TAMPA BAY OCEANOGRAPHY PROJECT

PLAN FOR FY 1990 TO FY 1992

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Estuarine and Ocean Physics Branch
Physical Oceanography Division
Office of Oceanography and Marine Assessment
NOAA/National Ocean Service
Rockville, Maryland 20852

NOTICE

This is a plan for conducting oceanographic studies of Tampa Bay to improve current and water level predictions for safe navigation, response to oil and hazardous materials spills, search and rescue operations, and environmental management. Since some features of the plan may change, schedules, instruments, survey locations, and data availability are approximate. Contact the Project Director for updated information.

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LIST OF ACRONYMS

ASCII	American Standard Code for Information Interchange
ATBM	Agency for Tampa Bay Management
ATON	Aids to Navigation
BMC	Boatswain's Mate Chief
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CT	Conductivity-Temperature
CTD	Conductivity-Temperature-Depth
CWO	Chief Warrant Officer
DAS	Data Acquisition System
DOS	Disk Operating System
DQA	Data Quality Assurance
DQC	Data Quality Control
DTNSRDC	David Taylor Naval Ship Research and Development Center
EGA	Enhanced Graphics Adapter
EOPB	Estuarine and Ocean Physics Branch
FIO	Florida Institute of Oceanography
FTS	Federal Telephone System
FY	Fiscal Year
HP	Hewlett-Packard
IDS	Information Dissemination System
NGVD	National Geodetic Vertical Datum
NGWLMS	Next Generation Water Level Measurement System
NIST	National Institute for Standards and Technology
NOAA	National Oceanographic and Atmospheric Administration
NODC	National Oceanographic Data Center
NOS	National Ocean Service
NWLON	National Water Level Observation Network
OMA	Oceanography and Marine Assessment
OSD	Ocean Systems Division
POD	Physical Oceanography Division
PORTS	Physical Oceanographic Real-Time System
QA	Quality Assurance
QC	Quality Control
RADS	Remote Acoustic Doppler Sensing
RISC	Reduced Instruction Set Computer
rms	Root Mean Square
SLLB	Sea and Lake Levels Branch
TDD	Telecommunications Device for the Deaf
TOP	Tampa Bay Oceanography Project
USC	United States Code
USCG	United States Coast Guard
USF	University of South Florida
VGA	Video Graphic Array

EXECUTIVE SUMMARY

The Office of Oceanography and Marine Assessment of NOAA's National Ocean Service (NOS) is conducting the Tampa Bay Oceanography Project (TOP). TOP consists of three major components: (1) a 15-month circulation survey (including currents, water levels, water temperature and salinity, winds, and other meteorological parameters) in Tampa Bay, Florida; (2) a three-dimensional, time-varying, curvilinear-grid circulation model; and (3) the nation's first fully integrated physical oceanographic real-time system (PORTS), including information on currents, water levels, and winds at locations where these data are critical for safe and cost-effective navigation.

TOP was undertaken in response to mariners' observations that NOAA's current and water level predictions did not reflect actual conditions, particularly near the New Sunshine Skyway Bridge (the site of two fatal marine casualties). The U.S. Coast Guard Marine Safety Office at Tampa and the Tampa Bay Pilots Association alerted NOS to the situation. After local interviews, NOS conducted a preliminary project to evaluate the quality of the existing current predictions. The results of the Quality Assurance Miniproject (Williams et al., 1989) confirmed that improved information was required.

The NOAA tidal current predictions are based on data collected in 1963. Since then, major changes in the shape of the basin occurred, principally the construction of Port Manatee and its approach channels, dredge depositions, construction of large rock islands to protect the piers of the New Sunshine Skyway Bridge, and natural shoaling. These physical changes altered the hydrodynamics, affecting the current predictions.

Strong local and regional interest in new circulation measurements, hydrodynamic modeling, and real-time data was expressed both by maritime and environmental groups. The maritime interests were represented by the Greater Tampa Bay Marine Advisory Council, and the environmental interests were represented by the Agency for Tampa Bay Management. Other Federal agencies represented in one or both groups include the Army Corps of Engineers, U.S. Geological Survey, U.S. Coast Guard, NOAA National Marine Fisheries Service, and NOAA National Weather Service. State, regional, and county organizations were also represented.

FY 1990 funding for TOP was provided through an add-on to NOS's base budget by the Congress, in response to the strong local and regional support. Completion of TOP is dependent on increases in FY 1991 and FY 1992.

The data and information products and services that will result are:

1. a circulation survey data set;
2. a circulation survey report;
3. revision of NOAA's tide and current prediction tables;
4. a model-generated circulation and water level forecast atlas;
5. model-generated simulations of circulation and water levels on magnetic media;
6. a technical report on the physical oceanography of Tampa Bay and model validation;
7. transfer of the circulation model to State of Florida;
8. real-time current data at the New Sunshine Skyway Bridge, the turn from B-Cut to Port Manatee, and the turn from K-Cut to Port Tampa;
9. real-time water level data at Port St. Petersburg, Port of Tampa, and at Port Manatee;
10. real-time wind data at a location near the New Sunshine Skyway Bridge; and
11. permanent transfer of Tampa Bay PORTS to the State of Florida.

In addition, graduate students will most likely use parts of the data set for dissertations, as has been the case in many other NOS estuarine circulation projects. NOS oceanographers are able to assist the academic community even to the extent of participating on students' committees. These activities add to the long term benefits of the project.

1. INTRODUCTION

The Tampa Bay Oceanography Project (TOP) will provide improved circulation and water level data for safe and cost-effective navigation of large ships, rapid response to oil and hazardous material spills, efficient search and rescue activities, and management of the estuarine environment of Tampa Bay, Florida. The three components of TOP are:

- An extensive 15-month circulation and water level survey;
- Calibration and validation of a numerical circulation model; and
- Installation of a physical oceanographic real-time system (PORTS).

The time schedules for the project and its components are given in Figure 1.

1.1 Need for Improved Navigation Data

The Commanding Officer, USCG Marine Safety Office, asked NOS to consider a tidal current survey to determine what changes in currents may have resulted from construction of the New Sunshine Skyway Bridge. A copy of a prior letter from the Tampa Bay Pilots Association to the Coast Guard stated that "The strength and direction of the tidal currents published in the tide and current tables does not seem to accurately reflect what is actually happening in the shipping channels." A summary of NOS interviews with members of the Tampa Bay community about NOAA current and tide predictions is given in Appendix A.

In response to these concerns, NOAA interviewed members of the Tampa Bay maritime community beginning in June 1988. Firsthand knowledge was gained by riding an inbound molten sulphur tanker, the M/V *Marine Duval*. These and subsequent interviews identified three critical locations requiring improved current data -- at the New Sunshine Skyway Bridge, at the intersection of B-Cut and Port Manatee Channel, and at the turn from K-Cut into Port Tampa. Three other locations were identified for improved water level data -- at Port St. Petersburg, at the Port of Tampa, and at Port Manatee2.

1.2 Basis for NOAA Current and Tide Prediction Tables

In the annual <u>Tidal Current Tables - Atlantic Coast of North America</u>, daily predictions are given for currents at Tampa Bay Entrance (Egmont Channel), including the times of slacks before ebb and flood, and the times and velocities of maximum ebb and flood currents. Time differences and speed ratios are provided at

37 locations in Tampa Bay. These data, derived from the analysis of current measurements that were made in 1963 and earlier, were used to prepare the NOAA Tidal Current Charts for Tampa Bay. This publication consists of charts that represent current vectors at hourly intervals of the average maximum tidal cycle, with corrections required to take into account time-varying gravitational effects of the earth-moon-sun system. Corrections to the tidal current charts are made using either the annual current tables or specially published tidal current diagrams.

In the annual Tide Tables - East Coast of North and South America, daily predictions are given for tides at St. Petersburg, including the times and heights of high and low water. Time and height differences are provided at nine locations in Tampa Bay. This information is based on data collected in 1977 through 1979.

1.3 Quality Assurance Miniproject for Tidal Current Prediction

To achieve an objective, quantitative assessment of the uncertainties in NOAA's current predictions, a Quality Assurance (QA) Miniproject was conducted. Measurements were made with two instruments during deployment periods from December 1988 through February 1989 at the reference station for current predictions (Egmont Channel), the New Sunshine Skyway Bridge, the intersection of B-Cut and Manatee Channel, and the intersection of K-Cut and Port Tampa Channel, where data had been collected during the 1963 survey. For a direct comparison, the locations and depths chosen for the analysis of the 1989 data correspond to those of the 1963 measurements. Extensive quality control procedures and subsequent processing showed that all of the newly-collected data were of high quality. The USCG Cutter *White Sumac* supported the QA Miniproject. NOAA is grateful to Aids to Navigation, Coast Guard Base St. Petersburg for that support.

The QA Miniproject and its results are described in a NOAA Technical Memorandum (Williams et al., 1989). Statistical analysis of the published NOAA predictions and those computed from the new measurements showed that differences in the times of slack waters and maximum ebb and flood currents exceed acceptable standards. These standards for currents and tides (Williams et al., 1989), a reasonable goal to set for prediction accuracy, state that, for all comparisons of predicted and observed values (for at least 30 days of data), 90 percent of the differences between

1. amplitude at high water and low water are within 15 centimeters,
2. time of high water and low water are within 15 minutes,
3. amplitude of maximum flood and ebb current are within 32 cm/s,
4. time of maximum flood and ebb current are within 30 minutes, and
5. time of slack before flood and ebb are within 15 minutes.

The times of these characteristics are particularly susceptible to changes in the shape of the estuarine basin. Since 1963, numerous changes have been made, including the construction of Port Manatee and dredging of Manatee Channel, deposition of the dredge spoils, construction of the New Sunshine Skyway Bridge with large rock island pier protectors, and natural shoaling.

Tidal current predictions were generated and compared to the new observations. Although the mean differences were smaller than the mean differences between the old and new predictions, the new predictions did not provide consistently adequate information. The causes of this variability include currents driven by wind stresses, freshwater runoff, and dynamic forcing by the adjacent shelf. These effects are more evident along the U.S. Gulf Coast than elsewhere in the nation because the tides are generally smaller there. Where tidal ranges are greater, currents can be predicted with proportionately higher reliability.

Better information for pilots can be provided in two ways. A circulation model can be used to simulate the circulation of Tampa Bay under varying meteorological and freshwater runoff conditions. For critical locations, however, real-time data provide the best reliability.

Through briefings to the Agency for Tampa Bay Management and the Greater Tampa Bay Marine Advisory Council, and in meetings with the Tampa Bay Pilots Association and Coast Guard officers, NOS informed interested parties about the results of its QA Miniproject and actions required to provide the required level of circulation and water level information for Tampa Bay.

1.4 Project Planning

In response to strong local and regional support, Congress appropriated funds for FY 1990 for NOS to conduct a circulation survey of Tampa Bay, apply a circulation model, and install a real-time current system at the New Sunshine Skyway Bridge. Dependent on subsequent funding in FY 1991, NOS plans to complete the circulation survey, calibrate the model, and install the remainder of the real-time system. During FY 1992, NOS plans to upgrade the information dissemination software for PORTS, complete the analysis of oceanographic and related meteorological data, complete the validation of the circulation model, publish a circulation atlas, revise the NOAA prediction tables, and produce a major technical report.

In December, 1989, NOS held a planning briefing and workshop in St. Petersburg. A preliminary plan was presented and suggestions for revision and for cooperative and collaborative interactions were encouraged. Information input resulting from the

December briefing and workshop is included in this plan. The attendees are listed in Appendix B.

1.5 NOAA Responsibility and Enabling Legislation

NOS is the NOAA line office that is required to provide the nation with tide and current predictions and related information. The basic authority for the NOAA Tide and Water Level Program and the Coastal Ocean Circulation Program is embodied in Title 33 of the United States Code (USC). The traditional information products are the annual prediction tables that are distributed to the private sector by NOAA Chart Agents and to the military by the Defense Mapping Agency. On an annual basis, NOS produces four volumes of tide prediction tables and two volumes of current prediction tables. Under the Code of Federal Regulations (CFR), all vessels of 1600 gross tons or more are required to carry the NOAA tables, or an acceptable equivalent, whenever in United States' navigable waters. Failure to do so can result in the arrest and prosecution of the ship's master. Pertinent excerpts from the USC and the CFR are contained in Appendix C.

2.e CIRCULATION SURVEYe

The first major component of TOP is an extensive survey of currents, water levels, temperature and salinity, and meteorological parameters that will begin in June 1990, and continue to the end of August 1991. While primarily to provide information for operational users of the Bay, the data from Tampa Bay PORTS will also be a part of the circulation survey. Measurement station information (station code and name, period, depth, and location) is given in Table 1. Typical instrument configurations are shown in Figure 2. Location maps for survey locations are shown in Figures 3 to 6, and schedule time lines are shown in Figures 7 to 9.

2.1 Current Measurements

Requirements

Requirements for the deployment of current meters are to: (1) provide current data needed for safe navigation at the New Sunshine Skyway Bridge, (2) represent currents along the Tampa Bay navigation channel, (3) provide data in regions of rapid change of tidal characteristics, (4) provide data in all important sub-embayments, (5) obtain sufficient data for model calibration and validation, (6) obtain data that can be used to supply model boundary conditions, (7) and select secure locations that will not interfere with navigation or trawling.

Instruments

The remote acoustic Doppler sensing (RADS) system, NOS's generic term for this type of instrument, will be the principal current meter used in TOP. The RADS used is the RD Instruments' acoustic Doppler current profiler. The RADS system employs the Doppler principle to measure remotely the speed and direction of the currents through the water column. It transmits a succession of acoustic pulses, and divides the resulting backscattered water mass echoes into as many as 128 depth cells or "bins" as small as 1-meter intervals. The range (maximum depth) is frequency dependent, and varies from about 30 meters for the 1200 kHz RADS to about 350 meters for the 75 kHz RADS. Once the range is specified, the highest frequency RADS available is used, since the data signal-to-noise ratio increases with increasing frequency. RADS deployed in the circulation survey will record data internally, either on magnetic tape or on a solid state recorder. The real-time RADS for Tampa Bay PORTS, besides recording data internally, will send the data via cable to a transmitter located nearby for a radio link to a receiver on land.

One 300 kHz RADS system (range 120 m) and two 600 kHz systems (range 60 m) will be operated in the relatively deep channel at the Bay entrance (Egmont Channel) and off the coast. These RADS will be deployed on the bottom, mounted vertically in a platform designed for instrument protection and leveling (Figure 2a). Inside the Bay, there will be six RADS, operating at 1200 kHz, mounted horizontally to maintain a low profile (Figure 2b). All RADS are equipped with pressure sensors. Each RADS platform will be equipped with a Seabird CT to determine water temperature, salinity, and density at the bottom.

One 600 kHz RADS will be towed in a downward-looking configuration on a stable catamaran. The towed RADS data, recorded by processing electronics on the vessel, are immediately available to scientists on board. This arrangement works well under low sea state conditions. The RADS scans the water current field below the vessel and enables the preparation of space-time maps of vertical slices through the water column. The towed RADS will be used to measure the current fields at the entrance to Tampa Bay, in the vicinity of the New Sunshine Skyway Bridge, and at the turn-offs to Port Manatee and Port Tampa.

Since for water depths less than about 3 meters, the use of RADS is not cost-effective and there is risk to the instrument, a less costly current meter, InterOcean's S4, will be used. The S4's, which operate on the principle of modulation of electromagnetic fields due to fluid flow, will be attached to tripod frames resting on the bottom, and will be fixed at about 2 meters above the bottom (Figure 2c).

<u>Current Measurement Locations and Schedules</u>

The current measuring stations will be either long term (occupied for the duration of the project), or short term (occupied for 60 days). The long term stations are required to resolve the first three diurnal harmonic constituents. The 60 day period was chosen to assure adequate length records for harmonic analysis, to provide 30 days of data for model calibration, and to provide a second 30 days of data for model validation. The locations of the current meter deployments in TOP are shown in Figures 3 to 6, and the schedule for deployment is shown in Figure 7. More precise information on deployment locations is given in Table 1.

Six long-term locations (labelled C-1 to C-6) were selected to represent conditions throughout the Bay and to serve as preliminary stations for the real-time current meters. Deployment will begin in June 1990 and continue through August 1991. Station C-1 will provide data for the model boundary conditions and station C-2 will provide data for calibrating flow in and out of the Bay. Station C-3 (under the New Sunshine Skyway Bridge) will be occupied from the beginning of the circulation survey with a real-time RADS as part of the Tampa Bay PORTS; the data from C-

3 will also be used for prediction and modeling purposes. Stations C-4 (off Port Manatee) and C-5 (near Port Tampa) will provide data at PORTS locations until the real-time RADS are deployed there during FY 1991. Station C-6, outside the Bay and beyond the influence of the Bay's tides, will serve to represent shelf currents.

Short-duration current meter deployments are designed to focus sequentially on relatively small geographic areas, and to cover a time interval of two months. These deployments will begin in June 1990 and continue through August 1991. One week is allocated at the end of each period for recovery, checkout, and redeployment of instruments. The instruments will be examined at mid-period for proper functioning and to be cleared of biological fouling.

The short-duration stations are numbered C-10 to C-53. The first digit in each two-digit station number indicates the period. Hence, the Period 1 stations are numbered C-10 to C-15, the Period 2 stations C-20 to C-26, etc. The current measurement periods coincide with the 5-month water level gage installation in each region (Section 2.2). The geographic distribution is summarized below:

Period 1............................Middle Tampa Bay
Period 2............................Lower Tampa Bay
Period 3............................Hillsborough Bay and Old Tampa Bay
Period 4............................Port Tampa, small scale processes
Period 5............................Port Manatee, small scale processes

Period 1 begins in the middle Bay because of the importance to navigation of the Sunshine Skyway Bridge, Port Manatee and the mid-Bay region. Period 2 concentrates on the lower Bay. The deeper water in the lower Bay and offshore will be monitored by lower-frequency RADS (300 kHz and 600 kHz), available to the project in August 1990. Period 3 concentrates on the upper Bay in winter, when meteorological forcing is expected to have maximum effect, especially in Hillsborough Bay. Periods 4 and 5 concentrate on the delineation of the small scale processes and three dimensional flow distributions in the Bay. Data gathered on these features will address the problem of extrapolating currents from one location (such as the New Sunshine Skyway Bridge) to other locations.

The towed RADS system will map the current structure at the Bay entrance (location CT-1) to determine boundary values and fluxes for the circulation model, and parallel to the New Sunshine Skyway Bridge (CT-2), and will be used in conjunction with the bottom-mounted current meters to map small space-time scales of variability. Towed RADS will be used at location CT-3 during the high resolution current meter deployments off Port Tampa (Period 4), and at CT-4 near the turn to Port Manatee (Period 5). Transects of current velocity will be made both along the axis of the channel and perpendicular to the channel. The locations of towed RADS transects are shown in Figure 6.

2.2 Water Level Measurements

Requirements

Water level data will be taken for calculating new values of the harmonic constants, revising the tide tables, updating tidal datums, and calibrating and validating the circulation model. Since no NOS data, other than for St. Petersburg and Clearwater, are available for times after 1985, historical secondary sites (gages in for at least a year) will in most cases be suitable for reoccupation, since structures and bench marks were previously established there.

Water level gage locations were selected to provide: (1) a reasonably uniform distribution along the shoreline; (2) a concentration of gages in regions of rapid change of tidal characteristics; (3) data to determine model boundary conditions; (4) observations in all important sub-embayments, and (5) backup in case of failed instruments.

Instruments

Water level measurements will be taken with the standard NOS gage, the Analog-to-Digital Recorder manufactured by Leupold & Stevens, Inc. This mechanical system consists of a stilling well and float-operated instrument that automatically records water levels every 6 minutes with a precision of 0.01 foot. Digitized water levels are stored on punched paper tape that is removed from the gage on a monthly basis and submitted for processing. The well is attached to a piling or other fixed structure so that it extends several feet below mean lower low water (Figure 2d). The gage is located near two or more bench marks so the tidal datums can be related to the National Geodetic Vertical Datum (NGVD). The water level is also measured visually on a graduated staff and recorded each day to provide an independent check on the values punched on the paper tape.

Water Level Gage Locations and Schedules

Water level data during the duration of the survey will be obtained from three sources: permanent gages that are part of the National Water Level Observation Network (NWLON), gages that will be located in the Bay for TOP, and real-time gages that will be installed permanently as part of PORTS. Locations are labeled by the letter E (for elevation) and a three-digit number. The number is the last three digits of the seven digit number listed in the Index of Tide Stations (NOS, 1985). The first four digits for all locations in TOP are 8726, with the exception of Venice Pier, whose number is 8725.

The two NWLON gages that will supply data are presently located at St. Petersburg (E-520) and Clearwater Beach (E-724). Fourteen gages will be deployed during TOP, with five being in operation from June 1990 to August 1991 to coincide with the long-term current meter deployments; the remaining nine will be in operation for 5 months each. All locations used during TOP have been previously occupied by NOS. Three real-time systems will be deployed during the second quarter of FY 1991.

Locations of the stations are shown in Figures 3 to 5, and the schedule of deployments is shown in Figure 8. Table 1 lists locations for water level gage locations and durations of deployment.

2.3 Meteorological Measurements

Requirements

Meteorological data are required for input to Tampa Bay PORTS, for documentation of meteorological conditions during the current measurements, and to provide model input on atmospheric forcing. These data are also needed to statistically determine the influence of wind stress on current at locations important for navigation. Relatively uniform coverage over the Bay is desirable.

Data on wind speed and direction and other parameters will be used to calculate wind stress over the Bay, the primary non-tidal forcing on the circulation. Barometric pressure is also needed by the model since fluctuations in barometric pressure cause changes in water level. Temperature and relative humidity over the water are needed to compute the drag coefficient of wind over water, as well as the heat fluxes.

Instruments

Meteorological data will be collected using instruments that measure wind speed and direction and atmospheric pressure over the water (Figure 2e). The basic installation consists of a Coastal Climate Co. Weatherpak, plus an anemometer, a compass, and a barometer. TOP will use four internally-recording systems, mounted at approximately 10 meters above the water.

The single real-time system will have, in addition to the standard set of instruments, a solar radiation sensor, a combined relative humidity and temperature sensor, and a shielded thermometer to measure air temperature 1 or 2 meters above the water.

Meteorological Station Locations and Schedules

Internally-recording data collection packages will be installed at Egmont Key to provide information on coastal winds (designated M-1), at the range marker close to the "T" in the channel south of the Inter-Bay Peninsula (M-3), at the head of Hillsborough Bay (M-4), and at Gandy Bridge in Old Tampa Bay (M-5). These data collection packages will be in operation during TOP from June 1990 through August 1991.

The real-time meteorological recording system will be mounted close to the New Sunshine Skyway Bridge, at the C-Cut lower range marker, far enough away to avoid interference of atmospheric flows by the Bridge structure. This system (M-2) will be deployed in June 1990 and will remain in Tampa Bay as part of PORTS. Figures 3 and 4 show the locations of the deployments (see also Table 1) and Figure 8b shows the deployment schedule.

2.4 Conductivity and Temperature Measurements

Requirements

Water density information is necessary to provide input to the circulation model. Conductivity and temperature measurements are required to calculate water salinity. Salinity influences water density and biota. Water density variations in estuaries set up a density driven component of the circulation, which varies with time of year, and recent temperature and rainfall history. Vertical salinity and temperature data identifies times and regions where stratification is present. Stratification has important influences on the oxygen content of the water, and is evidence for a lack of vertical mixing.

Instruments

Fixed-depth conductivity and temperature (CT) measurements will be made using Seabird SeaCat SBE-19 and SBE-19 CT sensors. These will be attached to RADS or S4 current meter platforms. Profiles of conductivity and temperature throughout the water column will be made by Seabird SeaCat SBE-9 conductivity-temperature-depth (CTD) sensors.

Station Locations and Schedules

CT time series measurements will be made at two levels in the water column (near surface and near bottom) at several locations to determine the variability of stratification and to provide model boundary conditions (Figure 2f). The locations outside the Bay (S-1), in the Middle Bay (S-2), and in the upper Bay (S-3) are shown in Figures 3 to 5. At location S-1, a nearby RADS will be equipped with a CT sensor to record bottom conductivity and temperature variations. Deployment schedules are given in Figure 9b.

CT time series measurements will also be made at all long-term RADS positions with Seabird CTs. Additional CT measurements will be taken at S4 current meter positions to provide time series of temperature and salinity in very shallow water to correlate with current speed and direction.

CTD profile measurements made from ships will determine water structure in the Bay, and offshore model boundary conditions. Locations for ship tracks are across the Egmont Channel entrance (ST-1), parallel to the New Sunshine Skyway Bridge (ST-2), and along and perpendicular to the navigation channel at several locations as shown on the map (Figure 6 and Table 1). The tracks will be repeated over several complete tidal cycles at least four times per year. CTD profiles along the ship tracks will be at a minimum of 500-meter horizontal increments.

2.5 Data Quality Assurance and Quality Control

The application of data quality assurance (DQA) principles will be a high priority for all phases of the TOP. DQA is defined here as the set of plans, specifications, and policies used to assure that the measurements program provides the highest quality data attainable with available resources. QC is the routine use of procedures to achieve and maintain a specified level of quality. DQA includes instrument acceptance tests, measurement quality control, processing and analysis quality control, and critical review of the final data and information products, including detailed documentation and estimates of uncertainty. Activities will be implemented to assure the optimum performance of each instrument, investigate system and environmental errors, and estimate measurement uncertainties. The goal is to provide maximum usefulness of the oceanographic data.

The DQA effort begins with acceptance testing and evaluation of each instrument. Measurement QC, an essential part of the DQA program, produces good measurements, predictions, and model simulations. All in-water instruments will be checked and calibrated before and after the field project. Instruments failing to meet specifications will be repaired or replaced. Measurement QC checks will be made during data collection in the field at all instruments, by either comparing readings with those of a closely-located similar sensor, or by evaluating the readings. During data processing and analysis, other checks are made such as plotting the data and inspecting for outliers, and comparing the data from each instrument to data from similar instruments located nearby. All archived data sets, publication and computer products will undergo review and validation before release.

The following QC procedures will be adhered to for each type of instrument.

RADS

NOS's QC procedures were first implemented during the QA phase of the Charleston Harbor Oceanography Project (Hayes et al., 1987). QC parameters are measured by the instrument and checked at the end of the deployment period for self-recording systems. These parameters include instrument heading and tilt, input and output voltages and electrical currents, echo amplitude, instrument status, and percent good pings.

Real-time RADS will be polled daily during weekdays and the data message will be checked for completeness, obvious erroneous values, spurious information, etc. Specially developed software checks will look for drop-outs, transmission noise, and other degradation.

The 1200 kHz RADS are calibrated for speed both before and after deployment in a towing tank at the David Taylor Naval Ship Research and Development Center (DTNSRDC) in Carderock, Maryland. RADS of frequency lower than 1200 kHz, which have larger beam patterns that would be reflected from the walls of the towing tank, are calibrated by RD Instruments in their lakeside towing facility in San Diego, California. Direction is calibrated on land by comparing instrument heading with that of a high quality magnetic compass.

Procedures developed in the QA Miniproject (Williams et al., 1989) will be followed. All data, both real-time and self-recording, will be checked for record length and missing records. Time series plots of data at several bins are visually scanned, verifying that the data are physically consistent. The plots will be examined for outliers, anomalous patterns and noise bursts. Statistics will be computed on the engineering QC parameters described above.

The "error velocity" (the sum of the Doppler velocities of all four RADS beams) will 2be calculated for all data. For uniform horizontal flow, the error velocity is zero for a perfect instrument mounted correctly. In practice, the error velocity should be very small; large errors indicate possible problems with instrument performance. The vertical velocity can also be calculated from the four RADS beams. In harbors and coastal waters, this is small, and provides another check on data quality.

Profile plots of the data, as well as time series and polar (vector) plots, will assess whether the data fall within expected error bounds based on historical data.

<u>S4 Electromagnetic Current Meters</u>

The S4 current meters will be calibrated before and after deployment in the towing tank at DTNSRDC, and examined for long term drift in the laboratory. The compasses will be calibrated at a shore based facility. After data retrievals in the field, plots will be made of north and east components of the current, and of instrument tilt and heading. These data will be checked for outliers, physical reasonableness, and statistical stability.

<u>Water Level Gages</u>

Initial processing of the water level data will be performed by NOS's Sea and Lake Levels Branch (SLLB). Extensive measurement checks and data QC have been developed by SLLB over many years of maintaining the NWLON (NOS, 1980). All water level gages are refurbished prior to deployment. Standard tests performed on the gages ensure they will measure water levels to their prescribed accuracy. The gages are calibrated before and after field observations. Geodetic leveling is performed in accordance with NOAA standards (Hicks et al., 1987) at the beginning and end of data collection to establish and verify tide staff stability (major shifts in staff stability can be detected through the comparison of the daily staff and gage readings and the geodetic levels).

Recorded water level gage data will be compared daily with independent visual tide staff readings and statistics on the differences will be computed in the office. The data are scanned on a monthly basis and data quality information is fed back to the field for corrective action. Data will be compared with predictions and historical observations for the particular site if available. Standard deviations and histograms of the differences will provide quantitative measures of the reliability of predictions. At historical stations, bench mark datum recoveries are made to determine bench mark stability.

<u>Meteorological Instruments</u>

Anemometers and other meteorological sensors are provided by the manufacturer with detailed specifications. Time series of meteorological data will be quality controlled using methods similar to those employed for the current meters. Plots will be checked for outliers, noise bursts, missing data, drift, and offset. For the real-time system, these checks will be made daily during weekdays; for the self-recording systems, the checks will be made with every data recovery.

Conductivity, Temperature, and Depth Sensors

Acceptance testing will be performed on all new and reconditioned instruments. The CT and CTD sensors will be calibrated at the Northwest Calibration Facility in Seattle, Washington, before and after deployment. In the field, profiles of conductivity and temperature are plotted and examined for outliers, missing data, and physical reasonableness, along with the derived quantities, salinity and density. Particularly for salinity, where "spikes" can occur due to differences in the time constants on the conductivity and temperature sensors, QC is essential to provide reliable data. The salinity spiking will be minimized by keeping the sensor package in a water bath on deck between casts, allowing the sensors to equilibrate at the surface, and then by adjusting the winch lowering speed to allow the conductivity sensor to come to equilibrium. Temperature and salinity data will be compared with historical data, as well as with data from adjacent locations. Water density will be calculated from the CTD data. The density-versus-depth profile provides another means of measurement QC since the stratification cannot be unstable. Depth profiles and plots of time series from the moored CT sensors will be examined for physical reasonableness, salinity "spikes", noise bursts, and sensor drift. Instruments which show suspected readings will be checked, and repaired or replaced as required.

2.6 Data Processing and Analysis

Data Processing

Instrument data collected during TOP will be processed using inhouse computer resources. The Estuarine and Ocean Physics Branch (EOPB) will use a Hewlett-Packard (HP) 9000/825 minicomputer to process data from RADS and S4 current meters, CT/CTD instruments, and meteorological instruments. After the data are copied from instrument recording media to on-line disk, the entire raw data set will be archived, and decoded and converted from ASCII hexadecimal to scientific units. They will be quality controlled using digital and graphical methods. The fully processed data set will also be archived in binary form. The data that will be archived are shown in Table 3. The present processing system does not attempt to smooth, filter or in any other way alter the observed data. Facilities exist to produce ASCII data sets from the binary processed files.

The SLLB will process the water level data using manual, graphical and digital quality control methods with a Concurrent Computer Corporation 3230 minicomputer system. Tidal datums such as mean sea level, mean low water, and mean lower low water will be computed from the monthly means and the bench mark elevations will be updated. The edited, 6-minute-interval time series, hourly values, tabulated times of high and low water, and bench mark sheets will be archived and made available to the public.

Data Analysis

The data analysis will be subdivided into tidal analysis and non-tidal analysis. Tidal analysis involves traditional methods to derive the tidal harmonic constituents from the data, making new predictions from them, comparing the new predictions with the present NOAA table predictions, and comparing the new data with the new predictions to assess their quality.

The tidal analysis elements are given below.

1. Analyze the currents and water levels at all stations, using harmonic analysis to determine the tidal constituents.

2. Determine amplitude and phase relationships between the current stations and between the tide stations using cross correlation and cross power spectral density techniques. Determine the linear correlations between real-time stations and other locations at which predictions are needed.

3. Perform a QA analysis (Williams et al., 1989) using the old predictions and the new data, determining the errors (rms error; histograms; confidence intervals using QA working standards) in the tidal component of water levels and currents.

4. Perform a QA analysis using the new predictions and the new data, determining the errors (rms error; histograms; confidence intervals using QA working standards) in the tidal component of water levels and currents. Determine the improvement of new predictions over old predictions by comparison of difference statistics.

5. Develop a new tidal current reference station from the harmonic constituents calculated from the data series at Egmont Channel. Develop predictions for secondary stations by relating the times and strengths of flood and ebb currents to those at Egmont Channel.

6. Develop tide predictions for secondary stations by relating the times and amplitudes of high and low water to those at St. Petersburg.

The non-tidal components of currents and water levels, obtained from the data by low-pass filtering to eliminate variations at tidal frequencies and above, are necessary for identifying all forces in the Bay's dynamics and for modeling these forces. These components will be evaluated by time series techniques (power spectral density functions, probability density functions, and auto- and cross-correlation). These statistical products will be used to estimate the effects of atmospheric forcing of the Bay circulation, as well as forcing due to fluctuations in water density, variations in runoff from tributaries, and low-frequency forcing from offshore.

2.7 Data Management

Information Systems

Three classes of computers will be used in TOP. Microcomputers will be used primarily for real-time data acquisition and dissemination (see Section 4.4. for hardware and software details). An HP 9000/825 minicomputer will serve for processing, quality control and assurance, analysis and archiving. With its high performance RISC architecture and nearly a gigabyte of online storage, the HP will process and manage the large amount of collected data. The Cyber 205 supercomputer located at the National Institute for Standards and Technology (NIST) will be used for numerical model development. These classes of computers can communicate and share data and information either by land line or magnetic media transport. For example, observed data processed by the HP 9000/825 can be brought to the Cyber 205 as input to the model, and model results can be shipped back to the HP 9000/825 for analysis.

Data Availability

All raw instrument data obtained from TOP will be temporarily archived by EOPB on magnetic media and stored in a data fire safe. Copies of the raw data will be made on 9-track tape and stored in an environmentally controlled computer room. Selected processed data will remain online on the HP 9000/825. Data media will be clearly identified and hard copy inventories will track and display what data are available at any point during the TOP. Water level data will be archived by SLLB. Table 3 shows the data that will be available.

Data temporarily archived will be available to the public in two formats. Raw data from the instrument can be provided in ASCII hexadecimal form. Processed and quality controlled RADS data can be provided in ASCII form in its entirety including all beams and bins. See Section 5.1 for a description of contacts for public requests. for data.

3. CIRCULATION MODELING

The second major component of TOP is the circulation modeling. New methods of prediction using numerical and statistical models allow for wind effects to be included in water level and current predictions. Modeling is also the most efficient approach to synthesizing the data from field observations.

3.1 Modeling Objectives and Schedule

A numerical circulation model of the Bay will improve navigational safety in several ways. It will interpolate tidal water level response characteristics between shoreline gages and throughout the Bay, including the navigation channels. The model will depict the water current profile over the vertical and at numerous locations throughout the Bay between current meter stations, allowing for a predictive capability that includes the combined effect of tides, winds and density gradients on water levels and currents. The model will provide a theoretical basis for unifying data from short-term observational programs and the conceptual knowledge of the important physical processes in the Bay. Model output can be used to develop new relationships for prediction and to assist in defining observational networks. The TOP modeling began in November 1989 and will continue for 3 years. Figure 10 contains the time lines for modeling.

3.2 Historical Background

<u>Oceanographic Characterization</u>

Tampa Bay, located on the west coast of Florida, is the largest estuary in the state. The y-shaped Bay extends 39 kilometers from the mouth at Egmont Key to the southern tip of the Interbay Peninsula, where 13-kilometer-long Hillsborough Bay meets 26-kilometer-long Old Tampa Bay. The surface area of the Bay is about 1031 square kilometers (Clark and MacAuley, 1989) and the mean depth is 4 meters, although the main Bay shipping channel is dredged to a nominal 13 to 14 meters.

Tampa Bay is subject to the tides of the adjacent Gulf of Mexico, which are mixed diurnal and semidiurnal. Mean ranges throughout the Bay are typically on the order of 0.7 meters. The phase lag is approximately 2.7 hours from the Gulf to upper Hillsborough Bay and 4 hours from the Gulf to upper Old Tampa Bay, due to the shallowness of the estuary. Because the tides are mixed, the diurnal inequality, or difference between successive highs or lows, is likely to be large. Following Defant (1958), the ratio

$$r = (K_1 + O_1)/(M_2 + S_2) = 1.42 \quad (1)$$

at St. Petersburg indicates that the tide is mixed but strongly semidiurnal. The inequality between successive ebb currents can be so large that at the times of maximum lunar declination the second ebb can disappear completely. Monthly variations in the tide are coupled to both the moon's declinational cycle (tropic tides) and the perigee-apogee cycle (spring-neap tides). A standard least-squares harmonic analysis (Zetler, 1982) of year-long tidal records that yields amplitudes of 37 constituents at St. Petersburg indicates that the shallow water tides and the overtides are negligible.

Strong meteorological forcing can affect significantly daily currents and water level variations in Tampa Bay due to the Bay's shallowness and the small astronomical tidal range. Extreme wind and storm surge conditions have occurred during the passage of hurricanes. Strong winds are likely to be associated with summertime localized thunderstorms and with wintertime frontal passages, and moderate winds will occur during daily landbreeze-seabreeze situations.

The Bay's climate is subtropical, with rainfall the heaviest during summer months of frequent convective thunderstorm activity (Flannery, 1989). During the late winter, cold fronts moving down the Florida peninsula bring less frequent but longer duration rain showers. Due to the limited drainage area, mean annual freshwater inflow is small, averaging only 65 cubic meters per second (1900 cfs). Peak flow in the annual cycle occurs in August-September, with a secondary peak in February-March.

Past Physical Oceanographic Studies of Tampa Bay

Dinardi (1978) described an extensive circulation survey of the Bay in 1963. These data have been used for the NOAA Tidal Current Tables and the Tidal Current Charts for Tampa Bay. The most recent NOS bathymetric surveys of the Bay occurred in 1957-58.

Goodwin and Michaelis (1976) report on a water level study carried out by the US Geological Survey during 1971-1973. During the study period, the maximum tide at St. Petersburg was recorded at 1.5 meters during Hurricane Agnes and the minimum tide was recorded at 0.9 meters below mean sea level.

Ross (see Goodwin, 1987, and Spaulding et al., 1988) has carried out several numerical modeling studies of tidal residual circulation and water quality in Tampa Bay. He and his associates used vertically averaged horizontal momentum equations, but ignored horizontal shear stresses and density gradients. The residual circulation was determined to be an important component in flushing the Bay.

Goodwin and Ross (1984) made comparisons of tidal amplitudes, residual tidal circulation, and storm surges on Tampa Bay using their respective vertically averaged numerical models. They estimated changes in circulation likely to occur after the completion of pier protection islands near the New Sunshine Skyway Bridge. While the overall circulation in the Bay was not altered significantly, there were noticeable changes in current vectors near the bridge.

Goodwin (1977, 1980, 1987) made highly detailed numerical simulation of currents to simulate the effects of dredging to the flushing of the Tampa Bay and Hillsborough Bay. He used a two-dimensional, vertically integrated numerical model with a grid cell size as small as 500 meters to produce relatively accurate estimates of the tidal currents. Goodwin (1987) achieved an average standard error of 3 centimeters between modeled and observed half-hourly water levels at 11 locations, although only 1.5 days of data were used. He also achieved an average standard error of 3 cm/s for a 40-hour period when comparing currents measured at a distance above the bottom equal to 40 percent of the total water depth and the model's vertically averaged currents. These studies demonstrated the importance of residual circulation in flushing the Bay.

Shaffer et al. (1986) describe the National Weather Service's storm surge modeling program for the U.S. East and Gulf coasts. Model basins include one developed for Tampa Bay. The vertically-integrated surge model operates on a polar grid that covers the central portion of the southwest Florida coast with a grid cell size of 4 kilometers, and has higher resolution (cell size approximately 1 kilometer) inside the Bay. This model does not, however, simulate astronomical tidal variations.

3.3 Model Requirements

To meet the modeling project's goals, the numerical model must:

1. simulate tidal, wind, density, and shelf-induced currents in Tampa Bay at small time scales (minutes) for long time periods (up to 12 months);
2. resolve currents in the navigation and port channels, and other locations important for navigation; and
3. meet QA working standards for accuracy.

Model characteristics include:

1. three-dimensional, time-dependent velocities, salinities and temperatures;
2. a free-surface;
3. non-linear horizontal advection;

4. horizontal and vertical density gradients;
5. variable grid spacing to resolve narrow channels; and
6. grid configuration allowing representation of thin barriers such as causeways.

Three space dimensions are required to simulate the vertical shear produced by bottom and wind stresses and by horizontal density gradients, and to resolve horizontal differences between the deep channels and the shallow side embayments. Resolution of currents over depth is a requirement for navigation under strong wind and tidal conditions, and is necessary for accurate modeling of bottom interfacial stresses. Vertical variations in water density generally occur near freshwater discharge locations, such as river entrances, and in deeper water under conditions of intense heating. Presently-available turbulence theory that provides methods of estimating vertical diffusive momentum and mass fluxes also requires information on the vertical variation on density and horizontal currents.

EOPB has a version of the Mellor-Blumberg circulation model (Mellor and Blumberg, 1987; Mellor, 1989) that will be used for the Tampa Bay project. The model includes a dimensionless sigma vertical coordinate, the level 2-1/2 turbulence closure representation, and an orthogonal curvilinear horizontal coordinate system. This model is presently being used for Long Island Sound tidal, wind, and density current simulations, and will be used for the Charleston Harbor (South Carolina) circulation and modeling project.

3.4 Model Application

Computer Resources

The EOPB model runs on NIST's Cyber 205 supercomputer at Gaithersburg, Maryland. Analysis of model output can be made either on the Cyber, or on EOPB's HP 9000/825 minicomputer. Extensive display graphics utilities exist on both machines, as well as on EOPB's MicroVax 2000 system.

Model Domain and Grid

The water domain of the model grid will cover the Bay from the mouth to the upper reaches, including Lower and Middle Tampa Bay, Old Tampa Bay, Hillsborough Bay, and the Manatee River, an area of approximately 1031 square kilometers. It is desirable to include some portion of the adjacent Florida shelf to model the complex flow through the entrance channels and direct wind effects. River flow from the Hillsborough, Alafia, Little Manatee, and Manatee Rivers, and other freshwater sources will be included.

For a fine mesh grid, minimum cell size will be on the order of the width of the shipping channel (130 meters). Due to the curvature (irregular alignment) of the channel, a grid based on a curvilinear coordinate system will be used. EOPB will apply automatic grid generating algorithms using digitized NOS coastline and bathymetry data.

The following suite of models will be explored: (1) a model covering the west Florida shelf to investigate the tidal and wind-driven currents offshore (for search and rescue activities) and for gaging the influence of wind setup at the mouth of Tampa Bay; (2) a coarse-mesh model (grid size 1 to 5 kilometers) for quick simulations of events when order of magnitude estimates are necessary; (3) the fine mesh grid described above; and (4) a superfine mesh (cell size on the order on tens of meters) nested within, and driven by, the fine mesh model (3) for studying the currents around the channels and intersections.

Grids generated for the model domain will be used to test the computed solution for sensitivity to grid configuration, timestep, and initial spinup interval. The final grid will then be used in the calibration and validation phase.

Sensitivity Analysis, Calibration, and Validation

During the sensitivity analysis, the important input parameters are varied over their expected range to see how the computed solution changes. These inputs, called the adjustable constants, include bottom and surface friction parameters and the turbulence parameters. Other input data that will be tested include bathymetry, grid configuration, and model timestep.

In the calibration phase, certain model inputs will be adjusted so the computed solution matches the observed data to the greatest extent possible. There will be several distinct time periods used for the calibration and verification process. Differences between data and model outputs will be quantified, and the calibration process will continue until predetermined criteria are reached. Since the Bay's dominant currents are tidally driven, it is desirable to select calibration and validation data, depending on the results of the field survey, for periods both when wind and other forcings are negligible and strong.

During the validation process, the adjustable constants are fixed at their calibration values, and the model is rerun for one or more time periods different from the calibration phase. Differences between observational data and model outputs will be quantified and compared to criteria for calibration accuracy.

Simulation of Astronomical Tides and Currents

Water levels at the mouth that drive the tidal currents throughout the Bay will be obtained from a 15-month installation of a pressure transducer fixed to a RADS unit to be positioned approximately 15 kilometers west of the entrance to Tampa Bay. Harmonic analysis will provide the constituent tides for modeling purposes. Additional tide data outside the Bay is available north at Clearwater Beach and south at Venice Pier.

QA working standards (Section 1.4) will be used for calibration and validation accuracy. To the extent possible, data will be chosen to reflect times when wind and other non-tidal forcing is negligible. The best measure of a model's accuracy is observational data; however, it is desirable to compare model output with previous modeling results such as water level and currents (Goodwin, 1987) and residual currents (Goodwin and Ross, 1984; Goodwin, 1987).

Simulation of Wind-Induced Variability and Density Currents

Water level variation due to wind influence will be simulated using the collected data. The tidal response must be determined first to isolate the wind's contribution. Wind data will be collected at five locations around the Bay, including Egmont Key which represents more coastal conditions. Wind speed and direction will be measured and used to estimate wind stress. The vertical atmospheric temperature gradient will be estimated from measurements at two levels to indicate the stability of the air column and to estimate drag coefficients. Standards of accuracy will be similar to those for tides (especially for water levels) as they may apply, but given the aperiodic variation in wind events the acceptability limits will be less restrictive.

Density currents are expected to be of low order, and are important only in certain localized regions such as the navigation channel and river discharges. These currents can be determined from the analysis of current meter and CTD data.

Simulation of Salinity and Temperature

Horizontal and vertical temperature and salinity distributions will be estimated from the CTD transects and compared with the model output. The location of a CT mooring just outside the Bay's entrance for 15 months will provide boundary conditions. Heat fluxes will be estimated from bulk exchange relationships using measured air and sea surface temperatures, relative humidity, atmospheric temperature gradients, and incoming solar radiation.

4. PHYSICAL OCEANOGRAPHIC REAL-TIME SYSTEM (PORTS)

The third major component of TOP is the installation of the Nation's first fully integrated physical oceanographic real-time system (PORTS). The Tampa Bay PORTS will include real-time current, water level, and meteorological data at multiple locations. NOS and others have implemented real-time water level systems before, but the Tampa Bay PORTS is the first to include currents, water levels, meteorological data, and a fully integrated data delivery system. The integrated data delivery system includes a data acquisition system (DAS) and an information dissemination system (IDS). Experimental real-time current systems were deployed by NOS in Delaware Bay, Charleston Harbor, and Long Island Sound. These experiments provided the experience necessary to design the real-time system for Tampa Bay.

4.1 Need for Real-Time Data

Although the model-generated circulation and water level forecast atlas for Tampa Bay will be a substantial improvement over traditional prediction tables and the tidal current charts (since it will include meteorological effects in addition to the astronomical tides), real-time data are required at locations where currents are particularly complex and cannot be predicted accurately.

<u>Currents</u>

Requirements for real-time currents were established for these locations where currents are particularly complex:

1. New Sunshine Skyway Bridge;
2. intersection of B-Cut and Manatee Channel; and
3. intersection of K-Cut and Port Tampa Channel.

The Coast Guard Marine Safety Office and the Tampa Bay Pilots Association pointed to the need for accurate current data at the New Sunshine Skyway Bridge, the site of two major maritime casualties involving loss of life. The new bridge piers are protected by massive rock island bumpers that have apparently altered the currents.

The turn from B-Cut to Manatee Channel, nearly 90 degrees, involves turning from a channel that is 152 meters wide and 13 meters deep to one that is 122 meters wide and 10.4 to 12.2 meters deep. It is important for pilots to know, well before reaching the hazardous turn, the current speed and direction there. Several pilots rank this location an even higher priority than the bridge. The turn from K-Cut to Port

Tampa Channel, about 100 degrees, is critical because ships must stop completely in a short distance.

Water Levels

Requirements for real-time water levels have been established for these locations that support port activities:

1. Port of St. Petersburg;
2. Port of Tampa; and
3. Port Manatee.

Wind-induced set up or set down of water levels affects both the safety and economy of vessel operations. At the Port of St. Petersburg, the critical need is for safe operation of large cruise ships. At the other ports, safe operation is also important, but considerable economic benefits are also to be gained.

Winds

Requirements for real-time winds at one location in the lower Bay have been established to support port activities. Winds measured at the range marker at the lower end of C Cut, beyond the influence of the New Sunshine Skyway Bridge, are representative of conditions in the lower Bay. Local winds interfere with ship steering, indicate whether mean water levels in the Bay differ from predicted tidal heights, and indicate the strength of nontidal currents.

4.2 Implementation of Tampa Bay PORTS

Tampa Bay PORTS will be implemented during a 3-year period beginning in FY 1990. FY 1990 activities include:

1. deploy one RADS current meter at the New Sunshine Skyway Bridge (Figure 11);
2. deploy a meteorological station near the bridge at the range marker for the lower end of C Cut (Figure 11);
3. install the data acquisition system (receivers and computer) at the U. S. Coast Guard Station, St. Petersburg; and
4. provide interim software for information retrieval.

FY 1991 activities include:

1. deploy two additional RADS current meters in the navigation channels leading to Port Manatee and Port Tampa (Figure 12);
2. deploy three water level gages at major ports (Figure 12);
3. complete information dissemination system software;
4. complete PORTS documentation; and
5. identify and train the host organization.

FY 1992 activities include:

1. upgrade the IDS in response to user experience during FY 1991; and
2. upgrade the PORTS documentation as required.
3. transfer Tampa Bay PORTS to a state organization.

The schedule for the PORTS activities is given in Figure 13.

4.3 Sensor Systems

Currents

RADS used for current measurement will operate at a frequency of 1200 kHz. They record data internally and simultaneously send out data via an armored conductor cable to a radio transmission site. The real-time data will be received at the Coast Guard base in St. Petersburg for processing and dissemination. Three RADS systems are planned to be installed.

The first real-time RADS will be located under the center span of the New Sunshine Skyway Bridge (Location C-3, Figure 11). It will have a naval bronze housing for corrosion resistance. The RADS will be bottom mounted in a protective platform within the shipping channel with the acoustic beams aimed towards the surface (Figure 14). The system will continuously measure a profile of the currents at 1-second intervals. The internally recorded data will be a backup data source (for research purposes) in the event that real-time transmission is lost.

The radio transmission site will be located on the northeast main pier protective Dolphin (Number 103) and will be connected by armored conductor cable to the RADS. The cable will terminate at an interface box which will convert the signals for radio transmission and provide power to the profiler. Solar cells will charge batteries for radio and profiler power. Internal batteries in the profiler will provide backup power. A VHF radio will be used to transmit the data every 10 minutes to the Coast Guard base, a distance of approximately 18 kilometers. The installation of this system is planned for June 1990.

A second RADS system will be deployed in FY 1991 at the intersection of B-Cut and Manatee channel (location C-4, Figure 12). This will be an identical 1200 kHz RADS in a bottom platform and connected by approximately 2 kilometers of armored conductor cable to the fixed range marker north of the Cut. A data transmission system, similar to that on the Dolphin under the New Sunshine Skyway Bridge, will transmit data at the same frequency but at a different time.

Another RADS system will be installed in FY 1991, at the intersection of K-Cut and Port Tampa Channel (location C-5, Figure 12). Approximately 1 kilometer of armored conductor cable will be laid to the fixed range marker north of Port Tampa, on which a data transmission system will be installed.

Water Levels

Three real-time water level gages will be installed in FY 1991. The gages will employ the latest in technology and will be similar to the primary field component of the NOAA's Next Generation Water Level Measurement Systems (NGWLMS) now being installed (Mero and Stoney, 1988). These systems are based on an Aquatrak air acoustic water level sensor. Power will be provided by either an alternating current source or by solar cells, depending on location. Data will be recorded in a data acquisition package and transmitted by radio at 6-minute intervals to the receiving station at the Coast Guard base in St. Petersburg. The gage locations (Figure 12) will support each of the three major port areas.

Meteorological Data

Real-time meteorological data will be collected at the fixed range marker north of the intersection of B-Cut and Port Manatee channel (location M-2, Figure 11). A Coastal Climate Weatherpak (or equivalent) 2will be installed in June of 1990. Wind speed and direction, air temperature, barometric pressure, relative humidity and solar radiation will be measured. The station will store the data internally as well as transmit data to the Coast Guard base at St. Petersburg at 10-minute intervals via radio. The meteorological station will operate on batteries that will be charged by solar cells.

4.4 Data Acquisition and Dissemination Systems

Data Acquisition System

The DAS will receive data via radio transmissions from all real-time systems 24 hours a day and will be located in the Operations Room of the U.S. Coast Guard Base, St. Petersburg. This continuously-manned area will provide security, is environmentally controlled for temperature and humidity, and is far from major electrical interferences. The location is within 18 kilometers of all real-time transmitters with an uninterrupted line of site.

The DAS uses a microcomputer with a Unix operating system, providing multitasking and addressing multiple inputs, and will have the following hardware components:

1. a 25-megahertz, 80386-based central processing unit;
2. a monochrome monitor;
3. a 4-megabyte random access memory;
4. a 150-megabyte fixed disk;
5. an 80387-based math coprocessor;
6. a 700 watt uninterrupted power source;
7. eight serial ports;
8. an internal cartridge tape backup system; and
9. radios, modems, cables, etc. to fulfill communication requirements.

Information Dissemination System

The purpose of the IDS is to provide analyzed PORTS data in predefined formats to users. The IDS consists of two parts, one based in the DAS microcomputer, the other (which is user-supplied) being either a microcomputer with modem or a push button telephone.

The basic communications interface with the DAS will be via phone at (minimally) 1200 baud with a user-supplied platform consisting of a microcomputer, referred to as the presentation portion of the IDS. Minimally configured, the user's microcomputer will be able to communicate with the DAS while in a terminal emulation mode. Incoming calls from the user's microcomputer may be sent to other interfaces by the DAS to facilitate voice mail/message service. Direct access to the real-time instruments will not be provided; all access will be done through the DAS. Other interfaces are not only possible but in some cases desirable. Radio communications, used by pilots, could be used to relay information from the presentation display.

Data processing for use in the dissemination system will be similar to stand alone or remote systems. The only difference will be the number of data types decoded and used. Only those needed by the DAS for the IDS will be processed. All algorithms used by the DAS will be identical to those used for processing data collected by the self-recording systems.

Data Quality Assurance and Quality Control

PORTS will follow a data quality assurance program to verify the quality of the data, beginning with the acceptance testing and evaluation of each instrument. QC checks will be made during data collection in the field, since the instruments are self-checking and therefore provide internal QC parameters. The DAS checks the incoming data by determining the age of the last data received, examining the differences in the present and the preceding values, and calculating the rates of change of important variables.

For RADS data, each 10-minute sample provides a percentage of good pings, an index of return signal quality, and an instrument status index. The percentage of good pings is computed by analyzing the signal-to-noise ratio of each ping return. The return signal quality is a measure of echo amplitude and spectral width. The instrument status combines percentage of good pings and return signal quality to provide an estimate of data quality and to identify sources of error. The DAS will make additional QC checks, including the age of the last set of incoming RADS data, the absolute change in current speed and direction at all bins, and rates of change of speed and direction. Data not meeting established criteria will be flagged.

Water level data will conform to the NGWLMS QC standard. During the 6-minute measurement period, the instrument collects 181 samples at 1-second intervals and computes the mean and standard deviation. Then the instrument removes outliers (those points more than three standard deviations away from the mean) and recomputes the mean. The instrument then transmits the mean value, the number of outliers and their standard deviation, data flats, data jumps, and expected maximum and minimums as QC indices.

Since meteorological instruments do not provide internal checks, data entering DAS must pass QC criteria as follows. The voltages of the internal and external batteries will be examined to determine if they lie within established limits. Internal and external instrument temperatures will be compared and the differences checked for normal variations. The standard deviation of wind direction will be checked for reasonable variation.

Data Formats

IDS data will be available as voice messages, text messages, graphics, and ASCII data files. Voice data produced from digital information is not new; there are ever increasing applications of voice-response technology. System users can receive the latest information at selected discrete points or a short term forecast for a selected area of concern. Interfacing the hardware with a voice-response system could offer a message system with several menu levels for needed information. This technology will be considered for inclusion in the IDS.

Text messages may satisfy many information requirements. Digital information could be analyzed and text consisting of phrases could be generated. These phrases could be combined to form a computer worded report, and relayed to a caller or read from a microcomputer screen. Those interested in a visual representation will be provided a series of graphics to choose from, including time series for selected time periods, vertical profiles of the water column, and other visual representations of the data using EGA/VGA graphic hardware. To download selected ASCII data files, using a terminal emulation package on the presentation microcomputer, the user would dial the DAS and extract data elements to download.

The IDS prototype is expected to generate comments from users that will result in changes to the final configuration. Users will be polled via phone and the system critiqued by surveys. Bulletins will be produced periodically to inform users of system changes, scheduled preventative maintenance, system upgrades and effective usage.

4.5 Transfer and Maintenance of PORTS

NOS plans to turn over the operation and maintenance of PORTS to a local host group that has:

1. legally recognition as a state entity;
2. long-term organizational stability and commitment;
3. technical expertise to perform the work inhouse or by contract; and
4. the ability to protect the data acquisition system.

NOS will provide initial training of personnel, documentation of the sensor hardware and software systems, and schedules for periodic maintenance, recalibration, and replacement of components.

Sensor Hardware Documentation and Maintenance Requirements

Sensor hardware documentation, based on manufacturer's operation and maintenance manuals, will be provided for all components. Maintenance procedures will be developed during FY 1990 and FY 1991 and provided to the host organization.

Maintenance requirements for the real-time current measuring systems will consist of periodic inspections, repairs, upgrades and eventual replacement. The design life of the system is 10 years. Initial inspections at 4-month intervals will consist of cleaning of sensors and visual observations. Underwater components will be retrieved from the bottom and damaged or failed components will be repaired or replaced. The lithium batteries for the profiler will be replaced at least every 3 years. The underwater cable will be inspected by divers.

Maintenance requirements for the real-time water level systems will consist of a semi-annual geodetic leveling check and an annual refurbishment. This will require diver inspection of the protective well and sounding tube and cleaning of marine growth. Repairs will be performed as required. The acoustic sensor must be recalibrated in a laboratory on an annual basis. The rechargeable batteries will be replaced at least every 4 years. The design life of this system is 15 years.

Maintenance for the meteorological system include cleaning the sensors and will be performed every 6 months. Repairs will be performed as necessary and the batteries will be replaced at least every 5 years. The design life of this system is 10 years.

Maintenance of Real-Time Data Acquisition and Dissemination Components

DAS and IDS hardware and software will be documented using the Federal Information Publication Standards will be used as a guide. All software will be documented in line as well as through operation manuals and user guides, including system and data flow charts. DAS microcomputer maintenance includes installing any upgraded versions of the operating system and software produced for TOP for IDS, and maintaining the peripheral equipment.

Costs of Operation and Maintenance

NOAA will sustain all costs for the operation and maintenance of the Tampa Bay PORTS through the end of FY 1991, at which time the system will be transferred to a Florida state entity. Upon transfer of the system, funds for operation and maintenance of the system will have to be provided by a different source, possibly a consortium of users who contribute to a state-managed fund. The mechanism for accomplishing this will be addressed and a resolution will be sought during FY 1990.

5. DATA AND INFORMATION PRODUCTS

The data and information products resulting from TOP are in direct response to needs described by the users and managers of Tampa Bay, and support NOAA's missions according to Title 33 of the United States Code. The products include archived data (available to the public), special data (available to collaborative investigators), a circulation survey report, technical reports and publications, revised tide and current prediction tables, and revised bench mark elevations relative to tidal datums. Tabular and graphical data will be available from the real-time systems. A circulation and water level forecast atlas produced from the numerical circulation model, will facilitate current and water level prediction for any location in the Bay, including the wind-induced component.

5.1 Circulation Survey Data

Oceanographic data collected during TOP's 15-month circulation survey will be available to any user. Organizations involved in collaborative or cooperative projects during TOP will be able to obtain data when it has been quality controlled by contacting the TOP Data Manager (Section 6). Project participation by local scientists is encouraged, particularly for masters and doctoral programs. Previous NOAA circulation programs have resulted in information used for dissertations and post doctoral research. Data from the circulation project can provide the basis for detailed studies of the physical processes of the Tampa Bay environment.

Availability of Current, CT, and Meteorological Data

Oceanographic data that passes the NOS QA criteria will be made available to the public following the project completion and data archiving. Raw instrument data obtained from TOP will be temporarily archived by EOPB on magnetic media and placed in ASCII as well as binary formats during various stages of processing and analysis. Processed and quality controlled RADS data can be provided in ASCII form in its entirety including all beams and bins. Data are available during the survey from:

Estuarine and Ocean Physics Branch, N/OMA13
NOAA/National Ocean Service
6001 Executive Boulevard
Rockville, MD 20852
(301) 443-8510

After completion of the survey, when data analyses indicate no serious undetected errors and the data are QA'd, current and CT data will be transmitted to the NOAA's National Oceanographic Data Center (NODC) for archiving. Since the archival format for RADS data has not been determined, these data may be transferred at a later time. The transferred data will be generally available from NODC upon request by June 1992 from:

User Services Branch, E/OC21
National Oceanographic Data Center
NOAA/National Environmental Satellite, Data,
and Information Service
Washington, D.C. 20235
(202) 673-5549

Meteorological data will be transferred to the NOAA's National Climatic Data Center (NCDC) for archiving. The transferred data will be generally available from NCDC upon request by June 1992 from:

Information Services Division, E/CC4
National Climatic Data Center
NOAA/National Environmental Satellite, Data,
and Information Service
Federal Building
Ashville, NC 28801
(704) 259-0871

Water Level Data

Raw water level data will be retrieved from the gages at the end of each month and processed. Analyzed water level and bench mark data will be available 3 months after retrieval and may be obtained from:

Tidal Datum Quality Assurance Section, N/OMA123,
Sea and Lake Levels Branch
NOAA/National Ocean Service
Rockville, MD 20852
(301)-443-8467

5.2 Circulation Survey Report

A TOP circulation survey report will contain background physical information about the estuary; discuss the survey plan; summarize the types of data collected; describe the measurement systems, locations and periods; and describe data QC, QA, availability and formats. The survey report, to be written after completion of data analysis, is expected in June 1992.

5.3 Revised NOAA Tidal Current and Tide Prediction Tables

Annual NOAA Tidal Current Tables give daily information on slack water times, and tidal current flood and ebb strengths and times of occurrence for Egmont Channel. Table 2 of the publication gives reference information (time differences and speed ratios) for 37 secondary locations inside the Bay. Flood and ebb predictions for Egmont Channel will be revised using the updated constituents processed from the data. Predictive information for the secondary locations will be revised using analysis results from observational data. New stations may be added.

Annual NOAA Tide Tables give daily information on times and amplitudes of high and low water each day for St. Petersburg. Table 2 of the publication gives reference information (time and height differences) for nine secondary locations inside the Bay. The St. Petersburg predictions will be revised using updated constituents processed from the water level data. Predictive information for the secondary locations will be revised using analysis results from observational data. New stations may be added.

5.4 Circulation and Water Level Forecast Atlas

Simulations from the numerical circulation model will be used to produce an atlas of water level and currents throughout the Bay. The atlas will be a powerful new tool because it will provide both current and water level information throughout the estuary, not only at locations where data were collected (as in the annual NOAA prediction tables), and will also provide information about meteorological effects. The new atlas will update the limited tidal current information presently available in the Tampa Bay Tidal Current Charts that show hourly surface and subsurface tidal current vectors for 55 locations, based on the survey reported by Dinardi (1978).

The new approach to creating an atlas was first used for Delaware Bay (NOS, 1987). Model-generated charts for the estuary depict hourly, vertically-averaged tidal currents at approximately 2000 points in the Bay and adjoining River. This approach will be adopted for Tampa Bay, with the inclusion of tidal phase information.

Wind setup and setdown can be simulated by the circulation model, and to some extent these changes can be represented on special charts. For example, persistent southwesterly winds will cause higher than normal tides in the upper Bay. Given wind speed, direction, and duration, it may be possible to generalize the Bay's response in an easily quantifiable way. Decisions on how to present this information can only be made after the model is validated under various weather scenarios.

5.5 Model Output Availability

Because of the volume of numerical information generated by computer models, it is desirable to explore new computer-based storage and display technologies. Microcomputer graphics can be used to present and synthesize data from files of currents and water levels stored on magnetic tape, diskettes or optical disks. This will provide for various meteorological conditions, more than can be displayed in a hard-copy atlas.

5.6 Transfer of Circulation Model to State of Florida

An important aspect of TOP is the transfer of the specially developed circulation model to the State of Florida. The host organization for ongoing applications will be identified no later than the second quarter of FY 1991 to ensure sufficient overlap with NOS and transfer of the model during the fourth quarter of FY 1992. Criteria for transferring the model are:

1. expertise to maintain, upgrade, and exercise the model;
2. experience with the Mellor-Blumberg 3-dimensional, curvilinear grid model;
3. a computer system capable of exercising the model; and
4. long-term organizational stability and commitment to operate the model.

5.7 Transfer of Tampa Bay PORTS to State of Florida

The major, unique feature of TOP is the installation and transfer of the nation's first fully integrated PORTS. NOS will cover the costs of PORTS procurement, development, installation and maintenance during the 15-month circulation survey. Approximately October 1, 1991, the system will be transferred to the State of Florida for ongoing operation and maintenance. Requirements of the host organization for transferring the PORTS are described in Section 4.5.

6. PROJECT MANAGEMENT AND STAFF

The Project Director is Dr. Henry R. Frey, Chief, Estuarine and Ocean Physics Branch (EOPB), Physical Oceanography Division (POD).

The Measurements and Modeling Project Coordinator is Dr. Kurt W. Hess, EOPB; he is also the Principal Scientist for Circulation Modeling and Information Products. The Data Manager is Thomas D. Bethem, EOPB. The Principal Scientist for Circulation Measurements and Data Analysis (other than water levels) is Dr. Robert G. Williams, EOPB, and Michael Connolly is the Circulation Survey Coordinator. The Principal Engineer for Water Level Measurements is Thomas Landon, Sea and Lake Levels Branch (SLLB), POD, and the Principal Scientist for Water Level Analysis is Stephen K. Gill, SLLB.

The Tampa Bay PORTS Project Manager is Dr. Frey. The Principal Engineer for Real-Time Measurements is Gerald F. Appell, Ocean Systems Division (OSD). The Data Manager and the Principal Computer Systems Analyst is Thomas D. Bethem, EOPB. The Principal Scientist for PORTS Applied Research is Dr. Williams.

Mail codes and telephone numbers for TOP managers are:

Henry R. Frey, N/OMA13	301-443-8510	FTS 443-8510
Kurt W. Hess, N/OMA13	301-443-8610	FTS 443-8610
Robert G. Williams, N/OMA13	301-443-8865	FTS 443-8865
Michael Connolly, N/OMA13	301-443-8865	FTS 443-8865
Thomas D. Bethem, N/OMA13	301-443-8501	FTS 443 8501
Gerald F. Appell, N/OMA4	301-443-8026	FTS 443-8026
Thomas Landon, N/OMA121	301-443-8807	FTS 443-8807
Stephen K. Gill, N/OMA122	301-443-8311	FTS 443-8311

The mail address for all TOP managers is:

NOAA/National Ocean Service
6001 Executive Boulevard
Rockville, MD 20852

The FAX number for all TOP managers is 301-443-8300. Hearing impaired individuals may call on TDD to 301-443-8513. A schematic of the project management and staff is shown in Figure 15. All project personnel are members of NOS's Office of Oceanography and Marine Assessment.

7. ACKNOWLEDGEMENTS

The support provided to NOAA's National Ocean Service by individuals and organizations in the Greater Tampa Bay Area is truly remarkable. TOP's preproject phase has been exemplary.

Support began with a letter from Captain Steve Day, Tampa Bay Pilots Association, to Captain Thomas Boerger, Coast Guard Captain of the Port, expressing concern about the current predictions near the New Sunshine Skyway Bridge. Captain Boerger quickly requested NOS to evaluate the problem and conduct a new survey. When Captain Jake Jacoby became the Captain of the Port and Commanding Officer, Marine Safety Office, Tampa, he became an enthusiastic supporter. Captain John Timmel, Tampa Bay Pilots Association and member of the Agency for Tampa Bay Management (ATBM), helped in numerous important ways and gave excellent input and feedback for this plan, as did Captain Day. Captain Byron Record, Chairman, Greater Tampa Bay Marine Advisory Council, and other Council members were responsive and encouraging while NOS evaluated the Bay's tide and current predictions. Joe Valenti, Deputy Director, Tampa Port Authority; Tim Travis, Director, St. Petersburg Port Authority; and Claude McGavic, Manatee Port Authority were especially supportive. Commissioner Jan Platt and members of the ATBM passed a resolution in support of TOP.

Representative Bill Young introduced and managed legislation to provide funds.

NOS is particularly grateful to the Coast Guard. Captain Brian Sonner, Group Commander, Coast Guard Group St. Petersburg (CG Group) provided logistical support for the QA Miniproject and has approved further support for installation of PORTS. CWO Mark Allen, Aids to Navigation (ATON), CG Group, is the quintessential "can do" man; his initiative is rare. CWO John Sitton, Commanding Officer, USCG Cutter *White Sumac*, and his crew provided outstanding vessel support. BMC James Evans, Officer-in-Charge, ATON Team, provided excellent small boat support.

The TOP Plan briefing and workshop held December 15, 1989, in St. Petersburg was supported by the Florida Institute of Oceanography (FIO) and the University of South Florida (USF). We are grateful to John Ogden, Director of FIO and the FIO contributors: Sandra Vargo, Dean Milliken, and Jerry Fountain. USF provided a lecture hall, audiovisual equipment, and refreshments.

The TOP Project Plan was developed by the team described in Section 6. Kurt Hess is the managing editor, and had the leading role in preparing this plan.

8. REFERENCES

Blumberg, A. F., and G. L. Mellor: A description of a three-dimensional coastal ocean circulation model. Three-Dimensional Coastal Ocean Models, (ed. Heaps), American Geophysical Union, Washington DC., 1 - 16.

Clark, P.eA., and R. W. MacAuley, 1989: Geography and Economy of Tampa Bay and Sarasota Bay. Tampa and Sarasota Bays: Issues, Resources, Status, and Management. NOAA Estuary-of-the-Month Seminar Series No. 11, 1 - 17.

Defant, A., 1958: Ebb and Flow: The Tides of Earth, Air, and Water. University of Michigan Press, Ann Arbor, Michigan, 121 pp.

Dennis, R. E., and E. E. Long, 1971: A user's guide to a computer program for harmonic analysis of data at tidal frequencies. NOAA Technical Report NOS 41. NOAA, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, Maryland, 31 pp.

Dinardi, D. A., 1978: Tampa Bay Circulatory Survey 1963. NOS Oceanographic Circulatory Survey Report No. 2, NOAA, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, Maryland. 39 pp.

Flannery, M. S., 1989: Tampa and Sarasota Bays: Watersheds and Tributaries. Tampa and Sarasota Bays: Issues, Resources, Status, and Management. NOAA Estuary-of-the-Month Seminar Series No. 11, 18 - 48.

Goodwin, C. R., 1987: Tidal-Flow, Circulation, and Flushing Changes Caused by Dredge and Fill in Tampa Bay, Florida. U.S. Geological Survey Water-Supply Paper 2282, 88 pp.

___, 1980: Preliminary simulated tidal flow and circulation patterns in Hillsborough Bay, Florida. U.G. Geological Survey Open File Report 80-1021, 25 pp.

___, 1977: Circulation patterns for historical, existing, and proposed channel configurations in Hillsborough Bay, Florida. Proceedings, 24-th International Navigation Congress, Leningrad, Subject 4, Section 4, 167 - 179.

___ and D. M. Michaelis, 1976: Tides in Tampa Bay, Florida: June 1971 to December 1973. U. S. Geological Survey, Tallahassee, Florida. Open File Report FL-75004, 338 pp.

___ and B. E. Ross, 1984: Evaluation of changes in circulation, spring tide, and hurricane surge characteristics in Tampa Bay caused by Sunshine Skyway pier protection system, (unpublished manuscript), 35 pp.

Hayes, J. G., H. R. Frey, R. G. Williams, J. M. Welch, W. L. Wilmot, 1987: Charlston Harbor Oceanography Project: A New Era for Circulation Measurements and Predictions. Proceedings, Oceans 87. Marine Technology Society, Institute of Electrical and Electronic Engineers/Ocean Engineering Society, Halifax, Nova Scotia, Sep. 28 - Oct. 1, 1987, Vol III.

Hicks, S. D., P. C. Morris, H. A. Lippincott, and M. C. O'Hargan, 1987: User's guide for the installation of bench marks and leveling requirements for water level stations. NOAA, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, Maryland, 73 pp.

Mellor, G. L., 1989: Documentation for a three-dimensional, primitive equation, numerical ocean model. Princeton University Report, 41 pp.

Mero, T. N., and W. M. Stoney, 1988: A description of the National Ocean Service Next Generation Water Level Measurement System. Proceedings of the Third Biennial NOS International Hydrographic Conference, Baltimore, Md., April 12 - 15. 8 pp.

NOS, 1987: Delaware River and Bay Tidal Circulation and Water Level Atlas. NOAA, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, Maryland, 49 pp.

___, 1985: Index of Tide Stations: United States of America and Miscellaneous Other Locations. NOAA, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, Maryland 143 pp.

___, 1980: Integrated Logistics Support Plan - Water Level Measurement Systems. NOAA, National Ocean Survey, Office of Oceanography, Rockville, Maryland.

Shaffer, W. A., C. P. Jelesnianski, and J. Chen, 1986: Hurricane storm surge forecasting. Preprints, Oceans 86, Washington, DC, Sept. 23-26, 1986, 1379 - 1385.

Spaulding, M. L., D. P. French and H. Rines, 1988: A Review of the Tampa Bay water quality model system. Applied Science Associates Pub. ASA 88-58. (Available from Southwest Florida Water Management District, 7601 Highway 301 North, Tampa FL 33637), 137 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, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, Maryland, 11 pp + figures.

Zetler, B. D., 1982: Computer Applications to Tides in the National Ocean Survey. Supplement to Manual of Harmonic Analysis and Prediction of Tides (Special Publication No. 98). National Ocean Service, 85 pp.

APPENDIX A. Summary of NOS Interviews in the Tampa Bay Community

The following paragraphs summarize the views of those interviewed in the Tampa Bay marine community during 1988.

NOAA current prediction tables and tidal current charts no longer provide useful and reliable information. Although the NOAA tide predictions are adequate under low wind conditions, meteorologically-induced water levels vary substantially. Inaccurate predictions of slack water times and maximum current velocities throughout Tampa Bay make it difficult, if not hazardous, to turn, dock, undock, or maintain position in channels.

The consensus is that current predictions are unreliable at numerous locations in Tampa Bay. Deepening of channels and shoaling in some areas apparently affected the Bay's hydrodynamics since NOAA's circulation survey in 1963. Pilots report increased currents at the New Sunshine Skyway Bridge. The 60-foot diameter concrete bumpers and arcuate-shaped protecting islands constructed under the suspension span of the Bridge, and the planned fish havens to be built nearby using the rubble from the old bridge, will tend to intensify the currents further. The pilots believe that slow or poor steering inbound traffic will find the bridge area particularly hazardous during spring ebb currents. The turns from Cuts B and K into the ports are hazardous and improved current information is critical there.

Unreliable current predictions are more serious than deficiencies in tide predictions, but better water level data are needed in or near the ports. Improved water level data are important in the northern part of Hillsborough Bay for safe piloting of ships carrying ammonia, sulphur, phosphate, bulk cargo, and oil products.

All ship movements would be inherently safer with real-time current and water level data, and this should have an effect on the number and extent of marine casualties.

Direct economic benefits are substantial and could be estimated using statistics on (1) the number of transits where the ships' drafts are equal to or greater than the project depths (Tampa had the second greatest number, 521 transits, of all U.S. ports in 1984), (2) time lost by ships waiting for depth windows to make transits (windows open wider when water levels are higher than predicted due to winds), (3) additional tons per inch of added draft of various cargos available during when water levels are higher than normal, and (4) more time-efficient turning, docking and undocking possible with improved current data.

APPENDIX B. Workshop Participants

The following individuals participated in the NOAA workshop on TOP at the Florida Institute of Oceanography on December 15, 1989.

Name	Association
Allen, Mark W., CWO	US Coast Guard Group, St. Petersburg (ATON)
Arnold, Bill	Florida Marine Research Inst., St. Petersburg, FL
Balfour, Robert	NOAA/National Weather Service, Ruskin, FL
Buck, Jeff	Tampa Bay Pilots Association, Tampa, FL
Bowhard, Gerri	Tampa Bay Regional Planning Council, St. Petersburg, FL
Challenger, Ron	WFLA-TV; Tampa, St. Petersburg, FL
Chapin, Lee	Chapin Associates, Tallahassee, FL
Ciwloth, S.	Safety Harbor, FL
Clark, Peter	Tampa Bay Regional Planning Council, St. Petersburg, FL
Condrick, John	Florida Council of Yacht Clubs, Tampa, FL
Cutler, Millard L.; PE	NOAA (Ret'd); Sunbelt Surveys, Pinellas Park
Eckenrod, Dick	Southwest Florida Water Management District, Tampa, FL
Fanning, Kent	Univ. of S. Florida, St. Petersburg, FL
Fletcher, Dick	WTSP-TV, St. Petersburg, FL
Ford, William; PE	Wade-Trim, Inc., Tampa, FL
Galperin, Boris	Univ. of S. Florida, Marine Science, St. Petersburg, FL
Goodwin, Carl	US Geological Survey, Tampa, FL
Kilgore, Frank	Gardinier Inc.; Tampa, FL
Kleinschmidt, Dean	Gardinier Inc.; Tampa, FL
Larsen, Ronald	Marine and Hydro Consultant, Inc., St. Petersburg, FL
MacDonald, LT Paul	US Coast Guard Marine Safety Office, Tampa, FL
Mahmand, Behzad	Florida Dept. of Natural Resources, St. Petersburg, FL
Marelli, Dan	Florida Dept. of Natural Resources, St. Petersburg, FL
Marois, William	Tierra Verde, FL
Moores, Donald D.	Florida Dept. of Environmental Regulation, Tampa, FL
Nicholson, Andrew	City of Safety Harbor, FL
Peene, Steve	Univ. of Florida., Gainesville, FL
Perry, Michael J.	Southwest Florida Water Management District, Tampa, FL
Quinn, Gene	Pinellas Co. Environmental Management, Clearwater, FL
Ross, Bernard	Univ. of S. Florida, Tampa, FL
Santmyer, Richard	Tampa Fire Hazmat, Tampa, FL
Savercool, Dan	Wade-Trim, Inc., Tampa, FL
Schant, Jim	Maritrans, Tampa, FL
Schmied, Ron	NOAA/National Marine Fisheries Service, St. Petersburg, FL
Schropp, Steve	Florida Dept. of Environmental Reg., Tallahassee
Sheng, Y.	Univ. of Florida, Gainesville, FL
Shinn, E. A.	US Geological Survey, St. Petersburg, FL
Squires, Andy	Bay Study Group, City of Tampa, Tampa, FL
Stilwell, LCDR Eric	US Navy, Naval Reserve Center, Tampa, FL
Stover, Bill	Port of Tampa, Tampa, FL
Street, Christopher	Port Manatee, Palmetto, FL
Stumpf, Rick	US Geological Survey, St. Petersburg, FL
Thompson, Douglas A.	Florida Dept. of Natural Resources, Tallahassee, FL
Tiffany, Bill; Director	Environmental Affairs, Manatee Co. Port Authority, Palmetto, FL
Timmel, Capt. John C.	Tampa Bay Pilots Association, Tampa, FL
Travis, Tim	Port of St. Petersburg, St. Petersburg, FL
Vargo, Sandra	Florida Institute of Oceanography, St. Petersburg, FL
Vorhees, Jan	Tampa Bay Regional Planning Council, St. Petersburg, FL
Webb, Fred	Hillsborough Community College, Tampa, FL
Weisberg, Robert	Univ. of S. Florida, Dept. Marine Science, St. Petersburg, FL
Woodbridge, David	Univ. of S. Florida, Tampa, FL
Zarillo, Gary	Florida Institute of Technology, Melbourne, FL

APPENDIX C. Excerpts from Authorizing Legislation

The basic authority for the NOAA Tide and Water Level Program and the Coastal Ocean Circulation Program is embodied in Title 33 of the United States Code (USC), Section 883 (as amended), the Reorganization Plan No. 2 of 1965 (that formed the Environmental Sciences Service Administration), and the Reorganization Plan No. 4 of 1970 (that formed NOAA). Pertinent excerpts from this authority are as follows:

33 USC, Section 883a. "...the Secretary of Commerce is authorized to conduct the following activities:

1. Hydrographic and topographic surveys;
2. Tide and current observation;..."

33 USC, Section 883b. "...the Secretary of Commerce is authorized to conduct the following activities:

1. Analysis and prediction of tide and current data;
2. Processing and publication of data, information, compilations, and reports..."

33 USC, Section 883d. "To improve the efficiency of the National Ocean Survey and to increase engineering and scientific knowledge, the Secretary of Commerce is authorized to conduct developmental work for the improvement of surveying...; and to conduct investigations and research in geophysical sciences (including...oceanography...)."

The requirement for vessels to carry National Ocean Service tide and current prediction tables is in the Code of Federal Regulations (CFR) for Navigation and Navigable Waters, as follows:

33 CFR, Paragraph 164.01. "This...applies to each self-propelled vessel of 1600 or more gross tons... when it is operating in the navigable waters of the United States except the St. Lawrence Seaway.

33 CFR, Paragraph 164.33. "Each vessel must have the following... For the area to be transited, the current edition of, or applicable current extract from:

(i) Tide Tables published by the National Ocean Service.
(ii) Tidal Current Tables published by the National Ocean Service..."

TABLE 1. STATION INFORMATION AND LOCATION DATA

IA. CURRENT METER SITES

Station	Location Names	Installation: Months	Period	MLW Depth (ft)	Meter	Lat.	Long.
C-1	Outer Egmont Channel	13	8/90 - 8/91	20	R-600	27°36.2'	82°49.9'
C-2	Inner Egmont Channel	13	8/90 - 8/91	85	R-600	27°36.6'	82°45.4'
C-3	New Sunshine Skyway Br.	15	6/90 - 8/91	45	R-1200	27°37.3'	82°39.3'
C-4	Manatee Channel Entrance	15	6/90 - 8/91	45	R-1200	27°39.7'	82°36.0'
C-5	Port Tampa	15	6/90 - 8/91	43	R-1200	27°51.7'	82°33.3'
C-6	Gulf of Mexico Entrance	13	8/90 - 8/91	60	R-300	27°35.7'	83° 0.0'
C-10	St. Petersburg Port	2	6/90 - 7/90	23	S4	27°45.7'	82°36.6'
C-11	Little Bayou, St. Petersburg	2	6/90 - 7/90	26	S4	27°42.8'	82°36.6'
C-12	Tarpon Key, Sun. Bridge	2	6/90 - 7/90	11	S4	27°39.8'	82°40.4'
C-13	Sunshine Skyway Bridge	2	6/90 - 7/90	23	S4	27°37.9'	82°39.6'
C-14	Beacon Key, Cut C	2	6/90 - 7/90	23	R-1200	27°41.1'	82°34.3'
C-15	Mangrove Point, Cut E	2	6/90 - 7/90	18	R-1200	27°44.9'	82°31.2'
C-20	Southwest Channel	2	8/90 - 10/90	21	R-1200	27°34.5'	82°45.4'
C-21	Passage Key Inlet	2	8/90 - 10/90	24	R-1200	27°32.5'	82°44.6'
C-22	Anna Maria Sound	2	8/90 - 10/90	8	S4	27°30.3'	82°42.1'
C-23	Mullet Key Channel	2	8/90 - 10/90	30	R-1200	27°36.6'	82°41.3'
C-24	Main Channel, Pinellas Bayou	2	8/90 - 10/90	18	S4	27°41.5'	82°32.5'
C-25	Indian Key, Sun. Bridge	2	8/90 - 10/90	8	S4	27°41.6'	82°40.9'
C-26	Palmetto, Green Bridge	2	8/90 - 10/90	8	S4	27°30.4'	82°34.7'
C-30	Cut J Channel	2	1/91 - 2/91	43	R-1200	27°48.5'	82°34.1'
C-31	Bird I., Cut C Channel	2	1/91 - 2/91	43	R-1200	27°50.8'	82°26.6'
C-32	Gandy Bridge, East	2	1/91 - 2/91	13	S4	27°54.0'	82°33.2'
C-33	Gandy Bridge, West	2	1/91 - 2/91	18	S4	27°52.6'	82°34.6'
C-34	Howard Frankland Bridge	2	1/91 - 2/91	15	S4	27°55.6'	82°35.0'

TABLE 1 (Continued) IA. CURRENT METER SITES

Station	Location Names	Installation: Months	Period	MLW Depth (ft)	Meter	Lat.	Long.
C-35	Courtyney Campbell Pkwy	2	1/91 - 2/91	12	S4	27°58.2'	82°37.3'
C-36	Hillsborough Bay Straits	2	1/91 - 2/91	36	R-1200	27°48.6'	82°26.9'
C-40	Christmas I., Port Tampa	2	3/91 - 5/91	20	S4	27°50.4'	82°34.6'
C-41	Picnic I., Cut K Channel	2	3/91 - 5/91	25	R-1200	27°50.4'	82°33.7'
C-42	Venetian Islands	2	3/91 - 5/91	10	S4	27°48.6'	82°35.3'
C-43	Old Tampa Bay Straits	2	3/91 - 5/91	13	S4	27°51.7'	82°35.0'
C-44	Intersection Gadsen/G Cut	2	3/91 - 5/91	29	R-1200	27°46.8'	82°31.0'
C-45	Coffeepot Bayou	2	3/91 - 5/91	30	R-1200	27°47.0'	82°36.0'
C-50	Point Pinellas, Manatee	2	6/91 - 7/91	12	S4	27°40.4'	82°37.3'
C-51	Outer Manatee Channel	2	6/91 - 7/91	21	S4	27°40.1'	82°36.6'
C-52	Inner Manatee Channel	2	6/91 - 7/91	24	R-1200	27°39.2'	82°35.4'
C-53	Port Manatee	2	6/91 - 7/91	15	S4	27°38.6'	82°34.7'
C-54	Intracoastal Waterway Light	2	6/91 - 7/91	19	S4	27°34.4'	82°41.5'

IB. TOWED RADS

Transects are planned for August and November, 1990; February, May and August, 1991.

Transect Number	Location	Location from	to
CT-1	Across Egmont Channel	27° 36.6' 82° 45.0'	27° 35.6' 82° 45.3'
CT-2	Parallel to Sunshine Skyway Bridge	27° 38.0 82° 40.1	27° 36.0' 82° 39.0'
CT-3	Channel near Port Manatee	(Towing Pattern to be Determined)	
CT-4	Entrance to Old Tampa Bay	(Towing Pattern to be Determined)	

TABLE 1 (Continued)

II. WATER LEVEL STATIONS

The symbol '-' under Installation Date means that the gage is presently installed as part of the NWLON. The symbol 'rts' under Duration means that the gage is a real-time system, which will be installed permanently.

Station Number	Name	Installation Date	Duration (months)	Latitude	Longitude
E-858	Venice Pier	6/1/90	5	27° 6.5'	82°27.5'
E-217	Cortez	6/1/90	5	27°28.0'	82°41.3'
E-243	Anna Maria	6/1/90	5	27°29.8'	82°42.8'
E-273	Desoto Point	6/1/90	5	27°31.4'	82°39.0'
E-347	Egmont Key	6/1/90	5	27°36.0'	82°45.6'
E-364	Mullet Key	6/1/90	15	27°36.9'	82°43.6'
E-384	Port Manatee	6/1/90	15	27°38.1'	82°33.6'
E-3841	Manatee PORTS	6/1/91	rts	27°38.1'	82°33.6'
E-428	Tierra Verde	6/1/90	5	27°41.3'	82°43.0'
E-520	St. Petersburg	-	15	27°46.4'	82°37.3'
E-5202	St. Petersburg PORTS	6/1/91	rts	27°46.4'	82°37.3'
E-537	Apollo Beach	6/1/90	15	27°47.2'	82°25.6'
E-641	Gandy Bridge	1/1/91	5	27°53.6'	82°32.3'
E-657	Davis Island	6/1/90	15	27°54.5'	82°27.1'
E-667	McKay Bay	1/1/91	5	27°54.9'	82°25.4'
E-6671	Tampa PORTS	6/1/91	rts	27°54.9'	82°25.4'
E-689	Bay Aristocrat Village	6/1/90	15	27°56.5'	82°43.2'
E-724	Clearwater Beach	-	15	27°58.6'	82°49.9'
E-738	Safety Harbor	1/1/91	5	27°59.3'	82°41.1'

TABLE 1 (Continued)

III. METEOROLOGICAL STATIONS

A = wind speed, wind direction. B = real time: wind speed and direction; air pressure, temperature (two levels), relative humidity; solar radiation.
* = permanent.

Station	Location	Measurements	Period	Latitude	Longitude
M-1	Egmont Key (Harbor Pilots' pier)	A	6/90 - 8/91	27° 35.3'	82° 45.5'
M-2	Bridge/Port Manatee (Lower C Cut range marker)	B	6/90 - *	27° 39.8'	82° 37.1'
M-3	Middle Tampa Bay (Upper Cut E range marker)	A	6/90 - 8/91	27° 47.0'	82° 31.0'
M-4	Upper Hillsborough Bay (Lower Cut D range marker)	A	6/90 - 8/91	27° 53.8'	82° 26.2'
M-5	Gandy Bridge	A	6/90 - 8/91	27° 52.8'	82° 34.2

TABLE 1 (Continued)

IV. CONDUCTIVITY-TEMPERATURE MEASUREMENTS

Bottom Locations

All RADS and S4 platforms will have an attached CT. The locations and times are the same as for Current Meter Stations C-1 through C-54.

Water Column Locations

At each of these locations there will be two moored CTs, one just above the bottom and one just below the surface. At Station S-1, the bottom instrument will be a CTD and will be anchored to a platform.

Number	Location	Depth (ft)	Installation Period	Latitude	Longitude
S-1	Ocean Boundary	26	6/90 - 8/91	27° 36.0'	82° 51.0'
S-2	Middle Bay	15	1/91 - 7/91	27° 42.0'	82° 35.0'
S-3	Hillsborough Bay	11	6/90 - 12/90	27° 53.0'	82° 28.0'

CTD Transects

Each will be occupied for 1 or 2 days each in August and November, 1990, and in February, May, and August 1991.

Number	Location	Length (nmi)	Spacing of Casts (nmi)	Number of Casts
ST-1	Across Egmont Channel	1.0	.25	5
ST-2	New Sunshine Skyway Bridge	3.4	.25	15
ST-3	St. Pete to L. Manatee Ri.	6.0	.5	13
ST-4	Bay Entrance to bridge	10.0	1.0	11
ST-5	Lower Navigation Channel	15.0	1.0	16
ST-6	Upper Navigation Channel	9.0	1.0	10

TABLE 2. INSTRUMENT REQUIREMENTS

Number	Equipment
I. CURRENT METER STATIONS	
Self-contained RADS Installations	
1	RADS (300 khz), platform, locator with acoustic pinger and release
2	RADS (600 khz), platform, locator with acoustic pinger and release
5	RADS (1200 khz), platform, locator with acoustic pinger and release
Real-time RADS Installations	
3	RADS (1200 khz), platform, transmitter
Shipboard RADS for Transects	
1	RADS (600 khz), ship platform
Shallow Water Current Meter Installations	
4	S4 (electromagnetic), anchor, locator
II. WATER LEVEL STATIONS	
3	Real-time water level sensors, transmitter
11	Self-recording water level sensors
III. METEOROLOGICAL STATIONS	
1	Real-time system: anemometer, barometer, thermometer, radiometer, humidity sensor. transmitter
3	Anemometer, barometer, thermometer
IV. CONDUCTIVITY-TEMPERATURE-DEPTH STATIONS	
7	RADS-mounted CT sensors
2	Moored CT systems: anchor, two CTs, floats, locators
1	Shipboard CTD sensor, electric winch.

TABLE 3. TYPES OF DATA TO BE ARCHIVED

The following data from each instrument will be archived and available after the survey. These data are in addition to instrument type, serial number, location (latitude and longitude), time of deployment, and water depth. Current directions are toward; wind directions are from. N/A means not applicable.

Instrument	Measured Variable	Time Series Interval	Units
RADS	total water depth	10 min	cm
for each bin:	beam current speeds	"	cm/s
	net current speed	"	cm/s
	net current direction	"	degrees
	net vertical current speed	"	cm/s
S4	current speed	10 min	cm/s
	current direction	"	degrees
Water Level Gage	relative elevation	6 min	feet
Anemometer	wind speed	10 min	m/s
	wind direction	"	degrees
Barometer	atmos. pressure	"	millibars
Thermometer	air temperature	"	C
RH Sensor	relative humidity	"	percent
Radiometer	solar radiation	"	langleys
CT	conductivity	"	millisiemens
	temperature	"	C
	salinity	"	ppt
CTD	depth	N/A	cm
	conductivity	"	millisiemens
	temperature	"	C
	salinity	"	ppt

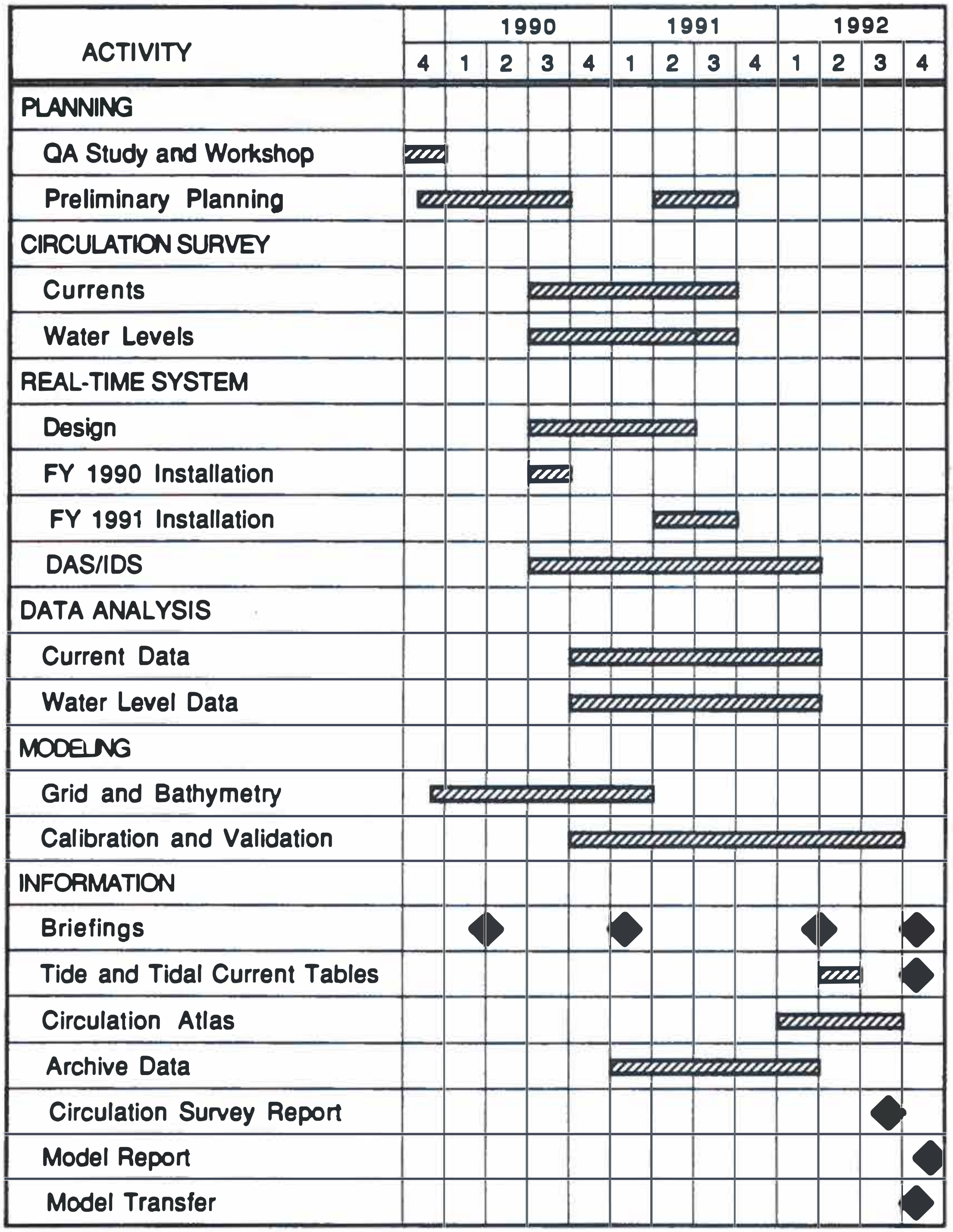


Figure 1. Schedule for components of the Tampa Bay Oceanography Project.

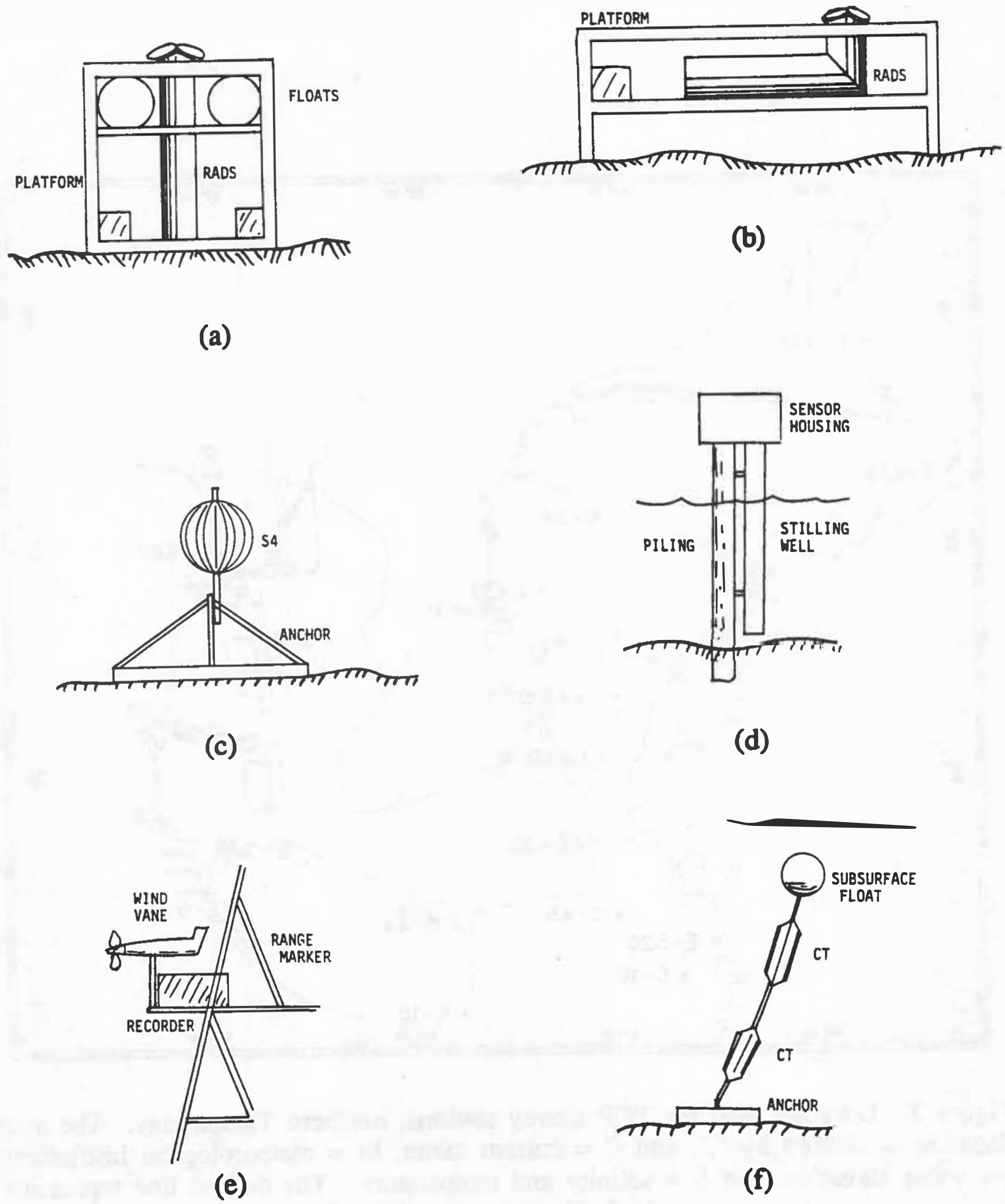


Figure 2. Sketches showing (a) upright RADS deployment, (b) horizontal RADS deployment, (c) S4 deployment, (d) water level measuring system, (e) meteorological instrument deployment, and (f) a moored CT deployment.

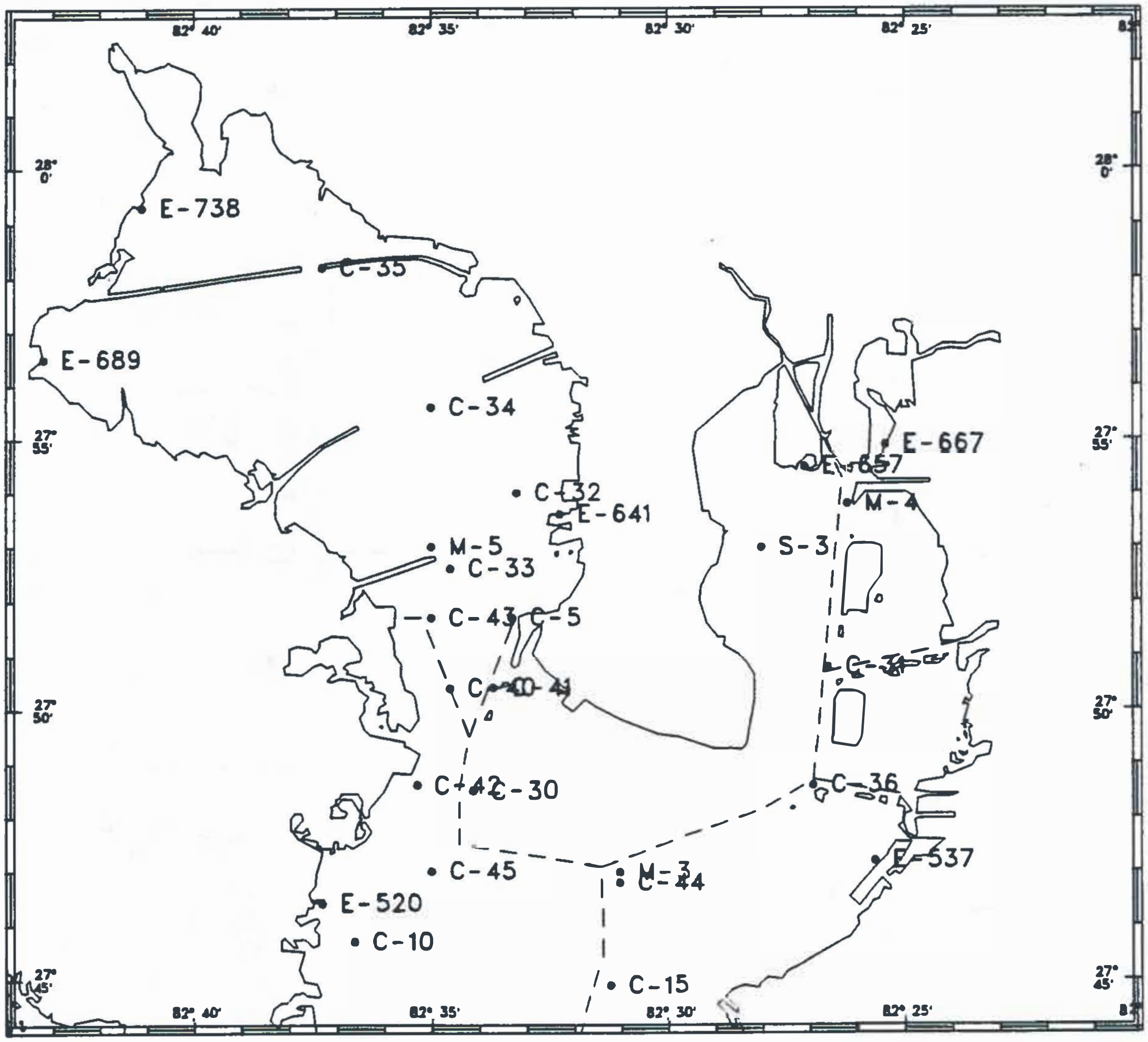


Figure 3. Location map for TOP survey stations; northern Tampa Bay. The station location is marked by ".", and C = current meter, M = meteorological instruments, E = water elevation, and S = salinity and temperature. The dashed line represents the dredged navigation channel.

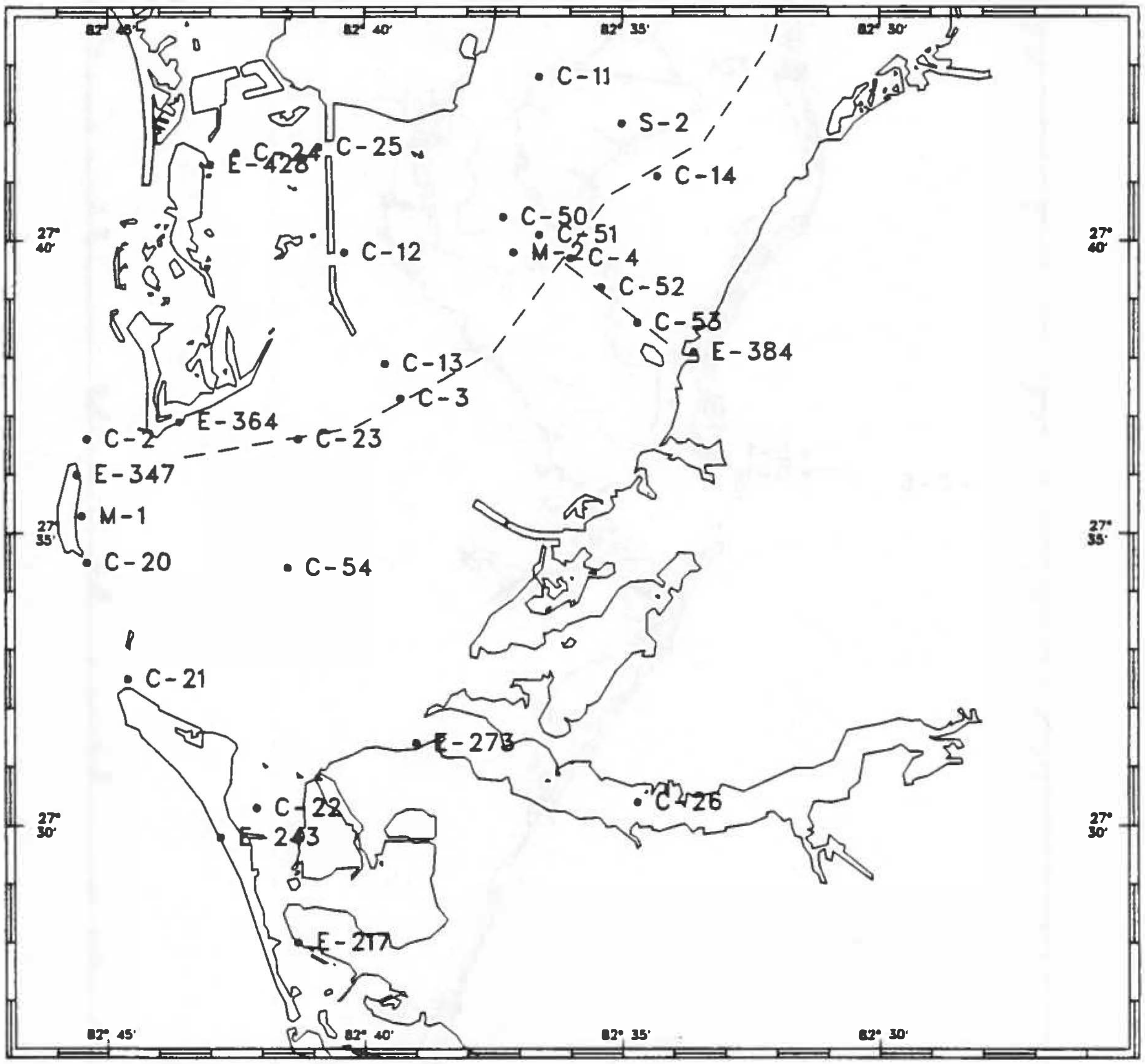


Figure 4. Location map for TOP survey stations; southern Tampa Bay. The station location is marked by ".", and C = current meter, M = meteorological instruments, E = water elevation, and S = salinity and temperature. The dashed line represents the dredged navigation channel.

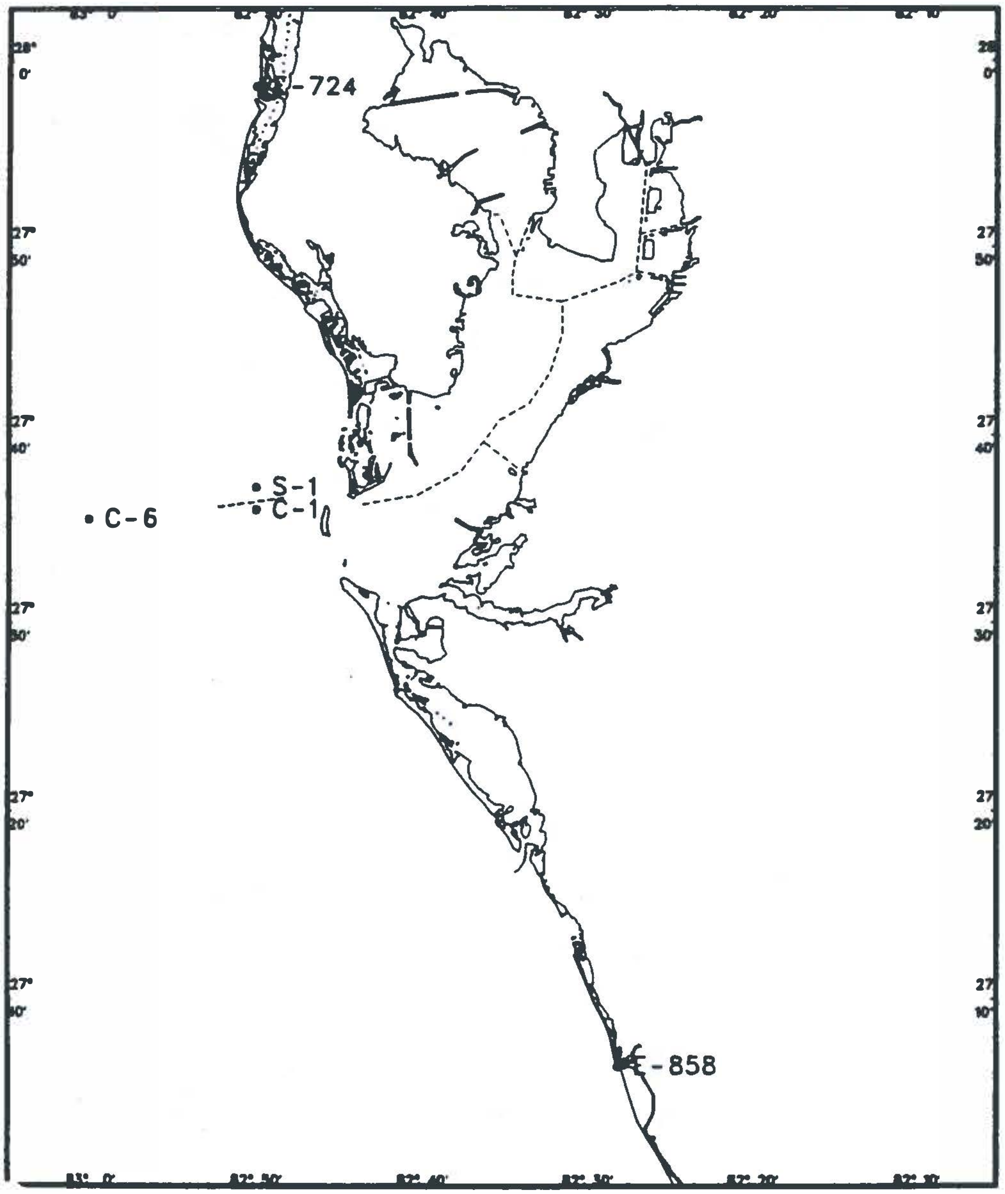


Figure 5. Location map for TOP survey stations; outside Tampa Bay. The station location is marked by ".", and C = current meter, E = water elevation, and S = salinity and temperature. The dashed line represents the dredged navigation channel.

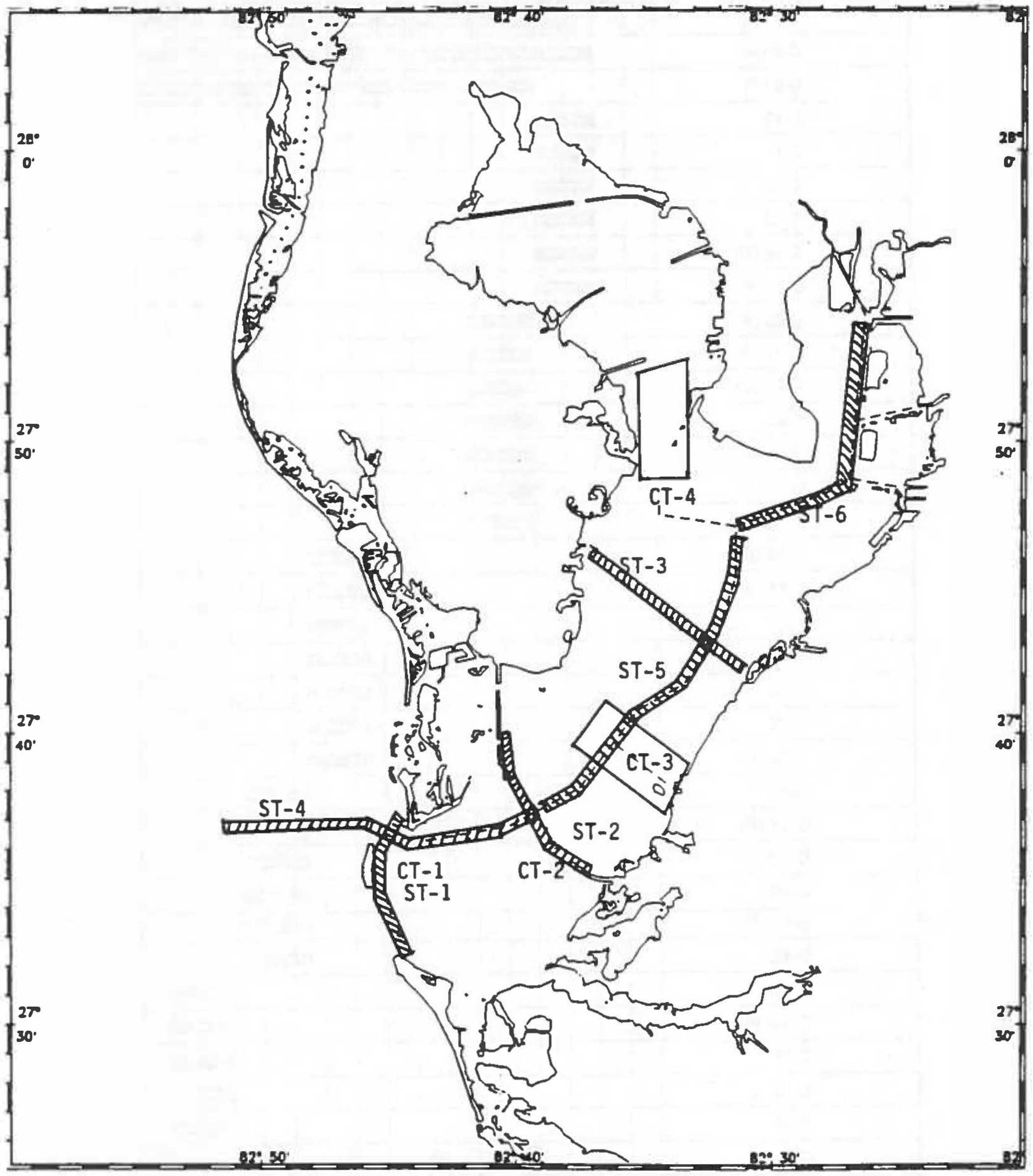


Figure 6. Location map for the towed RADS transects (CT-1 to CT-4) and the CTD transects (ST-1 to ST-6). The dashed line represents the dredged navigation channel.

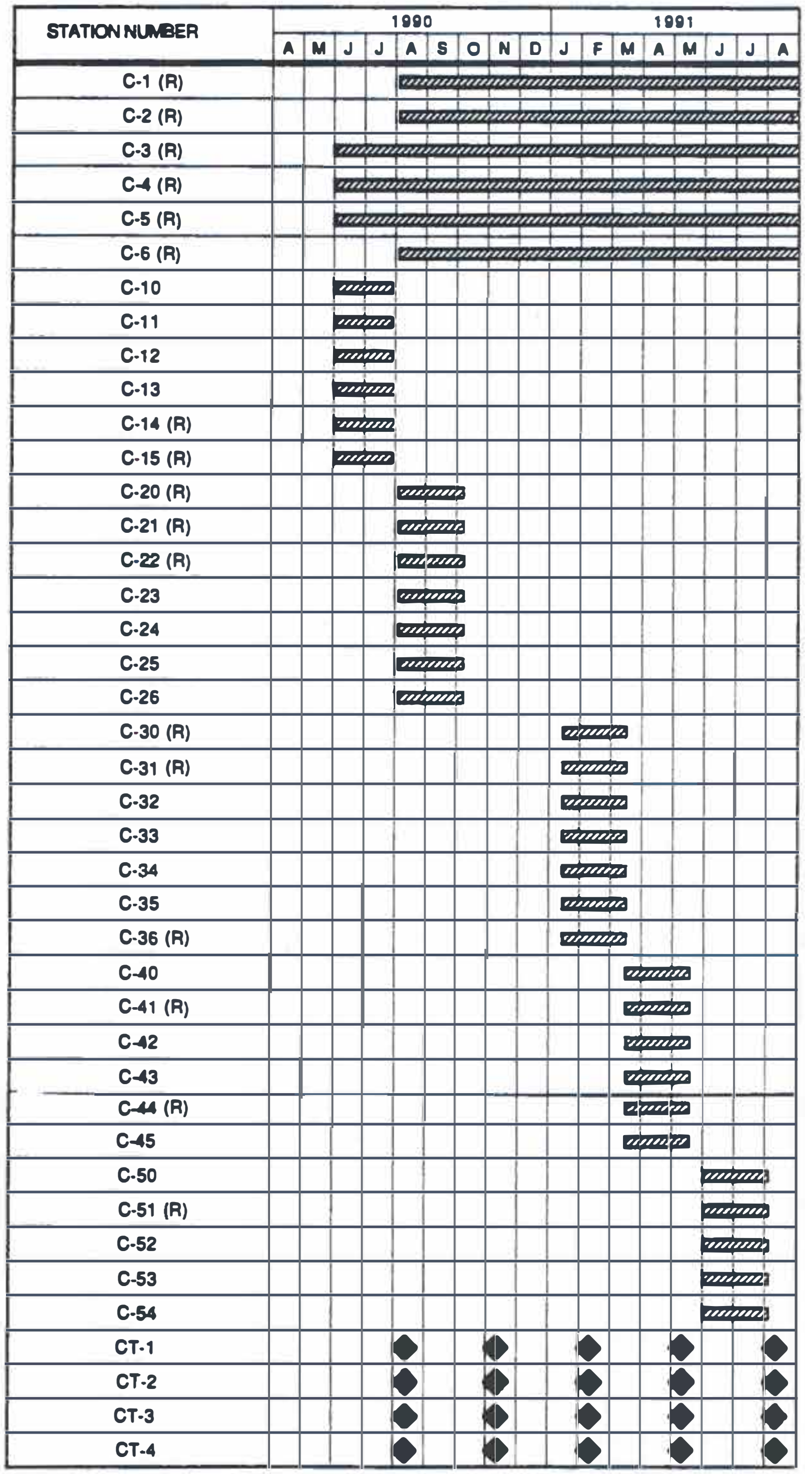


Figure 7. Schedule for TOP current meter deployments. RADS moorings are denoted by (R).

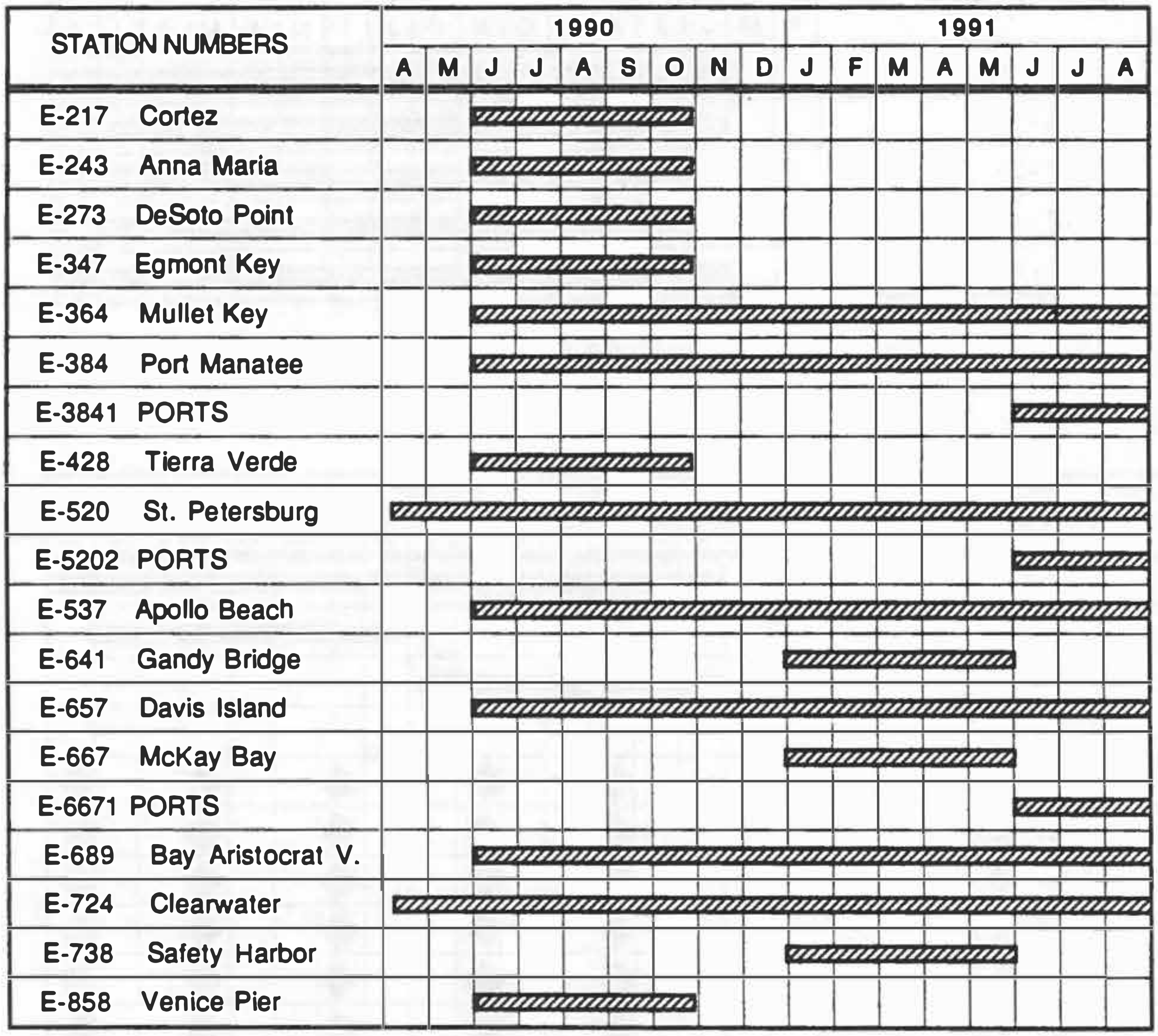
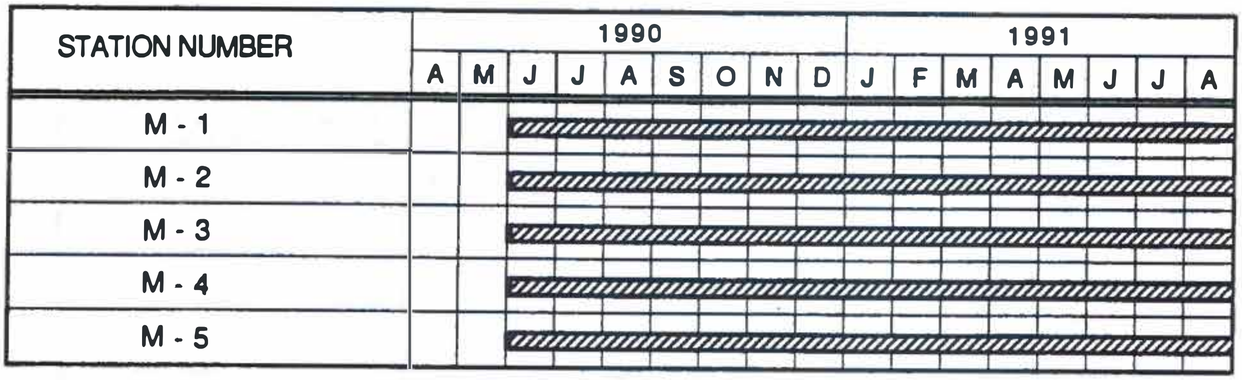
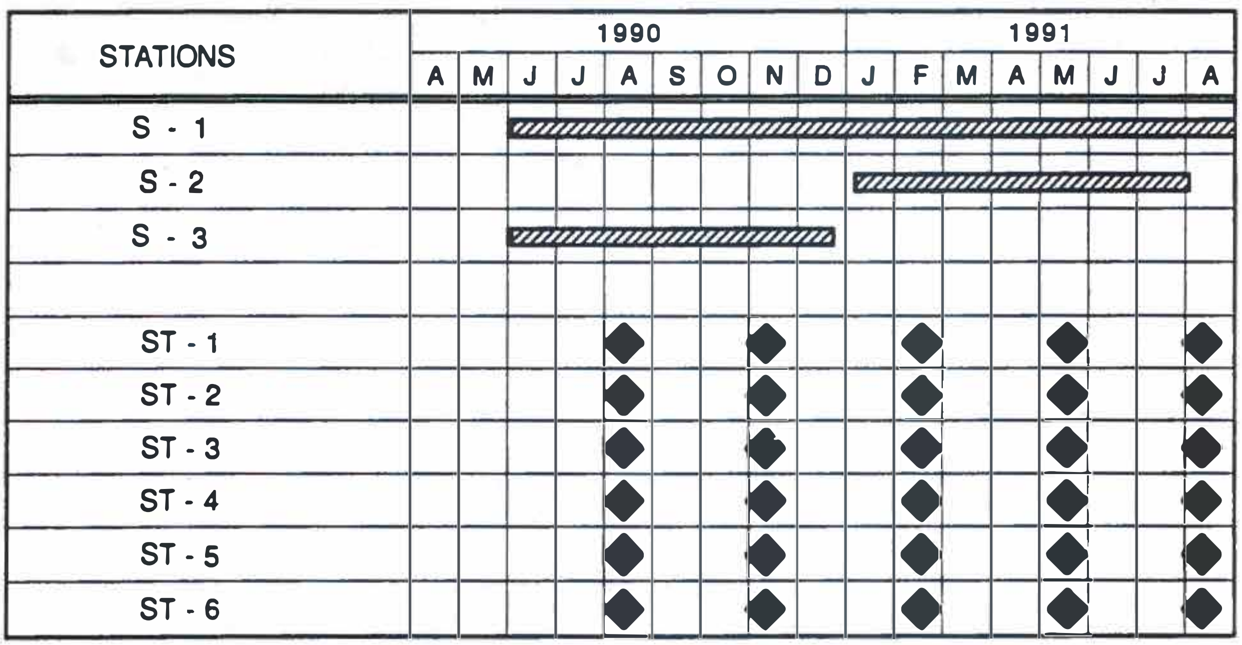


Figure 8. Schedule for TOP water level gage deployments.

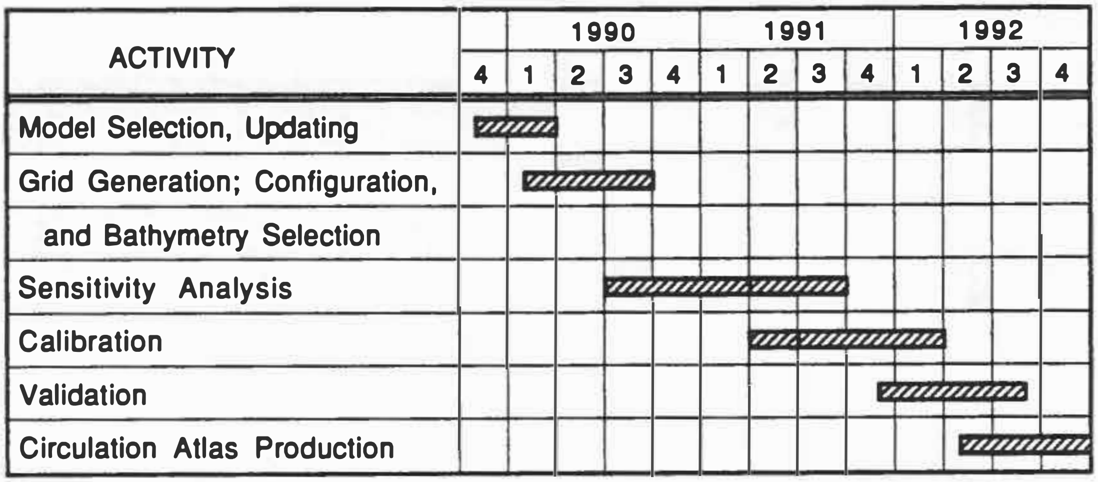


(a)

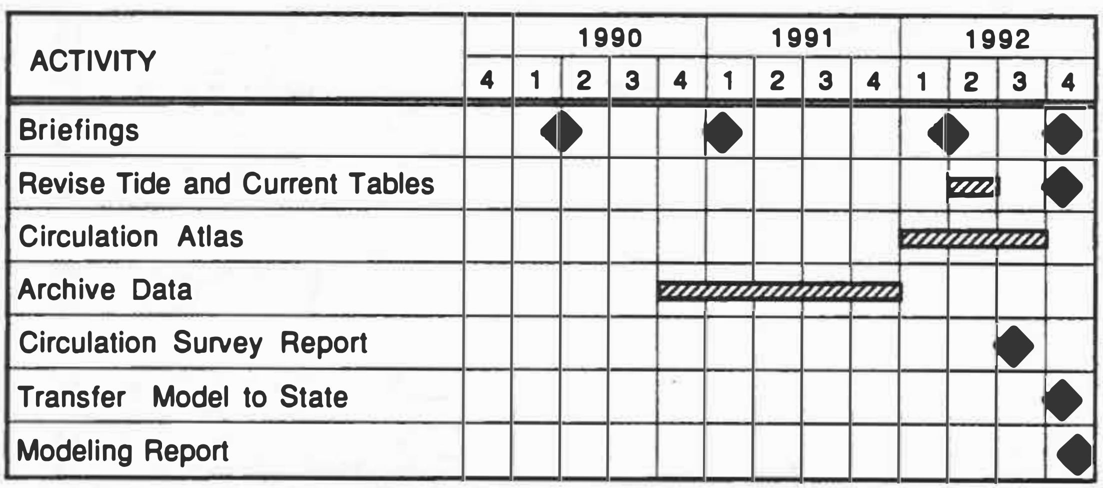


(b)

Figure 9. (a) Schedule for TOP meteorological instrument deployments. (b) Schedule for TOP conductivity and temperature instrument deployments.



(a)



(b)

Figure 10. Schedules for TOP (a) circulation modeling and (b) information products.

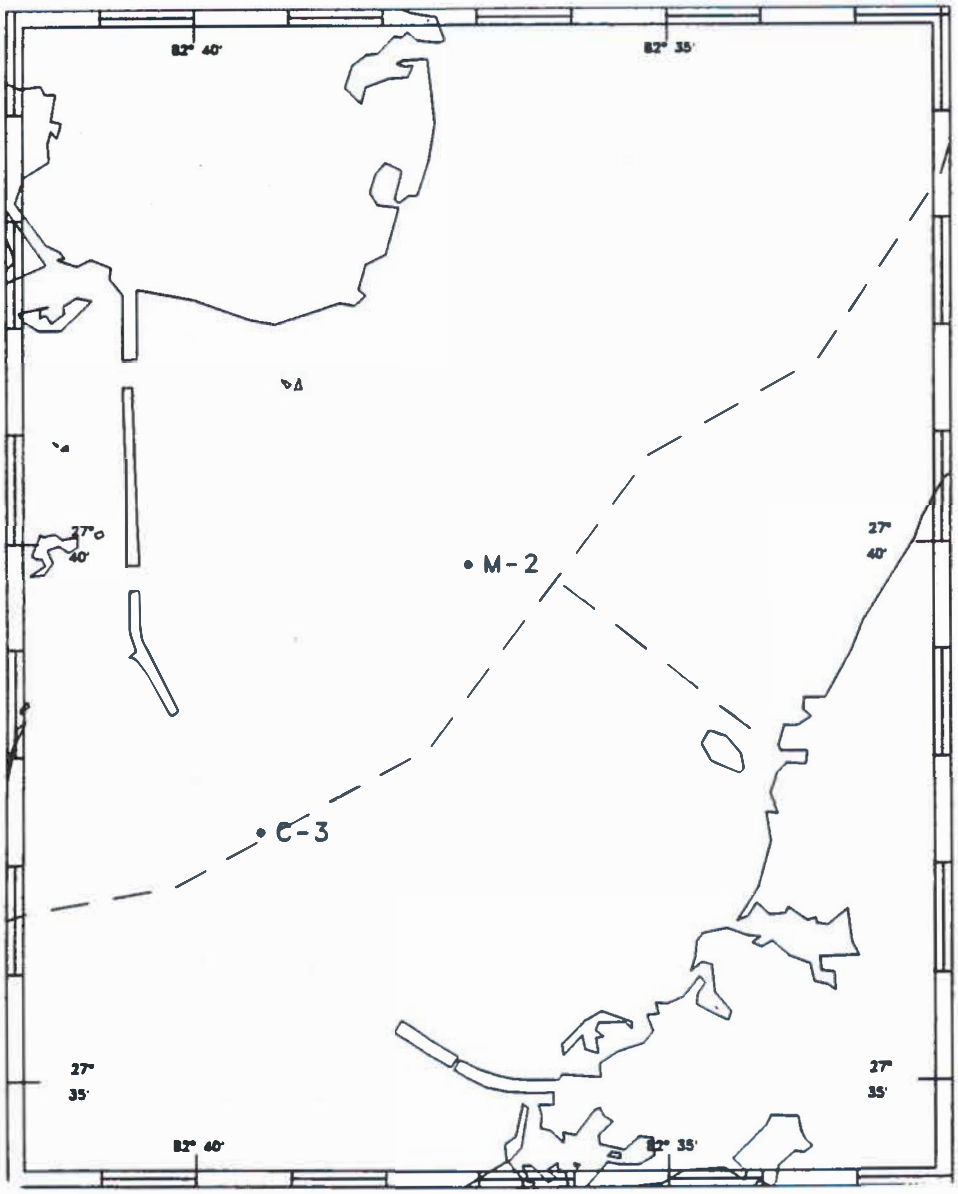


Figure 11. Location map for PORTS components to be installed in FY90. The station location is marked by ".", and C = current meter and M = meteorological instruments. The dashed line represents the dredged navigation channel.

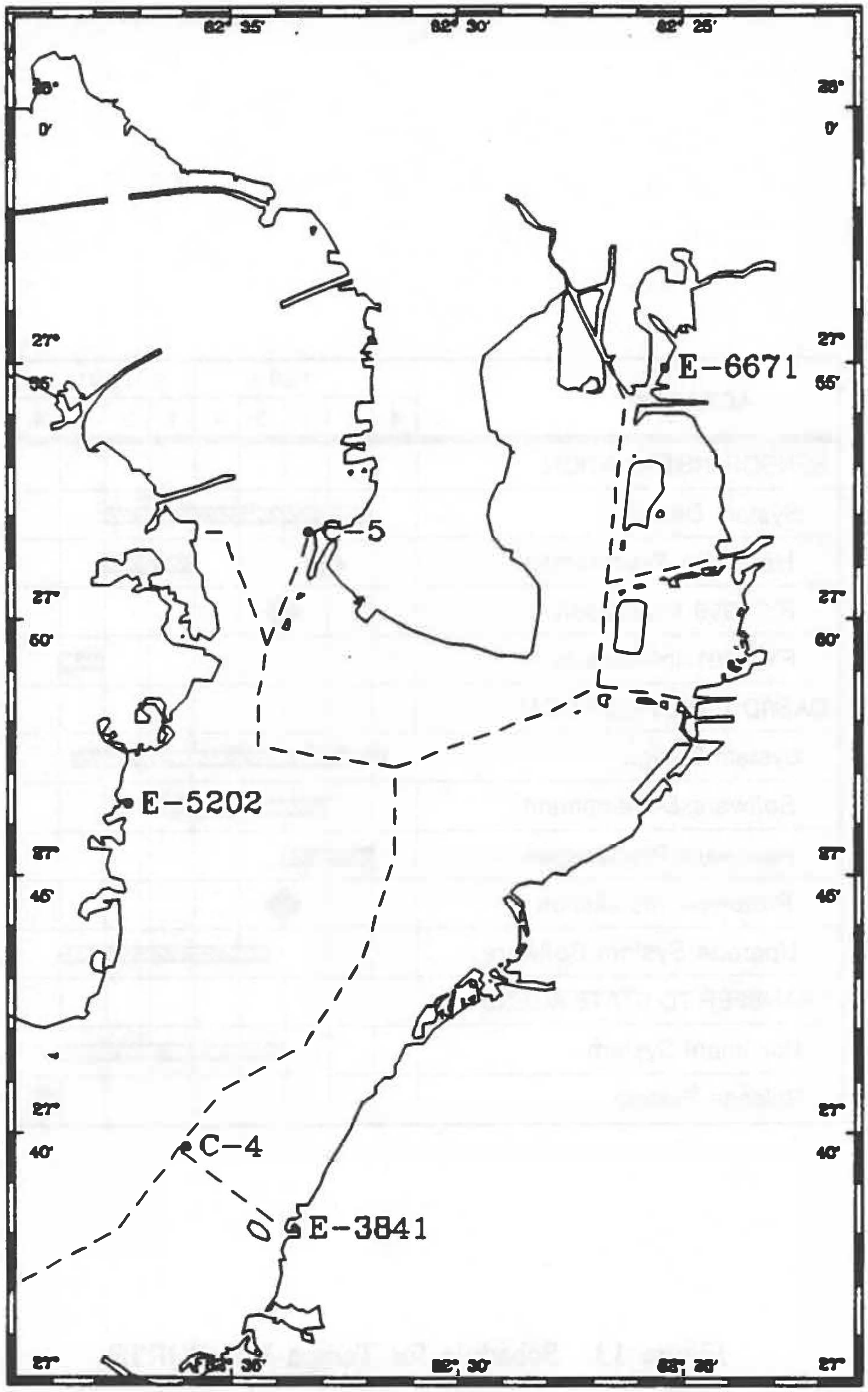


Figure 12. Location map for PORTS components to be installed in FY91. The station location is marked by ".", and C = current meter and E = water elevation. The dashed line represents the dredged navigation channel.

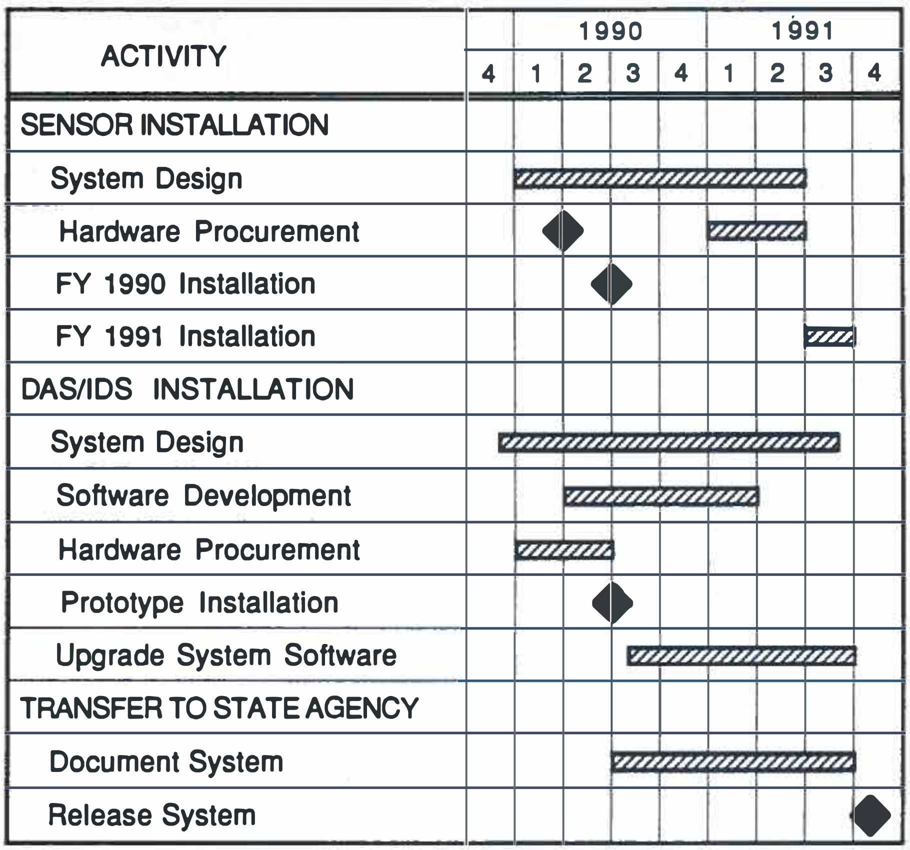


Figure 13. Schedule for Tampa Bay PORTS.

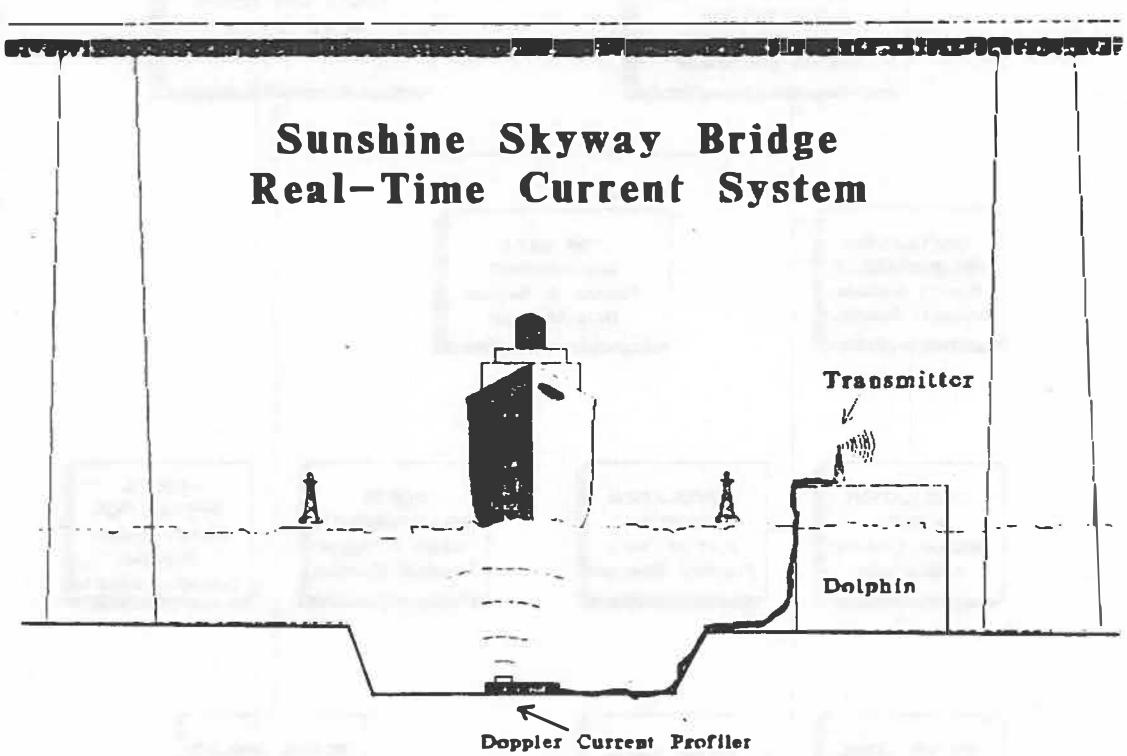


Figure 14. Sketch of the real-time current meter system at the New Sunshine Skyway Bridge.

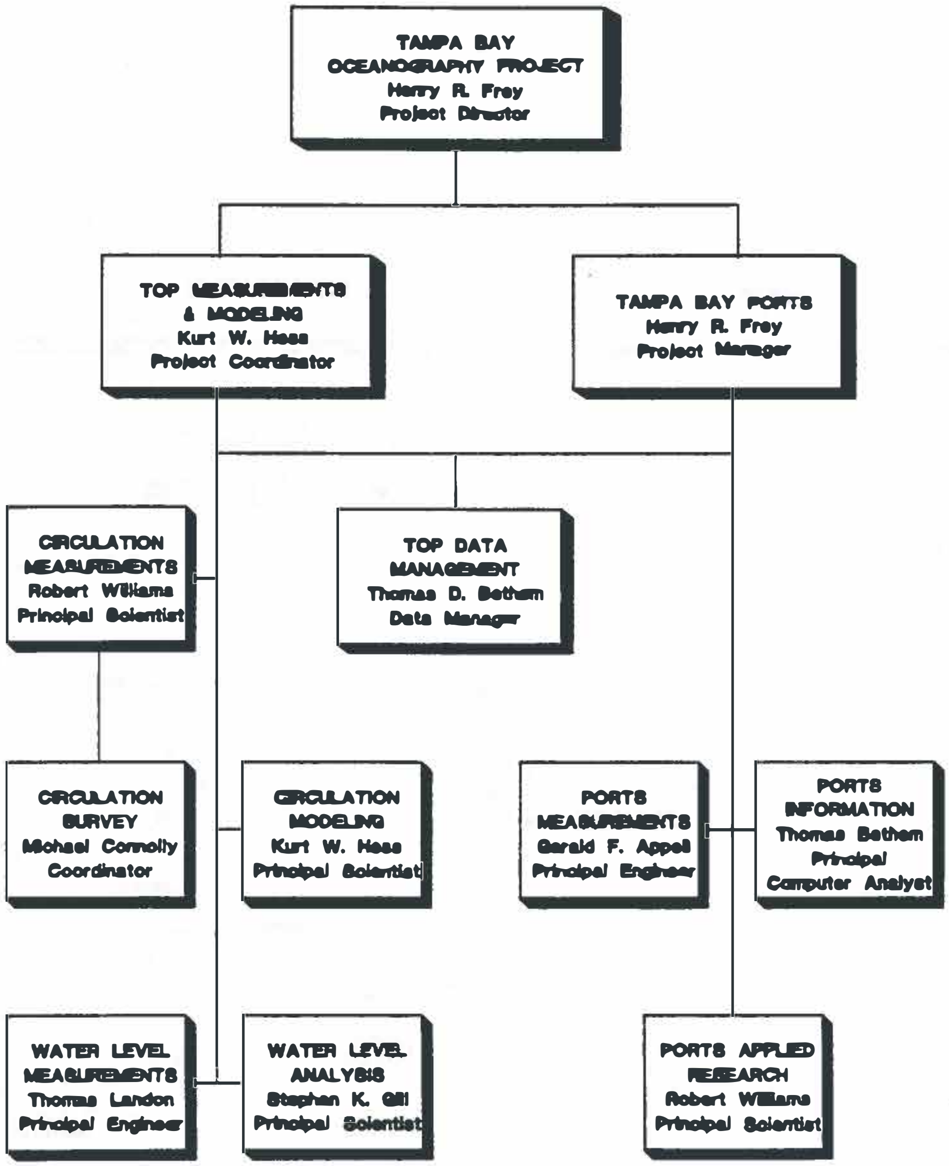


Figure 15. TOP management and staff.