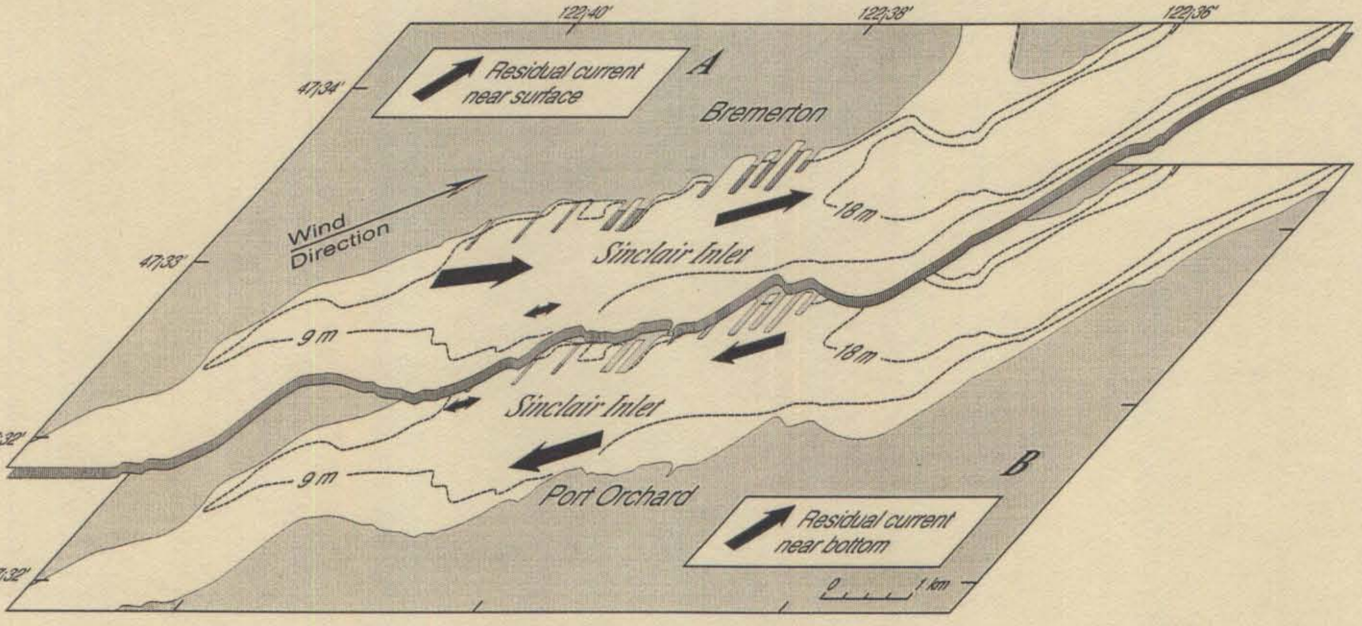
WATER VELOCITIES AND THE POTENTIAL FOR THE MOVEMENT OF BED SEDIMENTS IN SINCLAIR INLET OF PUGET SOUND, WASHINGTON

By J.W. Gartner, E.A. Prych, G.B. Tate, D.A. Cacchione, R.T. Cheng, W.R. Bidlake, and J.T. Ferreira



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ABSTRACT

Sinclair Inlet is a small embayment of Puget Sound in the State of Washington. The inlet, about 6.5 kilometers long and 1.5 kilometers wide, is the site of Puget Sound Naval Shipyard. There are concerns that bed sediments in the inlet may have been contaminated as a result of activities at the shipyard, and that these sediments could be resuspended by tide- and wind-driven currents and transported within the inlet or out of the inlet to other parts of Puget Sound. This study was conducted to provide information concerning the potential for sediment resuspension in the inlet.

To obtain the necessary data, vertical profiles of water current from about 2 meters above the bed to 2 meters below the water surface were monitored with acoustic Doppler current profilers (ADCPs) at three locations during a 6.5-week winter period and a 4.5-week summer period in 1994. In addition, during the winter period, water velocities between 0.19 and 1.20 meters above the bed were measured with current meters using an instrument package called Geoprobe, which was deployed near one of the ADCPs. Other instruments on the Geoprobe measured light transmissivity, and a camera periodically took photographs of the bottom. Instruments on the Geoprobe and on the ADCPs also measured conductivity (for determining salinity), temperature, and pressure (for determining tide). Samples of bed sediment and water samples for determining suspended-sediment concentration were collected at each of the current-measurement stations. Wind speed and direction were measured at three stations during a 12-month period, and tide was measured at one of these stations.

Water currents measured at the three locations in Sinclair Inlet were relatively weak. Typical speeds were 5 to 10 centimeters per second, and the RMS (root-mean-square) speeds were less than 8 centimeters per second. Tidal and residual currents were of similar magnitude. Residual currents near the bottom typically were flowing in the opposite direction of the prevailing wind, while surface currents were in the same direction as the prevailing wind. During most of the year, the prevailing wind was from the southwest quadrant; however, during July and August, the prevailing wind was usually from the northeast quadrant.

The RMS of the total shear velocity for each ADCP station and measurement period, which was estimated from observed profiles of current velocity, ranged from 0.31 cetimeters per second to 0.44 centimeters per second. The skin-friction component of the shear velocity was estimated to be no more than half the total. Critical shear velocity, estimated from particle sizes and density of the bed material, was 0.39 centimeters per second or larger. Comparisons of the skin-friction components of total bottom shear velocities with estimates of the critical shear velocity necessary for resuspension of the bed sediments indicate that resuspension occurs only infrequently, usually at times of maximum current during the tidal cycle. This conclusion is supported by measurements near the bed of light transmissivity, which is related to suspended-sediment concentration.

INTRODUCTION

Puget Sound Naval Shipyard (PSNS) and the Fleet and Industrial Supply Center are two contiguous U.S. Navy facilities in Bremerton, Washington, that occupy a 3-km (kilometer) long strip of land on the north shore of Sinclair Inlet of Puget Sound (fig. 1). Past and present work at these facilities, which started in the 1890's, include building, repairing, supplying, storing, and dismantling ships of the U.S. Navy. One unfortunate consequence of this long history of work is that concentrations of some metals and anthropogenic organic compounds in the soil and ground water at and near the shipyard and supply center, and in the water, sediments, and biota in parts of Sinclair Inlet are elevated, and in some places exceed regulatory limits (URS Consultants, 1994). Consequently, the Navy and its consultants are conducting investigations to determine the magnitude, extent, and fate of contaminants on shore and in the inlet, and to estimate the potential for and probable paths of movement in Sinclair Inlet of contaminants in solution and attached to bed and suspended sediments. The information from these investigations will be used to decide where environmental restoration is necessary, and to plan the work. These studies, including the one that is the subject of this report, are part of the Comprehensive Long-Term Environmental Action Navy (CLEAN) program.

In addition to the shipyard and supply center, there are other potential sources of contaminants to the inlet. These include discharges from sewage treatment plants that serve the cities of Bremerton and Port Orchard, storm-water runoff from these two cities and from highways and commercial establishments adjacent to the inlet, and accidental discharges from vessels at pleasure-craft marinas and ferry terminals in Bremerton and Port Orchard. The relative effects of these potential sources and of the shipyard and supply center on concentrations of metals and anthropogenic compounds in water, sediment, and biota at different places in the inlet are unknown.

Purpose

This report presents the results of a study in which vertical profiles of water velocity at three locations in Sinclair Inlet were measured and used to estimate the potential for bed sediments to be resuspended and moved by the water. The velocity data also were analyzed to determine the net direction of water movement at different depths at the three measurement locations during the measurement periods, to estimate long-period water circulation patterns in the inlet, and to relate water movement to wind direction. In addition to these analyses, the velocity and other data that were collected are being used to calibrate a numerical model of water movement in the inlet, which is being constructed as part of a different investigation of the CLEAN program.

Method and Scope

Vertical profiles of water velocity at three sites in Sinclair Inlet were monitored with acoustic Doppler current profilers (ADCPs) during two periods (fig. 2 and table 1). The first period, in late winter and early spring of 1994, was about 6.5 weeks long, and the second, in the summer of 1994, was about 4.5 weeks long. The ADCPs are capable of measuring water velocities in the vertical interval from about 2 m (meters) above the bed to 2 m below the surface. In addition, during the first monitoring period, water velocities at four levels between 0.19 and 1.20 m above the bed also were monitored near one of the ADCP sites with a set of electromagnetic current meters (EMCMs) mounted on an instrument package called Geoprobe (Tate and others, 1994). Time series of total bottom shear stress and effective bottom roughness height were computed by using regression analysis to fit the velocity data obtained with the Geoprobe to a logarithmic velocity profile (Sternberg, 1972). The skin-friction component of the total bottom shear stress, which is the primary component that controls the resuspension of particles on the bottom, was obtained from the total bottom shear stress by matching two theoretical velocity profiles at a distance of about two roughness heights above the bed. A drag coefficient for skin friction based on the velocity at the lowest level that was measured with the ADCPs was computed and used with the ADCP data to calculate the skin friction component of bed shear at all ADCP measurement locations and times. These skin-friction values and bed-sediment particle-size data were used in conjunction with published curves for determining critical shear stresses to identify periods during which bed sediments could be moved.

In addition to the velocity profiles, other data were collected to assist with the interpretation of the velocity data and to determine the conditions under which bed sediments could be moved. Instruments mounted on the ADCP platforms and Geoprobe measured electrical conductance and water temperature, which were used to compute salinity; and pressure, which was used to compute tidal stage. Instruments on the Geoprobe also monitored local light attenuation for estimating suspended-sediment concentrations, and a camera periodically took photographs of the bed. The photographs were used to make

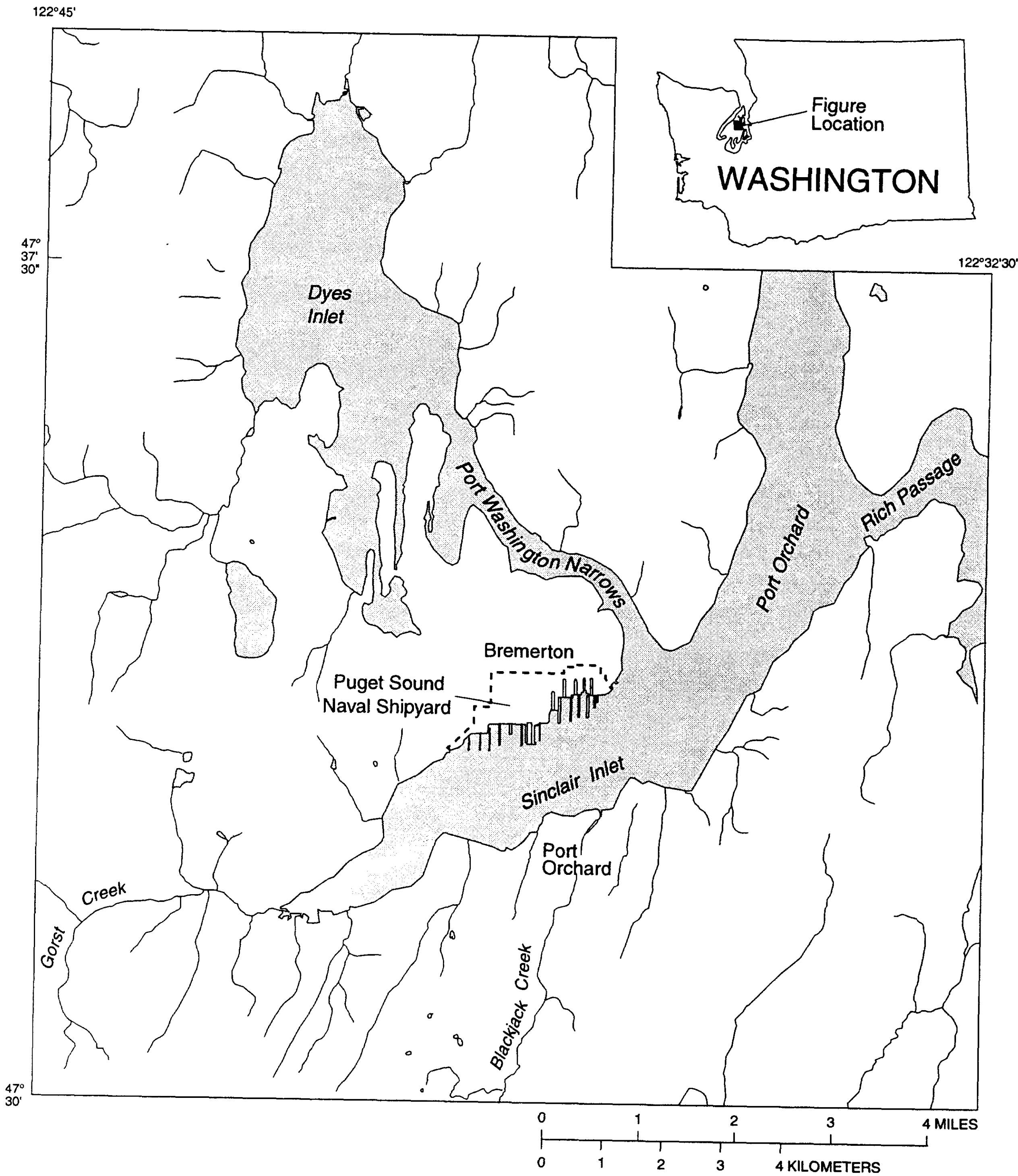


Figure 1. Location of Sinclair Inlet and Puget Sound Naval Shipyard, Washington.

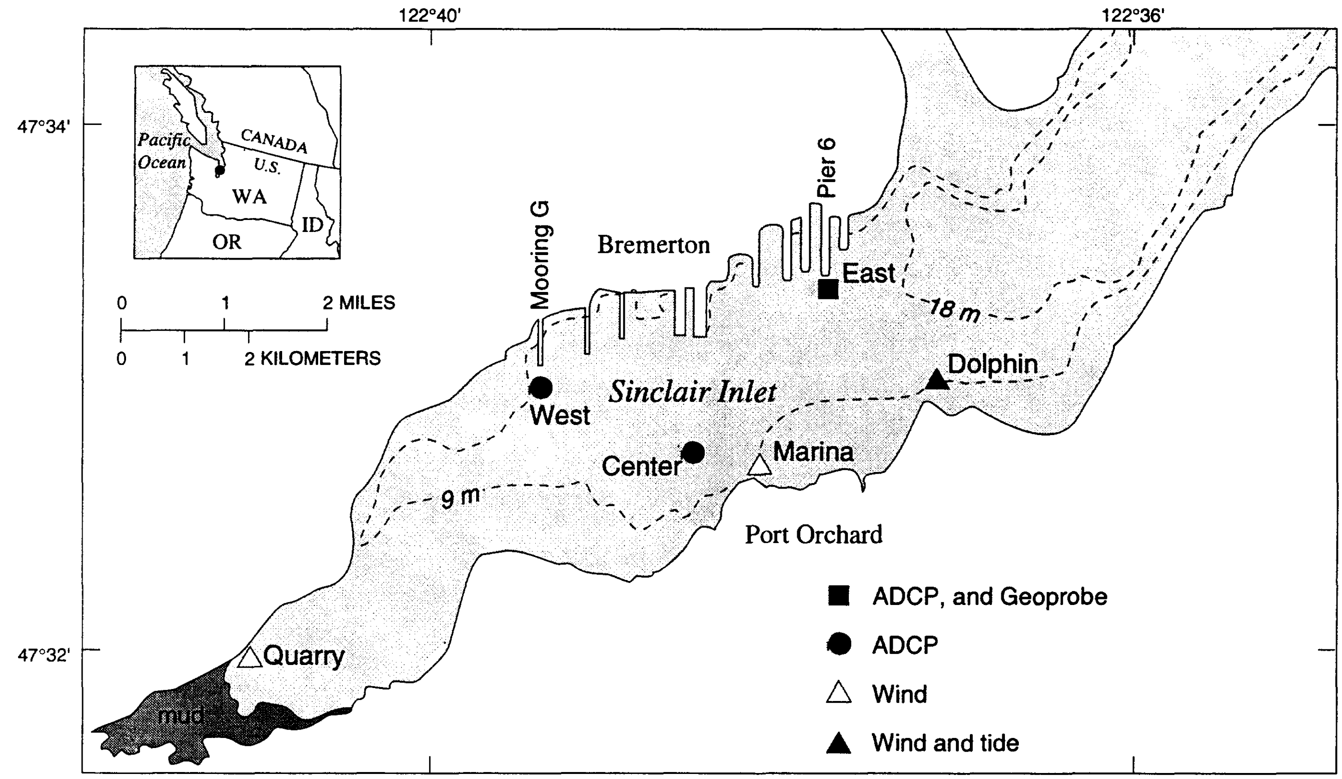


Figure 2. Sinclair Inlet, Washington showing locations of acoustic Doppler current profiler (ADCP), Geoprobe, wind, and tide stations.

Table 1.--*Data collection stations and types of data collected in Sinclair Inlet, Washington*

Short station name	U S Geological Survey Water Resources Division Station name	Station number	Latitude[1] (degrees-minutes-seconds)	Longitude (degrees-minutes-seconds)	Type of data collected[2]	Remarks[3]
East	Sinclair Inlet, north vel. meas. site	473323122374800	47-33-23 47-33-20	122-37-48 122-37-45	A,G,S	Water depth is 17 meters
West	Sinclair Inlet, west vel. meas. site	473259122392800	47-32-59 47-32-57	122-39-28 122-39-30	A,S	Water depth is 13 meters
Center	Sinclair Inlet, south vel. meas. site	473246122383500	47-32-46 47-32-47	122-38-35 122-38-34	A,S	Water depth is 14 meters
Quarry	Quarry dock in Sinclair Inlet near Gorst, Wash.	473159122411100	47-31-59	122-41-11	W	Wind gage altitude is 9.3 meters
Marina	Port Orchard Marina at Port Orchard, Wash.	473240122382100	47-32-40	122-38-21	W	Wind gage altitude is 7.0 meters
Dolphin	Dolphin site in Sinclair Inlet at Port Orchard, Wash.	473300122370700	47-33-00	122-37-07	W,T	Wind gage altitude is 7.9 meters

[1] The first and second latitude and longitude listed for the east, west, and center sites are the locations of the winter and summer deployments of an acoustic Doppler current profiler, respectively.

[2] A denotes acoustic Doppler current profiler that measures and records at 10-minute intervals the vertical profile of the horizontal components of the water-velocity vector from about 2 meters above the bed to 2 meters below the water surface, and conductivity, temperature, and pressure at one location about 1 meter above bed. This instrument collected data during two periods, February 16 or 17 to April 4, 1994, and July 28 to August 29, 1994.

G denotes Geoprobe that measures and records at 1-hour intervals three components of water velocity at four levels between 0.19 and 1.20 meters above the bed, infrared optical backscattering at five levels, infrared light transmissivity at three levels, pressure and temperature with two different instruments, and conductivity with one. Photographs of the bed are also taken at 2-hour intervals. This instrument collected data from February 18 to March 29, 1994.

S denotes collection and analyses of samples for suspended-sediment concentration, conductivity, and temperature from five different depths at seven times during about a 12-hour period on March 1,1994, and five times on August 19, 1994. Samples of bed sediments collected at one time were analyzed for particle size. Cohesive shear strength of bed material was measured in-situ.

W denotes wind speed and direction recorded at 15-minute intervals during a 12-month period beginning in March 1994.

T denotes tide stage recorded at 15-minute intervals during a 12-month period beginning in March 1994.

[3] Datum for water depth and wind-gage altitude is mean sea level.

independent estimates of bed-roughness height. Samples of bottom material were collected for determining particle-size distributions of bed sediments. A number of water samples were taken during one day of each ADCP deployment period to determine suspended-sediment concentrations. Wind speed and direction at three locations and tide stage at one location were monitored for a 12-month period.

This report describes equipment used to collect field data, methods used to process and analyze the data, and results of the analyses. Examples and summaries of data and analyses are presented in tables and figures. Characteristics of flow in the bottom boundary layer are described. Threshold values of the skin-friction component of bottom shear stress for sediment resuspension are presented along with descriptions of uncertainties in the analyses for determining the values. This report also describes the three-dimensional circulation pattern in the inlet that is suggested by the velocities observed at the three water-current monitoring locations.

Description of Sinclair Inlet

Sinclair Inlet of Puget Sound is about 6 km long on its northeast-southwest trending axis, and is about 1.6 km wide near its mouth and along more than half of its length (fig. 2). The inlet is connected to the main basins of Puget Sound by Port Orchard Passage and Rich Passage (fig. 1). Port Washington Narrows, whose south end is near the northeast corner of Sinclair Inlet, connects to Dyes Inlet and is that inlet's only connection to the rest of Puget Sound.

Hydrography

Sinclair Inlet is deepest near its mouth where depths are typically about 20 m at mean tide. Depths in front of the shipyard and supply center are about 15 m. Depths decrease toward the head of the inlet where large tide flats are exposed at low tide. Tides are semi-diurnal with two unequal high and two unequal low tides per cycle (24.8 hours). The mean tide range (difference between mean lower low water and mean higher high water) is 3.6 m. Bottom sediments are fine grained (probably silts) over much of the inlet, but are sandy near the inlet's mouth.

Salinity is about 30 o/oo (parts per thousand), but probably varies a few parts per thousand spatially and temporally. Vertical stratification due to salinity is slight, probably because no major freshwater streams discharge into the inlet. The largest two streams are Blackjack and Gorst Creeks that discharge into Sinclair Inlet on the south side of the inlet and near the inlet's mouth, respectively (fig. 1). Median values of the estimated annual mean discharges of these two creeks are 0.82 and 0.65 m^3/s (cubic meters per second), respectively (Williams, 1984).

Even though tide range in Sinclair Inlet usually exceeds 3 m, tidal currents in the inlet are normally less than 10 cm/s (centimeters per second) due to the inlet's relatively short length. Consequently, wind can affect currents as much as tide. Tidal currents are considerably larger at the mouth of Port Washington Narrows (which is outside the study area of the present project) because of the large volume of water that must pass through this narrow passage to and from Dyes Inlet during each tide cycle.

Climate

Mean annual precipitation at Bremerton on the north shore of the inlet is about 1,300 mm/yr (millimeters per year), most of which falls as rain during autumn, winter and early spring. Air temperatures are mild with winter temperatures usually above freezing and maximum daily temperatures in the summer usually below 30°C. Hills on the north and south sides of Sinclair Inlet are about 100 m high, which, in combination with the prevailing regional southwest-northwest trending winds, cause wind directions to be aligned with the longitudinal axis of the inlet most of the time. Regional winds are usually from the southwest except during the summer when often they are from the northeast (Phillips, 1968).

DATA-COLLECTION PROGRAM

This section describes methods used in the field and laboratory to collect the different types of hydrologic data measured as part of this study. Included are descriptions of instrumentation and sampling techniques used to obtain vertical profiles of water-velocity, measurements of wind and tide, and data on bottom and suspended sediments.

There were two types of instrument packages deployed by the U.S. Geological Survey (USGS) for making in-situ measurements. Those were the acoustic Doppler current profiler (ADCP) systems and the Geoprobe system.

Each ADCP system contained a narrowband or broadband ADCP. In this study, the ADCPs were attached to metal (aluminum, monel, or stainless steel) frames to protect the transducers, and to keep the transducer heads level at 0.7 m above the bed (fig. 3). In addition to the ADCP, an Ocean Sensors, OS200 conductivity-temperature-depth (CTD) data logger was attached to each of the three ADCP mooring platforms. The CTDs provided data for computing salinity and water level. Velocity profiles measured with the ADCPs and data from CTD units were recorded every 10 minutes. Table 1 lists pertinent deployment information including site location, deployment dates, and water depth at the measurement sites. Specifications for the ADCPs and the CTD unit are listed in table 2. Acoustic locator pingers were installed on all three frames as a navigation aid to be used during equipment recovery.

The ADCP systems were assembled and associated equipment tested by USGS personnel at the divers' workshop at PSNS. The systems were transported to the measurement sites on the divers' work vessel and then positioned on the bottom of the inlet and checked for level orientation by the divers. The position of the vessel at the time of deployment was determined by a Global Positioning System. The ADCP systems were recovered using the same vessel. Data off-load to laptop computer was completed immediately after equipment recovery.

The Geoprobe instrument system (fig. 4) was designed by the USGS to measure variables for computing sediment transport due to wave and current stresses on bottom sediments. The platform is a tripod 2.7 m high with a triangular base 3.1 m on a side. Instrument electronics and batteries reside in a cage at the top of the structure. The cage is triangular in cross section and is 1 m high. Instrument sensors are mounted below the cage in an area open to the current flow (fig. 4). The system contains four electromagnetic current meters (EMCMs) (fig. 4 and table 3) to profile water velocity in the bottom boundary layer. Data from five infrared optical backscattering sensors (OBS) and three infrared light-emitting-diode (LED) transmissometers are used to estimate the amount of inorganic sediment and solid organic material in suspension. The OBS array has sensors at roughly the levels of the current meters and one between the lowest current meter and the bed. LED transmissometers are mounted in the center of the two current meter couplets with a third 170 cm above the bed (fig. 4). Specifications for measurement instruments mounted on Geoprobe are listed in table 2a.

The OBS and LED optical instrument arrays operate over separate and slightly overlapping total suspended-matter concentration ranges. The OBS operates over concentration ranges which are higher than those over which the transmissometers operate, but the OBS is considerably less sensitive. Use of the two types of instruments ensures proper measurements of the suspended sediment profile over a wide range of concentrations to avoid data dropouts during extremely energetic events. The lower two LED transmissometers have 10 cm optical path lengths while the upper has a path length of 25 cm. The shorter path-length instruments are somewhat less sensitive than the longer, and operate over larger concentration ranges expected closer to the bed. The optical instrument suites were calibrated with bottom and suspended sediment samples taken during the experiment. Two samples were collected by Navy divers who periodically dove on the system to inspect and clean the optical windows, and one sample was obtained in early March by USGS personnel. The transmissometer optical ports were fitted with an anti-fouling device treated with trialchyltin chemicals to inhibit long term biasing of the data due to marine growth on the optical lenses. The OBS sensors had no anti-fouling treatment applied.

A Paroscientific Digiquartz pressure transducer mounted 276 cm above the bed measures wave and tidal pressure signals; it is capable of resolving 1 cm of water-elevation changes in 100 m depth. Thermistors at 15 and 178 cm above the bed measure temperatures. A Datasonics 210 kHz (kilohertz) sonar altimeter is used to measure any long term settling of the platform; sensor heights are corrected accordingly during data processing.

Water-salinity variations are logged by a pair of CTD sensors. An Ocean Sensors CTD sensor was mounted 100 cm above the bed on one of the tripod legs, and a Sea Bird CTD sensor was mounted 89 cm above the bed on another leg. These two instruments were deployed to evaluate their comparative performance. An Oceano ART-101 Acoustic Releasing Transponder was mounted on the tripod for identification and for locating the Geoprobe. A Helle 27 kHz emergency diver pinger was also installed on the frame as a precaution in the event that divers might need a navigation aid for locating the tripod in poor visibility conditions during recovery operations.

Bottom photographs were taken with a Benthos 35 mm oceanographic camera system mounted 151 cm above the bed with a strobe at 78 cm above the bed on an adjacent platform leg, thus giving 45 degree lighting

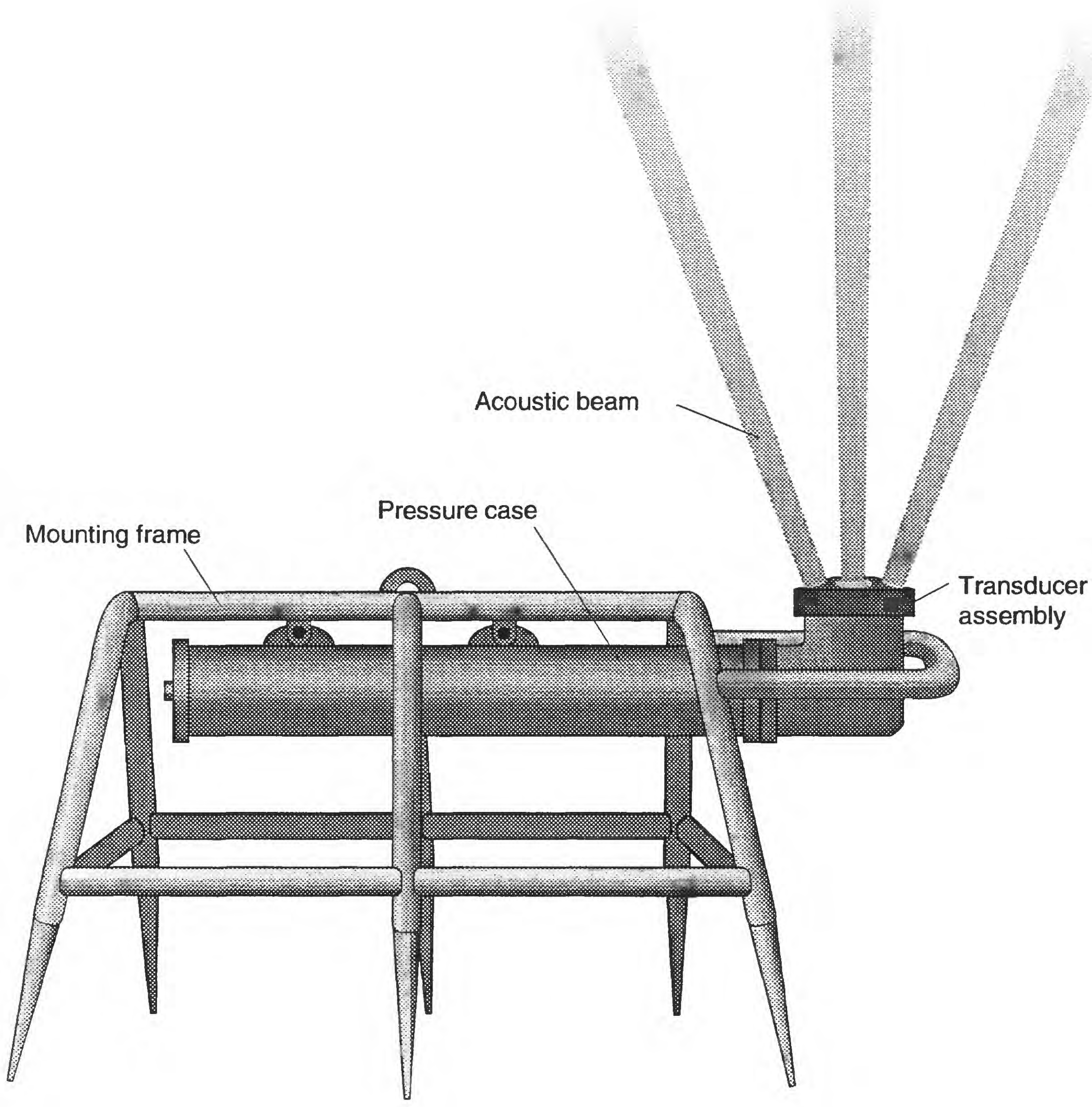
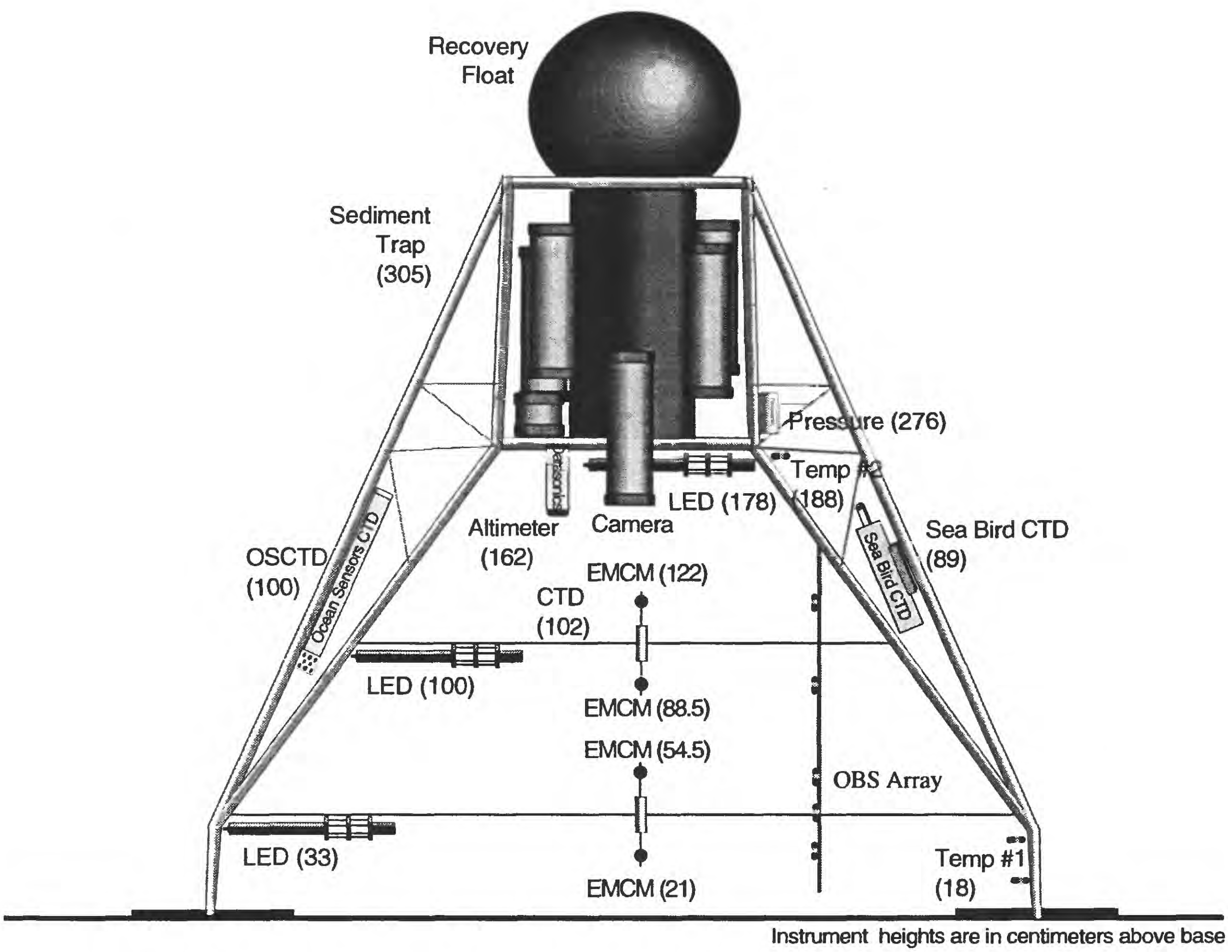


Figure 3. Acoustic Doppler current profiler.



EMCM = Marsh-McBirney electromagnetic current meter
CTD = Ocean Sensors conductivity-temprature-depth sensor
LED = Seatech infrared light emitting diode transmissometer
SED = Suspended sediment sampling nozzle
TEMP = Temperature sensor

Figure 4. Geoprobe instrument system. Numbers in parentheses are sensor heights, in centimeters, above the base.

Table 2.--*Specification for acoustic Doppler current profilers (ADCPs) and associated conductivity-temperature-depth (CTD) units*

[±, plus or minus; cm/s, centimeter per second; <, less than; °, degree; C, Celsius; mS/cm, millisiemens per centimeter; dBar, decibar; o/oo, parts per thousand; %, percent]

Equipment and parameter	Range	Accuracy	Resolution
ADCP (Broadband):			
Velocity[1]	±1000 cm/s	[2]< 1 cm/s	0.1 cm/s
Heading	0 to 360°	2°	0.2°
ADCP (Narrowband):			
Velocity	±1000 cm/s	[2]< 1 cm/s	0.1 cm/s
Heading	0 to 360°	2°	0.2°
OS200 CTD:			
Temperature	-2 to 35°C	0.01 %	0.001 %
Conductivity	0.5 to 65 mS/cm	0.02 %	0.001 %
Pressure	0 to 50 dBar	0.50 %	0.005 %
Salinity	1 to 45 o/oo	0.03 %	0.001 %

[1]Along beam components.
[2]Based on averaging a sufficient number of acoustic pings per data ensemble.

Table 3.--*Heights above bottom, and types of measurements made by the various instruments on the Geoprobe*

[cm, centimeter; CTD, conductivity, temperature, and depth; EMCM, electromagnetic current meter; mm, millimeter]

[1]Type of instrument	[2]Height above bottom (cm)	Type of measurement
Altimeter (1)	155	Platform height above bottom
Sea Bird CTD sensor (1)	87	Temperature, salinity, and water depth
Ocean Sensors CTD sensor (1)	98	Temperature, salinity, and water depth
EMCM (4)	19, 52.5, 86.5, 120	Current velocity and direction
Benthos 35 mm camera (1)	149	Seabed morphology and biology
Pressure sensor (1)	274	Water depth
Thermistor (1)	13, 176	Water temperature
Transmissometer (3)	23, 98, 173	Suspended-sediment concentration
Optical backscatter sensor (5)	15.5, 36, 50, 84, 117.5	Suspended-sediment concentration

[1] Number in parentheses is the number of instruments of the indicated type.
[2] Height of individual instruments.

for optimum bed-form definition and overall scene illumination. The camera has a 400 frame film capacity with variable internal settings to control time between frames. The time between photos during this study was 2 hours.

System-data-acquisition control and storage is performed by a Tattletale Model 6 data logger equipped with a 200 MByte hard disk. All data except photographic and CTD data are acquired and stored on the data logger's hard disk. Sampling and storage is program-controlled and is tailored to each specific field site and environment. Typically, 1 Hz pressure and temperature samples are averaged over 1 hour while 1 Hz current, pressure, temperature and optical data are taken for 1,024 seconds during an hourly data burst. Platform attitude and altimeter data are sampled once an hour at the beginning of each data burst (table 4).

Geoprobe system assembly and pre-launch checks were performed at the University of Washington's School of Oceanography. As one of the pre-deployment equipment checks, a current meter zero measurement was performed. A plastic shroud was installed around the electromagnetic current meter array to inhibit flow around the sensors allowing an accurate zero velocity calibration in situ to account for any system bias in the sensor signal. The system was set on the bottom of Lake Washington adjacent to the School of Oceanography facility pier and two complete 1,024 second data bursts were recorded. All sensor functions were verified, and the system was then readied for transit and final deployment in Sinclair Inlet. Using the University of Washington's R/V Clifford A. Barnes, with the aid of PSNS divers, the Geoprobe was deployed 80 to 100 meters south of the end of Pier 6, approximately 20 m north of the ADCP. The divers inspected the instruments for damage, estimated the platform settling depths, and the distance between the instrument packages, and collected sediment surface and near-bottom water samples. A sample of the top 2 cm of the sediment surface was taken about 5 m from the base of the tripod and a 1-liter water sample was taken at 1 m above the bed adjacent to the tripod leg. Divers observed that the tripod had settled to the top of the plastic footpads, placing the bottom current meter well above the sediment surface. This resulted in an apparent settling of about

Table 4.--*Data-sampling intervals for the various instruments on the Geoprobe*

[mm, millimeter; CTD, conductivity, temperature, and depth; EMCM, electromagnetic current meter]

Type of instrument	Sampling interval
CTD sensor	1 sample each 5 minutes beginning on the hour
EMCM	1 sample each second during each [1]burst
Pressure sensor	1 sample each second during each burst and 1 sample each minute during the remainder of each hour
Benthos 35 mm camera	1 sample each 2 hours at 9 minutes after the hour (mid-burst)
Compass package	1 sample at the beginning of each hour
Thermistor	1 sample each second during each burst and 1 sample each minute during the remainder of each hour
Transmissometer	1 sample each second during each burst
Optical backscatter sensor	1 sample each second during the first 256 seconds of each burst

[1] A burst was the first 1,024 seconds of each hour.

2 cm and sensor heights were adjusted accordingly during data processing. The divers described the bottom as "relatively smooth and flat with the exception of jellyfish-size depressions in the vicinity of the tripod, with small animal mounds about 1 to 2 cm in height dominating the local roughness." Before leaving the site, divers placed marker buoys a few tens of meters east and west of the instruments. In-situ data acquisition on the Geoprobe was conducted from 1358 hours, February 18, to 1458 hours, March 29, 1994. Each hour, 1,024 samples of current, pressure, optical parameters, temperature, and platform attitude were recorded at 1 Hz, beginning at the top of the hour. Pressure and temperature data were also averaged and logged hourly (table 4). A photograph of the bed was taken every 2 hours during a data burst. CTD data were recorded on two autonomous instruments mounted on the tripod legs.

The Geoprobe was recovered on board the R/V Barnes on March 29. Prior to recovery, a Navy diver performed a final inspection of the system and took photographs and a water sample. Diatom scrapings were taken from the acoustic transponder and other neoprene surfaces for analysis. A bulk sediment sample was preserved from the tripod footpad. During transit to the University of Washington facility in Seattle, preliminary analysis confirmed data recording, and verified the time of the data logger clock to be within system specifications. All sensors were still performing within nominal specifications, and the camera operation was verified. Data off-load to a laptop computer was completed.

Water Current

Two different types of instruments were used to measure vertical profiles of water-current velocity. An ADCP measured the velocity profile over most of the water column, and electromagnetic current meters on the Geoprobe measured the profile near the bed. Both instruments are described below.

Acoustic Doppler Current Profiler

An ADCP measures water-current-velocity profiles by transmitting sound pulses into the water column and determining Doppler or phase shift from acoustic echoes reflected from inorganic and organic particulate material in the water column. The ADCPs used in this study (RD Instruments model SC-1200) were self-contained units capable of storing data in internal erasable memory (EPROM). The SC-1200 ADCP transmits its acoustic signals at 1,228.8 kHz; it contains four acoustic transducers oriented 90° apart in azimuth that transmit acoustic signals 30° (20° for the broadband instrument) from the vertical (the so-called Janus configuration). Trigonometric relations convert the four velocity measurements along the acoustic beams into the three orthogonal components of the current-velocity vector (Lohrmann and others, 1990). Each pair of opposing beams is used to measure the vertical and one of the two horizontal velocity components. The two vertical velocity measurements are compared as a measure of data quality. An ADCP determines a velocity profile by sampling the reflected acoustic signals from each beam at discrete time intervals that correspond to depth intervals or bins. The size of a bin is determined by timing circuits in the instrument and can be adjusted by software. The average water motion within each bin is sensed and a velocity profile is determined from just above the instrument transducer to just below the water surface. In practice, velocities in the upper 15 percent (6 percent for the broadband instrument with 20° beam angles) of the water column cannot be determined because of parasitic acoustic side lobes that interfere with the primary acoustic signals. The distance from the transducer to the center of the first measured bin is a function of the blanking distance (typically 50 cm), which is the distance acoustic signals travel before transducers and associated electronics recover after sending a signal before they can receive the reflected acoustic signals.

During the first deployment (February 16 to April 4, 1994) a broadband ADCP was used at the east station (south of Pier 6, PSNS) and narrowband ADCPs were used at the center station (Port Orchard) and the west station (west of mooring G, PSNS) (fig. 2). During the second deployment (July 28 to August 29, 1994), broadband ADCPs, which provide higher resolution data than do narrowband units, were used at all three stations. In the case of the narrowband instruments, the bin size was set to 1 m and the bottom of the measured velocity profile was 2.2 m (center of bin 1) above the bed. In the case of the broadband ADCPs, the bin size was set to 50 cm, and the bottom of the velocity profile was 1.9 m above the bed. Sampling (ensemble) interval for each unit was set to 10 minutes. The number of pings (acoustic signals) that were averaged in each ensemble was sufficient to reduce the standard deviation of the velocity measurements to less than 1 cm/s. The measurement cycle required to transmit, compute and record the ensemble velocity information was about 10 to 20 seconds for the ADCPs. In narrowband ADCPs, system accuracy is limited by the combination of short term random errors and long term bias errors. The random errors are related to acoustic frequency, bin length, and number of pings per ensemble.

Bias errors, which are primarily the result of filter skew errors and noise bias errors, are generally less than 0.5 cm/s. See Chereskin and others (1989) and Burau and others (1993) for a complete description of velocity errors in ADCPs. The broadband ADCP is not affected by bias errors because it is not subject to noise bias and contains no tracker filters (Brumley and others, 1991).

Geoprobe - EMCM

Electromagnetic current meters (EMCMs) on the Geoprobe system were mounted at 19, 52.5, 86.5, and 120 cm above the bed (fig. 4 and table 3) to profile water velocity in the bottom boundary layer. The principle of operation for EMCM current meters is that water, flowing through an electromagnetic field created by the meter, produces a voltage that is proportional to the magnitude of the current speed. Platform attitude is monitored by a flux gate compass and bi-axial tilt sensors. Current meter measurements can be referenced to true north or to the direction of local bathymetry during data processing. The current meters calibrated before the experiment, had an accuracy of about 1.0 to 2.0 cm/s (speed) and 5° (direction).

Wind

Wind speed and direction were measured for about a 12-month period at three locations at or near the shore of the inlet (table 1 and fig. 2). Speed and direction at each location were measured with a vane-mounted propeller anemometer. Height of the anemometers ranged from 7.0 to 9.3 m above sea level. At the quarry and marina sites, measurements were made at 1-second intervals for all but the first and last 10 seconds of every 15-minute period (for a total of 880 measurements per period), and the average values of wind speed and direction during each 15-minute period were recorded with an electronic data logger. At the dolphin site, where water level was also measured, measurements were made at about 2.8-second intervals for all but the first and last 60 seconds of every 15-minute period (for a total of 280 measurements per period), and the average values were recorded.

Water level

Water level (tide) was measured at the dolphin site (table 1, fig. 2) during the same 12-month period as wind speed and direction were measured. Water level was measured with a pressure transducer that was attached to a group of timber piles (a dolphin) at an elevation about 2 m below the lowest expected water level. A relation between pressure and water-level elevation was obtained by measuring vertical distances to the water surface from points of known elevation on a pier that extends about 150 m from shore about 200 m southeast of the dolphin site. Averages of measurements made over 15-minute periods at the pier were related to the recorded average pressures. Pressure transducers on the Geoprobe and on each of the ADCPs also were used to monitor water levels during the deployment periods of these instruments.

Suspended Sediment

Water samples for determining vertical profiles of total suspended-sediment concentration, and temperature, salinity, and turbidity were collected at each of the three ADCP deployment sites six times during a tidal cycle on March 1, 1994, and four times on August 19, 1994. The inorganic component of the suspended-sediment concentration was determined for the samples collected in August. Samples were collected at distances of 0.5, 1.0, 2.0, 5.0, and 10.0 m above the bed using a 1.5-liter van-Dorn sampler, which was suspended by a steel wire with beads at fixed increments along its length for determining the depth of the sampler. Samples for suspended-sediment analyses were put into 1-liter bottles, and a 0.25-liter bottle was filled for analyses for other characteristics. Water temperature was measured in the 1-liter bottle immediately after filling.

The laboratory procedures for obtaining total suspended-sediment concentrations in these samples consisted of weighing the contents of the 1-liter bottle, filtering the contents through a glass-fiber filter, flushing the filter and sediment with distilled water, and determining the weight of the sediment on the filter after drying for a minimum of 2 hours at $105^{\circ}C$. The total suspended-sediment concentration, in mass of sediment per unit volume of water, was calculated by dividing the weight of the dried sediment by the weight of the water sample and multiplying by 1,020 grams per liter, the approximate density of the water sample. The inorganic suspended-sediment concentration was obtained by reheating the dried sediment and filter to $550^{\circ}C$ for 1 hour, weighing again, and recomputing the concentration.

Salinity was determined by bringing the sample to within $1^{\circ}C$ of $25^{\circ}C$, measuring its specific electrical conductance with a commercial meter that automatically corrects the conductance to $25^{\circ}C$, and using a computer program in Fononoff and Millard (1983) to compute salinity as a function of conductivity and temperature. Turbidity was determined with a commercial meter that measures the amount of light scattered as it passes through an aliquot of a sample.

In addition to the suspended-sediment samples that were collected and analyzed as described above, the suspended-sediment samples collected by the divers, including those from during the Geoprobe deployment, were analyzed with a Coulter Model TA II electronic particle-size analyzer. The Coulter Counter measures the volume of the individual particles in the sample; volume is converted to mean grain diameters in 16 size classes. The total size range of less-than-2-μm (micrometer) to 128 μm was analyzed by using multiple aperture tubes for each sample analysis.

A 100 ml (milliliter) split of each of the suspended sediment samples was filtered through a tared 0.4 μm pore-size membrane filter to determine concentration per unit volume of water and also to provide a sample for microscopic analyses.

Bottom Sediment

A sample of bottom sediment was collected with a vanVeen clam-shell type sampler at each ADCP site on the days of the first deployment of these instruments (February 16 and 17, 1994) and by the divers at the Geoprobe site when this instrument was deployed (February 18, 1994). Two different types of samples were removed from the vanVeen sampler for analyses. One, representative of the surficial material (the top 1 cm), was a relatively light-colored, loose material. The other, representative of subsurface material (about 1 to 10 cm depth), was darker, more compact and sticky. All bottom-sediment samples were analyzed to determine particle-size distributions, and the organic-matter content of samples collected with the vanVeen sampler were also determined. The cohesive strength of the bottom sediments was estimated at each of the three ADCP sites by making in-place measurements with a 25 mm by 25 mm vane-type shear meter. Measurements were made by a diver at three different depths below the sediment surface at each of two locations a few meters apart at the east and west stations and at one location at the center station.

Weight fractions of inorganic and organic material in a bottom-sediment sample was estimated by drying a 1-g (gram) subsample overnight at 105°C, weighing, reheating to 550°C for 1 hour, and weighing again.

The grain-size distribution of a bottom-sediment sample was determined by gently wet sieving representative aliquots through a series of precision sieves that ranged in mesh opening size from 20 microns to 250 microns. Two aliquots of each sample were analyzed; one aliquot was wet sieved without any prior treatment and the other was disaggregated using dilute hydrogen peroxide to digest organic matter followed by one minute of agitation with an ultrasonic cleaner. The results of these two methods give an estimate of the percentage of the sediment that is in the form of relatively large diameter aggregates (e.g., flocs or fecal pellets). In general these aggregates are predominantly fecal pellets that are produced by the benthic organisms. Since the aggregates are typically composed of small diameter particles, they can have an important effect on the overall hydraulic characteristics of the sediment (i.e., its response to erosive currents).

Finally, the less-than-20-micron size class of the bottom sediment was used to prepare samples for calibration of the Sea Tech Inc. beam transmissometers that were used to monitor turbidity conditions at the Geoprobe. The less-than-20-μm size class is used because these smaller particles control the beam attenuation measured by the transmissometers.

TIME-SERIES DATA PROCESSING AND ANALYSIS

Time-series data collected at the wind stations and at the ADCP and Geoprobe arrays were retrieved from field data-storage devices for processing. The data were checked for consistency and quality and were then processed using various numerical- and statistical-analysis techniques.

Wind Data

Wind-speed and direction data from each wind station were used to compute duration of winds of different magnitudes and wind run for different directions. Wind run, an often-used climatological parameter that takes into account wind speed and duration, is equal to the integral of wind speed over time. All wind speeds and directions in this report were computed from 15-minute averages. The average wind speed and direction for each 15-minute interval at each site can be retrieved from the U.S. Geological Survey's National Water Information System (NWIS).

Acoustic Doppler Current Profiler Data

Immediately after instrument recovery, the ADCP data were downloaded from memory to a personal computer and then converted to engineering units. A subsequent program saved only values from bins that contained good data by checking values of back scattered amplitude and error velocity checks. The ADCP data were considered "good" if back scattered amplitude (echo amplitude), a measure of backscattering strength or density of sound scatterers, decreased from bin to bin moving away from the transducers. A reversal of this trend indicates the presence of the water surface (or other large reflecting body) that invalidates computed velocities. Data quality was also evaluated based on the difference between the two computed vertical velocities. Based on the water depth and bin size, the highest bin expected to contain good data was determined, and all data from bins above that level were discarded. The time series of velocity data from each bin were plotted, harmonic analysis was performed to determine tidal constituents, and the data series were low-pass filtered.

Techniques to perform harmonic analysis are well documented, for example, Schureman (1976) and Foreman (1977). In this case a least-squares regression technique was used (Cheng and Gartner, 1984; 1985) to analyze time series of tidal velocity for each ADCP bin. Harmonic constants, determined from the time series of two mutually perpendicular components of horizontal velocity, were combined to define the tidal current ellipse for each tidal constituent. The primary direction for current flooding and ebbing is given by the direction of the major axis of the tidal ellipse. The maximum tidal current speed is given by the magnitude of the semi-major axis, and the phase angle can be used to relate to the phase for the same constituent deduced from the water-level time series.

The purpose for processing data through a low-pass filter is to remove responses in the data which are higher in frequency than some arbitrary cutoff value. Here the objective was to remove the astronomical tidal forcing comprising those frequencies with periods of about 12 and 24 hours and their harmonics. The data were filtered to remove the tidal signal by using a discrete Fourier transform filter (DFT) similar to that described in Walters and Heston (1982). A cosine taper was used between the specified stop frequency corresponding to a period of 30 hours and the specified pass frequency corresponding to a period of 40 hours to reduce "ringing" in the results at the beginning and the end of the filtered time series (Wang and Cheng, 1993). Nevertheless, some ringing persists after filtering velocity data if the data series are extended by padding with zeros in order to produce the required 2n data points in the time-series, where n is an integer. For that reason, time series of velocity are usually truncated to 2n data points. However, truncation of data from the first deployment to 2n points would make about 3 (of 7) weeks of data unavailable for analysis. Therefore, velocity data from the first field period were zero padded to the next 2n data points, but the last 40 hours of data (which might show ringing) were removed before plotting.

Time series of data from CTDs that were attached to the ADCP frames were converted to engineering units, and plotted to check data quality. When appropriate, salinity data were also low-pass filtered. Time series of water-level data obtained with instruments on the ADCP frame were harmonically analyzed and low-pass filtered similar to the ADCP velocity data. Harmonic analysis was performed on the long-term (13-month) water-level record from the dolphin wind station, however, those data were not filtered because of gaps in the data.

Field data consisting of unfiltered and filtered velocity data and results of harmonic analysis (as well as data from CTD instruments) was provided to URS, Inc., consultant to the Navy. These data are also archived on USGS UNIX-based computer systems. Original raw data files are backed up on floppy disks.

Geoprobe Data

Post-cruise inspection and system analysis indicate that the Geoprobe system performed quite well. Very little corrosion was found on individual sensors. The platform's cathodic protection performed as expected, and the optical antifoulant appeared to be quite effective in preventing biologic growth on the optical ports. With the exception of the sonar altimeter, all sensors were performing within specifications. Although the Datasonics altimeter did not operate correctly, platform attitude and sensor heights could be adjusted properly using diver settling observations. The Sea Bird CTD sensor did not record pressure data due to a programming error, but density data were collected properly by the Ocean Sensors instrument, and water-level data were recorded as part of the hourly averages. Clock drift in the Benthos 35 mm camera triggering circuit resulted in a loss of approximately 6 seconds per hour, explaining why a flash was observed on deck after recovery at 1930 hours instead of the predicted time of 1909.

Data are recovered from the data logger and downloaded in hexadecimal (HEX) format to a laptop computer. Copies of the HEX files are archived on a magneto-optical disk. The HEX data are then converted to counts for each individual reading. Counts are converted to voltages incorporating pre-deployment calibrations for the logging device and each instrument to yield values in engineering units for each sensor. Tripod orientation data measured by the compass are used to rotate the orthogonal current meter data to a geographic North coordinate system. The LED, OBS, pressure, and EMCM data are averaged over the recording interval (table 4). The CTD data and hourly burst average values consisting of the 1,024-second averages of data from the LED transmissometers, electromagnetic current meter, temperature probes and pressure sensors were furnished to URS, Inc., in June 1994, as well as archived on the USGS-PMG Unix-based computer system (and backed up on 8 mm tapes).

Electromagnetic Current Meters

The gain of the electromagnetic current meters are factory calibrated and accuracy is verified by the USGS to within ± 0.5 cm/s. Zero offset for each of the four current meter electronics/sensor units used in this study are applied to the velocity data during post processing. Post processing of the EMCM-velocity data included applications of low-pass filtering, and harmonic analysis techniques similar to procedures used in processing the ADCP velocity data.

Light-Emitting Diode (LED) Transmissometers

Each transmissometer is calibrated at the factory to read 5.0 VDC (100 percent transmission) in pure water and 0.0 VDC when the light path is blocked. After calibration, the blocked and full-scale in-air voltages are recorded; these are used thereafter as checks for sensor drift and degradation. Because the output of the LED degrades approximately 1 percent per 1,000 hours of operation, a full-scale in-air calibration is made before and after each deployment. These values are compared to the initial factory full-scale and zero values in air to determine the system drift. The corrected voltage output of the instrument (V_{actual}), in volts, is calculated using the linearization equation

$$V_{actual} = \frac{A}{B}(V_{obs} - Z)$$

where

- A is the factory full-scale reading;
- B is a field measured full-scale reading, in-air calibration value;
- V_{obs} is observed output during measurements, in volts; and
- Z is instrument output with the light path blocked, in volts.

Percent transmission (T) is computed with the equation $T = V_{actual}/5.0$ and it is used to compute the beam attenuation coefficient (C_p dimensionless), using the equation $C_p = -\ln(T)/L$, where L is transmissometer path length, in meters. Transmissometer calibrations are then completed by comparing C_p values to varying concentrations of the less-than-20-µm fraction of bottom surficial sediment collected at the Geoprobe site using a standard laboratory transmissometer calibration cell designed by USGS. This size fraction has the greatest effect on beam attenuation. The resultant calibration curves are then used to estimate the concentration of suspended particulate material at the level of each transmissometer. A description of this technique is given in Tate and others (1994). The general approach to providing the required information on the variation of beam attenuation as a function of particle size and concentration is based on the research of Baker and Lavelle (1984) and Moody and others (1987).

Optical Backscatter Sensors

The OBSs generally operated below their usable range and produced no meaningful data in this experiment, thus OBS results are not discussed further in this report.

Application of Data Logger Analog-to-Digital (A/D) Calibrations

Each of the Tattletale data logger A/D and associated multiplexer circuits has its own inherent offset and gain which must be compensated for in the sampled data. Data values are recorded as counts. Analog voltage inputs are digitized by a 12 bit A/D converter that gives a value of 4,096 counts for a full-scale input. The data logger and associated circuits are calibrated as a unit, and the raw data are corrected accordingly. This calibration is performed prior to each system deployment.

OBSERVED WINDS, TIDES, CURRENTS, AND SEDIMENT

Analysis of time-series of hydrologic and other data at Sinclair Inlet revealed much about hydrodynamic and benthic environments at the inlet. Analyses of wind speed and direction, coupled with descriptions of three-dimensional water circulation, were used to explore the possible role of wind-driven circulation within the inlet. Harmonic analyses of water level were used to describe tide characteristics such as tide range and form number. Harmonic analyses of water level and current velocity were used to show tidal-current structure at the three ADCP sites. Tidal current flow fields measured simultaneously with an ADCP and with the Geoprobe were compared. Analyses of bottom photographs and of particle sizes of bottom sediment were used to describe the intensity of tidal forces at the bottom. Finally, analyses of total and inorganic suspended sediment fractions, water temperature, and salinity are summarized in this section.

Winds

Because wind can affect water movement, knowledge of wind speed, direction, and duration may be important for understanding movement of water and sediment in Sinclair Inlet. This section summarizes 13 months of wind speed and direction data collected at the 3 measuring sites on Sinclair Inlet (table 1 and fig. 2). A following subsection "Currents" contains additional information about winds during the ADCP deployment periods.

Data were collected at the three measuring sites from early February 1994 through early March 1995. The data set from the quarry station for this period is complete; however, the data sets from the marina and dolphin stations contain gaps due to equipment malfunctions. Information in table 5 gives an indication of the amount of missing data. Summary tables and figures in this subsection show for selected stations: (1) duration (percent of time) of winds from different directions for a 12-month period (fig. 5); (2) duration of winds from different directions for each month (table 5); and (3) wind run for different directions by month (fig. 6 and table 6).

A notable feature of the observed wind-speed regimen on Sinclair Inlet is low wind speed. At the quarry station wind speed was less than 2 m/s (meters per second) more than 50 percent of the time and was less than 5 m/s nearly 90 percent of the time (table 6). Similarly low wind speeds were also observed at the other two sites. Wind speeds greater than 10 m/s were rare, and the maximum 15-minute average wind speed was less than 14 m/s at each of the three sites. The low wind speeds observed in this study, which contrast with wind speeds of 10 m/s and greater that are common to more exposed places around Puget Sound (Phillips, 1968), are probably the result of the relatively small size of the inlet, the shelter afforded by the surrounding hills, and may, in part, be a result of the proximity of the gages to the shoreline (fig. 2).

It has long been noted that winds in central and south Puget Sound are primarily from the southwest quadrant during the winter and parts of other seasons of the year, and from the north or northeast during parts of the summer (Phillips, 1968). The predominant wind directions at the quarry station, the most westerly of the three stations, was from the southwest and west-southwest, and the secondary prominent direction was from the east-northeast or northeast (fig. 5), which is in agreement with the pattern for south and central Puget Sound. However, the predominant directions appear to rotate counter clockwise when moving east from the quarry station (fig. 5). At the dolphin station the predominant direction was from the south if all wind speeds are considered, but winds from the south-southwest, north-northeast and northeast were common when speeds were greater than 5 m/s (fig. 5). Causes of the apparent rotation of the dominant wind direction are not known but may be related to the topography of surrounding hills and the shape of the inlet and nearby water passages. The presence of Port Washington Narrows north of the dolphin station may be one of the reasons for the more north-south alignment of winds at that site. The wind direction measured at the three stations was from the northeast only about 20 percent of the time during the March 1994 through February 1995 measurement period.

As expected, wind direction and speed varied seasonally. Wind run at the quarry station was generally from southwest during March, April, and June 1994, and from October 1994 through February 1995 (fig. 6). Wind run from the northeast quadrant nearly equalled or exceeded wind run from the southwest quadrant in July and August 1994.

Tides

Water-level (tide) data were collected at the dolphin wind station for a 13-month period, and at the Geoprobe and each of the ADCP sites during each deployment. Graphs of water level as a function of time (fig. 7) show that tides in Sinclair Inlet, as in most of Puget Sound, are mixed, semi-diurnal and diurnal. The neap-spring variations are pronounced, with tidal range varying between

Table 5.--*Duration, in percent of time, by month that observed winds at three stations on Sinclair Inlet are from different directions*

[Direction N is north, NNE is north-northeast, etc. These are directions from which the wind comes. Q denotes station at quarry dock, M is at marina, and D is at dolphin. Because of rounding errors, sum of values for different directions may not equal 100 percent; -- denotes durations not computed]

	March 1994			April 1994			May 1994			June 1994			July 1994			August 1994		
Direction	Q	M[2]	D[1]	Q	M	D[2]	Q	M[1]	D	Q	M[2]	D	Q	M	D	Q	M	D
N	0.9	3.5	--	1.3	1.7	1.0	1.7	--	2.3	1.4	2.5	1.4	1.3	1.2	1.7	1.1	2.3	1.5
NNE	2.3	7.0	--	2.6	2.8	7.8	3.0	--	12.6	3.0	3.5	14.6	3.5	4.5	16.9	1.7	3.8	12.1
NE	11.4	9.2	--	6.6	9.3	8.2	12.0	--	15.0	13.5	17.6	14.7	18.8	21.0	21.6	14.4	15.3	17.3
ENE	14.2	10.2	--	8.8	8.1	3.2	16.7	--	5.0	14.8	12.0	4.0	21.2	23.9	7.8	18.6	18.5	5.5
E	1.8	2.9	--	3.3	4.4	2.8	3.4	--	4.2	2.7	4.1	2.9	2.2	7.2	6.2	2.1	4.8	5.2
ESE	0.7	1.3	--	2.1	3.0	5.2	1.6	--	4.3	0.7	1.2	3.3	0.7	1.8	5.2	1.0	2.2	4.9
SE	0.6	1.4	--	1.1	3.2	6.2	1.1	--	6.2	0.5	0.6	5.1	1.2	1.1	6.0	1.0	1.2	6.3
SSE	1.0	1.8	--	1.8	3.0	7.9	1.4	--	8.9	0.3	0.7	8.8	1.3	1.1	8.0	1.5	1.7	10.3
S	1.3	7.5	--	2.1	6.8	19.6	2.0	--	15.8	2.0	5.4	17.6	1.3	4.8	12.8	1.5	3.9	13.6
SSW	8.0	27.0	--	9.4	27.0	18.7	6.0	--	13.5	7.4	23.4	14.1	4.0	15.8	6.6	5.3	15.1	9.2
SW	28.7	18.8	--	34.3	18.7	11.0	25.6	--	6.9	26.9	19.1	7.4	18.5	10.6	3.7	24.9	20.3	7.6
WSW	20.5	5.0	--	16.7	4.9	4.1	14.8	--	2.0	14.9	5.6	3.1	15.6	3.4	1.5	18.4	5.7	3.6
W	4.1	2.0	--	4.3	2.7	2.1	4.3	--	1.3	5.3	1.6	1.1	4.4	1.4	0.5	4.3	2.2	1.1
WNW	1.5	0.8	--	1.7	0.9	0.8	1.9	--	0.8	1.7	0.8	0.5	2.1	0.9	0.6	1.6	1.1	0.7
NW	1.2	0.7	--	2.0	1.3	0.4	2.2	--	0.6	2.6	0.7	0.8	2.2	0.5	0.5	1.7	1.1	0.5
NNW	1.9	2.9	--	1.8	1.4	1.1	2.1	--	0.7	2.4	1.3	0.8	1.6	0.7	0.6	1.0	0.9	0.7

	September 1994			October 1994			November 1994			December 1994			January 1995			February 1995		
Direction	Q	M	D	Q	M	D	Q	M	D	Q	M	D[2]	Q	M	D	Q	M	D
N	1.1	1.7	1.1	0.7	3.1	2.0	0.8	2.4	2.0	1.8	5.6	3.7	1.6	6.6	1.5	1.3	10.4	7.9
NNE	2.3	2.2	7.6	1.7	2.2	5.9	1.3	1.3	1.4	1.8	4.9	7.0	1.0	3.5	3.0	3.1	11.2	16.3
NE	12.7	10.5	18.2	4.9	6.0	7.6	2.1	0.9	0.9	6.6	2.0	1.4	4.8	3.1	4.0	16.1	8.5	8.2
ENE	16.6	19.9	5.0	8.1	7.8	2.4	1.2	0.5	0.6	3.8	1.7	1.2	7.3	5.1	2.0	14.7	7.1	3.1
E	3.9	6.5	3.7	2.2	2.7	2.2	0.6	0.9	1.1	1.0	1.6	1.8	3.0	7.0	3.4	1.8	3.0	4.2
ESE	0.8	2.3	3.7	0.5	1.3	2.5	0.2	1.4	1.5	0.8	1.4	2.1	1.3	4.1	6.1	0.9	2.5	3.3
SE	0.9	1.3	6.9	0.4	1.0	3.9	0.2	1.4	2.8	0.3	1.5	3.4	0.8	2.9	8.4	0.6	1.2	4.7
SSE	0.9	1.1	11.8	0.5	2.1	11.3	0.4	2.4	9.2	0.4	2.9	8.9	1.4	3.1	13.5	0.4	2.5	6.9
S	1.4	7.3	18.3	1.0	10.6	26.2	1.2	13.4	33.2	0.7	10.9	26.7	1.7	9.6	22.7	1.0	6.6	15.0
SSW	7.3	21.8	12.0	6.5	31.0	18.2	8.5	42.4	26.1	5.6	37.9	22.4	6.0	28.9	16.3	4.2	24.6	16.1
SW	27.8	17.3	7.4	32.3	22.7	10.8	34.9	21.2	13.0	32.9	18.0	11.2	30.1	14.1	7.4	27.1	12.7	6.0
WSW	17.2	4.3	1.9	29.9	4.2	3.1	30.0	6.4	4.0	26.0	7.0	5.6	27.4	4.6	3.1	18.8	3.8	2.2
W	2.9	1.6	0.9	6.3	2.2	1.5	11.7	2.0	0.9	10.6	1.6	1.5	7.1	2.6	1.0	4.9	2.2	1.4
WNW	1.6	0.5	0.4	2.1	1.2	0.8	3.1	0.9	0.9	4.6	0.8	0.5	3.1	1.4	0.7	2.2	0.8	0.5
NW	1.5	0.6	0.3	1.4	0.9	0.6	2.1	1.0	1.0	1.4	0.8	1.0	1.8	0.7	3.1	1.3	0.9	1.0
NNW	1.1	1.2	0.7	1.4	1.1	1.0	1.7	1.4	1.3	1.7	1.5	1.5	1.6	2.9	3.8	1.5	2.0	3.4

[1] data were missing for more than 10 days in month; durations were not computed.

[2] data were missing for 10 or fewer days in month; durations were computed from available data.

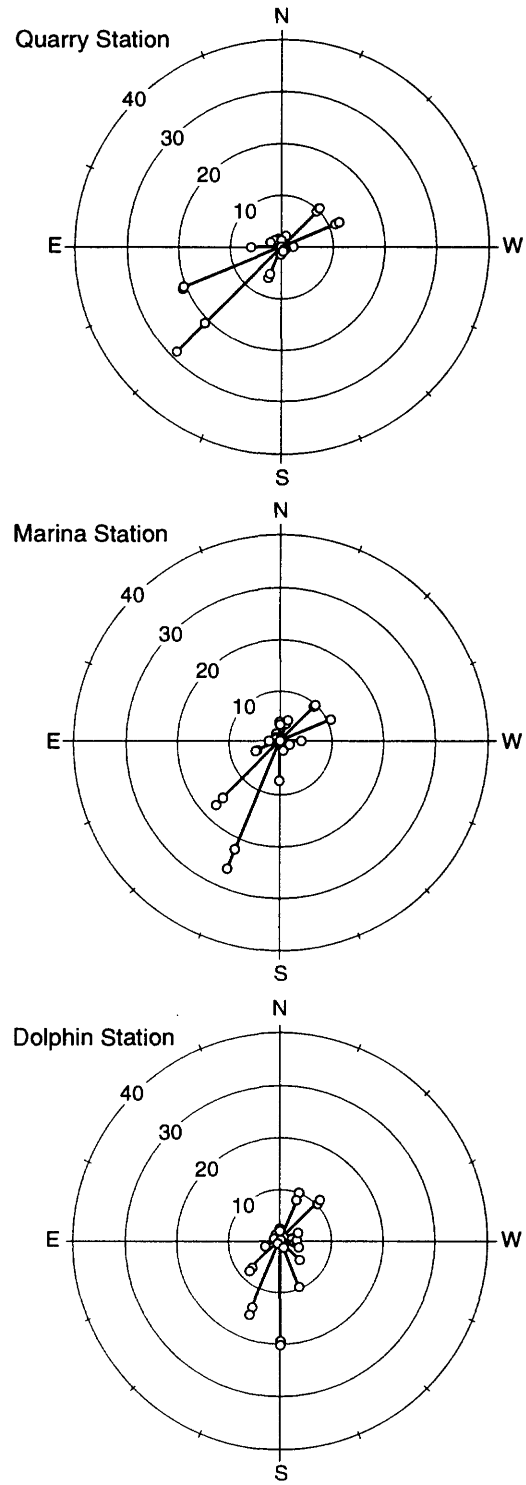


Figure 5. Duration of wind by direction and speed, expressed as percent of time, at three stations for the period March 1994 through February 1995. Length of a line segment from the center to the first circle represents percent duration for wind speeds less than 5 meters per second; remaining length to the second circle represents percent duration for wind speeds greater than 5 meters per second. Indicated direction is the direction from which the wind comes.

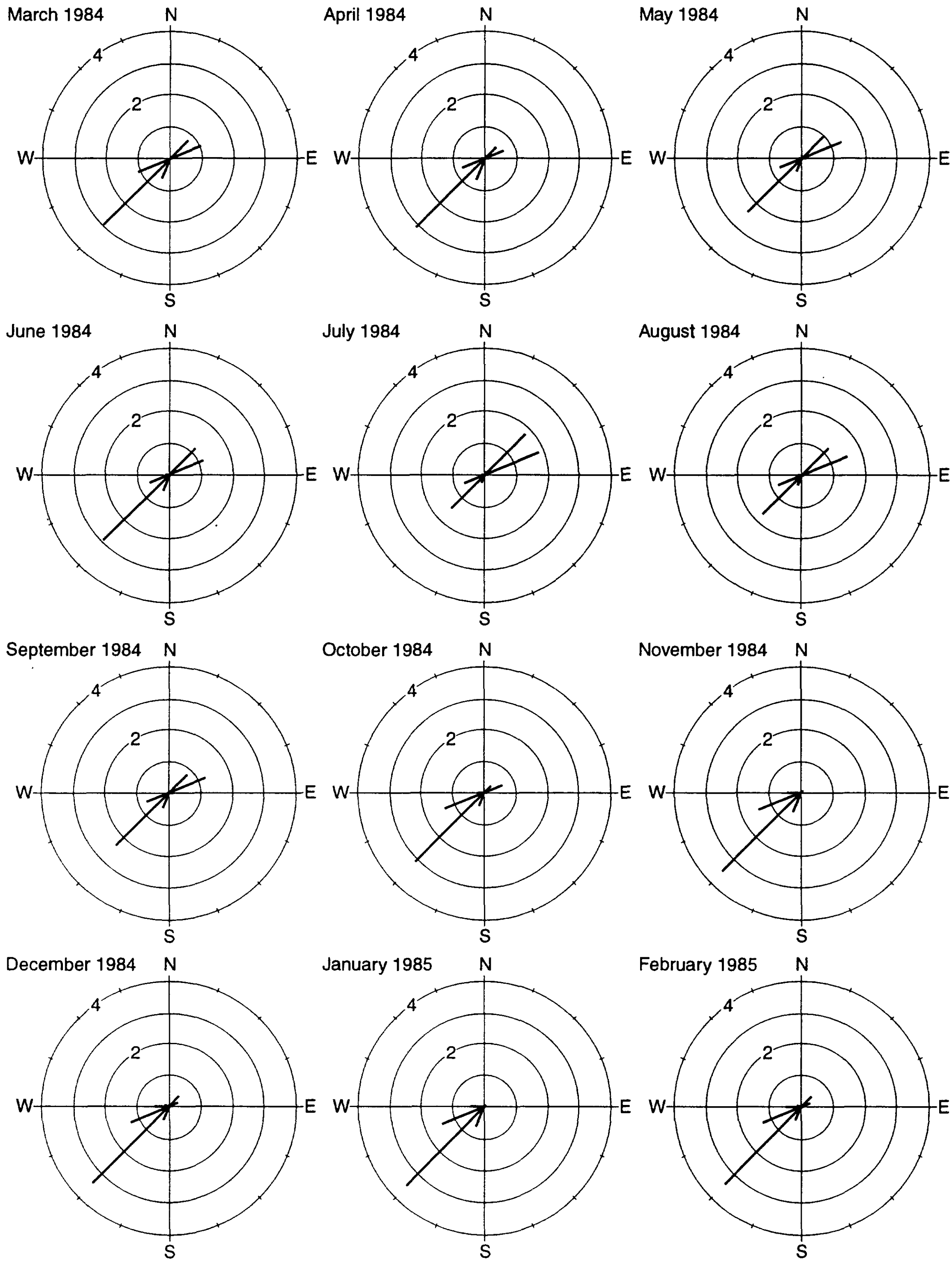


Figure 6. Wind run, in thousands of kilometers, at the quarry station, by month. Indicated direction is direction from which the wind comes.

Table 6.--*Summary of wind data from the quarry station for the 1-year period beginning on March 1, 1994*

[Direction N is north, NNE is north-northeast, etc. These are directions from which the wind comes. All wind speeds and directions are 15-minute averages. Because of rounding errors, sum of values for different directions may not equal value given for all direction]

Direction	Wind run, in kilometers	Proportion of time, in percent, that wind speed was less than indicated speed, in meters per second			Maximum wind speed, in meters per second
		2	5	10	
N	343	1.2	1.3	1.3	3.1
NNE	883	1.9	2.3	2.3	3.7
NE	9,295	3.1	9.6	10.3	6.5
ENE	11,170	3.3	11.3	12.2	7.7
E	1,078	1.6	2.3	2.3	4.5
ESE	222	0.9	0.9	0.9	2.9
SE	153	0.7	0.7	0.7	3.1
SSE	202	0.9	1.0	1.0	2.9
S	456	1.3	1.4	1.4	5.5
SSW	5,853	2.3	5.7	6.5	8.8
SW	31,856	9.9	20.8	28.5	13.1
WSW	11,463	14.9	20.2	20.9	9.3
W	2,256	4.9	5.8	5.8	4.6
WNW	557	2.1	2.3	2.3	3.1
NW	357	1.8	1.8	1.8	2.2
NNW	421	1.6	1.7	1.7	3.4
All	76,564	52.5	89.2	99.9	13.1

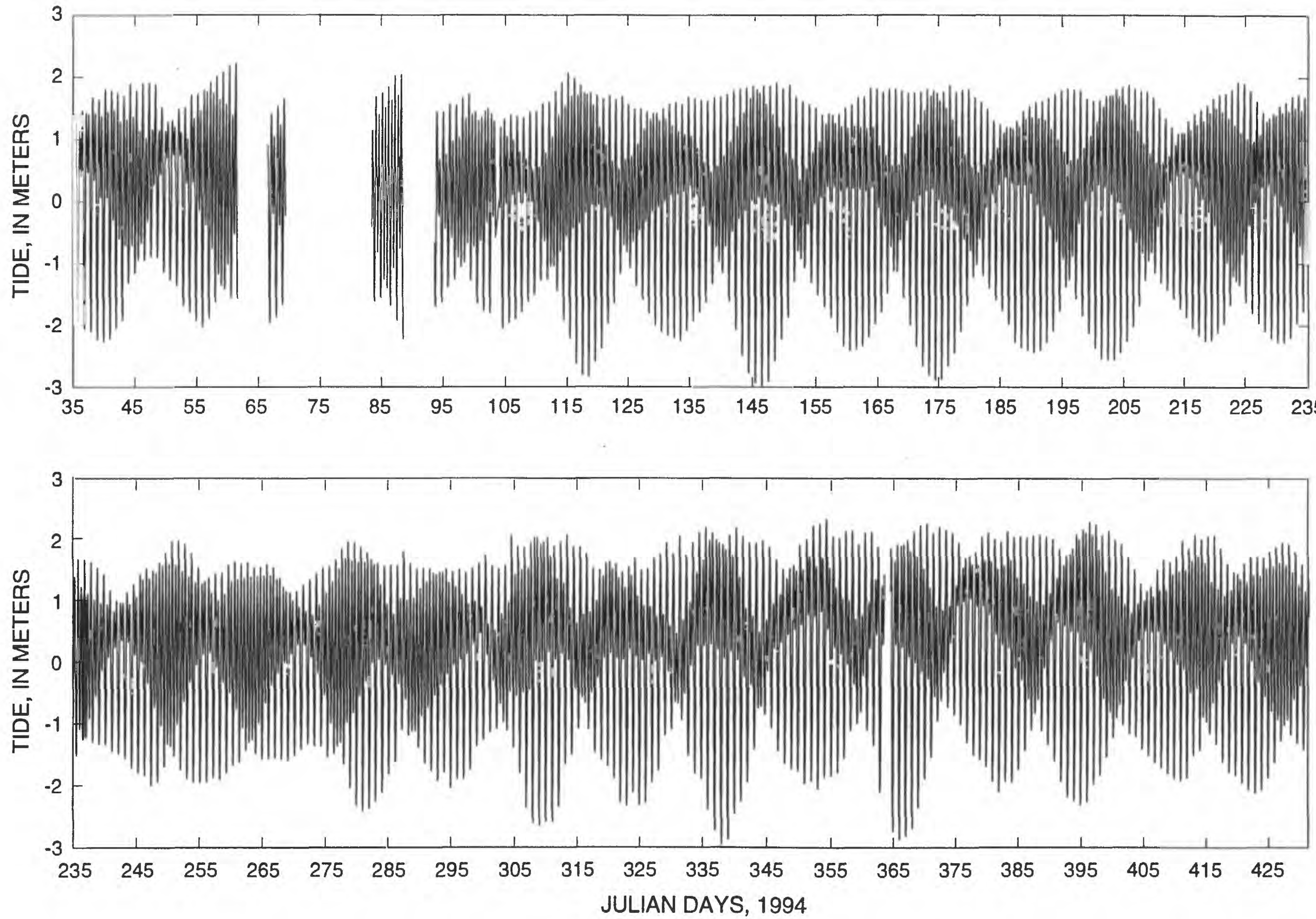


Figure 7. Tide at dolphin station from February 4, 1994 to March 8, 1995

about 2 and 4.5 m. Maximum diurnal inequalities in low tides generally (but not always) occur near time of spring tides. The tide levels during each mixed cycle are considerably different during neaps and springs.

Harmonic analyses of the water levels measured at the dolphin site and with the Geoprobe (table 7) show the relative importance of the different astronomical tidal constituents. (Results of harmonic analyses of tide data collected with instruments on the ADCPs are in Appendix B.) The first three primary constituents (in descending order) are M_2, K_1 and O_1. M_2 is a semi-diurnal component and K_1 and O_1 are diurnal components. (Numerical values of the frequencies and commonly used nomenclature for many of the astronomical tidal constituents are included in table 7). The first three primary constituents are followed by S_2, N_2 and P in various orders. As expected, because of the short length of Sinclair Inlet, the phases of the tides are nearly simultaneous and the amplitudes vary only slightly among the four data-collection sites.

A tidal form number, F, is defined as the ratio of the sums of the amplitudes of the diurnal tidal constituents to the sums of the semi-diurnal constituents. Here, a simplified definition of the form number is used, $F = (O_1+K_1)/(M_2+S_2)$ (Defant, 1958). Values of F between 0.25 and 3.0 are considered to be representative of mixed tides. The tidal form number computed for the observed tides in Sinclair Inlet range from about 0.8 and 1.0, which indicates mixed tides, as was concluded above by visual inspection of the graphs of water levels.

Currents

Water currents were measured with two different types of instruments. ADCPs measured velocity profiles over much of the water column at three sites during two deployment periods, and EMCMs on the Geoprobe measured velocities near the bed at one of the sites during one of the deployment periods. Although currents were relatively weak, usually less than 10 cm/s, agreement between velocities measured concomitantly by the Geoprobe at 1.2 m above the bed and by the ADCP at 1.9 m above the bed is excellent (fig. 8). Even though the sampling schemes for the two instruments were different and basic operating principles of the current meters are completely dissimilar, the two independent data sets are very similar. Corrected for differences in recording times, regression of the time series of velocity recorded by the two instruments shows an average difference of about 0.14 cm/s and an r^2 of about 0.73. This agreement lends a high degree of confidence to the current data from both systems. It also implies that the ADCP data can be utilized in combination with the estimates of drag coefficients for bottom shear stress computed from the Geoprobe velocity profiles to make estimates of bottom stress at times and locations where the Geoprobe was not deployed.

The velocity data collected in Sinclair Inlet are unique. These data show the tidal-current structures at three sites during the winter and summer periods. Embedded in the high resolution measurements of tidal currents is significant information relating the tidal forcing, wind forcing, residual circulation, and properties of bottom shear at the measurement sites.

The current data are summarized in this report in the following series of tables and figures. (All time series are available in digital format separate from this report.) Figures 9 to 14 show representative velocities measured by ADCPs, and figure 15 shows current velocity vectors measured by each of the four velocity meters on the Geoprobe. Representative plots of time series of residual (filtered to remove astronomical tidal components) velocities are shown in the subsection of this report titled "Residual Circulation Pattern". Results of harmonic analyses of time series of the ADCP velocity data for all bins and of the Geoprobe data for the uppermost velocity meter are presented in Appendix A and in the Harmonic Analyses subsection. Also given in the tables of Appendix A are the RMS (root-mean-squares) current speed, spring tide current maximum, neap tide current minimum, principal current direction, and tidal current form number, F. The tidal current form number was defined in the earlier subsection on tides.

Observed Currents

Tidal currents in Sinclair Inlet are expected to be weak because of the short length and semi-enclosed nature of the inlet. Time-series plots of the observed currents (figs. 9 to 15) show that typical current speeds are 5 to 10 cm/s, and seldom exceed 20 cm/s, even at times of maximum flood or ebb. Maximum current speed measured with the uppermost velocity meter on the Geoprobe was only about 16 cm/s (table 8). The RMS current speeds measured with the ADCPs at all three stations during both the winter and summer deployments, and with the Geoprobe at one station during the winter deployment, are less than 8 cm/s (fig. 16 and table 8). Generally the RMS speeds decrease from near surface to near bottom.

Table 7.--*Results of harmonic analysis of a 13-month water-level record at the dolphin station, and a 39-day record from the Geoprobe, Sinclair Inlet, Washington*

[Starting time of record at dolphin station is 12:15 Pacific Standard Time 4 February 1994, and record length is 395 days. Starting date of the Geoprobe data is 18 February 1994, and record length is 39 days. Amplitudes in parentheses are from analyses of Geoprobe data (without inference for minor constituents); other amplitudes and all epochs are from analyses of data from dolphin site]

Constituent		Frequency	Amplitude		Modified epoch		Greenwich epoch	
Symbol	Origin and name	(per day)	(centimeters)		(degrees)		(degrees)	
Sa	Solar annual	0.00274	12.87		2.87		3.20	
Ssa	Solar semiannual	0.00548	6.52		222.03		222.68	
Mm	Lunar monthly	0.03629	1.66	(4.93)	242.91	(336.31)	247.27	(340.67)
MSf	Lunisolar synodic fortnightly	0.06773	0.33	(4.13)	274.52	(133.85)	282.65	(141.97)
Mf	Lunar fortnightly	0.07320	2.53		80.45		89.23	
2Q1	Second-order elliptical lunar	0.85695	0.27	(2.79)	224.03	(262.57)	326.86	(5.40)
σ1	Lunar variational	0.86181	2.16		208.80		312.22	
Q1	Larger lunar elliptic	0.89324	7.71	(8.15)	149.19	(159.45)	256.38	(266.64)
O1	Principal lunar diurnal	0.92954	44.56	(48.03)	149.20	(142.45)	260.75	(254.00)
τ1	Lunisolar diurnal	0.93501	2.54		231.95		344.15	
M1	Smaller lunar elliptic	0.96645	4.24	(7.10)	200.22	(192.81)	316.19	(308.79)
P1	Principal solar diurnal	0.99726	24.69	(26.97)	161.08	(163.10)	280.76	(282.77)
S1	Radiational	1.00000	2.49		120.35		240.35	
K1	Lunisolar diurnal	1.00274	82.10	(89.59)	163.37	(160.16)	283.70	(284.84)
J1	Small lunar elliptic	1.03903	3.91	(4.01)	205.80	(185.03)	330.48	(309.72)
SO1	Lunisolar diurnal	1.07046	3.87		309.72		78.17	
OO1	Second-order lunar	1.07594	2.21	(2.62)	207.48	(266.96)	336.60	(36.07)
2N2	Second-order elliptical lunar	1.85969	2.34		92.16		315.32	
μ2	Variational	1.86455	2.40	(4.79)	6.47	(1.30)	230.22	(225.05)
N2	Larger lunar elliptic	1.89598	21.76	(20.40)	126.00	(113.49)	353.52	(345.36)
ν2	Larger lunar evectional	1.90084	5.11	(4.79)	135.07	(103.84)	3.17	(331.94)
M2	Principal lunar	1.93227	108.80	(110.56)	148.99	(140.95)	20.86	(12.82)
λ2	Smaller lunar elliptic	1.96371	2.11		166.92		42.57	
L2	Smaller lunar elliptic	1.96857	3.98	(4.61)	169.82	(152.50)	46.05	(28.73)
T2	Larger solar elliptic	1.99726	1.55		185.61		65.29	
S2	Principal solar	2.00000	26.56	(27.80)	168.35	(159.31)	48.35	(142.73)
K2	Lunisolar semidiurnal	2.00548	7.38	(7.73)	158.33	(168.67)	38.99	(49.33)
MK3	Lunisolar terdiurnal	2.93501	2.13	(1.52)	137.71	(140.26)	129.91	(132.46)
M4	Quarter diurnal lunar	3.86455	2.52	(2.70)	151.94	(140.79)	255.68	(244.53)
M6	Sixth diurnal lunar	5.79682	1.76	(1.92)	39.02	(9.05)	14.64	(344.67)

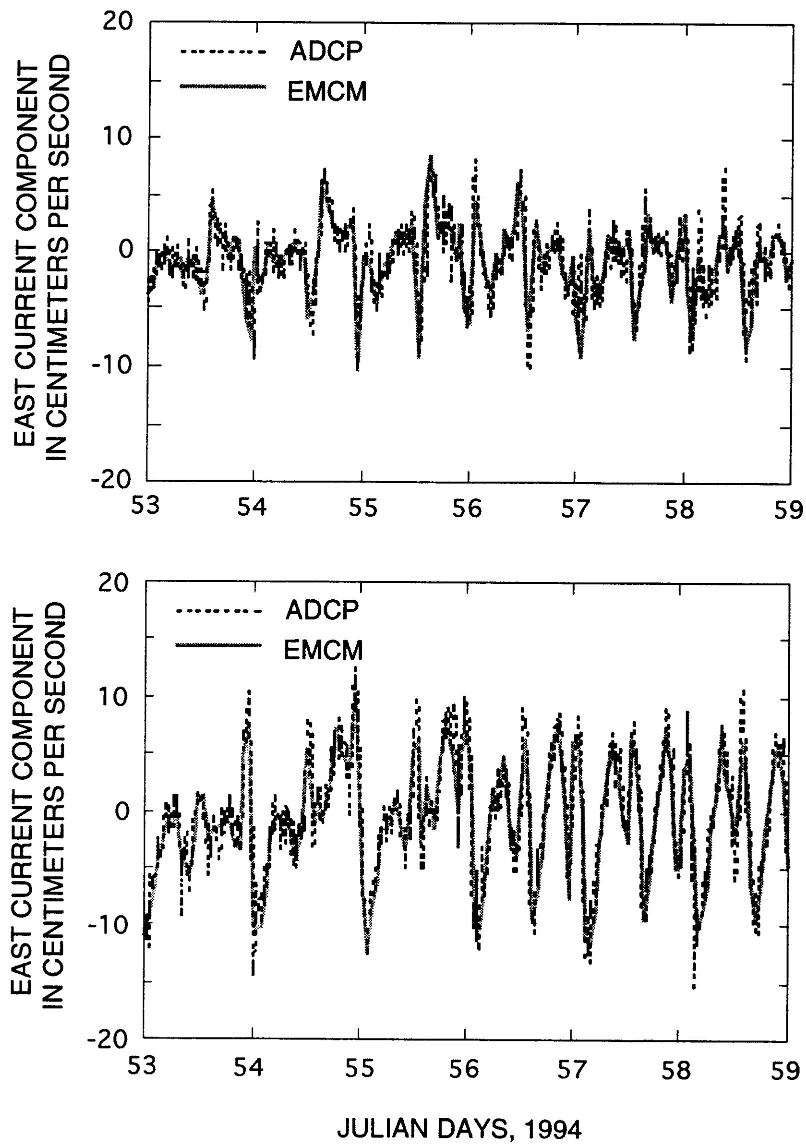


Figure 8. Hourly currents measured at the east station with the acoustic Doppler current profiler (ADCP) at 1.9 meters above the bed and with an electromagnetic current meter (EMCM) on the Geoprobe at 1.2 meters above the bed.

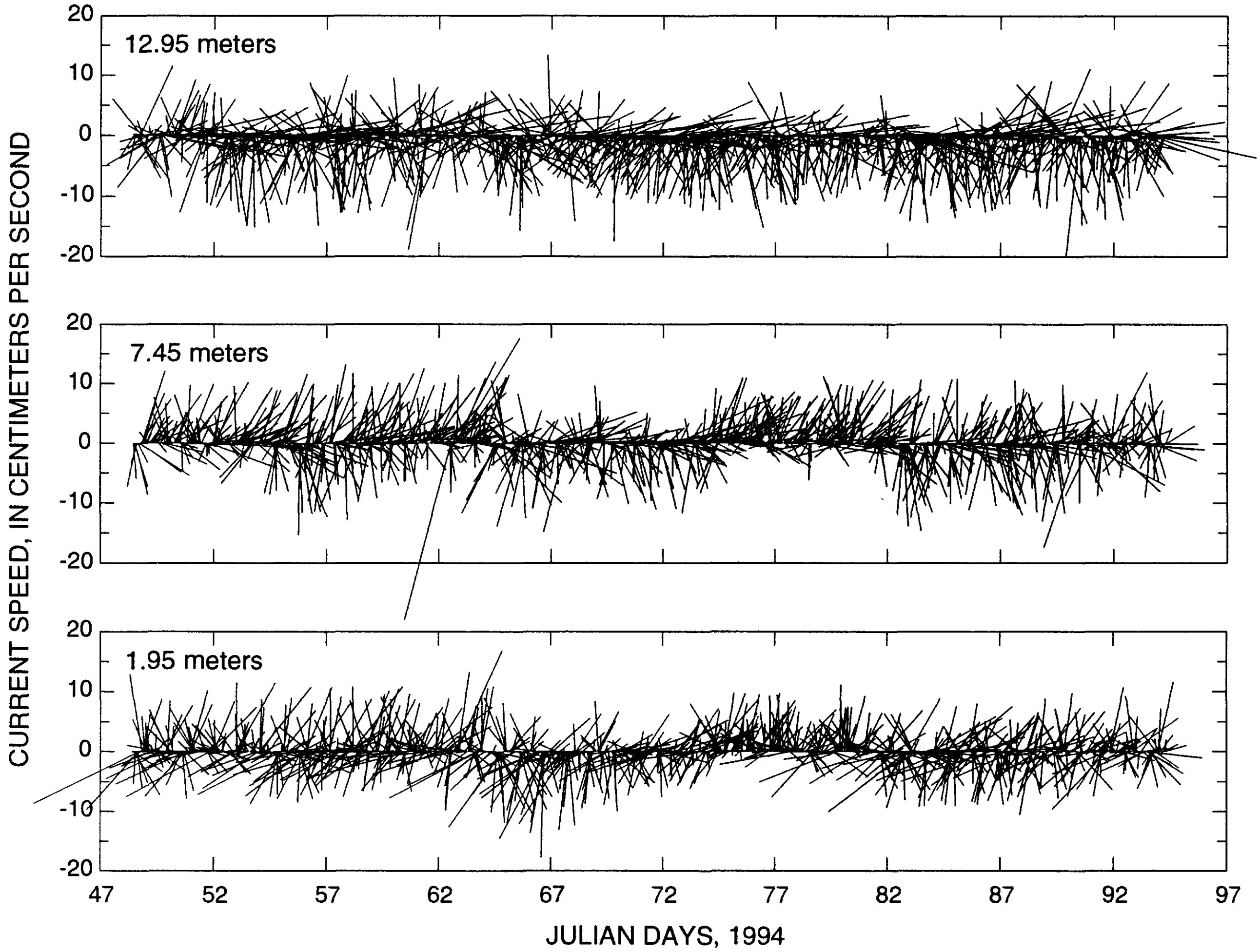


Figure 9. Current velocity vectors near bottom, middle, and near surface measured with the acoustic Doppler current profiler at the east station during the winter deployment period. Vertically upward vector is 250 degrees clockwise from North (into the inlet). Distances are above bed.

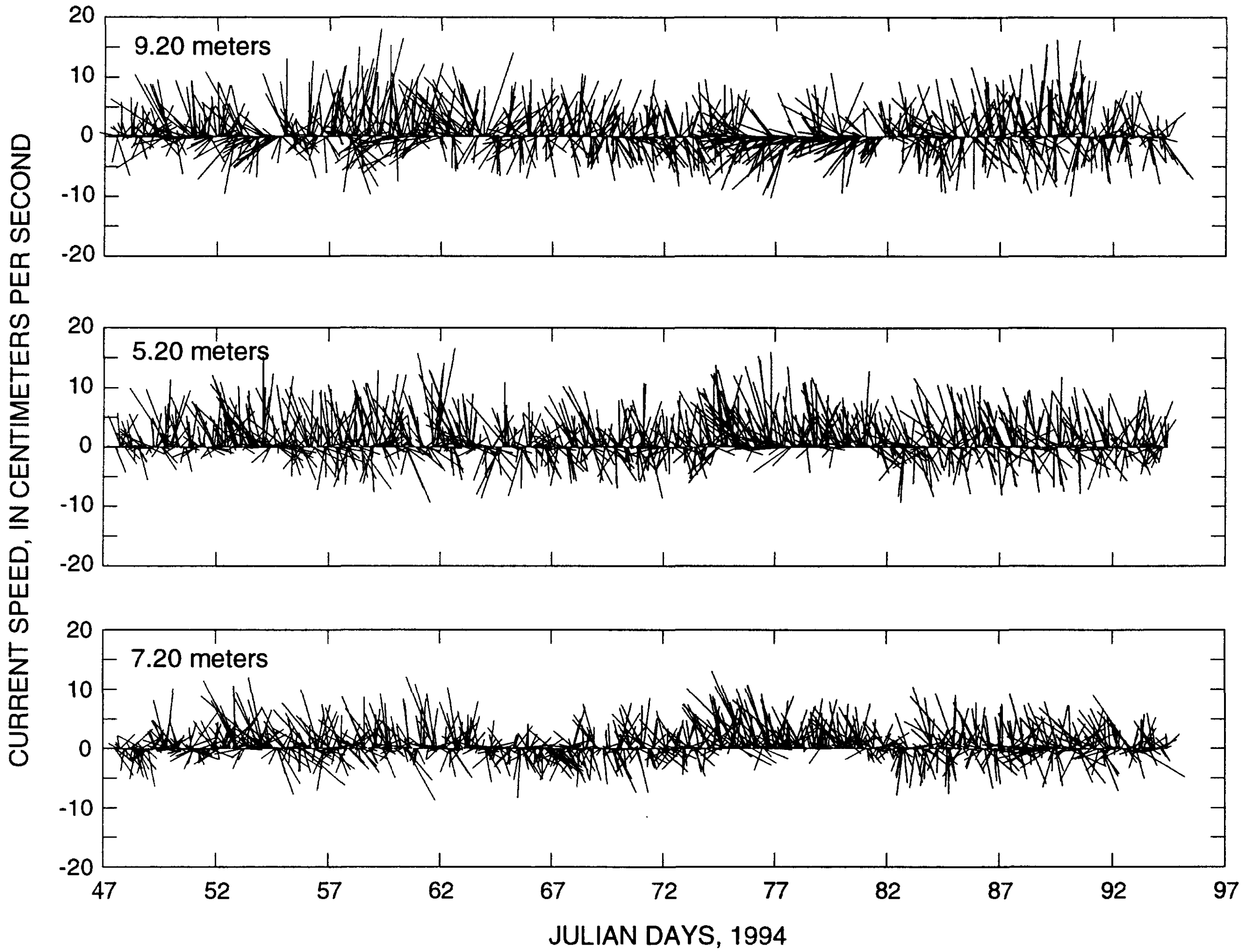


Figure 10. Current velocity vectors near bottom, middle, and near surface measured with the acoustic Doppler current profiler at the center station during the winter deployment period. Vertically upward vector is 250 degrees clockwise from North (into the inlet). Distances are above bed.

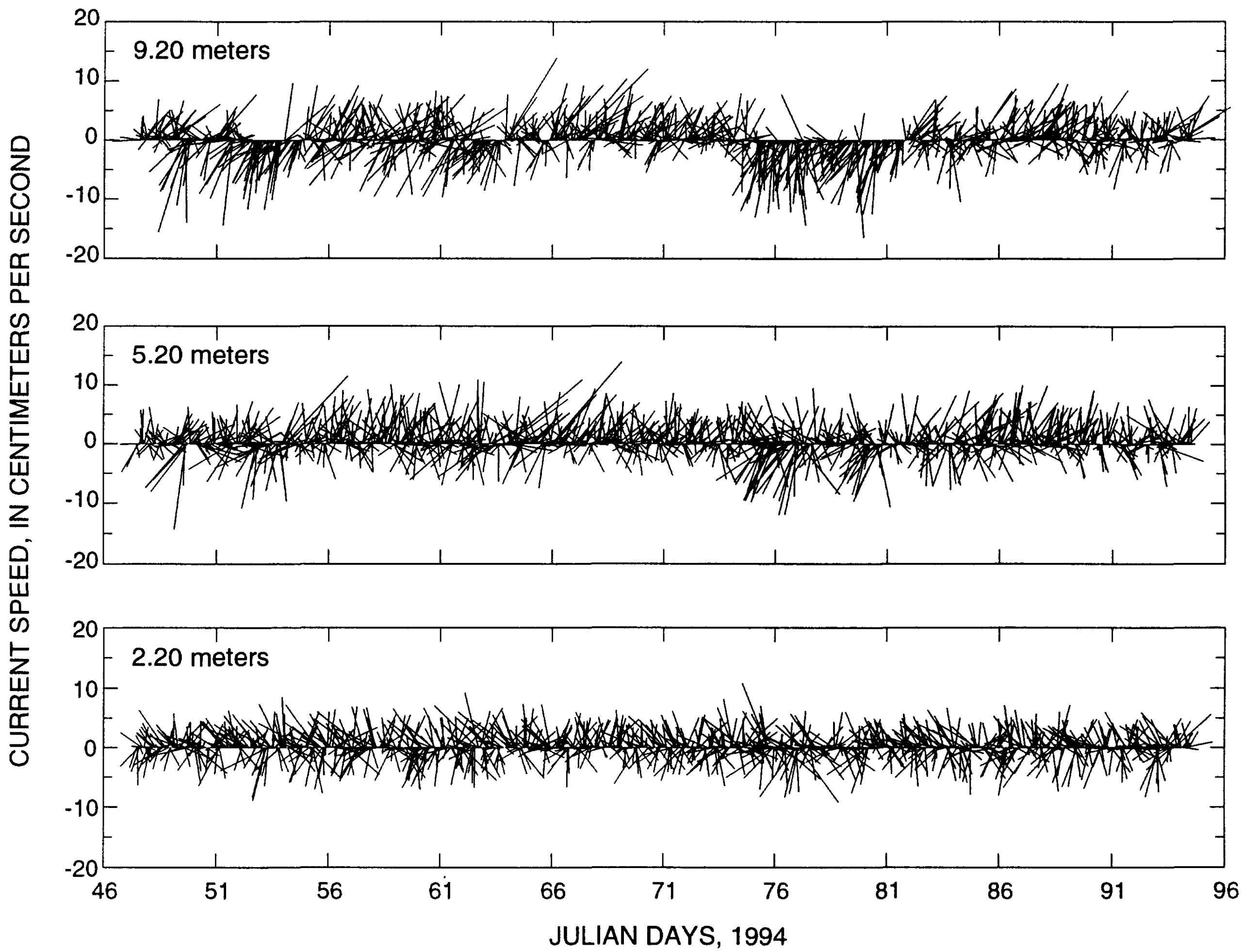


Figure 11. Current velocity vectors near bottom, middle, and near surface measured with the acoustic Doppler current profiler at the west station during the winter deployment period. Vertically upward vector is 250 degrees clockwise from North (into the inlet). Distances are above bed.

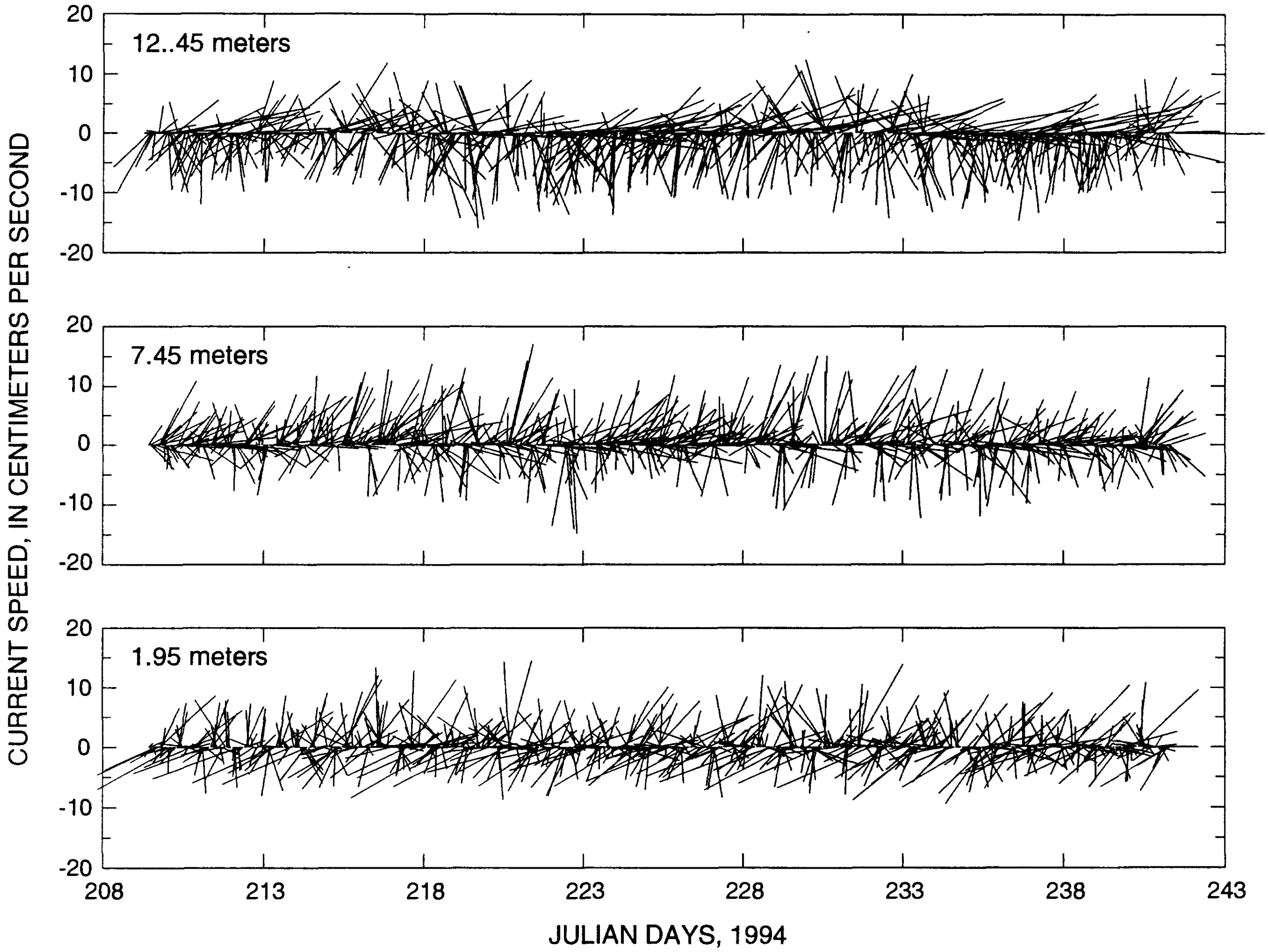


Figure 12. Current velocity vectors near bottom, middle, and near surface measured with the acoustic Doppler current profiler at the east station during the summer deployment period. Vertically upward vector is 250 degrees clockwise from North (into the inlet). Distances are above bed.

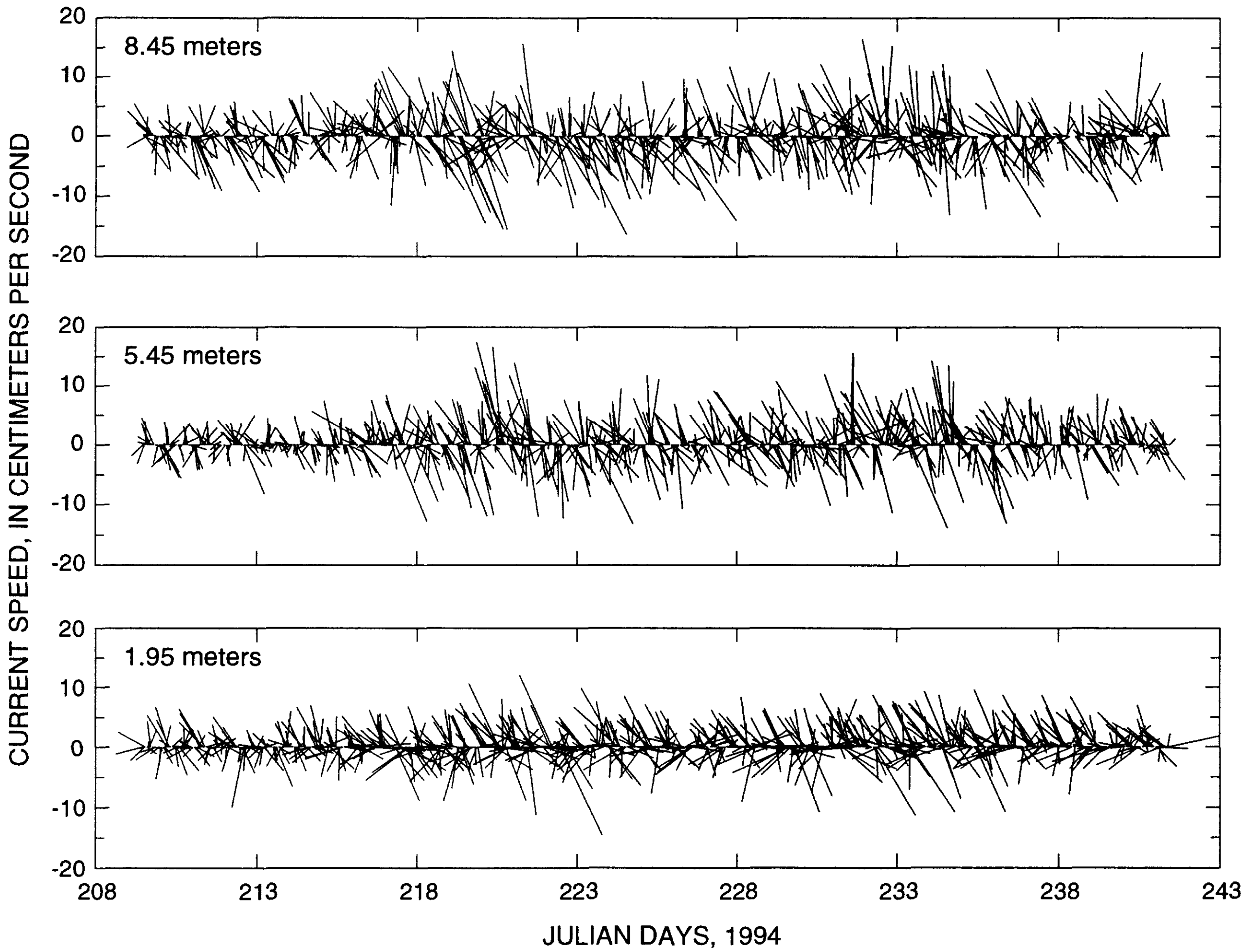


Figure 13. Current velocity vectors near bottom, middle, and near surface measured with the acoustic Doppler current profiler at the center station during the summer deployment period. Vertically upward vector is 250 degrees clockwise from North (into the inlet). Distances are above bed.

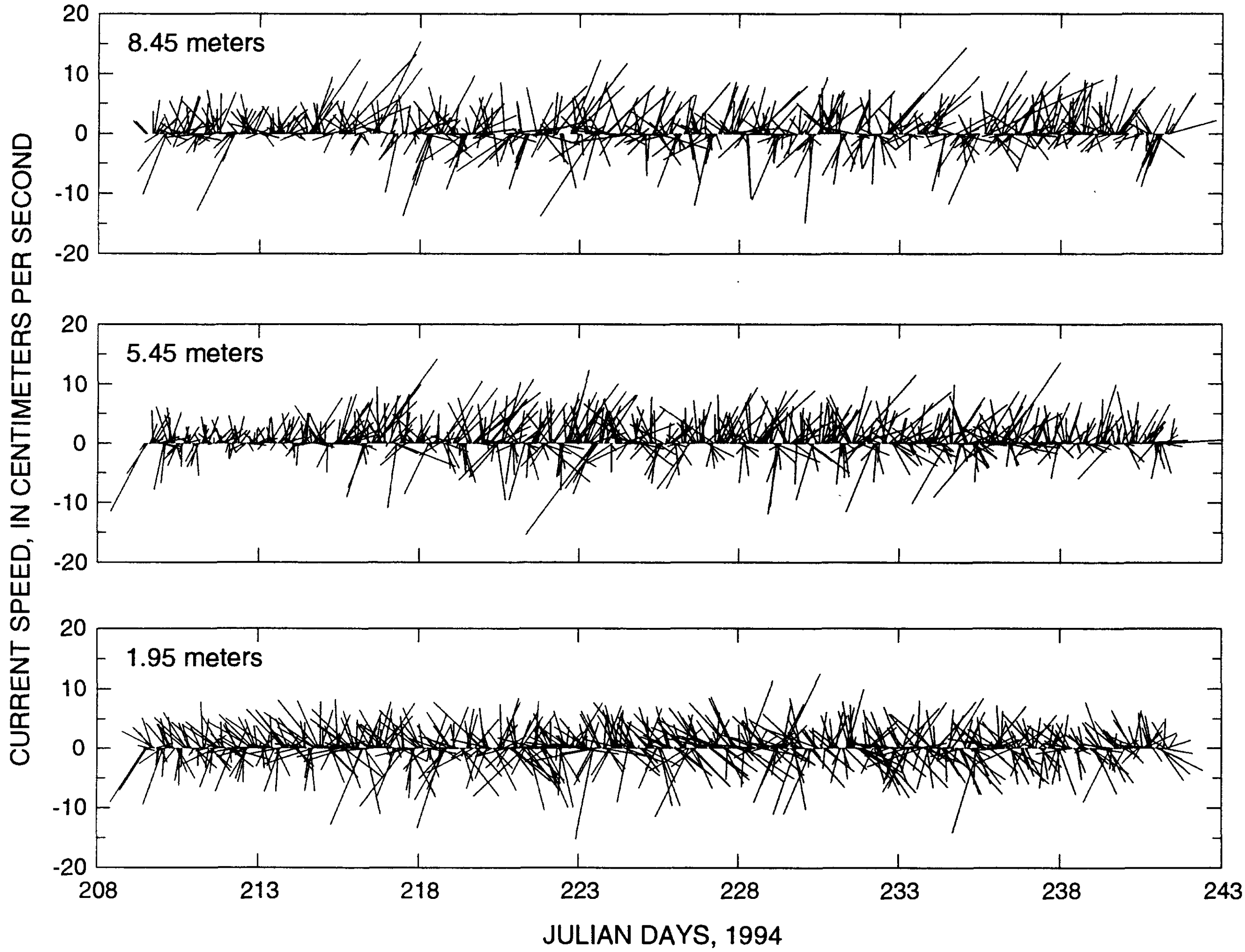


Figure 14. Current velocity vectors near bottom, middle, and near surface measured with the acoustic Doppler current profiler at the west station during the summer deployment period. Vertically upward vector is 250 degrees clockwise from North (into the inlet). Distances are above bed.

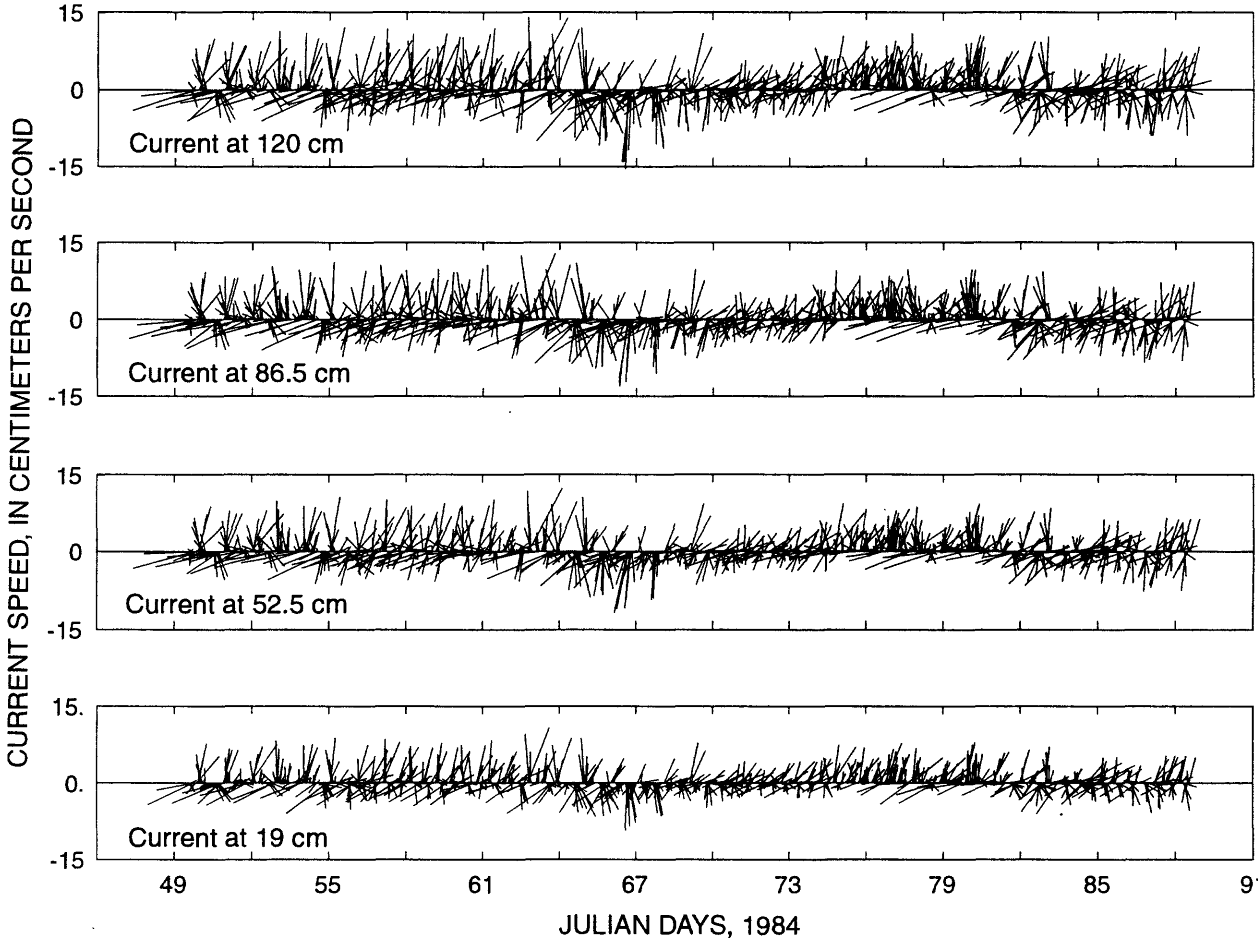


Figure 15. Hourly burst-averaged current velocity vectors measured with current meters on the Geoprobe at indicated distances above the bed. Vertically upward vector is 250 degrees clockwise from the North (into the inlet).

Table 8.--*Summary statistics for depth and velocities measured with instruments on Geoprobe (all velocity profiles)*

[m, meters; cm/s, centimeters per second; u, current speed; RMS, root mean square; Std. Dev., standard deviation; --, not computed]

Statistic	Depth (m)	[1] u_{19} (cm/s)	$u_{52.5}$ (cm/s)	$u_{86.5}$ (cm/s)	u_{120} (cm/s)
Minimum	15.02	0.51	0.41	0.56	0.53
Maximum	18.80	11.69	14.20	16.01	16.06
Mean	17.47	3.62	4.52	5.00	5.30
Std. Dev.	1.02	2.00	2.55	2.75	2.89
RMS	--	4.04	5.10	5.64	5.96

[1] Subscript indicates height of measurement above the bed, in centimeters.

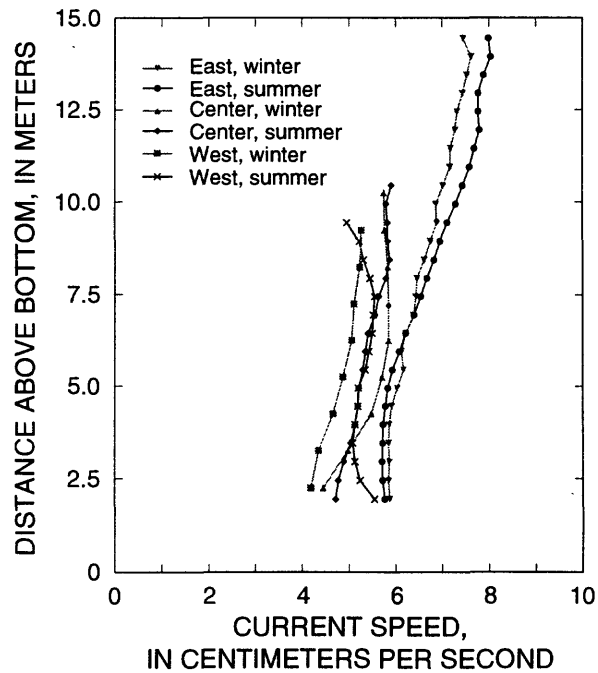


Figure 16. Root-mean-square (RMS) current speed as a function of distance above bottom at the east, center, and west stations during the winter and summer deployment periods.

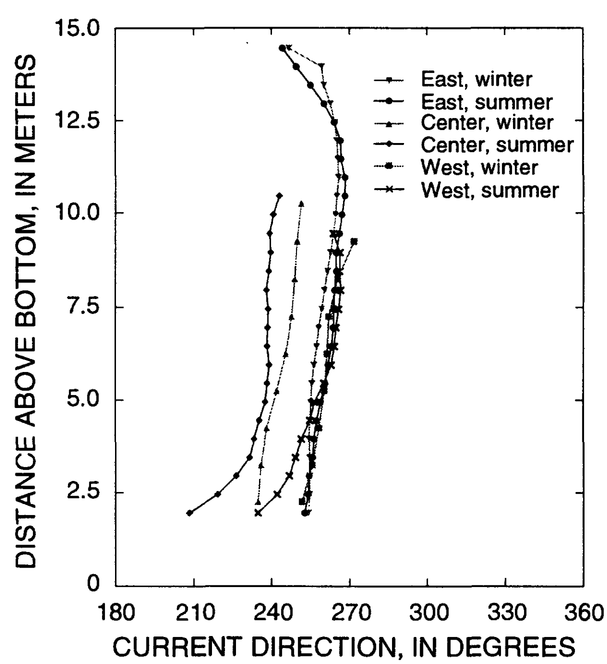


Figure 17. Primary current direction as a function of distance above bottom at the east, center, and west stations during the winter and summer deployment periods.

A plot of tidal current vectors measured with the Geoprobe (fig. 15) shows the largest vectors are oriented along the axis of the inlet although there are numerous substantial cross axis vectors present. The vectors from the four sensors track one another quite well, with no obvious major problems or differences in the vector current data. Variations of current direction with depth as measured by the ADCPs are as much as 30° (fig. 17). Because the tidal current speeds are very low, this current structure could be caused by wind. As will be shown later, the residual currents, probably wind driven, are of the same order of magnitude as the tidal currents. Thus, wind forcing might be of equal importance compared to astronomical tidal forcing.

Harmonic Analyses

Harmonic analyses was applied to current data to obtain the amplitude and phase (harmonic constants) of major astronomical tidal constituents (table 9, figs. 16 to 20, and Appendix A). Harmonic constants from the time series of east-west and north-south velocity have been cast in the form of a tidal ellipse; and major axis, minor axis, constituent direction, and phase are also shown. In the case of Sinclair Inlet where residual currents are the same order of magnitude as tidal currents, the results of harmonic analysis tend to be less consistent than if the tidal components of the currents were stronger. This is exemplified by the variation in relative amplitudes of the major astronomical constituents. The M_2 constituent is always largest, however, the relative magnitude of the remaining constituents varies from station to station, from one field period to the other, and from near surface to near bottom.

Table 9 lists the results of a harmonic analysis of the uppermost current-meter data from the Geoprobe (at 120 cm above the bed) during the winter deployment period. The expected result of the dominance of the semi-diurnal (M_2) and diurnal (K_1 and O_1) components was found as in the tidal data. But in addition, several harmonics (overtides) of these components have relatively large amplitudes. M_4 and MS_4 have amplitudes that are quite large; for example, the ratio of the major ellipse components, $M_4/M_2 = 0.71$. The overtides are quite striking in a power-spectral-density plot for the current (fig. 21) but not for the tide (fig. 22). In other studies the presence of strong overtides has been linked to frictional interactions of the primary tidal forcing with bottom and coastal topography. The tidal ellipse for the M_2 constituent has major and minor axes of 2.58 and 1.09 cm/s, respectively (table 9). The tidal ellipse for the K_1 constituent has major and minor axes of 2.12 and 0.33 cm/s, respectively.

Results of harmonic analysis of velocity data from the ADCPs are documented in appendix A. Summary sheets include the amplitude and phase information for five major tidal constituents, plus M_4 and MS_4 overtides. In addition to the harmonic constants, some additional computed quantities such as the RMS current speed, tidal-current form number, principal current direction,

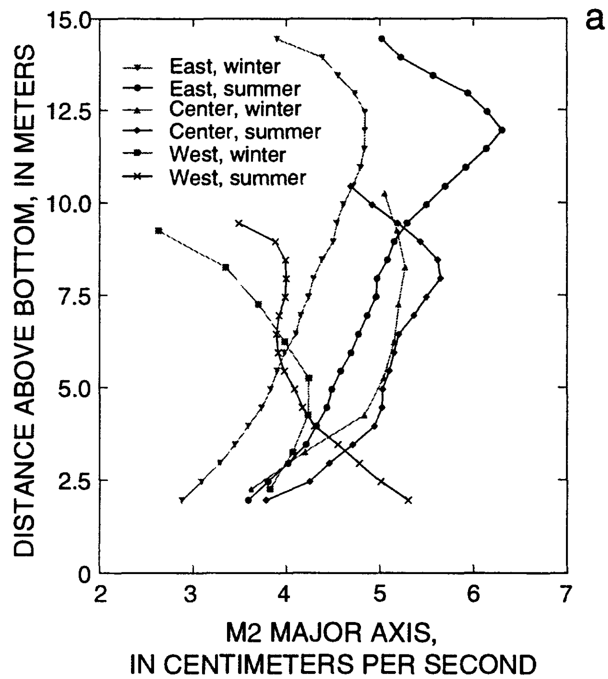
Table 9.--*Results of harmonic analyses of velocity data collected with the current meter on the Geoprobe situated 1.2 meters above the bed*

[cm/s, centimeters per second]

Constituent	Period (hours)	Frequency (per hour)	Amplitude: Major[1] (cm/s)	Amplitude: Minor[1] (cm/s)	Direction (degrees)[2]	Phase angle (degrees)
O1	25.84	0.0387	2.136	-0.165	248.4	88.7
K1	23.92	0.0418	2.123	-0.328	264.0	134.1
N2	12.66	0.0790	0.825	-0.296	223.8	71.0
M2	12.42	0.0805	2.580	-1.091	254.0	97.4
S2	12.00	0.0833	1.876	-0.513	246.3	79.6
M4	6.21	0.1610	1.822	0.231	104.3	64.4
MS4	6.11	0.1638	1.512	0.116	107.6	119.8

[1]The columns "Major" and "Minor" indicate the magnitude of the current along axes of the tidal ellipse.

[2]Clockwise from true north.



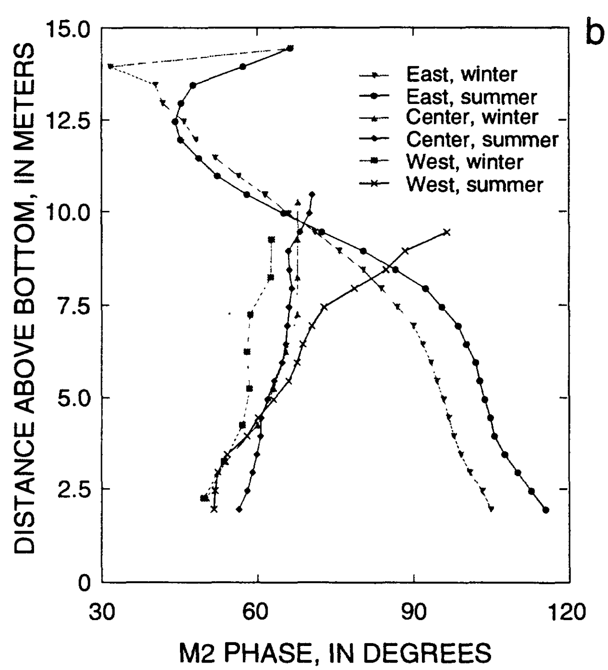
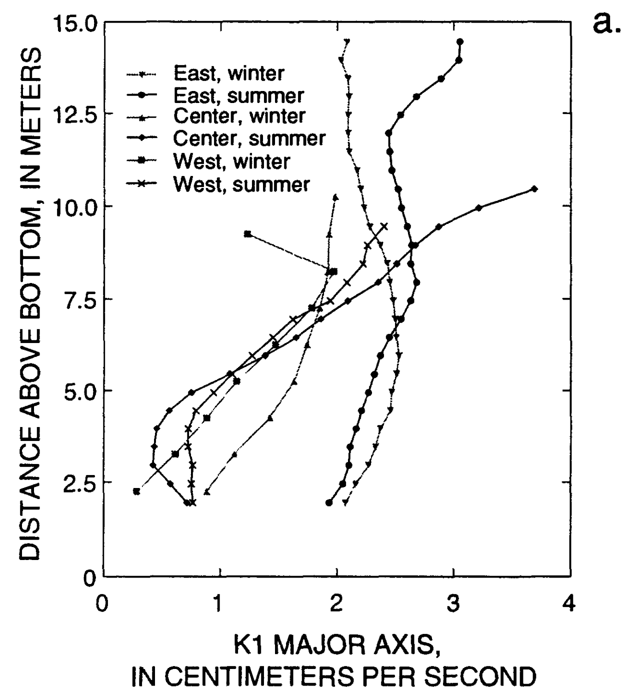


Figure 18. M2 major axis (a) and phase (b) as a function of distance above bottom at the east, center, and west stations during the winter and summer deployment periods. (M2 is principal lunar constituent of tide.)



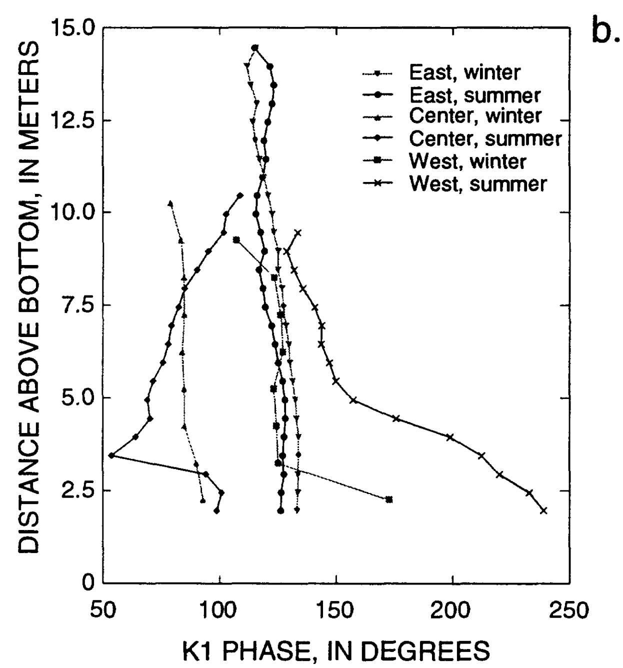


Figure 19. K1 major axis (a) and phase (b) as a function of distance above bottom at the east, center, and west stations during the winter and summer deployment periods. (K1 is lunisolar diurnal constituent of tide.)

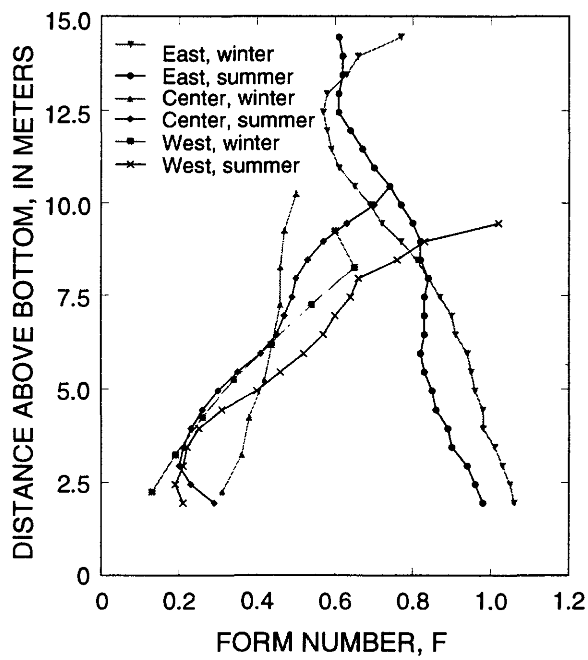


Figure 20. Current form number, F, as a function of distance above bottom at the east, center, and west stations during the winter and summer deployment periods.

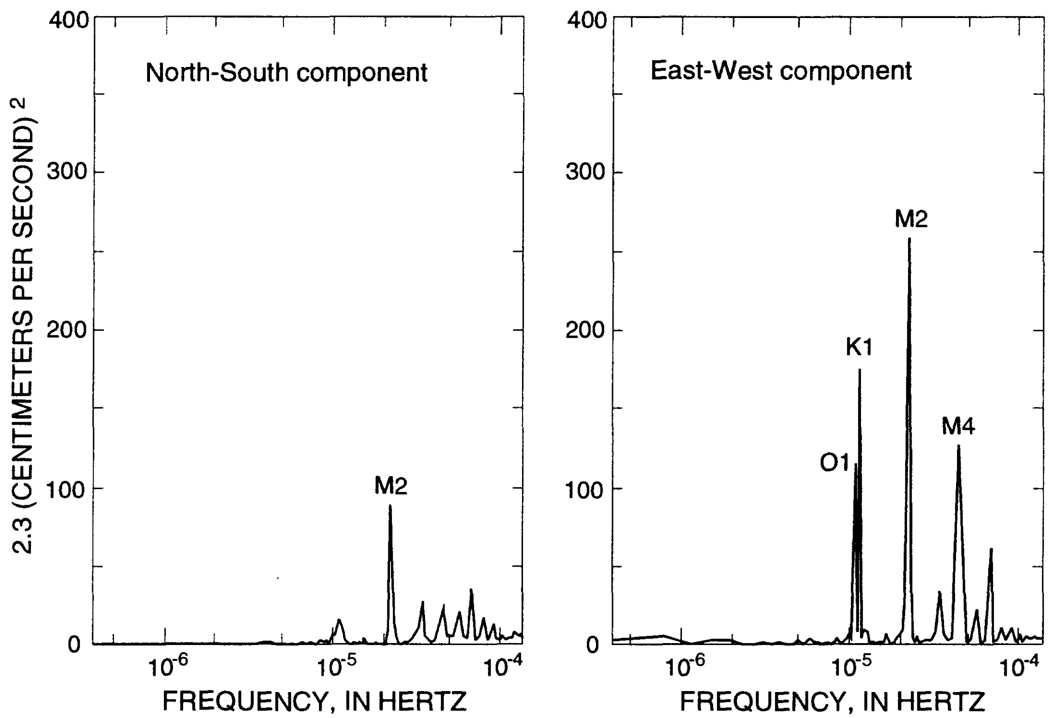


Figure 21. Auto-spectra of hourly velocity data from current meter at 1.2 meters above the bed on the Geoprobe. (Symbols are tidal constituents; M2, principal lunar; O1, principal lunar diurnal; K1, lunisolar diurnal; and M4, quarter diurnal lunar.)

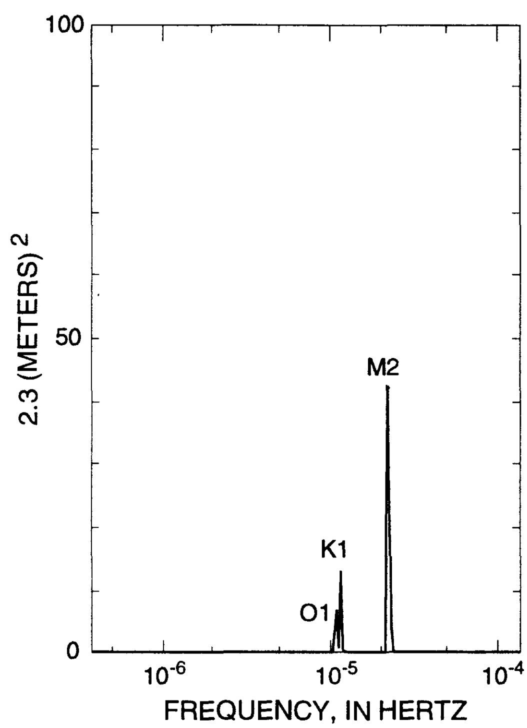


Figure 22. Auto-spectrum of tide data from the Geoprobe.

spring-tide current maximum, and neap-tide current minimum are given. Because the ADCPs record velocity profiles, vertical variations in tidal-current characteristics can be examined from analyzed data.

Sinclair Inlet is a relatively small embayment, thus little phase difference in currents is expected among the three study sites. Surprisingly, phase differences among the sites, and with depth at a single site, are found to be quite substantial (figs. 18 and 19). These results further suggest that wind forcing plays an important role in determining the three-dimensional structure of the currents. There are consistent changes in tidal current form number through the water column (fig. 20). The phases of tidal currents lead the tides by about 65° to 70° at the three stations (about 45° at the east station near bottom). These phase relations suggest that the tides in Sinclair Inlet propagate more like standing waves than as progressive waves. The physical setting of the inlet would suggest that tides would propagate as nearly pure standing waves. The departure of tides from standing waves could be a result of wind forcing.

Some of the ADCP data show evidence of unusual changes in principal current direction near the surface and the bottom (fig. 17). Principal directions are calculated using weighted values of directions of major tidal constituents derived from harmonic analysis. Large changes in principal direction could be the result of weak tidal currents and local wind forcing. When the astronomical forcing is dominant, harmonic analysis is an effective method for separating the wind-driven circulation from the astronomical tidal currents. However, because the tidal currents in Sinclair Inlet are very weak, the wind-driven circulation can be of the same order of magnitude as the tidal currents. Consequently, due to wind forcing, sometimes the ebbing and flooding cycles are not clearly definable. For example, data from the winter deployment show that the flooding and ebbing, especially at the east station, are not clearly defined. Initially, this observation raised some doubts about the validity of the data. However, because independent current measurements at this site with the ADCP and Geoprobe are in excellent agreement, the data are believed to be reliable, and the variable timing and directions of the ebb and flood currents at this and the other sites are probably real and caused by wind forcing.

The unfiltered observed (15-minute averages) and the low-pass filtered wind speeds and directions at the quarry station during the winter and summer deployments are given in figures 23 through 25, respectively. During the winter deployment period the wind speed was more steady than in the summer and generally was from the west (about 240°). As confirmed by the low-pass filtered wind data, when the mean wind speed was above 2.5 m/s (maximum about 6 m/s), the direction was steady from about 240°. When the mean wind speed was lower than 2 m/s, the direction was variable (fig. 23). In contrast, during the summer deployment, the wind speed was low and variable. When the mean wind speed was less than 2 m/s, wind directions changed diurnally along the axis of the embayment (i.e. between about 240° and 60°; fig. 24). The summer characteristics of the wind patterns could be caused by sea-land breeze in the summer. Different wind characteristics in winter and summer induced very different wind-driven circulation which was superimposed on the tidal currents.

Consider the current data at the east station from the winter period (fig. 9). The tidal currents are generally bi-directional except for calendar days between 49 and 53, 62 and 64, and 75 and 80. During these periods, which generally coincided with neap tides, the wind speed exceeded 3 to 4 m/s, and held steady from about 240°. Timing and directions of ebbing and flooding are less predictable during those times because of the superposition of the wind driven circulation (from sustained westerly winds) on weak (neap) astronomical tides. Tidal currents at both the west and center stations (figs. 10 and 11) exhibited properties similar to those at the east station in winter. For example, between days 74 and 80, the near surface (bin 7) tidal current direction at the west station was about 60° to 90°, the approximate wind direction at that time. Wind-driven circulation was most apparent at this site, probably because it is near the end of the inlet and water depth is shallower there than at the others sites, thus tidal currents from astronomical forcing would be expected to be small.

The effects of wind in the summer were somewhat different. As previously noted, wind speed was, on average, less than 2 m/s, but the directions changed more regularly in a diurnal cycle without the periods of sustained westerly winds seen during the winter period. Tidal currents, although generally weak, had a slightly more bi-directional character during the summer that they did during the winter period, although there was an occasional missing tidal cycle depending upon whether the wind-driven circulation reinforced or canceled the astronomical tidal currents (figs. 12 to 14).

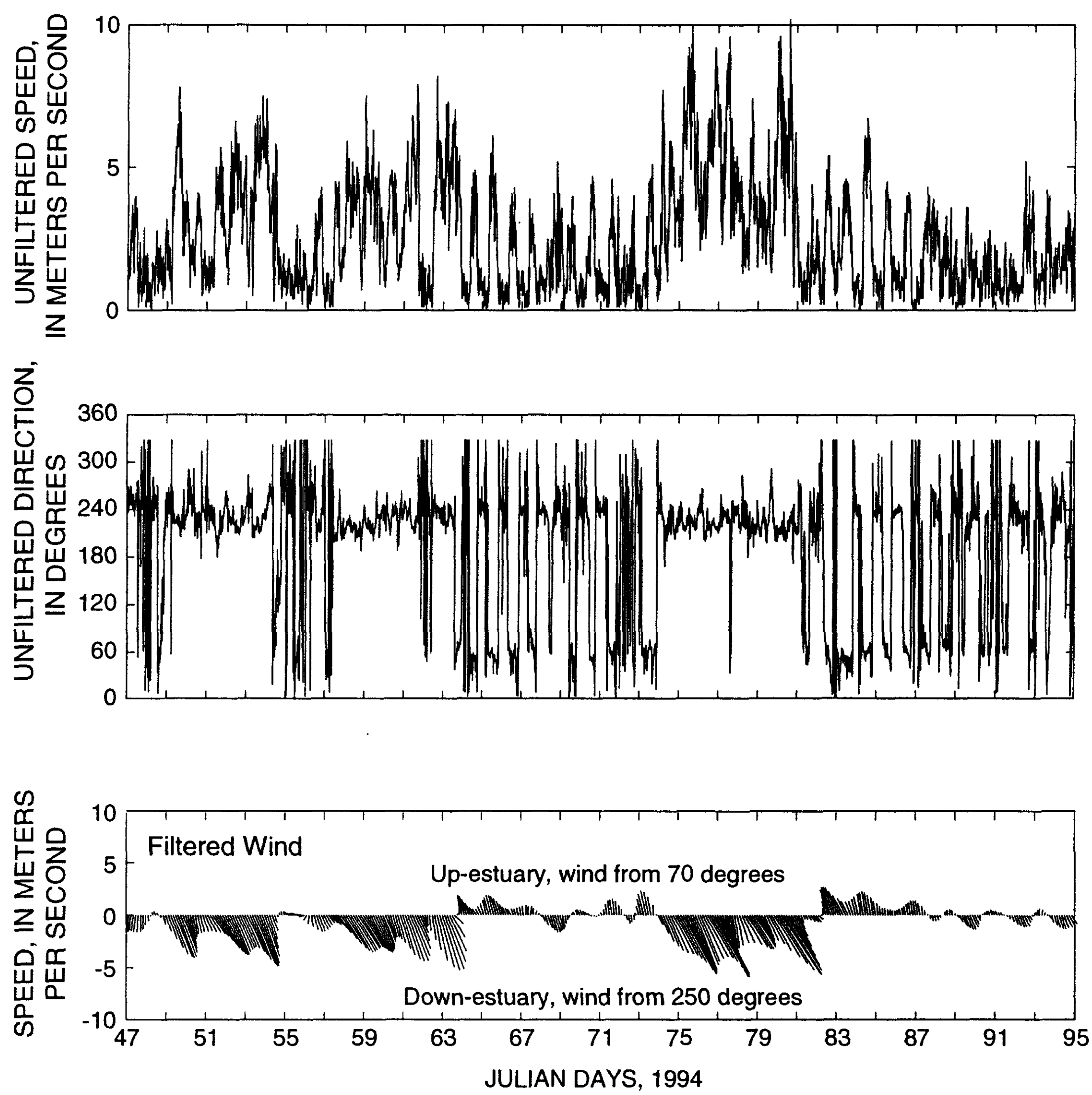


Figure 23. Unfiltered wind speed and direction, and filtered wind velocity vectors at the quarry station during the winter deployment period.

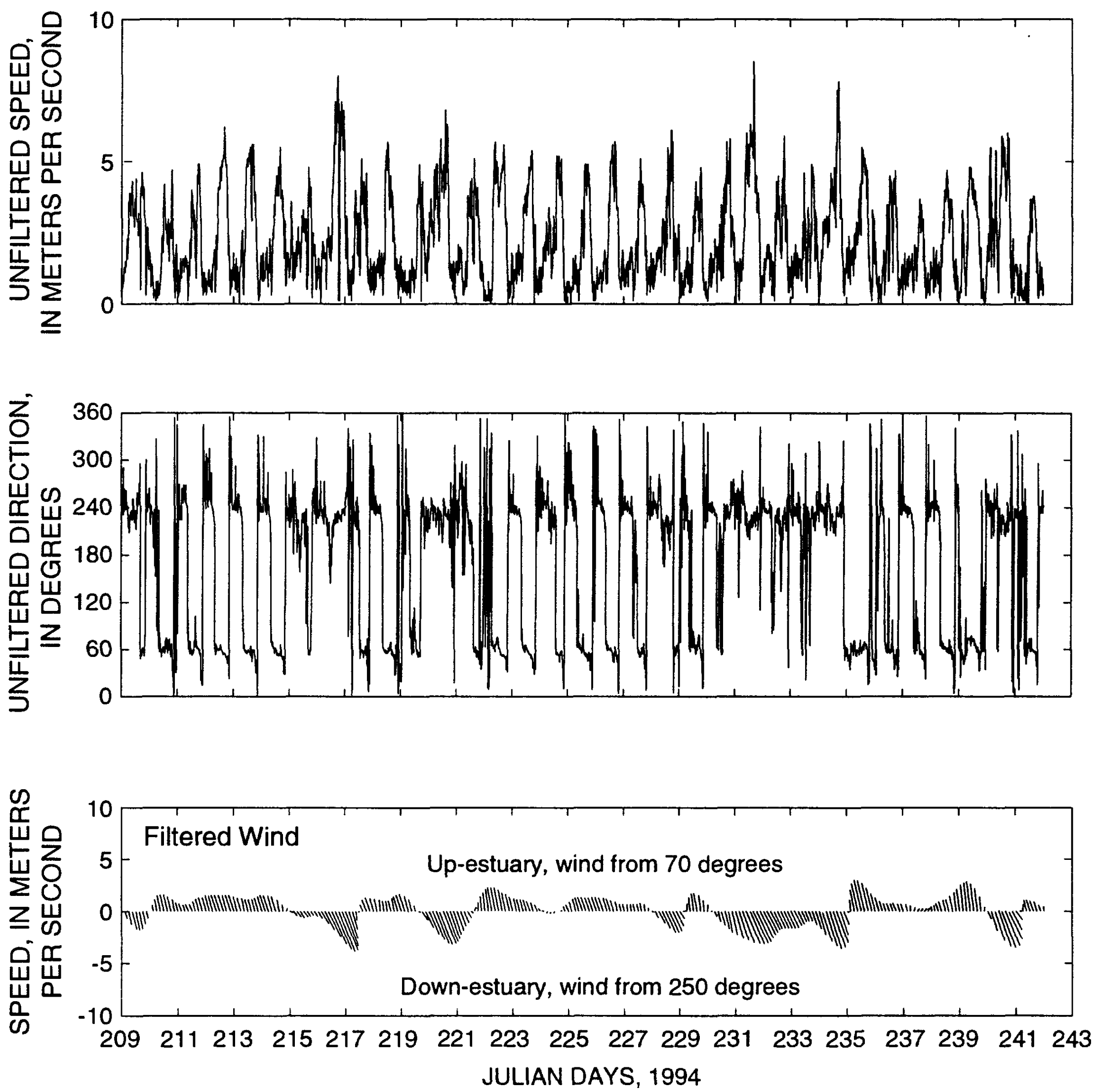


Figure 24. Unfiltered wind speed and direction, and filtered wind velocity vectors at the quarry station during the summer deployment period.

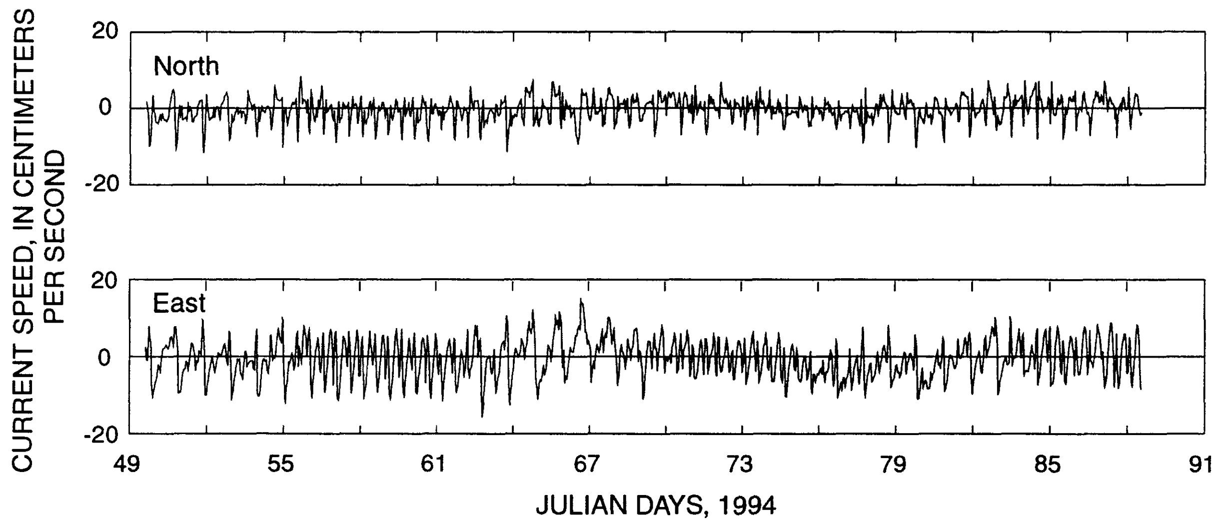


Figure 25. North and east components of the current velocity measured with the current meter on the Geoprobe, at 1.2 meters above the bed.

Residual Circulation Pattern

Residual circulation is the net or long-term-average current embedded in the flooding and ebbing motions of tidal currents. Driving mechanisms that control residual circulation include non-local forcing such as coastal sea level changes, and local forcing such as wind stress, river inflows, density gradients, and tidal current interactions with basin geometry and bathymetry. The characteristic time-scale of residual currents is typically several days or longer. Thus, the residual currents describe the net water movements after the high frequency motions of the water mass, such as the astronomical tidal signals, have been removed. Residual currents can be derived from time-series of velocity data using averaging or low-pass filtering techniques. In this application, a low-pass filter was applied to the time-series of the ADCP and Geoprobe velocity data to remove the high frequency variances with periods shorter than most astronomical tides. (A cut off of 30 hours was used for the ADCP data and 35 hours for the Geoprobe data). The resulting low-pass filtered data are displayed in the form of stick diagrams (figs. 26 to 32).

In most energetic tidal systems, the low-pass filtered velocities are an order of magnitude smaller than the tidal velocities. Interestingly, the low-pass filtered velocity data in Sinclair Inlet are of the same order of magnitude as the unfiltered (tidal) velocity data.

The low-pass filtered current vectors that describe residual currents near the bottom are from the Geoprobe (fig. 26). Low-passed currents from the lowest sensor are slightly dissimilar to the other three, which can be partially explained by the small magnitudes of the currents, which are often close to the estimated error of 0.5 cm/s for the instrument. A small systematic offset in one of the current components was also found for the lowermost sensor, contributing to the apparent slight directional differences in comparison to the other measurements. Residual bottom-current vectors and the hourly-averaged wind vectors plotted in figure 26 clearly show that the low frequency bottom flow is generally in an opposing direction to the wind. Apparently, the residual circulation in Sinclair Inlet has vertical structure in which the bottom flow is driven into and out of the Inlet in response to the upper current that is forced directly by the surface wind. This is more fully defined by examining the residual currents calculated from the three ADCP data sets from the two deployment periods.

Residual currents at 1.95 m above the bed and higher are defined by the filtered ADCP data shown in figures 27 to 32. Prior to day 64 during the winter deployment, residual flow at the east station is generally directed into Sinclair Inlet, except for near surface where flow is directed out of the inlet. There are a few brief periods of reversal near day 55 and 56. During this time winds were from about 240° (except near day 55 and 56).

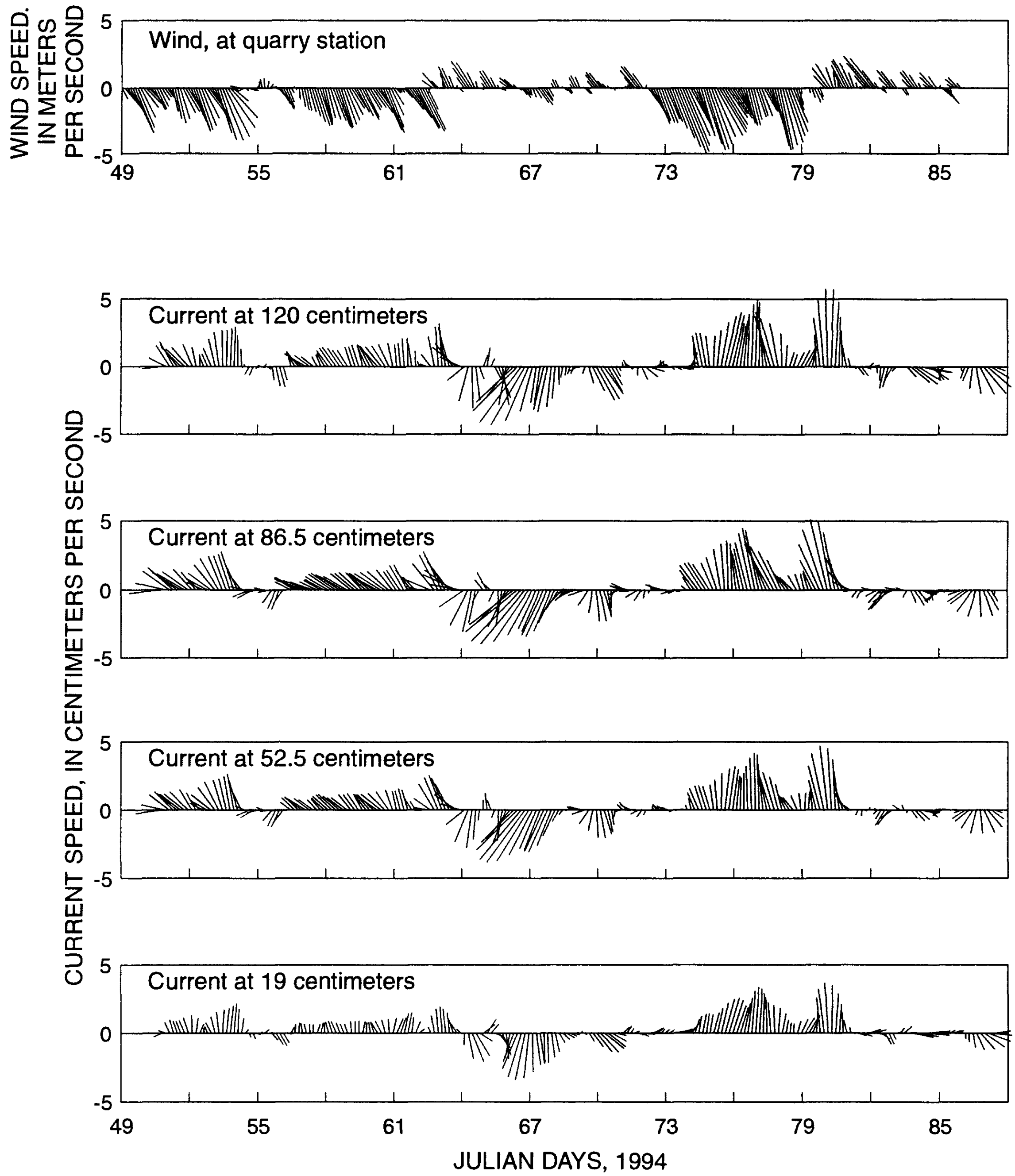


Figure 26. Low-pass filtered wind at quarry station and burst-average current vectors measured with instruments on the Geoprobe. Currents are at indicated distances above the bed. Vertically upward vector is 250 degrees clockwise from North (current into the inlet; wind out of the inlet).

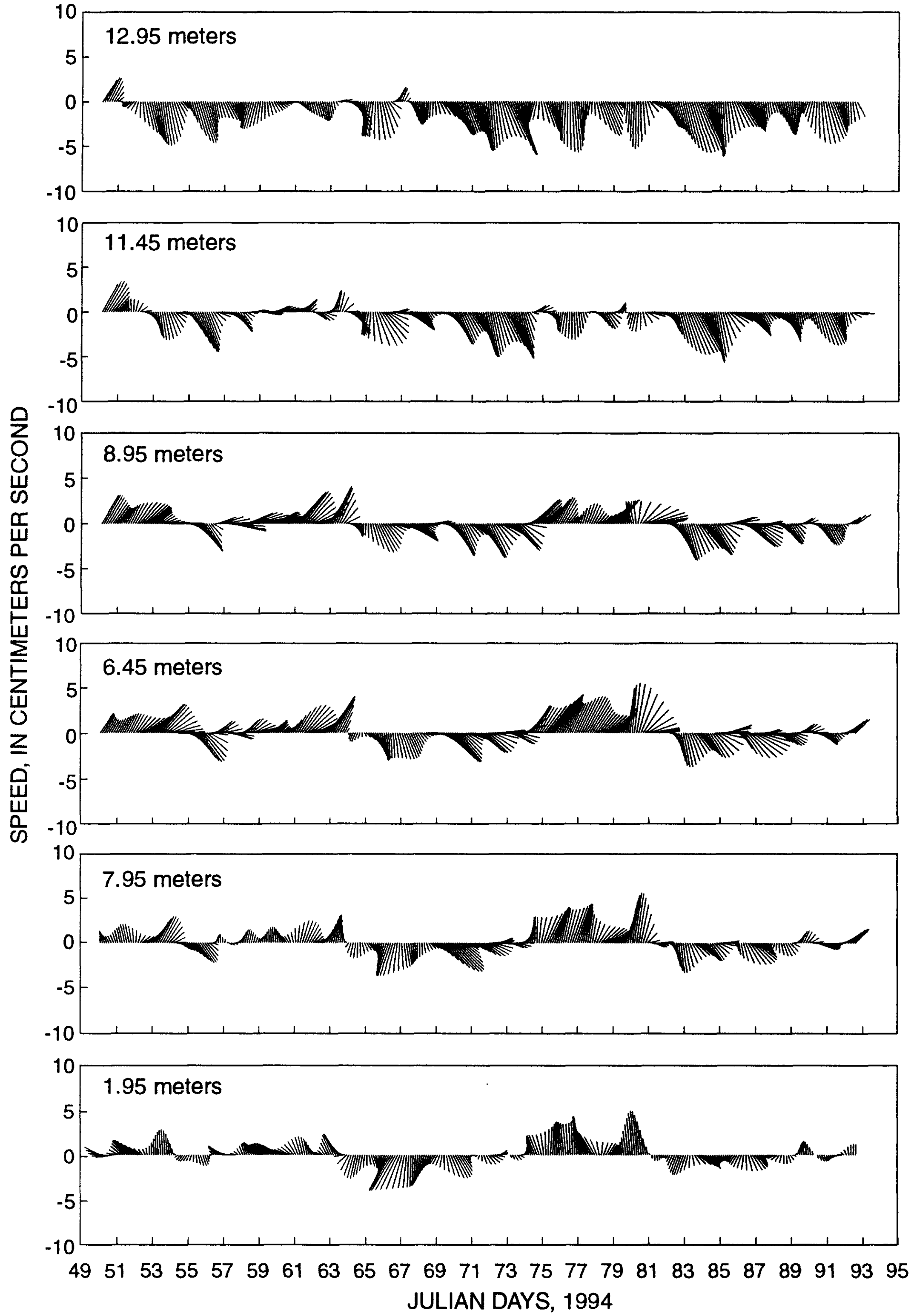


Figure 27. Stick diagrams of residual current vectors at the east station during the winter deployment period. Vertically upward vector is 250 degrees clockwise from North (current into the inlet). Distances are above bed.

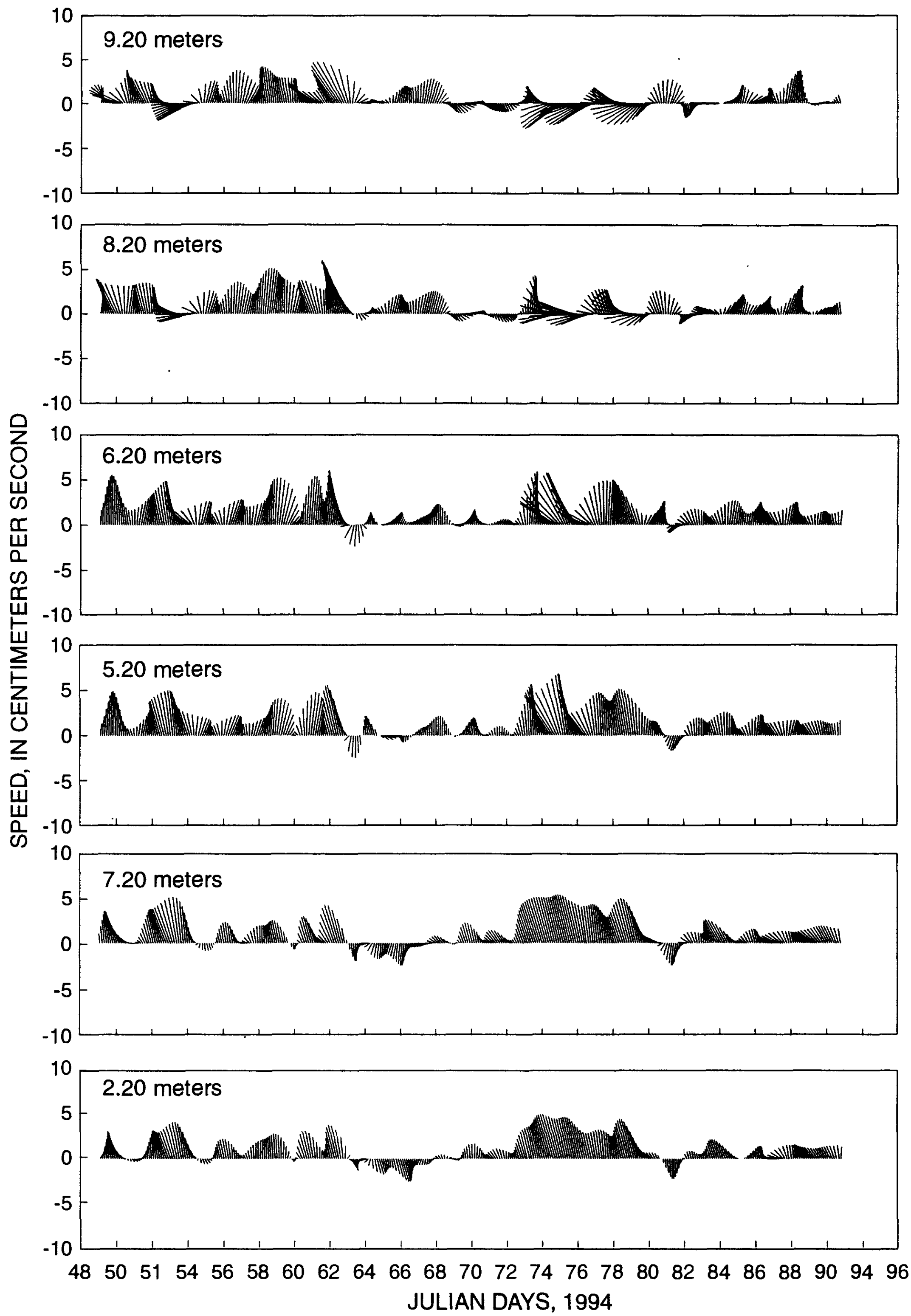


Figure 28. Stick diagrams of residual current vectors at the center station during the winter deployment period. Vertically upward vector is 250 degrees clockwise from North (current into the inlet). Distances are above bed.

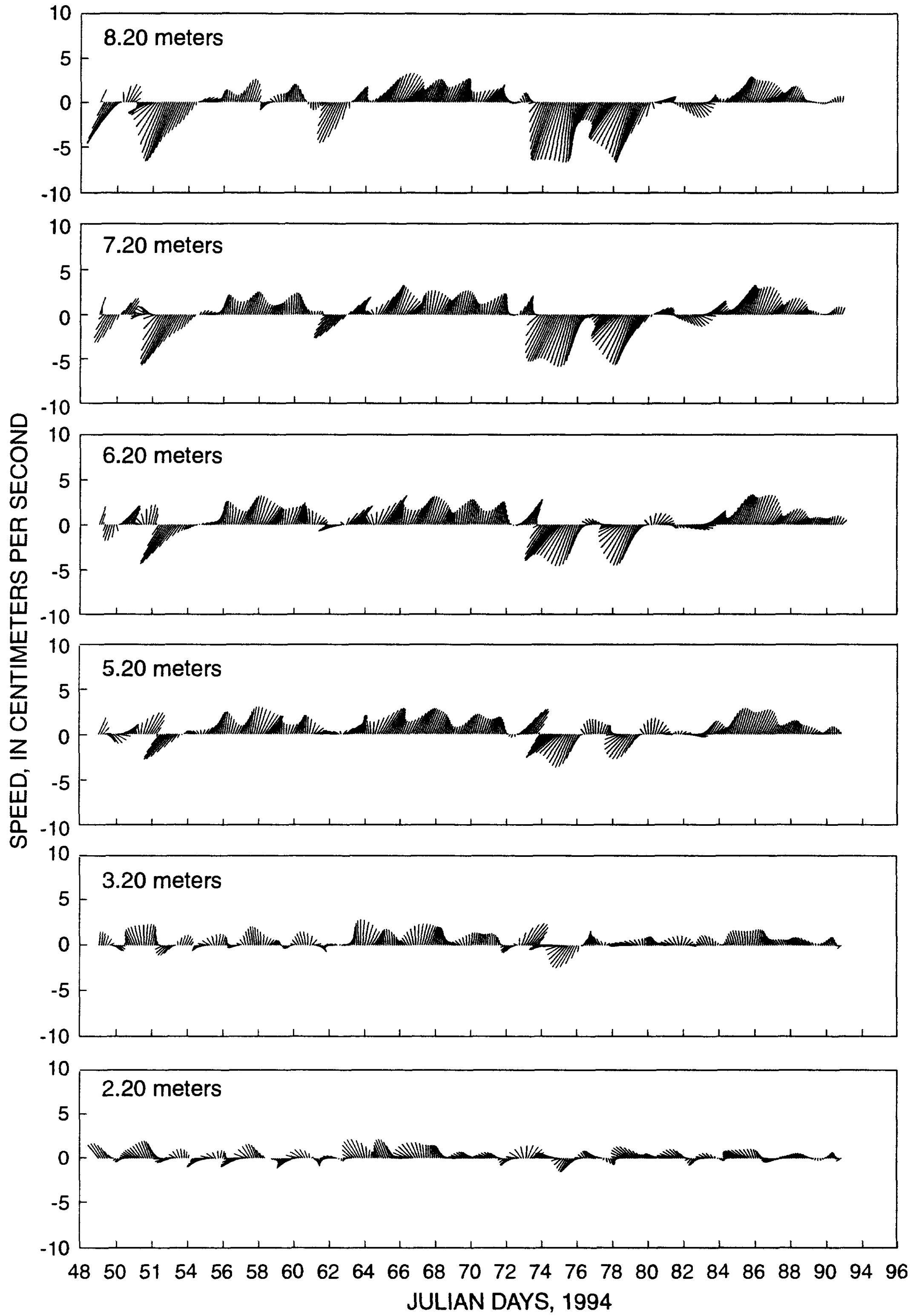


Figure 29. Stick diagrams of residual current vectors at the west station during the winter deployment period. Vertically upward vector is 250 degrees clockwise from North (current into the inlet). Distances are above bed.

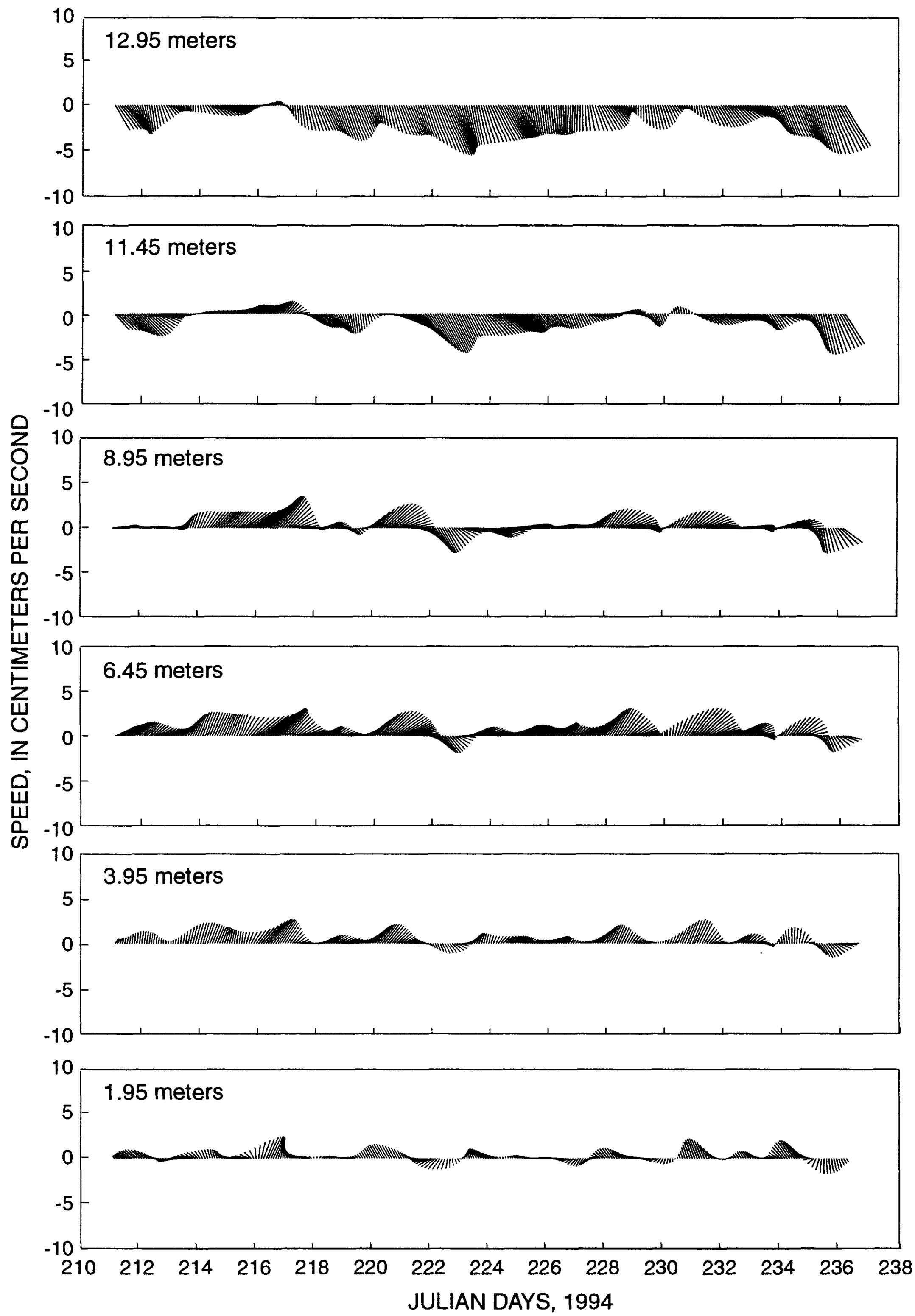


Figure 30. Stick diagrams of residual current vectors at the east station during the summer deployment period. Vertically upward vector is 250 degrees clockwise from North (current into the inlet). Distances are above bed.

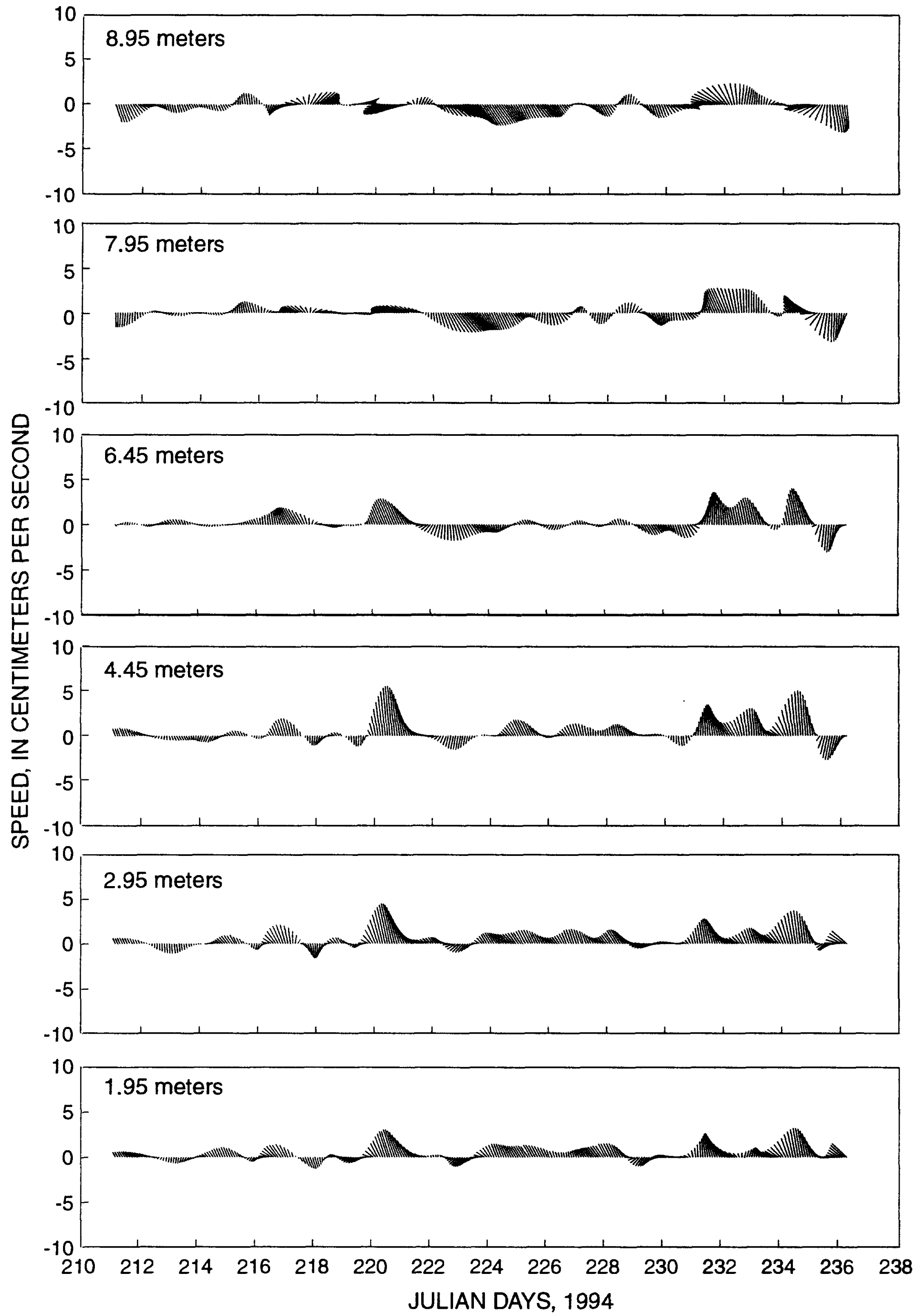


Figure 31. Stick diagrams of residual current vectors at the center station during the summer deployment period. Vertically upward vector is 250 degrees clockwise from North (current into the inlet). Distances are above bed.

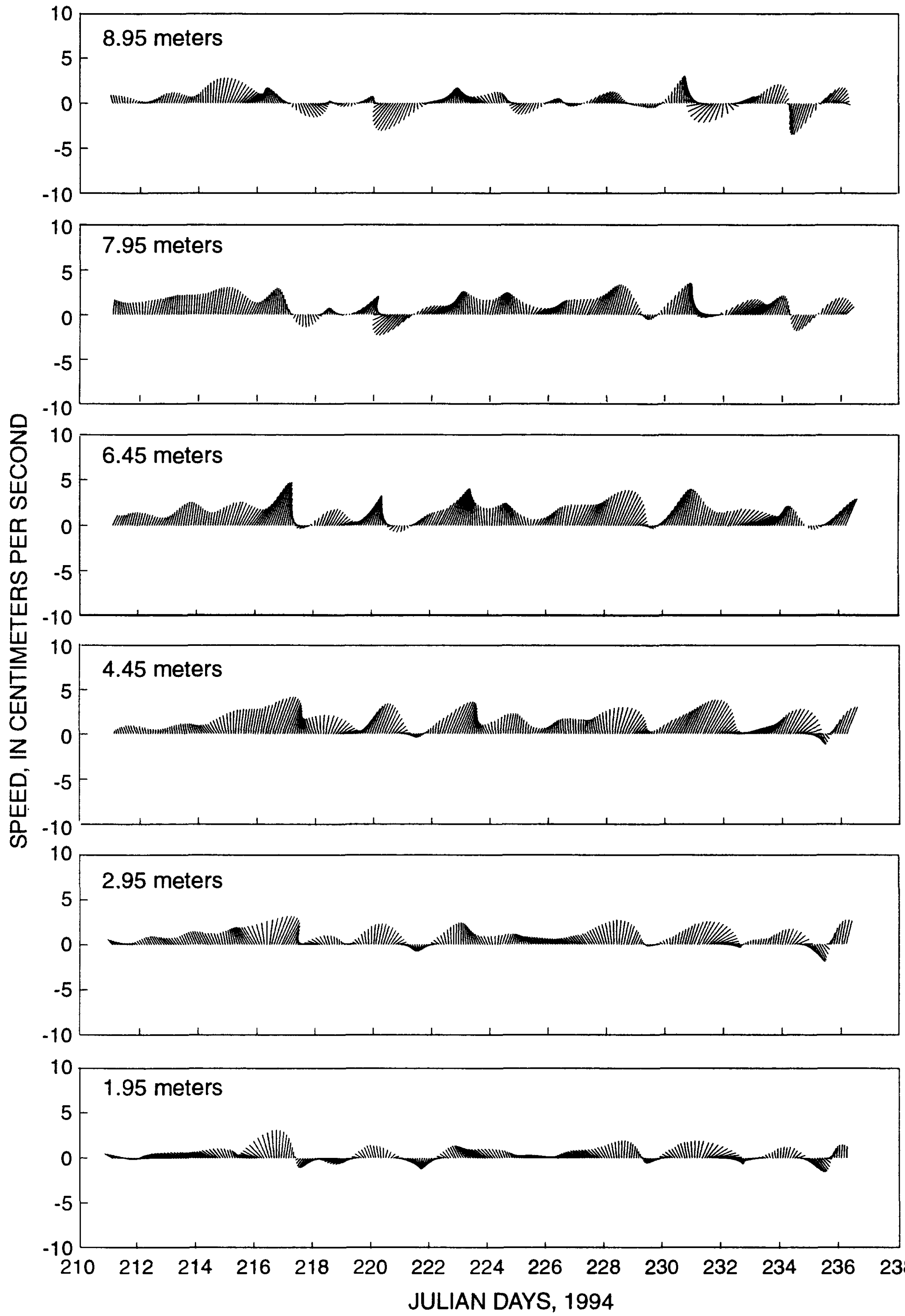


Figure 32. Stick diagrams of residual current vectors at the west station during the summer deployment period. Vertically upward vector is 250 degrees clockwise from North (current into the inlet). Distances are above bed.

At those times during the winter deployment period when the wind is weak and wind direction variable, for example from calendar day 64 to 73, and 81 to 92 (fig. 23), the residual currents for the entire water column at the east station are out of the inlet (fig. 27), while the residual currents at center station are small, variable but generally into the inlet (fig. 28). For the same period of time, stronger residual currents into the inlet are seen at west station over the entire water column (fig. 29). Between day 75 and 81 when the averaged wind speed was about 5 m/s from about 240° a pattern of near-bottom inflow and near-surface outflow was established (fig. 33). At both east and center stations the near-surface water mass was moving out of the inlet, and the near-bottom water mass was moving into the inlet (figs. 27 to 32). At the west station, which was located near the end of the Sinclair Inlet embayment and where the water was shallower than at the other two sites, surface currents were also driven out of the inlet by the wind, but bottom flows into the inlet were not well developed (fig. 29). The characteristics of the residual currents described in these windows of time showed the examples of the possible responses of the Sinclair Inlet system to the changing wind. The residual current structures were less clear for other periods of time, perhaps because the driving mechanisms for the residual current were not easily separable.

Winds were generally less than 3 m/s with no significant storms during the second ADCP deployment period (fig. 24). Wind direction still tended to be generally from the east or west, but periods of sustained westerly winds were much shorter than during the winter period. In fact, the winds seemed to have a diurnal nature, and were from the east. However, there were occasional short periods of strong winds from the west. Residual currents during the summer period were somewhat similar to those in the winter period, but were less well developed, probably because of the shorter periods of sustained winds from one direction. Most notable were westerly residual currents into the inlet at the east and center stations (figs. 30 and 31) near the bottom (and mid-depth at the east station) near times of prevailing westerly minds (days 217, 221, and 231). During times of diurnal winds (days 209 to 215 and 222 to 228), the most notable character to the residual currents was easterly flow out of the inlet near the surface at the east station and westerly flow into the inlet especially at mid-depth at the west station (fig. 32). Both the surface and near- bottom residual currents were smaller than the residual currents in the middle of the water column. This three-dimensional residual flow structure was probably caused by the local geometry and bathymetry. On average, there was a tendency to form a counter clockwise residual current gyre in Sinclair Inlet during the summer period.

Salinity and Temperature

Time series of near-bottom salinity and temperature are plotted using data from the ADCPs (figs. 34 and 35) and the Geoprobe (fig. 36). In addition, salinity-and temperature-data over the water column at different times on one day during each of the deployment periods are given in table 10. Because of bio-fouling of the conductivity sensors on the ADCPs during the summer deployment, there are only perhaps one week of salinity data from that deployment period that are deemed valid. However, when the conductivity sensors were fouled, the temperature sensors still functioned normally; therefore, temperature data from the summer field period are plotted in figure 35.

Generally, not much insight can be gained from the salinity or temperature records. Based on the measured data, the salinity differences within Sinclair Inlet during the deployment periods appear small. Continuously recorded near-bottom salinities collected using instruments on the Geoprobe and the ADCPs ranged between about 28.7 o/oo and 29.8 o/oo, and decreased during most of the winter deployment period. Near-bottom salinities measured with instruments on the ADCP at the east station are generally about 0.1 o/oo higher than those at the center and west stations, while salinities at the center and west stations are nearly identical. Superimposed on this longer-term trend are downward spikes, the largest of which have magnitudes of about 0.3 o/oo. Salinities in vertical profiles on August 19, 1994, were also in the 28.7 o/oo to 29.8 o/oo range, were fairly uniform, but tended to be slightly lower near the surface than near the bottom (table 10); however, salinities in the vertical profiles on March 1, 1994, had an upper limit of 30.8 o/oo and varied erratically over the depth.

During the winter deployment period temperatures measured at the Geoprobe increased slowly with time from about 8°C to nearly 9°C (fig. 36, table 11). A low frequency cycle in temperature is present that is probably related to the fortnightly spring-neap cycle, but the data records are too short to validate this oscillation. Superposed on these longer-term changes are spikes that were down during the early part of the record (day 50 to day 61)

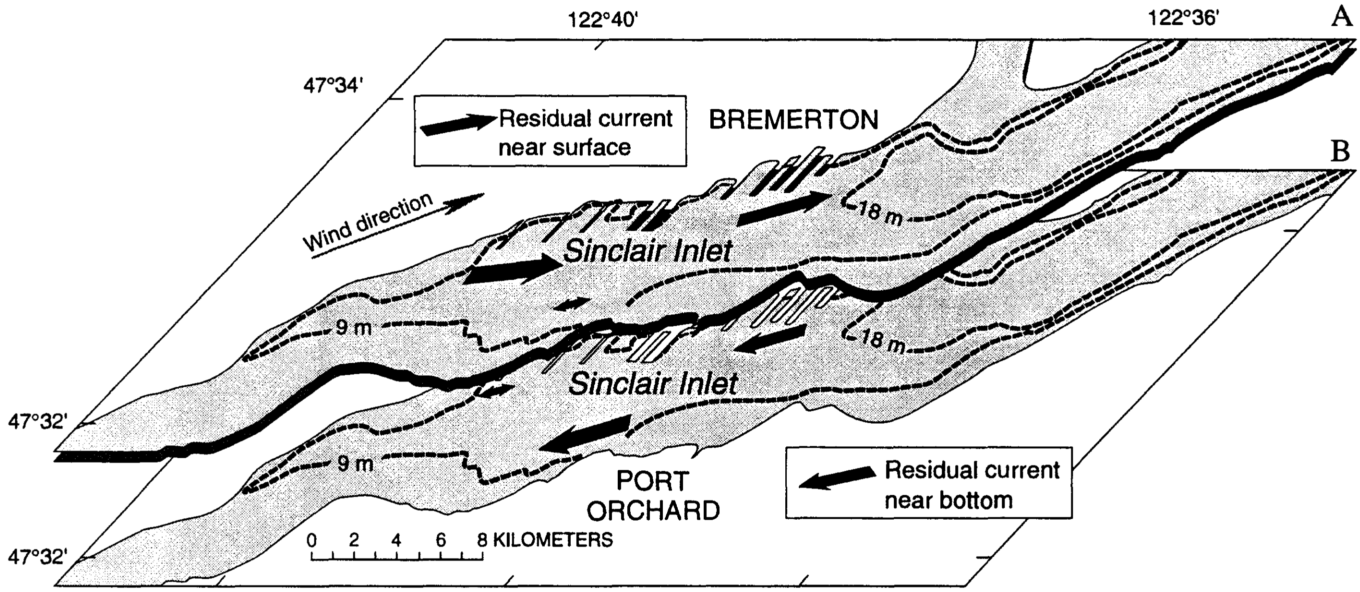


Figure 33. Residual circulation in Sinclair Inlet with a south westerly wind (winter deployment period). Figure A shows near surface residual motion; figure B shows near bottom residual motion.

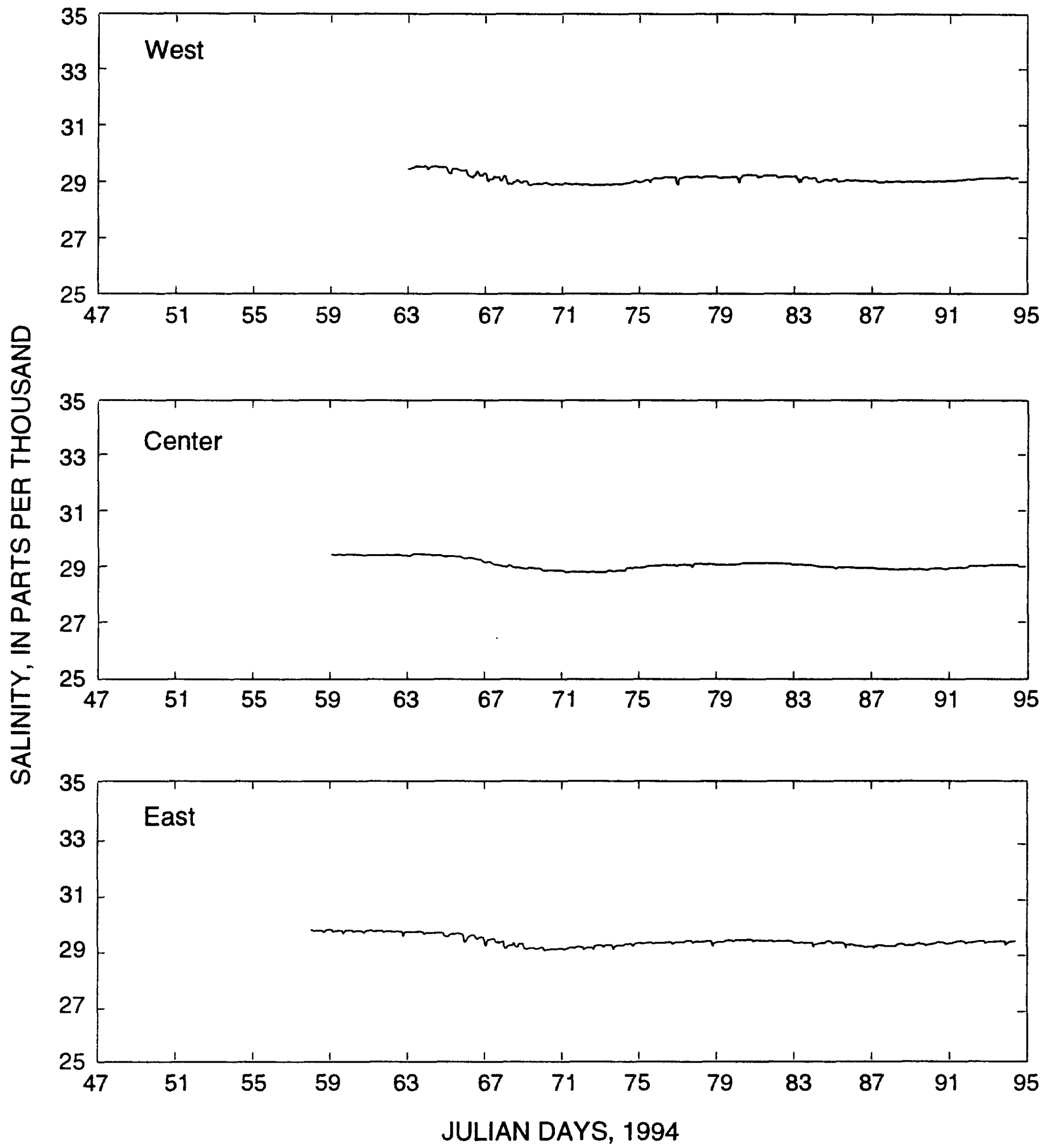


Figure 34. Salinity at the west, center, and east stations during the winter deployment period.

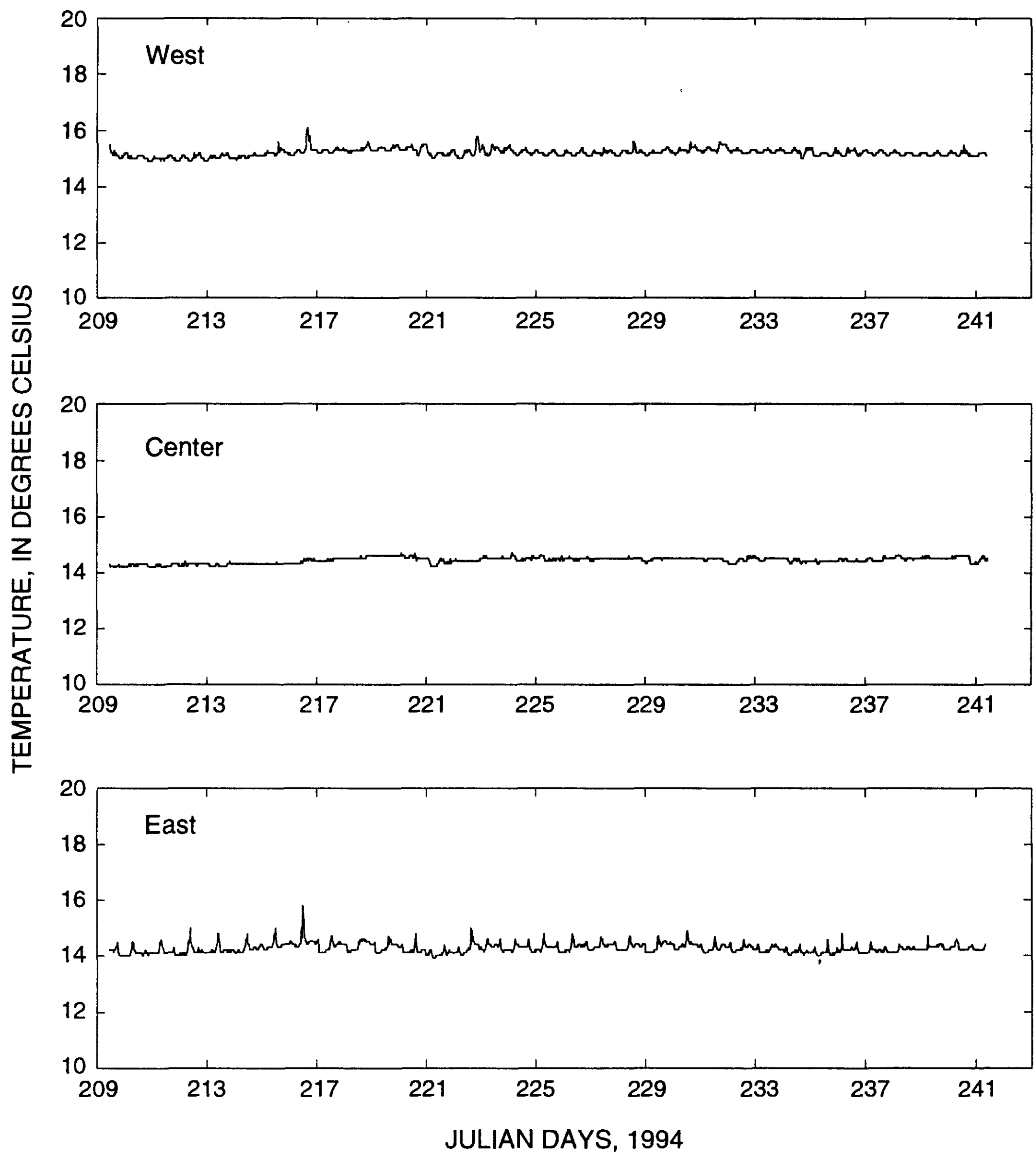


Figure 35. Temperature at the west, center, and east stations during the summer deployment period.

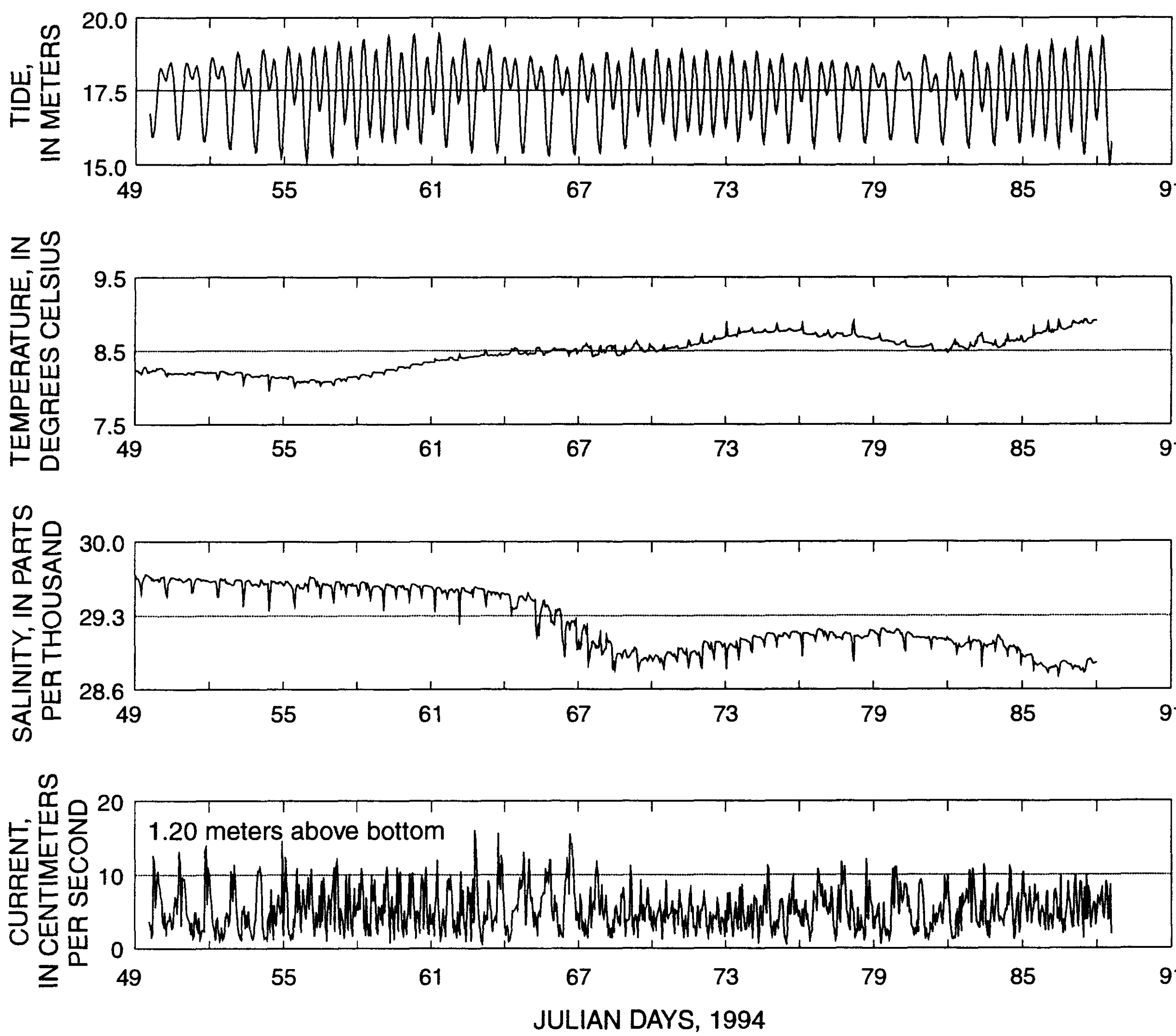


Figure 36. Hourly values of tide (depth), temperature, salinity, and current speed measured with instruments on the Geoprobe during the winter deployment period.

Table 10.-- *Water temperature, salinity, turbidity, and suspended-sediment concentrations in samples collected from three measurement stations in Sinclair Inlet at various phases of the tidal cycle on March 1 and August 19, 1994*

[m, meters; °C, degrees Celsius; o/oo, parts per thousand; NTU, nephelometric turbidity units; mg/L, milligrams per liter; --, no data]

Station	Distance above bed (m)	Time	Temperature (°C)	Salinity (o/oo)	Turbidity (NTU)	Suspended-sediment concentration: Total (mg/L)	Suspended-sediment concentration: Inorganic (mg/L)
Samples from March 1, 1994							
Center	0.5	0720	--	30.8	9.7	--	--
Center	0.5	0745	--	29.7	6.0	34	--
Center	1.0	0725	--	31.2	2.1	25	--
Center	2.0	0730	--	29.8	0.55	5	--
Center	5.0	0735	--	30.8	0.27	2	--
Center	10.0	0737	--	29.7	0.18	2	--
West	0.5	0751	--	29.7	2.7	25	--
West	1.0	0755	--	29.6	1.5	33	--
West	2.0	0759	--	30.6	0.36	3	--
West	5.0	0802	--	29.1	0.35	1	--
West	10.0	0805	--	30.0	0.33	2	--
East	0.5	0815	--	29.9	8.7	70	--
East	1.0	0822	--	29.8	0.43	4	--
East	2.0	0828	--	30.8	0.40	3	--
East	5.0	0825	--	29.8	0.20	3	--
East	10.0	0831	--	30.5	0.19	3	--
Center	0.5	0904	--	30.6	2.1	36	--
Center	1.0	0907	--	29.6	1.0	70	--
Center	2.0	0910	--	30.8	0.26	5	--
Center	5.0	0913	--	29.8	0.23	6	--
Center	10.0	0915	--	29.6	0.13	3	--
West	0.5	0923	--	29.7	5.5	74	--
West	1.0	0926	--	30.5	0.32	4	--
West	2.0	0929	--	29.5	0.26	2	--
West	5.0	0932	--	30.4	0.25	4	--
West	10.0	0935	--	29.2	0.12	3	--
East	0.5	0945	--	30.0	11.0	2	--
East	1.0	0947	--	29.9	1.5	13	--
East	2.0	0951	--	30.8	0.36	3	--
East	5.0	0953	--	29.2	0.25	2	--
East	10.0	0956	--	30.6	0.17	99	--
Center	0.5	1104	--	29.7	0.37	3	--
Center	1.0	1108	--	30.7	0.76	4	--
Center	2.0	1111	--	30.8	0.45	3	--
Center	5.0	1114	--	30.6	0.15	3	--
Center	10.0	1117	--	30.2	0.11	11	--
West	0.5	1122	--	30.5	6.5	36	--
West	1.0	1127	--	30.5	4.5	59	--
West	2.0	1131	--	30.6	0.43	10	--
West	5.0	1134	--	30.5	0.23	2	--
West	10.0	1136	--	29.7	0.19	3	--
East	0.5	1145	9.0	30.7	0.47	45	--
East	1.0	1150	8.5	29.8	0.44	3	--
East	1.0	1153	9.0	30.7	0.43	2	--
East	2.0	1157	8.5	30.8	0.43	2	--
East	5.0	1200	8.5	30.8	0.37	5	--
East	10.0	1203	9.0	29.8	0.22	3	--
Center	0.5	1307	9.0	29.7	4.4	34	--
Center	1.0	1311	9.0	29.7	0.31	4	--
Center	2.0	1314	9.0	29.7	0.30	4	--
Center	5.0	1318	8.5	29.7	0.18	2	--
Center	10.0	1321	9.0	28.8	0.46	4	--

Table 10.-- *Water temperature, salinity, turbidity, and suspended-sediment concentrations in samples collected from three measurement stations in Sinclair Inlet at various phases of the tidal cycle on March 1 and August 19, 1994--Continued*

Station	Distance above bed (m)	Time	Temper-ature (°C)	Salinity (o/oo)	Turbidity (NTU)	Suspended-sediment concentration Total (mg/L)	Suspended-sediment concentration Inorganic (mg/L)
Samples from March 1, 1994							
West	0.5	1326	9.0	29.7	7.1	49	--
West	1.0	1330	8.5	29.6	0.70	6	--
West	2.0	1333	8.5	29.6	0.46	5	--
West	5.0	1336	8.5	29.4	0.33	2	--
West	10.0	1339	--	28.9	0.25	3	--
East	0.5	1346	9.0	29.7	3.3	45	--
East	1.0	1349	9.0	30.8	0.39	2	--
East	1.0	1352	9.0	30.8	0.39	2	--
East	2.0	1355	9.0	29.7	0.37	2	--
East	5.0	1358	9.0	29.5	0.29	2	--
East	10.0	1401	8.5	29.5	0.26	2	--
Center	0.5	1601	--	29.4	1.6	22	--
Center	1.0	1604	--	29.4	0.23	3	--
Center	2.0	1607	--	29.4	0.22	3	--
Center	5.0	1610	--	29.2	0.20	2	--
Center	10.0	1612	--	28.9	0.17	2	--
West	0.5	1617	--	29.4	0.48	58	--
West	1.0	1620	--	29.4	0.32	4	--
West	2.0	1623	--	29.4	0.24	3	--
West	5.0	1626	--	29.2	0.14	2	--
West	10.0	1628	--	28.5	0.10	2	--
East	0.5	1635	--	29.4	0.56	9	--
East	1.0	1638	--	29.5	0.28	4	--
East	1.0	1641	--	29.3	0.28	4	--
East	2.0	1643	--	29.2	0.14	2	--
East	5.0	1648	--	29.2	0.14	3	--
East	10.0	1650	--	29.2	0.13	2	--
Center	0.5	1804	9.0	30.7	6.5	55	--
Center	1.0	1809	--	29.5	0.27	3	--
Center	2.0	1812	9.0	30.6	0.26	3	--
Center	5.0	1815	9.0	30.5	0.23	3	--
Center	10.0	1817	9.0	30.1	0.25	4	--
West	0.5	1829	9.0	30.6	2.7	20	--
West	1.0	1835	9.0	30.6	0.47	4	--
West	2.0	1839	9.0	30.5	0.34	3	--
West	5.0	1841	9.0	30.5	0.14	3	--
West	10.0	1844	9.0	30.5	0.13	3	--
East	0.5	1858	--	30.8	1.7	17	--
East	1.0	1901	9.0	30.8	5.7	44	--
East	1.0	1904	9.0	30.8	5.7	2	--
East	2.0	1908	9.0	30.8	0.37	9	--
East	5.0	1912	9.0	30.6	0.20	2	--
East	10.0	1915	9.0	30.7	0.37	2	--
Center	0.5	0640	14.7	29.6	7.7	64	7
Center	1.0	0645	14.6	29.7	2.9	22	3
Center	2.0	0648	14.7	29.8	0.76	5	2
Center	5.0	0655	15.0	29.7	0.55	4	2
Center	10.0	0658	15.7	29.5	0.51	3	1
West	0.5	0710	14.8	29.7	1.1	5	1
West	0.5	0713	14.9	29.7	1.0	4	2
West	1.0	0716	15.0	29.7	0.80	5	2
West	2.0	0720	15.1	29.7	0.75	4	1
West	5.0	0722	15.2	29.7	0.67	4	3
West	10.0	0726	16.3	29.3	0.57	3	1

Table 10.-- *Water temperature, salinity, turbidity, and suspended-sediment concentrations in samples collected from three measurement stations in Sinclair Inlet at various phases of the tidal cycle on March 1 and August 19, 1994--Continued*

Station	Distance above bed (m)	Time	Temperature (°C)	Salinity (o/oo)	Turbidity (NTU)	Suspended-sediment concentration	
						Total (mg/L)	Inorganic (mg/L)
Samples from March 1, 1994							
East	0.5	0735	14.3	29.8	7.3	51	6
East	1.0	0739	14.4	29.8	0.40	2	1
East	2.0	0741	14.5	29.7	0.39	5	2
East	5.0	0743	14.6	29.7	0.37	8	1
East	10.0	0745	14.8	29.7	0.52	2	1
Center	0.5	1000	14.8	29.7	1.9	8	1
Center	1.0	1005	14.9	29.7	1.5	7	1
Center	2.0	1008	15.0	29.7	0.65	3	1
Center	5.0	1011	15.5	29.7	0.55	3	2
Center	10.0	1013	17.2	29.1	0.50	3	2
Samples from August 19, 1994							
West	0.5	1020	14.9	29.7	2.8	14	2
West	0.5	1023	14.9	29.7	2.4	7	1
West	1.0	1027	15.0	29.7	1.4	6	2
West	2.0	1029	15.3	29.7	0.58	3	2
West	5.0	1032	15.8	29.7	0.47	2	2
West	10.0	1034	16.2	29.7	0.39	2	2
East	0.5	1042	14.5	29.7	2.0	10	3
East	1.0	1045	14.5	29.7	0.52	3	2
East	2.0	1047	14.6	29.8	0.45	3	2
East	5.0	1049	14.8	29.7	0.43	3	2
East	10.0	1051	15.3	29.7	0.40	2	2
Center	0.5	1330	14.6	29.7	1.6	8	2
Center	1.0	1336	16.0	29.7	1.2	6	2
Center	2.0	1343	15.1	29.7	0.75	4	2
Center	5.0	1346	16.0	29.7	0.50	2	2
Center	10.0	1348	17.0	29.6	0.60	2	2
West	0.5	1354	15.5	29.7	12.0	42	6
West	0.5	1358	15.6	29.7	4.1	15	3
West	1.0	1401	15.2	29.4	3.1	10	3
West	2.0	1403	15.0	29.7	2.0	10	1
West	5.0	1406	15.6	29.7	0.57	2	1
West	10.0	1408	17.0	29.5	0.53	3	1
East	0.5	1417	15.1	29.8	8.3	42	4
East	1.0	1419	15.0	29.7	0.80	4	1
East	2.0	1422	15.0	29.7	0.55	3	2
East	5.0	1422	15.5	29.7	0.51	3	2
East	10.0	1426	15.8	29.7	0.49	2	2
Center	0.5	1650	15.4	29.7	1.5	7	3
Center	1.0	1654	15.1	29.7	1.2	8	2
Center	2.0	1656	15.2	29.7	1.0	5	2
Center	5.0	1659	15.4	29.7	0.56	2	1
Center	10.0	1701	16.6	29.6	0.48	2	1
West	0.5	1708	15.4	29.7	1.4	4	1
West	0.5	1711	15.1	29.7	15.0	50	6
West	1.0	1713	15.3	29.7	0.85	5	2
West	2.0	1716	15.4	29.7	0.67	4	1
West	5.0	1718	15.6	29.6	0.57	3	1
West	10.0	1720	16.4	29.6	0.50	4	2
East	0.5	1730	14.7	29.7	15.0	63	7
East	1.0	1733	14.7	29.7	0.73	4	2
East	2.0	1736	14.7	29.7	0.54	2	1
East	5.0	1738	14.8	29.7	0.34	3	1
East	10.0	1740	15.3	29.7	0.32	3	2

Table 11.--*Summary statistics for temperature, salinity, and suspended-sediment concentration measured with instruments on the Geoprobe*

[°C, degrees Celsius; o/oo, parts per thousand; C_{98}, sediment concentration, subscript is height above bed in centimeters; mg/L, milligrams per liter; Std. Dev., Standard deviation]

Statistic	Temperature (°C)	Salinity (o/oo)	[1]C_{31} (mg/L)	C_{98} (mg/L)	C_{173} (mg/L)
Minimum	7.93	28.70	1.27	1.25	1.46
Maximum	9.00	29.70	4.90	5.21	3.63
Mean	8.48	29.25	2.34	2.09	2.27
Std. Dev.	0.23	0.28	0.58	0.47	0.39

but up during the latter part (day 62 to day 90). The timing of these spikes coincides with the downward spikes in salinity. These spikes also were evident in the record of another temperature sensor mounted on the Geoprobe (not shown). There is no obvious temperature stratification on the day during the winter period that vertical profiles were measured (table 10). During the summer deployment period, temporal and spatial differences in near-bottom temperature were small (fig. 35 and table 10); however, temperatures near the surface were about 1°C warmer than near the bottom (table 10). These data suggest that the salinity differences also would be small during this summer period. Temperatures at the east and center stations were nearly identical, while the temperature at the west station was about 1°C higher. Upward spikes in temperature are largest in the record for the east station, smaller but apparent at the west station, and nearly non-existent at the center station. This observation suggests that tidal excursion at the east station is slightly larger than at west and center stations. A rough estimate of tidal excursion at the east station, based on RMS current speed of 8 cm/s and an ebb-tide duration of 6 hours, is less than 2 km, which is less than the length of Sinclair Inlet.

Bottom Sediment

Results of particle-size analyses of bottom-sediment and other information suggest that Sinclair Inlet is a very low energy tidal environment with a median bottom sediment grain size at the Geoprobe site (east station) of less than 20 µm (table 12). Bottom photographs (figs. 37 to 41) , direct diver observations, and in-situ measurements of cohesive shear strength (table 13) indicate a relatively smooth, soft, muddy bottom. Bedforms and bottom roughness resulting from benthic biota feeding activity

Table 12.--*Particle-size distribution of bottom sediments near the Geoprobe (east station)*[1]

[µm, micrometer; AGS, aggregated sediment; DAGS, disaggregated sediment]

Size class (µm)	Weight percent AGS	Weight percent DAGS
250 - 500	2.5	0.8
125 - 250	5.7	1.5
90 - 125	7.9	3.4
63 - 90	9.4	0.6
45 - 63	10.3	1.3
20 - 45	17.7	29.5
less than 20	46.4	63.0

[1] The aggregated sediment was wet sieved with no prior treatment. The disaggregated sediment was treated with hydrogen peroxide to break down fecal pellets and other aggregates prior to wet seiving.

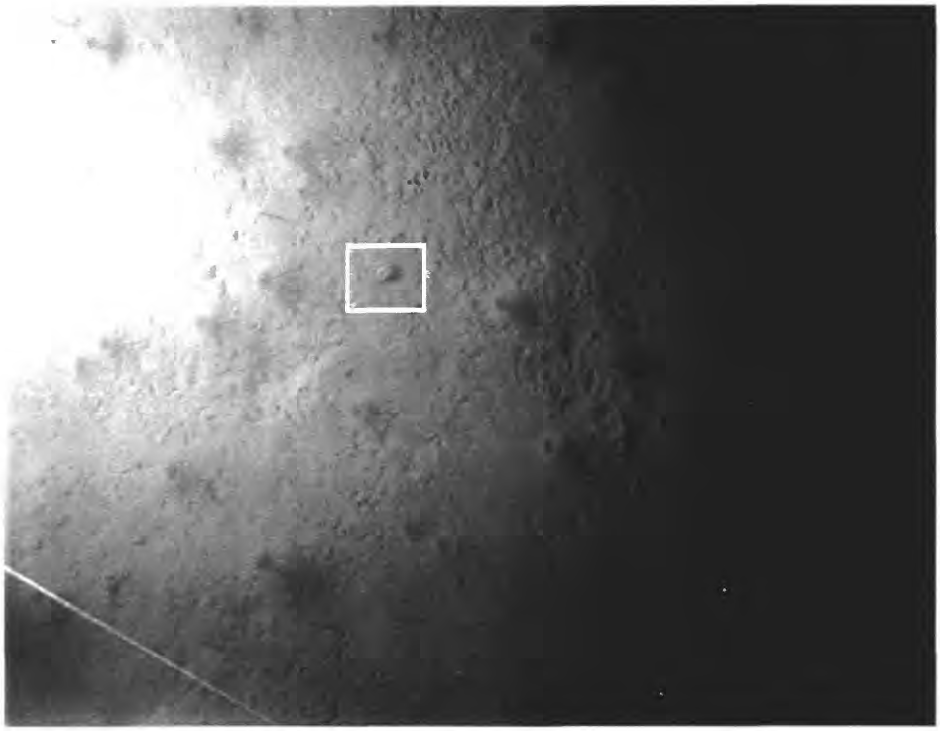


Figure 37. Photograph taken shortly after deployment on February 18, 1994. Note exposed Cerianthus anenome stalk in upper center of photograph (inside box). The top of the stalk is totally exposed and the surrounding sediment surface is relatively flat.

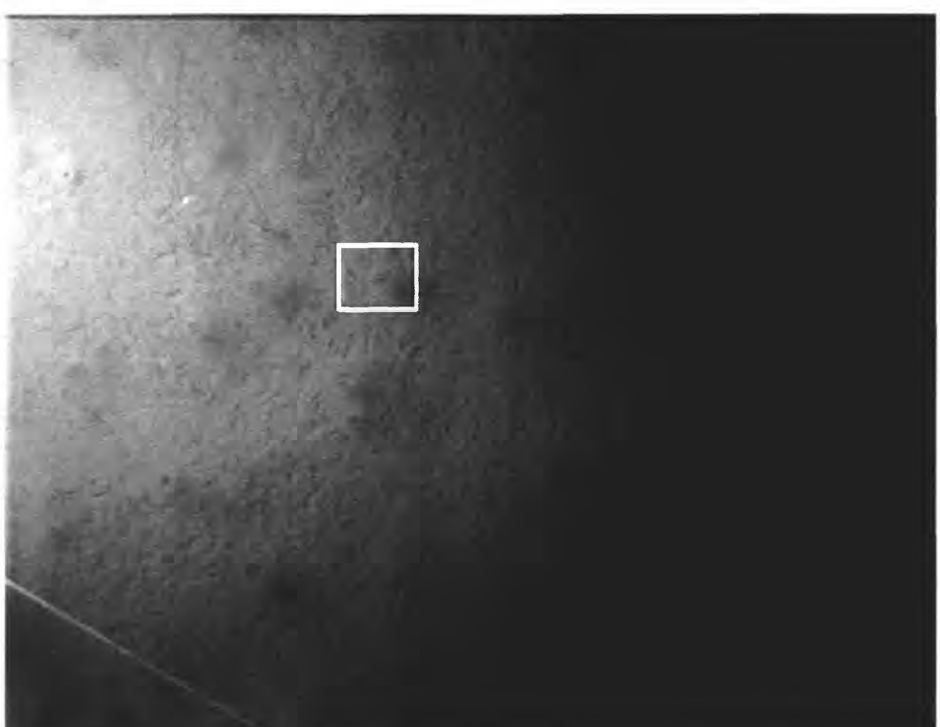


Figure 38. Photograph taken on March 4, 1994, shortly before recovery. Notice that the exposed anenome indicated in the February photo has reworked the surrounding sediment into a conical mound.

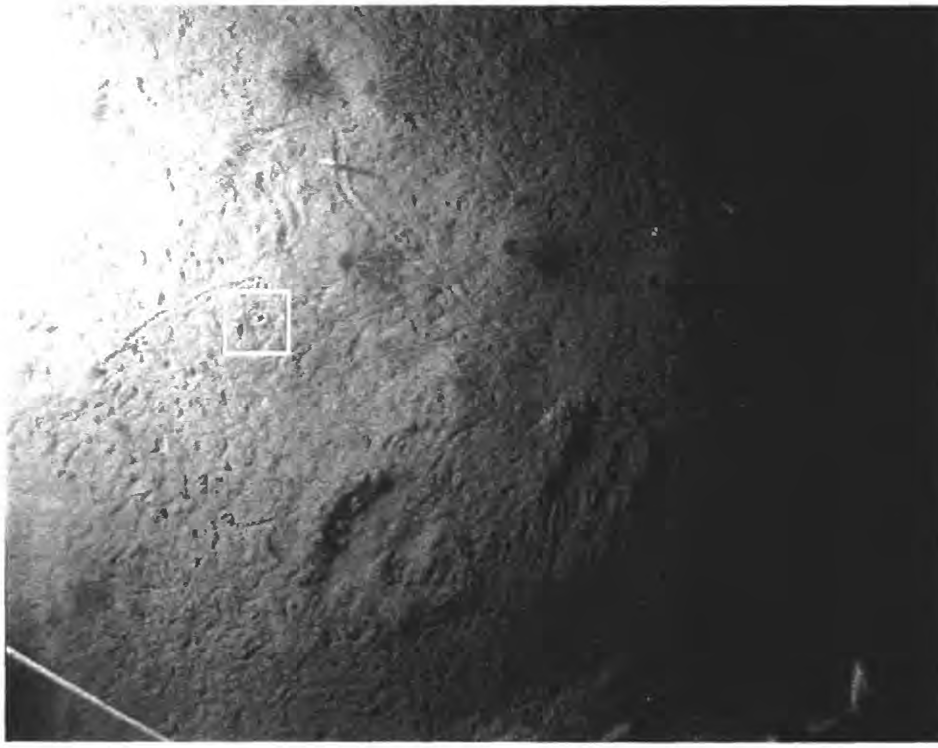


Figure 39. Photograph taken at 1435, March 1, 1994. Note large depressions in lower center of frame and exposed Cerianthus anenome stalk indicated in box.

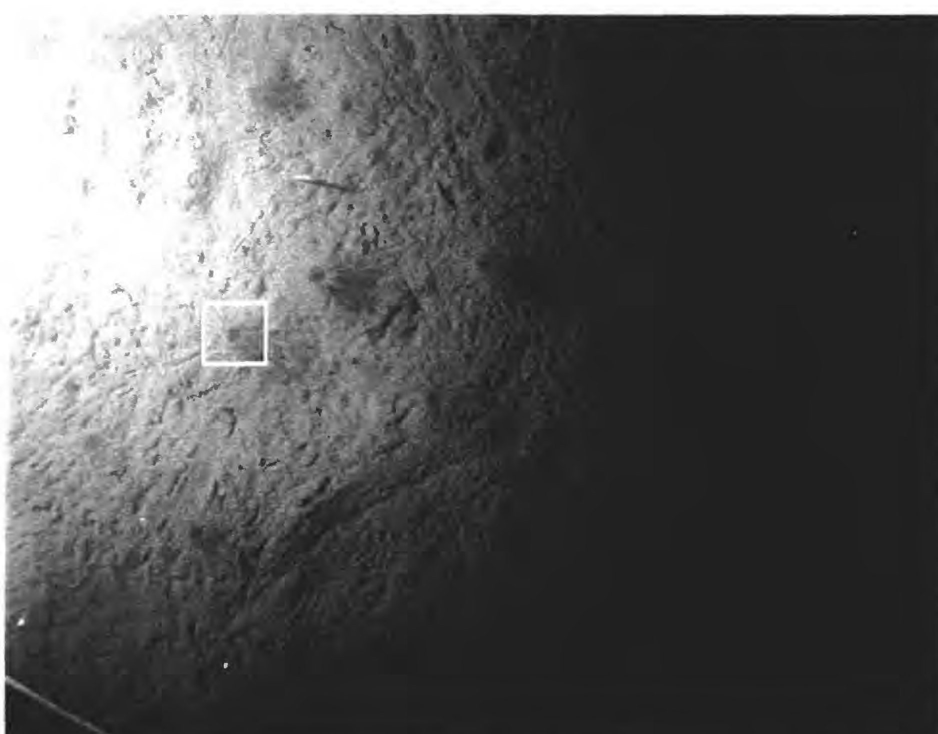


Figure 40. Photograph taken 16 hours later at 0635, March 2, 1994 shows reworking of depressions and development of a conical feeding mound around the previously exposed anenome.

Photo 1 taken at 1655, February 25

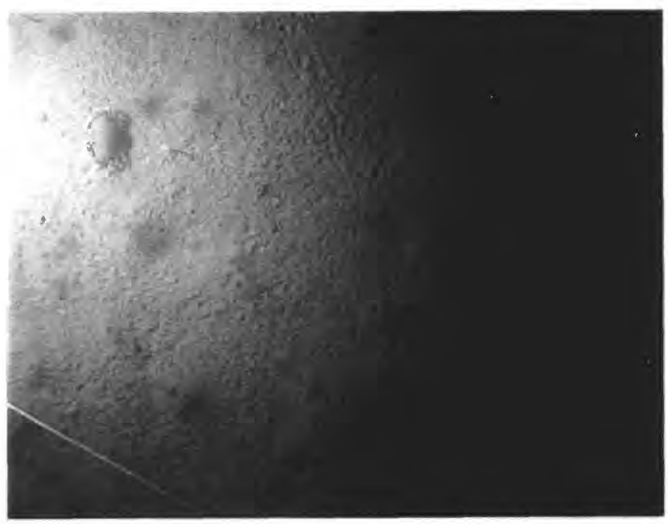


Photo 2 (+2 hours) taken at 1855, February 25

Photo 3 (+4 hours) taken at 2055, February 25

Figure 41. Four-hour photographic time series illustrating crab feeding effects on bottom morphology.

Table 13.--*Cohesive shear strength of bed sediment at three stations in Sinclair Inlet, Wash., estimated from in-place measurements with a vane-type shear meter*

Depth interval (centimeters)	Shear strength (thousands of dynes per square centimeter)
East station (two locations)	
0 - 2.5	14
3.8 - 6.4	14
11.4 - 14.0	14
0 - 2.5	14
3.8 - 6.4	12
11.4 - 14.0	14
Center station	
0 - 2.5	16
3.8 - 6.4	21
11.4 - 14.0	49
West station (two locations)	
0 - 2.5	14
3.8 - 6.4	26
11.4 - 14.0	54
0 - 2.5	12
3.8 - 6.4	26
11.4 - 14.0	49

occur on two principal scales. Burrowing anemones generate mounds approximately 10 cm in diameter with maximum heights of 4 cm. These features dominate the sea floor in the vicinity around the Geoprobe. The anemone has been identified from the photographs as Cerianthus, which uses a symmetrical network of tentacles spread radially onto the mud to feed. The tentacles leave a characteristic "sign" of marks radiating from the burrow opening, as illustrated in figure 40. The diameter of this feeding area may be as large as 60 cm (McGinitie and McGinitie, 1968). Feeding crabs generate depressions on the same scale (fig. 41). Smaller scale animal trails and tracks left by crabs and other mobile organisms are on the order of 2 to 3 cm in width and 1 cm or less in depth, and cover about 80 percent of the bottom. Although these tracks tend to be erased during peak tidal currents, the radial symmetry of the anemone mounds and the absence of current-generated ripples suggest that the bed sediment transport rates are low.

The bottom sediment at the Geoprobe site consisted of particles with a range of diameters from clay to fine sand (less than 2 µm to 500 µm). Median grain diameter for the aggregated sediment state is about 25 µm whereas the disaggregated sediment median diameter is about 15 µm (table 13; fig. 42). Nearly 30 percent of the sediment was in the form of aggregates that ranged from about 45 µm to 500 µm in diameter. The aggregates in the two largest size classes, 125 to 250 µm and 250 to 500 µm, were essentially all fecal pellets that we assume were produced by the feeding activities of benthic fauna. Polycheate worms are known to produce sand-sized pellets of the shape (oblate spheroids) found in the Sinclair Inlet sediment. After disaggregation with peroxide, the percentage of sand-sized (>63 µm) material in the sediment decreased from 25.5 to 6.2 percent, showing that the bulk of the "coarse" sediment owes its origin to the pellet-forming processes. The bottom sediment at all three ADCP sites consisted of about 8 percent organic material (table 14).

This bottom sediment contains an abundance of fine silt and clay and, therefore, it could respond as a cohesive mud to the bottom currents in Sinclair Inlet. However, the bottom photographs acquired by the Geoprobe indicate an abundant benthic fauna composed of both epifaunal and infaunal species. The activities of these organisms commonly cause the top 1 to 2 cm of the bed sediment to be very porous and loose; cohesive effects can be minimal under these conditions. The currents in Sinclair Inlet were always sub-threshold or only slightly above the threshold necessary to suspend sediment for even non-cohesive sediments, so we cannot comment on the exact response of the bottom sediment.

Suspended Sediment

Data on suspended sediment in Sinclair Inlet were from samples collected by divers during deployment and recovery of the Geoprobe, from samples collected at different points in the water column at a number of times during one day of each deployment period at each ADCP site, and by measuring light transmission and scattering with instruments on the Geoprobe located at various distances above the bed.

The samples collected during deployment and recovery of the Geoprobe contained low to moderate concentrations (1 to 6 mg/L) (milligrams per liter) of suspended particulate matter. The sample collected at deployment contained the least amount of material but its particle-size distribution, determined by Coulter Counter analysis,

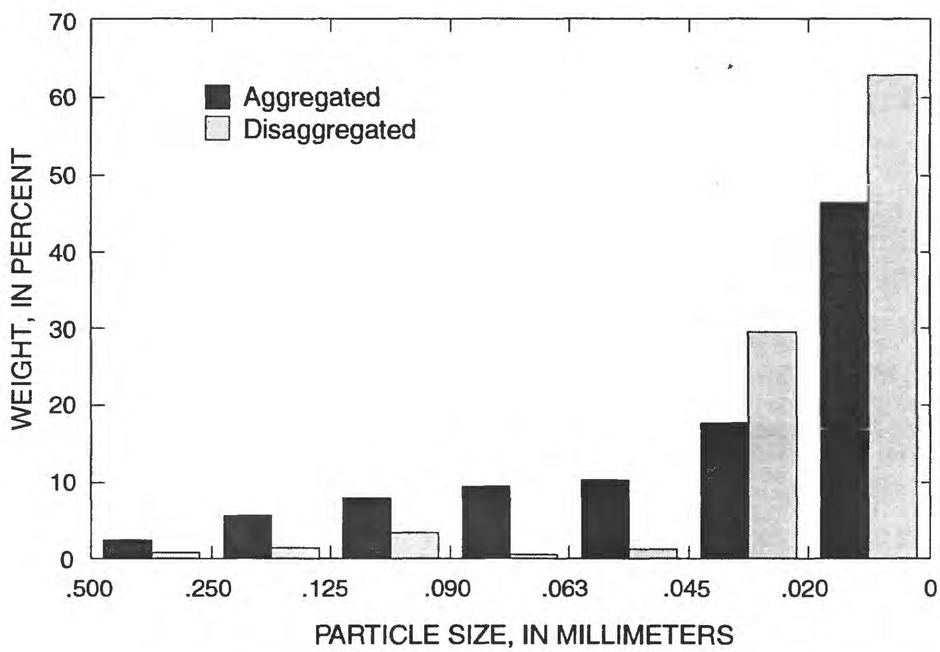


Figure 42. Weight percent of bottom sediment in seven particle size classes. Histograms show results of the wet sieving tests of aggregated and disaggregated aliquots of the bottom sediment at the Geoprobe east station.

Table 14.--*Relative amounts of organic and inorganic material in bed-sediment samples from three stations in Sinclair Inlet, Washington*

[Surface material is from about 0 to 1 centimeters depth; subsurface material is from about 1 to 10 centimeters depth; relative amounts are in percent dry weight]

Depth	Relative amount of Organic material	Relative amount of Inorganic material
	East station (two locations)	
surface	8.7	91.3
subsurface	7.0	93.0
surface	9.0	91.0
subsurface	7.0	93.0
	Center station	
surface	8.0	92.0
subsurface	8.0	92.0
	West station	
surface	8.3	91.7
subsurface	7.5	92.5

shows a prominent peak in the coarse silt and very fine sand classes (32 μm to 125 μm) and a much smaller secondary peak in the medium silt class (16 μm to 32 μm) (fig. 43). This contrasts with the sample collected at recovery, which is characterized by a well-defined single size mode in the medium silt class.

Microscope inspection of these suspended-sediment samples shows that the modal particles in the deployment sample are predominantly aggregates of many smaller grains. The aggregates are irregularly shaped and they differ markedly from the compact-looking, spherical or "football-shaped" fecal pellets that are so common in the bottom sediment. The suspended aggregates were most likely produced by the feeding activities of zooplankton. The pronounced shift in the modal size of the suspended particles from coarse during deployment of the Geoprobe to fine during recovery was caused by the addition of particles to the medium silt size class in the recovery sample and not by the absence of coarse aggregates. The number of relatively coarse aggregates per microscope field-of-view was unchanged in the recovery sample, but the sample contained an abundance of 20 to 25 μm grains (fig. 43). The 20 to 25 μm grains are largely biogenic particles (e.g., small diatom tests) and terrigenous silt grains. The abundance of the biogenic silt at recovery suggests a plankton bloom preceding sample collection.

Neither the suspended-sediment samples collected at deployment or recovery contain sand-sized terrigenous grains that one would expect to be present if current-generated resuspension of bed sediment was important. Moreover, microscopic inspection of the sand fractions of the bottom sediment confirms the small percentages of terrigenous sand grains in the sediment at the Geoprobe site. The bulk of the sand is either fecal pellets composed of silt and clay or siliceous and calcareous biogenic detritus. The grain size and compositional characteristics of this bottom sediment are entirely compatible with a low-energy depositional environment.

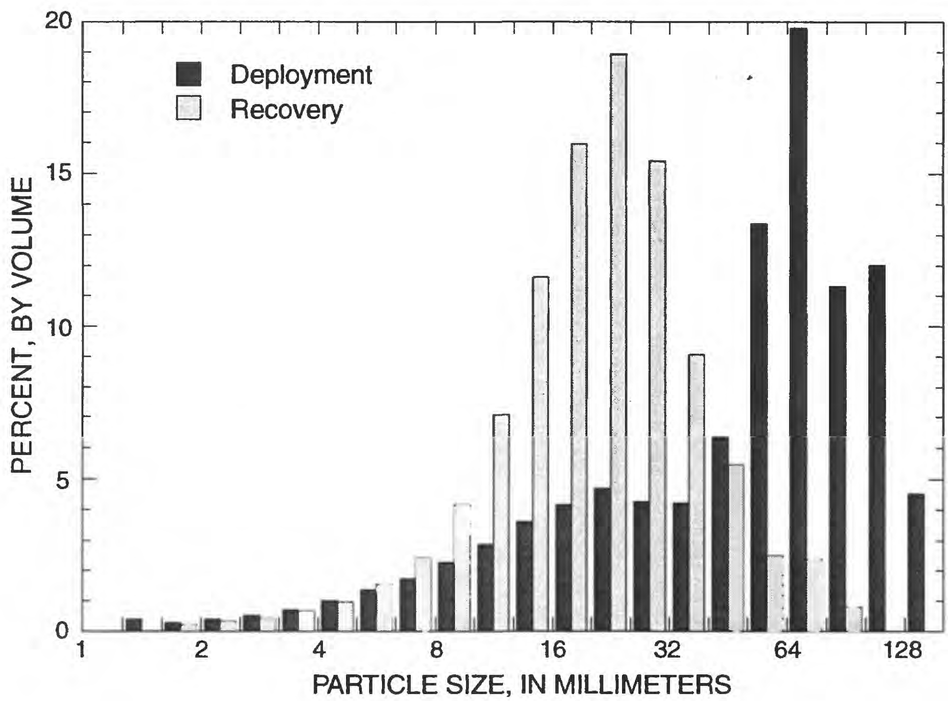


Figure 43. Size distribution of the suspended sediment particles in the samples collected by divers during the deployment and recovery of the Geoprobe. Results are in percent volume determined with a Coulter Counter.

Suspended-sediment concentrations at the three levels above the bottom, estimated from measurements of light transmission using instruments on the Geoprobe, are shown in figure 44 and summary statistics are given in table 11. In general, the concentrations are rather low, with a mean of 2.3 mg/L about 31 cm above the bed. The fluctuations in concentration (fig. 44) suggest that material is resuspended from the bottom due to the tidal stresses (approximately two peaks each day). Many of the individual peaks in the fluctuations can be identified in each of the transmissometer records, with diminishing amplitudes away from the bed. For example, well-defined peaks on day 62, just prior to days 70 and 76, and at the start of day 85 all appear in each record with decreased amplitudes upward. However, the amplitudes of the fluctuations are about 1 mg/L at the lowest level, indicating that the amount of material resuspended during each cycle is small.

Suspended-sediment concentrations were also low to moderate in most of the samples that were collected in the water column at each the three ADCP sites (table 10). Concentrations of total suspended sediment at distances of 2 m or more above the bed generally were less than 10 mg/L (table 10 and fig. 45), and concentrations of the inorganic fraction were about half (but ranged from about 10 to 100 percent) of the total concentrations. Concentrations of total suspended sediment in many of the samples from distances of 1 m or less above the bed were greater than 50 mg/L, but concentrations of the inorganic matter in these samples were 7 mg/L or less. Consequently, much of the suspended material in the samples from near the bed that had high total-suspended- sediment concentrations was organic matter. Although the larger concentrations of suspended sediment observed near the bed may

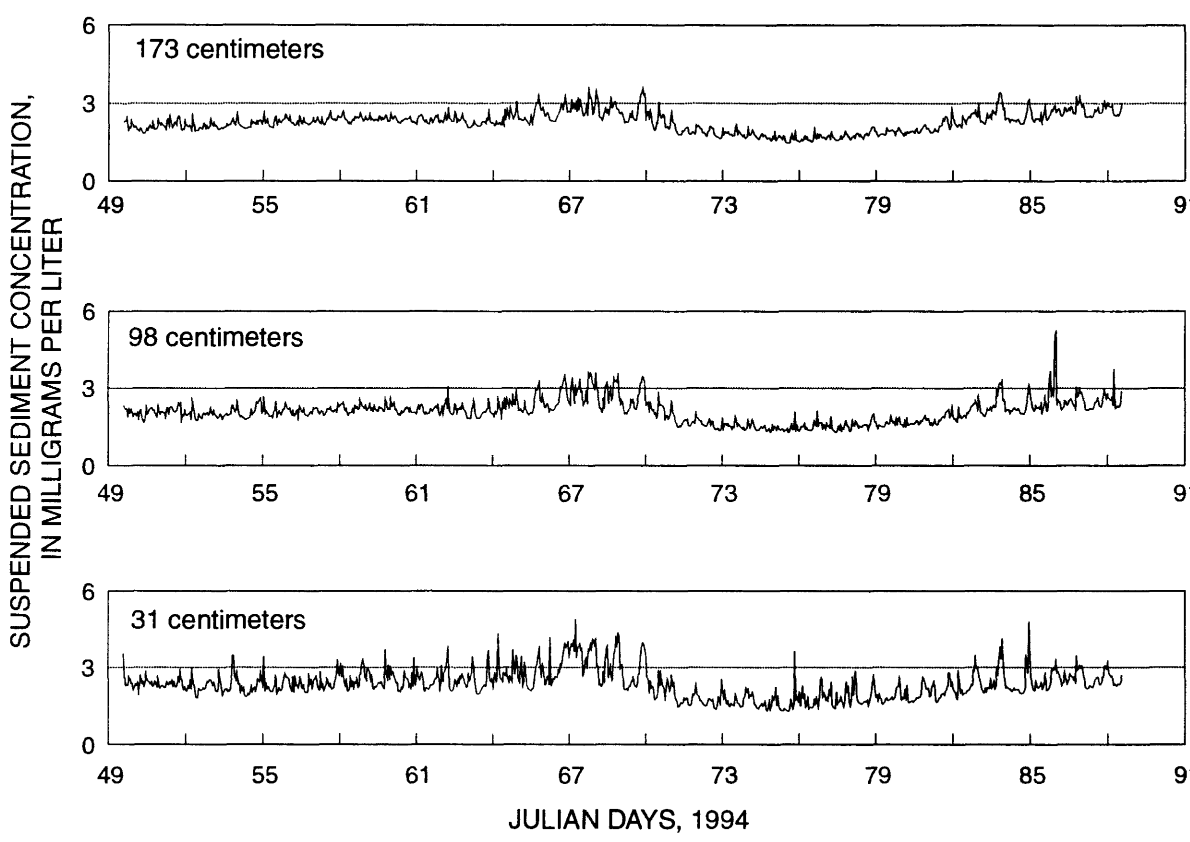


Figure 44. Suspended-sediment concentration at three distances above the bed. Concentration estimated from measurement of light transmissivity with instruments on the Geoprobe.

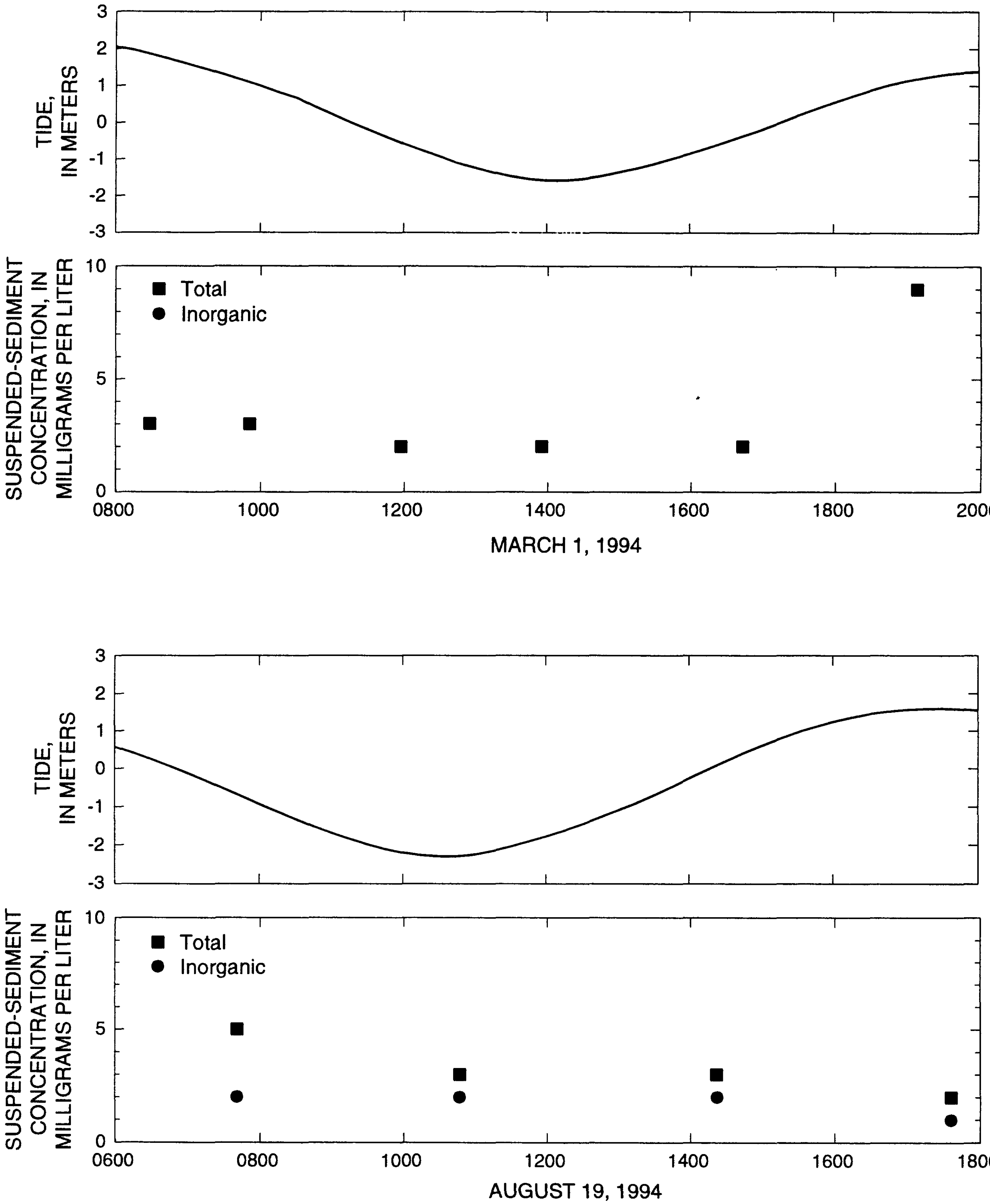


Figure 45. Tide and concentration of suspended sediment at a distance of 2 meters above the bed of Sinclair Inlet at the east station on March 1 and August 19, 1994.

have been caused by resuspension of bed material by tide- or wind-driven water currents, it is also possible that they may have been caused by disturbance of bottom sediment by the sampling device. As expected, turbidity appeared to correlate with concentration of total suspended sediment. Neither suspended-sediment concentration nor turbidity appeared to vary systematically among sites.

BOTTOM BOUNDARY LAYER AND SEDIMENT RESUSPENSION

Boundary-layer and sediment-suspension theory can be used with data collected with the ADCPs and the Geoprobe to identify conditions under which sediment resuspension could take place in Sinclair Inlet. Once resuspended, net sediment movement in the inlet would be dictated by residual circulation patterns. This section addresses the issue of sediment resuspension.

Near-Bed Velocity Profile

The current meters on the Geoprobe were located in the region near the bottom (19 to 120 cm above the bed) where the bottom boundary layer typically is characterized by a systematic decrease in mean current speed toward the bed. This region is often referred to as the wall layer as shown in figure 46. Below the wall layer, in the lowermost part of the bottom boundary layer, is the viscous sublayer, δ_1. This layer is very thin, and for most natural situations in estuaries and on continental shelves it is often disrupted or eradicated by fluid turbulence. For a fluid viscosity, υ, of 0.013 cm^2/s (square centimeters per second), and for shear velocities, u_*, in the range 0.5 to 2.0 cm/s, values which are typical of natural systems, thickness of δ_1 ranges from about 0.03 to 0.13 cm. (The shear velocity is defined as $u_* \doteq (\tau_0/\rho_f)^{1/2}$, where τ_0 is bottom shear stress in dynes/cm^2, and ρ_f is fluid density in g/cm^3.) Consequently, the lowermost velocity meter on the Geoprobe is well out of the viscous sublayer.

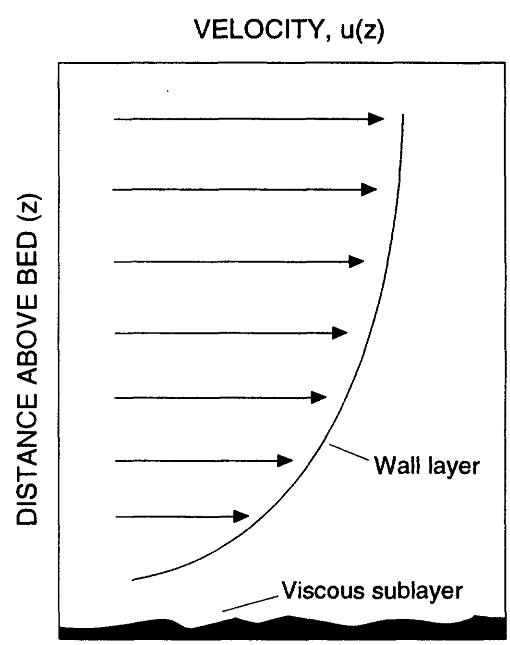


Figure 46. Typical bottom boundary-layer logarithmic velocity profile.

Roughness Reynolds number (R_*)	Flow characterization	Velocity-profile equation	
less than 5	smooth	$\frac{u(z)}{u^*} = \frac{1}{\kappa}\ln\left(\frac{zu_*}{\nu}\right) + 5.5$	(1)
5 to 70	transitional	$\frac{u(z)}{u^*} = \frac{1}{\kappa}\ln\left(\frac{z}{\alpha k_s}\right) + 8.5$	(2)
greater than 70	fully rough	$\frac{u(z)}{u^*} = \frac{1}{\kappa}\ln\left(\frac{z}{z_0}\right)$	(3)

where

$u(z)$ is current velocity, in cm/s, at a distance z above the bed, in cm;

κ is the von Karman constant, taken to be 0.4, dimensionless;

z_0 is a bottom-roughness height, $k_s/30$, in cm;

k_s is equivalent sand-grain roughness, in cm; and

α is an empirical factor that depends on R_*, dimensionless.

Basic Equations

The nature and shape of the velocity profile in the wall layer are dependent on the shear velocity, bottom roughness and, fluid viscosity. This dependence can be characterized by the dimensionless roughness Reynolds number , R_* , defined as $R_* = u_* k_s/\upsilon$, where k_s is the height of bed roughness elements, in cm. Particular ranges of R_* can be used to match flow characteristics to the correct velocity profile equation as shown above (Komar, 1976, and Schlichting, 1979):

In many studies of bottom friction it is convenient to define a drag coefficient for computing bottom shear stress (in terms of the shear velocity) from a current velocity measured at some distance above the bed. The drag coefficient, C_d, is usually defined by the expression

$$\tau_0/\rho_f = (u_*)^2 = C_d[u(z)]^2, \qquad (4)$$

and its value depends on the distance above the bed where u is measured. In this study a value of the drag coefficient for the bottom of Sinclair Inlet will be estimated from the data collected with the Geoprobe at the one measurement station during the winter deployment period. It will then be modified and used with velocities measured with the ADCPs to estimate shear stresses at all three measurement stations during both the winter and summer deployment periods.

Computation of Parameters for Estimating Bottom Shear Stress

Typically, in natural environments, the lower part of the bottom boundary layer is fully rough (R_*>70), and the logarithmic velocity distribution given by equation 3 applies. Here it will be assumed that equation 3 does apply, and R_* will be calculated later to verify this assumption. The velocity data collected with the four Geoprobe current sensors can be used to estimate u_* and z_0 from equation 3. The technique involves applying a

Table 15.--*Number of near-bed velocity profiles measured with Geoprobe that meet criteria for use in analysis*

[u_{120}, current speed at height of 120 centimeters above bed; cm/s, centimeters per second; >=, greater than or equal to]

Coefficient of determination (r^2)	Number of profiles	Number of profiles with u_{120} greater than 5 cm/s
all values	936	435
r^2 >= 0.90	395	271
r^2 >= 0.95	305	216
r^2 >= 0.99	96	72

least-squares regression to the four burst-averaged speed measurements each hour. The slope and intercept of the fitted regression line are used to compute u_* and z_0, respectively. This method has been described by Sternberg (1972), and its application to Geoprobe data was presented in Cacchione and others (1982). Also, a drag coefficient is calculated from the computed u_* and from u_{120}, the measured current velocity at the highest velocity sensor on the Geoprobe (120 cm above the bed).

A coefficient of determination, r^2, can be computed as part of the regression analysis, and this coefficient is a measure of the goodness of fit of equation 3 to the data. A detailed discussion of errors in the computation of u_* and z_0 using this regression technique is given in Cacchione and others (1982).

In this study only values of u_*, z_0, and C_d that are computed from profiles for which the r^2 is greater than 0.9 and for which u_{120} exceeded 5 cm/s are used. About 30 percent of the profiles meet these criteria, but only about 8 percent of the data would meet a criteria of r^2 greater than 0.99 (table 15). The elimination of the profiles with low values of r^2 and with rather low speeds precludes results based on profiles for which the boundary layer is poorly defined. In addition, the measurement accuracy of each current sensor is $\pm$ 0.5 cm/s, and consequently, low speeds have large relative errors. Because bed sediment in Sinclair Inlet is resuspended only during short periods with the highest bottom shear stress or current speed (as will be demonstrated later in this report), the set of velocity profiles that meet the r^2 and u_{120} criteria probably include most profiles from periods when resuspension could occur.

Values of u_{120}, u_*, C_d, z_0, and r^2 for individual profiles that meet the selection criteria are plotted in figure 47; summary statistics are given in table 16, and histograms for u_*, C_d, and z_0 are shown in figures 48, 49, and 50, respectively. The mean value of u_* computed from the

Table 16.--*Statistical summary of results of regression analyses of selected near-bed velocity profiles measured with the Geoprobe* (r^2>0.9 and u_{120}>5.0 cm/s)

[u_{120}, current speed at 120 centimeters above bottom; u_*, shear velocity; z_0, roughness height; r^2, coefficient of determination; C_d, drag coefficient; cm/s, centimeters per second; Std. Dev., standard deviation; Coef. of var., coefficient of variation in percent; --, not computed]

Statistic	u_{120} (cm/s)	u_* (cm/s)	z_0 (cm)	r^2	C_d
Minimum	5.02	0.28	0.02	0.90	0.002
Maximum	15.70	1.34	5.73	1.00	0.019
Mean	8.03	0.63	0.68	0.97	0.007
Std. Dev.	2.26	0.20	1.03	0.03	0.003
Coef. of var.	28	32	151	3	43

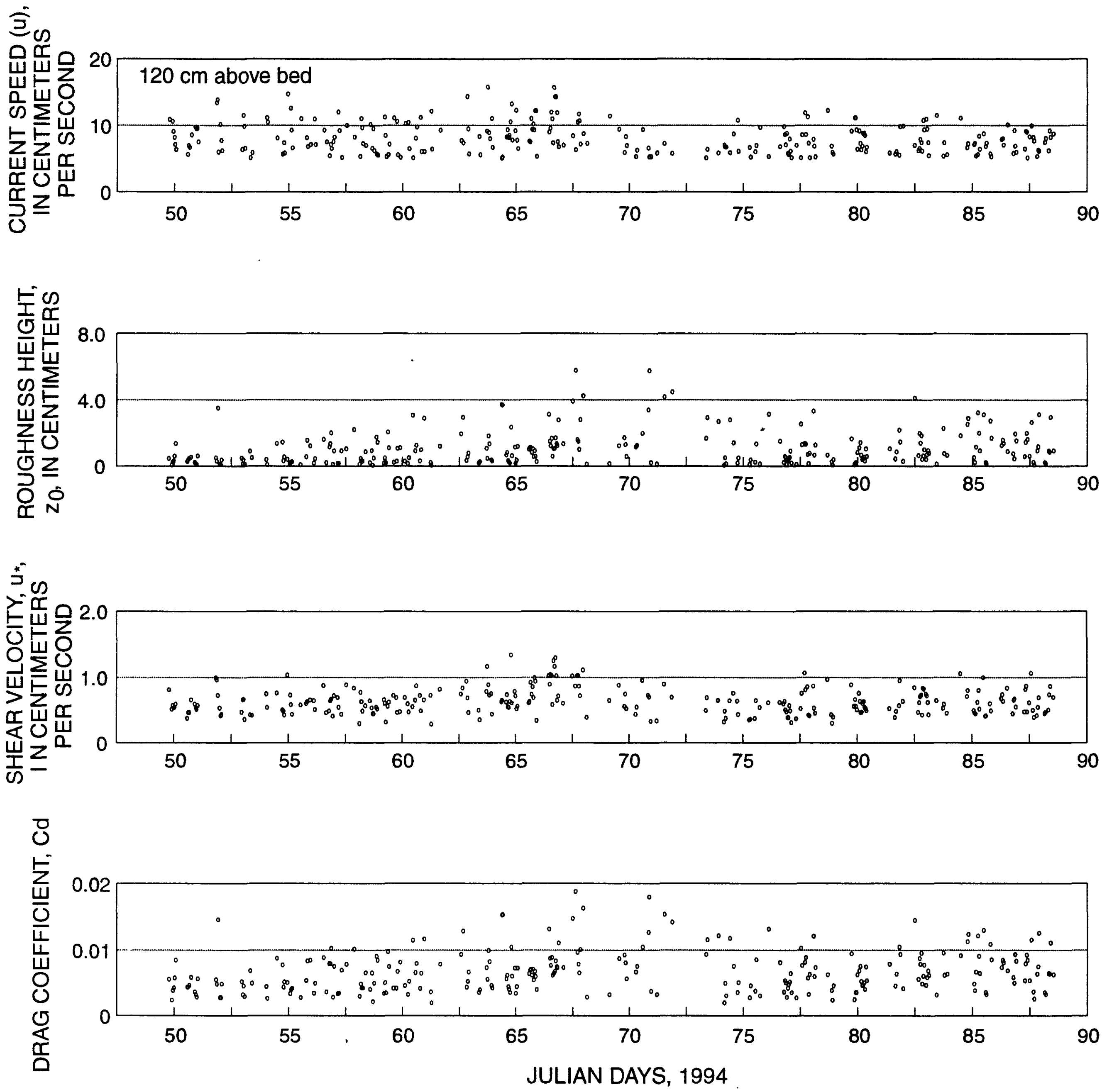


Figure 47. Bottom boundary-layer parameters estimated by regression of near-bottom current speed measured with current meters on the Geoprobe.

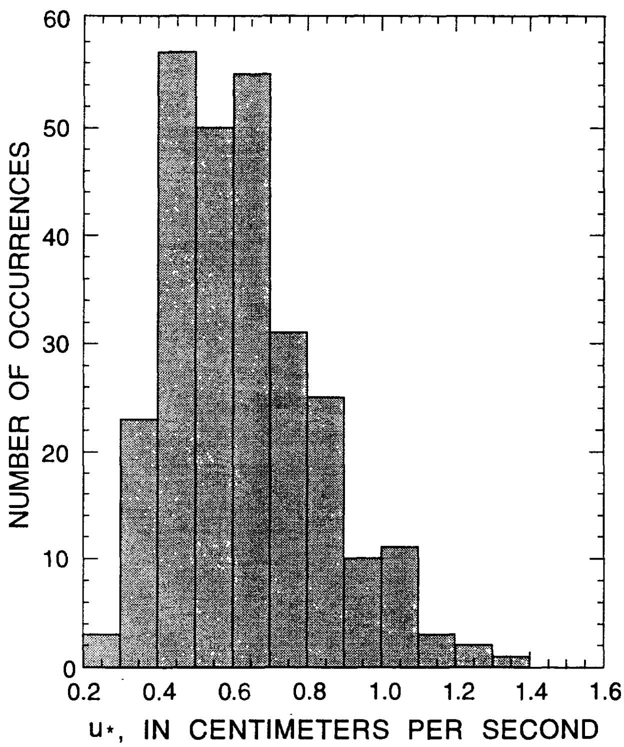


Figure 48. Histogram of shear velocities, u*, obtained by regression of near-bottom current speed measured with current meters on the Geoprobe.

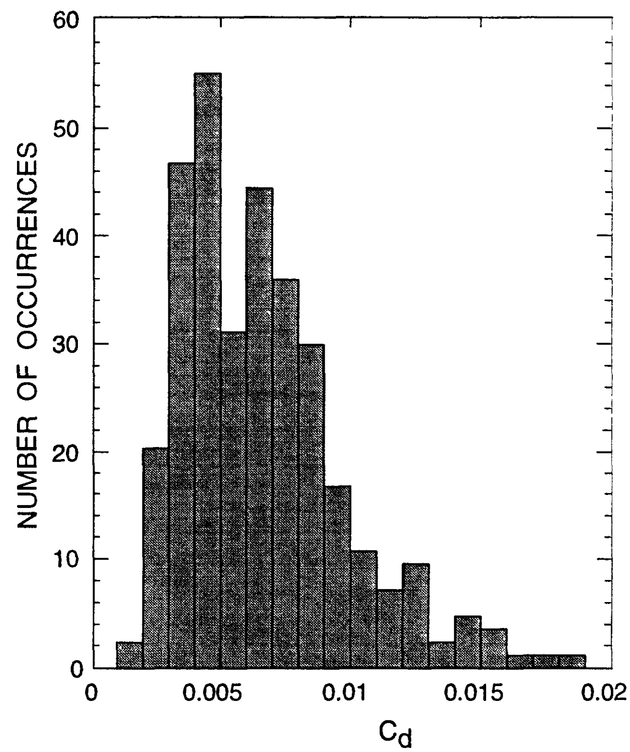


Figure 49. Histogram of calculated drag coefficients, Cd, from analysis of data collected with the Geoprobe.

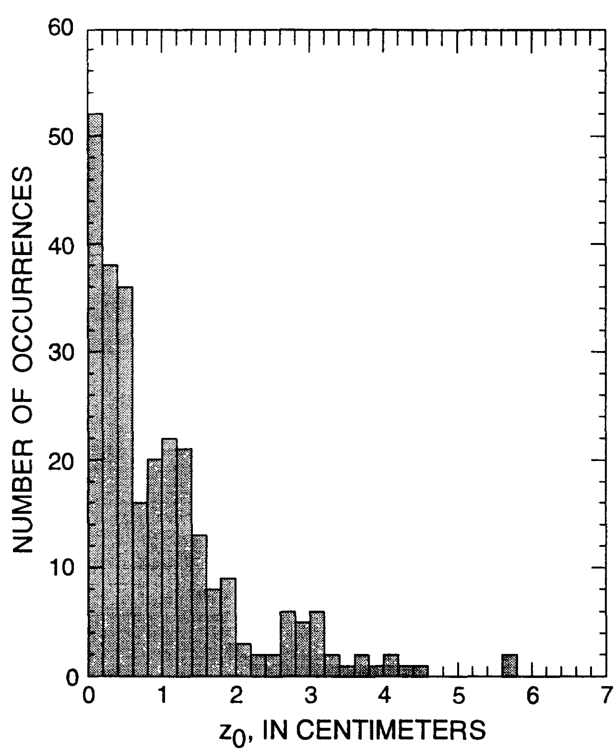


Figure 50. Histogram of roughness heights, z_0, obtained by regression of near-bottom current speeds, measured with current meters on the Geoprobe.

selected profiles is 0.63 cm/s (table 16); most values are in the range 0.3 to 0.9 cm/s and many of the values are clustered in the range 0.4 to 0.7 cm/s (fig. 48). The computed values are of the magnitude to be expected for the observed range in u_{120} (about 5 to 16 cm/s, table 16). The distribution of u_* values is slightly skewed toward higher values.

The mean value of the drag coefficient for the selected profiles, C_d, is 0.007, and the coefficient of variation is 43 percent (table 16). Most values of C_d are between 0.002 and 0.009 (fig. 49), and the distribution of C_d, like u_*, is skewed toward high values.

The mean value of z_0 used here (0.68 cm) is the geometric mean (the antilog of the mean of ln z_0) for the selected profiles. The distribution of z_0 appears to be an exponential function that decreases from low values (z_0 less than 0.25 cm) to higher values (fig. 50). Most values are less than about 2 cm. Wide scatter in z_0 derived from analysis of velocity profiles is common because computation of this parameter is highly sensitive to the intercept on a logarithmic axis. Small changes in the slope of the regression line cause large changes in z_0. Also, the relatively slow currents in Sinclair Inlet introduced higher uncertainties than is normal when performing these computations due to larger percentage errors in the speed measurements.

As was described earlier, the bed at the Geoprobe site was covered with burrowing anemones. The heights of these organisms above the general level of the bed was between 2 and 4 cm (as interpreted from the photographs, and indicated by divers). The anemones appeared randomly distributed over the bottom in the photographs, with an average spacing of about 20 cm. The mounds caused by the animals extended outward from the burrows in a circular pattern with an estimated diameter of about 10 cm. These features were the major physical forms on the bed, and probably dominated the hydrodynamic roughness that influenced the velocity profile in the wall layer. Unfortunately, the hydrodynamic effects caused by three dimensional roughness elements like animal mounds and burrows have not been studied extensively; a brief summary of different types of bed roughness in natural settings is given by Grant and Madsen (1986). However, an approach for characterizing bed roughness that is an alternative to equation 3 is to assume that roughness element height, $k_s = 30\ z_0$, equals the protrusion height of the anemones above the general level of the bed (2 to 4 cm). Under this assumption one calculates that z_0 is in the range 0.067 to 0.13 cm. The reason for the difference between these values and those obtained by regression using equation 3 is unknown.

Because equation 3 was used in the estimates of u_*, C_d, and z_0 it is necessary to check if the results are consistent with the assumption that the bottom or flow was fully rough (R_*>70). Using the minimum value of u_* (0.28 cm/s, table 16); a value of $k_s = (30\ z_0) = 20$ cm, which is computed using the mean value of z_0 (0.68 cm, table 16); and a value of ν equal to 0.013 cm^2/s; yields $R_* = 440$, which justifies the use of equation 3. Alternatively, if one uses the height of the anemone mounds (2 to 4 cm) for k_s, one obtains $R_* = 43$ to 86. For $k_s = 4$ cm the flow is fully rough ($R_* = 86$). For $k_s = 2$ cm, R_* is greater than 70 when u_* is greater than 0.46 cm/s, which is the case for about 80 percent of the velocity profiles that were utilized (fig. 46). Consequently, the use of equation 3 for estimating u_* is justified for most if not all of the velocity profiles that were analyzed.

Drag Coefficients for Use with Velocities Measured with ADCPs

Because the ADCPs and Geoprobe did not measure velocities at the same distances above the bed, it is necessary to modify the drag coefficients that were calculated using the data collected with the Geoprobe for calculating shear stresses from velocities measured using the ADCPs. The modifications will be based on equations 3 and 4.

Using equations 3 and 4 one can write

$$C'_d = C_d\left(\frac{u(z_1)}{u(z_2)}\right)^2 \quad \text{and} \qquad (5)$$

$$\frac{u(z_2)}{u(z_1)} = 1 + \frac{\sqrt{C_d}}{\kappa}\ln\left(\frac{z_2}{z_1}\right) \quad , \qquad (6)$$

where

C_d is the drag coefficient when the velocity at z_1 is used; and

C_d' is the drag coefficient when the velocity at z_2 is used.

Time series of u_* for all three measurement stations and both deployment periods (figs. 51 and 52) were computed using (1) current speeds measured with the ADCPs; (2) the mean drag coefficient obtained using data from the Geoprobe for C_d (0.007); (3) the distance above the bed to the uppermost current meter on the Geoprobe for z_1 (120 cm), and (4) the distance above the bed to the center of the lowest bin of an ADCP for z_2, (195 or 220 cm). These calculations resulted in a reduction in the drag coefficient from 0.007 to 0.0055 or 0.0058. Root-mean-square values of u_* (table 17) were calculated using the entire time series; no data were deleted as was done for regression analyses of the data collected using the Geoprobe.

Bed Skin Friction

In order to assess whether the u_* values obtained from the velocity profiles are large enough to resuspend the bottom materials, the computed values of u_* must be related to the bed skin-friction shear velocity (u_{*b}), which represents the component of total shear stress that acts directly on the individual grains on the bed. Recall that u_* derived from the velocity profiles includes the form drag contributed by the larger roughness elements (biogenic structures). One method of obtaining u_{*b} is to partition the bottom boundary layer into two layers that represent velocity profiles dependent on the two scales of roughness (Smith and McLean, 1977). In this case, the lowermost layer will depend on the roughness created by the sediment particles, and the upper layer will depend on the total roughness. For this study, the roughness height in the lower layer is assumed to be $z_{0b} = D_{ma}/30$, where D_{ma} is the median diameter of the aggregated sediment grains (0.0025 cm). For the upper layer $z_0 = k/30$, as described above. The height above the bed where the two layers meet, z_*, is uncertain, but a reasonable estimate would be between the height of the largest animal structures on the bed and twice this height.

Smith and McLean (1977) show that when both the lower and upper layers are fully rough, the relation for the shear velocities, which is obtained by equating the velocities in the two layers at the matching level, is given by:

$$\frac{u_{*b}}{u_*} = \frac{\ln(z_*/z_0)}{\ln\left(z_*/z_{0b}\right)} \quad . \tag{7}$$

Equation 7 is applicable if the bottom is hydraulically rough with respect to the sediment particles ($u_{*b}D_{ma}/\upsilon > 70$) such that equation (3) describes the velocity profile in the lower layer. We also propose a similar formulation if the bottom is hydraulically smooth ($u_{*b}D_{ma}/\upsilon < 5$) such that equation (1) describes the velocity profile in the lower layer,

$$\frac{u_{*b}}{u_*} = \frac{\ln(z_*/z_0)}{\ln\left(\frac{z_* u_{*b}}{\nu}\right) + 5.5\kappa} \quad . \tag{8}$$

Table 17.--*Estimated drag coefficients for calculating total bottom shear stress from current speed measured with acoustic Doppler current profiler (ADCP) at indicated distance above the bed, and root-mean-square of calculated shear velocities during winter and summer deployment periods*

[z_2, distance above bed of current measurement; cm, centimeters; C_d', drag coefficient; RMS u_*, root-mean-square shear velocity; cm/s, centimeters per second]

Measurement station	Winter deployment	Summer deployment
East	z_2 = 195 cm C_d' = 0.0058 RMS u_* = 0.44 cm/s	z_2 = 195 cm C_d' = 0.0058 RMS u_* = 0.44 cm/s
Center	z_2 = 220 cm C_d' = 0.0055 RMS u_* = 0.34 cm/s	z_2 = 195 cm C_d' = 0.0058 RMS u_* = 0.36 cm/s
West	z_2 = 220 cm C_d' = 0.0055 RMS u_* = 0.31 cm/s	z_2 = 195 cm C_d' = 0.0058 RMS u_* = 0.42 cm/s

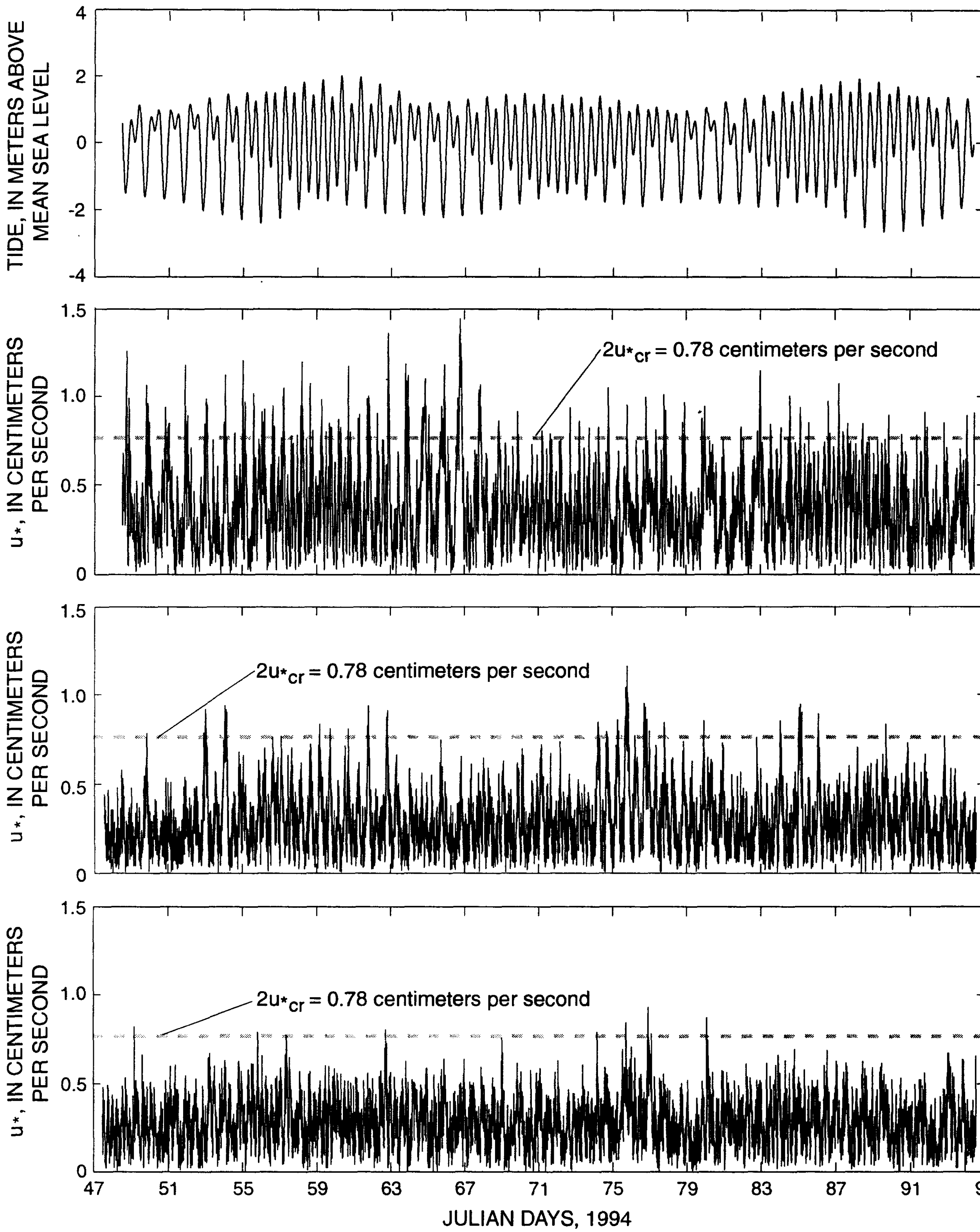


Figure 51. Comparisons of total bottom shear velocity, u_*, with critical shear velocity, u_{*cr}, for resuspension of bed sediments at the east, center, and west stations during the winter deployment period. Resuspension of bed sediments can be expected when the skin-friction component of the total shear velocity, which is equal to about 0.5 u_*, is greater than the critical shear velocity, which is the same as when u_* is greater than $2u_{*cr}$.

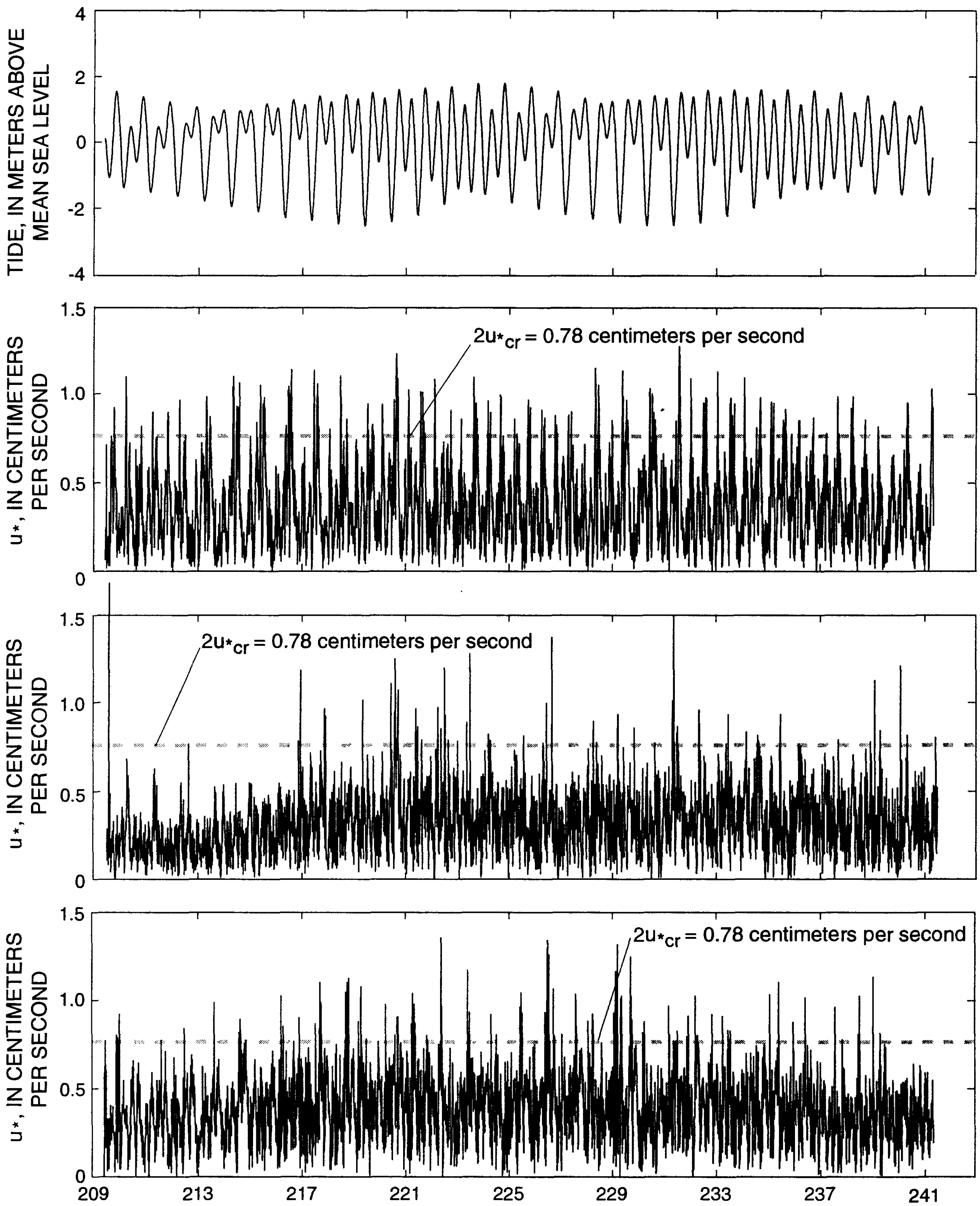


Figure 52. Comparisons of total bottom shear velocity, u_*, with critical shear velocity, u_{*cr}, for resuspension of bed sediments at the east, center, and west stations during the summer deployment period. Resuspension of bed sediments can be expected when the skin-friction component of the total shear velocity, which is equal to about 0.5 u_*, is greater than the critical shear velocity, which is the same as when u_* is greater than $2u_{*cr}$.

For any reasonable values of the variables in equations (7) and (8) we find that the bed is hydraulically smooth, and therefore, equation (8) is the appropriate function for relating u_{*b} to u_*. Using combinations of values of z_* equal to 4 cm and 8 cm, mean z_0 equal to 0.68 cm, and u_* equal to 0.28 and 1.34 cm/s (table 16), the range in the computed ratio u_{*b}/u_* is 0.22 to 0.48. Therefore, one can conservatively conclude that u_{*b} is no larger than about half u_* for the observed currents and bottom conditions in Sinclair Inlet. This result will be used to estimate u_{*b} from the values of u_* that were estimated using velocities measured with the ADCPs and the drag coefficient C_d'. These values of u_{*b} will be compared with estimated values of the shear stress necessary to initiate motion or resuspend the bed sediments.

Estimation of Critical Shear Stress

It is difficult to estimate the shear stress required to resuspend sediments on the bed in Sinclair Inlet because of the poor sorting of the bottom sediment and other factors. As reported earlier, the grain-size distribution extended over a range from clay to fine sand (fig. 42). Consequently, the bed sediments may be cohesive. In addition, approximately 30 percent of the bottom materials were present as aggregates of smaller particles. The worms and anemones which were abundant in the bottom photographs likely are major contributors to this type of grain population. Additionally, the feeding activities and active reworking of the sediment surface by benthic organisms could induce a variety of effects which either stabilize or destabilize the sediment surface. For example, the tracks and trails caused by crabs and other mobile bottom dwellers probably loosen the surface and make it more erodible. On the other hand, the fibrous tentacle arrays that extend radially outwards up to tens of cm from the burrowing anemones could inhibit grain mobility and stabilize the surface.

In spite of these complications, because the data collected using the light transmissometer on the Geoprobe suggest that some resuspension of the bed materials occurred, it is useful to consider the threshold conditions that produce entrainment of the bottom sediment. If it is assumed that the aggregated and disaggregated grains behaved non-cohesively, the results of Wiberg and Smith (1987) can be extended to obtain estimates of threshold or critical shear velocities ($u*_{cr}$) for the median size classes for each grain type. If the bed material is cohesive, then this analysis will underestimate the critical shear stress, and resuspension will occur less often than will be estimated.

Wiberg and Smith (1987) developed equations relating the critical shear stress (τ_{cr}), or alternatively u_{*cr}, to particle and fluid characteristics. Their results confirm the empirically based Shield's curve for predicting sediment entrainment for sediment of uniform size, and they extend the results for mixed grain sizes. As an approximation to the particle distribution at the bed surface, two scenarios are assumed. In the first scenario, disaggregated particles with a median diameter, D_{md}, of 0.0015 cm are resting on a bed of coarser, aggregated particles with a median diameter, D_{ma}, of 0.0025 cm. In the second scenario, aggregated particles are resting on a bed of disaggregated particles. These two scenarios are end-members from the standpoint of sediment resuspension. In the first scenario, smaller grains are resting on sediment characterized by a larger grain roughness and the ratio of median grain diameters, D_{md}/D_{ma}, is 0.6. In the second scenario, larger grains resting upon a surface of smaller grain roughness and D_{ma}/D_{md} is 1.7. The case for which $D_{ma}/D_{md} = 1$ is included within this range.

The technique used in this study to analyze sediment resuspension was adopted from work of Wiberg and Smith (1987). In this study, a nondimensional critical shear stress, τ_{*cr}, was computed from a nondimensional particle diameter, D_*, for the two grain-diameter scenarios using the equations

$$\tau_{*cr} = \frac{\tau_{cr}}{gD(\rho_s - \rho_f)} \tag{9}$$

and

$$D_* = 0.0047\left(\frac{gd^3(\rho_s - \rho_f)}{\upsilon^2 \rho_f}\right)^{1/3} , \tag{10}$$

where

τ_{cr} is critical shear stress, in dynes/cm^2;
ρ_s is density of a solid particle, in g/cm^3;
ρ_f is density of the fluid, in g/cm^3;
g is gravitational acceleration, in cm/s^3;
D is diameter of exposed grains for which critical shear stress is being computed, in cm; and
d is diameter of grains making up the bed on which the grains of diameter D rest, in cm.

Equations (9) and (10) are applied to the first grain-size scenario, for example, by setting D equal to D_{md} and by setting d equal to D_{ma}. It should be noted that the curves presented by Wiberg and Smith (1987) are for values of D_* greater than 0.005, which corresponds to d greater than about 0.005 cm. In this work, the curves have been extended to include the finer grain sizes found at Sinclair Inlet. Two values of $u_{*cr} = (\tau_{*cr}/\rho)^{1/2}$ were calculated for aggregates. One value for u^*_{cr} was computed assuming aggregate density was equal to the density of a solid particle (ρ_s = 2.65 g/cm^3), another value was computed using an assumed lesser density of an aggregate (1.8 g/cm^3). Calculated values of the critical shear velocity for the three cases range from 0.39 to 0.63 cm/s (table 18). As expected, the lowest critical shear velocity is for aggregated particles of low density resting on a bed of disaggregated grains.

Comparison of Bed Skin Friction with Critical Shear Stress

To determine how frequently bed sediments in Sinclair Inlet may be resuspended, the lowest estimated critical shear velocity, 0.39 cm/s, will be compared with the skin friction component of shear velocity, u_{*b}, which is assumed to equal 0.5 u_*. Comparisons will first be made using values of u_* computed by regression of data collected with the Geoprobe at the east station during the winter deployment. Then comparisons will be made using values of u_* computed using the drag coefficient, C_d', and velocities measured with the ADCPs at all three stations during both the winter and summer deployments. Because the actual critical shear velocity probably is greater than 0.39 cm/s and the skin-friction component of the shear velocity probably is less than 0.5u_*, comparing the two probably will overestimate the amount of time that the critical shear velocity is actually exceeded.

Analysis of the u_* values determined by regression analysis of the data collected with Geoprobe indicates that for about 22 percent of them $u^*_b = 0.5\ u_*$ is equal to or greater than u_{*cr} = 0.39 cm/s (or, equivalently, u_* is equal to or greater than 2 u_{*cr} = 0.78 cm/sec). Because these values of u_* were computed using only 29 percent of the data, most of which were for the largest current velocities (which implies the largest shear velocities) one can reason that the currents at the east measurement station during the winter deployment period were capable of moving bed material only about 0.29x22 percent = 6 percent of the time, or about 92 minutes per day. These percentages are in qualitative agreement with the light transmissometer data collected using the Geoprobe, which showed short duration spikes of increased sediment concentration during the short periods of maximum current velocity.

Table 18.--*Estimated critical shear velocities for grains of different sizes and densities*

[D, diameter of exposed grains; d, diameter of underlying grain; ρ_s, density of grain; ρ_f, density of fluid; D_*, dimensionless grain diameter; τ_{*cr}, dimensionless critical shear stress; τ_{cr}, critical shear stress; u_{*cr}, critical shear velocity; cm, centimeter; gm/cm^3, grams per cubic centimeter; cm^2, square centimeters; cm/s, centimeters per second]

D (cm)	d (cm)	D/d	ρ_s (gm/cm^3)	ρ_f (gm/cm^3)	D_*	τ_{*cr}	τ_{cr} (dynes/cm^2)	u_{*cr} (cm/s)
0.0015	0.0025	0.6	2.65	1.02	2.4x10^{-3}	0.17	0.41	0.63
0.0025	0.0015	1.7	2.65	1.02	1.5x10^{-3}	0.07	0.28	0.52
0.0025	0.0015	1.7	1.8	1.02	1.1x10^{-3}	0.08	0.15	0.39

Table 19.--*Amount of time that computed skin-friction component of shear velocity (0.5 times total shear velocity) equals or exceeds estimated critical shear velocity (0.39 centimeters per second) for resuspension of bed sediments at three measurement stations in Sinclair Inlet, Washington*

[-- denotes not computed]

Measurement station	Deployment period	Root-mean-square total shear velocity (centimeters per second)	Amount of time (Percent)	Amount of time (Average minutes per day)
		Computed using data collected with Geoprobe		
East	Winter	--	6.4	92
		Computed using data collected with Acoustic Doppler Current Profilers		
East	Winter	0.44	5.6	81
East	Summer	0.44	6.5	94
Center	Winter	0.34	1.2	17
Center	Summer	0.36	1.3	19
West	Winter	0.31	0.1	1
West	Summer	0.42	2.3	33

Analysis of the u_* time series obtained using current velocities measured with the ADCPs also show that critical shear stress is exceeded only sporadically, during very small parts of the tidal cycles (figs. 51 and 52). The amount of time that u_{*b} equals or exceeds 0.39 cm/s varies from 0.1 to 6.5 percent of the time or 1 to 94 minutes per day for each measurement station and deployment period (table 19). (Note that these are average values during the deployment periods, and that at some stations on some days critical shear stress is never exceeded.) At the east station critical shear stress is exceeded on almost every day during both the winter and summer deployment periods (figs. 51 and 52). At the west station critical shear stress also was exceeded almost daily during the summer period but on only less than about one-quarter of the days during the winter deployment period. At the center station critical shear stress also was exceeded more often during the summer period than the winter period, but the difference is not as large as at the center station.

Overall, the measurement stations in Sinclair Inlet are characterized by weak currents and corresponding weak shear stresses. During most of the time, the region is only marginally active in terms of bottom sediment movement. However, although bottom sediment resuspension was rather low during the two measurement periods, it must be noted that the winds were rather weak during these periods. Sediment resuspension and transport during storms would likely be greater than was observed.

SUMMARY AND CONCLUSIONS

A study was conducted at Sinclair Inlet, a small embayment of Puget Sound in the State of Washington, to aid in evaluating the potential for bed sediments in the inlet to be resuspended by tide- and wind-driven water currents. Some of these sediments may have been contaminated as a result of activities at the Puget Sound Naval Shipyard, which is located on the inlet and has been in operation since the 1890's. There is concern that these sediments may be resuspended and transported to other parts of Puget Sound. The inlet is about 6 km long, 1.6 km wide, and typical depths are about 15 m.

The approach taken was to measure and characterize the water currents, winds, bed sediments, suspended sediments, and other variables, and to use these data to compute and compare the shear stresses acting on the bed sediments with the critical shear stress necessary to resuspend the sediments. The current data were also used to estimate long-term circulation patterns in the inlet, and may be used in the future to calibrate a numerical model of water and sediment movement in the inlet.

Acoustic Doppler current profilers (ADCPs) were deployed at three stations during a 6.5-week winter period starting in mid-February 1994 and a 4.5-week summer period starting near the end of July of the same year. These instruments measured and recorded water velocities in the water column from about 2 m above the bed to 2 m below the surface. Other instruments deployed with the ADCPs measured water temperature and conductivity (from which salinity was calculated), water temperature, and water level. Water currents were also measured at distances 0.2 to 1.2 m above the bed with four electromagnetic current meters on an instrument system called a Geoprobe. The Geoprobe was deployed during only the winter period at a location very near one of the ADCPs. Other instruments on the Geoprobe measured conductivity, temperature, water level, and light transmittance for estimating suspended-sediment concentration. A camera on the Geoprobe periodically took photographs of the bottom.

In addition, from February or March 1994 to March 1995 wind speed and direction were monitored at three stations, and water level also was recorded at one of the stations. Samples of bottom sediment were analyzed to determine particle-size distribution, and organic content. Water samples were collected for determining suspended-sediment concentration during deployment and retrieval of the Geoprobe and at each of the ADCP stations on one day during each deployment period.

Observed wind directions at all stations during most of the year, and especially during the winter months, were predominantly from the southwest quadrant, approximately along the axis of the inlet; however, during July and August winds were predominantly from the northeast quadrant. Wind speeds were relatively low, less than 2 m/s about 50 percent of the time, and less than 5 m/s about 90 percent of the time. Observed tides were mixed semi-diurnal and diurnal with pronounced neap-spring variations. Tide range varied between about 2 and 4.5 m.

Observed currents in Sinclair Inlet were generally weak. Typical speeds were 5 to 10 cm/s; RMS (root-mean-square) speeds observed with the ADCPs and Geoprobe were all less than 8 cm/s, and the maximum speed observed at 1.2 meters above the bed with the Geoprobe was only about 16 cm/s. Tidal and residual currents were of similar magnitude, which suggests that wind affects currents in Sinclair Inlet as much as astronomical tide. The apparent circulation, as deduced from data at the three current measuring stations, was such that during periods of winds from the southwest quadrant, currents near the surface were out of the inlet (in the direction of the wind) on the north side but weak and variable on the south side; and currents near the bottom are into the inlet (opposite the direction of the wind) on the south side and near the inlet mouth on the north side but weak and variable on the north side nearer the head of the inlet.

The bed of Sinclair Inlet in the vicinity of the current measurement stations is soft and composed of aggregated fine-grained particles. Median particle size of the aggregated sediment is about 25 micrometers, but is 15 micrometers when disaggregated. About 8 percent is organic material. The surface of the bottom is relatively smooth but with mounds about 10 cm in diameter and a maximum of 4 cm high created by burrowing anemones. Suspended-sediment concentrations in samples collected at the times of deployment and retrieval of the Geoprobe were 6 mg/L or less. Although concentrations of total suspended sediment were as much as 50 mg/L in some of the samples collected at the ADCP stations, concentrations of the inorganic fractions were 7 mg/L or less in all samples. Suspended-sediment concentrations estimated from light-transmissometer data collected with the Geoprobe averaged only 2.3 mg/L at 31 cm above the bed. During some periods these data showed increases of about 1 mg/L twice per day, which suggests resuspension at times of peak tidal currents.

A range of critical shear velocities (shear velocity is defined as the square root of shear stress divided by water density) necessary to resuspend bottom sediments were computed (equations 8 and 9) using the observed bottom-sediment characteristics (particle sizes and density). The calculated critical shear velocities ranged from 0.39 cm/s to 0.63 cm/s for a range particle size and density. The lower value, 0.39 cm/s, was used to compare with shear velocities estimated from the observed current speeds.

The near-bottom current profiles measured using the Geoprobe were fit to logarithmic velocity distributions by regression analysis to yield estimates of shear velocity and roughness height. Drag coefficients based on the currents measured at 1.2 m above the bed were then computed. The average value was 0.007. To obtain shear velocities at the times and locations of the ADCP deployments, the drag coefficients were adjusted to be used with the velocities at the lowest points in the profiles obtained with the ADCPs (1.95 and 2.20 m above the bed). The corresponding drag coefficients are 0.0058 and 0.0055, respectively.

Because only the component of shear velocity due to skin friction (but not form drag on the anemone mounds and other large bed forms) is effective in resuspending bottom sediments, the skin-friction component of shear velocity was estimated by matching two logarithmic profiles (an inner one based on skin friction and an outer one based on total shear stress) at a height above the bed equal to one to two times the height of the anemone mounds (equation 8). Computations for a range of shear velocities and heights of matching point indicated that the skin friction component of shear velocity was no larger than one-half the total shear velocity. Consequently, a skin friction component of 0.5 times the estimated total shear velocity was compared with the critical shear velocity to determine if bed sediments were resuspended.

Skin-friction components of shear velocities that were estimated using current speeds measured with the ADCPs were less than the critical value for resuspending bottom sediment most of the time at all three stations during both deployments periods. The RMS shear velocity for each station and deployment period ranged from 0.31 cm/s to 0.44 cm/s, and the amount of time that the skin-friction component of shear velocity exceeded the critical value ranged from 0.1 to 6.5 percent, which is equivalent to an average of only 1 to 94 minutes per day.

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APPENDIX A

Harmonic Analyses of Current-Velocity Data

The tables in this appendix present the results of harmonic analyses of time series of current-velocity data collected with the acoustical Doppler current profilers. Analyses were performed for each bin (vertical interval) for each of the three stations for each of the two deployment periods. Astronomical tidal constituents are defined as follows:

Symbol	Origin and name
O1	Principal lunar diurnal
K1	Lunisolar diurnal
N2	Larger lunar elliptic
M2	Principal lunar
S2	Principal solar
M4	Quarter diurnal lunar
MS4	Lunisolar quarter diurnal

Appendix A.--Harmonic analysis of current-velocity data

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	1 = 1.95 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.74011	260.47	271.56
K1	1.00274	2.03507	312.26	314.56
N2	1.89598	0.48365	228.26	246.01
M2	1.93227	2.81553	275.32	288.71
S2	2.00000	1.14610	271.42	276.68
M4	3.86455	2.00757	47.21	73.98
MS4	3.93227	1.15382	112.68	131.32

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.98626	238.37	249.46
K1	1.00274	0.47182	271.53	273.83
N2	1.89598	0.36468	234.31	252.05
M2	1.93227	1.04725	218.83	232.22
S2	2.00000	0.39560	216.43	221.69
M4	3.86455	0.27176	191.24	218.02
MS4	3.93227	0.28812	259.71	278.36

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.97	0.33	241.4	86.4	301.7	Clockwise
K1	2.07	0.30	259.8	133.1	234.6	Clockwise
N2	0.60	0.03	233.0	68.2	336.9	Counter-clockwise
M2	2.88	0.85	257.3	104.9	180.2	Clockwise
S2	1.17	0.32	257.9	93.3	339.6	Clockwise
M4	2.02	0.16	276.3	253.5	0.4	Counter-clockwise
MS4	1.18	0.15	282.0	309.7	159.8	counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.78
Standard deviation, U series (cm/s)	=	3.65
Standard deviation, V series (cm/s)	=	2.71
Tidal-form number	=	1.00
Spring tidal current maximum (cm/s)	=	8.09
Neap tidal current maximum (cm/s)	=	1.62
Principal current direction (deg. t.)	=	254.14

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	2 = 2.45 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.82435	260.78	271.87
K1	1.00274	2.11540	312.14	314.44
N2	1.89598	0.55624	221.90	239.65
M2	1.93227	3.04567	271.86	285.25
S2	2.00000	1.22592	270.53	275.79
M4	3.86455	1.89679	49.74	76.51
MS4	3.93227	1.17291	113.31	131.96

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.03028	242.75	253.84
K1	1.00274	0.48039	288.32	290.62
N2	1.89598	0.29420	250.11	267.86
M2	1.93227	0.81617	222.24	235.63
S2	2.00000	0.36537	214.67	219.93
M4	3.86455	0.13971	145.22	172.00
MS4	3.93227	0.21954	249.30	267.94

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.08	0.28	241.2	87.6	301.7	Clockwise
K1	2.16	0.19	258.2	133.4	234.6	Clockwise
N2	0.62	0.13	243.8	65.4	336.9	Counter-clockwise
M2	3.09	0.61	259.7	103.2	180.2	Clockwise
S2	1.24	0.30	259.9	93.4	339.6	Clockwise
M4	1.90	0.14	270.4	256.5	0.4	Counter-clockwise
MS4	1.18	0.15	277.8	311.0	159.8	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.81
Standard deviation, U series (cm/s)	=	3.67
Standard deviation, V series (cm/s)	=	2.63
Tidal-form number	=	0.98
Spring tidal current maximum (cm/s)	=	8.57
Neap tidal current maximum (cm/s)	=	1.76
Principal current direction (deg. t.)	=	254.88

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name: East
Series start (Standard Time): Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-33-23N 122-37-48W
Bin number 3 = 2.95 meters above bed
Record length: 88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.87027	260.66	271.75
K1	1.00274	2.21086	311.61	313.91
N2	1.89598	0.60582	223.28	241.02
M2	1.93227	3.24928	268.72	282.10
S2	2.00000	1.29725	272.09	277.35
M4	3.86455	1.78342	50.60	77.37
MS4	3.93227	1.10872	114.74	133.38

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.09556	247.35	258.43
K1	1.00274	0.50496	303.09	305.39
N2	1.89598	0.22006	265.36	283.10
M2	1.93227	0.64648	231.81	245.19
S2	2.00000	0.33684	220.06	225.32
M4	3.86455	0.22848	88.71	115.48
MS4	3.93227	0.18068	244.69	263.34

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.16	0.22	240.0	88.4	301.7	Clockwise
K1	2.27	0.07	257.3	133.5	234.6	Clockwise
N2	0.63	0.14	254.1	64.7	336.9	Counter-clockwise
M2	3.29	0.38	260.8	101.0	180.2	Clockwise
S2	1.31	0.26	260.5	95.5	339.6	Clockwise
M4	1.79	0.14	264.2	257.8	0.4	Counter-clockwise
MS4	1.11	0.14	276.1	312.6	159.8	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.84
Standard deviation, U series (cm/s)	=	3.67
Standard deviation, V series (cm/s)	=	2.55
Tidal-form number	=	0.96
Spring tidal current maximum (cm/s)	=	9.03
Neap tidal current maximum (cm/s)	=	1.87
Principal current direction (deg. t.)	=	254.91

Station name: East
Series start (Standard Time): Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-33-23N 122-37-48W
Bin number: 4 = 3.45 meters above bed
Record length: 88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.88677	259.69	270.77
K1	1.00274	2.26567	311.60	313.90
N2	1.89598	0.66568	225.24	242.99
M2	1.93227	3.41213	266.43	279.82
S2	2.00000	1.30932	273.53	278.79
M4	3.86455	1.68301	53.44	80.21
MS4	3.93227	1.08782	117.02	135.67

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.13431	251.23	262.31
K1	1.00274	0.54279	312.07	314.37
N2	1.89598	0.15988	295.71	313.46
M2	1.93227	0.56337	244.67	258.06
S2	2.00000	0.25889	230.03	235.29
M4	3.86455	0.40901	67.07	93.84
MS4	3.93227	0.11473	220.13	238.77

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.20	0.14	239.1	88.5	301.7	Clockwise
K1	2.33	0.00	256.5	133.9	234.6	Counter-clockwise
N2	0.67	0.15	265.2	64.1	336.9	Counter-clockwise
M2	3.45	0.21	261.3	99.3	180.2	Clockwise
S2	1.32	0.18	261.7	97.7	339.6	Clockwise
M4	1.73	0.09	256.7	260.9	0.4	Counter-clockwise
MS4	1.09	0.11	271.4	315.5	159.8	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.85
Standard deviation, U series (cm/s)	=	3.63
Standard deviation, V series (cm/s)	=	2.47
Tidal-form number	=	0.95
Spring tidal current maximum (cm/s)	=	9.30
Neap tidal current maximum (cm/s)	=	2.00
Principal current direction (deg. t.)	=	254.90

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	5 = 3.95 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.83897	258.85	269.94
K1	1.00274	2.30718	310.71	313.02
N2	1.89598	0.71763	226.81	244.55
M2	1.93227	3.54883	264.61	278.00
S2	2.00000	1.32042	275.12	280.38
M4	3.86455	1.62554	56.00	82.77
MS4	3.93227	1.07523	117.99	136.63

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.17274	254.13	265.22
K1	1.00274	0.54489	325.81	328.11
N2	1.89598	0.15744	318.59	336.33
M2	1.93227	0.54330	259.68	273.06
S2	2.00000	0.25748	243.41	248.67
M4	3.86455	0.59070	60.08	86.86
MS4	3.93227	0.11927	183.23	201.88

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.18	0.08	237.5	88.6	301.7	Clockwise
K1	2.37	0.14	257.1	133.8	234.6	Counter-clockwise
N2	0.72	0.16	270.4	64.5	336.9	Counter-clockwise
M2	3.59	0.05	261.3	97.9	180.2	Clockwise
S2	1.34	0.13	260.5	99.4	339.6	Clockwise
M4	1.73	0.04	250.1	263.3	0.4	Counter-clockwise
MS4	1.08	0.11	267.3	316.9	159.8	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.89
Standard deviation, U series (cm/s)	=	3.60
Standard deviation, V series (cm/s)	=	2.42
Tidal-form number	=	0.92
Spring tidal current maximum (cm/s)	=	9.47
Neap tidal current maximum (cm/s)	=	2.06
Principal current direction (deg. t.)	=	254.68

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	6 = 4.45 meters above bed
Record length:	88 M2 Cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.87675	257.51	268.59
K1	1.00274	2.40163	309.53	311.84
N2	1.89598	0.78728	227.32	245.06
M2	1.93227	3.69125	263.32	276.70
S2	2.00000	1.33528	276.25	281.51
M4	3.86455	1.53415	59.90	86.67
MS4	3.93227	1.03782	122.20	140.85

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.14151	257.59	268.67
K1	1.00274	0.56606	332.28	334.58
N2	1.89598	0.20602	331.10	348.85
M2	1.93227	0.55088	271.96	285.34
S2	2.00000	0.27743	261.32	266.58
M4	3.86455	0.69274	54.52	81.30
MS4	3.93227	0.21751	151.56	170.21

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.20	0.00	238.7	88.6	301.7	Counter-clockwise
K1	2.46	0.21	257.6	132.9	234.6	Counter-clockwise
N2	0.79	0.20	273.8	64.1	336.9	Counter-clockwise
M2	3.73	0.08	261.6	96.9	180.2	Counter-clockwise
S2	1.36	0.07	258.6	100.9	339.6	Clockwise
M4	1.68	0.06	245.8	265.8	0.4	Clockwise
MS4	1.06	0.10	259.5	321.9	159.8	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.96
Standard deviation, U series (cm/s)	=	3.56
Standard deviation, V series (cm/s)	=	2.40
Tidal-form number	=	0.91
Spring tidal current maximum (cm/s)	=	9.75
Neap tidal current maximum (cm/s)	=	2.11
Principal current direction (deg. t.)	=	255.02

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name: East
Series start (Standard Time): Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-33-23N 122-37-48W
Bin number: 7 = 4.95 meters above bed
Record Length: 88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.92055	255.78	266.87
K1	1.00274	2.40922	308.59	310.89
N2	1.89598	0.84009	230.41	248.15
M2	1.93227	3.78930	261.97	275.35
S2	2.00000	1.32533	275.90	281.16
M4	3.86455	1.49742	64.63	91.40
MS4	3.93227	0.97728	125.87	144.52

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.07626	261.62	272.71
K1	1.00274	0.62610	335.09	337.40
N2	1.89598	0.17816	334.41	352.15
M2	1.93227	0.62225	288.11	301.49
S2	2.00000	0.27329	268.90	274.16
M4	3.86455	0.78879	51.61	78.38
MS4	3.93227	0.32737	125.17	143.81

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.20	0.10	240.8	88.3	301.7	Counter-clockwise
K1	2.47	0.27	256.7	132.4	234.6	Counter-clockwise
N2	0.84	0.17	273.1	67.5	336.9	Counter-clockwise
M2	3.83	0.27	261.6	96.0	180.2	Counter-clockwise
S2	1.35	0.03	258.4	100.9	339.6	Clockwise
M4	1.69	0.16	242.6	268.6	0.4	Clockwise
MS4	1.03	0.00	251.5	324.4	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.01
Standard deviation, U series (cm/s)	=	3.50
Standard deviation, V series (cm/s)	=	2.38
Tidal-form number	=	0.90
Spring tidal current maximum (cm/s)	=	9.86
Neap tidal current maximum (cm/s)	=	2.20
Principal current direction (deg. t.)	=	255.29

Station name: East
Series start (Standard Time): Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-33-23N 122-37-48W
Bin number: 8 = 5.45 meters above bed
Record length: 88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.90918	253.40	264.48
K1	1.00274	2.44153	307.21	309.51
N2	1.89598	0.89393	234.12	251.86
M2	1.93227	3.86551	260.51	273.90
S2	2.00000	1.32885	277.00	282.26
M4	3.86455	1.42680	69.57	96.34
MS4	3.93227	0.92823	129.95	148.60

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.03341	263.59	274.68
K1	1.00274	0.67649	339.86	342.16
N2	1.89598	0.22059	337.06	354.80
M2	1.93227	0.67532	298.78	312.17
S2	2.00000	0.27531	282.47	287.73
M4	3.86455	0.89140	44.35	71.13
MS4	3.93227	0.41291	111.77	130.42

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.16	0.16	241.8	86.8	301.7	Counter-clockwise
K1	2.51	0.36	256.6	131.4	234.6	Counter-clockwise
N2	0.90	0.21	273.4	71.1	336.9	Counter-clockwise
M2	3.90	0.41	262.1	94.7	180.2	Counter-clockwise
S2	1.36	0.03	258.3	102.5	339.6	Counter-clockwise
M4	1.65	0.33	239.2	269.6	0.4	Clockwise
MS4	1.01	0.12	246.8	325.7	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.10
Standard deviation, U series (cm/s)	=	3.48
Standard deviation, V series (cm/s)	=	2.41
Tidal-form number	=	0.89
Spring tidal current maximum (cm/s)	=	9.93
Neap tidal current maximum (cm/s)	=	2.20
Principal current direction (deg. t.)	=	255.77

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	9 = 5.95 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.89863	251.54	262.63
K1	1.00274	2.46889	305.80	308.10
N2	1.89598	0.91499	235.94	253.68
M2	1.93227	3.94507	259.13	272.52
S2	2.00000	1.28794	277.83	283.09
M4	3.86455	1.34008	76.38	103.15
MS4	3.93227	0.88988	135.86	154.51

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.96022	266.32	277.40
K1	1.00274	0.67164	342.42	344.72
N2	1.89598	0.27560	335.51	353.25
M2	1.93227	0.75428	306.24	319.63
S2	2.00000	0.29738	291.82	297.08
M4	3.86455	1.00172	39.91	66.68
MS4	3.93227	0.49904	97.25	115.89

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.12	0.22	243.6	85.6	301.7	Counter-clockwise
K1	2.53	0.39	257.4	130.1	234.6	Counter-clockwise
N2	0.92	0.27	273.1	72.7	336.9	Counter-clockwise
M2	3.98	0.55	262.4	93.6	180.2	Counter-clockwise
S2	1.32	0.07	257.3	103.8	339.6	Counter-clockwise
M4	1.60	0.50	235.1	270.8	0.4	Clockwise
MS4	0.98	0.28	244.0	326.5	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.16
Standard deviation, U series (cm/s)	=	3.45
Standard deviation, V series (cm/s)	=	2.47
Tidal-form number	=	0.88
Spring tidal current maximum (cm/s)	=	9.94
Neap tidal current maximum (cm/s)	=	2.25
Principal current direction (deg. t.)	=	256.47

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	10 = 6.45 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.92672	250.23	261.32
K1	1.00274	2.44354	305.10	307.40
N2	1.89598	0.88459	237.42	255.16
M2	1.93227	4.07672	257.47	270.86
S2	2.00000	1.28997	278.27	283.53
M4	3.86455	1.36592	83.61	110.39
MS4	3.93227	0.87472	140.47	159.12

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.87696	270.00	281.08
K1	1.00274	0.70556	342.63	344.93
N2	1.89598	0.32180	327.29	345.03
M2	1.93227	0.84284	318.69	332.08
S2	2.00000	0.33791	307.23	312.49
M4	3.86455	1.06763	36.49	63.27
MS4	3.93227	0.54344	89.78	108.43

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.10	0.27	246.4	84.6	301.7	Counter-clockwise
K1	2.51	0.42	256.7	129.7	234.6	Counter-clockwise
N2	0.88	0.32	269.9	75.2	336.9	Counter-clockwise
M2	4.10	0.73	264.1	91.9	180.2	Counter-clockwise
S2	1.32	0.16	256.9	105.1	339.6	Counter-clockwise
M4	1.60	0.67	235.0	274.1	0.4	Clockwise
MS4	0.96	0.39	244.0	328.0	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.25
Standard deviation, U series (cm/s)	=	3.40
Standard deviation, V series (cm/s)	=	2.53
Tidal-form number	=	0.85
Spring tidal current maximum (cm/s)	=	10.03
Neap tidal current maximum (cm/s)	=	2.36
Principal current direction (deg. t.)	=	257.61

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name: East
Series start (Standard Time): Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-33-23N 122-37-48W
Bin number: 11 = 6.95 meters above bed
Record length: 88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.93722	249.57	260.65
K1	1.00274	2.42855	303.52	305.82
N2	1.89598	0.89449	238.48	256.22
M2	1.93227	4.13410	255.65	269.04
S2	2.00000	1.27212	278.31	283.57
M4	3.86455	1.34874	90.17	116.95
MS4	3.93227	0.83859	145.27	163.92

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.80753	272.64	283.72
K1	1.00274	0.73675	341.18	343.48
N2	1.89598	0.34891	320.62	338.36
M2	1.93227	0.99102	325.84	339.23
S2	2.00000	0.39188	316.53	321.79
M4	3.86455	1.17335	31.69	58.47
MS4	3.93227	0.66435	81.36	100.00

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.08	0.30	248.6	83.8	301.7	Counter-clockwise
K1	2.50	0.44	256.1	128.3	234.6	Counter-clockwise
N2	0.90	0.35	266.4	77.6	336.9	Counter-clockwise
M2	4.15	0.93	265.1	90.1	180.2	Counter-clockwise
S2	1.31	0.24	255.9	106.2	339.6	Counter-clockwise
M4	1.57	0.86	232.5	274.1	0.4	Clockwise
MS4	0.92	0.54	239.1	324.5	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.32
Standard deviation, U series (cm/s)	=	3.35
Standard deviation, V series (cm/s)	=	2.61
Tidal-form number	=	0.84
Spring tidal current maximum (cm/s)	=	10.04
Neap tidal current maximum (cm/s)	=	2.42
Principal current direction (deg. t.)	=	258.23

Station name: East
Series start (Standard Time): Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-33-23N 122-37-48W
Bin number: 12 = 7.45 meters above bed
Record length: 88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.95647	248.05	259.13
K1	1.00274	2.39620	301.89	304.19
N2	1.89598	0.83481	241.20	258.95
M2	1.93227	4.23161	252.78	266.17
S2	2.00000	1.30882	279.80	285.06
M4	3.86455	1.35878	99.62	126.40
MS4	3.93227	0.82897	151.15	169.79

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.75230	276.90	287.98
K1	1.00274	0.81496	343.12	345.42
N2	1.89598	0.42736	317.14	334.88
M2	1.93227	1.15858	332.31	345.69
S2	2.00000	0.41068	328.24	333.50
M4	3.86455	1.24873	28.51	55.28
MS4	3.93227	0.72105	78.96	97.60

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.07	0.34	250.8	82.4	301.7	Counter-clockwise
K1	2.48	0.52	255.0	127.4	234.6	Counter-clockwise
N2	0.84	0.41	260.7	83.5	336.9	Counter-clockwise
M2	4.24	1.14	266.9	87.0	180.2	Counter-clockwise
S2	1.34	0.30	257.6	107.9	339.6	Counter-clockwise
M4	1.51	1.07	232.3	277.8	0.4	Clockwise
MS4	0.90	0.63	237.3	325.4	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.42
Standard deviation, u series (cm/s)	=	3.33
Standard deviation, v series (cm/s)	=	2.70
Tidal-form number	=	0.82
Spring tidal current maximum (cm/s)	=	10.12
Neap tidal current maximum (cm/s)	=	2.49
Principal current direction (deg. t.)	=	259.48

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	13 = 7.95 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.90884	248.21	259.30
K1	1.00274	2.35066	300.63	302.93
N2	1.89598	0.78003	241.97	259.71
M2	1.93227	4.29133	250.13	263.52
S2	2.00000	1.32878	278.67	283.93
M4	3.86455	1.34445	106.92	133.69
MS4	3.93227	0.81614	158.07	176.71

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.72993	282.18	293.27
K1	1.00274	0.87224	340.96	343.26
N2	1.89598	0.49630	311.54	329.29
M2	1.93227	1.34106	336.17	349.56
S2	2.00000	0.43872	342.93	348.19
M4	3.86455	1.32417	25.14	51.91
MS4	3.93227	0.79378	75.41	94.06

Tidal elipse (combined results for U and V series)

	Speed on indicated axis				Equili-brium	
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	angle (degrees)	Rotation
O1	2.01	0.39	251.7	83.0	301.7	Counter-clockwise
K1	2.45	0.54	253.4	126.7	234.6	Counter-clockwise
N2	0.81	0.45	251.6	90.2	336.9	Counter-clockwise
M2	4.29	1.34	268.6	83.9	180.2	Counter-clockwise
S2	1.34	0.39	261.1	106.5	339.6	Counter-clockwise
M4	1.43	1.23	228.0	275.8	0.4	Clockwise
MS4	0.86	0.75	231.1	321.5	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.49
Standard deviation, U series (cm/s)	=	3.31
Standard deviation, V series (cm/s)	=	2.80
Tidal-form number	=	0.79
Spring tidal current maximum (cm/s)	=	10.09
Neap tidal current maximum (cm/s)	=	2.51
Principal current direction (deg. t.)	=	260.55

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute= 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	14 = 8.45 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.86790	247.83	258.91
K1	1.00274	2.31822	297.82	300.12
N2	1.89598	0.74453	240.00	257.75
M2	1.93227	4.37501	247.23	260.62
S2	2.00000	1.36662	277.16	282.42
M4	3.86455	1.40497	114.94	141.72
MS4	3.93227	0.79185	163.79	182.44

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.71342	286.06	297.15
K1	1.00274	0.95739	340.67	342.97
N2	1.89598	0.60444	308.15	325.89
M2	1.93227	1.56282	338.51	351.90
S2	2.00000	0.48471	353.86	359.12
M4	3.86455	1.39050	24.15	50.93
MS4	3.93227	0.83277	74.23	92.88

Tidal elipse (combined results for U and V series)

	Speed on indicated axis				Equili-brium	
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	angle (degrees)	Rotation
O1	1.95	0.42	252.5	82.8	301.7	Counter-clockwise
K1	2.43	0.62	251.9	124.9	234.6	Counter-clockwise
N2	0.81	0.52	239.7	98.3	336.9	Counter-clockwise
M2	4.38	1.56	270.5	80.4	180.2	Counter-clockwise
S2	1.37	0.47	264.7	104.2	339.6	Counter-clockwise
M4	1.41	1.39	296.6	347.9	0.4	Clockwise
MS4	0.83	0.79	4.4	97.0	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.61
Standard deviation, U series (cm/s)	=	3.34
Standard deviation, V series (cm/s)	=	2.89
Tidal-form number	=	0.76
Spring tidal current maximum (cm/s)	=	10.13
Neap tidal current maximum (cm/s)	=	2.53
Principal current direction (deg. t.)	=	261.79

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	15 = 8.95 meters above bed
Record length:	88 M2 Cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.79748	246.91	257.99
K1	1.00274	2.21661	295.86	298.17
N2	1.89598	0.68832	239.10	256.85
M2	1.93227	4.49833	243.60	256.99
S2	2.00000	1.40267	274.55	279.81
M4	3.86455	1.43734	122.70	149.47
MS4	3.93227	0.74513	170.00	188.65

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.72838	288.61	299.69
K1	1.00274	1.09964	339.97	342.27
N2	1.89598	0.64963	308.59	326.34
M2	1.93227	1.76915	340.40	353.79
S2	2.00000	0.57463	3.11	8.37
M4	3.86455	1.45817	22.60	49.37
MS4	3.93227	0.90064	72.74	91.38

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.88	0.46	252.0	82.5	301.7	Counter-clockwise
K1	2.37	0.72	248.3	125.0	234.6	Counter-clockwise
N2	0.78	0.54	229.7	107.2	336.9	Counter-clockwise
M2	4.50	1.75	273.1	75.8	180.2	Counter-clockwise
S2	1.40	0.57	269.3	100.1	339.6	Counter-clockwise
M4	1.57	1.31	317.3	11.7	0.4	Clockwise
MS4	0.91	0.73	343.2	77.9	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.73
Standard deviation, U series (cm/s)	=	3.35
Standard deviation, V series (cm/s)	=	2.99
Tidal-form number	=	0.72
Spring tidal current maximum (cm/s)	=	10.16
Neap tidal current maximum (cm/s)	=	2.62
Principal current direction (deg. t.)	=	262.91

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	16 = 9.45 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.69048	246.20	257.29
K1	1.00274	2.11825	292.43	294.73
N2	1.89598	0.69241	235.36	253.11
M2	1.93227	4.52340	239.93	253.32
S2	2.00000	1.43581	270.82	276.08
M4	3.86455	1.43719	129.28	156.05
MS4	3.93227	0.70222	179.04	197.69

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.75698	291.80	302.89
K1	1.00274	1.15540	340.06	342.36
N2	1.89598	0.69676	304.20	321.94
M2	1.93227	1.96456	339.71	353.10
S2	2.00000	0.70353	5.34	10.60
M4	3.86455	1.51032	21.71	48.48
MS4	3.93227	0.96125	73.00	91.64

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.78	0.51	251.0	83.0	301.7	Counter-clockwise
K1	2.28	0.79	246.8	123.2	234.6	Counter-clockwise
N2	0.81	0.56	224.5	108.0	336.9	Counter-clockwise
M2	4.54	1.93	275.2	71.1	180.2	Counter-clockwise
S2	1.44	0.70	272.9	94.7	339.6	Counter-clockwise
M4	1.68	1.23	319.7	16.7	0.4	Clockwise
MS4	1.00	0.65	339.6	78.0	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.80
Standard deviation, U series (cm/s)	=	3.39
Standard deviation, V series (cm/s)	=	3.07
Tidal-form number	=	0.68
Spring tidal current maximum (cm/s)	=	10.03
Neap tidal current maximum (cm/s)	=	2.60
Principal current direction (deg. t.)	=	264.11

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	17 = 9.95 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.57248	244.97	256.06
K1	1.00274	2.03509	288.93	291.24
N2	1.89598	0.71995	233.44	251.18
M2	1.93227	4.57839	235.99	249.38
S2	2.00000	1.45895	266.57	271.83
M4	3.86455	1.48128	134.07	160.85
MS4	3.93227	0.68347	187.36	206.01

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.80767	292.78	303.86
K1	1.00274	1.27507	339.58	341.88
N2	1.89598	0.74036	308.02	325.76
M2	1.93227	2.18534	337.68	351.07
S2	2.00000	0.75779	8.96	14.22
M4	3.86455	1.54411	21.72	48.50
MS4	3.93227	0.98386	73.63	92.28

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.68	0.56	248.4	83.6	301.7	Counter-clockwise
K1	2.23	0.90	243.7	122.6	234.6	Counter-clockwise
N2	0.82	0.63	222.0	111.4	336.9	Counter-clockwise
M2	4.61	2.13	277.0	66.1	180.2	Counter-clockwise
S2	1.47	0.73	278.5	87.6	339.6	Counter-clockwise
M4	1.78	1.19	318.1	17.6	0.4	Clockwise
MS4	1.04	0.59	336.4	78.4	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	6.89
Standard deviation, U series (cm/s)	=	3.42
Standard deviation, V series (cm/s)	=	3.12
Tidal-form number	=	0.64
Spring tidal current maximum (cm/s)	=	9.98
Neap tidal current maximum (cm/s)	=	2.58
Principal current direction (deg. t.)	=	265.01

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	18 = 10.45 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.47861	243.78	254.87
K1	1.00274	1.96101	284.15	286.45
N2	1.89598	0.75354	231.19	248.93
M2	1.93227	4.65664	232.76	246.15
S2	2.00000	1.53290	262.69	267.95
M4	3.86455	1.44894	138.38	165.15
MS4	3.93227	0.66614	193.56	212.21

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.90203	294.94	306.03
K1	1.00274	1.38559	335.46	337.76
N2	1.89598	0.77813	308.03	325.77
M2	1.93227	2.40032	336.89	350.27
S2	2.00000	0.81419	9.80	15.06
M4	3.86455	1.56931	21.47	48.24
MS4	3.93227	1.01235	77.94	96.59

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.61	0.65	244.7	85.6	301.7	Counter-clockwise
K1	2.20	0.96	239.8	120.8	234.6	Counter-clockwise
N2	0.85	0.67	221.0	111.3	336.9	Counter-clockwise
M2	4.71	2.30	279.5	61.5	180.2	Counter-clockwise
S2	1.56	0.77	281.8	82.1	339.6	Counter-clockwise
M4	1.82	1.11	320.0	21.2	0.4	Clockwise
MS4	1.07	0.57	337.4	84.2	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.02
Standard deviation, U series (cm/s)	=	3.48
Standard deviation, V series (cm/s)	=	3.19
Tidal-form number	=	0.61
Spring tidal current maximum (cm/s)	=	10.07
Neap tidal current maximum (cm/s)	=	2.56
Principal current direction (deg. t.)	=	265.60

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year =1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	19 = 10.95 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.36927	241.88	252.97
K1	1.00274	1.89772	279.40	281.71
N2	1.89598	0.73280	234.33	252.07
M2	1.93227	4.71425	228.79	242.17
S2	2.00000	1.60786	260.77	266.03
M4	3.86455	1.42656	143.25	170.03
MS4	3.93227	0.59676	205.51	224.15

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.87580	293.11	304.20
K1	1.00274	1.46646	332.31	334.61
N2	1.89598	0.74099	303.64	321.38
M2	1.93227	2.54136	334.92	348.31
S2	2.00000	0.85956	9.83	15.09
M4	3.86455	1.51335	24.87	51.64
MS4	3.93227	1.06202	77.81	96.45

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	1.50	0.62	243.2	84.8	301.7	Counter-clockwise
K1	2.17	1.02	236.7	118.9	234.6	Counter-clockwise
N2	0.86	0.59	224.1	107.6	336.9	Counter-clockwise
M2	4.79	2.40	281.5	56.4	180.2	Counter-clockwise
S2	1.64	0.80	283.0	79.6	339.6	Counter-clockwise
M4	1.79	1.06	318.5	23.9	0.4	Clockwise
MS4	1.14	0.44	337.4	87.3	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.11
Standard deviation, U series (cm/s)	=	3.53
Standard deviation, V series (cm/s)	=	3.21
Tidal-form number	=	0.57
Spring tidal current maximum (cm/s)	=	10.10
Neap tidal current maximum (cm/s)	=	2.48
Principal current direction (deg. t.)	=	266.40

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	20 = 11.45 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.30959	241.09	252.17
K1	1.00274	1.80294	274.63	276.93
N2	1.89598	0.70591	237.78	255.52
M2	1.93227	4.73429	225.58	238.97
S2	2.00000	1.62886	257.71	262.97
M4	3.86455	1.38251	147.62	174.39
MS4	3.93227	0.56664	214.46	233.10

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.94484	289.75	300.84
K1	1.00274	1.50512	329.32	331.62
N2	1.89598	0.72813	303.36	321.10
M2	1.93227	2.66474	333.59	346.98
S2	2.00000	0.77818	8.53	13.79
M4	3.86455	1.43928	24.88	51.65
MS4	3.93227	1.01240	84.96	103.61

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	1.49	0.62	238.4	86.6	301.7	Counter-clockwise
K1	2.10	1.06	233.7	117.2	234.6	Counter-clockwise
N2	0.85	0.55	222.9	110.3	336.9	Counter-clockwise
M2	4.83	2.48	283.5	51.9	180.2	Counter-clockwise
S2	1.66	0.71	281.9	77.8	339.6	Counter-clockwise
M4	1.75	0.96	317.1	24.8	0.4	Clockwise
MS4	1.09	0.41	337.0	94.6	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.15
Standard deviation, U series (cm/s)	=	3.53
Standard deviation, V series (cm/s)	=	3.23
Tidal-form number	=	0.55
Spring tidal current maximum (cm/s)	=	10.08
Neap tidal current maximum (cm/s)	=	2.57
Principal current direction (deg. t.)	=	266.19

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	21 = 11.95 meters above bed
Record length:	88 M2 cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.22643	236.66	247.75
K1	1.00274	1.74224	270.44	272.74
N2	1.89598	0.72856	243.38	261.12
M2	1.93227	4.73211	222.56	235.95
S2	2.00000	1.60205	255.37	260.63
M4	3.86455	1.34049	152.14	178.91
MS4	3.93227	0.51191	229.33	247.98

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.91017	287.01	298.10
K1	1.00274	1.56364	323.93	326.23
N2	1.89598	0.70384	302.59	320.33
M2	1.93227	2.77086	330.30	343.68
S2	2.00000	0.78274	4.05	9.31
M4	3.86455	1.35514	28.69	55.46
MS4	3.93227	0.98452	87.39	106.04

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.40	0.61	237.7	83.3	301.7	Counter-clockwise
K1	2.09	1.05	230.2	115.3	234.6	Counter-clockwise
N2	0.88	0.50	226.9	109.1	336.9	Counter-clockwise
M2	4.84	2.58	284.2	48.2	180.2	Counter-clockwise
S2	1.63	0.73	281.2	75.6	339.6	Counter-clockwise
M4	1.68	0.90	315.6	27.7	0.4	Clockwise
MS4	1.07	0.29	335.9	99.1	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.25
Standard deviation, U series (cm/s)	=	3.58
Standard deviation, V series (cm/s)	=	3.27
Tidal-form number	=	0.54
Spring tidal current maximum (cm/s)	=	9.96
Neap tidal current maximum (cm/s)	=	2.51
Principal current direction (deg. t.)	=	265.83

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	22 = 12.45 meters above bed
Record Length:	88 M2 Cycle: 6559 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.16709	236.13	247.22
K1	1.00274	1.70270	266.96	269.26
N2	1.89598	0.71737	244.89	262.63
M2	1.93227	4.74210	220.36	233.74
S2	2.00000	1.56910	252.05	257.31
M4	3.86455	1.28977	156.73	183.51
MS4	3.93227	0.50357	233.75	252.40

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.87837	281.41	292.49
K1	1.00274	1.61570	321.11	323.41
N2	1.89598	0.67321	300.57	318.31
M2	1.93227	2.84185	326.83	340.21
S2	2.00000	0.73936	1.79	7.05
M4	3.86455	1.27926	31.95	58.73
MS4	3.93227	0.97231	91.09	109.74

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.36	0.54	236.1	82.0	301.7	Counter-clockwise
K1	2.09	1.07	227.6	114.3	234.6	Counter-clockwise
N2	0.87	0.46	228.2	107.8	336.9	Counter-clockwise
M2	4.84	2.67	284.0	45.9	180.2	Counter-clockwise
S2	1.59	0.69	281.1	72.5	339.6	Counter-clockwise
M4	1.61	0.84	314.6	30.8	0.4	Clockwise
MS4	1.06	0.28	335.8	102.9	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.33
Standard deviation, U series (cm/s)	=	3.62
Standard deviation, V series (cm/s)	=	3.26
Tidal-form number	=	0.54
Spring tidal current maximum (cm/s)	=	9.88
Neap tidal current maximum (cm/s)	=	2.52
Principal current direction (deg. t.)	=	265.00

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	23 = 12.95 meters above bed
Record length:	88 M2 cycle: 6515 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.09390	234.66	245.74
K1	1.00274	1.61314	262.88	265.18
N2	1.89598	0.73732	249.37	267.11
M2	1.93227	4.62185	217.81	231.20
S2	2.00000	1.51938	251.29	256.55
M4	3.86455	1.20567	162.38	189.15
MS4	3.93227	0.46642	247.11	265.75

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.92128	277.09	288.17
K1	1.00274	1.73997	318.11	320.41
N2	1.89598	0.66566	292.88	310.62
M2	1.93227	3.01126	323.23	336.62
S2	2.00000	0.78756	358.89	4.15
M4	3.86455	1.13229	32.25	59.02
MS4	3.93227	0.91106	93.12	111.77

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.34	0.51	231.6	82.5	301.7	Counter-clockwise
K1	2.10	1.10	221.2	115.9	234.6	Counter-clockwise
N2	0.92	0.37	229.0	106.1	336.9	Counter-clockwise
M2	4.73	2.84	285.5	41.7	180.2	Counter-clockwise
S2	1.54	0.74	281.6	70.9	339.6	Counter-clockwise
M4	1.50	0.70	312.2	32.0	0.4	Clockwise
MS4	1.01	0.19	334.4	106.7	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.45
Standard deviation, U series (cm/s)	=	3.67
Standard deviation, V series (cm/s)	=	3.24
Tidal-form number	=	0.55
Spring tidal current maximum (cm/s)	=	9.72
Neap tidal current maximum (cm/s)	=	2.42
Principal current direction (deg. t.)	=	263.55

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	24 = 13.45 meters above bed
Record length:	88 M2 cycle: 6175 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.02977	231.83	242.91
K1	1.00274	1.58656	257.16	259.46
N2	1.89598	0.87214	253.86	271.60
M2	1.93227	4.47110	216.82	230.20
S2	2.00000	1.39334	251.92	257.18
M4	3.86455	1.19697	174.20	200.98
MS4	3.93227	0.49790	253.29	271.93

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.06668	267.91	279.00
K1	1.00274	1.78281	315.12	317.42
N2	1.89598	0.78089	287.13	304.87
M2	1.93227	3.20067	317.53	330.91
S2	2.00000	0.87203	359.14	4.40
M4	3.86455	0.90088	26.85	53.62
MS4	3.93227	0.72715	87.47	106.11

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.41	0.46	223.8	81.7	301.7	Counter-clockwise
K1	2.09	1.15	218.8	113.7	234.6	Counter-clockwise
N2	1.12	0.33	228.8	106.2	336.9	Counter-clockwise
M2	4.55	3.09	284.3	40.4	180.2	Counter-clockwise
S2	1.43	0.81	285.7	68.1	339.6	Counter-clockwise
M4	1.44	0.40	305.6	32.3	0.4	Clockwise
MS4	0.88	0.10	325.9	101.6	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.54
Standard deviation, U Series (cm/s)	=	3.70
Standard deviation, V Series (cm/s)	=	3.22
Tidal-form number	=	0.59
Spring tidal current maximum (cm/s)	=	9.48
Neap tidal current maximum (cm/s)	=	2.43
Principal current direction (deg. t.)	=	261.04

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series Start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station Position:	47-33-23N 122-37-48W
Bin Number:	25 = 13.95 meters above bed
Record Length:	88 M2 Cycle: 5762 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.05694	227.57	238.66
K1	1.00274	1.49839	250.95	253.26
N2	1.89598	0.96817	244.02	261.77
M2	1.93227	4.26474	215.45	228.84
S2	2.00000	1.37250	254.01	259.27
M4	3.86455	1.14124	184.11	210.89
MS4	3.93227	0.48569	247.61	266.25

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.20453	266.76	277.85
K1	1.00274	1.78264	311.50	313.80
N2	1.89598	0.83821	281.19	298.93
M2	1.93227	3.54966	315.05	328.44
S2	2.00000	1.01909	343.99	349.25
M4	3.86455	0.71270	22.17	48.95
MS4	3.93227	0.51327	96.10	114.74

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.51	0.53	220.2	81.3	301.7	Counter-clockwise
K1	2.03	1.15	215.2	112.0	234.6	Counter-clockwise
N2	1.22	0.40	230.1	97.3	336.9	Counter-clockwise
M2	4.38	3.41	291.1	32.1	180.2	Counter-clockwise
S2	1.37	1.02	270.0	79.3	339.6	Counter-clockwise
M4	1.33	0.19	301.4	35.8	0.4	Clockwise
MS4	0.68	0.17	316.8	101.4	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.64
Standard deviation, U series (cm/s)	=	3.73
Standard deviation, V series (cm/s)	=	3.30
Tidal-form number	=	0.62
Spring tidal current maximum (cm/s)	=	9.29
Neap tidal current maximum (cm/s)	=	2.49
Principal current direction (deg. t.)	=	259.86

Station name:	East
Series Start (Standard Time):	Year = 1994 Month = 2 Day = 17 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-33-23N 122-37-48W
Bin number:	26 = 14.45 meters above bed
Record length:	88 M2 cycle: 5073 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.33184	241.00	252.08
K1	1.00274	1.13548	269.80	272.10
N2	1.89598	1.03107	241.35	259.10
M2	1.93227	3.88904	219.23	232.62
S2	2.00000	1.29565	236.66	241.92
M4	3.86455	1.25523	204.12	230.89
MS4	3.93227	0.29666	224.74	243.39

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.25563	254.21	265.30
K1	1.00274	1.82264	301.60	303.90
N2	1.89598	0.88559	278.10	295.84
M2	1.93227	3.67948	307.83	321.21
S2	2.00000	1.06289	346.34	351.60
M4	3.86455	0.39462	26.39	53.16
MS4	3.93227	0.49673	78.24	96.88

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.82	0.21	226.7	78.3	301.7	Counter-clockwise
K1	2.08	0.52	210.0	115.6	234.6	Counter-clockwise
N2	1.29	0.42	230.4	94.3	336.9	Counter-clockwise
M2	3.90	3.67	258.1	63.8	180.2	Counter-clockwise
S2	1.39	0.93	299.7	41.1	339.6	Counter-clockwise
M4	1.32	0.01	287.4	51.1	0.4	Clockwise
MS4	0.56	0.15	331.4	88.8	159.8	Clockwise

Root-mean-squares speed, (cm/s)	=	7.48
Standard deviation, U series (cm/s)	=	3.63
Standard deviation, V series (cm/s)	=	3.18
Tidal-form number	=	0.74
Spring tidal current maximum (cm/s)	=	9.19
Neap tidal current maximum (cm/s)	=	2.24
Principal current direction (deg. t.)	=	247.30

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	Center
Series Start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time meridian:	120 W
Station Position: 4	7-32-46N 122-38-35W
Bin Number:	1 = 2.20 meters above bed
Record length:	90 M2 Cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.39730	182.35	193.44
K1	1.00274	0.63669	266.21	268.53
N2	1.89598	0.54369	181.35	199.12
M2	1.93227	3.13297	208.81	222.22
S2	2.00000	0.89680	247.16	252.44
M4	3.86455	0.48482	162.48	189.31
MS4	3.93227	0.25627	206.62	225.32

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.42345	213.88	224.97
K1	1.00274	0.60958	275.20	277.51
N2	1.89598	0.46400	238.52	256.29
M2	1.93227	2.00437	238.00	251.41
S2	2.00000	0.68684	283.23	288.52
M4	3.86455	0.53226	215.89	242.72
MS4	3.93227	0.17702	264.42	283.12

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.56	0.16	222.9	30.3	343.2	Counter-clockwise
K1	0.88	0.07	226.3	92.8	251.1	Counter-clockwise
N2	0.63	0.34	233.2	40.9	47.3	Counter-clockwise
M2	3.62	0.85	238.9	50.2	238.2	Counter-clockwise
S2	1.08	0.34	234.2	85.1	14.4	Counter-clockwise
M4	0.64	0.32	220.5	39.6	116.4	Counter-clockwise
MS4	0.28	0.14	242.7	59.6	252.6	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	4.55
Standard deviation, U series (cm/s)	=	2.44
Standard deviation, V series (cm/s)	=	2.06
Tidal-form number	=	0.31
Spring tidal current maximum (cm/s)	=	6.14
Neap tidal current maximum (cm/s)	=	2.22
Principal current direction (deg. t.)	=	234.83

Station name:	Center
Series xtart (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time meridian:	120 W
Station position:	47-32-46N 122-38-35W
Bin number:	2 = 3.20 meters above bed
Record length:	90 M2 cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.51695	197.02	208.12
K1	1.00274	0.91135	266.12	268.44
N2	1.89598	0.56642	200.62	218.39
M2	1.93227	3.57932	216.85	230.26
S2	2.00000	1.03023	251.46	256.75
M4	3.86455	0.50947	175.02	201.84
MS4	3.93227	0.20471	212.62	231.32

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.59718	199.03	210.13
K1	1.00274	0.65902	270.68	273.00
N2	1.89598	0.48363	235.86	253.62
M2	1.93227	2.24812	229.87	243.28
S2	2.00000	0.65389	284.09	289.38
M4	3.86455	0.40628	225.15	251.98
MS4	3.93227	0.18719	269.52	288.22

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.79	0.01	220.9	29.3	343.2	Counter-clockwise
K1	1.12	0.04	234.2	90.0	251.1	Counter-clockwise
N2	0.71	0.22	230.5	52.8	47.3	Counter-clockwise
M2	4.20	0.43	238.2	53.9	238.2	Counter-clockwise
S2	1.18	0.31	239.6	85.4	14.4	Counter-clockwise
M4	0.59	0.27	234.8	39.5	116.4	Counter-clockwise
MS4	0.24	0.13	229.7	75.9	252.6	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	4.98
Standard deviation, U series (cm/s)	=	2.61
Standard deviation, V series (cm/s)	=	2.02
Tidal-form number	=	0.36
Spring tidal current maximum (cm/s)	=	7.30
Neap tidal current maximum (cm/s)	=	2.69
Principal current direction (deg. t.)	=	235.91

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time meridian:	120 W
Station Position:	47-32-46N 122-38-35W
Bin Number:	3 = 4.20 meters above bed
Record length:	90 M2 cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.69712	210.37	221.47
K1	1.00274	1.24812	265.06	267.37
N2	1.89598	0.66855	203.08	220.85
M2	1.93227	4.09152	227.51	240.92
S2	2.00000	1.20388	256.19	261.47
M4	3.86455	0.48685	180.39	207.22
MS4	3.93227	0.10664	231.53	250.23

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.66101	189.24	200.34
K1	1.00274	0.68613	253.76	256.07
N2	1.89598	0.60101	221.02	238.79
M2	1.93227	2.56236	224.21	237.62
S2	2.00000	0.60773	266.48	271.76
M4	3.86455	0.24055	239.75	266.58
MS4	3.93227	0.15816	290.15	308.85

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.94	0.18	226.6	31.5	343.2	Clockwise
K1	1.42	0.12	241.5	84.8	251.1	Clockwise
N2	0.89	0.14	228.2	48.8	47.3	Counter-clockwise
M2	4.83	0.12	238.0	60.0	238.2	Clockwise
S2	1.35	0.10	243.4	83.5	14.4	Counter-clockwise
M4	0.51	0.20	253.2	34.0	116.4	Counter-clockwise
MS4	0.17	0.08	206.1	115.3	252.6	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.48
Standard deviation, U series (cm/s)	=	2.70
Standard deviation, V series (cm/s)	=	2.03
Tidal-form number	=	0.38
Spring tidal current maximum (cm/s)	=	8.53
Neap tidal current maximum (cm/s)	=	3.01
Principal current direction (deg. t.)	=	238.15

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour = 12:28
Time meridian:	120 W
Station position:	47-32-46N 122-38-35W
Bin number:	4 = 5.20 meters above bed
Record length:	90 M2 cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.95899	214.17	225.26
K1	1.00274	1.49082	266.16	268.48
N2	1.89598	0.70005	208.68	226.45
M2	1.93227	4.36928	232.60	246.01
S2	2.00000	1.38139	259.16	264.45
M4	3.86455	0.39538	174.29	201.12
MS4	3.93227	0.13779	235.50	254.20

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.63245	184.83	195.93
K1	1.00274	0.70887	245.19	247.51
N2	1.89598	0.65862	218.74	236.51
M2	1.93227	2.54368	221.32	234.73
S2	2.00000	0.57344	253.12	258.40
M4	3.86455	0.14846	244.08	270.90
MS4	3.93227	0.11493	293.79	312.49

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.12	0.27	238.1	36.8	343.2	Clockwise
K1	1.63	0.23	245.5	84.8	251.1	Clockwise
N2	0.96	0.08	226.8	51.2	47.3	Counter-clockwise
M2	5.04	0.43	240.0	63.2	238.2	Clockwise
S2	1.49	0.06	247.5	83.6	14.4	Clockwise
M4	0.40	0.14	261.6	24.0	116.4	Counter-clockwise
MS4	0.16	0.09	234.6	95.2	252.6	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.71
Standard deviation, U series (cm/s)	=	2.68
Standard deviation, V series (cm/s)	=	2.06
Tidal-form number	=	0.42
Spring tidal current maximum (cm/s)	=	9.28
Neap tidal current maximum (cm/s)	=	3.03
Principal current direction (deg. t.)	=	241.98

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time meridian:	120 W
Station position:	47-32-46N 122-38-35W
Bin number:	5 = 6.20 meters above bed
Record length:	90 M2 cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.17255	217.81	228.91
K1	1.00274	1.62880	264.81	267.12
N2	1.89598	0.68585	211.63	229.40
M2	1.93227	4.59681	235.25	248.66
S2	2.00000	1.52045	263.79	269.08
M4	3.86455	0.33669	171.75	198.58
MS4	3.93227	0.17773	238.76	257.46

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.59422	183.36	194.46
K1	1.00274	0.66083	240.22	242.54
N2	1.89598	0.60542	205.77	223.54
M2	1.93227	2.39552	220.50	233.91
S2	2.00000	0.61507	240.28	245.57
M4	3.86455	0.04655	175.70	202.53
MS4	3.93227	0.09613	276.93	295.63

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.28	0.31	245.8	42.7	343.2	Clockwise
K1	1.74	0.26	249.3	83.9	251.1	Clockwise
N2	0.91	0.05	228.6	46.8	47.3	Clockwise
M2	5.15	0.54	242.9	65.6	238.2	Clockwise
S2	1.62	0.23	249.2	86.0	14.4	Clockwise
M4	0.34	0.00	262.1	18.7	116.4	Counter-clockwise
MS4	0.19	0.05	244.9	84.9	252.6	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.85
Standard deviation, U series (cm/s)	=	2.65
Standard deviation, V series (cm/s)	=	2.13
Tidal-form number	=	0.44
Spring tidal current maximum (cm/s)	=	9.80
Neap tidal current maximum (cm/s)	=	3.07
Principal current direction (deg. t.)	=	245.47

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time Meridian:	120 W
Station position:	47-32-46N 122-38-35W
Bin number:	6 = 7.20 meters above bed
Record length:	90 M2 cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.21185	219.34	230.44
K1	1.00274	1.75803	265.24	267.56
N2	1.89598	0.77631	208.97	226.74
M2	1.93227	4.73944	236.90	250.32
S2	2.00000	1.56339	263.66	268.94
M4	3.86455	0.24585	180.59	207.41
MS4	3.93227	0.23522	240.08	258.78

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.56923	184.25	195.35
K1	1.00274	0.64010	239.18	241.50
N2	1.89598	0.54583	185.60	203.37
M2	1.93227	2.19802	221.97	235.39
S2	2.00000	0.58920	246.61	251.89
M4	3.86455	0.08180	104.25	131.08
MS4	3.93227	0.10692	271.44	290.14

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.30	0.30	247.7	45.0	343.2	Clockwise
K1	1.85	0.27	251.5	84.8	251.1	Clockwise
N2	0.93	0.18	235.7	39.2	47.3	Clockwise
M2	5.20	0.52	245.6	67.7	238.2	Clockwise
S2	1.66	0.16	250.0	86.9	14.4	Clockwise
M4	0.25	0.08	265.0	25.8	116.4	Clockwise
MS4	0.25	0.05	247.8	83.5	252.6	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.85
Standard deviation, U series (cm/s)	=	2.67
Standard deviation, V series (cm/s)	=	2.14
Tidal-form number	=	0.46
Spring tidal current maximum (cm/s)	=	10.02
Neap tidal current maximum (cm/s)	=	2.99
Principal current direction (deg. t.)	=	247.69

Station name: Center
Series start (Standard Time): Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time meridian: 120 W
Station position: 47-32-46N 122-38-35W
Bin number: 7 = 8.20 meters above bed
Record length: 90 M2 cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.25669	222.54	233.64
K1	1.00274	1.83700	264.25	266.57
N2	1.89598	0.83257	198.99	216.76
M2	1.93227	4.87142	236.57	249.98
S2	2.00000	1.65475	259.97	265.26
M4	3.86455	0.19654	202.59	229.42
MS4	3.93227	0.14455	243.75	262.45

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.53794	189.89	200.99
K1	1.00274	0.60134	241.98	244.29
N2	1.89598	0.49209	170.51	188.27
M2	1.93227	2.05991	221.67	235.08
S2	2.00000	0.67305	255.13	260.42
M4	3.86455	0.22708	79.35	106.18
MS4	3.93227	0.06314	217.29	235.99

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.34	0.27	249.3	49.2	343.2	Clockwise
K1	1.92	0.22	252.9	84.6	251.1	Clockwise
N2	0.94	0.21	241.0	29.9	47.3	Clockwise
M2	5.27	0.49	247.6	67.8	238.2	Clockwise
S2	1.79	0.05	247.9	84.6	14.4	Clockwise
M4	0.27	0.14	322.4	84.0	116.4	Clockwise
MS4	0.16	0.03	248.0	78.6	252.6	Clockwise

Root-mean-squares speed, (cm/s) = 5.83
Standard deviation, U series (cm/s) = 2.68
Standard deviation, V series (cm/s) = 2.28
Tidal-form number = 0.46
Spring tidal current maximum (cm/s) = 10.31
Neap tidal current maximum (cm/s) = 2.90
Principal current direction (deg. t.) = 248.85

Station name: Center
Series start (Standard Time): Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time meridian: 120 W
Station position: 47-32-46N 122-38-35W
Bin number: 8 = 9.20 meters above bed
Record length: 90 M2 cycle: 6708 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.21639	225.34	236.44
K1	1.00274	1.85242	261.92	264.24
N2	1.89598	0.92341	191.59	209.36
M2	1.93227	4.87228	236.34	249.75
S2	2.00000	1.58383	255.81	261.09
M4	3.86455	0.15028	165.97	192.80
MS4	3.93227	0.17122	298.51	317.20

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.57666	210.05	221.15
K1	1.00274	0.54693	250.45	252.76
N2	1.89598	0.50706	150.03	167.79
M2	1.93227	1.81815	219.46	232.87
S2	2.00000	0.66769	242.18	247.47
M4	3.86455	0.24402	52.35	79.17
MS4	3.93227	0.10050	141.25	159.95

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.34	0.14	245.1	53.7	343.2	Clockwise
K1	1.93	0.10	253.8	83.3	251.1	Clockwise
N2	1.01	0.31	245.2	21.3	47.3	Clockwise
M2	5.18	0.50	250.2	67.8	238.2	Clockwise
S2	1.71	0.15	247.5	79.1	14.4	Clockwise
M4	0.25	0.13	340.8	68.9	116.4	Clockwise
MS4	0.20	0.03	299.4	142.8	252.6	Clockwise

Root-mean-squares speed, (cm/s) = 5.77
Standard deviation, U series (cm/s) = 2.88
Standard deviation, V series (cm/s) = 2.32
Tidal-form number = 0.47
Spring tidal current maximum (cm/s) = 10.16
Neap tidal current maximum (cm/s) = 2.87
Principal current direction (deg. t.) = 249.75

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 12:28
Time meridian:	120 W
Station position:	47-32-46N 122-38-35W
Bin number:	9 = 10.20 meters above bed
Record length:	90 M2 cycle: 5849 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.19966	229.88	240.98
K1	1.00274	1.85852	255.87	258.18
N2	1.89598	1.02863	203.85	221.62
M2	1.93227	4.79378	235.55	248.96
S2	2.00000	1.47093	254.93	260.22
M4	3.86455	0.07910	224.28	251.10
MS4	3.93227	0.13242	291.15	309.85

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.45965	235.97	247.07
K1	1.00274	0.68352	260.30	262.61
N2	1.89598	0.35387	125.77	143.54
M2	1.93227	1.62691	224.63	238.04
S2	2.00000	0.45937	221.86	227.15
M4	3.86455	0.15333	343.39	10.22
MS4	3.93227	0.01253	290.59	309.29

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.28	0.05	249.1	61.8	343.2	Counter-clockwise
K1	1.98	0.05	249.8	78.7	251.1	Counter-clockwise
N2	1.03	0.35	265.4	40.1	47.3	Clockwise
M2	5.05	0.29	251.5	67.9	238.2	Clockwise
S2	1.52	0.24	254.9	77.8	14.4	Clockwise
M4	0.16	0.07	342.8	17.6	116.4	Counter-clockwise
MS4	0.13	0.00	264.6	129.8	252.6	Clockwise

Root-mean-squares speed, (cm/s)	=	5.75
Standard deviation, U series (cm/s)	=	3.14
Standard deviation, V series (cm/s)	=	2.30
Tidal-form number	=	0.50
Spring tidal current maximum (cm/s)	=	9.84
Neap tidal current maximum (cm/s)	=	2.84
Principal current direction (deg. t.)	=	251.39

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59N 122-39-28W
Bin number:	1 = 2.20 meters above bed
Record length:	90 M2 cycle: 6707 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.29426	122.59	133.70
K1	1.00274	0.18487	280.69	283.02
N2	1.89598	0.23820	207.49	225.28
M2	1.93227	3.47003	218.46	231.90
S2	2.00000	0.76406	250.61	255.93
M4	3.86455	0.49967	192.33	219.22
MS4	3.93227	0.12343	206.69	225.44

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.20198	70.85	81.96
K1	1.00274	0.27110	179.25	181.58
N2	1.89598	0.21704	227.36	245.15
M2	1.93227	1.63472	205.31	218.76
S2	2.00000	0.23399	220.56	225.88
M4	3.86455	0.44316	118.66	145.54
MS4	3.93227	0.04000	111.83	130.59

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	0.33	0.14	240.9	300.1	327.0	Clockwise
K1	0.28	0.18	346.6	172.8	233.6	Clockwise
N2	0.32	0.06	227.8	54.3	14.3	Counter-clockwise
M2	3.82	0.34	245.1	49.6	204.6	Clockwise
S2	0.79	0.11	254.8	73.7	339.6	Clockwise
M4	0.54	0.39	236.6	13.5	49.2	Clockwise
MS4	0.12	0.04	271.8	46.0	184.2	Clockwise

Root-mean-squares speed, (cm/s)	=	4.19
Standard deviation, U series (cm/s)	=	2.20
Standard deviation, V series (cm/s)	=	1.97
Tidal-form number	=	0.13
Spring tidal current maximum (cm/s)	=	5.21
Neap tidal current maximum (cm/s)	=	3.08
Principal current direction (deg. t.)	=	251.71

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59N 122-39-28W
Bin number:	2 = 3.20 meters above bed
Record length:	90 M2 cycle: 6707 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.29912	178.63	189.74
K1	1.00274	0.55876	297.89	300.22
N2	1.89598	0.26604	195.98	213.78
M2	1.93227	3.82731	223.55	236.99
S2	2.00000	0.84039	242.11	247.43
M4	3.86455	0.53976	192.17	219.06
MS4	3.93227	0.19470	246.90	265.66

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.09909	138.46	149.57
K1	1.00274	0.27084	145.85	148.18
N2	1.89598	0.08882	220.61	238.41
M2	1.93227	1.53345	196.10	209.54
S2	2.00000	0.26372	204.39	209.71
M4	3.86455	0.40034	120.68	147.56
MS4	3.93227	0.12111	143.11	161.87

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	0.31	0.06	255.2	6.7	327.0	Clockwise
K1	0.61	0.12	294.1	125.1	233.6	Clockwise
N2	0.28	0.04	252.8	36.0	14.3	Counter-clockwise
M2	4.07	0.66	249.9	53.6	204.6	Clockwise
S2	0.87	0.16	255.6	64.8	339.6	Clockwise
M4	0.57	0.36	246.8	23.8	49.2	Clockwise
MS4	0.20	0.12	282.9	93.3	184.2	Clockwise

Root-mean-squares speed, (cm/s)	=	4.35
Standard deviation, U series (cm/s)	=	2.36
Standard deviation, V series (cm/s)	=	1.83
Tidal-form number	=	0.19
Spring tidal current maximum (cm/s)	=	5.85
Neap tidal current maximum (cm/s)	=	2.90
Principal current direction (deg. t.)	=	255.60

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59N 122-39-28W
Bin number:	3 = 4.20 meters above bed
Record length:	90 M2 cycle: 6699 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.42974	209.57	220.69
K1	1.00274	0.82802	302.00	304.33
N2	1.89598	0.23299	192.48	210.27
M2	1.93227	4.04831	227.03	240.47
S2	2.00000	0.89294	235.60	240.92
M4	3.86455	0.43464	192.43	219.31
MS4	3.93227	0.17622	260.79	279.54

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.12097	182.50	193.61
K1	1.00274	0.29644	122.00	124.33
N2	1.89598	0.16584	127.33	145.13
M2	1.93227	1.46538	191.71	205.15
S2	2.00000	0.29250	202.92	208.23
M4	3.86455	0.20169	155.85	182.74
MS4	3.93227	0.08554	133.96	152.72

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.44	0.05	255.7	38.9	327.0	Clockwise
K1	0.88	0.00	289.7	124.3	233.6	Counter-clockwise
N2	0.25	0.14	244.8	15.3	14.3	Clockwise
M2	4.23	0.81	252.9	57.1	204.6	Clockwise
S2	0.93	0.15	254.1	58.3	339.6	Clockwise
M4	0.47	0.11	248.2	33.8	49.2	Clockwise
MS4	0.18	0.07	288.6	106.4	184.2	Clockwise

Root-mean-squares speed, (cm/s)	=	4.66
Standard deviation, U series (cm/s)	=	2.65
Standard deviation, V series (cm/s)	=	1.92
Tidal-form number	=	0.26
Spring tidal current maximum (cm/s)	=	6.48
Neap tidal current maximum (cm/s)	=	2.86
Principal current direction (deg. t.)	=	258.26

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59N 122-39-28W
Bin number:	4 = 5.20 meters above bed
Record length:	90 M2 cycle: 6707 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.59112	219.95	231.06
K1	1.00274	1.07304	302.17	304.50
N2	1.89598	0.28818	199.43	217.23
M2	1.93227	4.07498	228.53	241.98
S2	2.00000	0.87720	233.39	238.70
M4	3.86455	0.34120	182.53	209.41
MS4	3.93227	0.17837	260.21	278.97

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.08424	252.77	263.89
K1	1.00274	0.39435	111.13	113.46
N2	1.89598	0.40759	102.80	120.60
M2	1.93227	1.45825	190.38	203.82
S2	2.00000	0.29340	209.74	215.06
M4	3.86455	0.08284	196.39	223.28
MS4	3.93227	0.05918	18.17	36.93

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.60	0.05	263.1	51.6	327.0	Counter-clockwise
K1	1.14	0.07	289.9	123.2	233.6	Counter-clockwise
N2	0.41	0.28	351.0	114.3	14.3	Clockwise
M2	4.24	0.87	253.6	58.5	204.6	Clockwise
S2	0.92	0.11	252.7	56.5	339.6	Clockwise
M4	0.35	0.02	256.7	30.2	49.2	Counter-clockwise
MS4	0.18	0.05	279.6	96.2	184.2	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	4.87
Standard deviation, U series (cm/s)	=	2.87
Standard deviation, V series (cm/s)	=	1.95
Tidal-form number	=	0.34
Spring tidal current maximum (cm/s)	=	6.90
Neap tidal current maximum (cm/s)	=	2.78
Principal current direction (deg. t.)	=	260.30

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59N 122-39-28W
Bin Number:	5 = 6.20 meters above bed
Record length:	90 M2 cycle: 6707 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.68401	231.36	242.47
K1	1.00274	1.43355	306.66	308.99
N2	1.89598	0.46384	222.11	239.91
M2	1.93227	3.85323	228.15	241.59
S2	2.00000	0.87898	232.07	237.38
M4	3.86455	0.33109	150.05	176.93
MS4	3.93227	0.19665	238.64	257.39

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.18770	297.63	308.74
K1	1.00274	0.39100	94.86	97.19
N2	1.89598	0.51029	101.72	119.52
M2	1.93227	1.36899	183.34	196.78
S2	2.00000	0.32724	202.17	207.49
M4	3.86455	0.10676	262.88	289.76
MS4	3.93227	0.17002	357.43	16.19

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	0.69	0.17	263.3	64.1	327.0	Counter-clockwise
K1	1.47	0.20	283.3	127.1	233.6	Counter-clockwise
N2	0.60	0.34	320.3	94.3	14.3	Clockwise
M2	3.98	0.93	255.0	58.0	204.6	Clockwise
S2	0.93	0.15	251.6	54.2	339.6	Clockwise
M4	0.33	0.10	277.8	354.6	49.2	Counter-clockwise
MS4	0.22	0.13	306.6	54.2	184.2	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.06
Standard deviation, U series (cm/s)	=	3.23
Standard deviation, V series (cm/s)	=	1.98
Tidal-form number	=	0.44
Spring tidal current maximum (cm/s)	=	7.07
Neap tidal current maximum (cm/s)	=	2.27
Principal current direction (deg. t.)	=	261.26

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59N 122-39-28W
Bin number:	6 = 7.20 meters above bed
Record length:	90 M2 cycle: 6707 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.72320	241.63	252.75
K1	1.00274	1.77099	304.77	307.10
N2	1.89598	0.66538	237.30	255.09
M2	1.93227	3.61686	228.33	241.77
S2	2.00000	0.88561	239.29	244.60
M4	3.86455	0.31022	131.61	158.49
MS4	3.93227	0.25267	233.91	252.66

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.35642	318.90	330.01
K1	1.00274	0.32575	71.19	73.52
N2	1.89598	0.51083	96.74	114.53
M2	1.93227	1.20530	177.80	191.24
S2	2.00000	0.37798	189.43	194.74
M4	3.86455	0.30478	290.72	317.61
MS4	3.93227	0.26155	339.01	357.76

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	0.73	0.35	262.0	76.6	327.0	Counter-clockwise
K1	1.78	0.26	276.4	126.2	233.6	Counter-clockwise
N2	0.79	0.27	305.5	88.8	14.3	Clockwise
M2	3.70	0.91	257.3	58.6	204.6	Clockwise
S2	0.92	0.28	253.0	59.4	339.6	Clockwise
M4	0.43	0.08	314.5	328.2	49.2	Counter-clockwise
MS4	0.29	0.22	318.8	31.6	184.2	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.11
Standard deviation, U series (cm/s)	=	3.45
Standard deviation, V series (cm/s)	=	1.92
Tidal-form number	=	0.54
Spring tidal current maximum (cm/s)	=	7.13
Neap tidal current maximum (cm/s)	=	1.73
Principal current direction (deg. t.)	=	261.97

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59N 122-39-28W
Bin number:	7 = 8.20 meters above bed
Record length:	90 M2 cycle: 6614 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.85844	250.63	261.75
K1	1.00274	1.96930	301.25	303.58
N2	1.89598	0.87167	242.49	260.29
M2	1.93227	3.32010	231.20	244.64
S2	2.00000	1.02158	258.05	263.36
M4	3.86455	0.23422	140.49	167.38
MS4	3.93227	0.25773	245.89	264.65

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.38216	331.30	342.41
K1	1.00274	0.34714	35.82	38.15
N2	1.89598	0.42151	89.97	107.77
M2	1.93227	0.96798	168.89	182.33
S2	2.00000	0.22165	178.08	183.40
M4	3.86455	0.30433	290.66	317.55
MS4	3.93227	0.34970	319.21	337.97

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.86	0.38	264.9	84.0	327.0	Counter-clockwise
K1	1.97	0.35	270.8	123.4	233.6	Counter-clockwise
N2	0.95	0.18	294.1	85.1	14.3	Clockwise
M2	3.35	0.85	261.8	62.5	204.6	Clockwise
S2	1.02	0.22	267.7	82.9	339.6	Clockwise
M4	0.37	0.10	323.5	328.3	49.2	Counter-clockwise
MS4	0.36	0.24	201.4	143.6	184.2	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.23
Standard deviation, U series (cm/s)	=	3.69
Standard deviation, V series (cm/s)	=	1.91
Tidal-form number	=	0.65
Spring tidal current maximum (cm/s)	=	7.21
Neap tidal current maximum (cm/s)	=	1.22
Principal current direction (deg. t.)	=	265.46

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 2 Day = 16 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-59n 122-39-28W
Bin number:	8 = 9.20 meters above bed
Record length:	90 M2 cycle: 5291 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.22713	220.99	232.11
K1	1.00274	1.20411	283.68	286.00
N2	1.89598	1.43878	244.39	262.19
M2	1.93227	2.62803	228.83	242.27
S2	2.00000	1.50025	283.40	288.71
M4	3.86455	0.07583	355.90	22.78
MS4	3.93227	0.33431	252.24	271.00

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.35932	327.35	338.46
K1	1.00274	0.43677	10.76	13.09
N2	1.89598	0.10065	63.57	81.37
M2	1.93227	0.55913	135.98	149.43
S2	2.00000	0.05986	114.36	119.67
M4	3.86455	0.47532	283.09	309.97
MS4	3.93227	0.28659	300.67	319.43

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.23	0.34	275.1	50.7	327.0	Counter-clockwise
K1	1.20	0.44	268.8	106.4	233.6	Counter-clockwise
N2	1.44	0.00	274.0	82.2	14.3	Counter-clockwise
M2	2.63	0.56	270.6	62.4	204.6	Clockwise
S2	1.50	0.01	272.2	108.7	339.6	Clockwise
M4	0.48	0.07	2.8	310.4	49.2	Clockwise
MS4	0.40	0.18	231.6	110.3	184.2	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.27
Standard deviation, U series (cm/s)	=	3.82
Standard deviation, V series (cm/s)	=	2.15
Tidal-form number	=	0.59
Spring tidal current maximum (cm/s)	=	6.57
Neap tidal current maximum (cm/s)	=	1.15
Principal current direction (deg. t.)	=	271.50

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	1 = 1.95 meters above bed
Record length:	60 M2 cycle: 4472 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.88954	255.76	266.84
K1	1.00274	1.76989	310.06	312.36
N2	1.89598	0.21580	205.76	223.50
M2	1.93227	3.51672	283.75	297.14
S2	2.00000	0.29921	299.32	304.58
M4	3.86455	2.55564	30.05	56.82
MS4	3.93227	1.13071	78.90	97.54

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.63717	216.96	228.04
K1	1.00274	0.90574	276.58	278.88
N2	1.89598	0.07465	212.17	229.91
M2	1.93227	0.87555	249.02	262.40
S2	2.00000	0.26672	321.66	326.91
M4	3.86455	1.28518	189.10	215.87
MS4	3.93227	0.20714	272.79	291.43

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.96	0.39	254.7	83.8	166.2	Clockwise
K1	1.93	0.46	245.4	126.2	20.9	Clockwise
N2	0.23	0.01	251.0	44.2	44.7	Counter-clockwise
M2	3.59	0.49	258.2	115.5	191.0	Clockwise
S2	0.39	0.08	228.5	134.4	315.0	Counter-clockwise
M4	2.83	0.41	295.8	232.8	22.1	Counter-clockwise
MS4	1.15	0.05	280.1	278.0	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.77
Standard deviation, U series (cm/s)	=	3.26
Standard deviation, V series (cm/s)	=	2.67
Tidal-form number	=	0.98
Spring tidal current maximum (cm/s)	=	7.88
Neap tidal current maximum (cm/s)	=	3.22
Principal current direction (degrees T)	=	252.71

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	2 = 2.45 meters above bed
Record length:	60 M2 cycle: 4472 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.98813	253.65	264.73
K1	1.00274	1.86131	308.73	311.03
N2	1.89598	0.19777	209.45	227.19
M2	1.93227	3.73409	279.87	293.26
S2	2.00000	0.43013	293.38	298.64
M4	3.86455	2.43053	30.08	56.85
MS4	3.93227	1.10068	80.11	98.76

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.58680	228.04	239.13
K1	1.00274	0.91957	283.66	285.96
N2	1.89598	0.09970	226.11	243.86
M2	1.93227	0.70645	264.36	277.74
S2	2.00000	0.20890	324.48	329.74
M4	3.86455	0.99782	177.48	204.25
MS4	3.93227	0.10034	274.72	293.36

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.06	0.24	254.9	82.9	166.2	Clockwise
K1	2.05	0.35	245.1	126.4	20.9	Clockwise
N2	0.22	0.03	243.8	50.5	44.7	Counter-clockwise
M2	3.80	0.19	259.6	112.7	191.0	Clockwise
S2	0.47	0.10	246.3	124.0	315.0	Counter-clockwise
M4	2.58	0.51	289.9	232.8	22.1	Counter-clockwise
MS4	1.10	0.03	275.0	278.9	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.72
Standard deviation, U series (cm/s)	=	3.22
Standard deviation, V series (cm/s)	=	2.58
Tidal-form number	=	0.96
Spring tidal current maximum (cm/s)	=	8.37
Neap tidal current maximum (cm/s)	=	3.34
Principal current direction (degrees T)	=	254.17

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin Number:	3 = 2.95 meters above bed
Record length:	60 M2 cycle: 4472 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.07096	251.92	263.00
K1	1.00274	1.88076	308.88	311.18
N2	1.89598	0.18987	194.56	212.30
M2	1.93227	3.97072	276.71	290.09
S2	2.00000	0.53290	295.53	300.79
M4	3.86455	2.26331	30.90	57.67
MS4	3.93227	1.04039	78.00	96.65

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.70779	239.68	250.76
K1	1.00274	0.96683	290.94	293.24
N2	1.89598	0.10020	284.77	302.51
M2	1.93227	0.63672	279.52	292.90
S2	2.00000	0.09316	315.62	320.88
M4	3.86455	0.72769	165.10	191.87
MS4	3.93227	0.05212	98.68	117.33

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.18	0.14	251.4	81.7	166.2	Clockwise
K1	2.10	0.27	243.5	127.5	20.9	Clockwise
N2	0.19	0.10	270.2	32.2	44.7	Counter-clockwise
M2	4.02	0.03	260.9	110.2	191.0	Counter-clockwise
S2	0.54	0.03	260.6	121.3	315.0	Counter-clockwise
M4	2.32	0.51	283.3	234.7	22.1	Counter-clockwise
MS4	1.04	0.02	267.3	276.7	146.0	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.71
Standard deviation, U series (cm/s)	=	3.15
Standard deviation, V series (cm/s)	=	2.51
Tidal-form number	=	0.94
Spring tidal current maximum (cm/s)	=	8.94
Neap tidal current maximum (cm/s)	=	3.59
Principal current direction (degrees T)	=	254.42

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin Number:	4 = 3.45 meters above bed
Record length:	60 M2 cycle: 4472 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.14222	250.52	261.60
K1	1.00274	1.90822	307.54	309.84
N2	1.89598	0.24037	175.28	193.02
M2	1.93227	4.17383	273.92	287.30
S2	2.00000	0.66876	289.67	294.93
M4	3.86455	2.12499	31.74	58.51
MS4	3.93227	1.01034	80.97	99.61

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.77137	245.86	256.95
K1	1.00274	0.92806	292.70	295.00
N2	1.89598	0.12601	283.43	301.17
M2	1.93227	0.59363	293.71	307.10
S2	2.00000	0.04432	349.54	354.80
M4	3.86455	0.53272	148.05	174.82
MS4	3.93227	0.19058	112.41	131.05

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.34	0.05	249.8	80.0	166.2	Clockwise
K1	2.16	0.12	245.5	127.6	20.9	Clockwise
N2	0.26	0.08	282.7	11.3	44.7	Counter-clockwise
M2	4.32	0.34	263.0	105.7	191.0	Counter-clockwise
S2	0.76	0.04	268.7	115.0	315.0	Counter-clockwise
M4	1.95	0.38	269.0	242.2	22.1	Counter-clockwise
MS4	1.01	0.07	251.7	286.8	146.0	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.72
Standard deviation, U series (cm/s)	=	3.04
Standard deviation, V series (cm/s)	=	2.48
Tidal-form number	=	0.90
Spring tidal current maximum (cm/s)	=	9.27
Neap tidal current maximum (cm/s)	=	3.71
Principal current direction (degrees T)	=	255 74

Station name: East
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian: 120 W
Station position: 47-33-20N 122-37-45W
Bin number: 5 = 3.95 meters above bed
Record length: 60 M2 cycle: 4472 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.19567	249.35	260.44
K1	1.00274	1.96523	306.78	309.08
N2	1.89598	0.25653	177.63	195.37
M2	1.93227	4.28361	271.78	285.17
S2	2.00000	0.75854	289.63	294.88
M4	3.86455	1.95159	35.22	61.99
MS4	3.93227	0.96244	86.94	105.59

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.80840	245.60	256.69
K1	1.00274	0.90362	298.05	300.35
N2	1.89598	0.09896	299.14	316.88
M2	1.93227	0.62853	304.98	318.37
S2	2.00000	0.04386	355.74	1.00
M4	3.86455	0.37958	120.27	147.04
MS4	3.93227	0.32377	99.47	118.12

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.34	0.05	249.8	80.0	166.2	Clockwise
K1	2.16	0.12	245.5	127.6	20.9	Clockwise
N2	0.26	0.08	282.7	11.3	44.7	Counter-clockwise
M2	4.32	0.34	263.0	105.7	191.0	Counter-clockwise
S2	0.76	0.04	268.7	115.0	315.0	Counter-clockwise
M4	1.95	0.38	269.0	242.2	22.1	Counter-clockwise
MS4	1.01	0.07	251.7	286.8	146.0	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.73
Standard deviation, U series (cm/s)	=	2.98
Standard deviation, V series (cm/s)	=	2.42
Tidal-form number	=	0.89
Spring tidal current maximum (cm/s)	=	9.57
Neap tidal current maximum (cm/s)	=	3.74
Principal current direction (degrees. T)	=	256.25

Station name: East
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour = 10:30
Time meridian: 120 W
Station position: 47-33-20N 122-37-45W
Bin number: 6 = 4.45 meters above bed
Record length: 60 M2 cycle: 4472 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.21667	249.34	260.43
K1	1.00274	2.04972	305.94	308.24
N2	1.89598	0.23054	185.65	203.39
M2	1.93227	4.39916	270.76	284.15
S2	2.00000	0.87180	289.80	295.05
M4	3.86455	1.77066	39.07	65.84
MS4	3.93227	0.89157	92.94	111.58

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.80543	248.03	259.12
K1	1.00274	0.82531	304.70	307.00
N2	1.89598	0.08062	299.47	317.21
M2	1.93227	0.69130	314.27	327.66
S2	2.00000	0.05627	16.64	21.90
M4	3.86455	0.35779	78.01	104.78
MS4	3.93227	0.43925	96.16	114.81

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.36	0.02	250.0	80.3	166.2	Clockwise
K1	2.21	0.02	248.1	128.1	20.9	Clockwise
N2	0.23	0.07	278.9	20.6	44.7	Counter-clockwise
M2	4.43	0.47	263.4	104.9	191.0	Counter-clockwise
S2	0.87	0.06	269.8	115.1	315.0	Counter-clockwise
M4	1.79	0.22	260.9	247.0	22.1	Counter-clockwise
MS4	0.99	0.02	243.8	292.2	146.0	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.78
Standard deviation, U series (cm/s)	=	2.94
Standard deviation, V series (cm/s)	=	2.39
Tidal-form number	=	0.86
Spring tidal current maximum (cm/s)	=	9.87
Neap tidal current maximum (cm/s)	=	3.70
Principal current direction (degrees T)	=	257.35

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	7 = 4.95 meters above bed
Record length:	60 M2 dycle: 4472 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.22499	249.49	260.57
K1	1.00274	2.14504	304.86	307.16
N2	1.89598	0.22797	204.70	222.44
M2	1.93227	4.45899	269.64	283.02
S2	2.00000	0.93610	292.56	297.82
M4	3.86455	1.63950	46.75	73.52
MS4	3.93227	0.87317	95.83	114.47

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.75346	251.09	262.18
K1	1.00274	0.75306	311.46	313.76
N2	1.89598	0.03657	328.08	345.82
M2	1.93227	0.74987	319.46	332.84
S2	2.00000	0.08715	74.83	80.09
M4	3.86455	0.46138	52.26	79.03
MS4	3.93227	0.50843	89.10	107.74

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.35	0.02	251.3	80.7	166.2	Counter-clockwise
K1	2.27	0.08	250.7	127.9	20.9	Counter-clockwise
N2	0.23	0.03	275.1	41.8	44.7	Counter-clockwise
M2	4.49	0.57	263.7	103.8	191.0	Counter-clockwise
S2	0.94	0.05	274.2	117.6	315.0	Counter-clockwise
M4	1.70	0.04	254.3	253.9	22.1	Counter-clockwise
MS4	1.01	0.05	239.9	292.8	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.83
Standard deviation, U series (cm/s)	=	2.84
Standard deviation, V series (cm/s)	=	2.41
Tidal-form number	=	0.85
Spring tidal current maximum (cm/s)	=	10.05
Neap tidal current maximum (cm/s)	=	3.62
Principal current direction (degrees T)	=	258.86

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	8 = 5.45 meters above bed
Record length:	60 M2 cycle: 4460 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.23135	248.76	259.84
K1	1.00274	2.23070	303.51	305.81
N2	1.89598	0.25394	223.92	241.66
M2	1.93227	4.55560	268.53	281.91
S2	2.00000	1.03550	295.34	300.60
M4	3.86455	1.54527	57.09	83.86
MS4	3.93227	0.82519	95.70	114.35

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.73752	253.51	264.60
K1	1.00274	0.65272	320.92	323.22
N2	1.89598	0.04716	354.03	11.77
M2	1.93227	0.88346	324.85	338.24
S2	2.00000	0.18251	114.64	119.89
M4	3.86455	0.61847	25.78	52.55
MS4	3.93227	0.55905	83.06	101.71

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.35	0.06	251.8	80.3	166.2	Counter-clockwise
K1	2.32	0.19	254.3	127.1	20.9	Counter-clockwise
N2	0.26	0.04	277.0	60.7	44.7	Counter-clockwise
M2	4.58	0.73	263.7	102.9	191.0	Counter-clockwise
S2	1.05	0.00	280.0	120.6	315.0	Counter-clockwise
M4	1.64	0.30	250.4	260.1	22.1	Clockwise
MS4	0.99	0.10	236.1	290.4	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.93
Standard deviation, U series (cm/s)	=	2.78
Standard deviation, V series (cm/s)	=	2.43
Tidal-form number	=	0.83
Spring tidal current maximum (cm/s)	=	10.30
Neap tidal current maximum (cm/s)	=	3.56
Principal current direction (degrees T)	=	260.52

Station name: East
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian: 120 W
Station position: 47-33-20N 122-37-45W
Bin number: 9 = 5.95 meters above bed
Record length: 60 M2 cycle: 4453 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.29625	248.67	259.75
K1	1.00274	2.30489	301.16	303.46
N2	1.89598	0.28680	231.40	249.14
M2	1.93227	4.66060	267.44	280.82
S2	2.00000	1.07337	292.34	297.60
M4	3.86455	1.51821	67.08	93.85
MS4	3.93227	0.77418	101.08	119.73

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.65974	257.95	269.03
K1	1.00274	0.62056	329.32	331.62
N2	1.89598	0.01819	345.61	3.35
M2	1.93227	1.03243	327.27	340.65
S2	2.00000	0.24458	114.45	119.71
M4	3.86455	0.78404	16.98	43.75
MS4	3.93227	0.60338	82.24	100.88

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.39	0.10	254.1	80.4	166.2	Counter-clockwise
K1	2.37	0.28	256.4	125.1	20.9	Counter-clockwise
N2	0.29	0.02	271.5	69.1	44.7	Counter-clockwise
M2	4.69	0.89	263.4	102.1	191.0	Counter-clockwise
S2	1.10	0.01	282.8	117.7	315.0	Clockwise
M4	1.61	0.57	249.0	266.1	22.1	Clockwise
Ms4	0.97	0.16	232.5	292.7	146.0	Clockwise

Root-mean-squares speed, (cm/s) = 6.08
Standard deviation, U series (cm/s) = 2.77
Standard deviation, V series (dm/s) = 2.45
Tidal-form number = 0.82
Spring tidal current maximum (Cm/s) = 10.55
Neap tidal current maximum (dm/s) = 3.61
Principal current direction (degrees T) = 261.77

Station name: East
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian: 120 W
Station position: 47-33-20N 122-37-45W
Bin number: 10 = 6.45 meters above bed
Record length: 60 M2 cycle: 4453 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.35634	247.62	258.70
K1	1.00274	2.40111	299.48	301.78
N2	1.89598	0.36677	243.61	261.35
M2	1.93227	4.74255	265.47	278.85
S2	2.00000	1.04930	293.45	298.71
M4	3.86455	1.47346	78.53	105.30
MS4	3.93227	0.75678	111.21	129.85

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.59481	263.82	274.91
K1	1.00274	0.62640	340.98	343.28
N2	1.89598	0.04621	152.50	170.24
M2	1.93227	1.16295	328.95	342.34
S2	2.00000	0.29971	121.26	126.52
M4	3.86455	0.98268	14.32	41.09
MS4	3.93227	0.71002	79.07	97.72

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.42	0.16	256.3	79.6	166.2	Counter-clockwise
K1	2.45	0.41	258.6	123.7	20.9	Counter-clockwise
N2	0.37	0.05	270.1	81.4	44.7	Clockwise
M2	4.77	1.03	263.4	100.3	191.0	Counter-clockwise
S2	1.09	0.04	285.8	119.3	315.0	Clockwise
M4	1.56	0.83	246.9	272.4	22.1	Clockwise
Ms4	1.00	0.29	227.2	294.9	146.0	Clockwise

Root-mean-squares speed, (cm/s) = 6.22
Standard deviation, U series (cm/s) = 2.75
Standard deviation, V series (cm/s) = 2.50
Tidal-form number = 0.83
Spring tidal current maximum (cm/s) = 10.74
Neap tidal current maximum (cm/s) = 3.66
Principal current direction (degrees T) = 263.01

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	11 = 6.95 meters above bed
Record length:	60 M2 cycle: 4445 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.43272	246.03	257.12
K1	1.00274	2.51312	297.60	299.90
N2	1.89598	0.47609	247.54	265.28
M2	1.93227	4.83056	263.56	276.94
S2	2.00000	1.14648	294.96	300.22
M4	3.86455	1.50523	89.62	116.39
MS4	3.93227	0.71031	115.39	134.04

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.56464	272.56	283.65
K1	1.00274	0.71516	350.54	352.85
N2	1.89598	0.06854	105.46	123.20
M2	1.93227	1.37073	329.69	343.07
S2	2.00000	0.35004	125.68	130.93
M4	3.86455	1.15284	11.68	38.45
MS4	3.93227	0.71367	73.41	92.05

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.49	0.25	258.1	78.3	166.2	Counter-clockwise
K1	2.55	0.56	259.8	122.2	20.9	Counter-clockwise
N2	0.48	0.04	276.5	85.9	44.7	Clockwise
M2	4.86	1.24	263.0	98.7	191.0	Counter-clockwise
S2	1.20	0.06	286.7	121.1	315.0	Clockwise
M4	1.55	1.10	251.1	282.7	22.1	Clockwise
MS4	0.94	0.36	224.8	292.9	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	6.40
Standard deviation, U series (cm/s)	=	2.77
Standard deviation, V series (cm/s)	=	2.58
Tidal-form number	=	0.83
Spring tidal current maximum (cm/s)	=	11.10
Neap tidal current maximum (cm/s)	=	3.60
Principal current direction (degrees T)	=	263.73

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	12 = 7.45 meters above bed
Record length:	60 M2 cycle: 4442 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.48018	244.50	255.59
K1	1.00274	2.59959	294.83	297.13
N2	1.89598	0.58275	247.93	265.67
M2	1.93227	4.91936	259.93	273.32
S2	2.00000	1.23839	292.59	297.85
M4	3.86455	1.53033	99.43	126.20
MS4	3.93227	0.70515	119.43	138.07

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.61688	280.61	291.70
K1	1.00274	0.81667	357.56	359.86
N2	1.89598	0.07043	93.64	111.38
M2	1.93227	1.66796	330.08	343.47
S2	2.00000	0.32513	125.99	131.25
M4	3.86455	1.29015	10.29	37.07
MS4	3.93227	0.75999	72.13	90.77

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.53	0.36	258.4	77.2	166.2	Counter-clockwise
K1	2.63	0.72	261.1	119.6	20.9	Counter-clockwise
N2	0.59	0.03	276.2	86.0	44.7	Clockwise
M2	4.96	1.56	262.7	95.6	191.0	Counter-clockwise
S2	1.28	0.07	284.4	118.7	315.0	Clockwise
M4	1.53	1.29	267.5	304.1	22.1	Clockwise
MS4	0.95	0.41	221.8	292.1	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	6.54
Standard deviation, U series (cm/s)	=	2.75
Standard deviation, V series (cm/s)	=	2.62
Tidal-form number	=	0.83
Spring tidal current maximum (cm/s)	=	11.39
Neap tidal current maximum (cm/s)	=	3.58
Principal current direction (degrees T)	=	263.82

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	13 = 7.95 meters above bed
Record length:	60 M2 cycle: 4433 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.54922	242.53	253.62
K1	1.00274	2.63947	293.53	295.83
N2	1.89598	0.66501	248.83	266.57
M2	1.93227	4.94325	256.48	269.87
S2	2.00000	1.28348	293.05	298.30
M4	3.86455	1.56575	110.69	137.46
MS4	3.93227	0.66955	120.81	139.45

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.62235	290.77	301.86
K1	1.00274	0.86271	354.03	356.33
N2	1.89598	0.04474	241.37	259.11
M2	1.93227	1.91357	331.18	344.57
S2	2.00000	0.31442	120.24	125.49
M4	3.86455	1.43147	12.74	39.52
MS4	3.93227	0.74241	70.70	89.34

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.58	0.46	260.5	75.3	166.2	Counter-clockwise
K1	2.68	0.74	260.1	118.6	20.9	Counter-clockwise
N2	0.67	0.01	266.2	86.5	44.7	Clockwise
M2	4.97	1.83	263.2	92.4	191.0	Counter-clockwise
S2	1.32	0.04	283.7	118.7	315.0	Clockwise
M4	1.62	1.37	298.5	342.2	22.1	Clockwise
MS4	0.91	0.42	220.4	290.9	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	6.67
Standard deviation, U series (cm/s)	=	2.79
Standard deviation, V series (cm/s)	=	2.70
Tidal-form number	=	0.84
Spring tidal current maximum (cm/s)	=	11.55
Neap tidal current maximum (cm/s)	=	3.56
Principal current direction (degrees T)	=	264.23

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	14 = 8.45 meters above bed
Record length:	60 M2 cycle: 4433 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.59940	242.07	253.15
K1	1.00274	2.58907	290.97	293.27
N2	1.89598	0.73197	248.69	266.43
M2	1.93227	5.06302	251.30	264.69
S2	2.00000	1.27657	294.06	299.32
M4	3.86455	1.57677	119.53	146.30
MS4	3.93227	0.62623	124.44	143.09

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.63830	296.56	307.65
K1	1.00274	0.95379	352.78	355.08
N2	1.89598	0.08758	261.90	279.65
M2	1.93227	2.13400	331.99	345.37
S2	2.00000	0.27035	109.55	114.80
M4	3.86455	1.61356	14.56	41.33
MS4	3.93227	0.75777	67.72	86.36

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.63	0.51	261.6	74.8	166.2	Counter-clockwise
K1	2.63	0.83	259.0	116.8	20.9	Counter-clockwise
N2	0.74	0.02	263.4	86.6	44.7	Counter-clockwise
M2	5.08	2.10	265.3	86.6	191.0	Counter-clockwise
S2	1.30	0.02	281.9	119.1	315.0	Counter-clockwise
M4	1.79	1.37	317.6	6.3	22.1	Clockwise
MS4	0.87	0.46	215.4	286.7	146.0	Clockwise

Root-mean-squares Speed, (Cm/s)	=	6.82
Standard Deviation, U Series (Cm/s)	=	2.85
Standard Deviation, V Series (Cm/s)	=	2.80
Tidal-form Number	=	0.82
Spring Tidal Current Maximum (Cm/s)	=	11.64
Neap Tidal Current Maximum (Cm/s)	=	3.77
Principal Current Direction (Deg. T.)	=	264.90

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name: East
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian: 120 W
Station position: 47-33-20N 122-37-45W
Bin number: 15 = 8.95 meters above bed
Record length: 60 M2 cycle: 4429 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.61809	240.79	251.87
K1	1.00274	2.55252	291.13	293.43
N2	1.89598	0.79651	247.18	264.92
M2	1.93227	5.14896	246.16	259.54
S2	2.00000	1.27189	295.96	301.22
M4	3.86455	1.56479	128.04	154.81
MS4	3.93227	0.55853	132.01	150.65

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.69277	298.45	309.54
K1	1.00274	1.13692	347.07	349.37
N2	1.89598	0.10496	295.47	313.21
M2	1.93227	2.39665	333.09	346.48
S2	2.00000	0.22850	96.11	101.37
M4	3.86455	1.76663	15.94	42.71
MS4	3.93227	0.78371	71.76	90.40

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.65	0.58	261.5	73.7	166.2	Counter-clockwise
K1	2.64	0.91	254.1	119.1	20.9	Counter-clockwise
N2	0.80	0.08	264.9	85.4	44.7	Counter-clockwise
M2	5.15	2.39	268.2	80.4	191.0	Counter-clockwise
S2	1.29	0.08	279.6	120.6	315.0	Counter-clockwise
M4	1.97	1.30	324.0	17.0	22.1	Clockwise
MS4	0.85	0.45	207.6	285.7	146.0	Clockwise

Root-mean-squares speed, (cm/s) = 6.95
Standard deviation, U series (cm/s) = 2.89
Standard deviation, V series (cm/s) = 2.88
Tidal-form number = 0.82
Spring tidal current maximum (cm/s) = 11.73
Neap tidal current maximum (cm/s) = 3.86
Principal current direction (ceg. T.) = 264.76

ADCP atation number: East
Series atart (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian: 120 W
Station position: 47-33-20N 122-37-45W
Bin number: 16 = 9.45 meters above bed
Record length: 60 M2 cycle: 4401 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.62071	238.05	249.13
K1	1.00274	2.47272	287.83	290.13
N2	1.89598	0.88187	245.72	263.46
M2	1.93227	5.28123	240.41	253.80
S2	2.00000	1.28986	298.84	304.10
M4	3.86455	1.63590	139.93	166.70
MS4	3.93227	0.52205	134.84	153.48

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.71022	299.17	310.25
K1	1.00274	1.25941	341.50	343.80
N2	1.89598	0.12343	299.79	317.54
M2	1.93227	2.58533	335.03	348.42
S2	2.00000	0.20808	88.17	93.42
M4	3.86455	1.89108	19.09	45.86
MS4	3.93227	0.77851	73.18	91.82

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.64	0.62	262.1	71.0	166.2	Counter-clockwise
K1	2.60	0.96	250.4	117.6	20.9	Counter-clockwise
N2	0.88	0.10	265.2	84.0	44.7	Counter-clockwise
M2	5.29	2.57	273.0	72.4	191.0	Counter-clockwise
S2	1.30	0.11	278.0	123.5	315.0	Counter-clockwise
M4	2.19	1.22	322.9	23.1	22.1	Clockwise
MS4	0.83	0.43	204.6	285.1	146.0	Clockwise

Root-mean-squares speed, (cm/s) = 7.11
Standard deviation, U series (cm/s)= 2.97
Standard deviation, V series (cm/s) = 2.96
Tidal-form number = 0.80
Spring tidal current maximum (dm/s) = 11.84
Neap tidal current maximum (dm/s) = 4.03
Principal current direction (degrees T.) = 266.13

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	17 = 9.95 meters above bed
Record length:	60 M2 cycle: 4391 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.67233	235.89	246.98
K1	1.00274	2.37748	283.43	285.73
N2	1.89598	0.89173	245.83	263.58
M2	1.93227	5.46733	235.34	248.73
S2	2.00000	1.31200	300.90	306.16
M4	3.86455	1.77448	147.59	174.36
MS4	3.93227	0.42910	131.56	150.21

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.75724	299.66	310.74
K1	1.00274	1.37547	336.19	338.49
N2	1.89598	0.20105	313.28	331.02
M2	1.93227	2.78646	336.25	349.64
S2	2.00000	0.19028	52.77	58.03
M4	3.86455	2.05425	21.59	48.36
MS4	3.93227	0.75093	77.58	96.23

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.69	0.67	262.4	68.9	166.2	Counter-clockwise
K1	2.55	1.02	246.8	115.5	20.9	Counter-clockwise
N2	0.90	0.18	264.8	84.6	44.7	Counter-clockwise
M2	5.50	2.72	277.3	65.1	191.0	Counter-clockwise
S2	1.31	0.18	273.1	125.7	315.0	Counter-clockwise
M4	2.43	1.21	322.0	27.0	22.1	Clockwise
MS4	0.80	0.33	202.5	285.8	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.29
Standard deviation, U series (cm/s)	=	3.04
Standard deviation, V series (cm/s)	=	3.01
Tidal-form number	=	0.77
Spring tidal current maximum (cm/s)	=	12.06
Neap tidal current maximum (cm/s)	=	4.33
Principal current direction (degrees T)	=	267.06

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	18 = 10.45 meters above bed
Record length:	60 M2 cycle: 4375 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.71019	233.23	244.31
K1	1.00274	2.28015	280.23	282.53
N2	1.89598	0.91357	246.93	264.67
M2	1.93227	5.60995	230.22	243.61
S2	2.00000	1.37837	302.14	307.40
M4	3.86455	1.78633	156.12	182.89
MS4	3.93227	0.38589	136.61	155.25

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.66137	296.37	307.45
K1	1.00274	1.55219	333.10	335.40
N2	1.89598	0.23203	330.04	347.78
M2	1.93227	2.89262	338.10	351.49
S2	2.00000	0.18832	33.65	38.91
M4	3.86455	2.12305	22.80	49.57
MS4	3.93227	0.69788	87.20	105.85

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.73	0.59	263.4	65.7	166.2	Counter-clockwise
K1	2.52	1.12	241.6	116.0	20.9	Counter-clockwise
N2	0.91	0.23	268.1	85.1	44.7	Counter-clockwise
M2	5.70	2.71	281.7	58.0	191.0	Counter-clockwise
S2	1.38	0.19	270.2	127.4	315.0	Counter-clockwise
M4	2.56	1.08	322.1	31.4	22.1	Clockwise
MS4	0.75	0.27	203.0	294.6	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.44
Standard deviation, U series (cm/s)	=	3.09
Standard deviation, V series (cm/s)	=	3.06
Tidal-form number	=	0.74
Spring tidal current maximum (cm/s)	=	12.33
Neap tidal current maximum (cm/s)	=	4.53
Principal current direction (degrees T)	=	268.14

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	19 = 10.95 meters above bed
Record length:	60 M2 cycle: 4348 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.68315	230.65	241.73
K1	1.00274	2.15316	278.68	280.98
N2	1.89598	0.89991	246.05	263.79
M2	1.93227	5.77622	225.73	239.11
S2	2.00000	1.47286	301.99	307.25
M4	3.86455	1.78285	162.24	189.02
MS4	3.93227	0.33500	150.41	169.06

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.62194	291.90	302.98
K1	1.00274	1.67512	331.19	333.49
N2	1.89598	0.28354	319.90	337.64
M2	1.93227	3.05864	337.26	350.65
S2	2.00000	0.24054	11.07	16.33
M4	3.86455	2.16082	23.38	50.15
MS4	3.93227	0.67068	95.37	114.02

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.70	0.54	263.4	63.1	166.2	Counter-clockwise
K1	2.47	1.16	236.3	118.3	20.9	Counter-clockwise
N2	0.90	0.27	264.5	85.4	44.7	Counter-clockwise
M2	5.92	2.78	284.2	52.3	191.0	Counter-clockwise
S2	1.48	0.22	266.6	127.8	315.0	Counter-clockwise
M4	2.63	0.96	322.2	34.3	22.1	Clockwise
MS4	0.70	0.26	198.7	301.2	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.59
Standard deviation, U series (cm/s)	=	3.13
Standard deviation, V series (cm/s)	=	3.12
Tidal-form number	=	0.70
Spring tidal current maximum (cm/s)	=	12.56
Neap tidal current maximum (cm/s)	=	4.67
Principal current direction (degrees T)	=	268.23

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	20 = 11.45 meters above bed
Record length:	60 M2 cycle: 4311 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.60956	227.69	238.78
K1	1.00274	1.99080	276.19	278.49
N2	1.89598	0.86254	244.21	261.96
M2	1.93227	5.97557	222.23	235.62
S2	2.00000	1.45525	299.11	304.37
M4	3.86455	1.76395	169.36	196.13
MS4	3.93227	0.29433	165.82	184.47

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.66100	286.59	297.67
K1	1.00274	1.80715	325.28	327.58
N2	1.89598	0.31636	296.60	314.34
M2	1.93227	3.11427	335.94	349.33
S2	2.00000	0.33007	351.33	356.59
M4	3.86455	2.06642	25.34	52.11
MS4	3.93227	0.63231	102.08	120.73

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.63	0.56	262.2	60.5	166.2	Counter-clockwise
K1	2.45	1.11	229.2	119.9	20.9	Counter-clockwise
N2	0.89	0.24	256.3	85.8	44.7	Counter-clockwise
M2	6.14	2.77	285.0	48.7	191.0	Counter-clockwise
S2	1.47	0.26	261.8	125.8	315.0	Counter-clockwise
M4	2.59	0.83	320.6	37.4	22.1	Clockwise
MS4	0.65	0.26	193.9	306.3	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.69
Standard deviation, U series (cm/s	)=	3.16
Standard deviation, V series (cm/s)	=	3.11
Tidal-form number	=	0.67
Spring tidal current maximum (cm/s)	=	12.69
Neap tidal current maximum (cm/s)	=	4.86
Principal current direction (degrees T)	=	266.80

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	21 = 11.95 meters above bed
Record length:	60 M2 cycle: 4253 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.53891	225.29	236.37
K1	1.00274	1.90277	276.97	279.27
N2	1.89598	0.77712	245.23	262.97
M2	1.93227	6.11191	219.24	232.63
S2	2.00000	1.52980	297.79	303.05
M4	3.86455	1.73914	177.31	204.09
MS4	3.93227	0.34483	182.13	200.77

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.71074	282.60	293.69
K1	1.00274	1.79552	319.57	321.87
N2	1.89598	0.42108	294.75	312.49
M2	1.93227	3.24485	334.36	347.74
S2	2.00000	0.42156	341.08	346.34
M4	3.86455	1.96755	26.73	53.50
MS4	3.93227	0.54953	108.44	127.09

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.57	0.59	260.9	58.5	166.2	Counter-clockwise
K1	2.44	0.95	227.3	119.0	20.9	Counter-clockwise
N2	0.83	0.30	247.6	91.4	44.7	Counter-clockwise
M2	6.31	2.85	286.1	45.2	191.0	Counter-clockwise
S2	1.56	0.28	258.3	125.2	315.0	Counter-clockwise
M4	2.54	0.66	319.0	40.8	22.1	Clockwise
MS4	0.56	0.32	195.1	315.9	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.80
Standard deviation, U series (cm/s)	=	3.16
Standard deviation, V series (cm/s)	=	3.09
Tidal-form number	=	0.64
Spring tidal current maximum (cm/s)	=	12.88
Neap tidal current maximum (cm/s)	=	4.88
Principal current direction (degrees T)	=	266.54

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	22 = 12.45 meters above bed
Record length:	60 M2 cycle: 4192 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.26506	225.00	236.08
K1	1.00274	1.88424	282.81	285.11
N2	1.89598	0.73356	234.36	252.10
M2	1.93227	5.98556	218.37	231.76
S2	2.00000	1.72570	291.59	296.85
M4	3.86455	1.57163	186.12	212.89
MS4	3.93227	0.45335	201.89	220.54

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.73078	271.01	282.10
K1	1.00274	1.84871	314.49	316.79
N2	1.89598	0.57732	291.07	308.81
M2	1.93227	3.27896	330.71	344.09
S2	2.00000	0.56159	332.07	337.33
M4	3.86455	1.69746	28.80	55.57
MS4	3.93227	0.55232	122.74	141.38

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.32	0.51	256.7	59.1	166.2	Counter-clockwise
K1	2.54	0.72	225.6	120.6	20.9	Counter-clockwise
N2	0.83	0.43	236.9	90.6	44.7	Counter-clockwise
M2	6.15	2.95	285.4	44.2	191.0	Counter-clockwise
S2	1.78	0.35	255.5	119.8	315.0	Counter-clockwise
M4	2.27	0.45	317.4	45.1	22.1	Clockwise
MS4	0.57	0.43	201.7	338.2	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.77
Standard deviation, U series (cm/s)	=	3.03
Standard deviation, V series (cm/s)	=	3.15
Tidal-form number	=	0.61
Spring tidal current maximum (cm/s)	=	12.80
Neap tidal current maximum (cm/s)	=	4.16
Principal current direction (degrees T)	=	264.16

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	23 = 12.95 meters above bed
Record length:	60 M2 cycle: 4015 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	2.02879	230.62	241.71
K1	1.00274	1.79365	289.00	291.30
N2	1.89598	0.65693	228.12	245.86
M2	1.93227	5.84344	218.02	231.40
S2	2.00000	1.89996	288.26	293.52
M4	3.86455	1.45906	194.33	221.11
MS4	3.93227	0.55851	219.85	238.49

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.68445	268.83	279.91
K1	1.00274	2.04392	308.62	310.92
N2	1.89598	0.73797	276.94	294.68
M2	1.93227	3.19640	324.27	337.66
S2	2.00000	0.67320	330.72	335.98
M4	3.86455	1.42084	34.43	61.20
MS4	3.93227	0.51689	127.39	146.03

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	2.10	0.41	254.6	64.8	166.2	Counter-clockwise
K1	2.68	0.46	221.0	122.4	20.9	Counter-clockwise
N2	0.90	0.40	220.0	94.0	44.7	Counter-clockwise
M2	5.94	3.02	281.8	45.3	191.0	Counter-clockwise
S2	1.97	0.44	254.6	117.0	315.0	Counter-clockwise
M4	2.01	0.36	314.2	50.9	22.1	Clockwise
MS4	0.56	0.51	284.5	71.8	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.77
Standard deviation, U series (cm/s)	=	3.00
Standard deviation, V series (cm/s)	=	3.05
Tidal-form number	=	0.61
Spring tidal current maximum (cm/s)	=	12.69
Neap Tidal current maximum (cm/s)	=	3.39
Principal current direction (degrees T)	=	260.23

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	24 = 13.45 meters above bed
Record length:	60 M2 cycle: 3820 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.74698	244.99	256.08
K1	1.00274	1.75926	297.22	299.52
N2	1.89598	0.65427	229.06	246.80
M2	1.93227	5.53955	218.73	232.12
S2	2.00000	2.07350	284.15	289.41
M4	3.86455	1.47649	200.10	226.87
MS4	3.93227	0.67379	219.97	238.61

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.79321	261.28	272.36
K1	1.00274	2.30242	303.23	305.53
N2	1.89598	0.86526	277.63	295.37
M2	1.93227	3.36452	316.82	330.21
S2	2.00000	0.68253	324.52	329.77
M4	3.86455	1.11733	41.91	68.68
MS4	3.93227	0.45359	125.66	144.30

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.91	0.20	246.2	78.8	166.2	Counter-clockwise
K1	2.89	0.15	217.3	123.3	20.9	Counter-clockwise
N2	1.00	0.43	213.4	99.7	44.7	Counter-clockwise
M2	5.57	3.31	277.6	47.6	191.0	Counter-clockwise
S2	2.14	0.43	255.3	112.4	315.0	Counter-clockwise
M4	1.82	0.34	306.5	54.7	22.1	Clockwise
MS4	0.68	0.45	275.2	62.1	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.89
Standard deviation, U series (cm/s)	=	2.99
Standard deviation, V series (cm/s)	=	2.99
Tidal-form number	=	0.62
Spring tidal current maximum (cm/s)	=	12.51
Neap tidal current maximum (cm/s)	=	2.44
Principal current direction (degrees T)	=	255.05

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	25 = 13.95 meters above bed
Record length:	60 M2 cycle: 3544 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.48726	263.26	274.34
K1	1.00274	1.80710	306.50	308.80
N2	1.89598	0.60000	216.90	234.64
M2	1.93227	5.21582	221.02	234.40
S2	2.00000	2.26225	281.07	286.33
M4	3.86455	1.54484	202.47	229.24
MS4	3.93227	0.76712	221.39	240.04

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.73663	250.81	261.90
K1	1.00274	2.45838	295.36	297.66
N2	1.89598	0.92950	266.72	284.46
M2	1.93227	3.62535	307.98	321.36
S2	2.00000	0.62539	335.92	341.18
M4	3.86455	0.82393	44.88	71.65
MS4	3.93227	0.37365	107.65	126.29

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.65	0.14	244.0	91.9	166.2	Clockwise
K1	3.04	0.28	216.2	121.6	20.9	Clockwise
N2	1.03	0.42	207.5	92.6	44.7	Counter-clockwise
M2	5.22	3.62	265.9	57.2	191.0	Counter-clockwise
S2	2.29	0.50	260.5	108.4	315.0	Counter-clockwise
M4	1.73	0.28	297.0	54.0	22.1	Clockwise
MS4	0.79	0.33	283.6	65.9	146.0	ClockwisE

Root-mean-squares speed, (cm/s)	=	8.04
Standard deviation, U series (cm/s)	=	2.89
Standard deviation, V series (cm/s)	=	3.03
Tidal-form number	=	0.62
Spring tidal current maximum (cm/s)	=	12.21
Neap tidal current maximum (cm/s)	=	1.55
Principal current direction (degrees T)	=	249.55

Station name:	East
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:30
Time meridian:	120 W
Station position:	47-33-20N 122-37-45W
Bin number:	26 = 14.45 meters above bed
Record length:	60 M2 cycle: 3124 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.32662	275.55	286.64
K1	1.00274	1.71390	307.59	309.89
N2	1.89598	0.58753	216.53	234.27
M2	1.93227	4.91702	220.68	234.07
S2	2.00000	2.33522	276.79	282.05
M4	3.86455	1.44330	199.42	226.20
MS4	3.93227	0.86083	214.12	232.77

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.69403	239.02	250.11
K1	1.00274	2.57330	286.36	288.66
N2	1.89598	1.10235	272.21	289.95
M2	1.93227	3.73299	299.89	313.27
S2	2.00000	0.62701	351.00	356.26
M4	3.86455	0.82978	56.09	82.86
MS4	3.93227	0.27031	92.71	111.35

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.45	0.38	245.4	99.8	166.2	Clockwise
K1	3.05	0.52	212.9	115.0	20.9	Clockwise
N2	1.16	0.46	200.0	101.7	44.7	Counter-clockwise
M2	5.02	3.59	253.1	66.4	191.0	Counter-clockwise
S2	2.34	0.60	265.5	103.2	315.0	Counter-clockwise
M4	1.60	0.45	297.0	54.3	22.1	Clockwise
MS4	0.87	0.23	280.0	55.4	146.0	Clockwise

Root-mean-squares speed, (cm/s)	=	7.99
Standard deviation, U series (cm/s)	=	2.80
Standard deviation, V series (cm/s)	=	3.03
Tidal-form number	=	0.61
Spring tidal current maximum (cm/s)	=	11.86
Neap tidal current maximum (cm/s)	=	1.08
Principal current direction (degrees T)	=	244.28

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	1 = 1.95 meters above bed
Record length:	60 M2 cycle: 4465 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.35792	352.07	3.17
K1	1.00274	0.70943	96.15	98.46
N2	1.89598	0.43033	195.09	212.86
M2	1.93227	3.15195	210.66	224.07
S2	2.00000	0.63966	264.63	269.91
M4	3.86455	0.46268	159.50	186.32
MS4	3.93227	0.50657	200.38	219.08

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.63908	238.28	249.38
K1	1.00274	0.06774	158.64	160.95
N2	1.89598	0.46887	230.33	248.09
M2	1.93227	2.38578	246.22	259.63
S2	2.00000	0.61371	263.29	268.58
M4	3.86455	0.95801	210.13	236.95
MS4	3.93227	0.26792	100.01	118.71

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	0.66	0.32	163.3	61.2	177.8	Clockwise
K1	0.71	0.06	87.5	98.7	33.4	Counter-clockwise
N2	0.61	0.19	222.0	52.2	68.3	Counter-clockwise
M2	3.78	1.16	234.6	56.4	215.1	Counter-clockwise
S2	0.89	0.01	226.2	89.3	339.9	Clockwise
M4	1.01	0.34	199.3	50.2	70.2	Counter-clockwise
MS4	0.51	0.26	277.4	42.9	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	4.72
Standard deviation, U series (cm/s)	=	2.51
Standard deviation, V series (cm/s)	=	2.37
Tidal-form number	=	0.29
Spring tidal current maximum (cm/s)	=	6.04
Neap tidal current maximum (cm/s)	=	2.84
Principal current direction (degrees T)	=	208.28

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	2 = 2.45 meters above bed
Record length:	60 M2 cycle: 4465 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.35343	315.57	326.67
K1	1.00274	0.56702	98.70	101.01
N2	1.89598	0.49187	204.10	221.87
M2	1.93227	3.50834	220.35	233.77
S2	2.00000	0.85052	269.39	274.67
M4	3.86455	0.57130	163.81	190.63
MS4	3.93227	0.37324	195.30	214.00

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.61916	243.21	254.30
K1	1.00274	0.09503	196.11	198.42
N2	1.89598	0.44959	221.18	238.94
M2	1.93227	2.44753	233.54	246.95
S2	2.00000	0.49091	262.82	268.10
M4	3.86455	0.63934	207.01	233.83
MS4	3.93227	0.26286	109.26	127.96

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	0.63	0.33	193.6	81.5	177.8	Clockwise
K1	0.57	0.09	91.3	100.8	33.4	Counter-clockwise
N2	0.66	0.10	227.7	49.6	68.3	Counter-clockwise
M2	4.25	0.46	235.3	58.0	215.1	Counter-clockwise
S2	0.98	0.05	240.1	93.0	339.9	Clockwise
M4	0.80	0.31	220.6	35.2	70.2	Counter-clockwise
MS4	0.37	0.26	264.5	30.2	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	4.77
Standard deviation, U series (cm/s)	=	2.48
Standard deviation, V series (cm/s)	=	2.25
Tidal-form number	=	0.23
Spring tidal current maximum (cm/s)	=	6.43
Neap tidal current maximum (cm/s)	=	3.34
Principal current direction (degrees T)	=	219.17

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	3 = 2.95 meters above bed
Record length:	60 M2 cycle: 4465 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.44484	301.33	312.43
K1	1.00274	0.39405	111.77	114.08
N2	1.89598	0.51082	207.70	225.47
M2	1.93227	3.66893	224.73	238.14
S2	2.00000	0.95637	271.98	277.26
M4	3.86455	0.60503	162.61	189.43
MS4	3.93227	0.26806	182.54	201.24

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.61822	251.57	262.66
K1	1.00274	0.31943	220.98	223.30
N2	1.89598	0.42843	220.74	238.51
M2	1.93227	2.53803	227.64	241.06
S2	2.00000	0.54970	254.51	259.80
M4	3.86455	0.45623	201.60	228.43
MS4	3.93227	0.22197	126.39	145.09

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.70	0.30	211.3	97.3	177.8	Clockwise
K1	0.42	0.28	118.6	94.0	33.4	Counter-clockwise
N2	0.66	0.07	230.1	50.8	68.3	Counter-clockwise
M2	4.46	0.11	235.3	59.1	215.1	Counter-clockwise
S2	1.09	0.14	240.7	93.0	339.9	Clockwise
M4	0.72	0.24	235.1	22.7	70.2	Counter-clockwise
MS4	0.31	0.16	234.4	0.9	195.0	Clockwise

Root-mean-squares speed, (cm/s	)=	4.89
Standard deviation, U series (cm/s)	=	2.54
Standard deviation, V series (cm/s)	=	2.24
Tidal-form number	=	0.20
Spring tidal current maximum (cm/s)	=	6.68
Neap tidal current maximum (cm/s)	=	3.64
Principal current direction (degrees T)	=	226.32

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	4 = 3.45 meters above bed
Record length:	60 M2 cycle: 4465 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.50278	278.06	289.16
K1	1.00274	0.16246	135.34	137.66
N2	1.89598	0.68589	217.60	235.37
M2	1.93227	3.89389	227.21	240.62
S2	2.00000	0.95141	277.80	283.08
M4	3.86455	0.55420	157.33	184.16
MS4	3.93227	0.21540	183.07	201.77

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.62920	249.70	260.80
K1	1.00274	0.43471	230.54	232.85
N2	1.89598	0.47762	213.30	231.07
M2	1.93227	2.65886	224.81	238.22
S2	2.00000	0.48728	252.62	257.90
M4	3.86455	0.28692	166.04	192.87
MS4	3.93227	0.26234	146.22	164.92

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.78	0.19	217.8	91.6	177.8	Clockwise
K1	0.43	0.16	177.7	53.7	33.4	Counter-clockwise
N2	0.84	0.03	235.2	54.0	68.3	Clockwise
M2	4.71	0.09	235.7	59.9	215.1	Clockwise
S2	1.05	0.19	244.3	98.2	339.9	Clockwise
M4	0.62	0.04	242.8	6.0	70.2	Counter-clockwise
MS4	0.32	0.10	218.0	359.2	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.04
Standard deviation, U series (cm/s)	=	2.62
Standard deviation, V series (cm/s)	=	2.26
Tidal-form number	=	0.21
Spring tidal current maximum (cm/s)	=	6.98
Neap tidal current maximum (cm/s)	=	4.01
Principal current direction (degrees T)	=	231.41

Station name: Center
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-32-47N 122-38-34W
Bin number: 5 = 3.95 meters above bed
Record length: 60 M2 cycle: 4465 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.72040	256.48	267.57
K1	1.00274	0.11692	247.50	249.81
N2	1.89598	0.81931	214.65	232.41
M2	1.93227	4.08134	228.54	241.95
S2	2.00000	1.02262	279.69	284.97
M4	3.86455	0.59005	153.61	180.43
MS4	3.93227	0.21187	200.46	219.16

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.65857	246.35	257.45
K1	1.00274	0.43502	241.28	243.59
N2	1.89598	0.47655	196.16	213.93
M2	1.93227	2.77983	224.27	237.68
S2	2.00000	0.56750	253.99	259.28
M4	3.86455	0.35893	150.38	177.21
MS4	3.93227	0.26907	171.07	189.77

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.97	0.09	227.6	83.0	177.8	Clockwise
K1	0.45	0.01	195.0	64.0	33.4	Clockwise
N2	0.94	0.13	240.5	47.9	68.3	Clockwise
M2	4.94	0.17	235.8	60.6	215.1	Clockwise
S2	1.15	0.22	242.3	99.3	339.9	Clockwise
M4	0.69	0.02	238.7	359.6	70.2	Clockwise
MS4	0.33	0.08	217.3	20.7	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.13
Standard deviation, U series (cm/s)	=	2.63
Standard deviation, V series (cm/s)	=	2.20
Tidal-form number	=	0.23
Spring tidal current maximum (cm/s)	=	7.51
Neap tidal current maximum (cm/s)	=	4.31
Principal current direction (degrees T)	=	233.27

Station name: Center
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian: 120 W
Station position: 47-32-47N 122-38-34W
Bin number: 6 = 4.45 meters above bed
Record length: 60 M2 cycle: 4457 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.86819	246.76	257.86
K1	1.00274	0.34372	261.15	263.46
N2	1.89598	0.94271	213.85	231.62
M2	1.93227	4.19833	228.57	241.98
S2	2.00000	1.07724	280.30	285.59
M4	3.86455	0.58770	149.70	176.52
MS4	3.93227	0.09261	213.42	232.12

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.65677	247.86	258.96
K1	1.00274	0.45791	240.41	242.73
N2	1.89598	0.53680	186.62	204.39
M2	1.93227	2.76102	224.29	237.71
S2	2.00000	0.65439	254.02	259.30
M4	3.86455	0.31552	126.16	152.98
MS4	3.93227	0.28682	194.21	212.91

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.09	0.01	232.9	78.3	177.8	Counter-clockwise
K1	0.56	0.10	216.4	70.1	33.4	Clockwise
N2	1.06	0.22	241.9	45.4	68.3	Clockwise
M2	5.02	0.17	236.7	60.7	215.1	Clockwise
S2	1.23	0.25	240.0	98.9	339.9	Clockwise
M4	0.66	0.11	242.9	351.5	70.2	Clockwise
MS4	0.30	0.03	197.1	34.6	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.19
Standard deviation, U series (cm/s)	=	2.66
Standard deviation, V series (cm/s)	=	2.16
Tidal-form number	=	0.26
Spring tidal current maximum (cm/s)	=	7.91
Neap tidal current maximum (cm/s)	=	4.31
Principal current direction (degrees T)	=	235.25

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	7 = 4.95 meters above bed
Record length:	60 M2 cycle: 4455 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.01546	237.29	248.39
K1	1.00274	0.59378	251.48	253.80
N2	1.89598	1.05180	215.11	232.88
M2	1.93227	4.24965	229.33	242.75
S2	2.00000	1.22419	278.13	283.42
M4	3.86455	0.52162	143.62	170.44
MS4	3.93227	0.04342	232.52	251.22

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.61126	240.14	251.23
K1	1.00274	0.47123	238.66	240.97
N2	1.89598	0.54096	183.52	201.29
M2	1.93227	2.68786	226.32	239.73
S2	2.00000	0.76083	251.77	257.05
M4	3.86455	0.34445	109.55	136.38
MS4	3.93227	0.30573	203.05	221.75

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.18	0.03	239.0	69.1	177.8	Counter-clockwise
K1	0.75	0.08	231.7	68.9	33.4	Clockwise
N2	1.15	0.26	245.0	46.9	68.3	Clockwise
M2	5.03	0.12	237.7	61.9	215.1	Clockwise
S2	1.41	0.29	239.4	96.4	339.9	Clockwise
M4	0.60	0.17	238.6	340.8	70.2	Clockwise
MS4	0.31	0.02	187.1	42.2	195.0	CLOCKWISE

Root-mean-squares speed, (cm/s)	=	5.21
Standard deviation, U series (cm/s)	=	2.66
Standard deviation, V series (cm/s)	=	2.14
Tidal-form number	=	0.30
Spring tidal current maximum (cm/s)	=	8.38
Neap tidal current maximum (cm/s)	=	4.05
Principal current direction (degrees T	)=	237.63

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	8 = 5.45 meters above bed
Record length:	60 M2 cycle: 4443 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.14605	228.52	239.62
K1	1.00274	0.89034	253.44	255.76
N2	1.89598	1.10334	214.60	232.37
M2	1.93227	4.33114	230.35	243.76
S2	2.00000	1.42205	271.74	277.03
M4	3.86455	0.50240	146.47	173.30
MS4	3.93227	0.05974	47.84	66.54

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.63387	233.04	244.13
K1	1.00274	0.62273	240.49	242.81
N2	1.89598	0.58858	185.93	203.70
M2	1.93227	2.68652	228.56	241.97
S2	2.00000	0.91577	246.39	251.67
M4	3.86455	0.35914	99.09	125.91
MS4	3.93227	0.25030	209.13	227.82

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.31	0.04	241.1	60.7	177.8	Counter-clockwise
K1	1.08	0.12	235.3	71.5	33.4	Clockwise
N2	1.22	0.25	243.7	46.5	68.3	Clockwise
M2	5.10	0.07	238.2	63.3	215.1	Clockwise
S2	1.66	0.34	238.3	89.9	339.9	Clockwise
M4	0.57	0.23	238.4	339.3	70.2	Clockwise
MS4	0.26	0.02	347.2	228.8	195.0	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.30
Standard deviation, U series (cm/s)	=	2.64
Standard deviation, V series (cm/s)	=	2.15
Tidal-form number	=	0.35
Spring tidal current maximum (cm/s)	=	9.14
Neap tidal current maximum (cm/s)	=	3.67
Principal current direction (degrees T)	=	238.29

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	9 = 5.95 meters above bed
Record length:	60 M2 cycle: 4441 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.30930	224.79	235.88
K1	1.00274	1.14917	258.85	261.16
N2	1.89598	1.10193	213.11	230.88
M2	1.93227	4.42489	231.78	245.19
S2	2.00000	1.57302	268.69	273.97
M4	3.86455	0.38472	155.00	181.82
MS4	3.93227	0.06394	359.09	17.79

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.70826	225.41	236.51
K1	1.00274	0.78424	241.53	243.85
N2	1.89598	0.56415	188.14	205.90
M2	1.93227	2.63565	230.33	243.75
S2	2.00000	1.00432	241.12	246.40
M4	3.86455	0.41203	92.18	119.01
MS4	3.93227	0.22258	218.41	237.11

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	1.49	0.01	241.6	56.0	177.8	Counter-clockwise
K1	1.38	0.19	236.1	75.7	33.4	Clockwise
N2	1.22	0.22	244.2	46.0	68.3	Clockwise
M2	5.15	0.06	239.2	64.8	215.1	Clockwise
S2	1.82	0.40	238.8	86.4	339.9	Clockwise
M4	0.48	0.29	220.7	326.6	70.2	Clockwise
MS4	0.23	0.04	347.1	234.8	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.35
Standard Deviation, U Series (Cm/s)	=	2.58
Standard Deviation, V Series (Cm/s)	=	2.13
Tidal-form Number	=	0.41
Spring Tidal Current Maximum (Cm/s)	=	9.84
Neap Tidal Current Maximum (Cm/s)	=	3.44
Principal Current Direction (Deg. T.)	=	293.07

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	10 = 6.45 meters above bed
Record length:	60 M2 cycle: 4425 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.39055	221.57	232.67
K1	1.00274	1.33481	261.15	263.46
N2	1.89598	1.06877	211.23	228.99
M2	1.93227	4.44936	232.40	245.81
S2	2.00000	1.64387	268.90	274.19
M4	3.86455	0.35466	168.46	195.28
MS4	3.93227	0.15612	16.66	35.35

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.75075	223.67	234.77
K1	1.00274	0.98914	245.29	247.60
N2	1.89598	0.54631	195.80	213.57
M2	1.93227	2.69996	231.10	244.52
S2	2.00000	1.08868	238.13	243.42
M4	3.86455	0.46196	93.56	120.38
MS4	3.93227	0.23419	247.60	266.30

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	1.58	0.02	241.6	53.1	177.8	Counter-clockwise
K1	1.65	0.22	233.8	77.9	33.4	Clockwise
N2	1.19	0.13	243.4	45.9	68.3	Clockwise
M2	5.20	0.05	238.8	65.5	215.1	Clockwise
S2	1.91	0.48	238.1	85.3	339.9	Clockwise
M4	0.48	0.33	202.1	316.0	70.2	Clockwise
MS4	0.26	0.11	331.7	253.5	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.41
Standard Deviation, U series (cm/s)	=	2.51
Standard Deviation, V series (cm/s)	=	2.16
Tidal-form number	=	0.45
Spring tidal current maximum (cm/s)	=	10.34
Neap tidal current maximum (cm/s)	=	3.22
Principal current direction (degrees T.)	=	238.29

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	11 = 6.95 meters above bed
Record length:	60 M2 cycle: 4416 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.42473	217.56	228.65
K1	1.00274	1.48947	261.42	263.73
N2	1.89598	0.99720	210.10	227.87
M2	1.93227	4.59021	233.10	246.51
S2	2.00000	1.68472	270.30	275.59
M4	3.86455	0.34224	178.15	204.97
MS4	3.93227	0.26482	18.74	37.44

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.73705	226.50	237.60
K1	1.00274	1.12660	248.99	251.30
N2	1.89598	0.57699	197.03	214.80
M2	1.93227	2.76979	230.34	243.75
S2	2.00000	1.09641	238.31	243.59
M4	3.86455	0.48580	92.87	119.70
MS4	3.93227	0.21361	252.60	271.30

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.60	0.10	242.8	50.5	177.8	Counter-clockwise
K1	1.86	0.19	233.1	79.2	33.4	Clockwise
N2	1.15	0.11	240.3	44.6	68.3	Clockwise
M2	5.36	0.11	238.9	65.8	215.1	Clockwise
S2	1.95	0.50	238.8	86.7	339.9	Clockwise
M4	0.49	0.34	186.5	304.2	70.2	Clockwise
MS4	0.31	0.15	304.9	236.3	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.56
Standard deviation, U series (cm/s)	=	2.52
Standard deviation, V series (cm/s)	=	2.24
Tidal-form number	=	0.47
Spring tidal current maximum (cm/s)	=	10.76
Neap tidal current maximum (cm/s)	=	3.16
Principal current direction (degrees T)	=	238.46

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	12 = 7.45 meters above bed
Record length:	60 M2 Cycle: 4394 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.38159	219.10	230.20
K1	1.00274	1.66191	264.26	266.57
N2	1.89598	0.91337	209.03	226.79
M2	1.93227	4.71842	234.25	247.66
S2	2.00000	1.63770	268.20	273.48
M4	3.86455	0.29402	199.06	225.88
MS4	3.93227	0.31710	28.89	47.59

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.67765	231.91	243.01
K1	1.00274	1.27784	253.02	255.34
N2	1.89598	0.55621	200.72	218.49
M2	1.93227	2.83916	228.76	242.18
S2	2.00000	1.00409	240.54	245.83
M4	3.86455	0.49723	96.46	123.29
MS4	3.93227	0.23829	266.17	284.87

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.53	0.14	244.2	52.6	177.8	Counter-clockwise
K1	2.09	0.20	232.6	82.4	33.4	Clockwise
N2	1.07	0.07	238.8	44.6	68.3	Clockwise
M2	5.50	0.23	239.0	66.2	215.1	Clockwise
S2	1.88	0.41	239.9	86.3	339.9	Clockwise
M4	0.50	0.28	349.2	117.1	70.2	Clockwise
MS4	0.35	0.18	300.9	244.5	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.64
Standard deviation, U series (cm/s)	=	2.51
Standard deviation, V series (cm/s)	=	2.26
Tidal-form number	=	0.49
Spring tidal current maximum (cm/s)	=	11.00
Neap tidal current maximum (cm/s)	=	3.07
Principal current direction (degrees T)	=	238.68

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	13 = 7.95 meters above Bed
Record length:	60 M2 cycle: 4346 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.24513	218.21	229.31
K1	1.00274	1.86273	265.23	267.55
N2	1.89598	0.84985	208.16	225.93
M2	1.93227	4.81367	235.58	248.99
S2	2.00000	1.51397	265.69	270.97
M4	3.86455	0.29400	209.17	236.00
MS4	3.93227	0.41060	46.95	65.65

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.61920	237.82	248.91
K1	1.00274	1.44471	258.17	260.48
N2	1.89598	0.51171	211.32	229.09
M2	1.93227	2.97296	227.26	240.68
S2	2.00000	0.93304	243.48	248.76
M4	3.86455	0.43856	107.04	133.87
MS4	3.93227	0.21485	262.91	281.61

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	1.38	0.19	244.4	53.0	177.8	Counter-clockwise
K1	2.35	0.14	232.3	84.9	33.4	Clockwise
N2	0.99	0.02	239.0	46.8	68.3	Counter-clockwise
M2	5.65	0.37	238.4	66.7	215.1	Clockwise
S2	1.75	0.30	239.3	85.1	339.9	Clockwise
M4	0.45	0.28	346.4	125.2	70.2	Clockwise
MS4	0.45	0.12	294.7	252.4	195.0	CLOCKWISE

Root-mean-squares speed, (cm/s)	=	5.79
Standard deviation, U series (cm/s	)=	2.53
Standard deviation, V series (cm/s)	=	2.37
Tidal-form number	=	0.50
Spring tidal current maximum (cm/s)	=	11.13
Neap Tidal Current Maximum (cm/s)	=	2.92
Principal Current Direction (degrees T)	=	237.99

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	14 = 8.45 meters above bed
Record length:	60 M2 cycle: 4260 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.25645	217.73	228.83
K1	1.00274	1.97340	268.59	270.91
N2	1.89598	0.73920	201.30	219.07
M2	1.93227	4.79222	235.25	248.67
S2	2.00000	1.42921	266.69	271.98
M4	3.86455	0.33373	228.76	255.59
MS4	3.93227	0.34907	39.96	58.65

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.56373	253.20	264.30
K1	1.00274	1.54387	266.64	268.96
N2	1.89598	0.48790	222.08	239.84
M2	1.93227	2.96823	226.30	239.71
S2	2.00000	0.74303	249.80	255.08
M4	3.86455	0.27729	123.17	149.99
MS4	3.93227	0.18830	271.87	290.56

Tidal elipse (combined results for U and V series)

	Speed on indicated axis					
Name	Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	1.34	0.31	248.8	53.9	177.8	Counter-clockwise
K1	2.51	0.04	232.0	90.2	33.4	Clockwise
N2	0.87	0.15	237.3	45.2	68.3	Counter-clockwise
M2	5.62	0.39	238.4	66.2	215.1	Clockwise
S2	1.60	0.19	243.1	88.5	339.9	Clockwise
M4	0.35	0.25	297.6	96.2	70.2	Clockwise
MS4	0.37	0.14	291.6	247.1	195.0	Clockwise

Root-mean-squares speed, (cm/s)	=	5.87
Standard deviation, U series (cm/s	)=	2.54
Standard deviation, V series (cm/s)	=	2.51
Tidal-form number	=	0.53
Spring tidal current maximum (cm/s)	=	11.07
Neap Tidal Current Maximum (cm/s)	=	2.86
Principal Current Direction (degrees T)	=	238.87

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	Center
Series start (Standard Time):	Year = 1994Month = 7Day = 28Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	15 = 8.95 meters above bed
Record length:	60 M2 cycle: 4057 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.24730	222.15	233.25
K1	1.00274	2.09114	273.65	275.96
N2	1.89598	0.69827	206.69	224.46
M2	1.93227	4.66288	234.57	247.99
S2	2.00000	1.44541	266.73	272.01
M4	3.86455	0.39234	237.88	264.71
MS4	3.93227	0.30009	28.01	46.70

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.66061	279.31	290.40
K1	1.00274	1.65846	271.24	273.56
N2	1.89598	0.60180	226.39	244.15
M2	1.93227	2.79688	227.20	240.61
S2	2.00000	0.67604	252.26	257.55
M4	3.86455	0.07522	111.00	137.83
MS4	3.93227	0.22310	289.12	307.81

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.31	0.53	250.7	61.3	219.6	Counter-clockwise
K1	2.67	0.05	231.6	95.0	78.6	Clockwise
N2	0.91	0.16	229.5	52.8	153.6	Counter-clockwise
M2	5.43	0.31	239.1	66.0	302.0	Clockwise
S2	1.59	0.15	245.4	89.5	69.9	Clockwise
M4	0.39	0.06	276.7	85.7	244.1	Clockwise
MS4	0.30	0.22	283.6	236.5	11.9	Clockwise

Root-mean-squares speed, (cm/s)	=	5.83
Standard deviation, U series (cm/s)	=	2.56
Standard deviation, V series (cm/s)	=	2.54
Tidal-form number	=	0.57
Spring tidal current maximum (cm/s)	=	10.99
Neap tidal current maximum (cm/s)	=	2.48
Principal current direction (degrees T)	=	239.59

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 11:19
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	16 = 9.45 meters above bed
Record length:	60 M2 cycle: 3699 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.23833	228.89	239.99
K1	1.00274	2.31538	282.09	284.41
N2	1.89598	0.66434	218.37	236.14
M2	1.93227	4.52330	235.75	249.16
S2	2.00000	1.60587	262.21	267.50
M4	3.86455	0.38131	231.55	258.38
MS4	3.93227	0.20692	22.74	41.44

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.98791	275.14	286.24
K1	1.00274	1.70040	274.51	276.83
N2	1.89598	0.67488	227.39	245.16
M2	1.93227	2.54597	231.76	245.17
S2	2.00000	0.63219	264.31	269.60
M4	3.86455	0.19618	306.65	333.47
MS4	3.93227	0.27959	275.70	294.40

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.46	0.60	234.1	76.6	249.8	Counter-clockwise
K1	2.87	0.18	233.8	101.8	111.2	Clockwise
N2	0.94	0.07	224.5	60.7	215.3	Counter-clockwise
M2	5.19	0.15	240.7	68.2	4.9	Clockwise
S2	1.73	0.02	248.5	87.8	135.0	Counter-clockwise
M4	0.39	0.19	260.1	83.2	9.9	Counter-clockwise
MS4	0.29	0.19	338.1	279.7	139.9	Clockwise

Root-mean-squares Speed, (Cm/s)	=	5.83
Standard Deviation, U Series (Cm/s)	=	2.64
Standard Deviation, V Series (Cm/s)	=	2.50
Tidal-form Number	=	0.63
Spring Tidal Current Maximum (Cm/s)	=	11.25
Neap Tidal Current Maximum (Cm/s)	=	2.06
Principal Current Direction (Deg. T.)	=	239.26

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 15: 9
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	17 = 9.95 meters above bed
Record length:	60 M2 cycle: 3389 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.13103	232.92	244.02
K1	1.00274	2.73514	282.58	284.90
N2	1.89598	0.60067	230.58	248.35
M2	1.93227	4.36328	236.99	250.41
S2	2.00000	1.65126	254.87	260.15
M4	3.86455	0.43338	224.67	251.49
MS4	3.93227	0.25503	35.82	54.51

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.02503	271.54	282.64
K1	1.00274	1.69776	274.91	277.22
N2	1.89598	0.69698	229.78	247.54
M2	1.93227	2.26821	235.66	249.07
S2	2.00000	0.62755	268.41	273.70
M4	3.86455	0.34771	321.13	347.95
MS4	3.93227	0.22359	276.30	295.00

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.44	0.50	228.6	81.1	270.8	Counter-clockwise
K1	3.21	0.19	238.3	102.8	133.8	Clockwise
N2	0.92	0.01	220.8	67.9	258.0	Clockwise
M2	4.92	0.05	242.5	70.1	48.4	Clockwise
S2	1.76	0.14	249.6	81.8	180.0	Counter-clockwise
M4	0.44	0.34	283.4	60.9	96.8	Counter-clockwise
MS4	0.29	0.17	307.5	258.3	228.4	Clockwise

Root-mean-squares apeed, (cm/s)	=	5.80
Standard seviation, U aeries (cm/s)	=	2.74
Standard seviation, V aeries (cm/s)	=	2.48
Tidal-form number	=	0.70
Spring tidal current maximum (cm/s)	=	11.33
Neap tidal current maximum (cm/s)	=	1.38
Principal current direction (degrees T)	=	240.65

Station name:	Center
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 18: 0
Time meridian:	120 W
Station position:	47-32-47N 122-38-34W
Bin number:	18 = 10.45 meters above bed
Record length:	60 M2 cycle: 2664 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.03163	234.01	245.11
K1	1.00274	3.34522	288.37	290.69
N2	1.89598	0.58957	250.35	268.12
M2	1.93227	4.20823	236.18	249.60
S2	2.00000	2.01294	257.84	263.13
M4	3.86455	0.18442	223.05	249.87
MS4	3.93227	0.05636	38.79	57.49

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.03286	269.11	280.21
K1	1.00274	1.58442	277.28	279.59
N2	1.89598	0.64078	232.97	250.74
M2	1.93227	2.07174	241.46	254.87
S2	2.00000	0.77834	278.03	283.31
M4	3.86455	0.34403	315.93	342.75
MS4	3.93227	0.19160	299.81	318.51

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.39	0.44	225.0	82.7	270.8	Counter-clockwise
K1	3.69	0.28	244.9	108.7	133.8	Clockwise
N2	0.86	0.13	222.5	78.7	258.0	Clockwise
M2	4.69	0.17	243.8	70.6	48.4	Counter-clockwise
S2	2.14	0.25	249.8	85.6	180.0	Counter-clockwise
M4	0.34	0.18	357.8	343.9	96.8	Counter-clockwise
MS4	0.19	0.06	357.1	317.7	228.4	Clockwise

Root-mean-squares apeed, (cm/s)	=	5.91
Standard seviation, U aeries (cm/s)	=	2.94
Standard seviation, V aeries (cm/s)	=	2.55
Tidal-form number	=	0.74
Spring tidal current maximum (cm/s)	=	11.91
Neap tidal current maximum (cm/s)	=	0.24
Principal current direction (degrees T)	=	243.04

Station name: West
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian: 120 W
Station position: 47-32-57N 122-39-30W
Bin number: 1 = 1.95 meters above bed
Record length: 60 M2 cycle: 4471 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.06211	122.67	133.78
K1	1.00274	0.73623	65.71	68.04
N2	1.89598	0.68018	204.88	222.68
M2	1.93227	4.38191	218.44	231.88
S2	2.00000	0.53856	233.71	239.03
M4	3.86455	0.68594	169.37	196.26
MS4	3.93227	0.14427	202.16	220.92

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.45927	329.21	340.32
K1	1.00274	0.43745	358.04	0.37
N2	1.89598	0.51307	222.84	240.64
M2	1.93227	2.97598	217.46	230.90
S2	2.00000	0.36296	307.22	312.54
M4	3.86455	0.84168	112.45	139.34
MS4	3.93227	0.35169	134.74	153.50

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.46	0.03	173.1	159.9	170.8	Clockwise
K1	0.76	0.39	252.5	238.9	25.9	Clockwise
N2	0.84	0.13	233.4	49.1	54.0	Counter-clockwise
M2	5.30	0.04	235.8	51.6	200.6	Clockwise
S2	0.55	0.34	252.5	69.9	324.9	Counter-clockwise
M4	0.96	0.50	214.7	339.2	41.2	Clockwise
MS4	0.36	0.13	190.4	337.4	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.55
Standard deviation, U series (cm/s)	=	2.93
Standard deviation, V series (cm/s)	=	2.53
Tidal-form number	=	0.21
Spring tidal current maximum (cm/s)	=	7.08
Neap tidal current maximum (cm/s)	=	4.44
Principal current direction (degrees T)	=	234.81

Station name: West
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian: 120 W
Station position: 47-32-57N 122-39-30W
Bin number: 2 = 2.45 meters above bed
Record length: 60 M2 cycle: 4471 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.15383	266.96	278.07
K1	1.00274	0.74735	51.86	54.19
N2	1.89598	0.67666	214.79	232.59
M2	1.93227	4.38562	222.29	235.74
S2	2.00000	0.58074	251.92	257.24
M4	3.86455	0.68941	173.81	200.70
MS4	3.93227	0.10268	199.39	218.15

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.32242	304.76	315.87
K1	1.00274	0.39697	325.34	327.67
N2	1.89598	0.28338	204.68	222.48
M2	1.93227	2.50242	205.92	219.37
S2	2.00000	0.27253	244.53	249.85
M4	3.86455	0.59687	106.05	132.94
MS4	3.93227	0.32601	134.16	152.92

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.35	0.09	202.2	130.0	170.8	Counter-clockwise
K1	0.75	0.40	267.4	232.8	25.9	Clockwise
N2	0.73	0.05	247.5	51.1	54.0	Clockwise
M2	5.01	0.62	240.8	51.8	200.6	Clockwise
S2	0.64	0.03	245.0	75.9	324.9	Clockwise
M4	0.76	0.50	235.5	356.5	41.2	Clockwise
MS4	0.33	0.09	188.2	335.2	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.24
Standard deviation, U series (cm/s)	=	2.87
Standard deviation, V series (cm/s)	=	2.21
Tidal-form number	=	0.19
Spring tidal current maximum (cm/s)	=	6.75
Neap tidal current maximum (cm/s)	=	3.97
Principal current direction (degrees T)	=	242.18

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	3 = 2.95 meters above bed
Record length:	60 M2 cycle: 4471 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.29070	250.90	262.02
K1	1.00274	0.75515	36.56	38.89
N2	1.89598	0.72158	224.49	242.28
M2	1.93227	4.35081	223.69	237.13
S2	2.00000	0.74265	264.32	269.64
M4	3.86455	0.71098	169.72	196.61
MS4	3.93227	0.15194	205.41	224.17

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.28744	270.08	281.19
K1	1.00274	0.41314	304.32	306.65
N2	1.89598	0.23192	163.37	181.17
M2	1.93227	2.15443	197.68	211.12
S2	2.00000	0.44722	218.00	223.31
M4	3.86455	0.39931	83.35	110.24
MS4	3.93227	0.38949	142.57	161.33

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.49	0.03	236.9	79.1	170.8	Clockwise
K1	0.72	0.44	273.1	212.4	25.9	Clockwise
N2	0.81	0.32	269.9	69.5	54.0	Clockwise
M2	4.55	0.89	247.5	54.2	200.6	Clockwise
S2	0.89	0.50	244.4	80.9	324.9	Clockwise
M4	0.66	0.27	273.6	13.2	41.2	Clockwise
MS4	0.41	0.22	178.2	356.3	165.5	Clockwise

Root-mean-squares Speed, (cm/s)	=	5.13
Standard deviation, U series (cm/s)	=	2.86
Standard deviation, V series (cm/s)	=	2.04
Tidal-form number	=	0.21
Spring tidal current maximum (cm/s)	=	6.75
Neap tidal current maximum (cm/s)	=	3.61
Principal current direction (degrees T)	=	246.77

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	4 = 3.45 meters above bed
Record length:	60 M2 cycle: 4471 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.40810	250.65	261.77
K1	1.00274	0.71461	28.17	30.50
N2	1.89598	0.81094	231.74	249.54
M2	1.93227	4.21875	225.42	238.86
S2	2.00000	0.83299	270.72	276.03
M4	3.86455	0.65723	164.86	191.75
MS4	3.93227	0.22258	250.86	269.62

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.26710	241.88	253.00
K1	1.00274	0.43725	295.00	297.33
N2	1.89598	0.31962	141.87	159.67
M2	1.93227	1.92538	195.44	208.88
S2	2.00000	0.59440	206.10	211.42
M4	3.86455	0.27183	67.52	94.41
MS4	3.93227	0.41363	158.48	177.24

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	0.49	0.03	236.9	79.1	170.8	Clockwise
K1	0.72	0.44	273.1	212.4	25.9	Clockwise
N2	0.81	0.32	269.9	69.5	54.0	Clockwise
M2	4.55	0.89	247.5	54.2	200.6	Clockwise
S2	0.89	0.50	244.4	80.9	324.9	Clockwise
M4	0.66	0.27	273.6	13.2	41.2	Clockwise
MS4	0.41	0.22	178.2	356.3	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.08
Standard deviation, U series (cm/s)	=	2.88
Standard deviation, V series (cm/s)	=	1.94
Tidal-form number	=	0.22
Spring tidal current maximum (cm/s)	=	6.64
Neap tidal current maximum (cm/s)	=	3.43
Principal current direction (degrees T)	=	249.07

Station name: West
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian: 120 W
Station position: 47-32-57N 122-39-30W
Bin number: 5 = 3.95 meters above bed
Record length: 60 M2 cycle: 4471 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.56959	244.10	255.21
K1	1.00274	0.71597	17.03	19.36
N2	1.89598	0.85453	237.18	254.98
M2	1.93227	4.02896	229.31	242.75
S2	2.00000	0.96065	277.62	282.94
M4	3.86455	0.59185	155.44	182.33
MS4	3.93227	0.25593	260.43	279.19

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.23667	228.45	239.56
K1	1.00274	0.37778	288.56	290.89
N2	1.89598	0.36041	141.51	159.31
M2	1.93227	1.76913	195.00	208.44
S2	2.00000	0.71148	200.69	206.01
M4	3.86455	0.18519	54.64	81.52
MS4	3.93227	0.37025	167.67	186.43

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
K1	0.72	0.38	268.9	198.8	25.9	Clockwise
N2	0.86	0.36	272.9	76.2	54.0	Clockwise
M2	4.30	0.93	249.0	58.0	200.6	Clockwise
S2	0.99	0.67	251.7	90.2	324.9	Clockwise
M4	0.59	0.18	273.7	3.5	41.2	Clockwise
MS4	0.37	0.26	176.4	3.9	165.5	Clockwise

Root-mean-squares speed, (cm/s) = 5.13
Standard deviation, U series (cm/s) = 2.98
Standard deviation, V series (cm/s) = 1.92
Tidal-form number = 0.25
Spring tidal current maximum (cm/s) = 6.62
Neap tidal current maximum (cm/s) = 3.21
Principal current direction (degrees T) = 251.48

Station name: West
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian: 120 W
Station position: 47-32-57N 122-39-30W
Bin number: 6 = 4.45 meters above bed
Record length: 60 M2 cycle: 4471 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.85736	241.97	253.09
K1	1.00274	0.78428	356.01	358.34
N2	1.89598	0.82480	232.61	250.41
M2	1.93227	3.92166	231.49	244.93
S2	2.00000	1.13427	283.12	288.44
M4	3.86455	0.64518	145.73	172.62
MS4	3.93227	0.28087	235.96	254.72

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.10385	212.33	223.44
K1	1.00274	0.28945	284.59	286.92
N2	1.89598	0.36852	147.66	165.46
M2	1.93227	1.69955	194.97	208.42
S2	2.00000	0.77810	200.24	205.56
M4	3.86455	0.08872	14.58	41.46
MS4	3.93227	0.36227	166.50	185.26

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
K1	0.79	0.27	262.4	175.7	25.9	Clockwise
N2	0.83	0.37	267.2	69.2	54.0	Clockwise
M2	4.17	0.95	249.7	60.1	200.6	Clockwise
S2	1.14	0.77	261.1	102.4	324.9	Clockwise
M4	0.65	0.07	275.2	353.2	41.2	Clockwise
MS4	0.39	0.25	206.9	23.2	165.5	Clockwise

Root-mean-squares speed, (cm/s) = 5.19
Standard deviation, U series (cm/s) = 3.03
Standard deviation, V series (cm/s) = 1.92
Tidal-form number = 0.31
Spring tidal current maximum (cm/s) = 6.96
Neap tidal current maximum (cm/s) = 3.10
Principal current direction (degrees T) = 254.77

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	7 = 4.95 meters above bed
Record length:	60 M2 cycle: 4471 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.19960	243.27	254.39
K1	1.00274	0.93881	336.02	338.35
N2	1.89598	0.82040	235.72	253.52
M2	1.93227	3.87850	234.73	248.17
S2	2.00000	1.29722	286.78	292.10
M4	3.86455	0.62740	133.55	160.44
MS4	3.93227	0.28335	236.47	255.23

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.11406	213.31	224.43
K1	1.00274	0.23410	266.00	268.33
N2	1.89598	0.42965	149.64	167.43
M2	1.93227	1.66770	193.48	206.92
S2	2.00000	0.82285	206.10	211.42
M4	3.86455	0.13627	310.50	337.39
MS4	3.93227	0.31756	159.62	178.38

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.20	0.06	265.3	74.2	170.8	Clockwise
K1	0.94	0.22	264.8	157.1	25.9	Clockwise
N2	0.82	0.43	267.2	72.1	54.0	Clockwise
M2	4.09	1.04	250.8	63.1	200.6	Clockwise
S2	1.31	0.81	260.5	106.2	324.9	Clockwise
M4	0.64	0.01	282.2	340.3	41.2	Counter-clockwise
MS4	0.34	0.26	211.7	23.8	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.20
Standard deviation, U series (cm/s)	=	2.95
Standard deviation, V series (cm/s)	=	1.91
Tidal-form number	=	0.40
Spring tidal current maximum (cm/s)	=	7.55
Neap tidal current maximum (cm/s)	=	3.04
Principal current direction (degrees T)	=	256.54

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	8 = 5.45 meters above bed
Record length:	60 M2 cycle: 4465 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.39051	241.89	253.00
K1	1.00274	1.09748	327.45	329.78
N2	1.89598	0.89203	238.46	256.25
M2	1.93227	3.82735	237.52	250.96
S2	2.00000	1.37198	290.38	295.70
M4	3.86455	0.66790	122.05	148.94
MS4	3.93227	0.22950	219.52	238.28

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.08061	249.60	260.72
K1	1.00274	0.14352	232.99	235.31
N2	1.89598	0.45134	138.77	156.57
M2	1.93227	1.57395	189.14	202.59
S2	2.00000	0.82101	206.18	211.50
M4	3.86455	0.25873	308.05	334.94
MS4	3.93227	0.28675	153.81	172.57

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.39	0.01	266.7	73.0	170.8	Counter-clockwise
K1	1.10	0.14	270.6	149.9	25.9	Clockwise
N2	0.90	0.44	276.4	79.4	54.0	Clockwise
M2	3.98	1.13	253.3	66.1	200.6	Clockwise
S2	1.38	0.81	264.7	112.5	324.9	Clockwise
M4	0.72	0.03	291.1	329.7	41.2	Clockwise
MS4	0.31	0.19	210.7	12.5	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.35
Standard deviation, U series (cm/s)	=	3.09
Standard deviation, V series (cm/s)	=	1.97
Tidal-form number	=	0.46
Spring tidal current maximum (cm/s)	=	7.85
Neap tidal current maximum (cm/s)	=	2.90
Principal current direction (degrees T)	=	260.11

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:49
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	9 = 5.95 meters above bed
Record Length:	60 M2 Cycle: 4459 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.52044	243.50	254.62
K1	1.00274	1.26653	324.45	326.78
N2	1.89598	1.02070	241.03	258.83
M2	1.93227	3.80138	238.67	252.12
S2	2.00000	1.44582	293.60	298.92
M4	3.86455	0.69272	110.61	137.50
MS4	3.93227	0.20513	199.79	218.55

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.11351	312.09	323.20
K1	1.00274	0.15589	207.75	210.08
N2	1.89598	0.45700	140.10	157.90
M2	1.93227	1.50318	183.12	196.56
S2	2.00000	0.75528	208.37	213.69
M4	3.86455	0.38720	306.11	332.99
MS4	3.93227	0.15321	124.30	143.06

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.52	0.11	268.4	74.7	170.8	Counter-clockwise
K1	1.27	0.14	273.2	147.1	25.9	Clockwise
N2	1.03	0.45	276.0	81.5	54.0	Clockwise
M2	3.91	1.21	256.0	67.7	200.6	Clockwise
S2	1.45	0.75	266.6	117.1	324.9	Clockwise
M4	0.79	0.09	298.7	321.1	41.2	Clockwise
MS4	0.21	0.14	249.9	24.6	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.43
Standard deviation, U series (cm/s)	=	3.14
Standard deviation, V series (cm/s)	=	1.95
Tidal-form number	=	0.52
Spring tidal current maximum (cm/s)	=	8.14
Neap tidal current maximum (cm/s)	=	2.71
Principal current direction (degrees T)	=	262.90

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	10 = 6.45 meters above bed
Record length:	60 M2 cycle: 4454 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.66734	243.52	254.63
K1	1.00274	1.44398	320.97	323.30
N2	1.89598	0.99907	236.05	253.84
M2	1.93227	3.82761	239.16	252.60
S2	2.00000	1.57694	292.82	298.14
M4	3.86455	0.74156	106.50	133.39
MS4	3.93227	0.14909	200.57	219.33

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.23761	318.15	329.27
K1	1.00274	0.14776	201.11	203.44
N2	1.89598	0.43223	143.70	161.49
M2	1.93227	1.49422	175.85	189.29
S2	2.00000	0.68150	211.50	216.81
M4	3.86455	0.49662	302.22	329.10
MS4	3.93227	0.15024	101.23	119.99

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.67	0.23	267.8	74.9	170.8	Counter-clockwise
K1	1.45	0.13	272.9	143.6	25.9	Clockwise
N2	1.00	0.43	271.2	74.4	54.0	Clockwise
M2	3.89	1.31	258.8	68.8	200.6	Clockwise
S2	1.58	0.67	265.4	116.2	324.9	Clockwise
M4	0.89	0.11	303.4	318.2	41.2	Clockwise
MS4	0.16	0.14	316.4	81.0	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.50
Standard deviation, U series (cm/s)	=	3.14
Standard deviation, V series (cm/s)	=	1.92
Tidal-form number	=	0.57
Spring tidal current maximum (cm/s)	=	8.59
Neap tidal current maximum (cm/s)	=	2.54
Principal current direction (degrees T)	=	264.13

Station name: West
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian: 120 W
Station position: 47-32-57N 122-39-30W
Bin number: 11 = 6.95 meters above bed
Record length: 60 M2 cycle: 4423 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.72356	245.29	256.41
K1	1.00274	1.61919	321.32	323.65
N2	1.89598	0.93659	235.87	253.67
M2	1.93227	3.89042	239.68	253.13
S2	2.00000	1.63783	291.74	297.06
M4	3.86455	0.64563	95.80	122.68
MS4	3.93227	0.12704	208.00	226.76

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.45436	325.91	337.02
K1	1.00274	0.19150	224.71	227.04
N2	1.89598	0.49395	142.23	160.03
M2	1.93227	1.45737	167.49	180.93
S2	2.00000	0.56700	225.30	230.61
M4	3.86455	0.58904	296.11	323.00
MS4	3.93227	0.08548	46.49	65.25

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.73	0.45	267.4	77.1	170.8	Counter-clockwise
K1	1.62	0.19	270.8	143.7	25.9	Clockwise
N2	0.94	0.49	272.7	75.1	54.0	Clockwise
M2	3.92	1.38	262.5	70.5	200.6	Clockwise
S2	1.66	0.51	261.3	114.3	324.9	Clockwise
M4	0.86	0.15	312.2	311.9	41.2	Clockwise
MS4	0.15	0.02	303.4	52.4	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.52
Standard deviation, U series (cm/s)	=	3.10
Standard deviation, V series (cm/s)	=	1.94
Tidal-form number	=	0.60
Spring tidal current maximum (cm/s)	=	8.92
Neap tidal current maximum (cm/s)	=	2.37
Principal current direction (degrees T)	=	264.74

Station name: West
Series start (Standard Time): Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian: 120 W
Station position: 47-32-57N 122-39-30W
Bin number: 12 = 7.45 meters above bed
Record length: 60 M2 cycle: 4328 data points

Results for U (+East) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.67695	248.92	260.03
K1	1.00274	1.93543	318.64	320.97
N2	1.89598	0.97285	234.59	252.39
M2	1.93227	3.98962	240.35	253.79
S2	2.00000	1.67143	294.68	299.99
M4	3.86455	0.46467	86.98	113.87
MS4	3.93227	0.06813	265.81	284.57

Results for V (+North) series

Constituent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.64888	326.80	337.91
K1	1.00274	0.15174	272.05	274.38
N2	1.89598	0.45491	147.76	165.56
M2	1.93227	1.34753	157.15	170.60
S2	2.00000	0.46121	235.11	240.43
M4	3.86455	0.70346	292.03	318.91
MS4	3.93227	0.11352	31.04	49.80

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Speed on indicated axis: Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.68	0.63	264.6	82.1	170.8	Counter-clockwise
K1	1.94	0.11	266.9	140.8	25.9	Clockwise
N2	0.97	0.45	268.1	71.5	54.0	Clockwise
M2	3.99	1.34	267.4	72.9	200.6	Clockwise
S2	1.69	0.39	261.6	118.0	324.9	Clockwise
M4	0.83	0.17	327.6	311.6	41.2	Clockwise
MS4	0.12	0.05	336.4	60.3	165.5	Counter-clockwise

Root-mean-squares speed, (cm/s)	=	5.55
Standard deviation, U series (cm/s)	=	3.14
Standard deviation, V series (cm/s)	=	1.93
Tidal-form number	=	0.64
Spring tidal current maximum (cm/s)	=	9.30
Neap tidal current maximum (cm/s)	=	2.05
Principal current direction (degrees T)	=	265.74

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	13 = 7.95 meters above bed
Record length:	60 M2 cycle: 4240 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.60493	255.29	266.40
K1	1.00274	2.07944	313.36	315.69
N2	1.89598	0.93591	241.07	258.87
M2	1.93227	4.00079	244.73	258.17
S2	2.00000	1.53850	292.37	297.68
M4	3.86455	0.27018	72.52	99.41
MS4	3.93227	0.12793	1.51	20.27

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.75970	327.43	338.55
K1	1.00274	0.07681	277.41	279.74
N2	1.89598	0.38291	163.61	181.41
M2	1.93227	1.14325	148.61	162.05
S2	2.00000	0.38631	259.38	264.70
M4	3.86455	0.73499	286.61	313.50
MS4	3.93227	0.13266	327.92	346.68

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.63	0.71	259.7	90.9	170.8	Counter-clockwise
K1	2.08	0.05	268.3	135.7	25.9	Clockwise
N2	0.94	0.37	264.0	76.5	54.0	Clockwise
M2	4.00	1.14	271.9	78.7	200.6	Clockwise
S2	1.57	0.21	257.9	116.1	324.9	Clockwise
M4	0.77	0.14	342.4	310.1	41.2	Clockwise
MS4	0.18	0.05	223.8	182.8	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.45
Standard deviation, U series (cm/s)	=	3.14
Standard deviation, V series (cm/s)	=	1.96
Tidal-form number	=	0.66
Spring tidal current maximum (cm/s)	=	9.28
Neap tidal current maximum (cm/s)	=	1.98
Principal current direction (degrees T)	=	266.59

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 10:59
Time meridian:	120 W
Station position:	47-32-57n 122-39-30w
Bin number:	14 = 8.45 meters above bed
Record length:	60 M2 cycle: 3960 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.76044	263.88	275.00
K1	1.00274	2.21225	309.44	311.77
N2	1.89598	0.86319	245.80	263.60
M2	1.93227	3.98427	250.95	264.40
S2	2.00000	1.27775	286.48	291.80
M4	3.86455	0.15692	17.84	44.72
MS4	3.93227	0.17986	25.35	44.11

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.78593	331.64	342.76
K1	1.00274	0.16725	316.06	318.39
N2	1.89598	0.20464	171.91	189.71
M2	1.93227	0.81684	150.46	163.90
S2	2.00000	0.31181	249.51	254.82
M4	3.86455	0.61929	278.83	305.72
MS4	3.93227	0.21029	301.30	320.06

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis: Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equilibrium angle (degrees)	Rotation
O1	1.79	0.72	258.6	99.6	170.8	Counter-clockwise
K1	2.22	0.02	265.7	131.8	25.9	Counter-clockwise
N2	0.87	0.20	266.0	82.7	54.0	Clockwise
M2	3.99	0.80	272.2	84.8	200.6	Clockwise
S2	1.30	0.18	258.7	110.2	324.9	Clockwise
M4	0.62	0.15	357.6	305.1	41.2	Clockwise
MS4	0.21	0.18	196.7	154.0	165.5	Clockwise

Root-mean-squares speed, (cm/s)	=	5.31
Standard deviation, U series (cm/s)	=	3.13
Standard deviation, V series (cm/s)	=	2.03
Tidal-form number	=	0.76
Spring tidal current maximum (cm/s)	=	9.30
Neap tidal current maximum (cm/s)	=	2.26
Principal current direction (degrees T)	=	266.15

Appendix A.--Harmonic analysis of current-velocity data--Continued

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour=10:59
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	15 = 8.95 meters above bed
Record length:	60 M2 cycle: 3559 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.78302	260.64	271.76
K1	1.00274	2.25664	306.06	308.39
N2	1.89598	0.81809	244.92	262.72
M2	1.93227	3.88324	254.94	268.38
S2	2.00000	0.99438	282.79	288.11
M4	3.86455	0.20909	358.98	25.87
MS4	3.93227	0.43670	27.44	46.20

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.82749	329.80	340.91
K1	1.00274	0.21290	8.35	10.68
N2	1.89598	0.18368	253.61	271.41
M2	1.93227	0.45509	160.40	173.84
S2	2.00000	0.19849	240.21	245.52
M4	3.86455	0.52948	270.52	297.41
MS4	3.93227	0.30919	282.89	301.65

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	1.81	0.76	258.6	96.6	240.5	Counter-clockwise
K1	2.26	0.19	267.5	128.6	101.1	Counter-clockwise
N2	0.84	0.03	257.5	83.1	196.2	Counter-clockwise
M2	3.88	0.45	270.5	88.4	345.5	Clockwise
S2	1.01	0.13	261.5	107.0	114.9	Clockwise
M4	0.53	0.21	0.7	297.7	331.0	Clockwise
MS4	0.45	0.29	287.8	237.9	100.4	Clockwise

Root-mean-squares speed, (cm/s)	=	5.22
Standard deviation, U series (cm/s)	=	3.26
Standard deviation, V series (cm/s)	=	2.08
Tidal-form number	=	0.83
Spring tidal current maximum (cm/s)	=	8.96
Neap tidal current maximum (cm/s)	=	2.43
Principal current direction (degrees T)	=	266.33

Station name:	West
Series start (Standard Time):	Year = 1994 Month = 7 Day = 28 Hour:Minute = 16:19
Time meridian:	120 W
Station position:	47-32-57N 122-39-30W
Bin number:	16 = 9.45 meters above Bed
Record length:	60 M2 cycle: 2967 data points

Results for U (+East) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	1.96078	261.89	273.00
K1	1.00274	2.38674	310.76	313.09
N2	1.89598	0.76601	236.41	254.21
M2	1.93227	3.48821	262.95	276.39
S2	2.00000	0.84434	297.59	302.91
M4	3.86455	0.16713	347.27	14.16
MS4	3.93227	0.44556	25.64	44.40

Results for V (+North) series

Con-stitu-ent	Frequency (per day)	Amplitude (cm/s)	Local epoch (degrees)	Modified epoch (degrees)
O1	0.92954	0.81727	321.43	332.54
K1	1.00274	0.30019	345.34	347.67
N2	1.89598	0.28152	276.01	293.81
M2	1.93227	0.22388	288.25	301.69
S2	2.00000	0.04952	266.69	272.01
M4	3.86455	0.38095	250.38	277.27
MS4	3.93227	0.46138	286.16	304.92

Tidal elipse (combined results for U and V series)

Name	Speed on indicated axis Major (cm/s)	Minor (cm/s)	Direction (degrees T)	Phase angle (degrees)	Equili-brium angle (degrees)	Rotation
O1	2.01	0.69	256.5	97.7	249.7	Counter-clockwise
K1	2.40	0.17	264.1	133.5	111.0	Counter-clockwise
N2	0.80	0.17	253.4	77.9	215.0	Counter-clockwise
M2	3.49	0.10	266.7	96.5	4.6	Counter-clockwise
S2	0.85	0.03	267.1	122.8	134.7	Clockwise
M4	0.38	0.17	356.3	275.7	9.3	Clockwise
MS4	0.49	0.41	321.0	270.6	139.3	Clockwise

Root-mean-squares speed, (cm/s)	=	4.96
Standard deviation, U Series (cm/s)	=	3.19
Standard deviation, V Series (cm/s)	=	2.10
Tidal-form number	=	1.02
Spring tidal current maximum (cm/s)	=	8.75
Neap tidal current maximum (cm/s)	=	2.26
Principal current direction (degrees T)	=	263.65

APPENDIX B

Harmonic Analysis of Water-Level Data

The tables in this appendix present the results of harmonic analyses (after tidal inference) of time series of water-level data collected with instruments mounted on the acoustical Doppler current profiler frames. Analyses were performed on data from each of the three stations and for each of the two deployment periods.

Station: East
Start time: February 17, 1994, 11:19 Pacific Standard Time
Record length: 46 days

Constituent		Frequency	Amplitude	Modified epoch	Greenwich epoch
Symbol	Origin and name	(per day)	(centimeters)	(degrees)	(degrees)
Mm	Lunar monthly	0.03629	4.63	320.74	325.10
MSf	Lunisolar synodic fortnightly	0.06773	3.72	123.92	132.05
2Q1	Second-order elliptical lunar	0.85695	2.91	262.39	5.23
Q1	Larger lunar elliptic	0.89324	7.78	153.11	260.30
O1	Principal lunar diurnal	0.92954	48.77	143.00	254.55
M1	Smaller lunar elliptic	0.96645	4.93	195.60	311.57
P1	Principal solar diurnal	0.99726	27.18	165.39	285.06
K1	Lunisolar diurnal	1.00274	90.31	162.44	287.13
J1	Small lunar elliptic	1.03903	5.79	158.40	283.08
OO1	Second-order lunar	1.07594	4.94	267.16	36.28
μ2	Variational	1.86455	4.96	9.35	233.10
N2	Larger lunar elliptic	1.89598	20.76	119.34	351.21
ν2	Larger lunar evectional	1.90084	4.88	109.69	337.79
M2	Principal lunar	1.93227	112.26	145.43	17.30
L2	Smaller lunar elliptic	1.96857	5.19	149.09	25.32
S2	Principal solar	2.00000	27.71	164.00	147.42
K2	Lunisolar semidiurnal	2.00548	7.70	173.37	54.02
MK3	Lunisolar terdiurnal	2.93501	1.52	137.16	129.36
M4	Quarter diurnal lunar	3.86455	2.64	149.54	253.29
M6	Sixth diurnal lunar	5.79682	1.97	21.29	356.91

Station: East
Start time: July 28, 1994, 10:30 Pacific Standard Time
Record length: 32 days

Constituent		Frequency	Amplitude	Modified epoch	Greenwich epoch
Symbol	Origin and name	(per day)	(centimeters)	(degrees)	(degrees)
Mm	Lunar monthly	0.03629	1.01	96.27	100.63
MSf	Lunisolar synodic fortnightly	0.06773	1.36	181.63	189.76
2Q1	Second-order elliptical lunar	0.85695	2.35	36.54	139.37
Q1	Larger lunar elliptic	0.89324	6.52	152.81	260.00
O1	Principal lunar diurnal	0.92954	50.85	148.86	260.40
M1	Smaller lunar elliptic	0.96645	5.36	244.03	0.01
P1	Principal solar diurnal	0.99726	25.52	165.62	285.29
K1	Lunisolar diurnal	1.00274	84.78	162.67	287.36
J1	Small lunar elliptic	1.03903	3.31	146.79	271.47
OO1	Second-order lunar	1.07594	5.50	246.74	15.85
μ2	Variational	1.86455	4.78	330.64	194.38
N2	Larger lunar elliptic	1.89598	22.56	114.73	346.60
ν2	Larger lunar evectional	1.90084	5.30	105.08	333.18
M2	Principal lunar	1.93227	115.55	144.88	16.75
L2	Smaller lunar elliptic	1.96857	1.95	143.57	19.80
S2	Principal solar	2.00000	28.84	162.22	145.64
K2	Lunisolar semidiurnal	2.00548	8.02	171.59	52.24
MK3	Lunisolar terdiurnal	2.93501	2.40	154.20	146.40
M4	Quarter diurnal lunar	3.86455	2.71	144.33	248.08
M6	Sixth diurnal lunar	5.79682	2.05	22.74	358.36

Station: Center
Start time: February 16, 1994, 12:28 Pacific Standard Time
Record length: 47 days

Constituent					
Symbol	Origin and name	Frequency (per day)	Amplitude (centimeters)	Modified epoch (degrees)	Greenwich epoch (degrees)
Mm	Lunar monthly	0.03629	4.55	319.65	324.01
MSf	Lunisolar synodic fortnightly	0.06773	4.51	121.25	129.38
2Q1	Second-order elliptical lunar	0.85695	3.57	254.95	357.78
Q1	Larger lunar elliptic	0.89324	8.07	149.05	256.24
O1	Principal lunar diurnal	0.92954	49.43	140.65	252.19
NO1	Smaller lunar elliptic	0.96645	4.62	192.78	308.75
P1	Principal solar diurnal	0.99726	27.82	162.52	282.19
K1	Lunisolar diurnal	1.00274	92.42	159.57	284.26
J1	Small lunar elliptic	1.03903	6.13	151.63	276.31
OO1	Second-order lunar	1.07594	5.62	269.50	38.61
μ2	Variational	1.86455	5.20	1.96	225.70
N2	Larger lunar elliptic	1.89598	21.36	115.03	346.90
ν2	Larger lunar evectional	1.90084	5.02	105.38	333.48
M2	Principal lunar	1.93227	114.62	140.05	11.92
L2	Smaller lunar elliptic	1.96857	5.41	143.28	19.51
S2	Principal solar	2.00000	28.50	158.53	141.95
K2	Lunisolar semidiurnal	2.00548	7.92	167.90	48.55
MK3	Lunisolar terdiurnal	2.93501	1.76	134.51	126.71
M4	Quarter diurnal lunar	3.86455	2.85	135.79	239.54
M6	Sixth diurnal lunar	5.79682	2.22	9.72	345.34

Station: Center
Start time: July 28, 1994, 11:24 Pacific Standard Time
Record length: 32 days

Constituent					
Symbol	Origin and name	Frequency (per day)	Amplitude (centimeters)	Modified epoch (degrees)	Greenwich epoch (degrees)
Mm	Lunar monthly	0.03629	1.49	80.59	84.95
MSf	Lunisolar synodic fortnightly	0.06773	1.86	175.43	183.56
2Q1	Second-order elliptical lunar	0.85695	2.40	30.59	133.43
Q1	Larger lunar elliptic	0.89324	6.67	153.26	260.45
O1	Principal lunar diurnal	0.92954	50.88	148.95	260.49
M1	Smaller lunar elliptic	0.96645	5.64	242.84	358.81
P1	Principal solar diurnal	0.99726	25.43	165.84	285.51
K1	Lunisolar diurnal	1.00274	84.48	162.89	287.57
J1	Small lunar elliptic	1.03903	3.23	149.69	274.37
OO1	Second-order lunar	1.07594	5.47	246.29	15.40
μ2	Variational	1.86455	4.56	329.13	192.88
N2	Larger lunar elliptic	1.89598	22.81	115.93	347.81
ν2	Larger lunar evectional	1.90084	5.36	106.28	334.38
M2	Principal lunar	1.93227	115.21	145.17	17.05
L2	Smaller lunar elliptic	1.96857	2.50	144.35	20.58
S2	Principal solar	2.00000	28.49	162.95	146.37
K2	Lunisolar semidiurnal	2.00548	7.92	172.31	52.97
MK3	Lunisolar terdiurnal	2.93501	2.64	154.98	147.18
M4	Quarter diurnal lunar	3.86455	2.69	144.91	248.66
M6	Sixth diurnal lunar	5.79682	2.05	20.78	356.40

Station: West
Start time: February 16, 1994, 11:19 Pacific Standard Time
Record length: 47 days

Constituent		Frequency (per day)	Amplitude (centimeters)	Modified epoch (degrees)	Greenwich epoch (degrees)
Symbol	Origin and name				
Mm	Lunar monthly	0.03629	3.89	314.61	318.96
MSf	Lunisolar synodic fortnightly	0.06773	4.37	122.33	130.46
2Q1	Second-order elliptical lunar	0.85695	3.35	255.23	358.07
Q1	Larger lunar elliptic	0.89324	7.82	150.42	257.61
O1	Principal lunar diurnal	0.92954	48.16	140.71	252.25
M1	Smaller lunar elliptic	0.96645	4.43	193.45	309.43
P1	Principal solar diurnal	0.99726	27.12	162.73	282.40
K1	Lunisolar diurnal	1.00274	90.09	159.78	284.47
J1	Small lunar elliptic	1.03903	6.02	151.69	276.37
OO1	Second-order lunar	1.07594	5.42	272.15	41.27
μ2	Variational	1.86455	5.01	2.86	226.61
N2	Larger lunar elliptic	1.89598	20.89	115.59	347.46
ν2	Larger lunar evectional	1.90084	4.91	105.94	334.04
M2	Principal lunar	1.93227	112.05	140.61	12.48
L2	Smaller lunar elliptic	1.96857	5.36	142.85	19.07
S2	Principal solar	2.00000	27.95	158.97	142.39
K2	Lunisolar semidiurnal	2.00548	7.77	168.33	48.99
MK3	Lunisolar terdiurnal	2.93501	1.55	139.14	131.34
M4	Quarter diurnal lunar	3.86455	2.65	140.45	244.19
M6	Sixth diurnal lunar	5.79682	2.12	10.35	345.97

Station: West
Start time: July 28, 1994, 11:00 Pacific Standard Time
Record length: 32 days

Constituent		Frequency (per day)	Amplitude (centimeters)	Modified epoch (degrees)	Greenwich epoch (degrees)
Symbol	Origin and name				
Mm	Lunar monthly	0.03629	1.58	80.44	84.80
MSf	Lunisolar synodic fortnightly	0.06773	1.72	174.04	182.17
2Q1	Second-order elliptical lunar	0.85695	2.33	31.85	134.68
Q1	Larger lunar elliptic	0.89324	6.61	153.27	260.46
O1	Principal lunar diurnal	0.92954	50.62	149.13	260.67
M1	Smaller lunar elliptic	0.96645	5.57	242.69	358.66
P1	Principal solar diurnal	0.99726	25.36	165.91	285.58
K1	Lunisolar diurnal	1.00274	84.25	162.96	287.64
J1	Small lunar elliptic	1.03903	3.22	149.45	274.14
OO1	Second-order lunar	1.07594	5.48	245.37	14.48
μ2	Variational	1.86455	4.58	330.27	194.02
N2	Larger lunar elliptic	1.89598	22.83	115.94	347.81
ν2	Larger lunar evectional	1.90084	5.36	106.29	334.39
M2	Principal lunar	1.93227	114.93	145.33	17.20
L2	Smaller lunar elliptic	1.96857	2.40	145.02	21.25
S2	Principal solar	2.00000	28.50	163.04	146.46
K2	Lunisolar semidiurnal	2.00548	7.92	172.40	53.06
MK3	Lunisolar terdiurnal	2.93501	2.51	154.65	146.85
M4	Quarter diurnal lunar	3.86455	2.64	145.88	249.63
M6	Sixth diurnal lunar	5.79682	2.04	22.63	358.25