File R-21-1

OCEANOGRAPHIC OBSERVATIONS AT
PORT SIMPSON BAY, BRITISH COLUMBIA
1981 - 1982

A Report Prepared for:

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EXECUTIVE SUMMARY

From May 1981 to March 1982, a series of oceanographic measurements were conducted in the vicinity of Dome Petroleum's proposed LNG terminal site at Grassy Point in Port Simpson Bay, B.C. The measurements included: detailed month-long measurements in May-June 1981 of the tide and currents using several at-depth recording meters for areas of interest within Port Simpson Bay; a series of current-follower drogue studies to complement the current meter measurements; a recording Waverider buoy system for almost a year to monitor waves near the proposed terminal site; a series of seasonal measurements of conductivity-temperature-depth (CTD) profiles and dissolved oxygen concentrations within and adjacent to Port Simpson Bay; and, continuous measurements of the annual wind field at Port Simpson using a remote recording weather station installed at Port Simpson.

The tide at Port Simpson is a mixed, semi-diurnal tide. The major tidal constituents calculated for the proposed LNG dock site from the May 1981 data were the same as those derived for Port Simpson by the Canadian Hydrographic Service from the 1902-26 Port Simpson records. Hence the tide at the proposed LNG dock site can be predicted from the tide tables using Prince Rupert as a reference port.

The relatively large tidal range (up to 7 m) in Port Simpson Bay did not result in large currents in May-June 1981. Direct current measurements in the surface layer showed that the wind had greater influence on the current than the tide, with the exception of a region near Inskip Passage. The complex bathymetry and multiple passages into Port Simpson Bay appear to have a significant effect on current movements. At mid-Bay the surface velocities in May 1981 had a mean speed of about 5 cm/s and were generally less than 10 cm/s. Although the mean direction was eastward at mid-Bay, it was found that the surface current at mid-Bay could set in any direction for short periods. At times of low winds there appeared to be a preferred counter-clockwise surface circulation in the mid-Bay area but with increasing winds the movement of surface water soon reflected the direction of the wind.

At the proposed LNG dock site in May 1981, the speed of near-surface currents had a mean of about 5 cm/s, was influenced by the wind and showed little preferred direction. The direction of water movement was observed both parallel and perpendicular to the shore for periods of several hours. Measurements at 26 m depth showed that deeper currents had a mean speed of about 3.5 cm/s and a preferred direction to the northwest, forming part of the general counter-clockwise circulation.

The results of four separate current-follower drogue studies in May-June 1981 indicate that most of the Port Simpson Bay water exchange appears to take place through Inskip Passage although there is also exchange through Rushbrook Passage and Dodd Pass. Direct freshwater input into Port Simpson Bay in summer is small. Most of the fresh water input into the brackish surface layer is likely to come indirectly from the Skeena and Nass Rivers.

During south winds on May 30/31, 1981, a southerly-flowing surface flow was observed into Port Simpson Bay through the eastern side of Rushbrook Passage with some northerly flow in western Rushbrook Passage, resulting in a general clockwise circulation in Port Simpson Bay east of Birnie Island. At other times a near-surface counter-clockwise eddy was observed east of Birnie Island in the surface layer, although a clockwise eddy was found in the deep water at this time.

During westerly winds (directions SW to NW) on May 31 and June 1, a southeast surface flow into Stumaun Bay was observed in the mid Port Simpson Bay area. In the absence of winds or under light and variable winds, a counter-clockwise surface circulation is set up in mid-Bay, possibly as a result of non-uniform tidal flows combined with the general northerly flow in Cunningham Passage.

The deep (greater than 20 m depth) currents in Port Simpson Bay were slower than at the surface and in general showed a counter-clockwise circulation leading to relatively weak northwest flow near the proposed dock site. Since the deep water is much less influenced by winds, it may reflect the general surface circulation under calm or light and variable wind conditions.

The 1981-82 wave observations at Port Simpson Bay indicate that in general there is very low wave energy near the proposed LNG terminal site in Port Simpson Bay. Measured significant wave heights were less than 1 m and peak periods usually shorter than 5 seconds. The in-situ wave field near the proposed LNG terminal appears to be dominated by local wind-generated waves. This appears reasonable considering the sheltering effects of the various islands and reefs adjacent to the proposed dock site and the fetch-limited nature of the surrounding waters. Unfortunately the wave record during December and January, when high waves are possible, was essentially void of useful information due to buoy malfunction. The highest observed significant wave height (0.82 m) occurred 14 January during a one-day stretch of useful information. The highest recorded wind event during the 1981-

1982 measurements happened 9 December, 1981 when hourly winds greater than 60 km/hour were recorded from the north but there were no wave data collected. Unverified reports by local residents indicate that estimated peak wave heights in Port Simpson Bay may reach as high as 2.5 m during the strongest westerly winds.

The seasonal CTD data indicate Port Simpson Bay is a well-defined two layer estuarine system during the spring, summer and fall. The brackish surface layer is about 10 m thick and separated by a strong halocline and thermocline from the deeper more saline oceanic waters. The relatively strong gradient between the two layers in the summer would effectively isolate the deeper water in Port Simpson Bay from direct wind effects.

From May through August 1981, the surface layer in Port Simpson Bay showed a general warming trend due to solar heating. Surface water temperature increased from about 11 to 14°C. Surface salinities were lowest in the May-June period, in some cases less than 20 °/oo. Vertical stratification, especially salinity, was strongest in May-June. A strong halocline and thermocline were located at the 6 to 10 m depth. By August a more gradual gradient was observed extending to depths of about 40 m. In August, the underlying water mass (below approximately 40 m) also had cooled by over 0.5°C suggesting an influx of cooler, more saline water at depth.

During the winter sampling months, the salinity and temperature stratification was less evident and Port Simpson Bay was relatively well-mixed. The November CTD profiles showed a total salinity variation throughout the column of only 2-4 ppt and the January profiles, 1 ppt. This may be compared to summer variations of 6-9 ppt. The temperature gradients in November and January also showed a thermal inversion in Port Simpson Bay, i.e. a shallow layer of cool water overlaying a warmer, slightly more saline water at depth. The surface layer cooling is attributed to the rapid decline in solar radiation through the fall with a resulting loss of heat from the surface layer to the atmosphere.

The seasonal measurements of dissolved oxygen within and adjacent to Port Simpson Bay, indicate that surface waters at Port Simpson are saturated or supersaturated with dissolved oxygen throughout most of the year. The highest annual near-surface dissolved oxygen concentrations (up to 8.7 mL/L or 133% saturation) were found in late May, probably due to increased photosynthesis during the phytoplankton bloom that occurs regularly at this time of year. The lowest dissolved oxygen concentrations were found near the bottom of Port Simpson Bay in August 1981. The August near-surface waters were saturated with oxygen but the concentrations decreased with depth to near-bottom levels of 4.3 to 4.8 mL/L or 60 to 70 percent saturation. During winter months the concentration of dissolved oxygen was more homogeneous with depth, ranging from 7.56 to 5.95 mL/L or 112 to 92% saturation.

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1. INTRODUCTION

This study was undertaken on behalf of Dome Petroleum Limited by Seakem Oceanography Ltd. and ESL Environmental Sciences Limited. In May 1981 ESL conducted a review of the oceanographic information available for Port Simpson and identified potential deficiencies in the oceanographic data base for project design and the environmental assessment of Dome's proposed LNG terminal at Grassy Point, B.C. (Figure 1). This information was incorporated in the 1981 Dome Petroleum Limited submission to the TERMPOL Committee (Dome Petroleum Limited, 1981). The present study was designed to complement other studies in addressing these shortcomings.

At the beginning of May 1981, three current meter moorings, a recording tide gauge and a Waverider buoy system were installed in Port Simpson Bay and Inskip Passage (Figure 2). During the last week of May 1981 a current-follower drogue study was conducted in waters adjacent to Port Simpson. Conductivity-temperature-depth (CTD) and dissolved oxygen profiles were also taken at this time. On 2 June 1981, the current meters were recovered and on 25 June the tide gauge was recovered. Wind data from Port Simpson were collected from 14 May 1981 through 16 December 1981 with additional wind information being supplied by the weather station at the Prince Rupert airport. Further CTD and dissolved oxygen profiles were taken on 25 August 1981, 26/27 November 1981 and 26/27 January 1982 in conjunction with servicing operations on the Waverider buoy and shore station. Replacement wave buoys were installed on 25 November 1981 and 26 January 1982 and final recovery was effected on 22 March 1982.

The instrumentation to monitor currents included both recording current meters (RCMs) and current-follower drogues. The RCMs provided a month long record at each location and the drogues provided nearly continuous shorter term information but over a much greater area. The CTD profiles provided information on the temperature, salinity and density structure of the waters in Port Simpson Bay.

In this report all data is reported in SI units. Also the standard convention of reporting current and wind directions is used; i.e. the current direction is that to which the water is moving and the wind direction is that from which the wind is blowing. In general the data analysis uses Greenwich Mean Time (GMT) indicated by a 'Z' after the time. Local time, when used is labelled (e.g. PDT).

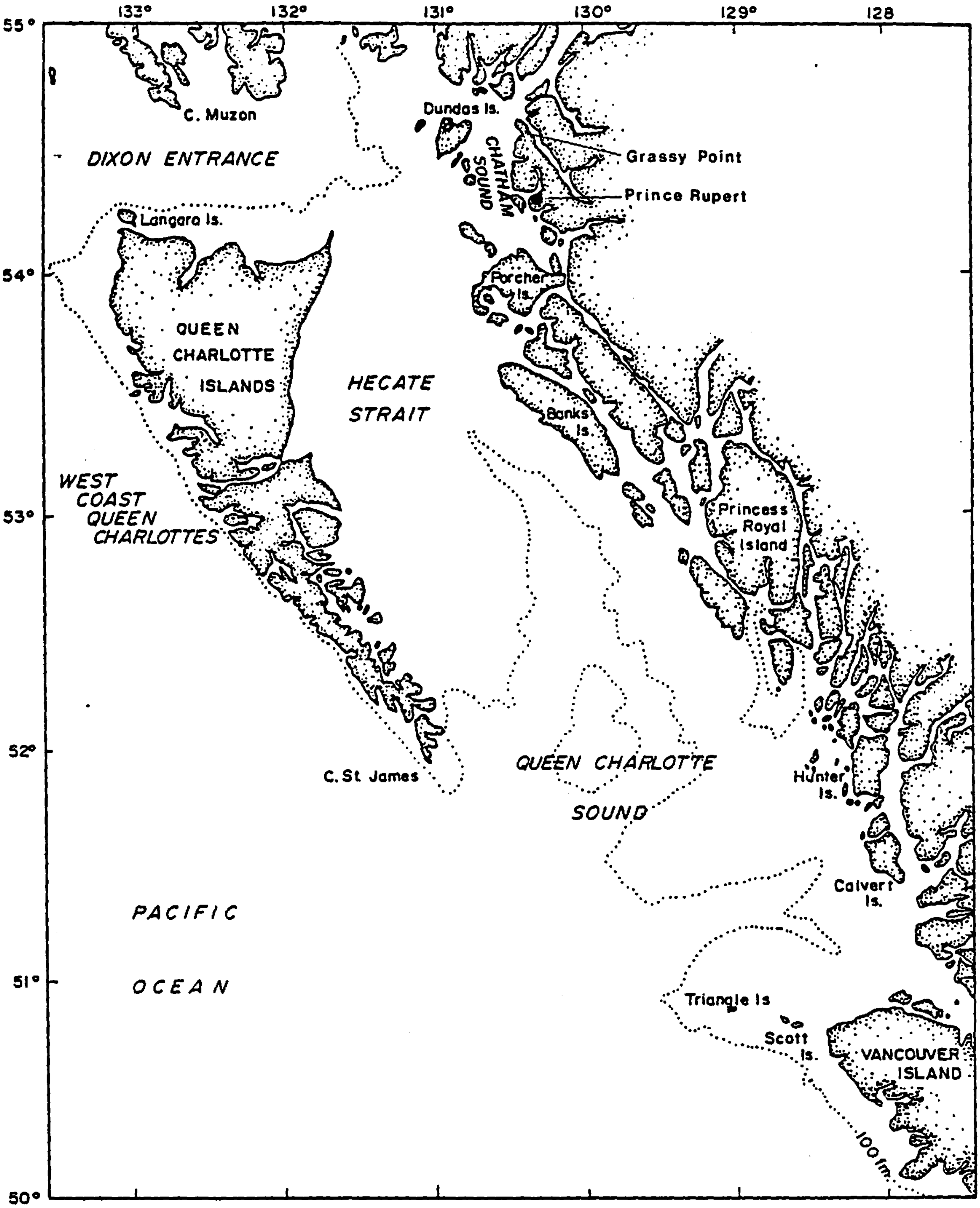


Figure 1. The North Coast of British Columbia.

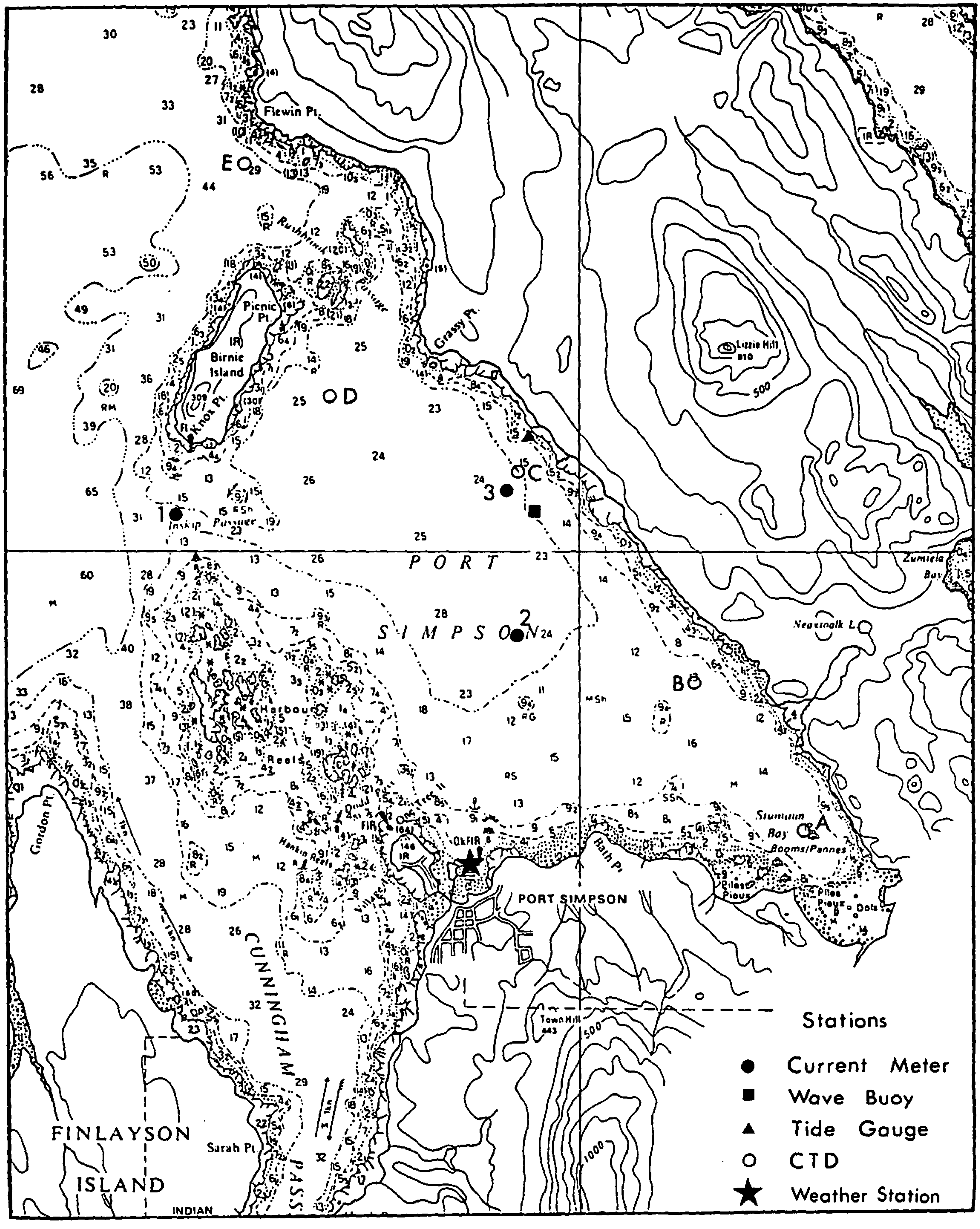


Figure 2. Map showing station locations.

2. DATA COLLECTION

2.1 Instrumentation and Equipment

Current Meters

The current meters employed in the study were the Aanderaa RCM 4 (see specifications in Appendix A). All of these instruments had been modified by Aanderaa Instruments Ltd., Victoria, B.C. to increase the battery capacity from a single 9 volt battery to three 9 volt batteries in order to increase reliability at low temperatures. This modification did not change any of the sensors. After modification, the compass was re-calibrated to verify that the new pressure case does not affect the direction measurements. Prior to deployment, all instruments were serviced and tested by Seakem.

Releases

The releases used with the moorings were Mesotech 501 AR acoustic releases with the corrosion protection option. In addition, the releases were modified to allow the use of larger mooring D rings in the hook and top fitting. These releases were used to recover the current meter moorings by sending a coded acoustic signal to the release which then freed the anchor, allowing the remainder of the mooring to float to the surface. Each release was tested by Seakem before deployment.

CTD and Water Samples

The conductivity/temperature/depth (CTD) probe employed in this study was an Applied Microsystems Ltd. CTD-12 instrument (see specifications in Appendix A). The instrument was operated in the low resolution (10 bit) mode of recording which gives resolutions of $t = 0.03\ C^{o}$, $S = 0.07\ ^{o}/oo$ and $p = 0.2$ dbar. Sensor accuracy is $\pm 0.01 C\ ^{o}$, $\pm 0.03\ ^{o}/oo$ and $\pm$ 1 dbar. Water samples for dissolved oxygen analyses were taken at depth using a 2-litre PVC Van Dorn bottle.

Tide Gauge

An Aanderaa Instruments Ltd. model TG4A tide gauge was used for tide measurements. Water elevation is measured by a pressure sensor in the instrument and data recording is similar to that of the current meters. The TG4A used in this study has a resolution of 3×10^{-4} dbar (equivalent to about 3×10^{-4} m) and an accuracy of ± 0.01 dbar.

Waverider Buoy System

The wave measurement system was provided by the Wave Climate Study of the Marine Environmental Data Service, Department of Fisheries and Oceans, Ottawa. The system consisted of a Datawell Waverider buoy containing an accelerometer to measure the vertical acceleration of the buoy and appropriate electronics to transmit the vertical displacement of the buoy to a receiving site. The receiving system, consisting of a receiver and tape recorder, was located at the settlement of Port Simpson. An electronic clock in the receiver controlled the recording of the data, turning the receiver and recorder on for 20 minutes every three hours.

Current-follower Drogues

The basic design of the drogues used in the study is shown in Figure 3. The sail or drag element was 3 m wide by 2 m deep and constructed of Polyweave, a strong flexible fabric. This design has been shown to align itself perpendicular to the flow after travelling two or three times its own length and thereafter to follow the current to within 10°. For surface drogues the wooden crosspiece sewn into the top of the sail was hooked to the surface float and the reinforcing rod at the bottom hooked to the base of the lower aluminum pole. In the case of deep drogues, 20 m of braided nylon cord was attached to the wooden crosspiece with the other end passed through the snap hook at the bottom of the aluminum pole and attached to the surface float. With this arrangement the surface drogues followed the flow between 0 and 2 m depth and the deep drogues between 20 and 22 m depth. For these drogues, the effect of wind drag on the drogue is small at low wind speeds (less than 5 m/s)

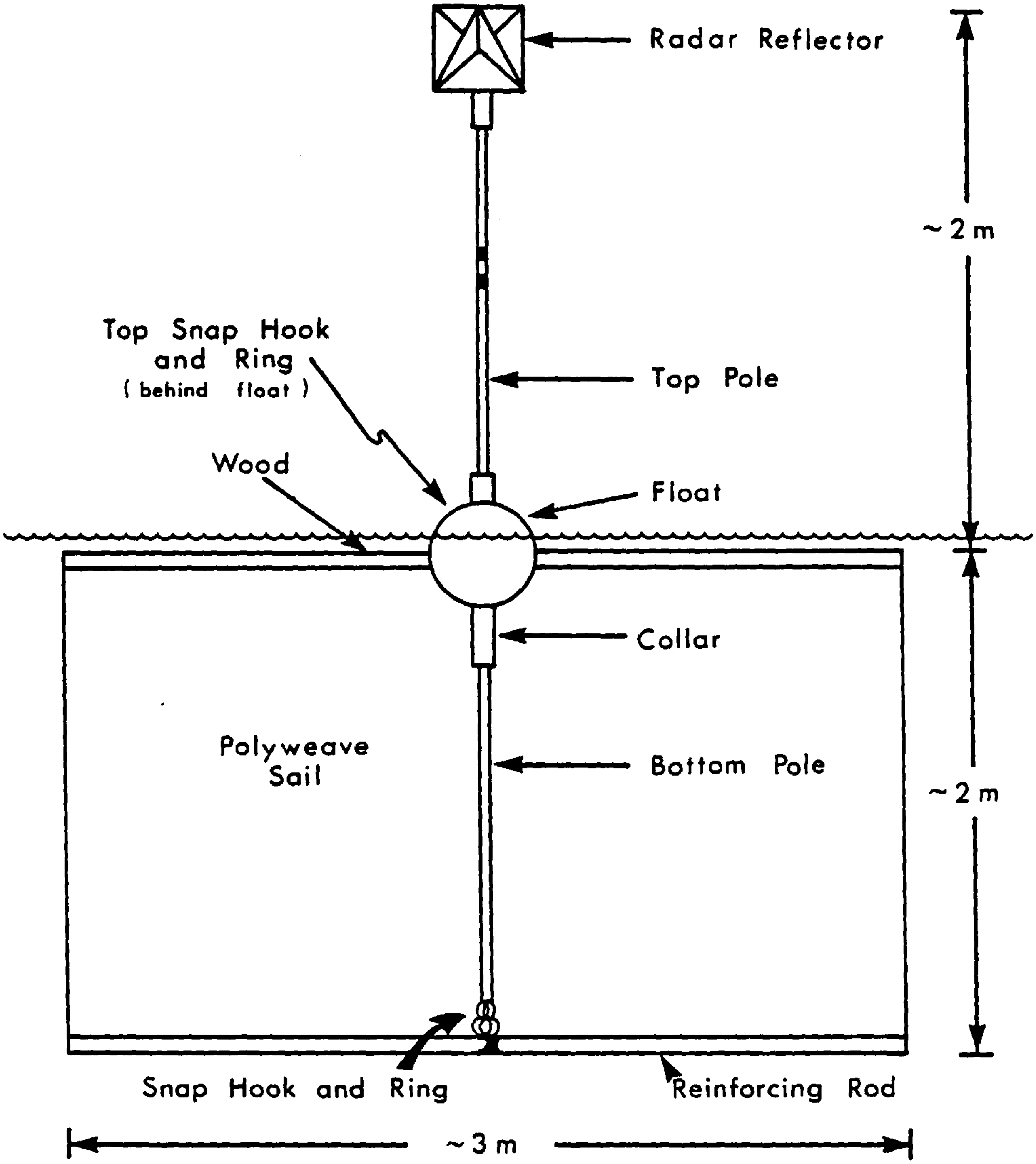


Figure 3. Current drogue design.

and is the greatest for a drogue in a vertically homogeneous, horizontal current. For the worst case the error is calculated to be 0.4 cm/s for a 1 m/s wind and 2 cm/s for a 5 m/s wind (Buckley, 1977). The usual presence of a vertical shear in the current reduces the wind induced error.

A 33 cm radar reflector was mounted at the top of each unit. A strobe light was attached below the reflector to aid in identification during night operations. Deployment and recovery of the drogues is a relatively simple affair and was undertaken from two small vessels, a herring skiff and a 4 m runabout.

The radar unit used to track the drogues was a Decca 202 aboard the Silver Token, an 11 m fishing vessel. This unit was used on a range of 3 nautical miles (5.6 km) for most of the study. Specified range accuracy was within 1.5% of maximum scale (approx. 0.08 km over a 5.6 km maximum scale) and bearing accuracy within approximately 2°. The error associated with reading the range from the radar unit was ±0.05 km.

Anemometer

a. Port Simpson

Meteorological parameters were recorded at Port Simpson using a Model 5100 Series Digital Weather Station manufactured by Meteorological Research, Inc. This automatic weather monitoring system consists of (1) a sensor array (measuring wind speed and direction, temperature and relative humidity) mounted atop a 10 meter tower and (2) a microprocessor-based recording unit designed to process and record data from the sensor array. The sensor array includes a 3-cup anemometer for measuring wind run and a single blade tail vane for measuring wind direction.

Wind speed is determined every 10 seconds by counting cup revolutions (1 rev. = 2.4 meters of wind run). Wind direction is sampled every 10 seconds. These data are stored in memory for a period of one hour, after which the averages are computed and recorded on tape (wind speed in m/s and wind direction in degrees from true north). The performance characteristics of both the wind speed and wind direction systems are presented in Table 1.

TABLE I

Digital Weather Station Performance Characteristics

	Wind Speed	Wind Direction
Range	0 - 50 m/s	0 - 360 degrees
Resolution	0.1 m/s	1 degree
Accuracy	1 percent of full scale	1 percent of full scale
Starting Threshold	0.33 m/s	0.33 m/s

b. Prince Rupert

Transport Canada maintains a meteorological monitoring station at Prince Rupert airport on Digby Island. A model U2A wind system designed by Atmospheric Environment Service is used for measuring wind speed and direction. The system includes a 3-cup anemometer and a directional wind vane mounted atop a 14 meter tower.

The system functions somewhat differently than the one in use at Port Simpson. The anemometer cups continuously drive a small generator which outputs a voltage that is converted to the instantaneous wind speed. This wind speed is read visually from a dial once each hour and on the hour (approximately a 5 second average). Instantaneous wind direction is also read from a dial and recorded at the same time (in tens of degrees from true north).

Wind speed is recorded to the nearest whole knot, while wind direction is recorded to the nearest 10 degrees. Winds below 1 knot are usually recorded as calms by the observer.

It should be noted that the hourly correlation analysis (discussed later) of wind speed (Port Simpson and Prince Rupert Stations) performed by ESL assumes that differences in averaging times at these two stations will not significantly affect long-term averages.

2.2 Techniques

Current Meter Moorings

Current meters were moored at three locations (see Figure 2). The moorings at Inskip Passage (Station 1) and in the middle of the bay at Port Simpson (Station 2) consisted of a single current meter while the mooring near the proposed dock site (Station 3) had two current meters. The instruments were set to operate at a sampling interval of 10 minutes. Details of the moorings are given in Tables II and III and Figure 4. Each mooring was installed anchor first and lowered to the bottom. At the suggestion of the Canadian Coast Guard, Prince Rupert, surface marker floats were attached to the sub-surface buoys by a slack line in order to mark the mooring locations for marine traffic. Recovery of a mooring was accomplished by triggering its acoustic release. The release dropped the anchor line and the remainder of the mooring floated to the surface for recovery.

CTD Profiles

The CTD profiles were taken by lowering the instrument on a line with an attached electrical cable. Measurements were recorded both internally on magnetic tape and at the surface on a printer. Hence measurements were available in real time. The instrument was operated by a surface trigger in the 10 bit resolution mode, allowing in-the-field verification of the data. Water samples were also collected for a calibration verification of the conductivity cell.

The stations occupied are shown in Figure 2. In addition to the regular CTD stations (A to E), additional profiles were taken at current meter stations 1 and 2. Table IV summarizes the measurements obtained. On 24 May each station was occupied twice, once at high water and once at low water, in order to look for differences due to tide. The stations were repeated twice more at intervals of several days to delineate changes on time scales of several days. Three further sets of CTD profiles were taken on 25 August 1981, 26/27 November 1981 and 26/27 January 1982 to provide information on seasonal variation.

TABLE II: Current Meter Mooring Locations

Station	Water Depth (m)	Latitude	Longitude	Location
1	35	54° 35.2'	130° 27.9'	Inskip Passage
2	44	54° 34.7'	130° 25.4'	Port Simpson, mid bay
3	44	54° 35.3'	130° 25.5'	near dock site

TABLE III: Current Meter Deployment Times

Station	Instrument Depth (m)	Instrument	Tape	Date (GMT)		Days of
				Installed	Recovered	Data
1	6	1501	6	2-5-81	2-6-81	31.6
2	6	1502	6	2-5-81	2-6-81	31.5
3	7	1500	6	2-5-81	2-6-81	31.0
3	26	3015	6	2-5-81	2-6-81	31.0

Note: All depths are relative to lowest low water

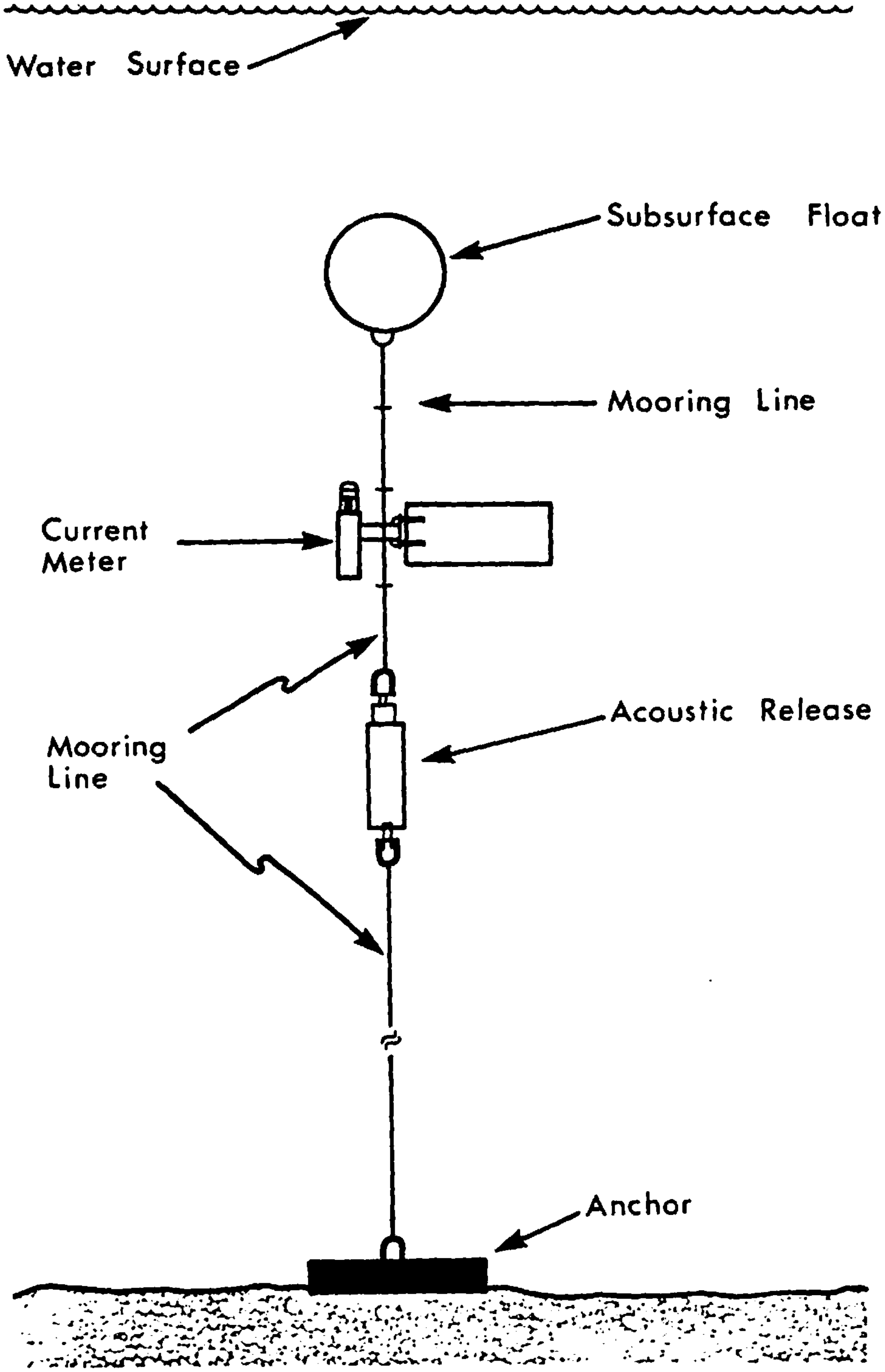


Figure 4. Current meter mooring diagram.

TABLE IV: CTD Measurements

Date	Time (Z)	Station	Profile Depth (m)
23-5-1981	2000	C	42
23-5-1981	2330	E	70
24-5-1981	0025	D	50
24-5-1981	0050	C	45
24-5-1981	0130	B	30
24-5-1981	0145	A	25
24-5-1981	1715	E	70
24-5-1981	1808	D	45
24-5-1981	1830	C	40
24-5-1981	1905	B	25
24-5-1981	1930	A	25
29-5-1981	1830	A	25
29-5-1981	1850	B	25
29-5-1981	1910	C	40
29-5-1981	2000	1	40
29-5-1981	2020	D	45
29-5-1981	2045	E	70
2-6-1981	1445	A	20
2-6-1981	1505	B	25
2-6-1981	1535	1	40
2-6-1981	1620	2	45
2-6-1981	1905	D	45
2-6-1981	1925	E	60
2-6-1981	2035	C	45
25-8-1981	1600	1	37
25-8-1981	1700	E	70
25-8-1981	1730	C	33
25-8-1981	1800	A	28
26-11-1981	1920	1	41
26-11-1981	1950	C	49
26-11-1981	2315	E	70
27-11-1981	0005	A	27
26-1-1982	2342	C	29
27-1-1982	0012	E	49

Dissolved Oxygen

Dissolved oxygen measurements were conducted in Port Simpson Bay and adjacent waters on four occasions in 1981-82: 23 May 1981; 25 August 1981; 26 November 1981; and 26 January 1982. The samples were taken at selected standard depths (sfc, 2 m, 5 m, 10 m, 15 m, 20 m, 30 m, 50 m) using a 2-L PVC Van Dorn bottle. A 300-mL aliquot from each water sample was transferred to a glass BOD bottle for determination of dissolved oxygen concentration. Manganous sulphate (3 mL) and alkali iodide (3 mL) were added in the field to preserve the sample for subsequent analysis following the spectrophotometric method of Duval et al. (1974) for the first three sampling programs and following the standard Winkler method for the last sampling program. The dissolved oxygen analyses were performed in the laboratory by Mr. C. Smith on contract to ESL. It was not determined until after the results of the second program were completed that the analytical technique described by Duval et al. (1974) for spectrophotometric determination of dissolved oxygen concentration may not be valid for marine samples. A comparison of selected samples from the third sampling program using both the accepted standard Winkler analyses and the spectrophotometric technique described by Duval et al. (1974) revealed that for these particular marine water samples, this spectrophotometric method may be affected by three factors: storage time, salt content and dissolved mineral discolouration of the collected samples. As a result the reliability of the dissolved oxygen concentrations measured at Port Simpson for the first three sampling periods (23 May 1981; 25 August 1981; and 26 November 1981) using the Duval et al. (1974) method (estimated accuracy ± 0.4 mL/L) is less than that of the last sampling period (26 January 1982) using the standard Winkler analysis (estimated accuracy ± 0.04 mL/L).

Tide Gauge

The tide gauge was installed at 0800 PST 2 May 1981 and was recovered at about 1400 PST 25 June 1981. The gauge was placed in a concrete anchor at a water depth of 10 m near the proposed dock site (Figure 2). Because alternate samples of pressure and temperature were recorded, a sampling period of 3.75 minutes was used to give pressure data every 7.5 minutes with an integration time of 27 s. The sampling scheme was chosen to give a rapid sampling rate, yet still give a minimum of 30 days of data. The rapid sampling allows the detection of water level fluctuations with time periods as short as 15 minutes. Recovery of the gauge was by diver.

Waverider Buoy

The buoy and shore station were installed on 1 May 1981 and retrieved 22 March 1981. The buoy was replaced on two occasions, 25 November 1981 and 26 January 1982. A standard Wave Climate Study mooring configuration with a 2 to 1 scope was used. Figure 2 shows the mooring location. Every three hours a 20 minute sample of the waves was recorded. Data processing and analysis was carried out by the Wave Climate Study, Department of Fisheries and Oceans.

Current Drogue Tracking

The circulation study was split into four tracking sessions, three of which covered complete tidal cycles (25 hrs). The dates and start/finish times of each session are shown in Table V together with an indication of the predominant wind condition. During sessions 1, 2 and 4 the Silver Token (the charter vessel) was secured with three anchor lines to provide a static working base. The position of the vessel was determined by taking radar fixes of various prominent natural features throughout each session. The bearing logged from the radar was with respect to the bow of the vessel, hence following each fix a note was made of the vessel's heading using the magnetic compass. These measurements are Lagrangian, i.e. the drogues move with water as opposed to measuring the water velocity at a point.

Drogues were deployed throughout the region using a large skiff and were constantly followed on the radar over the whole of each session. Range and bearing, vessel heading and any other relevant information were entered on log sheets and the tracks were plotted on a large scale chart of the area to provide a rough check of identification and velocity. At frequent intervals the small skiff was used to visually confirm the identification of each drogue and to recover any that had grounded or were no longer visible on the radar.

Wind Measurements

a. Port Simpson

The following is a site description of the Port Simpson Weather Station:

> Port Simpson townsite is located on the south side of Port Simpson Bay. The MRI Digital Weather Station was situated on the end of the breakwater north of the government dock about 200 meters from shore (Figure 2). The local topography at Port Simpson station offers some protection from winds from the east, south and west. The largest hills to the south along the Tsimpsean Peninsula substantially reduce exposure of the Port Simpson station to southeast winds. Station exposure from the NW through to ENE is relatively good, i.e. the winds blow across Port Simpson Bay from these directions.

The Digital Weather Station was installed on 14 May 1981. The base of the tower was approximately 4 m above mean sea level. The anemometer height was

TABLE V: Drogue Tracking Sessions

Session	Start (GMT)	Finish (GMT)	Predominant Wind
1	2330 24 May	0200 26 May	light, north-westerly
2	1616 27 May	1859 28 May	light, north-easterly
3	1742 30 May	0252 31 May	moderate, south-westerly
4	1508 31 May	1745 1 June	light, south-westerly

Notes:

1) Winds were measured from the government breakwater at Port Simpson

2) Mean hourly wind speeds never exceeded 6 m/s during the tracking sessions.

10 m. ESL personnel serviced the weather station approximately every two months. A complete record of data was obtained from 14 May 1981 through 16 December 1981. A faulty clock mechanism within the recording unit precluded wind data collection during the remainder of the study.

b. Prince Rupert

The following official site description for the Prince Rupert station is provided from AES files:

> The anemometer is located between the aircraft parking ramp and the runway, directly west of the terminal building. The surrounding area is hilly and wooded. There are mountains to the N, E and S with the Pacific Ocean to the W. There is a small hill 1/2 mile to the SE which affects winds from the SE to some extent.

It should also be noted that the station elevation is 34 meters above sea level and the anemometer height is 14 meters.

Operation began at Prince Rupert Airport in August, 1961. The daily log sheets (showing each hourly recorded wind speed and direction) have been obtained by ESL on a regular basis since May 1, 1981.

3. DATA ANALYSIS

3.1 Wind Data

Hourly measurements of wind speed and direction were recorded at Port Simpson from 14 May 1981 to 16 December 1981. As this record was incomplete compared to the duration of the wave study (1 May 1981 to 22 March 1982), an analysis was made to correlate the hourly winds at Port Simpson with those measured at the Prince Rupert airport on Digby Island. These results are described in a later section. From the available time series, plots of wind direction and speed were constructed. These figures consisted of every third hourly wind measurement taken at Port Simpson so as to coincide with the sampling periods of the Waverider buoy. The wind measurements at Prince Rupert were substituted for those periods when data were not available at Port Simpson.

3.2 Wave Data

The wave data were processed by the Wave Climate Study, Marine Environmental Data Service, Department of Fisheries and Oceans. The resultant standard data products consist of monthly time series plots of significant wave height, as well as a scatter diagram of the peak periods versus significant wave height, a peak period histogram, and an exceedance diagram derived from data collected over the entire sampling period (Marine Environmental Data Service, 1981). Here the significant wave height is defined as four times the square root of the area under the variance spectrum of the water surface elevation, whereas the peak period is the inverse of the frequency at which the maximum spectral density occurs. The exceedance diagram shows the observed percentage of the wave records for which the significant wave height exceeded a certain value plus the probable maximum wave height in a twenty-minute record.

3.3 Current Meter Data

Procedure

The RCM data tapes do not contain the information in standard units and hence cannot be used directly. A number of steps are required to process the data to the point of expressing the results in standard units.

The first step, referred to as translation, converted the data from the tape format to a computer readable format and stored the results on a diskette. A special tape translator was used to read these tapes and to transfer the data to our computer. The next step, editing the data, was necessary in order to trim from the data set the non-valid measurements taken by the RCM in the air prior to deployment and after retrieval, as well as correcting translation errors and spikes in the original data. The spikes were single anomalously high or low values, generally caused by incorrectly set binary bits in the data. Usually they were due to a single incorrect bit, resulting in a spike of a size that is an integral power of two. These errors were relatively easy to detect and correct. The editing program scanned the data for changes between successive values that were greater than operator set limits. If the program detected such a change, it stopped the computer and allowed the operator to accept or modify the data. In the case of a bit fault, the appropriate power of two was added or subtracted; in other cases a new value was calculated by interpolating from preceding and succeeding values. Translation errors sometimes resulted in obvious shifts of the values into the wrong channel and these were corrected by shifting the data back. In general, the data were good and were quickly edited.

The final step was to run the data through a calibration program that applied the instrument calibration constants to convert the raw data into values expressed in standard units. These results were then permanently stored on a disk.

Data Display

In order to examine the reduced RCM data, both histograms and time series plots were produced. The histograms were calculated for current speed and direction. To facilitate the intercomparison of results, a common scale was used.

Time series plots were produced for temperature, salinity, current speed and direction. The time used was Greenwich Mean Time (GMT) and the day was the day of the year where day 1 is 1 January and day 121 is 1 May, etc.

Progressive vector diagrams (PVDs) were also produced. These plots are produced from the current velocities by converting each speed measurement to the distance water moves during the instrument sampling interval. Starting at the origin, each calculated distance and corresponding direction is plotted as a vector, with successive vectors originating at the head of the previous vector. The resulting plot is a chain of vectors, where the distance from the origin to the end of the last vector is proportional to the mean current over the time period covered by the plot. PVDs are a method of showing low frequency water movements. The axes of the PVDs are in km north/south and east/west from the origin (north and east directions are positive). At fixed intervals an "x" and a number indicates midnight of the respective day.

Some basic statistics were calculated for each current meter data set. Among the statistics were the means and standard deviations of temperature, salinity and speed as well as extreme values of speed and current components.

3.4 Current-follower Drogue Data

A computer data file was created for each of four tracking sessions, each file containing the time, a range and bearing for each drogue fix and the vessel heading. Using the position of the tracking vessel, the fixes were converted to east/west (x) and north/south (y) co-ordinates with the origin set at 53° 30' N, 130° 30' W. The four chronologically ordered files were then sorted into individual drogue tracks or a sequence of positions for each drogue.

Blatant inconsistencies and dubious fixes, when coupled with logged comments, were removed from the files. Incorrect identifications were rectified and the resulting information comprising edited drogue positions and velocities was listed.

In order to obtain smoothed, interpolated positions, velocities and accelerations at 30 minute intervals, a cubic spline smoothing and interpolation routine was used. The technique is based on that of Buckley (1977) for processing drogue data, which, in turn, was based on the procedure described by Reinsch (1967).

Basically the technique smoothed the data by fitting cubic functions to groups of three adjacent data points to within a given tolerance which was related to the uncertainty of the individual data points. Data were interpolated to regular intervals from the fitted curve. The result was a smoothed track which passes within the selected tolerance distance of the raw data points. Since the uncertainty in the radar measurements was ± 50 m, this value was used as the smoothing tolerance.

The motion history of the drogues in each session was broken down into four parts (two in the case of session 3) to provide a clear picture of the circulation with reference to tidal highs and lows. A triangle at the beginning of each track represents the deployment location for that installation or the start of the track if it is a continuation of a track from a previous plot. The scale on each plot is in km relative to the origin 53°30' N, 130°30' W. Table VI shows the deployment and recovery times of each drogue installation throughout the study.

3.5 CTD Data

The data from the CTD were extracted from the magnetic tape, edited and calibrated in a manner similar to the RCM data. Salinities were calculated from the conductivity, temperature and pressure data using the technique of Bennet (1976). Some of the profiles were plotted to illustrate the variability of the parameters.

3.6 Tide Gauge Data

Data from the data tape were translated and edited following a procedure similar to the current meter data. The raw data were then processed by a calibration program which calculated gauge pressure and temperature and the time of each observation, as well as correcting for atmospheric pressure to give pressure due to the water. Air pressure data from Prince Rupert (provided by AES) were used since no air pressure data were measured at Port Simpson. However, since Port Simpson is only about 33 km from the Prince Rupert observation site at Digby Island, the Prince Rupert air pressures were representative of the pressures at Port Simpson

TABLE VI: Port Simpson Drogue Start/Finish Times (PST)

SESSION ONE, 24-25 MAY, 1981

Drogue/ Deployment Number	Time/Day		
	Start		Finish
Shallow (0-2 m)			
1/1	2245/24	-	1838/25
3/1	2240/24	-	1758/25
5/1	1907/24	-	1152/25
5/2	1200/25	-	1748/25
7/1	1630/24	-	2112/24
7/2	2132/24	-	1845/25
8/1	1649/24	-	0002/25
8/2	0011/25	-	1818/25
9/1	1703/24	-	1900/25
10/1	1753/24	-	1812/25
13/1	1639/24	-	1920/24
13/2	1950/24	-	0600/25
13/3	0610/25	-	1450/25
13/4	1512/25	-	1855/25
Deep (20-22 m)			
11/1	1806/24	-	0425/25
11/2	0449/25	-	1740/25
12/1	1822/24	-	1804/25
14/1	1858/24	-	1827/25

SESSION TWO, 27-28 MAY, 1981

Drogue/ Deployment Number	Time/Day		
	Start		Finish
Shallow (0-2 m)			
1/1	0928/27	-	1121/28
2/1	1112/27	-	2150/27
2/2	2300/27	-	1101/28
3/1	1027/27	-	0126/28
3/2	0133/28	-	1108/28
5/1	0440/28	-	1150/28
6/1	1642/27	-	0114/28
6/2	0120/28	-	1137/28
7/1	0942/27	-	1910/27
7/2	1925/27	-	2145/27
8/1	0916/27	-	0220/28
8/2	0234/28	-	1127/28
10/1	0935/27	-	1046/28
14/1	1013/27	-	1928/27
14/2	1936/27	-	2240/27
14/3	2247/27	-	1105/28
	Deep (20-22 m)		
9/1	0921/27	-	1159/28
11/1	0958/27	-	1428/27
11/2	1552/27	-	2023/27
11/3	2248/27	-	0212/28
11/4	0252/28	-	0820/28
12/1	0949/27	-	0048/28
12/2	0102/28	-	1050/28
13/1	1021/27	-	1117/28

TABLE VI: Port Simpson Drogue Start/Finish Times (PST) (cont'd)

SESSION THREE, 30 MAY, 1981

Drogue/ Deployment Number	Time/Day Start	Finish
Shallow (0-2 m)		
1/1	1050/30	1438/30
1/2	1617/30	1936/30
3/1	1205/30	1915/30
5/1	1202/30	1811/30
6/1	1042/30	1312/30
6/2	1322/30	1559/30
11/1	1056/30	1436/30
13/1	1046/30	1450/30
14/1	1342/30	1547/30
14/2	1730/30	1939/30
Deep (20-22 m)		
8/1	1107/30	1831/30
8/2	1835/30	1952/30

SESSION FOUR, 31 MAY - 1 JUNE

Drogue/ Deployment Number	Time/Day Start	Finish
Shallow (0-2 m)		
1/1	1216/31	1818/31
1/2	1832/31	1005/1
2/1	0900/31	1411/31
2/2	1426/31	2241/31
2/3	0015/1	1020/1
3/1	0856/31	1848/31
3/2	1911/31	1033/1
5/1	0847/31	2324/31
5/2	2345/31	0322/1
5/3	0705/1	1045/1
7/1	0834/31	1847/31
7/2	1859/31	2239/31
7/3	0024/1	1000/1
9/1	0822/31	0927/1
11/1	0953/31	1314/31
11/2	1323/31	1823/31
11/3	1833/31	2320/31
11/4	2354/31	0951/1
13/1	1020/31	1630/31
13/2	1725/31	2320/31
13/3	2356/31	0924/1
Deep (20-22 m)		
8/1	0841/31	0955/1
10/1	0825/31	0932/1
12/1	0818/31	1732/31
12/2	1740/31	0936/1
14/1	0808/31	0031/1
14/2	0037/1	1040/1

(T. Jandali, ESL; personal communication). In addition, pressure errors introduced by this approximation were smaller than those introduced by density changes in the water column.

The resulting pressure and temperature data were then plotted as a function of time. In addition the pressure data were averaged to produce hourly pressures which were then used to calculate the tidal constituents for the Port Simpson data. These constituents were calculated using a harmonic analysis procedure, the same as used by the Tides and Currents Group at the Institute of Ocean Sciences, Sidney, B.C. (Foreman, 1977).

4. RESULTS

4.1 Winds

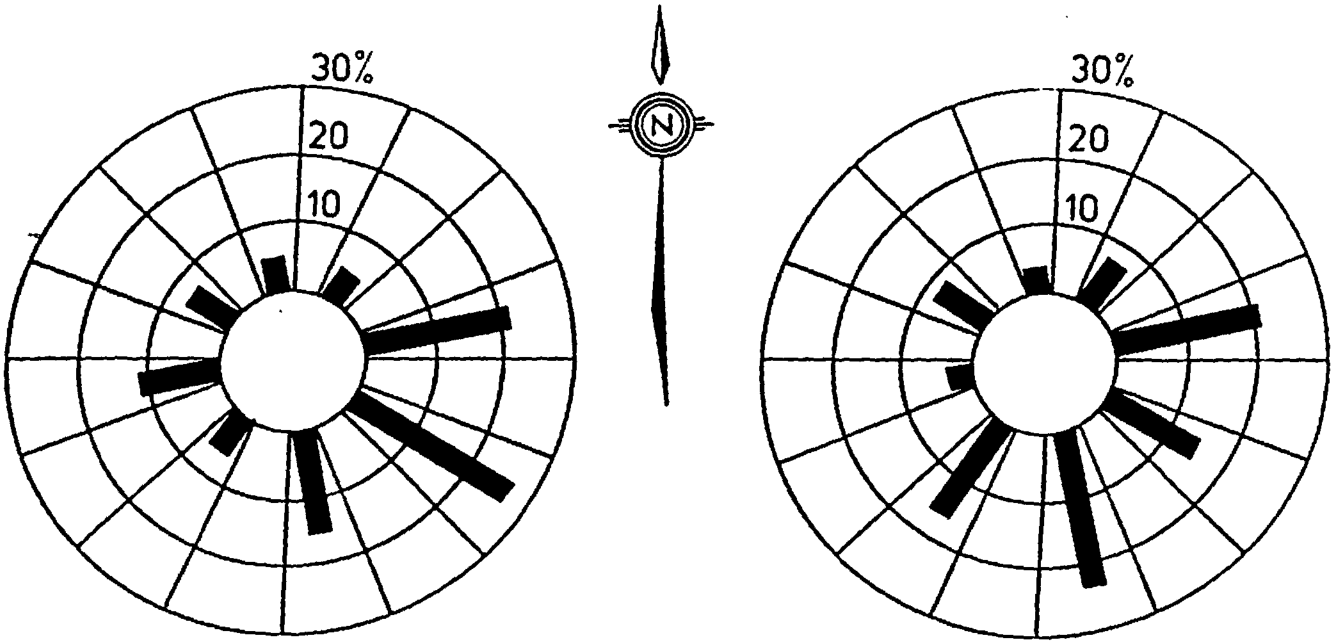
Simultaneous hourly measurements of wind speed and direction were recorded at Port Simpson and Prince Rupert during the period extending from May 14, 1981 to December 16, 1981. These data were correlated using the techniques developed by Walmsley and Bagg (1978) in order to improve the statistical reliability of the short-term data recorded at Port Simpson. Both short-term and estimated long-term annual frequency of wind at Port Simpson are depicted in Figure 5. Also shown for comparison are the corresponding short and long-term frequency distributions for Prince Rupert.

Topographic features at each station play a dominant role in dictating the prevailing wind patterns. A comparison of the mean monthly frequency of wind at Port Simpson (Table VII) and Prince Rupert (Table VIII), together with a qualitative assessment of topographic effects (see Section 2.2) suggests the following general patterns:

(a) The wind is most frequently from the SE at Prince Rupert. During these occasions, the wind at Port Simpson will most likely be from SSE, S or SSW. This is due to the influence of the topography of the Tsimpsean Peninsula.

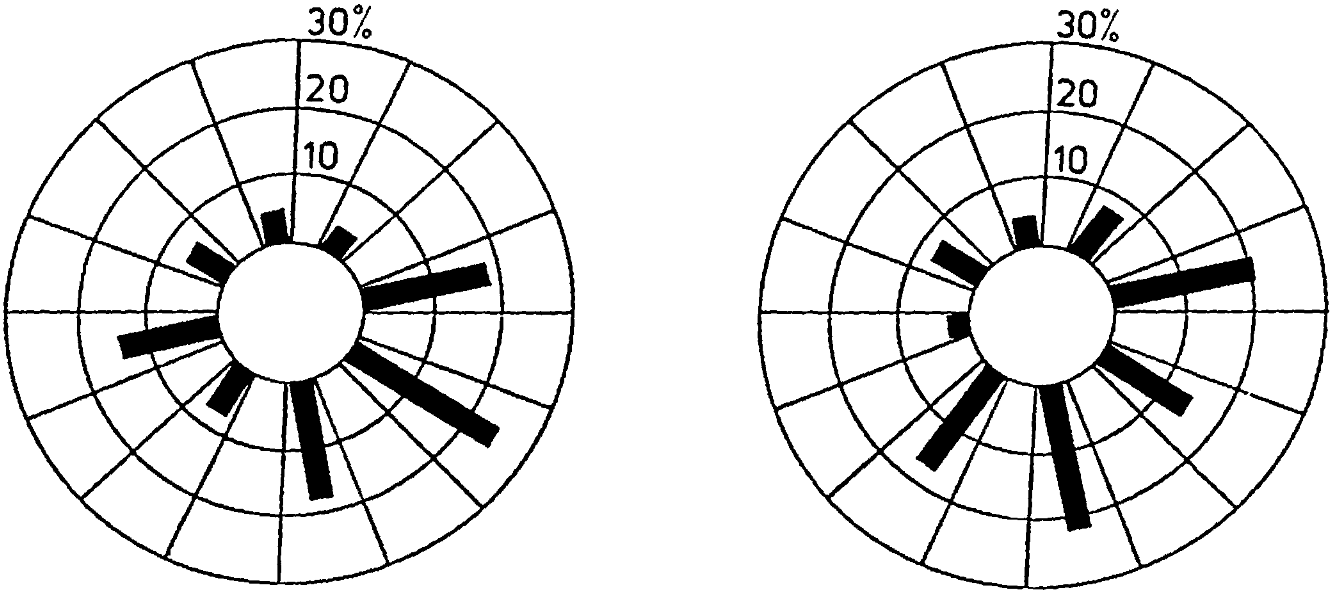
(b) A wind from the west at Prince Rupert tends to exhibit a shift to a wind from WNW and NW at Port Simpson. This is likely due to the local influence of Village Island on the anemometer location at Port Simpson.

(c) A comparison of mean speeds (by direction) contained in Tables VII and VIII indicate that on the average, speeds at Port Simpson are approximately 25 percent lower than those measured at Prince Rupert. Extreme hourly mean wind speeds and associated return periods for Port Simpson and Prince Rupert were estimated and are presented in Table IX.



PRINCE RUPERT
1961 - 1979

PORT SIMPSON
1961 - 1979
(ESTIMATED)



PRINCE RUPERT
May 1 - Nov. 30, 1981

PORT SIMPSON
May 14 - Dec. 16, 1981

Figure 5. Frequency of Wind Directions

TABLE VII

Mean Monthly Wind Speed Frequency

STATION: Port Simpson, B.C.
PERIOD OF RECORD: May 14 - December 16, 1981
PROJECT: V81-01
HT. ABOVE GROUND: 10 meters

	WIND SPEED (km/hr)											
DIRECTION	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	**≥51**	**TOTAL**	**MEAN SPEED**
NNE	73	20	9	16	14	7	3	1	2	1	6	152	13.0
NE	95	94	53	16	3	0	0	0	0	0	0	261	8.5
ENE	189	309	46	5	0	0	0	0	0	0	0	549	7.3
E	313	180	14	1	1	0	0	0	0	0	0	509	5.6
ESE	242	130	24	4	0	0	0	0	0	0	0	400	5.9
SE	207	107	58	8	2	0	0	0	0	0	0	382	6.8
SSE	179	87	119	66	43	20	4	0	0	0	0	518	11.4
S	171	164	141	96	46	18	10	8	3	0	0	657	12.2
SSW	99	188	184	146	42	19	3	3	0	0	0	684	13.0
SW	39	78	79	36	11	3	0	0	0	0	0	246	11.7
WSW	39	28	16	3	1	0	0	0	0	0	0	87	7.7
W	35	44	7	1	2	0	0	0	0	0	0	89	7.4
WNW	64	78	33	1	0	0	0	0	0	0	0	176	7.7
NW	112	132	16	1	0	0	0	0	0	0	0	261	6.7
NNW	69	29	0	1	0	0	0	0	0	0	0	99	5.1
N	76	22	12	4	0	3	1	0	0	0	0	118	6.8
CALM												18	0.0
TOTAL	2002	1690	811	405	165	70	21	12	5	1	6	5206	9.1

TABLE VIII

Mean Monthly Wind Speed Frequency

STATION: Prince Rupert, B.C.
PROJECT: V81-01

PERIOD OF RECORD: May 14 - December 16, 1981
HT. ABOVE GROUND: 14 meters

	WIND SPEED (km/hr)												
DIRECTION	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	**>51**	**TOTAL**	**MEAN SPEED**
NNE	23	20	4	0	0	0	0	0	0	0	0	47	6.5
NE	33	58	15	0	0	0	0	0	0	0	0	106	7.7
ENE	92	214	64	3	2	0	0	0	0	0	0	375	8.3
E	104	206	73	11	5	2	0	0	0	0	0	401	8.7
ESE	35	87	85	63	36	17	2	5	0	0	1	331	14.4
SE	47	100	197	179	174	123	42	30	8	7	1	908	19.7
SSE	35	77	85	88	84	57	27	31	8	7	4	503	20.2
S	49	126	84	35	23	8	6	6	0	2	0	339	12.7
SSW	54	66	35	4	10	9	0	0	0	0	0	178	10.0
SW	39	58	32	10	5	2	1	1	0	0	0	148	10.1
WSW	33	84	59	16	2	0	1	0	0	0	0	195	10.3
W	42	116	159	86	31	7	2	0	0	0	0	443	13.2
WNW	34	65	64	16	2	0	0	0	0	0	0	181	10.4
NW	24	42	39	16	2	1	0	0	0	0	0	124	10.8
NNW	28	37	33	14	3	1	0	0	0	0	0	116	10.5
N	22	33	22	0	0	0	0	0	0	0	0	77	8.5
CALM												663	0.0
TOTAL	**694**	**1389**	**1050**	**541**	**379**	**227**	**81**	**73**	**16**	**16**	**6**	**5135**	**11.9**

TABLE IX

Extreme Hourly Mean Wind Speed (km/h)

	Return Period (years)		
	10	30	100
Prince Rupert	90	99	109
Port Simpson	74	81	89

Prevailing wind patterns within Port Simpson Bay will be somewhat different than those recorded at the anemometer station (Port Simpson). It is estimated that wind over the open water will be more frequent and stronger from the west, stronger from the south and south southwest, and slightly more protected from the north wind.

The time series plots of every third hourly wind measurements, either from Port Simpson or Prince Rupert, are presented in Appendix B in conjunction with the significant wave heights from the wave data.

4.2 Waves

The monthly time series of characteristic (significant) wave heights as measured by the Waverider buoy are presented in Appendix B. Also plotted are the Port Simpson wind measurements (speed and direction) that coincide with the wave measurements (i.e. every three hours). Due to the incomplete wind record at Port Simpson, the winds at Prince Rupert are shown for the months of January 1982 through March 1982; and for the first half of May 1981. The statistical results of the complete wave record collected at Port Simpson are presented in Figures 6 to 8.

Appendix F presents a summary of the percentage of data return from the Port Simpson wave study. Over the entire sampling period there was a 51% recovery of wave data. Several problems were encountered and included buoy malfunction, radio signal interference, and the inability of the operator of the receiving station to devote adequate time to his duties. On 1 September a new station operator was employed. During the first sampling period, from the initial installment of the buoy (1 May 1981) until it was replaced (25 November 1981) with a second buoy, there was a data return of 62%. During the second period (25 November 1981 - 26 January

1982), the replacement buoy was found to be faulty, resulting in a very low data return. This buoy was then itself replaced with a third buoy on 26 January 1982.

In general, the observations indicate very low wave energy at Port Simpson, with amplitudes less than 1 m and peak periods usually shorter than 5 seconds (Figures 6 to 8). The findings indicate that the wave field at Port Simpson is dominated by locally generated seas. This appears reasonable considering the sheltering effect of the various islands and reefs near the proposed dock site; and the fetch-limited nature of the surrounding waters. However, the wave records collected during some of the winter months (December and January) were essentially void of useful information due to buoy malfunction. Overall, the highest observed significant wave height (0.82 m) occurred 14 January during a one-day stretch of good data. The highest recorded wind event during the 1981-82 measurement happened 9 December when hourly winds greater than 60 km/hour from the north were recorded but, unfortunately, no wave data were collected at this time.

An attempt was made to correlate the observed winds at the Port Simpson dock with the significant wave events. From the available measurements it does not appear that the relationship between winds and waves is straightforward in Port Simpson. Throughout the 1981-82 study period there were a number of high wind events, usually from the southerly quadrant. Most occurrences of these southerly high winds corresponded to an increase in wave activity at the wave buoy, but for a few occurrences they did not. In particular, the relatively high, short period (less than 5 seconds), wave events which occurred on 30 September - 1 October, 25-26 October, 30-31 October, 4-5 November, 25 November, 14 January (using the Prince Rupert winds as an indicator of local winds), and 18 February appeared to have been directly related to local wind forcing. However, an interesting event was recorded on 28 June. Although the local winds were generally light and variable in Port Simpson Bay, the Waverider buoy recorded relatively large waves (greater than 0.5 m) with relatively long peak periods (greater than 8 seconds). It appears are that these waves were not generated locally, but entered the Bay, probably through Inskip Passage, as a remotely generated swell. A possible source of the generating force for these "swells" comes from the Mariners Weather Log (1981) which shows the presence of a storm seaward of Dixon Entrance on 28 June. However, considering the varied bathymetry and shadowing effects of the geographic features around Port Simpson, it is doubtful that much wave energy would enter the Port Simpson area in the form of swells.

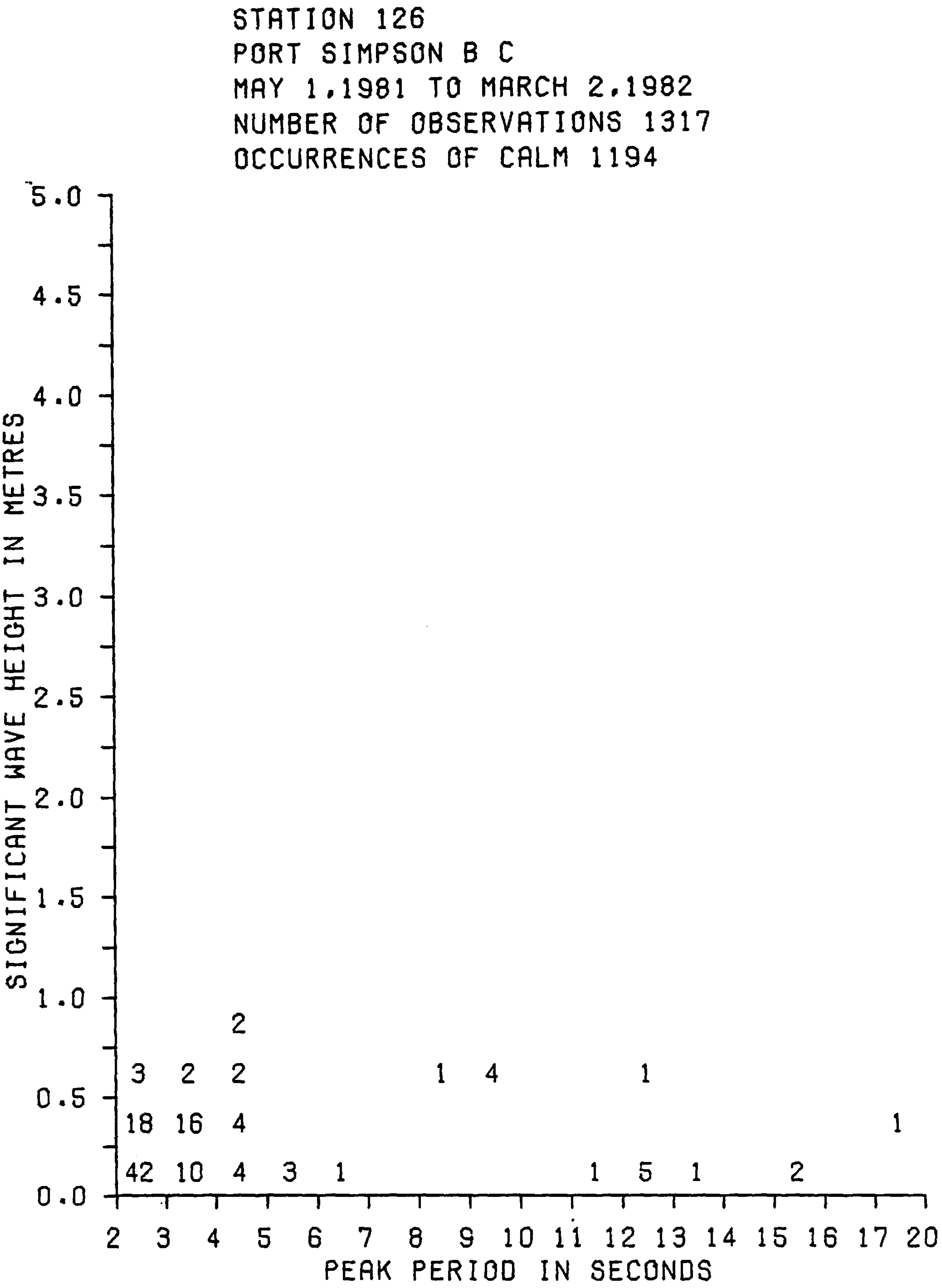


Figure 6. Scatter diagram of peak period versus significant wave height.

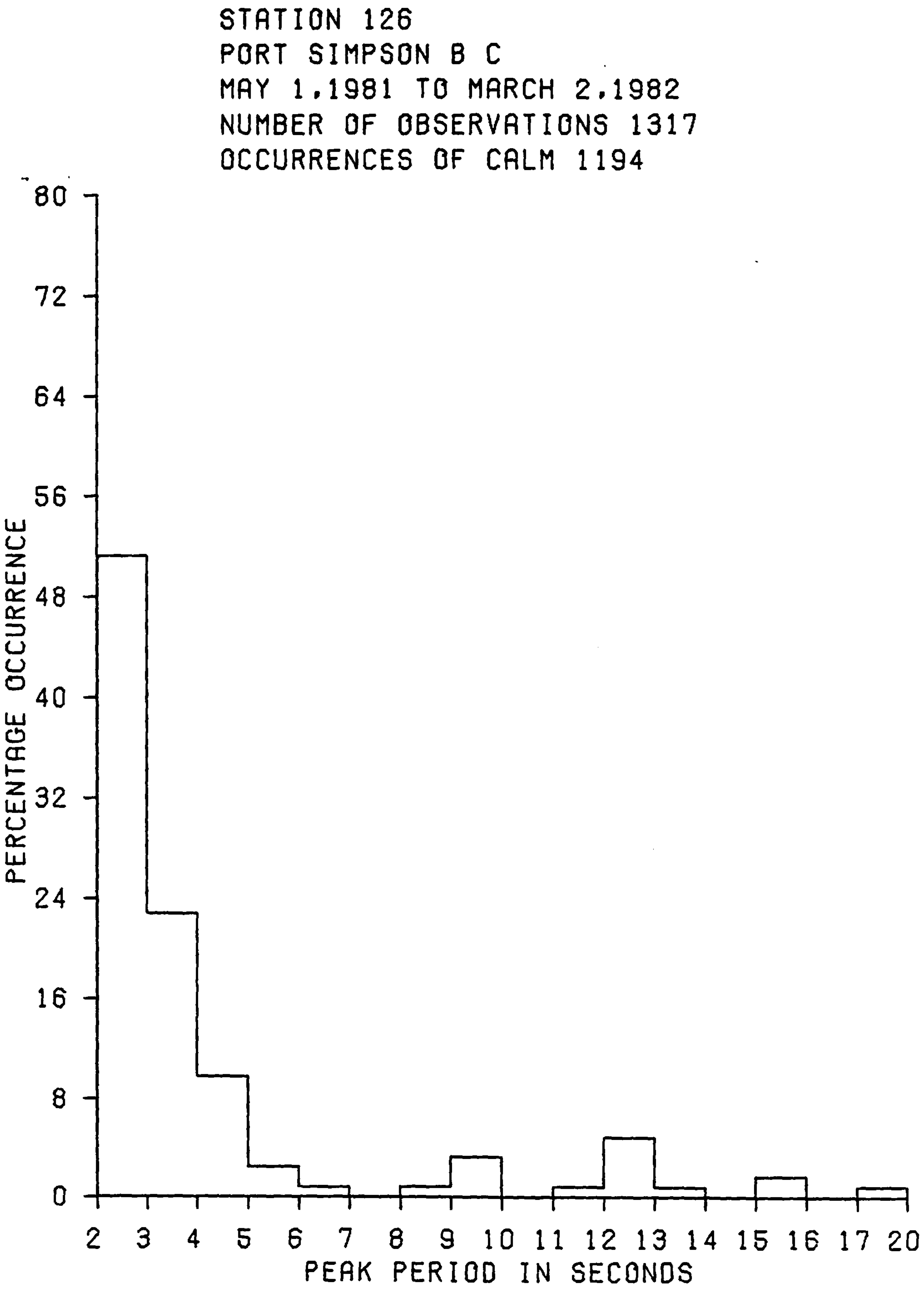


Figure 7. Peak period histogram.

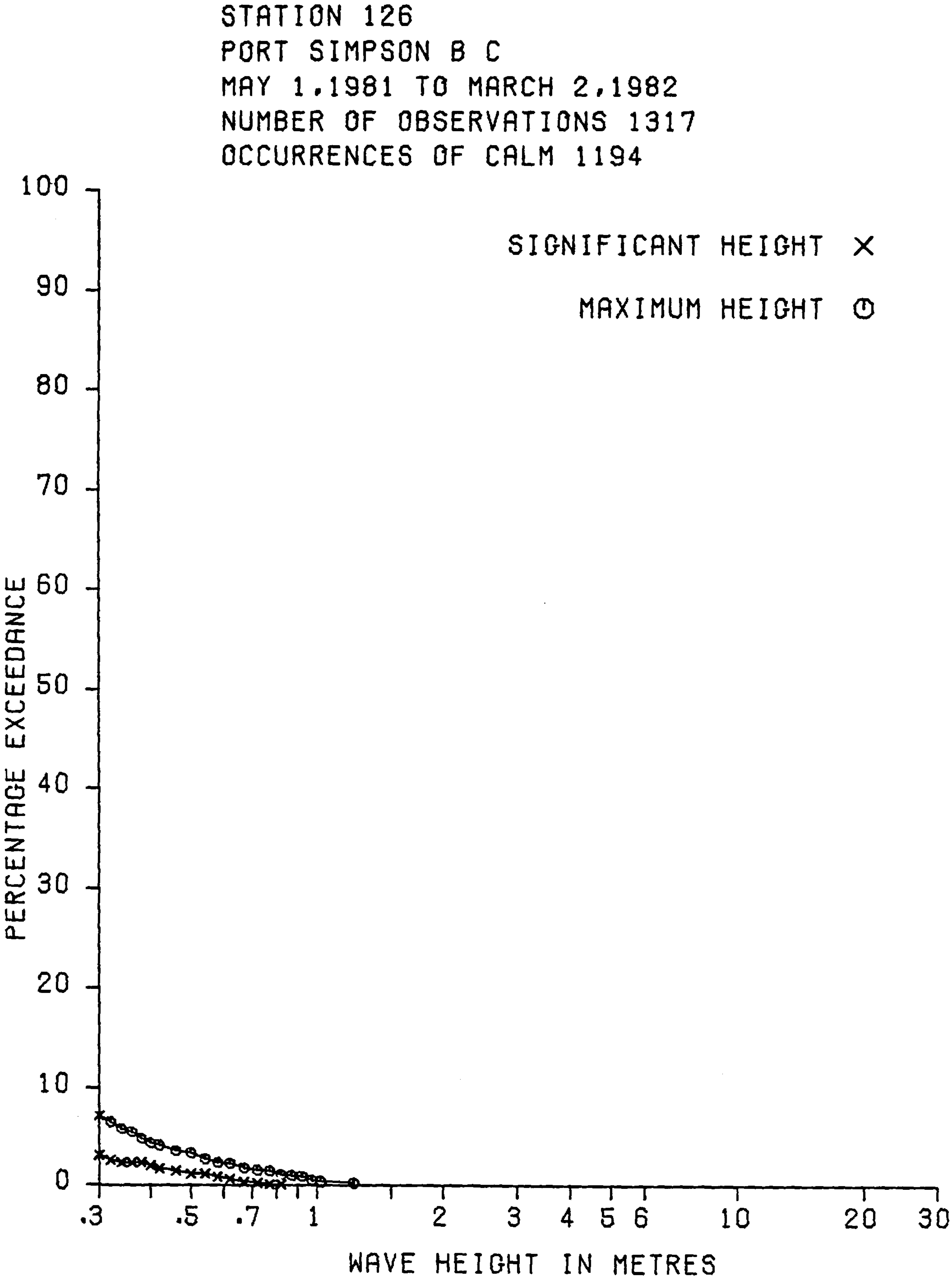


Figure 8. Exceedance diagram.

Residents interviewed at Port Simpson in 1981 estimated storm waves within the Bay to have been as high as 2.5 m during storms with exceptionally strong westerly winds (perhaps once every 2 or 3 years). The present data set showed no indication of these large wave events, although this may be a reflection of the year-to-year variations in the wave field.

4.3 Currents

Current Meter Data

Table X summarizes some of the May 1981 current meter statistics (see also Appendix E) while Figures 9 to 12 present time series plots of the data. In general the highest currents were in the near surface measurements and the smallest at 26 m in the deeper water. Velocities in Inskip Passage were greater than in Port Simpson Bay although the highest observed speed occurred at Station 2 in the middle of the bay. The largest mean velocity magnitude was observed at 26 m at Station 3 near the proposed dock site. Examination of the PVDs (Figures 13 to 16) shows that although the measured speeds were the smallest at the dock site, the direction of the current was more consistently in one direction, resulting in a larger mean velocity magnitude.

The near-surface Inskip Passage RCM showed the second largest mean velocity magnitude. The mean flow was outward, i.e. to the southwest. This may be a reflection of estuarine circulation which is a density driven circulation where brackish surface water (due to freshwater input to a body of water) moves seaward and deeper saline water flows into the inlet. The major direct freshwater source in Port Simpson Bay is Stumaun Creek which in May provides approximately 1.0 m^3/s of fresh water into the Bay (NEAT, 1975). However, this direct freshwater input represents only a very small fraction of the total fresh water in the mixed-layer in May. A typical 5 m semi-diurnal tidal exchange in Port Simpson Bay would exchange an estimated 73×10^6 m^3 of water. Hence it is probable that most of the freshwater contribution to the upper layer in Port Simpson Bay in May/June is from the Nass and Skeena Rivers.

The mean outflow measured in Inskip Passage may also be the result of meteorological forcing. Tidally induced circulation does not appear to be a major factor since periods of relatively small mean flow sometimes coincided with a large tidal range.

TABLE X: Current Meter Statistics

Station	Depth	Mean Speed (cm/s)	Std. Dev. (cm/s)	Mean Velocity Magnitude (cm/s)	Mean Velocity Direction (°T)	Max. Speed (cm/s)	Direction (°T)	% of Observations less than 5 cm/s
1	6	8.5	4.4	1.7	234	27.8	306	23.7
2	6	4.9	2.9	0.7	093	29.2	122	58.8
3	7	4.9	3.0	0.5	073	22.8	126	60.9
3	26	3.4	2.5	2.4	327	14.7	324	76.8

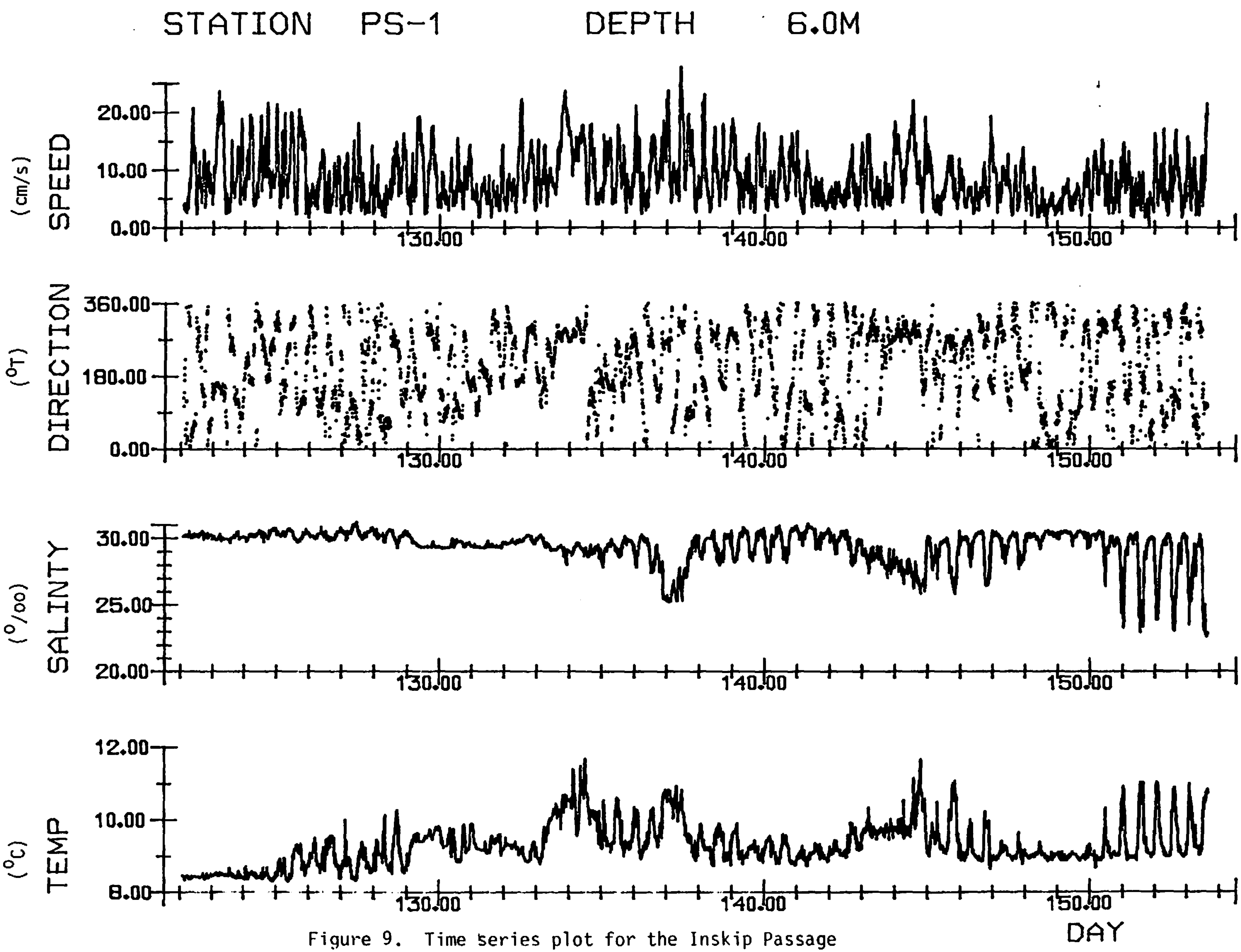


Figure 9. Time series plot for the Inskip Passage current meter.

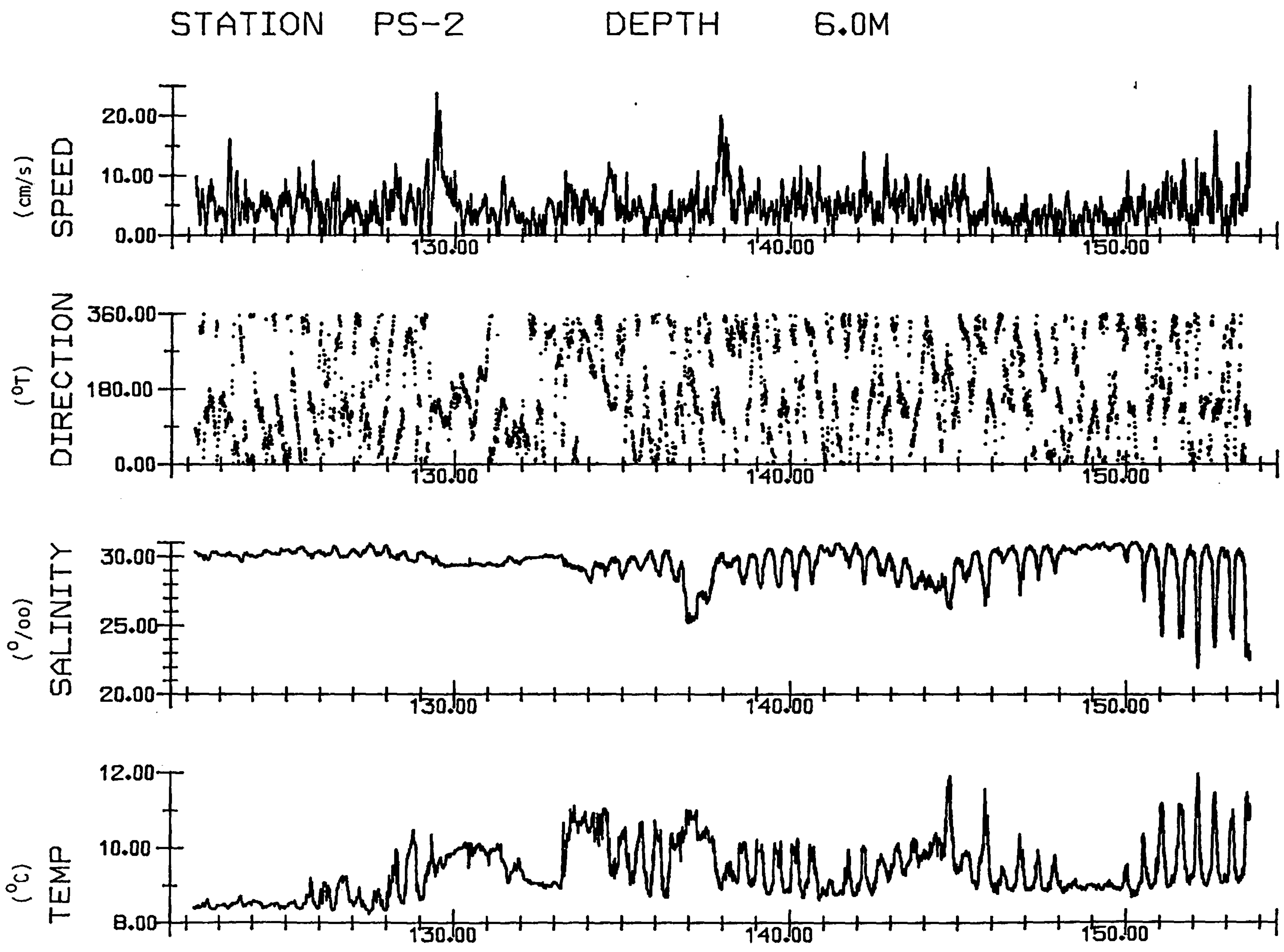


Figure 10. Time series plot for the mid-bay current meter.

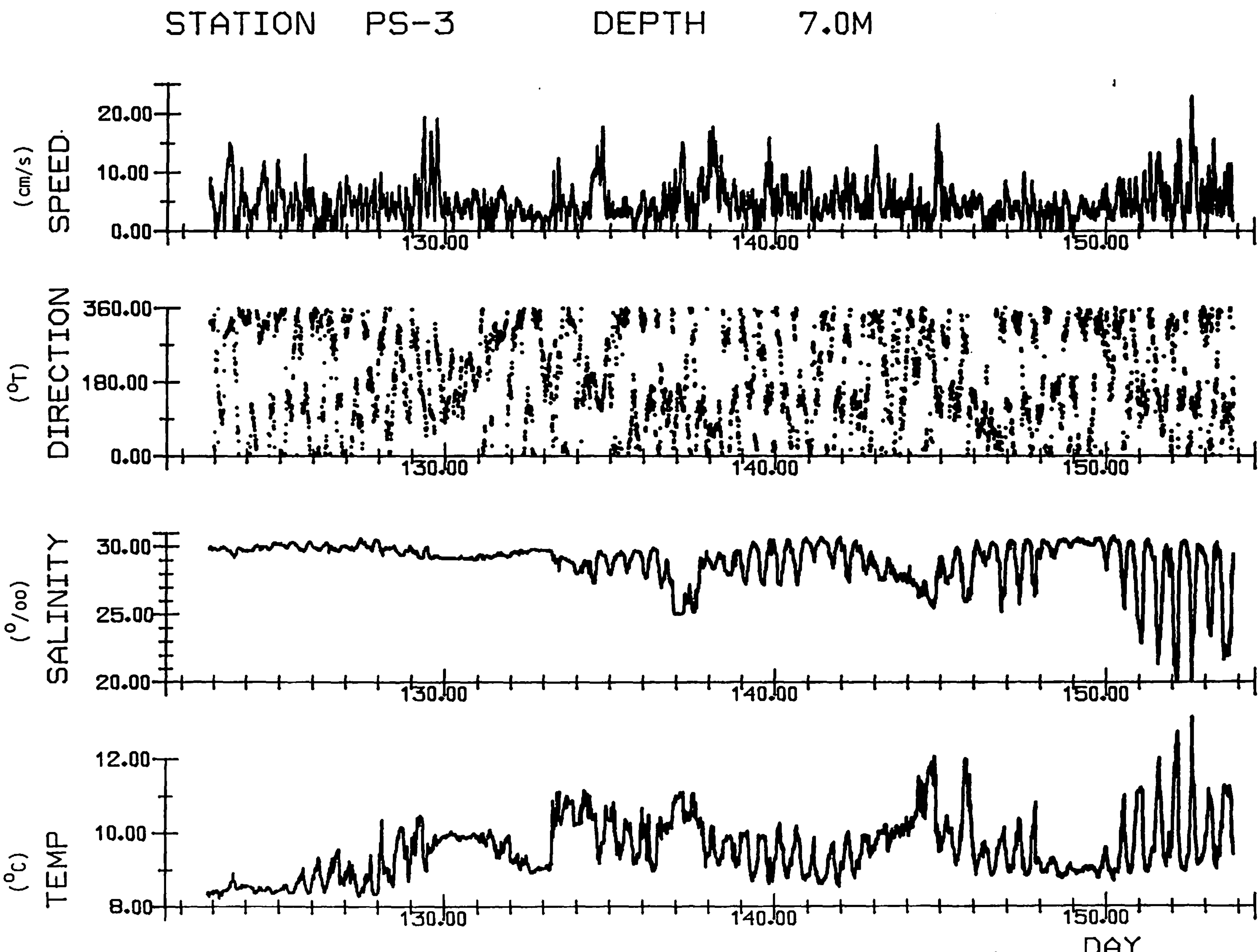


Figure 11. Time series plot for the dock site upper current meter.

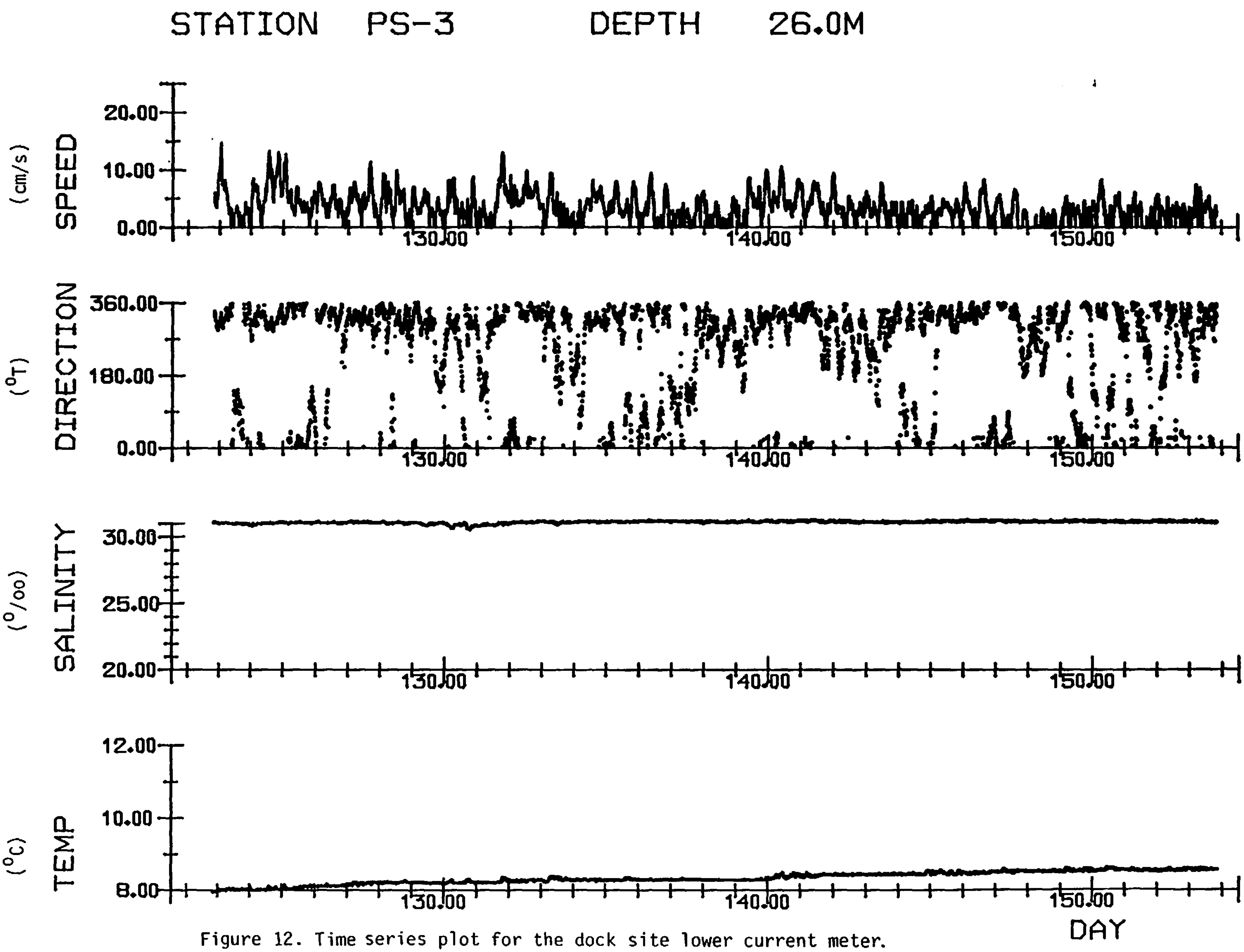


Figure 12. Time series plot for the dock site lower current meter.

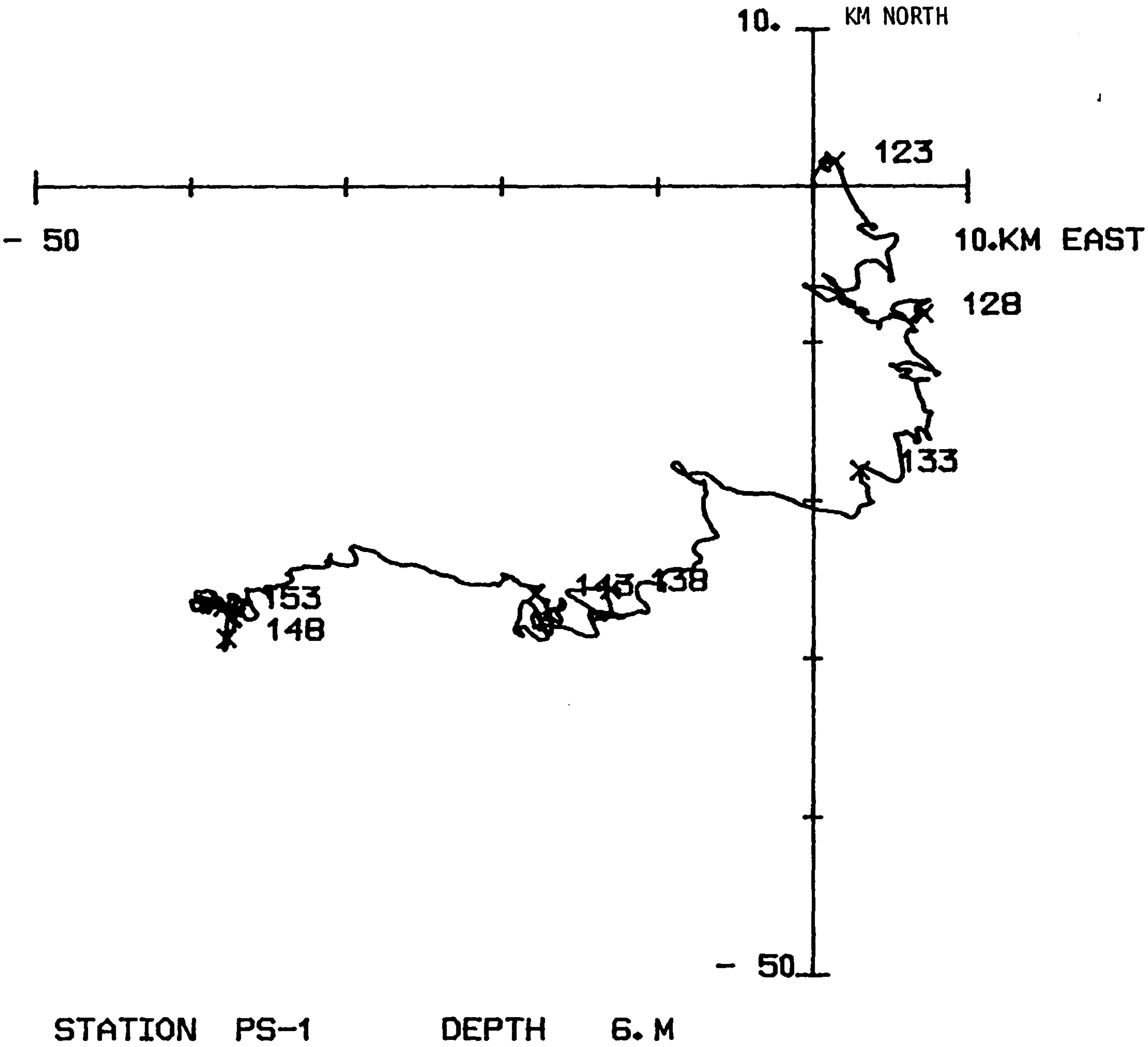


Figure 13. Progressive vector diagram for the Inskip Passage current meter; x denotes midnight of indicated day of year. distance scale in km.

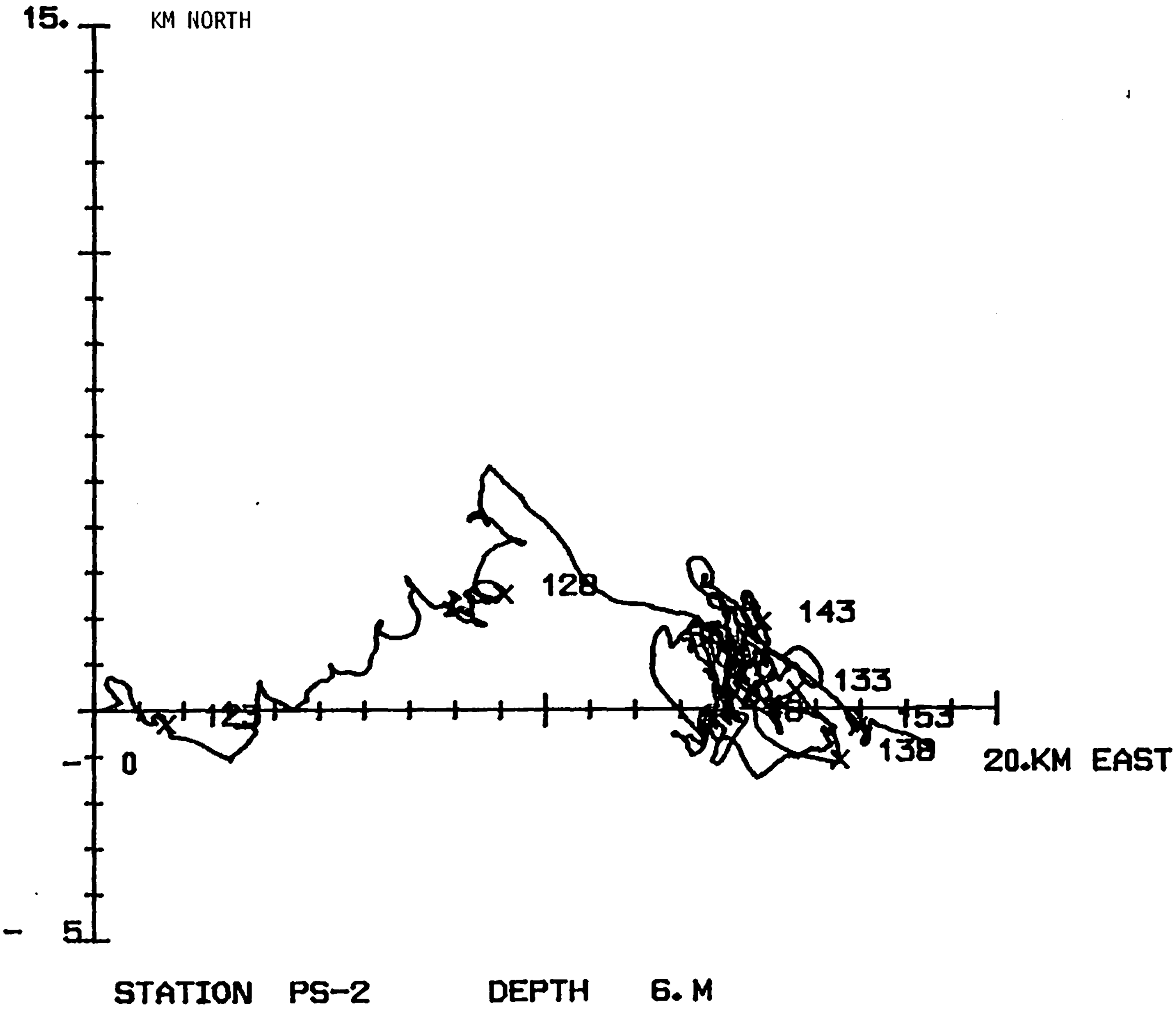


Figure 14. Progressive vector diagram for the mid-bay current meter; x denotes midnight of indicated day of year, distance scale in km.

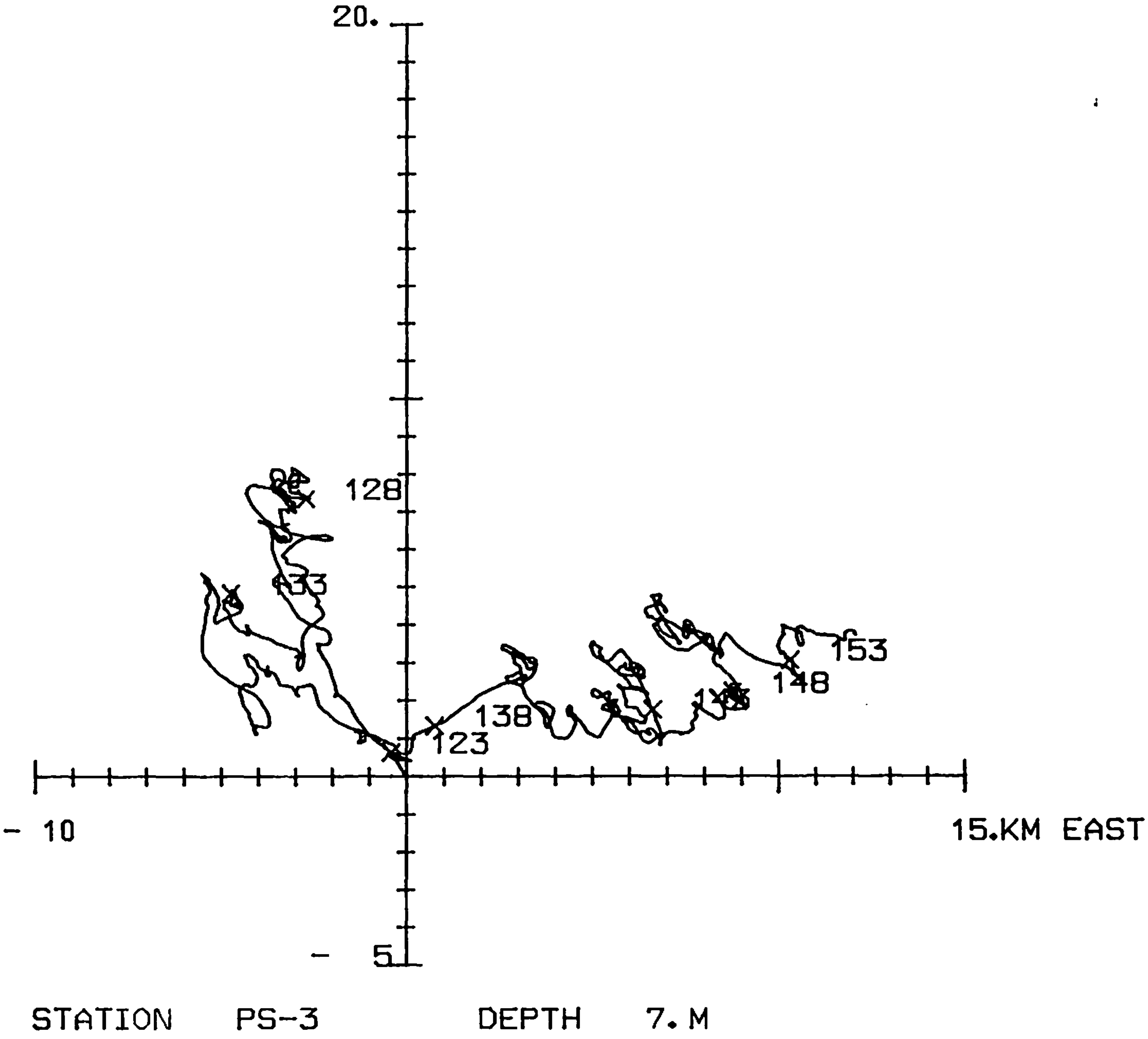


Figure 15. Progressive vector diagram for the dock site upper current meter; x denotes midnight of indicated day of year, distance scale in km.

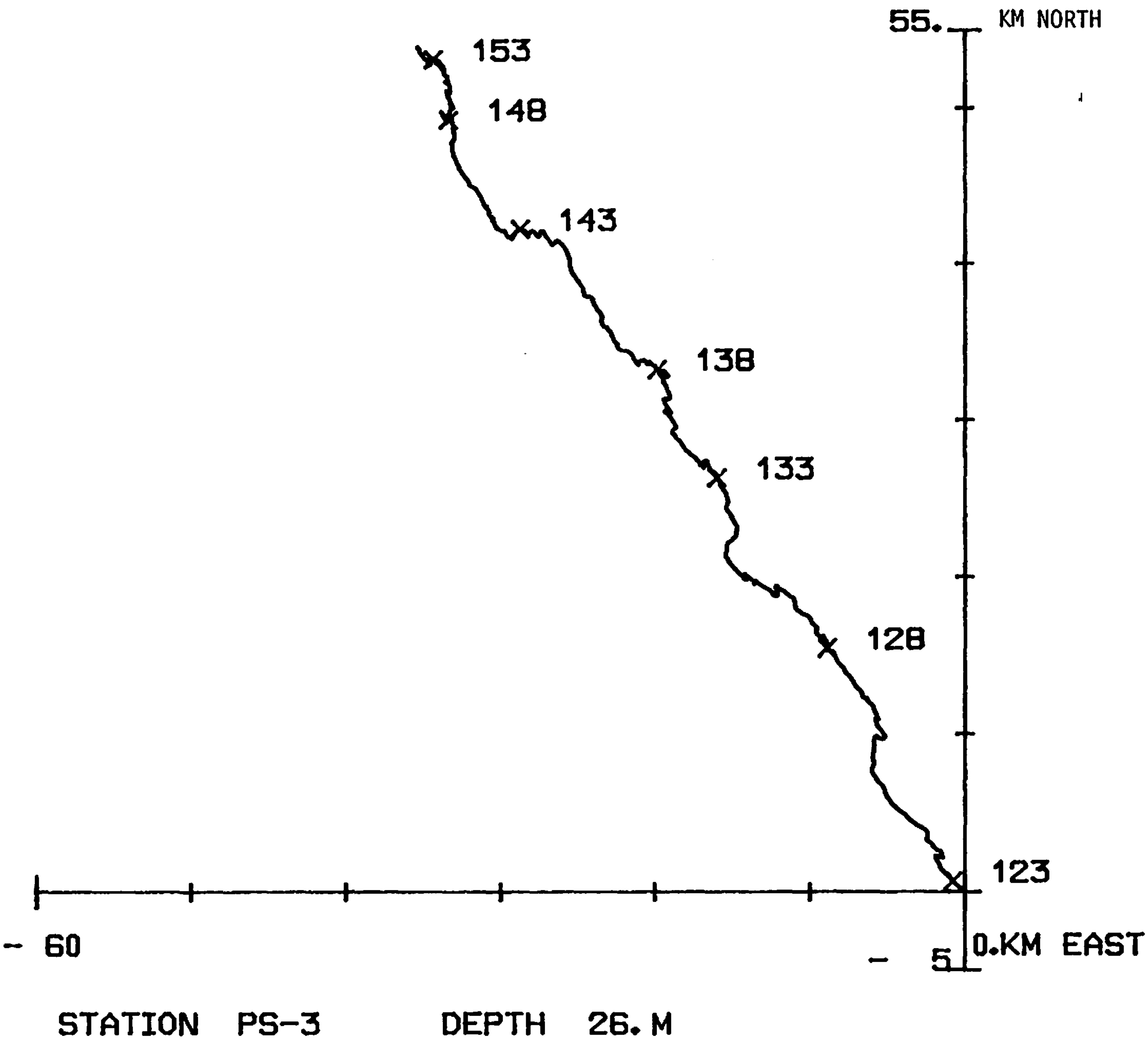


Figure 16. Progressive vector diagram for the dock site lower current meter; x denotes midnight of indicated day of year, distance scale in km.

It appears that the mean velocity magnitude at 26 m depth measured over 5 days at Station 3, (near the dock site) can vary by a factor of 4 on the basis of the month of data collected.

Current Drogue Data

Overall, the deep water drogues (20 to 22 m depth) in Port Simpson Bay showed generally lower velocities than the surface drogues. The highest observed deep water speed was about 12 cm/s with most velocities less than 10 cm/s. Figures 17 to 20 show the deep drogue tracks for the four tracking sessions. Average velocities are in the 1 to 3 cm/s range. A clockwise eddy was observed east of Birnie Island in Session 1. There appeared to be a tendency to counter-clockwise circulation in the central portion of the Port Simpson Bay basin. These results from the deep drogues are consistent with the measurements of the Station 3 deep current meter near the dock site. The speed observed in the deep drogues near the dock site was small with a mean speed of 3.3 cm/s and a maximum of 4.3 cm/s.

Nearly all the deep drogues exhibited the effects of the tide in their motions. This was confirmed by the in-situ measurements of deeper currents at the moored current meter near the dock site. However, there were some exceptions. Drogue 1001 on 27/28 May (Figure 18) showed no tidal influence in its movement except near low water.

The near-surface drogues (0 to 2 m) provided more information but there was less consistency from day to day. Session 1 (24-26 May, Figures 21 to 24) gave results that were easy to interpret. The circulation in the central region of the bay was a counter-clockwise gyre with velocities ranging from less than 1 cm/s to about 30 cm/s. Frequent observations were made of flotsam accumulation near the centre of the bay, further confirming the existence of the gyre. During this tracking session, winds were light and variable from the northwest quadrant. Some drogues moved out of the bay through Inskip Passage and Dodd Pass. One drogue left through Inskip Passage on a flood tide (drogue 1302). The general motion near the dock site was to the northwest, parallel to the shore.

During the second session (27-28 May) the wind was light, switching in direction from west and northwest to easterly for the last half. Surface drogues (Figures 25 to 28) were again observed leaving the bay, through Rushbrook Passage on

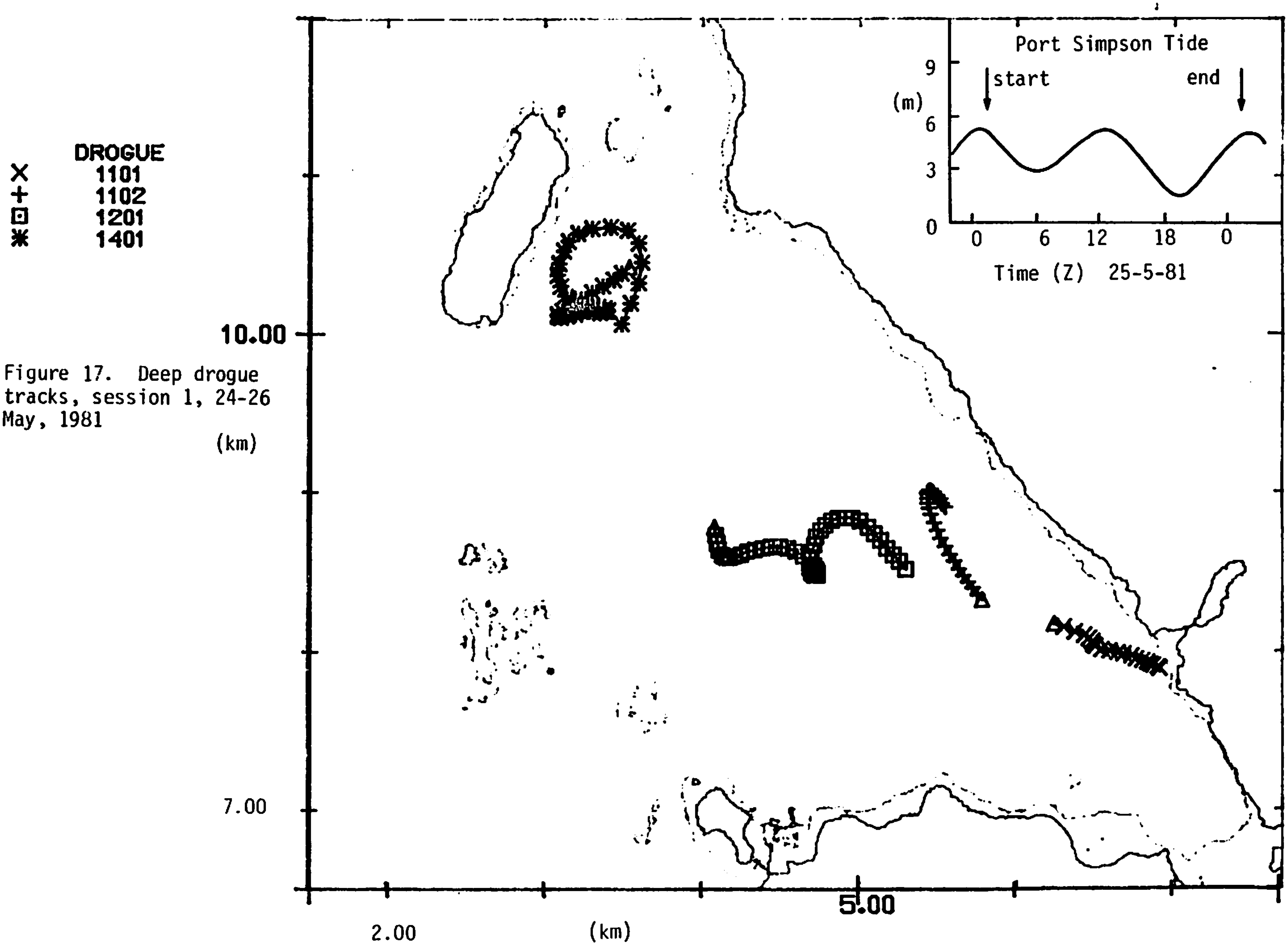
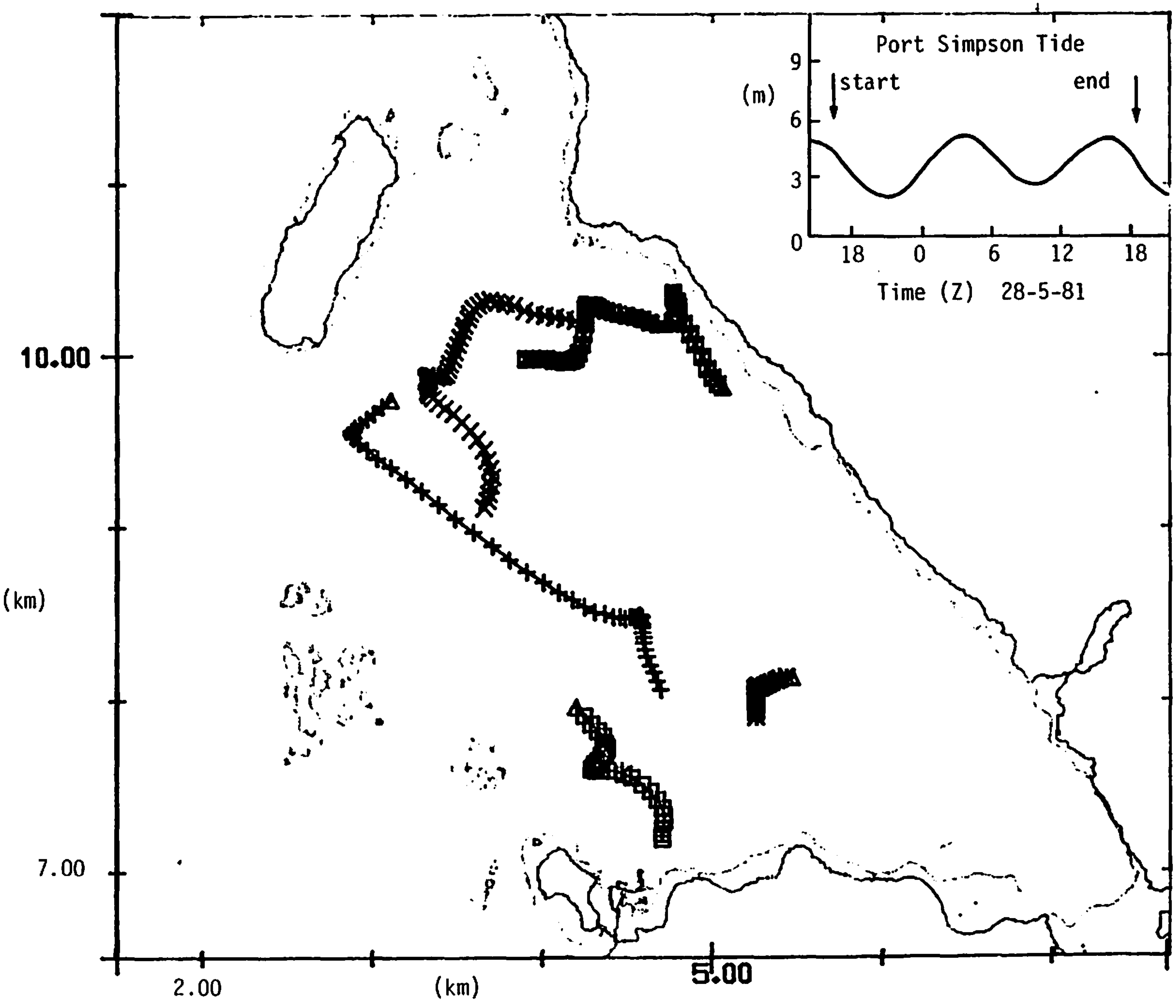


Figure 17. Deep drogue tracks, session 1, 24-26 May, 1981

DROGUE
× 0901
+ 1001
⊡ 1201
✳ 1202
⊠ 1301

Figure 18. Deep drogue tracks, session 2; 27-28 May, 1981.



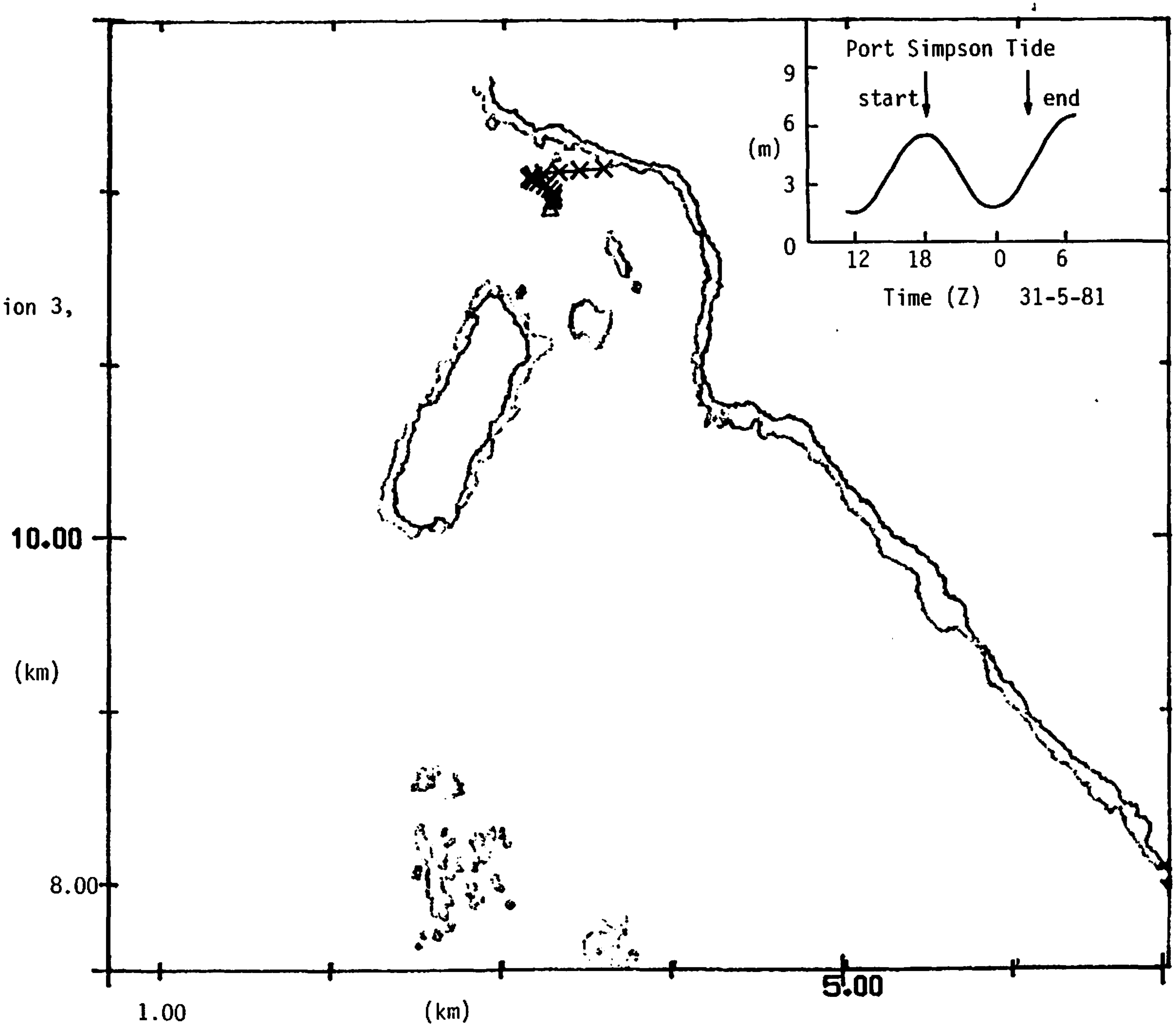


Figure 19. Deep drogue track, session 3, 30-31 May (Z)

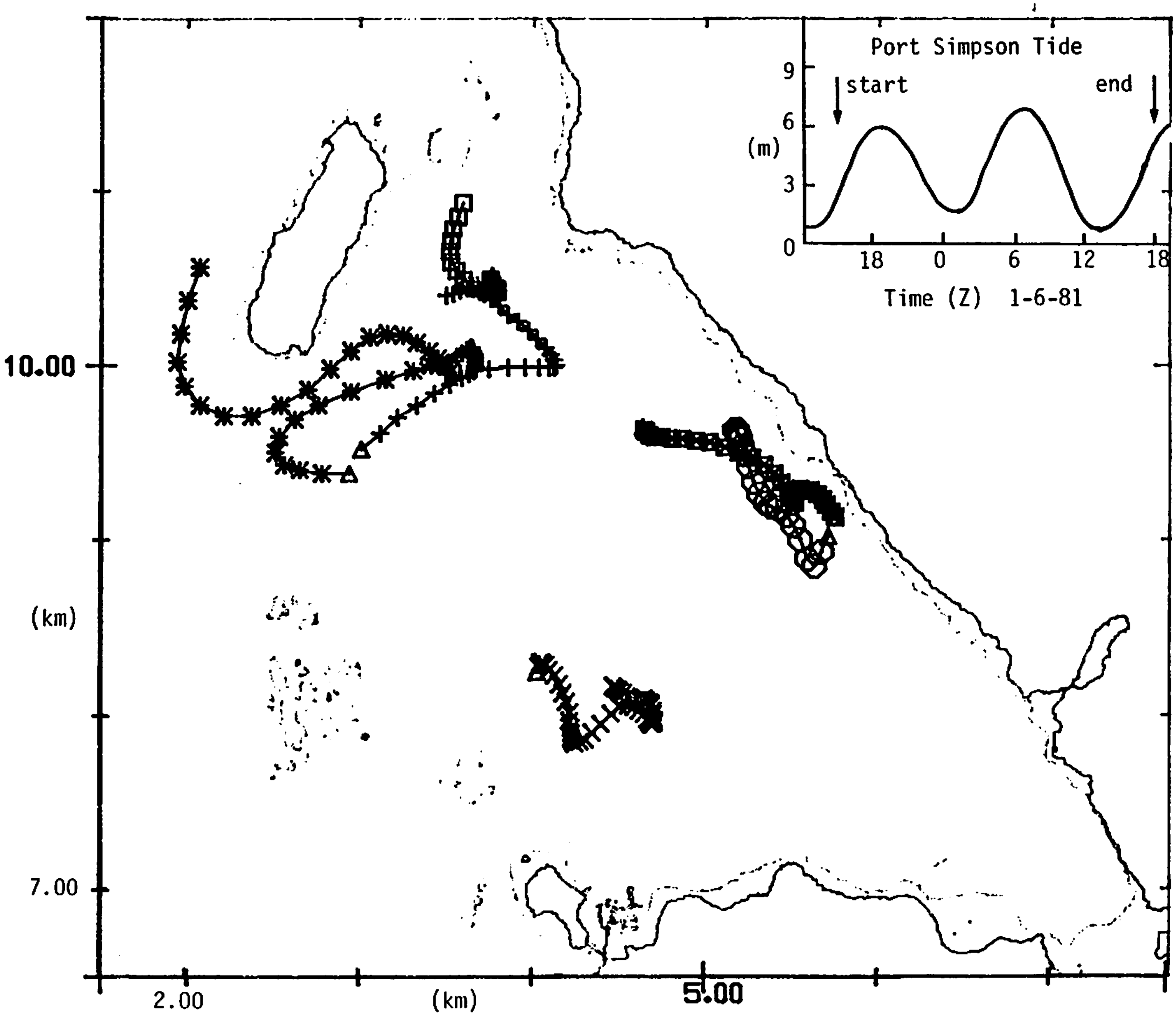


Figure 20. Deep drogue tracks, session 4, 31 May-1 June, 1981 (Z)

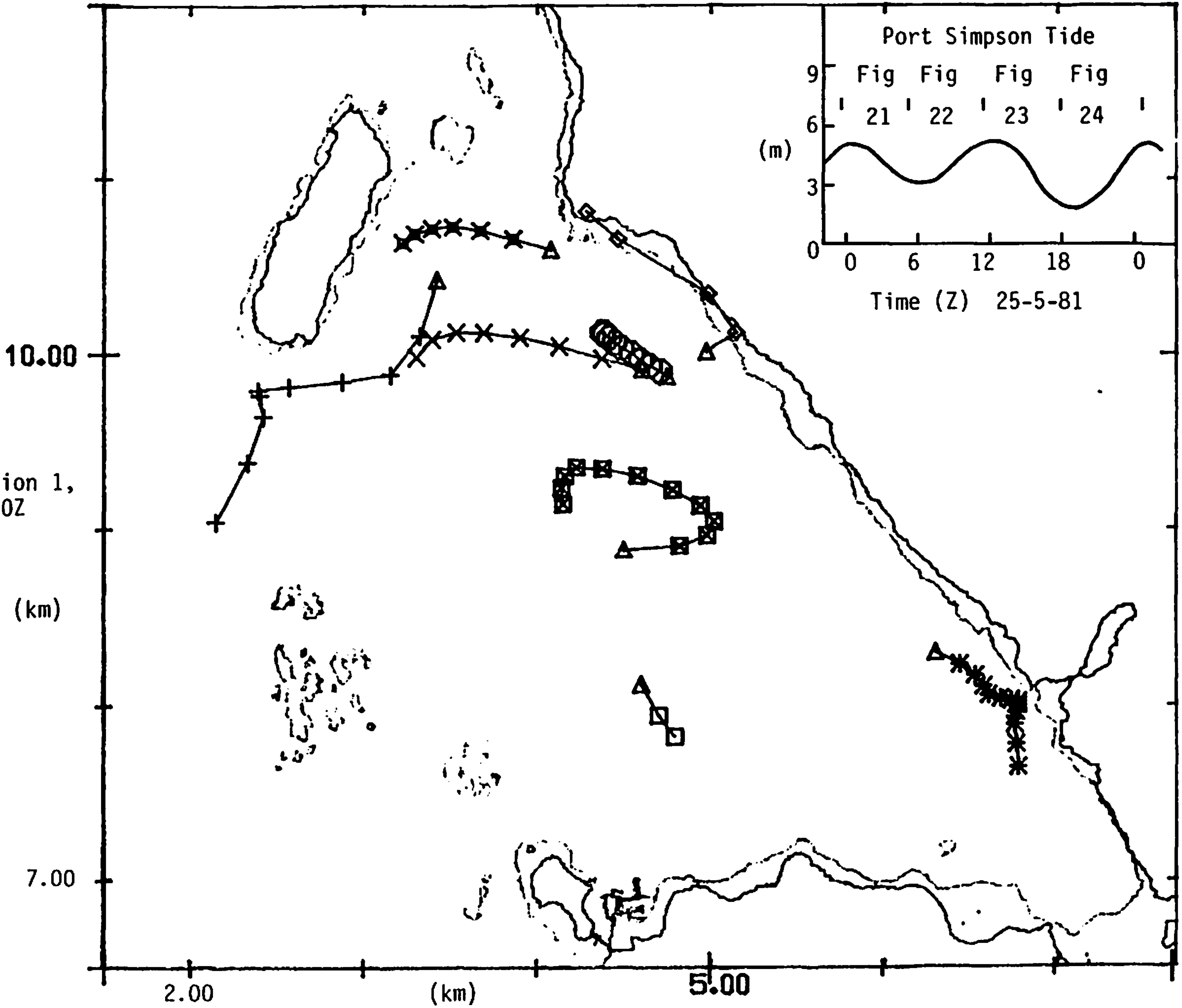


Figure 21. Surface drogue tracks, session 1, 2330Z 24 May to 0600Z 25 May, 1981.

DROGUE	
×	0101
+	0301
⊡	0501
✳	0702
⊠	0801
⊙	0802
◈	0901
⧗	1001
◆	1302

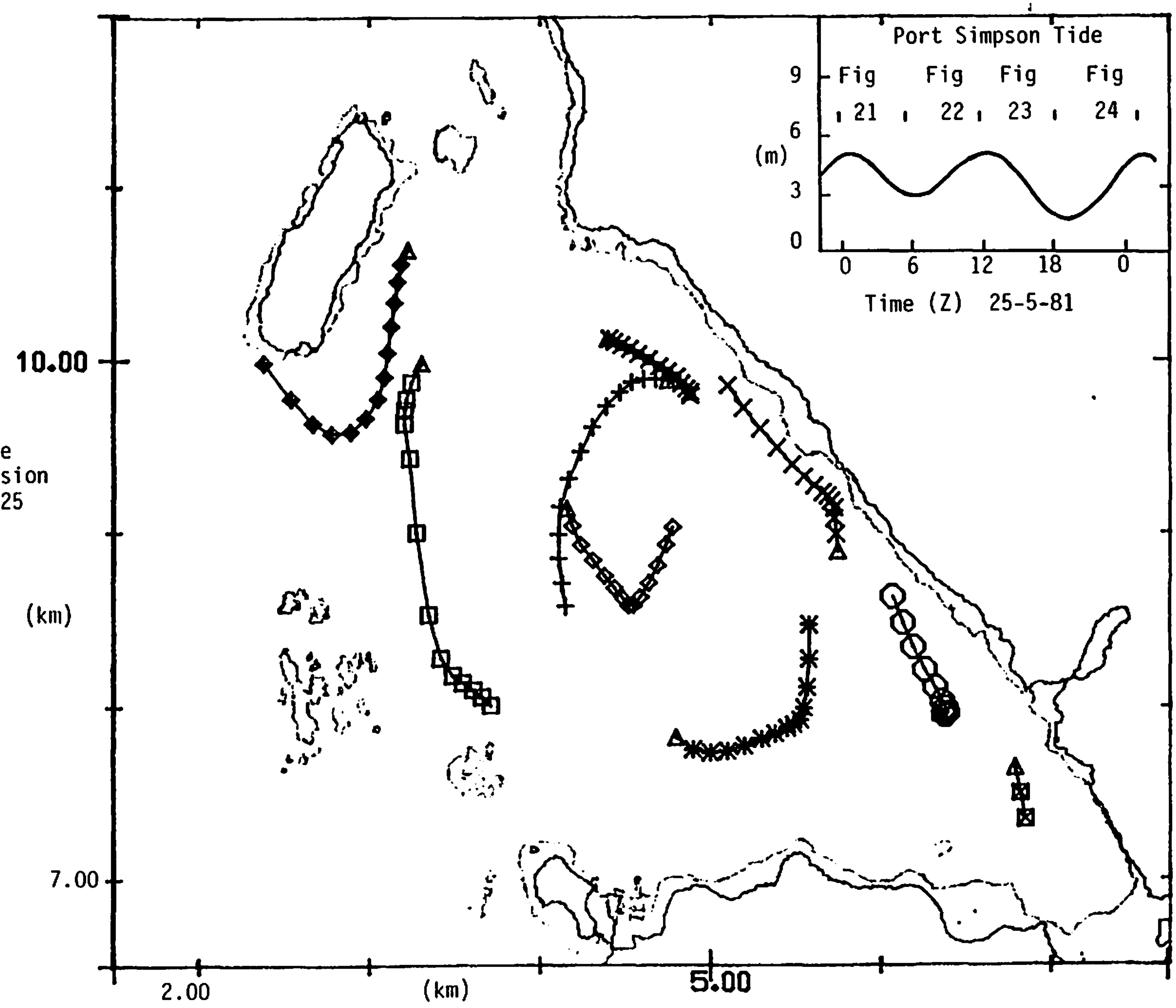


Figure 22. Surface drogue tracks, session 1, 0600 to 1230Z, 25 May, 1981.

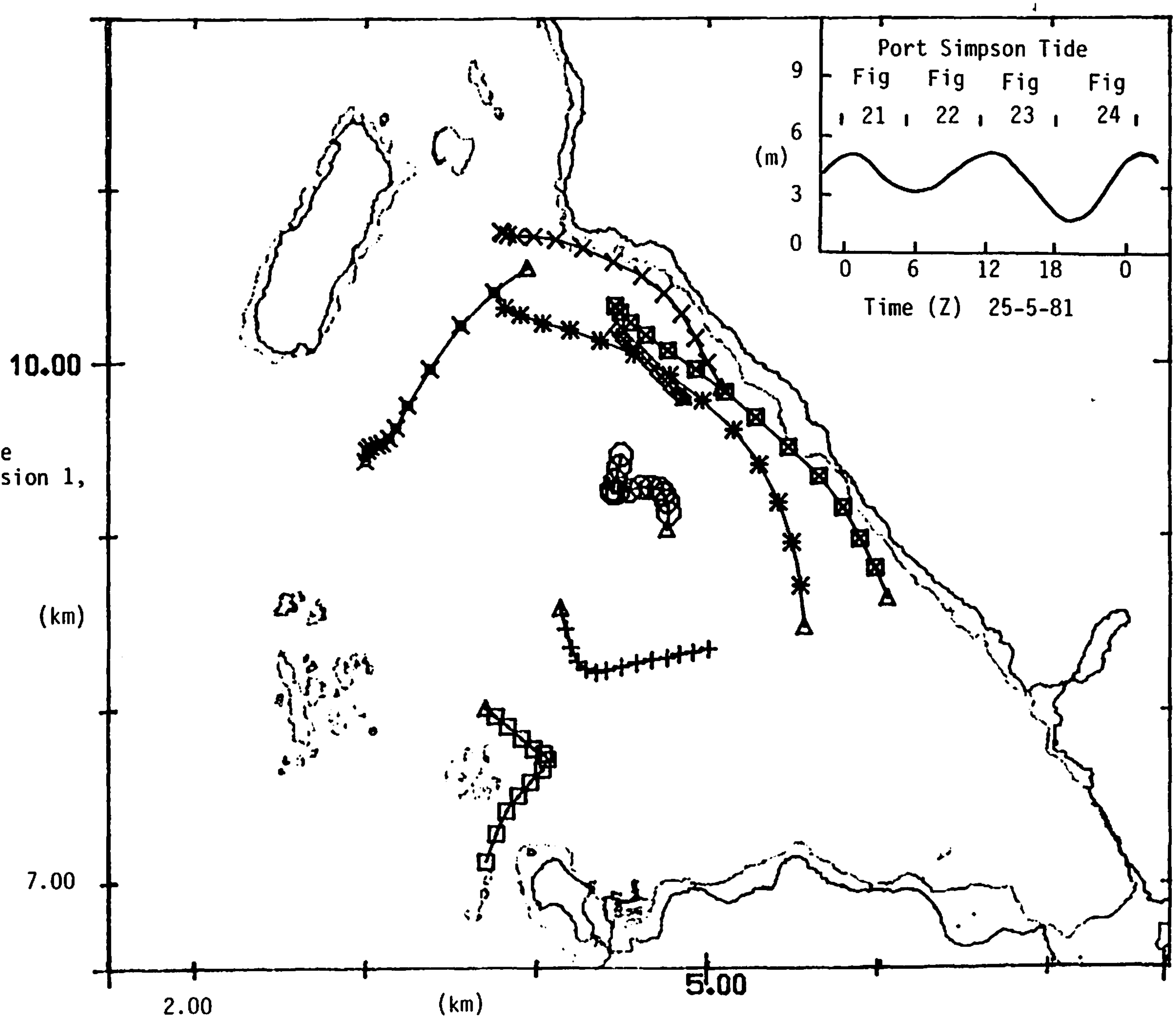


Figure 23. Surface drogue tracks, session 1, 1230 to 1900Z, 25 May, 1981.

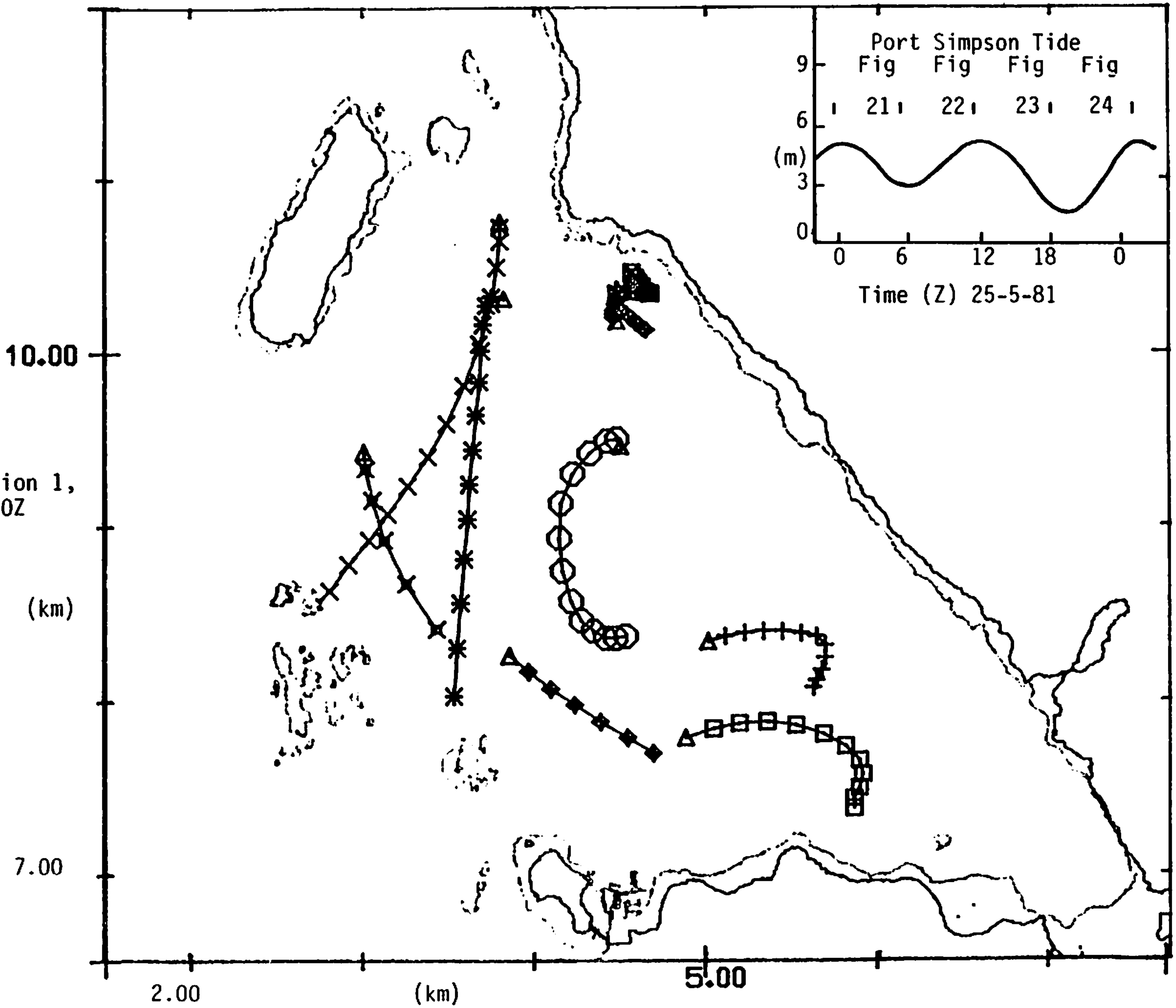


Figure 24. Surface drogue tracks, session 1, 1900Z 25 May to 0200Z 26 May, 1981.

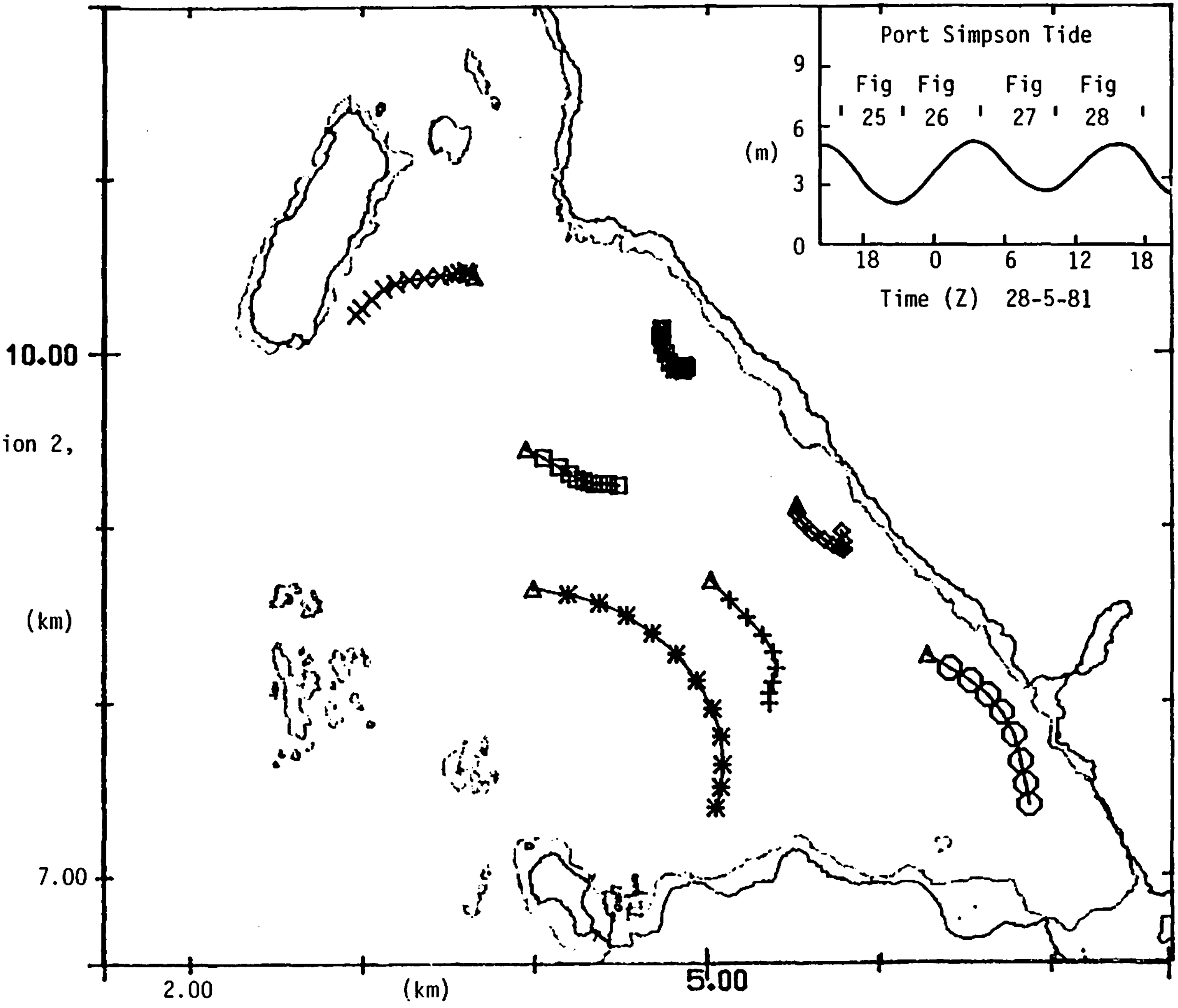


Figure 25. Surface drogue tracks, session 2, 1600Z to 2230Z, 27 May, 1981.

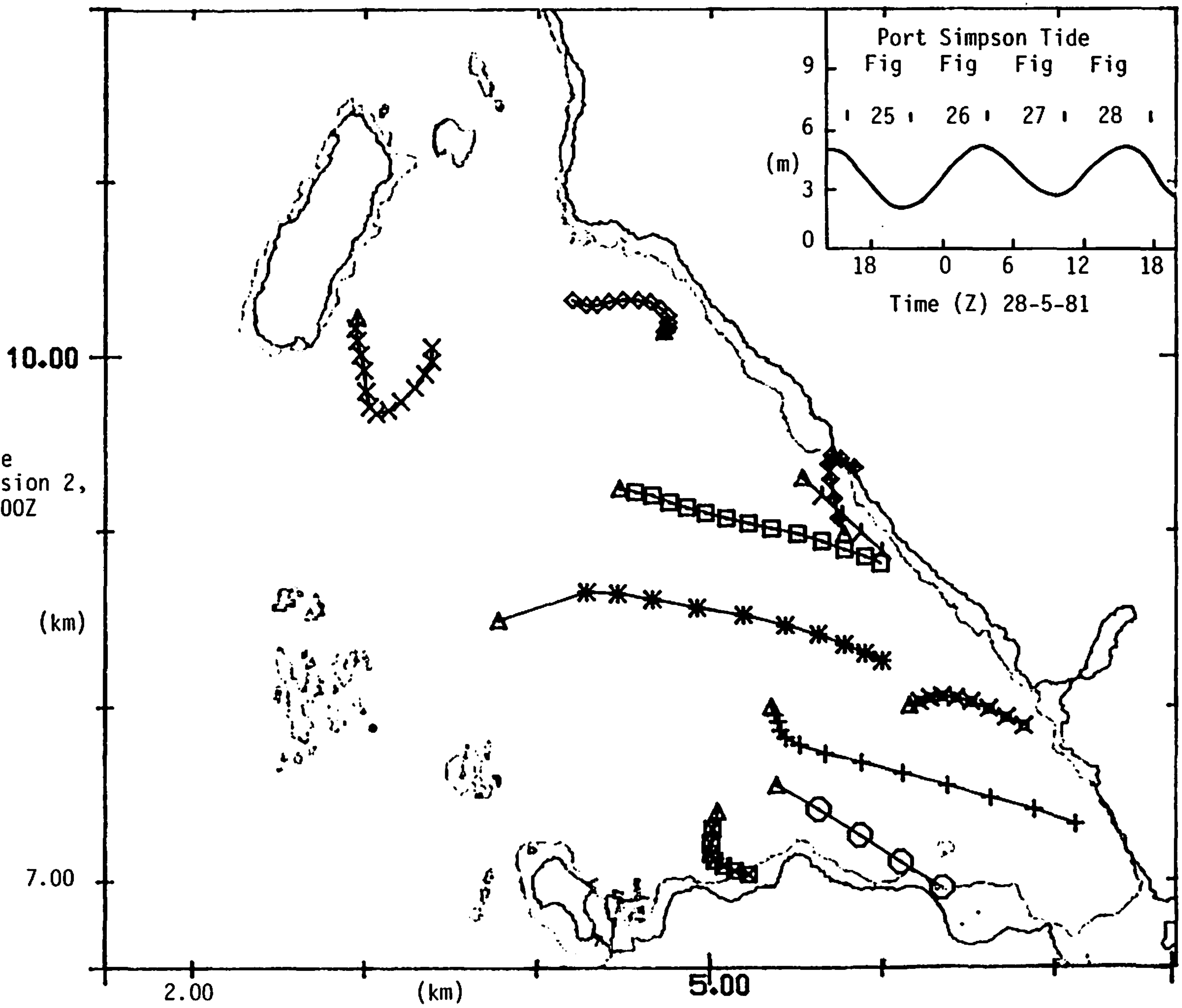


Figure 26. Surface drogue tracks, session 2, 2230Z 27 May to 0500Z 28 May, 1981

	DROGUE
×	0101
+	0202
⊡	0301
✳	0302
⊠	0601
⊙	0602
◈	0801
✖	0802
◆	1103
⅄	1104
★	1402
✳	1403

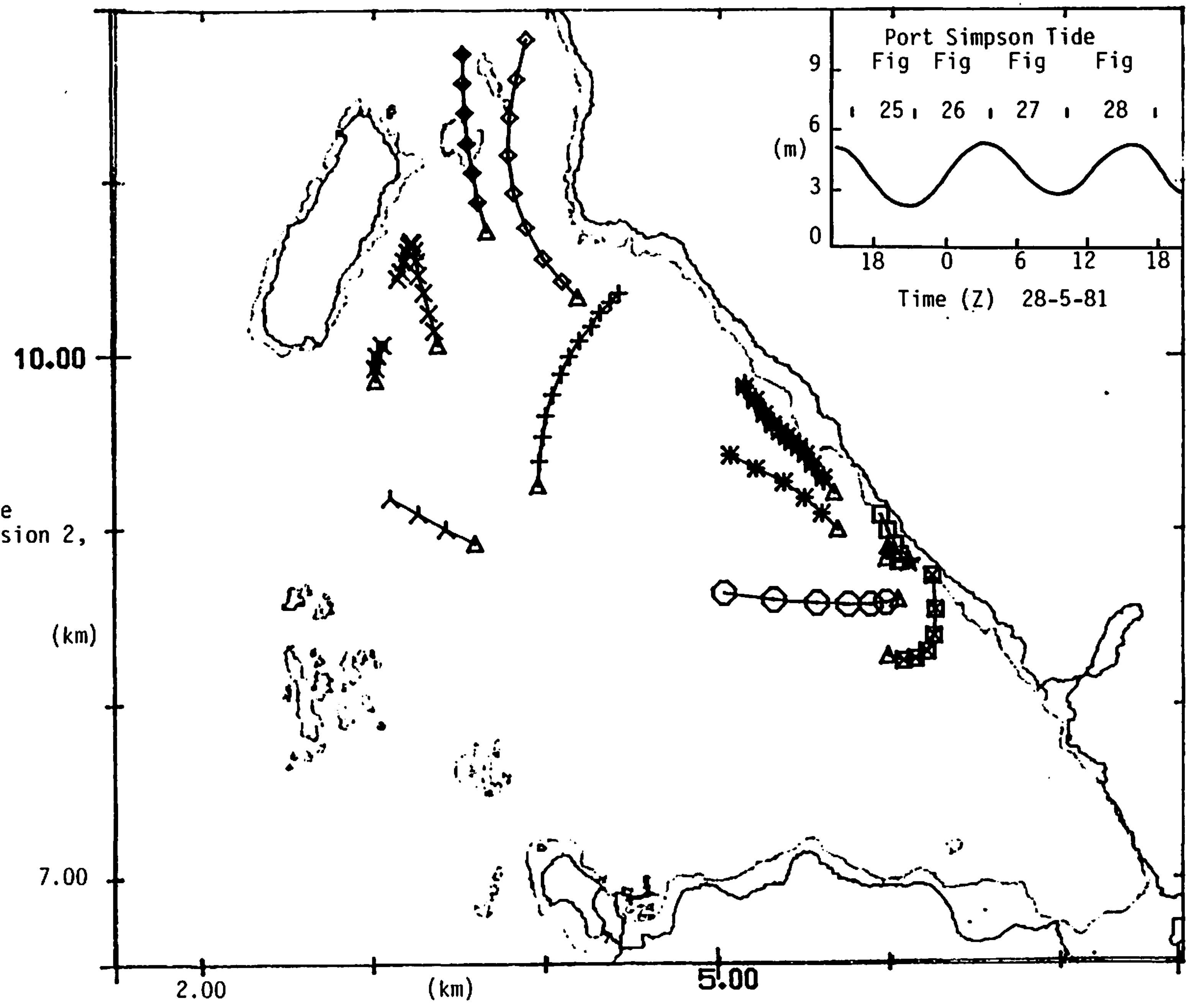


Figure 27. Surface drogue tracks, session 2, 0500 to 1130 Z 28 May, 1981.

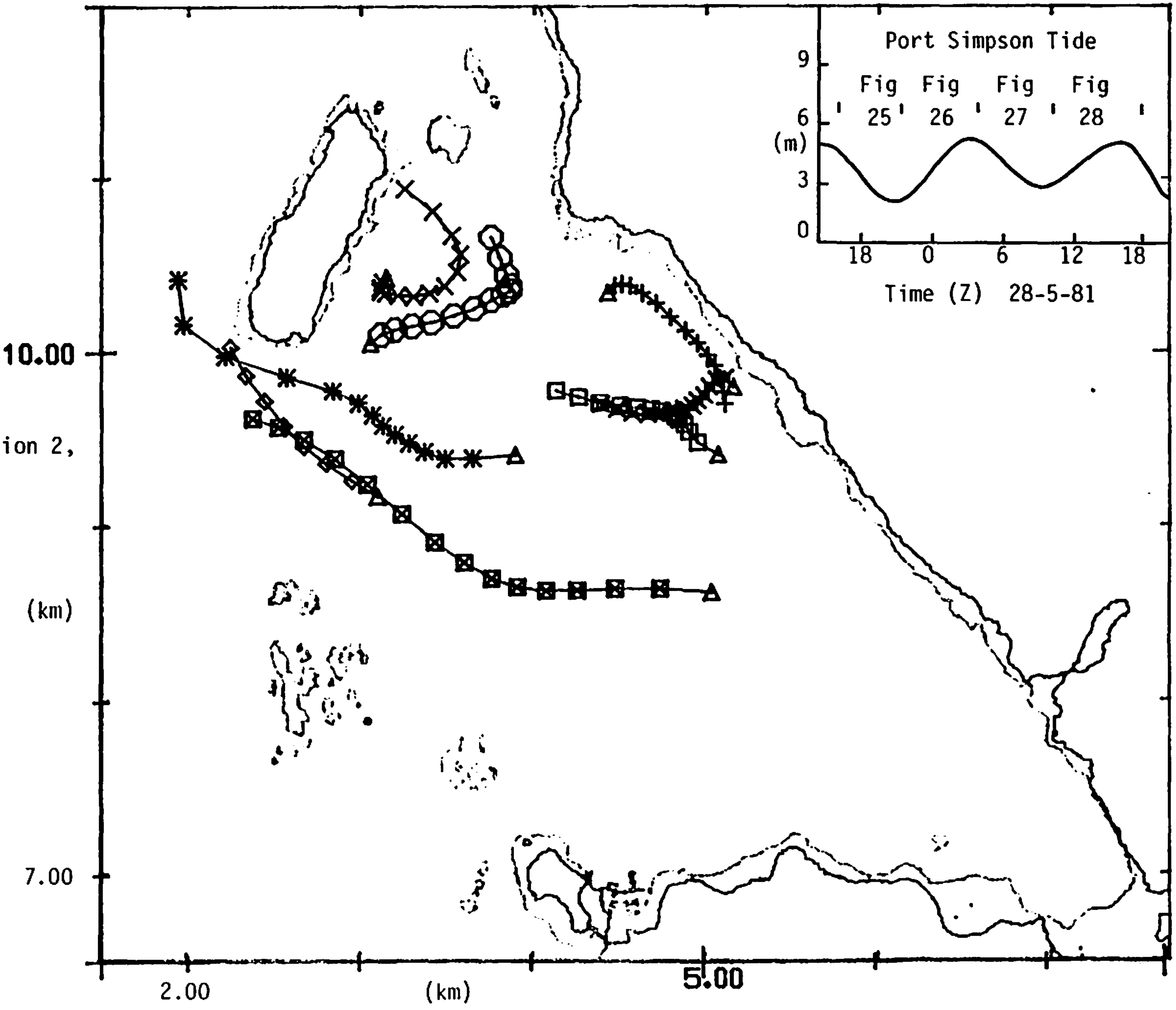


Figure 28. Surface drogue tracks, session 2, 1130 to 1900Z
28 May, 1981

the ebb and through Inskip Passage on the flood. Aside from this, the main tidal influence appeared to be in the higher speeds on the first flood cycle. The counter-clockwise circulation of the first tracking session was not in evidence. Instead there was a general flow to the southeast into Stumaun Bay during the first half of the session followed by general west or northwesterly flow in the second half. This correlated well with the observed change in wind direction. Near the proposed dock site both northwesterly and southeasterly flows were observed. During the first half of the session drogue 801 moved slowly northwestward from near the dock site and then early in the second half (on an ebb tide) it picked up speed and went out through Rushbrook Passage. A counter-clockwise eddy was found east of Birnie Island. Observed velocities ranged from less than 1 cm/s to 17 cm/s during the session.

Figures 29 and 30 show the results from the third tracking session during an ebb tide. The circulation in Rushbrook Passage was briefly examined during the strongest wind of all the sessions, about 5 m/s from the south-southwest. Observed current velocities ranged from less than 1 cm/s to 29 cm/s. The southerly wind probably caused a general increase in the northerly surface flow noted at times outside Port Simpson Bay in Cunningham Pass but not in the Bay itself. A general southerly inflow was observed through the eastern side of Rushbrook Passage with some indication of a return northerly flow on the western side of Rushbrook Passage. Drogues 101, 301 and 1101 released in eastern Rushbrook Passage showed the strongest southerly motion into Port Simpson Bay (Figure 29). Of the drogues released into western Rushbrook Passage, most moved north and then clockwise to the east and south through eastern Rushbrook Passage. The result was a tendency for a clockwise circulation east of Birnie Island during strong southerly winds.

The fourth and final tracking session (31 May/1 June) produced results (Figures 31 to 34) somewhat similar to the second session. Winds during session 4 were about 3 m/s from the southwest decreasing to easterly at approximately 1 m/s in the last half. During the first half the surface motion was generally southeast towards Stumaun Bay. Towards the centre of the bay there appeared to be a tendency towards clockwise circulation. Drogue 901 did move northwest into Rushbrook Passage during the ebb but it returned to the bay, eventually ending in a counter-clockwise eddy east of Birnie Island at the end of the session. The only other sign of tidal effects was in the south part of the bay. Velocities during the first half were the highest observed in all tracking sessions, the fastest exceeding 40 cm/s. As the wind dropped and changed direction for the second part of the tracking session,

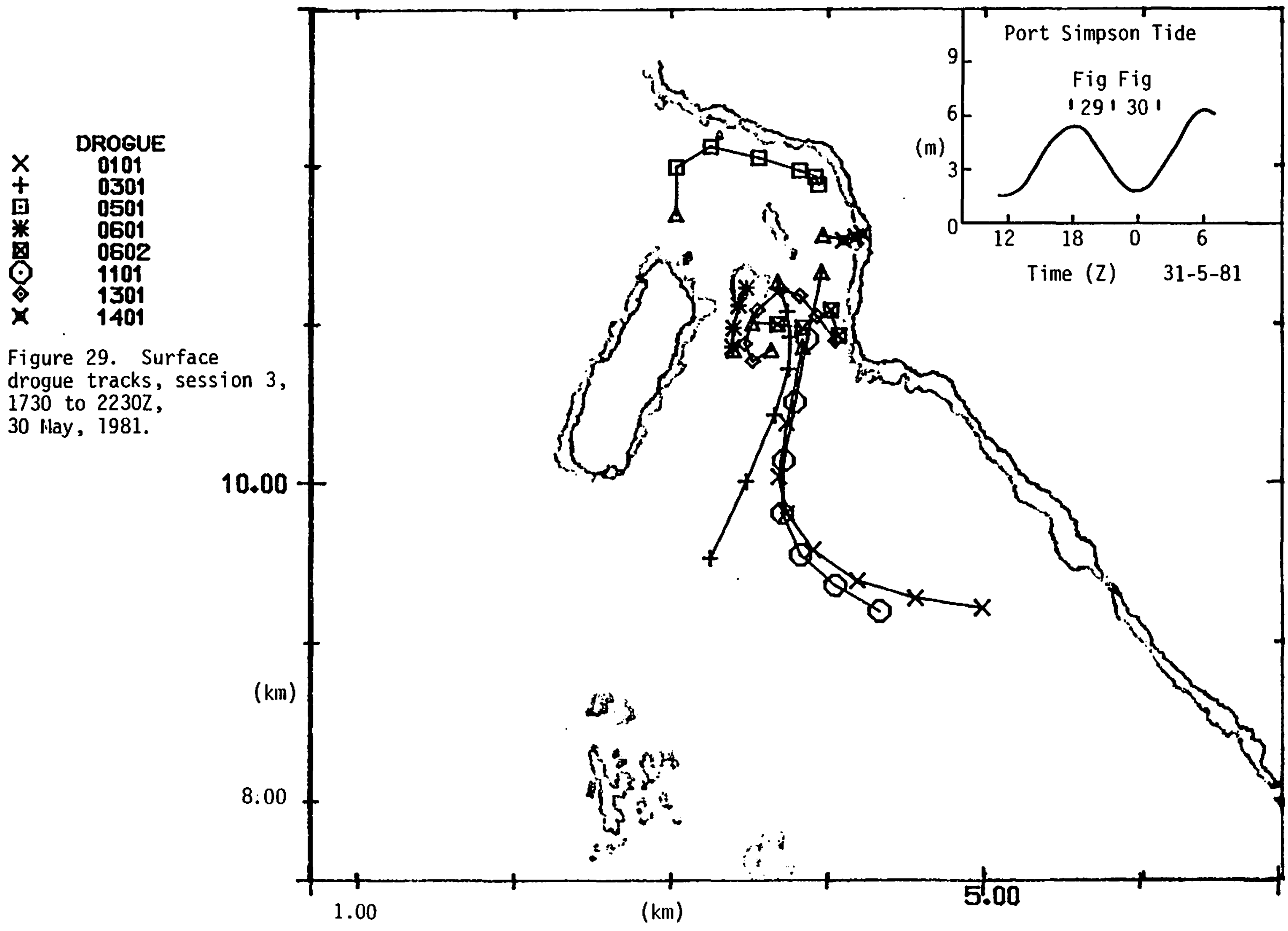


Figure 29. Surface drogue tracks, session 3, 1730 to 2230Z, 30 May, 1981.

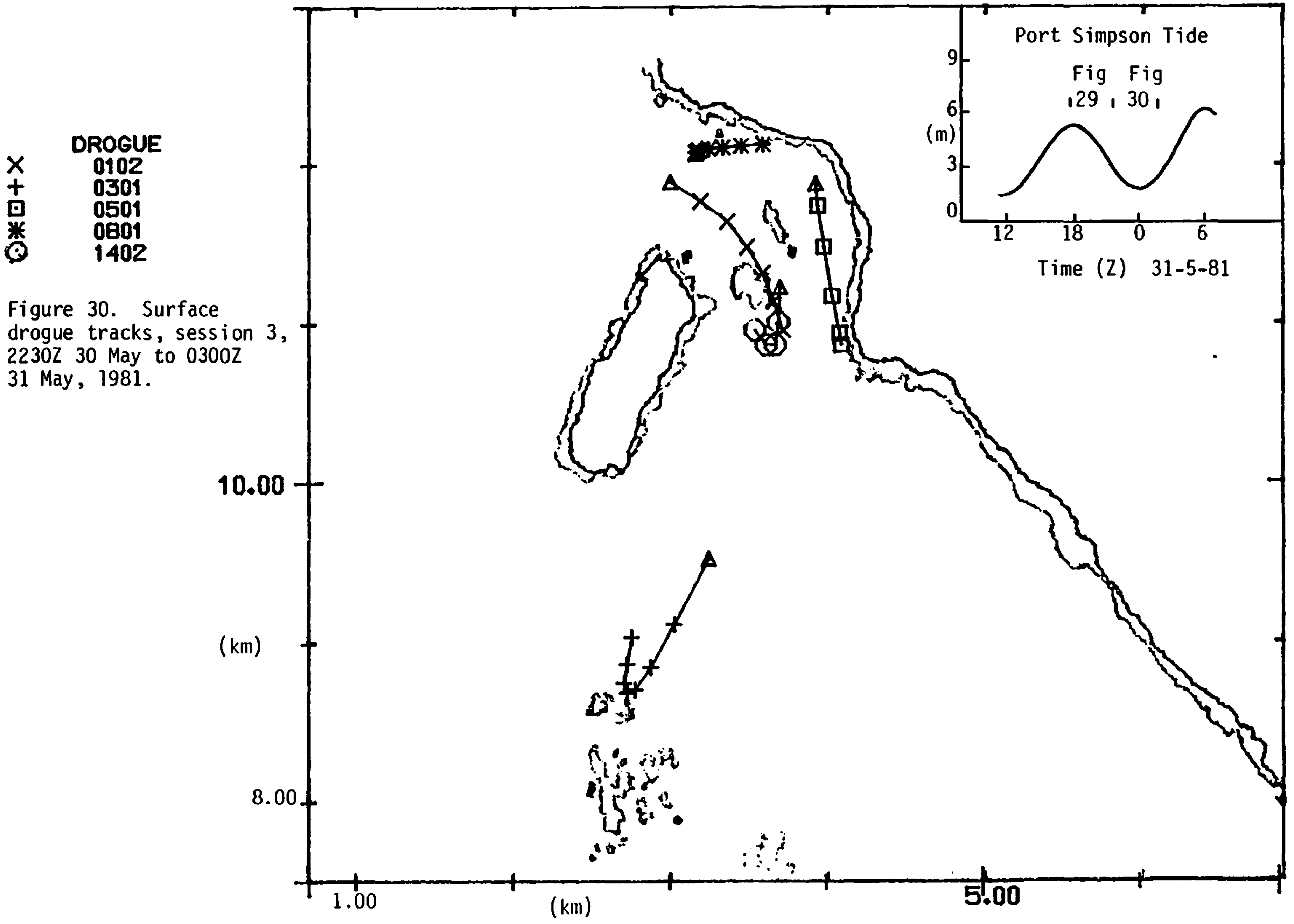


Figure 30. Surface drogue tracks, session 3, 2230Z 30 May to 0300Z 31 May, 1981.

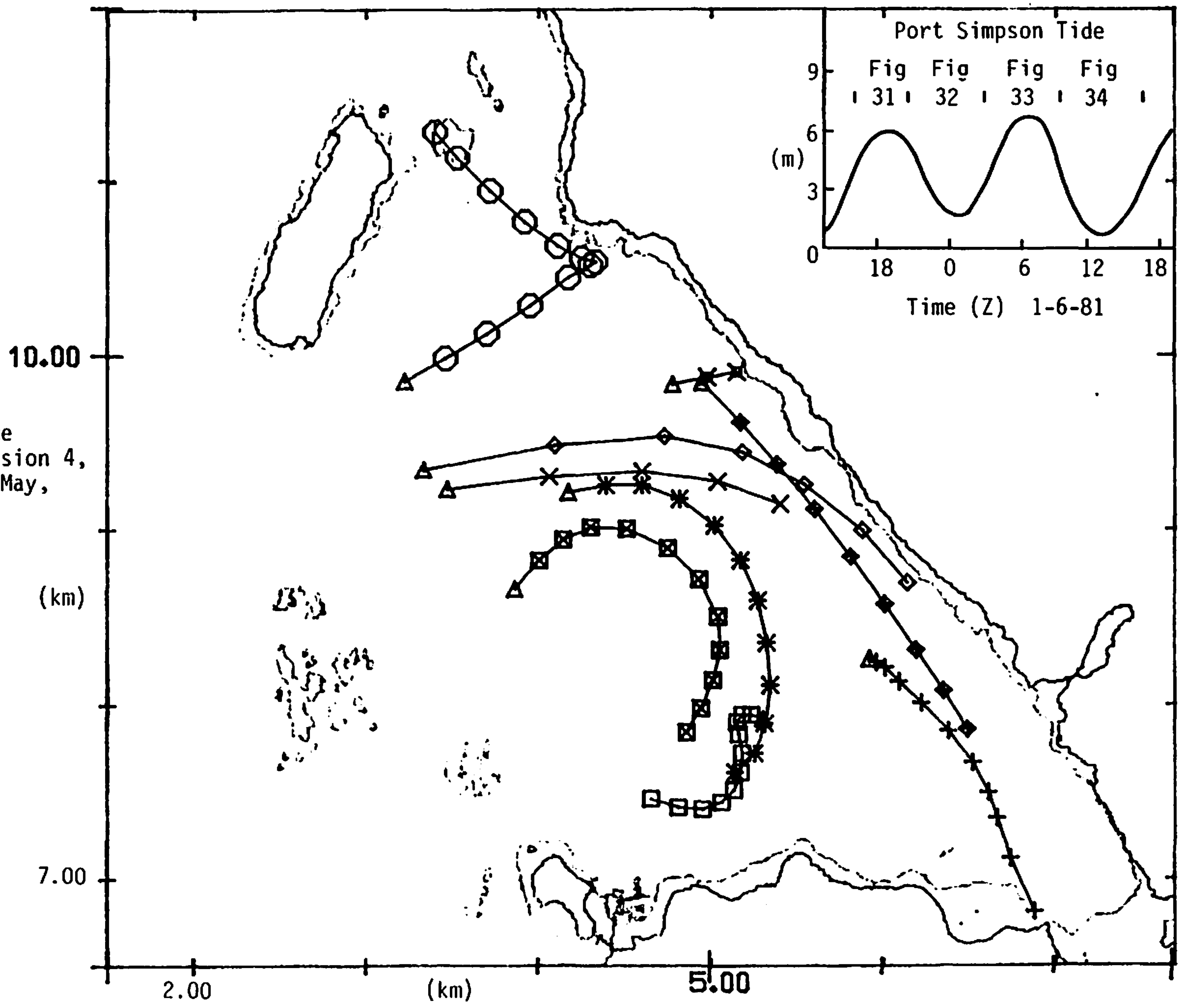


Figure 31. Surface drogue tracks, session 4, 1530 to 2130Z, 31 May, 1981

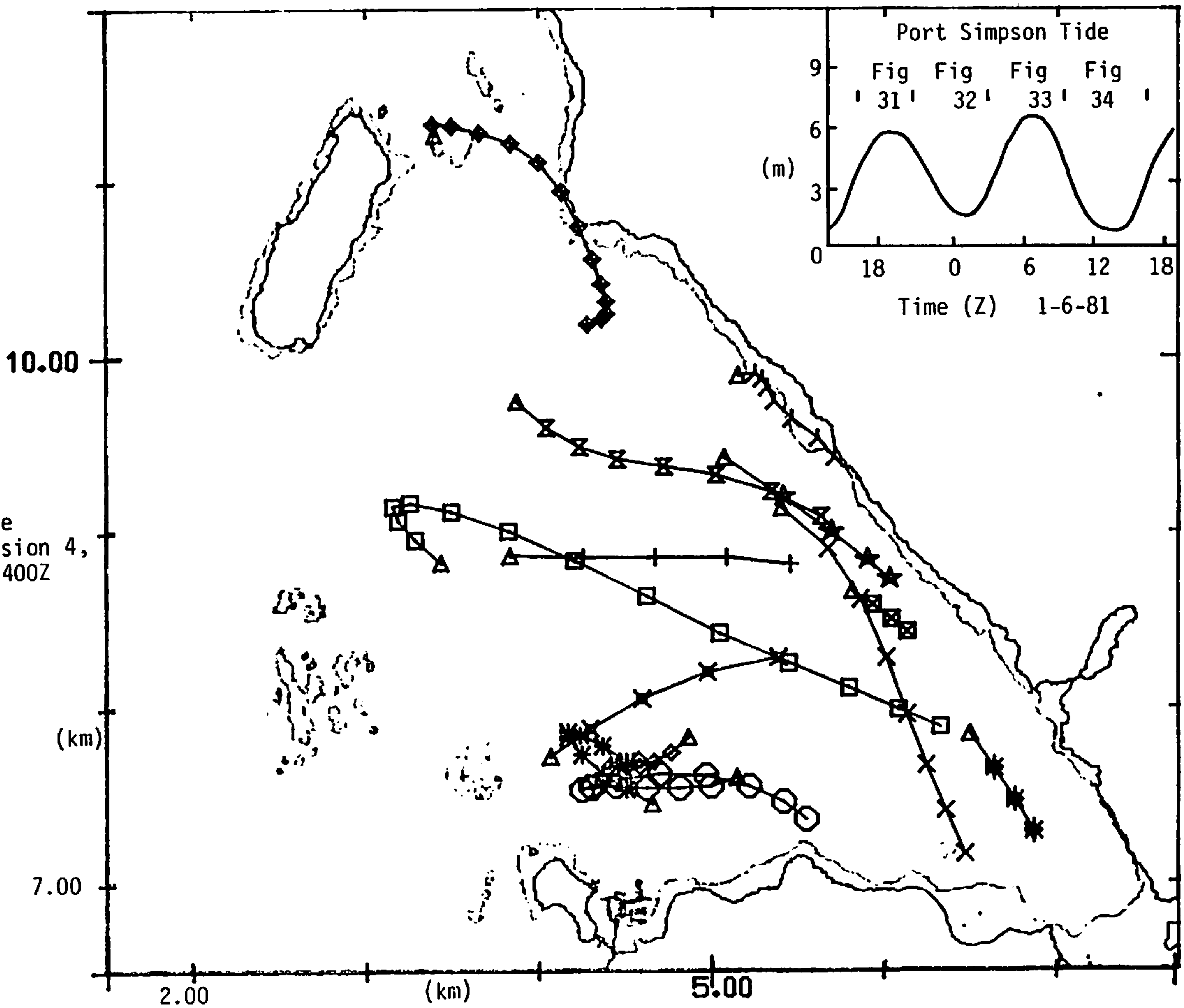


Figure 32. Surface drogue tracks, session 4, 2130Z, 31 May to 0400Z 1 June, 1981.

DROGUE

×	0102
+	0203
⊡	0302
✳	0503
⊠	0703
⬡	0901
◈	1104
✖	1303

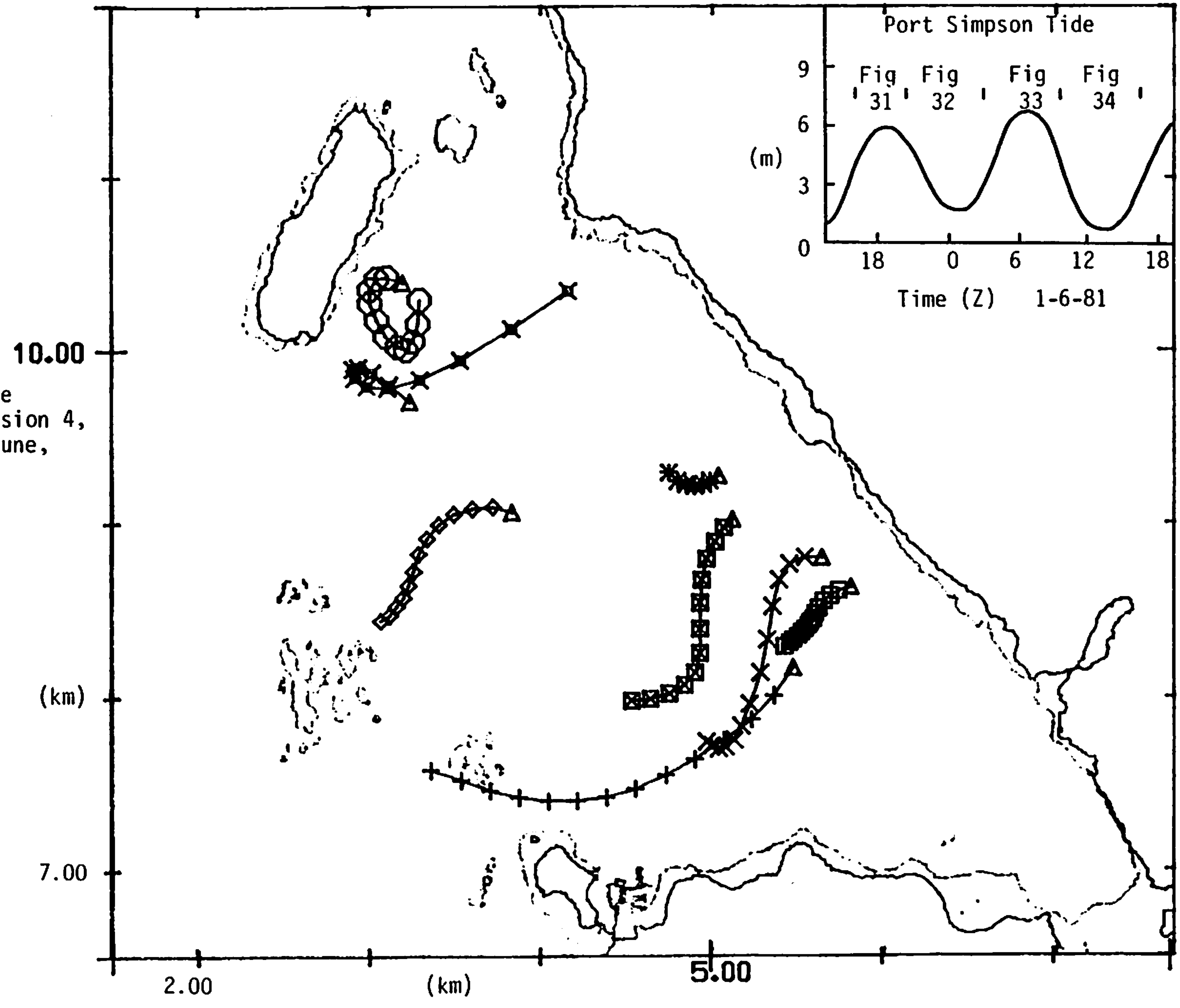


Figure 33. Surface drogue tracks, session 4, 1030 to 1730Z, 1 June, 1981.

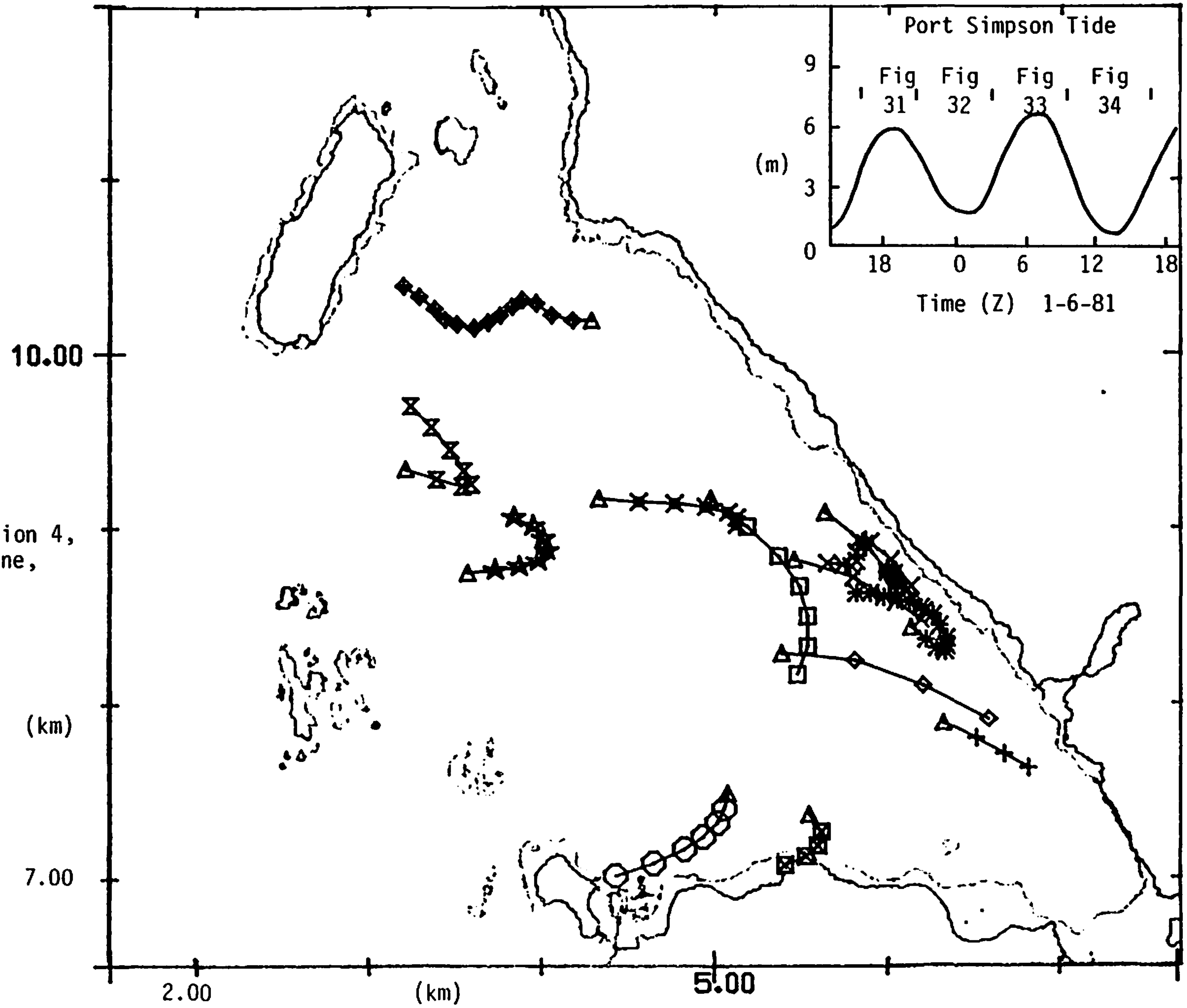


Figure 34. Surface drogue tracks, session 4, 0400 to 1030Z, 1 June, 1981.

drogue velocities decreased as well. The highest velocity was 23 cm/s during this time. There was evidence of tidal effects on the velocities both near Inskip Passage and along the shore between the dock site and Stumaun Bay. Generally, the wind had a greater influence than the tide, leading to southwest flow during the last part of the session. At this time drogue 203 left the bay through Dodd Pass on a flood tide.

4.4 Water Properties

a. CTD Measurements

The CTD results from the sampling periods in May 1981, June 1981, August 1981, November 1981 and January 1982 are tabulated in Appendix C. Figures 35 to 39 show composite and individual temperature and salinity profiles for stations during these periods. The composite plots show the range of salinity and temperature variations that have occurred at a given depth either over a period of repeated sampling at a single station or for a number of stations during one sampling period. Density as represented by sigma-t has not been plotted since sigma-t profiles are similar to the salinity profile. This is due to the fact that the main source of density variations is a change in salinity, temperature variations having only a minor influence.

The temperature and salinity variability over a period of 10 days in May-June 1981 at Station C (near the proposed dock site) is shown in Figure 35. Figure 36 shows a composite of temperature and salinity data from Stations A, B, C, D and E for the high tide period between 1715 to 1930 Z on May 24, 1981. Comparing Figures 35 and 36, it can be seen that the variability of both temperature and salinity at depth over the 10 day period at the proposed dock site (Station C) was greater than the geographic variability measured between all stations at high tide. This was particularly true for the surface layer and the region below the halocline/thermocline down to about 20 m. There was also a six to eight metre variation in halocline/thermocline depth at Station C over the 10 day period of the observations. For the same period the surface salinity varied by 7 ^{o}/oo and surface temperature by 3.1 C^{o}. For water depths below about 15 m, there was greater temperature and salinity variation between all the stations at high tide than there was at Station C over the period of 10 days.

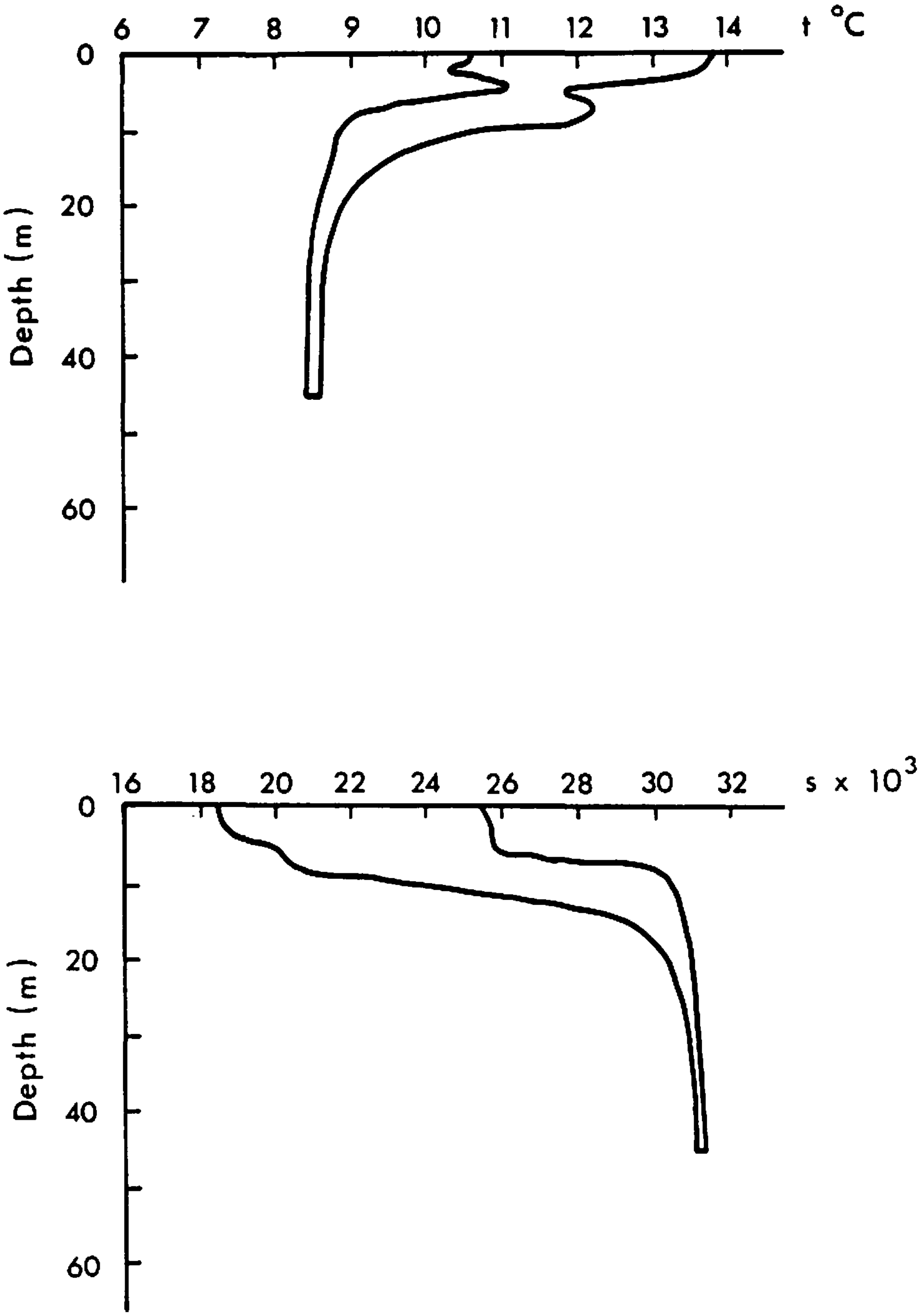
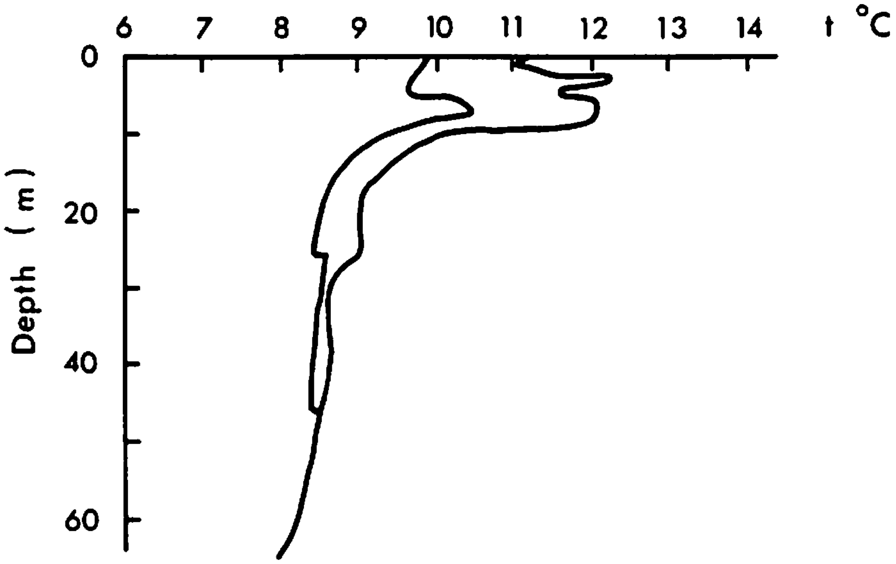


Figure 35. Composite temperature and salinity profiles at Station C (proposed terminal site) for a ten-day period from 2000 Z 23 May 1981 to 2035 Z 2 June 1981.



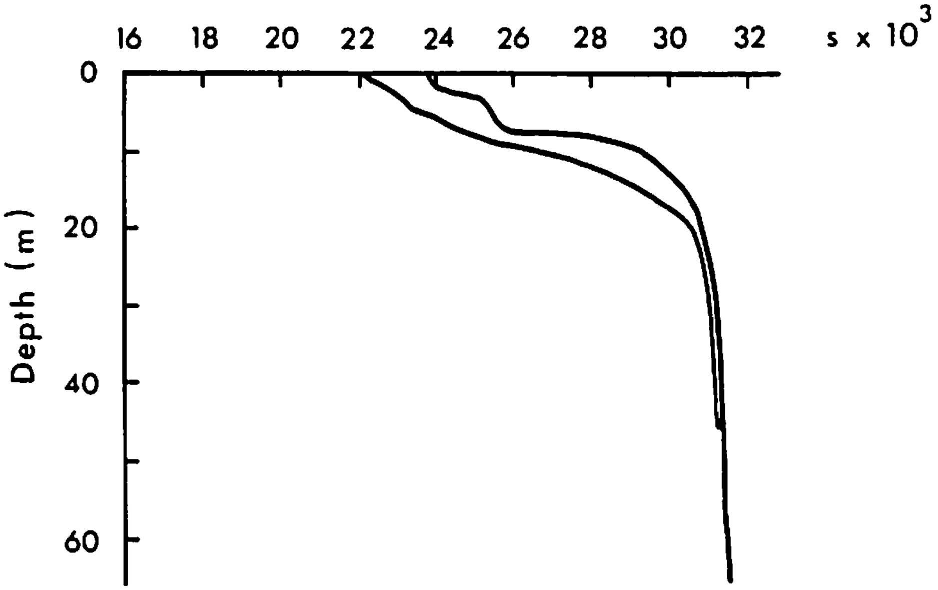


Figure 36. Composite temperature and salinity profiles from Stations A, B, C, D and E during the high tide period 1715 Z to 1930 Z, 24 May 1981.

These results indicate that the water near Port Simpson in May-June 1981 was relatively homogeneous over a horizontal length scale of 5 or 6 km, compared to variations over time scales of about 10 days. Variations in local freshwater runoff and the intrusion of water with different properties from outside Port Simpson Bay are the likely causes of the temporal variations. The density of the deep water (as parameterized by sigma-t), shows variations that amount to about 0.02 % at the 30 m depth over the 10 day period of observation at Station C.

Time series of temperature and salinity were recorded by the current meters, as well as temperature by the tide gauge during the May-June 1981 period (see Figures 9 to 12 and 40). The data showed variations in salinity and temperature associated with the tide plus some apparent trends. The variations seen at tidal periods in the shallow (less than 10 m) data are due to the gradient between surface and deeper waters moving past the instrument as the water surface rises and falls with the tide. The current meter at 26 m did not show this behaviour since it was at a depth where the salinity and temperature gradients are less pronounced. The other less regular variations were probably due to changes in the surface layer thickness as different water masses were advected into the area, or to wind mixing and deepening of the surface layer. The shallow instruments showed an increase in temperature and decrease in salinity over the month of May. However the deep current meter (26 m) near the dock site showed an increase in both temperature and salinity over the month of May. These trends are probably caused by the increase in spring estuarine circulation due to the Nass and Skeena Rivers in May-June together with a seasonal increase in the solar heat input.

At depths near the thermocline and halocline (6 to 10 m in these observations) temperature changes of more than 2 C^o and salinity changes of more than 5 $^o/oo$ occurred in time periods of less than a day. However, in the deeper water (Figure 12) temporal changes of salinity and temperature were smaller and more gradual.

Figure 37 shows composite plots of the CTD data collected at the Port Simpson stations on 25 August 1981. The surface temperatures in August (approximately 13-14^{o}C) were slightly greater than most surface temperatures measured in the May-June period. The August surface salinities were also higher (26-27 $^o/oo$). The relatively strong halocline and thermocline in May had also been replaced in August by a more gradual gradient extending down to about 40 m. Deeper temperatures (below 40 m) were about 0.5 C^o cooler than in May, while salinities were about 0.7 $^o/oo$ higher.

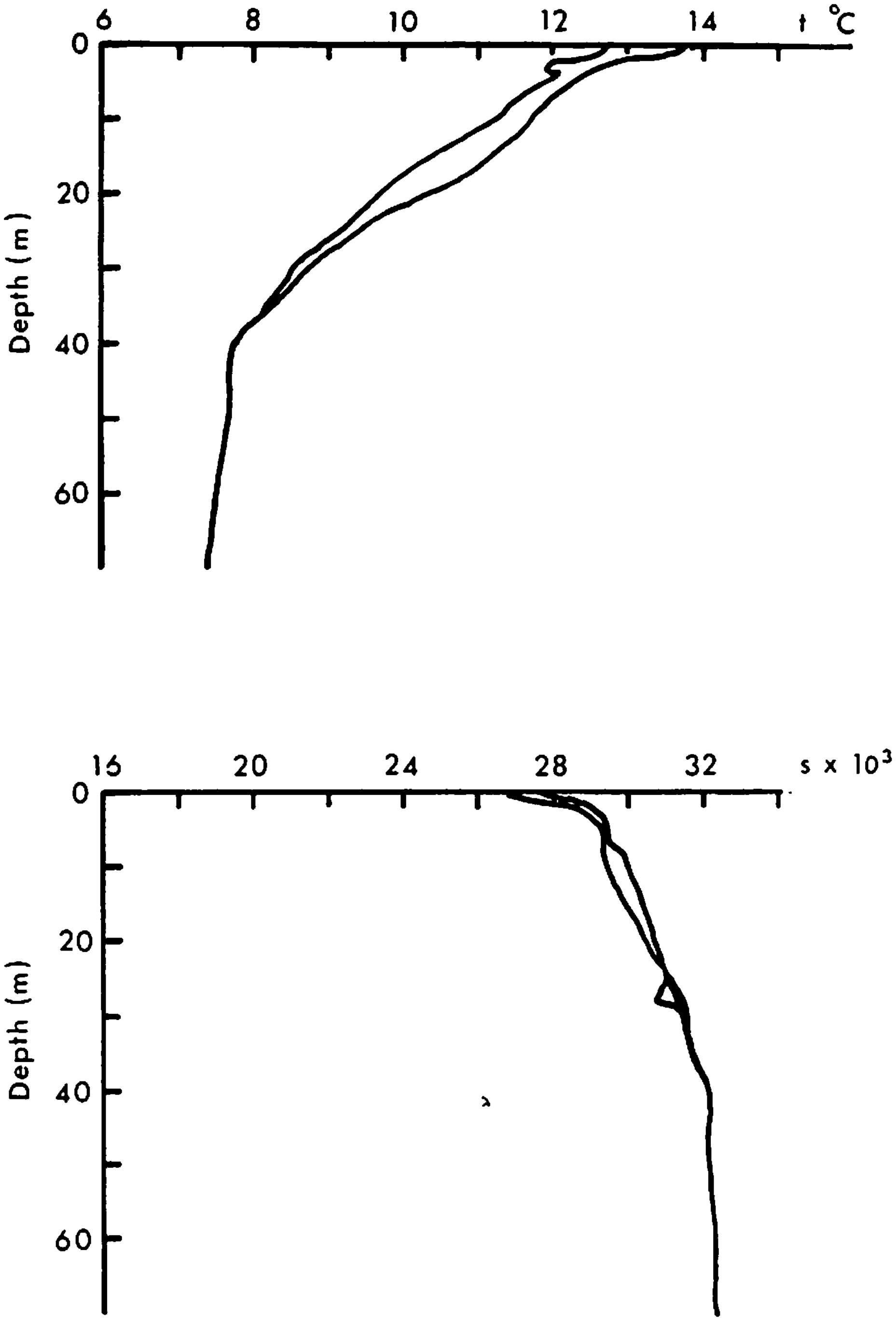


Figure 37. Composite temperature and salinity profiles for Stations A, E and I, 25 August 1981.

Figure 38 shows composite plots of the CTD data collected at Port Simpson stations on 26 and 27 November 1981. Surface temperatures in November (approximately 8-9°C) were much lower than those measured in spring and summer. The profile data indicate the presence of a thermal inversion, i.e. water temperatures increased with depth from about 8.3 to 9.9°C. Surface salinities were slightly greater than in the summer, ranging between 29.3 and 29.8 ‰. The pycnocline was salinity dominated and gradual, located between depths of about 5 to 40 m. In the deeper water (depths greater than 20 m) there was a uniform but slight increase in both salinity and temperature with depth.

Figure 39 shows the CTD profiles taken near the proposed dock site (Station C) in Port Simpson Bay and near Flewin Point (Station E) outside Port Simpson Bay. The temperature profiles indicate that further cooling has taken place in the surface layer since the November 1981 sampling. The thermal inversion was most apparent at Station C. Although there was little salinity structure at either station, there was a noticeable difference between temperature structures inside Port Simpson Bay (Station C) and outside the Bay (Station E). The major difference was a 1-1.5 C° cooler surface layer (to depths of about 15 m) inside the Bay.

b. Dissolved Oxygen Measurements

The results of dissolved oxygen analyses for the four sampling periods (23 May 1981; 25 August 1981; 26 November 1981; and 26 January 1982) at Port Simpson are tabulated in Appendix D. The measurements were taken at four representative sites (Figure 2) in the Port Simpson Bay area: Stumaun Bay (Station A), Grassy Point Dock Site (Station C), Flewin Point (Station E) and Inskip Passage (Station I). As discussed in Section 2.2, the estimated accuracy of the dissolved oxygen determinations during the first three programs was ± 0.4 mL/L, less than that of the last program (± 0.04 mL/L) because of the use of two different methods. Nevertheless the results indicated that the near-surface waters (depths less than 10 m) of Port Simpson Bay were saturated or super-saturated with dissolved oxygen most of the year.

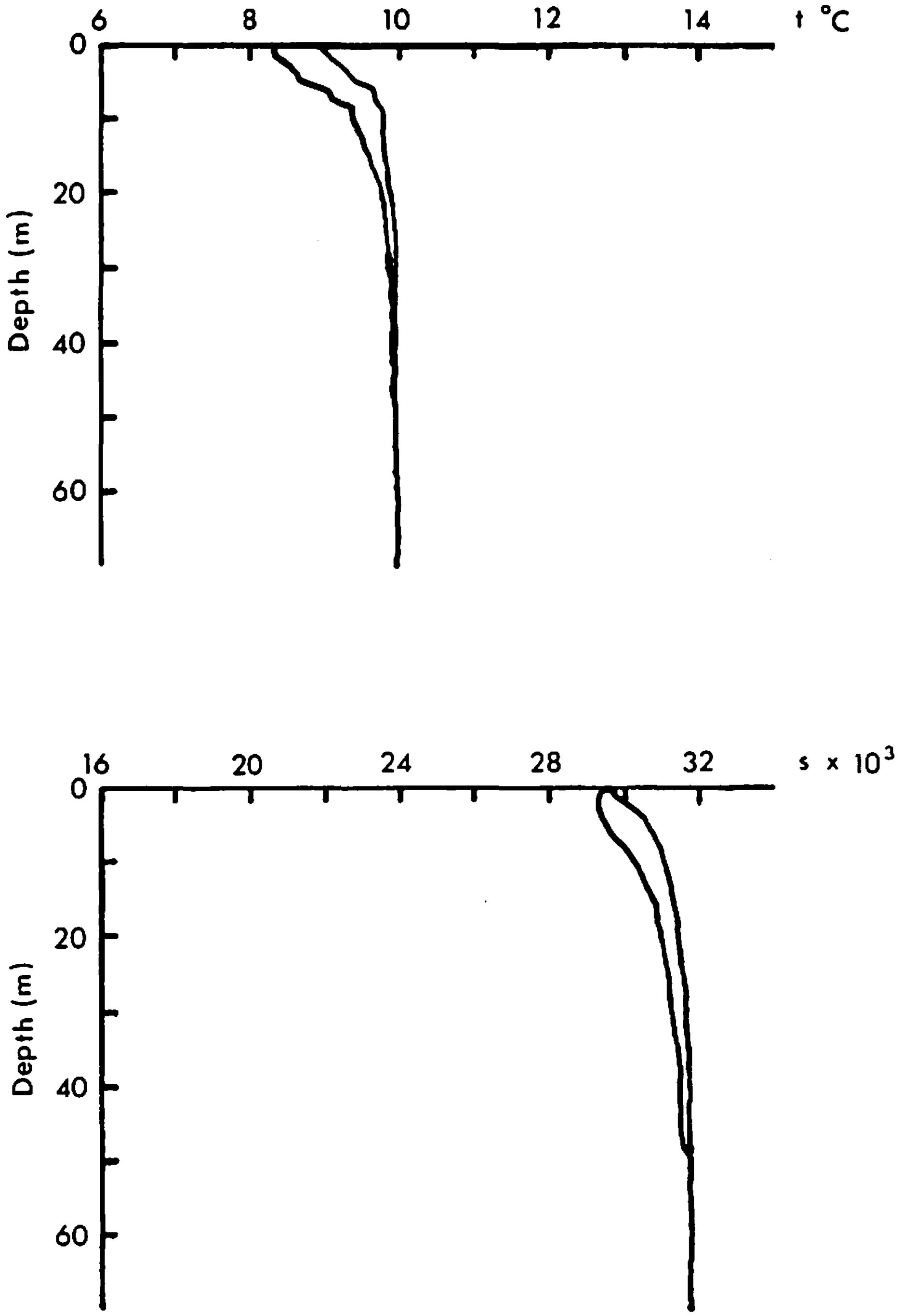


Figure 38. Composite temperature and salinity profiles for Stations A, E and 1, 26/27 November 1981.

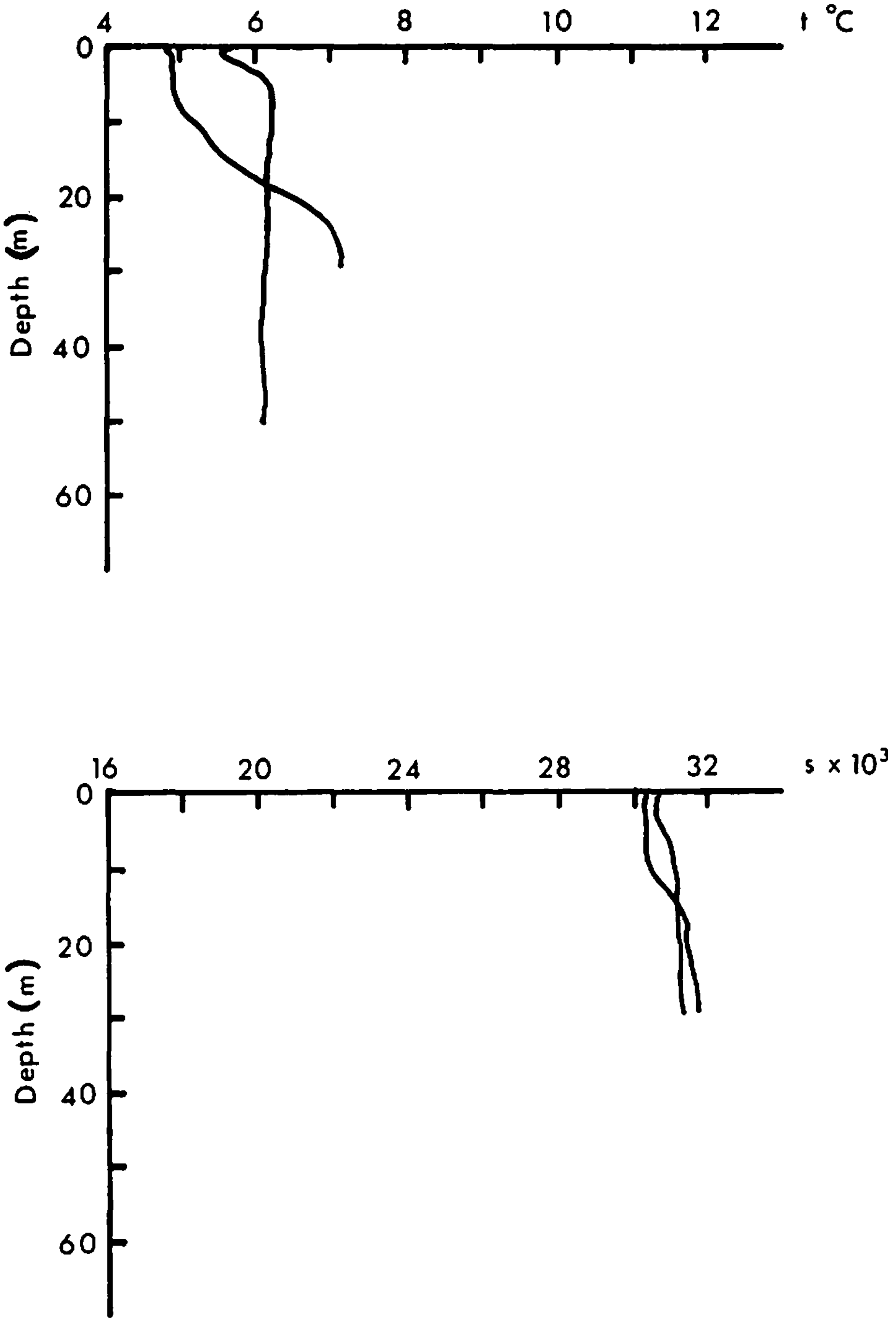


Figure 39. Temperature and salinity profiles for Station C and E, 26/27 January 1982.

The highest dissolved oxygen concentrations in Port Simpson Bay were measured during late May 1981, typically at about the 5 m depth. Concentrations in the near-surface (less than 10 m depth) waters in May ranged from 7.47 to 8.70 mL/L which corresponds to a saturation of 109 to 133%. The likely cause of these very high values was increased photosynthesis due to the phytoplankton bloom observed at that time of year. Fairbridge (1966) has reported that in the sea, oxygen levels in the photic zone may rise to 130% saturation or higher due to photosynthetic processes. The lowest concentration of dissolved oxygen in May (5.97 mL/L) was measured near the bottom in Stumaun Bay, but this concentration still represented 89% saturation.

In August 1981 the near-surface waters of Port Simpson Bay were also saturated or super-saturated with dissolved oxygen, however, the deeper waters below the 10 m isobath showed considerable stratification effects. The level of dissolved oxygen decreased with depth such that the near-bottom waters were only between 60-70% saturated (dissolved oxygen concentrations near the bottom ranged from about 4.3 to 4.8 mL/L).

In November 1981 and January 1982 the concentration of dissolved oxygen in Port Simpson Bay was more homogeneous with depth. The range in dissolved oxygen concentrations at all depths during both these sampling periods was 5.95 to 7.56 mL/L which corresponded to a variation in saturation of between 92% to 112%. The depth of maximum oxygen concentration was typically between 5 to 10 m.

4.5 Tides

The tide gauge results are shown in Figure 40. The pressure plotted is the measured pressure in decibars with air pressure (measured at Prince Rupert) removed. A change of water elevation of 1 m results in a pressure change of about 1 dbar in sea water. Thus the pressure plot can be interpreted as a water elevation plot. The tide is of a mixed semi-diurnal type with the maximum range of 7 m and a minimum range of 2 m between successive high and low waters. An examination of portions of the data has shown irregularities in the tidal signal that may be due to seiches. The natural seiche period of Port Simpson appears to be about 20-24 minutes based on a review of historical data collected from 1902-1926 (McDonald, 1982). The sampling rate of the tide gauge is capable of detecting variations of this period but such a signal would not be well resolved.

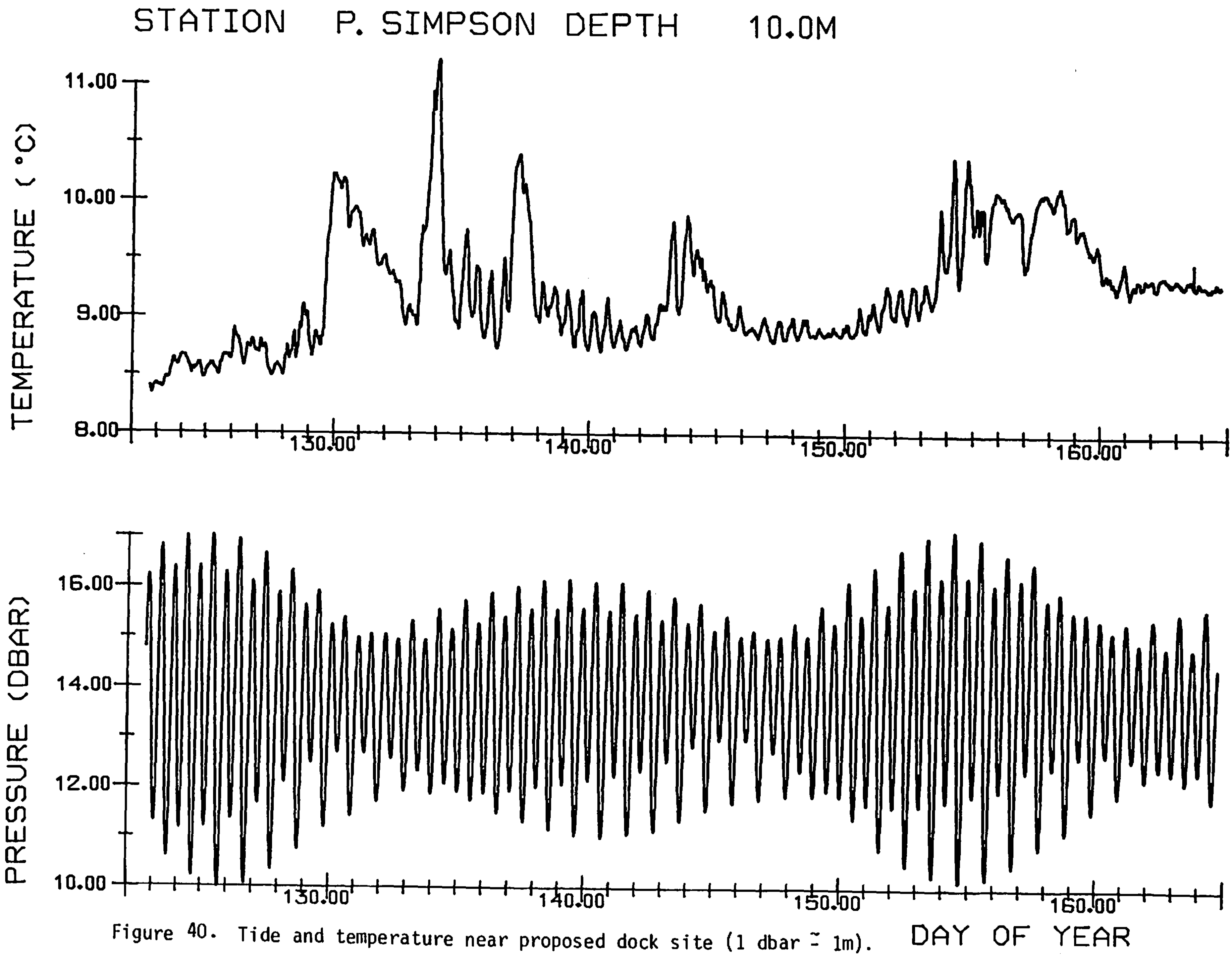


Figure 40. Tide and temperature near proposed dock site (1 dbar ≃ 1m).

The water temperature measured at the tide gauge shows some interesting features (Figure 40). First there is a small increase in daily mean temperature from the start to the end of the data record. This is presumably a reflection of the seasonal heating of the upper water column. A more obvious feature is the change of temperature on two time scales; that is, over several days and over half a day. The major variations at time scales of less than a day are associated with the tide, warm temperatures coinciding with low tide and cold temperatures with high tide. This is explained by the fact that the waters in Port Simpson Bay form a two layer system (see Figure 35), where the surface or upper layer floats on a denser lower layer, moving up and down with the tide. An instrument at a fixed depth relative to the bottom and near the interface between the two layers, will see relatively large and regular variations in temperature or salinity as the tide moves the water level and thus the interface up and down.

The large and less regular temperature variations (over periods of several days) are likely associated with weather events through either wind induced mixing of the upper water column or the advection of warmer water into the bay. The wind mixing produces a thicker, more uniform surface layer with salinity and temperature values between that of the deeper water and that of the surface layer prior to mixing. An example of this occurred around 9 May (day 129, Fig. 40). Winds measured at Prince Rupert airport (the Port Simpson weather station had not been installed) increased to 8 to 10 m/s (15 to 20 knots) from the southeast with higher gusts. The combination of a low tide and the deepening of the interface between the upper and lower layer resulted in an increase in temperature at the tide guage depth. As the mixing continued, the addition of the cooler, more saline deep water resulted in a cooler, more saline upper layer and hence a decrease in measured temperature. This phenomena can also be seen in the current meter data near the dock site (Figure 11). An intrusion of surface water with different temperature and/or salinity may also cause these changes. The Skeena and Nass rivers are the major local sources of fresh water during freshet.

As discussed in a previous chapter (section 3.6), a harmonic analysis was performed on the measured tidal data. A comparison of the tides measured near the proposed docksite with the historical results from the Port Simpson townsite is given in Table XI. The comparison is also shown in Figures 41 and 42 where only those major constituents with amplitudes greater than or equal to 0.01 m and periods

TABLE XI: Port Simpson Tidal Constituents

	Measured at Docksite*		Historical Results from Port Simpson **	
Name	Amplitude (m)	Greenwich Phase (°)	Amplitude (m)	Greenwich Phase (°)
Z0	3.72	0	3.69	0
MSF	.04	76	.02	178
2Q1	.03	207	-	-
Q1	.06	227	.05	237
O1	.31	241	.30	243
NO1	.02	273	-	-
P1	.16	265	.16	256
K1	.47	258	.51	259
J1	.03	294	.03	277
OO1	.02	285	-	-
EPS2	.02	232	-	-
MU2	.07	236	.04	232
N2	.43	236	.37	243
M2	1.84	265	1.86	267
L2	.06	280	.05	297
S2	.52	299	.61	299
K2	.14	322	.17	289
ETA2	.02	321	-	-
MO3	.01	88	.01	328
M3	.02	334	.02	326
SK3	.04	109	-	-

* Only major constituents with amplitudes greater than or equal to 0.01 m are included in this comparison.

** Tidal results from 1902 to 1926 provided by Tides and Currents Group, Institute of Ocean Sciences, Sidney, B.C.

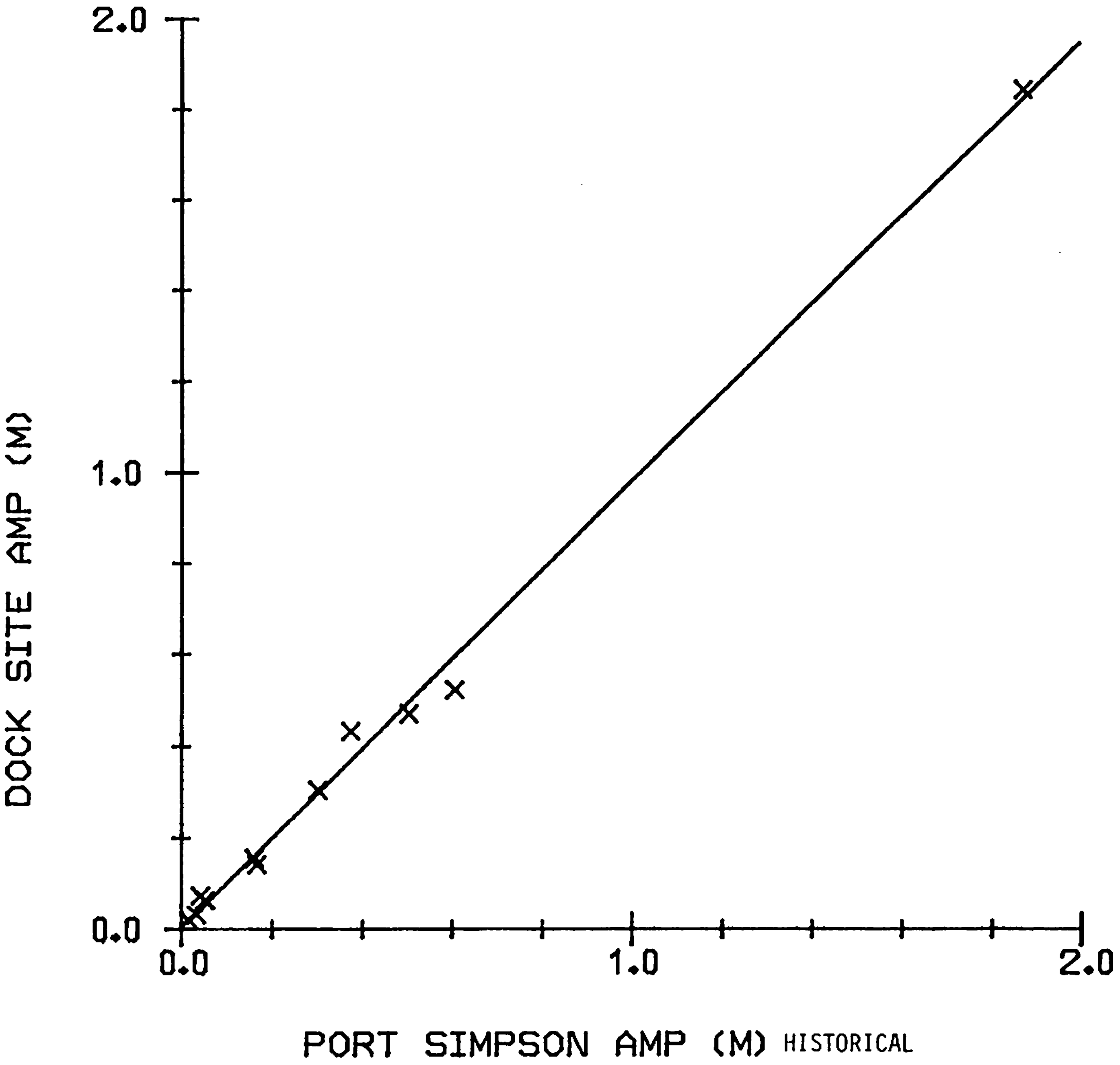


Figure 41. Comparison of calculated tidal constituent amplitudes from near the proposed dock site with those from previous measurements at Port Simpson.

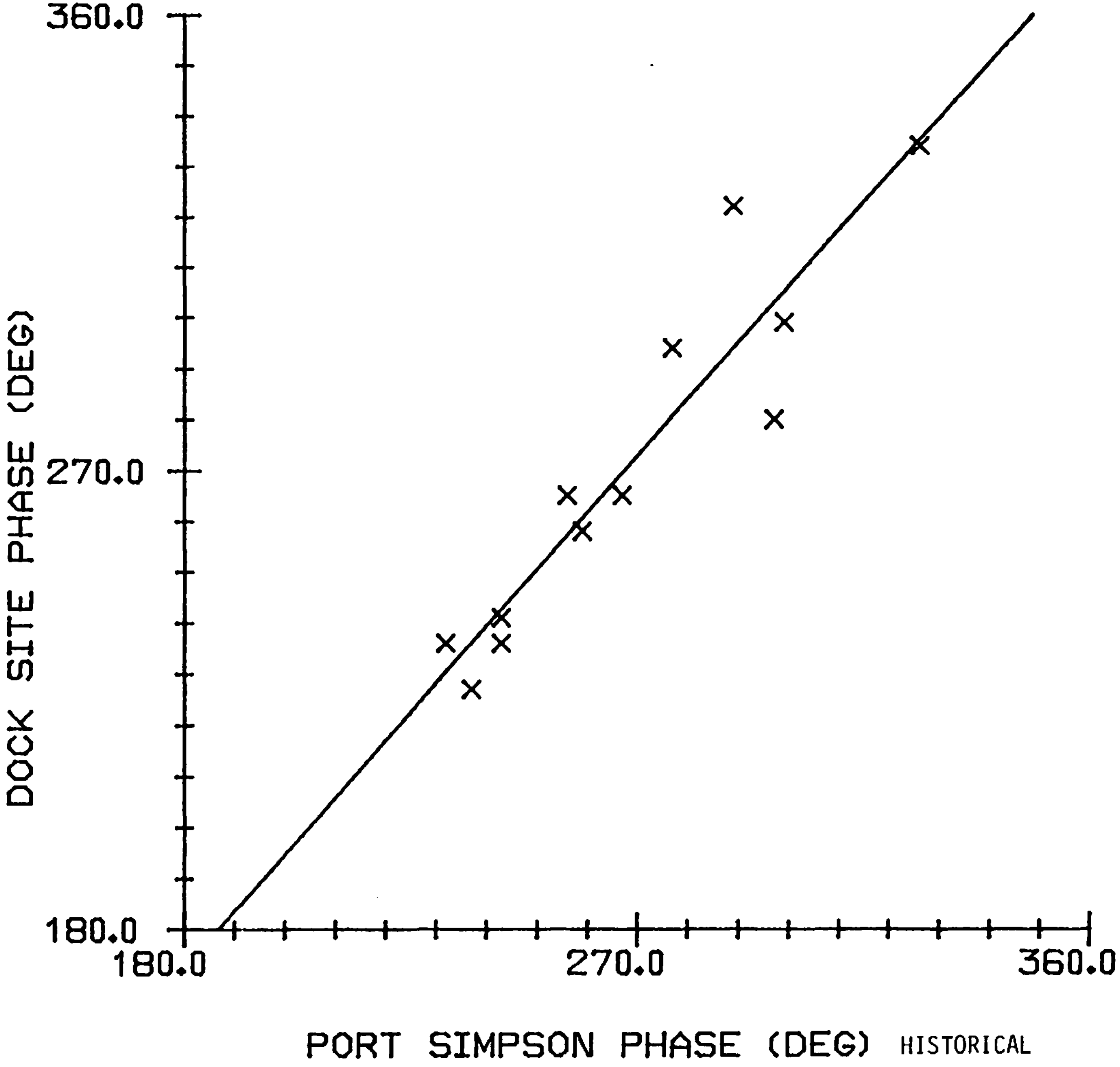


Figure 42. Comparison of calculated tidal constituent Greenwich phase angles corresponding to the amplitudes shown in Figure 41.

shorter than 10 days are shown. The limits were chosen due to the lower statistical reliability of results outside these limits as a result of the background noise level and record length of the time series. The results indicate there is less scatter in the amplitudes than in the phases. This can be attributed to the fact that our measurements of tide over approximately one month do not give as reliable a measure of phase as those from longer data records such as the 1902 to 1926 tidal results for Port Simpson from Fisheries and Oceans (Canadian Tide and Current Tables, 1981). As a result, the best fit line through the points in Figure 42 does not pass exactly through the origin. However allowing for the scatter of the data, there is a one-to-one correspondence of both amplitude and phase of the constituents calculated from the observations near the docksite with the historical results for Port Simpson. As shown in Table XII, Port Simpson is a secondary tidal port referenced to Prince Rupert. The results show that for predictive purposes, the tides at the docksite can be derived from the Prince Rupert tide tables.

TABLE XII.

Comparison of Tides at Simpson with Prince Rupert (from Canadian Tide and Current Tables, 1981; Volume 6)

DIFFERENCES								
Higher High Water			Lower Low Water			Range		Mean Water Level
Time (h min)	Mean Tide (m)	Large Tide (m)	Time (h min)	Mean Tide (m)	Large Tide (m)	Mean Tide (m)	Large Tide (m)	(m)
-0 04	-.24	-.27	+0 01	-.09	-.03	4.82	7.44	3.69

5. CONCLUSIONS

In May 1981 the surface velocities in the middle of Port Simpson Bay had a mean speed of about 5 cm/s and were generally less than 10 cm/s. Although the mean direction was eastward, the current can set in any direction. The set was both parallel and perpendicular to the shore for periods of several hours. At times of low winds there appeared to be a preferred counter-clockwise surface circulation in the mid-Bay area but with increasing winds the movement of surface water reflected the direction of the wind. The circulation of deep water in the bay appeared to be slowly counter-clockwise.

The tide at Port Simpson is a mixed, semi-diurnal tide. The major tidal constituents at the dock site were the same as those derived from the 1902-26 Port Simpson Records, allowing for the accuracy of the May 1981 measurements. Hence the tide at the dock site can be predicted from the tide tables using Prince Rupert as a reference port.

Near-surface current measurements at the proposed LNG dock site during May 1981 indicated mean speeds of about 5 cm/s influenced by the wind and showing little preferred direction. The movement was observed both parallel and perpendicular to the shore for periods of several hours. Measurements at 26 m depth showed that deeper currents had a mean speed of about 3.5 cm/s and a preferred direction to the northwest, forming part of the counter-clockwise circulation.

Most of the wave regime in Port Simpson Bay appears to be locally wind-generated with some evidence of remotely generated swell. During the 1981-82 wave monitoring program, significant wave heights greater than 1 m were not recorded. This was probably due to the geography and fetch-limited nature of the Bay although local residents have estimated waves as large as 2.5 m for storms with exceptionally high westerly winds (perhaps every 2 or 3 years).

The seasonal CTD data indicate Port Simpson Bay is a well-defined two-layer estuarine system during the spring, summer and fall. The brackish surface layer is about 10 m thick and separated by a strong halocline and themocline from the deeper, more saline oceanic waters. The relatively strong gradient between the two layers effectively isolates the deeper water in Port Simpson Bay from direct wind effects.

The seasonal measurements of dissolved oxygen within and adjacent to Port Simpson Bay, indicate that surface waters at Port Simpson are saturated or supersaturated with dissolved oxygen throughout most of the year. The highest annual near-surface dissolved oxygen concentrations (up to 8.7 mL/L or 133% saturation) were found in late May, probably due to increased photosynthesis during the phytoplankton bloom that was observed at the time. The lowest dissolved oxygen concentrations (less than 5 mL/L) were found near-bottom in late summer, with saturation levels ranging between 60 to 70%.

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APPENDIX A: INSTRUMENT SPECIFICATIONS

APPLIED MICROSYSTEMS LTD.

CONDUCTIVITY, TEMPERATURE & DEPTH MEASURING SYSTEM

MODEL CTD-12

FEATURES

- Accuracy ± 0.03 PPT equivalent salinity from 27 to 41 PPT; Temperature ± 0.01°C from - 2°C to + 30°C.
- In-situ digital recording on ¼ inch magnetic tape; entirely battery operated.
- Surface monitoring via two conductor wire.
- Plug programmable resolutions of 10, 11, 12 bits on all channels.
- Rugged 6 electrode cell construction. (External parts mostly plastic.)
- Small, light weight and portable.
- No encapsulated circuitry.
- Low cost.

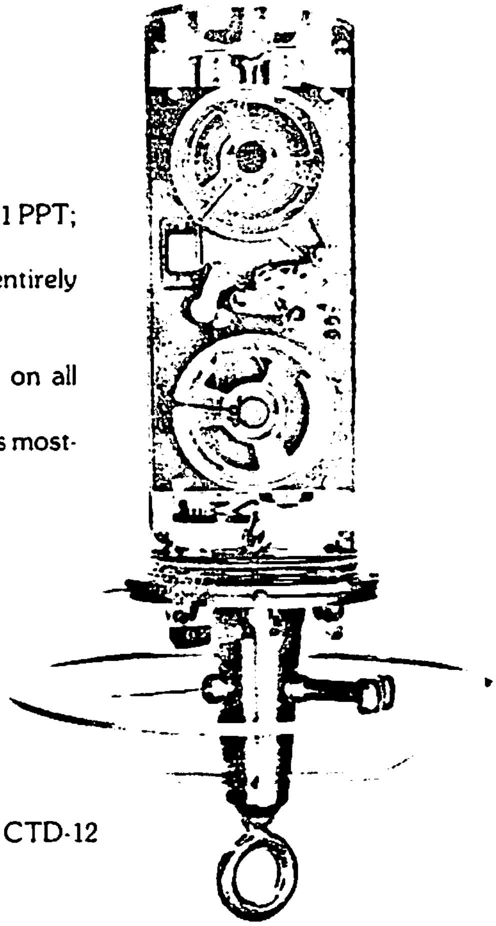


Fig. 1 CTD-12

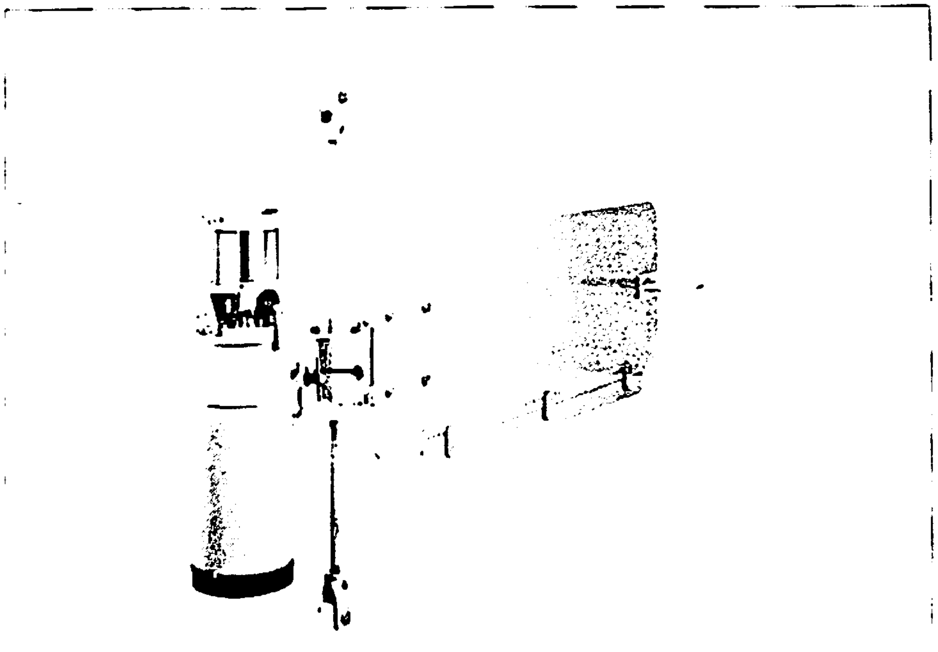
GENERAL DESCRIPTION

The CTD-12 (fig. 1) has been developed to meet the growing needs for a more efficient, more flexible means of gathering and processing ocean salinity data.

Conductivity, temperature and depth are sensed, measured, digitized and recorded rapidly at preselected intervals on ¼" magnetic tape. Flexible programming of data format allows for deployment under a variety of survey conditions.

The CTD-12 system is completely battery operated. Real time surface monitoring of salinity profiles is via a two conductor wire for printout on the Digi Print 701 data verifier. (fig. 3) (Also battery operated.)

Technical Data January, 1978



SPECIFICATIONS

MEASURING SYSTEM:

Self balancing bridge with sequential measuring of six channels and recording on magnetic tape. A ten bit binary word is used for each channel.
Measuring Speed: 4 seconds each channel.
The channels are:

1. REFERENCE:

This is a fixed reading that acts as a control on the performance of the *RCM*, and also as an identification of individual instruments.

2. TEMPERATURE:

Sensor Type: Thermistor (Fenwal GB32JM19)
Range:
Low Range: – 2.46°C to 21.40°C (standard).
High Range: 10.08°C to 36.00°C.
Wide Range: – 0.34°C to 32.17°C.
Accuracy: ± 0.15°C.
Resolution: 0.1% of range selected.
63% Responce Time: 12 seconds.

3. CONDUCTIVITY: (optional)

Sensor Type: Inductive cell.
Range: 0 – 77 mmho/cm., (standard).
25 – 72 mmho/cm
Resolution: 0.1% of range.

4. PRESSURE: (optional)

Sensor Type: Bourdon tube driving a potentiometer.
Range: 0-100 PSI, 0-200 PSI, 0-500 PSI, 0-1000 PSI, 0-3000 PSI, and 0-8000 PSI.
0-3000 PSI is standard.
0-8000 PSI is available for *RCM5* only.
Accuracy: ± 1% of range.
Resolution: 0.1% of range.
Calibration: Lowest calibrated pressure 14.24 PSI.
NOTE: Pressure sensors are not interchangeable between *RCM4* and *RCM5*.

5. CURRENT DIRECTION:

Sensor Type: Magnetic compass with needle clamped on to potentiometer ring.
Resolution: 0.35°.
Accuracy:
± 7.5°. speed within 2.5 to 5 cm/sec., or 100 to 200 cm/sec.
± 5°, speed within 5 to 100 cm/sec.
Maximum Compass Tilt: 12° from horizontal.

6. CURRENT SPEED:

Principle: Rotor with magnetic coupling through instrument case. The number of rotations during the period between 2 samplings are counted by an electronic counter. This counter has a pre-circuit with a choice between ten dividing factors, suited for sampling intervals from 0,5 to 180 minutes.
Standard is 4 rev/count.
Range: 2.5 to 250 cm/sec.
Accuracy: ± 1 cm/sec., or ± 2% of the actual speed, whichever is greater.
Starting Velocity: 2.0 cm/sec.

CLOCK:

Type: Quartz Clock 2574.
Accuracy: Better than ± 2 sec/day within 0°C to 20°C.
Sampling Intervals: 0.5, 1, 2, 5, 10, 15, 20, 30, 60 and 180 minutes, selected by interval selecting switch.
External Triggering: For calibration purposes, a six volts positive pulse to terminal on top end plate will activate the instrument.

RECORDING SYSTEM:

Type: Reel to reel 1/4 inch magnetic tape.
Coding: 10 bit binary words (short and long pulses) in serial form.
Storage Capacity: 10,000 samplings using 600 feet of magnetic tape on 3 inch reels.

TELEMETRY:

Acoustically:
By switching on and off carrier from acoustic transducer.
Frequency: 16,384 KHz ± 5 Hz.
Detection Range: Typically 800 meters with *Hydrophone Receiver 2247*.
By Cable:
5 volts negative, short and long pulses from terminal on top endplate. May be used for real time readings and for calibration purposes by use of *Printer* 2860.

POWER:

Battery: 9 volts, non-magnetic.
Size: 63 x 50 x 80 mm.
Capacity: sufficient for 10,000 samplings.

MOORING:

Spindle designed for 15 mm. maximum diameter rope. Gimbal mounting permits 25° deviation between spindle and instrument
Drag Force of RCM (typical values):
2.5 kg. at 105 cm/sec.
5 kg. at 155 cm/sec.
10 kg. at 195 cm/sec.
20 kg. at 250 cm/sec.

EXTERNAL MATERIALS:

Pressure Case: Cu Ni Si alloy (OSNISIL) and stainless acid proof steel. Epoxy coated.
Vane: 8 mm PVC plastic.
Other plastic parts: Polyamid & Polystyrene.
Other metal parts: Stainless acid proof steel and nickel plated bronze. Epoxy coated.

		RCM4	RCM5
DEPTH CAPABILITY:		2000m	6000m

NET WEIGHT:

Recording Unit,	in air	13.7kg	15.8kg
	in water	9.2kg	11.0kg
Vane Assembly,	in air	12.9kg	13.4kg
	in water	8.1kg	8.5kg

DIMENSIONS:

Recording Unit:	height	510mm	535mm
	diameter	128mm	
Overall length		1370mm	
Overall height		750mm	
Vane size		370 x 1000mm	

GROSS WEIGHT:

Recording Unit	19.1 kg	21.0 kg
Vane Assembly	20.6 kg	21.1 kg

PACKING: (RCM4 & RCM5)

Recording Unit:
Plywood instrument case, 190x230x610mm
Vane Assembly:
Plywood Case 155x400x1020 mm

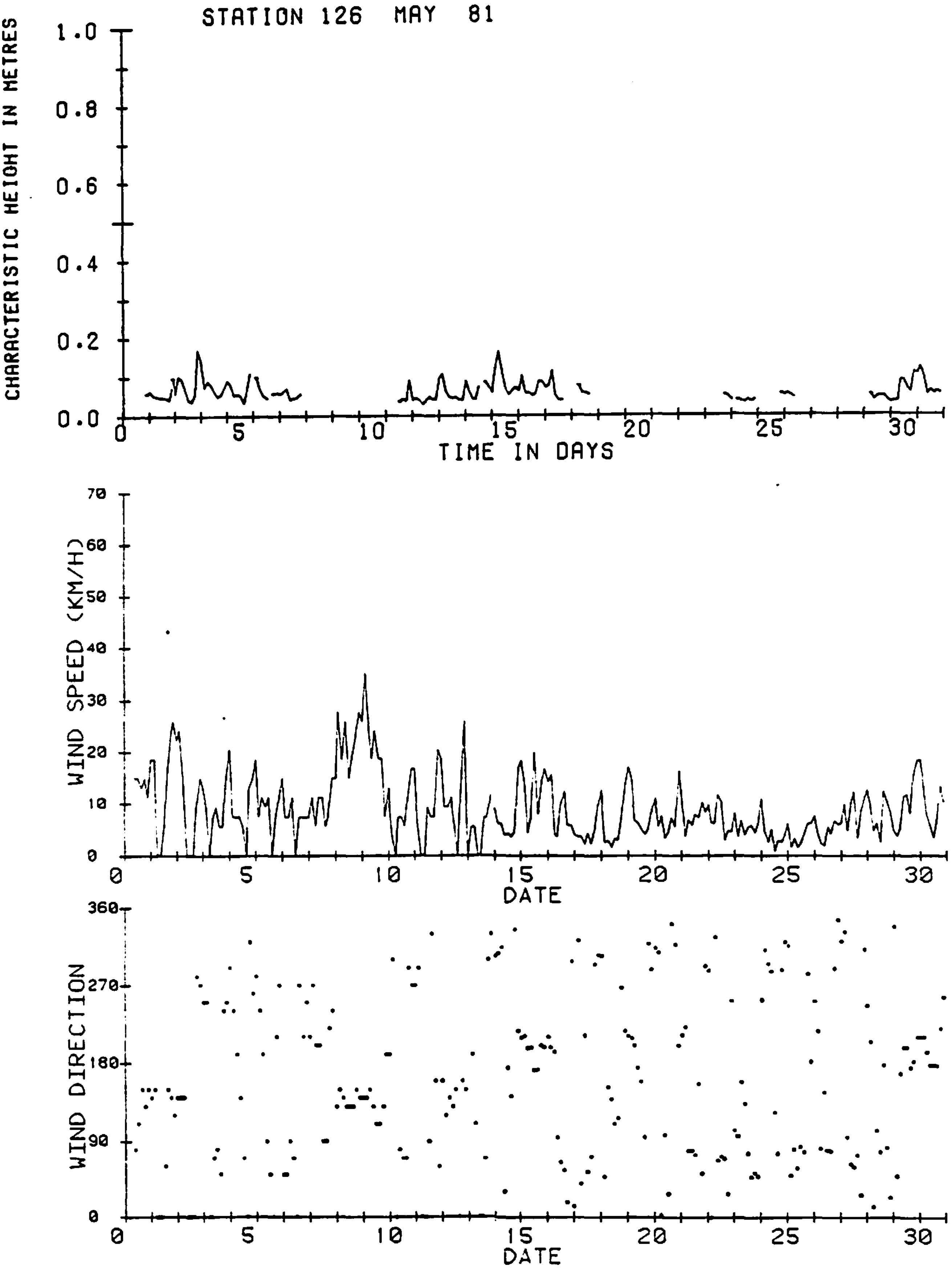
SPARES:

A set of recommended spares is delivered with each instrument. (rotor, bearings, o-rings etc.)

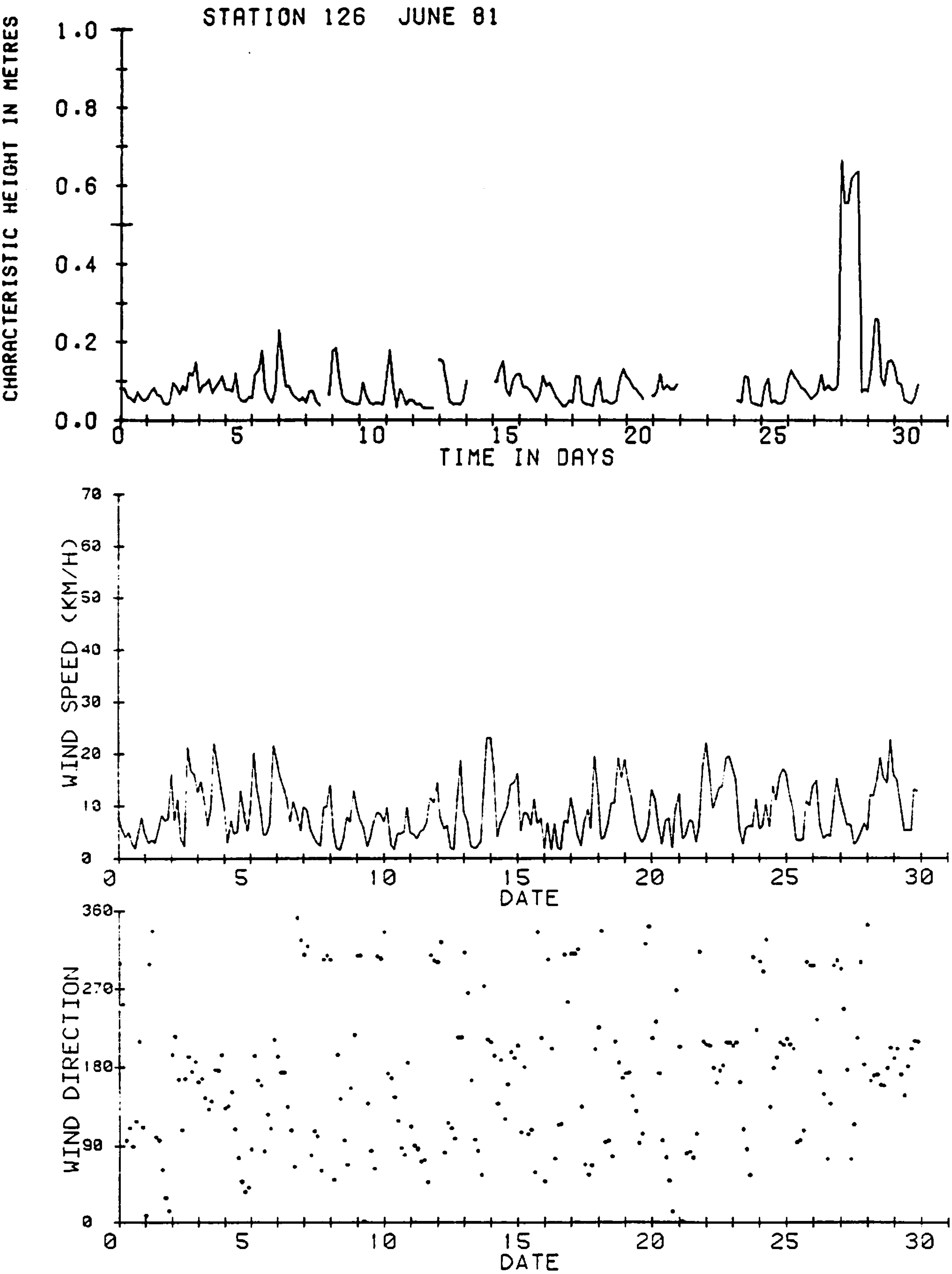
WARRANTY:

One year aganist faulty materials and workmanship.

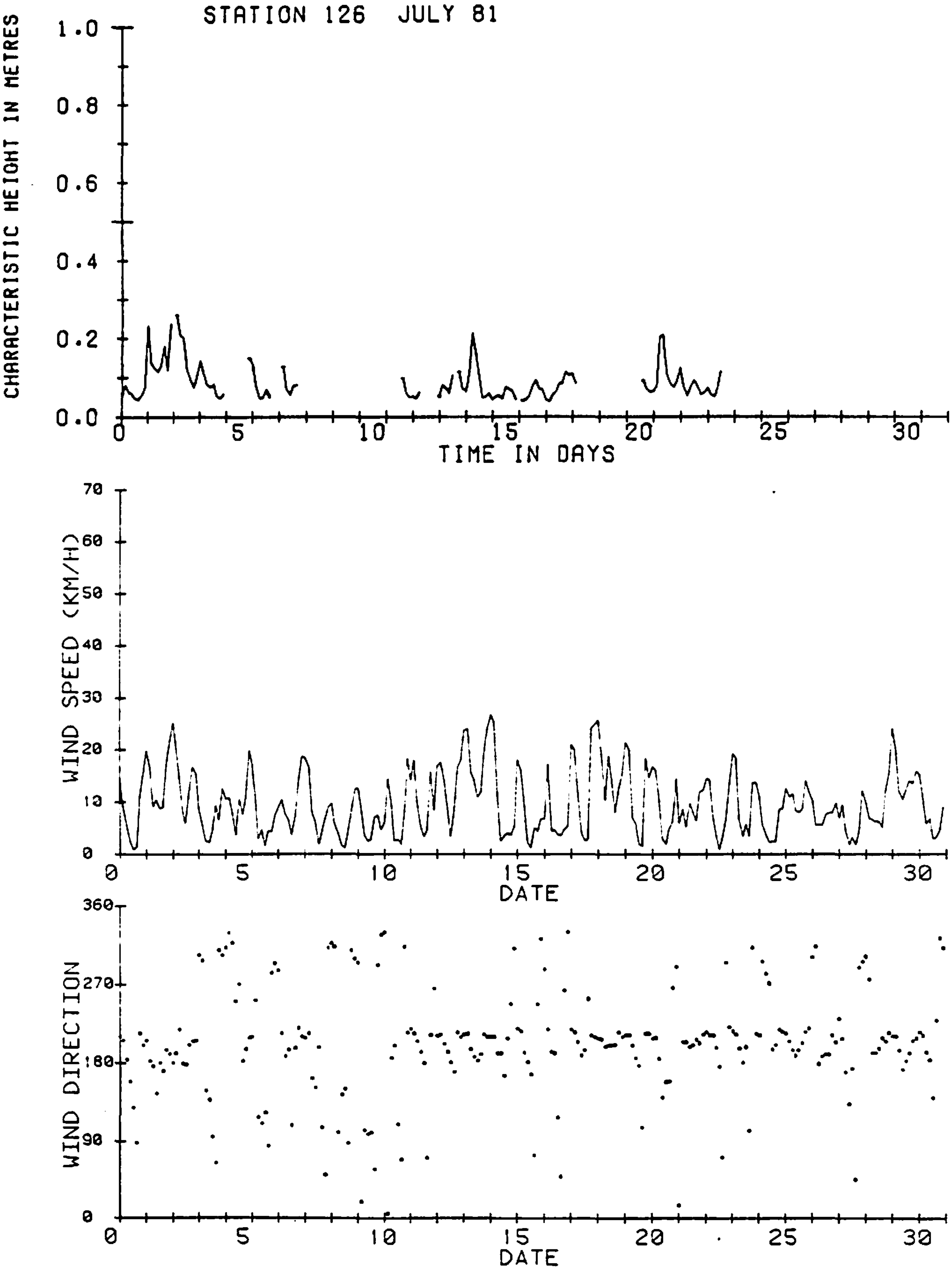
APPENDIX B: WIND AND WAVE DATA



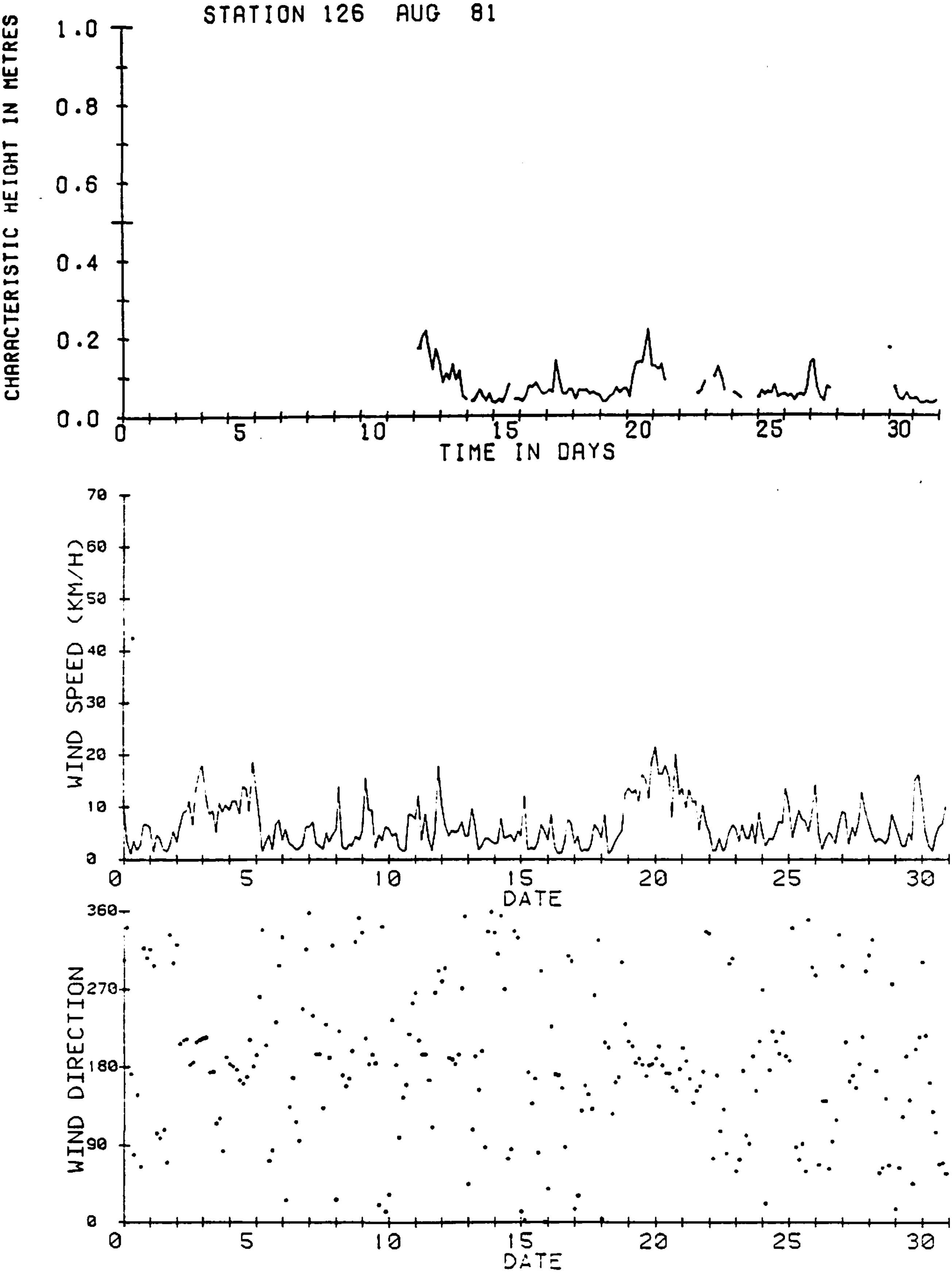
Characteristic wave heights at Port Simpson for May 1981. The wind measurement from 1 May through 14 May are from Prince Rupert while the winds from 15 May through 31 May are from Port Simpson.



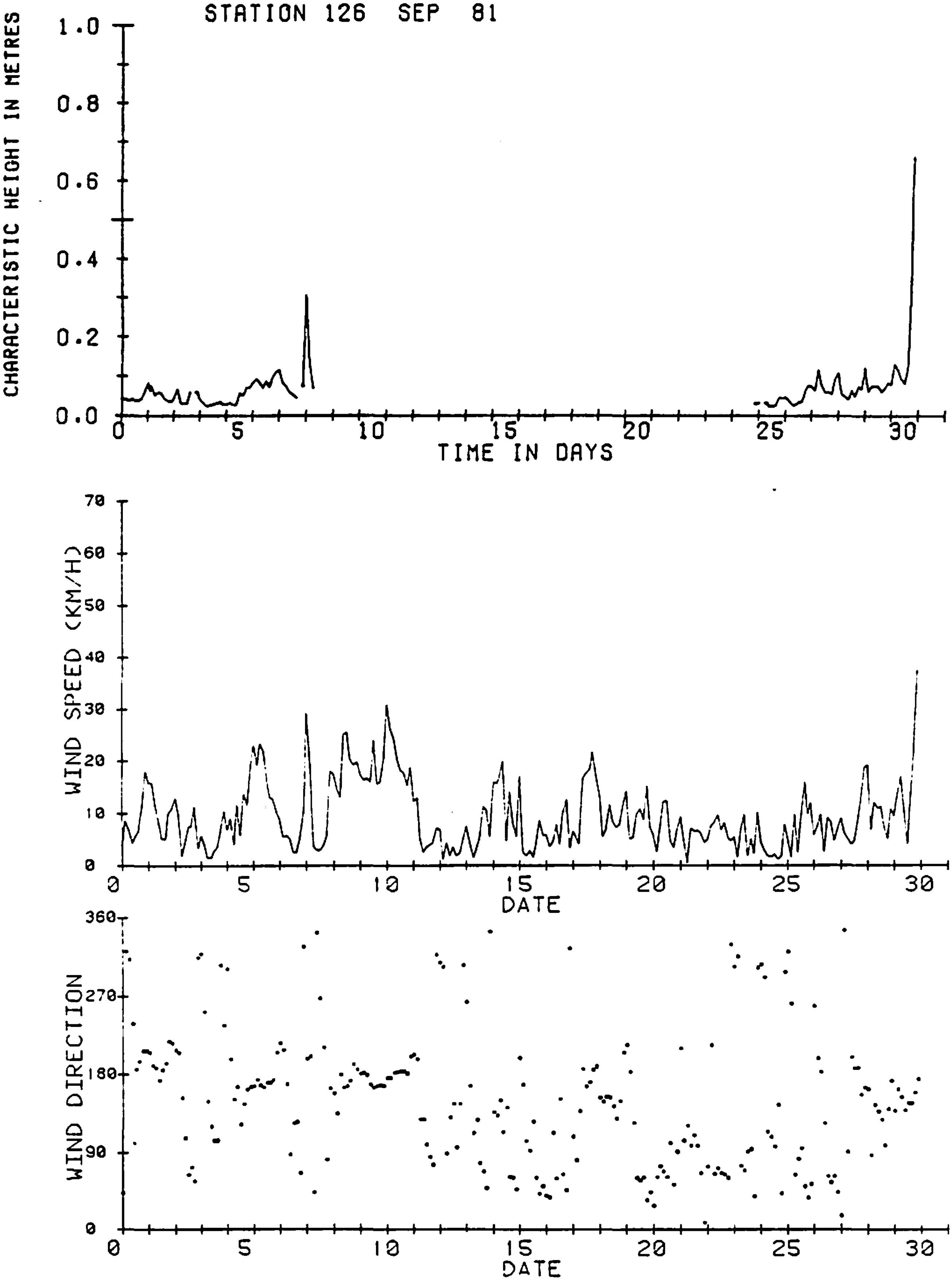
Characteristic wave heights and wind measurements at Port Simpson for June 1981.



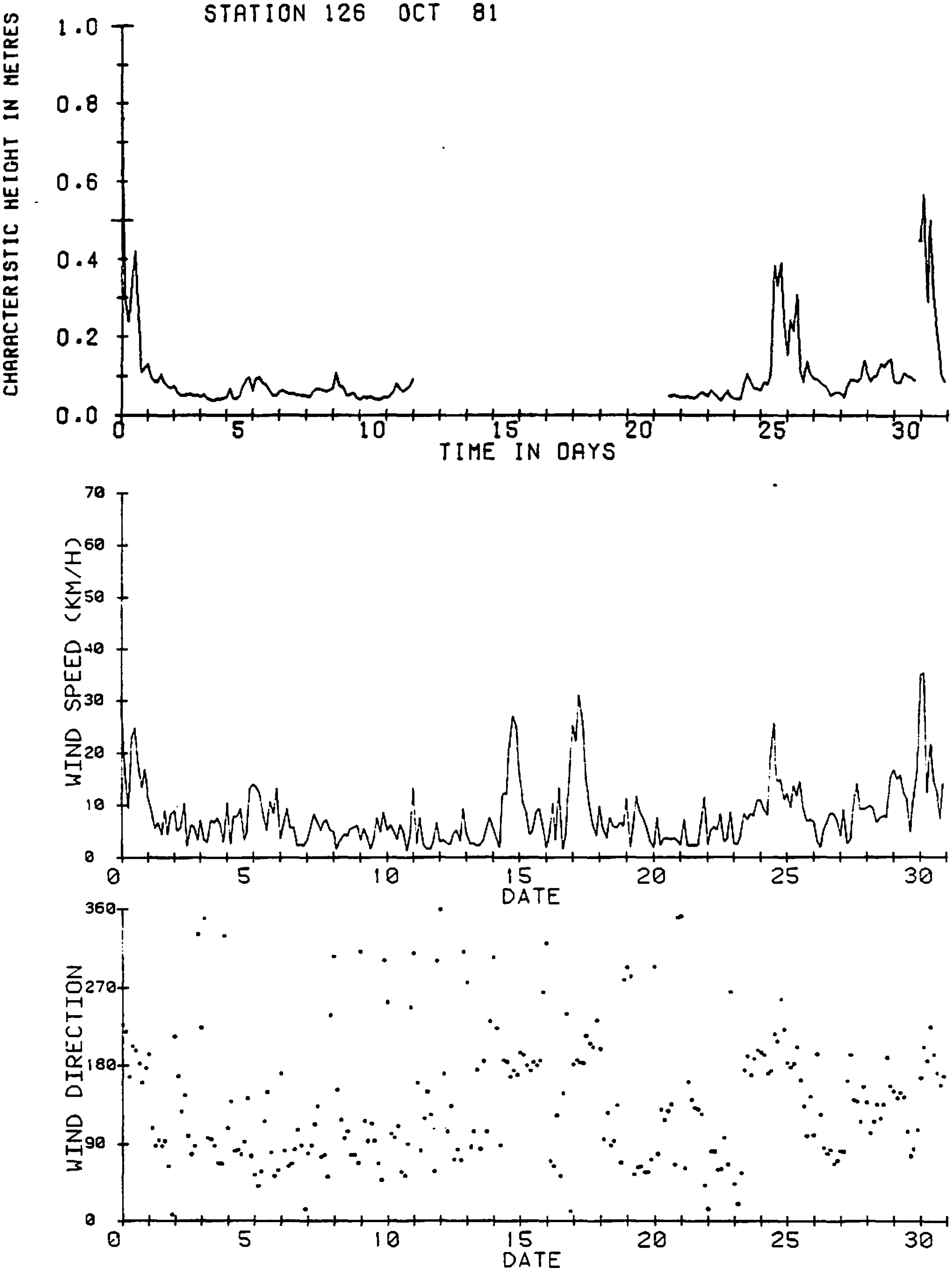
Characteristic wave heights and wind measurements at Port Simpson for July 1981.



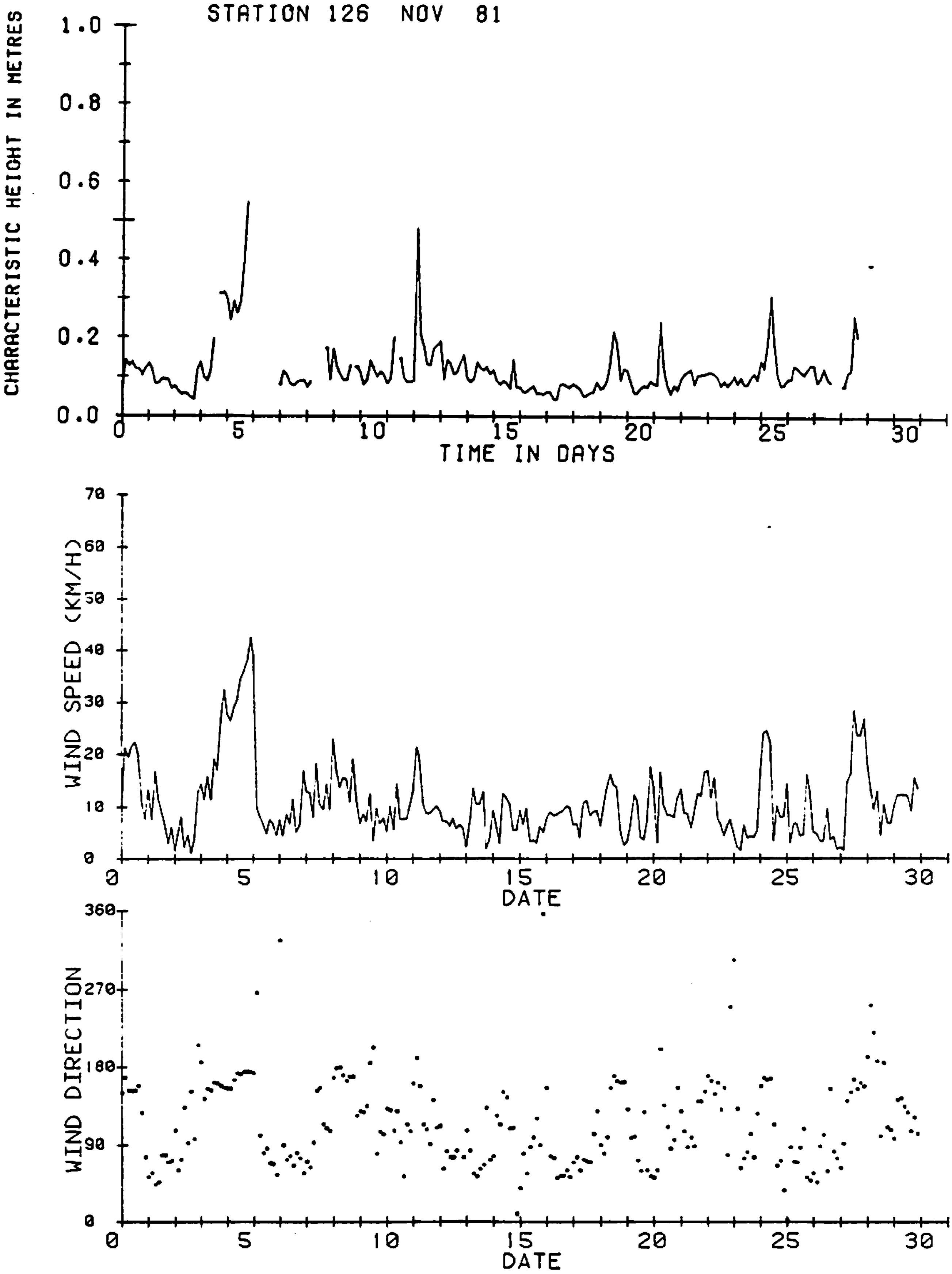
Characteristic wave heights and wind measurements at Port Simpson for August 1981.



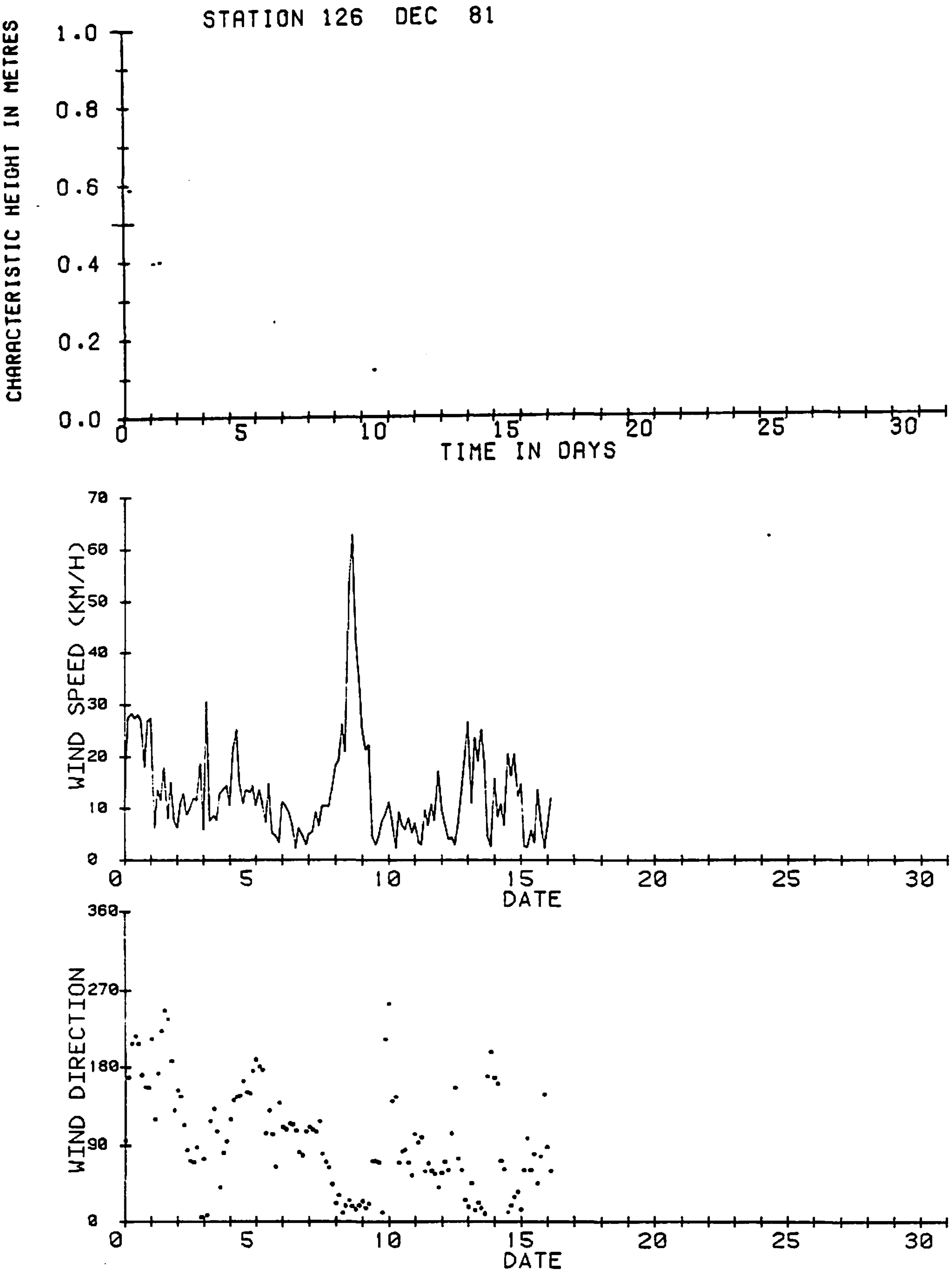
Characteristic wave heights and wind measurements at Port Simpson for September 1981.



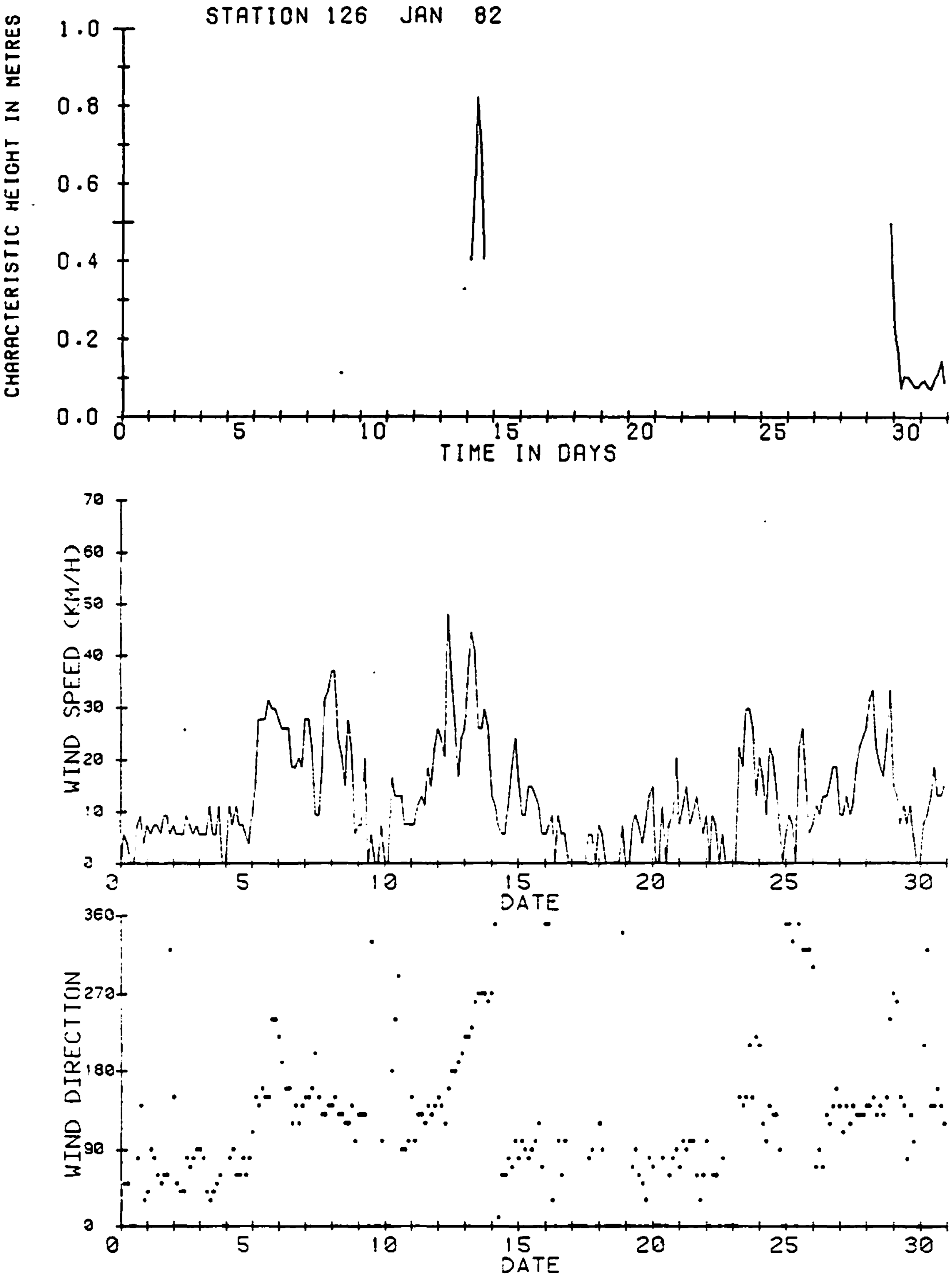
Characteristic wave heights and wind measurements at Port Simpson for October 1981.



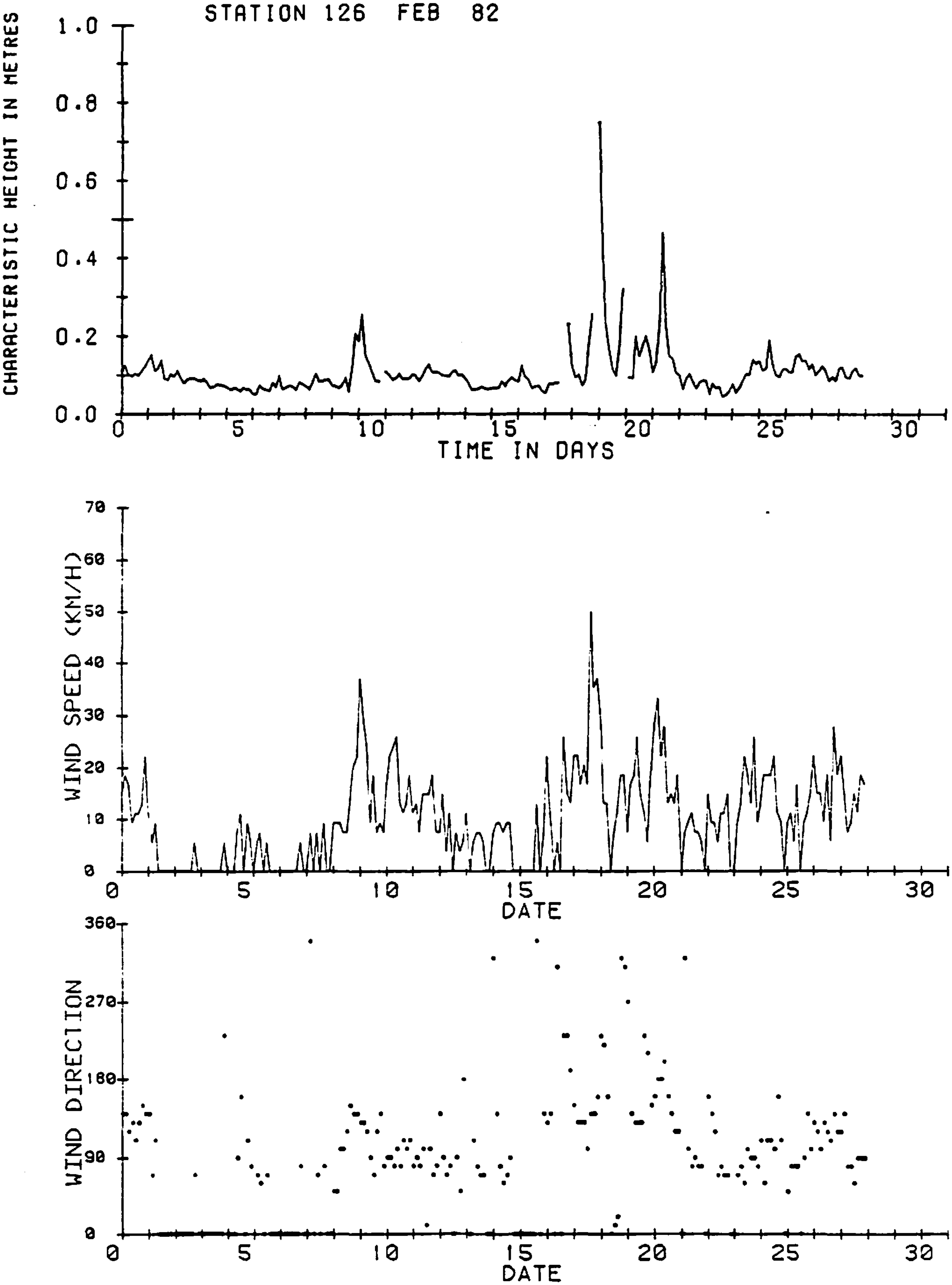
Characteristic wave heights and wind measurements at Port Simpson for November 1981.



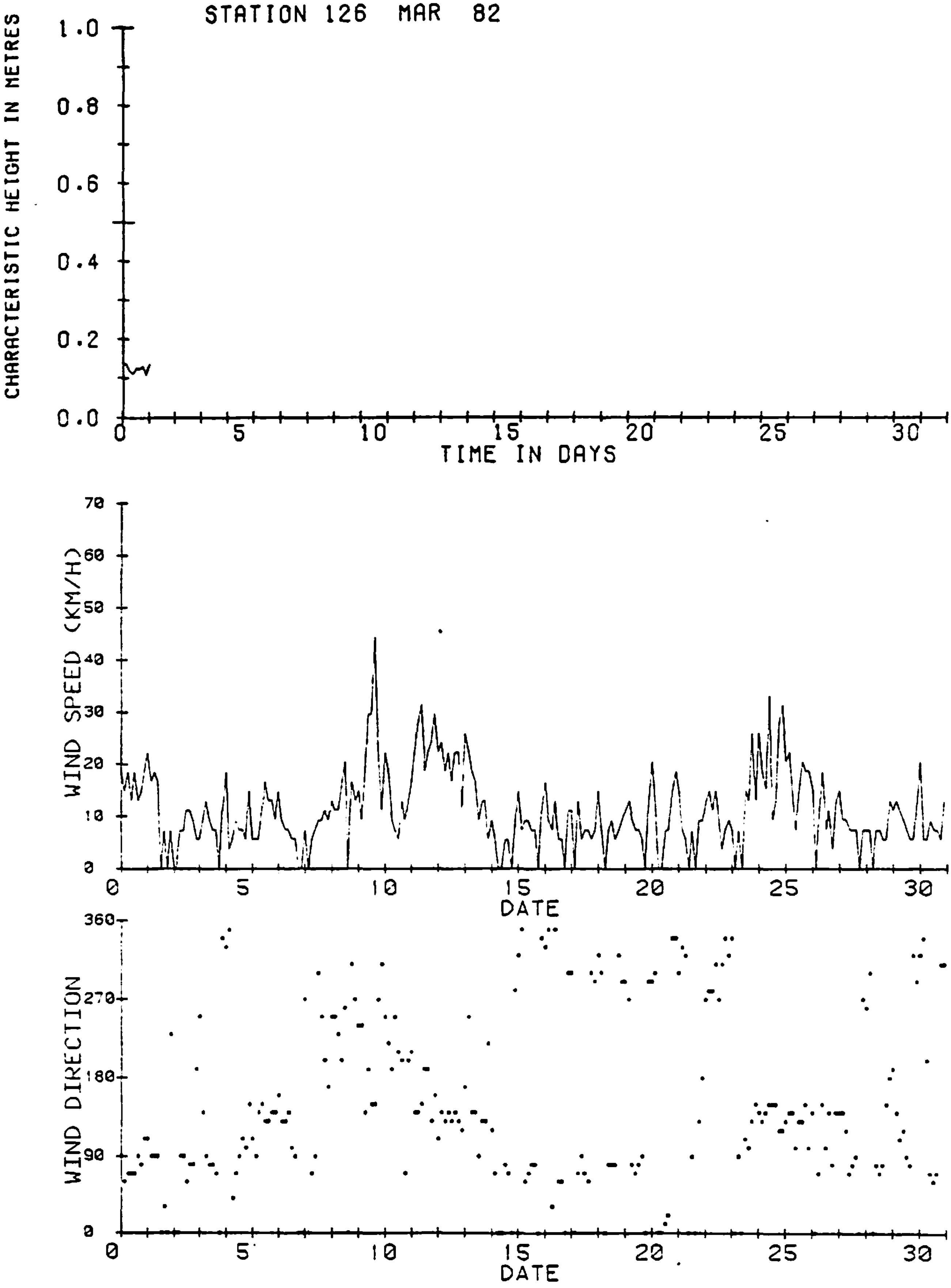
Characteristic wave heights and wind measurements at Port Simpson for December 1981.



Characteristic wave heights at Port Simpson for January 1982. Corresponding wind measurements from Prince Rupert.



Characteristic wave heights at Port Simpson for February 1982. Corresponding wind measurements from Prince Rupert.



Characteristic wave heights at Port Simpson for March 1982. Corresponding wind measurements from Prince Rupert.

APPENDIX C: CTD DATA

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: C
LAT: 54-35.00 N LONG: 130-26.00 W
TIME: 2000 (GMT) DATE: 23- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.73	25.50	19.14
1.0	12.53	25.60	19.25
2.0	12.35	25.66	19.33
3.0	12.28	25.64	19.32
4.0	12.18	25.67	19.37
5.0	12.07	25.68	19.39
6.0	11.64	26.16	19.84
7.0	10.78	26.98	20.61
8.0	10.28	27.35	20.98
9.0	10.01	27.80	21.37
10.0	9.91	28.16	21.67
15.0	9.04	30.06	23.28
20.0	8.63	30.83	23.94
25.0	8.57	30.95	24.04
30.0	8.51	31.12	24.18
35.0	8.48	31.14	24.20
40.0	8.45	31.20	24.25
42.0	8.42	31.34	24.37

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: E
LAT: 54-37.00 N LONG: 130-28.00 W
TIME: 2330 (GMT) DATE: 23- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.31	25.56	19.26
1.0	12.26	25.68	19.36
2.0	12.18	25.68	19.37
3.0	12.05	25.79	19.48
4.0	11.79	25.84	19.56
5.0	11.60	25.84	19.60
6.0	11.27	25.94	19.73
7.0	10.39	25.91	19.85
8.0	10.23	26.26	20.14
9.0	10.13	26.36	20.23
10.0	9.50	27.11	20.91
15.0	9.02	30.53	23.65
20.0	8.78	30.88	23.96
25.0	8.75	31.02	24.07
30.0	8.69	31.07	24.12
35.0	8.69	31.26	24.27
40.0	8.57	31.32	24.33
45.0	8.57	31.36	24.36
50.0	8.54	31.38	24.38
55.0	8.38	31.38	24.41
60.0	8.18	31.63	24.63
70.0	7.87	31.78	24.79

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: D
LAT: 54-36.00 N LONG: 130-27.00 W
TIME: 25 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	11.01	25.22	19.21
1.0	10.94	25.46	19.41
2.0	10.88	25.58	19.51
3.0	10.85	25.85	19.73
4.0	10.85	26.13	19.94
5.0	10.83	26.18	19.98
6.0	11.07	26.31	20.05
7.0	10.38	26.29	20.14
8.0	10.04	26.40	20.28
9.0	10.08	26.54	20.38
10.0	10.15	26.91	20.66
15.0	9.48	29.30	22.62
20.0	8.72	30.79	23.89
25.0	8.63	31.05	24.11
30.0	8.60	31.12	24.17
35.0	8.51	31.27	24.30
40.0	8.48	31.18	24.23
45.0	8.45	31.28	24.32
50.0	8.42	31.38	24.40

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: C
LAT: 54-35.00 N LONG: 130-26.00 W
TIME: 50 (GMT) DATE: 24- 5- 81

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	10.62	24.09	18.40
1.0	10.62	24.03	18.35
2.0	10.36	24.58	18.82
3.0	10.78	25.06	19.13
4.0	11.12	25.17	19.16
5.0	11.66	25.39	19.24
6.0	12.06	25.39	19.17
7.0	12.22	25.50	19.23
8.0	12.06	25.62	19.35
9.0	11.04	26.65	20.31
10.0	10.49	27.23	20.85
15.0	9.44	29.37	22.68
20.0	8.62	30.54	23.71
25.0	8.66	30.84	23.94
30.0	8.56	30.96	24.05
35.0	8.51	31.12	24.18
40.0	8.48	31.14	24.20
45.0	8.42	31.35	24.38

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: B
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 130 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	11.44	24.42	18.53
1.0	11.44	24.39	18.50
2.0	11.40	24.78	18.81
3.0	12.09	25.30	19.10
4.0	12.30	25.29	19.05
5.0	12.55	25.49	19.16
6.0	12.38	25.67	19.33
7.0	12.16	25.96	19.59
8.0	11.44	26.26	19.95
9.0	11.04	26.58	20.26
10.0	10.85	26.72	20.40
15.0	9.77	28.71	22.11
20.0	8.85	30.27	23.47
25.0	8.57	30.65	23.81
30.0	8.45	30.87	24.00

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: A
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 145 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	13.32	24.59	18.33
1.0	13.27	25.37	18.94
2.0	13.23	25.46	19.02
3.0	13.09	25.48	19.06
4.0	12.97	25.57	19.15
5.0	12.58	25.70	19.32
6.0	12.28	25.80	19.45
7.0	11.94	25.97	19.64
8.0	11.78	26.02	19.70
9.0	10.26	26.11	20.02
10.0	11.34	26.30	19.99
15.0	9.78	28.62	22.04
20.0	8.75	30.50	23.66
25.0	8.51	30.78	23.92

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: E
LAT: 54-37.00 N LONG: 130-28.00 W
TIME: 1715 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	10.12	23.04	17.66
1.0	9.88	23.40	17.98
2.0	9.74	23.70	18.23
3.0	9.66	23.90	18.39
4.0	9.64	23.94	18.43
5.0	9.64	23.94	18.43
6.0	10.38	24.85	19.03
7.0	10.54	24.62	18.82
8.0	10.34	25.86	19.81
9.0	10.26	26.22	20.11
10.0	9.97	27.14	20.86
15.0	9.39	29.41	22.72
20.0	8.97	30.76	23.83
25.0	9.04	31.06	24.06
30.0	8.64	31.04	24.10
35.0	8.66	31.28	24.29
40.0	8.66	31.28	24.29
45.0	8.54	31.35	24.36
50.0	8.45	31.39	24.40
55.0	8.36	31.39	24.42
60.0	8.25	31.52	24.53
70.0	7.99	31.56	24.60

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: D
LAT: 54-36.00 N LONG: 130-27.00 W
TIME: 1808 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	10.31	23.26	17.80
1.0	10.17	23.70	18.17
2.0	10.48	24.46	18.71
3.0	11.16	24.84	18.90
4.0	11.57	25.38	19.25
5.0	11.52	25.38	19.25
6.0	11.38	25.36	19.26
7.0	11.81	25.66	19.42
8.0	11.32	26.06	19.81
9.0	11.04	26.23	19.99
10.0	9.97	27.90	21.45
15.0	8.96	30.32	23.49
20.0	8.75	30.65	23.78
25.0	8.66	30.91	24.00
30.0	8.57	31.10	24.16
35.0	8.51	31.08	24.15
40.0	8.48	31.26	24.30
45.0	8.42	31.27	24.31

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: C
LAT: 54-35.00 N LONG: 130-26.00 W
TIME: 1830 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	11.29	23.83	18.09
1.0	11.00	23.82	18.13
2.0	11.51	24.34	18.45
3.0	12.28	25.11	18.92
4.0	11.52	25.04	18.99
5.0	11.31	25.15	19.11
6.0	11.58	24.99	18.94
7.0	11.29	25.37	19.28
8.0	11.88	25.58	19.35
9.0	11.88	25.92	19.61
10.0	9.99	28.43	21.86
15.0	8.80	30.25	23.46
20.0	8.62	30.73	23.86
25.0	8.55	30.93	24.03
30.0	8.50	31.10	24.17
35.0	8.48	31.18	24.23
40.0	8.42	31.27	24.31

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: B
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 1905 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	10.70	22.20	16.92
1.0	10.68	22.66	17.28
2.0	10.60	23.52	17.96
3.0	10.76	23.76	18.12
4.0	10.92	24.07	18.34
5.0	10.98	24.14	18.38
6.0	11.30	24.26	18.42
7.0	11.80	24.78	18.74
8.0	12.04	25.36	19.15
9.0	10.12	27.82	21.37
10.0	9.56	29.20	22.53
15.0	8.85	30.46	23.62
20.0	8.51	30.75	23.89
25.0	8.42	30.98	24.09

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: A
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 1930 (GMT) DATE: 24- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	10.91	22.40	17.05
1.0	10.66	22.86	17.44
2.0	10.58	23.05	17.60
3.0	10.63	23.26	17.76
4.0	10.66	23.34	17.81
5.0	11.02	23.86	18.16
6.0	12.07	24.98	18.85
7.0	12.06	25.78	19.47
8.0	9.97	28.15	21.65
9.0	9.63	28.93	22.31
10.0	9.42	29.31	22.64
15.0	8.76	30.52	23.68
20.0	8.45	30.80	23.94
25.0	8.42	30.98	24.09

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: A
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 1830 (GMT) DATE: 29- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	14.39	20.09	14.68
1.0	14.28	20.08	14.69
2.0	12.35	22.67	17.02
3.0	11.34	24.07	18.27
4.0	11.24	24.48	18.60
5.0	11.33	24.94	18.94
6.0	11.03	26.45	20.16
7.0	9.34	29.71	22.96
8.0	9.09	30.10	23.30
9.0	8.96	30.29	23.47
10.0	8.88	30.40	23.57
15.0	8.75	30.76	23.87
20.0	8.75	30.98	24.04
25.0	8.58	31.09	24.15

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: B
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 1850 (GMT) DATE: 29- 5- 81

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	14.01	20.10	14.76
1.0	14.03	20.15	14.79
2.0	13.24	20.82	15.45
3.0	12.31	22.16	16.64
4.0	11.07	24.11	18.35
5.0	11.08	25.48	19.40
6.0	10.08	27.85	21.40
7.0	9.46	29.14	22.50
8.0	9.26	29.44	22.76
9.0	9.16	29.90	23.13
10.0	8.94	30.19	23.39
15.0	8.60	30.71	23.85
20.0	8.72	31.01	24.07
25.0	8.63	30.98	24.06

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: C
LAT: 54-35.00 N LONG: 130-26.00 W
TIME: 1910 (GMT) DATE: 29- 5- 81

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	13.71	20.44	15.07
1.0	13.74	20.39	15.03
2.0	13.57	20.39	15.06
3.0	13.00	20.70	15.40
4.0	11.16	23.54	17.89
5.0	11.06	24.42	18.59
6.0	10.04	27.53	21.16
7.0	9.31	29.55	22.84
8.0	9.04	30.22	23.40
9.0	8.97	30.32	23.49
10.0	8.88	30.47	23.62
15.0	8.78	30.77	23.87
20.0	8.66	30.98	24.05
25.0	8.72	31.04	24.09
30.0	8.60	31.12	24.17
35.0	8.60	31.22	24.25
40.0	8.57	31.28	24.30

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS- 2 STATION: 1
LAT: 54-35.00 N LONG: 130-28.00 W
TIME: 2000 (GMT) DATE: 29- 5- 81

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	13.26	20.26	15.01
1.0	13.28	20.32	15.06
2.0	13.12	20.40	15.15
3.0	11.83	22.28	16.81
4.0	11.44	22.68	17.18
5.0	10.49	24.60	18.81
6.0	10.33	25.34	19.41
7.0	9.82	28.06	21.60
8.0	9.41	29.32	22.64
9.0	9.10	29.72	23.00
10.0	9.06	30.16	23.35
15.0	8.91	30.74	23.83
20.0	8.78	30.96	24.02
25.0	8.66	31.14	24.18
30.0	8.62	31.18	24.21
35.0	8.57	31.25	24.28
40.0	8.58	31.42	24.41

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2　　STATION: D
LAT: 54-36.00 N　　LONG: 130-27.00 W
TIME: 2020 (GMT)　　DATE: 29- 5-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.95	20.08	14.93
1.0	12.95	20.12	14.96
2.0	12.97	20.20	15.02
3.0	12.86	20.58	15.33
4.0	12.99	21.92	16.34
5.0	11.01	23.97	18.25
6.0	10.49	26.24	20.09
7.0	10.07	27.18	20.88
8.0	9.72	28.06	21.62
9.0	9.03	30.15	23.35
10.0	8.97	30.42	23.57
15.0	8.88	30.95	24.00
20.0	8.78	31.03	24.07
25.0	8.63	31.16	24.20
30.0	8.57	31.18	24.22
35.0	8.54	31.24	24.27
40.0	8.51	31.30	24.32
45.0	8.48	31.33	24.35

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: E
LAT: 54-37.00 N LONG: 130-28.00 W
TIME: 2045 (GMT) DATE: 29- 5- 81

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.54	19.46	14.52
1.0	12.52	19.53	14.58
2.0	12.64	19.99	14.91
3.0	12.73	20.40	15.21
4.0	12.74	20.68	15.43
5.0	12.42	21.28	15.94
6.0	12.38	21.37	16.02
7.0	10.12	26.55	20.38
8.0	9.14	28.74	22.23
9.0	8.64	29.22	22.68
10.0	8.88	29.61	22.95
15.0	9.07	30.78	23.83
20.0	9.06	31.04	24.04
25.0	8.67	31.08	24.13
30.0	8.63	31.16	24.20
35.0	8.63	31.24	24.26
40.0	8.57	31.28	24.30
45.0	8.51	31.34	24.36
50.0	8.44	31.48	24.48
55.0	8.23	31.46	24.49
60.0	8.14	31.58	24.60
70.0	7.87	31.67	24.71

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: A
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 1445 (GMT) DATE: 2- 6-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	13.14	18.10	13.38
1.0	13.14	18.17	13.43
2.0	13.11	18.28	13.52
3.0	13.18	18.47	13.65
4.0	13.14	18.68	13.82
5.0	13.04	18.89	14.00
6.0	12.97	19.46	14.45
7.0	12.79	20.07	14.95
8.0	11.60	20.55	15.51
9.0	11.94	21.55	16.23
10.0	11.01	25.01	19.05
15.0	9.16	29.75	23.02
20.0	8.78	30.47	23.64

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: B
LAT: 54-34.00 N LONG: 130-24.00 W
TIME: 1505 (GMT) DATE: 2- 6-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.73	17.99	13.36
1.0	12.73	18.18	13.50
2.0	12.84	18.47	13.71
3.0	12.88	18.45	13.69
4.0	12.95	18.45	13.68
5.0	12.70	19.44	14.48
6.0	11.66	19.96	15.05
7.0	11.46	20.53	15.52
8.0	11.17	21.22	16.10
9.0	10.65	25.67	19.62
10.0	10.21	27.26	20.92
15.0	9.10	29.83	23.09
20.0	8.66	30.24	23.47
25.0	8.63	30.46	23.65

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: 1
LAT: 54-35.00 N LONG: 130-28.00 W
TIME: 1535 (GMT) DATE: 2- 6-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.63	18.25	13.58
1.0	12.62	18.23	13.56
2.0	12.62	18.23	13.56
3.0	11.72	19.43	14.63
4.0	11.02	20.27	15.38
5.0	10.78	21.36	16.26
6.0	10.75	21.92	16.70
7.0	10.81	22.29	16.98
8.0	10.83	22.76	17.34
9.0	10.36	25.03	19.17
10.0	10.17	25.74	19.75
15.0	9.24	29.83	23.07
20.0	9.00	30.50	23.63
25.0	8.85	30.75	23.84
30.0	8.75	30.98	24.04
35.0	8.63	31.12	24.17
40.0	8.60	31.22	24.25

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: 2
LAT: 54-35.00 N LONG: 130-25.00 W
TIME: 1620 (GMT) DATE: 2- 6-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.80	18.50	13.74
1.0	12.83	18.48	13.72
2.0	12.83	18.48	13.72
3.0	12.68	18.81	14.00
4.0	12.04	19.42	14.57
5.0	11.84	19.72	14.83
6.0	11.34	20.56	15.56
7.0	11.12	21.25	16.13
8.0	10.80	22.75	17.34
9.0	10.81	23.28	17.74
10.0	10.81	24.04	18.33
15.0	9.10	30.08	23.28
20.0	8.69	30.77	23.88
25.0	8.74	31.00	24.06
30.0	8.63	31.05	24.11
35.0	8.60	31.11	24.16
40.0	8.63	31.12	24.17
45.0	8.57	31.21	24.24

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: D
LAT: 54-36.00 N LONG: 130-27.00 W
TIME: 1905 (GMT) DATE: 2- 6-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.83	18.51	13.74
1.0	12.76	18.48	13.73
2.0	12.73	18.47	13.73
3.0	12.69	18.55	13.80
4.0	12.62	18.74	13.95
5.0	12.18	19.26	14.43
6.0	11.64	20.30	15.31
7.0	11.37	21.24	16.08
8.0	11.14	21.62	16.41
9.0	10.91	22.74	17.31
10.0	10.66	24.20	18.48
15.0	9.12	29.96	23.19
20.0	8.94	30.52	23.65
25.0	8.82	30.74	23.84
30.0	8.78	30.91	23.98
35.0	8.67	30.98	24.05
40.0	8.63	31.16	24.20
45.0	8.60	31.22	24.25

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: E
LAT: 54-37.00 N LONG: 130-28.00 W
TIME: 1925 (GMT) DATE: 2- 6-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.91	18.66	13.84
1.0	12.93	18.66	13.84
2.0	12.92	18.66	13.84
3.0	12.83	18.73	13.91
4.0	12.22	19.23	14.40
5.0	10.75	21.51	16.38
6.0	10.73	21.62	16.47
7.0	10.78	22.00	16.76
8.0	10.78	22.38	17.05
9.0	10.78	22.54	17.18
10.0	10.73	23.12	17.63
15.0	9.18	29.88	23.12
20.0	8.94	30.78	23.85
25.0	9.00	30.95	23.98
30.0	8.91	31.10	24.11
35.0	8.68	31.16	24.19
40.0	8.57	31.28	24.30
45.0	8.54	31.31	24.33
50.0	8.46	31.34	24.36
55.0	8.42	31.42	24.43
60.0	7.84	31.67	24.71

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-2 STATION: C
LAT: 54-35.00 N LONG: 130-26.00 W
TIME: 2035 (GMT) DATE: 2- 6-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	13.02	18.48	13.69
1.0	12.95	18.48	13.70
2.0	12.70	18.58	13.82
3.0	12.52	18.86	14.06
4.0	12.18	19.48	14.59
5.0	11.52	19.97	15.08
6.0	11.48	20.08	15.17
7.0	11.54	20.28	15.31
8.0	11.37	20.98	15.88
9.0	11.21	22.77	17.29
10.0	11.01	23.08	17.56
15.0	9.30	29.71	22.97
20.0	8.91	30.32	23.50
25.0	8.69	30.78	23.89
30.0	8.66	30.91	24.00
35.0	8.62	31.02	24.09
40.0	8.63	31.12	24.17
45.0	8.63	31.12	24.17

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-3 STATION: 1
LAT: 54-35.15 N LONG: 130-27.88 W
TIME: 1600 (GMT) DATE: 25- 8-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.70	25.82	19.39
1.0	12.87	28.17	21.17
2.0	12.63	28.83	21.72
3.0	12.29	29.09	21.98
4.0	12.05	29.27	22.17
5.0	11.89	29.27	22.20
6.0	11.85	29.30	22.23
7.0	11.82	29.32	22.25
8.0	11.72	29.40	22.33
9.0	11.35	29.83	22.72
10.0	11.33	29.76	22.67
15.0	10.63	30.35	23.25
20.0	10.08	30.59	23.53
25.0	9.42	30.94	23.90
30.0	8.70	31.49	24.44
35.0	8.15	31.67	24.67
37.0	8.00	31.81	24.80

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-3 STATION: E
LAT: 54-37.00 N LONG: 130-28.00 W
TIME: 1700 (GMT) DATE: 25- 8-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	12.70	26.22	19.70
1.0	12.70	27.56	20.73
2.0	12.49	28.46	21.46
3.0	11.92	28.83	21.85
4.0	12.22	29.21	22.09
5.0	11.85	29.30	22.23
6.0	11.89	29.27	22.20
7.0	11.55	29.53	22.46
8.0	11.39	29.67	22.59
9.0	11.35	29.76	22.67
10.0	11.32	29.72	22.64
15.0	10.44	30.29	23.23
20.0	9.70	30.69	23.67
25.0	9.23	30.95	23.94
30.0	8.77	31.43	24.39
35.0	8.27	31.64	24.63
40.0	7.73	32.06	25.03
45.0	7.67	32.03	25.02
50.0	7.67	32.11	25.08
55.0	7.55	32.14	25.12
60.0	7.49	32.27	25.23
70.0	7.34	32.33	25.30

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-3 STATION: C
LAT: 54-35.00 N LONG: 130-26.00 W
TIME: 1730 (GMT) DATE: 25- 8-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	13.53	21.84	16.18
1.0	13.25	27.56	20.63
2.0	13.15	28.04	21.02
3.0	12.53	28.91	21.80
4.0	12.32	29.13	22.01
5.0	12.26	29.18	22.06
6.0	12.09	29.25	22.14
7.0	11.95	29.35	22.25
8.0	11.89	29.48	22.36
9.0	11.82	29.53	22.41
10.0	11.42	29.71	22.62
15.0	10.96	30.36	23.20
20.0	10.31	30.54	23.45
25.0	9.39	31.04	23.99
30.0	8.49	31.53	24.51
33.0	8.40	31.46	24.47

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-3 STATION: A
LAT: 54-33.88 N LONG: 130-23.51 W
TIME: 1800 (GMT) DATE: 25- 8-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	13.73	26.66	19.83
1.0	13.71	27.43	20.44
2.0	12.67	28.74	21.64
3.0	12.36	29.04	21.93
4.0	12.15	29.20	22.09
5.0	12.19	29.24	22.12
6.0	12.05	29.27	22.17
7.0	11.95	29.28	22.19
8.0	11.89	29.34	22.25
9.0	11.82	29.46	22.35
10.0	11.72	29.47	22.38
15.0	11.19	29.96	22.85
20.0	10.31	30.47	23.40
25.0	9.33	31.02	24.00
28.0	8.77	30.68	23.80

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-4 STATION: 1
LAT: 5-35.15 N LONG: 130-27.88 W
TIME: 1920 (GMT) DATE: 26-11-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	8.33	29.54	22.98
1.0	8.34	29.39	22.86
2.0	8.37	29.26	22.75
3.0	8.53	29.29	22.75
4.0	8.63	29.42	22.84
5.0	8.68	29.46	22.86
6.0	8.96	29.50	22.85
7.0	9.08	29.74	23.02
8.0	9.31	29.87	23.09
9.0	9.34	30.30	23.42
10.0	9.36	30.43	23.52
15.0	9.61	30.73	23.71
20.0	9.88	31.36	24.16
25.0	9.92	31.56	24.31
30.0	9.91	31.57	24.31
35.0	9.94	31.61	24.34
40.0	9.93	31.64	24.37
40.5	9.93	31.64	24.37

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-4 STATION: C
LAT: 54-35.33 N LONG: 130-25.33 W
TIME: 1930 (GMT) DATE: 26-11-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	8.10	29.62	23.03
1.0	8.11	29.34	22.81
2.0	8.43	29.56	22.98
3.0	8.50	29.59	22.99
4.0	8.86	29.76	23.07
5.0	8.91	29.77	23.07
6.0	8.96	29.82	23.10
7.0	9.07	29.93	23.17
8.0	9.15	30.04	23.25
9.0	9.33	30.20	23.34
10.0	9.56	30.34	23.42
15.0	9.70	30.90	23.83
20.0	9.80	31.02	23.91
25.0	9.88	31.24	24.07
30.0	9.87	31.27	24.09
35.0	9.92	31.42	24.20
40.0	9.92	31.50	24.26
45.0	9.92	31.50	24.26
48.7	9.94	31.50	24.26

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-4 STATION: E
LAT: 34-36.78 N LONG: 130-27.54 W
TIME: 2315 (GMT) DATE: 26-11-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	8.35	29.75	23.11
1.0	8.59	29.71	23.07
2.0	9.11	30.00	23.22
3.0	9.19	30.18	23.35
4.0	9.31	30.52	23.59
5.0	9.35	30.57	23.63
6.0	9.40	30.66	23.69
7.0	9.45	30.79	23.78
8.0	9.48	30.88	23.85
9.0	9.55	30.98	23.92
10.0	9.61	31.06	23.97
15.0	9.69	31.33	24.17
20.0	9.74	31.37	24.19
25.0	9.80	31.45	24.24
30.0	9.86	31.52	24.29
35.0	9.89	31.59	24.34
40.0	9.93	31.63	24.36
45.0	9.94	31.67	24.39
50.0	9.95	31.68	24.40
55.0	9.95	31.69	24.40
60.0	9.95	31.71	24.42
65.0	9.94	31.71	24.42
70.0	9.93	31.72	24.43

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-4 STATION: A
LAT: 54-33.88 N LONG: 130-23.51 W
TIME: 3 (GMT) DATE: 27-11-1981

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	8.81	29.68	23.02
1.0	8.85	29.77	23.08
2.0	8.84	29.71	23.03
3.0	8.85	29.72	23.04
4.0	8.97	29.78	23.07
5.0	9.45	30.20	23.32
6.0	9.63	30.43	23.47
7.0	9.64	30.54	23.56
8.0	9.68	30.58	23.58
9.0	9.77	30.69	23.65
10.0	9.78	30.76	23.71
15.0	9.82	30.95	23.85
20.0	9.87	31.16	24.00
25.0	9.93	31.26	24.07
27.0	9.94	31.30	24.10

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-5 STATION: C
LAT: 54-35.28 N LONG: 130-25.53 W
TIME: 2342 (GMT) DATE: 26- 1-1982

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	4.81	30.33	24.02
1.0	4.84		
2.0	4.84		
3.0	4.84		
4.0	4.87		
5.0	4.87		
6.0	4.87		
7.0	4.87		
8.0	4.93		
9.0	5.08		
10.0	5.17	30.30	23.96
14.0	5.47	31.10	24.56
19.0	6.27	31.34	24.66
24.0	6.93	31.56	24.75
29.0	7.11	31.69	24.83

SEAKEM OCEANOGRAPHY LTD.

CRUISE: PS-5 STATION: E
LAT: 54-36.78 N LONG: 130-27.54 W
TIME: 12 (GMT) DATE: 27- 1-1982

DEPTH(M)	TEMP(C)	SAL(PPT)	SIGMA-T
0.0	5.59	30.31	23.93
1.0	5.56	30.56	24.13
2.0	5.68	30.61	24.15
3.0	5.83	30.63	24.15
4.0	6.12	30.73	24.20
5.0	6.16	30.78	24.23
6.0	6.18	30.90	24.32
7.0	6.18	30.90	24.32
8.0	6.18	30.90	24.32
9.0	6.18	30.98	24.39
10.0	6.18	31.05	24.44
14.0	6.16	31.08	24.47
20.0	6.16	31.15	24.52
25.0	6.16	31.15	24.52
29.0	6.10	31.20	24.57
39.0	6.10		
49.0	6.10		

APPENDIX D: DISSOLVED OXYGEN DATA

SAMPLING PROGRAM: MAY 23/81

Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen* (mL/L)	% Saturation
STATION: A (STUMAUN BAY) LOW TIDE				
SFC	10.91	22.40	8.06	120.2
2	10.58	23.05	8.52	126.6
5	11.02	23.86	8.12	122.5
10	9.42	29.31	7.73	116.5
15	8.76	30.52	5.97	89.3
20	8.45	30.80	6.07	90.3
STATION: C (PROPOSED DOCK SITE) LOW TIDE				
SFC	11.29	23.83	8.08	122.6
2	11.51	24.34	8.53	130.5
5	11.31	25.15	8.70	133.2
10	9.99	28.43	7.97	121.0
15	8.80	30.25	6.46	96.6
20	8.62	30.73	6.94	103.6
STATION: E (FLEWIN POINT) LOW TIDE				
SFC	10.12	23.04	8.12	119.4
2	9.74	23.70	7.84	114.8
5	9.64	23.94	7.47	109.3
10	9.97	27.14	7.66	115.3
15	9.39	29.41	7.19	108.3
20	8.97	30.76	7.19	108.3
30	8.64	31.04	6.92	103.6
50	8.45	31.39	6.59	98.5

* Estimated Accuracy of Dissolved Oxygen Measurements ±0.4 mL/L.

SAMPLING PROGRAM: AUGUST 25/81

Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen* (mL/L)	% Saturation
STATION: A (STUMAUN BAY)				
SFC	13.78	26.66	7.05	114.8
10	11.72	29.47	6.84	108.5
20	10.31	30.47	5.43	87.6
25	9.23	31.02	4.73	71.8
STATION: C (PROPOSED DOCK SITE)				
SFC	13.53	21.84	6.89	108.4
5	12.26	29.18	7.47	119.7
10	11.42	29.71	5.89	93.0
20	10.31	30.54	4.92	76.2
30	8.49	31.53	4.58	68.5
STATION: E (FLEWIN POINT)				
SFC	12.70	26.22	7.71	122.4
5	11.85	29.30	6.81	108.2
10	11.32	29.72	6.51	102.6
20	9.70	30.69	5.57	85.2
30	8.77	31.43	4.37	65.8
50	7.67	32.11	4.30	63.4

* Estimated Accuracy of Dissolved Oxygen Measurements ±0.4 mL/L.

SAMPLING PROGRAM: AUGUST 25/81 (continued)

Depth (m)	Temperature (°C)	Salinity (‰)	Dissolved Oxygen* (mL/L)	% Saturation
STATION: 1 INSKIP PASSAGE				
SFC	12.70	25.82	7.61	120.5
10	11.35	29.76	6.65	104.9
20	10.08	30.59	4.97	76.6
35	8.15	31.67	4.76	70.8

* Estimated Accuracy of Dissolved Oxygen Measurements ±0.4 mL/L.

SAMPLING PROGRAM: NOVEMBER 26/81

Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen* (mL/L)	% Saturation
STATION: A (STUMAUN BAY)				
SFC	8.81	29.68	6.57	97.8
5	9.45	30.20	6.97	105.6
10	9.78	30.76	6.68	102.5
20	9.87	31.16	6.41	98.8
25	9.93	31.26	5.95	91.8
STATION: C (PROPOSED DOCK SITE)				
SFC	8.40	29.62	6.56	96.7
5	8.91	29.77	6.79	101.5
10	9.56	30.34	6.62	100.7
20	9.80	31.02	6.17	94.8
30	9.87	31.27	6.33	97.6
STATION: E (FLEWIN POINT)				
SFC	8.55	29.75	7.49	111.0
5	9.35	30.57	6.58	99.9
10	9.61	31.06	6.88	105.3
20	9.74	31.37	6.14	94.4
30	9.86	31.52	6.77	104.4

* Estimated Accuracy of Dissolved Oxygen Measurements ±0.4 mL/L.

SAMPLING PROGRAM: NOVEMBER 26/81 (continued)

Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen* (mL/L)	% Saturation
STATION: 1 (INSKIP PASSAGE)				
SFC	8.33	29.54	7.01	103.2
5	8.68	29.46	7.56	112.2
10	9.36	30.43	6.75	102.3
20	9.88	31.36	6.19	95.5
**50	9.93	31.64	6.29	97.2

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* Estimated Accuracy of Dissolved Oxygen Measurements ±0.4 mL/L.

** Values for Temperature and Salinity for Depth of 40.5 m.

SAMPLING PROGRAM: JANUARY 26/82

Depth (m)	Temperature (°C)	Salinity (°/oo)	Dissolved Oxygen* (mL/L)	% Saturation
STATION: C (PROPOSED DOCK SITE)				
SFC	4.81	30.33	6.95	94.6
5	4.87	30.33	7.15	97.5
10	5.17	30.30	6.90	94.8
30	7.11	31.69	6.44	93.5
STATION: E (FLEWIN POINT)				
SFC	5.59	30.31	6.90	95.7
10	6.18	31.05	7.15	101.1
20	6.16	31.15	6.75	95.5
30	6.10	31.20	6.85	96.8
50	6.10	31.30	6.78	95.8

* Estimated Accuracy of Dissolved Oxygen Measurements ±0.4 mL/L.

APPENDIX E: CURRENT METER STATISTICS

```
RCM STATISTICS, FILE : 1501-6  .CAL  DEPTH :   6.0 m  STATION : PS-1


Total number of records :  4548

Mean temp :  9.30     Std dev.:  .590   (C)

Mean sal: 29.38     Std dev.: 1.290   (ppt)

Mean speed:   8.5  Std dev.:  4.41   (cm/s)

Mean vel. magnitude:   1.7   (cm/s)  Mean direction:  234.0   (deg)

Mean major axis velocity :  -1.0     Std dev.:  5.87   (cm/s)

Mean minor axis velocity :  -1.4     Std dev.:   7.39   (cm/s)



                 Rec    Temp   Sal     Press  Dir     Speed   Component
                 No.   Deg C   ppt     dbar   deg     cm/s    Major   Minor

Speed max:  2213.  10.36  26.72    13.70 305.7   27.82   16.23  -22.60
Major max:  2211.  10.40  26.41    13.70 314.6   26.14   18.36  -18.61
Major min:  2316.   9.45  28.92    11.10 168.5  -23.06  -22.59    4.61
Minor max:  4548.  10.75  22.79     8.80 106.0   23.34   -6.45   22.43
Minor min:  2155.  10.50  25.74    11.50 272.8   23.62    1.15  -23.59

NOTE: Major and minor velocity components refer to N/S and E/W respectively


Number of records with speeds less than  5.0 cm/s is  1076
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RCM STATISTICS, FILE : 1502-6  .CAL  DEPTH :   6.0 m  STATION : PS-2


Total number of records :  4533

Mean temp :  9.38     Std dev.:  .697   (C)

Mean sal: 29.55     Std dev.: 1.250   (ppt)

Mean speed:   4.9  Std dev.:  2.88   (cm/s)

Mean vel. magnitude:    .7   (cm/s)  Mean direction:   92.6   (deg)

Mean major axis velocity :   -.0     Std dev.:  4.02   (cm/s)

Mean minor axis velocity :    .7     Std dev.:   3.95   (cm/s)



              Rec    Temp   Sal     Press  Dir    Speed   Component
              No.   Deg C   ppt     dbar   deg    cm/s    Major   Minor

Speed max:  4533.   10.75  23.17     6.70 121.9   29.22  -15.44   24.81
Major max:  2281.    9.27  29.51     9.40 341.0   16.34   15.45   -5.32
Major min:  1051.    9.55  29.56    11.70 153.8   20.82  -18.68    9.19
Minor max:  4533.   10.75  23.17     6.70 121.9   29.22  -15.44   24.81
Minor min:  2290.    9.39  29.42     8.60 232.5   15.22    3.30  -14.86

NOTE: Major and minor velocity components refer to N/S and E/W respectively


Number of records with speeds less than   5.0 cm/s is  2667
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RCM STATISTICS, FILE : 1500-6  .CAL  DEPTH :   7.0 m  STATION : PS-3


Total number of records :  4470

Mean temp :  9.54     Std dev.:  .776   (C)

Mean sal: 28.91     Std dev.: 1.599   (ppt)

Mean speed:   4.9  Std dev.:  3.03   (cm/s)

Mean vel. magnitude:    .5   (cm/s)   Mean direction:   72.9   (deg)

Mean major axis velocity :    .1     Std dev.:  3.94   (cm/s)

Mean minor axis velocity :    .5     Std dev.:   4.18   (cm/s)



                 Rec    Temp   Sal      Press  Dir     Speed   Component
                 No.   Deg C   ppt      dbar   deg     cm/s    Major    Minor

Speed max:  4290.  11.50  22.89      8.10 126.0   22.78  -18.40   18.42
Major max:  2910.   9.67  28.30     12.20 339.0   14.08   13.42   -5.16
Major min:  1720.   9.74  29.32     11.90 149.3   17.18  -14.77    8.77
Minor max:  4290.  11.50  22.89      8.10 126.0   22.78  -18.40   18.42
Minor min:   996.   9.75  29.24     10.00 266.9   19.14   -1.03  -19.11

NOTE: Major and minor velocity components refer to N/S and E/W respectively


Number of records with speeds less than   5.0 cm/s is  2724
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```
RCM STATISTICS, FILE : 3015-6  .CAL  DEPTH :  26.0 m  STATION : PS-3


Total number of records :  4470

Mean temp :  8.34     Std dev.:  .164   (C)

Mean sal: 31.11     Std dev.:  .085   (ppt)

Mean speed:   3.4  Std dev.:  2.49   (cm/s)

Mean vel. magnitude:   2.4   (cm/s)   Mean direction:  326.7   (deg)

Mean major axis velocity :   2.0     Std dev.:  2.70   (cm/s)

Mean minor axis velocity :  -1.3     Std dev.:   2.24   (cm/s)



               Rec    Temp   Sal     Press  Dir     Speed   Component
               No.   Deg C   ppt     dbar   deg     cm/s    Major    Minor

Speed max:     29.    7.99  30.96    16.00 324.0    14.66   11.86    -8.62
Major max:   1290.    8.22  31.00    16.00   2.7    12.70   12.69      .61
Major min:   4379.    8.59  31.22    16.00 173.7     7.33   -7.33      .82
Minor max:   1324.    8.29  31.01    16.00  67.6     9.06    3.45     8.38
Minor min:    247.    8.02  31.02    16.00 296.5    12.42    5.54   -11.12

NOTE: Major and minor velocity components refer to N/S and E/W respectively


Number of records with speeds less than   5.0 cm/s is  3423
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APPENDIX F: WAVE BUOY DATA RETURN

PERCENTAGE DATA RETURN OVERALL: 51%

BY PERIODS:

Period	Dates	Percentage (%)
1	1 May 81 - 25 November 81	62
2	25 November 81 - 26 January 82	7
3	26 June 82 - 22 March 82	56

BY MONTH:

Month	Percentage (%)
May	54
June	88
July	46
August	49
September	44
October	69
November	85
December	2
January	10
February	98
March	5