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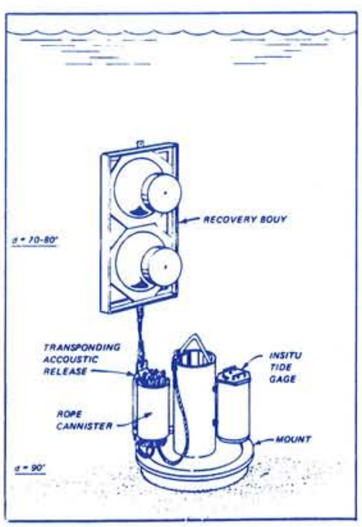
LOCATION MAP



TECHNICAL REPORT CERC-89-17

LOS ANGELES AND LONG BEACH HARBORS MODEL ENHANCEMENT PROGRAM

TIDAL CIRCULATION PROTOTYPE DATA COLLECTION EFFORT

Volume I

MAIN TEXT AND APPENDIXES A THROUGH C

by

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A tidal circulation study of the Los Angeles and Long Beach Harbors was conducted by the US Army Engineer Waterways Experiment Station. Field data were collected from 5 tide gages and 16 current meters for use in calibration and verification of a numerical circulation model. The methods and results of the field data collection effort are presented. Analysis was performed to verify the quality of the tidal data and the flow patterns revealed by the current data.

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A limited number of copies of Volumes II (Appendixes D through I) and III (Appendix J) were published under separate cover. Copies of Volume I (this report and Appendixes A through C) are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

PREFACE

This report was prepared by the Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES), and is a product of the Los Angeles and Long Beach Harbors Model Enhancement (HME) Program. The HME Program has been conducted jointly by the Ports of Los Angeles and Long Beach (LA/LB); US Army Engineer District, Los Angeles (SPL); and WES. The purpose of the HME Program has been to provide state-of-the-art engineering tools to aid in port development. In response to the expansion of ocean-borne world commerce, the LA/LB are conducting planning studies for harbor development in coordination with SPL. Ports are a natural resource, and enhanced port capacity is vital to the Nation's economic well-being. In a feasibility study being conducted by SPL, the LA/LB are proposing a well-defined and necessary expansion to accommodate predicted needs in the near future. The CE will be charged with responsibility for providing deeper channels and determining effects of this construction on the local environment.

This investigation involved collection of prototype tidal circulation data for use in the calibration and verification of a three-dimensional numerical circulation model. Data collection occurred between June and October 1987 by personnel of the Prototype Measurement and Analysis Branch (PMAB) and the Field Research Facility (FRF) Group, Engineering Development Division. Design and installation of the measurement system were under the supervision of Messrs. William Kucharski and William E. Grogg, Equipment Specialists, PMAB, with the assistance of the University of Southern California Marine Support Facility. The PMAB personnel involved in data collection were Messrs. Michael S. Dickey, Douglas C. Lee, Jeffery A. Sewell, C. Ray Townsend, and Ralley Webb. The FRF personnel were Messrs. Kent K. Hathaway, Michael W. Leffler, and Brian Scarborough and Ms. Adele Militello. Data collection was performed under the supervision of Mr. David D. McGehee, PMAB. Data analysis was performed by Mr. James P. McKinney, PMAB, and Mr. McGehee. Technical supervision was provided by Mr. Gary L. Howell, PMAB, and technical assistance by Dr. S. Rao Vemulakonda, Coastal Processes Branch, Research Division, WES, and Mr. William C. Seabergh, Wave Processes Branch, Wave Dynamics Division, WES. Additional data were provided by the US Air Force Technical Applications Center and the Sea and Lake Levels Branch of the National Ocean Service. The

PMAB personnel were under the direction of Mr. Thomas W. Richardson, Chief, Engineering Development Division, and Mr. J. Michael Hemsley, Acting Chief, PMAB. This study was under the general supervision of Dr. James R. Houston, Chief, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC.

During the course of the study, liaison was maintained between WES, SPL, and LA/LB. Mr. Dan Muslin, followed by Mr. Angel P. Fuertes, was SPL point of contact. Mr. John Warwar and Ms. Lillian Kawasaki, Port of Los Angeles, and Mr. Michael Burke, Mr. Rich Weeks, and Dr. Geraldine Knatz, Port of Long Beach, were LA/LB points of contact and provided invaluable assistance.

COL Larry B. Fulton, EN, was Commander and Director of WES during the publication of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

* A limited number of copies of Appendixes D-I (Volume II) and Appendix J (Volume III) were published under separate cover. Copies are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

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

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

Multiply	By	To Obtain
feet	0.3048	metres
inches	2.54	centimetres
knots (international)	0.5144444	metres per second
pounds (mass)	0.4535924	kilograms
pounds (force) per square inch	6.894757	kilopascals

TIDAL CIRCULATION PROTOTYPE DATA COLLECTION EFFORT

PART I: BACKGROUND

1. The Ports of Los Angeles and Long Beach (LA/LB), California, are conducting planning studies for harbor development in coordination with the US Army Engineer District, Los Angeles. The US Army Corps of Engineers (CE) is charged with the responsibility for providing deeper navigation channels and determining the effects of harbor expansion on the environment. To upgrade the CE's capability to determine these effects based on state-of-the-art modeling technology, the US Army Engineer Waterways Experiment Station (WES) is executing the Los Angeles/Long Beach Harbors Model Enhancement Program.

2. This program is separated into two major studies. The first will address long-period wave energy in the harbors and its effect on moored vessels. The second will provide improved tidal circulation modeling with a more efficient numerical model system that will couple hydraulics and water quality variables (CE 1987). The prototype data for model calibration and verification have been collected by the Prototype Measurement and Analysis Branch of the Coastal Engineering Research Center (CERC), WES. This report describes the methodology and results of that data collection effort.

3. Los Angeles and Long Beach Harbors are adjacent ports situated behind a rubble-mound breakwater in San Pedro Bay, California (Figure 1). In the initial WES study of the harbors, a fixed-bed three-dimensional (3-D) physical model (McAnally 1975) and a depth-averaged-flow, two-dimensional numerical model (Raney 1976) were developed. Advancements in the state of the art of prototype measurement and hydraulic simulation provided the means to enhance the models. The upgraded numerical model of this program provides simulation of the time series of the resultant 3-D water currents and water surface elevations in the harbors given the physical boundaries and the water surface elevations in the open ocean outside the harbor breakwater.

4. Boundary conditions are established by obtaining the positions of the shoreline, including structures, and the bathymetry of the area modeled. Water surface elevations measured using tide gages placed outside the harbor provide the input forcing function that drives the system. Measurements of tidal elevation and water currents at selected positions inside the harbor are compared with predicted values to calibrate and verify the model.

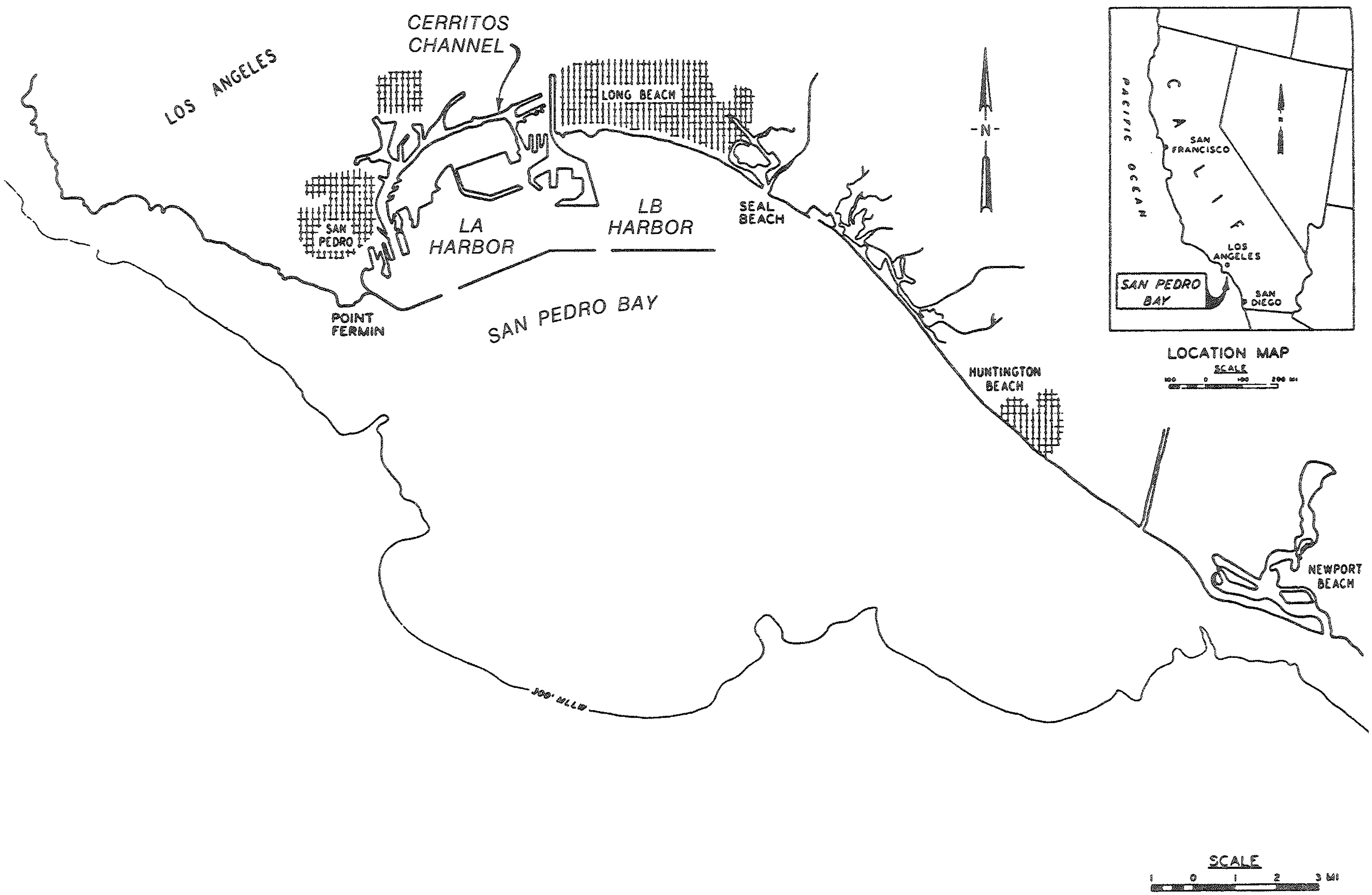

Figure 1. Study site location map

PART II: DATA COLLECTION

5. The general requirements and schedule for each task in the program were prescribed in the Management Plan for the Model Enhancement Program. Data collection was divided into three subtasks: tidal, in situ current, and current profile data. Data were collected for varying intervals between 10 June and 14 October 1987 (Table 1). Measurement intervals for each subtask varied, but deployment times were nested to provide a period of simultaneous data from all three elements from 6 to 14 August 1987. Requirements for the final data sets and the instrumentation and techniques used to obtain them are discussed in this section.

Tidal Data

Requirements

6. The requirement of the tidal data subtask was to obtain time series of water surface elevations at two outside and two inside locations for a minimum of 90 days. Each data set was to be a continuous record of elevations relative to a Mean Lower Low Water (MLLW) datum at 6-min intervals with an accuracy of at least 0.05 ft.*

7. Figure 2 shows the positions of the tidal measurement sites; geographic coordinates and depth of each measurement site are listed in Table 1.

Method

8. For the offshore sites, potential cable runs of several miles made hard wiring of power and signal to shore uneconomical. Erecting structures in water depths of 60 to 100 ft would be very expensive, and proximity to the shipping lanes and the heavy traffic volume precluded platforms and buoys because of the risk of collision. The remaining option was bottom-mounted pressure transducers with self-contained power and data storage capability. This option allowed a wide latitude in positioning and reduced the risk of unintentional and deliberate interference. The same approach was used at sites in the harbor for consistency of deployment/recovery techniques and data format.

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* A table of factors for converting non-SI units of measurement to SI units is presented on page 4.

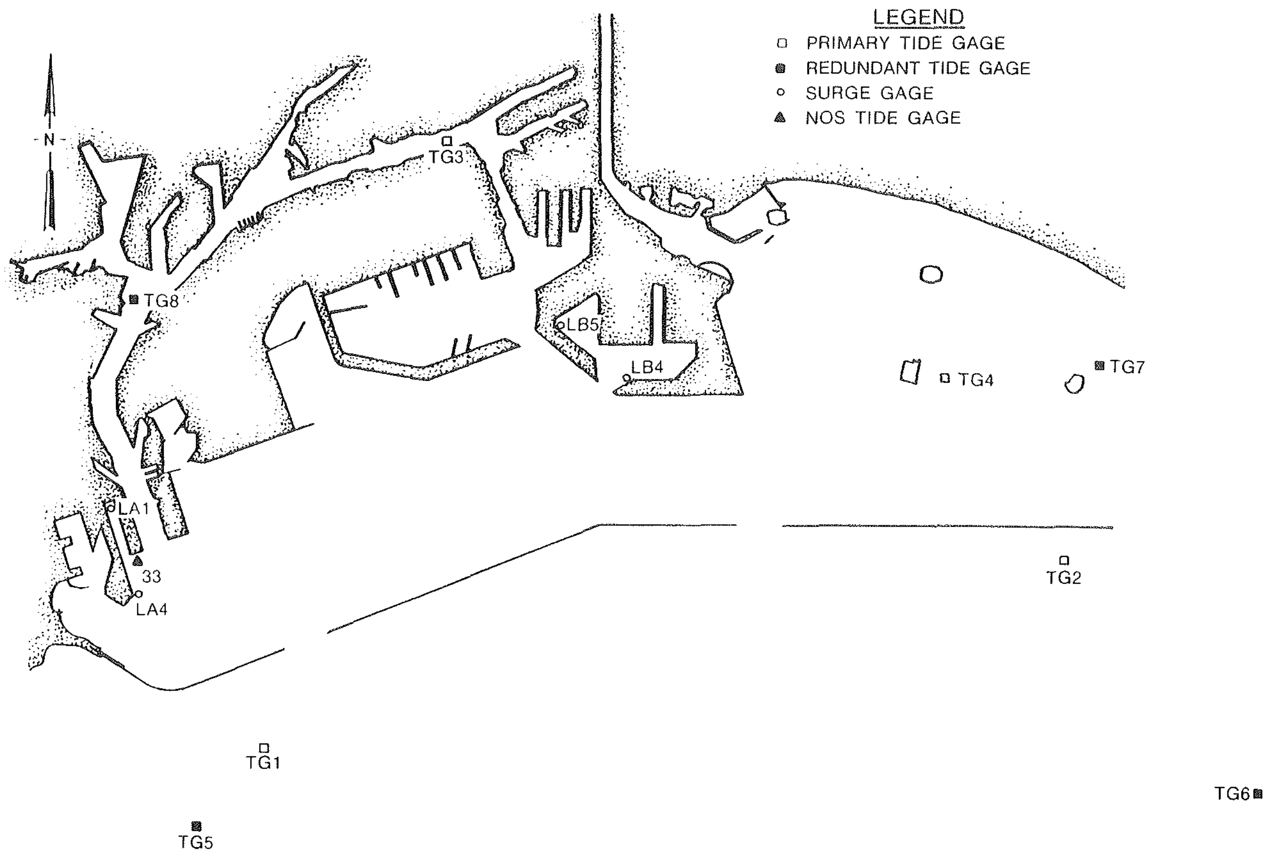


Figure 2. Tide gage deployment site map

9. The flexibility and relative security of this type of gaging are always offset by the potentially lower reliability of data recovery since gage nonperformance is only apparent after removal of the gage. To enhance reliability, redundant gages (TG5-TG8) were deployed for each of the four primary gages (TG1-TG4).

Instruments

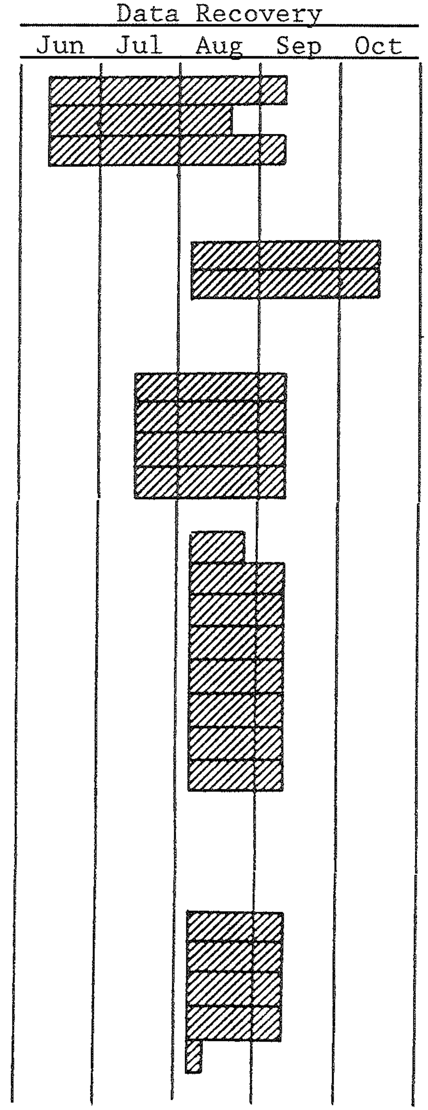
10. Details on all instruments, including manufacturer's specifications are found in Appendix A. The tide gage selected uses a vibrating quartz crystal pressure transducer whose output is proportional to absolute pressure. Oscillations of the crystal are counted over some selected sample interval, and this integrated pressure is averaged over that interval to filter wave frequency signals. The average pressure is recorded as a 16-bit digital word on a magnetic tape along with a time word from a quartz clock. Shorter sample intervals retain more information but require more storage on the tape, shortening deployment time. To obtain the required 3 months of data on one

Table 1

Gage Deployment Locations and Schedule

Site	Type	Position, deg N. Lat.	Position, deg W. Long.	Depth, ft MLLW Site	Depth, ft MLLW Gage	Instal. Date	Recov. Date
TG1	Tide	33° 41.80′	118 15.25′	75	72	6/10/88	9/9/87
TG2		33° 43.10′	118 08.50′	57	54	6/10/88	9/13/87
TG3		33° 46.08′	118 13.58′	28	25	6/10/88	9/9/87
TG4		33° 44.43′	118 09.45′	37	34	6/10/88	9/9/87
TG5		*	*			8/3/88	NA
TG6		33° 41.70′	118.07.00′	62	59	8/3/88	10/15/87
TG7		33° 44.50′	118.08.00′	25	22	8/3/88	10/15/87
TG8		33° 44.80′	118 16.43′	39	36	8/3/88	10/15/87
LA1	Wave	33° 42.56′	118 16.51′	24	18	7/15/87	9/7/87
LA4		33° 42.92′	118 16.51′	56	33	7/15/87	9/7/87
LA4		33° 44.42′	118 12.09′	43	30	7/15/87	9/7/87
LA5		33° 44.82′	118 12.71′	20	18	7/15/87	9/7/87
CM1S	Current	33° 46.13′	118 14.00′	30	5	8/3/87	9/9/87
CM1B					24	8/3/87	9/9/87
CM2S		33° 43.38′	118 16.06′	35	10	8/3/87	9/13/87
CM2M					17	8/3/87	9/13/87
CM2B					29	8/3/87	9/13/87
CM3S		33° 44.60′	118 12.69′	60	7	8/4/87	9/11/87
CM3M					32	8/4/87	9/11/87
CM3B					54	8/4/87	9/11/87
CM4S		33° 43.72′	118 14.35′	30	8	8/4/87	NA
CM4B					24	8/4/87	9/10/87
CM5S		33° 42.58′	118 15.36′	40	8	8/4/87	NA
CM5B					32	8/4/87	NA
CM6S		33° 43.60′	118 11.53′	65	10	8/4/87	9/10/87
CM6B					50	8/4/87	9/10/87
CM7S		33° 43.83′	118 08.60′	46	14	8/4/87	9/10/87
CM7B					40	8/4/87	9/10/87
CM8M		33° 44.25	118 08.00′	30	15	8/4/87	8/9/87
CM9M		33° 44.48	118 16.60′	30	15	8/3/87	NA

Data Recovery



* Gage not recovered.

deployment tape, an interval of 3.75 min (eight tide measurements/hour) was selected.

Mounting

11. The instrument housing is a 6-in.-diam. by 30-in.-long aluminum pressure case containing the transducer, electronics, data logger, and battery pack. The case was attached with stainless steel bolts to a vertical mount that was welded to a 600-lb railroad wheel. Gages inside the harbor had a subsurface retrieval buoy attached to the mount and an acoustic beacon for relocation by divers. Because of the depth outside the harbor, a subsurface buoy was attached to the wheel with a length of retrieval line coiled in a canister. The canister, in turn, was attached to the wheel with a transponder/acoustic release. The release served the dual purposes of a beacon, for locating the instrument package, and as a means of releasing the buoy and recovery line at the end of the deployment. Figure 3 shows a typical assembly in the deployed configuration.

Deployment/recovery

12. A temporary field office was leased on Terminal Island with adjacent dock space. This provided office and testing space, secure outdoor storage of heavy equipment and vessels, and a staging/loading area for operations.

13. All tide gages and in situ current meters were deployed from the University of Southern California research vessel "Sea Watch" through the cooperation of the USC Marine Science Laboratory on Terminal Island. An experienced crew, aided by the stern-mounted A-frame and ample work deck, installed the primary gages on 10 June and the backup gages on 3 August by lowering the mounts using the lift bail (Figure 4).

14. Positions were established with LORAN, radar bearings, and visual bearings to prominent targets on shore.

15. The planned recovery technique was to trigger the acoustic release, allowing the buoy to surface and enable retrieval from the surface without diver assistance. In the event of transponder failure, the gage positions could be relocated within ~100 ft, at which point a sweep would be made from the surface by dragging a chain between two vessels. Divers would then recover the gage by descending the sweep chain.

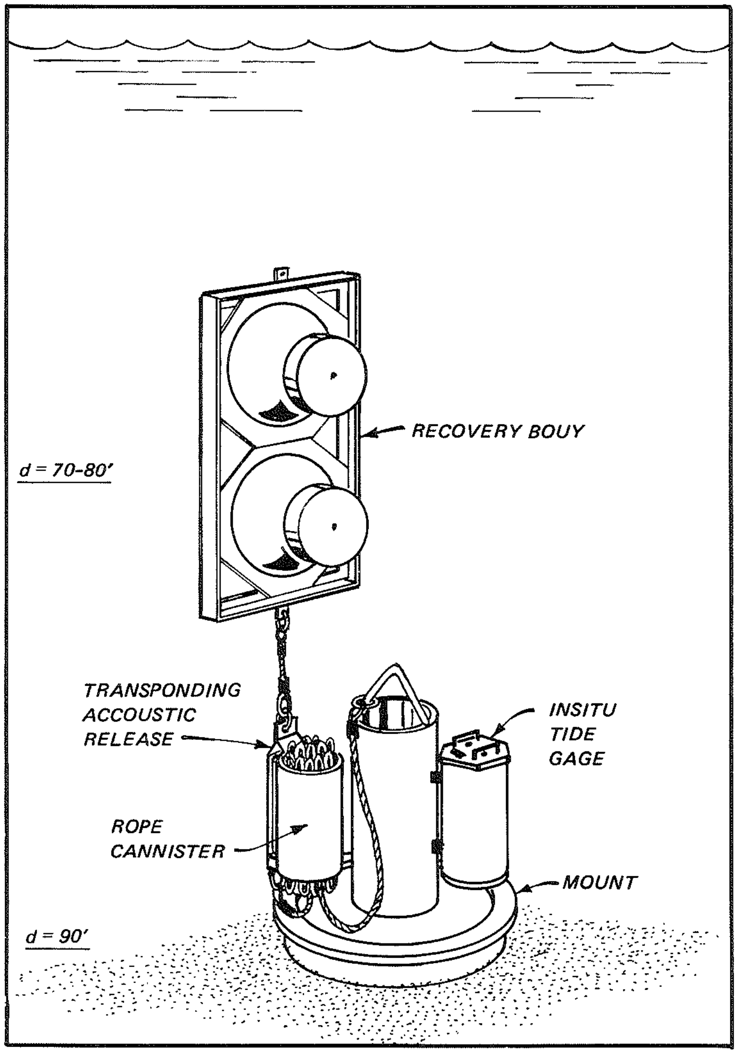


Figure 3. Tide gage mounting assembly

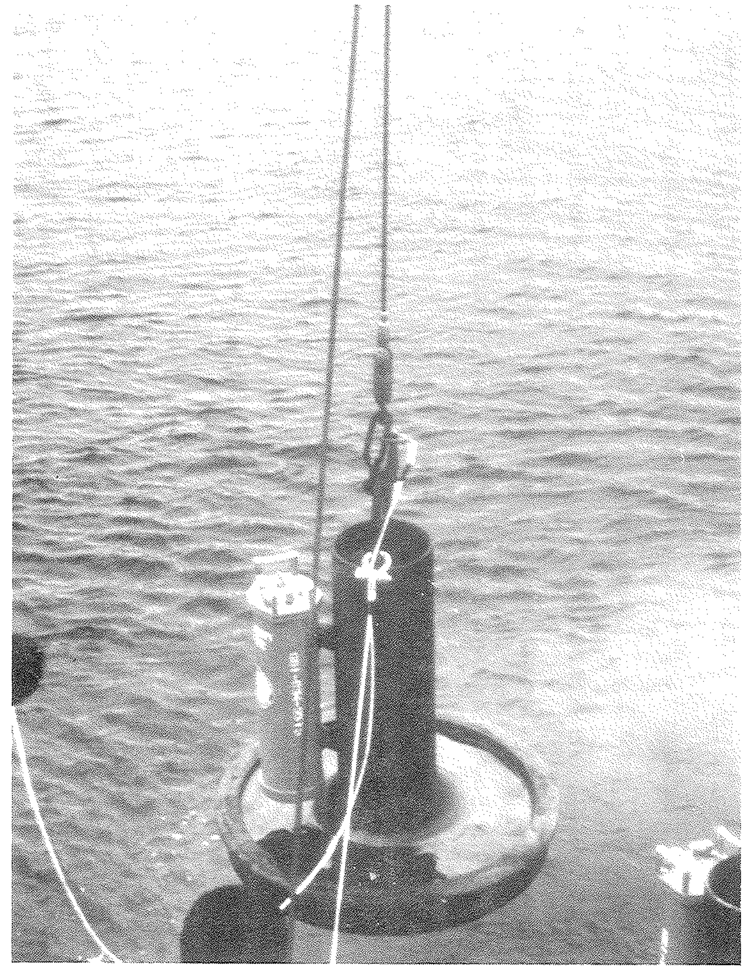


Figure 4. Tide gage deployment procedure

Additional tidal data

16. In addition to the eight tide gages specifically deployed for this study, data were available from a primary control tide station (33) located inside Los Angeles Harbor and from four pressure sensors located around the harbor perimeter (Figure 2). These four pressure sensors were installed by CERC to obtain long-term measurements of harbor surge events under a separate subtask of the Model Enhancement Program entitled Wave Data Acquisition. They were configured as low-frequency wave gages, but postprocessing of the time series also produces continuous tidal data.

17. These data were processed to provide additional boundary conditions for the model and for quality control checking of the primary tide data sets.

In Situ Currents

Requirements

18. The requirement for the in situ current subtask was a 30-day record of the vertical velocity profile at eight locations covering the major tidal exchange openings inside the harbor and at the harbor-complex perimeter. The acceptable resolution for the vertical stratification of the flow field was three points, representing a near-surface, middepth, and near-bottom cell at each site. Desired accuracy in speed and direction was ±0.1 knot and 2 deg, respectively. Samples were needed on a similar frequency to the tidal data, that is, continuous time series at average intervals near 3 min.

Method

19. The vertical profiles were obtained by deploying up to three current meters on a string supported by a surface buoy on a taut mooring. To reduce the risk of ship collision, the gage sites were moved to the sides of major entrances and channels. A total of 19 gages were available for the project. A deployment scheme was selected which increased the total number of sites to nine by reducing the number of meters on a string to one or two at certain sites not expected to have strong vertical gradients, while one meter was kept as a spare. Figure 5 shows the location of each site.

Instruments

20. The current meters were ducted-impeller type with an internal compass for direction (Figure 6 and Appendix A). Velocity is measured by counting impeller revolutions over the selected averaging interval, and an

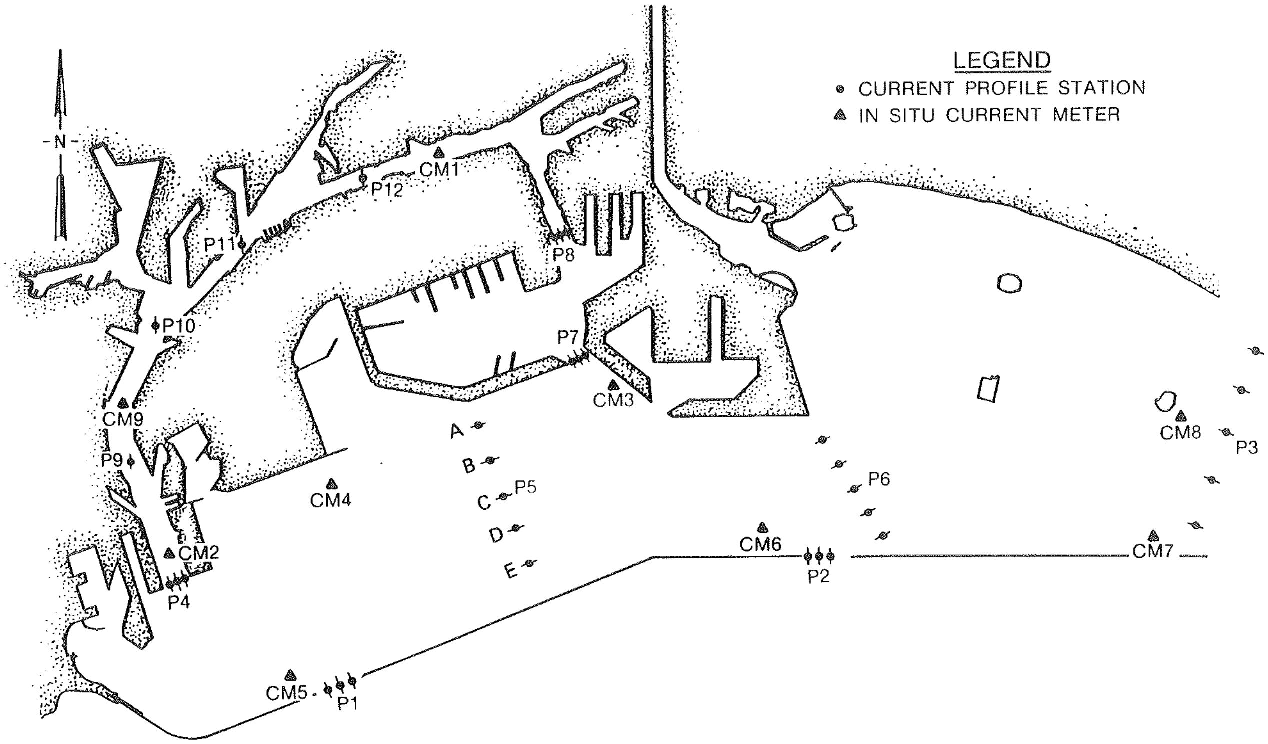


Figure 5. Current meter deployment site map

instantaneous direction is taken at the end of that interval. Both values, along with temperature and conductivity, are recorded on a magnetic tape. The averaging interval selected was 2 min, allowing a total tape capacity of 34 days.

21. Prior to deployment, each meter was calibrated at the US Geological Survey (USGS) calibration facility at the Stennis Space Center, Mississippi, by tank tow at three known velocities through still water. The calibration coefficients for each impeller/bearing combination were used in postprocessing the data. Compasses were bench checked and accepted if within manufacturer's tolerances without individual corrections.

Mounting

22. Figure 6 illustrates a typical current meter string in place. A spherical 36-in.-diam steel buoy was attached to a 900-lb railroad wheel with a 1/4-in.-diam mooring cable. A taut moor was maintained in spite of the tidal variation by including a length of 1-in.-diam rubber cord below the buoy. The cable was attached at either end with 3/8-in. screw-pin shackles. Each buoy supported an 8-ft mast with a radar reflector and amber marker light. For additional visibility, two or three "guardian" buoys of similar design