Uploaded to the VFC Website

February 2014

This Document has been provided to you courtesy of Veterans-For-Change!

Feel free to pass to any veteran who might be able to use this information!

For thousands more files like this and hundreds of links to useful information, and hundreds of "Frequently Asked Questions, please go to:

Veterans-For-Change

Veterans-For-Change is a A 501(c)(3) Non-Profit Organizaton
Tax ID #27-3820181
CA Incorporation ID #3340400
CA Dept. of Charities ID #: CT-0190794

If Veterans don't help Veterans, who will?

We appreciate all donations to continue to provide information and services to Veterans and their families.

https://www.paypal.com/cgi-bin/webscr?cmd=_s-xclick&hosted_button_id=WGT2M5UTB9A78

Note: VFC is not liable for source information in this document, it is merely provided as a courtesy to our members & subscribers.

TABLE OF CONTENTS (Continued)

2101

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF PLATES

2105

LIST OF PLATES (Continued)

DETAILED ENVIRONMENTAL ANALYSIS
OF PROJECT PACER HO

1. INTRODUCTION

This report is Part II of a three-part report on the environmental consequences of a project conducted on Johnston Island, labeled Project Pacer HO, designed to remove and incinerate the stocks of Herbicide Orange (HO) stored on Johnston Island since 1972. The three parts to the report are as follows:

Part I	Executive Summary
Part II	Detailed Environmental Analysis
Part III	Supporting Raw Data

1.1 Background

In April, 1970, the Secretaries of Agriculture, HEW, and Interior jointly announced the suspension of certain uses of 2,4,5-T*. As a result of this announcement, the Department of Defense suspended the use of Orange Herbicide since this herbicide consists of approximately 50 percent 2,4,5-T and 50 percent 2,4-D*. This suspension left the Air Force with 1.5 million gallons of Orange Herbicide in Vietnam and 0.8 million gallons in Gulfport, Mississippi. In September, 1971, the Department of Defense directed that the Orange Herbicide in Vietnam be returned to the United States and that the entire 2.3 million gallons be disposed in an ecologically safe and efficient manner. The 1.5 million gallons were moved from Vietnam to Johnston Island for storage in April, 1972.

The cost of maintaining the storage areas, and the ever present danger from the stored HO stocks, led the Air Force to conduct a study to develop mechanisms for the ecologically safe, efficient, and, if possible, low cost disposal of the approximately 2.3 million gallons of HO. After several proposals and draft Environmental Impact Statements, the ultimately accepted course of action was disposal by incineration aboard a specially

* 2,4,5-T is 2,4-T-trichlorophenoxyacetic acid, while 2,4-D is 2,4-dichlorophenoxyacetic acid. Both are commercial brand leaf herbicides.

designed incinerator vessel in an isolated location of the Pacific Ocean. The proposed incineration site met the criteria proposed in the Air Force document,[16] "Final Environmental Impact Statement on the disposition of Orange Herbicide by incineration".

1.2 Need for Field Operations

As a part of their final EIS, the Air Force stated, "a monitoring program will be conducted to document herbicide exposures and environmental exposures should they occur. It is anticipated that this program will generate sufficient data to demonstrate the personnel and environmental safety of this operation". Air Force policy was that an independent contractor would perform the monitoring program. Thus, Battelle was ultimately selected by the Air Force to conduct the monitoring program for activities on Johnston Island. The ship board monitoring was conducted by TRW under contract with the U.S.A.F.

1.3 Application of NEPA

The Air Force complied fully with the tenets of the National Environmental Policy Act through their submission of a well considered and complete EIS. It was decided that the monitoring program results would be presented in a format commonly used to prepare EIS's.

2. EXISTING ENVIRONMENTAL FEATURES OF JOHNSTON ISLAND

The physical and biological features of Johnston Atoll and surrounding waters have been well studied and documented. The ecological baseline descriptions presented in this report are based primarily on accounts published by government agencies or by scientists under government contract. The two major sources of information are "Ecological Baseline Survey of Johnston Atoll, Central Pacific Ocean" by [redacted] (1) and the "Natural History of Johnston Atoll, Central Pacific Ocean" by [redacted] and [redacted] (2). Both of these documents were prepared by the Smithsonian Institution, Washington, D.C. Tabular material and figures included in this section have been taken from the report prepared by [redacted] (2). An aerial photo of Johnston Island is presented in Plate 1.

2.1 Physical

2.1.1 Land

2.1.1.1 Location

Johnston Atoll is located between the latitudes of 16° 40' 26" and 16° 47' 25" North and longitudes of 169° 24' 15" and 169° 33' 58" West. It is one of the most isolated atolls in the Pacific. The nearest land mass to Johnston Atoll is the French Frigate Shoal in the northwestern Hawaiian Islands, approximately 450 nautical miles (nm) to the north-northeast. Honolulu, Hawaii is 717 nm to the northeast, Kingman Reef of the Line Islands is about 850 nm to the southeast, Howland Island is 1,050 nm to the south-southwest, and the Marshall Islands lie almost 1,200 nm southwest of Johnston Atoll.

2109

2.1.1.2 Topography

Johnston Atoll consists of four islands within a shallow lagoon partially enclosed by a semicircular reef to the north and west. Two of the islands are entirely man-made from dredged coral. These are Akau (North) Island at 16° 45' 52" N x 169° 31' 03" W and Hikina (East) Island at 16° 45' 26" N x 169° 29' 19" W, having land areas of 24 and 17 acres, respectively. The remaining two islands are highly modified natural islands, having been increased significantly from their original sizes. These are Johnston Island at 16° 45' N x 169° 32' W and Sand Island at 16° 45' N x 169° 30' W.

The smaller Sand Island (about 1,900 yards northeast of Johnston Island) was originally 10 acres in size with a maximum elevation of 15 feet above sea level. It has since been modified to include an area of fill of several acres about 500 yards west of the original island, and a causeway was constructed to join the two. The entire land mass (fill area, causeway, and original island) has been designated "Sand Island".

The only structures present on the original portion of Sand Island are the Loran-C transmitter building and the 625-foot transmitter tower. A few concrete foundations from buildings removed in the late 1950's and some gun emplacements still remain. Generally, the surface composition of the original island is a loose coral sand.

The largest island of the atoll, Johnston Island, was originally 46 acres with a maximum elevation of 48 feet. Manipulations made in 1939-1942, 1951-1952, and 1963-1964 enlarged the island to 570 acres using dredged coral from the lagoon, and leveled it to an average elevation of about 7 feet. The island is presently rectangular in shape with a 9,000 foot runway running in the southwest-northeast direction, almost along the island's main axis.

The surface of Johnston, Akau, and Hikina Islands, and the man-made portion of Sand Island are characterized by buildings, roads, and bunkers. Due to the packed, crushed coral surface composition of these

islands, vegetation is sparce. Only a few small lawns, scattered bushes and trees, and thinly scattered weed species exist. Figure 1 presents a schematic of the Islands and Reef of Johnston Atoll.

2.1.1.3 Geology

Johnston Atoll and its islands are situated atop a seamount of the mid-ocean Hawaiian Ridge. The surface lithology has been eradicated for the most part by construction activities on the island. The visible surface of Johnston Island is largely composed of dredged coral from the adjacent lagoon area. There is evidence of sea terraces that exist near the current mess facilities on the island more or less parallel with the main runway. Such terraces, step and grade towards the south tend to indicate that the basement seamount rim has undergone an uplift orogeny. Beachrock remnants are found on the original island's northwest and south central portions. The composition of this beachrock is primarily coral, fine sands and gravels that have been cemented together by calcium carbonates. Pumice rock was found erratically along a small section of the southeast shore of Johnston Island.

It has been cited in the literature[3] that the outer reefs to the south of Johnston Island are submerged as a result of the tilting of the seamount basement structure towards a strike to the southeast. Due to the volcanic origin of the seamount that supports Johnston Atoll and to the evidence of unequal thrusting and settling Johnston Atoll is not considered to be a geologically stable land form.

The literature is deficient in describing the form and substance of the supporting seamount. There are apparently no exploratory deep wells on Johnston Island. There is evidence that the outer reef which breaks the surface of the sea only on the northern shore is undergoing differential settling or thrusting.

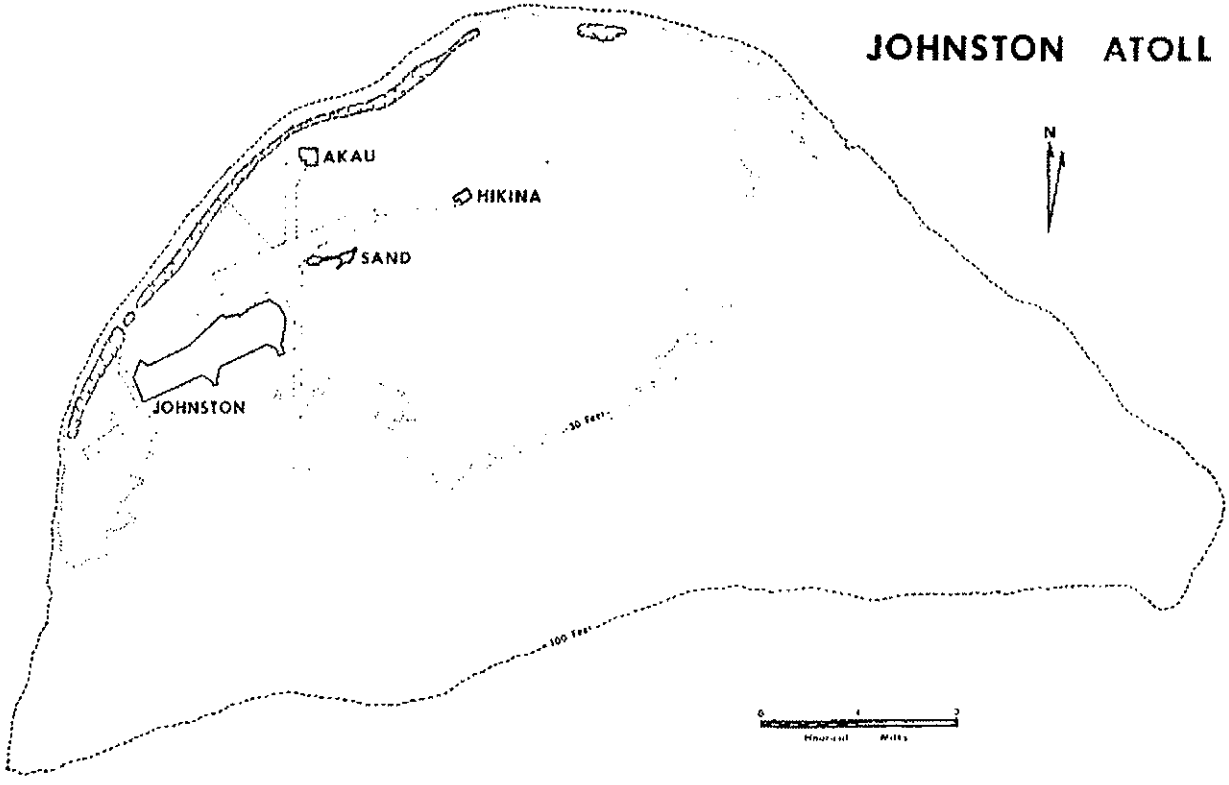


FIGURE 1. MAP OF JOHNSTON ATOLL; ADAPTED FROM AMERSON (1973)

[redacted]urveyed Johnston Island gravity utilizing the Bouguer Anomaly effects. These studies suggest that the mass densities beneath Johnston Island are intermediate in value as compared with the Hawaiian Islands and Line Islands. These studies found no evidence of dense magmatic structure existing in the upper structure of Johnston Atoll.

The physical geology underneath the Orange Herbicide drum storage area contains alternating layers of coral and beach sands which have been artificially deposited and compacted. The permeability rates would be expected to be high in this unconsolidated dredge fill.

2.1.1.4 Soils

The soils occurring on Johnston, Akau, and Hikina Islands and the man-made portion of Sand Island consist of compacted coral fragments ranging in size from sand to cobble sized coral rock. These fragments were derived from dredging operations in the deepening and lengthening of ship channels and seaplane landing areas. The entire islands of Akau and Hikina and the man-made portions of Johnston and Sand Islands were constructed from this material.

The soil occurring on the original portion of Sand Island is deep, loose, coral sand. This surface is quite similar to that of Johnston and Sand Islands prior to their disturbance by military construction.

2.1.2 Air

2.1.2.1 Meteorology During the Interval

Meteorology data were recorded at the NOAA weather station located on the eastern end of the island. An additional anemometer with strip chart recorder was maintained near the drum storage area (for the period July 20 to August 27, 1977) which recorded additional wind data for the western end of the island.

The meteorological records for wind speed, direction, temperature, dewpoint, and rainfall are presented in Figure 2. Superimposed on these data, collected by the NOAA station are the wind speed and direction at the west end anemometer for several sample weeks. These data are discussed further below. In these discussions, the recorded values are compared to norms which were assembled from 30+ years of data and presented in Amerson.(1)

a. Wind Speed and Direction

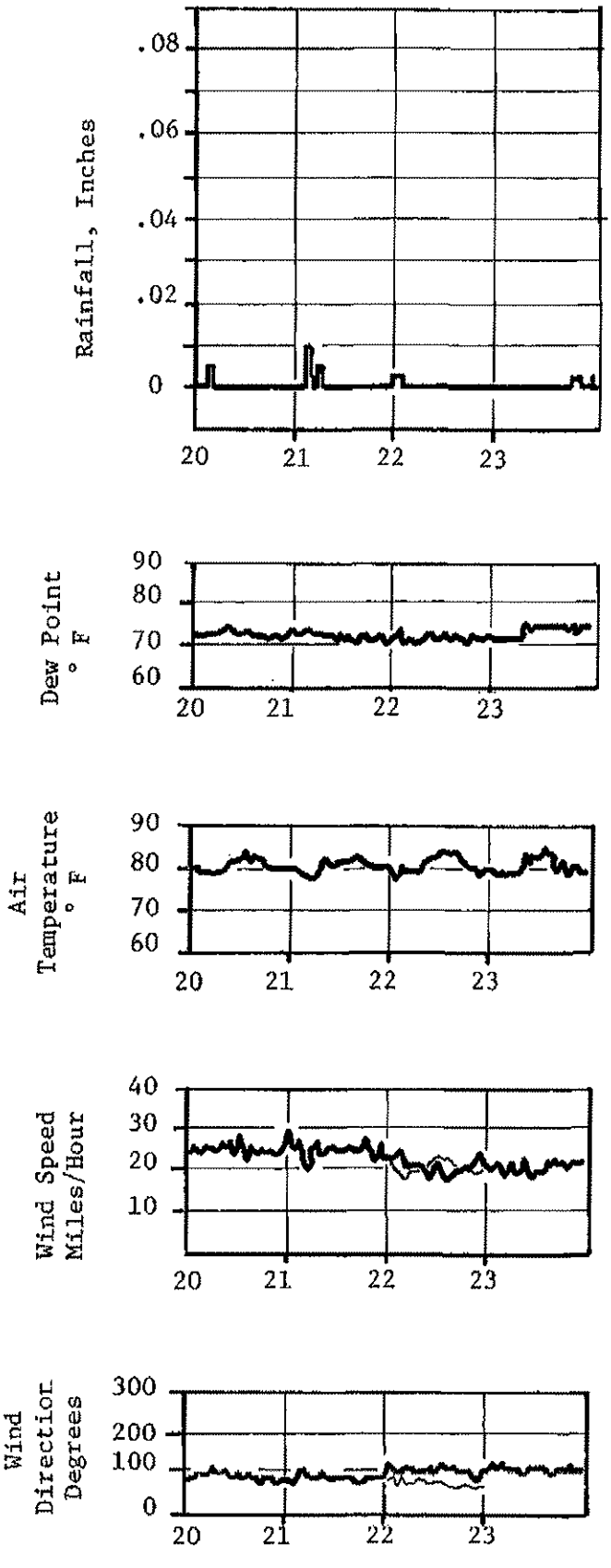
Surface trade winds were essentially constant throughout the period. Winds were from the east-northeast to the east-southeast at from 10 to 20 m.p.h. on most days. The exceptions occurred on August 8 and 9, 1977, and again over the interval August 14 to 16, 1977, when winds were at 0 to 10 m.p.h. from the northeast. Only one directional shift of significance occurred during the period. On August 10, winds were out of the south at about 10 m.p.h. Minimum variation from seasonal norms was experienced over the duration.

A comparison of the data taken at the two wind recording stations indicated only a negligible difference. Wind directions were very slightly more northernly at the drum storage station. Also, wind speeds were a few m.p.h. less at this station, attributable to the drag effect of the entire length of the island.

b. Temperature

As a result of air masses passing over the atoll having been conditioned by close contact with the ocean for thousands of miles, there is little daily variation in air temperature. Similarly, only very small seasonal differences exist (about 3° F), with August being the warmest month of the year.

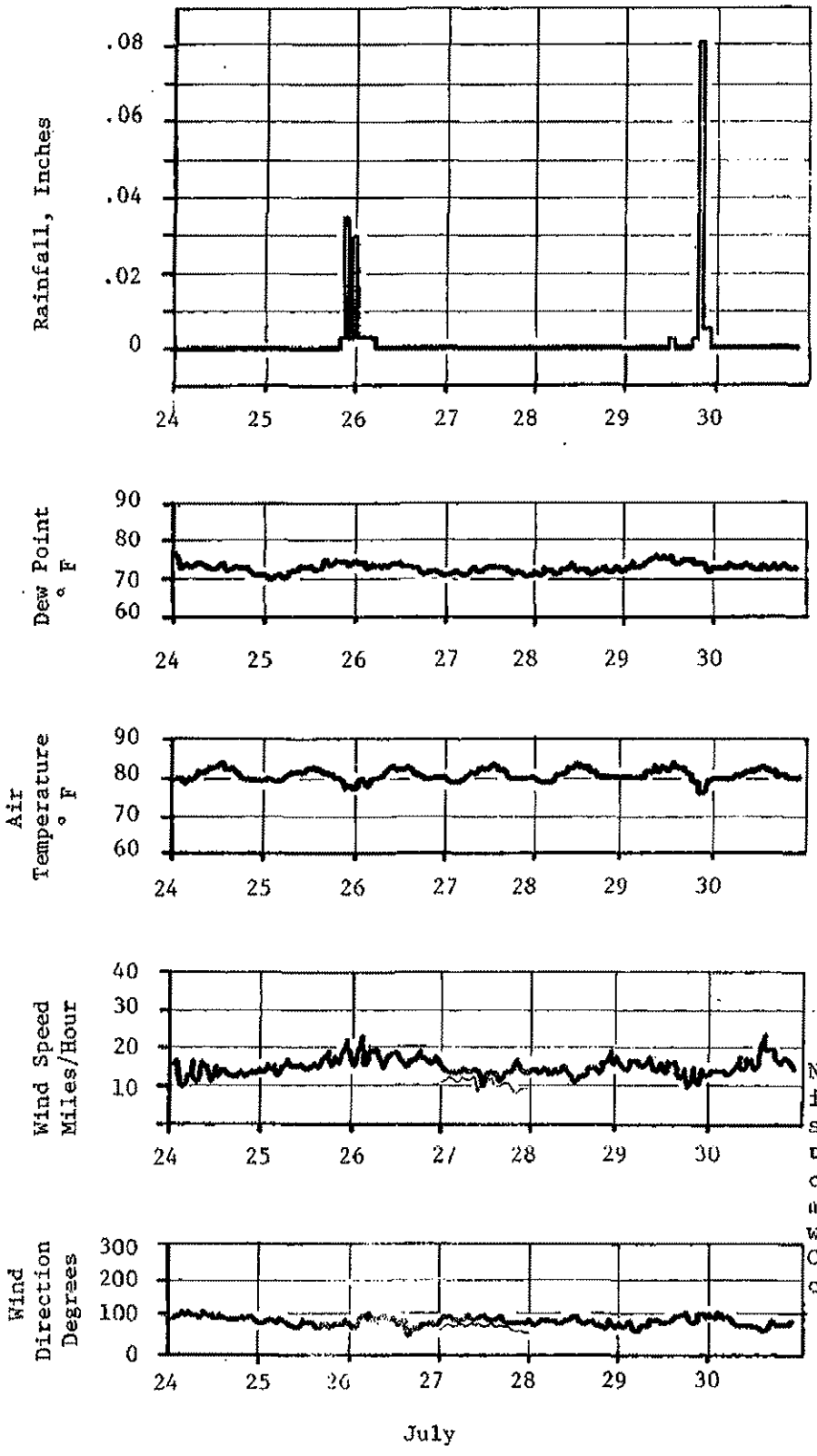
Throughout the period observed, daily highs ranged from 83° F to 85° F. Lows were usually between 77° F and 80° F, with a daily mean of 81° F, which is normal for this time of year.



Note: The dark line is the NOAA weather station data, while the light line is comparative information from the downwind weather monitor. One day each week is compared.

FIGURE 2. WEATHER OBSERVATIONS AT NOAA STATION, 1977

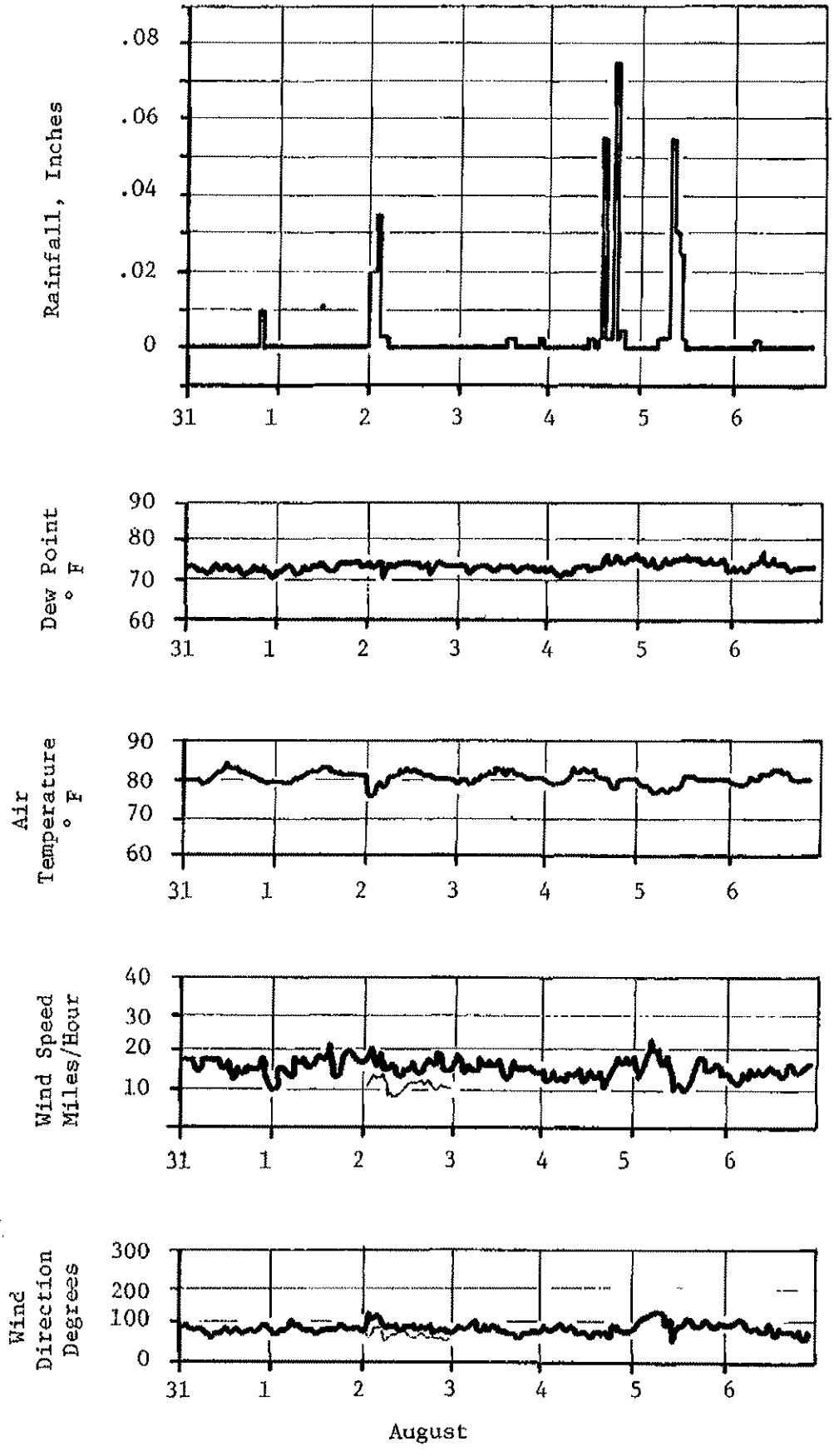
2115



Note: The dark line is the NOAA weather station data, while the light line is comparative information from the downwind weather monitor. One day each week is compared.

FIGURE 2. (Continued)

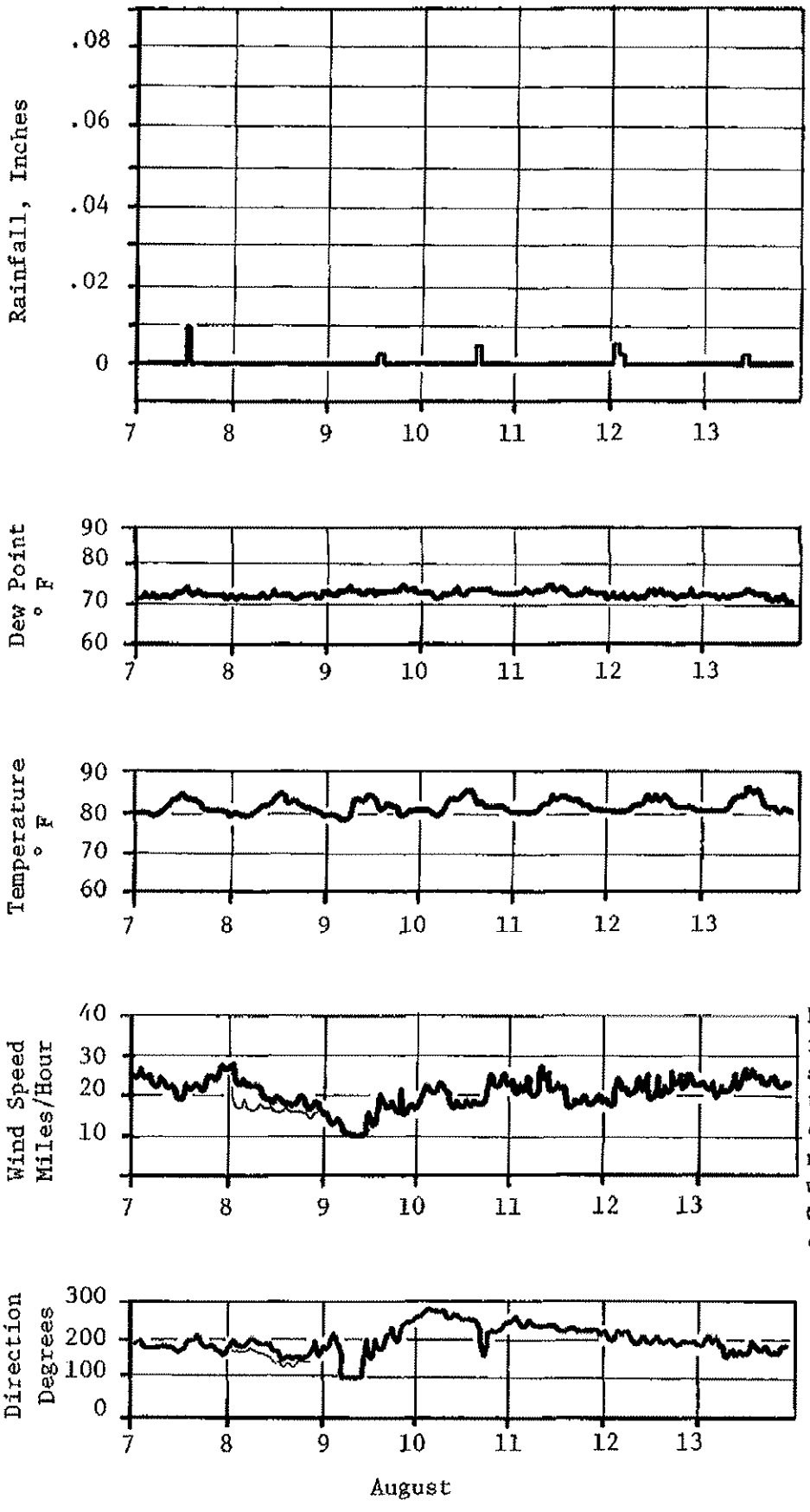
2116



Note: The dark line is the NOAA weather station data, while the light line is comparative information from the downwind weather monitor. One day each week is compared.

FIGURE 2. (Continued)

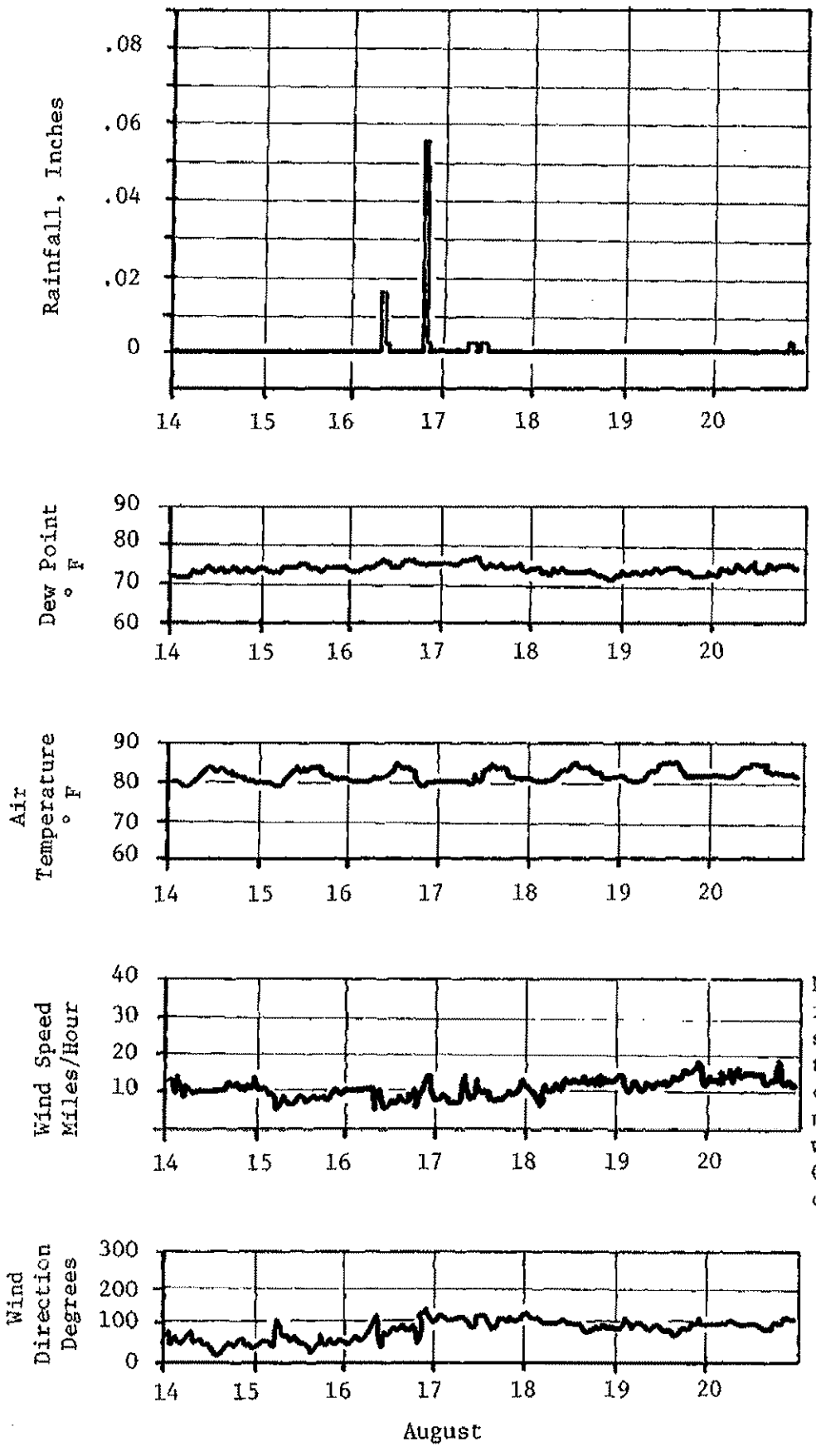
3117



Note: The dark line is the NOAA weather station data, while the light line is comparative information from the downwind weather monitor. One day each week is compared.

FIGURE 2. (Continued)

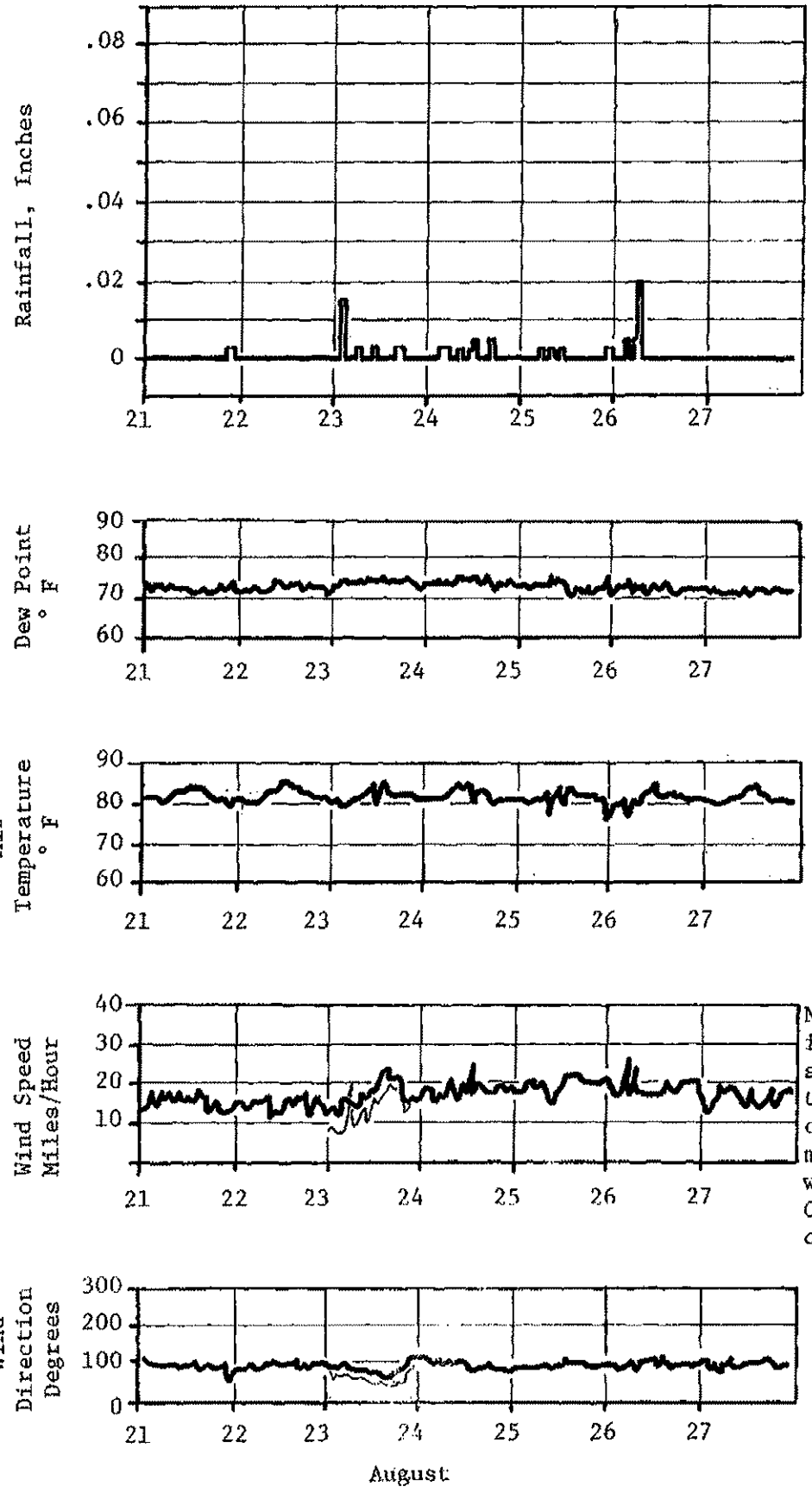
2118



Note: The dark line is the NOAA weather station data, while the light line is comparative information from the downwind weather monitor. One day each week is compared.

FIGURE 2. (Continued)

2119



Note: The dark line is the NOAA weather station data, while the light line is comparative information from the downwind weather monitor. One day each week is compared.

FIGURE 2 . (Continued)

2120

A very slight warming trend (1-2° F) was observed from the beginning of operations in late July through the end in late August. This was to be expected because the monthly mean for July is about a degree Fahrenheit less than that for August.

c. Precipitation

Rain is extremely variable on the island in both frequency and intensity. The accumulated measurable rainfall was 1.3 inches during the 39-day period. In addition to measurable quantities, trace amounts were observed over hourly intervals on 58 occasions. The heaviest rains (more than 0.10 inches/hr) occurred on July 29, August 4, August 5, and August 16. Rain was most frequent over the intervals August 3 through 5 and August 23 through 26. In comparison to the norm for the season, the period was a rather dry one, with rainfall at about 55 percent of the total expected. However, the rainfall was well within the observed extremes of 0.4 to 10 inches for the total period.

d. Dew Point

Dew point temperatures ranged from 70° F to 77° F throughout the period. Highest readings (75° F) were recorded during periods of rain. On no occasion, however, was the dew point ever reached.

2.1.2.2 Air Quality

Being remote from other terrestrial environments, the air at Johnston Atoll is clean, with none of the pollutants normally associated with urban areas. The only air contaminants expected at Johnston Island are those introduced at Johnston Island itself. Routine insecticide spraying was suspended during the HO operations on Johnston Island.

2121

The following sections discuss the applicable air standards, existing sources of HO atmospheric, and observed atmospheric HO concentrations prior to the dedrumming operations.

a. OSHA Standards

Christiansen[5] discusses the toxicity of 2,4-D and 2,4,5-T and its n-butyl esters. No inhalation toxicities are reported for any species.

The Occupational Safety and Health Administration has established 8-hour time weighted average concentration occupational standards for the acids of 2,4,-D and 2,4,5-T. For both chemicals the standard is 10 milligrams per cubic meter (10,000 $\mu g/m^3$).

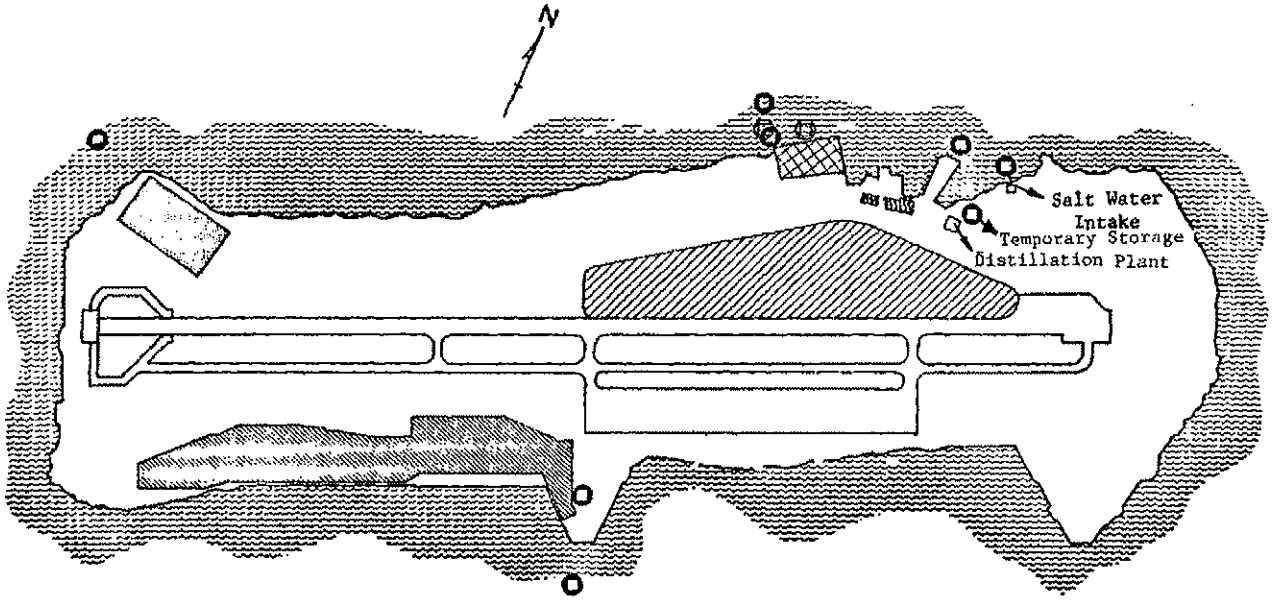
The constituents of Orange Herbicide, however, are the n-butyl esters of the acids. There are no OSHA (or any) standards for exposure to the esters. However, the reported animal toxicities in Christiansen[5] for the butyl esters are even lower than for the acids. It is reasonable to assume that 10 mg/m^3 is a realistic human TWA exposure limit for humans.

b. Existing Pollution Source

The herbicide was stored in a drum storage yard at the northwest corner of the island as illustrated in Figure 3. At this location, the prevailing winds rapidly removed any atmospheric HO away from Johnston Island and the atoll and dispersed it in the open Pacific. There were no other locations containing HO.

Prior to the disposal operation, the salty environment caused drums to corrode and thus leak. A team of men patrolled the drumyard looking for fresh HO sorbed on the ground, an indication of a leaking drum. While an exact measurement was not made, an estimate of from 20 to 70 would be found leaking each week.

The leakers were taken to the dedrumming facility where they were allowed to drain into a covered collection sump over a period of days. On a weekly basis, the collected drainage would be redrummed in new drums and restacked, while the old drums would be crushed and stacked.



Water Sampling Sites
Sediment Sampling Sites
Analytical Buildings (Bldgs 120/190)
Red Hat Area
Johnston Island Crew Facilities
Wharf
Dedrum Area

FIGURE 3. FEATURES OF JOHNSTON ISLAND

There is no measurement of the volume actually leaked. The incineration records show that the average drum contained 53.9 gallons, but it cannot be said that all drums were initially full.

c. Observed Ambient Air Pollution

While concentration measurements downwind of the site were not made prior to the HO operation, the values for 2,4-D and 2,4,5-T in the pre-operational period averaged 0.49 and 0.08 $\mu g/m^3$, respectively, at the downwind station. Furthermore, the odor of the trichlorophenols in the HO was intense across the entire downwind boundary of the drumyard.

The consistent, strong winds at Johnston Island are helpful in the removal and dispersion of HO from the atoll. It is expected that the atmospheric stability is typically Class B* during the day and Class D at night. With these stabilities, dispersion processes should reduce concentrations by a factor of 10 within 1.6 kilometers downwind (day) and 4.4 kilometers (night).

2.1.3 Water Environment

The existing water environment of Johnston Island consists of several components of the hydrologic cycle. Because of the small size of the island, cycling of material between the hydraulic components is expected to be rapid. The hydrologic components described below include the saltwater and freshwater portions of the cycle. The saltwater cycle is comprised of the lagoon circulation and the groundwater underlying the island while the freshwater cycle includes the rainfall and the drinking water and sanitary system.

* Turner's stability classes.

2.1.3.1 Hydrology of Johnston Island

Precipitation in excess of 0.01 inches occurs on the average of 162 days per year. The mean annual rainfall is 26.11 inches, however, variation from year-to-year is considerable. Monthly rainfall variations are small. During the period 1931-1972, July rainfall averaged about 1.6 inches while August rainfall was about 2.2 inches. In the Central Pacific tropical climate, evaporation is much greater than precipitation. This, together with the flat topography and permeability of the soils minimizes sheet runoff. Storm drainage is collected in a system of French drains, inlets, and open ditches which flow into the lagoon. Since most rains are very light, flow in these ditches is intermittent with evaporation being the predominant removal process. Tranpiration from plant surfaces is a very minor part of the hydrologic cycle of the island because of sparce vegetation due to the large areas of paved or otherwise impervious surfaces and base coral.

There are no permanent freshwater bodies on Johnston Island. The lack of surface water is due to the coarse texture and extreme permeability characteristic of the surface coral sands (Thorp[6]). Other factors contributing to the lack of significant amounts of fresh groundwater are the small land area, narrowness of the island and the high permeability which allows rapid mixing between the lagoon water and the percolating rainwater.

Johnston Island's water system uses both fresh and salt water. Raw sea water is pumped from the lagoon through a traveling screen to the Salt Water Pump House. From there it is pumped to the Distillation Plant and also into the salt water distribution system where it is used for sanitary purposes, fire protection, air conditioning condenser units, and power plant waste heat dissipation. The Distillation Plant houses twelve distillation units and related equipment; the Freshwater Treatment Plant consists of a pump station, soda-ash treatment area, and a chlorination room and storage facilities for approximately 740,000 gallons (Figure 3). The freshwater system is designed to support a population of approximately

4,500. Its total rated capacity is 318,000 gallons per day (gpd), but, allowing for maintenance and miscellaneous downtime, about 240,000 gpd can be expected at peak production.

Johnston Island has insufficient relief to permit use of a gravity sewage collection system; therefore, a forced system employing pumps and lift stations is used. The force main is a series of 3" to 16" cast iron and asbestos cement pipes in parallel runs along the north and south shores with connecting laterals. Raw effluent is discharged on the ocean bottom at a depth of 25.6 feet through a 10 inch pressure outfall pipeline which extends approximately 550 feet out from the southwest peninsula of the Island.

2.1.3.2 Oceanography-Currents and Tides

Johnston Island is approximately in the center of the North Equatorial Current which extends to the north and to the south of the island for several hundred miles. The velocity of this current is relatively constant from east to west at about 1/2 knot (0.41-0.63 mph; 0.61-0.82 ft/sec; 0.17-0.25 meters/sec).

The underwater platform on which Johnston Island is located is similar to those associated with many Pacific atolls. Like most other low islands in the Pacific, the main outer reef has a typical cross section, which includes surge channels, an algal ridge, and a reef flat, with coral heads rising abruptly in the deeper waters to the south and east of the main reefs. The outer slope is quite steep, between 16 and 100 fathoms, usually less than one-half mile in linear distance, with an average slope of 19°. The platform on which Johnston Atoll rests stops fairly abruptly at about the 16 fathom line at most points around the circumference of the atoll as the bottom begins to slope steeply down.[7,8,9]

The shallow lagoon area and its bordering reefs together form roughly the northwestern quarter of the triangular-shaped platform on which the atoll rests. At the deeper eastern end of the platform the submerged contours suggest the outline of earlier peripheral reefs. The

main difference between Johnston Atoll and other Pacific islands is the lack of continuous reef around the atoll. The main outer reef extends around less than one-fourth of the circumference of the platform. In addition, there is an extensive zone of shallows to the south of the main reef which is also an unusual feature.

The tidal range at Johnston Island, in common with other mid-Pacific islands, is relatively small and the effects of the tides upon the atoll are correspondingly minor. The absolute tidal range during the year (the difference between the lowest and highest tides of the year) is only 3.4 feet. The lowest low is minus 0.5 foot in June, while the highest high is plus 2.9 feet in June and July. The mean spring high tides are plus 2.2 feet while the mean spring low tides are minus 0.2 foot. The mean neap tides are plus 1.6 feet, while the mean neap low tides are plus 0.4 foot.[6,7,8] The time of the tidal crests and troughs is only slightly later than those of Honolulu, the nearest point for which a full tide table is available. High tides are 29 minutes later at Johnston Island than at Honolulu, while the low tides are 23 minutes later. The high-water interval from full tide to the change of tide is three hours and 15 minutes. Tide tables for July and August, 1977, are shown in Table III-14*. The maximum high tide during the assessment occurred from July 27 to 29 and measured plus 2.9 feet while the lowest tide was minus 0.1 feet on July 24, 28 and 31.

The ocean currents around Johnston Atoll exert a major influence on the localized circulation within the lagoon because of the "open" structure of the marginal reefs. In addition, the tides have a range within the lagoon only slightly less than in the deep water because of this feature.

Tidal currents within the lagoon show some variation with the season. During July and August, the normally strong westerly flow weakens somewhat. This allows a divergent flow field to be generated to the southwest of the atoll platform. This type of flow was characterized by

*This notation refers to Table 14 of Level III Report. The notation will be frequently used throughout this report.

a moderate offshore current with a general set toward the west. Local tides induce clockwise rotary to semi-rotary motions in the regional and local circulation patterns. During rising tides, the predominant flow is to the north in the east and west ship channels and to the northwest in the north channel (Figure 4). The normal current speeds are about 1/2 knot. During falling tide, however, the predominant flow was to the south in the east and west channels and to the southeast at about one knot in the north channel (Figure 5).[3,8,9]

These current movements are affected by the numerous patch reefs found in many places. The natural depths within the lagoon (except for the dredged portions) vary from a few inches to about 40 feet, because of the presence of coral heads and patch reefs. The greatest area lies between 15 and 25 feet underwater at mean sea level.

The lagoon inside the main atoll is about 14,000 yards long at its axis, which runs southwest from Small Island through the center of both Sand and Johnston Islands. At its widest point, just east of Sand Island, the lagoon extends about 3,500 yards from northwest to southeast. West of Johnston Island the lagoon narrows to a few hundred yards in width before coming almost to a point at the extreme southwestern corner of the atoll.

The total area of the lagoon within the reef is approximately 13 square statute miles. An exact measurement is difficult because of the need to measure the exact line of demarcation between the lagoon proper and the extensive coral flats which form the southeastern part of the atoll.[6,7] At the extreme northeastern corner of the lagoon, south of the opening between the main reef and North Island, there is an area of deeper water in which average depths of more than 40 feet have been reported, but the bottom still has many irregularities and numerous coral heads which almost broach the surface. Artificial dredging in the lagoon has left the seaplane landing area with a depth of eight feet cleared of obstructions, while the harbor and the entrance channel were originally dredged to 23 feet and have been swept to 14-1/2 feet. An approximate value for the volume of water enclosed by the reef is 1.5×10^{11} ft^3 (4.3×10^9 m^3). As observed

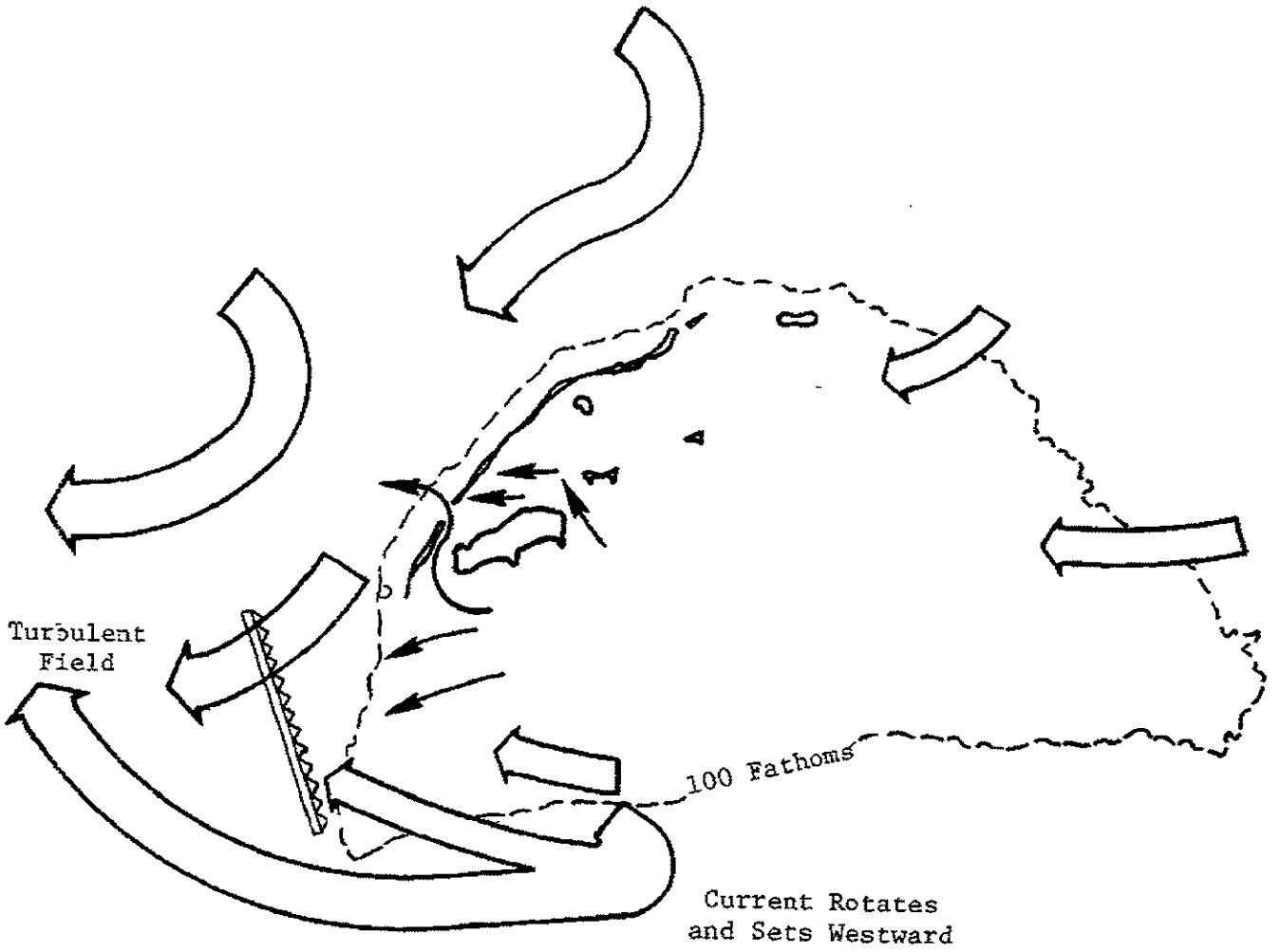


FIGURE 4. INFERRED LAGOON CIRCULATION (WESTERLY FLOW), JULY-AUGUST, 1965, KOPENSKY AND WENNEKENS, 1966

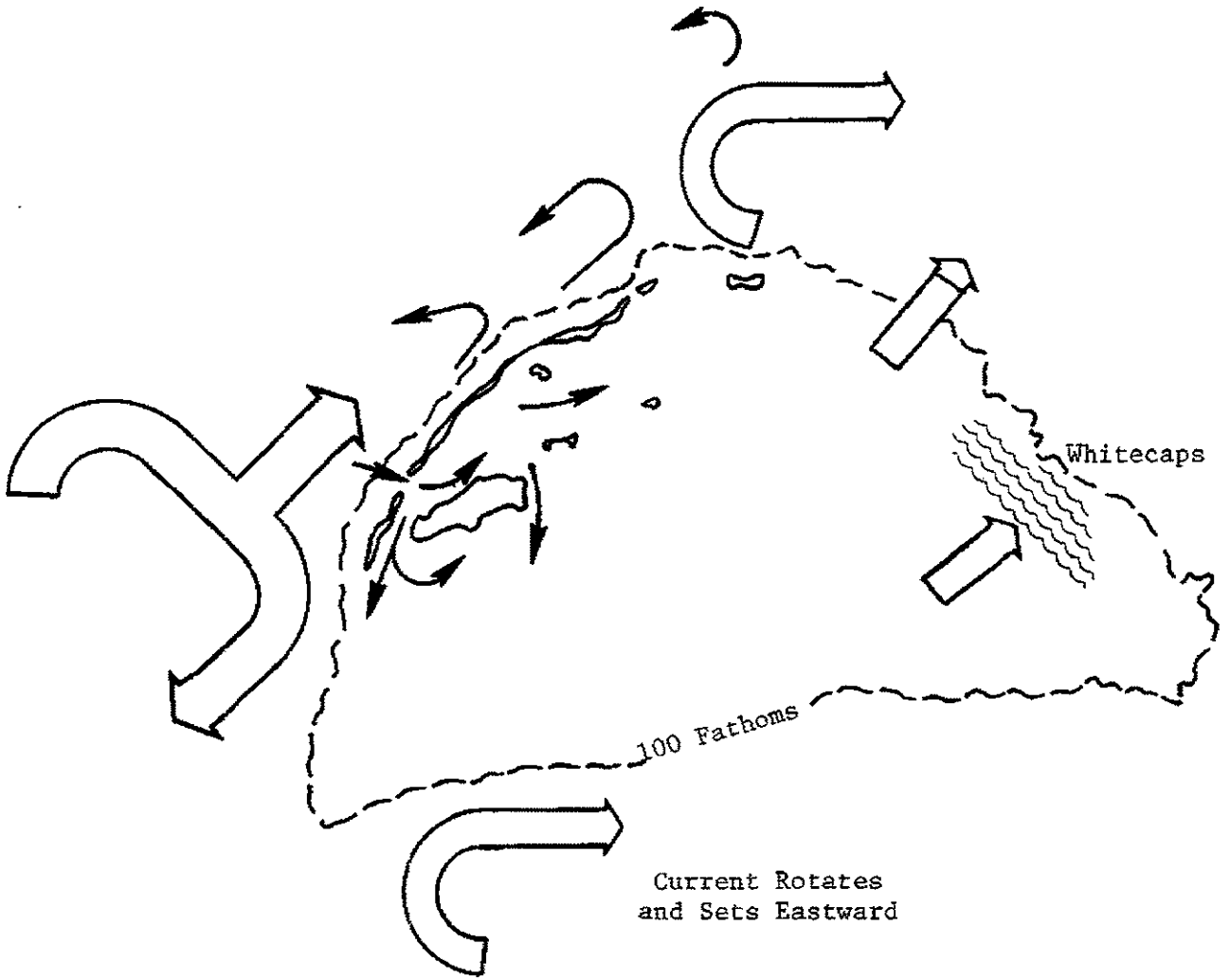


FIGURE 5. INFERRED LAGOON CIRCULATION (EASTERLY FLOW), JULY-AUGUST, 1965, KOPENSKY AND WENNEKENS, 1966

by Emery,[3] these coral heads influence the movement of sediments by blocking the current causing sand to be deposited on the upcurrent side and scouring the areas between the reefs. His examination showed these areas to be about half a fathom (0.9 meters) deeper than the surrounding floor and containing coarser sediment than the adjusted areas.

Mirco-scale currents at the wharf observed by the divers when taking sediment samples were a light west-to-east deep current and an east-to-west surface current at 20-25 feet (6.1-7.6 meters) seaward from the center of the wharf. Off the west end of the wharf, the deep current direction was south to north (Figure 6). These observations were made at 1100 hours on July 25.[10] Water depths immediately off the wharf were 35 feet (10.5 meters). A trough of 45-50 foot (13.7-15.2 meters) depth was noted about 25 feet (7.6 meters) from the base of the wharf.[10]

2.1.3.3 Water Quality Criteria/Standards

Limits on aqueous concentrations of 2,4-D and 2,4,5-T are classified as either criteria or standards.

The word "criterion" should not be used interchangeably with, or as a synonym for, the word "standard". The word "criterion" represents a constituent concentration or level associated with a degree of environmental effect upon which scientific judgment may be based. As it is currently associated with the water environment it has come to mean a designated concentration of a constituent that when not exceeded, will protect an organism, an organism community, or a prescribed water use or quality with an adequate degree of safety. On the other hand, a standard connotes a legal entity for a particular reach of waterway or for an effluent. A water quality standard may use a water quality criterion as a basis for regulation or enforcement, but the standard may differ from a criterion because of prevailing local natural conditions, such as naturally occurring organic acids, or because of the importance of a particular waterway, economic considerations, or the degree of safety to a particular ecosystem that may be desired.

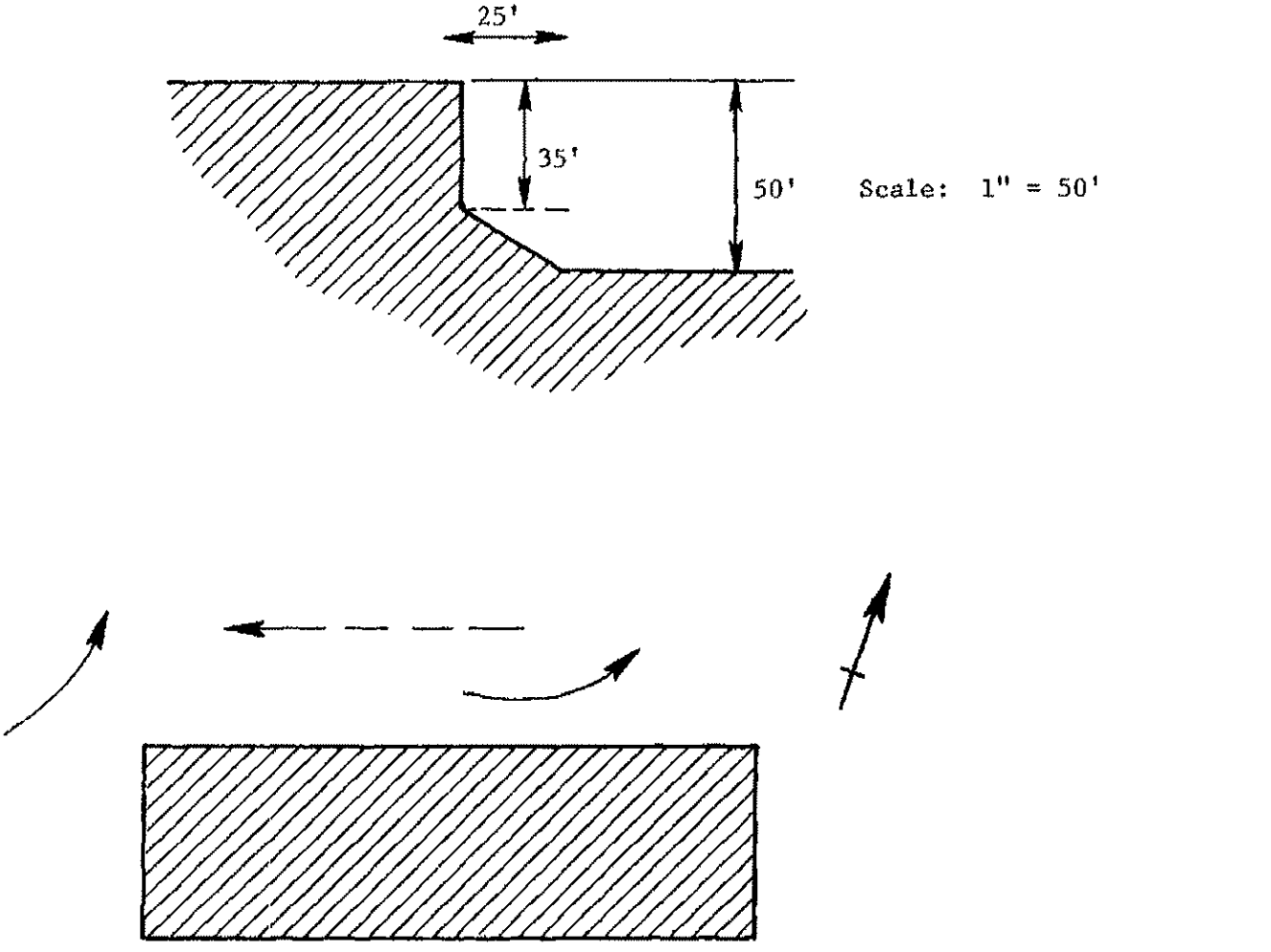


FIGURE 6 . MICROSCALE CURRENT DIRECTIONS AT THE MAIN WHARF, JULY, 1977

2132

Water quality criteria are not intended to offer the same degree of safety for survival and propagation at all times to all organisms within a given ecosystem. They are intended not only to protect essential and significant life in water, as well as the direct users of water, but also to protect life that is dependent on life in water for its existence, or that may consume intentionally or unintentionally any edible portion of such life.[13]

The criteria levels for domestic water supply incorporate available data for human health protection. Such values are different from the criteria levels necessary for protection of aquatic life. The interim primary drinking water regulations[14], as required by the Safe Drinking Water Act[15], incorporate applicable domestic water supply criteria. Where pollutants are identified in both the quality criteria for domestic water supply and the Drinking Water Standards, the concentration levels are identical. Water treatment consisting of flocculation, settling, and softening may not significantly effect the removal of certain pollutants, (such as the components of Orange Herbicide).

The ideal data base for aquatic life criteria application regarding Orange Herbicide would be information on a large number of tropical marine species common to the Johnston Atoll area over their entire life span and that of succeeding generations. Unfortunately, these data do not exist. Most of the available toxicity data on both acute and subacute effects are for freshwater organisms. These were obtained at temperatures below those typical of the Johnston Island environment or represent time frames of less than the organism's entire life span. Furthermore, independent environmental variables other than temperature have been found to be of importance in determining the toxicity of 2,4-D, 2,4,5-T or mixtures thereof.

The Environmental Health Laboratory at Kelly AFB, TX conducted bioassay tests in which Orange Herbicide was mixed with water at a theoretical concentration of 200 ppm. It was found that most of the herbicide rapidly sank to the bottom of the tank. None of the test organisms showed any adverse effects after two weeks exposure; however, all of the fish died within 24 hours at a concentration of 20 ppm in a similar experiment but with continuous agitation of the water.[16] Subsequent studies indicated that, in order to establish a dose/response relationship for the organism, some circulation of the water was necessary.

A second determinant of toxicity is the actual chemical form of the herbicide in water. The derivatives of 2,4-D and 2,4,5-T used in Orange Herbicide hydrolyze to the respective acids at varying rates. For ocean water, in studies conducted by the Air Force, 90 percent of the esters were hydrolyzed within 7 days. Toxicity of the acids is decidedly lower than the corresponding esters probably because of polarity influences on uptake mechanisms.[16] The many confounding effects make it difficult to apply a rational criterion which would protect all the potentially exposable organisms. Tests by the EHL Kelly AFB, TX on artificial sea water aystems produced marked differences between the theoretical concentration due to solubility effects. (Thus, static bioassay results found in the literature which are based on theoretical added concentrations of Herbicide may indicate a low toxicity (high side bias); the actual concentrations of HO in solution producing acute or subacute effects would be much lower).

The effect of temperature on organism response has received limited attention. Only one study was located which even stated the temperature at which the tests were conducted. This showed a strong temperature dependence, although only two temperatures, 17 and 20 C, were evaluated.[16]

The philosophy of EPA in assigning criteria has been to employ a safety factor to protect all life stages of the test organism in waters of varying quality, as well as to protect associated organisms within the aquatic environment that have not been tested and that may be more sensitive to the test constituent. Application factors have been used to provide the degree of protection required. Safe levels for certain chlorinated hydrocarbons and certain heavy metals were estimated by applying an 0.01 application factor to the 96 hour LC_{50} value for sensitive aquatic organisms.

A listing of available acute and subacute bioassay data is contained in Tables 1 and 2. In addition, McKee and Wolf presented the following discussion concerning 2,4-D.[17]

TABLE 1. ACUTE TOXICITY DATA FOR 2,4-D, 2,4,5-T AND DERIVATIVE ACIDS, SALTS, ESTERS, AMINES, AND ETHERS[a]

Test Compound	Test Organism	Test Conditions	Dose (mg/ℓ)	Response	Comments	Reference
2,4-D (DMA)	Fathead minnow		355	96 hr TL_{50}		16
2,4-D (DMA)	Bluegill		177	96 hr TL_{50}		16
2,4-D (DMA)	Channel catfish	17 C	193	96 hr TL_{50}		32
2,4-D (DMA)	Channel catfish	20 C	125	96 hr TL_{50}		39
2,4-D; 2,4,5-T estern (OH)	Fathead minnow	Freshwater	3.4	48 hr LC_{50}	14 ppm TCD	16
2,4-D (NBE)	Fathead minnow	Freshwater	2.8	48 hr LC_{50}		16
2,4,5-T (NBE)	Fathead minnow	Freshwater	5.0	48 hr LC_{50}		16
2,4-D	Fathead minnow	Freshwater	270	48 hr LC_{50}		16
2,4,5-T	Fathead minnow	Freshwater	333	48 hr LC_{50}		16
2,4-D (NBE)	Shrimp	Saltwater	5.6	48 hr LC_{50}		16
2,4,5-T (NBE)	Shrimp	Saltwater	33	48 hr LC_{50}		16
2,4-D (PGBE)	Daphnia magna	Freshwater	0.1	48 hr TL_{50}		33
2,4-D (PGBE)	Seed shrimp	Freshwater	0.3	48 hr TL_{50}		33
2,4-D (PGBE)	Scud	Freshwater	2.6	48 hr TL_{50}		33
2,4-D (PGBE)	Sowbug	Freshwater	2.2	48 hr TL_{50}		33
2,4-D (PGBE)	Glass shrimp	Freshwater	2.7	48 hr TL_{50}		33
2,4-D (IOE)	Bluegill		10-31	48 hr TL_m	Obtained from 3 manufacturers	34
2,4-D (PGBE)	Bluegill		17	48hr TL_{48}		34
2,4-D (BOEE)	Bluegill		1.4	48 hr TL_m		34
2,4-D (PGBE)	Fish	Saltwater	0.3	48 hr TL_{48}		35
2,4-D (AAS)	Bluegill		435-840	48 hr LC_{50}		36
2,4-D (DMA)	Bluegill		166-458	48 hr LC_{50}		36
2,4-D (IOE)	Bluegill		8.8-59.7	48 hr LC_{50}		36
2,4-D (DMA)	Fathead minnow		10	96 hr LC_{50}		36
2,4-D (AA)	Fathead minnow		5	96 hr LC_{50}		36
2,4-D (AS)	Fathead/bluegill		2	4 No. LC_{10}	Oil soluble	36
2,4-D (PGBE)	Fathead/bluegill		2	4 No. LC_{10}		36
2,4-D (BOEE)	Fathead/bluegill		2	72 hr LC_{50}		36
2,4-D (AEE)	Bluegill		1.4	48 hr LC_{50}		36
2,4-D (IBE)	Bluegill		1.3	48 hr LC_{50}		36
2,4-D (IPE)	Bluegill		1.1	48 hr LC_{50}		36
2,4-D (BOEE)	Fish	Saltwater	5	48 hr TL_m		36
2,4-D (PGBE)	Fish	Saltwater	4.5	48 hr TL_{48}		35
2,4-D	Fish		100	Threshold conc. for mortality		17
2,4-D	Perch		75	Threshold conc. for mortality		17
2,4,5-T	Perch		55	Threshold conc. for mortality		17
2,4,5-T	Bleak		60	Threshold conc. for mortality		17

(a) (DMD) = dimethylamine; (NBE) = normal butyl ester; (PGBE) = propylene glycol butyl ether; (IOE) = isooctylester; (BOEE) = butoxyethylester; (AAS) = alkanolamine salt; (AA) = acetamide; (AS) = amine salt; (IPE) = isopropyl ester.

(b) See literature cited for references.

2135

TABLE 2. SUB-LETHAL EFFECTS OF 2,4-D DERIVATIVES UPON AQUATIC ANIMALS[a]

Test Compound	Test Organism	Dose	Response
Butoxyethanol ester	Oyster	3.75 ppm (96 hrs)	50% Decrease in shell growth
Butoxyethanol ester	Shrimp	1 ppm (48 hrs)	No effect
Butoxyethanol ester	Phytoplankton	1 ppm	16% Decrease in CO_2 fixation
Dimethylamine	Oyster	2 ppm (96 hrs)	No effect on shell growth
Dimethylamine	Shrimp	2 ppm (48 hrs)	10% Mortality or paralysis
Dimethylamine	Fish (salt water)	15 ppm (48 hrs)	No effect
Dimethylamine	Phytoplankton	1 ppm (4 hrs)	No effect on CO_2 fixation
Ethylhexyl ester	Oyster	5 ppm (96 hrs)	38% Decrease in shell growth
Ethylhexyl ester	Shrimp	2 ppm (48 hrs)	10% Mortality or paralysis
Ethylhexyl ester	Fish (salt water)	10 ppm (48 hrs)	No effect
Ethylhexyl ester	Phytoplankton	1 ppm (4 hrs)	49% Decrease in CO_2 fixation
PGBE ester	Oyster	1 ppm (96 hrs)	39% Decrease in shell growth
PGBE ester	Shrimp	1 ppm 48 hrs)	No effect

[a] Source: Reference 16.

"In laboratory rests, the lowest concentration of 2,4-D to cause mortality of fish was 100 mg/ℓ, the threshold value of toxicity to perch and bleak (Alburnus Lucious) was 75 mg/ℓ. However, certain esters and amines of 2,4-D have been found to be more toxic and, particularly in still, shallow water, may harm fish at dosages used for weed control. Fingerling bluegills suffered losses of up to 40 and 100 percent from concentrations of 1 and 5 mg/ℓ, respectively, of the butyl ester. The isopropyl ester was somewhat less toxic but caused complete mortality of bluegills at 10 mg/ℓ, as did the alkalolamine at 40 mg/ℓ. A few fish also died during a 4-day exposure to 4 mg/ℓ of the latter material. The sodium salt was not observed to kill small rainbow trout below a concentration of 112 mg/ℓ.

The Fish and Wildlife Service tested a large number of phenoxyacetic acids and related compounds in rough screening studies in Lake Huron water at 12 C. Trout and bluegill were killed but sea lamprey were unaffected by 2,4-dichlorophenoxyacetic acid, butyl ester during a 24-hour exposure to 5 mg/ℓ.

Fish-food organisms vary in sensitivity to the derivatives of 2,4-D. Tests with the isopropyl ester showed that losses of over 25 percent were sustained by crustaceans at 0.1-0.4 mg/ℓ, insects at 0.4-2.0 mg/ℓ, and snails at 2.4-3.3 mg/ℓ. These animals were more resistant to poisoning by the mixed propylene glycol and butyl esters of 2,4-D, and certain species of insects and snails were not killed at 6.6 mg/ℓ.

It was found that the safe concentration to minnows was 1500 mg/ℓ and for sunfish and catfish 500 mg/ℓ. Some mortality of bream and bass occurred at 100 mg/ℓ and of carp at 65 mg/ℓ. A concentration of the sodium salt of 2,4-D of 260 mg/ℓ was not toxic to carp.

A mixture of neutral aromatic oils (57 percent), 2,4-D (12.5 percent), emulsifiers (8 percent), and water (to 100 percent) was toxic to three-month-old rainbow trout at a concentration of 3.0 mg/ℓ over a 24-hour period, and at 2.2 mg/ℓ over a 48-hour period.

A commercial weed killer that combines 6.25 percent 2,4-D and 6.25 percent 2,4,5-T with propylene glycol, butyl ether esters, and inert ingredients, in concentrations of 50 mg/ℓ or more caused the test fish to become immediately distressed. In a 72-hour period, a 25-percent kill occurred at 10 mg/ℓ, but no fish died at 5 mg/ℓ.

2137

It is clear that few saltwater species have been assayed and perhaps no tropical saltwater species have been tested. For short term (shorter than 24 hours) exposure, it can be assumed that less than one-half of an ester form of 2,4-D or 2,4,5-T added to water will be hydrolyzed to the less toxic acid form. Furthermore, the offsetting effect of higher temperatures should more than compensate for the lower toxicity of the hydrolyzed fraction. The 48 hour LC_{50} or TL_m values for saltwater fish species exposed to 2,4-D ranged from 0.3 mg/ℓ using the PGBE derivative to 5 mg/ℓ using the BOEE derivative. The Air Force's data using actual HO or normal butyl esters, is about the same, although a freshwater test organisms, the fathead minnow, Pimephales promelas, was used. Using the EPA methodology of determining a "safe" concentration as 1 percent of the 96 hr LC_{50}, a value between 0.01 and 3.6 mg/ℓ 2,4-D results for a water quality criterion, ignoring the possible inappropriateness of the test organisms or test conditions.

The toxicity of 2,4,5-T to aquatic species has been studied to a much lesser degree than the toxicity of 2,4-D. Comparative studies on 2,4-D and 2,4,5-T toxicity have been conducted by the Air Force on a number of species. Freshwater tests on fathead minnows showed the same trend as for 2,4-D, namely, that ester formulations were much more toxic than the acids. Measured toxicities of 2,4,5-T were 20-50 percent lower than for 2,4-D, however, the TCDD content of the 2,4,5-T tested was not stated. In tests using actual Herbicide Orange, the toxicity was intermediate to the two individual components.

Tests on other varieties of fish have been performed that show the opposite trend. Perch exhibited slightly greater toxicity response to 2,4,5-T. Again, the TCDD content was not given.

Finally, saltwater shrimp comparison tests showed the normal butyl ester of 2,4,5-T to be significantly less toxic than the NBE ester of 2,4-D.

The range of acute toxicities of 2,4,5-T observed in the data is 5.0 to 333 mg/ℓ. Using the EPA methodology of determining "safe" concentrations as one percent of the 96 hr LC_{50}, a value of between 0.05 and 3.3 mg/ℓ results for a water quality criterion.

Both the National Institute for Occupational Safety and Health (NIOSH) Registry and the Water Quality Characteristics of Hazardous Materials assign aquatic toxicity range ratings of 1-10 ppm for 2,4-D and 2,4-T (5,43). Concentrations of 2.5 mg/ℓ for each of the components (5 mg/ℓ of HO) has been selected as the criterion concentration.

According to the literature, pure 2,4-D and 2,4,5-T are considered to present a moderate toxicity to humans.

An extensive study of the literature on the human health and toxicity of the major and minor constituents of Herbicide Orange has been conducted by the National Academy of Sciences.[43] Judgements were made on a wide variety of organic substances relative to their carcenogenicity or the available information that would permit estimation of the "no observed adverse effect level".

After a substance had been identified as a carcinogen, the risk to man was expressed as the probability that cancer would be produced by continued daily ingestion over a 70 year lifetime of 1 liter of water containing 1 µg/ℓ of the substance. Assumptions required in the calculation were the conversion of the standard human dose to the physiologically similar dose in the animal and the application of an exponential risk model relating dose to effect.

2,4-Dichlorophenoxyacetic acid toxicity data for man and other terrestrial species were reviewed to determine permissible intake levels. Observations in man are primarily expost facto judgements of accidental or intentional (suicidal or medical) ingestion. Poisoning and death have been attributed to ingestion of dosages ranging from 67 to 100 mg/kg. Subjects in two other studies took or were exposed to lesser quantities or similar quantities over longer time periods with no harmful effects.

Observations in other species supported the moderate toxicity designation. LD_{50} values of 100-541 mg/kg were found for rats, mice, guinea pigs, chicks, and dogs. Salts and esters of 2,4-D showed an even lower degree of acute toxicity than the acid.

Subchronic and chronic effects have been measured using rats and dogs. Experiments with rats showed no adverse effect levels ranging from 30 to 1,250 mg/kg and those with dogs ranged from 20 to 500 mg/kg.

The results of these studies were analyzed to determine the daily no adverse effect doses. These were found to be up to 62.5 mg/kg/day and 10 mg/kg/day in rats and dogs, respectively. Based on these data, the acceptable daily intake for humans was calculated to be 0.0125 mg/kg/day. The NAS report stated that the substantial disagreements in the results of the subchronic and chronic toxicity studies were cause for concern and caution and that additional study is warranted. These deficiencies were considered in the determination of the no adverse effect level from drinking water shown in Table 4.

Toxicity data on 2,4,5-trichlorophenoxy acetic acid and 2,3,7,8-tetrachloro-p-dibenzodioxin were considered together since most of the 2,4,5-T preparations tested contained TCDD at 1-80 ppm. A few studies have been conducted with TCDD "free" material (< 0.05 ppm).

Observations of toxicity in man depend on the TCDD content of the test material. Two studies in which 2,4,5-T containing low concentrations of TCDD was used failed to produce toxic effects in the concentration range of 1.6-8.1 mg/day. Another study where contaminated 2,4,5-T was used produced cases of moderate to severe chloracne and several cases of porphyria.

Toxicity testing results on other species likewise depend on the TCDD content. Early data on 2,4,5-T show oral LD_{50} values for male rats, male mice, guinea pigs, and chicks were 500, 389, 381, and 310 mg/kg, respectively. TCDD contents were unknown. Testing of TCDD alone established its extreme toxicity as shown by LD_{50} values ranging from 0.6 to 115 µg/kg, depending on species.

Subchronic and chronic effects of 2,4,5-T and TCDD have been observed in relatively short-term studies on rats, mice, dogs, and guinea pigs. Effects most often observed included lesions, bone marrow irregularities, degenerative liver and thymus changes porphyria, serum enzyme changes and weight loss. 2,4,5-T doses eliciting adverse effects ranged from 2 mg/kg/day for dogs to 100 mg/kg/day for rats. TCDD doses yielding responses were as low as 0.1 µg/kg 5 days a week for 13 weeks.

2140

The conclusions reached by the NAS report were that contamination of 2,4,5-T with TCDD greatly increases the toxicity of the mixture from moderately toxic to very toxic. No adverse effect doses for 2,4,5-T were 10 mg/kg/day for dogs and mice and up to 30 mg/kg/day for rats and for TCDD were 0.01 µg/kg/day in rats. Acceptable daily intakes for humans were calculated as 0.1 mg/kg/day for 2,4,5-T and 10^{-4} µg/kg/day for 2,4,5-T and 10^{-4} µg/kg/day for TCDD. The lack of data on long term toxicity and the substantial differences in toxicity values for 2,4,5-T due to varying degrees of TCDD contamination were cited as reasons for conservative estimation of permissible drinking water concentrations, shown in Table 3. Maximum contaminant levels as contained in the Drinking Water Standards and in the 1976 Water Quality Criteria are shown for comparison.[13,15]

Ambient water standards are applied at the point of withdrawal for supply which in this case is the saltwater intake (site WS), while drinking water standards are applicable at the delivery end of the system (site P1). There are two additional factors which serve to alter the normally encountered conditions in a drinking water supply. First, the production of freshwater is intermittent. Higher than allowable levels at the saltwater intake are not of concern if freshwater is not being produced on a given day. Second, freshwater on Johnston Island is produced by distillation. The boiling points of 2,4-D, and 2,4,5-T acids are related derivatives are all greater than 160 C.[18] Therefore, the fraction of distillable HO at the process temperature is certainly less than 50 percent of the concentration on the saltwater side of the system. (See also Section 4.1.3 for more detailed discussion of these points).

Since the water quality criteria represent lifetime consumption levels, the short term exposure levels could conceivably be much greater than the average and still produce no effects if the subsequent exposure is correspondingly lower to offset the initial dose. The tour of duty for most military personnel is one year; however, some of the civilians have been on the island for upwards of 15 years. It is not expected that

2141

TABLE 3. WATER QUALITY CRITERIA/STANDARDS--
DRINKING WATER

Compound	Concentration in Water (µg/l)	Uncertainty or Safety Factor (a)	Reference (b)
2,4-D	100 (c) (Approval limit)	500	15
	100 (d) (MCL)	--	13
	87.5 (e) (No effect level)	1000	37
	4.4 (f) (No effect level)	1000	37
2,4,5-T	700 (e) (No effect level)	100	37
	35 (f) (No effect level)	100	37
TCDD	7×10^{-4} (e) (No effect level)	100	37
	3.5×10^{-5} (f) (No effect level)	100	37

(a) The uncertainty or safety factor is introduced to reflect the amount of information available on a specific contaminant. An uncertainty factor of 100 represents a good set of chronic oral toxicity data available for some animal species while a factor of 1000 was used with limited chronic toxicity data or when the only data available were from inhalation studies.

(b) See literature cited for references.

(c) Represents lifetime no adverse effects level assuming that 20 percent of the safe intake is from water. Standard man equivalent to 70 kg and 2 liter/day water consumption used.

(d) A maximum contaminant level (MCL) means the maximum permissible level of a contaminant in water which is delivered to the tape of the user.

(e) No adverse effect level assuming 20 percent of acceptable daily intake is supplied by water. Same standard conditions as in (a).

(f) No adverse effect level assuming 1 percent of acceptable daily intake is supplied by water. Same standard conditions as in (a).

2142

the lifetime consumption would be approached by anyone on Johnston Island. Therefore, the water quality criteria are probably conservative in estimating risk.

The most stringent standard appears to be the National Interim Primary Drinking Water Standard at 0.1 mg 2,4-D/ℓ.

Other water quality criteria pertain to the organoleptic properties of 2,4-D and its breakdown products, as well as potential non-OH related project effects such as oil and grease, turbidity, and reduced dissolved oxygen concentrations.

It has been reported that 2,4-D acid was decomposed in water exposed to the sun into 2,4-dichlorophenol, 4-chlorocatechol, 2-hydroxy-4-chlorophenoxyacetic acid, and 1,2,4-benzenetriol. Taste and odor thresholds for chlorinated aromatic hydrocarbons are very low.

[redacted] and [redacted] report the taste threshold for 2,4-D as 0.01 mg/ℓ, whereas the same concentration of dichlorophenol derivatives gives noticeable tastes.(17) Several investigators have reported the taste or odor threshold concentrations for various chlorinated phenols. For 2,4-dichlorophenol the reported taste values are 0.008 to 0.02 mg/ℓ and the odor values range from 0.00065 mg/ℓ at 30°C to 0.0065 mg/ℓ at 60°C.(19,20) Spills from 2,4-D manufacturing operations have reportedly produced unpleasant tastes in drinking water at dilution ratios as high as 10,000,000:1.(17)

Turbidity (suspended solids) influences on fish life are divided into those whose effect occurs in the water column or those whose effect occurs following sedimentation to the bottom of the water body. Five general effects on fish and fish food populations have been noted:

- direct effects on swimming fish by killing them or impairing physiological functions
- preventing the successful development of eggs and larvae
- modifying natural movements and migration
- reducing the availability of food
- blanketing of bottom sediments causing damage to invertebrates and spawning areas and increasing benthic oxygen demand.

Conversely, a partially offsetting benefit of suspended matter in water is the sorption of organics such as herbicides onto particles which leads to more rapid settling.[13] However, experiments conducted to ascertain the sorption properties of 2,4-D ester and sodium salt showed very low sorption capacity for three clay minerals (bentonite, kaolinite, and illite) and very good sorption for dry coral. Desorption properties of contaminated coral in seawater were not investigated.[21]

The criterion proposed by the EPA relates primarily to freshwater fish and other aquatic life and states that "settleable and suspended solids should not reduce the depth of the compensation point by more than 10 percent from the seasonal norm".[13] The compensation point is defined as that depth where the rates of photosynthesis and respiration are equivalent or approximately the depth at which one percent of the incident light remains.

The water quality criterion for dissolved oxygen similarly pertains to freshwater aquatic life. A minimum value of 5 mg O_2/l is given.[13]

Effects of oil and grease on ocean communities range from inhibition of oxygen transfer when heavy concentrations are present on the water surface to acute or sublethal toxicity to specific compounds present in the oil. Because of the range of possible compositions, criteria have been specified with respect to bioassay techniques on important species:

> For domestic water supply: Virtually free from oil and grease, particularly from the tastes and odors that emanate from petroleum products.
>
> For aquatic life:
>
> - 0.01 of the lowest continuous flow 96-hour LC_{50} to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals.
> - Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed.
> - Surface waters shall be virtually free from floating non-petroleum oils of vegetable or animal origin, as well as petroleum derived oils.

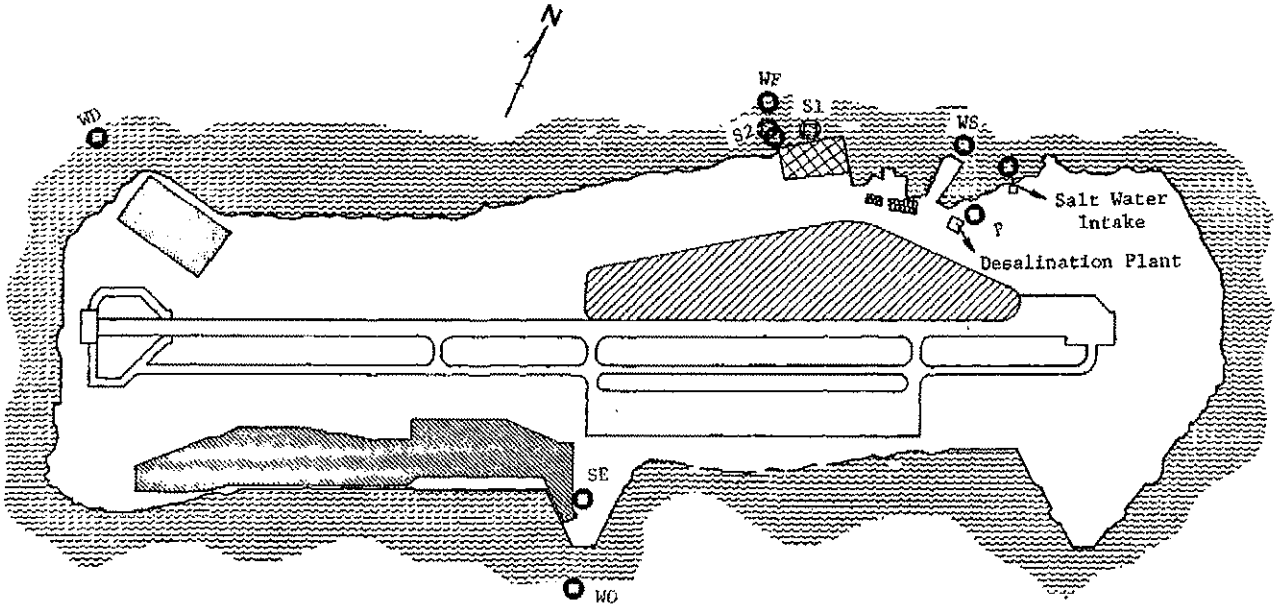
2.1.3.4 Existing Water Quality

The salt waters around Johnston Island and the freshwater system have been monitored for the presence of 2,4-D and 2,4,5-T since 1973. Eight locations, including an offshore control, have each been sampled a number of times. Table III-13 is a summary of baseline water quality data gathered by the Air Force from 1973 to 1977. The data show occasional instances of HO being detected at most of the locations. Of special significance to the disposal operation are those locations which were also sampled by BCL during Operation Pacer HO. These include the wharf, the south side of the island, the offshore area near the herbicide storage yard, the saltwater intake and the distillation plant. Corresponding site codes used in the Pacer HO operation are WF, WO, WD, WS, and P1, respectively (Figure 7).

The maximum concentrations historically observed by the Air Force in the offshore area near the Herbicide storage were on the order of 3 µg 2,4-D/liter and 0.6 µg 2,4,5-T/liter and those near the saltwater intake were 2.3 and 0.7 µg/ℓ, respectively. The other two offshore sites exhibited maximum concentrations below 0.5 µg/ℓ. Samples taken in the distillation plant never showed measurable concentrations, yet one sample from the storage reservoir showed 1.6 µg/ℓ of 2,4,5-T. This number is not only much higher than any of the other concentrations from the reservoirs, but also reverses the trend for the 2,4-D concentrations to be greater than those for 2,4,5-T.

Data gathered by Battelle during the baseline monitoring period from July 24 to July 27 shows 100 percent of all samples analyzed below the quantitative detection limit of 0.2 µg/ℓ (ppb) (Table 4).

It can therefore be concluded that the water environment at Johnston Island has in the past been affected by the storage of Orange Herbicide, but that, immediately prior to the dedrum/transfer operation, the water showed no serious degradation in quality from the herbicide.



Water Sampling Sites - (WD,WS,WF,WO, P,SE)

Sediment Sampling Sites

Analytical Building

Red Hat Area

Johnston Island Crew Facilities

Wharf

Dedrum Area

FIGURE 7. WATER AND SEDIMENT SITES

TABLE 4. OPERATION PACER HO DATA SUMMARY-WATER

PRE-OPERATIONAL

Location	No. Samples	Maximum in PPB D	Maximum in PPB T	Minimum in PPB D	Minimum in PPB T	Positive Average in PPB D	Positive Average in PPB T	Percent Positive D	Percent Positive T	Percent Trace D	Percent Trace T	Percent N.D. D	Percent N.D. T
WS saltwater intake	4	<.1	<.1	<.1	<.1	--	--	0	0	0	0	100	100
WF wharf	4	<.1	<.1	<.1	<.1	--	--	0	0	0	0	100	100
WO wastewater outfall	3	<.1	<.1	<.1	<.1	--	--	0	0	0	0	100	100
WD downwind dedrum	1	<.1	T	<.1	T	--	--	0	0	0	100	100	0
P1&P2 potable water	3	T	T	<.1	<.1	--	--	0	0	33	67	67	33
SE1&SE2 sewage	1	<.1	<.1	<.1	<.1	--	--	0	0	0	0	100	100
RW rainwater	0	--		--		--	--	--	--	--	--	--	--

3147

Other environmental indicators measured were temperature and dissolved oxygen. The mean monthly water temperature for Johnston Island for July and August is 26.4° C.[11,12] The water temperatures measured by BCL during the baseline period were 26.8° C at the wharf, 26.1° C at the saltwater intake, and 26.4° C at the wastewater outfall. Dissolved oxygen concentrations at all the offshore sites were near saturation for an assumed chloride concentration of 15 ppT (parts per thousand). No values below the water quality criterion of 5 mg/ℓ were observed. Dissolved oxygen concentrations were lower in both the potable water and sewage samples as expected. Potable water composite samples showed mean oxygen concentrations of 6.0 ± 0.3 mgO_2/ℓ or 81 percent of saturation at 32° C. Sewage samples were nearly anaerobic measuring only 1.1 ± 0.2 mg/ℓ of oxygen at a temperature of 32.5° C.

No acute adverse environmental effects in existing water quality were noted during the baseline monitoring.

2.1.4 Groundwater Quality

On Tuesday, August 25, two days after the dedrumming operation was completed, a 6 in. water sampling well was found in the barrel storage yard (Plate 2). The exact location is shown on the engineering drawings of the island and has since been filled in with coral. The well casing terminated flush with or just below the ground surface possibly permitting surface water to flow into the well. Therefore, it was judged not to be a good site for groundwater sampling. A sample of the water was nonetheless examined by smell and found to have a distinct odor of HO indicative of contamination. The water table was measured at the hole and found to be 9 feet 3 inches below the ground surface. This measurement was taken near a period of low tide.

The Air Force has monitored contaminants in test wells, as documented below:

Historical Groundwater Data Summary

Location	TCDD Detection Limit (PPT)	Analyses Results
Well hole-center of herbicide area	0.37	ND
Well hole-west side of herbicide area	0.24	ND

Location	Analyses Results, ng/ℓ 2,4-D Ester 200*	2,4-D Acid 100*	2,4,5-T Ester 50*	2,4,5-T Acid 20*
Well hole-center of herbicide area	ND	44,000	ND	1,200
Well hole-west side of herbicide area	ND	77,000	ND	3,600

2.2 Biological Environmental Features of Johnston Atoll

2.2.1 Terrestrial Environment

The terrestrial environment of Johnston Atoll has been extensively studied.[1,2] As a result, much is known about the plants and animals which inhabit the four islands of the atoll.

2.2.1.1 Plants

To date, 51 families, 109 genera, and 127 species of vascular plants have been identified from the four islands of Johnston Atoll[1,2] Table III-5). This number of plants is remarkable in view of the fact that only three species existed in 1923. These three plant species are believed to have reached the atoll by natural means, either by water currents, air, or birds. The majority of the remaining 124 species have been introduced by man. Undoubtedly, some of these introductions were intentional, others came as stowaways or adventives.

* Detection Limits, ng/ℓ.

Materials from land clearing and dredging operations have increased the size of the two original islands and have made two new islands, thus bettering the opportunity for more plant species to become established. Disturbed soil coupled with the freedom from competition from established flora have created conditions suitable for the establishment of many plant species. Undoubtedly, because of the poor soil and climatic conditions, many of the ornamental species intentionally introduced by man would not survive if not frequently cared for.

Of the 38 species of vascular plants found on Akau Island a majority have been transplanted from Johnston Island. This man-made island was completed in 1964, and by September, 1967, 31 species were found there. Fimbristylis cymosa grew over most of the island and was the most predominant species. Other species which were common were Spergularis marina, Sesuvium portulacastrum, Eleusine indica, and Cynodon dactylon. A similar plant distribution was noted in November 1973.

To date, only 14 species of plants have been recorded from Hikina Island. The construction of this island was completed in 1964 and by September, 1967, five species of plants were found growing there. Only three of the five species were abundant, Fimbristylis cymosa, Sesuvium portulacastrum and Spergularis marina. Two additional species, Eleusine indica and Lepturus repens, were also present in 1969. The flora was found to be similar in 1973.

In 1923, only three plant species were known to be growing on Johnston Island. Early photographs of the island reveal that Lepturus repens was the dominant species. By 1967, 111 plant species were recorded from Johnston Island, many of which were under cultivation by residents. Major species were Pluchea carolenensis, Conchrus echinatus and Casuarina equisetifolia. There are 54 species of plants which have been recorded from Sand Island. Only three species (Lepturus repens, Boerhavia repens, and Tribulus cistoides) were known to the original portion of Sand Island in 1923. Lepturus repens was the dominant species. By 1967, the number of plant species known to the original portion of Sand Island had increased

 3150

to 25. At this time the five most common species were Lepturus repens, Tribulus cistoides, Sesuvium portulacastrum, Boerhavia repens and Amaranthus viridis.

The man-made portion of Sand Island was completed in 1941. By 1967, 50 plant species had been recorded as growing on this portion of the island. The most common were Fimbristylis, Conyze, Sanchus, Cenchrus, Pluchea, Cynodon, Sesuvium, Euphorbia, and Scaevola. A similar distribution was found in November, 1973.

2.2.1.2 Invertebrates

The terrestrial invertebrate fauna of Johnston Atoll is not well known. Insects are the only member of the invertebrate fauna which have been studied to any extent. Insects totaling 68 species of 35 families are known from the four islands of Johnston Atoll (Table III-16).

2.2.1.3 Vertebrates

a. Fish

There are no freshwater fishes which inhabit the islands of Johnston Atoll.

b. Reptiles

Four species of reptiles are known from the terrestrial environment of Johnston Atoll. These species are Hemidactylus frenatus (house gecko), Hemidactylus garnotti (fox gecko), Lepidodactylus lugubis (mourning gecko) and Ablepharus boutonii poecilopleurus (snake eyed skink).

c. Birds

There are 56 bird species which are known to the islands of Johnston Atoll (Table III-17), which constitute a national bird refuge. These species belong to 10 orders, 19 families, and 38 genera. Twenty-

two species are classed as sea birds and 34 species are waterfowl, marsh, and land birds.

Of the 22 sea bird species recorded at Johnston Atoll, 12 are breeders, 3 are former breeders, and 7 are visitors (Table III-18). All of the 12 resident breeding species also nest in the Hawaiian Islands and other parts of the tropical Pacific. The three species which formerly bred at Johnston Atoll are Diomedia nigripes (Black-footed Albatross), Diamedia immutabilis (Laysan Albatross), and Sula dactylatra (Blue-faced Booby). The seven sea bird visitors to Johnston Atoll came from the north, south, and east Pacific.

The 34 species of waterfowl, marsh, and land birds recorded at Johnston Atoll are divided into five groups: regular migrants consisting of seven species, irregular visitors consisting of six species, stragglers consisting of two species, accidentals consisting of 16 species, and introductions consisting of three species (Table III-18).

The annual breeding and bird population cycles vary greatly among the bird species at Johnston Atoll. The sea birds breed during all seasons of the year (Figure 8). Nine of the 12 presently breeding sea-bird species breed during the spring and summer seasons. Thus, May through September is the peak breeding period for the sea birds of Johnston Atoll.

Many of the bird species known to Johnston atoll leave during part of the year while others stay throughout the year. There is however, a population buildup for each species sometime during the year.

The breeding population of sea birds of the Atoll consists of 12 species. However, only five species are dominant in terms of total numbers (Figure 9). The Sooty Tern, with a mean population of 300,000 to 310,000 breeding birds during March, April, and May, makes up 95 percent or more of the total Atoll population between March and July. Possibly as many as 600,000 Sooty Terns used Johnston Atoll annually.

Red-footed Boobies, whose mean population ranges up to 3,750 birds, ranks second in sea bird numbers in winter and spring. Most of these birds are transients for only a few young are produced each year.

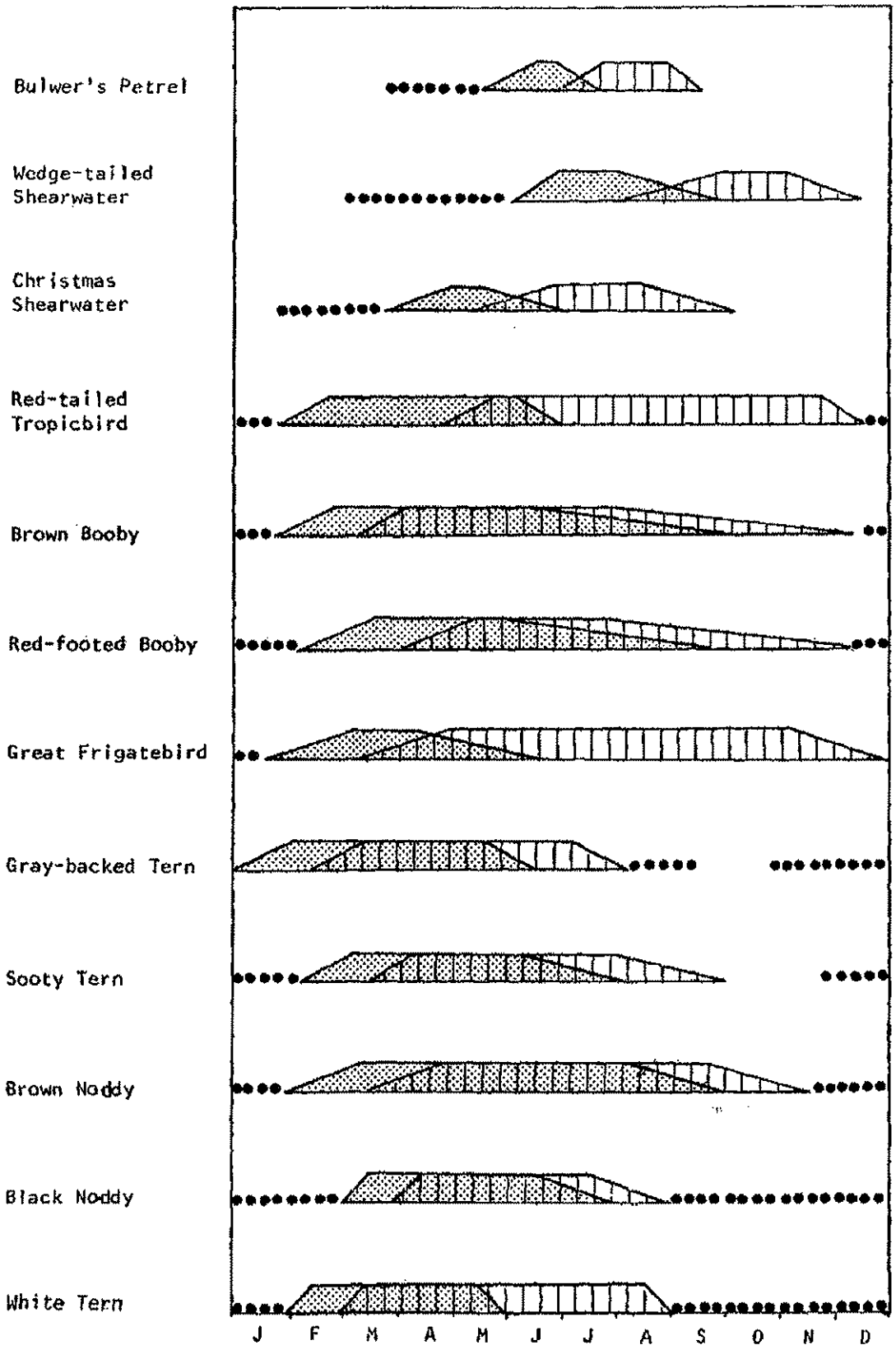


FIGURE 8. BREEDING CYCLES OF SEABIRDS AT JOHNSTON ATOLL: STIPPLED AREA REPRESENTS EGGS, BARRED AREA YOUNG, AND BLACK DOTS NONBREEDING BIRDS

2153

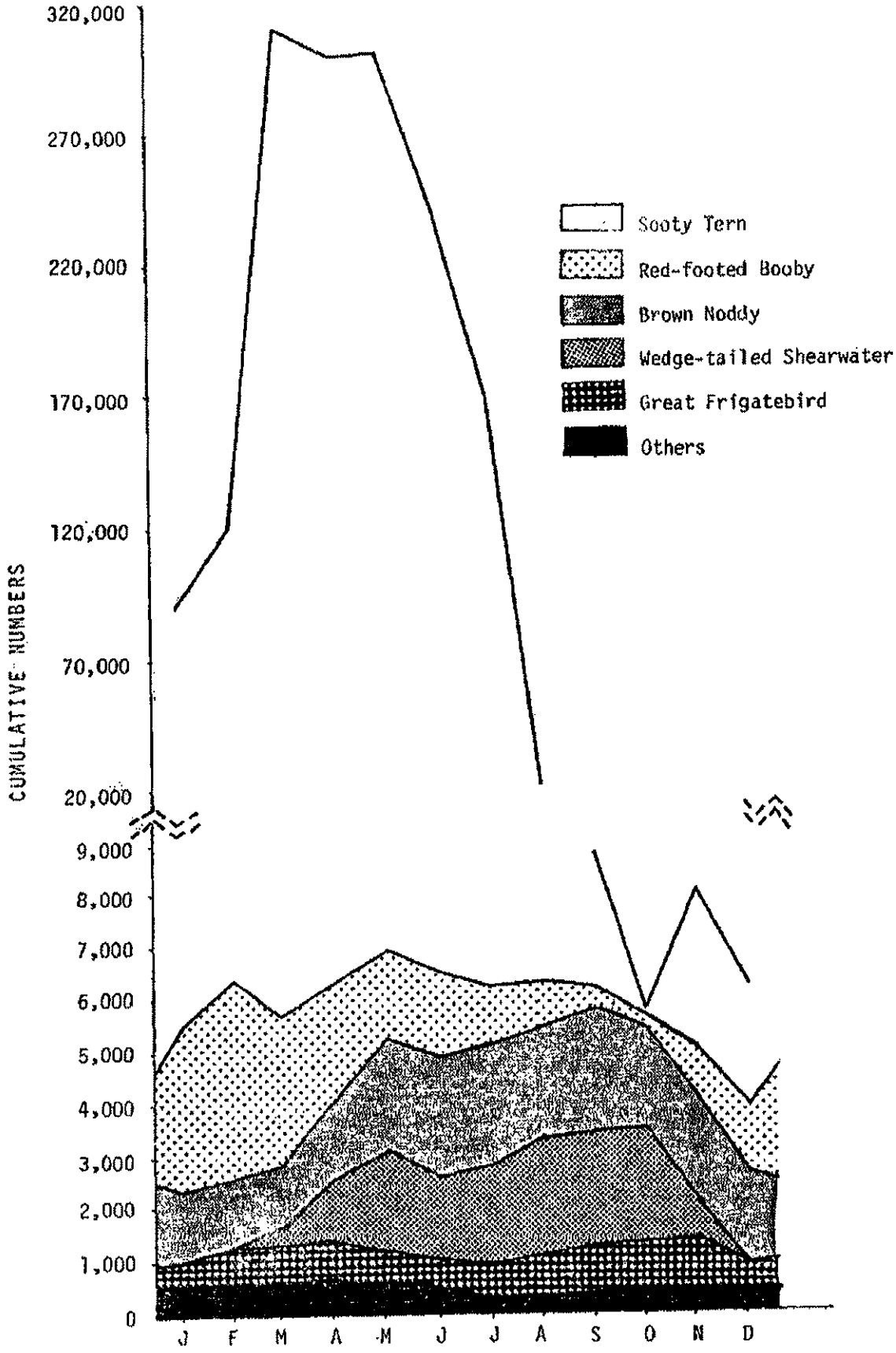


FIGURE 9. MONTHLY CUMULATIVE BIRD POPULATIONS, JOHNSTON ATOLL, 1963-1969

 3154

The Brown Noddy ranks third in mean population numbers. The Wedge-tailed Shearwater ranks fourth in numbers of adults using the Atoll but is present only from March to early December. The Great Frigatebird, with a main peak of 750 in March and April ranks fifth in population numbers. Mean monthly populations of all other species combined never totals more than 600 nor less than 300 birds.

Of the seven regular migrants, only the American Golden Plover, Wandering Tattler, and Ruddy Turnstone are known in all 12 months. Although the Wandering Tattler is present in low numbers throughout the year, American Golden Plovers and Ruddy Turnstones show peak populations of 120 and 100, respectively, in fall and mid-winter (Figure 10).

The four islands of Johnston Atoll vary with respect to size evaluation, soil, vegetation, and degree of human disturbance. Major differences exist in the ecological distribution of bird species between disturbed and non-disturbed islands. This is particularly true for the bird species which breed on the islands of the Atoll.

Fifty-two of the 56 bird species known to the Atoll are known to Sand Island. Of these 52 species, 44 are known from the original portion while 35 are known from the man-made part. Furthermore, 35 species are known from Johnston Island, while eight are from Akau Island and five are recorded from Hikina Island.

The bird populations of Akau, Kikina, and Johnston Islands are known to be small in comparison to that of Sand Island. The population cycles shown in Figure 8 are essentially those of the birds on Sand Island. During the spring and summer, Sooty Terns are most predominant species and nest on the bare ground over most of the island (Figure 11). The nesting areas for other species are shown in Figures 12 and 13. Brown Noddies nest on the ground around the perimeter of the island. Red-tailed Tropicbirds nest under low vegetation about the island. Wedge-tailed Shearwaters nest in burrows over much of the island. Brown Boobies nest on the ground on the southeast hill, the south edge, the northeast penninsula, and the southwest islet. Red-footed Boobies build their nests on the east hill, on the Tournefortia bush northeast of the transmitter buildings. Great Frigatebirds nest along the east hill and the south edge.

 2155

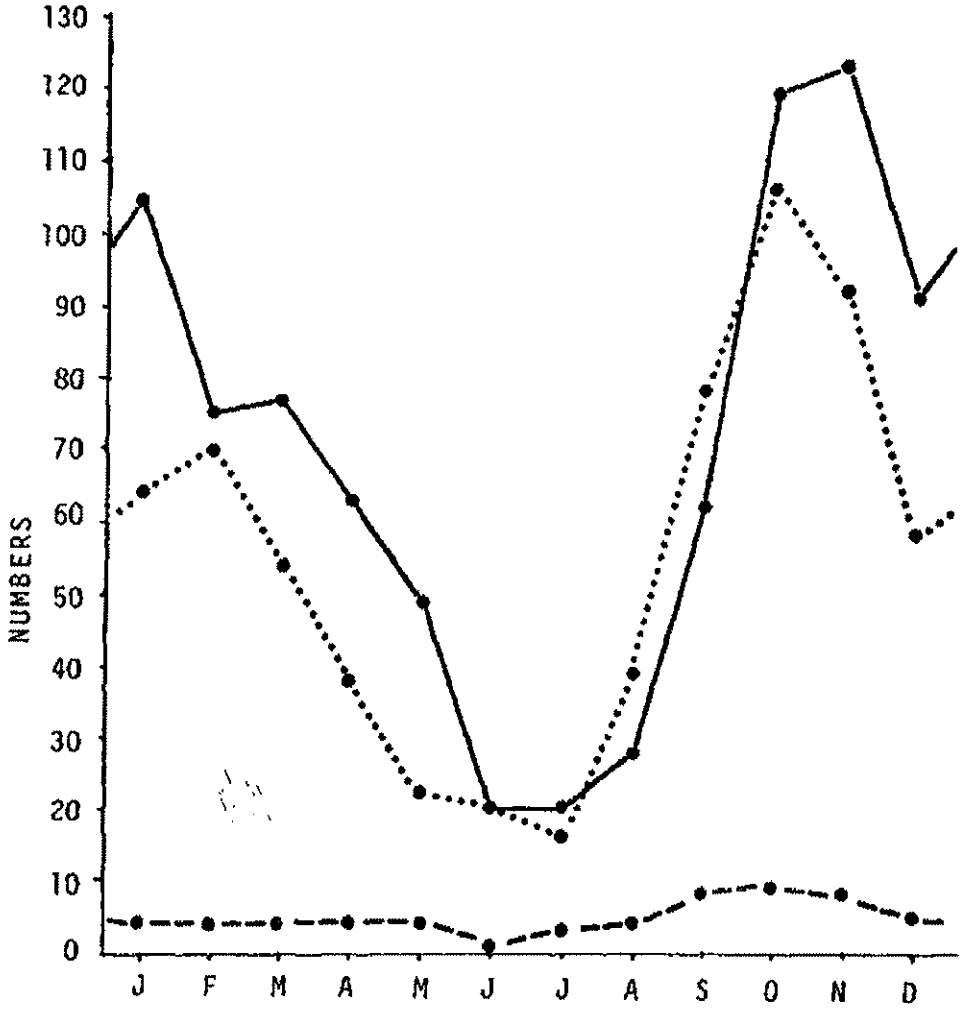


FIGURE 10. MONTHLY MEAN SHOREBIRD POPULATIONS FOR JOHNSTON ATOLL, 1963-1969; GOLDEN PLOVER (SOLID LINE), RUDDY TURNSTONE (DOTS), WANDERING TATTLER (DASHES)

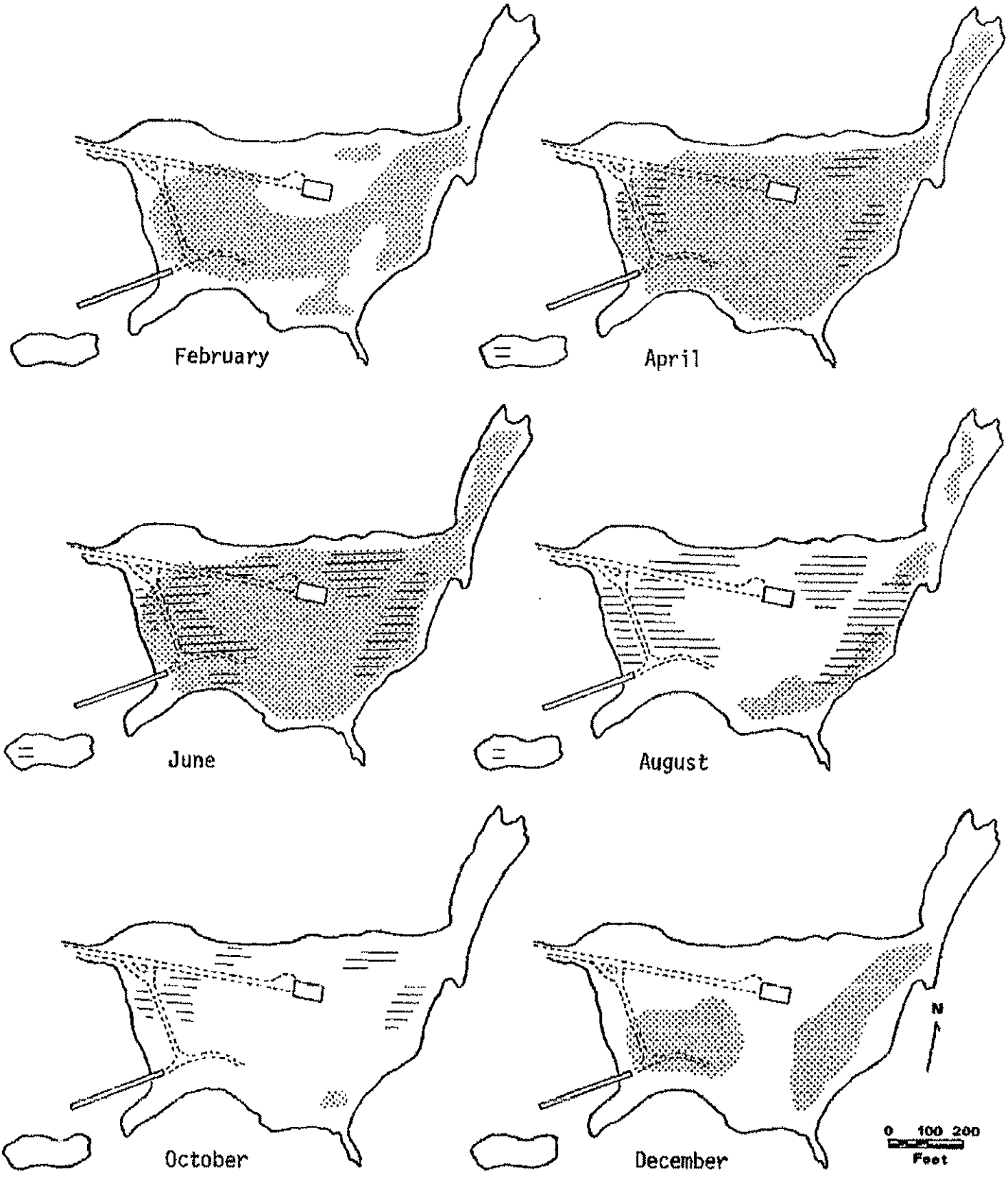


FIGURE 11. AREAS USED BY SOOTY TERNS (STIPPLED) AND WEDGE-TAILED SHEARWATERS (BARRED) ON SAND ISLAND, JOHNSTON ATOLL, 1965

 2152

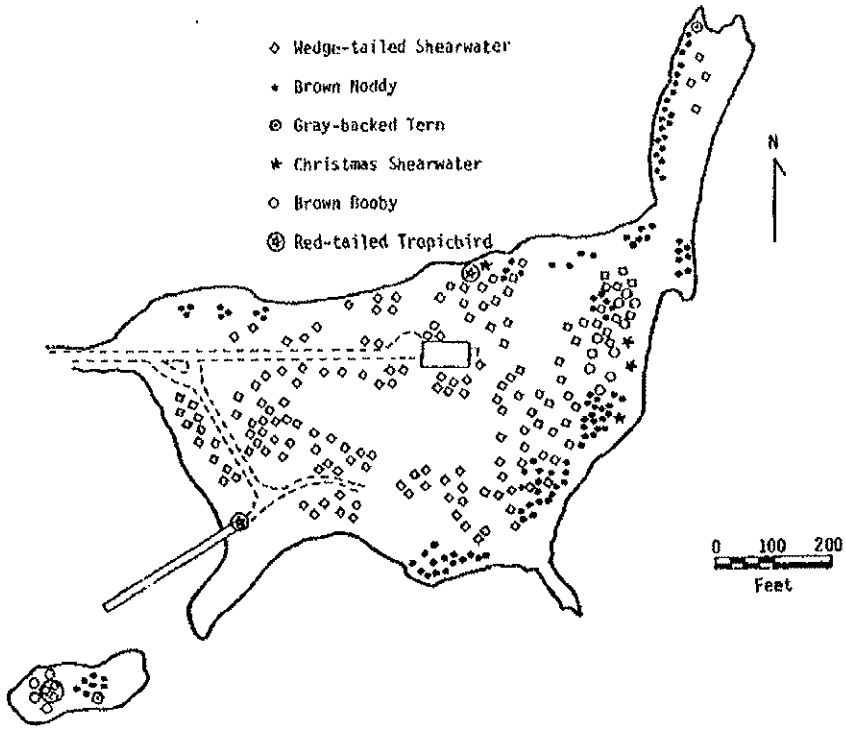


FIGURE 12. NESTING AREAS OF GROUND NESTING BIRDS (EXCEPT SCOTTY TERMS) ON THE ORIGINAL PORTION OF SAND ISLAND, JOHNSTON ATOLL, 1963

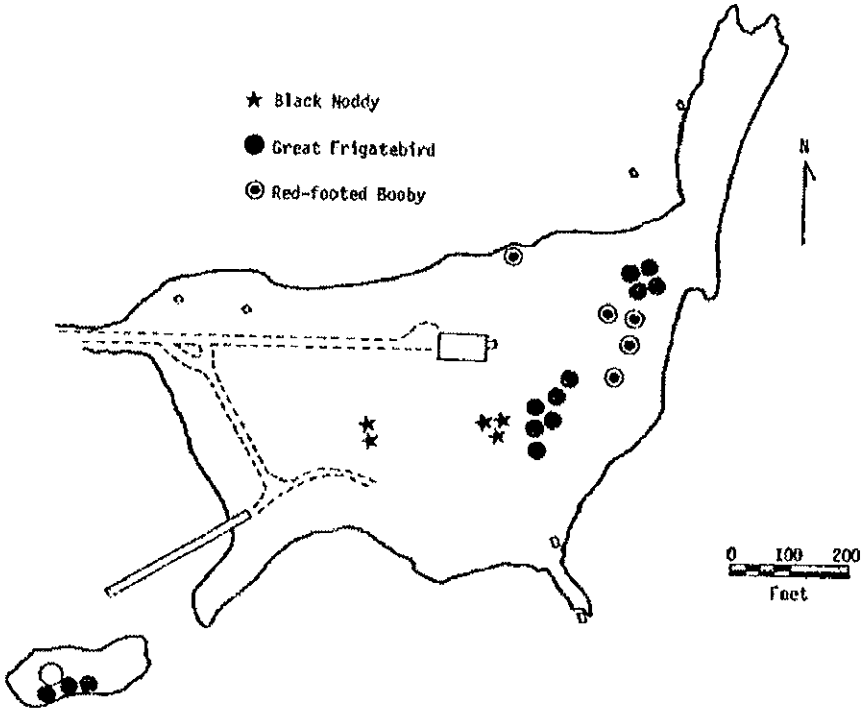


FIGURE 13. NESTING AREAS OF BIRDS WHICH NORMALLY NEST IN LOW VEGETATION ON THE ORIGINAL PORTION OF SAND ISLAND, JOHNSTON ATOLL, 1963

Mortality in the bird population of Sand Island has been studied. The main cause of mortality was birds flying into the guywire system of the LORAN-C antenna. This system contained 24 top-loaded guywires which stretched from the top of the 625 foot tower to concrete pillars located in the lagoon in a circle around the island. There also were three sets of guywires stretched from part way up the tower to two sets of concrete anchors located on or near the periphery of the island.

d. Mammals

There are no mammals native to Johnston Atoll. With the exception of human occupants, five species of mammals are known from the terrestrial and one species from the marine environment of the Atoll (Table III-19). It is likely that the two rodents arrived in ship or plane cargoes, while dogs, cats, and rabbits were purposely introduced by military and civilian personnel.

2.2.2 Marine Environment

The marine environment of Johnston Atoll has been studied to a considerable extent. It has been heavily disturbed by man during dredging operations associated with the deepening and lengthing of the ship channel and seaplane landing area.

2.2.2.1 Plants

Prior to the dredging operations of 1964 only one marine algal species was known to Johnston Atoll. In 1965, as part of a study of the effects of dredging on the marine environment, 67 species of benthic marine algae were collected from Johnston Atoll. Additional collections in 1966 added 26 more species to the known species list. In all, 93 species of benthic marine algae are known from the waters of Johnston Atoll. Of the

93 species, 12 were found only from the marginal reef, while 33 were found only in the lagoon waters (Table III-20). Of these 33 lagoon species, 11 occurred only in open water, 11 were found only in the inshore area of Johnston Island, and 2 were taken from the inshore area of Sand Island.

2.2.2.2 Invertebrates

The invertebrate fauna of Johnston Atoll is not well known. Several scattered collections have been made but no extensive systematic sampling programs have been conducted.

There are 18 species belonging to 11 genera of Cnidaria (hydras, jellyfish, sea anemones, and corals) which are known to Johnston Atoll (Table III-21). Fifty-eight species of Mollusca have been collected from the Atoll (Table III-22). To date, only 12 species of Annelida belonging to 8 families are known from the lagoon waters. These are listed in Table III-23. A total of 75 species belonging to 20 families of Crustacea have been recorded from the lagoon waters at Johnston Atoll (Table III-24).

2.2.2.3 Vertebrates

The marine vertebrates of Johnston Atoll are well known. Fish species have been studied most extensively and are separated into two categories: pelagic fishes and inshore fishes.

a. Fish

Numerous large pelacic fishes have been recorded around Johnston Atoll. Although no extensive species list exists for this area, various species of tuna, sharks, and barracuda are known to occur in the waters around the Atoll.

To date, a total of 194 species of inshore fishes have been recorded from the waters of Johnston Atoll (Table III-25). A majority of these species have also been found in the fish fauna of the Hawaiian

Islands. Only two of the 197 species have not been recorded elsewhere. These are Centropyge nigriocellus and Centropyge flammeus, neither of which is abundant at Johnston Atoll.

b. Mammals

The Hawaiian Monk Seal is the only mammal recorded from the marine environment of Johnston Atoll. These are known to have arrived from the resident population of the northwestern Hawaiian Islands. It is also likely that porpoises visit the Atoll's lagoon waters, although an official record has not been made.

2.3 Human Environment

2.3.1 Economic and Social

There is no indigenous population on Johnston Atoll. Rather, the population is transient representing 4 agencies; namely

(1) The Air Force, who administer the island.

(2) The Army, whose "Red Hats" guard and maintain a munitions storage area.

(3) The Coast Guard, who maintains the LORAN equipment on Sand Island.

(4) [redacted] and [redacted] Inc., staff, who perform island maintenance, food, laundry, medical etc. services.

There is not a local economy, all goods and services being provided by these agencies.

The island personnel live in a cooperative atmosphere with very little violence or crime. People who do not abide by the established standards of behavior are rapidly and permanently transferred from the island.

3. DESCRIPTION OF ORANGE HERBICIDE DISPOSAL PROGRAM

3.1 Purpose

Following the decision by the Secretaries of HEW, Agriculture, and Interior in 1970 to suspend some uses of 2,4,5-T, the Air Force conducted an environmental impact study to determine the most ecologically sound method to dispose of the 2.4 million gallons of Orange Herbicide stored on Johnston Island and at the Naval Construction Batallion Center, Gulfport, Mississippi. The approved alternative for accomplishing this objective was the dedrumming of the herbicide at Gulfport and on Johnston Island and the transferal of the TCDD-contaminated material to the Dutch-owned incinerator ship, M/V Vulcanus, for thermal destruction. The operational plan and subsequent activities discussed in this report represent the Air Force's efforts to implement the recommendations contained in the final environmental statement, and to comply with the provisions of EPA permits.(16)

3.2 Operational Procedures

3.2.1 Physical Manipulations

Physical manipulations as discussed include only those portions of the overall operation plan which specifically had implications for causing environmental degradation of the island or its immediate offshore area.

3.2.1.1 Drum Handling-Dedrumming

The 1.5 million gallons of Orange Herbicide stored on Johnston Island represented approximately 25,000 drums of 55-gallon capacity. These were stored in rows stacked three high in an area of about 3.5 acres on the northwest corner

of the island. A dedrum facility was modified* to allow transfer of the material from drums to bulk carriers for transport to the ship. The facility and operation basically consisted of a covered concrete pad and two fabricated metal racks upon which full drums were placed in four groups for 12 each. Drums were transported from the drum yard in sets of four using fork lifts equipped with specially designed clamps. Each set of 12 drums was handled independently by the dedrumming crew. Once the drums were on the rack and the fork lift had withdrawn, a crew member would punch one hole near the top of each drum to allow the crew's supervisory personnel to check the contents of the drum for Orange Herbicide.** Any suspicious looking drums were removed from the line and held for further testing prior to loading. Three closely spaced holes were then punched in the bottom of each drum and the fluid allowed to drain. A set drain period of 5 minutes was determined in prior testing to give the most rapid throughput of drums and still achieve good drainage.

Following the 5-minute drain, the inside of each of the drums was rinsed with 1 gallon of diesel fuel using a spray wand. Operators were instructed on the proper technique to cover the entire drum interior. After draining for 2 minutes, a second one-gallon spray rinse was initiated and 2 minutes allowed for draining herbicide and rinse drained into a trough which flowed into a sump equipped with pumps to transfer the material to a tank truck.

Quality control procedures were carried on through the entire operation. In addition to the testing of contents mentioned previously, samples of the second rinseate were obtained from about every hundredth drum. A total of 219 such samples were taken. A target value of the sum of the concentrations of 2,4-D and 2,4,5-T was derived from test rinses conducted by the Air Force at the Naval Construction Battalion Center, Gulfport,

---

* The facility had originally been installed for redrumming of leaking drums.

** Drums containing material other than HO were taken off the rack and sealed for future disposal action. Only HO was allowed to drain. As the EIS and permits were only for the destruction of HO, other chemicals could not be allowed to mix with the HO in the sump. Each barrel was examined by pipetting a sample prior to drainage. Visual and olfactory examinations were used to verify contents as being HO.

Mississippi. The level of rinse achieved was to be equivalent to the Environmental Protection Agency triple rinse procedure.[16] Recommendations on the Johnston Island drum rinse procedure were made by Battelle-Columbus Laboratories based on the results of these studies:

- Five spray rinse studies showed that the first rinse efficiency averaged 68 percent removal (range from 64 to 74 percent) while second rinses averaged 69 percent removal (range from 62 to 79 percent). As an approximation, the first and second rinses yielded the same efficiency of 68 percent removal.
- Thirty-five drainage studies showed that, on the average, total mass of 2,4-D and 2,4,5-T remaining in a drum after being allowed to drain for 5 minutes is 261.29 grams with a standard deviation of 139.73 grams.
- The herbicide mass removed in the second rinse was shown to be proportional to the first rinse residual. Increased draintime decreases residual and, hence, second rinse herbicide mass. Increased wash efficiencies on the first rinse also cause a decrease in the second rinse mass.
- Using 68 percent rinse efficiency, and the distribution of residuals from the drainage studies, it can be shown that 50.6 grams of herbicide in the second rinse represents 85 percent removal with 99 percent confidence bounds. Likewise, 46.1 grams represents 90 percent removal.
- Assuming the rinse volumes are exactly 1 gallon (3.785 liters), the sum of the concentrations of 2,4-D and 2,4,5-T for 85 and 90 percent removals (99 percent confidence) are, respectively, 13.36 mg/ml and 12.18 mg/ml in the second rinse. Nominal values will be at 56.4 grams or 14.9 mg/ml (for population mean, nominal 90 percent removal). Because of the overlap, a 68 percent confidence bound was suggested. Accordingly, the 85 percent removal for these upper and lower bounds requires maximum second rinse concentration of 15.30 mg/ml (Figure 14).

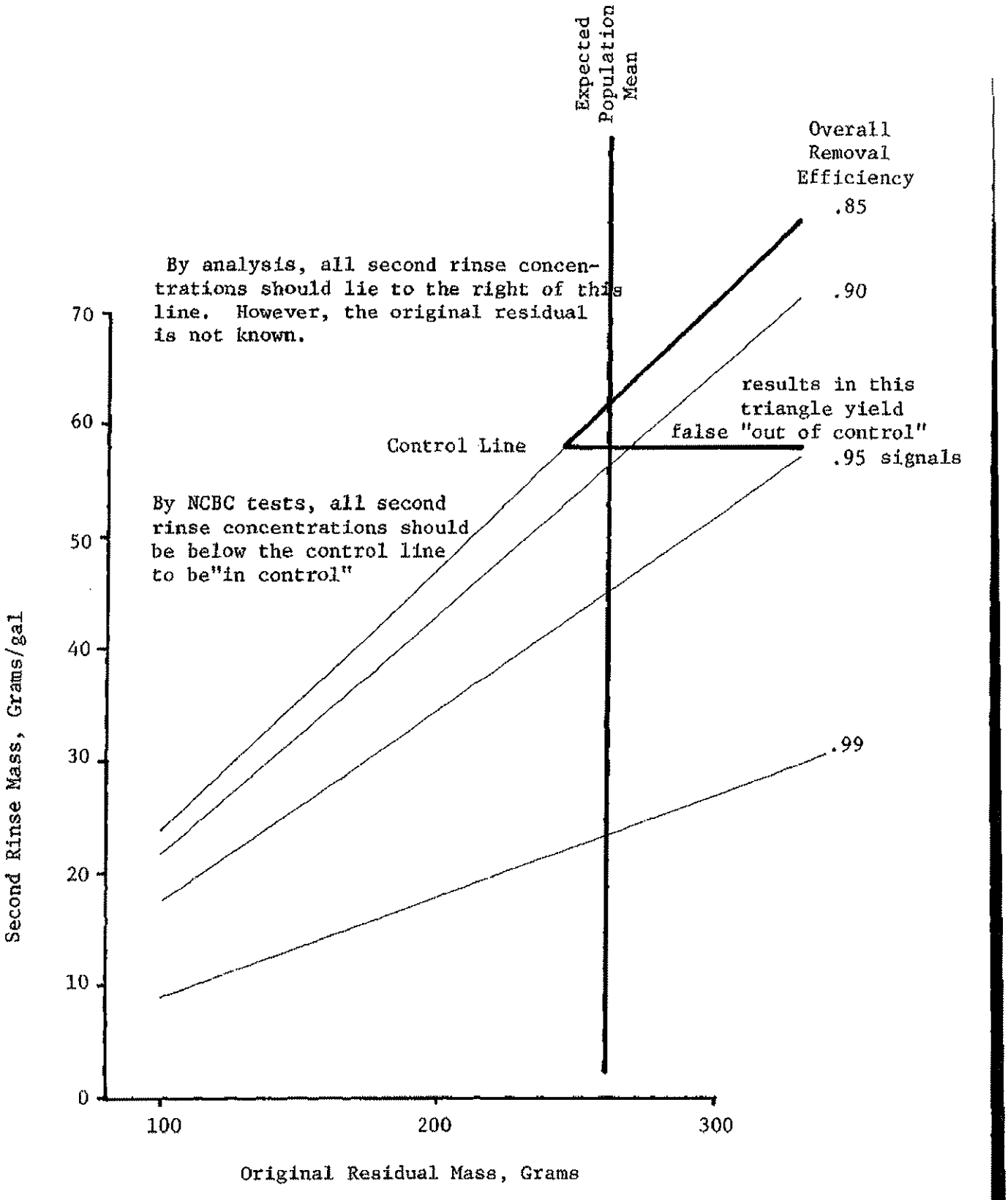


FIGURE 14. STATISTICAL DISTRIBUTION OF SECOND DRUM RINSE MASS

2/65

- Because of randomness in the original residual mass, the proposed quality control line is only one-half standard deviation from the expected value for the residual mass of any given drum. Thus, 34 percent of the individual sample results will appear to be out-of-control if plotted. Accordingly, a more accurate trend line can be constructed if only the average concentration of every five samples and the total running averages are plotted.

Figure 15 shows the results of the drum rinsing for all data obtained. Occasionally a series of samples would show a very high average and move the running average up toward the control line. This problem was encountered early in the program and again during the second loading operation. The operation was analyzed following the first loading to determine why the quality control program showed this behavior.

During the first half of Operation Pacer HO, 121 drum rinse samples were analyzed. The overall average concentration for these samples was 17.33 mg/ml of second rinse or 65.5 g/gal. To have achieved the required control level, the concentrations should not have exceeded 14.90 mg/ml.

It was noted during Battelle's observation of the dedrum operation that the pipet used to obtain drum rinse samples was often placed in close proximity to the pipet used to check the drums for suspicious material, inviting a mix-up. The effect that this would have on the rinse quality control would be to have one sample be very high and successive samples be diluted in proportion to the original contamination and the actual rinse efficience. Other possible reasons for the extremely high values observed, none of which have any bearing on the actual rinse efficiency achieved, are an unrepresentative sample of drum rinse or an accidental first rinse sample. The first is caused by a delay in taking the sample and results in a sample which has separated into its component phases. Since the HO is much more dense than either water or diesel fuel, a sample obtained from the bottom of the container would have exhibited a much higher concentration of herbicide than a well mixed sample. The second, although not directly observed, could easily have occurred during an operation of this nature.

2166

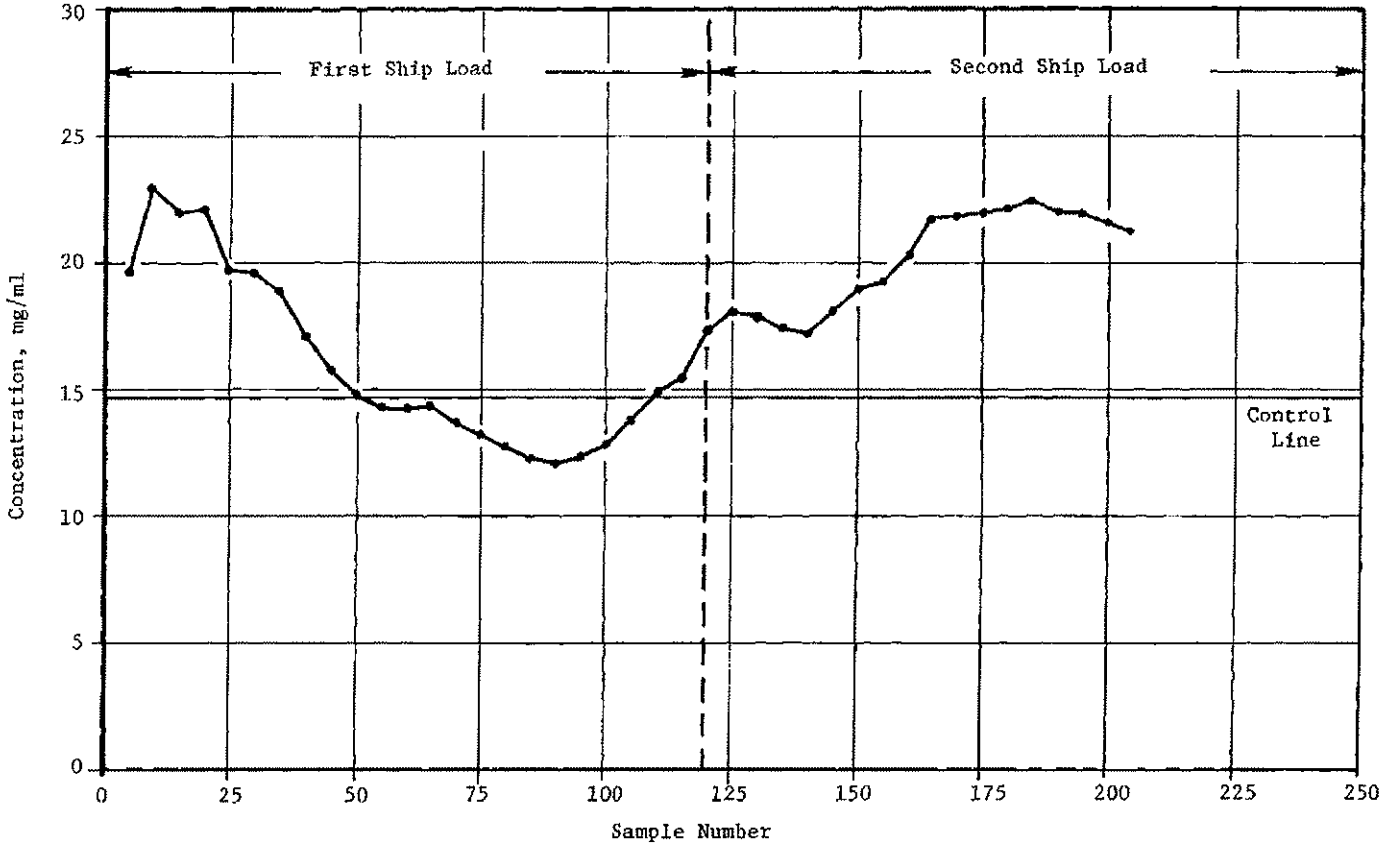


FIGURE 15. DRUM RINSE--QUALITY CONTROL CHART, RUNNING AVERAGES (ALL DATA)*

* Assuming N.D. (<1 mg/ml) = 1.0 mg/ml

Since it could not be determined which of the samples was affected, a statistical review of the rinse procedure was used to determine an upper bound for contaminated or otherwise biased samples.

At a nominal residual of 261 grams and a 69 percent efficiency for the first and second rinses, the concentration in the first rinse would be 47.57 mg/ml and in the second 14.77 mg/ml. Furthermore, for the standard deviation of 139 grams, one percent of the drums would be expected to show as much as 678 grams of residual. With "worst case" assumptions of a 64 percent first rinse and 79 percent second rinse, the expected second rinse concentration for one percent of the population is 50.94 mg/ml.

It was expected that, on the basis of the statistics, one percent of the drums sampled would have shown a true second rinse concentration of greater than 60 mg/ml. These could not legitimately be rejected as outliers. At the same time, the nominal first rinse concentration was about 48 mg/ml. If an accidental first rinse sample were included, its concentration would have been about the same as the "worst case" residual described above. A first rinse sample should be rejected. A compromise between the errors involved in including a first rinse sample as an estimator of second rinse efficiency and of rejecting a true second rinse which falls on the "tail" of the sampling distribution was needed. It seemed reasonable, therefore, to reject as outliers all samples showing second rinse concentrations in excess of 47.0 mg/ml. A total of nine samples were rejected during the first loading period and 14 during the second loading period. The resulting running averages are shown in Figure 16 and are seen to comply with control conditons.

Suggested improvements to the drum rinse quality control program were as follows:

- Control of the drum rinse sampling pipet should be by the person who counts drums. He should also be responsible for selecting the drum to be sampled so as to assure that one station is not biasing the sample.
- As the drum is sampled, he or another man should make sure that a second rinse sample is being taken and not a first rinse. It may be that in the confusion of the operation mistakes are being made.

3168

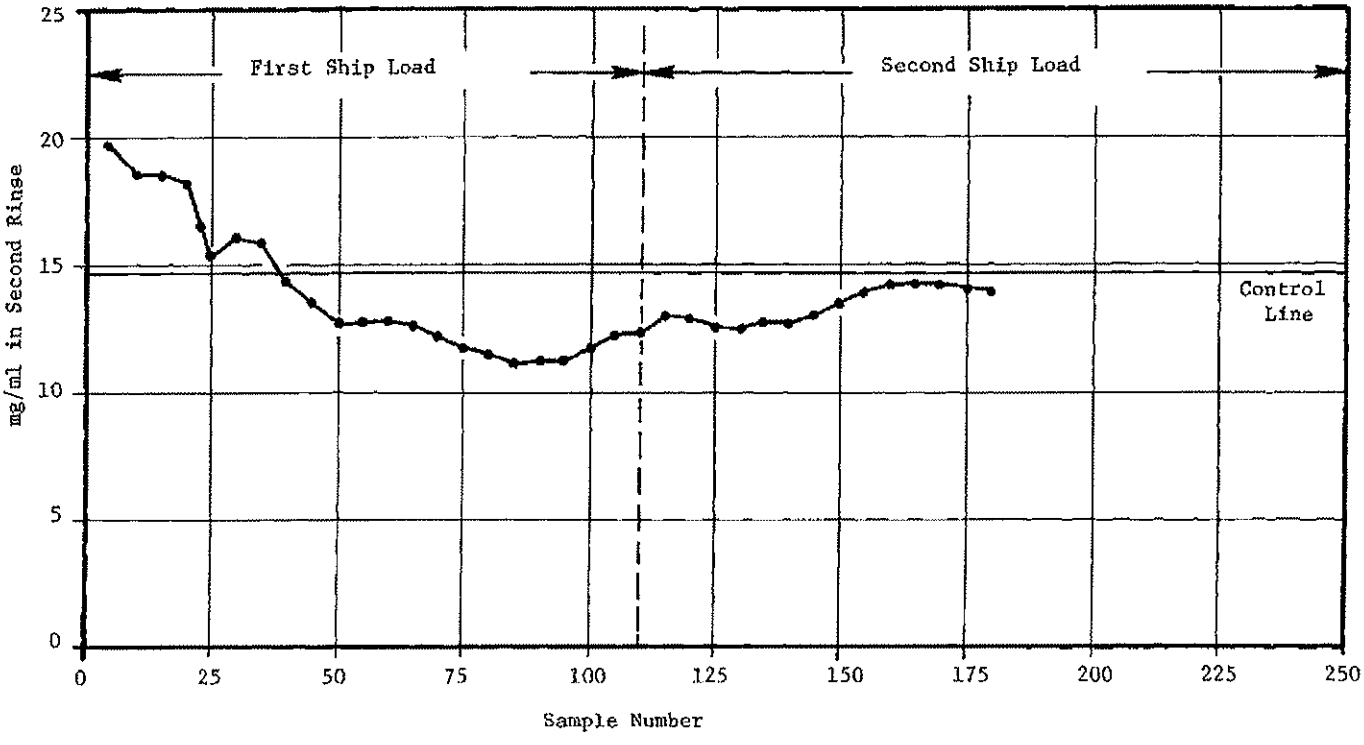


FIGURE 16. DRUM RINSE--QUALITY CONTROL CHART, RUNNING AVERAGES
(47 mg/ml cutoff on high end = 179 g/gal)

- The sample container should be stirred with the pipet before sampling to obtain a more homogeneous sample.
- The pipet should be specially marked with paint or other easily seen and indelible marker.
- The location of the sampling pipet should also be marked to avoid cross contamination with drum-test pipets. These should not be kept near the sample pipet.
- The sample should be drawn using the index finger rather than the thumb. This will maintain better control and permit faster sampling, thus, minimizing the possibility of inhomogeneity.
- The drum selected for the rinse sample should have only one drain hole punched in it. This facilitates the capture of the rinse in the gallon can.
- The drum counter is also responsible for assuring that the drum drains for exactly 5 minutes prior to the first rinse.

A second category of special drum rinse samples consisting of a set of four run in duplicate was used to verify that the concentrations of HO in 3,300 previously emptied drums was below the control line using only a single rinse. The material in these drums had been subjected to weathering for a period of from two weeks to over six years. The mean concentration using one gallon rinse was 3.56 mg/ml (13.5 g/gal) with a standard deviation of 3.21. Thus, there is negligible probability that the observed values do not meet the EPA triple rinse criterion. The Air Force's decision was to forego further quality control testing on the remaining emptied and weathered drums and to provide a single one gallon rinse to these drums.

After the second rinse had been allowed to drain for two minutes, the drums were removed from the racks by rolling them the northwest corner of the dedrum facility. Fork lifts with a ramp attached to the forks were used to transport the empty drums to the crusher.

3.2.1.2 Drum Crushing

The fork lifts transported six drums per trip to the crusher feed ramp. Drums were fed to the crusher one at a time. The crusher consisted of a large weight suspended between two I-beams. The drums were compressed along the longitudinal axis. There were no spray shields around the crusher to trap the mist of oils and residual HO which was released on impact (Plate 3). Several times the crushing operation fell behind the dedrumming operation and the empty drums were stacked up on the ground around the crusher.

Crushed drums were bundled and placed in storage on the seaward (downwind) side of the dedrum/crushing area. A large plastic sheet was used to protect the crushed drums from rain.

3.2.1.3 Transport of HO to Disposal Ship

Herbicide was pumped from the collection sump into standard Air Force R-5* refueling trucks (Plate 4) via a dry coupler bottom connection. Because of the difference in density between the HO and JP-4, the R-5's were only filled with 3,000 gallons of HO versus a 5,000 gallon capacity. During the filling operation, a drip pan under the coupler was used to prevent any herbicide from contaminating the loading pad. When disconnection took place, a few drops at most were observed to be discharged into the pan.

The refuelers transported the HO to the wharf via a road which was set aside for this purpose. Non-project related vehicles were forbidden traffic along this section of roadway.

3.2.1.4 Transfer to Disposal Ship

Once the refueler had reached the main wharf, the procedure was essentially reversed. The same type of dry couplings and spill prevention equipment were employed to pump out the tank and bulk transfer the material

---

* The pumps on the R-5 were bypassed to prevent their contamination and seal destruction by HO.

to the ship. The area in which the pumps and hoses were located was diked with sand bags and plastic so that as much as a full truck load of spilled material could be contained (Plate 5). All hose-to-hose couplings were similarly wrapped in plastic to catch any herbicide.

Under normal conditions, an R-5 could be emptied in about 20 minutes with another arriving to replace it just about the time it became empty. The only problems noted in this operation were the clogging of screens used to trap sludge particles, and the formation of a flow retarding vortex in the R-5's.

3.2.1.5 Cleanup

After the last HO had been transferred, all of the equipment, trucks, etc., were rinsed and decontaminated with diesel fuel which in turn was transferred to the ship.

3.2.2 Descriptions of Project Activities

This section provides, in outline form, all environmentally relevant project related activities contained in the official memos for the record or in BCL project records.

- July 23-- All personnel involved in the project were briefed by the Project Director on matters of spill prevention, countermeasures in case of spills and personal safety. Contingency equipment was inspected and positioned.
- July 23-24--BCL task leaders held discussions with corresponding Air Force officers regarding placement and start-up of land-based environmental monitoring (see Section 3.2.3).
- July 24--First day of baseline environmental monitoring.
- July 25--M/V Vulcanus arrived at approximately 1500 hours.
- July 26--Training operations for dedrum crew began at 1300 hours. Three drums were taken through procedure on day shift and three on night shift.
- July 27--Full-scale loading operations commenced at approximately 1500 hours. Several small leaks in R-5 were noted and corrected.

One badly leaking drum was located and removed to the dedrum rack. Clean-up was instituted. An estimated 25-30 gallons were spilled onto the coral storage area.

- July 28--A very small (<1 gallon) spill on the wharf was noted. No water contamination was observed and spill clean-up was accomplished.
- July 30-- During deballasting, an orange colored plume was observed on the port side of the M/V Vulcanus from 1100 hours to 1800 hours. Black oily trailings were visible in several places. Samples were taken at 1100 hours near the discharge of the deballast pump at a depth of 1 meter below the surface.
- July 31--Air Force was informed of preliminary air and water sampling results.
- August 1--The Air Force was advised on the trend of the drum rinse quality control results up toward the control line. Results of previous day's deballast water sample submitted to Air Force.
- August 2--EPA decision to require one tank filled with pure herbicide will result in 600-650 empty drums that have not been rinsed being temporarily stored near the dedrum facility. It was recommended that plastic be spread on the ground to prevent any spillage. Dedrumming resumed at 1900 hours after 24-hour hiatus.
- August 4--Drum rinse sampling procedure changed to obtain samples from all stations uniformly. Personal samples from pump operator inside dedrum facility eliminated because of low concentrations measured.
- August 5--Dedrumming completed 2100 hours. Land-based monitoring schedule for interim period submitted to TRCO. Improved procedures for sampling of drum rinse were suggested by BCL and accepted by the Air Force.

- August 6--M/V Vulcanus departed 0830 hours. Dedrum crew began rinsing and crushing 648 drums from temporary storage.
- August 11--All drums have been rinsed and crushed. Lab work load adjustments discussed with TRCO to permit analysis of wipe samples from ship at close of program.
- August 15--Results of first load lab analyses submitted by BCL to Air Force. Drum rinse quality control program improvements were brought up again. In the course of conducting tomato plant bio-assay studies, it was found that the plants uniformly were wilting due to the extreme evapotranspiration. The problem occurred because the pots, as provided, were too small and the peat potting medium lacked the necessary water holding capacity.
- August 16--Suitable volcanic mineral soil was added to the potting medium. The surface of the soil was covered with aluminum sheets to reduce evaporation. The plant wilting was eliminated. The previously damaged plants were replaced.
- August 17--All air, water, and biological observation schedules were reinstated. Drum rinse sampling monitoring was initiated preparatory to the second burn. Tomato plants downwind of the dedrumming facility continued to be affected by the herbicide. It was suspected that the vaporization of the HO from rows of crushed drums compounded this phenomenon. The bed of the truck used to haul tomato plants and equipment was found to be contaminated with HO. The bed was replaced immediately with clean materials. The loading of M/V Vulcanus began at 1300 hours. Continual spill reconnaissance was initiated.
- August 18--The industrial hygiene consultant notified the Air Force that some civilians were smoking adjacent to loaded R-5 refuelers. The operations officers were notified that no smoking materials or food should be taken into the dedrumming facility. Appropriate actions were taken to prevent future occurrences.

3174

- August 19--A brownish plume was observed and photographed, as the M/V Vulcanus was pumping ballast while berthed at the wharf. A grab water sample was taken near the stern of the ship. Dedrumming and ship loading was suspended at 0600 hours. No marine ecology impacts were observed. Fish were noted swimming in the area of the deballast plume. The potable water intake was closed during the deballasting operations.
- August 20--Slight water discolaration still existed between the M/V Vulcanus and the wharf.
- August 21--Battell's analytical laboratory reported that the deballast sample results had several peaks and without further dilution studies, they reported that they could not state the levels of 2,4,5-T or 2,4-D in the grab sample. Dilution studies and a rerun of the sample was requested.
- August 22--Deballast results were submitted to the Air Force.
- August 24--A ground water sample taken from a bore hole in the barrel yard storage area smelled strongly of herbicide orange. It was highly probable, due to the lack of a berm, that the surface contamination entered the bore hole or observation well. The post-operational monitoring program was begun.
- August 27--Numerous bird species were observed and surveyed on Akau, Hikina, and Sand Islands of the Johnston Atoll. (All were in apparent good health except birds with broken wings that had flown into antenna guywires.) Abundance and type of fish species were noted in the wharf area. No marine ecological stress was evident.
- August 28--Plant species on Johnston Island were surveyed. There was no evidence of native plants being affected by the Orange Herbicide disposal operations. This was the last day of post-operationsl monitoring.

3.2.3 Physical Monitoring Sampling Protocol

3.2.3.1 Chemical Sampling

a. Air

(1) Equipment and Procedures. In order to assess the impact on the air environment due to the possible presence of the N-butyl esters of 2,4-D and 2,4,5-T and the dioxin, TCDD, two methods were employed.

Air sampling for 2,4-D and 2,4.5-T was accomplished utilizing Chromosorb 102 as an adsorption medium, a granular polymer well suited for collection of chlorinated hydrocarbons. This material was packed in micropipet tubes which were then wrapped in aluminum foil and stored in rubber stoppered test tubes (Plate 6). In order to sample a volume of air of about 150 liters, a flow rate of 0.50 liters/minute for a period of about five hours was required. A good adsorption efficiency could be obtained at this flow rate. A five hour sampling time was adopted which corresponded to the length of one-half shift. This sampling procedure for the operations area avoided interruptions when the shifts were breaking for meals.

The sampling apparatus consisted of an MSA Model G Personnel Sampling Pump mounted on top of an upright clean 55 gallon barrel for all ambient stations. The chromosorb tubes were connected to the pumps with Tygon tubing or, for the samplers worn by workmen where greater flexibility was desirable, latex rubber. In order to minimize the likelihood of rainwater contamination, the tubes were attached so that the opening to the tube would face downward.

The pumps at the ambient stations were maintained on constant "high" recharge throughout the period, regardless of whether or not the pump was in use. The pumps worn by workmen were battery powered for the five hours. These pumps were then recharged in one of the sample-preparation rooms in Building 190 during the next half-shift.

Flow rates were checked at hourly intervals with a rotameter and adjusted to ensure that the 0.50 liter/minute flow was being maintained. In only a few instances did the pumps fail to maintain the desired flow.

Air sampling for TCDD was accomplished utilizing benzene as the absorption medium. The apparatus consisted of a train of four impinger columns, the first two filled with 350 and 250 ml of benzene, respectively, and the final two with activated carbon (Plate 7). Activated carbon was used to adsorb the vaporized benzene from air flow through the first two columns. The benzene columns were wrapped with aluminum foil to avoid photo-decomposition of the TCDD in the sample. Following the carbon columns, a paper filter was attached with Tygon tubing to prevent any carbon from entering the pump.

The pumps were operated directly off the 110-volt AC lines located at the sampling stations. The entire impinger train with pump was mounted on the same barrels as the MSA pumps at each station. As with the chromosorb apparatus, the flow rate through the impinger was periodically checked using a rotameter and adjusted as necessary at a bleeder valve. A rate of 1.0 liter/minute was chosen; however, this rate may have been in error by as much as 20 percent, as variability in the pumps' speed and the effect of increasing amounts of saturated carbon caused fluctuations in flow.

The established running time of five hours was about the maximum duration for maintaining flow without saturating both columns of carbon, which would result in a benzene breakthrough. About halfway through the study, it was found that the columns were becoming saturated after about 4 hours. As a result, the procedure was modified such that the last column filled with saturated carbon was removed and replaced with a column filled with fresh carbon during the sampling period. This enabled the entire half-shift to be represented as well as to provide a larger sample volume. Reasons for the more rapid adsorption rate are speculative, but it is believed that the carbon used in the second half of the study was of lesser quality

Samples were removed from the sites with the entire impinger trains intact within wooden holders. The benzene was drained into brown glass jars in one of the sample preparation rooms of Building 190 (Figure 3). The glassware was then rinsed once with benzene into the sample containers to collect any portions that my have adhered to the impinger walls. The samples were stored in a dark, cool room in Building 190 before being packed for shipment to the Occupational and Environmental Health Laboratory at Kelley Air Force Base for later TCDD analysis.

Prior to reuse in the field, the impinger glassware had three acetone rinses followed by one rinse with benzene.

(2) Air Sampling Sites. Four areas were sampled for the N-Butyl esters of 2,4-D and 2,4,5-T and TCDD. These were: (a) the dedrumming facility, (b) a position 310 feet west of this facility, (c) the wharf where the M/V Vulcanus was docked, and (d) the weather station. Figures 17, 18 and 19 show the locations of the air sampling sites.

The remaining three areas (b), (c), and (d) were ambient sites. Each station was characterized by an impinger and chromosorb apparatus placed upon clean, 55 gallon drums.

Site (a) Air inside the dedrumming facility was sampled to allow for a comprehensive industrial hygiene report. An impinger was located on a clean barrel at the southwest corner of the shelter for TCDD detection.

In order to obtain workmen's exposure to 2,4-D and 2,4,5-T, persons working inside the facility in close contact with the herbicide were required to wear an MSA pump around the waist with a chromosorb tube attached near the breathing zone. When a workman wearing a sampler would leave the area to take a break, the samplers were turned off preventing such potential contaminants as cigarette smoke from being drawn into the sample. This procedure assured the detected concentrations to be representative of that inside the facility. As a further precaution, most of the chromosorb tube was left wrapped in aluminum foil to minimize contact of the outer portion of the tube with the herbicide, a possible route to

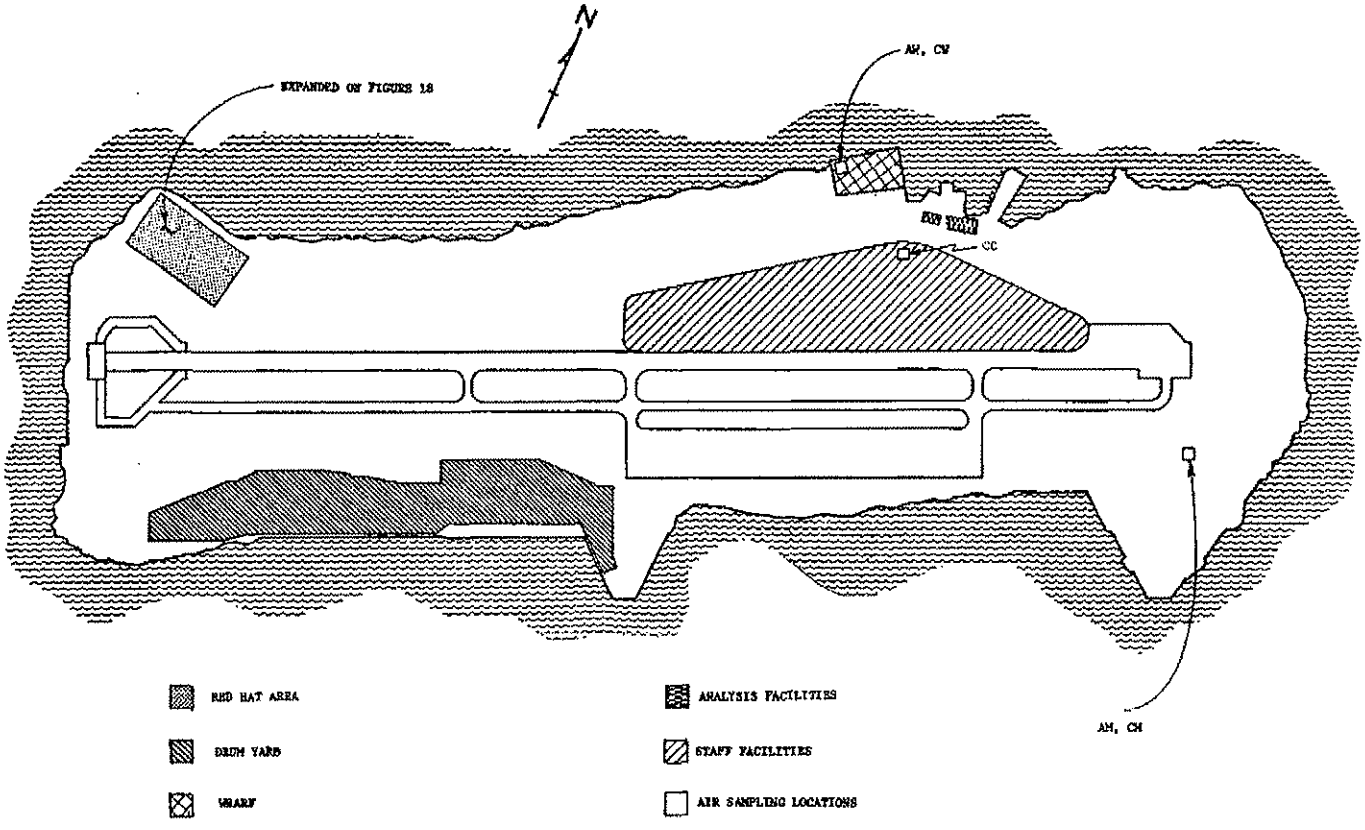


FIGURE 17. AIR SAMPLING SITES

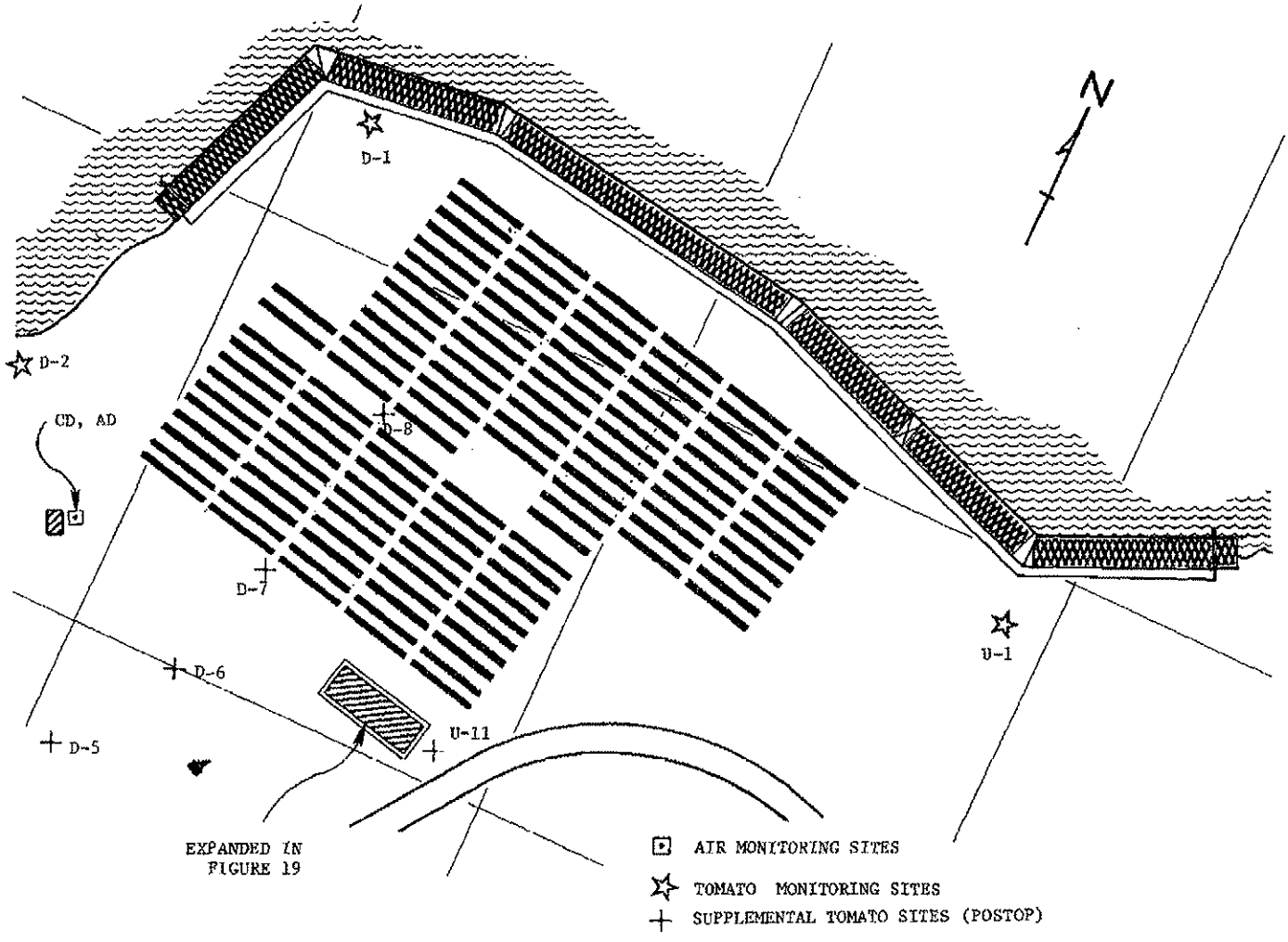


FIGURE 18. AIR MONITORING SITES, DRUMYARD

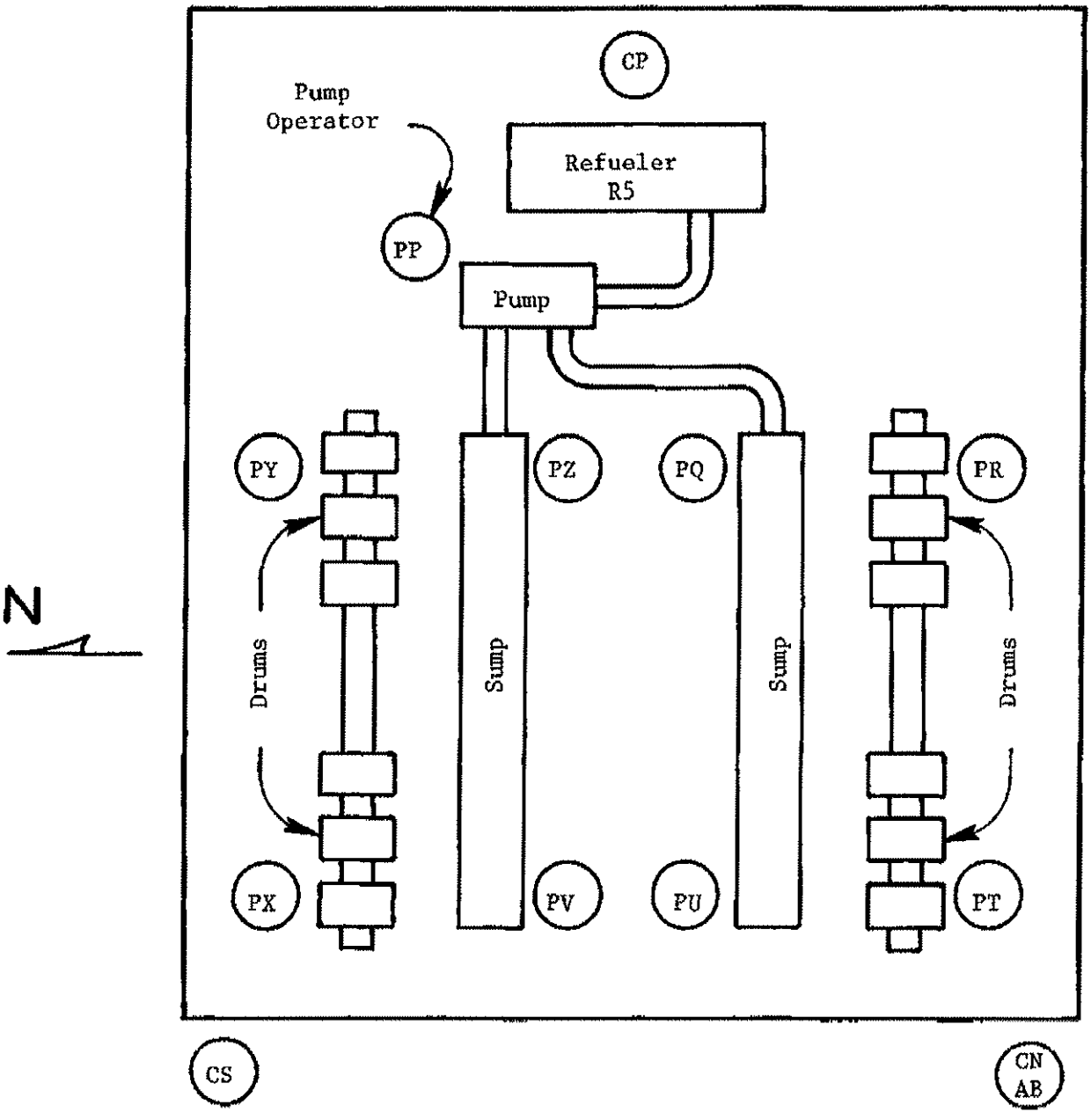


FIGURE 19. SAMPLING SITES AT DEDRUM FACILITY

contamination of the sample. Once the sampling duration was complete, the chromosorb tube was rewrapped in clean foil and sumitted to the lab. The tubes were then cut inside the laboratory and the lower contaminated portion of the tube discarded before removal of the Chromosorb 102 granules.

Because the pumps were turned off during breaks and some time was required for the crews to dress and undress during each half shift, the five-hour sampling time could not be achieved. In most instances, however, a sample volume of at least 100 liters was obtained at the 0.50 liter/minute flow rate.

In addition to the impinger and personnel samples, chromosorb samples were taken on occasion at two western (downwind) corners and at the center of the eastern wall of the dedrumming facility. Most of these were taken during inoperative periods, when crews were not dedrumming the herbicide.

Site (b) Located 310 feet west of the dedrum site, the downwind site was chosen to assess the affects of the barrel storage area, dedrumming the herbicide, and other operations on the air environment of this area. A comparison of the ambient levels at this station with observed tomato plant damage was possible due to the proximity of the plants with respect to the site.

The downwind station was located near the crushed drum storage area (to the south), the contaminated wood stockpile (to the southwest), and the wind recording station with anemometer. The effects of the crushed drum storage agea and the wood stockpile on detected concentrations at the downwind station was minimal due to the constance of the wind from perpendicular to opposing directions. The proximity of the anemometer with the station allowed a close correlation with immediate wind directions and speeds.

Site (c) A third air sampling station was established on the wharf at the western most light pole, approximately 300 feet from the truck-to-ship pumping station. Although winds were usually slightly out to sea with respect to this area, the position of the station does allow for an assessment of the ship's presence and pumping operations on the ambient air levels of the land adjacent to the wharf.

Site (d) The fourth site, located at the weather station, was utilized for measuring the air background levels and was far upwind of all operational areas.

(3) Air Sampling Intervals.

(a) Preoperational. Air sampling was conducted for a three-day period (July 24 to July 26) before dedrumming operations commenced for the purpose of establishing baseline for the study. Benzene and chromosorb samples were run daily at the weather station, wharf, and downwind sites. Additionally, three benzene samples (one/day) and three chromosorb samples (all on July 26) were run inside the dedrumming facility. These samples were representative of the late-morning, early-afternoon hours.

(b) Operational. Air sampling during dedrumming and associated operations commenced on July 27 and lasted through August 5 for the first loading of the M/V Vulcanus. The second loading took place over the interval August 17 through August 23. Generally, sampling during operations was limited to the five-hour half-shifts of the morning and evening. From the study performed at Gulfport, it was learned that the time of day had little effect on concentrations detected in the field. Nearly constant climatic conditions suport this idea for Johnston Island.

A total of 120 valid chromosorb samples were taken at the four areas of study during the two operational intervals. Their distribution is shown below.

- Weather station - 22
- Wharf - 18
- Downwind station - 26
- Personnel samples - 43
- Corners of dedrum - 11

Only eleven samples were taken at the edges of the dedrumming facility because it was decided that for purposes of sampling exposure in the working area, personnel sampling would be a more representative method. When possible, two separate personnel were monitored each half-shift. Early in the study, a third sample worn by the pump operator at the eastern end of the facility was taken to compare his exposure to that of workmen who were actually opening and draining the barrels.

In addition to the chromosorb samples above, benzene samples were run at the four sampling sites on the same two/day basis.

(c) Interim. Very limited air sampling was performed during the ship's burn of the first loading. On August 6 and 8, the downwind site and weather station site were sampled. On August 11, the wharf and weather sites were sampled, making the total number of samples taken during the interim period six chromosorbs and six benzenes. All of these samples were run during the morning hours.

(d) Post-Operational. Sampling after the ship's departure for the burn of the second loading extended from late afternoon on August 23 through the evening of August 26. The hourly intervals investigated were those of the morning and late afternoon-early evening. Moving the evening sampling up to include part of the afternoon allowed representatives of more daylight hours, thus a more accurate assessment of the effects of radiant energy on the barren, barrel storage area could be made. At the same time, the morning sampling interval was left unchanged for the basis of comparison with operational values.

A total of 32 Chromosorb and 25 benzene samples were taken at the downwind, wharf, weather station, and dedrum sites. Unfortunately, 10 of the chromosorb samples had to be discredited due to unreasonably high 2,4-D to 2,4,5-T ratios. It was found after the submission of three blank chromosorb tubes (in addition to the blanks submitted on August 3, August 11, and August 20) and other tests run in the laboratory that a box of thimbles used for the GC were contaminated. As a result, most of the chromosorb data from the afternoon of August 25 through the end of the study was lost.

The distribution of valid chromosorb data for the post-operational period, therefore, is as follows:

- Weather station - 4
- Wharf - 4
- Downwind station - 5
- Dedrum facility - 9

3.2.3.1 Chemical Sampling

b. Water

The sampling program for the water environment of Johnston Island consisted of four offshore sites and two onshore sites (Figure 20). The offshore sites were located in such a way as to monitor a particular land based HO operation while the onshore sampling points allowed assessment of the incoming herbicide load to the water treatment plant and the outgoing load from the sanitary waste system.

Samples were taken of the water near the main wharf at two points just off the bow of the ship at 10-11 meters of depth (Plate 7). The water current in this area and the density of the herbicide/diesel fuel mixture relative to seawater at 25°C were used to select locations where a spill would be likely to be found (See Section 2.1.3.3). Samples were obtained daily between 0800-0900 hours, 1300-1400 hours, and 1800-1900 hours using a landing craft or outboard motor boat. A set of brown glass jars of 1250 ml capacity, prewashed with acetone, were used for temporary storage. A plexiglass Van-Dorn bottle of 1-liter volume was used to obtain the samples from the water column. Immediately after transferring the sample to the glass jar, measurements of dissolved oxygen and temperature were made with a Yellow Springs Instrument Corporation salinity compensating polarographic unit. Jars were capped to prevent any degradation from sunlight.

The saltwater intake for the desalination plant was sampled daily at about the same times as the wharf samples and at a depth of

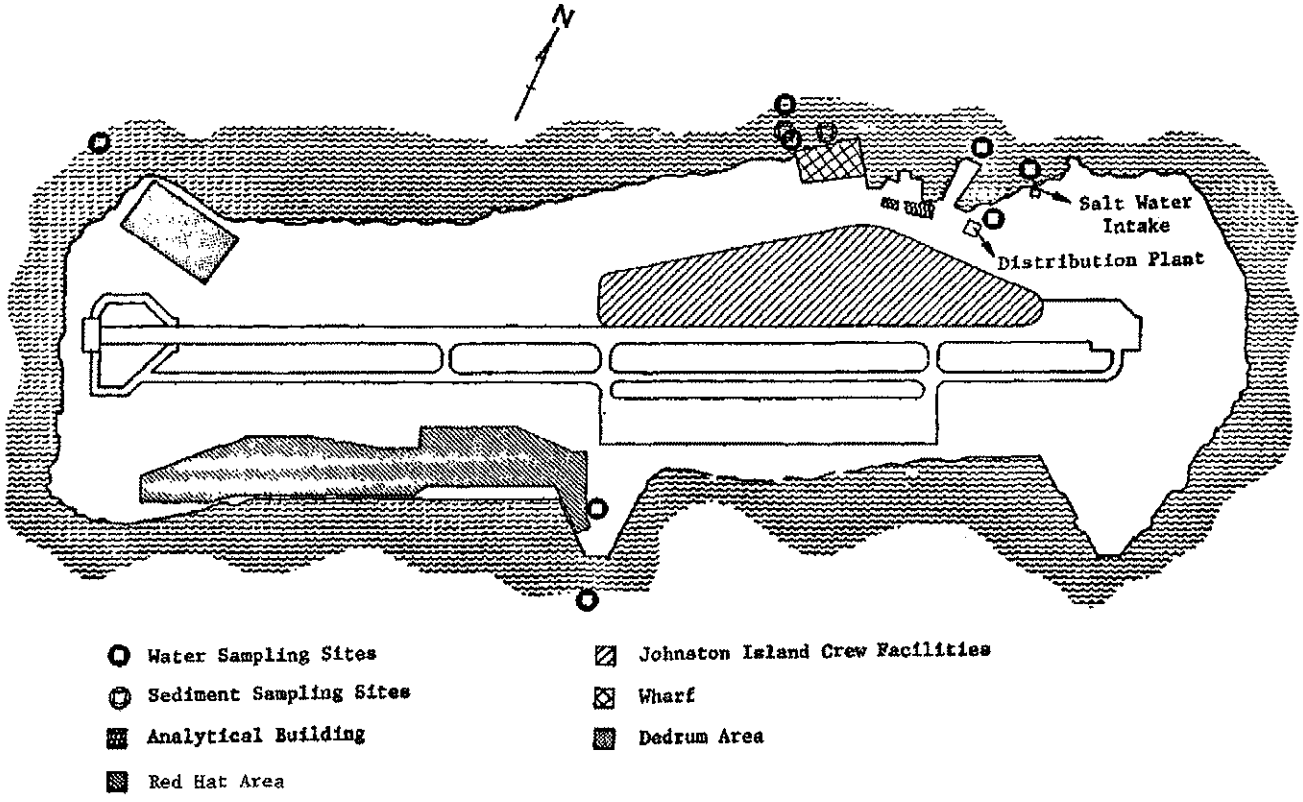


FIGURE 20. WATER AND SEDIMENT SITES

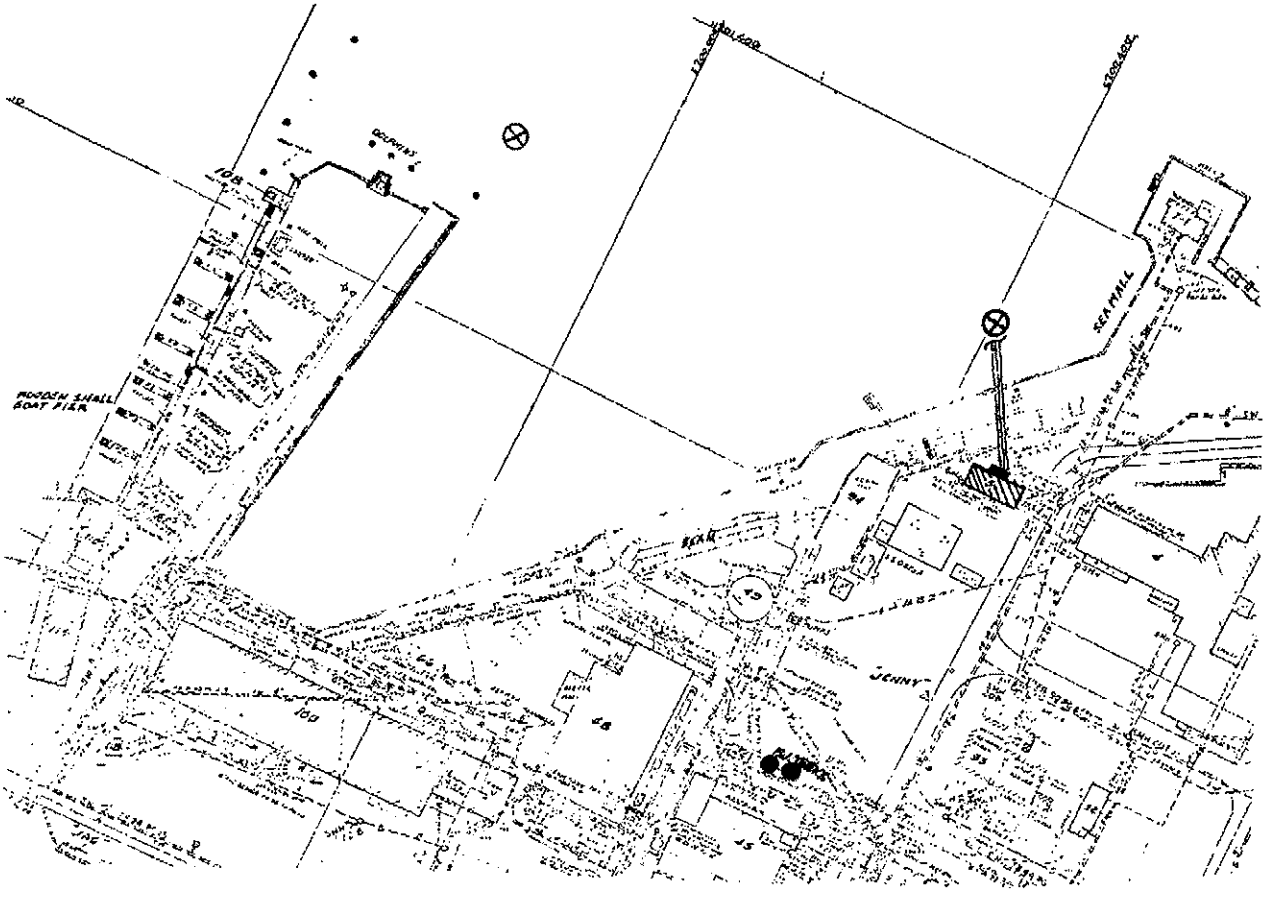


FIGURE 21. SALTWATER INTAKE SAMPLING POINTS

2187

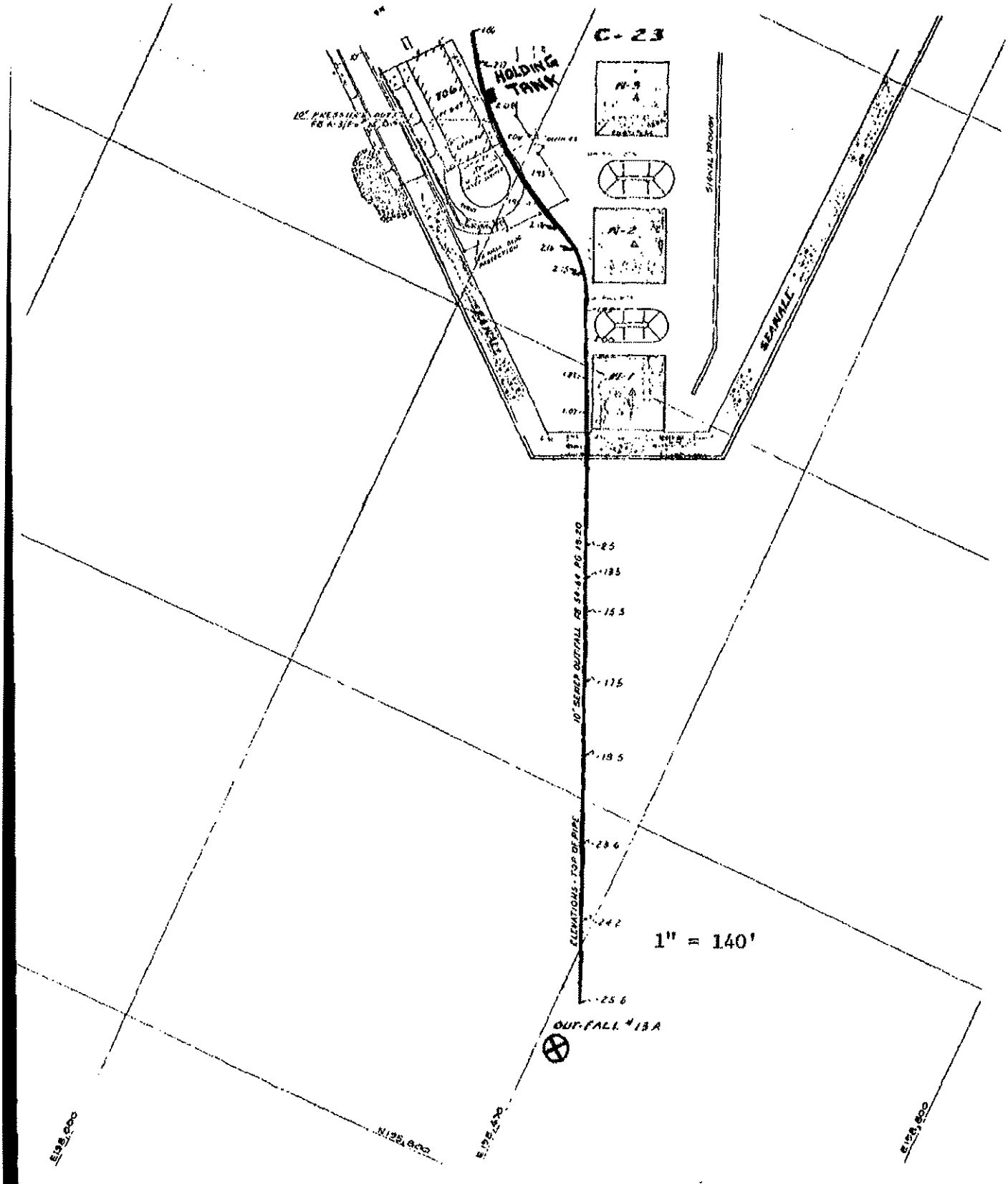


FIGURE 22. LOCATION OF SEWAGE OUTFALL SAMPLING SITE

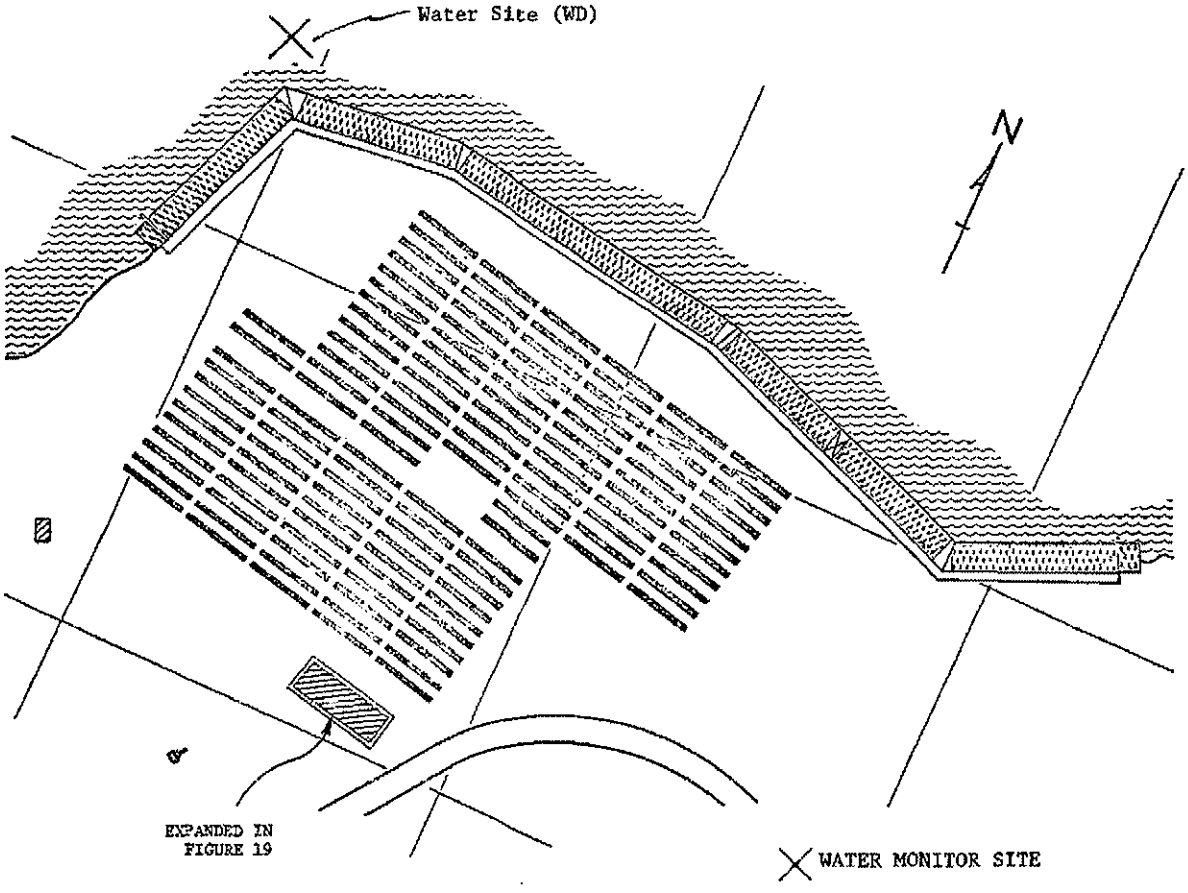


FIGURE 23. WATER MONITORINC SITE, DRUMYARD

five to six meters (about one meter from the bottom). Two coordinates were sampled--one at a point 5 meters offshore of the small boat piers and on a line from the north corner of the main wharf to the perpendicular drawn from the small boat pier and a second at the intake screen for the system, which consisted of three 24 in. intake pipes (Figure 21).

The third offshore location sampled on a regular basis was the sewage outfall on the south side of the island. Because of the difficulties in reaching this site with anything other than one of the landing craft, it was possible to sample this site only every other day. Samples were taken at a single point approximately 550 feet offshore and slightly down-current of the submerged sewage outfall. Raw sewage could occasionally be smelled in the samples. The sample depth was 6 to 8 meters; the depth to the top of the submarine outfall is 8.3 meters according to engineering blueprints of the waste disposal system (Figure 22). Samples were taken between 0800-0900 and 1300-1400 hours.

The fourth offshore site, sampled four times, was the shallow off-shore area near the drum storage yard (Figure 23). Water samples were taken at about 1400 hours once each during the baseline, first loading, second loading, and post-operational periods. During the baseline sampling, water was drawn from 5 meters depth and during the first loading period water from 2 and 8 meters was composited into a single sample.

At 1900 hours on days when sampling the wharf, saltwater intake, or sewage outfall, compositing was done on an equal volume basis from each of the two or three sets of bottles for that site. New brown glass 1250 ml jars were used for final storage. Replicates of each sample were submitted. Log sheets were filled out and submitted to the lab with the samples.

The onshore samples were obtained using Instrumentation Specialties Co. Model 1680 automatic water samplers equipped for discrete sampling. Sampling containers were glass, prewashed with acetone. Samples were taken over a 24-hour period once every 30 minutes. Sample volume was 180 ml. The units were dedictated to the particular sample type (sewage or drinking water) to prevent cross-contamination. Ice was packed around the sample containers to reduce sample loss. The temperature and pH was measured at the beginning and end of a sampling period.

The contingency plan called for analysis of individual hourly or similar short period samples in case of herbicide spillage or other unusual circumstances. This option was not exercised and all samples were composited using a syringe.

All samples were refrigerated after collection. Selected drinking water and other samples having relatively high levels of 2,4-D or 2,4,5-T were archived and shipped to OEHL (Kelly AFB, Texas for later TCDD analysis.

The location of one of the onshore samplers was in the freshwater system equalization tanks immediately downstream from the desalination plant and prior to chlorination (Figure 20). A location upstream of the chlorinator was chosen to mitigate any prior system contamination from HO and to eliminate potential analytical interferences from molecular chlorine or its derivatives. Samples were taken from a tap located at the bottom of the equalization tanks. The total capacity of the tanks is 30,000 gallons (113,550 liters) and the mean hydraulic residence time is 3 days[22]. The outflow rate for sampling was approximately 1 gallon/min (3.8l/min) which was maintained continuously throughout the assessment.

The sewage samples were drawn from a sump near lift station 2 shown in Figure 22. Pump cycles for discharge of the sewage to the ocean were approximately 5 minutes on followed by 15 minutes off during the day. Nighttime cycles were not observed, but were probably much less frequent because of lower non-domestic discharges. The sampler head was submersed about 2 to 3 feet depending on water level so that solids clogging was minimized. Samples were time proportional (30 minute frequency) rather than flow proportional. Small amounts of solids were found in the samples and were mixed before compositing. Rainwater runoff into the manhole was negligible.

Sediment sampling offshore of the M/V Vulcanus' berth was conducted during the baseline, interim, and post-operational periods. Samples were obtained by divers using scuba equipment(Plate 9). The same prewashed 1250cc amber glass bottles that were used for water samples were also used for sediments.

Sampling locations were about 20 feet directly off the wharf pump area and 30 feet off of the northwest corner in 35-40 ft. of water (Figure 20).

The supernatant water was decanted and the bottles recapped and frozen until shipped to OEHL Kelly Air Force Base, Texas for archiving.

3.2.4 Biological Monitoring Protocol

3.2.4.1 Bioassay Methodologies

Young, potted tomato plants. Lycopersicon esculentium, 25-38 cm tall were used as a biomonitoring organism to detect the presence of Orange Herbicide in the air. Tomato plants were used because of their reported sensitivity to HO damage in parts per trillion range(16). The injury symptom typical of HO damage, known as epinastic growth, is described as a curling and/or twisting of the apical portion of the plant.

Fourteen air biomonitoring sites or stations were selected on Johnston Island as shown on may in Figure 24. The tomato plants, selected for uniformity, were placed at each station. Of the fourteen stations, four designated as D1-D4 were located downwind of the dedrumming area while the remaining 10, designated as U1-U10, were located upwind of this area.

All tomato plants were examined once daily and symptoms of epinastic growth were recorded as being absent, slight, moderate, or severe. Slight injury,* as used herein, is the case where the epinastic growth was limited to the leaf tips and blades. The degree of injury where epinastic growth involved not only the leaf tips and blades but also the leaf petioles, was designated as moderate. Severe injury was characterized by epinastic growth involving the entire apical portion of the plant.

---

* See Plates 16-19 for pictures documenting these concentrations.

2192

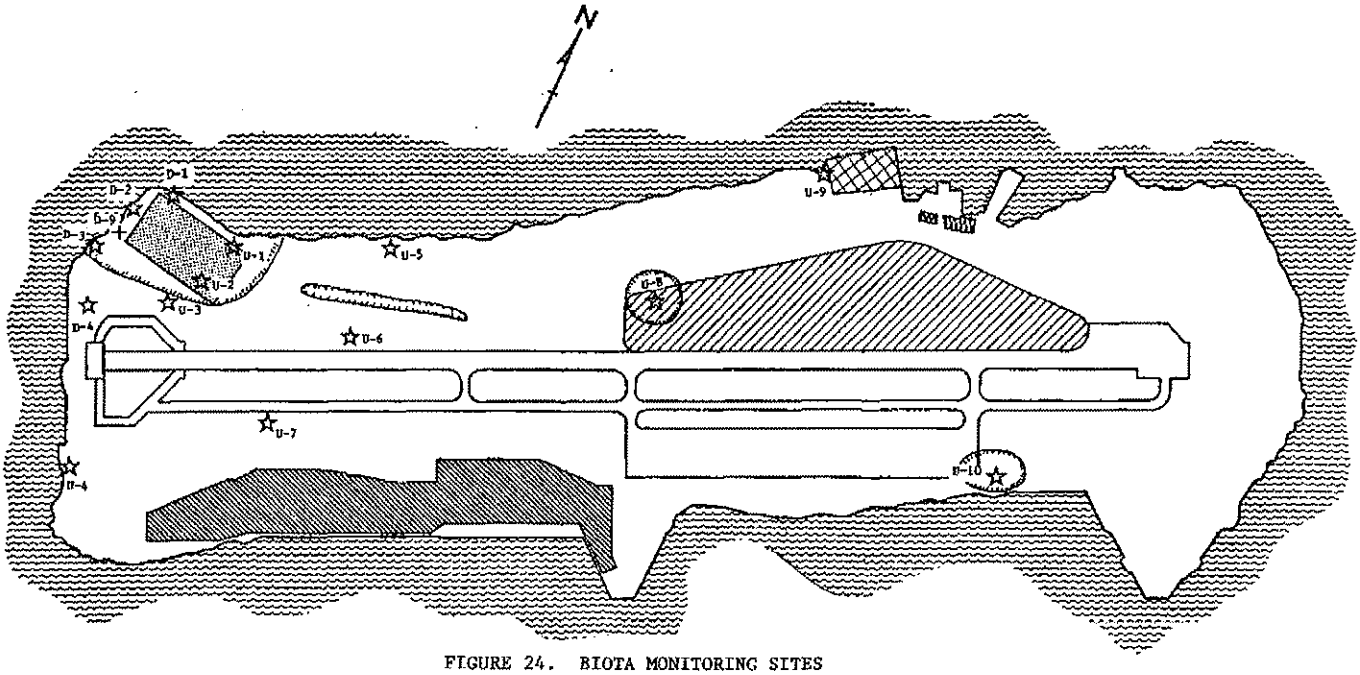


FIGURE 24. BIOTA MONITORING SITES

DRUM YARD

RED HAT AREA

WHARF

ANALYSIS FACILITIES

STAFF FACILITIES

TOMATO PLANT SAMPLING LOCATIONS

BIOLOGICAL OBSERVATION AREAS

SUPPLEMENTAL TOMATO SAMPLING LOCATION

The tomato plants were placed at the various stations on Sunday, July 24, and each station was photographed on each successive Saturday through August 27. Tomato plants were also photographed whenever the initial injury symptoms were noted. The plants at each station were changed at least every 1-2 weeks depending on their physical conditions. Whenever the plants at a station were changed a photographic record was made both of the old plants and the new plants which were put in their place.

Because of the high intensity of solar radiation and the constant wind, the tomato plants exhibited a high level of evapotranspirational demand. It was necessary to water the plants twice daily in order to prevent desiccation, and even then wilting was noted occasionally. Four weeks into the operation, the 4-inch plastic pots containing the tomato plants were placed in 1-gallon metal cans and foil was added to fill in around the plastic pot. This procedure improved the water holding characteristics of the growth medium and resulted in relieving much of the moisture stress previously observed.

The wind, which came predominantly from the northeast at speeds of as high as 20 knots, caused considerable physical injury when the tomato plants were first placed at the stations. This problem was resolved by placing a section of screen covered with aluminum foil and/or plastic material on the windward side of the plants.

3.2.4.2 Birds

Because of the large numbers of birds which inhabit the original portion of Sand Island and its relative close proximity to the dedrumming area, Sand Island was chosen as the primary site for monitoring the bird population of Johnston Atoll.* A preoperational bird survey was made

---

* Sand Island is upwind from Johnson Island. Few birds were observed on Johnson Island before, during or after operations.

on Sand and Hikina Islands on Tuesday, July 26. Bird surveys were repeated on Sand Island each Monday thereafter through August 22. A postoperational survey was made of the bird populations on Akau, Hikina, and Sand Islands on Saturday, August 27. No effort was made to evaluate the effect of dedrumming and transfer operations upon the bird population of Johnston Island because of the very small numbers involved.

The bird surveys included a weekly visual inspection of the birds on Sand Island for possible abnormalities within behavior, distribution, or dead birds.

3.2.4.3 Vegetation

Four areas, which are designated on Figure 24, were chosen for visual examination on a weekly basis for symptoms of herbicide injury. The initial vegetation survey was conducted on Wednesday, July 27 and was conducted each Saturday thereafter through August 27. The survey involved the examination of individual plants and plant parts for symptoms of epinastic growth. All species examined were also photographed to serve as a record.

3.2.5 Analytical Procedures

3.2.5.1 Pre-Departure Tasks

Analytical procedures have been developed and practiced for several years for the trace determination of 2,4-dichlorophenoxyacetic acid (2,4-) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) as their methyl and butyl esters.[23-31] These analytical procedures are based on sample preparatory techniques common to pesticide analytical procedures. Pesticide analysis typically consists of a rather complicated and precise series of sequential tasks requiring a good deal of laboratory skill and practice to generate reproducible results. Consequently, it was important to gain sound background information and experience regarding the detailed procedures used for 2,4-D and 2,4,5-T analysis prior to proceeding with routine sample preparation and analysis on Johnston Island.

Since recovery studies reported by other workers for 2,4-D and 2,4,5-T in the water sample preparation scheme was typically 50 percent or less, it seemed important to learn to perform this procedure as reproducibly as possible to assure consistent performance in the field. A series of spiked distilled water samples were carried through this rather involved preparation scheme. As a result, important sources of error and interferences were identified and provisions were made to eliminate these problems.

Additionally, this 2 week pre-departure training allowed the establishment of work schedules and formulation of a general plan for sample preparation and analysis during the JI dedrum operation. The chromosorb and drum rinse sample preparation and analysis schemes were similarly examined.

During the 2 week period prior to departure for JI we also briefly examined the gas chromatographic instrumentation and procedures. A hewlett-Packard Model 5833A gas chromatograph equipped with dual electron capture detectors (ECD's) was chosen for use because of its accurate flow control, reliable operation, and flexible "firmware" for data acquisition and manipulation. Attendance at a manufactuers' training seminar on the maintenance and operation of this instrumentation, allowed familiarization with the effects of temperature, carrier gas flow rate, composition and purity, and detector and column temperature on precision and accuracy. The formation and determination of the 2-chloroethyl esters as an improvement of the water sample analysis scheme was also examined. However, initial attempts indicated this to be a source of many potentially interferring electron capturing species, and this approach was abandoned.

As a result of several changes in the program schedule, our departure preceded the shipment approximately 900 pounds of equipment by one day and as a result, we were able to monitor the location of this shipment along its route. This equipment consisted of the 2 Hewlett-Packard 5833A gas chromatographs and a variety of general laboratory equipment.

Electron capture detection when used in gas chromatography is an extremely sensitive and selective tool. However, because of its sensitivity, it is very important to (1) vigorously eliminate any unwanted electron capturing species in the samples, (2) use inert and frequently changed

septa, and (3) maintain extremely pure carrier gas supply. As mentioned above, the formation of the 2-chloroethyl esters of 2,4-D and 2,4,5-T was examined as a means to increase sensitivity and avoid the problems of unwanted electron capturing species in the water sample extracts. This procedure consisted of esterifying the acids with 5 ml of 2-chloroethanol/BF_3 reagent at 60 C for 30 minutes. The 2-chloroethyl esters are more sensitive to ECD and are retained longer than the methyl esters with consequently higher operating temperatures. However, the lack of readily available high purity 2-chloroethanol forced a continuation of the BF_3/MeOH esterification procedure.

GC operating conditions were maintained at as high a temperature as possible, and specially constructed column systems and vials were obtained from Hewlett-Packard that were manufactured for high-sensitivity GC-ECD applications. These septa were constructed of an experimental elastomer which gave fewer electron-capture active contaminants than the normally supplied septa. Additionally it was recommended by Hewlett-Packard personnel that we use a Supelco carrier gas purifier Model 2-2315 as an effective way to remove traces of H_2O and O_2 from the carrier gas supply.

The gas chromatographs and associated equipment were shipped by commercial carrier. However, because of its size and weight, the shipment was delayed several times before reaching its destination and was finally transferred to a second carrier who completed the delivery. Despite these manipulations, the equipment arrived intact and undamaged and was immediately installed in the Pacer HO Lab Facility.

3.2.5.2 Pacer HO Analytical Laboratory Description and Operation

The facilities available on Johnston Island for use as the Pacer HO Analytical Laboratory were housed in two air-conditioned buildings located north (upwind) of the wharf area and just east of the small-boat docks (see Figure). The Pacer HO Analytical Facility was established in five rooms within these buildings one for each of the GC's, one for the drum rinse sample, one for the chromosorb and water sample preparation, and one room for cleanup

of the glassware used in the water and chromosorb sample preparation. Because of the risk of contamination of the water and chromosorb samples with the highly concentrated drum rinse samples, the latter were analyzed in a totally separate building.

The drum rinse sample preparation room and the GC used to analyze only the drum rinse samples were housed in Building 130 which was downwind of the water and chromosorb sample preparation facility (Building 120). Also housed in Building 130 were all of the laboratories used by the sample collection team. Although these facilities were air-conditioned, ventilation in the laboratories was not adequate for the large volumes of benzene and highly concentrated drum rinse samples being processed here. Consequently, an additional portable hood was installed in the drum rinse preparation room for all sample manipulations. The sink used for washing glassware was also vented.

Similarly, the water and chromosorb sample preparation room and the dishwashing room required additional ventilation to remove the copious solvent vapors resulting from these operations. One large lab bench was fitted with an overhead blower-equipped vent which also served to draw off ether and acetone fumes from the sink in the glassware cleanup area in the adjacent room. However, the hexane and ether fumes generated during certain stages of the water and chromosorb sample preparation were not efficiently removed by the ventilation system and the lab was occasionally evacuated for this reason. Also, several minor modifications were made in the plumbing and electrical systems for convenience in operating the equipment in the lab. The water and chromosorb sample preparation area was a former rocket fuel analytical lab equipped with a single hood and sink, a non-hooded sink, as well as bench space and several storage cabinets. The glassware cleanup area was located in an adjacent room, with the GC used to anlayze these samples in still a third room. A fourth room contained several cabinets and refrigerators and was used for sample storage, while a fifth room was equipped with several desks and was used as an office and clothes change area. (See Plates 10, 11, and 12)

With this arrangement, the sample preparation area was separated from the glassware cleanup, the GC, and sample storage with the objective of eliminating sample contamination from the laboratory environment.

A list of the equipment and supplies furnished by the Air Force and used in the Pacer HO Analytical Lab is given in the appendix. This list has been modified to indicate those items used in the laboratory and and estimate is made of the quantities that were actually needed.

3.2.5.3 Pacer HO Laboratory Management and Operation

The samples that were analyzed in the Pacer HO Analytical Lab included chromosorb, drum rinse and water samples from the land-based monitoring and chromosorb, trace line rinse impinger, water and wipe samples obtained from the ship, M/V Vulcanus. Prior to the first sample analysis, several preparatory tasks were performed.

A series of standard solutions were prepared of 2,4-D and 2,4,5-T methyl and butyl esters spanning the range of 1.5 ppb to 10 ppm. These standards were prepared from two stock solutions of the 2,4-D and 2,4,5-T methyl and butyl esters. The standard curve was obtained by analyzing these methyl and butyl esters by GC and plotting amount injected versus the measured peak area. The slope of this curve is amount/area or the response factor for the peak of interest. The values obtained by the graphical method were compared with those obtained by averaging the response factors for each peak obtained. These response factors were susceptible to change with time so they were monitored frequently by running a standard solution along with each set of samples. Additionally these data were plotted as each of the response factors obtained versus the amount injected. Typical plots of this type are given in Figure 25 and indicate the wide linear range common to pulsed-frequency ECD. Also from these plots, the lower limit of quantitation can be assigned (see Table 5). With increasing use of the instrument, both response and lower detectable limit changed due to fouling of the detector, much of which was reversed by cleaning with large injections of organic solvents followed by a thermal cleaning and rapid purge.

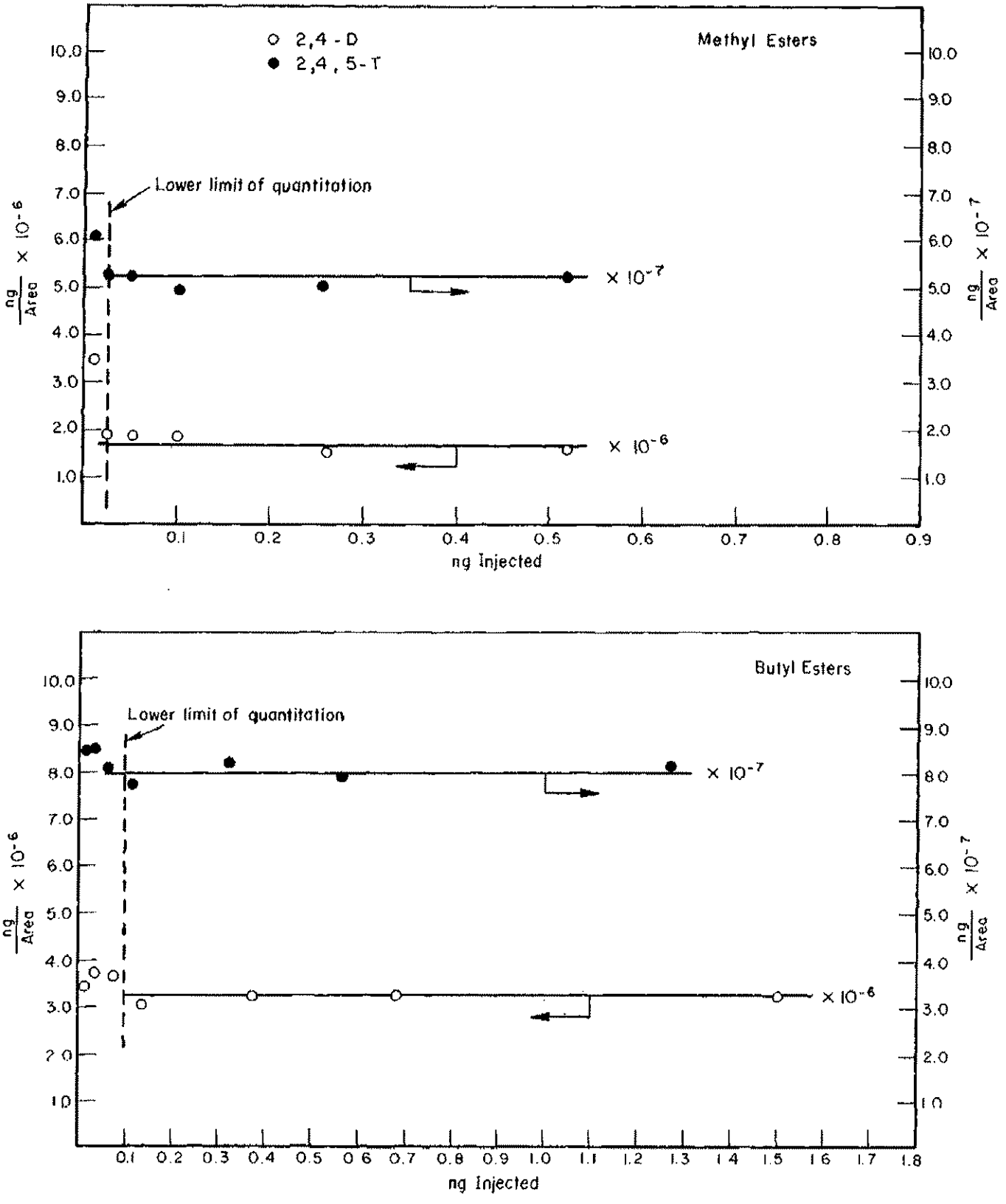


FIGURE 25. CHECK FOR LINEARITY

2200