CHAPTER ONE HUNDRED TWENTY SIX

SURVEY TECHNIQUES USED TO MEASURE NEARSHORE PROFILES

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Abstract

The three most common survey techniques used to measure nearshore profiles are (1) conventional boat-sonic depth sounder; (2) hydrostatic pressure profiler; and (3) the self powered Coastal Research Amphibious Buggy (CRAB). Theory of operation and methodology used for each technique are summarized and evaluated. Three separate field tests using survey data from each technique are evaluated for system repeatability. Data reduction, sea surface correction, and filtering methods for boat-depth sounder survey data are examined.

1. Introduction

The measurement of nearshore profiles is extremely important to coastal engineers concerned with navigation and shore protection structures, cross and longshore sediment transport, and seasonal shoreline changes. Accurately surveying the nearshore region between a relatively stable point on the beach to a depth of little or no elevation change is a frequent problem to the coastal engineer. As described by Seymour (1984), in many coastal engineering applications of nearshore surveying, the absolute elevation is not as important as the changes in elevation since the previous profile. Wave orbital velocities responsible for mobilizing the sediment decrease with increasing water depth, thus the amount of change in sand elevation is expected to decrease with distance offshore. In general, the bottom slope decreases with offshore distance such that the small changes in deeper water are integrated over a large area resulting in very significant sand volume changes. For example, a net change of 30,000 cubic meters over approximately one kilometer of beach represents an average change in depth of only 3 cm. This results in the parodox that the greatest accuracy of measurement is required at the greatest distance away from the known reference elevation.

Surveying the dry portions of the beach to a depth of 1 meter use conventional land surveying methods, using rod, level, and chain techniques with sufficient accuracy of plus or minus 1 cm. Surveying the underwater portion of nearshore beach profiles (-1 to -10 meters) has presented significant accuracy problems. The boat-depth sounder

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method is unable to operate thru the active surf zone region (-Im to -3m depth) and uses the sea surface as the vertical datum. Surface waves with a broad range of frequencies must be filtered out of the profile. Two other recently developed survey systems eliminate the sea surface reference uncertainty by measuring the bottom profile directly. The Hydrostatic Profiler, developed at Scripps Institution of Oceanography, is a portable system using the hydrostatic pressure principle to measure vertical differences between a pressure sensor that follows the profile on the ocean bottom and a reference sensor on the shoreline. The two pressure sensors are connected by a fluid filled tube and horizontal distance determined by measuring the extension of the tube. The Coastal Research Amphibious Buggy (CRAB) of the U.S. Army Coastal Engineering Research Center (CERC) is a self-powered stable platform that traverses the ocean bottom carrying a laser reflector above water. A total station survey instrument located over a known bench mark on land, shoots the reflector at discreet points to obtain precise X,Y,Z data from the dry beach to a depth of 10 meters.

This paper will briefly summarize and evaluate each of these survey techniques. Theory of operation, methodology, advantages, limitations, accuracy in repeatability, and depth sounder data filtering methods using actual field data are discussed.

2. Boat-Depth Sounder Method

2.1 Theory of Operation and Field Techniques

Surveys of the dry beach out to wading depth use the conventional rod, level, and chain technique. By selecting times of low tide, wave, and current conditions, it is possible to extend the rod and level technique seaward to a depth of about 1 meter with an accuracy of plus or minus 1 cm. The nearshore bathymetry (-1 to -10 meters) is usually measured by some type of Automated Bathymetry System (ABS). An ABS consists of state-of-the-art electronic equipment including a sonic depth sounder, depth digitizer, range-range positioning navigation system, printer, data logger, and cassette recorder. The ABS is secured to a small survey boat (Figure 1) and requires one boat operator, one field electronic engineer, and a minimum of two experienced surveyors for proper operation. Boat-depth sounder surveys are best performed during the highest possible tide to provide both overlap and data quality control with the rod and level survey. The general procedure for conducting these overlapping surveys is described in Nordstrom and Imman (1975) and shown in Figure 2.

Both the depth sounder and digitizer measure and record the elapsed time interval between transmission of an acoustic pulse and receipt of a return echo from the seafloor. To precisely relate this time interval to water depth, a speed of sound adjustment is made at the survey site. This adjustment is accomplished by conducting "bar" checks, a process of lowering a target ("bar") on a calibrated line to known depths below the depth sounder transducer. Both the depth sounder and digitizer are adjusted to display the proper depth precisely.

To assure that the survey boat remains on the correct range azimuth and to duplicate each survey line monthly or seasonally; a transit and

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Figure 1 Automated Survey System



Figure 2 Survey Overlapping Procedure (from Nordstrom and Imman, 1975)

electronic positioning responder is set over each profile bench mark. The transit operator gives course corrections to the boat operator via FM radio as shown in Figure 3. Two range survey targets are placed on-range on the beach to provide the boat operator a visual line. Offshore distance is measured directly from the responder located over the bench mark. The second positioning responder is located over a bench mark a sufficient distance up or down the beach to provide an accurate measure of the distance off-line at each position fix.

An Automated Bathymetry System used for an extensive series of nearshore surveys for the Nearshore Sediment Transport Study (NSTS) in Santa Barbara, California, is described in detail by Dean et al. (1982) and Gable (1981).

Bruno and Gable (1976) describe a series of nearshore surveys made at Channel Islands Harbor, California, using a more primitive but widely used "standard" survey method. For this method the survey boat operator is directed along the profile azimuth visually with on-line targets and course corrections updated via FM radio from an on-shore sextant operator. Every ten seconds, the analog depth strip recorder is marked and vessel position recorded on a plane sheet via plane table and alidade as shown in (Figure 4).

These boat supported survey systems, which use the sea surface as the vertical datum, suffer from the presence in the analog and digital record of surface waves with a broad range of frequencies. The measurement of the instantaneous sea level needed to adjust the depth sounder record is subject to numerous errors. These errors include the measurement of tide levels at locations several miles away, high frequency wind driven waves causing water level set-up, and waves of longer period (1-15 minutes) associated with surf beat and trapped edge waves.

2.2 <u>System Evaluation</u>

The advantages of using the boat-depth sounder techniques include: (1) the ability to survey over the sand-rock interface; (2) precise X,Y position with plus or minus 3 meter accuracy using microwave positioning equipment; (3) continuous depth sounder, analog and/or digital record; (4) proven electronic and survey equipment readily available for purchase or lease; and (5) after initial set up, rapid successive profile data is collected.

The disadvantages include: (1) wave and sea level uncertainties; (2) the inability to detect small relief features due to wave motion and data filtering techniques; (3) the inability to accurately survey thru the active surf zone; (4) the technique is highly labor and capital intensive; and (5) vertical motions of the boat relative to mean sea level, caused by waves of any frequency, introduce errors that are difficult to remove objectively.

2.3 <u>Repeatability Test and Filtering Techniques</u>

To determine the system accuracy of the depth sounder survey method, a series of three repetitive surveys were run over the same range line on the same day. An Automated Bathymetry System of the type described previously was used to collect the depth sounder data. All data was collected from Range W-8 at Leadbetter Beach, Santa Barbara,



Figure 3 Course Correction Procedure



Figure 4 Plane Table Survey Procedure

California, on 25 February, 1980. within a 45 minute period. All depth sounder data presented in Figures 5-9 have been corrected for tide. The three depth sounder repeatability runs presented in Figure 5 is the raw digital depth data. The variance in the raw data increases with distance offshore and is very close to the measured sea surface variance with a significant wave height of 41 cm. The average range at the indicated distances is 20.1 cm. The general trend of the beach slope can be seen; however, all bottom detail is lost due to the high signal to noise ratio. If a running mean filter is used on each survey run (Figure 6), this signal to noise ratio and variance is significantly reduced. The average vertical range is decreased by almost a factor of three. Varying the number of points to be averaged over each iteration determines the best fit for each data set. Fifteen points per iteration provided the best fit for this particular data set. Most high frequency noise has been filtered; however, some low frequency noise still remains masking small bottom features that may actually exist. The variance can be reduced even further with a corresponding loss of bottom detail by averaging more points per iteration. In Figure 7, a classical least squares has been applied to the digitized distance-elevation pairs to fit a polynomial curve to each raw survey data run. A seventh order polynomial was found to best fit this data set. The variance at distance 200, 300, 400, and 500 meters is smaller than that of the running mean fit. The average range of the polynomial fit is half that of the running mean. Taking the simple average over a specified distance interval of all three raw data runs is a technique also routinely used by some investigators in an attempt to filter out the sea surface changes. As seen in Figures 8 and 9, the averaged survey data is more coherent but the signal to noise ratio is still quite large compared with the running mean and polynomial fits of these averaged data.



Figure 5 Raw Digital Depth Data



Figure 6 Running Mean of Raw Data



Figure 7 Polynomial Fit of Raw Data



Figure 8 Averaged Raw Data with Running Mean Overlay



Figure 9 Averaged Raw Data with Polynomial Overlay

3. <u>Hydrostatic Profiler Method</u>

3.1 Theory of Operation and Field Techniques

The hydrostatic profiler is a profiling system which uses the hydrostatic pressure principle to measure vertical differences between a pressure sensor that follows the ocean bottom and a stationary reference sensor on the beach. The two pressure sensors are connected by a fluid filled tube and the horizontal (offshore) distance determined by measuring the extension of the tube. A schematic of the profiler configuration and theory of operation is provided in Figure 10. The hydrostatic profiler has six main components: (1) a highly sensitive pressure transducer and thermistor assembly at each end of the cable; (2) a cable containing the necessary electrical conductors, strength members, and a fluid filled tube that provides a hydraulic path between the transducers; (3) a winch mounted into the bed of a four wheel drive truck to house the reference sensor and to store and retrieve cable (Figure 11), (4) a pinch wheel distance counter (Figure 12); (5) a sled to carry the profiling transducer (Figure 13); and (6) a portable data logger to record data from all sensors. Visual target cones are set on the beach designating the range azimuth to be followed. The profiler sled is towed offshore using an inflatable surf rescue boat (Figure 14). The boat must stay on the correct range azimuth while pulling the sled and cable out to maintain an accurate horizontal (longshore) position. The profiler sled is lowered to the ocean bottom at the desired offshore position or depth. The data logger is activated and the sled is automatically winched shoreward at specified increments (usually every 5 meters). At each distance increment the profiler sled is stopped and remains stationary for a 1 to 2 minute period. This stationary period is needed to average out pressure fluctuations in the tube caused by accelleration of the fluid while winching. The profiler is finally stopped at an offset point on the beach which was previously surveyed horizontally and vertically to a known bench mark. This offset point is the initial point from which the entire profile is referenced. The theory of operation, design specifications, calibrations, operational deployment, signal processing, and performance evaluation of the profiling system is described in detail by Seymour and Bothman (1984).

3.2 System Evaluation

The advantages of using the hydrostatic profiler to measure nearshore profiles include: (1) the total elimination of sea surface elevation uncertainties by measuring the ocean bottom directly; (2) the ability to survey discreetly from deep water (-10m) through the active surf zone; (3) precise offshore distance measurements of plus or minus 1 meter and depth data of plus or minus 5 cm. (4) the profiling system is highly mobile, requires minimum manpower to operate, and can be easily transported to remote survey sites; and (5) small relief features (bars, troughs, etc.) are easily detected with very high resolution.



Figure 10 Schematic of Profiler Configuration (from Seymour and Bothman, 1984)



Figure 11 Cable Winch System on Four Wheel Drive Truck



Figure 12 Pinch Wheel Distance Counter and Winch System



Figure 13 Profiling Transducer Sled

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Figure 14 Profiler Deployment

The disadvantages include: (1) the longshore position of the profiler is very dependent on the skill and quality of deployment; (2) the profiler sled and cable is dragged over the ocean bottom and can be easily caught on obstructions such as rock, reef, wreckage, or debris; (3) data quality decreases with high waves, strong currents, and steep beaches due to cable strumming and high signal to noise ratio; (4) the offshore distance is limited by a fixed cable length and (5) equipment set-up and surveying time for one profile line takes a minimum of two hours.

3.3 Repeatability Test

To determine system accuracy, a series of three repetitive surveys were run over Range 181 at the CERC Field Research Facility at Duck, North Carolina, on 25 July, 1984, within a six hour period. The environmental conditions were ideal for such a test with low wave and current conditions. The hydrostatic profiler sled was deployed offshore each time by CERC's CRAB. There was no attempt to reoccupy identical positions. Therefore, elevations were compared by linearally interpolating data at five meter distances.

As shown in Figure 15, the variance at distance 200 and 400 meters for the three runs is quite small. The variance of 8.54 cm at distance 300 meters is due to actual elevation change of the offshore bartrough system. The average range for all three distances is 7 cm.



Figure 15 Hydrostatic Profiler Repeatability Test

4. <u>Coastal Research Amphibious Buggy (CRAB) Method</u> 4.1 <u>Theory of Operation and Field Techniques</u>

The CRAB is a 10.6 meter high vehicle which uses three hydraulically driven tires on the legs of a tall tripod (Figure 16). Power is supplied by an automobile engine on the platform above the maximum waterline. This vehicle, when combined with an electronic total survey station, allows rapid, accurate surveying of the surf zone and nearshore waters out to depths of 9 meters. The primary function of the CRAB is to support a prism cluster above water. The exact distance from the prism cluster to the bottom of the tripod wheels is measured precisely before each survey. Visual range targets are set on the beach designating the range azimuth the CRAB operator is to follow. A Zeiss Elta-2 electronic total survey station is set up over a known bench mark. This compact instrument contains an electronic distance meter, a self-reading electronic theodolite, a micro-processor, a rechargeable power supply, and an interchangeable solid-state memory. The instrument is aimed at the prism cluster mounted on the CRAB to obtain a data point (Figure 17). Within seconds the distance to the CRAB and the horizontal and vertical angles are automatically measured. The micro-processor instantaneously calculates the X,Y,Z coordinates of the position under the CRAB and stores them into memory. Direct instrument read-out allows the surveyor on-shore to help quide the CRAB operator in maintaining accurate horizontal position. Data points are measured discreetly along the profile range approximately every 10 meters. Each data point takes about 10 seconds to measure and one entire profile about 45 minutes to complete. A detailed description of the CRAB specifications, data processing, and system evaluation is provided in Birkemeier and Mason (1984).

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Figure 16 CERC's Coastal Research Amphibious Buggy (CRAB)



Figure 17 Zeiss ELTA-2 Survey Instrument Sighting on CRAB

4.2 System Evaluation

The advantages of using the CRAB profiling system include: (1) the total elimination of sea surface elevation uncertainties by measuring the ocean bottom directly, (2) the ability to survey discreetly from deep water (-10m) through the active surf zone; (3) precise instantaneous X,Y,Z data at discreet points; (4) ability to operate in high wave and strong longshore current conditions; (5) ability to conduct surveys with reduced long term cost, minimum manpower, and high accuracy of plus or minus 5 cm.

The disadvantages include: (1) the CRAB traverses over the ocean bottom and can easily be caught or damaged on obstructions such as rock, reef, wreckage or debris. (2) depth of profile is limited by fixed superstructure CRAB height of 11 meters; (3) high initial expense in CRAB construction and instrumentation purchase; (4) the size of the CRAB and cost of transportation make the system highly immobile and must be used for long periods within a limited geographic area; and (5)small relief features are not always detected due to wide wheel base.

4.3 Repeatability Test

To determine system accuracy, a series of three repetitive CRAB surveys were run over Range 183 at the CERC Field Research Facility at Duck, North Carolina, on 8 July, 1982, within a 4 hour period. Environmental conditions were moderate with 70 cm significant wave height and 9 second significant period. Longshore current velocities were low. The CRAB made no attempt to reoccupy identical positions. Therefore, elevations were compared by linearally interpolating data at five meter distances. As shown in figure 18, the variance at distance 200, 400. and 700 meters is quite small. The variance of 15.52 cm between distance 100 and 200 meters is due to actual elevation change of the berm. The average range for all four distances is 11.5 cm.



5. Discussion and Conclusion

The three survey techniques most frequently used to measure nearshore profiles are: (1) boat-depth sounder; (2) Hydrostatic Pressure Profiler; and (3) the Coastal Research Amphibious Buggy (CRAB). The sea sled technique, discussed by Sallenger et al. (1983), is presently used for special studies and not routine nearshore surveys. The sea sled is identical in principle to that of the CRAB; however, it is not self powered and is physically much smaller. Repeatability data from sea sled surveys was not available to include in this paper and therefore not discussed.

The boat-depth sounder technique is the most widely used and accepted method. All equipment is electronically proven and readily available worldwide. The field data collection and data processing techniques will vary with investigator. For example, surveys conducted to support Sea Grant's Nearshore Sediment Transport Study (NSTS) used a highly electronic automated survey system. To help filter out the effects of waves and low frequency oscillations, each profile line was surveyed three times and the depth and distance determined by averaging the values obtained over a five meter interval. The Army Corp of Engineers generally use electronic navigation equipment or a standard plane table technique for positioning with an analog or digital depth recorder. Each profile is surveyed only once and the raw data tabulated with no sea surface filtering whatsoever or is manually hand smoothed. The classical least squares fit, running mean, and averaging techniques in filtering tide corrected depth sounder data, remove all bias and subjectivity that is inherent to the normal hand smoothing and manuel digitizing techniques. However, due to the continual problem of using sea level as the vertical reference and correcting for both high and low frequency noise, depth sounder data will always possess a degree of uncertainty and ocean bottom detail will always be masked by fluctuations. A highly controlled repeatability test sea level conducted during small wave conditions using an automated survey system shows that the average range in digital depth was 20 cm.

As a result, depth sounder surveys are adequate for profile studies where gross seasonal changes or shoreline erosion trends are the goal. However, if confident measurements are required with fine detail and low volume error, such as sediment transport and bedform studies, the Hydrostatic Pressure Profiler or CRAB is highly recommended. The repeatability test for both of these survey systems show that the average range was less than 10 cm while all bottom detail was preserved. These systems follow the ocean bottom directly producing highly accurate detailed maps of the nearshore region.

Finally, it is acknowledged that the field data presented in this paper is not the ideal data set. Survey data from each technique was collected at different locations, times, and conditions. A future experiment has been designed to specifically address the repeatability of each technique simultaneously on the same beach.

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