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ABSTRACT

A fixed transducer system has been developed to monitor small-scale bottom elevation changes in the nearshore zone. The system consists of a downward-looking 200 kHZ echo sounder transducer fixed 2 m above the bottom to a frame anchored in the bottom sediment. Readings are taken at the surface by plugging the transducer cable into a small, self-contained digitizer, calibrating on a reference arm mounted 1 m below the transducer and then reading the transducer-to-bottom distance. Preliminary field trials of the system indicate a precision of ±1 cm and an accuracy of ±2 cm.

SOMMAIRE

On a conçu un système de transducteur fixe pour surveiller les changements d'évaluation de fond à petite échelle dans la région proche du rivage. Le système consiste en un transducteur à ultra sons de 200 kHZ dirigé vers le bas et fixé à deux mètres du fond à un cadre ancré au sédiment de fond. On fait les lectures à la surface en branchant le câble du transducteur à un petit convertisseur analogique numérique autonome, en effectuant des étalonnages au moyen d'un bras de référence monté à un mètre au-dessous du transducteur, et en relevant ensuite la distance entre le transducteur et le fond. Les essais préliminaires du système sur le terrain font état d'une fidélité de ±1 centimètre et d'une justesse de ±2 centimètres.

INTRODUCTION

The currently accepted procedures for monitoring changes in nearshore bathymetry are echo-sounding surveys and depth-of-disturbance (DOD) rod measurements. Sounding surveys have the advantage of measuring depth remotely and the disadvantage of low precision (±10 to 20 cm) due to the difficulty of achieving adequate horizontal and vertical control. DOD surveys rely upon direct measurement of bottom-mounted survey stakes by divers and produce high quality data (±1 cm) but at the expense of costly diver support. The fixed-transducer system is a hybrid of the two methods, designed to take advantage of their positive features. In essence, it consists of a modified DOD rod for which the diver observer is replaced by a fixed, downward-looking acoustic transducer which can be interrogated from the surface. Fixing the transducer eliminates the noise produced in conventional sounding data by horizontal and vertical control problems and provides precision comparable to the DOD approach without the need for diver support.

The system was developed at CCIW in 1978, modified after preliminary field trials, and then used in an array for monitoring nearshore changes off the Burlington Bar during the 1979 field season. This paper describes the equipment and operation of the system, the results of the 1979 field trials, and the potential for future development and application.

EQUIPMENT

The system consists of an acoustic transducer mounted on a T-frame anchored in the bottom sediment (Fig. 1) and a portable sounder-digitizer (Fig. 2) which serves as the display unit. A 1-in steel pipe, fastened to the T-frame exactly one metre below the transducer, provides a reference distance for calibration.

The transducer (Fig. 3) is a Raytheon type 2445AD with a frequency of 200 kHZ and a beam angle of 8 degrees. The standard cable plug is replaced with an Electro-oceanics 3-pin underwater connector. The cable is routed up the buoy line which marks the installation and fastened to the buoy frame so that it is accessible from the surface but not exposed.

The sounder-digitizer is based on a National Semiconductor ultrasonic transceiver operating at 200 kHZ with an output power of 12 watts. Accompanying circuitry is designed to yield a depth resolution of 1 cm. Figure 4 shows the sounder schematic. A rep rate generator provides the start pulse for the transceiver at a 10 kHZ rate. The start pulse also blocks receiver detection during transmission and starts the calibrated delay. At the end of the delay period, the counter is turned on and accumulates clock pulses generated by the clock circuit until it is gated off. The clock circuit is calibrated for a speed of sound of 1500 metres per second to provide a visual display directly in metres, decimetres and centimetres. Controls include an on-off switch, a gate switch for restricting the depth of returns during calibration, and a calibrate control which adjusts the delay to give a target reading of 1 m. The sounder is powered by internal, rechargeable 12 V NiCad batteries. Connection to the transducer cable is via a patch cord terminated with a Raytheon plug (the standard cable plug) and the Electro-oceanics underwater plug.

OPERATION

Field operations are carried out from a small outboard-powered whaler or aluminum boat with the low freeboard required for easy access to the transducer cable. The boat is tied up to the site buoy and the transducer cable is fished up and plugged into the patch cord from the sounder. The sounder is turned on and the gate control advanced until a reading is received from the target arm. This is adjusted with the calibrate control to read one metre. The gate control is then advanced further until the return from the bottom is detected. The depth displayed is based on an assumed velocity of sound of 1500 metres per second. This corresponds to fresh water with a temperature of 26°C. Temperature corrections are applied by measuring bottom and +1 m temperatures with a portable Martek temperature sensor, and selecting the appropriate velocity from Figure 5 or from the velocity-temperature tables of Del Grosso and Mader (1972). The entire operation, including the temperature measures, takes less than 5 minutes per site and can be handled in wave heights up to ½ m.

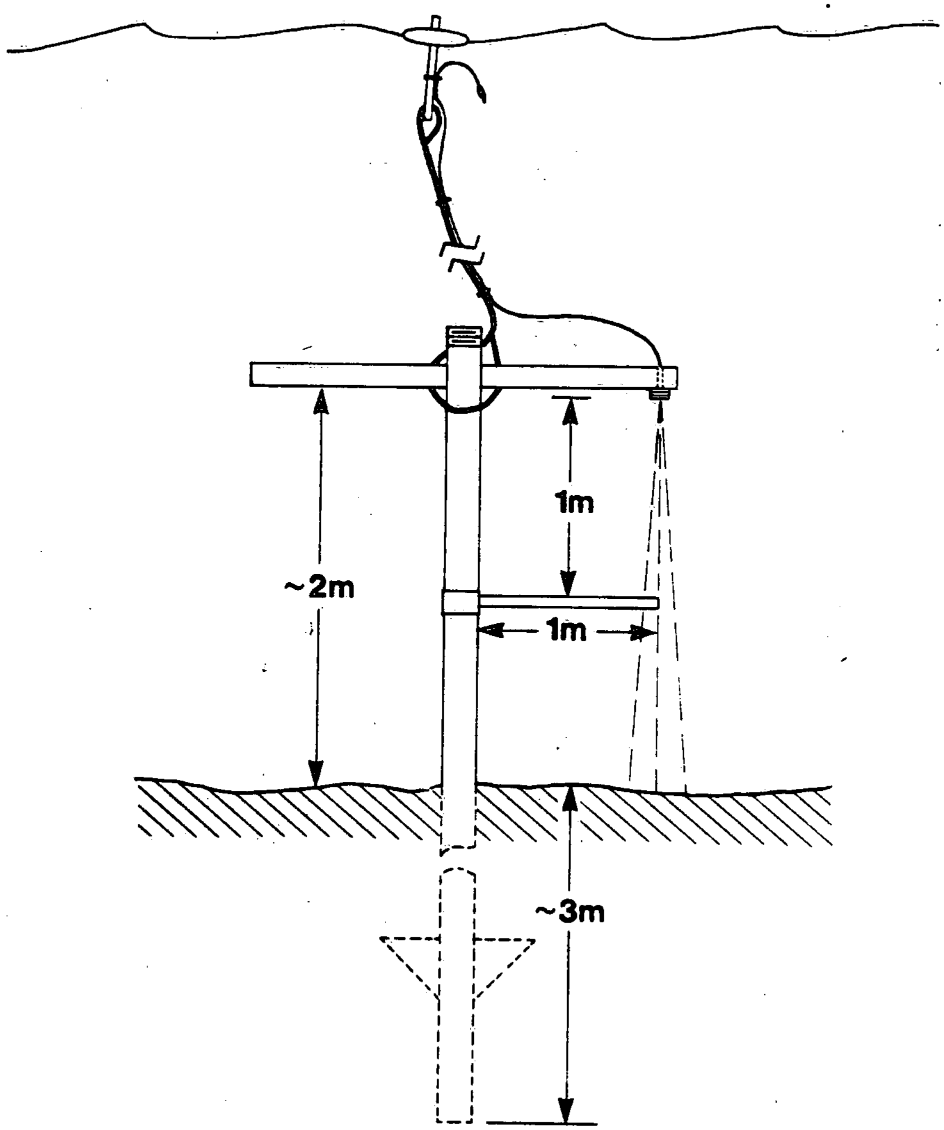

FIG. 1. FIXED TRANSDUCER SITE

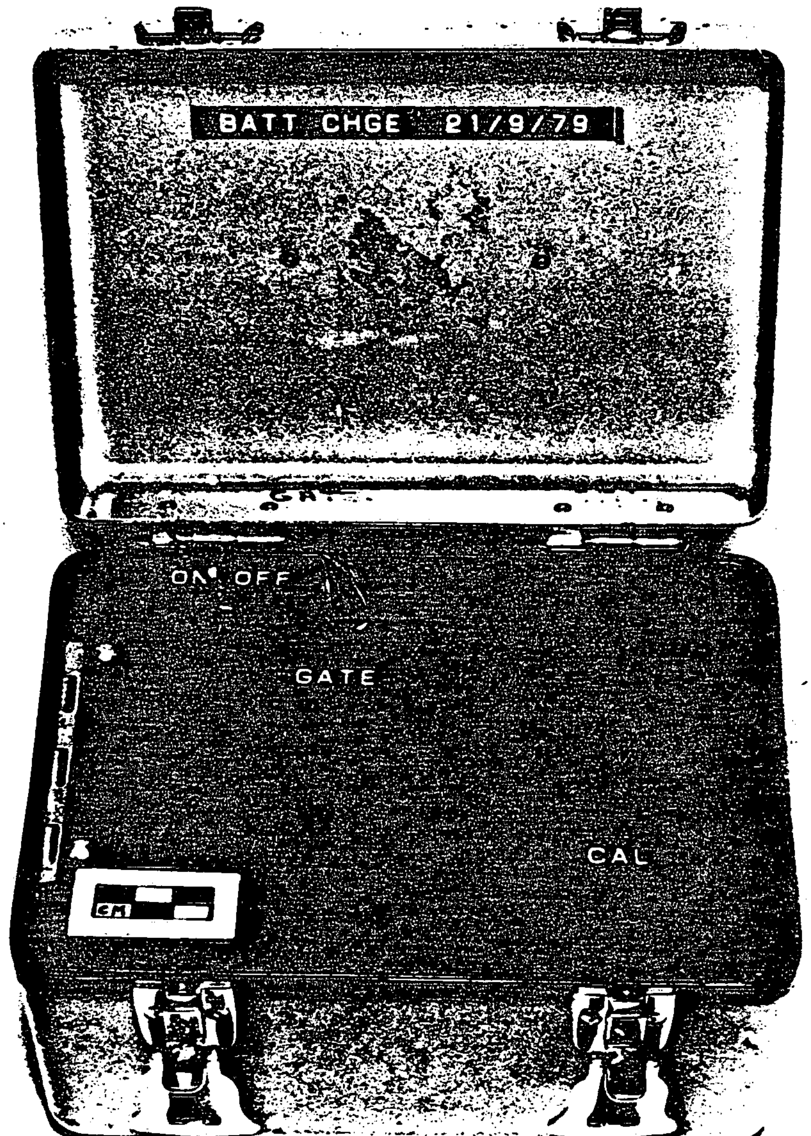

FIG. 2. SOUNDER-DIGITIZER

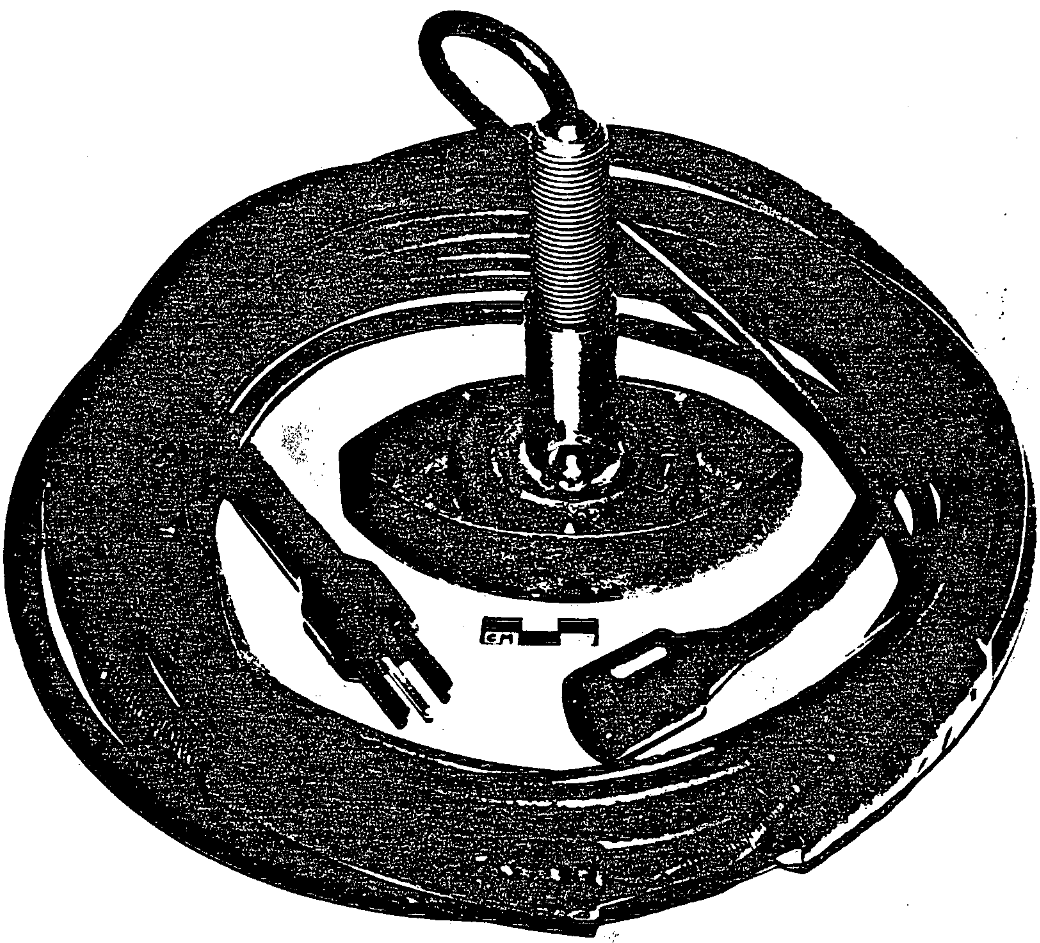

FIG. 3. TRANSDUCER

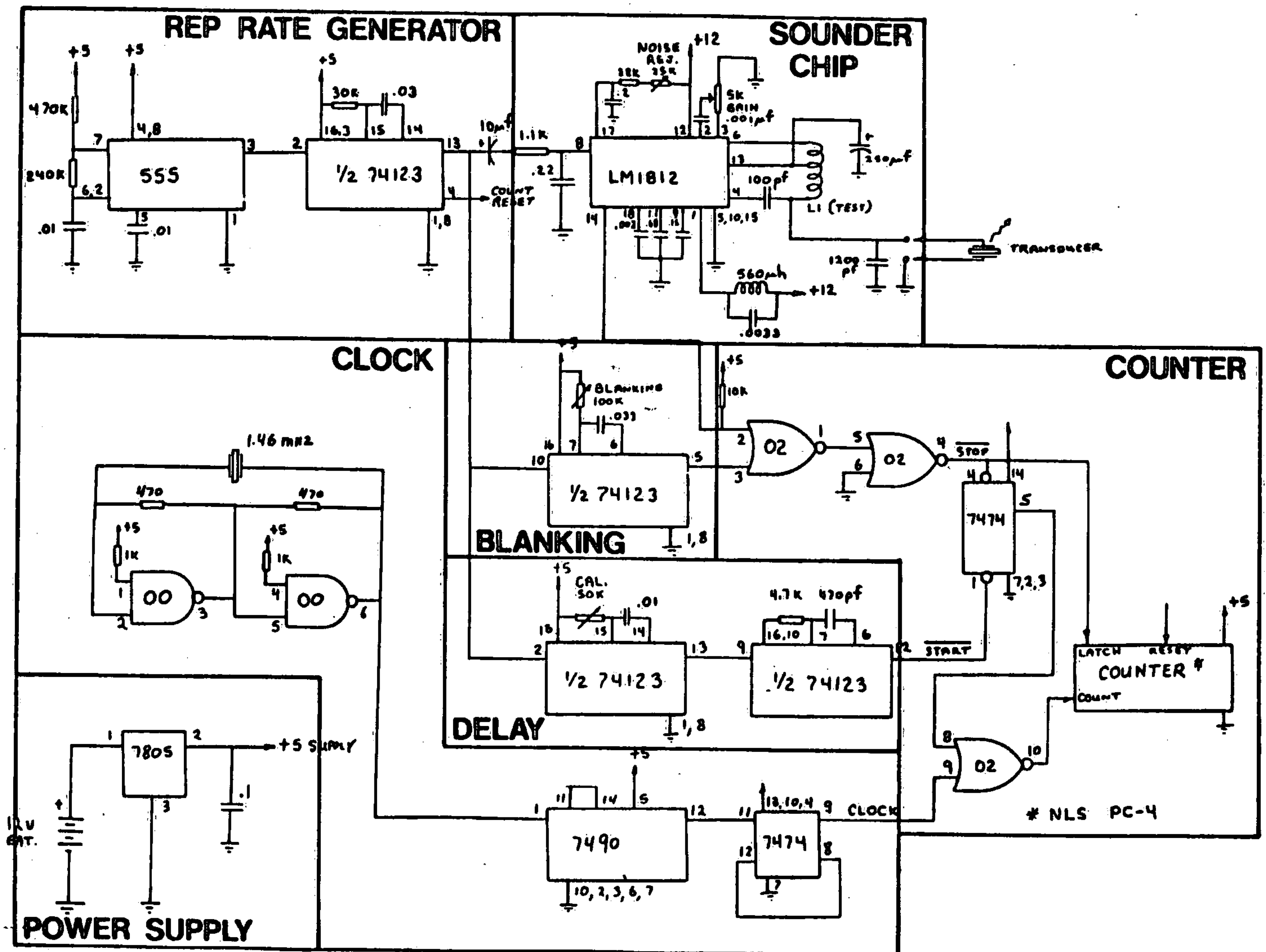

FIGURE 4. SOUNDER SCHEMATIC

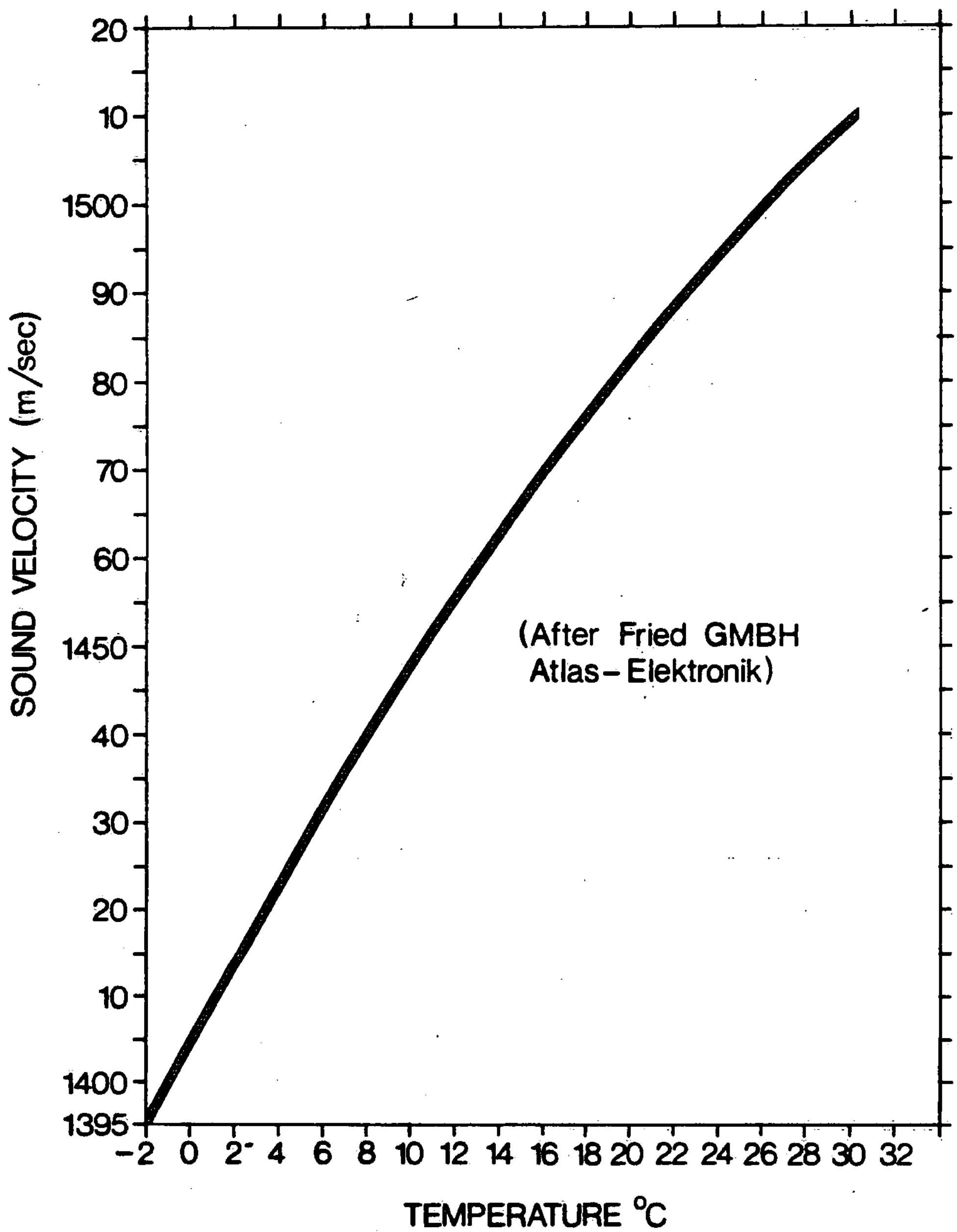

FIG. 5. VELOCITY OF SOUND vs, TEMPERATURE (for Zero Salinity)

FIELD TRIALS

Field trials of the system were carried out during the fall of 1979 at a site offshore from the Burlington Bar (Fig. 6). Thirteen units were installed along lines parallel and normal to the shoreline in a depth range of 2.5 to 7 m. Readings were taken at weekly intervals from mid-August onward. Simultaneous diver measurements with a calibrated rod were taken on two occasions to serve as a control on the accuracy of the acoustic readings. Precision of the diver measures was ± 1 cm.

RESULTS

Precision of the acoustic readings as established by repeated measurements during the same survey day was found to be ± 1 cm. Figure 7 compares the acoustic values with the diver data. The straight line is the 45° line representing perfect correspondence between acoustic data and control. Correlation is good; all acoustic values are within 3 cm of diver measures and most within 1-2 cm. The scatter is not symmetric about the straight line, however, and some bias is indicated. The tendency towards higher acoustic values is interpreted as the result of a mismatch between the reflectivities of the target arm and the bottom sediment. A broader, weaker return pulse from the sediment should have the effect of increasing the travel time and producing the higher acoustic values observed.

Some indication of the survival capability of the system is now available from its four months of continuous exposure in the field. Weather conditions during this period were generally light to moderate because of predominantly offshore winds. Wave heights of more than one metre occurred on only two occasions during minor and short-lived onshore storms. Transducer T-frames sustained no damage and showed no evidence of shifting or tilting, even in shallow water where exposure and public access subjected them to more than normal abuse. Frame stability is critical to the fixed-transducer approach because shifts of the transducer from its reference elevation will produce apparent changes in bottom elevation. The heavy frame construction and deep installation designed to minimize this problem appear to be adequate, at least for the conditions experienced to date.

Of the original 13 transducers installed at the beginning of trials, five remain serviceable, two failed within one month of installation, and six within three months of installation. This apparently poor record is largely the result of early failure of previously used transducers. Five of the sites were equipped with former hydrographic survey transducers. These failed first, apparently as the result of flooding through worn grommets at the cable entry point. Experience with the new transducers was better. Failure here occurred in only three of the eight units and was clearly the result of physical damage to the cable by fouling on the frame or chafing by the buoy line, problems to be expected when no provision is made for armouring the cable.

The sounder module failed once as the result of over-heating and damage to the transceiver chip. This was readily diagnosed and repaired with minimal downtime.

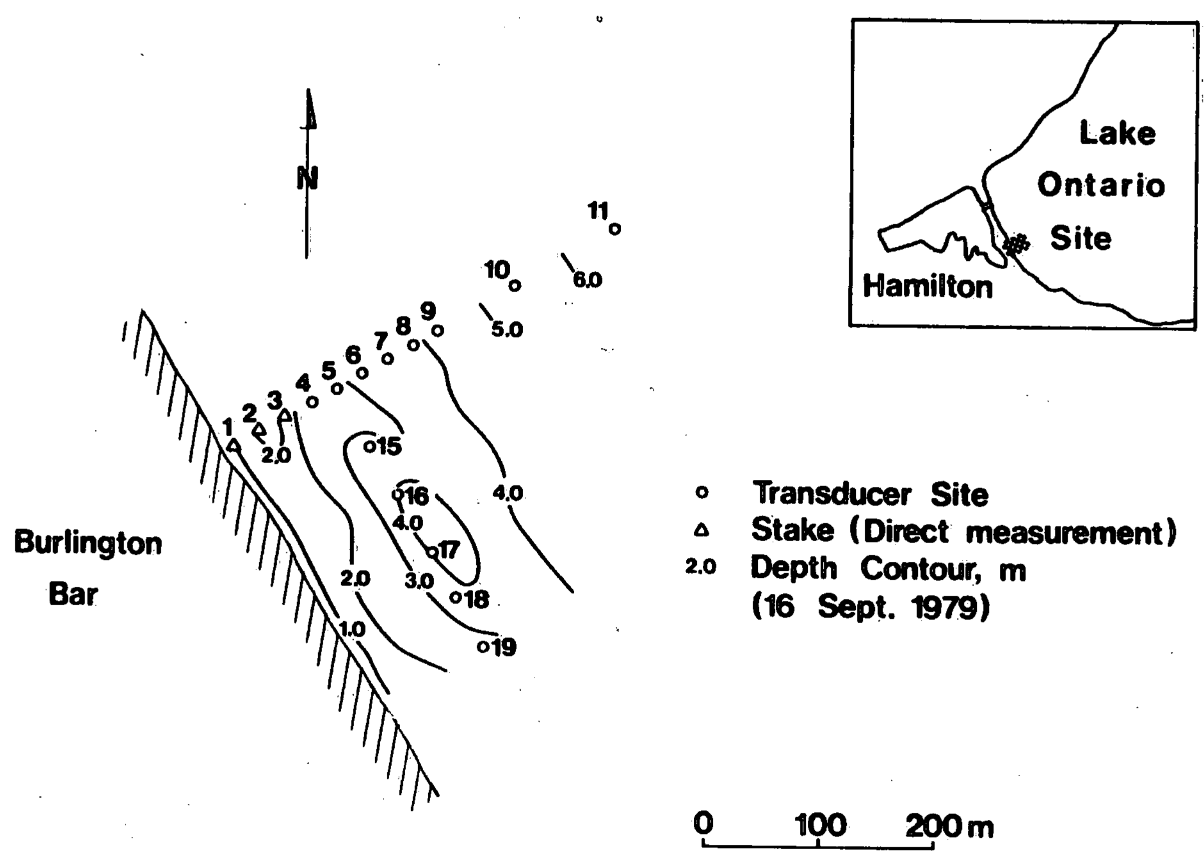

FIG.6 STUDY SITE

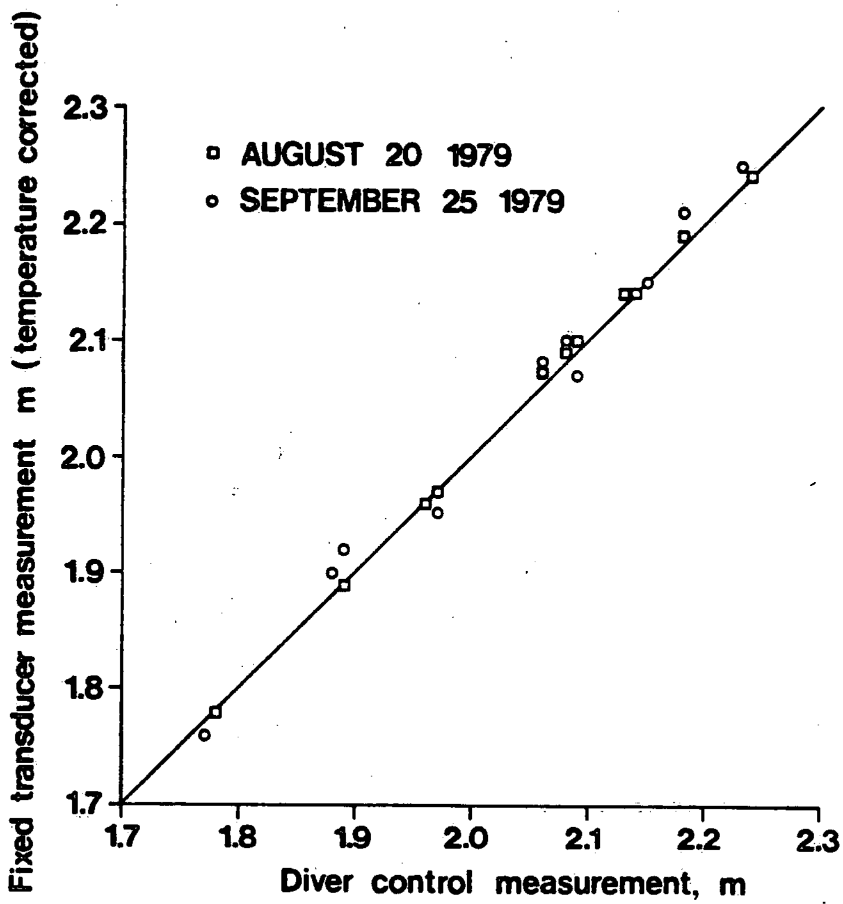

FIG. 7. COMPARISON OF DIVER AND ACOUSTIC DATA

SUMMARY AND FUTURE PROSPECTS

Table 1 summarizes the properties and advantages of the fixed-transducer system. In its present form, the equipment can provide point data on elevation change with 2-cm accuracy and at low cost. Total capital cost is approximately $650.00 per unit with a breakdown as follows: T-frame - $100.00, transducer and modified cable - $200.00, digitizer - $350.00 (original unit cost including development was $800.00). Additional installations reduce the unit cost because the digitizer is shared. Operational costs are more difficult to estimate since they depend on available facilities and personnel. Provision must be made for diver installation of the field equipment, initial site survey, periodic diver inspection, and a small-boat operation with one or two staff for data collection.

Endurance of the system is acceptable but could be improved by improving the seal at the cable entry into the transducer. In higher-energy conditions, use of electro-mechanical rather than standard cable might be advisable or, alternatively, two transducers could be installed on each T-frame to improve the chances of one survivor. This would provide the additional advantage of dual readings which could be cross-checked for consistency.

The current design of the digitizer requires that a temperature correction be applied because the clock crystal calibration at 1500 metres per second corresponds to a temperature of 26°C, 5 to 6 degrees higher than the maximum temperature at the site. Ideally, the clock crystal should be calibrated for the middle of the temperature range. Then, if the range were small (less than ±5°C), temperature errors would be small enough to ignore and, if the range were high, corrections could be applied to maintain accuracy or ignored, if reduced accuracy were acceptable. Ease of temperature measurement could be improved by equipping the T-frame with a thermistor linked to a separate digitizer display.

Manual operation of the system, as at present, limits data acquisition to safe working conditions (generally waves less than ½ m) and provides no information on the scale of reversible changes which occur during storms. Addition of a datalogger packaged for either surface or underwater installation would permit continuous monitoring during storm conditions and recovery of real-time depth-of-disturbance information.

Present experience with the equipment is limited to areas of net sedimentation with mobile sediment bottoms. The system should also be useful in studies of erosion of the nearshore slope in areas of exposed glacial sediments or bedrock. In this case, seasonal monitoring over a period of years could be used to resolve the low rates of erosion considered to be typical of this bottom type.

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TABLE 1

SUMMARY OF SYSTEM PROPERTIES

1. Accuracy of $\pm$2 cm
2. Fixed sensor to eliminate horizontal and vertical control problems (positioning, sounder calibration, water level monitoring)
3. Compact, portable, self-powered electronics package
4. Rugged, cheap, expendable underwater components
5. Operable from a small aluminum boat or whaler
6. One- or two-man operation
7. Operable in wave heights up to 0.5 m
8. Minimal diver support required
9. Fast measurement (about 5 minutes/site)
10. No special skills required for measurement

ACKNOWLEDGEMENTS

Bill Montgomery of the Development Section, OAS, designed and built the digitizer and assisted in lab testing. Graham LaHaie and Ken Hill of the Hydraulics Research Division assisted in the field trials. The Dive Unit of NWRI's Technical Operations Section was responsible for installation and monitoring of the field equipment.