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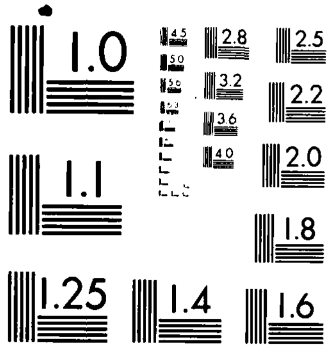
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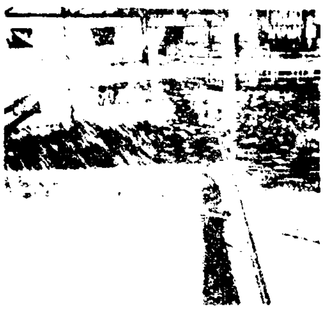

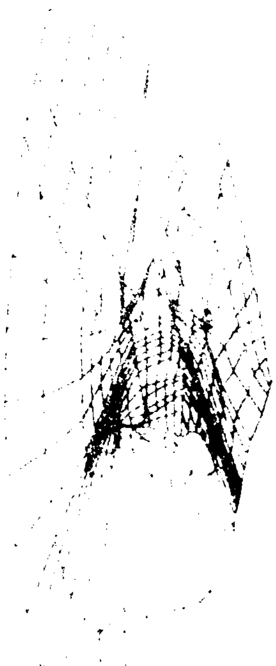

HYDRAULICS LABORATORY

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TECHNICAL REPORT HL-85-5

SPECTRAL ANALYSIS OF COLUMBIA RIVER ESTUARY CURRENTS

by

Barbara P. Donnell, William H. McAnally, Jr.

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
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A spectral analysis study was conducted to determine if wind-induced currents within the Columbia River estuary were sufficiently large to justify their inclusion in a numerical model of sediment transport within the estuary. Completion of the analysis showed that wind-induced current velocities were considerably less than 0.5 fps and consequently have little effect on instantaneous sediment transport.

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PREFACE

The analysis described in this report was conducted at the US Army Engineer Waterways Experiment Station (WES). The data described herein were collected during March and April 1978 by a joint effort of the US Army Engineer District, Portland (NPP), and WES. The US Coast Guard provided a vessel and crew for an installation of velocity meters. The work was funded by NPP as part of the ongoing WES model studies of the Columbia River.

Personnel of the Hydraulics Laboratory of WES performed this study during the period 1979 through February 1980 under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory; F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory; R. A. Sager, Chief of the Estuaries Division; and G. M. Fisackerly, Chief of the Harbor Entrance Branch. Publication of this report, scheduled for 1981, was deferred due to lack of funds. Mr. D. A. Crouse managed the data collection program. Dr. R. H. Multer provided coding for the digital filter used. The computer code used for spectral analyses is based on a code written by Mr. N. W. Scheffner. Additional programming, data analysis, and preparation of this report were performed by Ms. B. P. Donnell and Mr. W. H. McAnally, Jr.

COL Nelson P. Conover, CE, COL Tilford C. Creel, CE, and COL Robert C. Lee, CE, were Commanders and Directors of WES during the conduct of the study and the preparation of this report. COL Allen F. Grum, USA, was Director of WES during the publication of this report. Mr. Fred R. Brown and Dr. Robert W. Whalin were Technical Directors.

CONTENTS

CONVERSION FACTORS, NON-S1 TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
feet	0.3048	metres

SPECTRAL ANALYSIS OF COLUMBIA RIVER ESTUARY CURRENTS

PART I: INTRODUCTION

Objectives

1. The objective of this study was to analyze the prototype current velocity data from the Columbia River estuary and their relationships to local winds. This segment of the data collection effort and analysis was to determine if wind-induced currents within the estuary were sufficiently large to justify their inclusion in the Corps' efforts to model sediment transport in the estuary.

Background

2. In 1976, the U. S. Army Engineer District, Portland, requested that the U. S. Army Engineer Waterways Experiment Station (WES) conduct a hybrid model study--one using both physical and numerical models in an integrated manner--to address a number of sedimentation problems in the Columbia River estuary. The adopted hybrid modeling technique employed a large existing physical hydraulic model of the estuary, a numerical model for wave propagation, a numerical model for sediment transport, and several analytical techniques. When the physical processes of the estuary were reviewed, it could not be established if wind-induced currents played a significant role in its sedimentation. It was decided to proceed with the modeling efforts without attempting to incorporate wind-induced transport, but to measure and analyze winds and currents to help define the relative importance of winds. Although the original list of study topics included some items other than navigation channel shoaling, the final list was almost exclusively channel-related, so the goal of wind-current analysis became limited to defining the importance of wind-induced currents in navigation channel shoaling. This report presents results of the analyses.

PART II: DATA COLLECTION PROGRAM

3. Tidal elevations and current velocities were measured continuously from 9 March 1978 through 6 April 1978. Tidal elevations were measured at 13 stations as shown in Figure 1. Current speed and direction were measured at 12 locations, as shown in Figure 1, at 1, 2, or 3 points in the water column. Table 1 lists the measurement points, their locations, depths, and starting times. A plot of a representative tide station, Point Adams, gage 3, beginning at the start of the survey is shown in Figure 2. A complete presentation of tidal data is given by McAnally and Donnell (in preparation). The mean freshwater discharge for the period of the survey ranged from 126 to 271 thousand cubic feet per second.*

4. Currents were measured with Environmental Devices Corporation (ENDECO) model 105 recording current meters. The neutrally buoyant meters were tethered to a fixed mooring line by a 5-ft-long rope and swivel assembly. Current speed and direction were recorded photographically at 30-min intervals by an internal mechanism. Current speed is sensed by the rotation of a horizontal axis propeller. A complete description of the data collection program and presentation of the data are given by McAnally and Donnell (in preparation).

5. Wind data were obtained at 3-hr intervals for Astoria Airport. Wind speed is given in knots and direction is in tens of degrees clockwise from true north. A complete presentation of the data is given by the National Oceanic and Atmospheric Administration (NOAA 1978).

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

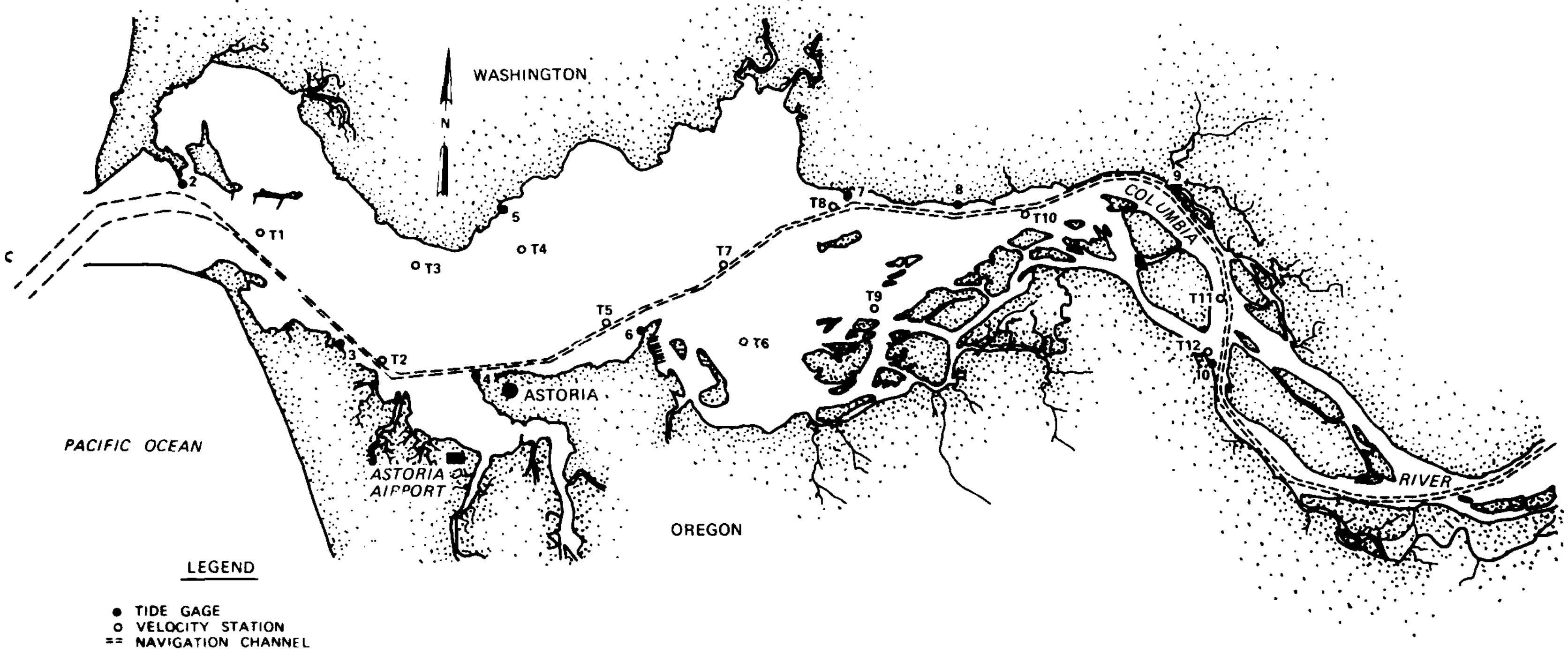

Figure 1. Location of tide and velocity gages

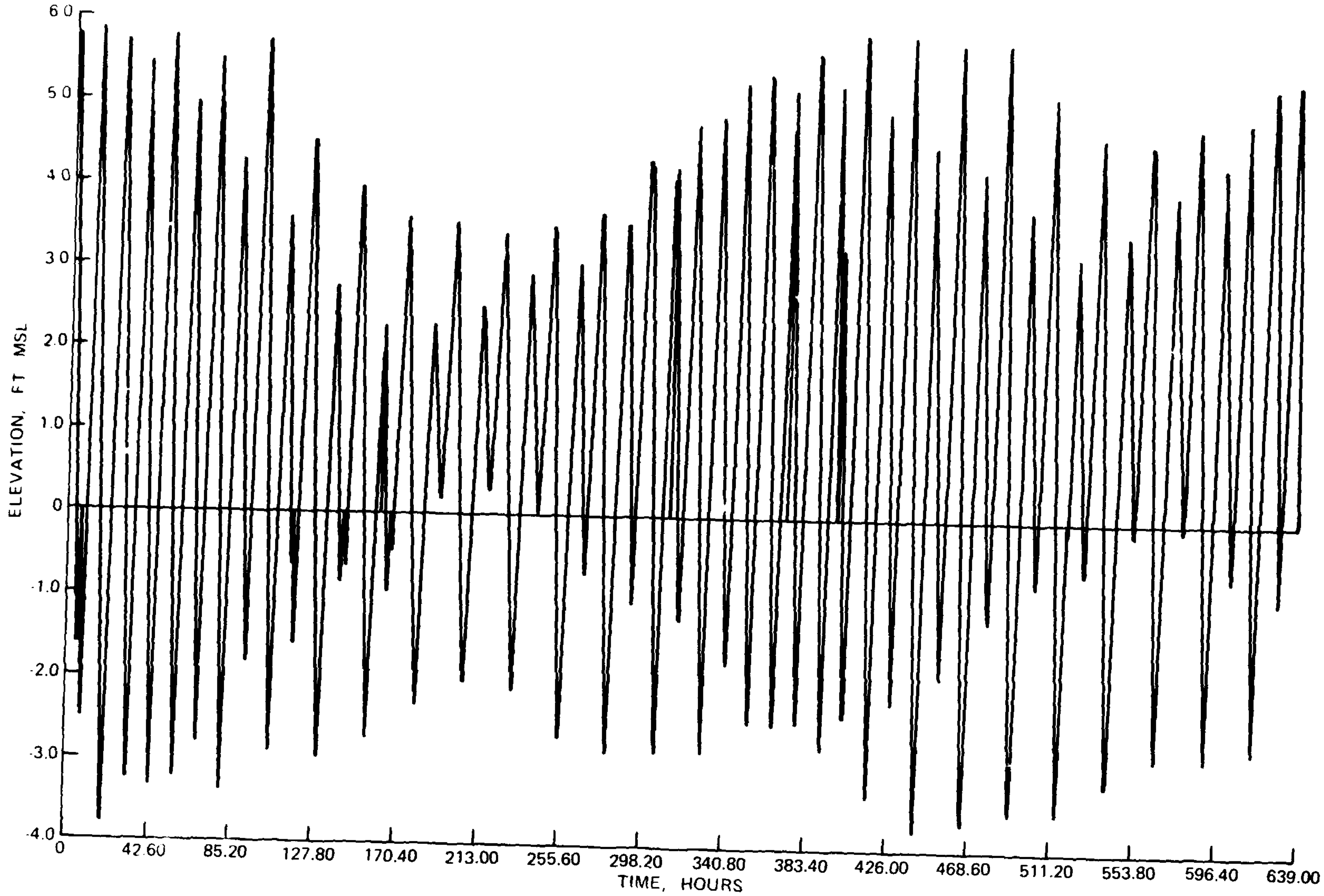

Figure 2. Tidal elevations at Point Adams (gage 3), March-April 1978

PART III: DATA ANALYSIS TECHNIQUES

6. This portion of the report describes cross-spectral analysis and filtering techniques that have been applied to the data as aids to interpretation. Spectral analysis is a complex mathematical technique, rooted in Fourier analysis, that is used to analyze time series data. The following paragraphs briefly describe the analysis technques and their interpretation. More detailed treatments can be found in Blackman and Tukey (1958), Jenkins and Watts (1969), Bath (1974), and Newland (1975).

7. This analysis treats time series data, a sequence of data points over a period of time, as a general function that can be described both in the time domain and the frequency domain. This dual representation is illustrated by the simple time domain function

$$g(t) = C_1 \sin(\sigma_1 t)$$

which can be expressed in the frequency domain as

$$G(\sigma) = C_1 \quad \text{for} \quad \sigma = \sigma_1$$

$$= 0 \quad \text{for} \quad \sigma \neq \sigma_1$$

This duality is used extensively in the following paragraphs.

Fourier Analysis

8. Any function $f(t)$ which satisfies the following conditions, can be represented by a Fourier series.

a. The function is periodic with period T_o such that the following holds for all time.

$$f(t) = f(t + T_o)$$

Since it is physically impossible to acquire a signal which begins at minus infinity and ends at plus infinity, it will suffice to have periodic data during an observable interval by using the finite Fourier series.

b. The function has a finite number of discontinuities in any period.

c. The function contains a finite number of minima and maxima during any period.

d. The function must be absolutely integrable in any period. Otherwise stated, the absolute value of the area under the curve for any period must be less than infinity.

The last three conditions are called Dirichlet conditions (Smith and Thornhill 1979). If $f(t)$ meets these conditions then it can be represented by a continuous Fourier series of the form.

$$\hat{f}(t) = \frac{a_o}{2} + \sum_{n=1}^{\infty} a_n \cos\left(n\pi \frac{t}{T_o}\right) + b_n \sin\left(n\pi \frac{t}{T_o}\right) \tag{1}$$

where

$$a_n = \frac{1}{T_o} \int_{-T_o}^{T_o} f(t) \cos\left(n\pi \frac{t}{T_o}\right) dt \qquad n = 0, 1, 2, \ldots$$

$$b_n = \frac{1}{T_o} \int_{-T_o}^{T_o} f(t) \sin\left(n\pi \frac{t}{T_o}\right) dt \qquad n = 1, 2, 3, \ldots$$

where

T_o = period

$\hat{f}(t)$ = approximation of $f(t)$

t = time

9. The complex form of the continuous Fourier series (Hamming 1973) is given by

$$\hat{f}(t) = \sum_{k=-\infty}^{\infty} c_k \exp\left[\left(2\pi \frac{i}{T_o}\right) kt\right]$$

where

$$c_k = \frac{1}{T_o} \int_0^{T_o} f(t) \exp\left[\left(-2\pi \frac{i}{T_o}\right) kt\right] dt$$

$$i = \sqrt{-1}$$

$$k = \text{integer}$$

which reduces to

$$c_k = \begin{cases} \dfrac{a_k - ib_k}{2} & k > 0 \qquad (3a) \\[2ex] \dfrac{a_k + ib_k}{2} & k < 0 \qquad (3b) \\[2ex] \dfrac{a_o}{2} & k = 0 \qquad (3c) \end{cases}$$

Equation 3a for c_k is also known as the complex amplitude of the k^{th} component and is sometimes denoted by $F(k)$. Equation 3b, the complex conjugate, is denoted by $\overline{F}(k)$.

10. The finite form of the Fourier series (Hamming 1973) is given by

$$\hat{f}(t) = \frac{A_o}{2} + \sum_{k=1}^{N-1} \left[A_k \cos\left(\frac{2\pi kt}{T_o}\right) + B_k \sin\left(\frac{2\pi kt}{T_o}\right)\right] + \frac{A_N}{2} \cos\left(\frac{2\pi Nt}{T_o}\right) \qquad (4)$$

where

$$A_k = \frac{1}{N} \sum_{p=0}^{2N-1} f(t_p) \cos \frac{2\pi kt_p}{T_o} \qquad k = 0, 1, 2, \ldots, N$$

$$B_k = \frac{1}{N} \sum_{p=0}^{2N-1} f(t_p) \sin \frac{2\pi k t_p}{T_o} \qquad k = 0, 1, \ldots, N-1$$

$$t_p = \frac{pT_o}{2N} \qquad p = 0, 1, 2, \ldots, 2N-1$$

2N = number of sample points

11. The continuous Fourier series is designated by lower case coefficients and the finite form by upper case coefficients. The finite Fourier series coefficients can be written in terms of the continuous Fourier series coefficients (Hamming 1973), as given below

$$A_o = a_o + 2 \sum_{m=1}^{\infty} a_{2Nm}$$

$$A_k = a_k + \sum_{m=1}^{\infty} (a_{2Nm-k} + a_{2Nm+k}) \qquad (5)$$

$$B_k = b_k + \sum_{m=1}^{\infty} (-b_{2Nm-k} + b_{2Nm+k})$$

where 2N equals the number of sample points. This comparison reveals that various frequencies present in the original signal are added together due to the sampling. This phenomenon, known as aliasing, will be discussed in paragraphs 34 and 35.

Spectral Analysis

12. The time and frequency domains duality is achieved in Fourier analysis by use of the Fourier transform pair. For the general, aperiodic function $f(t)$, the general transform pair is

$$f(t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} F(\sigma) \exp(i\sigma t)\, d\sigma \qquad (6a)$$

$$F(\sigma) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(t) \exp(-i\sigma t)\, dt \qquad (6b)$$

where σ equals frequency.

13. $F(\sigma)$ and $f(t)$ may be thought of as the frequency domain and the time domain representations of a general function F. They represent the same function expressed in different domains, and Equations 6a and 6b permit transition from one domain to the other.

Power density spectra

14. The frequency domain function $F(\sigma)$ in Equation 6 is the amplitude spectrum of $f(t)$. For an $f(t)$ composed of purely periodic functions, $F(\sigma)$ will consist of a series of lines representing the amplitude of the various frequency components as shown in Figure 3.

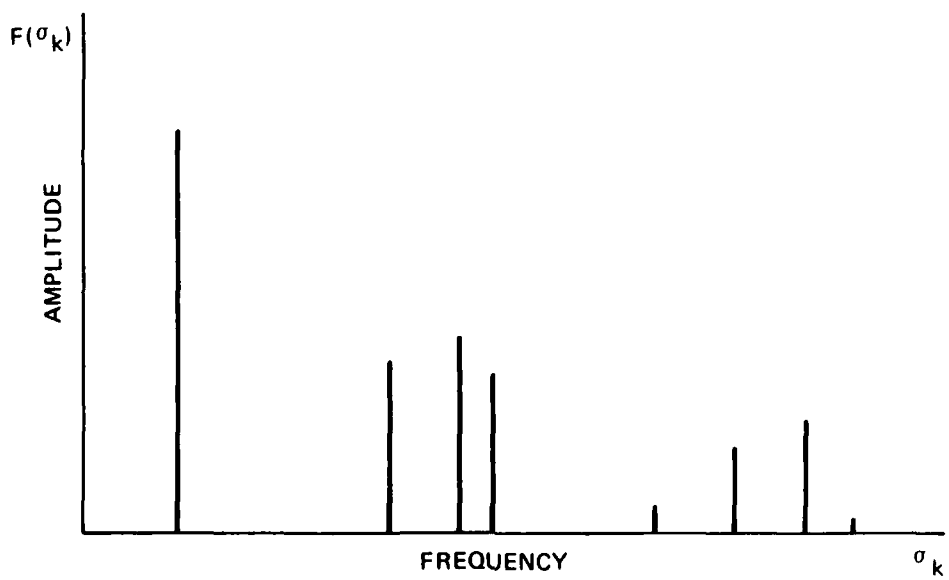

Figure 3. Amplitude spectrum of a sum of purely periodic functions

15. The phase spectrum of a harmonic $f(t)$ is given by the following equation and represents the phase shift of each of the periodic components from the beginning of the record

$$\varepsilon(\sigma_k) = \tan^{-1}\left(\frac{b_k}{a_k}\right) \tag{7}$$

and its plot is similar to that for $F(\sigma)$.

16. The auto-spectral density function (ASD), often called the "power density," expressed as

$$|F(\sigma_k)|^2 = \left(a_k^2 + b_k^2\right) \tag{8}$$

is a useful measure of the distribution of energy over the various component frequencies. Phase information is not retained. The term power spectral density is a holdover from communication engineering, where these techniques were developed. In most realistic applications the spectrum is described by a curve of power density or energy, leading to equivalence of the terms power spectral density and energy spectra. The computations described herein yield a power spectral density function, which when multiplied by appropriate physical constants would yield the power density. Since the absolute value of auto (power) density is not a desired output, we will use the auto (power) density function.

Auto-covariance

17. The auto-covariance represents the lagged product of a time series $X(t)$ (with the mean removed) multiplied by itself. It is defined as

$$\phi_{XX}(\tau) = \int_{-\infty}^{\infty} \left[X(t) - \overline{X}\right]\left[X(t + \tau) - \overline{X}\right] dt \tag{9}$$

where

τ = time lag, or the time interval which the series is shifted

$\overline{X}$ = mean of the $X(t)$ series

18. The auto-covariance is used to detect periodicities in a series, because its value will be large if the set of observations is multiplied by the same observations one period apart.

Cross-covariance

19. The cross-covariance is the lagged product of a time series $X(t)$ multiplied by another series $Y(t)$ as the Y series is shifted in time (lagged). The cross-variance is defined as

$$\phi_{XY}(\tau) = \int_{-\infty}^{\infty} \left[X(t) - \overline{X}\right]\left[Y(t + \tau) - \overline{Y}\right] dt \tag{10}$$

where $\overline{Y}$ equals the mean of the $Y(t)$ series.

20. The cross-covariance will exhibit maxima at periods that are common to both series.

Auto-spectral density

21. The auto-spectral density (ASD) of a function is the frequency representation (Fourier transform) of the auto-covariance, defined as

$$\Phi_{XX}(\sigma) = \int_{-\infty}^{\infty} \phi_{XX}(\tau) \exp(-i\sigma\tau)\, d\tau \tag{11a}$$

22. The auto spectrum does not retain phase information. If the frequencies in the original record are multiples of each other, the function will have a maximum at each time lag that corresponds to one or more periods of the highest harmonic.

23. The auto spectrum, a real function, can also be expressed as

$$\Phi_{XX}(\sigma) = \overline{F}_X(\sigma)\, F_X(\sigma) = \left|F_X(\sigma)\right|^2 \tag{11b}$$

where $\overline{F}_X(\sigma)$ equals the complex amplitude spectrum for the X series.

Cross-spectral density

24. The cross-spectral density (CSD) is the frequency domain

representation (Fourier transform) of the cross-covariance and is defined as

$$\Phi_{XY}(\sigma) = \int_{-\infty}^{\infty} \phi_{XY}(\tau) \exp(-i\sigma\tau) \, d\tau \qquad (12)$$

Another representation of the CSD is

$$\Phi_{XY}(\sigma) = \overline{F}_X(\sigma) F_Y(\sigma) \qquad (12b)$$

25. The cross spectrum will exhibit maxima at frequencies common to both series. It is an expression of energy in the mutual frequency components of X and Y . The cross spectrum is a complex function with a real part, the co-spectrum, and an imaginary part, the quad-spectrum. The co-spectrum represents the in-phase average product of X and Y . It will dominate (absolutely) the cross spectrum of two functions that are close to the same phase in time. The quad-spectrum represents the out-of-phase average product of X and Y .

Phase spectra

26. The phase spectrum, given by

$$\varepsilon_{XY}(\sigma) = \tan^{-1}\left[\frac{\text{quad-spectrum }(\sigma)}{\text{co-spectrum }(\sigma)}\right] \qquad (13)$$

is the lag between components of the same frequency in X and Y . If X and Y have no frequency in common, $\varepsilon_{XY}(\sigma)$ will be constant between $\sigma = -\pi/2$ and $\pi/2$. The response function amplitude (RFA) is given by

$$A_{XY}(\sigma) = \frac{|\Phi_{XY}(\sigma)|}{\Phi_{XX}(\sigma)} \qquad (14)$$

For a linear system in which an input X(t) produces an output Y(t) , knowing X(t) , the RFA, and the phase spectrum permits computation of

$Y(t)$. The $Y(t)$ spectrum is the product of the $X(t)$ and the RFA spectra. The phase spectrum represents the phase shift of each frequency component with respect to the input.

Coherency

27. The coherency function of two functions is defined by the coherence squared,

$$\gamma_{XY}^2(\sigma) = \frac{\Phi_{XY}(\sigma)^2}{\Phi_{XX}(\sigma)\Phi_{YY}(\sigma)} \tag{15}$$

which has values between 0 and 1 . If X and Y are linearly correlated $\gamma_{XY}^2 \to 1$. If they are completely uncorrelated $\gamma_{XY}^2 = 0$. The presence of a peak at the same frequency in the auto-spectral density curves of both X and Y is insufficient for correlation. Perfect linear correlation, a coherence function equal to 1, is achieved when the X and Y series are approximated by the same Fourier series (Equation 1) except for a constant multiplier; thus, the magnitude of the cosine terms with respect to the sine terms will be equal in the two series.

28. In summary, spectral analysis transforms time series data into the frequency domain and computes the distribution of energy over frequency of individual data records (auto-spectral density) and of the product of two data records (cross-spectral density). It quantifies amplitude and phase relationships between the two data records (response function amplitude and phase spectrum, respectively) and quantifies the degree of linear correlation between the records (coherency squared).

Practical Aspects of Spectral Analysis

29. The preceding paragraphs, concerned with the theoretical relationships of functions, do not address practical aspects of data analysis. An actual time series data record consisting of a finite number of observations at discrete intervals between data points introduces

several problems into the analysis. This section addresses these problems and how they are handled.

30. Time series consisting purely of constituent periodic functions can be represented as line spectra in which all of the energy is located at precise frequencies and the power spectrum can be represented as a series of lines on a $\left[F_X(\sigma)\right]^2$ versus σ graph (as in Figure 3). Aperiodic and periodic functions masked by noise or inadequate record lengths appear as continuous spectra in which the spectrum is blurred and occurs as a curve of power density on the $\left[F_X(\sigma)\right]^2$ versus σ graph.

Noise

31. The simplest definition of noise is that given by Godin (1972) as any variation in $f(t)$ that is not desired. Noise includes measurement error and actual physical phenomena that confuse the data. Application of Godin's definition means that the intent of the analysis determines what is noise and what is not. If the objective is to examine nontidal phenomena, then the tidal oscillations become noise. Since noise obscures those data record features of interest, it is desirable to remove it by filtering or to minimize its impact.

32. Noise occurs in the data and in the spectrum because of finite record length, the lag window's characteristics (paragraph 38), and others. This noise sometimes leads to nonsensical values of the spectral estimates, such as a negative auto-spectral density, coherency, or RFA. Although theoretical relationships dictate that ASD and RFA always be positive, and that coherency squared be between 0 and 1, actual data analyses often result in some values falling outside these bounds.

33. A source of noise in this report's data is the 12-day (or longer) period events that appear in the 0.0 to 0.003 frequency range. It is considered to be noise in the sense that storm events that are likely to affect currents within the estuary will have a duration of less than 12 days; thus, those processes of 12 day-periods or greater are of secondary interest.

Sampling interval

34. The time between successive data points is the sampling interval Δt which limits the period of a function $f(t)$ that can be

accurately represented by the sampled data points. The minimum period that can be distinguished is $2\Delta t$ (maximum frequency $1/(2\Delta t)$. Smaller periods (higher frequencies) are aliased as longer periods because the sampling interval makes them appear longer.

35. Aliasing is a part of our everyday world. A common example of aliasing occurs frequently in moving pictures when fast-spinning wheels are photographed by cameras whose shutter speed makes the time interval of sampling (framing) too large and gives the illusion of the wheels gradually slowing down, stopping, and then turning backward. The maximum frequency that can be accurately detected by sampling interval Δt is called the Nyquist frequency or folding frequency

$$ff = \frac{1}{2\Delta t} \tag{16}$$

It is called the folding frequency because frequencies higher than ff are folded onto lower frequencies in the spectrum. Thus, energy at odd integer multiples of ff will be aliased as ff and energy at even multiples will be aliased at zero frequency as shown in Figure 4. Equation 15 says that we must have at least two samples in the shortest period present in order to avoid aliasing.

Record length

36. For a purely periodic function a finite record length equal to a multiple of the fundamental periods can be used to completely describe the function. Aperiodic functions or basically periodic functions with nondeterministic information cannot be completely described by a finite record length since one segment of record will have somewhat different spectra than another segment. Thus, spectra of functions of the latter type (most practical data) are merely estimates of the actual spectra.

37. Since periodical record length is finite, the maximum lag T_m is also finite and limited by

$$T_m < T_n$$

where T_n is the record length. In practical terms T_m must be much smaller than T_n with the classical limitation being

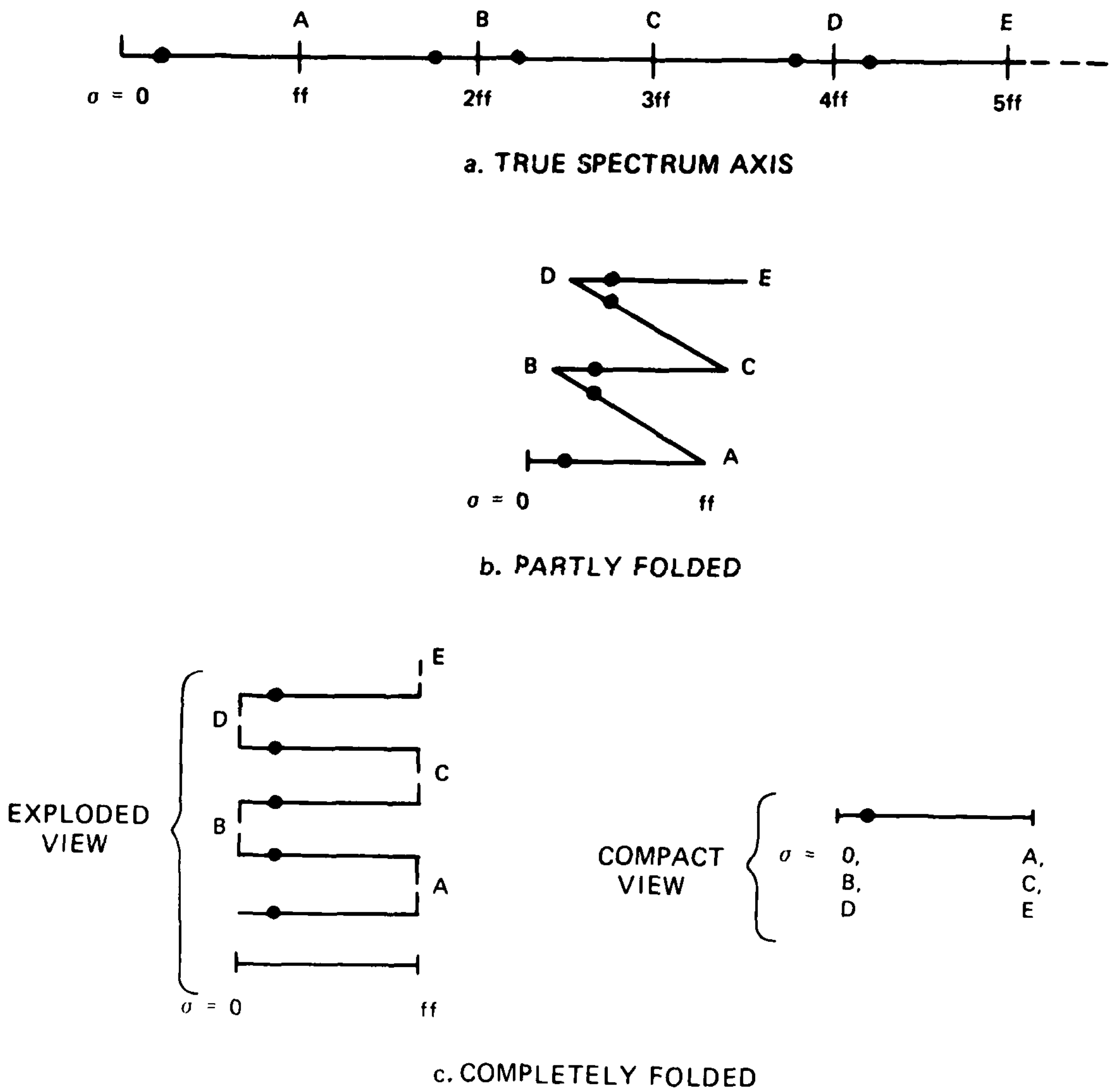

Figure 4. Spectrum folding due to aliasing (after Blackman and Tukey 1958)

$$T_m \leq \frac{T_n}{10} \tag{17}$$

although this limit is often exceeded. Finite record lengths and small maximum lags smooth (smear) the spectral lines.

38. Finite record length means that the limits on the integral in Equations 9 and 10 are reduced from $(-\infty$ to $\infty)$ to $(-T_{n/2}$ to $T_{n/2} - T_m)$. This is equivalent to multiplying the equation by $D(\tau)$ where

$$W_R(\tau) = \begin{pmatrix} 1, & |\tau| \geq & T_m \\ & & \\ 0, & |\tau| < & T_m \end{pmatrix} \tag{18}$$

which is a boxcar function as shown in Figure 5 and is called the lag window since it is the window through which we view the covariance, and thus it limits our knowledge of the covariance. When the cross-covariance, $\phi'_{XY}(\tau)$, (the *prime indicat*ing that it is an apparent or approximate $\phi_{XY}(\tau)$) is transformed into the frequency domain $(\Phi'_{XY}(\sigma))$, $w(\tau)$ is transformed into $W_R(\sigma)$, the spectral window, which relates the actual cross-spectral density to its estimated value by

$$\Phi'_{XY}(\sigma) = W_R(\sigma)\Phi_{XY}(\sigma) \tag{19}$$

$W_R(\sigma)$ is the frequency domain window through which we view the spectrum and it smears the spectrum, spreading the energy at each frequency to adjacent frequencies (leakage), adding negative energy to some frequencies, and adding some high frequency noise to the spectrum. Figure 5 illustrates the boxcar window as it appears in both the time and frequency domains. The frequency plot clearly shows the leakage-causing lobes to either side of the primary peak.

39. Since we automatically have a lag window by taking a finite record length, it would be to our advantage to design a window that would minimize the undesirable effects associated with the window. If the boxcar lag window is used, the spectrum is called the raw spectrum.

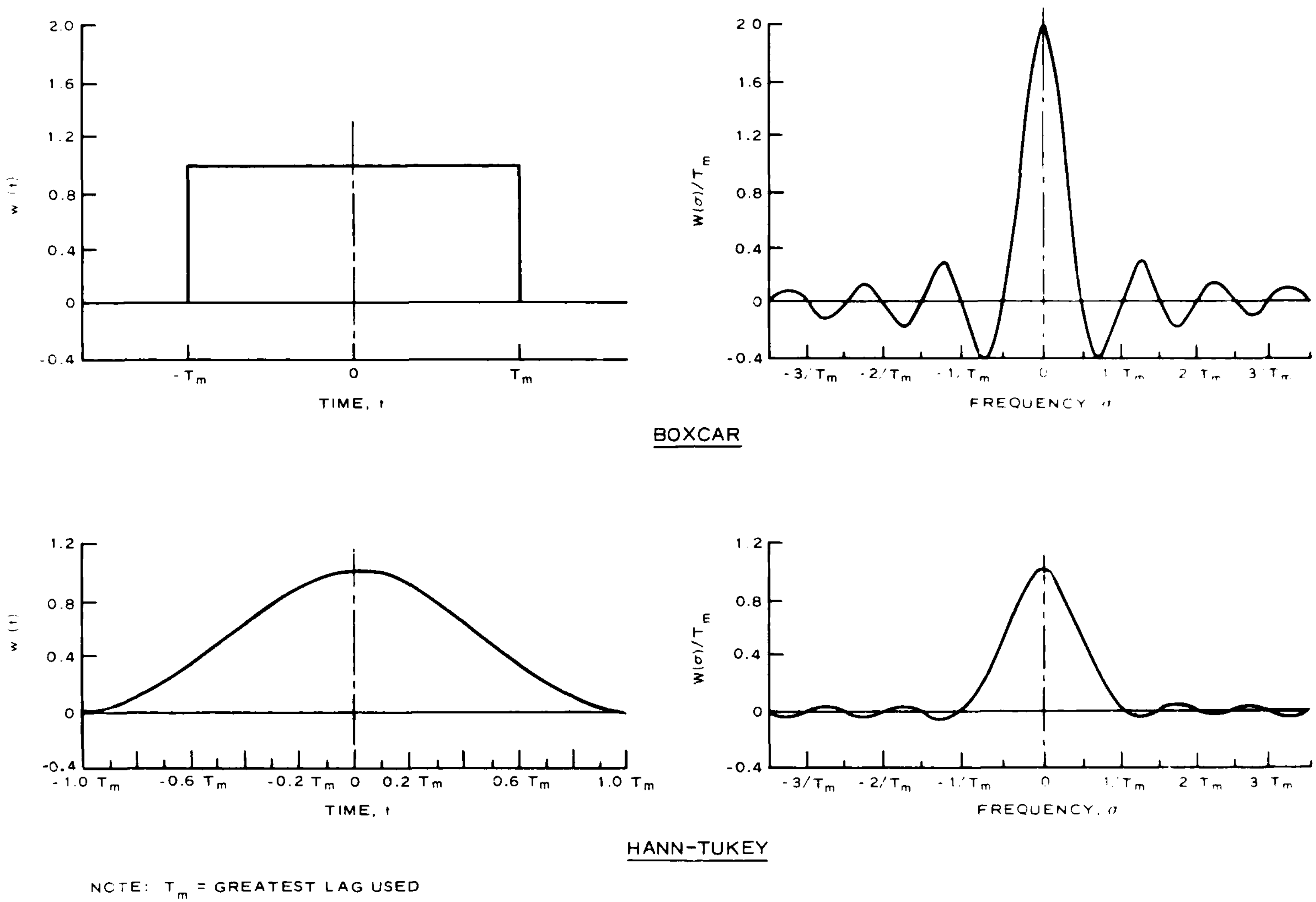

Figure 5. Lag windows

There are a number of other windows that accomplish various effects. The window chosen here is the Tukey-Hann window shown in Figure 5, which is designed to minimize leakage from strong peaks of power density. Application of the Tukey-Hann window results in a spectrum that is smoothed. The lag window through which we view the cross-covariance when applying the Tukey-Hann equation is:

$$w_S(\tau) = \begin{Bmatrix} 0 & \tau < -T_m \\ \frac{1}{2}\left[1 + \cos\left(\frac{\pi\tau}{T_m}\right)\right] & -T_m \le \tau \le T_m \\ 0 & \tau > T_m \end{Bmatrix} \tag{20}$$

Similarly, when the cross-covariance is transformed into the frequency domain, $w_S(\tau)$ is transformed into $W_S(\tau)$, the Tukey-Hann (smooth) spectral window. The lower half of Figure 5 illustrates the Tukey-Hann window in both the time and frequency domain. Note the decrease in amplitude of the peak and side lobes of the Tukey-Hann window as compared with the boxcar window. A smoothed spectrum provides benefits by minimizing spurious oscillations, but carries the disadvantage that smearing of energy at adjacent frequencies increases the effective bandwidth, thus decreasing ability to resolve energy peaks that are not widely separated in frequency.

40. One further effect of record length deserves mention. Some aperiodic functions, (for example, a step function) when spectrally analyzed, will contribute to the power density at a frequency corresponding to $1/T_n$ Changing the record length will cause the power density associated with the function to move to a new location corresponding to the new record length. This phenomenon does not eliminate the usefulness of the spectral analysis results, but may confuse interpretation because the frequency is not a property of the function.

Resolution versus stability

41. Resolution is a measure of how well various components are defined or are concentrated at the correct frequency. Energy density estimates are obtained at $\Delta\sigma = 1/(2T_m)$ and adjacent estimates are

overlapped considerably for the useful windows, but estimates $2\Delta\sigma$ apart do not have serious overlap so we can define the resolution to be

$$R = \frac{1}{T_m} \tag{21}$$

Thus a larger lag (large T_m) leads to better resolution.

42. Stability is a measure of the confidence with which we can view the estimates of energy density. It is possible to have high resolution but poor estimates because of low stability. Physical expressions of stability are less obvious than for resolution, but it can be said that a longer useful record length $(T_n - T_m)$ results in greater stability. Thus, it conflicts with the requirement for resolution. The usual criterion for stability is given by Equation 17.

43. Since the maximum lag has conflicting requirements on its length due to resolution and stability, choosing the best T_m can often be a problem. This is partly overcome by window closing in which successive spectral computations are made for larger and larger lag periods until the best maximum lag is found.

44. Stability may be more quantitatively expressed in terms of confidence intervals and variance. Confidence limits define the probability that the true value of the estimated variable is within a given range of values. Thus, they provide a quantitative measure of the reliability of the estimation technique. Computation of confidence limits requires use of the variance function.

45. The variance of the smoothed phase spectrum estimate can be expressed as a function of the degrees of freedom (ν)

$$\nu = \frac{2T_n B}{T_m} \tag{22}$$

where

B = standardized bandwidth

T_n = record length

T_m = maximum lag time

46. The Tukey-Hann window, alternately called either Tukey or

Hann, has a standardized bandwidth of 1.333. The boxcar window's standardized bandwidth is 0.5.

47. The auto-spectrum estimates have a χ^2 (chi-square) distribution with ν degrees of freedom. There is a $(1 - \alpha)$ probability that the true value of the auto-spectral density lies between

$$\text{upper limit} = \frac{\nu \, \overline{\Phi}_{XX}(\sigma)}{\chi^2_{\nu}\left(1 - \frac{\alpha}{2}\right)} \tag{23a}$$

$$\text{lower limit} = \frac{\nu \, \overline{\Phi}_{XX}(\sigma)}{\chi^2_{\nu}\left(\frac{\alpha}{2}\right)} \tag{23b}$$

where

ν = degree of freedom

α = probability that the true value lies beyond the specified limits

$\overline{\Phi}_{XX}(\sigma)$ = smooth ASD (i.e., ASD using the Tukey-Hann spectral lag window)

48. The amplitude and phase of the respone function are distributed as F (Fisher distribution) with 2 and $(\nu - 2)$ degrees of freedom. The confidence interval limits of the amplitude are

$$\text{upper limit} = \overline{A}_{XY}(\sigma) \times \left\{1 + \left[\frac{2}{\nu - 2} F_{2,\nu-2}(1 - \alpha)\left(\frac{1 - \overline{\gamma}_{XY}(\sigma)}{\overline{\gamma}_{XY}(\sigma)}\right)\right]^{1/2}\right\} \tag{24a}$$

$$\text{lower limit} = \overline{A}_{XY}(\sigma) \times \left\{1 - \left[\frac{2}{\nu - 2} F_{2,\nu-2}(1 - \alpha)\left(\frac{1 - \overline{\gamma}_{XY}(\sigma)}{\overline{\gamma}_{XY}(\sigma)}\right)\right]^{1/2}\right\} \tag{24b}$$

where

$F_{2,\nu-2}$ = Fisher distribution value

$\overline{A}_{XY}$ = smooth response function amplitude

$\overline{\gamma}_{XY}(\sigma)$ = smooth coherency squared

The limits of the confidence interval on the true phase are given by Liu (1974) as

upper limit = $\overline{\varepsilon}(\sigma)$

$$+ \text{arc sin}\left\{\left[\frac{2}{\nu - 2} F_{2,\nu-2}(1 - \alpha)\right]\left[\frac{1 - \overline{\gamma}_{XY}(\sigma)}{\overline{\gamma}_{XY}(\sigma)}\right]\right\}^{1/2} \tag{25a}$$

lower limit = $\overline{\varepsilon}(\sigma)$

$$- \text{arc sin}\left\{\left[\frac{2}{\nu - 2} F_{2,\nu-2}(1 - \alpha)\right]\left[\frac{1 - \overline{\gamma}_{XY}(\sigma)}{\overline{\gamma}_{XY}(\sigma)}\right]\right\}^{1/2} \tag{25b}$$

where

$\overline{\varepsilon}(\sigma)$ = smooth phase in degrees

$\overline{\gamma}_{XY}(\sigma)$ = smooth coherency squared

The expressions for upper and lower confidence limits illustrate that longer record lengths and shorter maximum lag lengths lead to a desirable narrowing of confidence limits about the estimated value of the parameter. They also show the trade-off between resolution and stability in choosing a lag window.

49. The relationship between resolution and stability is nicely demonstrated by a paradox of choosing a lag window. A boxcar window, with a standardized bandwidth of 0.5, permits better resolution than the Tukey-Hann window which has a standardized bandwidth of 1.33. The Tukey-Hann window's larger bandwidth means higher degrees of freedom

(Equation 22) and thus narrower confidence limits than the boxcar window with the same T_n and T_m. Narrower confidence limits indicate more reliable answers, which is so, but the estimates obtained by the Tukey-Hann window are more reliable estimates for the average over a wider frequency band, which means that the estimates may be worse, not better. It is therefore advisable to examine both raw and smoothed spectra to see if improved reliability obscures important features of the spectrum.

Low Pass Filter

50. A 30-point nonrecursive digital low pass filter was used to remove shorter period oscillations from the long-term current and wind data. The filter is designed such that oscillations of periods longer than 36 hr are passed while those shorter than 36 hr are removed from the record. A cutoff period of 36 hr was selected so as to remove tide effects from the record.

51. An ideal low pass filter fitting the above description would be a square wave in the frequency domain, with a value of 1 for frequencies less than 1/36 cph and zero for frequencies greater than 1/36 cph. The filter used here approximates a square wave by a Fourier series. The filter was developed by use of Fourier series coefficients based on the interval of $0 - \pi$ and adjusted by the Lanczos correction factor. The coefficients were derived from the following relations:

$$\beta_o = \frac{1}{\pi}\int_o^{\pi} f(\tau)d\tau$$

$$\beta_n = \frac{2}{\pi}\int_o^{\pi} f(\tau)\cos(n\tau)d\tau \tag{26}$$

where

$$f(\tau) = 1.0 \quad \text{if} \quad 0 \le \tau \le \pi/6$$
$$= 0.0 \quad \text{if} \quad \pi/6 < \tau \le \pi$$

52. The Lanczos correction factor, α_n, is of the form:

$$\alpha_n = \frac{\sin\left(\frac{n\pi}{N}\right)}{\left(\frac{n\pi}{N}\right)} \tag{27}$$

where

$n = 1,2,3,\ldots N$

N = half the number of data points used to apply the filter to a single data value

The final form of the filter, as applied to some data set at time t is:

$$P_F(t) = \beta_o P(t) + \frac{1}{2}\sum_{n=1}^{30} \beta_n \alpha_n \left[P_{(t-n\Delta t)} + P_{(t+n\Delta t)}\right] \tag{28}$$

where

P = point values of the original data

P_F = filtered point values

Figure 6 shows the frequency domain response curve for the 30 point filter. As shown by Equation 28, obtaining a filtered data value in the time domain consists of summing weighted values of the raw data value, the 30 preceding values, and the 30 succeeding values. This results in reduction of the data record length by 60 points, 30 on each end. Since the filter is symmetrical about the data point, it does not cause any phase shift in the filtered data.

53. The filter is applied to raw data in the time domain by Equation 28. Its application is equivalent to multiplying the filter's frequency domain representation by the data set's frequency domain representation.

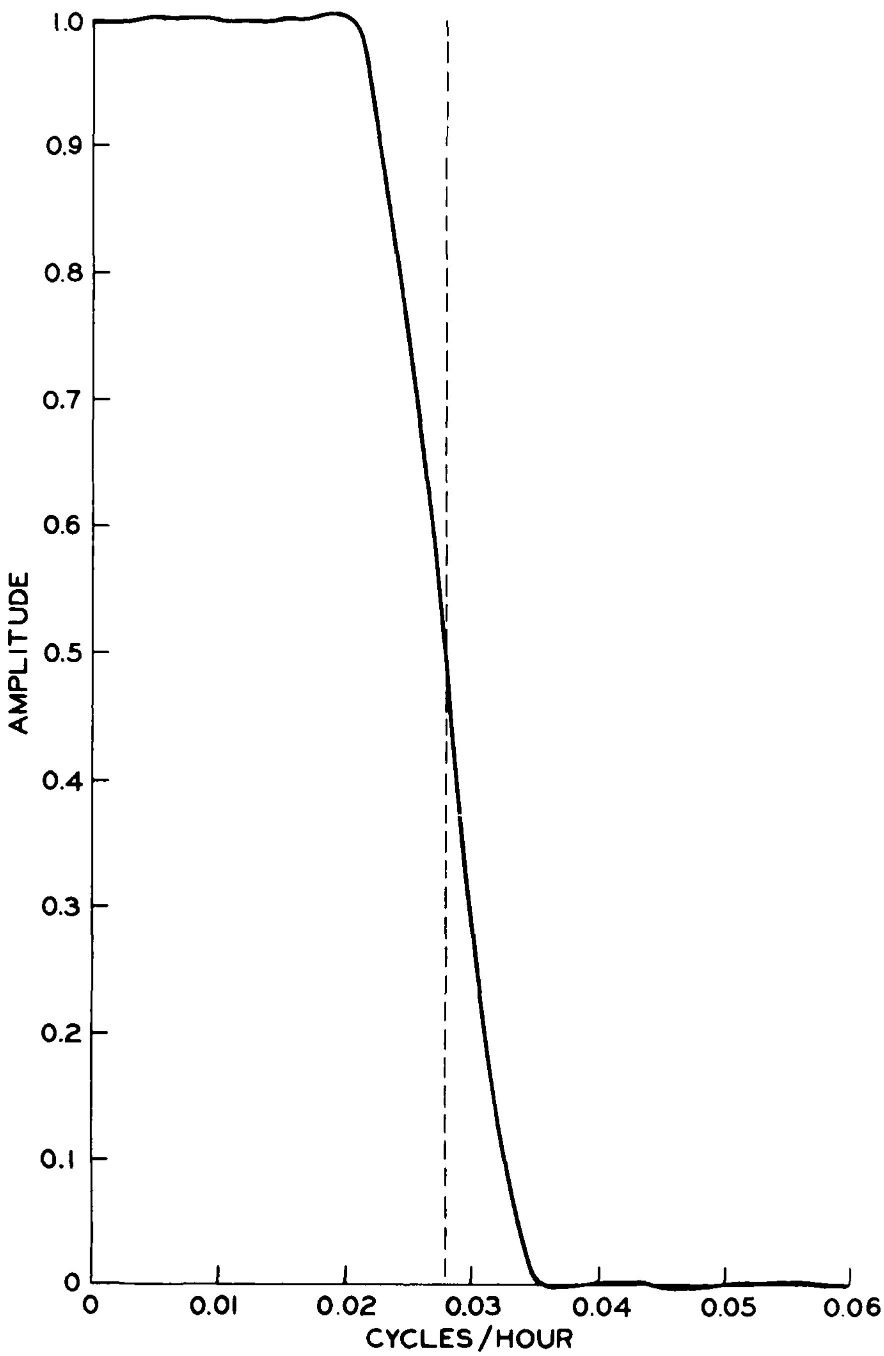

Figure 6. 36-hr filter response curve,
0.028 cph = 36 hr

PART IV: ANALYSIS PROCEDURES

54. Preparation of current velocities for analysis consisted of the following steps.

- a. Photographic recordings of current meter sensor readings from each meter were reduced by Environmental Devices Corporation, manufacturer of the meters. Current speed (fps) and direction (clockwise degrees from magnetic north) toward which the current was flowing at 30-min intervals were written to a magnetic tape which was sent to WES.
- b. The data were plotted as time-histories and checked for reasonableness.
- c. Component velocities in the east-west and north-south directions were computed and stored. For the east-west components, eastward flowing components were given a positive sign. Northern directions for the north-south components were also denoted positive. Directions west and south were given a negative sign. North-south component analyses were performed only for those station locations for which a significant wind fetch length offered opportunity for wind-induced currents in that direction.
- d. The low pass filter described in paragraphs 50-53 was applied to the component velocities and the filtered output was stored.

55. In the analysis, the data sets resulting from step (a)--current speed and direction received at WES--are referred to as original data. Data sets consisting of component velocities are identified by a code that consists of the letter C followed by a two-letter designation of either east-west components, EW, or north-south components, NS, and ending with station and depth designation. Thus a data set of east-west components of currents at sta T1, bottom, is identified by CEWT1B. Data sets resulting from filtering in step (d) are identified by the same code preceded by an F. The filtered version of CEWT1B is therefore identified by FCEWT1B. Time in the data sets is expressed in hours from the starting time of each original data set as listed in Table 1.

56. Wind velocities at Astoria Airport for the period of interest were processed by these steps:

- a. Wind speed (knots) and direction (clockwise degrees from true north) from which the wind was blowing were key-punched from copies of published climatologic records (NOAA 1978).

b. Speeds were converted from knots to fps and directions were converted to degrees (from magnetic north) and to the direction toward which the wind was blowing to make them consistent with current data.

c. This process was identical to step (c) for current velocities.

d. For each individual current station, there existed a corresponding wind file with the same starting date and time. This was necessary to prevent a bias phase lag. The titling procedure in this report does not distinguish each individual wind file needed to correspond with the various starting times and record lengths of the current stations, which explains slight variations in the ASD for the seven various wind files. For example, the wind file accompanying sta 4 and 5 has a starting time of 3-9-78 at 1000 hr while the wind file accompanying sta 7 has a starting time of 3-8-78 at 1600 hr. The title procedure used identifies component wind velocity by the lable ASTEW and ASTNS regardless of starting times. Similarly, filtered versions are identified by FASTEW and FASTNS.

57. The preparation process described above resulted in four data sets for each record of original data. Then cross-spectral methods were applied to various combinations of two data sets at a time in order to determine the characteristics of each data set and the relationships among them. The boxcar and Tukey-Hann lag windows were employed.

58. Current data were recorded at 30-min intervals while wind data were recorded at 3-hr intervals. Data points at 3-hr intervals were used for both in the succeeding analyses. A 3-hr time increment results in a folding frequency of 0.167 cph.

59. Usable data record lengths ranged from 486 to 507 hr. A maximum lag time of 150 hr was chosen after trials of 30, 60, 90, 120, 150, and 180 hr. The 150-hr lag provided spectral estimates at frequency intervals of 0.00333 cph between 0 and the folding frequency of 0.167 cph. A lag as large as this violates the 10 percent rule of Equation 17 but was necessary in order to adequately resolve the region of interest between 0 and 0.028 cph (1/36 hr). Units of ASD and CSD in these calculations are $(\mathrm{fps})^2$-hr, which is proportional to energy density. To

convert energy density to an equivalent fps amplitude of a periodic component, multiply by the frequency in cph, then by 2.0, and take the square root of the result.

PART V: RESULTS AND DISCUSSION

60. Results of data preparation and analysis are displayed in Tables 2-26 and are discussed in the following paragraphs. The original current data records are listed in McAnally and Donnell (in preparation).

61. The following describes trials with north-south and east-west components, both filtered and unfiltered, of original wind and current data, with several of the spectral functions presented in the preceding section. All sites were considered for east-west analysis. Velocity sta T11 was excluded from E-W analysis because of cross-channel wind obstructions near that station. Stations believed to have sufficient wind fetch to permit significant north-south component wind-induced currents were T1, T1B, T4, T5, T5B, T7, T11, and T11B. Sta T3 was not analyzed due to large gaps in the data. In order to fully identify a particular result, a string of modifiers indicating the data processing steps and the spectral parameter is required. Considerable economy of prose has been achieved by use of the data set codes described in paragraphs 55 and 56 and abbreviations for spectral parameters. Data set codes are identified the first time they are used. Abbreviations used are ASD for auto-spectral density function, (recall synonymous term power spectral density described in paragraph 16) CSD for cross-spectral density function, RFA for response function amplitude, and coherency for coherency squared. Ninety percent confidence limits for the smooth RFA and ASD were computed and are presented in the tables under the heading "Confidence."

Astoria Winds

62. Wind speeds and directions at Astoria Airport (Figure 1) are shown in Plate 1. The zero hour corresponds to 3-8-78 hour 1600 PST. The original wind data are listed in McAnally and Donnell (in preparation). The plot reflects the direction (referencing magnetic north) to which the wind was blowing. The plot of direction versus time gives a description of the data after the 180-deg adjustment process discussed

in paragraph 56. The plot of speed versus time shows the highest sustained wind speeds to occur between hours 105 and 120, hours 350 and 395, and hours 645 and 670. The vector plot of the wind data is helpful in determining a general direction and magnitude of the wind. For instance, from hours 350 to 395 the wind is varying between 10 to 30 fps at 300 to 360 deg, and is blowing a constant 70 deg at about 25 fps at hours 110 to 120.

63. Plate 2 shows east-west components of unfiltered (ASTEW) and filtered (FASTEW) Astoria wind velocities. The smaller amplitude, smoother curve is the filtered data. Note that the filtering process cannot be applied to the first 90 hr and last 90 hr of the data record without causing a phase shift; therefore the record is shortened by 180 hr. The largest east-west wind speeds occurred between hours 110 and 120 of the record and were toward the east. Other significant eastward wind periods were between hours 200 and 300, and between hours 510 and 550. A significant westward trend occurs only between hours 330 and 400.

64. A revealing demonstration of the filtering process is seen in Plate 2 at about hours 160 and 250. At hour 160 a period of winds blowing westward results in a filtered data peak with a magnitude (3 fps) roughly equal to the eastward peak at hour 250, even though the unfiltered eastward speeds were much higher than the unfiltered westward speeds. The filtered data set peaks are about equal because the high eastward velocities were relatively short-lived and separated by periods of west-blowing winds.

65. North-south wind components (ASTNS) and the filtered residual (FASTNS) are shown in Plate 3. Major northerly episodes occurred near hour 100, between hours 325 and 460, and after about hour 560. The periods of moderate southward winds are between hours 140 and 200, hours 230 and 305, and hours 470 and 550.

66. Table 2 illustrates raw and smooth cross-spectral analyses for ASTEW versus FASTEW. Comparison of the ASD for the two data sets shows the filtering effect--FASTEW ASD values at higher frequencies are progressively smaller than those of ASTEW, and several energy peaks in ASTEW beyond 0.03 cph (not shown in the table) are essentially removed from

FASTEW. In the low-frequency portion of the spectrum, relative magnitudes of ASTEW and FASTEW ASD oscillate in the pattern of the filter's response function as shown in Figure 5.

67. Examination of the smooth RFA and coherency illustrates further the filter's effect. The RFA have values of about 1.0 from 0.0 to 0.02 cph, then decline rapidly to a value of 0.35 at 0.03 cph. This is, and should be, the shape of the filter as shown in Figure 5, with some deviation due to aliasing and inaccuracies in the spectral estimates. The coherencies also demonstrate the filter, showing a linear relationship between ASTEW and FASTEW at low frequencies and a declining coherency at 0.03 cph.

68. The data set FASTEW is used repeatedly in analyses with current data, and its ASD, as well as that of FASTNS, is repeated in a number of subsequent tables to facilitate comparison with those of the currents (see paragraph 54d for further information). At this point it is useful to examine the FASTEW and FASTNS ASD to learn what we may expect in the following analyses. Two prominent peaks appear in the FASTEW ASD--a large one between 0.0033 cph and 0.01 cph and a smaller one at 0.02 cph. In the raw spectrum, relatively little energy appears at 0.0 cph, which will contain contributions from periods greater than 300 hr.

69. Cross-spectral results for ASTNS versus FASTNS are shown in Table 3. The raw FASTNS ASD differs from that of FASTEW in that there is only one peak instead of two. The peak at 0.0033 cph is somewhat narrower and two times greater in magnitude in FASTNS. In the smooth ASD, FASTNS appears to be very similar to that of the raw ASD except for a broadened and compressed appearance caused by the smearing effect of the Tukey-Hann window.

70. The purposes of this analysis are to determine if a significant relationship between wind and currents existed, and if so, the magnitude of current response to wind forcing. Evidence of such a relationship at a given frequency will consist of a coherency near 1.0 (but less than 1.1), a negative phase lag from wind to currents of significant magnitude to allow the current a reasonable response time, and an RFA that is consistent with known characteristics of wind-induced

currents, i.e., a near surface speed no more than about 4 percent of wind speed.

Station T1

71. Original current data for sta T1 (surface) are shown in Plate 4. The predominant ebb flow direction for the period is toward the west-northwest, about 300 deg, and predominant flood flow direction is to the east-southeast at about 100 deg. Maximum current speeds were about 5.5 fps.

72. Plates 5 and 6 illustrate the unfiltered and filtered components of current velocity in the east-west and north-south directions, respectively. It can be seen that the greater-than-36-hr-period currents are a small fraction of the measured current speeds. The filtered east-west (FCEWT1) currents appear to be approximately balanced whereas the north-south (FCNST1) filtered currents are predominantly northward.

73. Cross-spectral analysis between data sets FCEWT1 and FCEWT10 was performed in an attempt to identify those portions of the spectrum at T1 which were attributable to river runoff. If it can be assumed that (a) the spectrum at T10 is much less affected by wind than that at T1, and (b) the river runoff portion of the spectrum should contain more energy at T10 than at T1, then comparisons of the spectra should reveal whether the energy at a given frequency is of runoff origin. Assumption (a) is based on the observations that T10 currents should be relatively immune to north-south wind effects because the river is so narrow at that point; that winds from the east will be operating over a much shorter fetch at T10 than at T1; and that currents induced by west winds will tend to be dissipated by the geometry and shallows downstream from T10. Assumption (b) is valid because the estuary is narrower at sta T10 and the same freshwater flow will create higher velocities there than at sta T1 unless density stratification concentrates seaward flow in a thin upper layer. The data do not suggest that the latter occurs.

74. Table 4 shows results of cross-spectral analysis for data sets FCEWT1 and FCEWT10. Sta T10 exhibits raw energy peaks between

0 and 0.0033 cph and at 0.010 cph, but the raw and smooth auto density magnitudes are consistently smaller than those at corresponding points in the FCEWT1 spectrum. In the smooth spectra the ASD's of the two data sets are essentially equal at 0.0 cph. This, in combination with assumptions (a) and (b), suggests that energy due to river runoff, if present, is limited to frequencies well below 0.0033 cph.

75. Results of cross-spectral analysis of FASTEW and FCEWT1 are shown in Table 5. The ASD's show energy concentrations in FCEWT1 at about the same frequencies as the wind data except that the raw estimates exhibit three separate FCEWT1 peaks at 0.0, 0.01, and 0.02 cph as contrasted to the primary and secondary peaks which occur at 0.003 and 0.02 cph for the wind.

76. The strongest coherency between FASTEW and FCEWT1 occurs at 0.01, 0.02, and 0.023 cph where the raw coherency varies between 0.75 and 1.08. The raw response function amplitude (RFA) at those frequencies is about 0.05. At 0.01 and 0.023 cph the phase lag is positive which indicates that the current preceded the wind. However, at 0.02 cph the phase is negative for both the raw and smooth spectrum, indicating that the wind preceded the current by 2 to 5 hr. Notably, the RFA for the raw and smooth case at 0.02 cph is 0.05 and 0.03, respectfully. Such amplitudes coincide with observations that wind-induced surface currents have a speed of 2 to 5 percent of wind speed.

77. Table 6 shows raw and smooth cross-spectral analyses, respectively, for FASTNS and FCNST1. The current exhibits a series of ASD peaks in the raw spectrum, whereas in the smoothed spectrum the peaks blend into a continuous curve. Significant raw coherencies (0.66 and 0.67) with corresponding negative phase lags (-7 and -1 hr) occur at frequencies 0.006 and 0.016 cph, respectively. Smooth estimates at these frequencies retain their negative phase but coherencies drop considerably (0.27 and 0.17).

Station T1B

78. Original data for sta T1B (near bottom) are shown in Plate 7.

Flood phase currents are to the east southeast, about 100 deg, as at the near-surface sta T1. Ebb currents, however, are more to the west than the surface currents. Current speeds are significantly lower at the bottom position, with only a few readings exceeding 3.5 fps. A period of no speed (less than 0.2 fps) readings occurred between hours 485 and 530 and the data are seen to demonstrate unusual behavior for some time prior to and following the gap, indicating meter fouling during the period.

79. East-west components of T1B currents for the unfiltered (CEWT1B) and filtered (FCEWT1B) are shown in Plate 8. Filtered currents are of low magnitude and exhibit no obvious predominance toward the east or west.

80. North-south components of T1B are shown in Plate 9. The unfiltered (CNST1B) current speeds are substantially lower than east-west components of the previous plate, but the filtered results (FCNST1B) are roughly the same magnitude as FCEWT1B because CNST1B is less uniformly periodic than CEWT1B.

81. Table 7 contains raw and smooth spectra for FASTEW versus FCEWT1B. FCEWT1B demonstrates three ASD peaks at 0.0, 0.006, and 0.016 cph. The first two straddle the major peak at 0.003 cph in FASTEW. The third, and primary peak, coincides with the wind's secondary peak. At the 0.016-cph peak there is a relatively, high raw coherency of 0.57 and a negative phase of 8 hr. However, an unusually large raw RFA of 0.11 drops to 0.06 when smoothed. The smoothing process causes the narrowly separated peaks to merge, broadening and flattening the peak and reducing the coherency to 0.26.

82. Spectral results for filtered north-south components of wind and sta T1B currents are shown in Table 8 for the raw and smooth cases. The raw FCNST1B ASD exhibits peaks at 0.067 and 0.016 cph. The 0.067-cph frequency reveals not only a significant raw coherency of 0.87 but also a negative phase lag (28 hr) and a RFA of 0.02. The coherency drops considerably when smoothed. The fact that coherency does not have to accompany an ASD peak to be significant is demonstrated at the 0.01-cph frequency. Here the raw estimates have a coherency of 0.50, a

negative phase of 13 hr, and a RFA of 0.03. The smooth estimates maintain about the same values of coherency, negative phase, and RFA.

Station T2

83. Original data for sta T2 currents are shown in Plate 10. Flood currents were directed to the east-southeast and ebb currents to the west-northwest. The current rose demonstrates an apparent blind spot in the direction data at about 290 deg, which probably resulted from a malfunction of the meter. The spring-neap tidal range variation and diurnal inequality are quite noticeable in the plot of current speeds--where the neap phase of the tides clearly occurs at about hours 190 and 570, and the maximum ebb speeds between higher high water and lower low water are twice as large as the maximum flood speeds and the ebb between lower high water and higher low water. Maximum ebb current speeds at sta T2 were less than 5 fps, while maximum flood currents were less than 4 fps.

84. East-west components of flow are shown in Plate 11. Filtered east-west components (FCEWT2) are all negative, indicating a complete ebb bias in the nontidal current velocities for the period. Table 9 contains the spectral estimates for FASTEW versus FCEWT2. The raw ASD for FCEWT2 shows a primary peak between 0.0 and 0.003 cph and a smaller peak at 0.020 cph. Strong raw coherencies at 0.0067 and 0.02 cph are accompanied by positive phase lag. Smoothing results in negative phase and marginal coherencies of around 0.45 for frequencies of 0.013 and 0.016 cph.

Station T2B

85. Original data for sta T2B (near bottom) currents are shown in Plate 12. Flood currents were directed slightly south of east at a maximum of 2.75 fps and ebb currents were toward the west to west-northwest at a maximum of 2.75 fps. The speed versus time graph reveals a zero speed between hours 70 and 90.

86. East-west components of the current are shown in Plate 13. Filtered east-west components (FCEWT2B) are a mixture of flood and ebb; however, there are three rather prolonged ebb periods but none of flood.

87. Table 10 contains the spectral estimates for FASTEW and FCEWT2B. Both the wind and current have their raw secondary peaks near 0.023 cph. However, only at the primary peak for FCEWT2B (0.01 cph) is there a significant coherency with a negative phase lag. However, the smooth coherency drops to 0.31 as opposed to the 0.87 raw estimate.

Stations T3, T3C, and T3B

88. Records at all three depths of location T3 were marred by gaps in the data to an extent that prohibited spectral analysis. The original data for T3, T3C, and T3B are shown in Plates 14, 15, and 16.

Station T4

89. The original measured data for sta T4 are shown in Plate 17. The ebb flow direction for the period is toward the west-southwest at about 250 deg while the flood flow is to the northeast at about 45 deg. Maximum ebb current speeds are about 4.7 fps, and maximum flood currents are about 3.2 fps.

90. Plates 18 and 19 illustrate the unfiltered and filtered components of current velocity in the east-west and north-south directions, respectively. The filtered east-west (FCEWT4) currents are all negative, which indicates a westward (ebb) flow while the filtered north-south (FCNST4) currents are essentially balanced.

91. Results of spectral analysis of FASTEW and FCEWT4 are shown in Table 11. The raw ASD show energy concentrations in the two data sets to be at frequencies of 0.003, 0.006, and 0.02 cph. Estimates with significant coherency values have positive phase values which implies the unlikely event that the current preceded the wind, and are omitted from further consideration.

92. Results of spectral analysis of FASTNS and FCNST4 are shown

in Table 12. The wind and current's raw ASD indicate a large concentration of energy at the frequency 0.003 cph. A large raw coherency of 0.99 is slightly reduced to 0.73 when smoothed, but a positive phase lag eliminates it from consideration. Furthermore, this frequency is not of interest, as discussed in paragraph 33. Interestingly, at the 0.013 frequency there is a 0.48 raw coherency with a negative lag of 9 hr and an RFA of 0.03, but the smoothing process drops the coherency and RFA to 0.0 and raises the phase lag to negative 17 hr.

Station T5

93. Original current data for sta T5, surface, are shown in Plate 20. Flood currents were toward the northeast with maximum speeds of about 2 fps, and ebb flows were to the west-southwest with maxima of about 3 fps. The smaller neap phase velocities beginning at about 150 hr noted at sta T2 appear in the sta T5 record also; however, sta T5 directions for that period are shown to be consistently in the flood direction and the speeds do not exhibit the large maximum ebb values observed at sta T2. A long period of consistent flood velocities at this station is unlikely, so the data suggest rather a stuck direction indicator or fouling of the meter, perhaps by debris or the mooring lines. Plate 21 illustrates the east-west components of T5 currents, both unfiltered and filtered (FCEWT5). Other than the suspicious period of all flood flows, the predominant direction of FCEWT5 is ebb (negative). The combination of constant flood flows in one portion and predominant ebb flows in the remainder imposes an apparent large amplitude oscillation with a period slightly shorter than the length of the filtered record. This will show up as a high energy peak in ASD at about 0.002 cph.

94. North-south components of T5 currents are shown in Plate 22. The prolonged flood flow periods bias the filtered north-south components (FCNST5) in the same way they affected those in the east-west directions.

95. Raw and smooth spectra for FASTEW vs FCEWT5 are shown in Table 13. The expected large ASD peak does occur between 0.0 and 0.0033 cph with a value far in excess of any previously seen in the filtered

currents. Raw coherencies, with an accompanying negative phase, do not show significant correlation at any frequency. Smoothed estimates all have positive phase and relatively low coherency.

96. Spectral estimates for FASTNS versus FCNST5 are shown in Table 14. Raw estimates reveal a strange set of coherencies and a phase lag that oscillates from positive to negative. Smooth estimates are more settled. Smooth estimates that occur at frequencies 0.013, 0.023, and 0.026 all have significant smooth coherencies and negative phase lag, although there are no ASD peaks associated with these frequencies.

Station T5B

97. The original data for sta T5B (near bottom) is shown in Plate 23. The flood flow is to the northeast at a maximum of 2.5 fps. The ebb flow is toward the south-southeast about 170 deg with a maximum speed of 4.75 fps. It should be noted that this direction is cross channel rather than downstream. The flood direction is better aligned with the channel (northeast). Maximum flood current was about 2.4 fps.

98. The measured and filtered T5B currents for the east-west and north-south components are found in Plates 24 and 25, respectively. The filtered east-west current components (FCEWT5B) have a predominant flood of less than 0.7 fps while the filtered north-south current components (FCNST5B) indicate southerly ebb flow of less than 1.5 fps.

99. Table 15 contains raw and smooth cross-spectral estimates for FASTEW and FCEWT5B. Neither raw nor smooth estimates satisfy all of the coherency, RFA, and phase requirements to qualify for additional consideration.

100. The raw and smooth spectral estimates for FASTNS and FCNST5B are shown in Table 16. Raw coherency values are spurious and all values with a negative phase are much greater than one. The smooth estimates at frequency 0.016 have a coherency of 0.52, a RFA of 0.03, and a negative phase of 3 hr, which can be considered a marginal wind/current correlation.

Station T6

101. Plate 26 illustrates original current data for sta T6; currents there were essentially east-west oriented, with maximum flood speeds of about 2 fps and maximum ebb speeds of about 2.4 fps. The neap-spring cycle of tide ranges is evident in the current speed versus time plot, but higher ebb velocities corresponding to the diurnal maximum range are not a striking feature of the record. Currents at sta T6 appear to have been well channelized as evidenced by sharp ebb and flood reversals, with little rotation of the current vector between phases.

102. East-west components of sta T6 currents are plotted in Plate 27. The filtered data set (FCEWT6) is completely in the ebb direction with magnitudes of less than 0.4 fps, which is about the margin by which maximum ebb speeds exceeded maximum flood speeds. Relatively little periodicity is noticeable in the filtered data set. Because the currents were so consistently east-west, it was not necessary to perform a north-south analysis.

103. Spectral analysis results of FASTEW versus FCEWT6 are shown in Table 17. Frequencies of 0.003 and 0.013 cph have significant coherency and phase of 0.58, -48 hr, and 0.82, -9 hr, respectfully. Smooth estimates for these frequencies retain the negative phase but coherency drops to near zero. Furthermore, the 0.003-cph frequency is not of interest (see paragraph 33).

Station T7

104. The original current data (surface) for sta T7 are shown in Plate 28. The predominant ebb flow is directed toward the northwest (about 315 deg) at a maximum speed of 2.1 fps while the flood flow is toward the east-southeast (about 110 deg) at a maximum speed of 1.5 fps.

105. Plates 29 and 30 illustrate the measured and filtered components of currents in the east-west and north-south directions, respectively. The plots exhibit the small contribution (less than 0.5 fps) made by currents with periods greater than 36 hr. The filtered east-west

(FCEWT7) current indicates a small ebb predominance and the filtered north-south (FCNST7) current indicates a flood-predominant current of less than 0.5 fps.

106. Table 18 shows spectral analysis results between FASTEW and FCEWT7. The estimates at frequency 0.02 cph reveal a significant raw coherency of 0.95 with a corresponding phase lag of negative 3 hr. The coherency maintains a significant level of 0.50 and a negative 3-hr phase when smoothed. There is an ASD peak at 0.02 cph for FASTEW but not for FCEWT7. Although 0.01 cph does not have an energy peak, the raw coherency is 0.57. The phase lag is -22 hr, and the RFA is 0.01. The smoothed coherency is not significant, however, and the phase lag is positive.

107. Due to the geographical location of sta T7, analysis was performed for north-south currents versus both east-west and north-south winds. The spectral analysis of FASTEW and FCNST7 are shown in Table 19. A secondary CSD peak occurs at 0.02 cph where a raw coherency of 0.49 and a phase of -5 hr occur. Smoothing has relatively little effect on the estimates at 0.02 cph.

108. The spectral analysis of FASTNS and FCNST7 are shown in Table 20. The estimates at 0.01 cph for both the raw and smooth cases reveal favorably consistent phase, RFA, and coherency squared. The phase is approximately -13.5 hr and the coherency ranges between 0.58 (smoothed) and 0.84 (raw). At 0.016 cph, the raw phase is -1.0 hr with a 0.56 coherency but the smoothed estimates show a positive 2-hr phase and a minute coherency of 0.04. There were no ASD peaks at frequencies of either 0.01 or 0.016 cph.

Station T8

109. The measured current data for sta T8 are shown in Plate 31. The predominant ebb flow direction for the period is seen to be toward the west-southwest at about 260 deg, at a maximum speed of 4.0 fps. The flood currents are less than 1 fps toward the east-northeast.

110. Plate 32 illustrates the measured and filtered east-west

velocities of sta T8. The plot indicates a decisive ebb direction current averaging about 1.3 fps in the filtered current (FCEWT8). The dominance of ebb currents over flood currents at sta T8 through T12 is indicative of the predominance of freshwater discharge over the tide in the restricted upstream portion of the estuary. At any particular station in this area, the duration and magnitude of flood currents decrease as the freshwater discharge increases. Above some critical discharge, there is no longer a reversal of flow direction with the tide, although the magnitude of the ebb currents will increase and decrease as a function of the tide. This condition also was noted downstream at sta T6 and T7, although to a much lesser degree.

111. The spectral analysis results for data sets FASTEW and FCEWT8 are shown in Table 21. The raw results show that the primary frequency in common with both data sets is 0.003 cph, which as discussed in paragraph 33 is related to term events and thus is not of interest. The multiple peaks in the ASD of FCEWT8 are transformed into one peak with a slightly higher value when smoothed. A significant raw coherency of 0.94 with an accompanying negative 7-hr lag at 0.01 cph is transformed to a coherency of 1.48 and a positive 3-hr phase lag. Although 0.01 cph was one of the minor raw ASD peaks for the current, it was not a peak for the smoothed ASD.

Station T9

112. The measured speed and direction taken at sta T9 (surface) can be seen in Plate 33. The predominant flood flow is toward the northeast at 45 deg at a maximum rate of 1 fps. The ebb flow is to the west at about 260 deg with a maximum speed of 2.75 fps.

113. As expected, Plate 34 describing the measured (CEWT9) and filtered (FCEWT9) current still reveals a strong ebb (about 0.8 fps average) after the filtering technique was applied. The spectral analysis, as shown in Table 22, does not indicate a need to continue investigation. The only frequency with significant energy in both data sets is 0.0033 which has a large positive phase lag and a raw coherency of 0.89. This

frequency, as described in paragraph 33, is not of interest. At the 0.02-cph frequency, the smoothed spectral estimate shows marginally signigicant coherency of 0.49 and a phase lag of -6 hr.

Station T10

114. The plots of the original data (surface) are shown in Plate 35. The polar plot indicates a flood flow of about 45 deg toward the northeast at a maximum of 1.5 fps and ebb currents toward the southeast (240 deg) at a maximum speed of 3 fps. The measured (FCEWT10) and filtered (FCEWT10) currents are shown in Plate 36. As in the other upstream stations, the filtered data set shows a prominent ebb (about 0.9 fps average).

115. Table 23 shows results of spectral analysis of data sets FASTEW and FCEWT10. The high CSD values draw attention to frequencies between 0.0 and 0.0033, but these frequencies describe long-term events (see paragraph 33). A raw coherency of 1.0 with a positive phase of 10 hr is at the 0.016 frequency. The phase becomes a negative 3 hr with a 0.06 coherency when smoothed. These and other estimates at this station can be eliminated from consideration.

Station T11

116. Plate 37 shows the plots of the original current data for sta T11 (surface). The flood flow is less than 1.25 fps toward the south-southeast. The ebb flow is almost 4 fps toward the north. In Plate 38, the north-south components of the measured (CNST11) and filtered (FCNST11) currents are shown. The plot reveals a strong tendency toward the north, i.e. ebb flow (average about 1.6 fps).

117. The raw and smooth spectral analysis of FASTNS and FCNST11 are shown in Table 24. The raw and smooth coherency estimates are either much greater than 1.0 or insignificant. Consequently, sta T11 is omitted from further consideration.

Station T11B

118. The near-bottom measured current data for sta T11B are given in Plate 39. The flood flow is toward the south at a maximum velocity of 1 fps, while the ebb flow is to the north-northwest with a maximum of 3 fps.

119. The measured and filtered north-south components of the current are shown in Plate 40. The filtered version (FCNST11B) demonstrates a residual ebb flow of about 1.3 fps.

120. Table 25 contains the spectral estimates for FASTNS and FCNST11B. Other than the frequencies describing long-term events, only one frequency, 0.013 cph, has a negative phase lag (10 hr) with an accompanying coherency of 0.41, which is marginal. The smooth estimates for 0.013 cph has a positive 12-hr phase and a minute coherency of 0.01.

Station T12

121. The original current data taken at sta T12 (surface) are shown in Plate 41. The flood flow is to the southeast with a 1.5 fps maximum while the ebb flow is to the northwest at a maximum of 3 fps. The filtered east-west component of the current (FCEWT12) as seen in Plate 42 exhibits a predominant ebb flow (about 0.4 fps average).

122. Raw and smooth spectral estimates for FASTEW and FCEWT12 are given in Table 26. Other than long-term events, significant coherency values are not accompanied by negative phase lags. This factor eliminates this station from further investigation.

Summary of Results

123. Table 27 lists those data sets that exhibited either a raw or smooth coherence of about 0.5 to 1.0, negative phase lag, and RFA less than or equal to 6 percent. Nine wind-current combinations satisfy these criteria at one or two frequencies in either raw or smooth spectra, but only three--FASTNS-FCNST1B at 0.01 cph, FASTEW-FCEWT7 at 0.02 cph,

and FASTNS-FCNST7 at 0.01 cph--satisfy them in both raw and smooth spectra. Seven of the nine data sets satisfy the criteria at 0.01, 0.0167 cph, or both.

124. Also shown in Table 27 are the wind and current speed amplitudes, $|F(\sigma)|$, associated with the raw ASD of each data set. These values were calculated as described in paragraph 59. Neither group of speeds contains large values, with the maximum wind speed of 5.6 fps and maximum current speed 0.5 fps; however, a sustained wind of about 5 fps blowing in the same direction for 75 hr (frequency 0.0067 cph in FASTNS) can have a significant effect on water velocity. On the other hand, a wind-induced current of less than 0.5 fps is unlikely to make a major contribution to instantaneous sediment transport in the Columbia River estuary, but as a residual superposed current lasting multiple tidal cycles it could affect short-term sediment transport patterns.

125. Further analysis might confirm or cast doubt on the appearance of a causative relationship, and would permit an extrapolation to wind events other than those occurring during the measurement period. However, present capabilities do not offer the opportunity to carefully evaluate the contribution of wind-induced currents to sediment transport, except at the large expense of effort and funds. At this point these results do not justify that effort.

126. From the analysis, it appears probable that there was a linear causative relationship between wind and currents at sta T1B and T7 for frequencies of 0.01 to 0.02 cph during the period of measurement. There is a significant possibility that a similar relationship exists at the other stations listed in Table 27.

PART VI: CONCLUSIONS

127. Completion of analysis of the wind and currents of the Columbia River estuary leads to the following conclusions:

a. The strongest supportive evidence of wind-induced currents occurs at sta T-1 (surface) for the north-south component at a period of 100 hr, and sta T-7 (surface) for the east-west component at 200 hr, and the north-south component at 100 hr.

b. Wind-induced currents generally will be considerably less than 0.5 fps. Such velocities are unlikely to make a major contribution to instantaneous sediment transport, but as a residual superposed current lasting multiple tidal cycles short-term sediment transport patterns could be affected.

c. Based on the data analyzed, there is not sufficient evidence to include wind-induced currents in the Corp's model of sediment transport.

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Table 1

Station Locations and Conditions

Station No.	Location Oregon State Grid X	Y	Water Depth ft mllw	Meter Depth ft mllw	Data Begins PST
T1	1,117,318	960,690	52	5	1300 9 Mar 78
T1B	1,117,318	960,690	52	47	1300 9 Mar 78
T2	1,134,515	940,811	44	5	1300 9 Mar 78
T2B	1,134,515	940,811	44	39	1300 9 Mar 78
T3	1,140,499	954,471	55	5	1300 9 Mar 78
T3B	1,140,499	954,471	55	28	1300 9 Mar 78
T3C	1,140,499	954,471	55	50	1300 9 Mar 78
T4	1,156,153	956,554	30	15	1000 9 Mar 78
T5	1,168,114	944,825	39	5	1000 9 Mar 78
T5B	1,168,114	944,825	39	34	1000 9 Mar 78
T6	1,188,345	941,664	33	16	1300 9 Mar 78
T7	1,186,134	956,859	42	21	1600 8 Mar 78
T8	1,201,946	961,140	37	18	1600 9 Mar 78
T9	1,207,647	945,671	40	20	1300 9 Mar 78
T10	1,230,424	958,982	40	20	1600 9 Mar 78
T11	1,259,248	945,370	32	5	1600 9 Mar 78
T11B	1,259,248	945,370	32	27	1600 9 Mar 78
T12	1,256,881	937,453	13	7	1600 9 Mar 78

Table 2

CROSS SPECTRAL ANALYSIS RESULTS

RAW ASTORIA WIND E-W AND FILTERED ASTORIA WIND E-W

RAW SPECTRAL ESTIMATES

FREQ. CPH	ASTEW ASD	EASTEW ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-182.13	-280.59	-278.63	0.	278.63	0.	-1.53	1.52
0.0033	3104.82	3247.18	3225.79	-29.07	3225.92	-0.43	1.04	1.03
0.0067	2333.11	2363.72	2300.34	-11.55	2300.37	-0.12	0.99	0.96
0.0100	1514.07	1554.59	1586.44	5.92	1586.45	0.06	1.05	1.07
0.0133	434.65	300.67	316.47	-6.43	316.54	-0.24	0.73	0.77
0.0167	357.23	403.78	437.57	3.89	437.59	0.08	1.22	1.33
0.0200	895.24	762.05	771.35	55.47	773.34	0.57	0.86	0.88
0.0233	434.38	309.52	420.60	24.46	421.31	0.40	0.97	1.32
0.0267	635.20	246.40	334.50	36.89	336.52	0.66	0.53	0.72
0.0300	192.85	47.80	120.76	64.89	137.09	2.62	0.71	2.04

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	ASTEW ASD	EASTEW ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE EASTEW - ASD
0.	1461.34	1483.29	1473.58	-14.53	1473.65	0.	1.01	1.00	0.966< A < 1.050	789.0< Y <4014.8
0.0033	2090.15	2144.37	2118.32	-17.42	2118.39	-0.39	1.01	1.00	0.979< A < 1.048	1140.7< Y <5804.1
0.0067	2321.28	2382.30	2353.23	-11.56	2353.26	-0.12	1.01	1.00	0.977< A < 1.051	1267.3< Y <6448.1
0.0100	1448.97	1443.39	1447.42	-1.53	1447.42	-0.02	1.00	1.00	0.959< A < 1.039	767.8< Y <3906.8
0.0133	685.15	639.93	664.24	-0.76	664.24	-0.01	0.97	1.01	0.895< A < 1.044	340.4< Y <1732.1
0.0167	511.09	467.57	490.74	14.21	490.95	0.28	0.96	1.01	0.875< A < 1.046	248.7< Y <1265.6
0.0200	645.53	559.35	600.22	34.82	601.23	0.46	0.93	1.00	0.901< A < 0.961	297.5< Y <1514.0
0.0233	599.80	406.87	486.76	35.32	488.04	0.49	0.81	0.98	0.691< A < 0.937	216.4< Y <1101.3
0.0267	474.41	212.53	302.59	40.78	305.33	0.80	0.64	0.92	0.466< A < 0.821	113.1< Y < 575.3
0.0300	537.64	92.58	179.53	54.18	187.53	1.55	0.35	0.71	0.132< A < 0.566	49.2< Y < 250.6

Table 3

CROSS SPECTRAL ANALYSIS RESULTS

RAW ASTORIA WIND N-S AND FILTERED ASTORIA WIND N-S

RAW SPECTRAL ESTIMATES

FREQ. CPH	ASTNS ASD	FASTNS ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	130.39	116.08	82.94	0.	82.94	0.	0.64	0.45
0.0033	7726.01	7733.72	7770.26	50.43	7770.43	0.31	1.01	1.01
0.0067	2267.39	2078.87	2131.24	-49.69	2131.82	-0.56	0.94	0.96
0.0100	635.74	785.24	753.61	-21.26	753.91	-0.45	1.19	1.14
0.0133	543.02	430.22	439.88	-27.35	440.73	-0.74	0.81	0.83
0.0167	136.69	332.11	284.71	17.13	285.22	0.57	2.09	1.79
0.0200	228.86	31.50	70.98	-11.03	71.83	-1.23	0.31	0.72
0.0233	-197.25	57.60	0.36	13.47	13.47	10.53	-0.07	-0.02
0.0267	603.63	45.00	180.86	-21.44	182.12	-0.70	0.30	1.22
0.0300	530.05	133.91	267.26	-46.01	271.19	-0.90	0.51	1.04

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	ASTNS ASD	FASTNS ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FASTNS - ASD
0.	3928.20	3924.90	3926.60	25.22	3926.68	0.	1.00	1.00	0.992< A < 1.007	2087.8< Y <10623.5
0.0033	4462.45	4415.60	4438.68	12.79	4438.69	0.14	0.99	1.00	0.984< A < 1.005	2348.9< Y < 1951.6
0.0067	3224.13	3169.17	3196.59	-17.55	3196.64	-0.13	0.99	1.00	0.984< A < 0.999	1685.8< Y < 8578.0
0.0100	1020.47	1019.89	1019.59	-29.89	1020.02	-0.47	1.00	1.00	0.983< A < 1.017	542.5< Y < 2760.5
0.0133	464.62	494.45	479.52	-14.71	479.74	-0.37	1.03	1.00	0.990< A < 1.075	263.0< Y < 1338.3
0.0167	261.31	281.49	270.07	-1.03	270.07	-0.04	1.03	0.99	0.942< A < 1.125	149.7< Y < 761.9
0.0200	99.29	113.18	106.75	2.13	106.78	0.16	1.08	1.01	0.951< A < 1.200	60.2< Y < 306.3
0.0233	109.50	47.93	63.14	-1.38	63.15	-0.15	0.58	0.76	0.264< A < 0.890	25.5< Y < 129.7
0.0267	385.01	70.38	157.33	-18.86	158.46	-0.71	0.41	0.93	0.300< A < 0.523	37.4< Y < 190.5
0.0300	661.39	65.11	165.34	-33.57	168.72	-1.06	0.26	0.66	0.079< A < 0.431	34.6< Y < 176.2

Table 4

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED CURRENT E-W (T1) AND FILTERED CURRENT E-W (T10)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FCEWT1 ASD	FCEWT10 ASD	CO- SPECTRA	QUAD- SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	5.25	4.04	-4.66	0.	4.66	0.	0.89	1.02
0.0033	2.47	2.06	-1.43	-2.01	2.46	45.48	1.00	1.20
0.0067	2.56	-0.07	0.40	-0.45	0.60	-19.94	0.24	-1.96
0.0100	3.08	0.55	-0.26	-1.28	1.30	21.78	0.42	1.00
0.0133	0.15	0.02	0.29	0.20	0.35	7.28	2.39	34.85
0.0167	2.23	0.16	0.07	-0.42	0.43	-13.51	0.19	0.51
0.0200	2.30	0.04	0.45	0.11	0.46	1.85	0.20	2.27
0.0233	1.62	0.02	-0.28	-0.25	0.37	4.93	0.23	5.24
0.0267	0.44	0.01	0.10	0.25	0.27	7.18	0.62	29.02
0.0300	0.04	0.01	-0.03	-0.12	0.12	6.95	2.87	28.22

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FCEWT1 ASD	FCEWT10 ASD	CO- SPECTRA	QUAD- SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FCEWT10- ASD
0.	3.86	3.05	-3.05	-1.00	3.21	0.	0.83	0.87	0.527< A < 1.136	1.62< Y < 8.26
0.0033	3.19	2.02	-1.78	-1.12	2.10	26.75	0.66	0.69	0.228< A < 1.091	1.07< Y < 5.47
0.0067	2.67	0.61	-0.22	-1.05	1.07	32.54	0.40	0.70	0.145< A < 0.656	0.33< Y < 1.66
0.0100	2.22	0.26	0.04	-0.70	0.70	-24.04	0.32	0.84	0.185< A < 0.448	0.14< Y < 0.71
0.0133	1.40	0.19	0.10	-0.32	0.34	-15.31	0.24	0.43	-0.028< A < 0.509	0.10< Y < 0.51
0.0167	1.73	0.10	0.22	-0.13	0.25	-5.26	0.15	0.39	-0.030< A < 0.325	0.05< Y < 0.26
0.0200	2.11	0.06	0.17	-0.11	0.20	-4.71	0.10	0.31	-0.043< A < 0.236	0.03< Y < 0.17
0.0233	1.50	0.02	-0.00	-0.03	0.03	9.94	0.02	0.04	-0.086< A < 0.131	0.01< Y < 0.05
0.0267	0.64	0.01	-0.03	0.04	0.05	-5.33	0.07	0.33	-0.028< A < 0.172	0.01< Y < 0.03
0.0300	0.15	0.00	0.02	0.03	0.04	5.34	0.25	1.95	0.082< A < 0.424	0.00< Y < 0.01

Table 5

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T1)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FCEWT1 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-337.95	5.25	-26.26	0.	26.26	0.	-0.08	-0.39
0.0033	3382.44	2.47	10.17	-53.75	54.71	-66.07	0.02	0.36
0.0067	2197.57	2.56	-10.77	37.21	38.74	-30.77	0.02	0.27
0.0100	1571.40	3.08	-63.66	-34.44	72.38	7.89	0.05	1.08
0.0133	276.76	0.15	2.99	15.72	16.00	16.51	0.06	6.26
0.0167	352.80	2.23	-1.98	-6.87	7.15	12.32	0.02	0.06
0.0200	793.07	2.30	-33.47	23.57	40.94	-4.88	0.05	0.92
0.0233	384.29	1.62	-7.27	-20.31	21.57	8.37	0.06	0.75
0.0267	272.37	0.44	5.27	16.77	17.58	7.56	0.06	2.57
0.0300	78.75	0.04	-3.91	-18.00	18.43	7.20	0.23	100.78

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FCEWT1 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FCEWT1 - ASD
0.	1522.25	3.86	-8.04	-26.88	28.05	0.	0.02	0.13	-0.027< A < 0.064	2.05< Y < 10.44
0.0033	2156.13	3.19	-4.17	-17.57	18.06	63.87	0.01	0.05	-0.028< A < 0.045	1.69< Y < 8.62
0.0067	2337.25	2.67	-18.76	-3.44	19.07	4.33	0.01	0.06	-0.023< A < 0.040	1.42< Y < 7.22
0.0100	1404.28	2.22	-33.78	-3.99	34.01	1.87	0.02	0.37	-0.006< A < 0.055	1.18< Y < 6.00
0.0133	619.43	1.40	-14.92	-2.47	15.12	1.96	0.02	0.26	-0.015< A < 0.064	0.75< Y < 3.79
0.0167	443.85	1.73	-8.61	6.39	10.72	-6.09	0.02	0.15	-0.031< A < 0.080	0.92< Y < 4.68
0.0200	580.81	2.11	-19.05	4.99	19.69	-2.04	0.03	0.32	-0.014< A < 0.082	1.12< Y < 5.72
0.0233	458.51	1.50	-10.68	-0.07	10.68	0.04	0.02	0.17	-0.027< A < 0.074	0.80< Y < 4.05
0.0267	251.95	0.64	-0.16	-1.19	1.20	8.59	0.00	0.01	-0.044< A < 0.053	0.34< Y < 1.73
0.0300	118.96	0.15	0.13	-1.85	1.85	-7.97	0.02	0.20	-0.015< A < 0.046	0.08< Y < 0.39

Table 6

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T1)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTNS ASD	ECNST1 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	821.58	-0.65	25.62	0.	25.62	0.	0.03	-1.22
0.0033	7705.10	1.80	5.43	59.62	59.87	70.67	0.01	0.26
0.0067	1728.52	1.25	-35.97	11.33	37.71	-7.28	0.02	0.66
0.0100	578.54	1.35	1.58	33.52	33.56	24.25	0.06	1.45
0.0133	438.00	2.06	-10.90	-20.84	23.52	13.00	0.05	0.61
0.0167	341.69	0.76	13.93	-1.90	14.05	-1.29	0.04	0.76
0.0200	8.92	0.16	-9.20	-0.85	9.24	0.73	1.04	59.35
0.0233	115.04	0.52	2.62	4.70	5.38	7.24	0.05	0.49
0.0267	-6.36	0.23	-2.19	1.01	2.41	-2.57	-0.38	-4.03
0.0300	163.00	0.07	-2.60	4.05	4.81	-5.31	0.03	2.07

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTNS ASD	ECNST1 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE ECNST1 - ASD
0.	4263.34	0.58	15.52	29.81	33.61	0.	0.01	0.46	-0.000< A < 0.016	0.31< Y < 1.56
0.0033	4490.07	1.05	0.12	32.64	32.64	74.82	0.01	0.23	-0.006< A < 0.020	0.56< Y < 2.84
0.0067	2935.17	1.41	-16.24	28.95	33.19	-25.30	0.01	0.27	-0.007< A < 0.029	0.75< Y < 3.82
0.0100	830.90	1.50	-10.93	14.38	18.06	-14.66	0.02	0.26	-0.013< A < 0.057	0.80< Y < 4.06
0.0133	449.05	1.56	-1.58	-2.52	2.97	12.07	0.01	0.01	-0.050< A < 0.063	0.83< Y < 4.22
0.0167	282.57	0.94	1.94	-6.37	6.66	-12.18	0.02	0.17	-0.027< A < 0.074	0.50< Y < 2.54
0.0200	118.64	0.40	-0.46	0.27	0.54	-4.24	0.00	0.01	-0.051< A < 0.060	0.21< Y < 1.08
0.0233	58.16	0.35	-1.54	2.39	2.84	-6.81	0.05	0.39	-0.010< A < 0.108	0.19< Y < 0.96
0.0267	66.33	0.26	-1.09	2.69	2.90	-7.08	0.04	0.49	0.001< A < 0.087	0.14< Y < 0.70
0.0300	67.07	0.10	-1.92	1.88	2.69	-4.11	0.04	1.05	0.032< A < 0.048	0.05< Y < 0.28

Table 7

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T1B)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FCEWT1B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-337.95	1.19	6.32	0.	6.32	0.	-0.02	-0.10
0.0033	3382.44	-1.48	4.68	3.52	5.86	30.82	0.00	-0.01
0.0067	2197.57	5.70	41.85	59.19	72.49	22.81	0.03	0.42
0.0100	1571.46	1.81	-20.24	21.68	29.66	-13.05	0.02	0.31
0.0133	276.76	2.47	-14.59	-13.54	19.90	8.93	0.07	0.58
0.0167	352.80	8.13	-26.21	30.77	40.43	-8.26	0.11	0.57
0.0200	793.07	5.07	3.06	35.66	35.80	11.82	0.05	0.32
0.0233	384.29	5.41	-15.80	-17.05	23.25	5.62	0.06	0.26
0.0267	272.37	1.42	-10.02	-0.56	10.04	0.34	0.04	0.26
0.0300	78.75	-0.09	6.30	1.74	6.54	1.43	0.08	-6.20

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FCEWT1B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FCEWT1B - ASD
0.	1522.25	-0.14	5.50	1.76	5.77	0.	0.00	-0.15	-0.006< A < 0.014	-0.08< Y < -0.39
0.0033	2156.13	0.98	14.38	16.56	21.93	40.86	0.01	0.23	-0.008< A < 0.028	0.52< Y < 2.66
0.0067	2337.25	2.93	17.03	35.90	39.73	26.92	0.02	0.23	-0.013< A < 0.047	1.56< Y < 7.94
0.0100	1404.28	2.95	-3.31	22.25	22.50	-22.65	0.02	0.12	-0.025< A < 0.057	1.57< Y < 7.98
0.0133	619.43	3.72	-18.91	6.34	19.94	-3.86	0.03	0.17	-0.036< A < 0.100	1.98< Y < 10.06
0.0167	443.85	5.95	-15.99	20.92	26.33	-8.77	0.06	0.26	-0.037< A < 0.155	3.16< Y < 16.10
0.0200	580.81	5.92	-8.98	21.26	23.08	-9.32	0.04	0.15	-0.050< A < 0.129	3.15< Y < 16.02
0.0233	458.51	4.33	-9.64	0.25	9.65	-0.18	0.02	0.05	-0.070< A < 0.113	2.30< Y < 11.71
0.0267	251.95	2.04	-7.39	-4.11	8.45	3.03	0.03	0.14	-0.047< A < 0.114	1.09< Y < 5.53
0.0300	118.96	0.30	-0.24	-0.10	0.26	2.06	0.00	0.00	-0.046< A < 0.051	0.16< Y < 0.81

Table 8

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T1B)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST1B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	821.58	0.06	-5.95	0.	5.95	0.	0.01	0.73
0.0033	7705.10	0.06	-33.00	10.31	34.58	-14.45	0.00	2.53
0.0067	1728.52	1.22	16.39	-39.58	42.84	-28.13	0.02	0.87
0.0100	578.54	1.15	12.64	-13.02	18.15	-12.74	0.03	0.50
0.0133	438.00	-0.43	-11.91	-0.68	11.93	0.68	0.03	-0.76
0.0167	341.69	1.18	-6.50	3.88	7.57	-5.14	0.02	0.14
0.0200	8.92	0.97	0.17	3.35	3.35	12.09	0.38	1.30
0.0233	115.04	0.69	4.42	-3.43	5.59	-4.51	0.05	0.39
0.0267	-6.36	0.36	-0.21	-1.60	1.61	8.61	-0.25	-1.14
0.0300	163.00	-0.09	0.63	2.01	2.11	6.73	0.01	-0.29

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST1B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCNST1B - ASD
0.	4263.34	0.06	-19.48	5.15	20.15	0.	0.00	1.58	0.002< A < 0.007	0.03< Y < 0.16
0.0033	4490.07	0.35	-13.89	-4.74	14.68	15.71	0.00	0.14	-0.005< A < 0.011	0.19< Y < 0.95
0.0067	2935.17	0.91	3.11	-20.47	20.70	-33.91	0.01	0.16	-0.009< A < 0.023	0.49< Y < 2.48
0.0100	830.90	0.77	7.44	-16.58	18.17	-18.28	0.02	0.51	0.001< A < 0.042	0.41< Y < 2.09
0.0133	449.05	0.37	-4.42	-2.62	5.14	6.39	0.01	0.16	-0.014< A < 0.037	0.20< Y < 0.99
0.0167	282.57	0.73	-6.18	2.61	6.71	-3.81	0.02	0.22	-0.019< A < 0.067	0.39< Y < 1.96
0.0200	118.64	0.95	-0.43	1.79	1.84	-10.60	0.02	0.03	-0.070< A < 0.101	0.51< Y < 2.58
0.0233	58.16	0.68	2.20	-1.28	2.54	-3.59	0.04	0.16	-0.051< A < 0.139	0.36< Y < 1.83
0.0267	66.33	0.33	1.16	-1.16	1.64	-4.68	0.02	0.12	-0.039< A < 0.088	0.18< Y < 0.89
0.0300	67.07	0.06	0.24	0.41	0.47	5.55	0.01	0.05	-0.021< A < 0.036	0.03< Y < 0.17

Table 9

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND F-W AND FILTERED CURRENT F-W (T2)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCFWT2 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	-311.32	8.48	-40.55	0.	40.55	0.	-0.13	-0.62
0.0033	3394.47	4.01	44.49	66.72	80.20	46.92	0.02	0.47
0.0067	2173.68	3.30	-43.99	-50.80	67.20	20.46	0.03	0.63
0.0100	1576.77	1.29	-2.17	55.58	55.62	-24.38	0.04	1.52
0.0133	284.19	-0.01	3.61	-16.47	16.86	-16.17	0.06	-68.89
0.0167	353.34	1.05	-17.81	26.59	32.00	-9.37	0.09	2.75
0.0200	786.33	0.25	-3.38	-10.93	11.44	10.11	0.01	0.66
0.0233	404.92	0.32	-2.38	1.87	3.02	-4.55	0.01	0.07
0.0267	284.24	0.12	-3.95	-10.60	11.31	7.25	0.04	3.65
0.0300	79.21	0.20	-4.53	8.91	10.00	-5.84	0.13	6.21

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCFWT2 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCFWT2 - ASD
0.	1541.58	6.24	1.97	33.36	33.42	0.	0.02	0.12	-0.036< A < 0.079	3.32< Y < 16.90
0.0033	2162.82	4.95	1.11	20.66	20.69	72.44	0.01	0.04	-0.036< A < 0.055	2.63< Y < 13.40
0.0067	2329.65	2.98	-11.42	5.17	12.53	-10.16	0.01	0.02	-0.029< A < 0.039	1.58< Y < 8.06
0.0100	1402.85	1.47	-11.18	10.97	15.66	-12.35	0.01	0.12	-0.018< A < 0.040	0.78< Y < 3.97
0.0133	624.62	0.58	-3.19	12.31	12.71	-15.73	0.02	0.45	-0.002< A < 0.042	0.31< Y < 1.57
0.0167	444.30	0.59	-8.84	6.44	10.94	-6.01	0.02	0.46	-0.001< A < 0.050	0.31< Y < 1.59
0.0200	582.73	0.47	-6.74	1.65	6.93	-1.91	0.01	0.18	-0.013< A < 0.037	0.25< Y < 1.27
0.0233	470.11	0.25	-3.02	-4.45	5.38	6.64	0.01	0.24	-0.008< A < 0.031	0.14< Y < 0.69
0.0267	263.16	0.19	-3.70	-2.60	4.53	3.66	0.02	0.40	-0.003< A < 0.037	0.10< Y < 0.52
0.0300	122.08	0.12	-3.22	-0.07	3.22	0.12	0.03	0.69	0.009< A < 0.043	0.06< Y < 0.33

Table 10

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T2R)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT2R ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-311.32	1.53	-21.34	0.	21.34	0.	-0.07	-0.95
0.0033	3394.47	0.17	4.72	38.32	38.61	69.15	0.01	2.51
0.0067	2173.68	2.17	-28.13	-44.78	52.88	24.11	0.02	0.59
0.0100	1576.77	2.30	-40.66	38.81	56.21	-12.13	0.04	0.87
0.0133	284.19	0.01	1.59	-14.62	14.70	-17.46	0.05	62.97
0.0167	353.34	0.33	-3.27	1.04	3.43	-2.96	0.01	0.10
0.0200	786.33	-0.07	-2.52	-1.94	3.18	5.21	0.00	-0.19
0.0233	404.92	0.60	-5.28	-2.81	5.98	3.34	0.01	0.15
0.0267	284.24	0.18	-6.44	-2.96	7.09	2.57	0.02	0.96
0.0300	79.21	0.01	0.71	0.73	1.02	4.26	0.01	2.54

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT2R ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE ECEWT2R - ASD
0.	1541.58	0.85	-8.31	19.16	20.88	0.	0.01	0.33	-0.005< A < 0.032	0.45< Y < 2.31
0.0033	2162.82	1.01	-10.01	7.96	12.79	-32.09	0.01	0.07	-0.014< A < 0.026	0.54< Y < 2.74
0.0067	2329.65	1.70	-23.05	-3.11	23.26	3.20	0.01	0.14	-0.014< A < 0.034	0.91< Y < 4.61
0.0100	1402.85	1.69	-26.96	4.55	27.34	-2.66	0.02	0.31	-0.008< A < 0.047	0.90< Y < 4.58
0.0133	624.62	0.66	-10.19	2.65	10.53	-3.04	0.02	0.27	-0.010< A < 0.044	0.35< Y < 1.80
0.0167	444.30	0.15	-1.87	-3.62	4.07	10.45	0.01	0.24	-0.006< A < 0.025	0.08< Y < 0.42
0.0200	582.73	0.20	-3.40	-1.41	3.68	3.13	0.01	0.12	-0.010< A < 0.023	0.11< Y < 0.54
0.0233	470.11	0.33	-4.88	-2.63	5.54	3.37	0.01	0.20	-0.011< A < 0.035	0.17< Y < 0.89
0.0267	263.16	0.24	-4.36	-2.00	4.80	2.56	0.02	0.36	-0.005< A < 0.042	0.13< Y < 0.66
0.0300	122.08	0.05	-1.44	-0.70	1.60	2.40	0.01	0.42	-0.002< A < 0.028	0.03< Y < 0.14

Table 11

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T4)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCEWT4 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	-196.86	0.40	-49.90	0.	49.90	0.	-0.25	-31.30
0.0033	3400.88	0.73	17.47	13.36	21.99	31.17	0.01	0.20
0.0067	2276.06	2.39	-1.55	3.40	3.73	-27.28	0.00	0.00
0.0100	1610.35	2.10	-60.79	21.50	64.48	-5.41	0.04	1.23
0.0133	323.68	0.68	21.09	-4.83	21.63	-2.69	0.07	2.13
0.0167	380.45	0.77	8.15	10.63	13.39	8.75	0.04	0.61
0.0200	767.27	1.57	-24.17	-15.26	28.58	4.48	0.04	0.68
0.0233	415.68	0.53	-10.47	-4.04	11.23	2.51	0.03	0.57
0.0267	288.73	0.28	-9.19	4.33	10.16	-2.63	0.04	1.28
0.0300	58.16	0.13	-0.38	-4.96	4.98	7.92	0.09	3.29

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCEWT4 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCEWT4 - ASD
0.	1602.01	0.57	-16.21	6.68	17.54	0.	0.01	0.34	-0.004< A < 0.026	0.30< Y < 1.53
0.0033	2220.24	1.06	-4.13	7.53	8.58	-51.05	0.00	0.03	-0.017< A < 0.025	0.57< Y < 2.88
0.0067	2390.84	1.90	-11.61	10.41	15.59	-17.46	0.01	0.05	-0.020< A < 0.033	1.01< Y < 5.15
0.0100	1455.11	1.82	-25.51	10.39	27.55	-6.16	0.02	0.29	-0.010< A < 0.048	0.97< Y < 4.92
0.0133	659.54	1.06	-2.62	5.67	6.20	-13.54	0.01	0.06	-0.028< A < 0.047	0.56< Y < 2.86
0.0167	462.96	0.95	3.30	0.29	3.32	0.84	0.01	0.03	-0.036< A < 0.050	0.50< Y < 2.56
0.0200	582.67	1.11	-12.66	-5.98	14.01	3.51	0.02	0.30	-0.011< A < 0.059	0.59< Y < 3.00
0.0233	471.84	0.73	-13.58	-4.75	14.38	2.30	0.03	0.60	0.007< A < 0.054	0.39< Y < 1.96
0.0267	262.83	0.30	-7.31	-0.09	7.31	0.07	0.03	0.67	0.009< A < 0.047	0.16< Y < 0.82
0.0300	109.51	0.13	-2.46	-0.65	2.55	1.37	0.02	0.47	-0.001< A < 0.047	0.07< Y < 0.34

Table 12

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T4)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST4 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	786.81	0.61	22.24	0.	22.24	0.	0.03	1.04
0.0033	7758.99	2.74	143.62	17.03	144.63	5.63	0.02	0.99
0.0067	1622.39	1.10	-4.27	-0.86	4.36	4.76	0.00	0.01
0.0100	662.89	0.85	20.84	-25.65	33.05	-14.14	0.05	1.93
0.0133	413.44	0.96	-10.20	9.42	13.89	-8.90	0.03	0.48
0.0167	421.65	0.56	-0.01	3.21	3.21	-14.96	0.01	0.04
0.0200	5.38	0.42	5.54	4.47	7.11	5.40	1.32	22.50
0.0233	129.44	0.77	0.90	3.71	3.82	9.09	0.03	.15
0.0267	1.70	0.33	-2.60	-0.50	2.65	1.14	1.55	12.61
0.0300	149.02	0.00	1.49	-2.72	3.10	-5.68	0.02	16.05

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST4 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCNST4 - ASD
0.	4272.90	1.67	82.93	8.51	83.37	0.	0.02	0.97	0.016< A < 0.023	0.89< Y < 4.52
0.0033	4481.79	1.79	76.30	8.30	76.75	5.17	0.02	0.73	0.007< A < 0.027	0.95< Y < 4.86
0.0067	2916.66	1.45	38.98	-2.59	39.07	-1.58	0.01	0.36	-0.004< A < 0.031	0.77< Y < 3.92
0.0100	840.40	0.94	6.80	-10.69	12.67	-15.98	0.02	0.20	-0.014< A < 0.044	0.50< Y < 2.55
0.0133	477.85	0.84	0.10	-0.90	0.90	-17.36	0.00	0.00	-0.038< A < 0.042	0.44< Y < 2.26
0.0167	315.53	0.63	-1.17	5.08	5.21	-12.83	0.02	0.14	-0.023< A < 0.056	0.33< Y < 1.70
0.0200	140.46	0.54	2.99	3.96	4.97	7.36	0.04	0.32	-0.014< A < 0.085	0.29< Y < 1.47
0.0233	66.49	0.57	1.18	2.84	3.08	8.03	0.05	0.25	-0.031< A < 0.124	0.30< Y < 1.55
0.0267	70.47	0.36	-0.70	-0.01	0.70	0.05	0.01	0.02	-0.058< A < 0.078	0.19< Y < 0.96
0.0300	62.18	0.08	-0.15	-1.33	1.34	7.73	0.02	0.35	-0.007< A < 0.050	0.04< Y < 0.22

Table 13

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T5)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCEWTS ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	196.86	34.23	-64.40	0.	64.40	0.	-0.33	-0.62
0.0033	3400.88	25.47	60.71	217.86	226.16	62.02	0.07	0.59
0.0067	2276.06	-1.16	-33.92	-146.54	150.42	32.07	0.07	-8.60
0.0100	1610.35	2.21	-27.71	21.45	35.04	-10.49	0.02	0.34
0.0133	323.68	-0.54	-2.53	-48.22	48.29	18.12	0.15	-13.36
0.0167	380.45	1.04	1.70	28.42	28.47	14.43	0.07	2.05
0.0200	767.27	-0.46	-2.82	-35.70	35.81	11.87	0.05	-3.65
0.0233	415.68	0.55	-0.98	17.92	17.95	-10.34	0.04	1.41
0.0267	288.73	-0.00	-1.17	-20.68	20.72	9.04	0.07	-364.62
0.0300	58.16	0.29	-2.69	18.08	18.28	-7.55	0.31	19.88

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCEWTS ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FCEWTS - ASD
0.	1602.01	29.85	-1.85	108.93	108.94	0.	0.07	0.25	-0.046< A < 0.182	15.88< Y < 80.80
0.0033	2220.24	21.00	5.77	72.29	72.52	71.19	0.03	0.11	-0.056< A < 0.121	11.17< Y < 56.85
0.0067	2390.84	6.34	-8.71	-13.45	16.02	23.78	0.01	0.02	-0.043< A < 0.056	3.37< Y < 17.17
0.0100	1455.11	0.68	-22.97	-37.97	44.37	16.34	0.03	1.98	0.010< A < 0.051	0.36< Y < 1.85
0.0133	659.54	0.54	-7.77	-11.64	14.00	11.73	0.02	0.55	0.003< A < 0.040	0.29< Y < 1.47
0.0167	462.96	0.27	-0.49	-6.77	6.79	14.31	0.01	0.37	-0.004< A < 0.033	0.14< Y < 0.73
0.0200	582.67	0.17	-1.23	-6.26	6.38	10.96	0.01	0.42	-0.002< A < 0.023	0.09< Y < 0.45
0.0233	471.84	0.16	-1.48	-5.14	5.35	8.79	0.01	0.38	-0.003< A < 0.025	0.08< Y < 0.43
0.0267	262.83	0.21	-1.50	-1.34	2.01	4.36	0.01	0.07	-0.018< A < 0.034	0.11< Y < 0.56
0.0300	109.51	0.09	-1.11	0.14	1.12	-0.67	0.01	0.13	-0.015< A < 0.035	0.05< Y < 0.23

Table 14

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T5)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNSTS ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	786.81	20.58	-83.29	0.	83.29	0.	0.11	0.43
0.0033	7758.99	11.80	-131.98	-271.89	302.23	53.42	0.04	1.00
0.0067	1622.39	0.30	26.28	78.71	82.98	29.81	0.05	14.05
0.0100	662.89	1.47	8.62	-80.08	80.54	-23.29	0.12	6.68
0.0133	413.44	-0.34	1.88	35.21	35.26	18.11	0.09	-8.81
0.0167	421.65	0.65	3.99	-42.43	42.61	-14.11	0.10	6.60
0.0200	5.38	-0.05	0.57	30.65	30.66	12.35	5.70	-3180.98
0.0233	129.44	0.28	3.79	-28.34	28.60	-9.81	0.22	22.66
0.0267	1.70	-0.13	0.86	24.32	24.33	9.16	14.28	-2753.63
0.0300	149.02	0.10	0.74	-20.42	20.44	-8.14	0.14	27.07

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNSTS ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCNSTS - ASD
0.	4272.90	16.19	-107.63	-135.94	173.40	0.	0.04	0.43	-0.004< A < 0.085	8.61< Y < 43.82
0.0033	4481.79	11.12	-80.24	-116.27	141.27	46.16	0.03	0.40	-0.006< A < 0.069	5.92< Y < 30.10
0.0067	2916.66	3.47	-17.70	-48.64	51.76	29.17	0.02	0.26	-0.011< A < 0.046	1.84< Y < 9.39
0.0100	840.40	0.72	11.35	-11.56	16.20	-12.65	0.02	0.43	-0.002< A < 0.041	0.38< Y < 1.96
0.0133	477.85	0.36	4.09	-13.02	13.65	-15.11	0.03	1.09	0.021< A < 0.036	0.19< Y < 0.97
0.0167	315.53	0.23	2.61	-4.75	5.42	-10.20	0.02	0.41	-0.003< A < 0.037	0.12< Y < 0.61
0.0200	140.46	0.21	2.23	-2.37	3.25	-6.49	0.02	0.37	-0.006< A < 0.053	0.11< Y < 0.56
0.0233	66.49	0.09	2.25	-0.43	2.29	-1.29	0.03	0.84	0.020< A < 0.049	0.05< Y < 0.25
0.0267	70.47	0.03	1.56	-0.03	1.56	-0.13	0.02	1.06	0.017< A < 0.027	0.02< Y < 0.09
0.0300	62.18	-0.00	0.46	0.61	0.76	4.90	0.01	-2.69	-0.002< A < 0.026	-0.00< Y < -0.01

Table 15

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T5B)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT5B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-196.86	0.19	-27.06	0.	27.06	0.	-0.14	-19.16
0.0033	3400.88	1.35	-25.07	11.13	27.43	-19.95	0.01	0.16
0.0067	2276.06	0.49	10.11	18.87	21.41	25.75	0.01	0.41
0.0100	1610.35	0.26	-16.61	-17.43	24.07	12.88	0.01	1.41
0.0133	323.68	0.30	12.83	11.10	16.97	8.51	0.05	2.99
0.0167	380.45	0.05	-0.47	-4.64	4.67	14.03	0.01	1.11
0.0200	767.27	0.17	-1.12	4.62	4.75	-10.60	0.01	0.17
0.0233	415.68	0.03	-0.38	-4.20	4.22	10.10	0.01	1.53
0.0267	288.73	0.03	-1.49	6.51	6.68	-8.03	0.02	5.33
0.0300	58.16	0.02	0.29	-5.57	5.57	-8.06	0.10	26.50

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT5B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE ECEWT5B - ASD
0.	1602.01	0.77	-26.06	5.57	26.65	0.	0.02	0.57	0.003< A < 0.030	0.41< Y < 2.09
0.0033	2220.24	0.85	-16.77	10.28	19.67	-26.26	0.01	0.21	-0.008< A < 0.026	0.45< Y < 2.29
0.0067	2390.84	0.65	-5.36	7.86	9.52	-23.21	0.00	0.06	-0.011< A < 0.019	0.34< Y < 1.75
0.0100	1455.11	0.33	-2.57	-1.22	2.84	7.06	0.00	0.02	-0.012< A < 0.016	0.17< Y < 0.88
0.0133	659.54	0.23	2.15	0.03	2.15	0.18	0.00	0.03	-0.014< A < 0.021	0.12< Y < 0.61
0.0167	462.96	0.14	2.69	1.61	3.14	5.14	0.01	0.15	-0.009< A < 0.022	0.08< Y < 0.39
0.0200	582.67	0.10	-0.78	0.10	0.78	-0.99	0.00	0.01	-0.012< A < 0.014	0.06< Y < 0.28
0.0233	471.84	0.06	-0.84	0.68	1.08	-4.63	0.00	0.04	-0.009< A < 0.013	0.03< Y < 0.17
0.0267	262.83	0.03	-0.77	0.81	1.12	-4.87	0.00	0.18	-0.005< A < 0.013	0.01< Y < 0.07
0.0300	109.51	0.02	-0.13	-0.27	0.30	5.94	0.00	0.04	-0.010< A < 0.015	0.01< Y < 0.05

Table 16

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T5B)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNSTSB ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	786.81	3.71	-30.15	0.	30.15	0.	0.04	0.31
0.0033	7758.99	4.61	-133.54	-124.86	182.81	35.90	0.02	0.93
0.0067	1622.39	-0.03	22.51	56.28	60.61	28.42	0.04	-64.71
0.0100	662.89	1.24	7.75	-46.39	47.03	-22.37	0.07	2.70
0.0133	413.44	0.56	-16.27	33.38	37.13	-13.34	0.09	5.94
0.0167	421.65	0.54	-7.02	-20.20	21.39	11.81	0.05	2.01
0.0200	5.38	0.29	-3.72	18.16	18.54	-10.89	3.45	217.67
0.0233	129.44	0.11	-1.37	-12.66	12.74	9.98	0.10	11.22
0.0267	1.70	0.03	0.73	11.62	11.65	9.00	6.83	3002.53
0.0300	149.02	0.04	-0.96	-12.58	12.61	7.93	0.08	28.90

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNSTSB ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FCNSTSB - ASD
0.	4272.90	4.16	-81.84	-62.43	102.94	0.	0.02	0.60	0.005< A < 0.043	2.21< Y < 11.26
0.0033	4481.79	3.22	-68.68	-48.36	84.00	29.29	0.02	0.49	0.000< A < 0.037	1.72< Y < 8.73
0.0067	2916.66	1.45	-20.19	-14.67	24.96	15.00	0.01	0.15	-0.011< A < 0.028	0.77< Y < 3.91
0.0100	840.40	0.75	5.44	-0.78	5.49	-2.27	0.01	0.05	-0.022< A < 0.035	0.40< Y < 2.03
0.0133	477.85	0.72	-7.95	0.04	7.95	-0.06	0.02	0.18	-0.017< A < 0.051	0.39< Y < 1.96
0.0167	315.53	0.48	-8.51	2.78	8.95	-3.02	0.03	0.52	0.002< A < 0.054	0.26< Y < 1.31
0.0200	140.46	0.31	-3.96	0.86	4.05	-1.71	0.03	0.38	-0.007< A < 0.065	0.16< Y < 0.84
0.0233	66.49	0.14	-1.43	1.11	1.81	-4.51	0.03	0.36	-0.008< A < 0.062	0.07< Y < 0.37
0.0267	70.47	0.05	-0.21	-0.50	0.54	6.96	0.01	0.08	-0.017< A < 0.032	0.03< Y < 0.14
0.0300	62.18	0.02	-0.21	-0.89	0.91	7.11	0.01	0.70	0.005< A < 0.024	0.01< Y < 0.05

Table 17

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND F-W AND FILTERED CURRENT F-W (T6)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTFW ASD	FCEWT6 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	-311.32	1.40	-18.96	0.	18.96	0.	-0.06	-0.82
0.0033	3394.47	0.71	-19.71	31.55	37.20	-48.34	0.01	0.58
0.0067	2173.68	-0.10	13.28	-16.40	21.10	-21.26	0.01	-2.05
0.0100	1576.77	0.10	-11.79	13.95	18.27	-13.83	0.01	2.06
0.0133	284.19	0.28	5.52	-5.82	8.03	-9.69	0.03	0.82
0.0167	353.34	0.12	-0.94	-0.55	1.08	5.07	0.00	0.03
0.0200	786.33	0.01	-0.85	-2.53	2.67	9.91	0.00	0.79
0.0233	404.92	0.06	1.78	2.91	3.41	6.98	0.01	0.45
0.0267	284.24	-0.01	0.02	-3.34	3.34	-9.34	0.01	-6.47
0.0300	79.21	0.04	0.52	1.80	1.87	6.85	0.02	1.19

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTFW ASD	FCEWT6 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCEWT6 - ASD
0.	1541.58	1.06	-19.34	15.78	24.96	0.	0.02	0.38	-0.004< A < 0.036	0.56< Y < 2.86
0.0033	2162.82	0.68	-11.28	11.67	16.23	-38.33	0.01	0.18	-0.008< A < 0.023	0.36< Y < 1.84
0.0067	2329.65	0.15	-1.24	3.17	3.41	-28.63	0.00	0.03	-0.006< A < 0.009	0.08< Y < 0.41
0.0100	1402.85	0.10	-1.20	1.42	1.86	-13.86	0.00	0.03	-0.007< A < 0.009	0.05< Y < 0.26
0.0133	624.62	0.19	-0.42	0.44	0.61	-9.63	0.00	0.00	-0.016< A < 0.018	0.10< Y < 0.53
0.0167	444.30	0.13	0.70	-2.36	2.46	-12.25	0.01	0.10	-0.010< A < 0.021	0.07< Y < 0.36
0.0200	582.73	0.05	-0.22	-0.67	0.71	10.04	0.00	0.02	-0.008< A < 0.010	0.03< Y < 0.14
0.0233	470.11	0.03	0.68	-0.01	0.68	-0.10	0.00	0.03	-0.007< A < 0.009	0.02< Y < 0.09
0.0267	263.16	0.02	0.58	-0.49	0.76	-4.18	0.00	0.10	-0.005< A < 0.011	0.01< Y < 0.06
0.0300	122.08	0.02	0.23	-0.46	0.51	-5.84	0.00	0.13	-0.006< A < 0.015	0.01< Y < 0.05

Table 18

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T7)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT7 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-173.52	0.31	-0.94	0.	0.94	0.	-0.01	-0.02
0.0033	3245.88	0.12	-17.53	13.98	22.42	-32.15	0.01	1.31
0.0067	2259.46	0.16	16.29	5.22	17.10	7.40	0.01	0.79
0.0100	1579.03	0.22	-2.54	13.96	14.19	-22.13	0.01	0.57
0.0133	337.31	0.34	3.57	2.82	4.55	7.98	0.01	0.18
0.0167	397.09	0.19	-1.22	-5.10	5.24	12.76	0.01	0.36
0.0200	762.86	0.17	10.58	-3.46	11.13	-2.52	0.01	0.95
0.0233	398.84	0.07	4.07	0.63	4.12	1.04	0.01	0.59
0.0267	262.19	0.01	1.11	0.47	1.20	2.42	0.00	0.37
0.0300	38.71	0.02	-0.10	-0.18	0.21	5.64	0.01	0.07

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT7 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE ECEWT7 - ASD
0.	1536.18	0.21	-9.23	6.99	11.58	0.	0.01	0.41	-0.001< A < 0.016	0.11< Y < 0.58
0.0033	2144.42	0.18	-4.93	8.29	9.65	-49.41	0.00	0.24	-0.003< A < 0.012	0.09< Y < 0.48
0.0067	2335.96	0.17	3.13	9.59	10.09	29.98	0.00	0.26	-0.005< A < 0.011	0.09< Y < 0.45
0.0100	1438.71	0.24	3.69	8.99	9.72	18.79	0.01	0.27	-0.004< A < 0.017	0.13< Y < 0.65
0.0133	662.69	0.28	0.85	3.62	3.72	16.01	0.01	0.08	-0.013< A < 0.025	0.15< Y < 0.75
0.0167	473.59	0.23	2.93	-2.71	3.99	-7.13	0.01	0.15	-0.011< A < 0.028	0.12< Y < 0.61
0.0200	580.41	0.15	6.00	-2.85	6.65	-3.53	0.01	0.50	0.000< A < 0.022	0.08< Y < 0.41
0.0233	455.68	0.08	4.96	-0.44	4.98	-0.60	0.01	0.66	0.003< A < 0.018	0.04< Y < 0.22
0.0267	240.49	0.03	1.55	0.35	1.58	1.32	0.01	0.36	-0.002< A < 0.015	0.02< Y < 0.08
0.0300	89.99	0.01	0.32	-0.08	0.33	-1.28	0.00	0.12	-0.006< A < 0.014	0.01< Y < 0.03

Table 19

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT N-S (T7)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FENST7 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-173.52	0.06	22.39	0.	22.39	0.	-0.13	-50.95
0.0033	3245.88	0.45	-16.60	-16.11	23.14	36.79	0.01	0.37
0.0067	2259.46	0.02	-2.27	-2.10	3.09	17.86	0.00	0.25
0.0100	1579.03	0.11	3.18	5.23	6.12	16.31	0.00	0.21
0.0133	337.31	0.10	2.96	-1.71	3.41	-6.26	0.01	0.33
0.0167	397.09	0.04	2.59	0.14	2.60	0.51	0.01	0.38
0.0200	762.86	0.22	7.44	-4.99	8.95	-4.70	0.01	0.49
0.0233	398.84	-0.01	0.70	-2.44	2.54	-8.81	0.01	-1.10
0.0267	262.19	0.19	1.08	2.09	2.35	6.53	0.01	0.11
0.0300	38.71	0.01 *	1.53	1.08	1.87	3.28	0.05	15.59

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FENST7 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FENST7 - ASD
0.	1536.18	0.25	2.89	-8.06	8.56	0.	0.01	0.19	-0.006< A < 0.017	0.13< Y < 0.68
0.0033	2144.42	0.24	-3.27	-8.58	9.19	57.61	0.00	0.16	-0.005< A < 0.014	0.13< Y < 0.66
0.0067	2335.96	0.15	-4.49	-3.77	5.87	16.69	0.00	0.10	-0.005< A < 0.010	0.08< Y < 0.40
0.0100	1438.71	0.09	1.76	1.66	2.42	12.04	0.00	0.05	-0.006< A < 0.009	0.05< Y < 0.24
0.0133	662.69	0.09	2.92	0.49	2.96	1.98	0.00	0.14	-0.006< A < 0.015	0.05< Y < 0.25
0.0167	473.59	0.10	3.90	-1.60	4.21	-3.73	0.01	0.37	-0.002< A < 0.020	0.05< Y < 0.28
0.0200	580.41	0.11	4.54	-3.07	5.48	-4.73	0.01	0.45	-0.001< A < 0.020	0.06< Y < 0.31
0.0233	455.68	0.09	2.48	-1.94	3.15	-4.54	0.01	0.23	-0.005< A < 0.019	0.05< Y < 0.26
0.0267	240.48	0.09	1.10	0.71	1.30	3.42	0.01	0.08	-0.013< A < 0.024	0.05< Y < 0.25
0.0300	89.90	0.05	0.79	1.08	1.33	4.99	0.01	0.39	-0.003< A < 0.033	0.03< Y < 0.14

Table 20

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T7)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST7 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	224.13	0.06	-21.06	0.	21.06	0.	0.09	34.91
0.0033	7795.80	0.45	28.17	47.37	55.12	49.38	0.01	0.87
0.0067	1949.73	0.02	9.47	-6.47	11.47	-14.31	0.01	4.04
0.0100	834.66	0.11	5.52	-7.05	8.95	-14.42	0.01	0.84
0.0133	414.90	0.10	-0.88	-0.18	0.90	2.41	0.00	0.02
0.0167	414.66	0.04	-3.19	0.41	3.22	-1.22	0.01	0.56
0.0200	-1.25	0.22	2.70	-1.64	3.16	-4.34	-2.54	-37.28
0.0233	89.67	-0.01	-1.42	2.71	3.06	-7.43	0.03	-7.11
0.0267	21.98	0.19	-1.74	-2.03	2.67	5.14	0.12	1.69
0.0300	126.61	0.01	-1.29	0.15	1.30	-0.62	0.01	2.30

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST7 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCNST7 - ASD
0.	4009.97	0.25	3.56	23.69	23.95	0.	0.01	0.57	0.001< A < 0.011	0.13< Y < 0.68
0.0033	4441.37	0.24	11.19	22.07	24.74	52.60	0.01	0.57	0.001< A < 0.010	0.13< Y < 0.66
0.0067	3132.48	0.15	13.16	6.85	14.83	11.45	0.00	0.47	-0.000< A < 0.010	0.08< Y < 0.40
0.0100	1008.49	0.09	4.91	-5.19	7.14	-12.94	0.01	0.58	0.001< A < 0.013	0.05< Y < 0.24
0.0133	519.78	0.09	0.14	-1.75	1.75	-17.78	0.00	0.06	-0.009< A < 0.016	0.05< Y < 0.25
0.0167	310.75	0.10	-1.14	-0.25	1.17	2.05	0.00	0.04	-0.013< A < 0.021	0.05< Y < 0.28
0.0200	125.46	0.11	0.20	-0.04	0.20	-1.54	0.00	0.00	-0.028< A < 0.031	0.06< Y < 0.31
0.0233	50.02	0.09	-0.47	0.44	0.64	-5.14	0.01	0.09	-0.027< A < 0.053	0.05< Y < 0.26
0.0267	65.06	0.09	-1.55	-0.30	1.57	1.13	0.02	0.41	-0.004< A < 0.052	0.05< Y < 0.25
0.0300	56.13	0.05	-0.91	-0.53	1.05	2.82	0.02	0.39	-0.004< A < 0.041	0.03< Y < 0.14

Table 21

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T8)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCEWTA ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	-491.70	8.99	-18.24	0.	18.24	0.	-0.04	-0.08
0.0033	3403.10	3.75	0.49	102.65	102.65	74.77	0.03	0.83
0.0067	2048.12	-0.41	-9.27	-21.31	23.24	27.70	0.01	-0.64
0.0100	1506.88	0.51	-24.63	11.06	27.00	-6.72	0.02	0.94
0.0133	213.47	-0.21	3.23	-10.99	11.46	-15.33	0.05	-2.87
0.0167	306.12	0.30	-9.37	7.08	11.74	-6.18	0.04	1.49
0.0200	783.73	-0.00	4.67	-13.42	14.21	-9.84	0.02	-79.87
0.0233	345.38	0.16	0.33	5.69	5.70	10.32	0.02	0.60
0.0267	259.07	0.01	-2.45	-8.13	8.49	7.63	0.03	29.68
0.0300	100.54	0.06	-0.96	3.75	3.87	-7.01	0.04	2.47

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTEW ASD	FCEWTA ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCEWTA - ASD
0.	1455.70	6.37	-8.88	51.32	52.09	0.	0.04	0.29	-0.018< A < 0.089	3.39< Y < 17.25
0.0033	2090.66	4.02	-6.63	46.00	46.47	-68.16	0.02	0.26	-0.014< A < 0.059	2.14< Y < 10.89
0.0067	2251.56	0.86	-10.67	17.77	20.73	-24.59	0.01	0.22	-0.007< A < 0.026	0.46< Y < 2.33
0.0100	1318.84	0.10	-13.83	-2.54	14.06	2.90	0.01	1.48	0.005< A < 0.017	0.05< Y < 0.27
0.0133	559.99	0.10	-6.88	-0.96	6.95	1.66	0.01	0.89	0.008< A < 0.017	0.05< Y < 0.26
0.0167	402.36	0.10	-2.71	-2.57	3.73	7.24	0.01	0.36	-0.003< A < 0.021	0.05< Y < 0.26
0.0200	554.74	0.11	0.07	-3.52	3.52	-12.33	0.01	0.20	-0.006< A < 0.019	0.06< Y < 0.31
0.0233	433.39	0.08	0.72	-2.54	2.64	-8.83	0.01	0.20	-0.006< A < 0.018	0.04< Y < 0.22
0.0267	241.01	0.06	-1.38	-1.71	2.19	5.31	0.01	0.34	-0.003< A < 0.021	0.03< Y < 0.16
0.0300	130.39	0.02	-0.81	-1.32	1.55	5.40	0.01	0.87	0.007< A < 0.016	0.01< Y < 0.06

Table 22

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T9)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FCEWT9 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-311.32	3.98	-6.65	0.	6.65	0.	-0.02	-0.04
0.0033	3394.47	1.65	18.81	67.87	70.43	62.09	0.02	0.89
0.0067	2173.68	-0.03	-5.33	-32.97	33.40	33.67	0.02	-16.31
0.0100	1576.77	0.45	-19.78	25.38	32.18	-14.46	0.02	1.45
0.0133	284.19	0.00	2.59	-9.54	9.89	-15.58	0.03	166.34
0.0167	353.34	0.18	-0.80	1.95	2.10	-11.28	0.01	0.07
0.0200	786.33	-0.05	5.35	-8.67	10.19	-8.10	0.01	-2.89
0.0233	404.92	0.06	-0.55	5.89	5.91	-10.08	0.01	1.37
0.0267	284.24	0.01	-1.52	-3.49	3.80	6.92	0.01	6.10
0.0300	79.21	0.03	0.79	2.72	2.83	6.83	0.04	3.77

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	FCEWT9 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE FCEWT9 - ASD
0.	1541.58	2.81	6.08	33.93	34.47	0.	0.02	0.27	-0.013< A < 0.058	1.50< Y < 7.62
0.0033	2162.82	1.81	6.41	25.69	26.48	63.33	0.01	0.18	-0.013< A < 0.038	0.96< Y < 4.90
0.0067	2329.65	0.51	-2.91	6.83	7.42	-27.88	0.00	0.05	-0.011< A < 0.017	0.27< Y < 1.38
0.0100	1402.85	0.22	-10.58	2.06	10.78	-3.07	0.01	0.38	-0.002< A < 0.017	0.12< Y < 0.59
0.0133	624.62	0.16	-3.85	2.06	4.37	-5.87	0.01	0.19	-0.007< A < 0.021	0.09< Y < 0.43
0.0167	444.30	0.08	1.59	-3.58	3.92	-11.02	0.01	0.42	-0.001< A < 0.019	0.04< Y < 0.22
0.0200	582.73	0.04	2.34	-2.38	3.34	-6.32	0.01	0.49	0.000< A < 0.011	0.02< Y < 0.11
0.0233	470.11	0.02	0.68	-0.10	0.69	-0.97	0.00	0.05	-0.005< A < 0.008	0.01< Y < 0.06
0.0267	263.16	0.03	-0.70	0.41	0.81	-3.15	0.00	0.09	-0.006< A < 0.012	0.01< Y < 0.07
0.0300	122.08	0.01	-0.02	-0.31	0.31	7.93	0.00	0.08	-0.006< A < 0.011	0.01< Y < 0.03

Table 23

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T10)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT10 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-491.70	4.04	-26.70	0.	26.70	0.	-0.05	-0.36
0.0033	3403.10	2.06	-2.35	67.83	67.87	-73.35	0.02	0.66
0.0067	2048.12	-0.07	3.07	-13.63	13.97	-32.20	0.01	-1.31
0.0100	1506.88	0.55	-9.25	30.76	32.12	-20.35	0.02	1.24
0.0133	213.47	0.02	3.88	-10.75	11.43	-14.62	0.05	25.26
0.0167	306.12	0.16	3.75	5.90	6.99	9.59	0.02	1.00
0.0200	783.73	0.04	-5.59	-2.68	6.20	3.55	0.01	1.22
0.0233	345.38	0.02	-0.47	5.80	5.81	-10.16	0.02	5.99
0.0267	259.07	0.01	0.35	-4.61	4.62	-8.92	0.02	14.28
0.0300	100.54	0.01	0.54	2.75	2.80	7.31	0.03	6.26

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT10 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE ECEWT10- ASD
0.	1455.70	3.05	-14.53	33.91	36.89	0.	0.03	0.31	-0.011< A < 0.062	1.62< Y < 8.26
0.0033	2090.66	2.02	-7.08	30.51	31.32	-64.11	0.01	0.23	-0.011< A < 0.041	1.07< Y < 5.47
0.0067	2251.56	0.61	-1.36	17.83	17.88	-35.68	0.01	0.23	-0.006< A < 0.022	0.33< Y < 1.66
0.0100	1318.84	0.26	-2.89	9.28	9.72	-20.20	0.01	0.27	-0.004< A < 0.019	0.14< Y < 0.71
0.0133	559.99	0.19	0.56	3.79	3.87	16.99	0.01	0.14	-0.010< A < 0.023	0.10< Y < 0.51
0.0167	402.36	0.10	1.45	-0.41	1.50	-2.62	0.00	0.06	-0.011< A < 0.018	0.05< Y < 0.26
0.0200	554.74	0.06	-1.98	1.59	2.53	-5.38	0.00	0.18	-0.005< A < 0.014	0.03< Y < 0.17
0.0233	433.39	0.02	-1.55	1.08	1.88	-4.15	0.00	0.42	-0.001< A < 0.009	0.01< Y < 0.05
0.0267	241.01	0.01	0.19	-0.17	0.26	-4.28	0.00	0.03	-0.005< A < 0.007	0.01< Y < 0.03
0.0300	130.39	0.00	0.38	-0.56	0.68	-5.21	0.01	0.74	0.002< A < 0.008	0.00< Y < 0.01

Table 24

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T11)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST11 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	905.72	6.35	-1.56	0.	1.56	0.	0.00	0.00
0.0033	7697.96	4.28	-11.74	108.32	108.95	-69.85	0.01	0.36
0.0067	1758.84	1.94	51.34	-96.28	109.11	-25.80	0.06	3.50
0.0100	519.91	0.03	-13.06	44.52	46.39	-20.46	0.09	127.40
0.0133	433.68	0.30	14.22	-27.17	30.66	-12.99	0.07	7.34
0.0167	304.66	1.00	8.53	18.37	20.26	10.85	0.07	1.35
0.0200	6.83	0.48	-5.10	-16.72	17.48	10.14	2.56	93.71
0.0233	106.02	0.17	-0.84	15.01	15.03	-10.33	0.14	12.60
0.0267	2.12	0.49	0.83	-8.44	8.48	-8.79	4.01	69.92
0.0300	159.14	-0.13	-0.23	11.04	11.04	-8.22	0.07	-5.76

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST11 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCNST11- ASD
0.	4301.84	5.31	-6.65	54.16	54.56	0.	0.01	0.13	-0.019< A < 0.044	2.83< Y < 14.38
0.0033	4515.12	4.21	6.58	30.09	30.80	64.72	0.01	0.05	-0.022< A < 0.036	2.24< Y < 11.39
0.0067	2933.89	2.05	19.47	-9.93	21.86	-11.26	0.01	0.08	-0.017< A < 0.032	1.09< Y < 5.54
0.0100	808.08	0.57	9.86	-8.60	13.08	-11.42	0.02	0.37	-0.004< A < 0.037	0.31< Y < 1.55
0.0133	422.98	0.41	5.98	2.14	6.35	4.10	0.02	0.24	-0.011< A < 0.041	0.22< Y < 1.10
0.0167	262.46	0.69	6.55	-1.79	6.78	-2.54	0.03	0.25	-0.017< A < 0.069	0.37< Y < 1.87
0.0200	106.09	0.53	-0.63	-0.02	0.63	0.20	0.01	0.01	-0.062< A < 0.074	0.28< Y < 1.44
0.0233	55.25	0.33	-1.49	1.21	1.92	-4.67	0.03	0.20	-0.031< A < 0.101	0.17< Y < 0.88
0.0267	67.35	0.25	0.15	2.29	2.29	8.99	0.03	0.31	-0.015< A < 0.083	0.13< Y < 0.68
0.0300	67.21	0.08	0.22	1.17	1.19	7.35	0.02	0.27	-0.010< A < 0.046	0.04< Y < 0.21

Table 25

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND N-S AND FILTERED CURRENT N-S (T11B)

RAW SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST11B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED
0.	205.72	0.80	-25.43	0.	25.43	0.	0.03	0.90
0.0033	7697.96	1.23	-14.45	63.29	64.92	-64.28	0.01	0.45
0.0067	1758.84	0.91	23.90	-48.29	53.88	-26.53	0.03	1.82
0.0100	519.91	0.09	-12.00	8.40	14.64	-9.72	0.03	4.57
0.0133	433.68	0.29	4.48	-5.58	7.16	-10.68	0.02	0.41
0.0167	304.66	0.21	4.49	5.17	6.85	8.17	0.02	0.74
0.0200	6.83	0.55	-4.01	-1.29	4.21	2.49	0.62	4.72
0.0233	106.02	0.24	-2.50	5.02	5.61	-7.57	0.05	1.23
0.0267	2.12	0.15	1.60	-4.17	4.47	-7.18	2.11	64.89
0.0300	159.14	-0.00	-1.83	4.99	5.32	-6.47	0.03	-257.34

TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	FASTNS ASD	FCNST11B ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	RFA	COHERENCY SQUARED	CONFIDENCE RFA	CONFIDENCE FCNST11B- ASD
0.	4301.84	1.01	-19.94	31.64	37.40	0.	0.01	0.32	-0.004< A < 0.021	0.54< Y < 2.74
0.0033	4515.12	1.04	-7.61	19.57	21.00	-57.30	0.00	0.09	-0.009< A < 0.019	0.55< Y < 2.82
0.0067	2933.89	0.78	5.34	-6.22	8.20	-20.57	0.00	0.03	-0.013< A < 0.018	0.42< Y < 2.12
0.0100	808.08	0.35	1.10	-9.27	9.33	-23.13	0.01	0.31	-0.005< A < 0.028	0.18< Y < 0.93
0.0133	422.98	0.22	0.36	0.60	0.70	12.26	0.00	0.01	-0.020< A < 0.024	0.12< Y < 0.60
0.0167	262.46	0.31	2.36	0.87	2.52	3.35	0.01	0.08	-0.022< A < 0.042	0.17< Y < 0.85
0.0200	106.09	0.39	-1.51	1.90	2.42	-7.17	0.02	0.14	-0.031< A < 0.077	0.21< Y < 1.05
0.0233	55.25	0.29	-1.85	1.14	2.17	-3.78	0.04	0.29	-0.020< A < 0.099	0.16< Y < 0.80
0.0267	67.35	0.13	-0.28	0.42	0.50	-5.86	0.01	0.03	-0.035< A < 0.050	0.07< Y < 0.36
0.0300	67.21	0.04	-0.26	0.62	0.68	-6.26	0.01	0.17	-0.011< A < 0.031	0.02< Y < 0.11

Table 25

CROSS SPECTRAL ANALYSIS RESULTS

FILTERED ASTORIA WIND E-W AND FILTERED CURRENT E-W (T12)

RAW SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT12 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED
0.	-541.37	3.55	-28.39	0.	28.39	0.	-0.05	-0.42
0.0033	3413.28	2.09	-41.68	39.36	57.33	-36.13	0.02	0.46
0.0067	2093.51	0.04	7.88	-7.64	10.98	-18.38	0.01	1.31
0.0100	1494.44	0.25	-4.88	10.24	11.35	-17.92	0.01	0.34
0.0133	196.08	0.15	4.90	0.78	4.97	1.89	0.03	0.82
0.0167	314.09	0.25	1.61	-0.16	1.62	-0.97	0.01	0.03
0.0200	776.42	0.12	-0.99	-0.40	1.07	3.06	0.00	0.01
0.0233	305.80	0.49	-6.76	1.34	6.89	-1.34	0.02	0.32
0.0267	263.19	0.21	-5.01	-7.85	9.31	5.99	0.04	1.60
0.0300	107.78	0.00	0.48	2.27	2.32	7.22	0.02	12.32

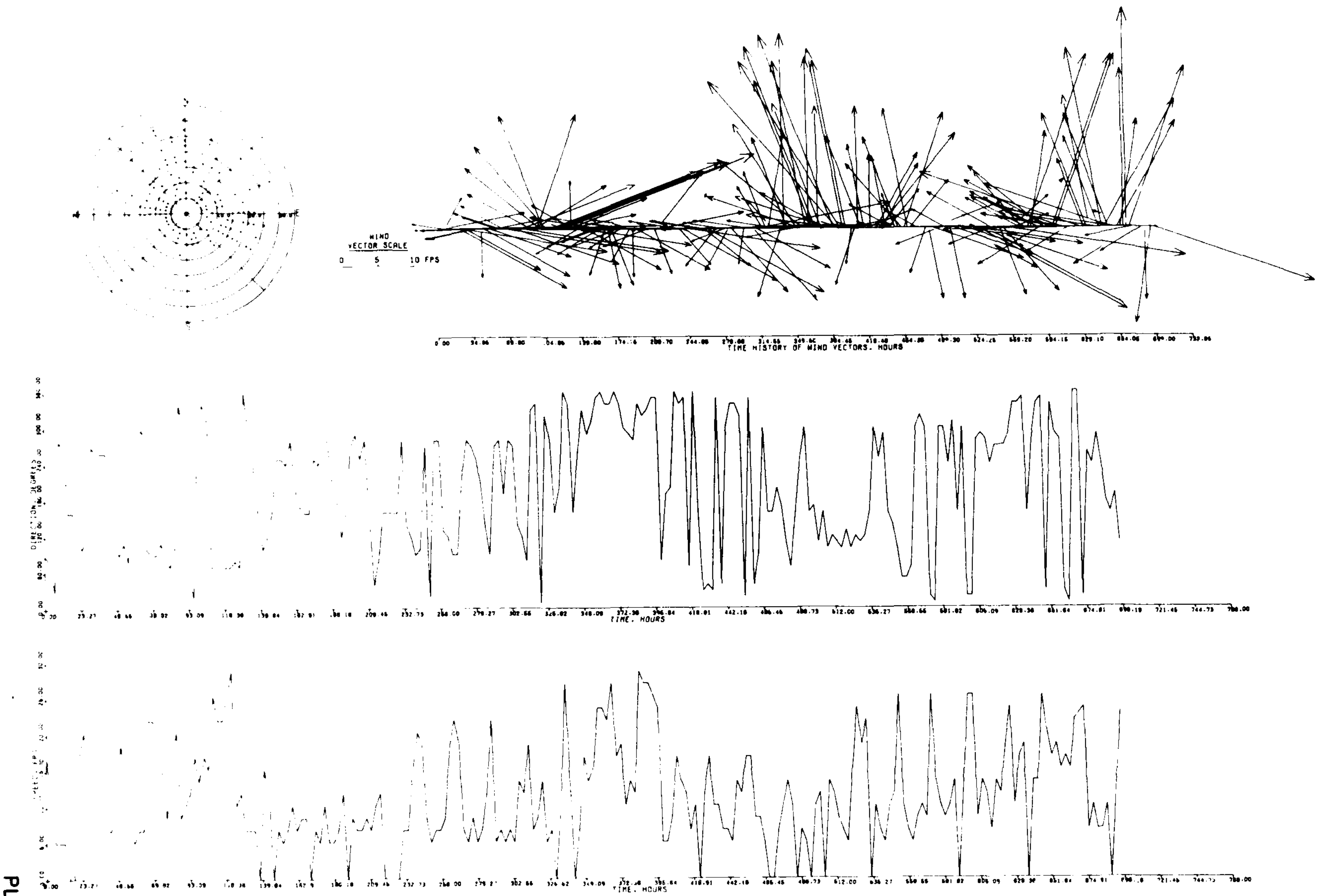
TUKEY-HANNING SMOOTHED SPECTRAL ESTIMATES

FREQ. CPH	EASTEW ASD	ECEWT12 ASD	CO-SPECTRA	QUAD-SPECTRA	CSD	PHASE HRS.	REA	COHERENCY SQUARED	CONFIDENCE REA	CONFIDENCE ECEWT12- ASD
0.	1435.95	2.82	-35.04	19.68	40.18	0.	0.03	0.40	-0.005< A < 0.061	1.50< Y < 7.64
0.0033	2094.67	1.94	-25.97	17.77	31.46	-28.65	0.02	0.24	-0.011< A < 0.041	1.03< Y < 5.26
0.0067	2273.69	0.61	-7.70	8.58	11.53	-20.04	0.01	0.10	-0.010< A < 0.020	0.32< Y < 1.64
0.0100	1319.62	0.18	0.76	3.41	3.49	21.52	0.00	0.05	-0.008< A < 0.013	0.09< Y < 0.47
0.0133	550.17	0.20	1.63	2.91	3.34	12.65	0.01	0.10	-0.011< A < 0.024	0.11< Y < 0.55
0.0167	400.17	0.19	1.78	0.01	1.78	0.07	0.00	0.04	-0.016< A < 0.025	0.10< Y < 0.52
0.0200	543.18	0.24	-1.78	0.09	1.79	-0.42	0.00	0.02	-0.017< A < 0.023	0.13< Y < 0.66
0.0233	412.80	0.32	-4.88	-1.39	5.07	1.89	0.01	0.19	-0.012< A < 0.037	0.17< Y < 0.88
0.0267	234.99	0.23	-4.07	-3.02	5.07	3.81	0.02	0.49	0.000< A < 0.043	0.12< Y < 0.61
0.0300	136.43	0.05	-0.87	-1.50	1.74	5.54	0.01	0.42	-0.002< A < 0.027	0.03< Y < 0.14

Table 27

Wind/Current Data Pairs with Apparently Significant Correlations

		Raw								Smooth				
			Wind		Current									
Data Set Pair	Frequency cph	RFA	ASD	Amplitude fps	ASD	Amplitude fps	Phase hr	Coherency Squared	RFA	Wind ASD	Current ASD	Phase hr	Coherency Squared
FASTEW-FCEWT1	0.0200	0.05	793.07	5.6	2.30	0.3	-4.88	0.92	0.03	580.81	2.11	-2.04	0.32
FASTNS-FCNST1	0.0067	0.02	1728.52	4.8	1.25	0.1	-7.28	0.66	0.01	2935.17	1.41	-25.3	0.27
	0.0167	0.04	324.69	3.3	0.76	0.3	-1.29	0.76	0.02	282.57	0.94	-12.18	0.17
FASTNS-FCNST1B	0.0067	0.02	1728.52	4.8	1.22	0.1	-28.13	0.87	0.01	2935.17	0.91	-33.91	0.16
	0.0100	0.03	578.54	3.4	1.15	0.2	-12.74	0.50	0.02	830.90	0.77	-18.28	0.51
FASTEW-FCEWT2B	0.0100	0.04	1576.77	5.6	2.30	0.2	-12.13	0.87	0.02	1402.85	1.69	-2.66	0.31
FASTNS-FCNST5B	0.0167	0.03	421.65	3.8	0.54	0.1	11.81	2.01	0.03	315.54	0.48	-3.02	0.52
FASTEW-FCEWT6	0.0133	0.03	284.19	2.7	0.28	0.1	-9.69	0.82	0.00	624.62	0.19	-9.63	0.19
FASTEW-FCEWT7	0.0100	0.01	1579.03	5.6	0.22	0.1	-22.13	0.57	0.01	1438.71	0.24	+18.79	0.27
	0.0200	0.01	762.86	5.5	0.17	0.1	-2.52	0.95	0.01	580.41	0.15	-3.53	0.50
FASTNS FCNST7	0.0100	0.01	834.66	4.1	0.11	0.0	-14.42	0.84	0.01	1008.49	0.09	-12.94	0.58
	0.0167	0.01	414.66	3.7	0.04	0.0	-1.22	0.56	0.00	519.78	0.09	-17.78	0.04
FASTEW-FCEWT8	0.100	0.02	1506.88	5.5	0.51	0.1	-6.72	0.94	0.01	1318.84	0.10	2.9	1.48



MEASURED ASTORIA WINDS

PLATE 1

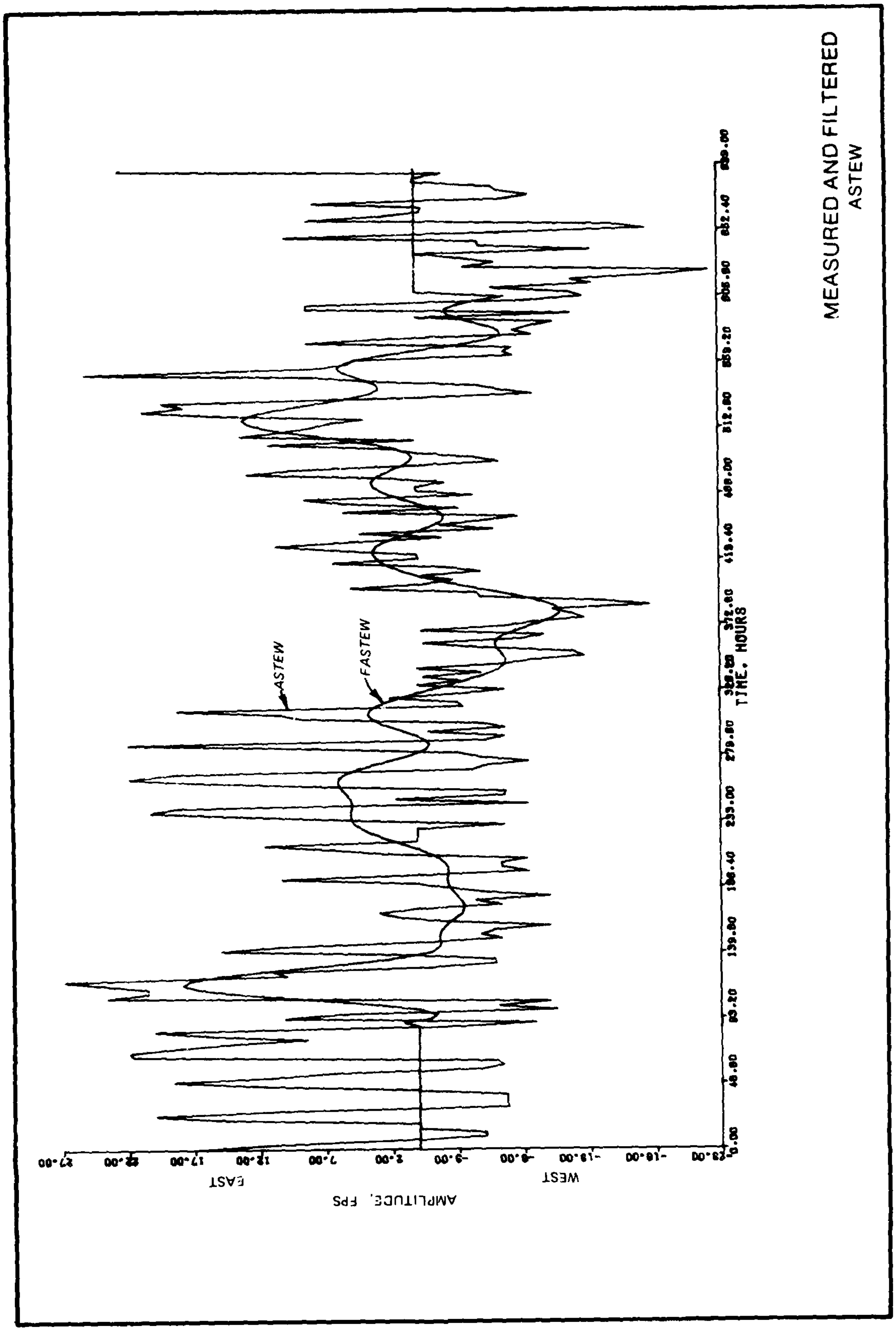
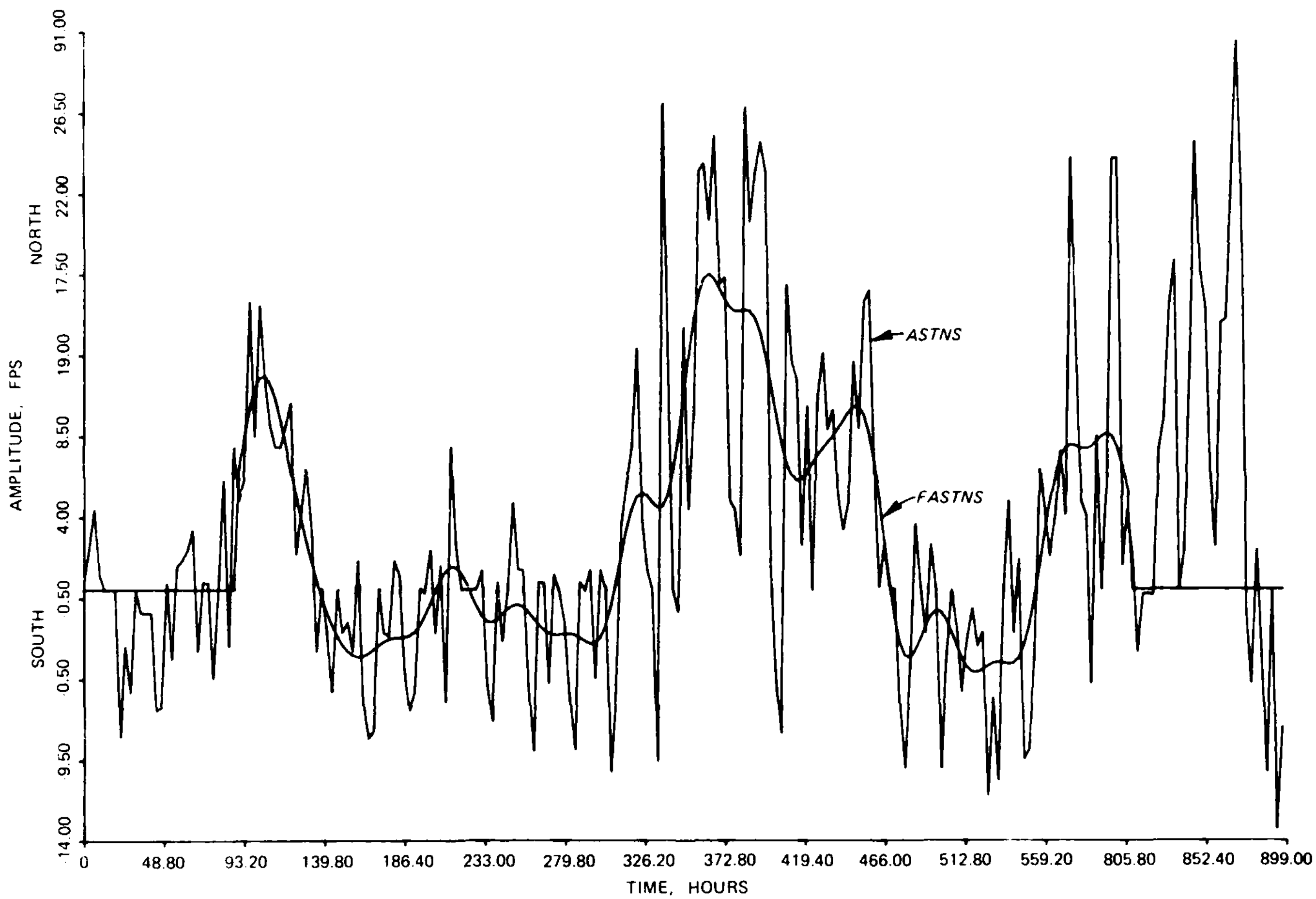
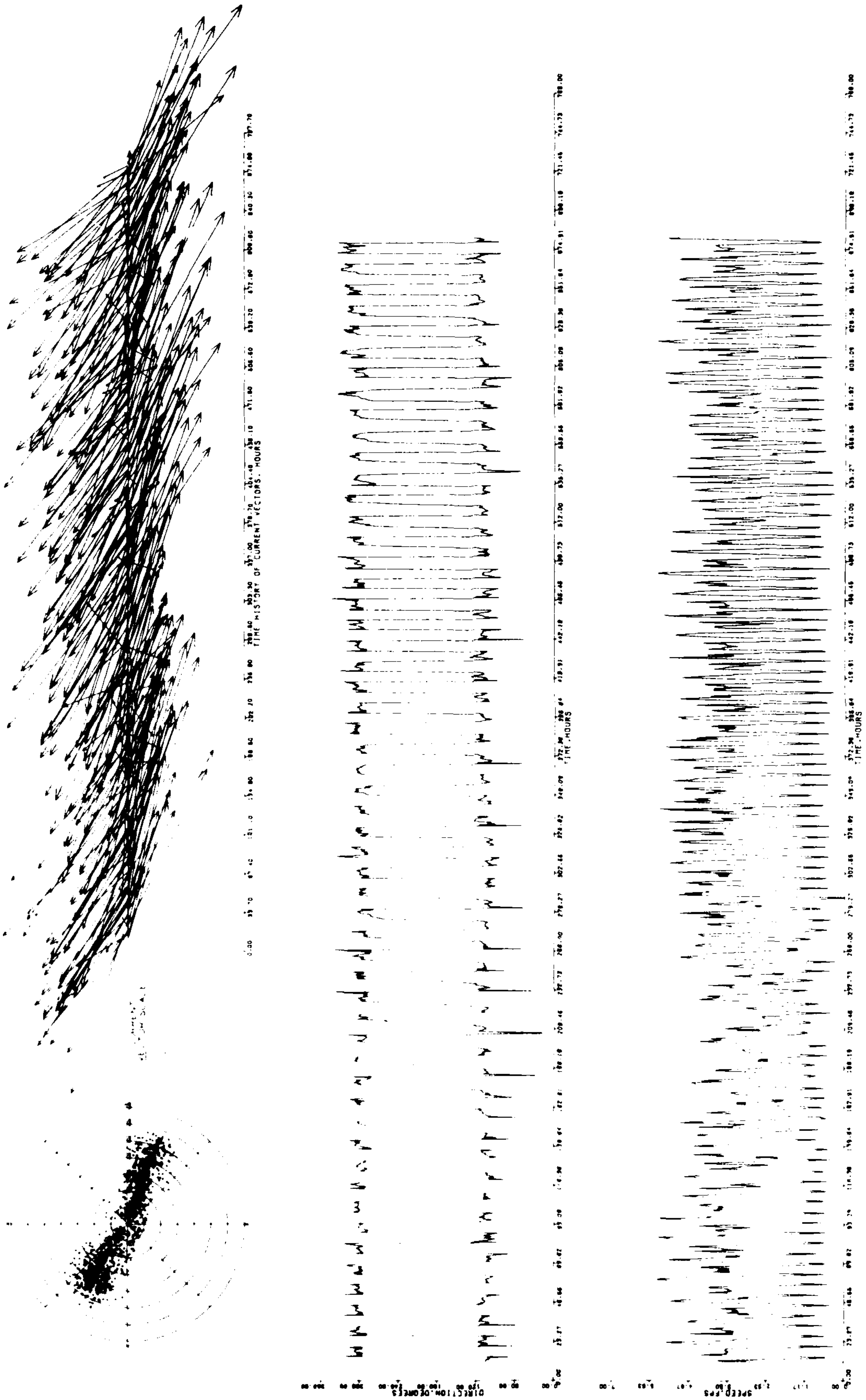

MEASURED AND FILTERED
ASTEW
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST
ASTEW
FASTEW

PLATE 2



MEASURED AND FILTERED
ASTNS



MEASURED STA T1 CURRENTS

PLATE 4

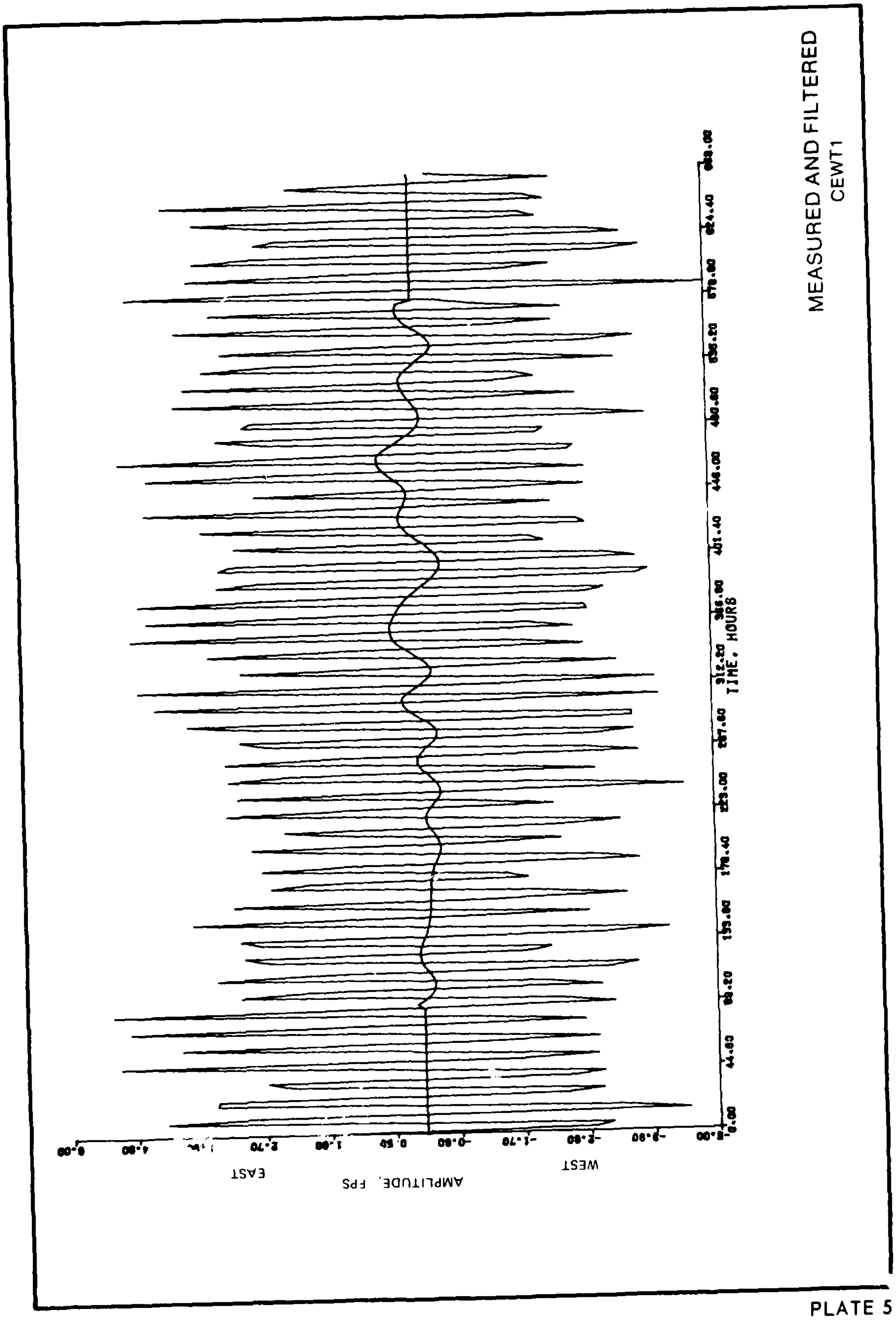
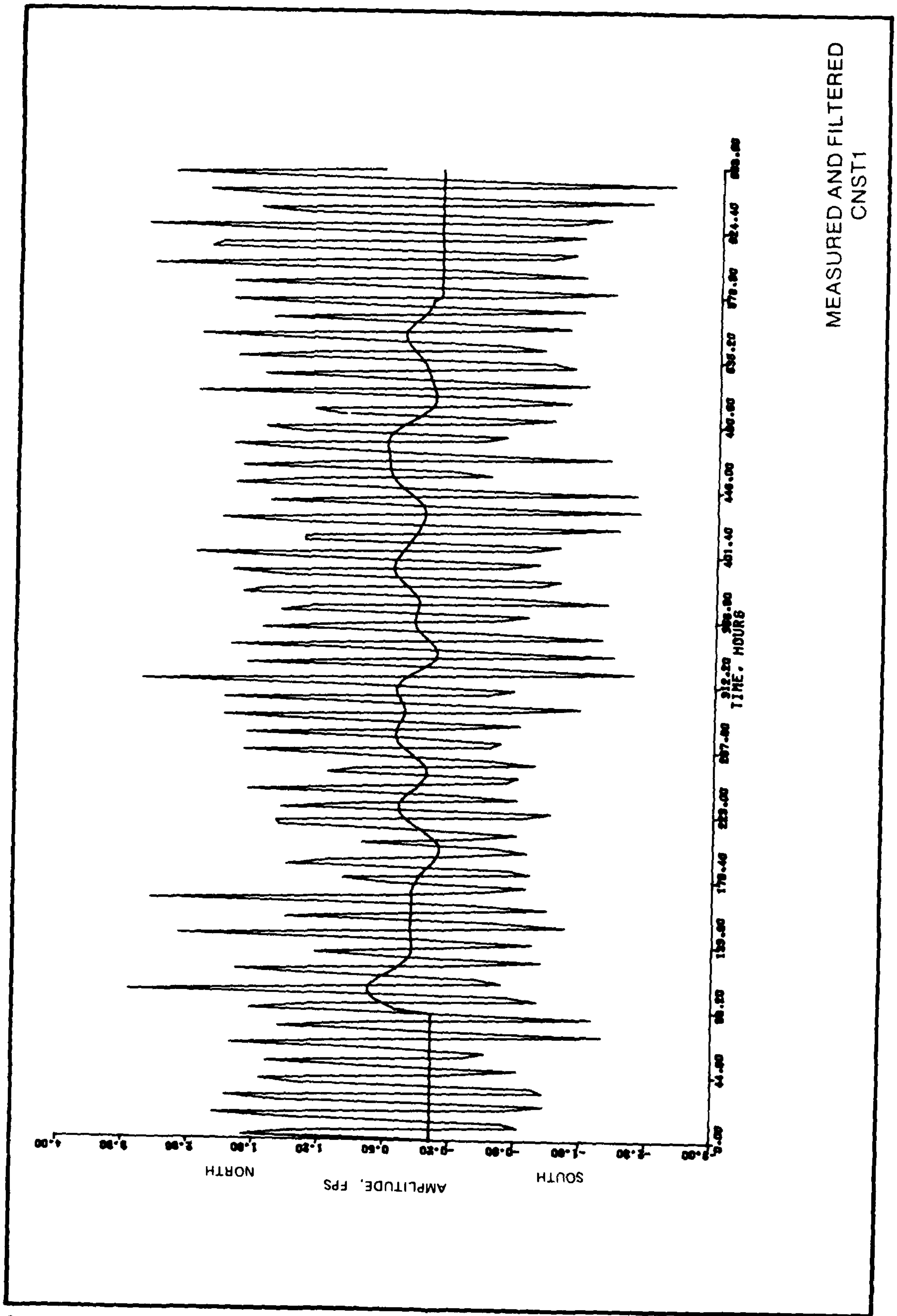
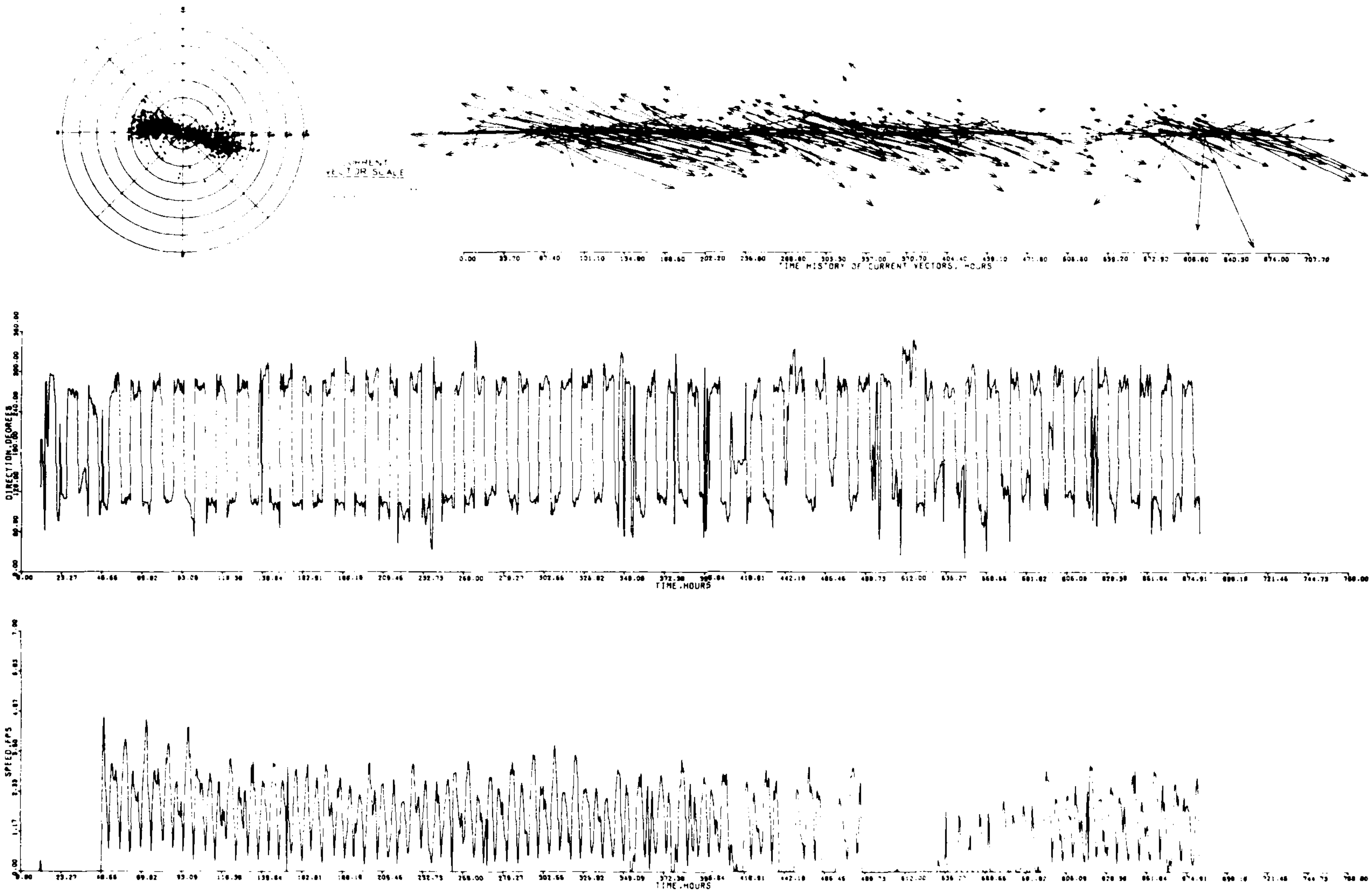

MEASURED AND FILTERED
CEWT1
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 5



MEASURED AND FILTERED
CNST1

PLATE 6



MEASURED STA T1B CURRENTS

PLATE 7

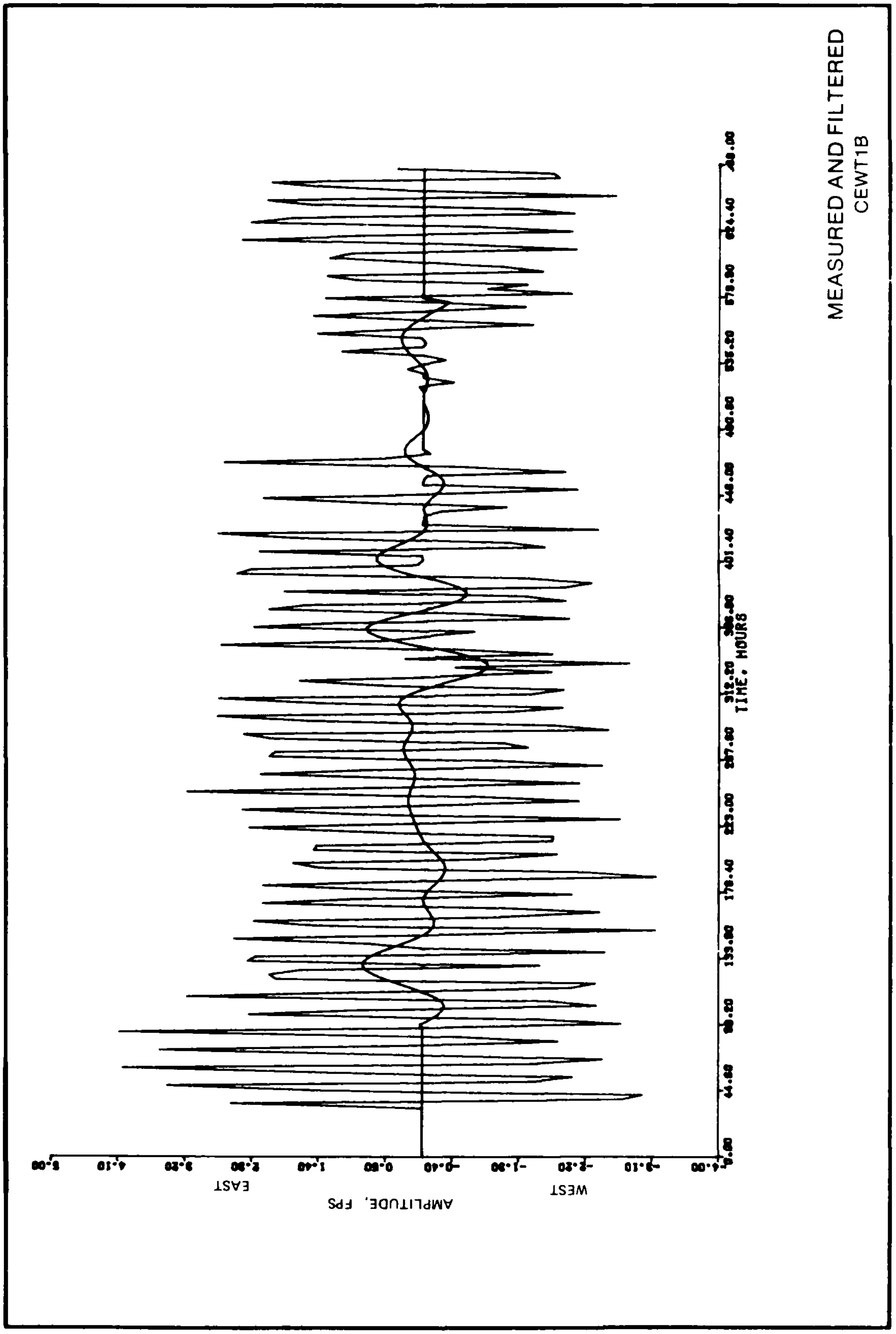
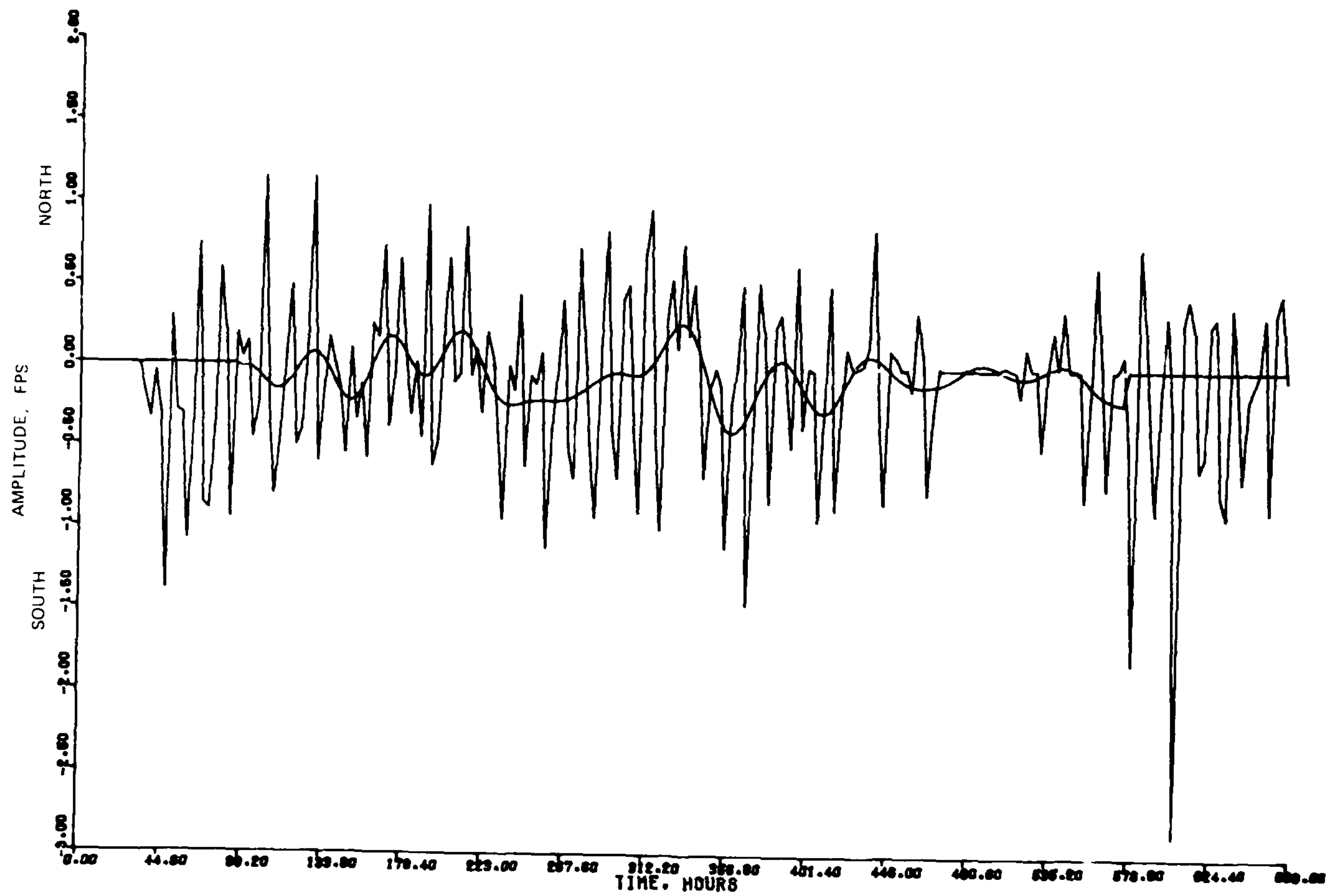
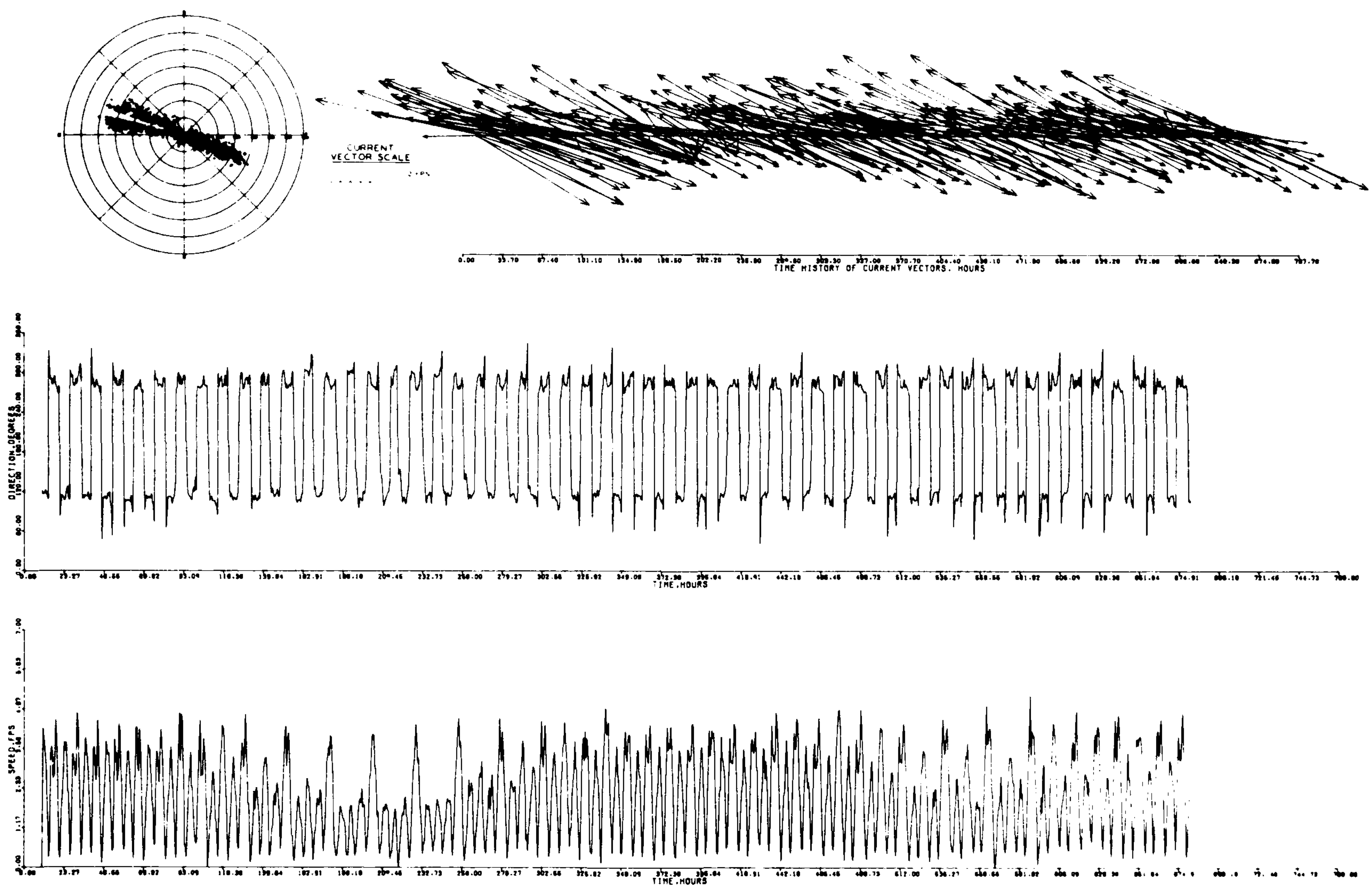

MEASURED AND FILTERED
CEWT1B
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 8



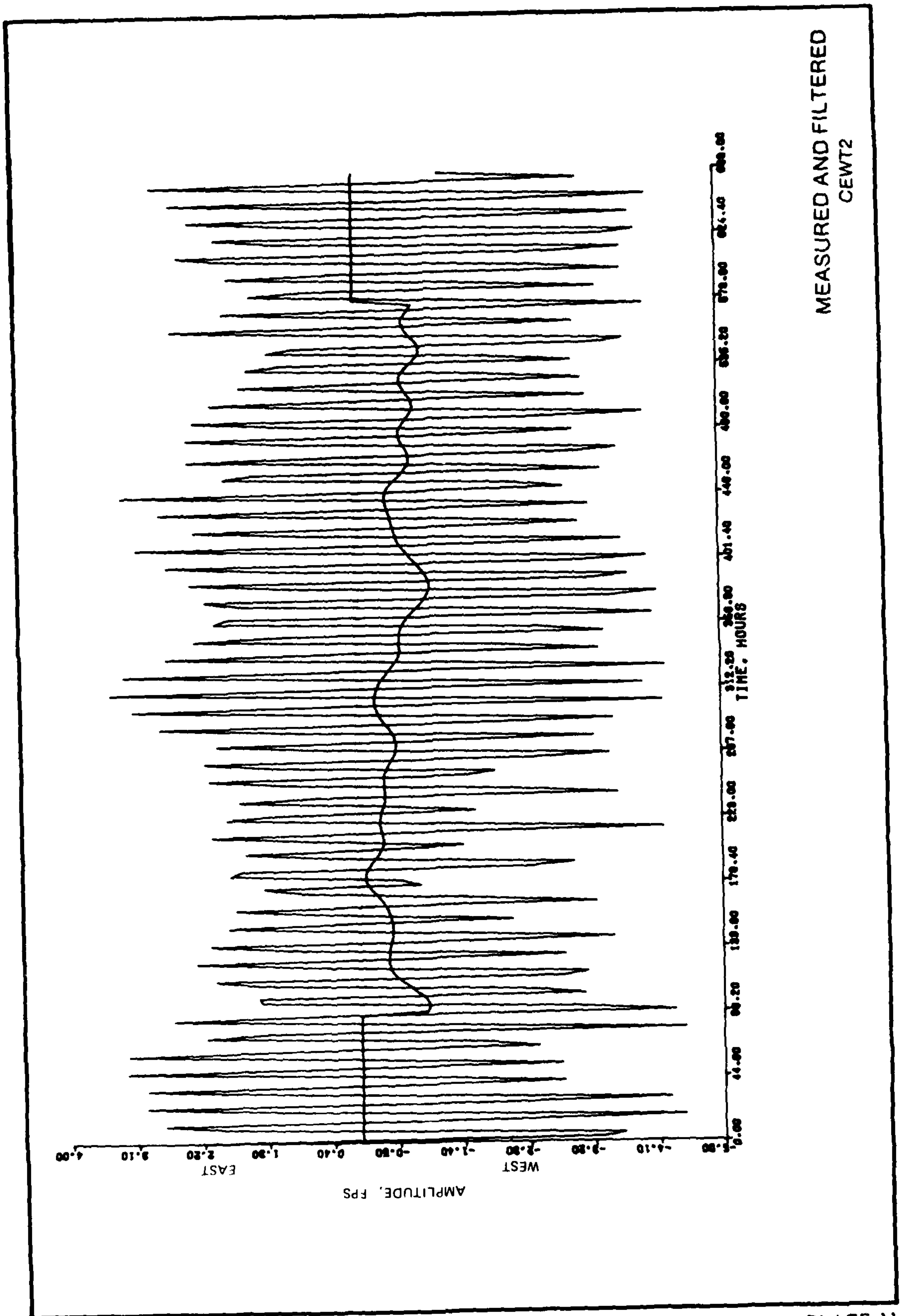
MEASURED AND FILTERED
CNST1B

PLATE 9



MEASURED STA T2 CURRENTS

PLATE 10


MEASURED AND FILTERED
CEWT2
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

MEASURED STA T2B CURRENTS

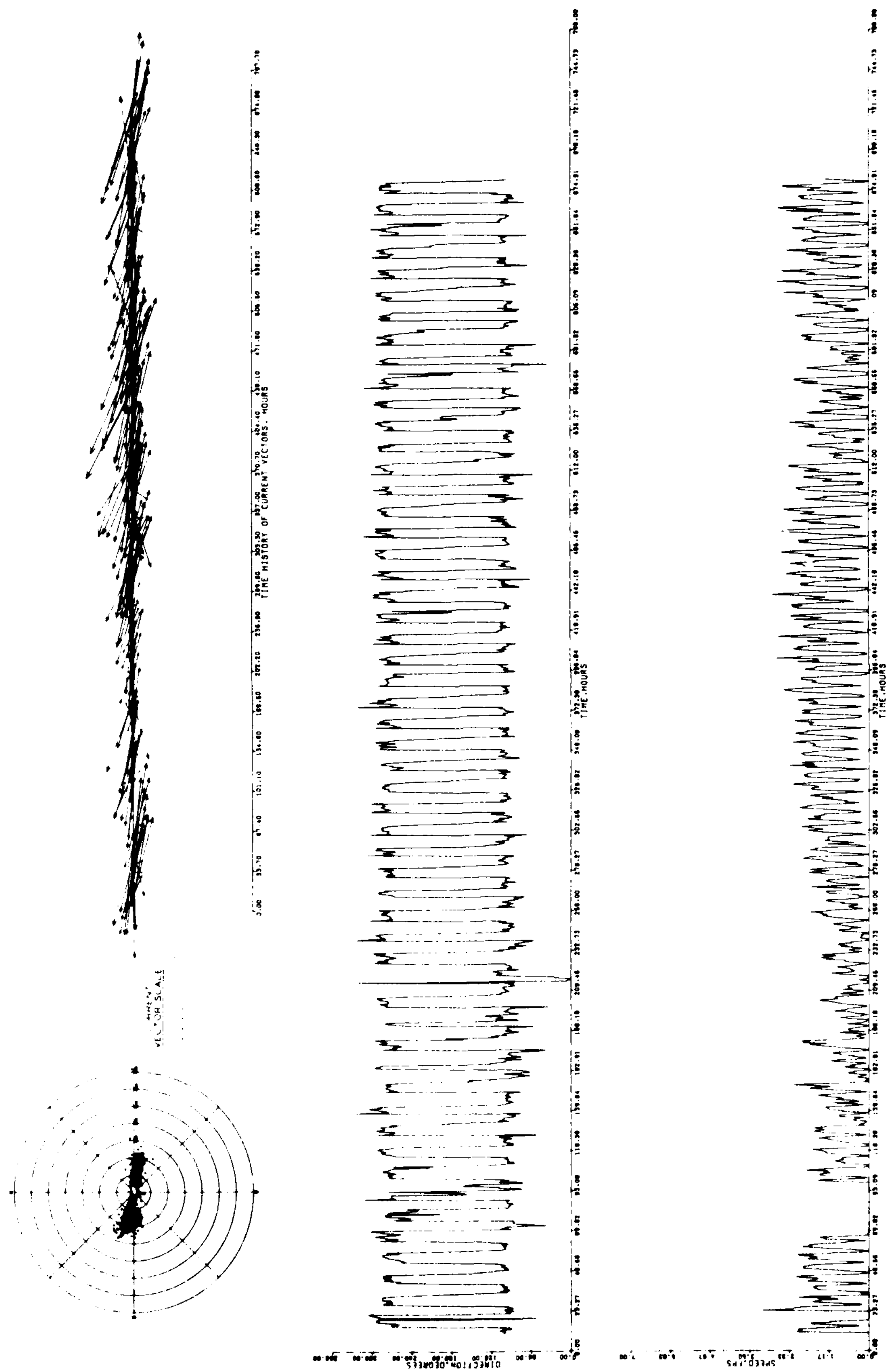


PLATE 12

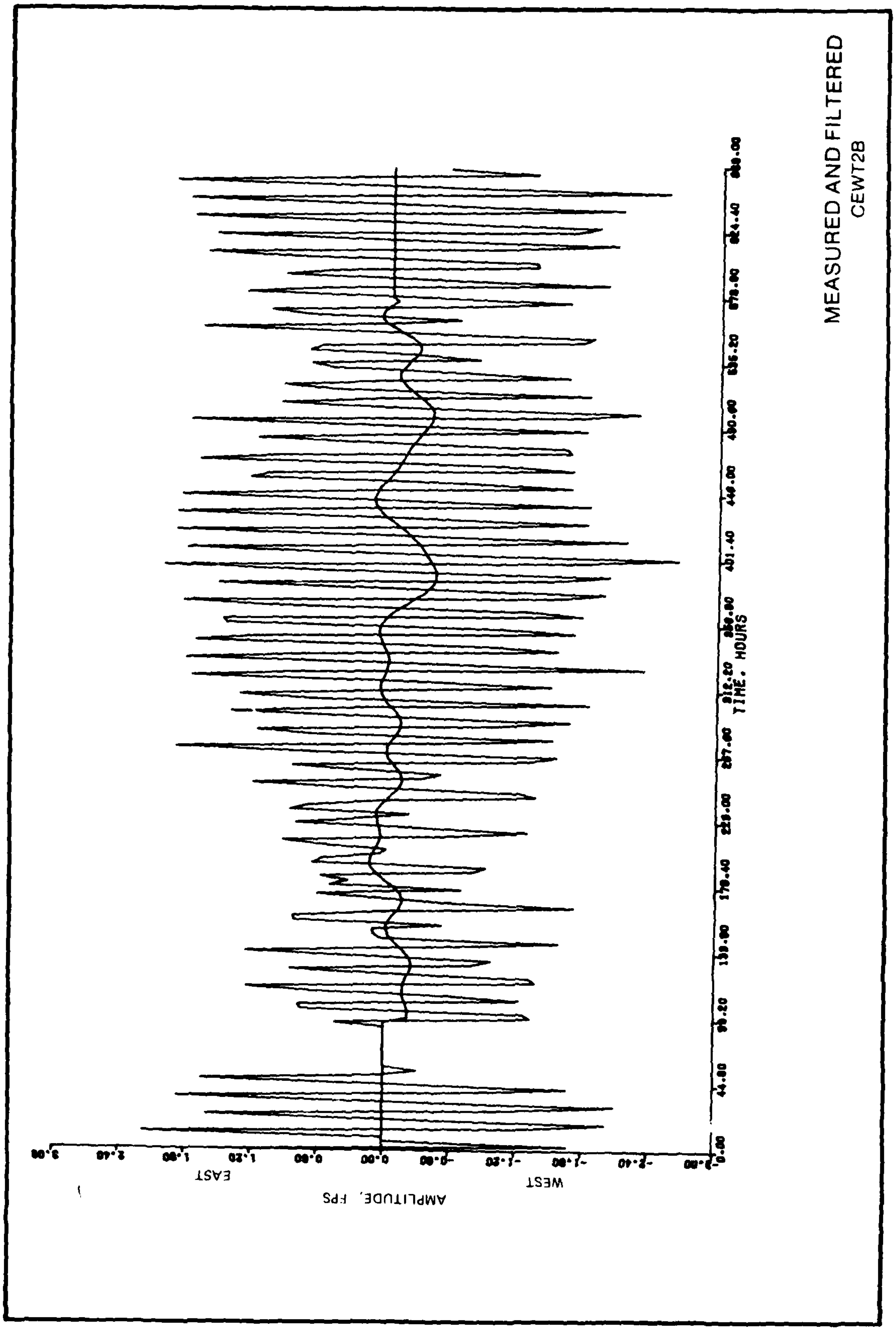
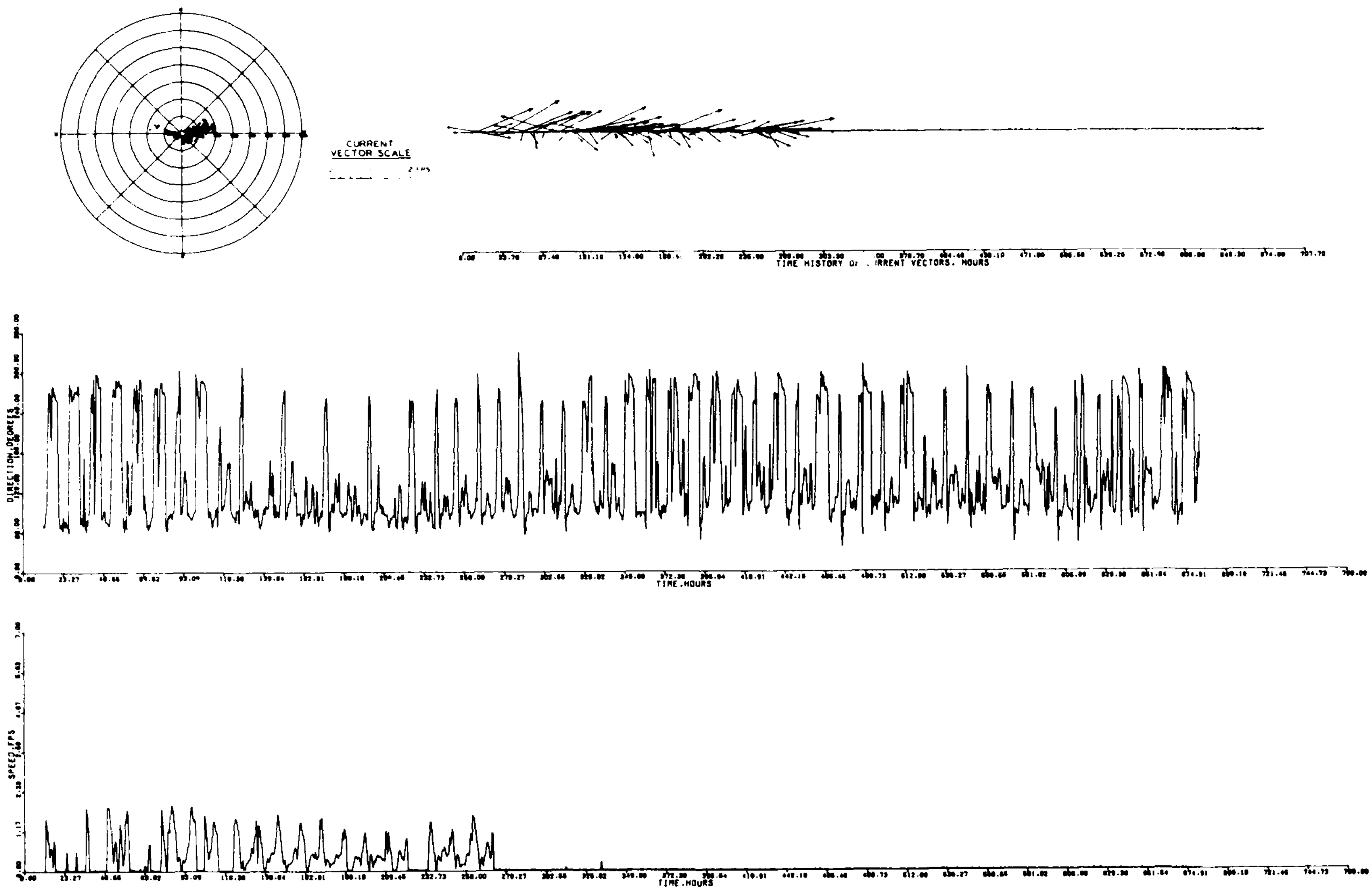
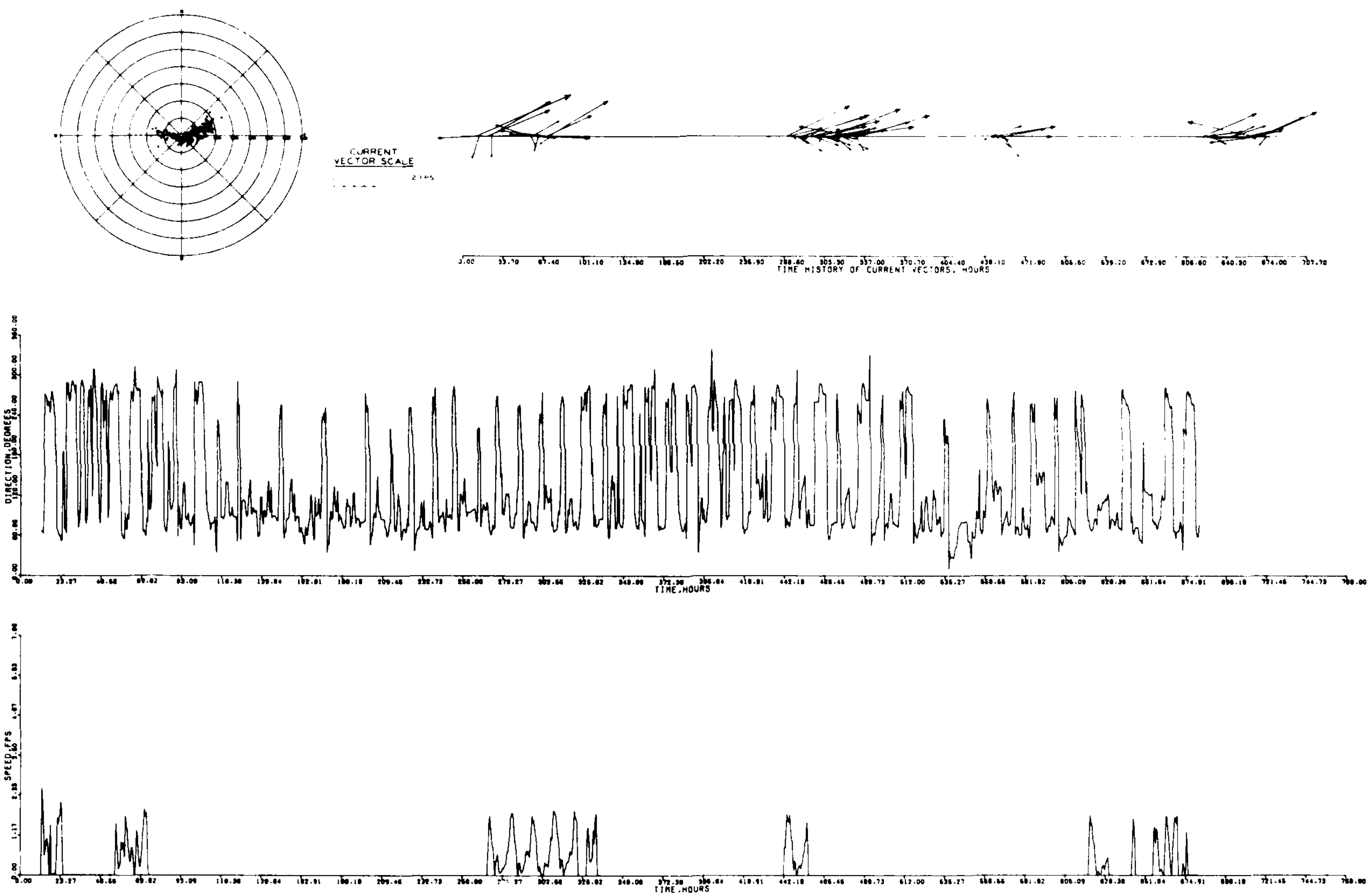

MEASURED AND FILTERED
CEWT2B
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 13



MEASURED STA T3 CURRENTS

PLATE 14



MEASURED STA T3B CURRENTS

PLATE 15

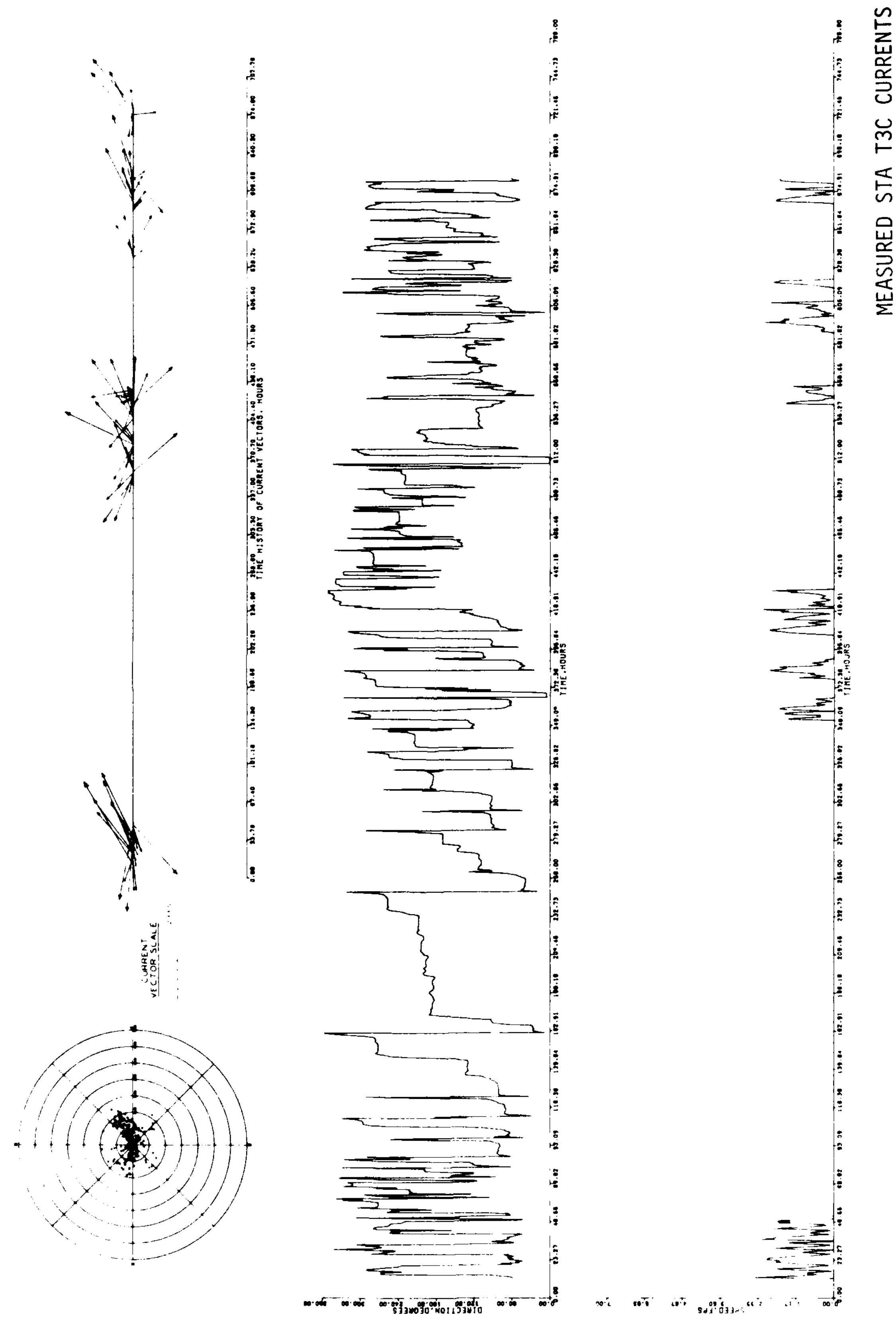
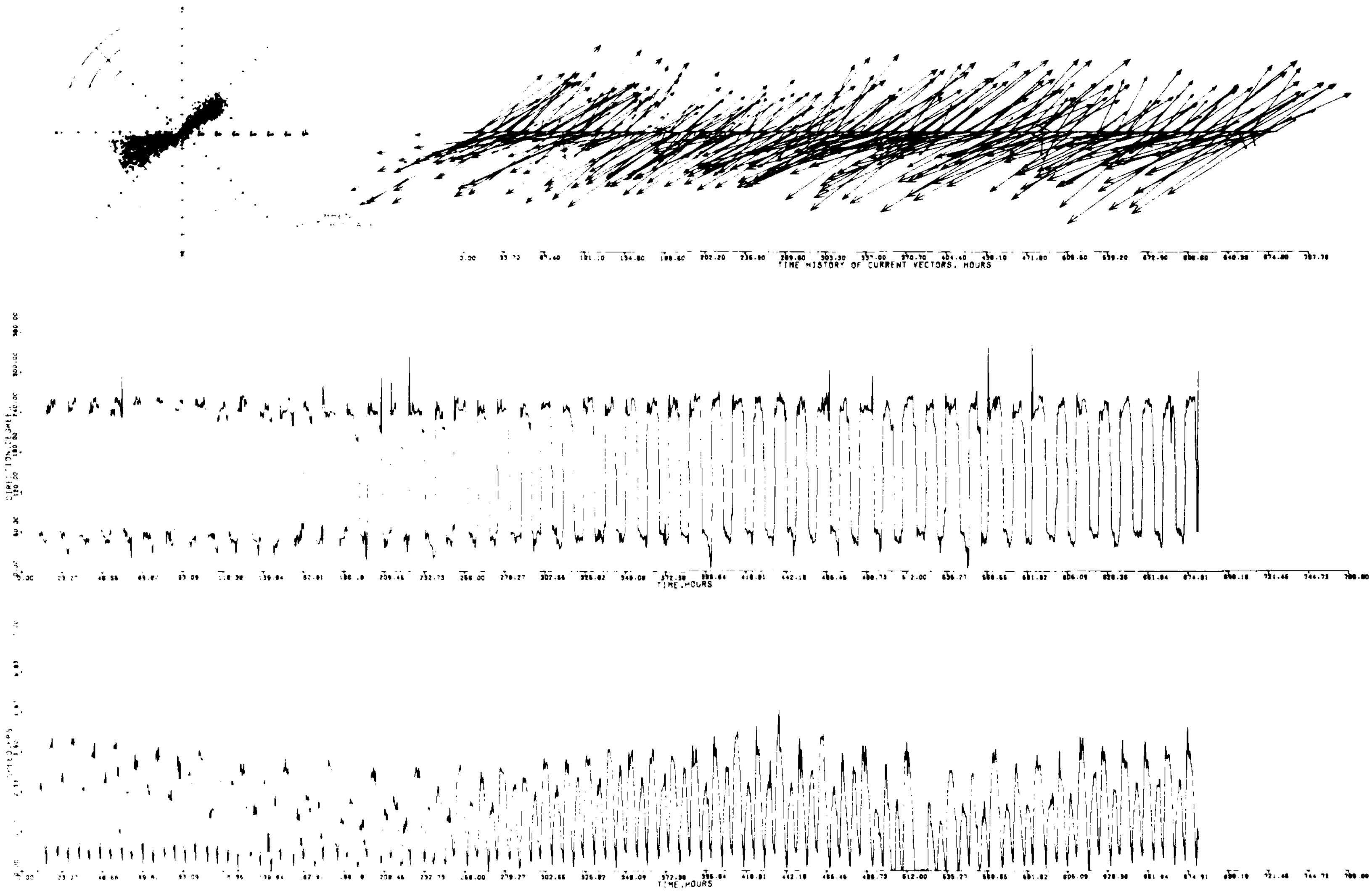

MEASURED STA T3C CURRENTS
TIME HISTORY OF CURRENT VECTORS, HOURS
CURRENT VECTOR SCALE
TIME, HOURS
DIRECTION, DEGREES
SPEED, FPS

PLATE 16



MEASURED STA T4 CURRENTS

PLATE 17

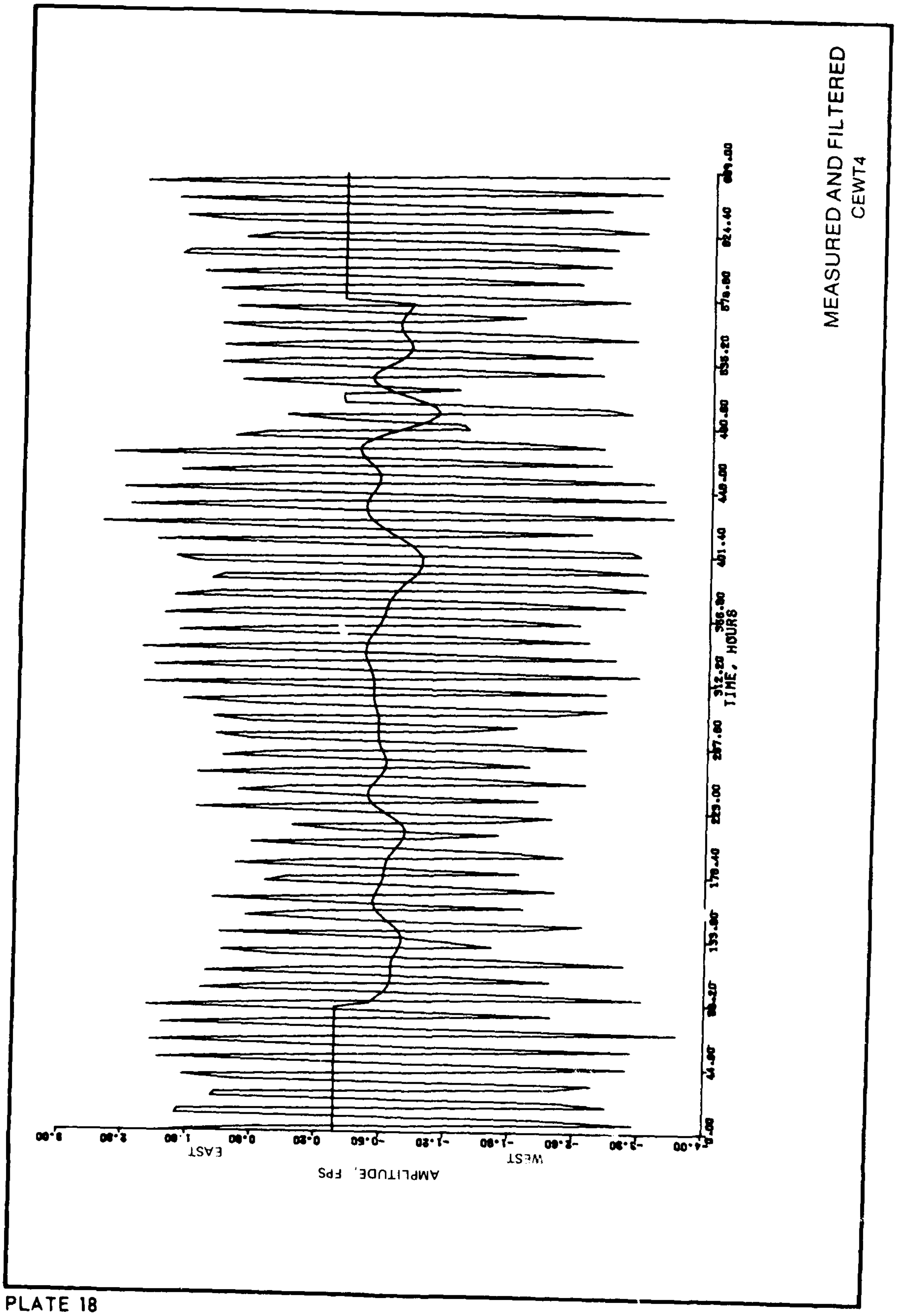

MEASURED AND FILTERED
CEWT4
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 18

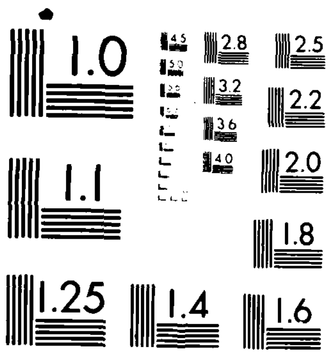
AD-A161 609 SPECTRAL ANALYSIS OF COLUMBIA RIVER ESTUARY CURRENTS (U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRAULICS LAB B P DONNELL ET AL SEP 85 2/2

UNCLASSIFIED WES/TR/HL-85-5 F/G 8/8 NL

END

FILMED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

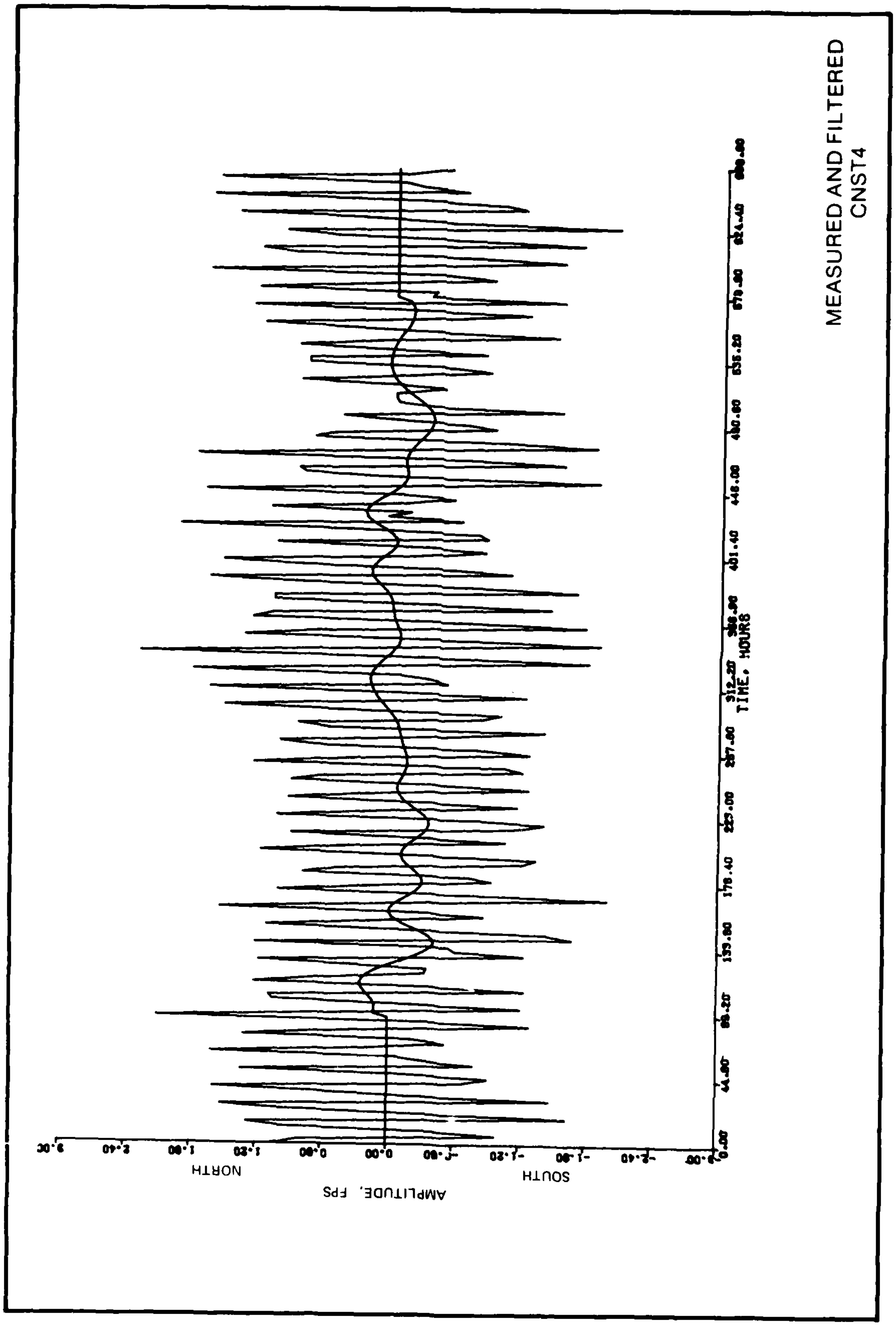
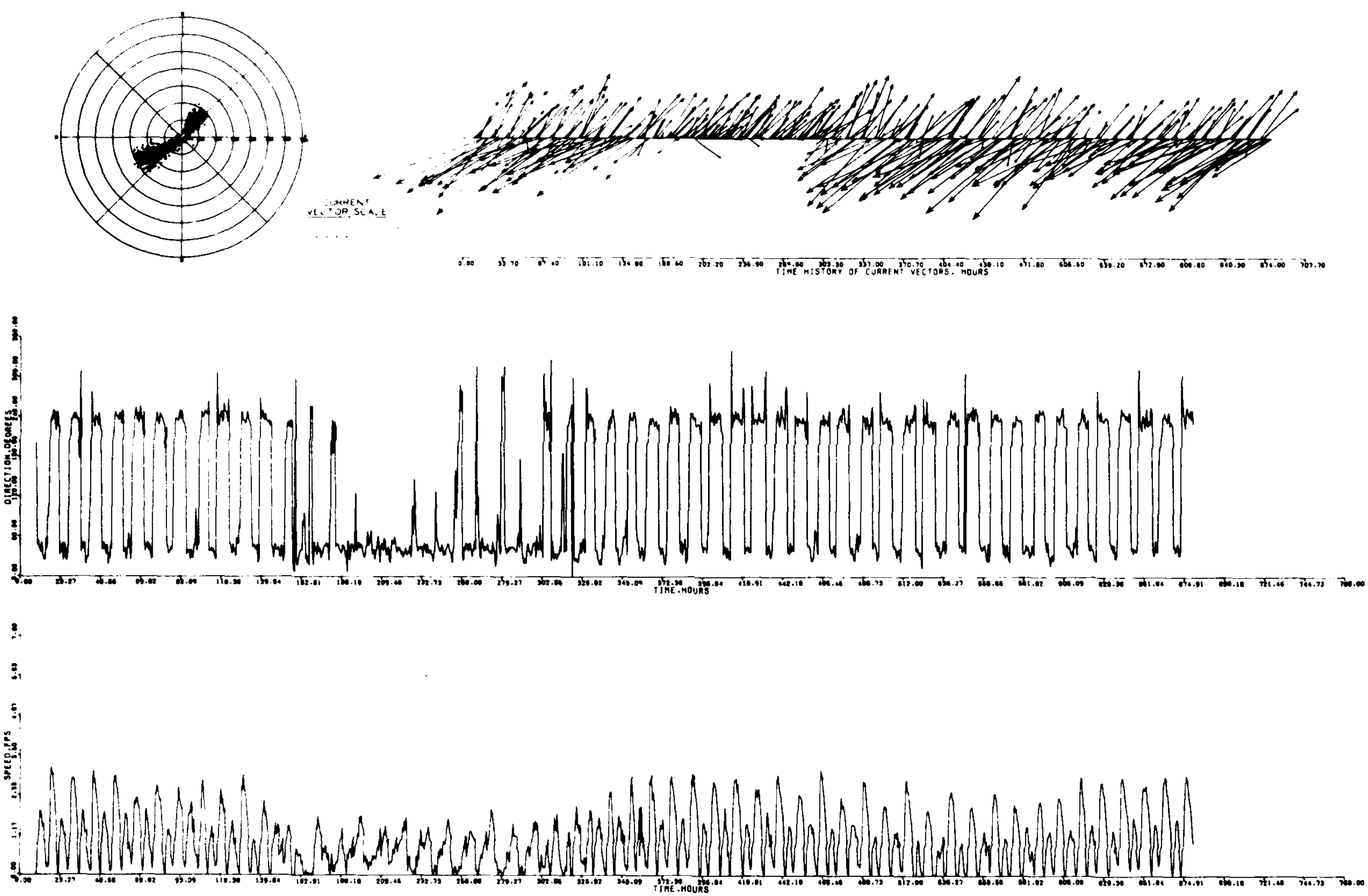
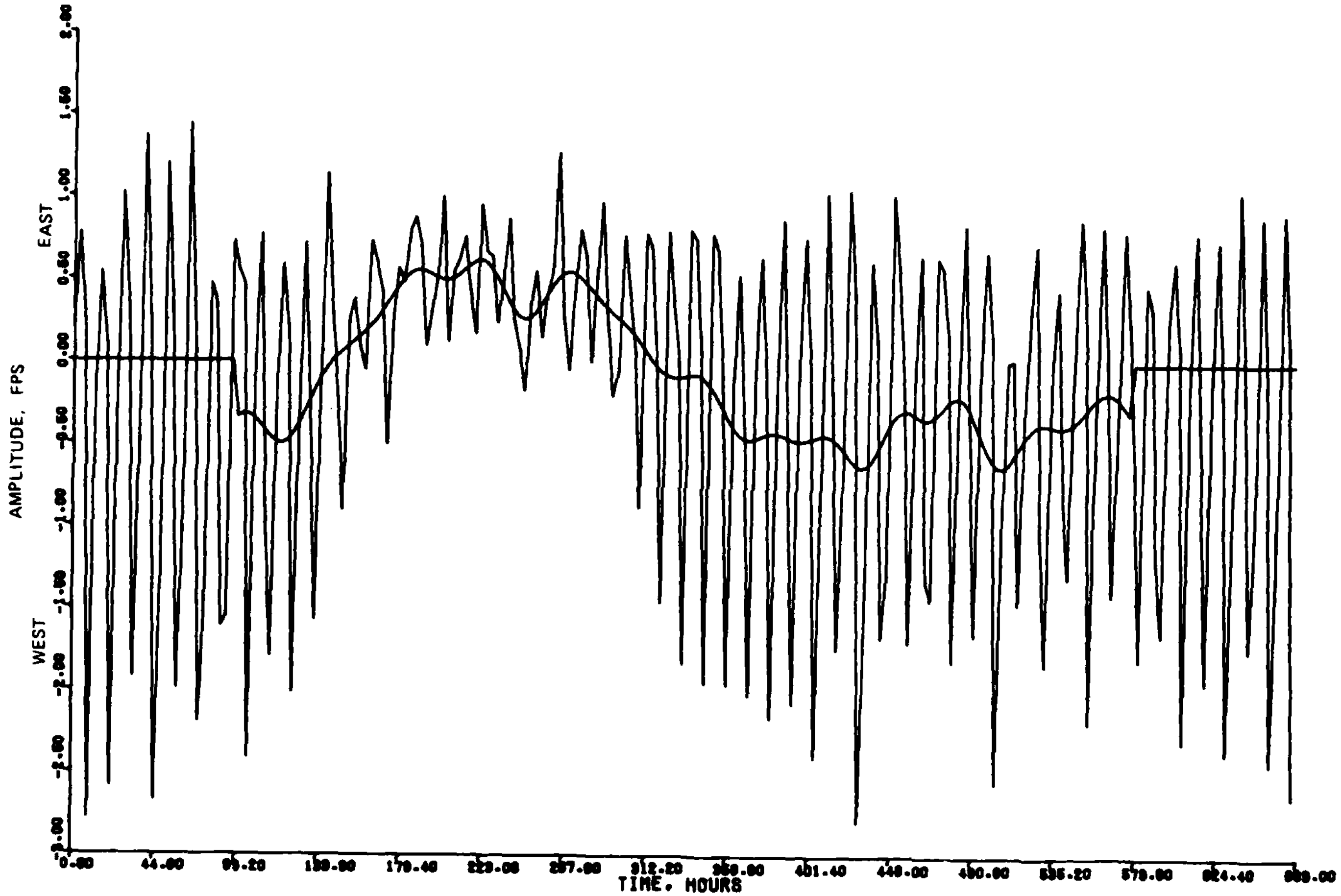

MEASURED AND FILTERED
CNST4
TIME, HOURS
AMPLITUDE, FPS
NORTH
SOUTH

PLATE 19

PLATE 20



MEASURED STA T5 CURRENTS



MEASURED AND FILTERED
CEWT5

PLATE 21

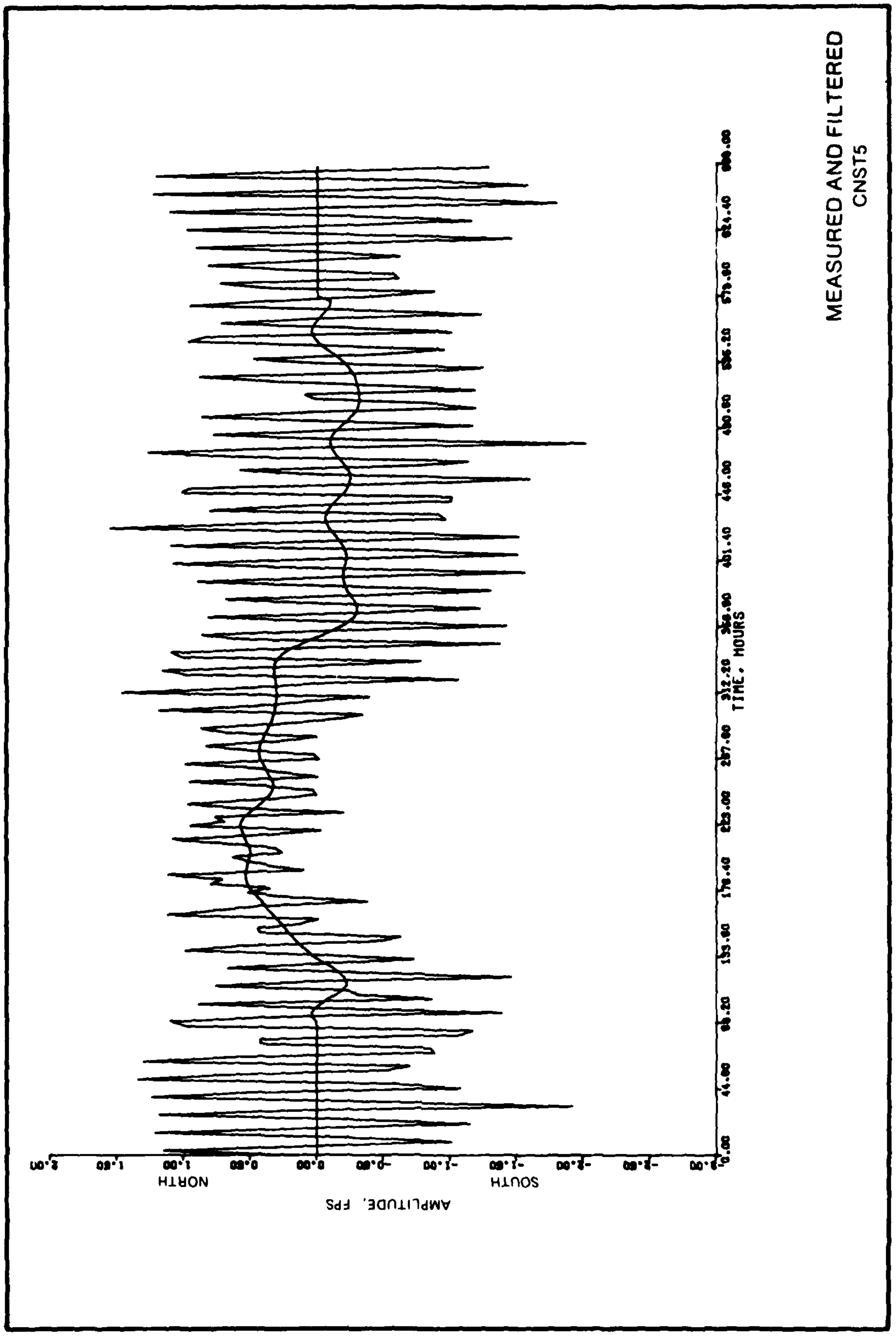
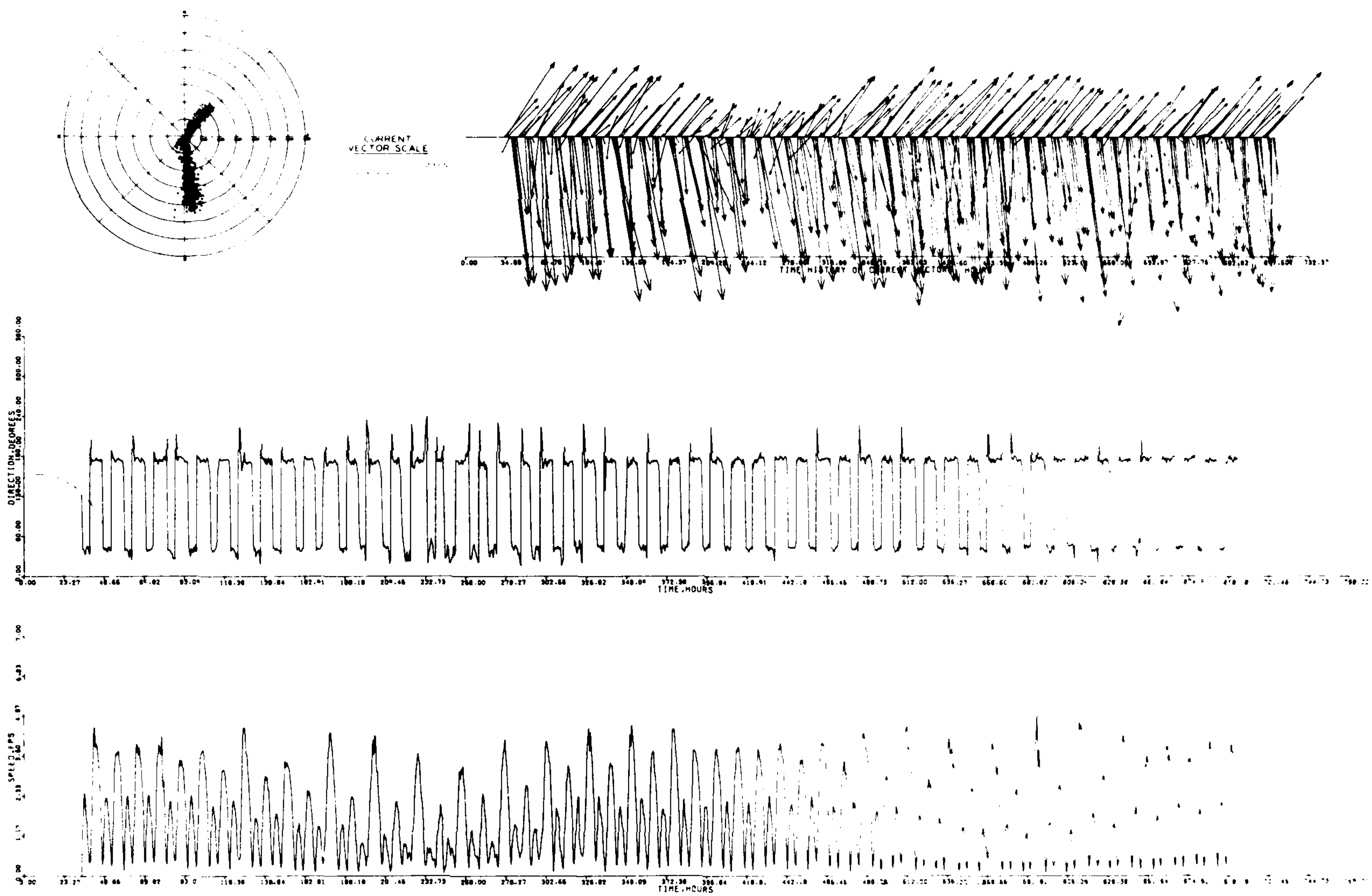

MEASURED AND FILTERED
CNST5
TIME, HOURS
AMPLITUDE, FPS
NORTH
SOUTH

PLATE 22



MEASURED STA T5B CURRENTS

PLATE 23

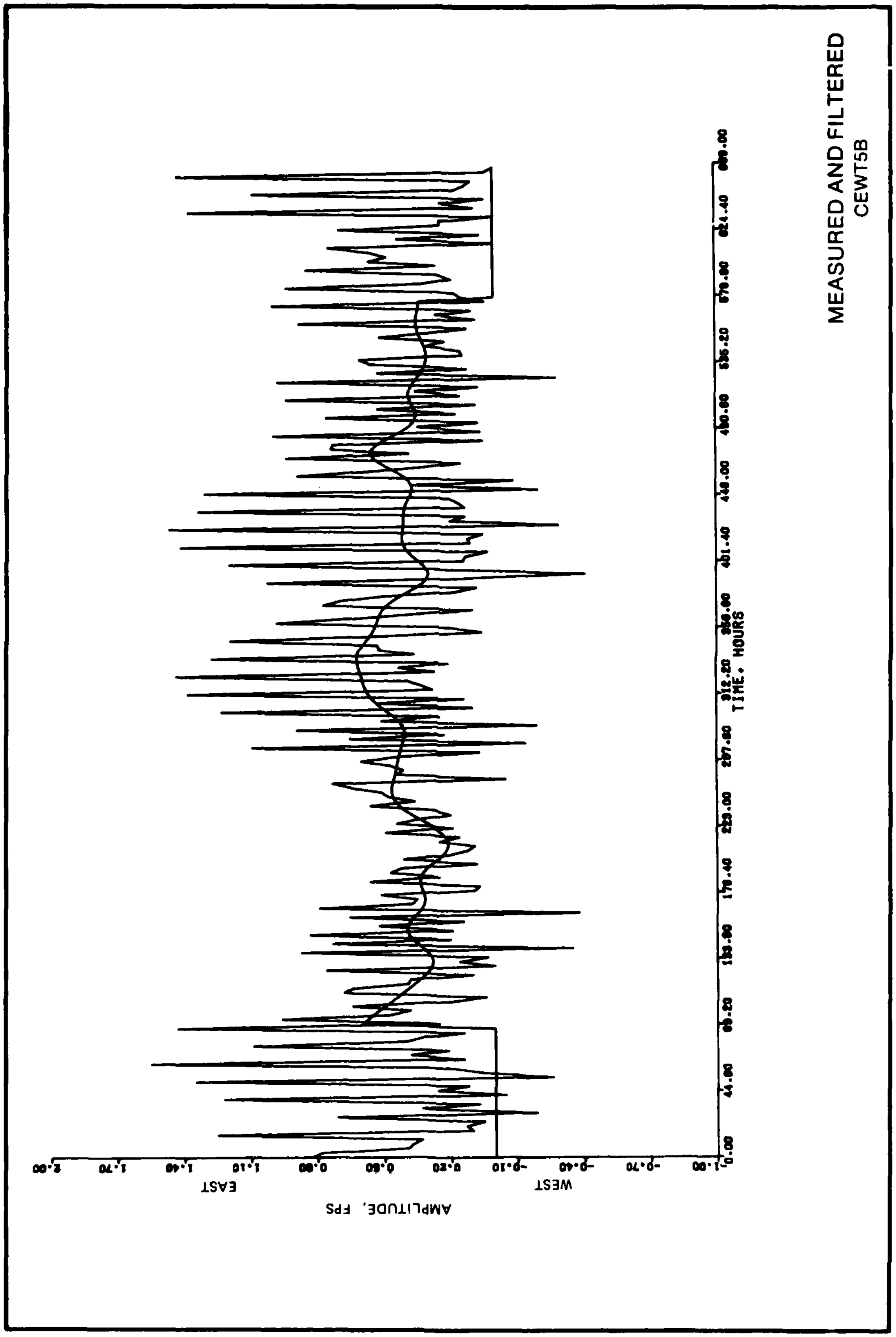

MEASURED AND FILTERED
CEWT5B
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 24

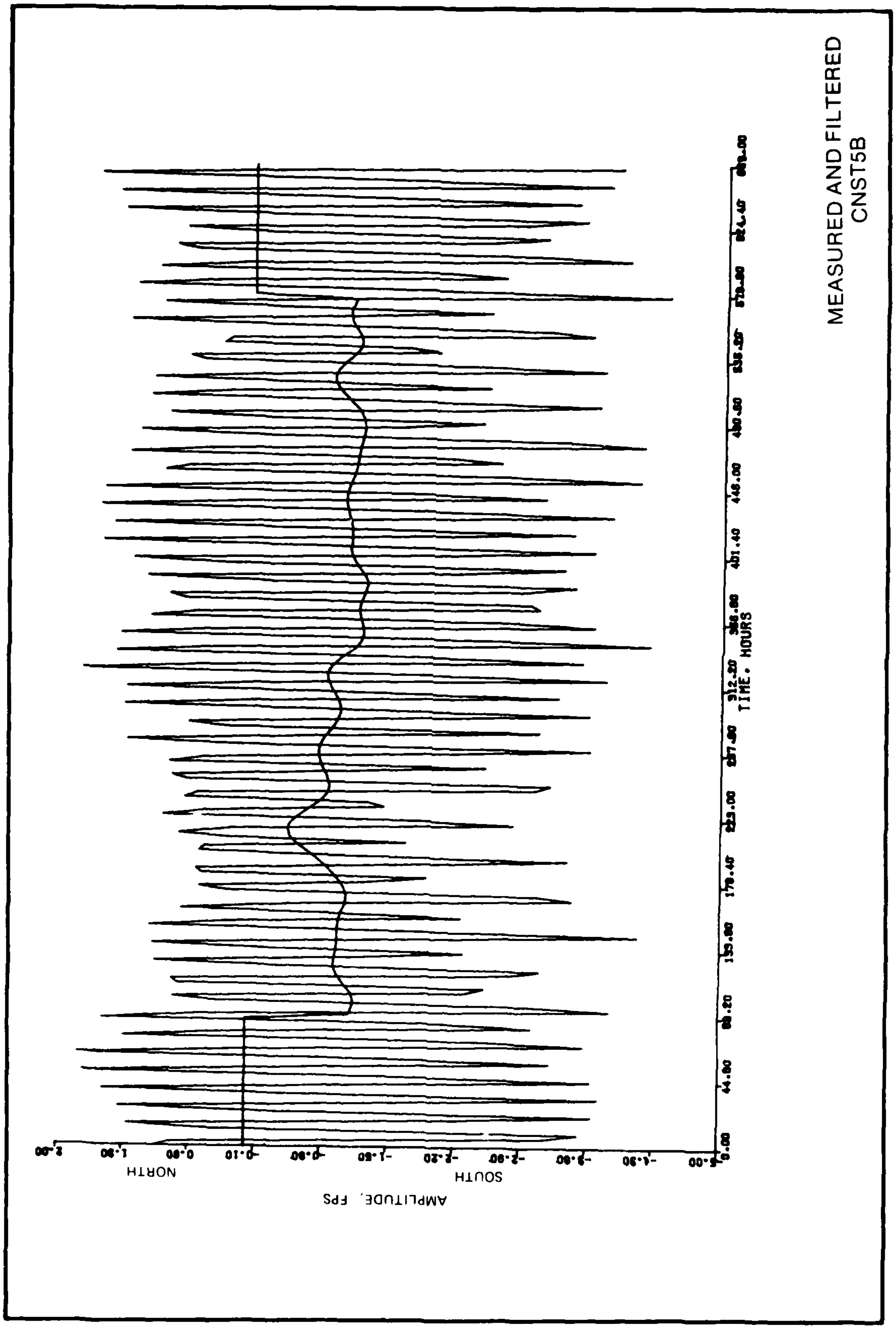
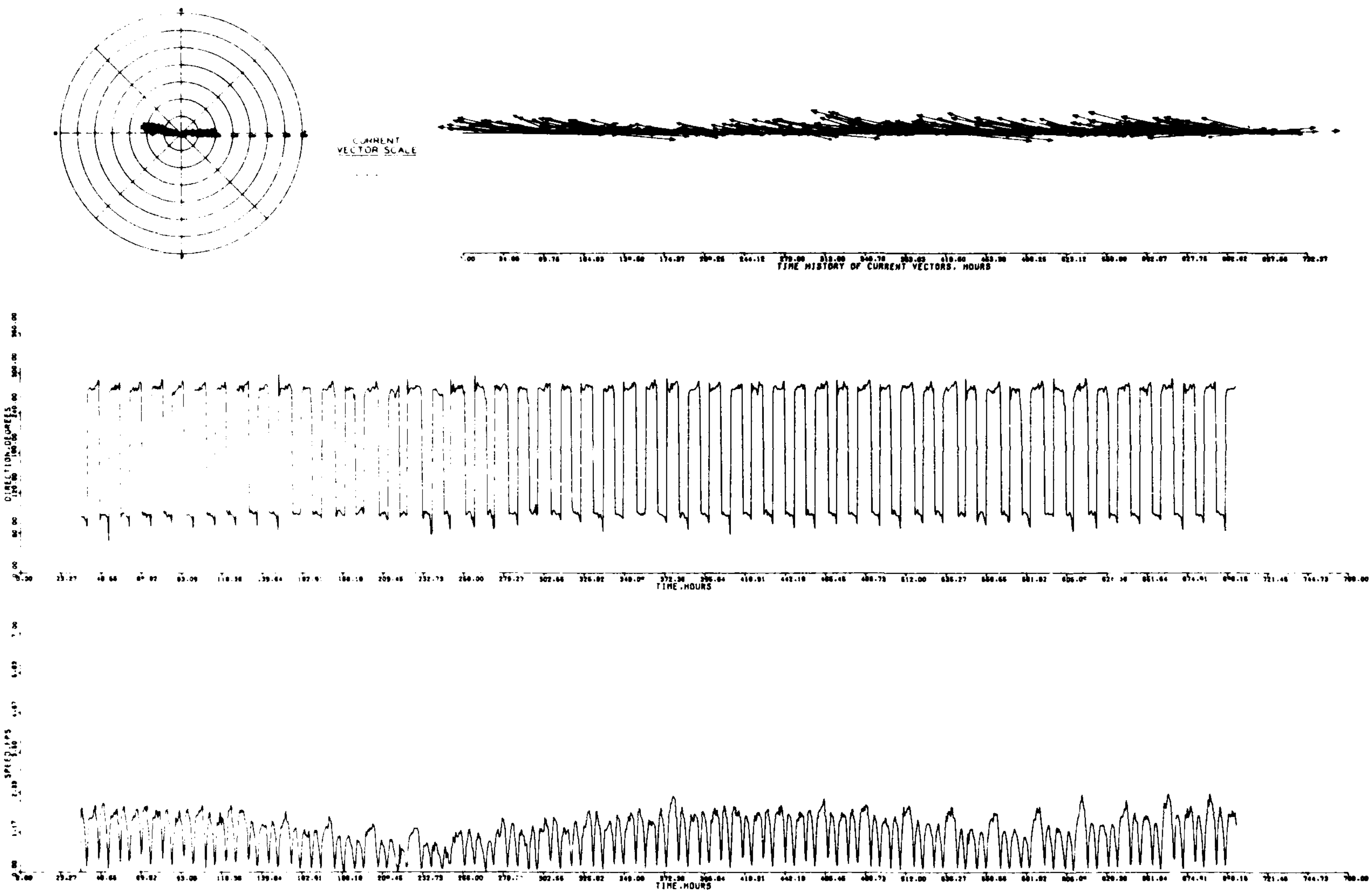
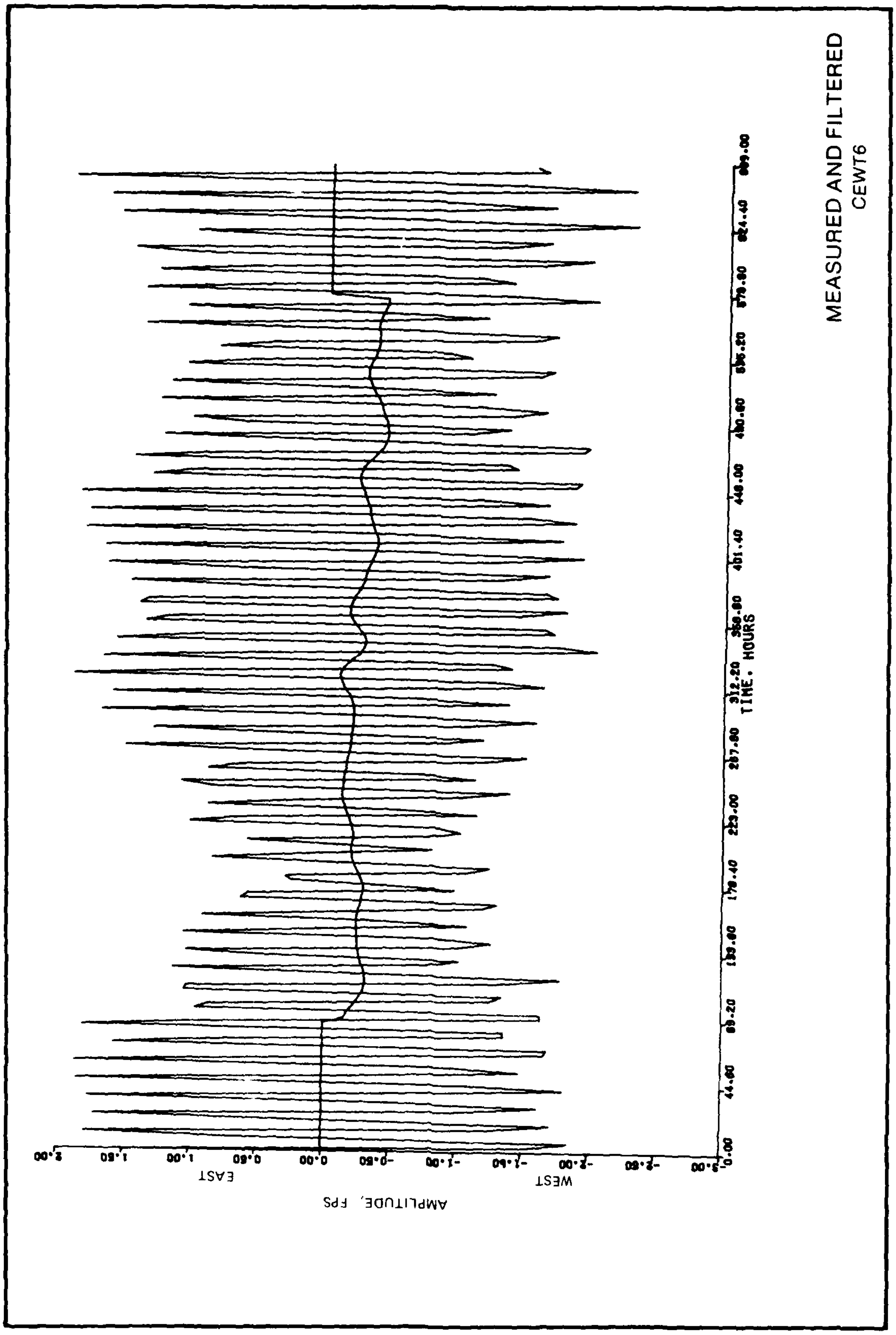

MEASURED AND FILTERED
CNST5B
TIME, HOURS
AMPLITUDE, FPS
NORTH
SOUTH

PLATE 25



MEASURED STA T6 CURRENTS

PLATE 26


MEASURED AND FILTERED
CEWT6
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

MEASURED STA T7 CURRENTS

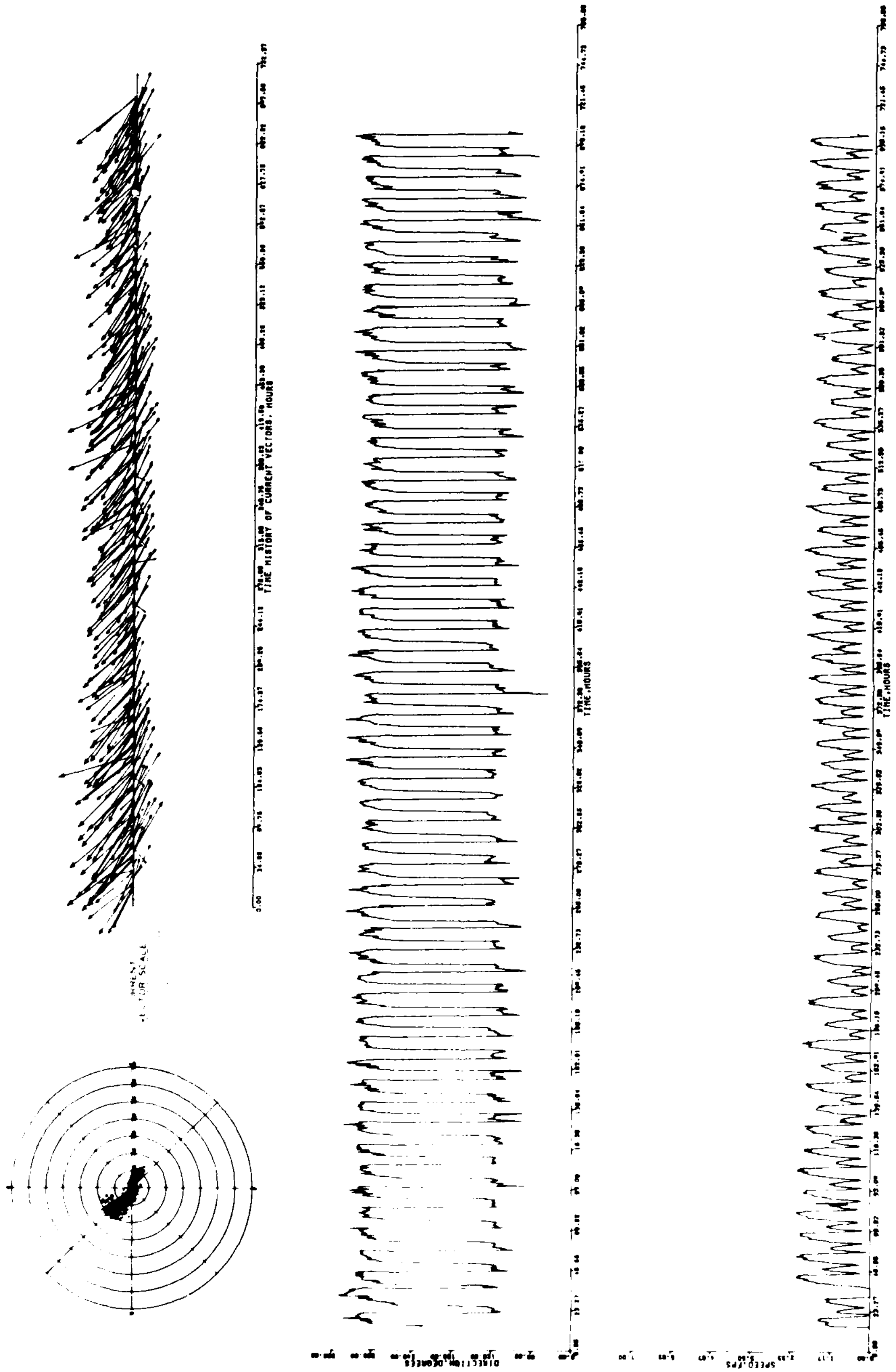
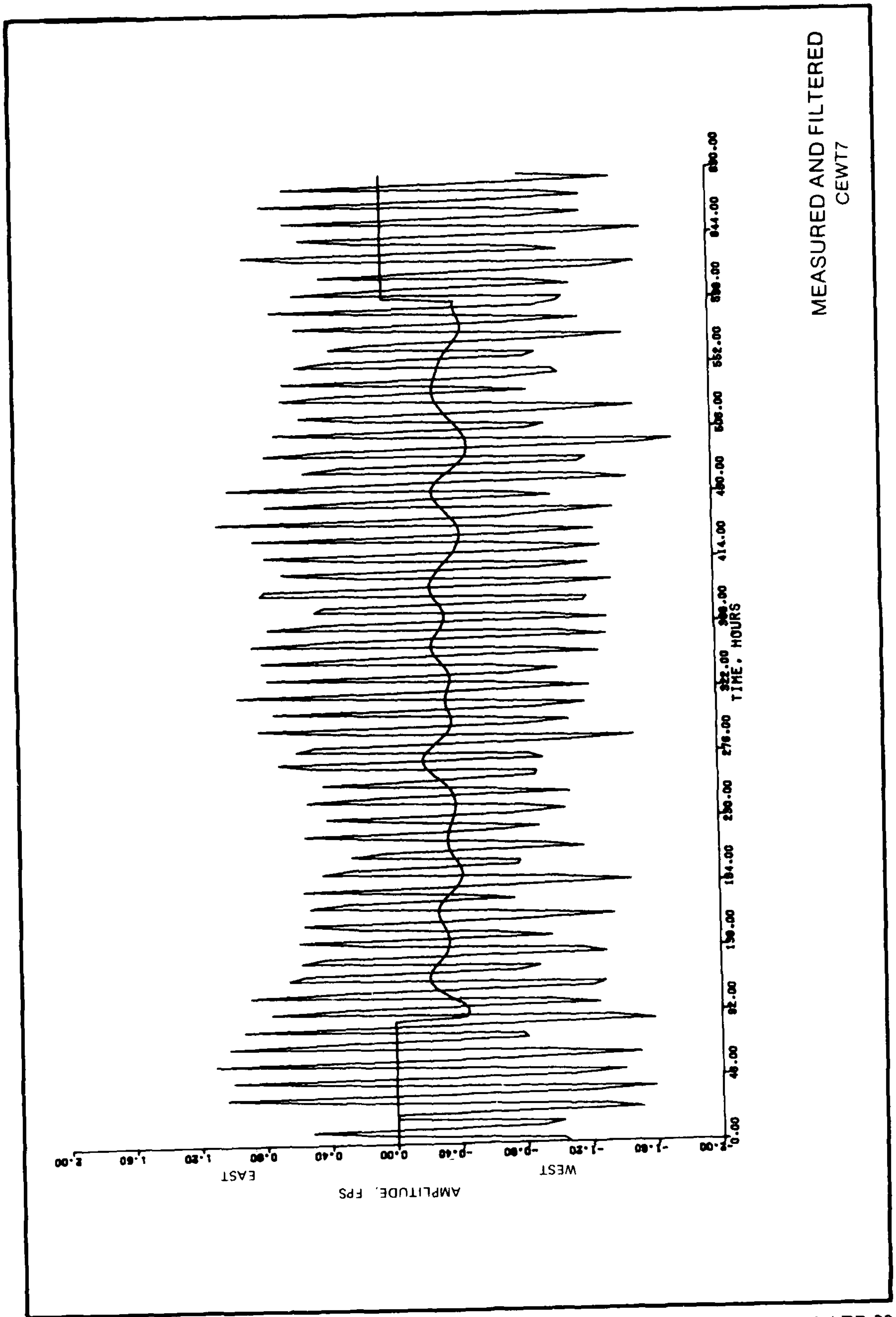


PLATE 28


MEASURED AND FILTERED
CEWT7
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

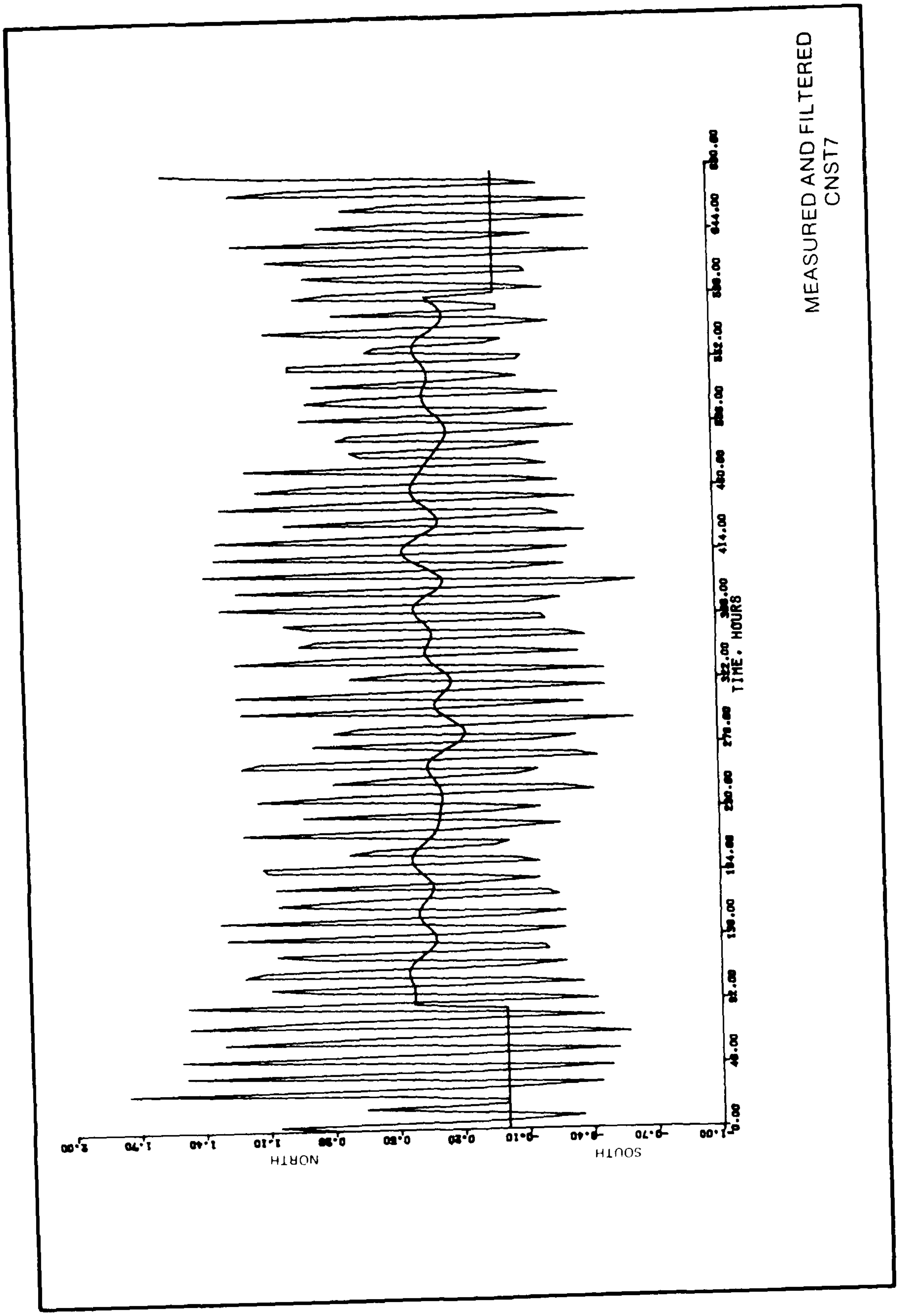
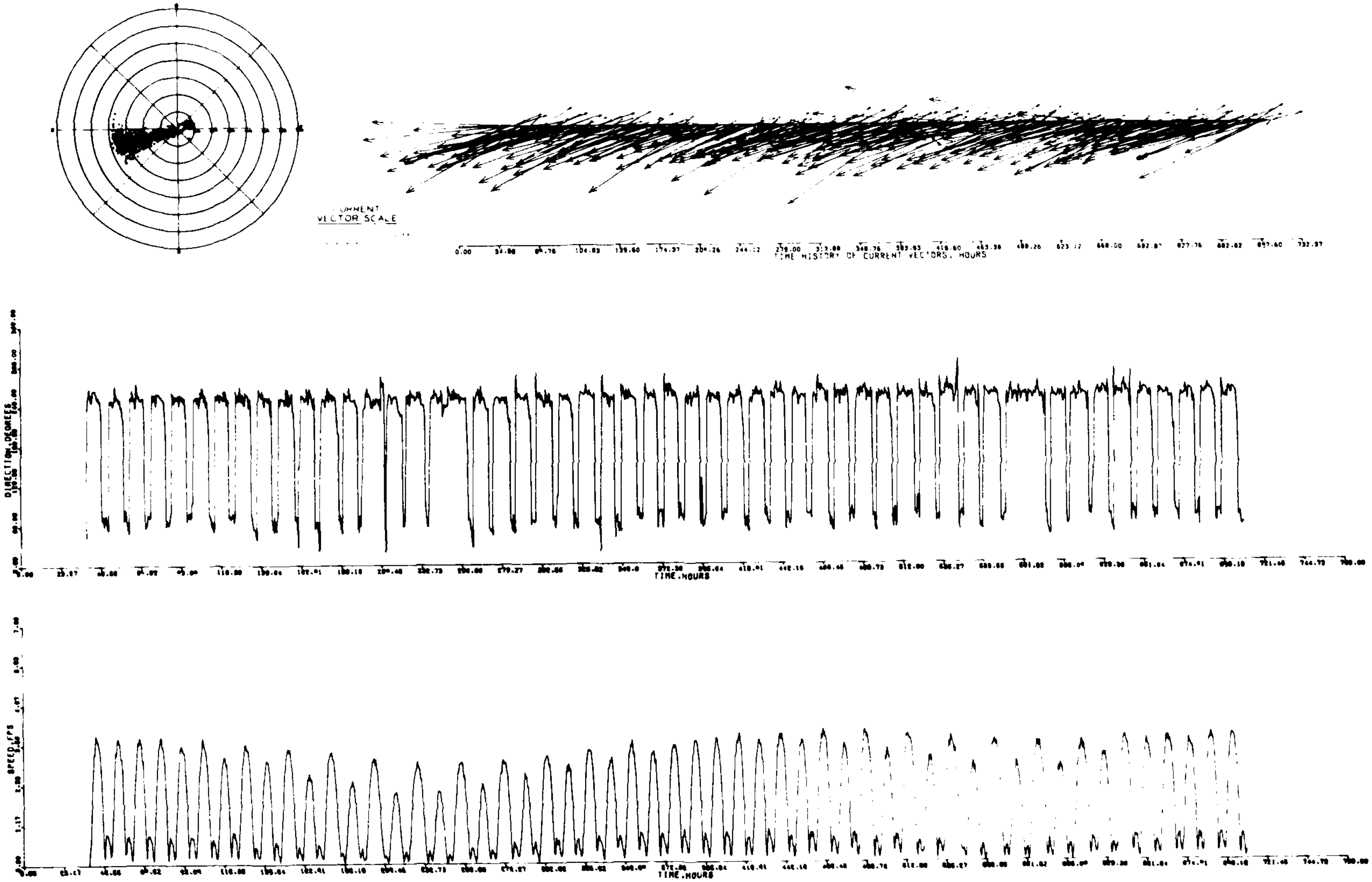


PLATE 30



MEASURED STA T8 CURRENTS

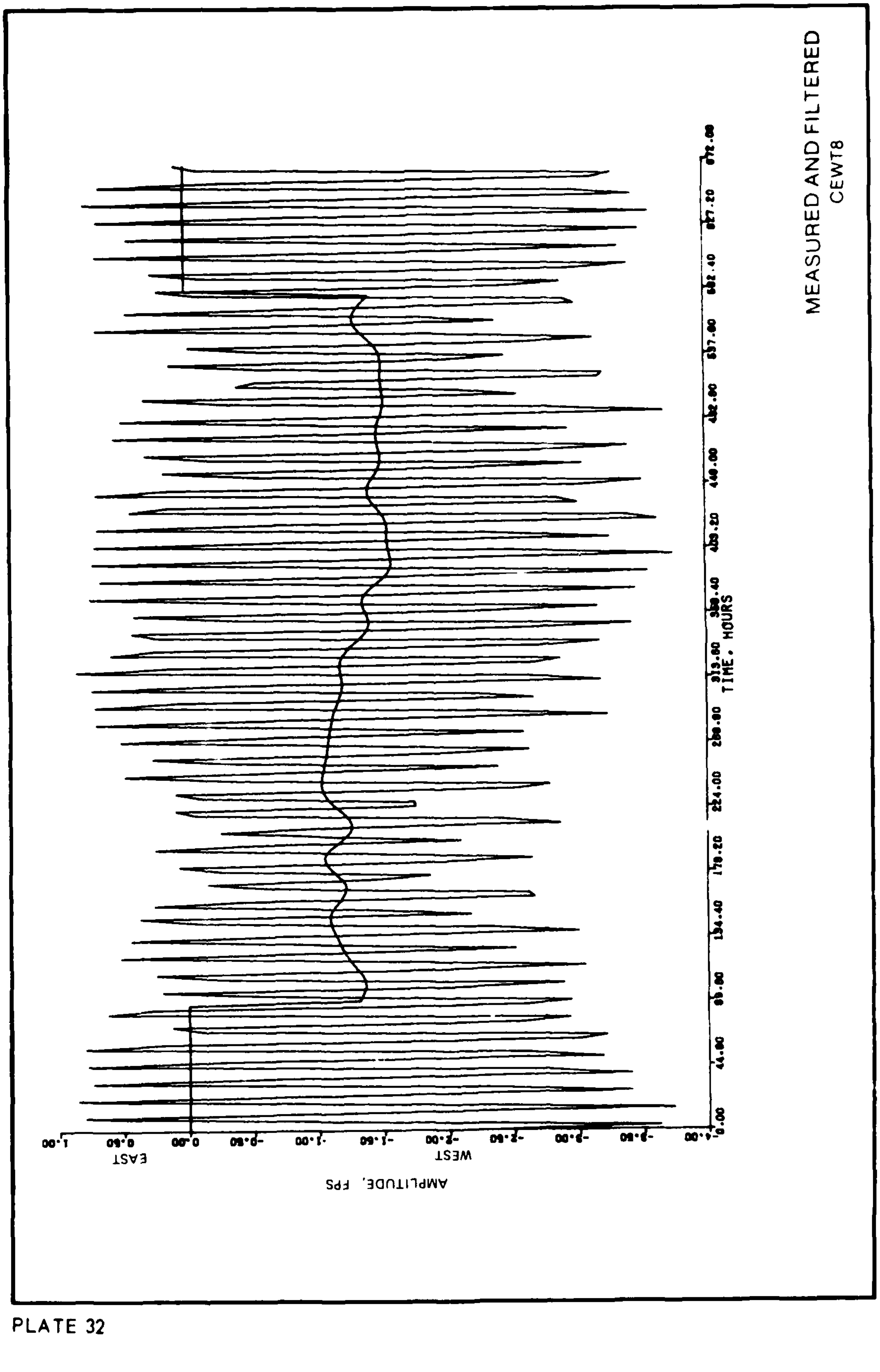
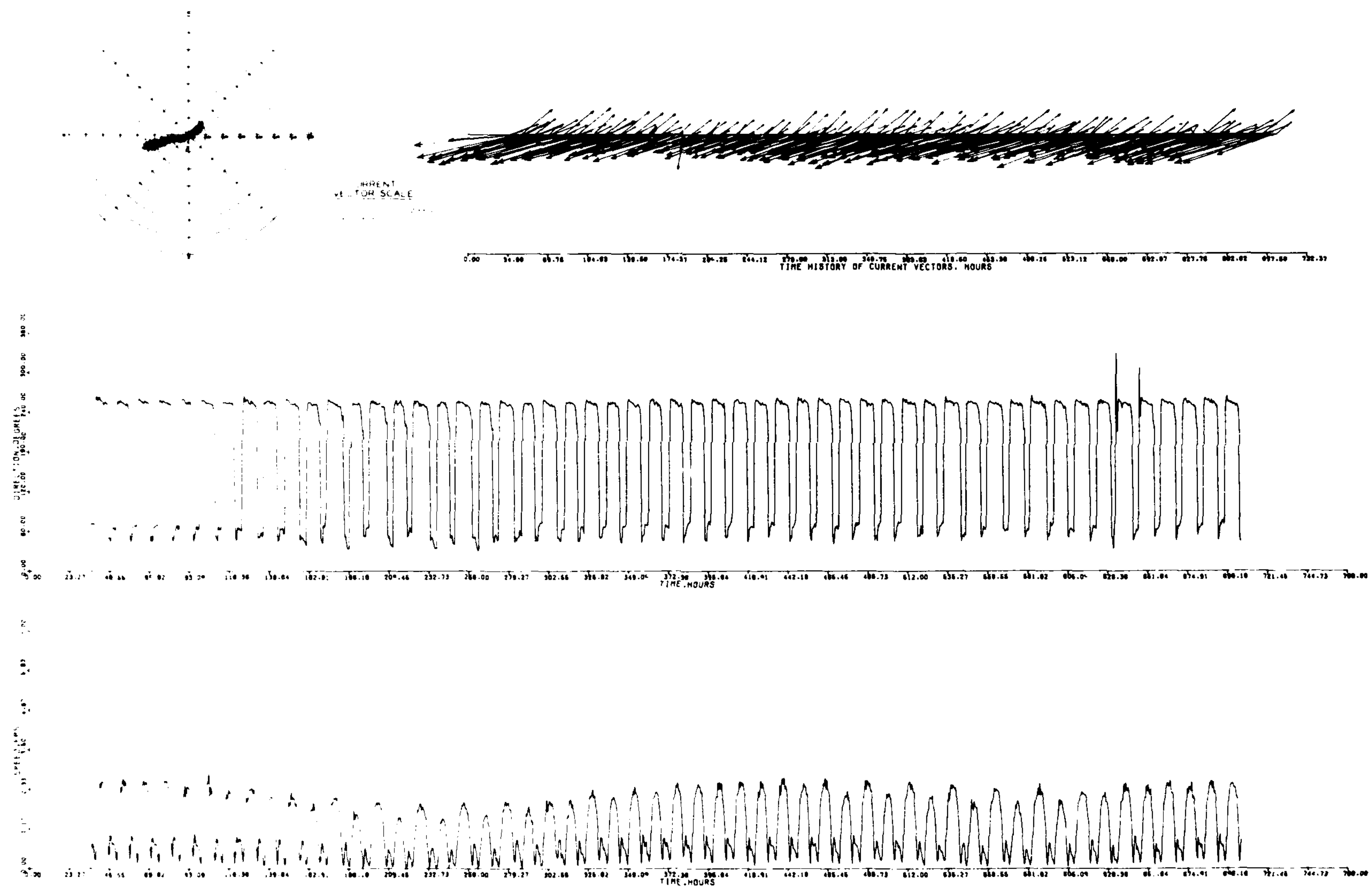

MEASURED AND FILTERED
CEWT8
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 32



MEASURED STA T9 CURRENTS

PLATE 33

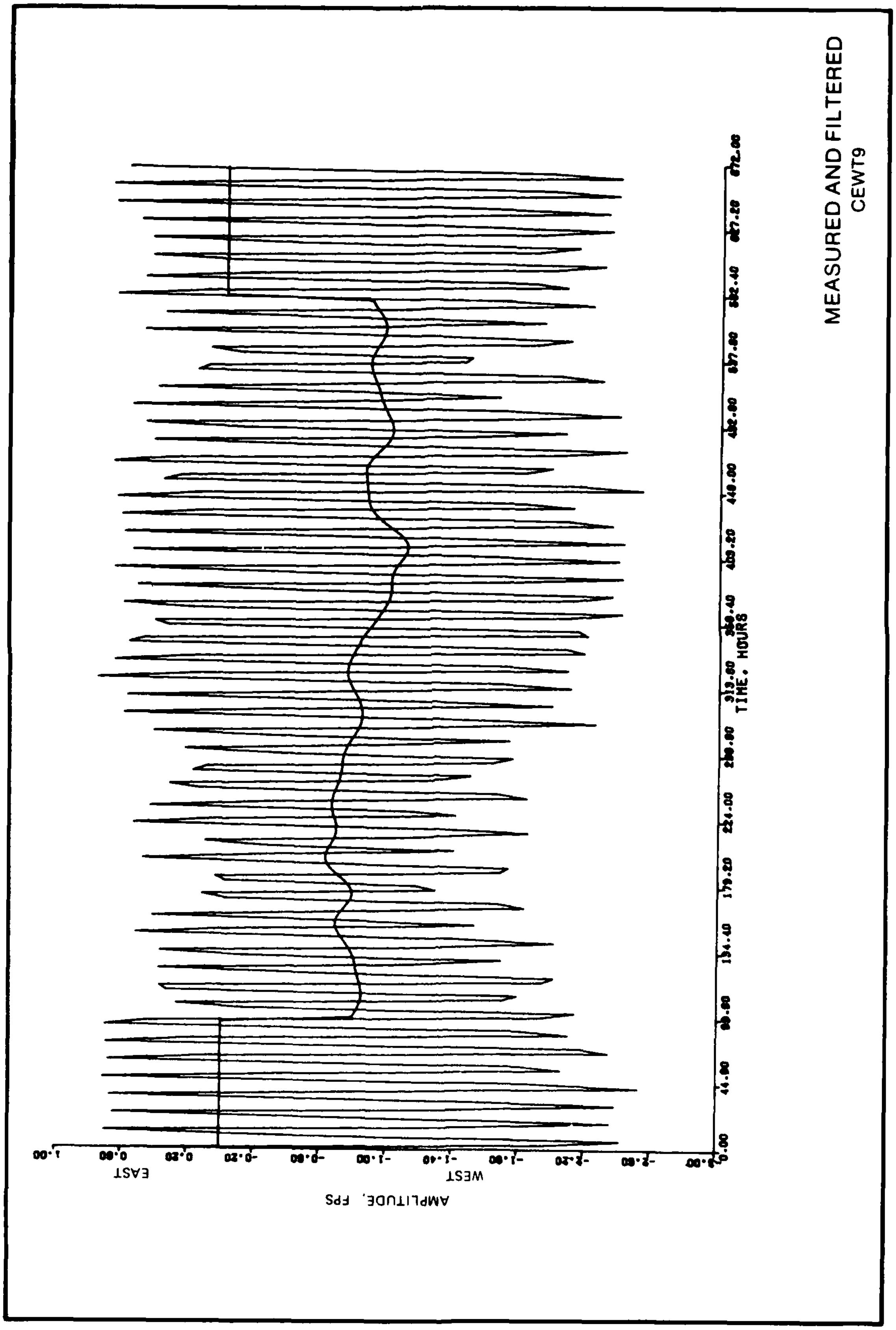
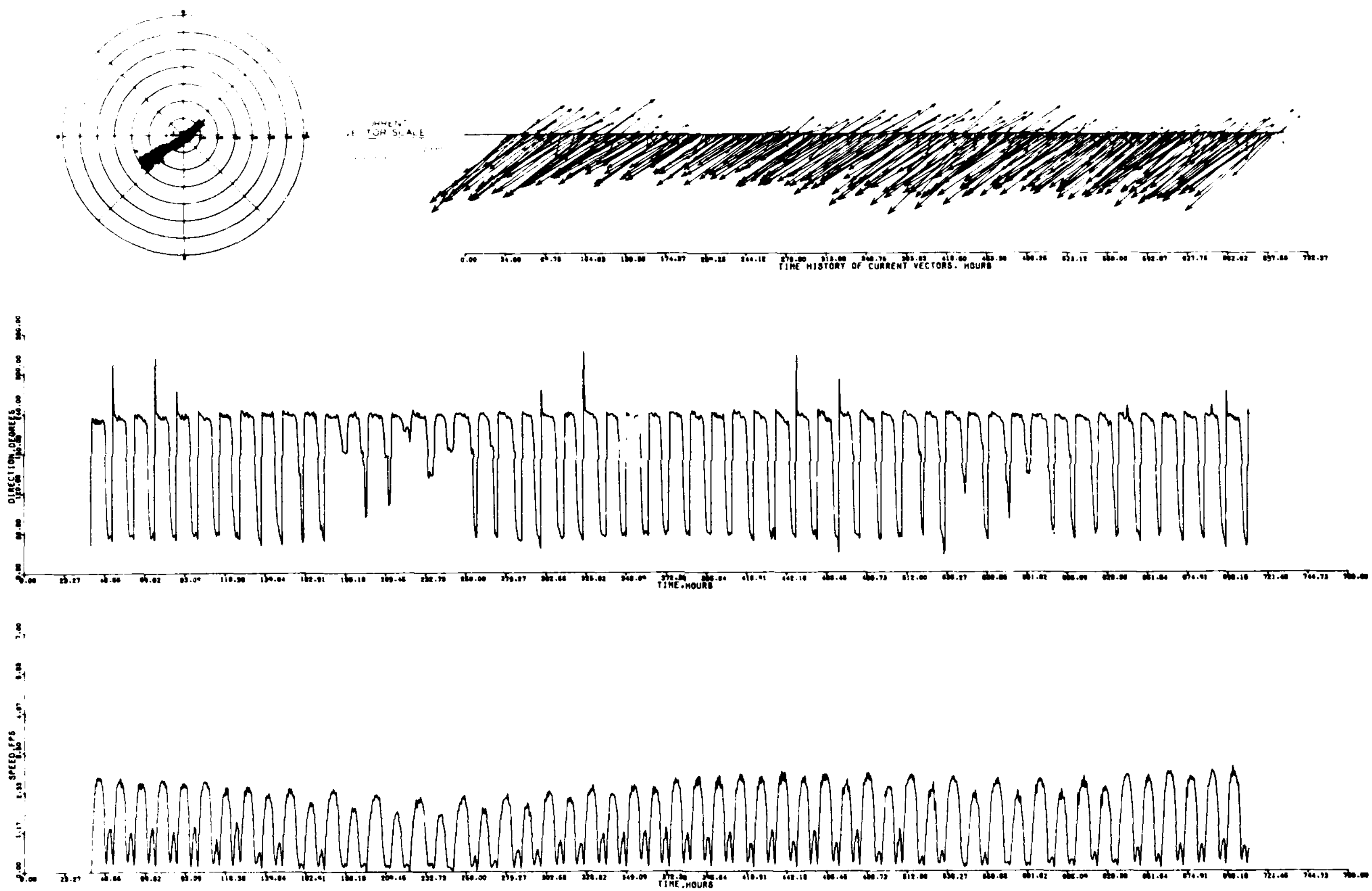

MEASURED AND FILTERED
CEWT9
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 34



MEASURED STA T10 CURRENTS

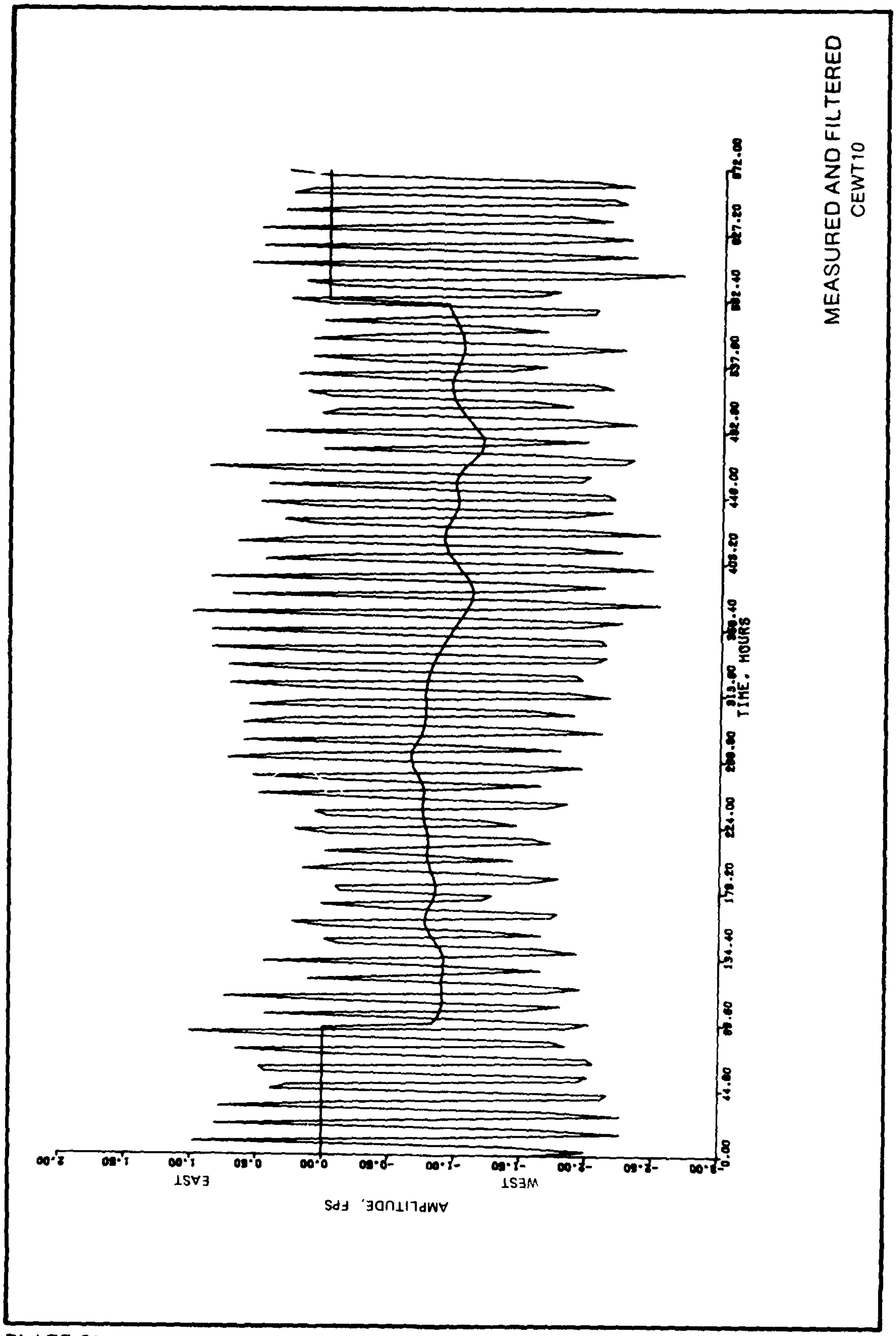
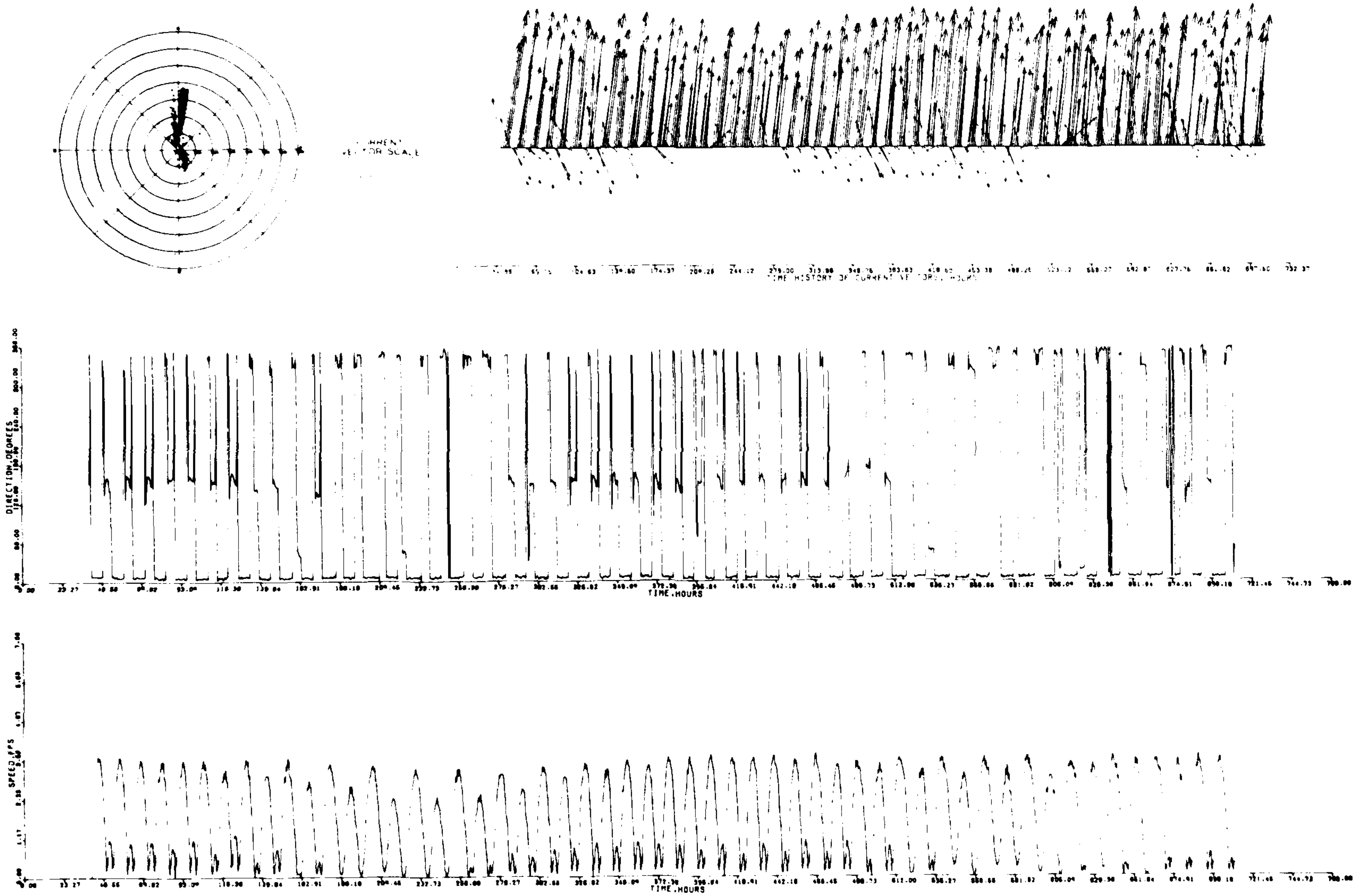

MEASURED AND FILTERED
CEWT10
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 36



MEASURED STA T11 CURRENTS

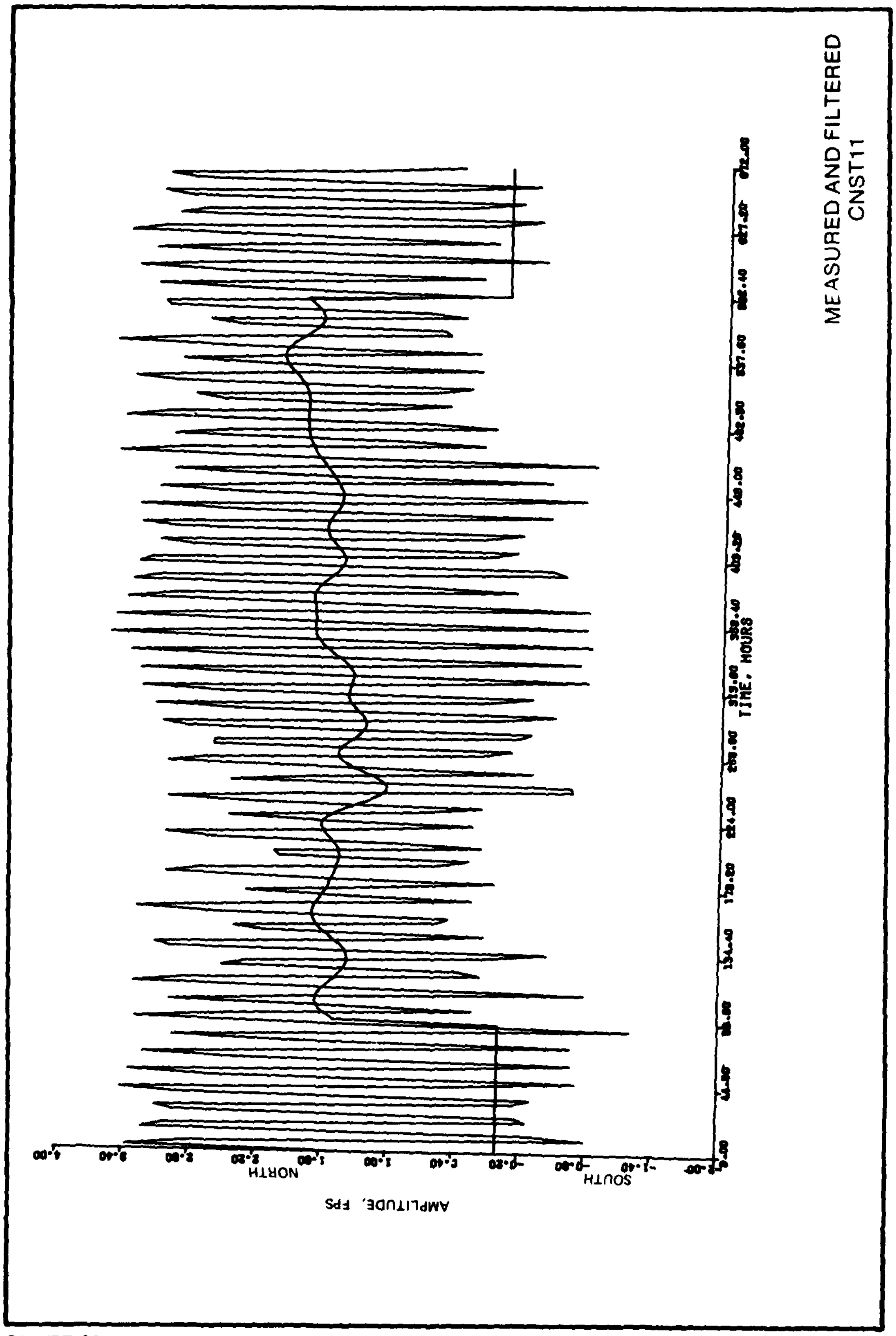
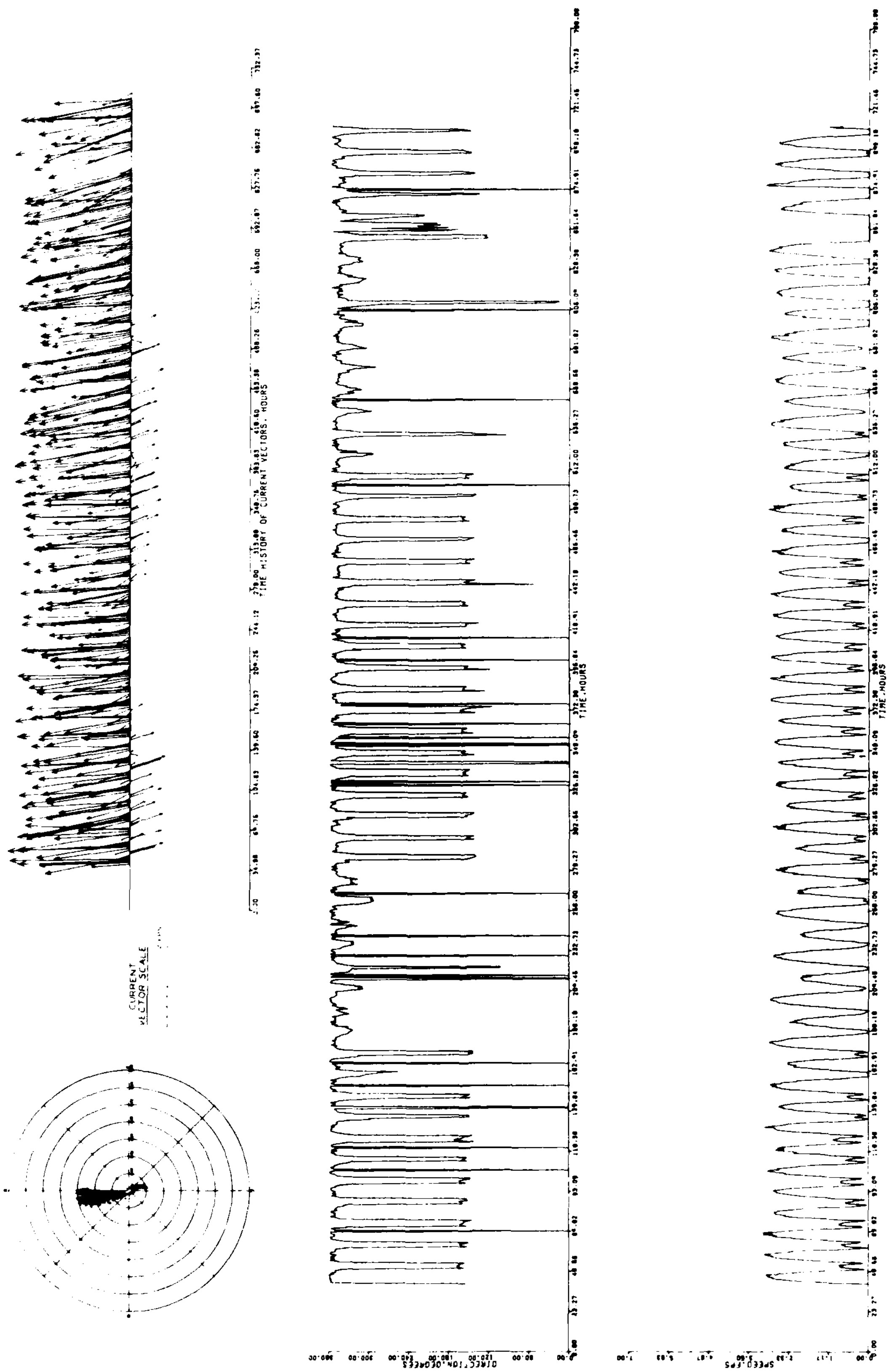

MEASURED AND FILTERED
CNST11
TIME, HOURS
AMPLITUDE, FPS
NORTH
SOUTH

PLATE 38



MEASURED STA 11B CURRENTS

PLATE 39

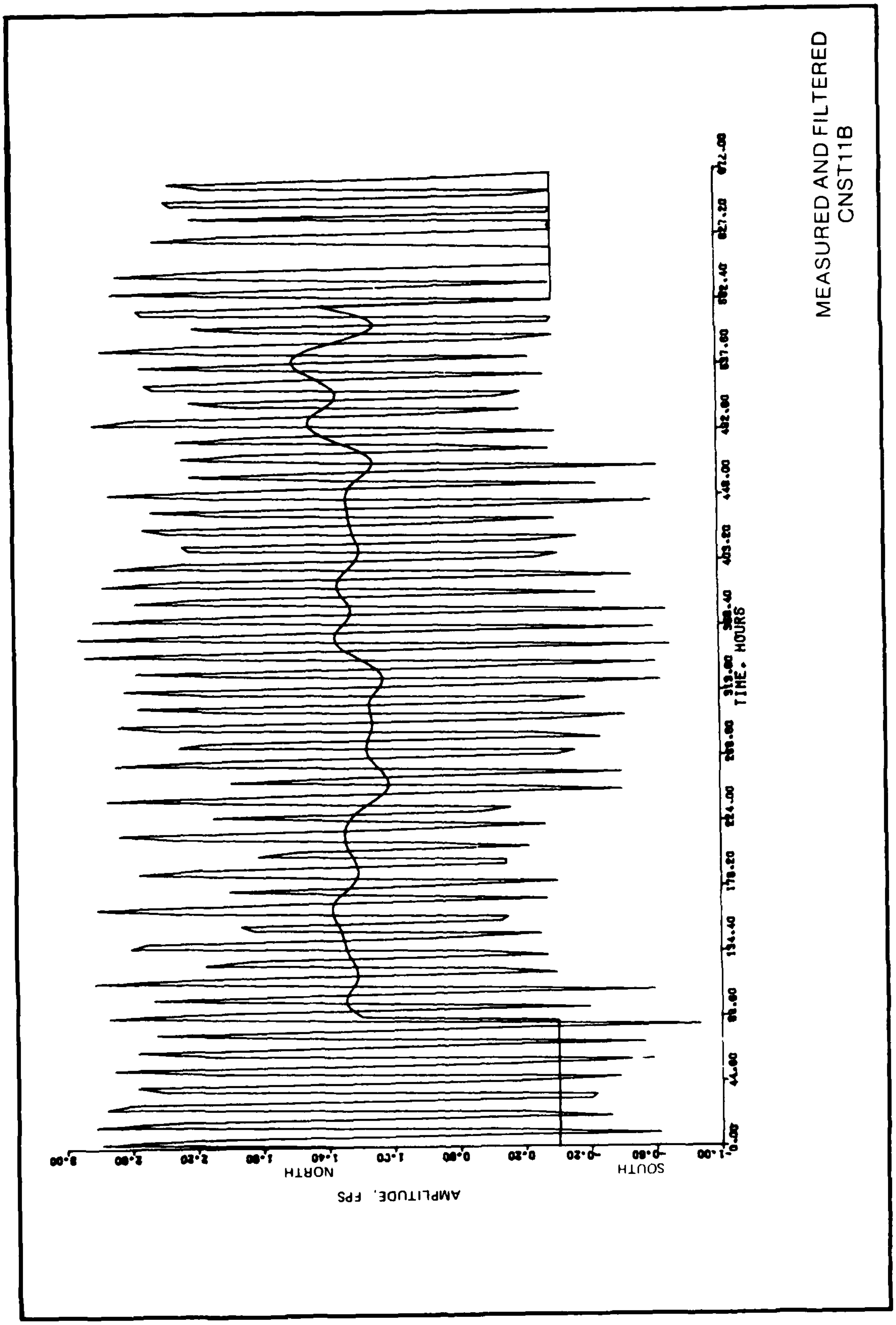
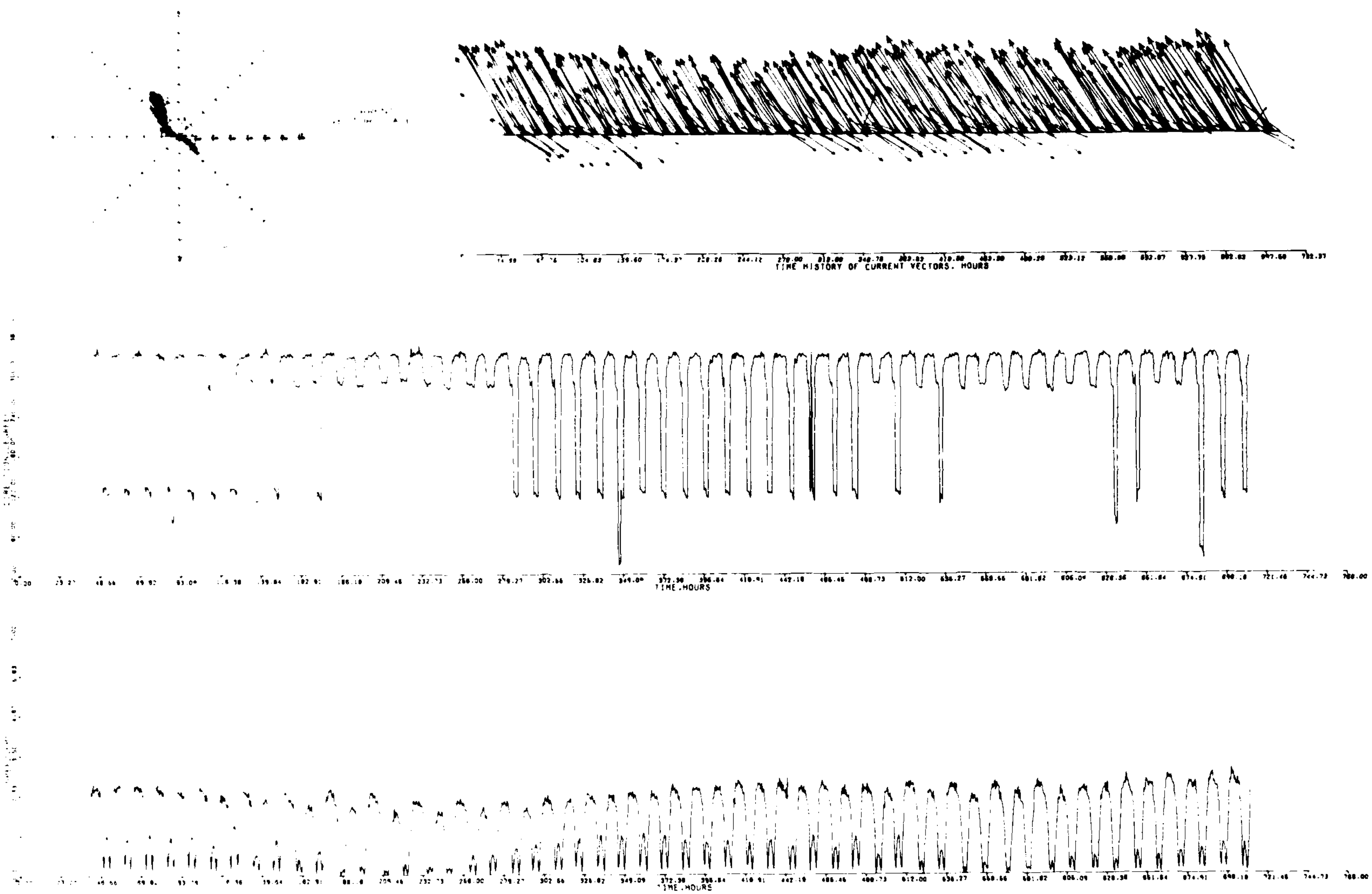

MEASURED AND FILTERED
CNST11B
TIME, HOURS
AMPLITUDE, FPS
NORTH
SOUTH

PLATE 40



MEASURED STA 12 CURRENTS

PLATE 41

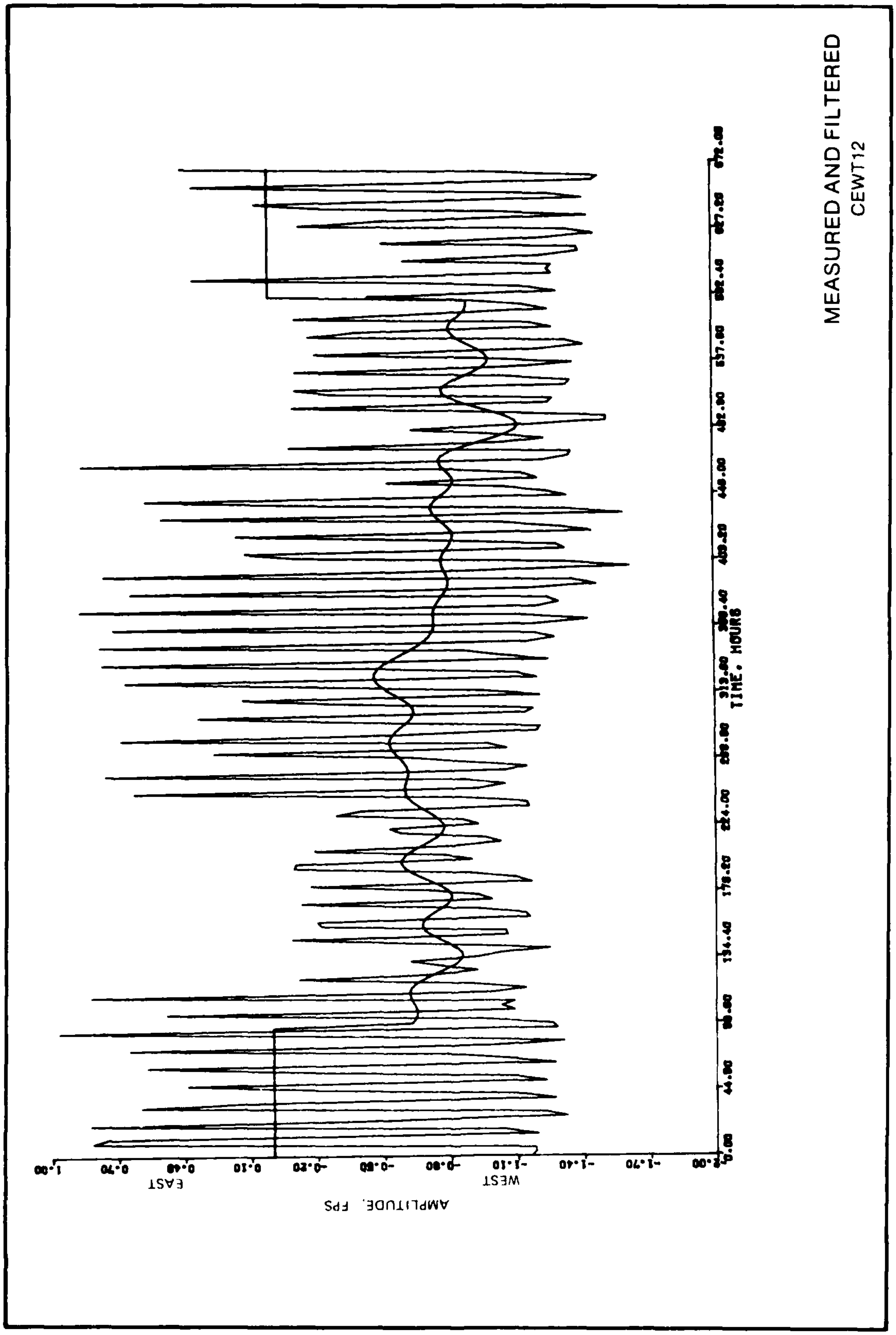

MEASURED AND FILTERED
CEWT12
TIME, HOURS
AMPLITUDE, FPS
EAST
WEST

PLATE 42

APPENDIX A: NOTATION

a_k	Finite Fourier series coefficients where k is an integer
a_n	Continuous Fourier series coefficients where n is an integer
$A_{XY}(\sigma)$	Response function amplitude of series X and Y
$\bar{A}_{XY}(\sigma)$	Smooth $A_{XY}(\sigma)$
ASD	Auto-spectral density
b_k	Finite Fourier series coefficients where k is an integer
b_n	Continuous Fourier series coefficients where n is an integer
B	Standardized bandwidth
c_k	Coefficient of complex form of continuous Fourier series where k is an integer
C_1	Constant
CSD	Cross-spectral density
f_f	Folding frequency or Nyquist frequency
$f(t)$	Function with respect to time
$\hat{f}(t)$	The Fourier series approximation of a function $f(t)$
$f(\sigma)$	Step function used for filter
$F(k)$	Complex amplitude of k^{th} component
$\bar{F}(k)$	Complex conjugate of $F(k)$
$F(\sigma)$	Fourier transform of a function $f(t)$
$F_X(\sigma)$	Amplitude spectrum
$\bar{F}_X(\sigma)$	Complex amplitude spectrum (complex conjugate of $F_X(\sigma)$)
$F_{2,v-2}$	Fisher (F) distribution with a numerator of 2 degrees of freedom and a denominator with $(v-2)$ degrees of freedom
$g(t)$	Time representation of a function G
$G(\sigma)$	Frequency representation of a function G
i	$\sqrt{-1}$
k	Integer
n	Positive integer
$2N$	Number of sample points
$P(t)$	The original value at time t
$P_F(t)$	The filtered value at time t
R	Resolution in the frequency domain
RFA	Response function amplitude

t	Time
t_p	Finite set of equally spaced points in the finite form of Fourier series
T_M	Maximum time lag
T_n	Record length
T_o	Period
$W_R(\sigma)$	Spectral window in frequency domain of $W_R(\tau)$
$W_R(\tau)$	Boxcar lag window in time domain
$W_S(\sigma)$	Spectral window in frequency domain of $W_R(\tau)$
$W_S(\tau)$	Tukey-Hann lag window in time domain
$\overline{X}$	Mean of time series X
$\overline{Y}$	Mean of time series Y
α	Probability that the true value lies beyond the specified limits
β_n	Coefficients for low pass filter where n is an integer
$\overline{\gamma}_{XY}(\sigma)$	Coherency square using Tukey-Hann spectral window (i.e. smooth)
$\overline{\gamma}^2_{XY}(\sigma)$	Coherency squared of series X and Y
Δt	Sampling interval
$\Delta\sigma$	Frequency interval
$\varepsilon(\sigma)$	Phase lag using Boxcar spectral window
$\overline{\varepsilon}(\sigma)$	Phase lag using Tukey-Hann spectral window (i.e. smooth)
$\varepsilon_{XY}(\sigma)$	Phase spectrum
ν	Degrees of freedom
π	3.14159
σ	Frequency
σ_k	Frequency corresponding to the k^{th} component
τ	Time lag, or the time interval which a series is shifted
$\phi_{XX}(\tau)$	Auto-covariance of series X(t)
$\phi_{XY}(\tau)$	Cross-covariance between series X(t) and Y(t)
$\Phi_{XX}(\sigma)$	Auto-spectral density of series X(t)
$\overline{\Phi}_{XX}(\sigma)$	Smooth $\Phi_{XX}(\sigma)$
$\Phi_{XY}(\sigma)$	Cross-spectral density of series X(t) and Y(t)
χ^2	Chi-square distribution
σ_n	Lanczos correction factor for filter

END

FILMED

1-86

DTIC