NOAA Technical Memorandum NOS OES 11

# Tidal Current Cycle Observations For Support of the NOS/USPS Tidal Current Prediction Quality Assurance Program

Silver Spring, Maryland
February 1995



**noaa** National Oceanic and Atmospheric Administration

**U. S. DEPARTMENT OF COMMERCE**
**National Ocean Service**

**Office of Ocean and Earth Sciences**
**National Ocean Service**
**National Oceanic and Atmospheric Administration**
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## TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ADCP | Acoustic Doppler Current Profiler |
| C&GS | Coast and Geodetic Survey |
| HW | High water |
| LW | Low water |
| MOA | Memorandum of Agreement |
| NOAA | National Oceanic and Atmospheric Administration |
| NOS | National Ocean Service |
| OES | Office of Ocean and Earth Sciences |
| PORTS | Physical Oceanographic Real-Time System |
| QA | Quality Assurance |
| USPS | United States Power Squadrons |

## ABSTRACT

Accurate tidal current predictions are essential to the safe passage, docking and undocking of vessels ranging in size from privately owned yachts to large tankers navigating the Nation's waterways. The National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA) publishes annual tidal current predictions for more than 2900 locations. NOS collects circulation measurements, analyzes the data, computes harmonic constituents describing the tidal current, and generates harmonic predictions of the tidal current based upon astronomical factors. Tidal currents are very sensitive to the effects of sediment accretion and erosion, dredge operations, and marine construction projects. NOS measurements supporting the tidal predictions are typically several decades old and of only a few days duration. The reoccupation of a location to evaluate predictions is seldom accomplished owing to the great expense in time and money. Consequently, the accuracy of the corresponding NOS tidal current predictions are degraded to an unknown extent by changes in the basin. Recently, the U.S. Power Squadrons (USPS) volunteered to reoccupy and measure currents at the site of NOS predictions. NOS will then compare observed and predicted times of selected tidal cycle events to give a qualitative and perhaps quantitative measure of NOS tidal current prediction accuracy. Discrepancies will be documented in the Notice to Mariners and possibly demonstrate a need for more comprehensive NOS surveys of selected areas.


## 1. INTRODUCTION

The forerunners of the National Oceanic and Atmospheric Administration (NOAA) began measuring and reporting current information for the Nation's waterways during the 1890's. NOAA **Tidal Current Tables**, which include predictions and associated information for more than 2900 stations, are printed each year for the convenience of the mariner and in the interest of marine safety. Where predictions for the times of slack water and the times and velocities of maximum flood and ebb current are not within National Ocean Service (NOS) working standards, discrepancies are noted in appropriate **Coast Pilots**, **Notice to Mariners**, and **Tidal Current Tables**. Improved predictions of tidal currents in estuarine areas are essential to support navigation of supertankers, to provide a starting point for the mitigation of hazardous material spills, and to help improve the margin of safety for heavily trafficked ports and harbors. This is especially true at major U.S. ports and other coastal areas, where an increase in commercial operations generates a requirement for improved prediction of current speeds. Yet, NOS predictions in these areas are often based upon current measurements acquired several decades ago. The NOS with the help of its many constituent organizations is focusing on modernizing navigation products and updating tide and tidal current predictions.

In accordance with Title 33 of the Code of Federal Regulations, NOAA **Tidal Current Tables** are required to be aboard vessels in excess of 1600 gross tons that operate in U.S. waters.[1] Table I of the NOAA **Tidal Current Tables** lists the predicted times of slack water and times and velocities

[1]33 CFR, Chapter 1, Sections 164.01 and 164.33

for both maximum flood and ebb currents for a given reference station. Table II provides speed ratios and time differences between secondary and reference stations. The speed of a current at times between slack water and maximum current may be estimated using Table III. Table IV allows the mariner to compute the duration of weak current near the time of slack water. These data describing the horizontal movement of water are used extensively by harbor pilots and other members of the maritime industry who have an investment in safe navigation and efficient docking.

The total current is difficult to predict because it is the sum of tidal and nontidal currents (Hicks 1989). Predicted tidal currents are based on the periodic astronomical forces and to a lesser extent, morphometry. They do not include the random effects of meteorological conditions. For this reason mariners should be cautioned that circulation patterns change with unusual weather conditions or when the basin is physically changed by severe weather, dredge operations, or the development of new structures. Wherever practical, efforts are presently underway to modernize tidal current predictions by adding new reference or secondary stations, modeling estuarine environments, and installing physical oceanographic real-time systems (Appell et al., 1991, Frey, 1991, and Nichols, 1993). The NOS encourages constituents such as the United States Power Squadrons (USPS) to provide feedback concerning the usefulness of published navigation tools.

## 1.1. Current Surveys

Systematic tidal current surveys of the Nation's principal waterways have been conducted on scales ranging from weeks to years. Observational methodologies have changed from short duration surveys during the first half of this century using 15 foot long current poles with log line and sextant to month-long surveys using state-of-the-art acoustic Doppler current profiler (ADCP) technology. Early measurements were conducted directly from a vessel and required continual attendance. Today's circulation measurements are conducted remotely from bottom-mounted ADCPs or buoyed arrays of electromagnetic current meters. Since January 1978, expensive oceanographic ventures with electronic current meters have been documented as NOS Oceanographic Circulatory Survey Reports (Long 1978, Dinardi 1978, Parker and Bruce 1980, Patchen et al. 1981, Brown and Dingle 1983, Watson 1984, Welch et al. 1985, Browne and Fisher 1986, Klavans et al. 1986, Earwaker 1990, and Nowadly 1992). Most of the surveys required the use of several vessels to occupy both reference and secondary station. Stations were usually located near harbor entrances and in main channels. Secondary stations were occupied for several tidal days. Presently, the NOS is in the process of accepting quality assured non-NOS data for the purpose of updating and expanding tidal current predictions. Minimally accepted data will have sampling intervals less than or equal to 30 minutes and a time series length on the order of months.

Reports by mariners of deviations between predicted and reported tidal currents in Tampa Bay, Florida prompted the NOS to conduct a current prediction quality assurance (QA) miniproject. QA miniprojects have involved the short duration deployment of the minimum number of instruments required to obtain sufficient data for objective statistical analysis of existing current predictions. To date, current prediction QA miniprojects have been conducted in Tampa Bay, Corpus Christi Bay, Houston Ship Channel, and San Francisco Bay (Williams et al. 1989, Williams et al. 1990, Williams et al. 1991, and Williams et al. 1992). These projects indicated that available tidal current predictions were outside of NOS working standards and recommended a thorough oceanographic survey, development of new tidal current predictions, development of a circulation model, and installation of a physical oceanographic real-time system (PORTS).

## 1.2. Nonelectric Current Measurements

Nonelectric current meters were historically used by the Nation to determine estuarine circulation. Such instruments are still viable for developing reasonable and inexpensive estimates of current speed and direction in shallow water. However, these measuring systems require constant attention during operation and data are highly dependent on the operator's skill in positioning their craft, recording the time, and reading current speed and direction. Thus, the highest percentage of measurement error will result from inadvertent operator mistakes.

Numerous investigators (Pritchard and Burt, 1951; Foerster, 1968; Kjerfve and Proehl, 1979; Kjerfve, 1982; and Kjerfve and Medeiros, 1989) have documented procedures for using submerged-drag variable-weighted current vanes for coastal oceanography. Validity of this class of nonelectric measurements is based on the fact that forces on the submerged-drag current vane are large compared to those on the stainless steel wire, and that the submerged-drag current vane maintains a nearly constant orientation independent of the wire angle. Thus, the wire angle with the vertical is proportional to the current's force on the vane. Velocity measurements are made from a moored boat by submerging a current vane of known weight to a specific depth. Once the vane is stationary in the current, measurements can be recorded. The angle of the wire from the vertical is used to determine current speed. Current directions are measured by shooting an azimuth in the direction of wire orientation with a compass. Additional wire can be either payed-out or reeled-in to obtain the velocity profile of the water column.

Kjerfve and Medeiros (1989) provided results from an intercomparison study of submerged-drag current vanes. These are the same vanes used in the NOS/USPS Tidal Current Prediction Quality Assurance Program. Field intercomparison tests against a Marsh McBirney 201M electromagnetic current meter found a standard error of 0.12 knots using the large weight while varying the wire angle from 1 to 50 degrees. A standard error of 0.08 knots was found using the medium sized weight while varying the wire angle from 3 to 63 degrees. The deviation of the vane from a vertical orientation was approximately zero degrees and independent of the wire angle. Only for the largest wire angles did the vane deviate as much as 10 degrees from the vertical. Nevertheless, this induces less than 1 percent error in the measured speed. Variations in water density from fresh to hypersaline also induce less than 1% error in the measured speed. The submerged-drag current vane may be used with wire angles ranging from zero to 50 degrees with the best dynamic range found from 10 to 30 degrees.

Kjerfve and Medeiros (1989) report that the drag force on the vane can be represented by the expression

$$F_D = \frac{C_D A \rho v^2}{2}, \tag{1}$$

where
$F_D =$ drag force,
$C_D =$ non-dimensional drag coefficient,
$A =$ cross-sectional area of vane normal to the current,
$\rho =$ density of the water,
and
$v^2 =$ square of the current speed.

This drag force is then balanced by the restoring force of gravity so that

$$\frac{C_D A \rho v^2}{2} = (mg)\tan(a), \tag{2}$$

where

$mg =$ weight of the submerged-drag current vane
and
$a =$ the deviation angle between the stainless steel wire and the vertical.

The following relation is obtained by solving for velocity in the balance of forces:

$$v = (\sqrt{2(mg)/A\rho C_D})(\sqrt{\tan(a)}). \tag{3}$$

Current velocity is found to be directly proportional to the square root of the tangent of the angle made by the downrigger wire (Pritchard and Burt, 1951). A table of velocity computations is found in Appendix A for three standard weights and a full-range of wire angles. Calibration tests indicate that the vane is most reliable and sufficiently accurate when used in estuaries having current speeds that fluctuate between 0.2 and 3.1 knots (Kjerfve, 1982; Kjerfve and Medeiros, 1989).

## 1.3. Current Prediction Techniques

Astronomical tides and tidal currents are caused by the periodic gravitational pull of the moon and sun. These cyclic motions and the frequencies and amplitudes associated with astronomic forcings are predictable using harmonic analysis. The NOS uses harmonic analysis techniques to analyze time series of current speed and direction (Schureman, 1958, Dennis and Long, 1971; and Zetler, 1982). Harmonic analysis separates time series of current measurements into a specific set of location dependent harmonic constants. This is because the tidal current can be regarded as the sum of harmonic movements of the form

$$y = H_0 + A\cos(at + \alpha), \tag{4}$$

where

$y$ = harmonic function of the angle $at$,
$H_0$ = the mean current,
A = the strength of current,
$a$ = the speed of the constituent,
t = time as measured from the Prime meridian,

and

$\alpha$ = initial phase of the constituent angle when $t = 0$.

Each cosine term is composed of an amplitude and a phase which when combined are considered to be tidal current constituents. Constituent periods and speeds are derived from astronomical data. Primary constituents are $M_2$, $S_2$, $K_1$, and $O_1$ which represent the tide producing forces of the sun-earth-moon system. The ratio of diurnal to semidiurnal constituent amplitudes can be used to identify an area as having either diurnal, semidiurnal, or mixed tidal current characteristics. The classification system is as follows:

$$R = \frac{K_1 + O_1}{M_2 + S_2}, \tag{5}$$

where tidal phenomena are semidiurnal (R = 0 to 0.25), mixed mainly semidiurnal (R= 0.25 to 1.5), mixed mainly diurnal (R = 1.5 to 3.0), and diurnal (R = 3.0 to ∞). Harmonic prediction involves reuniting identified constituents with prevailing astronomical relations. ows observed and predicted currents from a 29-day harmonic analysis of Aransas Pass, Texas tidal currents (Nichols, 1994). In this example 10 constituents are determined directly from the data (i.e., $M_2$, $S_2$, $N_2$, $O_1$, $K_1$, $M_4$, $M_6$, $M_8$, $S_4$, and $S_6$), and the remaining 14 are derived from $M_2$, $S_2$, $N_2$, $O_1$, and $K_1$ since they follow theoretical relationships (Schureman, 1958).

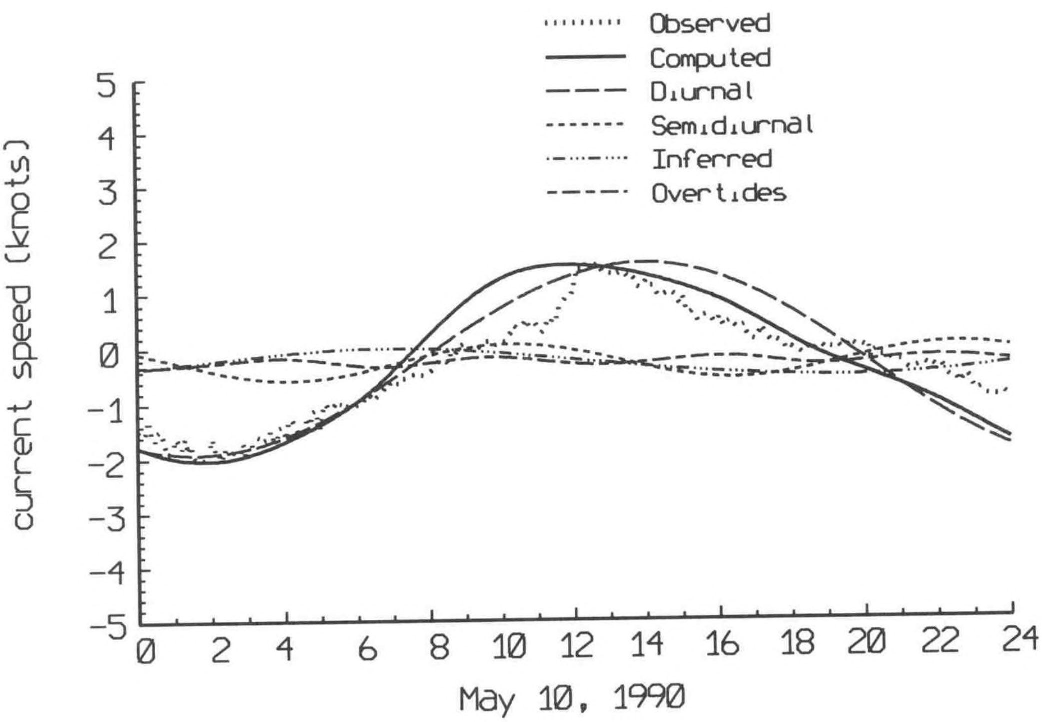


Figure 1. Computed tidal current predictions. By determining correct harmonic constants one can compute expected tidal currents, which approach the observed tidal current amplitude.

### 1.4. History of Cooperative Charting

The Cooperative Charting Program has been in existence for about 31 years and operates under the guidelines of a Memorandum of Agreement (MOA) signed on January 16, 1963, renewed January 1992, between the NOS and the USPS. Preliminary goals were directed toward evaluating nautical charts. The evaluation of aeronautical charts was added to the Agreement in 1981 and the Geodetic Mark Recovery Program was added during 1982.

USPS cooperative charting volunteers provide their vessels, practiced seamanship, skill and time to verify information published on the NOS nautical and aeronautical charts and to recover NOAA benchmarks. Members hone their skills in advanced boating courses and at annual USPS national and district conferences. For example, USPS District 5 participants receive a 6-hour program of instruction in sextants, bench marks, current surveys, channel surveys, and nautical-type corrections. Nautical chart information derived from the USPS is provided to the NOS to update the respective chart or to establish notices in the **Coast Pilot** which is an extension of the nautical chart. The USPS effort relevant to aeronautical charts involves the verification of navigation aids. The Geodetic Bench Mark Recovery Program involves USPS verification of the existence, serviceability, and locating directions for the actual marks, and is used to compare field data with the national network of bench marks. Information returned to the NOS is used to focus NOS attention on needed updates to specific nautical and aeronautical charts and to re-establish benchmarks associated with its national network.

In 1993, representatives of USPS and the Office of Ocean and Earth Sciences (OES) came to the realization that USPS volunteers might effectively reoccupy and measure the currents at sites where NOS makes tidal current predictions. Subsequent joint meetings and USPS District 5 sponsored workshops and conferences served as the venue to build the program goals, scope, and procedures. A NOS/USPS Tidal Current Prediction Quality Assurance (QA) Program was spawned to evaluate the published NOS tidal current predictions. Procedures and techniques for using nonelectric current meters for measuring the occurrence of slack waters were developed and prototype equipment was fabricated at the University of South Carolina (Figure 2). The methodology was further refined through joint NOS and USPS operational field tests. An example plot of tidal current predictions and observations is provided in Figure 3.

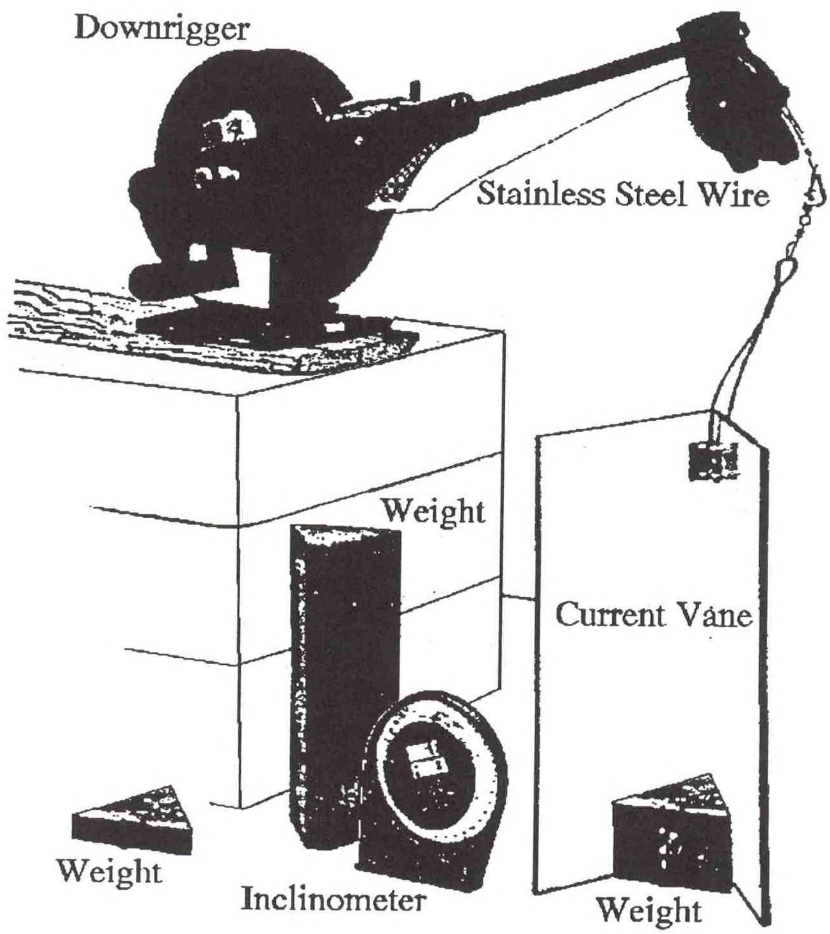


Figure 2. Schematic of a current vane. The vane is rigged to the downrigger's wire by snap swivel. The inclinometer measures wire angle. One of three weights is attached to the vane. Adapted from Kjerfve and Medeiros (1989).

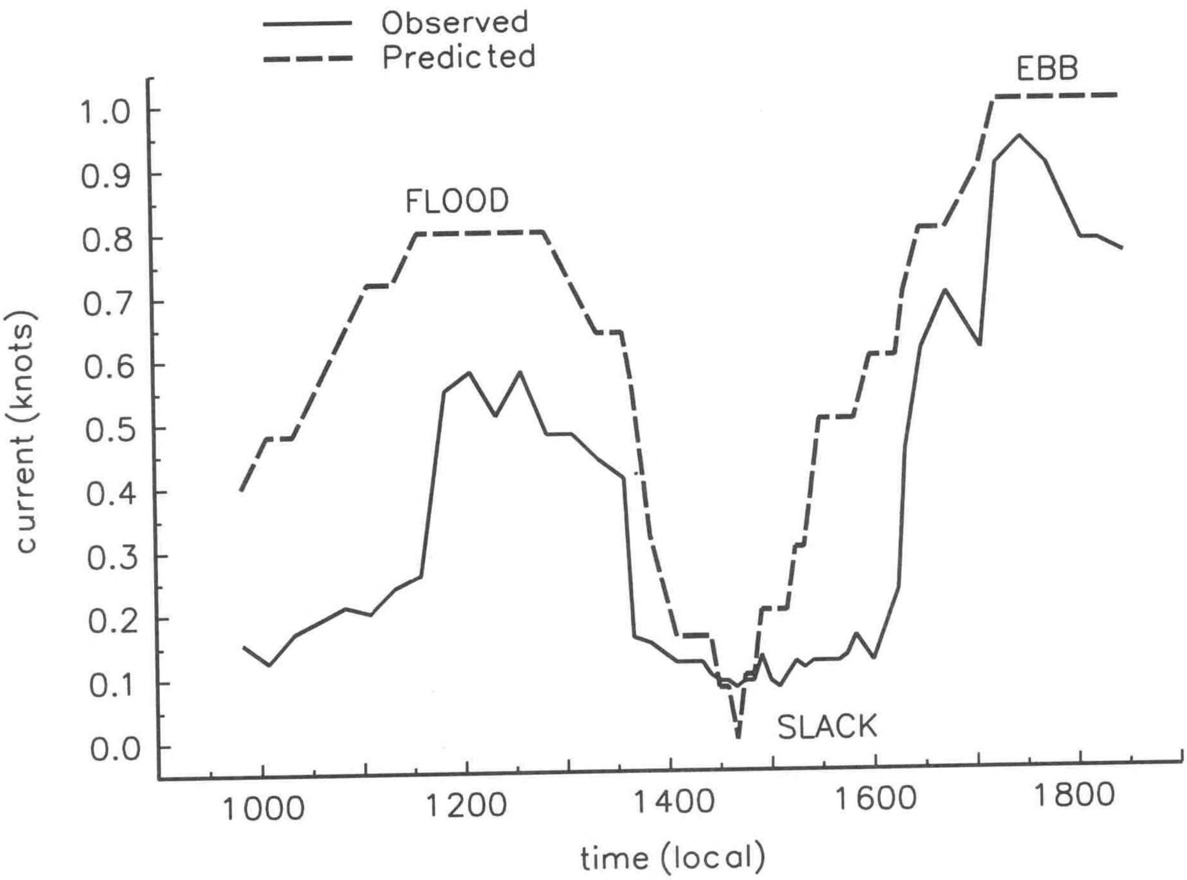


Figure 3. USPS nonelectric current measurements and NOS tidal current predictions near Thomas Point in the Chesapeake Bay on May 3, 1994.

The Tidal Current Prediction QA Program has evolved into a proof-of-concept pilot project between NOS and the USPS District 5 aimed at the measurement of slack waters. The USPS District 5 mariners are geographically located in Southern New Jersey, Delaware, Maryland, and Virginia. Such a pilot project facilitates good communication and coordination between NOS and its constituents. The NOS will administer the program, supply selected instrumentation, and analyze the collected data. After sufficient experience is gained by all parties the pilot project may be extended to other Districts of the USPS.

## 2. US POWER SQUADRONS TIDAL CURRENT PREDICTION QA PROGRAM

### 2.1. Program Elements

The purpose of the program is to gather sufficient current measurements at NOS-selected sites such that NOS can make qualitative statements concerning the accuracy of its tidal current predictions. These statements can be included in the NOAA **Tidal Current Tables** and distributed via the **Coast Pilot** and **Local Notice to Mariners**. Ideally, the measurements would be of such a quality and consistency to allow NOS to make a quantitative statement concerning prediction accuracy. These statements would further guide the mariner's use of the published predictions. Ultimately, if an area shows marked deviation from the published predictions, NOS could resolve to resurvey the area and generate new predictions.

Administration of the Tidal Current Prediction QA Program parallels the existing Cooperative Charting Program and even reuses many elements (NOS, 1989). Formal implementation began with the signing of an MOA between the USPS and the NOS/OES and NOS/Coast and Geodetic Survey (C&GS). The Tidal Current Prediction QA Program MOA is patterned after the Cooperative Charting MOA. This expedited agreement among all three parties and ensured compatibility with cooperative charting procedures. For example, the reporting of measurements made by USPS members are forwarded to NOS through the same channels used by the Cooperative Charting Program. NOAA Form 77-4 is used as a transmittal document. In like manner, USPS member contributions are recorded by NOS and forwarded to USPS Cooperative Charting Committee Chairmen (Appendix B).

Operational aspects of the program are shared by all parties. The NOS/OES provides nonelectric current meters, documentation on their use, sextants, station history logs, tide and tidal current tables, operational field logs, and editorial review of training (Appendix C). Appendix C also contains examples of the custody records that will be used when the equipment is passed from one USPS party to another. Before the respective USPS party signs for Tidal Current Prediction QA Program equipment, a thorough inventory should be conducted. NOS/OES is responsible for reviewing and analyzing the data collected by USPS, making all determinations regarding its use *vis-à-vis* the published tidal current predictions, and accepts sole responsibility for its products. NOS/C&GS provides program administration support utilizing the existing Cooperative Charting Program mechanisms. USPS maintains accountability for the instruments, administers portions of the program, agrees to follow NOS/OES guidelines for data collection, provides training support, and writes publications and training material relating to the program.

### 2.2. Field Procedures

Field work brings all of the operational elements together. Ideally, USPS volunteers will observe complete tidal cycles, remaining on station approximately 12.5 hours. At a minimum, they will observe the passage of slack water, remaining on station approximately 5 hours. For field operations, the USPS volunteer is provided with a NOS nonelectric current meter, sextant, station history log, station chartlet, tidal predictions, 3-arm protractor, and day shape. Operational field logs to record observations are found in Appendix C. As appropriate, the USPS volunteer provides additional hardware to mount the current meter's downrigger to the vessel, a hand-held compass readable from above, skill and patience. A device to measure wind speed and direction is helpful. If an observation of slack water is anticipated, the vessel should be on-station and ready to record observations 2 hours before the time of predicted slack. Appendix D includes a worksheet for computing tide and tidal current predictions. It should be noted that duration of slack water will be a function of the strength of current. Generally, the stronger the current the shorter the duration of slack. If observation of a full tidal cycle, 12.5 hours, is intended, no particular starting time is specified. However, the time of each and every element of the station occupation and current observation must be recorded to the nearest minute.

The USPS vessel proceeds to a position as near as possible to that formerly occupied by an NOS survey vessel. When possible the vessel should be anchored fore and aft so that its position will remain nearly fixed, without swinging with the current and wind. This is especially important in narrow waterways where a small change in position, especially in the across channel direction, might mean a considerable difference in the current. When this mooring is impracticable and a single anchor is used, the scope should be as short as possible to minimize swing while maintaining position without dragging. A slight breeze or swing of the boat on the anchor will show up as an erroneous current speed and direction of flow. Anchorage instructions are provide in Appendix E.

After the vessel has been moored, its exact position must be determined. The preferred method will involve the use of a Global Positioning System. Position verification and backup can be determined with sextant angles, compass bearings, radar, or loran. With the sextant, the volunteer will use the original reference objects and angles recorded in the station history log. When it is necessary to use one or more new objects, the reference objects should be selected so that the angles subtended will be fairly large, as angles less than 30 degrees cannot usually be expected to give strong positions. When the position of the station is to be determined by sextant angles, it must be kept in mind that this method will fail if the station occupied happens to lie in the circumference of a circle that also passes through all the reference objects. The coordinates, angles, bearings or loran time delays must be immediately recorded in the field log, and the position of the station plotted. The time, water depth, and weather information should also be recorded.

The downrigger should be mounted securely to the vessel and a safety line attached. The height of the downrigger tip above the water is recorded. The wire is brought inboard, a weight is selected, attached to the vane, and the vane attached to the wire. The wire is payed out until the desired depth in the station history log is attained. This requires a simple trigonometric computation or reference to the provided look-up table using the wire angle from the vertical and downrigger height as input (Appendix F). Vane depth is checked and adjusted before each observation of the current.

The procedures for taking current speed and direction observations follow those recommended by Dr. Kjerfve and refined by multiple field tests jointly conducted by NOS and USPS personnel. Current speed and direction measurements are taken every fifteen minutes. One half hour before and after slack water observations are taken every 5 minutes to better define the time of slack water. Readings with the hand-held compass and inclinometer are taken from the steel wire located in the vicinity of the downrigger arm. On a rolling vessel this is the most stable area along the wire. Before taking reading, examine the set of the wire and take readings along the set (the maximum angle). Not doing this will give erroneous readings. Have the same person, or team of two persons, take all officially recorded readings. Reading the angles is subject to some personal interpretation which is held constant by always using the same individual(s) to read the inclinometer and hand-held compass. On a rolling vessel, there is a great advantage to having the same two people record all inclinometer readings. One person steadies the inclinometer lightly against the wire while the second reads the angle. Expect some readings to be "off" relative to previous readings. Retain the "off" reading in the field log; do not alter your recordings. But also do not hesitate to immediately take another reading, recording the time of that reading. As the speed of current rises and falls it may be necessary to change weights. Ideally, the angle of the wire from vertical should neither exceed 30 degrees nor fall below 2 degrees as this is the range within which the vane current meter is calibrated. If the wire angle is outside these limits, it indicates the need to change weights. Whenever weights are changed, take a reading just prior to changing weights and another reading immediately following. Periodically, the vane should be raised to the surface to check for fouling.

Direction is taken using the top-reading hand-held compass. Attach a weighted string to one side of the compass. Position the other side lightly against the wire close to the downrigger. Bring the string into contact with the wire and read the azimuthal angle. The direction of the current is recorded in degrees magnetic.

Speed is determined by measuring the wire angle from vertical with the inclinometer. The speed is computed from a look-up table which uses this wire angle and the weight mounted in the vane as input (Appendix A) and is recorded in knots. For observations of slack water, this is repeated until the current is re-established after slack. For observations of full tidal cycles, this is repeated until the cycle is complete.

Vessel position should be rechecked a half hour after anchoring, every two hours through a full tidal cycle or midway through a 5-hour stay, and before weighing anchor. Each hour the wind speed and direction are measured and recorded. If basic meteorologic data is unavailable, the Beaufort Scale should be used for estimating wind speed and sea state (Appendix G).

At the completion of the observations, vessel position and water depth are recorded. Then, the equipment can be disassembled, cleaned with fresh water, inventoried, and repacked. <u>Originals</u> of the field logs are submitted using NOAA Form 77-4 as a transmittal document (Appendix B). The information forwarded by USPS to NOS, pursuant to this MOA, is solely for use by the United States Government.

## 3. PROGRAM BENEFITS

This program establishes an inexpensive measuring system to check NOAA tidal current predictions and relate the findings to the maritime community. A useful and sensitive measure of the quality of predictions involves documenting the change of direction of flow from flood to ebb, or vice versa. Knowing the precise time when a reversing tidal current goes through a period of slack water or zero velocity is important for many maritime operations. The USPS observations will be compared with NOS tidal current predictions as a quality assurance tool and differences documented for the maritime community in the NOAA **Tidal Current Tables**, **Coast Pilot**, and **Local Notice to Mariners**.

These USPS current surveys will provide documented knowledge of local circulation which increases navigation accuracy and safety. The experience gained through participation in cooperative charting adds measurably to the participants nautical skill. Work completed in the Cooperative Charting Program is considered toward the award of a Merit Mark (Appendix H). USPS member participation is encouraged since the program helps correct charts and tables aimed toward saving life and property.

## 4. ACKNOWLEDGMENTS

This Technical Memorandum was done as a follow-up to a Memorandum of Agreement between the U.S. Power Squadrons and the National Ocean Service. The concepts for this program were developed by D/LT Donald K. Carl, AP, former Chairman, Cooperative Charting Committee, District 5, USPS; Captain Craig Nelson, NOAA and Dr. Henry Frey, former Chief, Coastal & Estuarine Oceanography Branch, NOAA. Useful insights and technical support for establishing the measurement portion of the program were provided by Dr. Wayne Wilmot, NOAA and Dr. Björn Kjerfve and Mr. Steve Stonehill, both of the Belle W. Baruch Institute, University of South Carolina. Valuable insights concerning site selection, vessel positioning and anchoring procedures were provided by William Todd Ehret, NOAA. The program was established by Capt. Craig Nelson, Dr. Bruce Parker, Chief, Coastal and Estuarine Oceanography Branch, Mr. Richard Sillcox, Chief Information, Products, and Services Section, Mr. Harold Schantz, Coast & Geodetic Survey and D/LT Carl.

## 5. REFERENCES


Appell, G.F.; Mero, T.M., and Sprenke, J.J., 1991. Design of a Current, Water Level and Meteorological Information System For Tampa Bay, **IEEE Oceans Proceedings**, Volume 2, pp. 859-863.

Browne, D. R. and G. Dingle, 1983: New York Harbor Circulation Survey: 1980-81, **NOS Oceanographic Circulation Survey Report** No. 5, 91 pp.

Browne, D. R. and C. W. Fisher., 1986: Chesapeake Bay Circulation Survey: 1981-1983, **NOS Oceanographic Circulation Survey Report** No. 11, 25 pp + appendices.

Dinardi, D. A., 1978: Tampa Bay Circulatory Survey 1963, **NOS Oceanographic Circulation Survey Report** No. 2, 39 pp.

Dennis, R.E. and Long, E.E., 1971. A user's guide to a computer program for harmonic analysis of data at tidal frequencies., **NOAA Technical Report**, NOS 41, 31p.

Earwaker K. L., 1990: Long Island Sound Oceanography Project: 1988-1990, **NOS Oceanographic Circulation Survey Report** No. 10, 40 pp + appendices.

Foerster, J.W., 1968. A portable non-electric current meter. **Chesapeake Science**, 9, pp. 52-55.

Frey, H.R., Physical Oceanographic Real-Time Systems for Operational Purposes, **Oceans '91 Proceedings**, 2, 859-863, October, 1991.

Hicks, S.D., **Tide and Current Glossary**, National Ocean Service, National Oceanic and Atmospheric Administration, Rockville, Maryland, October, 1989, pp. 30.

Kjerfve, B., 1982. Calibration of estuarine current crosses. **Estuarine, Coastal and Shelf Science**, 15, pp. 553-559.

Kjerfve, B. and C. Medeiros, 1989. Current vanes for measuring tidal currents in estuaries. Estuarine, **Coastal and Shelf Science**, 28, pp. 87-93.

Kjerfve, B. and J.A. Proehl, 1979. Velocity variability in a cross-section of a well mixed estuary. **Journal of Marine Research**, 37, pp. 409-418.

Klavans, A. S., P. J. Stone, and G. A. Stoney, 1986: Delaware River and Bay Circulation Survey: 1984-1985, **NOS Oceanographic Circulation Survey Report** No. 9, 79 pp + appendices.

Long, E. E., 1978: Tide and Tidal Current Observations from 1965 through 1967 in Long Island Sound, Block Island Sound, and Tributaries, **NOS Oceanographic Circulation Survey Report** No. 1, 91 pp.

Nichols, C.R., 1993. Operational characteristics of the Tampa Bay Physical Oceanographic Real-Time System, Proceedings, **1993 International Conference on Hydro Science & Engineering**, Volume 1, part B, Washington, D.C., pp. 1491-1498.

Nichols, C.R., 1994: Special 1994 tidal current predictions for Aransas Pass, Corpus Christi, Texas, **NOAA Technical Memorandum** NOS OES 8, Office of Ocean and Earth Sciences, NOS, NOAA, Silver Spring, MD, 15 pp. + Appendix

National Ocean Service, 1989: **Cooperative Charting Manual**, Charting and Geodetic Services, NOS, NOAA, Rockville, MD.

Nowadly, F., 1992: Tampa Bay Oceanography Project: 1990 - 1991, **NOS Oceanographic Circulation Survey Report** No. 11, 25 pp + appendices.

Parker, B. B. and J. T. Bruce, 1980: Puget Sound Approaches Circulatory Survey, **NOS Oceanographic Circulation Survey Report** No. 3, 98 pp.

Patchen C. R., J. T. Bruce, and M.J. Connolly, 1981: Cook Inlet Circulatory Survey: 1973-75, **NOS Oceanographic Circulation Survey Report** No. 4, 89 pp.

Pritchard, D.W. and W.V. Burt, 1951. An inexpensive and rapid technique for obtaining current profiles in estuarine waters. **Journal of Marine Research**, 10, pp. 180-189.

Watson, W. A., 1984: Southeast Atlantic Coast Estuaries, Sapelo Sound to St. Simons Sound, Georgia Circulation Survey: 1980, **NOS Oceanographic Circulation Survey Report** No. 6, 41 pp.

Welch, J. M., J. W. Gartner, and S. K. Gill, 1985: San Francisco Bay Area Circulation Survey: 1979-1980, **NOS Oceanographic Circulation Survey Report** No. 7, 180 pp.

Williams, R.G., T.D. Bethem, and H.R. Frey, 1989: Tampa Bay current prediction quality assurance miniproject, **NOAA Technical Memorandum** NOS OMA 50, Office of Oceanography and Marine Assessment, NOS, NOAA, Rockville, MD 11 pp + figures.

Williams, R.G., H.R. Frey, and T.D. Bethem, 1990: Houston Ship Channel/Galveston Bay current prediction quality assurance miniproject, **NOAA Technical Memorandum** NOS OMA 53, Office of Oceanography and Marine Assessment, NOS, NOAA, Rockville, MD 12 pp + figures.

Williams, R.G., T.D. Bethem, G.W. French and H.R. Frey, 1991: Corpus Christi Bay current prediction quality assurance miniproject, **NOAA Technical Memorandum** NOS OMA 60, Office of Oceanography and Marine Assessment, NOS, NOAA, Rockville, MD 46 pp.

Williams, R.G., W.L. Wilmot, and H.R. Frey, 1992: San Francisco Bay Current Prediction Quality Assurance Miniproject, **NOAA Technical Memorandum** NOS OES 3, Office of Ocean and Earth Sciences, NOS, NOAA, Rockville, MD 40 pp.

Schureman, P., 1958. **Manual of Harmonic Analysis and Prediction of Tides**, U.S. Department of Commerce, Coast and Geodetic Survey Special Publication No. 98, Revised (1940 edition, reprinted 1988), Washington, D.C., 317p.

Zetler, B.D., 1982. **Computer Applications to Tides in the National Ocean Survey**, Supplement to the Manual of Harmonic Analysis and Prediction of Tides (Special Publication No. 98), U. S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, Maryland, 85p.

**Navigational Rules**: U.S. Department of Transportation, United States Coast Guard.

# APPENDIX A

NONELECTRIC CURRENT METER CURRENT AMPLITUDE SHEET

| WIRE ANGLE versus CURRENT SPEED and WEIGHT | | | | | | |
|---|---|---|---|---|---|---|
| Wire Angle Degrees | Vane (small wt.) | | Vane (medium wt.) | | Vane (large wt.) | |
| | knots | cm/sec | knots | cm/sec | knots | cm/sec |
| 2 | 0.05 | | 0.3 | | | |
| 4 | 0.08 | | 0.41 | | | |
| 6 | 0.09 | | 0.48 | | | |
| 8 | 0.11 | | 0.55 | | | |
| 10 | 0.12 | | 0.61 | | 1.21 | |
| 12 | 0.13 | | 0.67 | | 1.32 | |
| 14 | 0.15 | | 0.72 | | 1.42 | |
| 16 | 0.16 | | 0.76 | | 1.52 | |
| 18 | 0.17 | | 0.81 | | 1.61 | |
| 20 | 0.18 | | 0.85 | | 1.70 | |
| 22 | 0.19 | | 0.90 | | 1.78 | |
| 24 | 0.19 | | 0.94 | | 1.87 | |
| 26 | 0.20 | | 0.98 | | 1.95 | |
| 28 | 0.21 | | 1.02 | | 2.04 | |
| 30 | 0.22 | | 1.06 | | 2.12 | |
| 32 | 0.23 | | 1.10 | | 2.20 | |
| 34 | 0.24 | | 1.14 | | 2.28 | |
| 36 | 0.25 | | 1.18 | | 2.37 | |
| 38 | 0.26 | | 1.22 | | 2.45 | |
| 40 | 0.27 | | 1.27 | | 2.54 | |
| 42 | 0.28 | | | | 2.62 | |
| 44 | 0.29 | | | | 2.72 | |
| 46 | | | | | 2.81 | |
| 48 | | | | | 2.91 | |

# APPENDIX B

NOAA FORM 77-4

# INSTRUCTIONS FOR PREPARATION AND SUBMITTAL OF NOAA FORM 77-4
# FOR USPS/NOS COOPERATIVE CHARTING PROGRAM

## USE OF THIS FORM

1. PROCEDURES: The reporting member should, upon discovering a discrepancy or change, complete this form as soon as possible. Only a ball-point pen or a typewriter can be used. ALL FOUR COPIES should be forwarded to the Squadron Chairman. The Squadron Chairman should RETAIN COPY 4 and forward the remaining copies to the District Chairman. The District Chairman should retain copy 3 and forward the remaining 2 copies to the National Ocean Service (NOS). Cooperative charting credit reports will be issued by NOS on a monthly basis.

2. ADDITIONAL OBSERVERS: If more than one member is to receive credit for this report, enter the requested information on the BACK of NOS COPY 1. Be sure to indicate the percentage of credit to be issued to each member.

3. ACKNOWLEDGEMENT: To obtain an acknowledgement from NOS that this report has been received, enter your complete name and address in the appropriate place on the BACK OF COPY 2. Forward ALL COPIES to your Squadron Chairman. NOS will acknowledge COPY 2 and retain it for you (If you do not want an acknowledgment, retain copy 2 for your records).

4. SMALL-CRAFT FACILITY REPORTS: Use this form to submit Small-Craft Facility Reports. This form will replace NOAA Form 77-3 (NOAA form 77-3 can be used until the supply is exhausted).

5. SUPPORTING INFORMATION: Any supporting documentation you can supply to verify your report should be submitted along with this form and will result in additional credit for you. Such documentation could include photographs, newspaper articles, Corps of Engineers surveys, engineering drawings, etc. If you send a section from the current edition of the affected chart with the correction noted, a replacement chart will be returned to you free of charge.

## SUGGESTED ITEMS TO REPORT

1. SUBMERGED OBJECTS: Report uncharted rocks, submerged obstructions, unmarked or shifted shoals, wrecks, underwater cables, and pipelines. Report the simple fact that you know or think that there has been a change.

2. OBSTRUCTIONS: Report pilings, weirs, overhead cables, piers, new or misrepresented bridges. Include a sketch if you cannot explain it properly. When reporting the nonexistence of an obstruction, state when and by whom it was removed, if known.

3. CHANNELS: Report new channels and changes to existing channels by local interests. Include controlling depths, widths, and location of channel markers (this information is usually obtainable from the party who contracted for the new dredging). Try to obtain a copy of the after dredge survey.

4. LANDMARKS: Landmarks should be considered as any object sufficiently prominent to be of help to the navigator. Report tall, distinctive smokestacks, towers, spires, and tanks. Also, you may report an isolated building on a hill or promontory, a distinctive clump of woods or outcropping of rock, an isolated strip of sandy beach or other distinguishable feature. Less prominent landmarks may be reported around small unbuoyed or poorly buoyed harbors and anchorages. Include sketches if possible. It is equally important to report charted landmarks that no longer exist!

5. MARINE FACILITIES: Report new facilities not on current small-craft charts; also discontinued facilities that are on the charts. Report any glaring discrepancies in those facilities listed.

6. AIDS TO NAVIGATION: If you observe a discrepancy or problem with an aid to navigation, report this immediately to the nearest U.S. Coast Guard facility. Then, send a copy of your report to NOS, through your Squadron Chairman, to receive credit toward cooperative charting awards. Be sure to indicate on your report form that USCG was notified.

7. ERRORS IN COAST PILOTS: Report errors and inconsistencies in latest issues of NOS Coast Pilots. Critical changes will be published in Notices to Mariners.

8. MEASURING TIDAL CURRENTS: Only approved NOS current meters can be used to quality assure NOAA tidal current predictions. The USPS Tidal Current Prediction QA Program will key on the measurement of slack water and duration of slack water with nonelectric current meters. Field logs should be attached to NOAA Form 77-4 and submitted to the Squadron Chairman.

## HOW TO REPORT

1. REPORTING DEPTHS: Use the most accurate means available to you (lead line, setting pole, depth sounder). Always include the exact time and date of the sounding so that it can be corrected for lake surge, tide level, effect of current, etc. Do not try to correct it yourself. When using a depth sounder, be sure to make the proper allowance for the distance between the transducer and the water line. State on the report that you have done this. Report the fact that the object may be visible at low water but submerged at high water.

2. LOCATING AND REPORTING POSITIONS: Accuracy in reporting positions is vital. Use the best method available to you. If you need help locating a position, check with your Squadron Chairman. When plotting positions based on bearings, state clearly whether they are True or Magnetic, allowing for deviation if Magnetic, or deviation and variation, if True. Locations determined by cross bearings are good. Sextant bearings are best of all. A combination of bearings and distances (even if the distances are estimated) can be used. Always show your method of obtaining position on your report.

3. PLOTTING POSITIONS: Plot your information on the largest scale chart of the area. Where possible, cut out the pertinent section of the chart letter size (8½ x 11), or fold it accordingly. Include the chart number, edition, and correction date. Plot your changes clearly and accurately. Show all bearing lines and plotting information. Place explanatory notes or sketches in unused areas of the chart.

### IMPORTANT REMINDER

UP-TO-DATE CHART: An up-to-date NOS chart is essential to safe navigation and chart updating activities. Be sure that you are using the latest edition of the chart and that you have applied the local notices to mariners that were issued subsequent to the edition date of the chart.

NOAA FORM 77-4
(9-89)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
OMB Approved No. 0648-0022
Expires 07-31-92

# USPS-NOS COOPERATIVE CHARTING PROGRAM

Please TYPE or PRINT with ballpoint to ensure 3rd copy legibility. LEAVE SHADED AREAS BLANK

This report is authorized by law (33 U.S.C. 883b. Reorg. Plan No. 2 of 1965, 79 Stat. 1318, Reorg. Plan No. 4 of 1974, 84 Stat. 2090). It is used to prepare uniform and accurate observed chart correction reports that help maintain up-to-date nautical charts. While you are not required to respond, your cooperation is needed to make the results of this survey comprehensive, accurate, and timely.

| DIST | SQUADRON | LAST NAME NAME | FIRST MIDDLE INITIAL |
|---|---|---|---|
| | | | |

| STREET ADDRESS | CITY | ST | ZIP CODE |
|---|---|---|---|
| | | | |

| TELEPHONE ☐ HOME ☐ WORK ( ) | DATE OF INVESTIGATION | TIME OF INVESTIGATION | CHART NO./NAME | EDITION/DATE | OTHER OBSERVERS ☐YES ☐NO (LIST ON BACK OF THIS PAGE) |
|---|---|---|---|---|---|
| | | | | | |

| POSITION OF ITEM BEING REPORTED ON | | | TOTAL TIME EXPENDED | TOTAL MILES TRAVELED |
|---|---|---|---|---|
| LAT: | LONG: | MILE MKR. | | |

**EXPLAIN CHANGE OR CORRECTION BEING REPORTED**

FOR ACKNOWLEDGMENT, FILL OUT BACK OF COPY 2 | NEW CONTRIBUTOR YES ☐ NO ☐

| OBSERVER'S SIGNATURE | DATE SENT TO SQD. CHMN. | DATE REC'D DIST. CHMN. | DATE FORWARDED TO NOS |
|---|---|---|---|
| | | | |

**SMALL-CRAFT CHART FACILITY REPORT**

FACILITY NAME/NUMBER

STREET

CITY STATE ZIP

TELEPHONE NO. ( )

OWNERS NAME

☐ NEW ☐ UPDATE ☐ DISCONTINUED ☐ NO CHANGE

**LIST ITEMS AVAILABLE**

| | |
|---|---|
| APPROACH DEPTH | (LW - FT) |
| ALONGSIDE DEPTH | (LW - FT) |
| BERTHS(TRANSIENTS) | ☐ |
| MOORINGS(TRANSIENTS) | ☐ |
| UTILITIES(TRANSIENTS) | ☐ |
| LAUNCHING RAMP | ☐ |
| MAINTENANCE | ☐ |
| MARINE RAILWAY | ☐ |
| HARDWARE | ☐ |
| STORAGE | ☐ |
| BAIT & TACKLE | ☐ |
| FUEL | ☐ |
| RENTALS | ☐ |
| LODGING | ☐ |
| ICE | ☐ |
| WATER | ☐ |
| AMENITIES | ☐ |
| NAUTICAL CHART SALES | ☐ |
| VHF CHANNEL MONITORED | ☐ |
| TOWING ☐ YES ☐ NO | |

**2ND OBSERVER'S DATA**

DIST

NEW CONTRIBUTOR

☐ NO ☐ YES

LAST NAME FIRST NAME MIDDLE INITIAL

PERCENT OF TOTAL CREDITS

**3RD OBSERVER'S DATA**

DIST SQUADRON

NEW CONTRIBUTOR

☐ NO ☐ YES

LAST NAME FIRST NAME MIDDLE INITIAL

PERCENT OF TOTAL CREDITS

**4TH OBSERVER'S DATA**

DIST SQUADRON

NEW CONTRIBUTOR

☐ NO ☐ YES

LAST NAME FIRST NAME MIDDLE INITIAL

PERCENT OF TOTAL CREDITS

**5TH OBSERVER'S DATA**

DIST SQUADRON

NEW CONTRIBUTOR

☐ NO ☐ YES

LAST NAME FIRST NAME MIDDLE INITIAL

PERCENT OF TOTAL CREDITS

(reverse side of NOAA form 77-4)

# APPENDIX C

OPERATIONAL FIELD LOGS

NOAA FORM 37_19
(5-75)
(PRES. BY NDM 37-17)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

This is a carbonless paper set. No carbon paper is required.

**PROPERTY LOAN AGREEMENT AND RECEIPT**

| | | |
|---|---|---|
| TO: NAME AND ADDRESS OF ACCOUNTABLE PROPERTY MANAGEMENT OFFICE (Submit in triplicate) | From: ORGANIZATION | |
| | Signature of Authorized Official | |
| | Title | Date |

| | |
|---|---|
| NAME AND ADDRESS OF BORROWER | SHIPPING ADDRESS (If different from borrower) |
| DATE TO BE LOANED | DATE TO BE RETURNED |

EQUIPMENT TO BE LOANED

| QUANTITY | DESCRIPTION | COST |
|---|---|---|
| | | |

PURPOSE OF LOAN

CONDITIONS OF LOAN

1. The Borrower of the above equipment agrees to return same in like condition as received from the National Oceanic and Atmospheric Administration, normal wear and tear accepted, on or before the above return date, unless the loan period is formally accepted.
2. In case of loss or damage beyond repair the National Oceanic and Atmospheric Administration shall be reimbursed at the current price of replacement.
3. The equipment shall not be loaned or transferred to a third party without the written consent of the National Oceanic and Atmospheric Administration.
4. The Borrower shall account for the equipment whenever so requested.
5. The right is reserved to cancel the loan or recall the equipment whenever so requested.
6. The Borrower shall assume all transportation costs involved.
7. Government Saved Harmless.
8. Other conditions:

| | |
|---|---|
| APPROVED | RECEIVED (Please complete the information below and return original to the Accountable Property Management Office shown above.) |
| LOANING ORGANIZATION | BORROWING ORGANIZATION |
| SIGNATURE OF AUTHORIZED OFFICIAL | SIGNATURE OF AUTHORIZING OFFICIAL |
| TITLE | TITLE |
| DATE APPROVED: | DATE RECEIVED: |

NOAA FORM 37-19 SUPERSEDES PREVIOUS EDITION DATED (4-71) WHICH MAY BE USED.

# PERSONAL CUSTODY PROPERTY RECORD / HAND RECEIPT

**ISSUING NOS OFFICE:** Office of Ocean and Earth Sciences, Coastal and Estuarine Oceanography Branch, N/OES334, 1305 East-West HWY, Silver Spring, MD 20910. Point of Contact: Mr. Richard Sillcox, Telephone: (301) 713-2812, FAX: (301) 713-4501.

| **NAME** (Print full name) | **SIGNATURE** | **TELEPHONE** | | **USPS DISTRICT** | **INVENTORY** (Checked and Initialed) | **DATE** |
|---|---|---|---|---|---|---|
| | | Daytime | Evening | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**The last party to undersign agrees that**: I have received Vane Current Meter Assemblage number ____. I shall report to USPS Cooperative Charting authorities any breakage, loss, or replacement needs. I shall surrender the Assemblage to USPS Cooperative charting authorities upon demand.

**EQUIPMENT INVENTORY:**
CURRENT VANE ASSEMBLAGE # 0001

| Nomenclature | Manufacturer | Serial Number | Unit Price($) | Unit of Issue | Quantity On Hand | Reorder Point |
|---|---|---|---|---|---|---|
| Technical Memorandum | NOS | | N/A | EA | 1 | As Req'd |
| Storage Box | Baruch Institute | | * | EA | 1 | As Req'd |
| Current Vane | Baruch Institute | | * | EA | 1 | As Req'd |
| Downrigger with base plate | Cannon | | * | EA | 1 | As Req'd |
| Downrigger manual | Cannon | | * | EA | 1 | As Req'd |
| 0.3 kg weight | Baruch Institute | | * | EA | 1 | As Req'd |
| 1.6 kg weight | Baruch Institute | | * | EA | 1 | As Req'd |
| 6.2 kg weight | Baruch Institute | | * | EA | 1 | As Req'd |
| Inclinometer | Craftsman | | * | EA | 1 | As Req'd |
| Sextant | Davis | | 32.00 | EA | 1 | As Req'd |
| 3-armed protractor | Davis | | 14.00 | EA | 1 | As Req'd |
| Day Shape Signal (black ball) | Basic Designs | | 14.00 | EA | 1 | As Req'd |
| Inventoried By: (initials and date) | | | | | | |
| Inventoried By: (initials and date) | | | | | | |

* These items assembled or crafted for NOS by the Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia, SC. Their aggregate cost is $340.00.

# TIDAL CURRENT PREDICTION QUALITY ASSURANCE FIELD LOG

To be returned with NOAA Form 77-4

Original NOS Station Information

| STATION NAME | INSTRUMENT DEPTH(S) | LATITUDE / LONGITUDE | |
|---|---|---|---|
| Thomas Pt. Shoal Light, 0.5 n.mi. SE of | 16 feet and 33 feet | 38° 53' 37" N 076° 25' 50" W | CHARTED DEPTH 32 feet<br>SOUNDED DEPTH 38.1 feet |

| FIX BY HORIZONTAL ANGLES | | | |
|---|---|---|---|
| LEFT OBJECT NAME<br>Sandy Pt. Tank | CENTER OBJECT NAME<br>Matapeake Tank | RIGHT OBJECT NAME<br>Bloody Pt. Bar Light (Fl 6 sec 54') | CHECK OBJECT (<u>LEFT</u> / ~~RIGHT~~)<br>Bridge Upright |
| LEFT ANGLE<br>36° 12' | RIGHT ANGLE<br>108° 45' | CHECK ANGLE<br>21° 51' | |

| FIX BY LORAN | | | |
|---|---|---|---|
| 58950.6 weak | 27581.9 weak | 42644.2 | |

| FIX BY VISUAL BEARING or RADAR | | | |
|---|---|---|---|
| OBJECT (left)<br>Thomas Pt. Shoal Light | OBJECT (center)<br>Matapeake Tank | OBJECT (right)<br>Bloody Pt. Bar Light | OBJECT (check) |
| BEARING (true) / RANGE<br>310.0° | BEARING (true) / RANGE<br>045.5° | BEARING (true) / RANGE<br>153.5° | BEARING (true) / RANGE |

# TIDAL CURRENT PREDICTION QUALITY ASSURANCE FIELD LOG

To be returned with NOAA Form 77-4

## USPS Deployment Information

| | | | |
|---|---|---|---|
| VESSEL (name, model, length) | MASTER (name, address & phone) | TODAY'S DATE | CHARTED DEPTH (feet)<br>SOUNDED DEPTH (feet)<br>LOCAL TIME OF SOUNDING (am / pm) (DST / Std time) |
| ANCHOR METHOD USED<br>VESSEL ORIENTATION AT ANCHOR (degrees magnetic) | ESTIMATED POSITION UNCERTAINTY | LATITUDE ____ ° ____ ' ____ " N<br>LONGITUDE ____ ° ____ ' ____ " W | |

FIX BY GPS (latitude & Longitude) (or fix by LORAN [as many as 3 time delays])

| | | | |
|---|---|---|---|
| | | | |

FIX BY HORIZONTAL ANGLES

| | | | |
|---|---|---|---|
| LEFT OBJECT NAME<br>Sandy Pt. Tank | CENTER OBJECT NAME<br>Matapeake Tank | RIGHT OBJECT NAME<br>Bloody Pt. Bar Light (Fl 6 sec 54') | CHECK OBJECT (LEFT / ~~RIGHT~~)<br>Bridge Upright |
| LEFT ANGLE | RIGHT ANGLE | CHECK ANGLE | |

FIX BY VISUAL BEARING or RADAR (state model hand-held compass used)

| | | | |
|---|---|---|---|
| OBJECT (left)<br>Sandy Pt. Tank | OBJECT (center)<br>Matapeake Tank | OBJECT (right)<br>Bloody Pt. Bar Light | OBJECT |
| BEARING (magnetic, true) / RANGE | BEARING (magnetic, true) / RANGE | BEARING (magnetic, true) / RANGE | BEARING (magnetic, true) / RANGE |

# TIDAL CURRENT PREDICTION QUALITY ASSURANCE FIELD LOG

To be returned with NOAA Form 77-4

USPS On-Site Observations

| WIND SPEED & DIRECTION (taken every hour) | |
|---|---|
| WIND SPEED | WIND DIRECTION (from which wind is blowing)<br>(true or magnetic / circle one) |

| CURRENT MEASUREMENT (taken every 15 minutes, except every 5 minutes ½ hour before and after slack) | | | | | | | |
|---|---|---|---|---|---|---|---|
| DATE / TIME | DEPTH CHECKED (circle one)<br>Yes No | WEIGHT (circle one)<br>Small Medium Large | WIRE LENGTH (feet) | WIRE DOWN ANGLE (degrees) | WIRE BEARING (degrees magnetic) | CALCULATED DEPTH (feet) | CALCULATED SPEED (knots) |
| DATE / TIME | DEPTH CHECKED (circle one)<br>Yes No | WEIGHT (circle one)<br>Small Medium Large | WIRE LENGTH (feet) | WIRE DOWN ANGLE (degrees) | WIRE BEARING (degrees magnetic) | CALCULATED DEPTH (feet) | CALCULATED SPEED (knots) |
| DATE / TIME | DEPTH CHECKED (circle one)<br>Yes No | WEIGHT (circle one)<br>Small Medium Large | WIRE LENGTH (feet) | WIRE DOWN ANGLE (degrees) | WIRE BEARING (degrees magnetic) | CALCULATED DEPTH (feet) | CALCULATED SPEED (knots) |
| DATE / TIME | DEPTH CHECKED (circle one)<br>Yes No | WEIGHT (circle one)<br>Small Medium Large | WIRE LENGTH (feet) | WIRE DOWN ANGLE (degrees) | WIRE BEARING (degrees magnetic) | CALCULATED DEPTH (feet) | CALCULATED SPEED (knots) |

COMMENTS

# APPENDIX D

Tidal Current Prediction Worksheet

# TIDAL CURRENT TABLE WORKSHEET

| | | | |
|---|---|---|---|
| Locality: | | Date: | |
| Reference Station: | | | |
| Time Difference: | Slack Water: | | |
| | Maximum Current: | | |
| Velocity Ratio: | Maximum Flood: | | |
| | Maximum Ebb: | | |
| Flood Direction: | | | |
| Ebb Direction: | | | |
| Reference Station: | | Locality: | |
| Time | Speed & Phase | Time | Speed & Phase |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**VELOCITY OF CURRENT AT ANY TIME**

| | | |
|---|---|---|
| Interval between slack and desired time: | | Circle: (EBB) (FLOOD) |
| Inter. between slack and maximum current: | | |
| Maximum Current: | | |
| Factor, Table 3 | | |
| Velocity: | | |
| Direction: | | |

**DURATION OF SLACK**

| | | |
|---|---|---|
| Times of Maximum Current: | | |
| Maximum Current: | | |
| Desired Maximum: | | |
| Period-Table 4: | | |
| Sum of Periods: | | |
| Average Periods: | | |
| Time of Slack: | | |
| Duration of Slack: | From: | To: |

# TIDE TABLE WORKSHEET

| | | | | |
|---|---|---|---|---|
| Date: | | | | |
| Reference Station: | | | | |
| Secondary Station: | | | | |
| HW Time Difference: | | | | |
| LW Time Difference: | | | | |
| Difference in height of HW: | | | | |
| Difference in height of LW: | | | | |
| REFERENCE STATION | | | SECONDARY STATION | |
| HW | | | | |
| LW | | | | |
| HW | | | | |
| LW | | | | |
| HW | | | | |
| LW | | | | |
| HEIGHT OF TIDE AT ANY TIME | | | | |
| Time: | Date: | Locality: | | |
| Duration of Rise or Fall: | | | | |
| Time from Nearest Tide: | | | | |
| Height of Nearest Tide: | | | | |
| Correction from Table 3: | | | | |
| Height of Tide at: | | | | |

## APPENDIX E

ANCHORING INSTRUCTIONS

# ANCHORING INSTRUCTIONS

1. General. Current measurements from this program will be taken using nonelectric current meters attached to anchored boats. It is suggested that USPS boats that take current measurements be anchored fore and aft in order to minimize swinging with the current and wind. This is important because small changes in position can correspond to significant changes in current at some locations. In addition, swinging at anchor can introduce erroneous speed and direction components to the measurement of the true current. When fore and aft mooring becomes impracticable, a single anchor can be used. Single anchor moorings should have as short a scope as possible. Once the boat is anchored, its exact position must be determined.

2. Anchoring. Since the boat will have to anchor at a predetermined point, a practiced procedure should be followed to insure accuracy of placing the anchor. The navigator should plot the direction of approach track and turning bearing, and using predetermined sextant angles and compass bearing plot yards to go and a letting-go positions allowing for length of rode from the anchor position to the ultimate position of the boat. During the approach to the selected anchorage, fixes should be plotted at frequent intervals, the master should be provided with "distance to go" information, and at the moment of letting go, the position of the boat should be determined by two horizontal sextant angles and a check angle. Teamwork is important in order to reoccupy a NOS tidal current station. Before leaving dock, the mariner should accomplish the following:

- Know the wind and current effects on the survey boat before attempting to anchor.
- Review historic information used for determining reference or secondary station position.
- Check the latest nautical chart to verify which aids to navigation are still standing or relevant to the problem.
- Besides a chart study, a site trip or reconnaissance may be necessary.
- Know horizontal sextant angles and bearings and preplan boat positioning before arriving on station.
- Complete tide and tidal current prediction worksheets to determine approximate water depths during the survey.
- Ensure sufficient rode (i.e., anchor chain, cable or line, connecting shackles, bending shackles, and swivel pieces) for two anchors.

3. Letting Go and Heaving In. The suggested crew when anchoring would include:

- Helmsman to operate the boat.
- Navigator(s) to observe the shoreline and determine boat location (at least one person responsible for using the sextant and taking bearings).
- Anchor and line handler(s).

4. Practice. The method for letting go should provide good control over the anchor rode. As the boat rides away from the anchor, rode can be payed out until the desired scope is reached which anchors the boat on the predetermined point. When letting go the bow anchor, pay out enough rode to facilitate letting go with the stern anchor. Adjust both scopes in order to anchor at the predetermined point. While at anchor, a day shape shall be displayed between sunrise and sunset and appropriate anchor lights displayed between sunset and sunrise (reference U.S. Coast Guard Navigation Rules).

## APPENDIX F

NONELECTRIC CURRENT METER DEPTH SHEET

## WIRE ANGLE DEPTH WORKSHEET

| Date Time | Weight | Wire Length | Wire Down Angle | Wire Bearing | Calculated Depth | Calculated Speed | Wind Speed & Direction |
|---|---|---|---|---|---|---|---|
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| LENGTH of WIRE to PAY OUT versus WIRE ANGLE and FREEBOARD (to MAINTAIN a 15 FOOT MEASURING DEPTH) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wire Angle (Degrees) | Freeboard (Feet) | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2 | 16.01 | 17.01 | 18.01 | 19.01 | 20.01 | 21.01 | 22.01 |
| 4 | 16.04 | 17.04 | 18.04 | 19.05 | 20.05 | 21.05 | 22.05 |
| 6 | 16.09 | 17.09 | 18.10 | 19.10 | 20.11 | 21.12 | 22.12 |
| 8 | 16.16 | 17.17 | 18.18 | 19.19 | 20.20 | 21.21 | 22.22 |
| 10 | 16.25 | 17.26 | 18.28 | 19.29 | 20.31 | 21.32 | 22.34 |
| 12 | 16.36 | 17.38 | 18.40 | 19.42 | 20.45 | 21.47 | 22.49 |
| 14 | 16.49 | 17.52 | 18.55 | 19.58 | 20.61 | 21.64 | 22.67 |
| 16 | 16.64 | 17.69 | 18.73 | 19.77 | 20.81 | 21.85 | 22.89 |
| 18 | 16.82 | 17.87 | 18.93 | 19.98 | 21.03 | 22.08 | 23.13 |
| 20 | 17.03 | 18.09 | 19.16 | 20.22 | 21.28 | 22.35 | 23.41 |
| 22 | 17.26 | 18.34 | 19.41 | 20.49 | 21.57 | 22.65 | 23.73 |
| 24 | 17.51 | 18.61 | 19.70 | 20.80 | 21.89 | 22.99 | 24.08 |
| 26 | 17.80 | 18.91 | 20.03 | 21.14 | 22.25 | 23.36 | 24.48 |
| 28 | 18.12 | 19.25 | 20.39 | 21.52 | 22.65 | 23.78 | 24.92 |
| 30 | 18.48 | 19.63 | 20.78 | 21.94 | 23.09 | 24.25 | 25.40 |
| 32 | 18.87 | 20.05 | 21.23 | 22.40 | 23.58 | 24.76 | 25.94 |
| 34 | 19.30 | 20.51 | 21.71 | 22.92 | 24.12 | 25.33 | 26.54 |
| 36 | 19.78 | 21.01 | 22.25 | 23.49 | 24.72 | 25.96 | 27.19 |
| 38 | 20.30 | 21.57 | 22.84 | 24.11 | 25.38 | 26.65 | 27.92 |
| 40 | 20.89 | 22.19 | 23.50 | 24.80 | 26.11 | 27.41 | 28.72 |

## APPENDIX G

BEAUFORT SCALE

| Beaufort number or force | Wind Speed | | | | World Meteorological organization (1964) | Estimating wind speed | | | Sea State | |
|---|---|---|---|---|---|---|---|---|---|---|
| | knots | mph | m/s | km/hr | | Effects observed far from land | Effects observed near coast | Effects observed on land | Term and height of waves in meters | Code |
| 0 | < 1 | < 1 | 0.0-0.2 | < 1 | Calm | Sea like mirror. | Calm. | Calm; smoke rises vertically. | Calm, glassy, 0 | 0 |
| 1 | 1-3 | 1-3 | 0.3-1.5 | 1-5 | Light air | Ripples with appearance of scales; no foam crests. | Fishing smack just has steerage way. | Smoke drift indicates wind direction; vanes do not move. | | |
| 2 | 4-6 | 4-7 | 1.6-3.3 | 6-11 | Light breeze | Small wavelets; crests of glassy appearance; not breaking. | Wind fills the sails of smacks which then travel at about 1-2 mph. | Wind felt on face; leaves rustle; vanes begin to move. | Calm, rippled, 0-0.1 | 1 |
| 3 | 7-10 | 8-12 | 3.4-5.4 | 12-19 | Gentle breeze | Large wavelets; crests begin to break; scattered whitecaps. | Smacks begin to careen and travel about 3-4 mph. | Leaves, small twigs in constant motion; light flags extended. | Smooth, wavelets, .1-0.5 | 2 |
| 4 | 11-16 | 13-18 | 5.5-7.9 | 20-28 | Moderate breeze | Small waves, becoming longer; numerous whitecaps. | Good working breeze, smacks carry all canvas with good list. | Dust, leaves, and loose paper raised up; small branches move. | Slight, 0.5-1.25 | 3 |
| 5 | 17-21 | 19-24 | 8.0-10.7 | 29-38 | Fresh breeze | Moderate waves, taking longer form; many whitecaps; some spray. | Smacks shorten sail. | Small trees in leaf begin to sway. | Moderate, 1.25-2.5 | 4 |
| 6 | 22-27 | 25-31 | 10.8-13.8 | 39-49 | Strong breeze | Larger waves forming; whitecaps everywhere; more spray. | Smacks have doubled reef in mainsail; care required when fishing. | Larger branches of trees in motion; whistling heard in wires. | Rough, 2.5-4.0 | 5 |
| 7 | 28-33 | 32-38 | 13.9-17.1 | 50-61 | Near gale | Sea heaps up; white foam from breaking waves begins to be blown in streaks. | Smacks remain in harbor and those at sea lie-to. | Whole trees in motion; resistance felt in walking against wind. | Very rough, 4-6 | 6 |
| 8 | 34-40 | 39-46 | 17.2-20.7 | 62-74 | Gale | Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well marked streaks. | All smacks make for harbor, if near. | Twigs and small branches broken off trees; progress generally impeded. | | |
| 9 | 41-47 | 47-54 | 20.8-24.4 | 75-88 | Strong gale | High waves, sea begins to roll; dense streaks of foam, spray may reduce visibility. | | Slight structural damage occurs; slate blown from roofs. | | |
| 10 | 48-55 | 55-63 | 24.5-28.4 | 89-102 | Storm | Very high waves with overhanging crests; sea takes white appearance as foam is blown in very dense streaks; rolling is heavy and visibility is reduced. | | Seldom experienced on land; trees broken or uprooted; considerable structural damage occurs. | High, 6-9 | 7 |
| 11 | 56-63 | 64-72 | 28.5-32.6 | 103-117 | Violent storm | Exceptionally high waves; sea covered with white foam patches; visibility still more reduced. | | Very rarely experienced on land; usually accompanied by widespread damage. | Very high, 9-14 | 8 |
| 12 | ≥ 64 | ≥ 73 | ≥ 32.7 | ≥ 118 | Hurricane | Air filled with foam; sea completely white with driving spray; visibility greatly reduced. | | | Phenomenal, > 14 | 9 |

Beaufort wind scale with corresponding sea state conditions. This table is useful for estimating sea state or as an aid for guessing either wind speed or wave height. Material was obtained from DMA Pub. No. 9.

## APPENDIX H

USPS AWARDS PROGRAM

## USPS AWARDS PROGRAM

1. There are no requirements to hold advanced navigation grades or to have completed elective courses prior to participation in the cooperative charting program. However, participation with the tidal current prediction quality assurance program requires an advanced piloting rating. As USPS members become involved in Cooperative Charting they will gain new maritime skills through on the job training and appropriate USPS navigation courses.

2. In order to stimulate involvement and cooperation various certificates and awards relevant to these programs can be earned by individuals and Districts. The USPS national awards program presently includes the following awards and recognitions:

Admirals Award - Based on specific indicators averaged over the previous 5-year period.
Top District Award -
Top Squadron Award -
Top Individual Award -
Outstanding District Chairman (first-, second-, and third-place awards)

Awards will be made to the top individuals in nautical, aeronautical, and geodetic reporting groups. Cooperative charting patches (4" diameter, 6 colors, embroidered) will be awarded to the top 75 achievers, they will receive a "star" patch to be displayed around the circular cooperative charting patch. Individual, Squadron, and District Honor Role certificates are also provided. Work done in the Cooperative Charting Program is considered toward the award of Merit Mark. The Districts and Squadrons may also provide additional awards.

# ERRATA SHEET

**NOAA Technical Memorandum NOS OES 11**
**Tidal Current Cycle Observations For Support of the**
**NOS/USPS Tidal Current Prediction Quality Assurance Program**

Please note the correction made to the text in the last paragraph of page 5.

### 1.3. Current Prediction Techniques

Astronomical tides and tidal currents are caused by the periodic gravitational pull of the moon and sun. These cyclic motions and the frequencies and amplitudes associated with astronomic forcings are predictable using harmonic analysis. The NOS uses harmonic analysis techniques to analyze time series of current speed and direction (Schureman, 1958, Dennis and Long, 1971; and Zetler, 1982). Harmonic analysis separates time series of current measurements into a specific set of location dependent harmonic constants. This is because the tidal current can be regarded as the sum of harmonic movements of the form

$$y = H_0 + A\cos(at + \alpha), \tag{4}$$

where

y = harmonic function of the angle *at*,

$H_0$ = the mean current,

A = the strength of current,

*a* = the speed of the constituent,

t = time as measured from the Prime meridian,

and

$\alpha$ = initial phase of the constituent angle when $t = 0$.

Each cosine term is composed of an amplitude and a phase which when combined are considered to be tidal current constituents. Constituent periods and speeds are derived from astronomical data. Primary constituents are $M_2$, $S_2$, $K_1$, and $O_1$ which represent the tide producing forces of the sun-earth-moon system. The ratio of diurnal to semidiurnal constituent amplitudes can be used to identify an area as having either diurnal, semidiurnal, or mixed tidal current characteristics. The classification system is as follows:

$$R = \frac{K_1 + O_1}{M_2 + S_2}, \tag{5}$$

where tidal phenomena are semidiurnal (R = 0 to 0.25), mixed mainly semidiurnal (R= 0.25 to 1.5), mixed mainly diurnal (R = 1.5 to 3.0), and diurnal (R = 3.0 to ∞). Harmonic prediction involves reuniting identified constituents with prevailing astronomical relations. Figure 1 shows observed and predicted currents from a 29-day harmonic analysis of Aransas Pass, Texas tidal currents (Nichols, 1994). In this example 10 constituents are determined directly from the data (i.e., $M_2$, $S_2$, $N_2$, $O_1$, $K_1$, $M_4$, $M_6$, $M_8$, $S_4$, and $S_6$), and the remaining 14 are derived from $M_2$, $S_2$, $N_2$, $O_1$, and $K_1$ since they follow theoretical relationships (Schureman, 1958).