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The Dissolved Oxygen Cycle in Minette Bay, British Columbia

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ABSTRACT

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We present and analyze water property and moored instrument data collected during a year long study which began in August 1995. The renewal of Minette Bay deep waters occurs annually during the winter and early spring months. Renewal occurs in the form of multiple events, some of which penetrate to the bottom while others only affect the intermediate waters. These events are caused by the outbreaks of the Arctic air mass over the region. The cold air temperatures reduce run-off thereby increasing surface salinity while at the same time the strong outflow winds push the surface layer away from the head of Kitimat Arm and bring denser water closer to the surface. The cold outflow winds also cool and mix the surface waters. In the stagnant period from May to November, dissolved oxygen concentrations in the deep waters decline rapidly to near zero conditions by July and remain low until the late fall. From the dissolved oxygen budget of the deep waters we estimated maximum sediment oxygen uptake to be about $1 \text{ g O}_2 \text{ m}^{-2} \text{ d}^{-1}$. This uptake rate is lower than most rates observed in coastal marine environments. Examination of all the dissolved oxygen data showed that conditions before or early in the industrial development of the region were not significantly different from those observed in the 1995 to 1996 study. On the basis of these analyses we concluded that log storage and handling activities in the bay do not appear to have exacerbated the naturally occurring low dissolved oxygen conditions.

Key words: Dissolved oxygen, deep water renewal, Minette Bay, Kitimat Arm.

RÉSUMÉ

Stucchi, D.J. and T. Juhasz 1997. The Dissolved Oxygen Cycle in Minette Bay, British Columbia. Can. Tech. Rep. Hydrogr. Ocean Sci. 187: 73pp.

Nous présentons et analysons les propriétés de l'eau et les données provenant d'instruments amarrés, données collectées pendant une période de recherche d'un an commencée en août 1995. Le renouvellement des eaux profondes de la Baie de Minette se produit annuellement durant l'hiver et les premiers mois du printemps. Le renouvellement se produit sous forme de plusieurs événements, certains se propageant jusqu'au fond, alors que d'autres n'affectent que les eaux intermédiaires. Ces événements sont causés par l'arrivée de masses d'air arctique au-dessus de cette région. Les températures froides de l'air réduisent l'écoulement de surface, ce qui conduit à une augmentation de la salinité de surface. En même temps, les vents forts soufflant vers l'extérieur de la baie poussent la couche de surface loin de l'amont de Kitimat Arm ce qui entraîne l'eau plus dense près de la surface. Ces vents d'aval froids abaissent aussi la température des eaux de surface et les mélangent. Durant la période stagnante de mai à novembre, les concentrations d'oxygène dissout dans les eaux profondes décroissent rapidement jusqu'à atteindre un niveau presque nul en juillet, et elles restent basses jusqu'à tard dans l'automne. A partir du budget d'oxygène dissout dans les eaux profondes, nous avons estimé la consommation maximum d'oxygène par les sédiments à environ $1\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$. Ce taux de consommation est plus faible que la plupart des taux observés dans des environnements marins côtiers. Un examen des toutes les données d'oxygène dissout a montré que les conditions précédant ou au début du développement industriel de la région n'étaient pas significativement différentes de celles observées dans l'étude de 1995 à 1996. En se basant sur ces analyses nous avons conclu que le stockage de rondins et les activités de manutention dans la baie ne semblent pas avoir accentué les conditions naturelles de faible concentrations d'oxygène dissout.

Mots clés: L'oxygène dissout, le renouvellement des eaux profondes, la Baie de Minette, Kitimat Arm.

1. Introduction

Minette Bay is located at the head of Kitimat Arm about 150 km inland from the coastal waters of Hecate Strait. The bay is connected with coastal waters via Kitimat Arm, Douglas Channel, Whale Channel and Caamaño Sound. (Figure 1). The Kitimat River which enters Kitimat Arm at the mouth of Minette Bay supports all five species of salmonids, and the intertidal areas of the bay are important salmon rearing habitat (U. Orr, personal communication). Because Minette Bay is sheltered from the winds in the main channel of Kitimat Arm, the local logging industry uses the area for log storage, dumping, sorting and transportation.

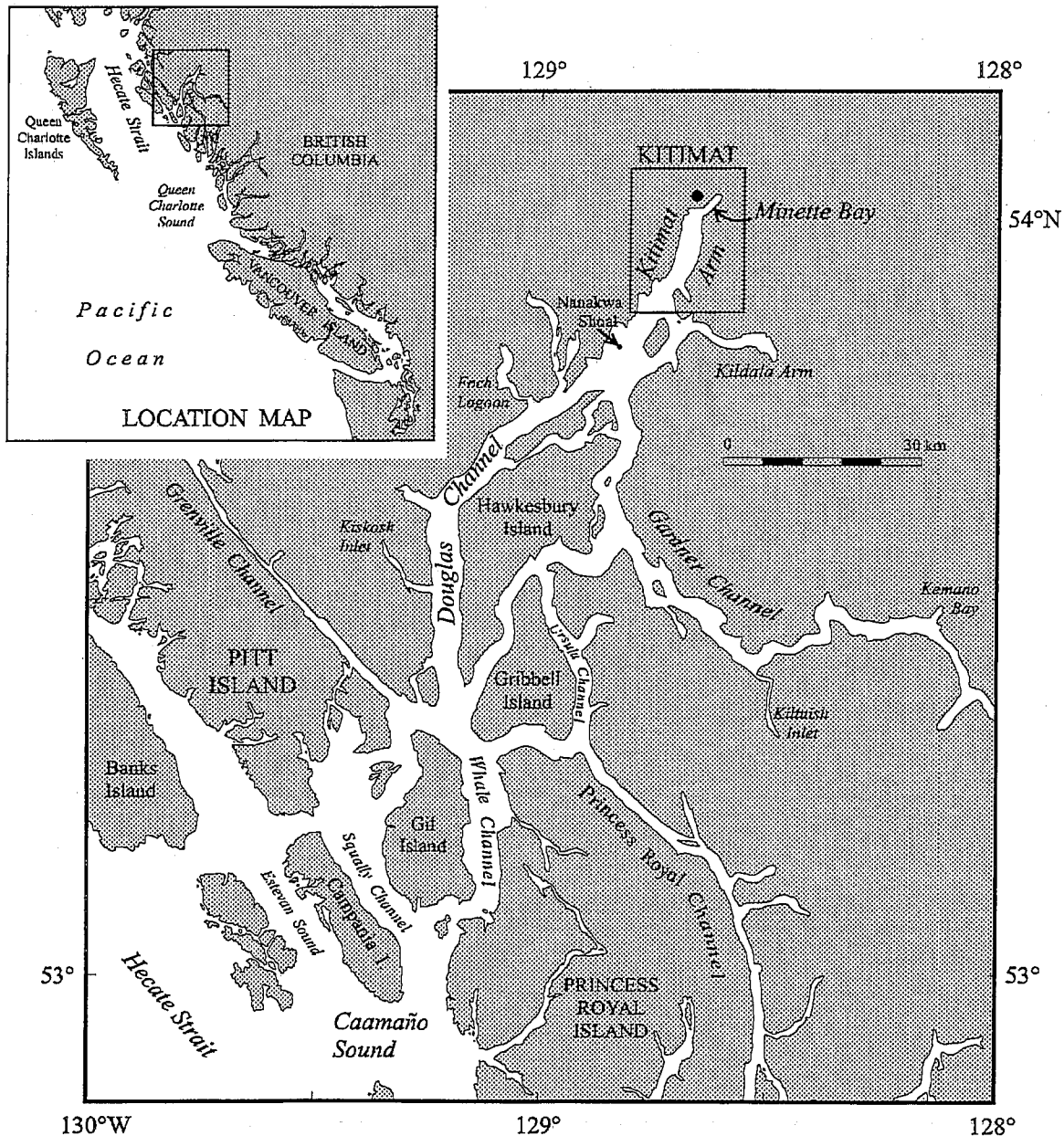


Figure 1. Map of the northern mainland coast of British Columbia showing Douglas Channel and Kitimat area.

Minette Bay is known to have poor water quality. Pickard (1961) in his review of the oceanography of British Columbia mainland fjords noted that this bay had low dissolved oxygen (DO) concentrations. Waldichuk *et al.* (1968) also reported low dissolved oxygen concentrations based on several cruises to this area. Bell and Kallman (1975) in their review of the status of environmental knowledge of the Kitimat River estuary report that the low DO conditions have been attributed to poor flushing and log handling and storage activities in the bay. Concerns have been raised that the poor water quality of the bay is exacerbated if not caused directly by the log handling practices there (Beak Consultants Ltd. 1971). Other habitat disruptions have been attributed to the industrial activities associated with log handling practices in this bay, e.g. bottom scouring, bark litter, and sinkers (Beak Consultants Ltd. 1972, Howard Paish & Associates Ltd. 1974).

The purpose of our study of Minette Bay was to determine if log handling in the bay significantly contributed to low DO concentrations. However, to investigate this question we needed to understand the oceanography and especially the dissolved oxygen cycle of this small, isolated bay. From August 1995 until October 1996, the Department of Fisheries and Oceans (Institute of Ocean Sciences and the North Coast Division of Habitat Management) with the support of Western Seaboard Transport (initially Kitimat Booming Contractors Ltd.) and Skeena Sawmills, West Fraser Mills Ltd. began a program of oceanographic measurements.

In this report we present the results of our study. We provide some introductory and historical information in this section, followed in the next section by background information on the tides, winds and hydrology of the area. Section 3 contains a description of the sampling program, methods and instrumentation we used in this study. In section 4, we present the observations, describe the renewal cycle of the waters of Minette Bay and the processes that drive the renewals. Section 5 is devoted to the problem of oxygen uptake rates and their calculations and comparisons with other localities. We end the report with a summary of our conclusion and a set of recommendations for further work. In our search for data from Minette Bay, we discovered two unpublished data sets in the archives of the late Dr. M. Waldichuk. (The Waldichuk Archives are maintained by the librarian at the Pacific Biological Station, Nanaimo, BC.) In September 1969 and again in July 1972, Dr. Waldichuk and his pollution monitoring group collected physical and chemical oceanographic data from the northern British Columbia coast. We have rescued these data and placed them in the IOS data archive. In appendix A we include all the water sampling data collected during our study.

The report by Bell and Kallman (1976) contains much of the historical information related to the environment and development of the Kitimat River Estuary including Minette Bay prior to the mid 1970's. Highlights of the development history of the area relevant to this review of the oceanography of Minette Bay begin in 1951 when the first construction crews arrived to build the Aluminum Company of Canada (Alcan) smelter and the accompanying town. Three years later, on August 3, 1954 the Alcan smelter produced its first ingot of aluminum (Bell and Kallman 1976). In 1953 the Kitimat District Municipality was incorporated and presently has a population of about 12,000.

With the opening up of the area by the smelter and the associated infrastructure, logging activity increased. In the early 1960's, the local logging industry began using Minette Bay for log storage and leasing. In 1970, the Eurocan pulp and paper mill began production and further enhanced the volume of logs moving through Minette Bay.

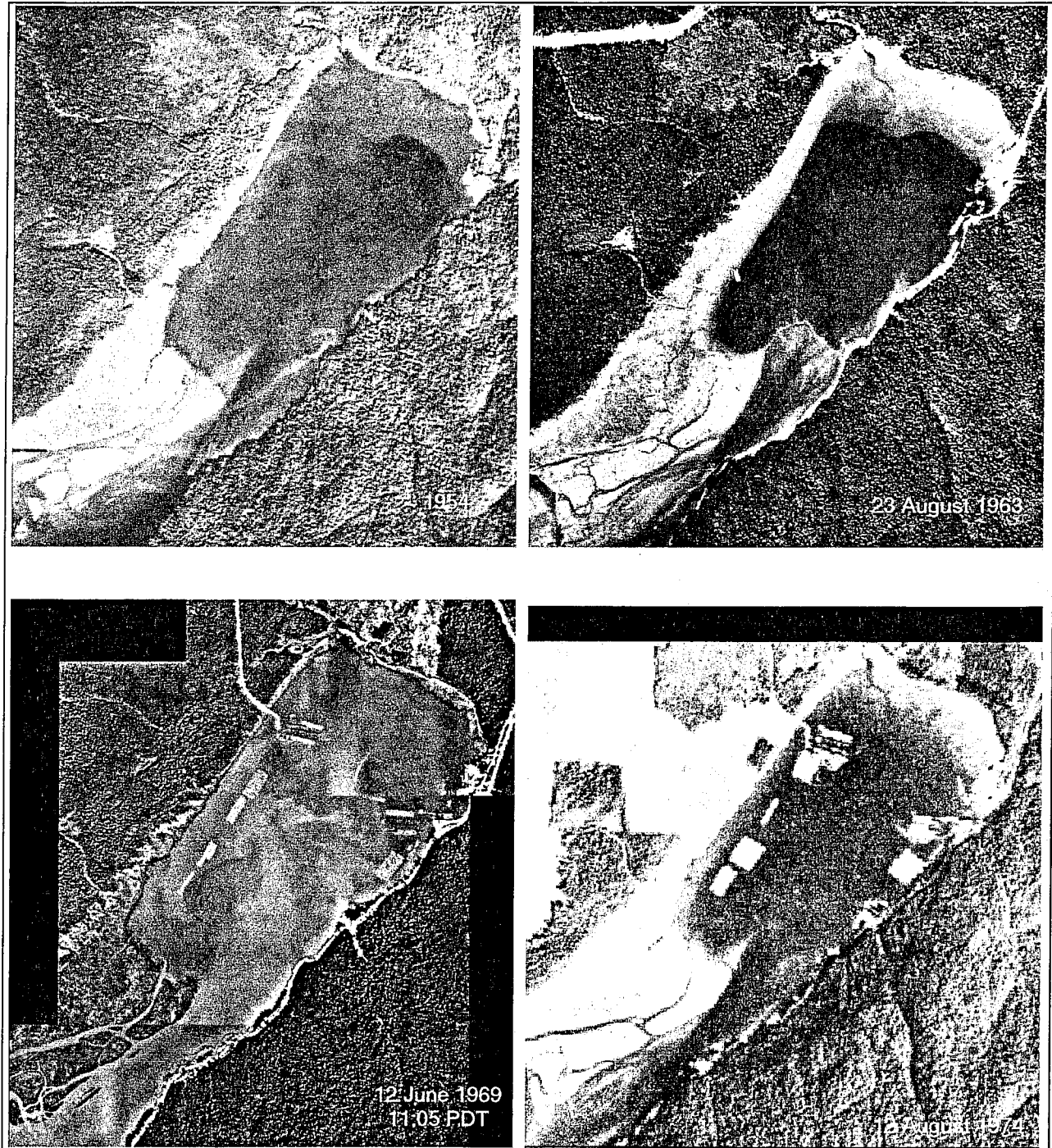


Figure 1. Sequence of aerial photographs of Minette Bay from 1954 to 1974.

The sequence of aerial photographs of Minette Bay shown in Figure 2 provides visual chronology of the growth of log storage and handling activities in Minette Bay. In 1954, there was no log storage in Minette Bay and the bay was undeveloped except for the road access to the northeast corner. By 1963, some log rafts and log handling facilities are visible along the northeast shore of the bay, and there is one raft of logs along the northwest shore. In 1969, many log rafts, log dumps and handling facilities with the accompanying road access are evident on both the northeast and northwest shores. The 1974 photograph shows a large number of log rafts in the bay on both shores and some logging activity on the northwest shore.

2. Review and Background

2.1 Geography

Minette Bay is a small rectangular shaped appendage (1 km X 5 km) located at the innermost end of Kitimat Arm, northeast of the Kitimat River delta (Figure 3). Maximum water depth in the bay is only 40m, but of particular interest is the broad and very shallow sill (3m depth at mean water level) that separates Minette Bay from Kitimat Arm (Figure 4). The main entrance channel is accessible only at high water and is located close to the east shore of the bay. At extreme low tides the 4 km long sill region dries and Minette Bay is cut off from Kitimat Arm. The deep water pocket of Minette Bay which is about 1km wide by 1.5km long is in the upper half of the bay. Most of the area of the bay is composed of inter-tidal flats. Table 1 provides details of the volume and surface area statistics of the bay. Just outside the sill of Minette Bay water depths in Kitimat Arm increase to more than 150m in a short distance.

From Minette Bay the main connection to the coast is through Kitimat Arm, Douglas Channel, around Gil Island by way of either Whale Channel or Squally Channel and then Caamaño Sound (Figure 1). There are two main basins in the passage to the coast. The innermost basin comprises Kitimat Arm and the northern half of Douglas Channel. The outer basin comprises the southern half of Douglas Channel out to Caamaño Sound. Water depths in both basins are deep; maximum depth of the inner basin is more than 400m, and in the outer basin, depths in excess of 600m are present in Squally Channel. The sill depth between the two basins is about 210m, and in Caamaño Sound there is a broad sill region of depth about 170m.

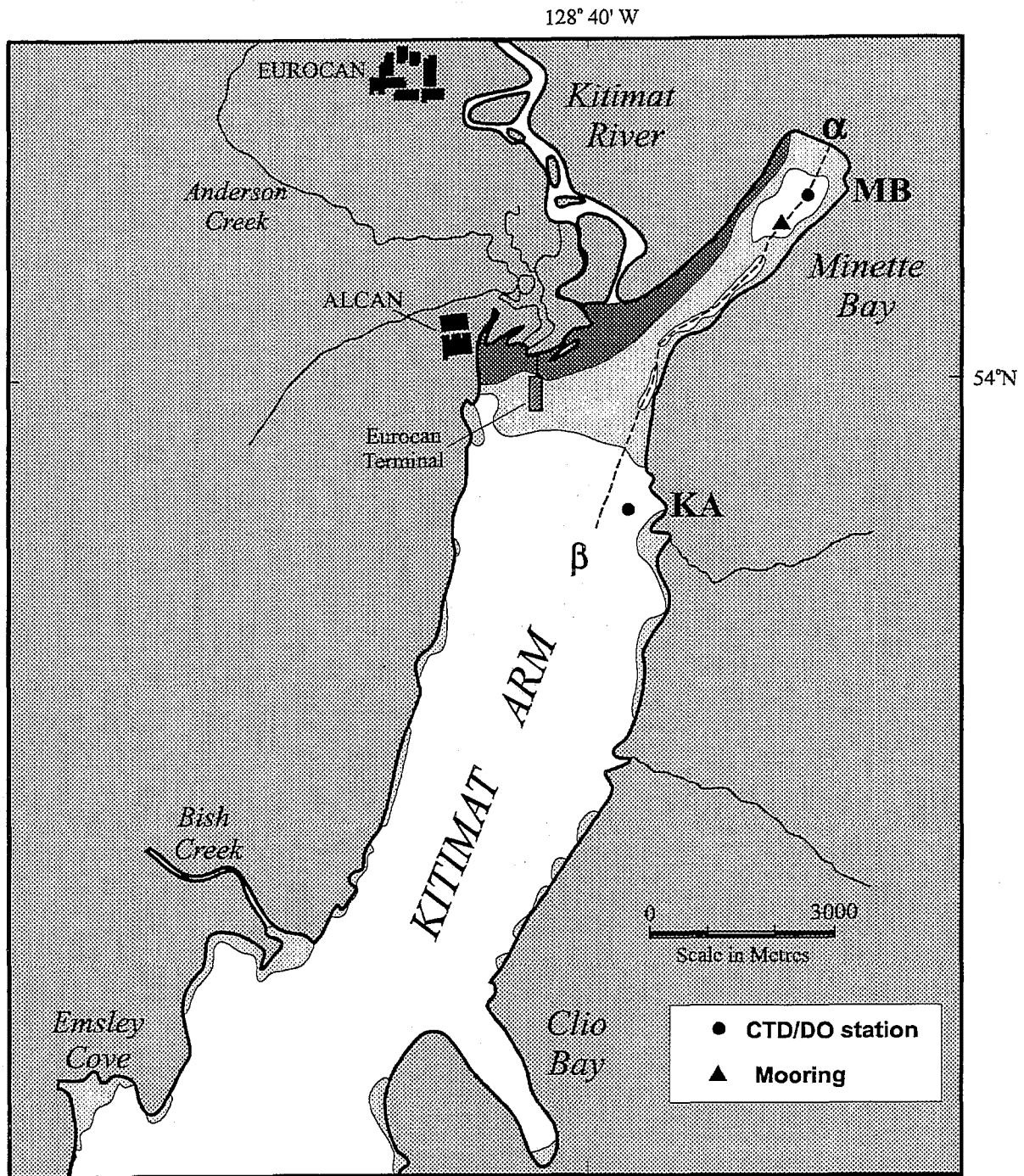


Figure 3. Map of Minette Bay showing location of sampling stations and mooring.

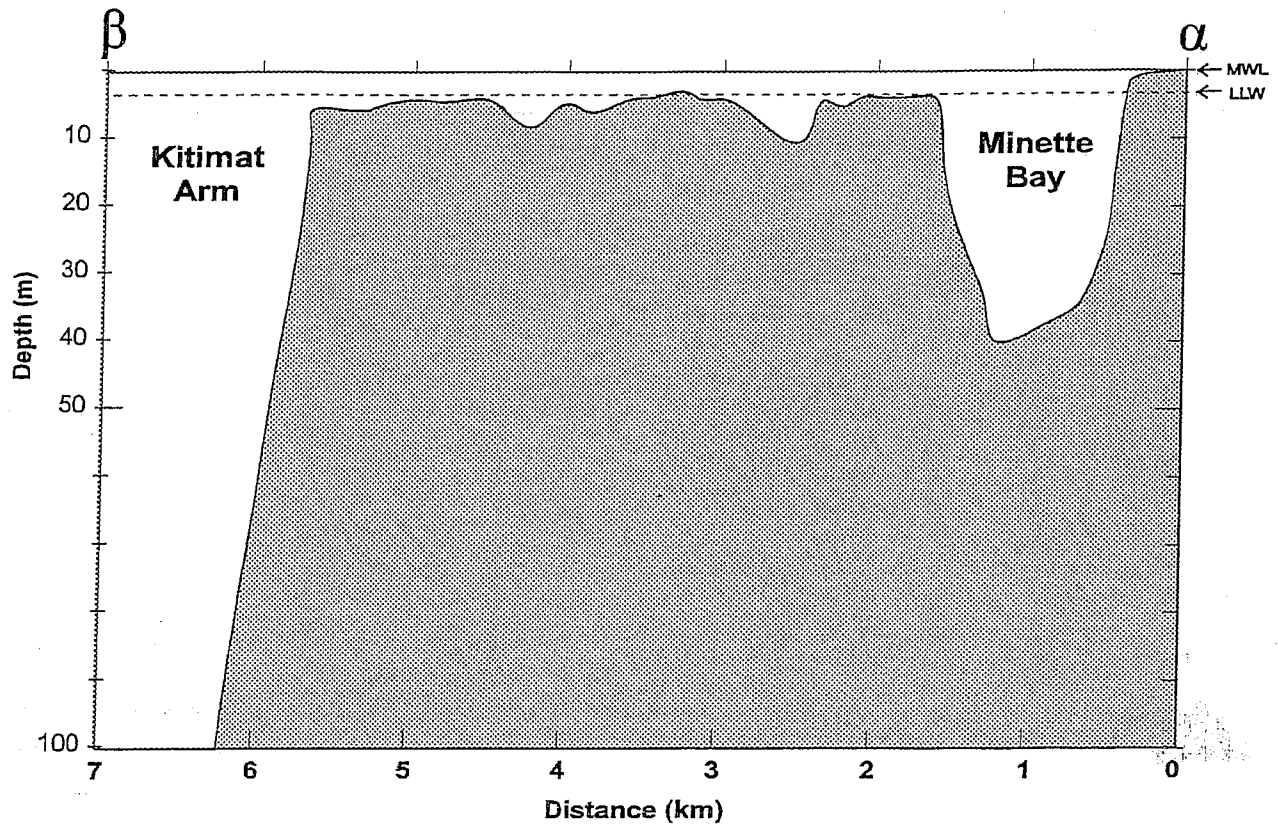


Figure 4. Axial depth profile from the head of Minette Bay (α) to Kitimat Arm (β).

Table 1. Surface area and volume of Minette Bay as a function of depth .

Depth (MWL) (m)	Area (km ²)	Layer Volume (10 ⁶ m ³)	Volume (10 ⁶ m ³)
0	3.593	7.938	33.786
3.3	1.218	5.783	25.848
8.3	1.095	5.243	20.065
13.3	1.002	8.705	14.823
23.3	0.739	3.173	6.118
28.3	0.530	2.085	2.945
33.3	0.304	0.503	0.860
35.3	0.199	0.272	0.357
37.3	0.073	0.079	0.085
39.3	0.006	0.006	0.006
41.3	0.000	0	0

2.2 Tides

The most conspicuous characteristic of the tides in this region is their large amplitude. Tides in Kitimat Arm are mixed mainly semidiurnal (two high and two low waters per lunar day). Tidal analysis of water level records is usually done by harmonic analysis (see Foreman 1978). In harmonic analysis the observed tidal record is treated as the sum of a finite number of harmonic constituents of the form

$$H_n \cos(\omega_n t - \theta_n)$$

where H_n , ω_n and θ_n are the amplitude, angular frequency ($= 2\pi/T_n$, where T_n is the period) and phase of the n th tidal constituent.

Table 2. Tidal constituents from harmonic analysis of Kitimat ($53^\circ 59.0'N$, $128^\circ 43.0'W$) water level (Index No. 9140).

Rank	Constituent	Period (hrs)	Amplitude (m)	Phase ($^\circ$) PST
	Z0	Mean	3.246	
1	M2	12.42	1.650	25.9
2	S2	12.00	0.525	48.7
3	K1	23.93	0.485	134.6
4	N2	12.66	0.333	3.0
5	O1	25.82	0.294	127.4
6	P1	24.07	0.153	131.0
7	K2	11.97	0.135	42.3

The lunar semidiurnal constituent M2 (12.42 hour period) has the largest amplitude (1.65 m) followed by the solar semidiurnal tidal constituent S2 (12 hour period) at 0.53 m (Table 2). During the largest tides the tidal range is 6.8 m, and during average tides the range is 4.4 m.

Surface currents in Kitimat Arm are reported to have strengths as large as 25 cm s^{-1} (0.5 knots) on the flood tide and 50 cm s^{-1} (1.0 knot) on the ebb (Canadian Hydrographic Service 1991). However, there are few measurements of surface currents in Kitimat Arm. As part of the 1977-1978 Kitimat Physical Oceanographic Study, Narayanan (1980), constructed a numerical model of tidal circulation of the Kitimat System - the system of channels and fjords from Kitimat Arm out to the coast. Computed barotropic (depth averaged) tidal currents for the M2 constituent in Kitimat Arm were small ($< 2 \text{ cm s}^{-1}$). At the head of Kitimat Arm, local winds and runoff are probably the main forcing for the currents. Buckingham (1980) investigated the response of the system to wind forcing, and Webster (1983) examined estuarine circulation in the Kitimat System. There are no published reports of the tidal currents in Minette Bay. However the currents over the shallow sill of Minette Bay are significant especially in the main entrance channel close to the east side of the bay.

2.3 Winds

Wind observations for Kitimat Arm originate from two locations; one from the Kitimat town site and the other from a weather buoy anchored on Nanakwa Shoal (Figure 1) about 20 km from the head of Kitimat Arm. The Nanakwa Shoal buoy is one of 16 weather buoys in an offshore network maintained by the Atmospheric Environment Service of Environment Canada and the Department of Fisheries and Oceans in association with AXYS Environmental Consulting Ltd. AXYS (1996) have recently provided a review of the buoy network: the sensors, data reduction, transmission, quality control and archival methods.

The climatology (Environment Canada) of the wind observations from the Kitimat town site over the period from 1967 to 1980 (Figure 5) shows that the winds align themselves with the orientation of the Kitimat River valley which is in a north-south direction. The winds from the Nanakwa Shoal weather buoy align themselves with axis of Douglas Channel and Kitimat Arm which is in a NE-SW orientation.

In the summer months the prevalent winds are from a southerly direction (Figure 5). In June and July, for example, 80% of the time the winds are from the southerly quadrant (SE to SW). These southerly winds in the summer are sea-breezes caused by the daytime heating inland. The winds reach their peak in late afternoon and diminish by nightfall. In the winter months the dominant wind direction is from the north. In January, 70% of the time the winds are from the northerly quadrant (NE to NW). Less than 2% of the time the winds are calm.

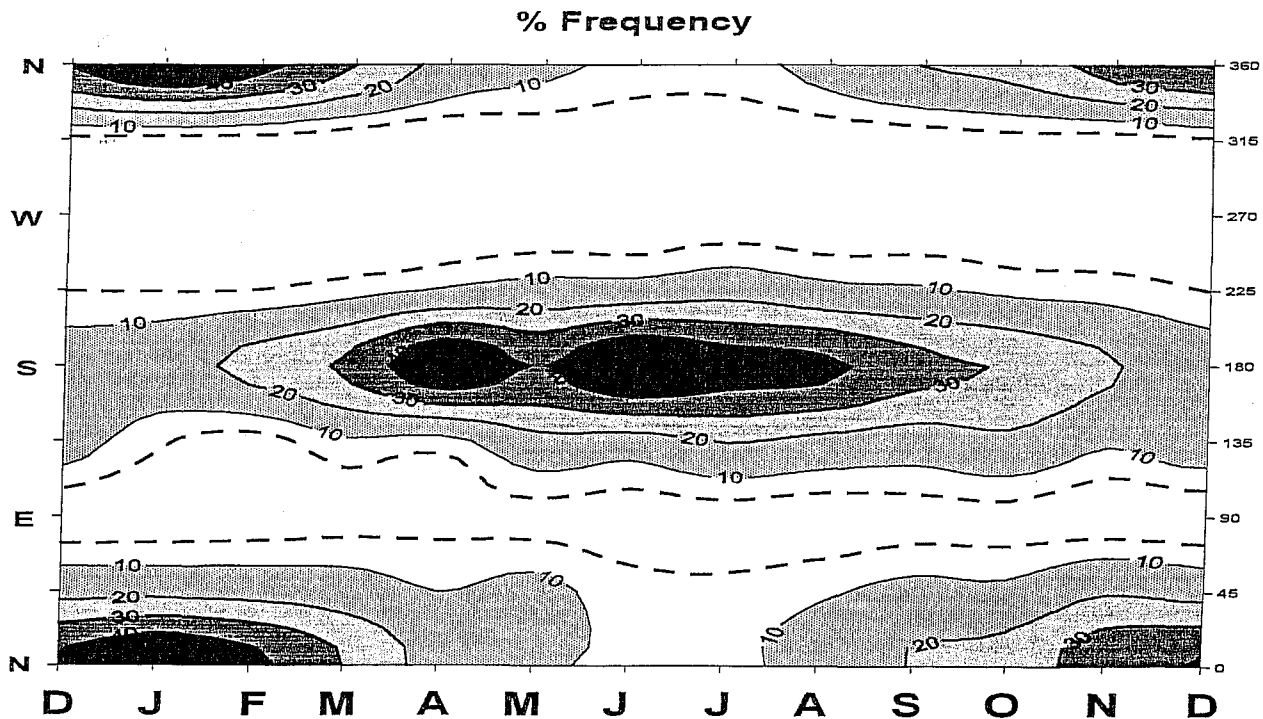


Figure 5. Contours of percentage frequency of Kitimat town site winds by direction and month.

Although there are two dominant directions for the winds the strongest winds are from the north (Figure 6). Monthly mean wind speeds peak at 23 km/hr in January. By contrast the mean monthly summer winds from the south are about half as strong. Maximum hourly wind speeds peak at 55 km/hr (Environment Canada 1982) for the months of November through to February. These strong northerly winds occur during outbreaks of the Arctic air mass over the province. As the cold dense air drains from the interior out to the coast through the river valleys and fjords, strong outflow winds known as katabatic winds arise. The wind and air temperature record (Figure 15) from the meteorological buoy on Nanakwa Shoal for the period of the study shows the strong and cold winter outflow winds. These katabatic winds persist for periods of several days at a time.

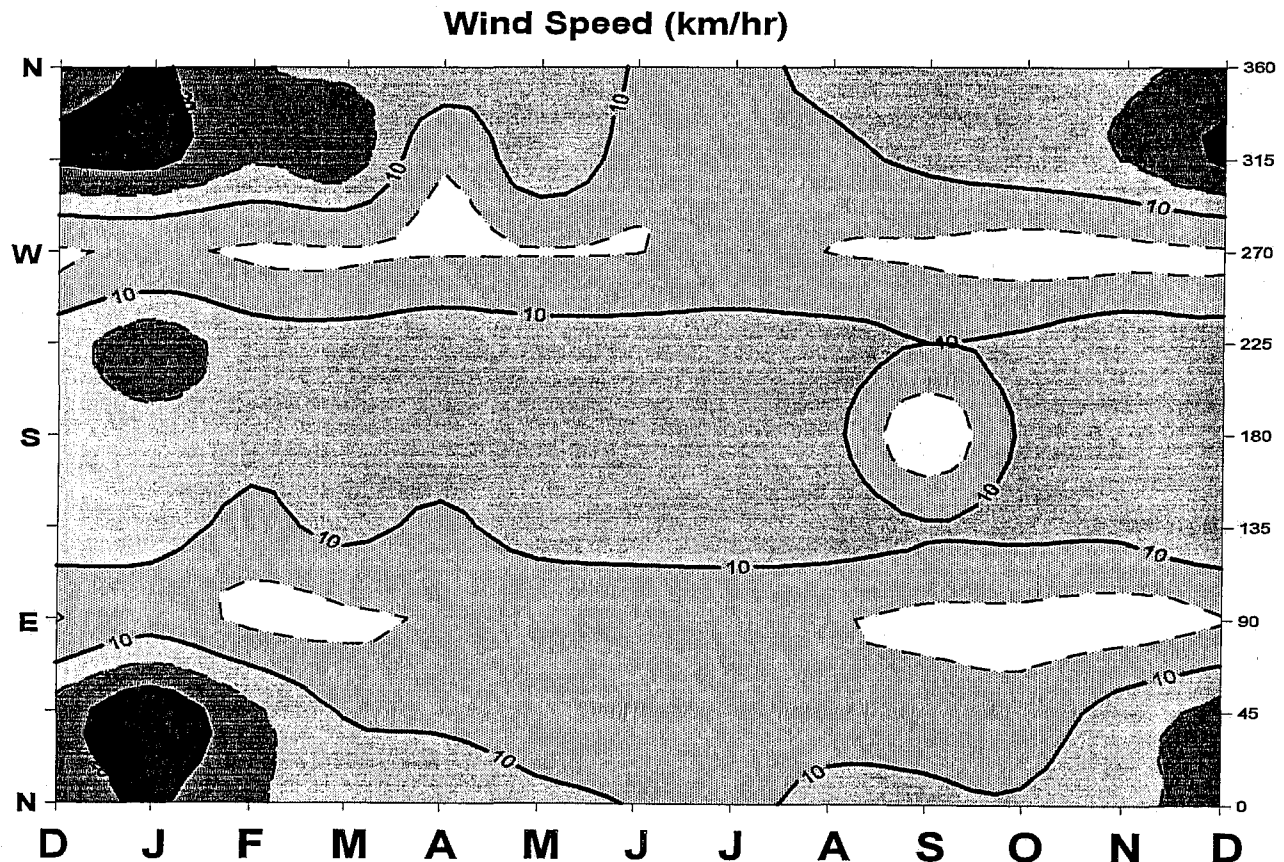


Figure 6. Contours of Kitimat town site wind speed (km/hr) by direction and month.

2.4 Run-off

The largest river in the area is the Kitimat River which enters at the head of Kitimat Arm and at the mouth of Minette Bay (Figure 3). The Kitimat River and its tributaries drain an area of approximately 1,990 km² (Environment Canada 1991). However, there are many smaller streams that enter Kitimat Arm, Douglas Channel and the other passages of the Kitimat system of fjords. Webster (1980) compared the relative watershed areas of these smaller ungauged streams and rivers with that of the Kitimat River and found

that the former was much larger. Assuming that run-off is proportional to the watershed area, Webster (1980) calculated that total discharge from the streams and rivers entering along the sides of Douglas Channel to be about three times that of the Kitimat River.

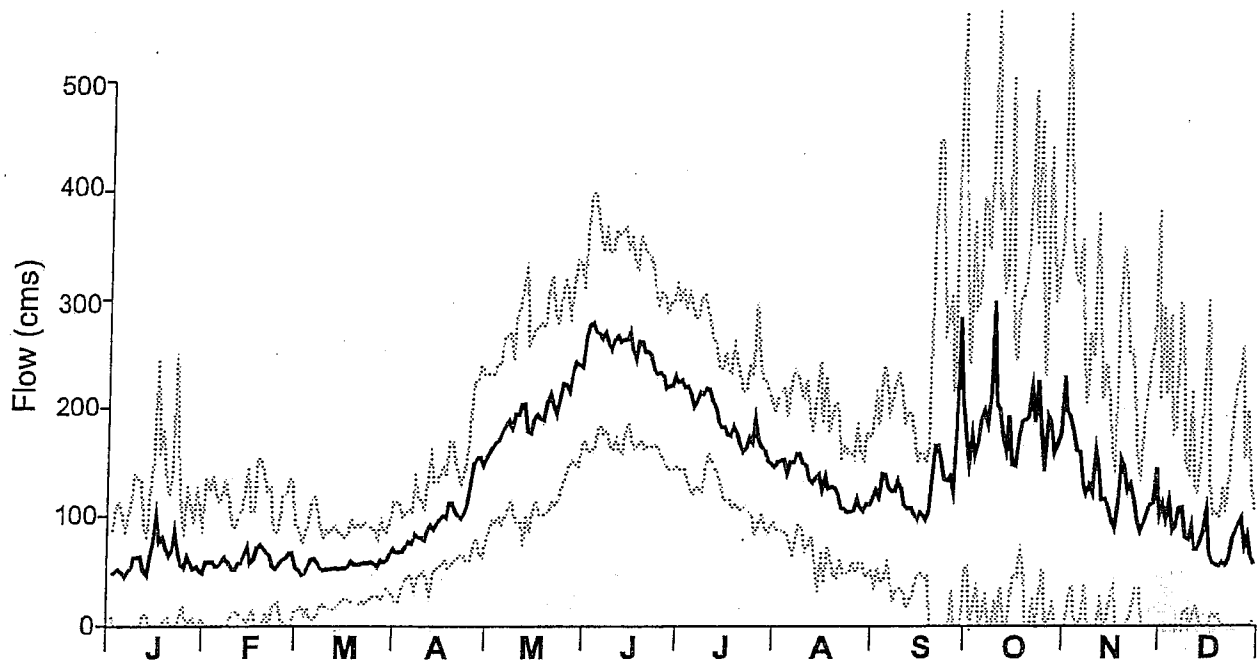


Figure 7. The average discharge curve of the Kitimat River (below Hirsch Creek) from 1962 to 1990. The light gray curves above and below the mean \pm one standard deviation.

The discharge curve of the Kitimat River has two peak discharge periods; the larger one in June caused by the melting of the stored run-off, and the smaller one in last quarter produced by the fall rain storms (Figure 7). On average minimum discharge occurs during the winter months January to March when the cold air temperatures lock up most of the precipitation in the form of snow and ice. The mean annual flow is $128 \text{ m}^3 \text{ s}^{-1}$ ranging from a maximum annual flow of $165 \text{ m}^3 \text{ s}^{-1}$ to a minimum annual flow of $101 \text{ m}^3 \text{ s}^{-1}$. The extremes of daily discharge range from $2,410 \text{ m}^3 \text{ s}^{-1}$ to a minimum of $9.2 \text{ m}^3 \text{ s}^{-1}$.

A noteworthy feature of the Kitimat River discharge curve is the large variability that occurs especially during the fall. The large standard deviation in the fall run-off curve reflects this large variability (Figure 7). The area of the catchment basin is relatively small and lacks the storage capacity or retention factor afforded by large lakes. Consequently large storms that end with warm temperatures produce large surges in the river's discharge. The October 1995 event (Figure 15) which reached a peak discharge of over $500 \text{ m}^3 \text{ s}^{-1}$ is an example of one of these fall events.

3. Sampling Program, Methods and Data

The year long sampling program which began in August 1995, consisted of two components, a synoptic water sampling component and the deployment of an instrumented mooring in Minette Bay. Almost all of the work was carried with the assistance of personnel from Kitimat Booming Contractors Ltd., (later Northern Seaboard Transportation Ltd.) using their tug the *BULL BLOCK*. The only exceptions were the surveys of May 10 and October, 1996 which were conducted using a small boat from the *CSS VECTOR*. Figure 8 summarizes the water property and moored instrument data collected over the 12 month period starting in August 1995. In all, there were seven trips to Minette Bay.

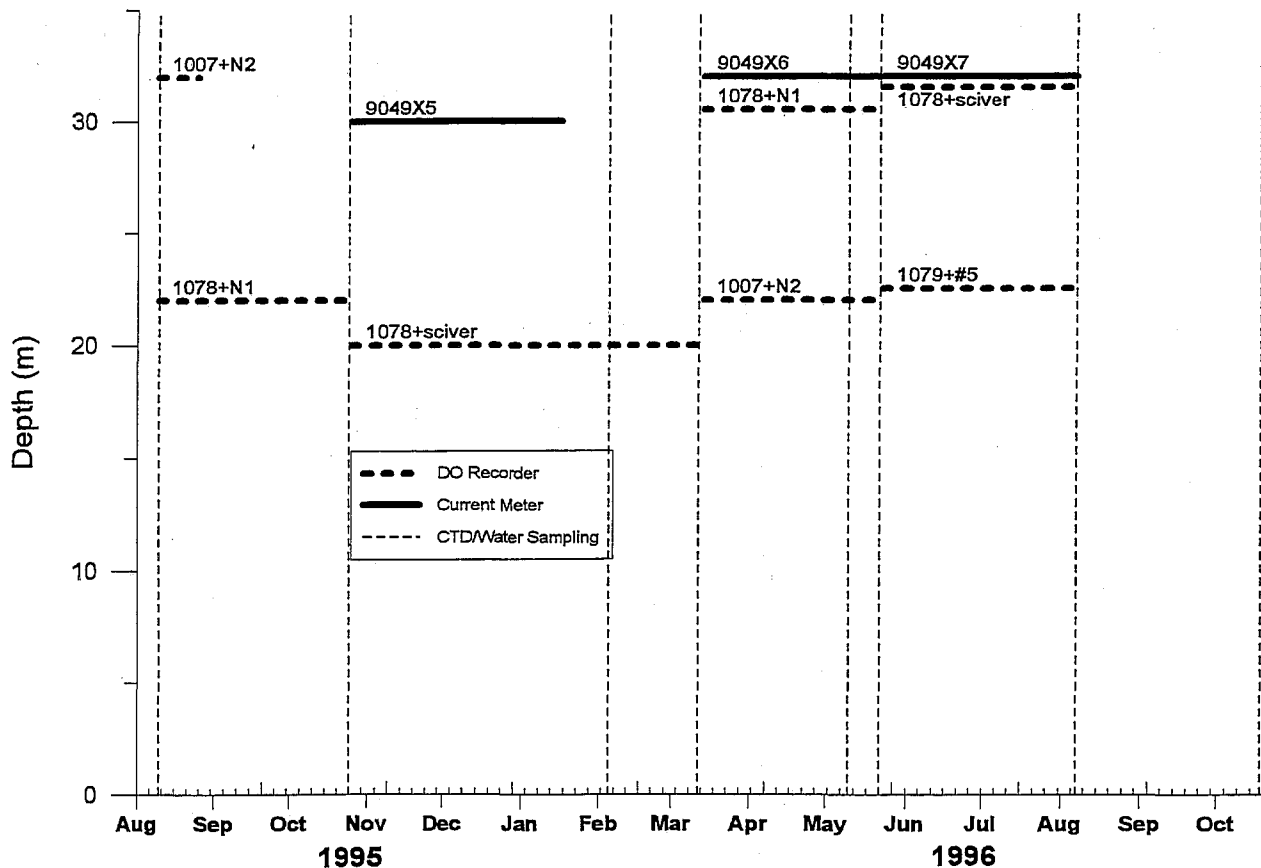


Figure 8. Summary of Minette Bay water sampling history and data return from moored instruments.

The water property sampling component consisted mainly of obtaining temperature, salinity and dissolved oxygen profiles at two stations, one in Minette Bay and the other in Kitimat Arm (Figure 3). In all but one of the surveys we used an Applied Microsystems Ltd. conductivity, temperature and depth profiler (CTD), model STD12, to collect the temperature and salinity profiles. During the May 10, 1996 survey only water sampling for salinity and DO determination were collected. Calibration checks on the

STD12 were taken at each station on each survey and used to correct the STD12 salinity data. The STD12 was calibrated at the start and end of the program. Table 3 lists the accuracy specifications for data collected with the STD12.

Table 3 List of instrumentation and manufacturers' accuracy specifications

Applied Microsystems Ltd STD-12	Pressure	± 0.5 db ($\pm 0.1\%$ FSP)
	Temperature	± 0.02 °C
	Salinity	± 0.02 psu (practical salinity units)

We obtained samples for dissolved oxygen from standard depths (0, 5, 10, 15, 20, 25, 30, 40, 50 m and bottom -1m) using 1.7 litre Niskin water sampling bottles. The water samples were "fixed" and then shipped to the Institute of Ocean Sciences and analyzed within 24 hours. A modified Winkler titration method (Strickland and Parsons 1965) was used to determine the dissolved oxygen content of the sample. The accuracy of the DO determination is about ± 0.05 ppm (parts per million) under ideal laboratory conditions.

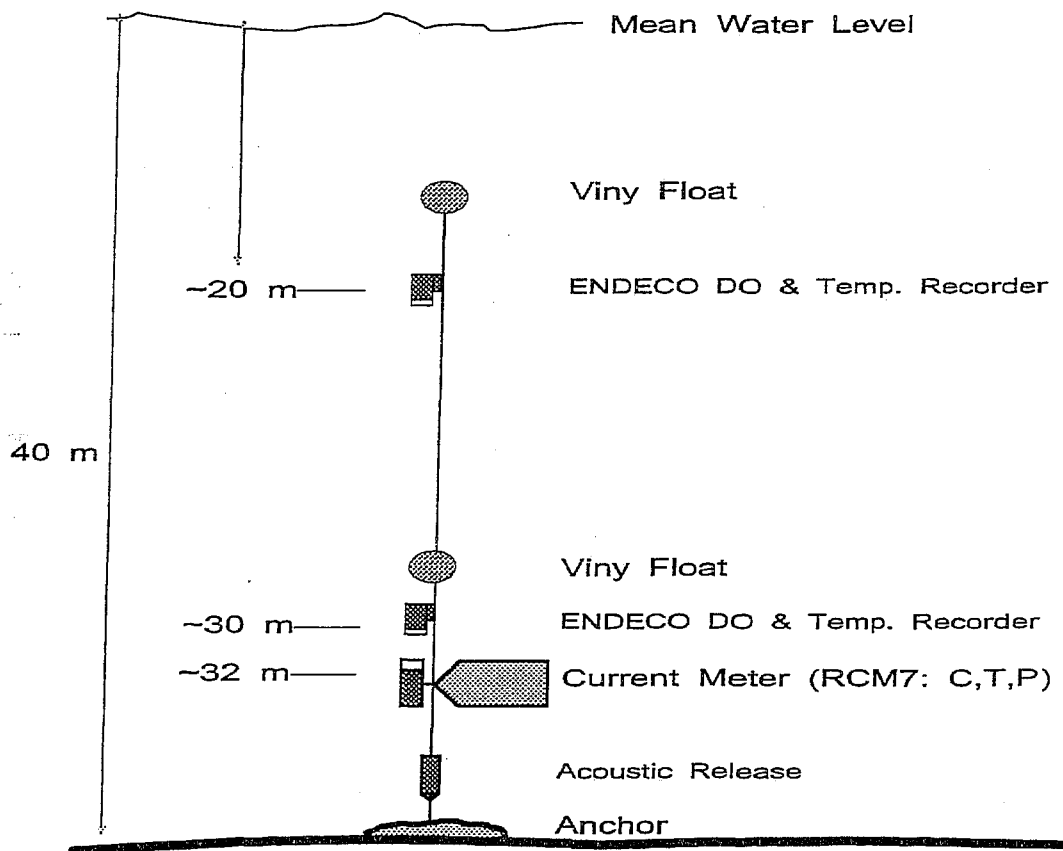


Figure 9 . Sketch of Minette Bay mooring.

We deployed and maintained a single mooring in Minette Bay (Figure 3) from August 1995 to August 1996. On this subsurface mooring we positioned two Endeco 1184 recording DO and temperature meters, one at approximately 22 m depth and the other at about 30m for each of the four deployments. On the last three deployments we

added an Aanderaa RMC7 current meter at about 32m (Figure 9). The Endeco 1184 recorders sampled every 15 minutes and the current meter which had temperature, conductivity and pressure sensors, sampled every 30 minutes. Unfortunately the data return from the dissolved oxygen recorders at 32m was only about 50%. During its initial deployment the current meter stopped after 85 days, thus no current meter data was collected from January to March 1996. The data return for the mooring is shown in Figure 8.

4. Deep Water Renewal

4.1 Hydrographic Data

The data set of water properties measurements from Minette Bay is not large; there are only about 20 profiles in total. Prior to 1992, there are only six profiles of temperature, salinity and dissolved oxygen concentrations from the bay and all but one of these were taken in either the summer or fall. The earliest reported measurements were taken in 1951 (UBC, 1951) prior to the development of the Alcan aluminum smelter. Waldichuk *et al.* (1968) sampled in Minette Bay in 1962, 1964 and 1967, and although previously not published also sampled in 1969 and 1972. It was not until 1992 that renewed interest in the water quality of Minette Bay generated the latest series of measurement - about 15 profiles of water properties (Appendix A).

In order to describe the annual cycle of temperature, salinity and dissolved oxygen in Minette Bay we contour plotted all the data versus time (annual time scale) and depth.

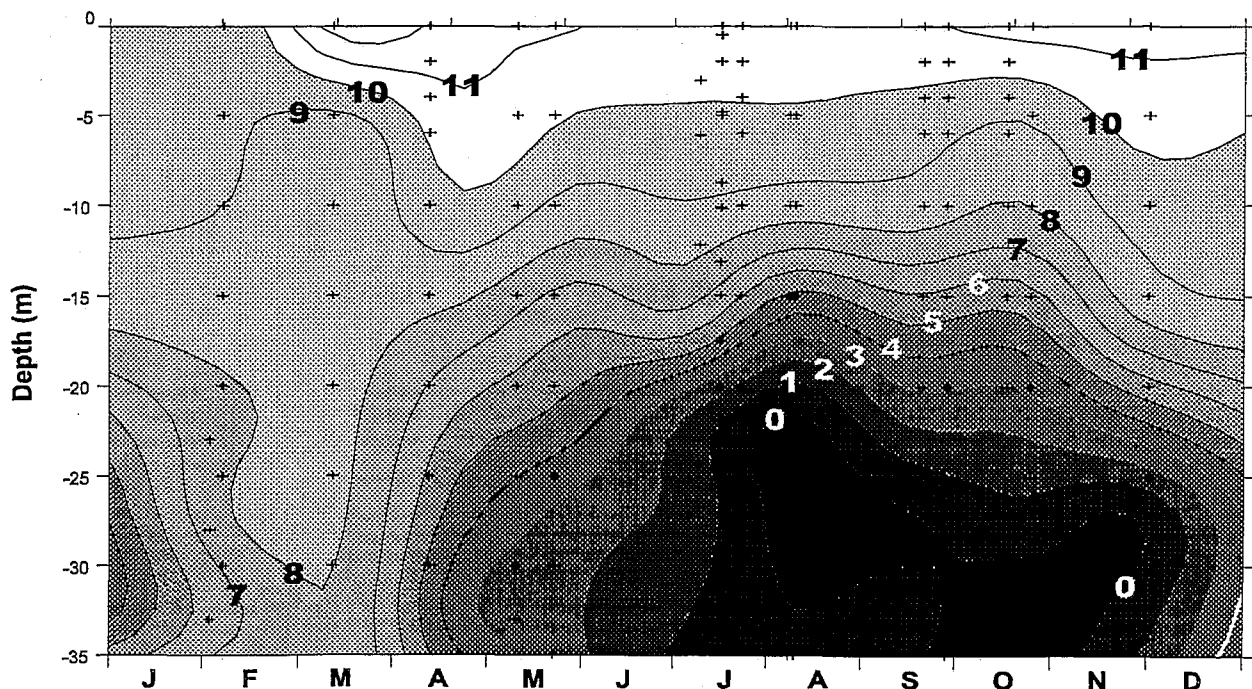


Figure 10. Depth-time contour plot of all dissolved oxygen (ppm) data from Minette Bay.

The annual cycle of dissolved oxygen (Figure 10) shows a large change in the deep waters (below 20m) of the bay. Dissolved oxygen concentrations are high (8 to 12 ppm) in the first quarter of the year, with little change from the surface to the bottom. In the second quarter, dissolved oxygen concentrations rapidly decline in the deeper waters to values less than 2 ppm, while near surface concentrations remain high. A strong vertical gradient in dissolved oxygen (oxycline) forms between 15m and 20m. Deep water oxygen values decline slowly to zero concentrations in last half of the year, while concentrations in the surface water remain high.

A similar contour plot (Figure 11) for Kitimat Arm data shows that the dissolved oxygen concentrations resemble those of Minette Bay above the oxycline. Like Minette Bay, the stratification in Kitimat Arm is also weakest early in the new year. However unlike Minette Bay, there is no low dissolved oxygen water in Kitimat Arm. There is an annual cycle in dissolved oxygen in Kitimat Arm below 20m depth, but the lowest concentrations (5 to 7 ppm), which occur in summer and fall, are much higher than those in Minette Bay. Thus, the low dissolved oxygen concentrations in Minette Bay must be generated within the bay and not transported in from Kitimat Arm.

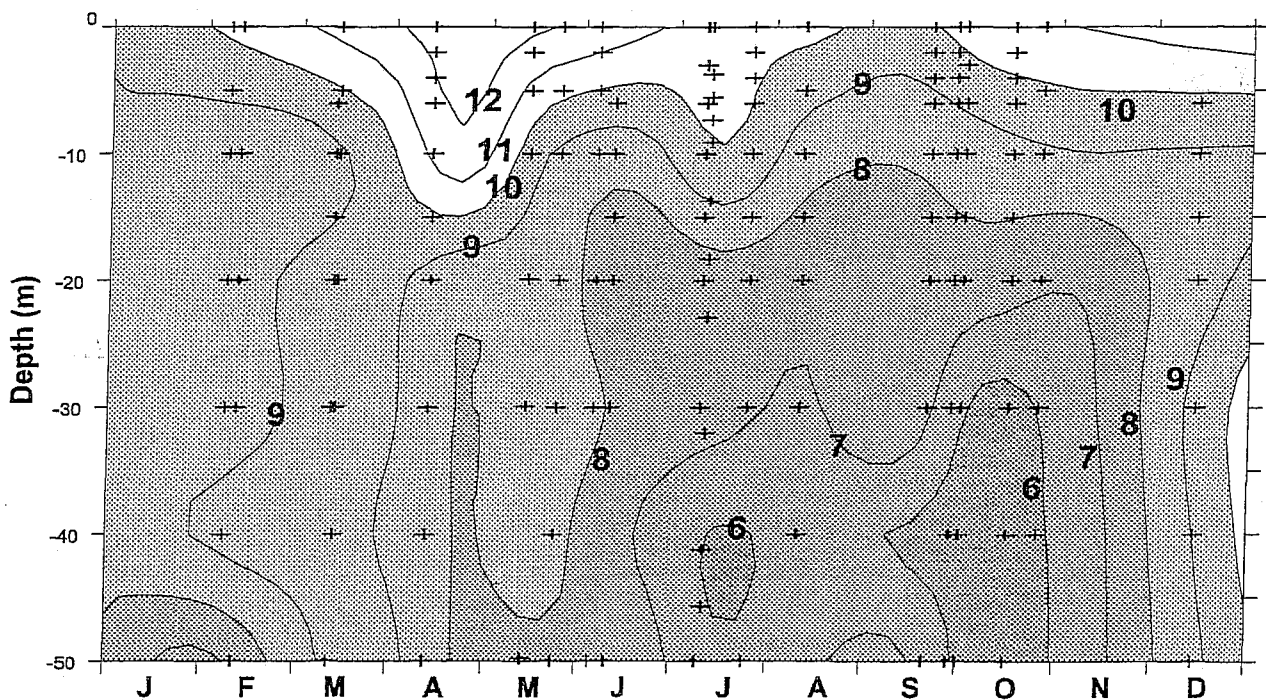


Figure 11. Depth-time contour plot of dissolved oxygen (ppm) data from Kitimat Arm.

The high dissolved oxygen concentrations over the entire water column in the first quarter indicate that this is the time when re-oxygenation of Minette Bay occurs. Although we do not have many samples from the first quarter of the year, the fact that we observe no low DO values at this time of year argues for a complete annual renewal or ventilation of deep waters of Minette Bay during the first quarter. The deep waters of the bay then remain stagnant from April to November.

As usual, the annual variation in temperature and salinity are most pronounced in the top half of the water column (Figure 12). Solar heating together with the supply freshwater from the Kitimat River create strong vertical temperature and salinity gradients near the surface. Unlike dissolved oxygen, the annual temperature and salinity variations are relatively small in the deeper waters. The deep water temperatures are cool at about 6°C indicating a winter turnover or replacement. Like dissolved oxygen, the vertical temperature and salinity gradients are weakest in the new year (Figure 12).

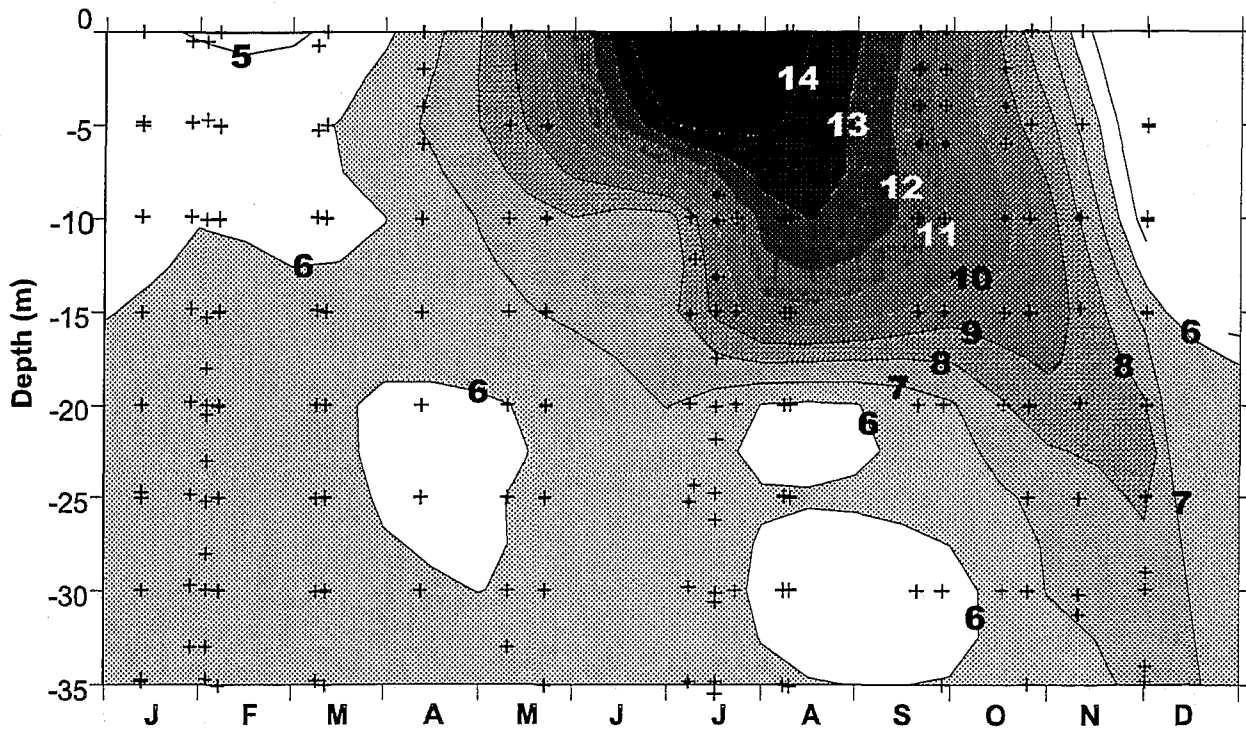


Figure 12. Depth-time contours of temperature from Minette Bay.

Re-oxygenation of the deep waters may occur by two mechanisms; one is the intrusion (advection) of denser water from Kitimat Arm, and the second is by vertical convection caused by an unstable density gradient. It is evident from successive salinity profiles taken from 1994 to 1996 that advective replacement of the waters of Minette Bay occurred over the winter and early spring. For example, during the winter of 1995/96 the salinity of the deepest waters of Minette Bay increased about 0.5 psu between October 25, 1995 and March 12, 1996 (Figure 13). Higher up in the water column the increase in salinity was much higher especially between October 1995 and February 1996. Because salinity increases can only result from the intrusion of higher salinity water, we conclude that there was a large scale intrusion of water from Kitimat Arm.

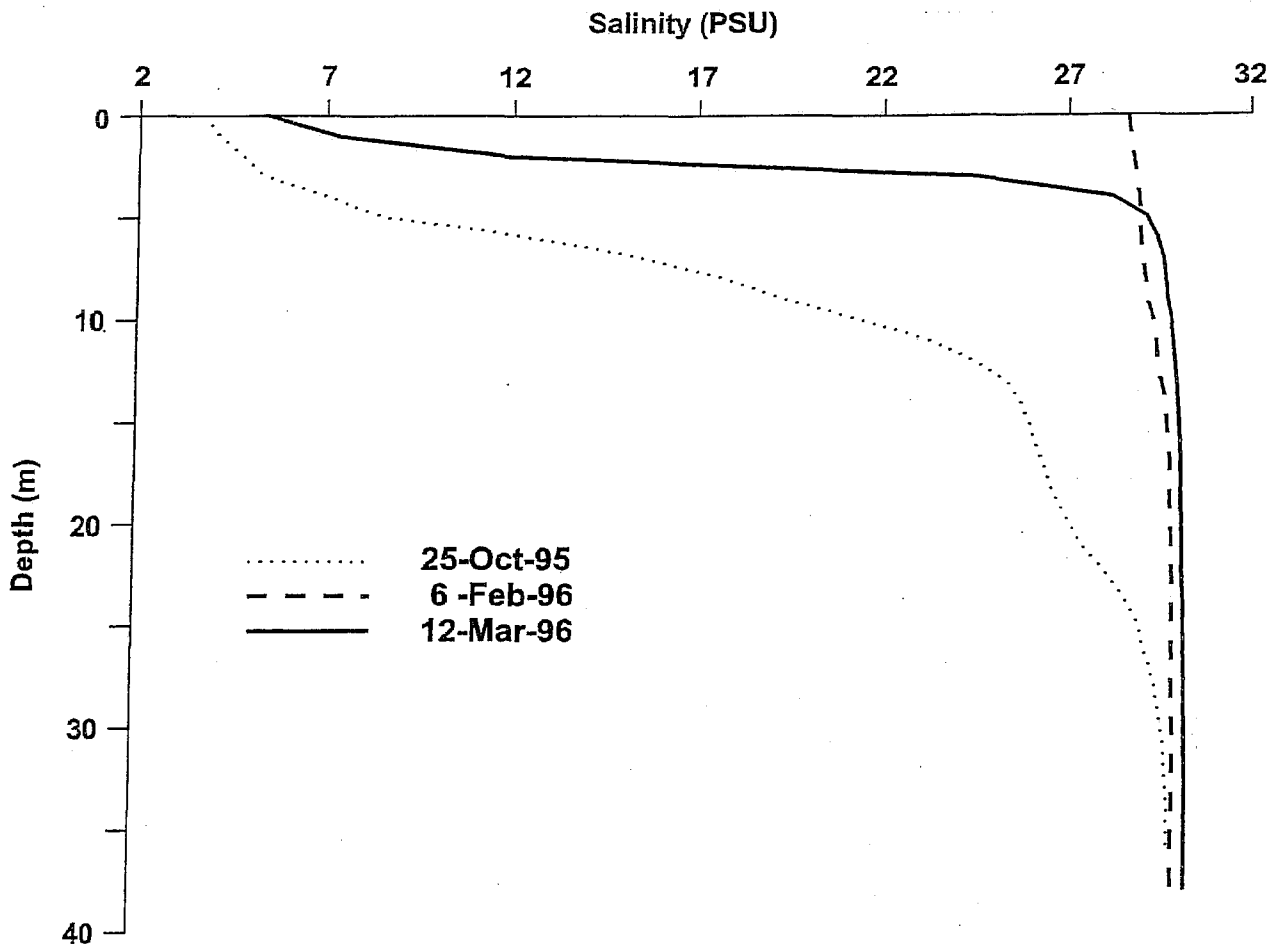


Figure 13. Salinity profiles from Minette Bay.

Over the winter season the waters of Minette Bay appear to be completely replaced with higher density (more saline) and oxygen rich waters from Kitimat Arm. The wholesale change in temperature, salinity and dramatic increase in dissolved oxygen are evidence that a complete renewal occurs over the winter months. Furthermore, based on successive measurements made in each year from 1992 to 1996, it appears that Minette Bay waters are replaced every winter. Through the late spring, summer and fall the deep waters of Minette Bay stagnate. Deep water salinity decreases slightly and temperature gradually increases, both indications that diffusive processes are at work.

4.2 Moored Instrument Data

From the annual cycles of temperature, salinity and dissolved oxygen, and successive profiles of water properties, we have deduced a general model of the renewal cycle for the water of Minette Bay. We have identified winter and spring as the times of year when denser, oxygen rich waters from Kitimat Arm replace the deep waters of Minette Bay. In this section, we present a detailed description of the renewal process using the

time series data collected by the moored DO meters and current meter. We then identify the processes that are responsible for the renewals using the hydrological and meteorological data from the winter of 1995/96.

Figure 14 presents all the data collected by the Endeco 1184 temperature and DO recorders, and the Aanderaa current meter as times series plots. The gaps between the time series of individual instruments results from the interruption caused by the recovery and subsequent re-deployment of the mooring. Often there is an offset in the DO time series between deployments and this is caused by the differences in depths between deployments and instrument calibration drifts. This offset is most noticeable at 20m where the vertical gradients in DO and temperature are large. We have marked with labeled arrows all the significant renewal events (Figure 14) in the year long record. In total, we have identified nine renewal events and in the subsequent discussion we will refer to them by their letter code, A through I.

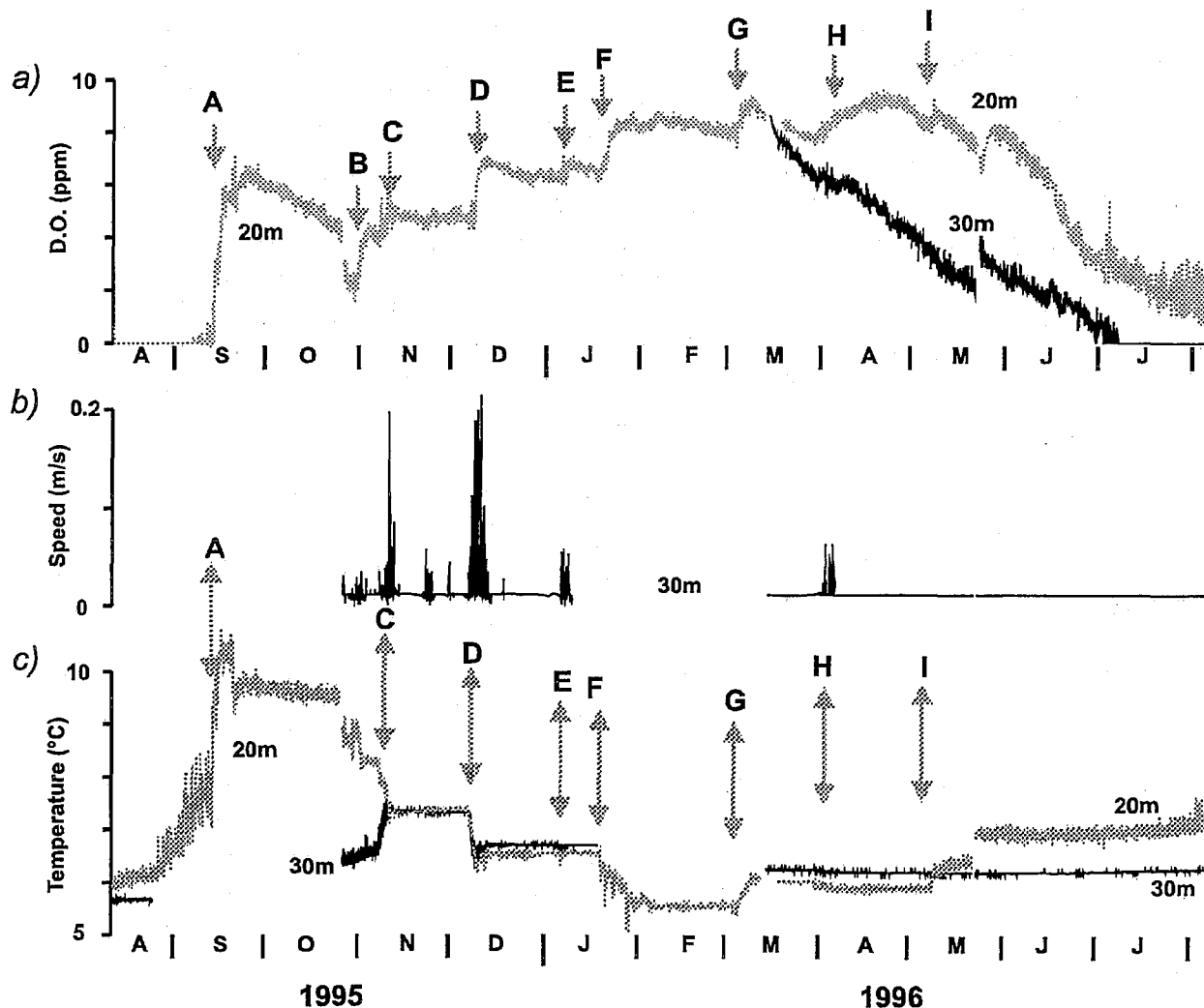


Figure 14. Time series plot from all instruments on the Minette Bay mooring.

The DO time series begins with zero concentrations of DO at both 20m and 30m, but by mid September 1995 the DO concentration at 20m dramatically increased to approximately 6 ppm. We have no data from 30m after August 25, but based on water property profiles in October 1995 we can safely assume that DO remained at near zero concentrations for the duration of the first deployment. Coincident with the DO increase, temperature at 20m also increased dramatically to over 10°C. The successive salinity profiles spanning this first deployment showed that warmer, saltier and more oxygenated water had moved into Minette Bay above 17m depth and mixed down to 20m and deeper. This renewal event (A) was only partial as the deepest waters remained depleted in oxygen.

In the second deployment, we observed at least six renewal events (B to G) which we identified by step increases in DO at 20m. The larger ones are event C in early November, event D on December 8 1995 and event F on January 21 1996. The temperature record at 20m showed coincident temperature decreases with the aforementioned DO steps, except for event G when temperature increased. At 30m, the temperature record from the current meter depth showed coincident temperature steps and current pulses. Events C and D produced the most pronounced temperature and current signals. Temperature increased about 1°C during the November event (C) and then decreased by about 1°C during the December event (D). The stronger currents ($> 0.2 \text{ m s}^{-1}$) at 30m during these two events were directed in a northeasterly direction signifying an inflow. Once again we had no continuous DO measurements from 30m over this period, but from the water property profiles spanning this deployment we observed a complete re-oxygenation of the Minette Bay deep waters. The salinity increased at all depths indicating that complete advective renewal had occurred. Clearly the time period from late October to mid-March was a period of multiple renewal events for the Minette Bay deep waters.

The third deployment period from mid-march to end of May 1996 was the first time we had data returned from all moored instruments. Following a decreasing trend in March, the DO trend from 20m abruptly changed sign in early April (event H) and DO gradually increased for most of April followed by an overall decrease in May. A minor event (I) early in May interrupted the decreasing trend. Temperature remained relatively constant at 20m except for the step increase on May 9, 1996 (event I). In the deep waters, DO declined steadily for the entire deployment period except for a slight leveling off at the beginning of April (event H). Overall DO concentrations at 30m declined by about 5 ppm (from 8 ppm to 3 ppm). The current meter showed no current activity except during event H when there was several days of weak (0.05 m s^{-1}) currents. It appears that during this third deployment there were two renewal events. One in early April (event H) which was a short lived and produced a minor influx of water into deep basin, and the other, in May (event I) caused a small increase in DO at 20m but did not penetrate to 30m.

The fourth and last deployment of the mooring was uneventful. DO at both 20m and 30m declined. At 20m DO declined steeply in the first half of the record resulting in an overall decline of about 7 ppm. At 30m the DO also steadily declined until early July

when DO content of the deep waters was completely depleted. The current meter at 30m depth recorded no current activity and the temperatures for all instruments remained nearly constant for the 76 day duration of the mooring.

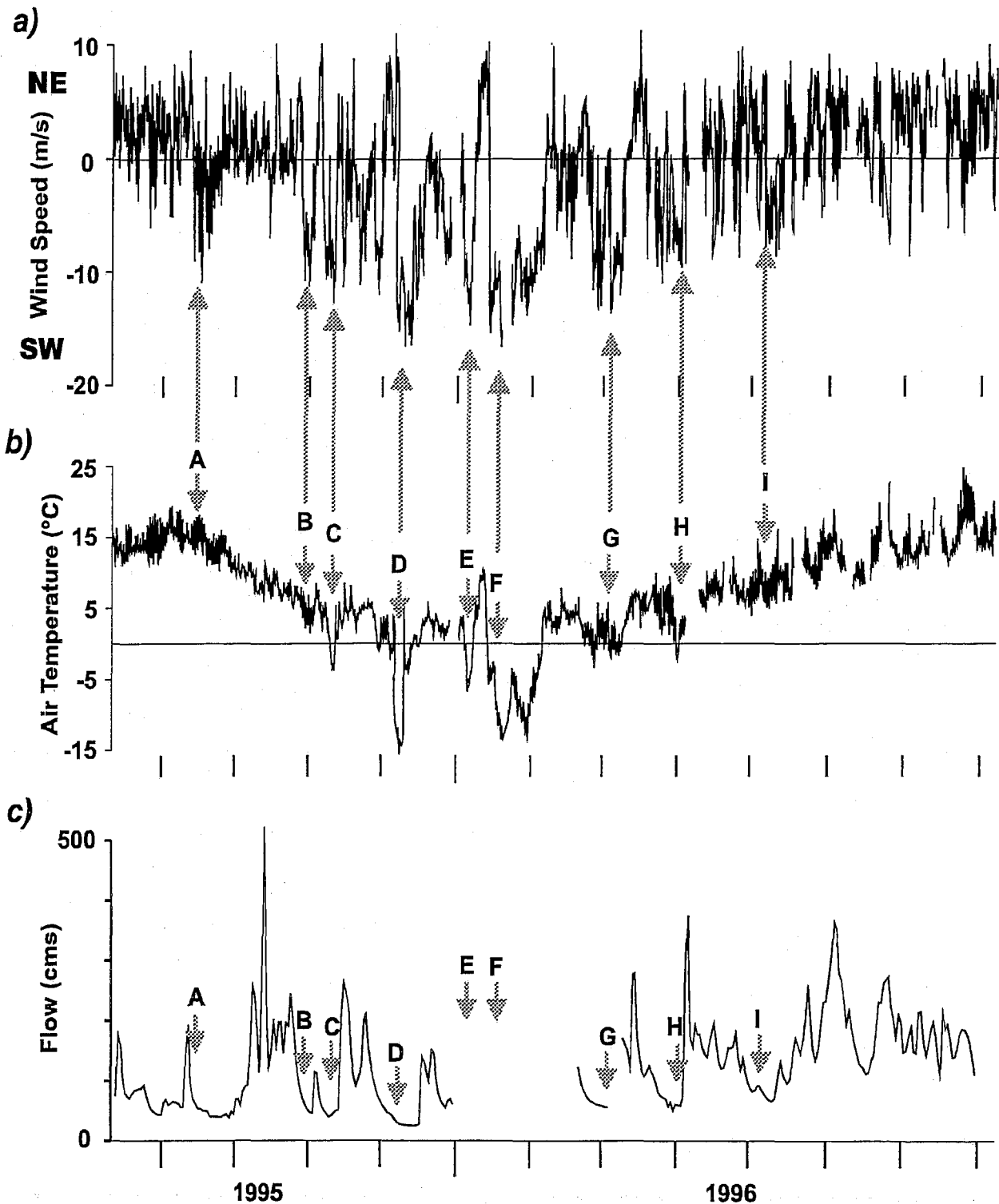


Figure 15. Time series plots of a) along channel wind and b) air temperature from Nanakwa Shoal weather buoy, and c) the Kitimat River discharge.

The density contrast between the surface waters of Kitimat Arm and the deep waters of Minette Bay determines whether or not deep water renewal occurs. Local run-off, winds and temperature are the principal factors influencing the density of the surface waters adjacent to Minette Bay. We have plotted (Figure 15) the time series of Kitimat River flow, winds and air temperature as measured by the AES buoy at Nanakwa Shoal for the same time period as the mooring in Minette Bay. To help us examine the relationships between the factors affecting density and the renewal events in Minette Bay, we have marked and labeled in Figure 15 the renewal events.

It is evident that renewal events coincide with periods of strong outflow (southerly) winds, cold (often below zero) air temperatures and low run-off. For example, event D in December 1995 occurs during a period of several days when air temperature approached -15°C , strong outflow winds blew (30 knots) and ice conditions were present in the Kitimat River resulting in low flows ranging from 25 to $30 \text{ m}^3 \text{ s}^{-1}$. This combination of factors was present for all of the winter and early spring renewal events. Although we do not as yet have run-off data for January and February 1996, ice conditions existed in the river for most of this time, and we may assume that flows were low. For the September and May events (A and I) air temperature does not appear to have been a factor. However, outflow winds were present and run-off was low. These were probably dry periods.

In winter, outbreaks of dry and cold Arctic air in the form of high pressure systems over the continent produce strong katabatic winds. The dense air in the high pressure systems drains to the coast through the river valleys and narrow fjords producing strong, cold and dry outflow winds. The effects on the surface density in fjords is pronounced. First, the cold Arctic air mass locks up most moisture in the form of ice and snow thus significantly reducing run-off. As the discharge of fresh water to the fjord diminishes the surface layer salinity increases. Second, the strong outflow winds blow the less dense surface layer out to sea and cause upwelling of denser waters at the head of the fjord as well as mixing. Third, the cold and dry outflow winds produce strong heat exchange from the ocean to the overlying air. Latent and sensible heat fluxes are large and as a result there is significant surface cooling.

The tidal range may be an additional factor controlling the renewal process in Minette Bay. Because the sill depth is so shallow in Minette Bay a higher tide increases the sill depth. Consequently at high tides (spring tides) not only is the sill region able to pass a higher volume of renewal water but inflows of water will be drawn from a greater depth in Kitimat Arm. Our comparison of the predicted tides at Kitimat with the renewal events showed no clear relationship. Meteorological and hydrological forcing appeared to determine the timing of the renewal events.

5. Oxygen Budget

In this section we examine the dissolved oxygen budget of Minette Bay in order to gain some insight into the rates of oxygen uptake and supply to the deep basin waters. The dissolved oxygen budget applies only to periods of stagnation, i.e. only during those

time periods when there is no advective renewal of deep waters. Furthermore, we exclude those waters in the euphotic zone, the base of which is taken to be at a depth of 20 m (Aure and Stigebrandt (1989).

Following the budget method as described by Gargett (1984) for a stratified fluid in a closed basin, the volume integrated conservation equation for dissolved oxygen is

$$\frac{\partial}{\partial t} \int_{\text{bot}}^z A(z') O_2(z') dz' = K_v(z) \cdot A(z) \cdot \frac{\partial O_2(z)}{\partial z} - F. \quad 1$$

The left hand side of equation 1 represents the time rate of change of the total dissolved oxygen content of the basin from the bottom to a depth z , where $A(z)$ is the variation in horizontal surface area for the basin as a function of depth (Table 1), and $O_2(z)$ is the dissolved oxygen concentration. The first term on the right hand side of equation 1 is the turbulent diffusive transport of dissolved oxygen through the surface area $A(z)$, where $K_v(z)$ is the vertical turbulent eddy diffusivity. The second term on the right hand side, F , represents the biological and biochemical processes that consume the supply of dissolved oxygen in the deep basin waters. There are several components to F , the dominant one usually being the vertical flux of organic matter from primary production in the euphotic zone. The component of concern in this study is the deposition of wood solids from the log handling activities onto the bottom and the resultant oxygen uptake as they decompose.

Periods of stagnation are identified by both decreasing water density and decreasing dissolved oxygen concentrations. Both conditions must be satisfied in order to identify the time period as one of stagnation. From the water sampling data collected in 1995 and 1996 periods of stagnation occur from late spring to late fall.

Before we could compute the supply of dissolved oxygen by turbulent diffusive processes or eddy flux, it was necessary to first calculate the eddy diffusivity, K_v . Using the budget method for density, we calculated K_v from the following equation

$$K_v(h) = \frac{\frac{\partial}{\partial t} \int_{\text{bot}}^h \rho(z) \cdot A(z) \cdot dz}{A(h) \cdot \frac{\partial \rho(h)}{\partial z}} \quad 2$$

where $\rho(z)$ is the density of seawater. Equation 2 is a simpler version of equation 1 because there is no biological or biochemical term. Density is a conservative quantity. We calculated K_v during periods of stagnation using the STD12 profiles to calculate the time rate of change of seawater density and the vertical density gradient.

The values of K_v computed (see Table 4) from the CTD data are comparable to those computed by Svensson (1979) for a small stratified sill fjord in Sweden. The K_v values in Table 5 are higher but there appears to have been a partial renewal of the waters below 20m during this period and this may account for the increase. Generally

however, the K_v values for Minette Bay are at the lower end of the range of values computed for several BC fjords (De Young and Pond 1988 and Smethie 1979).

Using the measured profiles of dissolved oxygen and assuming that the eddy diffusivities are the same for dissolved oxygen and density, the eddy flux of dissolved oxygen was computed. The total dissolved oxygen consumption, from the bottom to a specified depth, by biological and biochemical processes is then the sum of the eddy flux and the observed changes in dissolved oxygen (Table 4 and Table 5). The eddy flux of dissolved oxygen in the May to August period which ranges from 0.02 to 0.03 $\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$ contributes from 4% to 43% of the total uptake rate. The eddy flux is relatively constant when compared to the observed range total dissolved oxygen consumption rate.

Table 4. Oxygen budget results for the stagnant period from May 1996 to August 1996.

Depth (m)	K_v ($\text{m}^2 \text{ s}^{-1}$)	Eddy Oxygen Flux ($\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$)	Observed Uptake rate ($\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$)	Total Uptake Rate ($\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$)	Average DO (ppm)
20-bot	8.0×10^{-7}	0.02	0.47	0.49	1.5
25-bot	2.1×10^{-6}	0.03	0.25	0.28	1.2
30-bot	3.3×10^{-6}	0.02	0.13	0.15	0.9
35-bot	4.1×10^{-6}	0.03	0.04	0.07	0.8
37-bot	9.0×10^{-6}	0.02	0.03	0.05	0.8

During the March to May period, we know there were partial renewals that penetrated to a depth between 20m and 30m (Figure 14). These partial renewals replenished the declining oxygen content of some of the deeper waters. Consequently the observed uptake rates are lower bounds because they are based on the data gathered at the beginning and end of the period and do not take into account the intervening influxes of oxygen rich waters. The total uptake rate for the March to May period are about twice as large as in the May to August period. Although the eddy flux is larger it remains a minor component of the total oxygen uptake.

Table 5. Oxygen budget results for the period from March 1996 to May 1996.

Depth (m)	K_v ($\text{m}^2 \text{ s}^{-1}$)	Eddy Oxygen Flux ($\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$)	Observed Uptake rate ($\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$)	Total Uptake Rate ($\text{g O}_2 \text{ m}^{-2} \text{ d}^{-1}$)	Average DO (ppm)
20-bot	5.2×10^{-6}	0.08	0.94	1.02	6.3
25-bot	9.0×10^{-6}	0.07	0.71	0.78	5.8
30-bot	1.6×10^{-5}	0.13	0.47	0.60	5.4
35-bot	1.7×10^{-5}	0.02	0.19	0.21	5.2
37-bot	2.4×10^{-5}	0.01	0.12	0.13	5.2

The oxygen consumption in the deep basin waters occurs both in the water column and in the sediments. Estimates of the sediment uptake rate as a percentage of total oxygen demand are wide ranging. Kemp *et al.* (1992) found that sediment uptake rate in Chesapeake Bay contributed from 5% to 50% of the total oxygen uptake. In Minette Bay, we do not know the relative weighting of dissolved oxygen uptake between the water column and the sediments. For the sake of argument, we adopt an extreme point of view and assume that all the oxygen uptake is in the sediments. We then compare our sediment uptake rates with the extensive literature that exists on this subject.

Knock (1993) published an extensive literature review of the sediment oxygen demand, and, as expected, sediment uptake rates varied considerably. In coastal, estuarine and fjord environments sediment oxygen uptake rates range widely from 0.1 to 33 g O₂ m⁻² d⁻¹, however most measurements were in the range from 1 to 3 g O₂ m⁻² d⁻¹. The higher uptake rates indicate sediments receiving higher fluxes of organic matter. The enrichment of sediments with organic material is often associated with direct anthropogenic inputs like solids from pulp mills or sewage treatment plants or indirectly through the enhanced primary productivity of eutrophicated systems. Schaumburg (1973) specifically investigated the effects of log handling and storage practices on water quality in the Pacific Northwest. Measurements of sediment oxygen consumption by benthic bark beds in the Coos River, Oregon ranged from 2.3 to 4.4 g O₂ m⁻² d⁻¹.

Knock (1993) summarizes the debate about the affects of water column oxygen concentration on sediment oxygen demand. The consensus appears to be that low levels (1.5 to 3 ppm) of dissolved oxygen attenuate sediment oxygen demand. At higher oxygen concentrations the sediment uptake is unaffected. Thus the differences between uptake computed for the March to May period and that in the May to August period may be explained, in part, by differences in the water column oxygen concentrations. As the last columns in Table 4 and 5 show, the average dissolved oxygen concentrations are high in the March - May period, while in the May - August period, concentrations are much lower and in the range reported to affect sediment oxygen uptake.

Sediment uptake rates, as inferred from the oxygen budget in Minette Bay, are lower than most measurements in coastal, estuarine and fjord environments, and also lower than the measurements of Schaumburg (1973) on bark deposits. The area of Minette Bay covered by booming grounds we estimate to be about 0.5 km², of which only 18% overlies the stagnant basin waters, i.e. waters of depth greater than 20m. Sediment oxygen uptake rates in Minette Bay may be locally much higher in the bark beds underneath these log handling and storage areas. However, when averaged over the whole of the bay the uptake rates remain small.

There is an additional oxygen demand component that we have not previously mentioned, namely the anthropogenic organic load from the Eurocan pulp mill. The pulp mill discharges effluent which contains dissolved organic compounds and suspended solids, both of which will generate an oxygen demand as the organic constituents are metabolized by micro-organisms. The pulp mill discharges its effluent

into the Kitimat River; consequently the dissolved load remains in the fresh surface layer and exerts its oxygen demand there. However, some of the Kitimat River flow enters Minette Bay; consequently a fraction of the solids in the pulp mill's effluent will settle in Minette Bay and exert an oxygen demand there. We cannot quantify this contribution to the oxygen demand other than to presume it is small given the overall low uptake rate we calculated earlier.

5.1 DO Trend

We are fortunate that Dr. G. Pickard of UBC had the foresight to collect water quality data before the industrial development of the area, and that Waldichuk *et al.* (1968) conducted several pollution cruises in the 1960's, early in the industrial history of the region. We examined these early data together with the more recent data for trends in DO over the 45 years that the data span.

We limited our analysis of the DO data to only those data from the stagnant period; we excluded all data from the winter months. Furthermore we have broken down the data into three depth intervals; the surface layer 0 to 10m depth, the deep water >20m and an intermediate layer from 10m to 20m. There are three time bands of observations in the DO time series (Figure 16); the 1951 observations, a middle band of observations from 1964 to 1972 and the band of recent observations from 1993 to 1996.

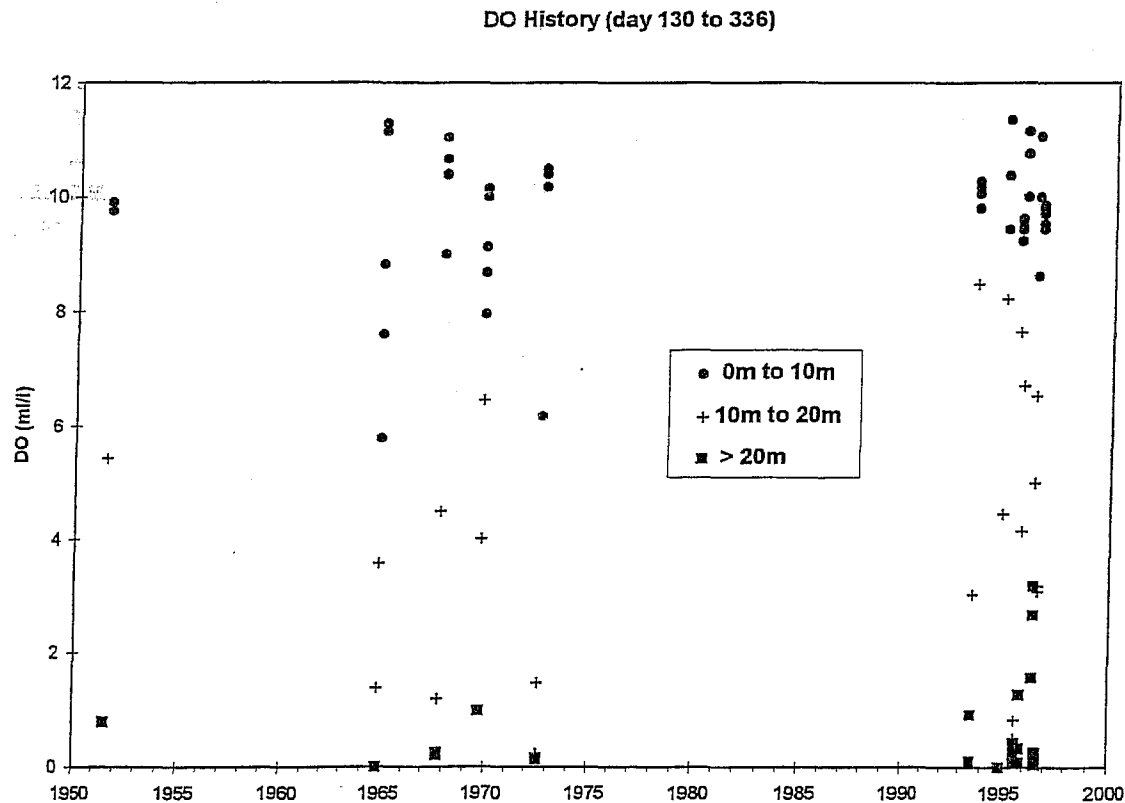


Figure 16. Time series plot of all stagnant period DO data from Minette Bay.

It is apparent from the examination of the time series of DO measurements in the three depth ranges that there is no outstanding trend. In the deep water the 1951, 1964, 1967 and 1969 data sets are not noticeably different or of higher dissolved oxygen content than the more recent data. In July 1951, the deepest (24m) measurement of dissolved oxygen had a value of 0.8 ppm which is lower than many of the more recent measurements. A linear regression analysis of the deep water DO data produces a regression line with a slight positive (i.e. increasing DO with time) slope, but the fit is not significant. No significant trends are detectable in either the surface layer and the intermediate layer though there is a suggestion of slightly higher DO values in recent years. In part this apparent recent increase in DO may be due to a larger number of samples in the 1993 to 1996 period. Given that the data set from 1951 to 1996 contains large data gaps, and that there is only one profile taken before the log handling practices began in Minette Bay it is not surprising that it is difficult to detect subtle trends in the water quality.

6. Conclusions and Recommendations

Our analysis of the early measurements in Minette Bay together with the more recent measurements has shown that over the winter and early spring (November to April) the waters of Minette Bay are displaced by the colder, more saline and high DO waters from Kitimat Arm. Based on measurements in successive years it appears that complete renewal of Minette Bay occurs annually.

The recording instruments which we moored over the winter of 1995/96 have shown that the exchange of Minette Bay waters occurs through a series of discrete renewal events, some of which penetrate to the bottom while others only penetrate to intermediate depths. The renewal events are mainly forced by outbreaks of the Arctic air mass over the northern BC. The cold air mass through several processes produces an increase in density of the Kitimat Arm surface water sufficient to displace the deep waters of Minette Bay. The cold air mass ($< -15^{\circ}\text{C}$) reduces the discharge of the Kitimat River and other local rivers to low discharges which in turn results in an increase in surface layer salinity. The cold air mass and high pressure system produce strong outflow winds in the inlets which increase the density of the surface waters of Kitimat by several processes. First the outflow winds effectively blow the surface layer away from the head of the arm, causing upwelling of denser water there. Second there is intense cooling of the surface waters as the latent and sensible heat exchange are large. Third, the strong winds produce local mixing which penetrates to greater depths under weakly stratified conditions. Outside the winter period, periods of low discharge and outflow winds may trigger a renewal event but these events are weak and do not penetrate to the bottom.

From about May to November the deep waters of the bay remain stagnant. Diffusive processes slowly change the temperature and salinity of the deep waters producing a gradual decline in density. DO concentrations in the deep waters decline rapidly during

the stagnant period. By July most of the DO in the deep waters is depleted and concentrations remains at or near zero until late into the fall.

We have estimated the oxygen budget for the bay during the stagnant period and have shown that the turbulent diffusive supply of oxygen is a small component. The biological and biochemical processes that consume oxygen dominate the budget. We used a worst case scenario approach and converted all the oxygen uptake to a sediment oxygen demand rate in order to compare with the extensive literature that exists for this parameter. The uptake rates in Minette Bay which range from about 0.1 to 1 g O₂ m⁻² d⁻¹ are lower than most measured in coastal, estuarine and fjord environments and are not indicative of an environment that is receiving an unusually high organic load. They are also considerably lower than measurements in bark beds underneath log storage and handling areas.

Our examination of the deep water DO for trends over the 45 year time span of measurements showed no significant trend. The UBC 1951 measurements which preceded the industrial development and measurements from the 1960's are not different from the recent measurements in the deep waters.

In summary, based on both the DO budget calculations and the historical DO data from the deep waters of Minette Bay we conclude that log handling practices in the bay have not exacerbated the naturally occurring low DO conditions in the bay.

Although we have shown in this study that log storage and handling practices have had no apparent effect on the DO concentrations, other deleterious effects on water quality and habitat are possible. We have not addressed these other impacts or habitat disruptions in this report. These impacts might include: the disruption of animal and plant life on and in the sediments by the grounding of log booms or scouring of the bottom sediments by the movement of log booms; the alteration of the natural composition of the sediments and the benthic community by the accumulation of bark, whole logs and other wood debris on the sediments underneath the log storage areas and in the log dump zone; anoxia in sediments due to an increased organic load; and toxic concentrations of leachates from the logs and other wood debris.

A mapping and analysis of the composition of the sediments, especially in and around the areas used for log storage would provide an assessment of the type and the extent of the impact of log handling activities in the bay. As a first approach, transects lines across the bay, using an underwater camera, could provide a cost effective way to visually inspect and classify the bottom sediments. Based on this preliminary information, sediment samples could be collected in key locations for quantitative analyses such as grain size distribution and organic carbon, C/N ratio as well as qualitative characteristics such as colour and texture.

The principal component of the sediments that needs to be examined is the benthic community. A series of benthic sampling locations should be determined based on the preliminary mapping of sediment characteristics, log handling impacts and visual

surveys. At these locations the benthic community should be sampled for diversity and species composition. This information by itself or in conjunction with historical surveys in the bay and Kitimat Arm may give a sense of the degree of impact that log handling operations are having on the ecology of Minette Bay.

As a final comment, it would be interesting to investigate the water properties in embayments having similar physical characteristics to Minette Bay. In Douglas Channel, not too distant from Minette Bay, there are two small inlets that have very shallow sills; one is Foch Lagoon which has a 4m deep sill at low water and the other is Kiskosh Inlet (Figure 1) which has a 2m deep sill. Kiskosh Inlet has a maximum depth of about 53m and is more like Minette Bay than Foch Lagoon which has a much deeper basin (250m). Their very shallow sills suggest that the deep basin waters in these two inlets may be oxygen depleted. A comparison with Minette Bay may be instructive as there are no log storage or handling activities in either of these inlets.

7. Acknowledgments

This has been a interesting project, and we thank Mr. Uriah Orr of the North Coast Division of the Habitat Management Branch (DFO) for introducing us to it, supporting us in our field operations and getting the funding to make it happen. We acknowledge and thank Mr. Ken Illingworth of Kitimat Booming Contractors Ltd., Mr. Scott Marleau of Skeena Sawmills Ltd. and Western Seaboard Transport for their financial support of this investigation. In addition to providing financial support Kitimat Booming Contractors Ltd., and later Western Seaboard Transport provided us with the use of their tug boat the *BULL BLOCK* and the assistance of their personnel. In particular we would like to thank Don, Fred, Brian, Hans, Mike and Jack from Kitimat Booming Contractors Ltd. and Richard Vangenne of Western Seaboard Transport for their assistance and cooperation in the field operations.

In our moment of need, when our mooring would not come up, the dive team of Mr. Scott Trent and Mr. Shane Neifer (North Coast Division of DFO) responded to our request for assistance and attempted to recover the mooring. We appreciated their quick response and efforts on our behalf. We also acknowledge the logistical support provided by Dr. Walt Cretney of IOS in making ship time available to us for the Minette Bay work while the *CSS VECTOR* was in Kitimat Arm. Finally, we thank Mr. Frank Whitney for reviewing this manuscript.

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9. Appendix A Dissolved Oxygen and CTD Data

Dissolved Oxygen Data

Station Lat.	Time (UTC) Long.	Date	Depth (m)	Salinity (psu)	Dissolved Oxygen (ml/l)
MBAY 54° 1.44' N	128° 37.14' W	17-Jul-93	0.0		7.04
			2.0		7.12
			5.0		7.19
			8.7		6.86
			13.1		5.94
			17.5		2.12
			21.9		0.64
			26.2		0.07
			30.6		0.08
MBAY 54° 1.50' N	128° 37.02' W	1-Dec-94	0		7.95
			5		7.26
			10		6.61
			15		5.75
			20		3.12
			25	29.678	0.00
			29		0.00
			34	30.538	0.00
MBAY 54° 1.56' N	128° 37.02' W	2-Feb-95	18	30.563	
			23	30.651	4.98
			28	30.690	5.37
			28		5.81
			33	27.846	4.15
KA 53° 59.10' N	128° 39.36' W	10-Aug-95	0	27.610	6.87
			5	29.208	7.27
			10	30.298	6.74
			15	30.515	5.39
			20	30.836	5.56
			30	31.305	5.40
			40	31.609	4.94
			57	32.149	4.04

Station Lat.	Time (UTC) Long.	Date	Depth (m)	Salinity (psu)	Dissolved Oxygen (ml/l)
MBAY 54° 1.38' N	128° 37.26' W	10-Aug-95	0	9.117	6.63
			0	9.118	6.60
			5	9.861	6.72
			5	9.860	6.74
			10	11.718	6.47
			10	11.722	6.46
			15	14.698	5.35
			15	14.780	5.35
			20	29.248	0.36
			20	29.248	0.57
			25	29.917	0.12
			25	29.917	0.04
			30	30.161	0.17
			30	30.161	0.23
			35	30.237	0.24
			38	30.295	0.27
MBAY 54° 1.56' N	128° 37.32' W	25-Oct-95	0	4.742	7.81
			5	8.080	7.53
			10	13.090	7.00
			15	24.766	4.69
			20	26.604	2.90
			25	28.277	0.89
			30	29.686	0.07
			36	29.926	0.23
KA 53° 59.22' N	128° 39.42' W	25-Oct-95	0	3.850	8.07
			5	16.106	7.10
			10	24.915	6.29
			20	29.710	4.96
			30	30.301	4.56
			40	30.578	4.41
			53	30.840	4.28

Station Lat.	Time (UTC) Long.	Date	Depth (m)	Salinity (psu)	Dissolved Oxygen (ml/l)
MBAY 54° 1.38' N	128° 37.32' W	18:25 26-Oct-95	0	5.447	7.76
			5	11.663	7.19
			10	20.479	5.86
			15	26.059	4.69
			20	27.032	2.58
			25	28.936	0.07
			30	29.750	0.29
			34	29.590	0.07
			34	29.588	0.05
KA 53° 59.16' N	128° 39.36' W	18:30 6-Feb-96	0	28.975	6.63
			5	29.378	6.56
			10	29.749	6.45
			20	30.240	6.44
			30	30.545	6.37
			40	30.765	6.29
			55	31.182	5.80
MBAY 54° 1.38' N	128° 37.26' W	23:20 6-Feb-96	0	28.015	6.61
			5	29.258	6.45
			10	29.398	6.41
			15	29.799	6.16
			20	29.843	6.12
			25	29.979	6.03
			30	30.038	5.96
			36	30.100	5.93
MBAY 54° 1.38' N	128° 37.26' W	21:44 7-Feb-96	0	23.826	7.06
			5	27.662	6.70
			10	28.608	6.52
			15	29.798	6.10
			20	29.917	6.02
			25	30.038	5.92
			30	30.068	5.93
			36	30.128	5.94
			36	30.128	5.89

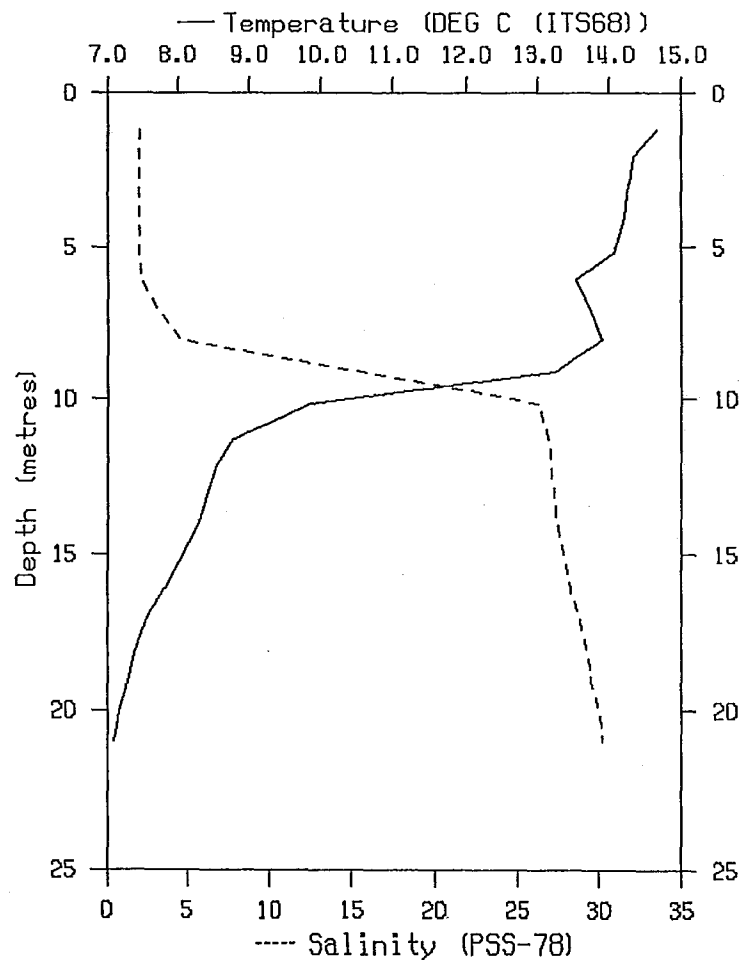
Station Lat.	Time (UTC) Date Long.	Depth (m)	Salinity (psu)	Dissolved Oxygen (ml/l)
MBAY 54° 1.38' N	22:10 12-Mar-96 128° 37.26' W	0	6.793	8.94
		5	29.543	6.21
		10	29.910	6.13
		15	30.138	6.08
		20	30.200	6.02
		25	30.286	5.97
		30	30.355	5.89
		36	30.383	5.67
KA 53° 59.16' N	15:20 13-Mar-96 128° 39.36' W	0	6.752	9.00
		5	26.650	7.13
		10	29.300	6.64
		20	30.281	6.56
		30	30.673	6.47
		40	30.804	6.41
		55	31.006	6.12
MBAY 54° 1.38' N	17:30 13-Mar-96 128° 37.32' W	0	5.931	8.88
		5	29.473	6.21
		10	29.816	6.14
		15	30.105	6.06
		20	30.147	6.04
		25	30.286	5.96
		30	30.323	5.93
		35	30.383	5.65
		36	30.383	5.67

Station Lat.	Time (UTC) Date Long.	Depth (m)	Salinity (psu)	Dissolved Oxygen (ml/l)
MBAY 54° 1.38' N	23:56 10-May-96 128° 37.26' W	0	23.764	6.93
		0	23.764	6.80
		5	25.571	6.37
		5	25.571	6.37
		10	26.668	5.99
		10	26.668	5.83
		15	28.559	4.84
		15	28.559	4.80
		20	29.838	3.15
		20	29.838	3.09
		25	30.014	2.41
		25	30.014	2.40
		30	30.091	1.92
		30	30.091	1.87
		33	30.111	1.67
		33	30.111	1.63
MBAY 54° 1.38' N	17:50 22-May-96 128° 37.26' W	0	12.735	7.74
		5	23.734	7.01
		10	26.189	6.04
		15	28.030	4.57
		20	29.286	3.50
		25	29.930	2.23
		30	29.989	1.87
		35	30.058	1.10
KA 53° 59.16' N	13:50 23-May-96 128° 39.42' W	0	9.059	7.96
		5	19.559	8.33
		10	29.313	6.06
		20	30.030	5.83
		30	30.407	5.88
		40	30.587	5.85
		50	30.894	5.64

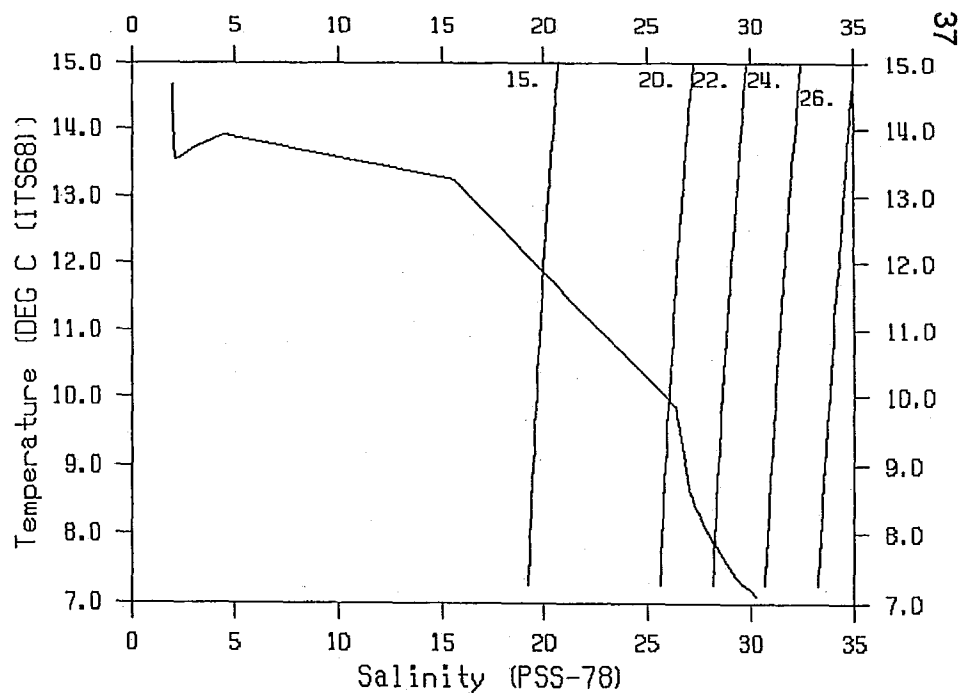
Station Lat.	Time (UTC) Long.	Date	Depth (m)	Salinity (psu)	Dissolved Oxygen (ml/l)
MBAY 54° 1.32' N	128° 37.38' W	23-May-96	0	12.390	7.73
			5	19.148	7.84
			10	24.404	6.71
			15	27.580	5.09
			20	29.159	3.60
			25	29.870	2.26
			30	29.983	1.71
			35	30.040	1.20
			0	0.000	0.00
MBAY 54° 1.38' N	128° 37.26' W	7-Aug-96	0	3.999	6.90
			0	3.999	6.86
			5	4.898	6.79
			5	4.898	6.81
			10	6.307	6.61
			10	6.307	6.68
			15	27.697	2.22
			15	27.695	2.15
			20	29.096	0.13
			20	29.092	0.15
			25	29.731	0.18
			25	29.731	0.10
			30	29.807	0.10
			30	29.792	0.06
			35	29.918	0.03
			35	29.918	0.03
KA 53° 59.16' N	128° 39.36' W	8-Aug-96	0	6.453	6.94
			5	16.991	7.12
			10	30.111	5.27
			20	31.345	4.68
			30	31.708	4.16
			40	31.914	3.91
			55	32.242	3.56

Station Lat.	Time (UTC) Date Long.	Depth (m)	Salinity (psu)	Dissolved Oxygen (ml/l)
MBAY	20:55 18-Oct-96	0	16.232	6.76
54° 1.50' N	128° 37.08' W	0	16.232	6.54
		4	21.952	5.25
		4	21.952	5.23
		9	23.510	4.68
		9	23.510	4.70
		14	24.475	4.07
		14	24.475	4.09
		19	25.711	2.83
		19	25.711	2.81
		24	28.976	0.06
		24	28.976	0.02
		29	29.677	0.04
		29	29.677	0.00
		34	29.734	0.00
		34	29.734	-0.01

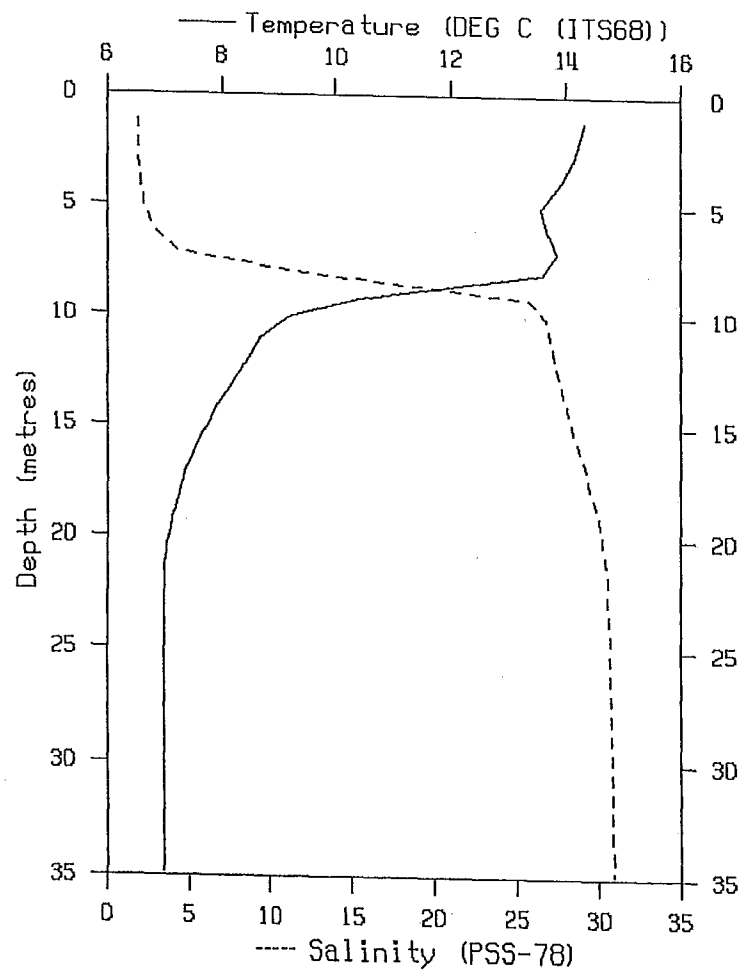
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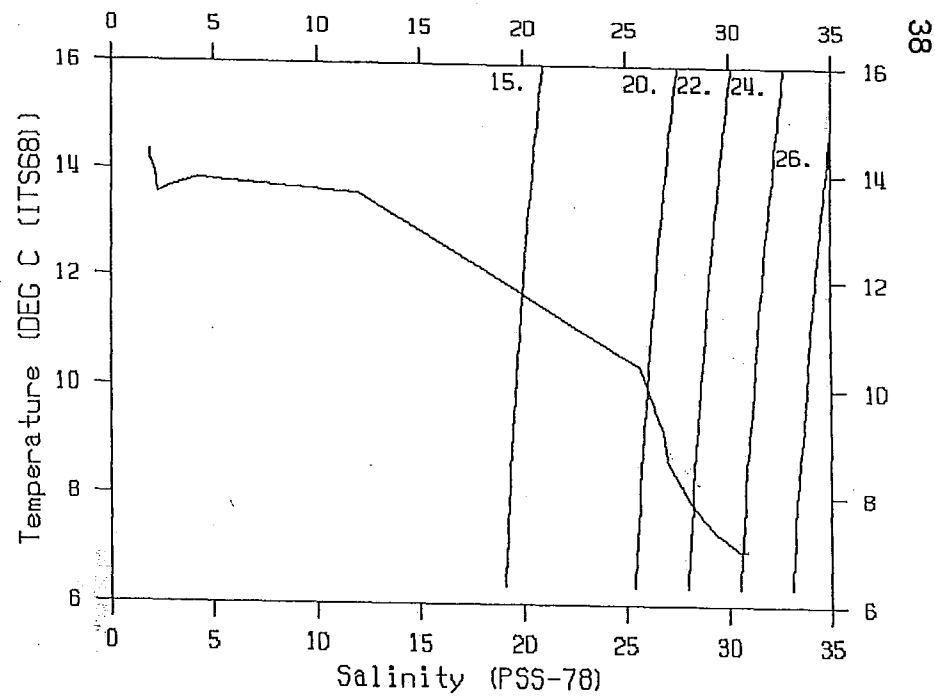
Depth	Temp	Sal	Sigma-t
1	14.66	2.01	.73
2	14.33	1.99	.77
3	14.27	1.99	.77
4	14.21	1.99	.78
5	14.07	2.01	.82
6	13.54	2.15	1.00
8	13.91	4.53	2.78
10	9.86	26.39	20.29
12	8.56	27.11	21.04
15	8.02	27.94	21.76
20	7.16	30.03	23.51



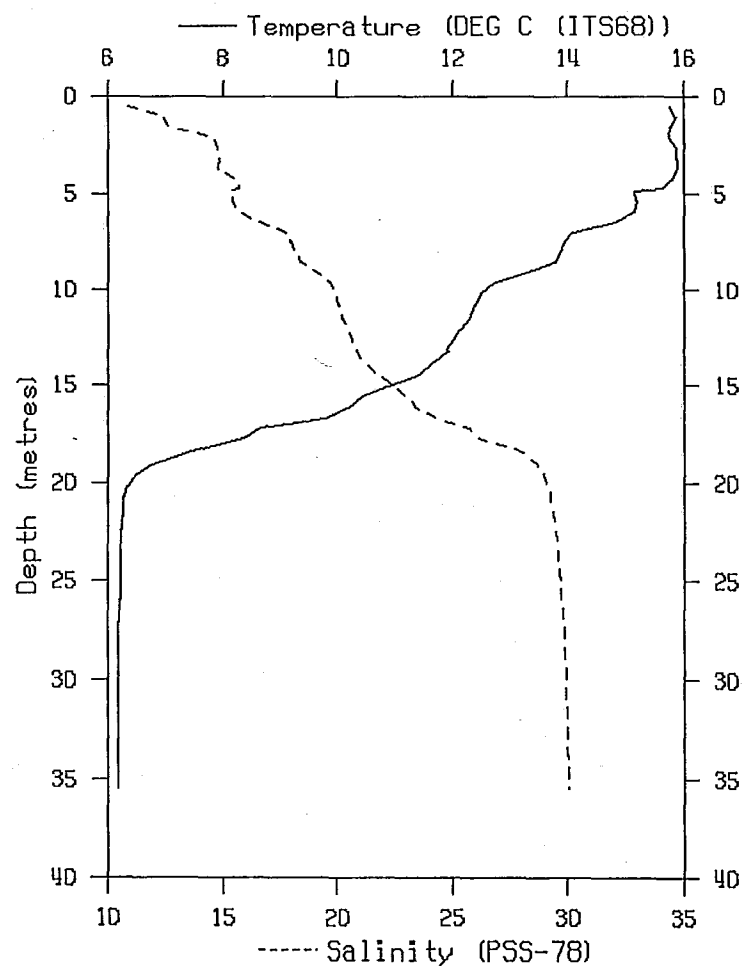
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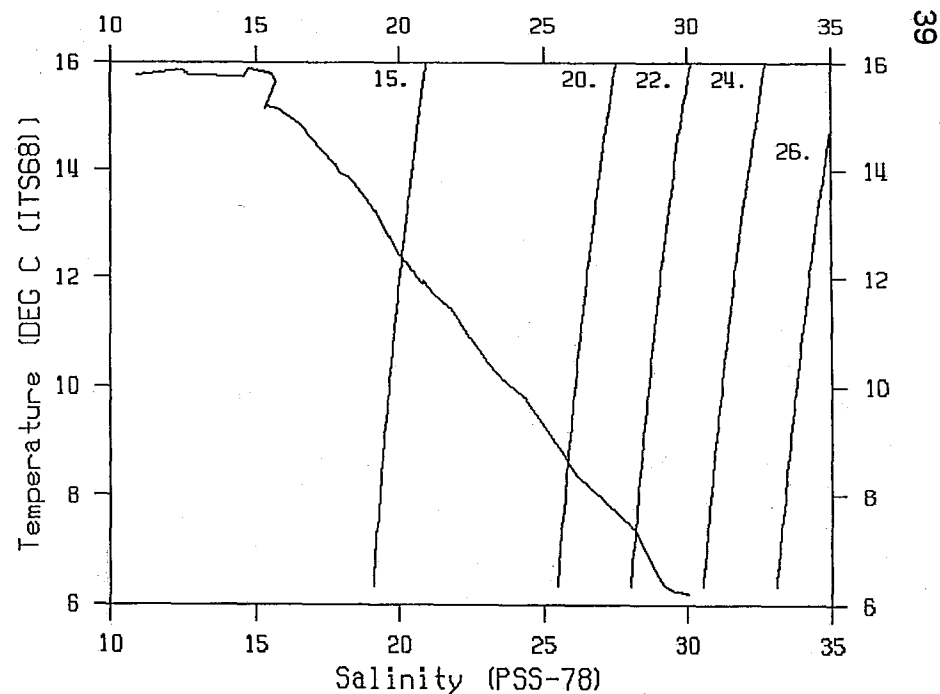
Depth	Temp	Sal	Sigma-t
1	14.34	1.89	.69
2	14.24	1.89	.70
3	14.15	1.90	.72
4	13.93	2.09	.90
5	13.57	2.26	1.08
6	13.69	2.91	1.57
8	13.58	12.08	8.64
10	9.22	26.80	20.70
12	8.41	27.39	21.27
15	7.73	28.43	22.18
20	7.08	30.23	23.68
25	6.99	30.68	24.05
30	6.98	30.83	24.16
35	6.98	30.88	24.20



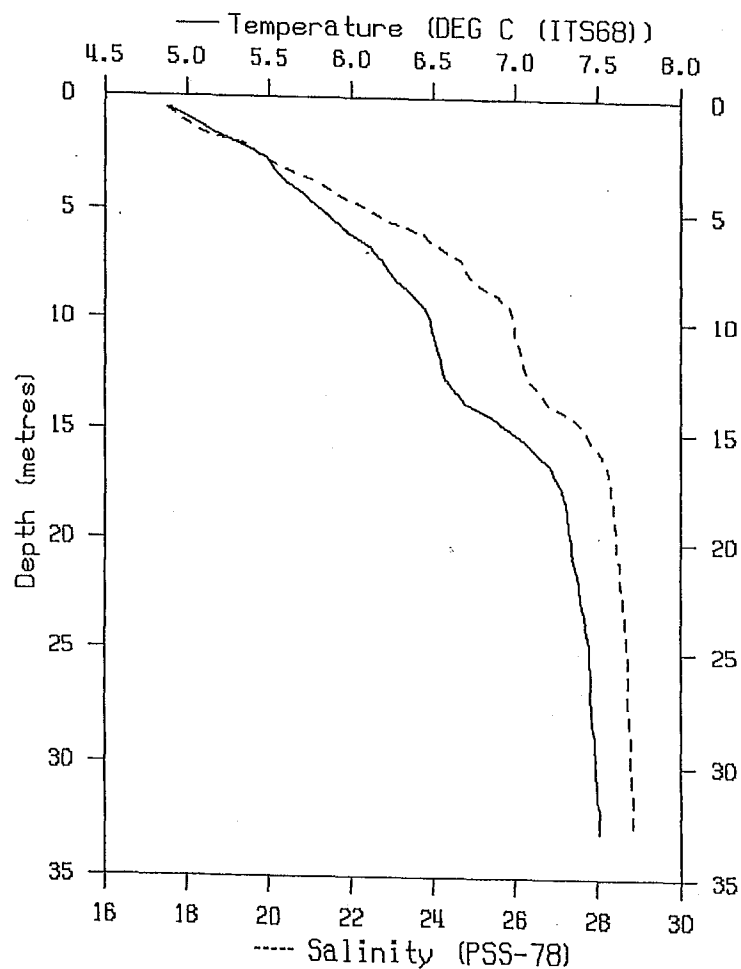
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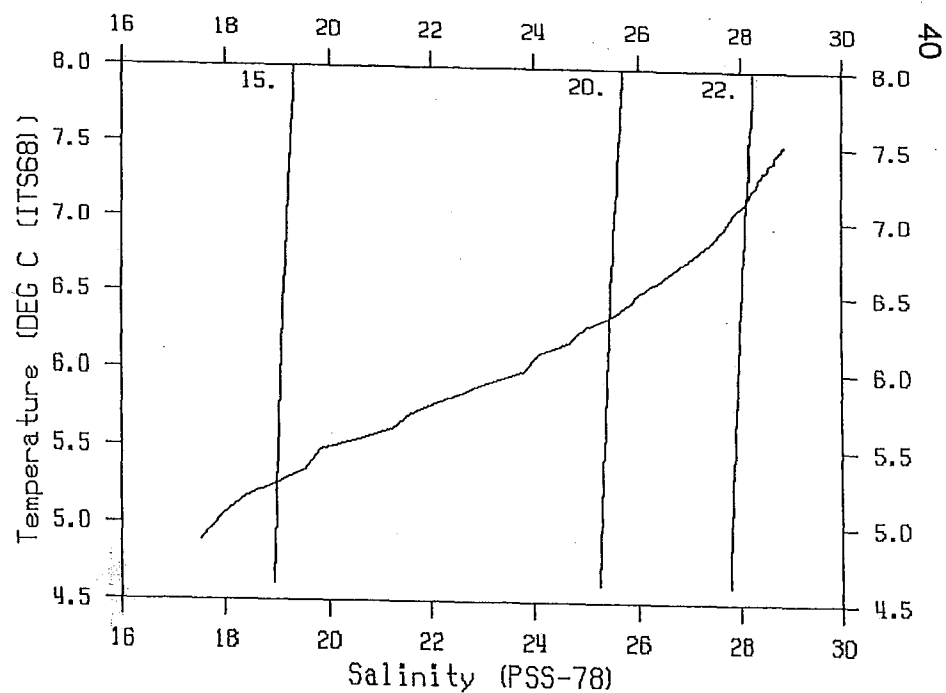
Depth	Temp	Sal	Sigma-t
1	15.81	11.70	7.96
2	15.76	13.65	9.47
3	15.89	14.80	10.32
4	15.85	15.19	10.62
5	15.33	15.50	10.96
6	14.99	16.14	11.51
8	13.83	18.30	13.38
10	12.64	19.80	14.74
12	12.14	20.47	15.34
15	10.90	22.47	17.08
20	6.43	29.08	22.85
25	6.24	29.69	23.36
30	6.20	29.91	23.54
35	6.19	30.04	23.64



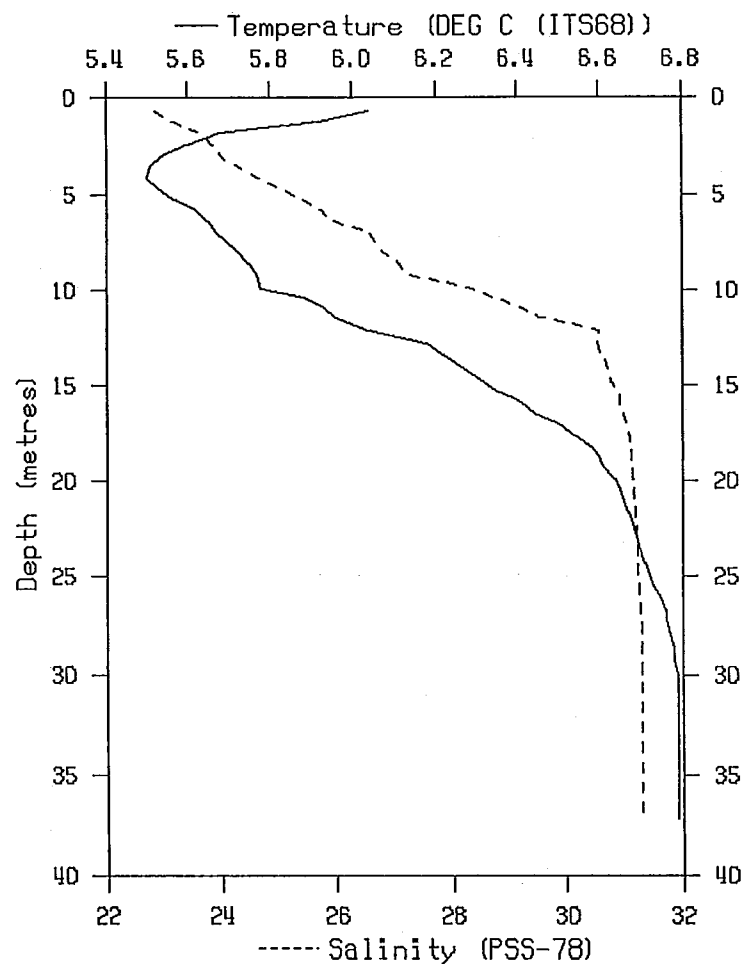
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 DATE/TIME : 28/01/94 17:53 UTC
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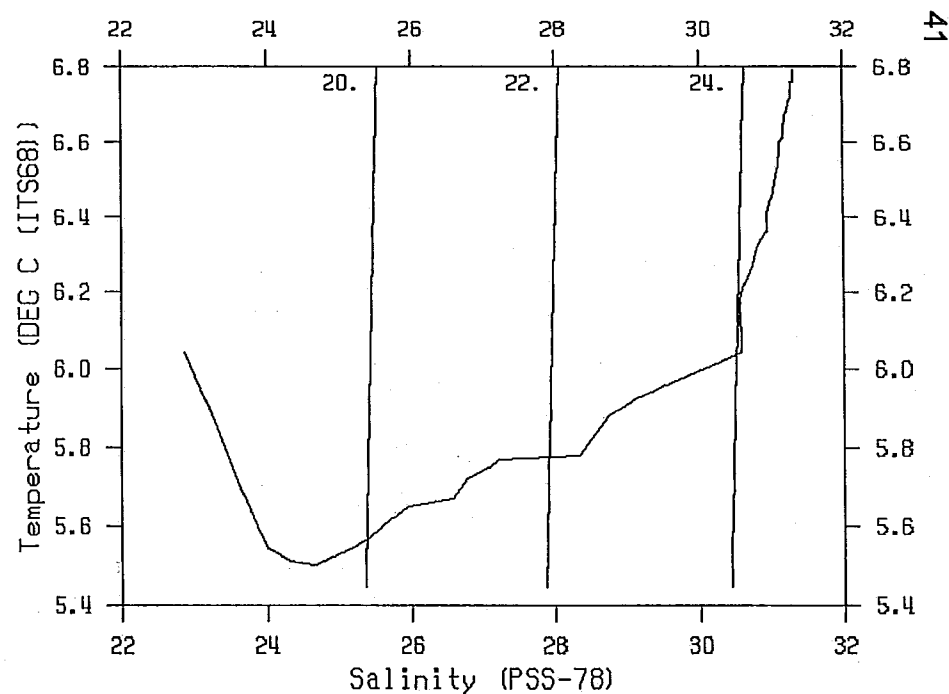
Depth	Temp	Sal	Sigma-t
1	4.97	17.74	14.05
2	5.26	18.99	15.01
3	5.51	20.17	15.93
4	5.67	21.45	16.92
5	5.85	22.61	17.82
6	5.99	23.78	18.73
8	6.26	24.94	19.61
10	6.49	25.99	20.41
12	6.55	26.22	20.58
15	7.01	27.77	21.75
20	7.34	28.47	22.26
25	7.45	28.73	22.45
30	7.49	28.82	22.51



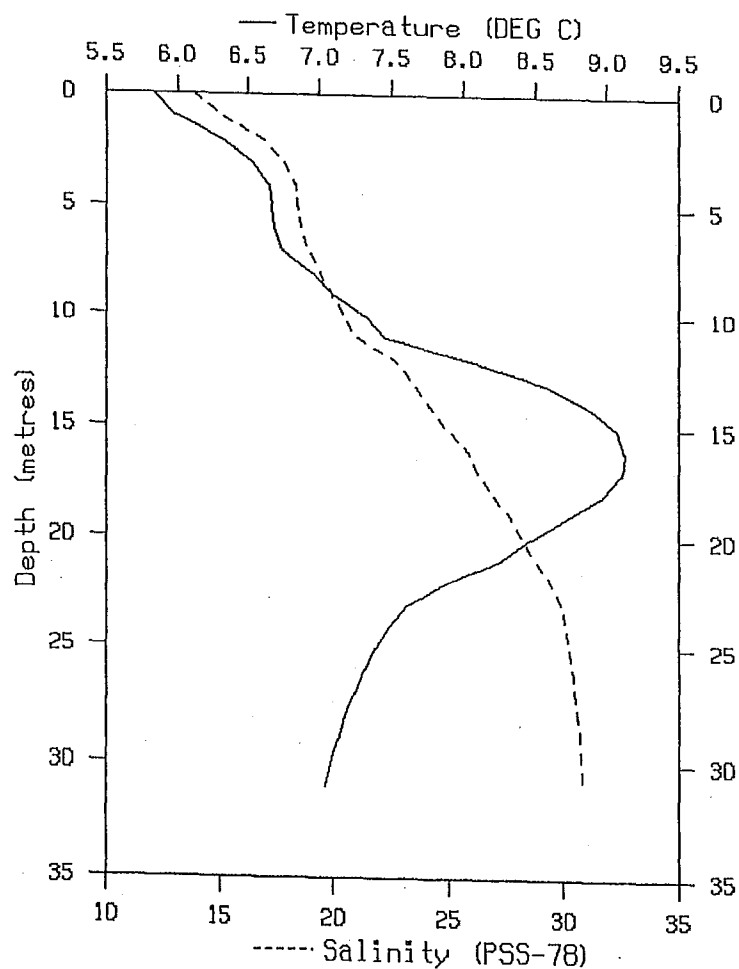
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 REFERENCE NO.: 94-25-002
 DATE/TIME : 10/03/94 23:30 UTC
 POSITION : 54- 1.4N 128-37.2W



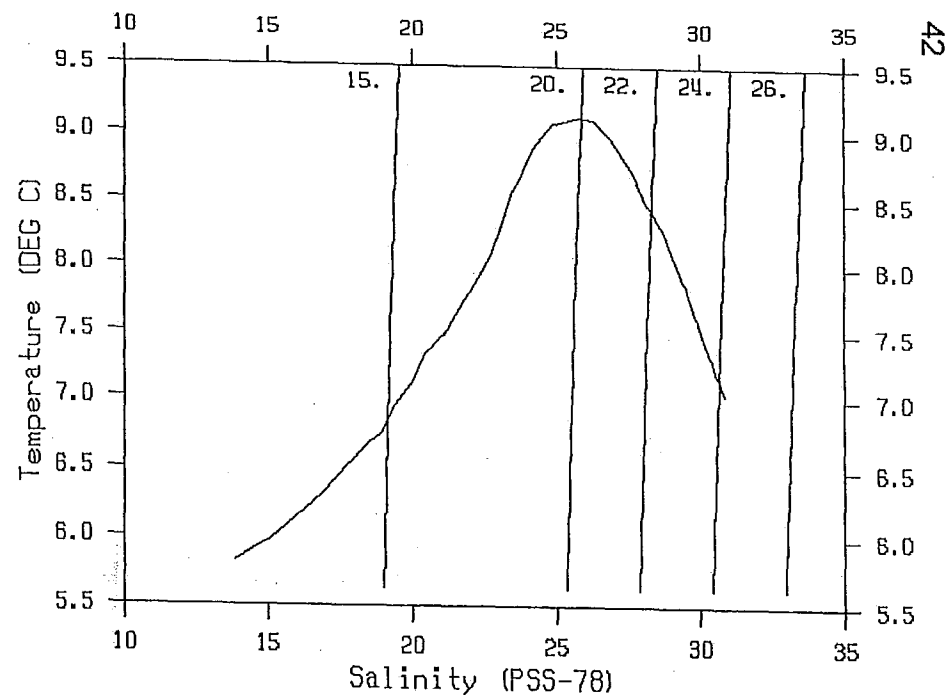
Depth	Temp	Sal	Sigma-t
1	5.98	23.03	18.14
2	5.64	23.78	18.76
3	5.54	24.02	18.96
4	5.51	24.49	19.33
5	5.55	25.24	19.92
6	5.64	25.85	20.39
8	5.72	26.79	21.13
10	5.83	28.56	22.51
12	6.04	30.57	24.08
15	6.34	30.85	24.26
20	6.64	31.16	24.47
25	6.72	31.26	24.54
30	6.79	31.29	24.55
35	6.79	31.30	24.56



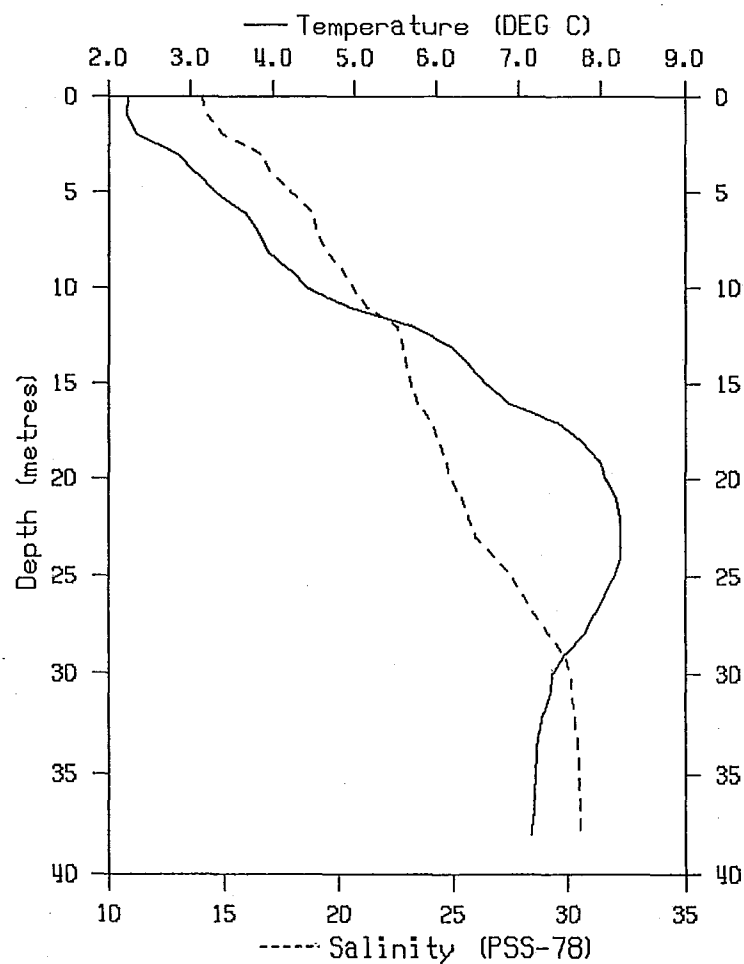
STATION : MB
 REFERENCE NO.: 94-05-008
 DATE/TIME : 10/11/94 20:30 UTC
 POSITION : 54- 1.5N 128-37.1W



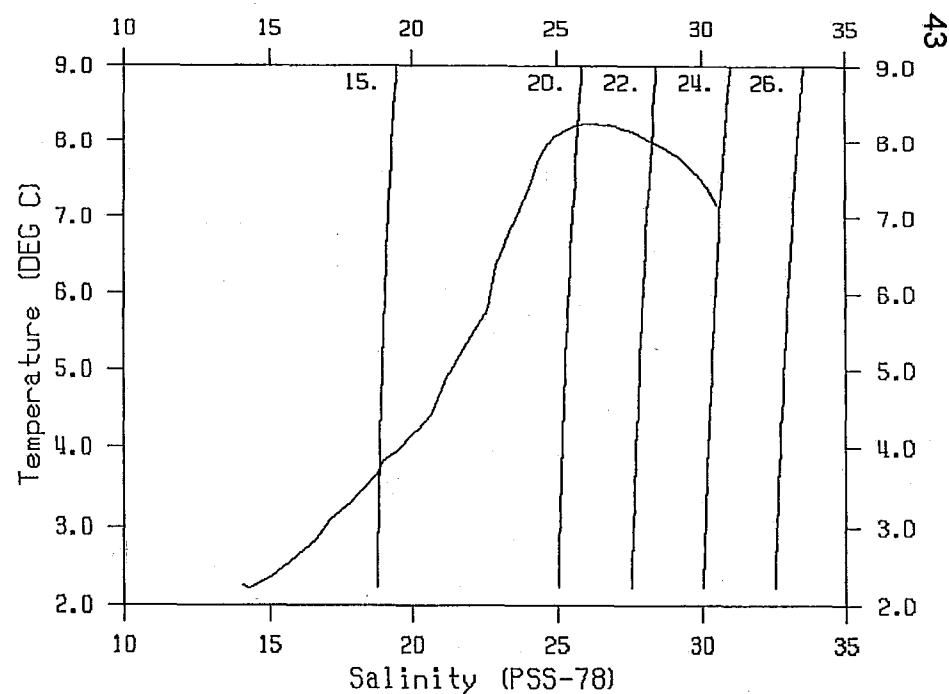
Depth	Temp	Sal	Sigma-t
0	5.83	13.85	10.92
1	5.98	15.13	11.92
2	6.31	16.91	13.29
3	6.53	17.86	14.02
4	6.65	18.35	14.39
5	6.67	18.45	14.47
6	6.69	18.58	14.57
8	6.95	19.43	15.21
10	7.33	20.46	15.98
12	8.08	22.72	17.66
15	9.08	24.94	19.27
20	8.47	28.21	21.91
25	7.40	30.27	23.67
30	7.08	30.78	24.11



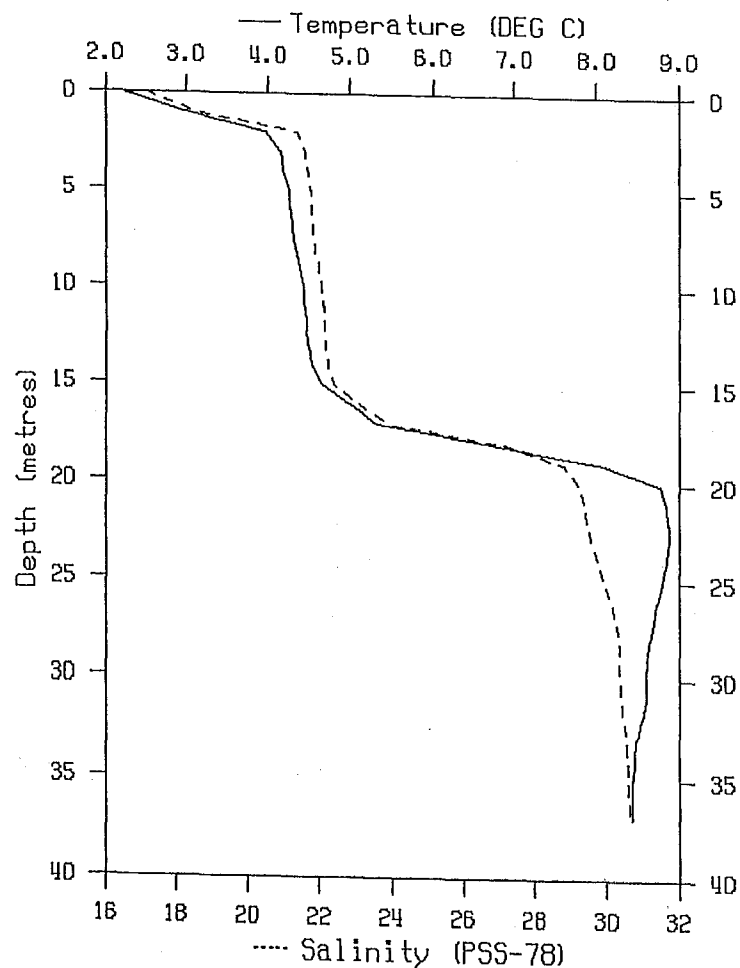
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 POSITION : 54- 1.5N 128-37.0W



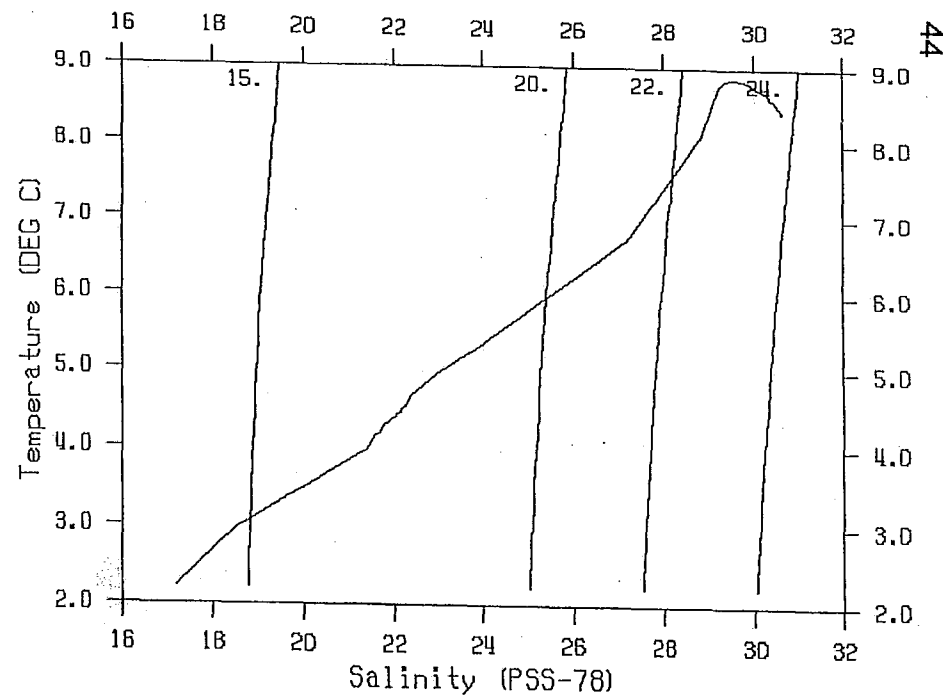
Depth	Temp	Sal	Sigma-t
0	2.24	14.11	11.29
1	2.22	14.29	11.43
2	2.35	15.05	12.04
3	2.85	16.66	13.31
4	3.08	17.11	13.65
5	3.32	17.93	14.30
6	3.65	18.82	14.99
8	3.92	19.44	15.46
10	4.42	20.66	16.40
12	5.73	22.56	17.79
15	6.62	23.22	18.22
20	8.07	24.97	19.43
25	8.15	27.59	21.47
30	7.42	30.10	23.53
35	7.20	30.49	23.87



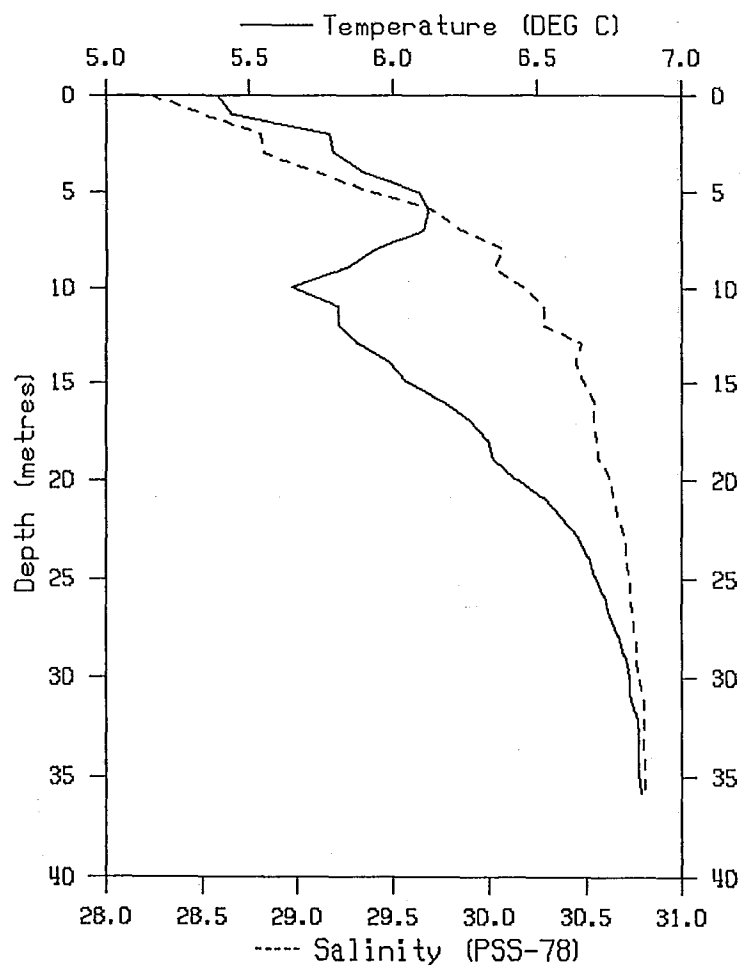
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 REFERENCE NO.: 94-05-010
 DATE/TIME : 01/12/94 20:00 UTC
 POSITION : 53-59.1N 128-39.3W



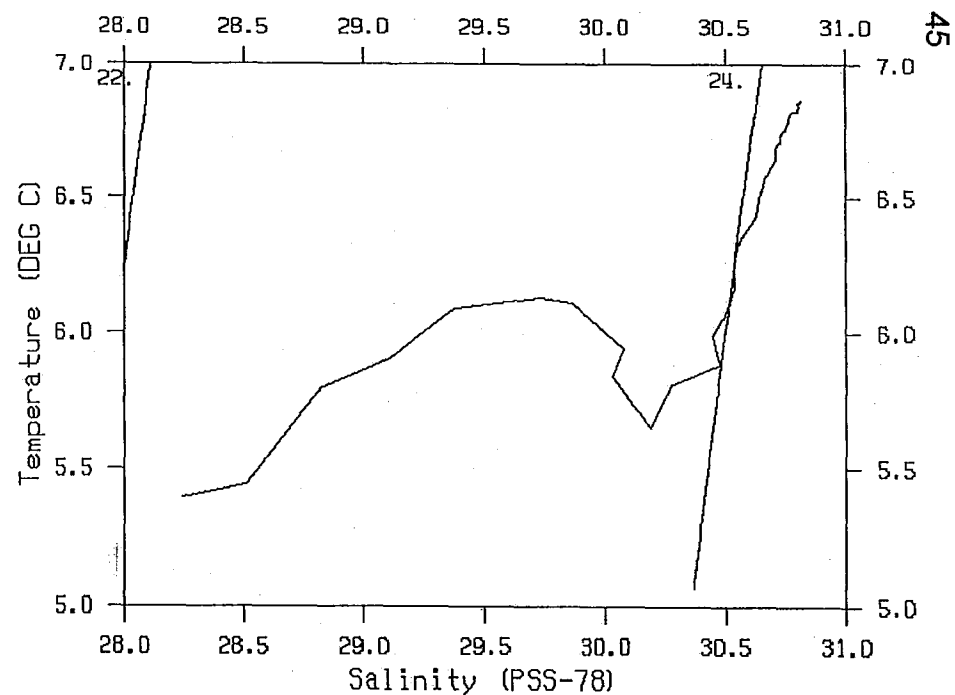
Depth	Temp	Sal	Sigma-t
0	2.23	17.20	13.76
1	2.99	18.58	14.83
2	3.97	21.38	17.00
3	4.15	21.60	17.16
4	4.19	21.69	17.23
5	4.27	21.77	17.29
6	4.28	21.78	17.29
8	4.34	21.90	17.38
10	4.44	22.07	17.51
12	4.47	22.15	17.57
15	4.66	22.38	17.74
20	8.77	29.24	22.67
25	8.81	29.95	23.22
30	8.60	30.38	23.59
35	8.44	30.60	23.78



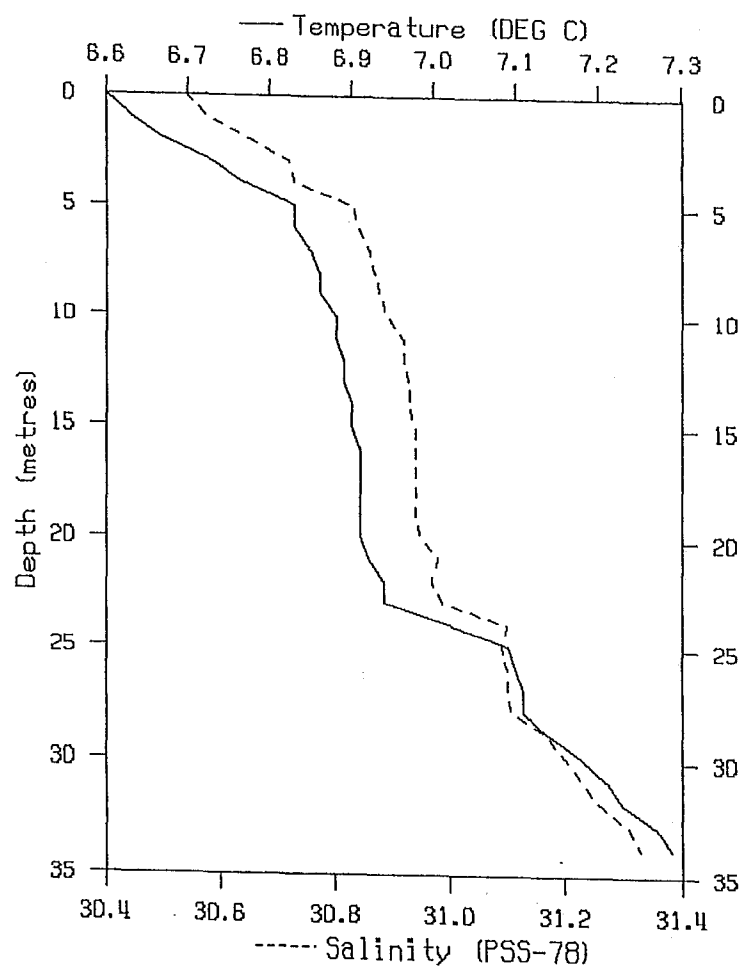
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 POSITION : 54- 1.5N 128-37.0W



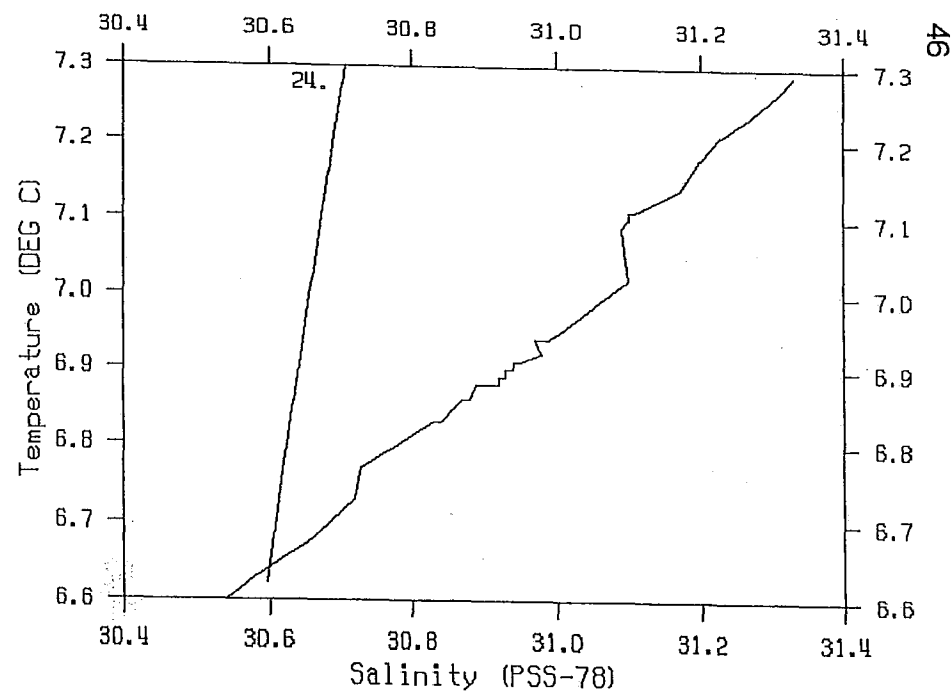
Depth	Temp	Sal	Sigma-t
0	5.39	28.24	22.31
1	5.44	28.51	22.52
2	5.78	28.81	22.72
3	5.80	28.83	22.73
4	5.90	29.11	22.94
5	6.09	29.38	23.13
6	6.13	29.73	23.40
8	5.94	30.08	23.70
10	5.65	30.19	23.82
12	5.81	30.28	23.87
15	6.05	30.49	24.01
20	6.43	30.63	24.08
25	6.70	30.73	24.12
30	6.82	30.78	24.15
35	6.85	30.81	24.16



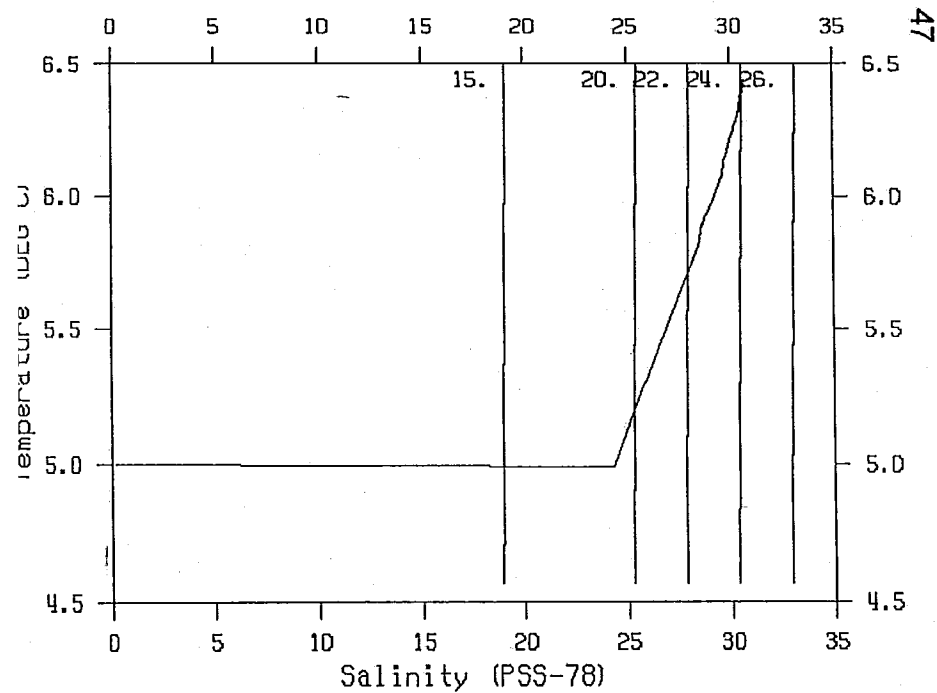
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 DATE/TIME : 12/01/95 17:49 UTC
 POSITION : 53-59.1N 128-39.3W



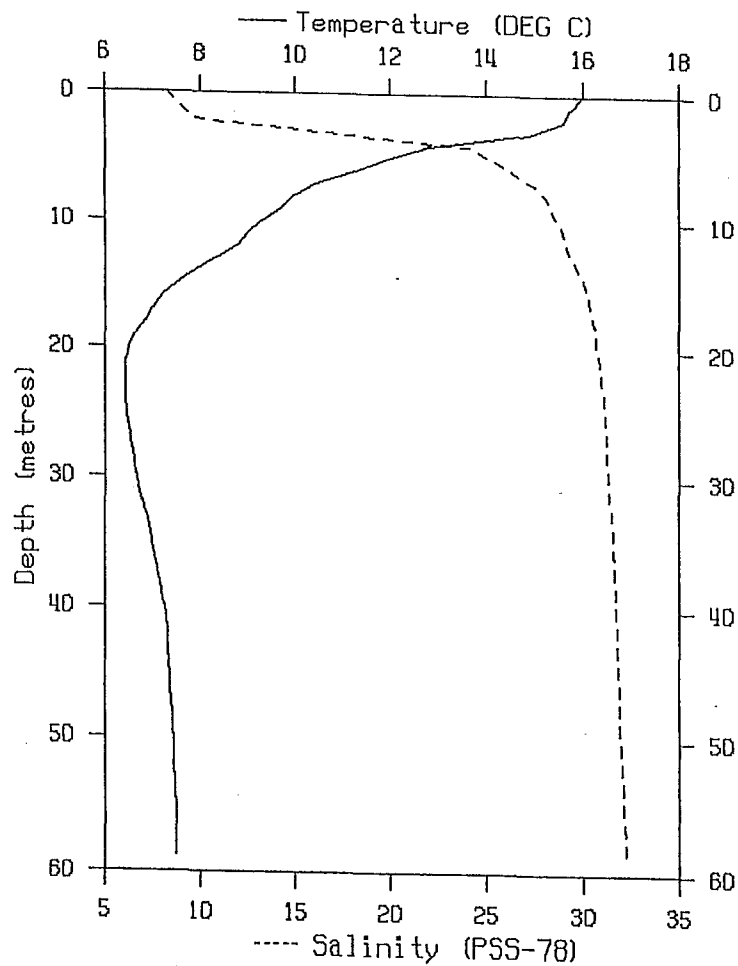
Depth	Temp	Sal	Sigma-t
0	6.60	30.54	23.98
1	6.63	30.58	24.01
2	6.67	30.65	24.06
3	6.73	30.72	24.11
4	6.77	30.73	24.11
5	6.83	30.83	24.18
6	6.83	30.84	24.19
8	6.86	30.87	24.21
10	6.88	30.89	24.22
12	6.89	30.92	24.25
15	6.90	30.94	24.26
20	6.91	30.95	24.27
25	7.09	31.09	24.35
30	7.18	31.20	24.43



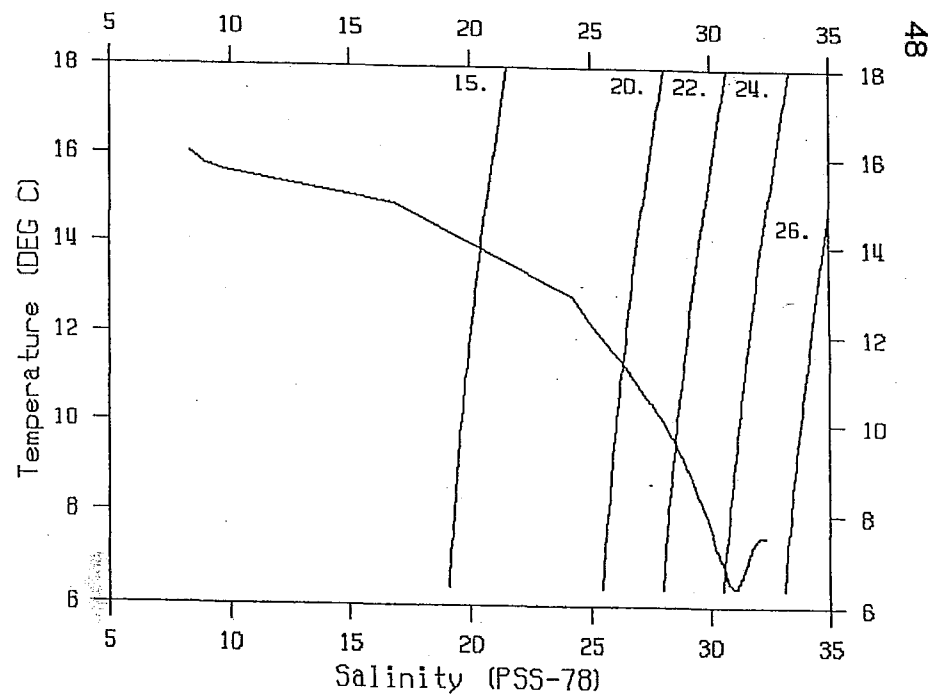
Depth	Temp	Sal	Sigma-t
0	5.00	24.21	19.16
1	4.99	24.34	19.26
2	5.30	25.86	20.44
3	5.56	27.17	21.44
4	5.81	28.45	22.43
5	5.89	28.69	22.61
6	5.93	28.86	22.74
8	6.07	29.59	23.30
10	6.15	29.83	23.48
12	6.28	30.31	23.84
15	6.35	30.49	23.98
20	6.39	30.60	24.06
25	6.41	30.65	24.09
30	6.44	30.70	24.13
35	6.44	30.71	24.14



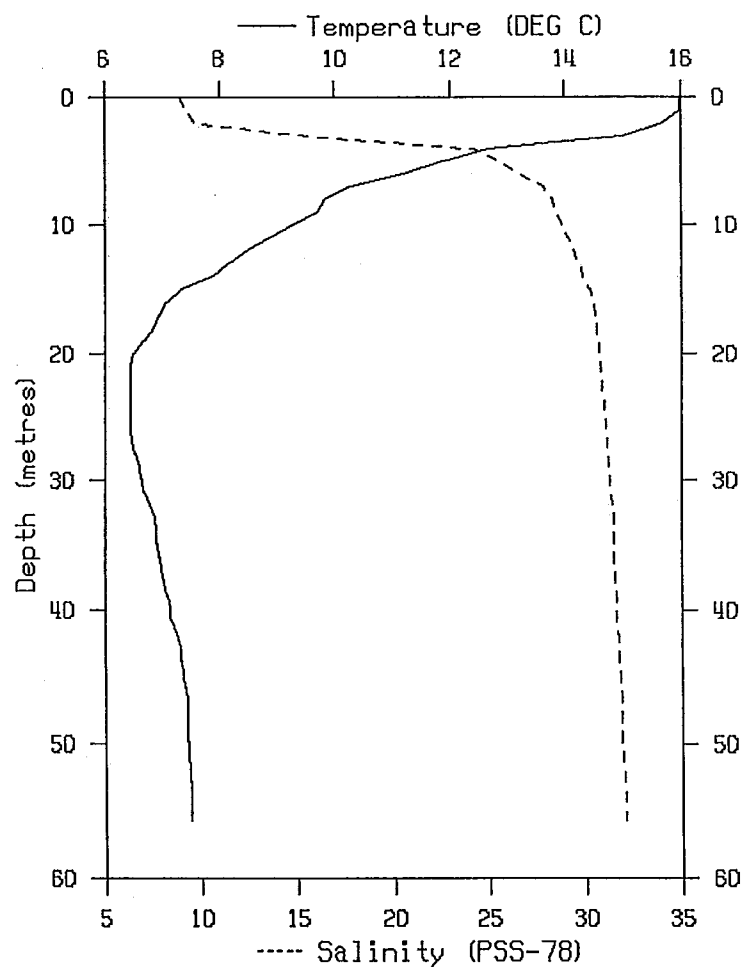
STATION : KA
 REFERENCE NO.: 95-09-004
 DATE/TIME : 10/08/95 19:02 UTC
 POSITION : 53-59.2N 128-39.4W



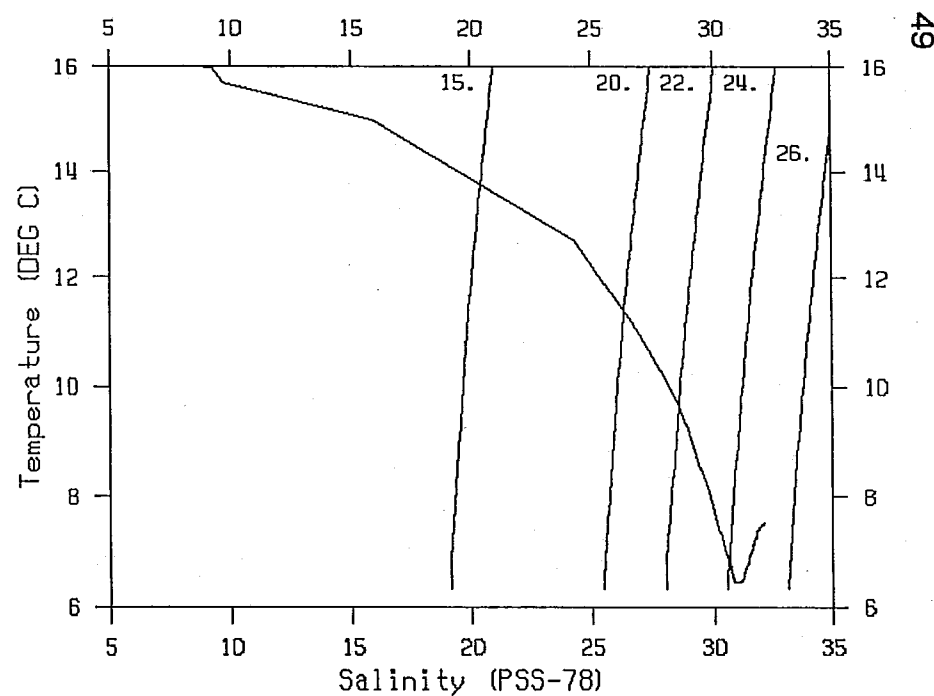
Depth	Temp	Sal	Sigma-t
0	16.02	8.29	5.32
1	15.78	8.98	5.89
2	15.62	9.73	6.49
3	14.89	16.87	12.09
4	12.83	24.24	18.13
5	11.97	25.42	19.19
6	11.30	26.45	20.10
8	10.00	28.16	21.64
10	9.32	28.82	22.26
12	8.78	29.25	22.68
15	7.55	30.14	23.55
20	6.52	30.81	24.21
25	6.47	31.15	24.48
30	6.67	31.33	24.60
35	7.01	31.57	24.74
40	7.26	31.73	24.84
50	7.44	31.93	24.97



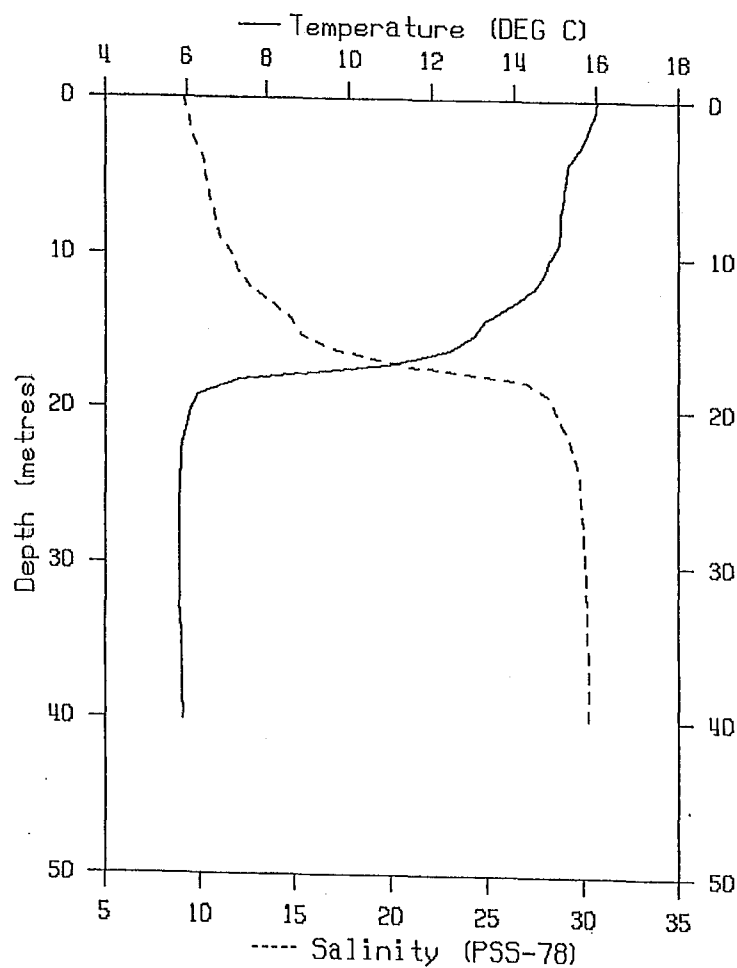
STATION : KA
 REFERENCE NO.: 95-09-005
 DATE/TIME : 10/08/95 19:28 UTC
 POSITION : 53-59.1N 128-39.4W



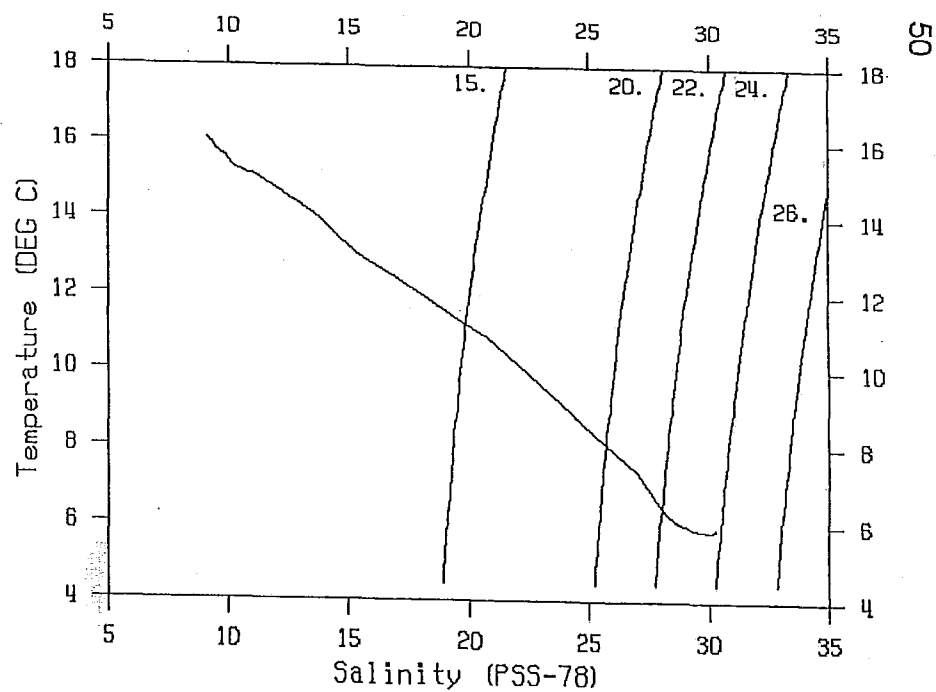
Depth	Temp	Sal	Sigma-t
0	15.99	8.94	5.82
1	15.99	9.26	6.07
2	15.70	9.77	6.51
3	15.00	15.90	11.33
4	12.68	24.33	18.23
5	11.89	25.59	19.34
6	11.18	26.66	20.29
8	9.84	28.36	21.82
10	9.30	28.87	22.30
12	8.51	29.46	22.88
15	7.34	30.27	23.68
20	6.52	30.81	24.21
25	6.45	31.08	24.43
30	6.65	31.30	24.58
35	6.93	31.52	24.71
40	7.14	31.65	24.79
50	7.45	31.92	24.96



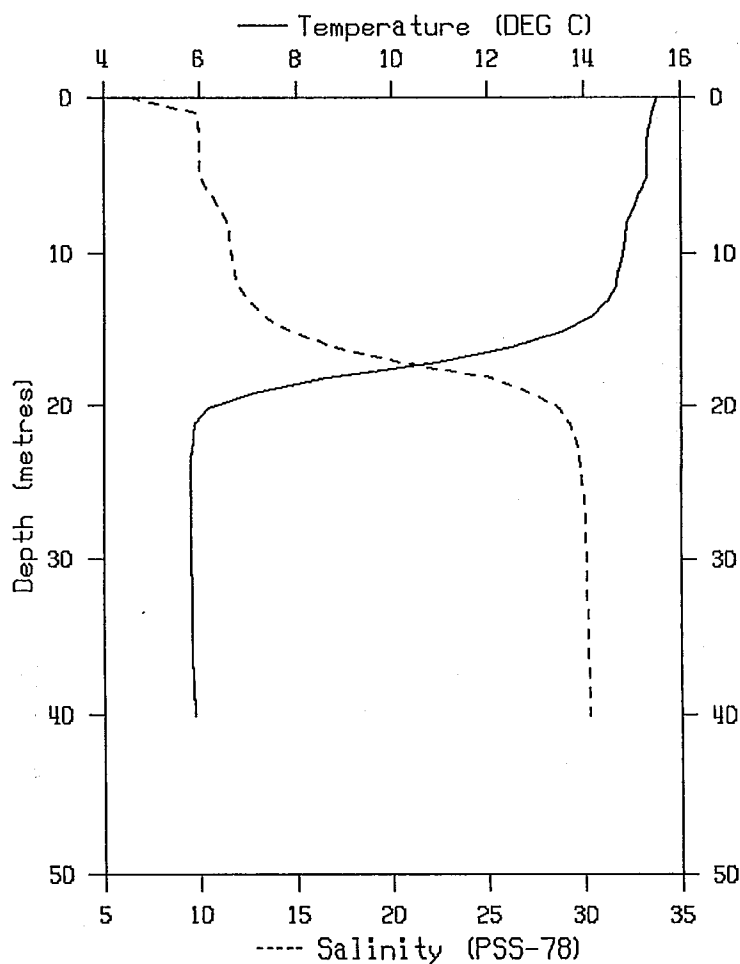
STATION : MB
 REFERENCE NO.: 95-09-006
 DATE/TIME : 10/08/95 20:56 UTC
 POSITION : 54- 1.4N 128-37.3W



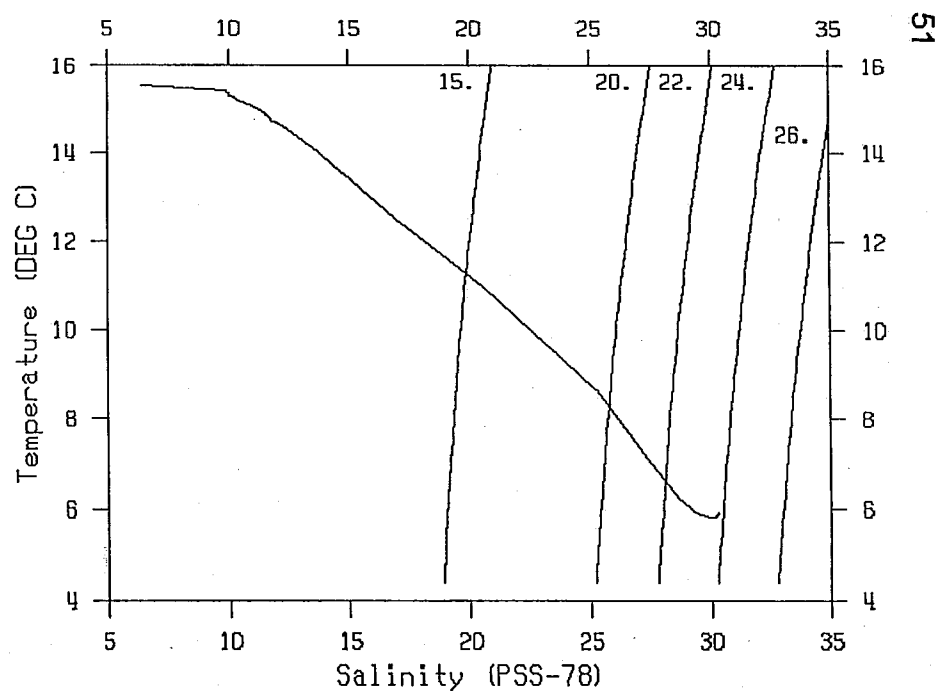
Depth	Temp	Sal	Sigma-t
0	16.03	9.18	6.00
1	15.96	9.39	6.17
2	15.79	9.50	6.29
3	15.59	9.89	6.62
4	15.32	10.24	6.94
5	15.27	10.35	7.03
6	15.22	10.51	7.16
8	15.13	10.86	7.45
10	14.86	11.76	8.18
12	14.46	12.72	8.99
15	13.05	15.33	11.23
20	6.10	28.60	22.51
25	5.83	29.89	23.56
30	5.83	30.13	23.75
35	5.88	30.27	23.86
40	5.90	30.30	23.88



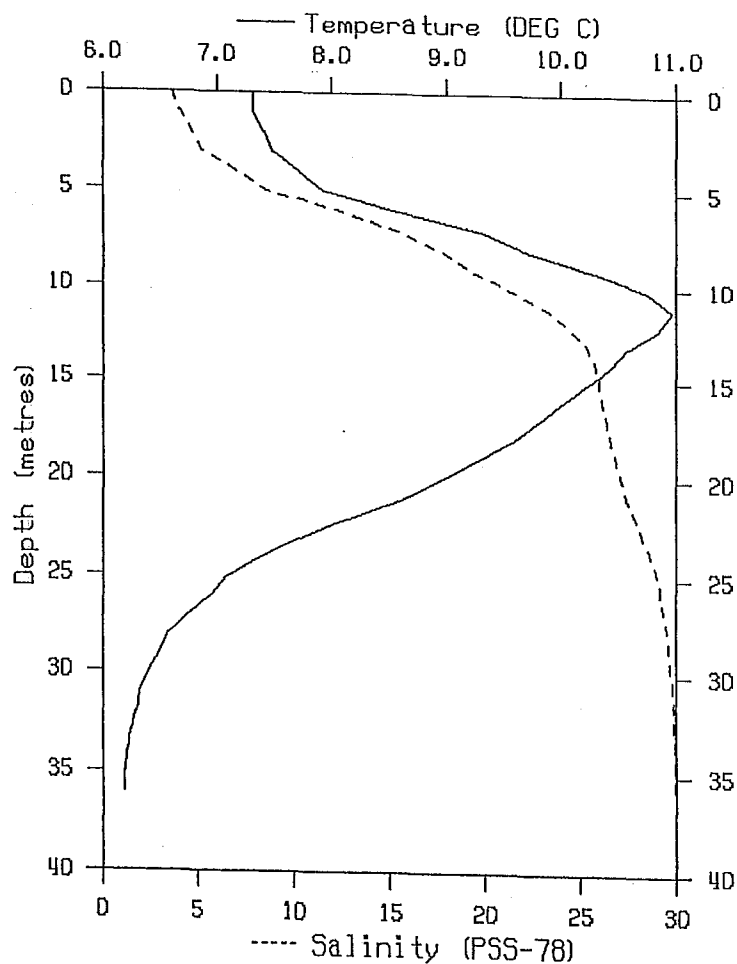
STATION : MB
 REFERENCE NO.: 95-09-007
 DATE/TIME : 10/08/95 21:17 UTC
 POSITION : 54- 1.4N 128-37.3W



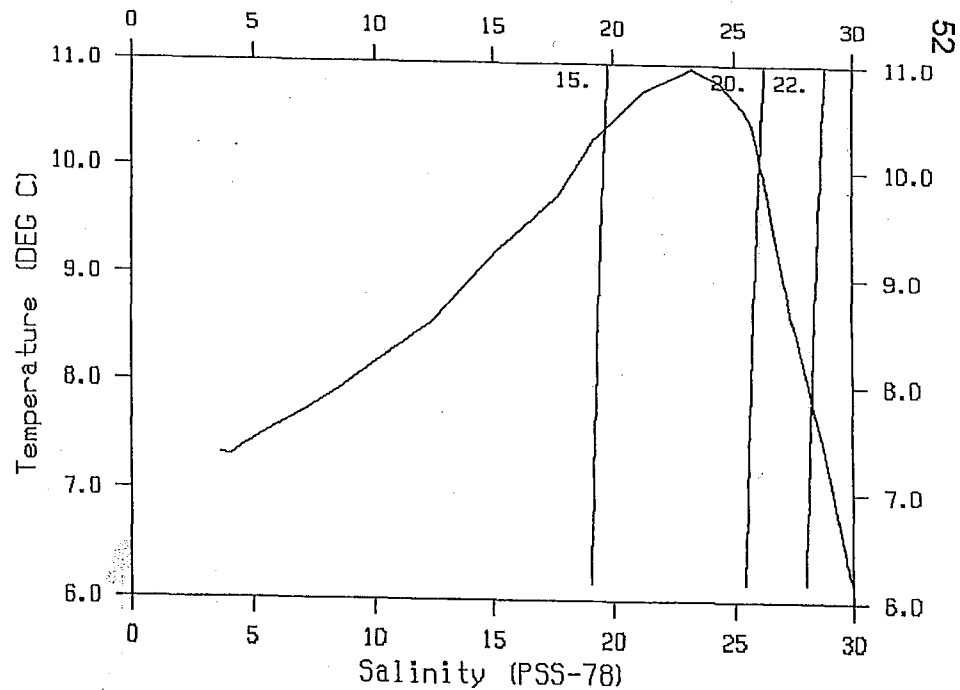
Depth	Temp	Sal	Sigma-t
0	15.56	6.44	3.99
1	15.43	9.90	6.66
2	15.36	10.00	6.75
3	15.32	10.05	6.79
4	15.34	10.01	6.76
5	15.32	10.11	6.84
6	15.18	10.52	7.18
8	14.90	11.52	7.99
10	14.81	11.69	8.14
12	14.68	12.08	8.46
15	13.55	14.74	10.69
20	6.20	28.74	22.61
25	5.82	29.97	23.63
30	5.83	30.16	23.78
35	5.86	30.24	23.84
40	5.90	30.30	23.88



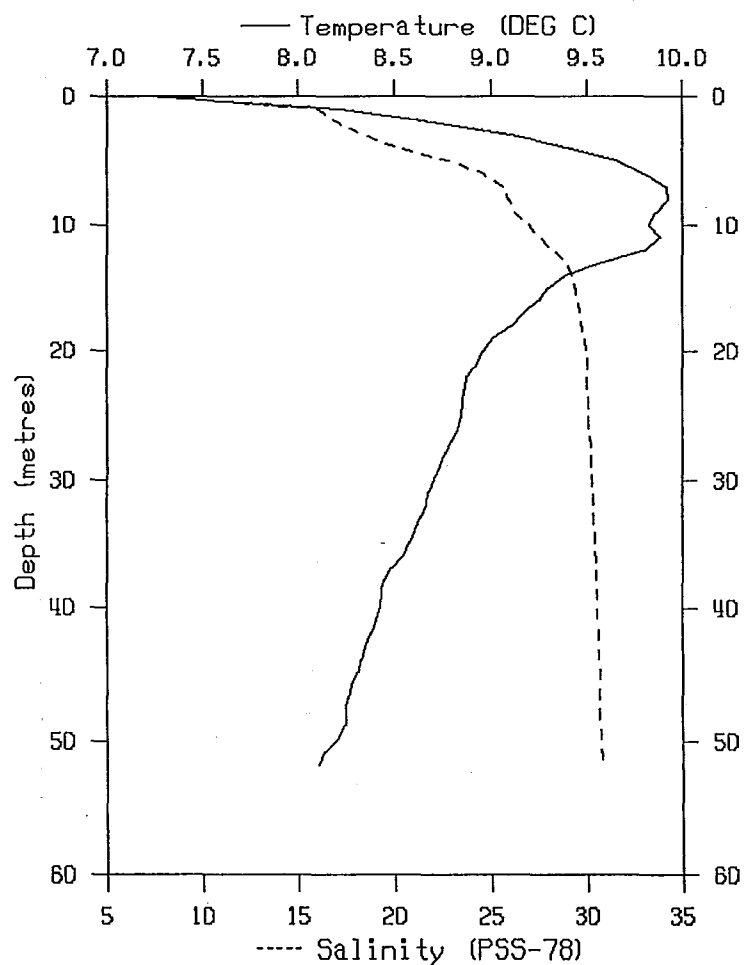
STATION : MB
 REFERENCE NO.: 95-09-008
 DATE/TIME : 25/10/95 18:30 UTC
 POSITION : 54- 1.5N 128-37.3W



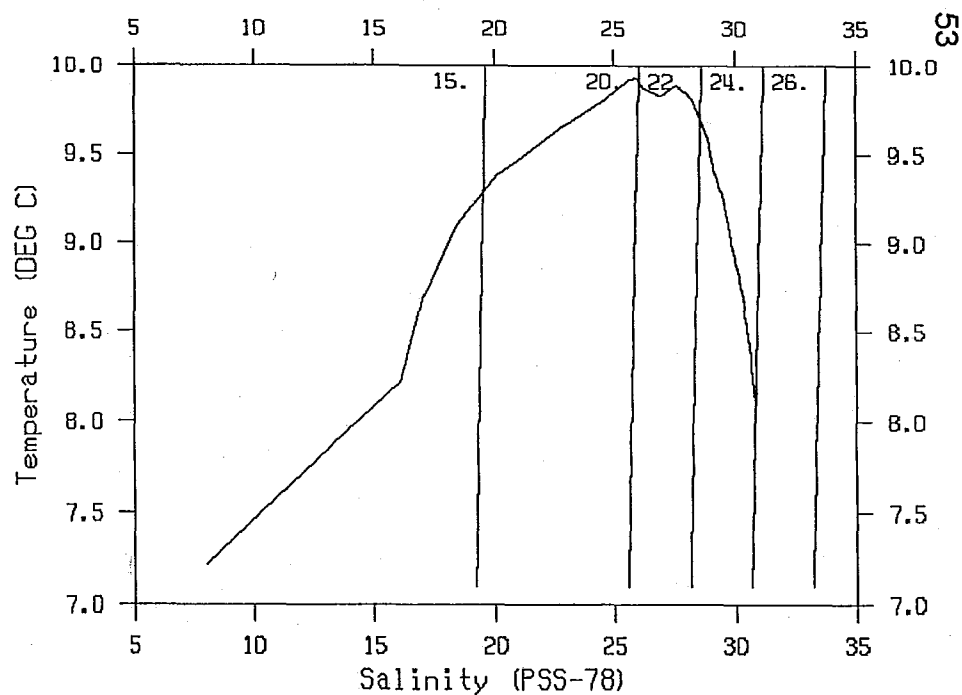
Depth	Temp	Sal	Sigma-t
0	7.33	3.67	2.81
1	7.32	4.08	3.14
2	7.42	4.72	3.63
3	7.49	5.29	4.08
4	7.72	7.05	5.44
5	7.94	8.60	6.64
6	8.57	12.45	9.59
8	9.74	17.73	13.56
10	10.75	21.35	16.24
12	10.84	24.43	18.61
15	10.23	26.00	19.93
20	8.94	27.15	21.01
25	7.09	29.06	22.76
30	6.41	29.73	23.37
35	6.21	29.92	23.54



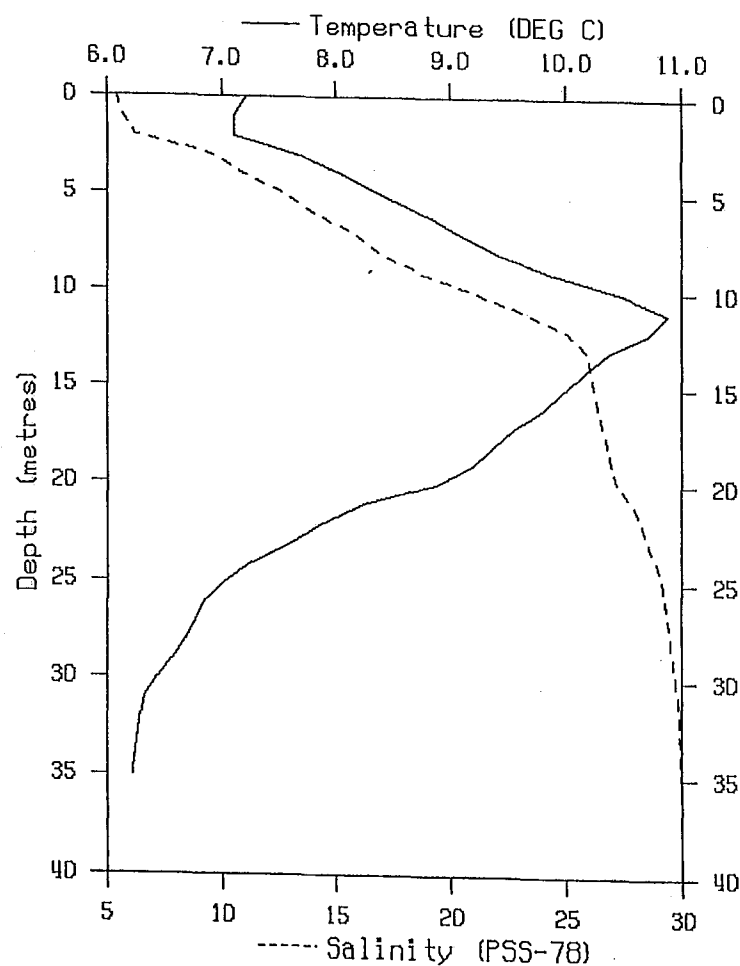
STATION : KA
 REFERENCE NO.: 95-09-009
 DATE/TIME : 25/10/95 20:20 UTC
 POSITION : 53-59.1N 128-39.4W



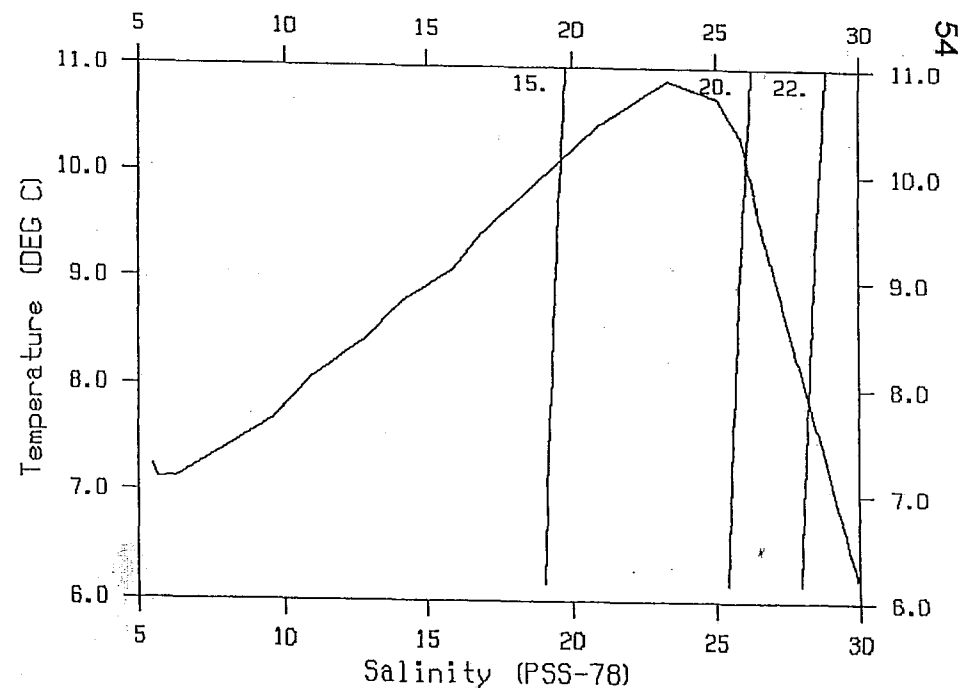
Depth	Temp	Sal	Sigma-t
0	7.22	8.04	6.26
1	8.22	16.10	12.47
2	8.70	17.09	13.19
3	9.10	18.45	14.21
4	9.39	20.21	15.54
5	9.66	22.95	17.64
6	9.81	24.67	18.95
8	9.93	25.97	19.95
10	9.83	26.99	20.76
12	9.81	28.24	21.73
15	9.30	29.40	22.72
20	8.96	29.97	23.21
25	8.85	30.12	23.35
30	8.71	30.32	23.52
35	8.58	30.44	23.64
40	8.43	30.59	23.78
50	8.21	30.75	23.93



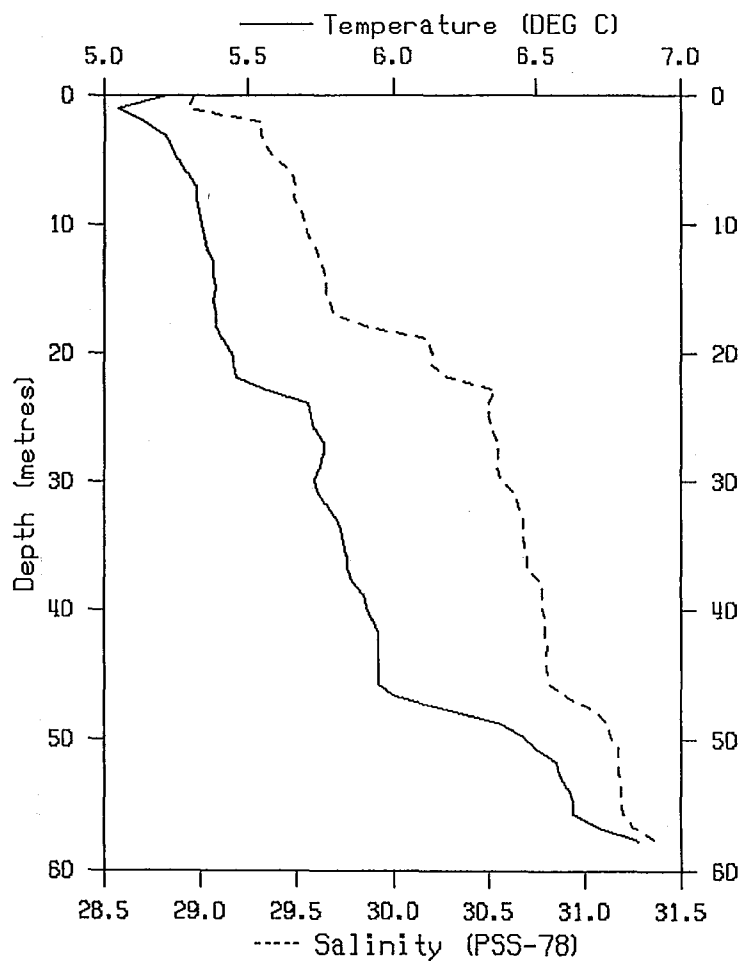
STATION : MB
 REFERENCE NO.: 95-09-010
 DATE/TIME : 26/10/95 18:12 UTC
 POSITION : 54- 1.4N 128-37.3W



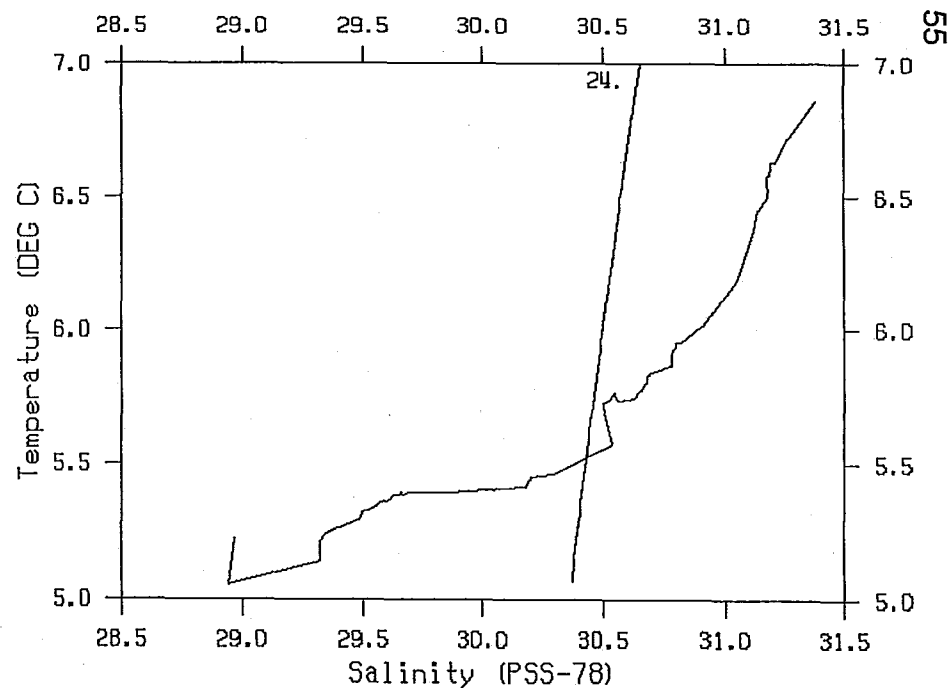
Depth	Temp	Sal	Sigma-t
0	7.23	5.47	4.24
1	7.11	5.68	4.41
2	7.12	6.30	4.90
3	7.68	9.64	7.47
4	8.08	11.05	8.54
5	8.41	12.80	9.88
6	8.79	14.17	10.91
8	9.43	16.98	13.02
10	10.47	21.03	16.03
12	10.71	25.11	19.16
15	9.99	26.23	20.14
20	8.87	27.27	21.12
25	7.02	29.15	22.84
30	6.45	29.72	23.36
35	6.23	29.93	23.55



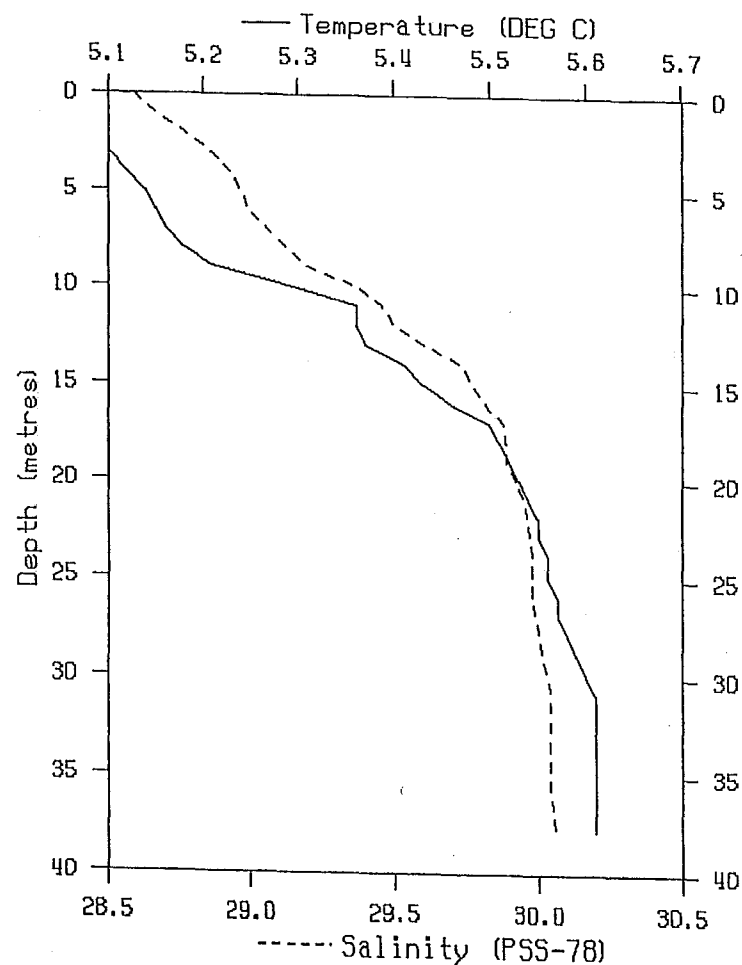
STATION : KA
 REFERENCE NO.: 96-04-001
 DATE/TIME : 06/02/96 18:05 UTC
 POSITION : 53-59.1N 128-39.3W



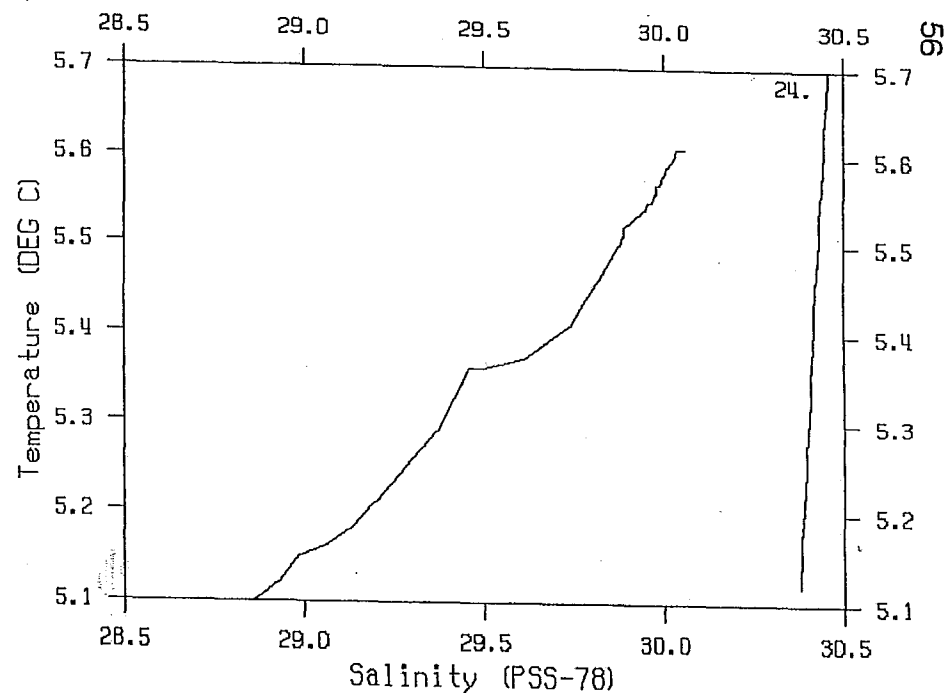
Depth	Temp	Sal	Sigma-t
0	5.22	28.97	22.90
1	5.05	28.94	22.90
2	5.14	29.32	23.19
3	5.21	29.32	23.18
4	5.24	29.35	23.20
5	5.26	29.40	23.24
6	5.29	29.48	23.30
8	5.32	29.49	23.30
10	5.34	29.55	23.35
12	5.36	29.61	23.39
15	5.39	29.66	23.43
20	5.44	30.20	23.85
25	5.72	30.50	24.06
30	5.73	30.57	24.11
35	5.83	30.69	24.19
40	5.91	30.78	24.26
50	6.45	31.14	24.48



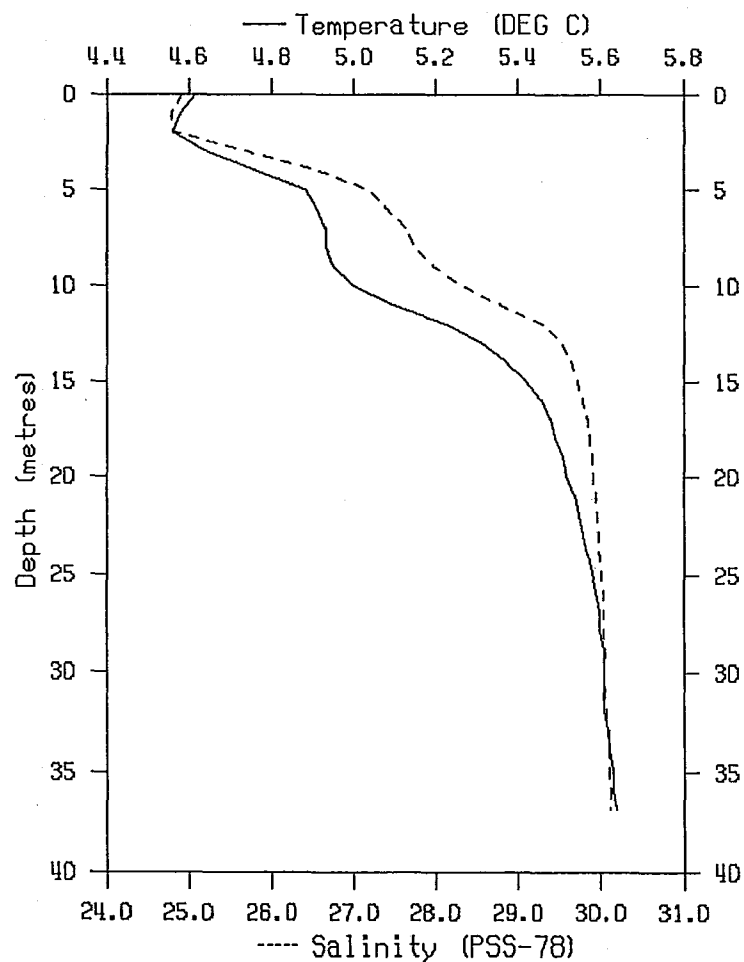
STATION : MB
 REFERENCE NO.: 96-04-002
 DATE/TIME : 06/02/96 23:00 UTC
 POSITION : 54- 1.4N 128-37.3W



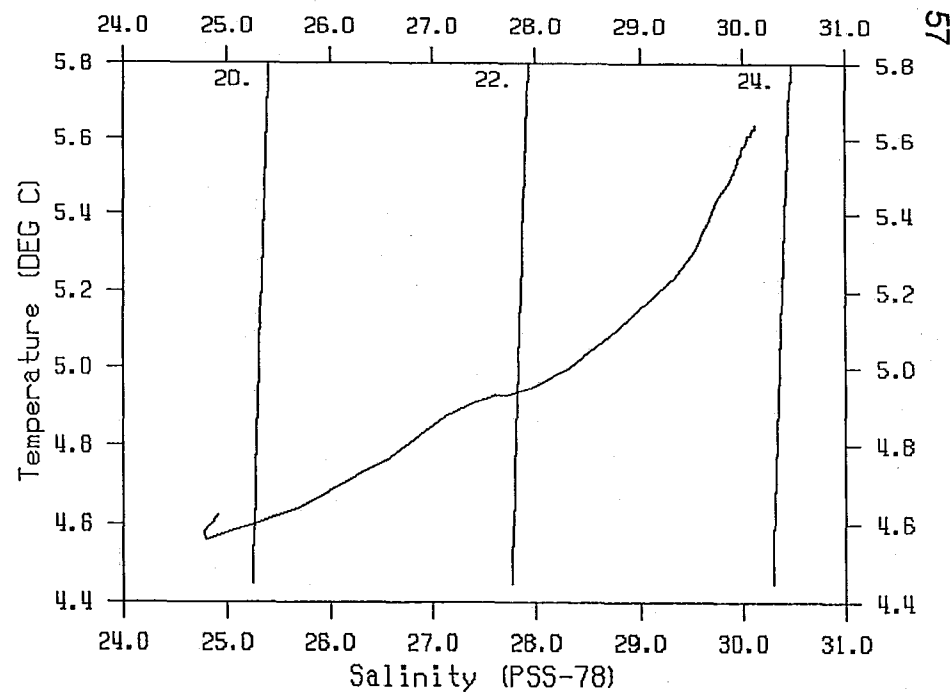
Depth	Temp	Sal	Sigma-t
0	5.10	28.59	22.61
1	5.10	28.67	22.68
2	5.10	28.77	22.76
3	5.10	28.86	22.83
4	5.12	28.93	22.88
5	5.14	28.97	22.91
6	5.15	28.99	22.92
8	5.18	29.13	23.03
10	5.29	29.37	23.21
12	5.36	29.50	23.31
15	5.43	29.77	23.51
20	5.53	29.92	23.62
25	5.56	29.98	23.66
30	5.60	30.03	23.70
35	5.61	30.04	23.71



STATION : MB
 REFERENCE NO.: 96-04-003
 DATE/TIME : 07/02/96 21:23 UTC
 POSITION : 54- 1.4N 128-37.3W

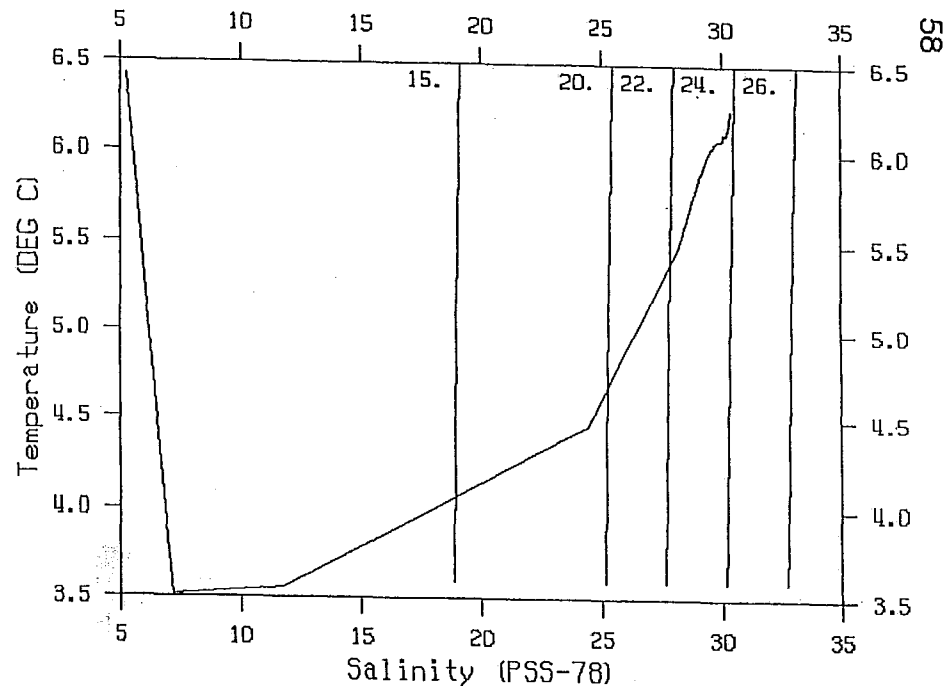
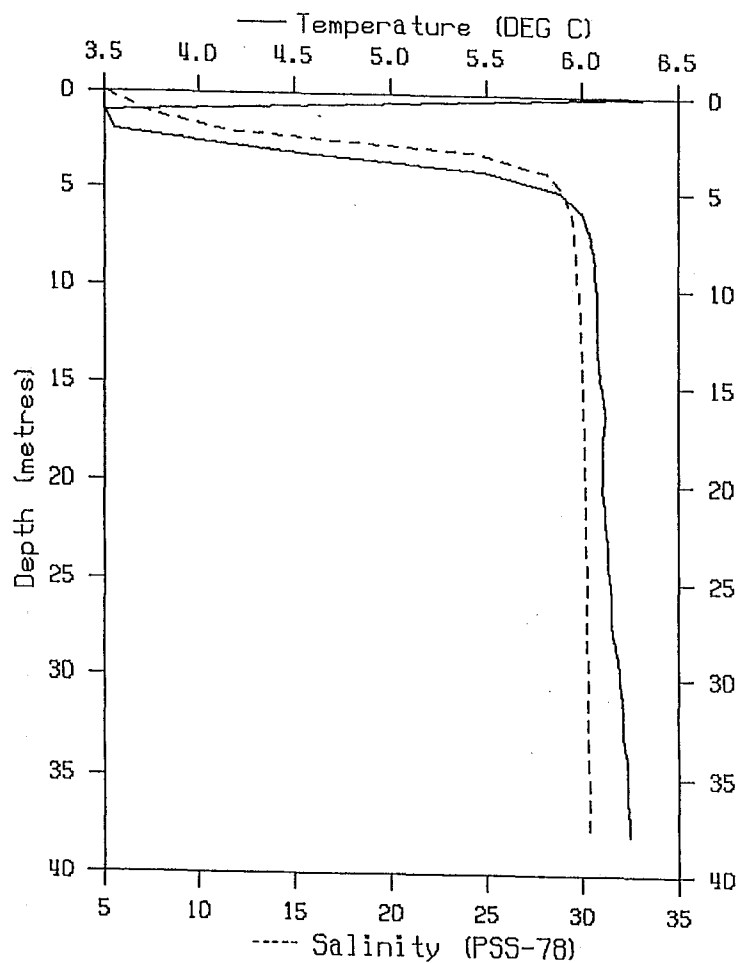


Depth	Temp	Sal	Sigma-t
0	4.62	24.92	19.75
1	4.58	24.79	19.65
2	4.56	24.81	19.67
3	4.64	25.71	20.38
4	4.76	26.55	21.03
5	4.88	27.17	21.51
6	4.91	27.42	21.71
8	4.93	27.74	21.96
10	5.00	28.33	22.42
12	5.23	29.31	23.17
15	5.42	29.73	23.48
20	5.52	29.92	23.62
25	5.58	30.01	23.69
30	5.61	30.05	23.71
35	5.63	30.11	23.76

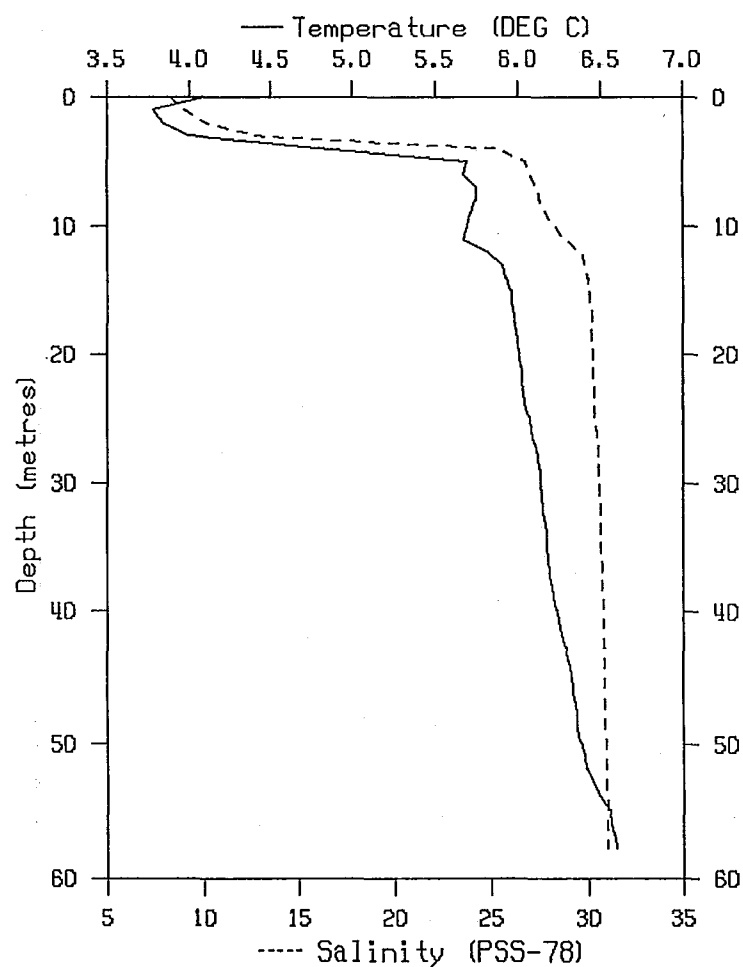


STATION : MB
 REFERENCE NO.: 96-04-004
 DATE/TIME : 12/03/96 21:40 UTC
 POSITION : 54- 1.4N 128-37.3W

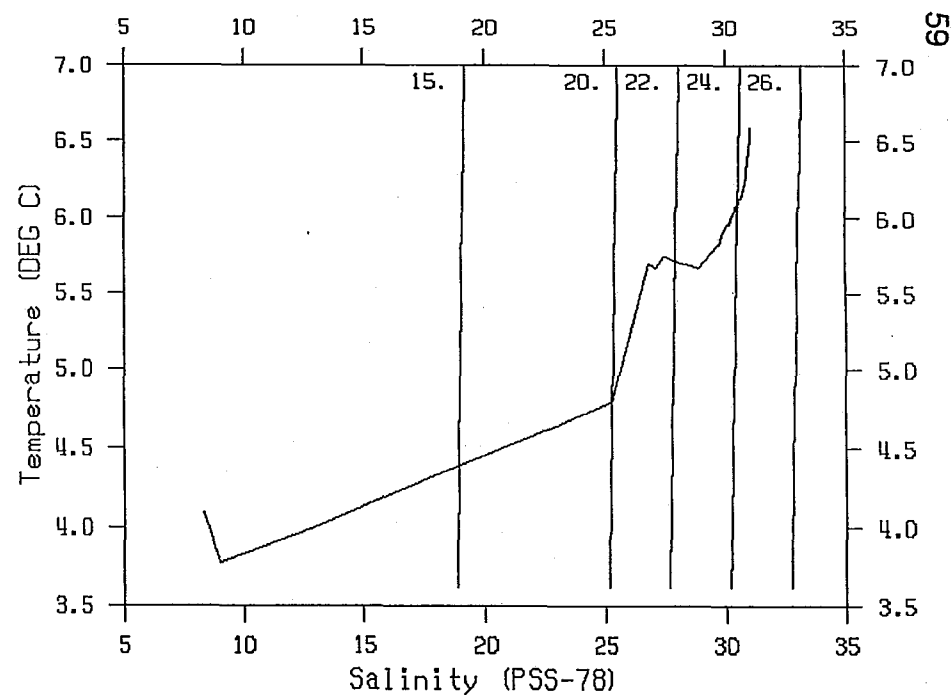
Depth	Temp	Sal	Sigma-t
0	6.42	5.26	4.12
1	3.51	7.22	5.77
2	3.56	11.78	9.40
3	4.46	24.42	19.37
4	5.48	28.21	22.27
5	5.89	29.15	22.97
6	6.00	29.45	23.20
8	6.06	29.69	23.38
10	6.08	29.86	23.51
12	6.08	29.98	23.60
15	6.11	30.09	23.69
20	6.11	30.20	23.77
25	6.15	30.28	23.83
30	6.20	30.35	23.88
35	6.24	30.40	23.92



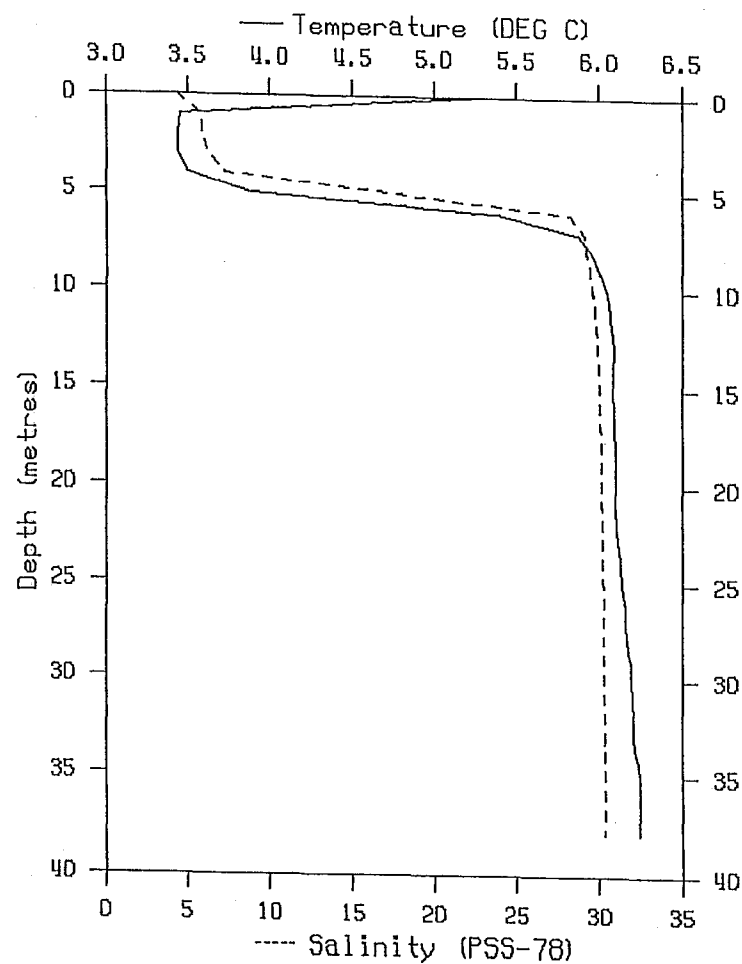
STATION : KA
 REFERENCE NO.: 96-04-005
 DATE/TIME : 13/03/96 15:10 UTC
 POSITION : 53-59.2N 128-39.3W



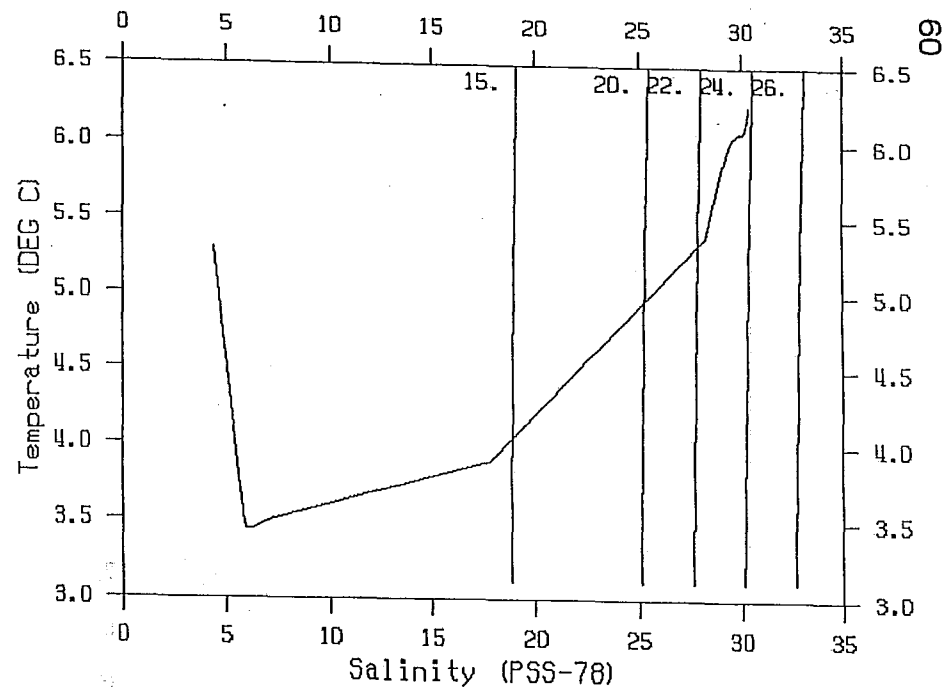
Depth	Temp	Sal	Sigma-t
0	4.09	8.31	6.63
1	3.78	9.05	7.22
2	3.84	10.12	8.07
3	3.99	12.81	10.20
4	4.79	25.28	20.02
5	5.70	26.86	21.19
6	5.67	27.11	21.39
8	5.75	27.55	21.72
10	5.70	28.34	22.35
12	5.82	29.74	23.45
15	5.96	30.11	23.72
20	6.01	30.29	23.86
25	6.07	30.44	23.97
30	6.13	30.63	24.11
35	6.17	30.73	24.19
40	6.23	30.82	24.25
50	6.37	30.94	24.33



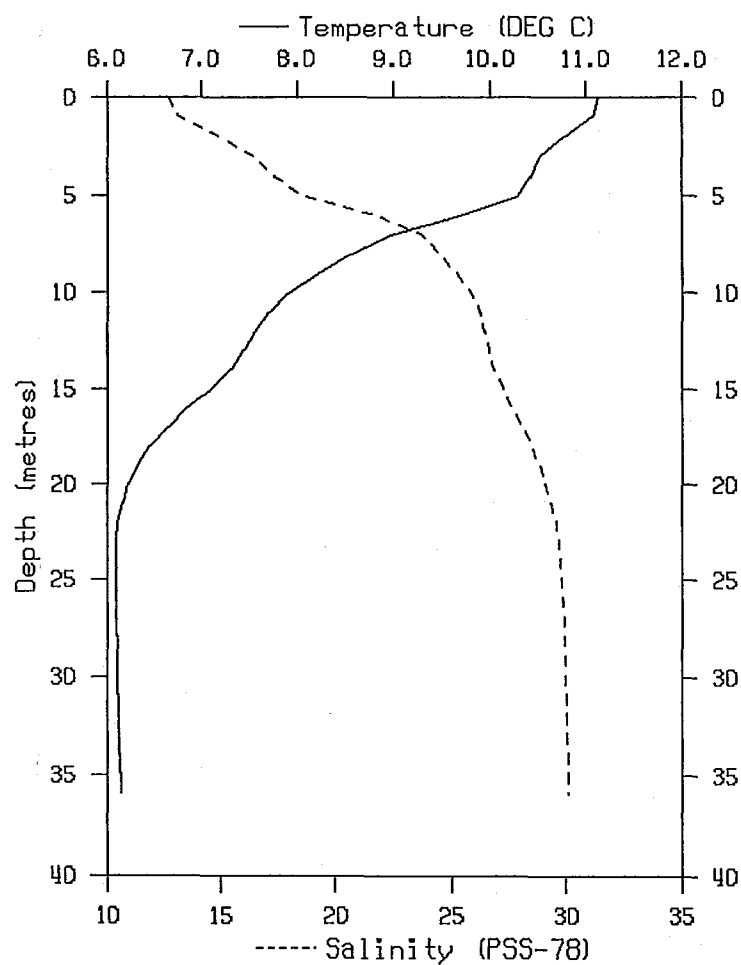
STATION : MB
REFERENCE NO.: 96-04-006
DATE/TIME : 13/03/96 16:45 UTC
POSITION : 54- 1.4N 128-37.3W



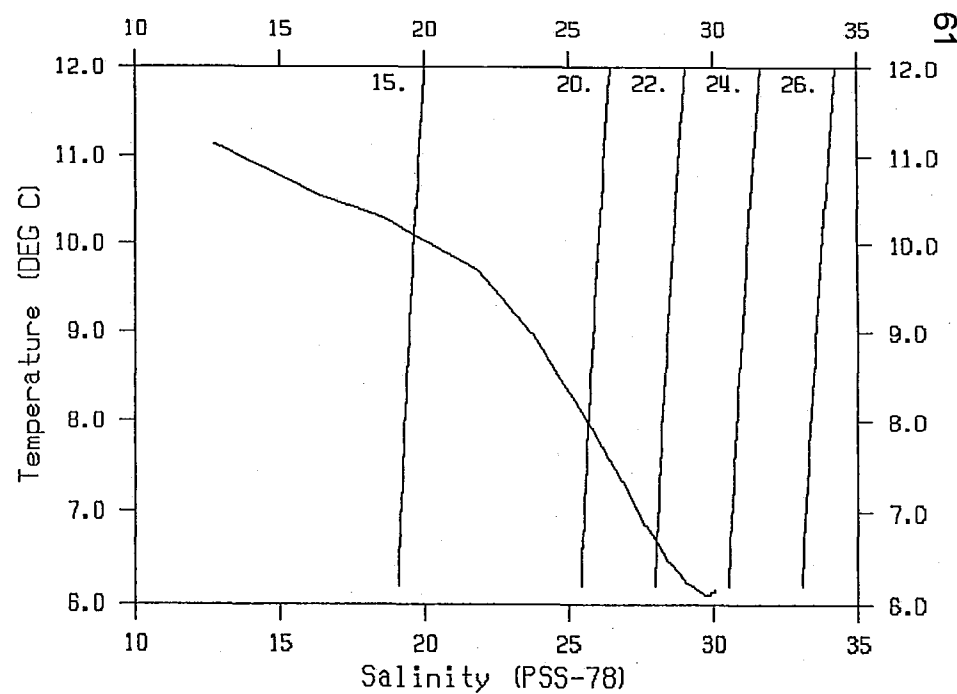
Depth	Temp	Sal	Sigma-t
0	5.29	4.43	3.51
1	3.46	5.90	4.72
2	3.44	5.90	4.72
3	3.44	6.24	4.99
4	3.51	7.35	5.88
5	3.89	17.78	14.15
6	5.38	28.26	22.32
8	5.96	29.30	23.08
10	6.05	29.65	23.35
12	6.08	29.90	23.54
15	6.08	30.04	23.65
20	6.10	30.16	23.74
25	6.14	30.26	23.82
30	6.19	30.33	23.87
35	6.25	30.39	23.91



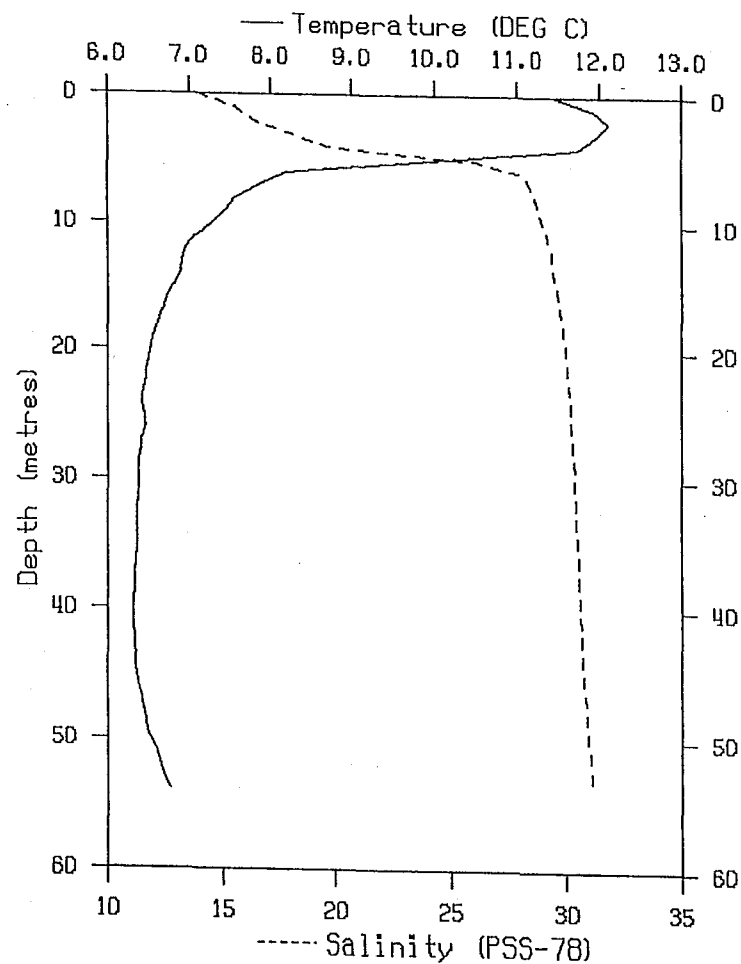
STATION : MB
 REFERENCE NO.: 96-04-007
 DATE/TIME : 22/05/96 17:20 UTC
 POSITION : 54- 1.4N 128-37.3W



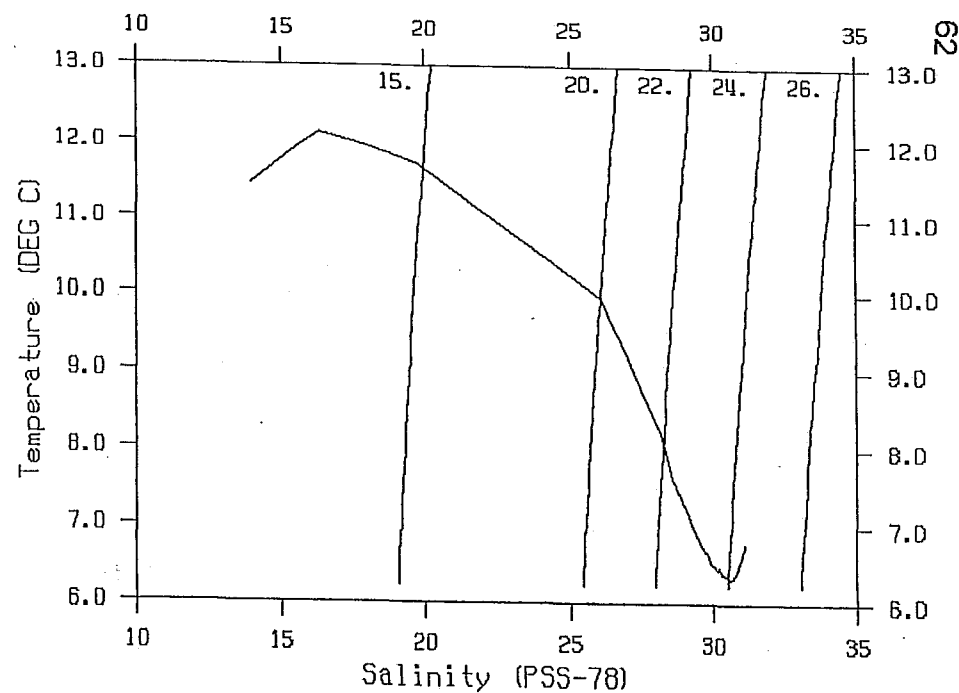
Depth	Temp	Sal	Sigma-t
0	11.14	12.75	9.52
1	11.08	13.22	9.89
2	10.79	14.99	11.30
3	10.53	16.44	12.46
4	10.43	17.37	13.19
5	10.29	18.64	14.20
6	9.69	21.84	16.77
8	8.56	24.54	19.03
10	7.91	25.88	20.16
12	7.57	26.45	20.65
15	7.12	27.24	21.32
20	6.23	29.10	22.89
25	6.10	29.82	23.48
30	6.12	29.99	23.61
35	6.15	30.06	23.66



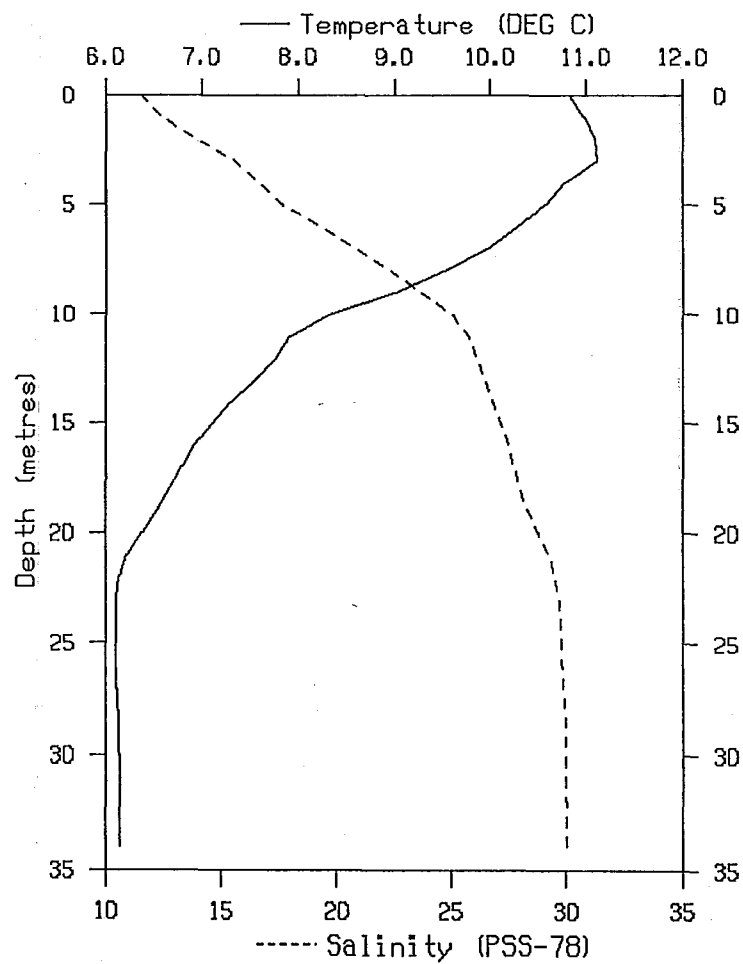
STATION : KA
 REFERENCE NO.: 96-04-008
 DATE/TIME : 23/05/96 13:25 UTC
 POSITION : 53-59.2N 128-39.4W



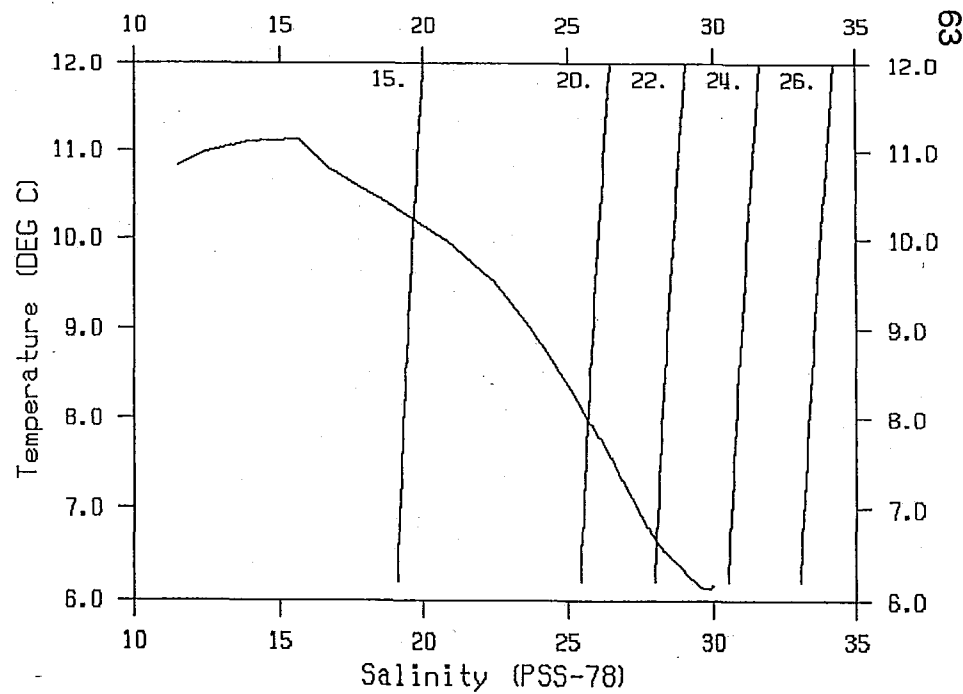
Depth	Temp	Sal	Sigma-t
0	11.44	13.96	10.41
1	11.92	15.57	11.59
2	12.12	16.39	12.19
3	11.95	18.01	13.47
4	11.73	19.69	14.80
5	9.97	26.07	20.02
6	8.22	28.18	21.92
8	7.58	28.67	22.39
10	7.28	29.01	22.69
12	6.96	29.36	23.01
15	6.81	29.56	23.19
20	6.54	29.97	23.54
25	6.46	30.24	23.76
30	6.38	30.36	23.87
35	6.36	30.49	23.97
40	6.32	30.59	24.06
50	6.52	30.94	24.31



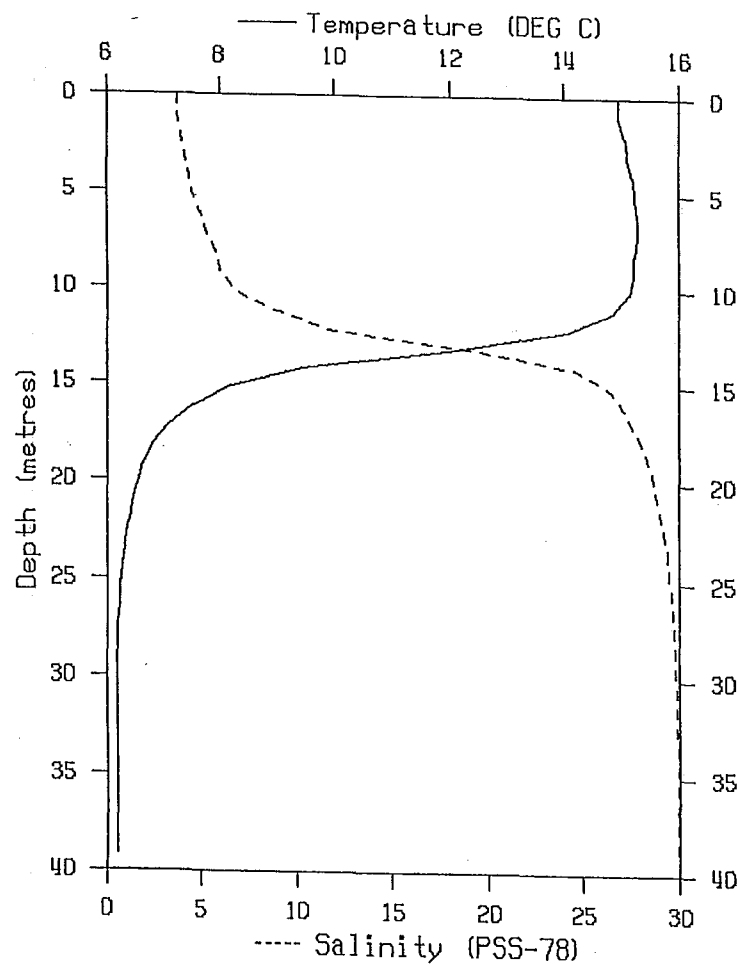
STATION : MB
 REFERENCE NO.: 96-04-009
 DATE/TIME : 23/05/96 14:40 UTC
 POSITION : 54- 1.4N 128-37.4W



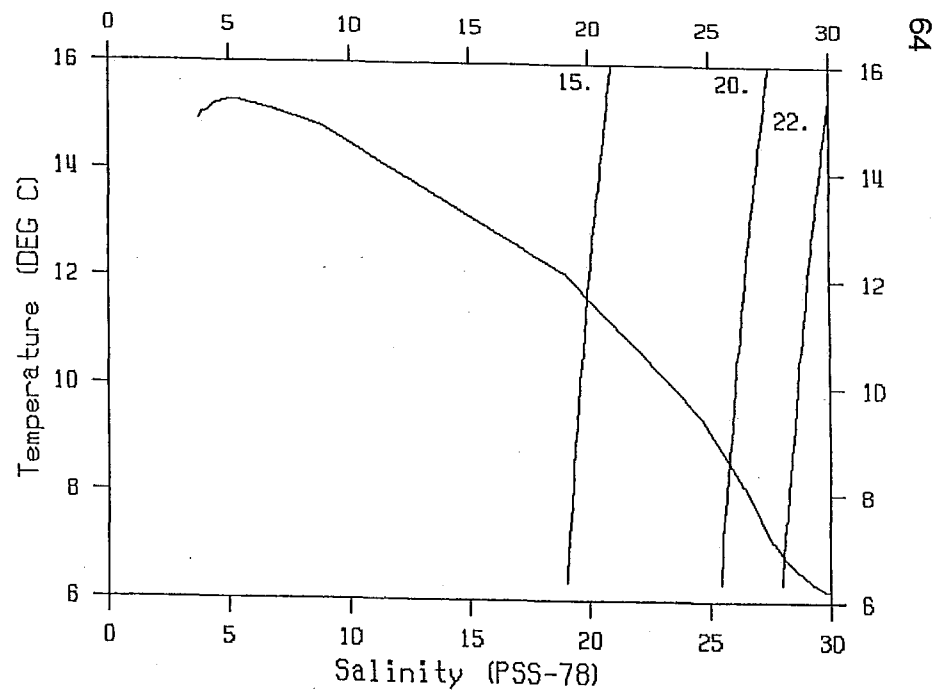
Depth	Temp	Sal	Sigma-t
0	10.83	11.50	8.59
1	10.99	12.47	9.32
2	11.10	13.92	10.43
3	11.13	15.64	11.76
4	10.79	16.74	12.66
5	10.59	17.69	13.42
6	10.29	19.30	14.71
8	9.54	22.38	17.21
10	8.32	25.12	19.51
12	7.77	26.14	20.38
15	7.12	27.19	21.28
20	6.39	28.79	22.63
25	6.12	29.79	23.45
30	6.15	29.98	23.60



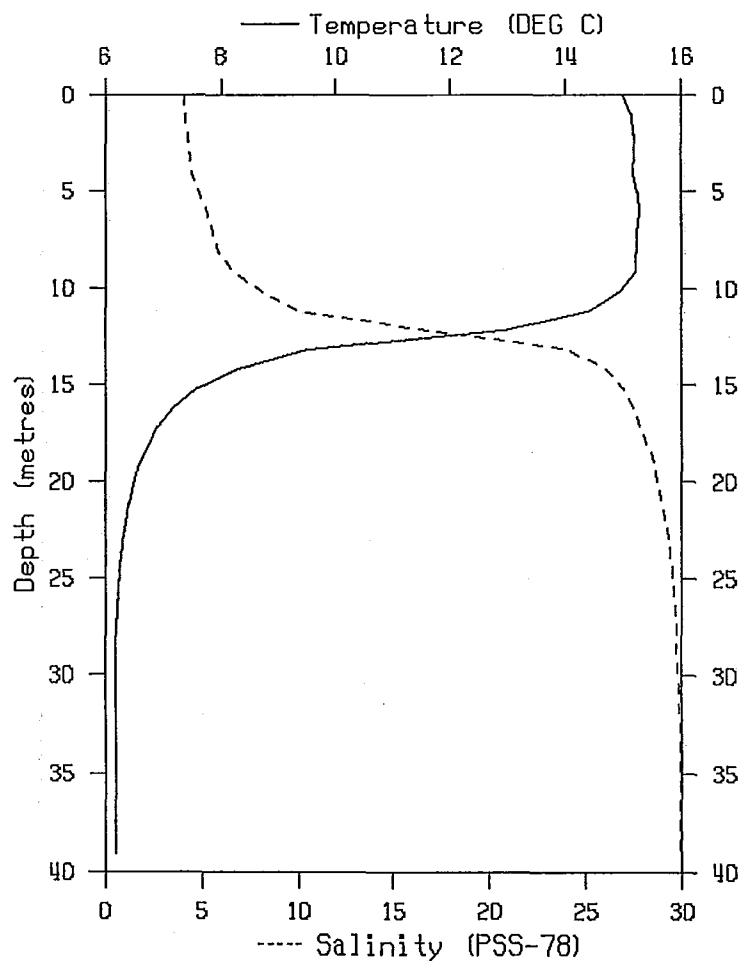
STATION : MB
 REFERENCE NO.: 96-04-010
 DATE/TIME : 07/08/96 16:54 UTC
 POSITION : 54- 1.4N 128-37.3W



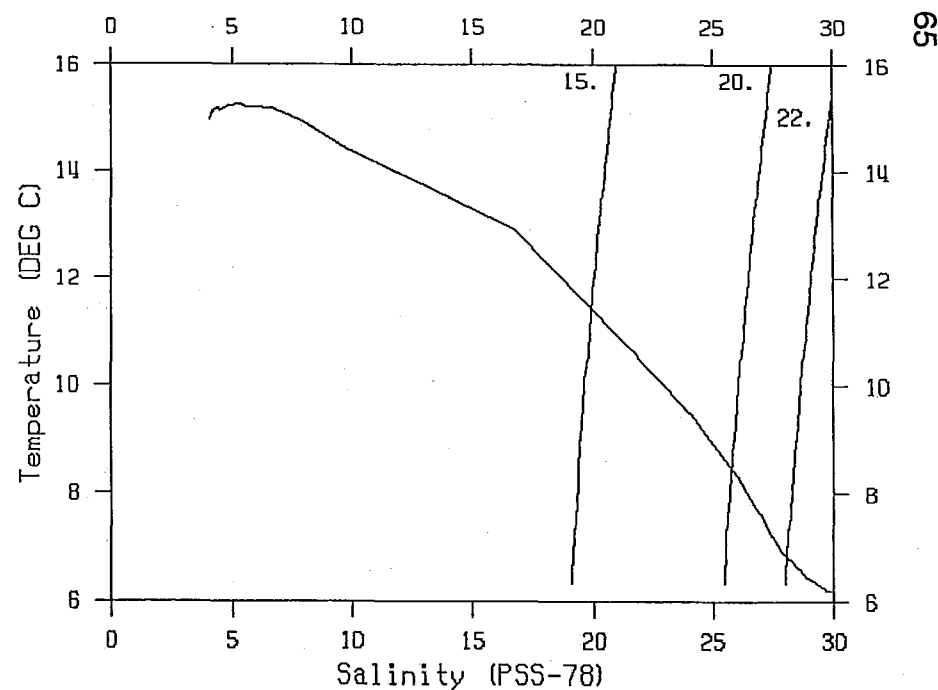
Depth	Temp	Sal	Sigma-t
0	14.95	3.77	2.04
1	14.94	3.79	2.06
2	15.07	3.98	2.18
3	15.10	4.16	2.32
4	15.20	4.43	2.51
5	15.24	4.56	2.60
6	15.29	5.00	2.93
8	15.23	5.82	3.57
10	15.15	6.78	4.32
12	14.06	11.59	8.19
15	8.14	26.43	20.56
20	6.55	28.72	22.56
25	6.26	29.56	23.25
30	6.19	29.80	23.45
35	6.19	29.92	23.54



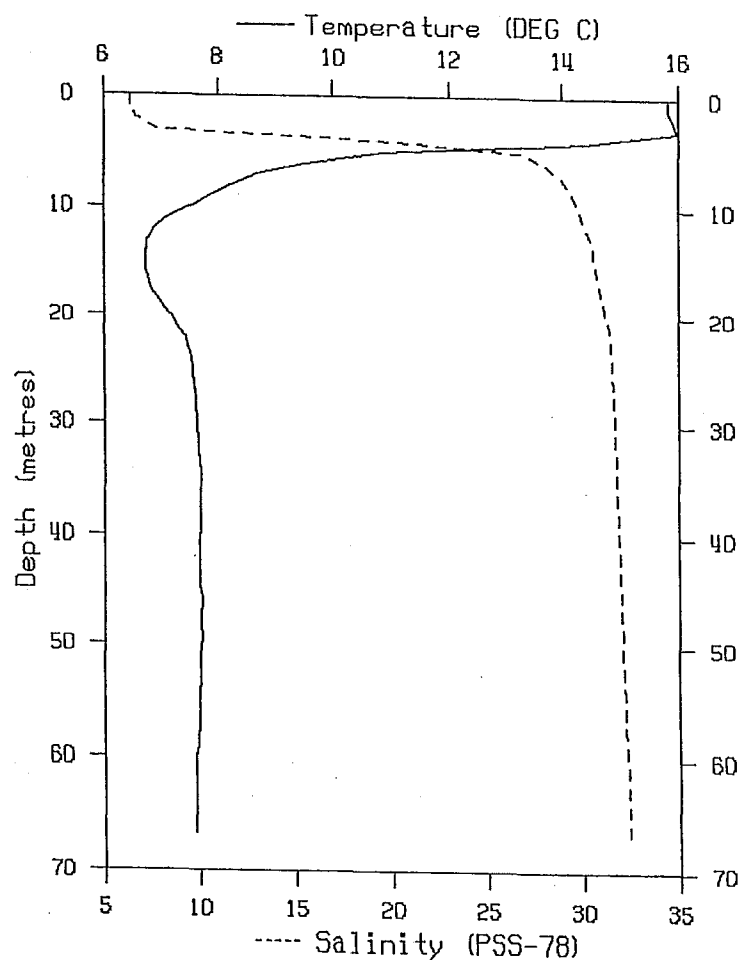
STATION : MB
 REFERENCE NO.: 96-04-011
 DATE/TIME : 07/08/96 17:09 UTC
 POSITION : 54- 1.4N 128-37.3W



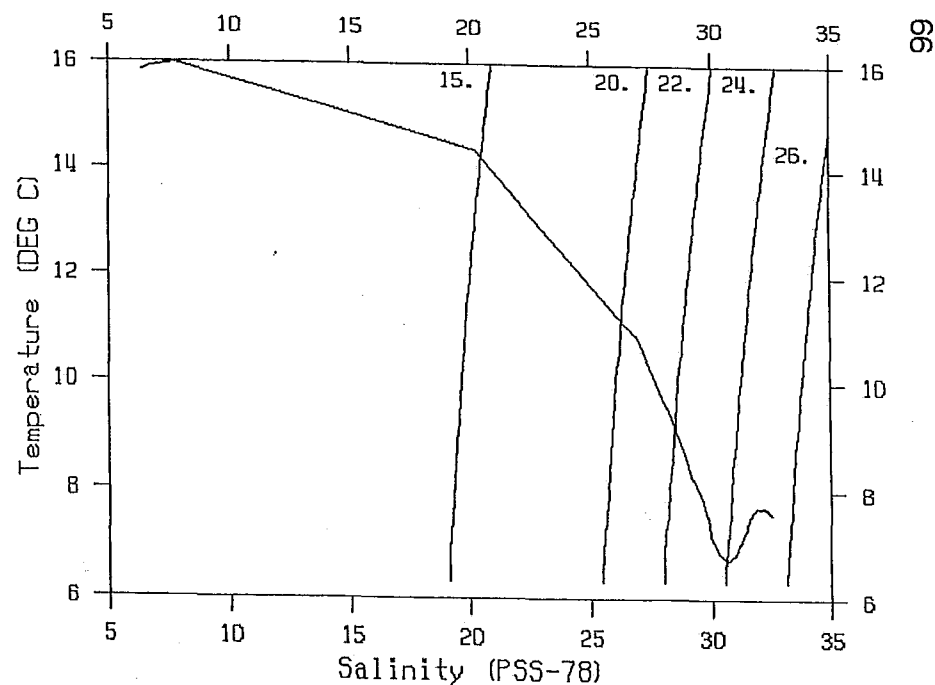
Depth	Temp	Sal	Sigma-t
0	14.97	4.07	2.27
1	15.12	4.20	2.34
2	15.16	4.27	2.39
3	15.18	4.40	2.49
4	15.15	4.50	2.57
5	15.23	4.92	2.88
6	15.26	5.33	3.19
8	15.21	5.91	3.64
10	14.92	8.04	5.32
12	12.92	16.77	12.36
15	7.61	26.98	21.06
20	6.50	28.76	22.59
25	6.25	29.53	23.23
30	6.19	29.80	23.45
35	6.18	29.92	23.55



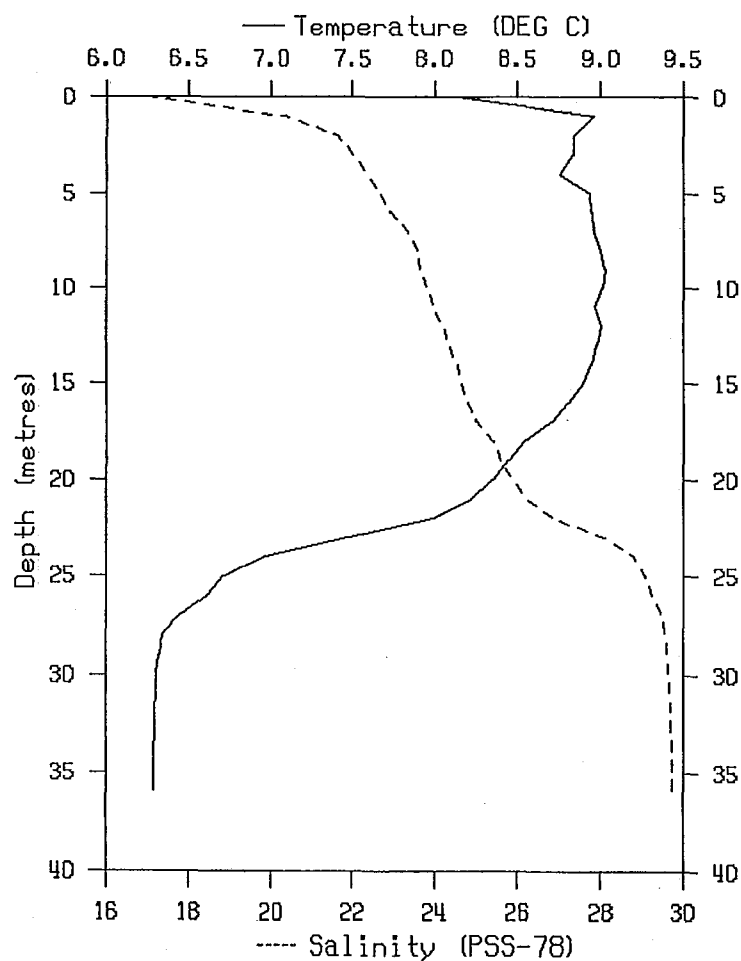
STATION : KA
 REFERENCE NO.: 96-04-012
 DATE/TIME : 08/08/96 15:45 UTC
 POSITION : 53-59.1N 128-39.3W



Depth	Temp	Sal	Sigma-t
0	15.85	6.41	3.91
1	15.83	6.40	3.91
2	15.92	6.81	4.21
3	15.99	7.75	4.91
4	14.36	20.26	14.79
5	10.88	26.90	20.52
6	9.55	28.18	21.73
8	8.24	29.26	22.76
10	7.55	29.84	23.31
12	6.90	30.28	23.74
15	6.75	30.65	24.05
20	7.18	31.29	24.50
25	7.57	31.59	24.68
30	7.64	31.68	24.74
35	7.70	31.80	24.83
40	7.70	31.93	24.93
50	7.72	32.11	25.07
60	7.63	32.34	25.26



STATION : MB
 REFERENCE NO.: 96-04-013
 DATE/TIME : 18/10/96 20:55 UTC
 POSITION : 54- 1.5N 128-37.1W



Depth	Temp	Sal	Sigma-t
0	8.14	17.00	13.19
1	8.96	20.35	15.70
2	8.84	21.64	16.73
3	8.84	22.04	17.04
4	8.76	22.37	17.31
5	8.94	22.69	17.53
6	8.95	22.94	17.73
8	9.00	23.58	18.22
10	9.01	23.83	18.41
12	9.01	24.25	18.74
15	8.90	24.67	19.08
20	8.36	25.92	20.13
25	6.72	29.08	22.82
30	6.31	29.66	23.33
35	6.29	29.73	23.38

