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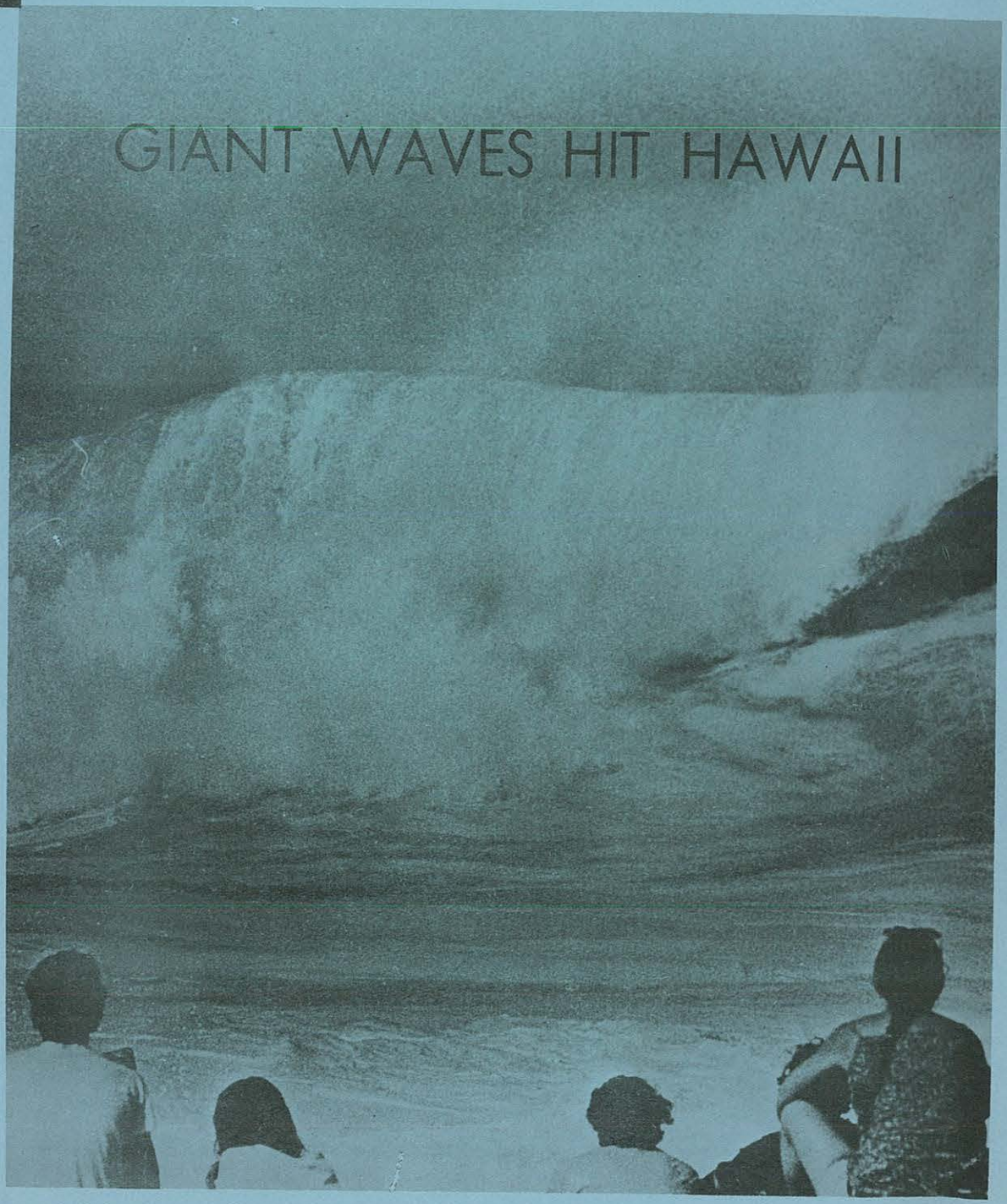
Environmental Science Services Administration
Weather Bureau



GIANT WAVES HIT HAWAII

PACIFIC REGION
HONOLULU,
HAWAII

September 1970

The Honolulu Advertiser

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GEORGE CHAPLIN *Editor*
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shining service

The Weather Bureau deserves a big pat on the back for its accurate forecasting of the destructive and deadly waves that hit the Islands this week.

Utilizing new techniques in the forecasting of ocean swells and sea conditions, the Weather Bureau Sunday morning issued an alert, predicting 30- to 40-foot surf by Monday.

The high waves struck only a few hours after the predicted time.

The warnings — updated every six hours — were distributed by telephone and teletype to the news media, public agencies and utilities firms.

A Weather Bureau spokesman said the newly intensified marine weather program went into effect shortly before the development of the big storm that caused the high surf.

Weather Bureau personnel modestly state they were only doing their job, but a grateful public says "Well done!"

The Honolulu Advertiser

December 4, 1969

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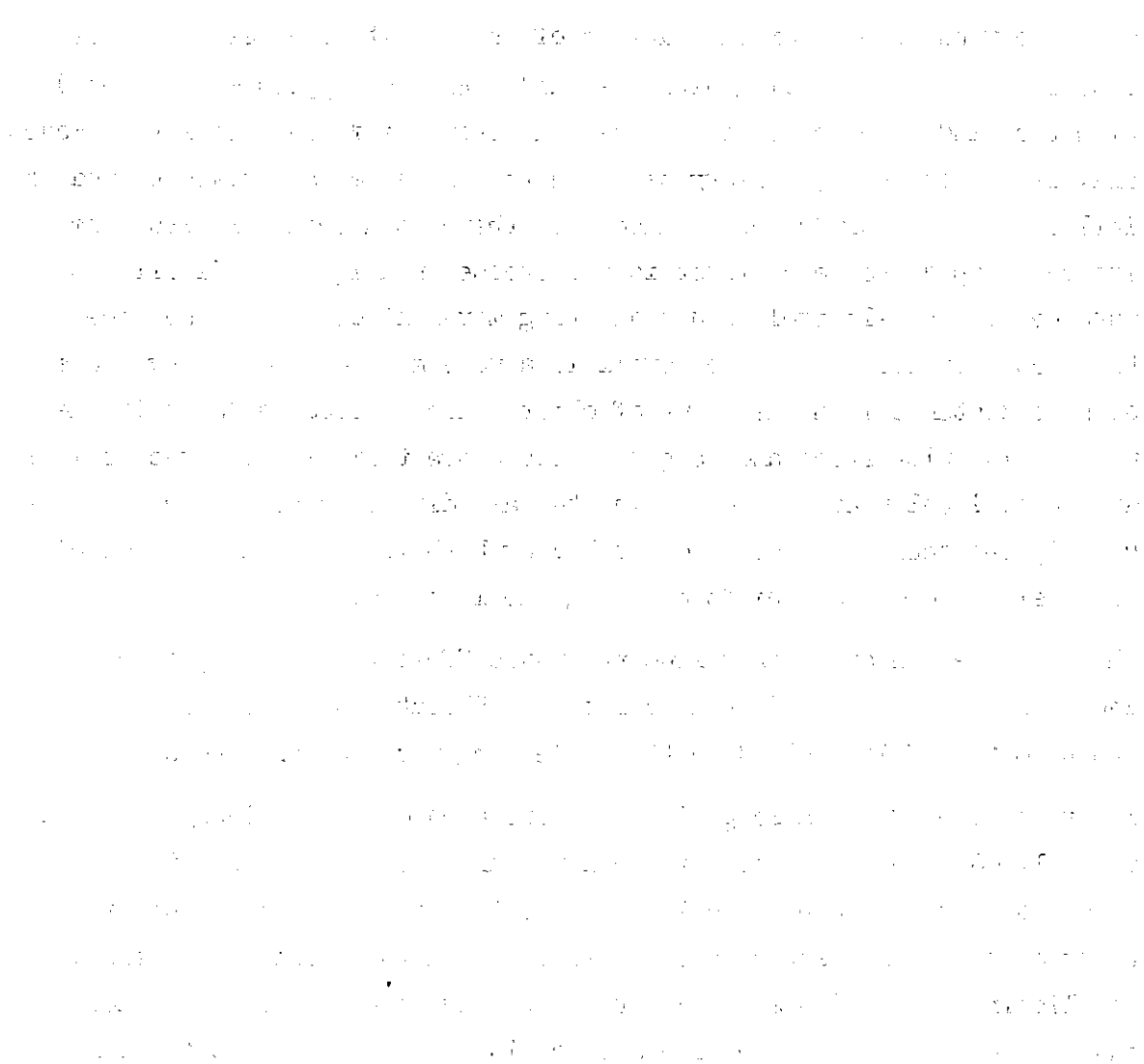
FOREWORD

When the wind blows over the surface of the sea it produces, at first, a series of ripples moving with the wind. As the ripples move forward with the wind they increase in size. A strong wind produces larger waves and, if it continues, a heavy sea results. After a wave moves beyond the influence of the winds which caused it, there is a change in its form. The most rapid change at first is a decrease in height and finally the wave becomes a relatively low undulating movement of the sea surface known as a swell. Therefore, swell is a wave motion produced by winds at some distance from the point of observation whereas a "sea" is the wave motion with steep and ragged crests characteristic of waves actively driven by local winds and moves in the same direction as the local winds. Usually the ocean surface is disturbed by both forms of wave motion with the swell from distant winds crossing the local sea.

When the swell nears a shoreline the waves "feel the bottom", slow down, grow in height and then collapse or "break" on the shore or reef. The term "surf" is applied to the collapsing waves or "breakers".

Early on November 30 a large low pressure area drifting slowly eastward about 1,500 miles northwest of the Hawaiian Islands, and carrying winds of 45 to 60 miles an hour in its southwest quadrant, sent unusually heavy ocean swell crashing against exposed coasts of all the islands, demolishing seaboard homes and parks, eroding beaches and shorelines, and leaving behind 1 death, a number of injuries and damages totaling over $1.5 million.



GIANT WAVES HIT HAWAII

I. GENERATION OF THE WAVES

During the last week in November 1969, a surface low pressure center developing east of Japan began to move eastward and by the end of the month had become almost stationary about 1,500 miles north-northeast of the Hawaiian Islands. By this time it had become a deep system covering most of the eastern Pacific north of the Hawaiian Islands to the Aleutian chain with winds over the southwestern quadrant averaging from 40 to 60 knots (Fig. 1).

On November 30, seas in the southwestern quadrant were calculated to have reached heights of from 30 to 40 feet.

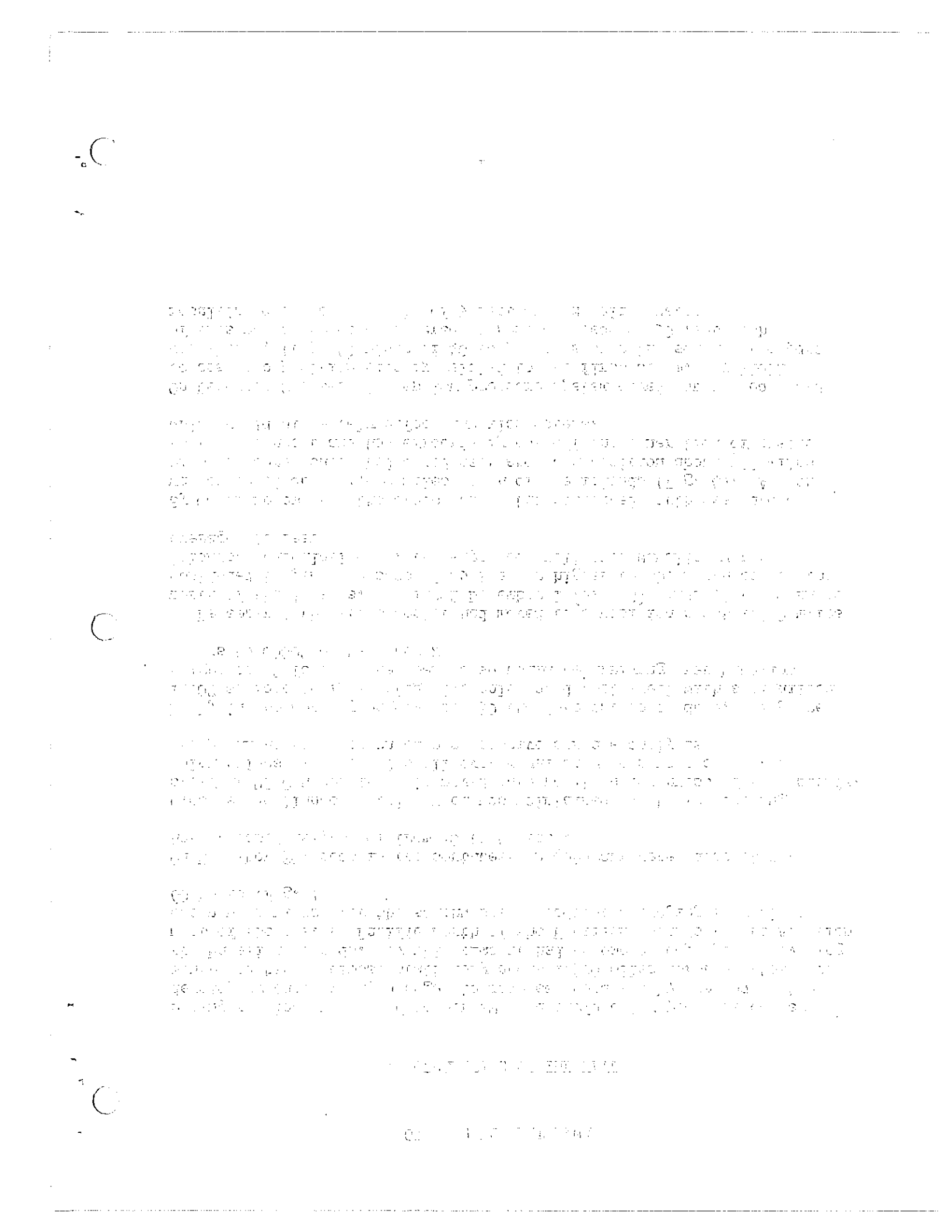
Close surveillance of this system was maintained by the forecasting staff at WBFO Honolulu as it moved into position northwest of the islands. Calculations of expected swell over Hawaiian waters were completed every six hours based on each successive surface analysis.

Early in the morning on November 30 the forecasters on duty, using the 1200Z surface analysis (Fig. 2), calculated that swell with a significant height of 18 feet in the open ocean would be arriving over Hawaiian waters by 0000Z on December 2.

On December 1 the storm center had moved to a position about 1,300 miles north of the Islands. At 1200Z December 1 (Fig. 3) winds 30 to 40 knots continued to generate seas of 25 feet or higher to the northwest of the Islands. Calculations of the expected swell over Hawaiian waters averaged 16 feet.

By 0000Z December 2 the storm center had continued north eastward and was situated about 1,600 miles north of the islands (Fig. 4). A weak high pressure center had moved eastward to a position about 900 miles to the northwest and had effectively cut off the generation of swells which would ultimately affect Hawaiian waters.

On December 2 a second deep low pressure system moved rapidly eastward to assume a position closely related to the first storm. By 1200Z December 2, (Fig. 5) winds of 40 to 50 knots over the southwest quadrant of this new storm were expected to generate seas of 30 feet with resulting deep water swells of 9 feet over Hawaiian waters.



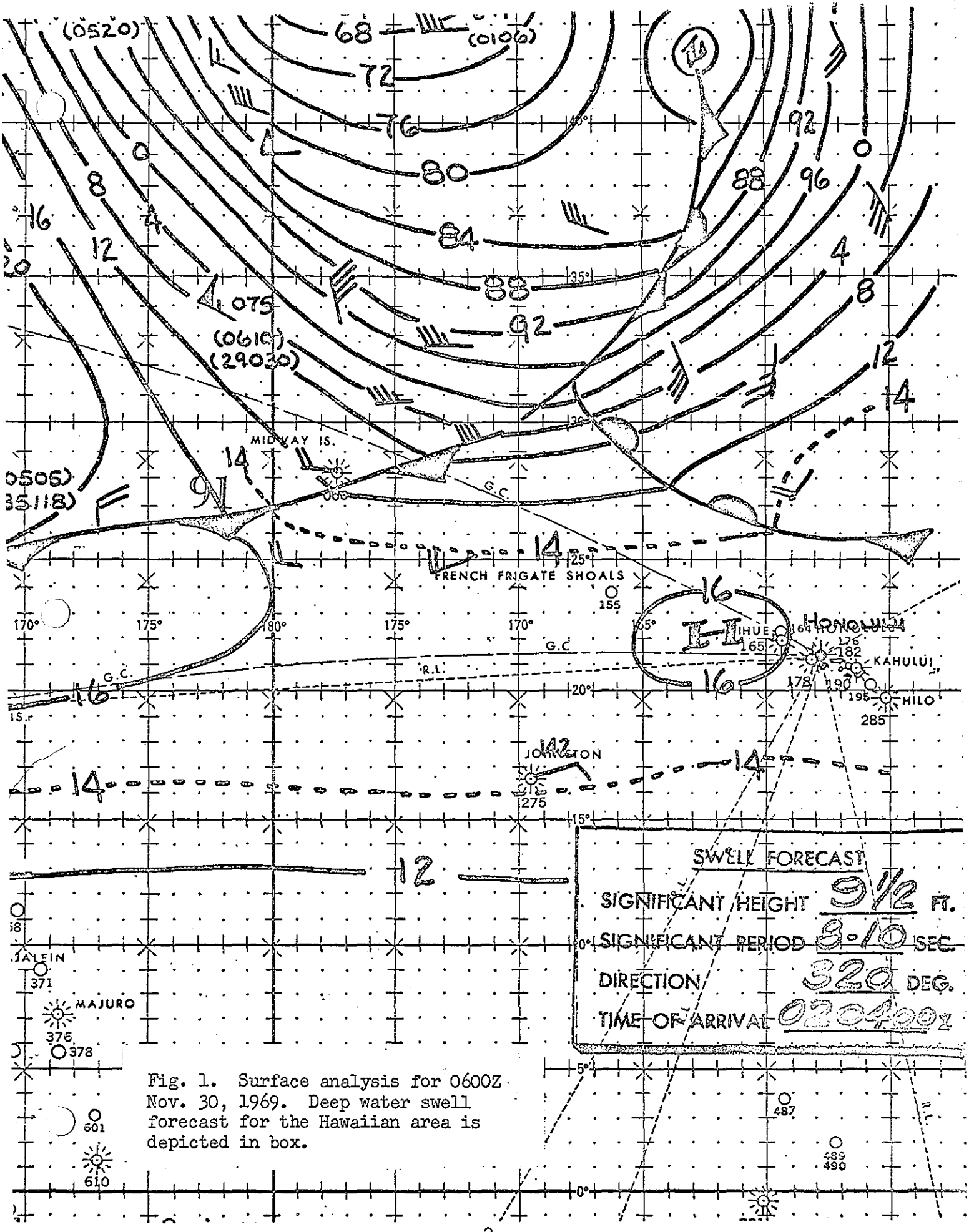


Fig. 1. Surface analysis for 0600Z Nov. 30, 1969. Deep water swell forecast for the Hawaiian area is depicted in box.

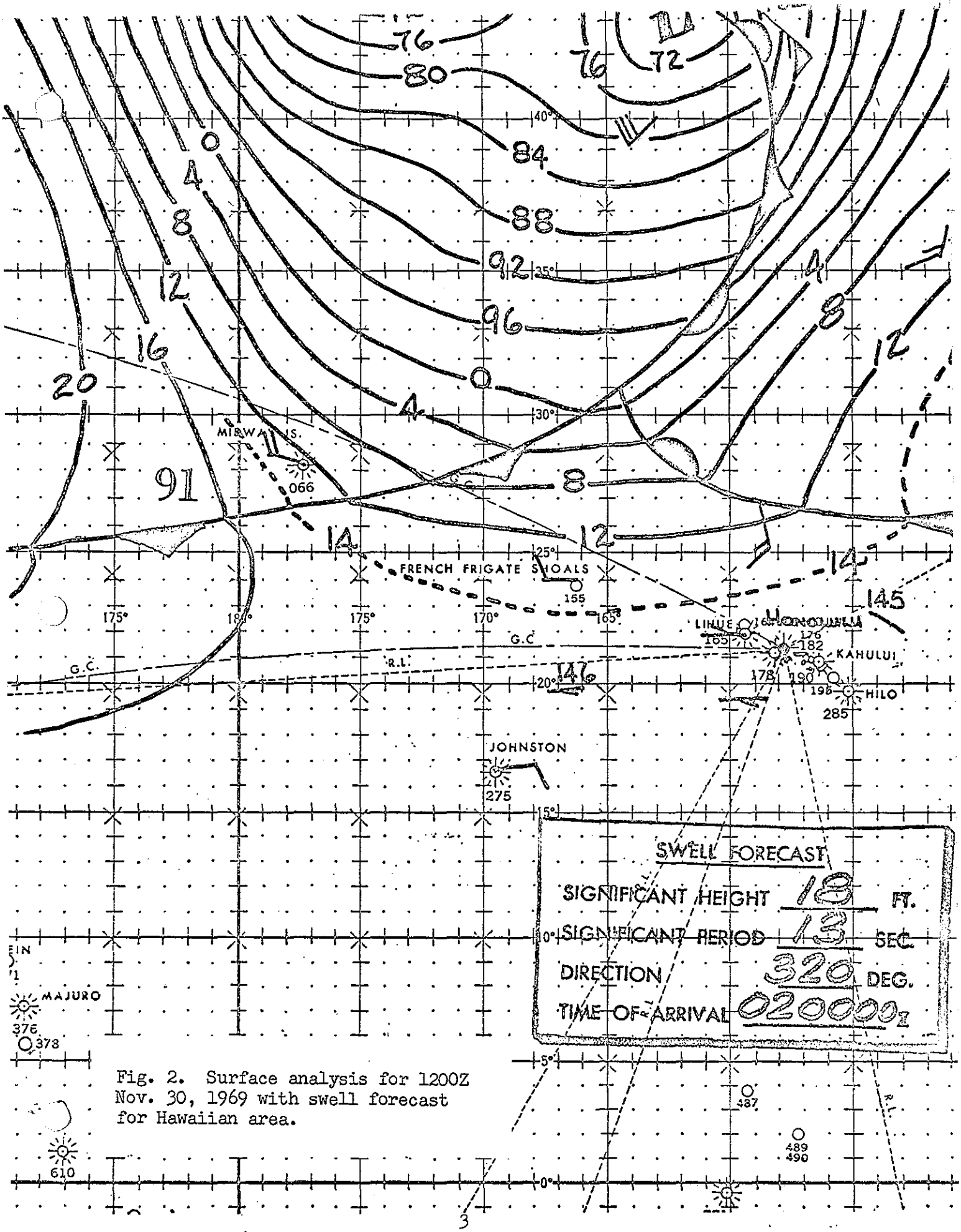


Fig. 2. Surface analysis for 1200Z Nov. 30, 1969 with swell forecast for Hawaiian area.

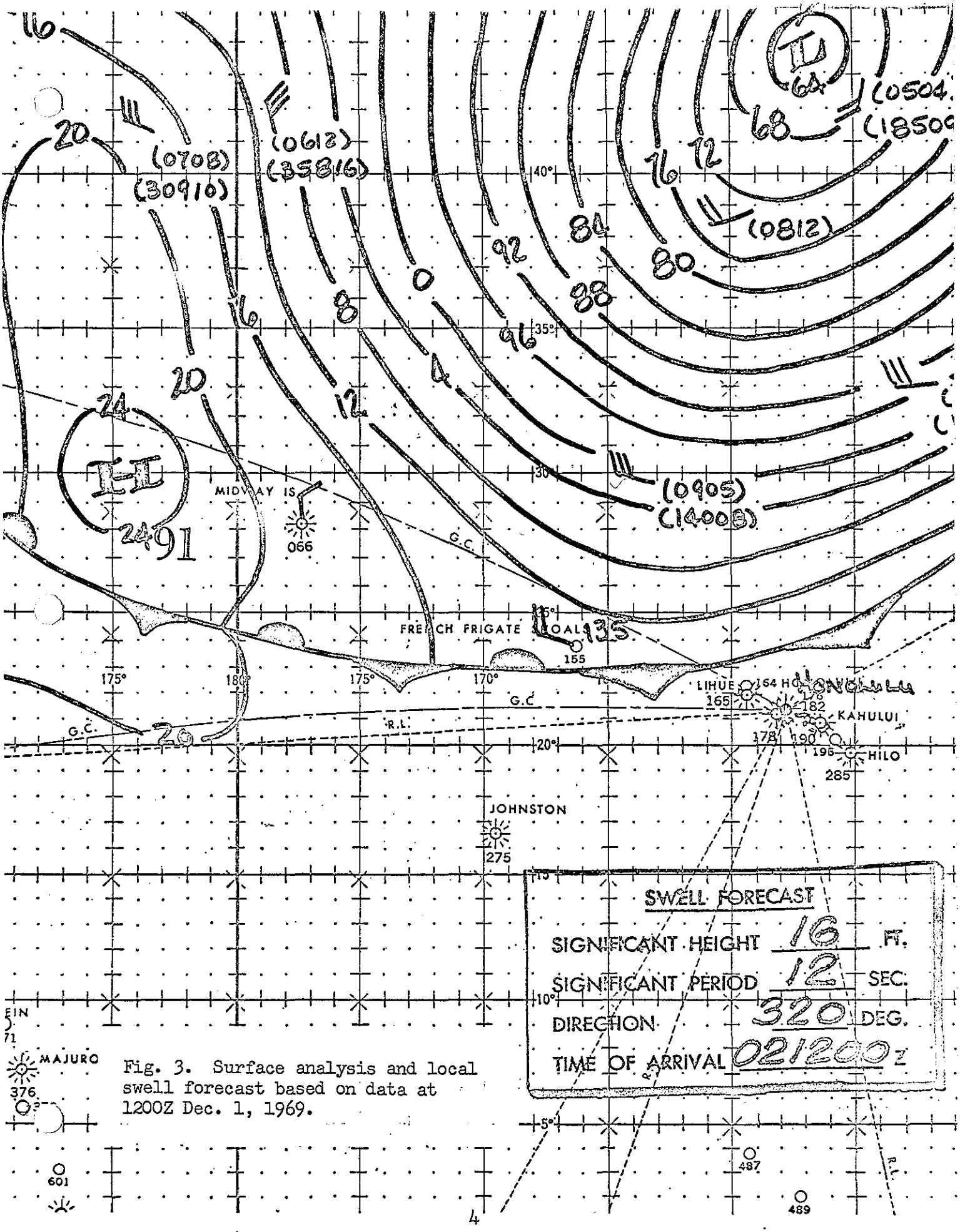


Fig. 3. Surface analysis and local swell forecast based on data at 1200Z Dec. 1, 1969.

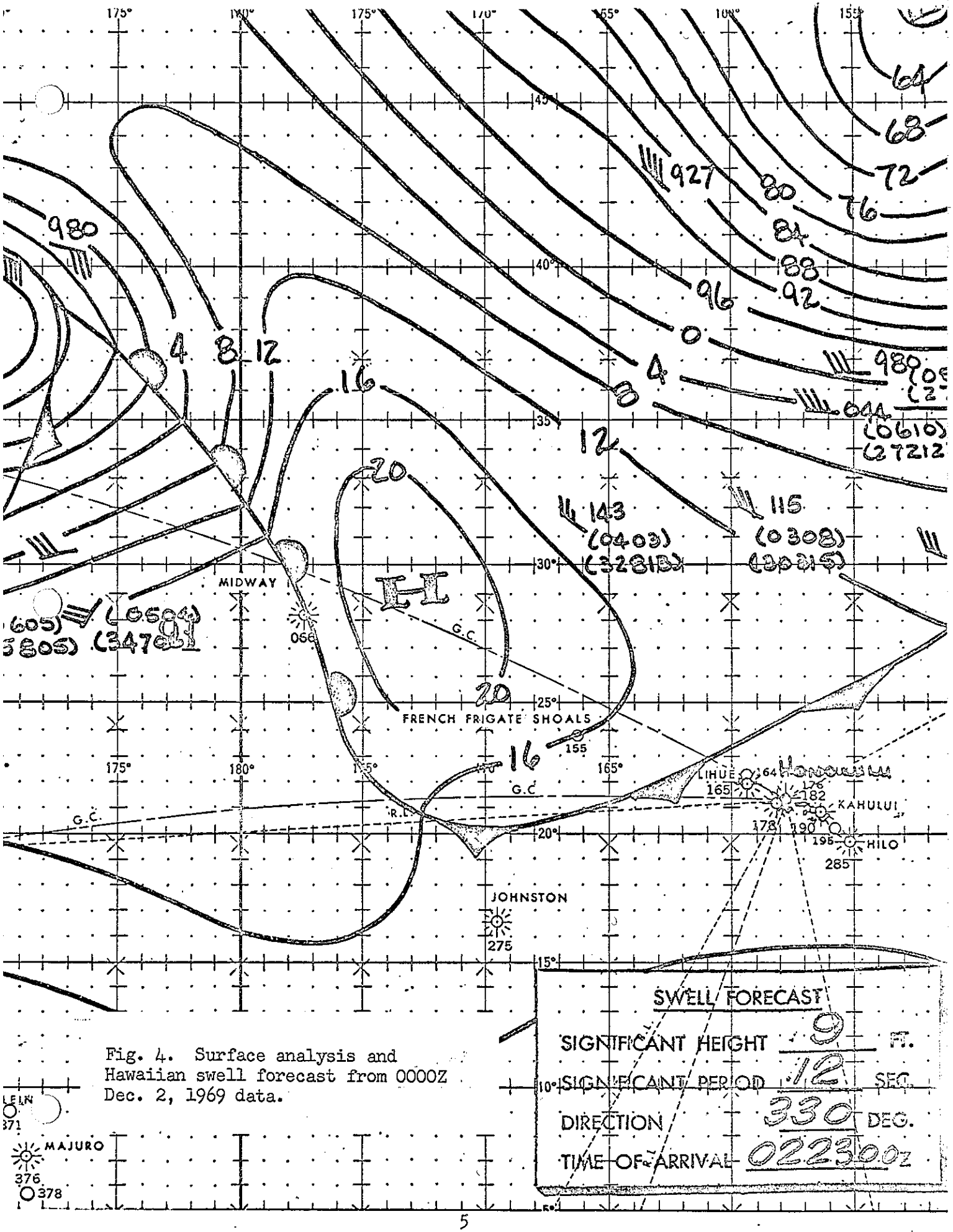


Fig. 4. Surface analysis and Hawaiian swell forecast from 0000Z Dec. 2, 1969 data.

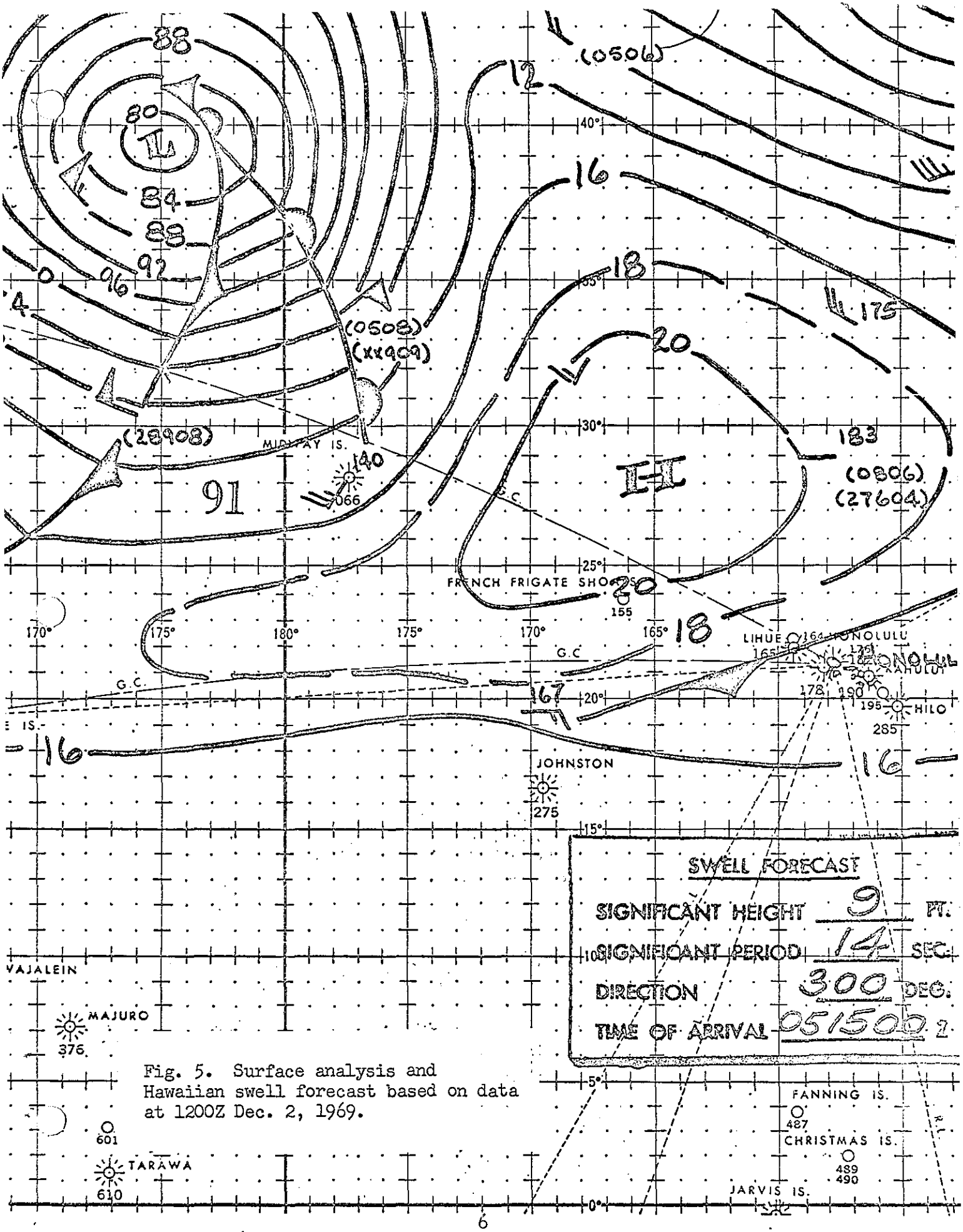


Fig. 5. Surface analysis and Hawaiian swell forecast based on data at 1200Z Dec. 2, 1969.

This new system continued to move rapidly eastward and at 0600Z December 3, was located approximately 800 miles to the northwest of the Island chain (Fig. 6). Winds over the generation area continued to average 40 to 50 knots and, as a result, local swells were expected to continue as high as 12 feet.

On December 4 the storm center began a more northerly track and by 1200Z was located 1,200 miles north of the Islands (Fig. 7). A high pressure ridge developing northwest of Hawaii continued to build in intensity and by 0000Z December 5, (Fig. 8), had cut off the generation of swells which would affect the Hawaiian Island chain.

II. THE ARRIVAL OF THE SWELL

The storm swell reached Kauai, northernmost of the Hawaiian Islands, during the afternoon of December 1 with waves reported up to 30 feet high. At Polihale Beach Park on the northshore, beach facilities and the access road were damaged and the beach severely eroded. On Kauai's west coast seas sweeping nearly 600 feet inland washed a foot deep into 15 homes under construction just north of Kokole Point, and left splash marks under the eaves of several located 350 feet inland and about 18½ feet above sea level.

The waves struck Oahu soon after dark on the 1st, pounding hardest at the well populated 12-mile stretch of northwest-facing coastline between Waialua Bay and Kawela Bay. Sunset Beach was battered worst, and its Ke Iki Road residential area virtually wiped out when waves, some of them estimated at 40 to 50 feet in height, and described as the largest in local memory, topped a heavily built-on 25-foot rise, demolishing 14 homes, crushing some, smashing others against utility poles and one another, and - of a few - leaving nothing behind but scattered appliances and timbers. Eight other houses and six cottages and their contents suffered lesser damage in the same onslaught. In the dip inland of the rise, water up to 6 feet deep inundated 12 homes and a number of parked cars. Losses in the Ke Iki Road area alone amounted to about $535,000 - almost half the $1.27 million total for all Oahu.

In the small boat harbor at Haleiwa boulders were torn from the breakwater and groin and 16 boats varying in length from 15 to 52 feet beached, battered, or sunk. Water covered an adjoining parking lot (3 to 4 feet above sea level) to a depth of 5 feet and heavily damaged 6 businesses and 4 automobiles in the area. Losses in and about the boat harbor were estimated at $324,000.

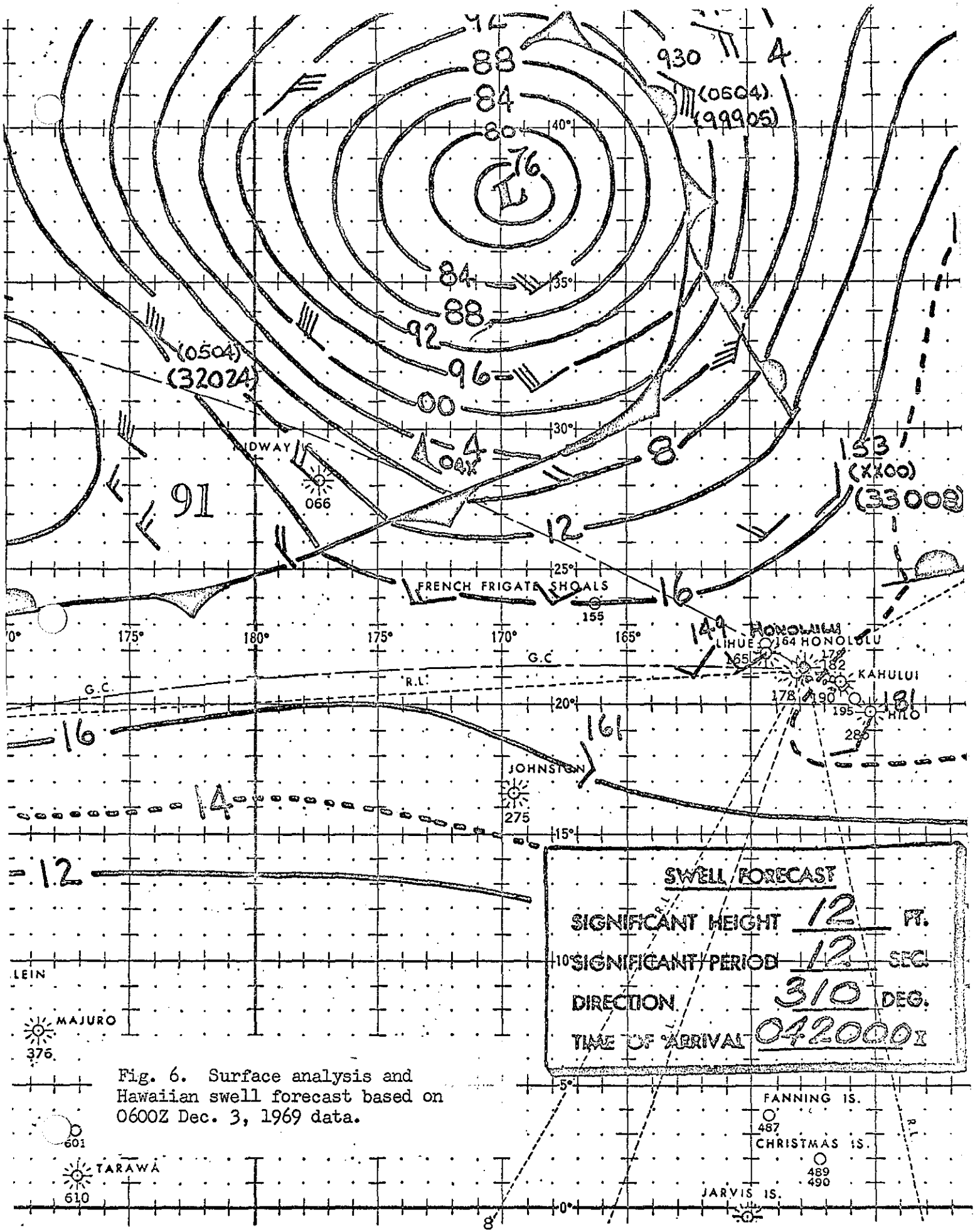


Fig. 6. Surface analysis and Hawaiian swell forecast based on 0600Z Dec. 3, 1969 data.

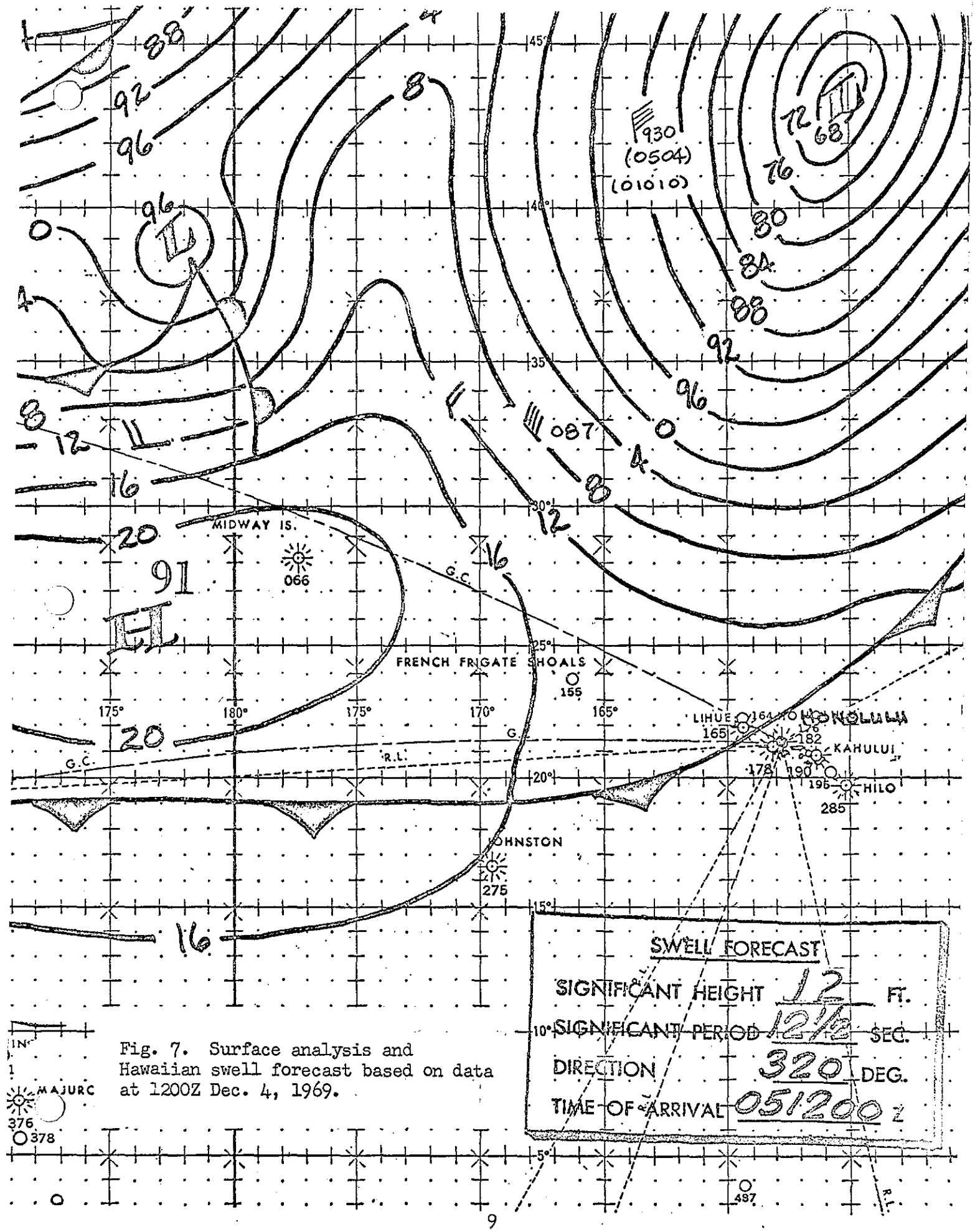


Fig. 7. Surface analysis and Hawaiian swell forecast based on data at 1200Z Dec. 4, 1969.

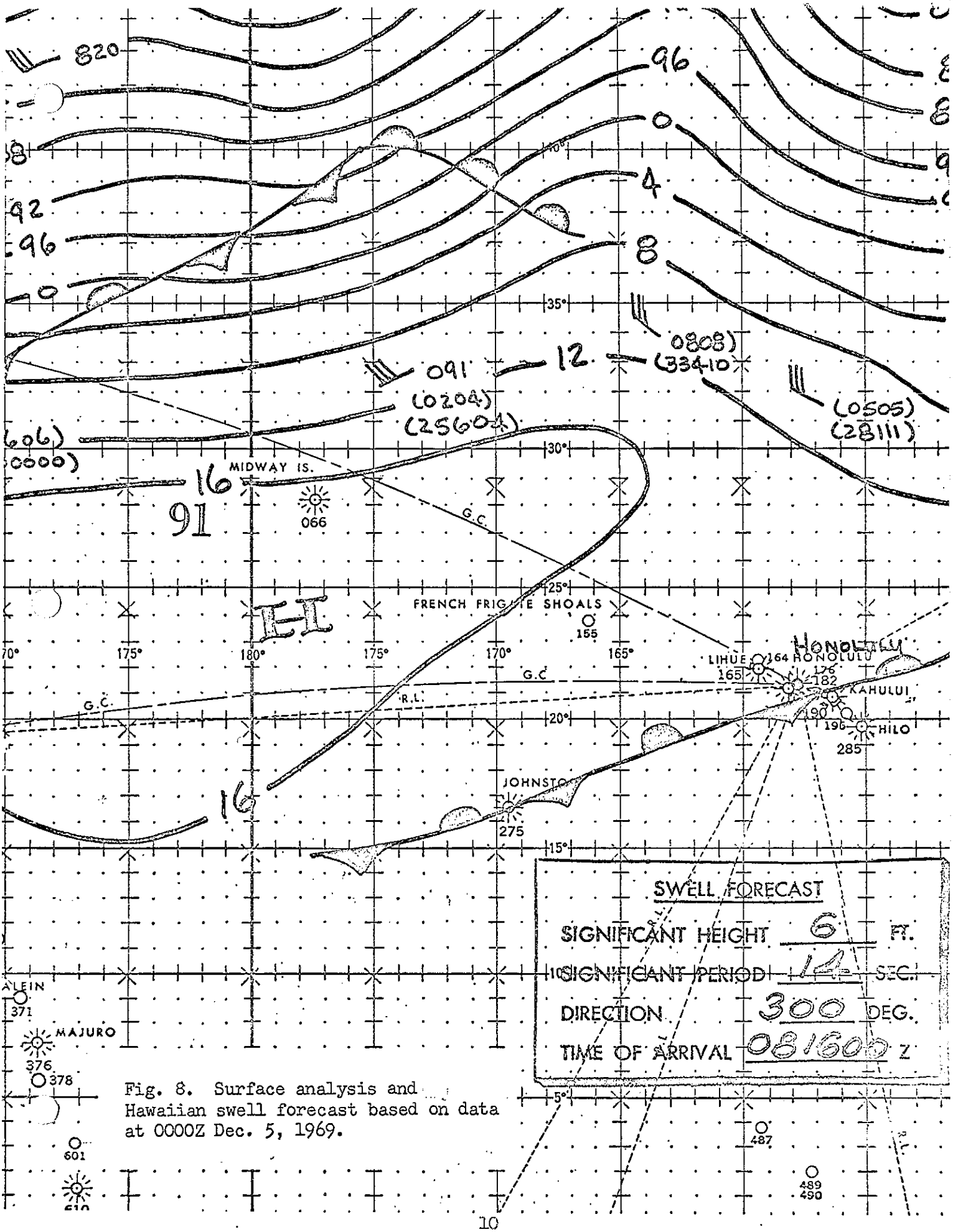


Fig. 8. Surface analysis and Hawaiian swell forecast based on data at 0000Z Dec. 5, 1969.

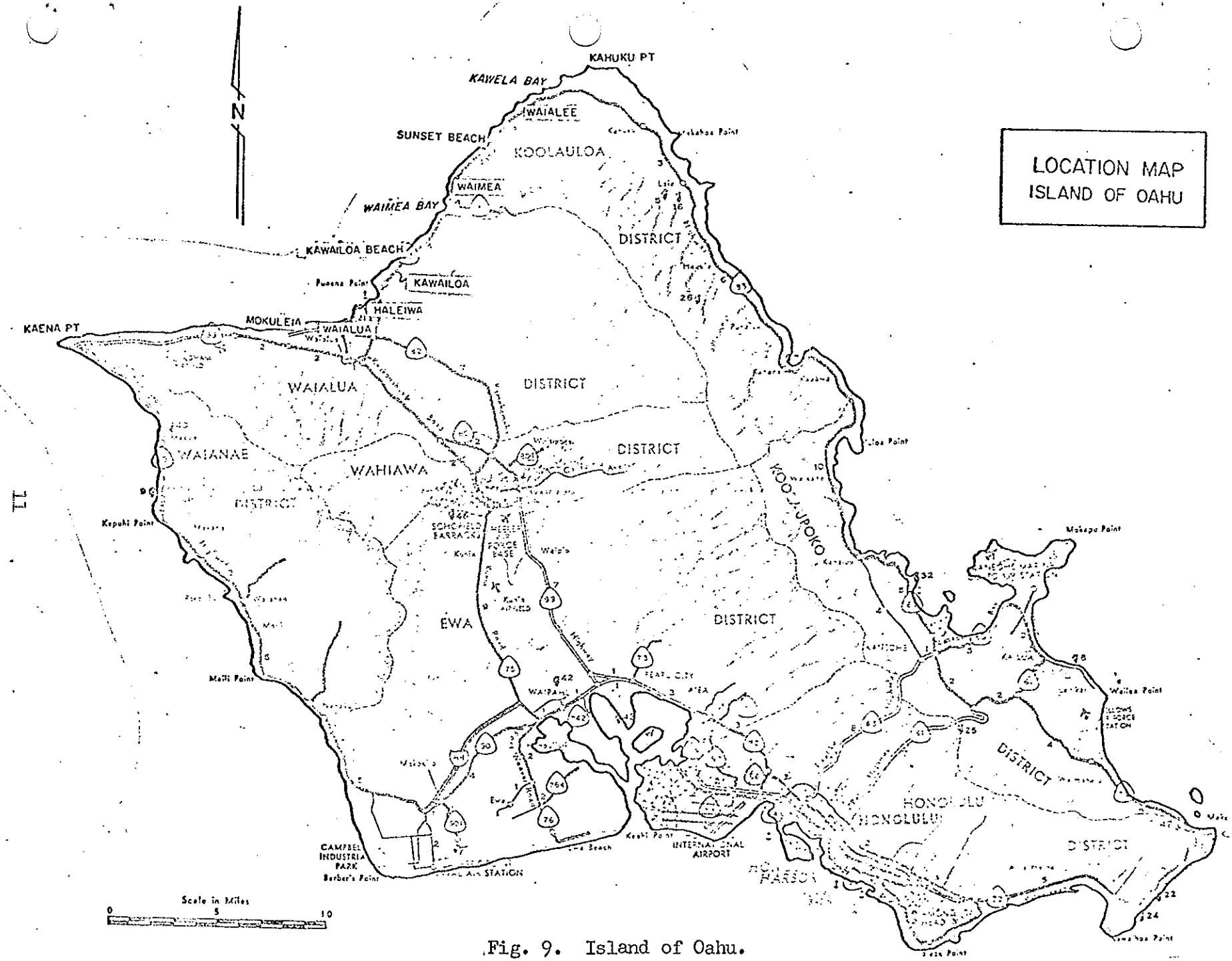


Fig. 9. Island of Oahu.

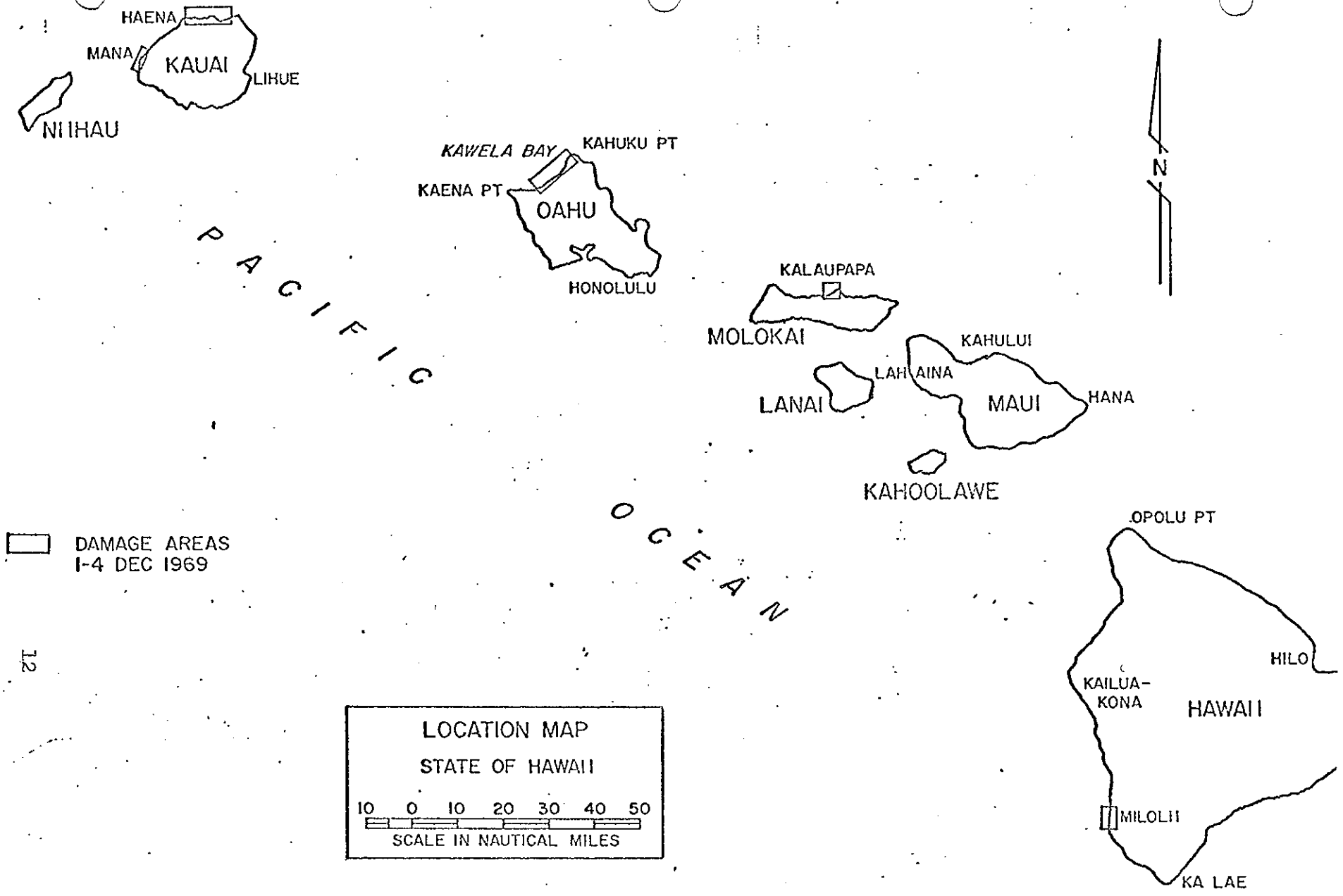

HAENA
MANA
KAUAI
LIHUE
NIIHAU
KAWELA BAY
KAHUKU PT
KAENA PT
OAHU
HONOLULU
PACIFIC
OCEAN
N
KALAUPAPA
MOLOKAI
KAHULUI
LAHAINA
LANAI
MAUI
HANA
KAHOOLAWE
OPOLU PT
HILO
KAILUA-
KONA
HAWAII
MILOLII
KA LAE
DAMAGE AREAS
1-4 DEC 1969
LOCATION MAP
STATE OF HAWAII
10 0 10 20 30 40 50
SCALE IN NAUTICAL MILES

Fig. 10

Haleiwa Beach Park, on the north side of Waialua Bay, was heaped with tons of sand eroded from nearby beaches.

At Kawela Bay surf rushing inland to an elevation of 22 feet above sea level destroyed 2 homes and damaged 12 others, 2 of them severely. A 10-year old girl was seriously injured and several other persons narrowly escaped drowning when their homes were mauled by the waves.

At Pupukea Beach Park waves swept 750 feet inland, and along the Pupukea-Waimea coast, damaged 24 houses and left swash marks and debris on the ground at elevations of up to about 35 feet above sea level. Elsewhere on Oahu's north coast about 40 homes on Waialua Bay and 25 in the Waialee and Kawailoa Beach areas sustained minor damage from water and undermining.

On Molokai on December 1 and 2, 40-foot surf destroyed a concrete mooring dolphin and deposited huge boulders in the Kalaupapa barge harbor, making it unsafe. Damage was estimated at about $25,000.

Hawaii Island was shielded by the islands to the northwest except for the extreme southwest coast where early on the 2nd the village of Milolii was struck by 20-foot waves which destroyed its entire fishing fleet, consisting of 9 fishing canoes and 2 skiffs, damaged 4 homes and the only grocery store and washed out 1,200 feet of beach road - for a damage total of $85,000.

On December 4 high surf from a second North Pacific storm added to previous damage, particularly at Kauai's Polihale Beach Park and at Oahu's Mokuleia Beach.

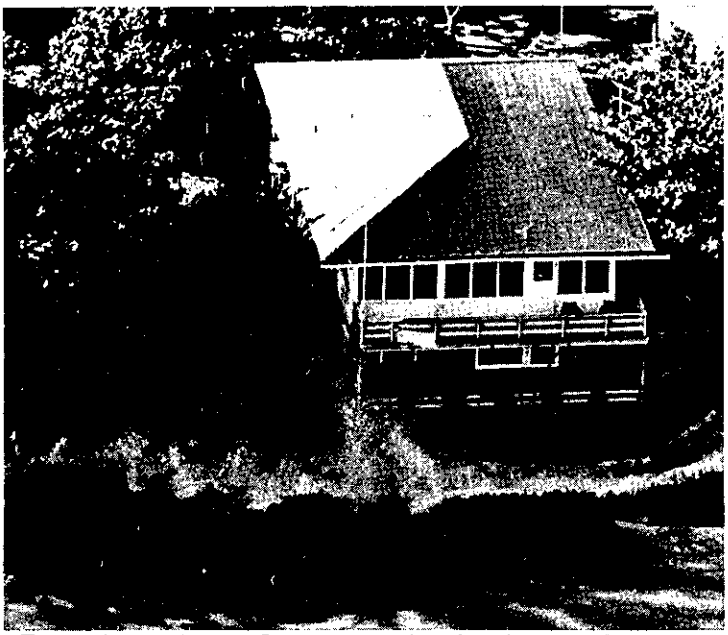
Total damage to all islands from both surf episodes was estimated at $1.51 million. One person drowned when he was swept away while watching the waves at Oahu's Waimea Bay.

Meanwhile, the swell rolled into the southern hemisphere reaching heights of 13 to 20 feet at the Gilbert and Ellice Islands and 10 feet at Rarotonga, South Cook Islands and at Tahiti, and causing slight damage at Samoa and the North Cook Islands.

The following page of pictures shows examples of damage to housing and, along with the cover, photographs of some of the great breakers hitting the shore. Since the greatest waves arrived at night, the photos are indicative of high, but not the highest seas.

Losses in Ke Iki residential area amount to almost half of $1.27 million r Oahu. (Advertiser photo)

Fury of wave action between Waimea Bay and Pupukea Beach Park off Kamehameha Highway. (Star-Bulletin photo)



o-story home looks as if it is ready to swept out to sea. (Star-Bulletin photo)

Pounding surf causes extensive damage at Sunset Beach. (Star-Bulletin photo)

Fig. 11

III. DAMAGE TO INDIVIDUAL ISLANDS

The following damage reports are extracted from a report of the U. S. Army Corps of Engineers (1).

a. Kauai. The surf of December 1 and 2 hit Kauai's west and north shores with waves up to 30 feet high, causing heavy erosion along the beaches and washing out sections of Anini Road. Roads along both coasts were temporarily closed when waves began breaking over the roadways, carrying sand and debris which were deposited on the roadways. High surf warnings in effect since November 30 were cancelled around midnight on December 2 as the waves subsided. The second storm, previously mentioned, generated high surf which again pounded the north and west coasts on December 3 and 4.

Several miles west of Mana village on the west side of the island, 15 duplex units under construction for the Pacific Missile Range had water damage from the high surf. These units, situated about 350 feet inland from the high water line, and with floor elevations of about $18\frac{1}{2}$ feet above mean sea level, were inundated with water to a depth of 1 foot. Splash marks from these waves were about 5 feet higher than the floor and at several units, the splash level was up to the caves. The extent of inundation was about 590 feet inland at this area. Building supplies were ruined, sewer manholes were filled, and the grounds were covered with sand. The contractor estimated damage to be about $25,000.

There was also heavy damage to the Polihale Beach Park and its facilities located on the west shore. Damage to restrooms, shelters, and the access road totaled about $50,000. In addition, the beach was badly eroded. Damages to other beach parks, and highways and roads were also extensive.

Damage to private property included the destruction of a garage and generator room in Haena, washout of retaining walls and lighting systems, and deposition of waterborne debris. Beach erosion was also extensive. There were no casualties during the storm.

b. Oahu. Heavy surf conditions during the night and early morning of December 1 and 2 caused severe damage to the north shores of the island from Kahuku Point southwestward to areas near Kaena Point. There were two fatalities directly attributable to this storm. A serviceman was swept out to sea, while the second person died from a heart attack after assisting in rescue operations. Several other

persons managed to save themselves or were rescued by firemen from the rough seas. At least 15 persons were known to be injured, several seriously enough to require hospitalization.

High surf warnings were issued in sufficient time for evacuation purposes. More than 1,200 residents evacuated their homes voluntarily, while others elected to remain. During the wave attack, many were trapped in their collapsed homes, but no one was fatally injured, although there were numerous reported "narrow escapes". Many residents were left homeless after their homes were demolished, while many more returned to find their homes and contents badly damaged. Power failure on the north shore added to the danger and hampered recovery efforts. A description of damages resulting from the December 1 and 2 high surf is given in the following paragraphs. All elevations are referenced to mean sea level (MSL) unless otherwise noted.

(1) Kawela Bay. Damages to homes and private property in the Kawela Bay area totaled $103,000. Wave runup of about 22 feet on the northern shores of the bay destroyed two homes, severely damaged two others, and caused minor to moderate damages to ten more. Household furnishings were ruined and numerous yards were littered with debris and beach sand. Low-lying areas and the private road leading into the residential area were also inundated with water about 1 to 2 feet deep.

One of the above homes floated intact about 150 feet down the slopes onto the road. Another house was moved 75 feet from its foundation by waves cresting 2 feet higher than the sand berm. After settling down, an electrical fire started and destroyed the house with all its contents.

A 10-year-old girl was seriously injured and several other people escaped from drowning when their residence, consisting of an old World War II concrete "pill box" was overtopped by the waves.

The High surf of December 4 did not cause any further damages in this area.

(2) Waialee. The coastal areas of Waialee, about one mile southwest of Kawela Bay, experienced heavy beach erosion from the storm. Sloping beach fronts were eroded into high vertical bluffs, and low-lying areas about 250 feet inland were flooded with salt water to a depth of 2 to 3 feet. Truck farmers incurred minor damages to crops, and six homes near the mouth of an unnamed stream, were damaged to some extent. Damages in this area, exclusive of sand loss, are estimated to be $6,000. All damages resulted from the first storm.

(3) Sunset Beach. Residential areas at Sunset Beach sustained the most damages in the State during the storm. Toward the northern end of the area, damages in Paumalu consisted mainly of debris and sand on lawns and minor inundation of roadways. One home had minor water damages to furniture and carpets. Along Ke Nui Road, one residence was partly demolished and another floated off its foundation onto a road. Structural and content damages to these two homes were about $21,000. Extensive erosion also occurred along the beaches in this area.

Toward the south end of Ke Waena Road, two homes were demolished, scattering appliances, furniture, clothing, and other personal belongings over the lawn and streets. Two other homes had extensive structural damages when the waves lifted the homes off their foundations. Minor structural and water damages to a fifth home were also noted. Damages to these higher quality homes and their contents amounted to about $113,000. Sections of Ke Waena Road were under a foot of water after the waves inundated the area.

The residential area of Ke Iki Road was severely damaged. Practically every home along this street was affected in some way, either by complete destruction or inundation by the surging water. In all, 14 homes were completely demolished, some of which were crushed together when swept more than 100 feet from their foundations.

These displaced homes severed utility poles and power lines and partially blocked the main highway. Other homes floated off their foundations, whirled around, and crashed into nearby homes. Several of these homes completely disappeared with scraps of lumber and appliances scattered everywhere. Eight other homes and about six more cottages had minor to severe damages. Units constructed of hollow concrete tile withstood the wave action; however, windows and doors were crushed, flushing contents and other belongings out the shoreward entrances. At least 12 more homes on lower lots were inundated with water up to six feet deep. Parked cars were under water and many were smashed against homes or buried underneath the collapsed buildings. Large quantities of sand were washed inland and waterborne debris was scattered throughout the area. Damages, including massive cleanup costs incurred in this area, were about $535,000. Except for beach erosion, there was no further damage in this area during the high surf conditions on December 4.

At Pupukea and Waimea in the Sunset Beach area, 24 residences experienced damages to structure and/or contents. High water marks and debris lines were noted at ground elevations up to about 38 feet in some yards on the shoreward side of the highway. Other

yards in less exposed areas had debris up to about the 28-foot elevation. Two of the 24 homes, located across the highway, were floated off their foundations, but damage was not too extensive. Pupukea Beach Park was littered with boulders and debris. This park probably prevented more damages to homes. Flooding was about two feet deep when the above homes were shifted. Damage in this community was about $25,000 for public, residential, and other private losses, including four automobiles.

(4) Waimea Bay - Kawailoa Beach. Waimea Bay, noted for its treacherous surf, had tremendous waves which flooded the parking lot and highway, leaving the area covered with rock and sand. Points more than 750 feet inland of the park were inundated. Wave action washed away much of the sand from the beach, leaving a high berm which was later reshaped by County employees.

Nineteen Kawailoa Beach residences were damaged to some extent, by undermining or inundation. House walks, garages, and patios were smashed and seawalls were washed out. Beaches all along this section of the coast lost a considerable amount of sand. Sections of the shoreside road were washed out and large quantities of sand and debris were deposited onto the exposed highway. Residential losses, including household contents, and damages to vehicles and buildings were about $15,000.

(5) Waialua Bay. Damage in this area was extensive, especially in the Haleiwa Small Boat Harbor area where small boat harbor structures, shore protection works, and the State-owned breakwater were damaged. These damages consisted mainly of displacement of armor stones and underlying material, and loss of backfill material. Considerable shoaling occurred in the diversion channel. In addition, about 5,000 cubic yards of beach sand from Haleiwa Beach Park was lost. Preliminary estimate of damages to the structures, sand loss, and the cost of removing the shoaled material is about $242,000.

Sixteen boats, varying in length from 15 to 52 feet, were either destroyed or had major damages. These boats were all moored in the harbor during the storm. Some were beached, while others were sunk in the berthing area. Boats which survived the wave action had longer mooring lines and were able to ride the surges in their slips, incurring only minor damages. The loss incurred by these boats was about $35,000.

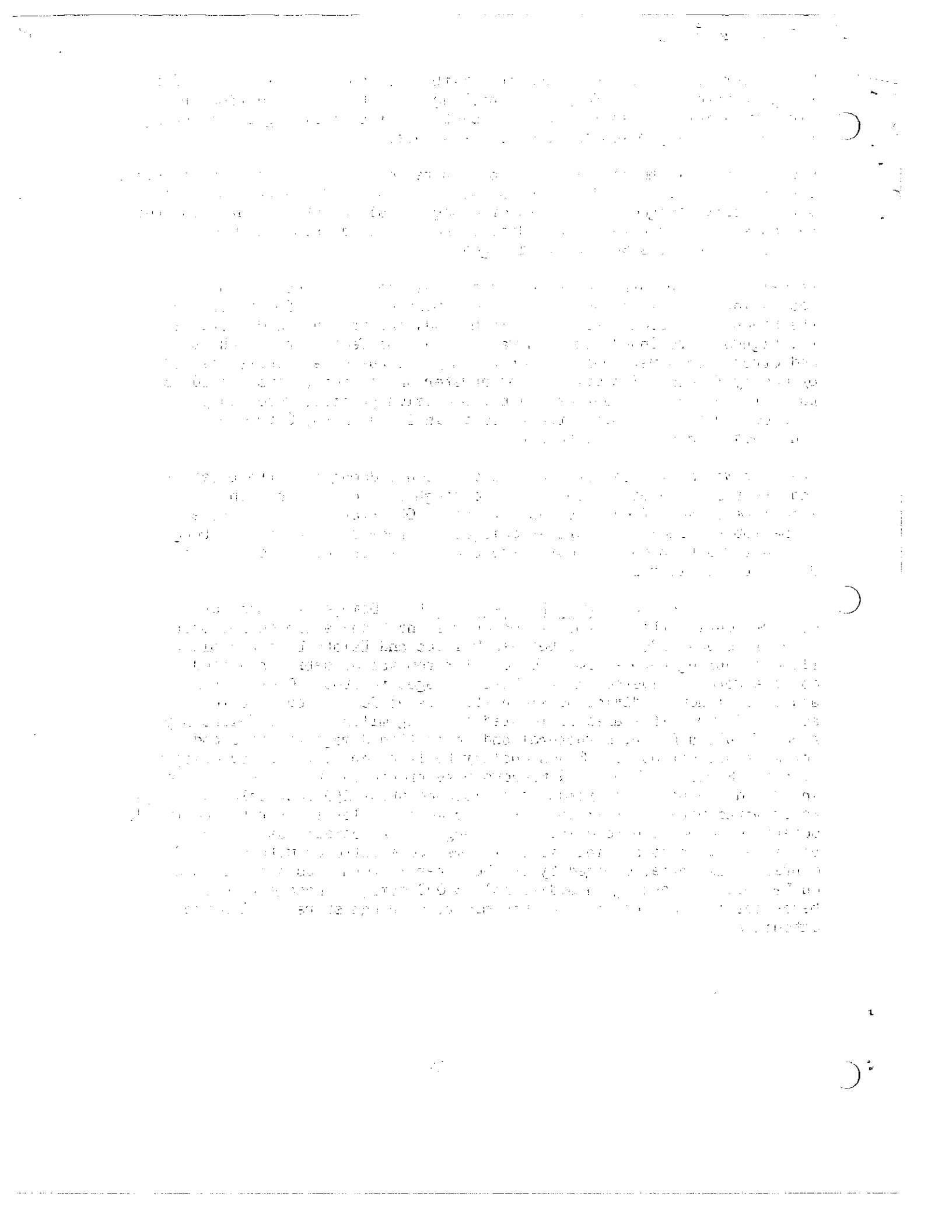
The harbor parking lot was inundated with water about 4-5 feet deep during the peak wave attack. Personnel checking their boats late during the night were intermittently forced to seek safety by climbing and clinging to nearby utility poles and similar structures.

Business establishments along the bay shore were also damaged. Merchandise, furniture, supplies, and storage areas were inundated and the buildings structurally damaged. Estimates of damage to six establishments, including restaurants and general merchandise stores, totaled about $25,000. In addition, four cars were badly damaged.

At Haleiwa Beach Park, on the north side of the bay, tons of sand were washed into the playground and adjacent parking areas. Restrooms and the beach concession were filled with sand, and the park and sections of the highway were inundated with water about two feet deep. Rock, sand, and other debris were washed over the highway but were quickly removed by County forces. The offshore breakwater and a groin, constructed as part of the Federally authorized beach erosion project, were badly damaged. Damage to these structures is included in the $242,000 mentioned in a previous paragraph.

The high waves of December 4 caused additional damages to the breakwater and other structures. Because of the rough surf conditions, an immediate survey of damages was not made. Observations from the shore on December 4 indicated further damages to these structures. Although the surf was high on this date, the conditions were not as severe as during the earlier storm.

(6) Haleiwa - Mokuleia Beach. Damages to these areas occurred during the storms of December 1 and 2 and again on December 4. Beach lots and side streets between Waialua and Kaiaka Bays had minor flooding during both storms. Except for removal of debris and sand, damages were considered minor. Water damages to about 40 other homes and several new subdivisions along the Waialua Beach area amounted to about $20,000. This area is located about $2\frac{1}{2}$ miles west of Kaiaka Bay. Along Mokuleia Beach, structural and inundation damage to homes and cottages was extensive. Seven quality built beach cottages had damages of about $50,000. Doors and windows were broken and water 2-3 feet deep inundated the homes and yards to a distance about 250 feet inland. High water marks were about 13-15 feet above mean sea level. Further westward, several more homes were damaged. A long timber seawall was washed out and streets, lawns and interiors of homes were littered with sand and debris. This area, damaged by the December 1 storm, was again struck on December 4, causing an additional $5,000 damage. Damage to other beach areas toward Kaena Point was minor, although shore erosion was extensive.



(7) Other. Elsewhere on the island of Oahu the storms of December 1 and December 4 caused much concern to areas on the west coast. Waves were higher than the normal winter waves. Except for damages at the Pokai Bay Small Boat Harbor in Waianae, damages elsewhere were minor. At this harbor, about $10,000 was estimated for damages to an existing wooden wharf and from silting at the boat ramp. Minor damage was also reported to the breakwater. On December 4, as a precautionary measure, residents of this coastal area were alerted and many evacuated to a Red Cross shelter area at Waianae School.

c. Molokai. Kalaupapa Settlement, an isolated community on the north shore, was the most severely damaged area on this island during the storm. Surf up to 40 feet high struck the barge harbor during the early morning of December 2. A concrete dolphin for mooring incoming barges was destroyed and the wooden ramp leading to the landing was also badly damaged. In addition, several large stones were washed into the barge basin, leaving a portion of the harbor with depths of 6-7 feet. This condition prevents barges from entering the basin.

About 1300 feet of the airport runway, which is located near the tip of the peninsula, and part of the airport service road were covered with debris, rock, and gravel. These were quickly cleared by settlement employees. The total damages on the peninsula are estimated to be $40,000.

d. Hawaii. The small south Kona village of Milolii, located on the southwest coast of the island, was hit hardest during the storm. The high surf struck this remote community early Tuesday, December 2, forcing some of the residents to evacuate their homes. Residents were evacuated to the Alae School grounds in Milolii.

The town's only grocery store, its contents, and three homes were badly damaged. A small community pavilion was demolished and approximately 1,200 feet of the beach front road was washed out. Stone walls along the roadside were destroyed and the State wharf was severely damaged. Rock and boulders up to $1\frac{1}{2}$ feet deep littered the ocean front properties, and several telephone poles were severed by boulders and tossed inland by the 20-foot waves. Nine outrigger canoes, including six with outboard motors, and two skiffs were lost. A boat trailer and various fishing supplies and equipment were also destroyed. These canoes, valued at about $5,400, were used for fishing. Public damages at Milolii are estimated to be $40,000 and private losses are about $33,000. There was no additional damage to this area during the storm of December 4.

In Kailua-Kona, high waves washed sand and debris over beach roads and into nearby public parks; however, damages were minor. Silting in the Kawaihae Small Boat Harbor near the entrance channel was also reported. An estimate of $5,000 was provided by the State for removal of the silt. No damage was reported elsewhere on the island.

A summary of damages in the Hawaiian Islands during both storms follows:

Kauai	Public Property	$112,700	
	Private Property	22,000	$ 134,700
Oahu	Kawela (Private)	103,000	
	Waialee (Private)	6,000	
	Sunset Beach (Private)		
	Ke Nui	21,000	
	Ke Waena	113,000	
	Ke Iki	535,000	
	Waimea-Pupukea	25,000	
	Waimea Bay-Kawailoa (Private)	15,000	
	Waialua Bay		
	Public (Federally authorized projects)	242,000	
	Public (Parks & Recreation)	21,600	
	Private (Boats & Business)	60,000	
	Haleiwa-Mokuleia (Private)	75,000	
	City & County Road Division	26,000	
	State Highway Department	26,000	
	Board of Water Supply	500	1,269,100
Molokai	Kalaupapa (Public)	40,000	40,000
Hawaii	Mililii (Public)	40,000	
	(Private)	33,000	
	Kawaihae (Public)	5,000	78,000
	Total:		$1,521,800

IV. HIGH SURF WARNINGS

Whenever surf which may damage property or endanger life is expected over the Hawaiian area a special warning or advisory is issued by the leading forecaster on duty. It is recognized that it is very difficult to specify an exact wave height which will result in damage since the shape of the ocean floor, slope of the beach, direction from which the wave arrives at the beach and the resulting refraction and reinforcement patterns produce widely differing types of surf. As a first approximation the forecaster considers that deep water swell of 15 feet or higher may produce damaging surf. When such swell are forecast to arrive over the local area the forecaster takes into consideration all facts available and determines the necessity of the issuance of a warning based on his judgment of all factors involved. This warning contains, to the limit of his ability, a statement of beaches and harbors expected to be affected, time of high surf, and estimates of heights of breakers along with any other information he considers pertinent to the situation.

High swells which may produce surf considered by the forecaster to be dangerous to surfers, swimmers, fishermen, etc., but not high enough to damage beachfront property are covered by a special weather advisory embedded in marine forecasts or by a "Special Weather Statement".

Heavy surf warnings and advisories issued by WBFO Honolulu are included in the broadcasts of local weather forecasts over the Weather Bureau-operated FM facility (KBA-99) in the forecasts prepared for Hawaiian waters which are broadcast in addition by the U. S. Coast Guard and the Hawaiian Telephone Company, and are passed by telephone to recipients whose interests may be affected by the expected surf. In addition, warnings and advisories are disseminated by teletype to local news media. State and local Civil Defense is alerted by the Police Department Dispatch Bureau through the "Oahu Civil Defense Emergency Call List" published by the Oahu Civil Defense Agency. The Police Department on the neighboring islands are also alerted by the Honolulu Police Department Dispatch Bureau; they, in turn, relay the warnings to their respective Civil Defense agencies.

The first alert of expected high wave action was issued by WBFO Honolulu at 8:20 a.m., Sunday, November 30, 1969, well in advance of the arrival of the first swells generated by the storm center.

> A heavy surf is in effect for the north and west coasts of all the Hawaiian Islands. A storm far to the northwest of the Hawaiian Islands is causing northwesterly winds in that area of more than 50 mph and high seas from the northwest which will reach the Hawaiian Islands as an open ocean swell from the northwest of 18 feet at Kauai by noon Monday and 15 feet at the Big Island of Hawaii by 10 p.m. Monday evening. This open ocean swell will cause breakers over the reefs and surf of 30 to 40 feet along the north and west coasts of all islands.

This was followed by the first warning at 2:50 p.m., Sunday, November 30, 1969.

> A heavy surf warning is in effect for the north and west coasts of all the Hawaiian Islands. A storm far to the northwest of the islands is causing northwesterly winds of 45 to 60 miles per hour and high seas in that area that will reach the Hawaiian Islands as a swell from the northwest 18 to 20 feet high over the open ocean that will cause high surf up to 30 to 40 feet along the north and west coasts. The high surf is expected to reach Kauai by noon Monday, Oahu by 3 p.m., Maui by 6 p.m., and Hawaii by 10 p.m. Monday. This will be by far the highest surf so far this year and caution is advised in areas that will be affected.

The first high waves struck the island of Kauai on the afternoon of December 1 - more than a full day after the issuance of the first alert.

Subsequent warnings were issued approximately every six hours until all warnings were cancelled at 11 a.m., Friday, December 5. (Appendix A contains a compilation of all warnings issued.)

V. FORECASTING TECHNIQUES

A knowledge of the height, speed, and direction of the progress of wind waves in a generating area is necessary if their arrival as swell at a distant coast is to be predicted. Direct reliable observations of these wind waves are rarely available, but their height and period can be determined from consecutive synoptic weather maps if the relationship between wind and waves is known.

In the area of wave formation the highest waves present at any time depend upon the wind speed, the stretch of water over which the wind has blown (the fetch), the length of time the wind has blown over the fetch (the duration of the wind), and the waves which were present when the wind started blowing (the initial state of the sea). These four factors can all be determined if a sequence of reasonably accurate weather maps is available showing the meteorological conditions over the ocean area in question. These maps must be based on a sufficient number of ships' observations to make possible the plotting of fairly accurate isobars from which wind factors can be determined. In the tropics, wind observations must be available from ships or exposed stations or islands. In middle and higher latitudes, direct wind observations on ships will serve as checks on wind estimates from the analyzed pressure gradients.

Thus, with adequate weather maps at one's disposal, an estimate of the significant wind waves can be made if accurate relationships between wave height and wind speed, fetch, and duration are known.

Forecasts of the arrival of swell from a remote fetch or generating area can also be made with a reasonable degree of accuracy if adequate and consecutive surface weather maps are available. In this case the factors to be determined from these weather maps are (1) the fetch, or generating area, (2) the wind direction, speed, and duration within the fetch, (3) wind conditions which may exist between the fetch and the target, and (4) the decay distance from the fetch to the target. Once these have been determined the technique for preparing wave forecasts is somewhat mechanical. However, it involves careful interpretation and interpolation of the data selected from the weather maps and careful use of graphs.

Due to the paucity of synoptic weather data for oceanic areas the observational data that may exist in pertinent areas cannot be used effectively for the direct computation of sea conditions. Its primary purpose, therefore, is to verify wind speeds computed from the isobaric structure on the weather maps.

A number of factors are involved in the computation of the surface winds responsible for sea conditions. These factors are the isobaric spacing and curvature, the mean latitude of the fetch, the stability of the air masses involved, and the determination of an average wind speed that has been instrumental in creating the sea. This wind determination is the weighted resultant of the synoptic wind speed computed from the maps spanning the time interval under consideration.

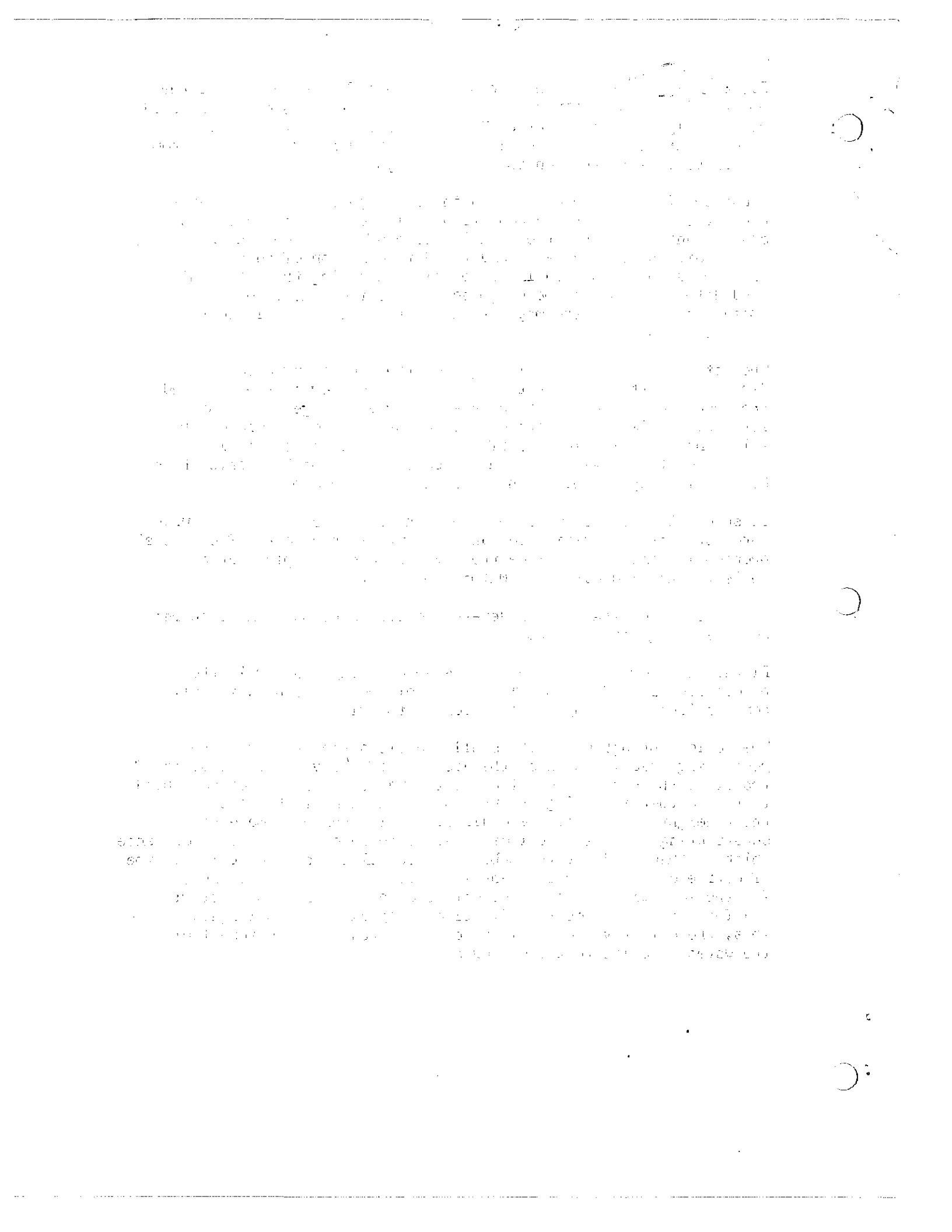
The fetch is the horizontal length of the generating area in the direction of the wind, that is, the distance between the rear and the front boundaries of the generating area. In general, the fetch boundaries are determined by coast lines or by one of the following: (a) fanning out of the isobars, (b) meteorological fronts, or (c) curvature of the isobars. When the boundaries have been decided upon, the fetch is measured on the map.

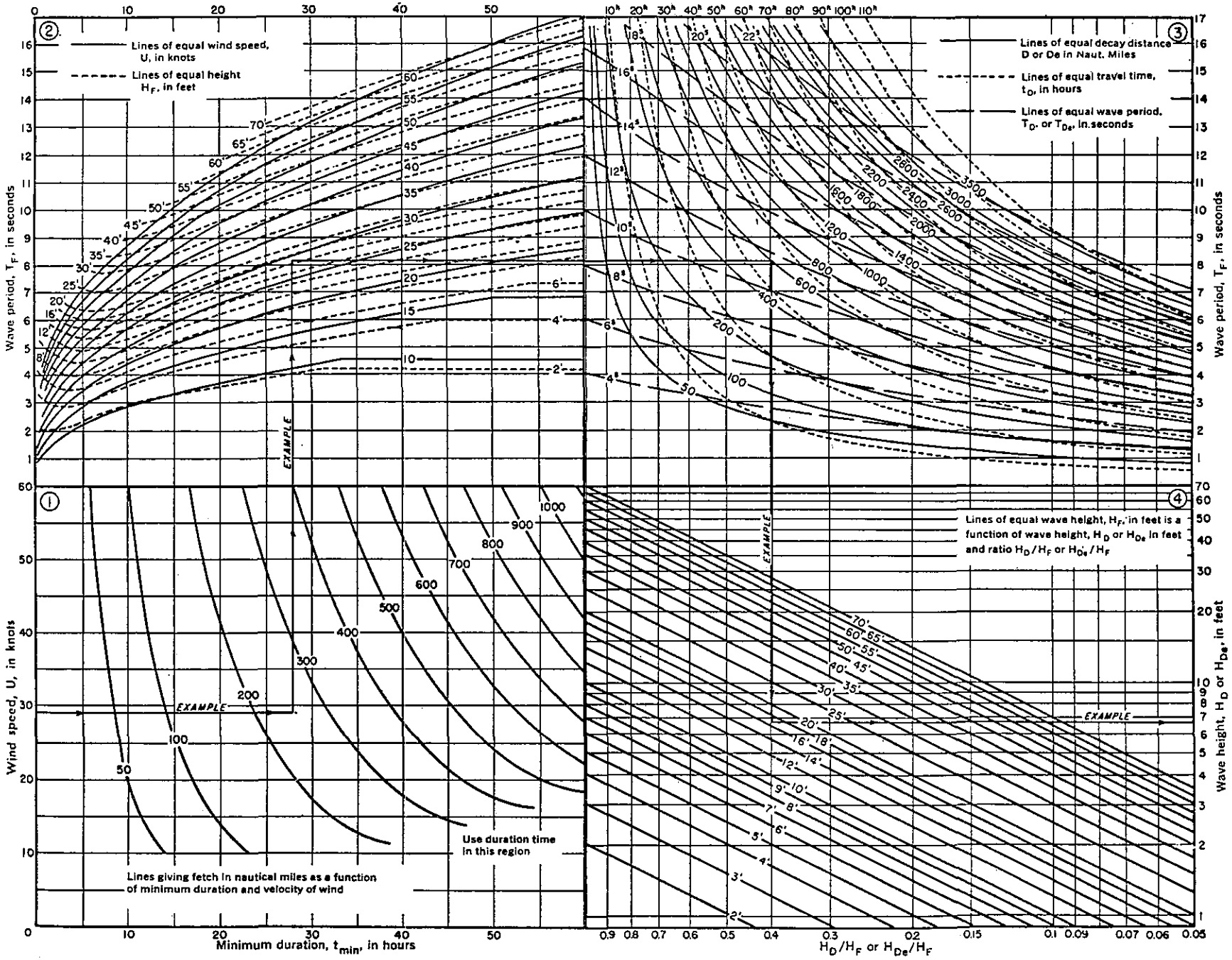
If successive weather maps show that the fetch is moving, the wave forecast must be modified to take account of this fact. The general problem is complicated since the movement can take place at any angle to the wind direction within the fetch.

The duration of the wind is determined from a comparison of current and preceding weather maps.

Either fetch or duration can be the determining factor in the production of wind waves. The lesser of the two is used for all computations involving the duration of the wind.

The region through which the swell travels after it leaves the generating area is known as the distance of decay. When, instead of traveling through an area of calm, the waves are subjected to a wind that is either following or opposing the motion of the waves, their height and period are modified. This change is made by substituting for the actual decay distance an effective decay distance which is then used for the subsequent calculations. For calm air the effective decay distance is equal to the actual decay distance; for the following winds the effective decay distance is shorter; and for opposing winds the effective decay distance is longer. Thus, the effective decay distance is related to the movement of the waves relative to the moving air stream.





EXAMPLE: U = 29 KNOTS, t_d = 28 HOURS, F = 600 NAUT. MILES, H_F = 16.7 FEET, T_F = 8.2 SECONDS, D = 600 NAUT. MILES, H_D/H_F = 0.40 , = 6.7 FEET, T_D = 11.6 SECONDS, t_D = 34 HOURS.

Fig. 12. Nomogram for wave generation and decay.

Fig. 12 is a nomographic representation of the wave growth and decay relationships which has been fashioned to eliminate certain readings of intermediate quantities and slide rule operations. This plate also contains an example. The following instructions are for using the four sections of the plate:

1. Enter 1 with the given value of the wind and proceed along a horizontal line from left to right to the given fetch or duration time, whichever occurs first.

2. From this point proceed upward along a vertical line into 2 to the intersection of the vertical line with the curve corresponding to the given value of wind speed. Read the value of wave height at end of fetch (and wave period at end of fetch if desired) at this point.

3. Proceed along a horizontal line into 3 to the intersection of the horizontal with the given value of the decay distance. Read wave period at end of decay distance and travel time of the swell at this point.

4. Proceed down along a vertical into 4 to the intersection of the vertical with given wave height at end of fetch line corresponding to the value found in 2. Proceed along the horizontal to the scale at the right, reading height of the swell at the end of decay distance from that scale.

A photographically expanded copy of this nomogram has been encased in plastic over which a vertical and a horizontal sliding hairline cursors have been placed. This allows rapid calculations to be made involving all four sections of the nomogram. Such boards have been distributed to WBFOs in the Pacific Region. To facilitate recording of results from use of the board, a "Sea and Swell Worksheet" has been developed (Fig. 13).

When the nature and the time of arrival of the incoming swells are known the forecaster proceeds to calculate the height of the expected surf.

The characteristics of the selected beaches on the island of Oahu have been investigated and are available to the forecaster in preparing a "breaker height forecast." On a breaker height forecast worksheet (Fig. 14) the forecaster enters the name of the beach, the direction of the beach normal and the average beach slope along with the previously calculated deepwater swell characteristics. Through simple calculations and with reference to graphs the forecaster arrives at breaker height for a particular beach area affected by the incoming swell.

SEA AND SWELL WORKSHEET

CHART DTG_____ FETCH NO._____

WIND SPEED OVER FETCH (U) $U =$ _____KTS.

LENGTH OF FETCH (F) $F =$ _____MI.

DURATION OF WIND (t_d) $t_d =$ _____HRS.

SEA IN FETCH

ENTER GRAPH 1 WITH U AND F OR t_d (WHICHEVER OCCURS FIRST)

READ SIGNIFICANT WAVE HEIGHT (H_F) AND PERIOD (T_F) FROM GRAPH 2 $H_F =$ _____FT.

$T_F =$ _____SEC.

SWELL AFTER DECAY

DECAY DISTANCE (D) $D =$ _____MI.

READ TRAVEL TIME (t_o), PERIOD (T_o) FROM GRAPH 3 $t_o =$ _____HRS.

$T_o =$ _____SEC.

READ HEIGHT OF SWELL WAVES (H_o) FROM GRAPH 4 $H_o =$ _____FT.

ADD t_o TO DTG OF CHART FOR ETA OF SWELL ETA = _____Z.

Fig. 13

BREAKER HEIGHT FORECAST WORKSHEET

Beach _____ Direction of Beach Normal _____ Slope _____

Deepwater Swell: Height (H_o) _____ Period (T_o) _____ Direction (DD_o) _____

Angle Between Beach Normal and Incoming Direction (a_o) _____

---

1. Determine wave steepness index (H_o/T_o^2) from Fig. 1. H_o/T_o^2 = _____

2. Determine breaker height index (K_1) from Fig. 2 using beach slope ratio and steepness index. K_1 = _____

3. Compute uncorrected breaker height. ($H_b = K_1 H_o$). H_b = _____

4. Determine breaker depth index (K_2) from Fig. 4 using wave steepness index (H_o/T_o). K_2 = _____

5. Compute breaking depth (d_b) $d_b = K_2 H_o$ d_b = _____

6. Using Fig. 3, determine characteristic of breaking. (PLUNGING - SPILLING - SURGING) _____

7. Compute deepwater swell wave length (L_o). $L_o = 5.12T_o^2$ L_o = _____

8. Compute ratio d_b/L_o. d_b/L_o = _____

9. Enter Fig. 5 with d_b/L_o and angle a_o to obtain the coefficient of refraction (K_d). K_d = _____

10. Compute corrected breaker height (H_b'). $H_b' = K_d H_b$ H_b' = _____

Fig. 14

The technique is based upon "single wave" theory. The techniques in this paper were developed from single wave theory by Svedrup and Munk and modified by Bretschneider (1). It is often referred to as the S-M-B method. This theory mathematically treats the swell components of the ocean wave spectrum as a group of waves having a uniform period and height as they approach a beach from the open ocean. Further, the waves are assumed sinusoidal in shape in the deep water. The long low regular wave trains known as "swell" fit this theory fairly well.

As the swells approach the shore, they "feel bottom" when the depth becomes less than about 1/2 the wave length. As the waves approach the beach the period remains constant, the wave length shortens, the wave height increases until the wave becomes unstable and collapses (breaks).

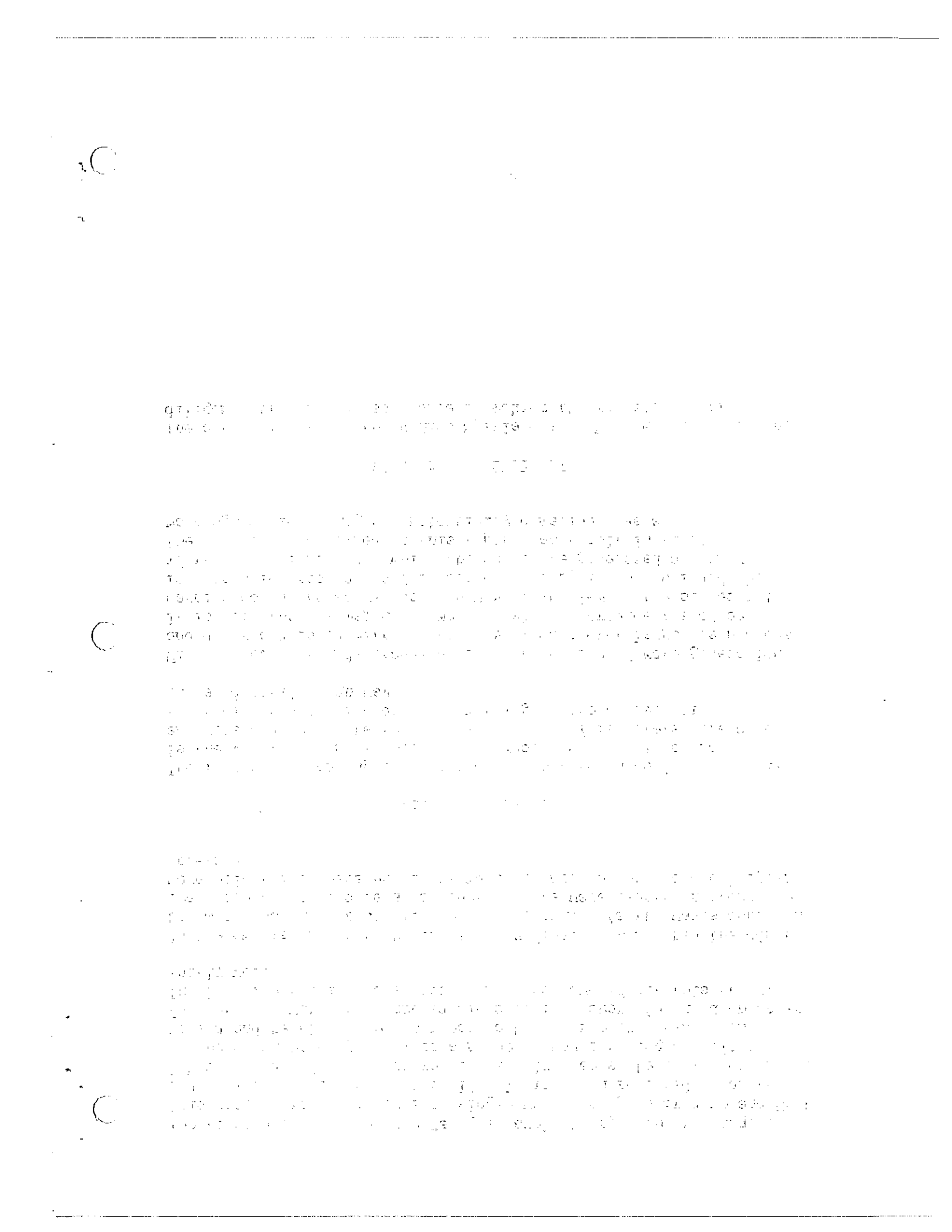
VI. CONCLUSIONS

The forecast of an unprecedented event is rare indeed! Rarer still is the verification of this event! Based on 6-hourly surface analyses and using the techniques outlined, forecasters were able to predict and provide adequate warning of the arrival of extraordinarily high waves.

With our current understanding of the processes of wave generation and decay and faced with the paucity of data over large ocean areas, it is felt that we may not always be able to provide the advance warning as in the above case. However, in view of the successful forecasts in this case and subsequent cases, it is concluded that, if the conditions under which the waves are generated are known, the techniques outlined in this report can result in timely warnings of impending and potentially damaging wave action.

VII. ACKNOWLEDGEMENT

The author wishes to thank Miss Sylvia Graff, WSFO Honolulu, for her diligent efforts and assistance in making the map illustrations.



REFERENCES

1. U. S. Army, Corps of Engineers, Honolulu District, Circular C57 "Storm of December 1-2 and 4, 1969, Hawaiian Islands", March 1970.

2. U. S. Navy Oceanographic Office "Techniques for Forecasting Wind Waves and Swell" Publication H. O. 604, 1951.

3. U. S. Army, Corps of Engineers, Beach Erosion Board Technical Report #4, 1966. Chapter 1.

APPENDIX A

SUMMARY OF FORECASTS AND WARNINGS

0820HST SUNDAY, NOVEMBER 30, 1969

A heavy surf alert is in effect for the north and west coasts of all the Hawaiian Islands. A storm far to the northwest of the Hawaiian Islands is causing northwesterly winds in that area of more than 50 mph and high seas from the northwest which will reach the Hawaiian Islands as an open ocean swell from the northwest of 18 feet at Kauai by noon Monday and 15 feet at the Big Island of Hawaii by 10 pm Monday evening. This open ocean swell will cause breakers over the reefs and surf of 30 to 40 feet along the north and west coasts of all islands.

1450HST SUNDAY, NOVEMBER 30, 1969

A heavy surf warning is in effect for the north and west coasts of all the Hawaiian Islands. A storm far to the northwest of the islands is causing northwesterly winds of 45 to 60 miles per hour and high seas in that area that will reach the Hawaiian Islands as a swell from the northwest 18 to 20 feet high over the open ocean that will cause high surf up to 30 to 40 feet along the north and west coasts. The high surf is expected to reach Kauai by noon Monday, Oahu by 3 pm Monday, Maui by 6 pm, and Hawaii by 10 pm Monday. This will be by far the highest surf so far this year and caution is advised in areas that will be affected.

1930HST SUNDAY, NOVEMBER 30, 1969

High surf warnings remain in effect for the north and west shores of all islands. A storm to the northwest of the islands will cause surf of 20 to 30 feet and locally higher to occur on Monday. The surf will reach Kauai during the morning and the island of Hawaii by late in the day. Persons near the beaches on the west and north shores of the islands at this time are urged to use caution.

2330HST SUNDAY, NOVEMBER 30, 1969

Little change in the high surf warning for Monday. Surf of 20 to 30 feet locally higher is expected over the north and west shores of all islands. The surf is expected to increase over Kauai north shores Monday morning and proceed to the island of Hawaii by night time. Caution is urged for people near the high surf areas.

0600HST MONDAY, DECEMBER 1, 1969

The high surf warning for the State of Hawaii is continued. An increasing high surf to 20 and 30 feet locally higher is forecast along the north and west shores of all the islands. The surf should begin along the west and north shores of Kauai and Oahu this morning, spread to similarly exposed shores of Maui this afternoon, and to the Big Island tonight. Residents of low-lying beach areas along these west and north coasts are advised to exercise great caution. Roads near sea level may be temporarily inundated.

1200HST MONDAY, DECEMBER 1, 1969

The high surf warning for the State of Hawaii is continued. A surf 20 to 30 feet high and locally to 40 feet in big surf areas is forecast along the north and west coasts of all the Hawaiian Islands. The surf should begin along the north and west coasts of Kauai by mid day today or early this afternoon, Oahu late this afternoon or early evening, Maui tonight, and Hawaii Tuesday morning. The surf will continue high Tuesday and into Wednesday. This will be the highest surf so far this season and surf will build up rapidly at the time of arrival. Caution is advised in areas affected by high surf especially beaches and roads near sea level.

1800HST MONDAY, DECEMBER 1, 1969

High surf warnings continue in effect for the State of Hawaii. A surf of 20 to 30 feet is forecast along the north and west shores of all islands. High surf reached north and west shores of Kauai early this afternoon and by 5 pm had reached heights of 20 to 25 feet in the Barking Sands area. Surf began to rise rapidly on the north shore of Oahu late this afternoon and had reached a height of 15 to 20 feet by 5 pm in some localities. The high surf will reach Molokai and Maui during the night and the northern part of the Big Island early Tuesday. Once it reaches a given place the surf will rise rapidly. This will be the highest surf of the year and will be a dangerously high surf. Especial caution is advised in areas usually affected by high surf coming from the northwest such as beaches and roads near sea level. A special note of caution is offered to any who may go to watch the surf. Some of the usually safe vantage points or lookouts may be swept by high waves this time. Highest surf on Kauai, Oahu and Molokai will probably be coincident with high tide Tuesday morning between 7 am and 9 am.

0000HST TUESDAY, DECEMBER 2, 1969

High surf warnings continue in effect for the State of Hawaii. A surf of 20 to 30 feet is forecast along the north and west shores of all islands. High surf reached the north and west shores of Kauai early this afternoon and later in the afternoon on Oahu. By tonight surf of 35 to 40 feet was reported on the north side of Kauai and 25 feet or more on Oahu where much property damage has already occurred on the north shore and in the Makaha area. The high surf has probably already reached Molokai although no reports are available and will reach Maui during the night and become dangerously high by morning. This is and will be the highest surf for quite a few years and is very dangerous. Especial caution is advised in areas usually affected by high surf coming from the northwest. This applies to beaches and roads near sea level. A special note of caution is offered to any who may go to watch the surf. Some of the usually safe vantage points or lookouts may be swept by high waves this time. Highest surf on Kauai, Oahu and Molokai will probably be coincident with high tide Tuesday morning between 7 am and 9 am. Although surf will continue high during the day it appears there will be a slow decrease on Kauai and Oahu by afternoon Tuesday and later on the islands of Molokai and Maui.

0600HST TUESDAY, DECEMBER 2, 1969

High surf warnings continue in effect for the north and west shores of all the Hawaiian Islands. A surf of 20 to 30 feet and higher at isolated points should reach its peak on Oahu near 9 am this morning, at high tide, and begin to subside slowly thereafter. We repeat higher, because reports of 35 to 40 feet were reported on the north shore of Kauai Monday afternoon. And a wave last night swept over a home, 26 feet above mean sea level at Sunset Beach, and left seaweed on the roof of this home. A plate glass window was demolished in another home near Waimea Bay. Also Chuns' Reef road was inundated at several points. Once again we feel it necessary to warn observers, who may be tempted to go down to the beach to observe this record-breaking surf. Keep away from all beach areas even the higher observation points. Such careless observers may be swept out to sea. Similar high peaks in the high surf along the northwest shores of Maui, Molokai and the Big Island should occur near the high tide marks for those islands, today. And following these high water marks this morning in the northern islands the surf will likely continue high during the day. It seems there should be a slow decrease on Kauai and Oahu by mid-afternoon today, and then decrease slowly on Molokai and Maui later this evening.

1200HST TUESDAY, DECEMBER 2, 1969

High surf warnings continue in effect for the north and west shores of all the Hawaiian Islands. The high surf is expected to continue 20 to 30 feet and higher at some big surf locations this afternoon and this evening. The high open ocean swells from the northwest are expected to continue and surf conditions will be affected by the times of high and low tides. High tide will be just before 11 pm on the north coast of Kauai, near 11:15 pm along the north shore of Oahu, near 10:30 pm tonight along the north coast of Maui, and near midnight along the north coast of Hawaii. Caution should be continued in areas affected by high surf especially near beaches and roads near sea level.

1800HST TUESDAY, DECEMBER 2, 1969

High surf warnings continue in effect for the north and west shores of all islands. With the exception of Kauai surf will fluctuate between 20 to 30 feet and will be dangerous. On Kauai a downward trend has begun and surf will be 10 to 20 feet dropping to an average of 10 feet by Wednesday morning. On Oahu and Molokai a definite downward trend will set in after high tide at around 11 pm. There will be no recurrence tonight of the extremely high surf of last night although conditions still remain dangerous. Maui and Lanai and Hawaii can expect a downward trend later in the night. Although the surf will continue rough it will be much lower on Wednesday than it was today.

0000HST WEDNESDAY, DECEMBER 3, 1969

High surf warnings are discontinued for Kauai but remain in effect for north and west shores of all other islands. Surf of 15 to 25 feet will be decreasing to 10 to 15 feet by Wednesday morning on Oahu and Molokai and the remainder of the islands by noon. Surf will continue dangerous during the night but is on the way down. Even though it will be much lower on Wednesday it will continue to be very rough and there will be occasional surges.

0600HST WEDNESDAY, DECEMBER 3, 1969

High surf warnings are discontinued for Kauai, but remain in effect for the north and west shores of all other islands. The surf averaging 15 to 20 feet is slowly decreasing. The surf on Oahu should decrease to 10 to 15 feet by noon today, but will continue very dangerous due to occasional surges. Similar decrease on Molokai today, and on Maui and the Big Island tonight.

1015HST WEDNESDAY, DECEMBER 3, 1969

Heavy surf warnings are again raised for the north and west coasts of the island of Kauai. Surf estimated at 20 to 30 feet will reach Kauai late Thursday morning emanating from a new storm area now 1000 miles to the northwest of the islands. Though the new storm is of much smaller radius than Monday's, present surf conditions could add to the new storm surge to cause dangerous surf along the exposed coasts. All residents in these areas are urged to take precautions. High surf warnings are now in effect for the north and west coasts of all islands.

1200HST WEDNESDAY, DECEMBER 3, 1969

Though surf is gradually decreasing over the north and west coasts of the islanss today we face the likelihood of a strong increase again by Thursday afternoon. A new storm now to the northwest of the islands has generated a swell sufficient to, in conjunction with present swells, cause a dangerous surf over exposed coasts tomorrow. Surf of 20 to 30 feet and possibly locally higher is estimated for all north and west shores of the islands reaching Kauai before noon Thursday and through to Hawaii by late afternoon.

1800HST WEDNESDAY DECEMBER 3, 1969

High surf warnings are in effect for the north and west shores of all islands. Surf will be down to 10 to 15 feet tonight and Thursday morning but a new and very large intense storm centered this evening 1100 miles north of the islands has winds of 50 to 70 mph in it which once again is creating a potentially dangerous situation for the same sections of the islands just hit by high surf. Surf will begin rising rapidly on Kauai about noon Thursday, on Oahu in the early afternoon on Molokai and Maui by evening and the Big Island early Thursday night. Surf heights once again will reach heights of 20 to 30 feet and in some spots up to 40 feet. There will be an additional factor this time not present during the recent high surf. The wind will be from the northwest 15 to 25 mph which means it will be a following wind which will tend to drive the surf. Every precaution should be taken in preparation for this dangerous situation. On the more pleasant side there is no danger tonight.

0000HST THURSDAY, DECEMBER 4, 1969

High surf warnings are in effect for the north and west shores of all islands. During the night and Thursday morning surf will be no higher than 10 to 15 feet but a new very large and intense storm centered about 1100 miles north of the islands has winds of 50 to 70 mph. These winds are once again generating large swells which threaten the islands with the same potentially dangerous situation and in the same sections as were recently hit by damaging surf. Surf will begin rising rapidly on Kauai about noon Thursday, on Oahu in the early afternoon, on Molokai and Maui by mid-afternoon and the Big Island in the evening or early night. Surf heights once again will reach 20 to 30 feet and in some spots up to 40 feet. Wind from the northwest will tend to drive the surf on shore. This is a condition we did not have with the previous high surf. Every precaution should be taken in preparation for this dangerous situation.

0600HST THURSDAY, DECEMBER 4, 1969

High surf warnings are in effect for the north and west shores of all islands. This morning the surf will be no higher than 10 to 15 feet but a new storm centered about 1200 miles north of the islands has winds up to 50 mph. These strong surface winds have once again generated large swells which threaten the north and west shores of the islands with another dangerous surf condition. The surf will rise rapidly on Kauai about noon today, on Oahu by mid-afternoon, on Molokai and Maui by late afternoon, and on the Big Island this evening. Surf heights will reach 20 to 30 feet and in some areas will go higher.

1000HST THURSDAY, DECEMBER 4, 1969

High surf warnings remain in effect for the north and west shores of all islands. A large storm center north of the islands continues to generate high waves which have now reached the northern and western shores of the island of Kauai where the surf was reported to have reached as high as 25 feet by 9 am. Surf along the northern and western shores of the island of Oahu is expected to continue to rise reaching heights of 25 to 30 feet or higher by noon as the waves continue to move southeastward through the island chain. Surf should rise rapidly on Molokai and Maui by mid-afternoon and on the island of Hawaii by late afternoon. High surf conditions are expected to continue for all islands through noon Friday.

1200HST THURSDAY, DECEMBER 4, 1970

High surf warnings remain in effect for the north and west shores of all islands. Surf has been reported to be rising rapidly along the northern shores of the island of Oahu where heights have now been reported up to 30 feet. A relatively short time period between wave crests coupled with a high tide near noon has increased the likelihood of dangerous surges of water beyond beach areas. Surf along the northern and western shores of Kauai and Oahu is expected to continue dangerously high through noon Friday with wave crests reaching 40 feet or higher. Surf should rise rapidly on Molokai and Maui by mid-afternoon and on the island of Hawaii by late afternoon as the waves continue to move southeastward through the island chain.

1600HST THURSDAY, DECEMBER 4, 1969

High surf warnings continue in effect for the north and west shores of all islands. Surf continues to be reported from 20 to 30 feet or more along the northern and western shores of the islands of Kauai and Oahu. Reports from the island of Maui at 3 pm indicate that the surf is rising along the northern shores at this time with a few wave crests reaching 20 feet or more. Surf is expected to continue to be dangerously high for all islands through noon Friday. Wave heights should begin diminishing for the island of Kauai early Friday morning and near mid-morning for the island of Oahu.

2000HST THURSDAY, DECEMBER 4, 1969

High surf warnings remain in effect for the north and west shores of all islands. Surf continues to be reported running 20 to 30 feet on the north shore of Oahu and a little less on Kauai. No recent reports are available from other islands the last from Maui being at 3 pm when heights up to 20 feet were reported. There will be fluctuations in height from time to time but surf will continue to be dangerously high until around 12:30 am when high tide occurs on the north shores. After that time there will be a slow decline in height with average heights of 15 to 20 feet expected on Kauai and Oahu after daybreak Friday. This same decline will follow a few hours later on Maui and Hawaii. Even though it will no longer be a damaging surf on Friday it will still be a dangerous surf and caution is advised against venturing near it.

0000HST FRIDAY, DECEMBER 5, 1969

High surf warnings remain in effect for the north and west shores of all islands. Currently surf is being reported at 20 to 25 feet on the north shore of Oahu but no reports are available from other islands. It is now within one half hour of high tide and no further rise in surf is anticipated. On the contrary from now on there will be a gradual decline in height reaching average heights of 15 to 20 feet on Kauai and Oahu by daybreak. On Maui and Hawaii there will be a lag of 4 to 6 hours but by daybreak the surf will be on the decline on those islands also. Although we are passing the destructive stages of the surf, it will still be a dangerous surf and all persons are cautioned to remain away from the beaches as there will continue to be surges.

0600HST FRIDAY, DECEMBER 5, 1969

High surf warnings remain in effect for the north and west coasts of all islands. The high surf is expected to decrease in height this morning along the north and west shores of Kauai and Oahu, to decrease along the shores of Maui later this morning, and to decrease along the north and west shores of Hawaii this afternoon. The surf is expected to continue to decrease tonight and Saturday. Although the most destructive surf is passing, it is still a dangerous surf and caution is advised near beaches as there will continue to be occasional surges in the warning areas.

1100HST FRIDAY, DECEMBER 5, 1969

The heavy surf warning for the north and west coasts of all islands is cancelled at 11 am. The latest observations from all islands indicate that the surf along these shores has returned to near normal for the winter months.