | 2.8 | 100 | | 3.7 | 80 |
| 10 | | 2.8 | 180 | | 2.8 | 170 | ≠ | | |
| 11 | | 2.8 | 60 | | 2.8 | 320 | | | |
| 12 | | 2.8 | 0 | | 2.8 | 350 | | | |
| 13 | | 2.8 | 180 | | 2.8 | 85 | | | |
| 14 | | 2.8 | 100 | | 2.8 | 80 | | | |

≠Measurement interrupted by thunderstorm.

*Current measurement at 1m off VV unit and 1 meter below water surface.

+Current measurement at 1m off VV unit and 14½ meters below water surface.

Table 7-2. Current Speed and Direction Measured at Station 5-2 on May 10, 1979 (SBE to SBF)

Maximum Water Depth = 15m

| Depth (m) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1015 | <2.8 | 330 | 1130 | 2.8 | 360 | 1235 | 2.8 | 180 |
| 2 | | 2.8 | 100 | | 3.7 | 20 | | 3.7 | 30 |
| 3 | | 3.3 | 320 | | 2.8 | 350 | | 2.8 | 360 |
| 4 | | 3.3 | 340 | | 3.7 | 320 | | <2.8 | 45 |
| 5 | | 3.7 | 305 | | 3.7 | 290 | | 2.8 | 110 |
| 6 | | 3.3 | 195 | | 2.8 | 285 | | 2.8 | 150 |
| 7 | | 4.6 | 265 | | 3.7 | 350 | | <2.8 | 260 |
| 8 | | 3.7 | 265 | | 2.8 | 290 | | <2.8 | 270 |
| 9 | | 3.7 | 350 | | 4.6 | 110 | | 2.8 | 270 |
| 10 | | 2.8 | 160 | | 3.7 | 100 | | 2.8 | 240 |
| 11 | | 2.8 | 350 | | 4.6 | 60 | | <2.8 | 80 |
| 12 | | <2.8 | 200 | | 2.8 | 40 | | 2.8 | 60 |
| 13 | | <2.8 | 110 | | <2.8 | 120 | | 2.8 | 90 |
| 14 | | <2.8 | 230 | | 2.8 | 70 | | 2.8 | 70 |
| 15 | | | | | 2.8 | 320 | | 2.8 | 100 |

| Depth (m) | Time (EDT) | Speed (cm/sec) | Direction (mag) | Time (EDT) | Speed (cm/sec) | Direction (mag) |
|---|---|---|---|---|---|---|
| 1 | 1335 | 8.9 | 0 | 1437 | 5.5 | 320 |
| 2 | | 7.2 | 10 | | 5.5 | 15 |
| 3 | | 8.9 | 10 | | 3.7 | 10 |
| 4 | | 7.2 | 15 | | 3.7 | 15 |
| 5 | | 5.5 | 10 | | 3.7 | 20 |
| 6 | | 2.8 | 70 | | 2.8 | 70 |
| 7 | | 3.7 | 90 | | 3.7 | 65 |
| 8 | | 2.8 | 85 | | 2.8 | 30 |
| 9 | | 3.7 | 135 | | 3.7 | 60 |
| 10 | | 2.8 | 120 | | 2.8 | 120 |
| 11 | | 2.8 | 90 | | 2.8 | 100 |
| 12 | | 3.7 | 90 | | 2.8 | 100 |
| 13 | | 2.8 | 70 | | 2.8 | 110 |
| 14 | | | | | 2.8 | 110 |
| 15 | | | | | 2.8 | 110 |

Table 8-1. Data from Flume With Formaldehyde Preserved Hydroids and Bryozoans

| | Settling Velocity (cm/sec) | Wet Weight of Animals (g) |
|---|---|---|
| Hydroids | 5.5 | 6.6 |
| | 8.3 | 12.4 |
| | 2.6 | 0.5 |
| | 5.0 | 3.1 |
| | 11.9 | 23.3 |
| | 2.8 | 0.2 |
| | 3.2 | 0.4 |
| Bryozoans | 3.7 | 20.5 |
| | 6.5 | 77.2 |
| | 4.0 | 18.2 |
| | 5.0 | 9.1 |
| | 3.4 | 3.7 |
| | 2.7 | 3.3 |
| | 3.9 | 8.2 |
| | 4.9 | 42.4 |

Table 8-2. Data from Flume Tests With Formaldehyde Preserved Hydroids and Bryozoans

| Flume Speed (cm/sec) | Comments |
|---|---|
| 5.4 | no movement |
| 6.7 | slight movement, some shifting |
| 8.1 | start to roll, then stop |
| 8.9 | definite rolling and sliding |
| 9.8 | rolling and sliding |
| 14.7 | rolling and sliding |
| 25.0 | rolling and sliding |

Table 8-3. Data from Flume Tests With Formaldehydr Preserved Hydroids and Bryozoans

| | Rolling/Sliding Velocity (cm/sec) | Flume Speed (cm/sec) |
|---|---|---|
| Hydroid | 2.0 | 8.7 |
| | 2.0 | 8.7 |
| | 1.4 | 8.7 |
| | 4.1 | 9.9 |
| | 5.2 | 9.9 |
| | 3.1 | 9.9 |
| | 5.1 | 9.9 |
| | 4.8 | 9.9 |
| | 4.4 | 9.9 |
| | 4.1 | 9.9 |
| | 9.1 | 14.7 |
| | 10.10 | 14.7 |
| | 7.75 | 14.7 |
| | 4.6 | 14.7 |
| | 10.8 | 14.7 |
| | 8.26 | 14.7 |
| | 9.9 | 14.7 |
| Bryozoan | 1.56 | 8.7 |
| | 1.56 | 8.7 |
| | 1.09 | 8.7 |
| | 4.46 | 9.9 |
| | 5.6 | 9.9 |
| | 4.6 | 9.9 |
| | 3.1 | 9.9 |
| | 9.0 | 9.9 |
| | 5.2 | 9.9 |
| | 1.9 | 14.7 |
| | 8.4 | 14.7 |
| | 9.2 | 14.7 |
| | 10.1 | 14.7 |

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