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RESEARCH REPORTS BY PRINCIPAL INVESTIGATORS

PHYSICAL STUDIES OF THE NEAR-SHORE CONTINENTAL SHELF OF SOUTH CENTRAL LOUISIANA: CURRENTS AND HYDROGRAPHY

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ABSTRACT

Measurements of currents and hydrography were made in the study area over an 18-month period in 1972-1974, as part of a multidisciplinary study to provide baseline information for evaluating the ecological effects of drilling and production of oil in offshore areas.

Both long and short duration current measurements indicated that there is a predominant drift eastward of the currents in summer and westward in winter and early spring, with tidal currents dominating during periods of transition. These findings support those reported by previous investigators.

Salinity, temperature, dissolved oxygen, and transmissivity were measured and analyzed for daily, seasonal, and areal trends. Large variations were shown to exist.

INTRODUCTION

Interpretation of the data obtained in this study is facilitated by first examining the general pattern of water circulation in the Gulf of Mexico (hereinafter referred to as the Gulf), as shown in figure 1. Using pilot charts, based upon ships' drift, Curray (1960) described the current patterns of the Gulf as follows:

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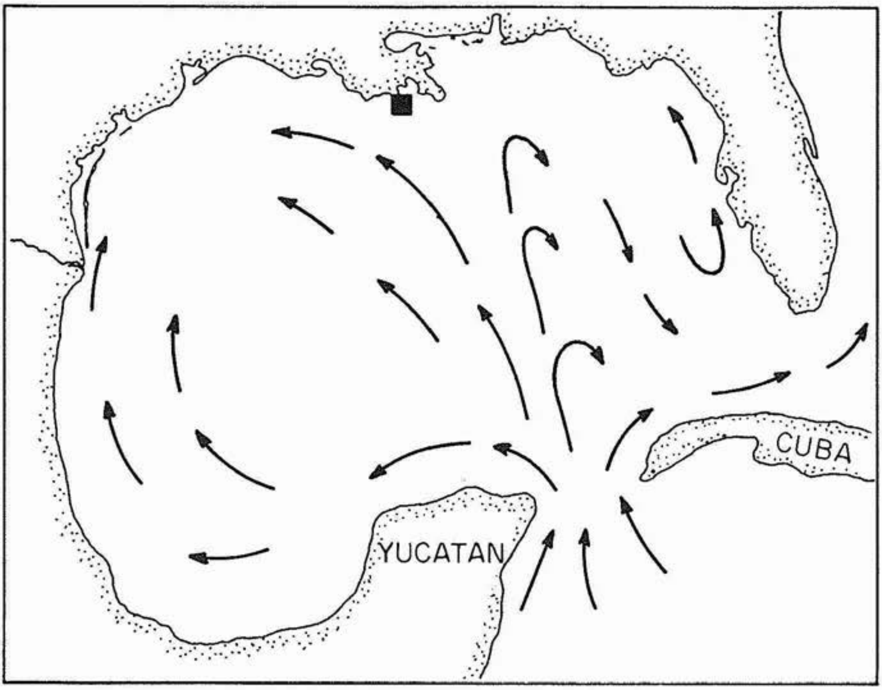

FIG. 1. GENERALIZED REGIONAL CURRENTS OF THE GULF OF MEXICO (U.S. Naval Oceanographic Office).

> Water from the Caribbean entering through the Yucatan Channel southeast of the Mississippi Delta, divides approximately along a line connecting with the Mississippi Delta. Part of the eastern flow turns sharply to the east along the northern coast of Cuba into the Florida current and the Gulf Stream and part circulates clockwise in the northeastern Gulf. . . . The western cell also consists of two parts, one circulating clockwise in the southwestern Gulf of Mexico and the other part circulating counterclockwise in the northwestern Gulf.
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> During January, February, and March, there is a strong westward and southwestward flow across the shallow Louisiana Shelf, extending as far south as about latitude 28°. This flow converges near the coast at about latitude 27°30′ to 28° with the northward current flowing past the Rio Grande. In May, the winds are nearly southeast and the convergence starts to shift northward to approximately latitude 28° to 29°. The northeastward shift of the convergence resulting from the strong southeast and south-southeast winds continues through July. . . . The most sudden change of the year is in September when the winds shift abruptly to the east and the convergence moves in response to the wind. During the fall months the convergence occurs between latitudes 27° and 28°30′, apparently because of the northeast winds. The southwest nearshore current increases to a maximum in the winter at the time the winds have the greatest north component. The shelf currents off Louisiana are to

> the west . . . throughout the year. The winds apparently influence only the intensities and minor fluctuations in direction.

Drift bottle studies (Kimsey and Temple 1962; Kimsey 1963) on the northwest Gulf indicate that the currents moved east and southeast along the Louisiana Shelf and west, south, and east just west of the Mississippi River Birdfoot Delta (hereinafter referred to as the Delta). There appeared to be a large-scale eddy developed in the "embayment" west of the Delta when the easterly current was deflected seaward by the Delta.

Currents on the near-shore shelf are primarily driven by local and regional wind systems, passage of the diurnal tide, and impingement of regional Gulf currents onto the shelf. The resulting speed and direction of flow of the shelf currents at any time, location, and depth are dependent upon the vector sum of the various driving forces present and the constraint provided by the orientation of the shoreline and near-shore bottom topography. Winds are probably the principal force controlling currents. Curray (1960) described the wind patterns of the Gulf as follows:

> In January the winds are northeasterly along the eastern and the central Gulf shore and in the Gulf itself, while there is an onshore southeasterly wind along the western shore. During March, the northerly component diminishes, and by May the winds are generally east-southeast everywhere in the region. The southerly component is strongest and most consistent in June, July, and August, producing strong *resultant winds*. This is a difference in uniformity of direction rather than in average wind speed. The wind speed averaged without regard to differences in direction is, in fact, lower during the summer months than during winter months. The direction, however, is much more uniform during the summer, and the vector *resultant wind* is higher. An abrupt change to easterly winds occurs in September. During November, the effect of the local storms called "northers" can be seen by the increase in the northerly component in both the sea and land stations.

Wind data gathered at Ft. Livingston Light, Grand Isle, Louisiana, indicate that the prevailing winds (according to Barrett [1971]) are: September through February, N to NE; April through August, generally SE to SW; and March, variable N to S. Both the regional and local wind patterns tend to produce surface currents to the west and southwest during the winter months. Local southwest winds coupled with development of northeasterly drift on the upper Texas coast, driven by strong southeast winds during the summer months, probably generate the easterly currents on the Louisiana Shelf.

In summary, the Offshore Ecology Investigation (OEI) study area is located on the northeast corner of a counterclockwise circulation cell in the northwest Gulf. The circulation is modified by local winds, tidal currents, and possibly by eddies caused by the projection of the Delta. An examination of the data should show an enhancement of the westerly current during the winter months and retardation or even reversal of it during summer months. Any effects due to tides should appear throughout the year superimposed on the net drift of the regional currents.

Tides in the Delta region are dominantly diurnal and have a maximum tide range of about 2.5 feet (75 cm) when the sun reaches maximum declination. The minimum range occurs when the sun is over the equator. Thus, annually the maximum tide range and, hence, the maximum influence of the tide on the shelf currents occurs in December and June, the minimum influence in March and September. The largest monthly fluctuations occur when the moon's declination is greatest; the cycle is fortnightly (National Ocean Survey 1972 and 1973).

The studies reported on herein were conducted to provide information about near-shore water current and hydrographic characteristics to confirm the work of earlier investigators and to supplement the biological, chemical, and physical data collected by other investigators.

Although the current data were not sufficiently complete to provide seasonal or annual estimates of direction frequency, they were representative of the currents at the study site for the duration of each of the measurements. Further, the data identified the major current patterns on the Louisiana Shelf and indicated their probable driving force. The site of the study, approximately 50 miles (92 km) west of the Delta and only 5 to 15 miles (9 to 28 km) offshore in water depths of less than 30 meters, is an area where shoreline influence on the regional shelf currents may be severe.

METHODS AND MATERIALS—CURRENTS

Measurements of current speed and direction were made with the Marine Advisors Model Q-12. Four meters were used to make long duration measurements in which the data were recorded within the instrument in integral Rustrak recorders. A fifth meter was used for point sampling of the currents. This meter was adapted to provide a direct readout of the data aboard the vessel. The instruments consist of a savonius rotor and a magnetically referenced direction vane. Both configurations are capable of reading on either of two scales: 0.05-2.0 knots or 0.05-5.0 knots. Accuracy of the system is ±2% of the reading for speed and ±10° for direction. Calibration of the systems was maintained by simulating the output of the savonius rotor at various speeds with a pulse generator and adjusting the readout to a standard established by the manufacturer.

The water depth at each sampling station was measured by an EDO Western, Model 353, piezoelectric transducer (34 kHz) and marked on a Gifft, Model 4000T, recorder. In addition, a metering wheel on the winch cable was used to establish water column sampling positions.

The R/V *Southwest Researcher I* was the principal sampling platform for the study. Cruises were made in August, September, October, and December 1972; January, February, April, July, and October 1973; and January 1974. Both long and short duration current measurements were made. Long duration (referred to as continuous) current measurements were made by suspending current meters from South Timbalier oilfield production platforms HOR-ST-66D and SH-ST-26C at the surface, mid-depth, and bottom, and date of emplacement, location, and duration were recorded. The current velocity was measured automatically every half hour for 3 minutes throughout each of these periods. Twenty of the 50 short duration measurements of the currents were made within a radius of 0.2 km of platform HOR-ST-54A (also called Exxon 54A in other papers in this collection) and 0.5 km of HOR-ST-66D and the GURC grid number of each station was recorded. Current measurements were made throughout the water column at each sampling station after the vessel was anchored or secured to a platform. A total of 4087 readings was made with short duration and continuous current meters.

RESULTS AND DISCUSSION—CURRENTS

Current direction modes

The continuous and short duration measurements indicate four major current direction modes. Figure 2 summarizes all continuous and short duration measurements taken from August 1972 to January 1974. Flood tidal currents are represented by the 315°-45° sector, and the ebb tidal currents occupy the 105°-225° sector. The winter westerly drift varies from southwest to northwest, occupying the 225°-315° sector, and the summer easterly drift (developed from strong southerly winds) occupies the 45°-105° sector. The respective mean speeds of flood and ebb tidal currents are the following: surface 0.45 knots, 0.35 knots; mid-depth 0.30 knots, 0.26 knots; and bottom 0.21 knots, 0.22 knots. The westerly drift flowed with an average speed of 0.82 knots at the surface, 0.26 knots at mid-depth, and 0.22 knots at the bottom. The easterly current flowed only slightly faster than the tidal currents at average speeds of 0.40 knots at the surface, 0.30 knots at mid-depth, and 0.23 knots at the bottom. The number of observations upon which these averages were based is tabulated and recorded. Since the current direction data are not continuous for an entire year, but represent the sum of a series of shorter-term measurements, the direction frequency may be biased. The frequency diagrams are intended to show which current directions are prominent.

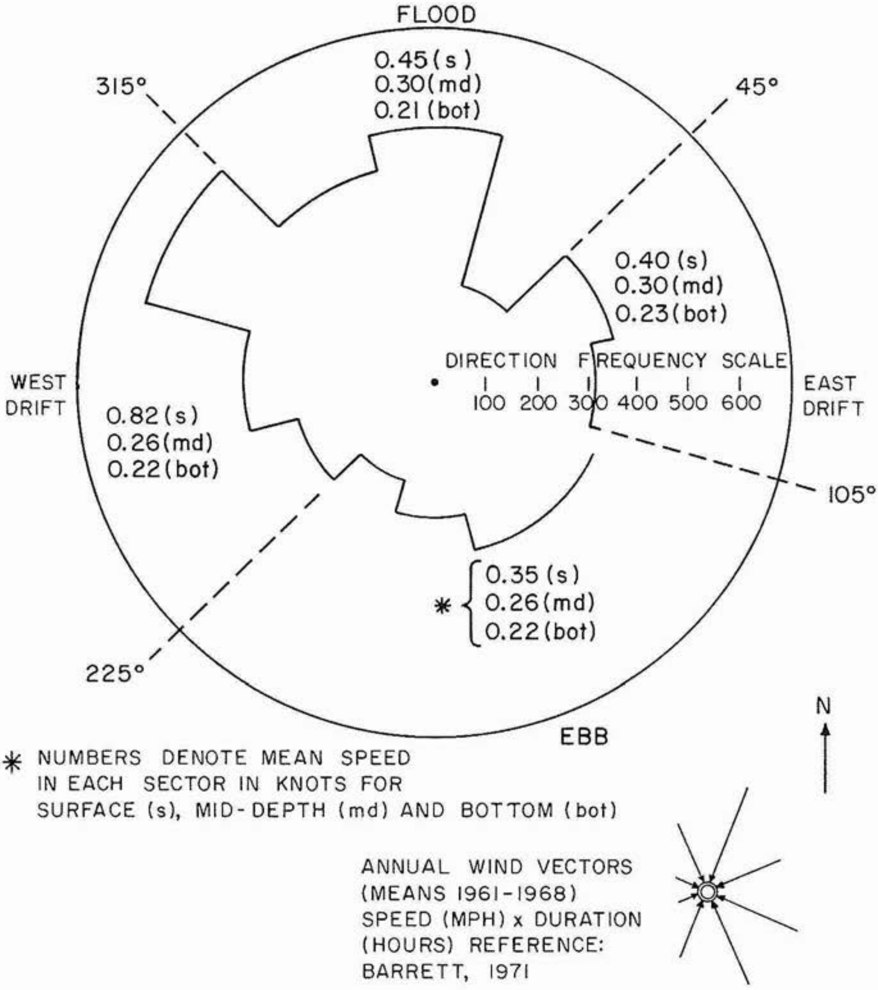

FIG. 2. CURRENT DIRECTION FREQUENCY DIAGRAM: All short duration and continuous measurements in total water column.

The effect of strong tidal currents on either an easterly or a westerly drift produces a pattern of loops with net movement in the dominant drift direction. The loops in the progressive current vector diagrams occur daily and are thought to be the result of Coriolis deflection of tidal current (MacMillan 1966). In the absence of a drift current, tidal forces produce a current pattern consisting of overlapping closed loops. During ebb tide the current was deflected to the west, and during floodtide the current was deflected to the east. The net result is depicted as an ellipse

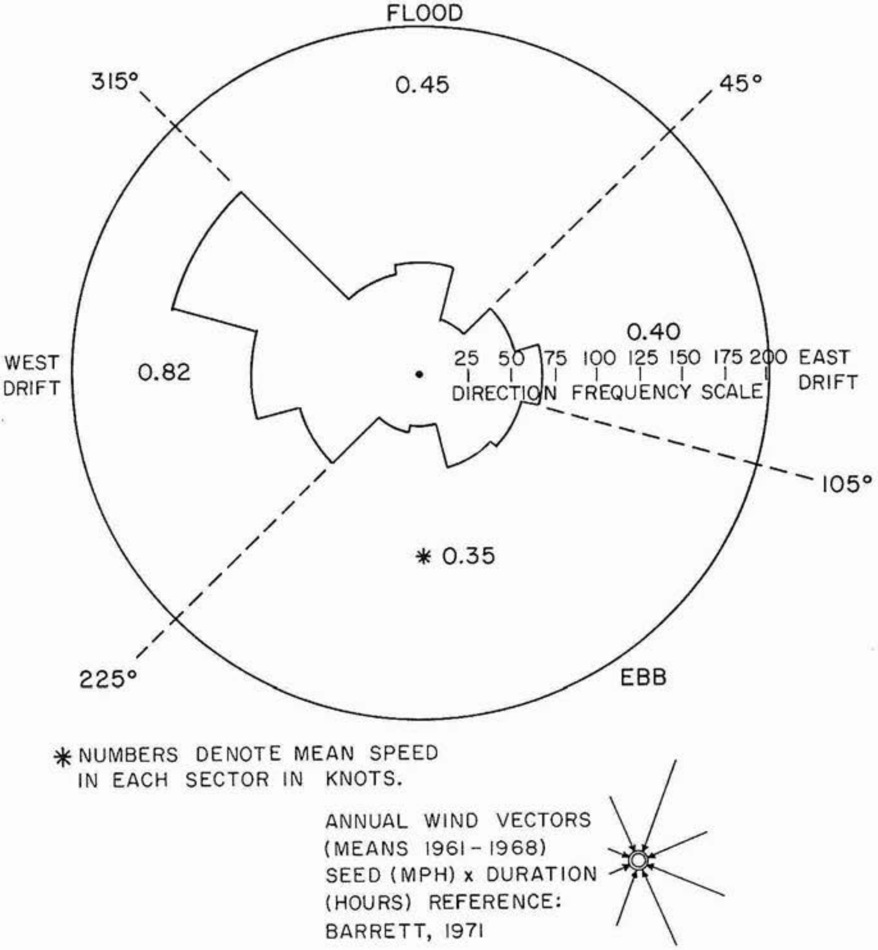

FIG. 3. SURFACE CURRENT DIRECTION FREQUENCY DIAGRAM: All short duration and continuous current meter measurements.

that traces the flow of the tidal current. When the strength of the easterly or westerly drift was increased, the daily loops were separated by a distance equivalent to the daily drift of the regional current. If the regional drift was fast relative to the velocity of the tidal currents, the loops no longer existed because the tidal velocities opposing the regional current never became fast enough to cause a current reversal.

Current direction frequencies

Direction frequency diagrams for each of the sampling depths (i.e.,

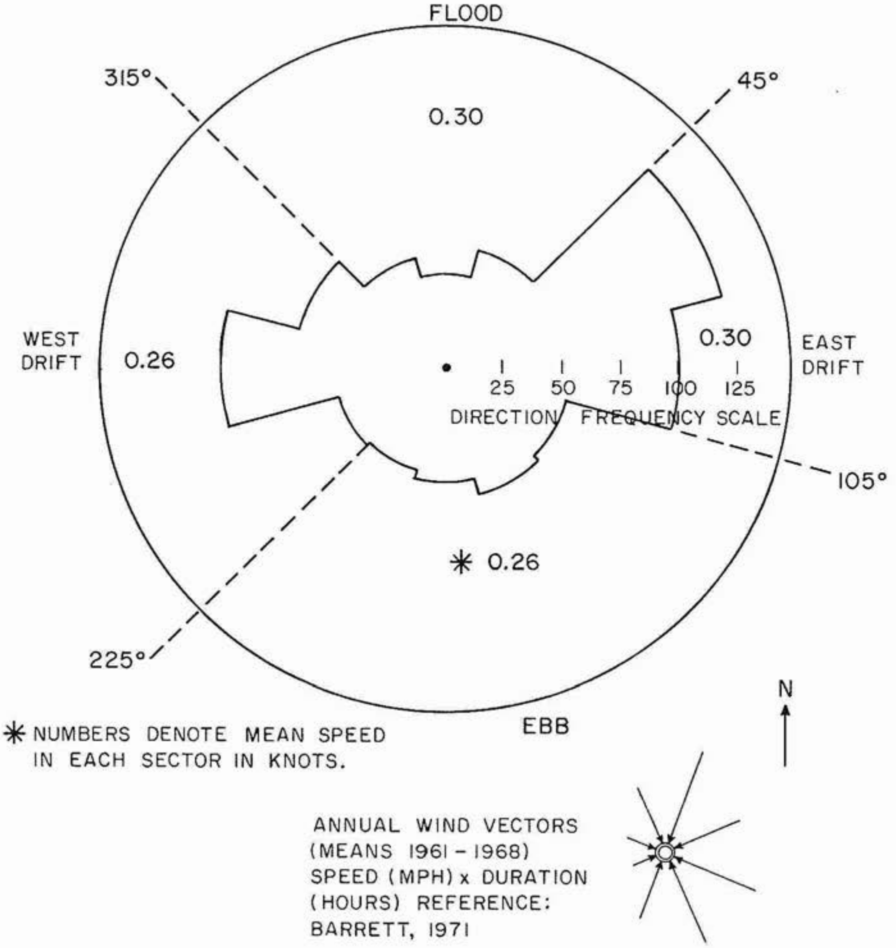

FIG. 4. MID-DEPTH CURRENT DIRECTION FREQUENCY DIAGRAM: All short duration and continuous meter measurements.

surface, mid-depth, and bottom) were constructed, based on both the short duration and continuous measurements (figures 3, 4, and 5). It can be seen from these diagrams that the wind-driven easterly and westerly drift currents were dominant at the surface and mid-depth, whereas onshore currents (flood tides) were dominant at the bottom of the water column. Ebb currents appeared the strongest at the surface and mid-depth, although either flood or ebb tides could dominate the current direction at any depth.

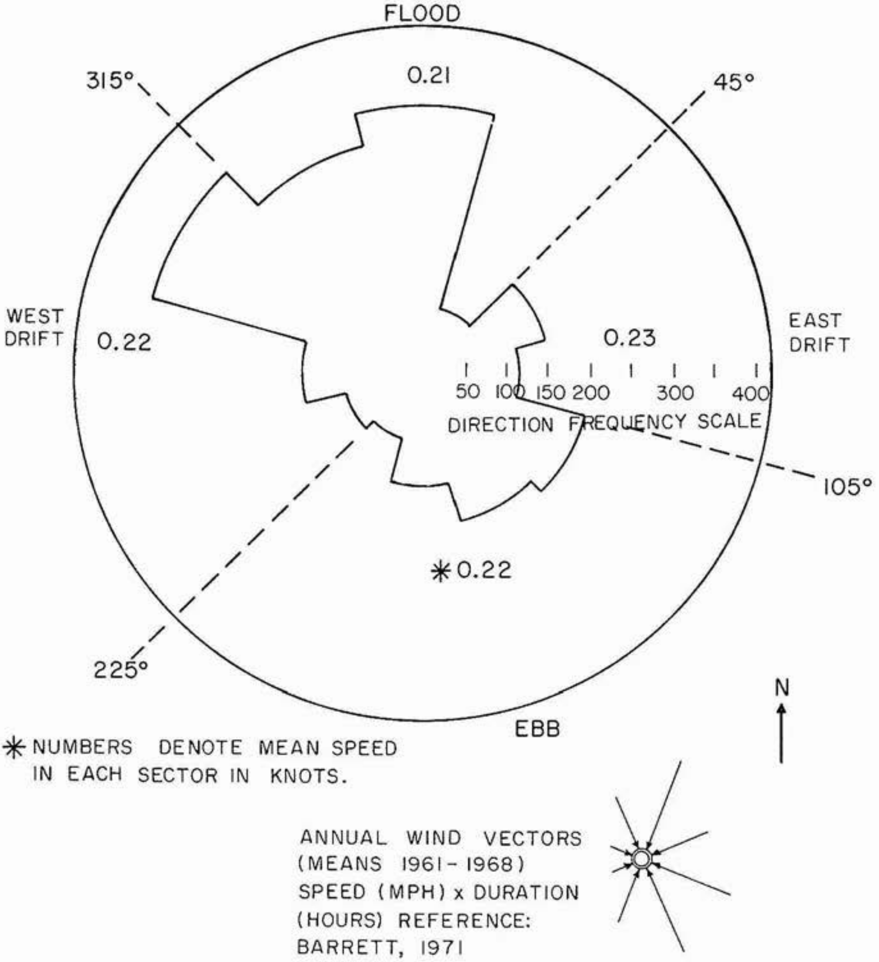

FIG. 5. BOTTOM CURRENT DIRECTION FREQUENCY DIAGRAM: All short duration and continuous current meter measurements.

Summer regime. The direction frequency diagrams for August 1972 depict surface currents to the east and northeast with some ebb and flood currents. Current flow in the ebb direction was the strongest at mid-depth, whereas the currents in the flood direction were most pronounced at the bottom. The direction frequency diagram for July 1973 also indicates that the easterly drift current was strong at the surface. At mid-depth the continuous readings indicated flow in the easterly, southerly (ebb tide), and northerly (flood tide) directions. The more variable currents at the bottom flowed predominantly to the east, west, and north. In general, the presence of strong easterly drift on the Louisiana Shelf during summer agreed with the findings of Kimsey and Temple (1962).

Winter regime. In December, the dominant surface currents flowed to the northwest. Mid-depth currents were primarily westerly and offshore, indicating the effect of ebb tidal currents, whereas the bottom currents were westerly but strongly influenced by the tides. A progressive vector diagram for December 5-8, 1972, shows a strong northwest surface drift with no tidal current loops. The effect of the tidal currents does not appear on the diagram because they were weak relative to the swift westerly surface current, which was driven by strong regional winds. Current data gathered in January, February, March, and April 1973 are also representative of the winter regime. An example of local wind modification of the currents was seen in January 1973. On the morning of January 23, the current was flowing to the west at 1.0 to 1.2 knots (50 to 60 cm/sec). At the same time the wind changed from westerly to northerly and became stronger. Near midnight the current had become southwesterly at 0.8 knots (40 cm/sec). The current became westerly again on January 26 after the north winds had subsided.

Transitional months. September and October current characteristics were transitional between the summer and winter regimes. The short duration current patterns for September 1972 depict the effect of the flood tides at all depths. However, the continuously recorded data from platform HOR-ST-66D show strong northeasterly drift in addition to significant flood and ebb currents. The progressive surface current vector diagram for September shows a strong easterly drift superimposed with pronounced tidal current loops on September 17. But by September 22, the loops disappear because the tidal currents became weaker as determined from the tide table. For several days preceding these current measurements, the winds were southerly, a phenomenon that may have given a northward component to the easterly drift current producing a net flow to the northeast. Apparently it was too early in the fall for the westerly drift to have developed.

The short duration current measurements for October 1972 were dominated by flood tide at the bottom and ebb tides at both mid-depth and the surface. The continuous surface measurements taken at platforms HOR-ST-66D and SH-ST-26C appear anomalous. The current at platform HOR-ST-66D was predominantly onshore and westward, while at SH-ST-26C (15 miles, or 24 km, to the northeast) the surface current for the same period was offshore and westward. Since October 1972 was characterized by neither an easterly nor westerly drift, the tidal currents appeared to have formed a large clockwise eddy just west of the Delta. With the development of either a strong easterly or westerly drift, such an eddy would probably soon dissipate. In October 1973, continuous current measurements showed well-defined westerly and southwesterly currents at surface and mid-depth, possibly indicating the establishment of the winter westerly drift as early as October.

Unfortunately, there are no current data for May or June. It is likely that the spring transitional period occurred then. Since the regional currents offshore were dominantly westerly and were enhanced by the winter north and northeast winds producing westerly surface drift with average speeds more than twice as great as easterly drift or tidal currents, the westerly drift was likely to persist until late in the spring, well after the south and southeast winds had begun on the Texas and Louisiana coasts. Drift bottle data from the Texas coast have indicated that tongues of southward-flowing waters were detectable within the general northward-flowing water mass well after the beginning of the strong southeastern wind season (Watson and Behrens 1970).

SUMMARY—CURRENTS

1. The net movement of the water column, which was driven primarily by regional winds, was easterly in the summer and westerly from winter through early spring.
2. Onshore and offshore currents prevailed in the fall and probably late spring.
3. Surface currents were generally easterly in the summer (0.40 knots) and westerly from winter through early spring (0.82 knots).
4. Mid-depth currents (0.26 knots) were easterly, onshore and offshore in the summer; westerly and offshore from winter through early spring.
5. Bottom currents (0.22 knots) were mostly onshore and easterly in the summer; westerly, onshore and offshore from winter through early spring.
6. Current speed decreased with depth.
7. The net annual movement of water in the study area was westerly.

CONCLUSIONS—CURRENTS

The currents of the near-shore continental shelf of south central Louisiana were variable throughout the course of this study. The currents varied with the seasons because regional winds produced an easterly flow during the summer months and a westerly flow from winter through early spring. Local winds caused some temporary changes in the direction of the currents. Onshore and offshore currents resulting from diurnal tidal action varied throughout the lunar cycle; the greatest effects were felt during the maximum declination of the moon. Current speed and direction varied with depth. The net annual movement of water in the study area was westerly for two reasons: The current flowed in that direction for nearly half the year, and westerly surface currents moved twice as fast as all other currents.

METHODS AND MATERIALS—HYDROGRAPHY

Seasonal and regional hydrographic measurements of salinity, temperature, transmissivity, dissolved oxygen, and current were made from surface to bottom along onshore-offshore traverses, along traverses trending roughly parallel with the shoreline, and along traverses including one or more offshore platforms. Water data were collected on four cruises in 1972, five in 1973, and one in January 1974, at 90 different sampling stations, many of which were reoccupied.

The water column and ancillary measurements were made with the following instruments:

Temperature and salinity. A Beckman Model RS5-3 direct reading portable salinometer was used to determine the *in situ* temperature, conductivity, and salinity. This instrument uses a thermistor probe in a balanced bridged circuit to measure temperature, and the conductivity is derived from the inductive coupling between the two coils in the probe. The salinity is automatically calculated by the readout unit from the temperature and conductivity measurements. The instrument is capable of the following accuracies:

Salinity ± 0.3 ppt (0-40 ppt)
Conductivity ± 0.5 millimhos/cm
Temperature ± 0.5° C

These accuracies were maintained by daily field calibration and verified by returning random samples from each sampling series for measurement using a Hytech, Model 6200, laboratory salinometer. The temperature measurements were calibrated by periodically checking the readings with a Kahlsico, Model 297WA105, porcelain scale thermometer.

Transmissivity. the light transmission properties were measured with a Hydro Products, Model 410BR, transmissometer with a 10 cm Model

411 head. This instrument provides a direct reading of the percentage of transmittance in an *in situ* water sample. Accuracy was maintained by "air calibration" at each station and by periodically calibrating the transmissometer to 100% in distilled water.

Dissolved oxygen. The dissolved oxygen in the water column was measured *in situ* with a Martek, Model DOA, dissolved oxygen analyzer. This instrument uses a gold/silver polarographic probe with a special Teflon membrane. Measuring accuracy is ± 1% of full scale on each of three selectable ranges: 0-2, 0-10, and 0-20 ppm. Calibration was maintained daily by checking the oxygen content of an air-saturated distilled water sample. Spot verification of *in situ* measurements was made using a standard Winkler titration method.

Water depth. The water depth at each sampling station was measured by an Edo Western, Model 353, piezoelectric transducer (34 kHz) and marked on a Hydro Products, Model 4000T, Gifft recorder. In addition, a metering wheel on the winch cable was used to establish water column sampling positions.

Wind velocity. Wind speed and direction were measured at each station from the same elevated vessel position with a Kahlsico, Model 03AM120, hand-held anemometer. The instrument accuracy is ± 1 knot in the range of 0-60 knots for speed and ± 10° for direction. The hand-held instrument was checked before and after each cruise with the laboratory wind speed monitoring system.

Air temperature. The thermistor probe of the Beckman, Model RS5-3, *in situ* salinometer was used to measure the air temperature. The readings were taken after the measurements in the water column to minimize the influence of solar heating of the probe head.

The R/V *Southwest Researcher I* was the principal sampling platform for the study. A total of 37 days of water column data was acquired during the 10 cruises. Measurements were made in August, September, October, and December 1972, in January, February, April, July, and October 1973, and January 1974.

The sampling program was designed to collect representative hydrographic data near an active production platform, at a sampling station outside the influence of petroleum activities, and at various other locations deemed necessary to provide the data required by other investigators. Whenever the vessel was on station for the purpose of sampling, observing, or measuring any parameter, water column information was acquired. The salinometer, transmissometer, oxygen probe, and current meter were fastened together to form the water quality package, which was attached to a winch-driven hydrowire. The extent to which the various water quality data were measured at each station was dependent on the duration of the primary sampling activity, and for current measurements, on whether or not the vessel was fixed by anchor or platform.

RESULTS AND DISCUSSION—HYDROGRAPHY

Seasonal trends

For each study period, all surface and bottom data for salinity, temperature, transmissivity, and dissolved oxygen were individually averaged from stations located in water 15 meters or deeper. Near-shore data were not included in the seasonal averages because of the added influence of local runoff, turbulence, etc.

Salinity. In general, throughout the year the surface salinity was lower than the bottom salinity. This was expected because of the surface effects of fresh water from local runoff and the Mississippi River. From August to December 1972, the surface salinity was only slightly lower than the bottom salinity, and some of the highest surface salinities were higher than some of the lowest bottom salinities (figure 6). During this period, no steep vertical salinity gradients were observed. The water column had little salinity stratification because the water was well-mixed throughout the fall and early winter.

By January 1973, the bottom salinity increased to near normal sea water salinity of 35-36 ppt. This appeared to be caused by a combination of the dominant onshore component of the bottom currents and the lessening of the fresh water runoff. Data from Houma, Louisiana, U.S. Weather Bureau, USDA Observer, show average monthly rainfalls of 6.1 inches (15.5 cm) for August-December 1972, and 3.3 inches (8.4 cm) for January-February 1973, hence a decrease in the source of fresh water during mid-winter. Throughout the period from January to September, the envelope of surface salinities and the envelope of bottom salinities did not intersect. January and February 1973 vertical salinity profiles show a pronounced salinity gradient beginning at about 10 meters, with a relatively well-mixed surface layer. Data gathered on January 13, 1974, were unusual in that the water column was temporarily mixed, the mixing probably caused by strong offshore winds. Because of these data and the lack of cruises in November and December, the graphic display for this period is dissimilar to that of the previous year.

On April 2, offshore surface salinities were as low as 13 ppt with a very steep gradient to 28 ppt at about 6 meters, and there was a gradual

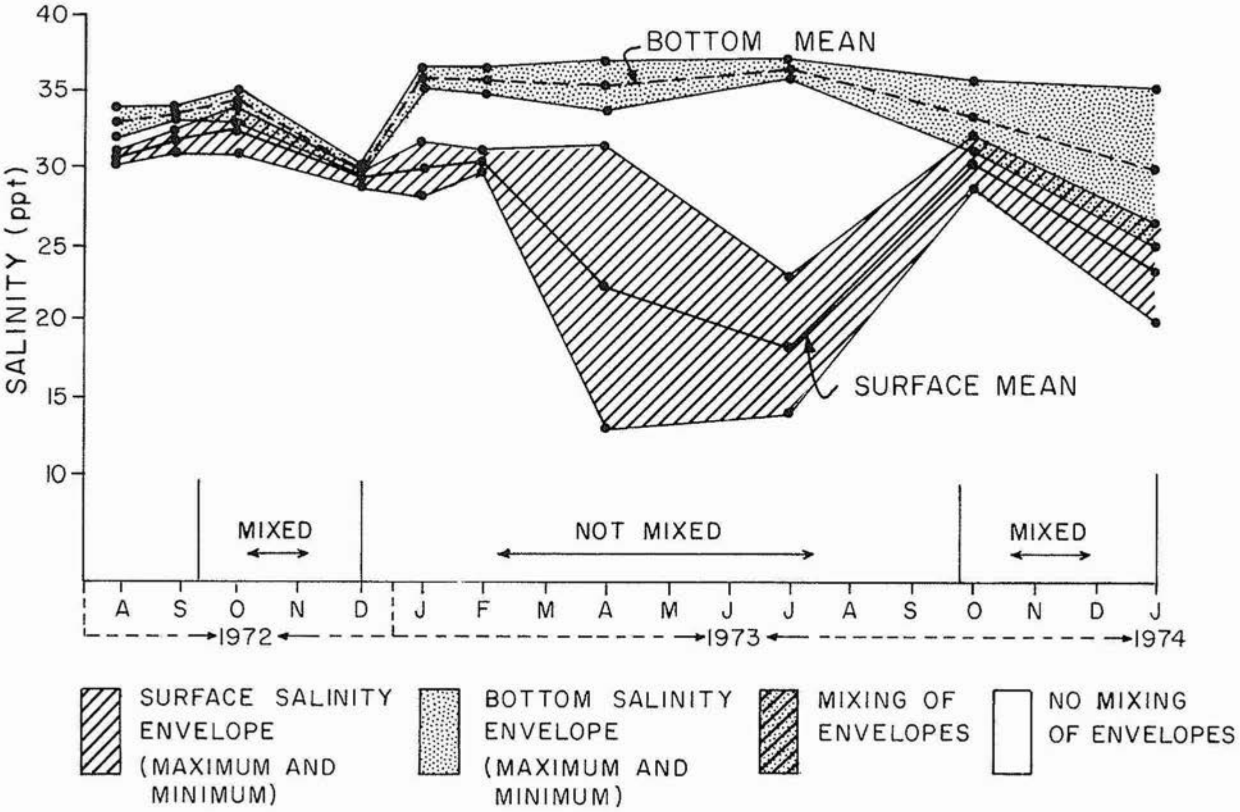

FIG. 6. MONTHLY MEANS OF SALINITY FROM SURFACE AND BOTTOM DEPTHS.

increase to near normal sea water salinities of 35 ppt at the bottom. The extremely low surface salinity in early April can be attributed to local runoff as well as to the spring flooding of the Mississippi River just 50 miles (93 km) to the east. March rainfall at Houma, Louisiana, was 9.5 inches (24.2 cm). During the late winter and spring, the surface currents on the nearshore Louisiana Shelf were predominantly westerly, with the result that the spring floods of the Mississippi River considerably diluted the surface waters west of its mouth. In July, the surface salinities were still low, averaging about 19 ppt with a steep gradient at 3-8 meters.

When offshore salinity data, taken during 1968-69, are compared with records of Mississippi River stage and discharge, they show a strong inverse correlation. Salinity was sharply reduced during the high spring stage and discharge of the Mississippi River in the area west of Southwest Pass (figure 7). The study found maximum offshore salinities of 29-30 ppt during November and December and minimum offshore salinities of 16-17 ppt, with the spring floods of the river from March through June (Barrett 1971). Our data indicate that offshore waters were mixed during the fall months, with surface and bottom salinities ranging from 20 to 35 ppt. Beginning with spring flooding, principally from the Mississippi River, surface salinity decreased sharply, and a pronounced salinity gradient developed at a depth of 3-12 meters. Bottom salinities increased to the level of normal sea water, indicating little exchange between surface and bottom waters.

Temperature. The offshore surface and bottom temperatures show seasonal trends that correlate with the seasonal changes in salinity. During the fall and early winter, when the water column was well mixed, bottom temperatures differed only slightly from surface temperatures (figure 8). Sometime during December or January 1972, the bottom temperature ceased to drop. This occurred with the increase in salinity of the bottom waters from about 30 to 36 ppt. The surface water temperature continued to decrease to a low of about 16° C, when the lowest bottom temperature observed was about 19° C.

Thus, during the cooler months (December, January, February, March, and perhaps part of April), the surface temperatures were lower than the bottom temperatures. By early spring, surface waters became warmer than bottom waters again. By July 1973, the surface water temperature reached an average of 30° C with bottom temperatures of 24° C. The large difference between surface and bottom water temperatures is in agreement with the salinity data, indicating little mixing of surface and bottom waters.

Dissolved oxygen. The seasonal trends of the surface and bottom

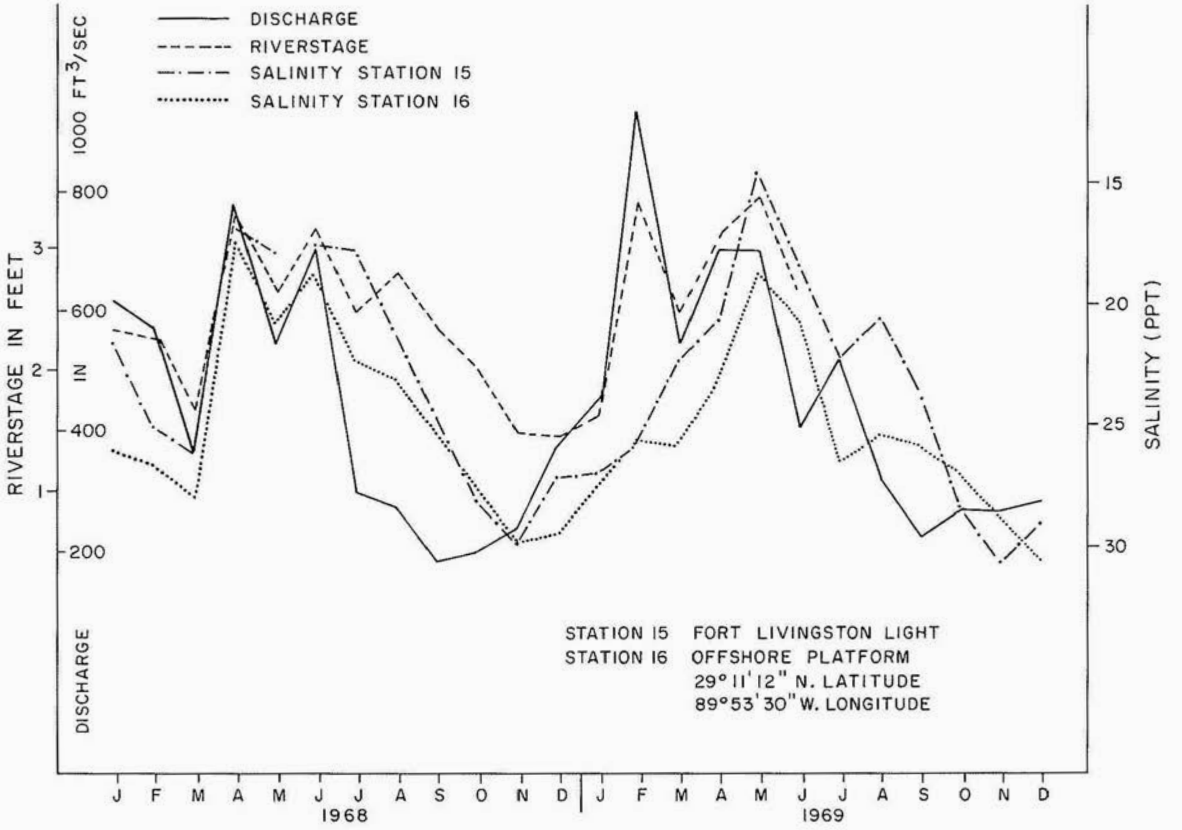

FIG. 7. RELATIONSHIP BETWEEN MONTHLY AVERAGE SALINITIES at stations 15 (Grand Terre slip) and 16 (Grand Isle offshore platform) and monthly average stage of the Mississippi River at head of passes and discharge at Tarbert Landing.

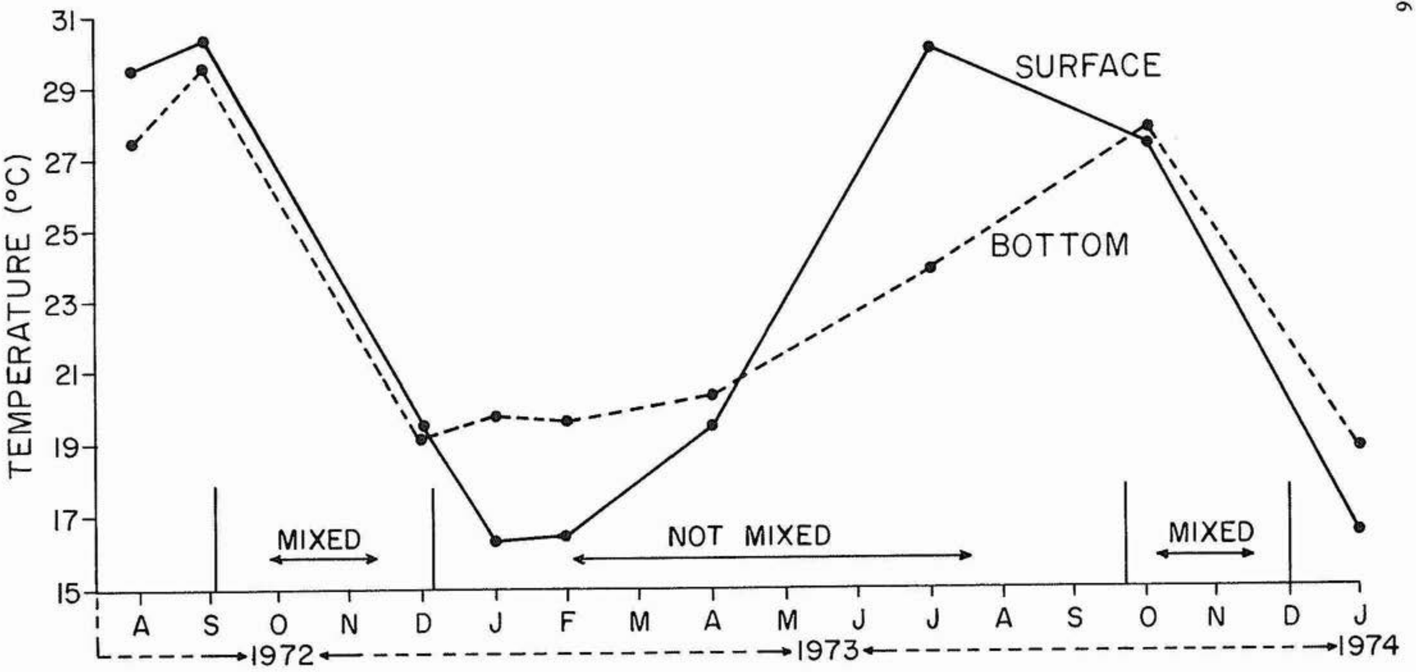

FIG. 8. MONTHLY MEANS OF TEMPERATURE FROM SURFACE AND BOTTOM DEPTHS.

dissolved oxygen in the offshore area reflect seasonal trends in temperature, mixing, salinity, respiration, and photosynthesis. High dissolved oxygen contents are promoted by low temperature, high wave turbulence, high rate of photosynthesis, and low salinity. Vertical mixing is a primary control on the vertical oxygen distribution.

Surface dissolved oxygen ranged from 6.0 ppm in the summer to 10.0 ppm in the winter. The highest dissolved oxygen figures corresponded to the period of coldest surface water (figure 9). Winter storms and the resulting wave action also increase the probability that surface waters will become saturated or supersaturated with oxygen. Figure 9 includes seasonal oxygen saturation index curves determined for the surface and bottom waters from monthly average salinities and temperatures, excluding mixing and biological effects. The rate of uptake by organisms probably has little effect on the surface dissolved oxygen because it can be easily replenished at the sea/air interface.

The seasonal variability in bottom dissolved oxygen was appreciable; dissolved oxygen reached a high of about 7.5 ppm during January and a low of less than 2.0 ppm during July 1973. Bottom dissolved oxygen shows almost a perfect inverse correlation with surface temperature and almost as good an inverse correlation with bottom temperature (figure 9). The major source of oxygen for the bottom waters was mixing with the surface waters above. Since organisms are ordinarily consuming at least part of the oxygen in the water column, the bottom waters are usually lower in dissolved oxygen than the surface waters, unless the column is well mixed or the bottom waters are from a completely different water mass.

The extremely low dissolved oxygen observed in the bottom waters during summer was probably a function of several factors. The near perfect inverse correlation with surface temperature implies that the bottom dissolved oxygen was controlled by temperature or by something that is temperature controlled. However, the less perfect correlation of bottom dissolved oxygen with bottom temperature and the lower variability of surface dissolved oxygen than of bottom dissolved oxygen suggest that the major factor controlling the variation of bottom dissolved oxygen from April to July was not solubility as controlled by temperature, but was respiration and decomposition.

Transmissivity. The transmissivity of the surface water, a measure of the water clarity, showed no recognizable seasonal trends. Throughout most of the year, the offshore surface transmissivity ranged from 80% to 90%. In water near the bottom, seasonal effects were detected; average transmissivity was highest during the summer (90-100%) and lowest in April (40%).

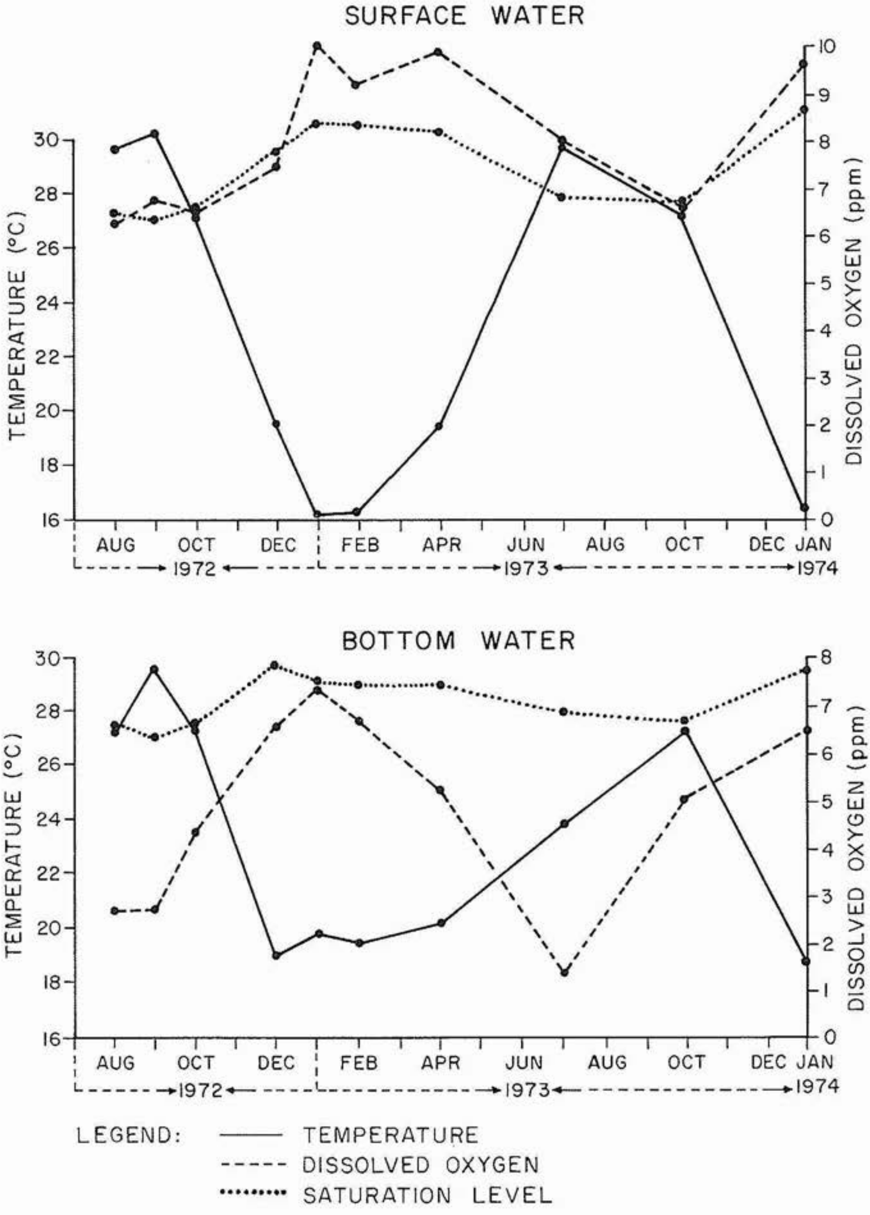

FIG. 9. MONTHLY MEANS OF TEMPERATURE, OBSERVED DISSOLVED OXYGEN, AND OXYGEN SATURATION SOLUBILITY.

The low transmissivity values in April showed a steep gradient near the bottom with clear water above. It appears that this may have represented downslope movement along the bottom of dense, sediment-laden waters. The coincidence in April of very low bottom transmissivities with spring flooding suggests that land-derived material suspended in runoff was the source of the turbid bottom layer. Also, strong flood-tide currents along the bottom may have been capable of some shoreward movement of a dense layer of suspended material. The maximum bottom current during the April cruise was moving northward at 0.34 knots (17.5 cm/sec.).

Although the surface waters were generally clearer than the bottom waters, the reverse was true in July 1973. Surface water runoff from the rivers and bays and high phytoplankton concentrations lowered the clarity of the surface waters. The strong density gradient in the upper waters may have been a deterrent to particle settling. The unusual clarity and the high salinity of the bottom half of the water column suggest that this water originated offshore.

Onshore-offshore trends

Salinity. Both surface and bottom salinity generally increased in the offshore direction. Near-shore salinities were usually lower because of the mixing of near-shore waters with local runoff coming through the tidal outlets. The salinity contours often dipped shoreward as a result of fresher, less dense water flowing seaward on the surface.

When the Mississippi River was in flood stage and the near-shore surface currents were flowing to the west, however, the offshore surface waters were significantly diluted by Mississippi River waters, and the surface salinity increased in the shoreward direction. A salinity profile taken on April 4, 1973, shows both of the trends noted above.

An anomalous condition occurred in the near-shore area in mid-January 1974. Strong north winds, which began on January 12, pushed cold brackish water out of the bays, and by January 13 this water dominated the water column on the shoreward side of platform HOR-ST-54A. In the area of the platform, the water remained stratified. The well-mixed water column was a temporary condition—stratification of the near-shore waters was re-established within a few days.

Temperature. Although surface temperature sometimes increased slightly in the offshore direction, it generally was constant regardless of onshore or offshore position on a given date. During the winter, bottom temperature increased in the offshore direction. By summer (July 1973), the bottom temperature trend was reversed; bottom temperatures decreased in the offshore direction.

Dissolved oxygen. The concentration of dissolved oxygen showed no well-defined trend in the onshore-offshore direction. Surface dissolved oxygen concentrations increased offshore, decreased offshore, or remained at the same level. Bottom dissolved oxygen decreased with depth and seemed to reflect local sources and sinks.

Transmissivity. Transmissivity increased in the offshore direction because there was more time for the land-derived particulate matter to settle. Also, the deeper offshore bottom was less frequently disturbed by wave action; consequently, mud was not locally introduced into the water column. In contrast, strong wave action in shallow water and muddy ebb tides and runoff leaving the bays caused greater sediment suspension in waters nearer shore.

Divers usually noticed a turbid layer near the bottom. This extensive low-transmissivity layer was well developed in the onshore-offshore profiles taken during April. The low-transmissivity zone was commonly more concentrated and thinner in the nearshore area and probably originated from dense turbid water leaving the bays or from wave turbulence on the near-shore bottom. The turbid water apparently flowed seaward along the bottom as a high density underflow. The salinity profile taken on April 4 shows evidence of seaward flow of low salinity water beneath more saline water. Apparently the density of this sediment-charged layer was sufficient to cause downslope movement.

Currents. The current direction diagrams accompanying most of the hydrographic profiles indicate one to five zones of water movement with depth. A correlation exists between the degree of mixing and the number of current direction zones in the water column. From August to December 1972, when there was little density stratification, three or fewer current zones were detected, but three or more were delineated when the waters were stratified. It appears that tidal currents and prevailing currents exist concurrently and independently of one another by occupying different density zones—ebb currents and east drift currents alternating from surface to bottom.

THE INFLUENCE OF OFFSHORE STRUCTURES ON HYDROGRAPHIC PARAMETERS

Many of the hydrographic profile transects include measurements taken at or near one or more offshore production platforms. Usually there was no detectable change caused by the platform, but on several occasions there were marked differences, which may have been caused by the production activities, in the water quality values.

A series of hydrographic changes occurred near platform HOR-ST-66D during the August 1972 cruise. On August 1, salinity, temperature, and dissolved oxygen appeared normal from surface to bottom: 30-32 ppt, 29-28.5° C, and 6.5-5.5 ppm, respectively. On August 2, there was a sharp drop in dissolved oxygen from 6.0 ppm at the surface to 1.8 ppm at the bottom. At a station 1500 feet (450 m) to the northwest, the bottom dissolved oxygen was 5.4 ppm, similar to that of the previous day. Neither salinity nor temperature was unusual. The two following days also showed low dissolved oxygen in the bottom waters throughout a 3-mile (5.5 km) distance from the platform. On August 3, however, the profile showed an increase in the salinity and a decrease in the temperature near the platform. In the middle water column, the maximum temperature decrease over 600 feet (180 m) was only about 0.4° C while the maximum salinity increase was about 1.2 ppt. The unusually low dissolved oxygen detected on August 2 was found by subsequent measurements to have had broad areal extent and does not appear to be associated with platform activities. It was probably a natural phenomenon, such as an intrusion of offshore waters, which happened to occur in the platform area at the time of the measurements.

On April 6, 1973, a profile transect passing near platform SH-ST-26C and extending about 6 miles (11 km) to either side of it showed unexpected large-scale changes in salinity, temperature, and dissolved oxygen. Transmissivity near the bottom increased in the vicinity of the platform and may have resulted from platform operations. Surface salinity increased from 21.6 ppt at 3 miles (5.5 km) from the structure to 32.7 ppt near the structure. Over the same distance the surface temperature increased 1.5° C. Unfortunately, the entire water column was not measured at closely-spaced intervals; consequently, it was impossible to determine the full area of influences of the higher salinity and temperature. Apparently associated with activities of the structure were low readings of dissolved oxygen, 5.0 ppm, relative to waters 5 miles (9.5 km) away, which had 10.3 ppm. Near the structure the dissolved oxygen profile is inverted, with lower concentrations of dissolved oxygen at the surface than at the bottom, indicating that the phenomenon was not affecting the bottom dissolved oxygen at that time.

With the exception of the data gathered near platform SH-ST-26C, no similar large-scale changes in water quality parameters attributable to the presence of offshore production platforms were detected.

SUMMARY—HYDROGRAPHY

1. The surface salinity was generally only slightly lower than bottom salinity during the fall months.

2. The water column was stratified from winter through summer; beginning in April, unusually steep vertical salinity gradients occurred in the upper column, reflecting the introduction of flood waters from the Mississippi River and elsewhere.

3. Salinity generally increased in the offshore direction but lenses of brackish water with higher salinity both landward and seaward were measured when westward drift and spring/summer flooding occurred.

4. Surface temperature was only slightly higher than bottom temperature from August to December, considerably higher from May to September, and significantly lower from January to March.

5. Surface dissolved oxygen normally ranged from 6.0 ppm in the summer to 10.0 ppm in the winter; at the same time, bottom dissolved oxygen ranged from 2.0 ppm to 7.0 ppm. Low temperature, high wave turbulence, and plankton blooms resulted in high dissolved oxygen concentrations. A stratified water column, high temperature, and biological activity were the primary causes of low dissolved oxygen levels in the bottom waters.

6. A seasonal transmissivity trend was observed in the bottom waters; it was highest in the summer and lowest in the spring. Clearest waters were generally found at mid-depth.

7. Transmissivities increased offshore, suggesting a near-shore origin of the suspended particulate material. Ebb tides were the probable downslope carrier of suspended muds, the likely source of the turbid layer. Strong flood tide currents along the bottom also may have been of sufficient strength to maintain particle suspension.

8. Only once throughout the course of the study was a significant change that appeared to be caused by activities of an oil production platform observed in the hydrographic parameters.

CONCLUSIONS—HYDROGRAPHY

The most impressive aspect of the hydrography of the study area was the large variation of salinity, temperature, dissolved oxygen, transmissivity, and currents with time, depth, and geographic location. Interactions of tides, the Mississippi River, runoff leaving the bays, and meteorological conditions were the primary agents of change. The study area was neither typically marine nor estuarine, but rather it was transitional. Consequently, organisms living there must be tolerant to large-scale variations in the environment.

Although some localized changes in hydrography linked to oil structures were measured, they were minor in comparison to vertical and seasonal changes caused by natural agents, especially the Mississippi River.

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