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ENVIRONMENTAL IMPACT STATEMENT
FOR
CONDENSER COOLING WATER DISCHARGE
Kekaha, Hawaii
September 1973

ENVIRONMENTAL IMPACT STATEMENT

FOR

CONDENSER COOLING WATER DISCHARGE

BY

KEKAHA SUGAR COMPANY, LIMITED

KEKAHA, KAUAI, HAWAII

September 1973

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Ecological effects of heated effluent on the biota off Kekaha Sugar Mill

by

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Introduction

For many years, Kekaha Sugar Company, located at Kekaha, Kauai (latitude 21°58.02'N, longitude 159°43.10'W) has pumped about 2 million gallons of water per day from 300-foot deep salt water wells. This water is used as a coolant for their steam generator number 5. The heated water is discharged into a dry stream bed that leads to the sea. The temperature of the discharge varies with the generator load between 84° and 114°F. Residence time of heated water within the 1000-foot stream bed is about 15 minutes.

Within the State of Hawaii, the Department of Health is responsible for environmental protection. By virtue of the provisions of Chapter 342, Hawaii Revised Statutes and the Federal Water Pollution Control Act Amendments (1972, P.L. 92-500) and all other applicable laws, Chapter 37 and 37A of the Public Health Regulations of the State Department of Health, authorizes the Department to issue Waste Discharge Permits and to establish zones of mixing.

In February 1973, the Department of Health issued a temporary Waste Discharge Permit to Kekaha Sugar Company after it was determined that the effluent from their mill contained only thermally enriched condensor cooling water. This permit (number 695) was issued in order to allow time for an impact study to be conducted. Before a permanent Waste Discharge Permit can be issued or a Zone of Mixing granted, the results of this study must be evaluated by the State Department of Health and the federal Environmental Protection Agency (EPA).

The philosophy underlying the State's water pollution control standards (Chapter 37A) is to prevent the degradation of the quality of the natural receiving waters. Implicit in this concept is the protection and propagation of marine flora and fauna. Reasonable adherence to this policy permits the State to abate existing and to control new sources of water pollution. Implementation of this goal at the present time involves application of the best practicable treatment. As a consequence, each source of pollution must be evaluated separately. Generally, State standards have been as or more stringent than federal standards; however, since the federal standards specifically emphasize the quality of the effluent water rather than the receiving water as does the State, it is anticipated that in the near future the State will amend its standards so as to comply with federal policy.

The purpose of this report is to provide the necessary data so that the agencies mentioned above are able to evaluate the environmental impact of the Kekaha Sugar Mill thermal discharge.

Description of study site

Kekaha Sugar Mill is located on the southwestern coast of the island of Kauai. The mill is approximately 1000 feet inland from the shoreline. At the mill, condensor cooling water is discharged into a mill ditch (Figure 1) and from there flows slowly downstream to the ocean (see Figures 4-8). Where the discharge crosses the beach, a stream bed has been cut in the sand at an oblique angle to the shore.

The ocean bottom off the discharge is a gradually sloping shelf of algal covered fossil limestone alternating with patches of sand. Adjacent to the shore is a narrow channel about 100 feet wide which runs parallel to shore. Longshore currents are strongest in the middle of this channel, where they flow predominantly to the northwest. The bottom of the long-shore channel is covered by sand. At its outer margin are many boulders and a considerable amount of algal covered rubble. Many juvenile fishes are abundant in this zone. The depth of the channel at midtide varies between 2 and 4 feet. There is no evidence of scour along the bottom of the longshore channel or along the inner margin of the algal reef platform.

Beyond the channel, a shallow fossil reef bench extends seaward for several hundred feet. During extreme low tides, portions of the bench are exposed to the atmosphere for short periods of time. It is covered predominantly by a rich community of algae. Living corals are conspicuously rare in this zone.

Normally the surf breaks at the seaward edge of the shallow bench or platform and rolls shoreward transporting considerable quantities of water inshore into the narrow channel. Because the platform is so shallow, a passing wave often transports the entire water column above it shoreward at the speed of the wave. Turbulence induced by breaking waves is greatest at the outer edge of the platform and gradually diminishes shoreward. The volume of water transported inshore across the bench is the principal factor inducing and sustaining the longshore currents.

At irregular intervals, passes or breaks occur in the reef bench. Some of the water which is transported over the bench into the longshore channel escapes seaward through the passes in the form of rip currents. Two passes are present, one on either side of the discharge (see Figures 4-8). A limited amount of plume water is transported seaward through these passes, especially at high tide.

Seaward of the reef bench the depth abruptly increases to about 6 to 8 feet. The topography here is made up of eroded fossil limestone blocks and large boulders. Algal cover approaches 70 percent. Corals are still rare but are more abundant than on the shallow wave-cut platform. Further offshore the bottom tends to be much flatter and patches of sand are common.

A second site for investigation was selected about 700 feet to the southeast of the discharge site. This area was studied in order to provide present and future comparisons, and therefore will be referred to henceforth as the control. The control area was selected on the basis of similarities in physiography with the discharge site. It is characterized by a narrow longshore channel adjacent to the beach, a shallow limestone bench, and offshore topography similar to the discharge site. However, differences between the two areas are evident; the reef platform is somewhat wider than at the discharge site and passes are less well developed. Turbulence at the inner margin of the reef platform is much less at the control than at the discharge site. Also, longshore currents are somewhat weaker at the control station. Several other areas further removed from the discharge site were examined and considered as possible control stations, but differences in reef structure, depth, circulation and species composition were even greater than the differences between the discharge site and the area selected for a control.

Research plan and methods

In order to evaluate the impact of the heated effluent, it was first necessary to define the horizontal and vertical dimensions of the plume. This was accomplished by measuring the temperature of the receiving water with a hand-held thermometer at various locations surrounding the stream discharge. Once this was done, an array of stations was selected where Taylor maximum-minimum thermometers were installed at the surface and on the bottom (Figure 2). These instruments record instantaneous temperature as well as the range over the time of immersion, thereby providing a measurement of temperature extremes for the given time period. In this case, the thermometers were left in the field for one week, sufficient to cover many tidal cycles as well as changes in wind and wave conditions which might alter the longshore currents and the pattern of mixing. Periodically, fresh water from a natural stream enters the mill ditch and causes dilution of the effluent. Therefore, salinity measurements in the zone of mixing in the ocean provided an additional means of contouring the dimensions of the plume. Salinity was measured with a refractometer accurate to 0.5 parts per thousand (American Optical Model 10419). Contour diagrams of surface and bottom isotherms and surface isohals were constructed to show diagramatically the zone of influence.

Samples of other parameters of water quality were taken in the stream between the dates 8-3-73 and 8-17-73, during hours of normal operation. These samples were analyzed by Brewer Analytical Laboratories. Analysis included B.O.D.$_5$, suspended solids, settleable solids, nitrate nitrogen, ammonia nitrogen and total phosphorous. Samples of the biota of the stream were also collected and identified.

Currents were measured in the stream and nearshore zone by tracing the course of drifting floats and timing their movements over known distances. A shallow water drogue was also used for this purpose. Underwater observations were made to determine the extent of scour and sand movement.

Having determined the pattern of mixing and transport, surveys were taken in those areas typifying representative habitats closest to the stream discharge. A fifty-foot long transect line (T-2, see Figures 7 and 8) was placed on the reef running normal to the shore at a point closest to the stream outlet on the beach. Galvanized stakes were driven into the reef to mark the beginning and the end of the transect (see Figure 2). The projected length of all organisms lying below the transect line was then recorded. This method yields estimates of density or coverage of the benthos (bottom living organisms). At five intervals selected at random along the line, a 1/16 meter square was placed on the bottom (Figure 3) and all algae were scraped from the substrate and placed in a plastic bag. These samples were frozen and later sorted and identified to the genus, or where possible, to the species level. Sorted samples were weighed to the nearest 0.1 gram, thereby yielding estimates of their standing crop biomass.

A similar transect (T-1) was taken further offshore at a depth of 10 feet approximately 50 feet beyond the outer edge of the reef platform. Because no deviations from ambient bottom temperature were detected at this location during the sampling period (9 days), a future transect at this station is not planned.

At the control station, two transects were taken at locations equivalent to the discharge site, one on the reef platform (T-IV) and the other just beyond it at a depth of 10 feet (T-III). Comparison of the shallow water transects, taking into account the small physical differences between them, should indicate the impact, if any, of the thermally enriched plume on the biota near the discharge site. Comparison of the deeper water transects off the discharge and control sites should give a measure of the spatial physical heterogeneity of the habitat and the patchiness of the species populations present.

The scheduling of samples over the year was planned to coincide with seasonal periods when the ambient water temperature is at a maximum and minimum. Because thermal enrichment is essentially superimposed on ambient temperature, samples taken at these two time periods should provide a measure of the enriched maximum and minimum temperature of the sea water in contact with the biota. Furthermore, since the discharge is intermittent during the winter, samples taken at this time of year should provide an indication of the thermal shock (biotic response to rapid change in temperature over a short period of time) that biota might be exposed to.

Data presented in the present report represents only the results of the summer investigation. Although some data is presented that was collected in winter months by the Department of Health, the major analysis in the winter including surveys of the biota will be conducted in January and February of 1974. The findings of that study will be appended to this report in March of 1974.

Results

Description of effluent

Observations of the effluent in the mill stream revealed that it contained no floating debris, scum or oil. However, occasionally suspended in the otherwise clear water were strands of blue green algae. Also, the water was characterized by a faint odor similar to that of molasses.

On the days when water temperature of the effluent was measured (7-28-73 and 8-5-73), the number 5 steam generator was operating at 68% and 80% capacity. At the time measurements were taken, the surface temperatures at the head of the stream were 38.1° and 39°C (100.6° - 102.2°F) respectively. At the lower end of the stream, values at most were only 0.5°C (.9°F) cooler, indicating there is insignificant cooling during the passage of the effluent downstream. Maximum-minimum thermometers left in the stream for one week showed temperatures to have ranged between 27.2° and 42.7°C (81° and 109°F). Peak load during the week was 88% of capacity.

Measurements of the salinity of the effluent disclosed two sources causing various amounts of fresh water dilution. The salinity of the mill discharge into the stream ranged between 20 and 22‰. Since no fresh water is added to the coolant water in the mill, these values must reflect the salinity of the well water pumped from 300 feet. Apparently there is some dilution due to mixing of fresh and intruded salt water at the depth of the well. Another source of fresh water was discovered entering the mill ditch at the very head of the "dry" stream bed, which apparently is not always dry. Mixing of the effluent with this source of fresh water lowered the salinity of the stream water to between 8 and 16‰.

The macro-biota in the stream itself was quite limited, consisting of two species of blue green algae, Hormothamnium sp. and Microcoleus sp., and one species of mosquito fish, Gambusia sp. Other organisms may inhabit the mud bottom or other cryptic habitats of the stream, however, these were not sampled. The blue green algae form mats along the bottom and sides of the stream. Occasionally, clumps of this material break free and are carried downstream into the sea. No marine organisms were observed to utilize the suspended blue green clumps as food.

Data concerning the water quality of water samples collected in the stream by Kekaha Sugar Company and analyzed by Brewer Analytical Laboratory are given in Table I.

Table I

Water quality of effluent in stream

Date sampled	BOD_5 mg/L	Suspended solids mg/L	Settleable solids mL/L	Nitrate nitrogen mg/L	Ammonia nitrogen mg/L	Total phosphorous mg/L
8-3-73	4.16	20	<0.1	0.042	0.01	0.45
8-8-73	2.25	31	<0.1	0.018	0.09	0.026
8-9-73	1.20	10	<0.1	0.088	0.03	0.09
8-10-73	1.40	7	<0.1	0.025	0.11	0.44
8-15-73	12.60	9	<0.1	0.062	0.02	0.126
8-16-73	1.60	1	<0.1	0.047	0.01	0.107
8-17-73	2.60	2	<0.1	0.042	0.07	0.108

It is difficult to interpret these data with respect to State standards since State standards refer to receiving rather than effluent waters. These data are presented here for future reference, should State standards be revised at a later date.

Receiving water and dimensions of plume

At the point where the stream flows across the sand and enters the unconfined water of the sea, a considerable amount of vigorous mixing takes place. This is due to the meeting of the stream waters with flooding and ebbing waves. The mixing which results produces eddies of warm and cool water which range between 0 and 5°C (0 and 9°F) above ambient. Changes in temperature of this magnitude were limited to a radius of about 100 feet from the mouth of the stream (see Figures 4-8). Between 100 and 250 feet from the stream outlet, the temperature of the surface and bottom water was rarely more than 1°C (1.8°F) above ambient (see Figures 4-8). With the exception of a narrow tongue running northwest in the nearshore channel (1°C above ambient), all surface and bottom water beyond 250 feet did not exceed the ambient temperature. Contours of surface salinity (Figure 9), as well as data collected by the Department of Health in 1972 (Figure 10), showed a very similar pattern of mixing.

Apart from the vigorous mixing, another reason why dilution is affected so rapidly is because heated water is never re-circulated through the mill. Recirculation is impossible because the mill intake is a 300-foot deep well. A ground water intake also avoids entraining plankton, fish eggs and larvae.

Measurements of the velocity of stream, longshore and wave currents are given in Figure 11. Wave currents, that is, movement of water over the shallow reef platform due to passing waves, are by far the swiftest currents in the area (6 feet/sec.). Water transport from this source induces and sustains the slower moving (0.93 - 1.83 feet/sec.) longshore currents. The maximum velocity of water flow in the stream was 2.32 feet/sec., which is about 3 times the longshore rate at the control station. The addition of water from the stream appears to cause a small increase in the longshore current off its mouth, but not sufficient to cause scour.

The receiving waters off the southwest coast of Kauai are classified by the State Department of Health as Class A. This means that the departure of temperature from natural cannot exceed 1.5°F without violating the standards. There is no standard set for salinity. Clearly the standard for temperature is consistently violated within 250 feet of the stream mouth and occasionally beyond, especially at the surface. However, as it will be shown in the next section, there are no detectable ecological effects associated with the effluent.

The objective of the standards set for Class A waters is the protection of recreational uses so that aesthetic enjoyment is not limited in any way. Ironically, the major impact on the use of the area by beachgoers and bathers has been to attract children who enjoy playing in the heated plume.

Biological impact

The benthic communities at all four stations where transects were taken were dominated by various species of algae. Data for the transects are given in Tables II-A & B, III-A & B, IV-A & B, and V-A & B. Table VI is a summary table listing totals and significant characteristics of each transect. Since no deviations from ambient bottom temperature were detected near the offshore discharge transect (T-1), differences between the benthic algal communities of T-1 and the offshore control transect (T-III) must be due to factors other than temperature. Therefore, a comparison between these two transects, which are at the same depth and distance offshore, should indicate to what extent the control area can truly be considered a control. Some differences between them are apparent. Transect I is dominated by *Hemitrema flabelliformis*; Transect III by *Zonaria variegata*. Transect I has 18 species; Transect III, 27 species. Similarities, however, are perhaps more obvious. Biomass (excluding *Porolithon*) and total living coverage are almost the same on both transects. The dominant species on each transect is relaively abundant on the other. These contrasts illustrate the difficulty of locating two exactly identical stations. On the scale of a 50 foot transect, there are bound to be some differences in topography, surge, current, etc. Also the strong tendency of vegetative species to establish patchy distributions due to asexual growth, may lead to differences in dominance.

The comparison between transects I and III serves to illustrate how much agreement one should expect to find between transects taken in essentially the same habitat, and provides a measure of the natural habitat heterogeneity, within the study area. Similarily, one would expect a comparable heterogeneity between the two inshore transects. The results indicate strong similarity between the algal communities of T-II and T-IV, along with some differences. Transects II and IV are both dominated by the same species, <u>Sargassum echinocarpum</u>, both have about the same number of species (30 versus 33), and both have a similar cover of living species. The major difference between transect II and IV is in the total standing crop of algae. For example, the biomass of <u>S. echinocarpum</u> sampled from the control transect (T-IV) was about four times greater than the biomass of this species sampled from the discharge transect (T-II). This difference is probably related to the stronger turbulence observed at T-II, which may physically remove plants above a certain size. Thermal enrichment does not appear to have measurably affected the species composition of the algal community at T-II.

DISCUSSION

Temperature is generally considered to be the most important single factor governing the distribution and abundance of life. For example, several life functions which are temperature dependent include respiration, growth, reproduction and behavior. Organisms, of course, do not respond to factors of the environment separately, but rather, their biology and behavior represent an integrated response to all factors acting in combination. Nevertheless temperature is often of such over-riding significance that governmental agencies charged with protecting the environment, require that thorough impact studies be conducted in situations where temperature has been altered.

Many studies have illustrated the magnitude and the kind of changes that do take place in sub-tropical marine communities when the temperature is artificially raised. Off the Turkey Point power plant in Florida, as much as 50 acres of the ocean bottom have become devoid of vegetation except for blue-green algae (Roesslev and Zieman, 1969). Similarly McCain (1972) found the glue-green algae Lyngbya is assiciated with elevated temperature at the discharge of the Kahalui Power Plant in Maui. Blue-greens were also found in the mill ditch of the Kekaha Sugar Company during this study.

Studies conducted by McCain and Peck (1973) and Jokiel and Coles (In press) off the Hawaiian Electric Power Plant at Kahe Point, Oahu, have described other changes in the marine environment associated with elevated temperature. McCain and Peck noted a marked increase in the standing crop of herbivorous fish in areas exposed to the thermal plume off Kahe. The authors suggest that the increased fish standing crop may be related to a measured increase in standing crop of benthic algae utilizable as food. Jokiel and Coles found thermal damage to reef corals at Kahe to be most severe in the late summer, coinciding with the time of annual ambient temperature maxima (27°C, 80.6°F). They determined that, with bottom temperature increases of 4-5°C (7.2-9°F) above the annual maximum, virtually all corals eventually died. At +3-4°C (+5.4-7.2°F), mortality was high and corals often were bleached due to loss of their symbiotic zooxanthallae. Sublethal effects, paling and bleaching, occurred at +2-3°C (+3.6-5.4°F). At temperatures +0-2°C (+0-3.6°F), there were no observable effects.

All of the studies are useful in interpreting what factors are determinant in controlling the community composition of the ecosystem off Kekaha Sugar Mill discharge. The kinds of changes that we would expect to find if temperature was affecting the community are as follows: blue green algae more abundant than normal, changes in the abundance of benthic algae, increases in herbivorous fishes and finally bleached corals. All of these changes have been associated with thermal stress elsewhere. None were observed off the ocean discharge at Kekaha.

The behavior of corals expelling their symbiotic zooxanthellae (bleaching) is an especially powerful indicator of thermal stress because it is easily observed and appears to be sensitive to the degree of stress. Although corals were rare at all stations, some were present and none showed any sign of bleaching. The paucity of corals in the entire nearshore area off Kekaha is probably related to water turbidity and strong wave turbulence which characterizes this coastline.

It is important to emphasize that only a very small area within 100 feet of the stream discharge is generally exposed to thermal enrichment greater than 1°C above ambient. This area is essentially limited to the nearshore channel. The bottom of the channel is largely covered by sand; therefore, few benthic algae are present. Only a relatively small number of mobile species, such as zooplankton and fish, come into contact with water heated above 1°C. Because of the longshore currents, passive species should not remain in contact for more than several minutes. The inshore channel behind the reef normally serves as a refugium for juvenile reef fishes. There is no evidence to suggest this function has been disrupted within the plume. Juvenile fish observed within the zone of mixing appeared to behave normally and were as abundant as they were at the inshore control station. Outside the reef, adult fishes were abundant at both the discharge and control sites.

Conclusions

1. The effluent discharge by the Kekaha Sugar Mill in the stream contains no floating debris, scum or oil. Temperature of the effluent ranges between 84° and 114°F. Salinity ranges between 20 and 22 ppt. Fresh water entering the stream from a natural source occasionally lowers the salinity of the effluent in the stream to between 8 and 16 ppt. Biota in the stream consists primarily of two species of blue green algae and mosquito fish. Clumps of the blue green algae occasionally are carried into the sea but do not appear to be utilized as a food source by any marine species.

2. A small zone of mixing exists at the mouth of the stream. Thermal enrichment of water more than 2°C above ambient was not found outside a 100-foot radius around the outlet. The +1.0°C (1.8°F) isotherm is for the most part confined within 250 feet of the stream.

3. The limited extent of the plume is due to vigorous mixing at the point of discharge and because heated water is never recirculated through the mill. The mill intake consists of a saline well; therefore, entrainment of zooplankton or fish eggs and larvae is not possible.

4. The addition of water from the stream appears to cause a small increase in the longshore current off the mouth but is not sufficient to cause scour.

5. Recreational use of the area by beachgoers and bathers appears to be enhanced since small children were observed to be attracted to

and enjoy playing in the heated plume.

6. There appear to be no detrimental ecological effects associated with effluent waters from the outfall. Species of algae, coral and fish which occupy habitats adjacent to the outfall appear to be normal, and are representative of nearshore marine communities of the area. None of the ecological changes known to be caused by thermal stress were observed off the Kekaha Sugar Mill discharge.

References

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McCain, J.C. and J.M. Peck, Jr. 1973. The effects of a Hawaiian power plant on the distribution and abundance of reef fishes. UNIHI - Seagrant - AR - 73 - 03. 16pp.

Roessler, M.A. and J.C. Zeman. 1969. The effects of thermal additions on the biota of southern Biscayne Bay, Florida. Proc. Gulf and Caribbean Fish. Inst. 22nd Ann. Session. pp.136-145.

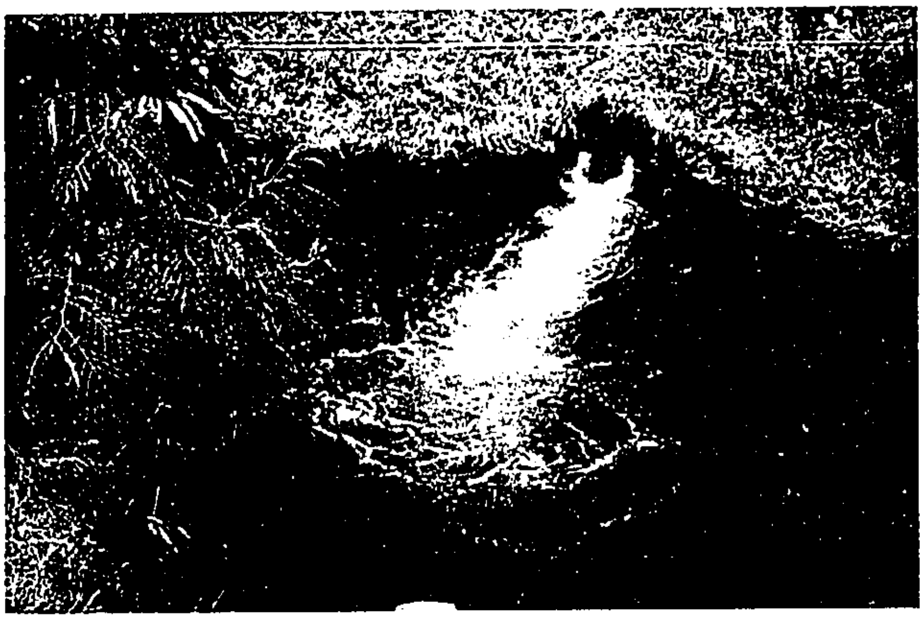


Figure 1. Mill effluent being discharged into stream.

Figure 2. A Taylor Maximum-minimum Thermometer wired to the bottom at Station 4. Note above: beginning of Transect II.

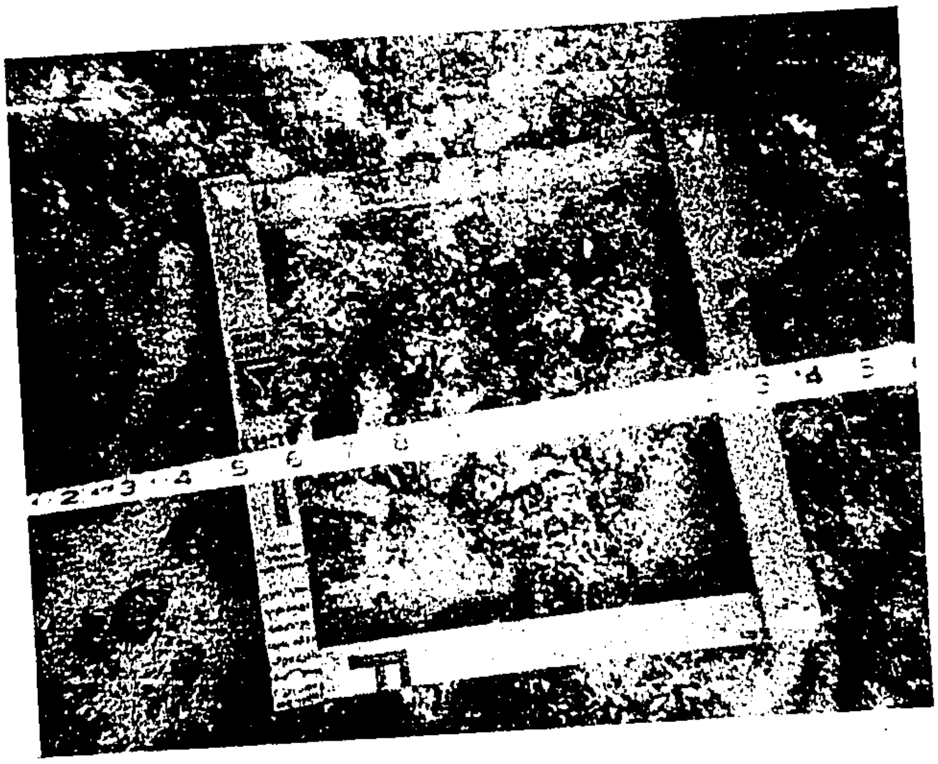


Figure 3. Samples of biomass were obtained by scraping all algae from the substratum within a 1/16 square meter quadrat.

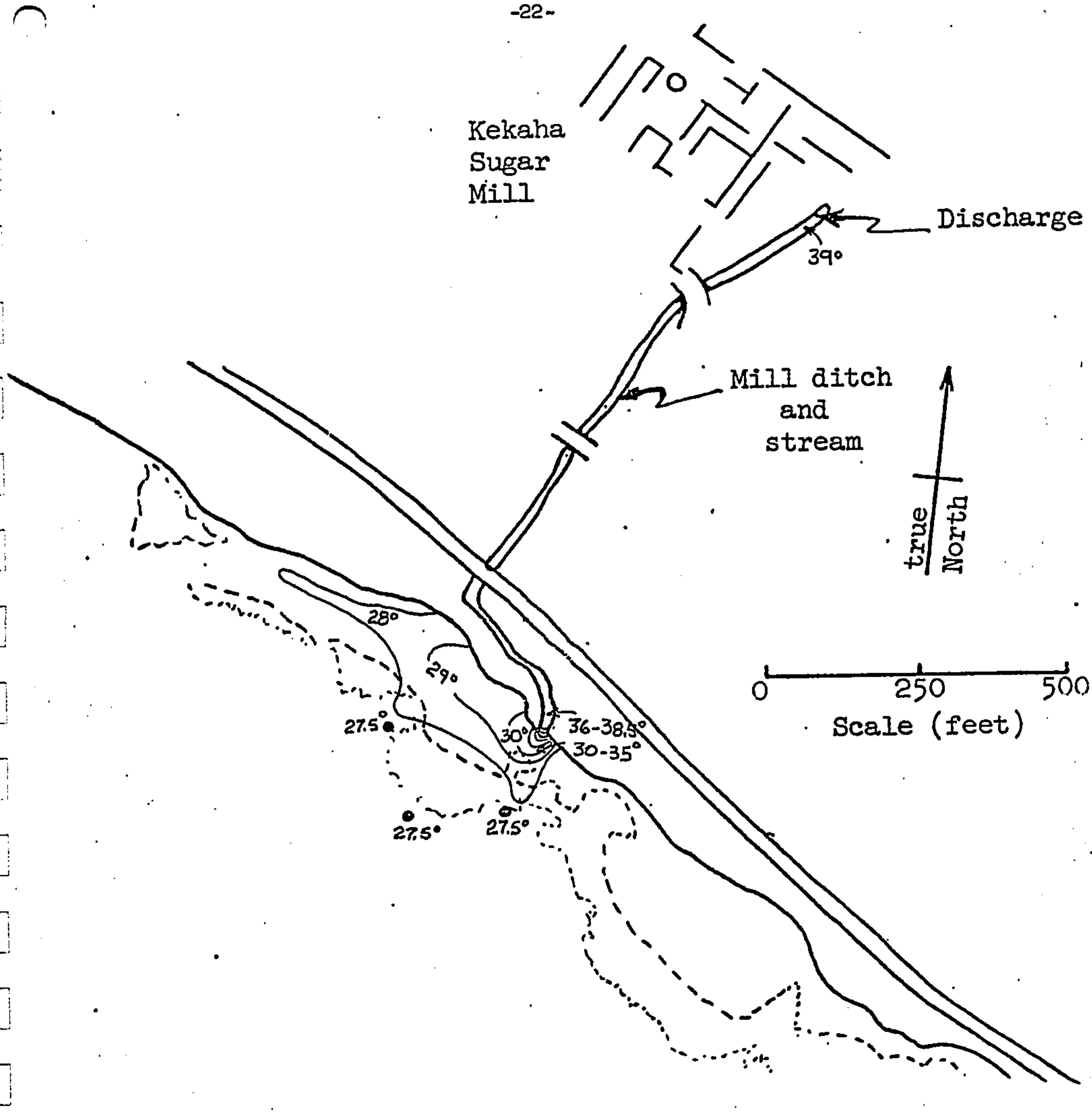


Figure 4. Surface temperature in the stream and ocean on 7-28-73, 10-11 A.M. The load of number 5 generator at this time was 68% capacity.

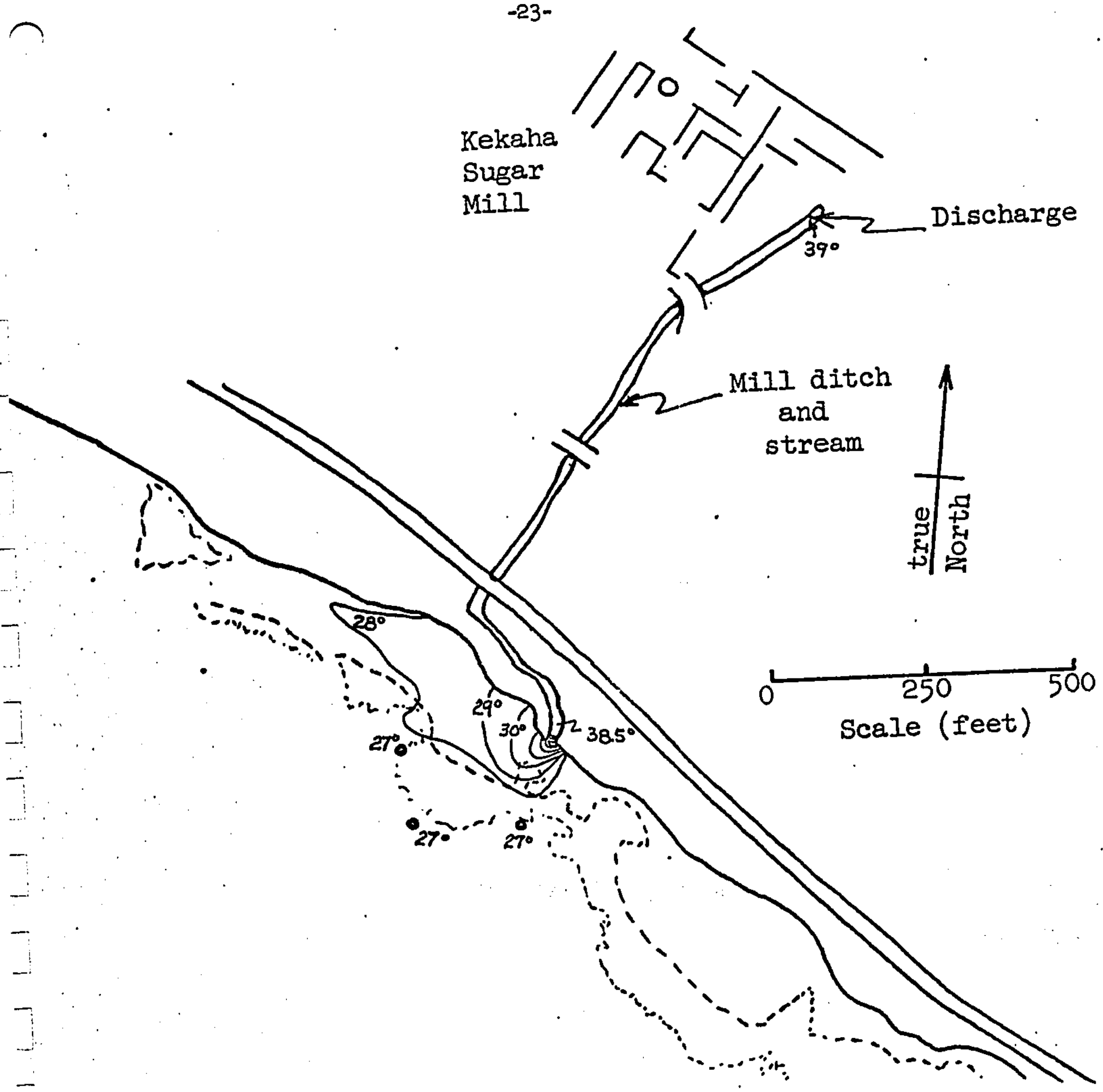


Figure 5. Bottom temperature in the stream and ocean on 7-28-73, 10-11 A.M.
No. 5 generator load = 68%.

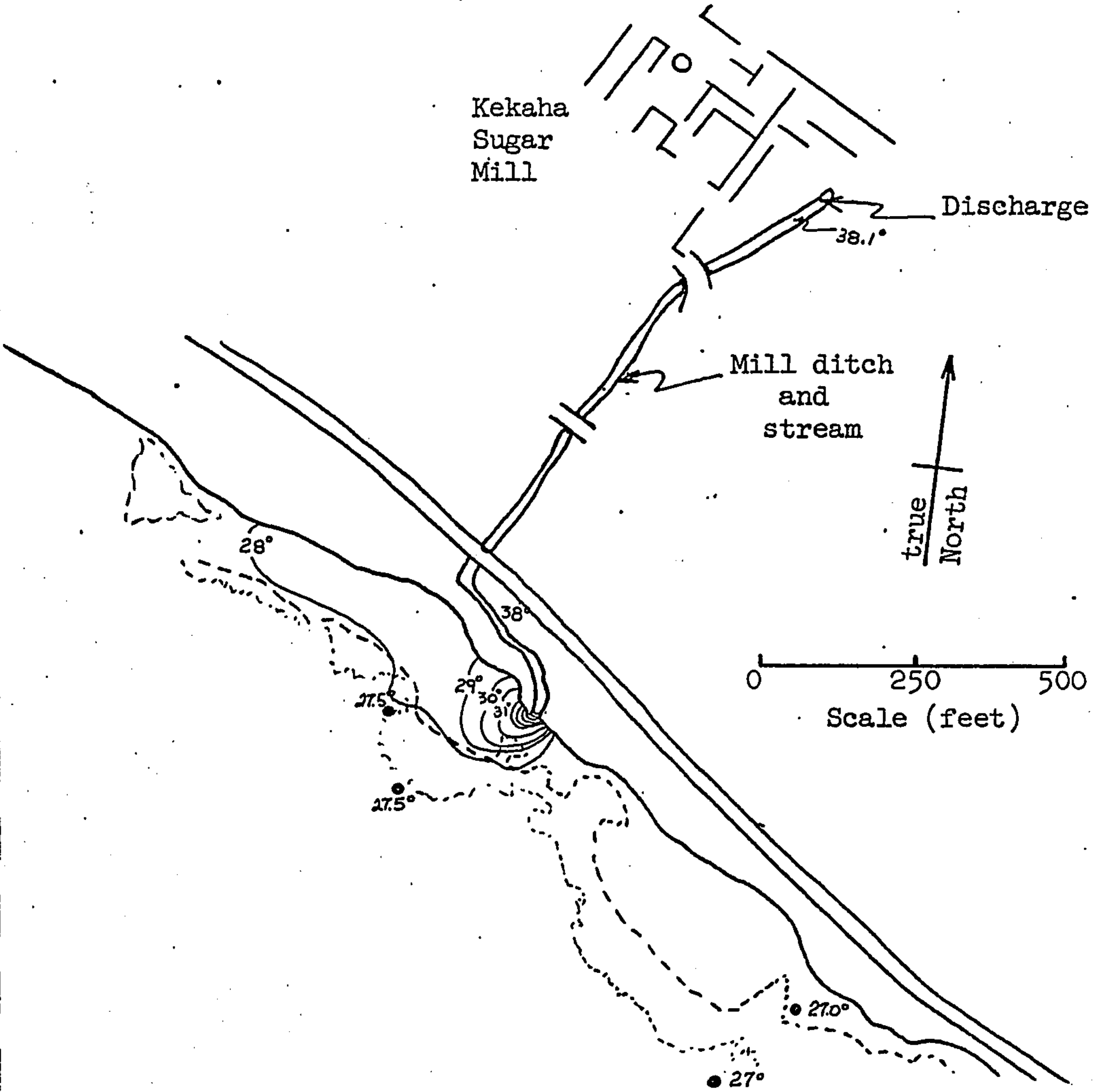
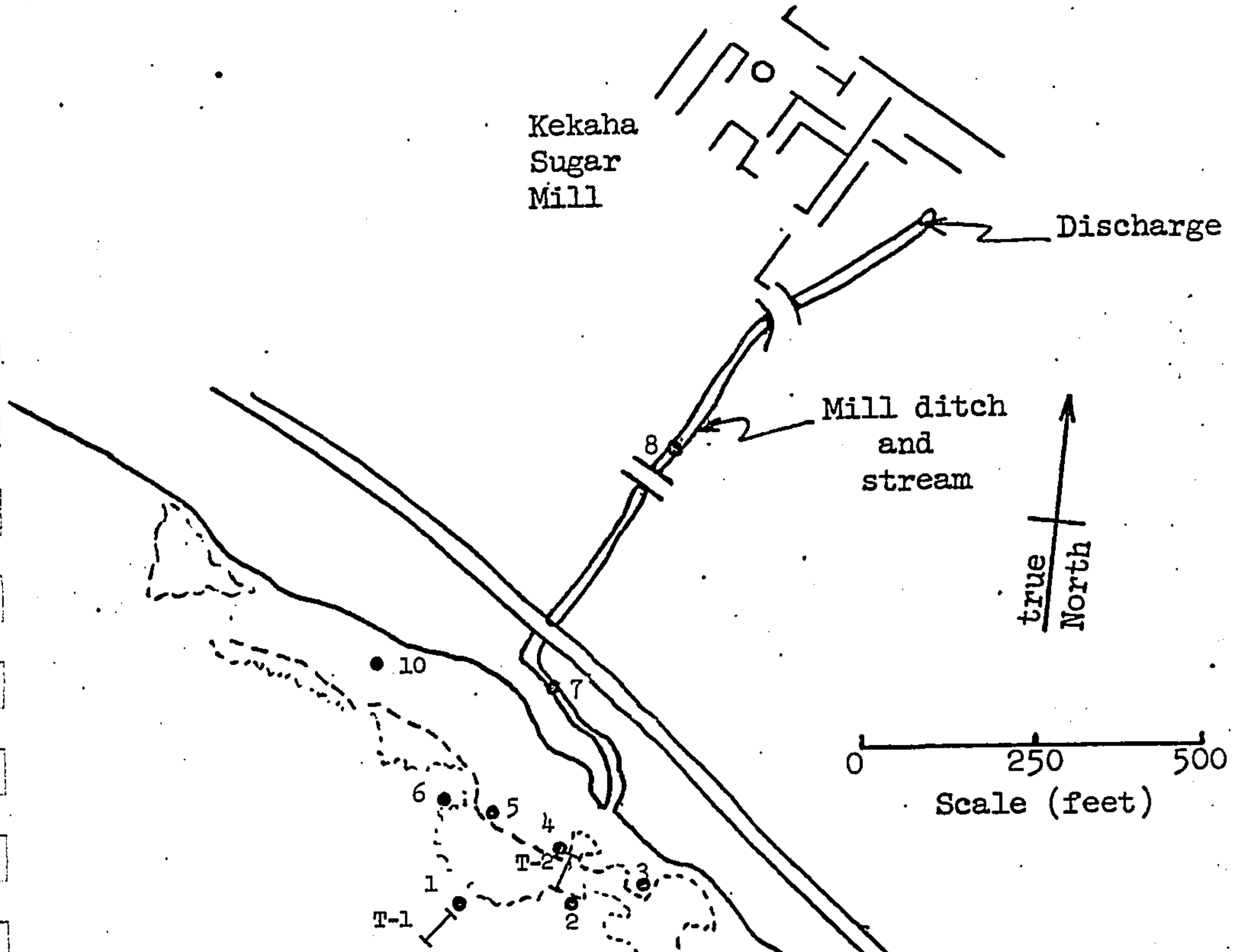


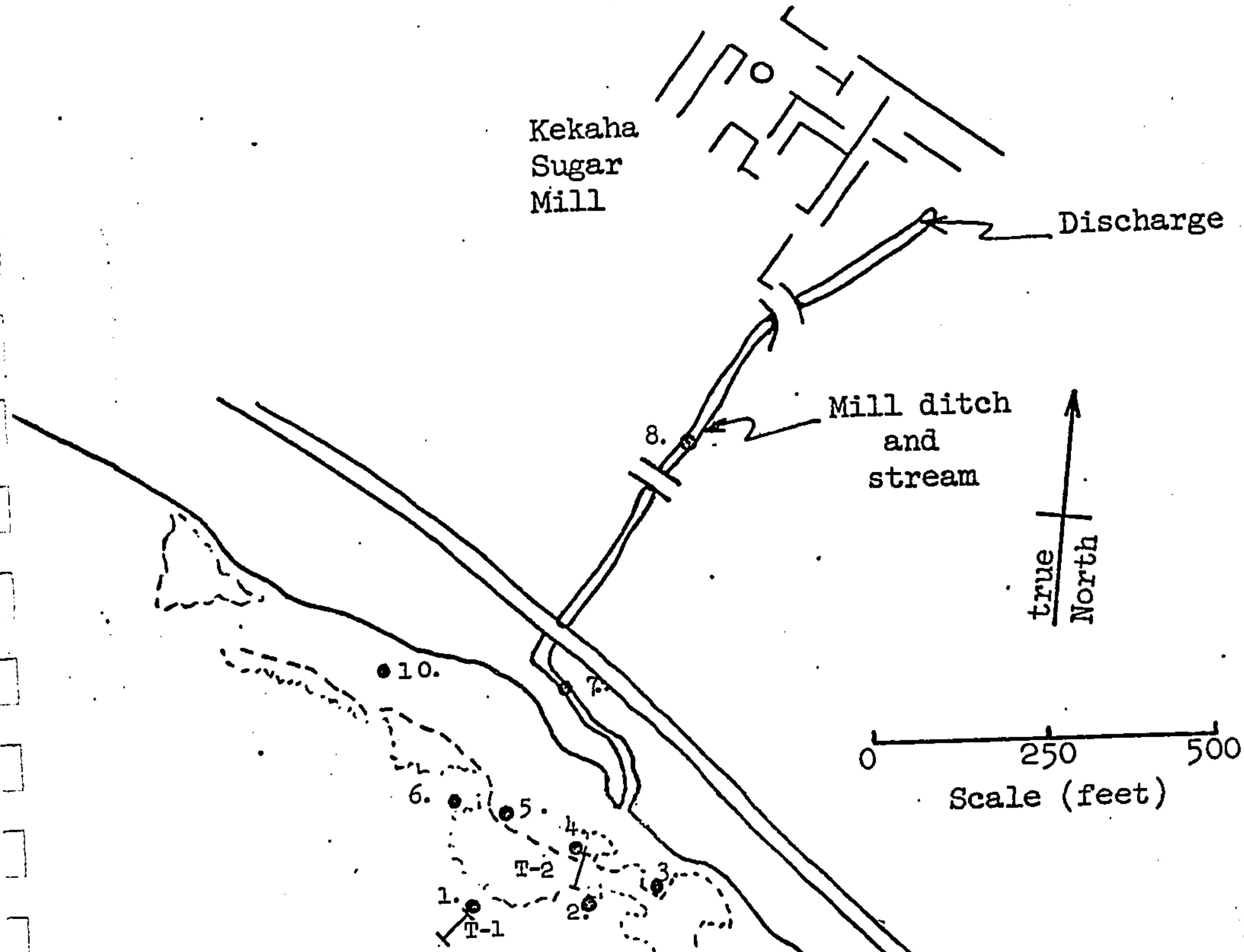
Figure 6. Surface temperature in the stream and ocean on 8-5-73, 14-1500. No. 5 generator load = 80%. Temperature in centigrade.



Thermometer	(depth)	Minimum	Maximum
1. surface		26.0	28.0
bottom	(8')	26.0	26.5
2. surface		26.5	28.0
bottom	(5')	26.0	26.5
3. bottom	(3')	26.0	27.5
4. bottom	(2')	26.0	28.0
5. bottom	(2')	26.0	26.5
6. surface		26.5	26.5
bottom	(5')	26.5	27.0
7. bottom	(1')	32.2	38.5
8. mid-depth		Installed	
9. bottom	(2')	26.5	27.0
10. bottom	(2')	Installed	
11. surface		27.0	27.0
bottom	(8')	26.5	27.0

Figure 7. Minimum and maximum temperature at indicated stations for one day

(7-28-73 to 7-29-73).



Thermometer	(depth)	Minimum	Maximum
. surface		*	*
bottom	(8')	26.0	26.0
2. surface		*	*
bottom	(5')	25.0	27.5
. bottom	(3')	25.5	26.5
4. bottom	(2')	25.0	28.0
5. bottom	(2')	24.5	26.0
. surface		*	*
bottom	(5')	26.5	26.5
7. surface		27.0	43.7
. mid-depth		28.3	40.0
. bottom	(2')	26.5	27.0
10. bottom	(2')	26.5	27.5
11. surface		*	*
bottom	(8')	26.5	27.0

* torn away b. waves

Figure 8. Maximum and minimum temperature at indicated stations for one week (7-28-73 to 8-4-73).

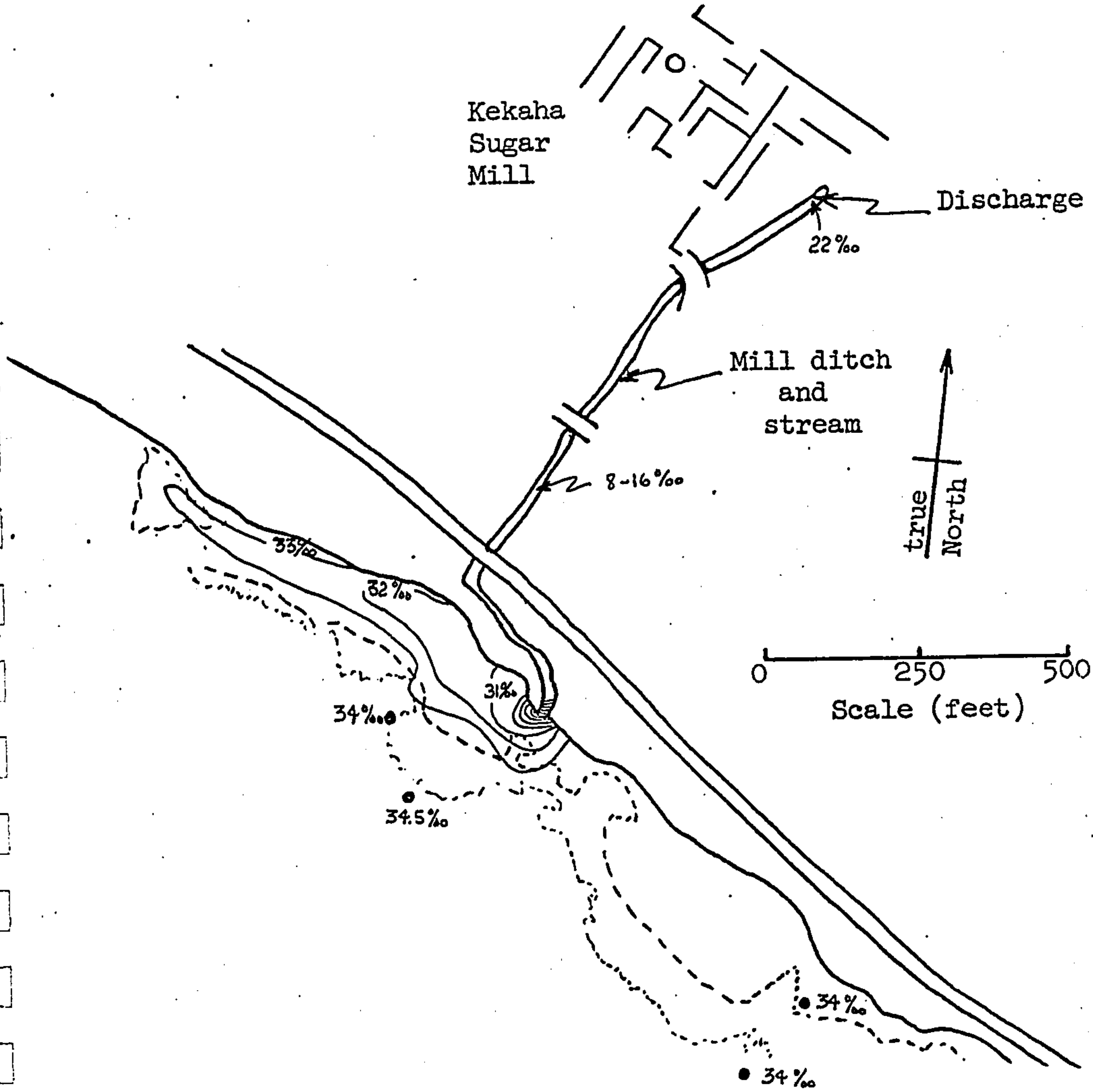


Figure 9. Surface salinity in stream and ocean on 8-5-73, 10-11 A.M.

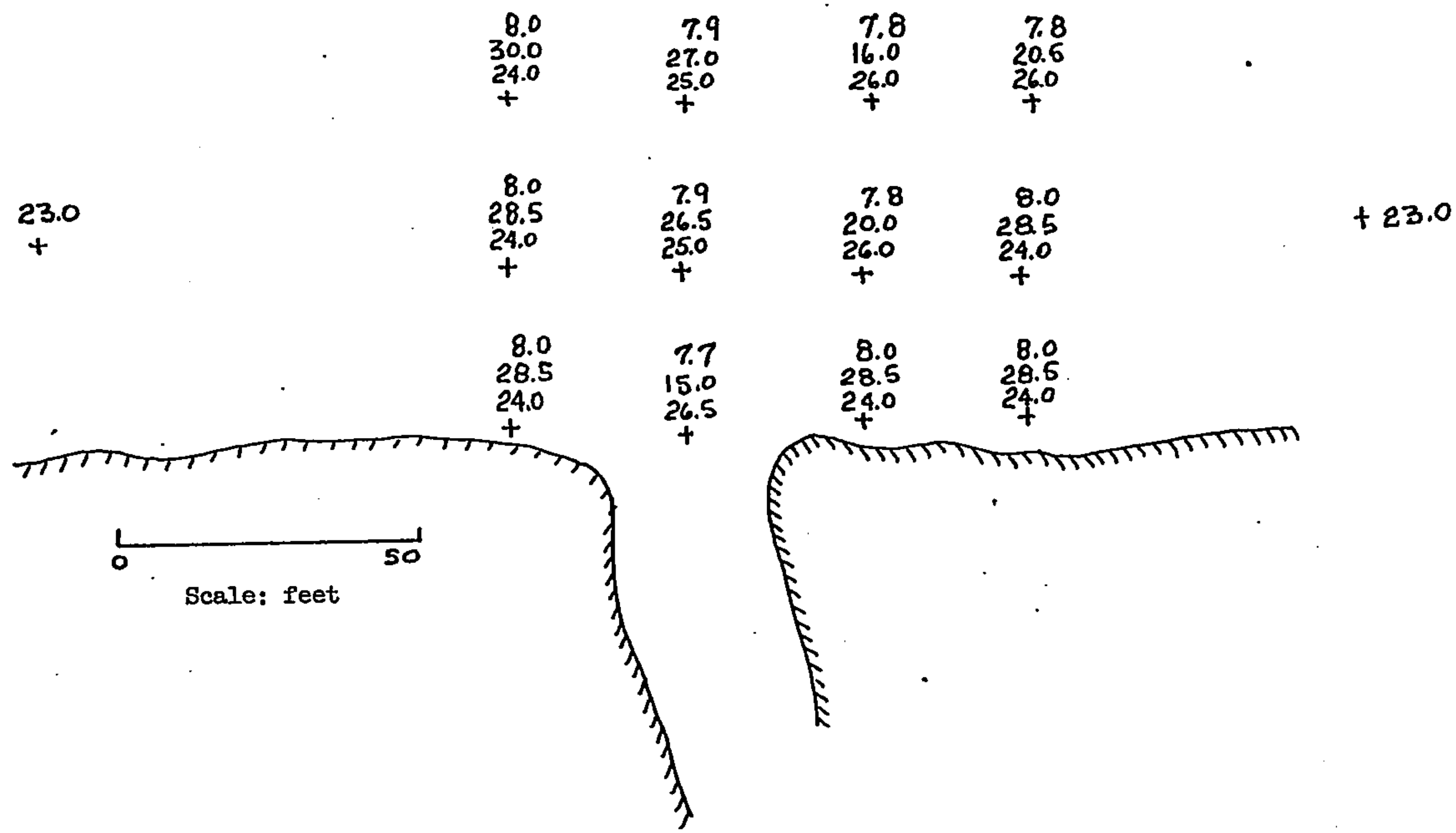


Figure 10. Water quality data collected by the Department of Health on 3-9-72 (11:00). Data are pH, top; salinity, middle; and temperature, bottom.

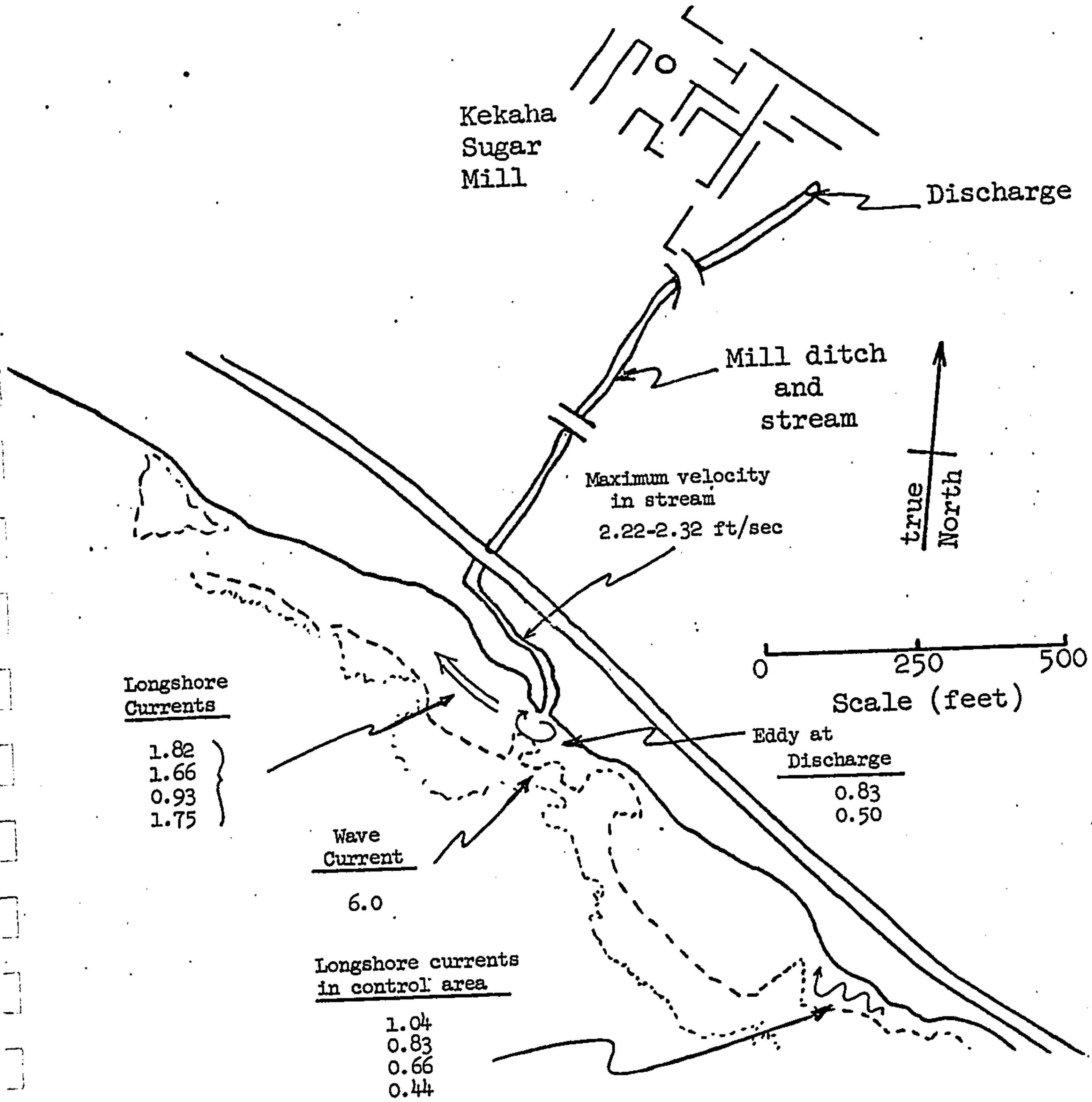


Figure 11. Stream, long-shore and wave induced currents at study site.

Inshore margin of shallow reef bench - - - - - -
Offshore margin of shallow reef bench ....

All values are in feet/second.

TABLE II-A

Species abundance on Transect I (10 feet depth off stream discharge)

Species	Length of thalli below line (inches)	Separate individuals or colonies	Total coverage	Percent coverage	Relative dominance
Hemitrema flabelliformis	14, 12, 24, 3, 3, 6, 40, 3, 9, 3, 6, 6, 7, 15, 12, 6, 8, 4, 3, 9, 6, 5, 3, 5, 3, 3	26	218	36	36
Zonaria variegata	4, 3, 6, 5, 4	5	22	4	4
Porolithon spp.	10, 8, 32, 9, 18, 3, 7, 6, 18, 3, 8, 10, 19, 7, 9	15	167	28	28
Zonaria hawaiiensis	2	1		<1	
Silt-covered rock	3, 9, 9, 6, 5, 3, 6, 10, 6, 6, 10, 7, 18, 10, 3, 8, 7, 5, 3	--	134	22	22
P. lobata	1	1		<1	0
Panuluris japonicus	3	1		<1	0
Sand	12, 6, 4, 4, 4, 4, 7, 7, 7	--	55	9	9
Polysiphonia sp.	1	1		<1	1
TOTALS		50	407	99	99

TABLE II-B

Biomass of samples collected on Transect I

Species	Sample A	B	C	D	E	Total
Chlorophyta (Green algae)						
<u>Chladophora socialis var hawaiiana</u>	--	--	--	--	<0.1	<0.1
<u>Chladophora luxurians</u>	--	--	--	<0.1	<0.1	<0.1
<u>Derbesia fastigata</u>	<0.1	--	--	--	--	<0.1
Pheophyta (Brown algae)						
<u>Dictyota crenulata</u>	0.1	--	--	--	<0.1	0.1
<u>D. divaricata</u>	<0.1	<0.1	--	--	--	--
<u>Zonaria variegata</u>	1.1	12.1	--	--	12.5	25.7
Rhodophyta (Red algae)						
<u>Amphiroa sp.</u>	<0.1	<0.1	<0.1	<0.1	0.9	0.9
<u>Antithamnion sp.</u> (?)	<0.1	--	--	--	--	<0.1
<u>Ceramium sp.</u> 1	<0.1	0.1	--	--	<0.1	0.1
<u>Ceramium sp.</u> 2	0.2	--	--	--	--	0.2
<u>Corollina sp.</u>	<0.1	--	--	--	--	<0.1
<u>Desmia sp.</u>	<0.1	--	--	--	<0.1	<0.1
<u>Hemitrema flabelliformis</u>	13.9	20.7	43.2	137.4	16.2	231.40
<u>Herposiphonia sp.</u>	--	--	--	--	<0.1	<0.1

Species	Sample A	B	C	D	E	Total
Rhodophyta (Red algae) (Cont.)						
Jania spp.	--	--	--	<0.1	<0.1	<0.1
Polysiphonia spp.	0.1	0.1	--	<0.1	<0.1	<0.1
Porolithon spp.	--	1.7	73.1	8.1	21.2	104.10
TOTALS	15.3	34.6	116.3	145.5	50.8	362.5

TABLE III-A

Species	Lengths of thalli below line (inches)	Separate individuals or colonies	Total coverage	Percent coverage	Relative dominance coverage	Relative dominance st. crop
Sargassum echinocarpum	4, 2, 7, 10, 10, 9, 1, 10, 5, 3, 2, 7, 1, 7, 2, 4, 6, 7, 6, 12, 10, 3, 7	23	135	22	27	48
Dictyota crenulata	1, 1, 1, 1, 1, 5, 5, 3, 5, 6, 4, 2, 2, 4, 2, 3, 4, 3, 6	19	59	10	12	2
Padina sp.	3, 5, 5, 2, 8, 2, 2, 2, 2, 2, 3, 5, 2, 5, 1, 2, 2, 1	18	54	9	11	9
Jania capillacea	2, 2, 2, 2, 2, 1, 2, 2, 1, 3, 1, 20, 19	unable to count	59	10	12	1
Gracilaria sp.	1, 1, 1, 1, 2, 2, 1, 3, 1, 2, 2, 1, 3, 3, 2, 3	16	29	5	6	3
Laurencia sp.	1, 2, 2, 5, 3, 1, 3, 1, 2, 1, 2, 1	12	24	4	5	3
Hypnea sp.	2, 1, 2, 4, 3, 3, 3, 4, 6, 6, 3	11	37	6	7	2
Ulva latuca	3, 1, 2, 3, 2, 1, 1, 1, 2, 1	10	17	3	4	6
Dictyosphaeria versluysii	3, 1, 3, 3, 6, 6	6	22	4	5	0
Acanthophora spicifera	2, 3, 2, 5, 3, 2	6	17	6	7	1
Sargassum sp.	2, 2, 8, 4, 3	5	19	3	4	6

Species	Lengths of thalli below line (inches)	Separate individuals or colonies	Total coverage	Percent coverage	Relative dominance coverage	Relative dominance st. crop
Liagora sp.	1, 1, 3	3	5	<1		0
Porolithon sp.	2, 2	2	4	<1		10
Codium sp.	1, 5	2	6	1		<1
Hemitrema flabelliformis	2, 2	2	4	<1		0
Sargassum piluliferum	2	1	2	<1		2
Cladophoropsis sp.	1	1	1	<1		4
Polysiphonia sp.	1	1	1	<1		<1
Zoanthus	1	1	1	<1		<1
TOTALS		139	496	83	100	

TABLE III-B

Biomass of samples collected on Transect II

Species	Sample A	Sample B	Sample C	Sample D	Sample E	Total
Chlorophyta (Green algae)						
<u>Caulerpa racemosa</u>	--	0.2	--	--	--	0.2
<u>Cladophora tildenii</u>	0.2	0.1	0.5	0.4	--	1.1
<u>Cladophoropsis luxurians</u>	1.7	0.1	3.5	0.7	3.2	9.1
<u>Codium reediae</u>	--	--	--	0.2	--	0.2
<u>Rhizoclonium sp.</u>	0.4	--	1.1	0.1	--	1.5
<u>Ulua lactuca</u>	2.5	2.3	2.7	3.6	--	11.1
Pheophyta (Brown algae)						
<u>Colpomenia sinosa</u>	0.9	0.1	0.5	0.2	0.1	1.7
<u>Dictyota crenulata</u>	0.8	0.1	0.1	0.7	1.7	3.3
<u>D. divaricata</u>	--	--	--	--	<0.1	<0.1
<u>Ectocarpus indicus</u>	0.8	0.4	--	--	--	1.2
<u>Padina sp.</u>	9.6	1.5	8.6	1.4	0.2	21.3
<u>Sargassum echinocarpum</u>	10.4	16.5	50.6	27.4	12.7	117.6
<u>S. piluliferum</u>	4.5	--	--	--	--	4.5
Unidentified <u>Sargassum</u>	7.2	0.7	6.9	--	--	14.8

Species	Sample A	B	C	D	E	Total
Rhodophyta (Red algae)						
Acanthophora spicifera	0.8	0.4	--	--	--	1.2
Amphiroa sp.	0.6	0.4	0.8	1.6	0.5	3.9
Centroceros claulatum	--	0.2	--	--	--	0.2
Corallina sp.	--	0.1	0.4	2.3	--	2.8
Geldiella sp.	<0.1	--	0.3	2.3	<0.1	2.6
Gracilaria spp.	1.1	3.1	0.8	0.6	0.5	6.1
Hypnea sp.	0.8	0.1	0.1	0.7	1.7	3.3
Jania capillacea	--	--	1.0	0.1	0.7	1.8
Jania sp.	--	<0.1	0.3	0.1	--	0.4
Laurencia spp.	1.1	3.1	0.8	0.6	0.5	6.1
Polysiphonia sp. 1	--	--	0.1	--	--	0.1
Polysiphonia sp. 2	--	--	<0.1	<0.1	--	<0.1
Porolithon onkodes	3.3	--	1.5	13.7	5.6	24.1
TOTALS	46.7	29.2	80.4	56.6	27.3	240.2

TABLE IV-A

Species abundance on transect III (10 feet depth off control)

Species	Lengths of thalli or colonies below line (inches)	Separate individuals or colonies	Total coverage	Percent coverage	Relative dominance coverage	Relative dominance wt.
Hemitrema flabelliformis	5, 3, 5, 4, 2, 10, 2, 4, 3, 6, 4, 3, 5, 8, 2, 11, 3, 5	18	85	14	19	12
Zonaria variegata	3, 2, 4, 4, 2, 4, 6, 4, 2, 4, 6, 6, 3, 8, 4, 12, 12, 12, 12, 8, 12, 12, 6, 5, 10, 7, 7, 3, 2, 5, 3, 10, 12	33	212	35	48	7
Porolithon sp.	7, 5, 7, 3, 4, 3, 4, 2, 3, 1, 6, 4, 3, 4, 4, 4, 6, 4, 5	19	79	13	18	77
Gracilaria sp.	1, 3, 1, 3, 8, 4, 3, 5	8	28	5	7	<1
Dictyota crenulata	1, 2, 2, 2, 1, 2, 2	7	12	2	3	<1
Desmia sp.	3, 2, 3, 6	4	14	3	4	<1
Cladophoropsis luxurians	3	1	3	<1		<1
Halymenia sp.	1, 1, 1	3	3	<1		<1
Jania sp.	1	1	1	<1		<1
Zoanthus sp.	1, 2	2	3	<1		<1
Porites lobata	1	1	1	<1		<1
TOTALS		97	441	73	100	

TABLE IV-B

Biomass of samples collected on transect III

Species	Sample A	B	C	D	E	Totals
Chlorophyta (Green algae)						
Acetabularia moebii	--	--	<0.1	--	--	<0.1
Caulerpa racemosa	<0.1	--	--	--	--	<0.1
Cladophora sp.	--	<0.1	<0.1	--	--	<0.1
Cladophoropsis luxurians	--	--	--	<0.1	<0.1	<0.1
Codium reediae	1.6	--	--	--	--	1.6
Ulua sp.	--	--	<0.1	--	--	<0.1
Pheophyta (Brown algae)						
Colpomenia sinosa	0.4	--	--	--	--	0.4
Dictyota crenulata	<0.1	<0.1	0.2	<0.1	0.2	0.5
D. divaricata	<0.1	--	--	--	--	0.1
Zonaria variegata	--	--	--	45.6	27.4	73.0
Rhodophyta (Red algae)						
Amphiroa spp.	--	--	0.2	0.3	0.1	0.6
Ceramium sp. 1	--	<0.1	<0.1	<0.1	0.1	0.1
Desmia sp.	--	--	2.3	0.1	--	2.3
Gelidium sp.	1.1	0.3	--	1.6	--	3.0

Species	Sample A	B	C	D	E	Totals
Rhodophyta (cont.)						
<u>Gracilaria</u> <u>sp</u>. 1	--	--	--	0.5	--	0.5
<u>Gracilaria</u> <u>spp</u>.	4.1	0.1	--	1.8	0.9	6.9
<u>Grateloupia</u> <u>sp</u>. (?)	0.8	--	<0.1	--	--	0.8
<u>Griffithsia</u> <u>ovalis</u>	--	--	--	--	0.1	0.1
<u>Halymenia</u> <u>sp</u>.	1.5	--	--	--	--	1.5
<u>Hemitrema</u> <u>flabelliformis</u>	6.5	54.5	39.7	4.9	27.2	132.8
<u>Jania</u> <u>capillacea</u>	--	--	0.3	<0.1	--	0.3
<u>Jania</u> <u>sp</u>.	0.3	<0.1	--	--	--	0.3
<u>Laurencia</u> <u>spp</u>.	--	--	<0.1	--	--	0.1
<u>Peyssonelia</u> <u>sp</u>.	11.5	9.1	8.7	--	--	29.3
<u>Polysiphonia</u> <u>sp</u>. 1	<0.1	0.1	1.4	--	--	0.5
<u>Polysiphonia</u> <u>sp</u>. 2	--	<0.1	--	--	--	0.1
<u>Porolithon</u> <u>spp</u>.	155.4	77.0	160.4	400.4	78.9	872.1
TOTALS	183.1	141.1	213.2	455.1	135.0	1127.5

TABLE V-A

Species abundance on transect IV (shallow reef bench off control)

Species	Lengths of thalli or colonies below line (inches)	Separate individuals or colonies	Total coverage	Percent coverage	Relative dominance coverage	Relative dominance wt.
Sargassum echinocarpum	8, 4, 10, 7, 6, 7, 9, 7, 12, 12, 6, 10, 8, 12, 8, 12, 12, 4, 6, 10, 12, 3, 3, 12, 12, 12, 12, 4	28	240	40	41	64
Dictyota crenulata	1, 1, 1, 1, 2, 3, 2, 4, 6, 6	10	27	4	4	1
Porolithon sp.	1, 3, 1, 3, 3, 1, 1, 2, 2, 4, 6, 6, 6	13	39	6	6	12
Jania capillacea	1, 2, 2, 4, 3, 2, 6, 6, 6, 8, 6, 6, 6	13	58	10	10	1
Codium reedae	2, 3, 1, 1, 2, 3, 2, 1, 1, 4, 6	11	26	4	4	0
Cladophoropsis sp.	3, 3, 2, 3, 2, 2, 1, 3, 3, 6, 3	11	31	5	5	1
Sargassum piluliferum	6, 12, 12, 10, 12, 12, 12, 12	8	88	15	15	3
Laurencia sp.	2, 4, 3, 1, 1, 2, 3, 1	8	17	3	3	8
Dictyosphaeria versluysii	1, 1, 1, 3, 2, 2, 3	7	13	2	2	0
Liagora	1, 2, 2, 3, 2, 2, 2, 3, 7	9	24	4	4	4
Galaxaura sp.	2, 4, 2, 2, 1	5	11	2	2	0
Gracilaria sp.	2, 1, 1, 2, 3, 1	6	10	2	2	1
Hypnea sp.	2, 2	2	4	1	1	0

Species	Lengths of thalli or colonies below line (inches)	Separate individuals or colonies	Total coverage	Percent coverage	Relative dominance coverage	Relative dominance wt.
Wrangalia sp.	2, 1	2	3	1	1	0
TOTALS		133	591	97	100	

TABLE V-B

Biomass of samples collected on transect IV

Species	Sample A	B	C	D	E	Totals
Chlorophyta (Green algae)						
Caulerpa racemosa	--	--	--	--	0.1	0.1
C. taxifolia	--	--	--	0.5	--	0.5
Cladophoropsis luxurians	1.5	1.4	1.1	0.8	1.8	6.6
Codium reediae	2.7	--	--	1.5	0.1	4.3
Halimeda sp.	--	0.2	--	0.1	0.2	0.4
Microdictyon sp.	7.1	--	4.3	0.9	3.3	15.6
Rhizoclonium sp.	--	--	0.1	--	--	0.1
Valonia aegragopila	0.1	0.2	--	--	0.1	0.2
Pheophyta (Brown algae)						
Colpomenia sinosa	0.1	--	0.2	--	0.1	0.3
Dictyota crenulata	--	--	--	--	0.1	0.1
Ectocarpus indicus	--	0.1	0.2	0.4	0.3	0.9
Padina sp.	--	3.2	0.2	2.1	--	5.5
Sargassum echinocarpum	105.5	78.2	39.6	125.8	55.8	404.9
S. piluliferum	15.2	--	--	--	6.9	22.1
Unidentified *Sargassum*	6.0	0.7	--	--	2.7	9.4

Species	Sample A	B	C	D	E	Totals
Rhodophyta (Red algae)						
Acanthophora spicifera	--	--	--	0.2	4.6	4.8
Amphiroa sp.	0.1	--	--	--	--	0.1
Corallina sp.	--	--	--	2.2	--	2.2
Gelidiella	--	0.1	--	--	--	0.1
Gracilaria spp.	0.4	0.5	--	--	--	0.9
Hypnea spp.	0.1	0.2	0.9	--	0.1	1.2
Jania capillacea	0.2	0.1	0.2	0.2	0.1	0.6
Laurensia sp. 1	8.7	--	1.9	1.5	30.0	42.1
Laurensia spp.	1.2	0.7	4.1	1.2	2.0	9.2
Liagora sp. 1	--	--	0.6	0.3	--	0.9
Liagora sp. 2	--	--	--	23.7	--	23.7
Polysiphonia sp.1	0.1	--	0.1	--	--	0.1
Polysiphonia sp. 2	0.1	0.1	--	--	--	0.1
Porolithon onkodes	4.3	8.6	38.9	22.2	4.3	78.3
Pterocladia sp.	--	--	0.6	0.3	--	0.9
Wrangellia penicillata	--	--	--	0.7	--	0.7
TOTALS	153.1	94.0	92.8	184.5	112	636.4

TABLE VI

Contrasts between transects I-IV

Transect	Offshore Discharge I	Offshore Control III	Inshore Discharge II	Inshore Control IV
Number species algae (transect and samples)	18	27	30	33
Biomass (gms)	362	1127	240	636
Biomass (excluding Porolithon* gms.)	258	255	216	558.1
Dominant species (cover)	Hemitrema flabelliformis	Zonaria variegata	Sargassum echinocarpum	Sargassum echinocarpum
Dominant species (biomass)	Hemitrema flabelliformis	Porolithon	Sargassum echinocarpum	Sargassum echinocarpum
Second dominant species (cover)	Porolithon sp.	Hemitrema flabelliformis	Dictyota crenulata	S. piluliferum
Second dominant species (biomass)	Porolithon sp.	Hemitrema flabelliformis	Porolithon	S. piluliferum
Total coverage on transect	407	441	496	591

* Biomass was calculated excluding Porolithon because invariably when scraping the substrate an indeterminant amount of underlying rock which is dead Porolithon comes off in the sample, thus biasing the estimate of biomass.

H. ALTERNATIVES TO PROPOSED ACTION

Several alternatives that are feasible from an engineering standpoint have been considered. With the determination that the present method of discharge causes no harmful impact on the environment, these other alternatives do not appear to offer enough benefits for total environment enhancement over the present practice.

The thermal discharge could be disposed by means of an under water diffusion system. However, this means the reef area will have to be torn up for a distance of over 1/2 mile in order to place the pipe in deep water and this is undesirable.

Previous investigation by a State and Federal Government as well as private companies into the feasibility and desirability of underground disposal wells has shown that this alternative is not recommended.

Other alternative would be to construct cooling towers, cooling basins, or spray ponds. In each case, these alternatives create other environmental problems. First is the increase in energy requirements to run the systems and second the additional use of chemicals to control further environmental impact caused by bacterial, algae and insect activity associated with the operation of these types of cooling systems.

The last alternative to consider would be to eliminate the salt water thermal discharge completely by not producing power for Kauai Electric. Since most of the power produced by Kekaha is from the utilization of bagasse, this would mean an additional burden on present available oil resources. It would also create an additional solid waste disposal problem. It is evident that this last alternative would create more environmental problems than it would solve.

I. <u>SHORT TERM VS. LONG TERM BENEFITS</u>

The impact of the thermal discharge is restricted to an area within a described arc of 350 feet from the point of entry into the receiving waters. The existence of the heated plume has served to enhance the desirability of the area for the bathers that frequent the beach.

The benefits in the long term are related primarily to production of electric energy for a Public Utility from an agricultural waste product (bagasse) rather than using other resources such as oil.

J. NATURAL RESOURCES COMMITMENT

The effect of using two million gallons per day of underground salt water for condenser cooling water and its assimilation by the ocean causes no irreversible and irretrievable commitment of any natural resource. No rare or endangered species of botanical or zoological origins are known to exist in the area around the point of discharge.

Environmental Impact Statement for Commercial Fishing Vessel Berthing Area Pier 16, Honolulu Harbor, Oahu

Job No. H.C. - 1422

Harbors Division
Dept. of Transportation
State of Hawaii

August 1982

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J. NATURAL RESOURCES COMMITMENT

The effect of using two million gallons per day of underground salt water for condenser cooling water and its assimilation by the ocean causes no irreversible and irretrievable commitment of any natural resource. No rare or endangered species of botanical or zoological origins are known to exist in the area around the point of discharge.