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Dredging Research Technical Notes

Stability Evaluation of the Octapod Sensor Mount

Purpose

This technical note reports on a study at the U.S. Army Engineer Coastal Engineering Research Center's (CERC) Field Research Facility (FRF) located at Duck, North Carolina, to determine the movement characteristics of a typical bottom-mounted sensor.

Background

Bottom-mounted sensors are often used for measurements of coastal waves, currents, and water levels. For most wave and current measurements, the vertical placement and stability of the sensor mount are not critically important. However, for long-term water level measurements, vertical stability is of paramount importance. Bottom-mounted sensors used for long-term water level measurements sometimes produce data sets which contain steps or trends in the mean water level explainable only by instrument malfunction or vertical movement of the mount.

Additional Information

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Equipment Description

The Octapod (Figure 1) is a 4-ft-tall, eight-sided, heavy steel instrument mount designed by CERC's Prototype Measurement and Analysis Branch (PMAB) to support and protect a variety of oceanographic sensors. The 1-ft-long leg extensions located at each of the eight corners were designed to bury into the bottom to prevent trawler nets from snagging the base plate and entangling the Octapod. Although the design of the Octapod used in this field evaluation has recently been extensively modified to make it more trawler-resistant, the stability results presented herein are still valid.

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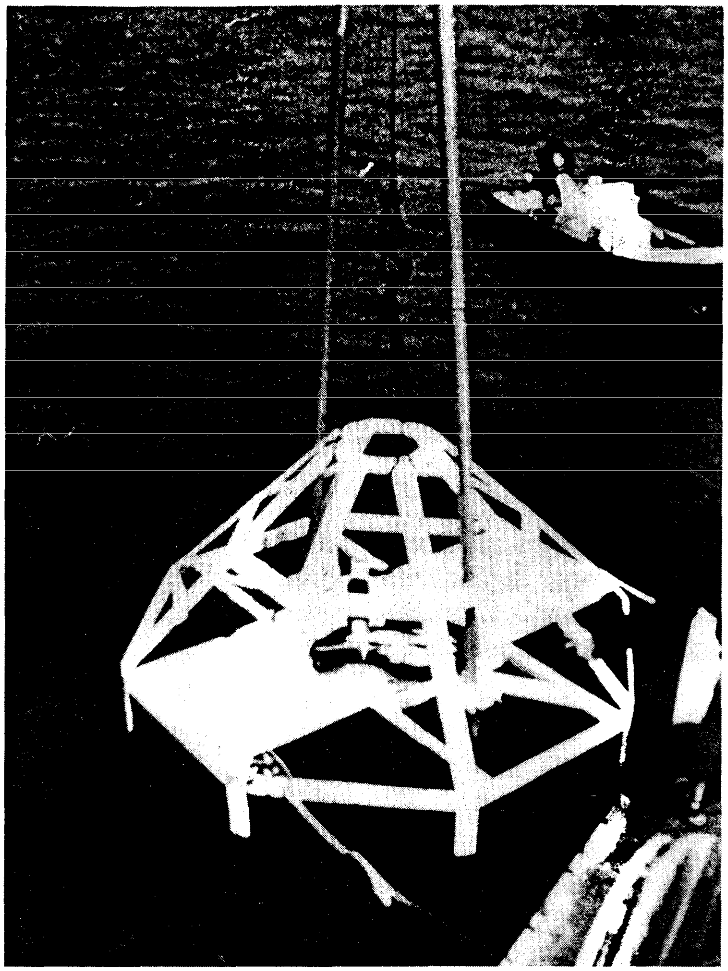

Figure 1. OCTAPOD being deployed

The modified design is six-sided and 2 to 3 ft tall, depending on application, with 2-ft-long leg extensions.

Experimental Procedure

To evaluate the Octapod's stability, a one-year test was carried out at the FRF. The results of this test are described below. The evaluation began by using the FRF's Coastal Research Amphibious Buggy (CRAB) to deploy the Octapod at a water depth of 16 ft. The Octapod was anchored to the bottom using two 10-ft-long jetted pipes positioned along a diameter, each approximately 1 ft from the center of the Octapod base. The bottom material at the Octapod location was mostly medium sand with some shell content. The presumption at the time of deployment was that the sand bottom would provide sufficient lateral stability to prevent significant pod tilt.

The Octapod's vertical position and tilt were routinely monitored using a Zeiss, Inc. Elta 2S electronic total station. Each measurement was taken by positioning the CRAB alongside the Octapod and inserting a 20.02-ft-long pole into a vertical pipe in the top of the Octapod. A notch on the bottom of the pole ensured that it was always seated on a cross bolt in the vertical pipe, thus ensuring that the pole was always in the same position for every series of measurements. The pole was equipped with two reflecting prisms, one at the top and one 4.05 ft below the top. Because of the way the prisms were mounted on the pole, the lower prism was offset 0.25 ft in front of the top prism and 0.15 ft to the right.

The Elta 2S was used to determine the position (X, Y, and Z) of each prism. Geometry was used to determine the tilt and the true vertical position of the top of the Octapod. The pole was flexible enough that wave action caused some horizontal movement. To minimize the effect of the pole movement, 10 repeated measurements were alternately made of each prism. These were then averaged and the Z values were adjusted for the 20.02-ft pole length and for the slight offset position of the prisms on the pole. Computed coordinates of the true elevation of the cross bolt and the tilt of the Octapod are listed in Table 1.

The Elta 2S is capable of measuring azimuth and elevation to 0.6 sec of arc and distances to a few millimeters, allowing for a vertical resolution of better than 0.01 ft at the distance of 2,200 ft which separated the Octapod and the Elta. Other sources of error were potentially larger. These sources included movement of the pole to waves, changing atmospheric conditions, errors in aiming at the prisms, and an out-of-level instrument. It was anticipated the Octapod would either remain vertically stable or move downward into the bottom. Some of the data points, however, indicated upward movement, which was very unlikely and probably the result of measurement errors.

Eleven measurements were made starting on 24 May 1988 (day 6 on the abscissa of Figure 2) and ending on 15 June 1989 (day 394). The measurements were not uniformly distributed through time; over half were taken during the first three months of the study when the greatest amount of settling was expected. Some additional measurements were attempted but could not be made because of high seas. In addition to the measurements of the Octapod, 24 surveys were conducted of profile line 188 located 80 ft to the south. Five of these surveys are shown in Figure 3. Table 2 lists interpolated depths at the position of the Octapod (1,570 ft) and at other nearby locations. Periodic diver inspections were made to observe the Octapod and note any scour or filling that took place.

Results

The variations in sea-floor depth at the Octapod are clearly seen in Figure 4 which plots the data in Table 2. The figure shows that at the location of the Octapod the bottom was extremely stable until a sequence of

Table 1. Location of the Octapod						
Survey Number	Date	Average Coordinates, ft			Computed Tilt, deg	Cumulative Change
		X	Y	Z		
1	05/24/88	76.38	1572.08	-12.70	0.8	0.00
2	06/07/88	75.59	1571.32	-13.00	2.2	-0.30
3	06/21/88	75.67	1571.06	-13.05	1.8	-0.35
4	07/08/88	76.00	1570.64	-13.12	2.8	-0.42
5	07/20/88	76.10	1570.80	-13.15	2.8	-0.45
6	08/08/88	75.56	1570.73	-12.98	2.3	-0.29
7	11/10/88	74.51	1569.97	-13.22	6.0	-0.52
8	11/24/88	75.00	1570.24	-13.15	3.1	-0.45
9	03/28/89	72.74	1569.22	-13.42	9.5	-0.72
10	05/31/89	72.86	1569.13	-13.23	10.8	-0.53
11	06/15/89	72.07	1568.27	-13.35	9.0	-0.65

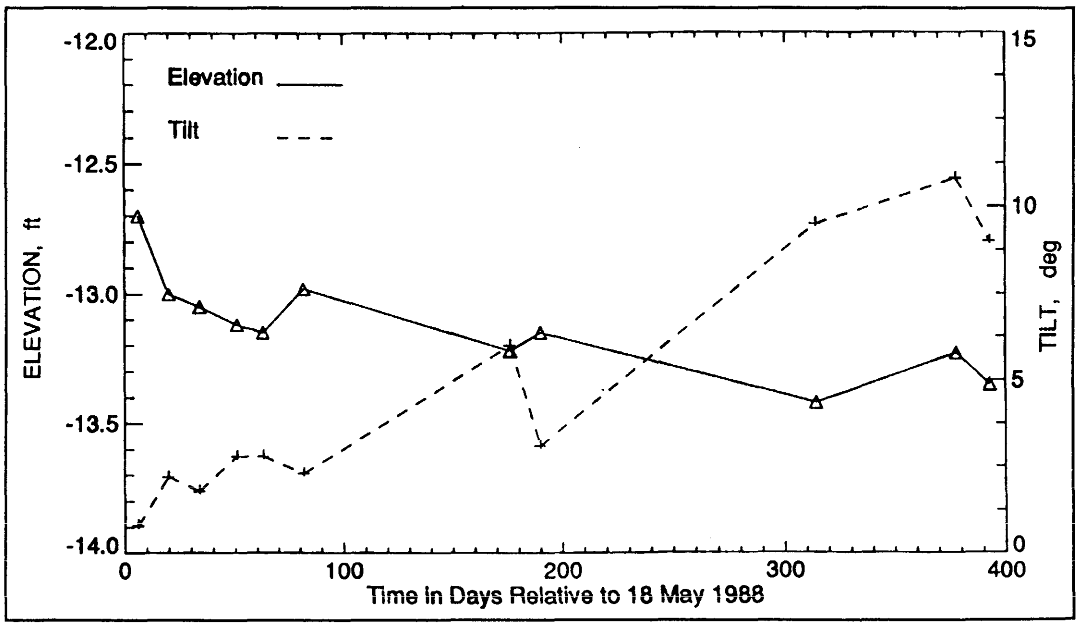

Figure 2. Octapod elevation and tilt

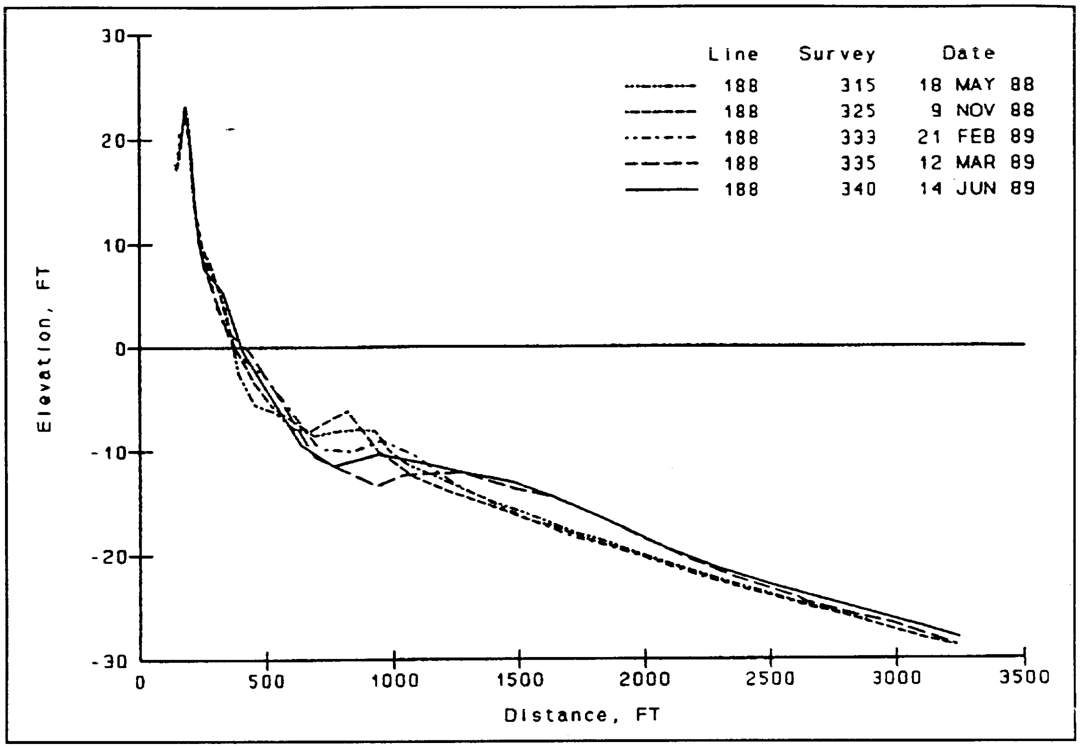

Figure 3. Representative surveys of Profile Line 188 during the study

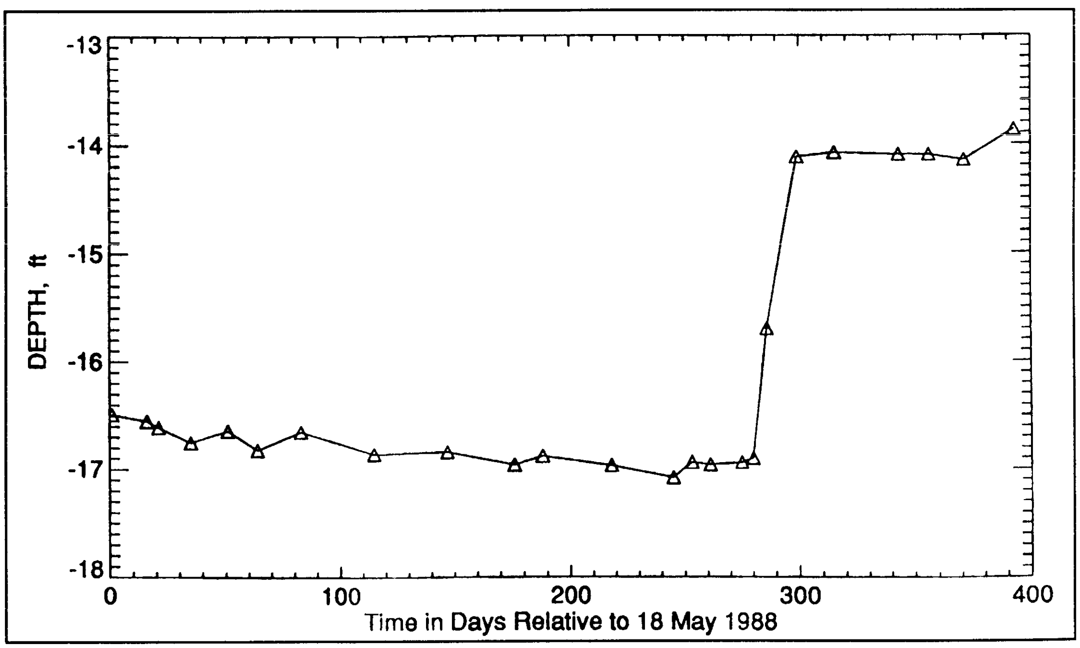

Figure 4. Variation in depth at the Octapod site

Table 2. Variations in Depth near the Octapod Location								
Date	Survey	Cumulative Days	Variation in Depth, ft, for Distance Offshore, ft					
			1510	1530	1550	1570	1590	1600
05/18/88	315	0	-15.96	-16.14	-16.31	-16.49	-16.67	-16.75
06/02/88	316	15	-16.06	-16.22	-16.39	-16.55	-16.72	-16.82
06/07/88	317	20	-16.04	-16.23	-16.42	-16.61	-16.80	-16.90
06/21/88	318	34	-16.18	-16.37	-16.57	-16.75	-16.92	-17.01
07/07/88	319	50	-16.13	-16.30	-16.47	-16.64	-16.81	-16.89
07/20/88	320	63	-16.22	-16.43	-16.68	-16.82	-16.95	-16.99
08/08/88	321	82	-16.07	-16.27	-16.47	-16.65	-16.83	-16.92
09/09/88	322	114	-16.31	-16.31	-16.70	-16.86	-17.02	-17.10
10/11/88	323	146	-16.19	-16.41	-16.62	-16.84	-17.05	-17.16
11/09/88	325	175	-16.46	-16.65	-16.84	-16.96	-17.07	-17.13
11/21/88	326	187	-16.41	-16.59	-16.73	-16.88	-17.02	-17.09
12/21/88	328	217	-16.40	-16.59	-16.78	-16.97	-17.16	-17.26
01/17/89	329	244	-16.54	-16.72	-16.90	-17.08	-17.25	-17.34
01/25/89	330	252	-16.25	-16.48	-16.71	-16.94	-17.13	-17.21
02/02/89	331	260	-16.37	-16.57	-16.76	-16.96	-17.15	-17.25
02/16/89	332	274	-16.35	-16.54	-16.74	-16.94	-17.14	-17.23
02/21/89	333	279	-16.34	-16.56	-16.77	-16.90	-17.17	-17.26
02/27/89	334	285	-15.08	-15.29	-15.49	-15.70	-15.91	-16.02
03/12/89	335	298	-13.81	-13.92	-14.02	-14.12	-14.23	-14.28
03/28/89	336	314	-13.68	-13.80	-13.92	-14.08	-14.15	-14.21
04/25/89	337	342	-13.61	-13.77	-13.93	-14.10	-14.27	-14.35
05/08/89	338	355	-13.58	-13.75	-13.93	-14.10	-14.28	-14.37
05/23/89	339	370	-13.65	-13.82	-18.98	-14.15	-14.32	-14.40
06/14/89	340	392	-13.35	-13.52	-13.69	-13.87	-14.04	-14.13

two storms occurred, the first on 24 February 1989 (day 282) and the second two weeks later on 7 March (day 296). Each of these storms moved significant amounts of material offshore, ultimately covering the Octapod with 2.7 ft of sediment.

Table 1 summarizes each of the Octapod measurements. Elevations computed based on each of the prisms compared favorably. Note that the adjusted X and Y coordinates given in Table 1 are for the location of the prisms, not of the Octapod itself. A detailed analysis of the 10 repetitions from each measurement session indicated that by using 10 measurements the tilt of the Octapod could be resolved to 1 deg and the elevation could be resolved to 0.1 ft. The variation in Octapod elevation and tilt are shown in Figure 2. Figure 2 clearly shows the rapid decrease in depth (0.3 ft) which occurred immediately following the first survey, an apparent response to the installation. It also shows the relative stability during most of the period and the points that indicate upward movement of the Octapod.

The most significant of these upward movements occurred during August when it "rose" 0.2 ft. This occurred during a survey that also shows a general upward movement of the entire profile of about 0.2 ft. Since there were no storm events, this apparently is an error which probably resulted from a slight tilt of the Elta 2S (0.0044 deg). The first survey in November is also suspect. It is 0.1 ft below the 24 November 1988 survey (day 191), and the 20 July (day 64) survey; the value for the tilt is much greater than for those other surveys.

A detailed analysis of the 10 observations from 10 November (day 177) showed that although one of the observations gave a tilt angle of 4 deg and an elevation of -13.2 ft (values closer to the 24 November value), all the remaining values clustered closely around the average value given in Table 1. It should also be noted that the diver observations of the Octapod during the summer and fall always reported scour, not only under the 8 tabs, which never settled into the bottom as originally intended, but under the entire structure, causing it to be supported only on the two closely spaced pipes.

The biggest and most definitive change occurred during the spring storms described above. These storms left the Octapod both buried and tilted. Table 1 shows three observations following the second storm. Since they show a range in elevation of 0.2 ft, and in tilt of 2 deg, and since it is unlikely that the Octapod moved after being buried, these three values have been averaged in order to compute the final position of the Octapod. The average values tabulated below show an effective drop of the Octapod of 0.6 ft and a tilt increase of 9 deg. About 0.3 ft of the drop occurred during the initial settling of the Octapod after deployment. Another 0.2 ft occurred during the fall months but at a slower rate. The final 0.2 ft apparently occurred prior to the burial caused by the storms.

Parameter	Value	Difference from 24 May 1988
Elevation	-13.3 ft	-0.6 ft
Tilt	10 deg	9 deg

Conclusions and Recommendations

As a result of this study, the following recommendations are made for use of the Octapod or similarly designed mounts:

- Allowable limits for settling, deposition, and tilt should be established prior to designing and installing the mount.

- To minimize the potential for tilt, a minimum of three jetted pipes, separated as far as practicable, should be used; pipe length should depend on depth to which jetting is possible, although the longer the better.

- When the-determination of elevation is critical, care should be taken to ensure that the survey instrument is of sufficient accuracy and is both properly calibrated and stationed.

The design of the Octapod has been highly modified based upon the results of this study. The design presently used is hexagonal in plan view as opposed to octagonal, has a wider base for increased stability, is lower in profile, and the bottom penetrating tabs have been replaced by longer leg extensions. The number of jetted pipes has been increased from two to three with the option of adding more, should the specific application warrant. The redesigned mount has proven less likely to be affected by trawler activities and less prone to bottom scour in the mount vicinity. Moreover, the redesigned mount can be readily disassembled for more convenient shipping.

The results of this study reflect only the stability characteristics of the Octapod in the physical setting of the FRF during the period of the deployment. A deployment site with different bottom sediment and wave conditions may result in different vertical stability characteristics. Geotechnical theory and practice indicate that jetted pipes are prone to short-term settlement when loaded. Such settlement may be unavoidable unless the pipes are installed by some other method, such as diving. The implication for sensor mounts installed using jetting is that elevations may not stabilize for perhaps months. Users planning operations where water-level gaging is crucial should factor this settlement period into the project schedule. The vertical stability of the mount may be monitored by optical methods such as used in this study, or by periodic comparison with data obtained from another nearby tide gage of known stability. Experience indicates the comparisons should be made during calm periods at low tide.

The experience gained in this study has led to the redesign of the sensor mount most commonly used by CERC for bottom-placed instrumentation. Moreover, the deployment and monitoring procedures used when water-level data are required have been modified to better ensure the vertical stability of the mount and the integrity of the data. The modified procedures include increasing the number, length, and spacing of the anchoring pipes and monitoring the acquired data for steps and trends as compared with both prior data acquired from the mount sensor and from independent sources. Long-term (greater than one year) experience using the modified design and deployment procedure has indicated that initial settling is less and occurs over a shorter period, and subsequent stability is greater than experienced in the present study.