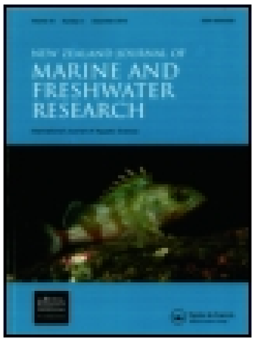

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INSTRUMENTS FOR INVESTIGATING SHORE AND NEARSHORE PROCESSES

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ABSTRACT

On shingle beaches, changes in foreshore elevation and sediment distribution landward of the break point are produced largely by variations in the uprush and backwash of waves. However, very little is known about the forces active in this zone.

A field instrument system which senses and records some of the parameters thought to influence beach erosion and deposition in this zone has been constructed. The equipment is also suitable for the investigation of a number of other shore and nearshore processes including erosion on sandy and rocky shores, and flow processes affecting littoral biological communities.

In the swash zone two sensing heads, a dynamometer and a depth recorder, sense variations in uprush and backwash velocities, energies, discharges, and depths of flow. Both devices are electromechanical and are coupled to a recording unit on land by PVC-insulated cable. The dynamometer (two force plates mounted back-to-back on a compression spring and coupled to variable resistances) has been calibrated, statically and in a flume, to obtain velocity determinations accurate to within 10 cm . sec^{-1} of true flow speed. Average swash zone velocities lie between 100 and 300 cm . sec^{-1}.

A parallel-wire resistance gauge mounted in a stilling tube records flow depths. As water level rises and falls in the tube it alters resistance in a control circuit. The land unit, amplifiers and a strip-chart recorder, receives the output from the dynamometer and flow depth gauge. The recorder is equipped with a trip-pen so that analysis of wave periods or other variables is possible in the field. With poles at known spacings across the shore and the trip-pen records, velocity distributions across the swash zone can be obtained. Measurements of velocity made near the bed with the dynamometer can then be related to the local surface velocity profile.

Problems with the instrument system include inability to record velocities at several points simultaneously, and unreliable records of backwash parameters with low breakers on shingle beaches because of the small volume of flow and rapid percolation of water into the beach face.

INTRODUCTION

Recently the search for a more satisfactory explanation of the processes of beach erosion and deposition has caused more sophisticated instrument systems, sediment tracing techniques, and analytic techniques to be applied to coastal problems (Dolan and Ferm 1966; Kidson *et al.* 1958; Schiffman unpublished, 1965; Ingle 1966; Harrison *et al.* 1968). Also, there is growing interest among marine biologists in quantifying environmentally significant factors such as degree of wave exposure (Carstens 1968).

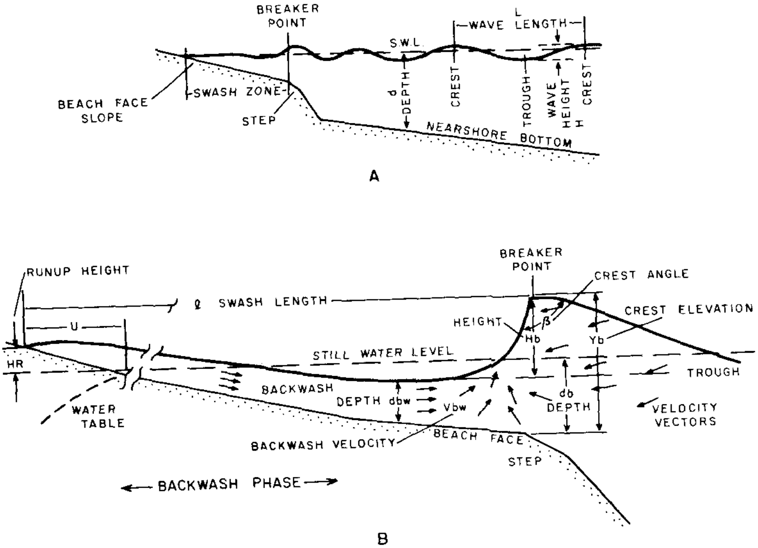

FIG. 1.—A. Characteristics of shoaling waves; B. Swash and breaker zones showing flow lines and significant dimensions. Flow in the swash zone is shown in the backwash phase. Hb = breaker height; Vbw = backwash velocity; dbw = backwash depth.

This report describes an instrument system designed to investigate swash zone processes on shingle beaches. Although the equipment is being used mainly to gather data on flow processes on shingle beaches, it is very probably suitable for investigating many other nearshore processes. Therefore the assessment here of the types of data yielded by the instrument system may help others in deciding on alternative applications. Fig. 1A shows the characteristics of shoaling waves and Fig. 1B indicates important parameters in the swash zone.

BEACH AND NEARSHORE MORPHOLOGICAL CHANGES: THE PROBLEM

Study of the forces active in foreshore erosion and deposition is difficult because of the complexity of the environment and also because the traditional approach to the subject has failed to provide a body of validly comparable field and laboratory data. Commenting on this problem, Dolan and Ferm (1966, p. 210) note that ". . . relationships between waves and coastal landforms are qualitatively obvious and have been verified experimentally by numerous investigators. Along most coasts, however, offshore waves undergo considerable modification before reaching the beach, dissipating energy across the inshore zone. Therefore, waves *per se* have little direct effect on the sub-aerial beach except in the form of swash and backrush" (*see* Fig. 1A). Koontz and Inman (1967) expanded this by demonstrating that as shoaling waves approach the break point, increasing proportions of the total flow energy become associated with the harmonic components of the basic wave motion. This considerably complicates the theoretical description of the types of water motion and bed disturbance known to occur in the nearshore environment, because first order equations for the wave motion no longer hold and equations of second or higher orders are difficult to work with. However, the work of Longinov (*in* Zenkovitch 1967, pp. 129–35) shows that study of these wave asymmetry processes is possible using field data derived from force and pressure sensing devices. In the breaker and swash zones water motion is highly asymmetrical and little theory has been developed, so that field measurements may prove important in satisfactory description of the flow forces.

Further, most field studies quote extremely few data on flow processes shoreward of the breaker zone (Kirk, unpublished 1970, pp. 54–5 and Table 2). Sampling flow velocities and energies on many different natural beaches and under widely varying wave conditions should provide statistical data useful in bridging the gaps between theoretical and empirical studies. There is great need for this type of data from shingle beaches where there is little transverse movement of the breaker and swash zones with the rise and fall of the tides. On such beaches most foreshore erosion and deposition is the direct result of the swash and backwash of broken waves, i.e., asymmetric residual wave motion which is translational in action (*see* Fig. 1B), rather than oscillatory as with unbroken waves in deepwater. Additionally, the steep seaward faces of shingle beaches usually have a sharp break of slope at the submarine toe of the beach (*see* Fig. 1), which produces rapid changes in the profiles of incoming waves immediately prior to breaking. These changes cannot be readily accommodated by present wave theory.

PRINCIPLES OF MEASUREMENT ON SHINGLE BEACHES

In the swash zone, water movements are of the impulse type rather than oscillatory and, because of percolation into the beach face, are usually shallow. Between the breaker line and the swash limit, the zone can be separated into a lower, permanently wetted section where effluent swash water and percolating ground water return to the surface, and an upper, intermittently wetted zone affected by wind action and the longer swashes of storms (*see* Fig. 1B). Because of variations in water level the demarcation between these zones varies continuously.

Because the turbulence of the flows adds large quantities of moving sediment to the water column, measurement of velocity is difficult. Schiffman (unpublished 1965) found that such conventional devices for measuring fluid flow as pitot tubes and propeller driven current meters were unusable in these types of flow. For the present investigation it appeared to be simpler to record flow by some Eulerian principle (mechanical or dynamical measurements of motion past geographically fixed points), than to track the paths of "parcels" of water with tracers or floats.

In the past, floats have been timed over measured distances to obtain swash and backwash velocities (e.g., Miller and Zeigler 1958), but the result derived is an *average* value from an environment in which flow velocity usually varies greatly within both a short distance and a short time, and very greatly between different waves. Further, Norrman (1964, p. 82) notes that floats may behave anomalously because of inertial effects.

Dolan and Ferm (1966) used a chart recorder and trip-pen to time the passage of swash fronts between rods evenly spaced across the shore. The distance between marks on the chart was thus inversely proportional to swash velocity. This considerable improvement over the float method suffers a similar disadvantage: both describe only surface flow and provide no information on velocities near the bed. Further, measurements of the passage of the swash front cannot be related to the behaviour of the body of the flow which follows it, and, more seriously, the method gives no data on the backwash.

INSTRUMENT REQUIREMENTS

Instruments for use in the swash zone must respond quickly to rapid and sometimes severe fluctuations in water head and velocity, and yet withstand large applied forces. They must also be able to withstand corrosion by salt water. Measurements of the various process and response factors affecting sediment transport and foreshore elevation must also be made on a number of different time scales. Study of sediment motion must be conducted at time scales of seconds or minutes, but morphological changes must be studied over hours or even days.

Some form of *recorded* output was essential for the instruments because of the short duration of the flows (12–15 s), and the corresponding fluctuations in energy. Ideally, an output form is required which permits ready abstraction of data and ease of analysis. Recording devices should be unaffected by salt spray so that sensitised chart paper is preferable to inked pens. The instruments should also be portable if use at numerous stations is intended, thus compactness, battery operation and low power drain are desirable features.

Instruments were built to these requirements and Fig. 2A is a schematic diagram of the component units in the system. Fig 2B shows typical operating positions of the sensing heads in the swash zone. The sensing heads or data gathering units will be described first and the shore unit (data control and output section) later.

INSTRUMENT SYSTEM

SENSORS 1: THE DYNAMOMETER

The instrument used to measure energy (velocity) is a type of dynamometer. Dynamometers are similar to strain-gauges and are often used by engineers to measure forces on marine structures. Figs 3 and 4 show the design and construction of the dynamometer, which is similar to that used by Schiffman (unpublished 1965) in studying swash and surf zone processes on sand beaches.

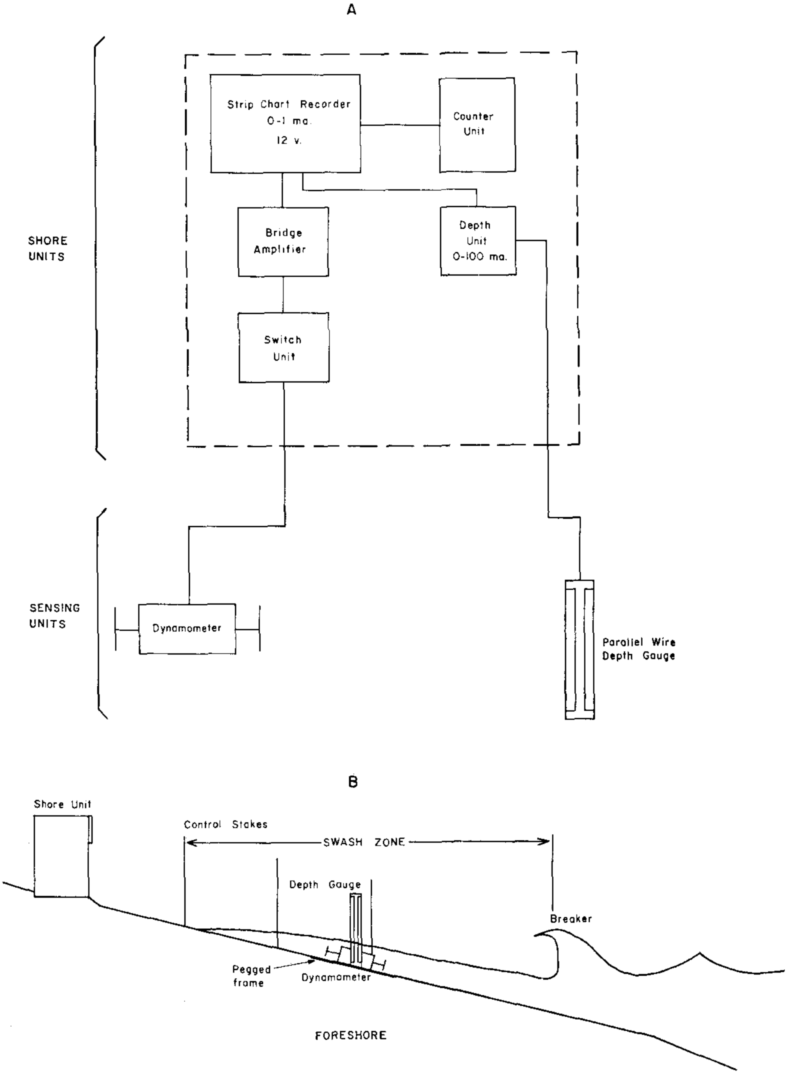

FIG. 2.—A. Principal units of the instrument system; B. Positions of the units in the swash zone.

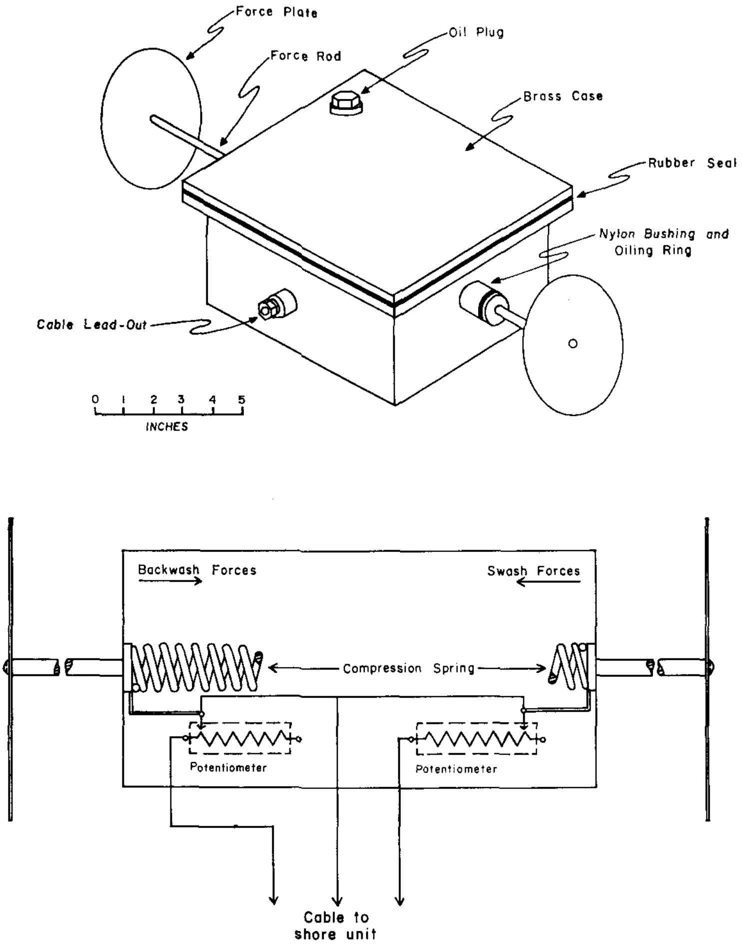

FIG. 3.—The dynamometer.

Schiffman (unpublished 1965, p. 225) stated that "the dynamometer . . . is of the electromechanical type. Two discs are used to measure, respectively, the force of water that has been given an acceleration shoreward by the breaking waves and the secondary movement of this water seaward under the influence of gravity. The forces acting on a disc are transmitted to a compression spring whose resulting displacement causes a corresponding change in a variable resistance. A pen recorder makes a permanent record of this change. Each rod acts independently on the spring and serves, in turn, as a backstop for the force exerted on the spring by the opposing rod. This gives the dynamometer a self-zeroing capability". The present instrument has been constructed according to these principles. The force rods are

FIG. 4.—Dynamometer mounted on conduit frame for velocity measurements near the bed.

mounted in nylon bearings which are sealed at both ends by O-ring seals, and motion of the rods is transmitted to a pair of rotary variable resistances by link pins connected to the inner ends of the force rods and crank arms connected to the shafts of the resistors. Guide bars prevent unwanted lateral movement of the link pins. Full working drawings of the instruments are available from the author.

The dynamometer components are housed in a watertight, oil-filled container which is coupled to the shore unit and DC power supply by 100 m of three-core PVC cable. The instrument is mounted in one of two ways for measuring swash and backwash velocities. First, it can be anchored to the beach face on a tubular steel frame (1.8 × 1 m) (*see* Fig. 4). The frame with the weight of the instrument upon it acts as a drogue and settles into the bed until the base of the dynamometer case is flush with the surface. Heavy gauge wire pins are then driven in at either end of the frame. Secondly, the instrument can be mounted on a vertical steel frame, the legs of which are driven into the beach (Fig. 5). Thus the unit can be raised to obtain average velocity profiles higher in the flows.

CALIBRATION

The dynamometer cannot be calibrated against similar instruments of known accuracy, and thus calibration must be done otherwise. The effect of electromechanical filtering on the recorded dynamometer response has to be taken into account. For instance, because of mechanical inertia, very short period fluctuations are not recorded.

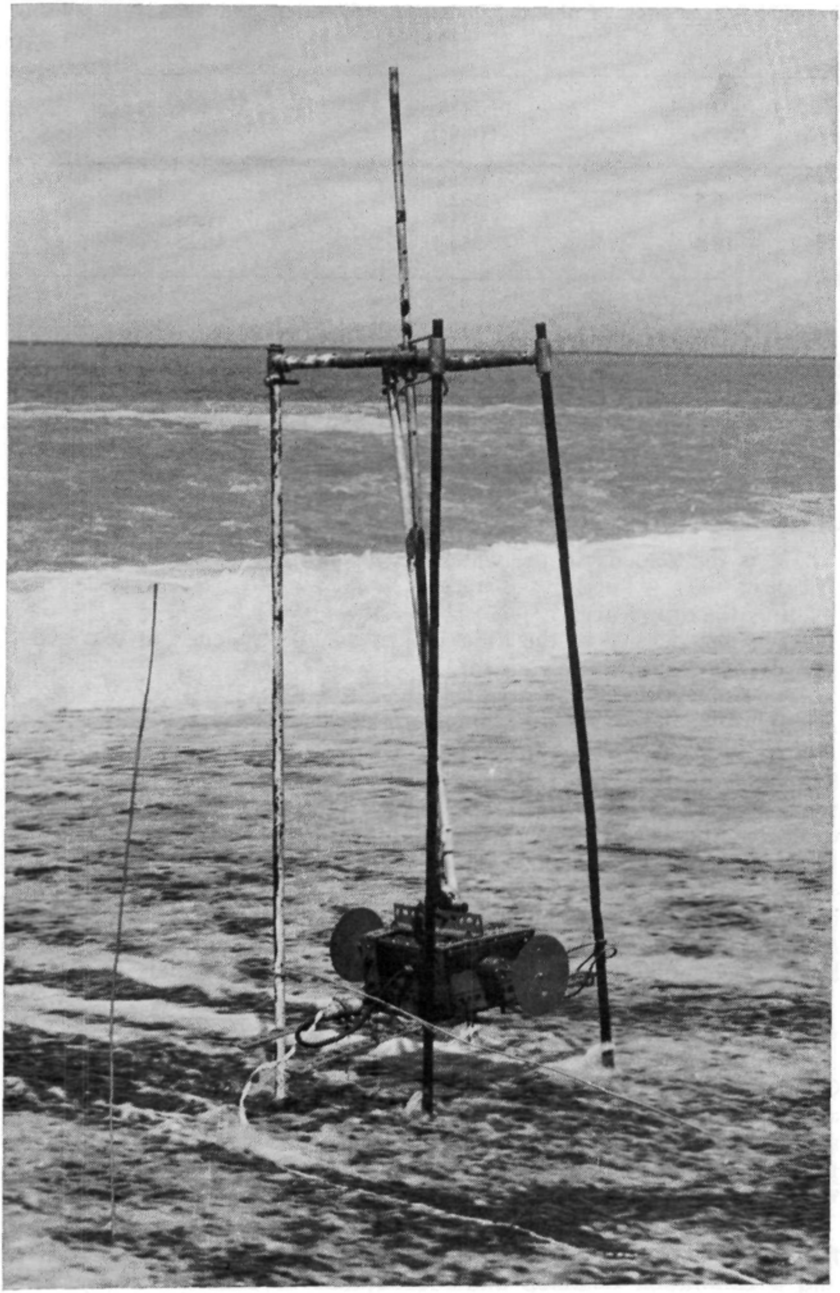

FIG. 5.—Dynamometer in vertical mounting used to obtain vertical profiles of velocity.

TABLE 1—Plate sizes of the dynamometer calibration and associated velocity ranges

Plate Radius (cm)	Plate Area (cm^2)	Velocity Range ($cm \cdot sec^{-1}$)
6.5	132.7	26.2–303.0
8.5	225.9	18.06–207.0
10.5	346.4	16.36–188.0

The dynamometer was calibrated by two methods. First, a static force calibration was carried out and the velocity calculated from an equation for the force of water due to drag on a plate normal to fluid flow. Following Schiffman (unpublished 1965) it is assumed that force is proportional to the square of the velocity:

$$V^2 = 2F \cdot (C_D \, \rho \, A\rho)^{-1} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1)$$

where

V is the velocity of the water flowing normal to the dynamometer disc;

F is the drag force;

ρ is the density of the fluid (taken as 1.03 $gr \cdot cm^{-3}$ at 0°C and 1 atm. pressure);

C_D is the coefficient of drag (taken to be 1.12);

A_p is the area of the dynamometer plates.

The drag coefficient is applicable to fully turbulent flows having high Reynolds numbers (Rouse 1961, pp. 214–5 and fig. 94). As in Schiffman's (unpublished 1965) design, three sizes of force plate were constructed to obtain a series of overlapping velocity ranges (Table 1), though only the smallest set has been used on the shingle beaches studied so far. There is a minimum velocity for each plate size that is determined by the smallest force that can move the plates and rods against the spring, while the maximum velocity is determined by the maximum spring compression force (approximately 2.75 kg).

Use of such a static calibration alone is unsatisfactory because the whole dynamometer might not have the drag characteristics of a circular plate opposing the flow (Dr A. J. Sutherland, Department of Civil Engineering, University of Canterbury, pers comm., 1968). An appropriate second calibration would be to subject the instrument to solitary waves in a wave tank, the recorded velocities then being compared with values calculated from wave theory, but facilities for this were not available.

Instead the dynamometer was mounted on the bed of a 1.2-m-wide flume at the Civil Engineering Department, University of Canterbury, and a calibration obtained under conditions of uniform, steady flow. The centers of the discs were placed at 0.4 of the flow depth, thus ensuring that they were in the region of the mean velocity core. Flow

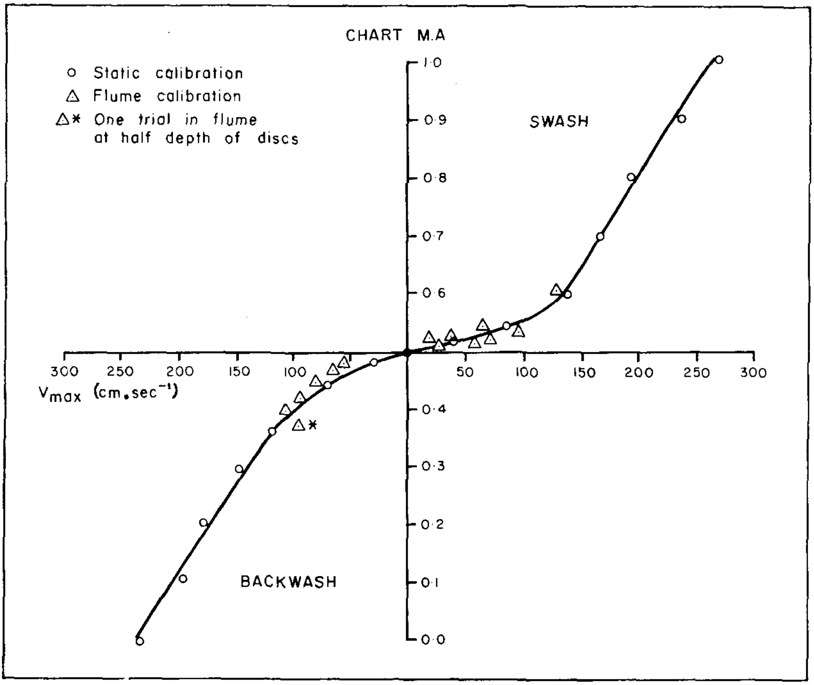

FIG. 6.—Calibration curves for dynamometer.

depth was measured with a point gauge mounted on a movable trolley and the flow velocity determined from the cross-sectional area of the flume and the input discharge ($V = Q \cdot A^{-1}$). The maximum velocity was approximately 110.0 cm$\cdot$sec^{-1} and runs were performed with both rising and falling stages to assess hysteresis effects. Though the maxmum velocity was not particularly high in the instrument's capability, it corresponds to the critical erosion velocity for particles of up to 10.0 mm diameter.

The results of these two calibration procedures are shown in Fig. 6. The solid line denotes the static calibration while the triangles give values determined in the flume. The calibrations are by no means linear, both discs having an initial region of slow response. For the higher velocity sections of the curves (100–300 cm$\cdot$sec^{-1}) the spring constants were 1.2 kg$\cdot$cm^{-1} and 1.13 kg$\cdot$cm^{-1} for the swash and backwash plates, respectively. The diagram shows general agreement between the two calibrations in the region of overlap. In general, the flume tests produced higher pen deflections for equivalent velocities than the static calibration. The mean difference between the two procedures was 10.5% for the swash disc and 12.7% for the backwash disc. A maximum difference of 29.0% was found for the dynamometer discs only half covered by the flow. Thus, the instrument may be used to obtain flow velocities to the nearest 10 cm$\cdot$sec^{-1}, at least up to 100 cm$\cdot$sec^{-1}.

The height of the column of water measured at the bed depends upon the diameter of the dynamometer disc and is similar to Schiffman's (unpublished 1965) instrument in being 15–20 cm at approximately 3 cm from the bed during field experiments.

FLOW PARAMETERS SENSED BY THE DYNAMOMETER

The chart record obtained from the instrument contains a series of impulse force curves against time. Hence, velocity values may be obtained directly, as can flow times; these are of great value in the analysis of continuous records. Also, a measure of *flow energy* may be derived by measuring the areas under the curves such that:

$$\int_{t_1}^{t_2} F.\,dt \sim E \qquad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

where F is the force on the dynamometer plates, and t_1 and t_2 the times when recorded flow began and ended.

The relative energy levels of the swash and backwash may be obtained by summing the areas under the respective sets of curves and dividing the totals by the interval of time over which each was operative. Measurement of the areas is easily accomplished with a planimeter or by use of graph paper and a projection device to enlarge the curves. Schiffman (unpublished 1965) notes that this arbitrary measure of energy reflects the number of readings in unit time together with the various parameters that influence the length of time that the individual forces act. Also, the data derived are conservative in the sense that the dynamometer has a lower response limit of considerable magnitude (e.g., 26 $\text{cm} \cdot \text{sec}^{-1}$ for the 6.5 cm radius plates; *see* Table 1), so that flows with velocity below this limit will not be recorded.

If a velocity profile of the swash or backwash is taken from a series of points with the dynamometer, it is possible to obtain average flow discharge values from the following expression:

$$Q = \int_{x_1}^{x_2} \overline{V}(x).\,dx \qquad \ldots\ldots\ldots\ldots \quad (3)$$

where $\overline{V}$ is the mean velocity at point x, and x_1 and x_2 are the stations nearest the breaker and furthest landward respectively.

Thus, the areas under the curves on a plot of velocity and position across the shore may be used to obtain a "water budget" of incoming and outgoing flows at any given station, so that interactions between water masses seaward and shoreward of the breakers may be assessed. Finally, the product of the forces acting on the discs and the physical displacement of the discs is a measure of the power expended by the flow in doing work on the dynamometer. This concept is identical with that employed in the theory of sediment transport so that there may be a close relation between power expended in sediment transport and that developed at the dynamometer for given flows.

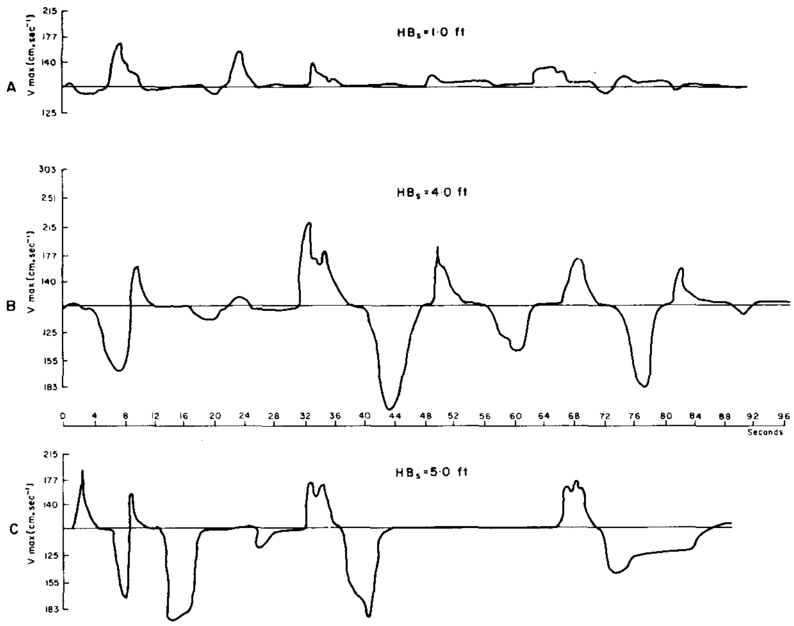

FIG. 7.—Typical dynamometer velocity traces.

Additionally, much useful information can be obtained by examining the shapes of the impulse force curves (Muraki 1966). Short, steep curves denote fast moving water associated with high impulse forces, but lower, more regular curves indicate lower pressures and slower but longer flows. Similarly, curves with multiple peaks indicate fragmentation of a water mass into "parcels" which are moving at different velocities and/or in different directions.

TYPES OF CHART TRACE

Some typical chart traces are shown in Fig. 7. Fig. 7A shows swash/backwash curves produced by a surging breaker ($H_b = 30$ cm). These waves produce swash of short length and very regular duration so that there is a pendulum-like motion against the shore. The observation site was a steep (12°), well-sorted shingle beach on which percolation losses were high. Consequently, few backwashes were recorded. Of particular interest is the pattern of flow. The trace shows several sharply defined, fast-moving crests which were followed by long, steady onshore flows averaging 3.23 s duration. Average backwash duration was 3.53 s.

Fig. 7B is a record of the swash/backwash from typical plunging breakers ($H_b = 1.2$ m), in which the crest fell vertically and enclosed an air pocket in the leading edge of each wave. These breakers delivered long swashes (15–25 m) and the record is notable for sudden reversals in flow direction. Inflections in the crests of the swash curves indicate that there were considerable velocity fluctuations within the main body of the flow. The water delivered to the shore appears broken into subunits or secondary wave trains; Schiffman (unpublished 1965) obtained similar records on sandy beaches. Backwash curves were non-linear; acceleration of the water masses began gradually and then increased rapidly.

Fig. 7C is a further record of plunging breakers ($H_b = 1.5$ m); of storm waves which delivered very turbulent swash and much spray; they broke much more confusedly than those previously described, and much of their energy was dissipated in vertical water movements. Hence the unevenness of the swash peaks is much more pronounced, but the mean velocity of the swash is only a little higher than that for the 1.2 m waves. Conversely, relative to the swash, the backwash traces shown in Fig. 7C are considerably larger than those shown in Fig. 7B. This increased backwash power at greater breaker heights occurs because however water is flung into the swash zone, it falls back to contribute to the backwash, which then flows back down the bed as one mass. Thus, backwash velocities can be recorded that are considerably greater than those of the swash giving rise to them.

SENSORS 2. THE DEPTH GAUGE

Since the head of water is of prime interest in flow structures and percolation velocities, a small version of the conventional parallel-wire wave gauge was constructed. The instrument consists of two heavy gauge, low resistance copper wires mounted inside a 6.35 cm inside diameter stilling tube. The water level rises and falls smoothly in the tube, successively removing (rising level) or adding (falling level) resistance to the control circuit; the generated impluse is transmitted to a separate shore unit by PVC cable and fed into a simple bridge balancing circuit. This instrument was cheaply made, easily calibrated in a tank, and required little maintenance. However, because the galvanometer in the recording device had a proper period of 0.9 s and a critical damping of 200Ω a phase-lag appeared in the depth records. All depth records must be adjusted accordingly.

RECORDER

The shore recording station is shown in Fig. 2A. The system comprises firstly, a 0–1 mA (full-scale), 12 VDC, Rustrak Model 188 strip chart recorder, which has only a single channel (and thus a current measuring system was chosen to lessen line loss in connecting cables); secondly, a transistorised bridge amplifier (constructed by the writer and also designed for use with a conventional pressure/transducer wave gauge) to control input from the dynamometer; and thirdly, a controlled bridge circuit for the depth recorder. The parallel wire gauge is employed as a shunt across one limb of the bridge, and its output can be switched to the chart. However, both control devices are provided with visual meters of flow depth and velocity. Since the

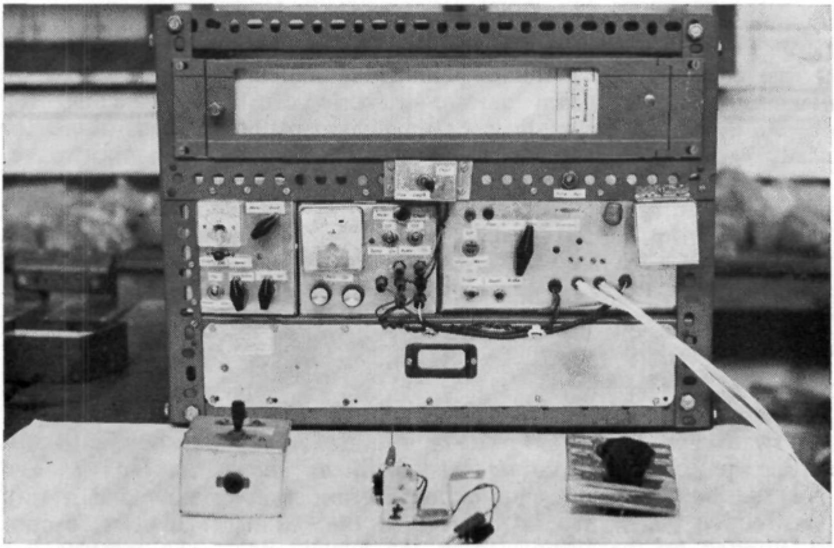

FIG. 8.—The recorder complex. Chart recorder at top, data control units at left and centre, switching panel at right. The battery pack at the base of the frame is 20″ × 14″ (51 × 36 cm).

recorder has only a single channel, an input switching system is necessary. The whole unit is powered by the three 6 V dry-cell batteries.

Fig. 8 shows the arrangement of the units. The whole assembly is mounted on a 50 × 35 × 25 cm metal frame and weighs about 6.5 kg. The system together with associated morphological and sediment sampling grids can be installed by a single operator in under one hour and is easily dismantled on conclusion of sampling.

The chart recorder employs sensitised paper so that salt spray and high humidity are no obstacles to operation. Recording is at the rate of 10 $\text{cm} \cdot \text{min}^{-1}$. In practice the system is used to sample swash/backwash parameters for perhaps 10 min in every hour of a tide cycle. Simultaneous measurements of morphological change and sediment movements are also made. An obvious disadvantage of the single channel system is that simultaneous recordings of several swash parameters cannot be made, but a time-pen unit added by the author can surmount this difficulty. A trigger key on a long cable is used to trip a solenoid driving an extra pen on the recorder. This pen can be readily removed when not in use and the cable is long enough for the trigger to be used by an observer in the water.

Time-pen data is useful in time-frequency analysis of many swash/backwash phenomena, e.g., to obtain time/deceleration curves for the swash, by tripping the key each time the swash front passes a stake in a series spaced at 3 m intervals across the shore (*see* Dolan and Ferm 1966) and to derive from this velocity profiles suitable for discharge analysis; and to relate point measurements of bed velocity by dynamometer to known surface velocity distributions. Thus, the objections to the use of float or time/deceleration methods alone are partly overcome. Time-pen data can also be used to monitor wave, breaker or swash periods, and to determine whether swash flow is maintained for the full duration of the uprush or whether it reverses before the swash front has attained its upper limit on the shore: the pen is tripped when a wave breaks and is released as the swash terminates. A cessation or reversal of flow is immediately apparent over the length of line traced by the pen.

SEDIMENT SAMPLER

Because the amounts of sediment moving in the water columns of the swash and backwash provide information on transport rate and sorting processes a sampler was built as shown in Fig. 9. The main design criteria were minimum deformation of flow and a trap construction which, having intercepted the sediment particles, cannot be emptied by the turbulence of the reverse flow. The sampler has seven trap nozzles arranged vertically with 10 cm centre spacings (Fig. 9). The lowest trap is centered 3.5 cm from the bed; each nozzle is 3.5 cm in diameter, thus presenting an area of 9.62 cm^2 to the flow. These traps consist of modified, heavy-gauge, plastic pipe-junctions; each has a fine brass gauze fixed across the rear.

The flow enters the barrel of each trap and passes out at the rear, leaving behind the entrained sediment. The nozzles were arranged on the sampler so that the diagonally mounted junction tubes were directed downwards and backwards. Thus, sediment entering the main barrel in the fluid is diverted down the inclined tube, where it is caught by a cloth bag. These bags are permeable and the sediment tubes are so long that there is little chance of sediment reaching the bags being lifted and removed by the reverse flow. Although the efficiency of this sampler has not been assessed, it is probably superior to more conventional rigid trap structures, where sediment particles fall into a cannister or bottle in which considerable lifting forces may occur.

In the field, the sampler is used for 2–5 min facing the swash; the bags are then changed and the instrument is set to face the backwash. The retentive gauze in the rear of each trap is sufficiently fine to trap all but fine sand. The device is pinned to the shore by long steel stakes, and is easily handled. However, an improvement would be a larger diameter trap barrel.

SURVEYS OF BED LEVEL

Changes in bed elevation are recorded every hour through the tide cycle. This is done using light-gauge galvanised wire stakes inserted in the bed at 3 m spacings, from the swash limit to the breakers. The exposed length of each rod is measured to the nearest millimeter each

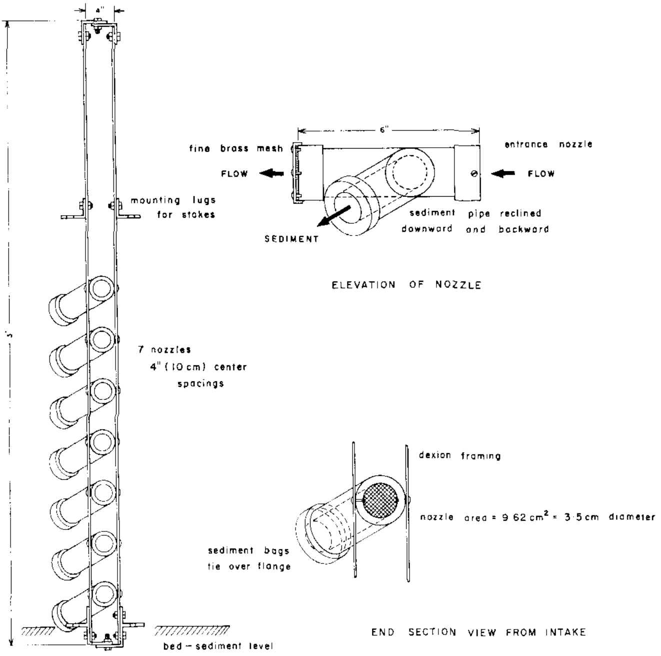

FIG. 9.—The sediment sampler.

hour using a steel tape on a Duralumin rod. The slope of the beach face is measured to the nearest degree with an Abney Level. Measurements of swash length and water table position are made with a linen tape.

DISCUSSION

OTHER APPLICATIONS

To date almost 4,000 individual swashes and backwashes have been recorded in 21 experiments on shingle beaches, for breaker heights of 0.3–3.0 m and for wave periods of 7.0–10.0 s. Similar recordings from sandy beaches, where the pattern of energy distribution is different, would be valuable.

The instrument system has been designed and developed to measure flow near the bed in shore and nearshore environments, and is potentially useful in the investigation of a wide range of physical and biological problems.

Much has been written on coastal erosion in areas of consolidated rocks, but very few measurements of flow properties exist. The system might thus be used to examine processes in the evolution of rocky shores.

The equipment provides a means of quantifying and describing biologically important factors such as degree of exposure to wave action. 'Exposure' refers collectively to features of flow that may differ markedly from site to site, e.g., at two sites mean velocities may be similar but maximum velocities different, so that one is subjected to greater turbulence than the other. Many marine animals, particularly molluscs, in strong currents adopt characteristic positions in relation to flow. Characteristic shapes of organisms affect resistance to flow: long, low shapes offer less resistance than high or broad ones, and smooth surfaces are less affected by flow turbulence than rough ones. Carstens (1968).

Thus, form drag and friction forces may limit some organisms. Effects of shock pressures on an organism are, by contrast, extremely rare and require the coincidence of several wave properties. Impact forces from extremely high pressures of low frequency and short duration are therefore more likely to limit the *abundance,* rather than distribution, of a species in high energy environments. These effects could be readily investigated with the system described.

CONCLUSIONS

The instrument system measured flow velocities and depths in the swash zone of shingle beaches. The equipment is durable, portable and easy to maintain in the field, and may be useful in studying environments on both hard and soft rock coasts.

The instrument system, with morphological and sediment sampling grids, can be installed by one person in less than an hour, and the equipment is later easily dismantled for transport to another site. It is intended primarily for short-term use at each site, usually during a 12-hour tidal cycle. However, the dynamometer and depth recorder could be used for long periods if provision was made for mounting the sensing heads in the water and for housing the chart recorder/amplifier.

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LITERATURE CITED

CARSTENS, T. 1968: Wave forces on boundaries and submerged objects. *Sarsia 34:* 37–60.

DOLAN, R. and FERM, J. 1966: Swash processes and beach characteristics. *Professional Geographer 18 (4)* : 210–3.

HARRISON, W., RAYFIELD, E. W., BOON, J. D., REYNOLDS, G., GRANT, J. B., and TYLER, D. 1968: A Time series from the beach environment. *ESSA Research Laboratory Technical Memorandum AOL-1.* 85 pp.

INGLE, J. C. 1966: "The Movements of Beach Sand". Elsevier; New York. 221 pp.

KIDSON, C., CARR, A. P. and SMITH, D. B. 1958: Further experiments using Radioactive methods to detect the movement of shingle over the seabed and alongshore. *Geographical Journal 124 (2)*: 210—8.

KIRK, R. M. unpublished 1970: "Swash Zone Processes. An Examination of Water Motion and the Relations Between Water Motion and Foreshore Response on Some Mixed Sand and Shingle Beaches, Kaikoura, New Zealand". Unpublished Ph.D. dissertation in geography, lodged in library of University of Canterbury, Christchurch, New Zealand. 378 pp.

KOONTZ, W. A. and INMAN, D. L. 1967: A multipurpose data acquisition system for instrumentation of the nearshore environment. *U.S. Army C.E.R.C. Technical Memorandum 21.* 38 pp.

MILLER, R. L., and ZEIGLER, J. M. 1958: A model relating dynamics and sediment pattern in equilibrium in the region of shoaling waves, breaker zone and foreshore. *Journal of Geology 66 (4)*: 417–41.

MURAKI, Y. 1966: Field observations of wave pressure, wave runup and oscillation of breakwater. Pp 302–21 *in Proceedings of 10th Conference on Coastal Engineering 1.*

NORRMAN, J. O. 1964: Lake Vattern – Investigations of shore and bottom morphology. *Geografiska Annaler 46 (1–2).* 238 pp.

ROUSE, H. 1961: "Fluid Mechanics For Hydraulic Engineers". (2nd Ed.) Engineering Society Monographs Dover, New York. 422 pp.

SCHIFFMAN A. unpublished 1965: "A Study of the Swash-Surf Energy System". *Unpublished MS thesis in geology lodged in library of the* University or Southern California. 51 pp.

ZENKOVITCH, V. P. 1967: Longinov's method. Pp. 129–35 *in* J. A. Steers (Ed.) "Processes of Coastal Development". Oliver and Boyd, London. 738 pp.