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COMPLETION REPORT

U. S. ATOMIC ENERGY COMMISSION

CONTRACT NO. AT-(

ENIWETOK PROVING GROUND FACILITIES

DECLASSIFIED BY WASHINGTON DECLASSIFICATION TEAM, WEEKS OF JULY 10 & JULY 17, 1972

CECIL PEARSON

VOL. V RECONNAISSANCE REPORT

HOLMES & NARVER, INC.

LOS ANGELES, CALIFORNIA

Special Rereview

Final Determination

Reviewers	Class.	Date
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1 September 1951

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COMPLETION REPORT

U. S. ATOMIC ENERGY COMMISSION
CONTRACT NO. AT-(29-1)-507

ENIWETOK
PROVING GROUND FACILITIES

Reviewers	Class.	Date
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VOL. V

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Final Determination

HOLMES & NARVER, INC.
LOS ANGELES, CALIFORNIA

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CONTRACT NO. AT-(29-1) - 507

PLANS
SPECIFICATIONS
SUPERVISION
JAMES T. HOLMES

REPORTS
EVALUATIONS
CONSULTATION
D. LEE NARVER

7 January 1949

HN-116
600.91

Manager, Santa Fe Directed Operations
United States Atomic Energy Commission
P. O. Box 1539
Los Alamos, New Mexico

Dear Sir:

We are pleased to present herewith our Report covering reconnaissance, planning, utilities, structures and construction program for the Atomic Weapons Proving Ground at Eniwetok Atoll, in accordance with your contract letter of instruction dated September 16, 1948.

This Report has been developed to meet the test requirements of the Los Alamos Scientific Laboratory.

Respectfully yours,

HOLMES & NARVER

By James T. Holmes
James T. Holmes

D. Lee Narver
D. Lee Narver

JTH:DLN:hs
1 Incl:
Report

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INTRODUCTION

AUTHORITY FOR REPORT:

By a letter from Mr. Carroll L. Tyler, Manager Santa Fe Directed Operations, U. S. Atomic Energy Commission, to Holmes and Narver, dated September 16, 1948, this firm was authorized to make a preliminary reconnaissance and study of the proving ground site at Eniwetok Atoll for the purpose of determining such information as is necessary to formulate a construction program, recommend types of construction, prepare cost estimates and submit a comprehensive report of our findings.

Authority for the basic functional criteria, such as population, radiology, date of tests, demand utility loads, and geographical distribution of various proving ground functions, derives from a series of conferences between representatives of Holmes and Narver, and J Division of the Los Alamos Laboratory, presided over by Dr. Alvin C. Graves during the week of November 15, 1948.

PURPOSE OF REPORT:

The purpose of this Report is an engineering analysis of design problems and construction problems involved in utilities and structures necessary for a proposed Atomic Energy Proving Ground at Eniwetok Atoll in the Marshall Islands. This Report will not undertake the scientific or experimental aspects of such a Proving Ground, but will analyze certain of the facilities necessary for such experiments, as well as a proposed schedule for accomplishing and operating such facilities. It is intended as a forecast of probable scope of work as a basis for which logistic scheduling can be accomplished, and approximate estimates of cost for budgeting purposes can be prepared. It may also constitute a framework for the formulating of policy and drawing of contracts for actual accomplishment.

SCOPE OF REPORT:

This Report will concern itself with installation and function of utilities and structures. It will report on, and evaluate existing facilities; and propose a definite program of design and construction. It will consider special problems of operation, and of mobilization, demobilization, logistics, and maintenance. It will make cost estimates based on suggestions, probabilities and schedules proposed in the Report.

Scope of this Report does not involve detailed design. It is intended, however, to explore the possibilities from the standpoint of sound engineering principles, giving alternatives where feasibility of more than one method or design is apparent, and setting forth specific recommendations for policy determination which will form a basis for subsequent contracts or organizational work, as well as procurement and financial arrangements to accomplish the necessary construction at the Proving Ground. It is intended to be sufficiently comprehensive that a person not wholly familiar with the vicinity of the proposed operations may properly evaluate the recommendations given herein. The magnitude and extent of facilities discussed in this Report are based on our understanding of the requirements of the Laboratory at Los Alamos. Within a general framework of criteria derived from conferences at Los Alamos, this Report will develop engineering recommendations which are supported by such calculations and studies as will establish that the conclusions in the Report are practicable from the standpoint of engineering design and construction in the field.

It is recognized that with the unprecedented scientific developments in the field of atomic weapons, it is impossible to make proving ground specifications today which will not be partially obsolete tomorrow. Great emphasis has been placed, therefore, on flexibility in problem analysis.

The intent of this Report, by approaching certain problems from the standpoint of many different alternatives, does not imply uncertainty as to the engineering analysis, but is intended to form a basis upon which policy decisions can now be intelligently made, and as a basis upon which such policies may be easily modified or supplemented in terms of later information. Similarly, construction planning must be sufficiently versatile to accommodate, without disruption, major changes, deletions and additions, up to the actual time of testing. This is believed to be one of the most vital objectives in conceiving the scope of this Report, and the entire Report should be so evaluated. This Report will assume a proving ground use equal to the period of two series of tests.

The discussions of final design, construction, and operation in this report presume the awarding of civilian contracts for the performance of proving ground establishment, exclusive of these services.

(a) Communication, between the Atoll and the outside world.

(b) Security regulations, policing, military patrol and aircraft operation.

(c) Hospitalization beyond ability of field medical service.

(d) Military air and surface transportation, to the extent available.

(e) Military supply of certain vehicles, boats, and equipment to the extent available.

(f) Military support of the Eniwetok garrison.

(g) Civil functions of government, affecting the common welfare, civil processes of law, and rules of the road by air and sea.

(h) Air-sea rescue, and evacuation of serious casualties and deceased.

(i) United States Postal service, or extending of APO facilities to all personnel at the site.

(j) Operation of boat transportation in the lagoon beyond the needs of construction.

Engineering design is proposed to be accomplished in the Zone of Interior for these reasons:

(a) The nature of design is such that it can be as adequately done in the Zone of Interior as in the field.

(b) Economies would be affected by reducing total personnel at the site as much as possible.

(c) No loss of productive time would be incurred by time in transit of personnel.

(d) Design forces would be close to manufacturer's data and consultation.

(e) Ready adaptation could be made in design in terms of available materials.

(f) Restricted data necessary to design can be readily controlled for security.

(g) Design forces are more accessible to the Laboratory personnel directing the requirements.

(h) No delay in start of design is implied, since the reconnaissance of October 1948, and the proposed advance field forces will supply sufficient initial data.

SECTION II

PRESENT CONDITION AT SITE

DESCRIPTION OF LOCALE:

The proposed proving ground makes use of a chain of islands in the Atoll of Eniwetok. Eniwetok is a typical coral atoll in the North Pacific Ocean, being one of the Marshalls. It lies westerly of Los Angeles 4500 nautical miles, about twice the distance of Honolulu and almost in line, by the great circle. It lies at latitude 11° 30' North and longitude 162° 20' East, at a point 1044 nautical miles E by S of Guam, 524 nautical miles SSW of Wake Island, and 354 miles WNW of Kwajelein. The atoll is roughly circular and approximately 22 nautical miles in its longest diameter.

The westerly half of the circumference is relatively shoal and usually submerged at high tide. The easterly half of the atoll consists of a number of small islands made of coral sand which emerge from the sea at all stages of the tide. All these islands, however, are underlaid by a shelf-like coral reef dotted with projecting irregular masses of coral at frequent intervals. Deep water occurs rather abruptly at the outer and inner perimeters of this shelf. On the lagoon side, however, in several cases, a sandy beach forms a transition from the island shore into the deeper water of the lagoon. Ocean swells break on the outer edge of the reef several hundred feet from the island shores, and the relatively shallow water between islands and adjacent to the shores is calm in usual wind conditions.

The lagoon has two navigable entrances, one of which may be entered by deep water vessels. The interior of the lagoon is navigable, although certain pinnacles of coral create hazards to navigation. Typical island vegetation consists of coco palm trees under which is found underbrush in varying degree. All vegetation has been removed from certain islands, and in other cases, the palm trees appear to have been systematically planted by men rather than accidentally propagated. The weather in this vicinity is tropical, and humid and is uniform in temperature, both in seasonal and in daily variation, being in the magnitude of 80°. It is in an area of tradewinds and of frequent rains which appear as periodical squalls or rain clouds, rather than being a pronounced seasonal phenomenon. The area is not inhabited by natives of the Marshall Islands, and the only residents of the atoll are garrison troops at Eniwetok. The nearest point of human habitation is Kwajalein, which is a Navy Station, and which maintains logistic support of the Eniwetok garrison.

REPORT OF FINDINGS:

Representatives of Holmes and Narver were at Eniwetok Atoll from October 4 to October 17, 1948 for the purpose of a survey of existing conditions at the project site.

The scope and mission is described in Letter Contract AT-(29-1)-507 dated September 16, 1948 between the AEC acting on behalf of the United States of American, and Holmes and Narver, Engineers, of Los Angeles, for the performance of Architect-Engineer services necessary to cover initial programming and preliminary planning required in connection with preparations of the Los Alamos Scientific Laboratory for weapon testing activities, as follows:

1. Preliminary reconnaissance and study of proving ground site at Eniwetok Atoll for the purpose of determing such information as is necessary to formulate a construction program.

The party was escorted by an official of J Division of the Los Alamos Laboratory, accompanied by two radiological monitors. The Holmes and Narver study was conducted by the Chief of Operations of that firm, together with their experts in mechanical, electrical, sanitary, hydraulic, and industrial fields of engineering, as well as hydrography and surveys.

Following will be a report of the factual findings of this reconnaissance.

Garrison at Eniwetok. During the reconnaissance trip, the survey team was based at Eniwetok Island and was furnished subsistence and transportation by the command. The garrison was very cooperative with the purpose and efforts of the reconnaissance team, within the limits of the facilities available to them. Every military courtesy was extended en route, and though air lift was critically short, a high priority was accorded the party and no delay was encountered.

Weather. During the two weeks which the team was at the Atoll, the weather was uniform in temperature, both day and night. The first half of the period, weather consisted of intermittent clouds and sunshine, with infrequent showers. During the latter half of the period, showers of rain were a daily occurrence. In general, rains can be seen approaching, as squalls under a heavy cloud mass coming across the surface of the sea, and traversing the lagoon. Moderate trade winds were experienced almost daily.

Insects. The islands are remarkably free of files and mosquitoes, due to the past and present campaign of control by DDT by the existing garrison. Some night flying insects are small enough to penetrate screens and are quite numerous around lights. On some of the shot islands, where control has not been practiced for several months, flies and other insects are very numerous. It is apparent that without control, insects in this climate would be a great annoyance. General health of the garrison was considered excellent.

Physical Conditions of Shot Islands. The shot islands are clear of any building or structure which was not functional in the previous test, with the exception of war-time landing boats on the Southerly end of Runit island, and with the exception of scattered debris on Engebi island. Around the zero tower area on Engebi, there is an extensive area of scattered, corrugated iron and other debris, apparently mangled by concussion, and there are remnants of camp structures, which have also suffered from the blast. On Engebi there are also large numbers of concrete slabs which were previously used as quonset bases. The vegetative ground cover is very sparse on most shot islands. The area immediately adjacent to the shot tower and probably for a 1,000 foot radius around the tower, is exposed ground with no apparent growth. In larger radii from the shot tower, weed growth has started. On Engebi, this takes the form of dense areas of burrs standing on grassy stems, approximately 18" high. On other islands, the burrs are not so much in evidence, but weedy growth has formed a ground cover on all shot islands, to some degree. There are a few coco palms which have gotten a start, and have sprouted to one to two feet in height on Biijiri and Runit. There are no bushes or other trees. There is considerable discarded material around all of the experiment buildings, such as wire and expended electrical equipment. None of the material now on the shot islands is regarded as salvagable to any degree of economic justification, except possibly buried cable and copper coaxial tubing.

Radio Activity on Shot Islands. The residual radio activity on shot islands is found to be appreciable for approximately 1,000 ft in radius from the shot tower locations. However, it is found to extend to greater distances in certain cases, and the intensities do not appear to be consistently a function of radius from the center of the tower. This means that any future construction activity should be accompanied by a system of monitoring. In an effort to determine how much movement of earth would be necessary in rehabilitating the shot tower area, on Aomon, a vertical section on zero line near the shot tower area was made and meter readings of various portions of this vertical section were taken. Conclusions are as follows:

(a) If approximately six inches of coral are removed, radioactivity in any area should be recuced to less than an eight-hour daily dose.

(b) Two feet of coral sand over the present craters should reduce present radioactivity to a sufficiently low level for all construction purposes. The few hot spots observed outside of the crater area may be removed by bulldozing the material to the edge of the island and covering with sand, in such a position that the lagoon will not be contaminated.

(c) The probable intensity of radioactivity in the craters by 15 May will be such that men can work in the craters for 3.4 hours on Engebi, 1.2 hours on Aomon, and 0.5 hours on Runit per day without exceeding a tolerance dose. For men in bulldozers working from the outside toward the center, these times may be appreciably longer. It should be sufficient to assume that a man will be able to work in this way for a half a day.

The only shot island paved around the tower in the last experiment was Engebi. The pavement is badly shattered, and samples taken of this pavement are intensely radio active; however, the soil under the paving is relatively uncontaminated, indicating the shielding effect of the paving.

Monitor results during this reconnaissance are available at the Los Alamos Laboratory.

Condition of Foundations under Original Shot Towers. The original towers were evidently placed on concrete piers, which are understood to extend about nine (9) feet below the ground surface. The towers have completely disappeared, with the exception of a few pieces of metal in the crater area, which might be identified as pieces of tower structure. The tops of the concrete piers have suffered some degree of shattering, and in some cases, this is considerable, the reinforcing steel being thoroughly exposed. This effect may be partly security demolition rather than blast effect; however, on the top of certain piers, where the legs of the tower emerged from concrete, short stubs of the tower legs are still remaining. There is abundant evidence of iron oxidation of the tops of various piers, and the surrounding soil area is apparently depressed. The tops of the tower supporting piers and stubs of tower legs, are intensely radio active. It is predicated, however, that this radio activity is only on the surface of the concrete mass, and penetrates very little.

Paving. The only paving at the time of the previous operation was apparently in the radius around the zero tower at Engebi. This paving was found in the condition of considerable shatter and irregularity in surface grade. It is understood to have been specified as a three-inch thickness; however, by visual inspection and by actual section taken of the paving, it does not appear that the paving is as thick as this at any point. It is not known whether the significance of this is compression from shock waves, or whether the design thickness was not achieved by the construction. It does not appear that any of this original paving is salvagable. The general characteristics of the paving fractures are tendencies toward uplift and shatter. Craters around original zero towers are not pronounced but the general area appears to be depressed in some degree. This was not determined accurately during the reconnaissance due to lack of instruments on which observations could be made quickly, and to the residual radio activity in the carters. It is estimated to be in the range of two to five feet below average terrain at the original tower position.

Special Equipment on Shot Islands. Equipment in the interior of special buildings on shot islands survived the blast, but scientific equipment has been removed. However, the air conditioning units in the buildings were examined and were found to be in good shape except that motors and expansion belts were missing in some cases. These units are all arranged for 100 percent recirculation and have six rows direct expansion cooling coil, and a four-row hot gas re-heating coil with air by-pass. For each unit there was a compressor, now missing, located outside of the building. There are capped pipe sleeves in the wall for all refrigerating lines. These units might be reused in other buildings of less importance, but are not considered adequate for a future operation.

Causeway. The connecting causeway between Biijiri and Aomon consists of driven steel sheet pile, inter-locked and stiffened horizontally by a steel waler, composed of double 16-inch channels, back to back, and tie rods which appear to continue through the structure and appear to be about three inches in diameter. The condition of the sheet piling is good, although there is some loss in section due to corrosion, and the surface is covered with considerable scale. Within the tide range, also, there are typical tubercules of electrolysis. This causeway piling will be substantial for a considerable time in the future. The roadways and curbs, which extend across the causeway, are not in perfect repair.

Coral Head Photo Tower. This tower was visited and inspected. The piers are fabricated H sections, fourteen inches by fifteen inches. From below low water to above high water the steel H sections are encased in concrete approximately four feet square. The steel columns above this are also encased in concrete approximately thirty inches in cross section. The concrete casing at its bottom surface is crusted with marine growth. On the underside and bottom six inches of the faces there is bad spauling. Steel below the concrete has a moderate amount of marine growth and there is no sign of excessive corrosion. The edges of the flanges of piling appear to have the original section. Rivet heads are corroded to some extent. This framework supports a platform of three-quarter by twelve inch boards supported on four inch by twelve inch joists laid flat, on approximately thirty inch centers. The three-quarter inch flooring is in bad shape. The steel structure of the tower is attached to the supporting framework by anchor bolts - those at the southwest corner are badly rusted. The steel frame-work of the tower structure has been painted over the galvanizing, and this paint appears to be in good shape and has adhered to the galvanizing. The paint used is apparently yellow zinc chromate. The galvanized house structure on top of the tower is not painted, but it appears to be in fair shape. One pane of glass is missing. There are two additional towers of this type in warehouses at Eniwetok, and one erected at Aniyaanii. The towers are equipped with hoist.

The floor of the tower itself is approximately eight feet above the water line. On the top step of the ladder which mounts the coral tower, a structural member consisting of about two inch angle iron projects into the upper part of the last step. This is an inconvenience to people in descending the ladder, and probably is a hazard to safety.

The cable landing was considered unsatisfactory for a permanent installation. The cable, in emerging from the water, ascended very closely to one of the concrete cased piers supporting the tower, and in the state in which it was found in this survey, it could have chaffed against the edge of the concrete pier. It had been restrained from doing so by a very light piece of rope. This rope was replaced with three-quarter inch manila line. The cable is mounted on the inside of one of the tower legs by a series of lashings or ties made of tarred-string, similar to Navy type marlin. Apparently, no other form of cable clamps were used. It appears that these cable landings could be redesigned to advantage. The cable itself appeared to be in good condition.

In addition to the lashing which was performed on the cable tower, an investigation was made of the equipment in the tower proper - electrical equipment and terminal facilities. The coral tower may be approached only by boat of the "M" type or other boat drawing less than twelve feet. No portion of the coral tower shoal is bare at any stage of the tide, but coral heads apparently project to within two fathoms of the surface in the general area. A steel ladder rises from two steel fender structures at the generator shack, which is apparently the route by which the tower was previously approached. This method of approach is inconvenient and hazardous.

Adjacent to the tower structure is a similar pile structure of steel H sections which support a generator shack, approximately fourteen feet by fourteen feet inside, with a wood floor. Generators have been removed. The shelter has corrugated iron walls and roof. The generator floor is five feet four inches above the wood floor and faces the tower. The generator building is about four feet from the edge of the tower platform.

Photo Tower - Aniyaanii. The 75-foot photo tower on Aniyaanii is in general good condition, and is similar to the Coral Head tower. It has also a hand-operated skip hoist which may have caused previous difficulty. The wheels on the skip hoist are narrow and tend to jump out of the standard steel channels which are used for guides. It is believed that the skip is inadequate and that motor operation would be more satisfactory. There are three cables extending up the tower; - one ten-conductor armored cable, two three-conductor rubber covered cables. The tower is guyed at the four corners, and is provided with a lightning arrestor. The tower is galvanized and is not painted; however, little evidence of corrosion is apparent except in some of the connections for the sheeting used in the cab at the top of the tower. The guy wires used on the tower appear to have been uncoated and were badly rusted. Also, a number of panes of glass were missing from the house at the top of the tower.

Land Survey Control. During the reconnaissance, evidence was recovered of the triangulation network maintained on previous mapping and control surveys. In general, a network appears to have been established from island to island, and extended out into the lagoon to include the coral head photo tower and another low tower structure which was used solely as a survey observation point. The monuments used in this triangulation survey are still recoverable. They consist of three inch brass plates of standard US Coast Survey type set in concrete flush with the ground. The survey observation point in the lagoon is constructed of a circular sheet pile enclosure approximately ten feet in diameter, apparently filled with coral to approximately eight feet above the sea level and capped with concrete. The condition of this installation is fair.

No bench marks for vertical control were discovered, and it is not believed that tide observations are being taken at the present time.

Horizontal Control. Two horizontal control surveys have been made in this area. An analysis of the methods and results of these surveys indicate that they do not meet the new requirements of this project.

U.S. Naval Control Survey. A survey by the USS Bowditch was made in 1944. This survey included a triangulation network covering that portion of the Atoll east of Bogombogo on the north and Igurin on the south. The apparent purpose of this survey was a hydrographic chart of the Atoll.

The survey was of third order accuracy and consisted of a base line on Runit island and triangulation stations on nine other islands. As the locations of control points are not readily adapted to the requirements of this project and some stations have been destroyed, retracing this survey is not recommended.

Astronomic Operations. Astronomic operations were taken by the USS Bowditch at station North Base on Runit Island and the geographical position of that station and the azimuth of a line between Station North Base and Station South Base were determined and used as the origin of the survey. This position and azimuth were accepted by the Joint Task Force Seven and became the origin of their later survey. Illustrative Plate 1 shows the layout of this network.

Joint Task Force Seven Survey. A survey was made in 1947-48 which established a control net of that portion of the Atoll east of Parry Island on the South of Engebi Island on the North. This survey is covered in the "Report of the Engineer, Joint Task Force Seven, Part Two."

As station South Base of the previous survey which was the South end of the base line had been destroyed, a new base line approximately 2600 meters in length was established on Runit Island between station North Base and a new station "Runit". This base was shorter than the former base line but was stated in the report to be of first order accuracy.

No astronomic observations were made by this survey. Although the original azimuth observations were made from stations North Base to station South Base, an examination of the correction obtained for the angles in the adjustment of the Naval survey showed that little accuracy was lost by using the computed azimuth of the line from station North Base to station Sand. It was therefore considered that reobservation was unnecessary.

In the computation of this scheme the latitude and longitude of station North Base and the forward azimuth of the line from Station North Base to station Sand were accepted and together with the elements of the Clarke spheriod of 1866, used to determine the datum.

An analysis of the report on this survey, together with information obtained on the reconnaissance trip of October 1948 by members of this organization reveal the following facts:

(a) Observations were made at night and apparently followed first order procedure. The base line was measured with Invar tapes and standard procedure followed. Triangle closure is within the allowable maximums.

(b) The geometry of the scheme does not conform to first or second order specifications of the U.S. Coast and Geodetic Survey, and can be considered no better than third order.

(c) The initial triangle in the base expansion figure has an R_1 of 52 which considerably exceeds the allowable maximums of 25 for first order and 40 for second order procedure. This weakens the whole scheme.

(d) The area covered by the survey is smaller than that required for this project. Proposed requirements would expand the net to double its present area with considerable magnification of the possible errors in the original net.

(e) The base line of the Joint Task Force Seven Survey can be used in a satisfactory scheme and can be assumed, based on available information, to have sufficient accuracy for the proposed second order scheme.

(f) The geographical position and azimuth are based on a wartime survey of doubtful precision. As the records of the Naval survey are not available, the method used in establishing position and azimuth are unknown, and it can be assumed speed may have been of more importance than extreme accuracy. However, this does not effect relative positions within the limits of the Atoll.

(g) The field work involved in retracing portions of this scheme and expanding to required size would almost equal that of establishing a new net without developing sufficient accuracy. It would be necessary to re-occupy most of the existing stations in order to establish additional ones. To do so, destroyed towers must be re-built at greater expense than those of the proposed scheme. Establishing a new scheme involves occupation of only four more stations than would be required to expant the present scheme.

Condition of Existing Triangulation Stations. Triangulation stations of the U. S. Naval survey were marked with a standard USN triangulation station disk set in concrete. Recovery of these stations was not attempted by the reconnaissance party but it is known that some have been destroyed, including station South Base and station Reef.

Stations of the Joint Task Force Seven survey are marked with a standard USC & GS disk set in concrete. These stations are believed to be recoverable, also some of the traverse stations established on the project islands.

Existing Towers. Existing towers, according to available information, may be occupied in establishing the proposed control scheme, as follows:

Aniyaanii Island	75' Steel Tower
Parry Island	75' " "
Eniwetok Island (N. End)	75' " "
Lagoon (Photo tower)	75' " "

Materials for additional towers are not available at the project site. Illustrative Plate 2 shows the relation of this net to the project areas.

Vertical Control. No information on existing vertical control is available at this time. The "Report of the Engineer Joint Task Force Seven" indicates that an assumed datum was used where elevations were required, such as differential levels on the Runit base line.

Water Transportation in the Lagoon. Boat transportation has been designed to maintain a security patrol of the Atoll, under direction of the Commanding Officer of the garrison. This patrol is now scheduled once each week to visit and traverse each of the islands of the Atoll, from Eniwetok to Bogallua. To provide this service, the garrison has two (2) LCM class landing boats, and two (2) amphibious craft (Dukw). At the time this survey team visited the island, only one "M" boat was in service, the other one being docked with pending repairs of bottom punctures and other difficulties which make it now unserviceable. Only one Dukw was in full operation, the other having mechanical deficiency. The procedure for a patrol or other travel by these craft is for the "M" boat to beach and drop its gate or ramp. The Dukw then drives aboard the "M" boat and parks in the well deck - the gate is closed, the boat pulls away - carries the Dukw to a destination island, where, if there is an approachable sandy beach, the procedure is done in reverse, and if there is a barrier reef, the Dukw is launched from the ramp at sea and makes its way over the reef to the beach. The condition of the equipment which was operating at the time of this visit was very depreciated, both in the case of the "M" boat and the Dukw. The "M" boat has engine irregularity, and a defective ramp which failed at one time during sea landing by the Dukw, and it takes considerable water, especially in choppy weather. On one return trip to Eniwetok, in about a 15 knot breeze, the well deck of the "M" boat accumulated approximately two feet of standing water. The Dukw is subject to continual mechanical failure of one kind or another, and it took considerable motor pool maintenance at night to keep it operating. At one time, the team was stranded for a few hours by engine failure, and other times by mechanical failure. This equipment is regarded by the garrison and the crews as being unfit for service. It was stated by the Commanding Officer, that if any subsequent surveys of this nature were planned by

AEC which would demand these boats every day and thus not permit extensive maintenance between trips, that sufficient advance notice would have to be given to the Armed forces to provide supplementary water transportation.

The trip across the lagoon from Eniwetok to Bogallua requires approximately three hours by "M" boat, with the Dukw as cargo. Travel in other parts of the Atoll is relative. The sea conditions in the Atoll during the two-week period of observance were favorable to small boat operations, consisting of no ocean swells, except in the immediate vicinity of the deep water entrance at Japtan, and only short surface waves created by local wind were experienced. These are dissipated rapidly with the drop in wind velocity.

This type of marine equipment, now in use, is very adaptable to the present requirements of the Atoll. It is particularly true of the Dukw that no other obvious form of vehicle or craft could give such expeditious access to the islands of the Atoll, particularly those bordered by a barrier reef.

<u>Ship Service to the Atoll</u>. Water transportation for freight haul and other purposes outside of Eniwetok Atoll is not based at Eniwetok, but is furnished through Kwajelein by schedule and by special request. Their method of making shipments to Eniwetok is to send boats of the LSM class, which usually discharge on the beach. For information on controlling depth of water within the lagoon, character of bottom and anchorage areas, reference can be made to Navy Hydrographic Office Map No. 6033. This map, as well as previous experience reported in the area, indicates that the interior of the lagoon has adequate depths and holding ground for anchorage to accommodate sea going vessels. Vessels may not be docked, however, due to the lack of pier facilities. Aids to navigation, such as lights, buoys, channel markers, etc., appear to be in place. Freight lightering from ship to shore appears to be best handled in Military landing craft which land on the beach directly.

It is apparent from the air that a number of submerged obstacles exist in the lagoon beach area of Eniwetok and Parry Islands. They consist of LSM boats and other sunken surface craft and pontoons.

Piers. On Eniwetok there is a pier near the South end of the lagoon side, which was constructed of pontoons with coral fill. Several of these pontoons have sunk and most of them are in very bad shape. The pier to be useable will have to be replaced. However, it could be extended out approximately one hundred to a hundred and fifty feet to deeper water. This pier was not used extensively as the personnel landing pier, but was used to land and dock heavy equipment from LSTs. Immediately adjacent to the pier described, there previously existed a beach on which LSTs could come in and drop their end-gate and discharge cargo. Further up the island, there exists a pontoon floating personnel landing pier, which was used as such during the last operation. A storm recently broke the several sections loose and they sank. Although the water approach to Eniwetok is good for LST boats, the pier facilities are not at all useable. There exists a beach approach suitable for "M" boats in the approximate vicinity of the Headquarters area on the lagoon side.

On the Southwest point of the island there exists a small wooden pier which is used for dumping garbage into the seaward side for disposal. This pier is in good condition and serves the purpose well at present for the garrison.

On Runit, there was a pier constructed of four (4) 12" "H" columns, approximately ten (10) feet by fifteen (15) feet center to center, driven into the coral, with top elevation of nine (9) feet above Mean Low Water Springs. Behind this was a rock fill which is practically gone. The steel is unprotected and rusty. This island was formerly used as a small boat repair yard, and there is a considerable extent of good beach near the South end, with apparently not too many coral heads off shore.

On Aomon, there was a pier consisting of two rows of converging pontoons, with some riprap placed between them - the other end of this is now submerged and the pier is of no value.

Some soundings were taken away from this pier in an effort to determine the general depth of the water in the immediate area. These soundings indicate a controlling depth of three feet at Mean Low Water Springs.

On Engebi, the pier consisted of timber cribbing - coral filled, faced on the end with five rusted pontoons, which are practically gone. It was approximately twenty feet wide by ninety feet long from high water line.

It was, like all piers, of temporary construction, and all are badly disintegrated. The coral fill, which was usually faced by steel pontoons, timber or other perishable material, might be re-used, providing the pontoons or timbers are removed first and the piers re-faced. However, there is little advantage to be gained from attempting to re-build existing piers if another location appears more favorable. Due to the fact that these islands are best approached by landing boats, piers do not seem of major importance except for personnel-handling by launches. There was no evidence of channels to approach these piers. The approaches are apparently clear sand but the average contour of the bottom appears to be no different off the face of the pier from that at the adjoining beach areas. It is believed that not much more could be gained as to navigable water by extending the length of these piers, unless such an extension went all the way to the edge of the shelf reef. In other words, the piers as they now exist, extend to about the controlling depth of the reef shelf, and, as indicated by soundings, the bottom is fairly constant for several hundred feet further off shore. It is possible that dredging would increase the controlling depth of pier approaches to some degree, but would require maintenance, due to sand accretion.

Air Strip - Eniwetok. The main air strip of the Atoll is on Eniwetok and is the source of Atoll communication with the outside world, and consequently is of vital importance to the garrison. It is an air strip having a coral surface of very smooth condition, is approximately 400 feet wide, and 7,000 feet long. It was generally in first class shape. At the Easterly end of the Eniwetok strip, there are a large number of stub ends of rubber hoses, projecting upward from the surface of the strip. This had to do with the control of drone planes during the last operation. At the present time, however, they are alarming to pilots unfamiliar with the strip, who take them for steel pipe projections. Also, there is some junk and expended, heavy equipment at the approach to the strip, which serves as a mental hazard to pilots. There is a control tower, and a seven-man crew which operates the Homing Station, serving to guide and direct planes to the Eniwetok strip. The crew which operates the strip, is housed and sheltered, in the area immediately adjacent to the strip, but are messed in the common mess hall at the administration area.

In addition to the facilities maintained by AACS (Aircraft and Airways Communication Service), the strip has at the present time emergency lighting which is maintained for night landing, adjacent to the strip and serving as special lights. There are merely surface type cones with surface wiring spread along the field. The hangars and aircraft service maintenance facilities consist of one hangar, sufficiently large to house approximately two L-5 type aircraft only.

The airport refueling consists of a portable gasoline truck, which is serving all refueling on this strip.

There are twelve (12) 1,000 barrel aviation gas tanks on Eniwetok.

It was observed that there are no air sea rescue facilities on Eniwetok island.

There is mobile fire fighting equipment at the air strip, but no ambulance facilities were observed.

Air Strip - Parry Island. Parry Island air strip has an extremely rough surface. Considerable bouncing is experienced when landing, even with an expert pilot in a small L-5 plane. The strip has a bare coral surface for only about half its length, or 300 feet, the remainder being grassy. It has high and low spots, together with hard and soft spots. The general direction of the strip is South 37 degrees West magnetic, which appears to be 27 degrees off wind. A three inch steel pipe parallels the North edge of the strip, and has one and one-half inch pipe risers at 120 feet intervals, equipped with valves for attaching hose for sprinkling the strip with sea water, all in very rusted condition. The balance of the strip is grown up in grass or weeds, and is extremely hazardous to aircraft when the bare coral strip is over-run.

It is our opinion that Parry strip is rougher than other strips due to poor sub-base preparation, and the grading has not been crowned in the middle of the strip. Therefore, standing water was observed on Parry strip, resulting in soft places. There are apparently no drainage ditches or catchment areas at the edges of the strip to accommodate heavy rainfalls.

Air Strip - Aniyaanii. The air strip on Aniyaanii reaches across the island, and the vegetation has been cleared away on both sides. However, pilots state that they do not like to use this air strip, their comment being that it is too short. It was measured and the strip found to be 40 feet wide by 630 feet long, and it could be extended 48 feet on the South end, and

60 feet on the North end. It has a steel mat surface and for approximately one-third of the length from the North end there is a hump - this may cause the feeling that the strip is too short. The bearing of the strip is South 48 degrees West magnetic, which should be within 12 to 16 degrees of prevailing wind direction. Possibly, the high palm tree growth on each side of the strip creates undesirable air currents which account for pilots' dislike of this particular field.

Air Strip - Runit. The Runit air strip is surfaced with steel matting and has a magnetic bearing of South 63 degrees East. This is probably 50 degrees off-wind. Weeds are growing up through the openings in the matting and unless some maintenance is provided in the near future, the field may become unusable. The mis-alignment of this strip may be occasioned by the fact that the island of Runit is very narrow and presents topographic limitations. The dimensions were approximated as 40 feet by 800 feet by pacing.

This air strip, as well as the air strip on Aniyaanii, Parry, Engebi, and Biijiri, do not have control towers, and are not provided with night landing facilities.

Air Strip - Biijiri. The air strip on Biijiri is poorly surfaced coral runway, which was not measured, although it is sufficiently short that only one of the two planes now operating is able to land there. On one landing, during this reconnaissance, the plane ran off the end of the runway and had to be pushed back by hand. Parallel to the existing strip is a strip partially constructed, somewhat longer but it is in a condition of being harrowed or scarified on the surface and not yet graded or rolled.

Air Strip - Engebi. The air strip on Engebi island has a coral surface, and lies South of and parallel with the original Japanese strip. The bearing taken on the air strip is South 70 degrees West, which is adequate orientation. The coral surface on the Engebi air strip is smooth and is quite satisfactory at this time. It appears to be well drained and has catch basins at intervals along both sides. There apparently is no underground drainage system, but the catch basins depend on the coral sand porosity for sub-surface drainage. The catch basin inlet grates are flush with the ground surface.

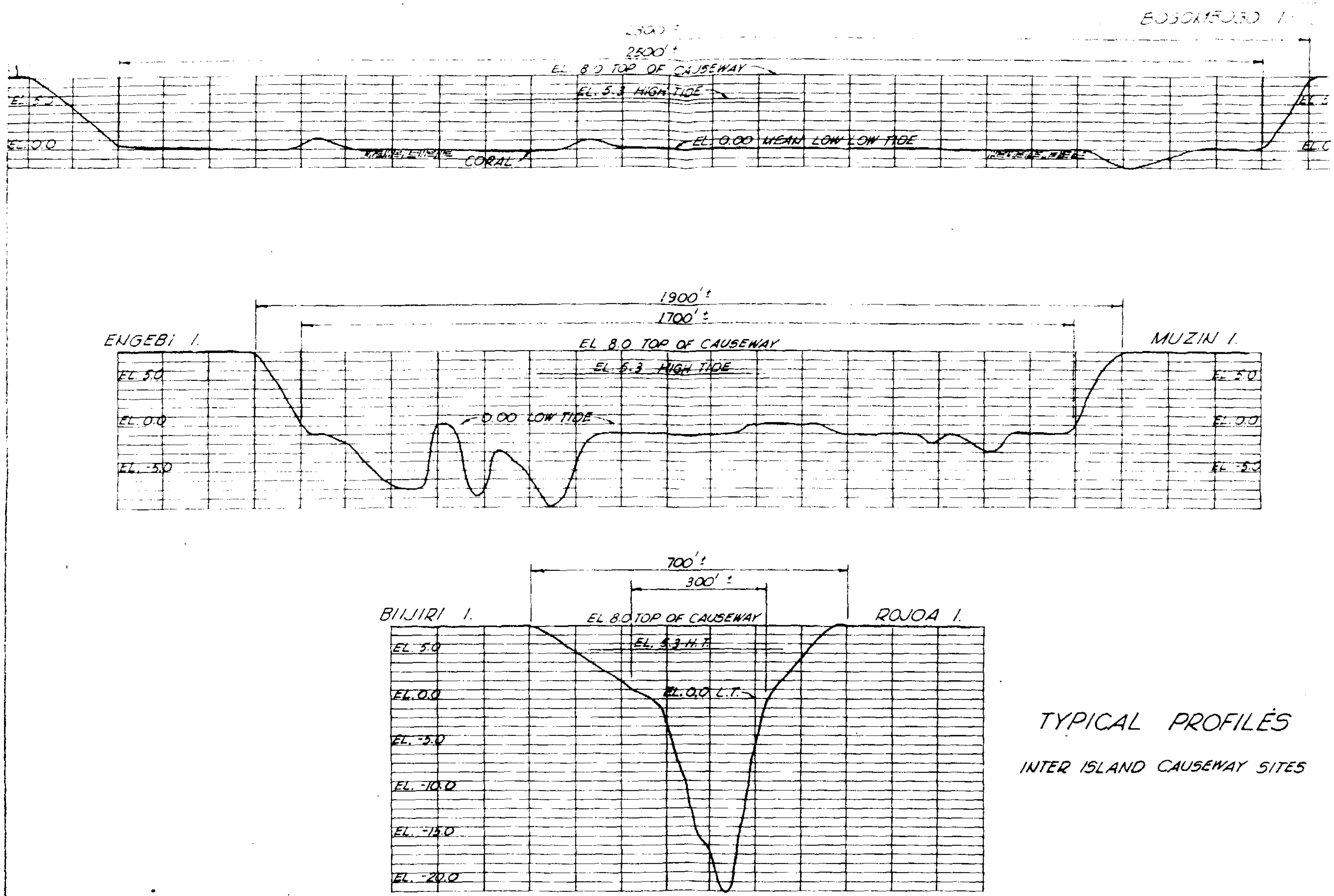
Bogallua. A reconnaissance was made of available real estate westerly of the island of Engebi for the purpose of determining a possible fourth location for an experimental site. The three islands nearest Engebi are suitable so far as area is concerned, but were not seriously considered because of their close proximity to Engebi. The most westerly island of the chain, Bogallua, appears to be favorably disposed for the purpose of another experiment, and is discussed in detail hereafter. Refer to Plate 3. Bogombogo, which lies directly northeast of Bogallua, is also suitable but does not present substantially more advantages than Bogallua. Still further northeastward the small group of three islands at Ruchi could conceivably be used by inter-connecting them with causeways; however, they are not in good alignment and would require considerable construction to inter-connect them. Bogallua has a long sand spit extending westerly from the west end of the island, which is not shown on most maps, and which makes Bogallua particularly adaptable to the purpose of an experiment. It is approximately 40 feet wide at an elevation of 7 feet above low tide, and approximately 130 feet wide between low water lines. On its extreme Westerly end there is a roughly circular enlargement 70 feet in diameter between high tide lines, which suggests a tower location. The sand spit is approximately 7 feet above low water, generally conforming to the elevation of the remainder of the island.

The sand spit contains only occasional low vegetation. The remainder of the island is covered with bushes 8 to 10 feet high, broad-leafed, tropical types, and some palm trees. It is relatively easy to clear of all vegetation. The sand spit has an attitude in collinear conformance with the axis of the main body of the island, which general axis is 60° magnetic azimuth. Rough measurement was taken in the field of the dimensions of this island; hence the map referred to in Plate 3 will scale fairly accurately for the size of the island.

Any of the islands westerly of Engebi will require more consideration to the water approach than the other islands of the lagoon, for the reason that the reef on the lagoon side is more pronounced, is in general wider, and the water which overlies it is more shallow than elsewhere. The sand spit on the westerly end of Bogallua contains some low vegetative growth which seems to indicate that the sand spit is of a permanent nature; however, future investigation should be made as to whether this sand spit is migratory in nature, or relatively stable.

A line of soundings were taken during the reconnaissance between Bogallua and its adjacent island easterly, Bogombogo. A profile of this can be seen on Plate 4.

<u>Japtan Island</u>. Although this island has not functioned in previous experiments, it deserves mention as having an elevation somewhat higher than other islands, and being possibly the most livable from the standpoint purely of housing and good camp conditions. It is covered with palm trees, has deep water close to the shore on the lagoon side, a good beach approach, and was previously used as burial ground site for American soldiers. It is now abandoned as a burial ground and bodies have been disinterred. This was originally a Naval installation during the war apparently, and there are



TYPICAL PROFILES

INTER ISLAND CAUSEWAY SITES

PLATE 4

some wuarters, buildings, and equipment on the island, including two elevated water tanks, but none of these installations appear to be now useable. The island has a pontoon pier which is now of no value as many of the plates are completely rusted out.

Parry Island. This island contains three pontoon piers, a marine railway, and a concrete seaplane ramp, all on the lagoon side. At the north end of the island is a borrow pit of rather coarse coral. There is considerable equipment and quonset buildings, but all are apparently badly rusted. At the North end of the island there is an 120-foot antenna tower used for high frequency radio. The control tower used during the last operation is of wood construction, about 11' x 11' in size, and approximately 20 feet above the ground. This is structurally in good condition. The air strip is not in good shape and is not in a condition of good stabilization or good wind orientation. All buildings are quonset huts, some with concrete slabs but most with plywood floors. In all cases, a considerable amount of repairs are required on doors, windows, screens, floors, and on some exterior sheet metal. The roads that exist would require reconditioning for use but probably could be re-located as economically as they could be re-built. Any piers required must be re-constructed or new ones built. The field power plants, water distillation units, refrigeration units, and all similar mechanical installations that still exist are rusted to such an extent that they must be considered as expended. The radio tower appears to be in good condition except for poor coating on the lower half. Also the steps forming the ladder are badly corroded, and possibly unsafe. The tower is guyed radially at the four corners from about the three-quarter point by 3/8" cables. These are moderately rusted and are attached to pieces of junked equipment lying on top of the ground, which serve as dead men.

The concrete seaplane ramp is about 50 feet wide and 100 feet long, and appears to be in good condition. It has a slope of about 6 feet more or less in 100 feet. The upper end is level with the average terrain at its termination. The piers are coral fill, faced with double pontoons. The pontoons are in a bad state of deterioration but the bulk of the fill remains intact. There is about 30 feet of fill between the pontoons. The beach approach is very favorable. The Northerly of the two piers is in better conidtion than the Southerly and is longer, being about 200 feet by 30 feet. It therefore extends into deeper water, probably six to ten feet at its face. A good sand beach continues northward from this pier. The marine railway or small boatway is located about 100 feet North of the north pier, and it consists of an angle iron as a rail, mounted on 12 x 12 ties. The gauge is 70 inches between rails. The railways appear to be in corroded condition but are still useable. The winch also appears to be in good condition, but the engine which was used to operate the winch, appears to be beyond use. The personnel pier, just North of the paved ramp, consists of a large steel barge anchored by cable. A two-inch wooden plank floor has been placed on top of the deck for additional stability, and appears to be quite necessary as the barge is heavily corroded.

Concrete Aggregates. Construction materials of this type are fairly uniformly distributed throughout the Atoll. There are a few exceptions, but in general sand is the basic soil of all the Atoll islands. This sand is apparently broken up coral, well water-worn, and not well graded, usually being uniformly coarse. Apparently the palm groves which existed on the island for at least twenty years, prior to the war, deposited a shallow organic silt on the surface of the ground which in some places is apparent, and in other places has disappeared. Surrounding the general sand bodies of the islands, and usually on the ocean side, there are occasional deposits of finger coral; - this is coarse, broken coral, only partially water-worn, apparently carried in from submerged coral heads. Most of the islands of the Atoll are surrounded and inter-connected by a coral reef which is shelf-like in character - the reef being covered by a uniform depth of shallow water, with the reef breaking off sharply on both sides into deep water. Surface of the reef is usually dense, well consolidated, conglomerate of coral and shells, apparently cemented by lime and geological phenomena. The shelf appears to be uniformly harder on the ocean side than on the lagoon side. Samples were obtained of all three general types of aggregate material mentioned, and these have been analyzed. The shelf-like reef described is a general condition extending several hundred feet on both sides of the islands of the Atoll, with the exception of the lagoon side of the most Southerly islands of the group, which have sandy beaches. On the actual shoreline of the islands, there is generally found a coral rock exposure, the type of rock being similar to the reef rock described, but having a definite dip and strike, and being in some degree stratified. The stratification appears to be accomplished by zones of very well consolidated material interspersed with zones of poorly consolidated material of the same type.

As to quantity, it is quite possible that sufficient material for the construction on any one island could be obtained on or adjacent to that island. Some checks were made on radio activing of ledge rock surrounding various shot islands; the results were not uniform. Radioactivity above background was found on Rojoa, which is the second island South of the shot island of Aomon; whereas, on the island of Engebi, ledge rock was found which had practically no radioactivity. This seems to be partly a function of whether the ledge rock sampled had unobstructed air line visibility to the top of the tower, or whether it was shielded by an obstruction in topoggraphy. In any case, the activity seems to be a surface phenomenon inasmuch as the monitoring of a sample, which is radioactive, will show one hot side and several cold sides.

Eniwetok Island - Garrison Personnel. Following is a list of Officers in the present garrison Table of Organization:

Commanding Officer, Major
Executive Officer, Captain
Adjutant and Signal Officer, Lieutenant
Supply Officer, Lieutenant
Engineer Officer, Lieutenant
Medical Doctor, Lieutenant
Air Force Pilot, Captain
Air Force Pilot, Lieutenant
Counter Intelligence Corps, No Rank

Enlisted men are rated men of various categories, 70 in number.

Garrison Power Supply. At the time of the reconnaissance, the Northerly power plant on Eniwetok consisted of two 50 KW units in 24-hour per day use, with one standby. A ten KW peak occurs between approximately 1600 and 1630. This plant is intended to provide power requirements for twelve future dependent families, in addition to a dependent laundry and an Enlisted Men's Club, as well as two existing dependent's quarters. A second power plant consists of three 75 KW units, two in standby, and one in operation at present. The operation is 24-Hours per day with a 75 KW peak occuring between approximately 0600 and 2200. The garrison has no plans to add additional loads. Adjacent to this plant are two 50 KW gasoline driven Signal Corps units. At the present time they are used only for signal transmission and movies. Its operating hours are 0700 to 1100, and 2000 to 2200. The fourth station is in the liaison hangar. It consists of one 15 KW gasoline driven power plant for lights and motors. The operating hours are 0700 to 1245 six days per week; the estimated maximum demand is 10 KW. There is a fifth station at the AACS. It consists of two 50 KW diesel units; the probable peak occurs between 0730 and 1245. At the present time they are in use 24-hours per day. The principal load consists of signal transmitters, etc., in connection with Air Forces. This is also the power source for the present emergency night lighting on the air strip. The distribution of power is by means of weather-proof wire and seems to be satisfactory, but it is not known how long the installation has been in place. The garrison has had no underground distribution experience except the service to the Administration building. In connection with electrical equipment, considerable maintenance difficulty is reported. There are three generator men on the island at the present time who operate, maintain, and adjust all the generators on the island, with the exception of those used by the Signal Corps and the AACS. The generator operators have 12 hour tours of duty each and are then off 24 hours.

Island Communication - Eniwetok. The Homer Station (AACS) at the airport is operated by seven men. The responsibility of this station is to guide and direct aircraft. They maintain and operate two Army Signal Corps BC-610 one to twenty megacycle transmitters. They have an input of approximately three KW and an output of approximately one KW. They operate on two circuits at nine and seventeen megacycles at the present time, and have been used from May through October of 1948. The receivers which are now used consist of three BC-779 Army Signal Corps units. They are now communicating with Kwajalien and Oahu by CW.

Water Temperature. Sea water temperatures observed on 13 October were 84°, while the air temperature was 82°. On the same day, during a squall, the air temperature was 81° and subsequently dropped to 78°. The sea water reading was taken at a depth of approximately seven feet, at a point immediately South of the landing on the lagoon side of Eniwetok. Another reading of 82° was taken at the Coral Head Photo Tower at 10 feet of submergence.

Water Supply. At the North end of Eniwetok there is an abandoned water distillation plant which contains twelve portable type, 3,000 gallons per day capacity, Cleaver-Brook units. These units were operated by internal combustion engines, and the mechanical difficulties of trying to maintain and operate these was such that their operation has been discontinued by the garrison.

It was learned that the per capita consumption of water on Eniwetok averaged somewhat less than 100 gallons per day per capita. This usage is broken down in the following manner: 1,000 gallons per day of salt water for flushing toilets, serving about 15 people; 2,500 gallons per day of fresh water or distilled water; 3,500 gallons per day of brackish well water for a total of approximately 7,000 for a population of 80, more or less. The well water was used for laundry, showers, and lavatories for enlisted personnel. This distilled water was made from sea water rather than from brackish water, and served about 15 people, whose entire water supply was this distilled water. The Mess Hall used distilled water for all purposes. Their present plant consists of five 3,000 gallons per day distillation units and supplies the entire island. One additional unit is used as a stand-by or as supply for spare parts. The air strip drains directly into the site of the main well from which the brackish water supply is now taken.

In connection with the distribution of distilled water, it was generally concurred by all using parties, that lower pressures were advisable for distilled water distribution systems, and that a separate system for fire protection using salt water was advantageous in situations similar to these.

Sewage Disposal. Sewage disposal is handled on Eniwetok by the discharge of raw sewage into the sea. Garbage is disposed by dumping at a point on the extreme Southern end of the island. Garbage appears to be entirely effaced between dumpings, due to the strong tidal currents which pass this area. This is no evidence of a nuisance at this disposal point.

Fuel Storage Facilities. It is understood from the reconnaissance that there are two 1,000 barrel tanks for diesel oil, and twelve 1,000 barrel tanks for aviation gas on Eniwetok, and three 1,000 barrel tanks for aviation gas on Parry. Motor gas was stored only in drums. Submarine lines were used to receive the fuel, a four-inch steel pipe for receiving diesel fuel, and a six-inch steel pipe for receiving aviation gas. Both receiving lines are of welded pipe.

Electrical Distribution. Electrical distribution on Eniwetok, which is the only island now possessing electrical distribution, consists of 120/208 volt, 4-wire Y distribution directly from the five generating stations previously mentioned. All of this distribution, with a very few exceptions, (individual services to individual buildings) is overhead on poles, and little difficulty has apparently been felt in maintaining and using this.

Buildings. Hardware on buildings is very short-lived at Eniwetok, especially if any portions thereof are of steel or iron. Window screens, even of bronze or copper, are not satisfactory, partly due to rapid corrosion and partly due to the fact that salt spray makes a deposit in the screens, which in a very short period of time reduces radically the effective passage of air. It was observed in Kwajalein that there is a tendency to place an emphasis on insect control in lieu of screening, thus obtaining maximum ventilation.

Fastenings in buildings, such as nails, etc., even though galvanized, do not stand up well.

All plumbing appears to be in rather deteriorated condition. Piping outside of building is, in general, very shallow, being entrenched into the ground only a few inches. Some steel pipe, having been in the ground only about six months, was badly deteriorated.

An inspection was made of various refrigerator units and, in most cases, the refrigeration equipment had deteriorated beyond the point where it would be feasible to recondition or re-use it in future operations. The refrigerators are typical Army portable, walk-in reefers, and generally lined with galvanized sheet metal which shows deterioration in many cases.

On the north end of the island, a large Club building exists in fair condition; however, the plywood floor areas are deteriorating and will need rehabilitation. The metal roof is rusted, and in the main barroom portions of the plywood floor are in bad condition. The building contains a Mess Hall in which the refrigerators are in good condition. There is a Cleaver-Brooks steam generating unit located where it is unprotected from the weather, and consequently it is rusted badly and cannot be re-used. An outdoor reefer, 8' x 12', and 6-1/2' high is in fair condition. The refrigerating machinery is exposed to the weather, however, and is in poor condition. There are several small Navy portable type reefers, 5' x 6' x 5-1/2' inside, condition is poor and probably these cannot be re-used. In the kitchen, such items as sinks, steamtables and dishwasher, are in bad shape, and two oil-fired ranges are of doubtful value. The five steam-jacketed kettles are in fair condition. There is also a Blakeselee mixer in fair condition.

The quonset huts for quarters are all in poor condition. A few are being maintained and are useable, but it is estimated that within six to nine months they will also be structurally unsound.

The garrison operates an ice cream freezer with a two and one-half gallon capacity for each ten minutes of operation, with a forty-gallon storage capacity in the same unit. This is serviceable and is used at present. There is an active freezer unit in operation and one in the warehouse. The present ice cream-making equipment could accommodate approximately three times the present personnel by daily operation.

The electric wiring in buildings was observed to be mainly exposed, non-metallic, sheathed cable with porcelain sockets, surface mounted. Some of the wiring was similar but concealed rather than exposed, and some was straight knob and tube wiring. Corrosion of sockets was noted in a marked degree in almost every case. For distribution in individual buildings, Multibreaker units were extensively used.

Guest Quarters - Eniwetok. Accommodations being maintained for guests consist of the so-called "VIP" quarters, which are in a double-decked quonset. On the upper deck, there are ten single rooms, with no washroom facilities. The lower deck contains five double rooms and three single rooms. There are two washrooms on this floor, in one of which the single toilet is inoperable. The other washroom also contains a single toilet. There are three showers and six wash basins in the two rooms. The building, structurally, is in fair shape; galvanized exterior having been maintained possibly better than some other buildings. The building requires some rebuilding, however. The upper deck is supported on steel members and extruded metal contacts between plywood sheets of flooring show signs of corrosion. The seaward face of the building is continuously screened and these screens are corroded and the meshing clogged. This building, however, can probably be maintained to survive. The building used for this purpose during Sandstone is also in good condition, but is now occupied and used as a Dispensary by the Medical Doctor in the garrison.

Equipment Maintenance. Adequate personnel, shops, and repair parts stock levels for garrison in the location of Eniwetok require more than the usual facilities for a garrison of this size, due to the accelerated depreciation of mechanical equipment. Any increase in the service demand of this garrison will require some attention to expanding these facilities.

Corrosion. There is an airplane dump on the oceanside of Eniwetok, where damaged, wartime aircraft are deposited, and these were examined for the effects of corrosion on metals of various types. They are exposed partly to tide and partly to salt spray, with alternate submerging and drying. It appears that all dural sheets, rivets, and forgings are in good condition, and the joints between these various parts did not show any sign of deterioration. There are signs of oxidation on some parts of other alloys, but this is negligible on the dural sheets. Copper tubing was in fair shape, although corroded. Cadmium-plated parts and steel bolts had broken down and were showing extremely advanced rusting. Chromium-plated parts were generally in good shape, but where the chrome had worn or was not of continuous bond, rust was appearing through the surface. Bronze parts were in good shape. Cast iron parts had surface rusted but were in fair shape. There is a large Butler rigid-frame warehouse which is covered with sheet aluminum, and which has been in existence for several years and is in excellent condition. It appears, in general, that certain aluminum alloys are an ideal material to withstand this climate. The climate is characterized, so far as corrosion is concerned, by a constant spindrift or salt spray conditon. The flat shelf of the reef on the oceanside of the islands breaks up the ocean swell into long surf lines which give rise to a cloud of spray, and the relative humidity being very high, this spray drifts with the tradewinds across the islands and through the buildings, making ideal conditions for rapid corrosion.

Laundry Facilities. Laundry facilities even for the reduced garrison are very poor. The laundry facilities for existing garrison consist of a washing machine of the Sears Roebuck family type, in rather poor condition, and there is, in general, no hot water. The large volume laundry required by the garrison for such items as sheets and bedding are transported to Kwajalein Island for this service. This requires several weeks' time, a period which the present stock level of linens on Eniwetok does not permit.

Vehicle Maintenance. The Engineering Officer at the garrison reports that at the time of the reconnaissance, he had two men maintaining thirty-one pieces of rolling stock. There are no diesel mechanics.

Stock Levels. At Warehouse "H", on Eniwetok, during the reconnaissance trip, the following rough inventory of the type of material observed to be in storage was made:

Certain amount of Accurate rubber tape, 3/4" x 30', Federal Spec. EHHT-111A, manufactured in March 1945.

Several boxes of carpenter tools.

Several boxes of Rubberoid Rapid Asphalt Paint.

Number of miscellaneous boxes.

Miscellaneous building wire for electrical construction, perhaps thirty 500-foot reels of miscellaneous sizes and miscellaneous types.

A number of 20-foot creosoted poles.

Ten piles of assorted lumber (varied in size), from possibly two by sixes to six by tens.

The following list of material was observed at Warehouse "E", on Eniwetok:

A large number of Superflash and Superflood lamps - several boxes of them.

20 boxes of acid for storage batteries.

A submarine hatch.

Approximately 50 storage batteries, dry and uncharged in their original boxes.

Two dismantled 75-foot towers.

In the open warehouse immediately North of Warehouse "D":

Two boxed Amtracks.

In Warehouse "D":

Approximately 100,000 feet of cable on twenty reefs. The reels were approximately seven (7) feet in diameter, and the label indicated 228.0 cu.ft., weight 12,718, General Cable, type 115-P. This is ten-conductor armored submarine signal and control cable.

A total of 218,900 feet of this type of cable is reported to be surplus from the previous operation stored on Eniwetok and Parry.

Some Simplex wire, submarine cable type 104 - this is three-conductor signal and control type.

Some Phelps-Dodge-Habirshaw cable, of the Habirshaw Cable and Wire Division, Type 104, three-conductor signal and control.

Behind the Quartermaster and Engineer Warehouses:

Six large reels of submarine signal and control cable.

The last-mentioned reels of cable are on two trailers in the open and are unprotected from the elements. The garrison was requested to haul these trailers into a warehouse or cover them with tarps.

The supply stock level reported by the garrison is equivalent to the needs of 100 men for a period of six months. In addition, a small PX store issues the usual basic requirements. The signal officer reports that all radio equipment is fungus-proof but not rust-proof, and that the high humidity presents considerable difficulty in maintaining equipment. The transmitters are kept on 24 hours per day in order that the heat generated will prevent damage from humidity. Areas which are not involved in the mechanics of equipment are kept wiped with diesel oil. The main telephone cable termination has been inclosed and four (4) 100 watt light bulbs are continuously left burning in the inclosure in order to reduce moisture and corrosion. Present telephone cables on Eniwetok have been installed approximately four years and present indications are that the existing cable is in good condition. Future life, however, is unpredictable.

Construction Equipment. The following is a list of operable construction equipment available on Eniwetok during the reconnaissance:

1 - 1/2 yard Concrete Mixer in running condition.

1 - 3/4 yard Northwest Crane which can be repaired.

1 - Gallion Motor Grader with 12' blade, in running condition.

1 - 20-ton Link Belt Toad-type Crane which needs repairs.

1 - 10-ton Road Roller in running condition.

1 - 1-1/2 yard Carryall Scraper which can be repaired.

1 - 20-ton Quick-way Crane which needs slight repairs.

1 - 20-ton Quick-way Crane in running condition.

1 - Angle-Dozer, Size D-8 in running condition.

1 - Ditch Digger which needs repairs.

2 - Sheeps Foot Rollers

Submarine Cable. The inter-connection of signal and control terminals on various islands by submarine cables was observed during the reconnaissance trip, and both the ten-conductor cables and the three-conductor were tested by methods described under "Design" in this Report. In general, cables emerge from the water to beaches in a condition of exposure. In some cases, there is excess length of cable on the beach and some damage has been effected by boat landings and by abrasion, possibly due to the scour of sand. In most cases, the armored cable was in excellent condition and not damaged, although there was one instance in which a boat or some other object had crushed a portion of it on the beach. Jute wrappings outside of the armor are in many cases frayed. Cables extending across the reef and dropping into the deeper water of the lagoon have not been sanded up to any great extent and may be traced visually from low-flying aricraft.

Conclusions as to Findings. General summary of the conditions found at Eniwetok Atoll during the reconnaissance trip of October, 1948, is that most existing installations are of temporary character, and deterioration has been well advanced. The garrison is unable to adequately maintain more than the minimum requirements for their own housekeeping. Transportation by water and air within the lagoon is at a minimum; air transportation being at present somewhat more reliable than surface transportation, due to relative condition of equipment. The shot islands are in a condition of residual radio activity to a moderate degree which can be compensated for by a grading program. Special blast resistant buildings used in the previous operation are in good condition and may be used again. Submarine cables interconnecting the islands are in good condition and may be used again, with protective maintenance on landing. Existing photo towers used during Sandstone are in good condition and may be used again. Buildings of the garrison and on Parry Island are largely quonset huts, and all sheet metal except proper aluminum alloy has been subjected to accelerated corrosion; therefore, all buildings appear to be short-lived.

Summary of Existing Conditions at the Atoll.

(a) Signal facilities are functioning adequately for present purposes.

(b) Fuel oil and gasoline storage is adequate for present requirements.

(c) Distillation units for fresh water supply are in need of maintenance and probably early replacement. There is no other source of fresh water although a brackish water well exists in the air strip area.

(d) Refrigeration facilities are adequate for the present garrison but inadequate for expanded requirements, and are in need of mechanical maintenance.

(e) Electric Generators are adequate for the present garrison but require constant maintenance and probably have a relatively short life.

(f) Sanitary waste disposal is adequate for present forces.

(g) Garbage disposal and trash incineration is adequate.

(h) Laundry facilities inadequate for any increase.

(i) Shop and repair facilities inadequate as are all maintenance requirements of supplies, tools and materials.

(j) Messing and baking facilities adequate for present garrison.

(k) Water transportation inadequate.

(l) Land transportation inadequate.

(m) Air-sea rescue - non-existent.

(n) Limited fire protection available is adequate only under present conditions of depreciated values.

(o) Post Exchange and stock level of PX items is adequate for minimum present needs.

(p) Recreation is limited, and club stocks are in poor supply.

The following buildings are at Eniwetok Island, are in a useable condition but require maintenance if they are to be perpetuated:

The Island Command Family Quarters.
The Island Command Headquarters Office.
The Dispensary.
The VIP Quarters.
Certain Warehouses.
The Mess Hall.
The Signal Building.
Certain Enlisted Men Barracks Buildings.
The Officers' Club.
The Chapel.
The Moving Picture Theater outdoors.
Airport Facilities.

Quotations. The following information and opinions were derived from unofficial discussion with responsible personalties at Kwajalein during the reconnaissance.

While it cannot be classified with the factual findings of the reconnaissance, it is believed to be informative, and it suggests aspects of the proving ground program not otherwise covered in this Report.

General content is emphasized more than precision or completeness of quotation, and conversation is paraphrased.

Kwajalein Atoll. At Kwajalein, during the passage of the reconnaissance team through that station, the utility and construction problems on Kwajalein were discussed. It was said that if the AEC authorizes further experiments in the area similar to Sandstone, the load imposed upon Kwajalein by the operation would be so great as to require additional capacity in present planning and construction. It was also said that AEC should participate in the cost of Kwajalein facilities if the Eniwetok proving ground was to be continually used. The basis for the reasoning is that Kwajalein would always remain the point of logistic support for Eniwetok, a key communication point for Eniwetok, and the present Naval Command which has jurisdiction over Eniwetok is centered at Kwajalein. In addition to this, the operation of drone planes during an experiment, if accomplished similarly to Sandstone, would impose a load upon Kwajalein comparable to that of Sandstone. The 14th Naval District Public Works Office has substantially completed design for Kwajalein facilities on the basis of a five-year program, and a fee contractor under contract to the 14th Naval District is operating at Kwajalein. The population of Kwajalein is about 2500, which the Commanding Officer says might be doubled during an experimental period at Eniwetok similar to Sandstone. All population at the Kwajalein Atoll is housed on the one island of Kwajalein. In connection with the mission of Kwajalein to support logistics for Eniwetok, it was stated that the Eniwetok garrison can sustain 50 guests, which Kwajalein could build up to 200. Any water transportation, either for freight in excess of 1,000 tons, or for transportation of personnel and material within the lagoon of Eniwetok under present arrangements would be supplied by COM-SERV-PAC.

In Kwajalein, they have had a great deal of difficulty with insulators on power distribution poles becoming encrusted with salt and arcing over. There is no record of any trouble of this sort having been reported on Eniwetok. However, the distribution on Eniwetok is a 220 volt system, and it is quite likely that they would not be faced with the same trouble as Kwajalein utilizes a 4,000 volt system.

CINCPAC, Pearl Harbor. Staff Officers in CINCPAC, COMSERVPAC, and 14th Naval District Public Works Office, were interested and cooperative during the routing of the reconnaissance party through Pearl Harbor. The command set up several conferences at which the engineering and construction experience of naval forces in the Atoll areas were discussed, as well as some of the major problems of operation Sandstone.

SECTION III

STATEMENT OF CRITERIA

GENERAL REQUIREMENTS:

The following definitive criteria were formulated in conferences with J Division, and constitute basic assumptions as to forward area planning.

Land Use, Experimental. Certain of the easterly chain of Eniwetok Atoll islands used in operation Sandstone would be designated for re-use as shot locations; these are Engebi Island, Aomon Island and Runit Island. In addition, a fourth test location would be considered.

Time Basis. The proving ground use period, as a basis for economic studies, would be the time required for two groups of tests, each group consisting of three or four weapon detonations, preceded by the necessary period of construction and preparation. After each group of tests, a roll-up period would ensue.

Land Use, Residential. Complete facilities would be provided for subsistence, quarters and supporting services, to accommodate twelve hundred persons, half military and half civilian, land based on the larger, southeasterly islands of the Atoll. Of this population, two hundred would be scientific personnel. Present garrison facilities would be perpetuated.

Camp facilities would be provided at or adjacent to each shot island, for the temporary accommodation of two hundred persons during construction, and during preparation for a test.

Land Use, Functional. The existing military garrison would continue to occupy Eniwetok Island. Parry Island would again function during a test period as the control point. Aniiyaanii Island and the Coral Head in the lagoon would again function as photo points. Experimental islands would function only as weapon detonation areas.

Special Buildings. Blast resistant buildings which survived previous tests would be again used and will be re-oriented as needed. Additional experimental structures would be later specified. On either Eniwetok Island or Parry Island, in addition to quarters, utilities, camp services, recreation facilities, shops, and warehouses, there would be a headquarters building, to contain office administrative space, main communication center, and photographic, instrument, and radio chemical laboratories. Existing buildings are to be rehabilitated wherever practical.

The control room and tower on Parry Island should be retained, but a new ground-level control center should be erected.

Special Structures. Towers to contain the weapon for a test shot are desired in a height of three hundred feet if practicable, taking into consideration mass of tower, and cost, and should be equipped with a power lift. Ground preparation around these towers should include reduction of present radioactive contamination to daily tolerance, if feasible, by excavation and filling. Preparation also includes paving and soil stabilization as a dust pallative prior to the next test.

Inter-Island Communication. An adequate, reliable communication system is important and should be provided with a back-up or emergency system. A main communications center should be provided at the headquarters building with adequate connections to sub-communications centers on or near each shot island, and to military radio links.

Test control circuits, independent of other circuits, are desired.

Inter-Island Transportation. The transportation of people, equipment and materials between useful islands of the Atoll should be provided for by a consideration of island inter-connection, air and surface transport, and the economies of pertinent facilities and structures.

Electrical Power. Electrical power should meet exacting requirements of operating reliability and voltage regulation. Economic studies should be made of feasible alternate solutions to the problems of generation and distribution. Power should be provided for the islands of Eniwetok, Parry, Aniyaanii, each shot island and Coral Head.

Water Supply. A dual water supply should be provided on each residential island; a salt water system and a fresh water system.

Waste Disposal. Adequate sewage collection systems, and sanitary disposal of sewage, trash and garbage should be provided on each residential island.

Maintenance. Repair and maintenance of existing utilities and buildings at Eniwetok Island and Parry Island, as well as proving ground facilities elsewhere in the Atoll, should be proposed.

PLANNING:

Selection of Shot Islands. The determining factors in a choice of shot locations are unit area and geographical separation. Among the requirements of a shot island, or group of islands used together for one shot, are:
(a) that the Zero Towers be at least three miles apart, (b) that the Zero Towers be remote from the Control Station and, (c) that the Timing Stations must not be closer than one thousand yards from zero.

These requirements eliminate the use of any island for a tower location south of Runit, as this island is the nearest one to Parry Island having sufficient length to locate the Timing Station one thousand yards away from zero. Going north, the next group of islands having sufficient length is that consisting of Aomon, Biijiri and Rojoa. This group can be used again as it was for operation Sandstone. The requirement of three miles between towers eliminates all islands between Aomon and Engebi. Engebi Island meets the requirements and was used in earlier tests. Therefore, the three previous locations can be re-used and it is necessary to go to the west to select another island to be used for the fourth location.

If the Zero Tower were located near the west end of Elugelab Island, sufficient distance could be obtained by placing the Timing Station on Teiteiripucchi Island. There is considerable water distance between these islands requiring a much longer causeway than was constructed between Aomon and Biijiri for Sandstone.

Another possible location is Bogallua Island which is at the extreme west end of the chain of islands at the north. There is a sand spit extending from the west end of this island that is not shown on a map published by the Hydrographic Office of the U. S. Navy in March 1946, but by examination of aerial photographs made in October 1947 and by observation of the reconnaissance party in October 1948, it appears evident that this spit exists and may be considered permanent. Locating the Zero Tower near the west end of the spit, the Timing Station can be placed one thousand yards away. There is also space on this island for a camp and airstrip. A rather long approach is required to reach the edge of the reef on the lagoon side, but a similar condition also exists at Elugelab. Bogallua Island seems more desirable, since no causeway is required and it is recommended as the selection for the fourth shot island.

Experiment Island Living Camps. It is considered desirable to provide temporary living quarters, which are either expendable or easily removable, either on an island adjacent to each shot island or on the shot island itself. The location on an adjacent island is preferable due to palm trees providing some shade, and less risk of radioactive contamination. However, on the basis of two uses of the facilities, it is difficult to justify a very great expenditure for causeways or other means of connection between the islands. Alternatives are discussed under Section IV, but for planning purposes it is assumed that economical solutions such as floating connections present operating difficulties sufficient to disqualify them.

Neither Aomon or Biijiri offer an area suitable for the camp and the water distance between Biijiri and Rojoa is relatively short, considerably shorter than between Engebi and Muzin or Bogallua and Bogombogo. In this case, it is recommended that the living quarters, sub-communication center and other facilities be located on Rojoa Island.

There is no other island within reasonable distance of Runit Island and since this island is nearly two miles long, it is recommended that the living camp be located at the south end of Runit.

Engebi Island is the largest island used for tests and there is adequate room for a camp. In addition, the length of a causeway to the adjacent Muzin Island makes the cost of such a connection unjustifiable for only two uses. A ferry or other floating connection is feasible, if operational conditions permit, but is not now recommended.

The distance between Bogallua Island and the adjacent Bogombogo Island is so great that it appears that the camp should be located on Bogallua Island, even though this island is small and will be somewhat crowded.

Proposed site plans will be found in Section IV.

Use of Eniwetok Island. During previous tests, headquarters for all services were on Eniwetok Island and all personnel, quartered on land, were housed in quonset buildings on this island. The steel quonset type structures have rapidly deteriorated until now very few are in usable condition. As a consequence, the present garrison occupation is scattered from practically one end of the island to the other, using remaining facilities.

To use Eniwetok as in the previous tests, the first construction required would be to regroup the garrison, and erect new buildings in one limited area. This would be necessary in order to remove buildings unfit for continual use, and to make way for a reasonable arrangement of new facilities for a large increase of population.

The advantage of doing so, in making Eniwetok the base island would be proximity to the air field and minimum duplication of existing facilities. Also, new construction would be readily accessible to the permanent garrison for use and maintenance during roll-up.

Use of Parry Island. Parry Island was used previously as the test control point, and as discussed in basic criteria, would be so used in the future. This implies certain utilities and quarters; and assuming a partial occupation of a base island other than Eniwetok, then several advantages emerge in favor of making Parry Island the base for Laboratory personnel and fuctions. The headquarters building, with its laboratories, communication center, and office space would thus be near the test control room, and quarters of personnel would be adjacent to both.

Only such repair or construction work need be immediately undertaken on Eniwetok as is required to meet the garrison needs at that time. A construction camp may be started at once on Parry Island and housing and other facilities that will ultimately be used by Laboratory personnel be erected for the use of the construction forces. This program would speed up construction and reduce cost.

The use of Parry for Laboratory headquarters has certain advantages during test operations. The scientific aspects of the tests carried on by the Laboratory could be accomplished without the congestion of different chains of command operating in the same camp. Parry Island is closer to shot islands than Eniwetok, and, therefore, shortens transportation routes. There is more available real estate on Parry Island, the use of which permits no disturbance of present disposition of garrison forces on Eniwetok Island, and permits more latitude for military expansion on Eniwetok.

The assumption is made that the weapon assembly will be ship-based, but ample ground space is available on Parry Island to lay out all structures required for a land-based operation. If the decision is made to make this a land-based operation, the necessary changes in planning, design and construction could be quickly and easily made.

The advantages appear to be in favor of Parry Island as a base camp for the Laboratory functions, and Eniwetok as a base for other services. This assumption is, therefore, made in following discussions.

<u>Island Connections</u>. The islands of the Atoll are connected by a coral reef which is barely awash at low tide. Between Eniwetok Island and Bogallua Island, there is only one break in this reef. The so-called "Deep Passage" is between Parry and Japtan Islands. The idea of connecting the several islands by means of causeways, bridges or combinations has been given consideration.

A connection between Eniwetok and Parry Islands would, in effect, make these two islands one, since it would be possible to go from any place on either island by land vehicles.

An economic study of such a connection was made. A causeway of filled ground was determined to be feasible, constructed of reef material in an earth-filled section. The cost of such a connection might approximate $1,428,000. It is not considered justified for the use criteria specified. For planning purposes, therefore, boat transportation is assumed between Eniwetok and Parry Islands, and personnel piers are located at the nearest ends of both islands, resulting in a boat trip of two miles. Other locations where road connections would be advantageous are: (a) from Rojoa to Biijiri, (b) Muzin to Engebi and (c) Bogombogo to Bogallua. These causeways would make possible the location of the living camps on the first-named islands, where there are trees, and camp conditions are better. Connections of any type between islands would be beneficial but costly. With the exception of a connection between Rojoa and Biijiri, it is believed the cost would not be justified on the basis of only two series of tests. The water distance between Rojoa and Biijiri is short and the area on Biijiri that is available for a camp site is entirely bare. Under these conditions, it is believed the cost is justified, so studies have been made of several methods of accomplishing this connection. In Section IV will be found a complete discussion of each method.

Materials. The climatic conditions at the Eniwetok Atoll are such that Materials ordinarily used in construction deteriorate rapidly and are not suitable, even on the basis of a short period of use. Careful consideration, therefore, has been given to selection of materials which are resistant to high humidity and to salt spray.

Airplane Requirements. For inter-island air transportation, L-5 planes were used during the last operation and proved satisfactory. Consideration should, however, be given to commercial plane types carrying two or three passengers. Planes requiring short runways are a distinct advantage inasmuch as the available space, in the direction of the prevailing wind, is very limited on some of the islands. The wind is so constant in direction during the spring of the year that single strips on each island will be adequate. A detailed discussion of requirements and the method of handling will be found in Section IV of this Report.

Design. A complete discussion of the many design problems involved constitutes Section IV of this Report. The governing criteria has been that the engineering requirements are special in nature, calling for original thought, and subject to possible changes as scientific discoveries develop and crystallize. It is understood that many things will be done that have never been done before, and this Report has been prepared with the thought in mind of meeting this challenge with engineering flexibility.

Construction. The problems of construction have been carefully considered, and Section V is devoted to analyses of these problems and recommendations of procedure. The time schedule has been developed to spread the construction operations over the entire period prior to the next test, in order to effect economies in these operations. The longer the construction period, the smaller will be the number of men required to do the work and the more efficiently these men can be employed. The work has been conceived and presented in Section V in five phases. Recommendations relative to operation during tests and during the roll-up are given in Section VI and Section VII of this Report.

SECTION IV

DESIGN

GENERAL:

The design of facilities for the Proving Ground will be based on information relative to the experimental operation furnished by J Division, information obtained by our reconnaissance party when the Atoll was visited in October 1948 and on economic considerations consistant with good engineering practice.

Materials. The condition of various materials was noted by the reconnaissance party and the findings are described in Section II of this Report. Because of the rapid deterioration of many materials, when exposed to the extremely corrosive action of high humidity and salt spray, much thought has been given to the selection of materials of construction and the protection thereof.

Planning. Planning will be based upon the program of two sets of experiments extending over a period of not more than five years, including construction and preparation for the tests. However, this policy is not to be construed as limiting the type of materials to a five year life, but rather that in justifying an expenditure only two sets of tests are to be considered. In the selection of materials and methods, utmost reliability is the most important factor to be considered. This subject has been discussed in greater detail in Section III of this Report.

The number of people to be provided for and the location of the population has also been discussed in Section III. The planning and design of facilities, as described in this section, are based upon the above criteria, that is: (a) New facilities for 600 people are provided on Parry Island, (b) maintain or replace existing utilities on Eniwetok Island and provide the necessary housing and facilities for approximately 600 military personnel, including Air Force and outside communication forces, as the present structures on this island will be largely unusable by the time they are required for the next experiments, (c) new facilities for approximately 200 on each of four islands; namely, Bogallua Island, Engebi Island, Rojoa Island, and Runit Island, which will be used during the preparation period for each test and will be either expendable or of light construction that can be readily and easily removed from these islands and stored on Parry Island during the roll-up or interim period.

The islands that constitute the usable land areas of the Atoll and with which this project is concerned, consist of separate deposits of coral sand supported by a shelf-like reef. These deposits have been built up to elevations varying from 8 to 15 feet above the level of the reef proper and also very considerably in size. The elevation of the reef proper is such that at periods of low tide, it is barely awash. The Island of Eniwetok, the largest of the Atoll, has an area of approximately 355 acres. Bogallua, probably the smallest island considered for possible exploitation by this Report, has an area of approximately 23 acres.

SURVEYS:

General. Section II of this Report describes the survey work that has been done at the Atoll with comments as to accuracy and adaptability to this project. The following describes proposed permanent horizontal and vertical control and scope of field work to be performed in connection with the design of the facilities. Field work necessary for construction is covered in Section V.

Permanent Horizontal Control. A control network based on the following recommendations would provide adequate primary control for any contemplated operations.

(a) Accept the geographical location of station North Base and the azimuth of the line from station North Base on Runit Island to station Sand on sand spit south of Runit, as established by the Naval survey. At a later date, if requirements warrant, re-observe for position and azimuth, and make necessary adjustments.

(b) For preliminary computations and design, accept length of base line established by the Joint Task Force Seven survey. Re-measure this line, if field work indicates it desirable, as insurance against an error in existing measurement.

(c) Establish a new network to meet the requirements of this project, incorporating into the scheme any existing stations or towers which would reduce the cost without sacrificing accuracy.

(d) The proposed scheme to be of second order accuracy from Parry Island on the south to Bogallua on the north. The tie to Eniwetok Island may be less than second order, but this is justified by our present understanding that Eniwetok will not function in scientific experiments.

The enclosed illustration Plate 5 shows the relation of the proposed net the the project areas.

(e) This scheme could be expanded to cover the complete Atoll if justified by future requirements.

(f) Second order accuracy expressed as a linear ratio allows a discrepancy between computed length and measured length of base or adjusted length of check line not to exceed 1 in 10,000.

Expressed as an anuglar error, the discrepancy in the average triangle closure shall not exceed three seconds, and the maximum discrepancy in any single triangle shall not exceed eight seconds.

Method of Survey. The proposed survey procedure will include the following operations:

(a) Where practical, existing station monuments of the two previous surveys will be recovered and incorporated into the proposed scheme. A minimum number of stations will be tied in to allow a check to be made between the results of this survey and that of the Joint Task Force Seven Survey.

(b) Existing towers can be adapted to the requirements of the survey and new towers erected at remaining locations as shown on following list:

TOWER ERECTION

Location	Station Name	Description	Required Elevation
Aniyaanii	Kodak	Use existing steel tower	Elev. 30'
Parry	Steel	" " " "	Elev. 30
Eniwetok	Priviledge	" " " "	Elev. 30
Lagoon	Photo	" " " "	Elev. 26
Runit	N. Base	Erect new 15' tower	Elev. 20
Runit	Runit	" " " "	Elev. 20
Engebi		New 10' tower on existing concrete structures	Elev. 25
Aomon		New 10' tower on existing concrete structures	Elev. 25
Lagoon		Erect new 25' tower	Elev. 15
Eniwetok (S)		" " " "	Elev. 35
Bogallua		" " " "	Elev. 25
Sand Spit	Sand	Erect new 10' tower	Elev. 10
Lagoon	Coral	Erect new 15' tower	Elev. 22

4 Stations - use existing towers
3 Stations - erect 25' towers
3 Stations - erect 10' towers
3 Stations - erect 15' towers
13

Adapting the four steel towers to survey requirements will consist of constructing a platform at the twenty-five foot level and erecting a wooden instrument tripod to the twenty-nine foot level. These heights may be modified after obtaining the heights of the tower bases above the level of the lagoon. Allowance is made for curavture of the earth and a ten-foot minimum clearance above the lagoon for the line of sight between stations.

Recommendations. It is recommended that four Bilby portable metal towers of the type used by the U.S. Coast and Geodetic Survey be obtained for use in this survey. These portable towers would reduce the time and expense of tower erection and would considerably reduce the expense involved in prefabricating and shipping wooden towers. Comparative requirements are shown.

If Bilby towers are obtainable they can be moved to new locations as observations of portions of the scheme are completed. Higher towers would be practical thereby reducing heights at other stations. The total requirements would be four Bilby portable towers and material for three ten and one fifteen foot wooden tower.

If prefabricated wooden towers are used it would not be practical to move them to new locations or to use higher towers. Total requirements would be three twenty-five and two fifteen foot prefabricated towers and instrument tripods, four prefabricated twenty-nine foot instrument tripods and materials for three ten and one fifteen foot wooden tower and tripod.

The additional temporary station to be established in the lagoon will require soundings to determine the contour of the bottom and prefabricating a base which can be dropped in place and weighted with sand bags.

Observations will be made at night by means of target lights and will follow accepted procedure of the U.S. Coast and Geodetic Survey. Radio communication between the observer and light tenders is recommended, but satisfactory communication can be obtained with signal lights.

A field calculation of the scheme will be made and sent to the design office for checking.

Station markers will be referenced to prevent loss by subsequent operations in the vicinity.

Permanent Vertical Control. To establish an accurate datum for vertical control would involve tidal observations over an extensive period. It is recommended that such observations be taken in cooperation with the U.S. Coast and Geodetic Survey.

This consists of setting up an automatic tide gauge if one is not in operation at the Atoll, and a periodical servicing of this instrument. It is believed that the Coast and Geodetic Survey would install the gauge and that operation of it would require very little time of this organization.

The Los Angeles office of the U.S. Coast and Geodetic Survey states that a project is under way to establish a datum for vertical control throughout the Pacific Island areas. This operation is reported to be in conjunction with the U.S. Army and will extend over a four-year period. It is believed that more definite information can be obtained from the Honolulu office of the U. S. Coast and Geodetic Survey.

It is recommended that the U.S. Coast and Geodetic Survey be advised that further tidal and current data are of interest to the AEC project, and that the U. S. Coast and Geodetic Survey be requested to make Eniwetok an observation point in any scheme of vertical control planned for North Pacific areas.

Tidal Datum. The tidal datum used for this area is Mean Low Water Springs, which may be defined as the mean of the low waters of the spring tides which occur within a day or two after the moon is new or full.

Tide predictions are obtained from the U.S. Coast and Geodetic Survey publication, "Tide Tables of the Pacific and Indian Oceans", and includes the following data for 1949 at Eniwetok Atoll:

Mean range	2.7
Spring range	3.9
Highest high tide	5.3
Lowest low tide	0.1

Illustrative Plate 6 shows tide characteristics.

A datum for immediate use can be obtained by adjusted simultaneous observations of tidal variations, as described under scope and sequence of field work. This datum will be approximate Mean Low Water Springs arrived at by applying corrections obtained from the U.S. Coast and Geodetic Survey publication "Tide Tables of the Pacific Ocean". Additional checks taken by this method should result in a tidal datum plane significant to less than a foot. This is within the requirements of preliminary design.

Scope and Sequence of Field Work. It is recommended that surveys be performed at the project site under supervision of the Chief Surveyor. Approximately 1 February 1949, the Chief Surveyor and a survey party should proceed to the site to obtain basic information for design and to establish horizontal and vertical control. The scope of each operation follows and will be in the sequence shown subject to changes made necessary by later developments.

(a) Profiles of craters. Sufficient profiles or cross sections will be taken of the craters to control grading to specified requirements. To expedite this survey, an assumed datum and local control should be satisfactory. Stakes will be set as required for the grading operation.

(b) Topography. Location of the approximate mean high tide line of the project islands will be mapped and sufficient elevations taken to show relative heights above tide level where essential to design purposes.

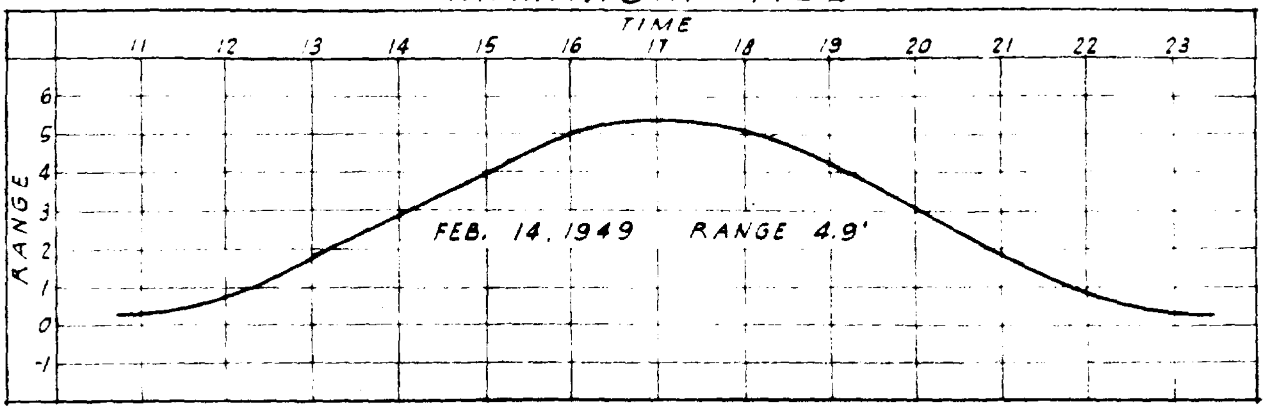
Existing improvements will be located where essential to design, but it is not considered necessary to locate all existing improvements within the areas.

Offshore profiles will be taken as required for water intakes,

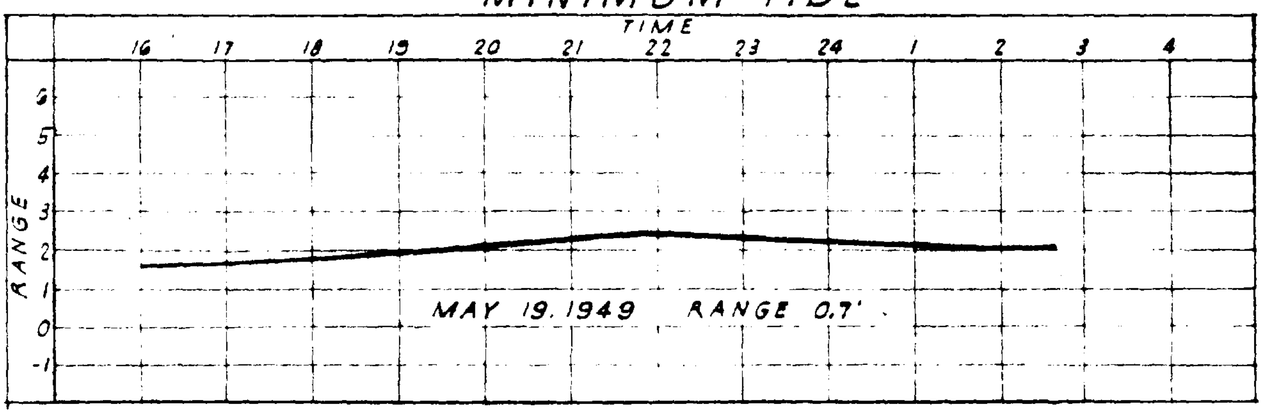
TIDE CHARACTERISTICS

TYPICAL RANGE 1949

MAXIMUM TIDE



MINIMUM TIDE



TYPICAL MONTHLY CYCLE

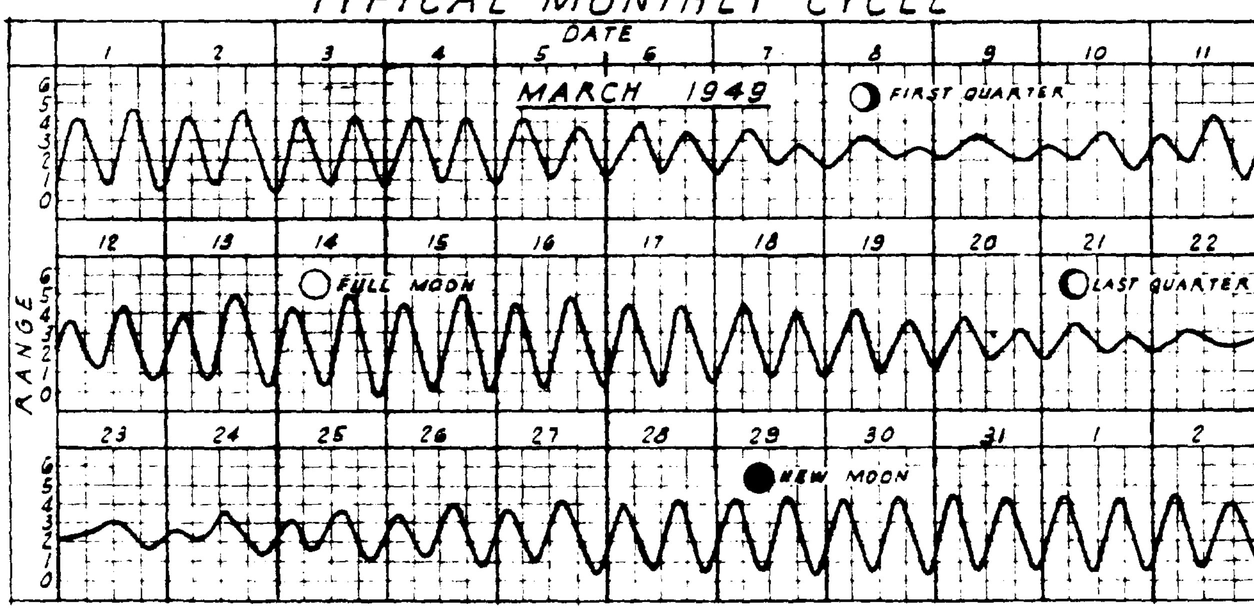


PLATE 6

sewer outfalls, piers and causeways.

(c) Control for Preliminary Surveys. Existing traverse points of the Joint Task Force Seven Survey will be recovered and used as the basis of preliminary horizontal control. These points will be supplemented by additional traverses where required.

Vertical control for these preliminary surveys will be obtained by simultaneous observations of tidal variations at the various islands. Tide staffs will be set up for this purpose. Differential corrections will be made to establish a datum common to the islands involved, and adjusted to mean low water springs by applying the tide prediction for the observed time as given in the Tide Tables of the Pacific Ocean 1949.

Personnel. Assuming that required materials and equipment will be available on arrival and that efficient inter-island transportation will be provided, a four man survey party is recommended for the initial surveys. This party will consist of a Chief of Party, Instrument Man, and two Chainmen.

It is anticipated that survey operations involved in establishing horizontal and vertical control, and in obtaining the basic information for design can be completed in approximately forty-eight party days of workable weather. This could be reduced by adding manpower, but not in direct ratio.

Supplementary Services of Chief Surveyor and Party. Consideration should be given to additional work which could be accomplished by the Survey party during preparation period, which would reduce later costs to the project. Suggested additional work would include the following:

(a) Establish secondary and construction controls on the project islands well in advance of actual construction. This would consist of most of the work outlined in the later.

paragraph on construction controls.

(b) Provide required alignment and grade for repair of existing facilities, grading of areas, etc.

(c) Re-measure base line on Runit Island.

(d) Make Harbor survey for obstacles and obstructions.

(e) Make any surveys required in connection with special investigations, location of proposed quarries, submarine cable, etc.

The Chief Surveyor will assist the Resident Engineer in quarry investigations, supervision of grading operations, evaluating present improvements regarding use in construction camp, and on any other requirement for special investigations or reports.

PERSONNEL BUILDINGS:

Our investigation or proposed construction for housing and service of personnel was controlled mainly by the requirement of materials to withstand the climatic conditions of this location and also by the desire to obtain an all-purpose unit that could be readily erected and length altered to fit requirements.

The cost analysis made included concrete structures, wood frames with various combinations of siding and roofing, and prefabricated structures using aluminum alloy for frame, covering and connections as well as galvanized steel buildings.

Types of Structures Considered. In this investigation of various type structures, we considered concrete structures cast in place, pre-cast slabs cast at central location near site and a combination of there two methods. Concrete blocks and concrete brick structures were considered, using blocks and brick made of coral aggregate in a centrally located plant and also with portable plant setup.

All of these concrete type structures were investigated for various combinations of roofs, such as cement asbestos, plywood, common wood sheathing, Gypsum slabs, galvanized iron and corrugated aluminum on wood trusses and also on metal trusses of galvanized iron or aluminum. Composition roofing was used over the Gypsum, plywood and common wood sheathing.

The cost analysis of the above concrete type structures showed the cast in place concrete as being highest and the concrete blocks with galvanized iron or corrugated aluminum sheets on wood trusses being the cheapest. This range was from $35.00 per square foot to $23.00 per square foot.

Aside from the cost element there are other features that are not advantageous of which the cooling problems are probably the most serious. In the concrete block building with double aluminum roof, it is not feasible to make a high percentage of the wall areas open for cross ventilation. It is therefore considered necessary to provide mechanical ventilation to make said structures livable and such added expense is not deemed justifiable.

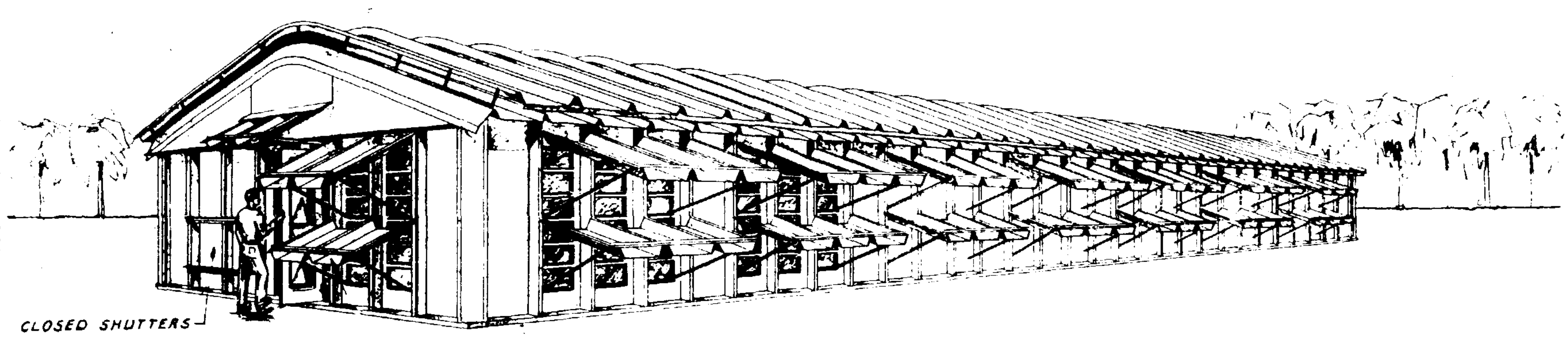
The analysis of wood frame structures with various roof and wall coverings showed that prefabricated buildings using plywood coverings could be erected for approximately $10.00 per square foot. Maintenance costs, however, are anticipated to be fairly high due to peeling of plywood and its warping when exposed to the weather. The wall areas can be opened up for fair cross ventilation but not enough to be considered adequate for comfort. Cement asbestos siding and roof sheets on wood frame construction can be built for approximately $10.50 per square foot, but maintenance costs anticipated due to their brittleness is higher than for plywood panels. The same ventilation problems are to be expected as noted for plywood covered frames.

Galvanized steel or aluminum sheet covering on wood frames are comparable to above in cost as the saving in siding is counterbalanced by the extra cost of field building the frame.

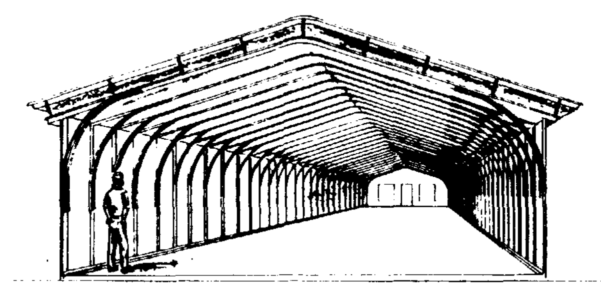
Galvanized steel prefabricated structures of various types are available but would require considerable modification to fill all requirements for the various uses to which they will be subjected. The useful life of a galvanized steel structure in the Eniwetok area is problematical due to scraping off or destroying the galvanizing during shipment and erection as well as from the electrolytic action when pinholes are present in the coating. This fact is shown in the A.S.T.M. Atmosphere Exposure Tests dated 2/27/46. Observations made at the site, showed very rapid deterioration of this material when exposed to the combination of high humidity and salt spray. Galvanized steel buildings are approximately 15 percent cheaper in initial cost than prefabricated aluminum buildings, but they do not give as comfortable housing conditions due to the high degree of heat reflection of aluminum.

Aluminum Structures. We, therefore, made an exhaustive study of all types of available or contemplated forms of aluminum structures. Of these structures, the vertical sidewall type as shown on Plate 7 seems to be nearest ideal due to east of erection, ventilation facilities and low initial cost. This type of structure is made up of pre-cut and die stamped elements which may be completely assembled in the field with no cutting or fitting and requiring only wrenches and screw drivers.

These structures are proposed to be erected on concrete slabs using aluminum anchor bolts and connections throughout. They are easily adapted to almost any desired size and combination using a standard width of 24 feet, entirely free of columns, with length as required in three foot increments. The standard height of sidewall is eight (8) feet but can be increased up to sixteen (16) feet. The walls can be made with three-fourths of the three foot wide panels open from within one foot of the floor to within a foot of the top of the panel,



EXTERIOR VIEW



INTERIOR VIEW

TYPICAL ALUMINUM STRUCTURE 24' WIDE

PLATE 7

with openings covered by top-hinged covers that form canopies for shade and protection from rain in the open position. When covers are open practically 60% of all wall area is open for ventilation. With the window opening covers all in the closed position the buildings will be tight enough to use for dry storage. No screens are contemplated except for mess halls, hospitals and latrines, as it is believed that insects can be controlled easily by a proper program of pest control.

Using available aluminum sheets of proven structural strength and corrosive resistance combines with aluminum connections, very minor maintenance would be required. The cost of such structures complete is approximately $7.50 per square foot.

It is proposed to use aluminum partitions in all buildings that require partitions although plywood is considered as an acceptable alternate for such interior walls. Plywood partitions have several good features, such as use as tack or bulletin boards, but their requirement of extra machinery and carpenters on the construction force and special non-corrosive connections causes their cost to be more than aluminum by fifty cents per square foot.

The double roof with adequate space between sheets for free circulation of air will materially assist in maintaining a cooler building.

During the roll-up period between experiments, aluminum buildings will not require maintenance for corrosion protection.

Use of Aluminum Structures. With the great flexibility as to height and length, the ease of erection and resistance to deterioration, it is considered advisable to adopt this type of structure for all personnel housing, mess halls, administration building, communication building, infirmary, laundry, shops, cold storage, and power plant on Parry Island and as necessary on Eniwetok Island. The utilization of the existing structures on Eniwetok that are in useable condition or that can be economically repaired, will be discussed later. This type of structure is also contemplated for office and communication buildings and mess halls on experiment islands.

Other Building Construction. If dispersed power plants are used, it is recommended that those plants adjacent to the Timing Buildings and the personnel housing areas on the experiment islands be housed in permanent structures of reinforced concrete, partially below ground and protected on the side toward the zero tower by earth revetment so that these plants will be protected and may be maintained between experiments. For those plants adjacent to zero towers and photo towers, if used, it is recommended that the aluminum structures be used. Under "Electrical Power Supply Systems" the relative merits of one or two central power plants and many small plants are discussed in detail.

Due to the short period of occupancy for personnel on experiment islands, it is proposed to utilize tents on concrete slabs for housing. It is proposed to provide canvas tents having wood frames, with a double roof. The upper roof being supported about a foot above the main roof on wood frame. The sides of the tents can be raised and supported as projecting canopies for ventilation. It is planned that all tents will be identical although some may be occupied by two men and some by four men. The use of tents provide great flexibility to add or omit quarters as changes in requirements develop and are low in cost of installation. The concrete slabs will remain without maintenance during the roll-up period and the tents may be expended.

Salvage. The aluminum structures and tents can be salvaged from the experiment islands, providing personnel for dismantling them will not interfere with experimental operations. In the cost estimate these items will be considered expended.

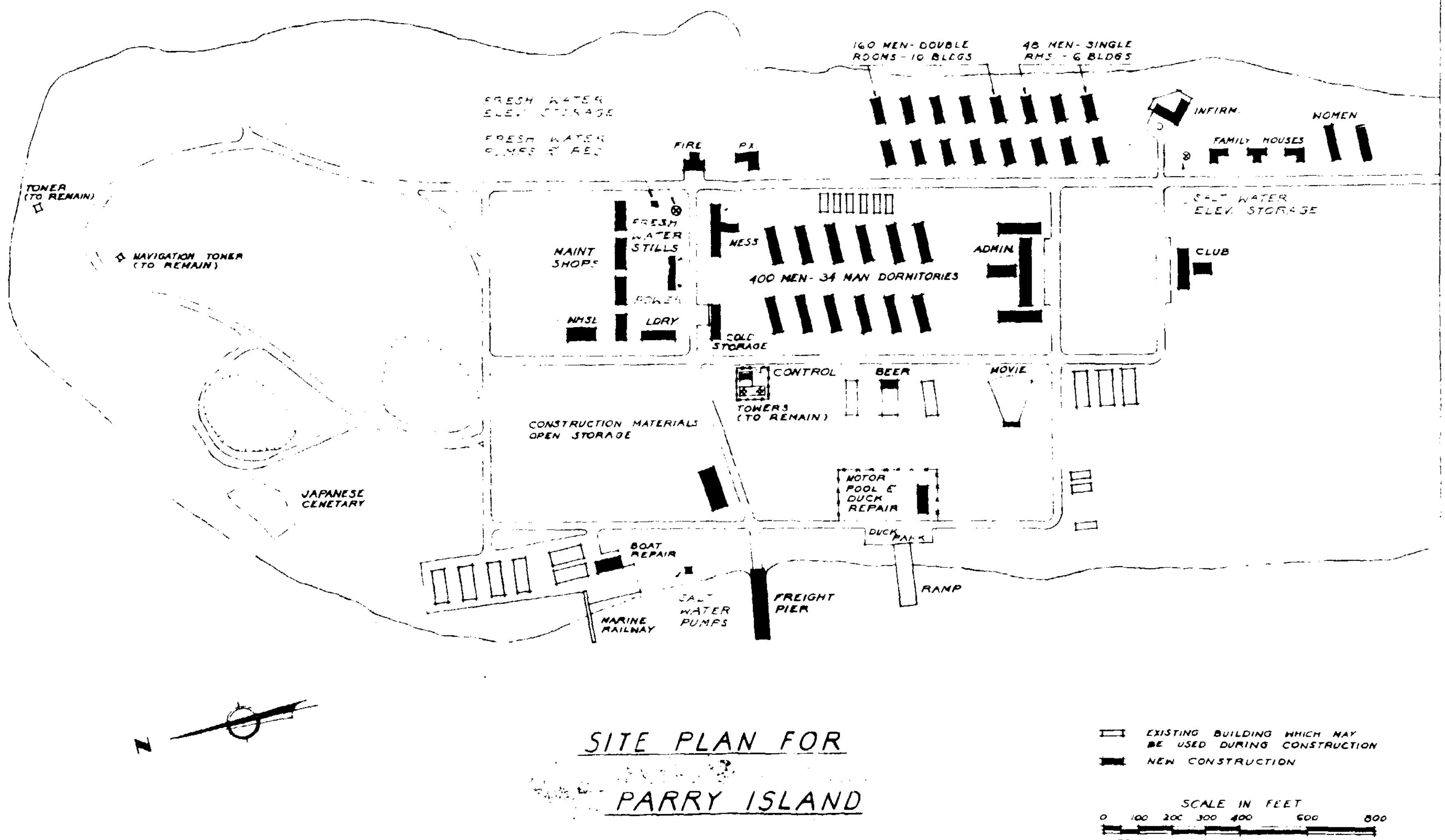
Site Planning. Preliminary site planning has been given consideration in connection with this Report, and several Plates are included which show in general an arrangement of buildings and facilities for Parry Island, Eniwetok Island and each of the Experiment Islands. This planning has been based upon the use of the prefabricated aluminum structure previously discussed, and to provide for six hundred personnel on Parry Island, consisting of two hundred Scientists, and four hundred assistants and workmen in the various trades, including construction and repair, six hundred Military personnel on Eniwetok, in the proportion of two hundred Officers and four hundred enlisted men, and two hundred on each of the Experiment Islands divided as follows: Fifty Scientists and Officers, and one hundred and fifty workmen and enlisted men. The number and classification of personnel is an assumption based upon preliminary thoughts of the Laboratory, and these quantities as well as the ratio of different classifications are subject to change at any time. In fact use of the aluminum structure lends itself very readily to great flexibility, inasmuch as the length of buildings can be varied easily in increments of three feet, and the number of buildings can readily be increased or decreased as requirements indicate.

Parry Island. This island is planned as the civilian headquarters island and inasmuch as there is no usable housing on the island, it is possible to plan the general arrangement of all facilities without regard to existing structures, except in a few locations which do not materially effect the general arrangement. There are a number of warehouses on Parry Island which at the present time are in relatively good condition, and it is planned to use these as long as they are fit for use. These warehouses will be useful during the early periods of construction. The general arrangement of housing quarters is toward the ocean side which is the windward side. Buildings for housing personnel are oriented to take the greatest advantage of the breeze, which is quite constant in direction.

Plate No. 8 shows the general arrangement of buildings. The quarters for Scientists have been located east of the main road and consist of six buildings, housing eight men each in single rooms, and ten buildings housing sixteen men each in double rooms. The general appearance of the buildings is shown on Plate 7, and schematic floor plans for the Scientists' quarters are shown on Plate 9. Across the main road and north of the location for the Administration Building, are twelve dormitories housing thirty-four men each, with Day Room and toilet facilities at one end of the building. Schematic plan of this building is shown on Plate 10.

It is understood that some women will be employed during the construction period and future experiments. For certain classes of work, such as secretarial work, switchboard operation, and similar categories, women are more efficient than the type of men who are available for this class of work. Also, it is understood that female scientific personnel will be included. There has, therefore, been included in the site plan, two buildings to house women. Women Scientists will be provided with single rooms and the other women will be quartered two to a room. These buildings are at the end of the grouping of buildings set off at some distance from male quarters. Three (3) two-family houses are indicated as ultimate planning to take care of the operating personnel or others who may remain on the island during the roll-up period.

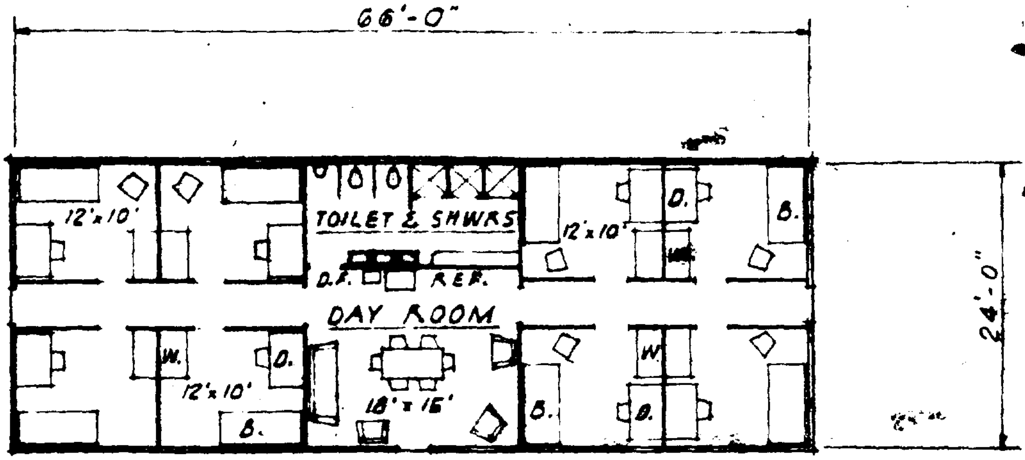
In additon to structures to house personnel, general administrative, control and functional buildings are also included. An Administration Building containing 16,000 sq. ft. of floor space is located at a central point, accessible to all who will be using this building. It will contain a Photographic Laboratory, Instrument Laboratory, a Radio Chemical Laboratory, and central communications facilities, in addition to general office space for the normal operation of the experiments. The mess hall is planned to seat three hundred persons at a time and will, therefore, serve six hundred people in two sittings.



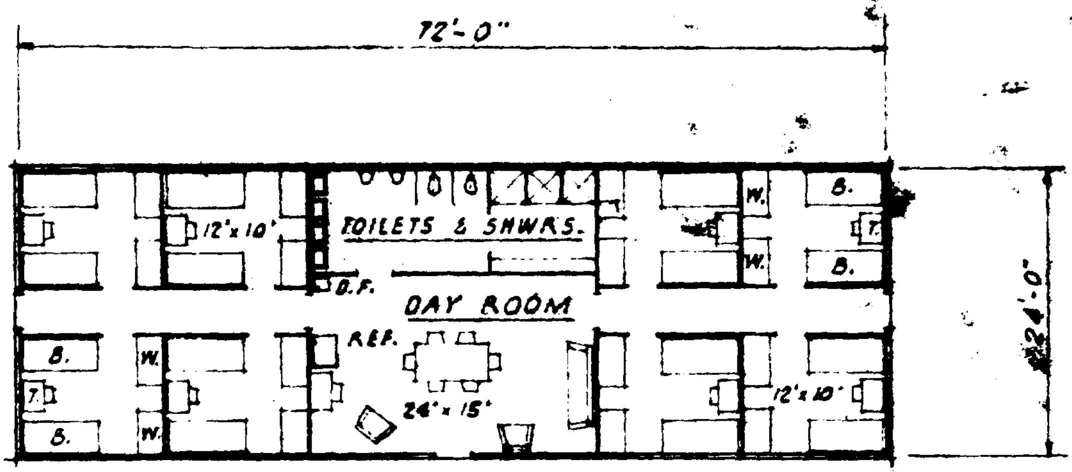
SITE PLAN FOR

PARRY ISLAND

PLATE 8



SINGLE ROOM BLDGS.



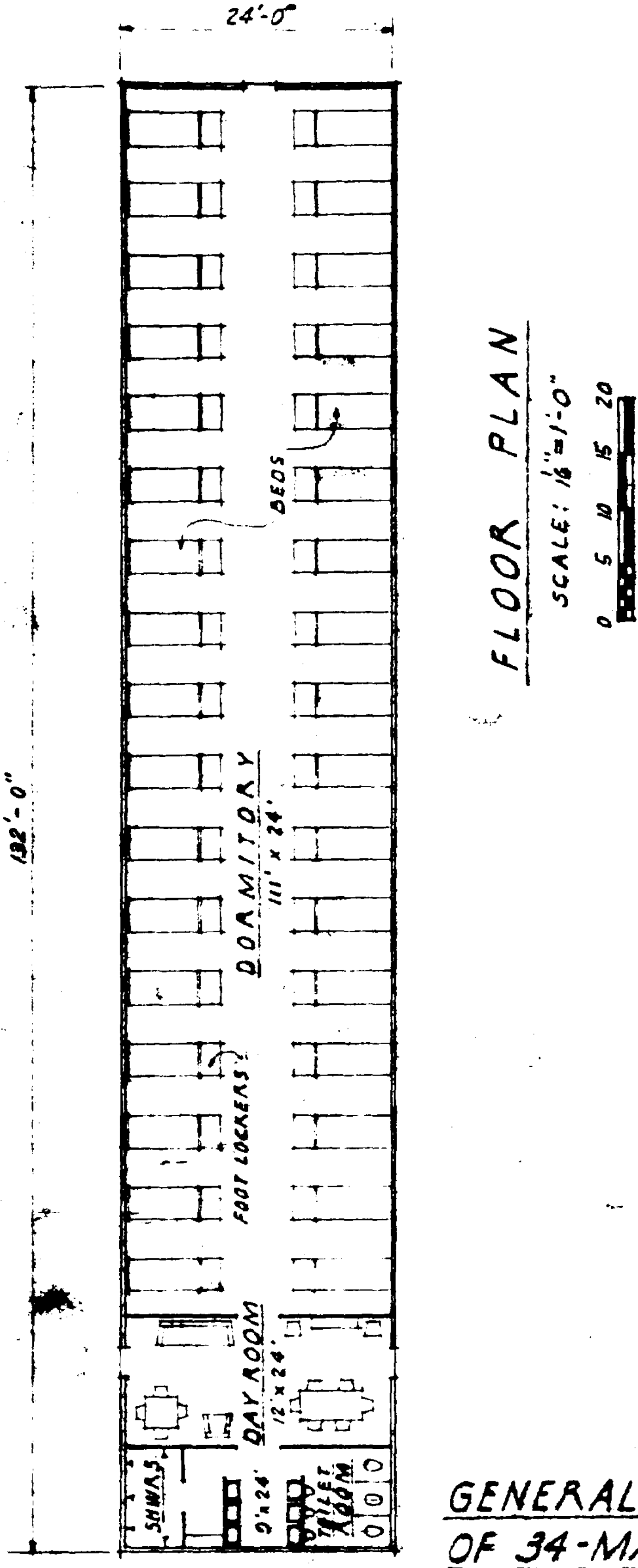
DOUBLE ROOM BLDGS.

SCALE: 1/16" = 1'-0"

0 5 10 15 20

GENERAL ARRANGEMENT OF QUARTERS FOR SCIENTISTS

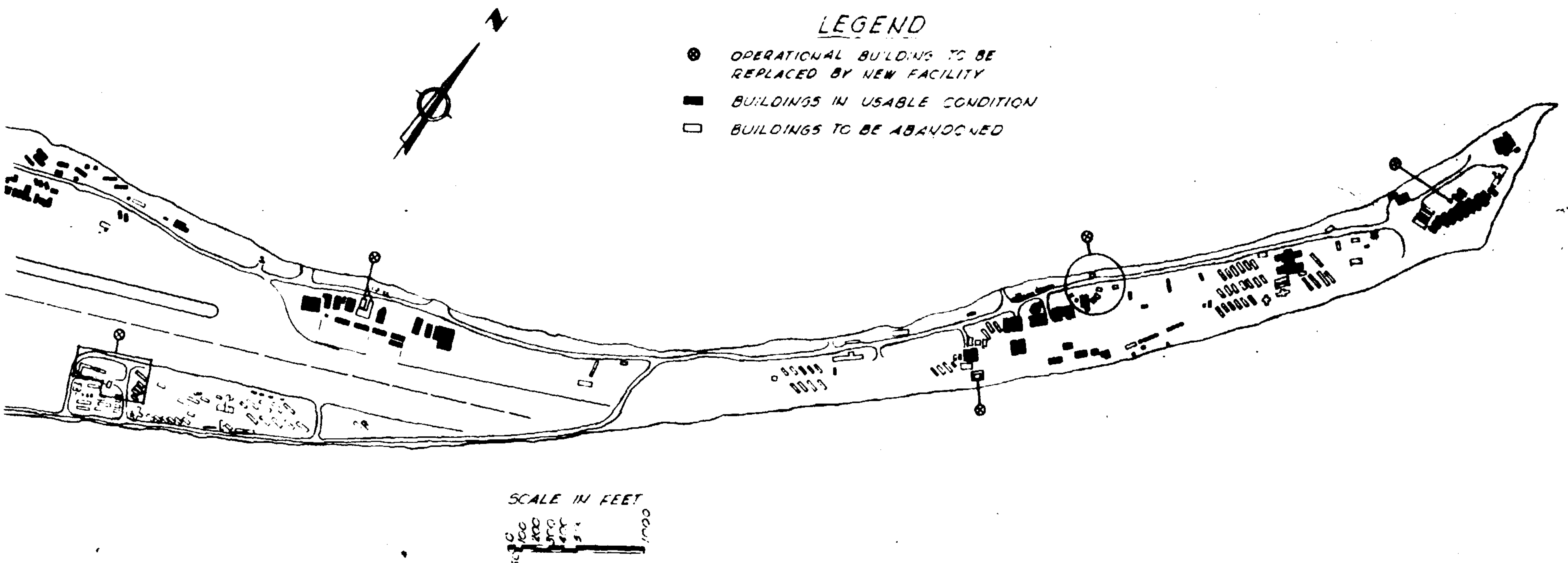
PLATE 9



GENERAL ARRANGEMENT
OF 34-MAN DORMITORY

jacent to the mess hall will be the central cold storage plant, and across the road will be the power plant serving Parry Island, and in this building ll also be included the water distillation equipment. In the same immediate rea is the laundry building. A new Control Room, twice the floor area of the one formerly used, will be constructed on the ground adjacent to the present ntrol room tower which will reamin. See Plate 11. Near the beach on the lagoon side will be boat repair and motor repair shops. In the area north of e power plant will be located all the maintenance shops and warehouses, which ll be used for dry storage of bedding and similar equipment during the roll-up period. Recreational facilities include a theater, a club for Scientists, d beer garden for the assistants and workmen. There is adequate room for athletic fields for soft ball, volley ball, hand ball, etc., which have not en laid out in the preliminary site plan. Additional buildings will include a Fire Station to house the fire fighting equipment, and housing for the personnel connected with this facility. Also, general stores similar to Army PX provided. Security policing is considered as being handled by the Military forces and only a headquarters building for this purpose is included in the te plan.

Eniwetok Island. On this island is now located the military establishment for the atoll. During the reconnaissance trip a survey was made of the condi-on of the existing buildings on the island, and it was found that a large mber of buildings were unfit for use. Plate 12 shows the condition of build-ngs; those in useable condition as of October 1948; those which should be im-diately abandoned and probably removed, and those which house necessary facilities and must remain until a new facility is provided. Plate 13 is another p of Eniwetok Island, showing the occupancy of the existing buildings by the garrison. The purpose of this map is to indicate the scattered occupancy. This

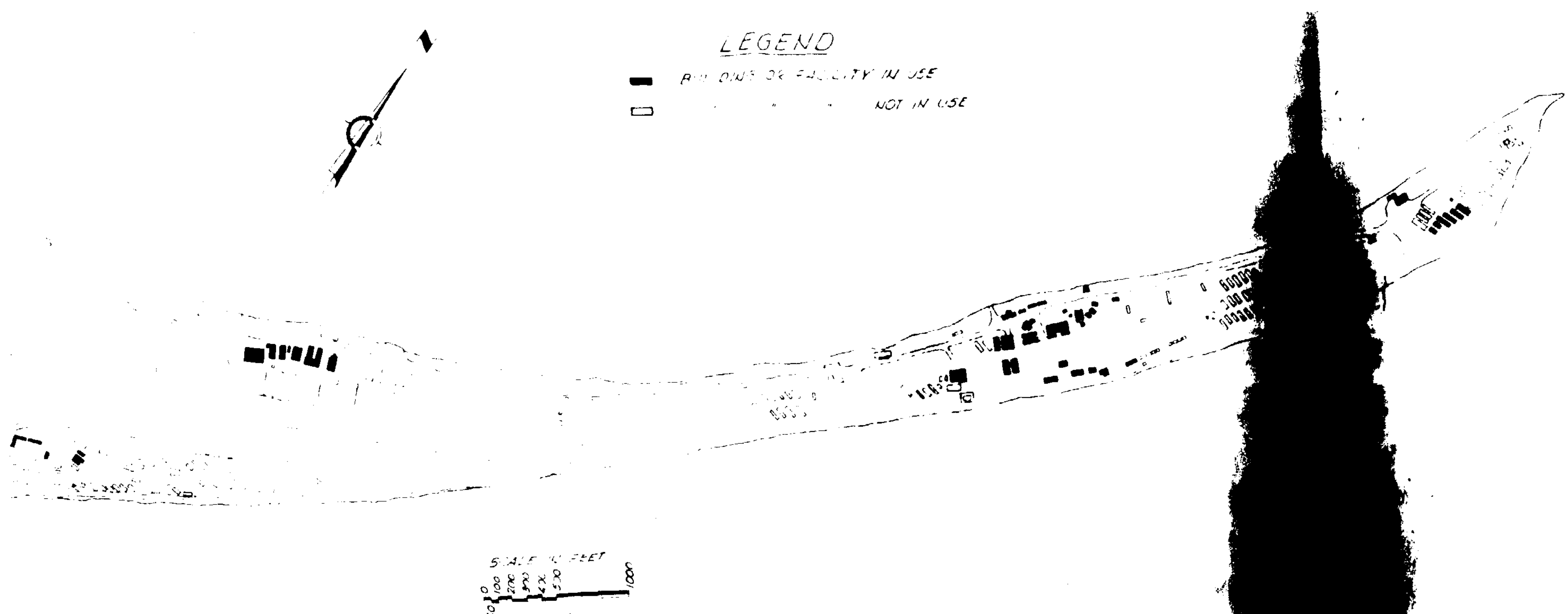


MAP OF ENIWETOK ISLAND

SHOWING

PRESENT CONDITION OF BUILDINGS

PLATE 12

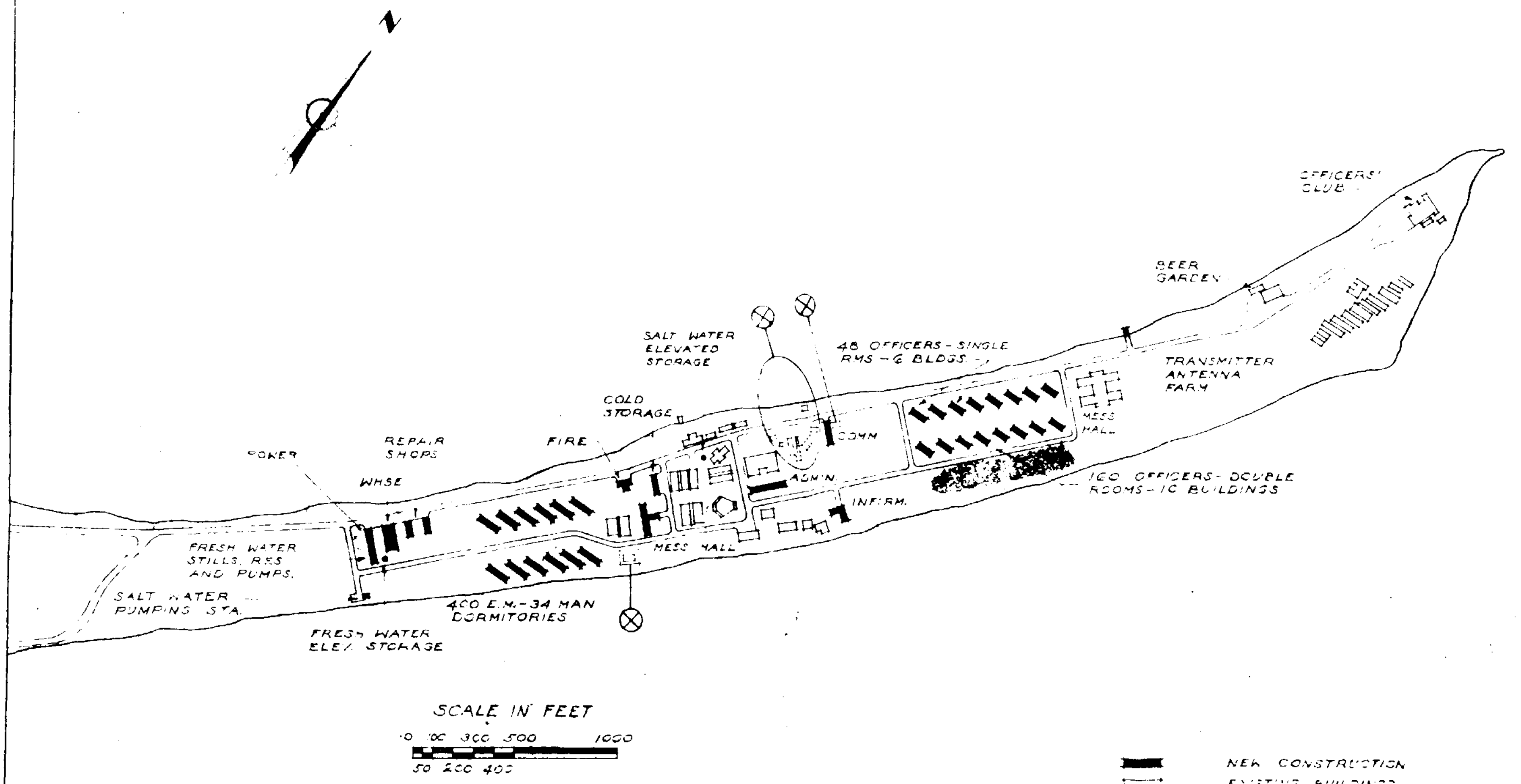


MAP OF ENIWETOK ISLAND

SHOWING

EXISTING BUILDING OCCUPANCY

PLATE 13



SITE PLAN OF ENIWETOK ISLAND

SHOWING ULTIMATE CONSTRUCTION

PLATE 14

is largely due to the condition of the buildings - those that are in use are the ones that are in the best repair regardless of location. In the general plan of housing civilian forces on Parry Island and leaving the entire island of Eniwetok for the military, the present garrison and any immediate enlargement thereof can be housed in and serviced through the useable, existing buildings. Some of these buildings may be useable for a longer period than anticipated. In any case, it is contemplated that new structures will be built only as and when needed to replace existing structures as they become unuseable, or as the demands of the garrison increase and more facilities are required. The ultimate plan which would contemplate complete replacement of existing facilities eventually, is shown on Plate 14. The buildings contemplated here are also of prefabricated aluminum construction, with the same flexibility as to size as those planned for Parry Island. In lieu of any definite figures as to the number and classification of military personnel which will use this island, the site plan has been developed on the basis of two hundred Officers and four hundred Enlisted Men. The Officers being housed in buildings similar to those planned for the Scientists on Parry Island, and the Enlisted Men in barracks similar to the dormitories as described above for Parry Island. Space is provided in this layout for expansion either of the Officers' quarters or of the Enlisted Men's quarters, as conditions might dictate. New Administration Building, Mess Hall, Communications Building, Warehouses, Commissary, Recreational Building, and Shop Buildings are provided on this site plan. This being an overall master plan, it will provide locations for buildings as they need to be constructed, so that in the final development a reasonable, logical arrangement will result. Of the existing structures, the present parachute drying building is in good condition and can be used for dry storage. The Administration Building, Mess Hall, Theater, Officers Club, and some of the warehouses and shop buildings now on the island, may be kept in service by repairs and overall below ground and partially above ground, with earth revetment on the zero side. By this type of construction it will be possible to salvage the power plant. The water distillation units, being of a portable type, can be removed before zero hour. The aluminum buildings can be readily dismantled and thus can be salvaged if it developes that personnel to dismantle these buildings will not be in the way of scientists at the time shortly before zero hour.

Facilities in Quarters. Consideration should be given to providing maximum comfort, without luxury. This means a good bed, adequate clothing storage space, comfortable chairs, desks in required quarters, and day rooms so laid out and furnished that they are suitable for their purposes, dry closets for clothing and personal effects, chilled drinking water in all quarters and domestic type electric refrigerators in day rooms of scientists quarters.

In providing these facilities, the governing thought is to supply as comfortable, well maintained housing as is practicable, which, when combined with a good mess and recreational facilities, will tend to keep the efficiency of the personnel, in all classifications, at top levels.

Plumbing Materials. Separate systems for the distribution of salt water and for distilled water are contemplated. This will require separate connections between the main outside lines and certain inside fixtures. Water closets and urinal flush tanks will be connected to salt water service and wash bowls and shower heads to distilled water service. Sewer drain lines will be common to both systems. No duplication of fixtures is involved by this arrangement.

All plumbing fixtures located in buildings on Parry and Eniwetok should be of corrosion resisting materials. It is contemplated to utilize vitreous china for lavatories, closet bowls, and urinals. Closet bowls and urinals will consequently be equipped with vitreous china tanks. Due to the use of salt water supply, fittings in flush tanks should all be rubber. Pipes, fittings and fixtures utilizing either distilled water or salt water supply should be of special copper alloy, or other materials capable of resisting the corrosive effect of the spindrift which permeates the atmosphere. Detailed construction specifications applicable to these materials will be the result of additional research and investigation.

Since latrine facilities on the shot islands are to be expended by experiment operations, the use of plumbing pipe and fixtures ordinarily adapted to minimum cost installations is contemplated. The expected useful life of this type of construction under the corrosive conditions present would not greatly exceed that required by experiment operations and ultimate economy of expendable costs is thus accomplished.

Electrical Materials. All lighting fixtures and wiring materials for use in buildings on Parry and Eniwetok and all lighting fixtures and wiring materials for those buildings which are intended for use in more than one operation should be of corrosion-resisting type. It is contemplated to use vapor-proof lighting fixtures. In general, exposed wiring using either exposed non-metallic sheathed cable or exposed corrosion-resisting conduit with moisture-resisting wire similar to Type TW thermoplastic might be used. Conduit, boxes, plates, and miscellaneous fittings might be aluminum alloy. Receptacles and switches may be of conventional construction. The heating element for dry closets may be either a special heating element available for this purpose or a standard lamp bulb enclosed with a wire screen. Construction specifications for these materials will be the result of additional research and investigation.

For those buildings, tents, etc. on Experiment Islands which are considered expendable with each operation, it is believed that the use of weatherproof sockets, bare lamps, and minimum open-type wiring will be satisfactory and most economical for the relatively short period of time for which these facilities will be used.

EXPERIMENTAL STRUCTURES:

Condition of Existing Structures. The reconnaissance trip, recently made, revealed that with minor repairs, all of the existing experimental structures can be re-used. It was recorded on this survey that the Timing Buildings were leaking around the doors.

Repairs to the topside structure of Coral Head Photo Tower are required, and the existing hoist is in very bad condition. Maintenance painting on the other two existing Photo Towers is needed.

Air conditioning units for Timing Buildings are partially dismantled, and some of the parts have disappeared.

Asphaltic coatings on limonite concrete Gamma stations are badly peeled.

Recommended Repairs. The Timing and Gamma Buildings should immediately have new rubber gaskets fitted around door openings so that a tight seal can be obtained. Also, it is recommended that canopies be constructed over doors to divert water from top of doors.

Radiation shields for doors of Gamma Buildings, truck mounted, and made to operate on tracks should be provided prior to any future experiment. Tracks should be graded so trucks will move toward the door by gravity and move back by winch.

Asphaltic coatings on limonite concrete structures should be immediately repaired.

Painting of existing Photo Towers should be completed with Zinc Chromate type paint so that they will be maintained in usable condition.

New air conditioning units should be provided for Timing Buildings and any existing portions of air conditioning units in these buildings should be salvaged for use in less important locations.

Lighting and communication repairs recommended for existing structures are described elsewhere in this Report.

Realignment of Gamma Stations. The tubes in Gamma Stations are now aligned to a former sight point approximately 200 feet high at center of Zero Tower location. As it is now recommended to locate new Zero Towers 75 feet beyond former Zero tower location and use a tower 100 feet higher, it will be necessary to change the alignment of the existing tubes.

Analysis was made as to the possibilities of reaming out present tubes and installing new tubes but the vertical displacement necessary and the difficulty of field drilling through limonite concrete was such that this proposal was abandoned. Similarly, a study of cutting out the entire tube rack and installing a new set of tubes properly aligned was discarded as possible but very difficult and expensive.

As the realignment figured for Gamma A Structure on Engebi, as an example, required approximately 3-1/2" vertical lift to meet the new requirements, it is recommended that the following procedure be followed: Excavate under front end of Gamma structure and install bearing pad. Use screw jacks to raise front of building to correct vertical elevation. Should horizontal change in alignment be considered necessary it is recommended that the Zero Tower be set on an extension of Gamma line instead of on Zero line extension. Dry packing or pressure grouting can be utilized to firm up this new alignment.

Additional Structures. Should additional tubes be required at present Gamma locations, it is proposed that new buildings of similar design to existing structures be built alongside present buildings.

Such blast structures and foundations as may be required for the experiments should be constructed when the actual requirements have been determined. The design of these facilities will be determined by the scientific requirements.

Zero Towers. In line with the design requirements calling for towers to be 250 or 300 feet high and capable of fulfilling the functions connected with the experiments, as listed in the specifications furnished by Mr. R. W. Henderson dated 9-24-48, complete analysis of various types of tower structures was made.

This analysis included free standing four-leg type towers with various base dimensions and also with counterbalancing messenger cable guys. Three-leg type guyed towers with constant triangular section above the 25-foot level and with guys affixed 50 feet below the top were investigated for above-listed heights.

From the preliminary design, it was determined that the three-leg triangular type guyed tower showed approximately 35% saving in weight over corresponding four-leg towers.

Recommendation is made, therefore, to utilize this triangular type tower due to lower initial cost, ease of erection and installation of appurtenances. The general appearance of the recommended tower is shown on Plate 18.

The design requirements governing the above analysis are briefly to develop a tower that will support loads of 10,000 lbs. on main hoist with 2,000 lbs. on elevator alongside, minimize the weight requirement of structure in the upper 100 feet of tower, withstand the pull of two parallel catenary messenger cables with their coaxial cables, support the necessary load of equipment and personnel in the house at top of tower, and to be capable of withstanding the wind loading based on conditions to be expected in the Marshall Islands.

Generally the locations of proposed Zero Towers were assumed on existing


100' FO

zero line seventy-five feet beyond center of tower used in previous experiment. Plates 19, 20, 21 and 22 show recommended location of four Zero Towers. However, the possibility of locating towers off islands on reefs was investigated and found to be practicable, providing the site is so selected that necessary fill for tower area and causeways can be made without excessive cost. The economic balance of land to offshore location comes when the cost of fill required for offshore site equals the cost of paving around shore tower and the regrading operations for decontamination or future experiment.

Samples of the soil were tested and evaluated, as shown on Plates 23, 24, 25, 26 and 27.

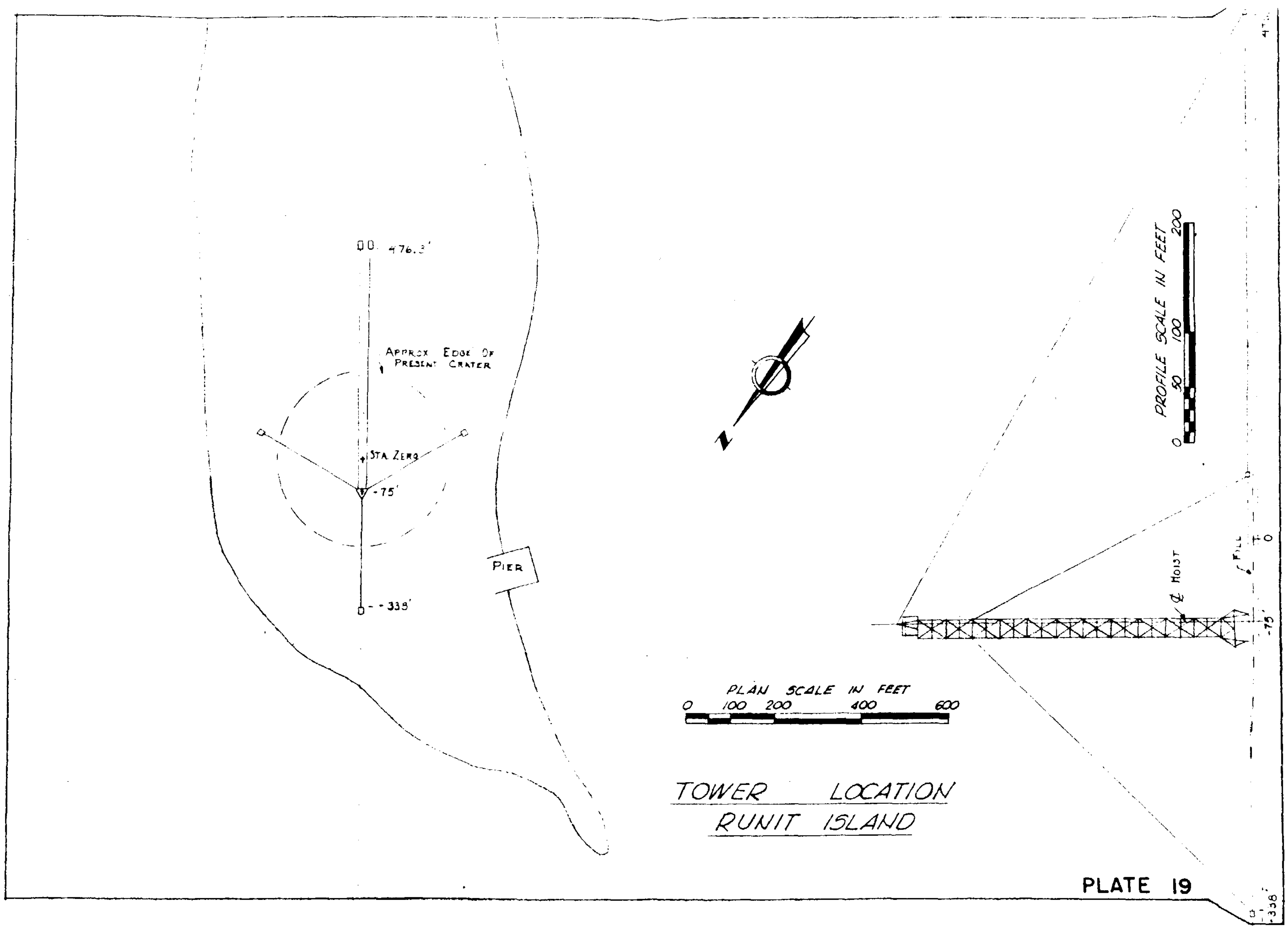
This data indicates that towers and anchors can be located on filled sites with bearing values of the compacted fill given the same magnitude as natural soil.

It is recommended, therefore, that footings for the Zero Tower structure be designed for founding about four feet below the surface of the site and with inter-connecting struts to take the horizontal components of the loads in the battered legs.

To enable field operations to proceed without delay regardless of conditions encountered at site, anchor footings should be designed to cover locations where they are founded in rock above high water level, in rock which may be submerged, in soil entirely above high level, in soil with anchor footing half submerged at high water level and in soil which will be entirely submerged at high water level.

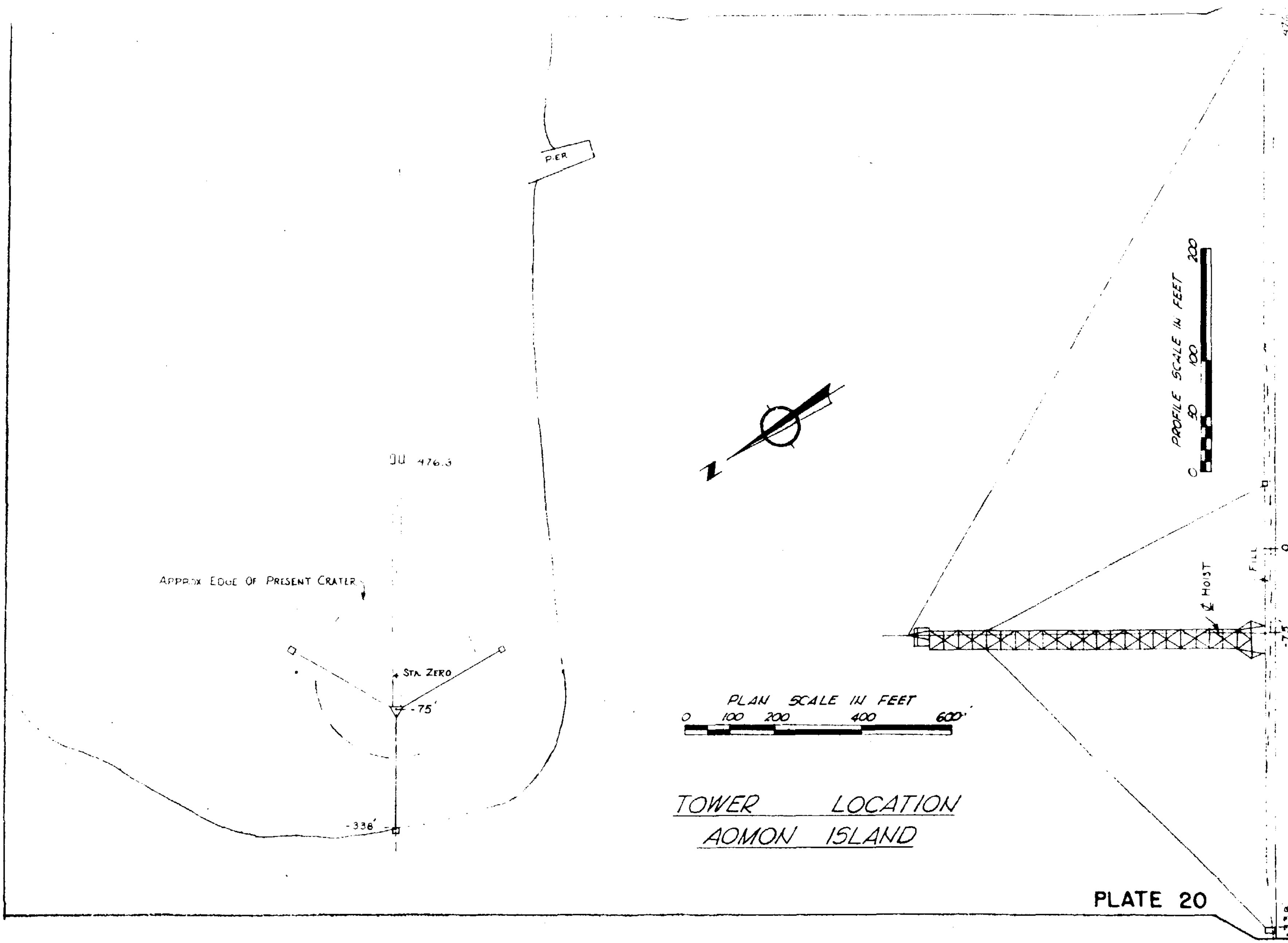
Photo Towers. Previous experiments demonstrated that the 75-foot high Navy type Radar Tower was suitable with minor alterations. It is, therefore, recommended that this type be used with alterations as hereinafter noted.

The two existing Photo Towers that are erected at Coral Head and Aniyaanii locations should be remodeled to cover criticisms appearing in the Technical



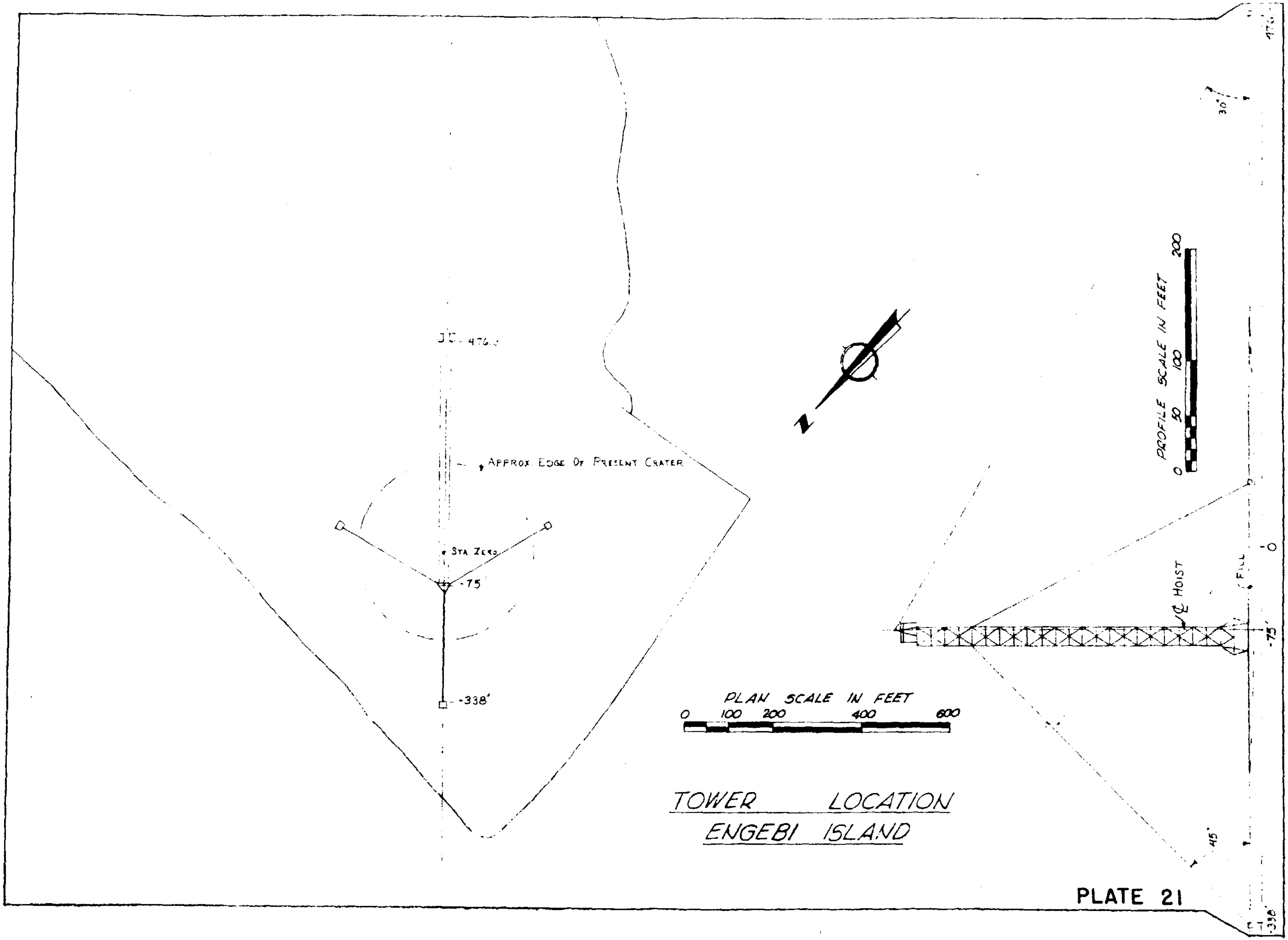
TOWER LOCATION
RUNIT ISLAND

PLATE 19



TOWER LOCATION
AOMON ISLAND

PLATE 20



TOWER LOCATION
ENGEBI ISLAND

PLATE 21

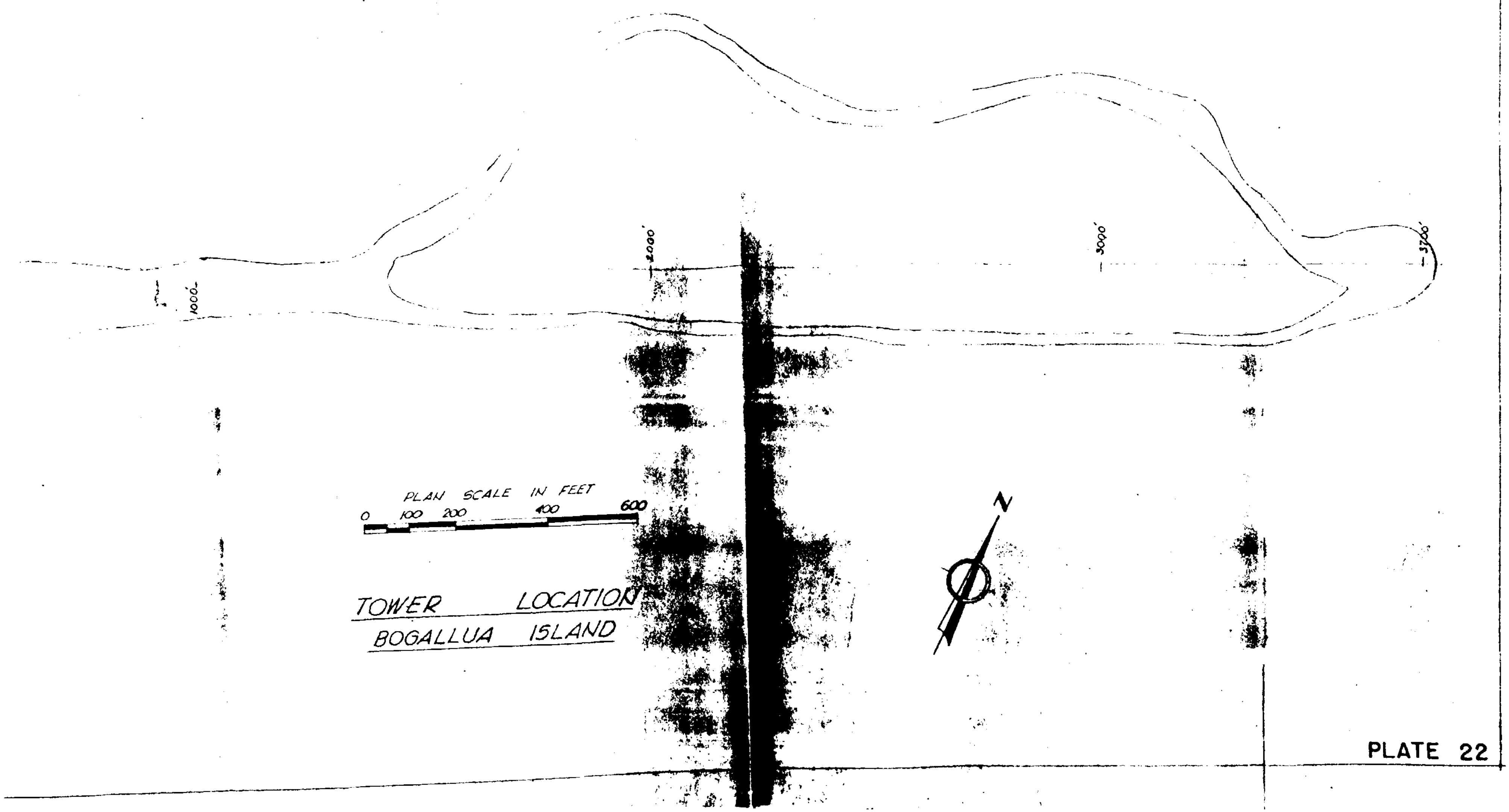
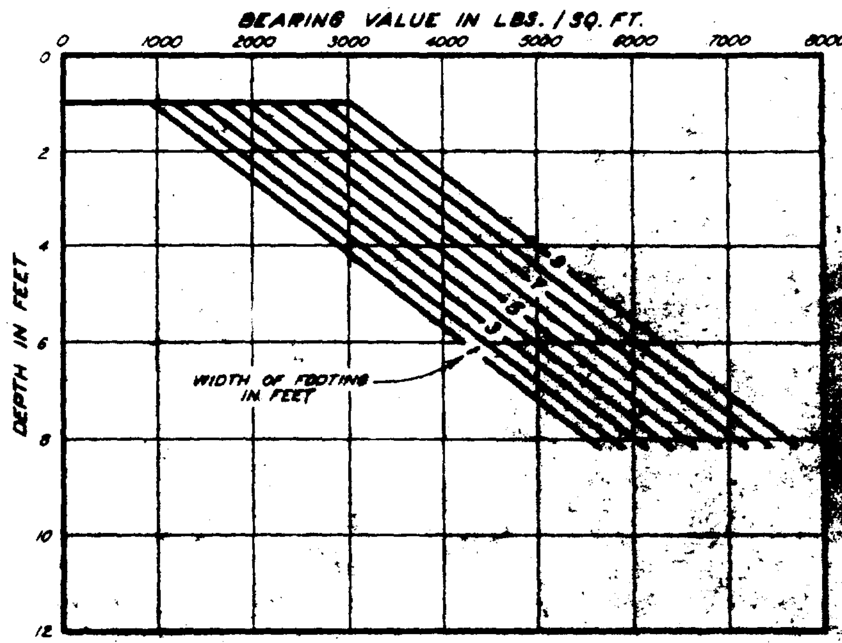

1000'
2000'
3000'
3700'
PLAN SCALE IN FEET
0 100 200 400 600
N
TOWER LOCATION
BOGALLUA ISLAND

PLATE 22

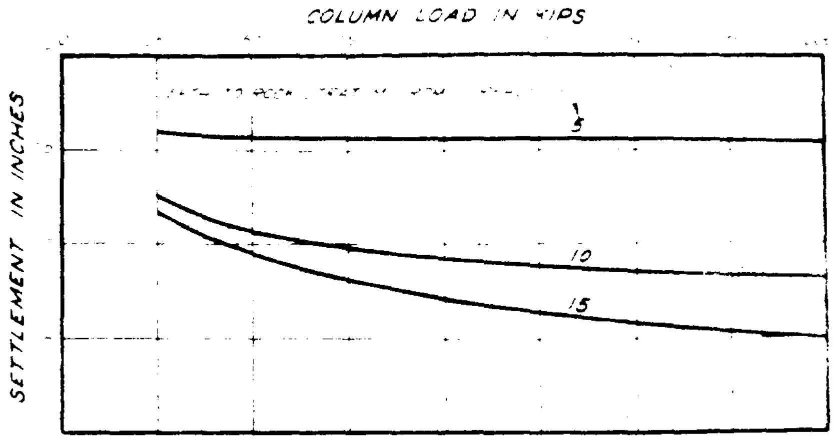


NOTE: THE GIVEN VALUES ARE INTENDED TO APPLY TO THE TOTAL OF ALL LOADS, DEAD, LIVE, AND SEISMIC.

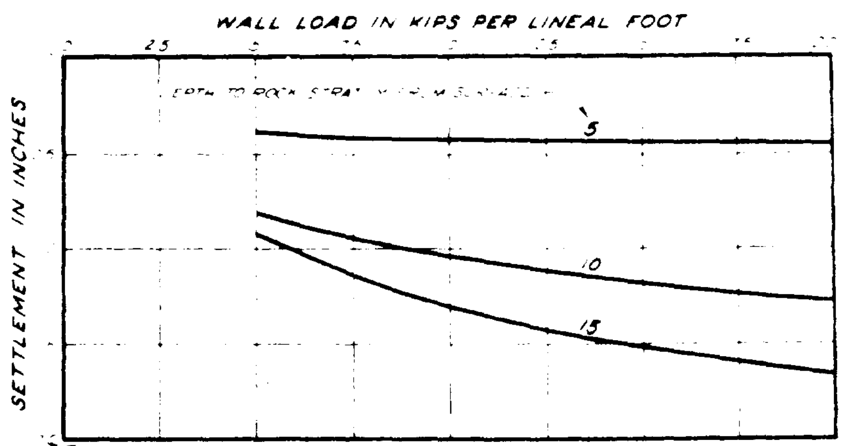
AVAILABLE BEARING VALUES

PLATE 23

SETTLEMENT OF COLUMN FOOTINGS



SETTLEMENT OF WALL FOOTINGS

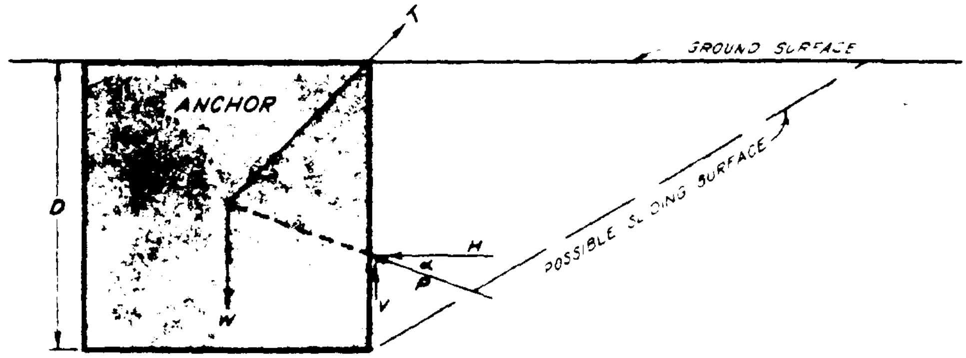


NOTE
[illegible] ARE
FOR FOOTINGS [illegible]
APPROXIMATELY 3 FEET [illegible] BEARING
VALUE OF 3000 LBS [illegible] FT.
[illegible] SETTLEMENTS WERE COMPUTED
FOR A RATIO OF DEAD LOAD [illegible]
LOAD OF ONE, FOR OTHER RATIOS OF DEAD
LOAD TO TOTAL LOAD THE SETTLEMENTS
WILL BE REDUCED [illegible]

SETTLEMENT ANALYSES

PLATE 24

TYPICAL ANCHOR



NOTES:

W = WEIGHT OF ANCHOR

T = TENSION IN ANCHOR CABLE

P = PASSIVE THRUST ON FACE OF ANCHOR

H = HORIZONTAL COMPONENT OF P

V = VERTICAL COMPONENT OF P

α = ANGLE OF FRICTION, SOIL ON CONCRETE

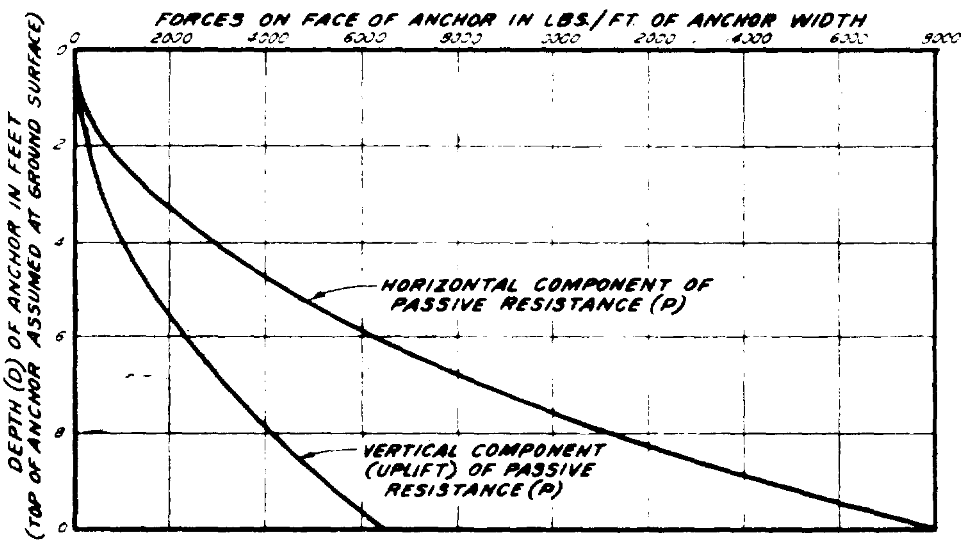
ASSUMPTIONS:

(1) SURFACE OF RUPTURE IS A PLANE

(2) FRICTIONAL RESISTANCE ON ALL SIDES OF THE ANCHOR EXCEPT THE FACE IS NEGLIGIBLE.

(3) THE ANCHOR IS OF GREAT LENGTH PERPENDICULAR TO THE DIRECTION OF CABLE PULL

PASSIVE RESISTANCE



BASIC DATA:

ANGLE OF INTERNAL FRICTION, φ = 30°

ANGLE OF CONCRETE FRICTION, α = 20°

SUBMERGED DENSITY OF SOIL = 54 LBS/CU FT

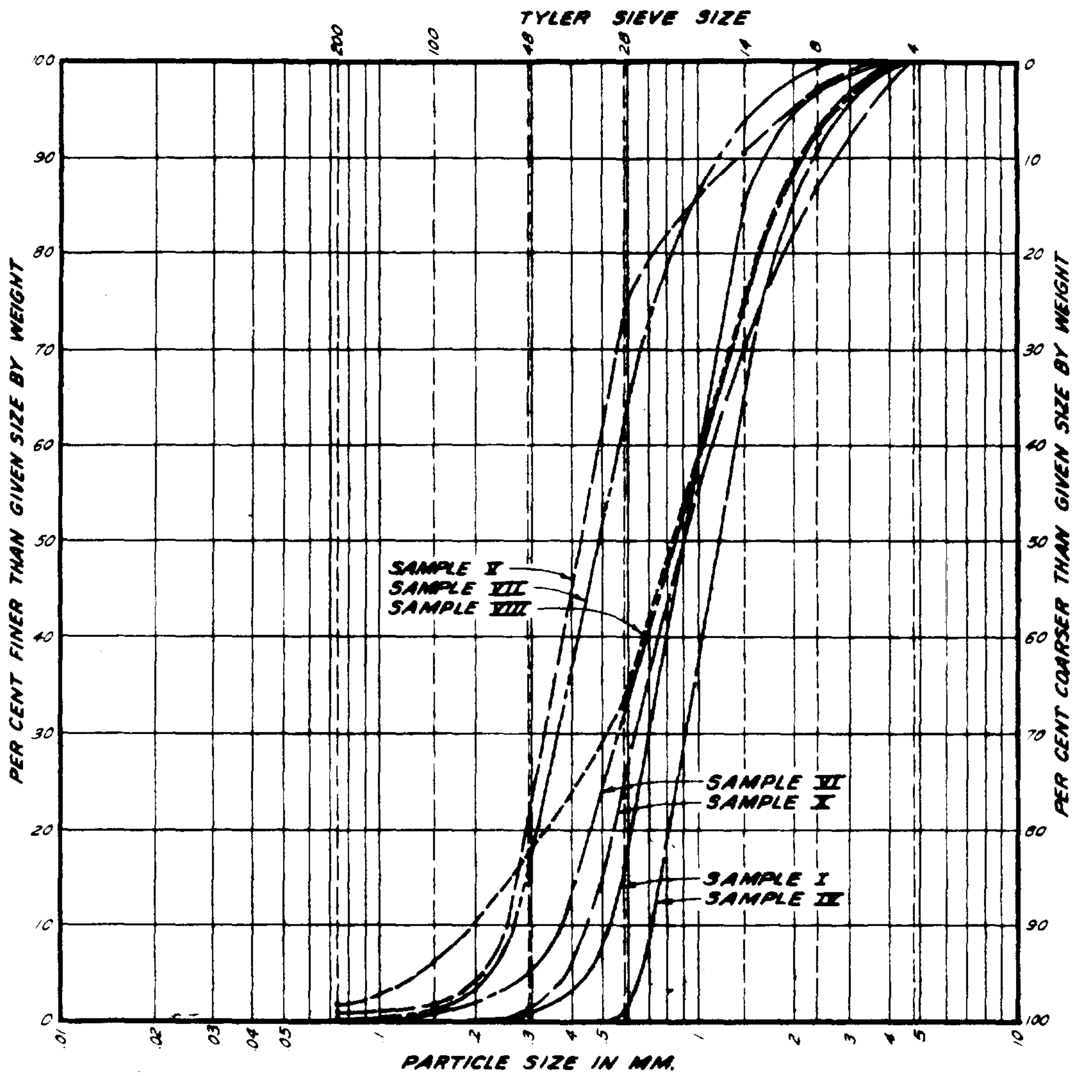
DESIGN NOTES:

THE LINE OF ACTION OF T SHOULD NOT LIE ABOVE THE INTERSECTION OF P AND W.

FOR CONSERVATIVE DESIGN, W MUST EQUAL THE VERTICAL COMPONENT OF T PLUS THE VERTICAL COMPONENT OF P.

ANALYSIS OF CABLE ANCHOR

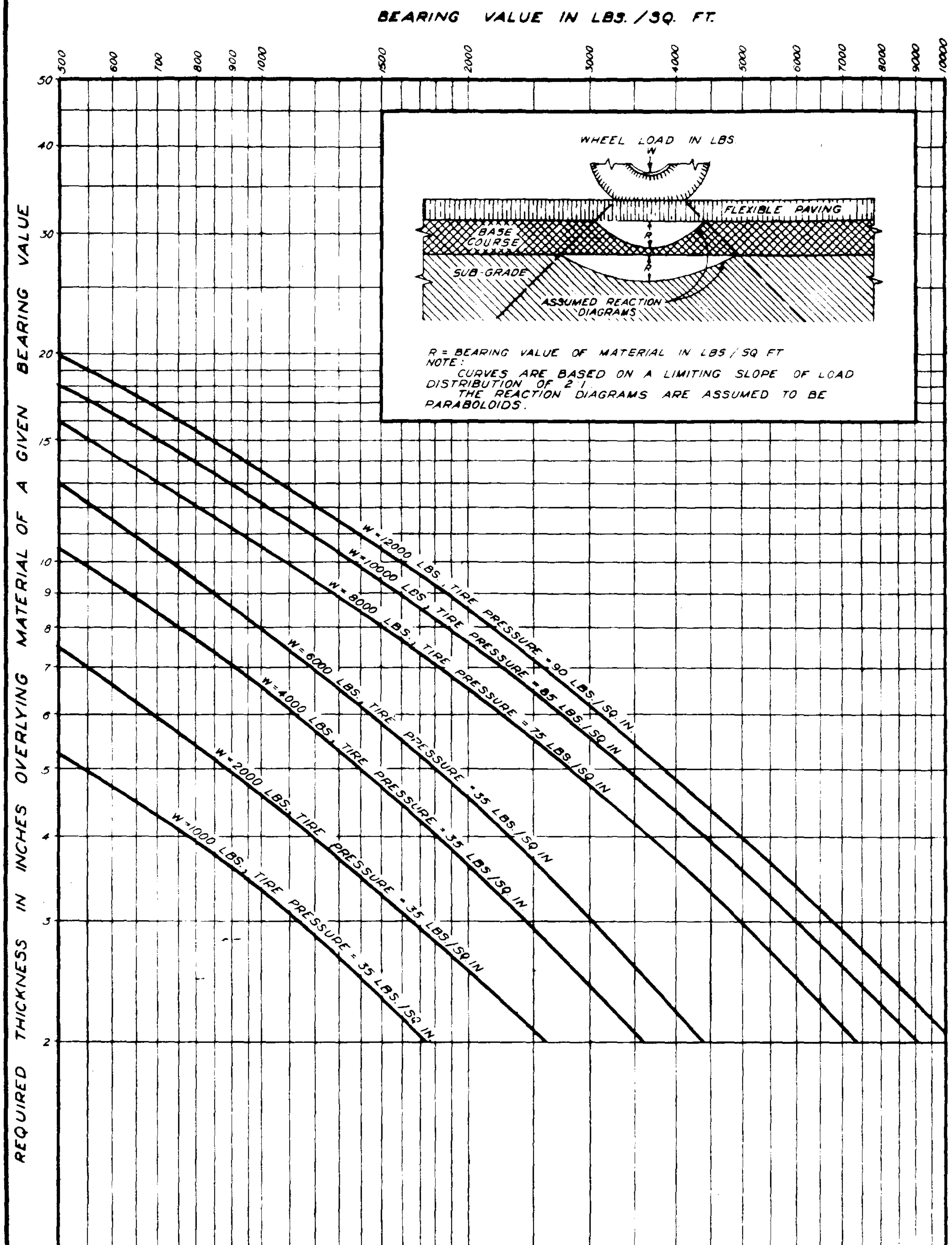
PLATE 25



NOTE:
PARTICLES COARSER THAN NO. 4 SIEVE WERE NOT INCLUDED IN THE ANALYSES.

MECHANICAL ANALYSES

PLATE 26



FLEXIBLE PAVING DESIGN

PLATE 27

Photography Sections of Sandstone Report as made by Mr. R. N. Davis. These criticisms are mainly alterations to permit easier and more convenient handling of cameras and openings for their location. Also, new hoists are recommended to be installed in all Photo Towers.

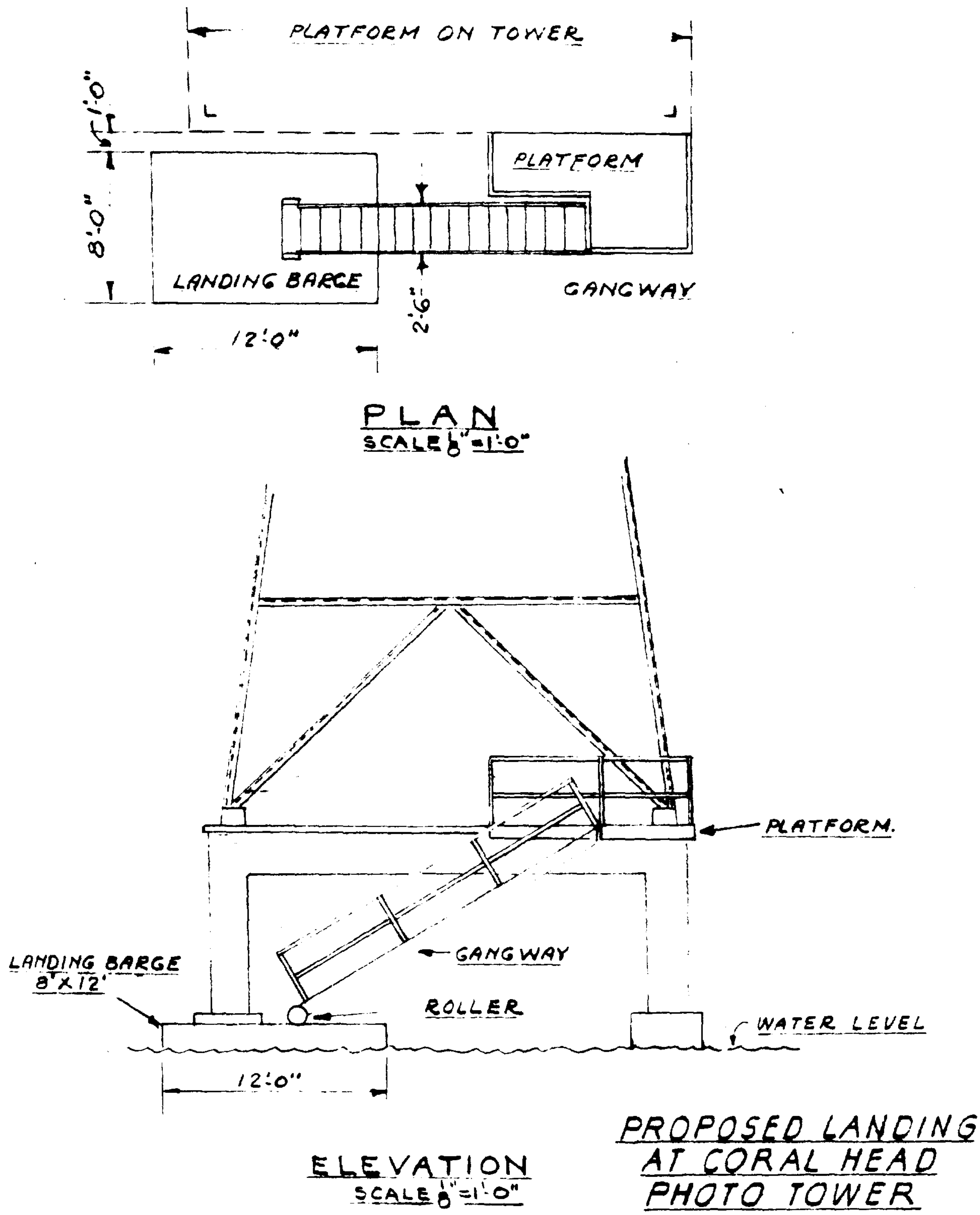
On Coral Head, it is recommended to install a float and ladder as shown on Plate 28 to facilitate landing thereon and prevent damage to cameras. Toilet facilities are recommended to be installed at the Coral Head site.

Two spare towers are now packaged and stored on Eniwetok which can be used, provided some replacements of parts that were removed therefrom are made and alterations carried out along lines suggested in the aforementioned Sandstone Report.

The present Coral Head Tower will be used for all experiment locations and the existing tower on Aniyaanii will cover Runit. One of the presently stored towers should be erected on Runit to cover Aomon and the other stored tower should be erected on Aomon to cover Engebi. A newly-purchased tower can be erected on Engebi to cover the Bogallua site.

This utilization of existing structures would limit the procurement to only one new complete tower, hoists for all towers, float and ladder for Coral Head, and such repair parts as necessary to alter existing structures and replenish parts needed to complete the stored towers.

Electrical Facilities. Although exact requirements are not now firm, it is anticipated that existing and new buildings on Experiment Islands will need power for motors, lighting, and instrumentation. At the Zero Tower, a motor generator or two motor generators will be required to obtain a source of direct current for the elevator and hoist. It should be possible to salvage these units prior to each experiment and re-use the same units for subsequent experiments. Lighting in the tower room, obstruction lights for aircraft and



PROPOSED LANDING
AT CORAL HEAD
PHOTO TOWER

PLATE 28

floodlights on poles to illuminate the ground area about the tower will be required. It is anticipated that lighting will be required for the Photo Tower, the Timing Station, the Gamma Stations, the Blast Buildings and other miscellaneous buildings. A 1,000 watt vertical pylon light was provided behind the Timing Station for "Operation Sandstone", and it is probably that this will be required for future operations.

When instrumentation requirements are firmed up, additional power and lighting requirements for instrumentation buildings of all types should be studied in detail prior to final design, and full consideration given to the operating conditions and corrosion problem which will exist.

Structures for Bogallua Island. Should this location be utilized for a test, it will be necessary to construct new structures for all types used for the experiments.

It is recommended that if more tubes are required in Gamma Buildings at this site that a two-cell structure be built using a center wall of coral concrete 12 inches thick. The roof and remaining walls of the structure should be of limonite concrete of thickness used on existing Shot Island Gamma structures.

All new experimental structures are expected to be modified in incorporating new requirements as determined from the "Operation Sandstone" and subsequent investigations.

WATERWORKS SYSTEMS:

Water Supply Sources - Well Waters. As described at the beginning of this Section of the Report, the islands of the Atoll consist of coral and supported on a shelf-like reef.

Due to the extreme porosity of the soil, and to the general level contour of the islands, a large percentage of the annual 77 inches of rainfall enters the subsoil, and tends to form a fresh water lense, which normally might be expected to float upon the saline water table below. The usual shape of the islands, however, is long and narrow and the shape of the lense therefore is similar, and when subjected to the influence of the tides and to the draft created by operation of the wells, soon becomes unstable. The yield from the wells then becomes brackish and unpotable. The degree of concentration of the saline content of the waters from these wells also varies with the rate of pumping as well as with the total volume withdrawn from the lense. With continued pumping, the water becomes not unlike sea or lagoon water and the well as a source of fresh water results in failure. Brackish waters in varying degrees of salinity have little or no advantages over sea water as permissible uses for such waters can only be measured by uses applicable for waters with comparable maximum salt content.

Catchment of Rain Water. The average rainfall of approximately 77 inches per year indicates that it might be feasible to collect enough runoff from impervious areas to provide a source of water supply.

Closer examination of the records of rainfall show that fairly long periods, wherein very little precipitation occurs, are not unlikely. Consequently, large impervious areas for catchment of rainwater, and large storage works for retaining it would be required to insure an adequate supply.

Only on the Island of Eniwetok does there exist an impervious area of sufficient size to consider as worthy of possible exploitation for this purpose. This area is the air strip, which if paved would comprise a surface of 300 ft. wide by 7,000 ft. long and having an area of 48 acres. Collection of surface water from this strip is feasible by reason of the layout and slope of the strip; but the use of this strip in the past and its probable use in the future as a base for the operation and wash-down of drone planes subjected to radio-active contamination disqualifies this area.

Other additional impervious areas, such as roofs of buildings, etc. are of such limited extent, that considered individually, are of inconsequential value, and considered collectively are of doubtful value as to total area, and under most optimistic circumstances would provide only a portion of the fresh water requirements. The complexities incident to the installation and operation of a waterworks system where only portional supply requirements are indicated further depreciate off-hand apparent advantages.

Parry Island resolves itself into the same category as Eniwetok Island with the exception of the air strip limitations. While this strip is not subject to radio-active contamination, neither is it comparable in size (the paved surface being 50' wide x 800 feet long with an area of one acre) and hence has little value as a catchment area when analyzed in terms of requirements.

Air strips on the experiment islands are directly exposed to extreme contamination and are disqualified for this reason. In addition the subsequent destruction of extensive permanent type works required by rain water catchment on these islands is not justified.

<u>Distillation of Sea Water</u>. Continued research and development both during the war and since, has resulted in the production of equipment with water-to-fuel ratios of as high as 200 to 1 and to the elimination of many of the imperfections of the invasion type units. These units are now manufactured by several firms and their operation can now be considered both successful and satisfactory. Although units may be custom-built for any specified capacity, standard sizes are generally rated at 90 gallons per hour, 375 gallons per hour, and 600 gallons per hour. Larger sizes of approximately 2000 - 2500 gallons per hour are also available. Manufacturers generally recommend the installation of a number of smaller units for any desired total capacity, in

order to take advantage of the flexibility of operation provided thereby. Chief among the difficulties of operation of the earlier type machines was the unreliability of the gasoline engine drivers. The later machines may be equipped with either electric motor or diesel engine drives.

Consequently, with the reliability of large capacity distillation units established, it is recommended that the distillation of sea water be utilized as the source of supply for the potable water supply for the island installations contemplated by this project.

Distillation units of the type herein contemplated require some means of raising the temperature of the water to be distilled. This is accomplished by using an outside source of steam where available, by electric heater, or by the use of the diesel engine cooling water of the diesel drive of the distillation unit. The utilization of diesel engine drives for these units seems most appropriate for the following reasons:

The demand factor of the island power plant may be reduced accordingly, the distillation units may operate independent of the power plant, the services of diesel mechanics required for maintenance and operation of the power plant will likewise be available for maintenance and operation of the distillation units, and the elimination of outside source of steam or electric heating results in simplicity of installation and operation with consequent lower operational costs.

Types of Water Systems Proposed. Regardless of the adequacy and efficiency of present day manufacture of equipment, the distillation of water, when utilized as a source of supply for a water works system, is an unusual and expensive process.

In order to minimize the use of distilled water, a dual or split system is proposed for each island installation. This means that separate distribution systems will be required. One system will distribute distilled water to such services as are necessary and one system will distribute sea water to services not requiring potable water. This method of dual distribution systems is not uncommon in industrial plant practice where waters having different chemical and mineral analyses, or where waters at different pressures are required within the same area.

In the case of the island installations, this method is economically possible due to the following facts: The area comprising each installation is small, hence the lengths of pipe lines are short; the drafts upon the system are light, permitting the use of relatively small pipe sizes; the excavation for pipe lines is shallow, the character of the soil is advantageous, and a joint or common intake and raw water pumping station is feasible and desirable.

However, elevated storage in two separate smaller units must be provided, rather than one larger storage on a single tower. A certain amount of duplication of plumbing within some of the buildings will be required, although the extent of this duplication and the number of such buildings is limited.

For the purpose of this Report, it may be stated that, in general, the sea water system will be used for toilet flushing, equipment washing, fire protection and similar services, and that distilled water will be utilized for all other purposes. The division of usage of total volume of water consumed is estimated on a 50-50 basis. Raw water supplied to the stills equals twice the distilled water yield, hence distilled water, loss in distillation, and sea water usage, each equal one-third of the total raw water pumped.

The "Engineering Manual for War Department Construction" of water supply systems designates 100 gallons per capita per day as a satisfactory design basis for mobilization type of projects, and further stipulates that for all projects involving a population of less than 5000, a "capacity factor" of 1.5 times the population figure be used to allow for flexibility of operation, future expansion of unforeseen peak demands. Inasmuch as the type of project contemplated by this Report is similar, and that this criteria is substantiated by standard practice in the design of certain municipal and industrial works, these figures have been used for the installations on Parry and Eniwetok Islands.

Calculations for the experiment island camps, due to the extremely temporary nature and to the absence of various facilities requiring water service at the larger installations have been scaled downward in accordance with "Theatre of Operations" type of construction.

Total consumption for these installations is therefore estimated at 70 gallons per capita per day and total raw sea water pumpage at 105 gpcd. This raw water total is likewise broken down in equal third parts or 35 gpcd day each for distilled water, loss in distillation, and sea water usage.

Construction Camp on Parry Island. In Section V of this Report, the peak construction personnel is estimated to be approximately the same as the personnel quartered on Parry at experiment time and it, therefore, appears reasonable to provide distillation units suitable for the final use as early as possible for use during the construction period.

Certain modifications of the construction camp water system on Parry Island will unquestionably have to be made in the transition from construction camp to permanent camp, but much of the material and equipment required by the construction camp may be adapted and used in the ultimate installation.

Parry Island Water Systems. Having assumed a population of 600 persons (construction personnel superseded by test personnel), a capacity factor of 1.5 and a daily per capita consumption figure of 100 gallons, the estimated total daily volume of water consumed would be 90,000 gallons of which it is estimated 45,000 gallons are distilled water and 45,000 gallons are sea water. To this total should be added 45,000 gallons for losses in distillation for total daily volume of 135,000 gallons to be handled by intake and raw water pumping station.

Intake and Sea Water Pumping Station. Due to the remoteness of Parry Island from the shot islands and to the tidal currents that sweep through the deep passage at the north end of the island into the lagoon, thus providing ever changing ocean water at this point, and to the ease of construction and maintenance of a water intake located on the lagoon side, it is contemplated to utilize these advantages by locating the proposed intake on this side of the island.

In the design of a system of this sort, it is customary to predicate the operation of all units on a 24-hour basis and to depend upon the capacity factor and on the occasional operation of duplicate or standby units to provide the additional capacities required at times of peak demand. On this basis the average raw water pumping rate for a daily volume of 135,000 is 94 gallons per minute. Minimum fire protection service for this type of installation is assumed, and will require 500 gallons per minute. This rate is predicated on the assumption of two hose streams of 250 gallons per minute each. Discounting any reserve from elevated storage or from the domestic pumps, this capacity must be obtained by the installation of at least one fire pump. Under these conditions, the pumping plant would contain of three 100 gpm pumps, two electric driven and one gasoline engine driven and one 500 gpm gasoline driven fire pump. Each of the 100 gpm pumps will handle the average demand and standby and peak demand service is thus provided by either electric driven or gasoline engine driven pump capacity. These pumps will be constructed of materials adapted for salt water service.

Distillation Units. Daily production of distilled water, having been estimated at 45,000 gpd, including a capacity factor of 1.5. This is an hourly production rate of 1,875 gallons and it is believed that three 600 gph units would be adequate. Due to their large capacities, these units are of heavy, rugged construction and consequently are not adaptable for portable service.

In the development of the final design of the system, consideration will be given to the advisability of housing these units in or contiguous to the power house for simplicity of operation and maintenance.

In order to eliminate the construction of a raw water supply tank for the distillation unit and the installation of separate low capacity and low head pumps to supply this tank, it is contemplated to take the raw water supply for the distillation units from the sea water distribution system. The additional costs of lifting the small quantities involved for the short periods of time required by this arrangement are considered negligible in view of the initial construction costs required by the installation and maintenance of the additional pumps and tank.

Distilled Water Surface Storage and Pumping Station. A receiving tank for distilled water as it is produced by the stills should be provided. This storage would correspond to the clear well storage in connection with a standard water filtration plant and serves only as a cushion between the production of distilled water and pumps supplying the system. Capacity should be ample for fairly continuous pump operation but need not be more than 50% of one day's supply or 22,500 gallons. This reservoir should be constructed to receive by gravity the product of the stills and should be constructed of concrete, covered, and ventilated to assist in further cooling of the distillate, and should be adequately baffled to insure continuous displacement of its contents. In connection with this distilled water reservoir, there will be required a pumping station to lift the distilled water through the system to elevated storage "floating" thereon. The pumping rate if calculated by the previously indicated method utilizing 24-hour operation would be 31 gallons per minute. Inasmuch as pumping-head characteristics of the pumps required for this service will be similar to those required for the salt water distribution system, and as additional capacities above calculated capacities result in decreasing the pumping time only, (although it does slightly increase the power demand rate but not necessarily the total consumption of power), in the interests of standardization of equipment it is justifiable to install pumps of identical capacity, head characteristics and construction with those of the salt water system, thereby providing for the possibility of inter-change of parts or of inter-change of complete units. The pumps to be installed in the distilled water pumphouse should consist of three 100 gpm pumps, two electric driven and one gasoline engine driven, to provide either electric or gasoline engine driven standby.

Distilled Water Elevated Storage. Elevated storage of distilled water should be provided in an amount of between 20 and 50 percent of the total daily volume of 45,000 gallons, or in an amount ranging between 9000 and 22,500 gallons. A standard size tank within this range is one having a capacity of 15,000 gallons. This capacity is required to permit flexibility in the pumping operation sequence. This flexibility may be especially desirable if pumps having higher capacities than the normal calculated rate are utilized.

Most domestic water works systems operate under pressures varying from 25 to 100 pounds per suqare inch. Due to the small level area encompassed by this installation, minimum pressures may be utilized to advantage, as pipe friction losses may be kept low and minimum pressures will help prevent undue waste or excessive use of distilled water.

A standard hemispherical bottom tank of 15,000 gallons on a standard height of 50'-0" to the bottom capacity line will exert pressures of from 21.5

to 31 p.s.i. static pressure on the system.

In the final design of the system, consideration will be given to the possibility of replacing this elevated storage with a compression tank, although, this method does not appear to be readily adaptable to this installation, due to the necessity for automatic controls and auxiliary equipment that such an installation generally requires.

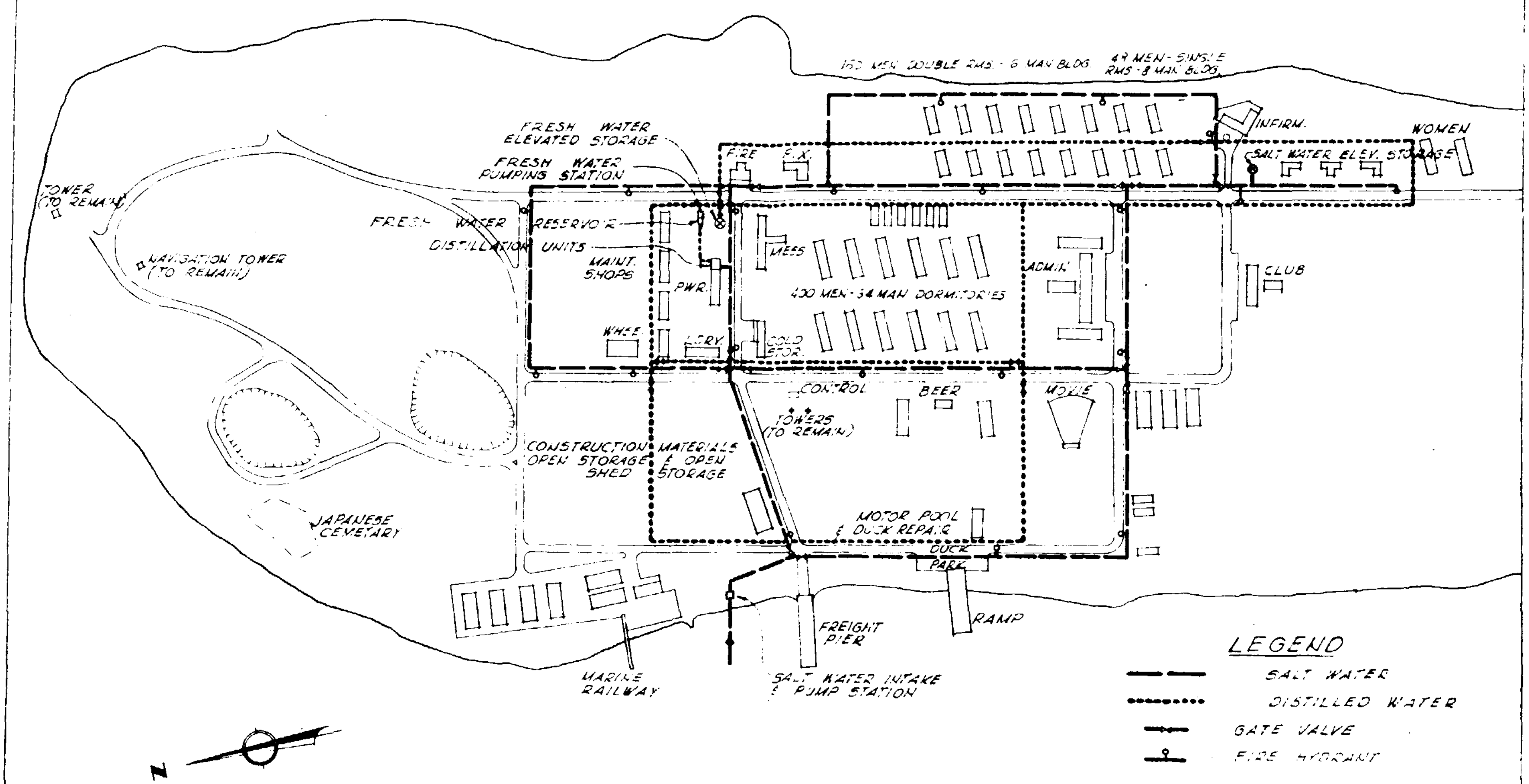
Sea Water Elevated Storage. As previously stated, elevated storage capacity should approximate 20 to 50 percent of the daily volume. Due to the relatively continuous pumping cycle of the salt water pumps, this elevated storage may be established at nearly the minimum figure of 20% of the total volume, 27,500 gallons. A standard size tank near this figure is one of 30,000 gallons capacity. If located on a tower 50'-0" in height to the bottom capacity line, static pressures varying from 21.5 to 32 psi will also be exerted upon the system.

Distribution Systems. Both the sea water and the distilled water distribution systems will be constructed of either cement asbestos (Transite) or cast iron pipe, whichever is the more readily procurable. Costs are comparable and either is expected to give satisfactory service. Pipes will be laid with a minimum depth of two feet of earth cover for protection against traffic and other hazards.

To minimize losses due to friction, a "loop" system of distribution is contemplated. The general arrangement of the system is shown on Plate 29.

Fire hydrants will be located on the salt water distribution system only and at interval which will permit any building to be protected by two 300-foot lengths of fire hose.

Eniwetok Island Water Systems. It is proposed that facilities equal and



WATER LAYOUT - PARRY ISLAND

SCALE IN FEET
0 100 200 300 400 600 800
50

PLATE 29

[redacted]

comparable to those required by operations on Parry Island, likewise be established on Eniwetok Island. Inasmuch as the extent of the installation is equal and the general conditions similar, it follows that the water works system likewise may be similar in design. Consequently, all calculations previously set forth as applicable to the system on Parry Island are applicable to Eniwetok also. The arrangement of the distribution system as made necessary by the different grouping of the buildings is essentially the only variable factor, and is indicated on Plate 30.

Shot Islands Water Systems. It has been previously stated that the design of the water supply systems on the shot islands will be based on a basis of 35 gallons per capita per day allowance for distilled water usage and 35 gpcd allowance for sea water usage with additional allowance of 35 gpcd for loss of water in the distillation process. It is not anticipated that the design figure of 200 population for each island will be exceeded, and consequently no capacity factor has been used. The total daily volumes of water required are therefore 7000 gallons of distilled water, 7000 gallons sea water usage and a total of 21,000 gallons total sea water pumped. In general, the same type of layout and design, greatly reduced in capacities and scope as previously discussed for Parry Island will be followed in the design of the systems for these camps. Due to the extremely temporary nature of these installations, certain other aspects of the design will be modified accordingly.

Intake and Sea Water Pumping Station. Due to the greater possibility of lagoon water becoming more radio-actively contaminated than the ocean water beyond the reef, it seems advisable that the intakes for the shot islands be located on the seaward side of the reef. Instead of pumping capacities being predicated on a 24-hour basis, a 12-hour cycle has been used. Thus, the raw water pumping rate for 21,000 gallons in 12 hours is 30 gpm. The use of two

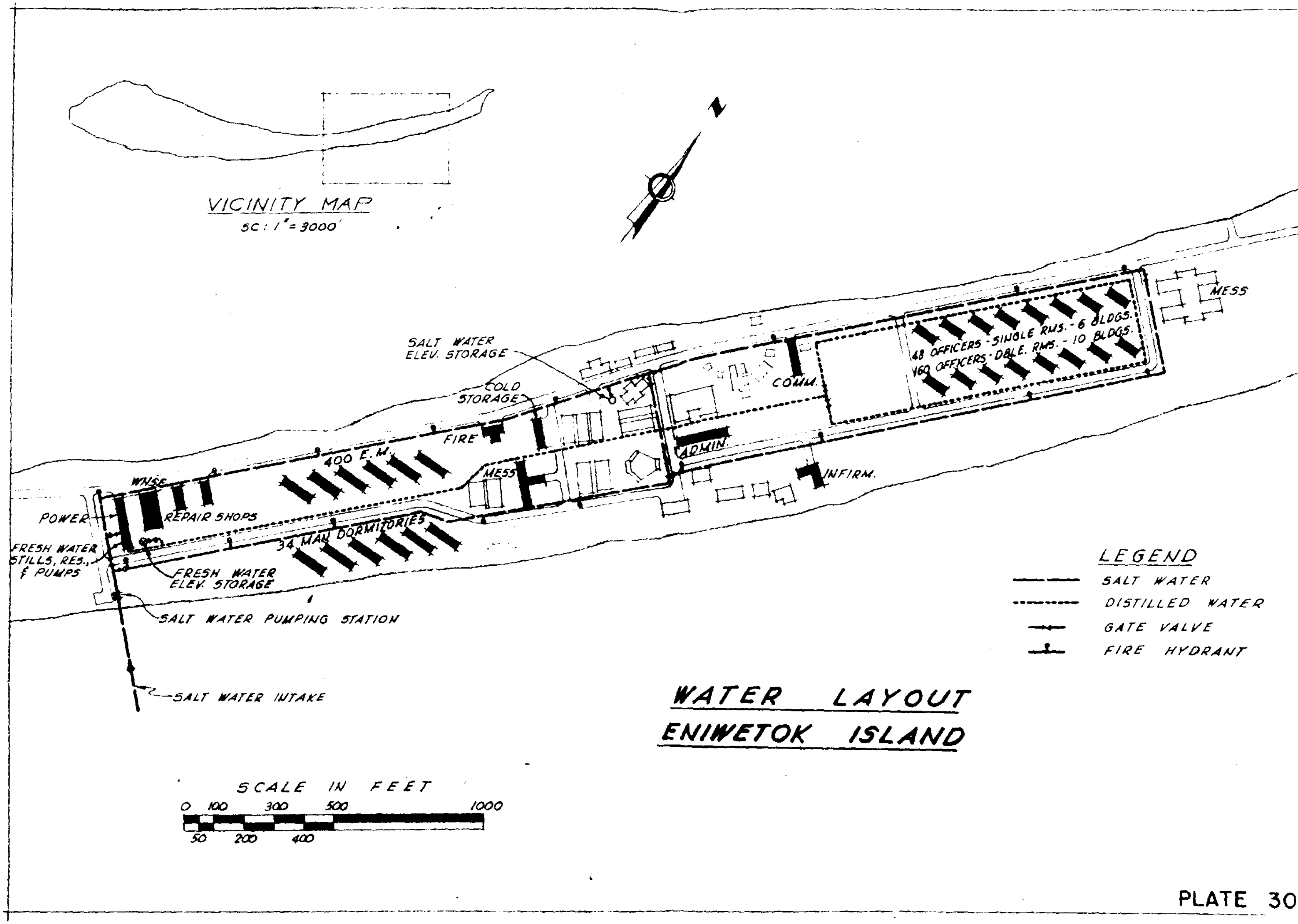

VICINITY MAP
SC: 1" = 3000'
SALT WATER ELEV. STORAGE
COLD STORAGE
FIRE
400 E.M.
MESS
ADMIN.
COMM.
INFIRM.
48 OFFICERS - SINGLE RMS. - 6 BLDGS.
160 OFFICERS - DBLE. RMS. - 10 BLDGS.
MESS
WHSE.
POWER
REPAIR SHOPS
34 MAN DORMITORIES
FRESH WATER STILLS, RES., & PUMPS
FRESH WATER ELEV. STORAGE
SALT WATER PUMPING STATION
SALT WATER INTAKE
LEGEND
SALT WATER
DISTILLED WATER
GATE VALVE
FIRE HYDRANT
WATER LAYOUT
ENIWETOK ISLAND
SCALE IN FEET
0 100 300 500 1000
50 200 400

PLATE 30

(2) 35 gpm pumps is therefore indicated. It is anticipated that electric power will be available and electric driven motors may be used. No fire protection other than that provided by a chemical cart is contemplated.

Distillation Units. On the basis of 24-hour operation of the distillation units, 290 gallons per hour production would be necessary. The use of four 90 gph distillation units would furnish this capacity with sufficient surplus capacity for standby service, flexibility of operation, and for peak demands.

It is contemplated that these units will have diesel engine drives and be of permanent installation type construction. Consideration will be given to mounting each of these units on mobile truck-trailer type frames for extreme portability. Expendable temporary shelter area will be larger than would be required without these mountings but the equipment may thus be withdrawn without delay or interference with general evacuation proceedings immediately prior to zero hour. In addition to the salvage value, this mobility might be highly advantageous in coping with unforeseen demands for water distillation imposed by unanticipated short-time requirements on any of the other islands.

Distilled Water Surface Storage and Pumping Station. A distilled water receiving tank or clear well having a capacity of 50% of 7,000 gallons or approximately 3,500 gallons should be provided. Two (2) identical pumps of 35 gpm capacity each should be provided to lift the distilled water to elevated storage and for furnishing pressure on this system. These pumps may also be interchangeable with the salt water pumps.

Elevated Storage. Both elevated storage of distilled water and that of salt water could be placed on a common wooden tower. The height of this tower need not be over 20 feet, as extremely low pressures of about 10 pounds per square inch would provide satisfactory operation. These tanks and towers could be of such economical construction that they could be considered expendable, and hence need not be removed at the time of an experiment. The salt water tank should have a capacity of approximately 4,000 gallons and the distilled water tank a capacity of approximately 2,000 gallons.

Distribution Systems. The distribution systems, because of the nature of the service rendered, will be of cast iron or Transite pipe. As the number of buildings to be served is limited and as no special fire protection facilities, such as fire hydrants and high pressure on the system, are contemplated, the system may consist of short lines of small size pipe connecting the elevated storage with the installations to be served.

The description of the water system as set forth is to be considered typical of all the shot islands. Certain modifications in arrangement of distribution piping will be required to conform to the plot plan of each camp, as determined from the shape and available space on each of these islands.

Engebi Island. This is the largest of the shot islands, with the camp located on the ocean side near the southern end. The arrangement of the water distribution system is shown on Plate 31.

Rojoa Island Water System. The island of Rojoa, situated just southeast of Biijiri, will be connected with Biijiri by bridge or causeway and will become the site of the camp for the experiment on Aomon Island. The Islands of Biijiri and Aomon are already connected by a serviceable causeway. These three islands consequently will function as one. This arrangement of the water distribution system is shown on Plate 32.

Runit Island Water System. The Island of Runit is long and narrow, and the only available site for a camp is on a small irregular shaped area at the extreme southern end of the Island. This area of usable space is connected with the main island by a long narrow sand spit which is considered a part of the island. This area is further limited in extent of usable space by the existence of an "M" boat storage yard that completely utilizes the extreme southern tip.

The description of the water system as previously set forth for shot Islands, will likewise apply to this installation. The distribution will also be arranged to conform to the plot plan of this camp and is shown on Plate 33.

Bogallua Island. If it is determined that the Island of Bogallua is to be utilized as a fourth shot island, facilities similar to those of the other three will be provided. A possible arrangement of the system is shown on Plate 34.

Operation of Systems During Roll-up Period. Inasmuch as the overall capacities of the water works systems for the individual island installations must necessarily be predicated on the loads upon these systems prior to and during an experiment, it follows that the design of these systems and that the selection of sizes of equipment be such that these systems may function with nearly equal efficiency under the greatly reduced loads imposed upon them during the roll-up or interim period between experiments. Primarily, these low-demand periods will result in reduction of daily operational time. Operation by rotation in sequence of duplicate or multiple units of equipment should insure adequate maintenance for subsequent operational peak periods. Equipment thus operated should have a useful life far beyond the now contemplated two-experiment life of the proving ground. Underground piping and appurtenances, due to the character of their construction and nature of service rendered, require little maintenance over a long period of years. Elevated storage tanks on structural towers, however, will probably require painting with some corrosion

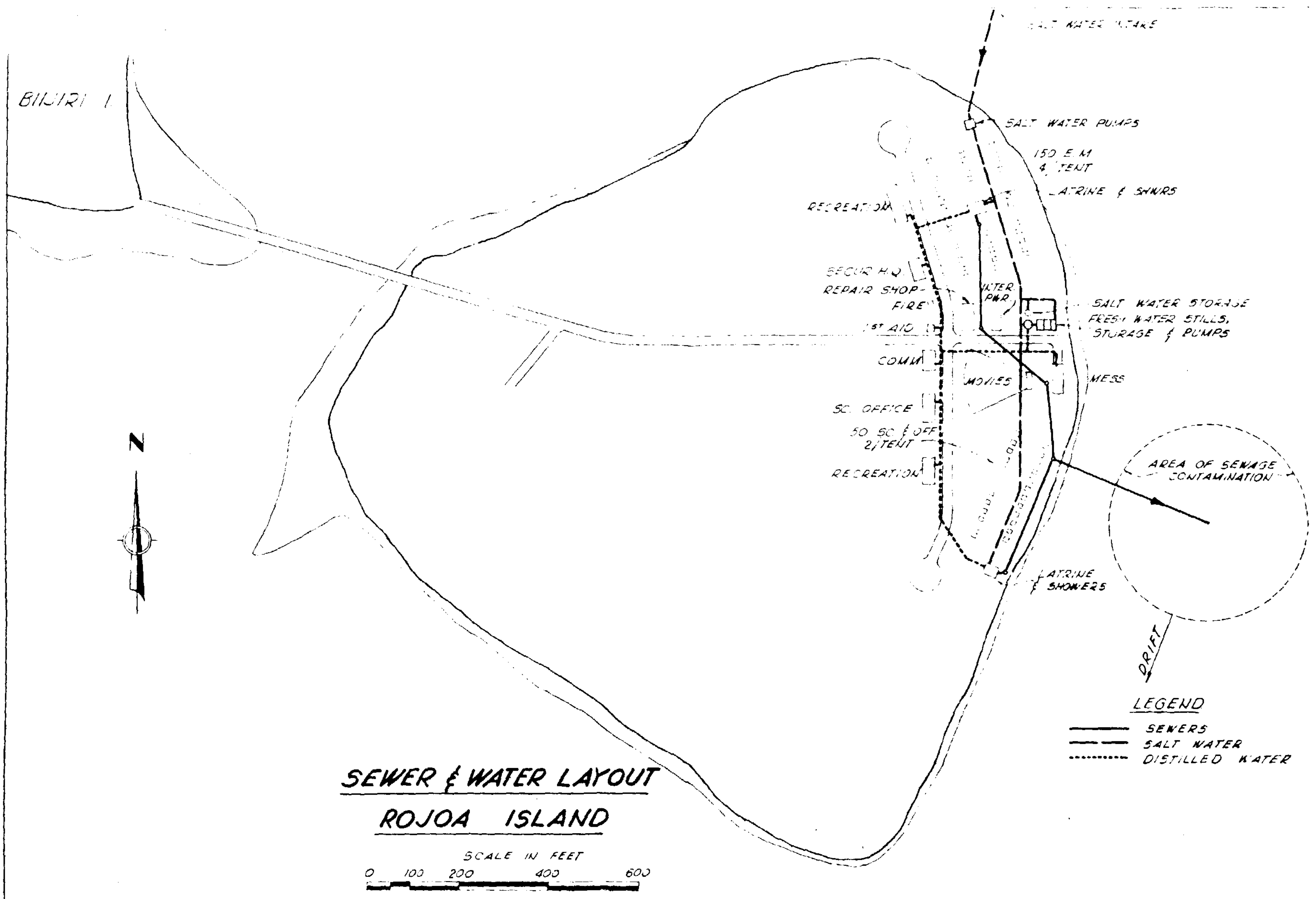
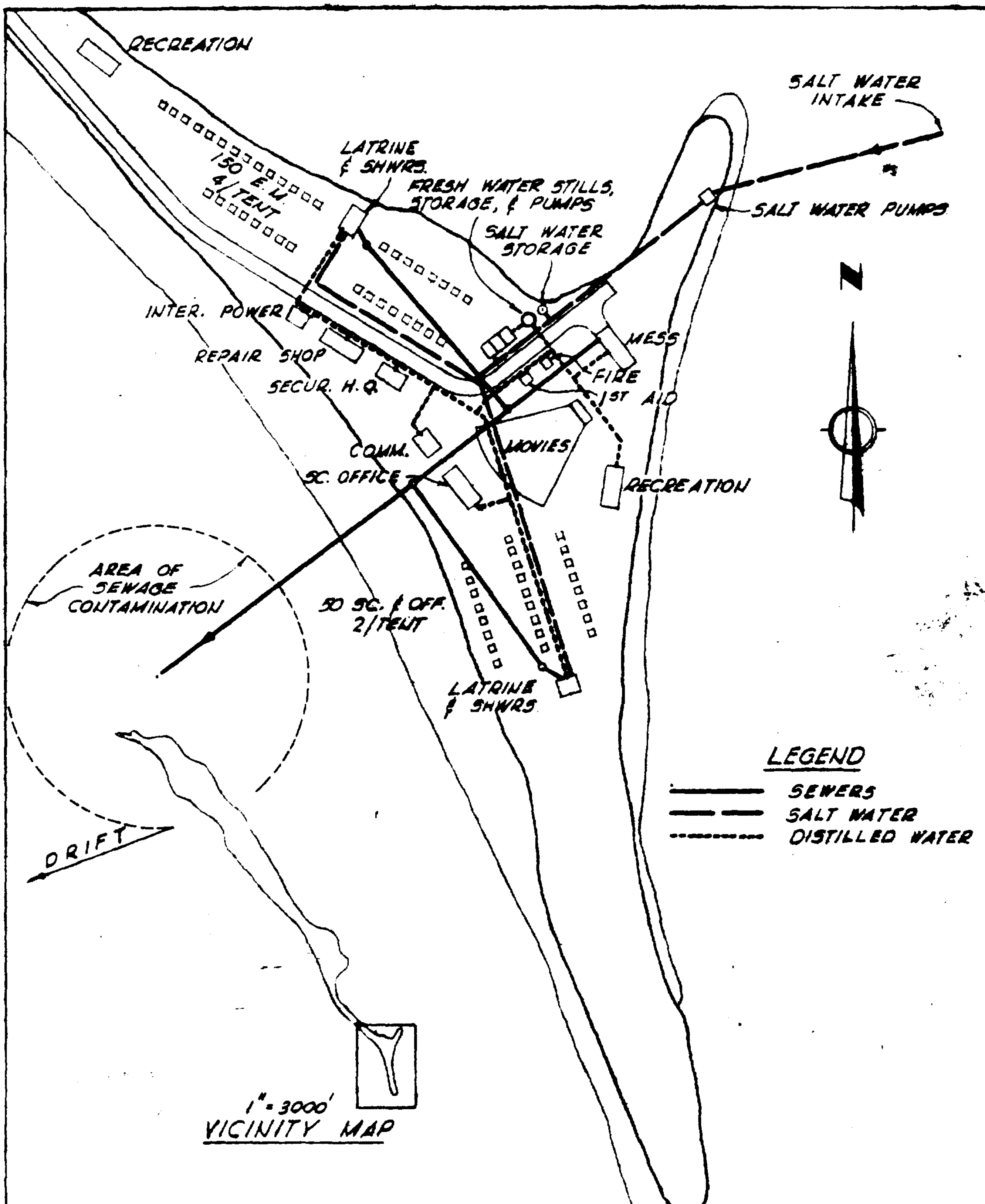
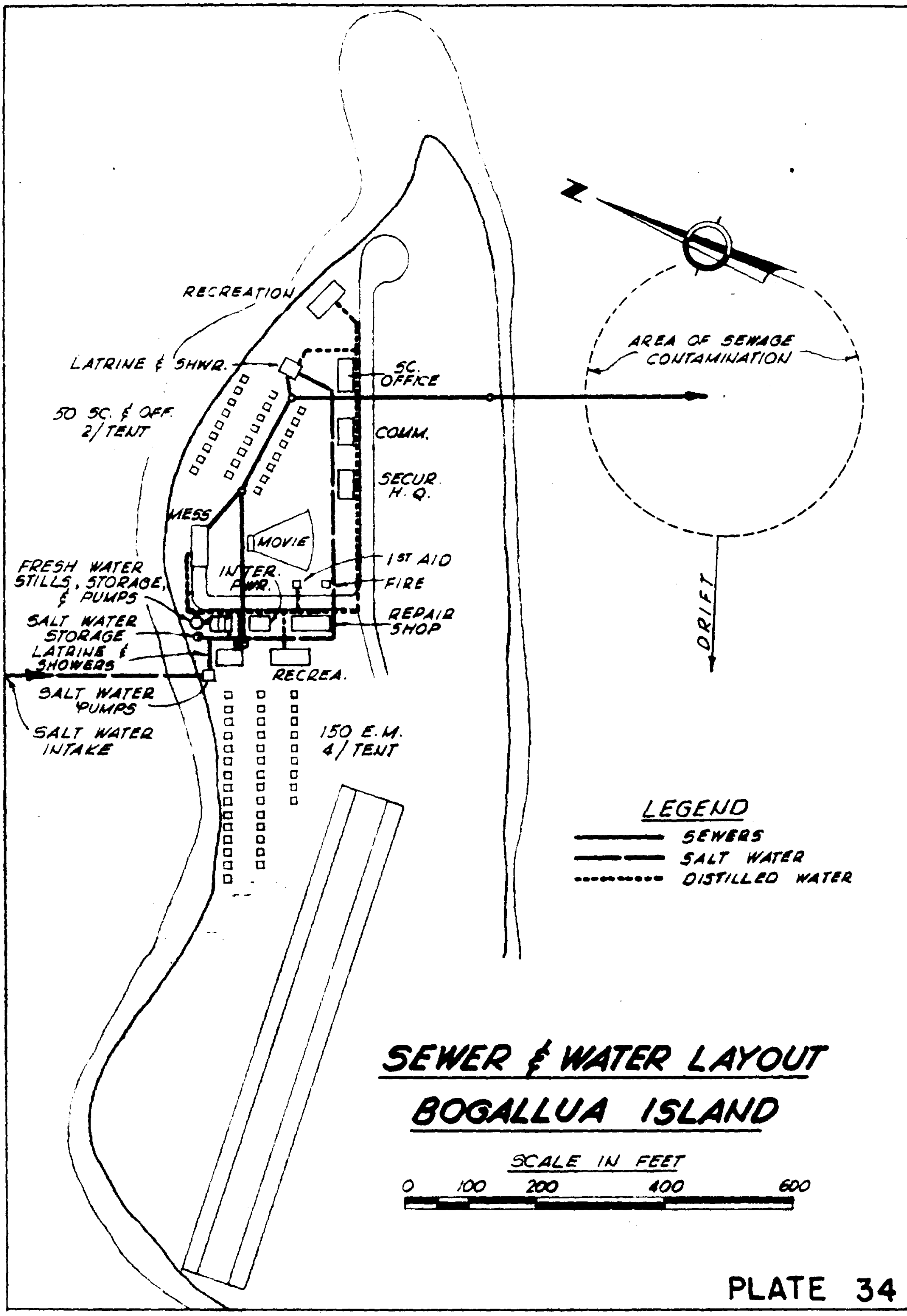

SALT WATER PUMPS
150 E.M.
4/TENT
LATRINE & SHWRS
RECREATION
SECUR H.Q.
REPAIR SHOP-
FIRE
INTER.
PWR.
SALT WATER STORAGE
FRESH WATER STILLS,
STORAGE & PUMPS
1ST AID
COMM
MOVIES
MESS
SC. OFFICE
50 SC & OFF
2/TENT
RECREATION
AREA OF SEWAGE
CONTAMINATION
LATRINE
& SHOWERS
DRIFT
N
LEGEND
SEWERS
SALT WATER
DISTILLED WATER
SEWER & WATER LAYOUT
ROJOA ISLAND
SCALE IN FEET
0 100 200 400 600

PLATE 32



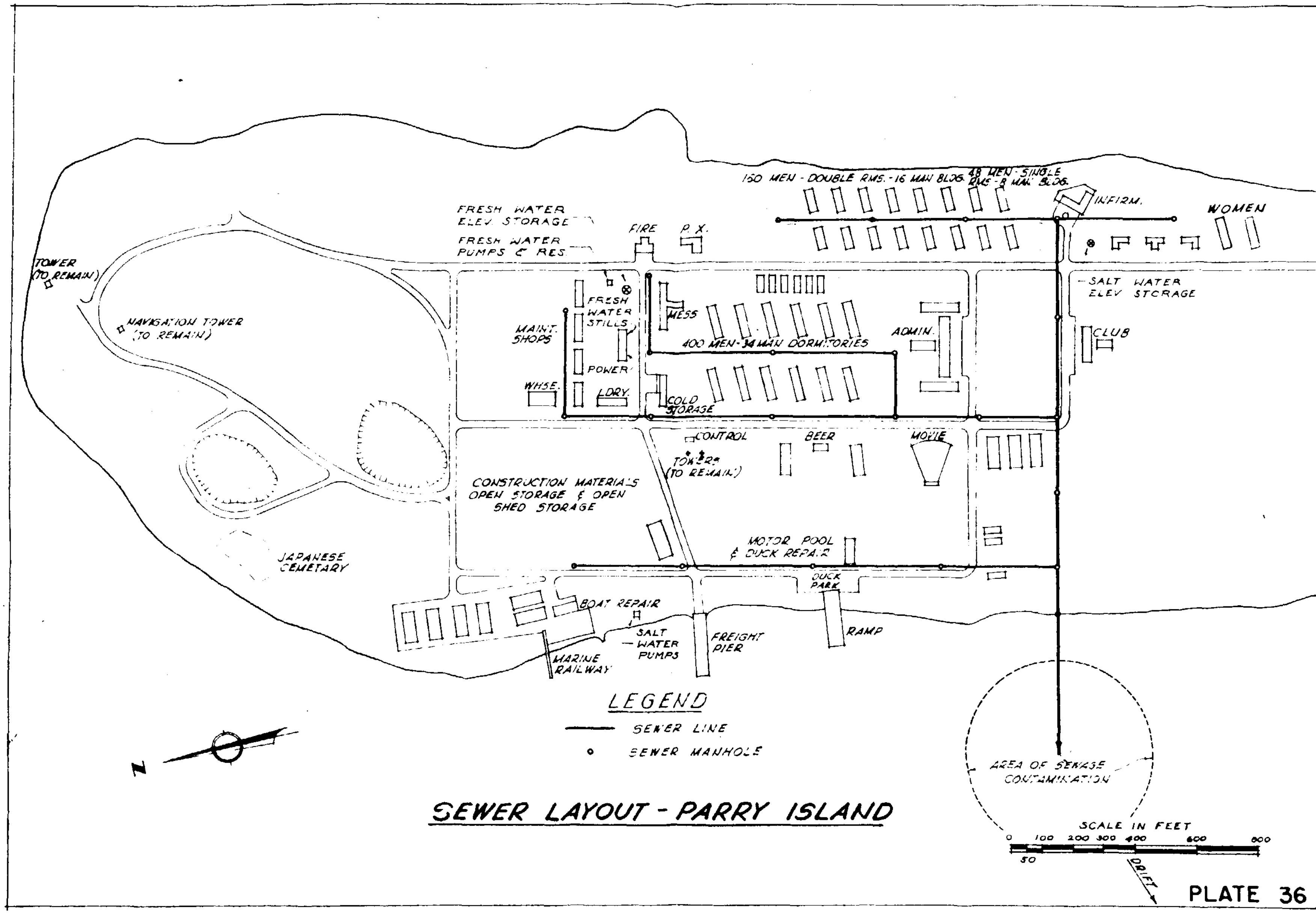
SEWER & WATER LAYOUT RUNIT ISLAND

PLATE 33



SEWER & WATER LAYOUT BOGALLUA ISLAND

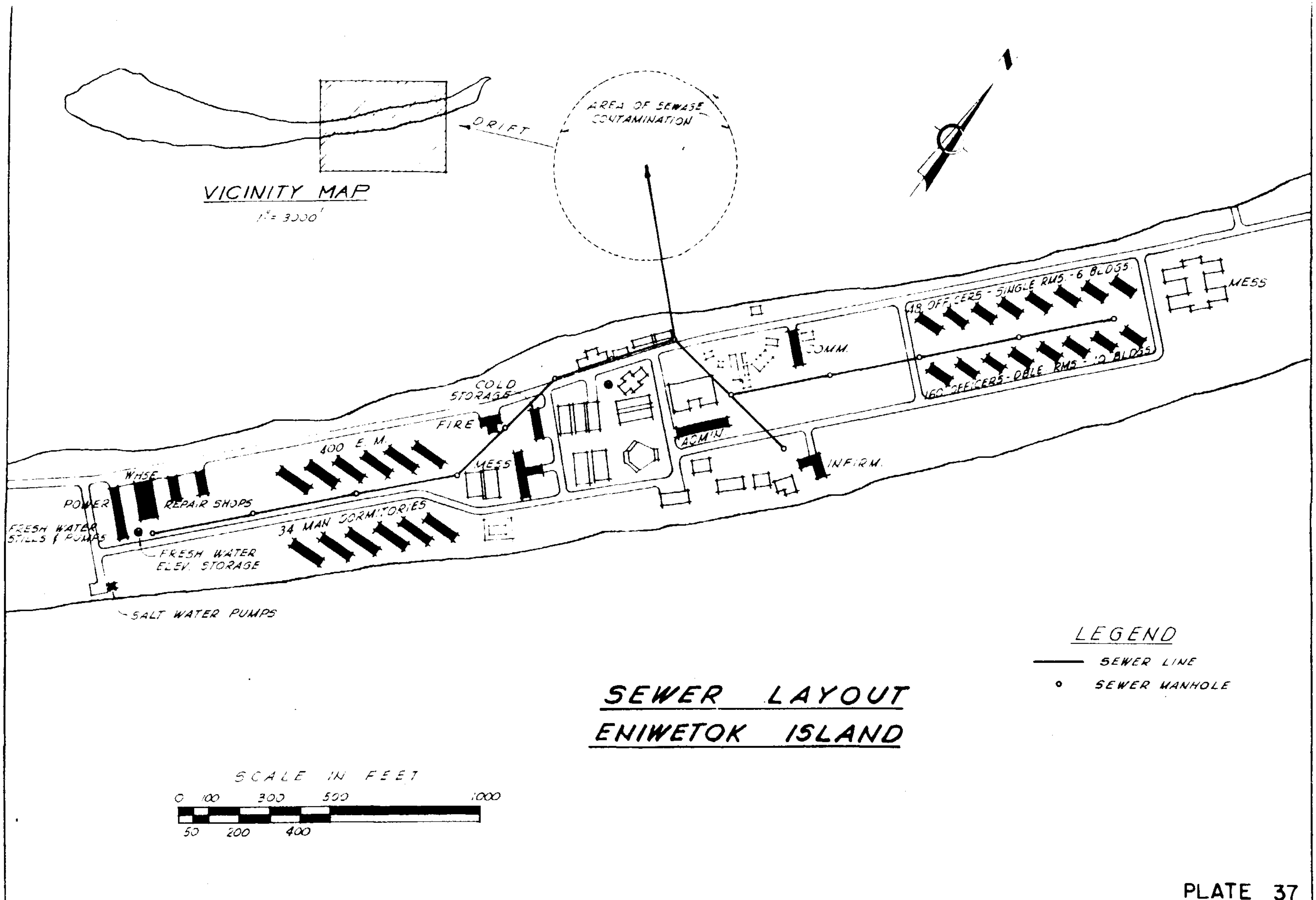
PLATE 34



SEWER LAYOUT - PARRY ISLAND

PLATE 36

[redacted]



VICINITY MAP
1" = 3000'
DRIFT
AREA OF SEWAGE CONTAMINATION
48 OFFICERS - SINGLE RMS. - 6 BLDGS.
160 OFFICERS - DBLE. RMS. - 10 BLDGS.
MESS
COMM.
ADM'N.
INFIRM.
COLD STORAGE
FIRE
MESS
400 E. M.
WHSE.
REPAIR SHOPS
POWER
FRESH WATER STILLS & PUMPS
34 MAN DORMITORIES
FRESH WATER ELEV. STORAGE
SALT WATER PUMPS
LEGEND
SEWER LINE
SEWER MANHOLE
SEWER LAYOUT
ENIWETOK ISLAND
SCALE IN FEET
0 100 300 500 1000
50 200 400

PLATE 37

resistant coating at least once during each roll-up period.

Expendable Items. The waterworks system serving the facilities on each of the shot islands will be required to continue in operation until a few hours before zero hour. As previously mentioned, provision is being made for the rapid removal of the distillation units. These units comprise the largest single item of capital investment cost of the system. Salvage of these units coupled with anticipated re-use of essentially all underground piping leaves few items that must be considered expendable. These items consist of small water storage tanks on temporary wooden frame towers, temporary shelters for equipment, and the small pumping units. It is conceivable that at least a portion of these pumping units, if not all, could be salvaged also. The number of units salvaged will depend on actual timing of zero hour operations. This timing of operation and its relationship to waterworks operations can hardly be foreseen and, therefore, may result in total loss of some of this equipment.

SANITARY SEWER SYSTEMS:

All camps or installations on the various islands contemplated by this Report will be provided with systems for the collection and disposal of waterbourne sewage. The installation of this type of construction for the Islands of Parry and Eniwetok which will be occupied to some extent on a year-round basis requires no justification.

The installation of such systems on the shot islands is economically justified on a periodic short-term-occupancy basis by the fact that re-use of essentially all items of the sewer system proper is possible. Plumbing and fixtures of latrines, etc. will be destroyed as would any other facility erected for disposal of human wastes. The slight additional difference in resulting costs is consdquently justified when considered in terms of the health, comfort, and morale of the occupants.

Although standard sanitary engineering practice has, in recent years, established 8" diameter pipe as a minimum size for sewers other than building service connections, it is believed that the use of 6" pipe as a minimum size for the installations contemplated by this report is justified. This size pipe in most instances will provide adequate capacity for the flows contemplated and the savings in cost of pipe, shipping, and laying will more than compensate for any additional maintenance that may be required by the use of this smaller minimum size pipe. Inasmuch as the overall quantities are not considerable, and due to excessive breakage incurred by long distance shipping of vitrified clay sewer pipe, it is believed that ultimate economy will be obtained by the use of cast iron or transite pipe for this purpose. Stockpiles of pipe for maintenance and repair service are then interchangeable for either water or sewer service.

For access to the sewer for maintenance and repair, the system will be provided with manholes at all points of juncture of lines and at intervals along the line at not to exceed 400 feet.

Wye-branches will be inserted in the line at strategic points along the main lines to accommodate connections with the service lines from the buildings.

SANITARY SEWAGE DISPOSAL:

Ocean Currents. From available information and from observations made on the site, it has been determined that, in general, the ocean currents in the vicinity of the atoll are predominately from east to west, and tend to sweep across the atoll in this direction. These currents are of lesser magnitude in areas wherein the coral reef is unbroken. Between the islands of Japtan and Parry is a section of broken reef which is known as the Deep Passage, the water having sufficient depth to safely accommodate the largest of ships. Across the lagoon almost directly west of the deep passage is a shallow opening through the reef, and which is designated the Southwest Passage, while between these two gaps on the South end of the atoll is a third opening called the Wide Passage. The Wide Passage has considerable depth and provides a convenient outlet for flows entering the lagoon through the Deep Passage. The direction of this flow is advantageous for the disposal of sewage into the lagoon, especially as applied to the Islands of Parry and Eniwetok, the points of greatest concentration. Otherwise the currents tend to sweep the atoll circumferentially in a westerly direction and are shown on Plate 35. Sewage from shot island installations will consist of slight volumes and the general remoteness of these islands from other islands of habitation eliminates much of the hazard of disposing of sewage into the lagoon.

Subaqueous Outfall Sewers. It is contemplated that each island installation will require one or more subaqueous outfall lines to extend the point of discharge of sewage a sufficient distance from shore to preclude any possibility of the periphery of the sleek field from reaching the shore and consequently subjecting the beaches to bacterial contamination.

Competent authorities on sewage treatment and disposal have determined that the area of a sleek field is related to the contributing population. From the accepted formula, the area of the field for a population of 600 is approximately seven acres. Assuming the shape of the Sleek field to be circular and discounting any distortion of shape due to influence of ocean currents, the radius of this sleek field would be 310 feet. The length of outfall should then exceed 310 feet as measured lagoonward from the water's edge at periods of low tide. The ocean or tidal currents, unquestionably will tend to move the entire field offshore, but nevertheless, it is considered advisable to allow a factor of safety of 50% of the radius of the field and to establish

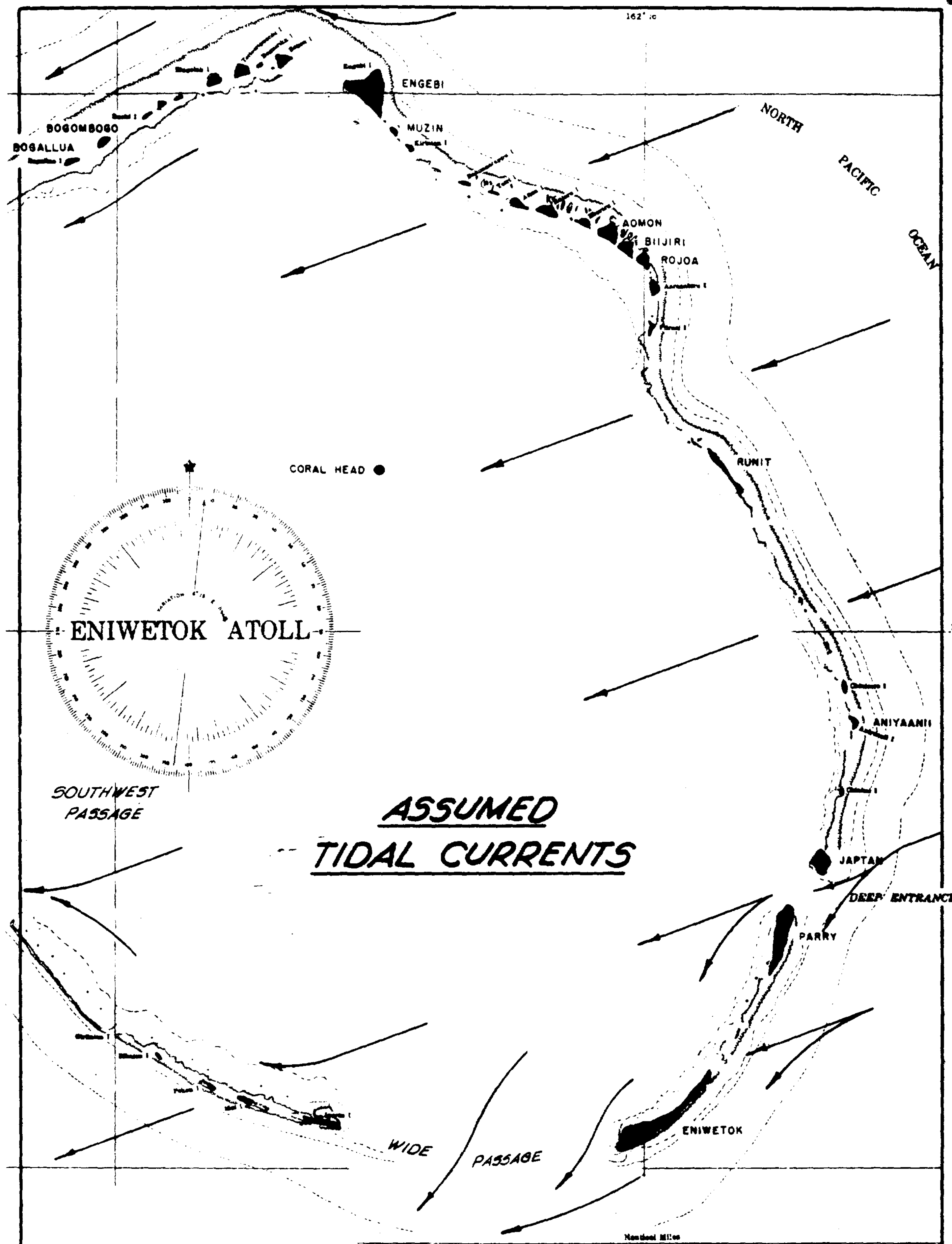

ENGEBI
MUZIN
BOGOMBOGO
BOGALLUA
NORTH PACIFIC OCEAN
AOMON
BIIJIRI
ROJOA
RUNIT
CORAL HEAD
ENIWETOK ATOLL
ANIYAANII
SOUTHWEST PASSAGE
ASSUMED TIDAL CURRENTS
JAPTAN
DEEP ENTRANCE
PARRY
ENIWETOK
WIDE PASSAGE
Nautical Miles

PLATE 35

the lengths of outfall sewers at Parry and Eniwetok at approximately 450 feet.

Similarly, the area of the Sleek field for a shot island with a population of 200 would be 3.3 acres, the radius of the field 250 feet and the length of the outfall sewer should be established at 325 feet.

Reference is made to the following Plates for layouts of sanitary sewer systems for the various islands involved. These Plates also show tentative locations of outfall sewers and resulting sleek fields.

Plate No. 36 - Parry Island
" " 37 - Eniwetok Island
" " 31 - Engebi Island
" " 32 - Rojoa Island
" " 33 - Runit Island
" " 34 - Bogallua Island

GARBAGE AND TRASH DISPOSAL:

Eniwetok Island. During the occupation of this island by the Armed Forces and since that time, garbage collected from island facilities has successfully been disposed of by simply dumping over the end of a short pier at the southwesterly end of the island. Ocean currents, previously described in this Report, carry this refuse out to sea. All trace of refuse disappears with each change of tide.

Trash collected was used in an attempt to reclaim an area lying just beyond the end of the westerly end of the air strip. Subsequent dumping of junk and trash has extended this area to a size easily capable of absorbing deposits contemplated by future operations on the island. It is recommended that these simple and effective methods be continued.

Parry Island. Again referring to the experiences of the Armed Forces, garbage was most successfully disposed of by hauling in floating equipment to a point near the Wide Passage and dumping where ocean currents carried it out to sea. This method prevented any possible contamination or unsightly nuisance creation at Eniwetok. Trash was burned in the open at remote areas where fire hazard was minimized and wind direction would cause least nuisance from smoke and odors. This procedure is likewise recommended for this island, although garbage could be burned in open trenches, (using oil as the burning medium) should equipment for hauling to sea not be available.

Shot Islands. Since the occupancy of the shot islands will be both limited as to number of personnel and as to length of time, and since most of the construction will be expended, the installation of incinerators for these islands is hardly justified. It is believed that garbage from these islands could be collected daily or on every other day and disposed of in a manner similar to and with the same facilities suggested for disposal of garbage on Parry Island. If personnel and equipment are not available for such service as needed, garbage could be burned in open trenches. Similarly, trash could be burned in the open at a logical location. During the interim or roll-up period, no such operations would be involved.

ELECTRICAL POWER SUPPLY SYSTEMS:

General Requirements. During construction and operation power will be required on the islands of Eniwetok, Parry, Aniyaanii, Runit, Rojoa, Biijiri, Aomon, Engebi, and Bogallua. It will also be required at Coral Head in the lagoon during operations for experiment purposes. On Eniwetok, it will be necessary to provide energy for lighting, motors, and communication facilities for the military garrison there. On Parry Island, power will be used initially for construction forces located on this island. During the operation lighting, power, and communication facilities must be supplied for personnel housed and working on this island. The balance of the islands, referred to as Experiment Islands, will require energy to serve camps for construction, test, and military security personnel in addition to instrumentation utility and instrumentation controlled voltage needs.

Load Cycle. After construction is complete the typical load cycle during operations for two-experiment use of these facilities is assumed to be approximately as follows: A two-month period building up from interim to maximum load as personnel arrive at the Atoll would be followed by a two-month period during active preparation for the experiments and the actual tests. Then, there would be a roll-up or interim period of twenty months or longer during which time only maintenance personnel would be on Parry Island and a small garrison of troops on Eniwetok for security. Then the two-month build up and two months at maximum load for the second set of experiments would complete the cycle.

Maximum Demands. The first step in analyzing the power system is to determine the locations and magnitudes of power demands. For the purposes of this report, maximum power demand estimates have been made as follows:

Eniwetok	Present demand for approx. 80 men	= approx.	165 KW
	520 additional men at .5 KW per man	= "	260 KW
	Estimated maximum demand during experiment	= "	425 KW

Assumed maximum demand during interim period (between experiments)= 200 KW.

Parry	600 men at .5 KW/man (estimated maximum demand during experiment)	=	300 KW
	Assumed maximum demand during interim	=	50 KW
Coral Head Photo Tower	Estimated maximum demand during experiment (Size of previous generator)	=	15 KW
	Assumed maximum demand during interim	=	0

Experimental Islands. It will be assumed that only one of the Experiment Islands will be at full activity while the remaining three islands would be operating at half activity, or load. The estimated demand for one Experiment Island at full activity is determined as follows:

200-man camp at .5 KW/man	= 100 KW
Instrumentation utility	= 85 KW
Instrumentation controlled voltage	= 15 KW
Estimated maximum demand during experiment	= 200 KW
Assumed maximum demand during interim	= 0 KW

The estimated maximum demand for the remainder of the Experiment Islands is one-half the above value.

A diversity factor (ratio of system demand in kilowatts to sum of individual demands) of 1.0 is assumed. This results in an estimated system demand as follows:

	Maximum Demand in KW During Experiment	Maximum Demand in KW During Interim
Eniwetok	425	200
Parry	300	50
Experiment Island- 1	200	-
Experiment Islands- 3	300	-
Photo Tower	15	-
Total	1240	250

Plate No. 38 indicates a resume of this power system load analysis.

Type of Sources. In order to supply the demands shown above, the following types of power sources will be considered: hydro plant, steam plant, and a diesel plant or plants.

A hydro plant is not a feasible power source because insufficient area and elevation are available on the small flat islands to develop sufficient power.

A central steam plant would require large expensive building construction and equipment for the small load involved. Specially trained high-pressure

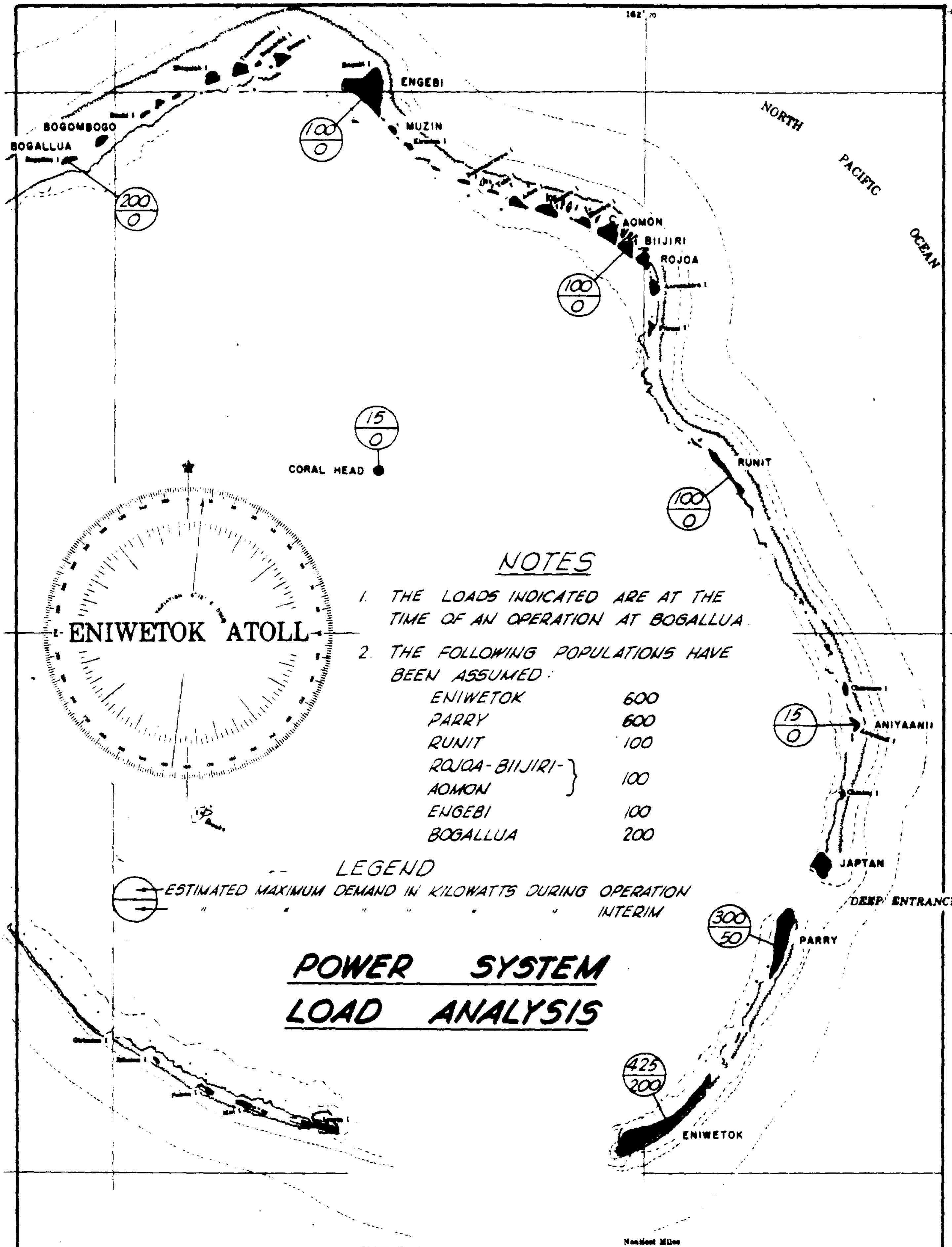

ENGEBI
MUZIN
BOGOMBOGO
BOGALLUA
NORTH PACIFIC OCEAN
AOMON
BIIJIRI
ROJOA
RUNIT
CORAL HEAD
ANIYAANII
JAPTAN
DEEP ENTRANCE
PARRY
ENIWETOK
ENIWETOK ATOLL
100/0
200/0
100/0
15/0
100/0
15/0
300/50
425/200
NOTES
1. THE LOADS INDICATED ARE AT THE TIME OF AN OPERATION AT BOGALLUA
2. THE FOLLOWING POPULATIONS HAVE BEEN ASSUMED:
ENIWETOK 600
PARRY 600
RUNIT 100
ROJOA-BIIJIRI-AOMON 100
ENGEBI 100
BOGALLUA 200
LEGEND
ESTIMATED MAXIMUM DEMAND IN KILOWATTS DURING OPERATION
" " " " " " INTERIM
POWER SYSTEM LOAD ANALYSIS

PLATE 38

steam operators would be required, and this personnel could not be used for other purposes to any advantage. The possible advantage of having exhaust steam available for water distillation is nullified by recent development of distillation equipment that does not require steam and is now considered superior to steam units. The total maximum electrical demand is relatively small and since three units are indicated - two to carry the entire load with one standby unit - these units would be of the 700 KW turbo-generator size. The cost of this equipment, in small sizes, is relatively high per kilowatt. A steam plant would be less flexible and would present less possibility of convenient salvage or relocation than smaller diesel units. The above items, plus the fact that such a low plant factor (ration of average generator load to total rated capacity of equipment supplying load) can be expected from the typical load cycle previously described, indicate that a steam plant would not be economical for the small and intermittent loads which will be served.

A diesel plant, or diesel plants, will be the most economical solution to the power source problem consistent with reliability. Diesel operators and mechanics can be used to good advantage to maintain and operate other diesel equipment which will be used. The smaller units involved will lend themselves most readily to relocation or salvage of this equipment when and if it is no longer needed for the experiments.

Number and Location of Diesel Plants. There are many different solutions to the problem of number and location of diesel plants to serve the scattered loads involved in an experiment. Three different solutions will be analyzed in this Report: many small plants, two plants, and one plant.

Many Small Plants. With this method, several plants would be located on each Experiment Island, one near each load center. One plant would be located on Parry Island to serve the test personnel, and similarly, one plant located on Eniwetok Island would serve the military personnel quartered there. Approximately 16 plants totaling 2600 KW would be required for eight islands (Eniwetok, Parry, Aniyaanii, Runit, Coral Head, Biijiri, Engebi, and Bogallua. Plate No. 39 shows a preliminary layout of the locations of many small plants. Details developed in actual design may indicate changes in the number, size and location of plants. Generating unit sizes are chosen in such a manner that each plant can carry its estimated maximum demand with the largest unit out of service.

The many plant scheme of power supply is similar to that used for Operation Sandstone. However, the proposed system would be more reliable than the previous one for a number of reasons. One difficulty and cause of uneasiness was that the engine-generator sets were of the light, high speed, advanced base type and had been in service at other locations previously. On their delivery to Eniwetok, it was necessary to completely overhaul them. Keeping these units running was a major maintenance job. It is proposed to use new, slower, heavily constructed units, which have proven to be reliable. The use of telemetering and possibly supervisory control between critical points on Experiment Islands and the Control Island will permit closer observation of conditions and control of the experiment. Further than this, it is probable that the actual construction of the plants will be accomplished with more suitable materials under less pressure of time resulting in better structural, mechanical, and electrical facilities.

It appears feasible to place the power plants adjacent to the Timing Building and to the Living Camps on the Experiment Islands in permanent reinforced concrete structures constructed partially below ground and protected on the side toward the zero tower by earth revetments. In addition to providing maximum protection of the equipment against the elements of weather or mechanical damage, such a method should make it possible to use the generating equipment on

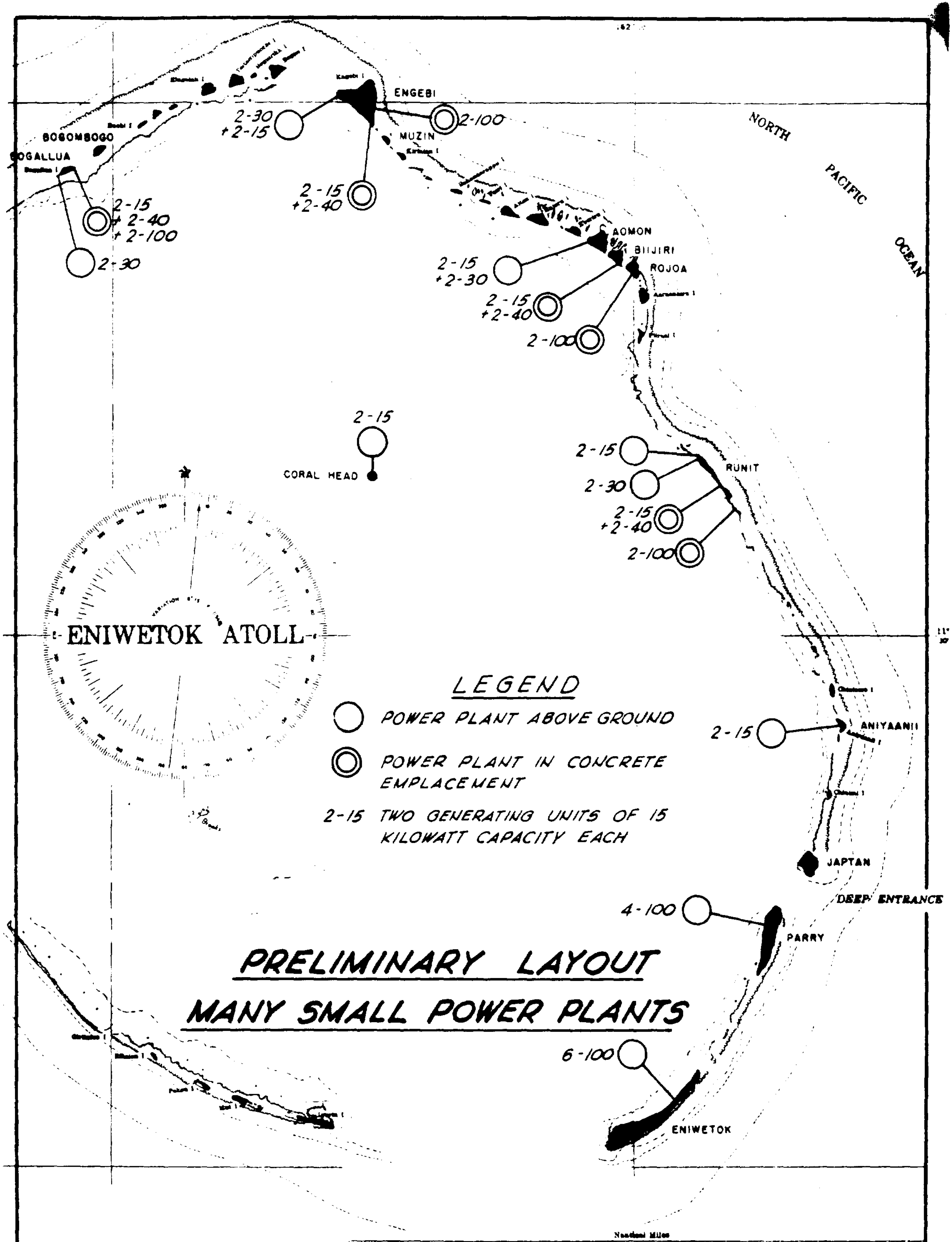

ENGEBI
2-30
+2-15
2-100
MUZIN
BOGOMBOGO
BOGALLUA
2-15
+2-40
2-15
+2-40
+2-100
2-30
NORTH
PACIFIC
OCEAN
AOMON
BIIJIRI
ROJOA
2-15
+2-30
2-15
+2-40
2-100
2-15
CORAL HEAD
2-15
RUNIT
2-30
2-15
+2-40
2-100
ENIWETOK ATOLL
LEGEND
POWER PLANT ABOVE GROUND
POWER PLANT IN CONCRETE EMPLACEMENT
2-15 TWO GENERATING UNITS OF 15 KILOWATT CAPACITY EACH
2-15
ANIYAANII
JAPTAN
DEEP ENTRANCE
4-100
PARRY
PRELIMINARY LAYOUT
MANY SMALL POWER PLANTS
6-100
ENIWETOK
Nautical Miles

PLATE 39

Experiment Islands for two or more operations. Such construction is recommended. The Zero Tower power plants are considered expendable and should be constructed above ground. The Photo Tower power plants should be constructed above ground so that units can be readily removed and salvaged prior to the shot on the Experiment Island on which it is located.

Consideration was given to the possibility of providing only one power plant rather than several for each Experiment Island. Because the distance between load centers is in general too great for economical distribution at utilization voltage (120/208 volts), transformers would be required to step up the voltage for feeders and step it down for utilization. The added cost of underground 5000 volt primary feeders from a single plant plus this transformation would be greater than the savings resulting from reduced power plant costs. Since there would be no appreciable operating saving or other apparent advantage to the single plant scheme for each Experiment Island, it will be eliminated from further consideration at this time in favor of the following plan.

On a typical Experiment Island, two generating units of 15 KW capacity each would be installed for each Photo Tower; two generating units of 30 KW each would be installed for each Zero Tower; four generating units, two 15 KW and two 40 KW units would be installed for each Timing Building; and two generating units of 100 KW each would be installed for each Shot Island Camp. At shot time, all of the units in those plants that are required to be energized would be left running. They would feed to a common bus, thence to the load. Even assuming that the largest unit in each station fails during the relatively short unattended period (and this is not likely), the following capacities would still be available to carry the load:

Photo Tower	15 KW
Zero Tower	30 KW
Timing Building	70 KW

The possibility that more than one unit would fail in this period of time is quite remote. If this should occur, however, the meter in the control room on Parry would indicate to the test director a drop in voltage in sufficient time to stop the sequence of operation if necessary and postpone the experiment. After the trouble is corrected and the power source re-established, the test could proceed.

The plant for Parry Island would consist of four 100 KW units. This would permit three units running to carry the estimated maximum demand of 300 KW during the peak period with one unit out of service. During the interim period, one unit would carry the estimated demand of 50 KW, and by rotating the units in service, all could be kept dried out and in first-class operating condition. Thus, during the entire load cycle of this plant, it would operate with reasonable reliability and efficiency. If it became apparent that the maximum demand during the peak period was going to be greater or less than 300 KW, the number of units could be increased or decreased to meet these changed conditions. To this end, it is recommended that sufficient room be provided in this power plant for the possible future addition of a fifth 100 KW unit.

The plant for Eniwetok would consist of six 100 KW units. This would permit five units running to carry the estimated maximum demand of 425 KW with capacity to spare during the peak period while one unit is out of service. During the interim period, two units would carry the estimated demand of 200 KW. The units in service should be rotated for purposes of most effective maintenance. The 100 KW unit size was selected rather than 200 KW size in order to provide interchangability with units used elsewhere in this scheme and to reduce the number of spare parts required. This plant would also operate with reasonable reliability and efficiency throughout its entire load cycle. If the estimated maximum demand during the peak cycle should be as much as 500 KW, the load could still be carried with one unit out of service. If the demand should prove to be less than anticipated, units could be removed from this plant and be used elsewhere as required.

The many small plant scheme has the following advantages: Lowest first cost (no inter-island power distribution required); and greatest system flexibility. It has the following disadvantages: High replacement cost, since approximately 240 KW would have to be replaced at Experiment Islands for each operation if concrete emplacements for power plants are provided as recommended, and approximately 1480 KW would have to be replaced if they are not; highest operating cost; lowest reliability, since it is not possible to have the power plants on Experiment Islands attended at experiment time. This will result in a weak link in the power system during the most critical phase of its operation. This disadvantage, however, will be materially reduced by adequate remote voltage indication at the control location.

Two Plants. To serve all requirements of the Atoll with two central plants, the logical locations are on Aniyaanii and Eniwetok. Aniyaanii is the island nearest the experimental islands on which personnel might remain to attend the plant during the actual tests. The plant on this island would be used to supply all Experiment Islands and Coral Head. Japtan Island has also been considered for this purpose and has the advantage of being closer to deep water, making the receipt of fuel from tankers simpler. On the other hand, it is approximately two miles further away and the additional transmission lines would be more costly than the longer fuel receiving line. Japtan has no other advantages, so it appears that Aniyaanii should be used for the location of the shot island power plant, if two plants are used. The possible power plant sites, as selected during the reconnaissance trip, on Aniyaanii and Japtan are shown on Plates 40 and 41, respectively. The second plant would serve Parry and Eniwetok Islands, the two islands that will be continuously occupied.

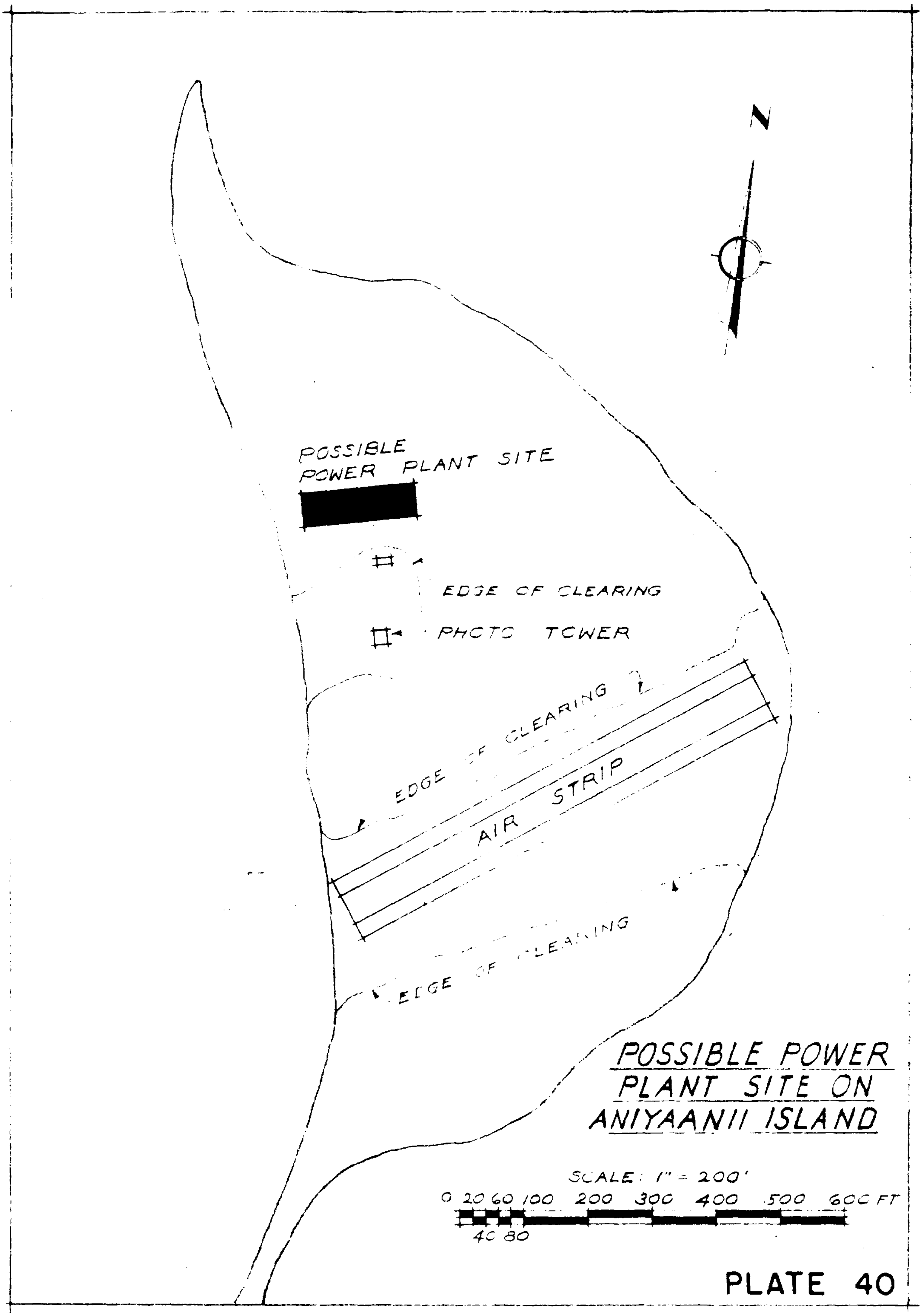
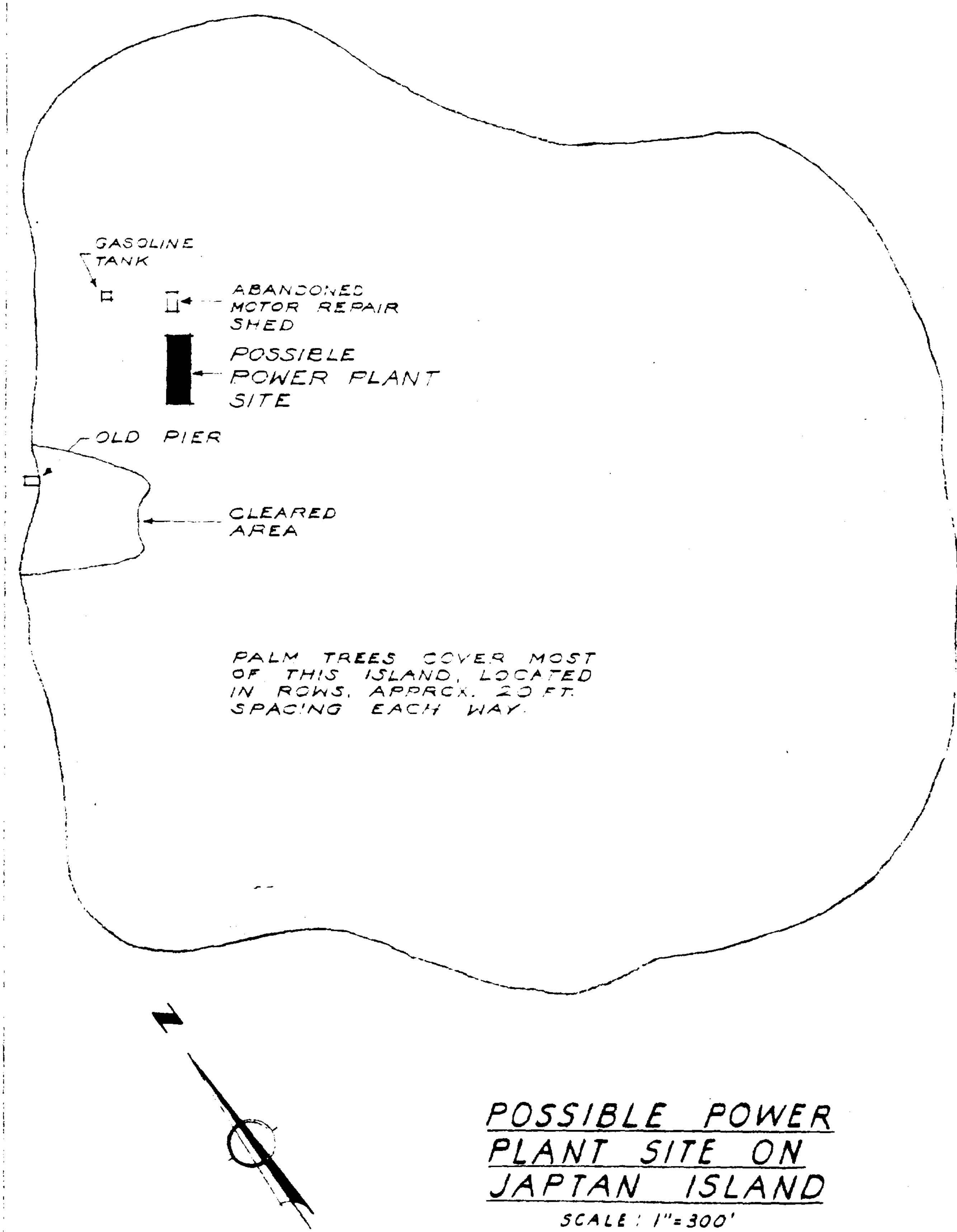

N
POSSIBLE POWER PLANT SITE
EDGE OF CLEARING
PHOTO TOWER
EDGE OF CLEARING
AIR STRIP
EDGE OF CLEARING
POSSIBLE POWER PLANT SITE ON ANIYAANII ISLAND
SCALE: 1" = 200'
0 20 60 100 200 300 400 500 600 FT
40 80

PLATE 40



POSSIBLE POWER PLANT SITE ON JAPTAN ISLAND

SCALE: 1" = 300'

PLATE 41

Power will be required practically from end to end of Eniwetok and on the north half of Parry. Of possible sites, the one shown on Plate 40 is the nearest the center of load and, therefore, would be most desirable. The estimated maximum demand for Parry and Eniwetok is 725 KW during experiments and 250 KW during the interim period between experiments. The estimated maximum demand for the Experiment Islands and Coral Head is 515 KW. It would be desirable to have all generator units the same size so that only one set of spare parts would be required. Also, each plant should have sufficient capacity so the maximum demand can be carried with one unit out of service. These conditions can be met by a 1500 KW plant consisting of three 500 KW units on Eniwetok and a 1000 KW plant consisting of two 500 KW units on Aniyaanii. A tie would be provided to transfer power between plants. This method has the following advantages: Lower operating costs than many plants; slightly lower first cost, including distribution, than one-plant system; physical separation of full time and experimental facilities; both stations could be attended at experiment time. This method has the following disadvantages: Higher operating costs than one plant; higher first cost than many plants. A weekly trip to Aniyaanii would be required during the interim period for inspection and dry-out runs to keep the equipment in operating condition. Transportation to base repair shops on Parry would be difficult if and when required. Operating personnel would be required on Aniyaanii at experiment time unless this plant is equipped with telemetering and supervisory control for remote operation from Parry.

One Plant. The other alternative would be to serve all requirements from one central plant. The ideal location of one central plant for the most economical distribution of electrical energy would be near the geographical center of the transmission system and also near the electrical load center. On the assumed basis of submarine cable distribution, the geographical center is off the north end of Runit Island. The electrical load center is about midway between Runit and Aniyaanii during peak load, between Parry and Eniwetok during the interim period.

It would be unsafe for personnel to be stationed north of Aniyaanii during a test on Runit, so that any location north of Aniyaanii is eliminated. Acceptable sites for a central power plant were found on Aniyaanii, Japtan, Parry and Eniwetok. From the standpoint of economical electrical distribution, Aniyaanii is the most desirable because it is nearest the center of load and Eniwetok is the least desirable. On the other hand, the only use of Aniyaanii, as now conceived, is for a Photo Tower that is used for a shot on Runit Island. If a power plant were located on Aniyaanii, personnel would have to be stationed on this island continuously, a pier, water distillation plant, water storage and sewerage would have to be provided for the power plant and operating personnel. These facilities would not otherwise be required. It, therefore, appears undesirable to locate a central power plant on this island.

Inasmuch as there is no contemplated use for Japtan Island, the same reasoning applies to this island.

Parry Island will be occupied by scientists and their assistants during experiments and by maintenance forces during the roll-up period between tests. The entire electrical load during the roll-up period will be on Parry and Eniwetok Islands. All utilities will be available. Therefore, it appears that Parry Island is the logical location for one central power plant, if other conditions should point to this method of supplying electrical energy.

As developed above, the estimated maximum demand during experiments will be about 1240 KW and during the interim between experiments will be about 250 KW. To supply these loads, the logical equipment would be four units of 500 KW capacity each. The entire load could be carried with one unit out of service and the interim load could be carried by one unit. It would seem that possibly one or more small units would carry the interim load more economically. However, it will be highly desirable to operate all units periodically to keep them in first-class operating condition. Furthermore, if all units are the same size, spare parts will be interchangeable and a smaller stock will be required. It is for these reasons that four 500 KW units appear to be the best selection. This method has the following advantages: Lowest operating costs; plant would be located close to operating personnel, maintenance shops, and Control Room; no hazard to operating personnel would be involved at experiment time; greatest reliability. It has the following disadvantage: Highest first cost.

Requirements During Construction. As developed elsewhere in this Report, it is contemplated that construction forces will be initially housed at Eniwetok in small numbers and later will be based at Parry and will require power for their operations prior to the completion of the final plant or plants. The garrison at Eniwetok will also require power during this period. To these ends it is recommended that:

(1) Adequate personnel and parts be provided to maintain the existing stations on Eniwetok.

(2) That a detailed survey be made of all units now on Eniwetok (both installed and in storage) to determine whether any of these units might be us able and available for construction power requirements.

(3) That small low-voltage advance base type units (with diesel or gasoline engine prime movers) be provided for construction purposes. The estimated requirements are as follows:

2 - 15 KW units
2 - 50 KW units
3 - 100 KW units

If many small plants are selected for the ultimate power systems, it is possible that some of these units can be used in the ultimate system. If not, they may be salvaged and used as emergency stand-by units.

No attempt will be made to arrive at recommendations as to the number and location of plants for the ultimate power supply system until inter-island power distribution has been considered in this Report since both components are important factors. Recommendations for the entire power supply and distribution system are included under "Electrical Power Distribution".

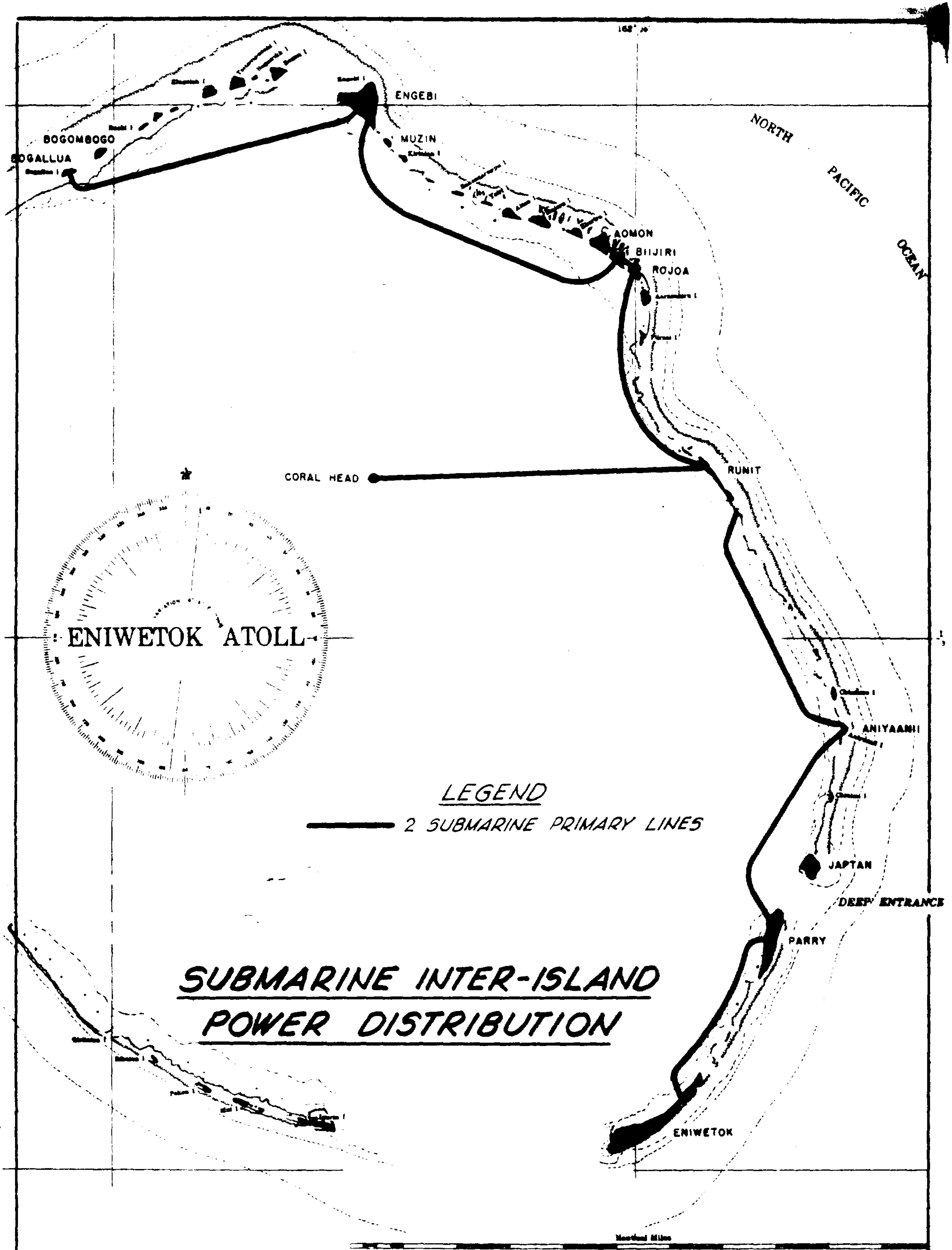
ELECTRICAL POWER DISTRIBUTION:

Inter-Island Power Distribution. If the single-plant system is adopted as a power source, a number of features are recommended for the distribution system in order to insure reliability. It has already been recommended that adequate plant capacity be provided to permit carrying the maximum estimated demand of 1240 KW with one generating unit out of service. It is recommended that double radial primary circuits be extended to each island. Each circuit should have adequate capacity to serve the entire load. It is probable that the power plant generating voltage would be 4.16 Kilovolts. Distribution to Parry, Eniwetok and Coral Head will be most economical at this voltage. The most economical voltage to serve Coral Head, in spite of the distance to it, is 4.16 KV because of the small load involved. The cost of 5 KV submarine cable from Runit to Coral Head, plus step-down transformers at Runit and Coral Head, is less than the cost of 15 KV submarine cable from Runit to Coral Head plus step-down transformers at Coral Head. Distribution to the balance of the Experiment Islands will be most economical at 13.8 KV. Under normal operating conditions, at estimated maximum demands and 80 percent power factor, the maximum design voltage drop to Eniwetok is approximately 5 percent and that the most remote Experiment Island approximately 3 percent. Plate 42 indicates the basic single-line schematic power distribution from a single plant.

Three different methods for carrying the two primary feeders to various islands will be considered: Mainly overhead, submarine cable, and a combination of submarine and overhead distribution.

The mainly overhead inter-island power distribution system (See Plate 43) consists of a single line of creosoted wood poles set in concrete shoulder above high tide, cross arms, insulators, and bare wire to carry two circuits from island to island along the reef. Experience in this portion of the Pacific indicates that creosoted poles set in concrete will last for a period of years well beyond the construction period and two experiments. It is believed that the concrete shoulder above high tide may be necessary in order to protect the underwater portion of the pole from marine borers. The salt spray in the air presents a serious maintenance and operating problem. It has a tendency to reduce the effective flashover value of insulators. For this reason, it is proposed to utilize insulators with substantially higher flashover values than those normally used in the United States for comparable system voltages. Submarine cables would be used with this system to extend from Parry to japtan and from Runit to Coral Head. It is not believed that the additional reliability secured by carrying each circuit on a separate pole line would justify the increase in cost. The mainly overhead method has the following advantages:- Lowest first and ultimate cost; repairs are easier and faster. This method has the following disadvantages: Salt spray and humid air present corrosion and maintenance problems; overhead conductors are more subject to wind, airplanes, other mechanical damage, or lightning hazards than submarine cable. Pole line replacement necessitated by experiments is estimated at 20 percent for each operation. Overhead construction is probably less reliable than submarine cable due to the problems indicated above.

The submarine cable inter-island power distribution system (See Plate 44) consists of armored cable laid on the floor of the lagoon. This cable would



SUBMARINE INTER-ISLAND POWER DISTRIBUTION

PLATE 44

be buried and protected on the approach to the islands to beyond low tide. This method has the following advantages: Probably fewer repairs would be required than for overhead construction; there would be no difficulty due to salt spray or corrosion; there would probably be no replacement cost; reliability should be greater than for overhead construction, particularly at operating time. This method has the following disadvantages: Higher initial and ultimate cost, based on two-experiment period, repairs when and if required will be more difficult, time-consuming, and expensive.

A combination submarine and overhead inter-island distribution, one feeder submarine, the other overhead where practical, compares with the previously discussed methods of inter-island distribution as follows: Cost, both initial and ultimate, will be less than submarine, greater than overhead; maintenance probably less than overhead, more than submarine; replacement slightly less than overhead, more than submarine; reliability probably better than overhead, equal to submarine.

If the two-plant system is adopted as a power source, the same type of distribution systems can be considered.

If many small plants are adopted as the power supply system for the operations, no inter-island power distribution will be required.

Power Distribution on Islands. If the single power plant system is used, it is necessary to distribute both primary and secondary voltages on each island to the loads. Primary distribution feeders from the central power plant would carry energy at primary voltage to step-down transformers near each load center. In critical locations, one transformer bank would be provided on each primary feeder and a secondary transfer switch would automatically throw the load to the second bank in the event that this first bank failed. Power would then be carried to the actual loads at secondary or reduced voltage.

If many small plants are utilized, power distribution will be normal-use voltage corresponding to the secondary voltage from a transformer station. In either case, voltage regulators should be installed as required to maintain constant voltage at critical locations. Power distribution on the islands may be either overhead on poles or underground.

Overhead distribution has certain advantages, mainly lower cost, simpler repairs and greater flexibility. Its disadvantages are that more maintenance is required during operating periods due to salt spray, humidity and possibly winds or other mechanical damage, as well as more replacements required if it is used in areas affected by the experiment.

Underground construction (either direct burial or in ducts) has the following advantages: Less maintenance and replacement would be required; less interference in some cases with the construction and operation of the experiment would be occasioned. Its disadvantages are higher cost, more difficult repairs, and less flexibility in the installed system.

It is recommended that overhead distribution on islands be used where practical on those islands or portions of islands where the experiment operation will not interfere with such construction and where trenches in suitable locations are not required by other facilities and available to power. On this basis, overhead distribution might be used on Eniwetok, Parry and for the construction camp portion of Experiment Islands. Underground distribution should be used for primary radial feeders (if used) on Experiment Islands and as much as possible for secondary feeders and branch circuits serving instrumentation utility and instrumentation controlled voltage loads.

See Plates 45, 46 and 47 for typical schematic island power distribution layouts and Plate 48 for typical Experiment Island Single Line Diagram.

Estimated Costs. Cost estimates have been prepared in order to determine which of the many different types of power supply systems discussed will be most desirable for two-experiment use of these facilities.

The initial cost of the two-plant system is estimated to be approximately eight percent to twelve percent less than that for the comparable one-plant system. A further detailed cost estimate breakdown of the two-plant system is not included since it is believed that the disadvantage of the two-plant system outweigh its advantages, including this slightly lower cost.

This leaves us with the following alternatives to consider:

(a) Many small plants,

(b) Single plant with mainly overhead inter-island distribution,

(c) Single plant with combination overhead and submarine inter-island distribution, and

(d) Single plant with submarine inter-island distribution.

The tabulation below indicates the results of estimating the major variables which might affect a decision as to the type system to be used. Maintenance, fuel, amortization, and other similar costs are omitted. The two-experiment load cycle previously discussed has been assumed.

	Many Small Plants	Single Plant Mainly Overhead Distribution	Single Plant Combination Distribution	Single Plant Submarine Distribution
Initial Cost	$1,000,200	$2,750,000	$4,902,800	$5,559,000
Replacement	89,300	133,600	108,100	- -
Operation	663,000	156,900	156,900	156,900
	$1,752,500	$3,040,500	$5,167,800	$5,715,900

Recommendations. Because of the considerable economic advantage which the many-plant system would have over other power supply systems for two-experiment use, it is recommended that this system be adopted. We believe the degree of reliability indicated in the discussion under "Number and Location of Plants" is satisfactory.

Flexibility. It is believed that populations and estimated loads at the various locations are maximum to be anticipated. In the event that these preliminary figures should prove to be too high, the reduction in estimated demands would favor many small plants, since this system is more flexible. Reductions in the size of submarine cable would not decrease system costs in proportion to the decrease in capacity.

In the event that it is decided to use these facilities for a longer period of time than the two-experiment use which is contemplated, the case becomes stronger for a single power plant.

It is probable that neither of the above-mentioned variations would change the recommendations as to type of power source. Reduction in load will not prevent the satisfactory operation of the recommended small plants, it will merely decrease their efficiency, and the increase in fuel cost would be negligible in the overall picture. A material reduction in loads would make possible a reduction in size of the units to be obtained and a consequent reduction in cost. If the fourth Experiment Island is not used, the power plant and distribution on this island will not be required.

COMMUNICATIONS:

General Requirements. It is intended to discuss in this Report only those communications required on the Atoll. All communications extending off the Atoll are excluded.

The needs of the Proving Ground for reliable communications between Experiment Islands, Headquarters on Parry Island, and ships anchored in the lagoon are particularly vital during the period before each experiment. The Armed Forces will require the use of communication facilities on Eniwetok and the Experiment Islands for security personnel operations. Construction personnel will utilize communications between the various islands during the construction period.

The Pacific Telephone and Telegraph Company's plant includes overhead, underground and submarine wires and cables. For approximately twenty years they have operated a telephone system between the mainland and Catalina Island. They have utilized two cables, each with a single conductor and sheath, with a 4-channel carrier signal superimposed on each. This system has never been out of service. Once or twice in this twenty-year period, one of these cables has been accidentally dug up. For the past two years, this wire-carrier system has been supplemented by an eight-channel pulse-modulated unit similar to that described under "Radio". The only operating difficulty encountered has been some fading due to atmospherics. Practically all of their long distance circuits are carrier channels, and they have some 900 circuits going out of Los Angeles.

The net result of their broad experience is to the effect that wire, radio, or carrier systems, properly applied, can be relied upon to give dependable service.

It is extremely difficult to predict the peak and average communications loads for future operations. However, Plate 49 indicates schematically a telephone system which is believed to be adequate and reasonable. In discussing the various possible types of voice communication systems which may be employed for future operations, this telephone system will be used as a basis.

The following types of systems will be considered: Wire telephone, radio, and carrier used in conjunction with wire telephone or radio.

Wire Telephone. In preliminary planning for the telephone system, it is assumed that telephone instrument requirements will be as follows:

Eniwetok - 100 field or office type

Parry	- 100	field or office type
4 Experiment Islands	- 120	field type
Total Instruments	- 320	
	x 1.5	Factor for spares and possible additional requirements
Total Instruments	- 480	

A common battery automatic or a magneto type manual system can be employed. Each type has certain advantages. The common battery automatic system is most convenient and speedy to use. The magneto system is more durable, rugged and simple, as well as less costly. It is believed that the greater reliability and other advantages of the magneto type will be more important than the convenience and the speed of the automatic system.

Several different types of telephone instruments will be considered for possible use.

For offices and in locations not subject to direct salt spray, fungus and vermin-proofed aluminum alloy standard metal clad megneto phones could be used. Their estimated cost is $57.00 for a wall phone and $82.00 for desk type. Sound power phones which convert voice energy to electrical energy for transmission might also be used for this purpose. Their use would eliminate the necessity for batteries at each phone. The estimated cost of either wall or desk type sound power units is approximately $133.00 per instrument. Army Signal Corps field type phones Type EE-8A could also be used for office. Their cost would be approximately $153.00 per unit for new instruments. It is possible that satisfactory surplus units might be obtained.

For outdoor use, either field Type EE-8A phones or sound power phones would be suitable. The field type phone with batteries is of more rugged construction and would cost approximately $153.00 per unit new. The field type sound power unit would be satisfactory from the standpoint of reliability and would eliminate the necessity for batteries. Its estimated cost is $174.00 per instrument.

In the cost estimate incorporated in this Report, it is assumed that the magneto type manual system will be used, that the following number and type of instrument will be required:

120 wall type aluminum alloy standard metal clad units (tropicalized)
120 desk " " " " " " " (" ")
240 field type Army Signal Corps EE-8A

and that 24,000 feet of underground and 24,000 feet of overhead telephone lines will be required. It is further assumed that the following number and size of switchboards will be required:

1 - 200-line board
1 - 100-line board
5 - 50-line boards

During the time immediately prior to an experiment, it is anticipated that there will be a need for some means of calling personnel from the field on Experiment Islands to a telephone. It is believed that a public address system should be provided on each Experiment Island for this purpose. It is assumed that one microphone, one amplifier, and six speakers will be used for each Experiment Island. These units should be moisture and fungus proofed, and it is probable that marine type units would be most desirable for the relatively large area coverage and severe weather operating conditions which are to be met.

The estimated cost of these items constituting basic requirements for communication on (but not between) the islands is as follows:

Switchboards	$21,400
Telephone Instruments	70,000
Line Wires	53,900
	$145,300

Cable to provide wire trunking facilities for communicating from ship to shore and between islands may be either submarine or mainly overhead. Plate 49, previously referred to, indicates the assumed submarine cable schematic. The alternative would be to carry most of the cable overhead on a pole line similar in construction to that discussed for power distribution. Poles could be shorter and cross-arms would not be required. Cable to buoys for ships and between Parry and Japtan would still be submarine. In either case, half of the load on each telephone switchboard should be borne by each of two cables so that in the event one cable does fail, due to possible damage, the other cable would still serve to connect the switchboards while a repair or replacement was made. Further analysis will be necessary during design to arrive at the final number of pairs of wires required in each location, and additional analyses both during design and operation in the field will be required to determine the proper number of private and multiple trunks to each board.

The submarine cable system would probably require less maintenance, repair, and replacement than the overhead system, but when require, it would probably be more time consuming and expensive. The estimated cost of this type of communications cable installation is approximately 30 percent less than the alternate mainly overhead type, and it is recommended that this type of installation be made if the wire telephone method of communications is adopted. Its estimated cost is $1,237,100.

Thus, the total estimated cost of the wire telephone communications system is:

Basic Requirements	$145,300
Submarine Cable	$1,237,100
	$1,382,400

The wire telephone system is simple, reliable, and not subject to atmospheric conditions to the extent other systems are. It is also desirable from the standpoint of security, since it is unable to carry messages outside of the Atoll.

Radio. It is possible to utilize radio to provide trunking facilities from ship to shore and between islands instead of cable, as previously discussed.

Because of the large number of trunks considered between islands, probably the only radio equipment which would make a system equivalent to the telephone layout would consist of pulse-position modulated eight-channel transceivers. These units, which operate in the three megacycle region, are highly directive with a beam width of approximately 2°. They would have an effective range of thirty to fifty miles. Atmospheric conditions should have little effect, but possible fading due to atmospherics would be one disadvantage of this system as compared with the wire telephone communications system. Whether such equipment is now available or will be in the near future is problematical. It would probably be more costly than the basic telephone system and would certainly require highly specialized maintenance personnel.

Because of the disadvantages of less security, the possibility of fading, and the probable higher cost, radio communication will not be considered further at this time. Should further investigation and study indicate that requirements are not as great as assumed and that a smaller number of trunks are needed, that the disadvantages mentioned above are not objectionable, and that suitable equipment becomes available at lower cost, this type of communications trunking system would warrant additional consideration.

Wire Telephone with Carrier. Carrier telephony is that form of telephony in which the transmitted electric wave is a wave resulting from the modulation of a single-frequency wave by a modulating wave. It may be used in conjunction with either wire or radio telephony. One communications wire or radio circuit can be utilized to carry a number of voice modulated channels. It is possible to apply carrier equipment to submarine telephone cable and thus increase the number of voice channels carried by each conductor.

Because cable costs do not decrease in proportion to the number of pairs, the ratio between 6 and 16 pairs being approximately 84 percent, it is unlikely that the cost of the wire telephone system could be decreased by utilizing carrier equipment in conjunction with wire circuits unless it is possible to utilize one or more conductors of the existing or new signal and control cable for this purpose. It appears quite doubtful that this would be practical. The extent to which such a system of carrier on submarine control and signal conductors can be successfully applied, even if practical, is also doubtful so far as we have been able to learn.

Radio with Carrier. It is possible to apply carrier equipment to radio equipment in such a manner as to obtain several voice channels with each combination of transmitters and receivers. It would probably be impractical to provide such a system with facilities comparable to the basic telephone system being considered. However, in the event that inter-island calls other than those to Parry can be routed through Parry, and in the event that other disadvantages to radio type of communications are not objectionable, approximately twenty-six 4-channel duplex transceivers might be utilized. Because the cost of submarine cable trunking constitutes such a large portion of the total cost of a wire telephone communications system, the probable cost of a communications system employing radio and carrier trunking as described above would be approximately 20 to 25 percent of that utilizing submarine cable trunking.

Radio Back-up System. Regardless of the provisions which are made to make the principal communications system flexible and reliable, there is always a possibility that due to unforeseen last-minute special requirements or operating difficulties, it might not fulfill all communications requirements. For this reason, the possibility of providing an emergency radio back-up system should be considered. For this purpose, it is recommended that ten mobile high-frequency transceivers be provided for probable distribution on Eniwetok, Parry, Aniyaanii, Runit, Coral Head, Biijiri, Engebi, Bogallua, and two ships. In addition, one spare unit should be provided. Twenty-five watt units similar to those in use by the Bell System, but tropicalized, would be suitable. Either manual or automatic operation might be used for the radio back-up.

The manual system has certain advantages over the automatic. In the first place, it is less costly (total estimated cost $43,800). In the second place, it may be faster, since the person originating a call need not go through a control center. Third, it will be simpler to maintain.

The automatic system (estimated cost $57,700) also has certain advantages. Central control could determine call preference (establish priority). This might be advantageous in case of emergency. The central station also eliminates the necessity for a constant attendant at each station in that a bell or gong can be used to call the operator to the station. This type of system also permits typing the very high frequency radio back-up to the land-line telephone system if desired.

<u>Conclusions</u>. Local telephone systems will be required and should be provided for communication on individual islands. Public address systems will be required and should be provided on Experiment Islands. The most satisfactory but one of the most expensive means of trunking between islands is cable. If this method is adopted, it is recommended that submarine rather than overhead cable be utilized. The practicability of using some type of tadio trunking depends upon further knowledge and analysis of requirements and further study and analysis of available equipment. Regardless of the principal type of communications employed, it is recommended that the system be backed up by very

high frequency radio transceivers for emergency use. For communications during the construction period, it is recommended that a portion of the field telephones and mobile radio transceivers intended for the ultimate installation be used to provide limited communication facilities. It is anticipated that existing control and signal cables can be used for limited inter-island telephone communication until the communication cables are installed.

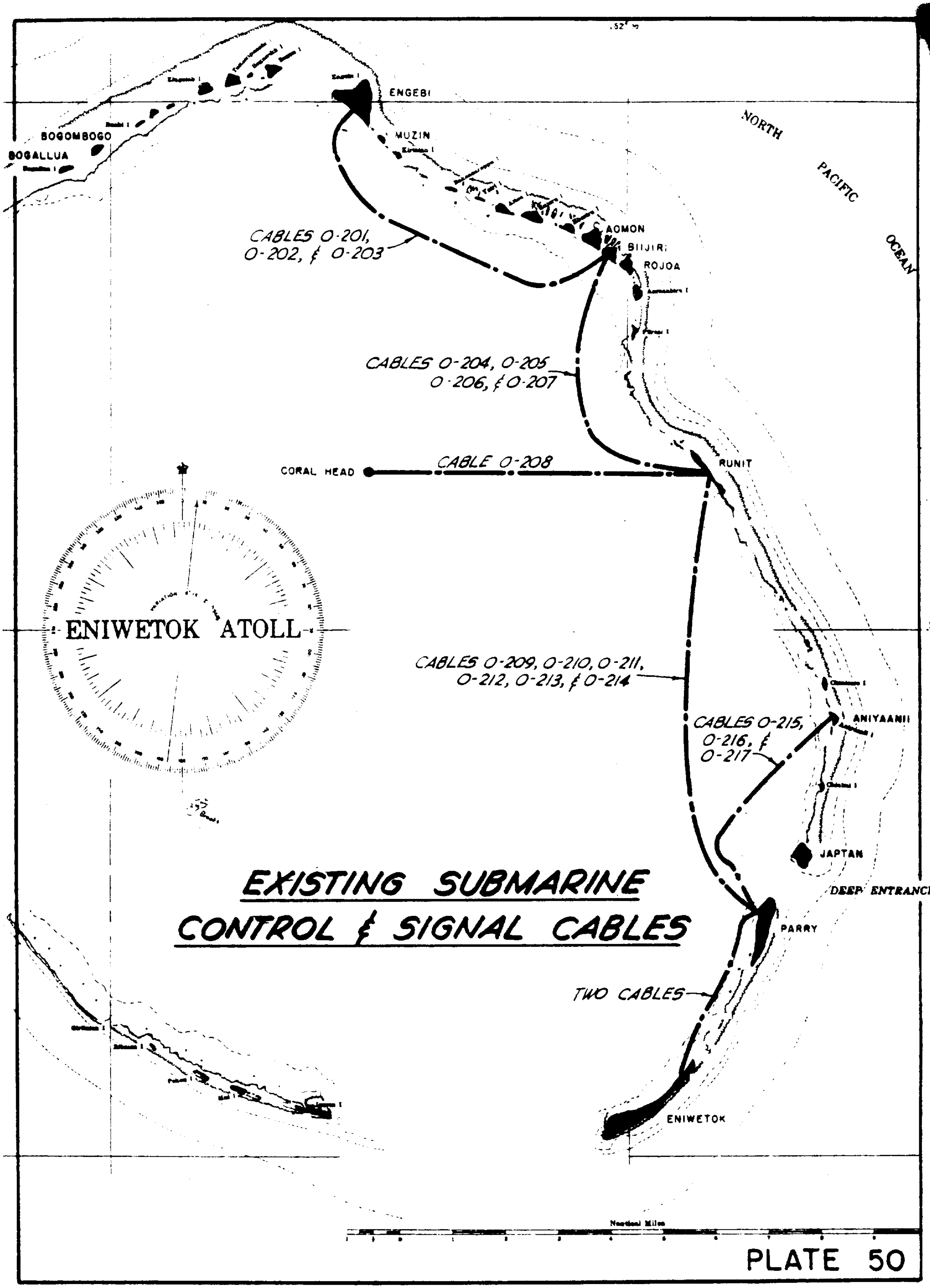
The estimated cost of these ultimate communications installations is as follows:

Telephone System	$1,382,400
Radio Rack-up System	43,800
Public Address Systems	7,300
Total	$1,433,500

CONTROL AND SIGNAL CABLES:

Existing Control and Signal Cable Installed Submarine. There are existing submarine control and signal cables which were installed on the floor of the lagoon in January, February and March of 1948 for use in "Operation Sandstone". (See Plate 50). Indications are that these cables will be usable for future operations. Tests were made on the reconnaissance trip in October, 1948, to check the physical and electrical condition of these cables.

In general, the cables appeared to be in good mechanical condition. However, one cable on the beach at Runit had been damaged, apparently by a landing craft. In many cases, cable was exposed on the beaches in such a manner as to be subject to possible damage by landing craft, construction operation, etc. The cable riser ties at Coral Head Photo Tower were found to be inadequate. Additional rope lashing was provided as a temporary remedy for this trouble. Most of the terminal cans and strips arreared to be in good condition, however, it was necessary to cut many of the cans open, since keys were not available for the existing padlocks.



ENGEBI
MUZIN
BOGOMBOGO
BOGALLUA
NORTH PACIFIC OCEAN
AOMON
BIIJIRI
ROJOA
CABLES O-201, O-202, & O-203
CABLES O-204, O-205 O-206, & O-207
CORAL HEAD
CABLE O-208
RUNIT
ENIWETOK ATOLL
CABLES O-209, O-210, O-211, O-212, O-213, & O-214
CABLES O-215, O-216, & O-217
ANIYAANII
JAPTAN
DEEP ENTRANCE
PARRY
TWO CABLES
ENIWETOK
EXISTING SUBMARINE CONTROL & SIGNAL CABLES

PLATE 50

Two factors will be considered so far as electrical characteristics are concerned. The first of these is copper resistance; the second is insulation resistance. The reciprocal of these values indicates the ability of the cable to carry desired electrical currents along the conductors and to resist the flow of undesirable currents from the conductors to ground. Tables I and II on the following pages indicate the comparative values of these characteristics as obtained in March, 1948 and in October, 1948.

TABLE I

TEST RESULTS

10-CONDUCTOR SUBMARINE CONTROL AND SIGNAL CABLES

Cable No.	Copper Resistance per pair, ohms - - - 16 March 1948, Rowan - - -					Copper Resistance per pair, ohms - 9 October 1948, Clark-Larson -				
	A-B	C-D	E-F	G-H	J-K	A-B	C-D	E-F	G-H	J-K
0-201	216.8	219.4	219.6	219.2	219.9	218.9	221.6	221.8	221.4	221.1
0-202	210.5	212.4	212.8	213.2	212.3	212.6	214.6	215.0	215.3	214.5
0-203	218.3	221.8	221.0	222.4	220.9	220.5	223.9	223.2	224.6	223.2
0-204	195.4	197.6	198.1	197.4	197.0	197.2	199.5	199.9	199.3	198.8
0-205	172.7	172.6	172.1	172.4	172.0	174.4	174.3	173.8	174.1	173.7
0-206	180.2	181.4	181.4	182.1	181.8	182.0	183.1	183.1	183.8	183.5
0-207	179.5	181.7	181.4	181.7	181.6	181.5	183.6	183.8	183.6	183.7
0-208	200.4	203.4	203.8	203.9	203.4	202.3	205.3	205.7	205.7	205.3
0-211	284.8	285.5	286.0	285.9	286.5	287.1	288.0	288.6	288.3	289.3
0-212	278.1	278.2	280.0	280.2	279.3	280.5	280.6	282.5	282.7	281.8
0-213	263.3	264.6	265.8	265.8	266.0	265.7	267.0	268.0	268.0	268.2
0-214	259.1	259.6	260.6	258.9	259.6	261.5	261.9	263.0	261.1	261.9

Cable No.	Insulation resist. to ground per pair megohms - 16 March 1948, Rowan - - - - - - -					Insulation resist. to ground-per par megohms 9 October 1948, - - - - - - - Clark-Larson - - - - - -				
0-201	2.5	1.7	1.2	1.7	1.9	0.800	0.800	0.600	0.600	0.600
0-202	3.6	1.0	1.79	1.74	0.75	0.900	0.500	0.400	0.250	0.300
0-203	2.8	1.4	1.45	1.5	1.9	0.900	0.600	0.500	0.500	0.500
0-204	4.2	0.90	0.68	0.63	0.63	1.000	0.300	0.250	0.200	0.200
						0.800	0.300	0.225	0.200	0.200
0-205	3.7	0.075	0.070	0.075	0.040	0.400	0.030	0.027	0.029	0.021
						0.350	0.030	0.030	0.030	0.030
0-206	6.5	5.0	5.0	4.2	6.5	0.500	0.150	0.100	0.100	0.095
						1.000	0.200	0.125	0.125	0.100
0-207	4.5	4.5	3.5	4.1	7.5	0.800	0.250	0.250	0.200	0.200
0-208	2.8	1.1	0.75	0.67	0.77	1.000	0.450	0.300	0.250	0.250
0-211	2.5	0.70	0.37	0.43	0.38	0.700	0.300	0.175	0.175	0.160
0-212	2.2	0.29	0.30	0.28	0.29	1.200	0.700	0.175	0.090	0.090
0-213	2.6	0.60	0.37	0.42	0.38	0.700	0.220	0.150	0.175	0.150
0-214	0.90	0.80	0.75	0.60	0.025	0.330	0.250	0.275	0.250	0.260

TABLE II

TEST RESULTS

3-CONDUCTOR SUBMARINE CONTROL AND SIGNAL CABLES

Cable No.	Copper Resist. per pair, ohms - - 16 March 1948, Rowan - -			Copper Resistance per pair, ohms - 9 October 1948, Clark-Larson -		
	A plus B	A plus C	B plus C	A plus B	A plus C	B plus C
0-209*	60.5 60.5 121.0	60.5 60.6 121.1	60.5 60.6 121.1			
0-210	56.8 56.7 113.5	56.8 56.8 113.6	56.7 56.8 113.5	110.0	109.0	111.2 (This cable obviously damaged on beach at Runit)
0-215**	28.51 28.88 57.39	28.51 28.43 56.94	28.88 28.43 57.31	57.4	57.4	57.35
0-216	38.38 38.39 76.77	38.38 38.40 76.78	38.39 38.40 76.79	77.4	77.4	77.35
0-217	41.90 41.90 83.80	41.90 41.92 83.82	41.90 41.92 83.82	84.5	84.5	84.65

Cable No.	Insulation resist. per cond. megohms - - 16 March 1948, Rowan - -			Insulation resist. per cond. megohms 9 October 1948, Clark-Larson		
	A	B	C	A	B	C
0-209*	40.	1.0	0.001			
0-210	38.	40.0	43.0	.000	.000	.000
0-215**	102.	102.	102.	20.	20.	20.
0-216	0.03	84.	84.	0.000	3.0	1.0
0-217	84.	0.018	84.	8.0	8.0	.010

* - This cable is not terminated at either end - 2-conductors leaky) Per
** - All type 113-3 conductor armored cable) Rowan

These tables indicate that copper resistances were found to be essentially unchanged, while insulation resistances were found to be materially less in October than in March. The very slight changes in copper resistances are to be expected and may be attributed to such variable conditions as temperature or the use of different test leads and measuring instruments.

The decrease in insulation resistances is not surprising. It may or may not be significant, and only further cable tests made periodically for the next two years will indicate whether or not these cables will be usable for future operations. In the first place, a 50% decrease in insulation for this initial period might represent a normal reduction due to aging in water. Secondly, temperature differences at test times may have contributed to this difference. Finally, different instruments and techniques used for the two tests might easily account for the difference observed. If it is recommended that future cable tests be made at approximately six-months intervals during the next two years.

Cable Test Procedure. The following instruments were used in making the October, 1948, cable tests:

(a) Wheatstone bridge; "16333" on case in white paint; nameplate, "Los Alamos Electronics Lab. EL 133"; Leeds and Northrup type S test set No. 5300.

(b) Megger; "No. 8591, Inventory, Los Alamos Electronics Lab. EL-478" on case; "250 volt Megger, Registered Trade Mark, Made in England, License No. 400728, James G. Biddle Company, Philadelphia" on instrument face.

The Wheatstone bridge was very satisfactory for testing copper resistances. The Megger, however, was a small hand-driven model and did not lend itself to convenient or accurate reading of insulation resistances. Upon completion of the October tests, all tools used in making tests except these instruments were placed in a box labeled "Splicing Test Set" and stored in Warehouse "H" on Eniwetok for future use.

The first step in making the tests was to locate and open the various terminal cans. To test a typical ten-conductor cable, the conductors were jumpered together in pairs at one of the two terminals. The wheatstone bridge was utilized to measure the copper resistance of each cable pair. Next, a ground was secured (usually the cable armor) and potential applied between this ground and the copper wire of each pair by the Megger. Insulation resistances to ground were read approximately 20 seconds after the potential was applied, since this interval was determined by experiment to be as significant as longer intervals. Air temperature of 78 to 82 degrees F. and water temperature of 82° to 84° F. at approximately 10-foot depth were observed. Temperatures were quite constant. The next cable test should be made with the same instruments and a similar technique. Additional insulation resistance tests should also be made using a more suitable instrument, such as a motor-driven Biddle Megger. Provisions should be made to shield cable ends while this testing is being done.

Cable Landings. It is recommended that at all locations where cable is brough ashore from the lagoon to any of the islands, that portion on shore and within two feet below low tide be placed in a trench. Where a sandy beach is available, this can be accomplished by removing the sand with a drag-line and laying the cable in the trench. Tide action below the low water line can be expected to cover the cable with sand within a short time, and that portion above low tide should be covered to the grade of the beach.

Where coral rock is within two feet of the surface of the beach or within two feet below low tide, it should be removed. It is anticipated that this can be accomplished by use of jack-hammers, since all of the coral observed on the lagoon side of all the islands was relatively soft. Where cable is to be laid in a trench cut from coral rock, the bottom of the trench should be back-filled with sand or finely broken coral rock to provide a suitable bed for the cable, and the cable should be covered with such material to a depth of approximately one foot. The trench should then be filled with concrete to prevent the back-fill material from scouring and to provide additional mechanical protection.

Existing cables should be brought together into one trench where feasible and covered as soon as possible after the next test to prevent their being damaged by other construction operations. Care should be taken that the cables be separated from utility lines by at least a foot of sand.

New cables which may not be procured in time to be placed in the same trench as the existing cable should be treated in the same manner. Trenches for new cable should be adjacent to the existing cable but with adequate separation to prevent the damaging of existing cables when the new trench is prepared.

The damaged cable on the beach at Runit should be repaired before being placed in the trench. Signs of sufficient size to adequately mark all trench locations and cable landings should be posted at the time this work is done.

Existing Control and Signal Cable Installed Underground. There are existing underground control and signal cables on the Experiment Islands starting at the Timing Stations and running toward the previous Zero Towers and Photo Towers. The present location and condition of these cables are not known. It may be desirable to locate and test these cables to determine if it will be practical and economical to utilize them for future operations.

Existing Control and Signal Cable not Installed. There is a total of

218,900 feet of surplus 10-conductor armored cable, some of which is in or near warehouses on Eniwetok; the balance is reported to be on Parry partly coiled on the beach at the LSM landing south of the dock and partly on a defective reel. These cables should also be tested to determine whether or not they can be used for future operations.

Assumed Requirements for Future Operations. For the purposes of this Report, it is assumed that existing submarine control and signal cable can be re-used and that one 10-conductor submarine cable will have to be laid between Parry and Bogallua for additional control and signal cable requirements. It is further assumed that sufficient cable in satisfactory condition exists on the Atoll for this purpose.

It is probable that all signal terminal strips will have to be replaced before the next operation. All locks on terminal boxes will have to be replaced and proper disposition of their keys made. Most of the terminal boxes will have to be repaired and maintained or replaced prior to the next operation.

It is assumed that underground signal and control cables from Timing Buildings to Zero Towers and Photo Towers on the Experiment Islands originally installed for "Operation Sandstone" will not be re-usable and that approximately 34,400 feet of existing cable will have to be installed to replace these.

These may be buried directly in the earth or installed in underground ducts (conduit runs). The latter method is both more desirable and more expensive. It is more desirable in that the underground duct system is more flexible. Additional conductors would be easily installed between Timing Station and Zero or Photo Towers in a short time. Whether this additional flexibility, plus the increased probability of saving some control cable each experiment, is worth the additional cost of providing and installing ducts (assumed 13,400 lineal feet of four 3-inch conduits) and the required manholes is a question to be determined. The estimated cost of installing but not providing underground 10-conductor cable in the same quantities as required for "Operation Sandstone" is $178,500 for direct burial in trench, $337,500 for installation in underground conduits.

In the event that additional control and signal cable is required, it will be possible to obtain and install it during construction. It is recommended that a spliced length of cable sufficiently long to replace any individual length of submarine cable in the control and signal cable network be coiled and stored ready for use in the even of any emergency which might arise.

Conclusions and Recommendations. It is recommended that additional cable tests be made on existing control and signal cables and that cable landings be protected and marked. It is assumed that the existing submarine control and signal cable will be usable, that the existing underground control and signal cable will not be usable, and that existing cable (not installed) will be usable and available in sufficient quantities to replace existing underground cable and, in addition, to install one 10-conductor submarine cable between Parry and Bogallua. The estimated cost of these facilities (assuming cable installation in underground conduits on 3 Experiment Islands) is $398,900.

FUEL HANDLING AND STORAGE:

Existing Facilities. There was a tank farm on Eniwetok Island consisting of fourteen (14) 1,000 barrel steel tanks, located above ground, and of light weight advance base construction. During Sandstone, it was found that some of these tanks leaked and several of them were in rusted condition. It is believed that by the time it becomes necessary to use these facilities again, most of the tanks, if not all of them, will be in unusable condition. In addition to the tanks on Eniwetok, there are three (3) 1,000 barrel tanks on Parry Island. The condition of these tanks are somewhat better than those on Eniwetok, although their life is problematical.

Eniwetok Island. It is planned that Eniwetok Island will be occupied by the security garrison during interim periods, and by Military forces, including the Air Force participating in the experiment during the time of tests. All aviation gasoline storage for the Atoll should be located near the air strip on this island. Also, motor gasoline and diesel oil for the use of military vehicles, and diesel driven generators, and water distillation units, should be located in the vicinity of the aviation gasoline storage.

Parry Island, if occupied continuously as a J Division base during the period of the experiments, and by the maintenance crew during the interim period will require diesel oil and motor gasoline. It is believed that storage of aviation gasoline is not required on Parry, because of its proximity to the storage facilities adjacent to the main air strip on Eniwetok. It is proposed that motor gasoline and diesel oil for use on the Experiment Islands will also be received and stored on Parry Island. The period of intense activity at experiment time is approximately two months, and it would be advantageous if no fuel deliveries are required during this period. For this reason, it is recommended that sufficient storage for both diesel oil and motor gasoline be provided to supply all the needs of this two months period.

Experiment Islands. The number of vehicles in use on each experiment island will be limited and the amount of power to be generated by diesel driven equipment is small. Furthermore, the period of occupancy will be short. To meet these requirements it seems desirable and economical to transport both fuels, in drums or tanks, by boat, from a central storage on Parry Island.

Storage Capacity. It is recommended that all fuel storage tanks be similar and that each one shall be of the horizontal, cylindrical type, having a 1,000 barrel capacity. The tanks should be of heavy welded, steel construction, placed in an excavation of one to two feet and covered with coral for protection against salt spray.

It appears that adequate storage can be obtained by providing the following tankage:

> On Eniwetok Island - four (4) tanks for aviation gasoline; four tanks for motor gasoline, and three (3) tanks for diesel oil.
> On Parry Island - two (2) tanks for motor gasoline, and four (4) tanks for diesel oil.

Other Facilities. Provision should be made to receive fuel from tankers through submarine line run out to deep water and provided with flexible hose connections, through which fuel can be pumped either by shipboard pumps or land pumps. The receiving line should be 6 inch, extra heavy steel pipe, welded and coated with a protective coating. These lines should be trenched-in to beyond the tide lines to avoid the effect of wave action. Land pumping stations for each of the three fuels should be provided. The pipe connecting fuel tanks, pumping station and dispensing location, should be extra heavy steel pipe, welded and provided with a protective coating. In addition, it is recommended that cathodic protection be installed for all tanks and all lines.

ROADS AND PAVING:

General. It is anticipated that the following types of paving will be used and that these will cover the requirements for the improvements mentioned.

Dust Treatment. Where it is desirable to treat the surface for the purpose of keeping the dust from rising, a light road oil such as SC-1 may be used. Tests should be made on samples of the material to be treated to determine the effectiveness of this treatment, and if satisfactory, this method could be used for area treatment and probably on some of the roads. The surface to be treated would be sprayed with from one-third to one-half gallon of oil per square yard, and some areas, particularly roads would require periodic treatment.

Road-Mix. Roads which are travelled frequently or which for any reason require a better type of surface should be surfaced with a road-mix surfacing. Due to the frequency of rains, blade mixing would not be expected to be satisfactory and a traveling mixer should be used. This type of mixer has a loader which elevates the material from a windrow, mixes it with a proportioned quantity of asphalt in a pug mill and discharges it behind as a windrow of mixed material. A cut-back asphalt such as type MC-3 should be used for this purpose. After mixing, the material is bladed into position and compacted by rolling.

Asphaltic Paving. Where a hot-mix type of paving is required, it is proposed that a single aggregate sand asphalt be used. Preliminary sieve tests indicate that on the average the sand available on the islands is suitable for this purpose, so far as gradation is concerned, and that with the addition of 5 to 10% of fine material would be almost ideal for this purpose. This material would be mixed in a plant which might be moved from island to island. The material would be excavated from the area to be paved or from a suitable borrow pit, dried, heated and mixed in the plant, and then transported to the area to be surfaced. After being spread to the desired thickness it would be rolled. Asphaltic cement would be used in this type of paving, which would be more rigid than the road-mix type.

Quantities. The quantities of each type of paving which it is estimated will be required are summarized as follows:

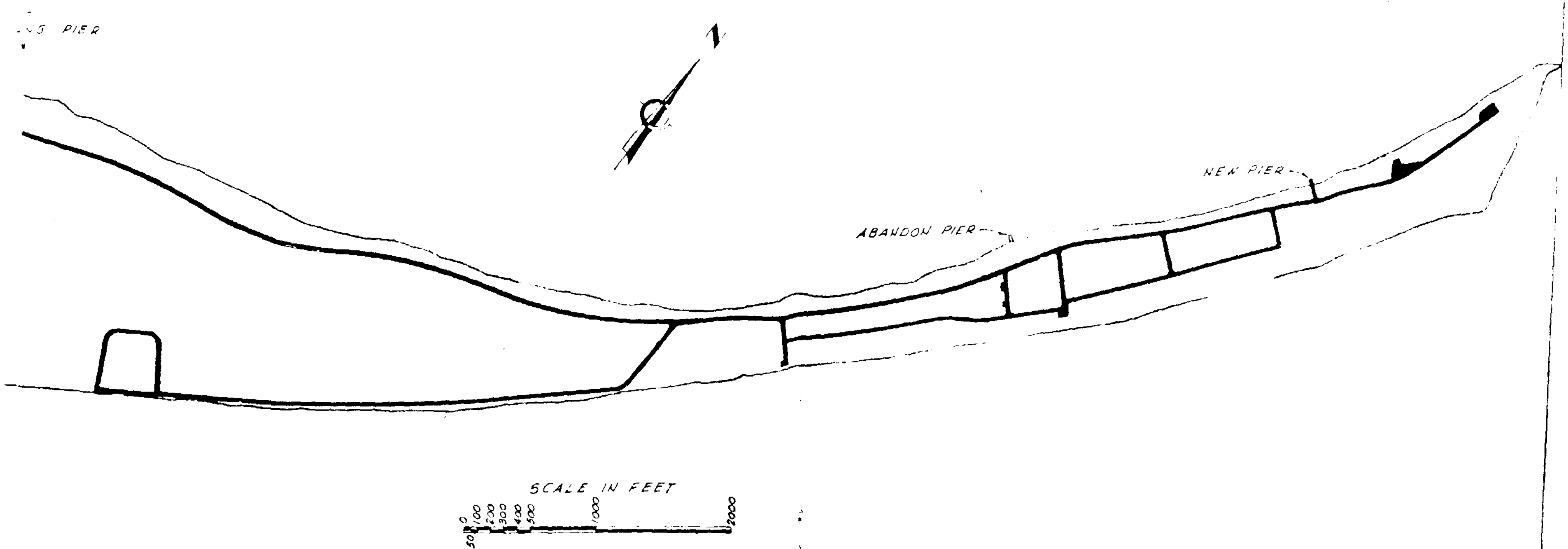
4" Road-mix	17,200 cu. yds.	using 1,740 tons of cut-back asphalt.
3" Hot-mix (Air strips)	4,300 tons	using 260 tons of asphalt.
3" Hot-mix at towers	26,000 tons	using 1,560 tons of asphalt.
$1\frac{1}{2}$" " " " "	17,400 tons	using 1,050 tons of asphalt.

It is estimated that 27,000 drums will be required to transport the asphalt.

Roads. Roads will be required on each of the islands hereinafter listed. The approximate locations of the roads that it is now anticipated will be required are shown on the various Plates listed after each island. Where existing roads are advantageiously located they should be utilized and improved as required. Width of surfacing is tentatively established at 20 feet.

It is anticipated, pending laboratory tests on the aggregate available, that roads will be paved with 4 inches of road-mix surfacing. This surfacing should be done with a traveling mixer as described in the "Paving" section of this Report. It is possible that part of the roads can be suitably treated by applying a light dust oil periodically, instead of surfacing with road-mix. If this treatment proves effective, it is estimated that its cost will be approximately one-third that of road-mix.

Island	Plate No.	Lin. Ft. Roads	Sq. Ft. Roads
Eniwetok	51	27,850	557,000
Parry	52	13,400	290,800 (a)
Runit	53	8,320	166,400
Rojoa	54	3,800 (b)	76,000
Biijiri	55	2,150	43,000
Aomon	56	1,600	32,000
Engebi	57	7,380	147,600
TOTAL		64,500	1,312,800
Bogallua	58	3,900 (c)	78,000
TOTAL		68,400	1,390,800



ROADS & PIERS - ENIWETOK ISLAND

PLATE 51

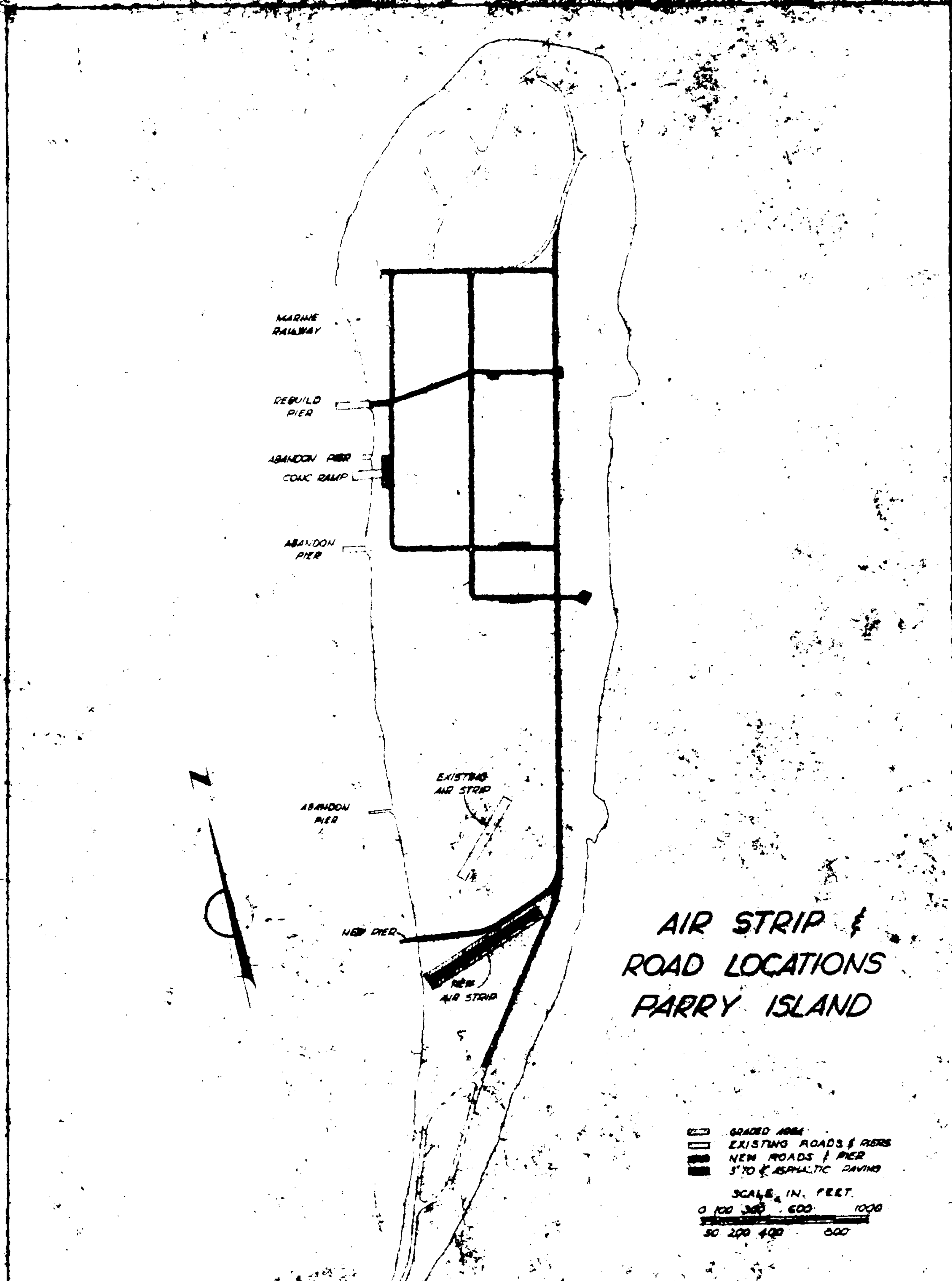

MARINE RAILWAY
REBUILD PIER
ABANDON PIER
CONC RAMP
ABANDON PIER
EXISTING AIR STRIP
ABANDON PIER
NEW PIER
NEW AIR STRIP
AIR STRIP & ROAD LOCATIONS PARRY ISLAND
GRADED AREA
EXISTING ROADS & PIERS
NEW ROADS & PIER
ASPHALTIC PAVING
SCALE IN FEET
0 100 300 600 1000

PLATE 52

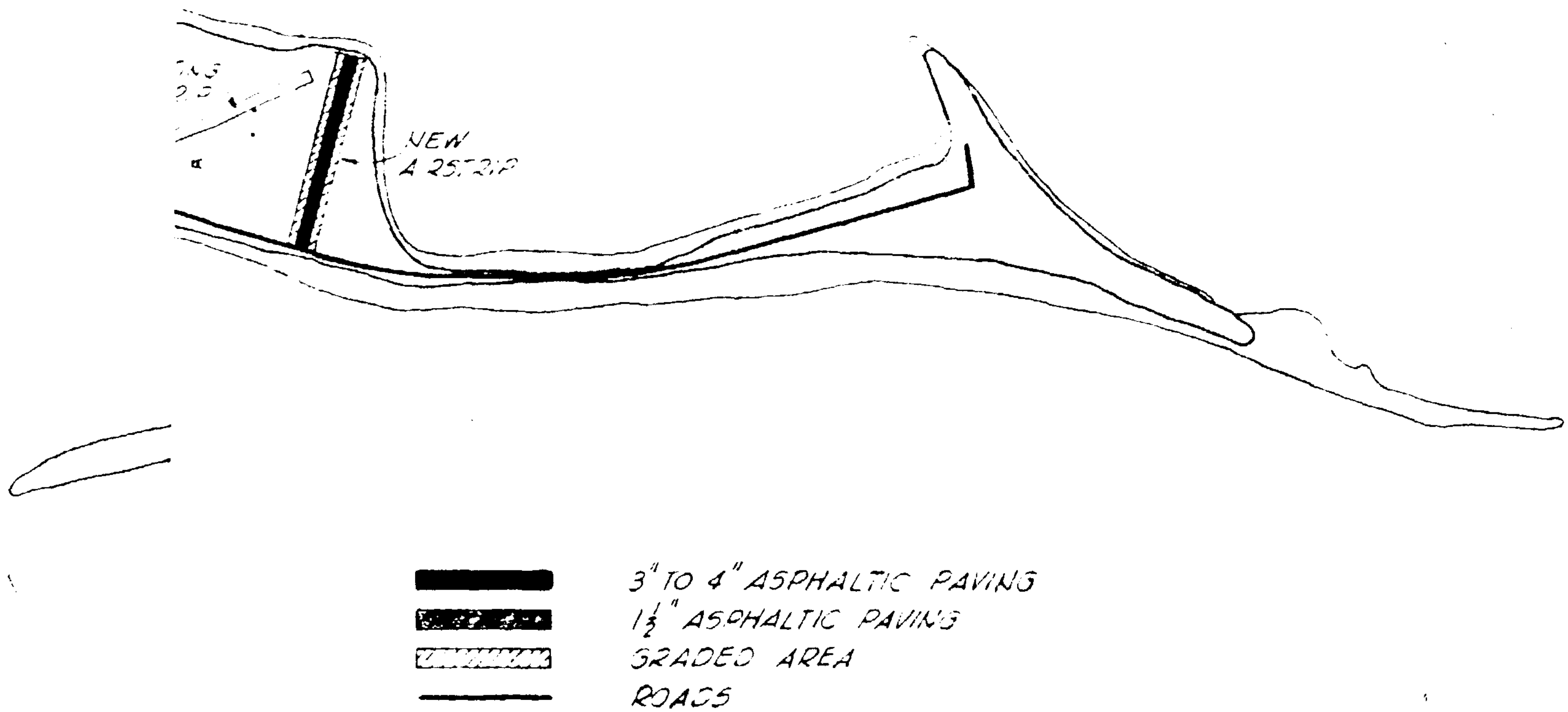
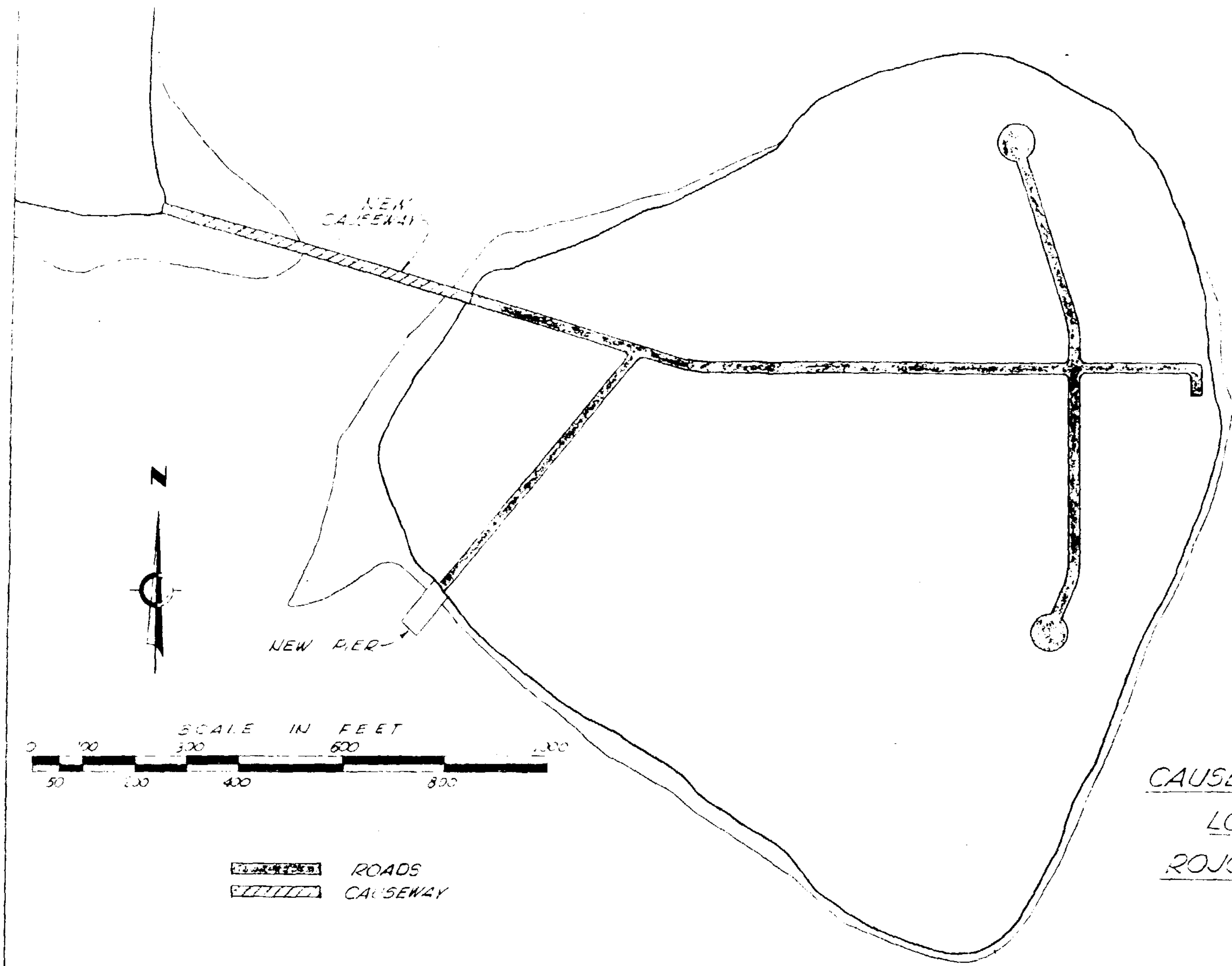
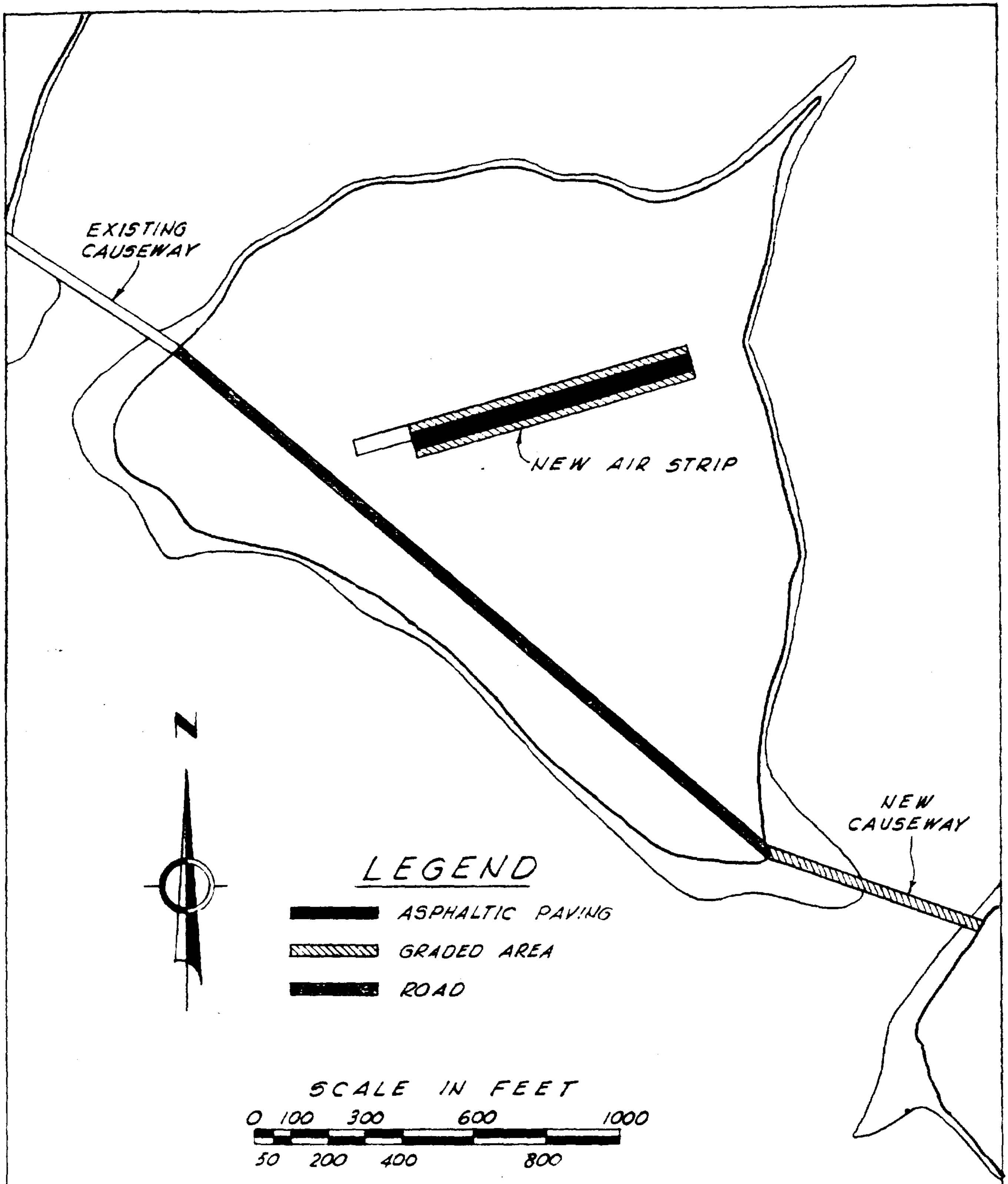

NEW
AIRSTRIP
3" TO 4" ASPHALTIC PAVING
1½" ASPHALTIC PAVING
GRADED AREA
ROADS

PLATE 53



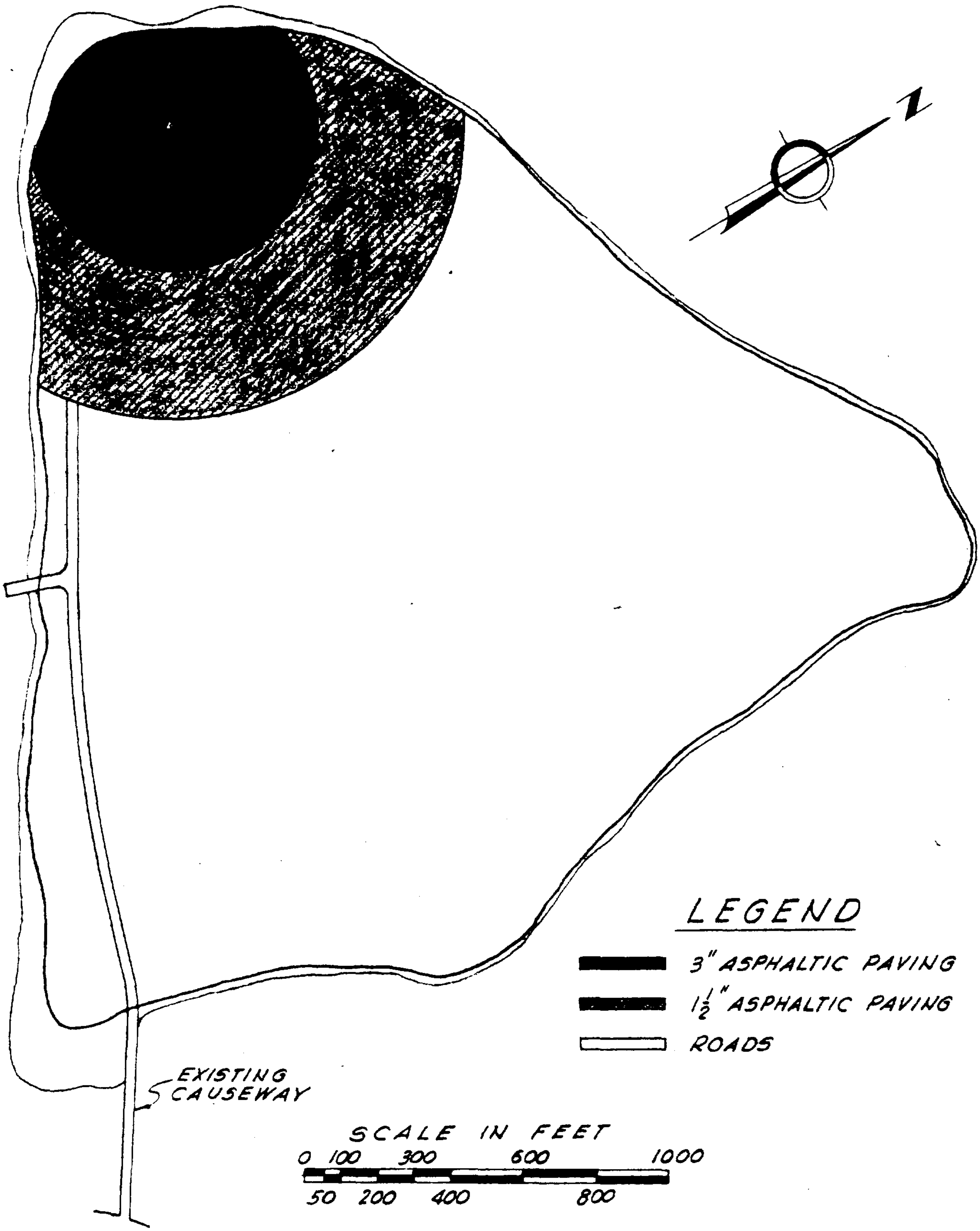
CAUSEWAY & ROAD LOCATIONS ROJOA ISLAND

PLATE 54



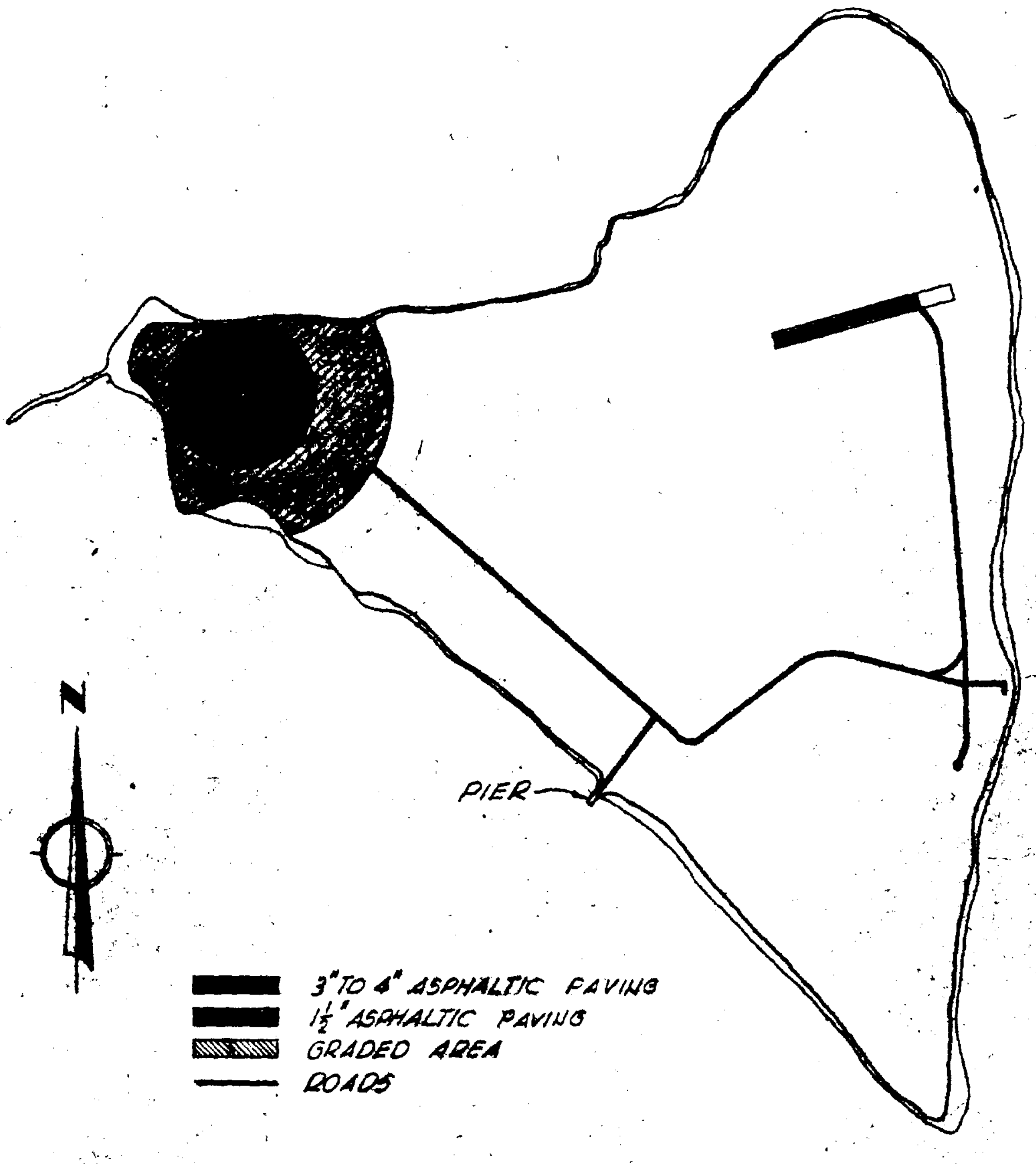
AIR STRIP & ROAD LOCATION
BIIJIRI ISLAND

PLATE 55



PAVING PLAN, ROADS, & PIER
AOMON ISLAND

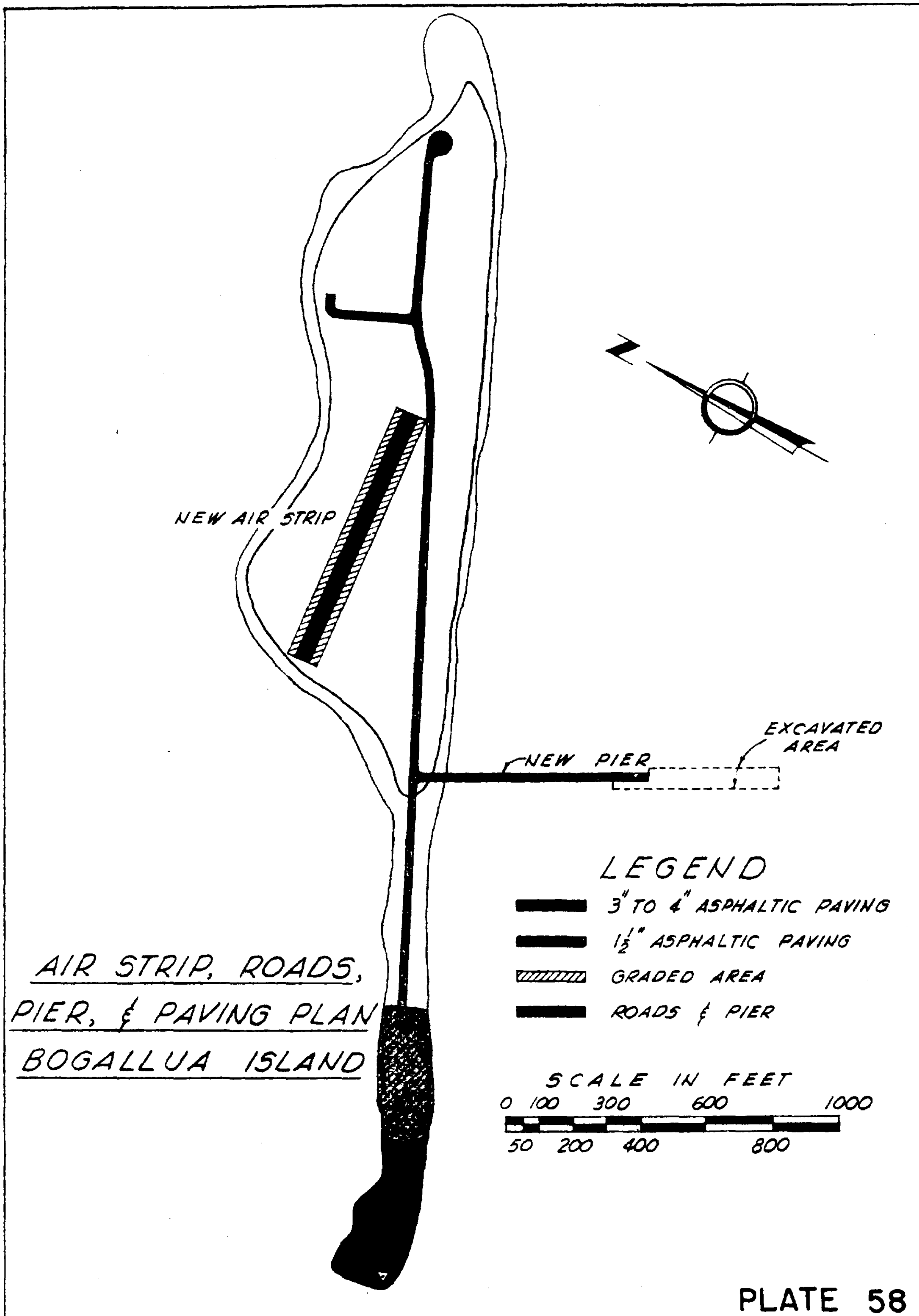
PLATE 56



AIR STRIP, PAVING PLAN, & ROADS
ENGEBI ISLAND

SCALE IN FEET
0 200 400 600 800 1000

PLATE 57



AIR STRIP, ROADS, PIER, & PAVING PLAN BOGALLUA ISLAND

PLATE 58

(a) Includes 22,800 sq. ft. of parking area

(b) Includes causeway

(c) Includes pier

AIR STRIPS:

General. Landing strips are planned to be a single strip designed for use by military L-5 planes, or comparable commercial types. They require a minimum length of 600 feet and a width of 50 feet of hard surface. A cleared area 25 feet wide on each side of the paved runway is to be provided. Approach angle to clear a 50 foot high obstruction requires 750 feet (15:1) and take off angle requires 900 feet, (18:1). While 600 feet is considered theoretically sufficient, the pilots using the present strips indicated that longer strips would be highly desirable and we are therefore using 800 feet for preliminary design wherever possible.

Runways should be crowned in the center sufficiently to provide drainage for the surfaced portion. Where possible, run off from the strip should be drained away by grading toward the beach, and where this is not feasible sufficient seepage area should be provided.

Prevailing winds particularly during the spring and early summer are from the Northeast and East, as shown on Plate 59. Landing strips have been oriented to approximately N 70° E True where possible.

Runway paving should be of a type that will provide a smooth, hard surface capable of supporting L-5 planes for the duration of the experiments. It is contemplated that either a cold-mix type of paving laid with a traveling mixer and using cut-back asphalt, or a hot-mix type using sand aggregate will be used. For a further discussion of paving methods and materials see "Roads and Paving" in this Section of the Report.

Due to the hazards involved, it is not contemplated that these strips will be used for night operations, and for this reason it is not proposed to provide air strip lighting or control towers. A wind sock should be provided at each strip.

Eniwetok. The main air strip of the Atoll is on Eniwetok. It is the source of air communication with the outside world, and consequently is of vital importance. This strip is approximately 400 feet wide by 7,000 feet long and has a smooth coral surface.

At the Easterly end of the Eniwetok strip there are a number of stub ends of rubber hoses sticking up out of the strips which were used in the control of drone planes during the last operation. These have the appearance of steel projections and since they are no longer needed, it is recommended that they be removed.

No new construction is contemplated at this strip. If however, surfacing should later become advisable, equipment will be available for this work and it could be accomplished during periods when the equipment is not needed for other work.

Parry. The present air strip on Parry Island runs N 43° E. It is approximately 600 feet long, but only about half its length is well graded, the rest being extremely rough.

It is proposed to re-locate this strip in a new location approximately 500 feet South of the present location and to reorient it to run N 70° E, as shown on Plate 52. This will leave the area between the present and proposed locations for possible future development if it should later become desirable.

The proposed strip would have a paved length of 800 feet with space for a future extension to 1,000 feet if desired. This would be desirable, so that a four-place plane could shuttle to Eniwetok and possibly Engebi.

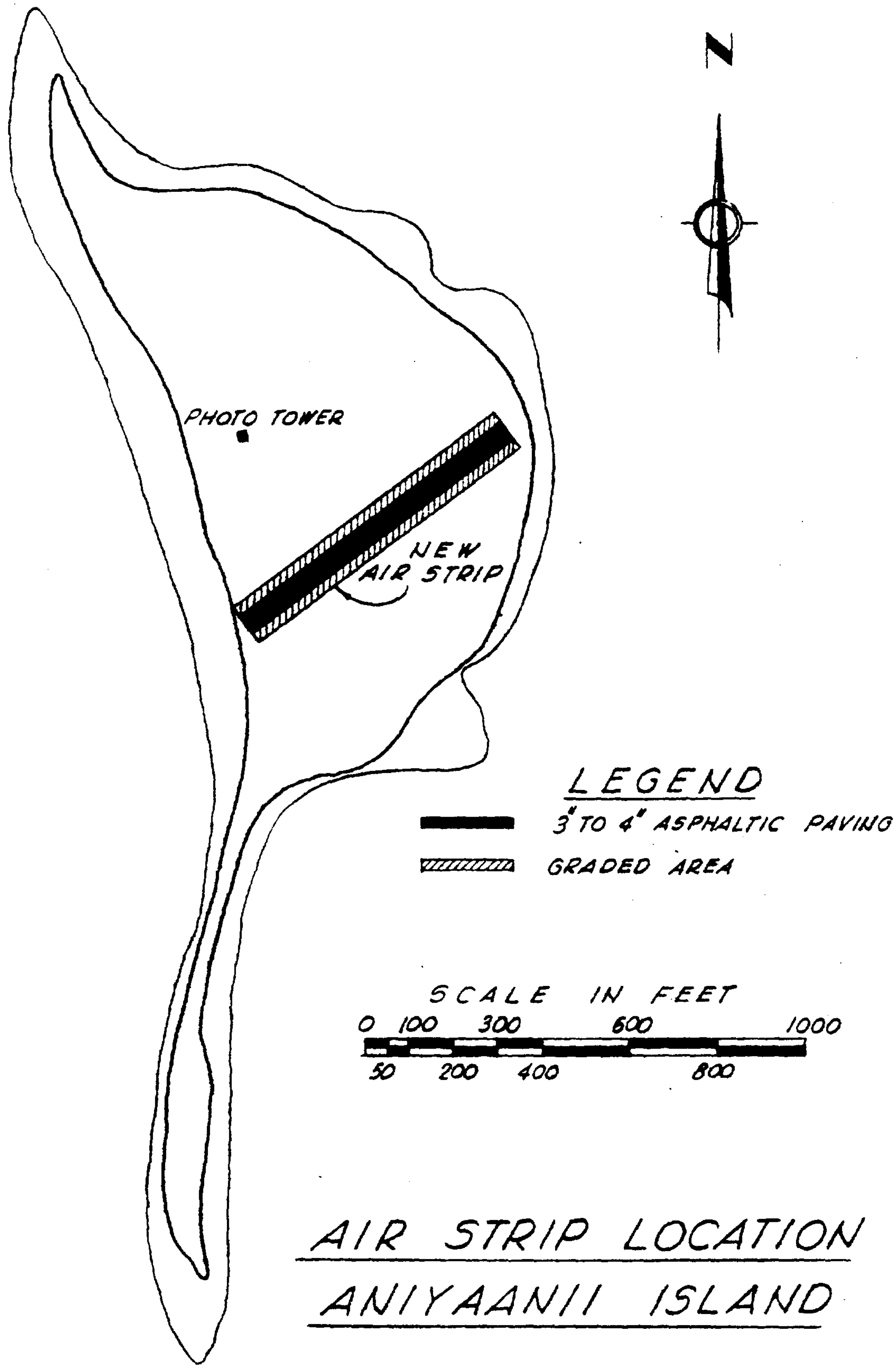
Aniyaanii. The present strip is a steel mat 40 feet wide by 630 feet long. It is proposed to remove the steel mat and regarde the strip to remove an abrupt grade change now existing approximately 200 feet from the North end. It is also proposed that the strip be lengthened 48 feet on the South end and 60 feet on the North end, making a total length of 738 feet.

The present strip has a bearing of N 54° E, and it is proposed to retain this orientation, since any improvement in direction would reduce the length of the runway. See Plate 60.

Runit. The existing runway is surfaced with steel matting 40 feet wide by approximately 800 feet long. It has a bearing of S 57° E, which varies from the ideal of N 70° E by 53°. Use of this runway is very difficult and the strip is practically unusable when cross-wind velocities exceed 10 miles per hour. For this reason it is considered advisable to re-locate the strip and to construct it with a bearing of N 70° E, as shown on Plate 53. The length of runway which can be obtained in this location is approximately 700 feet. Additional survey data will be necessary in order to determine the exact length which can be obtained, and if necessary, fill should be constructed at the end of the strip to provide the 700 foot runway.

Biijiri. The runway of the Biijiri strip is poorly surfaced coral. Although its length is not definitely known it is assumed to be approximately 600 feet. One of the two planes now operating on the Atoll cannot land on this strip and the other sometimes over-runs the runway. The bearing of the strip is approximately N 75° E. South of and parallel with the existing strip, construction has been started on another longer runway. It is understood that the surface was harrowed under a recent Army maintenance project, but it has not been graded or rolled.

It is proposed that the new air strip be constructed south of and parallel



AIR STRIP LOCATION
ANIYAANII ISLAND

PLATE 60

with the existing strip to utilize the grading work already started. It is proposed that the new strip be 800 feet in length, and located as shown on Plate 55. More length could be had on Aomon, but its proximity to the Zero location would mean more costly re-building between Shots than Biijiri.

Engebi. The air strip on Engebi Island has a smooth coral surface and lies South of and parallel with the original Japanese strip. It has a bearing of N 76° E. Catch basins with grates flush with the surface have been constructed along each side of the runway at 200 foot intervals. Water from these drains seeps to the sub-surface thru the coral sand.

It is proposed that the surfaced runway be constructed in the same location and with the same orientation as the present runway, and that its Southwesterly end be approximately 2800 feet from the tower location. Available data indicates that with a glide angle of 51 to 1 the nearest interfering portion of the coaxial cable will be approximately 325 feet from the extended center line of the runway.

A runway length of 800 feet is proposed, the location to be as shown on Plate 57. This could be extended to accommodate a four-place plane for an Eniwetok or Parry shuttle to Engebi.

Bogallua. If the island of Bogallua is to be developed into a shot Island, an air strip should be provided as shown on Plate 58. No air strip has heretofore been constructed on the island, and the location indicated provides a strip 800 feet long with a bearing of N 85° E. This bearing is only slightly less desirable than the ideal selected. It was selected to avoid having planes taking off over the camp area.

Quantities. The following are the estimated quantities of paving that will be required for each air strip.

Island	Sq. Ft.
Parry	40,000
Aniyaanii	36,500
Runit	35,200
Biijiri	40,000
Engebi	40,000
Bogallua	40,000
	231,700

GRADING AND PAVING OF AREAS:

Grading - Tower Areas. Tower area grading, for the purpose of reducing radiation to tolerance limits, will be required during the early stages of the construction period. It is believed that the removal of the top 6 inches of soil or the covering of a radio-active area with 2 feet of sand will accomplish this purpose. Grading is primarily for the purpose of reducing radioactivity at the surface and to remove any pronounced surface irregularities or sharp grade variations.

In order to determine the type of equipment and the method of operation to best accomplish these purposes, it has been suggested that the existing Trinity crater be graded experimentally to insure that this work will progress efficiently on the Atoll. In this way, the equipment that will be needed and the methods to be used can be determined in advance of actual operations.

Paving - Tower Areas. The construction of hot-mix asphaltic paving of all land area within 400 feet from each of the towers, to a depth of 3 inches, and all land area from 400 to 800 feet from the towers to a depth of 1½ inches is proposed. This paving should be laid by a self-propelled finishing machine in order to minimize the direct contact with the sub-grade by personnel. The asphalt to be used in this paving is tentatively specified to conform to the requirements for steam refined paving asphalts in accordance with Section 65 of the State of California, Department of Public Works, Division of

Highways Standard Specifications, dated April 1945. The quantities of asphalt required in the paving are estimated as follows:

Island	400' Rad.	400' to 800' Rad.	Total
Runit	450 tons	225 tons	675 tons
Engebi	563 "	450 "	1013 "
Aomon	464 "	338 "	802 "
Bogallua	81 "	34 "	115 "

Area Stabilization. Stabilization of the Zero Line or other areas for the purpose of reducing the amount of dust which will rise therefrom may be accomplished by any of several methods, depending upon the particular requirements. These methods are: soil cement stabilization, road-mix asphalt mat surfacing, oil spraying with light road oil, planting of vegetation as a ground cover, and spraying with water to keep the ground moist. Costs could be expected to range downward in the order named, and the selection of method will depend upon the area to be treated and the rseults required.

Soil cement stabilization might be expected to shatter and produce a considerable amount of dust under blast effect. Asphalt road-mix surfacing to a thickness of 2 to 3 inches should give effective dust control; whereas soil-cement treatment should be from 3 to 4 inches thick to reduce shattering.

If suitable ground cover vegetation can be obtained, it is anticipated that this method would be relatively inexpensive and effective over large areas. If such vegetation is not available, spraying with a light road oil should be effective where the requirements do not justify the use of road-mix. Sprinkling with water might be used as a temporary measure, particularly during construction.

If additional areas, not included in the estimate are to be stabilized, the estimated cost of such stabilization is $0.20 per square yard for oiling and $1.10 per square yard for road-mix 3" thick.

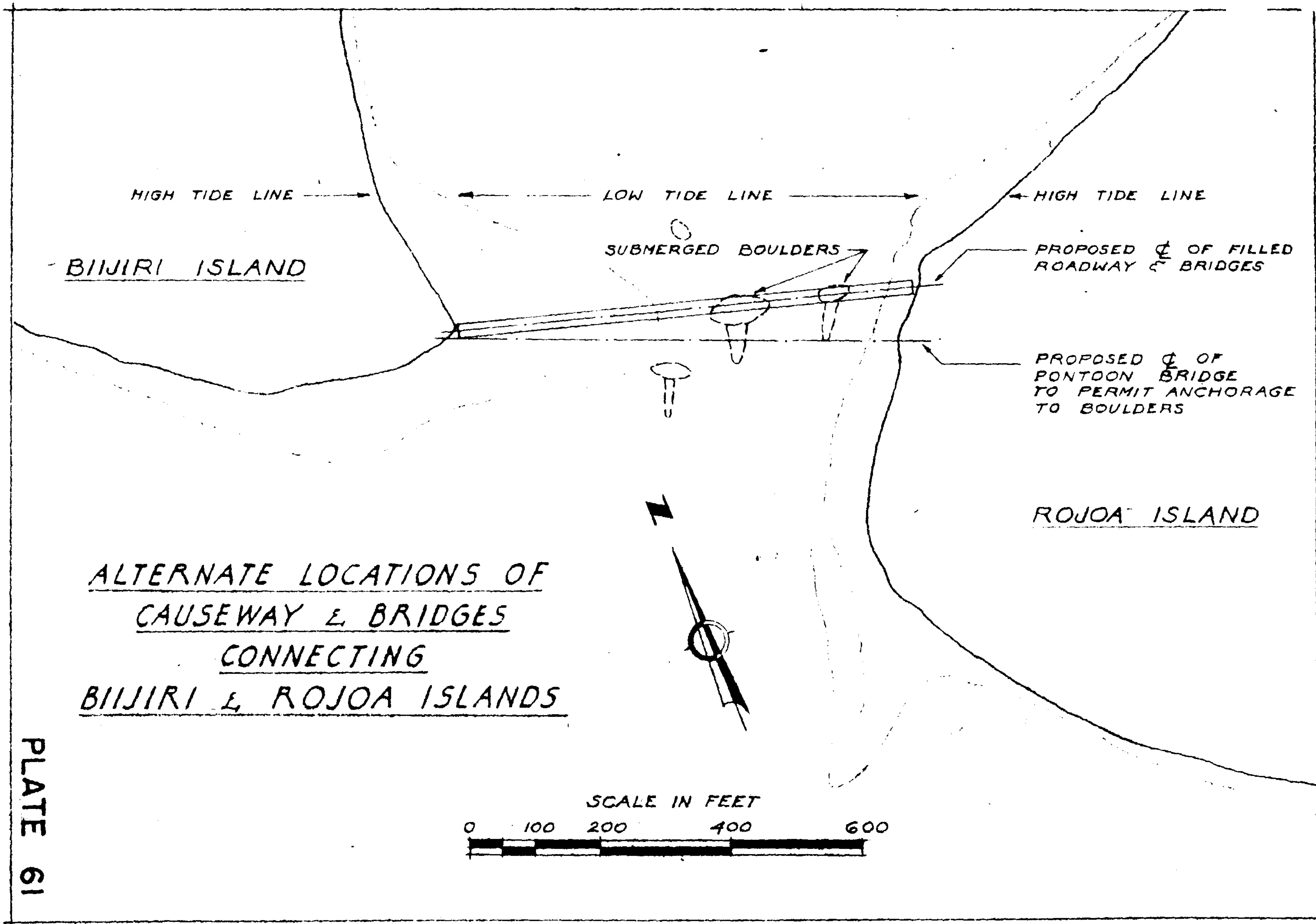


PLATE 61

ALTERNATE LOCATIONS OF CAUSEWAY & BRIDGES CONNECTING BIIJIRI & ROJOA ISLANDS

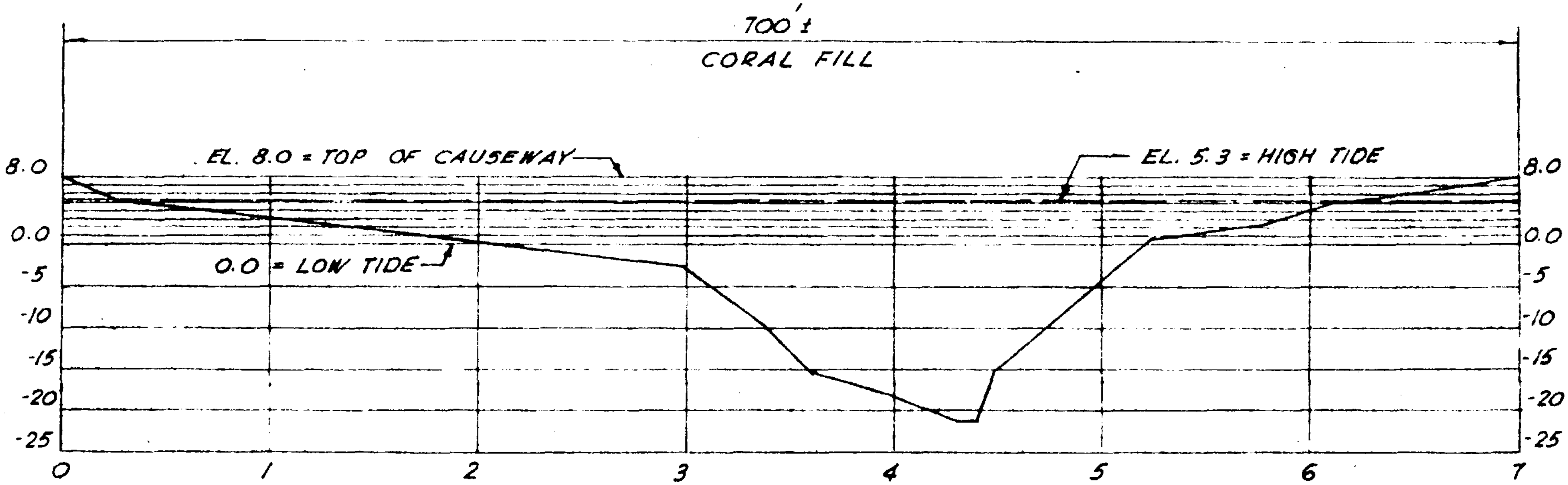
CAUSEWAYS:

General. The proposed causeway connecting Biijiri and Rojoa Islands will cross a channel approximately 700 feet wide and 21 feet deep near its center. A continuous current flows through this channel from the ocean toward the lagoon with unknown velocity. Plate 61 shows alternate locations.

Six schemes for crossing this channel have been studied as hereinafter described. Additional soundings between the two islands and also further information concerning the velocity of the current through the channel will be required before a decision can be reached as to which of these schemes will be the most economical.

Scheme No. 1. Plate 62. A causeway consisting entirely of coral fill would be the simplest and most permanent of the methods studied if the difficulty of making the final closure can be overcome. It is known, however, that a considerable amount of difficulty was encountered in closing the sheet piling connections between Aomon and Biijiri Islands due to washing out of the beach as the piling neared the island. The possibility of placing large culvert pipes through the fill to allow the current to flow through has been considered, but additional information concerning the nature and velocity of the current is needed before the feasibility of this method can be definitely determined.

Scheme No. 2. Plate 63. This scheme involves the use of a Bailey type bridge span, estimated on the basis of present information to be 180 feet long with poured concrete footings on coral rock. These footings would consist of tremie poured concrete, using forms sunk into place. Information available indicates that the bottom of these footings would be about 9 feet below low tide, but additional survey data may prove that a better crossing location is available. In that case, a shorter span or shallower footings or

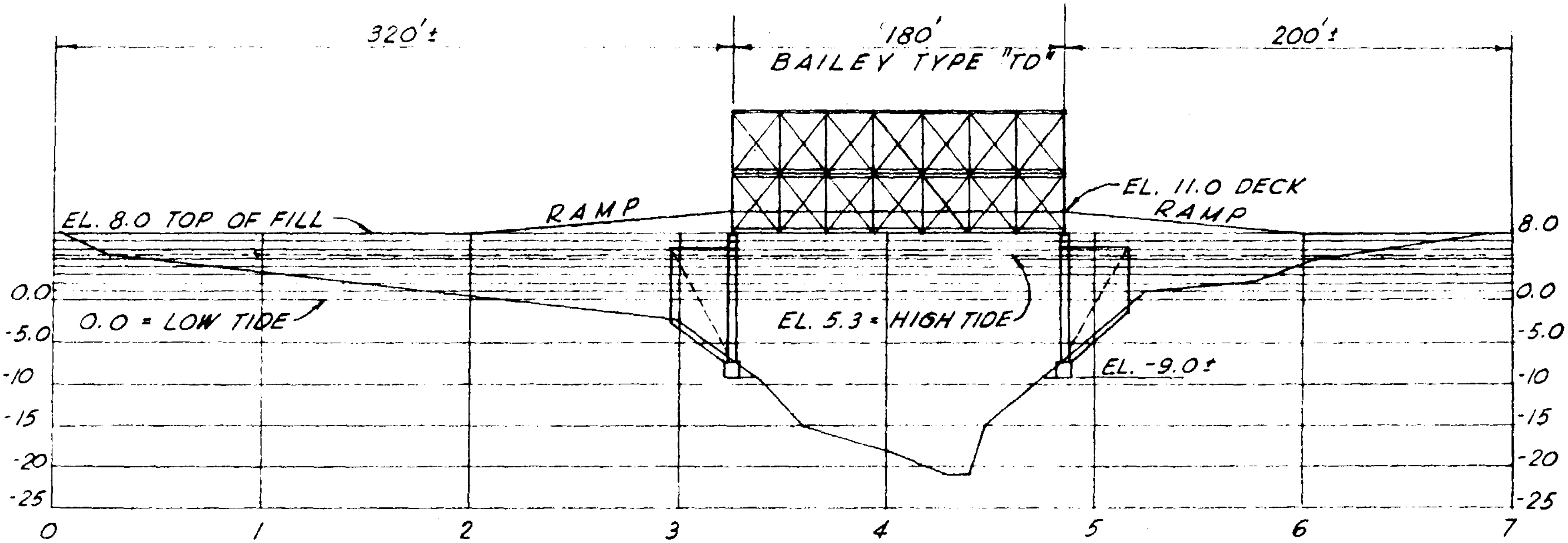


SCALES: HOR. 1" = 80'
VER. 1" = 20'

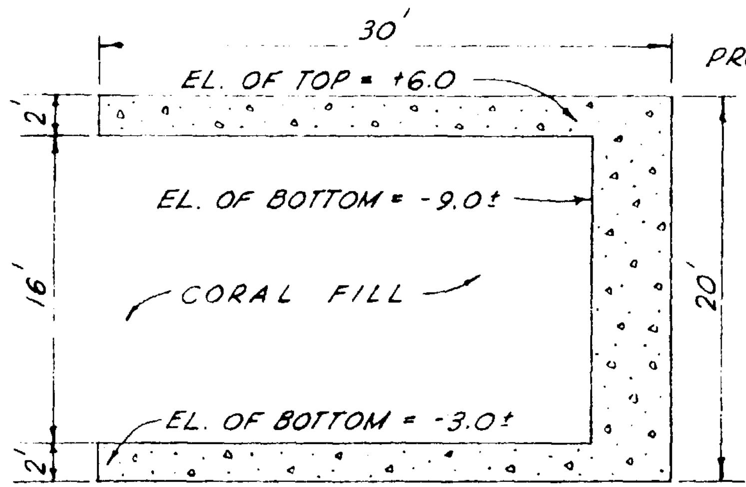
13,500 CU. YD. CORAL FILL
20' TOP, 2:1 SLOPES

PROFILE OF CAUSEWAY
BIIJIRI TO ROJOA
SCHEME 1 - CORAL FILL

PLATE 62



PROFILE SCALES: HOR. 1" = 80'
VER. 1" = 20'



PLAN - TYPICAL ABUTMENT
SC: 1" = 10'

4,000 CU. YDS. CORAL FILL
ONE 180' BAILEY SPAN
CONC. ABUTMENTS & WALLS

PROFILE OF CAUSEWAY
BIIJIRI TO ROJOA
SCHEME 2 - 180 FT. BAILEY BRIDGE

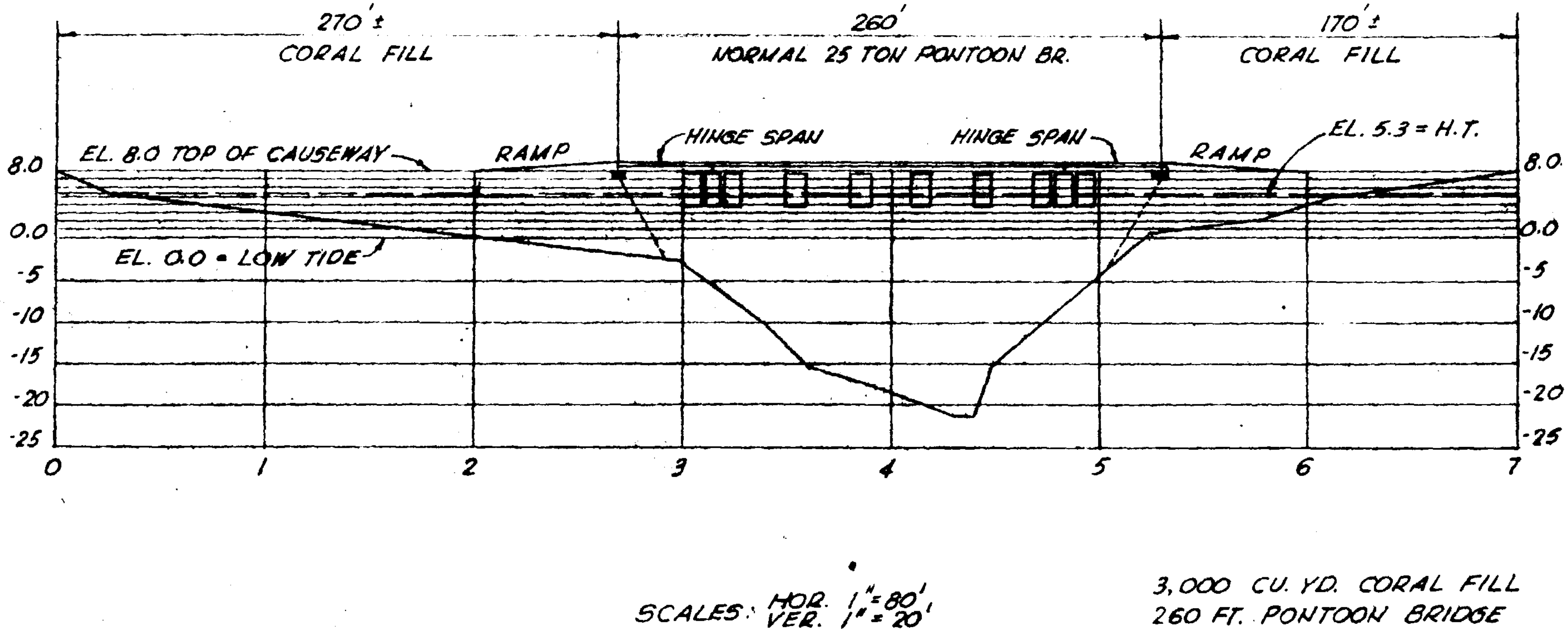
PLATE 63

both may be obtainable.

Scheme No. 3. Plate No. 64. This scheme involves the use of coral fill and a pontoon bridge approximately 260 feet long. Hinge spans would be anchored to coral fill approaches and use would be made of submerged coral heads to anchor the pontoons. Further information concerning the availability of suitable coral heads for this purpose will be necessary before the feasibility of this scheme can be determined.

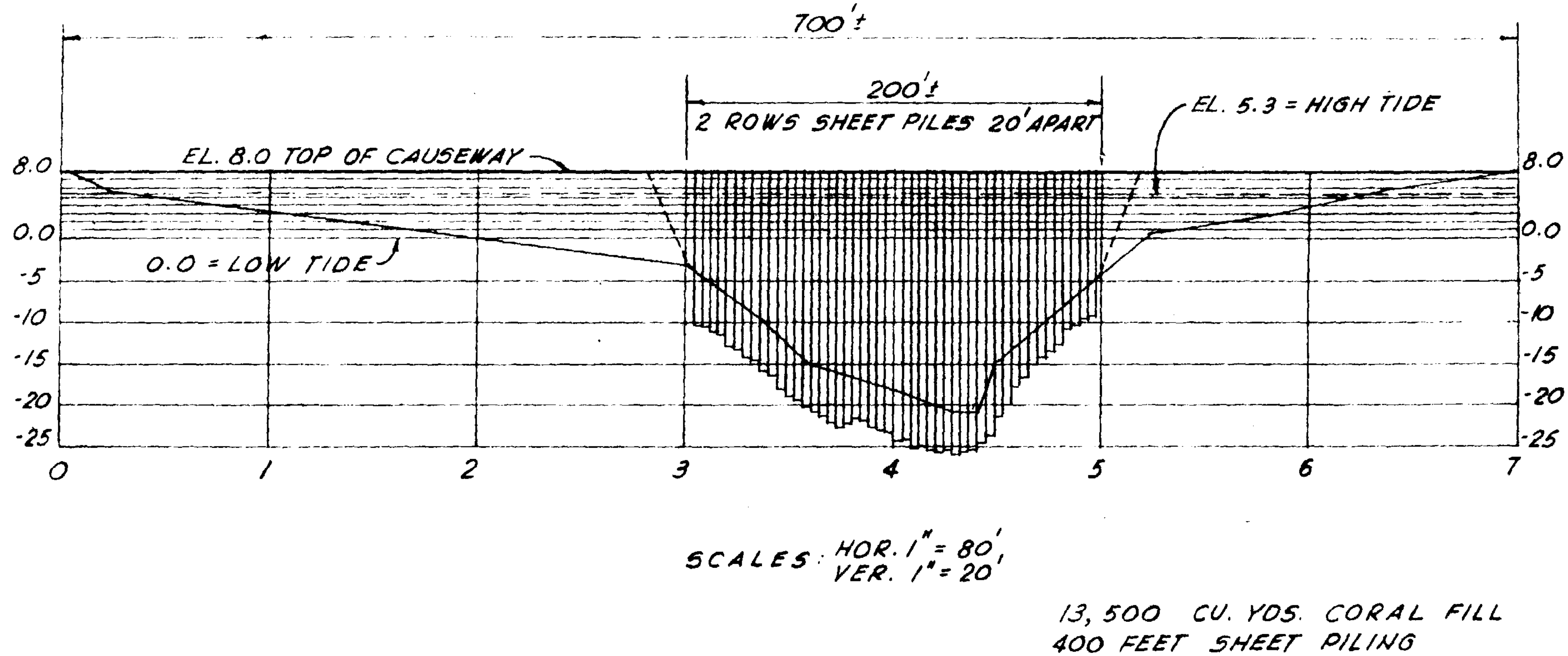
Scheme No. 4. Plate No. 65. Under this scheme steel sheet piling would be used in conjunction with coral fill in order to make the final closure. It is contemplated that a double row of piling across the deepest part of the channel would accomplish this purpose and that fill would then be made between and on both sides of the piling so that rusting of the steel will not affect the stability of the causeway. The use of large rock in the fill would minimize the tendency to wash out prior to complete closure, and once this closure is made it is believed there would be little tendency toward washing out. This would require the use of a pile driver, and it is believed that unless a pile driver will be required on other work it will not be an economical method. The hardness of the coral requires that it be shattered before driving of sheet piling is possible, and this adds materially to the cost of this method.

Scheme No. 5. This scheme involves the use of a wooden barge to ferry personnel and vehicles across the deepest portion of the channel. Approximately 3,000 cubic yards of fill would be used to provide access to the ferry landings which would be approximately 260 feet apart. Considering the relatively short period of operation it would undoubtedly be more economical to provide an operator for the ferry than to provide automatic electric operation



PROFILE OF CAUSEWAY
BIIJIRI TO ROJOA
SCHEME 3 - 260 FT. PONTOON BRIDGE

PLATE 64



PROFILE OF CAUSEWAY

BIIJIRI TO ROJOA

SCHEME 4 - 400 FT. SHEET PILING

PLATE 65

by individuals.

Scheme No. 6. If the transporting of vehicles will not be required, a Dukw could be utilized to transport personnel between the islands. This would require that more vehicles be available to transport personnel on the islands, but would not require any construction.

Summary. Which of these schemes should be adopted will depend primarily upon the degree of operating convenience that must be obtained. Scheme 6 would be the cheapest but would provide the least amount of convenience, with Scheme 5 second in these regards. Scheme 3 would be next lowest in first cost but it should be anticipated that the pontoons and cables would need to be replaced before each period of use. Schemes 1 to 4 inclusive would be approximately equal in convenience of use and a choice between them will depend upon additional information to be obtained regarding the conformation of the channel and the currents. In the cost estimate which is a part of this Report, Scheme 2 involving the Bailey bridge, has been used. However, if after further investigation of the channel has been made, Schemes 1, 3, or 4 should prove more economical, it should be adopted as the method to use. Scheme 5 is estimated to cost approximately 50% of the first cost of Scheme 2, and an additional $15,000.00 operating cost per experiment.

Protection of Causeway Between Aomon and Biijiri. This causeway consists of a row of steel sheet piling on each side, with coral fill between. The piling is rusting considerably, primarily between high and low tide. It would be difficult and expensive to attempt to coat that portion of the steel which is alternately wet and dry, and even if this were done that part next to the fill would remain unprotected. In order to protect the structure against the possibility of failure of the steel and consequent washing out of some of the fill, it is recommended that the condition of the piling be watched carefully and if it shows signs of possible failure, fill be placed outside the piling to hold the existing fill in place.

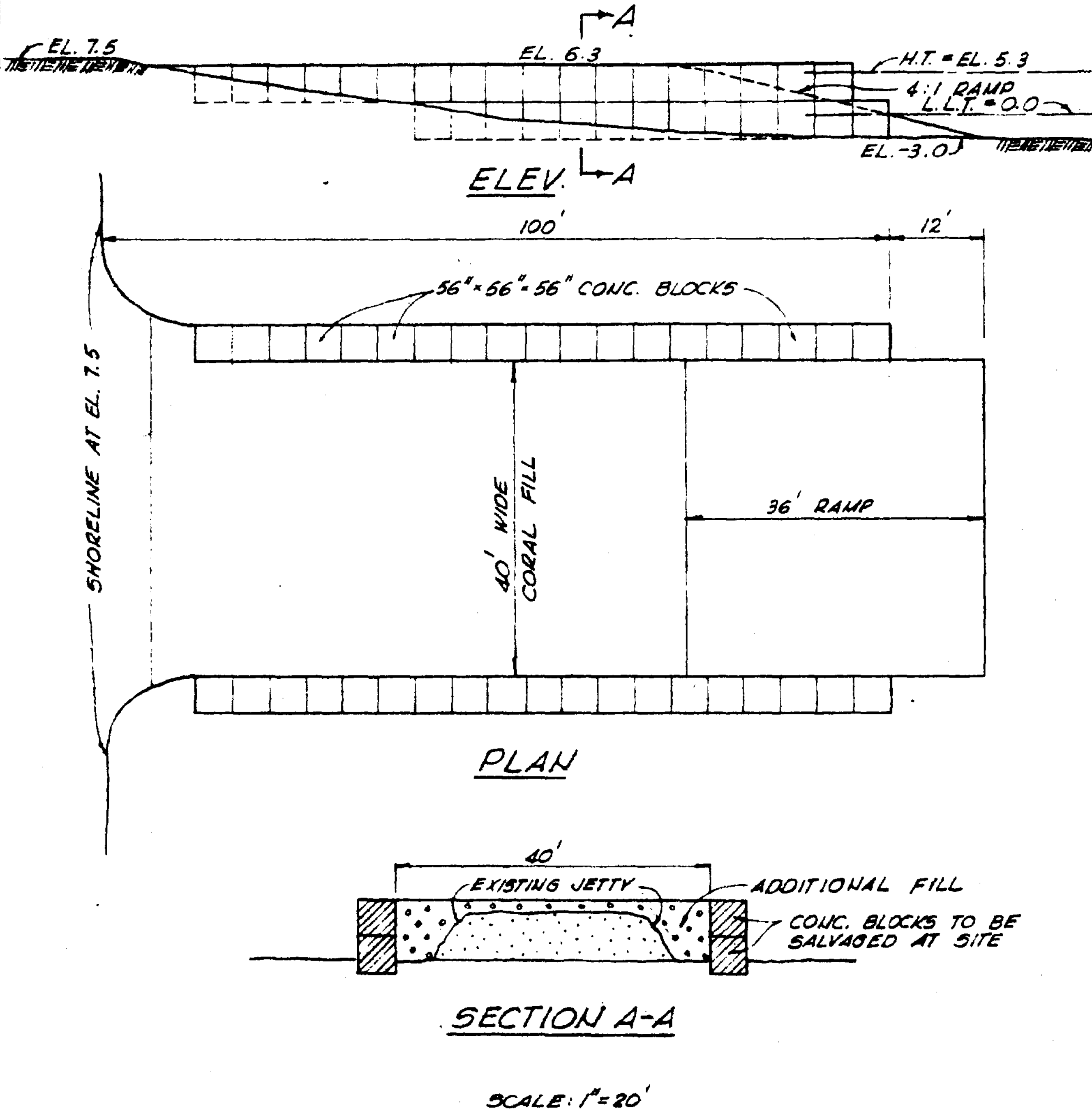
Other Causeways. On the basis of a five year period of operation it is not considered economically justified to connect other islands with causeways. However, should a considerably longer period be adopted, such connections might be justified. It is estimated that the cost of such causeways would be approximately $7,000. per 100 linear feet for a top width of 20 feet.

PIERS:

General. Piers should be provided on each of the shot islands, in a location that provides convenient access to the tower, and also on the islands of Parry, Eniwetok, and Rojoa. For the proposed locations of piers on the shot islands, see Plates 53, 56, 57, and 58. Unless Aniyaanii is selected as a power plant site it will have no requirements for the loading or unloading of heavy equipment or frequent embarking or disembarking of personnel except during the construction of the air strip, and it is considered unnecessary to provide it with a pier. Equipment to be used at the photo tower will be relatively light and undoubtedly can be hand-carried or transported in a truck which can be landed from an M boat.

Shot Islands. There are approximately 175 concrete blocks distributed among the islands of Runit, Engebi, and Aomon, and it is planned that these will be used in the reconstruction of the piers on these islands, as shown on Plate 66. These blocks are of various sizes, averaging about 56 inches on each outside dimension, and have 8 inch walls.

It is estimated that the piers will average 100 feet in length, in order to reach the maximum depth on the coral shelf. It is estimated that



SKETCH OF PIER RECONSTRUCTION
RUNIT, ENGEBI, & AOMON ISLANDS

PLATE 66

approximately 65 blocks will be required for each pier, and if the number of hollow blocks is insufficient, they can be augmented with blast footing blocks which are also available on the shot islands.

Eniwetok. On Eniwetok (See Plate 51), there is a pier near the South end on the lagoon side, which was constructed of pontoons with coral fill. These pontoons are in very bad shape and it is proposed that this pier be repaired and restored to use.

About one-third of the length of the island from the Northeast end there is a floating pontoon personnel landing pier which was used during the last experiment. Several sections of this pier were broken loose and sunk recently by a storm, and it is not now usable. It is proposed that this pier be abandoned and a new pier constructed farther along the lagoon to the Northeast, in the location indicated on Plate 51. This new pier should be as near Parry Island as possible in order to recuce the length of travel by boat to minimum.

There is also a small wooden pier on the Southwest point of Eniwetok which is used for dumping garbage into the seaward side. This pier is in good condition and serves its purpose well. It is recommended that no change be made in this pier.

Parry. On Parry Island there are two main piers; two personnel piers, a concrete seaplane ramp and a marine railway, as shown on Plate 52. The southernmost pier is a personnel pier which is in poor condition. It is not located advantageously for the proposed scheme and it is recommended that it be abandoned.

The next pier northward was a freight pier constructed of steel pontoons, two deep, with coral fill between. The steel is badly deteriorated and the fill is partially washed out. It is not anticipated that this pier will be required in the future, and it is recommended that it be abandoned.

The next pier, beyond the concrete ramp, is a large steel barge anchored by cables. It has a two-inch wooden plank floor on top of the deck, and was used as a personnel pier. Since it is badly rusted and not advantageously located, it is recommended that it be abandoned.

The most northerly pier is similar in construction to the freight pier heretofore described but it is in better condition. It is also longer, being about 200 feet long by 30 feet wide and extends into deeper water. It is recommended that this pier be repaired as required and put in condition for use for the duration of the operation. Further detailed inspection of this pier will be necessary in order to determine the nature and extent of the repairs that will be necessary.

In order to provide as short a water travel distance as possible between Eniwetok and Parry Islands, it is recommended that a new personnel pier be constructed near the airstrip as shown on Plate 52. A location at the southerly tip of the island would involve traffic crossing the airstrip. In addition, it is considered good planning to reserve the area South of the stip as an exclusion area. During peak operations, this pier would be used extensively by persons traveling between islands, and shuttle bus service should be provided to transport them to their destination on Parry. A telephone should be provided near the pier so that during periods when travel does not warrant scheduled bus service, individuals can call the motor pool to request transportation.

Further analysis of anticipated traffic volumes and flows may determine that the apparent reduction in water travel time between Eniwetok and Parry Islands effected by locating the personnel pier at this point may not compensate for increased water travel time between Parry Island and the other islands lying to the North. Furthermore, if this pier were located near the center of the development on Parry Island, the possibility of reduction of bus facilities, if not their complete elimination, should be considered before final location is determined.

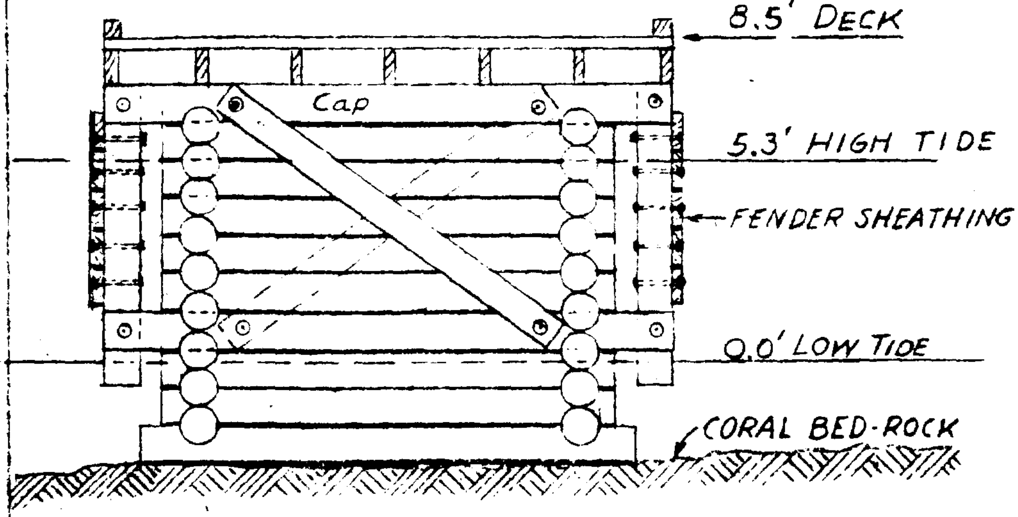
Rojoa. Since the housing on the Island of Rojoa will be approximately a mile from the pier on Aomon, it is proposed that a pier be constructed on Rojoa as shown on Plate 54.

Bogallua. If Bogallua is to be used as a shot island, it will be necessary to construct a pier of coral fill from the island to the edge of the coral reef in the lagoon. No soundings are available for this area, but is known that this shelf is covered with from two to five feet of water. In order to obtain material to make this fill, it will be necessary to (1) blast the material loose from the reef, (2) locate a sufficient quantity of suitable material on Bogallua, or (3) barge the material from an adjacent island. It is estimated that for a fill 900 feet long and 20 feet wide on top approximately 10,000 cubic yards of material will be required.

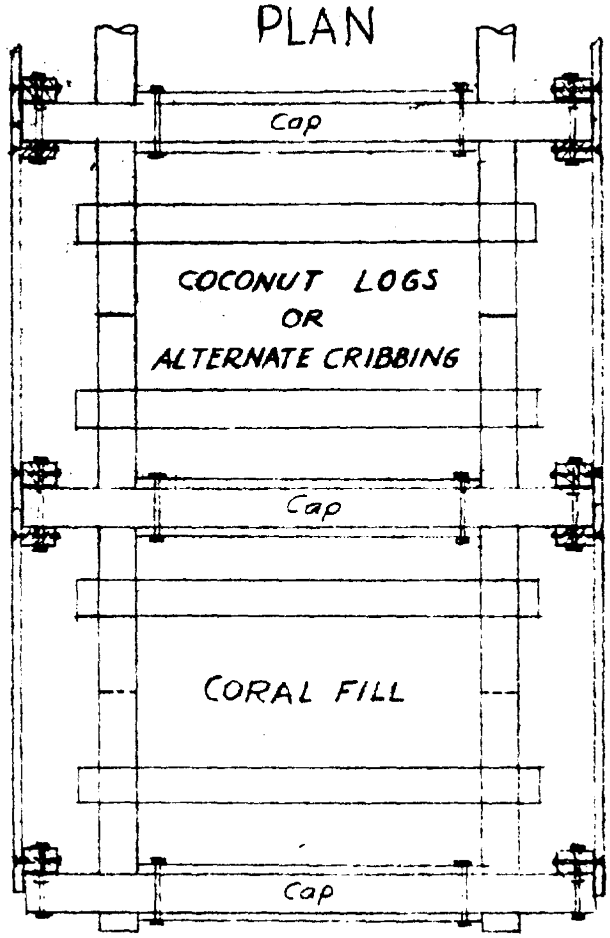
In order to provide space for small boats to dock, it is suggested that the outer 60 feet be provided with docking space constructed as shown on Plate 67 or Plate 68. Examination should be made of the Coconut log cribbing used for pier construction by the Navy on Eniwetok in 1944. If this cribbing has remained intact, it is recommended that coconut logs be used for cribbing on the new construction. If not, treated timber or concrete cribbing will be required.

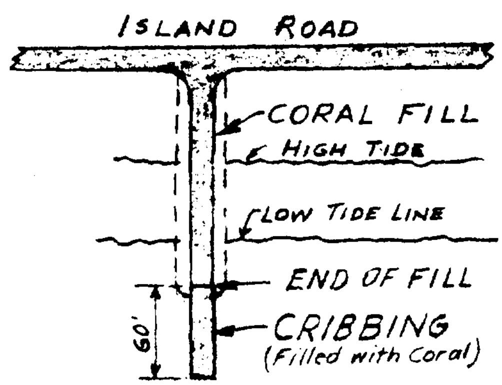
As an alternate to constructing the pier to the edge of the reef, consideration should be given to excavating a channel for portion of the distance and filling with the excavated material, as shown on Plate 68. The economy of this method will depend upon the hardness of the reef, but if it is no harder than is anticipated, this method will undoubtedly be the most economical.

SECTION



PLAN

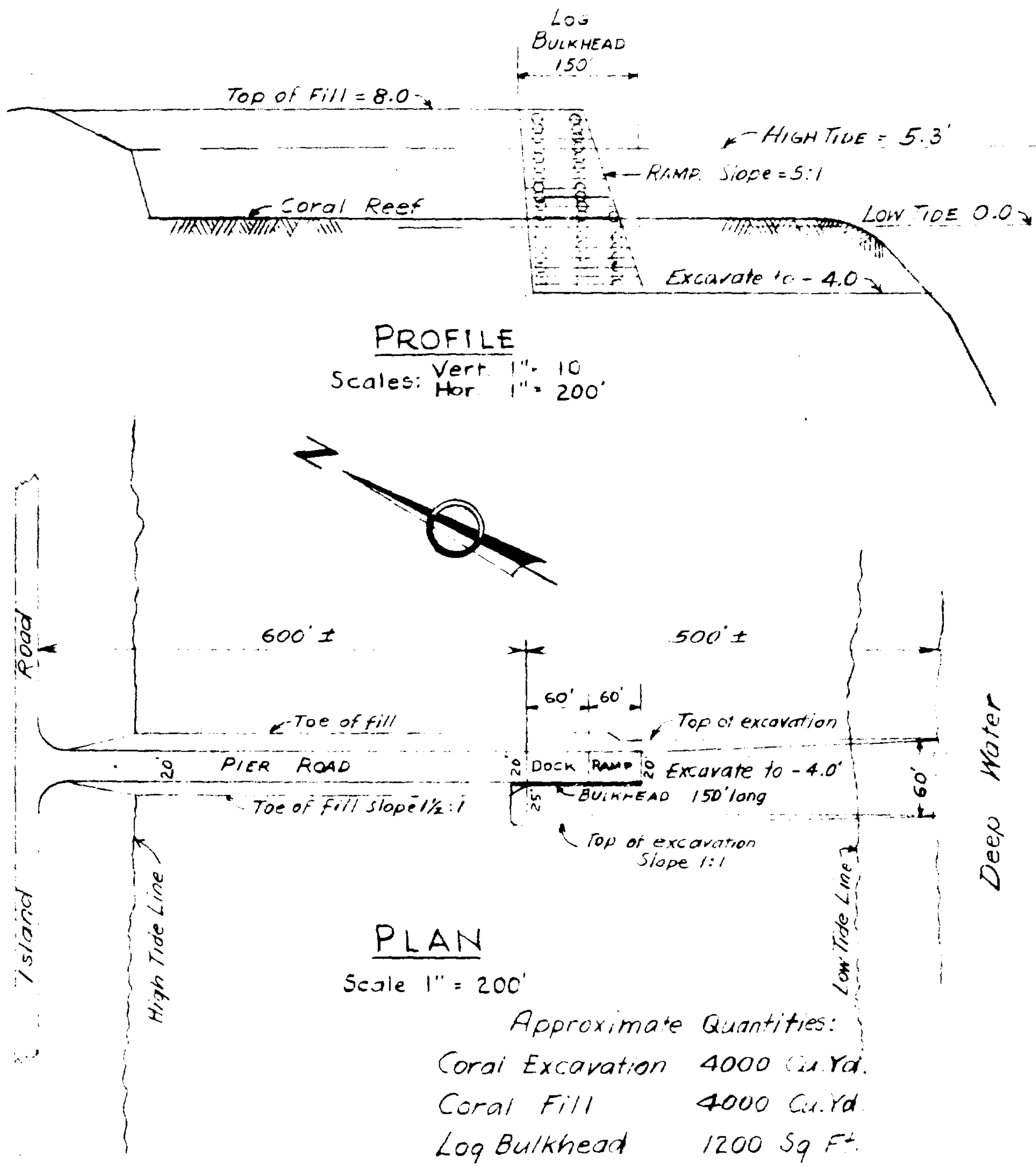




TYPICAL PLAN NEW PIERS

ALL FASTENINGS TO BE BRASS BOLTS.

PLATE 67



BOGALLUA PIER

PLATE 68

New Pier Construction. Plate 67 shows the proposed construction for new piers. These will be required on the islands of Eniwetok, Parry and Rojoa.

Pages 22, 78, 79 and 97 omitted from this Section

SECTION V

CONSTRUCTION

STATEMENT OF CONSTRUCTION PROBLEMS:

The basic philosophy of the choice of Eniwetok Atoll for a proving ground hinges upon its geographical location. Factors of isolation, sparse human habitation, low real estate value and few economic resources, lack of interest to commerce, agriculture or industry, are all tangible values to the atomic weapons test, but, conversely, introduce unique problems of construction. Eniwetok Atoll shares most of the problems common to other remote overseas construction jobs, and imposes additional ones. Examples of such job characteristics are as follows:

(a) All materials and persons must be transported to the site from the United States.

(b) Climatic characteristics as affecting men and materials must be adjusted for.

(c) The dispersal of units of work at the site into several islands makes operation cumbersome.

(d) No permanent buildings or utilities now exist at the site, creating a problem of maintenance and interim construction in addition to permanent work in place.

(e) Housekeeping and camp services are a special requirement.

(f) Communication and transportation within the project area are more difficult than in a contiguous land area.

(g) Certain installations due to their scientific importance, require special materials and unusual precision of installation.

(h) Certain installations are complex specialized structural problems, such as lofty towers on small sandy isles.

(i) Climatic effect on materials and equipment magnifies problems of storage and mechanical repair.

(j) The continual rapid development of atomic science imposes changing criteria, and requires great flexibility in construction and design.

(k) The characteristic of intensive occupation by large population, followed by long periods of virtual de-activation, creates special problems of durable construction and maintenance.

(l) The special nature of proving ground use introduces unusual radiological hazards to personnel, and requires special handling of certain construction operations.

(m) The site is not a port of call for air or surface freight carriers, military or commercial, beyond the relatively minor needs of the present garrison, comprising less than a hundred persons.

(n) Available topographic area at the site is exceedingly limited, and almost at sea level elevation.

(o) Soil for fill is limited, and sand and rock for concrete aggregate is of coral origin and requires special handling.

(p) Natural fresh water supply is non-existent, and catchment of rain water peculiarly difficult.

General Concepts. Solutions to the characteristic job problems outlined above are developed in some detail in Section V. However, a basis concept must be assumed as a working hypothesis. Following are the essential elements of a basic philosophy:

(a) Maximum prefabrication, accounting, procurement, as well as engineering design, to be accomplished in the Zone of Interior, to minimize personnel at the site.

(b) Export of all persons and things from the United States, there being no indigenous labor or local materials capable of developments at the site, except concrete aggregates.

(c) Maximum monility of construction plants and equipment, to minimize duplication of fixed construction facilities on many islands.

(d) Maintenance and new interim construction to be performed in such a manner as to have a maximum of potential conversion to permanent proving ground facilities.

(e) The construction forces to be self-sustaining.

(f) Construction forces to procure and operate their own water transportation and communication inter-island within the lagoon, to the extent needed for construction.

(g) Establishment of horizontal and vertical control for scientific installations, by triangulation and other land surveys in a high order or accuracy.

(h) Subcontracts for specialized functions, are proposed, to be lump-sum contracts in so far as practicable but not restricted thereto.

(i) Planning of material storage, and mechanical installations at the site to place special emphasis on resistance to climatic deterioration.

(j) Planning of types of equipment, material stock levels, as well as table of organization, to obtain maximum reasonable versatility, recognizing that rescheduling, change orders and unexpected additions will be imposed throughout construction.

(k) Integration of all proving ground support services and facilities, to assure continuity and reliability despite alternate periods of peak activity and de-activation.

(l) Immediate measures to be taken in the field to reduce radiological hazards prior to active construction.

(m) Request use of military air and surface overseas transport to the extent available, but when no feasible or practicable, utilize any other means obtainable.

(n) To make most effective use of available real estate, conception of Eniwetok Island as containing the military garrison, and Parry Island the construction personnel, administration and quarters.

(o) Utilize local sand and crushed coral rock for concrete and paving.

(p) Conduct the construction in a series of consecutive phases, over the entire period from now to the next test, island by island where possible, and to be progressively planned and integrated so as to effect greatest efficiency of men and machines, and controlled economies of funds. These phases are discussed below:

CONSTRUCTION PROGRAM:

General. The construction of the proving ground involves operations of an unusual character. The individual items of construction are so diverse that it would be inefficient to attempt them concurrently. Therefore, two things are indicated: (a) a consecutive series of operations, accomplished with minimum specialized crews in the field, and (b) as long a span in calendar time as possible for the construction period. The length of construction time is consequently either fixed by the accumulation of time for these consecutive operations, or by the time required by certain features which involve long term procurement of materials, under which circumstances the construction span is not strictly a function of field operations.

Thus, it is imperative that the construction be started at once. Further examples for this reasoning are as follows: The proving ground installations will be required, because of limitations of available real estate at the Atoll, to occupy the same islands as previous bomb detonations. These islands are now radioactive but a study of the degree and characteristics of radioactivity at the site indicates that the condition can be alleviated to the point of radio-safety for personnel by a grading operation, as heretofore described. Obviously, this grading operation should be accomplished at an early date by a number of limited personnel, so that successive construction operations will not subject personnel to radiological hazards. Obviously, an extensive quarry operation must be started and carried forward in several phases. The reef must be drilled and shot, and a quantity of rock stockpiled; then a crusher and screening plant must be set up, and graded stock piles accomplished before it is practicable to send any concrete construction workers into the field. Waterfront structures should be built before the volume of surface water transportation builds up to the point where these waterfront structures are vitally needed. The camp construction uses building trades which are not applicable in large degree in any other operation. There are other very specialized operations that should be done in sequence and will require different type of personnel. One example of this is cable laying, others are communications, erection of towers, mechanical installations, trenching, and pipe laying.

Yet, in spite of the diversity of these operations in terms of the specialized manpower requirements, they will all make similar demands upon transportation of men and things within the Atoll; they will make similar demands upon housekeeping facilities; similar demands upon heavy equipment such as cranes, tractors, trucks, etc. It is therefore obvious that to attempt these operations simultaneously in any degree would involve a great deal more heavy equipment, and a great deal of duplication of facilities; whereas, to start the construction at an early date and continue it consecutively over a considerable period of time, would enable the capital investmen in equipment at the site to remain at a minimum, and the population in the field at any one time to be as small as possible. Further cost savings can be effected by this philosophy in prefabrication in the Zone of the Interior, where the overall cost of skilled labor will be less, and the availability of materials and fabricating machines will make the overall cost less.

Construction Schedules. The following pages show tentative construction schedules, indicating in a general way, the sequence and coordination of the various parts. This plan is predicated on the program outlined in this Report which may be subject to variation. If there are major changes in the work to be accomplished, the same general sequence of work will probably hold over generally the same periods of time, the variation being met by change in the number of employees. On this particular operation, the importance of detailed and accurate scheduling of the various features cannot be overemphasized. With the distance involved, producing excessive delays in delivery of supplies and personnel, complicated by shortages of material in certain lines, scheduling must be extremely accurate, not only so far as operations in the field are concerned, but it must be carried back through shipping, purchasing and completion of design drawings to minimize extensive delays in the field.

There are no particular disadvantages to extensive study and the preparation of logical and complete operation schedules, except for the cost of preparation and the possible adverse effect on outside agencies, when such schedules must be more or less regularly revised to meet changing conditions, delivery dates, etc. The basic advantage is smooth operation and effective use of personnel at the site. Under any conditions, delays and work stoppages may develop due to an improper meshing of related functions. These difficulties tend to be exaggerated with construction in remote areas.

Sequence of Operations. In general, it would appear logical to use construction crews in sequence; first on Parry, then on Eniwetok, following through with the smaller facilities on the outlying islands.

The principle disadvantage of a sequence of operation by islands, as outlined, is that more than normal demands will be made upon water transportation during certain periods. Offsetting this is the fact that cost of supervision will be decreased considerably, and the effectiveness of supervision will be increased.

Phase 1, February 1949 to July 1949 is defined as the period of mobilization and site preparation necessary to initiate field construction. It derives field data for engineering design, and makes physical preparations at the site for the construction operations to follow. It mobilizes manpower and material and opens logistic channels. It places an advance party in the field to accomplish the following important efforts prior to general construction:

(a) Sufficient grading and earth moving on islands previously used for atomic bomb detonation, so that the residual radioactive contamination is reduced to a safe tolerance for the personnel who will follows. To thus reduce the human rish to the smallest possible numbers of persons is a self-evident advantage.

(b) Maintenance and rehabilitation of utilities and quarters at Eniwetok so that the initial small construction crews need not be self-contained but may be sustained by the military garrison during initial camp construction. This effects economy and efficiency in permitting initial construction forces to be less numerous and almost completely productive of works in place.

(c) Maintenance and repair of equipment and facilities essential to the next experimental operation. The sooner that progressive deterioration due to the unusual Atoll environment is arrested, the greater the economies effected.

(d) Land surveys essential to the engineering design, being concurrently accomplished in the Zone of Interior.

Phase I is a span of time rather than a scope of work. However, the following activities are proposed, to be accomplished in the maximum degree permitted by available equipment, inter-island transportation, and weather.

1. Establish resident engineer at site.
2. Grading of Engebi, Aomon and Runit, for radio-safety.
3. Clear and grub Bogallua, if selected as the fourth site.
4. Maintain air strips (weed removal, reshape and blade, roll and water surface).
5. Remove condemned buildings from Eniwetok and Parry.
6. Sustain the garrison's facilities to care for fifty guests.
7. Insect control on Eniwetok, Parry, Aniyaanii, Runit, Rojoa, Biijiri, Aomon, Engebi, Bogallua.

8. Protective coatings for present towers.

9. Land survey (triangulation, mapping, design data).

10. Cable testing.

11. Repair and maintenance of heavy equipment and boats.

12. Initial procurement.

13. Causeway protection, if required.

These items, if not completed on June 30, 1949, will be added to Phase II.

Phase II - July 1949 to December 1949. This phase initiates interim construction and brings personnel and stock levels to peak strength. The potential of the present garrison to supply subsistence, quarters, transportation and construction machinery will probably be saturated by the imposition of the Phase I load upon their self-support and security patrol obligations. It is believed desirable that Phase II be characterized by a self-sustaining construction force. Initial arrivals will, therefore, be of the building trades who would erect a construction camp. For reasons discussed in Section III and under "Construction Camp" in this section, this would be on Parry Island. As facilities are expanded, personnel of various classifications will expand progressively to full peak. Phase II is defined as the total scope of interim construction, characterized by maintenance and repair of existing facilities and installation of new facilities and supplies necessary to sustain and utilize large numbers of people in the field. Such construction is distinguished from that pertaining directly to the experimental function of the proving ground. The scope of work outlined below will, therefore, by definition be Phase II regardless of the estimated time of commencing Phase III:

1. Maintenance of Eniwetok garrison utilities and transportation.

2. Build construction camp on Parry Island with self-contained utilities.

3. Rebuild piers on Eniwetok, Parry, Runit, Aomon, Engebi, and re-open approach channels.

4. Build pier and shoot channel, Bogallua, if fourth site is to be used.

5. Open quarries.

6. Cable landing protection.

7. Temporary inter-island communication (existing cable, except add line to Bogallua).

8. Start procurement.

9. Transportation of material and construction workers.

Phase III - December 1949 to December 1950. Phase III will include some items which are recurring in other phases, such as procurement, but, in general, will be that period of peak activity during which installations which characterize the Atoll as a proving ground are designed and constructed. The completion date is estimated to be the end of 1950; however, it is recommended that functions outlined below not be completely demobilized until the date of the first experiment, to assure that late changes and emergency installation requirements are met adequately. The end of Phase III will, therefore, be the completion of all permanent and semi-permanent facilities required.

1. Complete temporary type 150-man camp, on Bogallua, Engebi, Rojoa, and Runit. (Utilities and temporary power, concrete slabs).

2. Causeway, Biijiri to Rojoa.

3. Set up crusher, batch plant, paving mix machine.

4. Cable laying.

5. Tower erection.

6. Rehabilitate warehouse space, Parry.

7. Permanent utilities.

8. Permanent Reefer plant.

9. Airstrip sub-base and paving.

10. Shipping total bill of materials.

11. Concrete construction and permanent buildings.

12. Purchase of boats and vehicles for operating phase.

13. Communication facilities.

14. Paving of roads and areas.

Phase IV - July 1949 to March 1951. This period is defined as the operating phase. It is concurrent with construction and with scientific experiments and weapons testing. The scope is discussed in detail under Section VI.

Phase V - April 1951 to January 1952. This period will be defined as the roll-up. It will begin with the conclusion of a testing program, secure the area, and extend through the period of quiescence, as necessary. It will be discussed in detail under Section VII.

Tentative construction progress schedules for Phases I, II and III are shown on Plates 69 and 70, and manpower requirements are shown on Plate 71.

OPERATIONS SUPPORTING CONSTRUCTION:

Decontamination of Ordnance. At some period prior to Phase II of construction, at which time it will be necessary to open quarries, particularly on the north end of Engebi Island, it is recommended that a decontamination survey be made for the purpose of locating and removing anti-personnel mines which are understood to have been planted there during Japanese occupation of Engebi Island. It is believed that a number of such mines have been already

CONSTRUCTION PROGRESS SCHEDULE

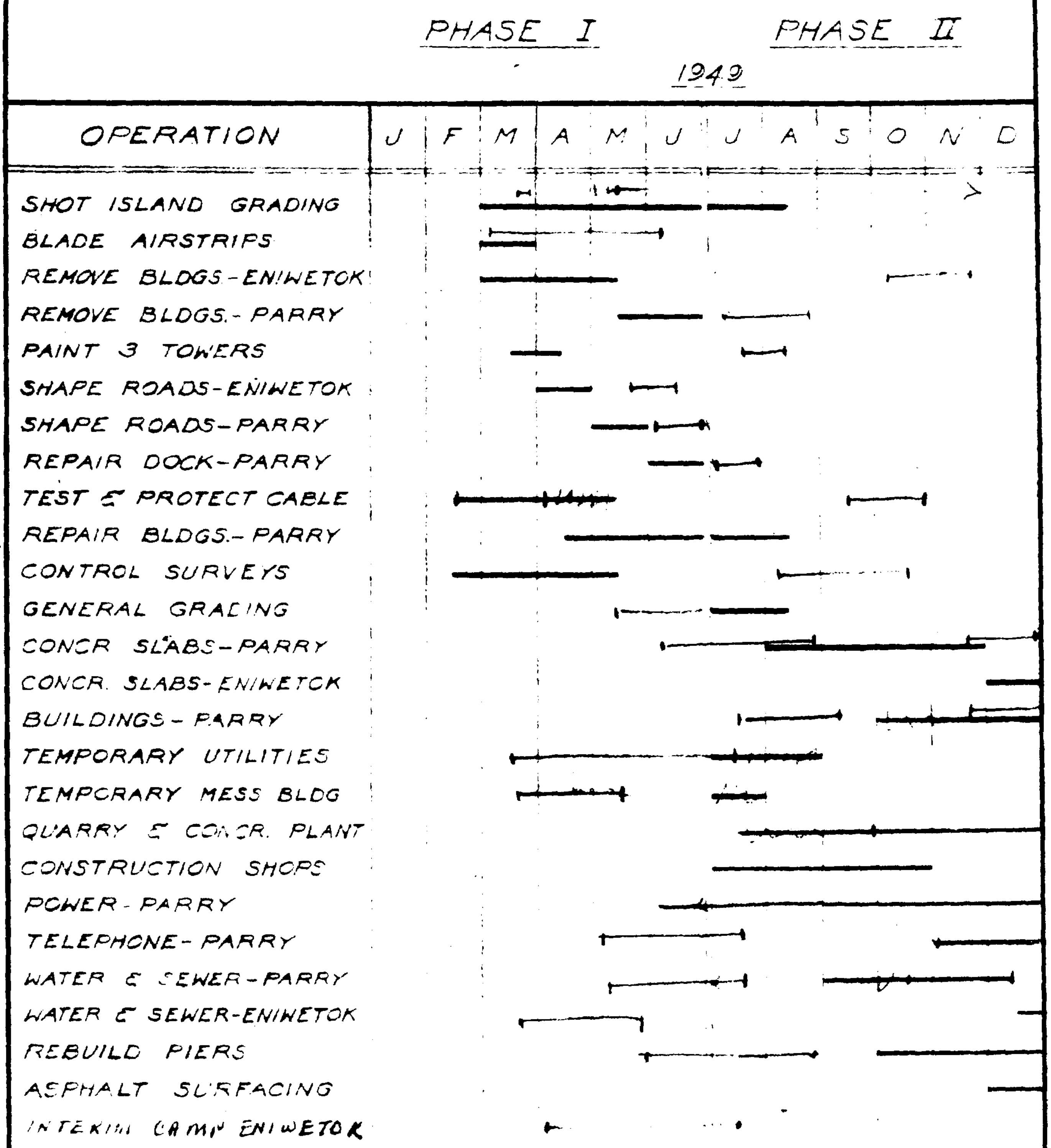


PLATE 69

CONSTRUCTION PROGRESS REPORT

PHASE III

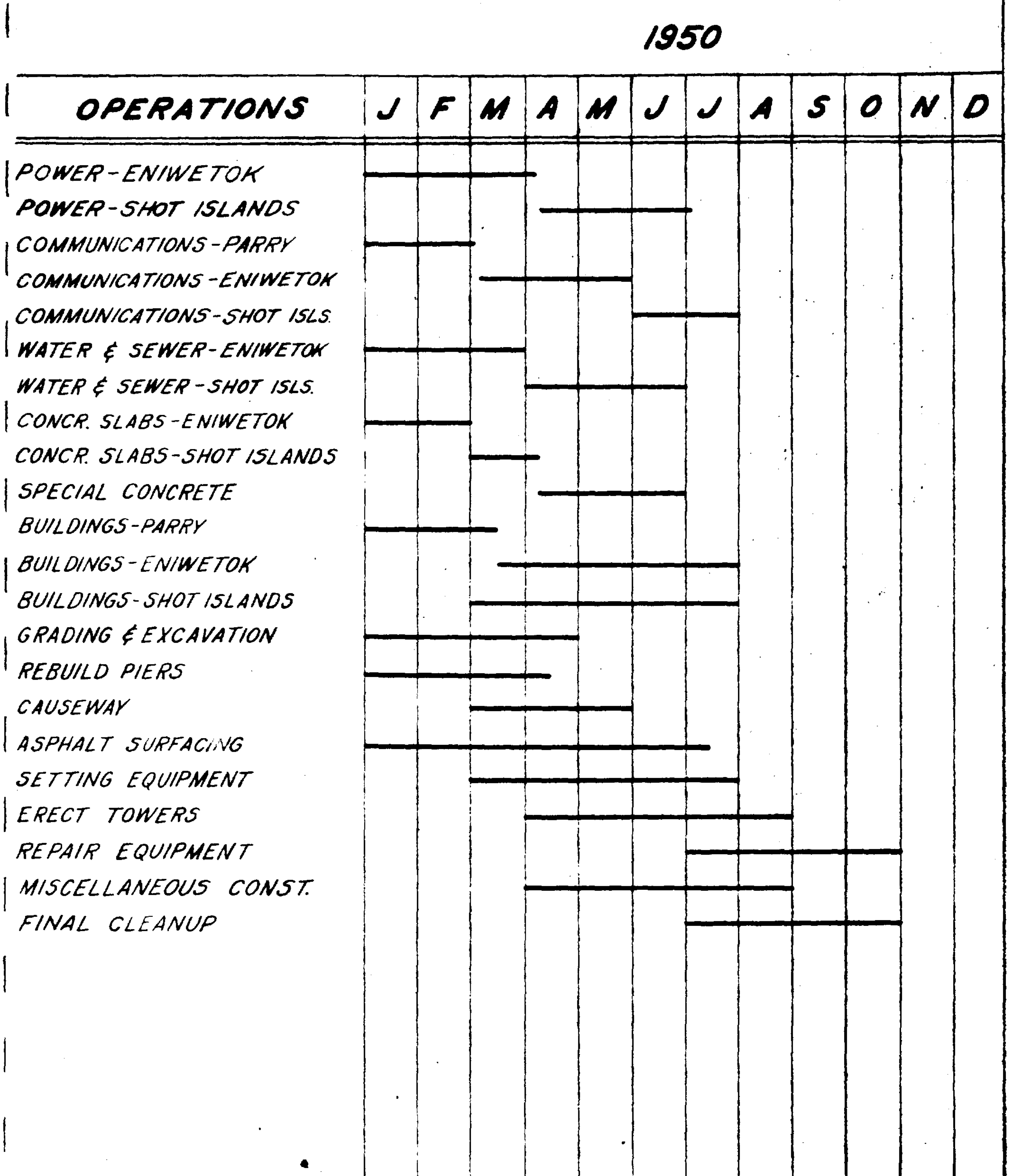
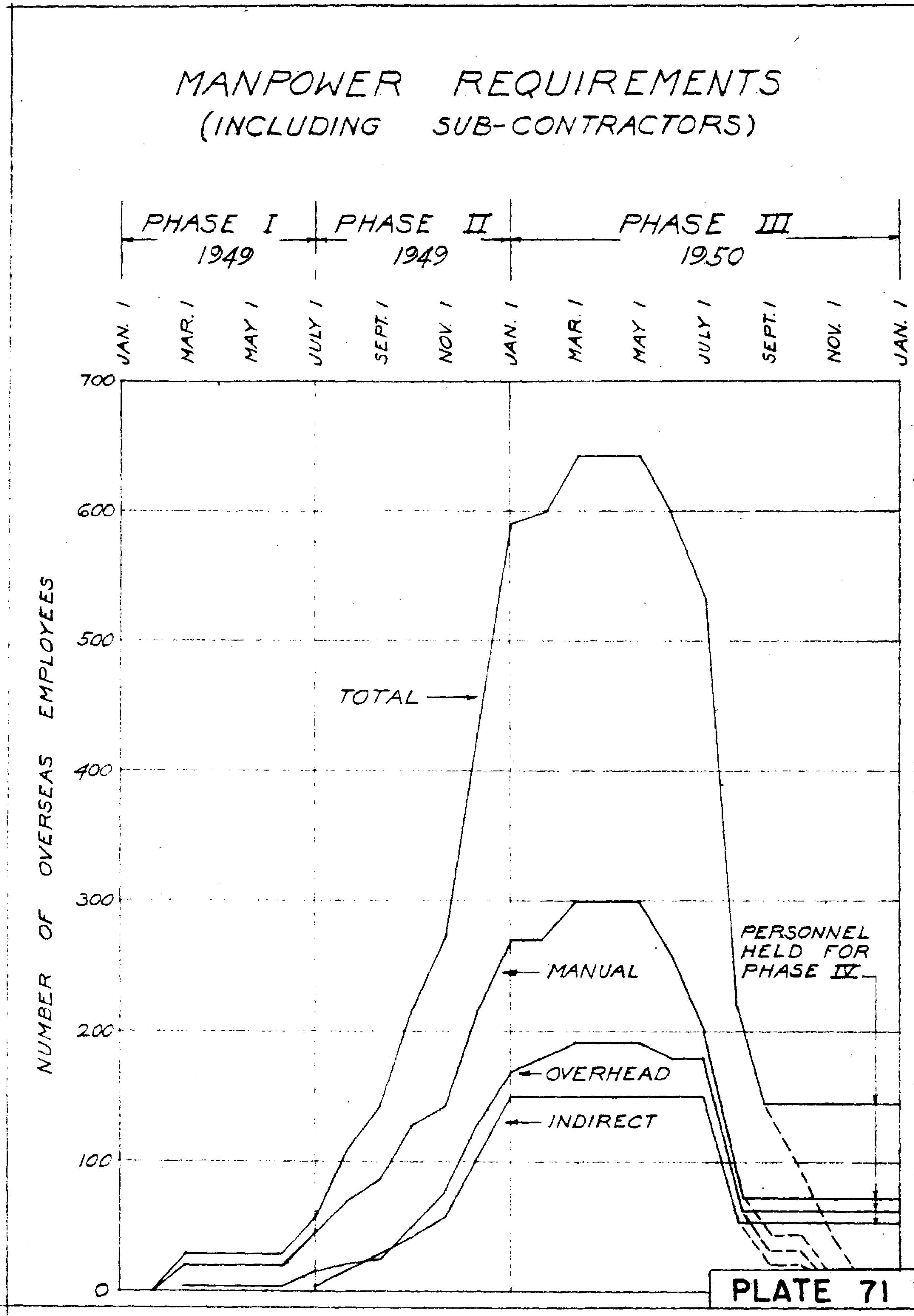


PLATE-70



MANPOWER REQUIREMENTS
(INCLUDING SUB-CONTRACTORS)
PHASE I 1949
PHASE II 1949
PHASE III 1950
JAN. 1
MAR. 1
MAY 1
JULY 1
SEPT. 1
NOV. 1
JAN. 1
MAR. 1
MAY 1
JULY 1
SEPT. 1
NOV. 1
JAN. 1
700
600
500
400
300
200
100
0
NUMBER OF OVERSEAS EMPLOYEES
TOTAL
MANUAL
OVERHEAD
INDIRECT
PERSONNEL HELD FOR PHASE IV

PLATE 71

removed but it is possible that not all hazards to personnel have been eliminated, and a sweep of this area should be accomplished inasmuch as intense activity will follow here, both with heavy equipment and personnel.

Grading to Reduce Radioactivity. The grading to be accomplished during Phase I should be one of the earliest and most intensive operations, to the extent required to reduce the radio activity at sites of former bomb detonation and to the degree that construction personnel may work in the areas without absorbing more than a tolerance dose in one day of work. This involves removal of scrap metal and stubs of former tower legs by submergence in deep sea water. This would be followed by scraping the top surface of soil in the radius around former tower location where intensity is greatest, and depositing this material at the edge of the shot island. Following this, the crater areas would be graded by the process of filling with uncontaminated material borrowed from the more remote ends of shot islands. The degree of grading would be sufficient to bring the craters to near their original contour and adding such additional cover as is necessary to provide radioactive screening. Earth movements would be made only under conditions of wet soil - this may involve sprinkling or spraying with salt water pumped out of the lagoon during these grading operations.

Planting. During Phase I, considering that a period of two years will intervene before tests are conducted, it is recommended that a program of planting, consistent with reasonable economy, should be conducted, designed to provide additional shade housing areas, and to provide ground stabilization on shot islands.

Testing of Electrical Cables. Under "Control and Signal Cables" in Section IV of this Report, the testing of existing cables is discussed. In those cases where it is determined that existing cables now in place may be incorporated into the future work, means will be taken to protect them at the island landings against future deterioration. During Phase I, a trench will be dug from the termination of the good section of cable to some distance below low water line so that cables can be consolidated and moved into one trench, backfilled, located by survey and protected with adequate warning signs. Other usable cable now on the Atoll either in reels or installed underground but not in use will be recovered, moved into storage and suitably protected for future use.

Purchasing Criteria. Since labor will be hired in and transported from the States, the cost of transportation and sustenance in the field must logically be added to wage cost for labor. It follows that the productive accomplishment of labor at the project site will always result in higher unit costs than the same effort by the same labor in the continental United States. For this reason, we recommend that every possible consideration be given to materials and supplies as completely fabricated before shipment as practicable, so that the cost of installation may be held to a minimum. It is realized that this will require a much closer control over delivery dates and shipment so that complete units or advance parts may be sent at the proper time. If the facilities are to be locally constructed out of a lumber pile, there should be fewer delays waiting for missing pieces of equipment. On the other hand, a marked cost economy will be gained by prefabrication and the main objection can be overcome by careful planning and checking of supplies delivered.

This procedure is recommended, and to make it function properly, it will be necessary to set up a warehouse, and competent material checkers and expediters at the port of embarkation to insure proper packaging and completeness of units.

As a corollary of this, consideration must be given to selection of parts and materials as light in weight as possible. Ordinarily, lightweight materials are more expensive in first cost, but this first cost is offset by reduction of overseas transportation charges, and by reduction of labor cost in unloading and handling at the site. The extent to which this policy is followed must be a matter of special consideration of each individual type or piece of equipment. Also, in general, equipment shipped assembled, should be unitized and be kept as light as consistent with economy, taking into consideration difficulties of handling and cost of assembly at the site.

Packaging should be designed for low breakage, even at some cost premium. Cement, for example, should be boxed as well as bagged.

Any items required protective coating should be given base treatment in the Zone of Interior.

To effect economies, where practical and feasible, it is recommended that equipment, supplies and material be obtained from the National Military Establishment. It is recommended that procurement be the responsbility of the A-E, and that he be authorized to procure through other sources when in his opinion procurement from the Military Establishment is not feasible or practical.

Warehouse and Stock Control. After preparation of design drawings in the Zone of Interior, the design organization should make a take-off of materials and prepare requisitions. There should be in addition a requisition section under the Engineering Department at the site. This section to prepare requisitions for those materials which will not be incorporated into the work, but which will be necessary for the construction, such as form lumber, material for plant, camp supplies, and similar items. These requisitions would then be turned over to the warehouse department so that they may prepare cards for each item of material. When material is then received, it will be inventoried and recorded on these cards. When withdrawn from the warehouse, a request will be submitted by the section which is to use the materials and this will also be recorded on the card so that at any time there is a complete and running record of material available for future use. The material which is to be installed or used on the work, the material received, and the material withdrawn will thus tally reasonably close, the variation being loss, breakage, etc. This system may be keyed into cost control, also, for current data on the relationship between budget funds, and expenditures obligated.

It is anticipated that all material will be stored on Parry Island adjacent to the construction camp; and in an area fenced off from all other activities. Under a warehouse superintendent, this will be received from the stevedore gangas, sorted and stored either under cover or in outdoor hardstands as required. The warehouse superintendent, under the control of the Service Manager, will be responsible for receiving, issuing and accounting for all materials, supplies and equipment which are received on the work.

Cost Accounting. Direct labor and material costs should be segregated and applied to major items of project breakdown. To this should be added subsidiary controls and records, so that commitments for expenditure may be compared with budget estimates on a current basis, and basic unit costs will be derived for forecasting accomplishment of work in place and closely estimating cost aspects of reduced or increased work scope.

Safety Program. An active safety program is advisable not only to reduce payments for time lost due to accidents and for disability but also to reduce the disruption to the work schedule always incidental to accidents. The contractor should constantly publicize safety.

Also of importance is protection against contamination in the early phases of construction and of the roll-up period. The hazard is proposed to be eliminated by grading operations in shot tower areas, as previously described. While the hazard exists, however, it is proposed to so organize the work schedule, and the disposition of men, so that careful compliance is achieved with radsafe directives of the Laboratory, and such monitors as it may assign to the work.

Local Transportation. In general, transportation will be by water with a lesser amount on land. With few exceptions, all transportation will be pooled for general use so that such items can be used with maximum efficiency and filled to maximum load. Certain scheduled boat runs to service outlying work must be established when such work is in progress. Whenever a group of men is working in an area where no transportation is available, provision must be made so that emergency boats can be available on short notice. Under this system, all transportation will be held under control of a superintendent of transportation and will be kept in the boat or motor pool when not in use. It is also advisable to assign operators to specific pieces of equipment and vehicles, and, in so far as possible, to permit such pieces of equipment to be operated at all times by the same personnel, so that they can be held responsible for routine maintenance. The normal exception to such a rule is that certain motor vehicles are assigned to individuals.

Unloading Ships. The problem of stevedoring at the Atoll will be one which presents itself only on occasions, and the amount of work at each occasion will vary considerably. It is not anticipated that any personnel should be employed specifically for this purpose. Dependent upon the cargos involved, it will be necessary to divert certain crews from other duties when a ship arrives and assign them to the work of unloading.

It is not economical to construct piers at the Atoll for the purpose of unloading freighters. Such piers would be of considerable length and size and their cost would be excessive for the purpose accomplished. It is anticipated that incoming ships will anchor off-shore in the lagoon and be unloaded by lighter. To the extent that trucks or flat bed trailers and LCMs are available, these should be used so that the ship cargo handling equipment can spot the cargo directly on a vehicle in the hold of an LCM. Depending upon specific conditions encountered with any cargo, other expedients for efficient unloading may be improvised from time to time.

Communications. Most of the construction will be handled on the islands of Parry and Eniwetok, so it will be advisable to run regular boat service. Supplementing this, some field telephone service must be established between field activities and base islands. Present control cables could be used for this purpose. This will require a PBX and a telephone operator in the construction camp supplemented with branch telephone lines. To some extent at all times and certainly when construction activities begin in a major way on the shot islands, these islands must be served by some reliable communication for efficient operation and in case of emergencies. While work is in progress, and LCM in addition to freight carriers should be in regular operation calling on schedule at each of the outlying islands.. This LCM can carry daily supplies of food, mail, motion picture film, construction material, and personnel and can also furnish periodically, such services as store facilities, barber shop, etc. It also will be advisable to furnish regular service by L-5 plane daily for visits of supervisory personnel and for priority and classified communications. It is anticipated that such service will take care of all routine communications necessary with the outside islands. It is also recommended that two-way radio be installed for use in cases of emergency. It is realized that such a system will be subject to message interception by outside agencies; however, since it is to be used for emergency only it is not considered that any messages of a classified nature need be transmitted over such a system.

SURVEYS:

General. The proposed permanent horizontal and vertical control and scope of field work to be performed in connection with the design of the facilities and the first phase of construction have been described in Section IV.

Construction Surveys. The field work necessary for construction will include the following operations and will, in general, consist of giving alignment and grade sufficient for efficient construction operations.

(a) Grading of areas, establish limits of areas and provide grade stakes as required.

(b) Roads and pavement. Stakes will be set for alignment and sufficient grades established to control grading and surfacing.

(c) Layout of buildings, docks, towers and causeway. In general, layout will consist of offset stakes at corners and elevations where required.

(d) Utilities. Alignment stakes will be set on offset lines and grades established as required.

(e) Submarine cable laying. Will be controlled by tying in the cable as laid by intersection of simultaneous observed angles from traverse stations ashore.

(f) Gamma building tilt. Alignment and grade as required will be given for orientation of these buildings.

(g) Alignment of special buildings, towers, etc. during construction may be required to obtain accurate and efficient completion to specifications.

(h) Checking of concrete forms in place before the pour will be made where requested by the Inspectors to assure satisfactory construction.

The Survey Forces will be available at all times to assist in efficient construction operations.

Secondary and Construction Controls. Secondary control will be established where required by breakdown from the primary triangulation net. In general, this will consist of recovering the instrumentation lines used in the previous experiments on Engebi, Aomon and Runit Islands, and establishing new instrumentation lines on Bogallua Island. These lines will be tied to the primary control scheme and their positions accurately calculated. Additional traverses will be added where required by design.

Construction controls will consist of traverses and bench marks in the proposed construction areas. They will be located where advantageous to layout of construction, and will be mainly local controls that can be tied to the overall system if desirable.

With the primary control network established as proposed, secondary control can be added at any point within the Eastern portion of the Atoll to meet changes in project requirements.

Survey Records. Permanent records will be kept of all control surveys and layout of construction. From these records, "As-Built" drawings may be made at completion of the construction program.

Referencing of Controls. It is recommended that vertical and horizontal control on shot islands installations will be carried to reference points of sufficient stability that future re-observation of shot islands will indicate gross blast effects.

Personnel Required. The anticipated maximum of survey personnel would be three full parties at peak of construction. If construction controls are established before start of construction, one party should be able to handle all surveys through Phase II; and this party plus two additional parties, all anticipated surveys in Phase III. This would mean one party throughout the period of construction where any layout is required, plus two parties for approximately six months at the peak.

The schedule assumes that a program of expanded construction is adopted extending thoughout the next two years in an orderly series of operations, island by island. Low manpower estimates are in line with the most economical concept of the project. Any telescoping of the time schedule will revise manpower requirements.

CONSTRUCTION PLANT AND MATERIAL:

General Policy. At this stage, it must be recognized that any comments on construction plant and material must be considered only in a general way until detailed design has progressed to such an extent that a more definite determination of the requirements can be ascertained. However, certain general policies can be stated as follows:

Mobility. As previously mentioned, the work is separated into small units at several different locations and the principal means of transportation is by water. Consequently, it follows that construction equipment and to a certain extent plant, should be designed for mobility, and should be carefully selected for transportation in the craft available for use. This would be a factor working against the selection of large and heavy equipment even if its operation in any one place would be more efficient.

Salvage. Several types of equipment such as grading equipment, cable laying barge, asphalt plant (if purchased), and other construction equipment will not be used long enough to be completely depreciated due to wear alone. Consequently, salvage value must be given consideration in all purchases.

Floating Equipment. Since water is the principal means of transportation and since most of the facilities are reasonably close to the shoreline, consideration should be given to setting up plant on barges or other craft to a greater extent than would normally be considered feasible.

Aggregate. Aggregate for concrete can either be imported, ready crushed, or can be produced from coral at the site. The principal disadvantages of using local coral are as follows:

Coral aggregate produces a concrete which does not have the resistance to wear and weathering that concrete made with hard rock aggregate does. In view of the limited life of this project, this is not an important consideration.

Coral aggregate has a tendency to crush to the size at which the rollers are set, and to dust. The result of this is that additional rollers must be provided, set at four or five different sizes, rather than the two which can be effective for crushing hard rock. Experience with coral is that the gradation of aggregate is not too satisfactory, although it is workable. In addition, there will be a large percentage of fines. It is realized that a certain amount of these will be blown away by the wind, but there will still remain too large a percentage of inert finer material, which will require a richer cement mixture than normally is considered economical. With a volume of concrete to be placed, this richer mixture will probably be more economical than installation of washing equipment to remove the fines. These fines may also be used to improve paving mixes.

With a limited amount of aggregate required on this project, the cost of purchase and erection of crushing equipment will be proportionately high. However, this will be reduced considerably because this plant can also be used for production of aggregate for asphalt surfacing.

The advantage of coral aggregate then is only economy. It is recommended that coral aggregate be produced locally for use in concrete, to the extent design strength requirements are met.

Quarry and Concrete Plant. Aggregate which is readily available at the southern end of the Atoll is of a poor quality compared to that available on Engebi. On the other hand, requirements for concrete on Eniwetok and Parry permit a grade of concrete lower than the requirements for the shot islands. On Eniwetok and Parry, substantially all of the concrete will be for use in slabs under buildings; and consequently, it is recommended that a quarry on Parry be opened up early for the production of concrete for this purpose. Aggregate requirements will be in the general order of ten to twenty-five tons per hour and portable crushing equipment of this capacity is readily available. Consequently, it is proposed first to install ashore on Parry a portable rock-crushing plant with a maximum capacity of about twenty-five tons per hour which will produce the quantity of aggregate for concrete work on Parry and Eniwetok. Aggregate will be stockpiled, separated by coarse and fine directly from the plant. On the far side of the stock pile conveyors will be installed in each pile of aggregate so that the material may be raised to elevated bins, having a capacity of approximately one day's concreting operation. From these bins, material will be batched into a battery of two one-cubic-yard mixers. Normally, one mixer will be sufficient to carry on concreting operation. The second mixer will be installed to take care of peak loads and to serve as a standby in case of breakdown. Material will be hauled from this plant to the various slabs on Parry Island, using two two-cubic-yard trucks. It will be necessary that the trucks be provided with an agitator to prevent segregation during delivery. Transit-mix trucks have been considered but are not yet firmly recommended because their cost relative to capacity is usually high for short hauls, and the amount of concrete work now involved is not believed sufficient to justify equipment of this type, particularly since it must be moved over soft areas of ground in many cases to get to the site where concrete is to be placed.

It would be more economical to leave the quarry, the crushing plant and the concrete mixing plant on Parry even during placing operations on Eniwetok. The distance involved is only three miles so that the agitating trucks may be loaded up at the plant on Parry, transferred to an LCM or other craft and moved directly to Eniwetok, with probably a delay of no greater than one hour between mixing and placing. For operations on the shot islands, which are later on the time schedule, we recommend that the Parry quarry be abandoned and the crushing plant dismantled and moved to the quarry site on Engebi, which contains a higher quality of coral. In this case, large quantities will be placed on several different islands, so consequently, it is proposed to equip one LSM with elevated aggregate hoppers in one end, feeding by gravity into a one-yard mixer. This equipment will be placed as far aft as possible so that the ship may beach at the shore of the various islands and charge the agitating concrete trucks directly aboard the ship. In this case, it is anticipated that the LSM will return to the quarry at periodic intervals depending upon the distances involved, to reload with additional quantities of aggregate and cement.

As outlined above, using a land base plant in the early stage of the operation and using the floating plant in the later stage would be the most economical method by which aggregate may be produced and concrete mixed and transported to the site of the work. It also gives the additional advantage that a softer rock may be handled in the early stage of the operation where the requirements of concrete are not as rigorous as they are in the later period.

Concrete Control. Experience has indicated that coral as an aggregate is subject to extensive variations and rapid changes. For instance, percentage of dust in the coarse aggregate stock pile may vary from five to twenty percent. This dust is produced by the rubbing together of particles of aggregate and consequently will vary, depending upon the length of time that material has been in the stock pile and the amount of work that has been done in leveling it out to prevent segregation. The dust naturally will cause a marked variation in strength of the concrete. In addition, coral in the natural quarry varies in hardness from place to place and consequently the final material may have sharp variations in gradation and particularly in the amount of fines. It has been noted that these variations will be sufficient, sometimes almost hourly, to cause a considerable change in the ultimate strength of the concrete. Concrete cylinders broken in twenty-eight days at Okinawa indicate a variation in strength from sixteen hundred pounds to forty-five hundred pounds per square inch. This variation in strength was due to a combination of many circumstances, but most of the conditions were the result of the normal variations in coral aggregate, including varying moisture content.

Consequently, we recommend that some form of laboratory concrete control be established in the field for this operation. Laboratory at the batch plant should be equipped to make sieve analysis and analysis of moisture content, which vary sharply from time to time. Supplementing this, some sort of strength test should be made. With the limited amount of structural concrete involved, we do not believe that it would be economical to purchase and deliver to the site a standard cylinder breaking machine. However, a beam machine is comparatively light and inexpensive, and should be installed at the site of the work. Supplementing breaking of beams (which will give a fair indication of strength of concrete), it is proposed to cast standard cylinders and forward these to a testing agency as discussed under Subcontracts. Adjustment can be thus readily made in the field to the design mix, to assure uniform results.

Testing Agency. Certain testing will be required of samples sent in from the field, particularly aggregate, sand, concrete cylinders, etc. The closest physical laboratory available to Eniwetok is the Corps of Engineers establishment at Honolulu. Also, there is a C of E laboratory in the Los Angeles district. In so far as these government facilities are available, and they are equipped to handle specific types of testing, it would be advisable to use them to the greatest extent possible. However, it is realized that there will be times when they are rushed and so unable to make the tests, or there may be items which they are not equipped to handle. Consequently, it is suggested that contractual authority to have a private testing agency or agencies supplement services available from the C of E.

Asphalt Plant. In order to provide the maximum amount of flexibility in the use of paving equipment, it is proposed that a continuous mix type of plant be used, and that the mixer be adaptable to use as either a traveling mixer for producing road-mix, or in a central plant in which a single aggregate is dried, heated and mixed. The central plant should be readily portable, since it will be required that it be set up on at least five different islands.

A plant having a capacity of from 60 to 100 tons per hour would require a drier, which would be its heaviest unit, weighing approximately 21 tons. It is estimated that a plant of this size would require approximately 20 weeks to produce the required amount of hot-mix, including moving time, and approximately 5 weeks to produce the required amount of road-mix.

In addition to the asphalt plant, the usual equipment, including motor graders, bulldozers, asphalt distributor, and rollers, will be required. A self-propelled asphalt finishing machine is recommended for placing hot-mix.

Trenches for Utilities. It is anticipated that most trenching for water, sewer and electrical utilities will be done in earth with only a small percentage through rock. In many cases, trenches for electric cable will be shallow and can easily be made by a standard blade grader. In other cases, for the deep trenches, it appears that these can satisfactorily be dug by light excavating equipment such as Barber-Green trenching machines. In those places where it is unusually soft and tends to sluff in, it is believed that it is more economical to use a backhoe or clam, rather than attempt to sheet the trenches and dig by hand.

The trenches should be relocated in the field in so far as possible to avoid rock excavation, but where it is unavoidable, the rock should be excavated by means suitable to its hardness to depths below the elevation at which the utilities will be installed. This additional depth to be backfilled with sand to give even bearing for the pipe or cable. All trenches to be backfilled by hand until the lines have been covered, after which trenches may be filled with a caterpillar tractor or by other similar means.

Base Shops. Certain base shops must be maintained for the prosecution of the work. In general, the following will probably be needed, although this is not necessarily complete: heavy equipment repair shops, motor vehicle repair, boat repair, machine, electrical, plumbing and sheet metal, and paint shops. Work in these shops will be limited in extent, so economy of personnel and equipment dictates that they all be located in one area adjacent to the construction camp. This will permit greater specialization, and all work done can be transported to the site as complete units. It will be the duty of these repair shops to maintain and repair all parts and equipment and to continue fabrication to the greatest feasible extent before incorporation into the work.

ORGANIZATION, PERSONNEL AND EMPLOYMENT:

General. The undertaking of the Project outlined in this Report requires a well-qualified staff, organized along clearly defined functional lines of coordinated responsibility and delegated authority, under the direct supervision of the Resident Engineer.

Organization. The Field Engineering Division should prepare the plans for a Construction Plant; provide schedules of materials required, and compile all reports associated with the progress of the construction work. This Division should be relied upon for guiding the construction efforts, interpreting plans, and to insure that the quality of the end results is in accordance with the established standards.

The Construction Division to undertake the actual building work by the direction and supervision of workers, and subcontract work, in accordance with the plans, specifications, etc., promulgated through the office of the Resident Engineer.

The Service Division to organize and direct all camp operations or facilities normally required on a Project of this type.

The Office and Fiscal Division to carry out its functions as a separate unit of service to the field organization, but, concurrently be responsible to the Home Office of the Contractor for the administration of basic policies of fiscal procedures and control.

The Resident Engineer should coordinate, supervise, and be responsible for the work of the foregoing Divisions; to act as chairman of regularly-held Staff Meetings, and to administer certain duties such as liaison with other agencies, confidential reports to the Home Office, etc.

Wages. In overseas employment, it is extremely important, from the economic-efficiency angle, to hire workers who are well qualified to give maximum production. Hence, it is sound policy to offer equitable and competitive wages and salaries in order to secure the most efficient producers.

To accomplish this purpose, particularly when employment is at a full-time peak in the mainland, good salaries and appropriate incentives should be offered to induce workers to leave the security of homeland conditions for overseas work.

In a recent study made of basic wage and employment conditions in the Western Ocean Division of the Army, and on private foreign contracts, it has been clearly demonstrated that good wages and salaries and incentives are necessary for good work, maximum hours of production, and, at the same time, cope with the mainland prevailing full-time employment peak and high wage standards.

Because of the foregoing conditions, recruitment of qualified workers may be required from all parts of the continental United States and its territories.

Work Week. In overseas work, as distinct from homeland occupations, it is recognized that maximum economy dictates that the work week should be set at the maximum possible, without undue loss of efficiency. Therefore, it is recommended that a regular straight-time work week of 48 hours be established, with provision for overtime pay of time and one-half, and/or differential rates, for time worked over 48 hours per week, if and as required by the Management.

This recommendation is in comparative line with the Army-Navy basic 40-hour wage and salary scales, prevailing in the Pacific area, and with the 40-hour wage rates prevailing on the West Coast, except for the added bonus incentive recommended to meet competitive conditions, and for the satisfactory completion of the employment agreements.

Employment Agreement. Formal type of employment agreement is considered necessary for both manual and non-manual workers, for the following reasons:

(a) The term should be for 12 months, subject to termination by the employer at any time, if the employee's services are not necessary.

(b) To afford protection against hastily considered resignations, which become costly due to replacements, and also cause the employee to forfeit his privileges of return transportation and contract completion incentives.

(c) Based on a study of other contractors' overseas operations, the form of Employment-Agreement should be generally in accordance with the established terms and conditions, used for CPFF under the Western Ocean Division of the Army, and current contracts offered by private contractors.

Female Personnel. Employment of female personnel in certain non-manual classifications is advisable, despite rough living conditions, and the moral problem involved. This is ample precedent for this recommendation; such positions as telephone operator, stenographer, nurse, etc., can be filled by males, but the class available is definitely limited and inferior. In addition, many men available for manual or non-manual employment have wives, most of whom are qualified for certain non-manual office duties, provided they are afforded proper living quarters.

Other Categories. There are other categories of employment, such as janitors, messengers, kitchen help, laundry workers, etc., which should be recruited in the Pacific Islands area, rather than from the mainland, because of the high cost of employment, compared to the value of their work.

Screening. All prospective employees should be carefully reviewed and screened for ability and personal qualifications. It will also be necessary to have all personnel take physical examinations, inoculations and Security Clearances, as may be directed by the Commission.

Contracts. The foregoing principal conditions of organization, personnel, employment, etc., as recommended, and many other details of procedures and requirements should be carefully studied and incorporated in contracts to be executed with both the Contractor, its subcontractors, and their respective employee employment agreements.

SUBCONTRACTS:

General Principles. Various parts or sections of the work may be awarded to subcontractors for certain special reasons. The practice of awarding such subcontracts is not only common, but universal on any piece of construction work which is extensive in its nature. Under present circumstances, there are several conditions which would justify this procedure:

To employ special management skills and methods.

To effect hire of special skilled personnel for short time work when such personnel is not available for hire on the open market.

To avoid difficulties of operating with certain trade groups or unions.

To acquire the use of specialized equipment for a specific operation when purchase or rental of such equipment is not economically justified.

The principal disadvantage of awarding a subcontract is that each subcontractor must be paid a profit or fee. It is recommended that the contractor be authorized to negotiate subcontracts, when in his opinion there is adequate and demonstrable justification therefor. Lump-sum contracts are preferable but not always acceptable in offshore areas, where uncertainties are numerous.

A firm list of proposed subcontracts is not attempted because the best interests of the job can be served only by deciding after preliminary negotiation with subcontractors available at the time required. The lists following are examples of possibilities of such services.

Conditions. It would seem advisable that certain standard conditions applicable to all subcontractors be established and adhered to in so far as possible. Suggested conditions are as follows:

The prime contract wage scale and employment agreement shall be used unless otherwise approved.

To the maximum extent feasible, available personnel at the jobsite shall be employed by the subcontractor, and subcontractors personnel generally will be available for assignment to other phases of the work, provided their year of service has not been completed and provided that their services are not immediately required by the subcontractor for other work.

To the maximum extent possible, the subcontractor will use prime contractor's personnel at the site for general overhead services such as stenographic, payroll, warehousing, etc.

All subcontractor personnel will live and mess in the construction camp without special privileges.

Subcontract Units. Within the framework above outlined, certain phases of the work may or may not be subcontracted. It is not intended that the following list be complete, but it is included as a framework for discussion of the principles and policies governing award of subcontracts.

Overseas Air Transportation. The military air lift, being free issue to this project, should be used to the extent available and feasible. The possibility of commercial air lift is mentioned as an alternative or a supplement. Frequently, such air lift of personnel is more economical than surface transportation, when the time of transit by ship is converted to the double penalty of non-productive wages in route, and loss of working time at the site. The demand on air lift would, therefore, be considerable. Also, by the nature of the construction schedule, large passenger lists, suitable for surface passage, would require considerable standby pay during its accumulation.

Commercial air lines now pass through Wake. Also, at lease one contract carrier, unscheduled, is operating at various trans-Pacific points. Such connections are considered feasible.

Ocean Transportation. In the degree that military transport is free issue, and to the extent its facilities can adequately perform this function, such government resources should be used. It is possible, however, that construction and supporting supplies will be in part transported from the mainland to the Atoll by private-owned bottoms. Therefore, it appears logical to consider the awarding of a subcontract to some shipping agency which will handle stevedoring in the United States, and transportation by water to the Atoll. Obviously, direct purchase and operation of a freighter carrying only a small percent of capacity outbound and nothing inbound, cannot be considered economical. As an alternate, there are several freight lines operating regularly between here and the Orient, with many of the ships passing close to Eniwetok; and some of these lines carry refrigerated cargo as well as bulk cargo. Loads on the various lines and on the various ships of any line will vary widely from time to time. Such variations in load creates fluctuation in the incentive tonnage but it may be estimated as in the range of a thousand tons. Tariffs vary with types of cargo for shipping on a tonnage basis but for estimating purposes might be considered as $35 per 2000 pounds or 40 cubic feet for tractors, fabricated structual shapes, cable, and the like.

An alternate might be trans-shipment from a scheduled stop such as Guam, or possibly Kwajalein, and military LST to Eniwetok. In any case, lighterage and stevedoring would be necessary at the Atoll.

Overseas Transportation of Men and Things. Advantages of Military Transport are:

(a) Costs are understood to be free issue to this project.

(b) Security is controlled as to freight and personnel destination.

(c) Small shipments could be made without tonnage incentive.

(d) Logistic support of the Eniwetok garrison requires military transport in any case.

Advantages of commercial transport are:

(a) Control of sequence of items from warehouse to ship.

(b) Designation of one, convenient port of embarkation.

(c) Space commitments are firm and not subject to priority displacement or delay.

(d) Routes are uniform and time in transit predictable.

(e) Free access to pier-side transit sheds for control of convenient and orderly loading.

(f) Recourse is had for loss, damage or pilferage.

(g) Time distribution and integrity of delivery of refrigerated cargo is more favorable.

Recommendations. It is recommended that both military and commercial facilities, by sea and air, be made available to the contractor during the construction period, to be used variously or together, as conditions at the time direct. It is recommended that the contractor be given by direction expeditious military channels for transportation requests, and this project be given the highest practicable priority.

Testing and Inspection. Dependent upon materials used in the design of the facilities and upon the location of the plants where these materials are to be fabricated, it may be necessary to do a certain amount of factory inspection and testing in the United States. There are inspection and testing agencies which specialize in this type of work on a large scale and nationally. The advantage of awarding a subcontract for this work is that an hour or so inspection daily may be adequate for certain processes, and the agency may have an Inspector permanently at that factory for other assignments. In addition to this, certain physical laboratory test of material such as coral aggregate, concrete, water or other materials will be required, and periodic testing by a laboratory already staffed and equipped is advisable.

Construction Camp Operation. It is possible to award a subcontract which will cover a large number of the functions involved in the messing, shops, stores, laundry, etc. in the construction camp. This unit could include U.S. purchasing of food and housing supplies, operation of the camp at the job site, supervision and operation of dining halls, routine handling of matters in connection with housekeeping and recreation. An economic study of this matter should be made at the time of the requirement to properly evaluate a recommendation.

Submarine Cable and Electrical Work. Laying of submarine cable and particularly making splicing (which presently appears must be made in the field) is an operation requiring specially qualified personnel. Our investigation of these operations to date indicates that knowledge of submarine cable laying and splicing is limited to a few concerns. The splicing of this cable, which must be done from floating plant, is extremely important because it will be placed under water where failures or breakages are difficult and expensive to correct. Personnel for making cable splices have always been very difficult to employ, particularly on overseas work. It might be advantageous to subcontract the proper type of floating equipment and personnel to undertake this work.

The actual operation of laying cable will be limited to a fairly short period of time, and it might be advisable to use the same personnel on other work. The work most nearly associated with cable laying and work which also requires specialized personnel, is the installation of high voltage electrical work up to and including installation of step-down transformers. To a certain extent, the mechanics used on the submarine laying and splicing operations will also be qualified to do high voltage electrical work. Consequently, this could be added to the same subcontract.

Tower Erection. The construction program includes four 300' steel towers which weigh something over 50 tons each. Erection of these towers represents certain special problems. High steel workers are engaged in a trade distinct from other trades. They ordinarily operate only for specialized erection, so that it would be impossible to use them efficiently in other categories and it would be equally impossible to use other trades at the site for the efficient erection of towers. It would also be unreasonably hazardous for personnel not familiar with this work. For this reason, it is recommended that a separate subcontract be awarded to cover the erection of steel towers. This might be an extension of the contract for tower fabrication, especially since the fabricator will be required to test erect one tower in this country to demonstrate proper fabrication. In addition to erection of these towers, the work may include similar work such as water tanks or photo towers, and all such similar work should be included in the same subcontract.

CONSTRUCTION CAMP:

Main Camp Location. A considerable study has been made of the best location for a main construction camp, based upon a maximum number to be housed of approximately 700. Of the construction effort, it appears that perhaps 50% of the work to be done will be on Parry Island, with 30% on Eniwetok, and the remainder in scattered locations. A main camp will be the center of operations and will include, adjacent thereto, the principal warehousing, shops, equipment dumps, and repair centers. A location on Parry Island or Eniwetok appears to be the only possible alternative sites for this camp. The Parry Island site is less desirable than Eniwetok in the following features:

(a) The center of outside air and wire communications is located on Eniwetok.

(b) The present garrison, with its existing base facilities, recreation and command post, is now on Eniwetok. Separating construction facilities creates certain inconveniences of liaison and duplication of recreation and other facilities.

(c) Certain additional boat transportation must be provided.

(d) It is contemplated that some operation and maintenance personnel will have to be furnished to keep existing facilities functioning satisfactorily for the use of the garrison.

On the other side of the picture, the location on Parry Island has certain very definite advantages, as follows:

(a) An actual physical separation of civilian from military will minimize notice of differences in the conditions between the two groups; such as discipline, food, living quarters, hours of work, etc. This should tend to reduce dissatisfaction from both parties.

(b) The construction forces can be a self-contained unit, maintaining their own camp regulations, utilities, warehousing, shops, etc. This is considered a very positive advantage to both organizations and will greatly simplify keeping functions and operations separate.

(c) The bulk of the construction activities will be concentrated on Parry Island in any case.

(d) The permanent camp for the Los Alamos Laboratory forces is proposed to be constructed on Parry Island, and there will be little, if any, requirement to inhabit these buildings and to use these facilities before completion of the construction work. Consequently, it would be possible to establish a priority of construction of the various factors in such a way that a large part of the permanent facilities can be used temporarily to house construction personnel.

(e) Supplies delivered by ship can be lightered to shore with equal ease on either island, but if Parry is used, it will have the advantage of keeping all supplies physically separated from the garrison supplies.

For these reasons, it is recommended that the main construction camp and associated facilities be constructed on Parry Island. Under this plan, it is believed that opportunity to operate as a separate unit will be advantageous both to the efficiency to the construction operations and to the control of the military garrison.

Outlying Camps. Some of the work on the outlying islands must be carried on at considerable distances from the main camp, and it appears logical to construct subsidiary camps at certain places, so that time lost by commuting is held to a minimum. The unit cost per man of operating a second camp, particularly a small one, is high, since many facilities must be duplicated. However, as on Parry, such camps could be converted to a permanent facility. Considering this, it appears probable that some camps on the more remote work sites will be economical. It would be entirely possible to organize this work so that tents and portable equipment is used to the maximum extent, moving from island to island as the work progresses. For instance, a portable water distillation unit, motor generator set, and field kitchen equipment can be set up on one island, with tents, and progressively moved as the permanent facilities are completed. Under these circumstances, it would appear advisable to service each of these camps daily, with scheduled trips of a service craft which should carry bakery goods, possibly basic cooked foods, sales store services, and other facilities which would be too inconvenient to provide for the short period ashore.

Method of Construction. At the present time, there are several buildings on Parry Island which are in sufficiently good condition to be usable. It is planned that at the beginning of construction Phase II, a crew will repair and remodel certain of these buildings to provide necessary housing, dining, office, warehousing, and similar facilities as a start toward the complete construction camp. In addition to this, it may be necessary to construct a few special buildings to be used temporarily, but this should be avoided to the maximum extent. It seems logical that the first effort for the basic construction force would be to erect sufficient of the permanent buildings so that the balance of the construction camp and all of its functions can be housed either in the salvaged buildings or in buildings which are constructed for permanent use. It will be necessary in the initial unit of the camp to provide water and power, and it is not anticipated that the permanent equipment can be delivered early enough for use at this time, although it might be possible to make temporary installation of some equipment to be used later on the outlying islands. However, these utilities will be kept to a minimum, and will be replaced with permanent utilities at the earliest date. Every effort should be made not only in buildings but also in the construction of roads and utilities, so that the units, when built, will be permanent rather than temporary.

Principal disadvantages of this procedure is that the facilities constructed for later use will be subject to a certain amount of wear and tear before they are turned over. Nevertheless, the great economy involved in a procedure of this type will greatly out-balance the wear and tear, plus the cost of rehabilitation, if and when such is necessary. This same procedure should be used for the outlying camps as well.

Living Quarters. It is recommended that living quarters at the construction camp be silimar in general size and appointments to those planned for the permanent development, varying from open dormitories for manual labor and single rooms for the top class of personnel. All living quarters will be provided with dry closets or lockers to reduce relative humidity.

In addition to this, the separate buildings proposed for women during tests can be used for women employed during construction. It is not anticipated that housekeeping facilities will be available in any of these quarters. However, to permit married couples, both of whom are workers, to live in dormitory rooms, might be a recruiting incentive.

Dining Halls. The mess hall constructed for the permanent development can be used for serving construction personnel. To economize on space and cost of service, we recommend serving cafeteria style with two (2) sittings per meal.

Services. Supporting the construction camp, there must be space for a number of different functions. The following list is not intended to be complete but includes most of the facilities for which provision must be made: dispensary, sales store, cobbler shop, barber shop, laundry, refrigerated storage, dry food storage, housing storage, mail distribution center, administration office, fire station, guard headquarters, and utilities. In many instances, more than one of these activities can be established in the same building.

Recreation. It is recognized that a comparatively small number of men will be employed over a period of approximately a year. There are no recreational facilities on the Atoll which will be available to these people, and to maintain morale, some provisions must be made. A basic principle should be that the facilities constructed will represent the minimum investment cost with a maximum benefit to the largest number of people. Some of these will be constructed for the permanent camp and these can be built at a sufficiently early date so that they can be used by the construction forces. Some of the activities which now seem feasible are as follows: club building, possibly including soda fountain and snack bar; outdoor motion picture area, fields for soft ball, volley ball and horseshoes; outdoor boxing arena; game room, library and writing room.

Operation Policies. Outside of the opportunity to save money, the most important circumstance affecting morale and consequently reducing the number of resignations is the success with which the construction camp is operated. When it is considered that the difference in cost between good food and well-managed camp against poorly prepared and mediocre food and a poorly operated camp is only a small proportion of the total cost of the work, and can be off-set rapidly by reduced efficiency and increased labor turn-over, it will be realized how important it is to maintain this operation at a high level.

Food. Usually, in a construction or military camp, the reason for deterioration of the quality of the food served is poor preparation rather than poor quality of supplies. For this reason, we believe that competent cooks and chefs should be employed and that diligent effort be made to keep food served up to high standards as well as to maintain cleanliness. Since there will be a fairly large number of so-called white collar personnel and female employees, it might seem advisable to have two (2) dining rooms; however, one dining room is practicable if regulations of dress be insisted upon. It is believed that a natural segregation will occur without the management directing physical separation of manuals and non-manuals.

Health. The problem of providing for health of employees on this project is rather expensive and difficult, and full provision cannot be made. With the possibility of industrial accidents and a normal expectation of 5% of illness, a dispensary and emergency hospital must be maintained. This will require the services of a Resident Physician and several nurses or hospital corpsmen. With a staff of this size, most cases can be taken care of, even those requiring emergency hospitalization, but it is anticipated that cases will arise where personnel must be evacuated either on an emergency or routine basis to adjacent bases or ships where more complete treatment can be effected. Supplementing a base dispensary, it will be necessary to maintain first-aid stations on islands where fairly large numbers of people are working remote from the main camp.

Medical Services. It is believed that one medical doctor should be employed by the contractor. Supplies, equipment and nurses designated by the doctor should be established in the construction camp, in a dispensary. A hospital cannot be justified.

It is recommended that the nearest military hospital be authorized to accept patients designated by the contractor's doctor as hospital cases or cases requiring surgery, and that the air forces evacuate such patients from Eniwetok Atoll. It is also recommended that patients classified by the contractor's doctor or a military hospital as medical discharges be accepted by military hospital ships or planes for evacuation to the Zone of Interior.

It is recommended that the nearest military hospital be authorized to transfer civilian cases from this project to a higher echelon, in the Medical Corps when it is deemed necessary or desirable.

Dental Services. It is not believed that a full-time dentist at the site is essential; however, the availability of dental care is absolutely necessary. The following alternatives are possible:

(a) Authorize a dentist from Kwajalein to spend a specified time, such as one day per week, at Eniwetok Atoll. This would, however, require installation of dental facilities in the dispensary.

(b) Authorize dental cases to be flown to Kwajalein for treatment. This would involve considerable loss of productive man-hours.

(c) Employ a dentist, to serve in the dispensary at Parry Island in some dual capacity, such as laboratory technician or pharmacist, which would justify free time employment.

Alternate (c) appears to be most workable.

Currency. It is recommended that the garrison finance officer be authorized to recognize civilian dollar instruments for conversion to cash for payroll and similar purposes, and that the A.P.O. accept civilian money orders. In lieu of this, the contractor should set up a bank on Parry Island, using script for island exchange to minimize cash reserve.

Camp Maintenance. Normal and routine maintenance of the camp will be taken care of by the camp operation crews. Where maintenance is beyond the scope of the ability of size of these crews, it will be handled by the construction forces.

MAINTENANCE:

Scope. It is recognized that certain existing facilities which were used during the first experiments, either for technical purposes or for support of personnel, have deteriorated badly and those items which can be repaired for re-use will require early maintenance. It is not anticipated that at this date, all such items can be mentioned, but the following tabulation includes a few of the more important functions.

Buildings. The Gamma buildings should be cleaned on the outside and a new mastic or bituminous protective coat should be applied at an early date. The gaskets on the water-tight doors should be repaired and modified to prevent leakage. Steel buildings that can be used should be thoroughly painted. Buildings in dangerous condition should be dismantled.

Utilities. The electric and water utilities on Eniwetok Island are still operating, but in a poor state of repair. It is anticipated that a maintenance force will be assigned the task of a general over-hauling, repair and maintenance of existing utilities on Eniwetok. In some cases, it is possible that complete replacement of units will be necessary.

Towers. The steel towers now standing should be painted at an early date to prevent further corrosion and later some items, such as stairways which have deteriorated beyond repair, should be replaced.

Navigation Aids. Certain navigation aids, markers and anchorages have been established in the lagoon. It is recommended that a survey be made of existing conditions and arrangements made to repair or replace all buoys, lights, moorings, and other aids to navigation that are necessary for satisfactory operation to the extent this function is not now the mission of a military agency.

CONSTRUCTION SUGGESTIONS, MISCELLANEOUS.

1. In airstrip paving operations, the perforated steel mats might be salvaged and used for beach landing ramps and parking areas.
2. In power driven equipment, interchangeable small units would facilitate handling, repair, replacement.
3. A radio broadcast station for programs and general information to the men is good for morale and coordination.
4. Space for religious services should be provided if requested by employee groups.
5. A public address system is desirable in any camp.

SECURITY.

Although it is not within the scope or prerogatives of such a report as this to recommend on security measures, it is believed of benefit to mention those items that affect efficiency and practicability of construction.

If the project is to be classified, procurement, shipping, and mobilization of manpower can be expedited by applying the lowest possible classification to all matters except the nature and schedule of actual tests.

Judicious advance publicity releases pertaining to construction will minimize rumors and remove the press incentive for guesswork alarming to the public and embarrassing to manpower recruitment.

Investigation and clearance of all personnel, including manual workers, in advance of their travel to the site, involves tremendous difficulty in keeping them available during the investigation period. During construction Phases I, II, and part of III, the risk is considered small of sending personnel to the site, as soon as agency clearance forms are submitted, and pending investigation. As the scheduled time for special test facilities approaches construction, sufficient persons will presumably have been cleared that by selection and control at the site, only cleared personnel will see significant structures. Persons who by reason of advance design or planning duties require functional knowledge of test structures should presumably be cleared in advance of these duties.

It is recommended that shipments be repackaged and reworked at a controlled warehouse at the port of embarkation and consigned directly to Eniwetok. Vendors should be instructed to ship only to the warehouse, except in special circumstances where this procedure would involve unusual cost or impracticable rehandling.

It is recommended that the individual features of the project be variously classified rather than a blanket overall classification, which would necessarily have to be evaluated at the maximum of its components.

Assignment of personnel to the project will necessitate disclosing the location of the work, its approximate duration, and the general type of work, living conditions, wages, and mode of transportation, in order to commit people to an employment agreement. It is suggested that the less air of secrecy which surrounds employment discussion, the less likely is curiosity to lead to security violations. It is, therefore, suggested that the following subjects be unclassified:

(a) Construction is contemplated at Eniwetok Atoll.

(b) A certain named firm, or firms, is committed to such work.

(c) The work encompasses the usual crafts, equipment and materials necessary to maintain and reconstruct a military garrison in the Pacific. These can be defined.

(d) All contracts are with agents of the United States Government.

(e) Span of employment is nominally one year, with extensions or reductions of time as the job requires.

(f) Photographs of construction camp.

(g) Maps and photographs of the Atoll which do not disclose experimental or test structures.

SECTION VI

OPERATION DURING EXPERIMENTS

OPERATIONS INVOLVED:

This section covers Phase IV of the activities of the Contractor and although concurrent with Phase III, extends that period and embraces certain performances more closely associated with the scientific tests.

Plan of Experimental Operation. The plan of operation is to prepare three islands, Engebi, Aomon and Runit, and possibly a fourth island, Bogallua, for tests.

Parry Island is proposed as the control center and administrative base, as well as to contain scientific installations similar to those required by the previous tests.

Photographic towers on the coral head in the lagoon and on Aniyaanii will be retained; and two or three additional towers will be used in succession on shot islands.

It is now believed that certain assembly and field laboratory functions will be ship based.

All Services to Support Scientific Requirements. The operation during experiment period should be based on a concept of all other agencies at the proving ground being in a supporting position, with respect to the scientific or test personnel and to the scientific experimental requirements. This means that performance of the details of the operation should be accomplished by the Military and by the Contractor, with a minimum of dependence upon Scientific Personnel for guidance and assistance.

Operational Functions. To obtain this continuity in supporting functions to the scientific experiment, it is believed that the following operations by the Contractor should be continued throughout this period:

(a) Construction forces for installation and construction required for experiments and not previously specified.

(b) Operation of heavy equipment, and land transportation required for installation and handling of scientific apparatus.

(c) Operation of maintenance and repair shops.

(d) Operation of all island utilities, and the repair thereof.

(e) Camp services, with the exception of Eniwetok Island.

(f) Shipping, longshoring and warehousing.

(g) Material control and expediting, as well as material accountability, exclusive of scientific equipment and experimental apparatus.

(h) Operation of inter-island communications within the Atoll.

(i) Scheduling of air and surface transportation.

(j) Liaison between scientific personnel and military personnel, pertaining to utilities and services not of a security character, or not having to do with military policy.

(k) Scheduling and conduct of commercial shipping and commercial air carriers, if required.

(l) Maintaining a boat pool for transportation of men and materials pertaining to construction, installation and camp services. This will be in addition to boat pools which may be required by the military for ship-to-shore or other services.

MANNER OF HANDLING SUPPORTING OPERATIONS:

Inter-Island Transportation and Communication Control. The contractor responsible for operation of facilities should establish a Superintendent of Transportation. He would function as port captain and traffic control chief in all areas except Eniwetok Island and its approaches. The military chief of operations or Atoll commander would publish rules of the road for land, sea and air, and assign a liaison officer to coordinate with the Superintendent of Transportation on military movements. Within this framework the Superintendent of Transportation would schedule all movements of carriers acting to support the civilian functions of construction, installation and experimentation. During the test period, the Test Director would assign a liaison man to coordinate its requirements with the Superintendent of Transportation. Communication originating on land, except Eniwetok Island, will be the responsibility of the Superintendent of Transportation for maintenance and operation. Messages directed outside the Atoll will be transferred to military signal channels at Eniwetok.

Aircraft Operation. Small reconnaissance type of aircraft, designated in Army nomenclature as the L-5, which is similar to the Piper cub of commercial use, is the only practicable type of plane other than the helicopter which can be successfully used for Inter-Island transportation within the topographic limitations of the Atoll. This plane is extremely useful, however, in transportation of personnel on urgent missions between islands, both during construction in correlating movements of men and material, and during the operation. A slightly larger plane is desirable, however.

It is believed that more efficient drone plane operation probably could be established by the military on Eniwetok, rather than on Kwajalien, providing that maintenance shops are added and smaller planes used. Concentration of AEC forces on Parry Island enables sufficient latitude and space to permit the drone operation to be based on Eniwetok Island.

Late Construction of Special Buildings and Instrumentation. To forecast and incorporate into the comprehensive plan of the proving ground, all the detailed requirements and facilities for scientific tests for an experiment to be held in the future, is not now possible. While it is anticipated that in general, design and construction will keep pace with, and be currently adjusted to the progress and development of these requirements, it is also advisable to prepare for last minute or "on-the-spot" requirements. To this end the nucleus of a construction force should be maintained to accomplish these purposes. This crew would maintain and operate such construction equipment as is necessary and will furnish the manpower requirements for installation services.

To enable the above plan to operate smoothly and efficiently, a small crew of specialists working in conjunction with the scientists on the details of "on-the-spot" problems, together with limited blueprinting and reproduction facilities are necessary. Similarly, stenographic, clerical and similar services should be provided.

Installation Crews and Equipment. Under this heading and included as a portion of the overall operational phase are certain functions that rightfully cannot be accounted for under construction or under operational items. These operations are concerned strictly with the transporting, handling, installations, preliminary testing and adjustment of scientific instruments and equipment required by the experiment and which are considered outside the scope of a construction contract. Scientific personnel, utilizing construction equipment and assisted by construction craftsmen, will install and prepare such instruments in accordance with their own requirements. A diversity of special skills, carefully selected from the construction forces would be retained for this purpose. The time required for these operations begins with the completion of major construction features and extends to the moment of the actual tests.

Utilities Operation. The operation and maintenance of such utilities as power generation, transmission, communications, water works, sewer lines, roads and airstrips, and fuel handling and storage, will require only a limited number of such skills as diesel mechanics, electricians, telephone operators and repairmen, linemen, still operators, construction equipment operators and laborers. Personnel whose training and familiarity with specific equipment, location and function of appurtenances and general operating routine of each independent utility has been developed during the major construction program, will be retained beyond that period to insure a complete smooth working installation for the primary benefit of the scientific experiments. The knowledge of this personnel with regard to spare part requirements and spare part stock levels will also be advantageous.

It is anticipated that demands on all utilities will increase from interim construction requirements to a maximum during the period wherein scientific personnel arrive at the Atoll. The demands would remain at this peak level during active preparation for the experiments and during the actual tests. The greatest demands on an experiment island utilities would thus be made in the period just prior to the shot. At this time, it will also be necessary to provide operators on each experiment island for operating power plants, communications facilities, and water distillation units.

Prior to zero hour, salvageable material would be removed. Personnel formerly housed on these experiment islands would be removed to base camps on Parry and Eniwetok islands.

Personnel for operation of all utilities on these base camps would be required throughout the experiment.

Operation of Camp Services. The operation of camp services will include furnishing personnel and supplies for maintaining all incidental equipment and buildings of the proving ground. This implies operation of shop facilities such as equipment repair, electric, plumbing, painting, garage and boat repair throughout this period.

Other camp services include the operation of housing and messing facilities, recreational facilities, laundry, and cold storage or reefer plants with the maintenance of uninterrupted supplies required by these operations. Furnishing equipment and personnel for unloading, warehousing, and distributing these supplies as well as construction materials and equipment is also included.

Freight Handling. It is recommended that all freight destined for Eniwetok Atoll, with the exception of military freight consigned for the use of the military garrison at Eniwetok Island, be directed to a central assembly point in the Zone of the Interior. This point could effectively be a warehouse in the Los Angeles harbor area, to which procurement items from vendors would be consigned, as well as scientific equipment. At this point, such re-packaging as necessary would be accomplished, and the assembly of loads for surface or air transport would be accomplished in a systematic related manner. All such freight would be appropriately marked and insofar as possible, would be consigned at this point to the individual island in Eniwetok Atoll, in which it will be ultimately used. A code mark would accomplish this and would enable considerable elimination of re-handling at Parry island. Freight could also be marked with an identification number for accountability. It is recommended that the integration of freight handling and consignment, both in the Zone of

Interior and at the Atoll, could be best handled by an organization under a Chief of Transportation, set up by the operating contractor.

Zone of Interior Operations. Obviously, no plan of operation of a remote installation could be successful without connection with a base for source of supply, manpower, and transportation. This base is presumed to be the state-side office of the Architect-Engineer-Construction-Management Contractor. It will maintain liaison with Los Alamos and as a result of this liaison will initiate all subsequent action. In addition, although concurrently, this office will be concerned with and responsible for procuring, expediting, inspecting, warehousing and shipping of all supplies, materials and equipment required by the operating phase of proving ground activities, as differentiated from similar items pertaining to the actual construction of the proving grounds. Similarly it should attend to the recruiting and hiring of personnel and arrange for its transportation overseas, whether by private carrier, or by means of facilities of the Armed Forces.

SECTION VII

OPERATION BETWEEN EXPERIMENTS

OPERATIONS INVOLVED:

General. The period referred to as Phase V of the construction program will be defined as the roll-up. It will begin with the conclusion of a testing program, includes securing the area, and extends through the period of quiescense as necessary. It covers such items as these:

- Salvage
- Storage
- Demobilization
- Maintenance
- Protection of structures and utilities
- Resident maintenance personnel
- Security and radio safety
- Issue completion report

Roll-up Preparation. The operations immediately prior to the detonation of a bomb is conceived in this Report to involve the salvage of a maximum amount of valuable facilities which are subject to damage or destruction by bomb effects, providing that such salvage can be practically accomplished without interfering with installation and other work at the forward area, and providing that the removal of any such salvage can be accomplished in a period up to twenty-four hours prior to bomb detonation. Practicability of the elements of this salvage are discussed in Section IV under various headings in the analysis of probelms of design.

It is recommended that adequate storage facilities be provided on Parry Island for the roll-up period, it being felt that any items remaining on shot islands, if subjected to open storage and idleness throughout this roll-up period will suffer such deterioration that dependability for future use would be in question. Maximum mobility is being considered for mechanical units involving a high capital outlay on the shot islands, and maximum protection is being considered for those facilities which may remain on the shot islands and still be re-used for another experiment. The mobility of mechanical equipment enables the removal of such equipment to be accomplished in the last few days prior to a shot, with a minimum accompanying use of heavy construction-type equipment. Removed equipment could be either loaded on barges which may then be accumulated at mooring adjacent to each shot island, and towed in a chain to Parry Island for further disposition or removed in "M" boats by decrements; hence it is not believed necessary to maintain a large fleet of "M" boats for this purpose alone.

Demobilization. As part of the demobilization following the testing period, the following functions are proposed to be performed as soon as radiological conditions permit: salvage, storage, a system of maintenance of permanent utilities and structures, and a protection of structures and utilities. Such structures as are considered undesirable to leave in place from the standpoint of security would be removed, demolished or obliterated, as directed. The Gamma Stations, being of a special aggregate subject to oxidation, would be wire-brushed and scrubbed to clean the surface from oxides and coated with an asphalt base coating, which should then be covered with sand or other sun protection. The metal parts of permanent structures on shot islands should be coated with long-lasting preservatives such as cosmoline. Cable landings should be reposted with warning signs. It is also suggested that areas of intense radio activity be fenced and marked. On Parry Island, warehousing of materials to be left at Proving Ground should be accomplished; those which are subject to deterioration should be stored in dehumidified warehouse, and arrangement for shipment back to the Zone of Interior of other materials should be made.

Operation of Utilities during Roll-up. Following the experiments, it will be necessary to have operators for the utilities on Eniwetok. In addition to these, a small but competent crew of utilities personnel will be required to weatherproof and maintain utilities provided for Parry and the Experiment Islands. Power plants in concrete emplacements on Experiment Islands and other equipment left in place rather than stored, should be visited, checked and operated frequently. It is possible that mechanics in accomplishing these duties could accompany the regular security patrol. Units in service in power and water plants should be rotated in sequence to keep them dehumidified, lubricated, and in operating condition, and consequently useful for a future series of tests.

Other Services. After evacuation of the Atoll by scientific, military and construction forces concerned primarily with the tests, the contractor should maintain a nuclear force to preserve all incidental items as are considered worthy. These services would include proper storage of furniture and equipment that require moving from place of use to warehouse, the application of protective measures on items not requiring moving to warehouse for protection, maintenance of transportation and construction equipment not returned to the Zone of Interior or reclaimed by the Armed Forces. Other services may include routine tests on submarine signal and communications cables for determination of rate of deterioration and other repetitive observations, the resurvey of terrain in shot areas to determine blast effects, the completion of "As Built" drawings not previously accomplished during Phases III and IV, and either the preparation or the furnishing of data for the preparation of the "Completion Report".

RECOMMENDATIONS:

It is recommended that during the roll-up period a military garrison be maintained at the Proving Ground to perform the following mission:

(a) Security surveillance of the closed area.

(b) Safeguarding of Government property.

(c) Maintenance of offshore communication and of aircraft transportation facilities.

(d) Provide subsistence and quarters for resident representatives of AEC or their agents during the period between tests, and provide subsistence and quarters, as well as air and surface transportation within the lagoon to visiting scientific and survey parties during the roll-up period.

(e) Provide all facilities necessary to be a self-sufficient garrison, including medical personnel and facilities competent to protect surveillance details or surveillance personnel from radiological hazards.

It is recommended that the construction contractor maintain sufficient personnel at the site during the roll-up to assure the perpetuation in good repair of all hydraulic, mechanical, electrical, and structural facilities essential to the next scientific test.

It is recommended that a laboratory representative be in residence, to maintain radiological data and inspect and maintain scientific equipment. The resident personnel during roll-up could more economically and happily live at the Eniwetok garrison for subsistence, quarters and recreation. Such resident personnel should remain without replacement for approximately eighteen months. As inducement to do so, family quarters might be authorized. This would add to stability of personnel and continuity of services vital to the proving ground.

SECTION VIII

RECOMMENDATIONS

SUMMARY OF BASIC RECOMMENDATIONS:

The following is a summary of the recommendations made in the preceding sections of this Report and are repeated here to provide a concise review of the major recommendations resulting from a detailed study of the problems involved in the design, construction and operation of a Proving Ground for testing atomic weapons.

1. That the engineering design be accomplished in the Zone of the Interior to facilitate liaison with the Laboratory at Los Alamos and supply sources.
2. That immediate occupancy of the site by small advance engineering and construction forces is desirable and economical.
3. That the period of time for construction be spread to limits consistent with sound planning and with present scheduled experiment target dates.
4. That Parry Island be developed for construction camp and later be converted to headquarters island for the Laboratory operations.
5. That Eniwetok Island be reserved for use and exploitation by the Military.
6. That the present garrison facilities on Eniwetok be rehabilitated and maintained.
7. That camps be established on each Experimental Island, excepting Aomon-Biijiri in which case the camp be established on Rojoa Island involving a causeway or connecting link with Biijiri.
8. The the Island of Bogallua be designated as the site of a fourth Experimental Island, should it be determined that a fourth experiment

is desired for testing and research.

9. That a maximum use of Zone of the Interior fabrication should be used to reduce to a minimum the use of "on the site" labor.

10. That the use of corrosive resistant materials in construction of non-expendable items is justified.

11. That concrete, exclusive of Gamma buildings, be made from coral aggregate, produced locally.

12. That triangular type guyed towers, 300 feet high, be used for the Zero Towers.

13. That the present Gamma Buildings be re-oriented for the new tower height by tilting.

14. That the distillation of sea water be used to provide for all potable uses and for limited domestic service.

15. That a scheme incorporating the use of many small plants throughout the Proving Grounds be utilized for generation of power.

16. That permanent, protected enclosures be provided for power plants adjacent to Timing Buildings and Living Camps on shot islands.

17. That overhead distribution of electrical power be used on Eniwetok and Parry Islands and in the Living Camps on or adjacent to the shot islands.

18. That a local system of telephones, backed up by a radio system, for inter-island communication be installed and that these systems of communications be operated by civilian personnel. That dependence be placed upon the military for the necessary communication connecting link with locations outside of Eniwetok Atoll.

19. That permanent horizontal and vertical control surveys be established.

20. That present submarine control and signal cables be retested periodically during construction.

21. That hot-mix asphaltic paving be used for the area surrounding Zero Towers and for air strips.

22. That an asphaltic road-mix surfacing be used for frequently traveled roads.

23. That stabilization of zero line and other areas for the purpose of reducing the amount of dust which will rise be accomplished by asphaltic road-mix surfacing.

24. That existing piers near the south end of Eniwetok, the north pier on Parry and on Runit, Aomon and Engebi Islands be repaired and reconstructed.

25. That new piers be constructed near north end of Eniwetok, near air strip on Parry, at Rojoa and at Bogallua if that island is used.

26. That new fuel storage with submarine receiving lines to deep water be provided.

27. That sheet aluminum alloy for building construction be allocated immediately.

28. That the entire program of planning, design, construction operation and maintenance can best be accomplished under a single contractual agreement covering all phases of the program.

SECTION IX

COST ESTIMATE

SCOPE:

The estimates presented for work under Phases I, II and III cover facilities as recommended in this Report and summarized in Section VIII. These estimates include all anticipated expenditures in connection with engineering and construction, except the Architect-Engineer-Construction-Management (AECM) fee.

The estimates for Phase IV and V are developed to include all AECM costs based on operation under the assumptions listed below. Basis of time schedule is:

Phase IV-A, Experiment	Dec. 1950 through March 1951
Phase V-A, Roll-up	April 1951 through Dec. 1952
Phase IV-B, Experiment	Jan. 1953 through April 1953
Phase V-B, Roll-up	May 1953 through Aug. 1953

It is assumed that during Phase IV, the Los Alamos Laboratory will station not over 250 people in the camp on Parry and on the shot islands and that the AECM contractor will assign 100 mechanics and helpers to work under their direction. In addition, approximately 250 others will be required to operate the utilities and facilities.

During Phase IV, A and B, the additional services furnished include purchase, preparation and serving of food; operation and housekeeping of rooms, offices, etc.; medical, laundry, barber, sales store and recreation services; maintenance and operation of utilities, including telephone operators; local air, water and motor transportation for personnel and supplies; light stevedoring and warehousing of "Laboratory" supplies; fire protection.

During Phase V, A and B, the services furnished include stationing a local force to maintain and operate periodically all utilities and plant; warehouse all supplies; provide accommodations for a limited number of guests; clean up areas after experiments and reconstruct once the four shot towers, repave shot areas once with asphalt; rebuild shot island camps and utilities as necessary once; and finally salvage such material as warrants saving.

This program contemplates that other agencies will, without cost, furnish all ocean transportation for their own supplies and personnel; provide crews for local air flights; supply all outside communications; station guards; and that military forces will provide their own support and maintenance, except for operation of utilities. Through all of these estimates, no allowance has been made for costs of any kind which will be incurred by the Laboratory, either in connection with superivision of the work or for purchase or installation of experimental equipment. Costs of military support are not included and in addition, we have assumed that military agencies will furnish on memorandum receipt all necessary small craft, vehicles and airplanes including the crews for operation of aircraft.

BASIS OF ESTIMATES:

General. Estimates have been prepared using as an origin current labor, material and equipment costs on the West Coast. These costs have been modified by our experience on foreign work and also as a result of conferences with Naval officers at Pearl Harbor who have had experience in this area. At the present time, we have no specific data in a form that can be used as a guide of the cost of previous work of similar nature on Eniwetok or adjacent Atolls. It is our understanding that military transportation may be available without charge for both personnel and material. Our past experience indicates that such transportation cannot be considered 100 percent reliable through the course of the entire project because demands with higher priority may divert shipping to other channels. For this reason and to be on the safe side, we have estimated that all personnel and material will be moved to and from the Atoll via private commercial transportation.

Accuracy. These estimates have been prepared by take-off from preliminary plans of all items entering into the work with all accuracy possible at this time and by a careful study of the type of organization required and labor conditions involved. Figures presented are the result of a digest of these detailed estimate work sheets. Several factors must be recognized in this connection. First, the plans are in a preliminary and incomplete stage so that quantities and items of work can be taken off in a preliminary way only, subject to revision when detail plans have been completed. Second, most of the manufacturers, and particularly those supplying electrical equipment, are very hesitant about quoting firm prices for future delivery. It is entirely probable that material prices in the future will rise and only the possibility of a moderate increase has been taken into consideration herein. Third, production of labor at the site and labor turnover is a feature which cannot be forecast with great accuracy. A figure has been added, as indicated later, to anticipate this feature, but this must be recognized as a considered opinion at best. Fourth, labor will be transported to the island on a guaranteed work-week basis. Excessive cost of delay due to such causes as extended strikes has not been anticipated.

Labor Costs. Direct labor includes labor directly chargeable to specific items of work and the cost of hauling material from the Parry Island warehouse to the actual job site. U. S. labor cost in California is the origin of the estimates for direct labor. To this have been added certain differentials to cover additional cost for work overseas.

Material Costs. We have estimated the quantities and cost of material for the construction of this work and have added 15 percent to cover loss, waste, breakage, and similar items. Under normal circumstances, we believe that this figure is high, however, it must be recognized that all materials will be handled several more times and will be transported a greater distance than is normally the case of work in the United States. In addition to this, it may be necessary to over-order in some cases as an insurance against delay in the work caused by shortages of specific types of material. The long-time lag involved in purchase and transportation balanced against labor cost of delay may dictate such over-order of material.

Transportation Costs. The cost of transportation in the estimate includes delivery of material dockside; additional warehousing and storage dockside if required and loading aboard the carrier; cost of ocean transportation and insurance; and the cost of longshoring at the Atoll. Warehouse operations in the embarkation port, except dockside, are included as overhead.

Equipment Costs. Due to the fact that the construction equipment now at the jobsite needs extensive repair, it is anticipated that some equipment will be purchased new in United States.

A majority of the construction equipment needed for this project has an average estimated life of eight years under ordinary climatic conditions and use; however, it is felt that the average life of the equipment on the site will be greatly reduced and that maintenance and repair will be increased. In view of the variables affecting the life and efficiency of construction equipment on this project, estimated equipment costs have been determined from an analysis of each type of construction and the equipment needed to efficiently expedite the overall project. In each case, equipment cost includes the U. S. standard equipment rental rate for the construction involved, plus normal operating, maintenance and repair cost, plus an arbitrary factor of 50 percent to cover the variables of climatic and job site conditions, and transportation to job site. Normally, this arbitrary factor would be low but it is realized that some percentage of the equipment will be available without cost on memorandum receipt from the military.

Detail Estimates. On the following pages are cost estimates for Phases I, II, III, IV, and V of the construction and operation program, both in detail and summarized.

DETAIL ESTIMATES: PHASES I, II AND III:

Summary. The summary of the detailed estimates including the cost of the development of Bogallua as a fourth shot island but not including the AECM fee, is as follows:

Direct Costs, (see detail estimate)

Material	$5,549,400	
Labor	3,846,950	
Equipment	1,819,200	
Transportation	1,424,300	
Sub-total, direct costs		$12,639,850
Field overhead indirect manual and non-manual labor costs including recuriting, transportation of personnel, sick time insurance, etc. (see detail estimate)	$2,532,050	
Extra construction costs for camp and office, wear and tear on equipment.	188,500	
Operating costs of camp utilities; motor vehicles, boats, aircraft and equipment not charged directly to units of work; office and miscellaneous supplies; travel.	664,000	
Home Office cost of design, purchasing, expediting, accounting, liaison, travel, job control.	600,000	
Stateside warehousing and material handling.	70,000	
Sub-total, overhead costs		$ 4,054,550
GRAND TOTAL, PHASES I, II AND III		$16,694,400

Bogallua. Deduction for cost of work on Bogallua, assuming overhead will be substantially the same, is:

Material	$ 281,100	
Labor	227,300	
Equipment	70,900	
Transportation	67,400	
TOTAL	$ 646,700	$ 646,700

Estimate of Direct Cost. The detail estimate of direct costs, without overhead, including Bogallua as a fourth shot island, is as follows:

Item	Material (Cost in Dollars)	Labor	Equipment	Transp. Material
Shape and Stabilize areas	38,100	205,300	340,200	-
Asphalt paving	404,200	267,200	509,000	477,100
Dust pallative on roads	26,100	4,400	4,500	45,400
Causeway Biijiri to Rojoa	70,400	57,800	38,700	12,700
Shot and photo towers	121,300	43,900	18,500	17,600
Buildings, aluminum and tents	1,863,700	396,800	173,200	517,200
Refrigeration plant & accessories	190,300	20,800	3,800	11,000
Water facilities	739,800	447,200	58,000	67,000
Sewers	188,300	204,700	19,800	16,000
Fuel facilities	218,700	176,700	65,400	41,600
Electric facilities	611,000	18,400	65,800	62,500
Telephone system	681,500	80,400	227,800	57,600
Control & Signal system	62,400	167,400	54,000	18,400
Radio back-up system	28,200	2,800	1,300	900
Public address system	4,100	900	200	300
Furniture;dining,housekeeping,etc.	96,600	8,400	2,200	2,400
Equipment; fire, kitchen, etc.	99,400	9,600	2,200	2,400
Pier construction	60,300	137,800	197,300	22,600
Special shot island buildings	29,000	15,200	6,300	42,000
Phase I field work, except towers	16,000	139,700	31,000	9,600
TOTALS	5,549,400	2,405,400	1,819,200	1,424,300

Additions to Labor Cost. The estimated cost of labor as of Eniwetok is as follows:

Total direct manual labor as on estimate, Page IX - 7		$2,405,400
Personnel recruiting, transportation, standby time, etc.	$623,720	
Sick leave at 4% of direct labor.	96,210	
Compensation insurance at 5% of direct labor.	120,270	
Climate factor at 25% of direct labor representing lost time due to rain, gales, non-delivery of material, reduced efficiency from incomplete crews or working out of classification, and other factors not generally encountered in the U.S.	601,350	
Total additions		1,441,550
TOTAL COST of labor as of Eniwetok, used in Summary		$3,846,950

Detail Estimate of Field Overhead Labor Costs.

Maintenance and Operation, Eniwetok Utilities	$ 108,000
Maintenance and Operation, Parry Utilities	76,200
Transportation Repair Shop	134,900
Transportation Services	194,800
Warehousing	102,000
Guards and Fire Department	85,100
Dining Service	171,000
Camp Housekeeping	96,900
Recreation and Miscellaneous Services	53,400
Medical	71,800
Main Office	295,600
Field Engineering	270,300
Top Supervision	253,500
Total Labor, Salaries, Wages	$1,913,500
Sicktime and Insurance at 4-1/2%	86,100
Recruiting, Transportation and Standby	532,450
TOTAL Field Overhead Labor Costs	$2,532,050

Estimate - Phase V-A. The following estimate for Phase V-A includes cost for replacement of the maximum amount of facilities that may be damaged during the experiments on four shot islands.

The deduction shown following the estimate for Phase V-A has been estimated on the basis that the degree of damage to certain of the facilities will not require this maximum replacement. The actual cost will undoubtedly be between these two figures.

It is assumed that activity in the center (3 inch) paved area around the towers will be such that all of this pavement must be removed and that all paving around towers (both 3 inch and 1-1/2 inch) will be relaid. The deduction shown following the estimate for Phase V-A omits all paving reconstruction. Also included in the maximum estimate is the cost of rebuilding completely all building superstructures for the outlying camps. If it is possible to salvage this material for re-erection, the material cost can be reduced considerably. Replacement for the water system includes new material and installation labor for all shot island water tanks, one-half of the pumps and all water system buildings. The deduction contemplates the re-installation of pumps and stills only. On the maximum estimate, it is assumed that replacement of electrical work will include, on the shot islands, twenty percent replacement of underground buildings, loss of all above ground power plants and all overhead distribution lines. The deduction estimate is on the basis that only one-third of this loss will be sustained. Special buildings are included in the maximum estimate on the assumption that the second experiment might require several new buildings of types different from those originally constructed. The deduction assumes that there will be no such buildings required. All other items are considered nominal, so no credit is reflected in the deduction.

ESTIMATES - PHASES IV AND V

Summary. The summary of the detail estimates for all AECM costs, exclusive of fee is as follows:

Phase IV-A Experiment	$1,511,000
Phase V-A Roll-up	1,856,800
Phase IV-B Experiment	1,511,000
Phase V-B Roll-up	240,500
TOTAL COST - PHASE IV AND V	$5,119,300

Estimate Phase IV. Phase IV-A and Phase IV-B are identical and the following is the detail estimate for Phase IV-A:

ITEM	MAT'L.	LABOR	EQUIP.	MATERIAL TRANSP.
Utility Operation	46,900	91,500	2,800	40,000
Dining Service	-	72,900	-	15,000
Housekeeping	10,000	94,000	2,000	-
Recreation	-	21,300	-	-
Medical Service	20,000	18,800	-	500
Local transportation and repairs	85,000	83,900	-	13,000
Warehousing	-	15,900	-	-
Fire protection	-	6,600	-	-
Field Engineering	1,000	22,900	-	-
Experiment support personnel	-	169,700	-	-
General Office	10,000	44,000	-	500
Field management	-	24,200	-	-
Sub-totals	172,900	665,700	4,800	69,000

Total direct cost	912,400
Insurance and sick time, average 7% of labor	46,600
Personnel recruiting, standby, travel	520,000
Home office procurement, accounting, liaison, travel & job control	32,000
TOTAL COST - PHASE IV SINGLE OPERATION	$1,511,000

ESTIMATE - PHASE V-A. The detail estimate of costs for Phase V-A is as follows:

ITEM	MATERIAL	LABOR	EQUIP.	TRANSP. MATERIALS
Remove Center Paving	1,500	6,800	29,100	-
Asphalt Paving	143,400	114,200	213,800	167,900
Dust Pallative	13,100	2,300	2,400	22,700
Towers	79,200	39,000	16,200	15,600
Buildings and Tents	60,700	24,000	5,800	6,500
Water System	60,000	26,400	5,600	14,400
Sewer System	800	1,200	400	100
Fuel System	2,100	1,700	700	400
Electrical System	91,600	36,800	18,900	5,800
Telephone System	2,100	1,200	400	100
Control and Signal System	1,400	1,200	400	100
Radio Back-up System	1,400	1,200	400	100
Public Address System	700	600	400	100
Equipment, etc.	2,100	700	400	200
Special Buildings	29,000	15,100	6,300	42,000
Sub-total, reconstruction	489,100	272,400	301,200	276,000
Cleanup shot islands	19,800	25,000	27,700	2,600
Supervision and operation	20,900	227,700	-	2,600
Sub-totals	529,800	525,100	328,900	281,200

Total direct cost	1,665,000
Insurance and sick time, average 7% of labor	36,800
Personnel recruiting, standby, travel	75,000
Home office, procurement, accounting, liaison, travel & job control	80,000
TOTAL COST - PHASE V-A	$1,856,800
Deduction estimate for less than maximum replacement	$1,009,700

ESTIMATE - PHASE V-B. Final roll-up period. Salvage is not credited because the amount is doubtful.

ITEM	MATERIAL	LABOR	EQUIP.	TRANSP. MATERIALS
Cleanup shot islands	19,800	25,000	27,700	2,600
Prepare equipment for salvage	10,400	42,000	9,000	1,300
Supervision and operation	5,200	62,700	9,000	700
Sub-totals	35,400	129,700	45,700	4,600

Total Direct Cost	215,400
Insurance and sick time, average 7% of labor	9,100
Home office procurement, accounting, liaison, travel & job control	16,000
TOTAL COST - PHASE V-B	$240,500

SECTION X

PHOTOGRAPHS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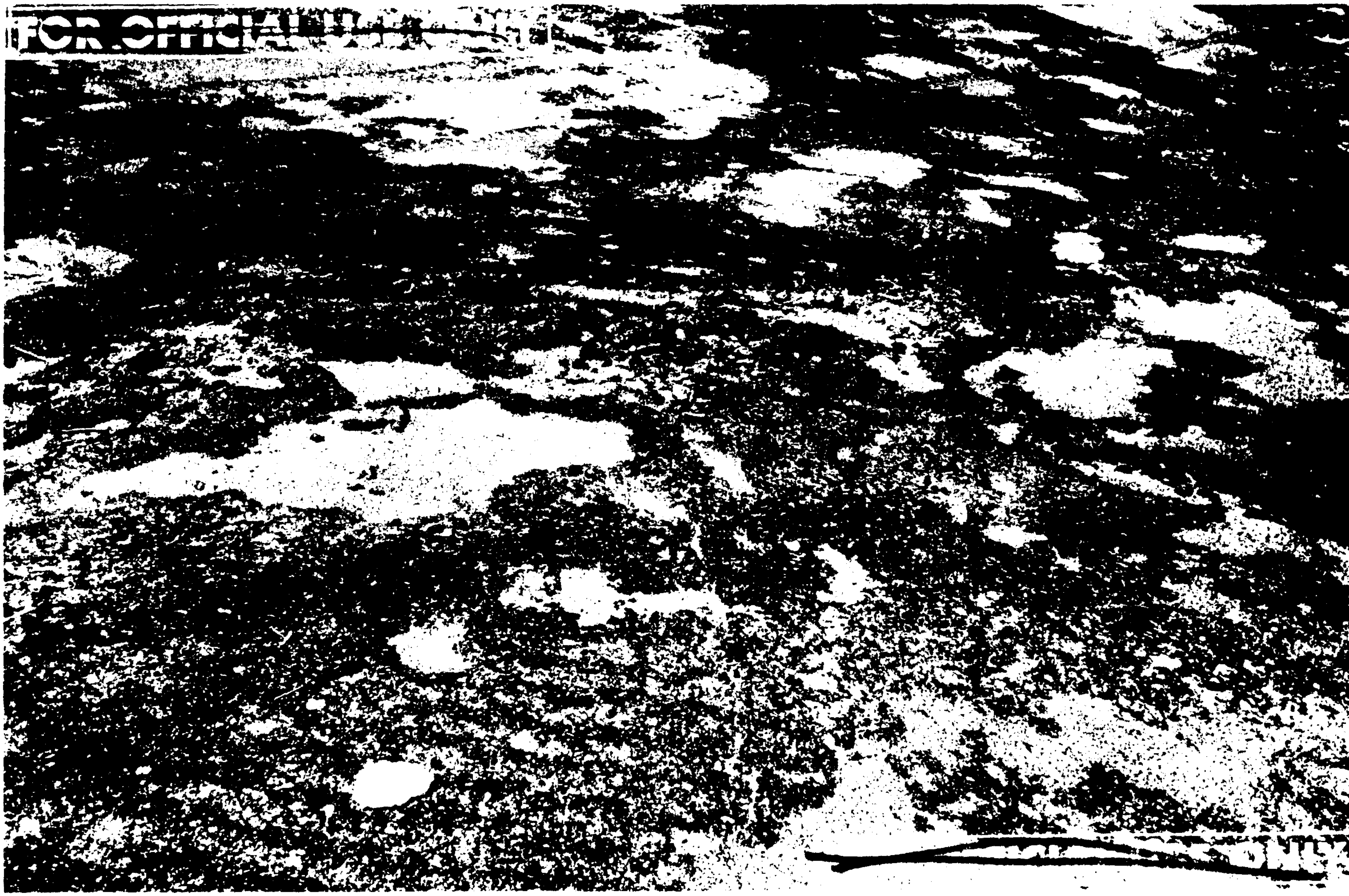

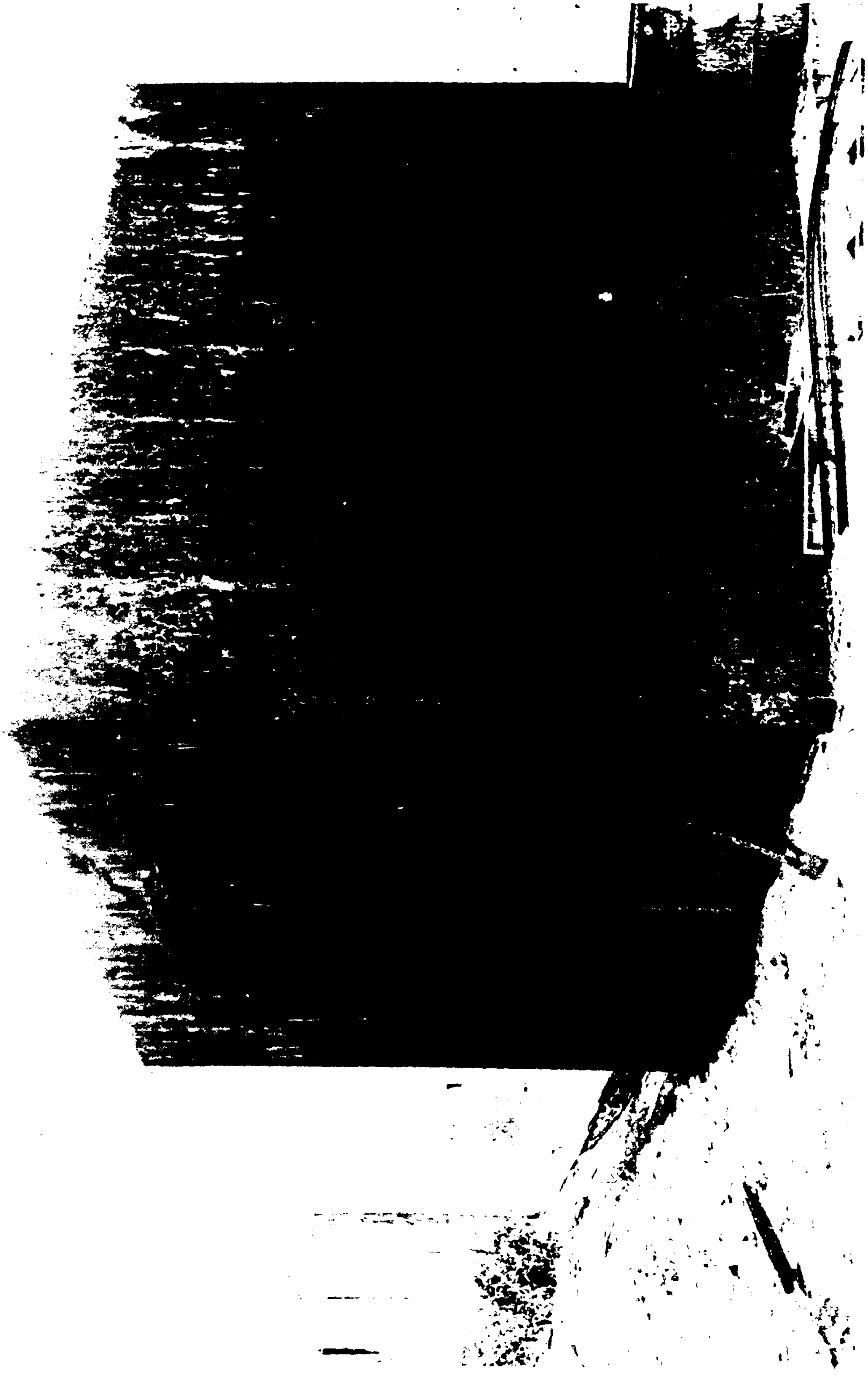

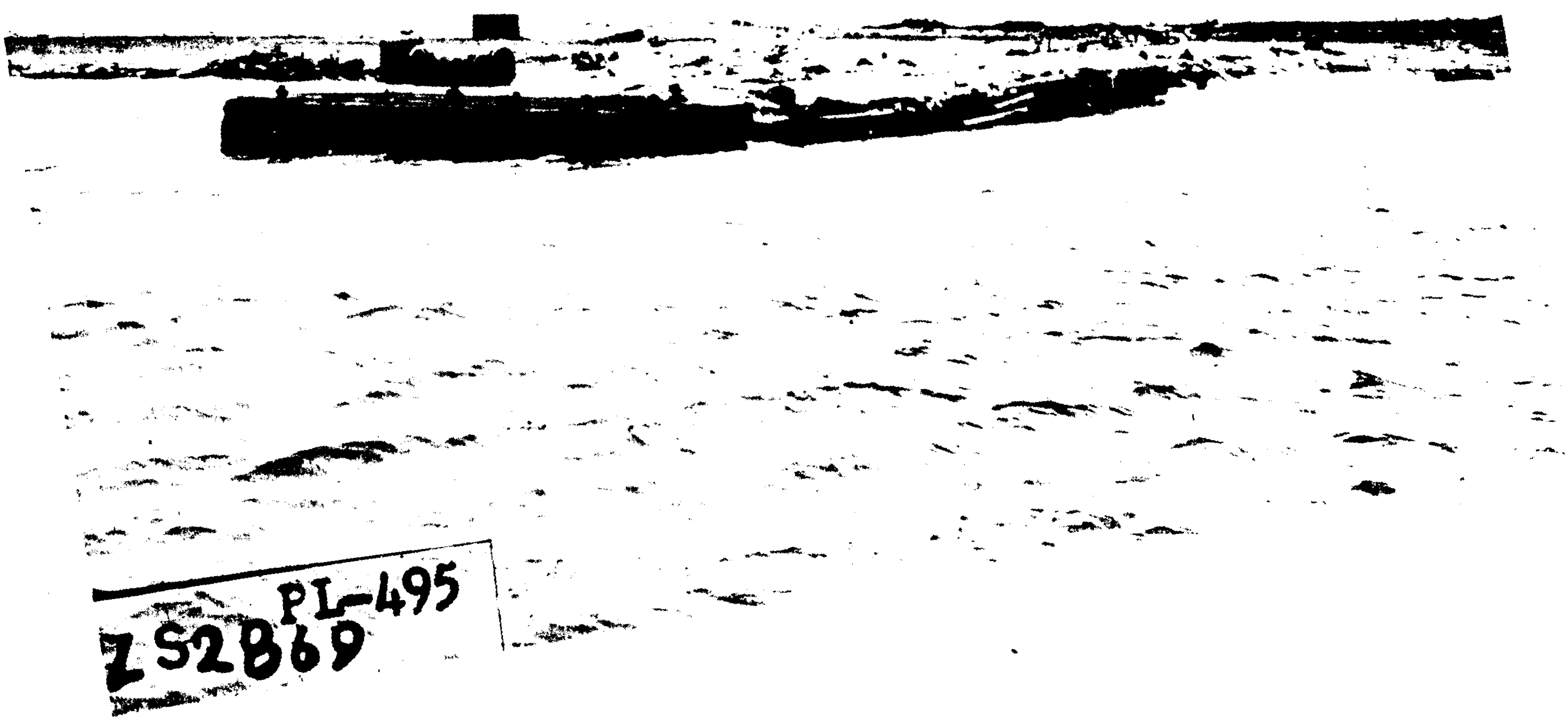
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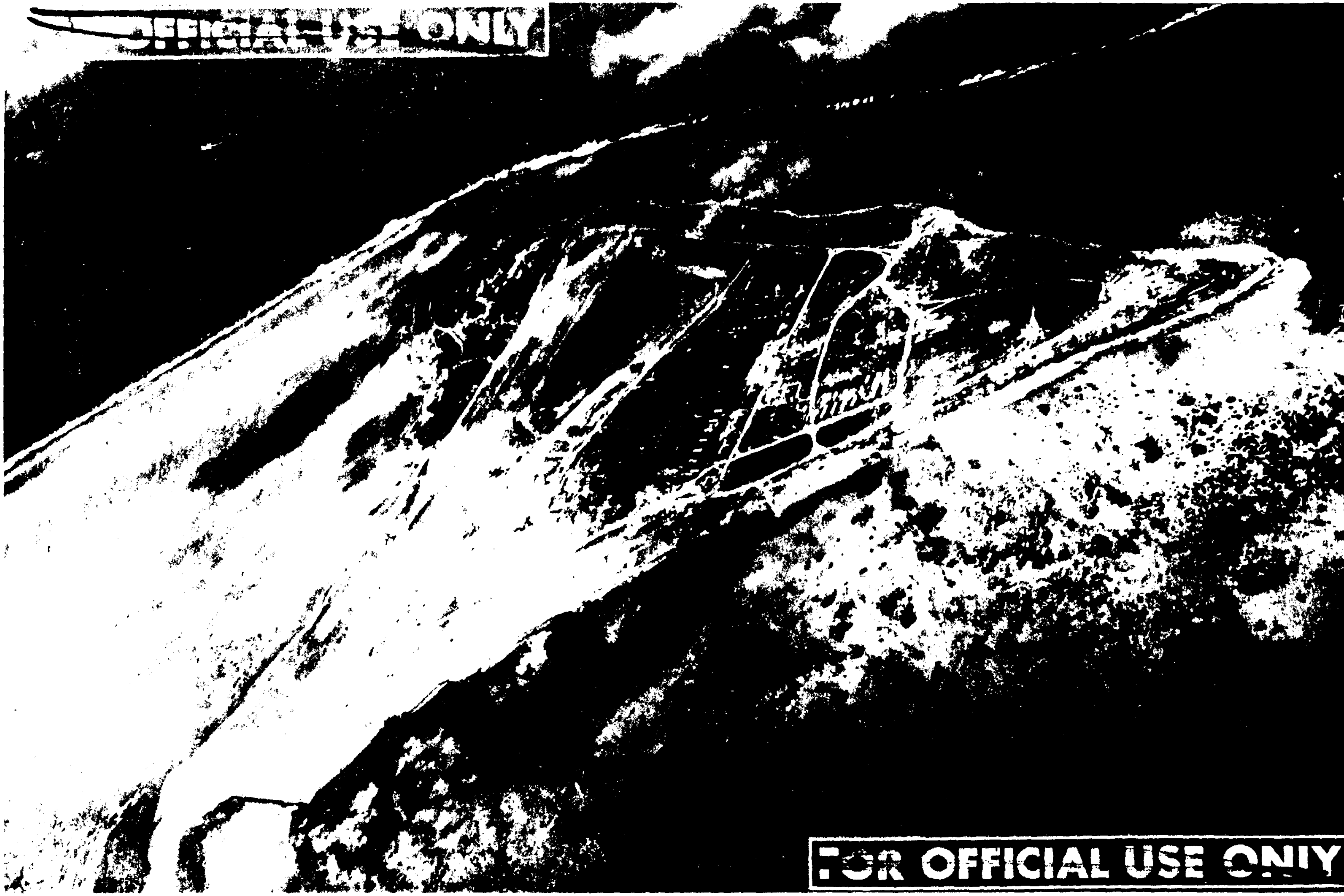
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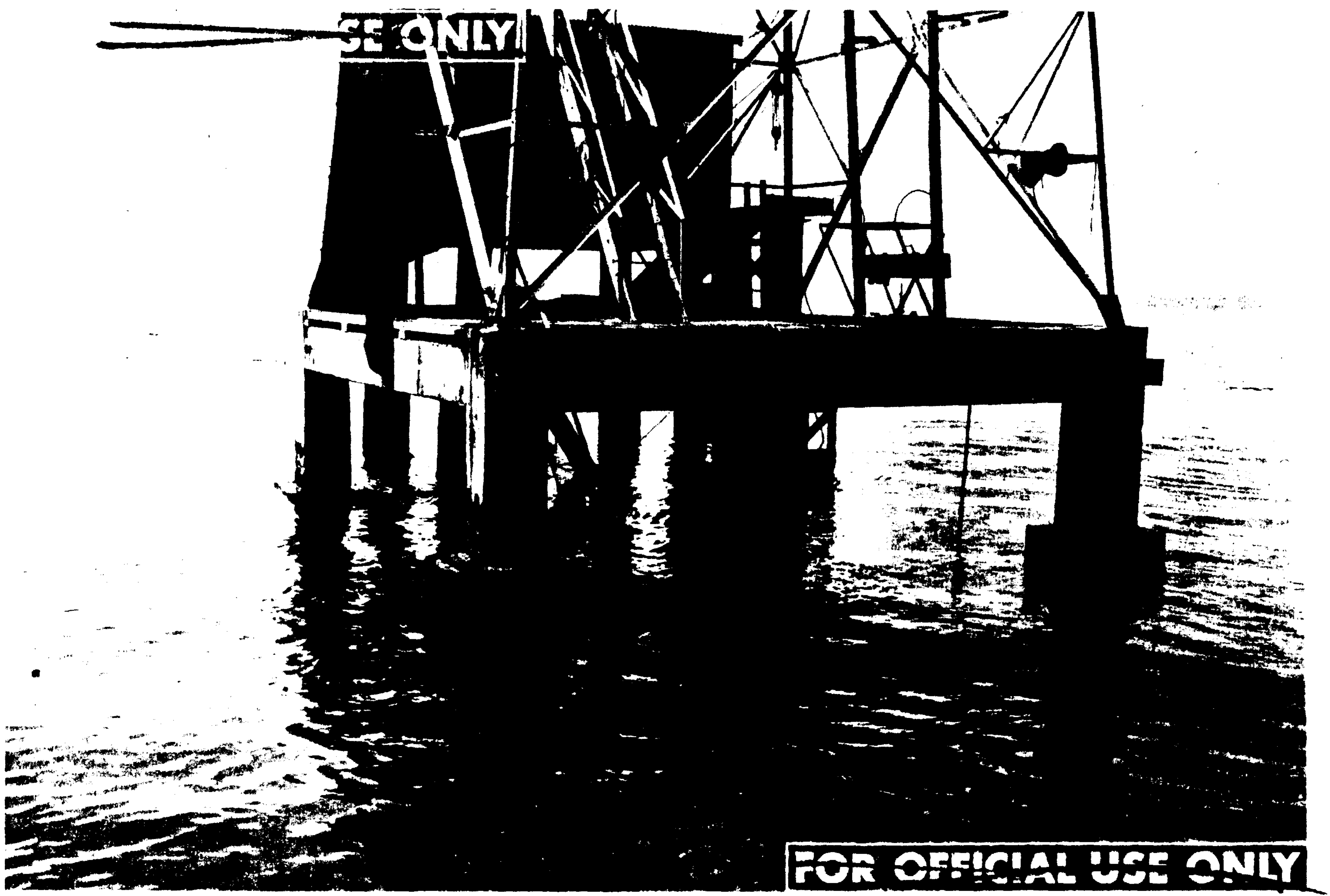
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