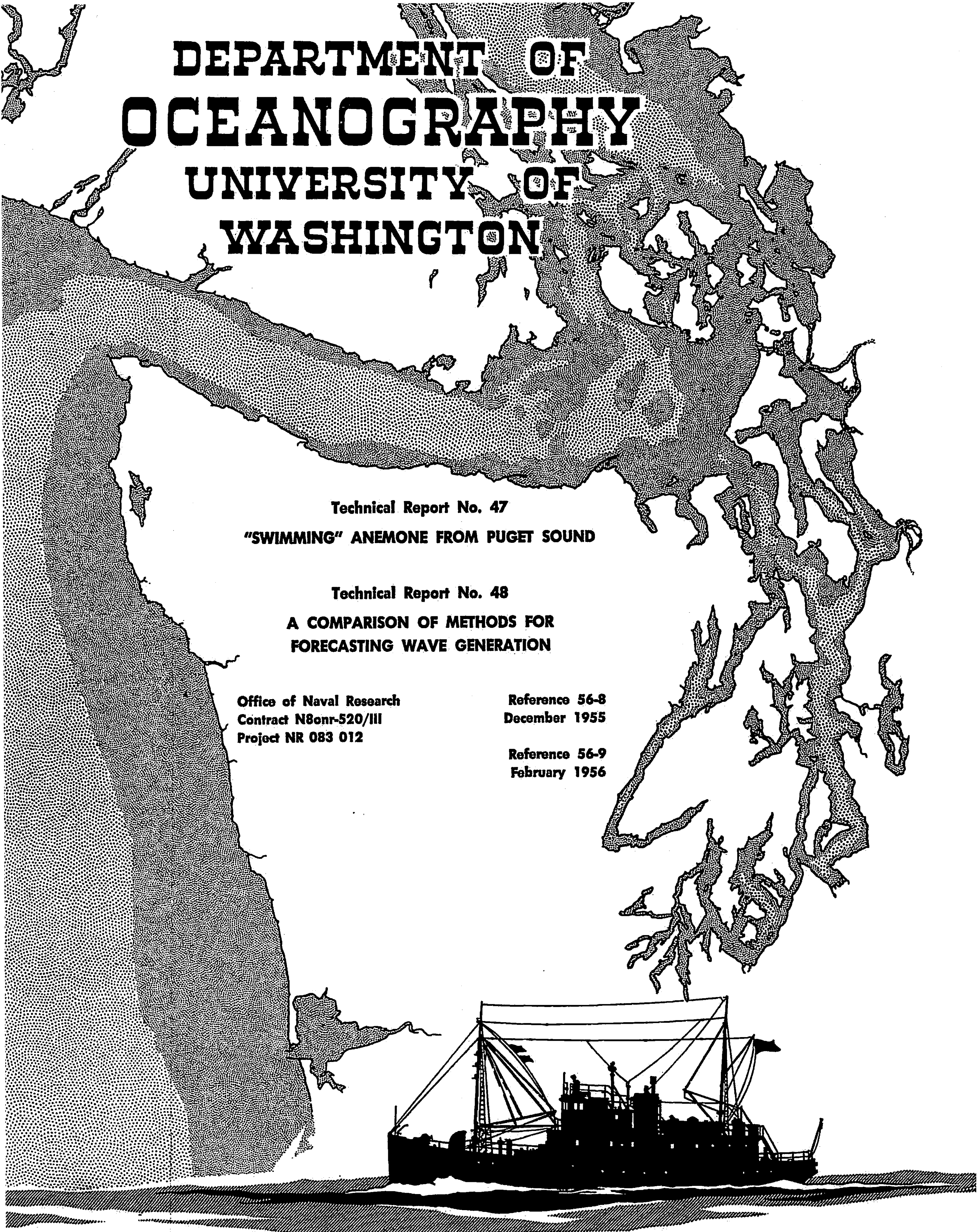

DEPARTMENT OF OCEANOGRAPHY UNIVERSITY OF WASHINGTON

Technical Report No. 47

"SWIMMING" ANEMONE FROM PUGET SOUND

Technical Report No. 48

A COMPARISON OF METHODS FOR FORECASTING WAVE GENERATION

Office of Naval Research
Contract N8onr-520/III
Project NR 083 012

Reference 56-8
December 1955

Reference 56-9
February 1956

SEATTLE 5, WASHINGTON

UNIVERSITY OF WASHINGTON DEPARTMENT OF OCEANOGRAPHY
Seattle, Washington

Technical Report No. 47

"SWIMMING" ANEMONE FROM PUGET SOUND
by
Charles S. Yentsch and Donald C. Pierce

Technical Report No. 48

A COMPARISON OF METHODS FOR FORECASTING WAVE GENERATION
by
Maurice Rattray, Jr. and Wayne V. Burt

Office of Naval Research
Contract N8onr-520/III
Project NR 083 012

Reference 56-8
December 1955

Reference 56-9
February 1956

Clifford A. Barnes
for Richard H. Fleming
Executive Officer

Deep-Sea Research, 1956, Vol. 3, pp. 140 to 144. Pergamon Press Ltd, London.

A comparison of methods for forecasting wave generation‡

MAURICE RATTRAY, JR.* and WAYNE V. BURT†

Abstract—Wave heights and periods in the generating areas of an unusually severe storm and its forerunner were hindcast by three different methods and compared with observations. Wave height agreement was good for all methods. Period agreement was poor ; however, all reported periods fell within the spectral range determined by the Pierson-Neumann-James method. The description of a sea in terms of its spectrum is indicated.

DURING the last war a method was developed by SVERDRUP and MUNK (SVERDRUP and MUNK 1947, U.S. Navy Hyrodraphic Office 1951) for forecasting the heights and periods of wind waves at sea from a knowledge of the wind velocity, its duration and the fetch over which it blew. On the basis of additional data, these relationships were later modified by BRETSCHNEIDER (1952a, b). In both methods the resulting waves were described by a " significant wave height," and a " significant period " defined as the average height and period of the one-third highest waves. More recently, a number of papers (JAMES, 1954; NEUMANN, 1953 ; PIERSON, NEUMANN and JAMES, 1954) have given a method for forecasting ocean waves by means of wave spectra and statistics. Results of LONGUET-HIGGINS (1952) enable calculation of a " significant height " from the derived energy spectrum for comparison with results from other methods. An average " period " of all the waves with crests above and troughs below mean sea level can also be obtained, which, although it has a somewhat different definition than the " significant period ", can be expected to have a similar value.

At present there is a shortage of good observational data with which to compare these forecasting methods under various conditions. It is necessary that comparisons be made in both the generating and decay areas to verify the particular relations applicable to each case. Ideally, the generating area should be studied first, but unfortunately this is generally not the case since waves, especially the larger ones, are most often observed after they have left their generating area. In an investigation of the storm responsible for the loss of the S.S. *Pennsylvania* with all hands on January 9, 1952, at approximately 51°N 141°W, it became apparent that this storm could be used to give excellent comparisons between the different methods for forecasting wave generation in a range of wave heights seldom encountered (up to 48 feet or 14·6 metres). Conditions were extremely favourable for an accurate forecast ; waves were observed by trained, experienced observers at two weather ships in the generating area ; the wind remained between 45 and 55 knots (23·2 and 28·3 metres per second) for 33 hours, with 18 consecutive hours of winds over 50 knots (25·8 metres per second) ; the wind was relatively uniform over a 500-mile (927 kilometres) fetch ; accurate anemometer wind observations were obtained from the two weather observa-

‡Contribution No. 188 from the Department of Oceanography of the University of Washington.
*Department of Oceanography, University of Washington, Seattle, Washington.
†Department of General Science, Oregon State College, Corvallis, Oregon. A part of this work was supported by an Office of Naval Research contract with Oregon State College.

tion ships, the Canadian Weather Ship *Stonetown* occupying Station Papa at 50°N 145°W, and the USCGC *Wachussetts* en route to Station Sugar at 48°N 162°E. Figure 1 shows the storm at the height of its intensity, and includes the location of all weather reporting ships in the area. In particular, notice the favourable position of the USCGC *Wachussetts*, which has just passed through the upwind end of the storm area responsible for the large waves observed at the *Stonetown*.

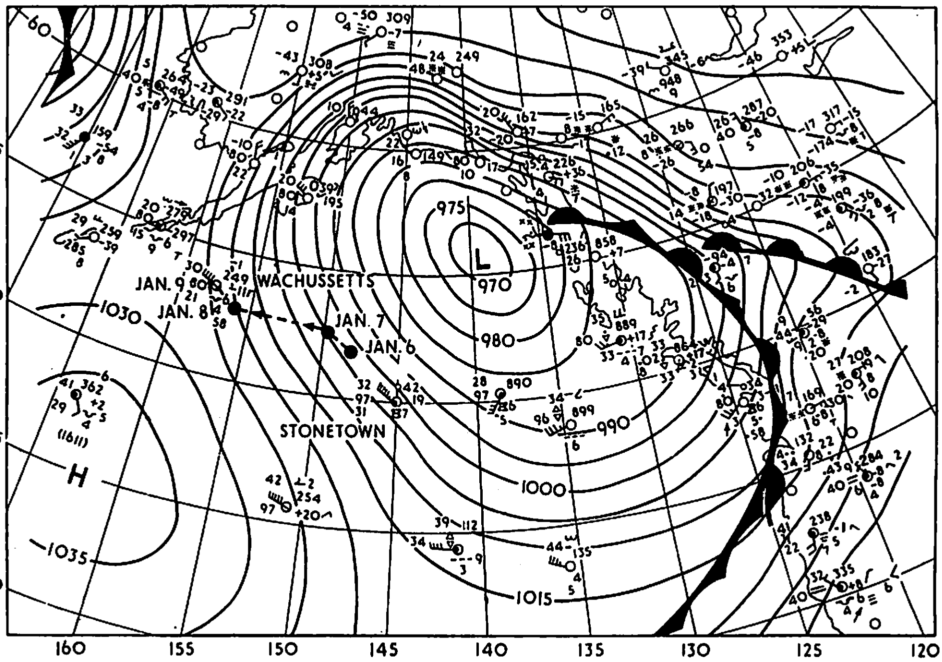

Fig. 1. Northeast Pacific weather map for 1230 Jan. 9, 1952. Noon positions of USCGC *Wachusetts* are shown for Jan. 6, 7, 8 and 9.

This storm was unique in its wave-making ability. A survey of the historical weather maps back to 1922 (U.S. Weather Bureau) showed only one other storm in the Gulf of Alaska capable of maintaining waves of this size for such an extended period of time. Several features combined to create the unusual situation : the track of the storm as it entered the Gulf of Alaska was such that its generating area started at the upwind end of the final fetch, and moved in the wind direction; it intensified in such a position (Fig. 1) that it drew in an unusually cold air mass from the interior of Alaska, causing a flow of very unstable air over the fetch with a maximum sea-air temperature difference at Station Papa of 12°F (6·7°C) ; and, as the storm intensified, it stagnated, permitting this maximum wind to remain over the same fetch.

Wave heights and periods for this storm and its forerunner were calculated independently by the two authors using the Sverdrup-Munk, Bretschneider and Pierson-Neumann-James methods. Synoptic weather maps (U.S. Weather Bureau 1952) for every 6-hour interval were split into regions of different wind velocities, and then a stepwise process used to determine the wave characteristics over the whole fetch at the end of each six hours. The results are shown together with the Station Papa wave and wind observations in Fig. 2.

The overall agreement on wave heights is good. The Sverdrup-Munk, and Bretschneider results are for all practical purposes identical, and are shown by the same curves. They give excellent agreement with the observed values. The small differences can easily be explained by the averaging processes necessarily used to represent the actual wind field. The Pierson-Neumann-James method seems to

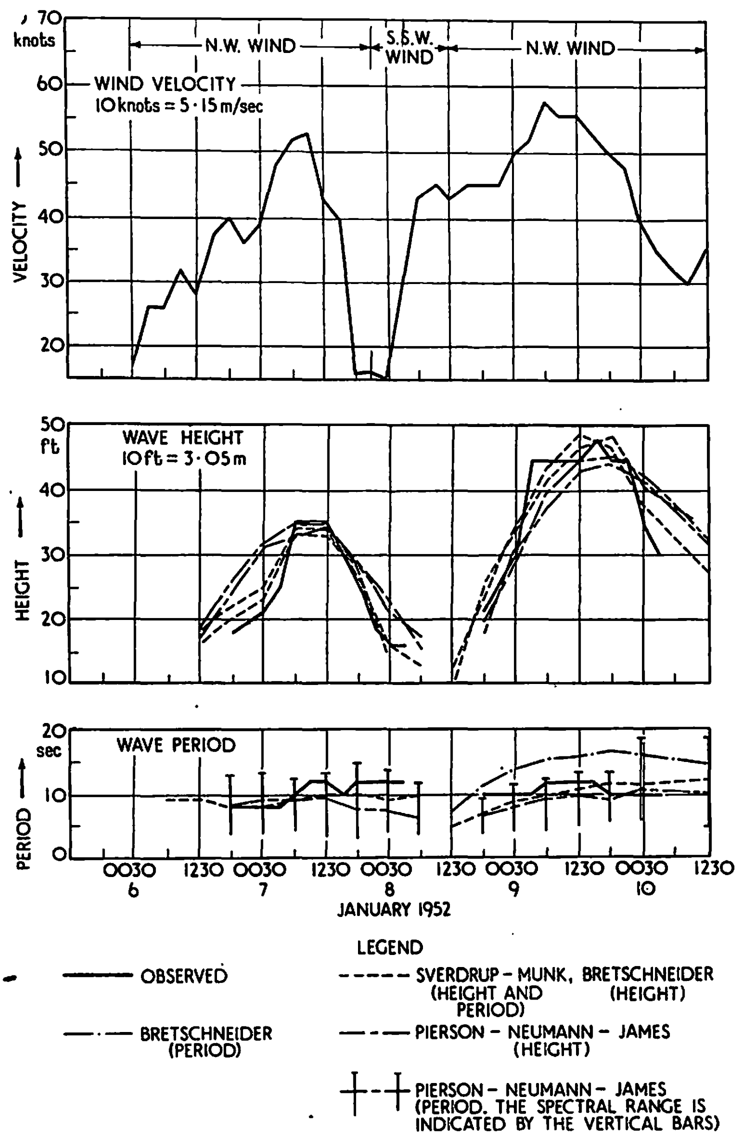

Fig. 2. Comparison of hindcast and observed waves at Ocean Station Papa (50°N., 145°W.).

give some characteristic differences from these particular observations. With wind speeds in the range 30-40 knots, this method gives a faster build-up of wave height than that observed. This is shown from 1230 January 6, to 0030 January 7, while with higher wind speeds it gives a slower build-up as shown, 0030 January 7 to

0630 January 7, and 0030 January 9 to 1230 January 9. The decay calculated by the use of Filter IV modified for gradual decrease of wind and the angular spreading factor agrees quite favourably with the observations and the Sverdrup-Munk theory in the first storm, but not quite so well in the second. In the first storm, Station Papa was near to the edge of the fetch, which accounted for the more rapid decay. The weather ship ceased taking three-hourly wave observations at 0330 on January 10 due to the necessity of carrying out rescue operations, and thus further decay cannot be compared for this storm.

The agreement between calculated and observed periods is not particularly good. The Sverdrup-Munk values give best agreement, generally within ± 2 seconds, but their variation from the observed values follows no fixed pattern. The Bretschneider values are consistently about 60% higher than those given by Sverdrup-Munk. The Pierson-Neumann-James average " periods " are generally comparable, but somewhat less then the Sverdrup-Munk " significant periods " as might be expected. In all cases the observed " significant period " fell within the spectral range of periods given by their method.

This comparison between wave-forecasting methods shows that in the generating area either the Sverdrup-Munk or Bretschneider results gives a result closely comparable to this set of observations. With a knowledge of the " significant height " most other height data can be calculated. The Pierson-Neumann-James heights are also good, but are not in as close agreement with this set of observations as the forecast heights obtained by the other two methods. The overall agreement on periods is not very good. The Sverdrup-Munk theory gives a rough agreement which is satisfactory for some purposes, but in order to describe the sea more completely, it is evidently necessary to obtain information on its spectrum. Unfortunately observational data available were not suited to determine the applicability of the Pierson-Neumann-James procedure in this regard.

ACKNOWLEDGEMENTS

Attention was drawn to this storm by Messrs. Stanley B. Long, C. Calvert Knudsen and Edward C. Biele of Bogle, Bogle and Gates in connection with the loss of the S.S. *Pennsylvania*. The investigation of the wave characteristics in the storm by use of H. O. Publ. No. 604 was supported by Bogle, Bogle and Gates. The meteorological features of the investigation used in this paper were obtained from Dr. Robert G. Fleagle and Mr. Edwin F. Danielson.

REFERENCES

Bretschneider, C. L. (1952a), The generation and decay of wind waves in deep water. *Trans. Amer. Geophys. Union*, **33** (3), 381-389.

Bretschneider, C. L. (1952b), Revised wave forecasting relationships. *Proc. Second Conf., Coastal Engineering*, 1-5.

James, R. W. (1954), An example of a wave forecast based on energy spectrum methods. *Trans. Amer. Geophys. Union*, **35** (1), 153-160.

Longuet-Higgins, M. S. (1952), On the statistical distribution of the heights of sea waves. *J. Mar. Res.*, **11** (3), 245-266.

Neumann, Gerhard (1953), On ocean wave spectra and a new method of forecasting wind-generated sea. *Beach Erosion Board, Tech. Mem.* No. 43, 42 pp.

Pierson, W. J. Jr., Neumann, Gerhard and James, R. W. (1954), Practical methods for observing and forecasting ocean waves by means of wave spectra and statistics. New York University, College of Engineering, Res. Div., 322 pp.

SVERDRUP, H. U. and MUNK, W. H. (1947), Wind, sea and swell : theory of relations for forecasting. *H. O. Pub.* No. 601, 44 pp.
U.S. Navy Hydrographic Office (1951), Techniques for forecasting wind waves and swell. *H. O. Pub.* No. 604, 38 pp.
U.S. Weather Bureau (1952), Synoptic Weather Maps for January, 1952, Seattle, Washington.
U.S. Weather Bureau, Historical Weather Maps, Daily Synoptic Series, Northern Hemisphere, Sea Level, Washington, D.C.

Printed in Great Britain by The Salisbury Press Ltd., Publicity House, Wilton Road, Salisbury, Wilts. (95252)

Department of Oceanography
University of Washington

UNCLASSIFIED RECHNICAL REPORT DISTRIBUTION LIST

3 Chief of Naval Research
Department of Navy
Washington 25, D.C.
Attn: Code 446 (1)
463 (1)
466 (1)

1 Commanding Officer
Office of Naval Research Branch Office
346 Broadway
New York 13, New York

1 Commanding Officer
Office of Naval Research Branch Office
John Crerar Library Building
86 East Randolph Street
Chicago 1, Illinois

1 Commanding Officer
Office of Naval Research Branch Office
1030 East Green Street
Pasadena 1, California

1 Commanding Officer
Office of Naval Research Branch Office
1000 Geary Street
San Francisco 9, California

3 Commanding Officer
Office of Naval Research Branch Office
Navy #100, Fleet Post Office
New York, New York

2 Office of Naval Research
Geophysics Branch
Washington 25, D.C.
Attn: 416

1 Office of Naval Research Resident
Representative
University of Washington
Seattle 5, Washington

2 Chief, Bureau of Aeronautics
Department of the Navy
Washington 25, D.C.
Attn: PH 41 (1)
AY -3 (1)

3 Chief, Bureau of Ships
Department of the Navy
Washington 25, D.C.
Attn: Code 312 (1)
320 (1)
845 (1)

1 Chief, Bureau of Yards and Docks
Department of the Navy
Washington 25, D.C.

1 Chief of Naval Operations
Department of the Navy
Washington 25, D.C.
Attn: Op-533D

1 Commander, Naval Ordnance
Laboratory, White Oak
Silver Spring 19, Maryland

1 Commanding Officer
U. S. Navy Mine Countermeasure Station
Panama City, Florida

1 Commanding Officer
U. S. Navy Underwater Sound Laboratory
New London, Connecticut

2 Department of Aerology
U.S. Naval Post Graduate School
Monterey, California

3 Director, U.S. Navy Electronics Labora'
San Diego 52, California
Attn: 2230

6 Director, Naval Research Laboratory
Washington 25, D.C.
Attn: Technical Services
Information Officer

8 Hydrographer
U.S. Navy Hydrographic Office
Washington 25, D.C.
Attn: Division of Oceanography

10/20/54 (Rev. 6/21/56)

1 Project Arowa
U. S. Naval Air Station
Building R-48
Norfolk,Virginia

1 Superintendent, U.S. Naval Acedemy
Annapolis, Maryland

5 Armed Services Technical Information Center
Documents Service Center
Knott Building
Dayton 2, Ohio

1 Assistant Secretary of Defense for Research and Development
Pentagon Building
Washington 25, D.C.
Attn: Committee on General Sciences

1 Chief, Air Weather Service
Department of the Air Force
Washington 25, D.C.

1 Chief, Armed Forces Special Weapons Project
P.O. Box 2610
Washington D.C.

2 Chief, U.S. Weather Bureau
2400 M Street N.W.
Washington 25, D.C.
Attn: Dr. H. Wexler

1 Commandant (OAO)
U. S. Coast Guard
Department of the Treasury
Washington 25, D.C.

1 Commanding General
Research and Development Division
Department of the Air Force
Washington 25, D.C.

1 Commanding General
Research and Development Division
Department of the Army
Washington 25, D.C.

1 Commanding Officer
Cambridge Field Station
230 Albany Street
Cambridge 30, Massachusetts
Attn: CRHSL

1 Director, U.S. Coast & Geodetic Survey
Department of Commerce
Washington 25, D.C.

2 Director, U.S Fish & Wildlife Service
Department of the Interior
Washington 25, D.C.
Attn: Dr. L. A. Walford

1 National Research Council
2101 Constitution Avenue
Washington 25, D.C
Attn: Committee on Undersea Warfare

1 Office of Technical Services
Department of Commerce
Washington 25, D.C.

1 U.S. Army Beach Erosion Board
5201 Little Falls Road N.W.
Washington 16, D.C.

2 U.S. Fish & Wildlife Service
Pacific Oceanic Fishery Investigation
P.O. Box 3830
Honolulu, T.H.
Attn: Librarian (1)
T. S. Austin(1)

1 U.S. Fish & Wildlife Service
Scripps Institution of Oceanography
La Jolla, California

1 U.S. Fish & Wildlife Service
Woods Hole
Massachusetts

1 U.S. Waterways Experiment Station
Vicksburg, Mississippi

1 Allen Hancock Foundation
University of Southern California
Los Angelea 7, California

1 Bingham Oceanographic Laboratories
Yale University
New Haven, Connecticut

1 Department of Conservation
Cornell University
Ithaca, New York
Attn: Dr. J. C. Ayers

1 Department of Engineering
University of California
Berkeley, California

1 Department of Meteorology & Oceanography
College of Engineering
New York University
University Heights, New York 53, N.Y.
Attn: Dr. W. J. Pierson

1 Department of Zoology
Rutgers University
New Brunswick, New Jersey
Attn: Dr. H. K. Hasking

1 Director, Bermuda Biological Station for Research
St. George's, Bermuda

1 Director, Chesapeake Bay Institute
Box 42 R.F.D. #2
Annapolis, Maryland

1 Director, Hawaii Marine Laboratory
University of Hawaii
Honolulu, T.H.

1 Director, Lamont Geological Observatory
Torrey Cliff
Palisades, New York

1 Director, Marine Laboratory
University of Miami
Coral Gables, Florida

1 Director, Narragansett Marine Laboratory
Kingston, Rhode Island

1 Director, National Institute of Oceanography
Wormley, Near Godalming
Surry, England

2 Director, Scripps Institution of Oceanography
La Jolla, California

2 Director, Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

1 Dr. Wayne V. Burt
Oregon State College
Corvallis, Oregon

1 Head, Department of Oceanography
Texas A & M College
College Station, Texas

1 Hudson Laboratories
Columbia University
145 Palisades Street
Dobbs Ferry, New York

1 Institute of Oceanography
Univeristy of British Columbia
Vancouver, British Columbia, Canada

2 Project Officer
Laboratory of Oceanography
Woods Hole, Massachusetts