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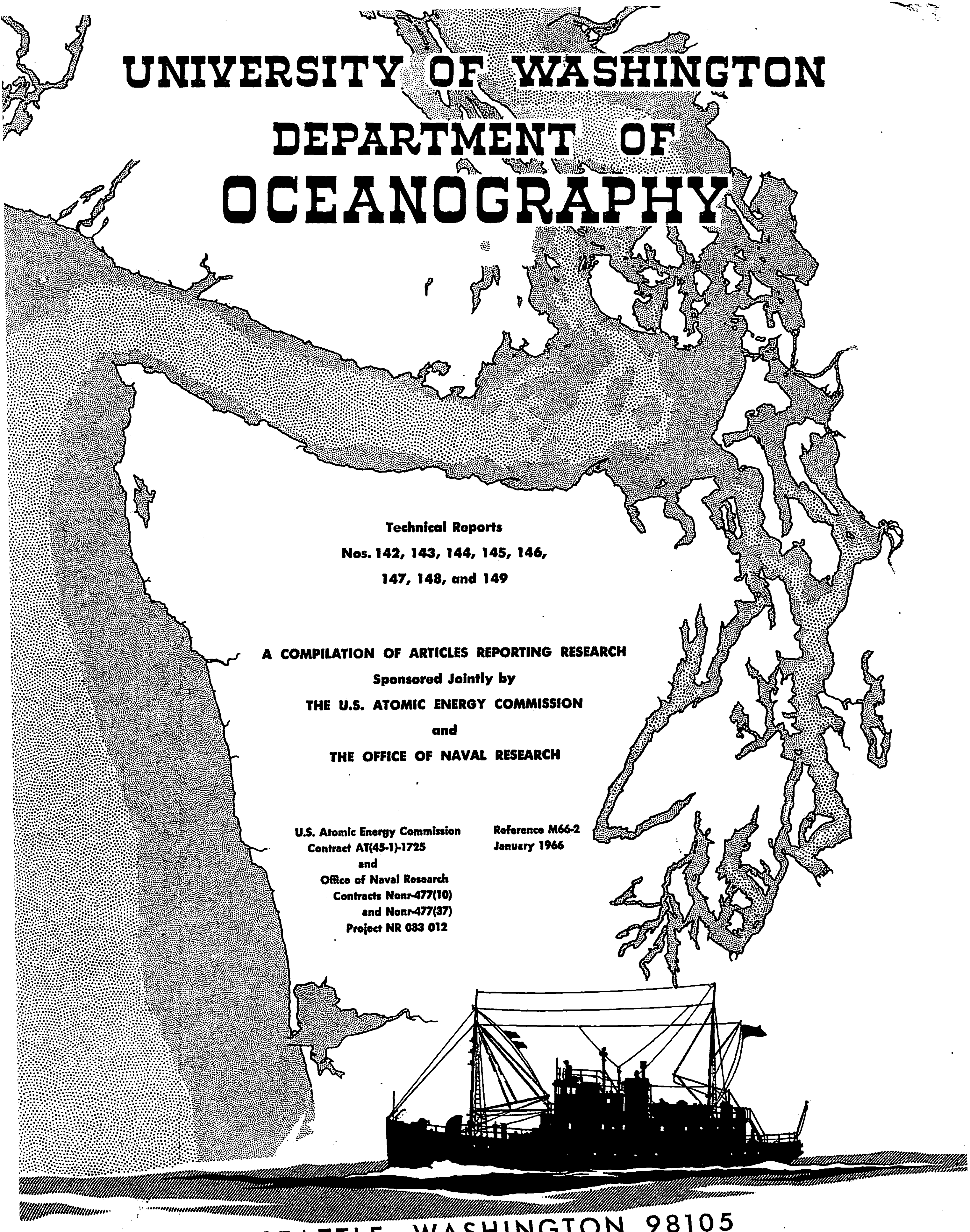

Technical Reports
Nos. 142, 143, 144, 145, 146,
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RICHARD H. FLEMING
Chairman

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Clifford A. Barnes
CLIFFORD A. BARNES
Principal Investigator

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Technical Report No. 142

BIO-LITHOLOGY OF NORTHEAST PACIFIC SURFACE SEDIMENTS, by Y. R. Nayudu and B. J. Enbysk. Marine Geology, 2(4):310-342. 1964. (AEC: RLO-1725-42)

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GRAPHIC REPRESENTATION OF THE SALINITY DISTRIBUTION NEAR THE COLUMBIA RIVER MOUTH, by Betty-Ann Morse and Noel McGary. Pp. 923-942 in Ocean Science and Ocean Engineering 1965, vol. 2. Marine Technology Society, Washington, D. C. 1965. (AEC: RLO-1725-3)

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UNIVERSITY OF WASHINGTON
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TECHNICAL REPORT NO. 148

GRAPHIC REPRESENTATION OF THE SALINITY DISTRIBUTION NEAR THE COLUMBIA RIVER MOUTH

Betty-Ann Morse and Noel McGary

ABSTRACT

The presence of Columbia River water in the northeast Pacific Ocean is shown by reduction in salinity which property distinguishes the river effluent from the coastal belt of quite low salinity water as well as from the more saline offshore ocean waters. The 32.5°/oo isohaline surface is chosen as a convenient and practical isopleth for demarking Columbia River effluent from ambient water in both area and depth during various times of the year.

The Columbia River discharge normally reaches a maximum during June and a minimum in September. Salinity distributions are shown for these terminal months of a period during which the detectable accumulation of Columbia River water has steadily increased to cover an area of approximately 400,000 sq km. Detailed salinity data near the river mouth for the two months show a movement of river water to the north and close association of this movement with the local tidal curve.

INTRODUCTION

Most cruises in this investigation to determine the distribution of the Columbia River water in the northeast Pacific Ocean have been concerned with macro-scale phenomena in an area of 420,000 sq km extending from the Strait of Juan de Fuca 700 km south past the California border and 600 km from the coast west to 132° W. Each cruise covered a time interval of two to three weeks. Other cruises have been designed to give detailed structure in localized areas, particularly near the river mouth. Typical conditions found in June and September during both large and small scale surveys will be discussed.

BACKGROUND INFORMATION

The area of observations (Fig. 1) extends from 48° 15' N south 550 km to 43° N, and 450 km west from the Washington-Oregon coast to 130° W. In late May and early June 1963, over 200 stations were occupied by the University of Washington's R. V. BROWN BEAR and the C. N. A. V. OSHAWA. In September 1963, the BROWN BEAR made observations at 145 stations between 47° N and 43° 15' N. In addition, repeated oceanographic casts were made in the area 10 by 20 km near the Columbia River mouth in June and September 1964. Several internal boundaries between the river discharge plume and ambient waters were sighted during these cruises. As an example, in February 1965, a well-defined interface was seen (Fig. 2) 16 km west of the Columbia River mouth during an ebb tide and the Columbia River in flood.

The 1963 discharge curve (Fig. 3), similar to the average curve, shows the Columbia River contribution at a maximum during June and a minimum in September. These are the two periods to be discussed.

The distribution of identifiable river water at sea will be influenced in part by winds and river discharge rates. Wind

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dominance patterns (Fig. 4) averaged over a three-year period from 1961 to 1963 indicate similar winds in June and part of September. For both periods, 80 to 90% of the winds average less than 20 kt. During June, 60% of the winds blow from the north (290 to 030°) and 20% from the southeast to southwest compared with 42% northerly and 35% southerly in September. The wider range of direction in September is caused by the shift to the southerly winds which are dominant in the winter. In the southern section, winds are higher and more predominantly from the north. Of these two factors, wind and discharge rate, the latter appears to have more effect on the subject salinity distributions than the former.

The physical characteristics of the ambient water structure have been discussed by Budinger, Coachman and Barnes (1964). Salinity was chosen as the water property most suitable for graphic interpolation in this area because it is an easily determined conservative variable that distinguishes river effluent from ocean water. This discussion will be limited to the water above the halocline which in this area is normally less than 170 m. In the deeper waters below 170 to 200 m, the salinity slowly increases with depth from 33.8 to 34.4°/oo at 1000 m; then to 34.67°/oo at 4000 m (Dodimead, Favorite and Hirano, 1963).

REPRESENTATIVE ISOHALINE SURFACE

Budinger, Coachman and Barnes have suggested the 32.5°/oo isohaline surface as a convenient feature to show the horizontal and vertical extent of the Columbia River effluent. Fig. 5 shows the locations of the intersection of this 32.5°/oo isohaline with the sea surface at various times from January to October. This isohaline moves offshore and to the south as the season progresses. From early winter to late spring, it extends from west to east at about 47° N, turning south at a distance of 40 to 200 km from the coast. Lower salinities occur towards the north and inshore. The curve for March illustrates an inshore accumulation of low salinity water from winter runoff and evidence of less saline water to the south about 50 km offshore. During late March and early April, a well-defined lobe develops at 46° N, 160 km off and slightly southwest of the river mouth, and extends 100 km farther west. Coastal runoff south of the river is insufficient to obliterate the areas of higher salinity water inshore.

The maximum Columbia discharge in May and June and a shift in the dominant winds from southerly to northerly and northwesterly contribute to the configurations for the following two months. By late June, the effluent has appeared south of 42° N. The northwest portion of the index isohaline then occurs at 45° 30' N, 150 km south of the May-June position. During the summer months, spreading of the mixed water over a large area continues as evidenced by the September-October location of the boundary. Areas of higher salinity water, results of upwelling, occur south of the river mouth. The surface water becomes well-mixed during the fall storms as the winds shift again to southerly. By November (not shown) the 32.5°/oo isohaline has receded to 43° 30' N and 128° W.

SALINITY DISTRIBUTION

The surface salinity distributions for June and September 1963 are shown in Fig. 6. Water with salinity of less than 29°/oo is found from 50 to 120 km southwest from the river mouth in June. The steady, low speed winds from the northwest in June help to maintain the lower salinity patches found to the southwest. During the September period, most of the water of salinity less than 29°/oo is located in an area within 40 km west and 75 km north from the river mouth. The northerly position is attributed in part to the Coriolis effect and to the lack of a steady wind system for the period preceding the observations. The smaller area of low salinity water is in part due to the reduced river discharge rate.

The salinity distributions at 10 m (Fig. 7) are similar to those at the surface for the respective seasons. Several patches of water of 29 to 31°/oo salinity are found in June at varying distances from the river mouth. Along the coast in September, several areas of high salinity water contributed by upwelling are present at 43° and 45° 30' N.

Vertical distributions of salinity from 0 to 150 m depth for June and September are shown in Fig. 8. In June, along the depicted profile which extends due west from the river mouth, the water is of low salinity and stratified in the upper 5 m. At the surface, water of 29 to 30°/oo is interspersed with that of 30 to 31°/oo. In September, for a section about 20 km south of the mouth, only a small amount of water of less than 31°/oo salinity is found; it extends to 5 m depth between 15 and 40 km offshore. In both periods, the 33°/oo isohaline is found offshore at a depth of 70 to 100 m but rises to 25 m near the coast. Farther offshore, the structure of the upper 20 m is much more nearly unifrom in September than in June, as would be expected from continued wind mixing and reduction in river flow during the intervening period.

Complete descriptions of the movement and mixing processes in this area require continuing and closely spaced and timed measurements of water characteristics at many locations. It is impractical to obtain this information over any sizeable area. However, in June 1964, water characteristics were measured at close intervals in both space and time in an active mixing area within 35 km of the river mouth. Five locations (Fig. 9) were spaced for maximum areal coverage and sampled during all stages of the tide, a predictable variable known to affect both water movement and mixing. The locations are in a triangular pattern which can be extended to an hexagonal grid pattern with stations separated by 10 km in distance and one hour in time.

These locations were sampled over a 29-hour period in June and a 51-hour period in September. The discharge rate at the Columbia River mouth in June averaged 19,000 cu m per sec as compared with 3,400 cu m per sec in September. In June, the winds were from the north-northwest at 18 kt or less. During the September observations, the light winds from variable directions of the previous 8-hour period increased to southerly winds at speeds of 20 kt. The tidal range was 1 m in June and 2.1 m in September.

For each location, salinity data were plotted as functions of depth and time. These graphs were superimposed upon a tidal curve for the same period at the North Jetty of the river mouth. Synoptic plan views were constructed of all five locations showing salinity distribution at the surface, 3,6 and 10 m. The interpolated salinity patterns in Fig. 10 illustrate the high and low tide conditions at the surface and 6 m for June and September. High salinity water is found consistently inshore south of the river mouth and is most saline in June at 6 m. The isohalines align southwest on the southern side in June and east to west in September. At the time of low tide in June, water of less than 26°/oo salinity was found at all stations and was deeper than 6 m at three locations. The patterns during the low tide again emphasize the difference in river outflow for these seasons. In a high discharge period, the surface salinity remains less than 26°/oo over part of the area even at high tide following the flood. The river water is found predominantly from directly off to northwest of the river mouth.

Salinity profiles for a 28-hour period in September, which are illustrated in Fig. 11, show close association with the tidal curve. The presence of low salinity water in the upper 5 m can be seen at the northern locations, W, X and V. The salinity of the water at location Z reached a maximum at high tide. The wind appeared to have little effect on the salinity distributions although the lowering of the salinity as shown by the slight depression of the isopleths at W, X and V near the end of the period may reflect the increase in southerly winds and consequent movement of more river water to the north. Below 5 m at all locations, the water structure is quite uniform. This treatment of the data defines the bottom interface of the river water as it enters the ocean, and the profiles show a rapid transition zone with large, homogeneous water masses below a highly stratified, rapidly changing regime.

SUMMARY AND FUTURE WORK

Salinity data from cruises in the Columbia River effluent area have been used to establish locations of the 32.5°/oo isohaline surfaces which distinguish the river effluent from ambient coastal and oceanic water. The near surface waters are less stratified during low discharge in September than during high discharge in June. In both June and September much of the river water is found to the north of the river mouth and changes in water structure are closely associated with local tides.

Plans are being drawn for aerial surveys to observe the water movement near the river mouth and for additional ship surveys for more detailed measurements of water characteristics.

ACKNOWLEDGMENTS

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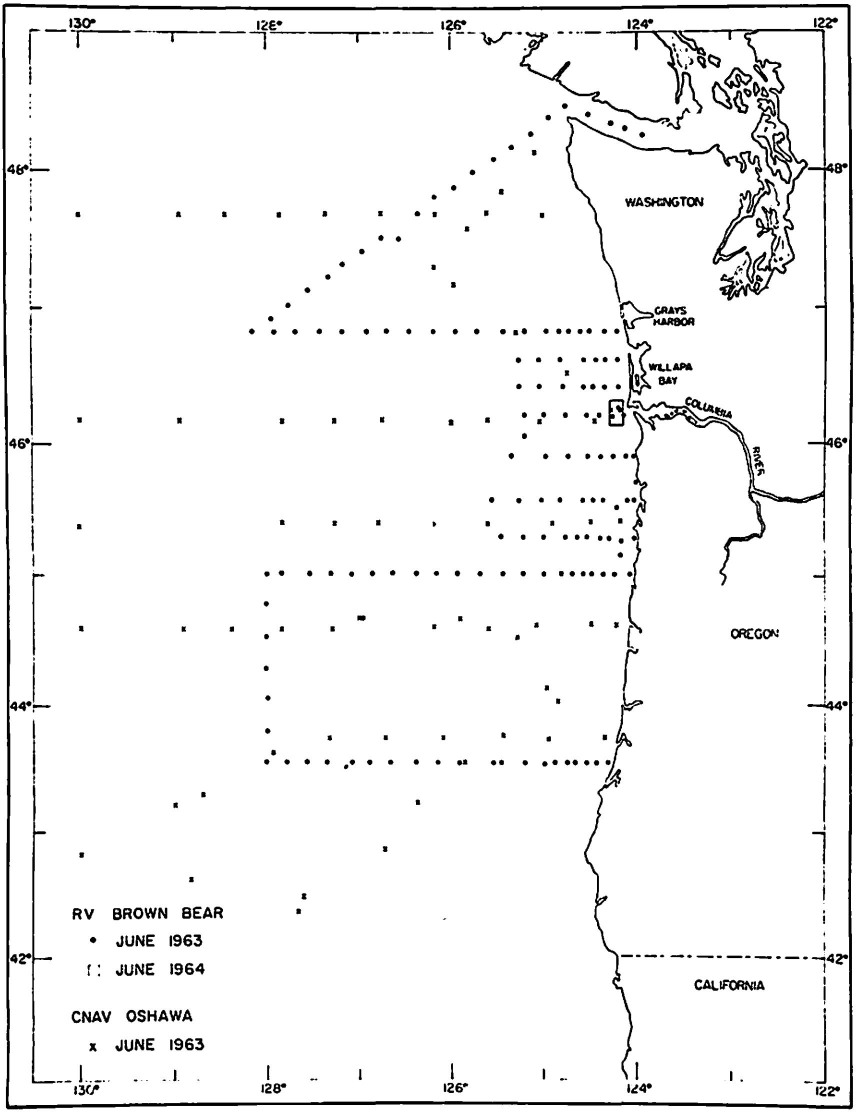

Figure 1a. Locations of observations.

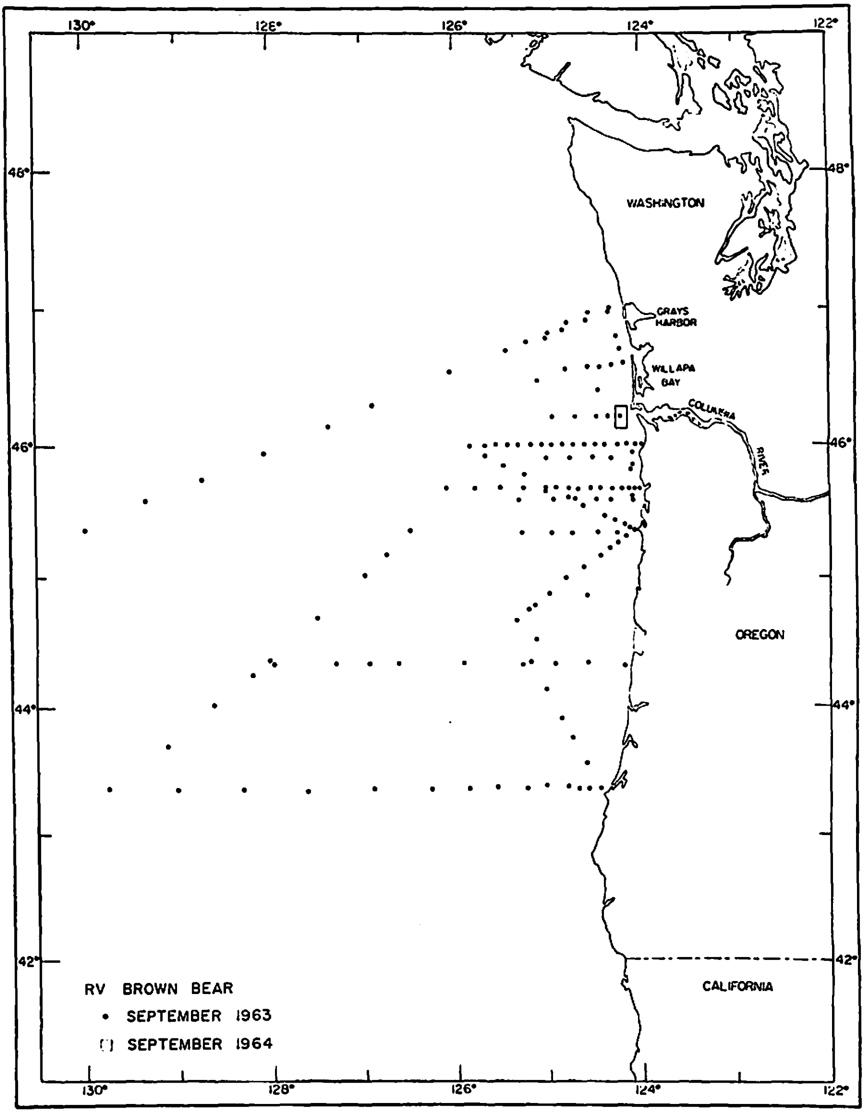

Figure 1b. Locations of observations.

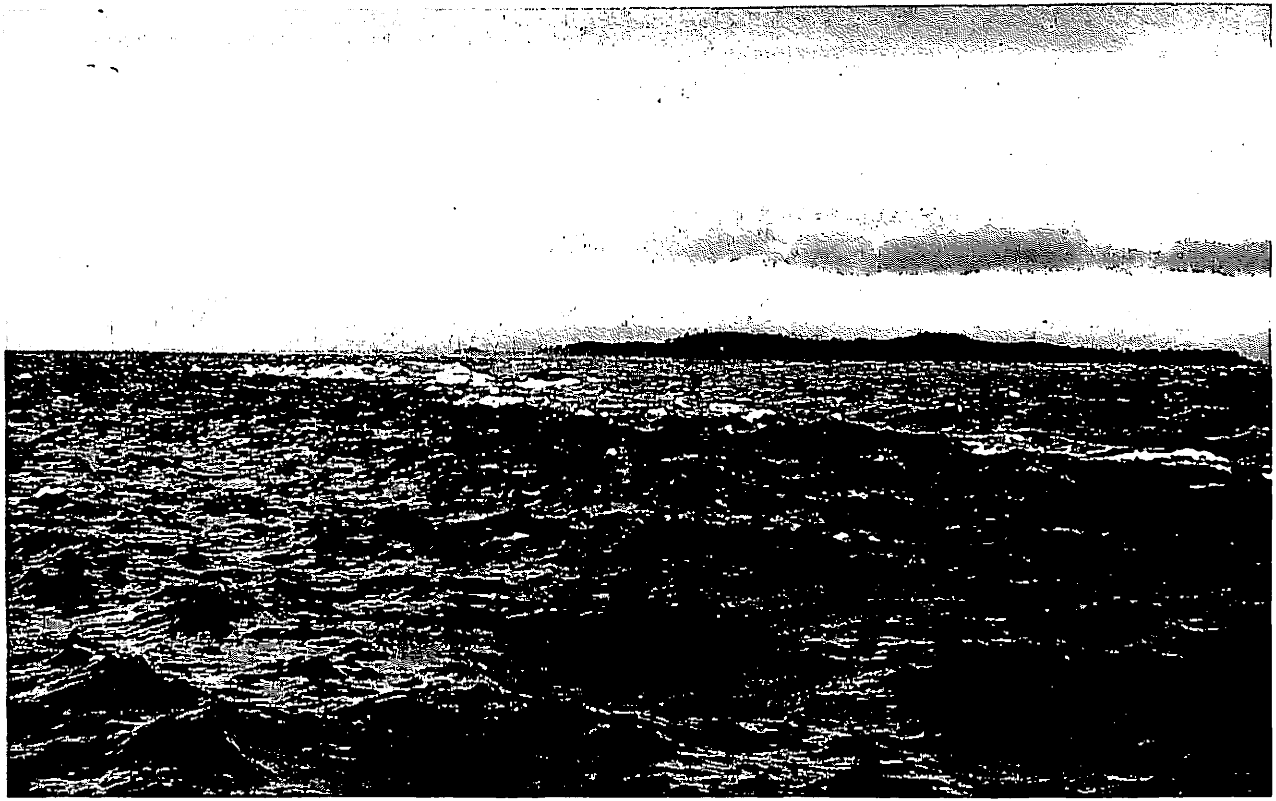

Figure 2. Front near Columbia River, February 1965.

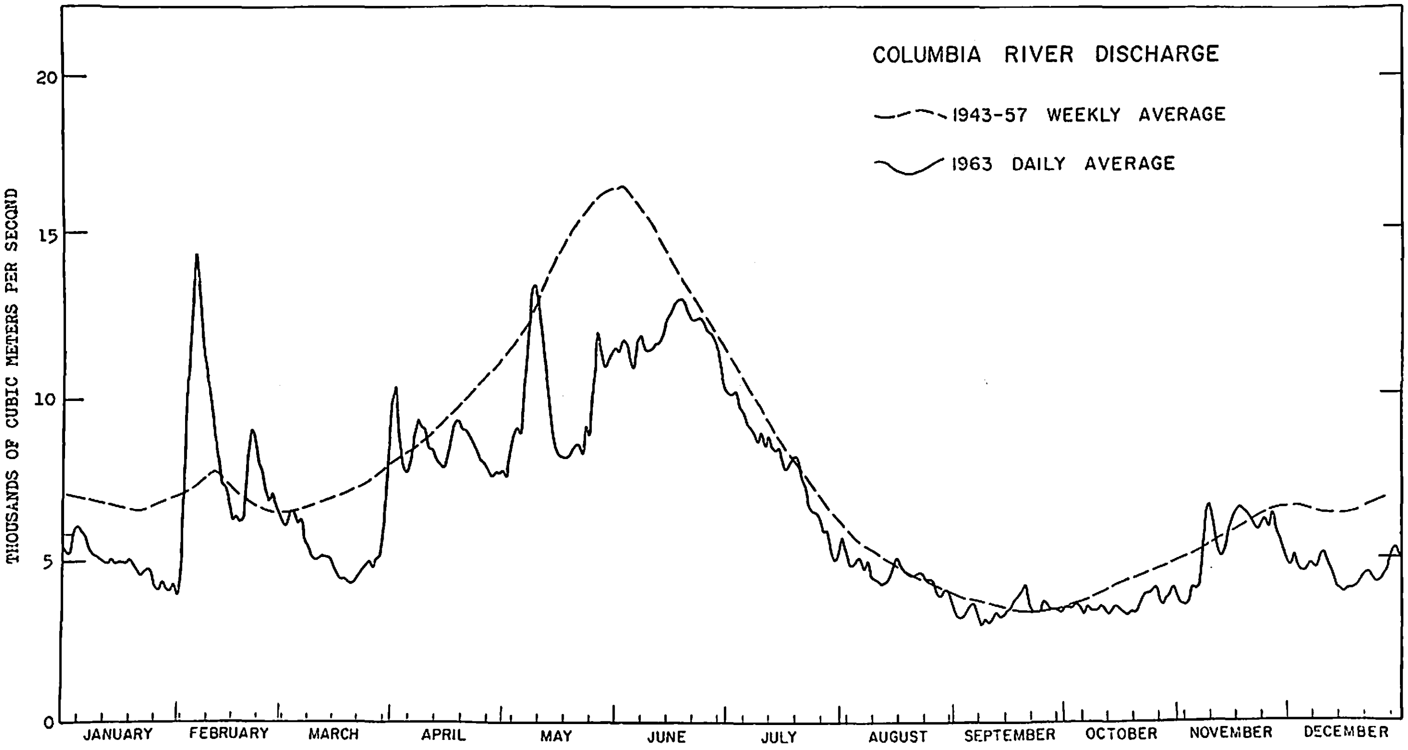

Figure 3. Daily discharge from Columbia River, 1963.

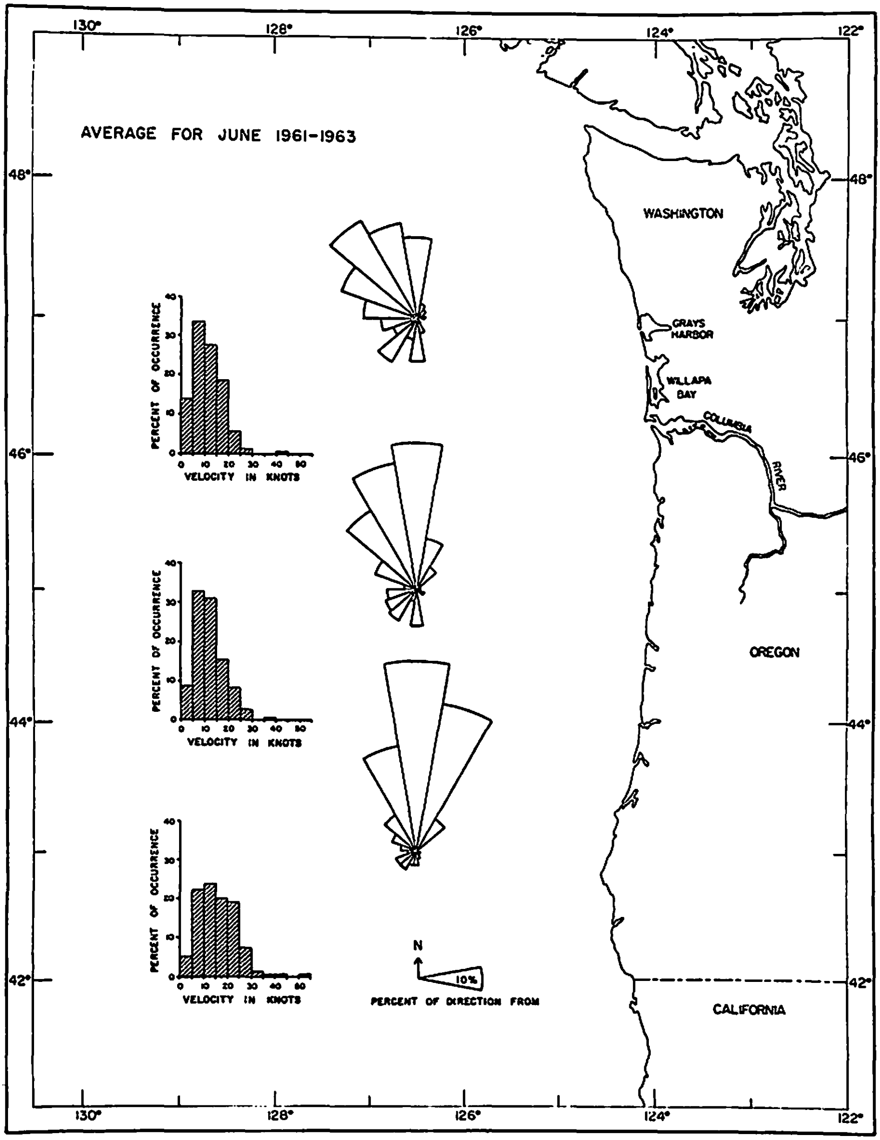

Figure 4a. Calculated mean winds for June, 1961 - 1963.

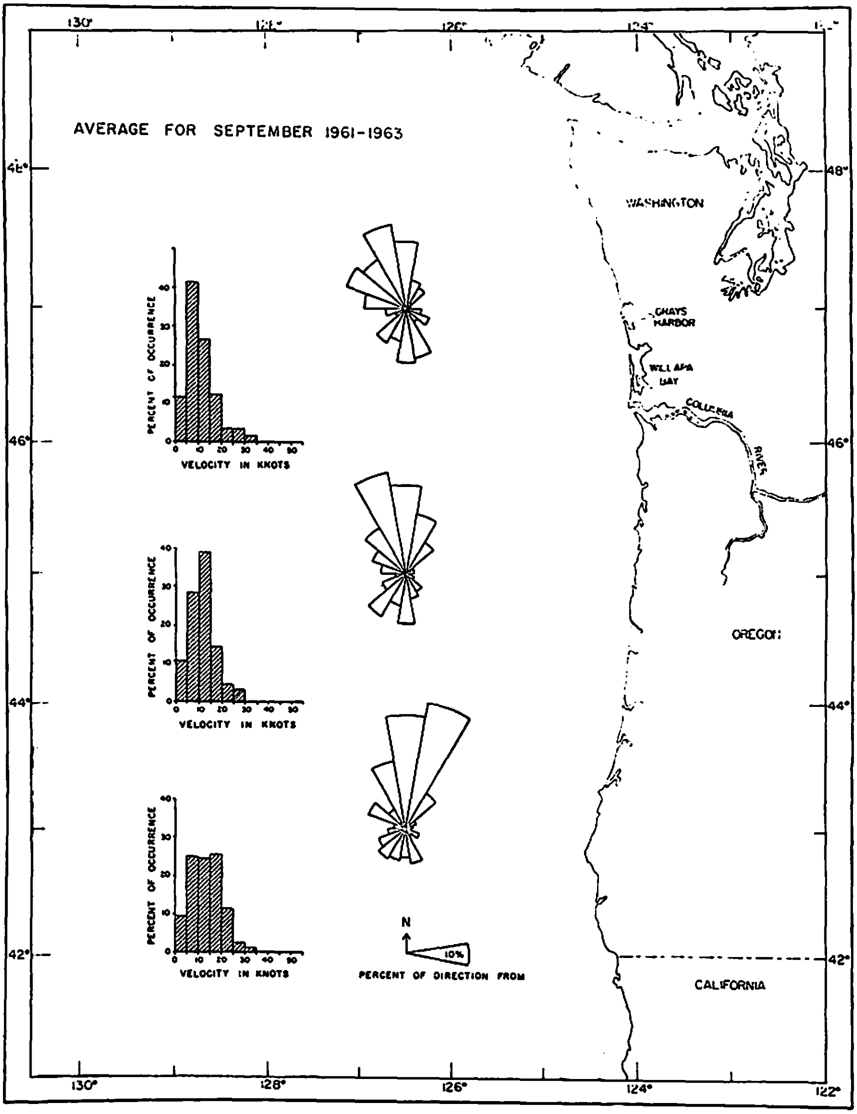

Figure 4b. Calculated mean winds for September, 1961 - 1963.

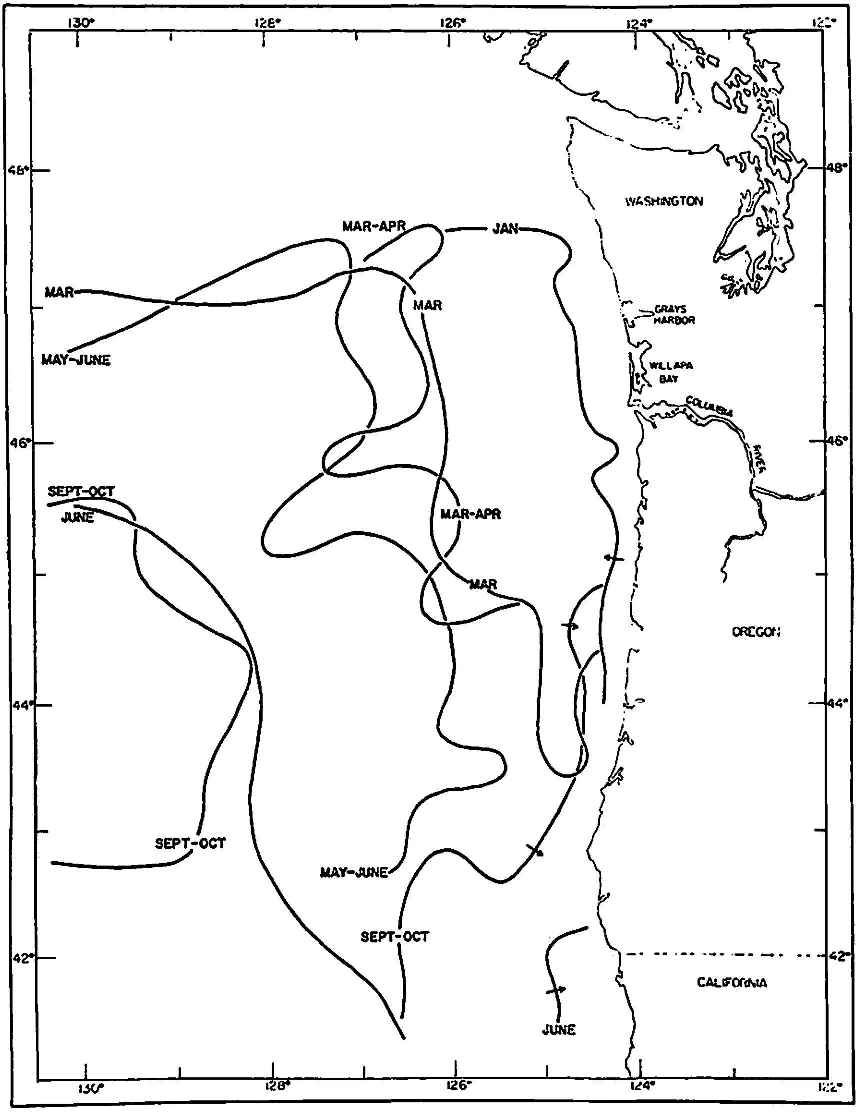

Figure 5. Locations of 32.5 °/oo isohaline.

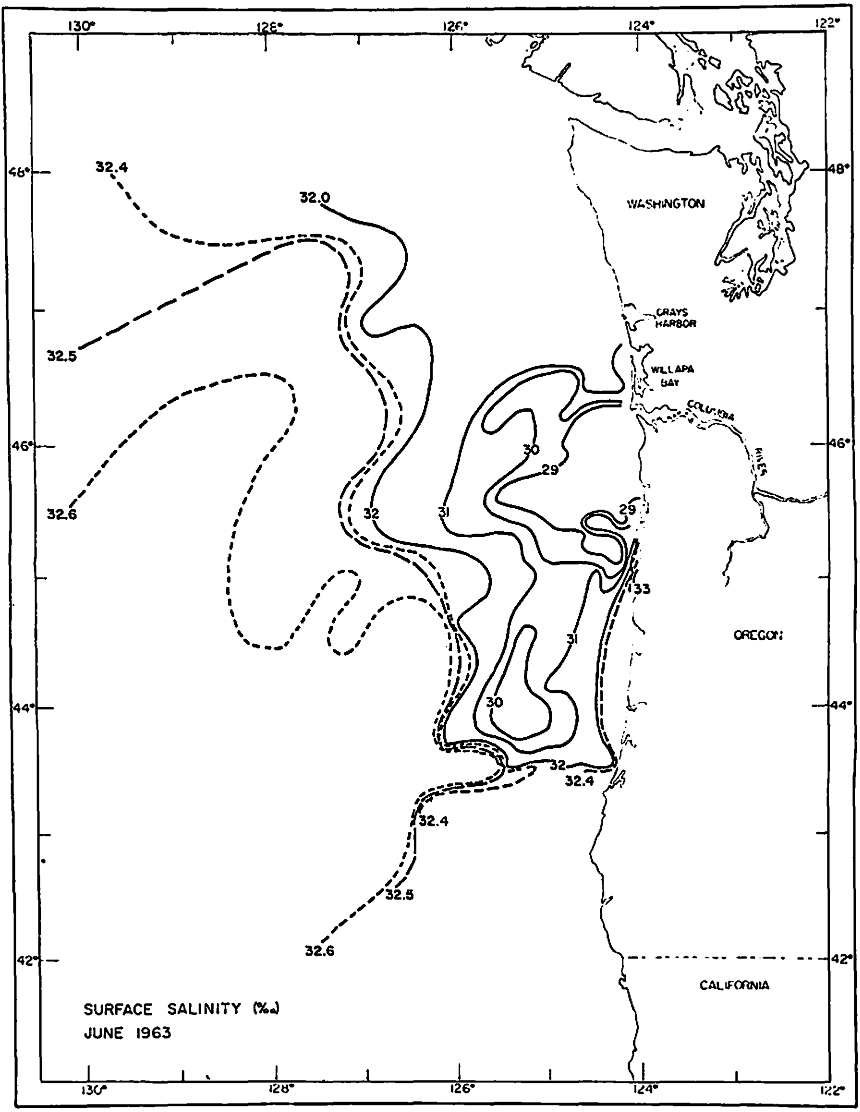

Figure 6a. Surface salinity (°/oo) distribution for June 1963.

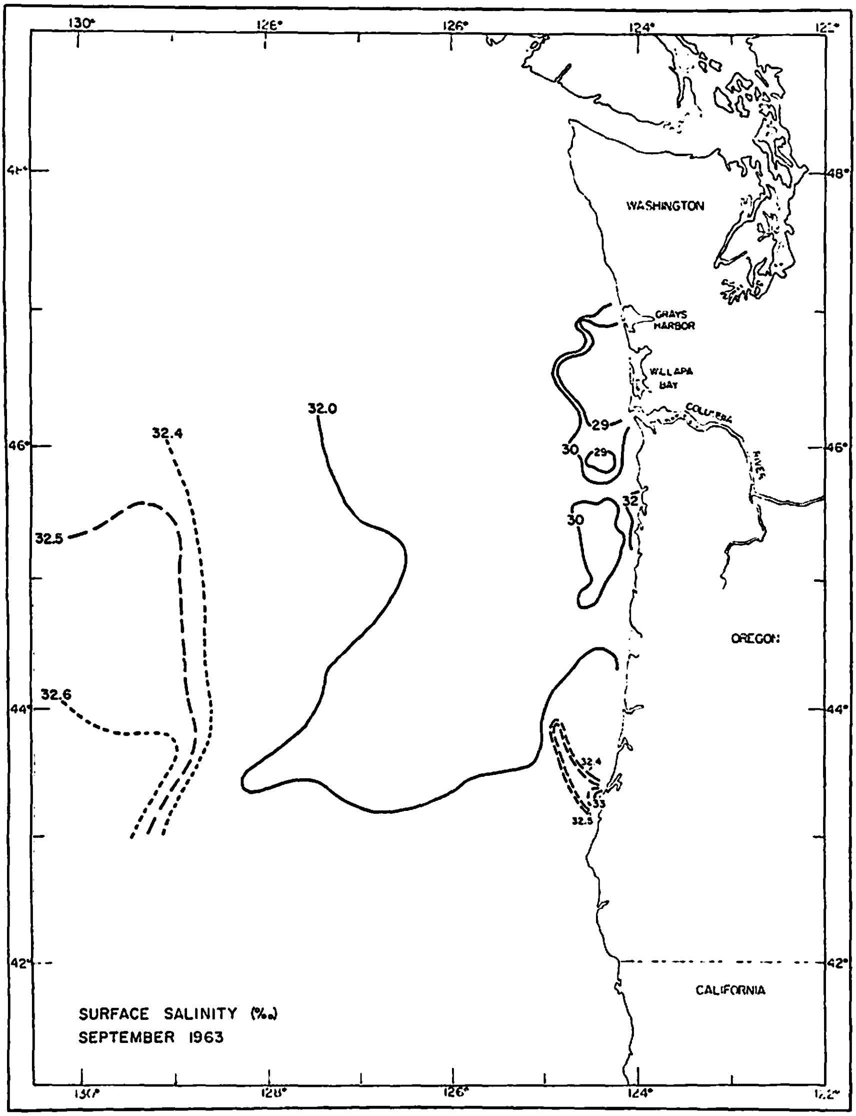

Figure 6b. Surface salinity (°/oo) distribution for September 1963.

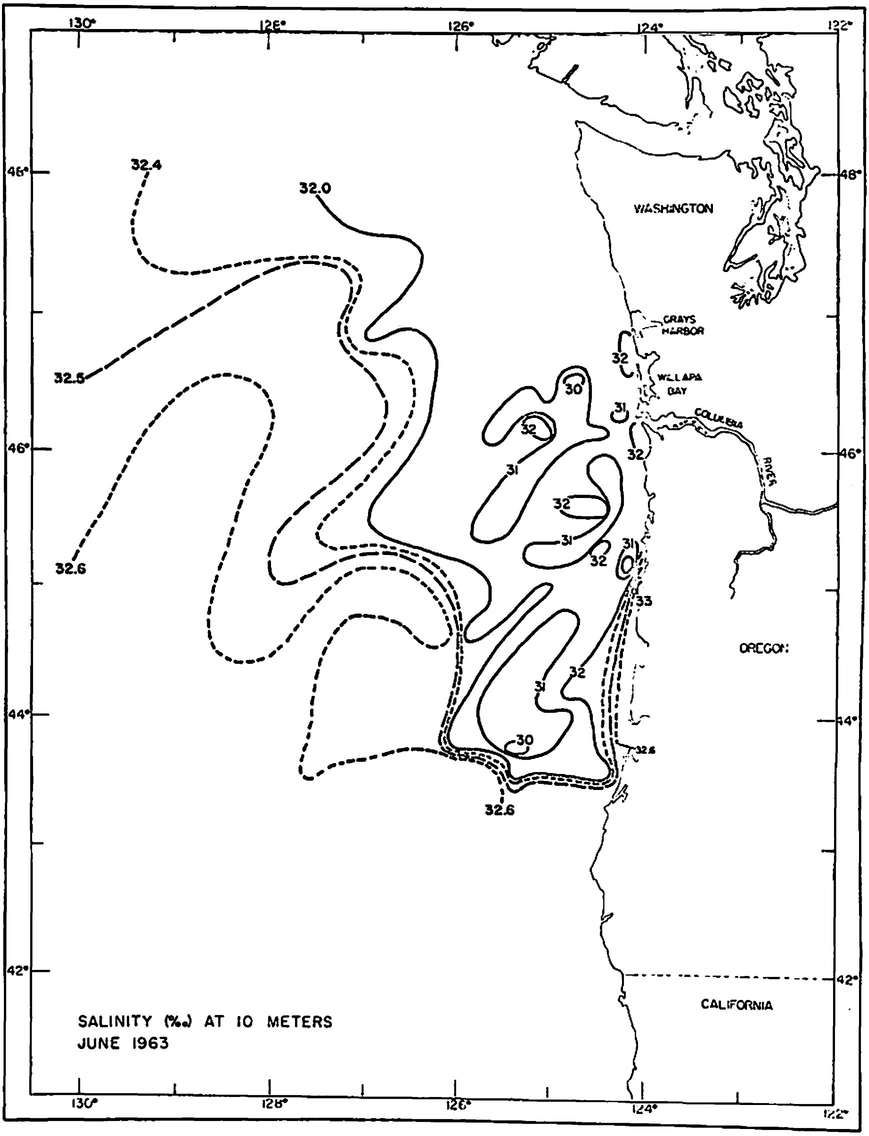

Figure 7a. Salinity (°/oo) distribution at 10 meters for June 1963.

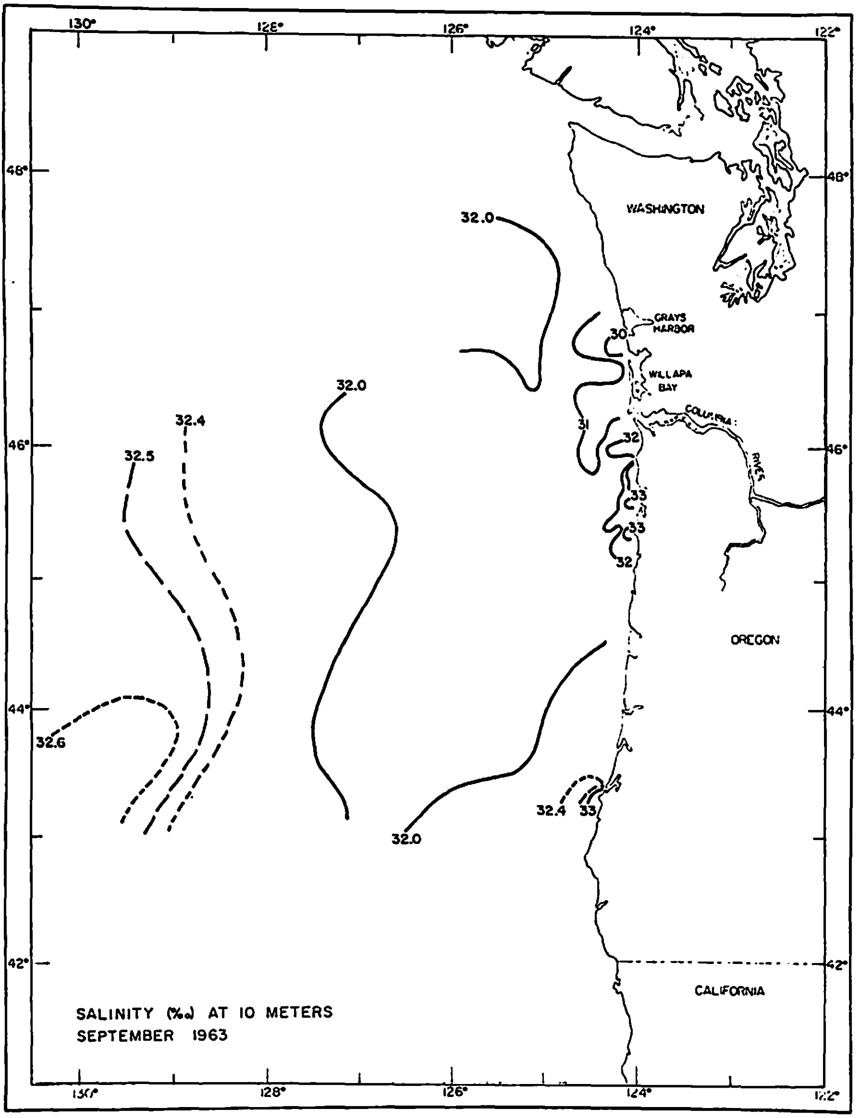

Figure 7b. Salinity (°/oo) distribution at 10 meters for September 1963.

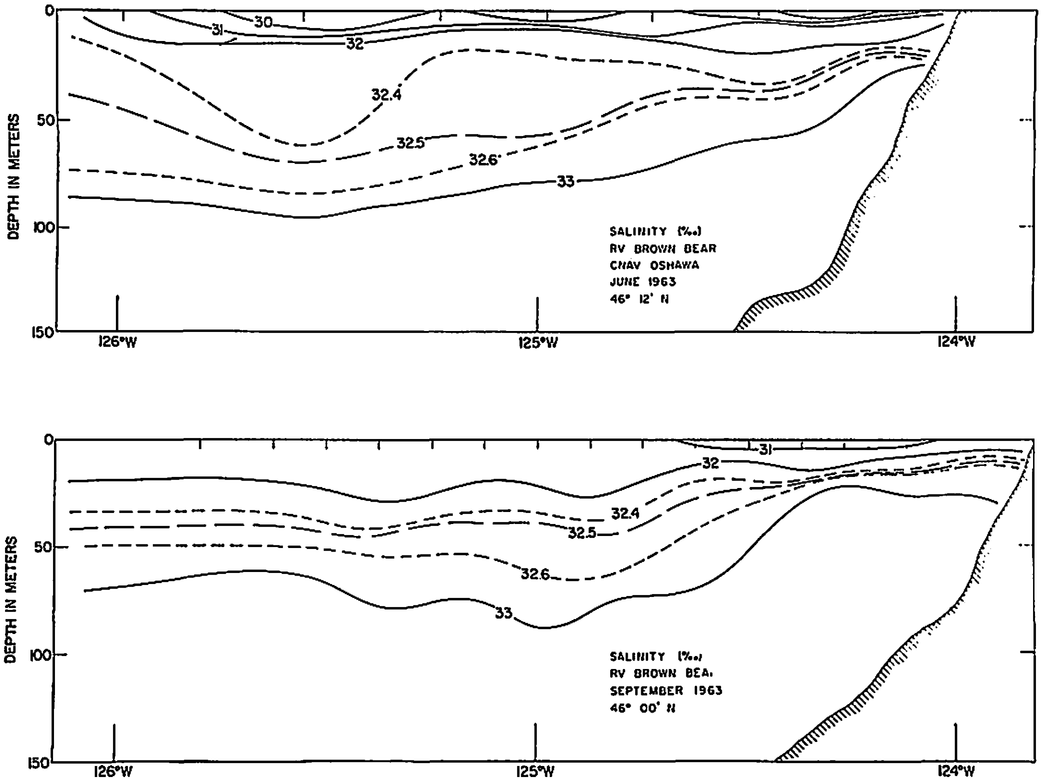

Figure 8. Vertical distributions of salinity (^{o}/oo) for June and September 1963.

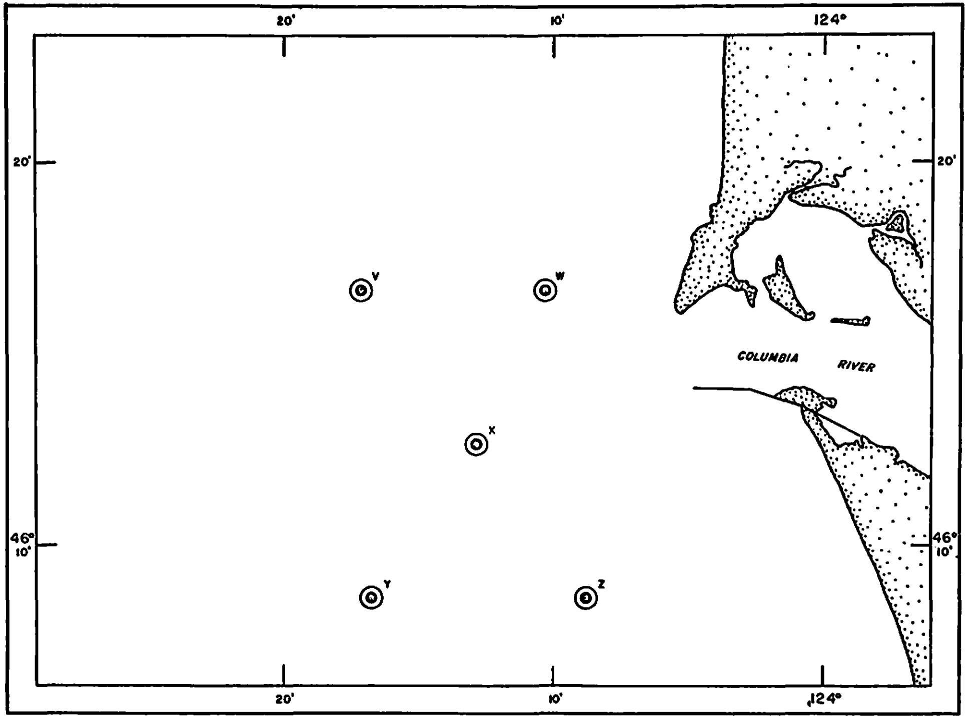

Figure 9. Station locations, 1964.

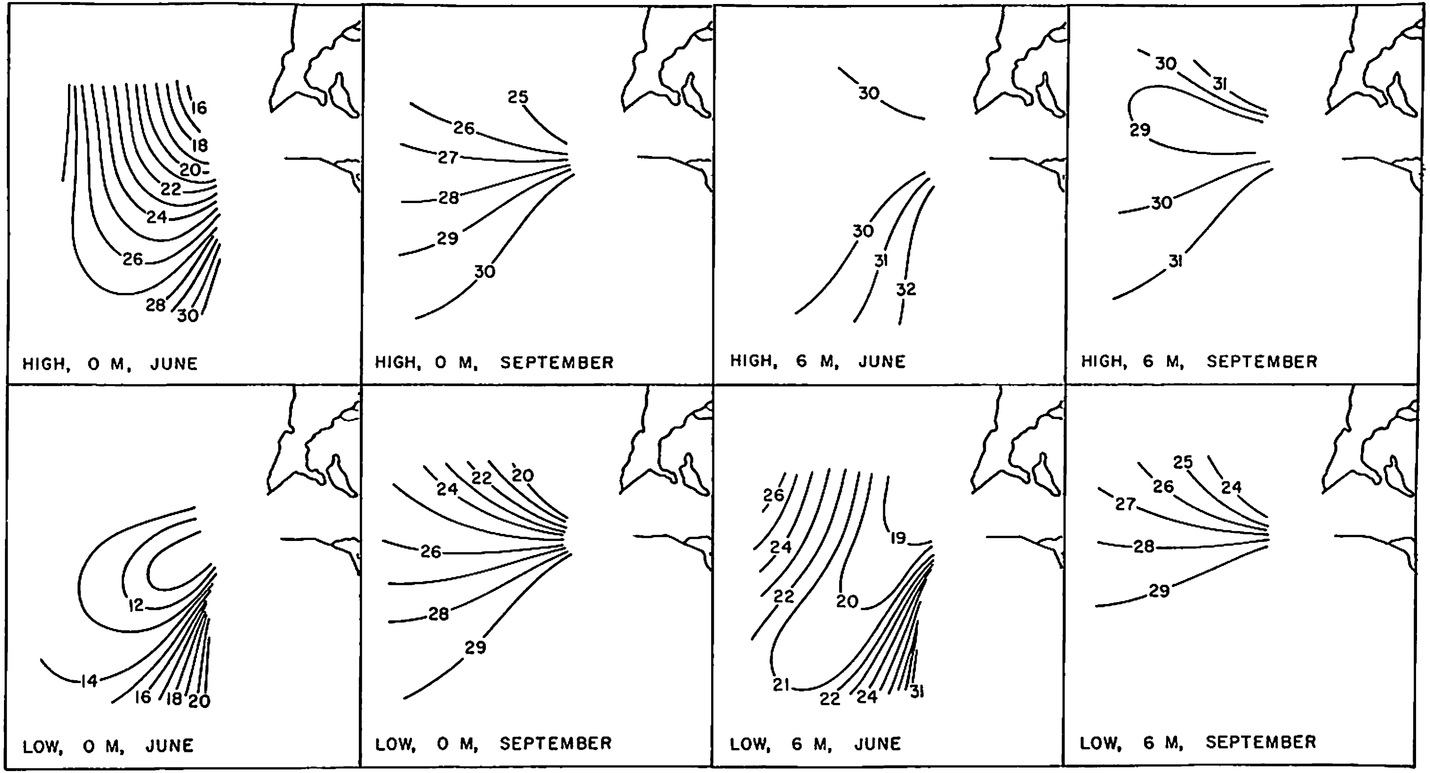

Figure 10. Interpolated salinity patterns referenced to time of tide at North Jetty.

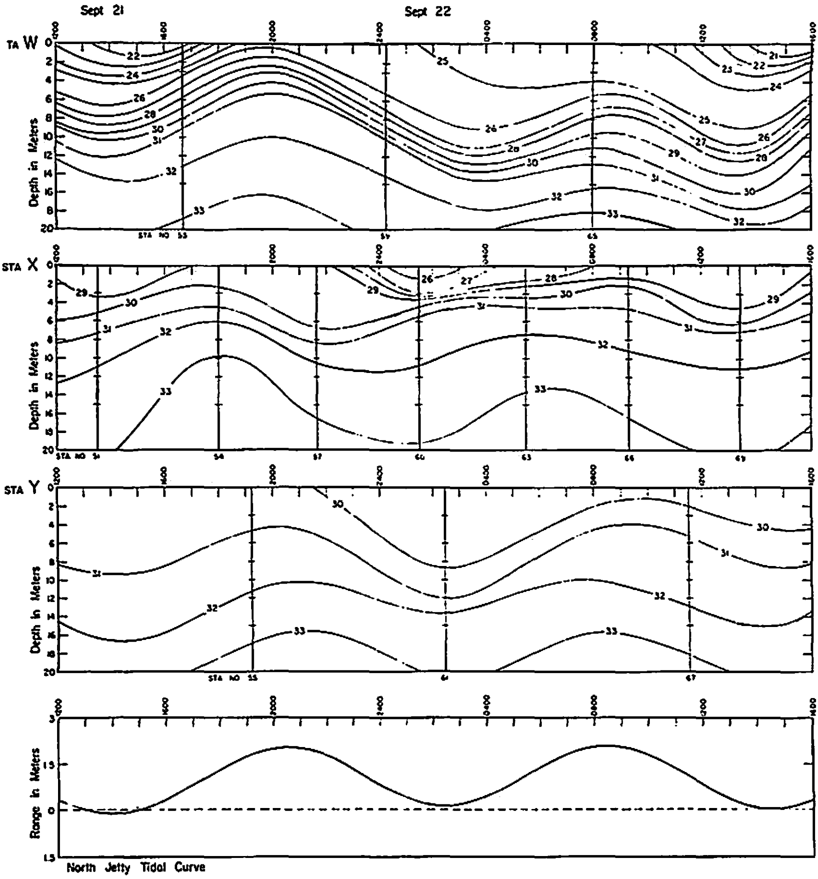

Figure 11a. Salinity (°/oo) profiles for W, X and Y, September 1964.

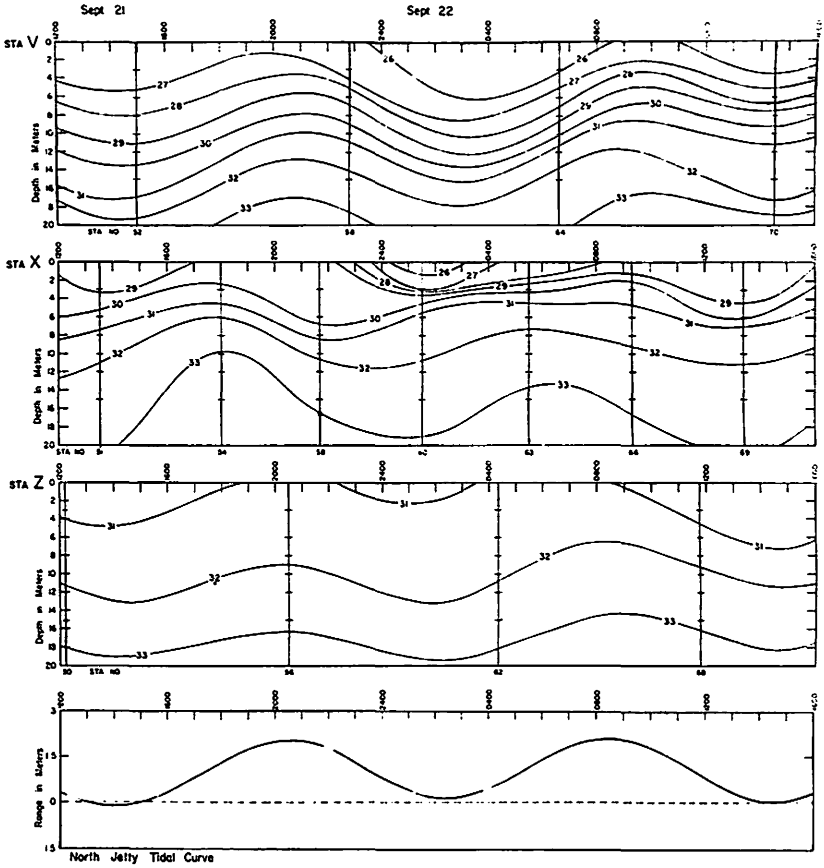

Figure 11b. Salinity (°/oo) profiles for V, X and Z, September 1964.