II. WIND, WAVE, AND STORM CONDITIONS AT JALUIT

JANUARY 7-8, 1958

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The central physical events that led to the remarkable geomorphic, vegetative, and other changes on the islets and submerged reefs of Jaluit Atoll were the extreme wind and wave conditions that accompanied the storm. For this reason as well as from the viewpoint of intrinsic interest it is pertinent to reconstruct as accurately as possible the sequence of wind and wave conditions on January 7-8. In so doing, it is necessary to evolve a reconstruction that yields a coherent physical description of the storm itself: of its shape, size, intensity, and movement.

There are four major lines of evidence as to wind and wave conditions during the storm. These are the general (basic) tide conditions as given by standard tide tables, the accounts of natives, the vegetative evidence (especially direction of tree fall), and the geomorphic evidence. There are other, lesser, lines of evidence, as, for example, the destruction of a steel tower and the movement of a large storage tank. Each of these lines of evidence will be considered in turn, with a factual presentation of the observations together with my own comments as to their significance and accuracy. Thereafter I will present a summary of what I consider to be the significant, concordant evidence, at the same time making clear why certain evidence has been discarded or adjusted. Finally, I will estimate what the succession of wave and wind events were as related to the nature and movement of the storm that was the generating agent.

Basic tide conditions

Figure 2 shows the mean tidal height at Jaluit Atoll from 0500 to 2400, 180th meridian time, January 7, 1958.* The significant feature of this curve is the range of 6 feet, which is a very large range compared with the average, for this was a spring tide day. The upper portion of Fig. 2, which refers to wave conditions upon different islets, is discussed below.

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* Time and height of the two pairs of high and low tide points are taken from U. S. Coast and Geodetic Survey 1957. Intermediate (hourly) values have been obtained through applying the short form for interpolation given in this reference.

Accounts of natives

Accounts of the sequence of events during the storm were given to me by the Head Chief of Majurirek Village, by Mr. Katje, a Marshallese employee of the Trust Territory, and by Mr. Morris, the Head Chief of Imroj Village and the Head of the Chiefs' Council for the Atoll of Jaluit. The account by the chief of Majurirek Village, was given through an interpreter. In contrast, Katje and Morris gave their accounts in quite good English, though two or three times Morris switched to Marshallese, which was then translated by Katje. In each instance the informant was asked to describe in his own words what took place and in what order, especially with reference to wind, wave, rain, and falling trees. Only after he had completed his narrative was the speaker questioned regarding specific points. The accounts of each of these three are given below, with a distinction being made between information that was volunteered and that which was given in answer to questions, since there might be a tendency for any one of them to answer a question in such a manner as to attempt to please the person asking it. All the accounts have to do with conditions on January 7th or in the early morning on the 8th. The accounts are from my abbreviated notes and are not intended to give the exact words or an exact translation of the words of the speaker. All times are local (approximately 180th meridian).

Account of Head Chief of Majurirek Islet, with reference to conditions on Majurirek

Information volunteered: Around 8 in the morning the wind was from the north, not too strong. About 10 o'clock the wind started to blow "full", still from the north. Around 2 o'clock in the afternoon the wind went to northwest and at the same time there was a little wave that came in from the east and onto the islet (on the lagoon side). By late afternoon, around 4 o'clock, there were big waves from the east, and these went up the shore quite a way. Then for about four hours the wind was very full and it went from northwest to west to southwest and then to south. After this (about 10 p.m.) the wind died down.

Question: How far up the shore did the big wave come (from the lagoon in early afternoon)? Answer: About 10 to 15 feet up the shore. Question: When did the trees start falling down? Answer: From the time when the wind was full from the north through the time it was very full from the northwest and west. Question: Were there waves from the ocean? Answer: Yes, but only small ones. Question: Did it rain? Answer: Yes, there were heavy rains from around the middle afternoon until past midnight.

Account by Mr. Katje with reference to conditions on North end of Jaluit Islet (Jabor)

Information volunteered: At about 9 o'clock the first big wave came from the east, and it went over the southern part of Jabor (the narrow part). The wind then was from the north. The second big wave came across from the east around noon. Still the wind was from the north. About 3 p.m.

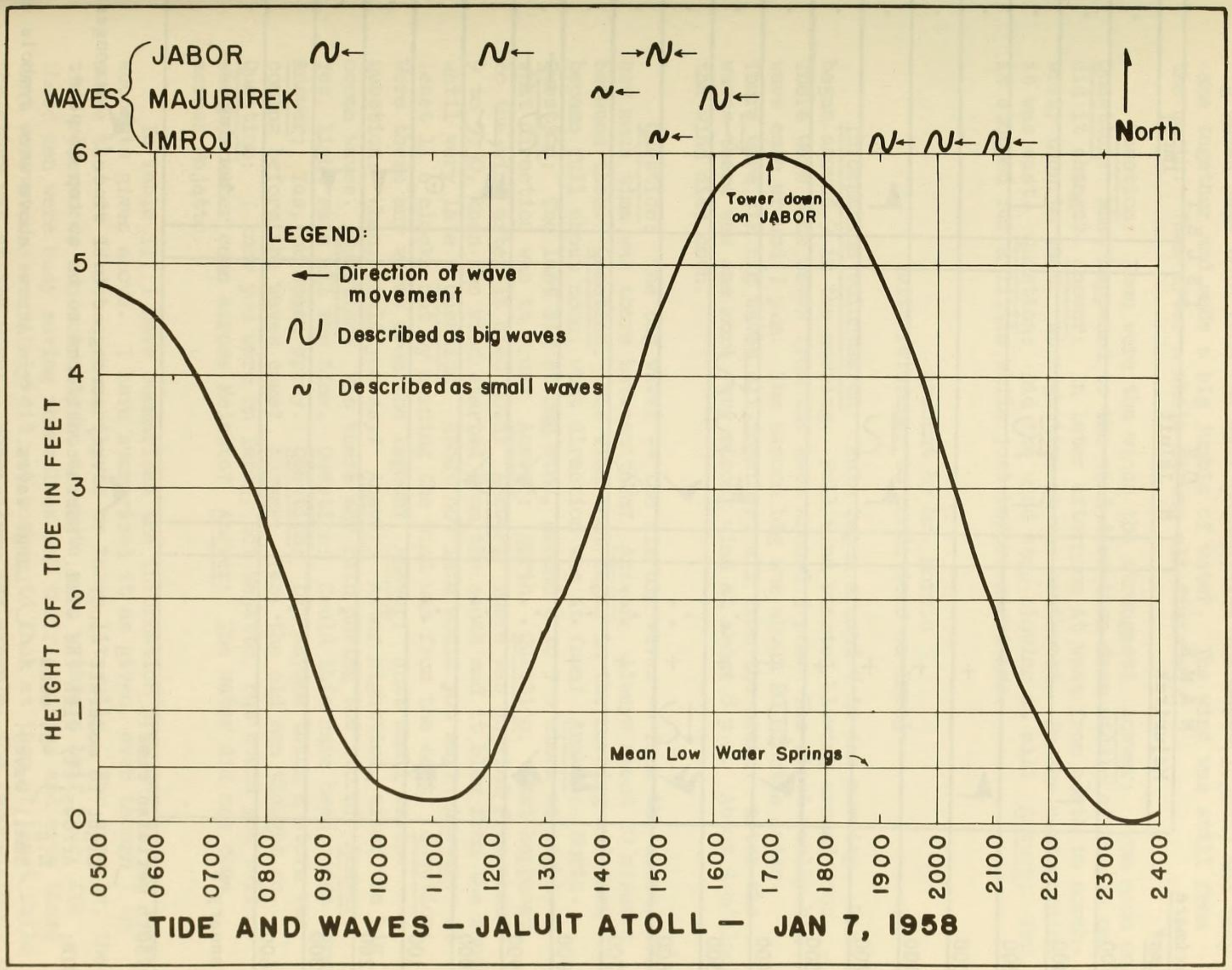
WAVES
JABOR
MAJURIREK
IMROJ
North
LEGEND:
Direction of wave movement
Described as big waves
Described as small waves
Tower down on JABOR
Mean Low Water Springs
HEIGHT OF TIDE IN FEET
0
1
2
3
4
5
6
0500
0600
0700
0800
0900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
TIDE AND WAVES — JALUIT ATOLL — JAN 7, 1958

FIGURE 2

TABLE II.

SUMMARY OF EVIDENCE BY INFORMANTS

Approximate Time*	NAME OF ISLET: Majurirek		N. Jaluit		Imroj
0700					.
0800	⌜				.
0900			⌜ ⇜		⌜ .
1000	⚑ +				.
1100	+				.
1200	+		⚑ ⇜		⚑ .
1300	+				.
1400	⚑ ⇜ +				.
1500	+ ∴		⚑ ⇜ ⇜		⇜ .
1600	⚑ ⇜ + ∴		⚑		.
1700	+ ∴		⊙		.
1800	⚑ + ∴				.
1900	⚑ ∴		⚑		22 ⇜ .
2000	∴		⚑		⚑ ⇜ .
2100	⚑ ∴				⊙ .
2200	⌟ ∴				⚑ .
2300	∴				⚑ .
2400	∴				
January 8.					Morning ⌝

*180th meridian time

⌜ Light to moderate wind. ⚑ Very strong or full wind. ⚑ Strongest wind

NOTE: Arrows fly with the wind. North considered to be at top of page.
E.g. ⌟ =S. wind

~ Small waves. ∿ Large waves. ⇜ Arrows above wave symbols show direction from which the wave came.

• Light rain. ∴ Heavy rain. + Trees falling or being snapped.

⊙ Calm or very light wind.

big waves came both from the east (ocean) and the west (lagoon) and they came together and made a big jumble of water. The wind was still from the north. Then after a while it was all finished.

Question: When were the winds the strongest? Answer: From noon on. Question: What happened to the wind direction from middle afternoon on, did it change? Answer: In later afternoon it went from north to northwest, then to west. At nighttime it was southwest. By the next morning it was east. Question: Did the wind stop blowing at all? Answer: Yes, it stopped for a little while just before nighttime.

Account by Mr. Morris
with reference to conditions on Imroj

Information volunteered: Rain began around 7 in the morning. Wind began around 9 in the morning. Full wind started blowing around noon. There were some waves from the east around 3 p.m. The first really big wave came around 7 p.m. The second big one about 20 minutes later. There were six big waves all together, all from the ocean. After the waves there was one more very strong wind at about 8 p.m. About 9 o'clock the wind died down.

Question: The big waves -- the six big waves -- from the ocean, about how much time was there between them? Answer: Always about 20 minutes between them. Question: The wind that began in the morning and then became full about noon, what direction was it from? Answer: North. Question: The last big strong wind, around 8 to 9 o'clock at night, what direction was it from? Answer: North. Question: What happened to the wind after it died down? Answer: There was no wind from about 9 to 9:30, then the wind started from the south and it blew from the south until very late. Question: About how late would you say? Answer: At least 11 o'clock; but by morning the wind was from the east. Question: Were there any waves from the lagoon? Answer: Just small waves. Question: When, would you say? Answer: After nighttime, after the big ocean waves. Question: Was there any rain during the storm? Answer: Yes, light rain all the time. Question: Could this have been ocean spray? Answer: Yes, or ocean spray. Question: Did anyone think a storm was coming before the waves came? Answer: Yes, the old men thought so. Question: I know you were on Imroj, not Mejatto, but could you tell whether water came across Mejatto? Answer: The water did not come across Mejatto.

In Table II, I have summarized the information provided by the three accounts given above. I have summarized it as given, even though I am aware that it is not necessarily to be taken literally. For example, the time references can scarcely be accurate even within a half hour, for these men were busy saving themselves and their families and even those that wore watches certainly did not bother to look at them at least while the storm was at its worst. Note, also, for example, the inconsistency in Morris' account: He says there were six waves at 20-minute intervals, all between 7 and 8 p.m. I will refer to Table II later on and will then attempt to justify correcting it to accord with other evidence.

Vegetational evidence

Some evidence as to the direction of first very strong winds is given by the direction of dominant treefall and breakage on the different islets. This information is summarized in schematic map form in Fig. 3. In this figure two directions are shown where treefall and breakage was commonly observed throughout a direction range of 30-60°. With the exception of two of the islets for which arrows are shown, there was good concordance of dominant direction of fall (within the range of the wind arrows). The exceptions were northernmost Jaluit (Jabor) where Fosberg observed tree-fall from all directions, even though falls from the east to northeast seemed most common (wind E to NE). Similarly, on Kinajon Fosberg reported a wide variety of directions, though again with some dominance (north to northwest winds). Fosberg and Wiens are agreed on the overwhelming dominance of north to south fall (north wind) on Lijeron and they and I are all agreed on the dominance of west to east fall (west wind) in central Jaluit Islet (beginning about 300 yards south of the southernmost Japanese block house at the southern edge of Jabor). As for the dominant direction on north central Mejatto (about 1000 yards from the northern tip), I made a methodical count of trees snapped off and, judging from the scars, found that 45 had snapped towards the southwest (NE wind), 2 toward the south (N wind), 2 toward the east (W wind), and one toward the northwest (SE wind).

From the uprooting and snapping off of trees, what conclusions can be reached regarding windspeeds? From discussions with Fosberg and judging from my own observations on Guam after that island was sideswiped by typhoon LOLA*, I believe the following estimates are warranted:

(1) On Mejatto, where palms and many other kinds of trees were snapped off, sustained windspeeds certainly exceeded 125 knots (from NE among other possible directions);

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* LOLA passed south of Guam in November, 1957. Two or three weeks later I stopped on Guam and spent seven days in the field studying what the effects of the storm had been upon the land and upon the vegetation. Recorded windspeeds on Guam reached a maximum of 83 knots sustained speed and 103 knots for the peak gust, both on top of Mt. Alutom. Speeds in less exposed locations, as along the southern and eastern coasts, were around 50 to 70 knots sustained (over 60 at the Naval Air Station). It is reasonable to suppose that very locally, because of funneling effects and the like, speeds elsewhere reached 70 to 80 knots, sustained. Where breadfruit or pandanus stood in exposed locations, they were often down or snapped off a few feet below the crown. Yet I saw no palms either snapped off or down except in the coastal region from Inarajan to Merizo -- a region that had been inundated. Casuarina, like the palms, also stood well against the wind. Thus on the open beaches on the east coast of Guam, a few miles south of Ylig Bay, there were open stands of Casuarina, that had been well exposed to the winds, and among these many hundred trees I found only one that was down, and it stood east (ocean-ward) of the strand line where washing out of roots must have occurred just as it was observed to have occurred among neighboring trees that were still standing.

Figure 3

Dominant Directions of Tree Fall or Snapping

Directions are shown by wind arrows with reference to winds that would produce observed fall (assuming trees fall toward downwind direction). Wind arrows fly with the wind. Directions shown to eight points only. Where two arrows are shown dominant fall was from two directions as shown.

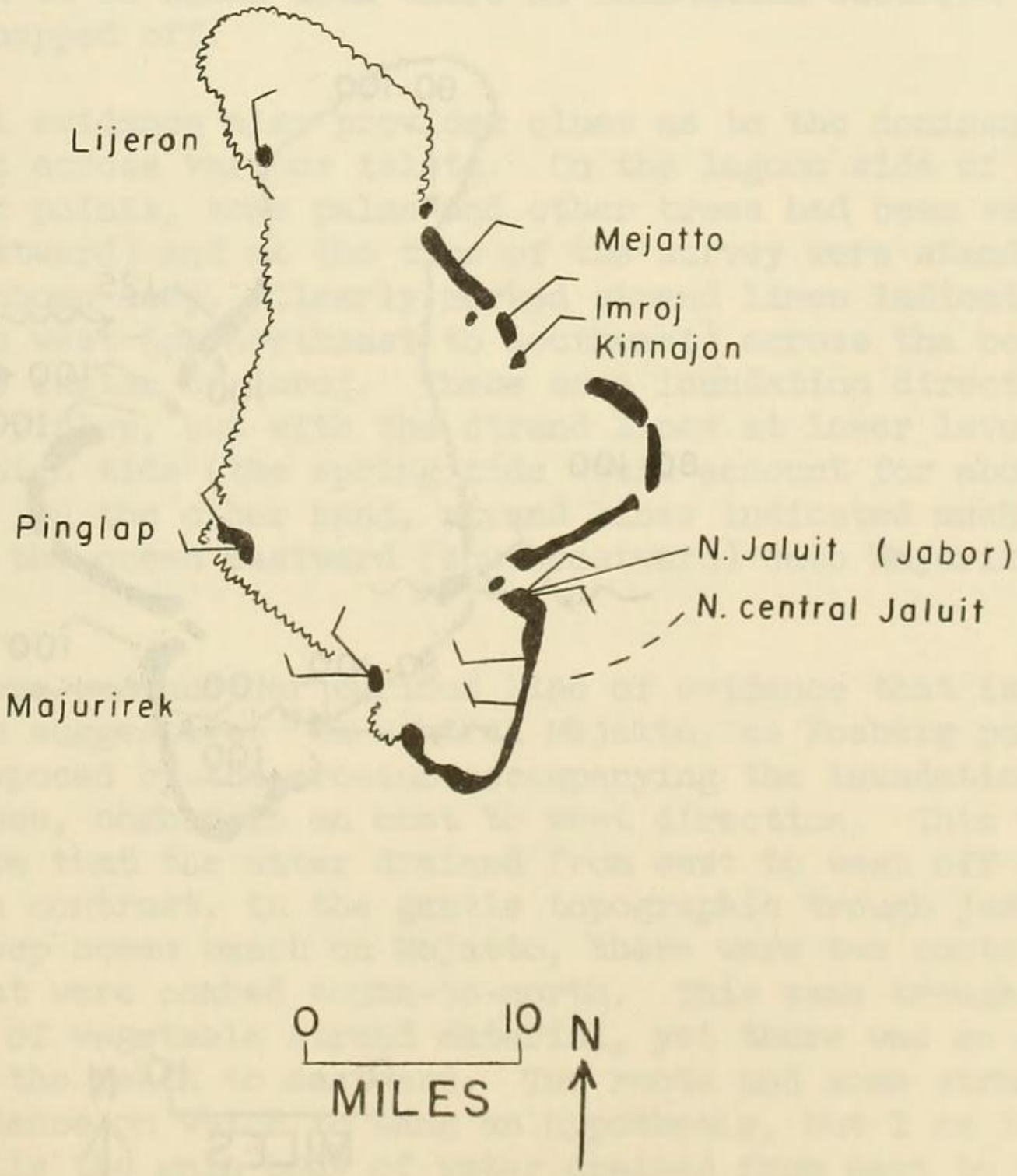


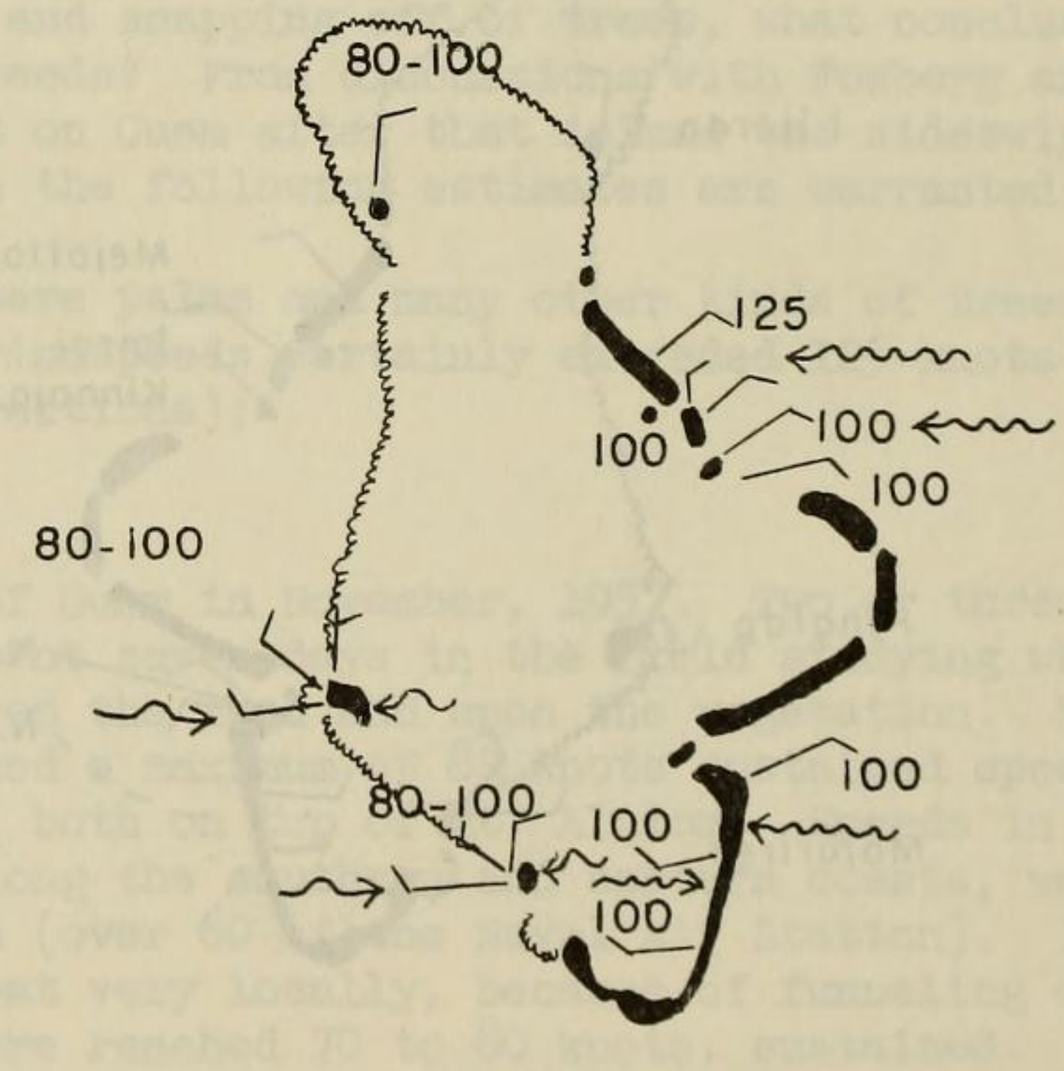
Figure 4

Minimum Speeds of First Strong Winds and Dominant Directions

Of Water Movement Across

Islets

(Deduced from vegetative and geomorphic evidence. Wind directions are to 8 points; windspeeds, in knots. Wind arrows fly with wind. Wavy arrows show direction of dominant water movement, with longer arrows representing major inundations and shorter arrows representing lesser inundations.)



(2) On Imroj and Kinajon the maximum windspeeds were perhaps slightly less (certainly, however, in excess of 100 knots). Here, as on the islets of Majurirek, Pinlep, and Lijeron, allowance must be made for the extent of tree stands -- the massing of trees on relatively wide islets. The same massing occurred at the northern and southern tips of Mejatto, where relatively few trees were snapped off or blown down compared to the 90% or more that were snapped or down throughout the central 2-2½ miles of Mejatto.

(3) The vegetative evidence shows that windspeeds on Jaluit Islet were also in excess of 100 knots (snapping from west to east south of Jabor, direction confused but generally east to west in northern Jabor). However, as Fosberg noted, beyond South Point there were far fewer trees snapped or uprooted than to the north of South Point.

(4) The evidence on Majurirek and Pinlep shows maximum sustained winds (from between north and west at time of fall or snapping) of at least 80 knots and probably at least 100.

(5) On Lijeron the maximum sustained winds were from the north at speeds comparable to those on Majurirek and Pinlep.

In general, no estimate of windspeed is warranted where trees were blown over during inundation. The above estimates are made on the basis of trees observed to be blown down where no inundation occurred or on the basis of trees snapped off.

Vegetational evidence also provides clues as to the dominant direction of water movement across various islets. On the lagoon side of Mejatto at several different points, some palms and other trees had been washed westward (or southwestward) and at the time of the survey were standing in water several fathoms deep. Clearly marked strand lines indicated inundation from east to west (or northeast to southwest) across the ocean beaches and almost to the center of Imroj. These same inundation directions held on Majurirek and Pinlep, but with the strand lines at lower levels, 4-7 feet above mean high tide (the spring tide would account for about 1 foot of this amount). On the other hand, strand lines indicated much lesser inundations from the ocean eastward (southeastward) onto Majurirek and Pinlep.

Finally, there was another curious line of evidence that is not conclusive but is suggestive. On central Mejatto, as Fosberg pointed out, the palm roots exposed by the erosion accompanying the inundation were, with two exceptions, combed in an east to west direction. This would appear to indicate that the water drained from east to west off this part of the islet. In contrast, in the gentle topographic trough just back (west) of the steep ocean beach on Mejatto, there were two roots (the only ones visible) that were combed south-to-north. This same trough contained large quantities of vegetable strand material, yet there was no source for such material on the beach to eastward. Two roots and some strand debris are not much evidence on which to hang an hypothesis, but I am inclined to guess that while the main body of water drained from east to west, some remained in the topographic trough and that thereafter this water was blown northward by a strong south wind, thus accounting for the perverse

combing of the roots. As for the strand material, it may well have been brought in from the ocean during periods of strong tradewinds after the storm, having been derived initially during the storm not from Mejatto at all but from islets to the southeast -- to the east and south of Northeast Pass.

My interpretations of the vegetational evidence, discussed above, are summarized in schematic map form in Fig. 4.

Geomorphic evidence

On the several islets that were visited by the members of the field party, there is ample and usually quite consistent geomorphic evidence as to the direction of movement of water onto or across the land. To what extent the water came upon or across the land simply as huge, wind-driven waves and to what extent as a true surge -- a term that requires a local rise in sea level due to the friction of wind upon the water -- is another matter, and one on which the geomorphic evidence is not conclusive. Almost certainly both these factors were involved, at least on such eastern islets as Jaluit and Mejatto, which were under water to depths of at least one or two feet, as the following discussion makes clear.

The geomorphic evidence consists of depositional and erosional forms of the following kinds:

Depositional

Subaerial at least at low tide

1. Bars and ridges, emergent at least at low tide
   a. Upon reef flat, but separated from the land at mid-tide.
   b. Upon the reef flat, but tied to the land at mid-tide.
   c. New or augmented beach ridges upon the islets above high tide.
2. Patches or sheets of rubble
   a. Upon the reef flat, below water at mid- to high tide.
   b. Upon islets and emergent at high tide.
3. Irregular debris mounds upon islets, above high tide.
4. Pronounced strand lines upon islets, above high tide.

Submarine

1. Sediments, chiefly fine, deposited on floor of lagoon to west of several of the eastern islets.

2. Submerged portions of bar and ridge forms in lagoon to west of northern Jaluit Islet.

Erosional

Subaerial at least at low tide

1. Scour channels cut across islets (or for distances of many tens of yards across much of islet)

2. Scour pits and plunge holes, upon islets, roughly round to oval and without such channel features as marked elongation with undercutting for distances of at least tens of yards along sides to form distinct lateral boundaries

3. Breaks in older boulder ridges or in ridged beach rock

4. Beach scarp, cut in unconsolidated materials

5. Evidence of removal of fines in irregularly-shaped areas upon islets

Submarine

No evidence was seen directly of marked erosion below low water height, although at least one scour channel on Mejatto extended as a submarine feature for a distance of a few tens of yards into the lagoon. Presumably there was erosion of the reef front on the ocean side of the eastern islets, with rock fragments being torn from the reef or plucked from crevices on the reef front where they may have lodged after breaking off some time prior to the storm. However, the reef front on the ocean side was not examined.

These geomorphic features are described in future chapters. Here all that will be done is to mention these features, islet by islet, as they constitute evidence of water movement.

MEJATTO: Evidence: Gravel sheets thickest and most extensive on eastern (ocean) side of islet, thinning out and usually disappearing on western (lagoon) side; pot holes and scour pits excavated east to west as evidenced, for example, by their lying to the west of such obstructions as massive tree roots; fine sediments deposited chiefly along western side of islet and onto adjacent reef-flat and submarine slopes on lagoon side; most prominent scour channels begin on eastern side at break in old boulder ridge and extend westward. (Non-geomorphic evidence: Dead trees in lagoon with tendency to cluster near western end of scour channels.)

Conclusion: Dominant water movement was from east to west (ocean to lagoon) and water moved entirely across the islet except in the extreme north and south.

IMROJ: Evidence: Of the same kind as for Mejatto, but without the striking fine-sediment features on the west side and except that islet was not completely inundated.

Conclusion: Dominant water movement east to west.

NORTHERNMOST JALUIT

Evidence: Gravel ridge upon reef flat, ocean side, comprised largely of corals typical of reef front*; gravel sheet thinning out from east to west (toward lagoon); boulder about 4 X 4 X 6 feet lying 15 yards to west of ridged beach rock from which it was torn (and into which it could have been fitted); fine sediment deposits on western (lagoon) side; rubble from paved road carried east to west, into lagoon.

Conclusion: Dominant water movement east to west.

CENTRAL JALUIT (southern Jabor and southward extending a distance of about 1 mile south of old Sydneytown at the water tank).

Evidence: Gravel ridge upon reef flat on ocean side lower than farther north (0.5-4 yards high as contrasted with 3-8 yards farther north, except for one mound-like feature which was about 6 yards high, about 30 yards in diameter) and giving way to rubble patches in some places. Emergent ridge in lagoon, evidently composed of a high percentage of fine sediments as judged by view from shore; this ridge paralleled the shore at a distance of about 200 yards, and was barely emergent at high tide. Piece of glass found among debris that formed ridge on reef flat on ocean side. Rubble sheet more patchy than farther north and consists of only scattered coral-rock fragments in series of shallow channels that extend from near the ocean side (a few yards or tens of yards away) westward into the lagoon. Large water tank displaced from west to east a distance of about 200 yards (see p. 21).

Conclusion: Dominant water movement from west to east across islet.

PINLEP: Evidence: Small wave-cut scarp on western side of islet. Remnants of pronounced strand-line at about 5 feet above mean sea level on northern and eastern sides.

Conclusion: Dominant water movement probably alternately from east and from west.

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* See Banner's description, p. 76.

MAJURIREK: Evidence: Pronounced but small scarp, 3-4 feet above mean sea level, seemingly wave-cut, on western and southwestern side of islet. This scarp under-cuts some palms.

Conclusion: Dominant water movement, west to east. If there was water movement from east to west it was probably slight.

The conclusions stated above concerning dominant water movement onto or across the various islets are summarized in schematic map form in Fig. 4.

Other evidence regarding wind, wave, and storm conditions

Miscellaneous evidence is as follows:

(1) Mejatto-- All houses and other buildings were demolished, leaving not a trace that I could find. These were chiefly thatched native huts, though some were made from pieces of wood or lumber.

(2) Imroj-- Thatched huts were destroyed. Those made of boards were at least severely damaged, while some were totally demolished and others were partially demolished (roofs off, walls blown or washed in, etc.).*

(3) Central to northern Jabor-- Radio tower (steel tower) went down about 5:10 p.m., when radio went off the air (J. B. Mackenzie states this time is correct within a few minutes; he was on Majuro, where the broadcast was being received). All buildings demolished except for Japanese-built blockhouses, which were sunk 5-8 feet in the coral rock. Most buildings were completely swept away, leaving no trace, including the plywood buildings constructed only 12-18 months before by Holmes & Narver, American contractors. Some metal and wood remnants of buildings were found strewn about in an area to the east of the blockhouse building that was used as the headquarters for the Trust Territory government officials. One of the two water tanks was moved about 200 yards eastward from its concrete platform. An almost perfectly straight trench was scoured out to a depth of 3-4 feet, and this appears from old aerial photographs to have been a narrow water trench in Japanese times. (The trench runs almost due east from the lagoon to the ocean.) Scouring to a depth of 6-8 feet occurred at the NW corner of the southernmost blockhouse, leaving an irregularly shaped pit about 12 yards in diameter.

(4) Pinlep and Majurirek-- We were told that virtually all buildings had been blown down: that thatched huts were flattened by wind and that wooden shacks "flew apart". We observed some wood debris here and there but all buildings that I saw had been put together again, so this was not a direct observation.

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* For a different estimate of degree of damage, see Wiens, p. 29.

(5) Path of storm-- According to J. B. Mackenzie, who surveyed the damage at Mili Atoll, OPHELIA caused the most wave and water damage on the north side of that atoll. Mili is at 6°10'N, 171°55'E. According to Fleet Weather Central (1958) OPHELIA was heading WNW when located to the west and slightly north of Jaluit, after passing over Jaluit.

Reconstruction of events as related to field evidence

It is impossible for me even to imagine a series of storm events that would follow in logical order according to what is known about typhoon structure and movement and that would satisfy all the evidence cited above. Virtually all the evidence would be satisfied by supposing that a small, intense typhoon with multiple centers passed over Jaluit on January 7-8, but this relatively easy solution of the problem does not seem warranted since I have found no known instance of multiple eyes in a typhoon a mere 50 to 70 miles across, which must have been the diameter (diameter of winds over 63 knots) of this one to satisfy even the preponderance of the evidence. What is most common is an eye, evidently often irregular in shape, and which changes its size and shape almost constantly. My reconstruction follows, placed side-by-side with the evidence both pro and con. The reconstruction is represented by the series of schematic maps in Fig. 5.

RECONSTRUCTION	EVIDENCE AND REMARKS
1. On January 7, 1958 at 9 a.m. (180th meridian time) a small intense typhoon was approaching Jaluit, moving in a direction from 80° towards 260° at a speed of 5 to 7 knots. The storm was following a sinuous path and was later to curve first due westward, then west-northwestward as it crossed Jaluit. At the time the circulation about the storm was well defined with winds of 50 knots or more extending outward to a distance of 25-30 miles in the southwest quadrant, 30-40 miles in the NE quadrant, and 40-50 miles in the northwest quadrant. The northwest quadrant held the strongest winds, which were over 100 knots near the storm center, and the winds in this quadrant and around slightly into the west were strengthened well in advance of the storm by greatly intensified tradewinds that under the influence of the storm circulation had previously backed (shifted	1. a. Supporting evidence: Winds were northerly at North Jaluit and Imroj at this time (Table II). There was light rain at Imroj, which is consistent, and that Katje failed to report rain at N. Jaluit is immaterial since he failed to report rain at any time -- and no rain at any time is a virtual impossibility. Katje stated large waves from the east were pounding the Jaluit reef. I accept this and point out that it was almost low-low tide so that this would help loosen debris along the reef front. Quite likely some of this coral debris was being already thrown up on the reef to form the debris bar that later was so evident on the ocean side of N. Jaluit. There is no evidence that winds were yet strong enough to topple trees or snap them. The winds were still probably moderate as reported by Morris and Katje, and I accept this as partial evidence, consistent with later evidence, that the center of the storm was still far distant, about 45 nautical miles away. The estimated speed of 5-7 knots brings the storm center in at about 4-5 p.m., and this later

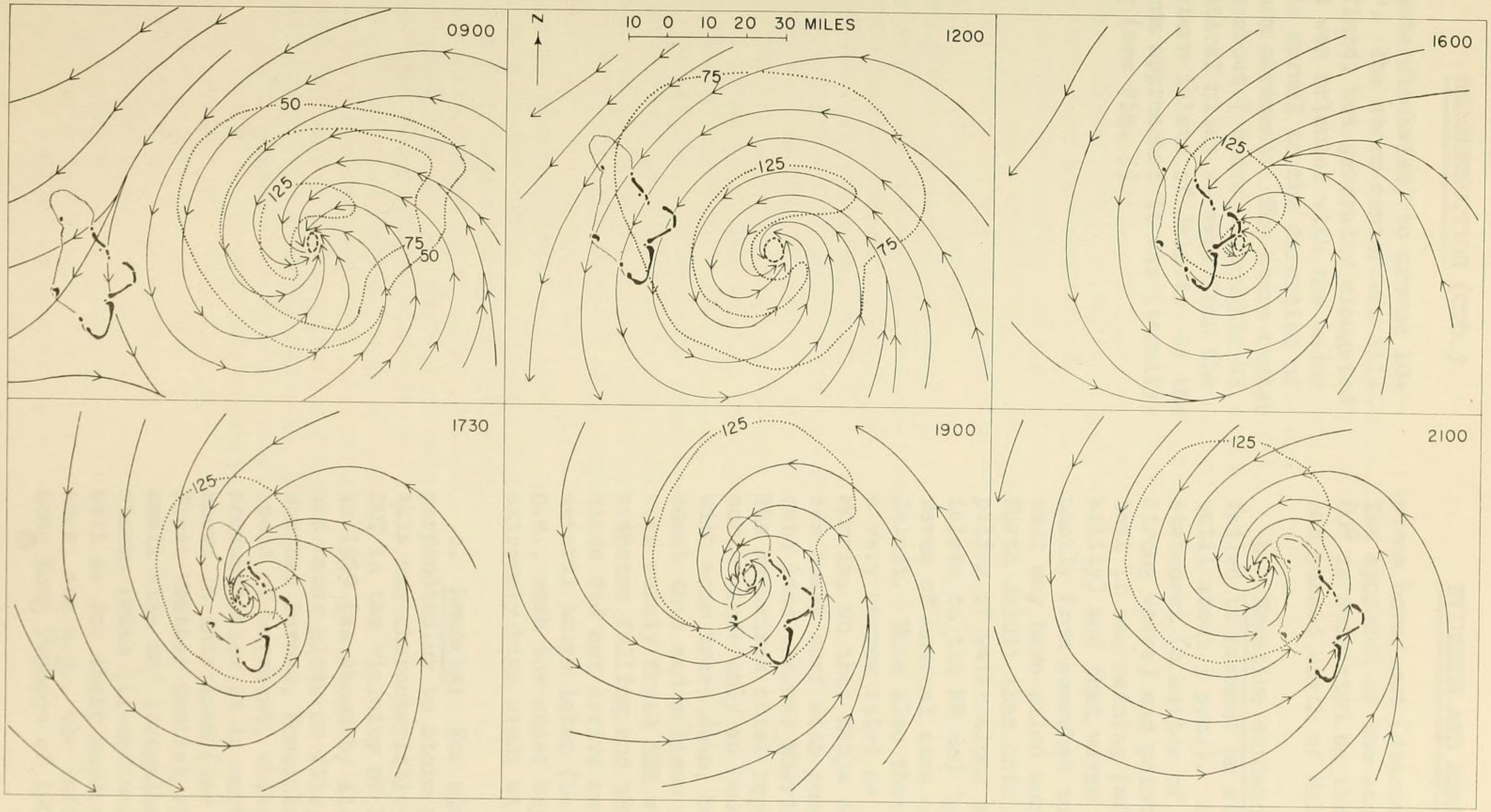


FIGURE 5 Schematic Streamline Charts Typhoon OPHELIA

JALUIT AREA JAN. 7, 1958 — Legend: ← Windflow Isotach (knots) Center winds <10 knots

RECONSTRUCTION (CTD.)

counterclockwise) to around 10-20°. The storm center was ill-defined, but generally elongated and was oriented with the major axis normal to the direction of storm movement. The storm center was about 7 hours -- roughly 45 nautical miles -- away from the eastern islets of Jaluit. As the storm approached it was itensifying (see Fig. 5).

EVIDENCE AND REMARKS (CTD.)

seems borne out (discussed below). The approach of the storm from about 80° is supported by the fact that it had passed north of Mili Atoll.

b. Negative evidence: Morris failed to comment on strong waves until about 3 p.m.). I discount his statement (a matter of what one calls strong waves) and point out further that it was raining (affecting visibility) and that waves coming dominantly from somewhat to the north of east may have piled more heavily onto North Jaluit than onto Imroj due to piling of water along ocean side of islets to the NE and "guiding" of waves of unusual size onto North Jaluit. Note also that Katje was on a very narrow islet as compared with Morris, so that Katje could readily see heavy surf with some waves topping onto land whereas Morris could not. The Majurirek chief reported strong north winds only an hour later (10 a.m.) with some trees down, but I must discount this and believe that the winds were merely fresh NNE with a few branches falling and that the extreme winds did not arrive on Majurirek until several hours later (between 3 and 4 p.m., when the chief began to report extremely high winds with heavy rain).

c. Remarks: For elongate centers perpendicular to storm path, note that this was characteristic of hurricane DOT in the vicinity of Kauai, Hawaii, in 1959 (as shown by aircraft reports and radar plots on file, mss. U. S. Weather Bureau, Honolulu); and for speed of movement, while 5-7 knots is somewhat slow it is certainly not unknown in this area (see data for LOLA, Fleet Weather Central 1957). As for small size and irregular shape of these storms (with ill-defined centers), as well as for their suddenness of appearance, see e.g., the information on the Hong Kong Typhoon of 1906 (Gibbs 1908).

RECONSTRUCTION (CTD.)

2. January 7. 12 (noon). The storm center was now about 30 nautical miles east of Southeast Pass and the storm was now approaching from about 100° (moving towards 280°) along the path shown in Fig. 5 and with winds as also shown in that figure. Waves were very strong from the east and against the reef on the ocean side of the islets from Northern Jaluit northward. It was just past low-low tide and debris had now been heaped high upon the ocean reef front in Northern Jaluit. There were N to NE winds at speeds in excess of 80 knots from Northern Jaluit northward (on eastern islets) and there was some toppling of trees that were poorly rooted or were awash near the eastern edges of the islets. There was snapping of branches on a wide scale, but no snapping of trunks of any but the very weakest trees. At Majurirek and Pinlep the winds were very fresh and northerly. With the ill-defined center, elongated now N-S, the windspeeds slacked off rapidly from N. Jaluit southward (Fig. 5). Occasional waves threw water across northernmost Jaluit, from east to west, but on Imroj (which is a higher islet) the waves only moved well up onto the eastern side. Nor had waves begun to sweep across Mejatto as yet, although there was heavy pounding of the boulder ridge along the eastern side of that islet. No waves of any magnitude were yet upon the western islets, though the very fresh northerly winds were piling some water into the southern part of the lagoon and producing some water up the beaches with superimposed small waves generated in the limited fetch area within

EVIDENCE AND REMARKS (CTD.)

2. a. Supporting evidence: The wind situation generally fits that given by the three informants, although winds were not directly from the north as reported. The wave (water) across North Jaluit was as reported by Katje. Dominant tree-fall and tree breakage directions support the view that not many trees were down or were snapped this early in the sequence. Before this happened the storm must tighten, change direction slightly, and come in so as to provide very high windspeeds from the northeast quadrant from N. Jaluit northward on the eastern islets.

b. Negative evidence: The Chief on Majurirek said trees were falling at this time. I believe he must have been off on his time or else that he was referring only to a very few trees (poorly rooted) going down or to breakage of branches, which would require only a wind of 50 knots or so. In this I am consistent in that field evidence shows the preponderance of trees going down before a wind from NW to W (falling SE to E) rather than from N or NE (Fig. 3).

c. Remarks: The elongate center with windspeeds decreasing very abruptly within a distance of a few hundred yards on N. Jaluit is necessary to account for the amazingly sharp transition from trees down from the NE to E (northernmost Jaluit) and from west to east (just south of northernmost Jaluit). This point is elaborated upon in the sequence that follows and in the corresponding evidence and remarks.

RECONSTRUCTION (CTD.)

the lagoon. Water was also running in through the eastern passes and the lagoon was perhaps 1-2 feet above normal level in the southern end; but still it was just above low-low tide so this did not represent an abnormal condition with reference to mean sea level.

3. January 7. 4 p.m. The storm center had become smaller and better defined and was now a few miles to the east of northernmost Jaluit (see Fig. 5 for location and for winds). The tide had been rising and was almost high-high. Water was crossing central and northern Jaluit from east to west, and was also crossing all but the extreme ends of Mejatto. Maximum winds were being or had been experienced during the past few hours from northernmost Jaluit northward (on eastern islets). Speeds exceeded 100 knots and trees were toppled. With extreme gust speeds exceeding 150 knots trees were snapped in this area, but there was a very sharp wind gradient and north central Jaluit had not yet received winds of these speeds. On Majurirek and Pinlep winds were from N to NW at speeds of close to 100 knots and trees began to fall where they were poorly rooted and much exposed (not shielded by massing) as along the upper beach on the north to northwest sides of these islets. The storm was now moving from about 70° and towards 250°.

4. January 7. 5 p.m. The chief significance of this time is that now the storm center had just passed into the lagoon and now also it was high-high tide. Within the past hour the waves crossing Mejatto and Jaluit had entered the lagoon and set up further waves that in combination with the basic tidal condition had

EVIDENCE AND REMARKS (CTD.)

3. a. Supporting evidence: Tree fall evidence fits this reconstruction with a single exception of E to W orientation of many of the fallen trees in northernmost Jaluit (see below). The general sequence of events as described by informants bears out the reconstruction here, but I have had to move up Morris' statements re Imroj (that is make them earlier by 3-5 hours than what he stated) and have had to move back (make later by 2 hours) the statements of the Majurirek chief.

b. Negative evidence: Some of this is covered immediately above, where a time adjustment is explained. The other principal negative item is that the sequence as given in this reconstruction does not explain the east-to-west orientation of many of the fallen trees on northernmost Jaluit (Jabor). Some may have been swung around by water moving W-E; but the broad northernmost part was not thoroughly inundated. A temporary second eye centered over northern Jaluit Islet would take care of things, but since I am rightly or wrongly eschewing multiple centers I did not draw my map to cover this (Fig.5).

4. a. Supporting evidence: The time adjustments referred to above still apply; otherwise the evidence from informants as well as the vegetational and geomorphic evidence support this phase of the reconstruction of storm events.

RECONSTRUCTION (CTD.)

caused flooding up-beach upon Majurirek, Pinlep, and other western islets. Trees fringing the beach had had their roots washed out and many had blown down before winds that were now backing to west at over 100 knots. By 5:30 p.m. or shortly after there were very strong NW to W winds across the southern part of the lagoon and this produced waves that now moved west to east from the lagoon onto Jaluit Islet. By 5:30 the strongest winds were past on the eastern islets north of northernmost Jaluit, but these strong westerly winds began to affect central Jaluit which was already wetted down; and between the flow of water (west to east) and the west winds, tree breakage and tree toppling now set in here. The radio tower had already gone down in northernmost Jaluit and about now (5:30) the water tank was floated eastward from its former location.

5. January 7. 7 p.m. (See Fig. 5). The storm was still intensifying and had accelerated slightly, to perhaps 5 knots. Furthermore, it had grown somewhat in size and the center was now better defined. It was centered over the northwest part of the lagoon. Winds were westerly on Majurirek and Pinlep, with speeds over 100 knots. Winds were southerly on the eastern islets, with speeds around 80-100 knots. The water had largely drained from Mejatto and from the very highest parts of Jaluit. It was raining very hard on the western islets, but there was only moderate rain on the eastern islets. Winds were now maximum and northerly on Lijeron, and trees were going down there. Some were snapping.

EVIDENCE AND REMARKS (CTD.)

5. a. Supporting evidence: With time adjustment already noted, this fits the evidence.

6. January 7. 8 p.m. About now the storm center cleared Jaluit Atoll, moving slightly north of west with the center passing a few miles to the south of Lijeron. This was an elongate center, oriented N-S (Fig. 5). Winds continued strong southerly over the northeast islets, were out of the SW and strong on the southeast islets, were very strong and out of the SW on the southwest islets, and were going to very strong northerly at Lijeron.

6. a. Supporting evidence: The evidence is all supporting (informants, vegetation, geomorphic) except that again a time adjustment is needed for Morris' account re Imroj. The south wind over Mejatto helps explain the orientation of combed roots, as suggested above (pp. 9-10). The Lijeron and Pinlep tree-fall evidence supports the view that the center must have moved westward out to sea between these islets, with a very elongate center to account for the lack of many east-west treefalls on Lijeron. Note that Lijeron and Pinlep were largely not under water, so water could not swing many fallen trees around here as it might have done on Jaluit or Mejatto.

7. January 7. 9-10 p.m. As the storm continued WNW away from the atoll the west to east wave within the lagoon carried some water against and slightly onto such northeast islets as Imroj and Mejatto.

8. January 7. 11 p.m.-midnight. Winds had slackened and now were generally southerly to southwesterly across the atoll. Unusual wave activity had ceased save for swells that arrived on the western islets from the WNW and that appeared as unusual surf on the west to northwest sides of Majurirek, Pinlep, and other western islets but that had little geomorphic effect because it was now at or very close to low-low tide.

9. January 8. Midnight-7 a.m. Winds lightened continuously during this period and winds continued to back with fresh trades reestablished by morning. These trades washed ashore onto Mejatto and other islets vegetable debris that was carried out to sea on the eastern side of the atoll, chiefly material blown northeast to north from more southerly islets such as Kinajon.

7-9. Remarks: These sequences are consistent with the evidence as shown in Table II, in Figures 2, 3, and 4, and in the text on geomorphic evidence (pp. 10-13). The sequences also fit the fact that the storm was located to the west and slightly to the north of Jaluit on January 8 (see Fleet Weather Central 1958).

RECONSTRUCTION (CTD.)

The near high-high tide during this period promoted this wash-in of debris and helped form the pronounced debris line later observed. There was also some wash-up of debris onto the west to northwest side of the western islets during this same period because of the arrival of swell from the storm whose center was now (7 a.m.) 55-60 nautical miles away to the WNW.

EVIDENCE AND REMARKS (CTD.)

FIGURE 6

THE SOLID LINE OUTLINES THE 1945 LAND AREA AS SHOWN BY AERIAL PHOTOS; BARS ARE LOCATED IN APPROXIMATE POSITIONS

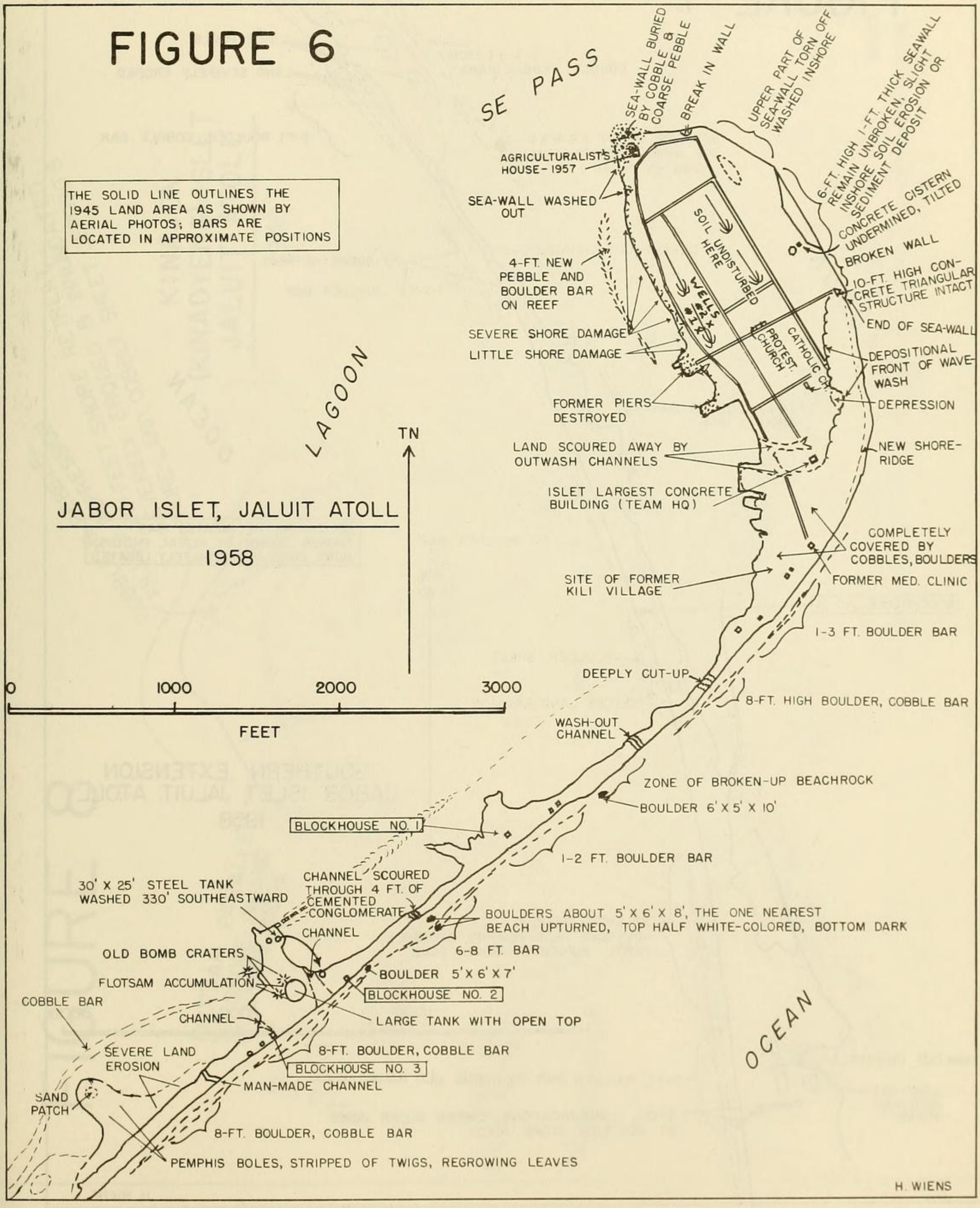


FIGURE 7

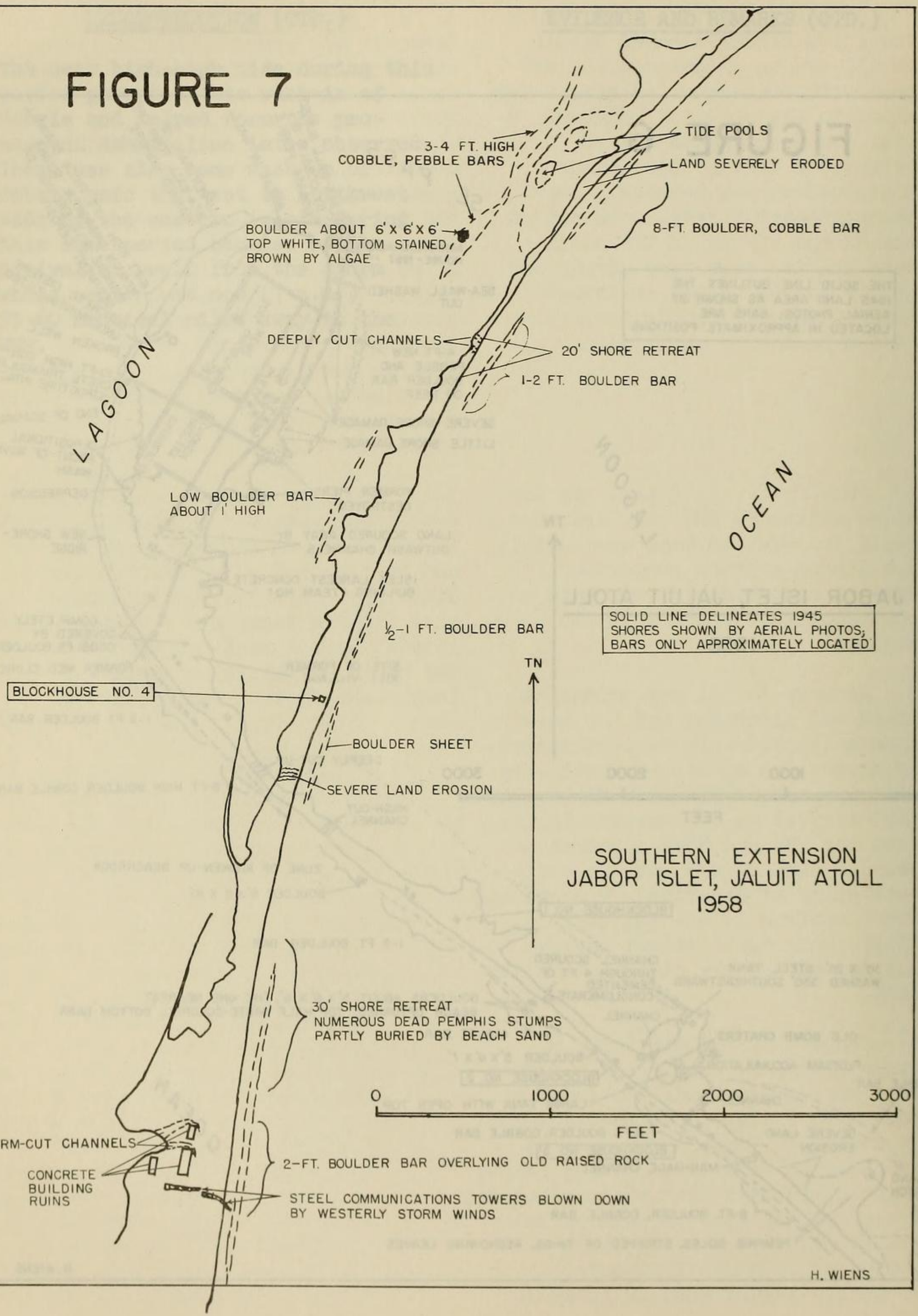
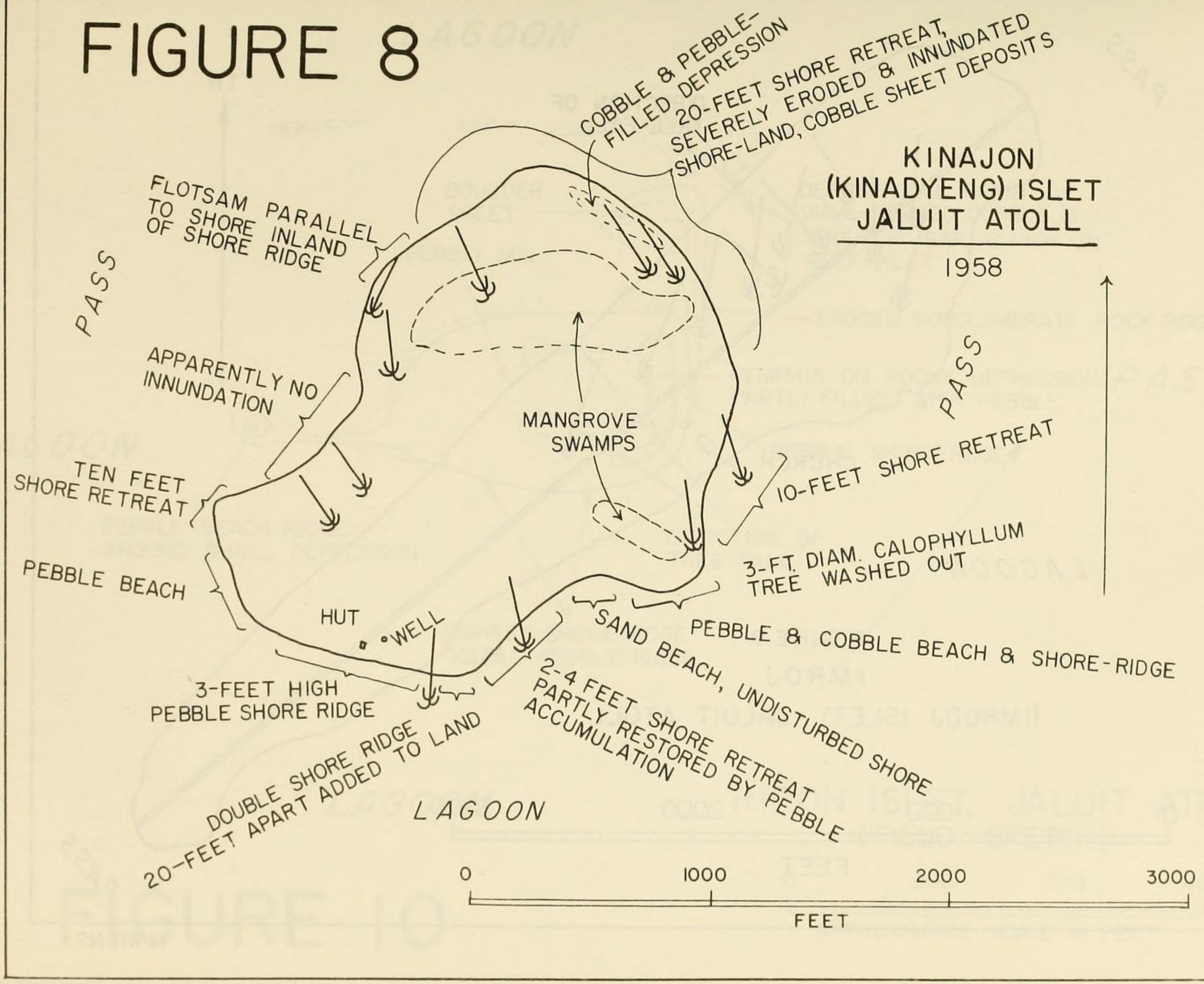

TIDE POOLS
3-4 FT. HIGH
COBBLE, PEBBLE BARS
LAND SEVERELY ERODED
BOULDER ABOUT 6' X 6' X 6'
TOP WHITE, BOTTOM STAINED
BROWN BY ALGAE
8-FT. BOULDER, COBBLE BAR
DEEPLY CUT CHANNELS
20' SHORE RETREAT
1-2 FT. BOULDER BAR
LAGOON
OCEAN
LOW BOULDER BAR
ABOUT 1' HIGH
½-1 FT. BOULDER BAR
SOLID LINE DELINEATES 1945
SHORES SHOWN BY AERIAL PHOTOS;
BARS ONLY APPROXIMATELY LOCATED
TN
BLOCKHOUSE NO. 4
BOULDER SHEET
SEVERE LAND EROSION
SOUTHERN EXTENSION
JABOR ISLET, JALUIT ATOLL
1958
30' SHORE RETREAT
NUMEROUS DEAD PEMPHIS STUMPS
PARTLY BURIED BY BEACH SAND
0
1000
2000
3000
FEET
STORM-CUT CHANNELS
CONCRETE
BUILDING
RUINS
2-FT. BOULDER BAR OVERLYING OLD RAISED ROCK
STEEL COMMUNICATIONS TOWERS BLOWN DOWN
BY WESTERLY STORM WINDS
H. WIENS

FIGURE 8


KINAJON
(KINADYENG) ISLET
JALUIT ATOLL
1958
COBBLE & PEBBLE-FILLED DEPRESSION
20-FEET SHORE RETREAT, SEVERELY ERODED & INNUNDATED SHORE-LAND, COBBLE SHEET DEPOSITS
FLOTSAM PARALLEL TO SHORE INLAND OF SHORE RIDGE
PASS
APPARENTLY NO INNUNDATION
MANGROVE SWAMPS
PASS
TEN FEET SHORE RETREAT
10-FEET SHORE RETREAT
3-FT. DIAM. CALOPHYLLUM TREE WASHED OUT
PEBBLE BEACH
HUT
WELL
SAND BEACH, UNDISTURBED SHORE
PEBBLE & COBBLE BEACH & SHORE-RIDGE
3-FEET HIGH PEBBLE SHORE RIDGE
2-4 FEET SHORE RETREAT PARTLY RESTORED BY PEBBLE ACCUMULATION
DOUBLE SHORE RIDGE 20-FEET APART ADDED TO LAND
LAGOON
0
1000
2000
3000
FEET

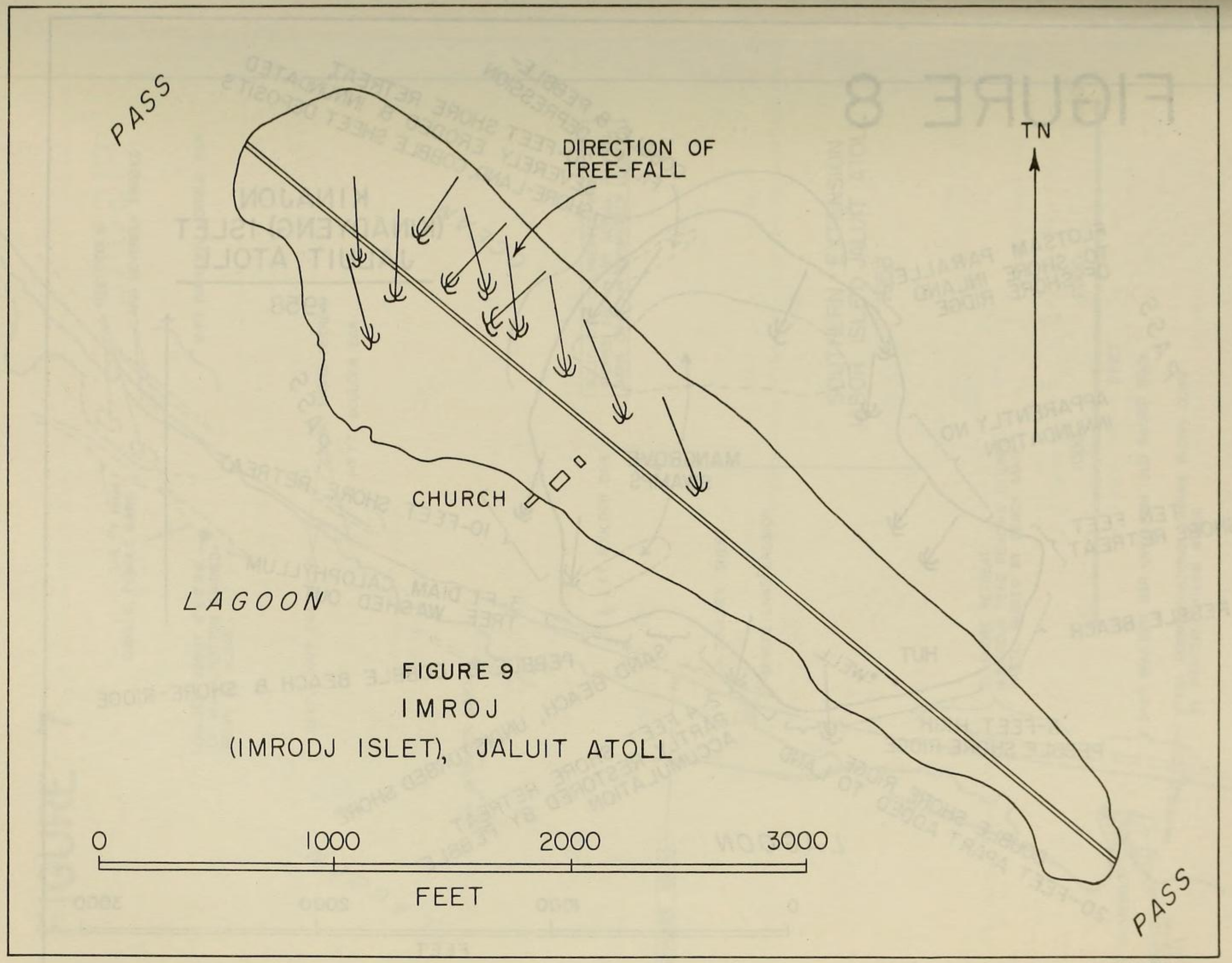
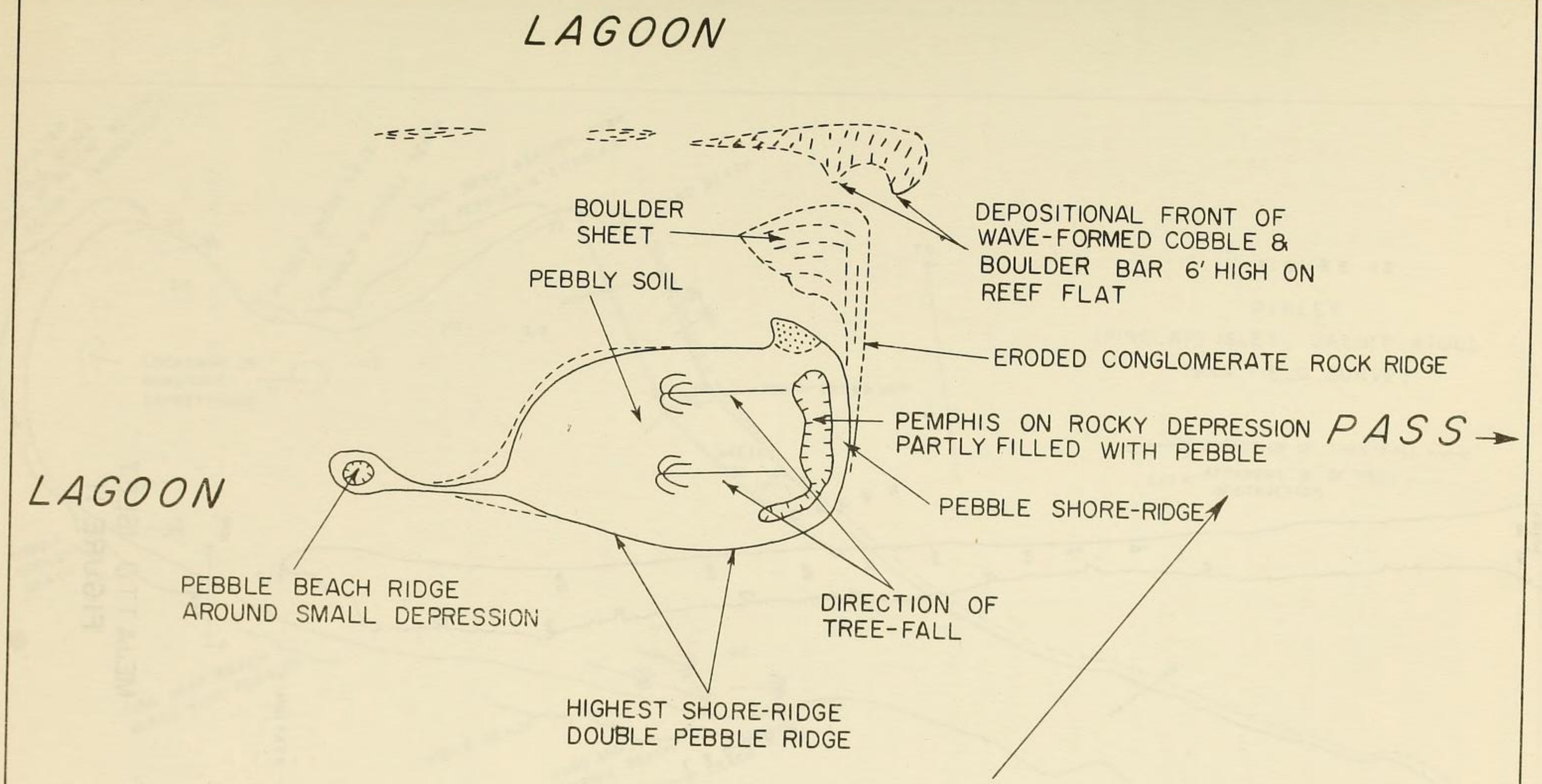


FIGURE 9

IMROJ

(IMRODJ ISLET), JALUIT ATOLL

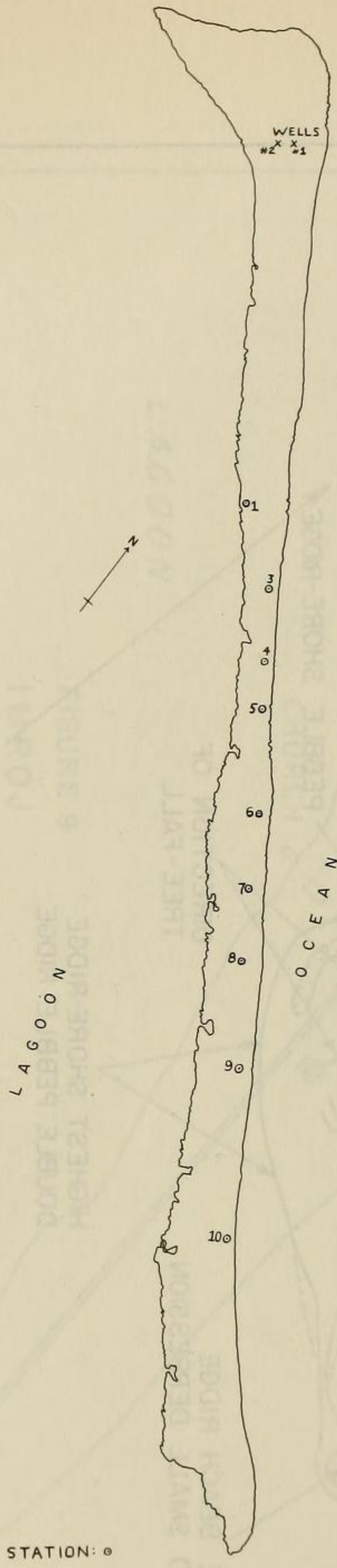
H. WIENS



RIBON ISLET, JALUIT ATOLL
(FIELD SKETCH)

0 200 300 400
APPROXIMATE SCALE IN FEET

FIGURE 10



MEJATTO ISLET
FIGURE 11

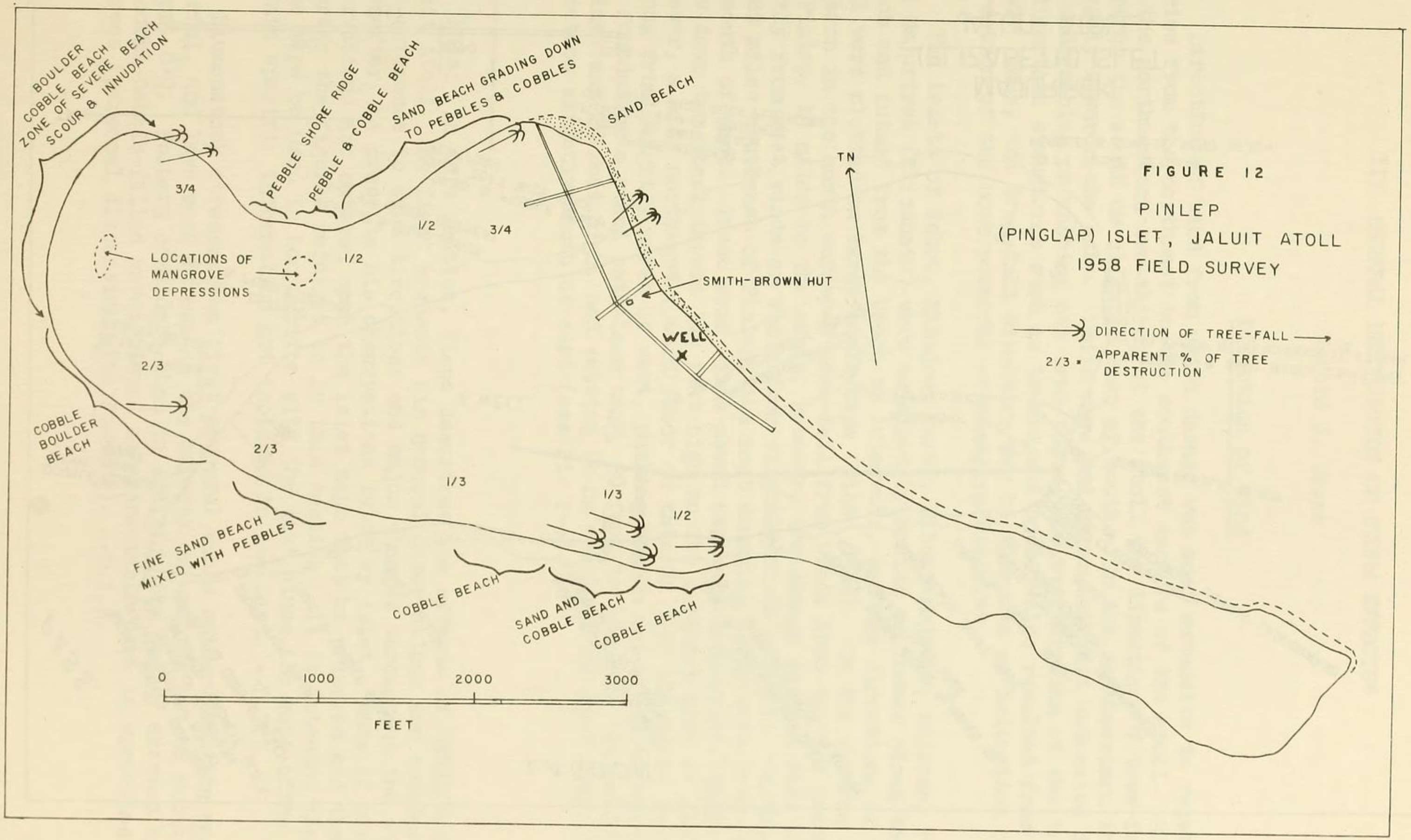
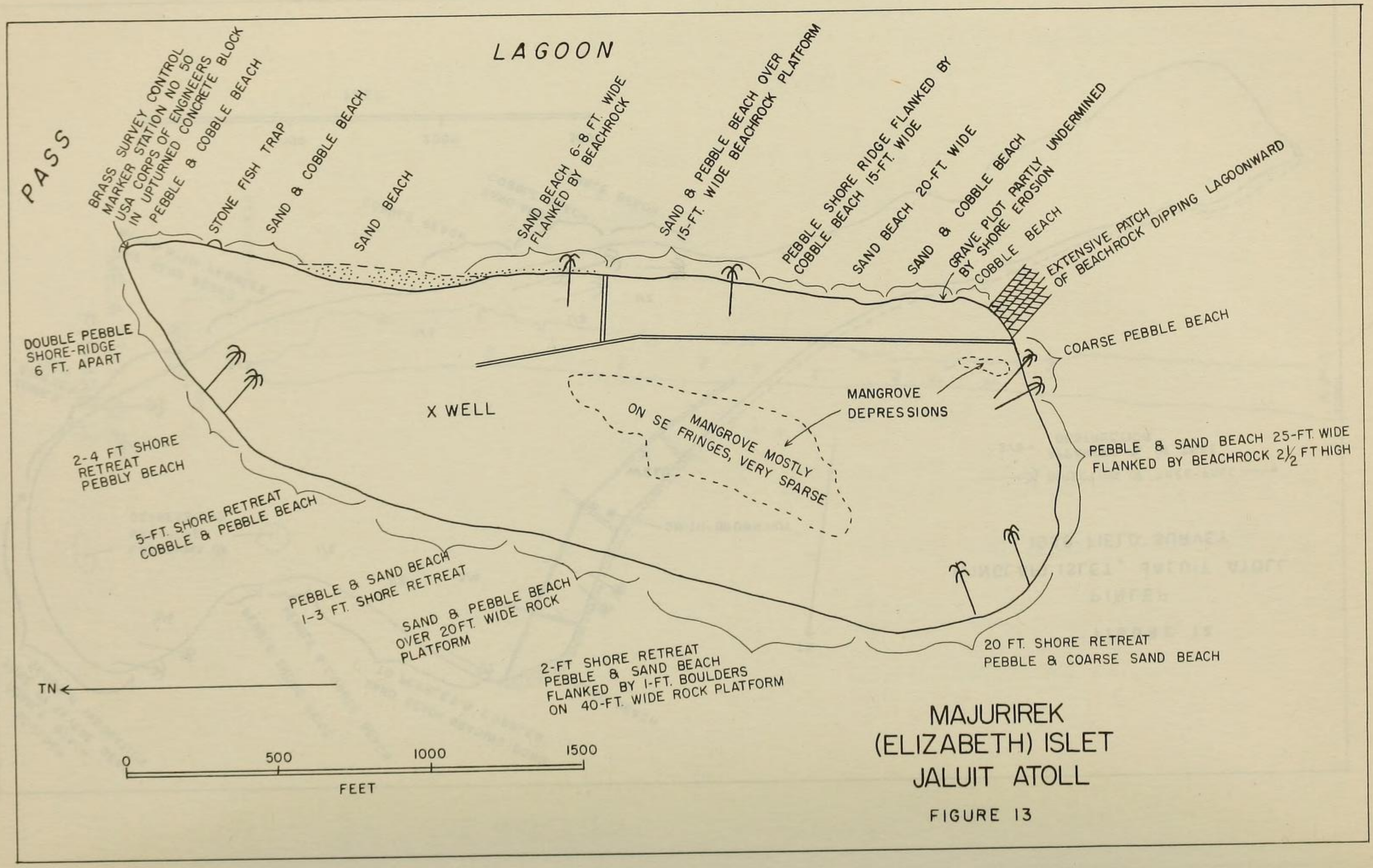


FIGURE 12

PINLEP
(PINGLAP) ISLET, JALUIT ATOLL
1958 FIELD SURVEY

DIRECTION OF TREE-FALL

2/3 = APPARENT % OF TREE DESTRUCTION



MAJURIREK (ELIZABETH) ISLET JALUIT ATOLL

FIGURE 13