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Selecting Wave Gauge Sites for Monitoring Harbor Oscillations: A Case Study for Kahului Harbor, Hawaii

by Michele Okihiro, R. T. Guza, W. C. O'Reilly
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Prepared for Headquarters, U.S. Army Corps of Engineers
and State of Hawaii, Hawaii Department of Transportation

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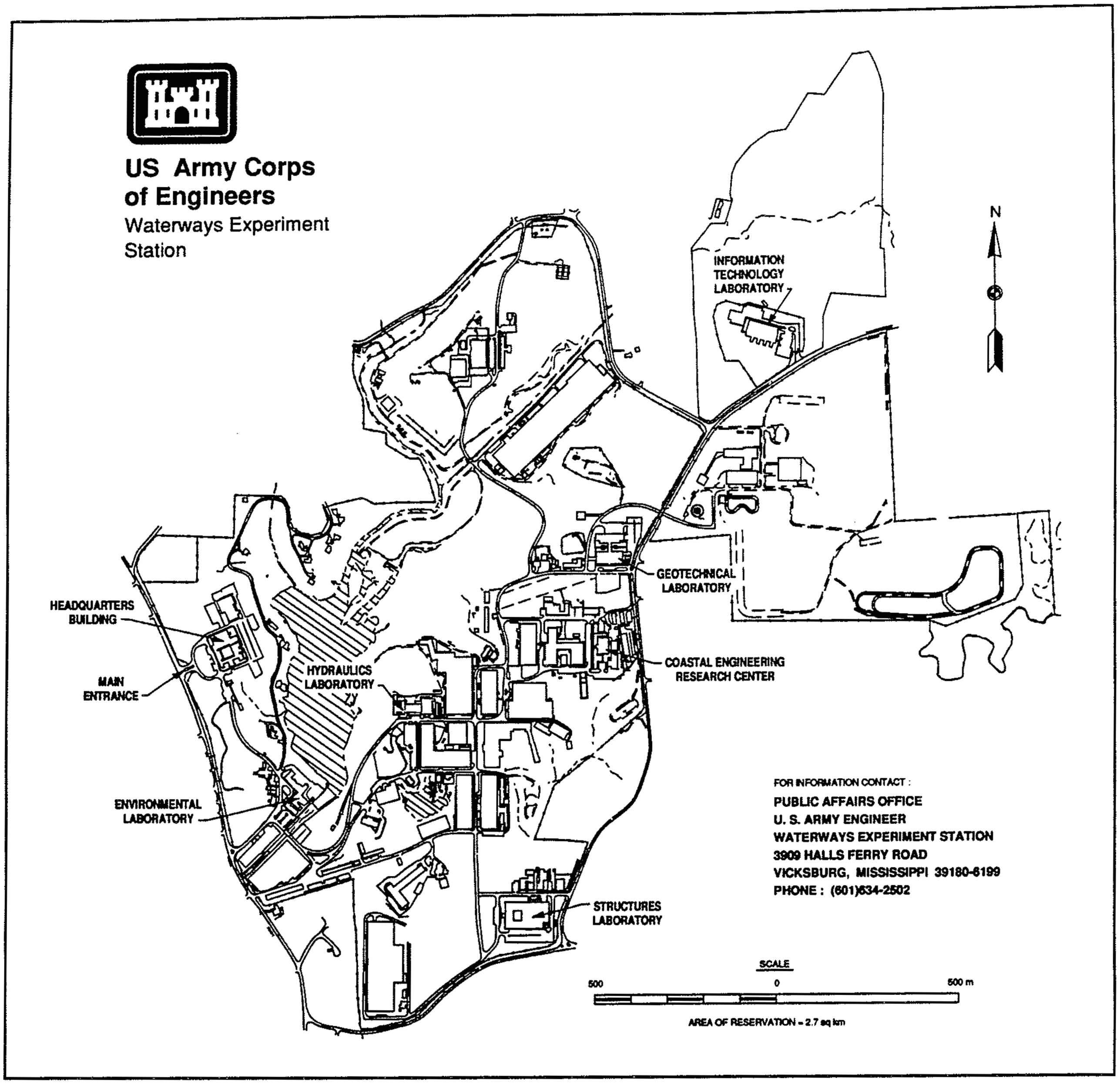

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Preface

This report is published by the U.S. Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC). The work was funded by the Field Wave Gaging Program (FWGP), a work unit of the U.S. Army Corps of Engineers Coastal Field Data Collection Program (CFDCP)and the Harbors Division of the State of Hawaii Department of Transportation (HDOT). At Headquarters, U.S. Army Corps of Engineers Technical Monitors for the CFDCP are Messrs. John G. Housley, John H. Lockhart, and Barry W. Holliday. The Program Manager of the CFDCP is Ms. Carolyn Holmes, CERC; the Principal Investigator of the FWGP is Mr. David McGehee, CERC. At HDOT, Mr. Robert Nagao is Head of the Planning Office, and Mr. Calvin Tsuda is Deputy Director for Harbors Division.

Mr. McGehee was under the supervision of Mr. William L. Preslan, Chief, Prototype Measurement and Analysis Branch, and Mr. Thomas W. Richardson, Chief, Engineering Development Division (CERC). Dr. James R. Houston was Director of CERC and Mr. Charles C. Calhoun, Jr., was Assistant Director of CERC.

Dr. Robert Guza was supported by the Office of Naval Research, which also provided access to a CRAY Y-MP computer for numerical modeling. HARBD model grids were created using the gridding software packages TRIGRID (Fisheries and Oceans, Canada) and MENTAT (MARC Analysis Research Corporation).

This report is the third in a series funded by the FWGP describing the methods used to select sites for wave gauges. The particular application is for the Kahului Harbor Study, a reimbursable work unit funded by the State of Hawaii Department of Transportation.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES and COL Bruce K. Howard, EN, was Commander.

1 Introduction

Purpose

Wave measurements are required to observe and ultimately predict the response of the ocean to dynamic loading. While remote sensing techniques may eventually provide continuous spatial definition of wave energy for large regions, current engineering practice relies on point measurements from wave gauges. The U.S. Army Corps of Engineers' Field Wave Gaging Program (FWGP) operates a nationwide network of wave gauges and serves as the Corps' central access point for all U.S. wave data. The program also supports a variety of activities to enhance the quality and efficiency of wave data collection, processing, and distribution. This is the third in a series of FWGP reports describing, through case studies, the process of selecting sites for wave gauges.

The selection of sites for measuring wave energy in a particular environment is often a heuristic exercise wherein engineering judgement is used to balance the sometimes conflicting requirements of defining the processes (physics), ensuring data capture (logistics), and managing resources (economics). Balancing these aspects may never yield to purely analytic solution, but tools can be developed to quantify benefits and costs. In O'Reilly and McGehee (in preparation) a technique borrowed from metallurgy-simulated annealing is described that optimizes the information content of a network within a region (assumed to have uniform incident conditions at its outer boundary). Basco and McGehee (1990) walk through all the steps involved in selecting the exact gauge location once a general site has been identified. This paper illustrates use of two different wave transformation models to optimize gauge sites in a local gauge network for a harbor oscillation study. The harbor under consideration is Kahului Harbor, Hawaii.

Background

As with the other Hawaiian Islands, Maui is almost totally dependent on ocean transportation for its basic supplies, and Kahului Harbor is the only commercial deep-draft harbor on this island. In order to handle the growing cargo tonnage generated by the growth in population and expanding economy, and to keep pace with the technological and operational changes occurring in the maritime industry, modifications to the present port facilities are being planned (Hawaii Department of Transportation (HDOT) 1989). HDOT requested that the U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC) conduct a study of the existing conditions at Kahului Harbor and make recommendations to maximize the use of available areas for harbor expansion and navigational improvements.

Although existing swell conditions at Kahului Harbor have not resulted in complete closure of the harbor, they have hampered the efficient use of some berths. Though unlikely, there is concern that supply lines to the island might be cut off if the entrance channel were temporarily blocked (HDOT 1989). It is not clear whether the existing problems are due to swell entering the harbor or lower frequency 'seiche' motions, though significant swell can be observed throughout the harbor when northerly storms occur. Operational problems in many harbors are due to seiche (also called surge or resonance) which is characterized by a concentration of energy in standing wave modes at the resonant frequencies, typically between 0.001 and 0.01 Hz for small harbors. Energy at these frequencies is amplified within the harbor, relative to outside the harbor, whereas harbor motions at other frequencies are suppressed. In harbors the size of Kahului, the lowest frequency resonances may be driven by atmospherically excited internal and shelf waves, whereas higher frequency modes are usually driven by nonlinear interactions between swell and sea. The forcing and damping of resonant modes may differ from harbor to harbor depending on the harbor geometry, surface wave climatology and general oceanographic properties, (i.e., stratification and wind field) in the surrounding offshore area. It is not presently possible to quantitatively predict the magnitude of harbor seiches either numerically or with physical models, owing to the complexity of the seiche excitation and damping processes. In situ observations are essential to the characterization of harbor seiche and to provide the unknown values of parameters necessary for modeling studies.

Kahului Harbor Site Description

Kahului Harbor is situated at the apex of a large V-shaped bay formed by an indentation on the north shore of the island (Figure 1). Offshore bathymetry at this site is complicated (Figure 2). East of the harbor the bathymetry is characterized by shallow areas (< 3 m) which extend nearly 1-2 km offshore whereas to the west the bottom slope is steeper and relatively constant. Directly offshore of the entrance channel the depth is about 10 m.

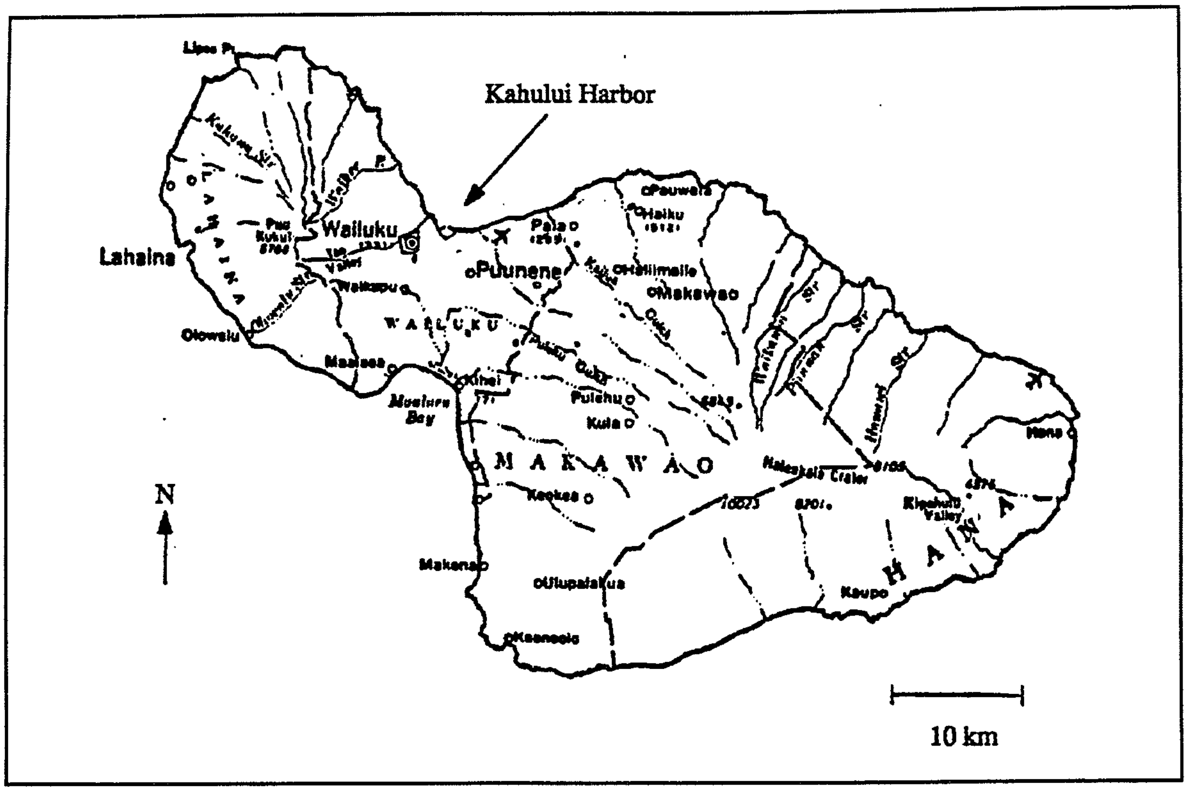

Figure 1. Kahului Harbor Site, Maui, Hawaii

Overall harbor dimensions are approximately 1 km by 1 km, although depths along the unused western and southern perimeter are only a few meters (Figure 3). The present operational harbor basin defined by the 10- to 11-m depth contour (Figure 3) is approximately 730 m long and 600 m wide. The ~200-m-wide entrance channel faces northward and is bounded by two rubble-mound breakwaters. Although under most wave conditions these breakwaters successfully protect the harbor, energetic northerly swell reaches all piers and sometimes interferes with harbor operations (HDOT 1989).

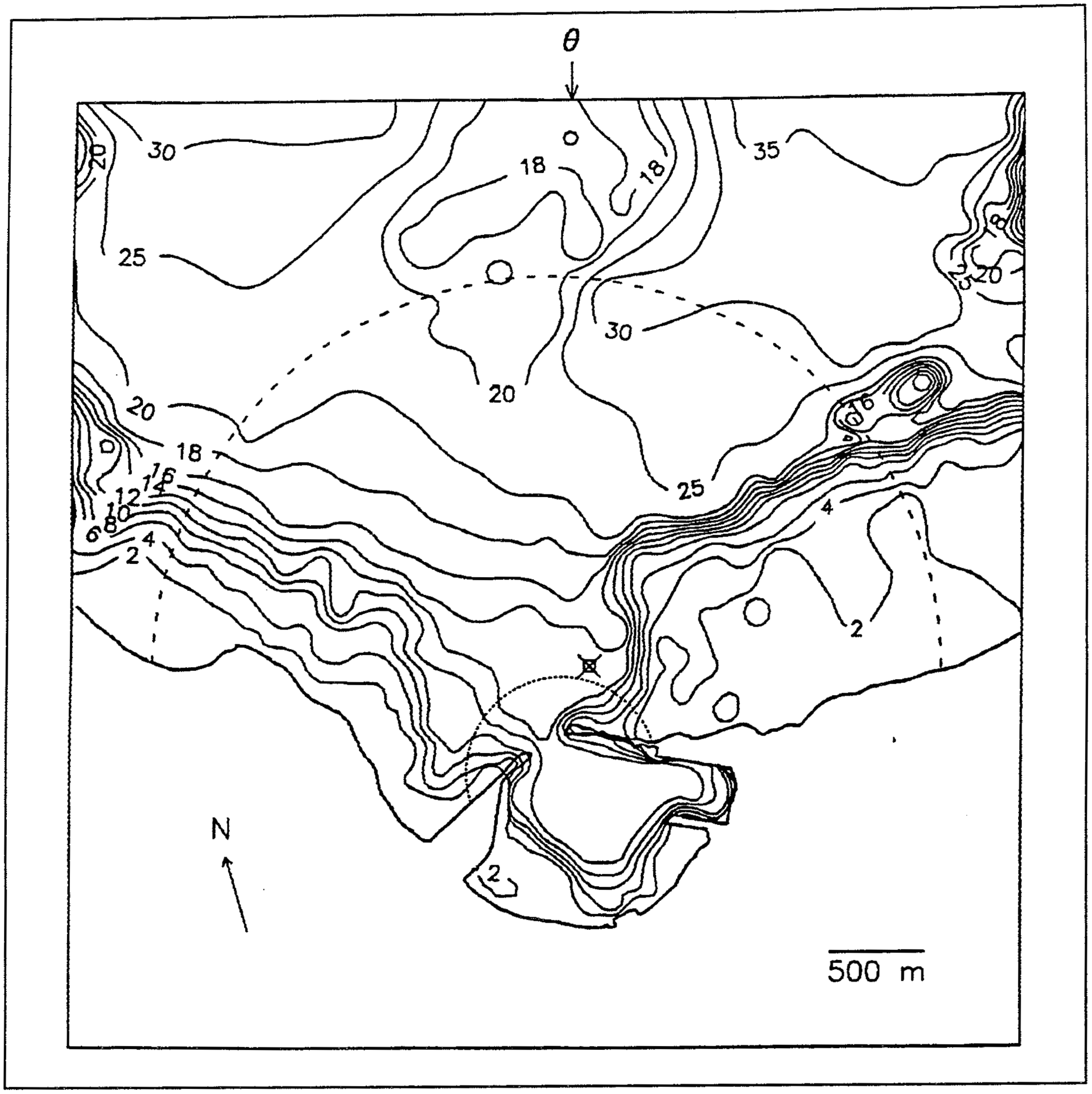

Figure 2. Offshore and harbor bathymetry at Kahului, Maui. Dashed line indicates the near-field HARBD numerical model grid boundary for Test 1 and the dotted line is the boundary for all other tests. θ (top of figure) is the incident wave direction. The site selected for the offshore slope array is shown by a crossed square

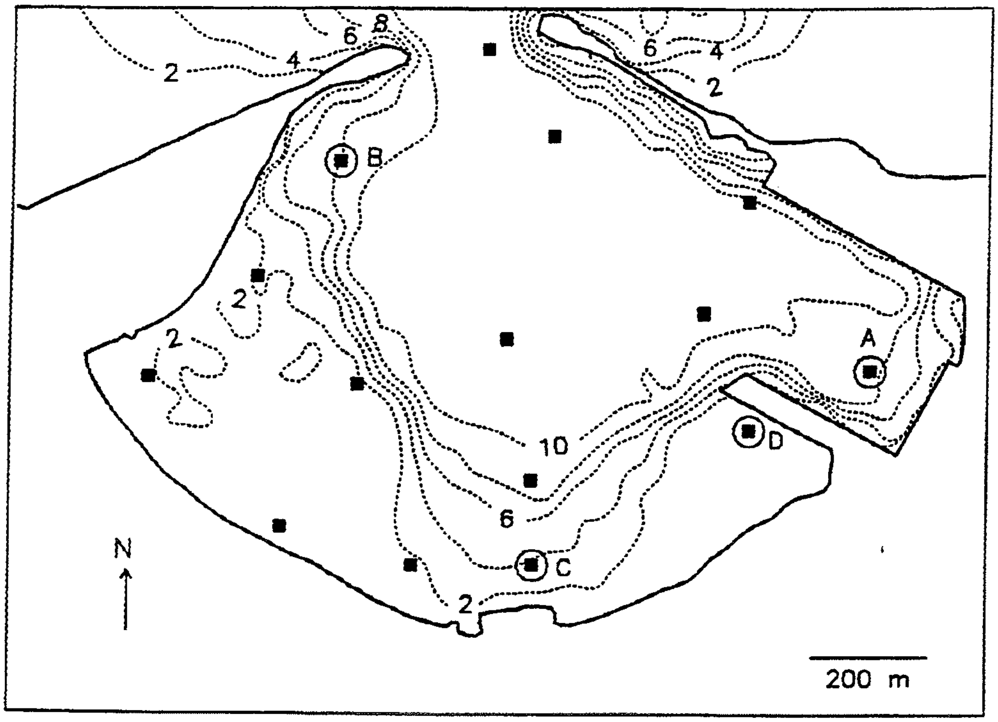

Figure 3. Harbor bathymetry and sensor locations. The solid symbols indicate positions for which HARBD model results are shown in subsequent figures and the lettered circles are the harbor sites selected for field data collection