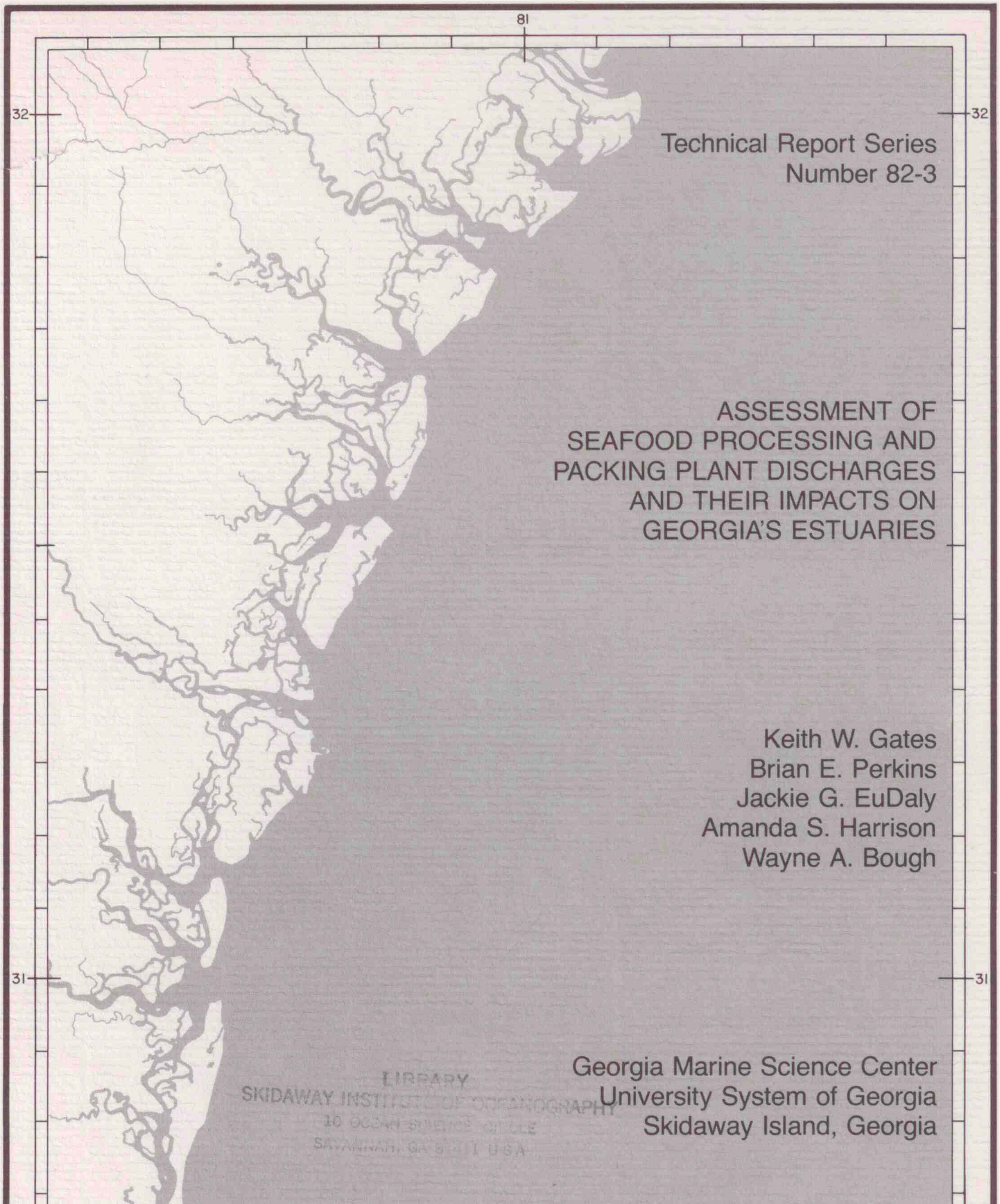

Technical Report Series
Number 82-3

ASSESSMENT OF SEAFOOD PROCESSING AND PACKING PLANT DISCHARGES AND THEIR IMPACTS ON GEORGIA'S ESTUARIES

Keith W. Gates
Brian E. Perkins
Jackie G. EuDaly
Amanda S. Harrison
Wayne A. Bough

Georgia Marine Science Center
University System of Georgia
Skidaway Island, Georgia

ASSESSMENT OF SEAFOOD PROCESSING AND PACKING PLANT DISCHARGES AND THEIR IMPACTS ON GEORGIA'S ESTUARIES

Technical Report 82-3

by
Keith W. Gates
Brian E. Perkins
Jackie G. EuDaly
Amanda S. Harrison
Wayne A. Bough*

The University of Georgia
Marine Extension Service
P.O. Box Z
Brunswick, GA 31523

The Technical Report Series of the Georgia Marine Science Center is issued by the Georgia Sea Grant College Program and the Marine Extension Service of the University of Georgia on Skidaway Island (P.O. Box 13687, Savannah, GA 31406). It was established to provide dissemination of technical information and progress reports resulting from marine studies and investigations mainly by staff and faculty of the University System of Georgia. In addition, it is intended for the presentation of techniques and methods, reduced data, and general information of interest to industry, local, regional, and state governments and the public. Information contained in these reports is in the public domain. If this publication is cited, it should be cited as an unpublished manuscript. (Sea Grant College Program, Grant #04-8M01-175)

*Present address: P.O. Box 1837 S.S.S., Springfield, MO 65085

ACKNOWLEDGEMENTS

The technical assistance of Ms. Kathy Bennett, Ms. Lea Dowdy, Ms. Sandy Gale, Ms. Cindy Nolen, Mr. William Stringfellow, and Mr. Marc Wright is gratefully acknowledged.

This publication is a result of work sponsored by the National Fisheries Institute, the University of Georgia, and the National Oceanic and Atmospheric Administration, U. S. Department of Commerce, through the National Sea Grant Program (Grant #04-8M01-175). The U. S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that might appear hereon.

ABSTRACT

A study to determine the impact of seafood packing and processing effluents discharged to southeastern estuarine waters was conducted in July and August of 1979. The environmental impact of current seafood processing wastes on Georgia's estuaries appears to be minimal when compared with the natural organic load. One large estuary demonstrated a high residual capacity to receive processing effluents without significant change. The BOD load from shrimp thawing, peeling, sorting, and cleaning operations at a large seafood processing plant was shown to be equivalent to the organic material generated by a 302 m^2 plot (57 ft. x 57 ft.) of salt marsh. NH_4-N levels were greater than, but the same order of magnitude as, natural runoff from marsh land.

TABLE OF CONTENTS

LIST OF FIGURES

Figure		Page

LIST OF TABLES

Table		Page

Table		Page

INTRODUCTION

A study to determine the impact of seafood packing and processing effluents discharged to Georgia's estuarine waters was conducted during July and August of 1979 (Figure 1). The study concerned the effects of effluents on two estuarine systems:

(i) a relatively undeveloped area consisting of three small estuarine creeks, two of which are normally exposed to seafood packing by-products (Figure 2).
(ii) a large commercially and industrially developed estuary that receives effluents from a seafood processing plant and three packing houses (Figure 3).

Fishing boats unload their catches at packing houses, where the seafood is washed, sorted, packed in ice, and held for shipment to wholesale and retail outlets and seafood processing plants. Most fresh products are shipped on ice with little further processing. Shrimp are normally headed at sea if time permits, but during the peak harvesting periods, at least part of the catch is brought in to be headed at the packing houses. A typical packing house employs up to 20 people, handles 1,000 to 1,500 pounds of shrimp per day (of which 60% to 70% are headed at sea), and discharges from 1,500 to 9,000 gallons of effluent (Scott et al.,1978). Seafood processing plants are much larger operations, employing several hundred workers to manufacture cooked, breaded, and frozen products. In contrast to packing operations, seafood processing plants utilize between 10,000 and 30,000 pounds of shrimp and generate from 100,000 to 300,000 gallons of effluent per day (Scott et al.,1978).

Although 1979 was a good shrimping year, most of Georgia's summer harvest was headed at sea, resulting in little or no activity at the packing houses (Wise and Thompson 1977). During the project, the only known seafood effluent discharged into the undeveloped estuary resulted from the heading of a boatload of rock shrimp at one packing house. However, in July and August the processing plant discharged into the developed estuary approximately 215,000 gallons of effluent per day from shrimp thawing, peeling, sorting, and cleaning operations. The effluent passed through a hydroseive screen which removed shrimp hulls and other solids larger than 0.02 inches in diameter. Wash-down water, domestic sewage, and any breading remaining after dry clean-up were discharged to the municipal sewage plant.

MATERIALS AND METHODS

The following chemical and biological parameters were determined for estuarine water and processing discharge samples collected during the study:

(a) Temperature measurements for surface and bottom estuarine waters and effluent samples were made using a three-liter plastic Van Dorn bottle equipped with a mercury thermometer.
(b) Surface, bottom, and effluent salinities were determined with an American Optical hand-held refractometer.
(c) pH readings of surface, bottom, and effluent samples were made with a digital pH meter (Association of Official Analytical Chemists,1975).
(d) Winkler titrations (American Public Health Association,1976) (U.S. Environmental Protection Agency,1976) were used to measure in situ dissolved oxygen levels of surface, bottom, and effluent samples.
(e) The nephelometric method (American Public Health Association, 1976) (U.S. Environmental Protection Agency,1976) was used to measure turbidities of surface, bottom and effluent samples.
(f) Ammonia nitrogen values were determined spectrophotometrically for surface, bottom, and effluent samples (Martin,1972).
(g) Biological Oxygen Demand (BOD) determinations were completed for surface, bottom, and effluent samples (American Public Health Association,1976) (Houser,1965) (U.S. Environmental Protection Agency,1976).
(h) MPN total coliform populations were ascertained for surface and effluent samples (American Public Health Association,1976).
(i) MPN fecal coliform levels were monitored for surface and effluent samples (American Public Health Association, 1976).
(j) Total aerobic plate counts incubated at 20C for 7 days and 35C for 48 hours were completed for surface and effluent samples (American Public Health Association,1976) (Food and Drug Administration,1978).
(k) Marine agar plate counts from surface and effluent water samples were incubated at 20C for 7 days (Schleper,1972).
(l) Rainfall data was obtained from the Federal Aviation Administration, Aviation Weather and Pilot Briefing Section, McKinnon Airport, St. Simons Island, throughout the study.

Based on preliminary hydrographic data (temperature, salinity, and dissolved oxygen profiles) and surface microbiological concentrations, eight sampling stations in the northern less developed estuary (including two control stations) and seven stations in the southern industrially developed estuary (including one control station) were chosen for the study. Subsequently, the stations and a representative sample of discharged seafood effluent were monitored at high and low tide on a total of four occasions in July and August of 1979.

The data was analyzed by single and multiple analyses of variance to determine any significant differences (0.05 level) between effluents and receiving waters, stations within an area, and differences between the northern and southern sampling areas (Remington and Shork,1970) (Schefler,1969).

SAMPLE SITE SELECTION

Four estuarine sampling sites (three relatively undeveloped estuarine rivers between Doboy Sound and Sapelo Sound on Georgia's central coast, and one large commercially and industrially developed estuary that drains the area around Brunswick, Georgia) were chosen for the study (Figure 1). The undeveloped northern sampling area (Figure 2) included the Duplin River, Shellbluff Creek, and Cedar Creek. The developed southern sampling area (Figure 3) encompassed three portions of the Brunswick Estuary, St. Simons Sound, the Brunswick River, and the Brunswick East River.

Surface to bottom temperature, salinity, and dissolved oxygen profiles, and surface MPN total coliform populations, MPN fecal coliform populations, marine agar plate counts (at 20C), and total aerobic plate counts (at 20C and 35C) were determined for stations between the mouths of the four estuarine systems and the ends of their navigable waters (American Public Health Association,1976) (Food and Drug Administration, 1978) (Schleper,1972) (U.S. Environmental Protection Agency,1976). Five stations in the Duplin River, four stations in Shellbluff Creek, five stations in Cedar Creek, and ten stations in the Brunswick Estuary were profiled. Results from the initial hydrographic and bacteriological investigations were evaluated to determine station locations that were monitored during the remainder of the study:

(a) The Duplin River, designated the control estuary, is approximately five miles long and drains the western portion of Sapelo Island. No seafood processing establishments are located along this river, which drains a state refuge with little domestic or commercial development. Temperature (Figure 4), salinity (Figure 5), and dissolved oxygen (Figure 6) profiles indicate a well-mixed system, surface to bottom, with the greatest horizontal gradient for all three parameters between the mouth of Barn Creek and a large mound of sawdust 1.5 miles upstream from Barn Creek (Figure 2). Sapelo Dock, at Marsh Landing, and the mouth of Barn Creek (1.5 miles upstream from Sapelo Dock) had the lowest microbiological populations (Table 1) with MPN total coliform values of 7.5 organisms/100 ml and 9.3 organisms/100 ml, respectively. Surface and bottom water samples were collected from stations at Sapelo Dock and Barn Creek for the remainder of the study.

(b) Shellbluff Creek, with discharges from two seafood packing houses and several private homes, is a 0.75-mile-long waterway situated approximately 4.5 miles northwest of the mouth of the Duplin River (Figure 2). Four stations were chosen for the first microbiological and hydrographic survey. Temperature (Figure 7) and salinity (Figure 8) data revealed an estuary that was well mixed horizontally and vertically, with gradual reductions in dissolved oxygen concentrations (Figure 9) moving upstream and below three meters. MPN fecal coliforms reached a maximum of 24 organisms/100 ml at the packing house station and at the bend approximately 500 yards upstream from the packing houses, while MPN total coliform values peaked at the telephone pole 0.25 miles west of Marker "162" (Table 2). Three sample stations (i) at the mouth of the creek (Marker "162"), (ii) at the center of the creek (0.75 mile upstream from the first station) next to the packing houses, and (iii) at the bend above the packing house (500 yards at a heading of 96°), were chosen. Surface and bottom water samples were collected at each station.

(c) Cedar Creek, one mile long and one mile north of Shellbluff Creek (Figure 2), is the most developed estuary in the northern area, with numerous private dwellings, a crab plant that discharges into an oxidation pond, and one packing house that discharges directly into the creek. Preliminary sampling of five stations on Cedar Creek revealed a well mixed estuary with little horizontal or vertical variation in temperature (Figure 10), salinity (Figure 11), or dissolved oxygen (Figure 12). MPN total coliform and MPN fecal coliform populations were greatest at the old wrecked boat (0.25 mile upstream from the creek's mouth) and between the crab plant and the packing house (Table 3). Three stations were selected for routine monitoring of surface and bottom water quality: (i) at the mouth of the creek, (ii) 750 yards upstream from the mouth between the crab plant and the packing house, and (iii) 800 yards from the second station at a heading of 327°.

(d) The portion of the Brunswick estuarine system monitored during the study (approximately 7.5 miles) included the Brunswick East River, the Brunswick River, and St. Simons Sound (Figure 3). The estuary receives industrial and domestic wastes from Brunswick and its surrounding areas, including the effluent from thawing, peeling, sorting, and cleaning operations of a major seafood processing plant discharging into the Brunswick River, and during normal shrimping years, the discharges from the heading tables of three packing houses. Ten preliminary stations were sampled to determine temperature (Figure 13), salinity (Figure 14), and dissolved oxygen (Figure 15) profiles and surface microbiological levels (Table 4). The estuary is well mixed with little vertical or horizontal temperature differential. There is no evidence of vertical salinity stratification; however, a horizontal gradient exists, showing a gradual decrease in salinity moving shoreward of Marker "19." Dissolved oxygen values were high and well mixed vertically, seaward of the East River Range Marker and "K" Street. The most rapid surface to bottom decrease in oxygen concentrations occurred at the two most inland stations, "K" Street and the end of the East River. Fecal coliform populations reached their highest levels inland of the Range Marker, and were indicative of sanitary sewage contamination discovered during an earlier unpublished microbiological and chemical survey. Surface and bottom water samples were regularly collected from seven stations in the southern area:

(1) Marker "19," located between the southern end of St. Simons Island and the northern end of Jekyll Island served as the control station for the southern area (5.75 miles downstream from the seafood processing plant and 7 miles from the packing houses).
(2) Marker "24," located in the Brunswick River southeast of Brunswick Point, which also served as a station (2.75 miles downstream from the processing plant and 4 miles from the packing houses) monitored monthly from September 1973 for the Brunswick Junior College estuarine water quality study (Brunswick Junior College, 1975) (Brunswick Junior College, 1976) (Brunswick Junior College, 1977).
(3) The central span of the Sidney Lanier Bridge in the Brunswick River 1.75 miles downstream from the seafood packing houses and 0.5 mile downstream from the processing plant discharge.
(4) Brunswick River 350 yards, at a heading of 113° from Marker "26," within 100 feet of the submerged discharge pipe from the seafood processing plant.
(5) East River State Docks at the foot of Fourth Avenue, approximately 0.5 mile downstream from the packing houses, the site of another Brunswick Junior College sampling station monitored since 1975 (Brunswick Junior College, 1975) (Brunswick Junior College, 1976) (Brunswick Junior College, 1977).
(6) East River at the foot of Prince Street, centered between three packing houses.
(7) The East River range markers located between Prince and "K" Streets.

RESULTS AND DISCUSSION

Data Collection and Treatment

The water quality in the northern (undeveloped estuary) and southern (developed estuary) areas was assessed at high and low tides to determine the effects of processing and packing effluents on monitored environmental parameters at the extremes of the tidal cycles. The field study, conducted during the summer of 1979, was completed during a period of reduced shrimp landings. Most harvested shrimp were headed at sea, which resulted in little or no activity at the packing houses. The only effluent sample collected from an operational packing house was taken in the northern sampling area at Shellbluff Creek (Figure 2). The grab sample was collected during the heading of approximately 1,000 pounds of rock shrimp from a single boat. A large seafood processing plant discharged a daily average of 215,000 gallons of effluent into the Brunswick River (southern area) from thawing, peeling, cleaning, and sorting operations (Figure 3). Four twenty-four hour composite samples were collected concurrent with estuarine sampling in July and August to characterize the chemical composition of the effluent (Table 5). Four grab samples were taken on the same days to assess the physical and microbiological parameters of the discharge (Tables 6, 7).

Microbiological levels and chemical parameters determined for each estuarine station sampled during July and August at high and low tides in the undeveloped and developed areas are listed in Tables 8-23. Rainfall data is presented in Table 24. Temperature, salinity, dissolved oxygen, and ammonia nitrogen profiles for each estuarine sampling run are presented in Figures 16-47.

One-and two-way analyses of variance were used to assess significant differences ($P < 0.05$) in chemical and microbiological parameters determined during the study (Remington and Shork 1970) (Schefler 1969). The statistical relationships between stations, within sample areas, between the northern and southern sample areas, and between effluent and receiving waters were examined. Additionally, influences of tidal stages and tidal interaction with other parameters were explored.

Control Stations

Analysis of variance of chemical and microbiological data collected at the two control sites in the undeveloped northern area (Sapelo Dock and Barn Creek on the Duplin River, Figure 2) and similar data collected at the single control station in the developed southern area (Marker "19" on St. Simons Sound, Figure 3) revealed few significant differences between the control stations. At low tide, the mean northern area marine agar plate count (4.47×10^3 organisms/ml) was significantly greater ($P < 0.01$) than the mean southern station plate count (1.99×10^3 organisms/ml). At high tide, the mean aerobic plate counts at 20C and 35C were significantly greater ($P < 0.01$ and $P < 0.05$, respectively) in the northern sampling area (mean values of 380 and 199 organisms/ml) than those found in the southern sampling area (mean value of 166 and 126 organisms/ml). Although the reported microbiological levels in the northern control area were significantly greater than the values determined for the southern control station, the differences of less than one order of magnitude would have little impact on the environmental quality of the undeveloped northern area. Mean high tide surface (6.13 mg/l) and bottom (6.38 mg/l) dissolved oxygen values at the southern area control station were significantly greater ($P < 0.01$) than the mean oxygen levels of the northern area control stations (5.27 mg/l surface and 4.99 mg/l bottom). A similar pattern was exhibited for bottom waters at low tide with a southern mean of 5.22 mg/l and a northern mean of 4.45 mg/l ($P < 0.05$). The southern control station's proximity to the open ocean permits a greater exchange of oxygenated ocean water (Figure 3) than the northern control stations (Figure 2). Oxygen transfer is enhanced by rapid currents in the 17.5-meter channel of the southern area, compared with the shallower 7-meter entrance to the Duplin River. Significantly higher surface and bottom dissolved oxygen values at high tide indicate increased water exchange with oxygenated high-salinity ocean water, while significantly higher bottom oxygen levels at low tide reflect salt wedge intrusion along the bottom of St. Simons Sound. A significantly lower ($P < 0.05$) mean bottom oxygen saturation value of 75% at high tide for the Duplin River, compared with 97% saturation at Marker "19" (southern area), reflects poor water exchange across the shallow sill at the mouth of the river. At high tide, a mean bottom BOD value of 1.55 mg/l for the northern control station was significantly greater than the southern load of 0.91 mg/l, and is an additional indication of poor transfer and dilution across the Duplin River sill. The mean surface suspended solids load at the southern control station is significantly greater at low tide (208 mg/l, $P < 0.01$) and at high tide (115 mg/l, $P < 0.05$) than the northern concentrations of 73 mg/l and 74 mg/l, respectively.

Comparison of the northern and southern control stations discloses several differences that must be factored into any conclusion about the impact of seafood processing and packing wastes on the estuarine systems examined during the study. Water exchange, specifically oxygenation, is not as rapid or complete in the shallow undeveloped northern systems as it is in the developed Brunswick River estuary. The natural BOD load of the bottom waters in the northern area is greater than that of the southern area. The southern area surface particulate load is higher; however, the percent organic composition would appear to be lower than that of the northern area, as evidenced by reduced or equivalent BOD loads for southern waters.

Experimental Stations

Two-way analysis of variance was used to determine any significant differences between the six undeveloped northern experimental stations and the six developed southern stations for each of the chemical and microbiological parameters monitored by the study. Stations were considered fixed factors (row values), and tidal stage was considered a random factor (column values), giving the following degree of freedom ratios: (i) Rows M_R/M_I, (ii) Columns M_C/M_W, and (iii) Interaction M_I/M_W (Remington and Shork, 1970). The mean aerobic plate count (20C) for all experimental stations in the southern area (1.10×10^3 organisms/ml) was significantly greater ($P < 0.01$) than the mean count in the northern area (530 organisms/ml). There was no significant difference between tidal stages; however, a significant ($P < 0.01$) synergistic interaction between the tidal stage and sampling area was determined. Aerobic plate counts at 35C exhibited the same relationship, with a southern mean of 1.26×10^3 organisms/ml and a northern mean of 350 organisms/ml ($P < 0.01$, interaction $P < 0.01$). As with the control stations, the southern mean surface (4.85 mg/l) and bottom (4.33 mg/l) dissolved oxygen values were significantly higher ($P < 0.01$) than the southern surface (4.15 mg/l) and bottom (3.76 mg/l) measurements. No significant tidal differences or interactions were determined. Percent oxygen saturation followed the same pattern, with a mean southern surface value of 73%, a bottom value of 65%, and northern values of 65% and 61%, respectively ($P < 0.01$). No significant differences or interactions were exhibited. Mean northern surface total suspended solids concentrations (78 mg/l) were significantly greater ($P < 0.01$) than the southern values (66 mg/l). No significant interaction or tidal differences were noted. Southern mean surface (7.70) and bottom (7.66) pH levels were significantly greater ($P < 0.01$) than the northern values of 7.47 and 7.45, respectively. Significant tidal differences or interactions were not indicated. Mean NH_4 levels of the southern experimental station (170 mg/l) were significantly greater ($P < 0.01$) for bottom waters than detected levels in the northern area (61 mg/l). No significant tidal differences were determined. The analysis of variance table indicated that a significant interaction ($P < 0.01$) existed between tidal stage and sampling area; however, the nature of the interaction could not be determined.

The differences in the northern (undeveloped) and southern (developed) experimental station were similar in many respects to the results obtained from the control stations. Dissolved oxygen and oxygen saturation levels were higher in both surface and bottom waters collected from the southern experimental stations, indicating more efficient water exchange in the portion of Brunswick River estuarine system surveyed. Total aerobic plate counts (at 20C and 35C) were greater in the southern experimental area which reflects the commercial and industrial development of the Brunswick River estuarine system. NH_4 levels in the bottom waters of the southern estuary were elevated. The mean pH of northern surface and bottom experimental waters was less than the pH values in the south, which could result from the leaching of humic acids, tannins, and lignins from marsh vegetation and soil and reduced mixing with oceanic water (mean pH 8.1 ± 0.2) (Martin, 1970). The mean pH values in the northern and southern areas are within the optimum values required by most estuarine organisms and fall within the range (pH of 7.5 - 7.9) considered normal for Georgia's estuaries (Stickney and Miller, 1973).

Northern Area Experimental and Control Stations

Total water column environmental data collected at the two control stations and at the six experimental stations in the northern area were examined by two-way analysis of variance, with high and low tidal samples considered random variables, to ascertain any significant differences between stations. A low tide mean aerobic plate count (20C) of 290 organisms/ml was significantly less ($P < 0.01$) than the mean high tide population of 790 organisms/ml. No significant differences between stations or tidal interactions were detected. The mean aerobic plate count (35C) at low tide (212 organisms/ml) was significantly less ($P < 0.01$) than the mean number of microorganisms determined at high tide (499 organisms/ml). A significant difference ($P < 0.01$) in total aerobic plate count (35C) within the undeveloped northern sample area was determined for the following mean station values:

Main Dock Sapelo (Duplin River)	153 org/ml
Mouth of Shellbluff Creek ("162")	253 org/ml
Cedar Creek (Mouth)	282 org/ml
Duplin River (Barn Creek)	309 org/ml
Cedar Creek (Packing House/Crab Plant)	325 org/ml
Shellbluff Creek (Packing House)	376 org/ml
Cedar Creek (Last Dock)	421 org/ml
Shellbluff Creek (Bend above Packing House)	473 org/ml

A significant tidal interaction ($P < 0.01$) was detected. Although the number of microorganisms enumerated was relatively small, a definite pattern was apparent. Those stations upstream from the packing houses, the last dock on Cedar Creek, and the bend above the packing house on Shellbluff Creek indicated a synergistic tidal effect that results in the upstream concentration of microbial numbers during high tides.

The mean marine agar plate count (20C) at high tide (8.93×10^3 organisms/ml) was significantly greater ($P < 0.05$) than the mean count at low tide (6.15×10^3 organisms/ml) The difference in mean marine plate counts (20C) at the following undeveloped northern sampling stations was significant ($P < 0.01$):

Main Dock Sapelo (Duplin River)	3.42×10^3 org/ml
Duplin River (Barn Creek)	6.20×10^3 org/ml
Mouth of Shellbluff Creek ("162")	7.33×10^3 org/ml
Cedar Creek (Mouth)	7.50×10^3 org/ml
Cedar Creek (Last Dock)	7.53×10^3 org/ml
Cedar Creek (Packing House/Crab Plant)	8.20×10^3 org/ml
Shellbluff Creek (Packing House)	8.51×10^3 org/ml
Shellbluff Creek (Bend above Packing House)	1.88×10^3 org/ml

No tidal interactions were evident. As with the aerobic plate counts, the mean marine agar organisms reached a maximum at high tide. The packing house station and the stations upstream from them again had the highest microbial populations. Total MPN coliforms indicated a significant but undefined interaction ($P < 0.05$) between tidal stage and station location, but no significant differences between stations and tidal stage.

A significant increase ($P < 0.01$) in the mean dissolved oxygen content of northern stations' waters at high tide (4.36 mg/1) was noted when compared with low tide concentrations (4.03 mg/1). The following mean dissolved oxygen values at the eight undeveloped northern stations were significantly different ($P < 0.01$):

Shellbluff Creek (Bend above Packing House)	3.54 mg/l
Cedar Creek (Last Dock)	3.70 mg/l
Cedar Creek (Mouth)	3.97 mg/l
Cedar Creek (Packing House/Crab Plant)	3.99 mg/l
Shellbluff Creek (Packing House)	4.21 mg/l
Mouth of Shellbluff Creek ("162")	4.30 mg/l
Duplin River (Barn Creek)	4.77 mg/l
Main Dock Sapelo (Duplin River)	5.10 mg/l

No significant tidal interactions were determined. The stations farthest upstream on Shellbluff Creek (3.54 mg/l) and Cedar Creek (3.70 mg/l) exhibited the lowest dissolved oxygen levels and the poorest water quality, as was the case for the microbiological parameters. Three of the four lowest oxygen values were recorded in Cedar Creek, the most developed northern estuary. The two control stations displayed the best water quality, while the packing house stations exhibited intermediate to low water quality.

Percent dissolved oxygen saturation was significantly greater ($P < 0.05$) at high tide (65%) than at low tide (59%). Mean percent dissolved oxygen saturation differed significantly ($P < 0.01$) for the eight undeveloped northern stations:

Shellbluff Creek (Bend above Packing House)	53%
Shellbluff Creek (Packing House)	53%
Cedar Creek (Last Dock)	55%
Cedar Creek (Mouth)	60%
Cedar Creek (Packing House/Crab Plant)	60%
Mouth of Shellbluff Creek ("162")	65%
Duplin River (Barn Creek)	74%
Main Dock Sapelo (Duplin River)	78%

There were no significant tidal interactions. Percent oxygen saturation means followed a pattern similar to dissolved oxygen values, with the poorest water quality exhibited at the ends of the creeks, near the packing houses, and at the mouth of Cedar Creek.

Mean high tide pH readings (7.56) were significantly greater ($P < 0.01$) than low tide readings (7.45). A significant difference ($P < 0.01$) was determined for the mean pH values recorded from the northern area stations:

Cedar Creek (Last Dock)	7.29
Cedar Creek (Packing House/Crab Plant)	7.42
Shellbluff Creek (Packing House)	7.44
Shellbluff Creek (Bend above Packing House)	7.48

Cedar Creek (Mouth)	7.49
Shellbluff Creek (Mouth)	7.58
Duplin River (Barn Creek)	7.64
Main Dock Sapelo (Duplin River)	7.71

The trend exhibited by other significantly different chemical parameters was repeated with pH; the lowest levels were determined at the upstream stations on Cedar and Shellbluff Creeks and at the packing house stations. Higher pH values, approaching oceanic, were recorded at the Duplin River stations. The observed pH appears to be directly related to the dynamic balance between the degree of oceanic mixing and the leaching of acidic marsh components.

During the survey (a period of little or no packing house activity in the northern area), all significantly different parameters monitored in the northern area increased at high tide. Increased aerobic plate counts (at 20C and 35C) and marine agar plate counts (20C) at high tide indicate transport of a wide variety of microorganisms from higher salinity areas outside the study area. The low levels of microorganisms involved are indicative of a clean environment. Although there were no significant differences between the MPN coliform values determined during the study, a median value of 24 total coliform/100 ml (with $< 10\%$ of the samples > 230 total coliforms/100 ml) classifies the location as a suitable shellfish growing area (Houser, 1965). Predictably, dissolved oxygen levels, percent oxygen saturation, and pH increased with the mixing of incoming oceanic waters at high tide. The comparison of individual stations revealed the poorest water quality for microbiological as well as chemical parameters at the packing house stations and at the stations upstream from the packing houses in Cedar and Shellbluff Creeks. Both creeks have shallow (1.5 to 3 meters deep) sills just beyond their entrances, followed by deeper pools next to the packing houses. Both features reduce the effectiveness of tidal mixing and increase the possibility of stagnation and nutrient concentration in the creeks.

<u>Southern Area Experimental and Control Stations</u>

The statistical treatment of the environmental data collected at the seven southern area stations, comparing station to station, was the same as that carried out for the northern area. The mean aerobic plate counts (20C) listed below for the seven developed southern sampling stations were significantly different ($P < 0.01$):

Marker "19"	202 org/ml
Sidney Lanier Bridge	569 org/ml
Range Marker East River	694 org/ml
Marker "24"	750 org/ml
Fourth Avenue East River	1.28×10^3 org/ml
Prince Street East River	1.51×10^3 org/ml
Discharge Pipe, Seafood Processing plant	3.07×10^3 org/ml

No significant difference between high and low tides was determined; however, a significant but undefined interaction ($P < 0.01$) between tidal stage and station was noted. The greatest mean populations of aerobic plate count organisms (20C) were within 100 feet of the processing plant discharge pipe, at a station 0.5 mile upstream from the pipe, the site of a large commercial dock at the foot of Fourth Avenue, and at Prince Street, which is centered between the idle packing houses.

The mean low tide aerobic plate count (35C) population (1.99×10^3 org/ml) was significantly greater ($P < 0.01$) than the mean high tide population (494 org/ml) for all seven southern stations. Significant differences ($P < 0.05$) were indicated between mean 35C plate counts:

Marker "19"	238 org/ml
Range Marker East River	761 org/ml
Marker "24"	770 org/ml
Sidney Lanier Bridge	891 org/ml
Prince Street East River	1.50×10^3 org/ml
Fourth Avenue East River	1.65×10^3 org/ml
Discharge Pipe, Seafood Processing Plant	3.08×10^3 org/ml

No significant tidal interactions were detected. Aerobic plate counts (35C) indicated microbial distribution patterns that were similar to samples incubated at 20C with maximum populations at the processing plant discharge pipe, followed by Fourth Avenue, and Prince Street. The fewest plate count organisms were determined for the two most seaward stations, Marker "19" and "24," and for the most inland station, the East River Range Marker.

The distribution of MPN total coliforms was significantly different ($P < 0.01$) within the seven developed southern sampling stations:

Marker "19"	1.3 org/100 ml
Marker "24"	7.9 org/100 ml
Sidney Lanier Bridge	9.9 org/100 ml
Fourth Avenue East River	21.5 org/100 ml
Prince Street East River	179.5 org/100 ml
Range Marker East River	223.3 org/100 ml
Discharge Pipe, Seafood Processing Plant	1.91×10^3 org/100 ml

No significant tidal differences or interactions were determined. The seafood processing plant discharge point had the highest microbial load. The remaining stations followed a simple dilution pattern, with a reduction in total MPN coliform counts moving seaward from the end of the East River.

Mean dissolved oxygen concentrations were significantly greater ($P < 0.01$) at high tide (5.05 mg/l) than at low tide (4.45 mg/l). A significant difference ($P < 0.01$) was determined for the dissolved oxygen values at the seven southern stations:

Range Marker East River	4.16 mg/l
Prince Street East River	4.23 mg/l
Discharge Pipe, Seafood Processing Plant	4.46 mg/l
Sidney Lanier Bridge	4.71 mg/l
Fourth Avenue East River	4.78 mg/l
Marker "24"	5.18 mg/l
Marker "19"	5.71 mg/l

There was a significant interaction ($P < 0.05$) that produced a synergistic effect between tidal stage and dissolved oxygen concentrations at the monitored stations. Oxygen concentrations generally increased at more seaward stations and at high tide, as would be expected with greater mixing of oceanic waters. The exception was the seafood processing plant discharge point, which had lower dissolved oxygen values than would be anticipated by its relative seaward position.

Mean percent oxygen saturation followed a similar pattern with a significant increase ($P < 0.01$) at high tide (76%) over low tide (68%). Station saturation values differed significantly ($P < 0.05$):

Range Marker East River	63%
Prince Street East River	64%
Discharge Pipe, Seafood Processing Plant	69%
Sidney Lanier Bridge	71%
Fourth Avenue East River	73%
Marker "24"	78%
Marker "19"	87%

Percent oxygen saturation values displayed no tidal interaction; however, the relative saturation values at each station followed the same pattern exhibited by the dissolved oxygen values. Although no significant differences were determined between tidal or station BOD loads, a significant but undefined interaction ($P < 0.05$) was shown between mean low tide (1.72 mg/l), high tide (1.15 mg/l), and station levels.

A significant difference ($P < 0.05$) was determined for pH values reported for the seven southern stations:

Discharge Pipe, Seafood Processing Plant	7.62
Sidney Lanier Bridge	7.64
Fourth Avenue East River	7.65

Prince Street East River	7.69
Range Marker East River	7.71
Marker "24"	7.77
Marker "19"	7.85

No significant tidal differences or interactions were detected for pH.

Environmental parameters monitored in the southern developed area were less affected by tidal stage than those in the northern area. Aerobic plate counts (35C) were significantly greater at low tide than at high tide. Dissolved oxygen and percent oxygen saturation values followed the pattern established in the northern area with increased levels determined during high tides. The largest microbial populations were encountered at the seafood processing plant discharge pipe, with mean aerobic plate counts of 3.07×10^3 org/ml (20C) and 3.08×10^3 org/ml (35C) and MPN total coliform counts of 1.91×10^3 org/100 ml. The highest quality water was found at the two most seaward stations, Markers "19" and "24." The remainder of the stations appeared to adopt a simple dilution pattern, increasing microbiological quality with seaward movement. Dissolved oxygen and percent oxygen saturation values generally increased seaward of the East River Range Marker, with the exception of the reduced readings at the seafood processing plant discharge point. The lowest mean pH value was recorded at the seafood processing plant discharge point, but a value of 7.62 would cause no stress on the estuarine environment. The southern sampling area appears to be under greater environmental stress than the northern area; however, a greater exchange capacity with incoming seawater is apparent. Although the three packing houses located on the East River were not operating during the study, the seafood processing plant discharged approximately 215,000 gallons of effluent per day into the Brunswick River, allowing the plant's impact on the estuary to be monitored.

Northern Packing House Effluent

One packing house effluent sample was collected during the study. The monitored environmental parameters from the sampled effluent produced during the heading of approximately 1,000 pounds of rock shrimp at the packing house on Shellbluff Creek were compared with the analyses of surface and bottom receiving waters within fifty feet of the discharge point (Packing House Station, Shellbluff Creek), 500 yards upstream from the discharge point (Bend above the Packing House, Shellbluff Creek) and approximately three-eighths of a mile downstream from the discharge point (Marker "162," Mouth of Shellbluff Creek) by one-way analyses of variance to quantify the effluent's significant effects on the environment. The mean effluent and station values for each monitored parameter and any significant differences are presented in Table 25. An effluent BOD level of 421 mg/l was significantly greater ($P < 0.01$) than the surface and bottom BOD values for the receiving waters; however, the impact on the estuary appeared to be minimal. No significant differences were detected between surface estuarine stations. A bottom BOD value of

2.9 mg/l at the downstream station was significantly greater ($P < 0.05$) than the BOD levels at the discharge point (1.9 mg/l) and upstream from the packing house (2.2 mg/l). Suspended solids levels in the effluent (13 mg/l) were significantly less ($P < 0.01$) than the mean surface and bottom levels of the receiving waters. The surface and bottom waters at the downstream station had significantly fewer ($P < 0.05$ and $P < 0.01$, respectively) suspended solids (64.5 mg/l and 104 mg/l, respectively) than the other stations. The station at the mouth of Shellbluff Creek (Marker "162") is downstream from the shallow entrance sill and is exposed to more water exchange than the two upstream stations, indicating that the reduced solids load resulted from natural estuarine water exchange and was not associated with the packing house discharge. Discharge NH_4 levels (179 μg/l) were significantly greater ($P < 0.01$) than the receiving water levels. The surface station NH_4 level at the discharge point (52 μg/l) was significantly greater ($P < 0.05$) than the mean surface NH_4 values at the upstream (35 μg/l) and downstream (27 μg/l) stations, the first elevated environmental parameter in the receiving waters. The effect was limited to the discharge point, however. There was no significant difference between the dissolved oxygen concentrations of the effluent and surface estuarine waters, but the effluent level (4.27 mg/l) was significantly greater ($P < 0.05$) than the dissolved oxygen levels of the bottom waters. The aerobic plate counts at 20C showed no significant differences between the effluent and the estuarine stations or between the stations. The discharge aerobic plate count at 35C (1.35×10^4 org/ml) was significantly greater than the receiving waters at the discharge point (708 org/ml), the upstream station (759 org/ml),and the downstream station (288 org/ml). There were no significant differences between the estuarine stations, indicating minimal impact from the effluent. The effluent marine agar plate count (20C) was not significantly different than the receiving waters. The marine agar plate count at the mouth of the creek, Marker "19" (9.55×10^3 org/ml), was significantly less ($P < 0.01$) than the two upstream estuarine stations. Again, the reduction appeared to be related to estuarine mixing at the mouth of Shellbluff Creek and not to the packing house discharge.

Although the results from a single packing house effluent sample form a limited data base, there appeared to be little immediate impact on Shellbluff Creek. Effluent BOD, NH_4, and aerobic plate count loads (35C) were significantly greater than the receiving waters, but the NH_4 level was the only elevated parameter at the packing house discharge point. The ability of small estuarine creeks to maintain nominal water quality under sustained packing house operations cannot be determined from a single sample during a period of packing house inactivity. The potential for water quality deterioration exists, particularly upstream from the packing house, an area of reduced water exchange.

Southern Processing Plant Effluent

Four 24-hour composite and four grab samples were collected from the processing plant effluent during July and August, concurrent with estuarine sampling in the southern developed area. Two samples were collected at high tide and two at low tide. The plant discharge averaged 215,000 gallons per day during the study period. Mean data values and significant differences were determined from effluent samples and surface and bottom estuarine samples collected within 100 feet, 0.5 mile downstream (Sidney Lanier Bridge), and 0.5 mile upstream (Fourth Avenue East River) from the discharge pipe; these are presented in Tables 26, 27, 28, and 29.

Effluent BOD loads (means ranged from 255-295 mg/l) were significantly greater ($P < 0.01$) than the mean BOD levels of surface and bottom receiving waters at low and high tides (0.67 - 6.41 mg/l). A low tide surface BOD of 13.00 mg/l in July and a surface low tide value of 2.19 mg/l during August at the discharge point were both significantly greater ($P < 0.01$) than the respective upstream or downstream stations. During July, significantly higher BOD loads did not extend to the downstream station at low tide; however, a mean August bottom BOD at the Sidney Lanier Bridge of 1.75 mg/l was significantly greater ($P < 0.05$) than the discharge point concentrations. A BOD load of 6.41 mg/l at the bottom of the upstream station (August) was significantly greater than the two bottom downstream estuarine samples. The high BOD load is indicative of a BOD source upstream from the Fourth Avenue station or the entrapment of organic materials in the twelve-meter basin at Fourth Avenue. Mean bottom low tide BOD levels for the East River at two stations upstream from Fourth Avenue, Prince Street, and the East River Range Marker, were between 0.28 mg/l and 1.19 mg/l (Tables 13, 21). Decreased BOD values upstream and downstream from Fourth Avenue support the probable entrapment of decaying organic materials at the bottom of Fourth Avenue basin, increasing the station's BOD load. The BOD load from the seafood processing plant could add organic materials to the basin as the effluent mixed with incoming waters during flood tides. A July bottom BOD value at the upstream station (Fourth Avenue) of 2.67 mg/l, was significantly greater ($P < 0.05$) than the discharge point or the downstream station (Sidney Lanier Bridge) levels at high tide. As in the previous example, the Fourth Avenue basin could be collecting organic material from the seafood processing plant and/or other sources. The August BOD's show no significant differences among the three bottom estuarine samples, although the surface high tide sample at the downstream station (0.71 mg/l) was significantly less ($P < 0.05$) than the other stations. The decreased BOD reflects mixing of higher quality oceanic water by flood tides.

Effluent suspended solids collected at low tide during July and August (120 mg/l and 98 mg/l, respectively) were significantly greater ($P < 0.01$) than solids concentrations in the surface receiving waters (mean ranged from 41 mg/l to 93 mg/l) but were significantly less ($P < 0.05$) than the bottom water levels at the July sampling. Bottom low tide suspended solids levels were significantly higher ($P < 0.01$) at the Fourth Avenue station (528 mg/l) in July, while August samples (79 mg/l) were significantly less ($P < 0.05$) than the plant discharge point or the Lanier Bridge. The August effluent suspended solids sample (80 mg/l) was significantly less ($P < 0.01$) than the levels recorded from the bottom receiving waters at high tide. No other significant differences were determined between the July and August effluent samples and estuarine waters at high tide. July and August high tide surface suspended solids samples at Fourth Avenue, 29 mg/l ($P < 0.01$) and 57 mg/l ($P < 0.05$) respectively, were significantly less than the load at the other estuarine stations. Bottom water from Fourth Avenue had a significantly greater ($P < 0.01$) solids concentration (633 mg/l) at high tide in July.

The mean plant discharge NH_4 levels were significantly greater ($P < 0.01$) (mean range 1616 μg/l to 2649 μg/l) than the estuarine receiving waters for all sampling trials. The August surface high tide (103 μg/l) and low tide (57 μg/l) NH_4 levels at the discharge point were significantly greater ($P < 0.01$) than the NH_4 concentrations at the next upstream and downstream stations. The bottom levels at Fourth Avenue, the upstream station (256 μg/l), were significantly greater ($P < 0.01$) than bottom concentrations at the remaining stations. July samples from the discharge station had significantly greater ($P < 0.01$) surface NH_4 levels (150 μg/l) at low tide than the upstream or downstream stations. The bottom low tide NH_4 sample from the Fourth Avenue station (271 μg/l) was significantly greater ($P < 0.01$) than the other estuarine bottom samples. Again at high tide, the upstream station (688 μg/l) had significantly greater ($P < 0.01$) NH_4 concentrations than the discharge point (420 μg/l), which in turn had significantly higher levels ($P < 0.01$) than the Sidney Lanier Bridge or downstream stations (101 μg/l). As with the BOD load and total suspended solids, the Fourth Avenue station appears to be acting as a trap to collect organic materials that decay in the station's bottom waters.

Dissolved oxygen levels were significantly greater ($P < 0.01$) in the effluent (mean range 5.60 to 7.55 mg/l) than the estuarine waters. The July low tide bottom value (3.79 mg/l) and the August high tide surface level (4.35 mg/l) at the discharge point were significantly less ($P < 0.01$) than the up or downstream stations. The surface high tide dissolved oxygen concentrations at the downstream station (5.83 mg/l) was significantly greater ($P < 0.05$) than the other estuarine stations, indicating increased mixing at the Lanier Bridge. Surface low tide dissolved oxygen levels determined in July and August (4.47 mg/l) at the downstream station were significantly less ($P < 0.05$, $P < 0.01$, respectively) than the upstream stations and may represent an immediate oxygen uptake by the plant discharge as it flows seaward during ebb tides.

Aerobic plate counts (mean range 2.29×10^5 to 5.62×10^6 organisms/ml at 20C and 1.23×10^5 to 1.95×10^6 organisms/ml at 35C) and marine agar plate counts (mean range 1.51×10^5 to 4.27×10^6 organisms/ml at 20C) recovered from the processing plant effluent were significantly greater ($P < 0.01$) than the receiving water populations in all cases. At low tide, July aerobic plate counts (20C, 1.70×10^4 organisms/ml) and marine agar plate counts (20C, 4.68×10^4 organisms/ml) were significantly greater ($P < 0.01$) at the discharge point than the upstream or downstream stations (mean range 1.35×10^3 to 1.05×10^4 organisms/ml). August low tide aerobic plate count populations (35C, 4.27×10^3 organisms/ml) were significantly greater ($P < 0.01$) at the discharge point than the upstream

(468 organisms/ml) or downstream (537 organisms/ml) stations. The same pattern was followed for marine agar plate counts (6.17×10^3 organisms/ml) at low tide, which were significantly greater ($P < 0.01$) than the upstream (3.71×10^3 organisms/ml) or downstream (2.40×10^3 organisms/ml) stations. The effluent's effect on the microbial populations of the estuary cannot be detected at the Sidney Lanier Bridge, one-half mile downstream. July high tide 20C aerobic plate counts (766 organisms/ml) and 35C aerobic plate counts (537 organisms/ml) at the discharge point were significantly greater ($P < 0.05$) than the respective populations downstream at the Sidney Lanier Bridge (324 organisms/ml and 282 organisms/ml, respectively) and significantly less ($P < 0.01$) than the upstream populations of 3.09×10^3 organisms/ml and 2.04×10^3 organisms/ml. Flood tide waters appeared to transport microbial organisms discharged from the plant upstream, where they accumulated in significantly greater numbers at the Fourth Avenue station during the July sampling run. The high tide results from August show significantly higher ($P < 0.05$) populations of aerobic plate count organisms at 20C (1.58×10^3 organisms/ml) and 35C (1.78×10^3 organisms/ml) and marine organisms at 20C (3.24×10^5, $P < 0.01$) associated with the discharge point than those organisms determined up or downstream from the station. The marine microbial level (20C) of 2.19×10^4 organisms/ml at the upstream station was significantly greater ($P < 0.05$) than the downstream station at high tide (6.46×10^3 organisms/ml), and represented the single August indicator of organism transport upstream from the processing plant discharge point.

The seafood processing plant discharged 215,000 gallons of effluent per day from peeling, sorting, thawing, and cleaning operations, contributing the following physical, chemical, and biological components to the estuary:

BOD (pounds)	494
Suspended Solids (pounds)	161
NH_4-N (pounds)	4
Aerobic Organisms, 20C	1.34×10^{15}
Aerobic Organisms, 35C	1.81×10^{15}
Marine Organisms, 20C	1.08×10^{15}
Total Coliforms	7.66×10^{11}
Fecal Coliforms	5.45×10^{10}

The BOD load at the discharge point was significantly higher than surrounding waters in two of four surface samples. The increase ranged from less than 1 to 12 mg/l. The effluent appears to be well diluted before it reaches the downstream station (Sidney Lanier Bridge). In two instances, (i) at high tide (2.67 mg/l) and (ii) low tide (6.41 mg/l), BOD values in the bottom waters of the upstream station (Fourth Avenue) were significantly greater than the downstream station. The BOD levels, particularly from the bottom waters, determined for the upstream station were one of several indications of organic entrapment and breakdown in the ship basin next to the Fourth Avenue dock. The seafood processing plant effluent is not the only possible source of materials collecting in the basin, but it must certainly contribute to the overall load at that station. The effluent suspended solids load is relatively low and within the normal range of natural estuarine fluctuations. At high tide the suspended solids load of the effluent was significantly less than the receiving waters for one bottom sample, with no difference for the remaining samples. At low tide, two surface and one bottom sample contained significantly fewer suspended solids than the effluent. The large bottom suspended solids load determined from high tide (633 mg/l) and low tide (528 mg/l) samples collected at Fourth Avenue in July supports the conjecture that materials accumulate in the ship basin.

NH_4 levels in the effluent (mean range 1616-2649 µg/l) were significantly greater than the receiving water levels on all sampling runs. Dilution and dispersion of the NH_4 is intermittent and less rapid than the other monitored chemical parameters. Significantly higher NH_4 levels were determined in three of four surface samples and in one bottom sample at the discharge point. Elevated NH_4 levels were detected in three of four bottom samples collected from the Fourth Avenue station. The dissolved oxygen content of the effluent was significantly greater than the receiving waters on all occasions (mean range 5.60 - 7.55 mg/l). A significant reduction in dissolved oxygen content at the discharge point provided evidence of immediate oxygen demand caused by mixing of the effluent with receiving waters in July (bottom low tide value of 3.79 mg/l) and August (surface high tide of 4.35 mg/l). A surface reduction in dissolved oxygen was demonstrated at the downstream station in July and August at low tide (4.47 and 4.47 mg/l).

Effluent aerobic (20C and 35C) and marine (20C) plate counts were significantly greater than all receiving water populations sampled. The plant discharge point had significantly higher levels of (i) aerobic plate count organisms (20C) on three of four sampling runs, (ii) aerobic plate counts (35C) on three of four determinations, and (iii) marine agar plate counts on three of four occasions. The effluent appears to be rapidly diluted during low tides with no significant increase in microbial numbers at the Sidney Lanier Bridge. Microbiological populations upstream at the Fourth Avenue station rose significantly following flood tides with increased aerobic plate count organisms at 20C (3.09×10^3 organisms/ml) and 35C (2.04×10^3 organisms/ml) in July and increased marine organisms (6.46×10^3 organisms/ml) in August.

The fecal coliform levels of the processing plant effluent (geometric mean of 2889 organisms/100 ml) exceed State of Georgia microbiological guidelines for waters classified for recreation, and waters used for fishing, propagation of fish, shellfish, game, and other aquatic life, but remained under geometric limit of 5000 fecal coliforms/100 ml used to designate agricultural or navigational waters (Georgia Department of Natural Resources,1974). A geometric mean of 139 fecal coliforms/100 ml at the discharge point exceeds the 100 organisms/100 ml limit set for coastal recreation waters but was well within state requirements of the river's current classification for fishing, propagation of fish, shellfish, game, and other aquatic life (a geometric mean of 1,000 fecal coliforms/100 ml). The remainder of the southern area stations were within the fecal coliform limits set for recreation waters (Georgia Department of Natural Resources,1974).

NH_3 levels in the Northern and Southern Areas

The recent proposal by the U.S. Environmental Protection Agency (Federal Register, Vol. 42, No. 2, January 3, 1980) to include ammonia in the toxic pollutants list (1977 Amendments to the Clean Water Act, 33 U.S.S. 1251 etseq.) could have had an adverse effect on the seafood processing industry and represented a significant reversal of EPA policy. On August 29, 1979, EPA withdrew 1983 BAT (Best Available Technology Economically Achievable) standards until completion of a new study that will propose new BCT (Best Conventional Technology) standards to replace the defunct BAT standards and present BPT (Best Practical Control Technology Currently Available) standards. Pollutants listed as toxic under section 308(a) are not eligible for waivers from BAT based on water quality [section 301(g)] or economic [section 301(c)] grounds. Listing of a pollutant under section 307 may also affect the date by which BAT requirements are met, and could lead to the immediate establishment of effluent standards under section 307.

Un-ionized ammonia, NH_3, which is 50 times more toxic than $[NH_4]^+$, has been identified as a probable toxic agent by the U.S. EPA at levels above 20 µg/l (Emerson et al., 1975) (Thurston et al., 1978) (Trussel, 1972). The ammonia-ammonium equilibrium shifts toward NH_3 with increasing pH and temperature and toward $[NH_4]^+$ with increasing ionic strength, salinity in estuarine waters (Bower and Bidwell,1978) (Trussel,1972). As the proportion of un-ionized ammonia varies with environmental conditions and cannot be directly controlled in the ambient water, EPA proposed to list total ammonium, $[NH_4]^+$, as a toxic pollutant. The proposed maximum permissible level of total ammonium was not stated in the Federal Register, but a single standard for all water types and locations was implied.

The NH_3 levels listed in Tables 30 and 31 were calculated using Bower and Bidwell's (Bower and Bidwell, 1978) calculations (as referenced by the January 3, 1980 Federal Register) from $[NH_4]^+$ determinations completed during the monitoring operations of estuarine stations and processing and packing house discharges in the northern and southern sampling areas. The tentative EPA guideline of 20 µg NH_3/l was not exceeded by any estuarine station in the northern or southern sampling areas. The packing house effluent at 5.75 µg NH_3/l was well below the guidelines. The processing plant discharge exceeds the tentative ammonia guidelines with maximum and minimum NH_3 concentrations of 75.23 µg/l and 39.11 µg/l, respectively. The maximum NH_3 level at the plant discharge point reached 10.87 µg/l for bottom water samples. Marker "19" (10.68 µg NH_3/l) approached and Marker "24" (18.04 µg NH_3/l) exceeded (nearing the EPA limit) the NH_3 concentrations of the discharge point at 5.75 miles and 2.75 miles downstream from the plant, respectively. Marker "19" and "24" were located in areas of strong tidal currents and were exposed to tidal mixing with oceanic waters.

Other monitoring parameters indicated little or no processing plant influence on the seaward stations. NH_3 levels were elevated at the Fourth Avenue East River station with a maximum concentration of 17.54 μg/1. Natural maximum NH_3 levels monitored in St. Simons Sound 5.75 miles seaward of the processing plant approached NH_3 levels determined at the plant's discharge point. Two estuarine stations in the southern area approached 20 μg NH_3/1. Both samples were collected from the bottom, near the entrance to St. Simons Sound and in the basin at Fourth Avenue, a site of intermittent concentrations of decomposing organic materials believed to be transported to the area by tidal flow.

CONCLUSIONS

Cedar Creek, Shellbluff Creek, and the Duplin River were characterized by relatively shallow sills at the mouths of the rivers with deeper basins further upstream. Water exchange across the sills was limited, particularly in Shellbluff Creek and Cedar Creek, as evidenced by decreased oxygen concentrations. BOD levels from the northern control stations indicated a naturally occurring organic load greater than that determined for the southern control station. More microbial organisms were transported into the area at high tide than were flushed out during low tide. Levels were low, however, with mean coliform populations below those required for shellfish growing areas (Houser,1965).

The northern sampling area was exposed to little packing house activity; however, the basins next to the packing houses and the shallow upstream stations at the end of Shellbluff Creek and Cedar Creek were the area's most stressed waters. The impact of full packing house production on the shallow monitored creeks cannot be reliably predicted from one grab sample, but water quality at the packing house basins and at the shallow upstream portions of the small estuaries could be degraded to an unacceptable degree if overloaded with packing wastes. The single packing house discharge sample had significantly higher NH_4, BOD, and microbiological levels than the receiving waters, and significantly elevated the NH_4 levels at the packing house discharge point. Nitrogen is a limiting factor in most southeastern estuaries, and excessive amounts could produce phyto-plankton blooms and an ensuing reduction in water quality (Haines,1979) (Ho and Barret,1975) (Rhyther and Dunstan,1971) (Thayer,1974) (Thurston et al., 1978). The remaining parameters had little impact on the receiving waters.

Baseline water quality data have been established during a poor shrimping year with little or no packing house activity for several small coastal Georgia estuaries which are normally exposed to seafood packing wastes. Comparison of the baseline data with future studies during normal production years will be required to establish the impact of packing house wastes on small southeastern estuaries.

Despite the lack of packing house activity during the study, the seafood processing plant discharged a daily average of 215,000 gallons of seafood processing wastes into the East River. The southern area was characterized by (i) greater tidal mixing than the northern area, (ii) net transport of microorganisms out of the estuary with maximum populations at low tide, (iii) water quality generally increasing with seaward movement and following a simple dilution pattern, and (iv) greater environmental stress than the northern area. BOD, NH_4, and microbial levels were significantly greater in the effluent than the southern receiving waters.

BOD loads increased approximately one mg/l at the discharge point in 40% of the samples tested. Good downstream mixing and dilution of the BOD load was demonstrated, but flood tides produced an occasional BOD increase in the basin at the upstream station (Fourth Avenue East River). Dissolved oxygen levels fell below the Georgia Environmental Protection Division minimum of 4.0 mg/l for recreational and fishing waters in both the developed and undeveloped areas, including the Duplin River or control estuary, and Cedar Creek which received no processing or packing effluents during the study. The data indicate that in summer, dissolved oxygen levels below 3.0 mg/l are not uncommon for undeveloped portions of Georgia's estuaries.

NH_4 dispersion was less rapid and more intermittent than the other parameters, with levels at the discharge point elevated significantly in 50% of the samples. NH_4 levels were significantly higher at the Fourth Avenue station in 75% of the bottom samples. Again, the water quality of the deep basin at Fourth Avenue decreased relative to the surrounding stations.

Low tides brought rapid dilution of microbiological populations seaward of the processing plant discharge point, which had significantly greater populations than surrounding waters in 75% of the samples, and high tides led to the entrapment of microorganisms at the Fourth Avenue station. Although effluent MPN fecal coliform populations (geometric mean of 2889 organisms/100 ml) exceeded State of Georgia EPD guidelines for waters used to propagate fish and shellfish (the current classification of the Brunswick River and the East River), the waters at the discharge point (geometric mean of 139 organisms/100 ml) were within the guideline (Georgia Department of Natural Resources,1974). All other stations were within EPD mean fecal coliform maximum levels for recreational waters (Georgia Department of Natural Resources,1974).

Ebb tides appeared to rapidly flush the estuary of pollutants, showing a simple dilution pattern for plant discharges, moving seaward. The impact of the seafood processing waste was dissipated within 0.5 mile of the processing plant discharge point. Flood tide interactions were more complex, resulting in occasional upstream transport and entrapment of processing and other East River wastes in the basin at Fourth Avenue. As in the northern area, the deep basins and upstream stations were most sensitive to the impact of the seafood processing wastes. Generally, the effect of the processing plant effluent was dissipated within one-half mile of the discharge pipe, while occasional hydrographic conditions resulted in the deterioration of water quality one-half mile upstream from the plant. None of the monitored parameters reached critical levels, but basins and areas subject to poor tidal flushing could place constraints on seafood processing waste disposal.

Measurable, statistically significant differences in a number of monitored chemical and biological parameters were determined for seafood packing and processing effluents generated from peeling, sorting, thawing, cleaning, and heading operations and for the receiving waters of developed and undeveloped estuaries. Generally, the effects were short-lived and rapidly dissipated with tidal flushing. Shallow sills and deep basins reduced tidal exchange and led to increased organic loads, even in areas that did not receive seafood wastes. Georgia's coastal estuaries normally carry a high particulate and dissolved organic load from the natural flushing of vast, highly productive coastal marshes (Reimold et al., 1975) (Stickney and Miller, 1973). Calculations converting the seafood processing plant's daily BOD load (494 pounds) to a given weight of organic material (in terms of glucose/glutamic acids, 1:1) produced daily organic load values equivalent to the organic material discharged from a 302 m^2 plot (57 feet x 57 feet) of salt marsh per day (American Public Health Association, 1976) (Reimold et al., 1975). The impact of small packing houses and processing plants discharging only seafood waste, not breading or sewage, is small when compared to the estuarine organic load.

In addition to a normally large organic load, Georgia's estuaries appear to have a great assimilative reserve capacity for organic materials, as indicated by three 1976 studies conducted at stations in the developed estuary (Brunswick Junior College, 1975) (Georgia Environmental Protection Division, 1976) (Reimold et al., 1976). The six-year average for shrimp landings prior to 1979 was 6.9×10^6 pounds (heads on), making 1979 an above-average year with 7.8×10^6 pounds landed (Wise and Thompson, 1977). The packing houses in the developed estuary were operational. In addition to the present processing plant BOD load (225 - 295 mg/l) from the peeling, sorting, thawing, and washing operations, all processing effluents with a combined BOD load of 900 - 3400 mg/l were discharged to the Brunswick River (Georgia Environmental Protection Division, 1976) (Reimold et al., 1976). River BOD levels near the present discharge pipe (600 feet from the previous discharge point) that ranged from 3.2 - 5.2 mg/l were within the 1979 range of 0.9 - 13.3 mg/l (Brunswick Junior College, 1975) (Georgia Environmental Protection Division, 1976) (Reimold et al., 1976). The mean BOD value at the basin 0.5 mile upstream (Fourth Avenue) from the plant (2.93 mg/l) was slightly greater than the previous study's mean value of 1.84 mg/l, but the ranges, 1.10 - 5.70 mg/l and 0.59 - 6.50 mg/l, respectively, were similar (Brunswick Junior College, 1975) (Georgia Environmental Protection Division, 1976) (Reimold et al., 1976). The results indicate relatively stable biological oxygen demands at different processing loads. July and August dissolved oxygen values at the processing plant discharge point, Fourth Avenue, and at the Lanier Bridge (mean values of 4.46 mg/l, 4.78 mg/l, and 4.71 mg/l, respectively) were within Georgia EPD guidelines for estuarine waters (Georgia Department of Natural Resources, 1974). Summer dissolved oxygen values taken from an EPD study in August of 1976 (Georgia Environmental Protection Division, 1976) at two stations, the Lanier Bridge and near the present processing plant dishcharge (mean 3.92 mg/l), fell below the Georgia Department of Natural Resources dissolved oxygen standard of 4.00 mg/l for estuarine waters during a period of large processing plant BOD loads and normal packing house operations (Georgia Department of Natural Resources, 1974) (Georgia Environmental Protection Division, 1976) (Reimold et al., 1976) (Wise and Thompson,1977). However, the dissolved oxygen levels were within the range of values determined for the undeveloped estuaries that received no seafood discharges. The data indicate that the Brunswick East River estuary can absorb relatively large BOD loads from seafood processing and packing plants with few adverse effects.

NH_4 levels in the runoff water from a salt marsh in Georgia (1028 µg/l) approached the mean range 1616 - 2649 µg/l NH_4 concentrations determined in the processing plant discharge (Haines,1979). An ammonia level of 20.4 µg/l was obtained by converting the concentration in the salt marsh (1028 µg/l) to NH_3, assuming a pH of 7.5, salinity of 18‰, and a temperature of 28C (Bower and Bidwell,1978). The salt marsh runoff from a pristine area exceeded EPA's proposed NH_3 maximum permissible level of 20 µg/l (Bower and Bidwell, 1978) (Haines, 1979). Additional NH_3 levels of 10.7 µg/l and 18.0 µg/l at the two most seaward stations, Marker "19" and Marker "24," support the natural occurrence of high NH_3 levels in Georgia's estuarine waters. The greatest NH_3 concentration within 0.5 mile of the processing plant occurred at the bottom of the Fourth Avenue (upstream) station (17.5 µg/l) and fell within EPA's tentative NH_3 guideline and naturally occurring NH_3 levels determined from less developed areas.

In the December 1, 1980 Federal Register, the Environmental Protection Agency withdrew its proposal to add ammonia to the Toxic Pollutant List. In announcing the decision, EPA cited several conclusions developed in this study:

a. Ammonia is biodegradable and does not persist in the aquatic environment.
b. EPA's listing of ammonia as a toxic pollutant would result in stringent treatment requirements that would have to be met in areas where increased ammonia removal would not materially improve the lot of aquatic organisms.
c. Total ammonia should not be listed as a toxic pollutant, because in natural waters only a fraction of total ammonia is in the toxic un-ionized form. Since the fraction varies with water quality and temperature, the parameter of concern should be un-ionized ammonia.
d. Marine waters are so well suited for absorbing and using ammonia that it poses no problem in such waters.

The environmental impact of current seafood processing wastes on Georgia's estuaries appears to be minimal when compared with the natural organic load. One large estuary demonstrated a high residual capacity to receive processing effluents without significant change. Problems could develop from the entrapment of organic wastes in basins, and further study during periods of normal packing volume is required. BOD and NH_4-N levels in processing wastes were shown to be greater than, but the same order of magnitude as, natural runoff from marshland.

REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION. 1976. Standard Methods for the Examination of Water and Wastewater, Fourteenth Edition, pp. 411-447, 132-134, 543-550, 550-554. American Public Health Assoc., Washington, D.C.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1975. Official Methods of Analyses of the Association of Official Analytical Chemists, p. 606. Association of Official Analytical Chemists, Washington, D.C.

BOWER, C. E. and J. P. BIDWELL. 1978. Ionization of ammonia in seawater; effects of temperature, pH, and salinity. J. Fish. Res. Board Can. 35: 1012-1016.

BRUNSWICK JUNIOR COLLEGE. 1975. Water Quality Investigation of Estuaries of Georgia. 73 pp. Environmental Protection Division, Georgia Department of Natural Resources, Atlanta, Georgia.

BRUNSWICK JUNIOR COLLEGE. 1976. Water Quality Investigation of Estuaries of Georgia 1975. 94 pp. Environmental Protection Division, Georgia Department of Natural Resources, Atlanta, Georgia.

BRUNSWICK JUNIOR COLLEGE. 1977. Water Quality Investigation of Estuaries of Georgia 1976. 116 pp. Environmental Protection Division, Georgia Department of Natural Resources, Atlanta, Georgia.

EMERSON, K., R. C. RUSSO, R. E. LUND, and R. V. THURSTON. 1975. Aqueous ammonia equilibrium calculations: Effects of pH and Temperature. J. Fish. Res. Board Can. 32: 2379-2383.

FOOD AND DRUG ADMINISTRATION. 1978. Bacteriological Analytical Manual. P. IV-1 to IV-10, V-1 to V-6. Association of Official Analytical Chemists, Washington, D.C.

GEORGIA DEPARTMENT OF NATURAL RESOURCES. 1974. Rules and Regulations for Water Quality Control, Chapter 391-3-6 revised June, 1974, pp. 701-731. Georgia Environmental Protection Division, Atlanta, Georgia.

GEORGIA ENVIRONMENTAL PROTECTION DIVISION. 1976. Brunswick Estuary Study. 52 pp. Georgia Environmental Protection Division, Department of Natural Resources, Atlanta, Georgia.

HAINES, E. B. 1979. Nitrogen pools in Georgia coastal waters. Estuaries 2(1): 34-49.

HO, CLARA L. and BARNEY B. BARRETT. 1975. Distribution of nutrients in Louisiana's coastal waters influenced by the Mississippi River. Louisiana Wildlife and Fisheries Commission; Oysters, Water Bottoms, and Seafood Division Technical Bulletin No. 17: 1-39.

HOUSER, LEROY S. 1965. National Shellfish Sanitation Program Manual of Operations. Part 1, Sanitation of Shellfish Growing Areas, p. 32. U. S. Department of Health, Education, and Welfare, Public Health Service, Washington, D.C.

MARTIN, DEAN F. 1970. Marine Chemistry, Vol II, Theory and Application, pp. 117-124. Marcel Dekker, Inc., New York, N.Y.

MARTIN, DEAN F. 1972. Marine Chemistry, Vol I, Analytical Methods, pp. 148-152. Marcel Dekker, Inc., New York, N.Y.

REIMOLD, R. J., W. A. BOUGH, and M. A. HARDISKY. 1976. Dissolved oxygen and biochemical oxygen demand in the Brunswick Estuary and King Shrimp Company, Inc. process effluent. 26 pp. University of Georgia Marine Resources Extension Center. Brunswick, Georgia.

REIMOLD, R. J., J. L. GALLAGHER, R. A. LINTHURST, and W. J. PFEIFFER. 1975. Detritus production in coastal Georgia salt marshes, pp. 217-228. In: Estuarine Research, Vol. I: Chemistry, Biology, and the Estuarine System. Academic Press, Inc., New York, N.Y.

REMINGTON, RICHARD D. and M. ANTHONY SHORK. 1970. Statistics with Applications to the Biological and Health Sciences, pp. 299-301. Prentice-Hall, Inc., Englewood Cliffs, N. J.

RHYTHER, J.H. and W. M. DUNSTAN. 1971. Nitrogen, phosphorous, and eutrophication in the coastal marine environment. Science 171: 1008-1012.

SCHEFLER, W. C. 1969. Statistics for the Biological Sciences, pp. 104-119. Addison-Wesley Publishing Co., Reading, Mass.

SCHLEPER, CARL. 1972. Research Methods in Marine Biology, pp. 281-289. University of Washington Press, Seattle, Washington.

SCOTT, PAUL M., MARC D. WRIGHT, and WAYNE A. BOUGH. 1978. Characterization of waste loading from a shrimp packing house and evaluation of different screen sizes for removal of heads, pp. 214-224. In: Ranzell Nickelson (ed.), Proceedings of the Third Annual Tropical and Subtropical Fisheries Conference of the Americas. Texas A&M University, College Station, Texas.

STICKNEY, ROBERT T. and DAVID MILLER. 1973. Chemical and biological survey of the Savannah River adjacent to Elba Island. Technical Report Series Number 73-3. 68 pp. Skidaway Institute of Oceanography, Savannah, Georgia.

THAYER, G. W. 1974. Identity and regulation of nutrients limiting phytoplankton production in shallow estuaries near Beaufort, N.C. Oecologia 14: 75-92.

THURSTON, R. V., R. C. RUSSO, and C. E. SMITH. 1978. Acute toxicity of ammonia and nitrite to cutthroat trout fry. Trans. Am. Fish. Soc., 197(2), 361-368.

TRUSSEL, R. P. 1972. The percent un-ionized ammonia in aqueous solutions at different pH levels and temperatures. J. Fish. Res. Board Canada. 29: 1505-1507.

U. S. ENVIRONMENTAL PROTECTION AGENCY. 1976. Methods for Chemical Analysis of Water and Wastes, pp. 11-12, 249-265. U. S. Environmental Protection Agency, Cincinnati, Ohio.

WISE, J. P. and B. G. THOMPSON. 1977. Fisheries of the United States, 1976, p. 96. U. S. Department of Commerce, NOAA, Washington, D.C.

FIGURES

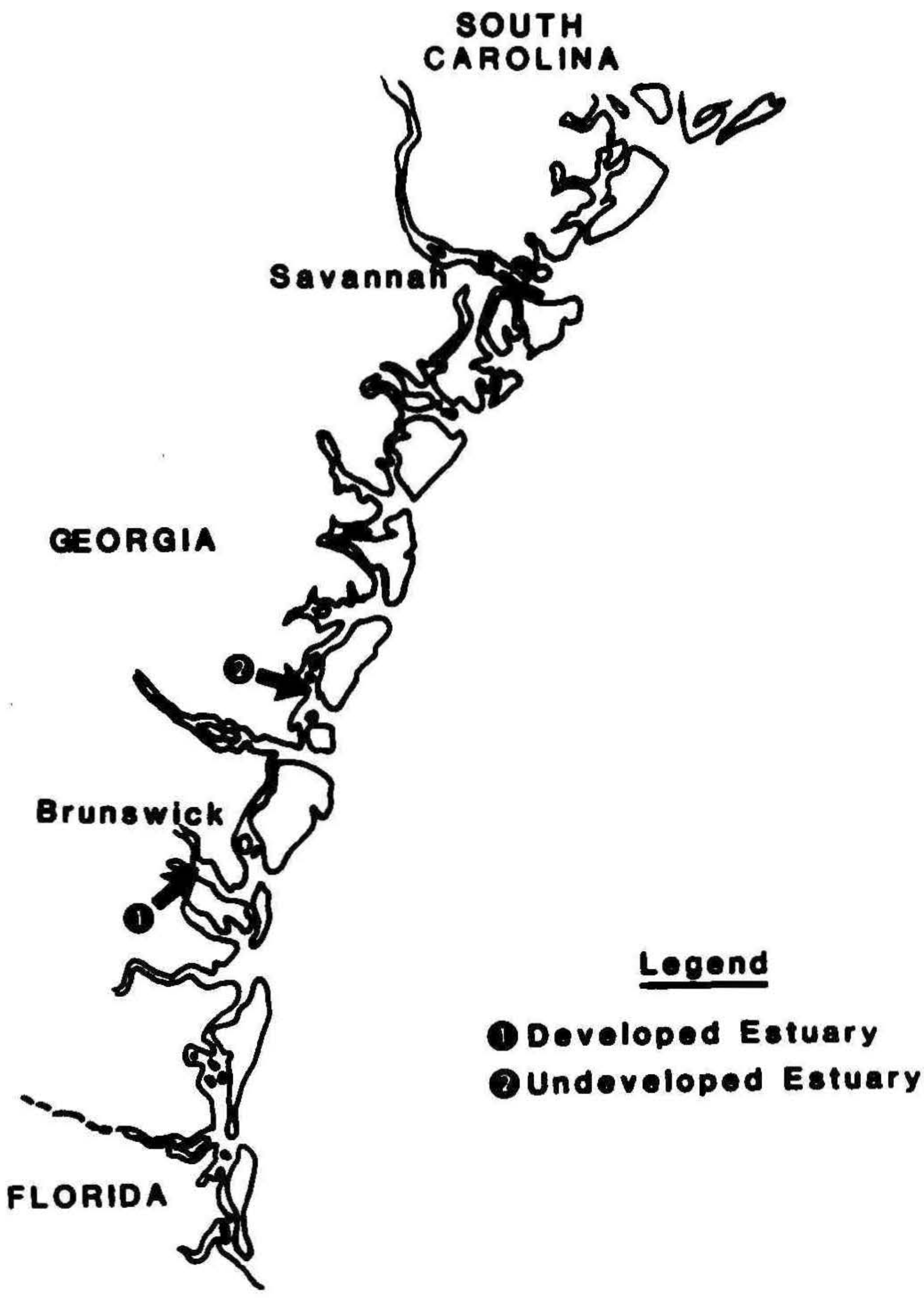

FIGURE 1. Study Areas.

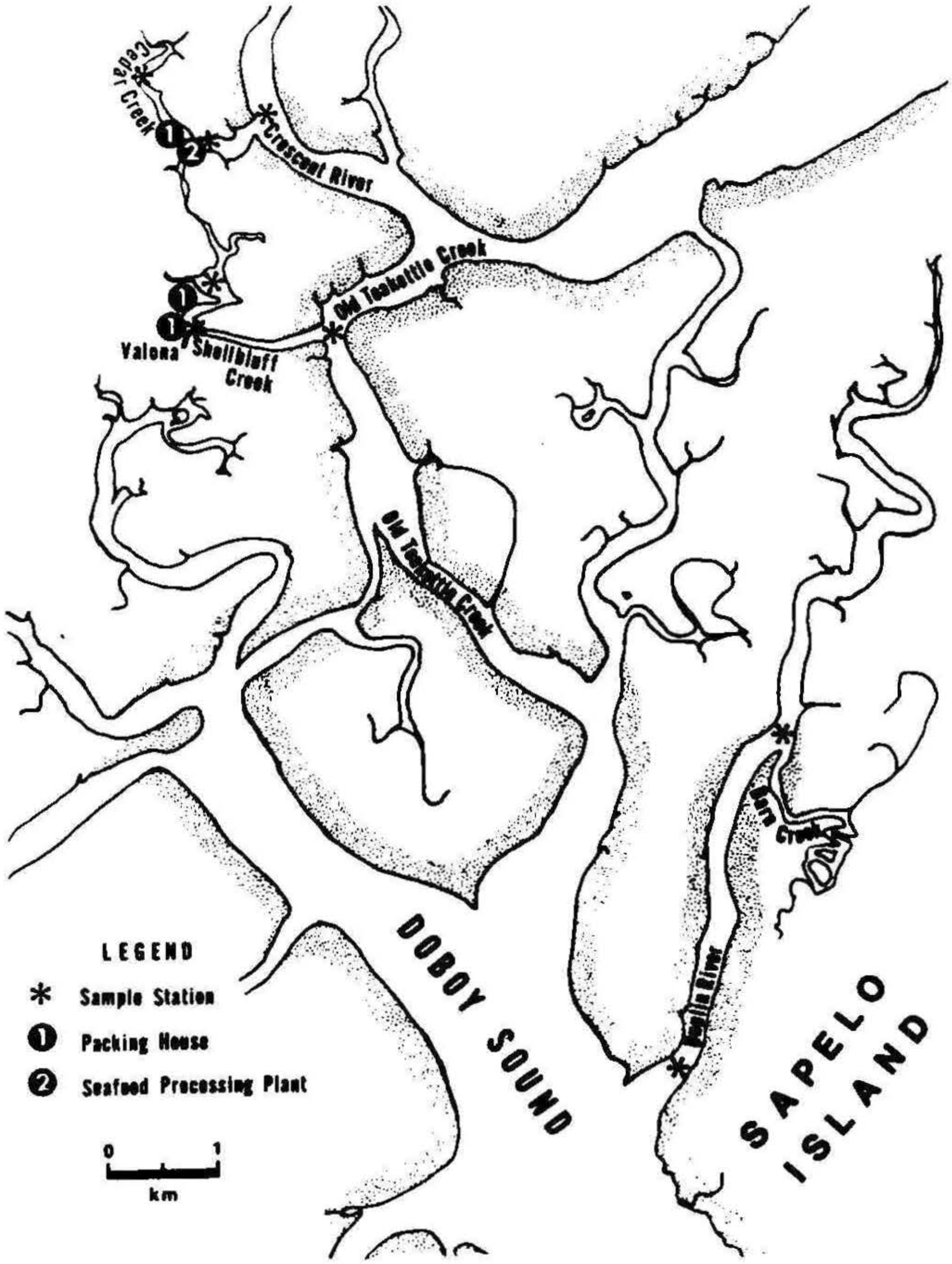

FIGURE 2. Undeveloped Estuary.

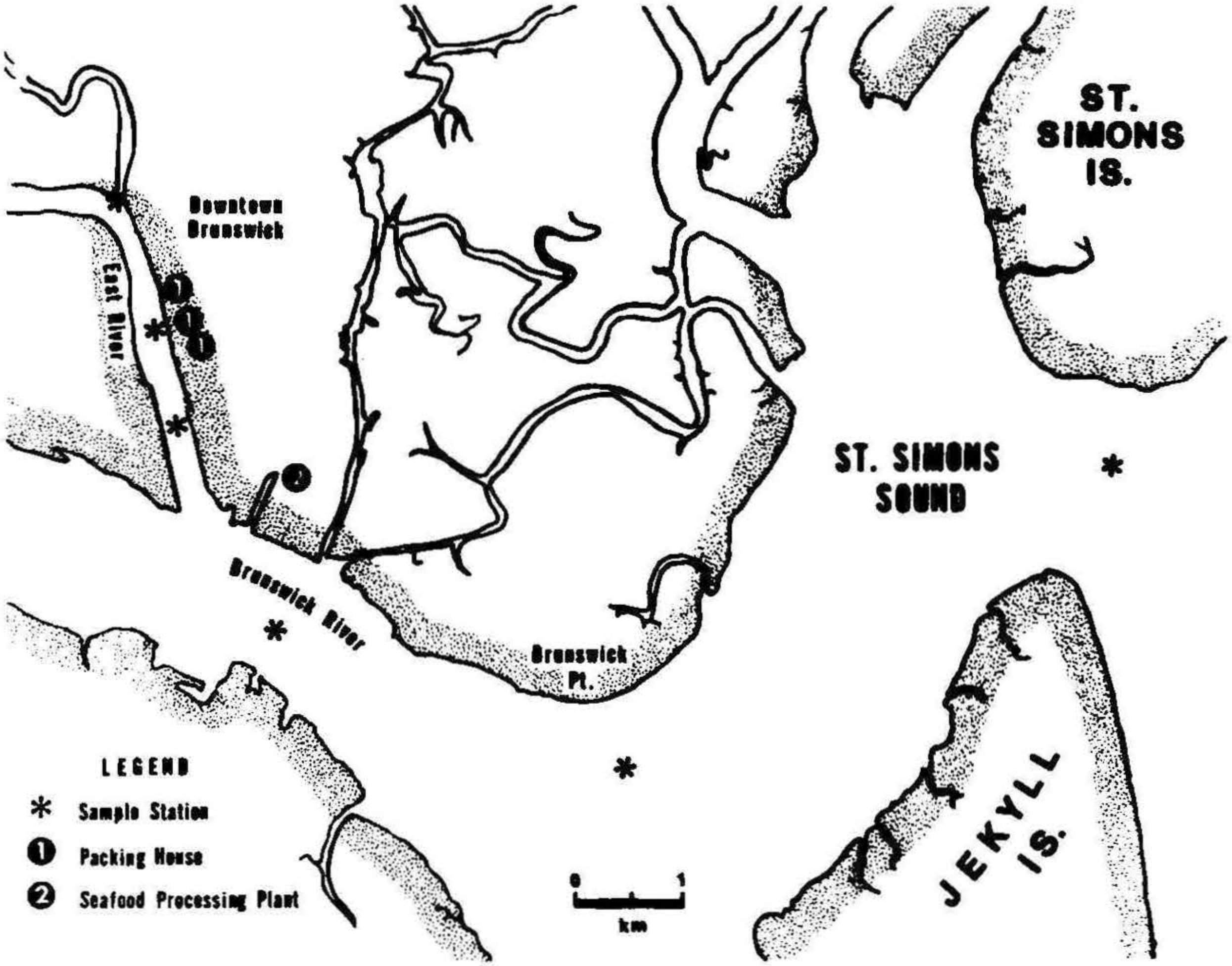

FIGURE 3. Developed Estuary.

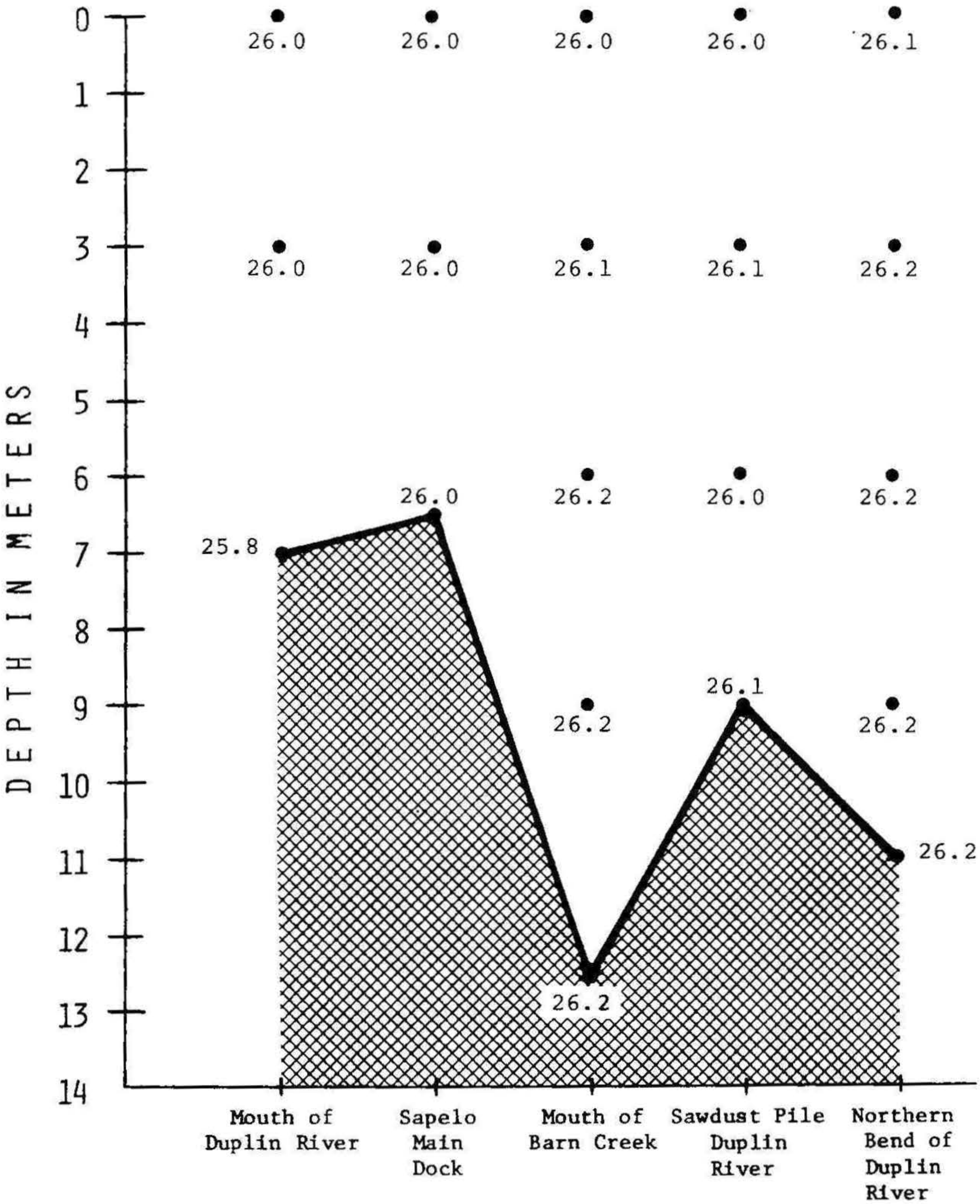

FIGURE 4: Duplin River Temperature (°C) Profile (Hydrographic Survey).

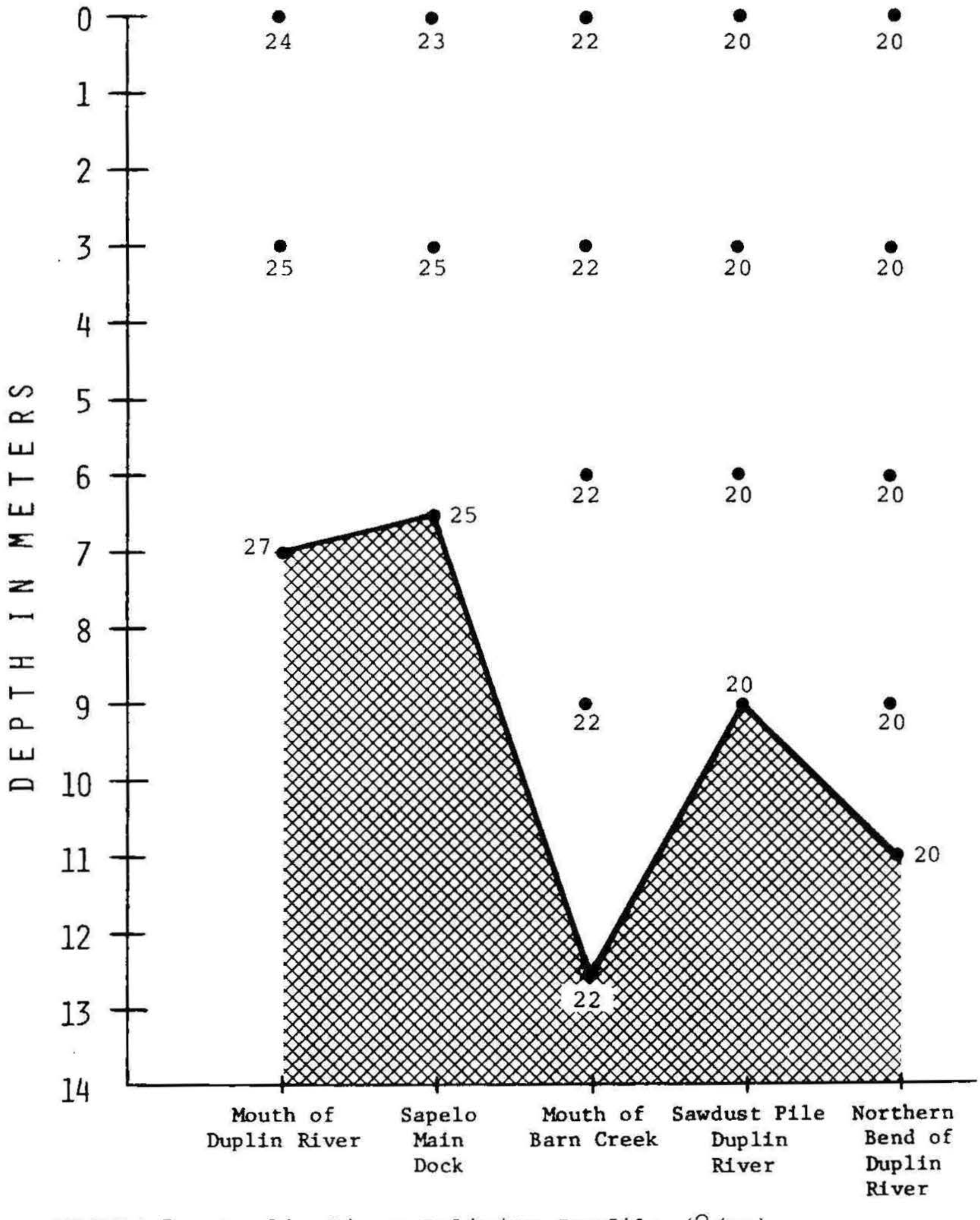

FIGURE 5: Duplin River Salinity Profile ($^{o}/oo$)
(Hydrographic Survey).

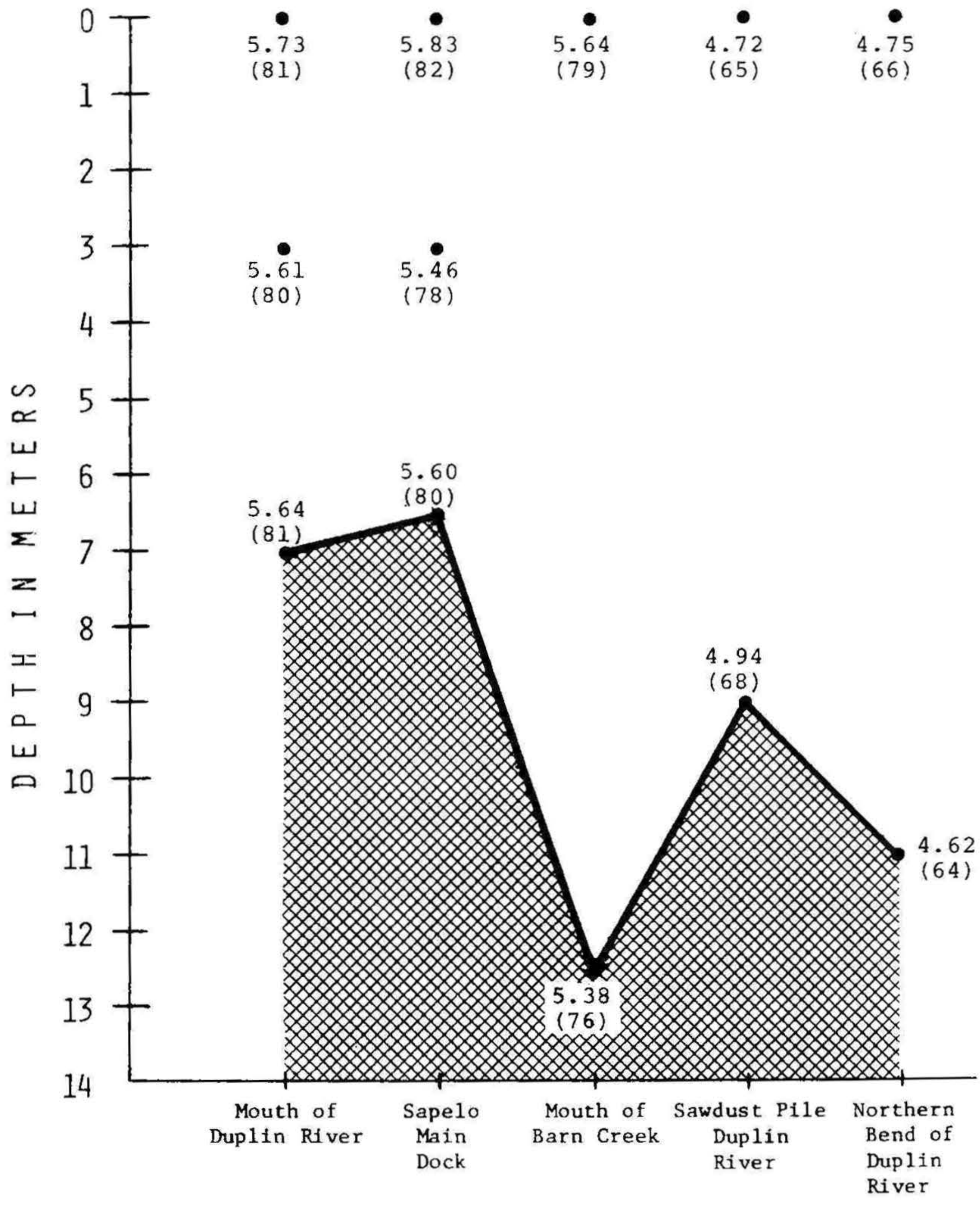

FIGURE 6: Duplin River D.O. (mg/l) and (% Saturation) Profile (Hydrographic Survey).

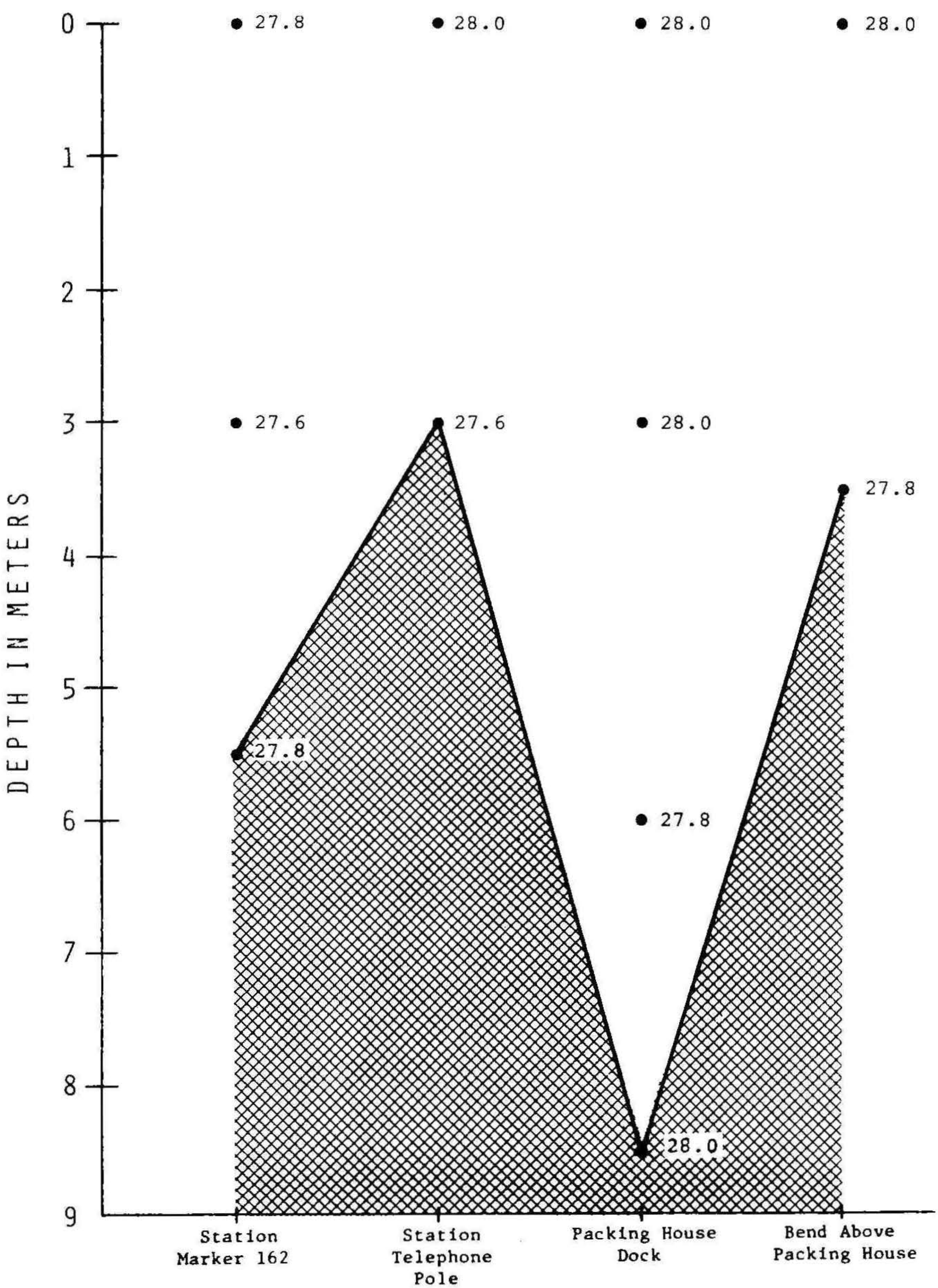

FIGURE 7: Shellbluff Creek Temperature (°C) Profile (Hydrographic Survey).

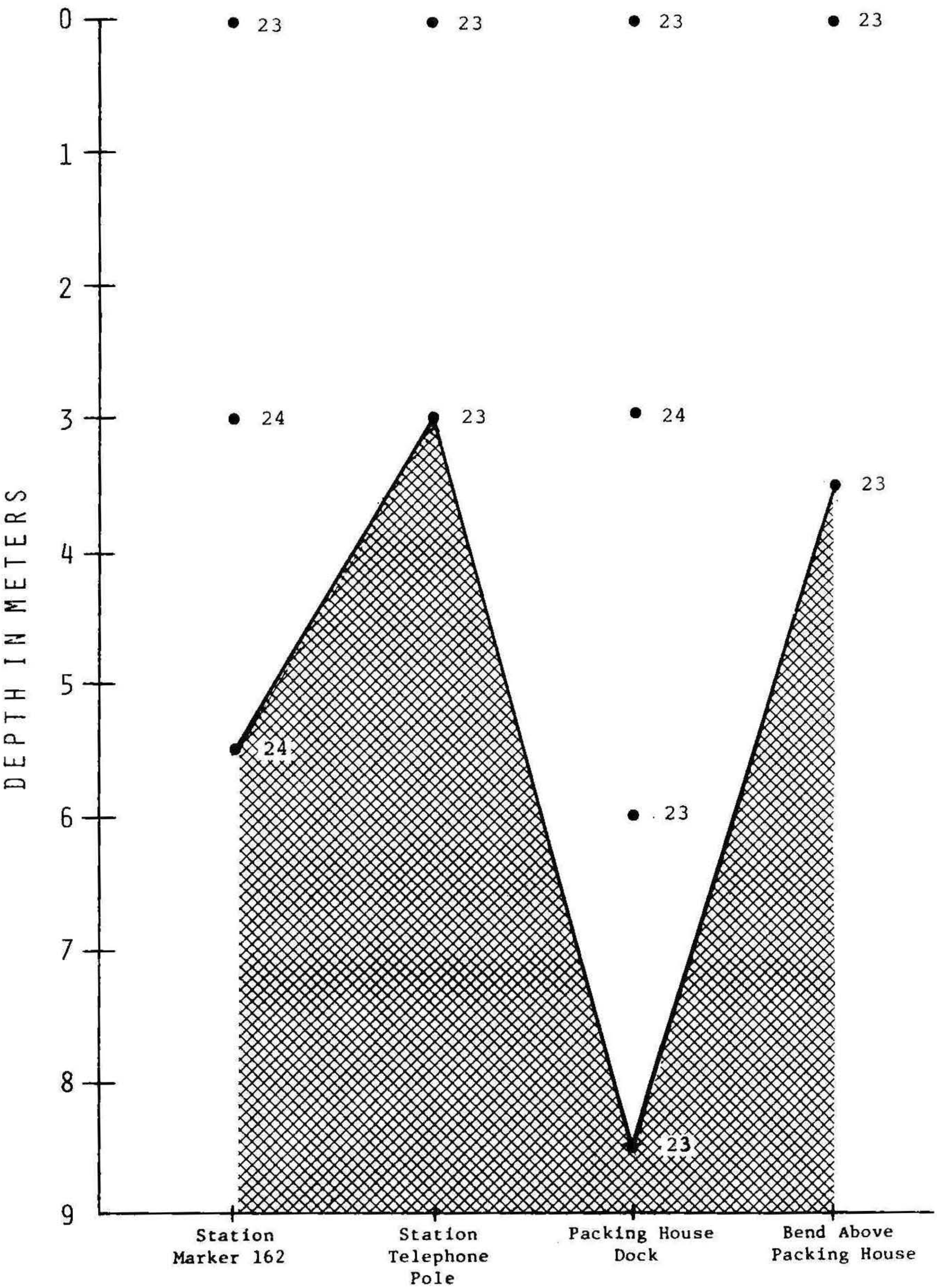

FIGURE 8: Shellbluff Creek Salinity Profile ($^{o}/oo$) (Hydrographic Survey).

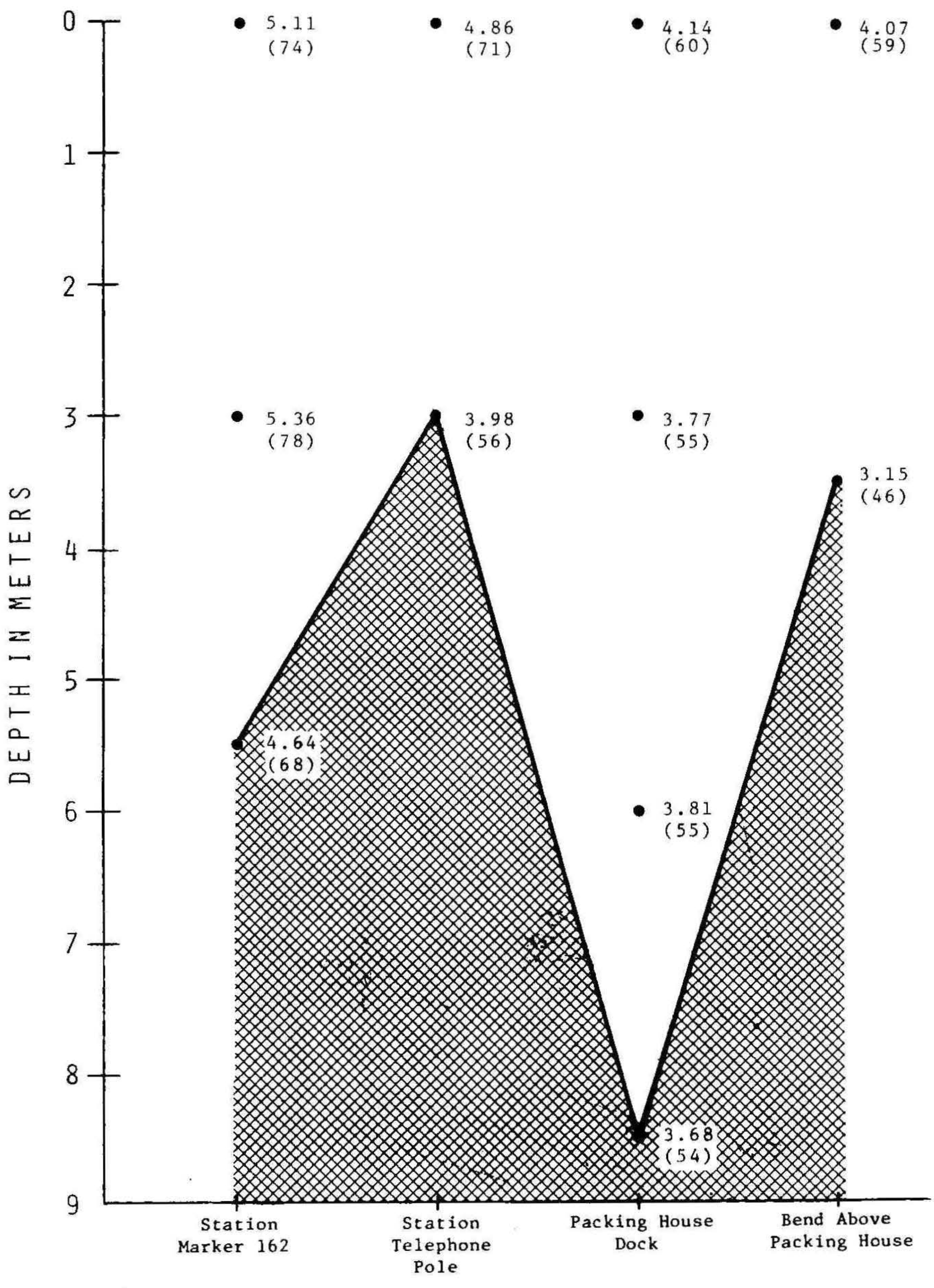

FIGURE 9: Shellbluff Creek D.O. Profile (mg/l) and (% Saturation) (Hydrographic Survey).

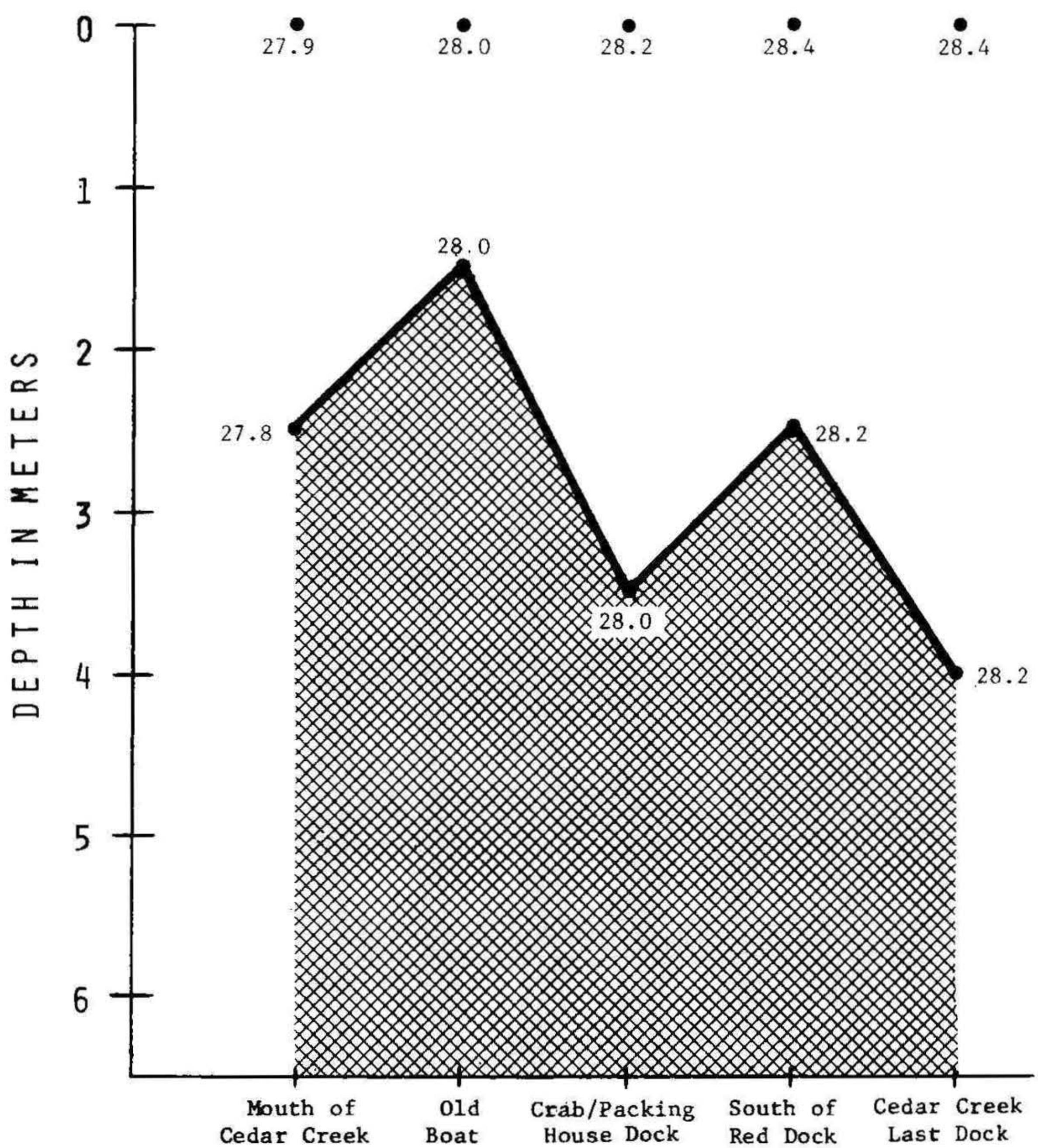

FIGURE 10: Cedar Creek Temperature (°C) Profile (Hydrographic Survey).

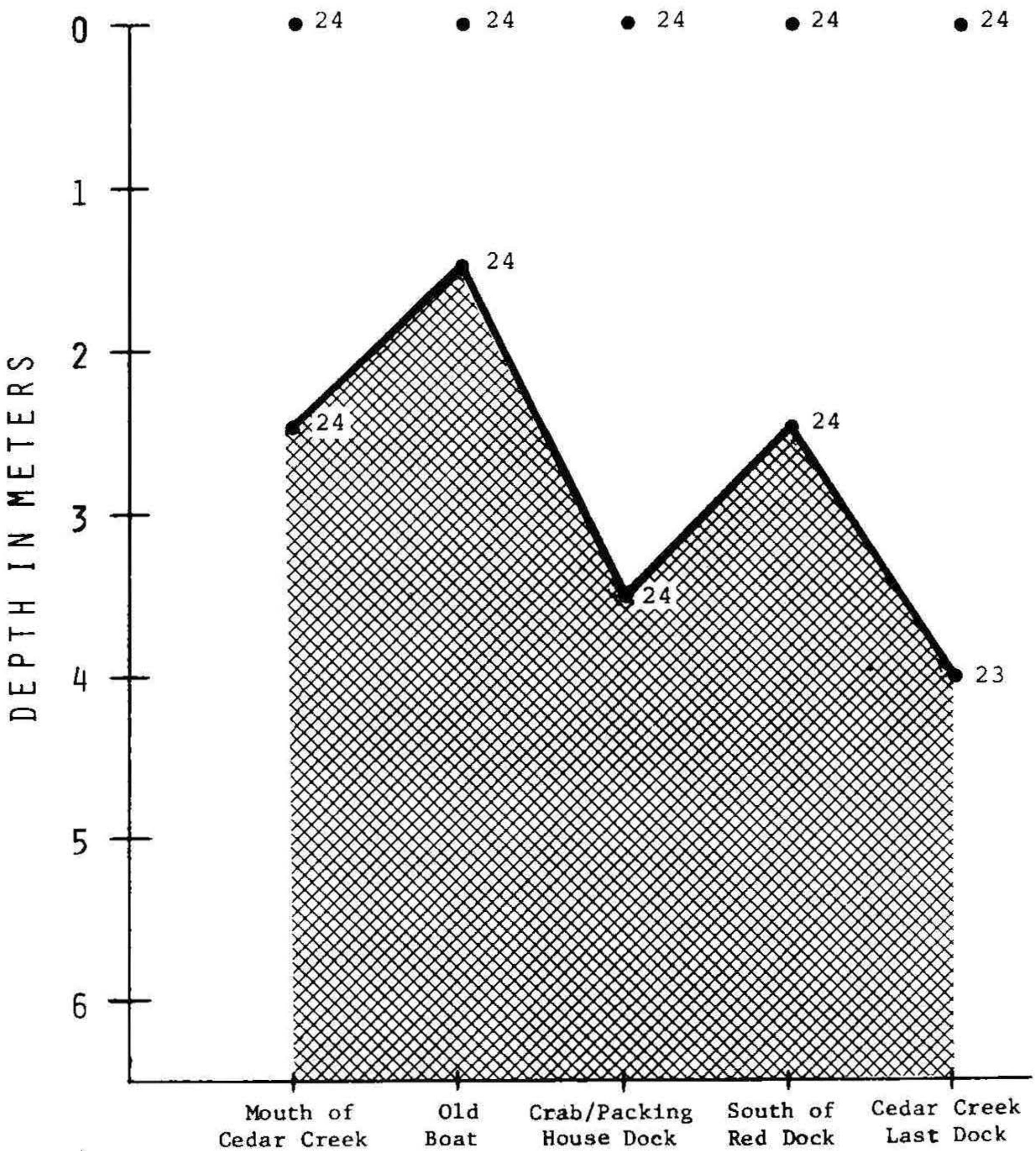

FIGURE 11: Cedar Creek Salinity Profile (°/oo) (Hydrographic Survey).

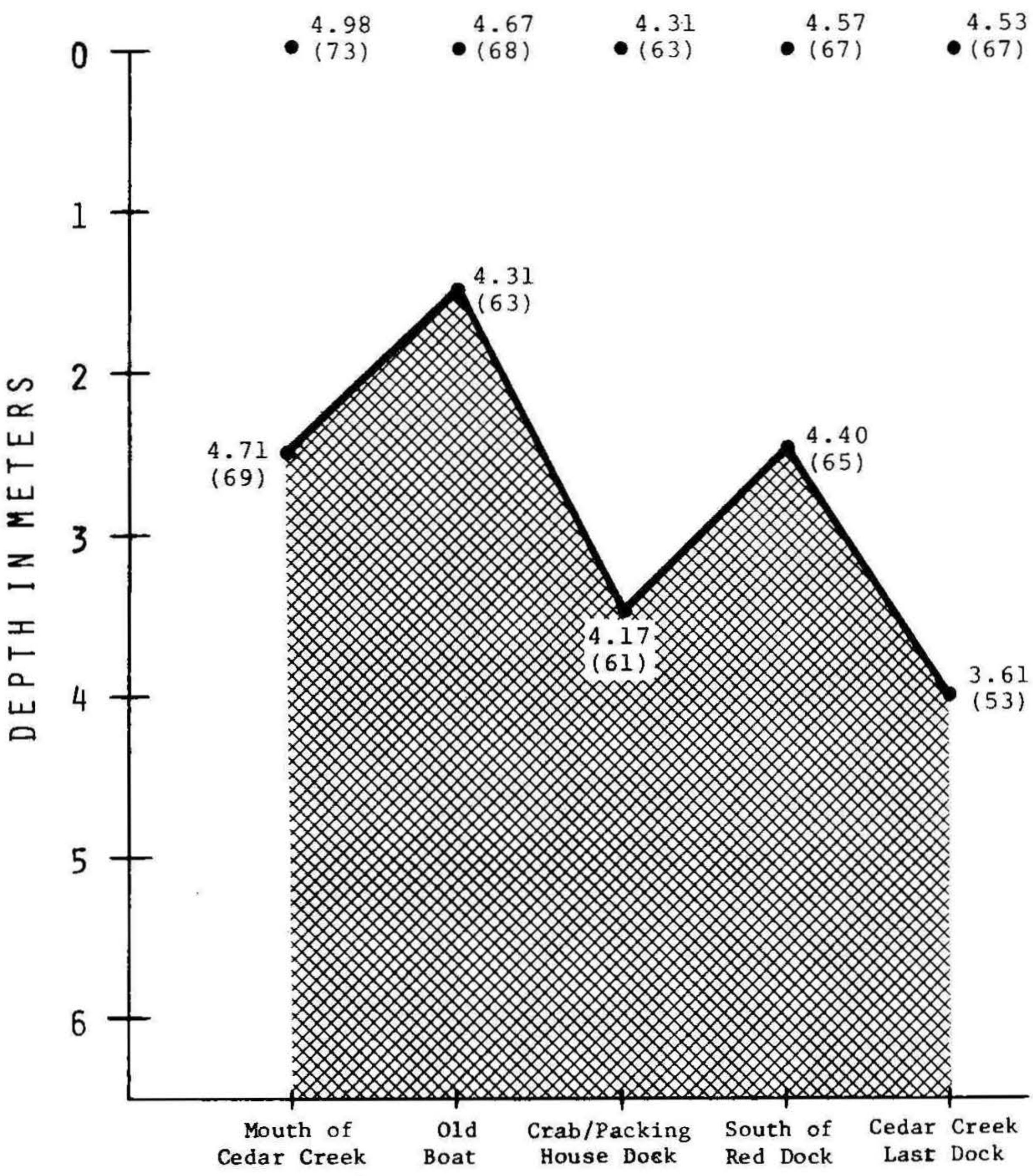

FIGURE 12: Cedar Creek D.O. (mg/l) and (% Saturation) Profile (Hydrographic Survey).

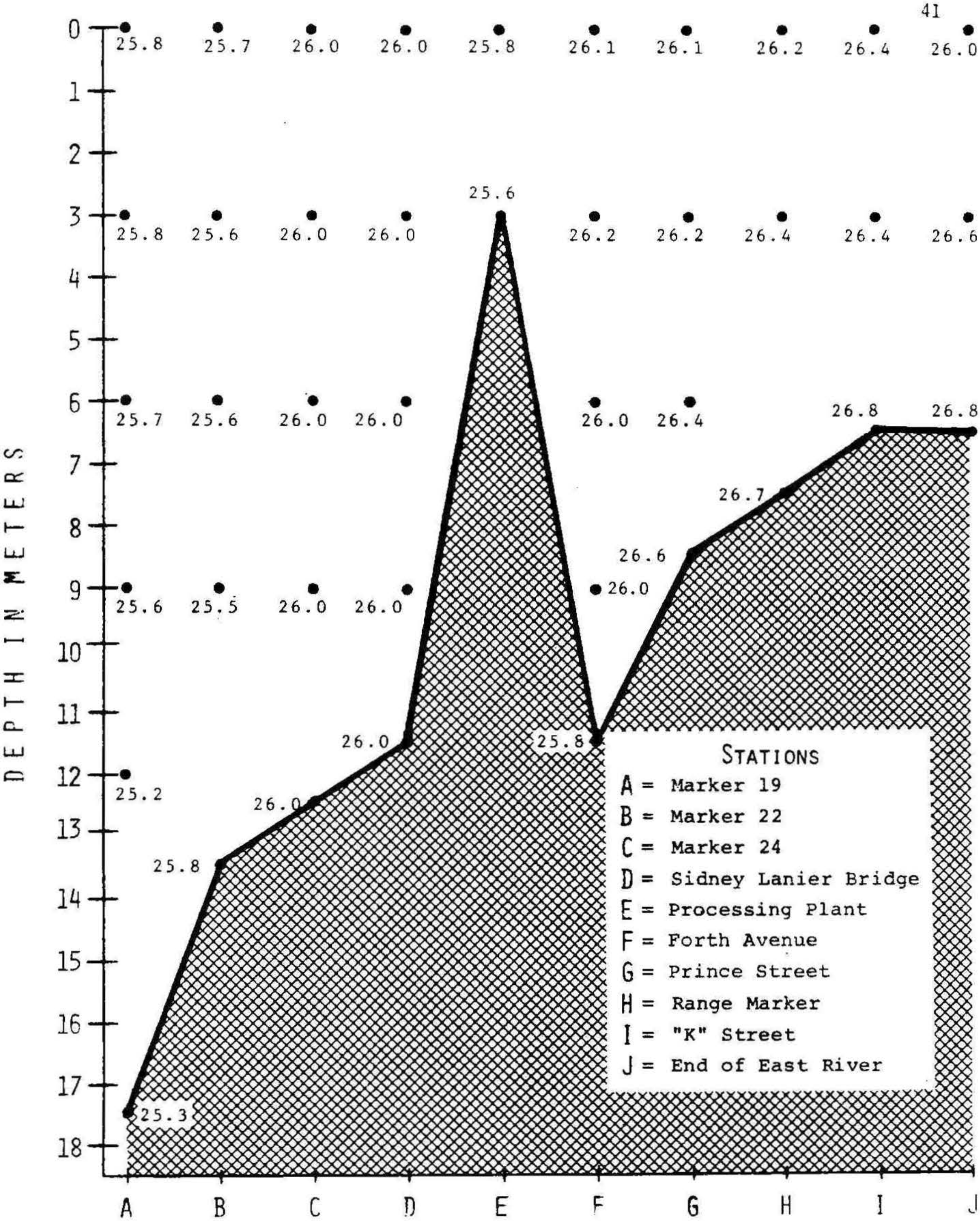

FIGURE 13: Brunswick Estuary Profile (Southern Area) Temperature (°C) (Hydrographic Survey).

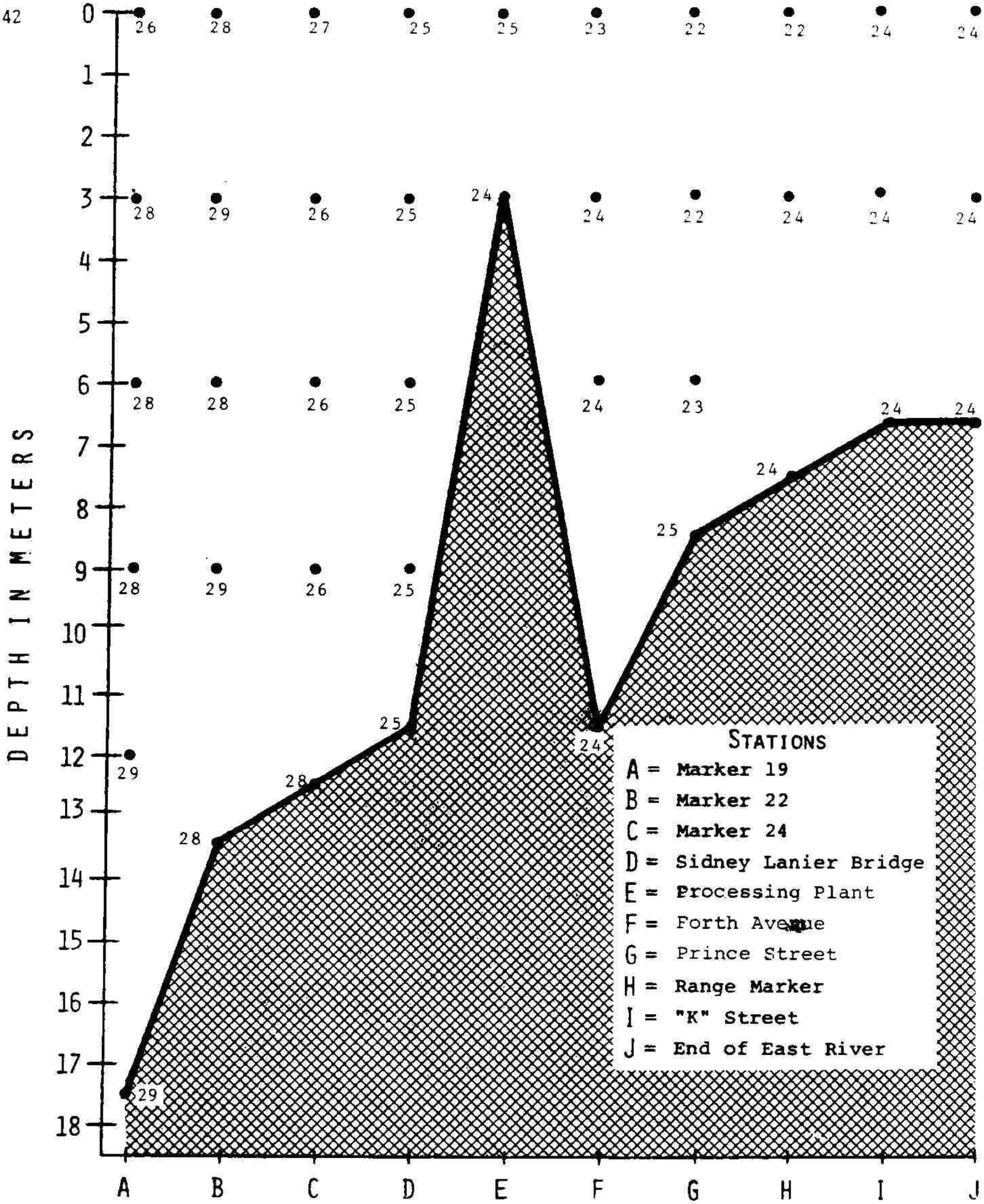

FIGURE 14: **Brunswick** Estuary Salinity Profile (°/oo) (Southern Area) (Hydrographic Survey).

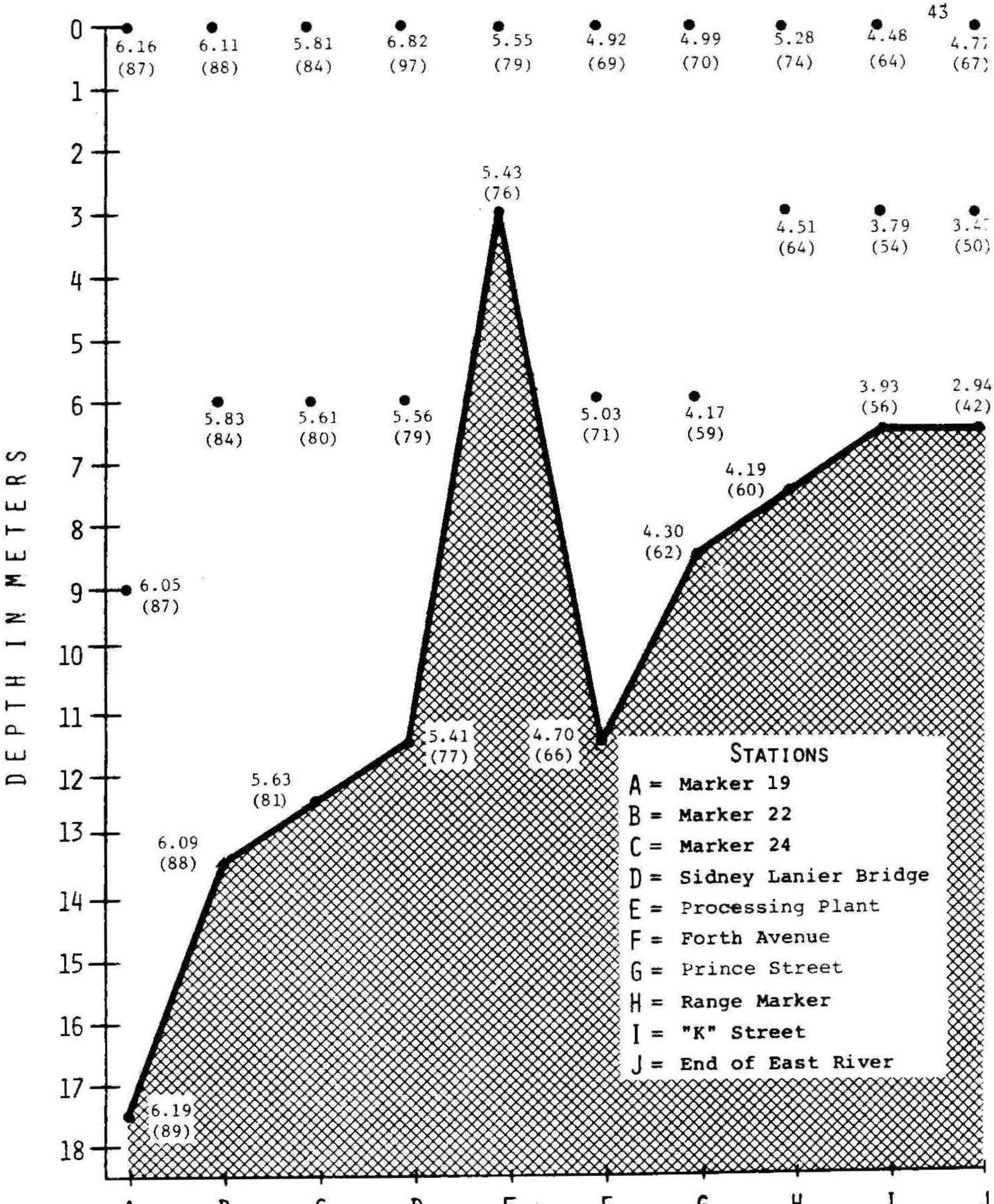

FIGURE 15: Brunswick Estuary Profile (Southern Area) D.O. (mg.1) and (% Saturation) (Hydrographic Survey)

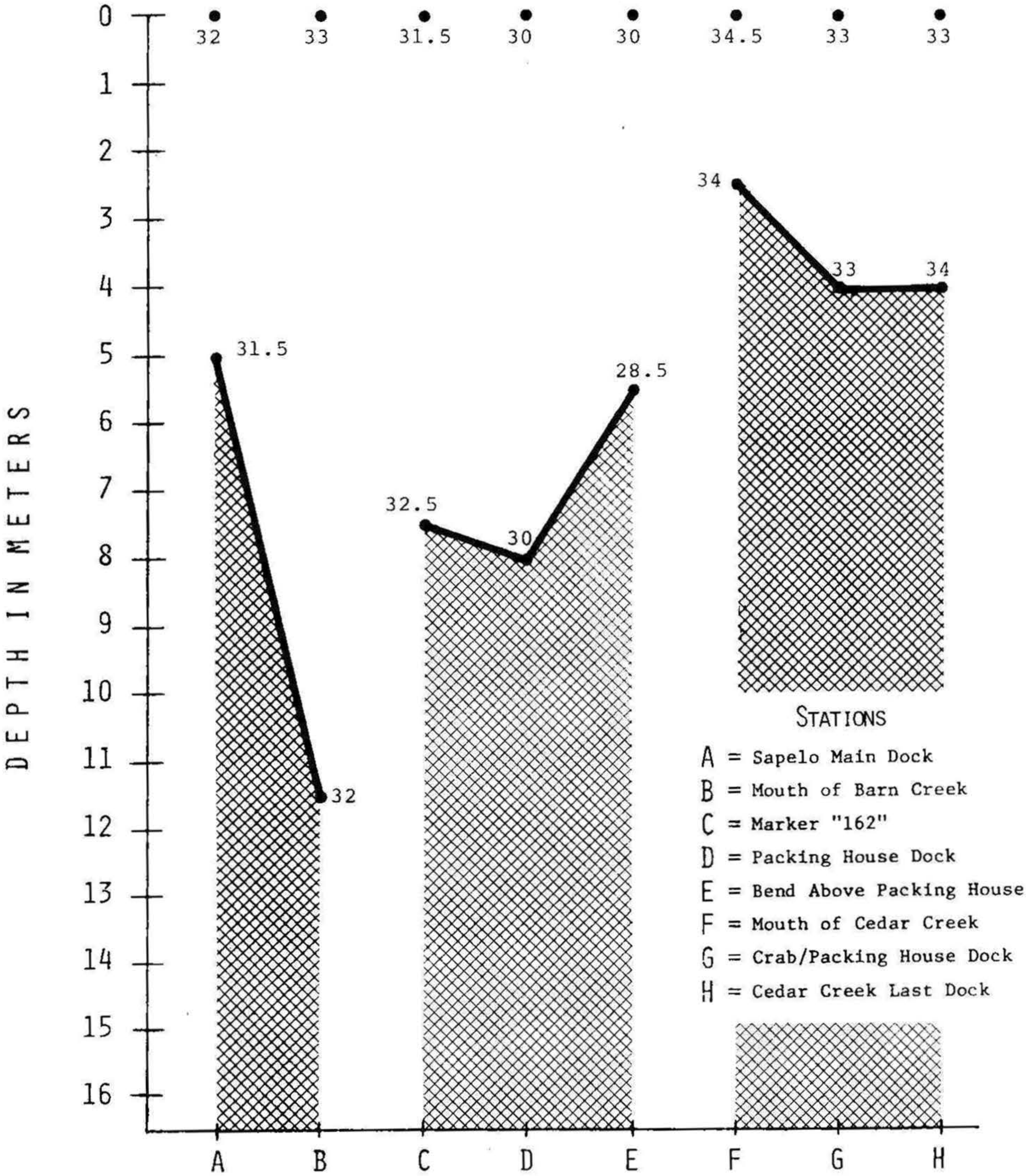

FIGURE 16: Northern Sampling Area Temperature Profile (°C) at Low Tide during July.

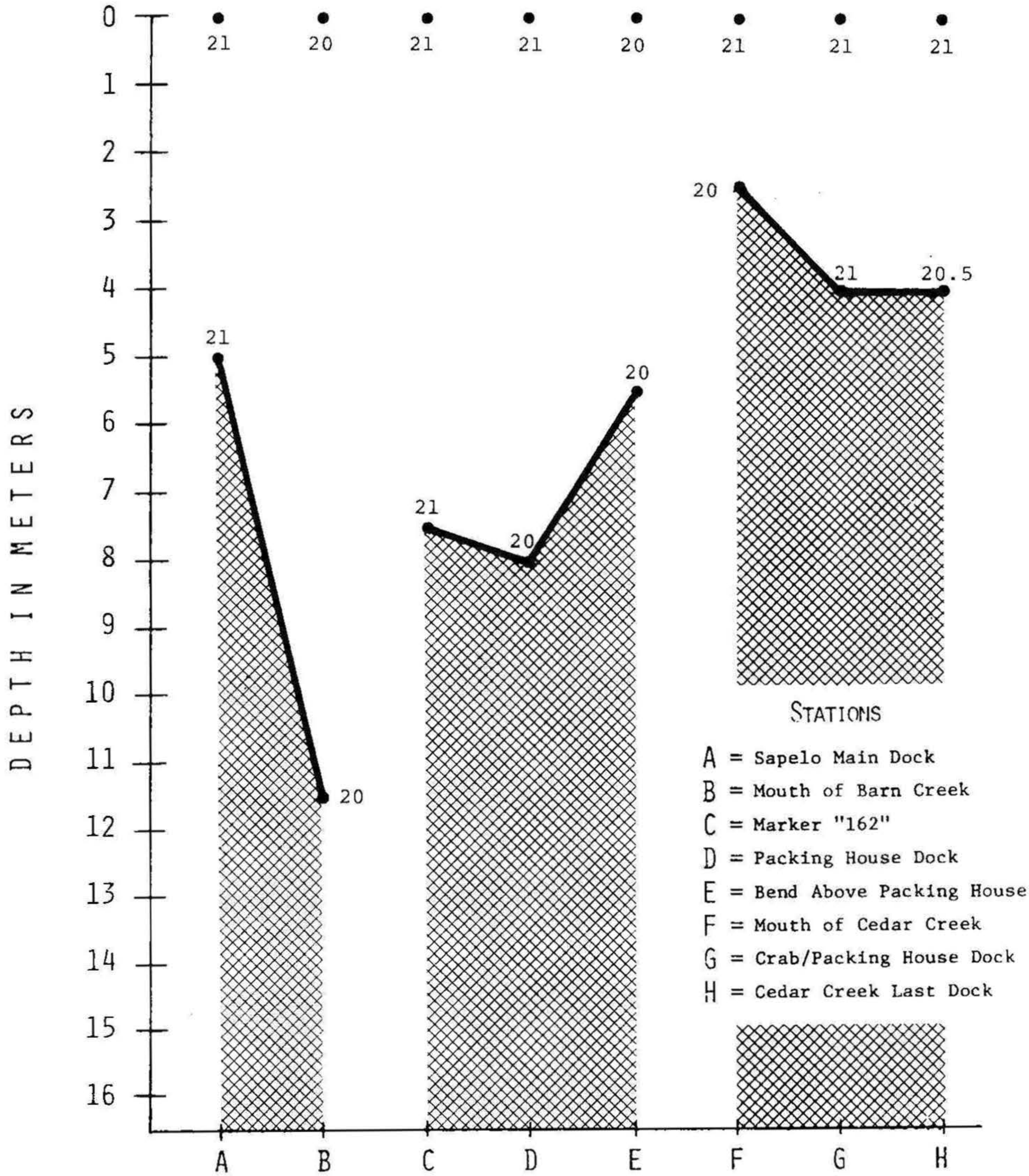

FIGURE 17: Northern Sampling Area Salinity Profile (o/oo) at Low Tide during July

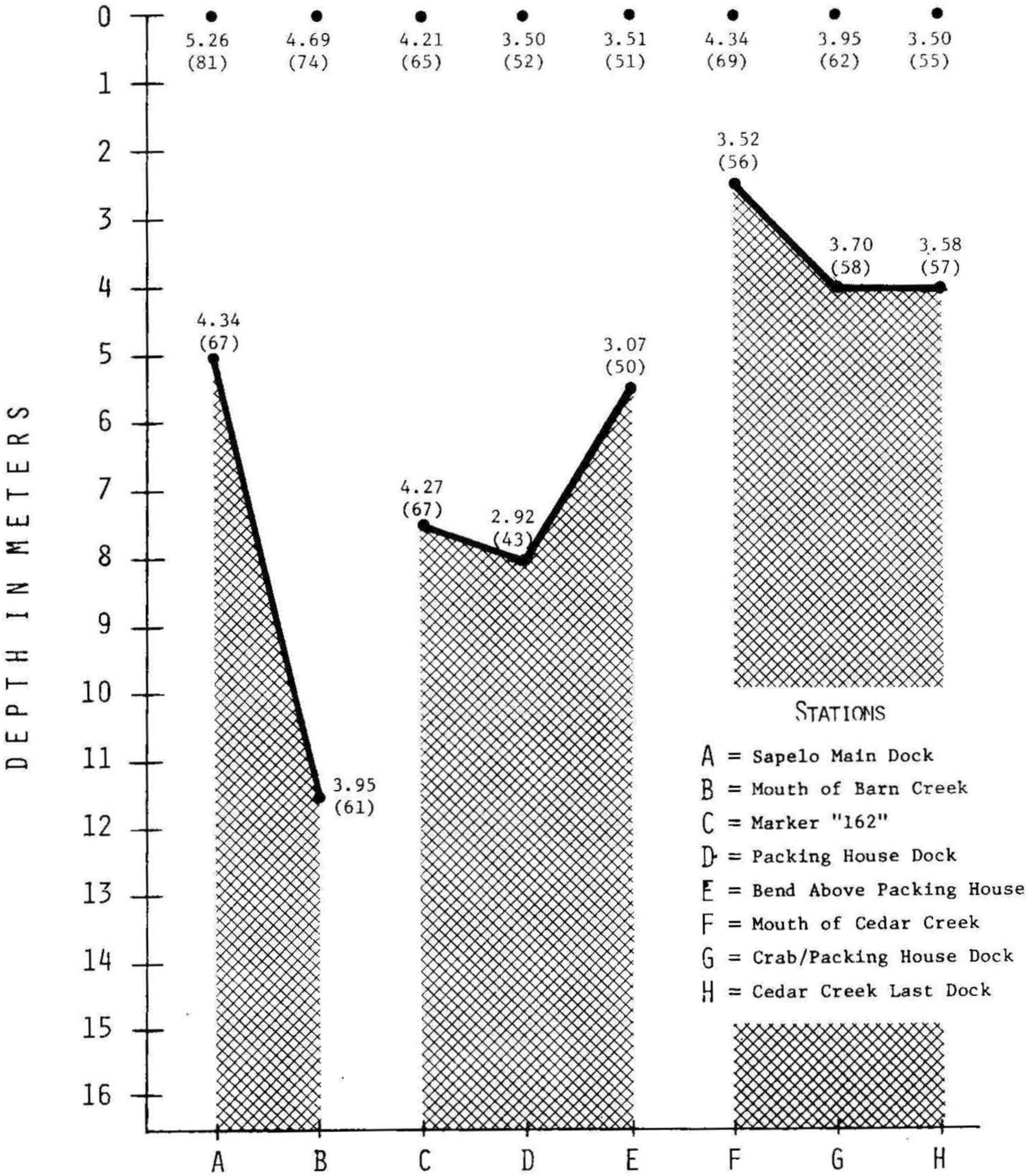

FIGURE 18: Northern Sampling Area D.O. Profile (mg/l) and (% Saturation) at Low Tide during July.

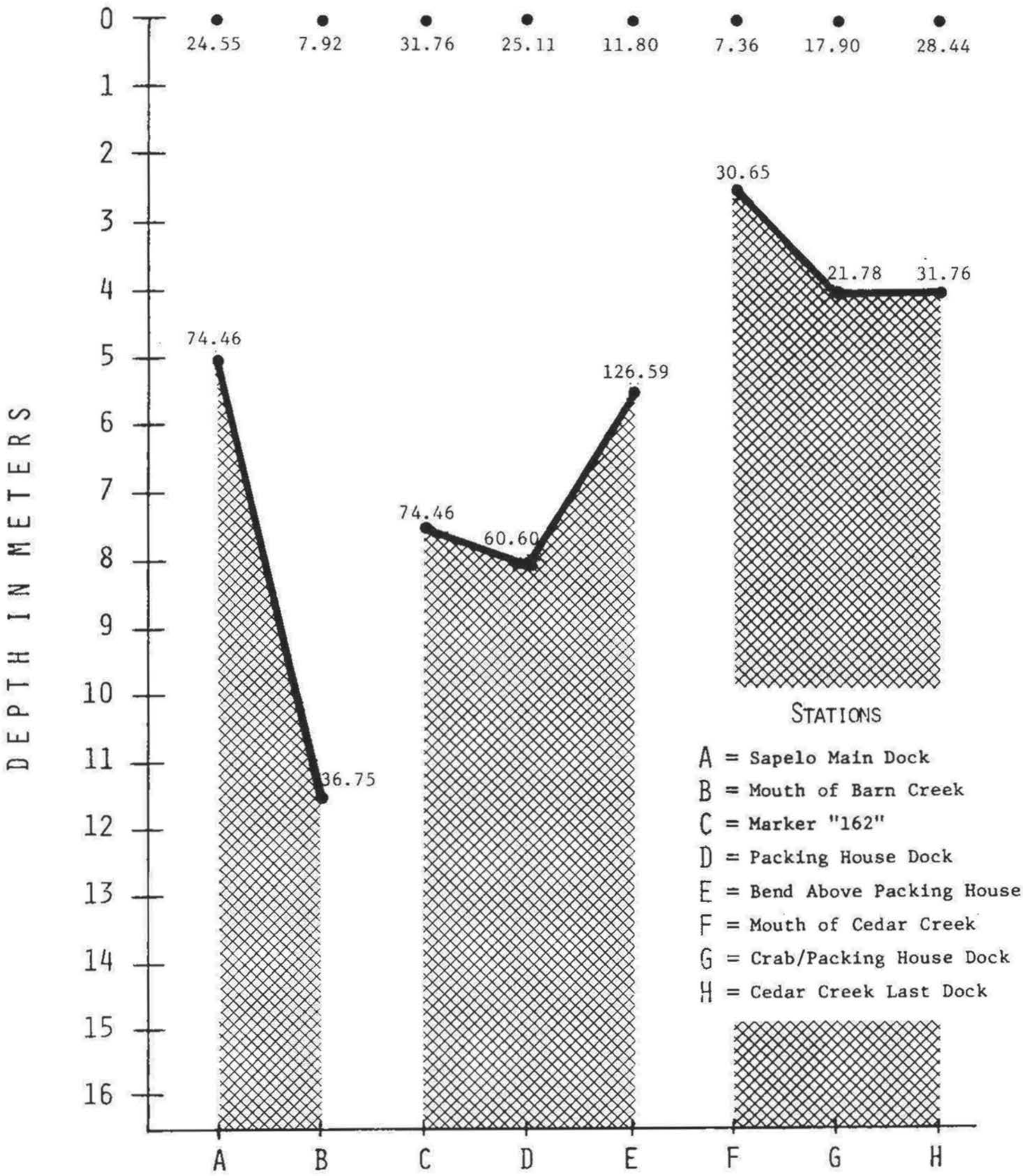

FIGURE 19: Northern Sampling Area NH_4-N (µg/l) Profile at Low Tide during July.

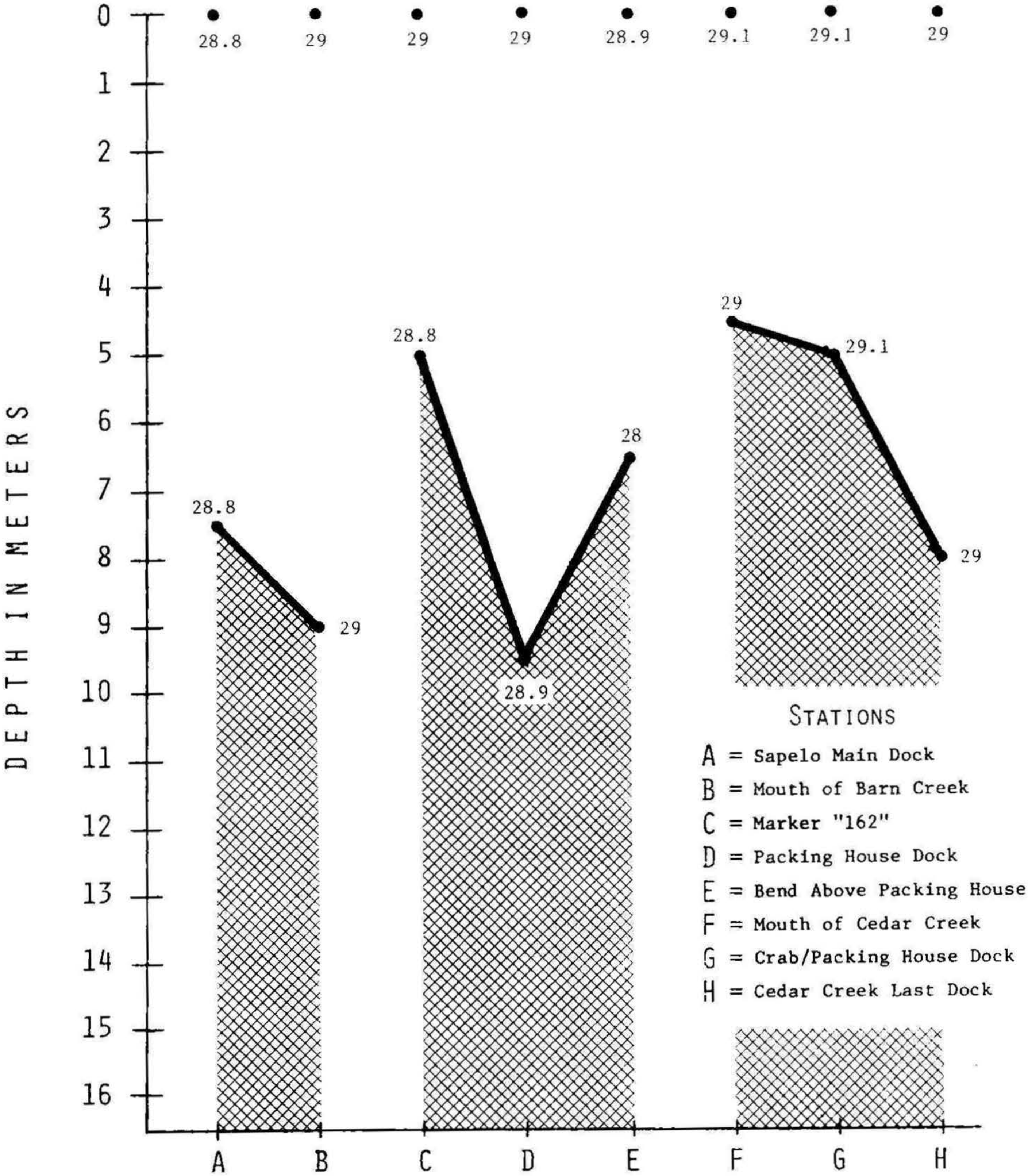

FIGURE 20: Northern Sampling Area Temperature (°C) Profile at High Tide During July.

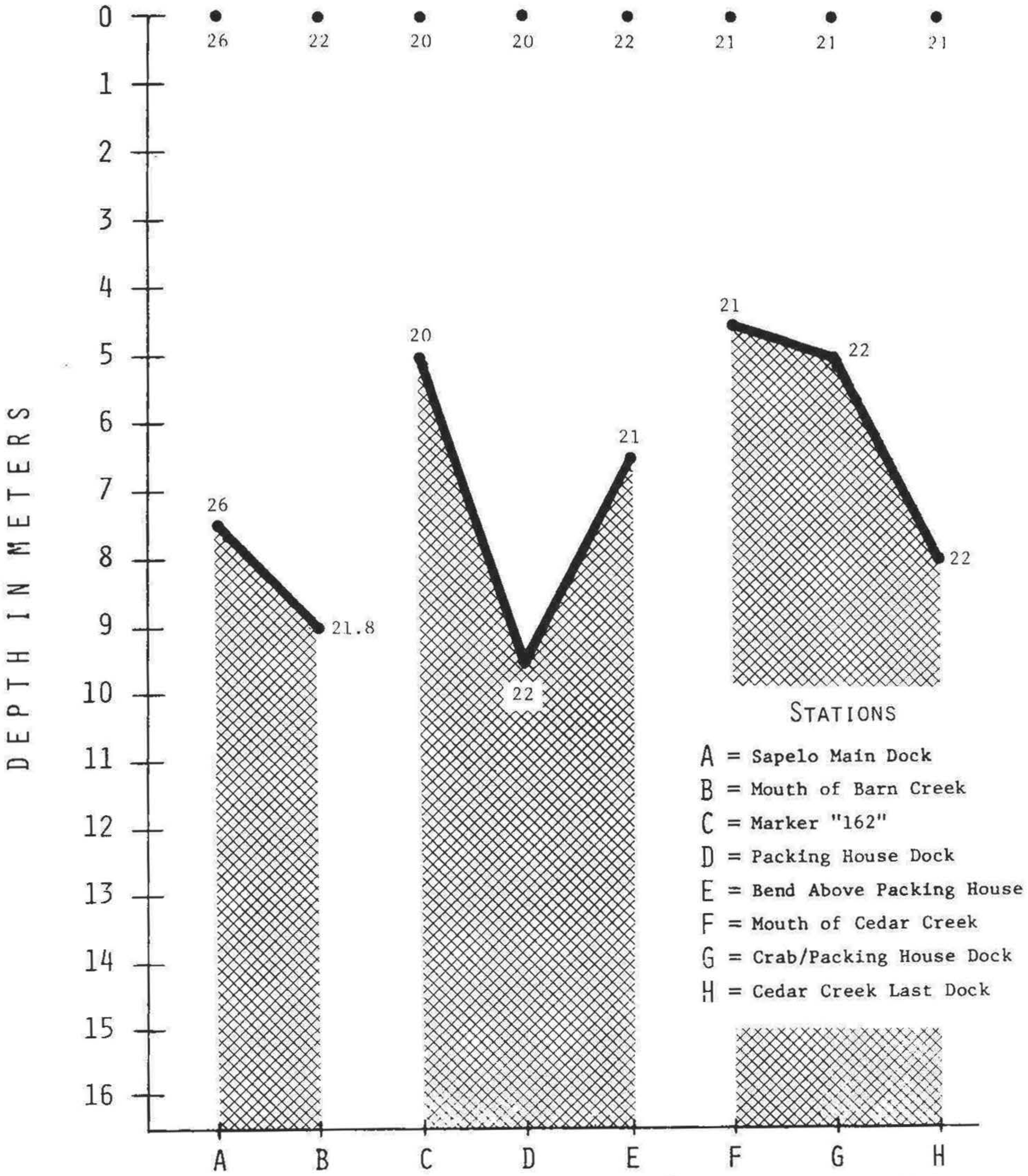

FIGURE 21: Northern Sampling Area Salinity (°/oo) Profile at High Tide During July.

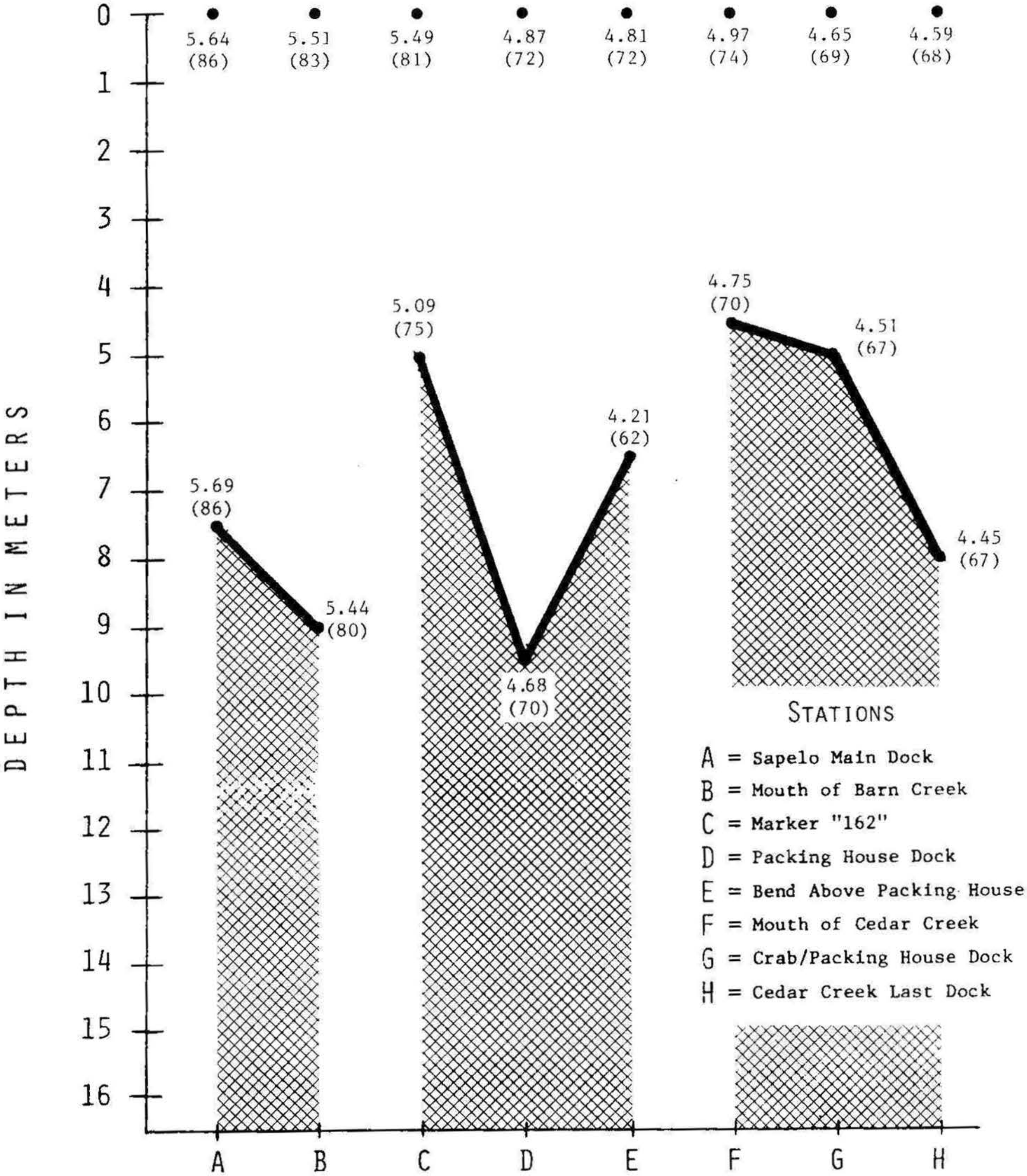

FIGURE 22: Northern Sampling Area D.O. (mg/l) and (% Saturation) Profile at High Tide During July.

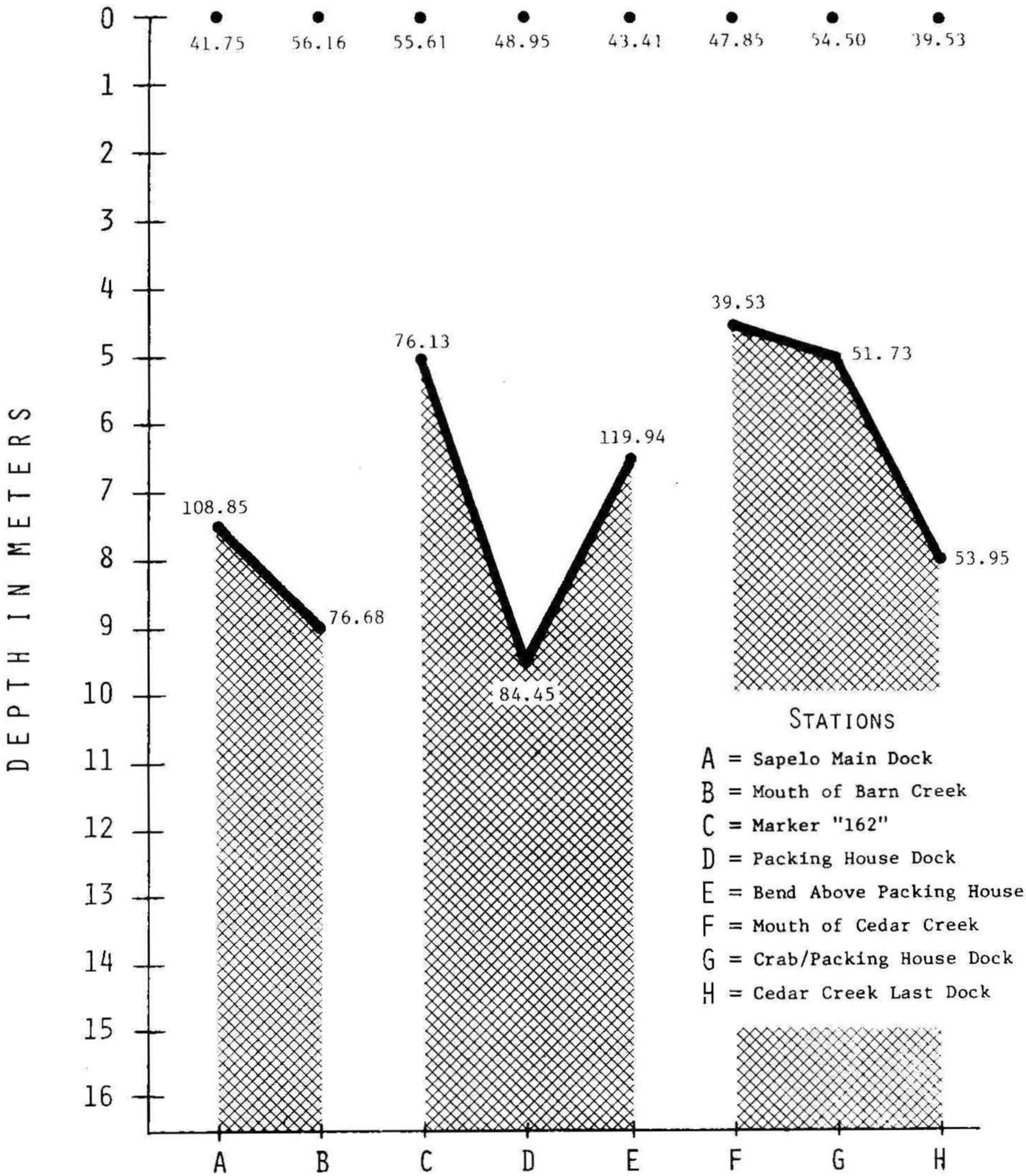

FIGURE 23: Northern Sampling Area NH_4-N (μg/l) Profile at High Tide During July.

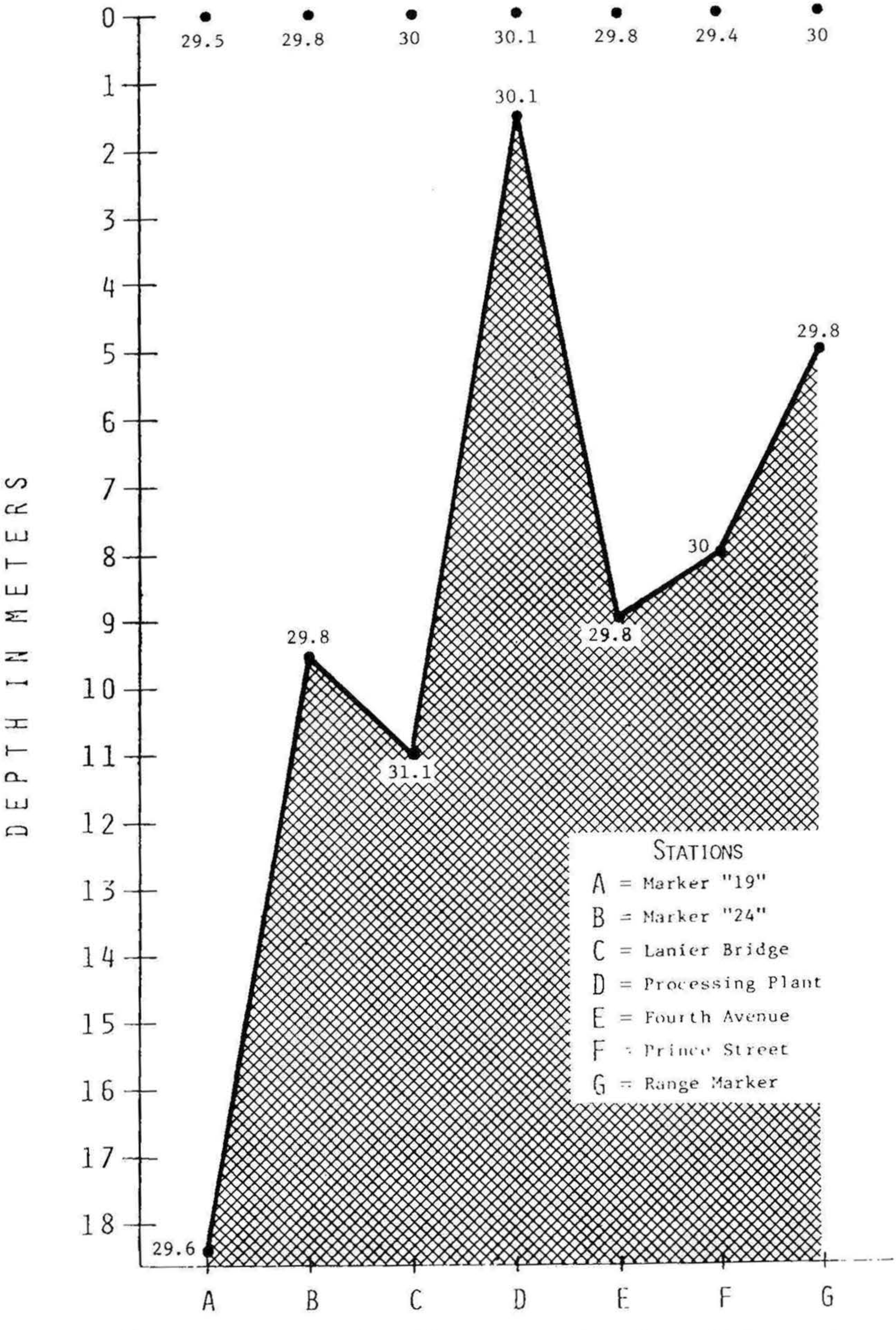

FIGURE 24: Southern Sampling Area Temperature (°C) Profile at Low Tide during July.

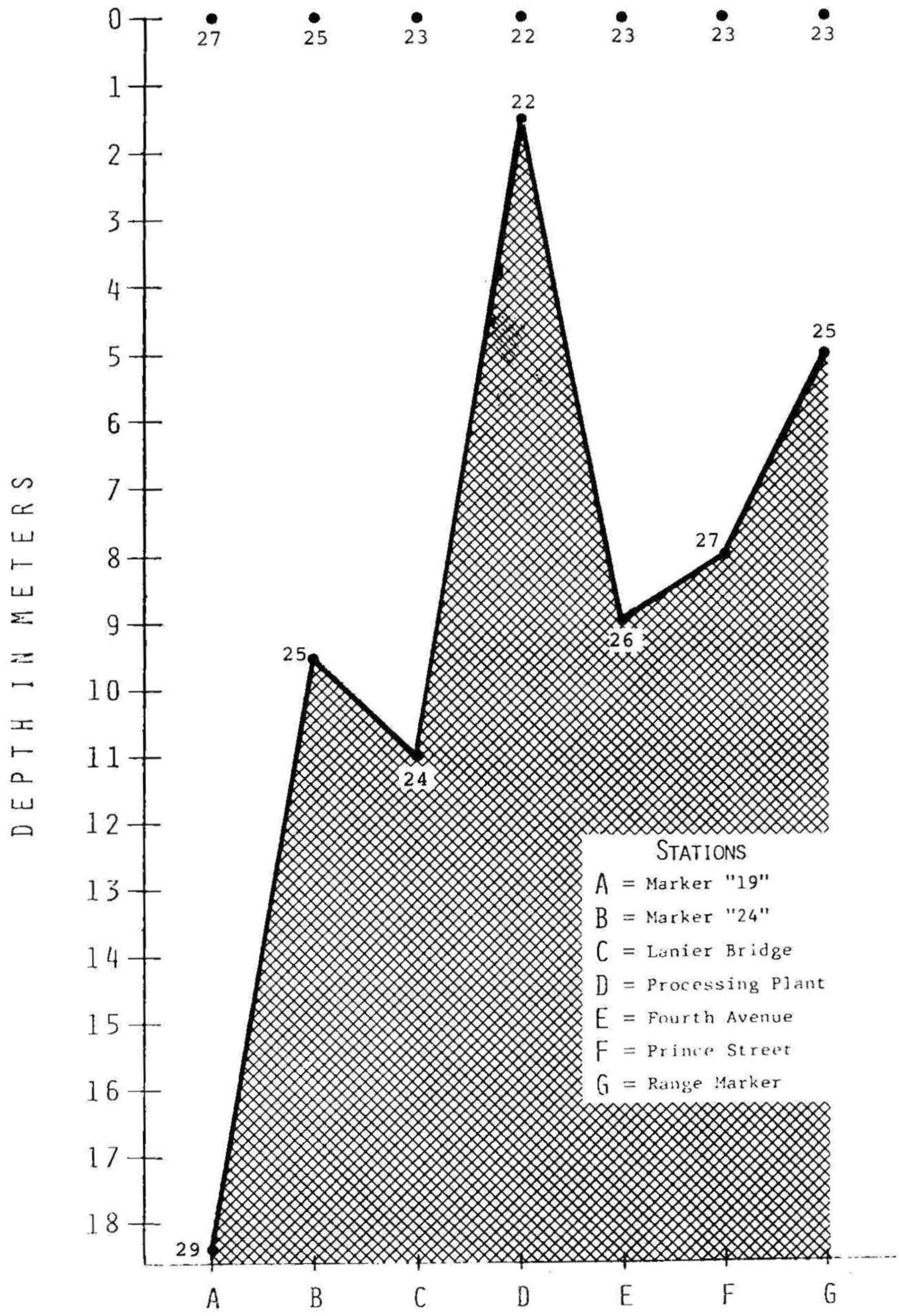

FIGURE 25: Southern Sampling Area Salinity ($^{o}/oo$) Profile at Low Tide During July.

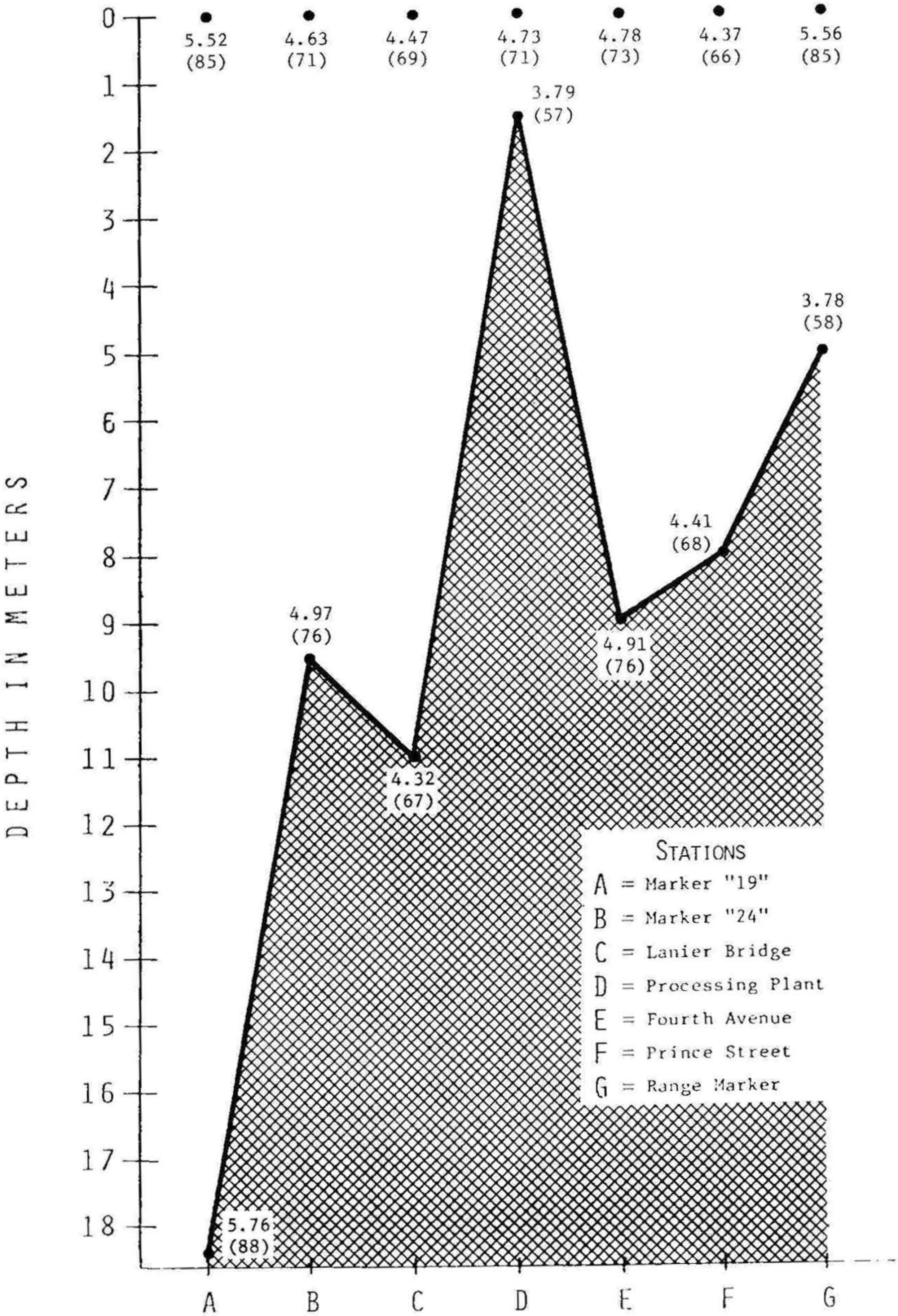

FIGURE 26: Southern Sampling Area D.O. Profile (mg/l) and (% Saturation) at Low Tide During July.

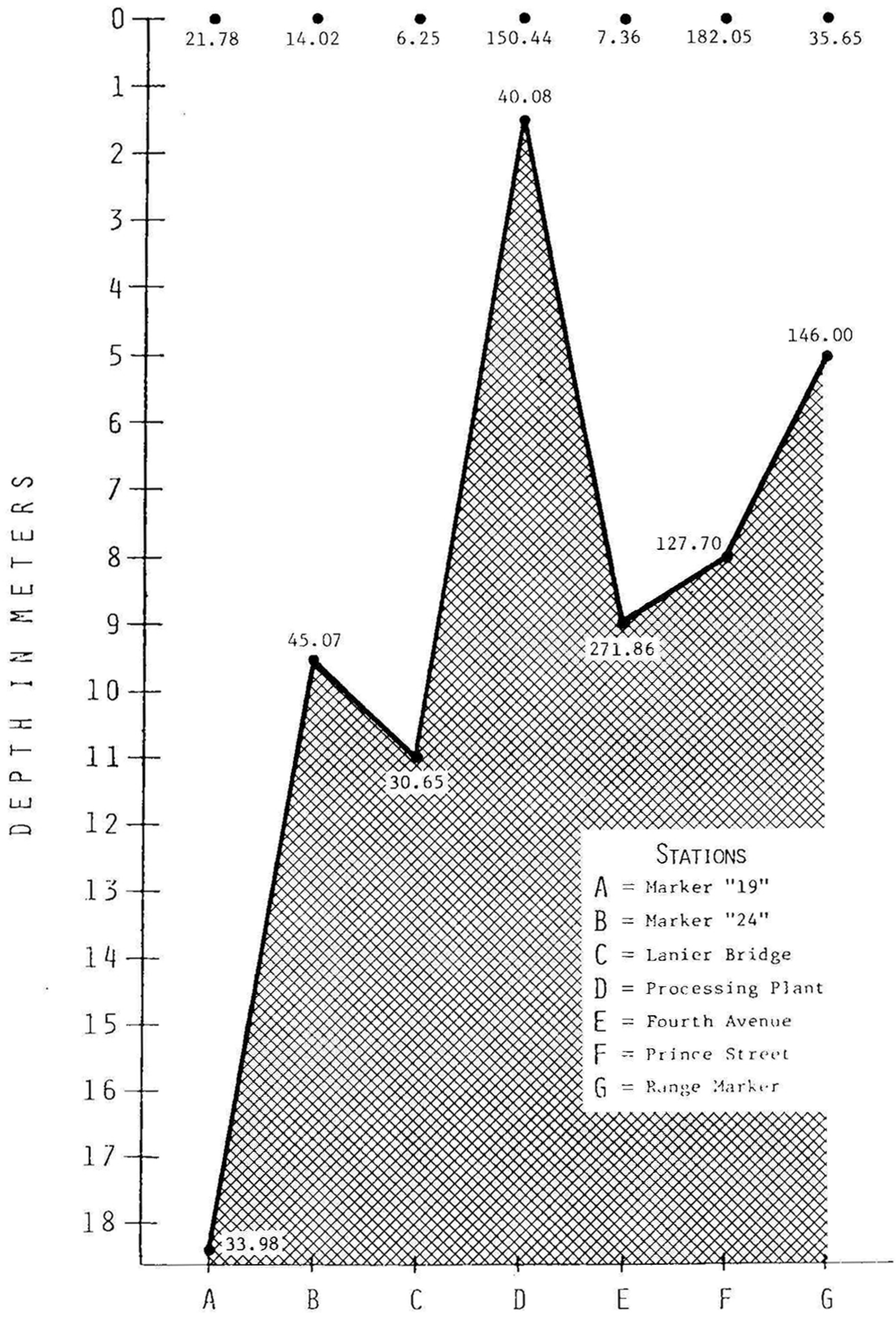

FIGURE 27: Southern Sampling Area NH_4-N (µg/l) Profile at Low Tide During July.

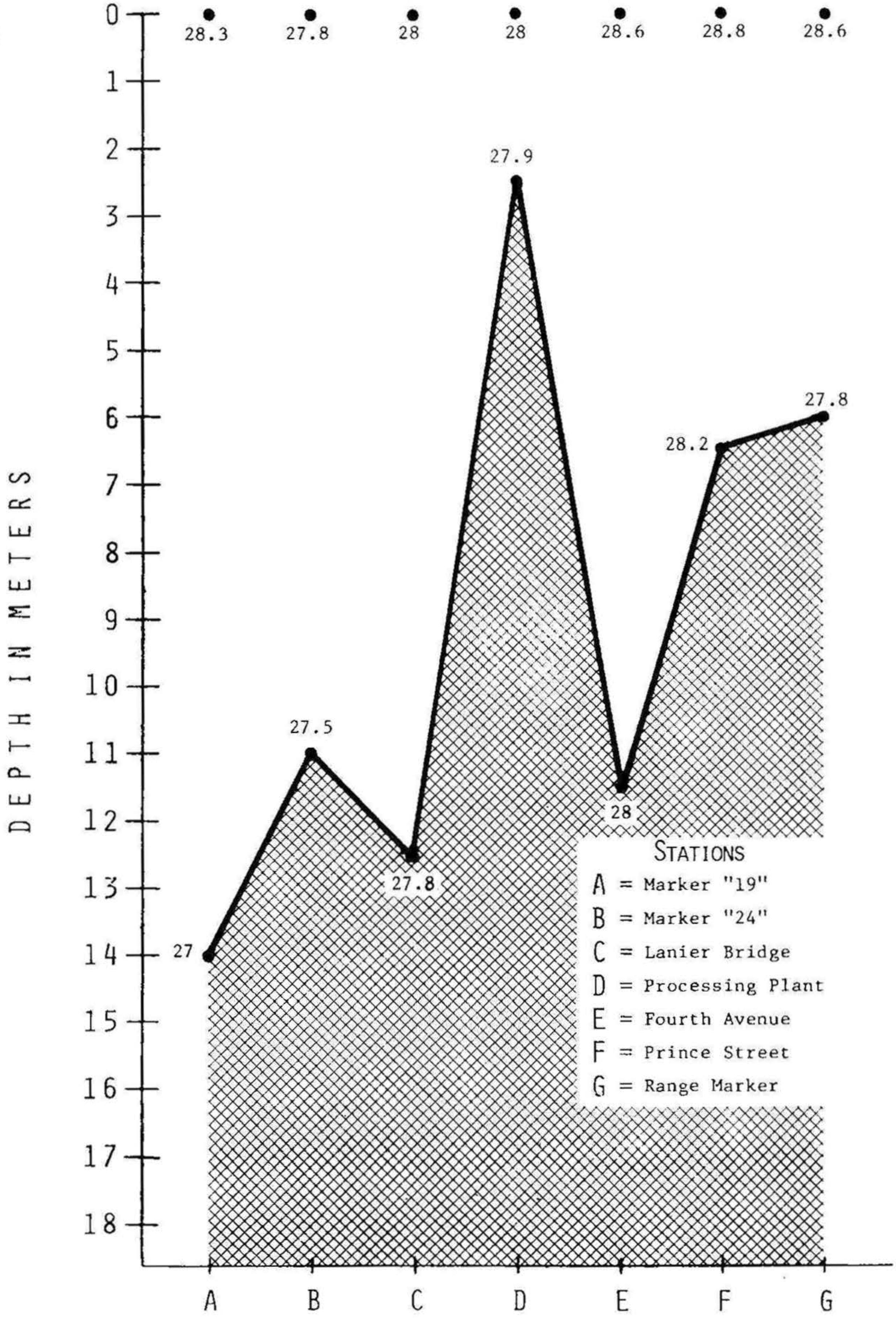

FIGURE 28: Southern Sampling Area Temperature (°C) Profile at High Tide During July.

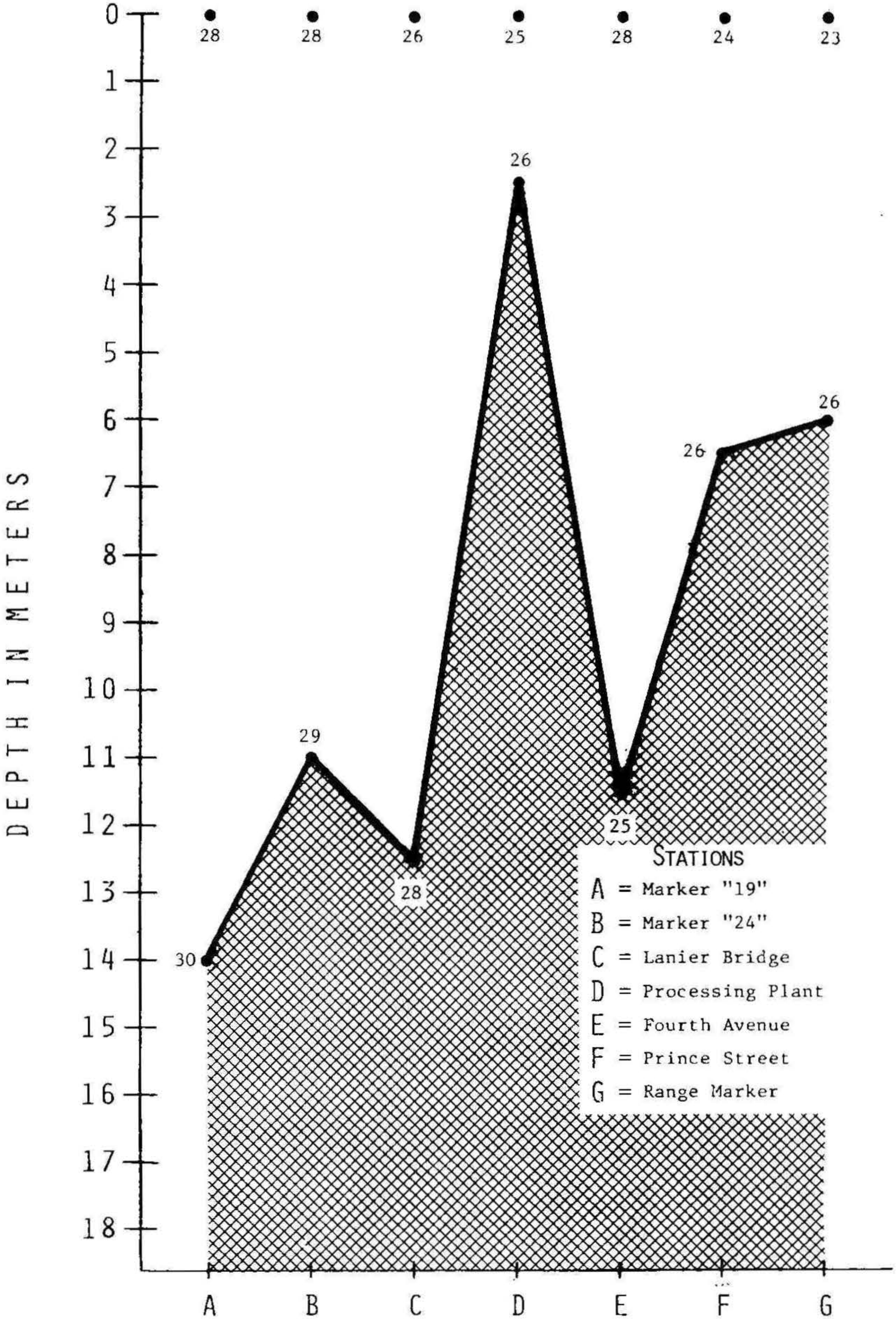

FIGURE 29: Southern Sampling Area Salinity ($^{o}/oo$) Profile at High Tide During July.

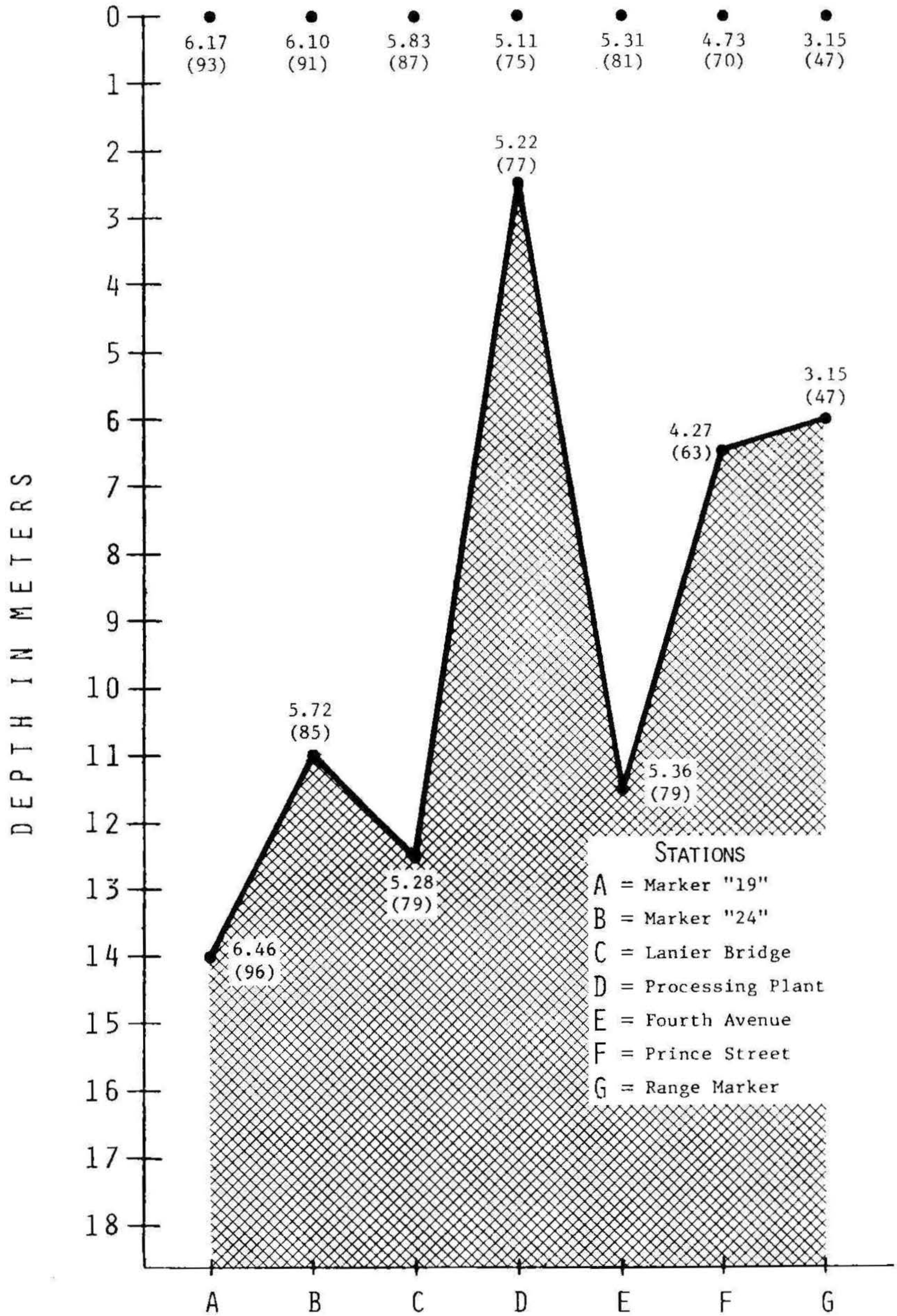

FIGURE 30: Southern Sampling Area D.O. Profile (mg/l) and (% Saturation) at High Tide During July.

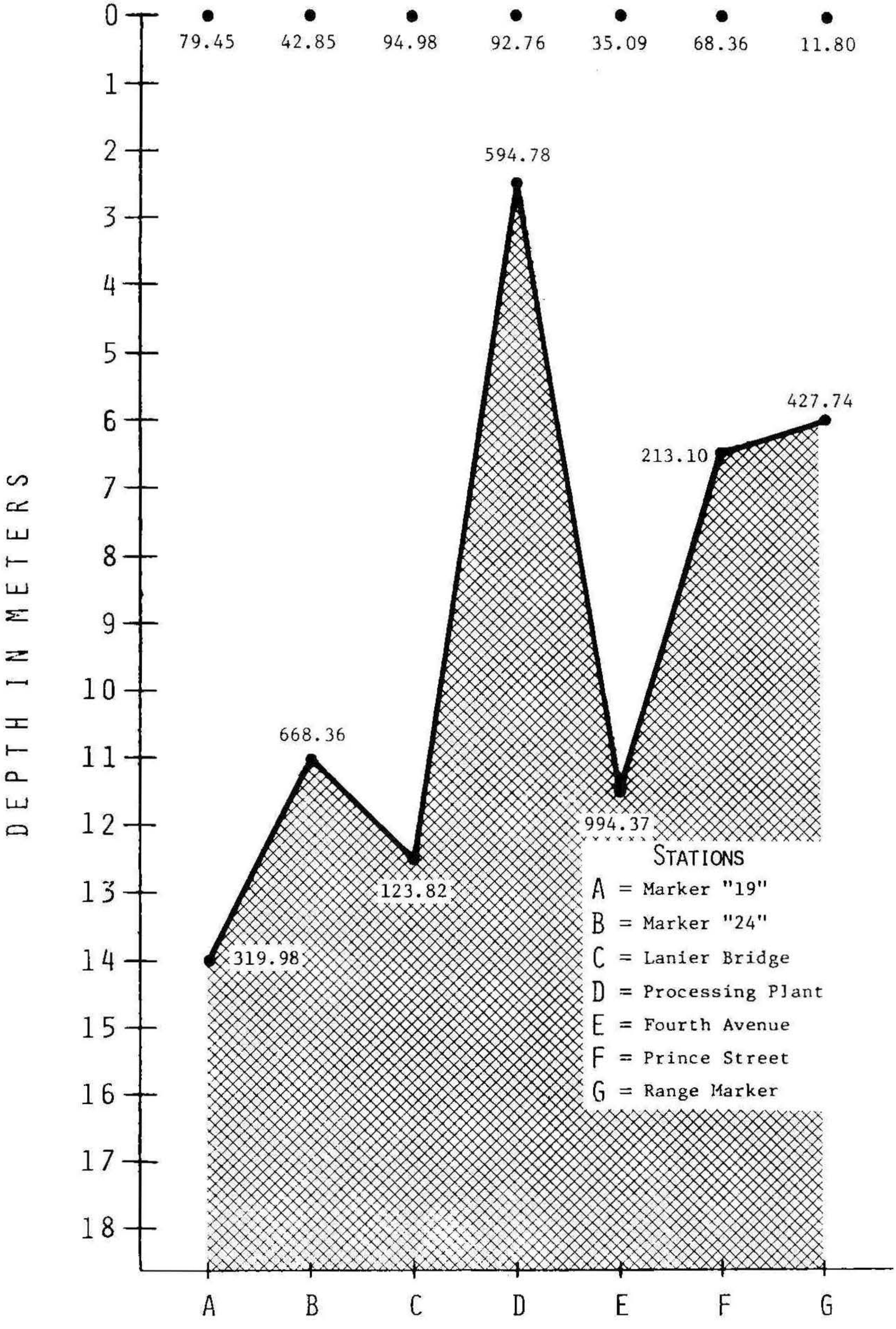

FIGURE 31: Southern Sampling Area NH_4-N (µg/l) Profile at High Tide During July.

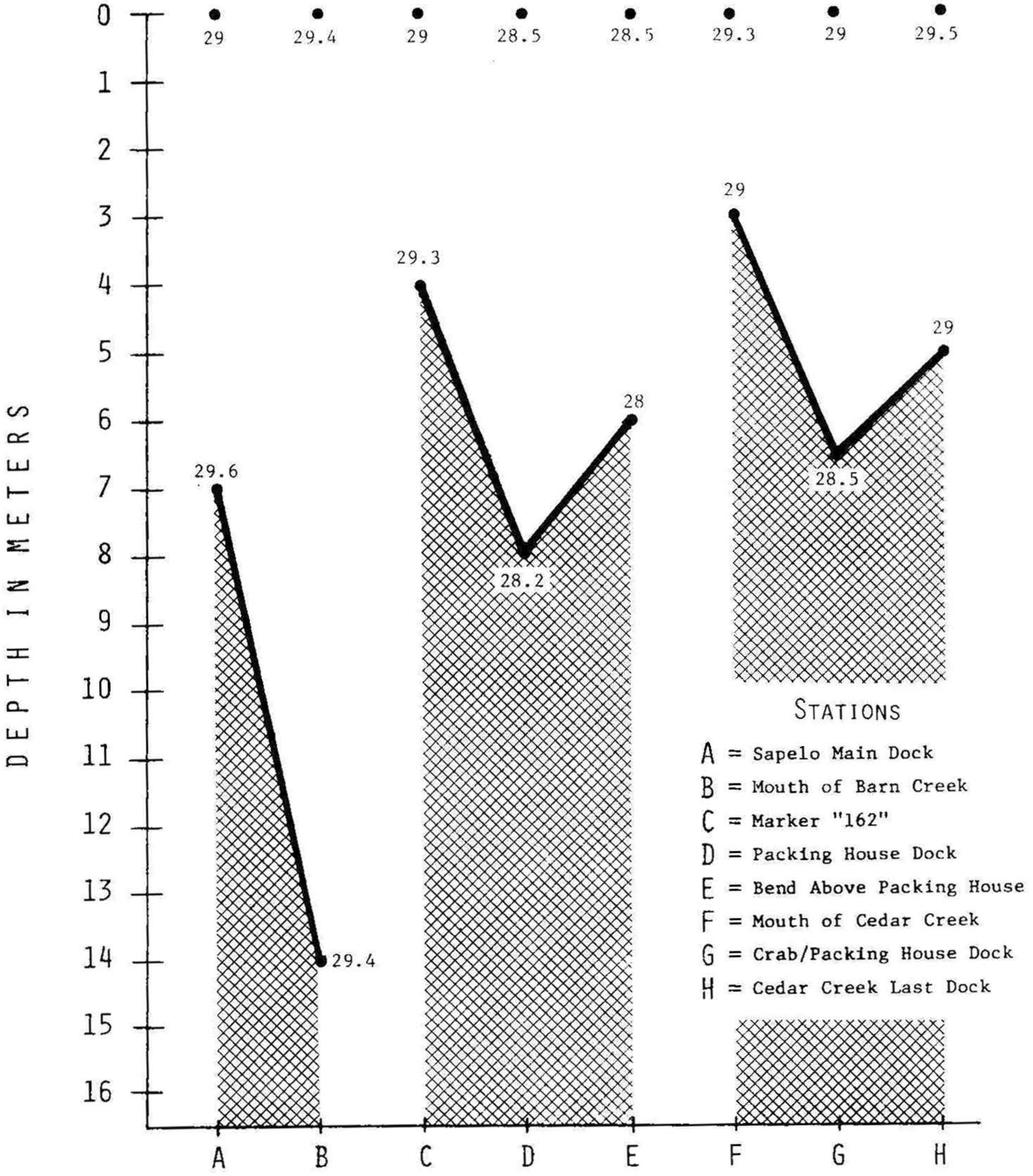

FIGURE 32: Northern Sampling Area Temperature (°C) Profile at Low Tide During August.

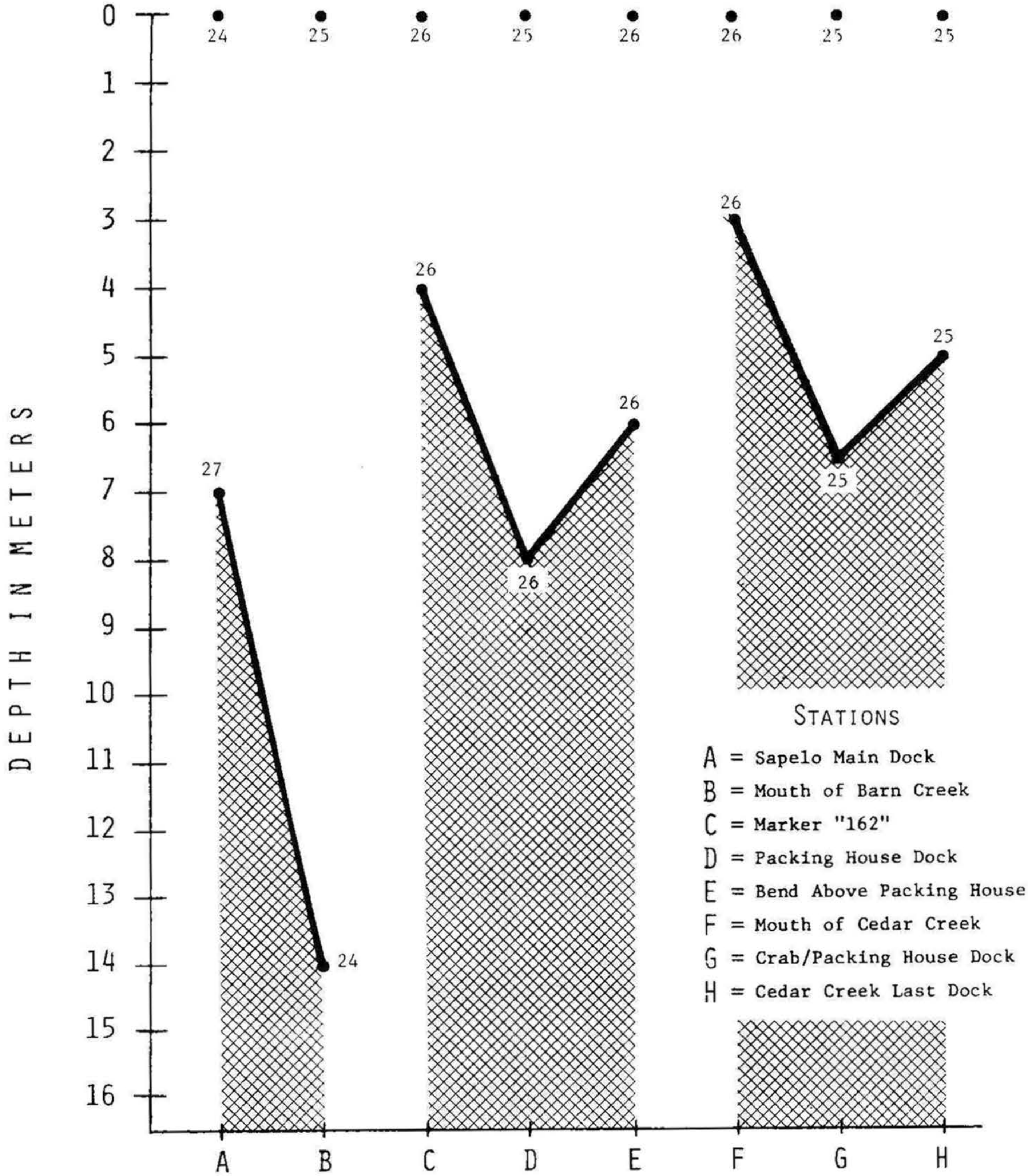

FIGURE 33: Northern Sampling Area Salinity (o/oo) Profile at Low Tide During August.

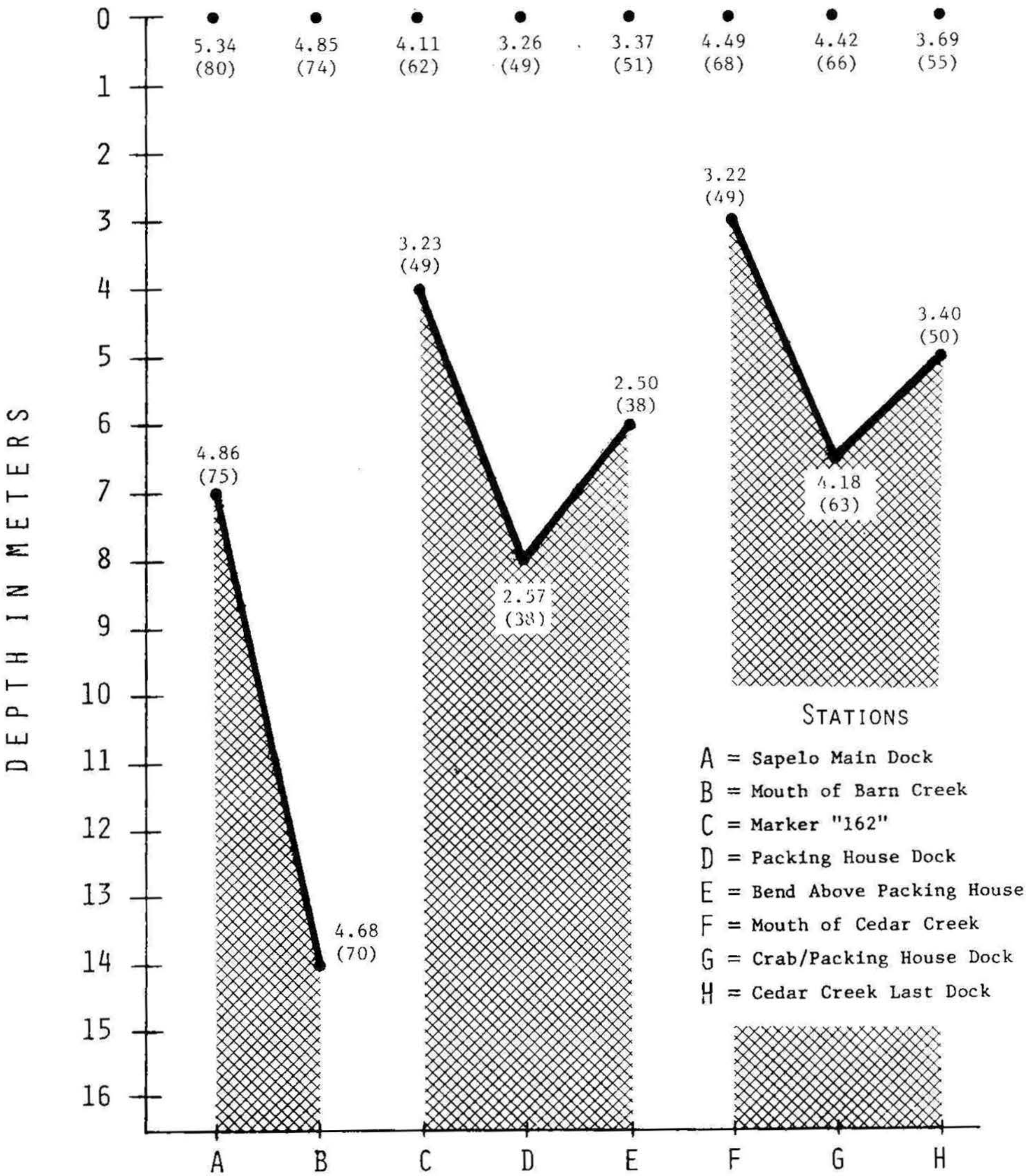

FIGURE 34: Northern Sampling Area D.O. (mg/l) and (% Saturation) Profile at Low Tide During August.

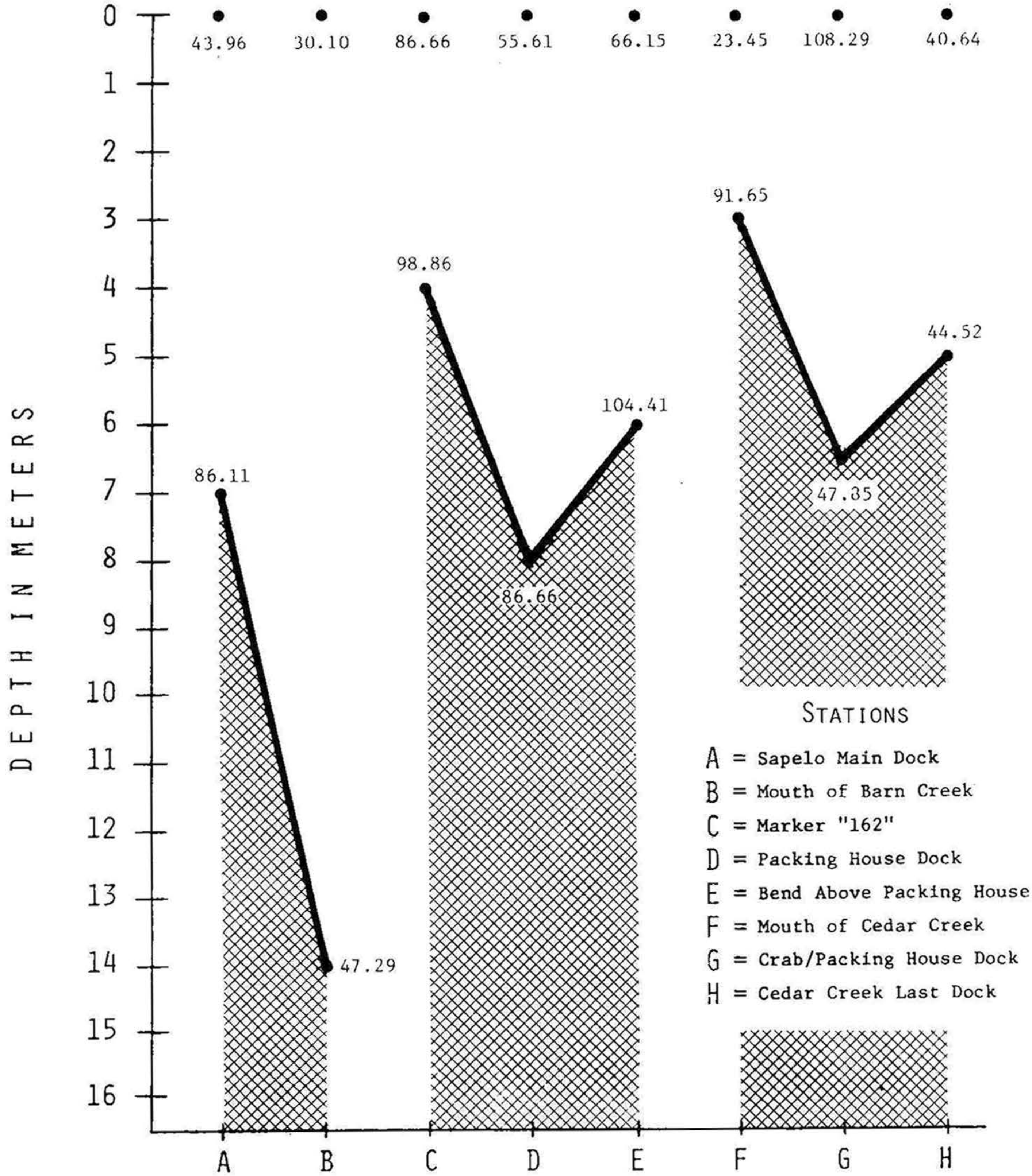

FIGURE 35: Northern Sampling Area NH_4-N (µg/l) Profile at Low Tide During August.

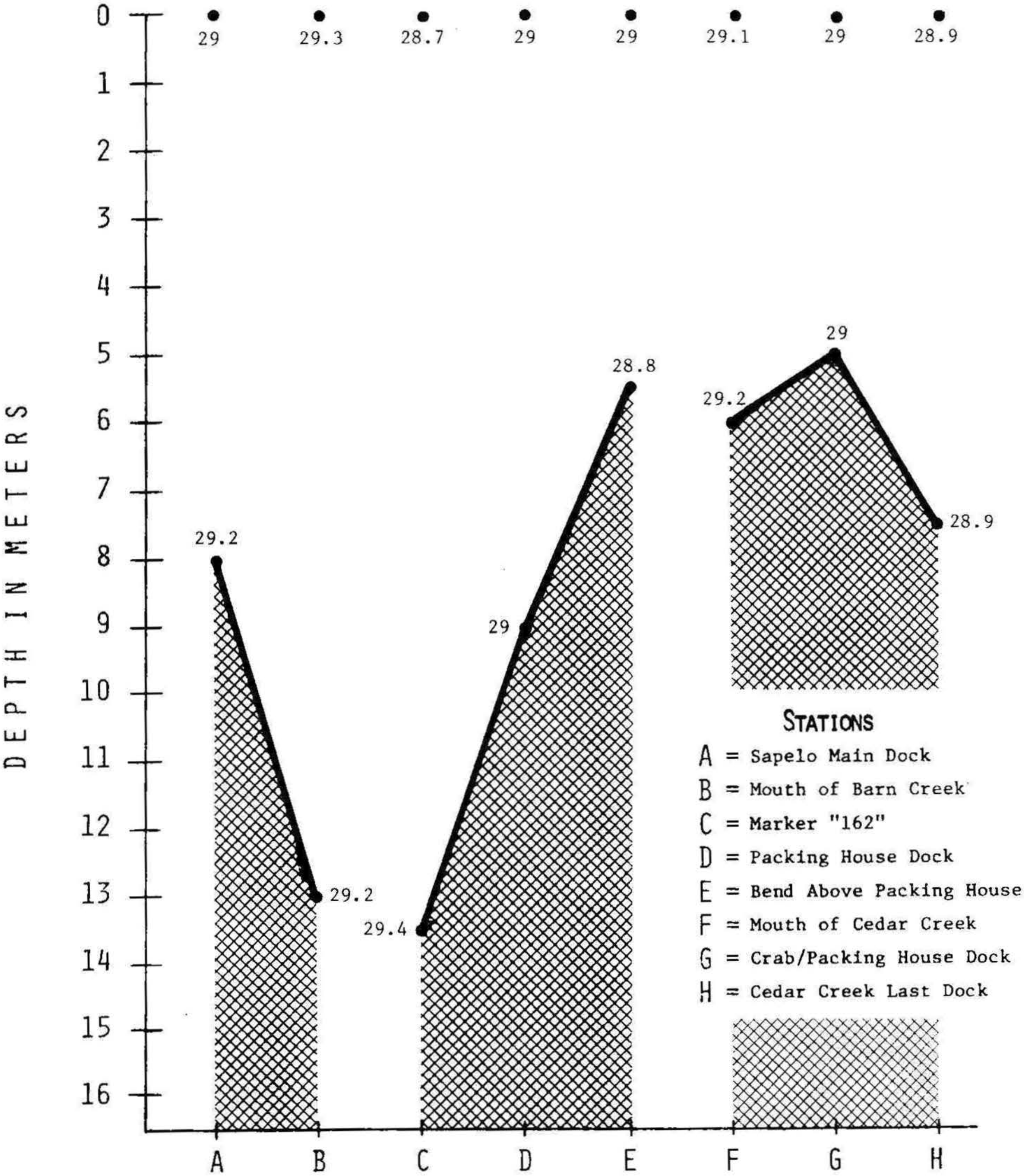

FIGURE 36: Northern Sampling Area Temperature (°C) Profile at High Tide during August.

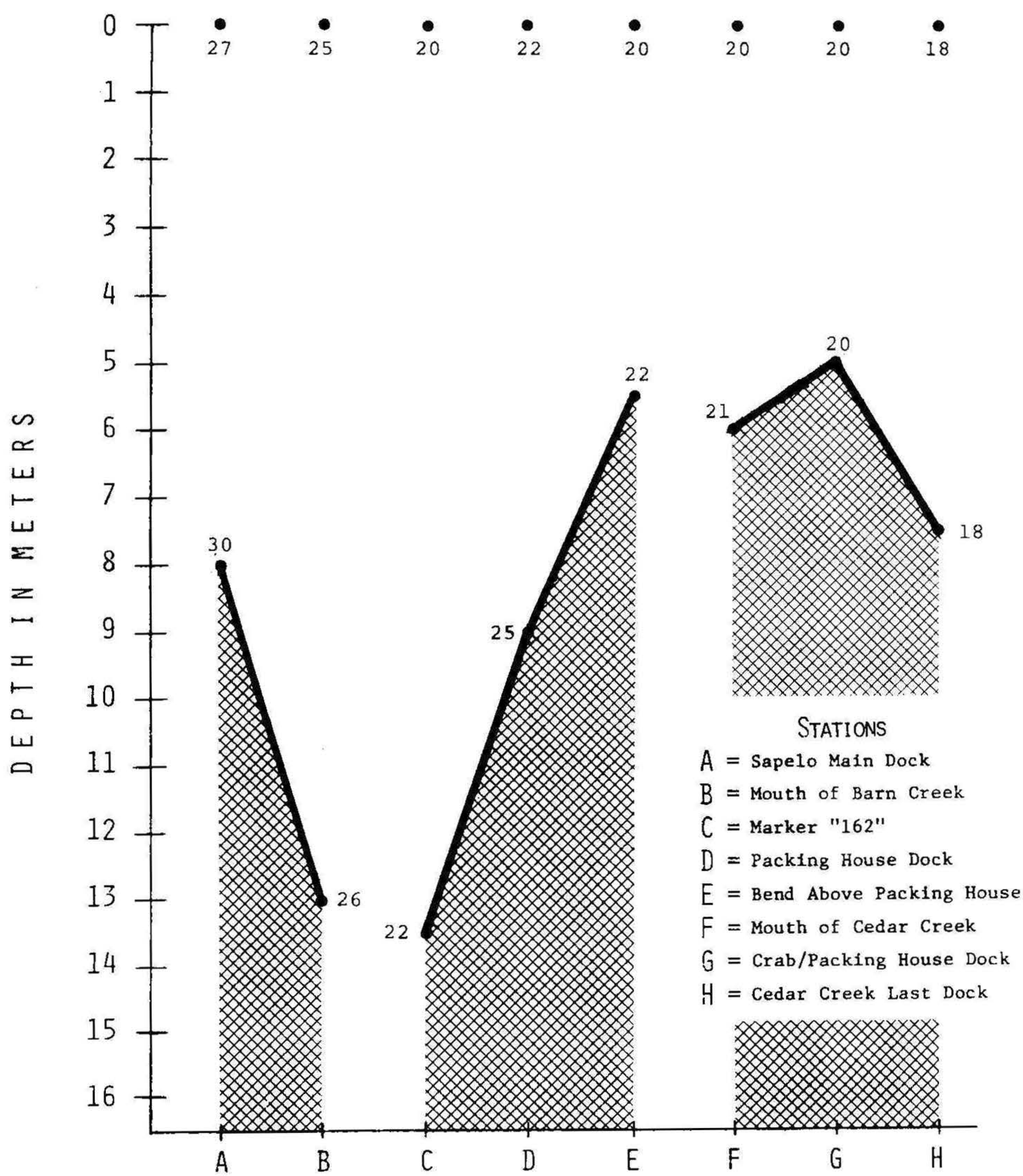

FIGURE 37: Northern Sampling Area Salinity ($^{o}/oo$) Profile at High Tide during August.

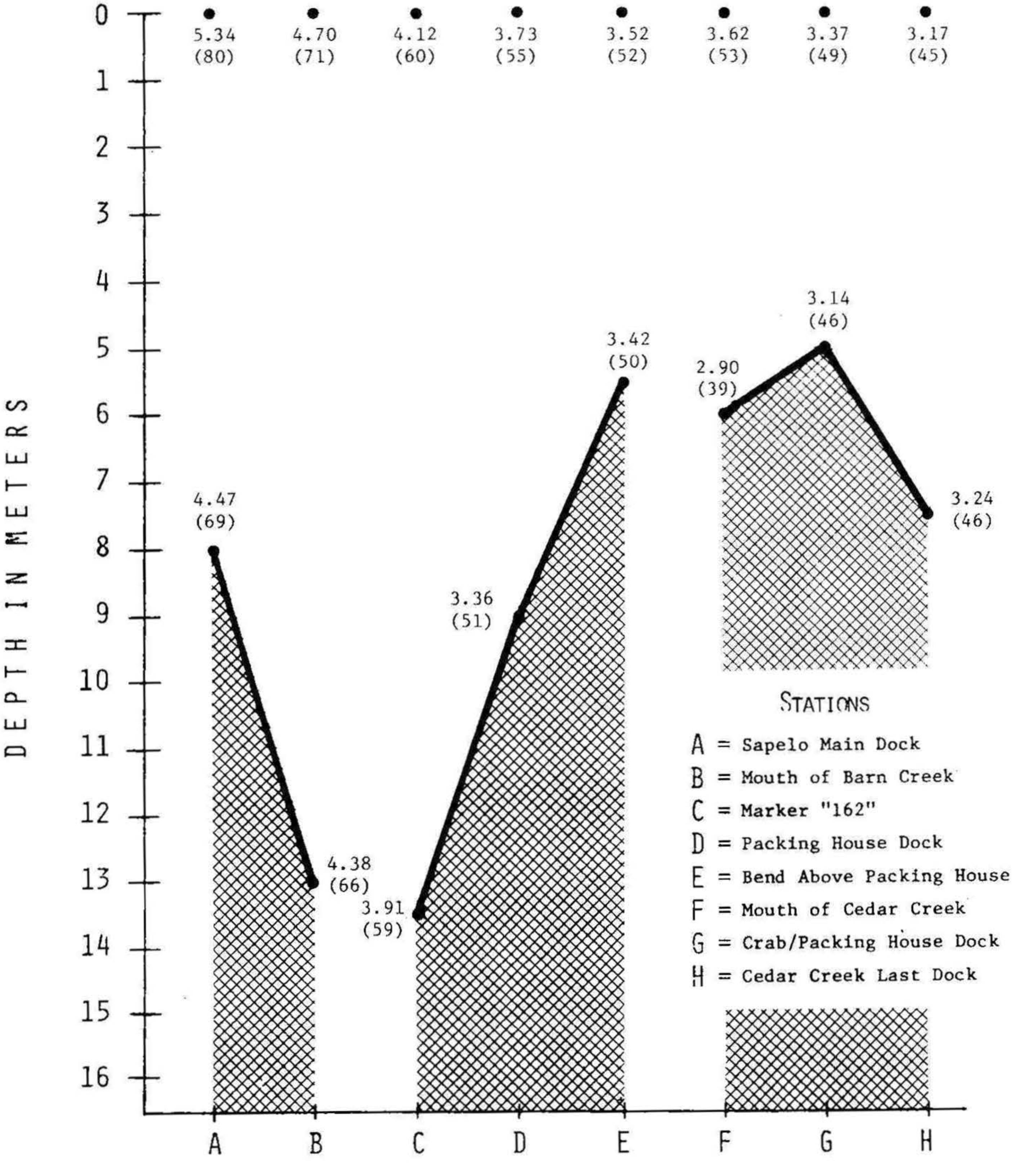

FIGURE 38: Northern Sampling Area D.O. Profile (mg/l) and (% Saturation) at High Tide during August

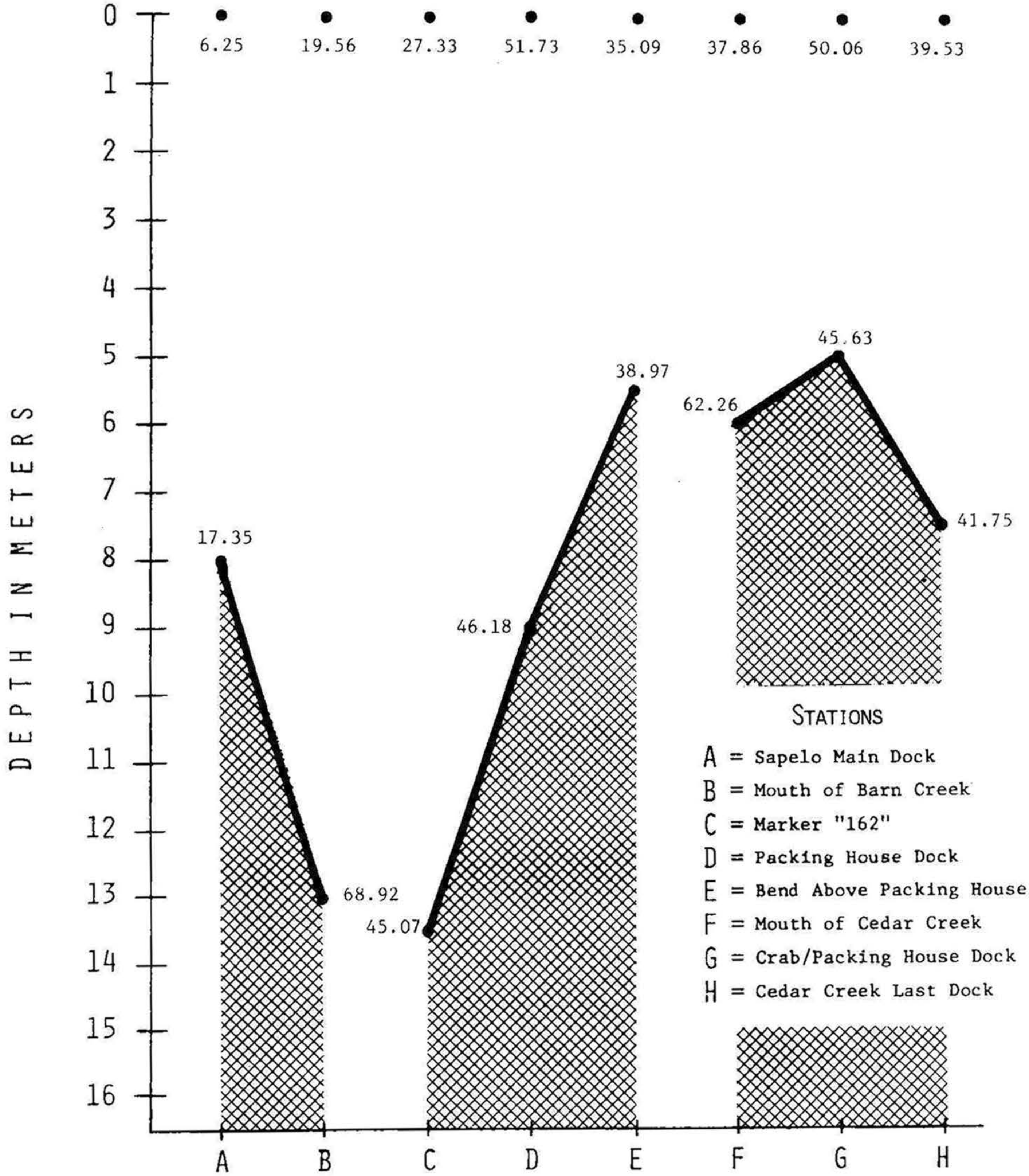

FIGURE 39: Northern Sampling Area NH_4-N (µg/l) Profile at High Tide during August.

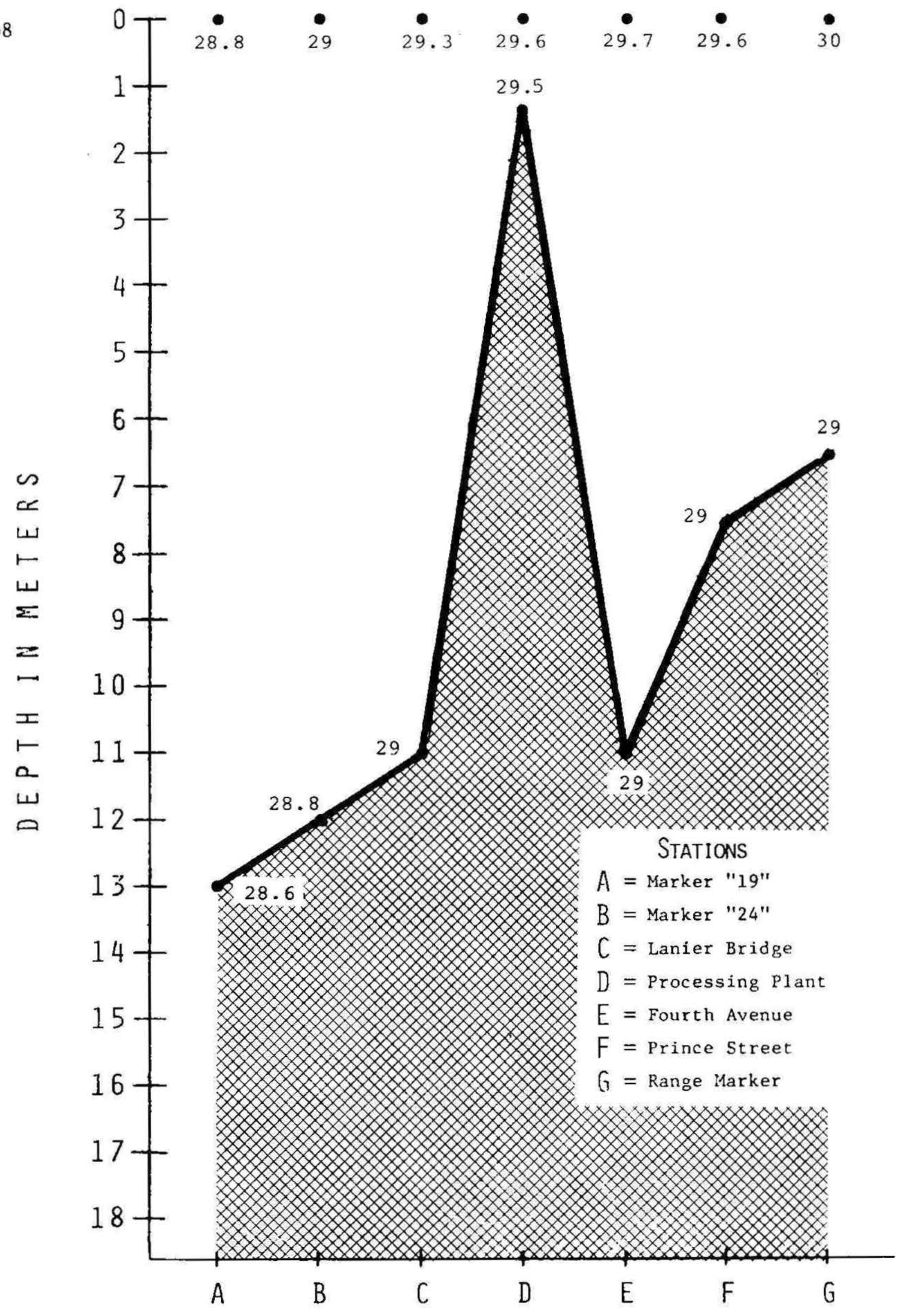

FIGURE 40: Southern Sampling Area Temperature (°C) Profile at Low Tide During August.

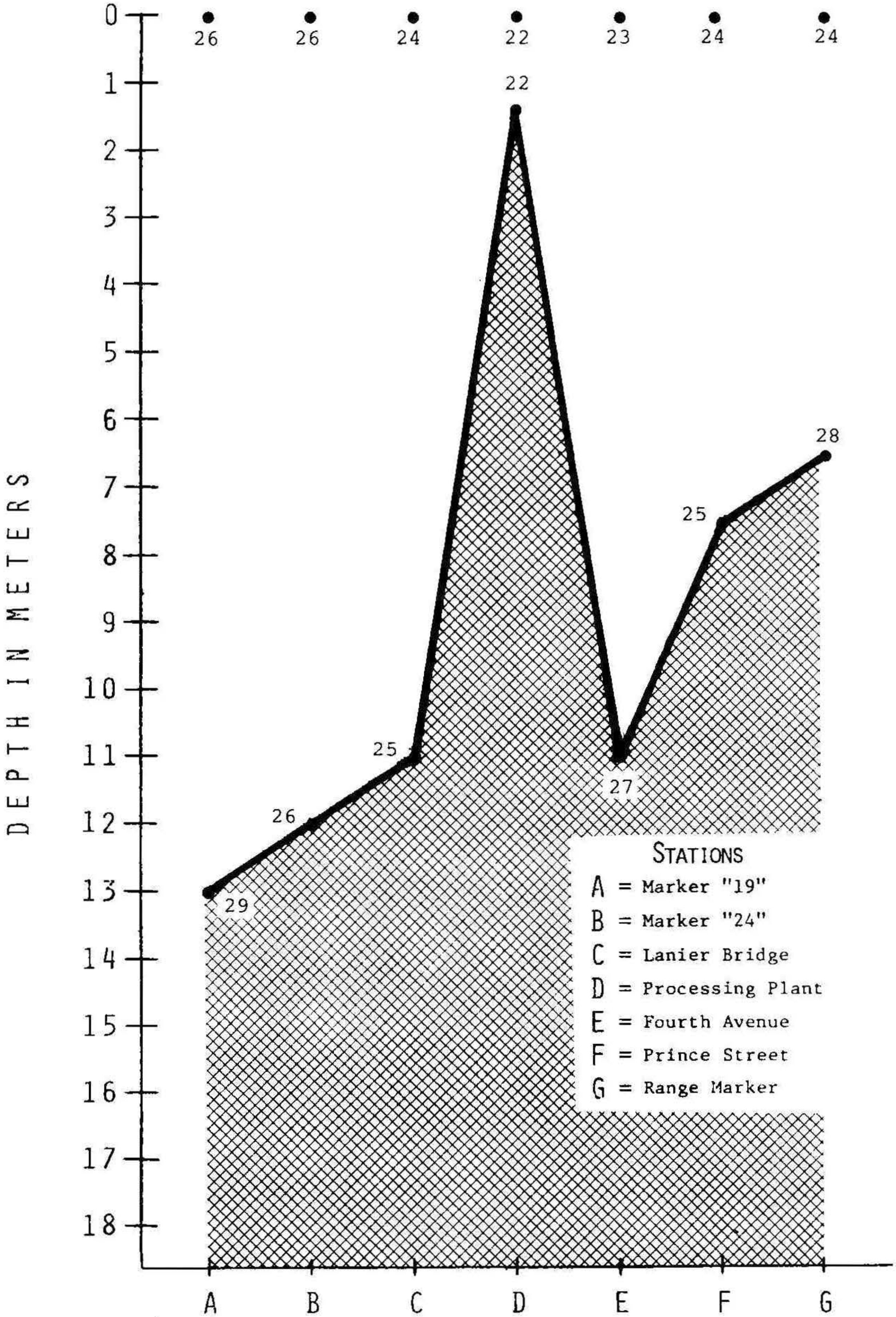

FIGURE 41: Southern Sampling Area Salinity (o/oo) Profile at Low Tide During August.

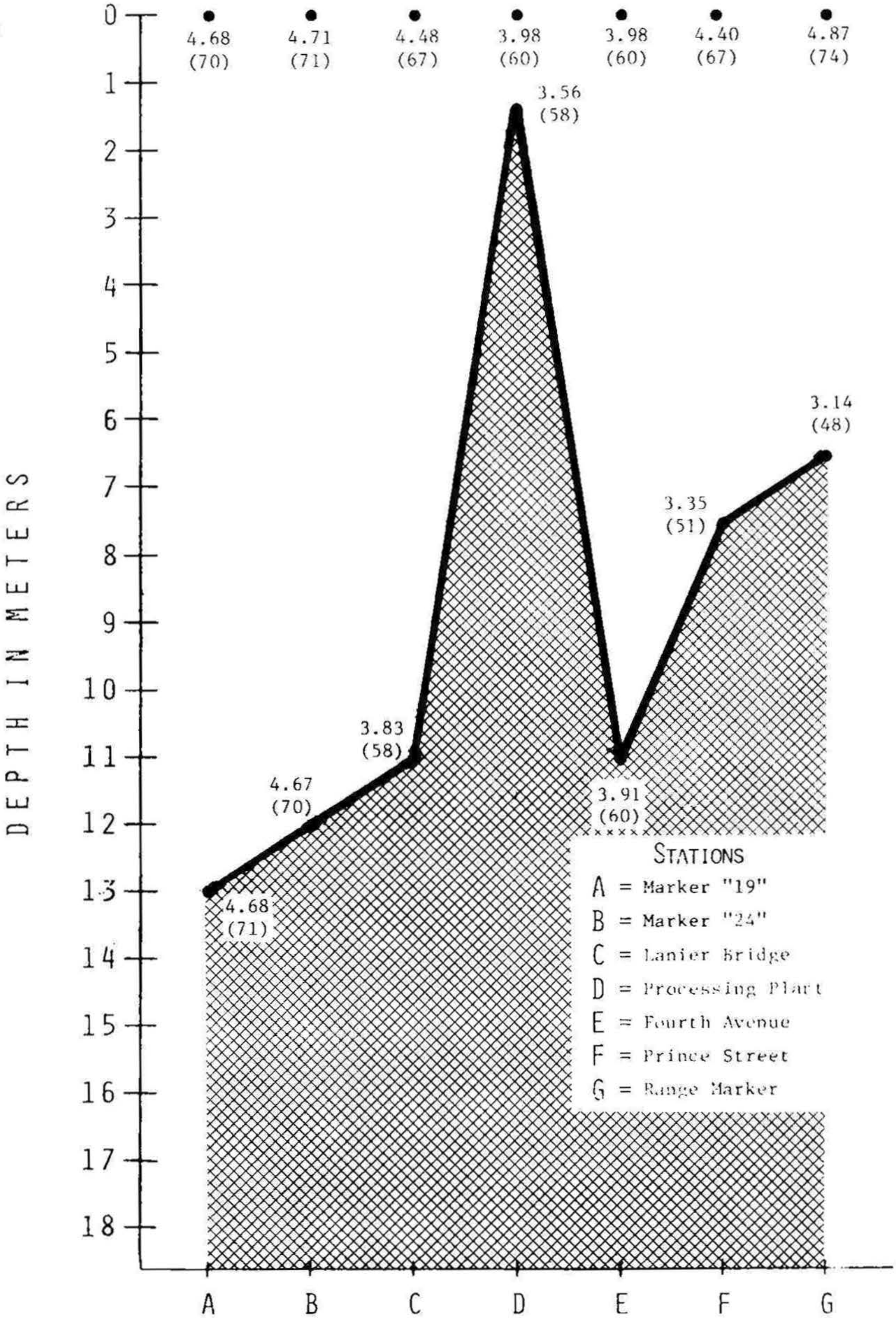

FIGURE 42: Southern Sampling Area D.O. Profile (mg/l) and (% Saturation) at Low Tide During August.

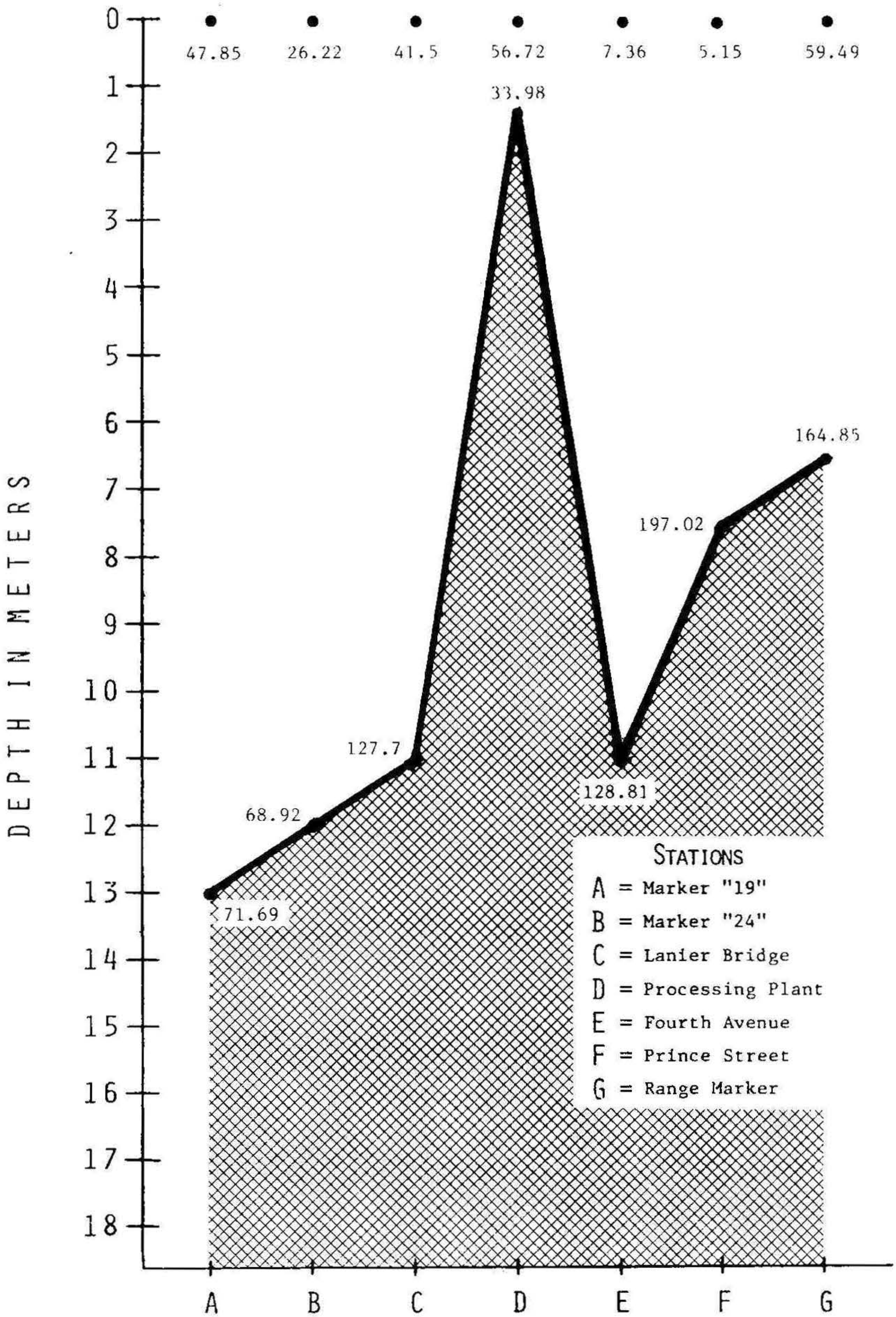

FIGURE 43: Southern Sampling Area NH_4-N (μg/l) Profile at Low Tide During August.

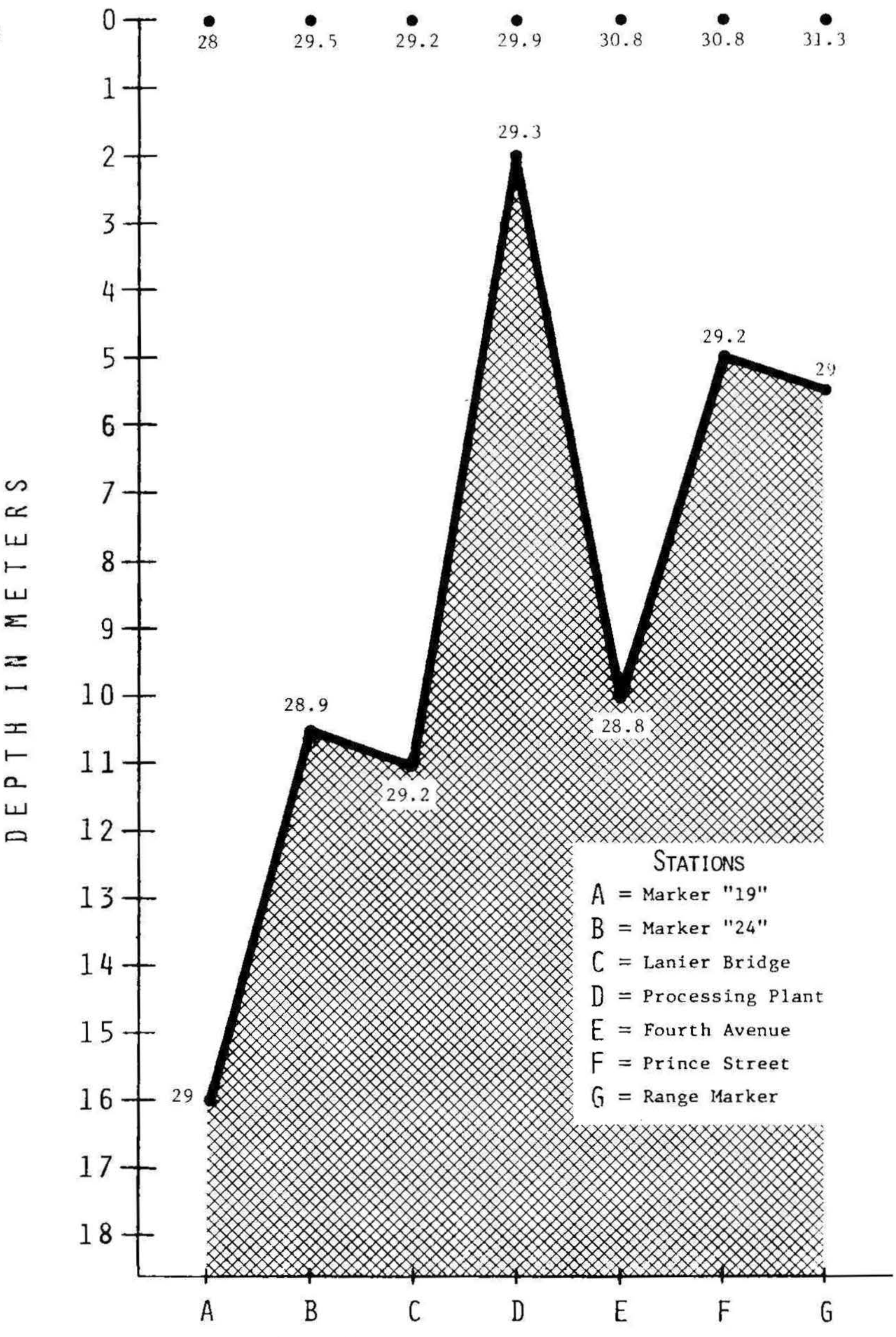

FIGURE 44: Southern Sampling Area Temperature (°C) Profile at High Tide During August.

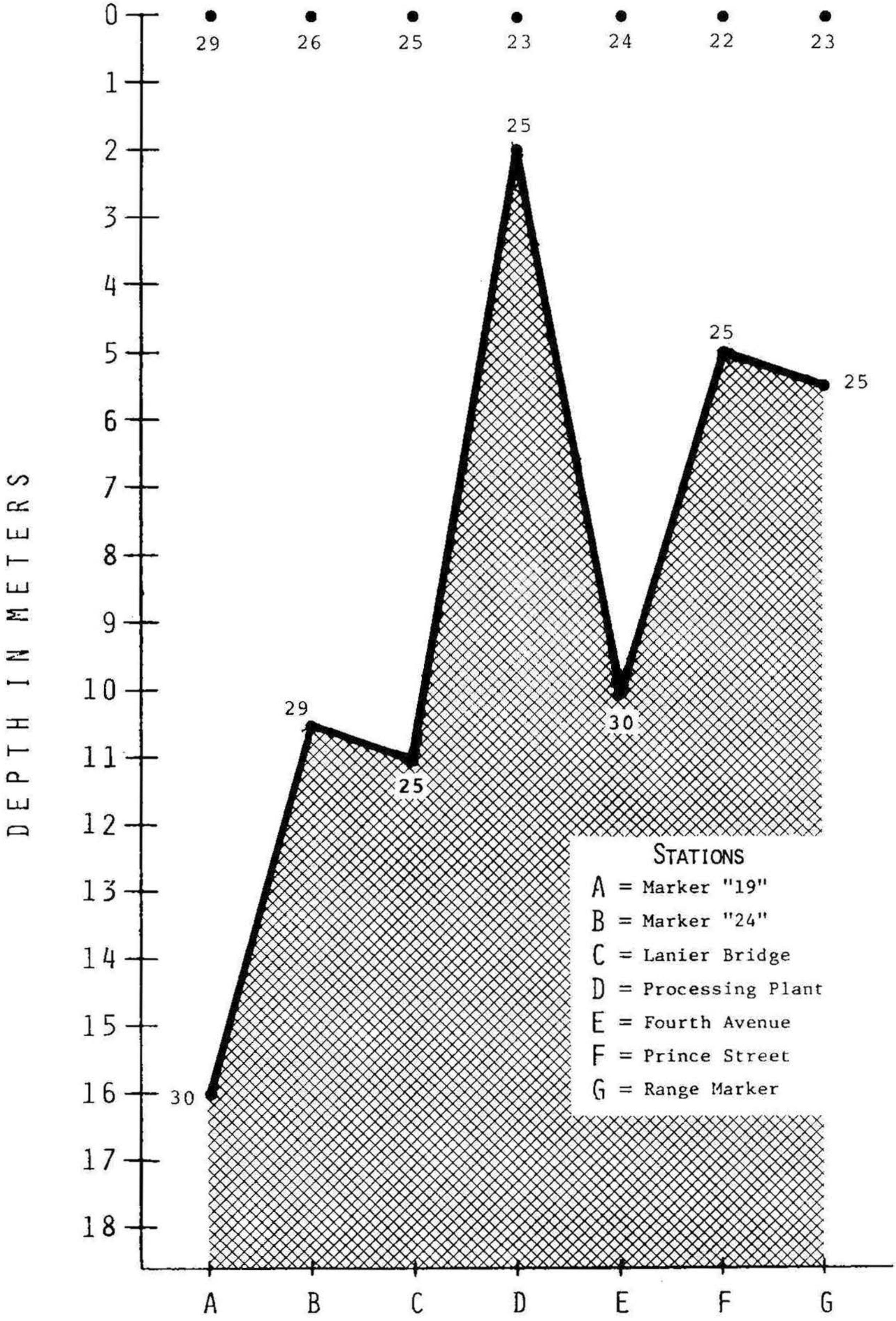

FIGURE 45: Southern Sampling Area Salinity (o/oo) Profile at High Tide During August.

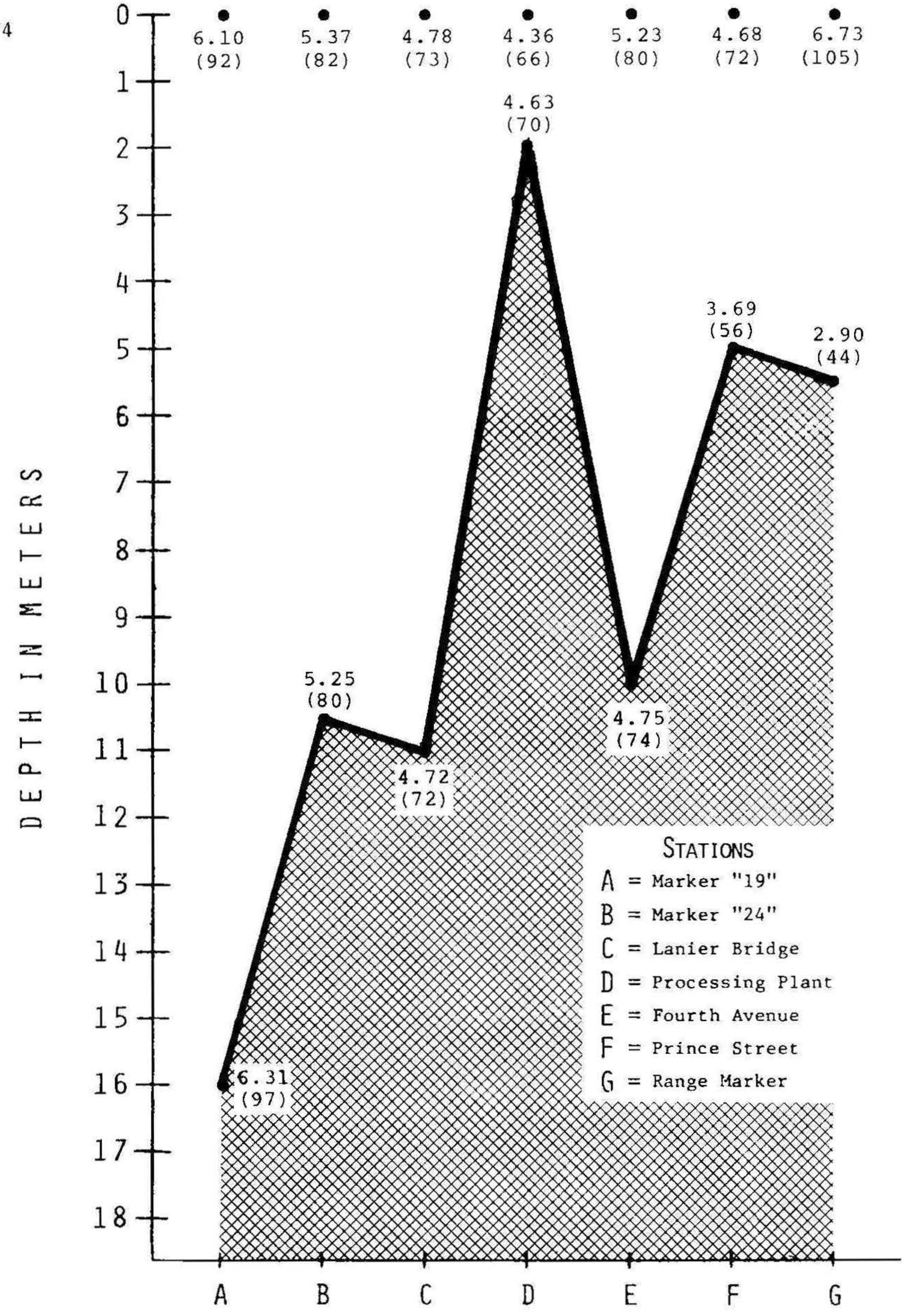

FIGURE 46: Southern Sampling Area D.O. Profile (mg/l) and (% Saturation) at High Tide During August.

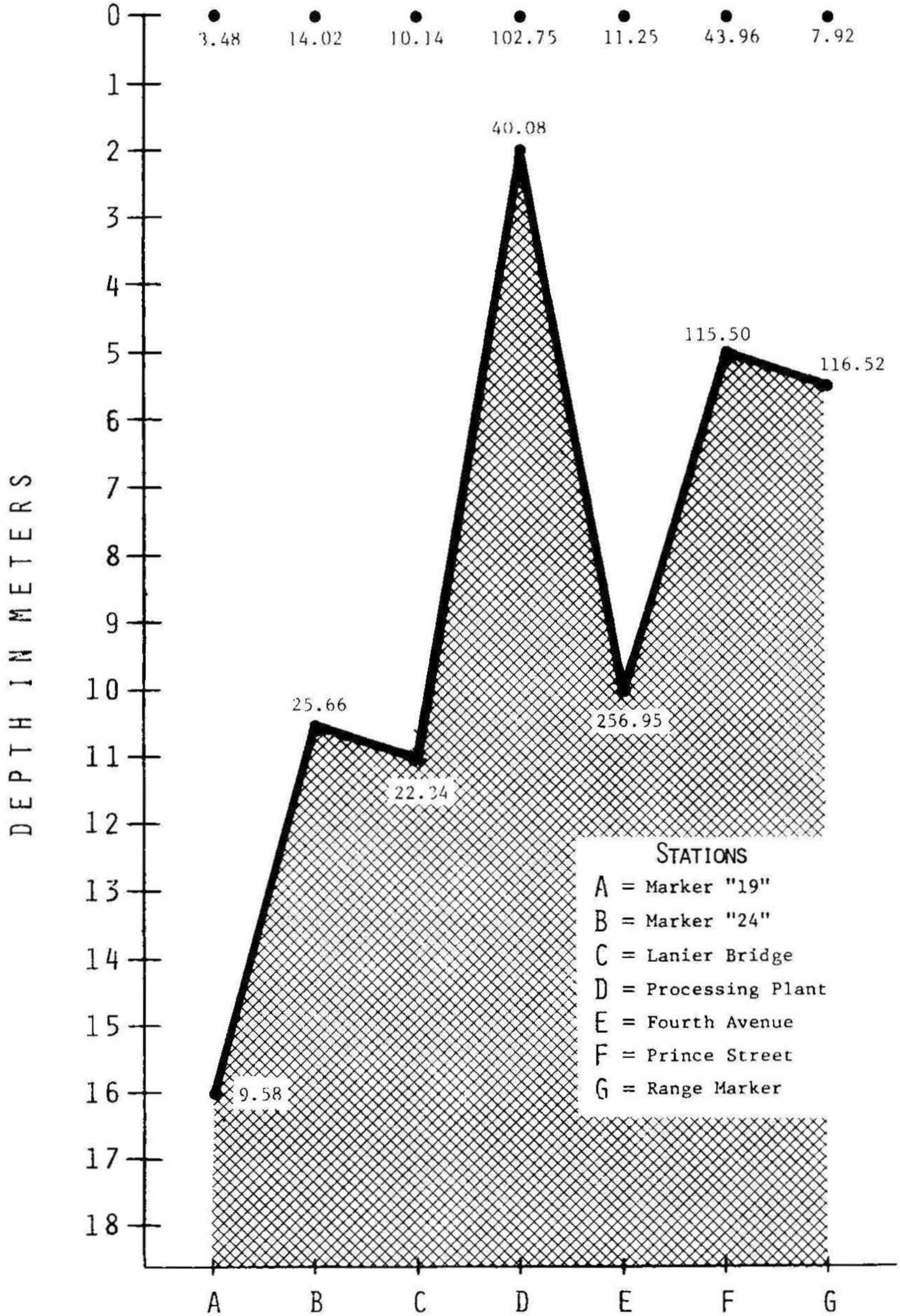

FIGURE 47: Southern Sampling Area NH_4-N (µg/l) Profile at High Tide During August.

TABLES

TABLE 1. MICROBIOLOGICAL LEVELS OF THE DUPLIN RIVER, INITIAL HYDROGRAPHIC SURVEY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Mouth of Duplin River	345	260	3.42×10^4	24	9.3
Sapelo Main Dock	340	265	1.40×10^4	7.5	3.9
Mouth of Barn Creek	745	195	6.80×10^3	9.3	9.3
Sawdust Pile Duplin River	1.29×10^3	315	1.20×10^4	46	7.5
Northern Bend of Duplin River	611	295	2.05×10^4	21	15

TABLE 2. MICROBIOLOGICAL LEVELS OF SHELLBLUFF CREEK, INITIAL HYDROGRAPHIC SURVEY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Mouth of Shellbluff Creek Marker "162"	320	231	5.90×10^3	46	0.45
Telephone Pole 1/4 Mile West of Marker "162"	240	174	5.05×10^3	>240	0.93
Packing House Station	447	194	6.40×10^3	110	24
Bend Above Packing Houses	550	163	5.50×10^3	110	24

TABLE 3. MICROBIOLOGICAL LEVELS OF CEDAR CREEK, INITIAL HYDROGRAPHIC SURVEY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Mouth of Cedar Creek	165	106	5.15×10^3	21	2.3
Old Boat	1.27×10^3	625	4.65×10^3	>240	24
Dock Between Crab Plant and Packing House	935	690	6.50×10^3	>240	24
South of Red Dock	420	226	5.85×10^3	110	7.5
Last Dock Cedar Creek	230	178	5.00×10^3	7.5	4.3

TABLE 4. MICROBIOLOGICAL LEVELS OF THE BRUNSWICK ESTUARY, INITIAL HYDROGRAPHIC SURVEY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Marker "19"	276	252	2.54×10^3	24	4.3
Marker "22"	350	205	2.34×10^3	46	2.3
Marker "24"	370	285	3.55×10^3	15	4.3
Lanier Bridge	525	555	1.81×10^3	110	9.3
Processing Plant Discharge Pipe	660	715	3.52×10^3	$\geq$240	15
East River at Fourth Street	116	975	1.58×10^4	$\geq$240	24
East River at Prince Street	705	675	7.80×10^3	$\geq$240	15
East River Range Marker	1.42×10^3	1.48×10^3	2.20×10^4	$\geq$240	46
East River at K Street	505	620	4.95×10^3	$\geq$240	$\geq$240
End of East River	455	290	4.10×10^3	$\geq$240	46

TABLE 5. CHEMICAL ANALYSES OF PACKING HOUSE AND PROCESSING PLANT EFFLUENTS

STATION	pH	BOD mg/l	SUSPENDED SOLIDS mg/l	TURBIDITY FTU	AMMONIA NITROGEN μg/l
Packing House Effluent	7.89	421	13	5	179
Processing Plant Effluent (July Low Tide)	7.56	296	119	30	2046
Processing Plant Effluent (July High Tide)	7.64	255	60	24	1616
Processing Plant Effluent (August Low Tide)	8.50	281	98	--	2446
Processing Plant Effluent (August High Tide)	7.71	270	80	32	2649

TABLE 6. PHYSICAL ANALYSES OF PACKING HOUSE AND PROCESSING PLANT EFFLUENTS

STATION	TEMPERATURE °C	SALINITY ‰	DISSOLVED OXYGEN mg/l	% OXYGEN SATURATION
Packing House Effluent	21	2	4.28	56
Processing Plant Effluent (July Low Tide)	26	0	7.56	92
Processing Plant Effluent (July High Tide)	--	--	7.46	--
Processing Plant Effluent (August Low Tide)	23	3	5.60	67
Processing Plant Effluent (August High Tide)	25	0	7.56	92

TABLE 7. MICROBIOLOGICAL ANALYSES OF PACKING HOUSE AND PROCESSING PLANT EFFLUENTS

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Packing House Effluent	3.85×10^3	1.35×10^4	1.55×10^4	150	43
Processing Plant Effluent (July Low Tide)	3.70×10^5	2.25×10^5	2.35×10^5	≥24,000	2,400
Processing Plant Effluent (July High Tide)	4.75×10^6	1.95×10^6	4.35×10^6	≥2,400	1,100
Processing Plant Effluent (August Low Tide)	6.60×10^5	4.05×10^5	6.60×10^5	≥240,000	11,000
Processing Plant Effluent (August High Tide)	2.31×10^5	1.27×10^5	1.53×10^5	110,000	2,400

TABLE 8. MICROBIOLOGICAL LEVELS, NORTHERN SAMPLING AREA AT LOW TIDE DURING JULY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Duplin River Main Dock Sapelo	225	185	4.70×10^3	2.3	2.3
Duplin River Barn Creek	405	600	5.85×10^3	2.3	0.9
Mouth of Shellbluff Creek Marker "162"	365	255	8.60×10^3	24	24
Shellbluff Creek Packing House Station	375	226	1.02×10^4	75	9
Shellbluff Creek Bend above Packing House	505	285	1.13×10^4	21	2
Mouth of Cedar Creek	385	179	5.35×10^3	24	4.2
Cedar Creek Dock Between Crab Plant & Packing House	475	217	8.15×10^3	14	4
Cedar Creek Last Dock	550	235	9.15×10^3	110	24

TABLE 9. CHEMICAL PARAMETERS, NORTHERN SAMPLING AREA AT LOW TIDE DURING JULY

Station	pH		BOD mg/l		SUSPENDED SOLIDS mg/l		TURBIDITY FTU		AMMONIA NITROGEN µg/l	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Duplin River Main Dock Sapelo	7.32	7.44	2.31	1.48	88	206	7	99	20	61
Duplin River Barn Creek	7.41	7.32	1.70	1.11	54	97	6	32	6	30
Mouth of Shellbluff Creek Marker "162"	7.33	7.41	1.19	1.24	42	429	9	180	26	61
Shellbluff Creek Packing House Station	7.35	7.28	0.99	1.06	102	73	8	20	21	50
Shellbluff Creek Bend above Packing House	7.31	7.20	1.59	0.08	61	110	8	36	10	104
Mouth of Cedar Creek	7.50	7.43	1.02	1.99	58	134	19	47	6	25
Cedar Creek Dock Between Crab Plant & Packing House	7.37	7.32	1.53	1.44	58	90	20	30	15	18
Cedar Creek Last Dock	7.18	7.23	1.92	1.51	--	90	--	22	23	26

TABLE 10. MICROBIOLOGICAL LEVELS, NORTHERN SAMPLING AREA AT HIGH TIDE DURING JULY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Duplin River Main Dock Sapelo	395	232	3.65×10^3	110	15
Duplin River Barn Creek	435	260	4.71×10^3	9.3	1.5
Mouth of Shellbluff Creek Marker "162"	560	525	4.50×10^3	7.5	3.9
Shellbluff Creek Packing House Station	320	305	3.85×10^3	46	24
Shellbluff Creek Bend above Packing House	--	--	--	--	--
Mouth of Cedar Creek	295	253	4.25×10^3	24	4.3
Cedar Creek Dock Between Crab Plant & Packing House	600	366	6.40×10^3	110	24
Cedar Creek Last Dock	645	435	7.10×10^3	24	24

TABLE 11. CHEMICAL PARAMETERS, NORTHERN SAMPLING AREA AT HIGH TIDE DURING JULY

Station	pH		BOD mg/l		SUSPENDED SOLIDS mg/l		TURBIDITY FTU		AMMONIA NITROGEN µg/l	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Duplin River Main Dock Sapelo	7.71	7.80	0.54	1.42	38	670	20	276	42	109
Duplin River Barn Creek	7.75	7.70	0.96	1.42	80	144	10	66	56	77
Mouth of Shellbluff Creek Marker "162"	7.71	7.62	0.96	1.61	51	196	8	34	56	76
Shellbluff Creek Packing House Station	7.56	7.46	0.74	0.44	32	142	9	58	49	84
Shellbluff Creek Bend above Packing House	7.51	7.44	0.67	1.90	81	436	8	146	43	120
Mouth of Cedar Creek	7.40	7.52	1.05	1.48	88	72	2	22	48	40
Cedar Creek Dock Between Crab Plant & Packing House	7.45	7.43	1.05	0.99	67	32	22	25	55	52
Cedar Creek Last Dock	7.38	7.40	0.89	1.12	62	92	24	36	40	54

TABLE 12. MICROBIOLOGICAL LEVELS, SOUTHERN SAMPLING AREA AT LOW TIDE DURING JULY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Marker "19" St. Simons Sound	247	838	1.89×10^3	0.3	0.3
Marker "24" St. Simons Sound	2.40×10^3	3.27×10^3	6.20×10^4	<0.3	<0.3
Sidney Lanier Bridge	1.37×10^3	2.65×10^3	3.02×10^3	4.3	4.3
Discharge Pipe Seafood Processing Plant	1.71×10^4	2.25×10^4	4.45×10^4	≥2,400	93
Fourth Avenue East River	2.19×10^3	5.70×10^3	1.05×10^4	9.1	9.1
Prince Street East River	6.75×10^3	5.75×10^3	4.06×10^5	240	93
Range Marker East River	390	400	1.56×10^4	43	15

TABLE 13. CHEMICAL PARAMETERS, SOUTHERN SAMPLING AREA AT LOW TIDE DURING JULY

Station	pH		BOD mg/l		SUSPENDED SOLIDS mg/l		TURBIDITY FTU		AMMONIA NITROGEN µg/l	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Marker "19" St. Simons Sound	7.79	7.98	0.68	1.54	105	182	5	35	22	34
Marker "24" St. Simons Sound	7.75	7.80	0.86	0.80	50	157	5	30	14	45
Sidney Lanier Bridge	7.69	7.70	0.75	1.18	55	152	6	20	6	31
Discharge Pipe Seafood Processing Plant	7.66	7.62	13.00	1.32	93	205	22	64	150	40
Fourth Avenue East River	7.68	7.80	0.76	1.34	59	528	5	220	7	272
Prince Street East River	7.74	7.81	1.68	1.19	82	118	4	93	182	128
Range Marker East River	7.81	7.75	1.67	1.08	53	107	4	54	36	146

TABLE 14. MICROBIOLOGICAL LEVELS, SOUTHERN SAMPLING AREA AT HIGH TIDE DURING JULY

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Marker "19" St. Simons Sound	205	157	4.85×10^3	4	<3
Marker "24" St. Simons Sound	370	143	2.95×10^3	9	4
Sidney Lanier Bridge	325	283	6.15×10^3	11	4
Discharge Pipe Seafood Processing Plant	790	535	1.22×10^4	460	93
Fourth Avenue East River	3.90×10^3	2.08×10^3	9.65×10^3	15	15
Prince Street East River	1.04×10^3	815	1.13×10^4	240	23
Range Marker East River	3.50×10^3	3.15×10^3	1.87×10^4	240	93

TABLE 15. CHEMICAL PARAMETERS, SOUTHERN SAMPLING AREA AT HIGH TIDE DURING JULY

Station	pH		BOD mg/l		SUSPENDED SOLIDS mg/l		TURBIDITY FTU		AMMONIA NITROGEN μg/l	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Marker "19" St. Simons Sound	7.80	7.94	0.84	1.07	104	234	34	112	65	236
Marker "24" St. Simons Sound	7.85	7.86	0.89	1.73	72	313	20	224	35	470
Sidney Lanier Bridge	7.79	7.45	1.02	1.18	87	206	18	42	78	102
Discharge Pipe Seafood Processing Plant	7.60	7.65	0.88	1.95	64	94	21	174	76	421
Fourth Avenue East River	7.61	7.64	0.67	2.27	29	633	6	252	29	689
Prince Street East River	7.60	7.63	0.96	0.27	79	164	13	53	56	175
Range Marker East River	7.73	7.53	1.35	1.23	65	192	12	55	10	309

TABLE 16. MICROBIOLOGICAL LEVELS, NORTHERN SAMPLING AREA AT LOW TIDE DURING AUGUST

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Duplin River Main Dock Sapelo	143	92	2.11×10^3	2.3	2.3
Duplin River Barn Creek	760	316	6.70×10^3	9.3	9.3
Mouth of Shellbluff Creek Marker "162"	100	107	8.00×10^3	2.3	2.3
Shellbluff Creek Packing House Station	300	435	6.50×10^3	$\geq$240	110
Shellbluff Creek Bend above Packing House	670	305	7.70×10^3	46	24
Mouth of Cedar Creek	139	77	2.21×10^3	4.3	2.3
Cedar Creek Dock Between Crab Plant & Packing House	149	109	3.30×10^3	24	24
Cedar Creek Last Dock	237	189	4.70×10^3	110	110

TABLE 17. CHEMICAL PARAMETERS, NORTHERN SAMPLING AREA AT LOW TIDE DURING AUGUST

Station	pH		BOD mg/1		SUSPENDED SOLIDS mg/1		TURBIDITY FTU		AMMONIA NITROGEN µg/1	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Duplin River Main Dock Sapelo	7.80	7.87	1.04	2.09	68	187	8	126	44	86
Duplin River Barn Creek	7.67	7.65	1.10	1.71	82	120	7	26	30	47
Mouth of Shellbluff Creek Marker "162"	7.72	7.56	1.08	2.75	104	173	7	81	87	99
Shellbluff Creek Packing House Station	7.45	7.38	1.82	1.52	72	91	5	27	56	87
Shellbluff Creek Bend above Packing House	7.71	7.60	1.41	1.47	95	166	4	75	66	104
Mouth of Cedar Creek	7.73	7.51	0.89	3.42	99	523	5	224	23	92
Cedar Creek Dock Between Crab Plant & Packing House	7.49	7.46	1.82	1.95	92	106	6	9	31	41
Cedar Creek Last Dock	7.00	7.44	1.93	2.00	64	80	6	25	41	45

TABLE 18. MICROBIOLOGICAL LEVELS, NORTHERN SAMPLING AREA AT HIGH TIDE DURING AUGUST

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Duplin River Main Dock Sapelo	300	140	3.75×10^3	2.3	0.9
Duplin River Barn Creek	445	190	4.15×10^3	4.3	4.3
Mouth of Shellbluff Creek Marker "162"	670	315	9.55×10^3	46	4.3
Shellbluff Creek Packing House Station	2.00×10^3	700	2.09×10^4	24	9.3
Shellbluff Creek Bend above Packing House	1.78×10^3	750	2.43×10^4	≥ 240	24
Mouth of Cedar Creek	1.79×10^3	1.16×10^3	3.20×10^4	4.3	4.3
Cedar Creek Dock Between Crab Plant & Packing House	2.90×10^3	1.31×10^3	2.70×10^4	46	46
Cedar Creek Last Dock	2.90×10^3	1.63×10^3	1.05×10^4	≥ 240	≥ 240

TABLE 19. CHEMICAL PARAMETERS, NORTHERN SAMPLING AREA AT HIGH TIDE DURING AUGUST

Station	pH		BOD mg/1		SUSPENDED SOLIDS mg/1		TURBIDITY FTU		AMMONIA NITROGEN μg/1	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Duplin River Main Dock Sapelo	7.85	7.91	1.70	1.82	111	159	8	56	6	17
Duplin River Barn Creek	7.82	7.77	1.57	1.53	70	477	7	132	20	70
Mouth of Shellbluff Creek Marker "162"	7.62	7.70	1.45	2.86	71	64	8	20	27	45
Shellbluff Creek Packing House Station	7.91	7.77	1.55	1.90	108	116	43	46	52	46
Shellbluff Creek Bend above Packing House	7.64	7.46	2.01	2.23	95	124	32	66	35	39
Mouth of Cedar Creek	7.44	7.38	--	1.83	111	200	40	104	38	62
Cedar Creek Dock Between Crab Plant & Packing House	7.39	7.32	1.84	1.34	142	135	41	46	50	46
Cedar Creek Last Dock	7.31	7.42	1.86	1.77	90	110	34	41	40	42

TABLE 20. MICROBIOLOGICAL LEVELS, SOUTHERN SAMPLING AREA AT LOW TIDE DURING AUGUST

Station	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Marker "19" St. Simons Sound	246	250	2.14×10^3	0.7	0.4
Marker "24" St. Simons Sound	295	685	2.49×10^3	1.5	2.3
Sidney Lanier Bridge	565	2.85×10^3	2.42×10^3	24	2.9
Discharge Pipe Seafood Processing Plant	4.30×10^3	4.20×10^3	6.25×10^3	$\geq$2,400	93
Fourth Avenue East River	465	2.25×10^3	3.80×10^3	39	15
Prince Street East River	700	1.82×10^3	2.03×10^3	28	15
Range Marker East River	335	1.07×10^3	335	150	39

TABLE 21. CHEMICAL PARAMETERS, SOUTHERN SAMPLING AREA AT LOW TIDE DURING AUGUST

Station	pH		BOD mg/l		SUSPENDED SOLIDS mg/l		TURBIDITY FTU		AMMONIA NITROGEN µg/l	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Marker "19" St. Simons Sound	7.67	7.71	1.15	1.02	312	188	6	58	48	72
Marker "24" St. Simons Sound	7.65	7.60	0.79	1.38	64	236	6	100	26	69
Sidney Lanier Bridge	7.53	7.54	0.68	1.75	42	128	6	44	10	39
Discharge Pipe Seafood Processing Plant	7.52	7.48	2.19	1.31	62	121	21	46	57	34
Fourth Avenue East river	7.52	7.57	0.97	6.42	63	78	6	29	7	129
Prince Street East River	7.80	7.66	0.95	0.42	51	116	6	30	5	197
Range Marker East River	7.77	7.68	0.82	0.28	44	71	7	22	59	165

TABLE 22. MICROBIOLOGICAL LEVELS, SOUTHERN SAMPLING AREA AT HIGH TIDE DURING AUGUST

Stations	Aerobic Plate Counts 20C org/ml	Aerobic Plate Counts 35C org/ml	Marine Agar Plate Counts org/ml	MPN Coliforms org/100 ml	MPN Fecal Coliforms org/100 ml
Marker "19" St. Simons Sound	137	102	1.58 x 10^3	0.3	0.3
Marker "24" St. Simons Sound	1.28 x 10^3	1.15 x 10^3	7.45 x 10^3	21	2.3
Sidney Lanier Bridge	455	315	6.55 x 10^3	0.3	0.3
Discharge Pipe Seafood Processing Plant	1.58 x 10^3	1.84 x 10^3	3.28 x 10^5	$\geq$2,400	460
Fourth Avenue East River	690	330	2.20 x 10^4	23	3
Prince Street East River	1.90 x 10^3	625	2.80 x 10^4	210	43
Range Marker East River	550	305	3.90 x 10^4	460	43

TABLE 23. CHEMICAL PARAMETERS, SOUTHERN SAMPLING AREA AT HIGH TIDE DURING AUGUST

Station	pH Surface	pH Bottom	BOD mg/l Surface	BOD mg/l Bottom	SUSPENDED SOLIDS mg/l Surface	SUSPENDED SOLIDS mg/l Bottom	TURBIDITY FTU Surface	TURBIDITY FTU Bottom	AMMONIA NITROGEN µg/l Surface	AMMONIA NITROGEN µg/l Bottom
Marker "19" St. Simons Sound	7.95	7.98	0.76	0.75	125	155	9	43	3	10
Marker "24" St. Simons Sound	7.80	7.82	0.20	1.49	99	222	6	100	14	26
Sidney Lanier Bridge	7.71	7.70	0.71	0.89	102	105	22	31	10	22
Discharge Pipe Seafood Processing Plant	7.67	7.69	1.16	1.04	82	153	22	63	103	40
Fourth Avenue East River	7.82	7.59	1.45	0.87	57	128	4	31	11	257
Prince Street East River	7.68	7.64	1.68	1.53	54	126	4	34	44	116
Range Marker East River	7.85	7.58	2.49	0.80	66	89	4	24	8	167

TABLE 24. RAINFALL IN INCHES AT McKINNON AIRPORT, ST. SIMONS ISLAND, JUNE 20, 1980 THRU AUGUST 31, 1980.

JUNE		JULY		AUGUST	
Date	Rainfall	Date	Rainfall	Date	Rainfall
6/20	Trace	7/1	0	8/1	1.45
6/21	0	7/2[a]	0	8/2	Trace
6/22	Trace	7/3	0	8/3	0
6/23	0	7/4	0	8/4	Trace
6/24	0	7/5	1.89	8/5	1.50
6/25	2.97	7/6	Trace	8/6	0
6/26[a]	0	7/7	0.17	8/7[b]	0
6/27[a]	0	7/8	1.03	8/8	0
6/28	0	7/9	0.11	8/9	0
6/29	0	7/10[b]	0.10	8/10	0
6/30	0	7/11	1.33	8/11	0.51
		7/12	Trace	8/12	0.02
		7/13	0.40	8/13	0
		7/14	0	8/14[b]	0
		7/15	0	8/15	0
		7/16	0	8/16	0.01
		7/17[b]	0	8/17	0.81
		7/18	0.48	8/18	0
		7/19	0.12	8/19	0
		7/20	0	8/20	0
		7/21	0.05	8/21[b]	0
		7/22	0.29	8/22	0
		7/23	Trace	8/23	0.41
		7/24[b]	0	8/24	0.01
		7/25	0.03	8/25	0
		7/26	0.65	8/26	0
		7/27	0	8/27	Trace
		7/28	0	8/28[b]	0.60
		7/29	0	8/29	0
		7/30	0.80	8/30	0
		7/31[b]	0.90	8/31	0

[a] Hydrographic samples collected

[b] Complete estuarine samples collected

TABLE 25. MEAN CHEMICAL AND MICROBIOLOGICAL PARAMETERS OF THE PACKING HOUSE EFFLUENT, IMMEDIATE RECEIVING WATERS, AND ESTUARINE STATIONS UP AND DOWNSTREAM FROM THE DISCHARGE POINT (AUGUST, HIGH TIDE).

PARAMETERS	EFFLUENT[1]	DISCHARGE POINT	UPSTREAM	DOWNSTREAM
BOD				
Surface	421[a]	1.5	2.0	1.5
Bottom	421[a]	1.9	2.2	2.9[b]
Suspended Solids				
Surface	13[a]	109	95	65[b]
Bottom	13[a]	117	125	105[a]
NH_4				
Surface	179[a]	52[b]	35	27
Bottom	179[a]	46	39	45
DO				
Surface	4.27	3.79	3.51	4.12
Bottom	4.27[b]	3.35[b]	3.41	3.91
Aerobic 20C	3.23×10^3	1.99×10^3	1.78×10^3	676
Aerobic 35C	1.35×10^4[a]	708	759	288
Marine 20C	1.55×10^4	2.09×10^4	2.45×10^4	9.55×10^3[a]

1 Single sample collected, results repeated to differentiate significant differences.

a Significant 0.01 level

b Significant 0.05 level

TABLE 26. MEAN CHEMICAL AND MICROBIOLOGICAL PARAMETERS OF THE PROCESSING PLANT EFFLUENT, IMMEDIATE RECEIVING WATERS, AND ESTUARINE STATIONS ONE HALF MILE UP AND DOWNSTREAM FROM THE DISCHARGE POINT (JULY, HIGH TIDE).

PARAMETER	EFFLUENT[1]	DISCHARGE POINT	UPSTREAM	DOWNSTREAM
BOD				
Surface	255[a]	0.87	0.67	1.02[b]
Bottom	255[a]	1.95	2.67[b]	1.18
Suspended Solids				
Surface	60	65	29[a]	87
Bottom	60	94	633[a]	206
NH_4				
Surface	1616[a]	76	29	78
Bottom	1616[a]	420[a]	688[a]	101
DO				
Surface	7.47[a]	5.11	5.31	5.83[b]
Bottom	7.47[a]	5.23	5.36	5.28
Aerobic 20C	5.62×10^6[a]	776[b]	3.09×10^3[a]	324
Aerobic 35C	1.95×10^6[a]	537[b]	2.04×10^3[a]	282
Marine 20C	4.27×10^6[a]	1.20×10^4	9.77×10^3	6.03×10^3

1 Single sample collected, results repeated to differentiate significant differences.

a Significant 0.01 level

b Significant 0.05 level

TABLE 27. MEAN CHEMICAL AND MICROBIOLOGICAL PARAMETERS OF THE PROCESSING PLANT EFFLUENT, IMMEDIATE RECEIVING WATERS, AND ESTUARINE STATIONS ONE HALF MILE UP AND DOWNSTREAM FROM THE DISCHARGE POINT (JULY, LOW TIDE).

PARAMETER	EFFLUENT[1]	DISCHARGE POINT	UPSTREAM	DOWNSTREAM
BOD				
Surface	295[a]	13.00[a]	1.33	1.17
Bottom	295[a]	1.32	0.97	0.69
Suspended Solids				
Surface	120[a]	93	59	55
Bottom	120[b]	205	528[a]	152
NH_4				
Surface	2046[a]	150[a]	7	6
Bottom	2046[a]	40	271[a]	31
DO				
Surface	7.55[a]	4.73	4.78	4.47[b]
Bottom	7.55[a]	3.79[a]	4.91	4.31
Aerobic 20C	3.55×10^5[a]	1.70×10^4[a]	2.19×10^3	1.35×10^3
Aerobic 35C	2.24×10^5[a]	2.24×10^4	4.57×10^3	2.63×10^3
Marine 20C	2.29×10^5[a]	4.68×10^4[a]	1.05×10^4	3.02×10^3

[1] Single sample collected, results repeated to differentiate significant differences.

[a] Significant 0.01 level

[b] Significant 0.05 level

TABLE 28. MEAN CHEMICAL AND MICROBIOLOGICAL PARAMETERS OF THE PROCESSING PLANT EFFLUENT, IMMEDIATE RECEIVING WATERS, AND ESTUARINE STATIONS ONE HALF MILE UP AND DOWNSTREAM FROM THE DISCHARGE POINT (AUGUST, HIGH TIDE).

PARAMETER	EFFLUENT[1]	DISCHARGE POINT	UPSTREAM	DOWNSTREAM
BOD				
Surface	270[a]	1.16	1.45	0.71[b]
Bottom	270[a]	1.04	0.87	0.90
Suspended Solids				
Surface	80	82	57[b]	102
Bottom	80[a]	153	129	105
NH_4				
Surface	2649[a]	103[a]	11	10
Bottom	2649[a]	40	256[a]	22
DO				
Surface	7.55[a]	4.35[a]	5.23	4.78
Bottom	7.55[a]	4.63	4.75	4.71
Aerobic 20C	2.29×10^{5}[a]	1.58×10^{3}[b]	676	447
Aerobic 35C	1.23×10^{5}[a]	1.78×10^{3}[b]	316	309
Marine 20C	1.51×10^{5}[a]	3.24×10^{5}[a]	2.19×10^{4}[b]	6.46×10^{3}

1 Single sample collected, results repeated to differentiate significant differences.

a Significant 0.01 level

b Significant 0.05 level

TABLE 29. MEAN CHEMICAL AND MICROBIOLOGICAL PARAMETERS OF THE PROCESSING PLANT EFFLUENT, IMMEDIATE RECEIVING WATERS, AND ESTUARINE STATIONS ONE HALF MILE UP AND DOWNSTREAM FROM THE DISCHARGE POINT (AUGUST, LOW TIDE).

PARAMETER	EFFLUENT[1]	DISCHARGE POINT	UPSTREAM	DOWNSTREAM
BOD				
Surface	281[a]	2.19[a]	0.97	0.69
Bottom	281[a]	1.31	6.41[a]	1.75[b]
Suspended Solids				
Surface	98[a]	62	63	41
Bottom	98	121	79[b]	128
NH_4				
Surface	2446[a]	57[a]	7	10
Bottom	2446[a]	49	129	39
DO				
Surface	5.60[a]	3.98	3.98	4.47[a]
Bottom	5.60[a]	3.86	3.91	3.83
Aerobic 20C	3.98×10^{5}[a]	4.17×10^{3}	2.45×10^{3}	2.82×10^{3}
Aerobic 35C	6.61×10^{5}[a]	4.27×10^{3}[a]	468	537
Marine 20C	6.46×10^{5}[a]	6.17×10^{3}[a]	3.71×10^{3}	2.40×10^{3}

1 Single sample collected, results repeated to differentiate significant differences.

a Significant 0.01 level

b Significant 0.05 level

TABLE 30. CALCULATED MAXIMUM AND MINIMUM NH_3 (μg/l) LEVELS SURFACE AND BOTTOM, NORTHERN SAMPLING AREA.

STATION	MAXIMUM SURFACE	MINIMUM SURFACE	MAXIMUM BOTTOM	MINIMUM BOTTOM
Duplin River Main Dock Sapelo	1.72	0.27	4.20	0.86
Duplin River Barn Creek	2.10	1.79	2.57	0.53
Mouth of Shellbluff Creek Marker "162"	2.84	0.45	2.10	1.55
Shellbluff Creek Packing House Station	0.96	0.34	1.69	1.25
Shellbluff Creek Bend above Packing House	2.04	0.13	2.22	0.75
Mouth of Cedar Creek	0.82	0.19	1.87	0.77
Cedar Creek Dock Between Crab Plant & Packing House	1.04	0.31	0.94	0.34
Cedar Creek Last Dock	0.26	0.32	0.92	0.34
Packing House Effluent	5.75	--	--	--

TABLE 31. CALCULATED MAXIMUM AND MINIMUM NH_3 (µg/l) LEVELS SURFACE AND BOTTOM, SOUTHERN SAMPLING AREA.

STATION	MAXIMUM SURFACE	MINIMUM SURFACE	MAXIMUM BOTTOM	MINIMUM BOTTOM
Marker "19" St. Simons Sound	2.37	0.17	10.68	0.54
Marker "24" St. Simons Sound	1.38	0.52	18.04	1.02
Sidney Lanier Bridge	2.77	0.21	1.65	0.71
Discharge Pipe Seafood Processing Plant	4.95	1.33	10.87	0.72
Fourth Avenue East River	0.70	0.16	17.54	3.01
Prince Street East River	6.41	0.21	5.64	3.21
Range Marker East River	2.34	0.41	6.05	5.41
Processing Plant Effluent	75.23[a]	39.11[a]	--	--

[a] Exceeded proposed EPA guideline of 20 µg NH_3/l.