Technical Report CERC-94-12
September 1994

US Army Corps
of Engineers
Waterways Experiment
Station

Periodic Inspections of Kahului and Laupahoehoe Breakwaters, Hawaii

Report 1
Base Conditions

by Dennis G. Markle, WES
Stanley J. Boc, Pacific Ocean Division

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Prepared for Headquarters, U.S. Army Corps of Engineers

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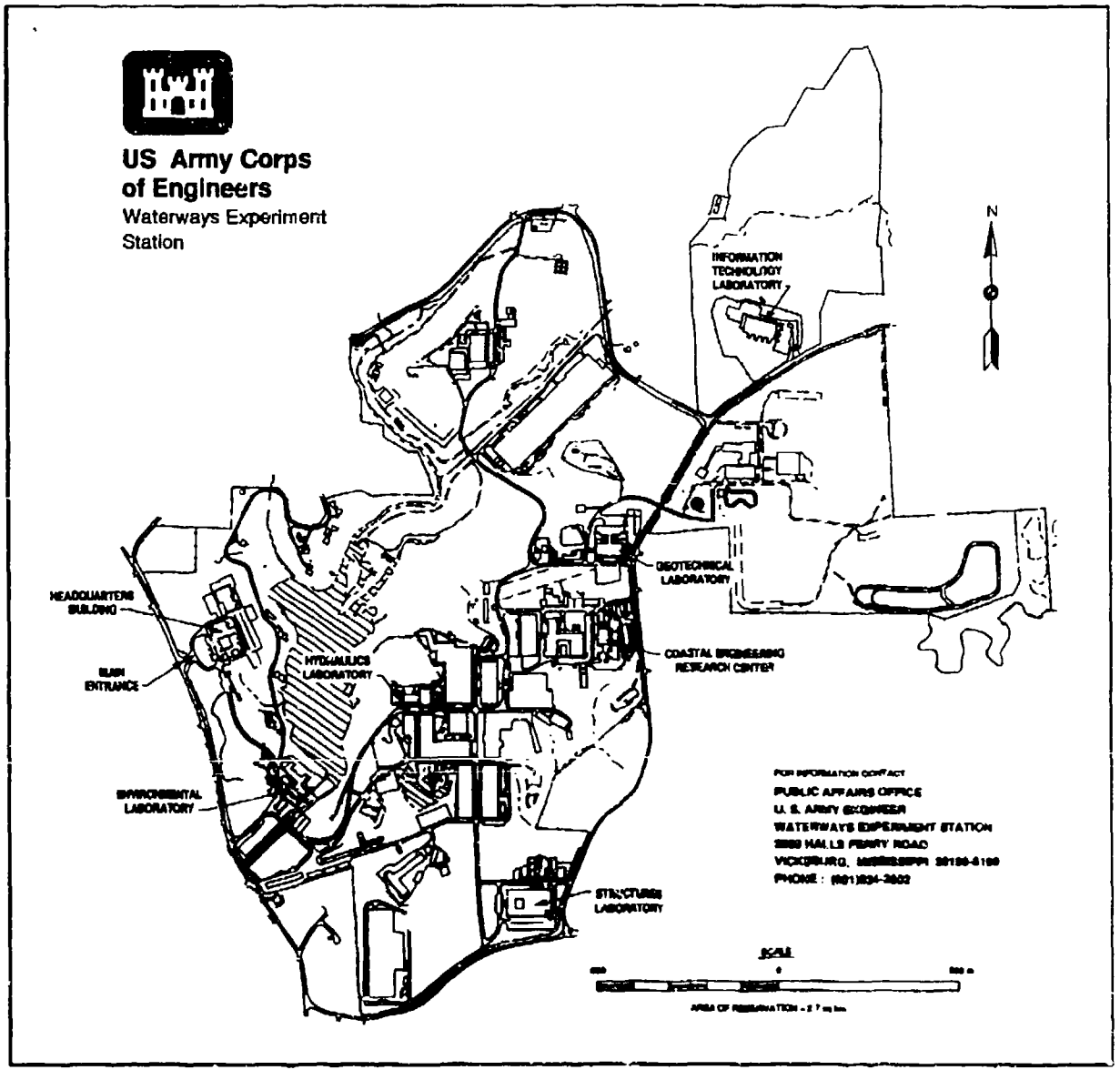
Report 1 of a series

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 22121



Waterways Experiment Station Cataloging-in-Publication Data

Markle, Dennis G.
Periodic inspections of Kahului and Laupahoehoe breakwaters, Hawaii. Report 1, Base conditions / by Dennis G. Markle, Stanley J. Boc ; prepared for U.S. Army Corps of Engineers.
90 p. : ill. ; 28 cm. — (Technical report ; CERC-94-12 rept. 1)
Includes bibliographic references.
1. Rubble mound breakwaters — Hawaii — Laupahoehoe — Inspection. 2. Breakwaters — Hawaii — Kahului — Evaluation. 3. Rubble mound breakwaters — Maintenance and repair — Evaluation. 4. Cement coating. I. Boc, Stanley J. II. United States. Army. Corps of Engineers. III. U.S. Army Engineer Waterways Experiment Station. IV. Coastal Engineering Research Center (U.S.) V. Title. VI. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; CERC-94-12 rept. 1.
TA7 W34 no.CERC-94-12 rept. 1

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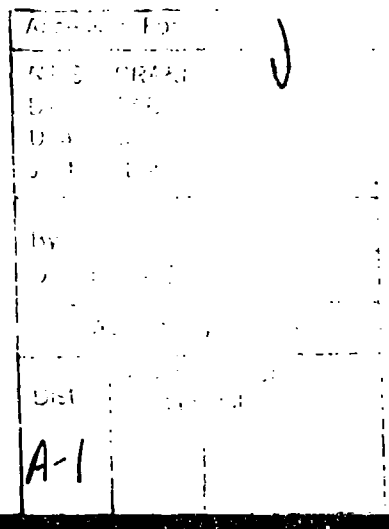

Preface

This report was prepared as part of the Monitoring of Completed Coastal Projects Program (MCCP) at the U.S. Army Engineer Waterways Experiment Station (WES). Work was carried out under Work Unit 22121, "Periodic Inspections." Ms. Carolyn M. Holmes, WES Coastal Engineering Research Center (CERC), is Program Manager of the MCCP and Messrs. John H. Lockhart, Jr., John G. Housley, and Barry W. Holliday, Headquarters, U.S. Army Corps of Engineers, are the Technical Monitors.

This report is the first in what will be a series of reports tracking the long-term structural response of the Kahului breakwaters, Kahului Harbor, Maui, Hawaii, and Laupahoehoe breakwater, Laupahoehoe Boat Launching Facility, Hawaii, Hawaii, to their environment. The information contained in this report was gathered from land and aerial survey data obtained by R.M. Towill Corporation, Oahu, Hawaii, under contract to the U.S. Army Engineer Division, Pacific Ocean (POD), from ground surveys conducted by the Surveying Branch of POD, and from walking inspections of the structures by Messrs. Dennis G. Markle, Jeffrey A. Melby, and George F. Turk, CERC, and Mr. Stanley J. Boc, POD.

This work was conducted during the period February 1990 through April 1993 under the general supervision of Dr. James R. Houston, Director, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Director, CERC; and under the direct supervision of Mr. C. E. Chatham, Chief, Wave Dynamics Division, CERC. This report was prepared by Messrs. Markle and Boc.

Director of WES during publication of this report was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
tons (force)	8.896444	kilonewtons
inches	2.54	centimeters
pounds (force)	.004448	newtons

1 Introduction

Background

Under the Periodic Inspections work unit, selected past Monitoring of Completed Coastal Project (MCCP) structures, and/or structures with unique design aspects that have probable applications to other projects, are considered for inclusion in a periodic monitoring program. Selected sites are presented as candidates for development of a periodic monitoring plan. Those sites receiving favorable response during MCCP program review are inspected and a monitoring plan is developed and presented for approval. Once the monitoring plan for a site is approved and funds are provided, the site is reinspected on a periodic basis (frequency of surveys are set based on a balance of need and funding for each monitoring site) to obtain long-term structural performance data.

Monitoring Approach

Primary inspection tools used are relatively low-cost remote sensing techniques with limited ground truthing surveys. A majority of the periodic inspections consist of capturing the above-water conditions of the structures at periodic intervals using high-resolution aerial photography. The degree of data analysis, using photogrammetric methods developed for and successfully applied at the Manasquan jetties, New Jersey, and the Crescent City breakwater, California, vary from site to site. A visual comparison of the periodic aerial photographs is used to gauge the degree of in-depth analysis needed to quantify structural changes (primary armor unit movement). Where local wave data are being gathered by other projects or agencies and acquisition of these data can be made at a relatively low cost, wave data are correlated with structural changes. Where these detailed data do not exist, general observations and/or documentation of major storms occurring in the area are presented along with the monitoring data. Use of ground surveys is limited to the level needed to establish the accuracy of photogrammetric techniques.

When a structure has been photographed at low tide, an accurate, permanent record of all visible areas is obtained. Through the use of

stereoscopic, photogrammetric instruments in conjunction with the photographs, details of structural geometry can be defined at a point in time. By direct comparison of photographs taken at different times, as well as the photogrammetric data resolved from each set of photographs, geometric changes of the structure can be defined as a function of time. Thus, periodic inspections of the structures will capture permanent data that can be compared and analyzed to determine if structure changes are occurring that indicate possible failure modes and the need to monitor the structure(s) more closely.

The breakwaters at Kahului Harbor, Maui, Hawaii, and Laupahoehoe, Hawaii, Hawaii, were nominated by the U.S. Army Engineer Division, Pacific Ocean (POD). A brief overview of the history of these unique structures follows.

Kahului Harbor

Kahului Harbor is the only deep-draft harbor on the island of Maui. Maui is the second largest of the Hawaiian Islands. The harbor is approximately 94 miles[1] southeast of Honolulu and is centrally located on Maui's north shore (Figure 1).

The harbor is exposed to winds and waves from the north and northeast. Both northeast tradewind waves and northern swell impact on Kahului Harbor. The trade winds predominate the summer season, producing 6- to 10-sec, 4- to 12-ft deepwater waves. Intense winter storms in the north Pacific Ocean create northern swell during the months of October through March. Deepwater waves can attain heights of 25 ft with wave periods from 12 to 18 sec. These storms and, more recently, hurricanes are the sources of the largest waves that reach the Hawaiian islands.

Kahului Harbor is rich in construction, repair, and rehabilitation history as reported by POD (1981) and Sargent, Markle, and Grace (1988). The harbor complex got its start when a berthing area, dredged entrance channel and 400-ft-long, armor stone east breakwater were constructed by the Kahului Railroad Company in 1900. The Corps of Engineers' first involvement with the project came in 1913 when the east breakwater was extended 400 ft. The west breakwater was constructed to a length of 1,950 ft in 1919. In 1931, the east and west breakwaters were extended to their current lengths of 2,766 ft and 2315 ft, respectively. All original construction used a single layer of keyed and fitted, 8-ton armor stone placed between the +13-ft mean low lower water (mllw) crest and -15 ft mllw (Figure 2). Side slopes above -15 ft mllw were 1V on 2H on the heads and 1V on 1.5H on the trunks. Below -15 ft mllw, the 1V on 1H sloped structure was constructed of quarry run stone (25 lb minimum stone weight).

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page v.

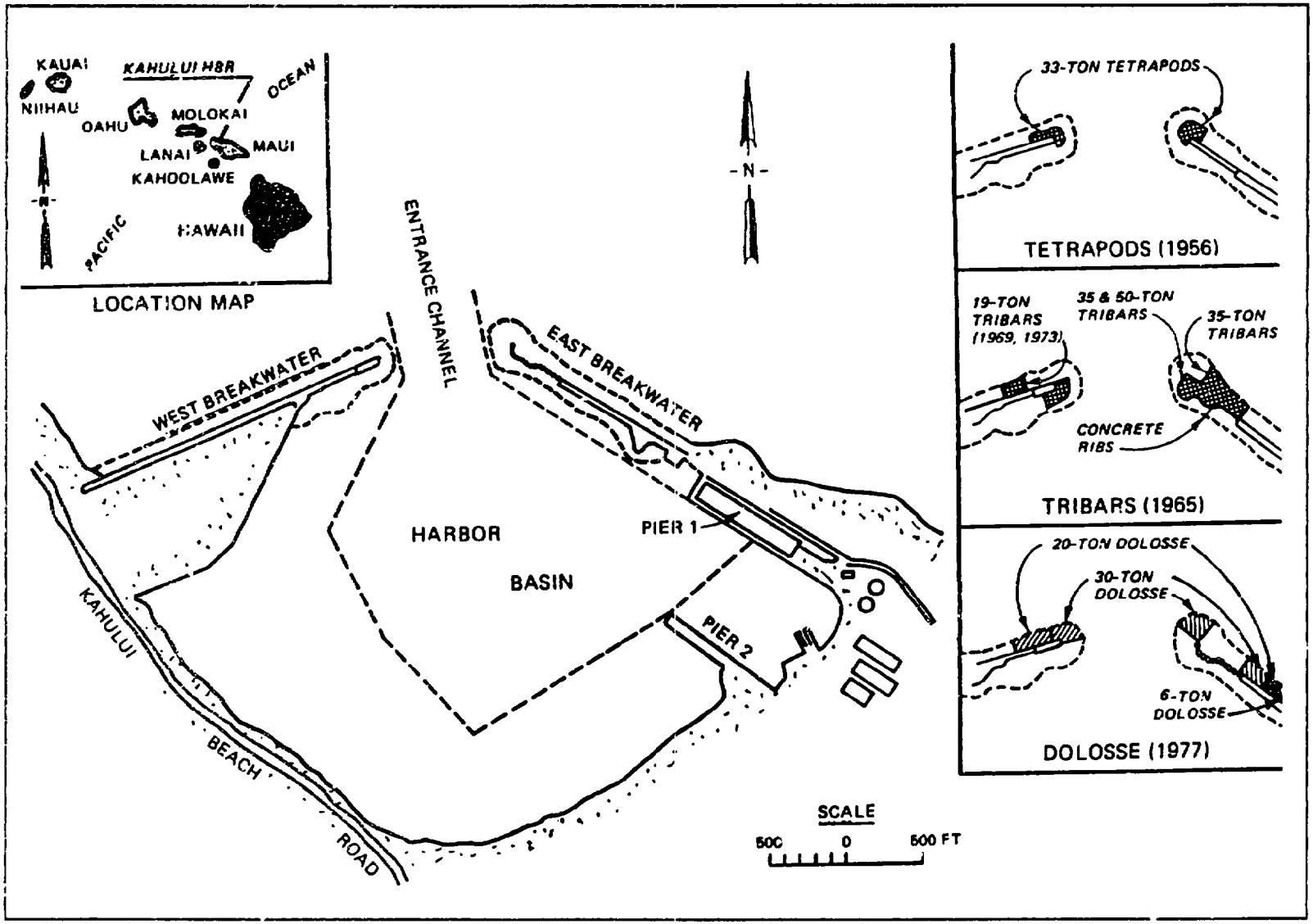


Figure 1. Kahului Harbor, Maui, Hawaii

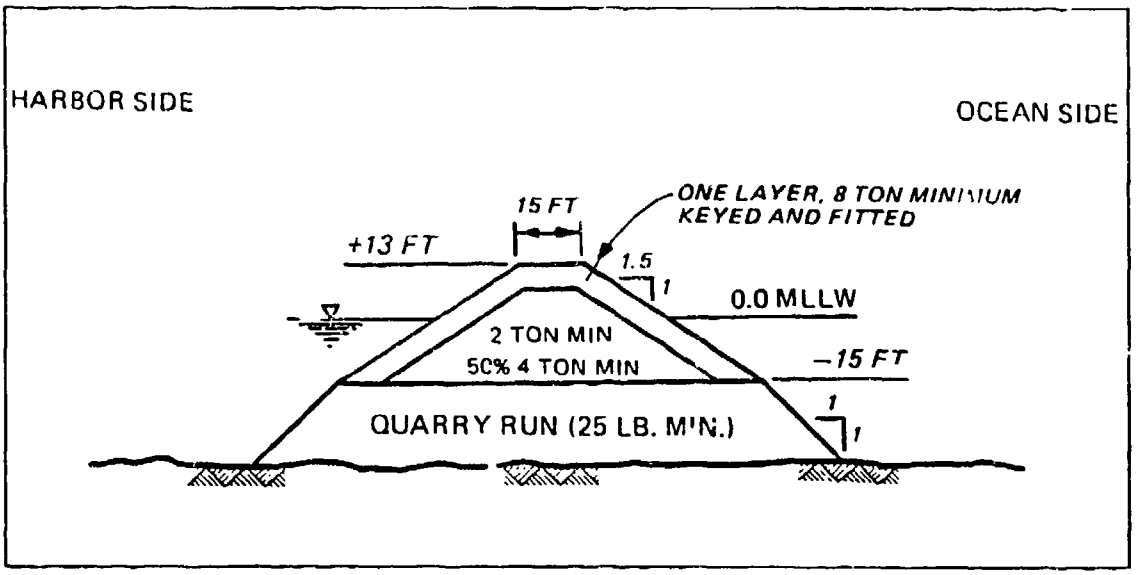


Figure 2. Kahului breakwater construction of 1913 (typical cross section)

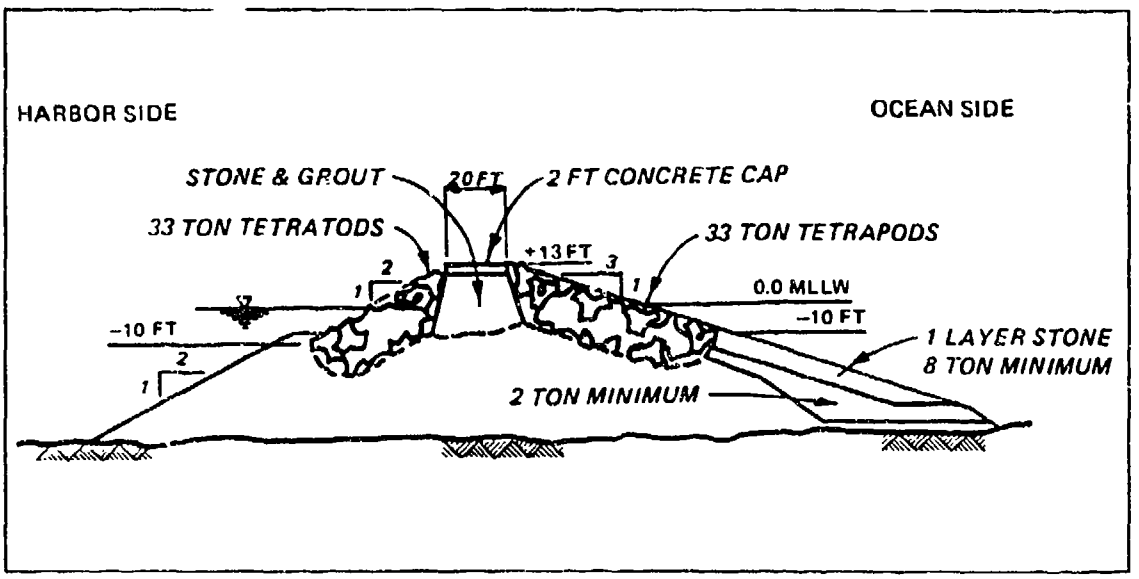


Figure 3. Kahului breakwater repairs of 1956 (typical cross section)

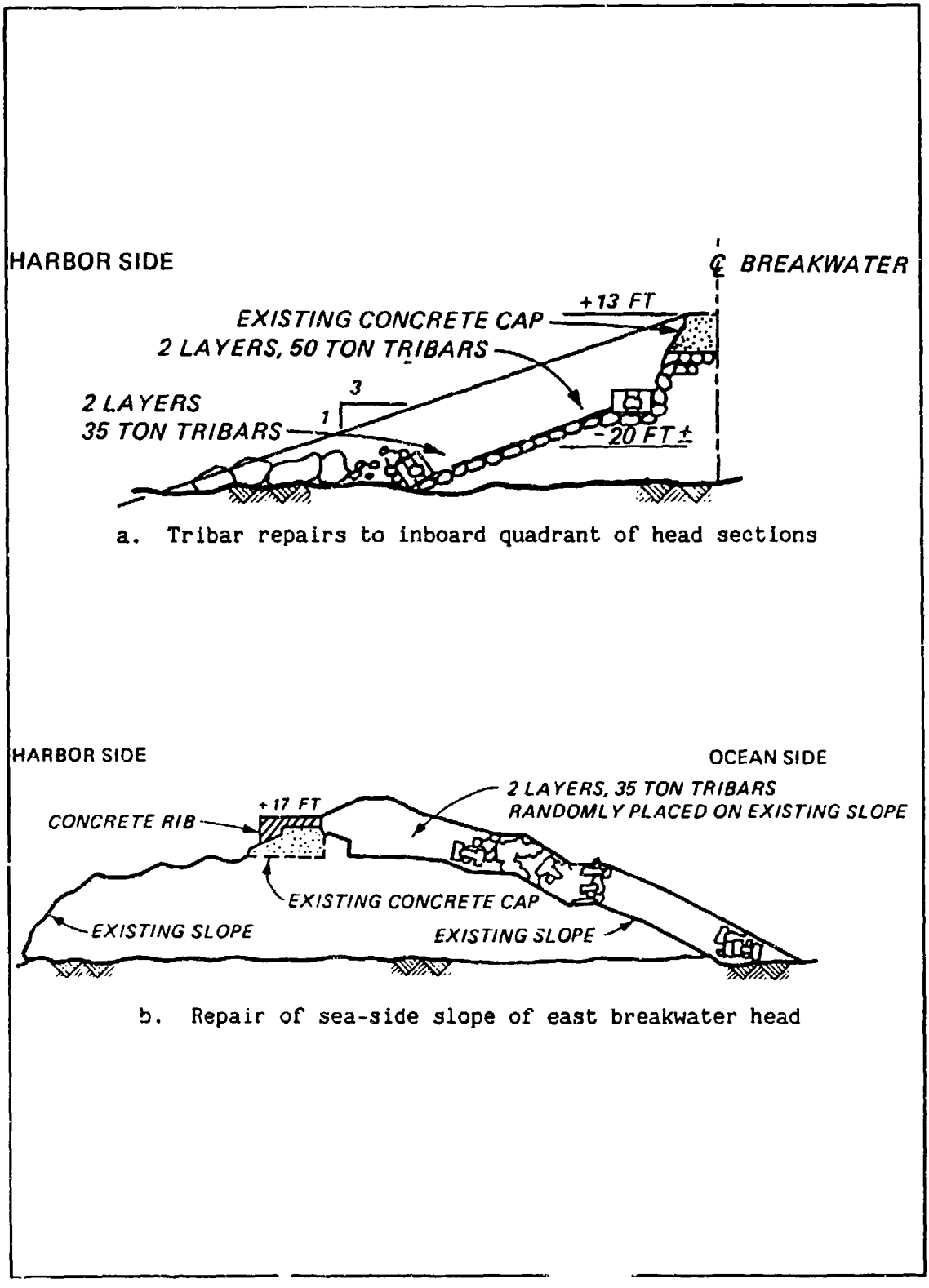
Between 1931 and 1954, both breakwaters were severely damaged on numerous occasions and each repair or rehabilitation was carried out by restoring the structure to original conditions with 8-ton keyed and fitted armor stone. In March of 1954, storm waves, with estimated 34-ft breaker heights at the structure heads, attacked Kahului Harbor for a 3-day period. The outer 185 ft and 300 ft of the east and west breakwaters, respectively, were severely damaged. This extensive damage initiated actions to base needed repairs on current design criteria rather than restoring the structure to its prestorm conditions. In 1956, repairs were completed on both breakwaters using 33-ton unreinforced tetrapods and a concrete cap (Figure 3). The new armor units were placed on the heads of both breakwaters and extended 250 ft shoreward along the sea-side face of the west breakwater trunk.

A storm in 1958 with estimated wave heights of 25 ft at the structures caused extensive damage to both breakwaters. A breach in excess of 150 ft was opened up on the east breakwater at the transition between the armor stone and tetrapods. On the west breakwater, all of the tetrapods on the harbor-side quarter of the head were swept away. The 1V on 2H slope used in this area was felt to be the major design deficiency. Temporary repairs of the east breakwater, consisting of a large monolithic concrete cap and placement of 12-ton or larger armor stone on the seaside face, were completed in 1959.

A major breakwater rehabilitation was completed in 1966. Both heads and 355 ft just shoreward of the east head were included in the repair (Figure 4), which was model tested at WES (Jackson 1964). The inboard quarters of both heads were armored with two layers of 35-ton tribars on the upper one third of the slope, while the lower two thirds were protected by a double layer of 50-ton tribars. A two-layer system of 35-ton tribars was placed from the new concrete rib cap to the toe of the rehabilitated sea-side slope of the east breakwater trunk.

A storm in 1967 severely damaged the west breakwater trunk. This area was repaired in 1969 by construction of a concrete rib cap and placement of 260 reinforced tribars, weighing 19 tons each, on the sea-side slope. In November of the same year, the shore end of the 19-ton tribars was damaged by 15- to 20-ft breaking waves. This area was repaired in 1973 by an 80-ft shoreward extension of the concrete rib cap and 19-ton tribars. The shoreward extent of the tribars was buttressed with 25 tribars, weighing 35 tons each (Figure 5).

An inspection conducted in 1973 revealed that the 33-ton tetrapods on the sea-side quadrants of both heads had sustained considerable damage and they, along with the 8-ton stone areas on both trunks, were in need of repair. The following repairs were completed in 1977: on the west breakwater, 257 reinforced dolosse (30 tons each) were placed in two layers over the 33-ton tetrapods on the sea-side quadrant of the head; 291 reinforced dolosse (20 tons each) were placed on the seaside of the west breakwater trunk; on the east breakwater, 610 reinforced dolosse (30 tons each) were placed in a double layer over the 33-ton tetrapods on the sea-side quadrant of the head,



a. Tribar repairs to inboard quadrant of head sections

b. Repair of sea-side slope of east breakwater head

Figure 4. Kahului breakwater repair, 1966

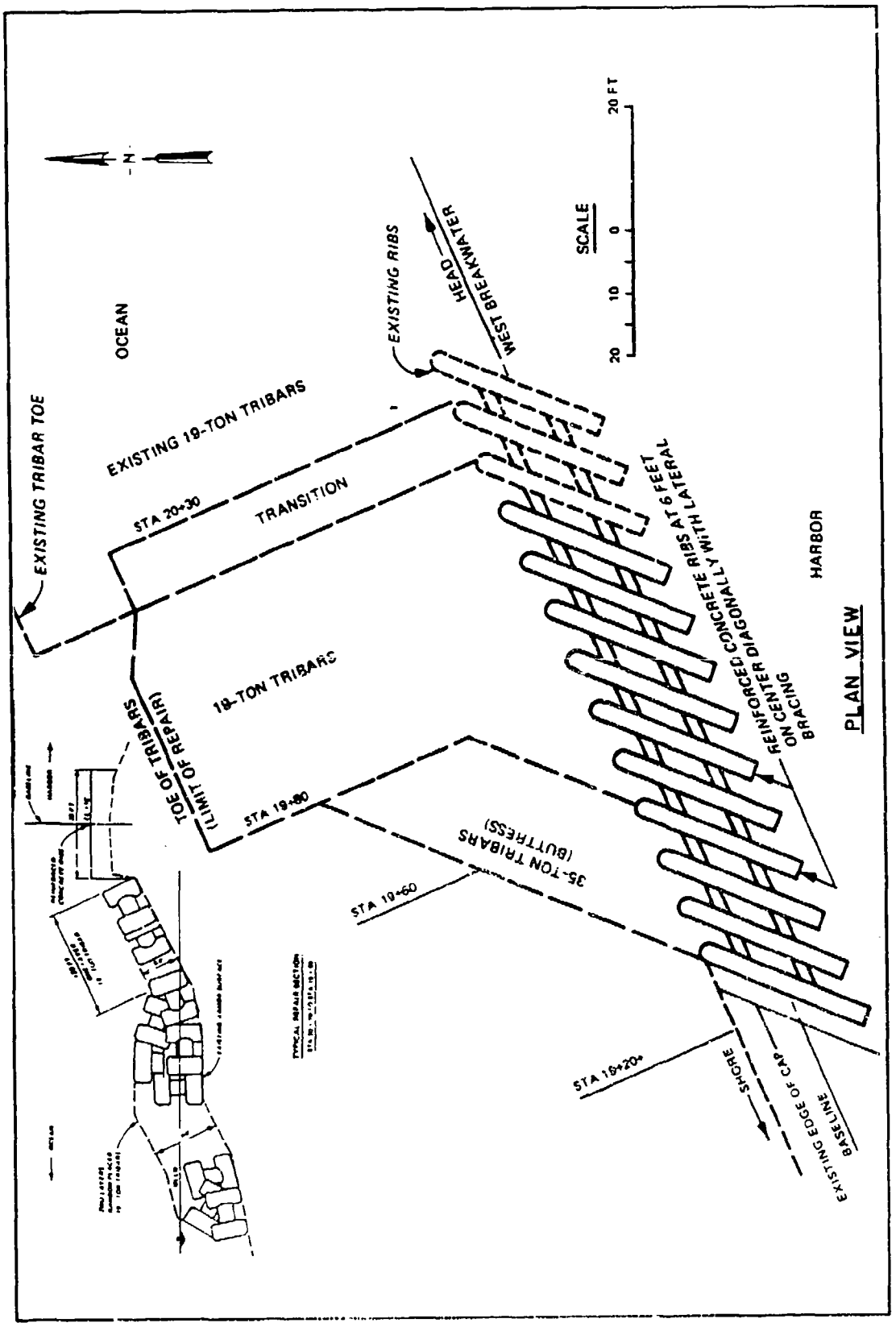


Figure 5. Kahului and west breakwater repairs of 1973

164 reinforced dolosse (20 tons each) were placed in a double layer on the sea-side slope of the trunk beginning shoreward of the 35-ton tribars; and, extending shoreward, two layers of 6-ton unreinforced dolosse (455 units) were placed on the sea-side slope of the east breakwater trunk.

The most recent repairs, model tested by the U.S. Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC) (Markle 1982), were completed in 1984. This rehabilitation was carried out in an attempt to eliminate the need for future "piecemeal" repairs. On the east breakwater, one layer of 9-ton tribars was placed on the harbor side between sta 19+50 and 27+15; also, a concrete rib cap was constructed between sta 19+50 and sta 23+80. On the west breakwater, one layer of 6.5-ton tribars was placed on the harbor-side slope from sta 19+35 to sta 22+00. Between sta 17+75 and sta 19+35, single layers of 6.5-ton and 11-ton tribars were placed on the harbor-side and sea-side slopes, respectively. A concrete rib cap also was constructed in this area and at sta 17+75, the 11-ton sea-side tribars were buttressed with 25-ton tribars. Five hundred and forty tribars weight 6.5 tons each, 755 tribars weighing 9 tons each, and 10 tribars weighing 25 tons each, were placed during the 1984 rehabilitation work.

Laupahoehoe Boat Launching Facility

Laupahoehoe Point is located on the north coast of the Island of Hawaii approximately 25 miles north-northwest of Hilo (Figure 6). The County of Hawaii's Laupahoehoe Point Park borders the shoreline of Laupahoehoe Point. The park is primarily used for day picnics, family gatherings, and as a tourist scenic attraction and rest stop. Historically, Laupahoehoe Boat Launching Facility served as a landing where livestock were imported to the area. The park has a concrete loading dock, restrooms, a picnic area, a pavilion, and a paved parking area. In addition, a concrete launching ramp was constructed within the park limits in 1970. By 1984, the existing launching ramp became unsafe. The ramp was located within what would appear to be a sheltered cove, but waves reflecting off adjacent rocky shores created hazardous conditions a large percentage of the time. Local fishermen found launching conditions too hazardous even under relatively calm ocean conditions. For this reason, the county declared the ramp unsafe and posted a sign, "Boat Ramp Closed."

The waters offshore of Laupahoehoe are very popular and productive for fishing most of the year, but the area was under-used due to closing of the launching ramp. The closest safe launching area was located in Hilo, 25 miles away. This extra travel time required more ice, limiting catch hauling capacity and available hours for fishing. As well as hampering fishing, the closed ramp severely limited the ability of the Hilo Rescue Squad and Coast Guard in responding to emergencies on the northeast Hawaii coast.

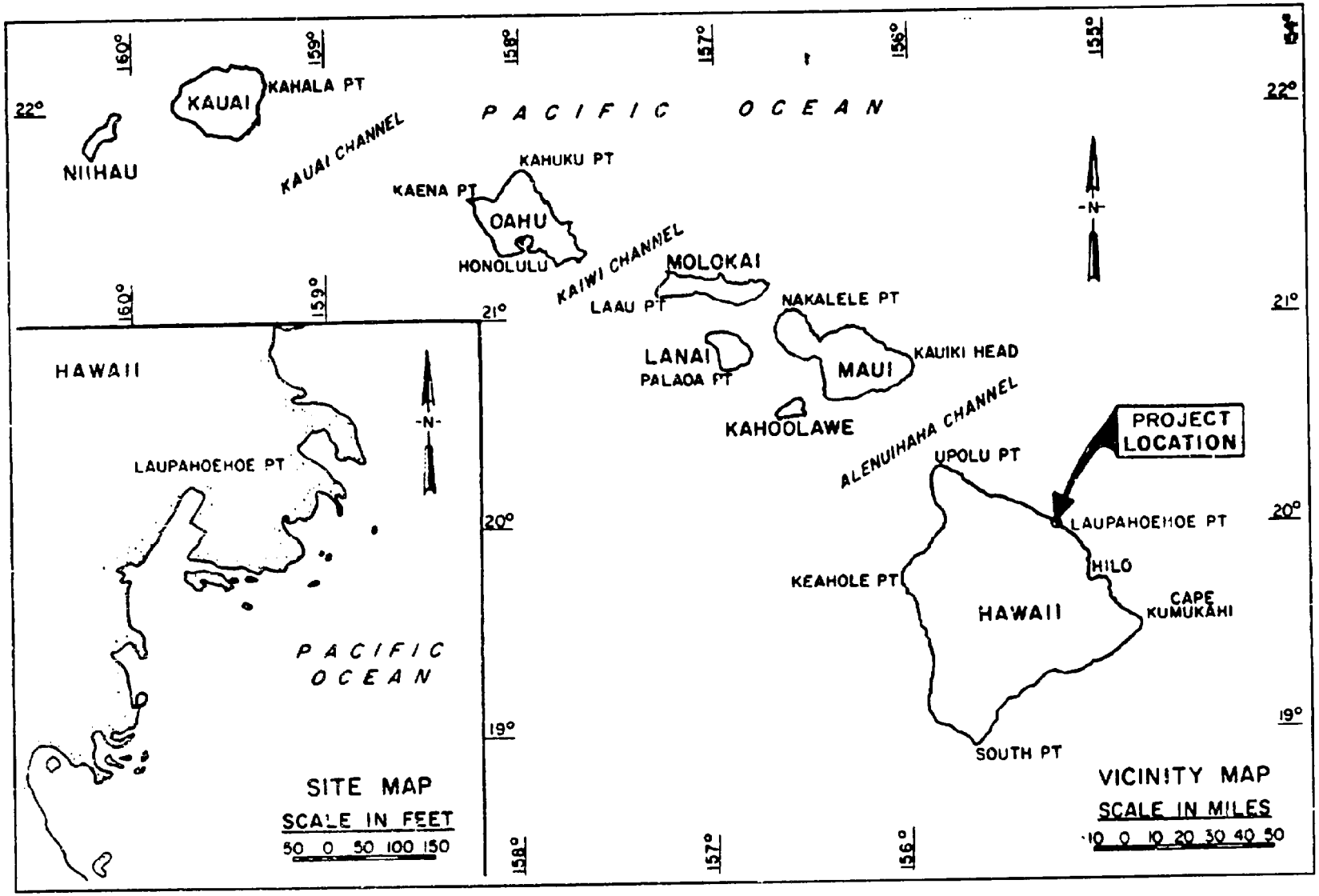


Figure 6. Project location map for Laupahoehoe Boat Launching Facility

POD developed plans to improve conditions in the area with the following plan objectives, taken from POD (1984):

a. Improve commercial fishing opportunities in the North Hilo and Hamakua Districts during the 1985-2135 period of analysis.

b. Improve recreational boating opportunities for the people of the North Hilo and Hamakua Districts.

c. Provide protection for trailer boat launching and recovery during all but storm conditions.

d. Limit the protected water area to launch and recovery operations, allowing sufficient maneuvering room.

e. Minimize conflicts with existing and planned uses of the affected area.

A 250-ft-long rubble-mound breakwater protecting a 9.5-ft-deep entrance channel, 7.5-ft-deep turning basin, and a boat-launching ramp was completed in 1988 (Figures 7 and 8). The design layout for the facility and stability of the breakwater were optimized through physical model studies conducted by CERC (Bottin, Markle, and Mize 1987). The breakwater is armored with 30-ton reinforced dolosse and the crest is stabilized with a concrete rib cap. The toe of the dolosse was keyed into the hard basalt bottom by means of a trench excavated around the perimeter of the breakwater. The rib cap is supported on concrete pipe columns.

The initial design of the breakwater core called for the vertical placement of the core stone adjacent to the dolosse and under the concrete rib cap. However, the breakwater stability model study noted that the stone beneath the rib cap showed some displacement and consolidation during testing. The constructability review of the plans also noted that the vertical placement of the breakwater core stone would be a formidable task in the area's year-round rough ocean conditions.

A stable breakwater core was achieved through the innovative design of a reinforced concrete pipe (RCP) rib cage (Figure 7). The RCP rib cage utilized two rows of 60-in. class 4 RCP, set vertically as columns, on 14-ft center. Each row's RCP columns were spaced 8 ft on center with reinforcing steel and concrete placed inside of each pipe. The RCP columns and concrete rib cap formed a containment cage for the core and capstone. The RCP rib cage clearly provided a stable breakwater core and crest that maintained the energy- dissipating characteristics of the breakwater and was constructable in the rough waters of the project site.

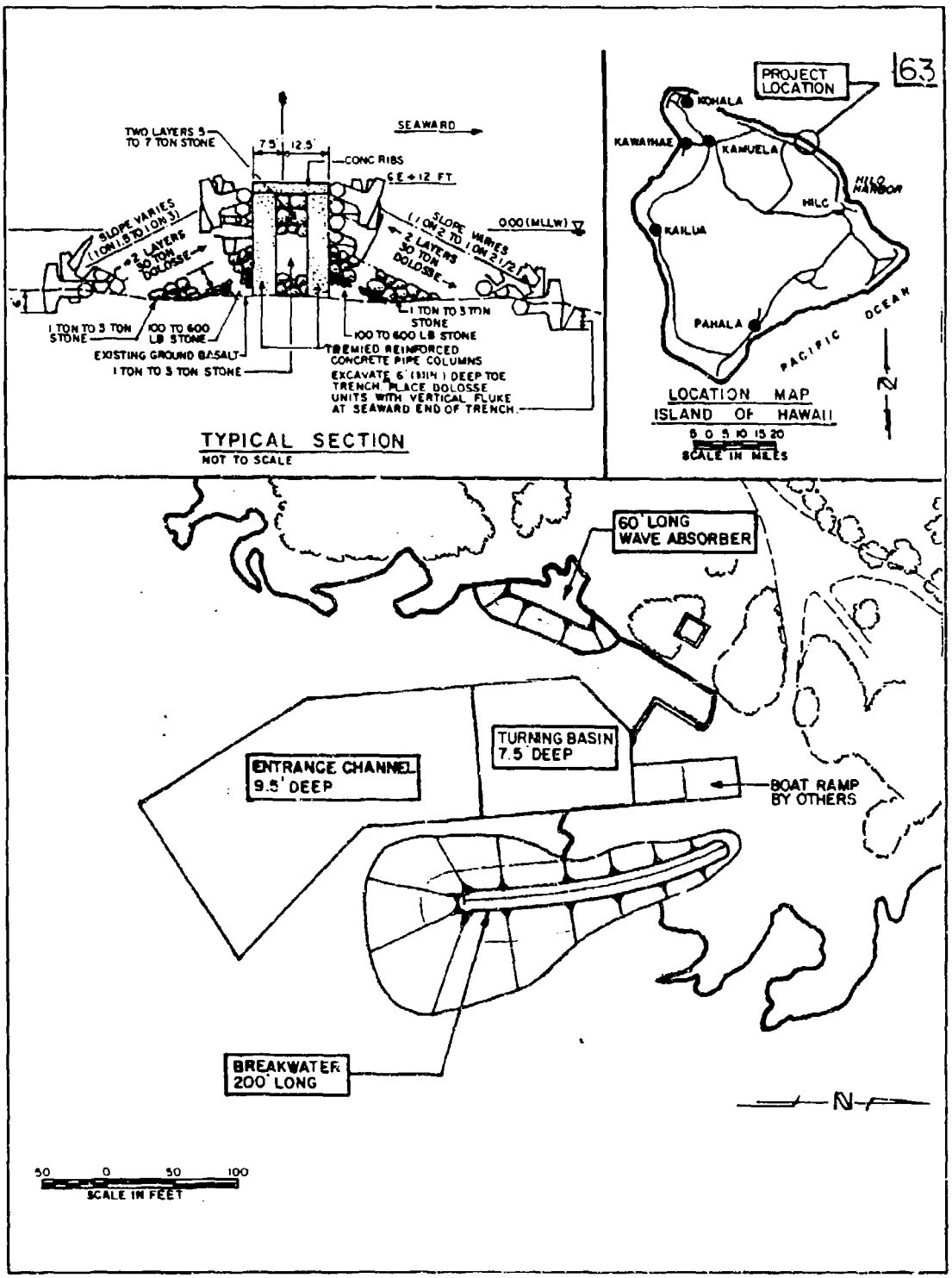


Figure 7. Detail plan layout and breakwater cross section for Laupahoehoe Boat Launching Facility

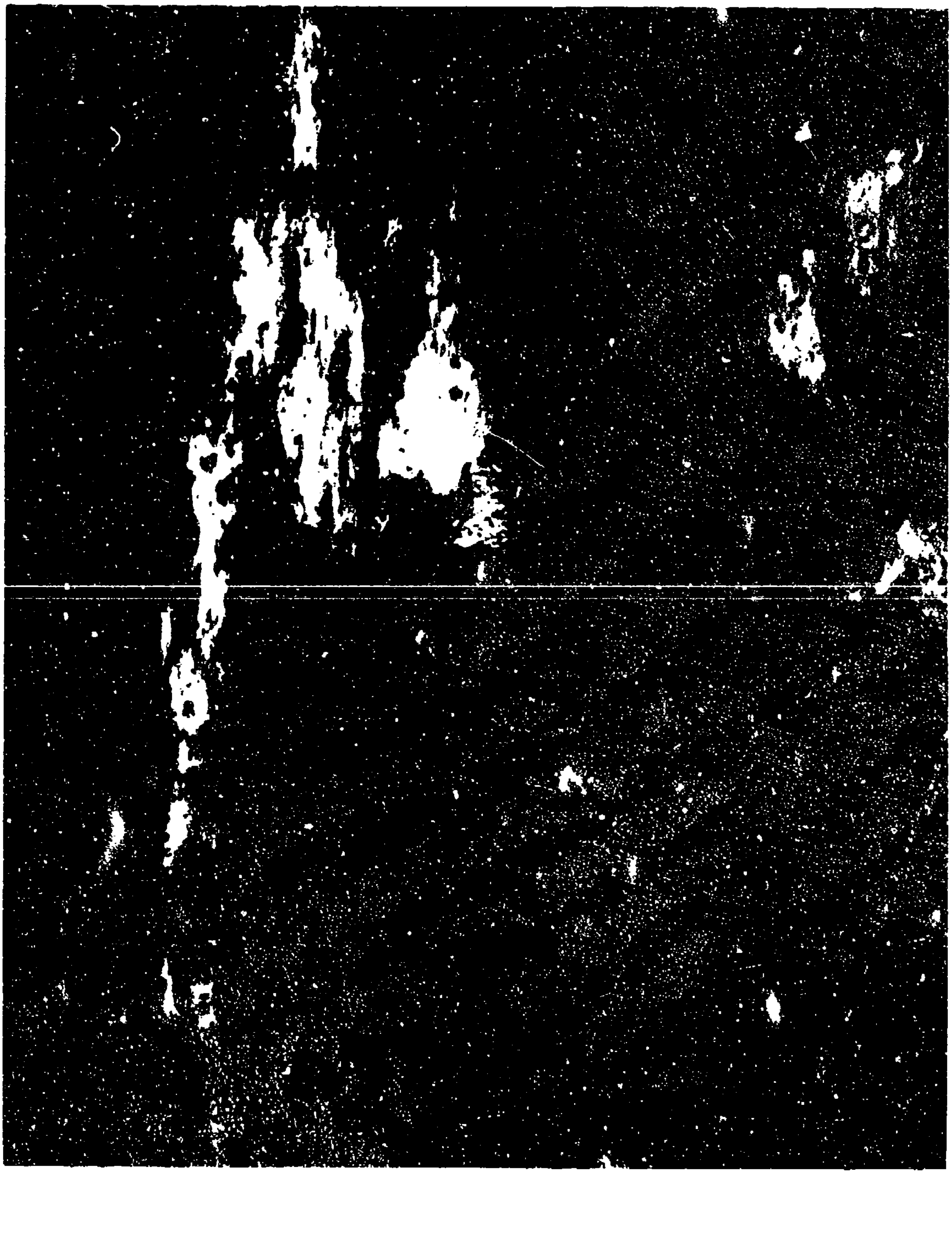


Figure 8. Aerial view of Laupahoehoe Boat Launching Facility

The Problem

As reviewed earlier in this report, the east and west breakwaters at Kahului Harbor have undergone many repairs since the U.S. Army Corps of Engineers became involved with the project in 1913. Most of the repairs were only marginally successful before a unique breakwater capping method, referred to as a concrete rib cap, was developed and tested on the prototype structures. The ribs increase crest stability, reduce wave overtopping, provide buttressing for crest armor units, allow ease of access for maintenance, and are less reflective than solid concrete caps. Initially, rib caps were cast first, with subsequent placement of the armor units. During construction, it was discovered that it was difficult not to leave a gap between the armor units and rib cap on the upper sea-side slope. This procedure was later reversed (armor units are placed first and then the rib caps are formed and cast in place) in order to try to achieve better armor unit buttressing. Periodic photogrammetric surveys of the Kahului breakwaters will aid in understanding the long-term performance of the rib caps and their stabilizing effects on the armor units and the breakwaters as a whole. They also will give a basis for comparing the stability of areas which used different construction procedures.

The 250-ft-long dolos armored breakwater constructed at the Laupahoehoe Boat Launching Facility also utilized a concrete rib cap. Due to the interior geometry of the structure, cylindrical reinforced concrete pipes were stood on end and backfilled to provide a stable support for the rib cap. The structure also used a unique toe entrenchment technique to assist in stabilizing the toe to the 30-ton dolosse on the hard basaltic bottom. These unique design features appear to the eye to be performing well structurally, and periodic photogrammetric surveys will provide a basis for a long-term structural assessment of the project and its possible application at other sites. This fits well with the Periodic Inspections' hypothesis that "Periodic remote inspections can provide long-term response data."

Purposes

The purposes of the study reported herein were:

a. To develop methods using limited land-based surveying, aerial photography, and photogrammetric analysis to assess long-term stability response of armor unit layers and concrete rib caps on the Kahului and Laupahoehoe breakwaters.

b. To conduct initial land surveys, armor unit breakage inspections, aerial photography, and photogrammetric analyses to (1) test and improve developed methodologies and accurately define armor unit movement over the entire above-water armor unit fields, and (2) set base conditions for breakwater armor units and rib caps, which can be used as controls when the structures are revisited in the future under the Periodic Inspections work unit.

2 Monitoring Plan and Data

Armor Unit Targeting and Ground Surveys

Monuments for both horizontal and vertical reference were established on land and on the caps of the breakwaters to serve as control points for the land-based survey work as well as the photogrammetric work. Targets were established on the concrete armor units to serve as a control to check the accuracy of the photogrammetric work. Ten, ten, and five concrete armor units dispersed over the sea sides and lee sides of the East and West Kahului breakwaters and the Laupahoehoe breakwater, respectively, were targeted and surveyed. A mixture of sizes and types of armor units were targeted (Table 1). Three targets were placed on each concrete armor unit. Target locations were selected to maximize their visibility in aerial photography and to allow for accurate representation of armor unit movement. Each circular target is separated into four, 90-deg quadrants. Adjacent quadrants were painted highly contrasting colors, and opposing quadrants were painted the same color. This style target provides a precise center point at which measurements can be made by both land surveys and photogrammetric work. To minimize the need for repainting targets, an epoxy-based marine paint is recommended. Each target was labeled with a unique pair of alphanumeric characters. The alpha characters identify the unit and the breakwater on which it resides, and the numeric characters identify the target on the armor unit. For example, armor unit "KEA" indicates a unit on the Kahului East breakwater that is unit A of 10 units A through J targeted on Kahului east, which has three targets labeled KEA-1, KEA-2, and KEA-3 (Figure 9). Figures 10-14 show the locations of all targeted units on the Kahului and Laupahoehoe breakwaters.

The targets on the concrete armor units had their positions surveyed in September 1991 and October 1992. The first survey work, along with initial targeting, was conducted by POD's surveying branch, while the later surveying was completed by R.M. Towill Corporation. Results of these surveys are shown in Tables 2-4 and field survey maps are on file at WES. Measured x, y, and z coordinates for each survey are reported along with the relative change that occurred in each coordinate between the two surveys and the vector magnitude of change detected. The horizontal datum is based on

Figure 9. Details of armor unit targeting

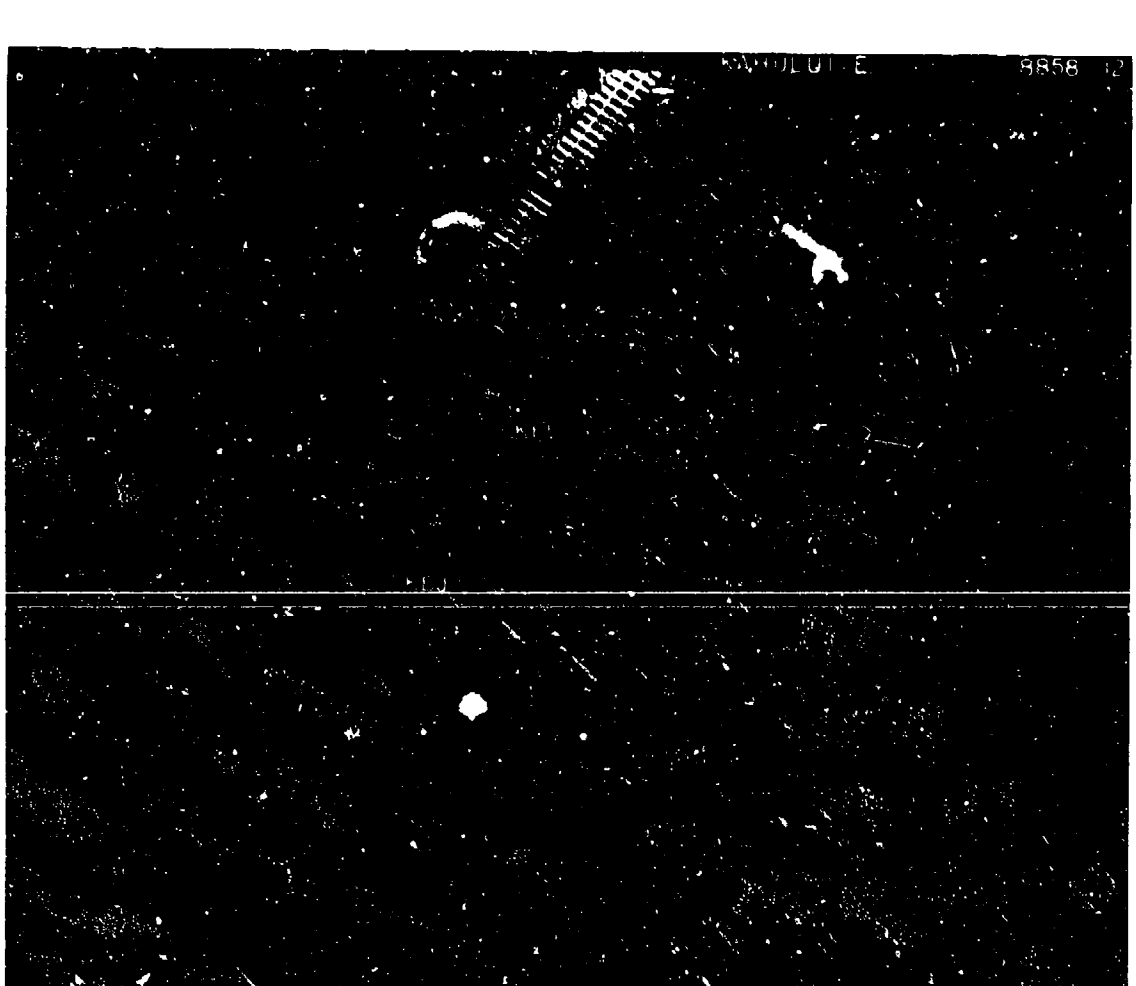


Figure 10. Targeted armor unit locations on shoreward end of Kahului East breakwater

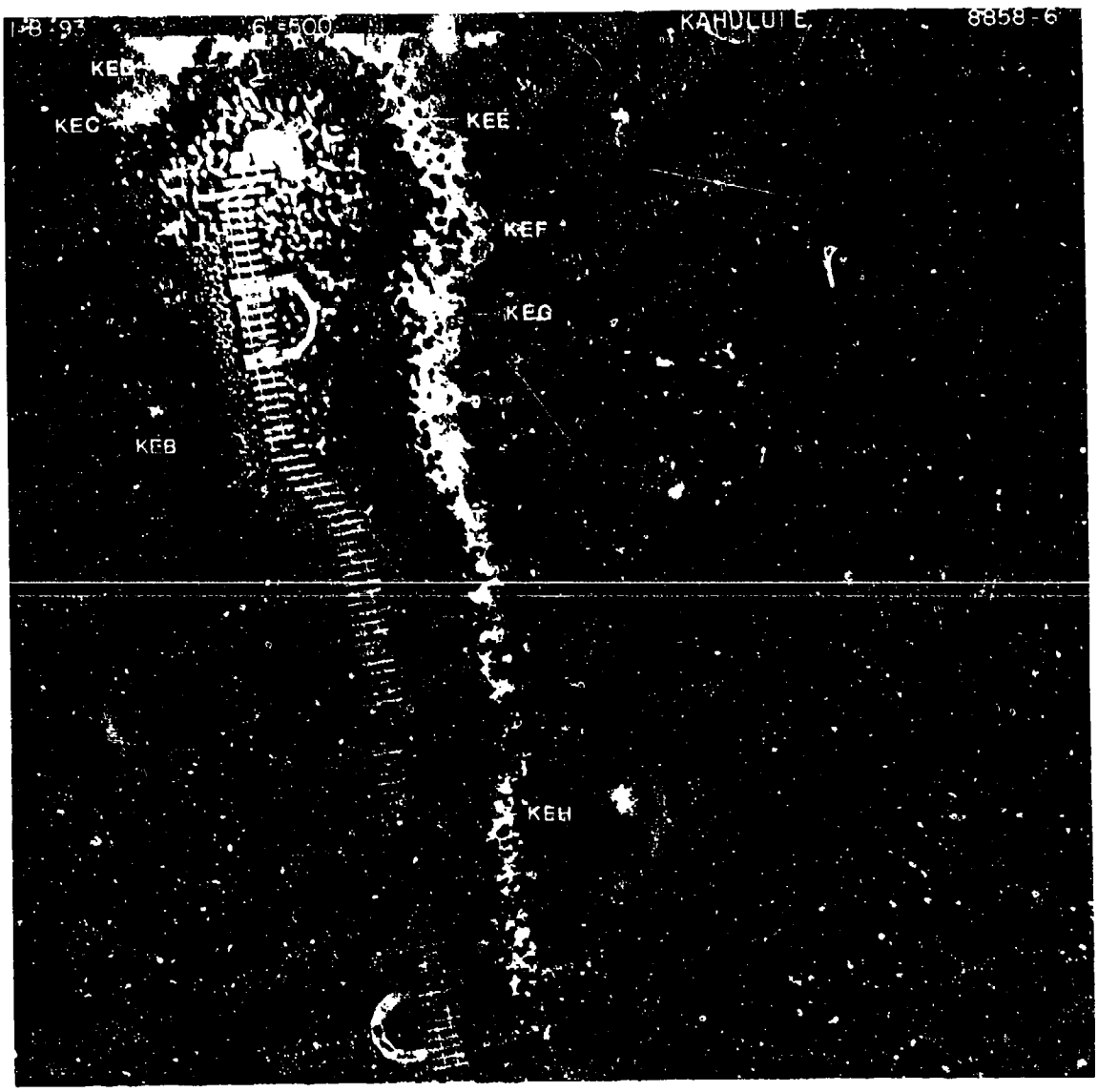


Figure 11. Targeted armor unit locations on seaward end of Kahului East breakwater

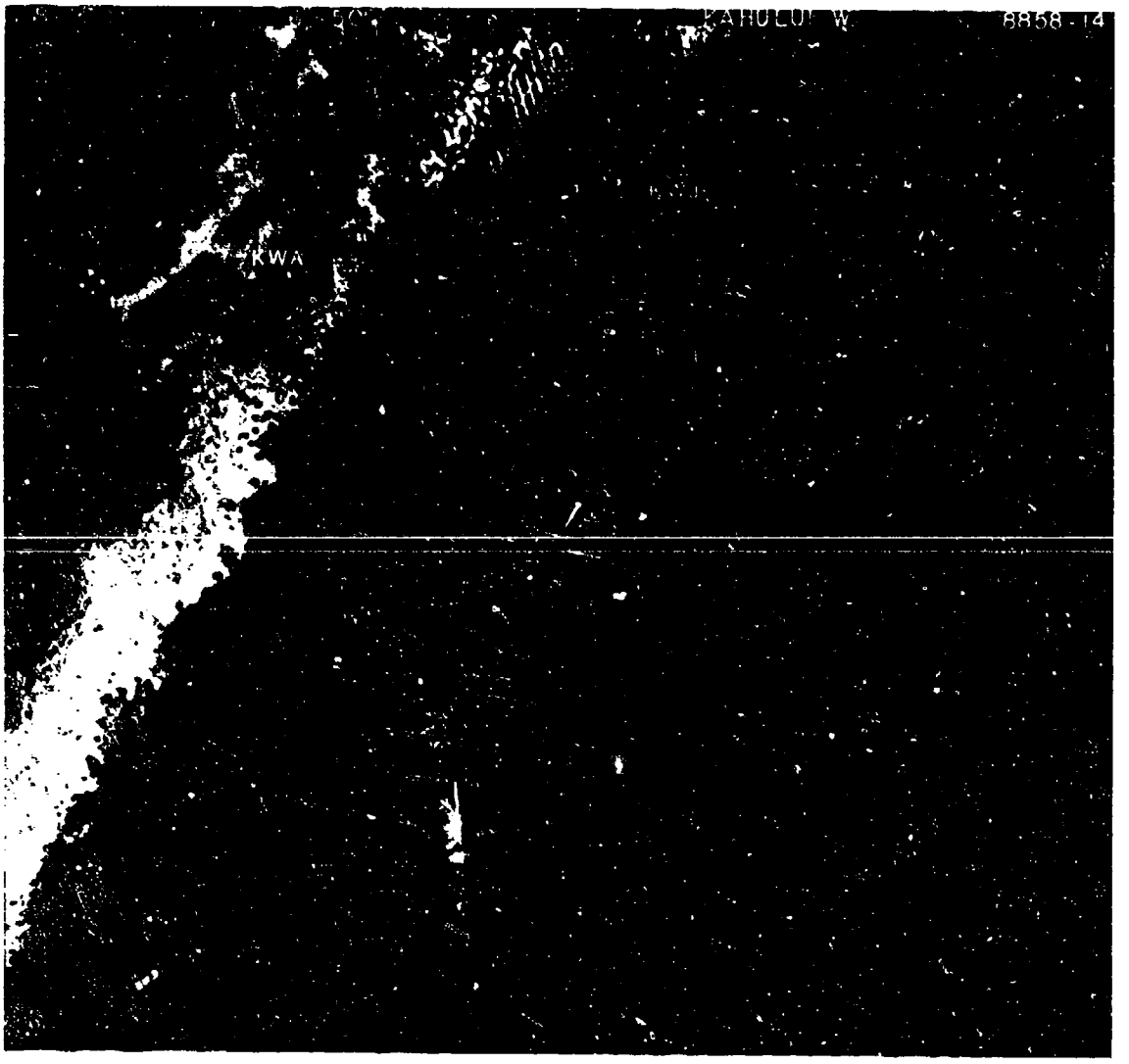


Figure 12. Targeted armor unit locations on shoreward end of Kahului West breakwater

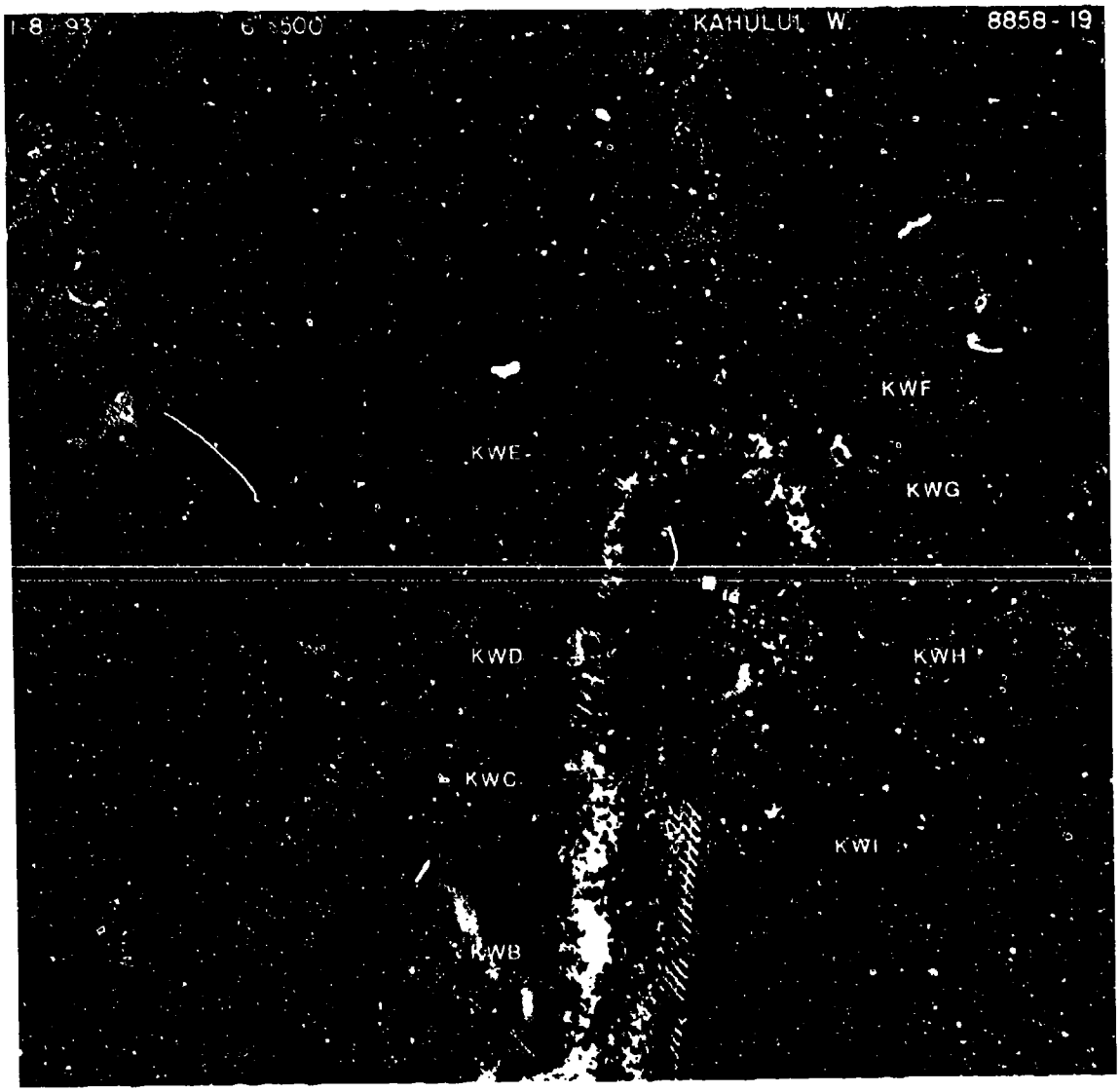


Figure 13. Targeted armor unit locations on seaward end of Kahului West breakwater

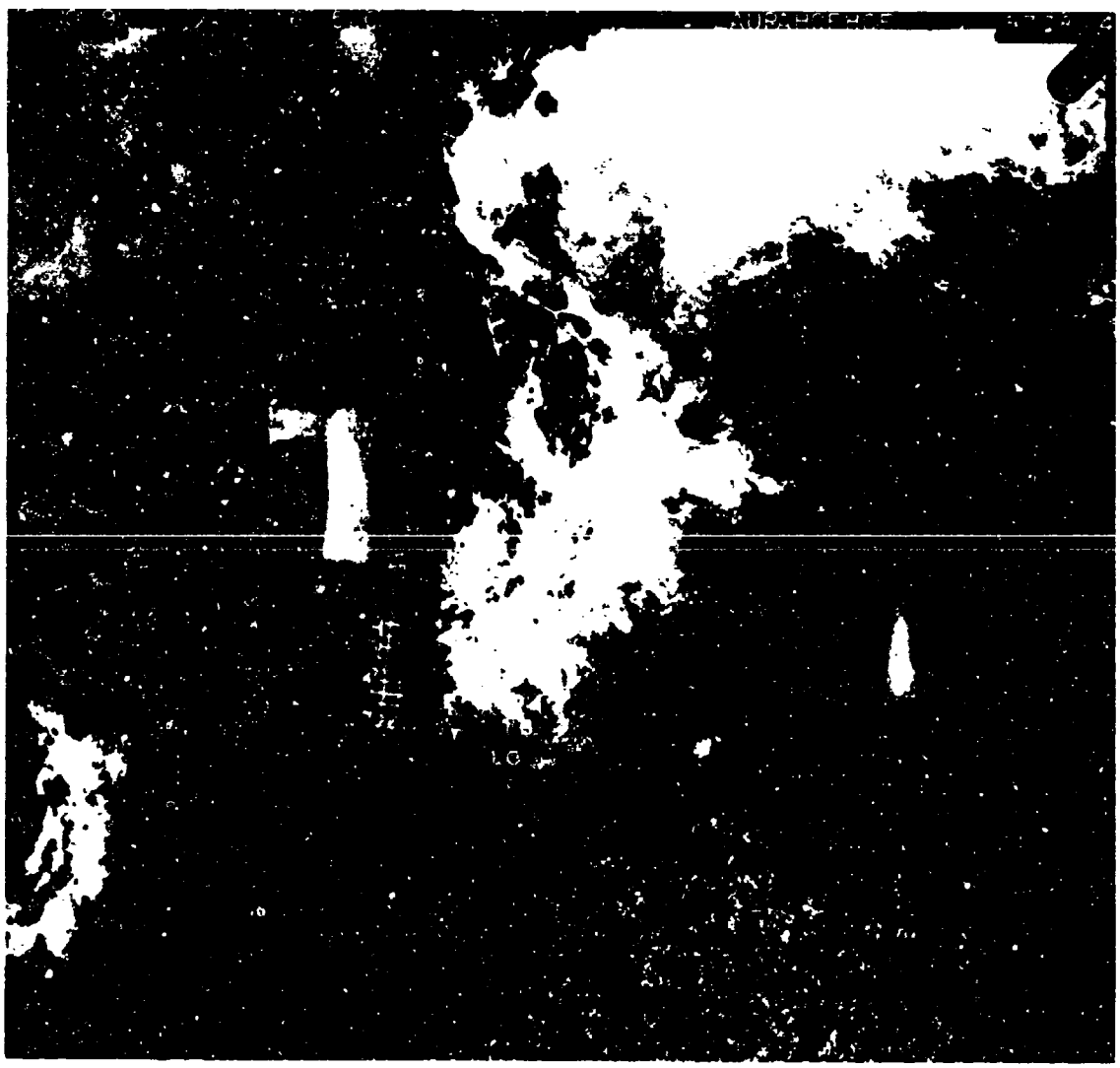


Figure 14. Targeted armor unit locations on Laupahoehoe breakwater

the Hawaii State Plane Coordinate System, Zone 1, and elevations are relative to mllw.

Table 1
Kahului and Laupahoehoe Breakwaters, Description of Targeted Armor Units

Location	Unit	Description
Kahului East	KEA	9-ton tribar
	KEB	9-ton tribar
	KEC	35-ton tribar
	KED	30-ton dolos
	KEE	30-ton dolos
	KEF	35-ton tribar
	KEG	35-ton tribar
	KEH	30-ton dolos
	KEI	30-ton dolos
	KEJ	9-ton dolos
Kahului West	KWA	11-ton tribar
	KWB	35-ton tribar
	KWC	30-ton dolos
	KWD	30-ton dolos
	KWE	30-ton dolos
	KEF	30-ton dolos
	KWG	35-ton tribar
	KWH	30-ton dolos
	KWI	6.5-ton tribar
	KWJ	6.5-ton tribar
Laupahoehoe	LA	30-ton dolos
	LB	30-ton dolos
	LC	30-ton dolos
	LD	30-ton dolos
	LE	30-ton dolos

The purpose for armor unit targeting and conducting ground surveys of the targets was to generate a set of control data by which the accuracy of the photogrammetric survey work could be validated and defined. A discussion and presentation of the photogrammetric surveying data for the armor unit targets and a comparison to the ground survey data can be found later in this report.

Table 2
Dolosse Target Movement Record from Ground Surveys
Laupahoehoe, Hawaii

Horizontal Datum: Hawaii State Plane Coordinate System, Zone 1

Agency	Date	Survey	Northing (Y) Feet	Easting (X) Feet	Elevations (El) Feet	Relative Movement (YXZ + Vector)			
						Y	X	Z	Vector
Target: LA1									
USCOE	09-10-91	Ground	421,935.29	588,382.70	11.86				
RMTC	10-12-92	Ground	421,935.29	588,382.59	11.88	0.00	(0.01)	0.02	0.02
Target: LA2									
USCOE	09-10-91	Ground	421,928.98	588,392.94	15.28				
RMTC	10-12-92	Ground	421,928.98	588,392.94	15.30	0.00	0.00	(0.02)	0.02
Target: LA3									
USCOE	09-10-91	Ground	421,922.73	588,383.32	10.46				
RMTC	10-12-92	Ground	421,922.74	588,383.31	10.50	0.01	(0.01)	0.04	0.04
Target: LD1									
USCOE	09-10-91	Ground	421,851.87	588,354.79	5.57				
RMTC	10-12-92	Ground	421,851.85	588,354.83	5.63	(0.02)	0.04	0.06	0.07
Target: LD2									
USCOE	09-10-91	Ground	421,844.90	588,361.96	13.05				
RMTC	10-12-92	Ground	421,844.90	588,361.96	13.09	0.00	0.00	0.04	0.04
Target: LD3									
USCOE	09-10-91	Ground	421,840.32	588,351.09	9.06				
RMTC	10-12-92	Ground	421,840.28	588,351.11	9.11	(0.04)	0.02	0.05	0.07
Target: LE1									
USCOE	09-10-91	Ground	421,894.16	588,362.42	8.17				
RMTC	10-12-92	Ground	421,894.16	588,362.43	8.20	0.00	0.01	0.03	0.03
Target: LE2									
USCOE	09-10-91	Ground	421,881.52	588,362.28	8.74				
RMTC	10-12-92	Ground	421,881.53	588,362.3[illegible]	8.79	0.01	0.02	0.05	0.05
Target: LE3									
USCOE	09-10-91	Ground	421,888.09	588,352.28	12.13				
RMTC	10-12-92	Ground	421,888.11	588,352.30	12.17	0.02	0.02	0.04	0.05
Target: LC1									
USCOE	09-10-91	Ground	421,862.44	588,389.72	5.52				
RMTC	10-12-92	Ground	421,862.45	588,389.69	5.57	0.01	(0.03)	0.05	0.06
Target: LC2									
USCOE	09-10-91	Ground	421,858.26	588,399.48	11.89				
RMTC	10-12-92	Ground	421,858.25	588,399.49	11.92	(0.01)	0.01	0.03	0.03
Target: LC3									
USCOE	09-10-91	Ground	421,850.11	588,391.01	7.80				
RMTC	10-12-92	Ground	421,850.11	588,391.00	7.83	0.00	(0.01)	0.03	0.03
Target: LB1									
USCOE	09-10-91	Ground	421,884.25	588,392.29	10.59				
RMTC	10-12-92	Ground	421,884.25	588,392.32	10.63	0.00	0.03	0.04	0.05
Target: LB2									
USCOE	09-10-91	Ground	421,874.74	588,398.31	15.89				
RMTC	10-12-92	Ground	421,874.75	588,398.30	15.90	0.01	(0.01)	0.01	0.02
Target: LB3									
USCOE	09-10-91	Ground	421,872.66	588,387.30	10.48				
RMTC	10-12-92	Ground	421,872.65	588,388.30	10.51	(0.01)	0.00	0.04	0.04

Table 3
Dolosse Target Movement Record from Ground Surveys
Kahului-East, Maui, Hawaii

Horizontal Datum: Hawaii State Plane Coordinate System, Zone 1

Agency	Date	Survey	Northing (Y) Feet	Easting (X) Feet	Elevations (Ft) Feet	Relative Movement (YXZ + Vector)			
						Y	X	Z	Vector
Target: KEC1									
USCOE		Ground	207,201.71	565,596.78	7.80				
RMTC	10-06-92	Ground	207,201.72	565,596.80	7.82	0.01	0.02	0.02	0.03
Target: KEC2									
USCOE		Ground	207,210.32	565,592.15	10.54				
RMTC	10-06-92	Ground	207,210.33	565,592.18	10.56	0.01	0.03	0.02	0.04
Target: KEC3									
USCOE		Ground	207,209.51	565,602.21	11.01				
RMTC	10-06-92	Ground	207,209.53	565,602.26	11.02	(0.02)	0.05	0.01	0.05
Target: KED1									
USCOE		Ground	207,271.81	565,609.22	18.06				
RMTC	10-06-92	Ground	207,271.81	565,609.24	18.05	0.00	0.02	(0.01)	0.02
Target: KED2									
USCOE		Ground	207,272.69	565,621.02	14.20				
RMTC	10-06-92	Ground	207,272.69	565,621.04	14.20	0.00	0.02	0.00	0.02
Target: KED3									
USCOE		Ground	207,262.35	565,614.44	11.90				
RMTC	10-06-92	Ground	207,262.34	565,614.46	11.90	0.00	0.02	0.00	0.02
Target: KEE1									
USCOE		Ground	207,298.90	565,669.83	13.83				
RMTC	10-06-92	Ground	207,298.90	565,669.82	13.82	0.00	(0.01)	0.01	0.01
Target: KEE2									
USCOE		Ground	207,297.91	565,681.96	16.37				
RMTC	10-06-92	Ground	207,297.88	565,681.95	16.34	(0.03)	(0.01)	0.03	0.04
Target: KEE3									
USCOE		Ground	207,287.86	565,675.75	12.23				
RMTC	10-06-92	Ground	207,287.85	565,675.74	12.20	(0.01)	(0.01)	0.03	0.03
Target: KEF1									
USCOE		Ground	207,265.53	565,722.83	13.70				
RMTC	10-06-92	Ground	207,265.53	565,722.81	13.66	0.00	(0.02)	0.04	0.04
Target: KEF2									
USCOE		Ground	207,271.71	565,732.35	8.51				
RMTC	10-06-92	Ground	207,271.71	565,732.33	8.51	0.00	(0.02)	0.00	0.02
Target: KEF3									
USCOE		Ground	207,259.12	565,732.54	9.31				
RMTC	10-06-92	Ground	207,259.11	565,732.51	9.30	0.01	(0.03)	0.01	0.03
Target: KEG1									
USCOE		Ground	207,221.10	565,749.84	9.73				
RMTC	10-06-92	Ground	207,222.10	565,749.79	9.73	0.00	(0.05)	0.00	0.05
Target: KEG2									
USCOE		Ground	207,228.84	565,755.53	10.62				
RMTC	10-06-92	Ground	207,228.84	565,755.48	10.61	0.00	(0.05)	0.01	0.05
Target: KEG3									
USCOE		Ground	207,220.56	565,758.51	9.33				
RMTC	10-06-92	Ground	207,220.58	565,758.48	9.31	0.02	(0.03)	0.02	0.04

(Continued)

Table 3 (Concluded)

Horizontal Datum: Hawaii State Plane Coordinate System, Zone 1

Agency	Date	Survey	Northing (Y) Feet	Easting (X) Feet	Elevations (Ft) Feet	Relative Movement (YXZ + Vector)			
						Y	X	Z	Vector
Target KEB1									
USCOE		Ground	207,112.98	565,756.80	6.41				
RMTC	10-06-92	Ground	207,112.95	565,756.81	6.44	(0.03)	0.01	0.03	0.04
Target KEB2									
USCOE		Ground	207,107.60	565,755.54	4.66				
RMTC	10-06-92	Ground	207,107.57	565,755.55	4.68	(0.03)	0.01	0.02	0.04
Target KEB3									
USCOE		Ground	207,111.69	565,751.39	4.77				
RMTC	10-06-92	Ground	207,111.65	565,751.39	4.80	(0.04)	0.00	0.03	0.05
Target KEH1									
USCOE		Ground	207,058.40	565,995.97	15.93				
RMTC	10-06-92	Ground	207,058.39	565,995.95	15.98	(0.01)	(0.02)	0.05	0.05
Target KEH2									
USCOE		Ground	207,065.20	566,066.10	17.95				
RMTC	10-06-92	Ground	207,065.18	566,066.09	18.00	(0.02)	(0.01)	0.05	0.05
Target KEH3									
USCOE		Ground	207,053.09	566,007.42	15.23				
RMTC	10-06-92	Ground	207,053.08	566,007.36	15.26	0.01	(0.06)	0.03	0.07
Target KEA1									
USCOE		Ground	206,888.65	566,164.10	5.32				
RMTC	10-06-92	Ground	206,888.63	566,164.13	5.42	(0.02)	0.03	0.10	0.11
Target KEA2									
USCOE		Ground	206,885.59	566,168.95	5.44				
RMTC	10-06-92	Ground	206,885.58	566,168.99	5.47	(0.01)	0.04	0.03	0.05
Target KEA3									
USCOE		Ground	206,882.93	566,163.89	4.53				
RMTC	10-06-92	Ground	206,882.91	566,163.92	4.58	(0.02)	0.03	0.05	0.06
Target KEI1									
USCOE		Ground	206,939.66	566,179.90	11.67				
RMTC	10-06-92	Ground	206,939.62	566,179.93	11.68	(0.04)	0.03	0.01	0.05
Target KEI2									
USCOE		Ground	206,945.20	566,187.63	17.08				
RMTC	10-06-92	Ground	206,945.24	566,187.48	17.12	0.04	(0.15)	0.04	0.16
Target KEI3									
USCOE		Ground	206,934.69	566,188.89	15.40				
RMTC	10-06-92	Ground	206,934.64	566,188.93	15.45	0.05	0.04	0.05	0.08
Target KEJ1									
USCOE		Ground	206,883.12	566,270.52	9.47				
RMTC	10-06-92	Ground	206,883.08	566,270.53	9.50	(0.04)	0.01	0.03	0.05
Target KEJ2									
USCOE		Ground	206,887.47	566,275.84	8.00				
RMTC	10-06-92	Ground	206,887.45	566,275.76	8.04	0.02	(0.18)	0.04	0.19
Target KEJ3									
USCOE		Ground	206,882.00	566,277.04	12.64				
RMTC	10-06-92	Ground	206,881.97	566,276.98	12.64	(0.03)	(0.06)	0.00	0.07

Table 4
Dolosse Target Movement Record from Ground Surveys
Kahului-West, Maui, Hawaii

Horizontal Datum: Hawaii State Plane Coordinate System, Zone 1

Agency	Date	Survey	Northing (Y) Feet	Easting (X) Feet	Elevations (Ft) Feet	Relative Movement (YXZ + Vector)			
						Y	X	Z	Vector
TARGET: KWA1									
USCOE		Ground	206,990 71	564,375 09	8 54				
RMTC	10-05-92	Ground	206,990.72	564,375 08	8 64	0.01	(0 01)	0 10	0 10
TARGET: KWA2									
USCOE		Ground	206,986 89	564,378 34	12 16				
RMTC	10-05-92	Ground	206,986 89	564,378 32	12 27	0 00	(0.02)	0 11	0.11
TARGET: KWA3									
USCOE		Ground	206,985 46	564,372.57	10 48				
RMTC	10-05-92	Ground	206,985.46	564,372 58	10 57	0 00	0 01	0.11	0 11
TARGET: KWB1									
USCOE		Ground	207,060 20	564,486 30	7 75				
RMTC	10-05-92	Ground	207,060 21	564,486 35	7 78	0.01	0 05	0 03	0.06
TARGET: KWB2									
USCOE		Ground	207,064 88	564,491 58	9 29				
RMTC	10-05-92	Ground	207,064.92	564,491 63	9 34	0.04	0 05	0.05	0 08
TARGET: KWB3									
USCOE		Ground	207,058 08	564,493 29	7 36				
RMTC	10-05-92	Ground	207,058 11	564,493 31	7.40	0.03	0 02	0 04	0.05
TARGET: KWC1									
USCOE		Ground	207,111 52	564,614 45	10 85				
RMTC	10-05-92	Ground	207,111.52	564,614 46	10 87	0 00	0 01	0 02	0 02
TARGET: KWC2									
USCOE		Ground	207,105 09	564,607 87	16 72				
RMTC	10-05-92	Ground	207,105 09	564,607 87	16 76	0.00	0 00	0 04	0 04
TARGET: KWC3									
USCOE		Ground	207,114 05	564,603 88	12 12				
RMTC	10-05-92	Ground	207,114 07	564,603 88	12 15	0 02	0 00	0 03	0 04
TARGET: KWD1									
USCOE		Ground	207,141 40	564,698 16	11 72				
RMTC	10-05-92	Ground	207,141 56	564,698 20	11 76	0 16	0 04	0 04	0 17
TARGET: KWD2									
USCOE		Ground	207,153 46	564,694 05	12 78				
RMTC	10-05-92	Ground	207,153 47	564,694 05	12 82	0 01	0 00	0 10	0 10
TARGET: KWD3									
USCOE		Ground	207,144 07	564,687 20	17 00				
RMTC	10-05-92	Ground	207,144 06	564,687 21	17 03	(0 01)	0 01	0 03	0 03
TARGET: KWE1									
USCOE		Ground	207,173 46	564,787 93	14 09				
RMTC	10-05-92	Ground	207,173 41	564,787 94	14 12	(0 05)	0 01	0 03	0 06
TARGET: KWE2									
USCOE		Ground	207,185 57	564,789 00	11 71				
RMTC	10-05-92	Ground	207,185 55	564,788 98	11 74	(0 02)	(0 02)	0 03	0 04
TARGET: KWE3									
USCOE		Ground	207,180 11	564,777 62	12 13				
RMTC	10-05-92	Ground	207,180 06	564,777 63	12 16	(0 05)	0 01	0 03	0 06

(Continued)

Table 4 (Concluded)

Horizontal Datum: Hawaii State Plane Coordinate System, Zone 1

Agency	Date	Survey	Northing (Y) Feet	Easting (X) Feet	Elevations (Fl) Feet	Relative Movement (YXZ + Vector)			
						Y	X	Z	Vector
TARGET KWF1									
USCOE		Ground	207,148 76	564,803 96	13 18				
RMTC	10-05-92	Ground	207,148 72	564,803 93	13 21	(0 04)	(0 03)	0 03	0 06
TARGET KWF2									
USCOE		Ground	207,150 11	564,816 13	10 13				
RMTC	10-05-92	Ground	207,150 11	564,816 12	10 14	0 00	(0 01)	0 01	0 01
TARGET KWF3									
USCOE		Ground	207,158 17	564,810 55	17 88				
RMTC	10-05-92	Ground	207,158 11	564,810 55	17 91	(0 06)	0 00	0 03	0 07
TARGET KWG1									
USCOE		Ground	207,100 46	564,795 79	11 10				
RMTC	10-05-92	Ground	207,100 45	564,795 77	11 12	(0 01)	(0 02)	0 02	0 03
TARGET KWG2									
USCOE		Ground	207,098 28	564,805 42	9 26				
RMTC	10-05-92	Ground	207,098 26	564,805 40	9 28	0 00	(0 02)	0 02	0 03
TARGET KWG3									
USCOE		Ground	207,107 84	564,802 60	10 68				
RMTC	10-05-92	Ground	207,107 84	564,802 56	10 68	0 00	(0 04)	0 00	0 04
TARGET KWH1									
USCOE		Ground	207,044 63	564,753 76	9 54				
RMTC	10-05-92	Ground	207,044 63	564,753 76	9 57	0 00	0 00	0 00	0 00
TARGET KWH2									
USCOE		Ground	207,035 80	564,744 59	9 03				
RMTC	10-05-92	Ground	207,035 81	564,744 70	9 07	0 01	0 01	0 04	0 04
TARGET KWH3									
USCOE		Ground	207,032 94	564,756 16	12 87				
RMTC	10-05-92	Ground	207,032 94	564,756 14	12 89	0 00	(0 02)	0 02	0 03
TARGET KWI1									
USCOE		Ground	207,032 85	564,592 43	8 05				
RMTC	10-05-92	Ground	207,032 84	564,592 52	8 12	(0 01)	0 09	0 07	0 11
TARGET KWI2									
USCOE		Ground	207,031 22	564,597 29	6 76				
RMTC	10-05-92	Ground	207,031 29	564,597 35	6 77	0 07	0 06	0 01	0 09
TARGET KWI3									
USCOE		Ground	207,028 07	564,593 19	6 03				
RMTC	10-05-92	Ground	207,028 06	564,593 25	6 10	(0 01)	0 06	0 07	0 09
TARGET KWJ1									
USCOE		Ground	206,971 56	564,472 08	4 70				
RMTC	10-05-92	Ground	206,971 58	564,472 11	4 75	0 02	0 03	0 05	0 06
TARGET KWJ2									
USCOE		Ground	206,967 37	564,469 01	4 37				
RMTC	10-05-92	Ground	206,967 38	564,469 04	4 42	0 01	0 03	0 05	0 06
TARGET KWJ3									
USCOE		Ground	206,972 12	564,466 88	4 71				
RMTC	10-05 92	Ground	206,972 15	564,466 91	4 77	0 03	0 03	0 06	0 07

Aerial Photography

High-resolution stereo-pair, aerial photographs were obtained on two different occasions (Table 5) for each of the breakwaters from fixed-wing aircraft. At least four monuments were established for control of each stereo pair and these controls were verified or reestablished before each flight. Horizontal control was based on the Hawaii State Plane Coordinate System and elevations were referenced to mllw. Photographs were to be acquired with a combination of camera lens and airplane elevation that would result in negatives and contact prints with a minimum scale of 1 in. equal to 100 ft. As seen in Table 5, all photographs met or exceeded this requirement. The stereo pairs for one flight for each breakwater are shown in Figures 15-19.

Table 5
Listing of Stereo-Pair Aerial Photographs

Breakwater	Scale(s) of Negatives	Date of Photographs
Laupahoehoe	6 in = 500 ft	10 October 1991
Laupahoehoe	6 in = 500 ft	11 November 1992
Kahului West	6 in = 500 ft & 6 in = 400 ft	19 October 1991
Kahului West	6 in = 500 ft	8 January 1993
Kahului East	6 in = 600 ft	19 October 1991
Kahului East	6 in = 500 ft	8 January 1993

Photogrammetric Analysis of Armor Unit Targets

Stereo pairs were placed in a Wild Heerburg BC3 Analytical Stereoplotter and coordinates of the armor unit targets were read and recorded. These data are presented in Appendix A. For each target, the following information is listed: (a) date of flight, (b) survey type, (c) Northing, Easting, and Elevation coordinates, (d) relative change in coordinates since last aerial flight, and (e) cumulative change in coordinates since first aerial flight. In this case, since only two flights have been made, relative and cumulative values are the same. Data for Laupahoehoe are presented first, then East Kahului, and finally, West Kahului. The purpose of the photogrammetric analyses of the targets was to compare these data to data derived from ground survey work (Tables 2-4) to establish the accuracy of photogrammetric work and thus give validity to the detection methods that were used to ascertain armor unit movement on the breakwaters. Comparisons of the September 1991 ground survey data and the October 1992 aerial data are presented in Table 6 for East Kahului, West Kahului, and Laupahoehoe breakwaters. Plots of these data are

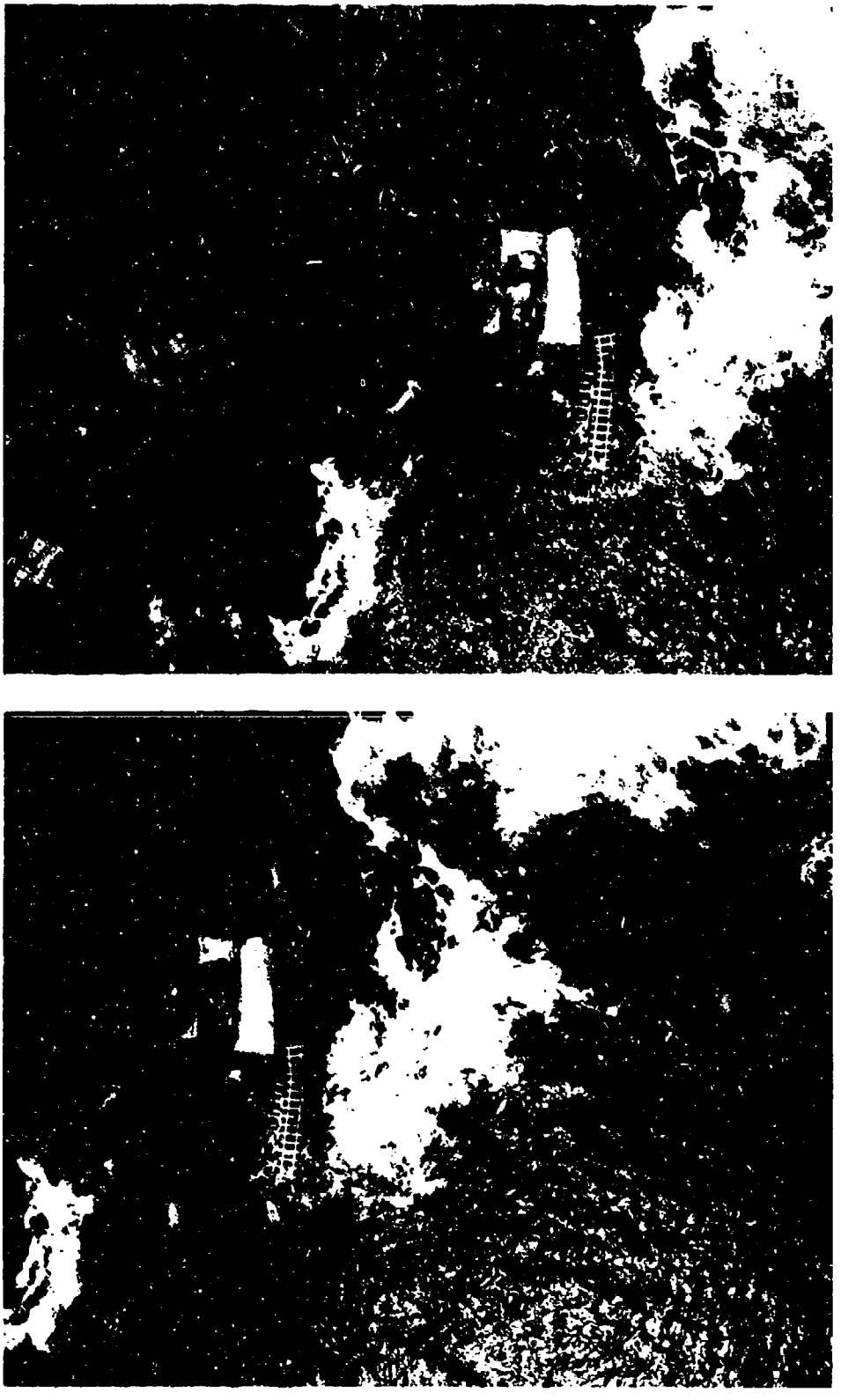


Figure 15. Stereo pair photographs of Laupahoehoe breakwater taken 10 October 1991

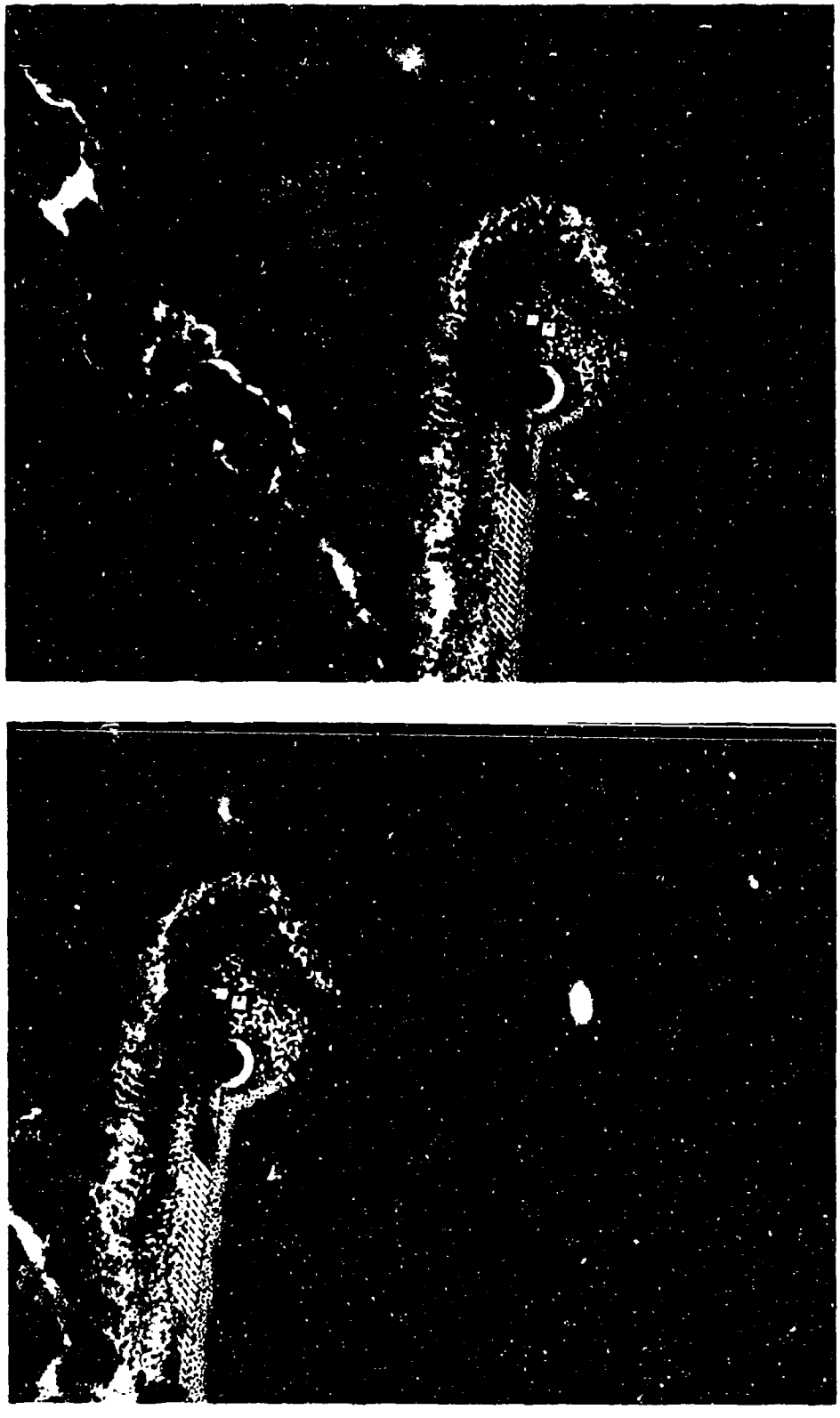


Figure 16. Stereo pair photographs of outer portion of Kahului West breakwater taken 8 January 1993

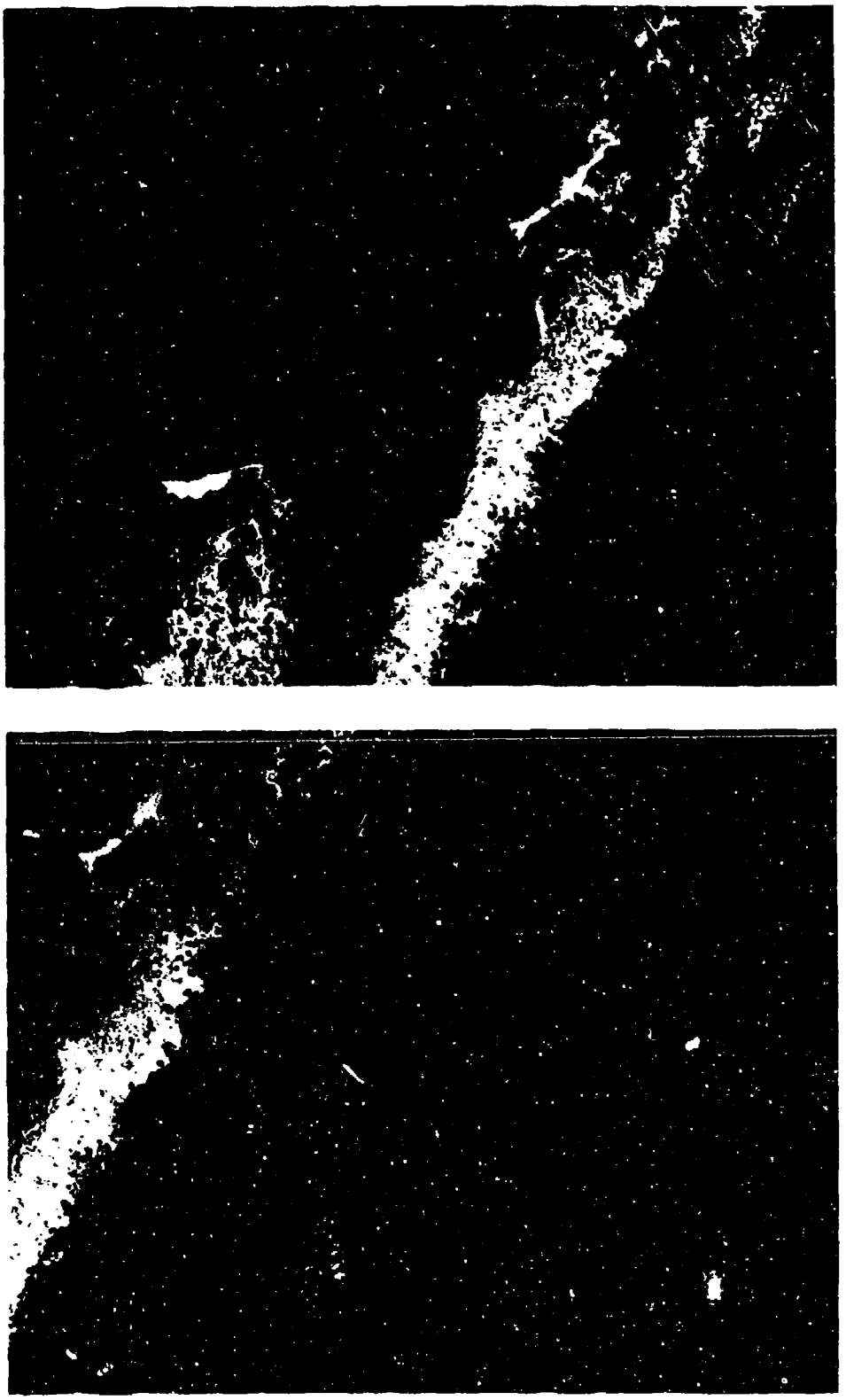


Figure 17. Stereo pair photographs of inner portion of Kahului West breakwater taken 8 January 1993

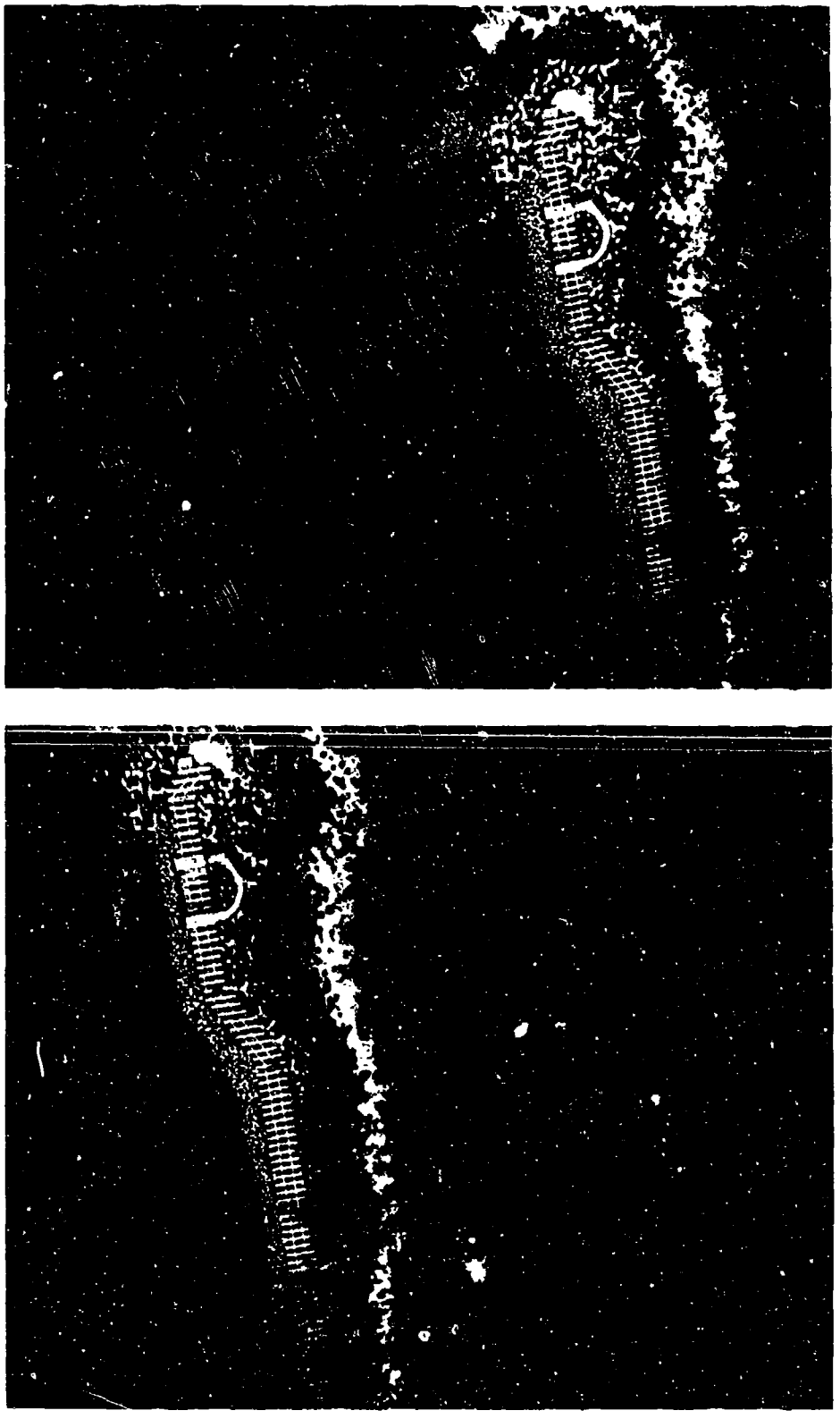


Figure 18. Stereo pair photographs of outer portion of Kahului West breakwater taken 8 January 1993

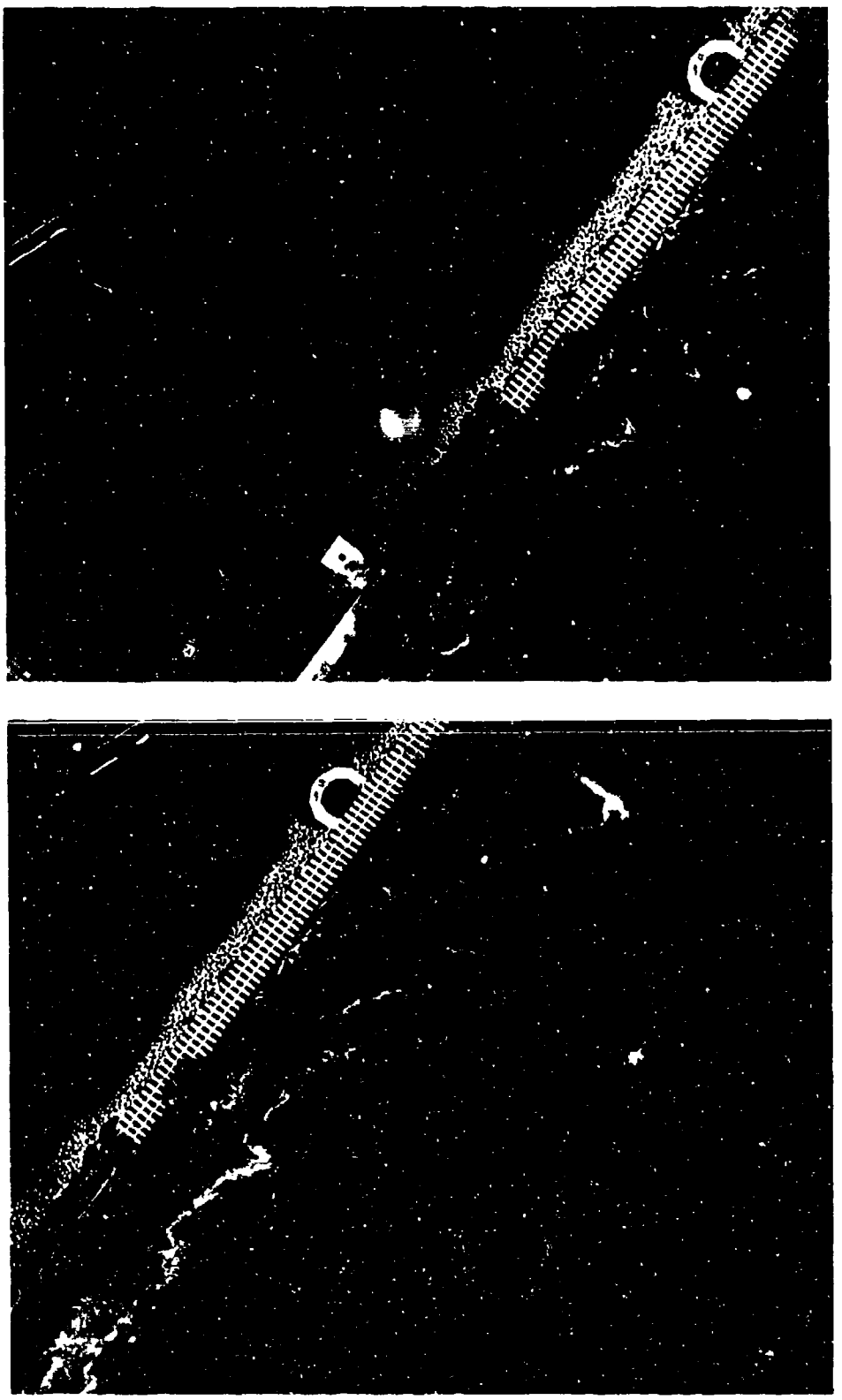


Figure 19. Stereo pair photographs of inner portion of Kahului West breakwater taken 8 January 1993

Table 6
Comparison of Ground and Aerial Surveys of Armor Unit Targets

TARGET ID	GROUND (SEP 1991) NORTH Ng	GROUND (SEP 1991) EAST Eg	GROUND (SEP 1991) ELEV ELg	AERIAL (OCT 1991) NORTH Na	AERIAL (OCT 1991) EAST Ea	AERIAL (OCT 1991) ELEV ELa	ABSOLUTE VALUE OF DIFFERENCE BETWEEN AERIAL AND GROUND SURVEYS Ng-Na	Eg-Ea	ELg-ELa
KAHULUI EAST BREAKWATER									
A1	206888.41	566164.46	5.30	206888.43	566164.38	5.27	0.02	0.08	0.03
A3	206882.68	566164.26	4.44	206882.66	566164.18	4.36	0.02	0.08	0.08
A2	206885.34	566169.32	5.35	206885.34	566169.28	5.27	0.00	0.04	0.08
B2	207107.54	565755.63	4.66	207107.46	565755.61	4.65	0.08	0.02	0.01
B3	207111.63	565751.48	4.77	207111.56	565751.41	4.79	0.07	0.07	0.02
B1	207112.89	565756.87	6.41	207112.85	565756.85	6.40	0.04	0.02	0.01
C2	207210.32	565592.15	10.54	207210.37	565592.01	10.46	0.05	0.14	0.08
C1	207201.71	565596.78	7.80	207201.73	565596.66	7.71	0.02	0.12	0.09
C3	207209.51	565602.21	11.01	207209.57	565602.11	10.93	0.06	0.10	0.08
D2	207272.89	565621.02	14.20	207272.99	565621.00	14.16	0.10	0.02	0.04
D3	207262.35	565614.44	11.90	207262.42	565614.33	11.74	0.07	0.11	0.16
D1	207271.81	565609.22	18.06	207271.93	565609.14	17.97	0.12	0.08	0.09
E1	207298.90	565669.82	13.75	207299.01	565669.83	13.81	0.11	0.01	0.06
E3	207287.86	565675.75	12.15	207287.88	565675.75	12.17	0.02	0.00	0.02
E2	207297.91	565681.96	16.28	207297.99	565681.97	16.32	0.08	0.01	0.04
F2	207271.71	565732.35	8.43	207271.72	565732.39	8.49	0.01	0.04	0.06
F3	207259.12	565732.54	9.22	207259.06	565732.56	9.30	0.06	0.02	0.08
F1	207265.54	565722.84	13.60	207265.60	565722.84	13.62	0.06	0.00	0.02
G1	207222.10	565749.85	9.64	207222.09	565749.87	9.70	0.01	0.02	0.06
G3	207220.56	565758.50	9.24	207220.55	565758.58	9.29	0.01	0.08	0.05
G2	207228.84	565755.52	10.53	207228.79	565755.58	10.60	0.05	0.06	0.07
H1	207058.23	565996.22	15.88	207058.21	565996.16	15.82	0.02	0.06	0.06
H3	207052.93	566007.66	15.18	207052.93	566007.63	15.13	0.00	0.03	0.05
H2	207065.03	566006.35	17.90	207065.04	566006.31	17.83	0.01	0.04	0.07
I3	206934.44	566189.26	15.31	206934.45	566189.22	15.34	0.01	0.04	0.03
I1	206939.42	566180.27	11.58	206939.43	566180.19	11.61	0.01	0.08	0.03
I2	206944.95	566188.00	16.99	206945.03	566187.77	17.04	0.08	0.23	0.05
J3	206881.75	566277.41	12.55	206881.75	566277.32	12.60	0.00	0.09	0.05
J2	206887.22	566276.21	7.91	206887.36	566276.09	7.95	0.14	0.12	0.04
J1	206882.87	566270.89	9.38	206882.88	566270.84	9.44	0.01	0.05	0.06

(Sheet 1 of 3)

Table 6 (Continued)

TARGET ID	GROUND (SEP 1991) NORTH Ng	EAST Eg	ELEV ELg	AERIAL (OCT 1991) NORTH Na	EAST Ea	ELEV ELa	ABSOLUTE VALUE OF DIFFERENCE BETWEEN AERIAL AND GROUND SURVEYS Ng-Na	Eg-Ea	ELg-ELa
				KAHULUI WEST BREAKWATER					
A1	206990.71	564375.09	8.54	206990.76	564375.09	8.53	0.05	0.00	0.01
A3	206985.46	564372.57	10.48	206985.48	564372.57	10.47	0.02	0.00	0.01
A2	206986.89	564378.34	12.16	206986.92	564378.34	12.12	0.03	0.00	0.04
B3	207058.08	564493.29	7.36	207058.02	564493.18	7.39	0.06	0.11	0.03
B1	207060.20	564486.30	7.75	207060.11	564486.21	7.75	0.09	0.09	0.00
B2	207064.88	564491.58	9.29	207064.83	564491.48	9.33	0.05	0.10	0.04
C2	207105.09	564607.87	16.72	207105.12	564607.89	16.75	0.03	0.02	0.03
C3	207114.05	564603.88	12.12	207114.09	564603.90	12.14	0.04	0.02	0.02
C1	207111.52	564614.45	10.85	207111.54	564614.50	10.80	0.02	0.05	0.05
D1	207141.40	564698.16	11.72	207141.57	564698.16	11.70	0.17	0.00	0.02
D2	207153.46	564694.05	12.78	207153.50	564694.02	12.75	0.04	0.03	0.03
D3	207144.07	564687.20	17.00	207144.10	564687.18	16.95	0.03	0.02	0.05
E1	207173.46	564787.93	14.09	207173.46	564787.89	14.12	0.00	0.04	0.03
E2	207185.57	564789.00	11.71	207185.60	564788.95	11.70	0.03	0.05	0.01
E3	207180.11	564777.62	12.13	207180.10	564777.56	12.12	0.01	0.06	0.01
F1	207148.76	564803.96	13.18	207148.73	564803.92	13.21	0.03	0.04	0.03
F2	207150.11	564816.13	10.13	207150.13	564816.13	10.16	0.02	0.00	0.03
F3	207158.17	564810.55	17.88	207158.16	564810.51	17.92	0.01	0.04	0.04
G1	207100.46	564795.79	11.10	207100.48	564795.78	11.13	0.02	0.01	0.03
G2	207098.28	564805.42	9.26	207098.30	564805.43	9.28	0.02	0.01	0.02
G3	207107.84	564802.60	10.68	207107.88	564802.58	10.74	0.04	0.02	0.06
H1	207044.63	564753.76	9.54	207044.61	564753.78	9.52	0.02	0.02	0.02
H2	207035.80	564744.69	9.03	207035.78	564744.66	9.01	0.02	0.03	0.02
H3	207032.94	564756.16	12.87	207032.92	564756.14	12.89	0.02	0.02	0.02
I	207031.22	564597.29	6.76						
I	207028.07	564593.19	6.03						
I	207032.85	564592.43	8.05						
J2	206967.37	564469.01	4.37	206967.35	564468.97	4.34	0.02	0.04	0.03
J3	206972.12	564466.88	4.71	206972.14	564466.89	4.70	0.02	0.01	0.01
J1	206971.56	564472.08	4.70	206971.55	564472.05	4.71	0.01	0.03	0.01

(Sheet 2 of 3)

Table 6 (Concluded)

TARGET ID	GROUND (SEP 1991) NORTH Ng	EAST Eg	ELEV ELg	AERIAL (OCT 1991) NORTH Na	EAST Ea	ELEV ELa	ABSOLUTE VALUE OF DIFFERENCE BETWEEN AERIAL AND GROUND SURVEYS Ng-Na	Eg-Ea	ELg-ELa
LAUPAHOEHOE BREAKWATER									
A1	421935.29	588382.70	11.86	421935.30	588382.69	11.86	0.01	0.01	0.00
A3	421922.73	588383.32	10.46	421922.73	588383.31	10.48	0.00	0.01	0.02
A2	421928.98	588392.94	15.28	421928.98	588392.93	15.30	0.00	0.01	0.02
B3	421872.66	588387.30	10.48	421872.67	588387.29	10.53	0.01	0.01	0.05
B1	421884.25	588392.29	10.59	421884.27	588392.28	10.62	0.02	0.01	0.03
B2	421874.74	588398.31	15.89	421874.77	588398.30	15.91	0.03	0.01	0.02
C3	421850.11	588391.01	7.80	421850.14	588390.99	7.83	0.03	0.02	0.03
C1	421862.44	588389.72	5.52	421862.53	588389.72	5.52	0.09	0.00	0.00
C2	421858.26	588399.48	11.89	421858.28	588399.46	11.93	0.02	0.02	0.04
D3	421840.32	588351.09	9.06	421840.32	588351.09	9.09	0.00	0.00	0.03
D1	421851.87	588354.79	5.57	421851.88	588354.78	5.61	0.01	0.01	0.04
D2	421844.90	588361.96	13.05	421844.93	588361.97	13.06	0.03	0.01	0.01
E1	421894.16	588362.42	8.17	421894.18	588362.41	8.19	0.02	0.01	0.02
E2	421881.52	588362.28	8.74	421881.53	588362.27	8.77	0.01	0.01	0.03
E3	421888.09	588352.28	12.13	421888.12	588352.27	12.16	0.03	0.01	0.03

(Sheet 3 of 3)

presented in Appendix B. Both the plots and tabular data show close comparison between ground and aerial survey data. No storm conditions occurred between the September 1991 ground survey and the October 1991 aerial flights, so no armor unit movement was anticipated. Therefore, the two data sets provide a good check of the accuracy of the photogrammetric analyses. The data show typical differences of a few hundredths of a foot between the ground and aerial surveys of targets. Maximum differences were equal to or less than 0.17 ft, and this level of difference was rare in the data set. In the armor unit movement analysis discussed later in this report, efforts were made to resolve magnitudes of armor unit movement that equaled or exceeded 0.5 ft. These data show that this accuracy can be resolved using photogrammetric analysis.

Photo Maps

Aerial images were used to produce halftone, screened, and rectified photo maps of the armor unit fields and concrete rib cap areas on the East and West Kahului breakwaters and the entire Laupahoehoe breakwater. These photo maps are in positive reverse reading form on 28-in. by 40-in. double-matte Mylar sheets and were produced at a scale of 1 in. equals 20 ft. These high-resolution maps allow for visual inspection of the above-water portions of the breakwaters and comparison between maps produced during different time periods. Reduced reproductions of the 10 October 1991 photo map for Laupahoehoe, and 8 January 1993 photo maps of Kahului West and Kahului East, are presented in Figures 20-22, respectively. Full-scale, original photo maps for both years' aerial flights are on file at the authors' offices at WES and POD.

Armor Unit Movement Detection

A methodology was developed to detect movement that occurred between successive aerial surveys of all armor units visible above the waterline. Breakwater stereo pairs taken during the first year's flight were mounted in the stereoplotter and the XYZ coordinates of three prominent, reproducible points on each visible armor unit were read and recorded in a computer file. The second year's stereo pairs then were analyzed in the same manner. The two coordinate files then were converted to AutoCAD files and when both files were displayed on a video screen armor unit movement between the two years was easily detected. Coordinates of the points for the armor units which appeared to show movement equal to or greater than 0.5 ft were stored to a separate file and magnitudes of the XY vector changes for each of the three points on the armor unit were calculated. Table 7 presents the data on 10 armor units that met or exceeded the threshold movement between the 1991 and 1993 aerial flights. All of these units were on the Kahului breakwaters (six and four on the west and east breakwaters, respectively). No units

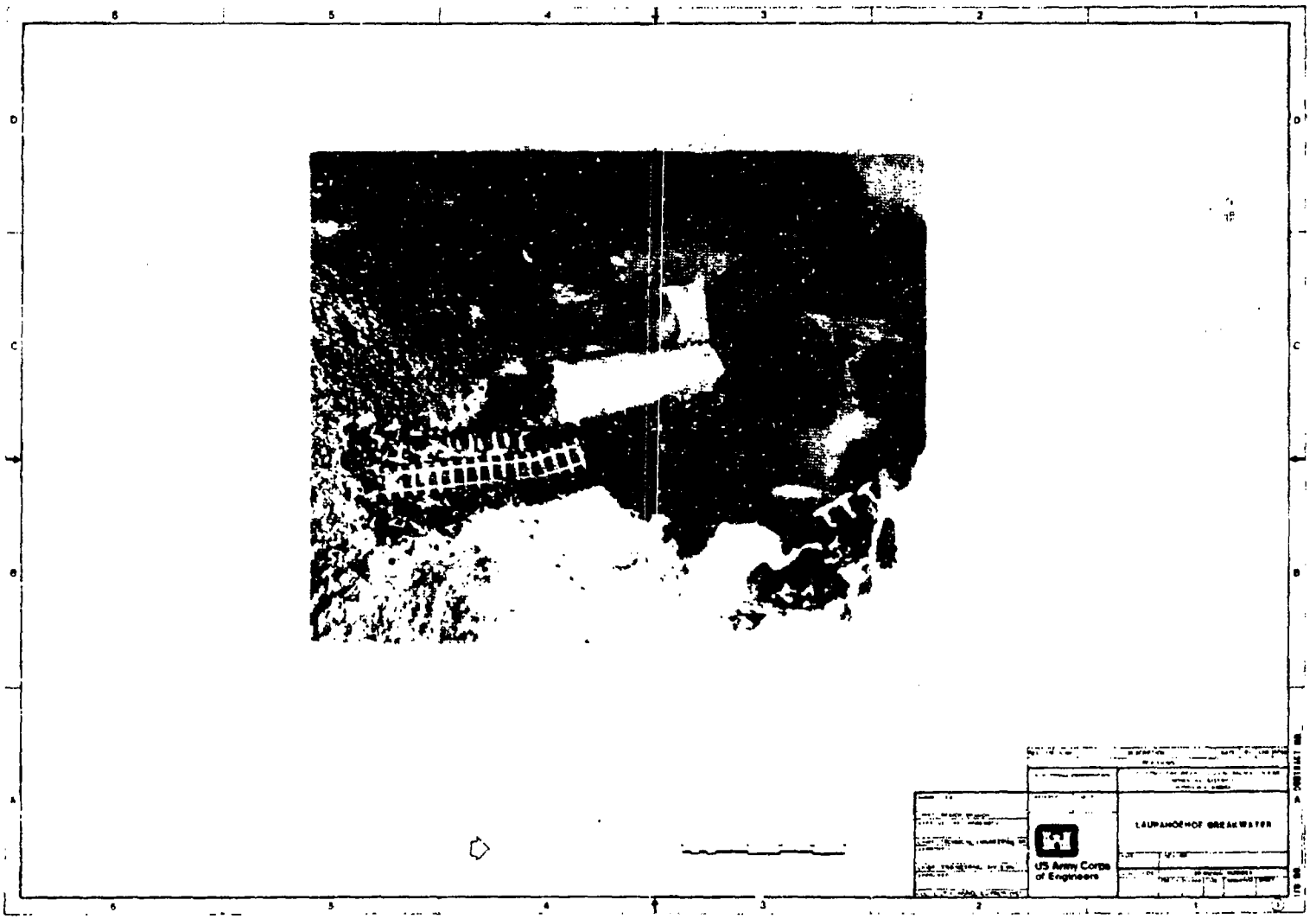


Figure 20. Rectified photo map of Laupahoehoe Boat Launching Facility from 10 October 1991

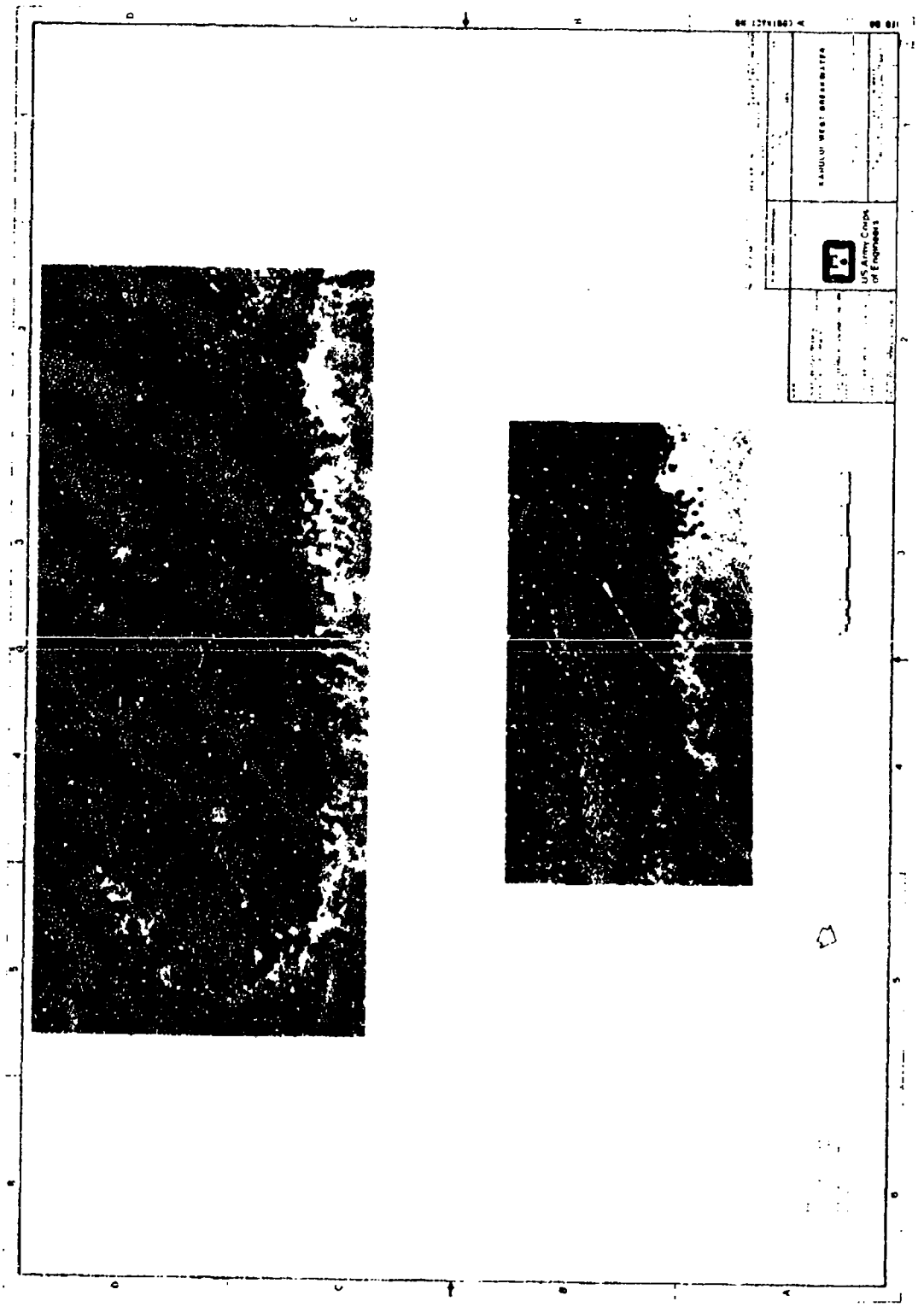


Figure 21. Rectified photo map of Kahului West breakwater from 8 January 1993

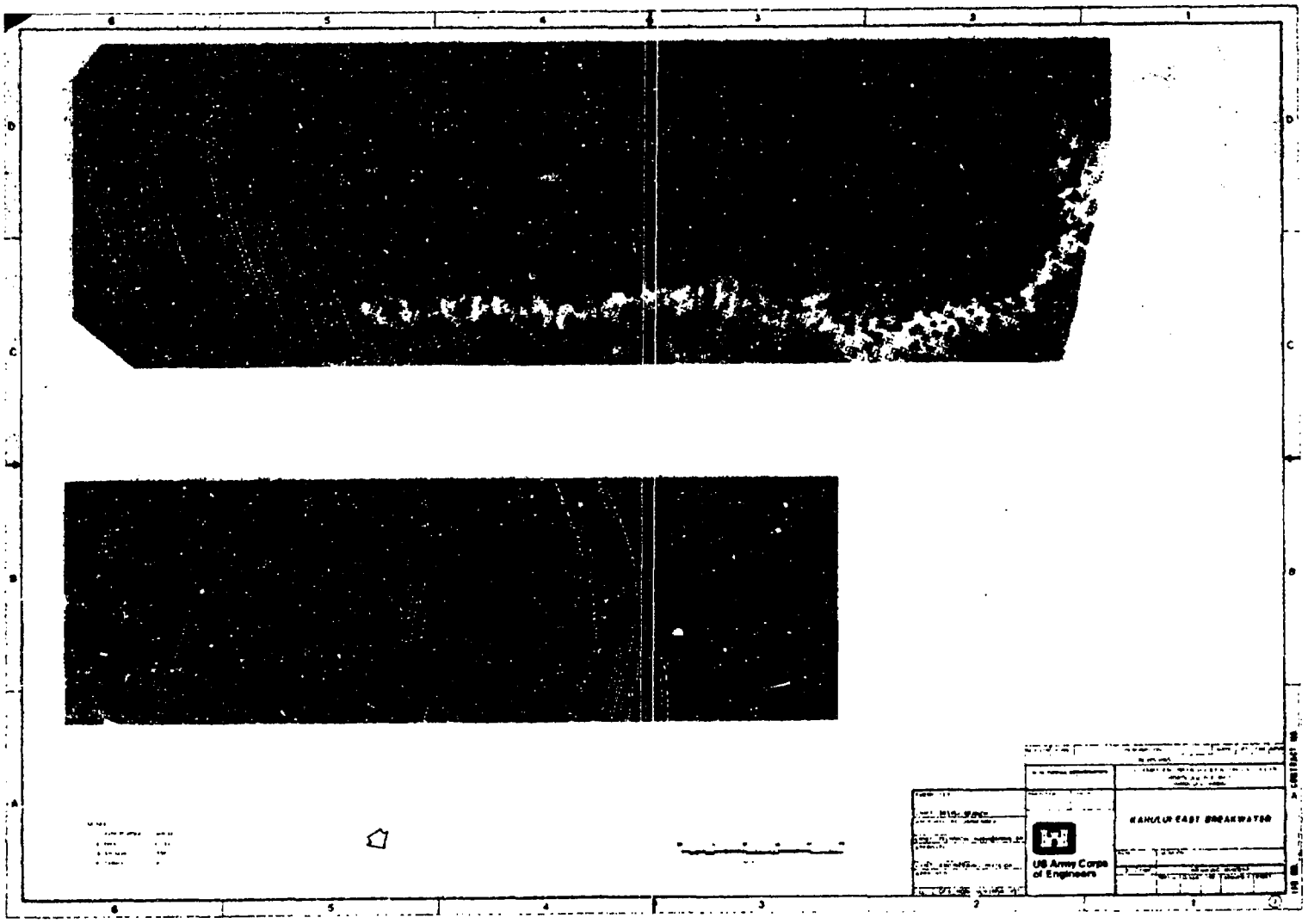


Figure 22. Rectified photo map of Kahului East breakwater from 8 January 1993

Table 7
Targeted and Untargeted Armor Unit Movement Detection

	NORTHING X	EASTING Y	ELEV Z		NORTHING X	EASTING Y	ELEV Z	Relative Movement X	Y	Z	XYZ Vector (Ft)	XY Vector (Ft)
				KAHULUI EAST								
(1)	565,945.040	207,122.640	8.83	(1) 1992	565,944.780	207,122.890	8.78	0.30	(0.25)	0.05	0.394	0.391
	565,937.900	207,126.470	6.10		565,937.390	207,126.850	5.85	0.51	(0.38)	0.25	0.789	0.636
	565,945.800	207,130.330	4.48		565,945.500	207,130.520	4.32	0.30	(0.19)	0.16	0.880	0.355
(2)	565,708.540	207,276.910	7.74	(2)	565,708.590	207,276.810	7.90	(0.05)	0.40	(0.16)	0.980	0.403
	565,709.000	207,288.460	12.52		565,709.030	207,288.340	12.39	(0.03)	0.12	0.13	0.997	0.124
	565,720.130	207,283.970	8.40		565,719.890	207,283.470	8.69	0.24	0.50	(0.29)	0.626	0.555
(3)	565,606.970	207,269.090	12.07	(3)	565,607.090	207,268.940	12.16	(0.12)	0.15	(0.09)	1.205	0.192
	565,596.450	207,269.730	6.39		565,597.160	207,269.830	6.86	(0.71)	(0.10)	(0.47)	1.479	0.717
	565,603.950	207,280.990	6.05		565,603.950	207,280.990	6.05	0.00	0.00	0.00	0.000	0.000
(4)	565,611.100	207,275.550	14.49	(4)	565,611.270	207,275.080	14.61	(0.17)	0.47	(0.12)	1.566	0.500
	565,605.540	207,284.750	7.73		565,605.720	207,284.330	7.99	(0.18)	0.42	(0.26)	1.635	0.457
	565,616.870	207,286.670	15.10		565,616.810	207,286.480	15.14	0.06	0.19	(0.04)	1.648	0.199
				KAHULUI WEST								
(5)	564,597.610	207,109.760	6.30	(5)	564,597.900	207,110.320	7.31	(0.29)	(0.56)	(1.01)	1.199	0.631
	564,590.740	207,106.370	13.20		564,590.830	207,106.430	13.20	(0.09)	(0.06)	0.00	0.108	0.108
	564,600.180	207,100.570	11.37		564,600.170	207,100.470	11.34	0.01	0.10	0.03	0.105	0.100
(6)	564,584.640	207,102.690	9.28	(6)	564,584.650	207,102.490	9.44	(0.01)	0.20	(0.16)	0.256	0.200
	564,582.170	207,096.020	10.73		564,582.240	207,096.030	10.78	(0.07)	(0.01)	(0.05)	0.087	0.071
	564,577.720	207,100.950	7.75		564,578.340	207,101.560	10.24	(0.62)	(0.61)	(2.49)	2.638	0.870
(7)	564,547.410	207,077.990	15.40	(7)	564,547.350	207,078.060	15.08	0.06	(0.07)	0.32	0.333	0.092
	564,547.110	207,071.430	12.19		564,548.110	207,071.560	12.38	(1.00)	(0.13)	(0.19)	1.053	1.008
	564,541.260	207,074.550	13.46		564,541.200	207,074.490	13.19	0.06	0.06	0.27	0.283	0.085
(8)	564,434.390	207,034.120	13.11	(10) 1992	564,434.190	207,034.090	12.79	0.20	0.03	0.32	0.379	0.202
	564,428.470	207,027.820	13.04		564,427.870	207,027.850	13.12	0.60	(0.03)	(0.08)	0.606	0.601
	564,426.220	207,035.790	9.60		564,426.260	207,035.790	9.27	(0.04)	0.00	0.33	0.332	0.040
(9)	564,322.150	206,968.640	7.22	(9)	564,322.060	206,968.710	7.07	0.09	(0.07)	0.15	0.188	0.114
	564,315.520	206,968.890	6.72		564,316.270	206,968.880	4.91	(0.75)	0.01	1.81	1.960	0.750
	564,319.700	206,974.010	5.01		564,319.660	206,973.960	4.99	0.04	0.05	0.02	0.067	0.064
(10)	564,328.560	206,907.720	4.71	(10)	564,328.480	206,907.510	4.71	0.08	0.21	0.00	0.225	0.225
	564,327.470	206,903.130	2.35		564,327.590	206,902.330	5.32	(0.12)	0.80	(2.97)	3.078	0.809
	564,323.700	206,905.900	4.45		564,323.640	206,905.690	4.57	0.06	0.21	(0.12)	0.249	0.218

meeting the threshold movement were detected on the Laupahoehoe breakwater. The point showing maximum magnitude for each of these 10 units was noted by arrows designating direction and magnitude of movement on transparent overlays for the 1993 photo maps. These movement vectors are shown on the photo maps displayed in Figures 21 and 22.

When the breakwaters are reinspected and subsequent aerial flights are made, this movement detection methodology will be used to determine and present armor unit movement. This will allow subtle changes occurring on the breakwaters, which are typically missed during normal visual breakwater inspections, to be quantified. During past inspections of the older rib cap areas of the Kahului breakwaters, it could not be determined whether the gaps between the rib cap and armor units on the upper sea-side slope were increasing or whether that was how these areas were constructed. Through periodic aerial photography and application of this movement detection analysis, areas in the armor unit fields that are showing movement can be detected and monitored more closely to determine the probable causes of changes. In some areas, motion above the waterline may indicate changes occurring under the water that could be jeopardizing the structural integrity of the breakwater. Also, when storms occur at a level that could result in armor unit motion, these analysis methods can be applied to measure the resulting changes and response of the breakwaters to these storms.

Helicopter Inspections

In April 1992, low-level helicopter inspections were made of the Kahului and Laupahoehoe breakwaters to obtain closeup 35-mm photographs. The 35-mm photographs, along with aerial photographs showing the approximate locations of these photographs, are shown in Figures C1-C16 in Appendix C. The purposes of these inspections were: (a) to provide oblique photographs that could easily be viewed to gain insight into the conditions of the breakwaters, and (b) to obtain a count of visible armor unit breakage. Findings from the inspections and review of the 35-mm photographs and the 1991 stereo pairs revealed that 13, 3, and 0 armor units were broken on the Kahului West and East breakwaters and the Laupahoehoe breakwater, respectively. Selected 35 mm photographs were combined with the rectified photo maps to show details of armor unit breakage locations on the Kahului breakwaters. These were reduced and are presented in Figures 23 and 24. In September 1992, a walking inspection of the Kahului breakwaters was carried out by Melby and Turk (1993) to obtain details on concrete armor unit breakage for input to ongoing research being funded under work units in the Coastal Engineering Research Program and the Repair, Evaluation, Maintenance, and Rehabilitation Research Program. Close study of the structures revealed that 28 and 11 units were broken on the West and East Kahului breakwaters, respectively. These breakage figures, along with those revealed from the aerial inspections, are presented in Table 8.

Table 8
Concrete Armor Unit Breakage Summaries for Kahului Breakwaters

			Number broken		Number cracked
Breakwater	Armor	Size tons	Aerial	Melby and Turk	Melby and Turk
West	Dolos	30	5	8	3
West	Dolos	20	5	13	4
West	Tribar	19	2	6	5
West	Tribar	50	0	1	0
West	Tribar	6.5	1	0	0
East	Dolos	3	0	0	1
East	Dolos	6	3	9	0
East	Tribar	35	0	2	2

The walking inspection by Melby and Turk (1993) occurred several months after the aerial inspections, but the time factor does not account for the considerably larger number of broken armor units revealed by the hands-on inspection when compared to the aerial surveillance results. The difference is associated with the difference in accuracy and visibility between the two methods. The aerial inspection does not pick up on the cracked, but yet unbroken, units, and the broken units in shadows, in the splash zones and in the underlayers. This observation shows that breakage counts obtained from the aerial, or remote sensing, technique must be understood to not be totally accurate and for a definite understanding of breakage quantities, a hands-on walking inspection of the armor unit fields is essential. The aerial inspection fulfills its anticipated results in that it will reveal to some degree the breakage and its distribution and it will give insight into when closer inspections of the armor unit fields are needed to ascertain accurate counts on armor breakage.

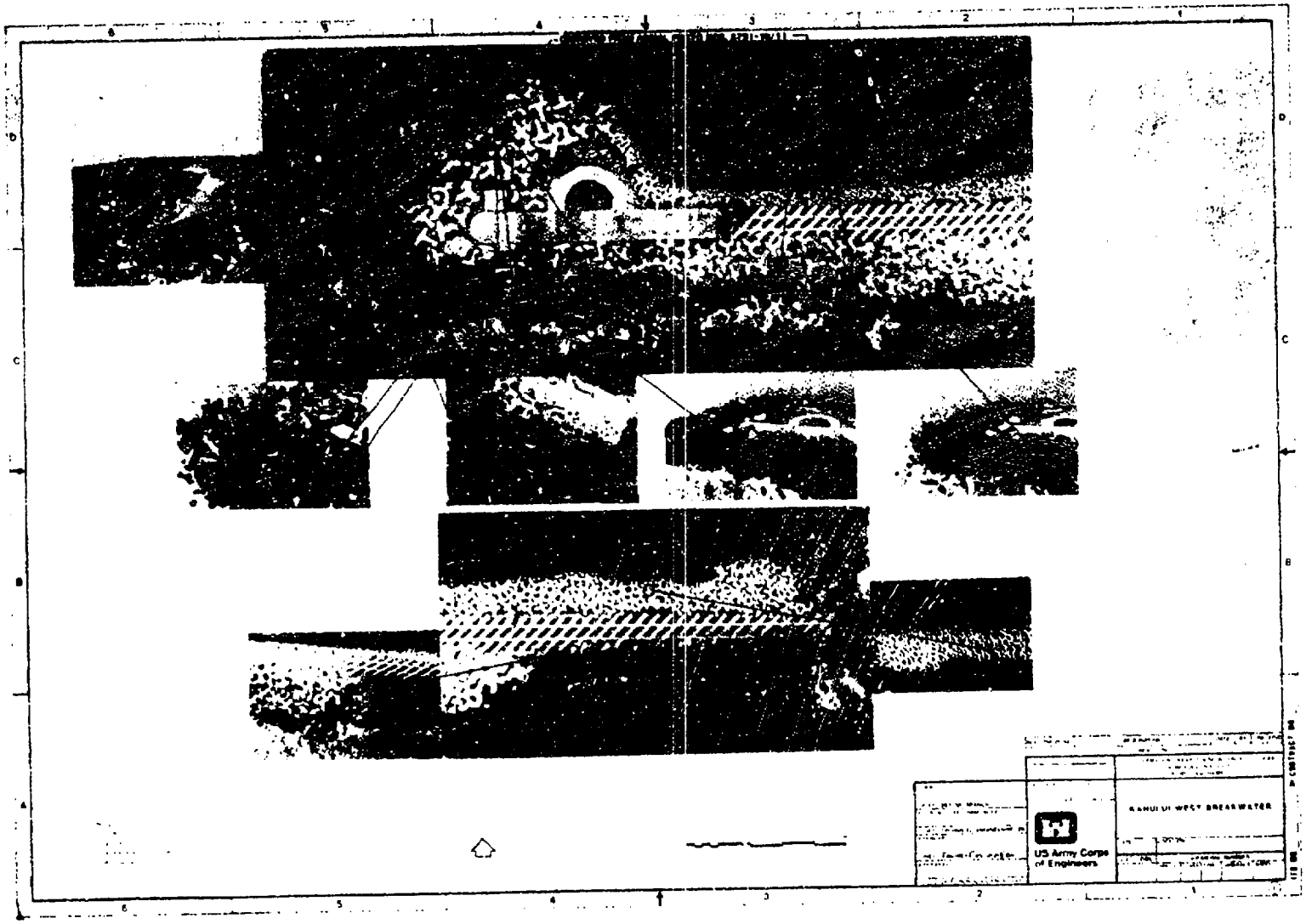


Figure 23. Armor unit breakage inspection of Kahului West breakwater

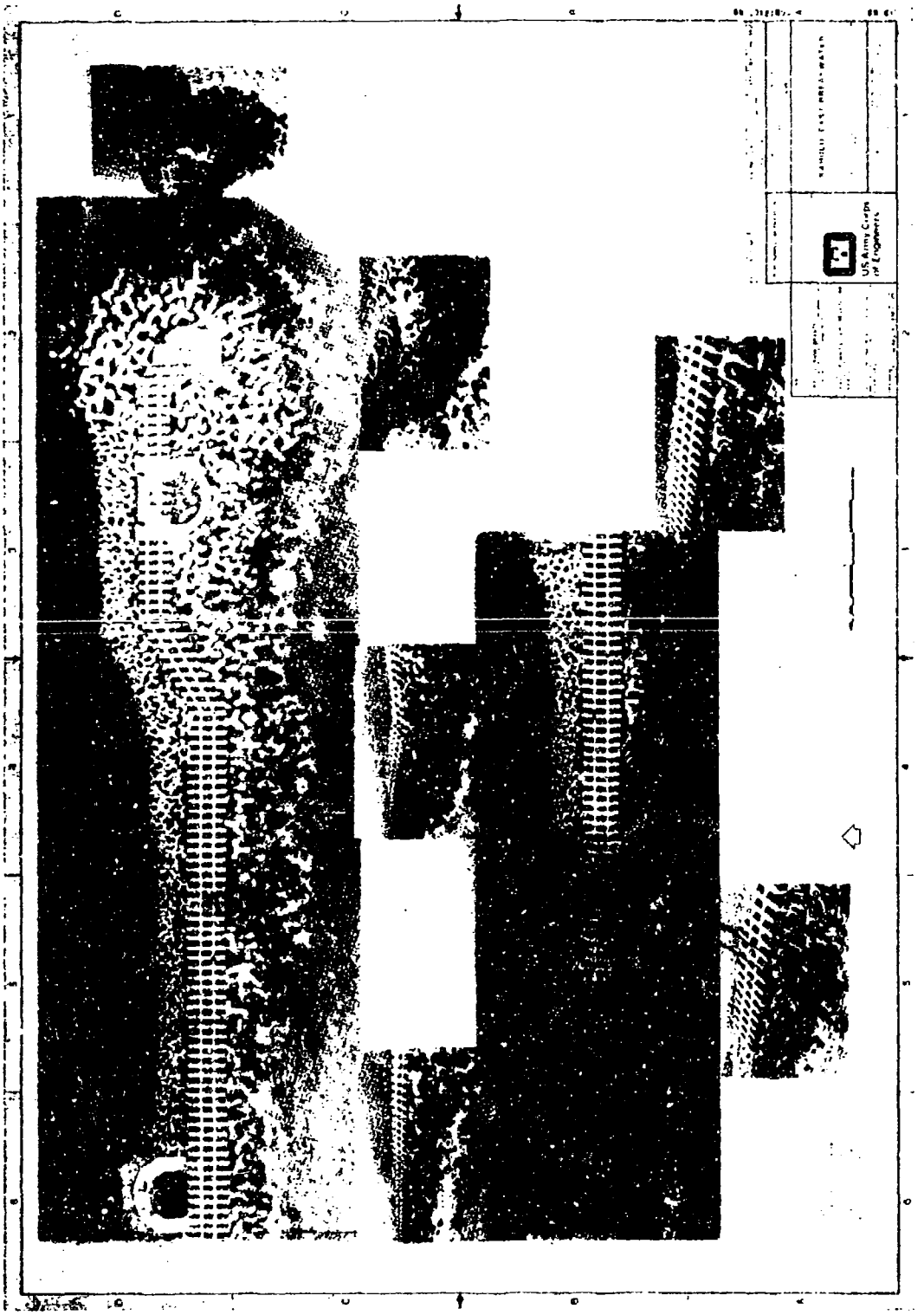


Figure 24. Armor unit breakage inspection of Kahului East breakwater

3 Summary

By means of limited land surveys, low-level helicopter inspections with 35-mm photography, aerial photography, and photogrammetric analysis, base conditions have been established for the Kahului and Laupahoehoe breakwaters. Accuracy of the photogrammetric analysis techniques has been checked through comparison of ground and aerial survey data on armor units that had been specifically targeted and surveyed for this purpose. A method using high-resolution, stereo pair aerial photographs, a stereoplotter and AutoCAD files, has been developed and tested to analyze the entire above-water armor unit fields to quantify armor unit movement that exceeds a threshold value of 0.5 ft. During testing of the method, it was observed that very little change, in regard to armor unit movement, occurred during the 1991-1993 monitoring, but this should be anticipated, as the wave climate to which the structures were exposed was very mild during this time period. Low-level helicopter surveys of concrete armor units revealed no breakage on the Laupahoehoe breakwater and only minimal amounts of breakage on the Kahului structures. A walking inspection of the Kahului breakwaters conducted under another research study revealed higher levels of armor breakage than found by aerial studies. The level of breakage is still minimal, but the area at the confluence of the sea-side of the head and trunk of the west breakwater is beginning to show a slight concentration, or cluster, of breakage and this area should be monitored more closely than other areas. Also, the land-based breakage survey revealed that the accuracy of aerial breakage inspections can be questionable and that for more accurate armor unit breakage counts, detailed walking inspections should be conducted over the armor unit fields.

Now that the base (control) conditions have been defined at a point in time and a method has been developed to closely compare subsequent years of high-resolution aerial photography of the Kahului and Laupahoehoe breakwaters, these sites will be revisited during future years under the Periodic Inspections work unit to gather data by which assessments can be made on the long-term response of the structures to their environment. Insight gathered from these efforts will allow definite decisions to be made based on sound data as to whether or not closer surveillance and/or repair of a structure is required to reduce the chance that it will fail catastrophically.

Also, the periodic inspection methods developed and validated for these structures can be used to gain insight into other Corps' structures.

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Appendix A
Aerial Survey Data for Armor Unit Targets

Armor Unit Target Movement Record From Aerial Surveys
Laupahoehoe Breakwater, Hawaii

Target Id: A1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421935.30	588382.69	11.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421935.34	588382.68	11.94	0.04	-0.01	0.08	0.09	0.04	-0.01	0.08	0.09

Target Id: A2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421928.98	588392.93	15.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421929.03	588392.89	15.35	0.05	-0.04	0.05	0.08	0.05	-0.04	0.05	0.08

Target Id: A3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421922.73	588383.31	10.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421922.77	588383.29	10.51	0.04	-0.02	0.03	0.05	0.04	-0.02	0.03	0.05

Target Id: B1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421884.27	588392.28	10.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421884.27	588392.30	10.74	0.00	0.02	0.12	0.12	0.00	0.02	0.12	0.12

Target Id: B2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421874.77	588398.30	15.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421874.78	588398.31	15.91	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.01

Target Id: B3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421872.67	588387.29	10.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421872.70	588387.44	10.50	0.03	0.15	-0.03	0.16	0.03	0.15	-0.03	0.16

Target Id: C1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421862.53	588389.72	5.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Armor Unit Target Movement Record From Aerial Surveys
Laupahoehoe Breakwater, Hawaii

Target Id: C1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
92/11/22	AERIAL	421862.53	588389.73	5.55	0.00	0.01	0.03	0.03	0.00	0.01	0.03	0.03

Target Id: C2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421858.28	588399.46	11.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421858.29	588399.46	11.89	0.01	0.00	-0.04	0.04	0.01	0.00	-0.04	0.04

Target Id: C3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421850.14	588390.99	7.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421850.21	588391.03	7.90	0.07	0.04	0.07	0.11	0.07	0.04	0.07	0.11

Target Id: D1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421851.88	588354.78	5.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421851.86	588354.75	5.60	-0.02	-0.03	-0.01	0.04	-0.02	-0.03	-0.01	0.04

Target Id: D2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421844.93	588361.97	13.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421844.95	588361.93	13.06	0.02	-0.04	0.00	0.04	0.02	-0.04	0.00	0.04

Target Id: D3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421840.32	588351.09	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421840.29	588351.06	9.09	-0.03	-0.03	0.00	0.04	-0.03	-0.03	0.00	0.04

Target Id: E1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421894.18	588362.41	8.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421894.20	588362.41	8.21	0.02	0.00	0.02	0.03	0.02	0.00	0.02	0.03

Target Id: E2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421881.53	588362.27	8.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421881.54	588362.25	8.73	0.01	-0.02	-0.04	0.05	0.01	-0.02	-0.04	0.05

Target Id: E3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/10	AERIAL	421888.12	588352.27	12.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92/11/22	AERIAL	421888.10	588352.26	12.20	-0.02	-0.01	0.04	0.05	-0.02	-0.01	0.04	0.05

Armor Unit Target Movement Record From Aerial Surveys
East Kahului Breakwater, Hawaii

Target Id: A1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206888.43	566164.38	5.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206888.41	566164.38	5.28	-0.02	0.00	0.01	0.02	-0.02	0.00	0.01	0.02

Target Id: A2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206885.34	566169.28	5.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206885.34	566169.26	5.34	0.00	-0.02	0.07	0.07	0.00	-0.02	0.07	0.07

Target Id: A3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206882.66	566164.18	4.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206882.66	566164.15	4.41	0.00	-0.03	0.05	0.06	0.00	-0.03	0.05	0.06

Target Id: B1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207112.85	565756.85	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207112.94	565756.76	6.45	0.09	-0.09	0.05	0.14	0.09	-0.09	0.05	0.14

Target Id: B2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207107.46	565755.61	4.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207107.54	565755.49	4.70	0.08	-0.12	0.05	0.15	0.08	-0.12	0.05	0.15

Target Id: B3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207111.56	565751.41	4.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207111.64	565751.33	4.82	0.08	-0.08	0.03	0.12	0.08	-0.08	0.03	0.12

Target Id: C1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207201.73	565596.66	7.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Armor Unit Target Movement Record From Aerial Surveys
East Kahului Breakwater, Hawaii

Target Id: C1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
93/01/08	AERIAL	207201.62	565596.80	7.82	-0.11	0.14	0.11	0.21	-0.11	0.14	0.11	0.21

Target Id: C2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207210.37	565592.01	10.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207210.26	565592.19	10.66	-0.11	0.18	0.20	0.29	-0.11	0.18	0.20	0.29

Target Id: C3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207209.57	565602.11	10.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207209.47	565602.26	11.01	-0.10	0.15	0.08	0.20	-0.10	0.15	0.08	0.20

Target Id: D1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207271.93	565609.14	17.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207271.74	565609.27	18.13	-0.19	0.13	0.16	0.28	-0.19	0.13	0.16	0.28

Target Id: D2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207272.99	565621.00	14.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207272.81	565621.08	14.31	-0.18	0.08	0.15	0.25	-0.18	0.08	0.15	0.25

Target Id: D3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207262.42	565614.33	11.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207262.25	565614.50	12.04	-0.17	0.17	0.30	0.38	-0.17	0.17	0.30	0.38

Target Id: E1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207299.01	565669.83	13.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207298.86	565669.87	13.84	-0.15	0.04	0.03	0.16	-0.15	0.04	0.03	0.16

Armor Unit Target Movement Record From Aerial Surveys
East Kahului Breakwater, Hawaii

Target Id: E2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207297.99	565681.97	16.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207297.86	565682.00	16.32	-0.13	0.03	0.00	0.13	-0.13	0.03	0.00	0.13

Target Id: E3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207287.88	565675.75	12.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207287.77	565675.77	12.24	-0.11	0.02	0.07	0.13	-0.11	0.02	0.07	0.13

Target Id: F1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207265.60	565722.84	13.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207265.55	565722.83	13.63	-0.05	-0.01	0.01	0.05	-0.05	-0.01	0.01	0.05

Target Id: F2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207271.72	565732.39	8.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207271.71	565732.38	8.46	-0.01	-0.01	-0.03	0.03	-0.01	-0.01	-0.03	0.03

Target Id: F3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207259.06	565732.56	9.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207259.09	565732.52	9.25	0.03	-0.04	-0.05	0.07	0.03	-0.04	-0.05	0.07

Target Id: G1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207222.09	565749.87	9.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207222.09	565749.82	9.71	0.00	-0.05	0.01	0.05	0.00	-0.05	0.01	0.05

Target Id: G2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207228.79	565755.58	10.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Armor Unit Target Movement Record From Aerial Surveys
East Kahului Breakwater, Hawaii

Target Id: G2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
93/01/08	AERIAL	207228.80	565755.48	10.55	0.01	-0.10	-0.05	0.11	0.01	-0.10	-0.05	0.11

Target Id: G3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207220.55	565758.58	9.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207220.59	565758.51	9.25	0.04	-0.07	-0.04	0.09	0.04	-0.07	-0.04	0.09

Target Id: H1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207058.21	565996.16	15.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207058.36	565996.06	15.93	0.15	-0.10	0.11	0.21	0.15	-0.10	0.11	0.21

Target Id: H2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207065.04	566006.31	17.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207065.14	566006.22	17.90	0.10	-0.09	0.07	0.15	0.10	-0.09	0.07	0.15

Target Id: H3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207052.93	566007.63	15.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207053.06	566007.53	15.23	0.13	-0.10	0.10	0.19	0.13	-0.10	0.10	0.19

Target Id: I1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206939.43	566180.19	11.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206939.43	566180.15	11.51	0.00	-0.04	-0.10	0.11	0.00	-0.04	-0.10	0.11

Target Id: I2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206943.53	566187.77	17.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206943.53	566187.76	16.97	0.01	-0.01	-0.07	0.07	0.01	-0.01	-0.07	0.07

Armor Unit Target Movement Record From Aerial Surveys
East Kahului Breakwater, Hawaii

Target Id: I3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206934.45	566189.22	15.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206934.43	566189.19	15.30	-0.02	-0.03	-0.04	0.05	-0.02	-0.03	-0.04	0.05

Target Id: J1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206882.88	566270.84	9.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206882.86	566270.83	9.37	-0.02	-0.01	-0.07	0.07	-0.02	-0.01	-0.07	0.07

Target Id: J2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206887.36	566276.09	7.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206887.23	566276.13	7.91	-0.13	0.04	-0.04	0.14	-0.13	0.04	-0.04	0.14

Target Id: J3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206881.75	566277.32	12.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206881.72	566277.32	12.56	-0.03	0.00	-0.04	0.05	-0.03	0.00	-0.04	0.05

Armor Unit Target Movement Record From Aerial Surveys
West Kahului Breakwater, Hawaii

Target Id: A1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206990.76	564375.09	8.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206990.72	564374.97	8.51	-0.04	-0.12	-0.02	0.13	-0.04	-0.12	-0.02	0.13

Target Id: A2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206986.92	564378.34	12.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206986.89	564378.20	12.16	-0.03	-0.14	0.04	0.15	-0.03	-0.14	0.04	0.15

Target Id: A3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206985.48	564372.57	10.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206985.46	564372.42	10.43	-0.02	-0.15	-0.04	0.16	-0.02	-0.15	-0.04	0.16

Target Id: B1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207060.11	564486.21	7.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207060.14	564486.33	7.84	0.03	0.12	0.09	0.15	0.03	0.12	0.09	0.15

Target Id: B2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207064.83	564491.48	9.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207064.87	564491.58	9.38	0.04	0.10	0.05	0.12	0.04	0.10	0.05	0.12

Target Id: B3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207058.02	564493.18	7.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207058.06	564493.30	7.43	0.04	0.12	0.04	0.13	0.04	0.12	0.04	0.13

Target Id: C1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207111.54	564614.50	10.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Armor Unit Target Movement Record From Aerial Surveys
West Kahului Breakwater, Hawaii

Target Id: C1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
93/01/08	AERIAL	207111.51	564614.52	10.84	-0.03	0.02	0.04	0.05	-0.03	0.02	0.04	0.05

Target Id: C2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207105.12	564607.89	16.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/06	AERIAL	207105.11	564607.90	16.67	-0.01	0.01	-0.08	0.08	-0.01	0.01	-0.08	0.08

Target Id: C3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207114.09	564603.90	12.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207114.05	564603.96	12.16	-0.04	0.06	0.02	0.07	-0.04	0.06	0.02	0.07

Target Id: D1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207141.57	564698.16	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207141.53	564698.17	11.74	-0.04	0.01	0.04	0.06	-0.04	0.01	0.04	0.06

Target Id: D2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207153.50	564694.02	12.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207153.42	564694.02	12.78	-0.08	0.00	0.03	0.09	-0.08	0.00	0.03	0.09

Target Id: D3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207144.10	564687.18	16.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207144.06	564687.20	16.95	-0.04	0.02	0.00	0.04	-0.04	0.02	0.00	0.04

Target Id: E1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207173.46	564787.89	14.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207173.35	564787.80	14.04	-0.11	-0.09	-0.08	0.16	-0.11	-0.09	-0.08	0.16

Armor Unit Target Movement Record From Aerial Surveys
West Kahului Breakwater, Hawaii

Target Id: E2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207185.60	564788.95	11.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207185.43	564788.82	11.70	-0.17	-0.13	0.00	0.21	-0.17	-0.13	0.00	0.21

Target Id: E3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207180.10	564777.56	12.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207179.97	564777.48	12.10	-0.13	-0.08	-0.02	0.15	-0.13	-0.08	-0.02	0.15

Target Id: F1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207148.73	564803.92	13.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207148.67	564803.79	13.17	-0.06	-0.13	-0.04	0.15	-0.06	-0.13	-0.04	0.15

Target Id: F2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207150.13	564816.13	10.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207150.07	564815.93	10.07	-0.06	-0.20	-0.09	0.23	-0.06	-0.20	-0.09	0.23

Target Id: F3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207158.16	564810.51	17.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207158.10	564810.39	17.84	-0.06	-0.12	-0.08	0.16	-0.06	-0.12	-0.08	0.16

Target Id: G1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207100.48	564795.78	11.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207100.53	564795.64	11.17	0.05	-0.14	0.04	0.15	0.05	-0.14	0.04	0.15

Target Id: G2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207098.30	564805.43	9.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Armor Unit Target Movement Record From Aerial Surveys
West Kahului Breakwater, Hawaii

Target Id: G2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
93/01/08	AERIAL	207098.32	564805.24	9.31	0.02	-0.19	0.03	0.19	0.02	-0.19	0.03	0.19

Target Id: G3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207107.88	564802.58	10.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207107.89	564802.41	10.74	0.01	-0.17	0.00	0.17	0.01	-0.17	0.00	0.17

Target Id: H1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207044.61	564753.78	9.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207044.76	564753.72	9.69	0.15	-0.06	0.17	0.23	0.15	-0.06	0.17	0.23

Target Id: H2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207035.78	564744.66	9.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207035.91	564744.62	9.17	0.13	-0.04	0.16	0.21	0.13	-0.04	0.16	0.21

Target Id: H3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	207032.92	564756.14	12.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	207033.05	564756.05	12.98	0.13	-0.09	0.09	0.18	0.13	-0.09	0.09	0.18

Target Id: I1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
93/01/08	AERIAL	207032.86	564592.49	8.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Target Id: I2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
93/01/08	AERIAL	207031.31	564597.32	6.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Target Id: I3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
93/01/08	AERIAL	207028.03	564593.24	6.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Armor Unit Target Movement Record From Aerial Surveys
West Kahului Breakwater, Hawaii

Target Id: J1 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206971.55	564472.05	4.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206971.46	564471.91	4.76	-0.09	-0.14	0.05	0.17	-0.09	-0.14	0.05	0.17

Target Id: J2 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206967.35	564468.97	4.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206967.24	564468.89	4.46	-0.11	-0.08	0.12	0.18	-0.11	-0.08	0.12	0.18

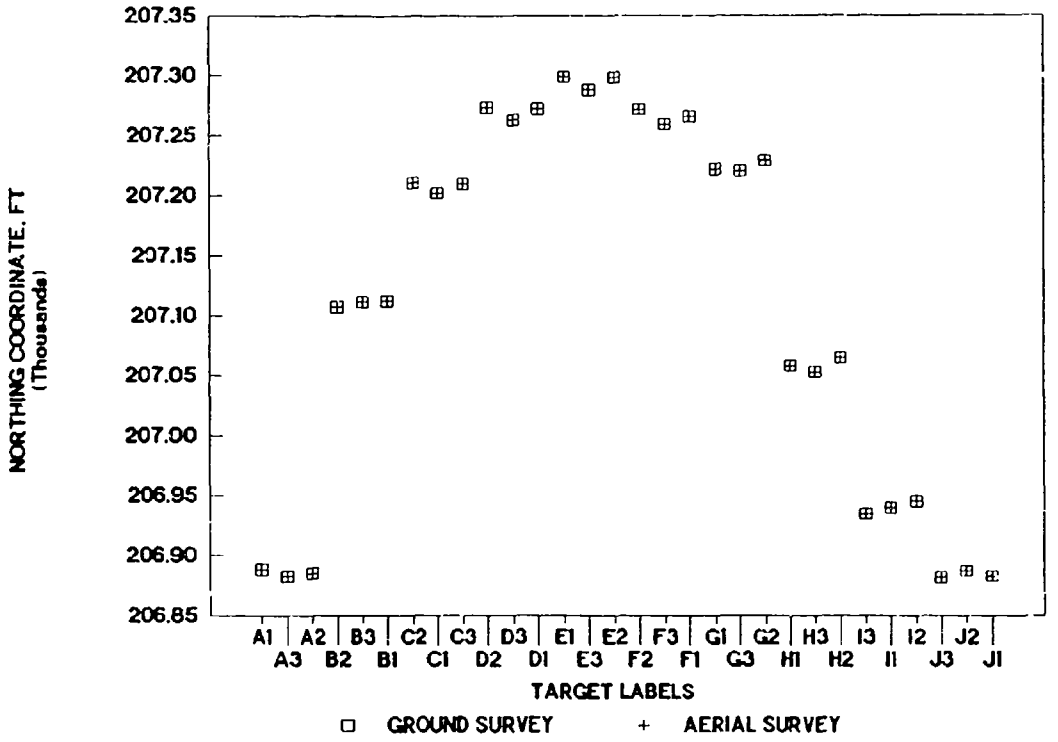
Target Id: J3 Type of Survey: AERIAL

Date	Survey	Northing(Y) ft.	Easting(X) ft.	Elev.(Z) ft.	Relative Movement (YXZ)				Cumulative Movement (YXZ)			
91/10/19	AERIAL	206972.14	564466.89	4.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93/01/08	AERIAL	206972.00	564466.73	4.84	-0.14	-0.16	0.14	0.25	-0.14	-0.16	0.14	0.25

Appendix B
Comparison of Ground and Aerial Survey Data of Armor Unit Target Coordinates

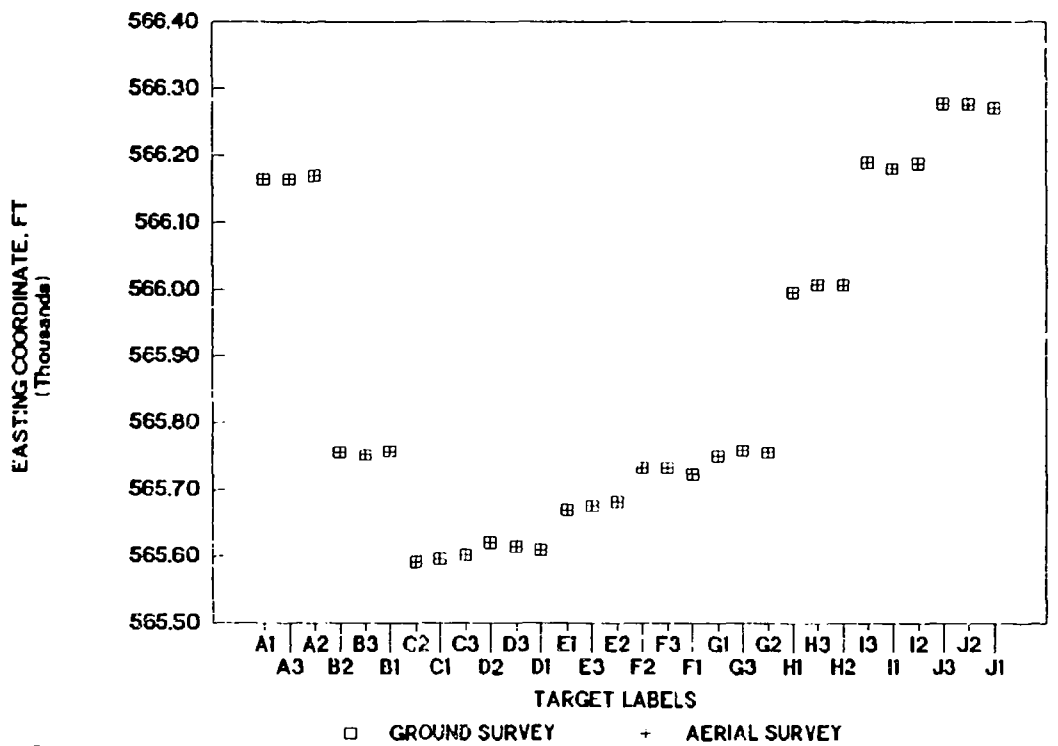
KAHULUI EAST BREAKWATER

Northing Survey Points



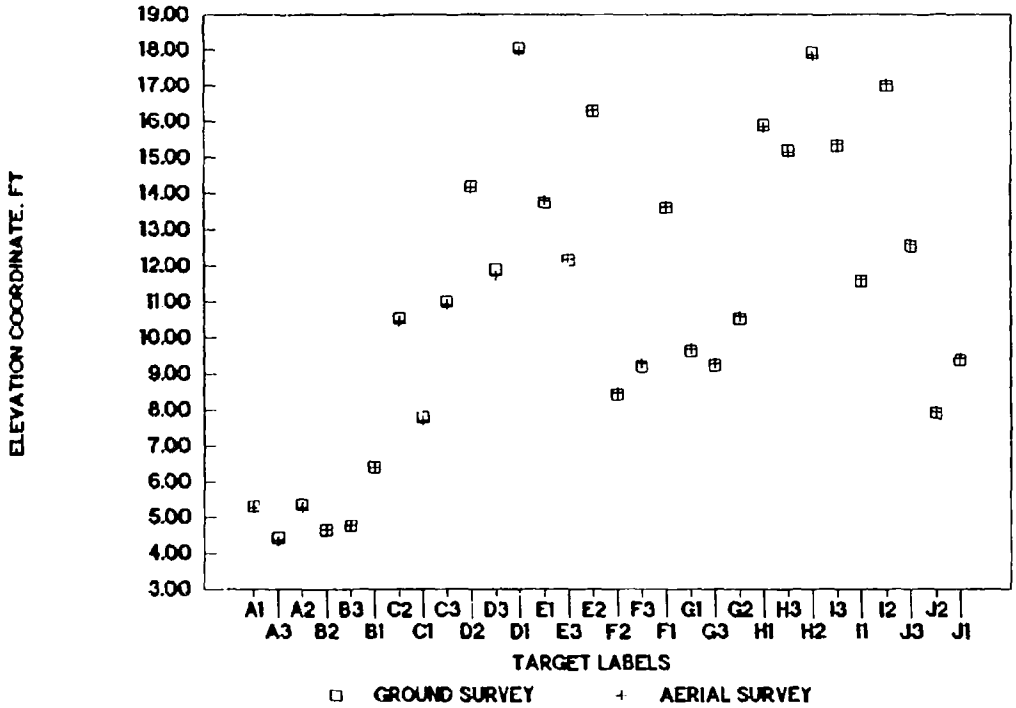
KAHULUI EAST BREAKWATER

Easting Survey Points



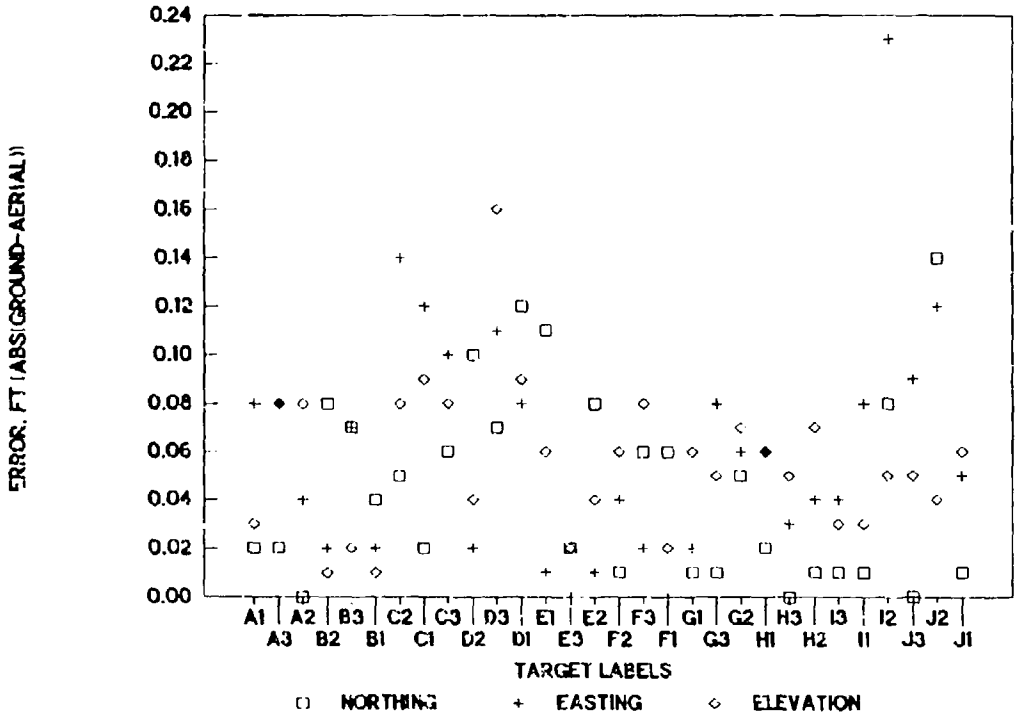
KAHULUI EAST BREAKWATER

Elevation Survey Points



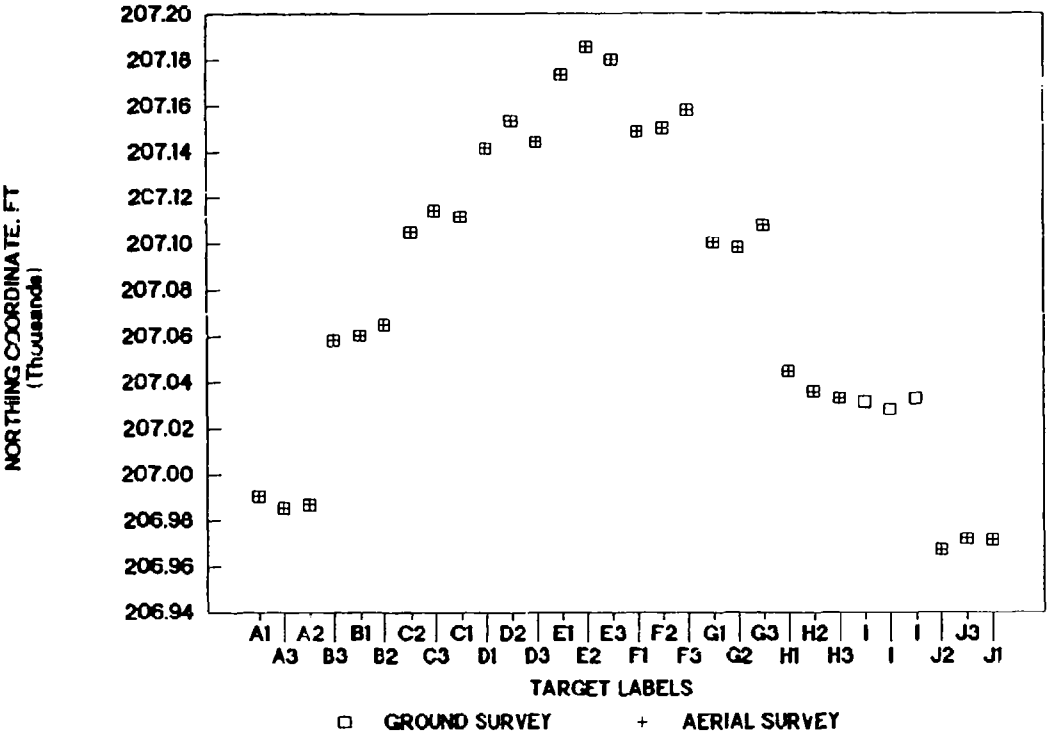
KAHULUI EAST BREAKWATER

ERROR BETWEEN AERIAL AND GROUND SURVEY



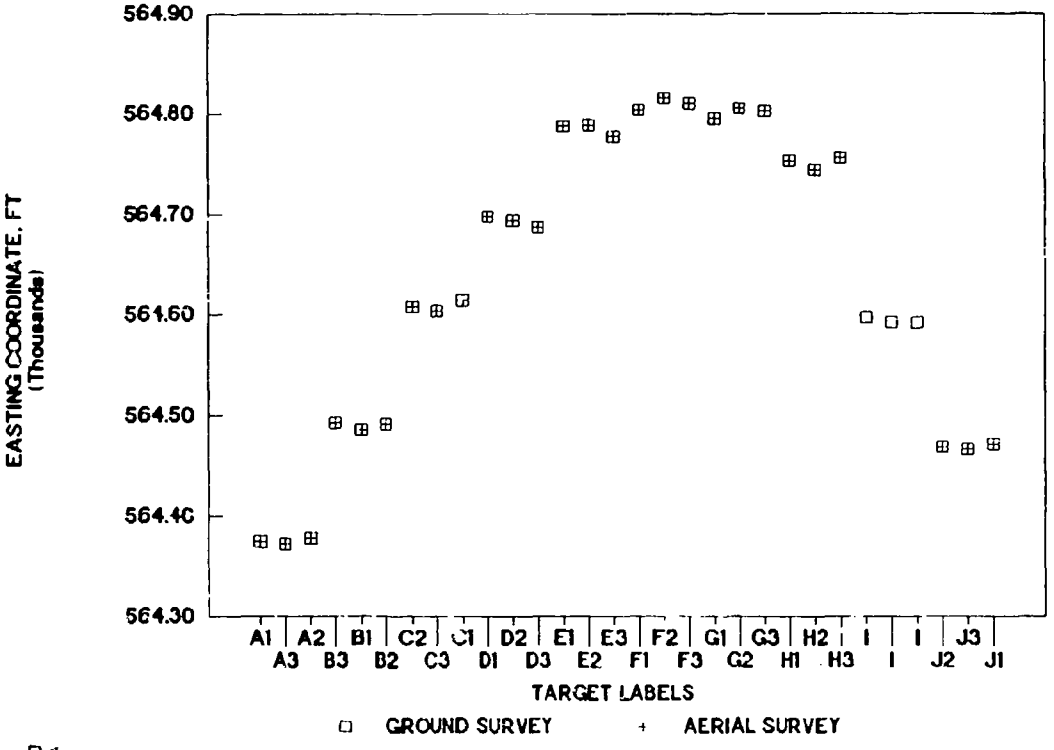
KAHULUI WEST BREAKWATER

Northing Survey Points



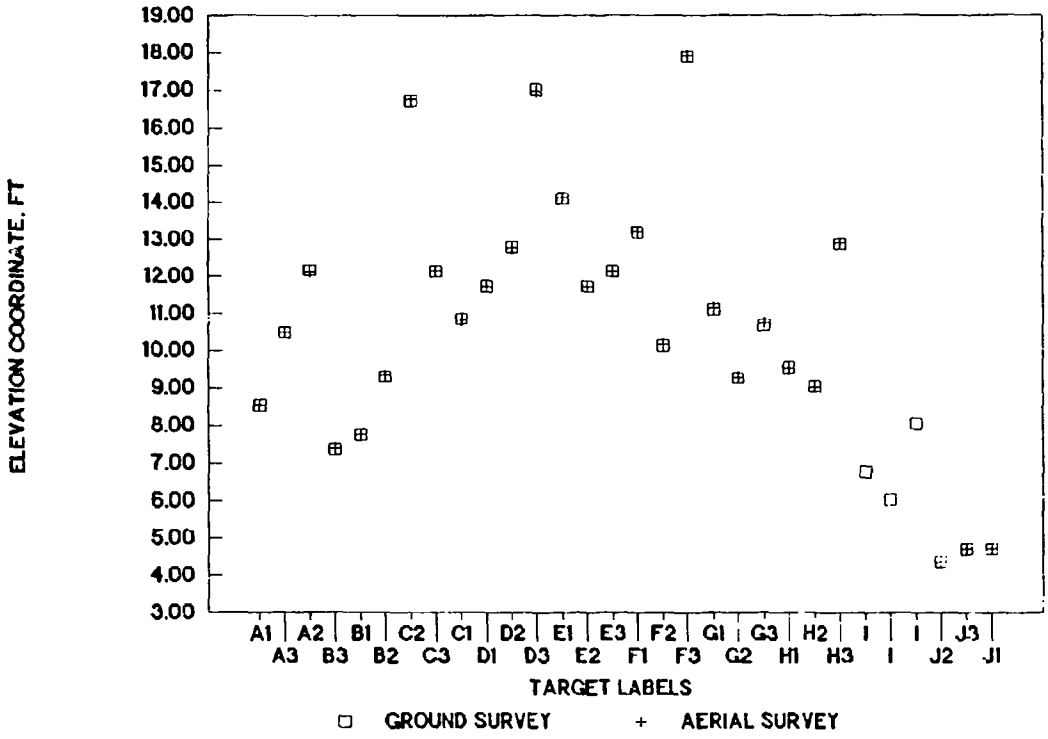
KAHULUI WEST BREAKWATER

Easting Survey Points



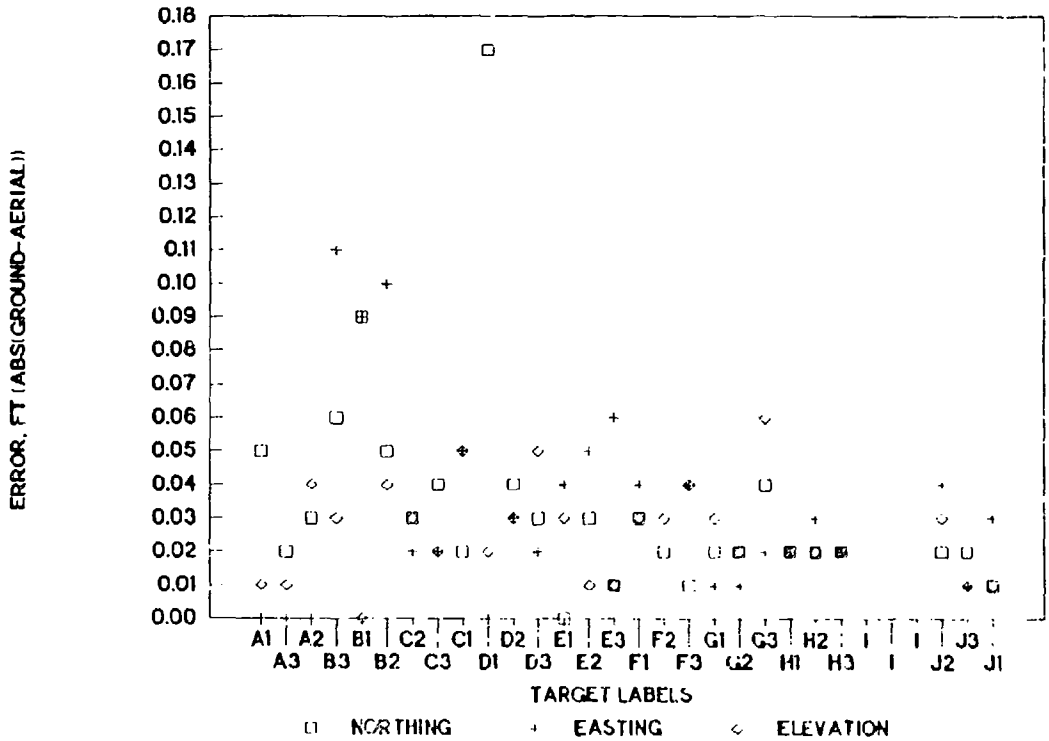
KAHULUI WEST BREAKWATER

Elevation Survey Points



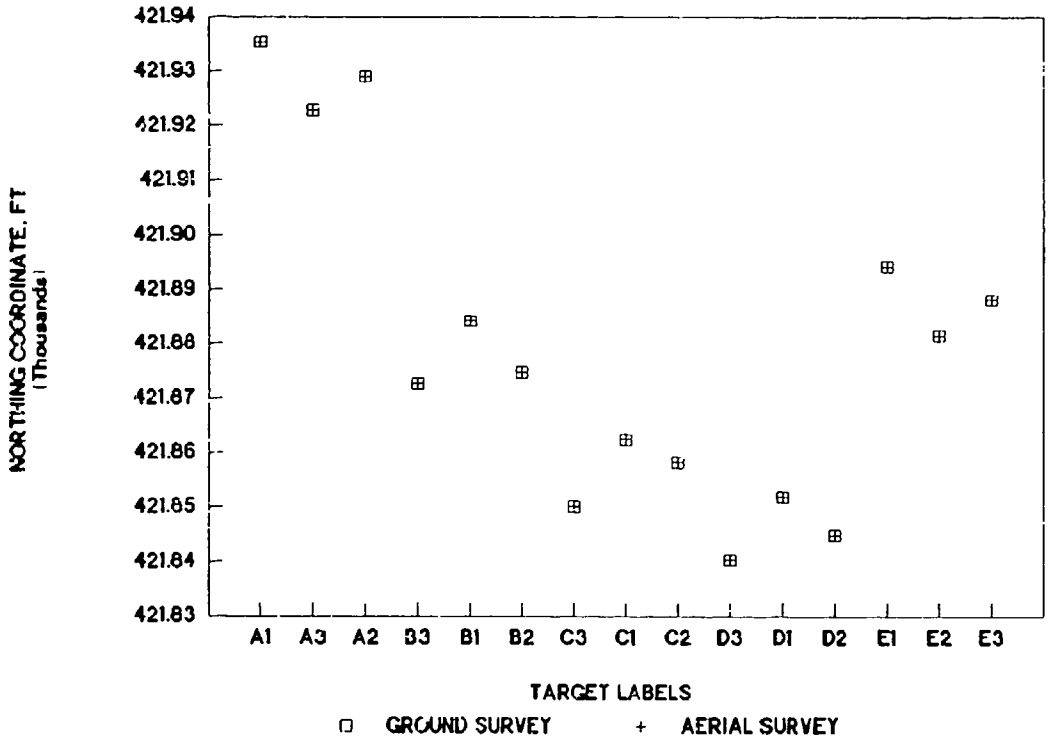
KAHULUI WEST BREAKWATER

ERROR BETWEEN AERIAL AND GROUND SURVEY



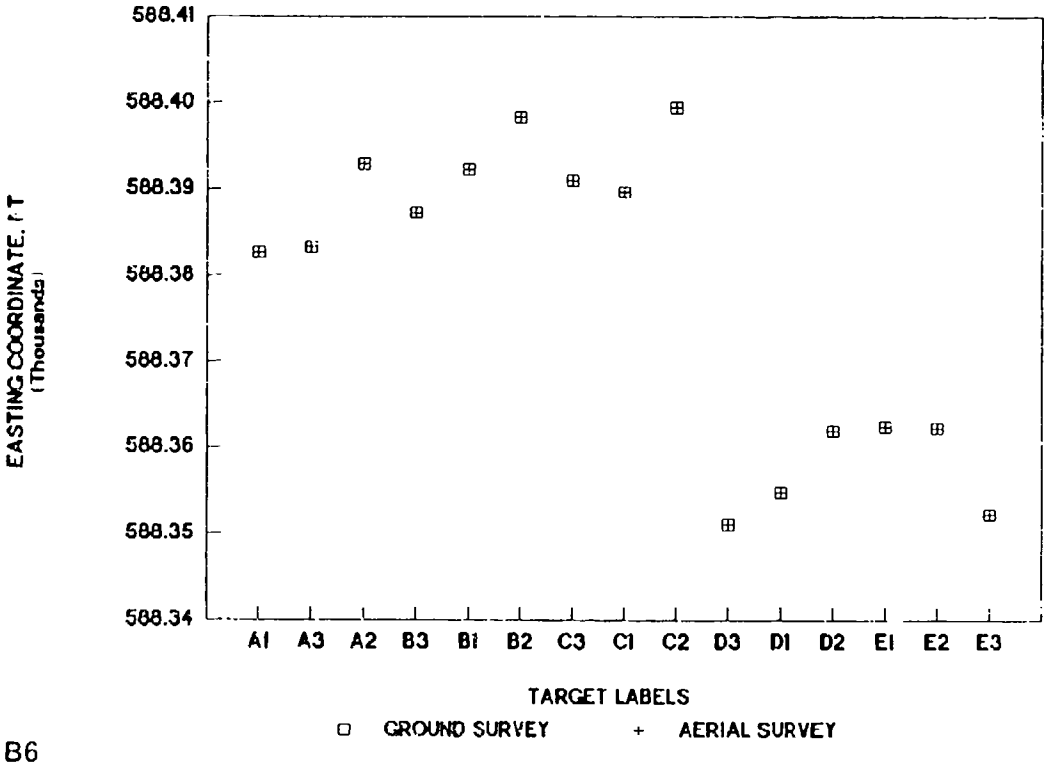
LAUPAHOEHOE BREAKWATER

Northing Survey Points



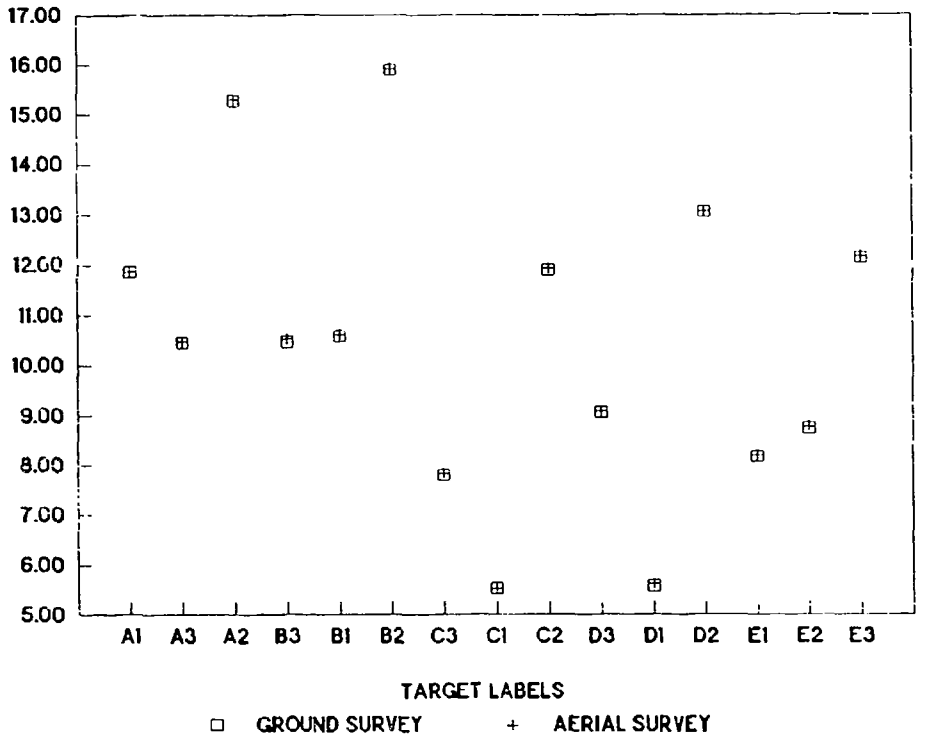
LAUPAHOEHOE BREAKWATER

Easting Survey Points



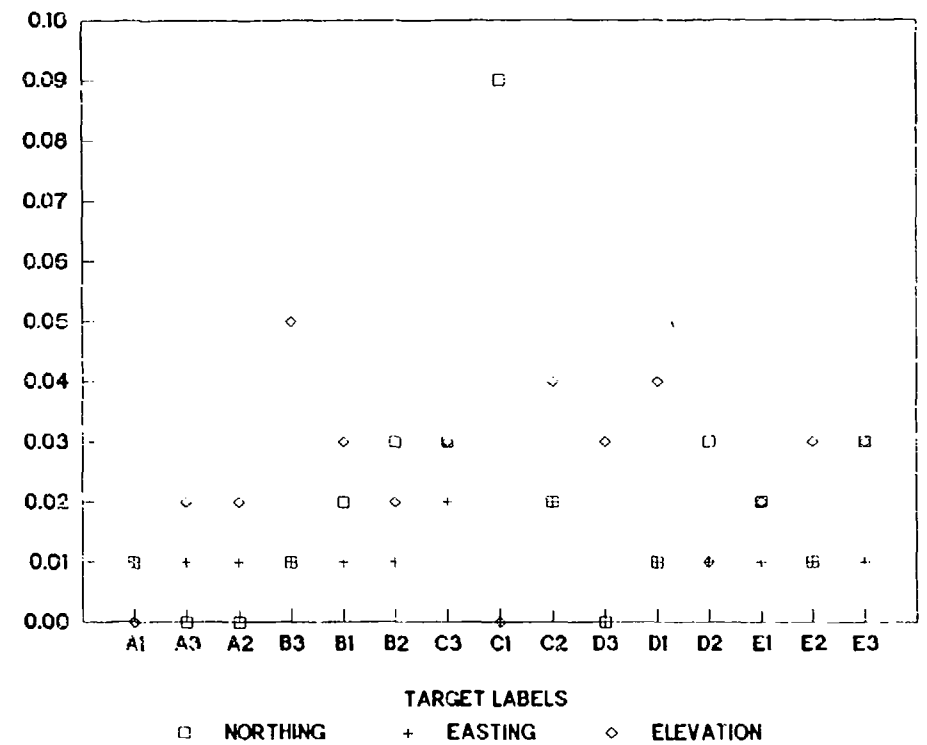
LAUPAHOEHOE BREAKWATER

Elevation Survey Points



LAUPAHOEHOE BREAKWATER

ERROR BETWEEN AERIAL AND GROUND SURVEY



Appendix C
35-mm Photographs from April 1992 Helicopter Inspection

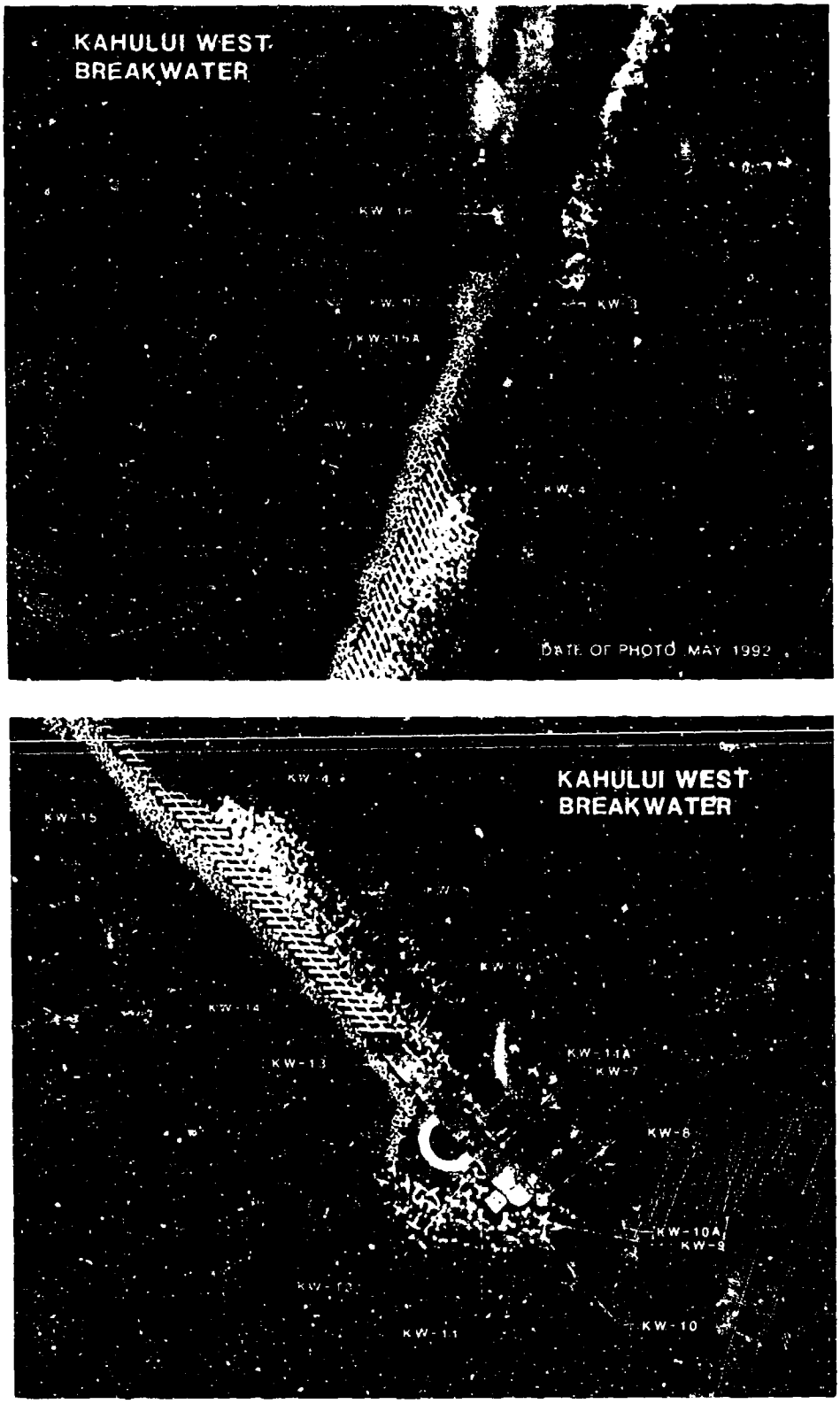


Figure C1. Aerial views of Kahului West breakwater showing locations of 35-mm photographs taken during April 1992 helicopter inspection

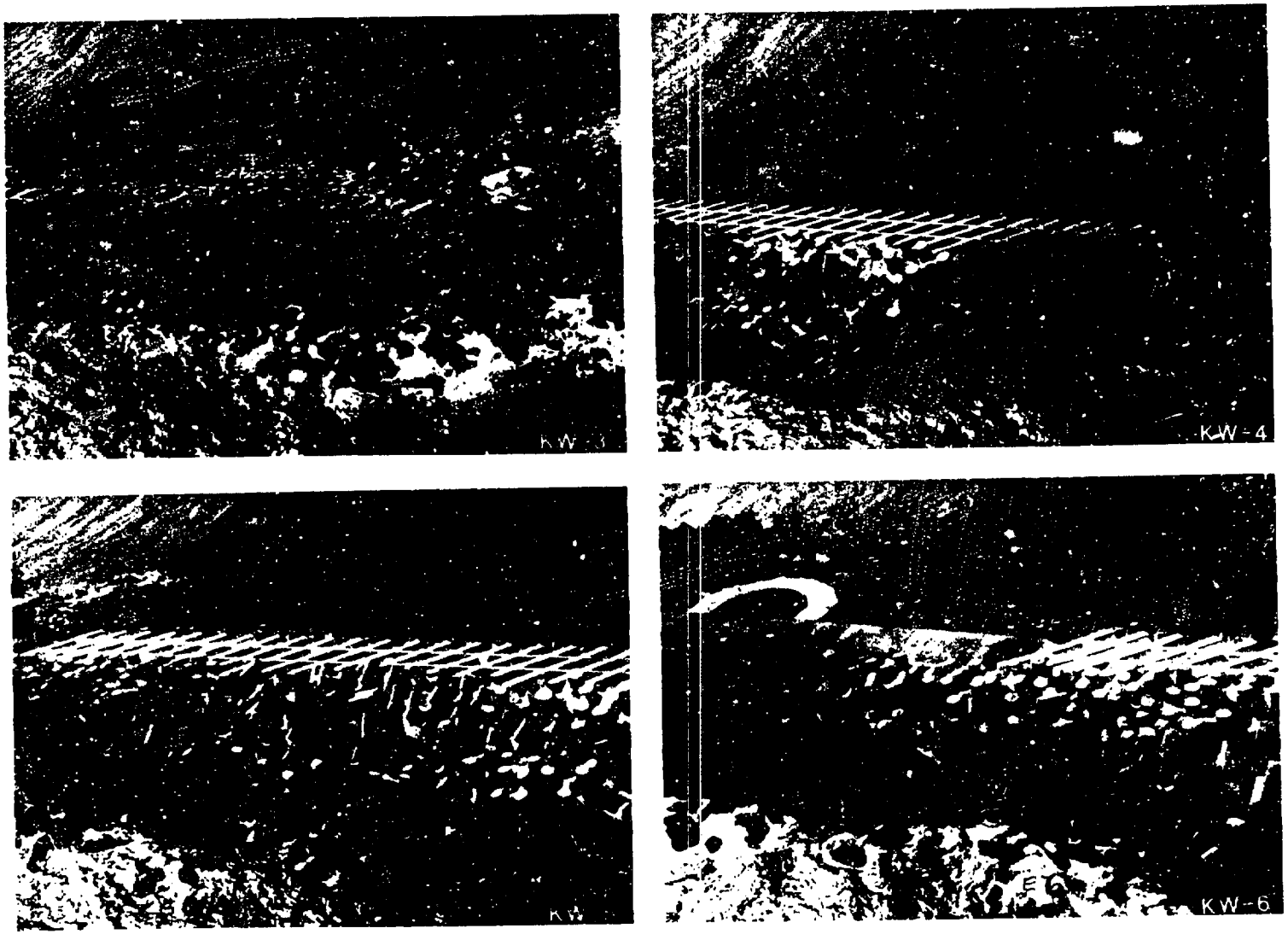


Figure C2. Kahului West breakwater 35-mm photographs from April 1992, KW-3 to KW-6

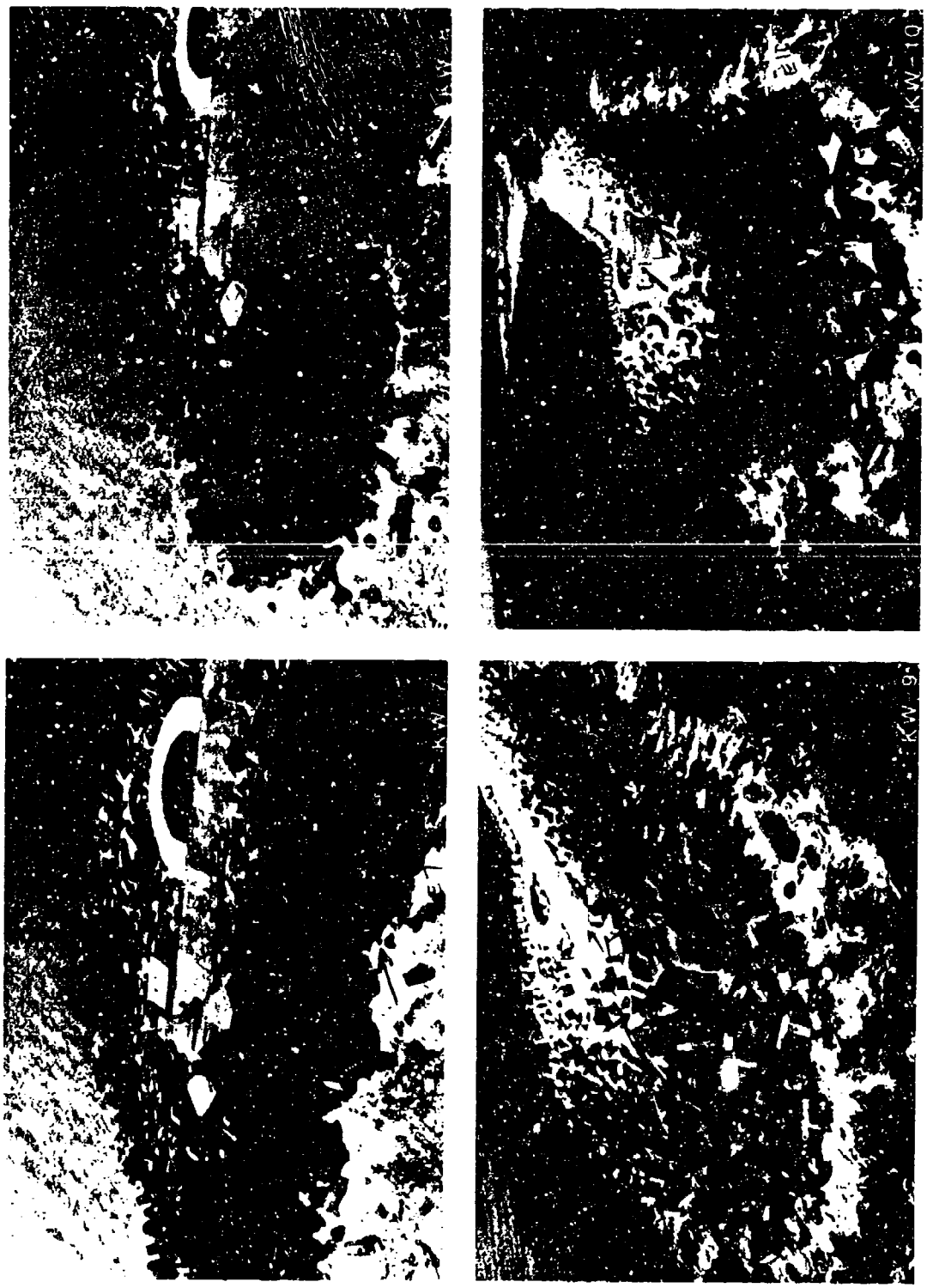


Figure C3. Kahului West breakwater 35-mm photographs from April 1992, KW-7 to KW-10

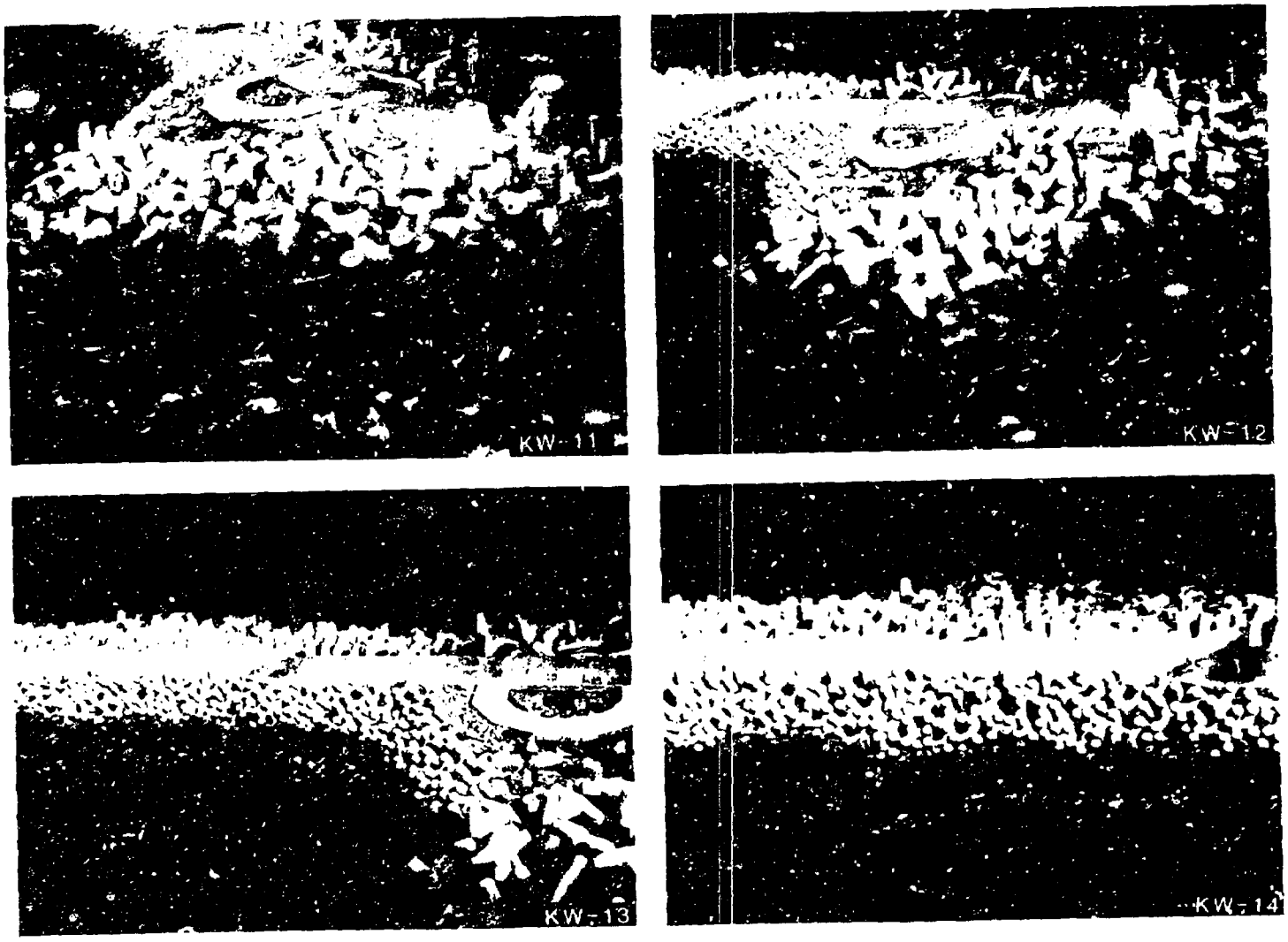


Figure C4. Kahului West breakwater 35-mm photographs from April 1992, KW-11 to KW-14

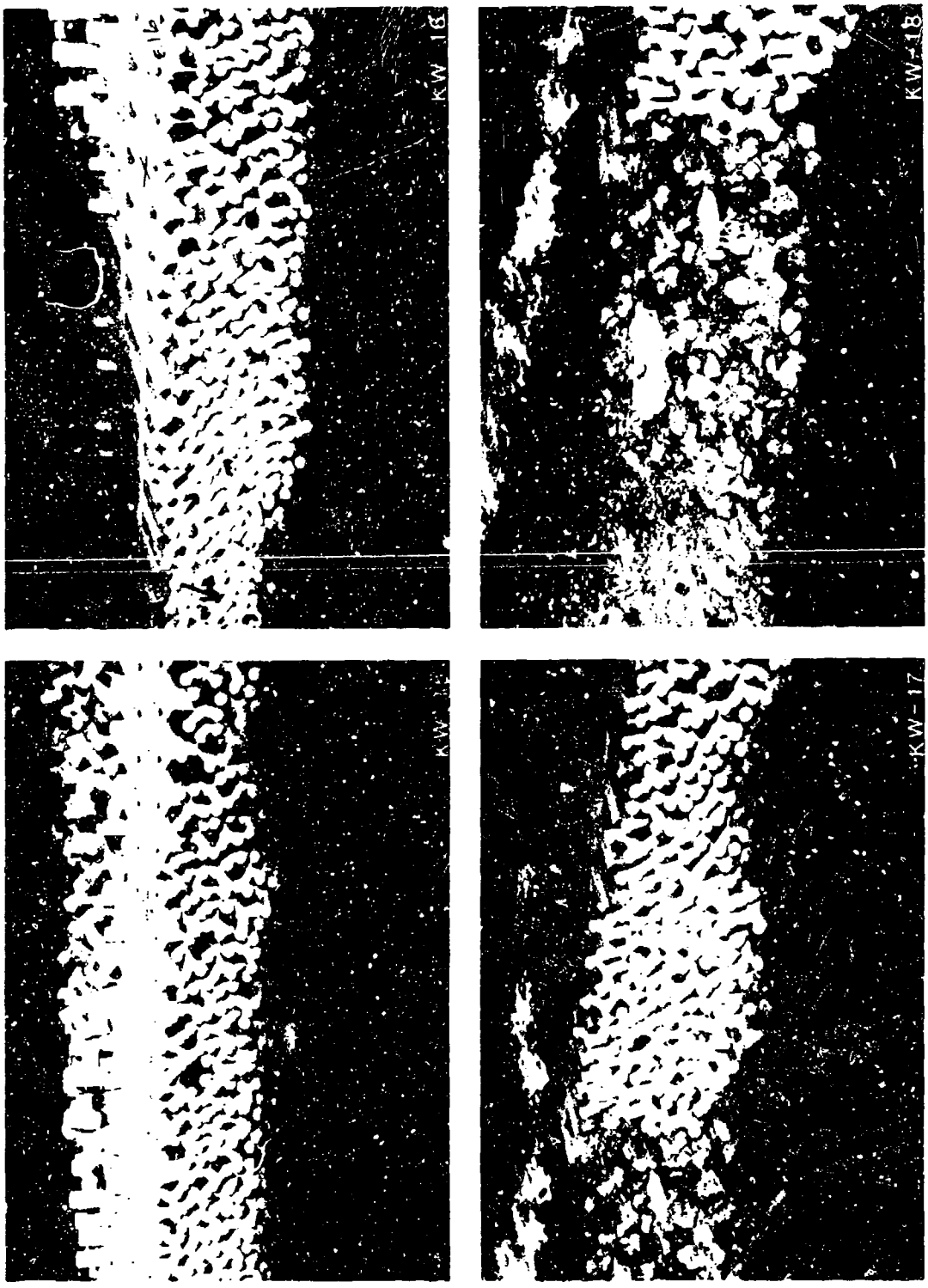


Figure C5. Kahului West breakwater 35-mm photographs from April 1992, KW-15 to KW-18

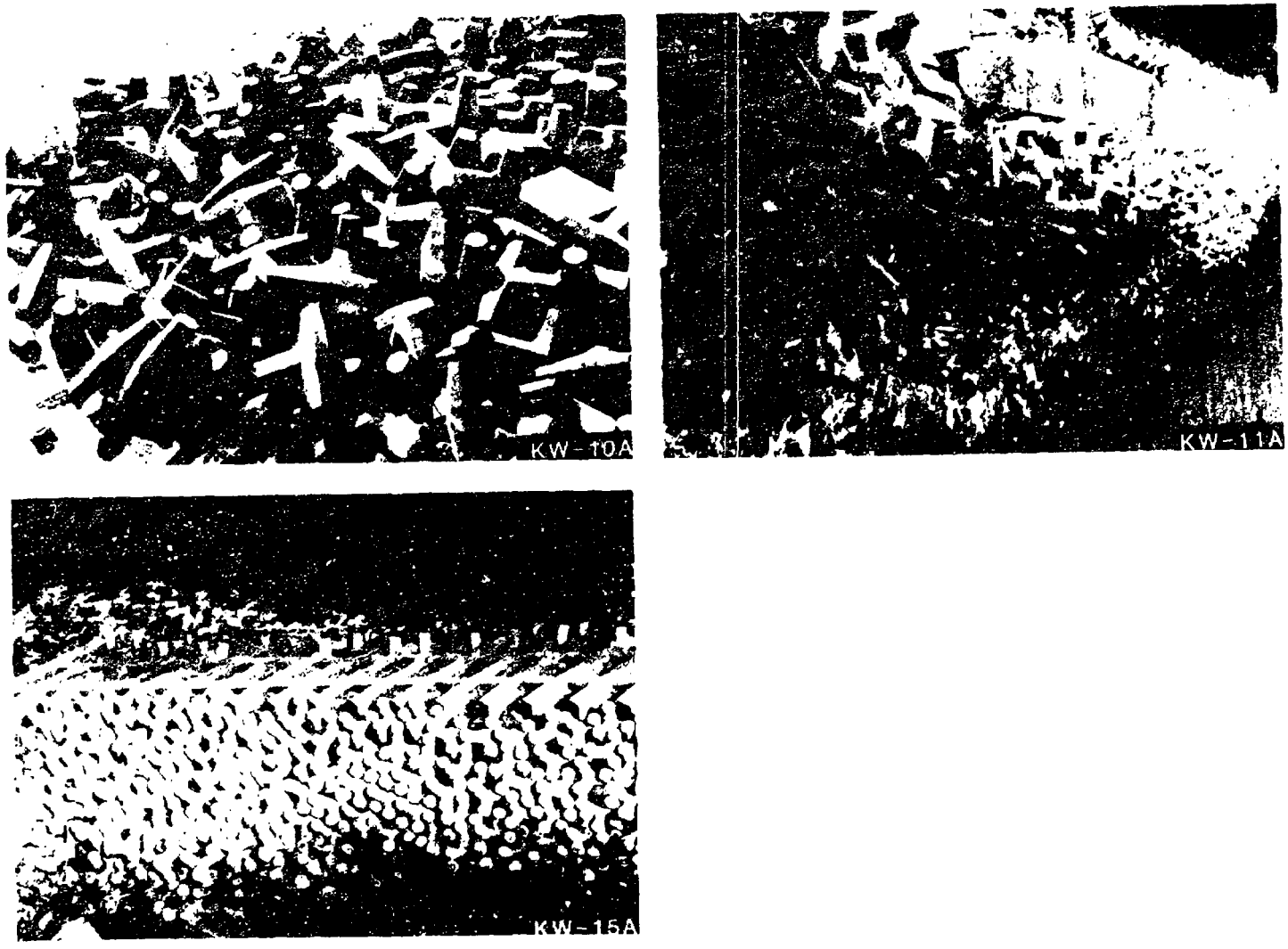


Figure C6. Kahului West breakwater 35-mm photographs from April 1992, KW-10A to KW-15A

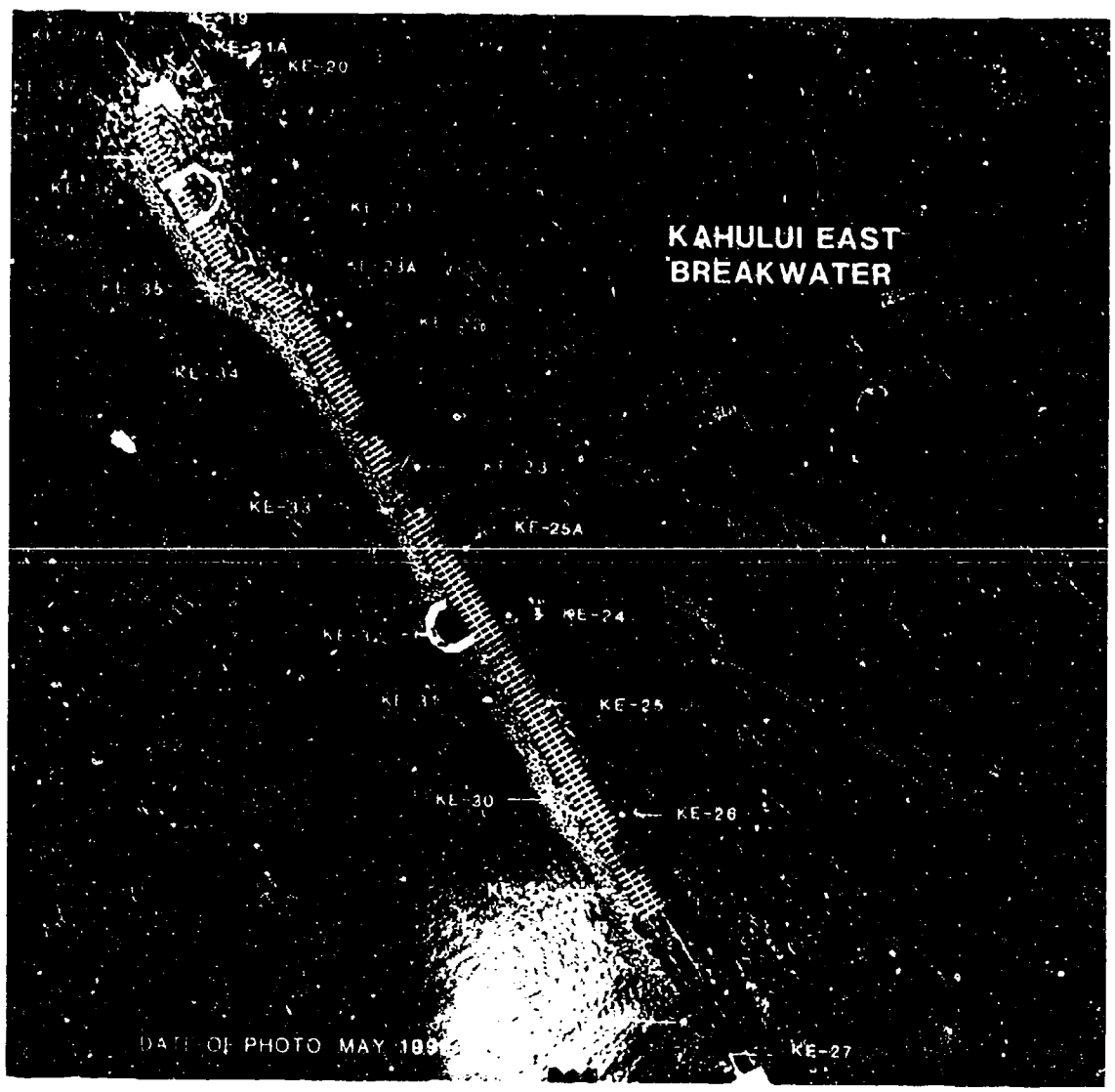


Figure C7. Aerial view of Kahului East breakwater showing locations of 35-mm photographs taken during April 1992 helicopter inspection

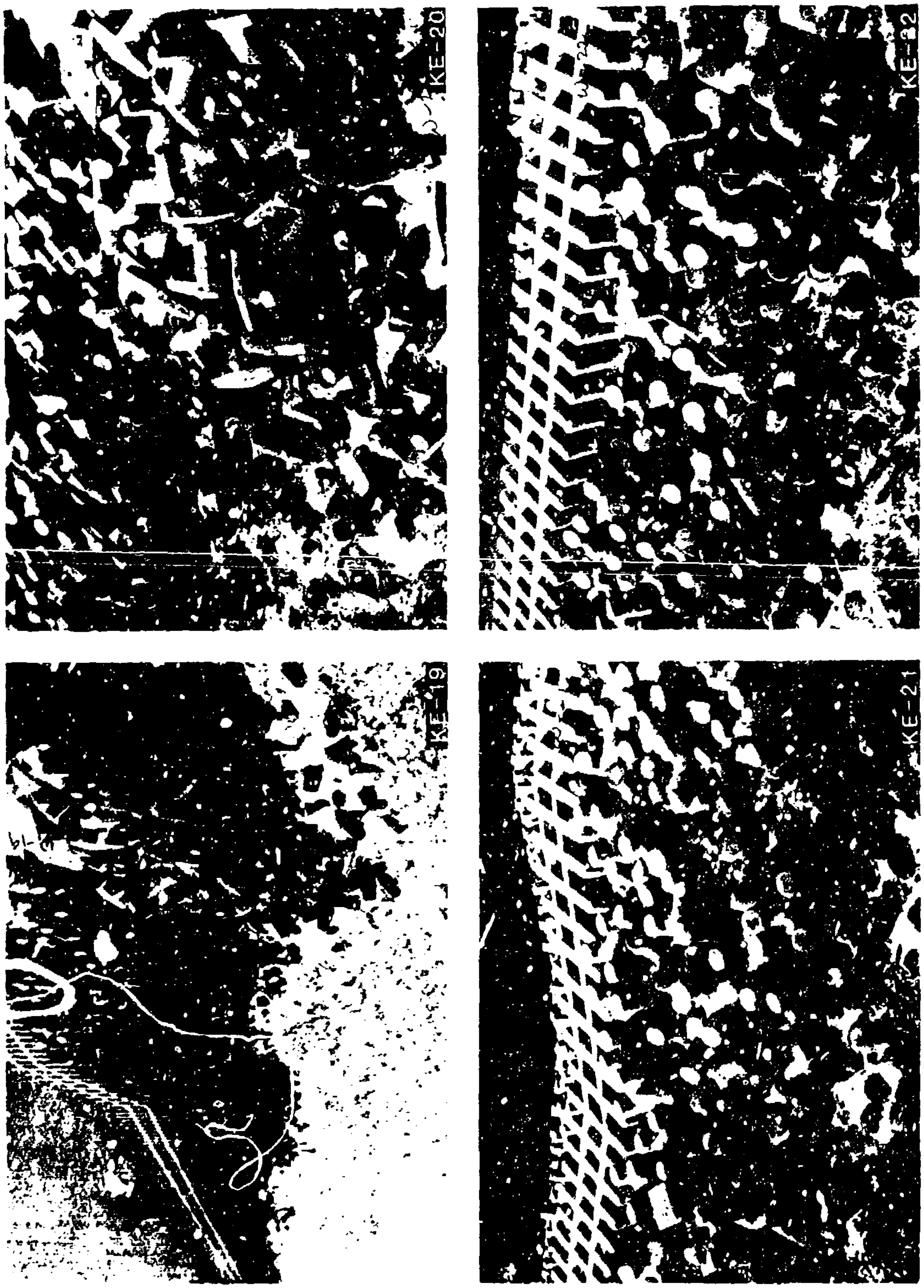


Figure C8. Kahului East breakwater 35-mm photographs from April 1992, KE-19 to KE-22

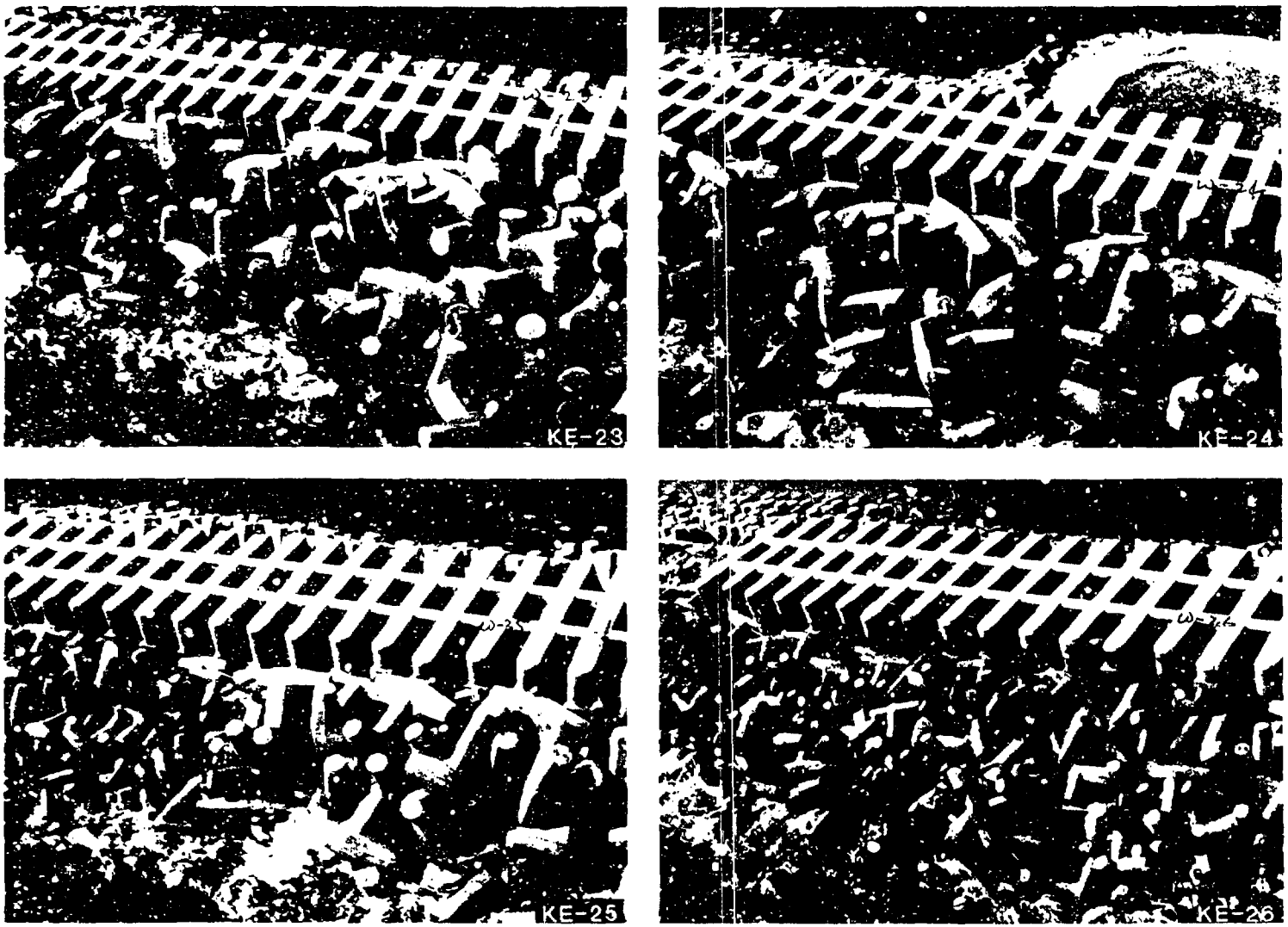


Figure C9. Kahului East breakwater 35-mm photographs from April 1992, KE-23 to KE-26

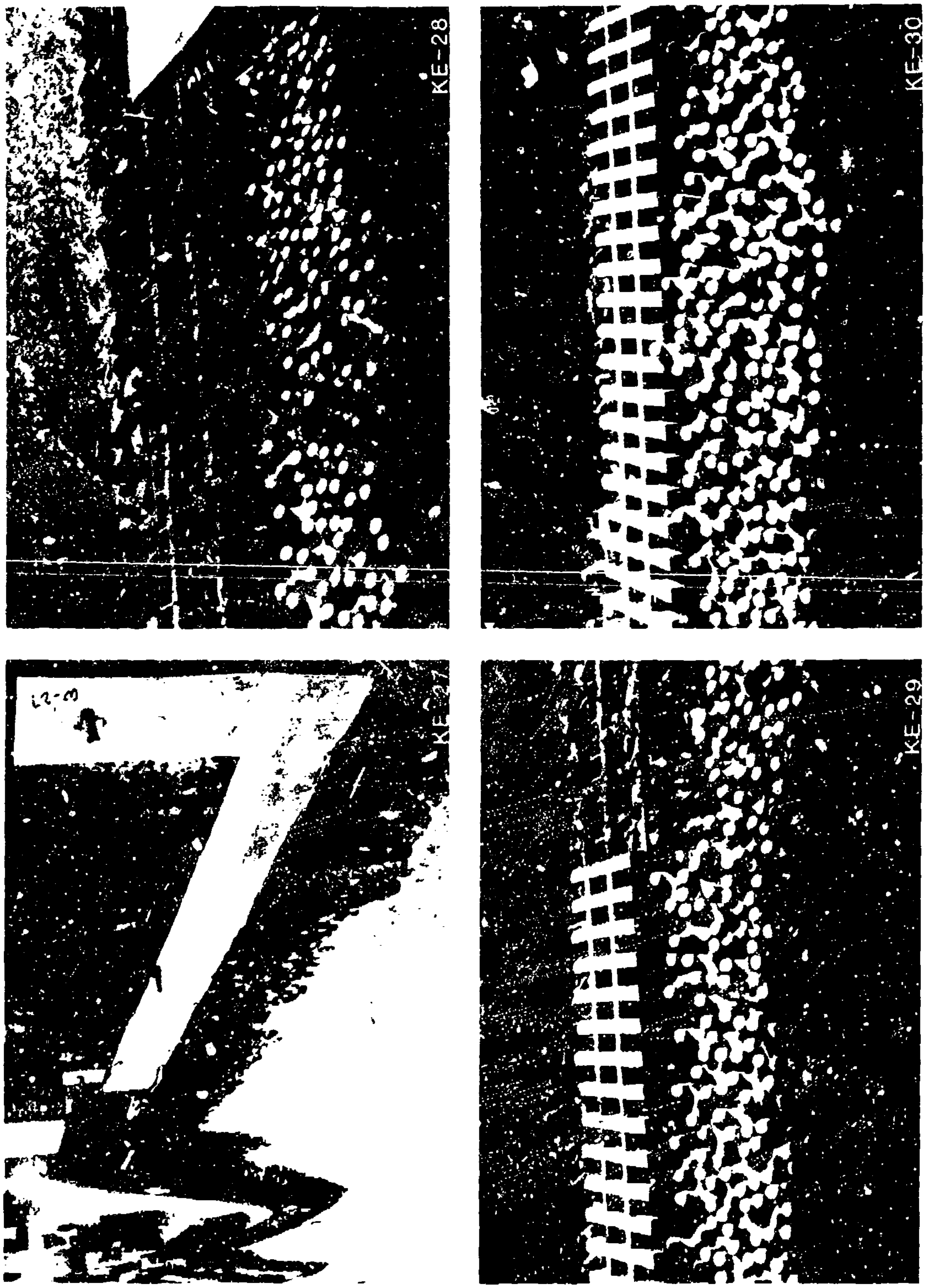


Figure C10. Kahului East breakwater 35-mm photographs from April 1992, KE-27 to KE-30

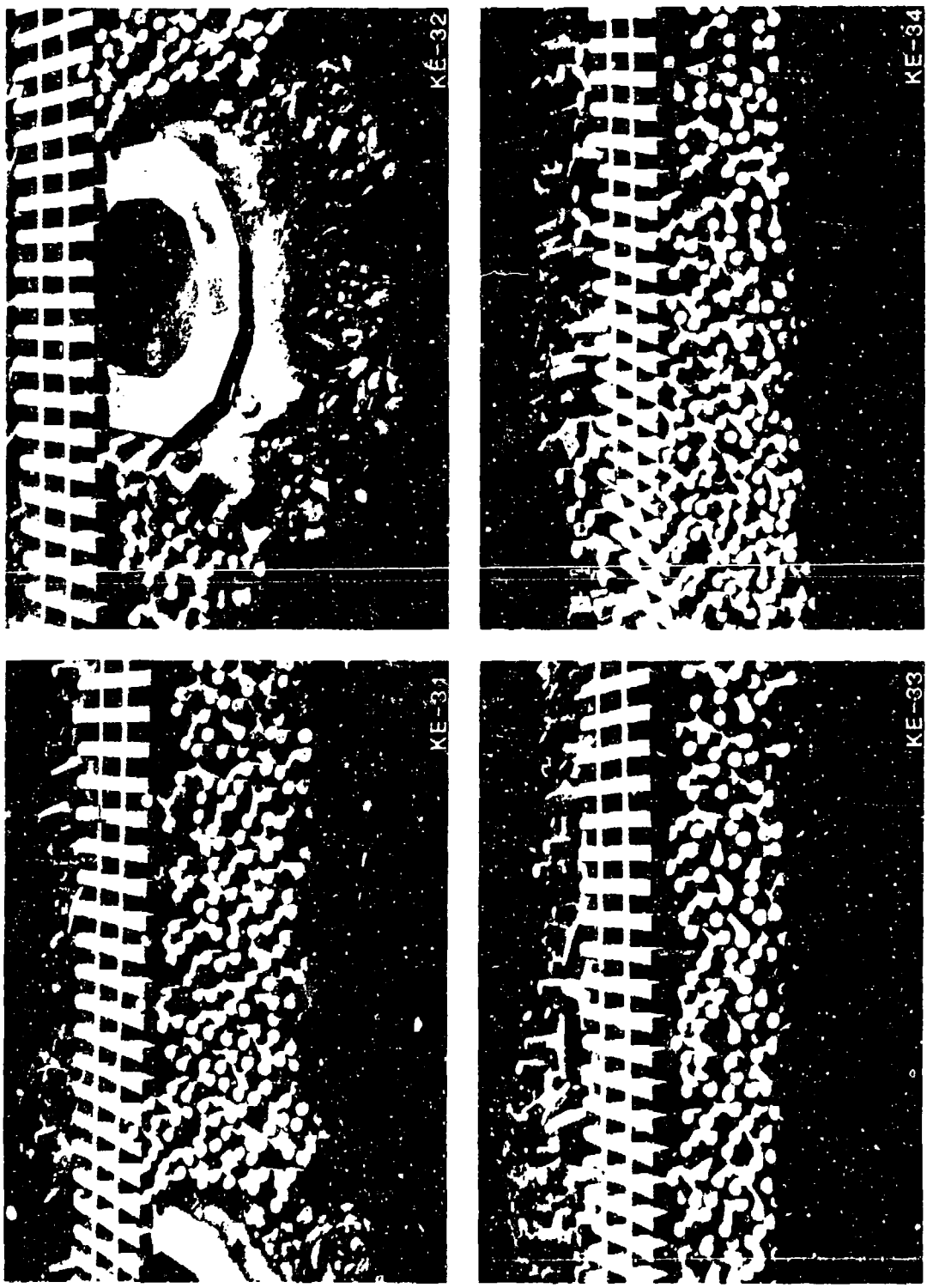


Figure C11. Kahuku East breakwater 35-mm photographs from April 1992, KE-31 to KE-34

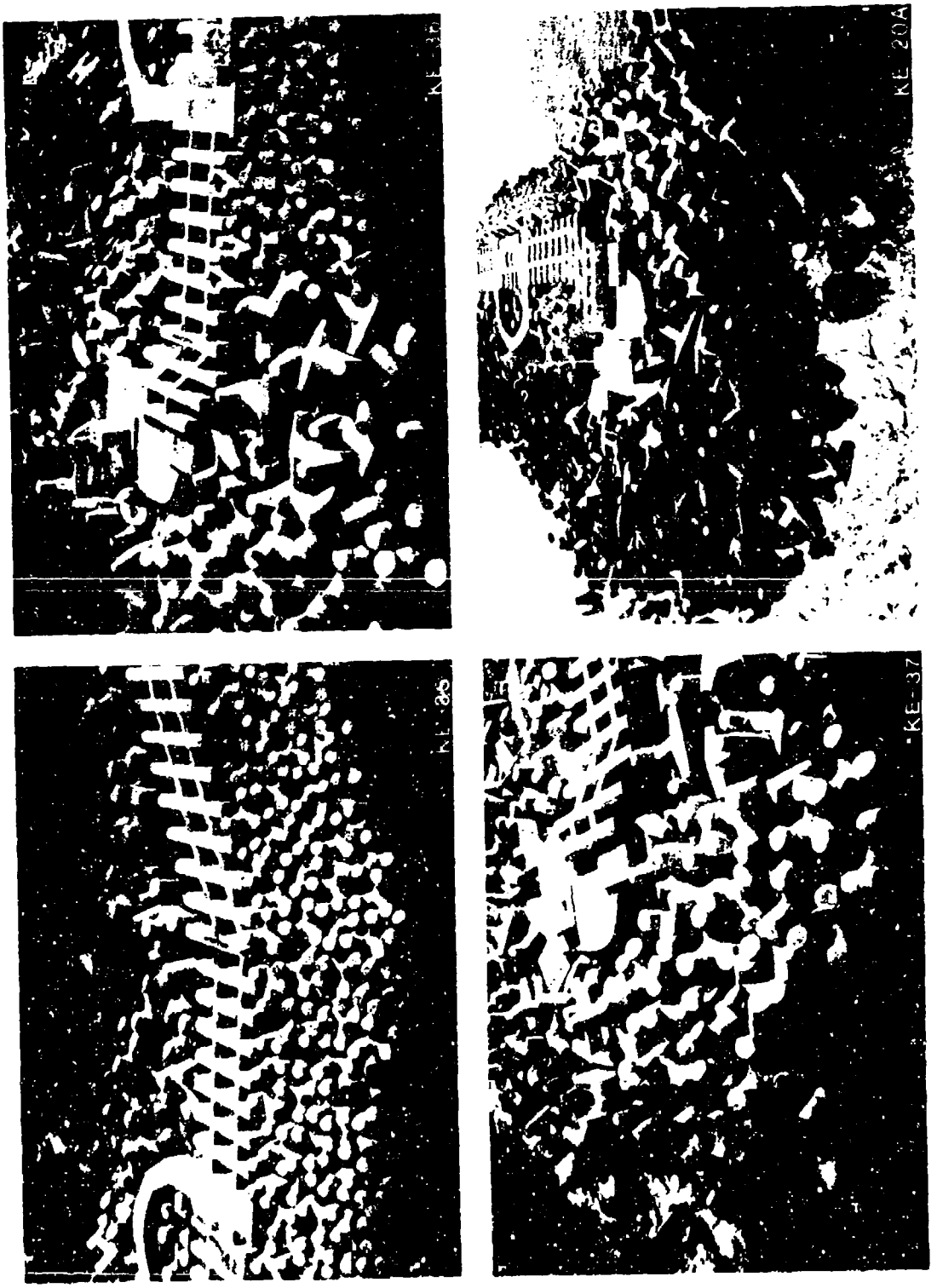


Figure C12. Kahului East breakwater 35-mm photographs from April 1992, KE-35 to KE-20A

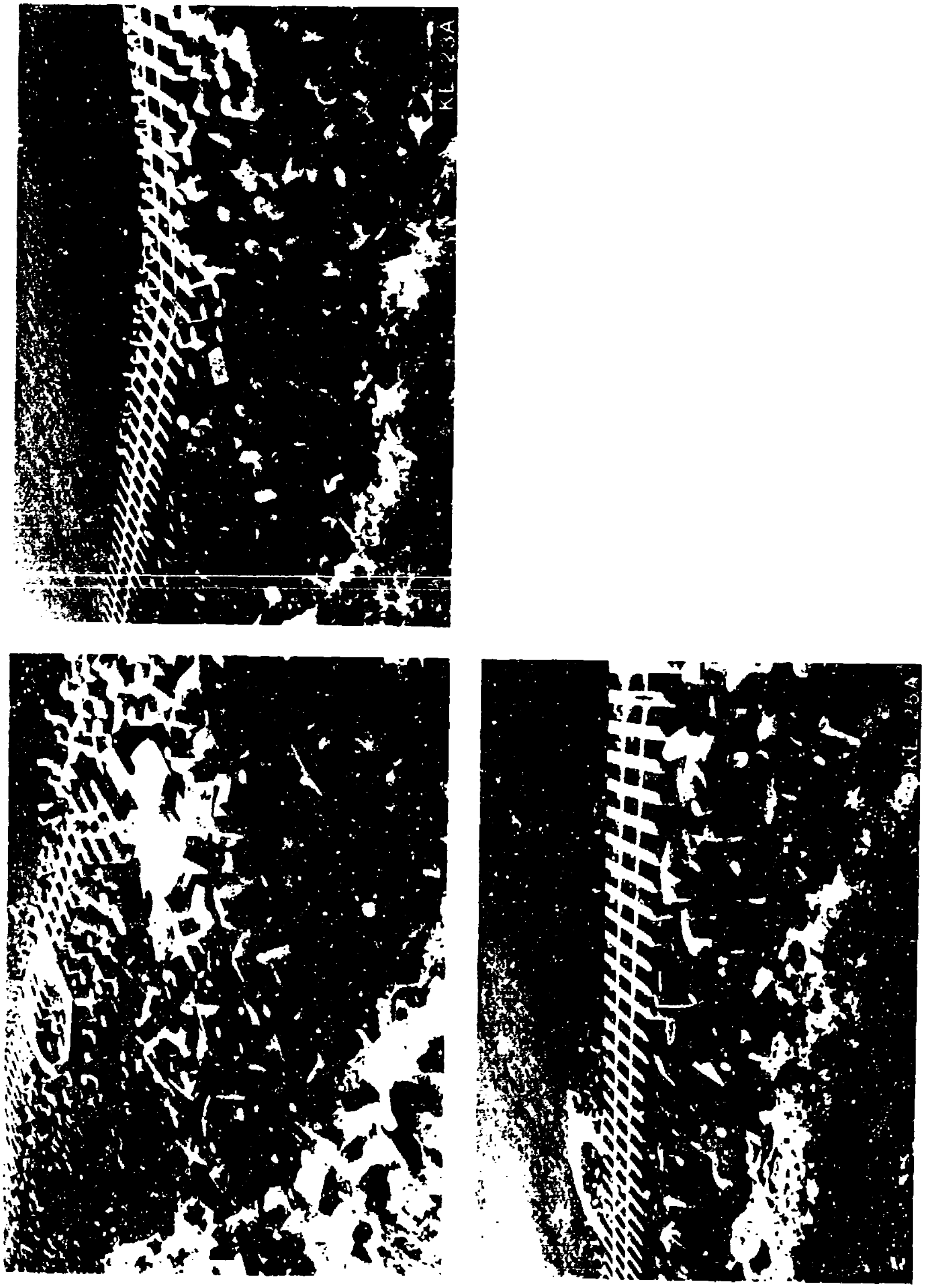


Figure C13. Kahului East breakwater 35-mm photographs from April 1992, KE-21A to KE-25A

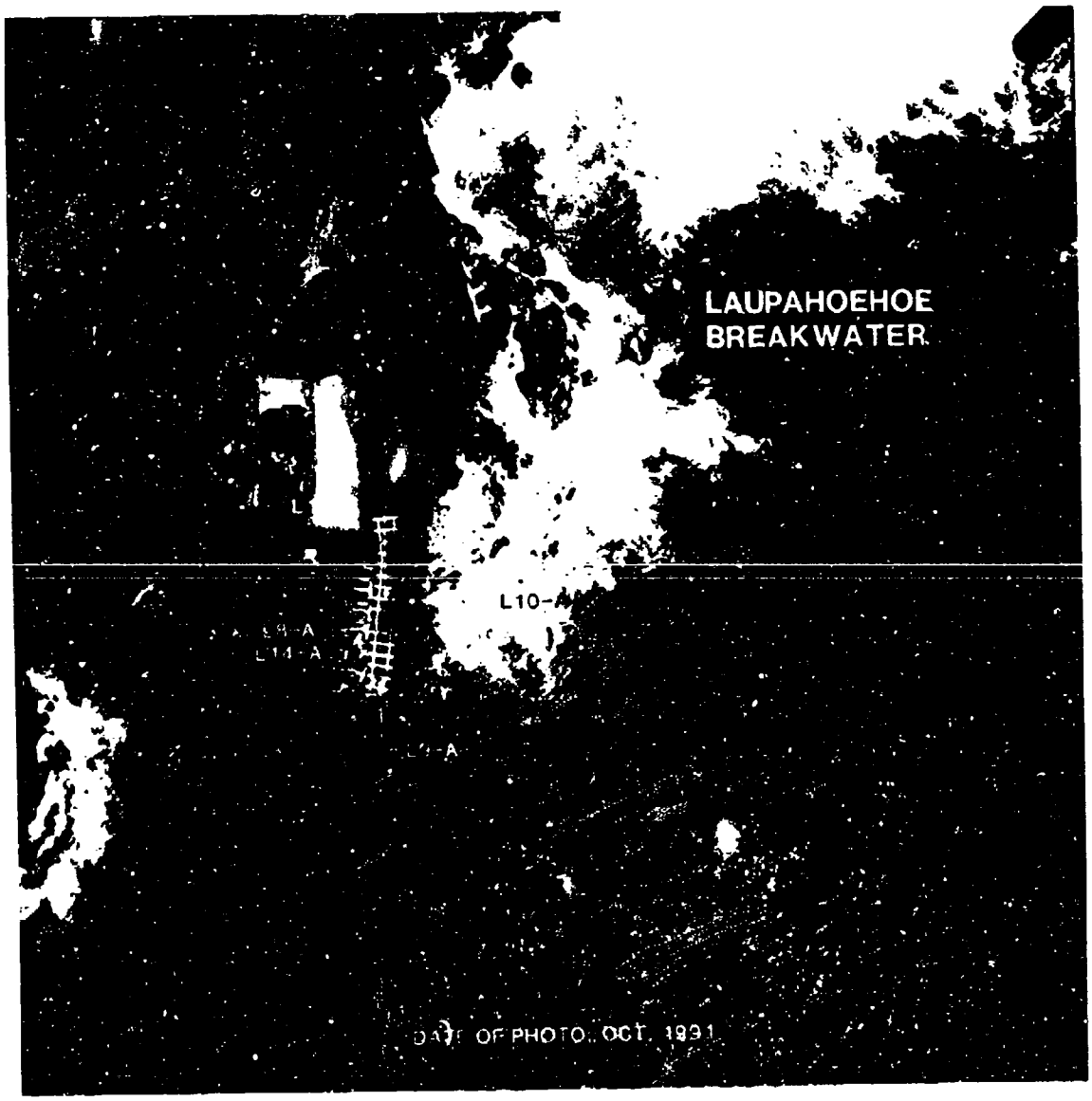


Figure C14. Aerial view of Laupahoehoe breakwater showing locations of 35-mm photographs taken during April 1992 inspection

Figure C15. Laupahoehoe breakwater 35-mm photographs from April 1992, L-8A to L-10A

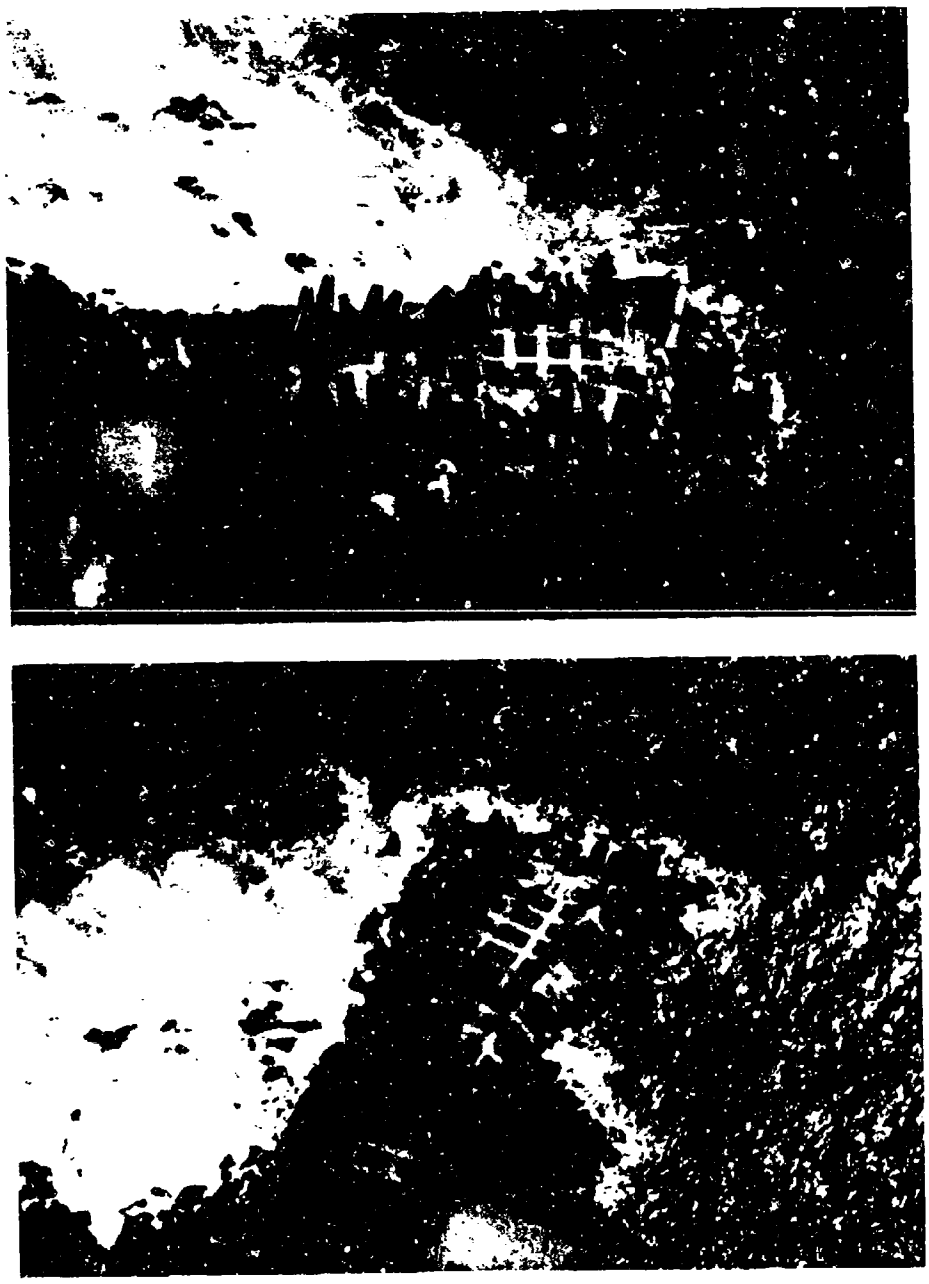


Figure C16. Laupahoehoe breakwater 35-mm photographs from April 1992, L-14A and L-15A

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1994	Final report

4. TITLE AND SUBTITLE
Periodic Inspections of Kahului and Laupahoehoe Breakwaters, Hawaii

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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U.S. Army Engineer Division, Pacific Ocean, Bldg. 230, Ft. Shafter, HI 96858-5440

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report CERC-94-12

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Under the Monitoring of Completed Coastal Projects (MCCP) work unit, Periodic Inspections, past MCCP structures and structures with unique design aspects that have probable applications to other projects are considered for inclusion in a periodic monitoring program. The emphasis of the work is to measure the long-term response of the above-water portions of the structures to their environment.

The rubble-mound breakwaters at Kahului Harbor, Maui, Hawaii, and Laupahoehoe Boat Launching Facility, Laupahoehoe Point, Hawaii, Hawaii, are armored with concrete armor unit and concrete rib caps. By means of limited land surveys, low-level helicopter inspections with 35-mm photography, aerial photography, and photogrammetric analysis base conditions have been established for the breakwaters.

Now that the base (control) conditions have been defined and a method has been developed to closely compare subsequent years of high-resolution aerial photography of the Kahului and Laupahoehoe breakwaters, these sites will be revisited during future years to gather data by which assessments can be made on the long-term response of the structures to their environment. Insight gathered from these efforts will allow definite decisions to be made based on sound data as to whether or not closer surveillance and/or repair of a structure is required to reduce the chance that it will fail catastrophically.

14. SUBJECT TERMS

Armor stability	Photography
Breakwaters	Rubble mound
Photogrammetry	Surveying

15. NUMBER OF PAGES
90

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		