CHAPTER 49

SYNOPTIC OBSERVATIONS OF SAND MOVEMENT

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ABSTRACT

The U S Army Corps of Engineers' Coastal Engineering Research Center, in cooperation with the Atomic Energy Commission, initiated a multi-agency program to create a viable radioisotopic sand tracing (RIST) program Other agency participants in this program have been the Los Angeles District, Corps of Engineers, U S Air Force (First Strategic Aerospace Division), U S Navy (Pacific Missile Range), U S Army Mobility Equipment Command, National Aeronautics and Space Administration, and the State of California (Dept of Navigation and Ocean Development) CERC, together with the AEC's Oak Ridge National Laboratory has developed tagging procedures, hardware development, field surveys and data handling techniques that permit collection and analysis of over 12,000 bits of information per hour over a survey track of approximately 18,000 feet Data obtained with the RIST system can be considered as nearly synoptic observations of sediment transport in a single environmental zone or in adjacent beach, surf and offshore zones

Using sand tagged with isotopes of gold, experiments have been carried out at several sites on the California coast Surf, Point Conception area, Point Mugu, and Oceanside Data from the studies carried out in beach areas unmodified by littoral barriers indicate that under a given set of wave conditions the alongshore velocity of sediment transport differs from zone to zone such that transport seaward of peaking-breaking waves < transport on the beach face < transport in the plunge and surf zone Because of these differences, tracing surveys confined solely to the foreshore or offshore zones produce data only partially indicative of transport in the zone of immediate concern to coastal engineers

INTRODUCTION

Recognizing the engineering need to better understand coastal processes, the U S Army Corps of Engineers' Coastal Engineering Research Center, in cooperation with the Atomic Energy Commission, initiated a multi-agency program to create a viable radiosotopic sand tracing (RIST) program To date cooperating agencies have included the Los Angeles District, Corps of Engineers, U S Mobility Equipment Command, the U S Air Force 1st Strategic Aerospace Division and Western Test Range, U S Navy Pacific Missile Range, the National Aeronautics and Space Administration, and the State of California Department of Navigation and Ocean Development In addition to the development of the techniques and technology necessary to trace nuclide labelled particles in the marine environment objectives can be summarized as understanding the mechanics

of sediment movement, both entrainment and transport, patterns of movement, and the volume of sediment movement Relative to the application of these goals to engineering needs field experiments have been carried on straight coastal segments unaltered by engineering works as well as coastal segments effected by engineering works such as groins and harbor jetties

Tagging procedures, hardware development, field surveys and data handling techniques have been developed in cooperation with AEC's Oak Ridge National Laboratory that permit collection and analysis of over 12,000 bits of information per hour over survey track of approximately 18,000 feet Details of model studies, tagging procedures, detection instrumentation, and data handling are discussed elsewhere in these proceedings (James, Acree et al, and Brasheer et al) However for clarity and perspective some statements about these items are necessary to this discussion Search for isotopes and tagging procedures suitable for sand tracing have emphasized two criteria, health physics and the engineering behavior of tagged sand (Duane and Judge, 1969, Acree et al 1969) To date, isotopes of gold (198/199) have been used most extensively The gamma energy (0 4 Mev) is suitable as is the three day half life

Sand indigenuous to a study area is collected approximately 4 weeks before the scheduled field experiment and shipped to Oak Ridge National Laboratories where it is tagged and returned via common carrier to the field site Tagging is a surface tag but is done in such a manner as to simulate a mass tag (Stevens, et al 1969) Tests were conducted at CERC to determine if the gold tagging process modified the characteristics of the untagged sand No detectable differences in specific gravity occurred and there was no observable change in the shapes of grains Overall hydraulic equivalence of the tagged sand to the naturally occurring sand was demonstrated by granulometric analyses conducted on the CERC Rapid Sediment Analyzer (a device used to determine the grain size distributional characteristics of sediment, especially grains in the size range from 62 to 2,000 microns, as they settle through a 1-meter column of water) Distance to be covered and areas involved in most field operations require a mobile detector system with continuous transmission of data to an on-board data recording system The detector vehicle developed is a ball like device which is towed behind an amphibious vehicle (Fig 1) Signal from the detectors is transmitted by cable to the recording system on-board the amphibious vehicle By means of a programmed interrogator other data pertinent to surveying is coordinated with the radiation data and read into the real time data display and on to punched paper tape

Surveying is accomplished at a speed of approximately three knots (5 ft per second) Data obtained with the RIST system can be considered as nearly synoptic observations of sediment transport in a single zone or on adjacent beach inshore and offshore zones

FIELD EXPERIMENTS

Field experiments involving tracing of sand simultaneously in one or more of the three environmental zones have been carried out at several California

sites Surf, Pt Conception, Pt Mugu, and Oceanside In each program at least one shore perpendicular line source was emplaced and followed for several days as the dispersal pattern continued to grow In some programs a point source was also utilized to more specifically identify the movement of sand from a particular location During most recent experiments conducted at Pt Mugu, as well as on the small beach in the harbor at Oceanside, patterns of sediment movement were observed that were similar to those observed during the initial experiments at Surf (Duane, 1970) These indicate that the observed patterns are real and operative on any beach, and indicative of natural processes

At Pt Mugu the first line source (comprised of 30 packets each containing approximately 15 cc of sand in water soluble material and placed 30 feet apart) was emplaced from approximately -3 ft MLLW to -30 ft MLLW Two wave sets were active a shorter period higher wave from the west was dominant The first RIST survey was made 5 hours after injection (Fig 2) Evident is a rapid dispersion in the swash zone, movement upcoast is greater in the breaker and surf zone than on the beach face At least one survey per day was made for the next 3 days as the dispersal pattern developed Swell during the 3 days was from the southwest H = 3 to 5 ft , T = 12 seconds, superposed was a wind chop directed from the northwest with an 8 second period Currents seaward of the breaker zone were north as were those measured in swash zone, although some reversals there were noted Typical of currents measured offshore are depicted in Figure 3 Seventy-two hours after injection a zone apparently void of tagged material separated the offshore zone from the inshore zone and the beach face This zone void of labelled sand coincides with the approximate seaward limit of the zone of peaking and breaking waves

On 28 September oceanographic conditions changed and a second line injection was made, approximately 1,000 feet downcoast This line extended from approximately -1-foot MLLW to approximately -18 ft MLLW Patterns of sediment movement observed from this injection are unidirectional Swell during the next several days was from the northwest H = 3 ft T = 12 sec Currents offshore and in the swash zone were downcoast (Fig 4) Zonal differential transport rate exists but is not of the same relative magnitude as that observed previously, movement of sand towards the beach face is also evident (Fig 5) The gap in radioactivity along the injection line and observed at the first Pt Mugu drop coincident with the low tide breaker zone developed rapidly and seemed to grow in width To gather additional data on the movement of sand in and from the breaker zone during oceanographic conditions then extant, a point source was emplaced there The dispersal pattern of tagged sand was monitored three times in 27 hours Obvious movement is alongshore and to the beach and alongshore (Fig 6) Greatest alongshore rate is in the breaker zone and not the beach face No tagged sand was observed to move seaward through the surf and breaker zone

The oceanographic mileaux adjacent to an engineering structure such as a breakwater is somewhat different than the mileaux adjacent an unmodified coastal segment This is amply demonstrated by the water depth in which sand was observed moving at Oceanside -28 ft MLLW (Fig 7) This depth is nearly twice that observed offshore at Pt Mugu, and under closely similar wave conditions At Oceanside during the time of observations, no sediment was noted moving through the structure Clearly observed, however, was southward

jetty and shore-parallel movement of nuclide labelled sand up to and slightly into the harbor entrance under a southerly directed current and wave regime (Fig 8) Several days later under northerly directed wave and current regime two point sources of labelled sand, were emplaced one in the harbor entrance at -18 ft MLLW and one offshore at -30 ft MLLW Evident is a bifurcating transport system The sand placed in the harbor entrance moved into and down the dredged channels, the seaward point source moved northward parallel to the bottom contour and did not enter the harbor (Fig 9)

SUMMARY

During periods when only one wave train impinges on the coastline unidirectional transport is evident In these instances, marked truncation of labelled sand occurs updrift (within 10 ft) of the injection site Further these data indicate that under given wave conditions the alongshore velocity of sediment transport differs from the offshore zone through the inshore zone to the beach face such that transport seaward of peaking - breaking waves < transport on the beach face < transport in the inshore (plunge and surf) zone A conceptual model for this process is illustrated in Figure 10 Dimensions of these zones would change with tide and wave regime

Present technology and techniques make the RIST system a useful engineering and research tool However, while the identification of the zonal differential transport rate as well as the pattern of sediment movement is of some use to the practicing engineer, full practical value into design considerations will not be reached until the zonal volume rate of transport is obtained Types and dimensions of sedimentary structures observed offshore, in the surf zone, and on the beach are indicative of differing depths of active sand transport Isotope data and plugs of fluorescent and radioactive sand also indicate differing depths of sand movement in different environmental zones These differences, coupled with the differing lateral transport rates introduce complexities to realistic determination of volume sediment movement in the nearshore zone Simple diffusion models are unsuited and any studies confined to one environmenta zone cannot relate the true picture of sediment transport in the nearshore zones important to the coastal engineer Work within the RIST program is continuing toward a solution to the problem of volume rate of sand transport with indications of some success although it is premature to report that progress herein

REFERENCES

Acree, E H , Case, F N , Cutshall, N H , and Brashear, H R , (1969), "Radioisotopic Sand Tracer Study (RIST) Status Report for May 1966-April 1968", ORNL-4341, Contract No W-7405-eng-26

Acree, E H , Brashear, H R , & Case, F N (1970), "A System for Tracing Radionuclide-Tagged Sand", (this volume)

Brashear, H R , Acree, E H , Case, F N , Turner, P A , and Duane, D B (1970), "Analysis of Radioisotopic Sand Tracer Study Data" (this volume)

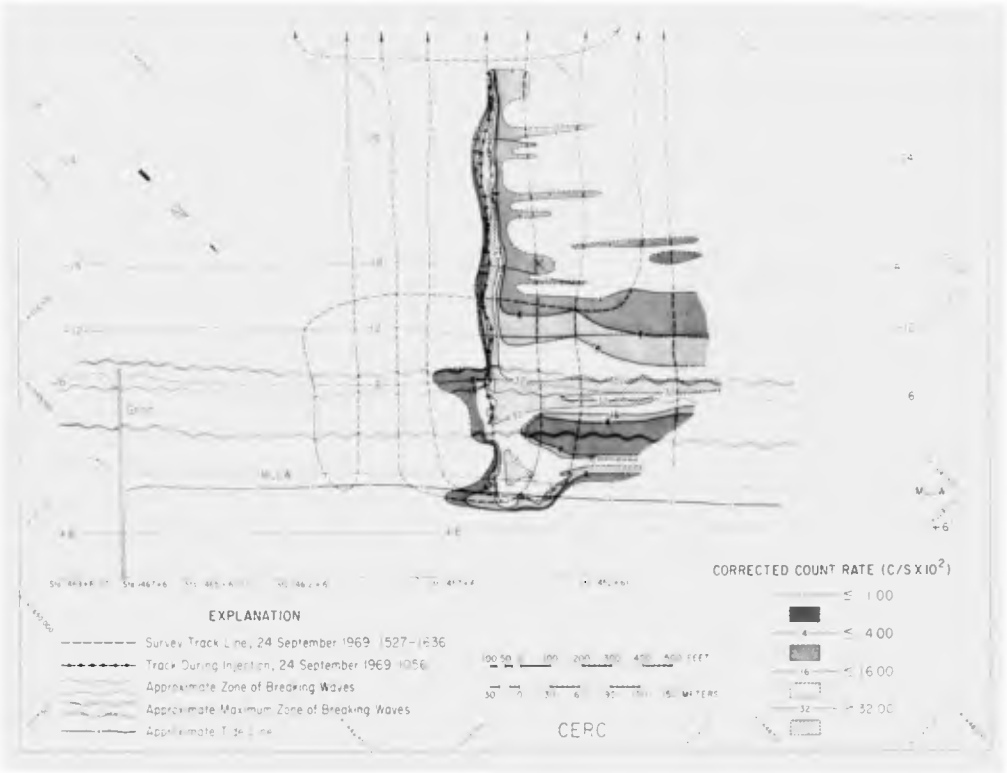
Duane, D B , (1970), "Tracing Sand Movement in the Littoral Zone Progress in the Radioisotopic Sand Tracer (RIST) Study, July 1968-February 1969", U S Army Coastal Engineering Research Center, Miscellaneous Paper 4-70

Duane, D B , and Judge, C W , 1969, "Radioisotopic Sand Tracer Study, Point Conception, California, Preliminary Report on Accomplishments July 1966-June 1968", U S Army Coastal Engineering Research Center, Miscellaneous Paper 2-69

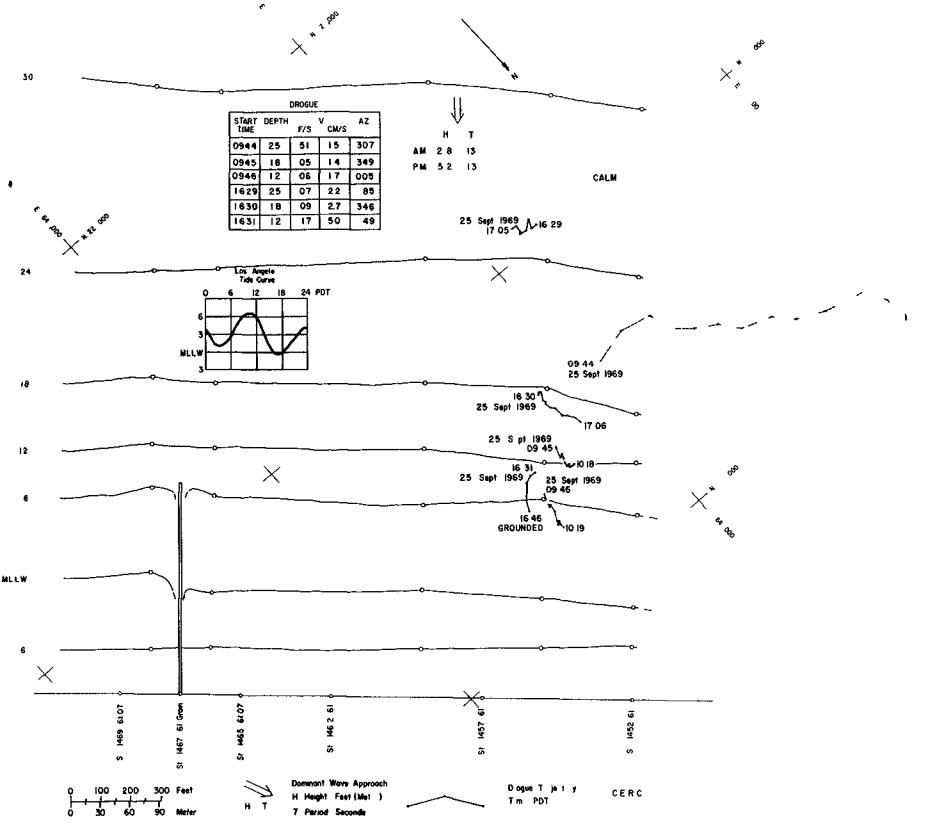
James, W R (1970), "A Class of Probability Models for Littoral Drift," (this volume)

Amphibious LARC XV towing radiation detector vehicle entering surf. The ball-like device is connected to the LARC and the onboard data acquisition system by means of electromechanical cable.

FIGURE 1

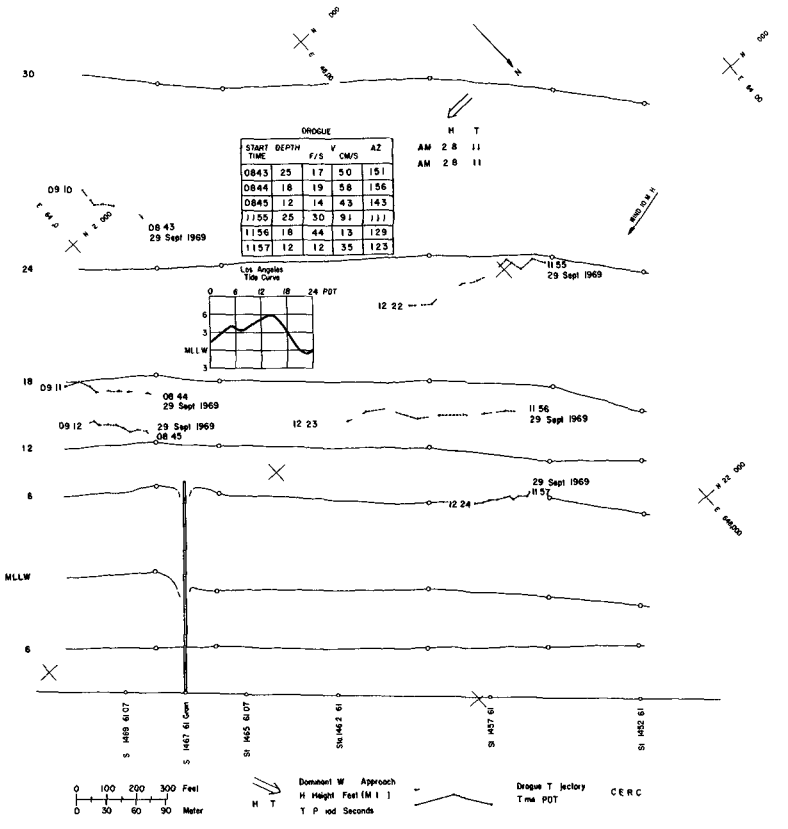


Dispersal pattern of gold-tagged sand observed approximately 5 hours after injection. Note that in this and all site figures, the groin had no panels emplaced and structurally was a pier.



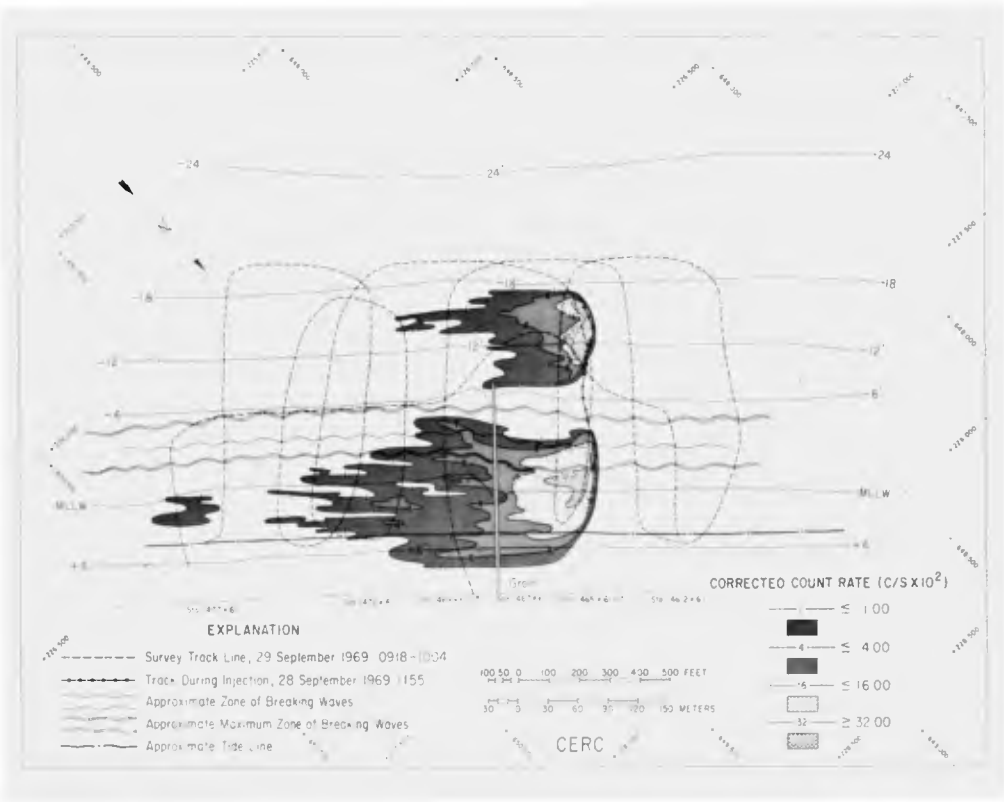
Current drogue patterns, velocities, and tide curve representative of conditions during tests 24-27 September, 1970

FIGURE 3



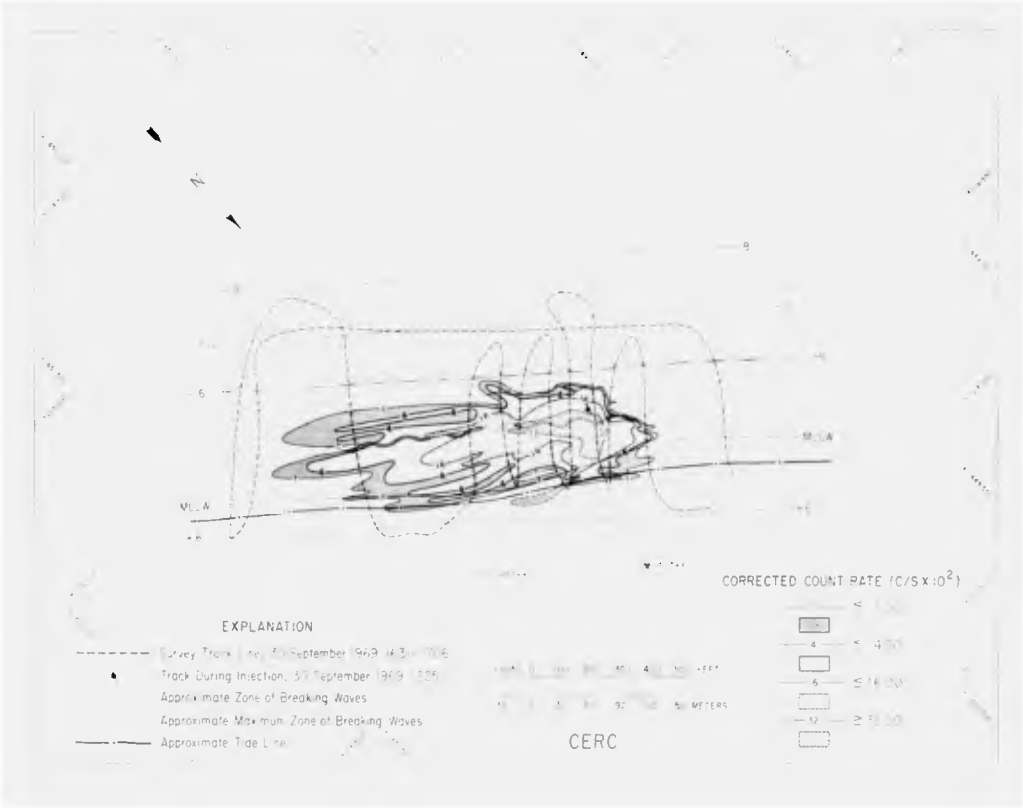
Current drogue patterns, velocities, and tide curve representative of conditions during tests 28 September-1 October, 1970

FIGURE 4



Dispersal pattern of gold-tagged sand observed approximately 23 hours after injection. Note patterns of sand moving through the pier-like structure.

FIGURE 5

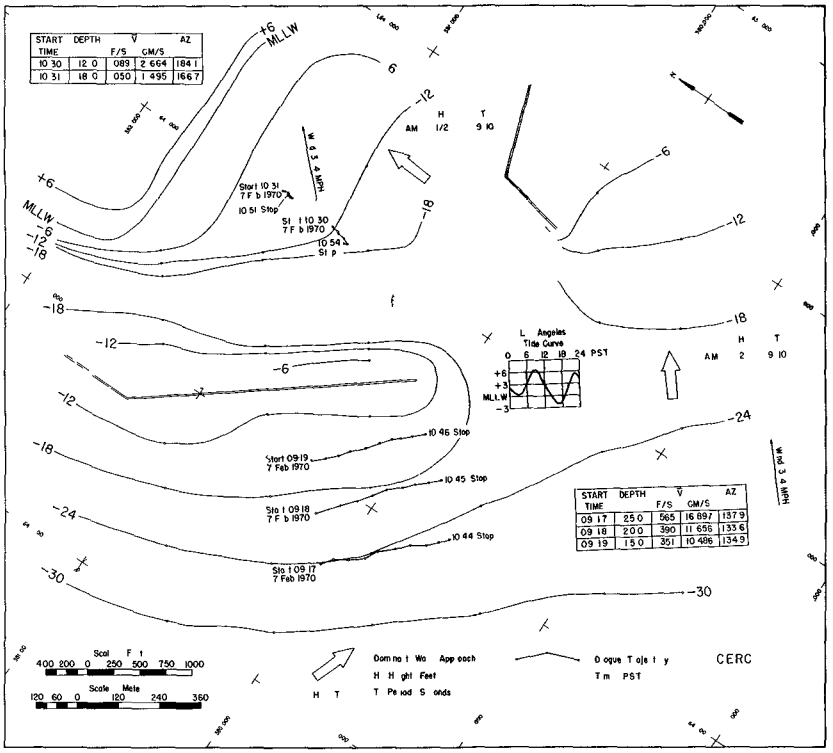


Dispersal pattern of gold tagged sand observed approximately 4 hours after emplacement as a point source in the surf zone.

FIGURE 6

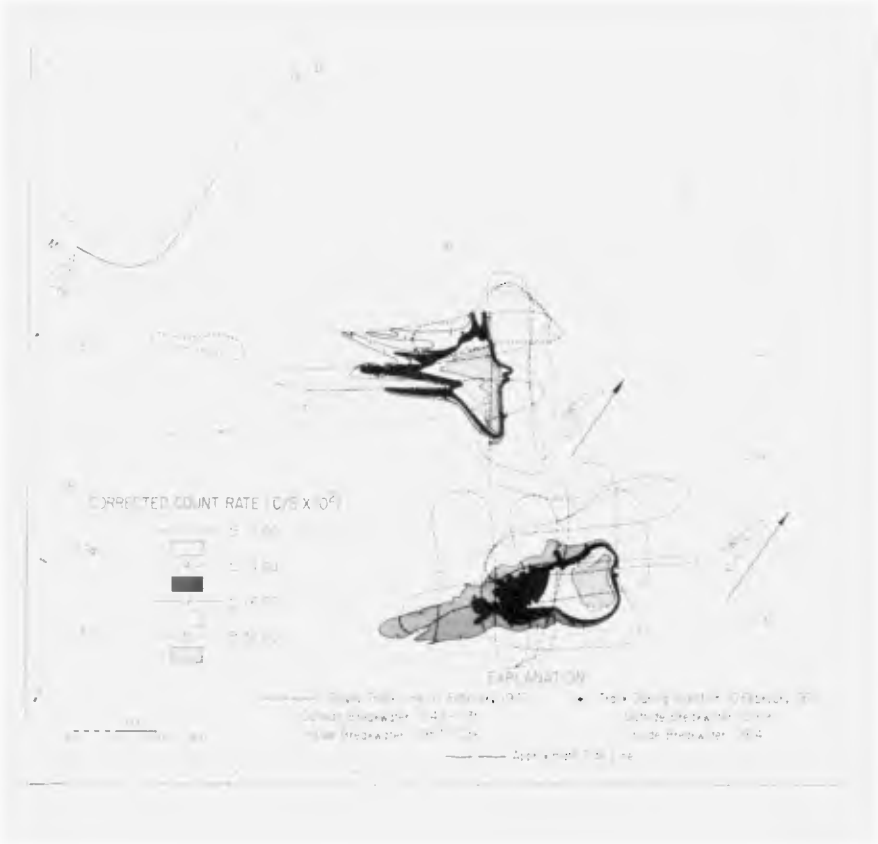
Dispersal patterns of gold-tagged sand placed outside and inside harbor approximately 48 hours after emplacement.

FIGURE 7



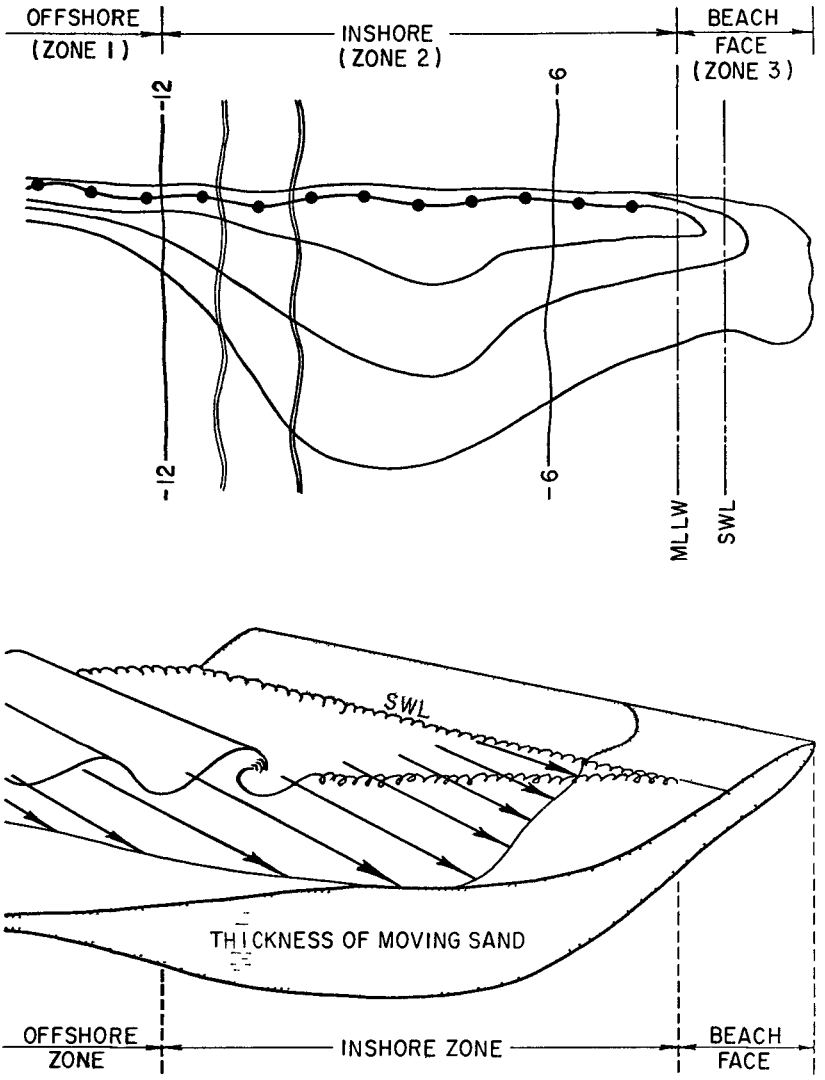
Current drogue patterns, velocities, and tide curve representative of conditions during tests 4-8 February 1970

FIGURE 8



Dispersal patterns of two point source injections of gold-tagged sand observed approximately 24 hours after injection and just after sea and swell had returned to eastward-directed approach.

FIGURE 9



Conceptual model for sediment transport in the littoral zone, numbers refer to depth of bottom below mean lower low water (MLLW) (A) Schematic map of sand dispersal system showing regions of high, medium, and low level radiation (B) Schematic isometric projection showing relative thickness of sand layer involved in transport, length of arrows proportional to rate of transport

FIGURE 10