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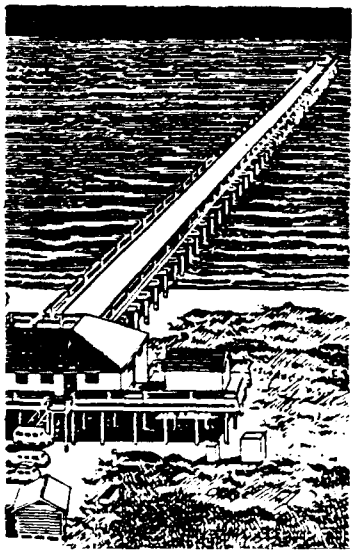
TECHNICAL REPORT CERC-91-2

LOS ANGELES AND LONG BEACH HARBORS ADDITIONAL PLAN TESTING

NUMERICAL MODELING OF TIDAL CIRCULATION AND WATER QUALITY



by

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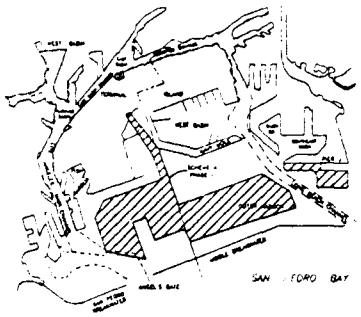

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13. ABSTRACT *(Maximum 200 words)*

The purpose of the study described in this report was to determine the impact of Phase 1 of three different plans (Schemes A, C, and D) for the Ports of Los Angeles and Long Beach on three-dimensional (3-D) hydrodynamics and water quality. This objective was accomplished by applying a 3-D numerical hydrodynamic model called CH3D in conjunction with a modified version of a water quality model called WASP. In a previous study under the Harbor Model Enhancement Program, the two models were calibrated and verified for the harbors using field data collected in the summer of 1987, and their use was demonstrated for Phase 1 of Plan B. The present study follows the same methodology as the previous study. Study results showed that in an overall sense, no single plan was significantly better or worse than the others. The landfill of the plans did not alter the tidal range and phase significantly. The greatest change in velocity occurred at the entrances to the harbors. Net circulation in the Inner Harbor areas showed a strong tendency to reverse under all four plan conditions.

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The plans will result in less rapid flushing in the Inner Harbor-Back Channel-Middle Harbor of the Port of Long Beach and impact dissolved oxygen in the same areas. However, dissolved oxygen concentrations for plan simulations were above 6.0 g/m^3.

PREFACE

The work described in this report was performed jointly by the Coastal Engineering Research Center (CERC) and the Environmental Laboratory (EL) at the US Army Engineer Waterways Experiment Station (WES) and is a product of the Additional Plans Testing Project for the Ports of Los Angeles and Long Beach. The purpose of the project is to determine how facilities expansion and channel deepening corresponding to Phase 1 of three different plans (Schemes A, C, and D) will affect circulation and water quality in the harbors and local vicinity.

The investigation was conducted during the period February through June 1989. Dr. S. Rao Vemulakonda and Ms. Lucia W. Chou of the Coastal Processes Branch (CPB), Research Division (RD), CERC, conducted the circulation aspect of the study under the direct supervision of Mr. Bruce A. Ebersole, Chief, CPB, and Mr. H. Lee Butler, Chief, RD, and under the general supervision of Dr. James R. Houston, Chief, CERC, and Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC.

Mr. Ross W. Hall of the Water Quality Modeling Group (WQMG), Ecosystem Research and Simulation Division (ERSD), EL, conducted the water quality aspect of the study under the direct supervision of Dr. Mark S. Dortch, Chief, WQMG, and Mr. Donald L. Robey, Chief, ERSD. and the general supervision of Dr. John Harrison, Chief, EL, and Dr. John W. Keeley, Assistant Chief, EL. This report was written by Dr. Vemulakonda and Mr. Hall.

During the course of the study, liaison was maintained between WES, the US Army Engineer District, Los Angeles (SPL), and the Ports of Los Angeles and Long Beach. Overall WES management of the study was performed by Mr. William C. Seabergh of the Wave Processes Branch (WPB), Wave Dynamics Division (WDD), CERC. Mr. Alan Alcorn was the SPL point of contact. Mr. John Warwar and Ms. Lillian Kawasaki, Port of Los Angeles, and Mr. Rich Weeks, followed by Mr. Angel P. Fuertes, and Dr. Geraldine Knatz, Port of Long Beach, were port 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.

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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
acres	0.00404686	square kilometres
cubic feet	0.028317	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
miles (US statute)	1.6093	kilometres
miles per hour (mph)	0.4470	metres per second
square feet	0.0929	square metres
square miles	2.589846	square kilometres

LOS ANGELES AND LONG BEACH HARBORS
ADDITIONAL PLAN TESTING

NUMERICAL MODELING OF TIDAL CIRCULATION AND WATER QUALITY

PART I: INTRODUCTION

1. Los Angeles and Long Beach (LA/LB) Harbors are located adjacent to each other in San Pedro Bay on the California coast and share a common breakwater system that encloses one of the largest harbor systems in the world (Figure 1). Over the years, the harbors have expanded to meet the demands of world commerce and national security by deepening channels and using the dredged material to create additional landfill for facilities. Thousands of acres of landfill have created the harbor complex as it exists today (Figure 2).

2. To meet future needs, the Ports of Los Angeles and Long Beach have recently undertaken a long-range cooperative planning effort known as the 2020 Plan. A special study known as the Operations, Facilities, and Infrastructure (OFI) Study was performed to determine the cargo handling requirements. The study determined a variety of phased plans which could accommodate future needs. Incorporated in the plans are deepening of existing channels, creation of new landfill, and new development on existing land.

Objective

3. The purpose of the study described in this report is to determine the impact of Phase 1 of three different plans (Schemes A, C, and D), suggested by the OFI study, on three-dimensional (3-D) hydrodynamics and water quality by comparing circulation, flushing, and dissolved oxygen (DO) resources under existing and planned conditions. This objective will be accomplished by applying state-of-the-art, 3-D numerical hydrodynamic and water quality models. The hydrodynamic model (HM) results will be used to drive the separate water quality model (WQM) which will determine the effects of the plans on water quality in the harbor complex. For completeness, model

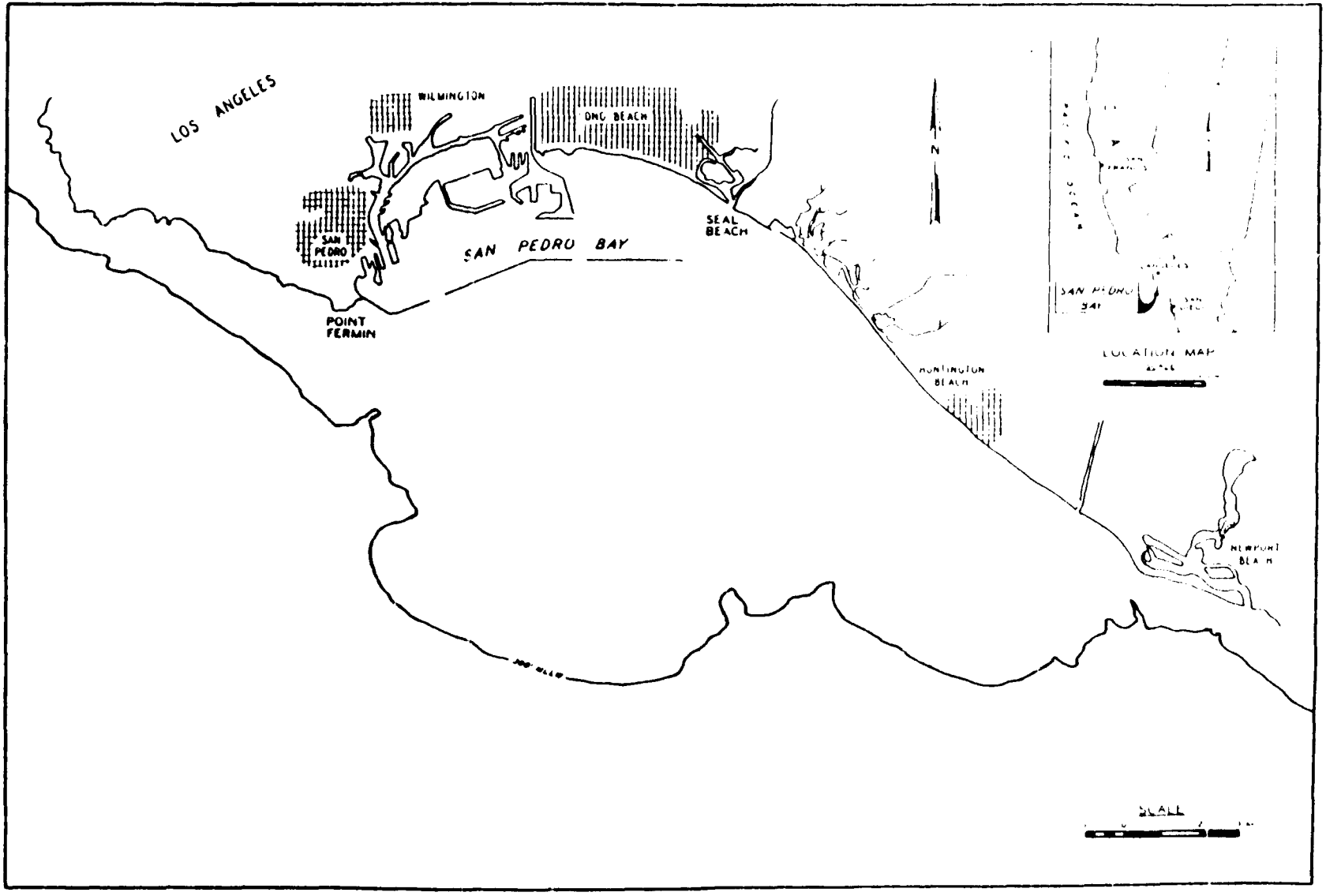

Figure 1. Vicinity map

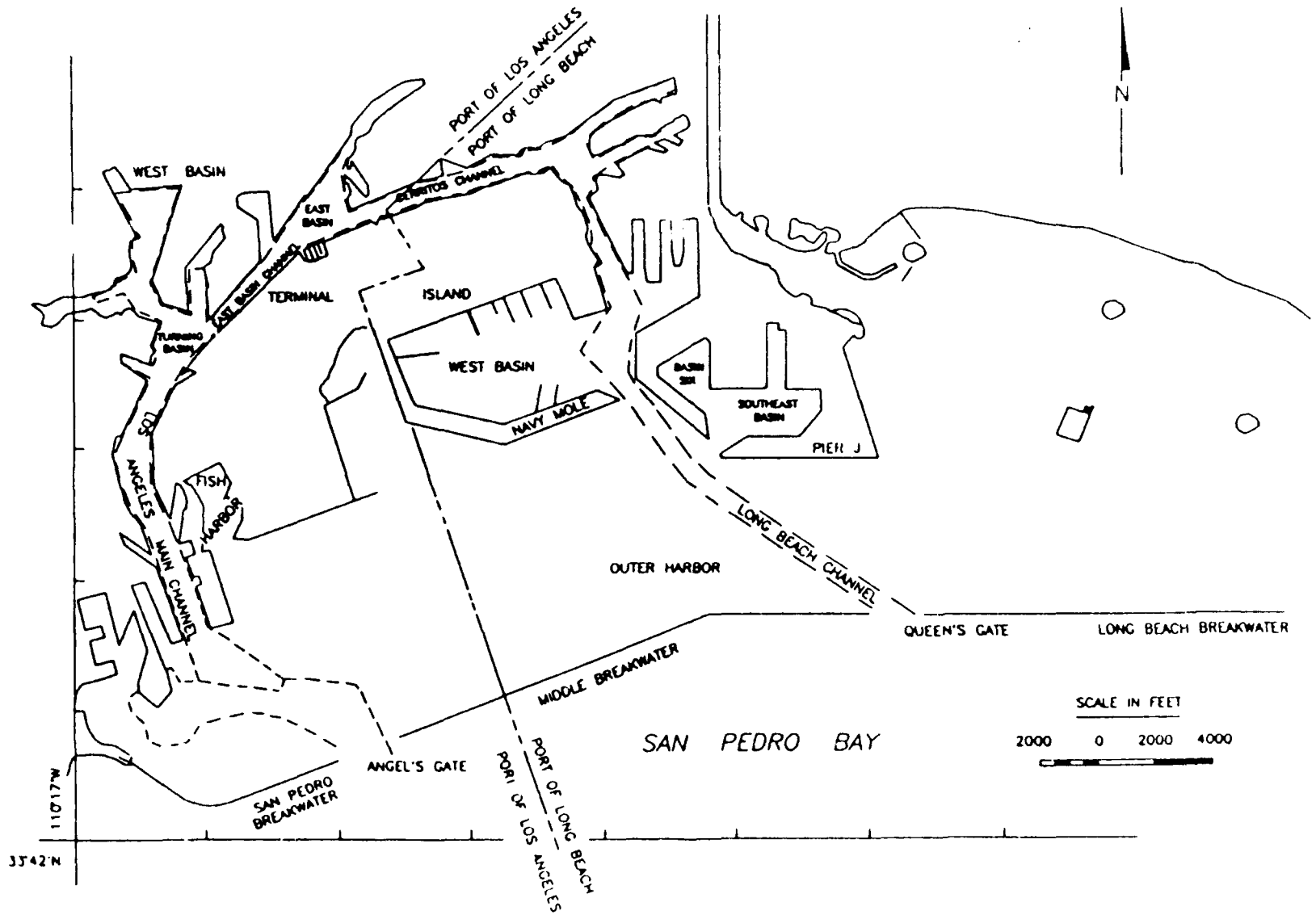

Figure 2. Location of city boundary and various channels and basins in the LA/LB Harbors

results for Phase 1 of Scheme B, previously determined under the Harbor Model Enhancement (HME) Program (Coastal Engineering Research Center (CERC) 1990; Hall 1990), also will be included in this report.

Report Organization

4. Part II of this report reviews previous tidal circulation and water quality modeling work performed by US Army Engineer Waterways Experiment Station (WES) for LA/LB Harbors. In Part III, the hydrodynamic model is discussed and its relationship to the water quality model examined. Part IV discusses the water quality model and Part V the results of hydrodynamic testing of plan conditions. In Part VI, the results of water quality testing of plans are discussed, and Part VII contains a summary of results and conclusions.

PART II: PREVIOUS STUDIES

5. A physical model of the LA/LB Harbors was constructed at WES in 1973 to study tidal circulation and harbor oscillations. The initial tidal circulation test results were reported on by McAnally (1975). The 1:400 horizontal scale, 1:100 vertical scale distorted model was calibrated with a limited prototype data set. Some difficulties were encountered in the measurement of the relatively low velocities which normally exist in the harbors inside the breakwaters. A satisfactory calibration was obtained, and the model was tested for a number of plan conditions. However, during the mid-1970's, computer modeling of hydrodynamics was becoming more feasible as computer memory and speed increased. It was felt that computer modeling would be an alternative approach to modeling tidal circulation in harbors with relatively low velocities (normally less than 1 ft*/sec). Also, the physical model was heavily used at the time to examine harbor resonance conditions for wave periods in the 30- to 400-sec range.

6. During 1975-76, a numerical model was applied by WES to study tidal circulation in the LA/LB Harbors. The model selected for use was a two-dimensional (2-D), depth-averaged numerical model of the hydrodynamic equations. This model neglected the vertical components of velocity and acceleration, and the general 3-D governing hydrodynamic equations were integrated over the water depth. In this way, 3-D geometry could be considered. The model solved the governing equations using a finite difference approximation of the equations and an alternating direction semi-implicit technique. Application to San Pedro Bay required use of a grid of 20,000 finite difference cells, each cell representing a 300-ft square of the harbor region. The model reproduced a 25-hr prototype tide sequence and was applied by Raney (1976a,b) and by Outlaw and Raney (1979) for plans which included a proposed Outer Harbor oil terminal in the Port of Long Beach in conjunction with a proposed Los Angeles Harbor deepening project. These studies indicated that the plans resulted in only minor overall changes in tidal circulation in LA/LB Harbors and that any changes were very local in nature.

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

7. Improvements were implemented in the previously discussed model which increased numerical stability permitting reproduction of longer prototype scenarios. Also, utilization of a stretched grid having the capability to be smoothly varied permitted simulation of a complex plan form by locally increasing resolution. Figure 3 shows the grid as applied to LA/LB Harbors. Details of this model, known as the Waterways Experiment Station Implicit Flooding Model (WIFM), can be found in Butler (1978a,b,c and 1980). Outlaw* was the first to apply this model to LA/LB Harbors when he studied the Los Angeles Harbor deepening and creation of a 190-acre landfill adjacent to Fish Harbor. The model was calibrated with the 1971 prototype data. Results indicated the channel deepening project had no substantial effect on tidal elevation, phase, circulation, and flushing. Once again a 25-hr prototype tide scenario was used.

8. The WIFM was used by Seabergh and Outlaw (1984) to study the 2020 Master Plan. Tidal scenarios used were for spring, mean, and neap tides; each scenario was for a 70-hr duration. The version of WIFM used for this study included the addition of the constituent transport equation (Schmalz 1983) so that the dispersion of a conservative substance (a dye, for example) could be followed over time. Results of this study indicated that a major Outer Harbor landfill would create some minor redistribution of flow into and out of the harbors, though no change in tidal range occurred. An interesting effect noted was the change in net circulation in the Inner Harbor (i.e., Los Angeles Harbor's Main Channel and Long Beach Harbor's Cerritos Channel). Existing net circulation is east to west, i.e., from Long Beach toward Los Angeles, while for the plan studied, net circulation became west to east. These net circulations were about 10 and 17 percent, respectively, of the average flow in the back channel. Another application of WIFM was made for the Port of Los Angeles' Deep Draft Dry Bulk Export Terminal, Alternative No. 6 (Seabergh 1985), in which a landfill was studied on the Los Angeles side of the Outer Harbor.

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* D. Outlaw, Memorandum for Record, 5 March 1985, "Analysis of Tidal Circulation for Los Angeles and Long Beach Harbors Navigation Channel Improvements," US Army Engineer Waterways Experiment Station, Vicksburg, MS.

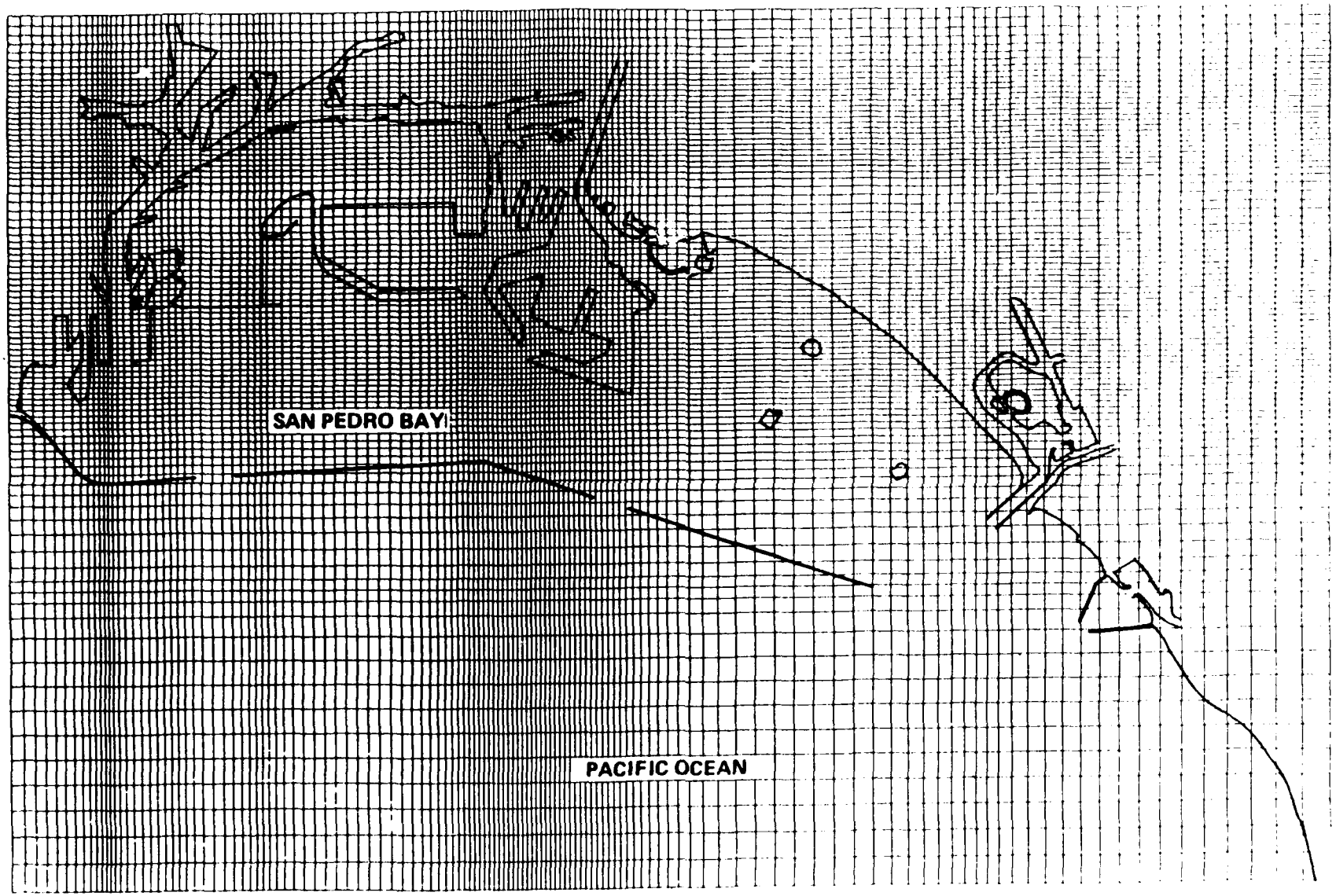

Figure 3. Grid layout over the LA/LB Harbors

9. In all of these studies, the plans examined called for landfills in different regions of the harbor complex. Associated with the landfills are greater channel and harbor depths, which are necessary to accommodate larger ships and to provide a source of material for the landfill by dredging. Forecasted requirements indicate some portions of the LA/LB Harbors may have depths as great as 90 ft, National Geodetic Vertical Datum (NGVD) of 1929. Currently the average depth of the harbors is on the order of 40 ft. With increased depths comes the possibility for greater variations in velocity, temperature, and density with depth. Therefore, in order to better evaluate flow conditions (and thus water quality) in the harbors, it became necessary to advance to a 3-D modeling system, that is, a model which can resolve hydrodynamic and water quality parameters at different depths in the water column. The previous modeling efforts have been performed with depth-averaged models, which have been effective in aiding understanding of the harbors' global hydrodynamics but cannot provide the detailed input required for a water quality model study of a deep harbor where vertical variations are significant. As a result of these considerations, the ports together with the US Army Engineer District, Los Angeles (SPL), funded WES on the HME Program in 1987. As a part of the HME, WES developed 3-D hydrodynamic and water quality models of the harbors (CERC 1990, Hall 1990) and calibrated and verified the models, using extensive field data taken for this purpose in the summer of 1987 (McGehee, McKinney, and Dickey 1989; and Tekmarine, Inc. 1987). In addition, the models were used to determine the 3-D hydrodynamics and water quality under existing conditions, and model use was demonstrated by applying the models to a plan condition determined by the OFI study and selected by the ports (Phase 1 of Scheme B) and estimating the impact of the plan on hydrodynamics and water quality of the harbors. The study described by the present report follows up on these efforts and uses the same modeling technology.

PART III: HYDRODYNAMIC MODEL

10. The models selected for simulating 3-D hydrodynamics and water quality are based on the methodology used in HME. For convenience, the following description of the hydrodynamic model CH3D is reproduced from CERC (1990).

Model CH3D

11. Model CH3D is a time-varying 3-D hydrodynamic model for simulating circulation affected by tide, wind, river inflow, and density currents induced by salinity and/or temperature gradients. Assuming hydrostatic pressure distribution and employing the eddy-viscosity concept, the basic equations can be written for a right-handed coordinate system (Figure 4) as shown in Figure 5. In the governing equations u, v, and w are the velocities in x-, y-, and z-directions; f is the Coriolis parameter defined as $2\Omega\sin\phi$ where ϕ is the latitude; ρ_0 is the reference density; p is the pressure; g is the acceleration due to gravity; T is the temperature; S is the salinity; A_H, K_H, and D_H are the horizontal eddy coefficients; and A_V, K_V, and D_V are the vertical eddy coefficients. The nonlinear inertia terms and the advection terms have been written in conservative forms. Source/sink terms may be included in Equations 3.5 and 3.6 (Figure 5) to account for such effects as radiation, precipitation, and evaporation.

12. Boundary conditions at the water surface include specification of the wind stress and heat flux and satisfying the kinematic and dynamic conditions. At the bottom, the boundary conditions include specification of heat flux and use of a quadratic stress law.

13. Use of a vertical-stretching relationship (Figure 6) leads to a smooth representation of the topography and the same number of vertical cells in the shallow and deep regions of the water body.

14. The CH3D computer code can be used to simulate 2-D or 3-D unsteady currents in Cartesian or curvilinear grids. To treat curvilinear grids, the governing equations are transformed into a boundary-fitted coordinate system (Figure 7). The resulting equations are very complex and will not be repeated

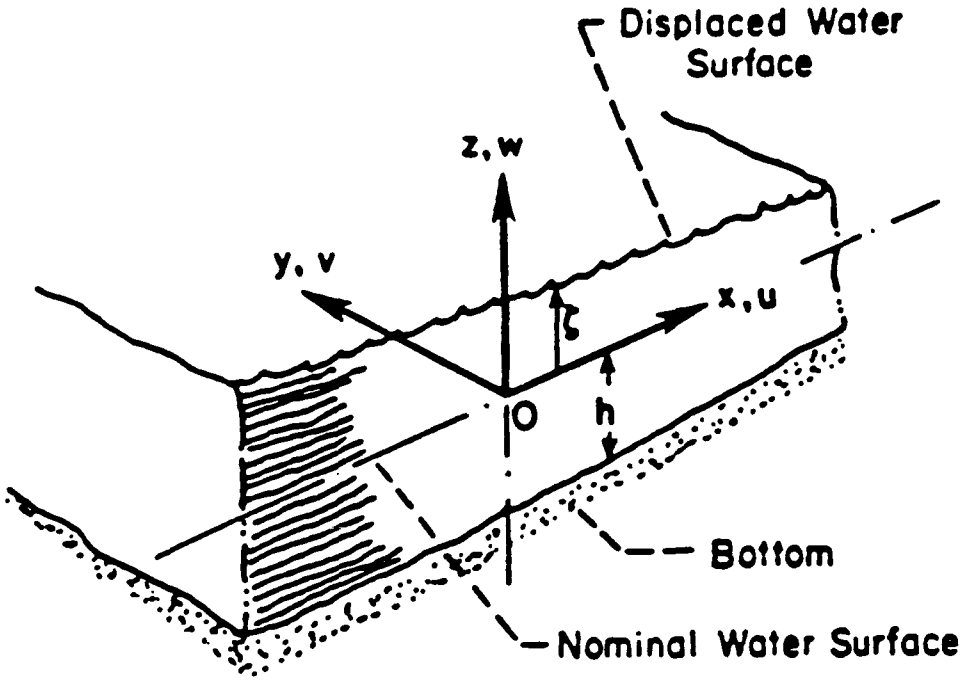

Figure 4. Coordinate system

here*. To alleviate various problems experienced in similar model developments, the dependent and independent variables are transformed into the new coordinate system. Equations in transformed coordinates (ξ , η , σ) are obtained in terms of the contravariant velocity components. These components are locally orthogonal to the grid lines, permitting more accurate specification of boundary conditions.

15. To facilitate a more efficient numerical scheme, an external-internal mode-splitting technique is used. Numerical computation of the internal mode, which is governed by the slower baroclinic vertical flow structure dynamics, is separated from the computation of the vertically integrated variables (external mode), which are governed by the fast barotropic dynamics.

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* Y. P. Sheng, 1986, "A Three-Dimensional Mathematical Model of Coastal, Estuarine, and Lake Currents Using Boundary Fitted Grid," Draft Report prepared for WES, Vicksburg, MS.

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{3.1}$$

$$\frac{\partial u}{\partial t} + \frac{\partial u^2}{\partial x} + \frac{\partial uv}{\partial y} + \frac{\partial uw}{\partial z} = fv - \frac{1}{\rho_o}\frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\left(A_H \frac{\partial u}{\partial x}\right)$$

$$+ \frac{\partial}{\partial y}\left(A_H \frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(A_v \frac{\partial u}{\partial z}\right) \tag{3.2}$$

$$\frac{\partial v}{\partial t} + \frac{\partial uv}{\partial x} + \frac{\partial v^2}{\partial y} + \frac{\partial vw}{\partial z} = - fu - \frac{1}{\rho_o}\frac{\partial p}{\partial y} + \frac{\partial}{\partial x}\left(A_H \frac{\partial v}{\partial x}\right)$$

$$+ \frac{\partial}{\partial y}\left(A_H \frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial z}\left(A_v \frac{\partial v}{\partial z}\right) \tag{3.3}$$

$$\frac{\partial p}{\partial z} = - \rho g \tag{3.4}$$

$$\frac{\partial T}{\partial t} + \frac{\partial uT}{\partial x} + \frac{\partial vT}{\partial y} + \frac{\partial wT}{\partial z} = \frac{\partial}{\partial x}\left(K_H \frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_H \frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_v \frac{\partial T}{\partial z}\right) \tag{3.5}$$

$$\frac{\partial S}{\partial t} + \frac{\partial uS}{\partial x} + \frac{\partial vS}{\partial y} + \frac{\partial wS}{\partial z} = \frac{\partial}{\partial x}\left(D_H \frac{\partial S}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_H \frac{\partial S}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_v \frac{\partial S}{\partial z}\right) \tag{3.6}$$

Figure 5. Governing equations

$$\sigma = \frac{z - \zeta}{\zeta + h} \approx \frac{z}{h}$$

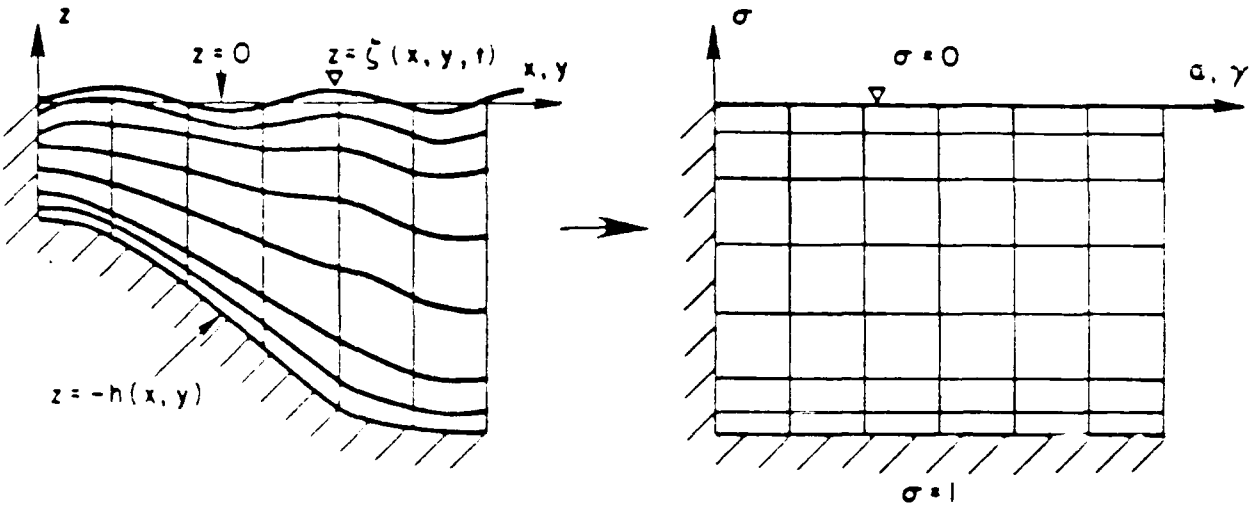


Figure 6. Vertical coordinate transformation

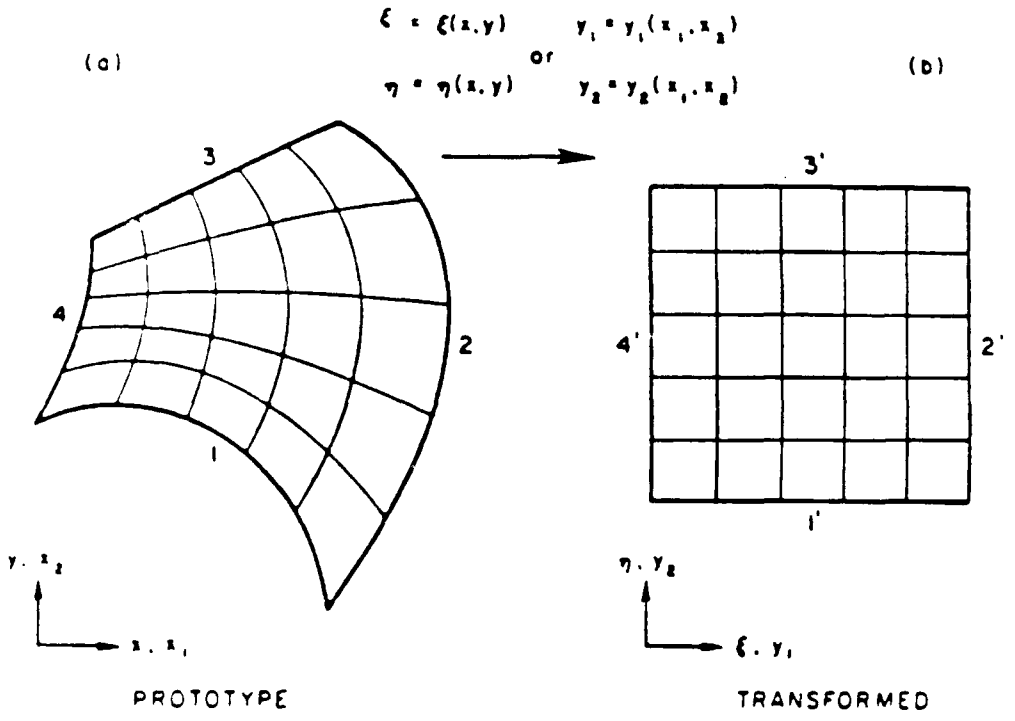


Figure 7. Boundary-fitted coordinate transformation

16. To apply a finite difference solution method, the study area is approximated by a computational grid composed of a 3-D lattice network of cells. Bathymetry and land-water interfaces, such as shorelines and breakwaters, are specified for each vertical column of cells. Flow field parameters, such as velocities or surface elevations, are evaluated at each cell. In order to improve model accuracy, mathematical mapping or transformation techniques are applied independently to the horizontal and vertical grid coordinates. The horizontal grid directions are mapped into a general curvilinear system. This allows a greater density of cells in regions of rapid change while coarser cell resolution can be used in the remainder of the grid.

17. In the external mode, the vertically averaged conservation of mass and momentum equations are solved, using an alternating-direction algorithm similar to that used by Butler and Sheng (1982), to obtain the vertically integrated horizontal velocities and water surface elevations. The vertical velocity distribution is resolved in the internal mode. Here an implicit-explicit scheme is used to compute the vertically integrated perturbation velocities.

Grid Selection

18. For the HM, the grid used in this study is the same grid (Figure 3) used in HME. The study area was represented by a smoothly varying rectilinear grid containing 12,032 grid cells (128 cells in the east-west direction and 94 cells in the north-south direction) with the grid aligned to coincide with the Inner Harbor entrance channels. The minimum cell width was 235 ft, and smaller cells were concentrated in areas where channel resolution was necessary. The grid extended seaward of the Middle Breakwater approximately 4.2 miles and covered an area of about 146 square miles.

19. In the vertical, a stretching mechanism is used to smoothly represent the bathymetry. It permits the same number of cells in shallow and deep portions of the water body. The HM and WQM used three layers in the vertical.

Model Input Data

20. Boundary conditions chosen for all model runs were the application of measured tidal elevations at the seaward and western open boundaries, wind stress on the water surface, and a quadratic bottom stress using the Manning's n coefficient. Since wind stress was applied at the surface, measured tidal elevations were used to drive the open boundary. These data contained the effects of wind stress at the boundary.

21. Initial conditions for all model runs included setting all internal grid cell velocities to zero and selecting a starting time in the tidal and wind records consistent with the assumption of a quiescent water body. The model requires a large input data stream which includes information relating to physical constants, turbulence/wind/friction parameters, grid characteristics (depth, coordinate locations), and input/output control variables.

Conditions Tested

22. Following the procedure used in the HME, the plans were tested under two standard sets of conditions, which were used in model calibration and verification under the HME. The period from 7 to 11 August 1987, called the "calibration period," represented a large spring tidal event. Measured tidal elevations (Figure 8) were used to drive the open boundary starting at 0000 hr on the 7th of August (5232 hr). Wind data for this period (Figure 9) were used to compute the surface stress boundary condition. The wind direction shown is the direction, measured in degrees from the north, from which the wind is blowing.

23. A time step of 60 sec was used in all model runs. The set of model coefficients used were $n = 0.02$, $A_H = 20{,}000$ cm^2/sec and $A_V = 10$ cm^2/sec. The period 19 to 23 August 1987 represented a mean tide condition and is called the "verification period." Figure 10 displays the measured and model tidal elevations imposed at the open boundary starting at 0000 hr on the 19th of August (5520 hr). Wind data for this period (Figure 11) were used to compute the surface stress boundary condition.

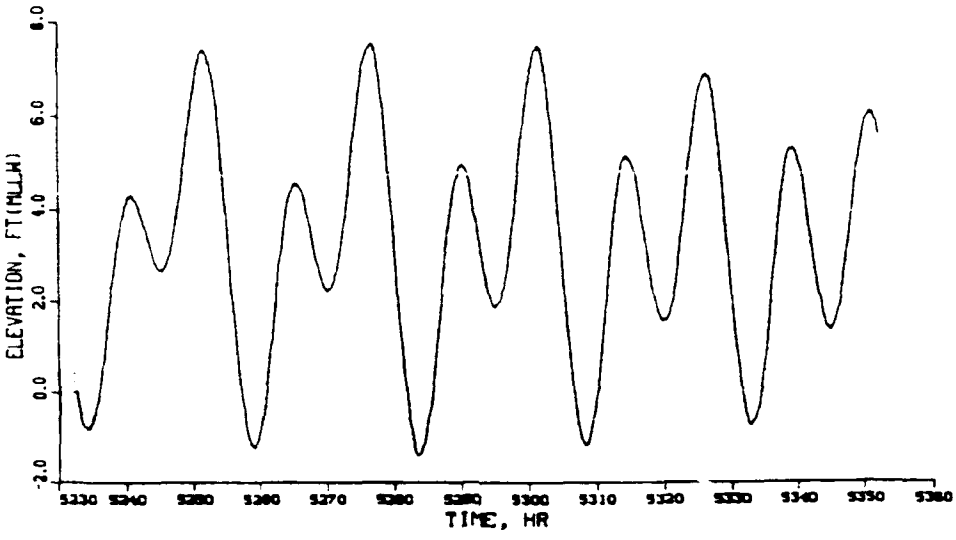
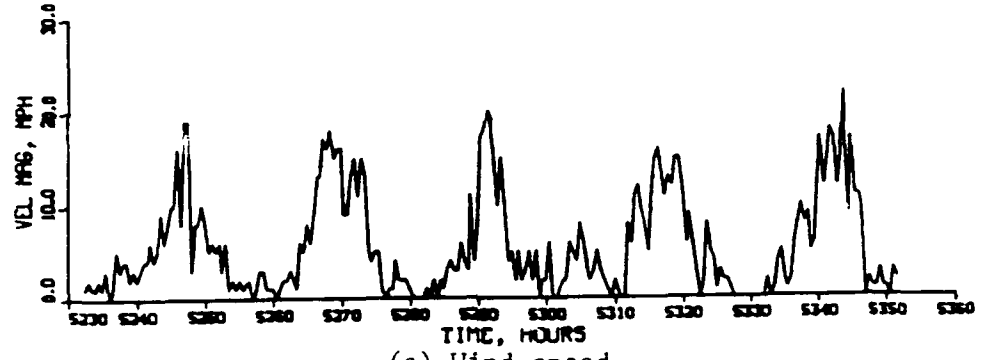
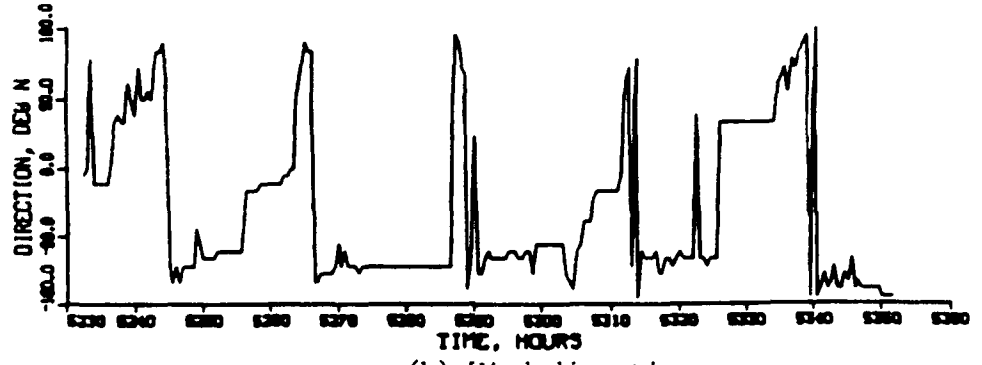


Figure 8. Ocean tide boundary condition for calibration period



(a) Wind speed



(b) Wind direction

Figure 9. Wind data for calibration period

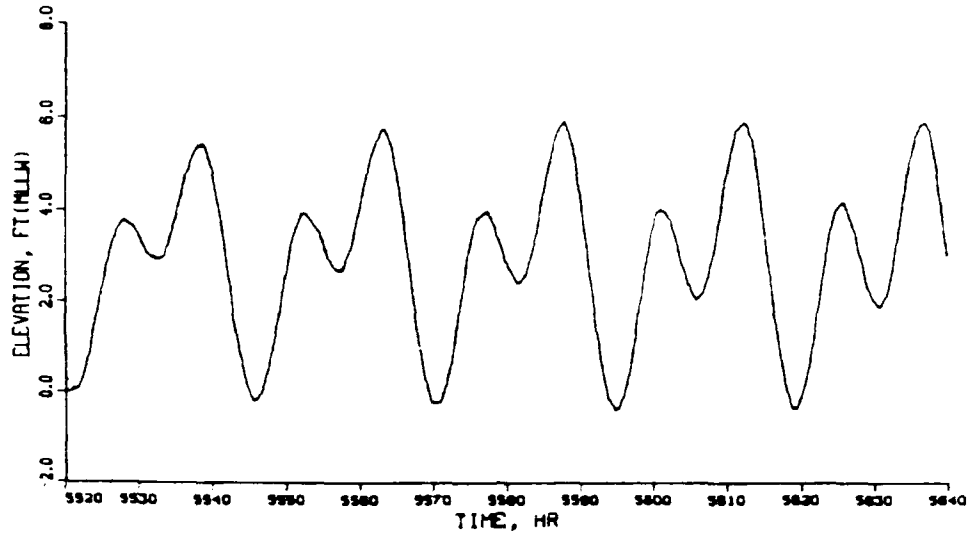
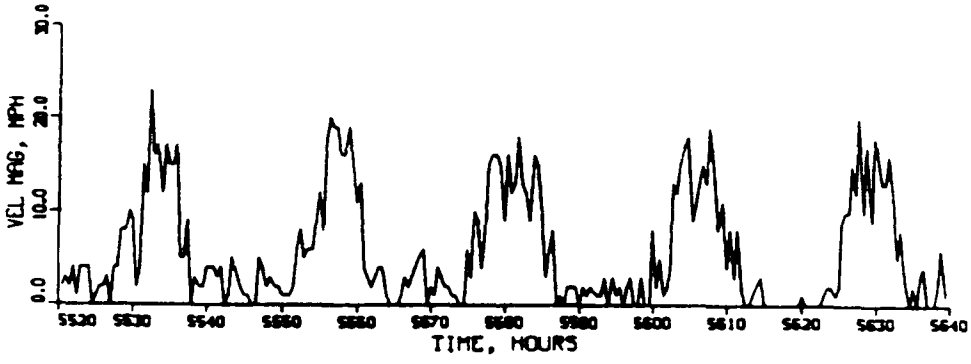
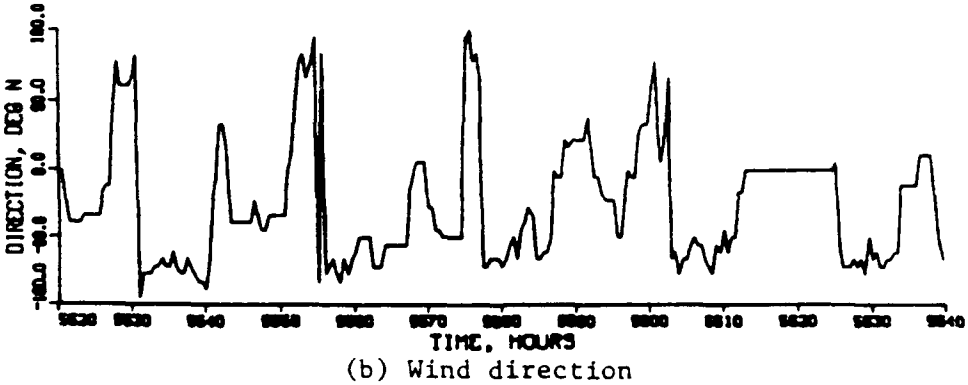


Figure 10. Ocean tide boundary condition for verification period



(a) Wind speed



(b) Wind direction

Figure 11. Wind data for verification period

PART IV: WATER QUALITY MODEL

24. The WQM selected for this study was a modification of the Environmental Protection Agency WASP code (Ambrose, Vandergrift, and Wool 1986). Major adaptations included: (a) improved advective and diffusive transport schemes, (b) provisions for the input and processing of 3-D hydrodynamic data from CH3D, and (c) implementation of kinetic routines specific to the San Pedro Bay application.

Advective and Diffusive Transport Schemes

25. The original WASP model formulation considers both advective and diffusive transport through faces of adjacent cells of arbitrary size, shape, and distribution. For the HME study, horizontal flows were distinguished from vertical flows, and improved transport schemes were implemented.

26. The horizontal advective transport scheme used was a modified version of QUICKEST (Quadratic Upstream Interpolation for Convective Kinematics with Estimated Streaming Terms) scheme (Leonard 1979, Hall and Chapman 1985, and Ray Chapman and Associates*). An implicit vertical advective and diffusive transport scheme was implemented. Central differences were used for both vertical advection and diffusion terms.

Model Linkage

27. The hydrodynamic and water quality models were linked by spatially and temporally averaging CH3D output to drive the WQM. The hydrodynamic model used extensive spatial resolution to resolve geometric features of the harbors. The CH3D spatial resolution was of the order of 100 m and required a time step of 60 sec for stability. In contrast, the WQM has characteristic time scales determined by the kinetic rate coefficients on the order of hours.

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* Ray Chapman and Associates, 1988. "Analysis and Improvement of the Numerical and Physical Mixing Characteristics of the WASP Box Model," Final Report, Contract DACW39-87-C-0060, prepared for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Water quality analyses allow a spatial resolution an order of magnitude less than that used by CH3D. Reductions in spatial and temporal resolution greatly reduced computer time and storage required for the WQM.

28. Plate 1 is a schematic of the CH3D grid used for the existing conditions. Existing conditions will be henceforth referenced as "Base." Since the WQM required less spatial resolution than CH3D, spatial characteristics of the hydrodynamic grid such as cell volumes, cell surface areas, cell facial areas, and cell lengths were summed resulting in an "overlaid" WQM grid. Plate 2 represents the resulting WQM grid overlying the CH3D grid for the Base condition. The WQM grid maintained the same vertical resolution as the CH3D grid of three vertical layers. Plates 3 through 6 represent the overlaid WQM grid for Phase 1 of Schemes A, B, C, and D of the 2020 Plan, respectively.

29. Overlaying the WQM grid decreased the number of computational cells by a factor of 12. The larger WQM cell sizes allowed an increase of the time step used from 60 to 900 sec while maintaining computational stability.

30. The hydrodynamic data were averaged over 1-hr intervals. Subtidal oscillations, characterized by a pulsating flow pattern with areas of flow direction reversal, were simulated in CH3D. The flow pulsations occurred at a frequency of 1 hr. Therefore, the influence of the subtidal flow oscillations on the HM time-averaging interval was investigated (Hall 1990). A comparison between 15- and 60-min HM time-averaging revealed that 60-min hydrodynamic model averaging was equivalent to 15-min averaging.

31. A test was conducted to ensure that the transport properties of CH3D were maintained with the interfacing (Hall 1990). After CH3D was calibrated, a tracer injection was simulated. The same tracer injection was simulated using the WQM. A comparison of the two tracer injections, CH3D and WQM, indicated that transport properties were nearly equivalent.

Kinetic Routines

32. The WQM study focused on DO resources and flushing characteristics of the harbor system. The WQM simulated the following variables: DO, 5-day carbonaceous biochemical oxygen demand (CBOD5), ammonia nitrogen (NH_4-N), nitrite plus nitrate nitrogen (NO_2 + NO_3-N), algal biomass as carbon (C), orthophosphate (PO_4-P), and a conservative tracer. Initial temperatures were

specified horizontally constant yet vertically stratified based on the water quality sampling program conducted during August 1987 by Tekmarine, Inc. However, temperatures varied temporally through the specification of ocean boundary temperatures. Salinity was specified temporally and spatially constant at 32 ppt. The water quality sampling program revealed rather homogeneous salinities except near the Terminal Island Treatment Plant (TITP) effluent and the Los Angeles River. Salinities were used in the WQM for calculating DO saturation. Global specification of a constant salinity was adequate since a 2-ppt variation in salinity at the temperatures observed results in only a 1-percent variation in DO saturation.

33. The water quality kinetic algorithms were adapted from the WES 2-D laterally averaged model of hydrodynamics and water quality, CE-QUAL-W2 (Environmental and Hydraulics Laboratories 1986), and HydroQual's Potomac Eutrophication Model (Thomann and Fitzpatrick 1982). The water quality kinetic routines are detailed in Hall (1990).

PART V: PLAN TESTING AND RESULTS: HYDRODYNAMICS

34. The plans tested in the models during the course of the present study to analyze hydrodynamic/water quality impact were Phase 1 of Schemes A, C, and D, shown in Figures 12-14. These plans were called Plans 2, 3, and 4, respectively. For completeness, results of model testing for Phase 1 of Scheme B (designated Plan 1, Figure 15) from the HME are also included in this report. To represent each plan, appropriate grid changes were made to approximate landfills and dredged depths for all channel alterations (Figure 16). As indicated in Part III, standard conditions adopted for comparing plans with existing harbors were the two periods used for model calibration and verification. Simulations of existing and plan conditions for the month of August 1987 were also made to support water quality modeling efforts.

35. Several methods were used to analyze impacts of the plans on hydrodynamic processes in the harbor complex. These included comparisons of elevations and currents at specific locations, tidal prism changes, flow changes through several cross sections, and changes in circulation patterns of the harbors.

Tidal Elevations

36. Gage locations for comparing computed tidal elevations and currents for existing and plan conditions are shown in Figure 17. Generally the same gage locations were used for all four plans except special gage location 12A (Figure 18) was used for Plans 2 and 4 since it was more appropriate. Plates 7-16 display tide hydrographs for the calibration period for existing and plan conditions at gage locations TC1, TC3, TC5, TC14, and TC17, and Plates 17-26 for the verification period. Existing and plan condition plots are superimposed, and no discernible differences in amplitude or phase are noted. From these results it can be concluded the plans have no significant effect on tidal elevations or phase throughout the harbor complex.

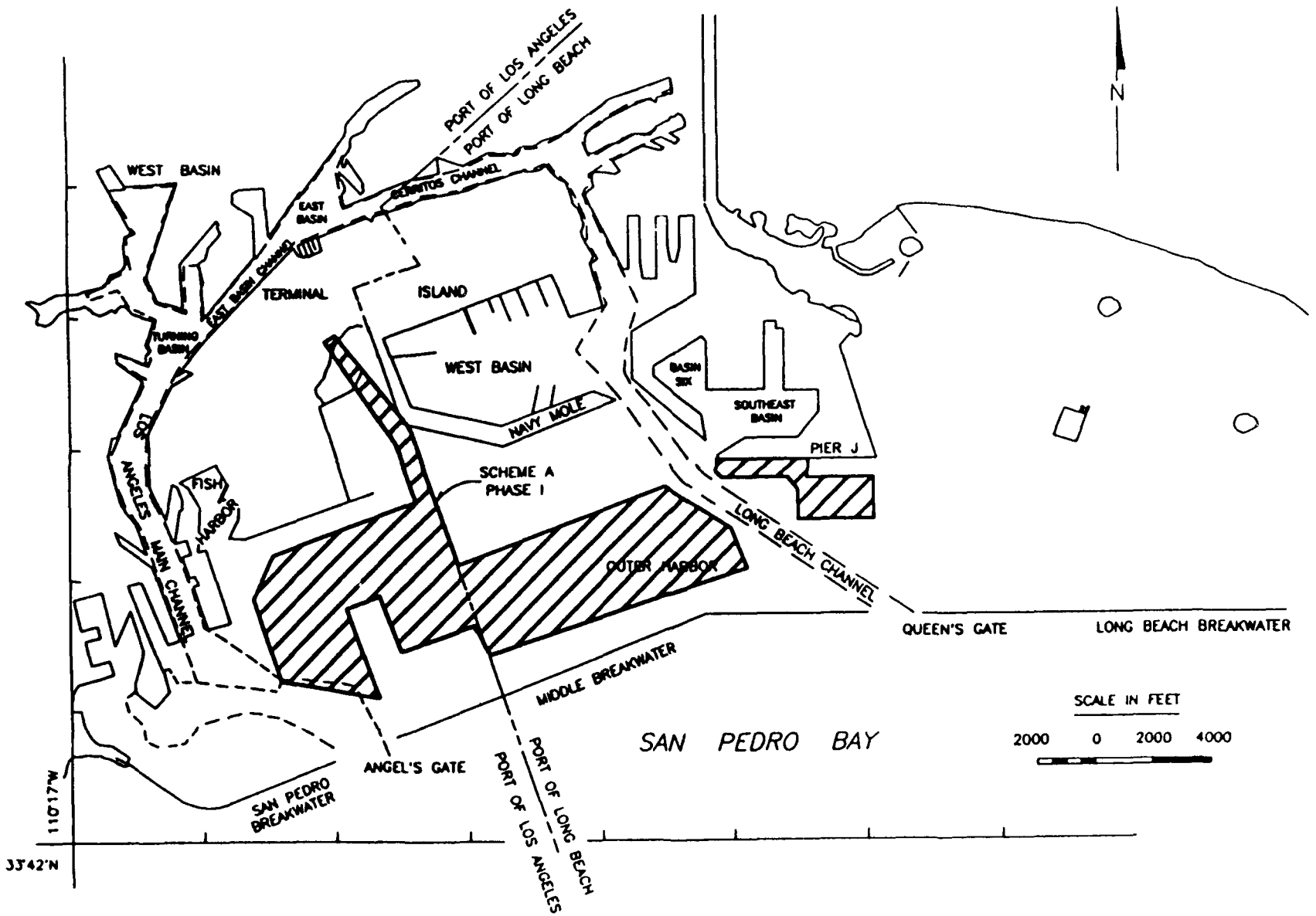

Figure 12. Harbor layout for Scheme A, Phase 1 (Plan 2)

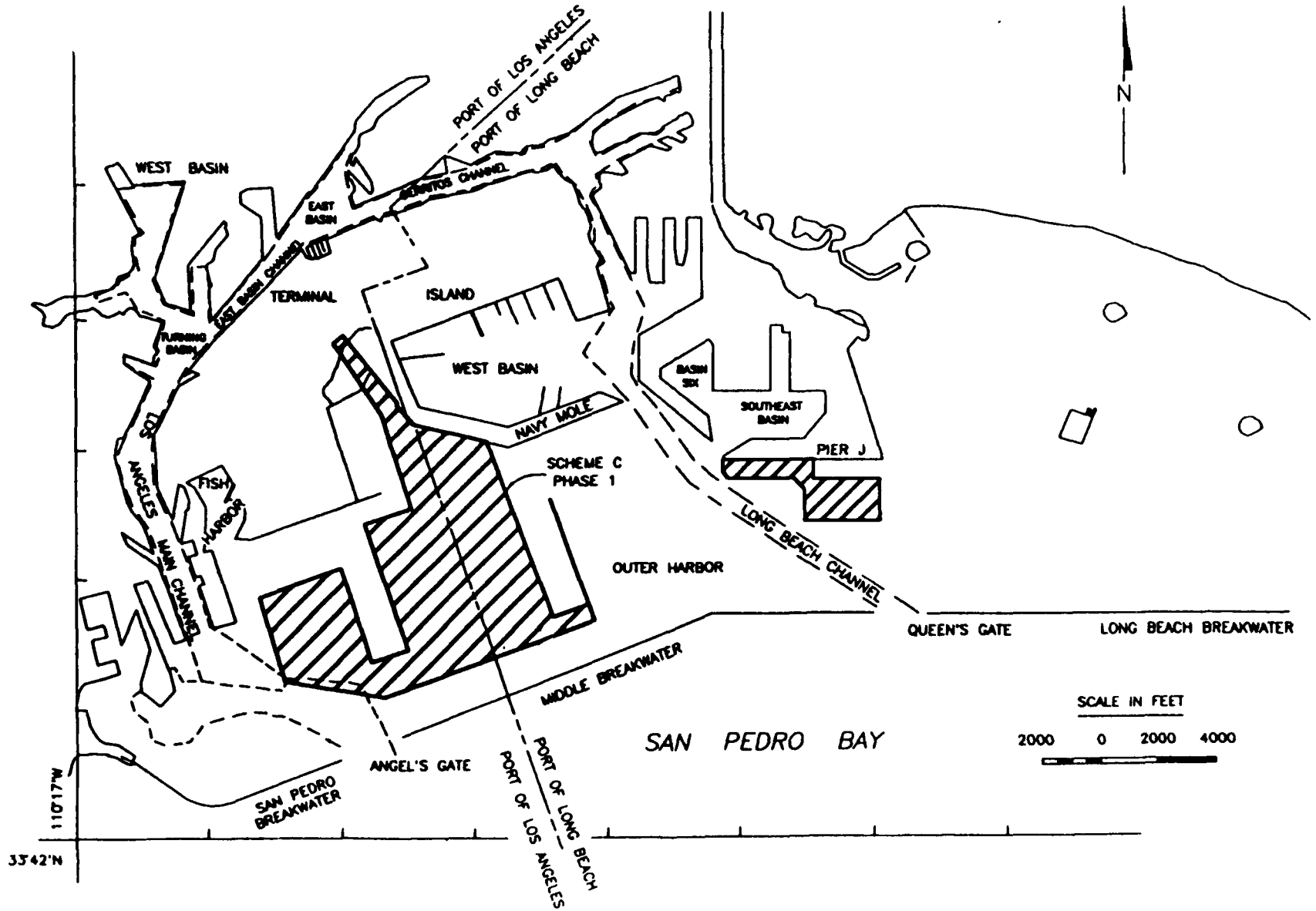

Figure 13. Harbor layout for Scheme C, Phase 1 (Plan 3)

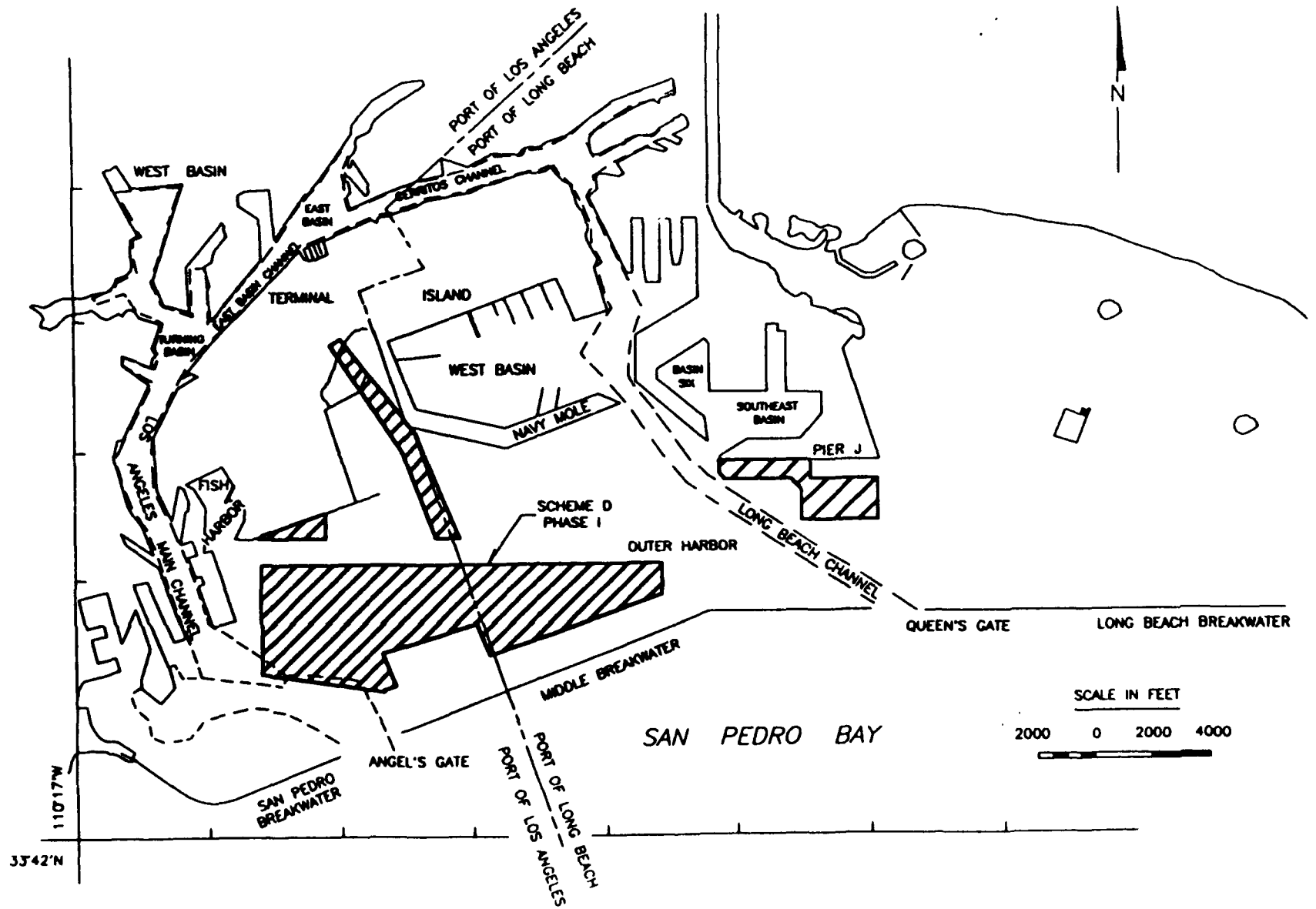

Figure 14. Harbor layout for Scheme D, Phase 1 (Plan 4)

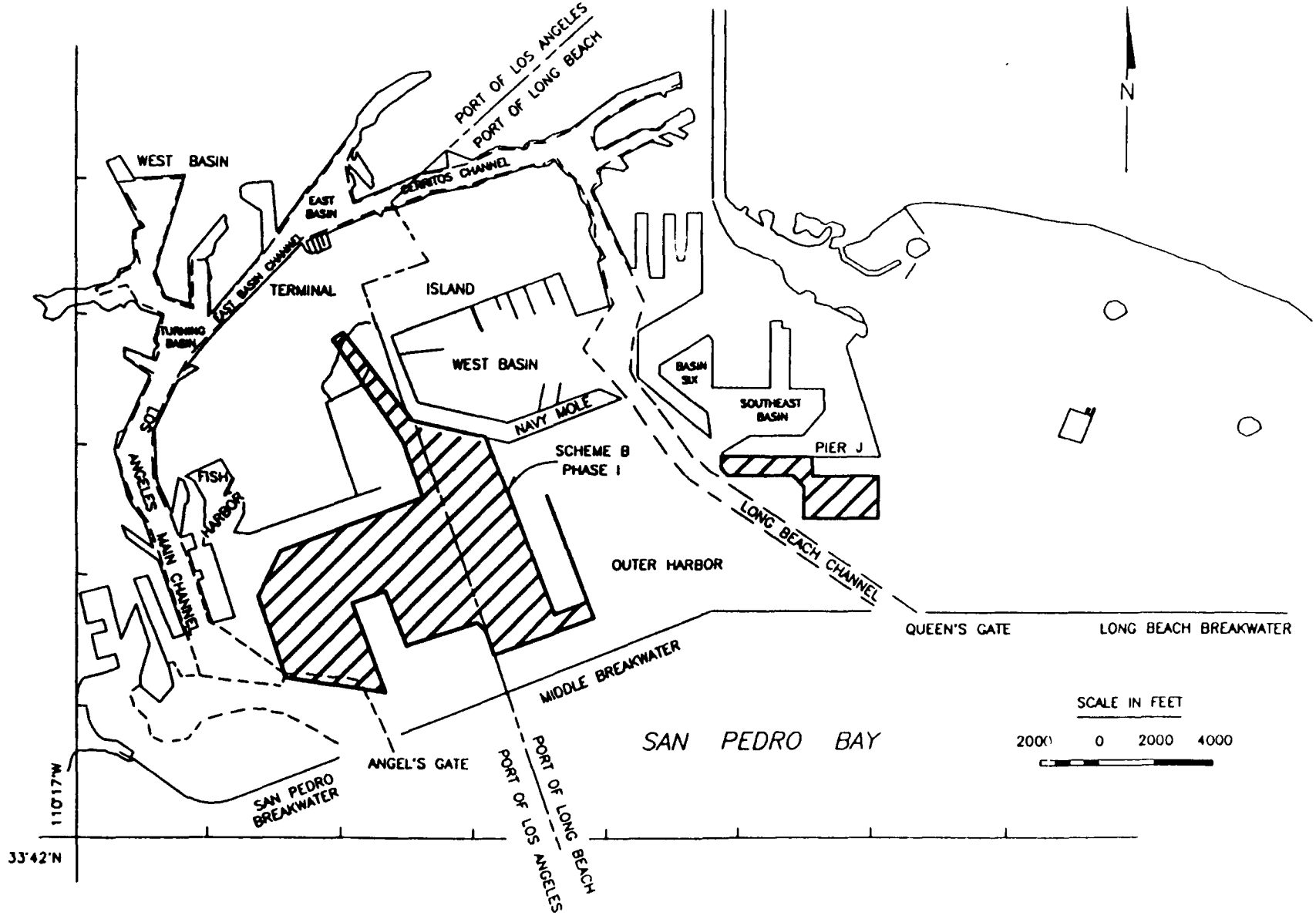

Figure 15. Harbor layout for Scheme B, Phase 1 (Plan 1)

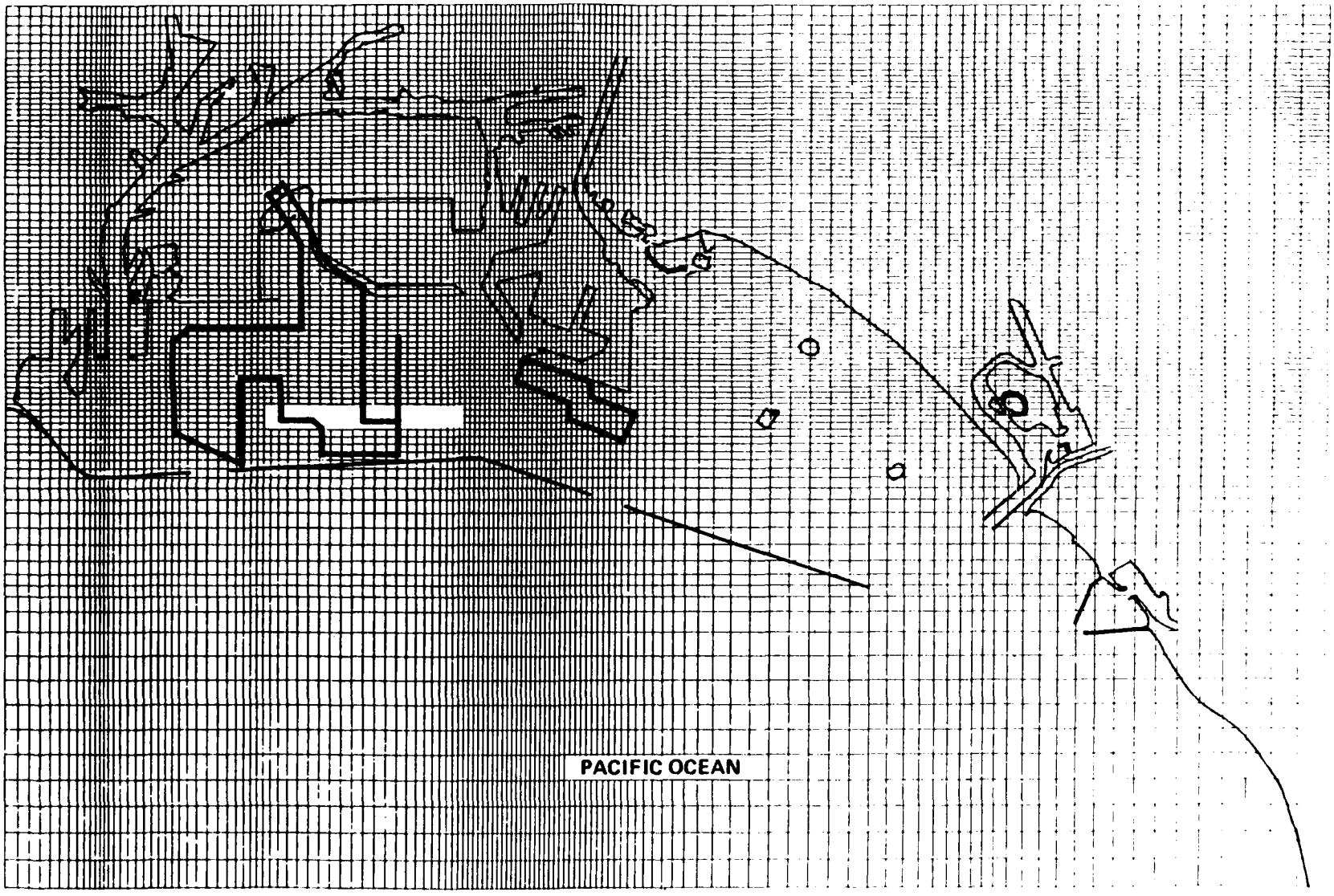

Figure 16. Representation of Scheme B, Phase 1 landfill in computational grid

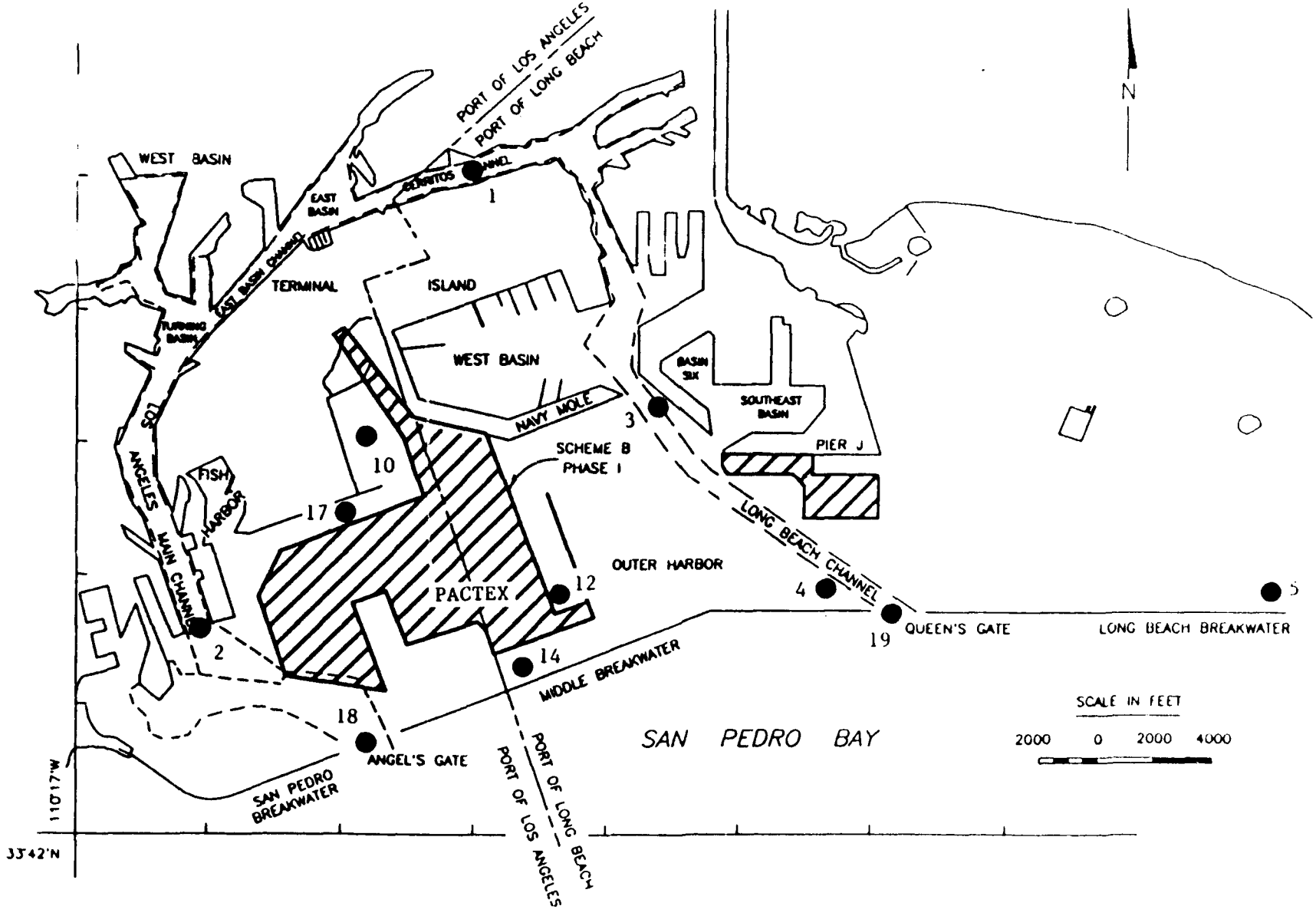

Figure 17. Tide and current gage locations for plan impact analysis

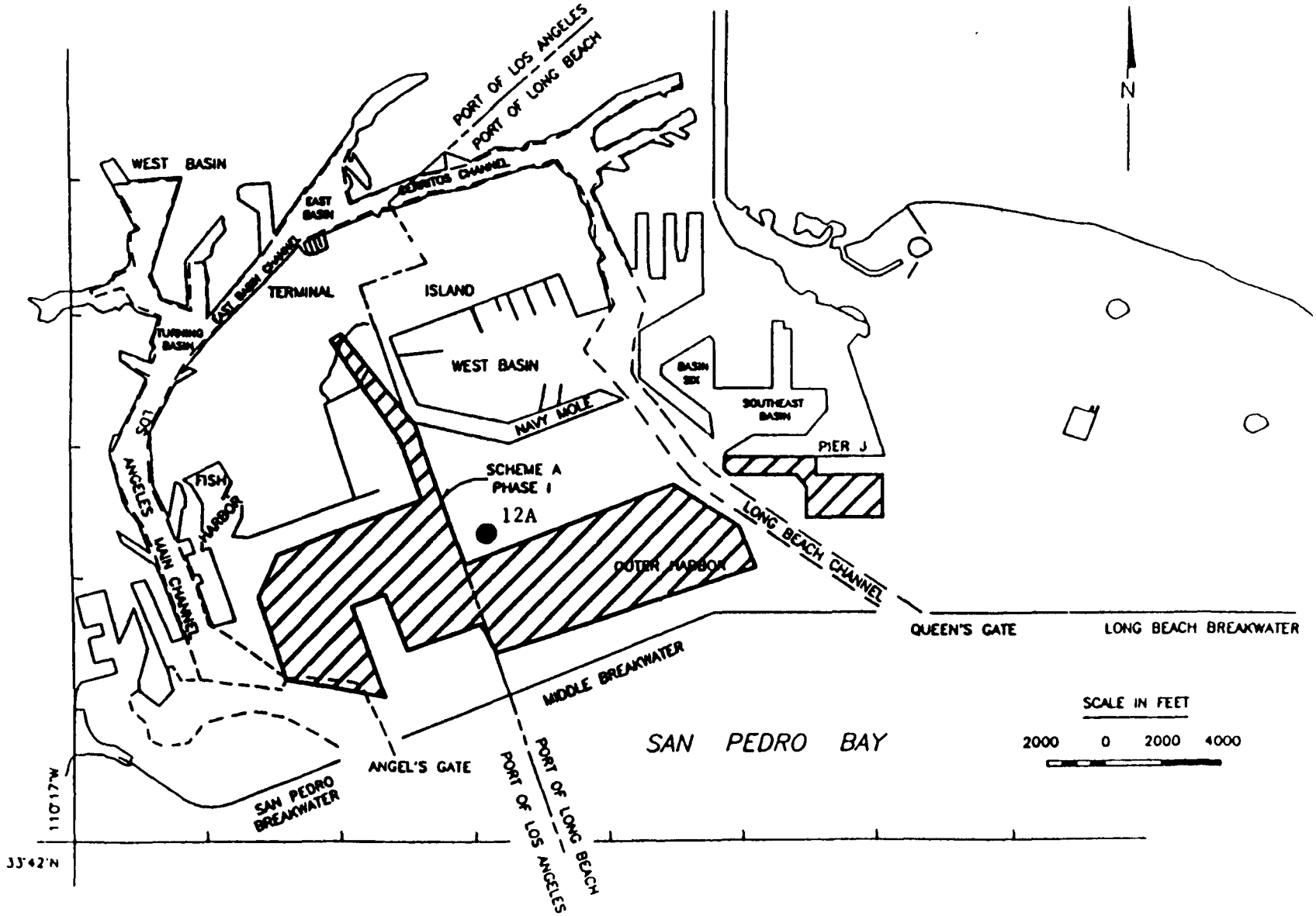

Figure 18. Special gage location for Plars 2 and 4

Tidal Currents

37. Plates 27-98 display velocity time series for the calibration period, with and without plans at several gage locations, and Plates 99-170 for the verification period. Existing and plan condition plots are superimposed to permit easy visual inspection of impact. The following comments are based on comparisons made for the calibration period and the surface layer. Unless otherwise noted, behavior is similar at other levels and for the verification period. In general, differences between various plans are rather subtle and difficult to quantify. As may be expected, behavior is similar for Plans 1 and 3 because the plan geometries are similar. Velocities through the main entrances to the harbors are reduced both because of reduction in discharges through the entrances due to new landfills and increased channel depths.

a. Gage C1 (Cerritos Channel) (Plates 27-34 and 99-106): Very small differences are observed in magnitude and phase throughout the water column for Plans 1, 3, and 4. Velocity magnitude is reduced more for Plan 2.

b. Gage C2 (Main Channel) (Plates 35-42 and 107-114): Peak velocity during the 5-day period is about the same or increases slightly for Plans 1, 3, and 4. It decreases slightly for Plan 2. Primary differences are noted in flood phase—the velocity magnitude increases.

c. Gage C3 (Long Beach-Pier F) (Plates 43-50 and 115-122): Peak velocity decreases by 20 to 50 percent. In general, velocity magnitude decreases throughout a tidal cycle. Velocity direction at the surface is different from that at middepth and bottom for existing and plan conditions. Significant phase shift is noted at lower layers.

d. Gage C4 (Queen's Gate-Interior) (Plates 51-58 and 123-130): Peak magnitude decreases (up to 25 percent) for Plans 1 and 3, slightly less for Plans 2 and 4. Velocity magnitude is generally reduced throughout a tidal cycle. Velocity direction is consistently east at the surface and different from that at middepth and bottom for existing conditions and plans. Significant phase shifts are noted in lower layers.

e. Gage C5 (East Entrance-South) (Plates 59-66 and 131-138): More velocity reduction is observed during a flood cycle. Velocity direction at the surface differs from that at middepth and bottom for both existing and plan conditions. Some phase shift is noted.

f. Gage C14 (New Middle Breakwater Channel) (Plates 67-74 and 139-146): This gage corresponds to new construction near PACTEX terminal. For plan conditions, the velocity magnitude is considerably higher at the surface and reduced at the lower levels. Obviously, the depth-averaged velocity magnitude is increased because of channelization. For existing conditions, the direction at the surface exhibits oscillatory behavior and at the lower layers is primarily to the west. For plan conditions, the direction is primarily to the east at the surface and in the lower layers exhibits oscillatory behavior typical of tides.

g. Gage C18 (Angel's Gate) (Plates 75-82 and 147-154): Velocities are reduced considerably (30 to 50 percent), with greater percentage reduction during the verification period. Direction at the surface differs slightly from that at lower layers for both existing conditions and plans. Some phase shift is noted.

h. Gage C19 (Queen's Gate) (Plates 83-90 and 155-162): Velocities are reduced by 20 to 30 percent, with greater reduction during ebb phase. Direction at the surface differs slightly from that at middepth and bottom. Some phase shift is noted, more in lower layers.

38. For both test periods, current behavior was analyzed in newly constructed slips, Gages C12, and C12A (see Figures 17 and 18 for locations of gages), Plates 91-98 and 163-170.

a. Gage C12 applies to Plans 1 and 3. At this gage, the behavior is similar for Plans 1 and 3. Compared with existing conditions, the velocity magnitude decreases for the two plans. Since for plan conditions the gage is no longer in open water, the velocity direction is no longer oscillatory but is approximately steady. The direction in lower layers is opposite to that at the surface.

b. Gage C12A applies to Plans 2 and 4. At this gage the behavior is similar for the two plans. For existing conditions, the velocity is highest at the surface, and its direction exhibits oscillatory behavior except near the surface. For the two plans, the velocity is less at the surface and greater at the bottom than for existing conditions. Thus it tends to be more uniform for the plans. Its direction is approximately steady and varies from toward the north at the surface to toward the west at the bottom.

Tidal Discharges

39. Total tidal discharges through several ranges (Figure 19) established in the model grid are shown in Plates 171-184 and 185-198 for the

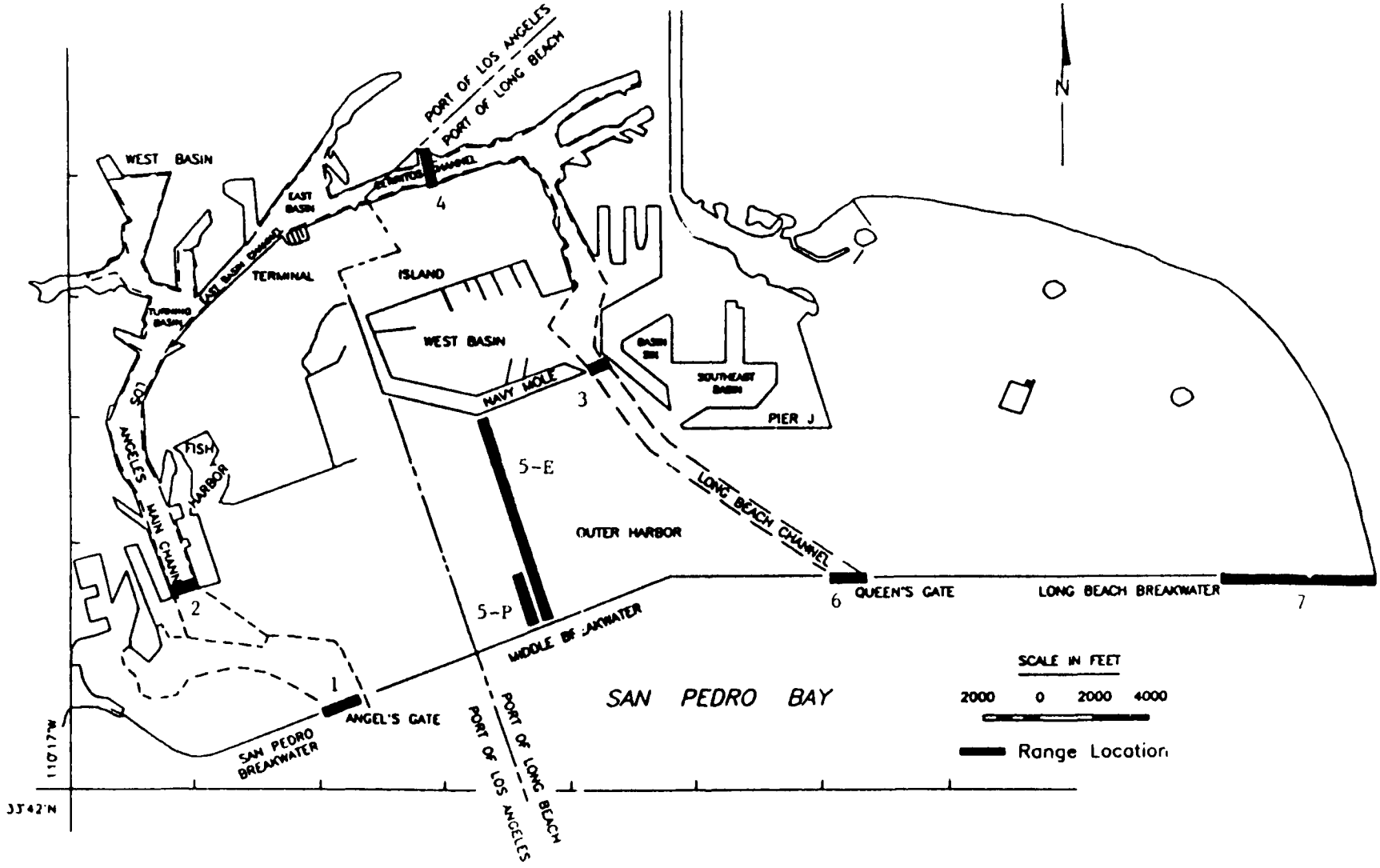

Figure 19. Range locations for plan impact anal is

calibration and verification periods, respectively. Existing and plan condition results are superimposed for visual inspection of impact. Results show the expected small reduction in discharge through the entrances, especially Angel's Gate (Range 1) caused by the introduction of new landfill for plans. The Middle Harbor Range (Range 5) was taken from the Navy Mole to the Middle Breakwater for existing conditions and Plan 4 (Range 5E). For Plans 1, 2, and 3, this range was taken from the PACTEX landfill to the Middle Breakwater (Range 5P). Its location is shown in Figure 19. Plates 179-180 and 193-194 display results from this range. For Plans 1 and 3, the discharge cycles are similar to existing conditions with a 2- to 3-hr phase lag. For Plans 2 and 4, there is a reduction in amplitude as well as phase shift.

40. In addition to comparing time series of discharge, the discharge was integrated over a specific period during the simulation to estimate changes in net channel flow and tidal prism of the harbors. For the latter purpose, Ranges 1, 6, and 7, located across Angel's Gate, Queen's Gate, and the East Entrance, respectively, were used. Range 7 extends from the easternmost tip of the breakwater to the shore south of Anaheim Bay. Because of the rectilinear nature of the grid, it was convenient to take Range 7 in this manner. The total water surface area bounded by these three ranges is approximately 660 x 10^6 sq ft. The total landfill areas associated with Plans 1, 2, 3, and 4 within the harbor complex are 63 x 10^6, 71.1 x 10^6, 62.5 x 10^6, and 60.5 x 10^6 sq ft, respectively. These represent reductions in available water surface area of 9.5, 10.8, 9.5, and 9.2 percent, respectively, and are expected to cause corresponding losses of tidal prism.

41. A period of 2 lunar days (hours 5282-5331.6 in the 7-11 August period and 5571-5620.6 in the 19-23 August period) was chosen to calculate total flood and ebb volumes. Since the tidal range is fluctuating over the entire period and is influenced by wind, the total flood volume into the system will not equal total ebb volume out of the system. The approach adopted is to sum results over each range and average inflow and outflow volumes for the two tidal cycles. Tables 1-4 give total flood and ebb volumes for both simulation periods and prism computations. Percent reductions for both periods are similar and compare well with the expected reduction.

Circulation

42. To aid in comparing plans with existing conditions, plate figures for circulation during near peak flood, peak ebb, and slack water for existing conditions are repeated along with patterns for plan conditions to permit easy visual inspection of plan impact (Plates 199-213 for calibration and Plates 214-228 for verification). The reader is reminded that velocity vectors are plotted at every third grid line. The major conclusion reached is that the new landfill eliminates the gyre circulation in the Outer Harbor and peak flood and ebb velocities in the outer breakwater entrances are reduced. Specific comments for the three snapshot periods are:

a. Peak flood—Changes in circulation patterns are confined to the Outer and Inner Harbor areas. Results for Plans 1 and 3 are similar. For the specific point in the calibration period at which the peak flood snapshot was taken, flow direction in Cerritos Channel for Plans 2 and 4 is the same as for existing conditions (i.e., to the west), whereas for Plans 1 and 3, it is to the east. Note the velocity magnitudes are small in either case (on the order of 0.1 to 0.15 fps). This trend is true for all three levels. A stronger clockwise eddy is noticeable within the Navy Basin for Plans 1 and 3. Flow is accelerated near the surface in the new channel near PACTEX for all plans. In the new slip near PACTEX and Middle Breakwater, flow direction is reversed from surface to bottom for all plans. The velocity magnitudes are small.

b. Peak ebb—Changes in circulation patterns are again confined to the same areas as for peak flood. Results for Plans 1 and 3 are similar. For all four plans, flow in Cerritos Channel has the same direction as for existing conditions for all three levels (easterly). In the slips and channels near the new landfill on Los Angeles side, velocity direction at surface is opposite to that at middepth and bottom for all four plans. For the Plan 4 channel between the new landfill and the shallow-water habitat, the velocity direction is opposite to that for existing conditions for all three layers.

c. Slack water—Plan condition results show the absence of the large gyre observed for existing conditions. For the verification period, for all plans the surface velocities outside the breakwaters and through the entrances are greater than the velocities for existing conditions at this time. Also, the velocities in the PACTEX channel near the Middle Breakwater are greater than the velocities for existing conditions and in the opposite direction.

43. In order to determine the effects of plans on net circulation in the Inner Harbor areas (Los Angeles Main Channel, East Basin Channel, Cerritos Channel, and Back Channel), the discharges across Ranges 2, 3, and 4 (Figure 19) were integrated over two lunar cycles for existing conditions and plans and net flow volumes across the ranges were computed. The direction or sign of the discharges was duly taken into account in these calculations. The resulting net flow volumes are shown in Tables 5 and 6 for calibration and verification, respectively. Ranges 2 and 3 are located across the entrances to Los Angeles Main Channel and the Navy Basin, respectively, whereas Range 4 is located across Cerritos Channel (Figure 19). The following sign conventions are used for net flow volumes (Tables 5 and 6) and net flows. At both Ranges 2 and 3, positive and negative signs respectively indicate the net flow across the ranges is to the north and south. At Range 4, positive and negative signs denote the net flow across the range is to the east and west, respectively.

44. Considering existing conditions, it is seen that for both calibration and verification, the net flow is negative at Ranges 2 and 4, and positive at Range 3. This means the net flow is directed towards the south at Range 2, towards the north at Range 3, and towards the west at Range 4, implying a net counterclockwise circulation (i.e., from Long Beach to Los Angeles) in the Inner Harbor areas. This agrees with the results of previous WES studies, as mentioned in Part II. Similarly, it can be deduced from Tables 5 and 6 that for Plans 1 and 3, the net circulation is clockwise during the calibration period and has a strong tendency towards the clockwise direction during the verification period. For Plan 2, the net circulation is clockwise for both calibration and verification. For Plan 4, the net circulation has a strong tendency towards the clockwise direction for both calibration and verification.

45. In summary, with the introduction of plans, tidal elevations remain unchanged; however, current velocities through the harbor entrances are reduced along with the tidal prism. There were some changes in the harbor circulation, but these changes were primarily confined to the Outer Harbor and Inner Harbor areas. Results indicate the plans have a strong tendency to cause a reversal in the net circulation through the Inner Harbor.

Hydrodynamic Simulations for Water Quality Modeling

46. Hydrodynamic information for running the WQM was provided by simulating most of the month of August 1987. Appropriate tidal elevation and wind forcing data were used and several HM runs were made to complete a 28-day simulation (1-28 August 1987), and the results were concatenated to form a continuous output file of HM results averaged over 1-hr intervals. Similar information was produced for both existing and plan conditions.

PART VI: PLAN TESTING AND RESULTS: WATER QUALITY

Flushing Studies

47. Flushing studies consisted of insertion of a conservative tracer and noting movement and dilution of the tracer. The flushing studies provide a qualitative comparison between Base and the Harbor Enhancement Schemes. A decrease in the flushing rate prolongs the period of time that oxygen-demanding substances exert their influence on the DO concentration. A decrease in flushing rate can intensify other potential water quality problems and indicates that more detailed water quality analyses are required. In this study, the flushing studies provided identification of areas within the harbor that exhibited decreases in flushing. Such areas were selected for more detailed characterization during subsequent DO simulations.

48. Four flushing comparisons between Base and the enhancement plans are presented: (a) Tracer Simulation 1—insertion of tracer in all WQM cells interior to the breakwater, (b) Tracer Simulation 2—insertion of tracer in East Basin Channel, (c) Tracer Simulation 3—insertion of tracer in the embayment adjacent to the Outer Harbor located between West Basin of Middle Harbor and Fish Harbor, and (d) Tracer Simulation 4—insertion of tracer in the West Basin of Middle Harbor. Tracer Simulation 1 identified areas of less flushing while Tracer Simulations 2 through 4 examined potential local water quality problems like accidental spills.

49. Figures 2 and 20 provide clarification of the location of the tracer experiments. Figure 2 is a map of the study area and Figure 20 indicates the cells inserted with tracer. The East Basin Channel comparison was selected because of minimal flushing observed from the simulations; the embayment between West Basin and Fish Harbor was selected because Schemes A, B, and C appear to isolate these waters; and the West Basin of Middle Harbor was selected because initial tracer comparisons indicated decreased flushing with harbor enhancement.

50. The boundaries were specified exterior to the breakwaters. Tracer could exit the Outer Harbor through the breakwater openings, but only water without tracer material could enter the Outer Harbor from the ocean boundary. The initial tracer concentration was arbitrarily set to 10.0. The tracer

SAN PEDRO BAY - BASE

Water Quality Model Grid Overlaid

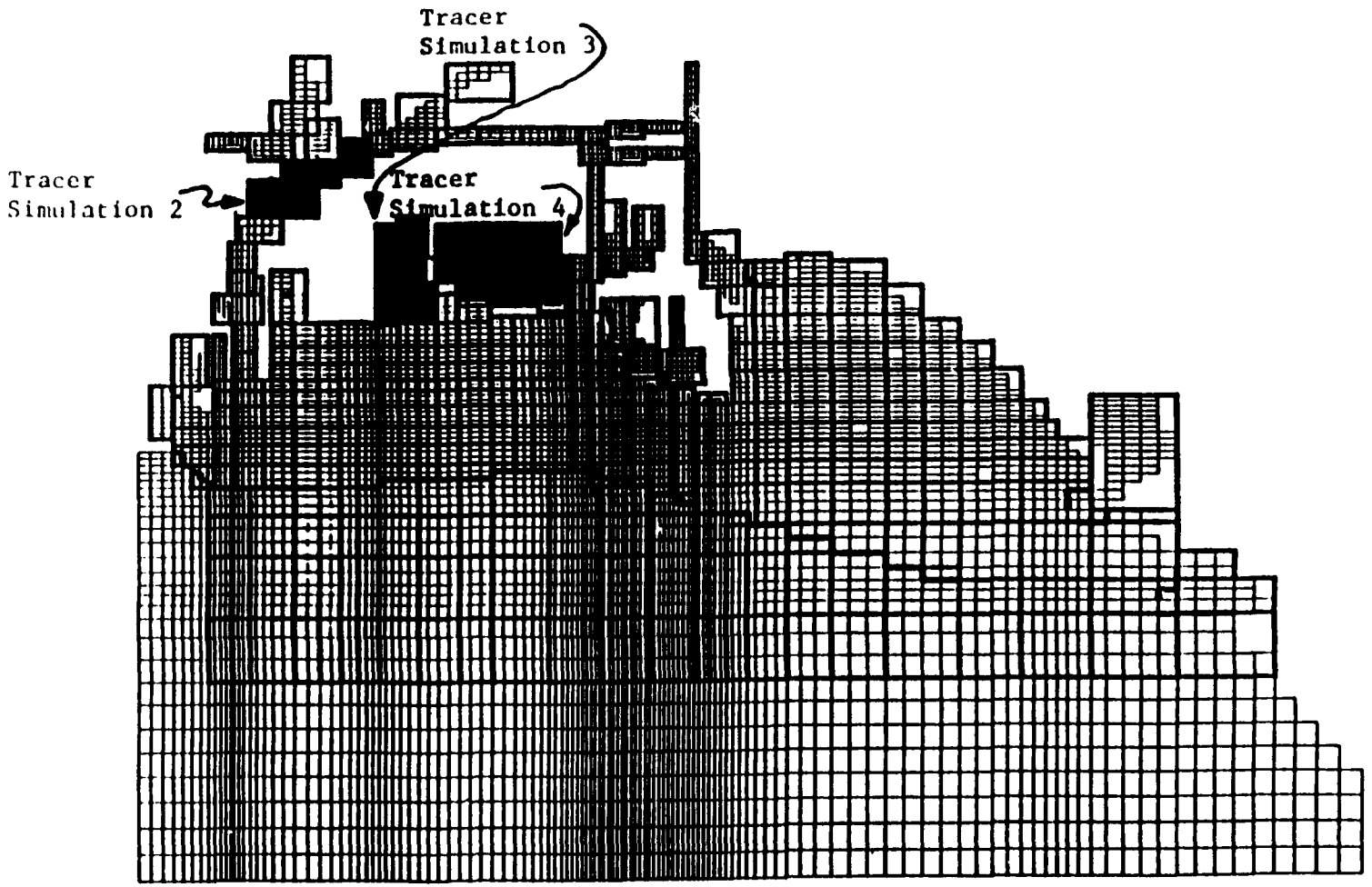

Figure 20. Locations of tracer injections

studies used the HM simulated flow data for the period 1 August 1987 through 28 August 1987.

51. Tracer Simulation 1 was the insertion of tracer in all WQM cells. Plates 229 through 234 display the dilution of tracer in the Base condition at 5-day intervals while Plates 235 through 258 display the dilution of tracer in the enhancement plans. Examination of the figures reveals that circulation through Los Angeles Main Channel is rather static, but slightly counter-clockwise in the Base condition and clockwise in Schemes A, B, C, and D. The clockwise circulation in the enhancement plans is apparent through the movement of tracer into Inner and Middle Harbors.

52. Examination of Plates 234, 240, 246, 252, and 258 (Tracer Simulation 1 after 25 days for Base and Schemes A, B, C, and D) reveals that tracer is more rapidly flushed from the Inner Harbor-Back Channel-Middle Harbor of the Port of Long Beach under existing conditions than under plan conditions. Based on the areal extent of residual tracer concentrations greater than 7.0, Schemes B and C flush more completely than Schemes A and D.

53. It should be noted that flushing is reduced south of the Naval Base Mole for Scheme A (Plate 240). Because of reduced flushing observed south of the Naval Base Mole for Scheme A, the area was selected for more detailed characterization during subsequent DO simulations. This station was in addition to the 23 locations selected in the earlier report (Hall 1990).

54. Shade plots for Tracer Simulations 2, 3, and 4 are not presented; Plates 229 through 258 indicate the general circulation pattern and corroborate the conclusions discussed in subsequent tracer simulation experiments. The earlier report (Hall 1990) presents shade plots for the tracer simulations under Base conditions and Scheme B conditions.

55. The tracer concentrations in the cells corresponding to the initial tracer injection in East Basin Channel (Tracer Simulation 2) were averaged and plotted as a function of time (Plate 259). Examination of Plate 259 reveals that East Basin Channel flushes more rapidly in the enhancement plans than in the existing condition. Tracer concentration in the existing conditions was asymptotically approaching 20 percent of initial concentration after 25 days. In contrast, tracer surface layer concentrations achieved 20 percent within 7 days in the enhancement plans. Bottom layer flushing was slower than the surface; the bottom layer required 9 days to achieve 20 percent of initial

concentration. The flushing was nearly equivalent between the enhancement plans.

56. Tracer Simulation 3 consisted of insertion of tracer between West Basin and Fish Harbor. Plate 260 indicates that flushing occurs slightly less rapidly in the enhancement plans (20 percent in 14 days) than in the existing conditions (20 percent in 10 days). The flushing rates of the enhancement plan conditions were nearly equivalent; however, Scheme A displayed slightly more rapid flushing.

57. The result of Tracer Simulation 4, insertion of tracer in the West Basin of Middle Harbor, is presented in Plate 261, which indicates that 20 percent of initial concentration was not achieved in 25 days in Scheme A; 20 percent was achieved in 25 days in Schemes B, C, and D; and 20 percent was achieved in 16 days for the existing condition. The conclusion is that flushing occurs less rapidly in the enhancement plans than in the existing condition and that Scheme A flushed less rapidly than Schemes B, C, or D.

58. The four flushing studies indicated areas that exhibited decreased flushing. Ten locations were selected for more detailed characterization during subsequent DO simulations (Figure 21). The selected locations are noted as X-1 through X-10. X-10 was an additional location not simulated in the earlier report (Hall 1990). The locations prefixed with the letter I or B represent the interior and boundary stations sampled during August 1987.

Water Quality Studies

59. Kinetic constants, boundary conditions, and initial conditions used are detailed in the earlier report (Hall 1990). Boundary conditions included observed water quality at the ocean boundary, measured sediment oxygen demand (SOD), light exchange and reaeration through the surface, and water quality of the TITP discharge. The TITP discharge was simulated for the Base condition, but was not in the plan simulation. Initial conditions were specified by assuming horizontally constant yet vertically stratified water quality based on the water quality sampling program conducted during August 1987 by Tekmarine, Inc. The initial values represented averages measured during the first week of August 1987. No algae or CBOD5 was detected during the first week of sampling. Therefore, the monthly average data values of algae were

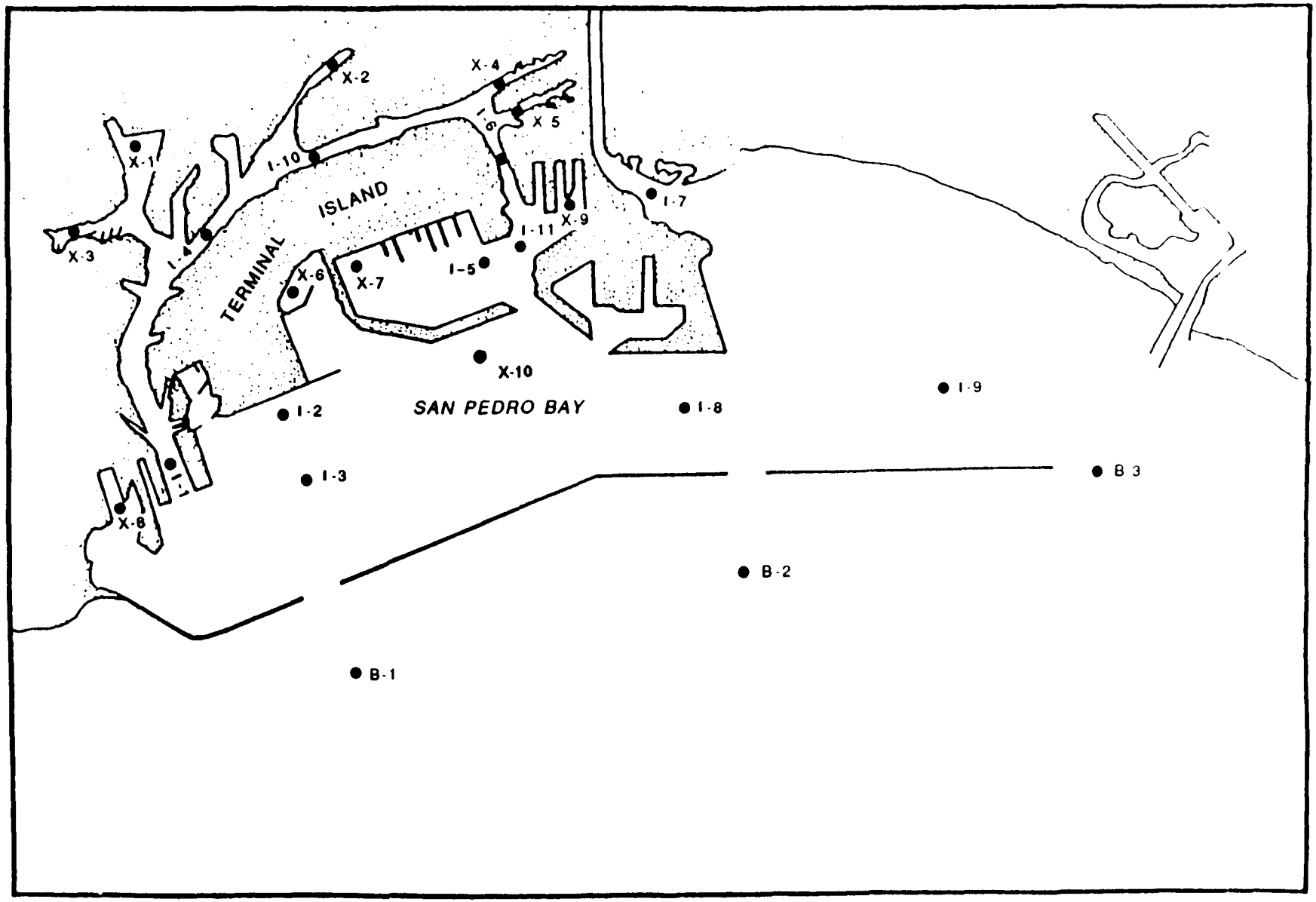

Figure 21. Water quality stations

used for initial conditions. The initial phosphorous concentration was substantially inflated by the values measured near the TITP sewage effluent. The "inflated" phosphorous initial concentrations were used in the enhancement scheme simulations.

60. Plates 262-307 display simulated algae (Alg), PO_4-P, NH_4-N, NO_2+NO_3-N, CBOD5, and DO at the surface and bottom. The solid line represents the Base condition, and the dashed lines represent the different enhancement conditions. The circles represent observed values. The station numbering corresponds to the identification in the water quality sampling program (Tekmarine, Inc. 1987), with the addition of 10 locations prefixed with "X" (Figure 21). Water quality Station I-3 is not represented in the enhancement schemes because of landfill. Stations I-10 and I-11 were sampled for SOD and sediment organic nitrogen; therefore, water column constituents were not measured and not displayed on the plates. The simulated period extended from 1 August 1987 (Julian Day 213) through 28 August 1987 (Julian Day 240).

61. The measured and simulated results are in general agreement except for Station I-7. Apparently, the Los Angeles River is contributing some flows to the bay that were not modeled. The water quality sampling program (Tekmarine, Inc. 1987) revealed less saline, nutrient-enriched surface waters at Station I-7 (Figure 21).

62. Discrepancies at several stations between computed and observed values (such as I-4 in East Basin Channel, Plate 265) near the beginning of the month are due to the use of "global" nitrogen nutrient values which exceed initial measured values at some stations. The "global" initial nutrient values represented the average over all interior stations for each layer. Algae were nitrogen limited in the simulations; slight variations in initial nitrogen concentrations resulted in variations in the simulated algal concentrations. However, the simulated DO was insensitive to minor variations in initial nitrogen concentrations. The excess nitrogen resulted in rapid growth of algae followed by a gradual decline. Greater algal growth in the existing conditions, particularly at Stations X-6 and X-7, are due to TITP effluent contributions of nitrogen.

63. The apparent discrepancies between simulated Base condition and measured algal biomass such as displayed at the surface at Station I-1 (Plate 262) are not significant. Measured algal biomass varies between 0.0

and 0.5 g C/m^3 (0 to 14 mg chlorophyll a (Chl-a)/m^3), and simulated algal biomass was rather constant near 0.2 g C/m^3 (6 mg Chl-a/m^3). Water quality standards for algal biomass do not exist. However, it is generally accepted that algal concentrations greater than 25 mg Chl-a/m^3 (0.875 g C/m^3) are undesirable. Both measured and simulated algal concentrations were below the criterion of 25 mg Chl-a/m^3 and much less than the general visible algal concentration of 100 mg Chl-a/m^3.

64. Examination of Plates 262-309 reveals that both observed and simulated DO decreased at all stations during August 1987. The decrease in DO was due to a decrease in boundary DO concentration. For example, the measured boundary surface layer DO at Angels Gate (Station B-1, Figure 21) decreased from 9.0 g/m^3 on 4 August 1987 to 7.4 g/m^3 on 25 August.

65. Simulated DO of the enhancement plans was either equal to or less than existing conditions. Maximum deviations of 0.5 g/m^3 occurred in Inner Harbor-Back Channel-Middle Harbor of the Port of Long Beach (Stations I-5, I-6, I-11, and X-5). It should be noted that Tracer Simulation 1 revealed decreased flushing in these areas.

66. The bottom waters exhibited lower DO relative to the surface waters. The maximum deviations between surface and bottom waters occurred in Cerritos Channel (Station I-10), Back Channel (Station I-6), Middle Harbor (Station I-11), East Basin of Middle Harbor (Station X-9), and the dead-end channels connected to Inner Harbor (Stations X-4 and X-5). It should be noted that only the stations in Back Channel (I-6) and Middle Harbor (I-11) exhibited differences between existing and enhancement conditions. Differences in DO between existing conditions and enhancement plans were not greater than 0.5 g/m^3. The minimum predicted DO at all stations and all depths was 6.0 g/m^3. The minimum of 6.0 g/m^3 was predicted in the bottom layer in West Basin of Middle Harbor (Station X-7).

67. The only differences observed between enhancement plans were for Stations I-1 and X-8. Station I-1 is located at the junction of Outer Harbor and the Los Angeles Main Channel. The DO simulated at Station I-1 in Scheme D was about 0.25 g/m^3 greater than the other plans. Similarly the bottom layer DO simulated at Station X-8 (located in the West Channel of Los Angeles Harbor) was about 0.5 g/m^3 greater in Scheme D than in the other enhancement plans; the surface layer DO variations was less than 0.5 g/m^3.

PART VII: SUMMARY AND CONCLUSIONS

Tidal Circulation

68. Based on the results of the 3-D numerical model tidal circulation study of the Los Angeles and Long Beach Harbors for existing and plan conditions, it is concluded that:

a. The hydrodynamics for Plans 1 (Scheme B) and 2 (Scheme C) were similar, which is to be expected since the plan geometries are similar and their landfill areas are approximately equal.

b. In an overall sense, no single plan was significantly better or worse than the other plans. The performance of all four plans tested was approximately equal, though there were minor differences.

c. The landfill of the plans did not affect the filling of the harbors since tidal ranges were maintained and no discernible differences in phase of surface elevations were noted.

d. Integrated volumes into the system were reduced by an amount equivalent to the reduced harbor surface area (about 10 percent).

e. The plans caused only small changes in the flow distribution throughout the harbor complex.

f. Velocity magnitude and direction were changed at specific locations. The greatest change in magnitude occurred at the entrances to the harbors. Peak flood and ebb velocities at Angel's and Queen's Gates were reduced up to 50 and 30 percent, respectively, for a large spring tide condition. The decrease in velocity was due to increased channel depths and reduction of harbor surface area served by these channels. While the percentage changes were large, it should be noted that velocity magnitudes throughout the harbor are small (less than 1 ft/sec). Even for a large spring tide (tide ranges of almost 9 ft) maximum velocities in Angel's Gate are less than 1.5 ft/sec.

g. Net circulation in the Inner Harbor areas (Los Angeles Main Channel, East Basin Channel, Cerritos Channel, and Back Channel) showed a strong tendency to reverse under all four plans. The net circulation under existing conditions is counterclockwise (i.e., from Long Beach to Los Angeles), while under plan conditions, it tended to be clockwise.

h. Circulation vector plots provided information on overall flow patterns in the harbors. Existing condition patterns were dominated by large horizontal eddies within the Outer Harbor. Introduction of the plan landfills eliminated these eddies. The plans also caused stronger gradients in velocity profiles. Often upper and lower layers were characterized by flows in opposite directions, especially in the new slips and channels.

Water Quality

69. The results of the WQM study indicate that Phase 1 of Schemes A, B, C, and D for LA/LB Harbor enhancement will reduce circulation and flushing in several areas, such as West Basin, Middle Harbor, and the embayment between West Basin and Fish Harbor. Residual circulation in the Los Angeles Main Channel is expected to change from counterclockwise (existing conditions) to clockwise for the enhancement schemes. The enhancement schemes will result in less rapid flushing in the Inner Harbor-Back Channel-Middle Harbor of the Port of Long Beach. Schemes B and C flush more completely than Schemes A and D in these areas.

70. The main DO impacts of the enhancement plans are experienced in the Inner Harbor-Back Channel-Middle Harbor of the Port of Long Beach. Simulated differences did not exceed 0.5 g/m^3. The bottom waters exhibited lower DO than the surface waters, but simulated concentrations were greater than 6.0 g/m^3 The simulated DO indicated little difference between enhancement plans. The only difference observed was that Scheme D provided slightly greater DO at the junction of Outer Harbor and the Los Angeles Main Channel (0.25 g/m^3) and in the West Channel of Los Angeles Harbor (0.5 g/m^3). However, because of the observed small deviations, no plans are preferred for DO.

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Table 1

Total Flood and Ebb Volumes (10^6 cu ft) for Plan 1 During Two Lunar Cycles

	Calibration				Verification			
	Flood		Ebb		Flood		Ebb	
Range No.	Ex*	Plan 1	Ex	Plan 1	Ex	Plan 1	Ex	Plan 1
1	5830	5280	5210	3930	5190	4530	3330	2410
6	3570	3580	3880	3750	2320	2380	3080	2880
7	5340	4110	5490	5800	2690	2170	4620	4720
Total	14740	12970	14580	13480	10200	9080	11030	10010
Average	Ex 14660		Plan 1 13225		Ex 10615		Plan 1 9545	
Difference		1435				1070		
Percent Change		-9.8				-10.1		

* Ex - existing conditions.

Table 2

Total Flood and Ebb Volumes (10^6 cu ft) for Plan 2 During Two Lunar Cycles

	Calibration				Verification			
	Flood		Ebb		Flood		Ebb	
Range No.	Ex	Plan 2	Ex	Plan 2	Ex	Plan 2	Ex	Plan 2
1	5830	4900	5210	3650	5190	4200	3330	2320
6	3570	3760	3880	3930	2320	2790	3080	2870
7	5340	4000	5490	5660	2690	2080	4620	4810
Total	14740	12660	14580	13240	10200	9070	11030	10000
Average	Ex 14660		Plan 2 12950		Ex 10615		Plan 2 9535	
Difference		1710				1080		
Percent Change		-11.7				-10.2		

Table 3

Total Flood and Ebb Volumes (10^6 cu ft) for Plan 3 During Two Lunar Cycles

	Calibration				Verification			
	Flood		Ebb		Flood		Ebb	
Range No.	Ex	Plan 3	Ex	Plan 3	Ex	Plan 3	Ex	Plan 3
1	5830	5360	5210	3830	5190	4560	3330	2330
6	3570	3590	3880	3800	2320	2380	3080	2930
7	5340	4110	5490	5830	2690	2160	4620	4770
Total	14740	13060	14580	13460	10200	9100	11030	10030
Average	Ex 14660		Plan 3 13260		Ex 10615		Plan 3 9565	
Difference	1400				1050			
Percent Change	-9.5				-9.9			

Table 4

Total Flood and Ebb Volumes (10^6 cu ft) for Plan 4 During Two Lunar Cycles

	Calibration				Verification			
	Flood		Ebb		Flood		Ebb	
Range No.	Ex	Plan 4	Ex	Plan 4	Ex	Plan 4	Ex	Plan 4
1	5830	4880	5210	3640	5190	4340	3330	2290
6	3570	3910	3880	3870	2320	2790	3080	2900
7	5340	4200	5490	5850	2690	2130	4620	4990
Total	14740	12990	14580	13360	10200	9260	11030	10180
Average	Ex 14660		Plan 4 13175		Ex 10615		Plan 4 9720	
Difference	1485				895			
Percent Change	-10.1				-8.4			

Table 5

Net Flow Volumes (10^6 cu ft) During Two Lunar Cycles for the Calibration Period

Range No.	Ex*	Plan 1	Plan 2	Plan 3	Plan 4
2	-109	56	87	28	52
3	179	-11	-8	-1	15
4	-166	22	36	13	2

* Ex - existing conditions.

Table 6

Net Flow Volumes (10^6 cu ft) During Two Lunar Cycles for the Verification Period

Range No.	Ex	Plan 1	Plan 2	Plan 3	Plan 4
2	-138	26	31	22	20
3	179	21	-10	23	25
4	-157	5	26	3	2

SAN PEDRO BAY - BASE

Hydrodynamic Model Grid

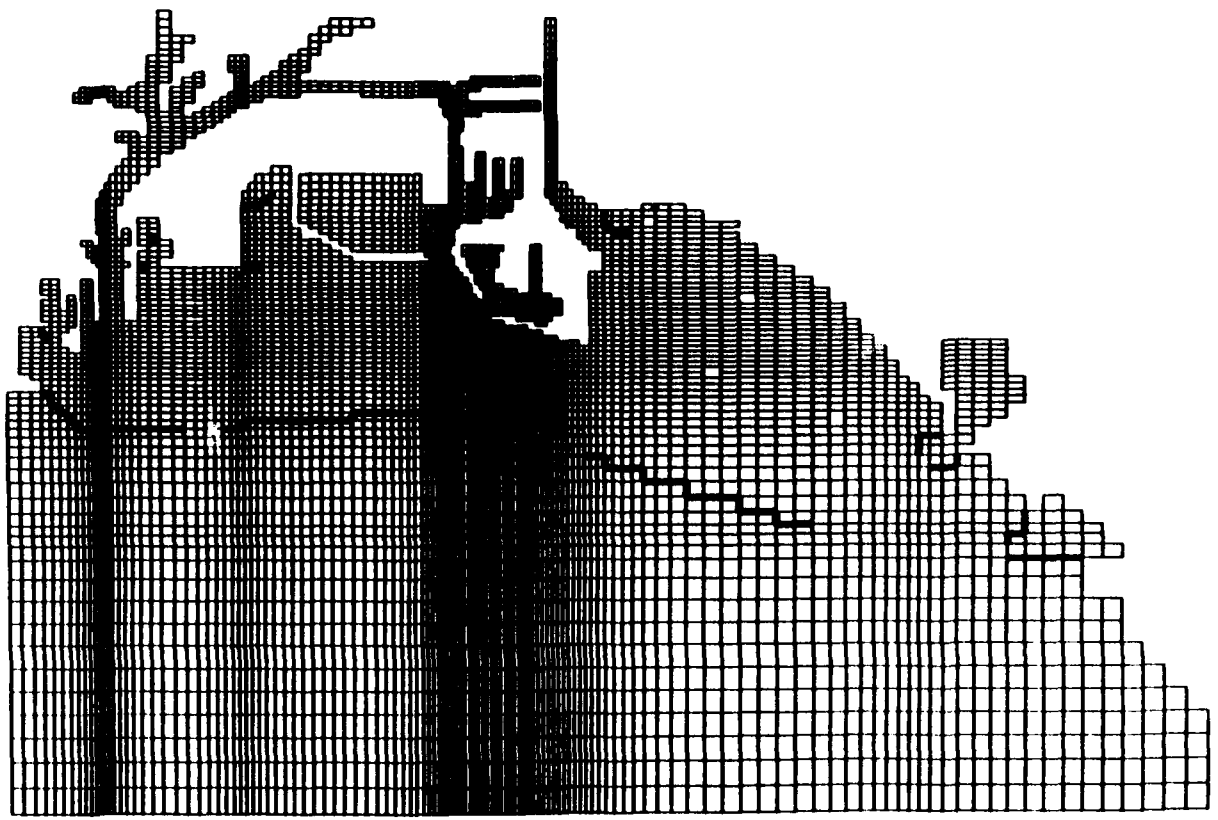
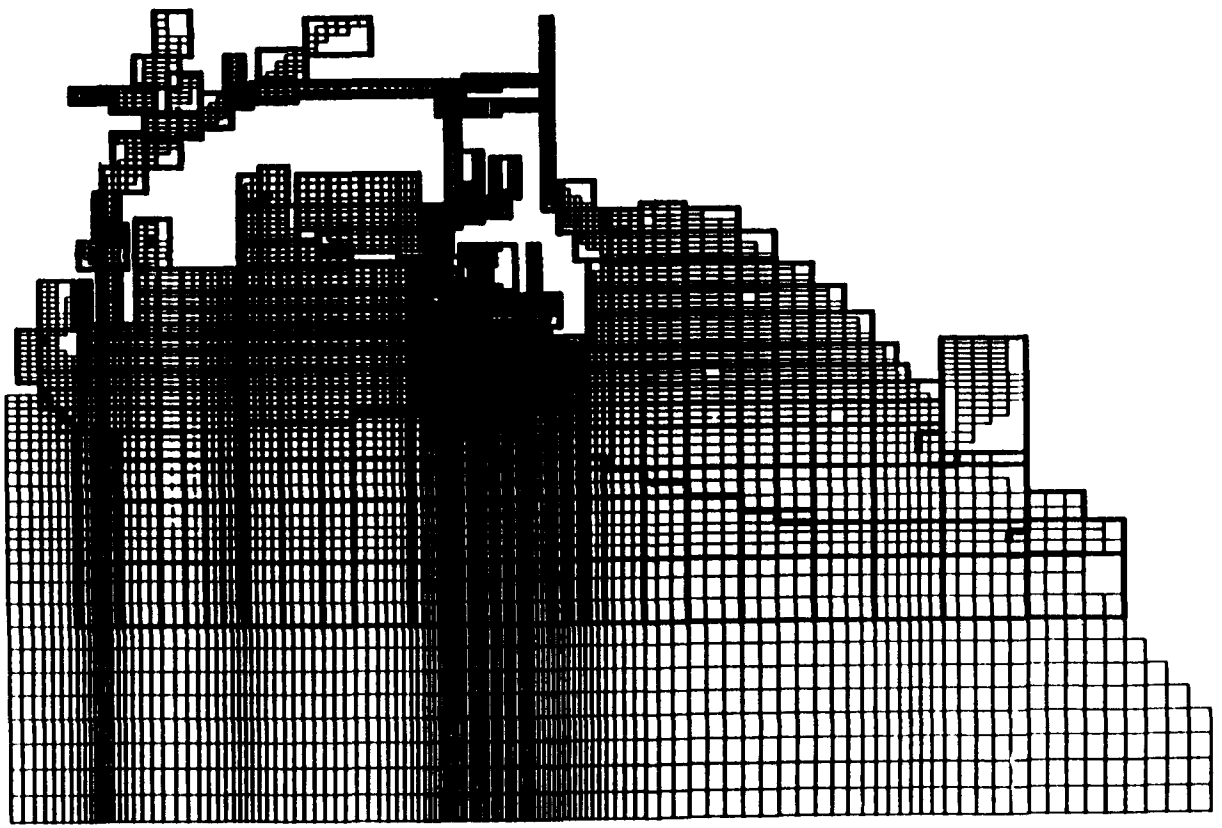


PLATE 1

PLATE 2

SAN PEDRO BAY - BASE

Water Quality Model Grid Overlaid



SAN PEDRO BAY - SCHEME A

Water Quality Model Grid Overlaid

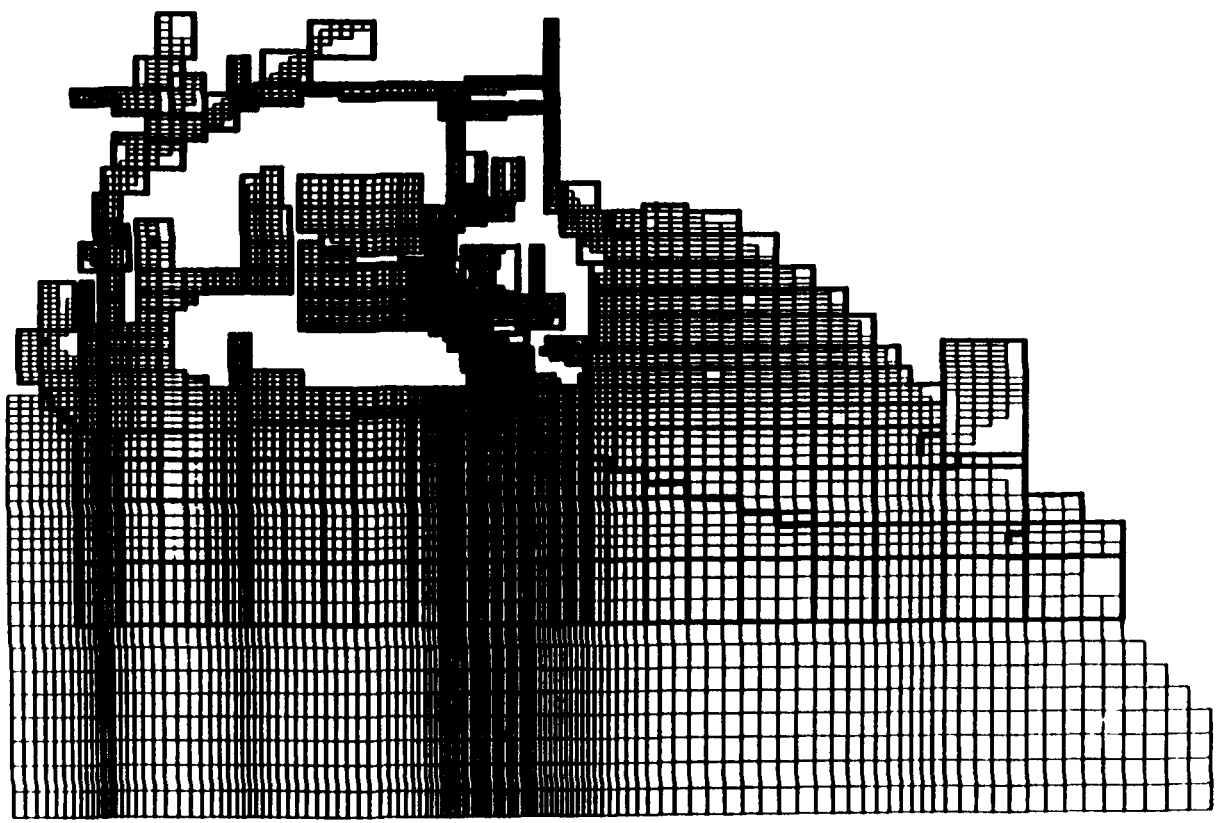
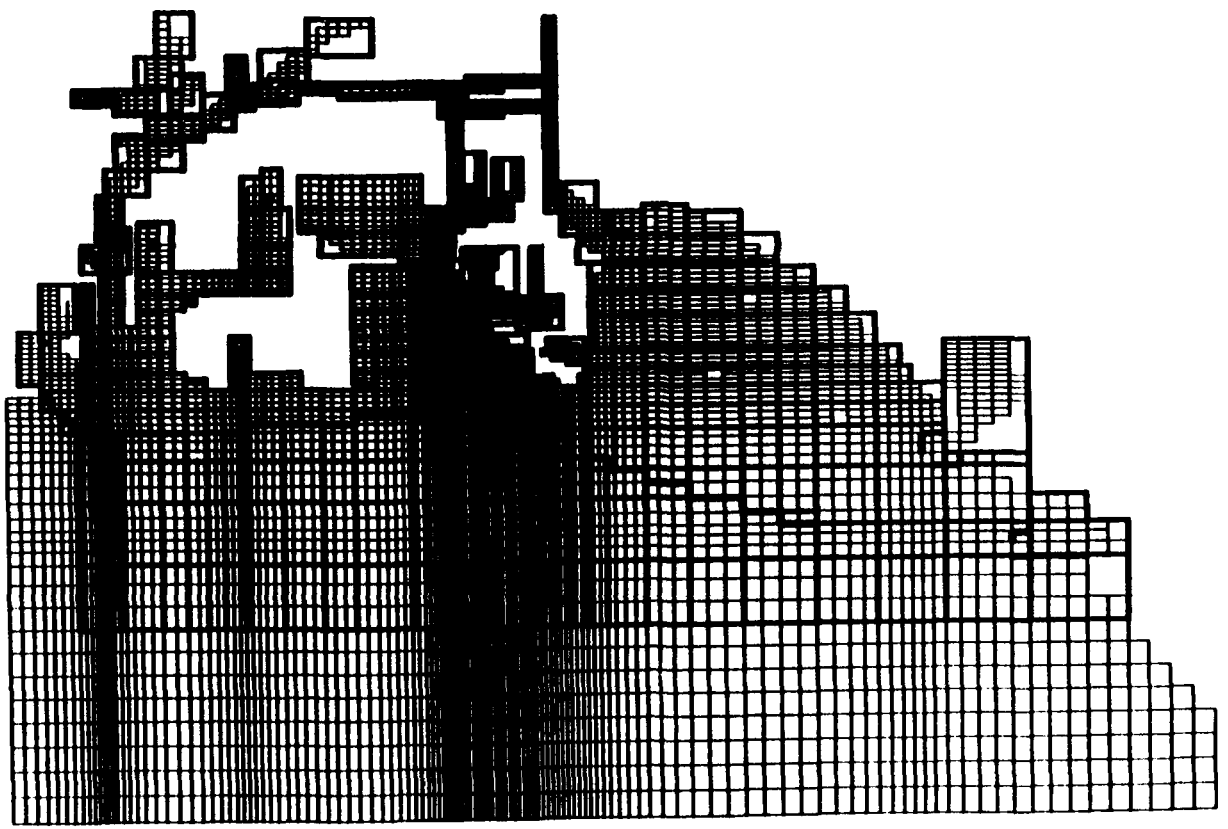


PLATE 3

PLATE 4

SAN PEDRO BAY - SCHEME B

Water Quality Model Grid Overlaid



SAN PEDRO BAY - SCHEME C

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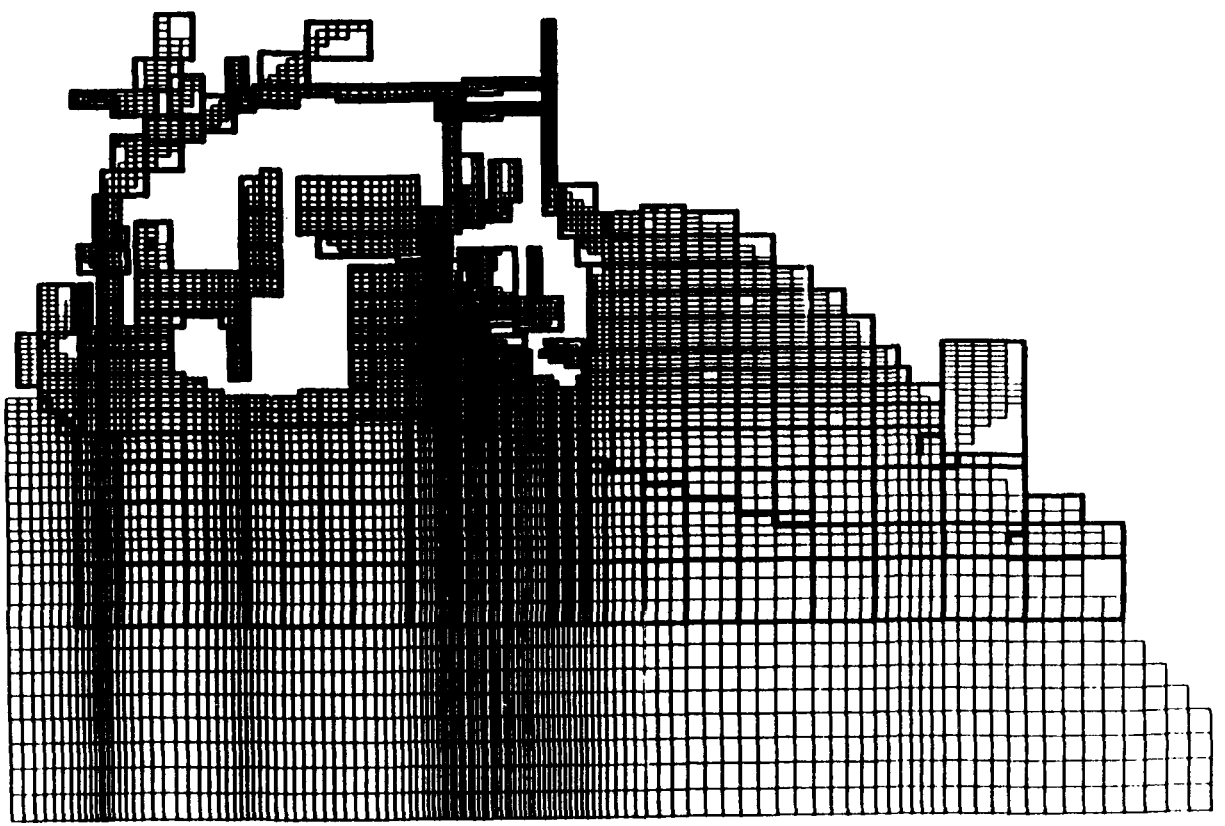
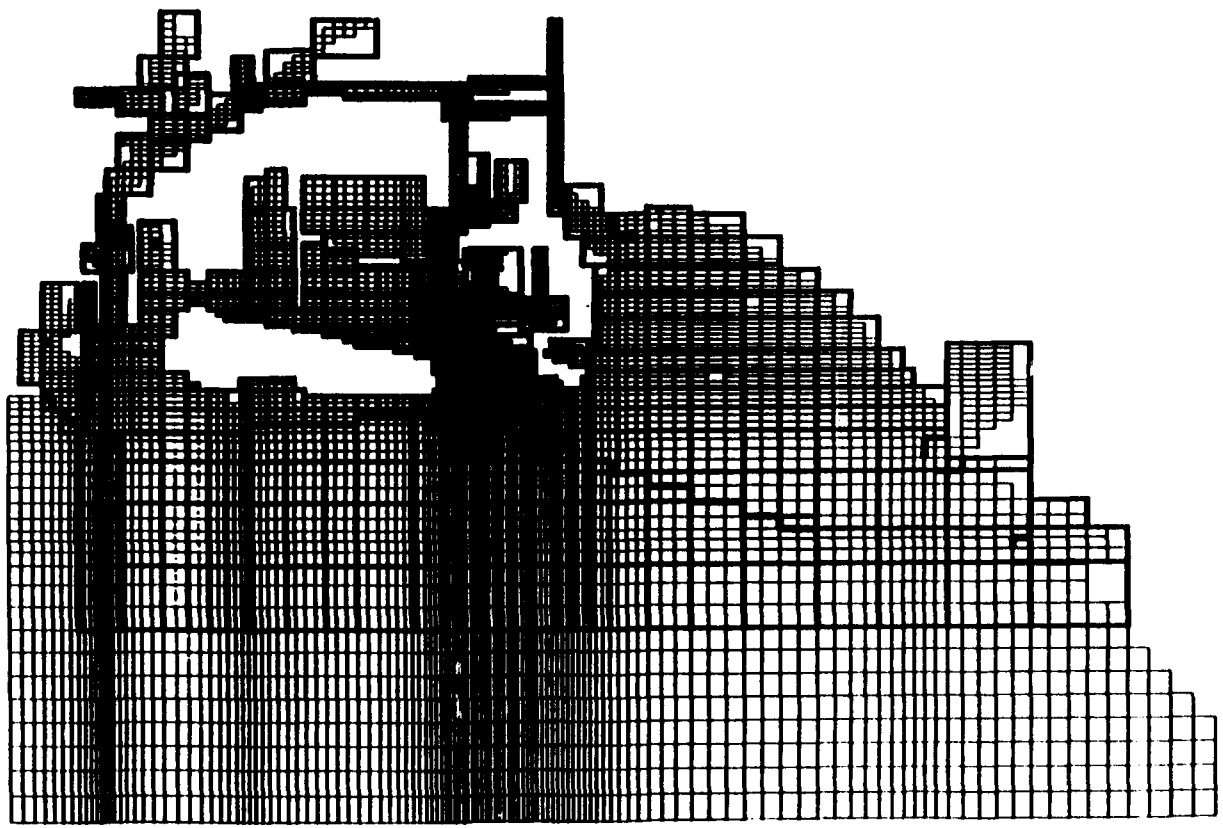


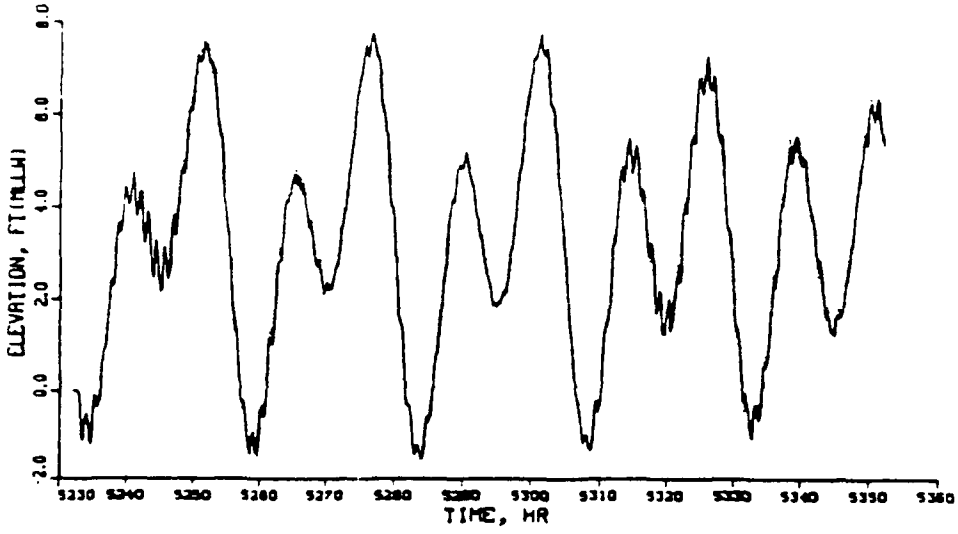
PLATE 5

PLATE 6

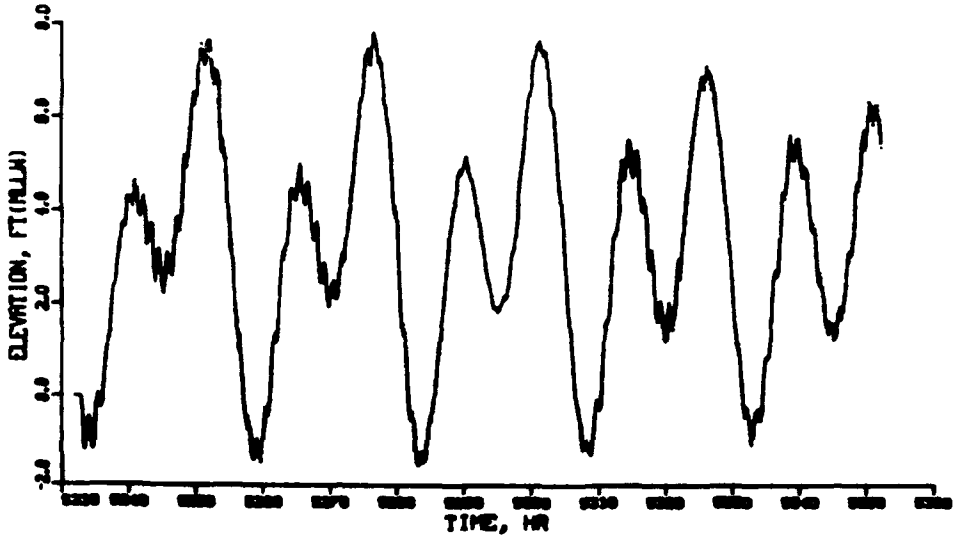
SAN PEDRO BAY - SCHEME D

Water Quality Model Grid Overlaid





PLAN 1



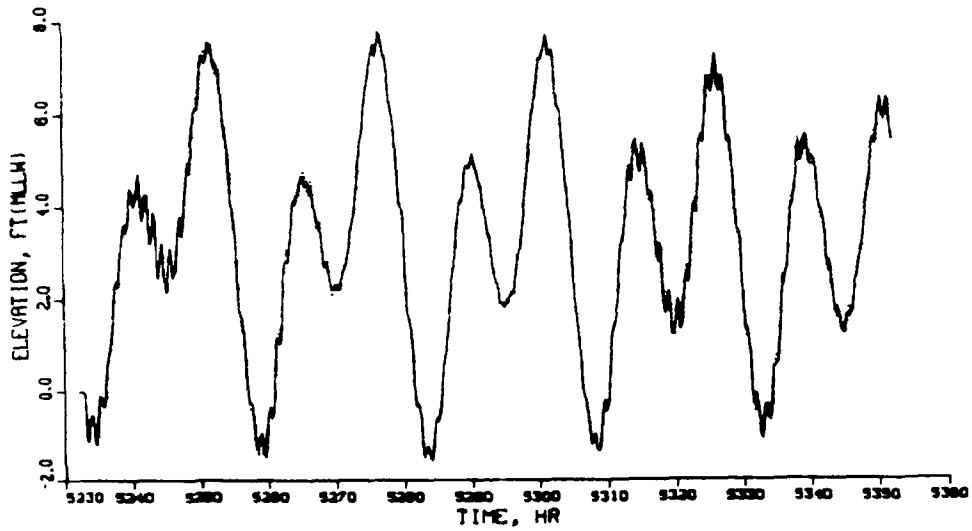
PLAN 2

TIDAL ELEVATIONS **CALIBRATION PERIOD**

GAGE TC1

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 7



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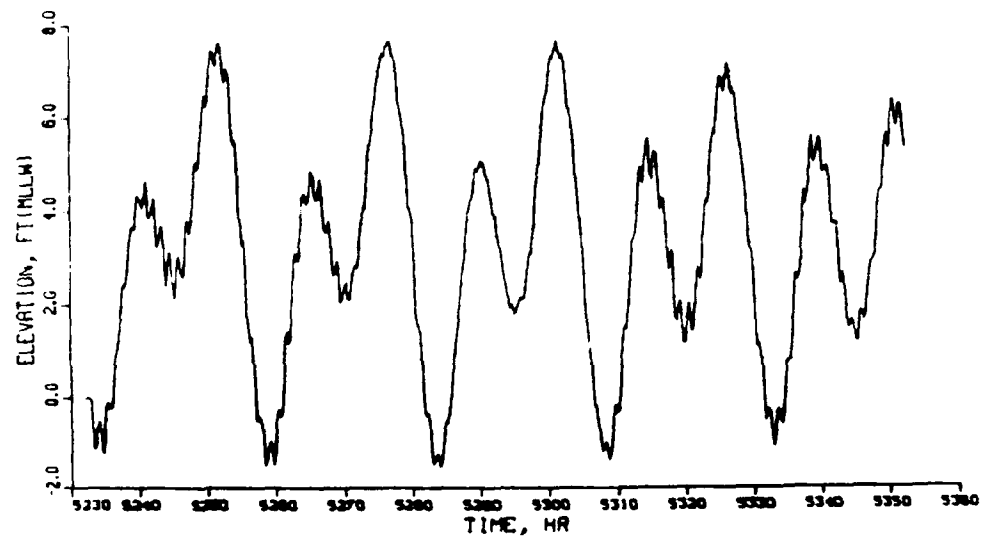


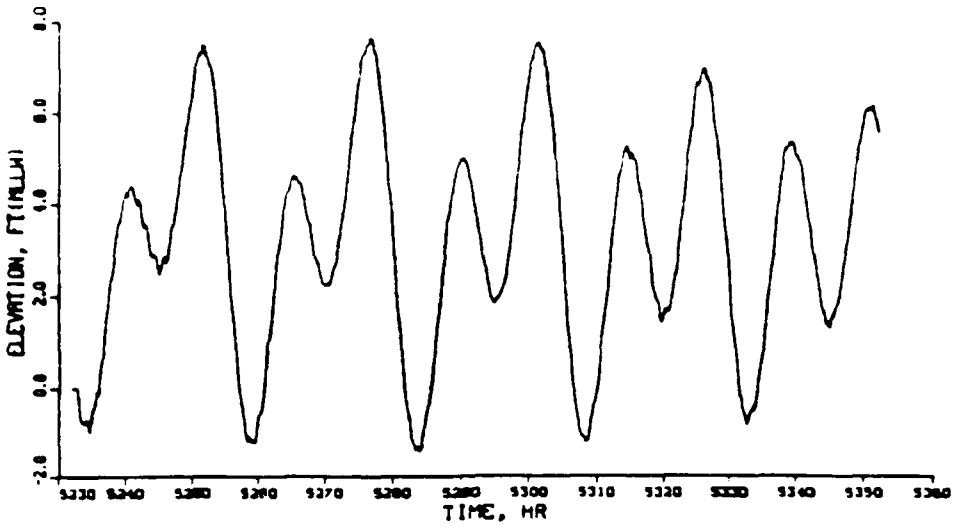
PLAN 4

TIDAL ELEVATIONS **CALIBRATION PERIOD**

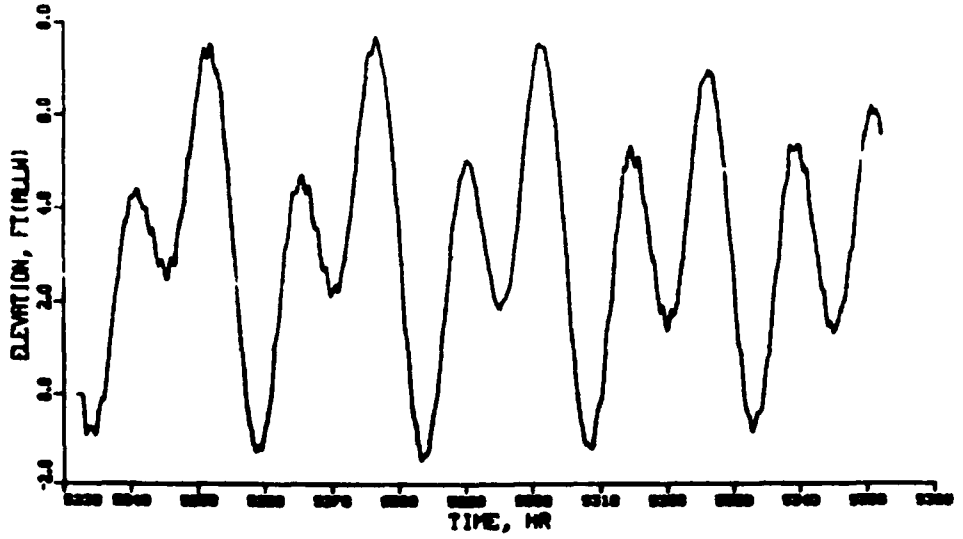
GAGE TC1

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 8



PLAN 1



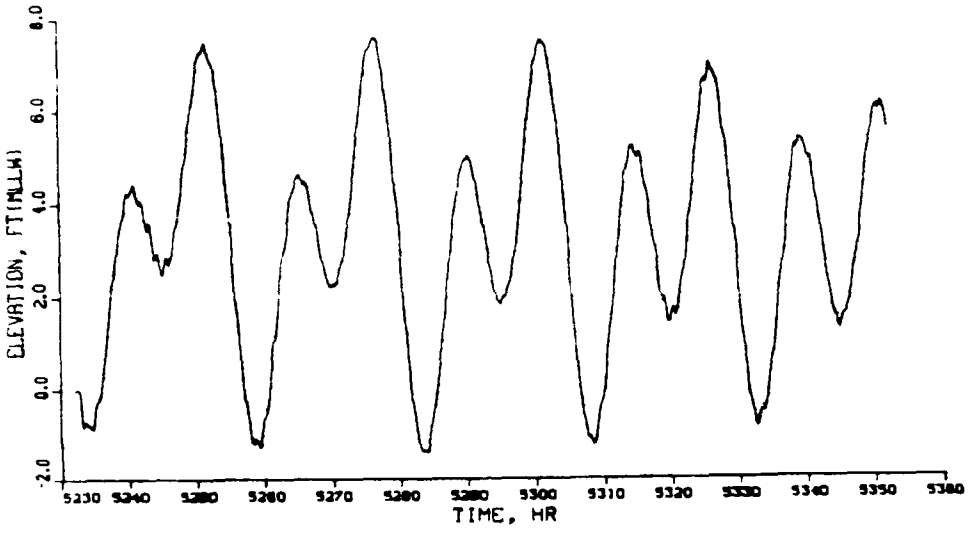
PLAN 2

TIDAL ELEVATIONS **CALIBRATION PERIOD**

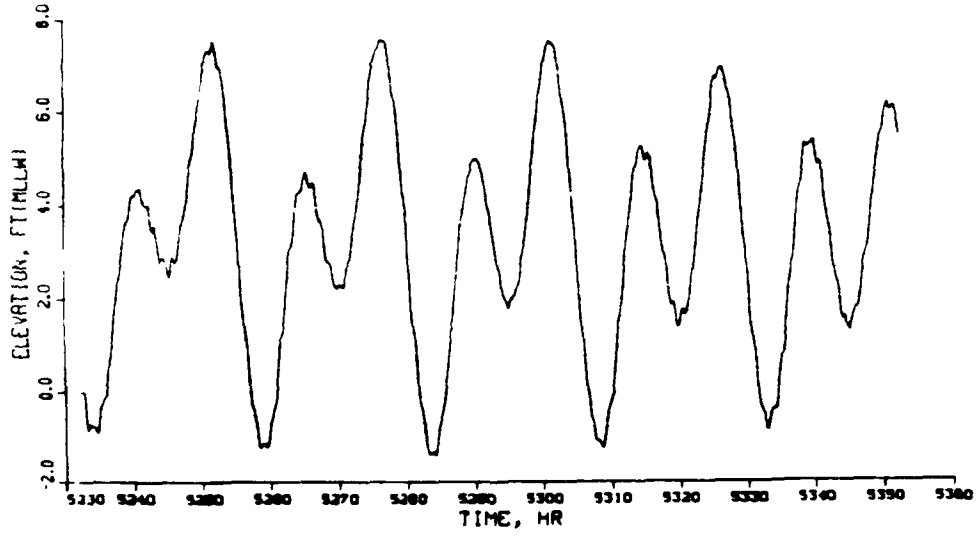
GAGE TC3

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 9



PLAN 3



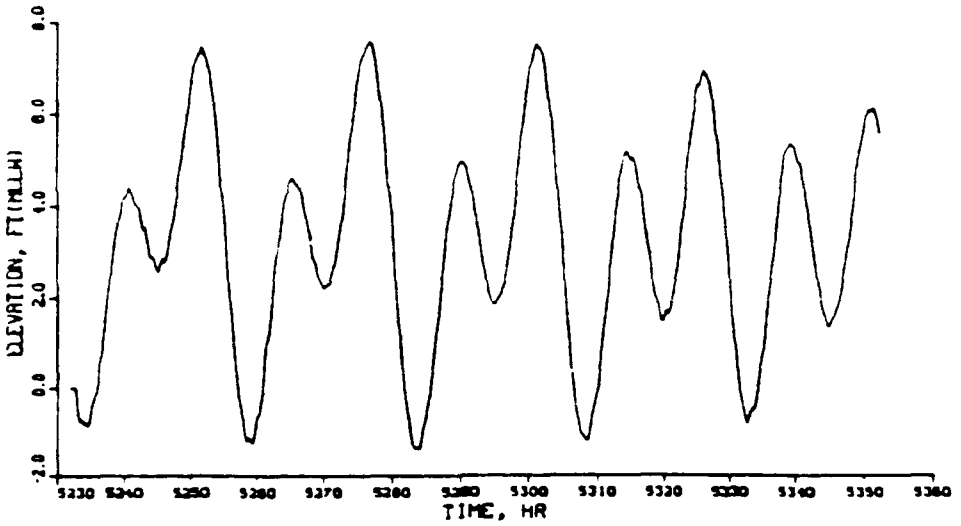
PLAN 4

TIDAL ELEVATIONS **CALIBRATION PERIOD**

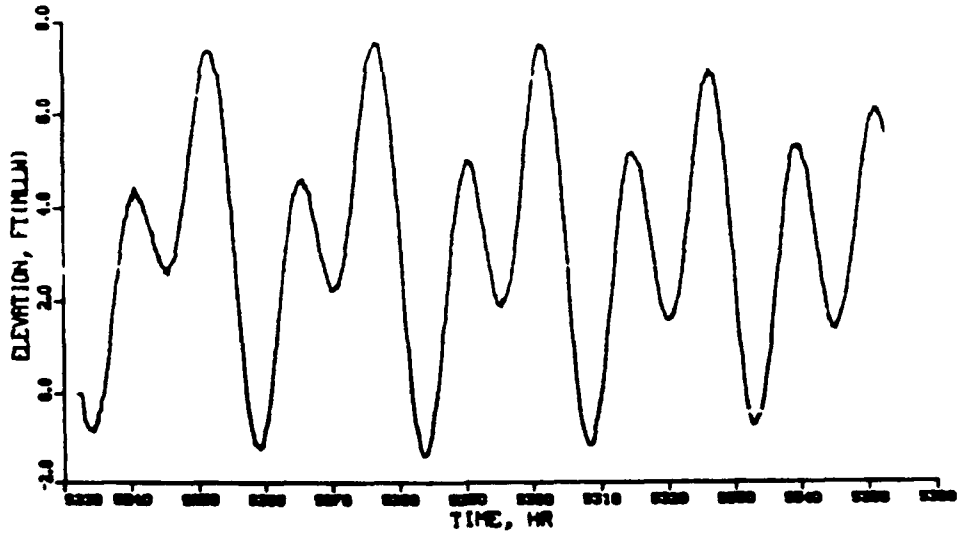
GAGE TC3

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 10



PLAN 1



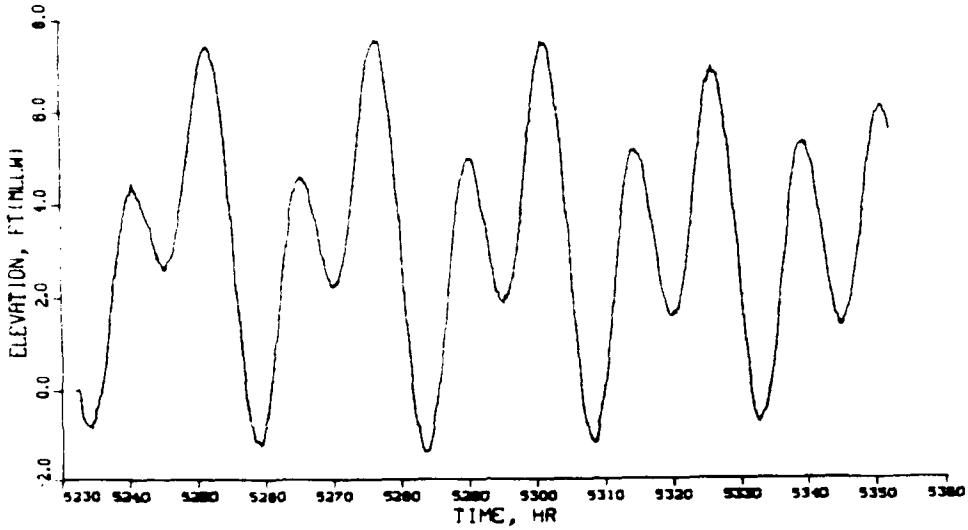
PLAN 2

TIDAL ELEVATIONS **CALIBRATION PERIOD**

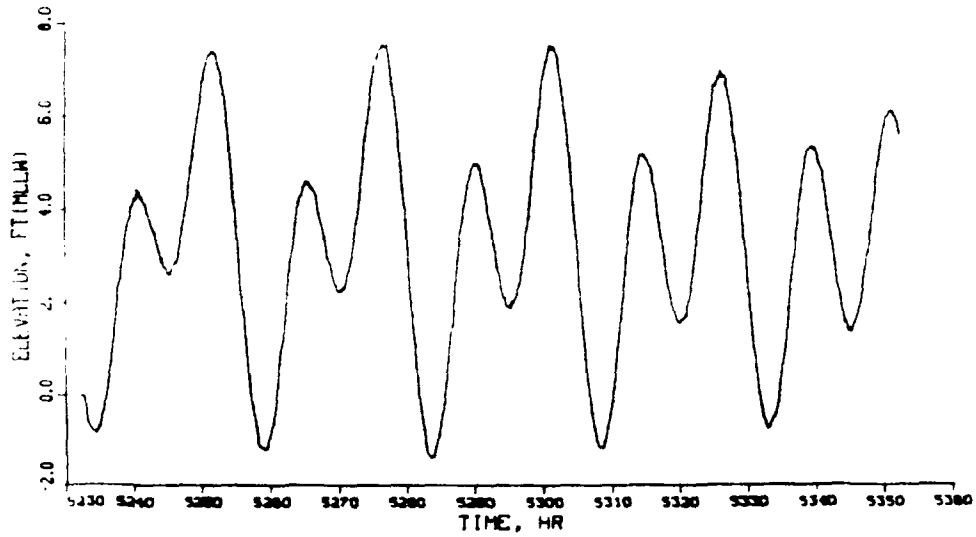
GAGE TC5

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 11



PLAN 3



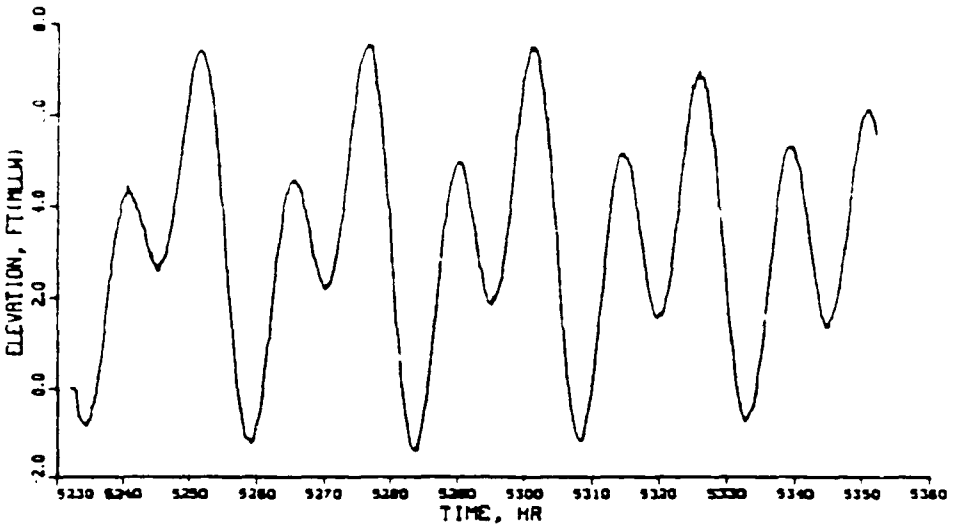
PLAN 4

TIDAL ELEVATIONS **CALIBRATION PERIOD**

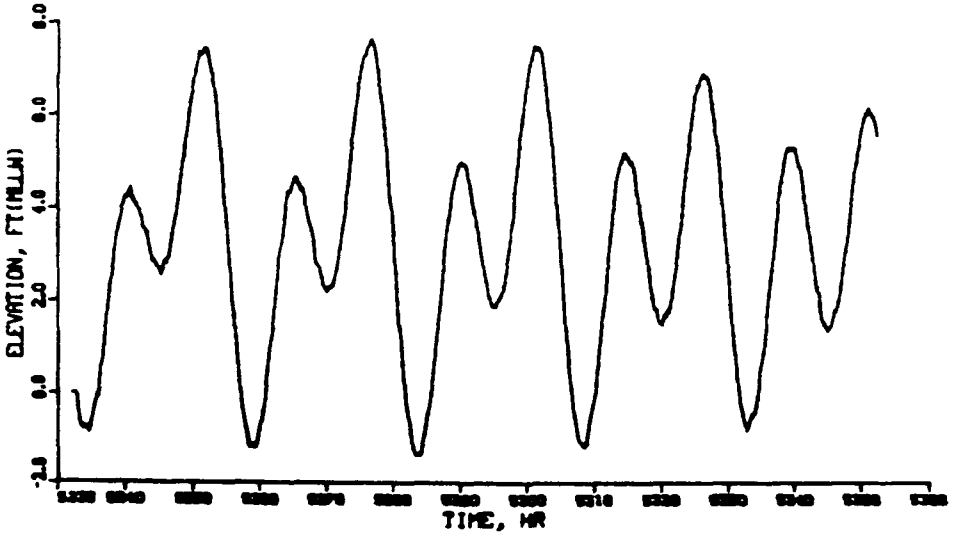
GAGE TC5

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 12



PLAN 1



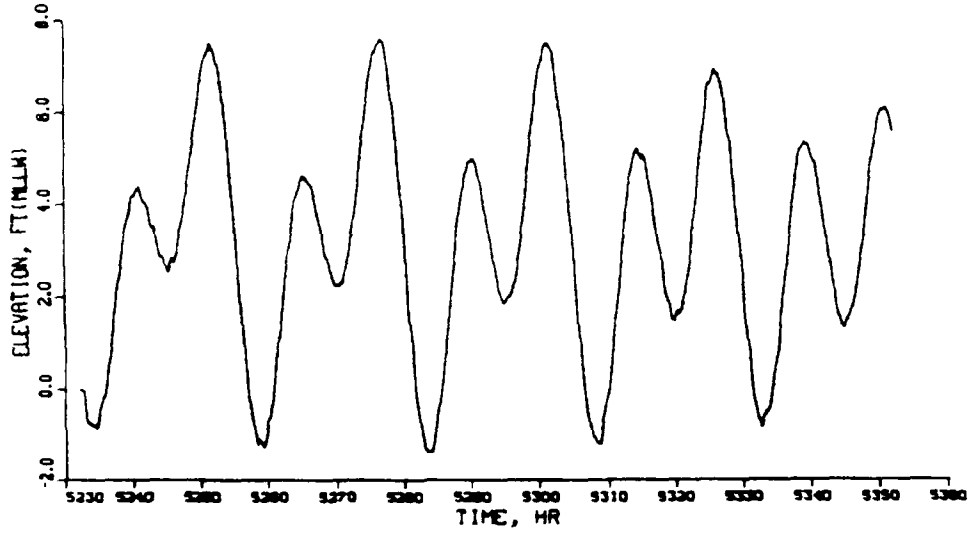
PLAN 2

TIDAL ELEVATIONS **CALIBRATION PERIOD**

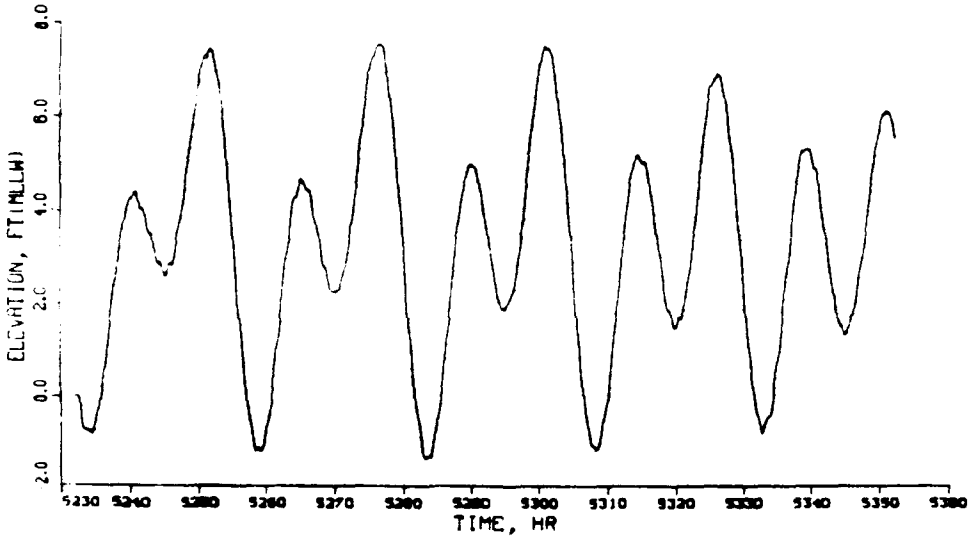
GAGE TC14

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 13



PLAN 3



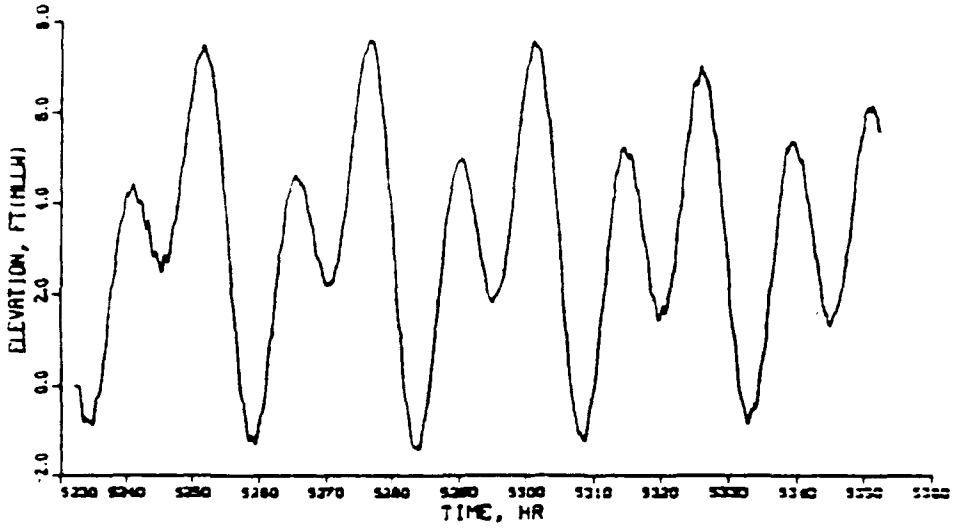
PLAN 4

TIDAL ELEVATIONS **CALIBRATION PERIOD**

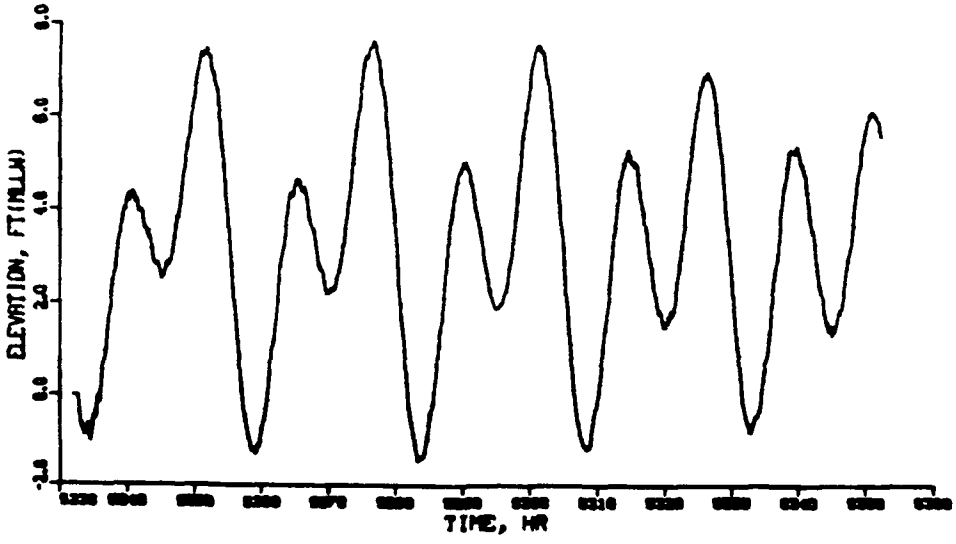
GAGE TC14

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 14



PLAN 1



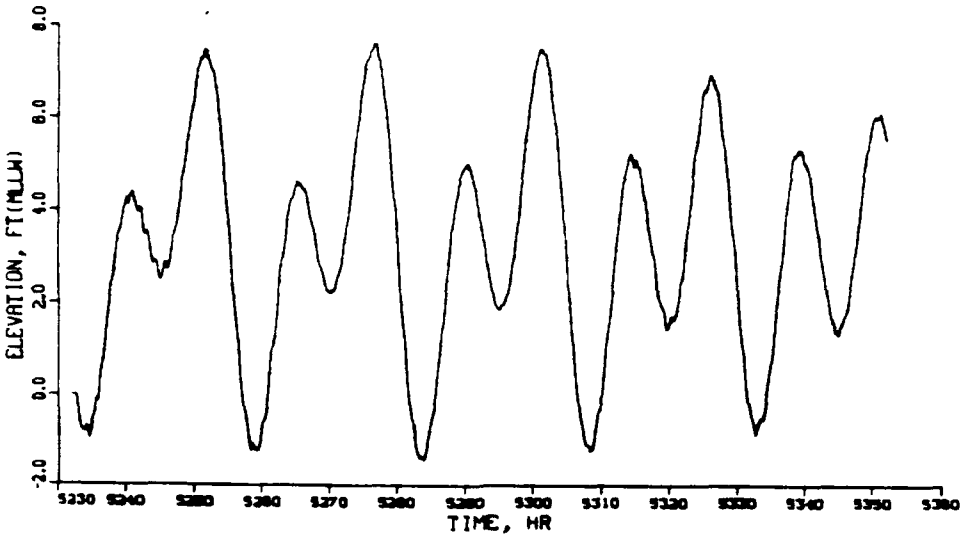
PLAN 2

TIDAL ELEVATIONS **CALIBRATION PERIOD**

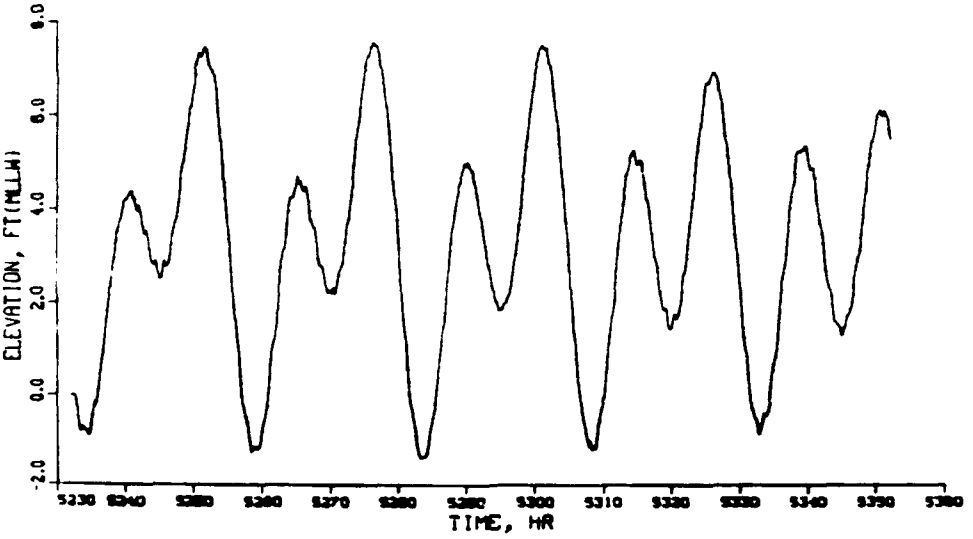
GAGE TC17

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 15



PLAN 3



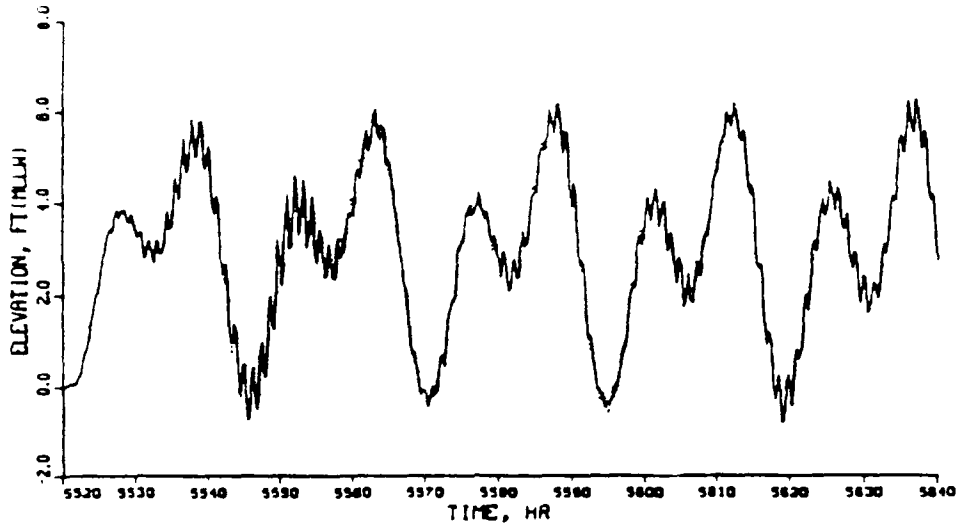
PLAN 4

TIDAL ELEVATIONS **CALIBRATION PERIOD**

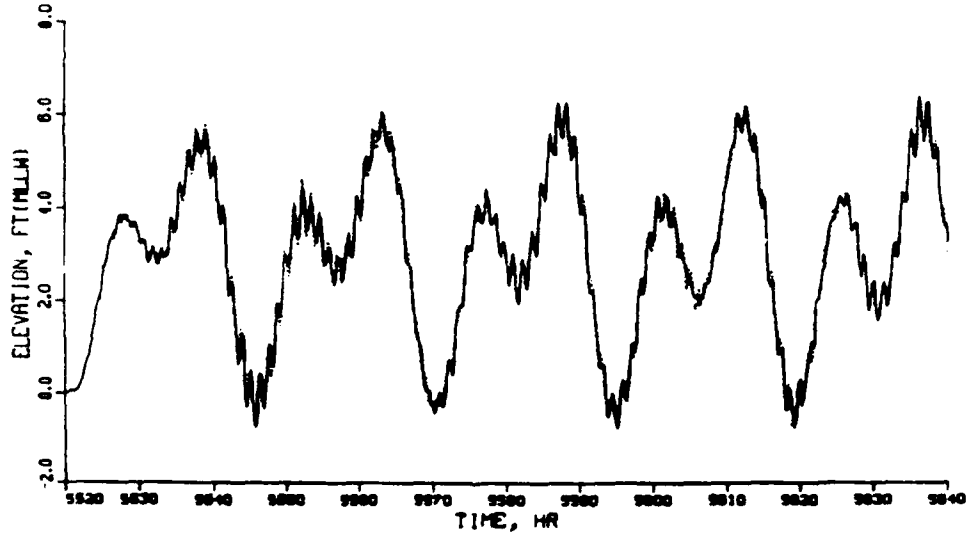
GAGE TC17

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 16



PLAN 1



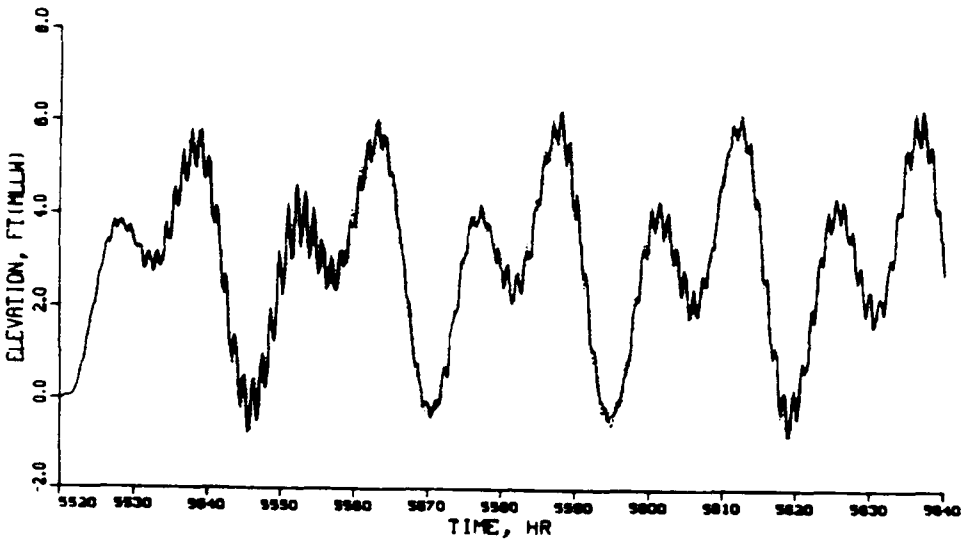
PLAN 2

TIDAL ELEVATIONS **VERIFICATION PERIOD**

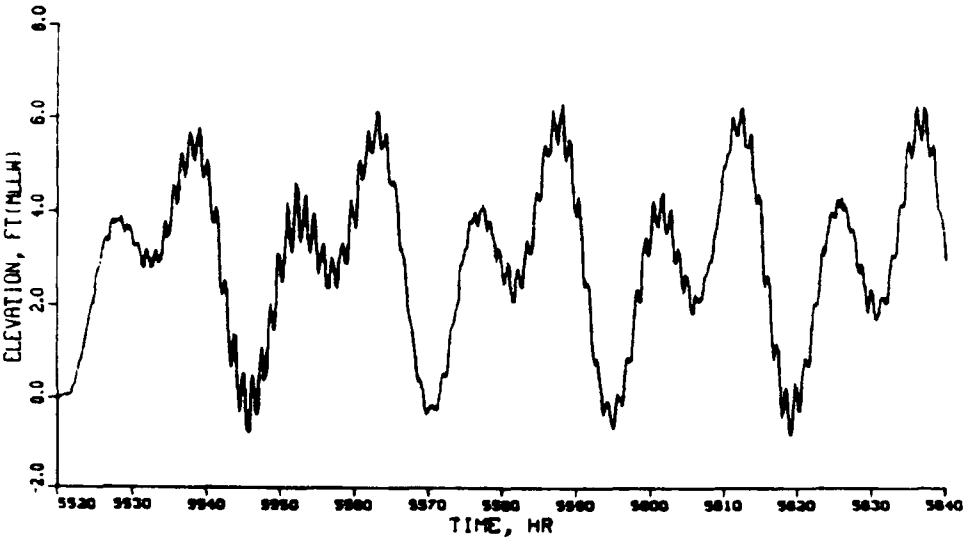
GAGE TC1

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 17



PLAN 3



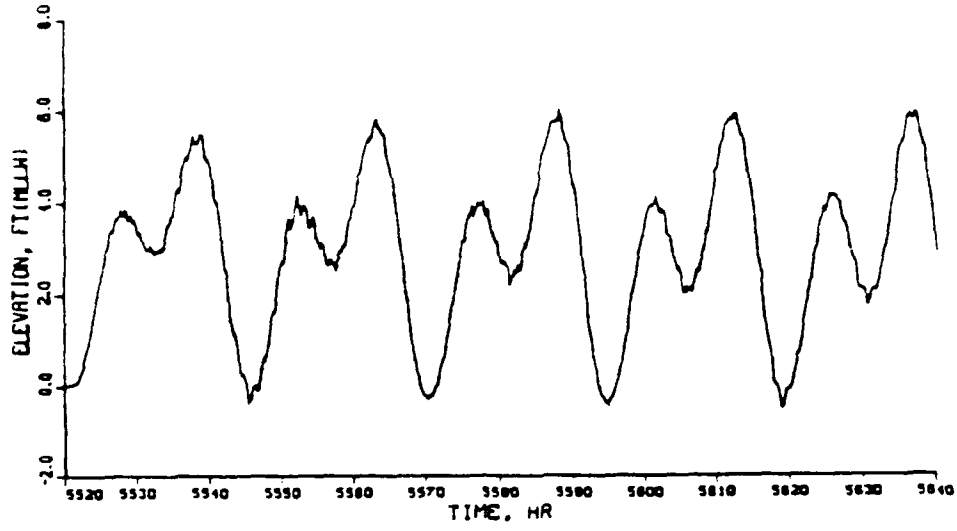
PLAN 4

TIDAL ELEVATIONS **VERIFICATION PERIOD**

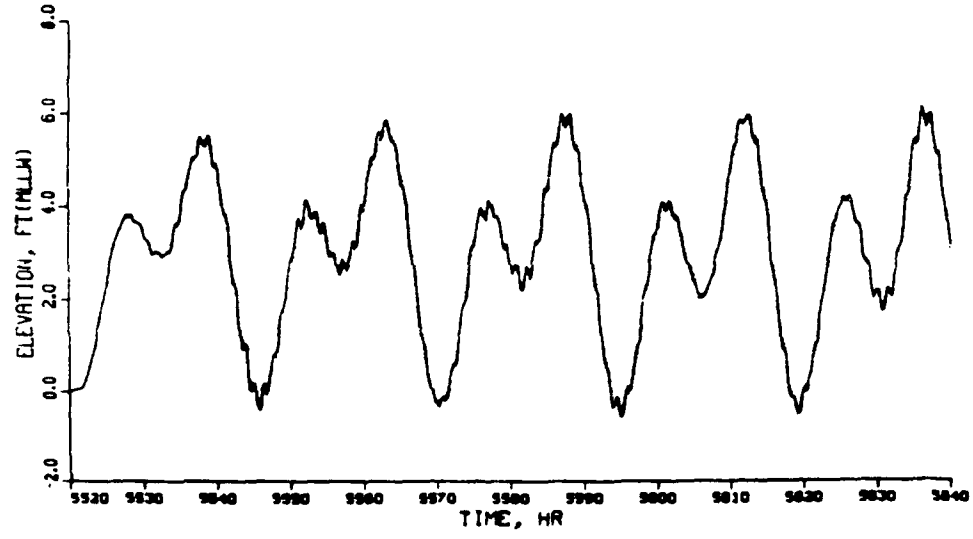
GAGE TC1

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 18



PLAN 1



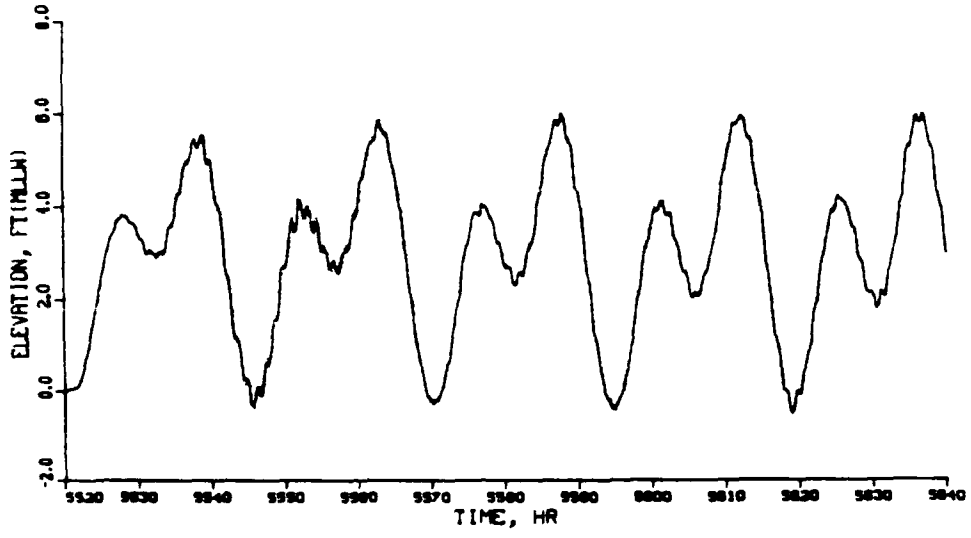
PLAN 2

TIDAL ELEVATIONS **VERIFICATION PERIOD**

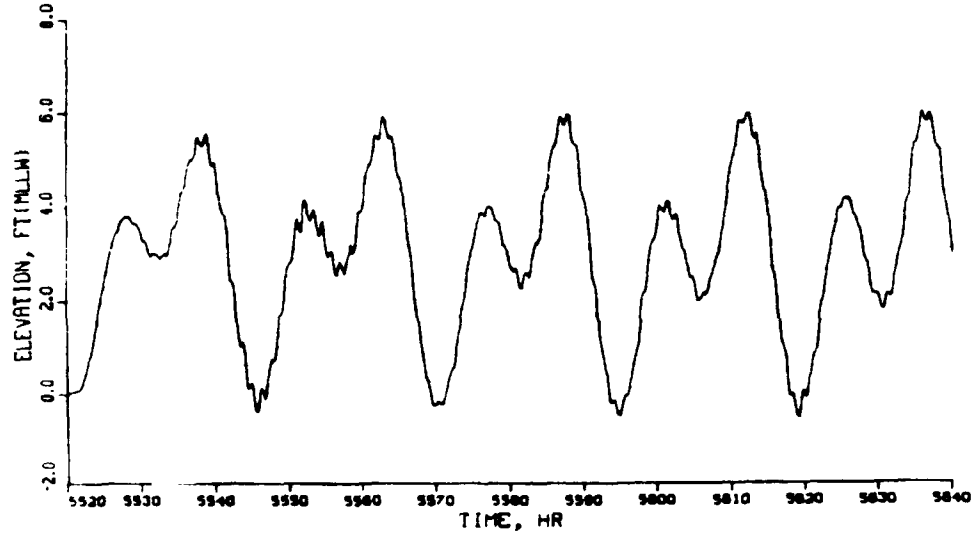
GAGE TC3

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 19



PLAN 3



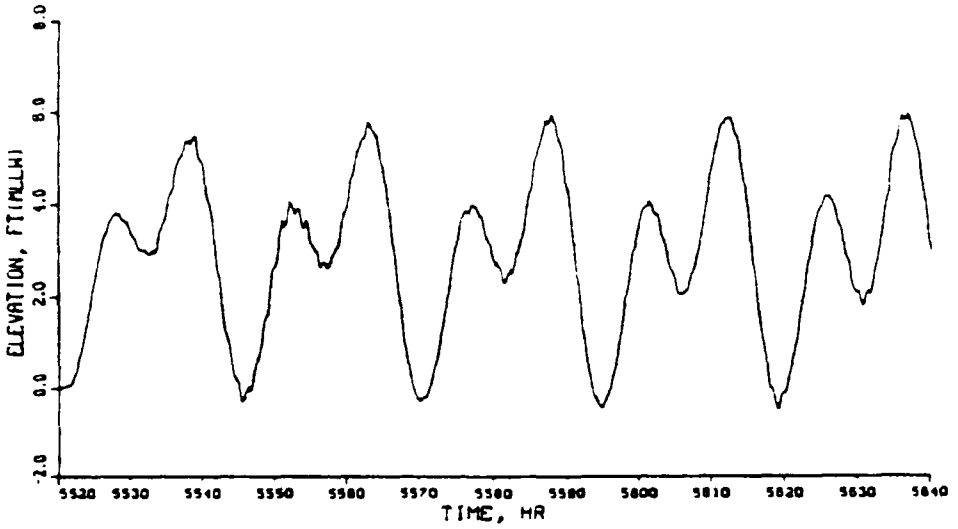
PLAN 4

TIDAL ELEVATIONS **VERIFICATION PERIOD**

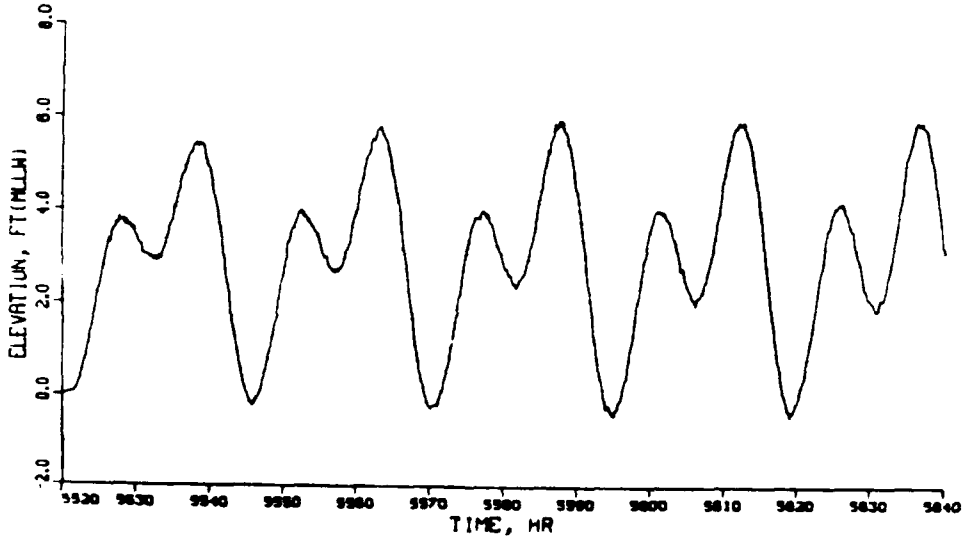
GAGE TC3

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 20



PLAN 1



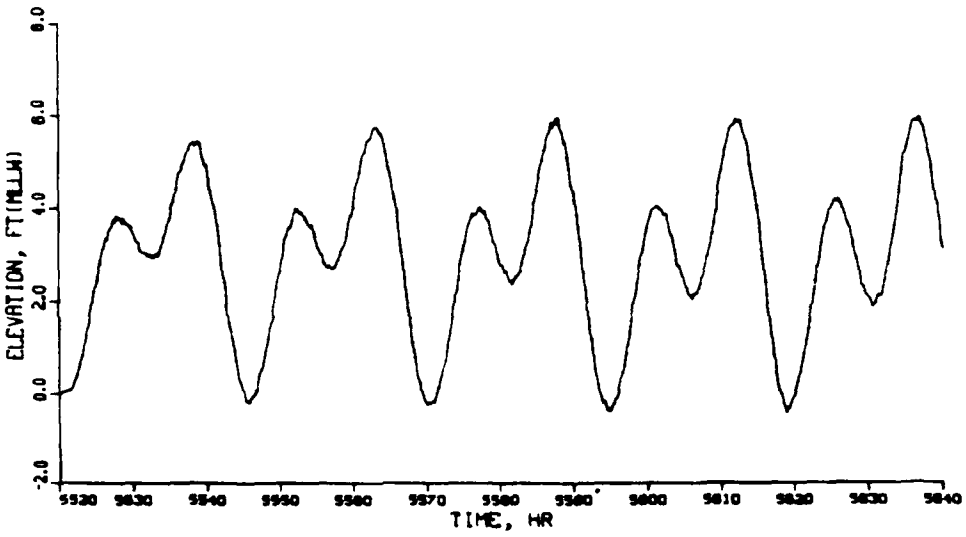
PLAN 2

TIDAL ELEVATIONS **VERIFICATION PERIOD**

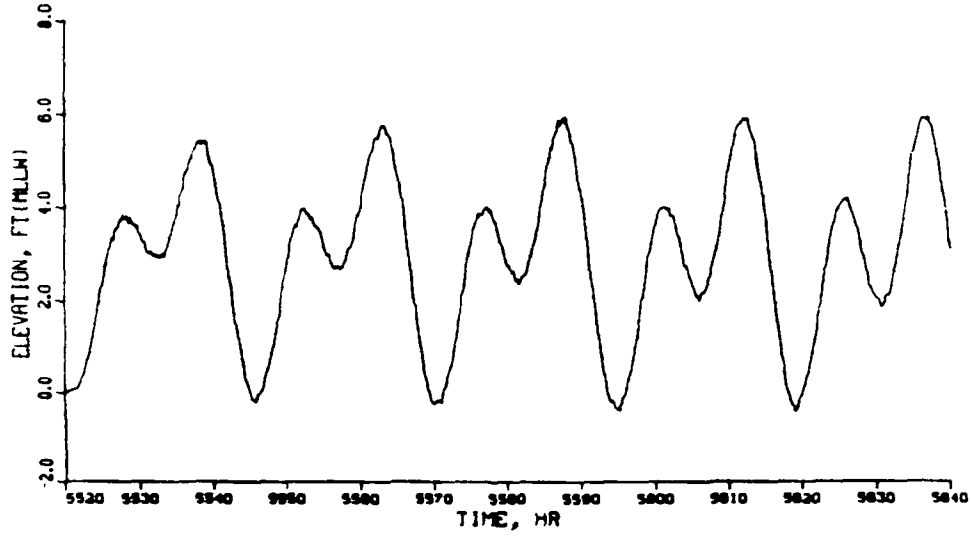
GAGE TC5

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 21



PLAN 3



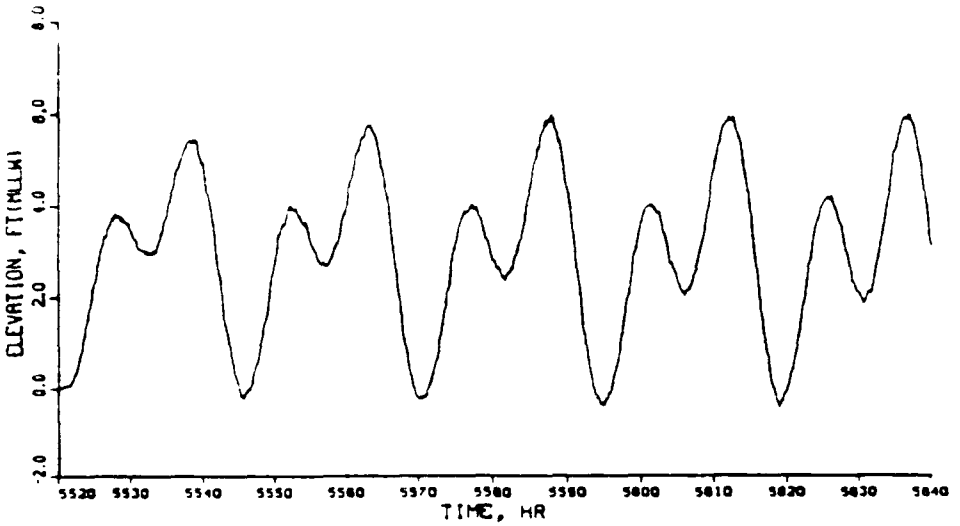
PLAN 4

TIDAL ELEVATIONS **VERIFICATION PERIOD**

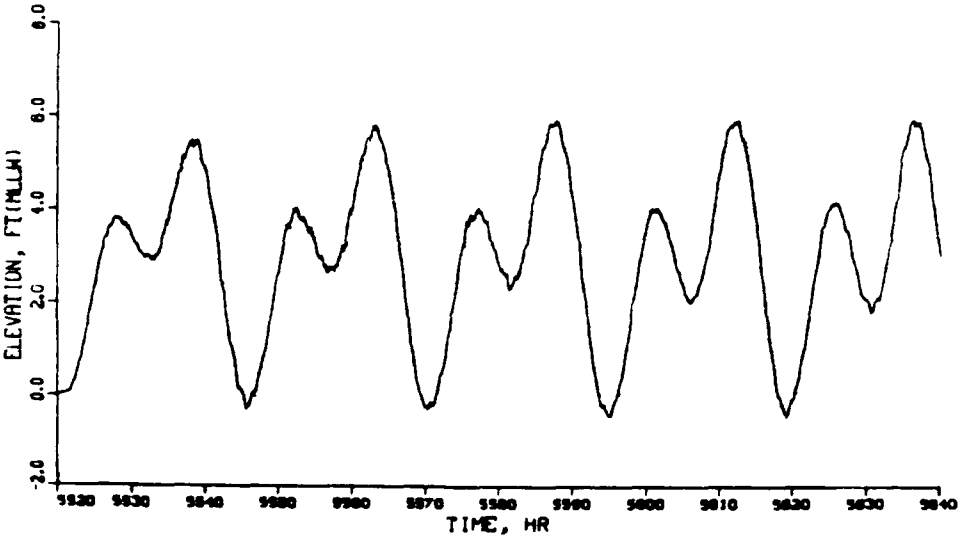
GAGE TC5

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 22



PLAN 1



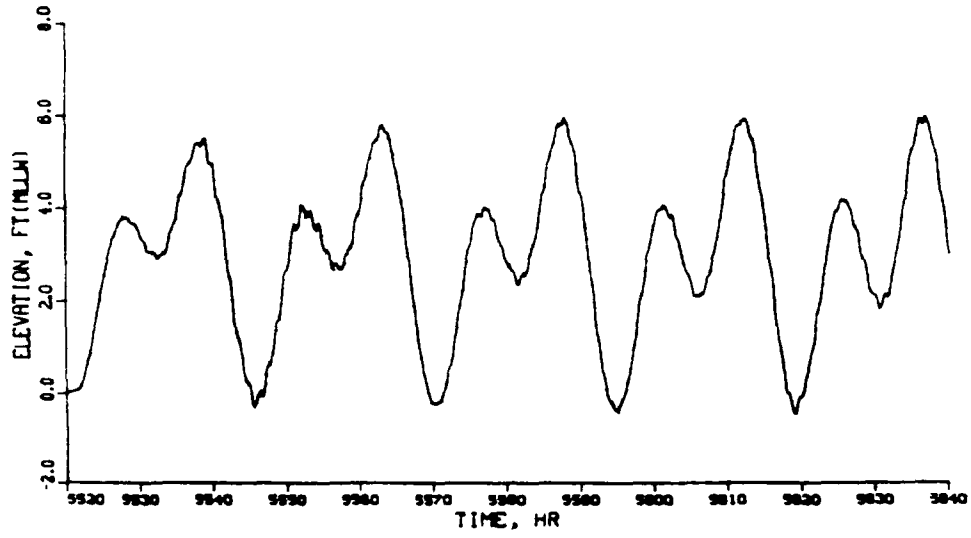
PLAN 2

TIDAL ELEVATIONS **VERIFICATION PERIOD**

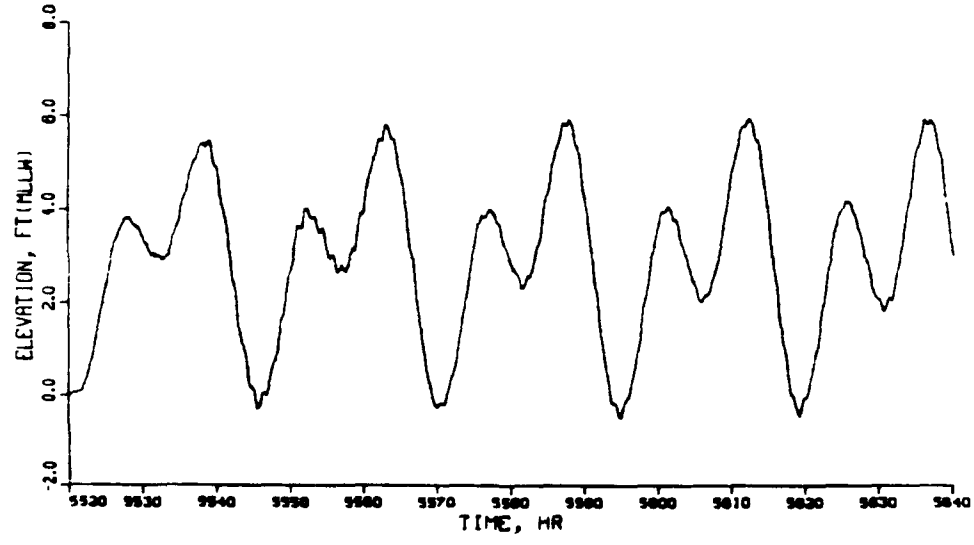
GAGE TC14

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 23



PLAN 3



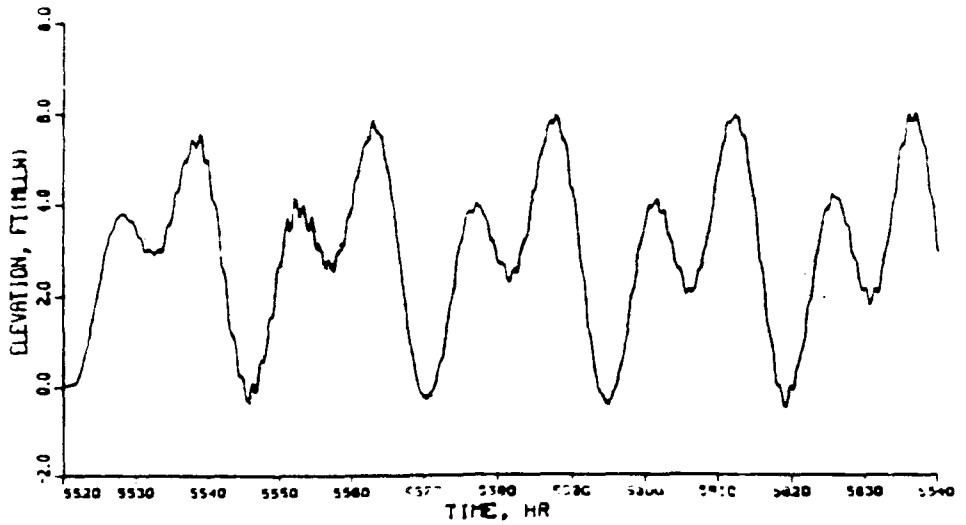
PLAN 4

TIDAL ELEVATIONS **VERIFICATION PERIOD**

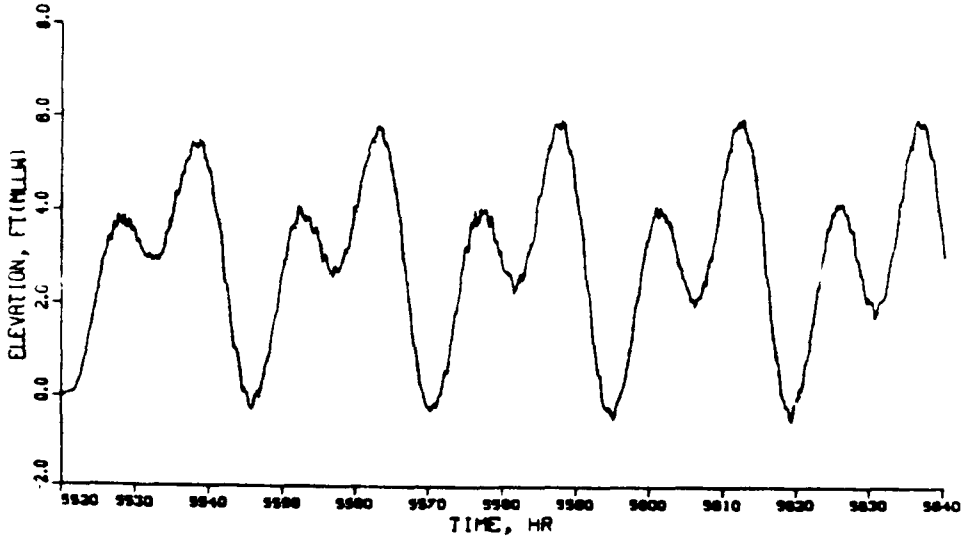
GAGE TC14

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 24



PLAN 1



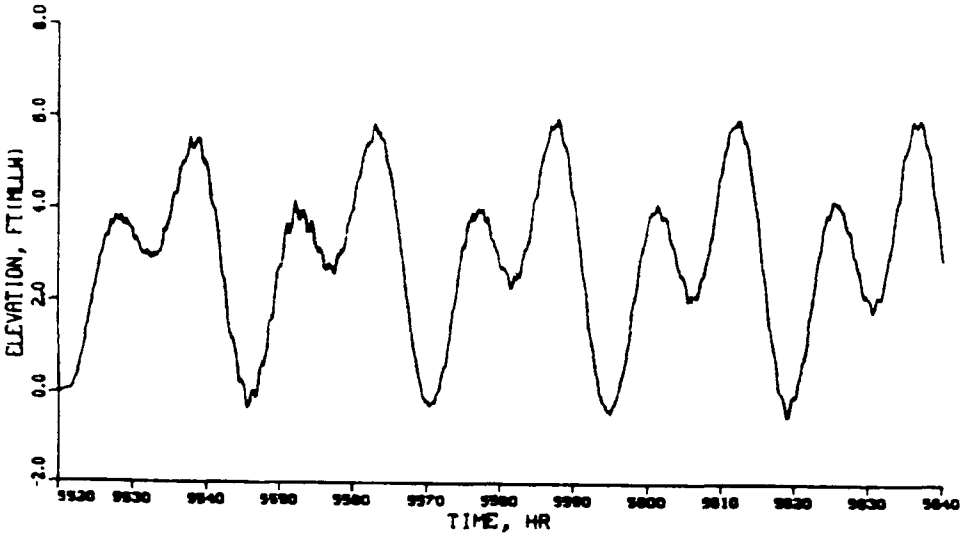
PLAN 2

TIDAL ELEVATIONS **VERIFICATION PERIOD**

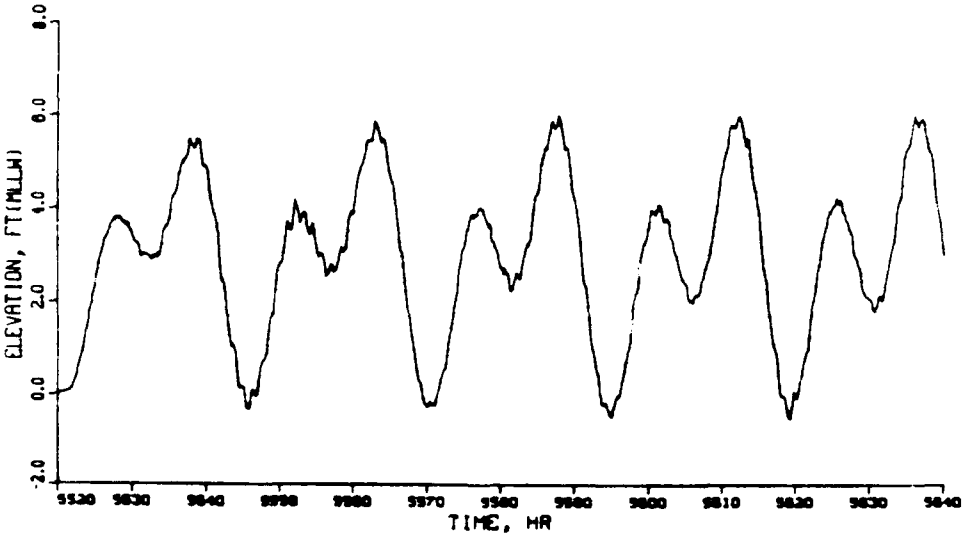
GAGE TC17

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 25



PLAN 3



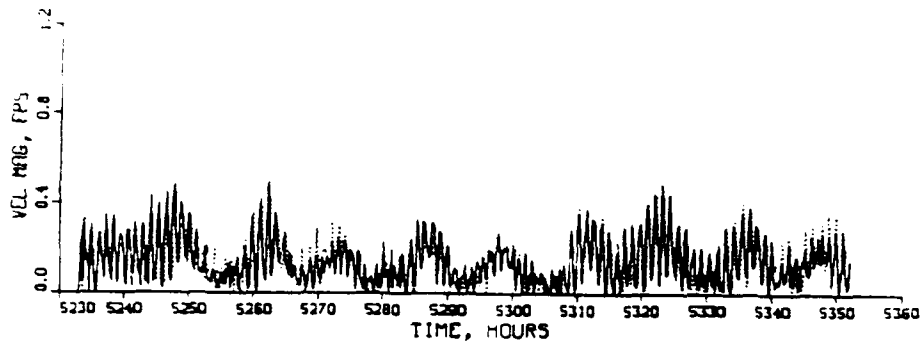
PLAN 4

TIDAL ELEVATIONS **VERIFICATION PERIOD**

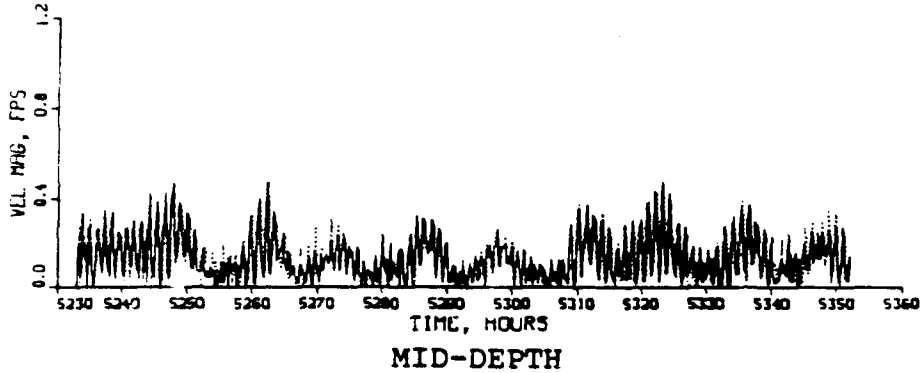
GAGE TC17

PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

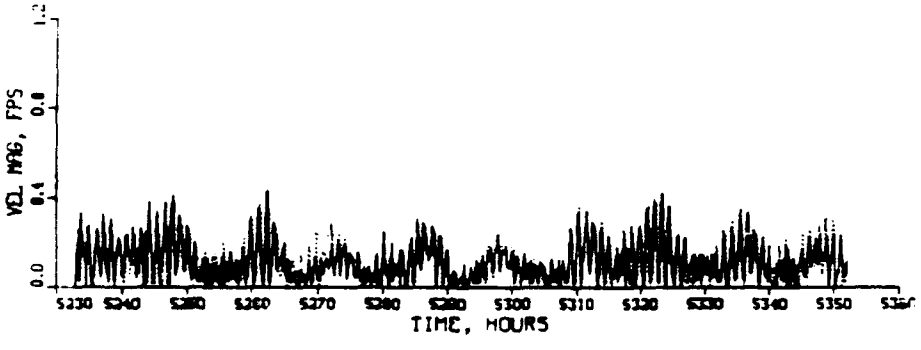
PLATE 26



SURFACE



MID-DEPTH



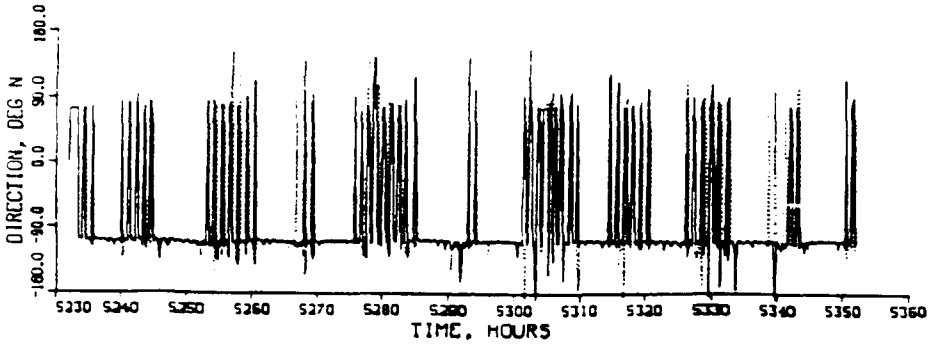
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

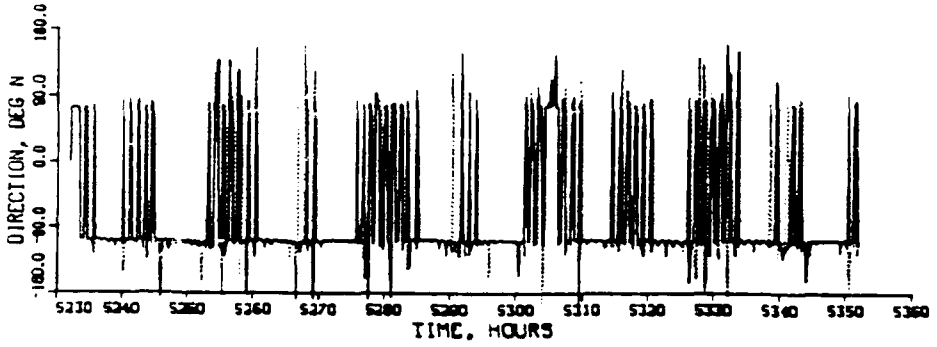
MAGNITUDE GAGE C1

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

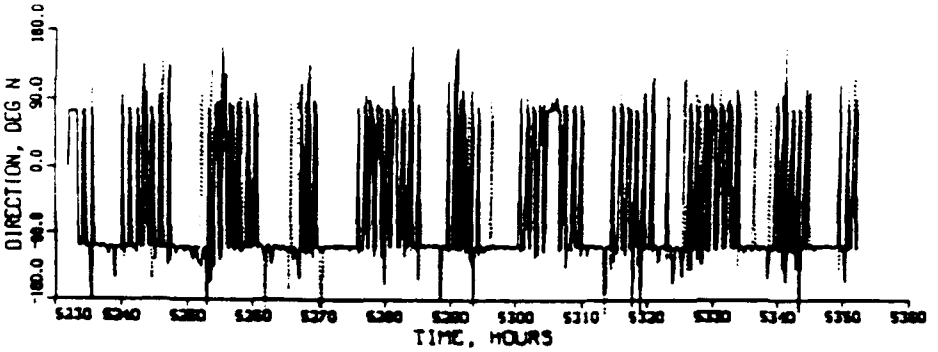
PLATE 27



SURFACE



MID-DEPTH



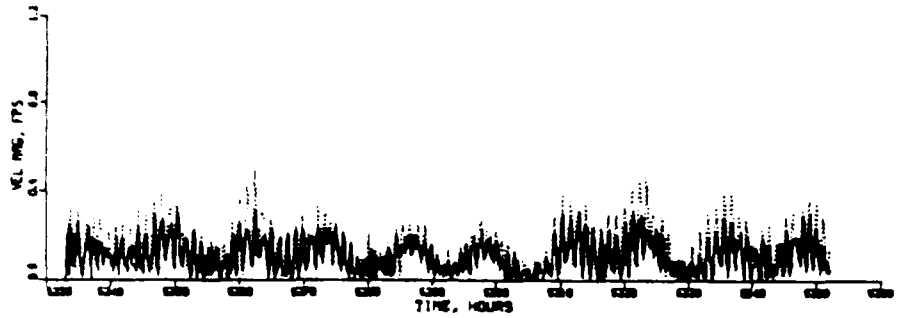
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

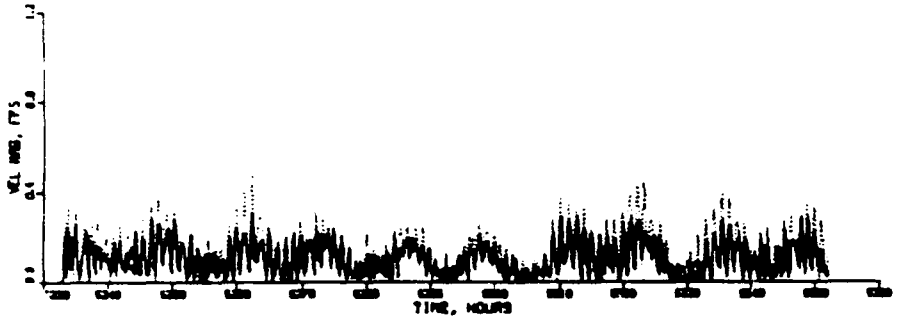
DIRECTION GAGE C1

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

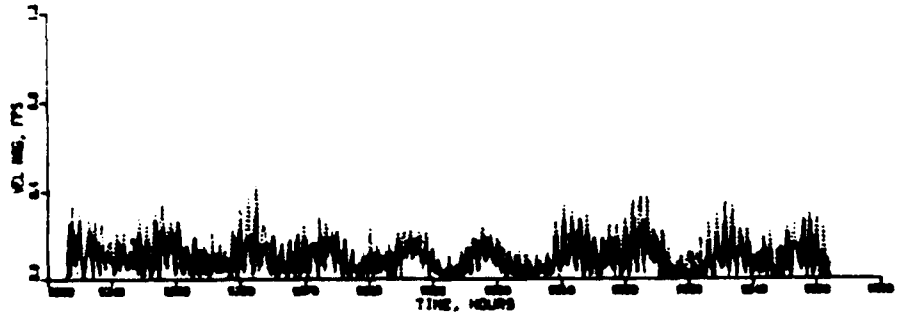
PLATE 28



SURFACE



MID-DEPTH



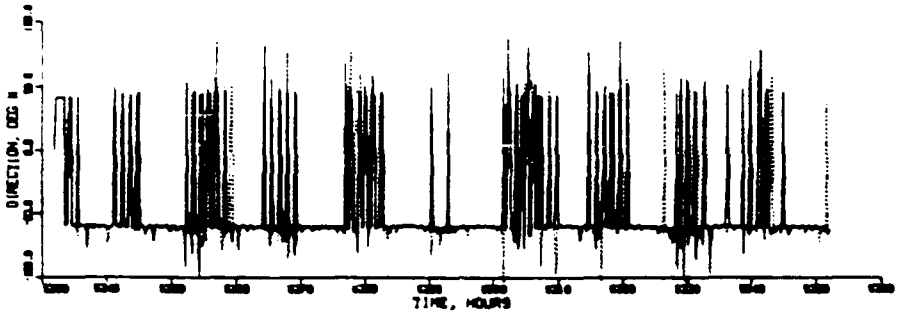
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

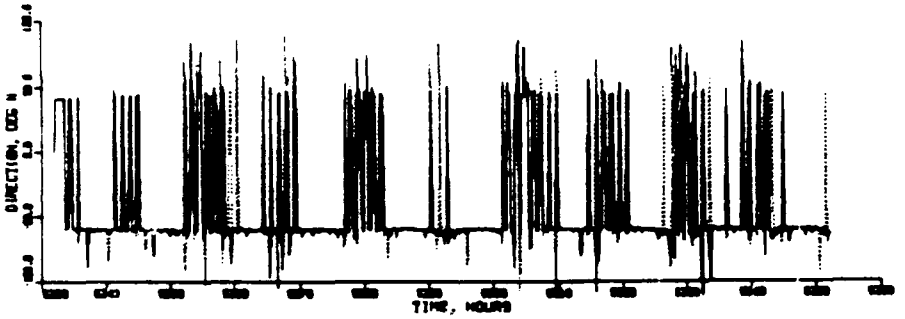
MAGNITUDE GAGE C1

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

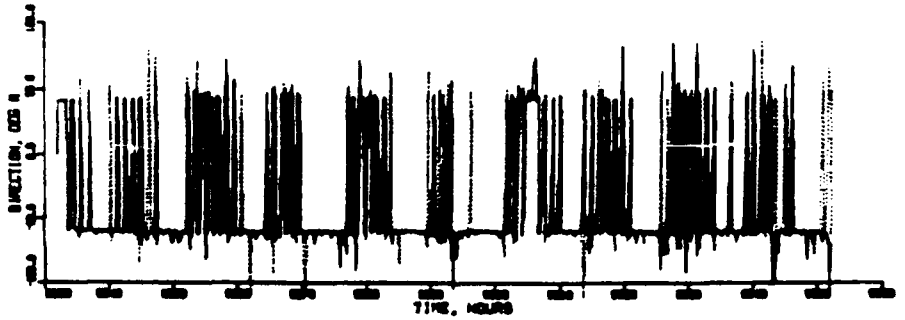
PLATE 29



SURFACE



MID-DEPTH



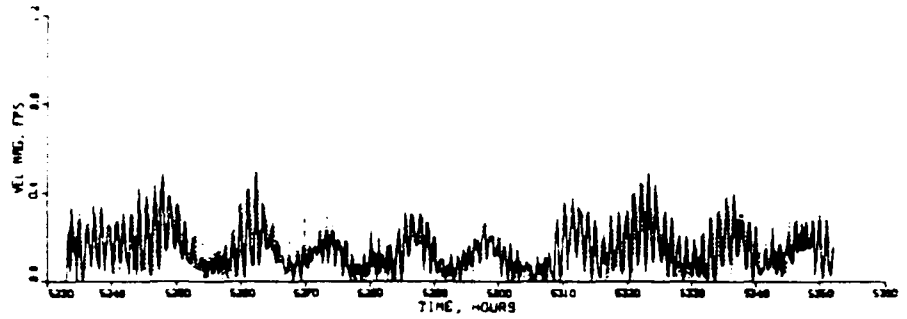
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

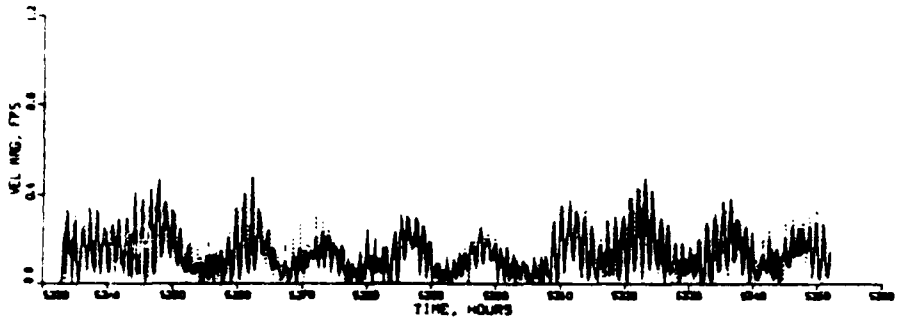
DIRECTION GAGE C1

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

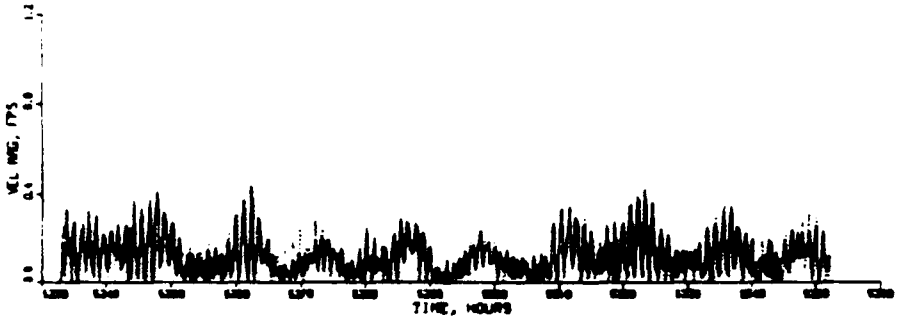
PLATE 30



SURFACE



MID-DEPTH



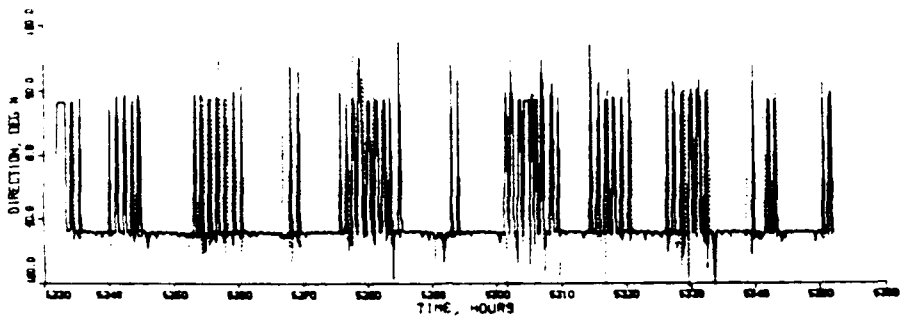
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

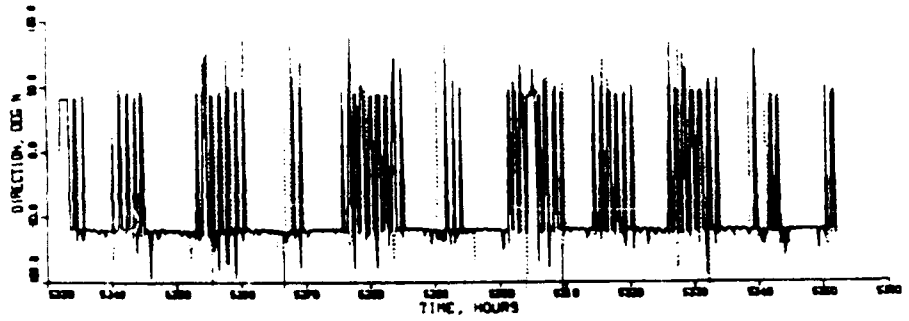
MAGNITUDE GAGE C1

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

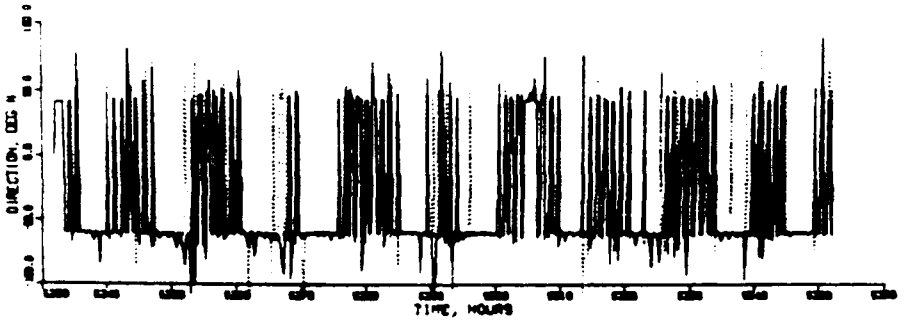
PLATE 31



SURFACE



MID-DEPTH



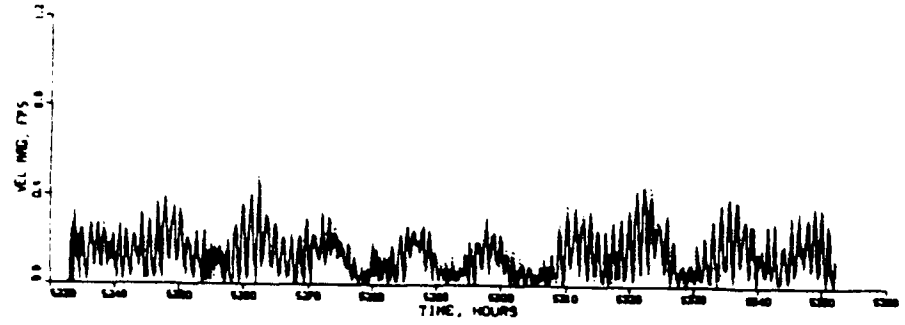
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

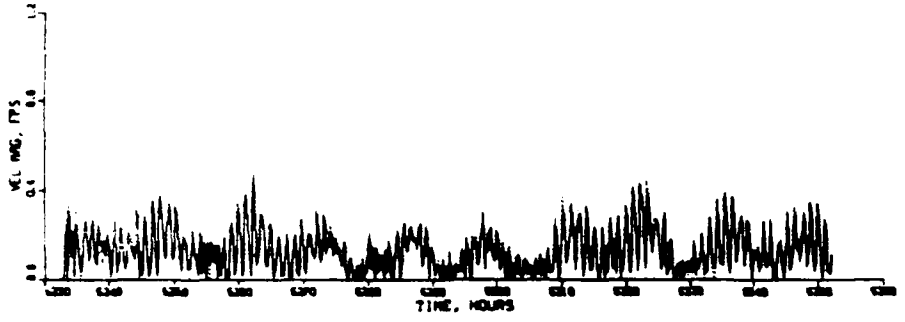
DIRECTION GAGE C1

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

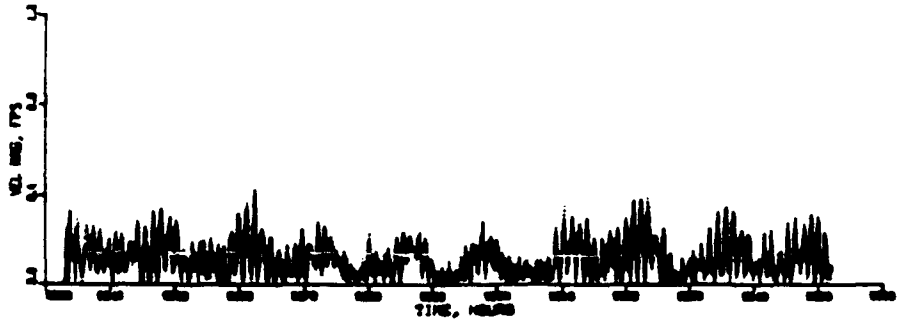
PLATE 32



SURFACE



MID-DEPTH



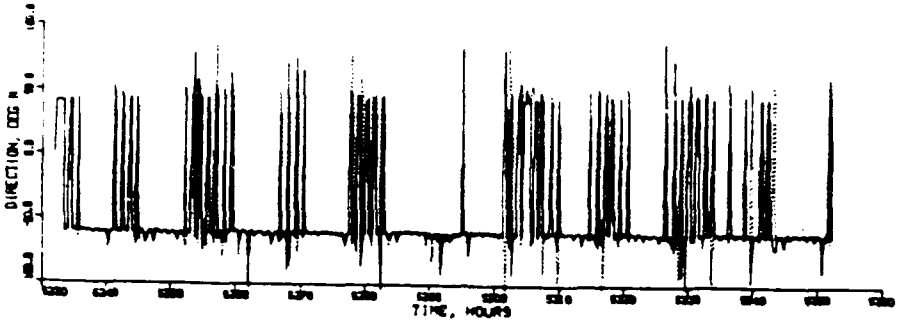
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

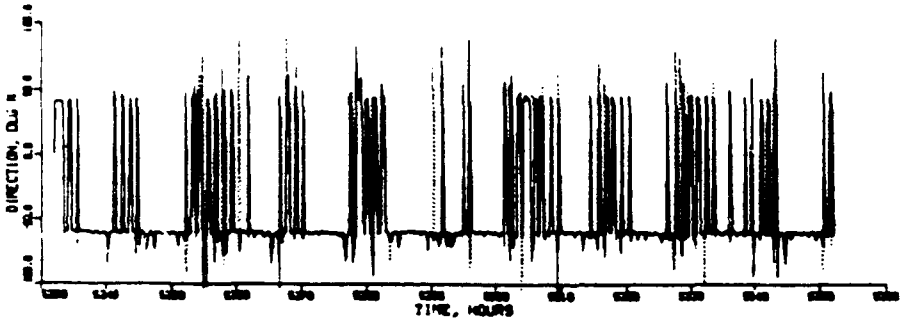
MAGNITUDE GAGE C1

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

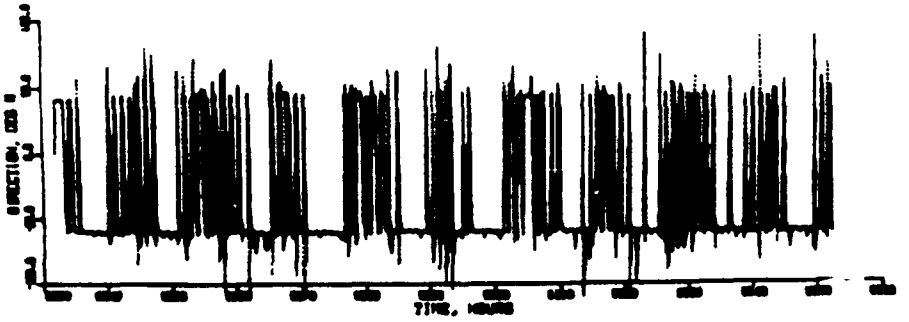
PLATE 33



SURFACE



MID-DEPTH



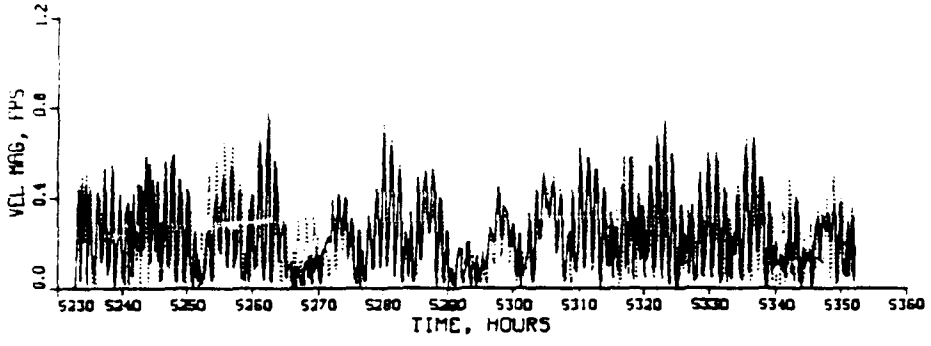
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

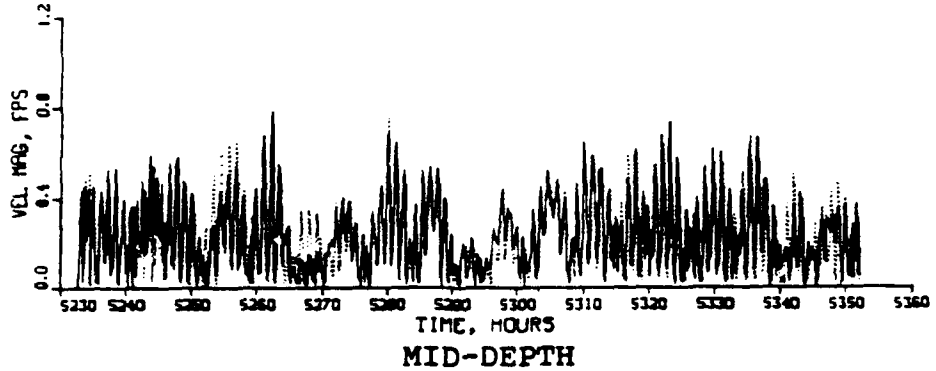
DIRECTION GAGE C1

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

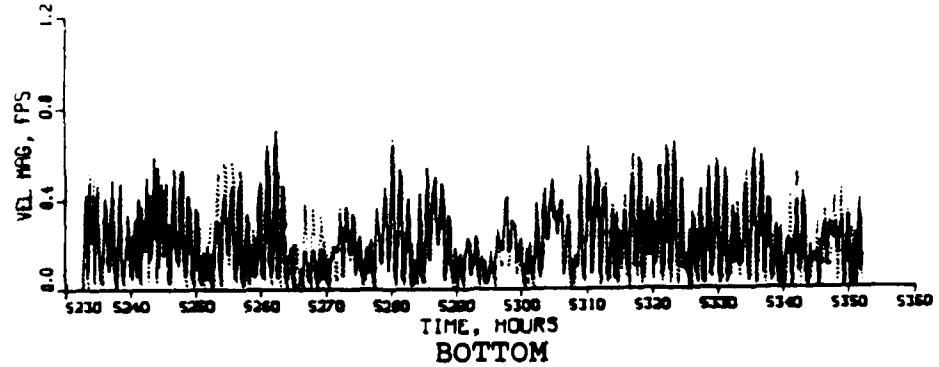
PLATE 34



SURFACE



MID-DEPTH



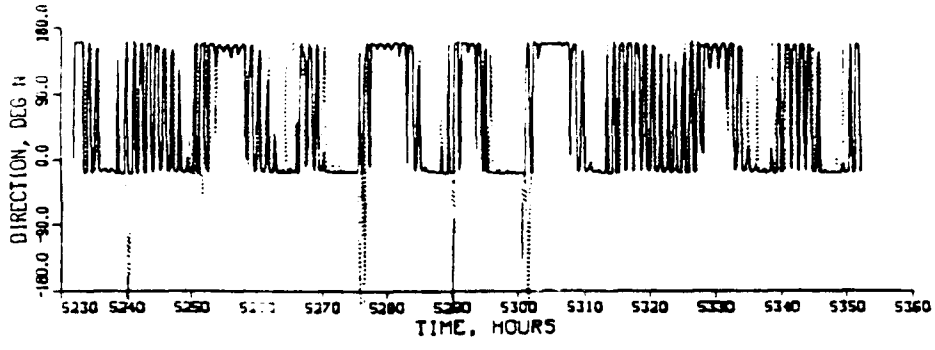
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

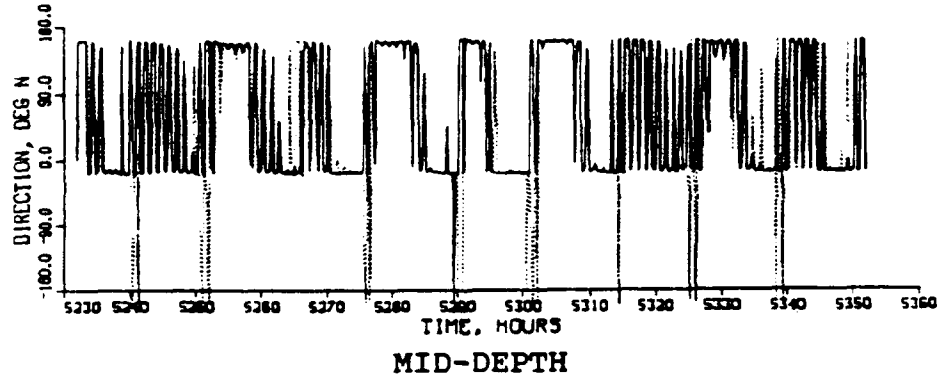
MAGNITUDE GAGE C2

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

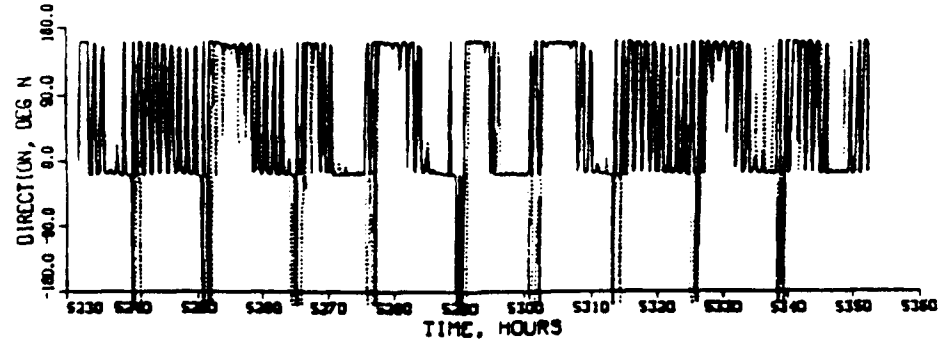
PLATE 35



SURFACE



MID-DEPTH



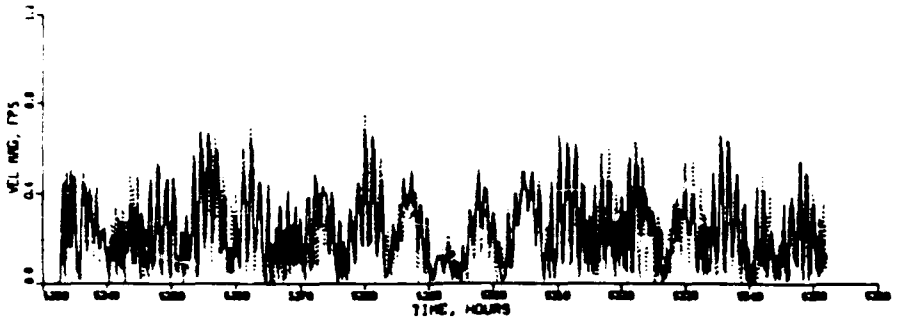
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

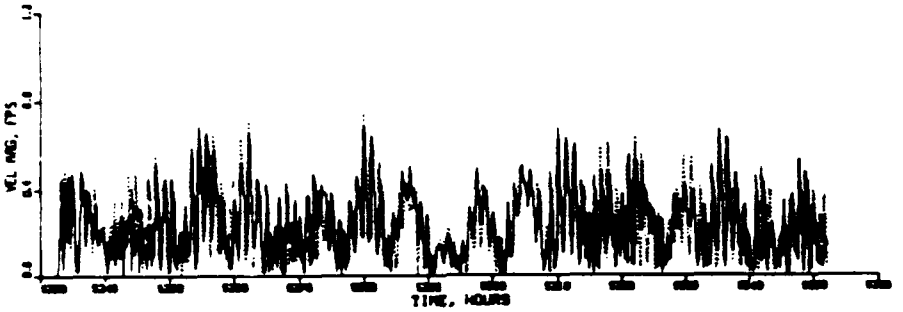
DIRECTION GAGE C2

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

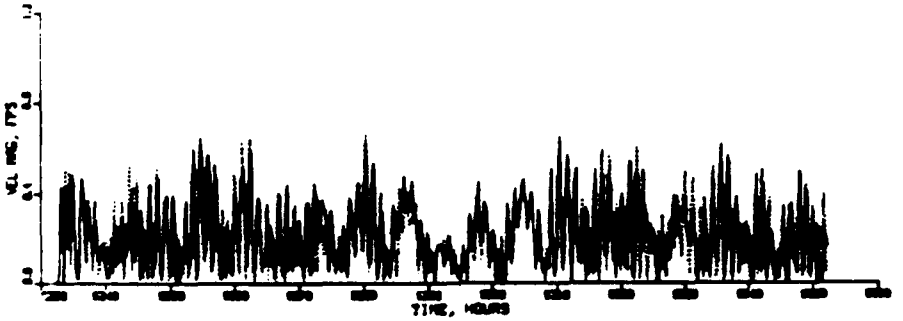
PLATE 36



SURFACE



MID-DEPTH



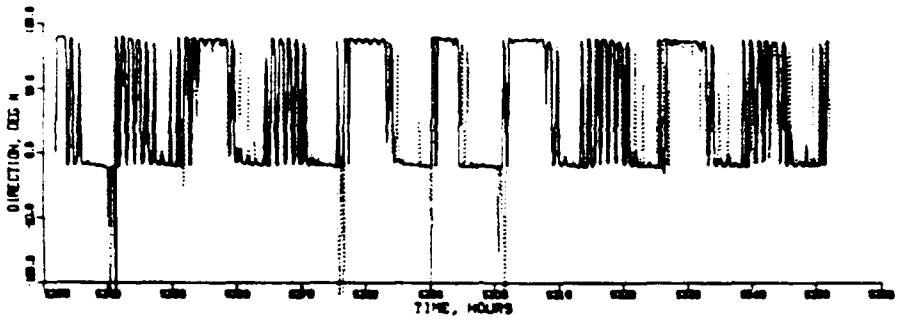
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

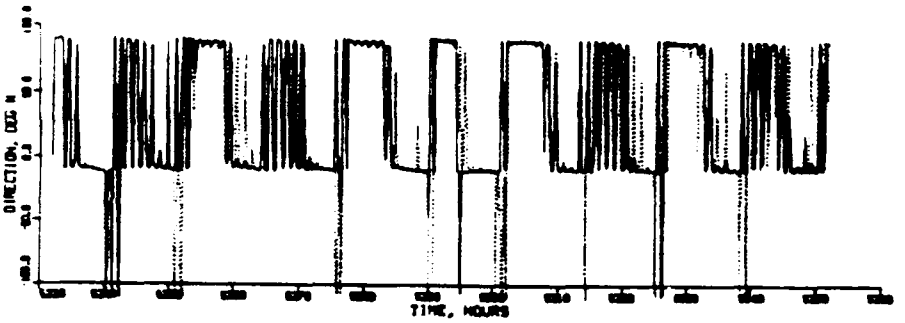
MAGNITUDE GAGE C2

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 37



SURFACE



MID-DEPTH

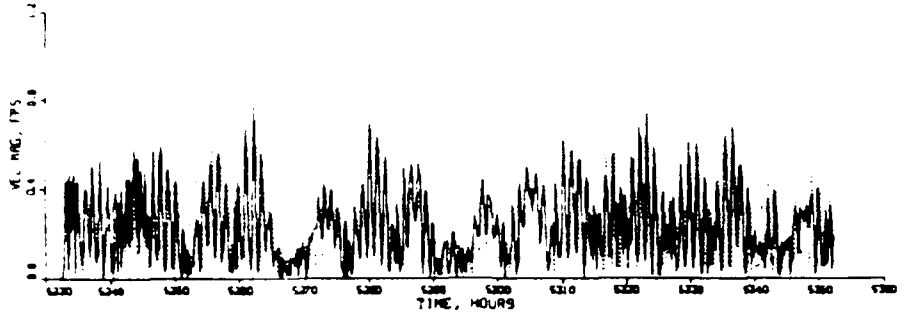
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

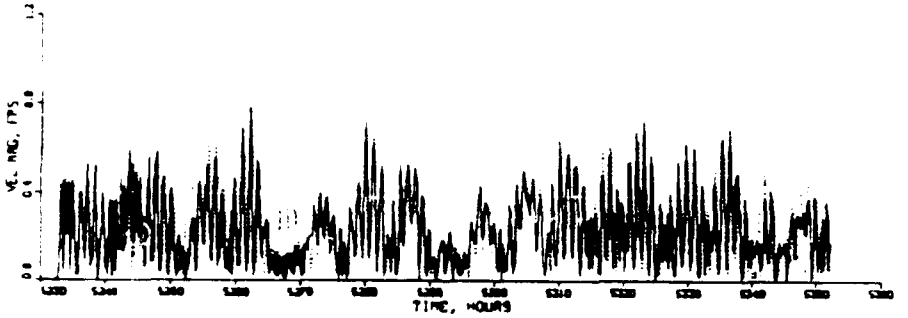
DIRECTION GAGE C2

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

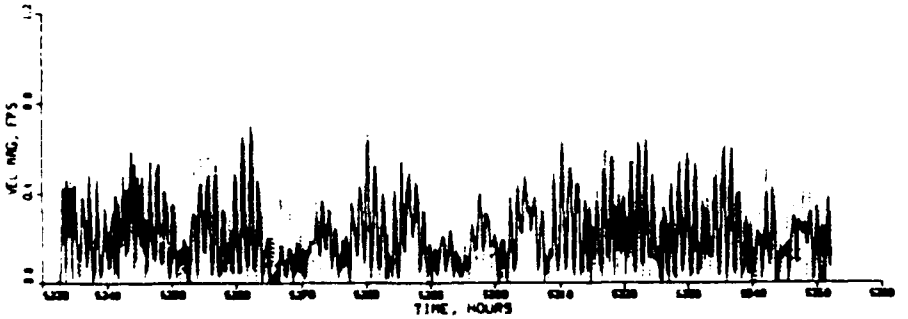
PLATE 38



SURFACE



MID-DEPTH



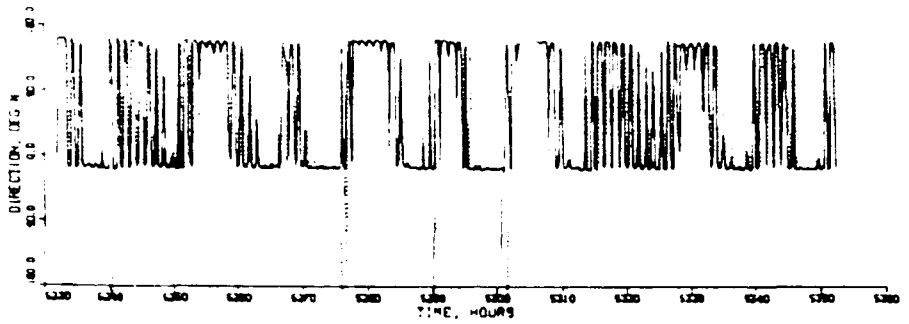
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

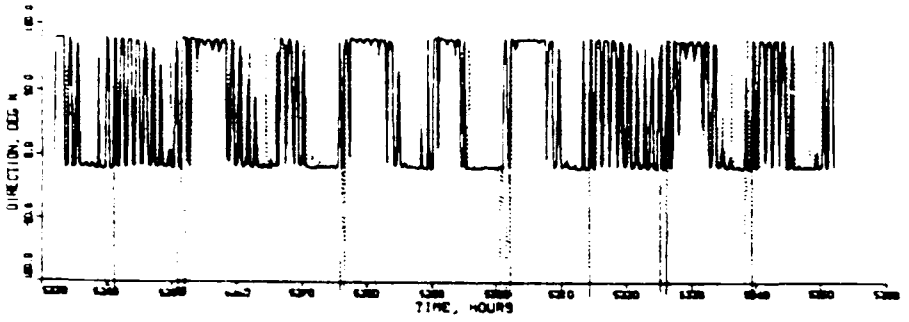
MAGNITUDE GAGE C2

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 39



SURFACE



MID-DEPTH

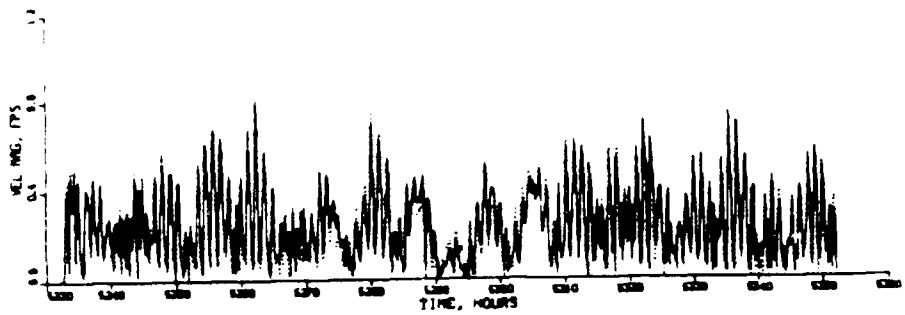
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

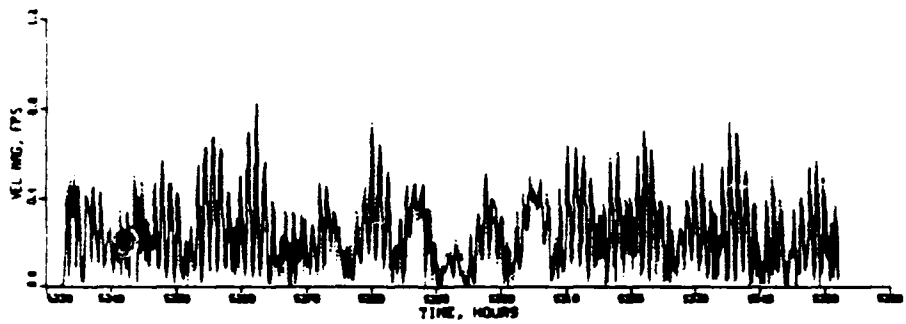
DIRECTION GAGE C2

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

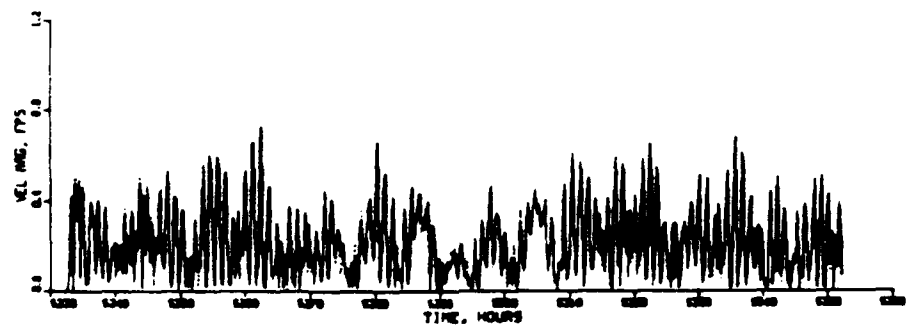
PLATE 40



SURFACE



MID-DEPTH



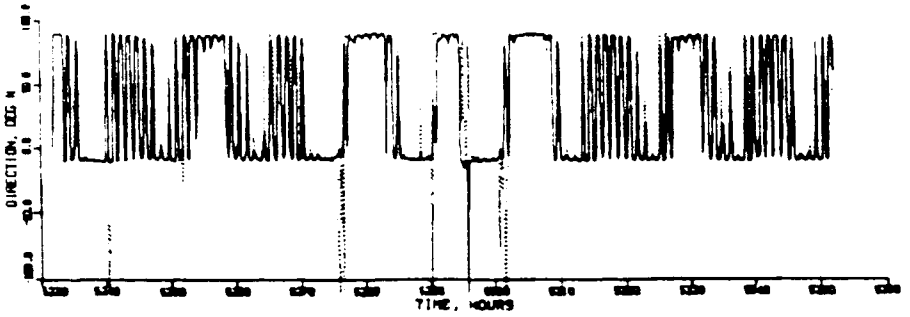
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

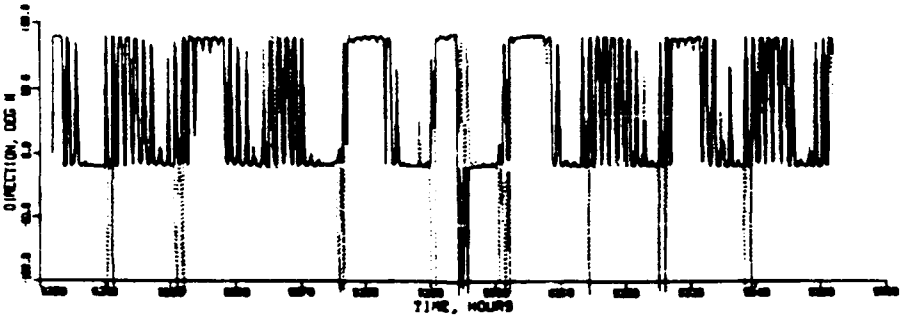
MAGNITUDE GAGE C2

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

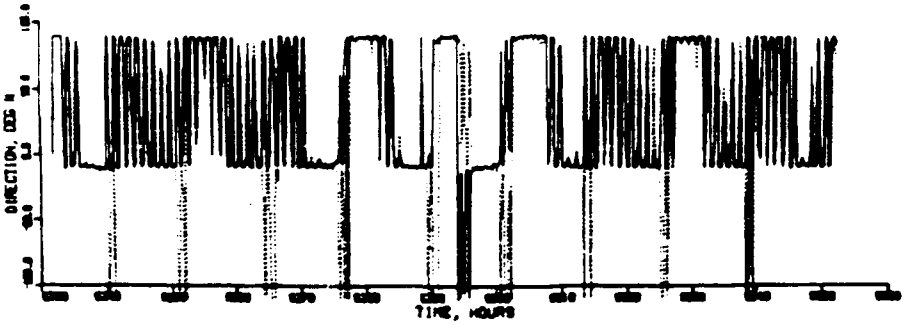
PLATE 41



SURFACE



MID-DEPTH



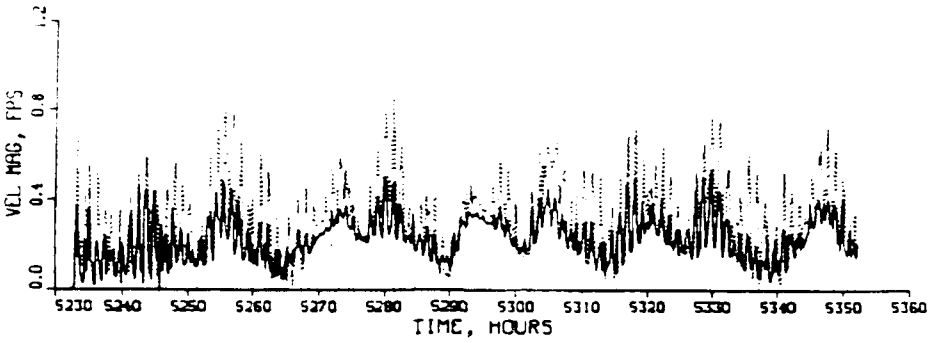
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

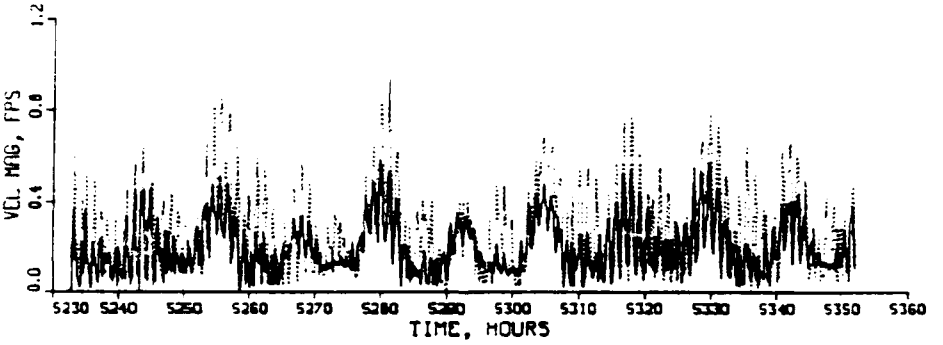
DIRECTION GAGE C2

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

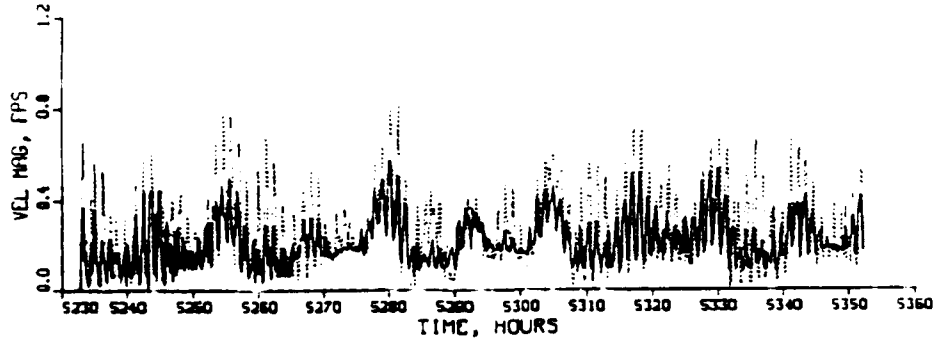
PLATE 42



SURFACE



MID-DEPTH



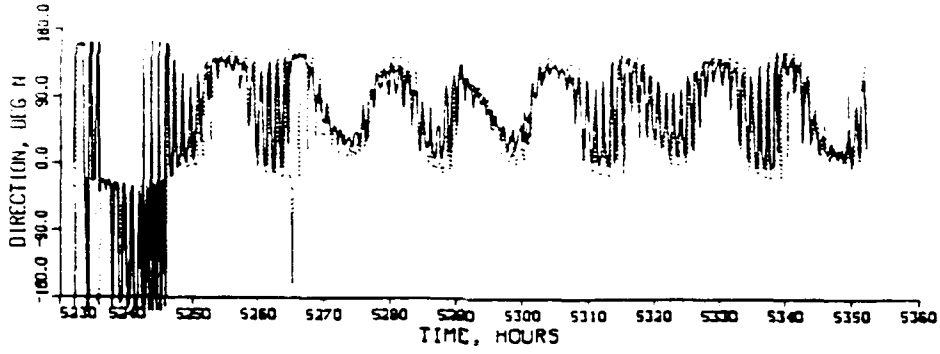
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

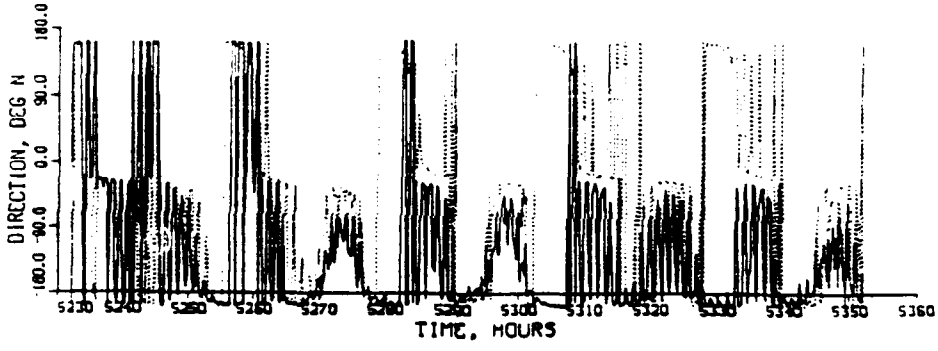
MAGNITUDE GAGE C3

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

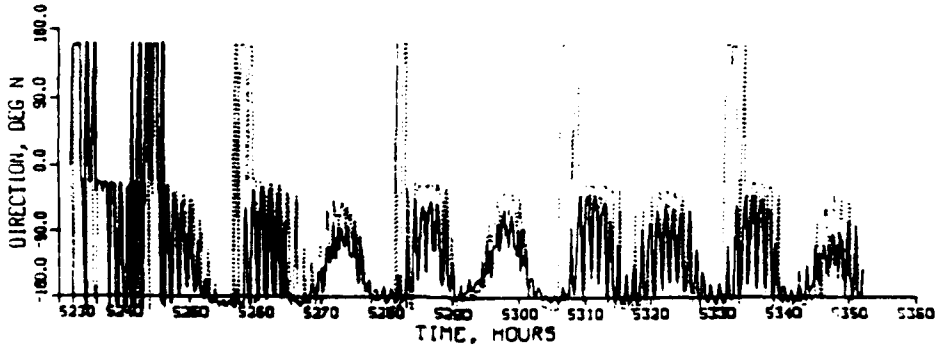
PLATE 43



SURFACE



MID-DEPTH



BOTTOM

TIDAL VELOCITY

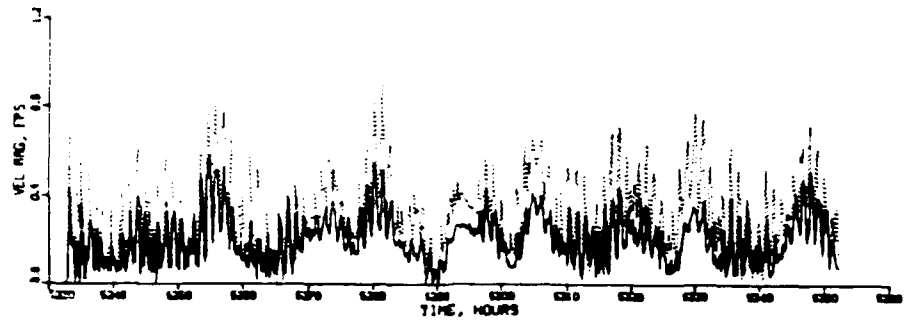
CALIBRATION PERIOD

DIRECTION

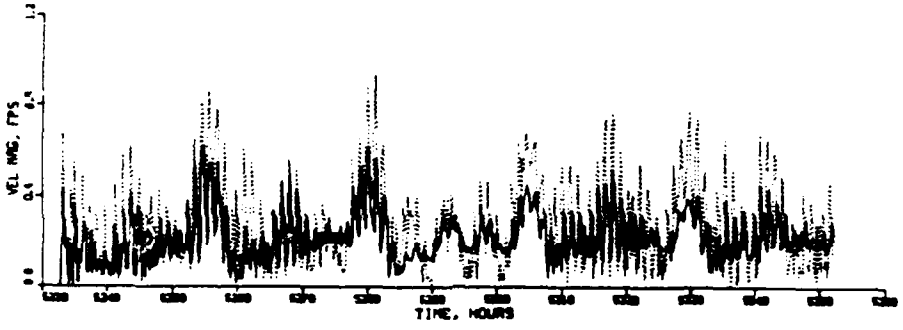
GAGE C3

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

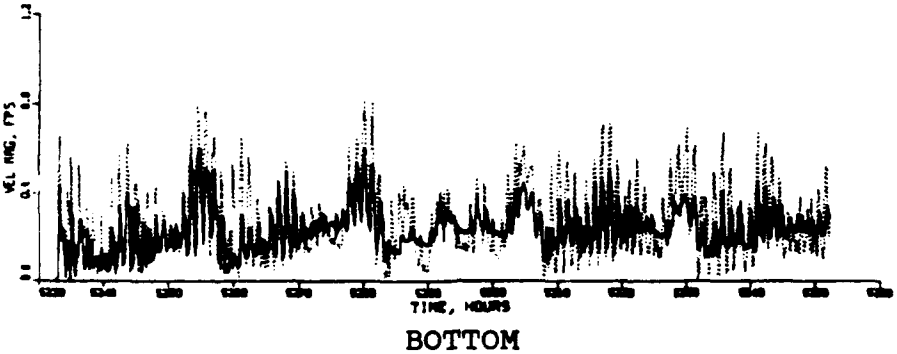
PLATE 44



SURFACE



MID-DEPTH



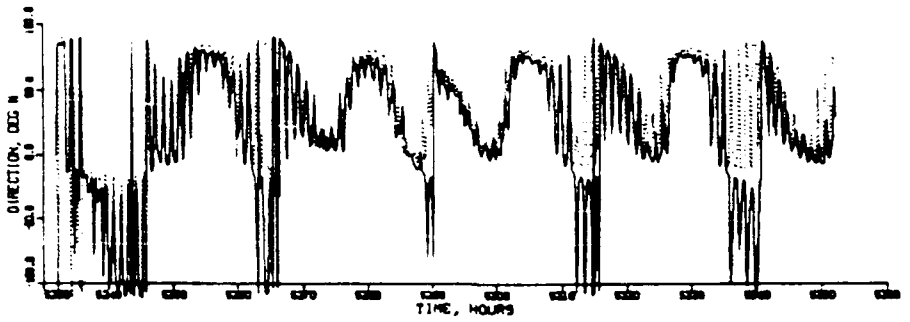
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

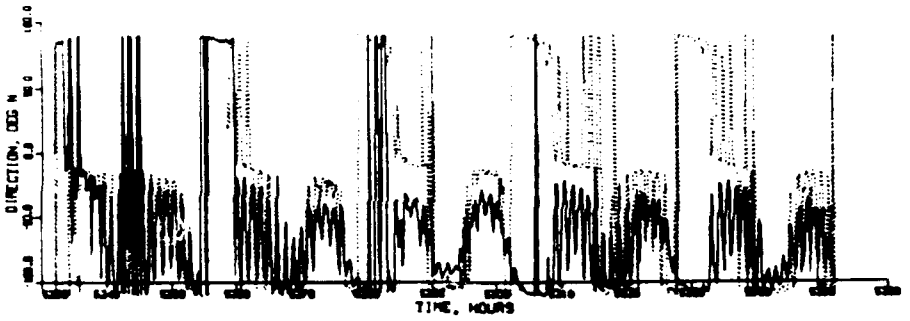
MAGNITUDE GAGE C3

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

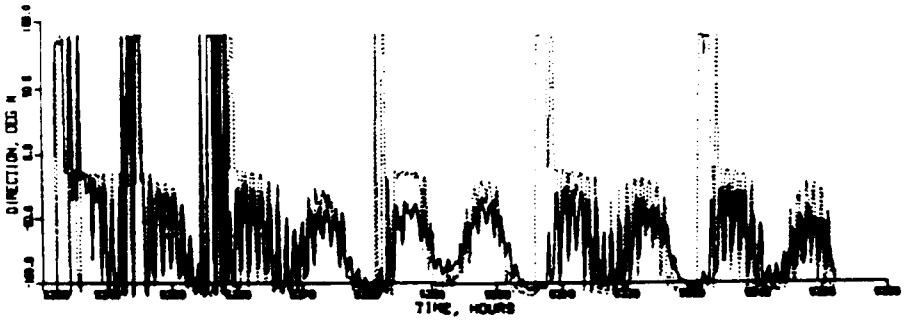
PLATE 45



SURFACE



MID-DEPTH



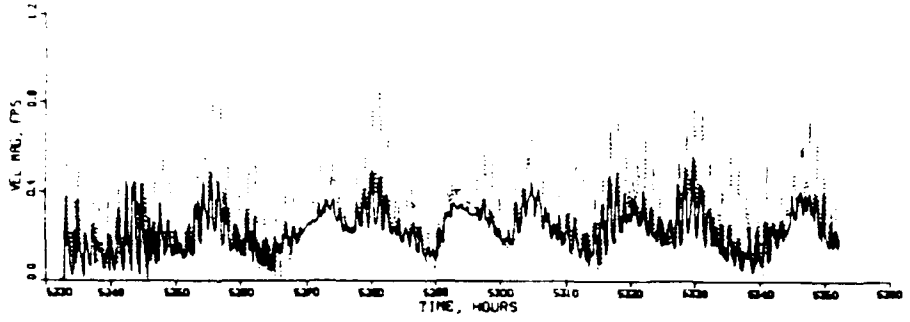
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

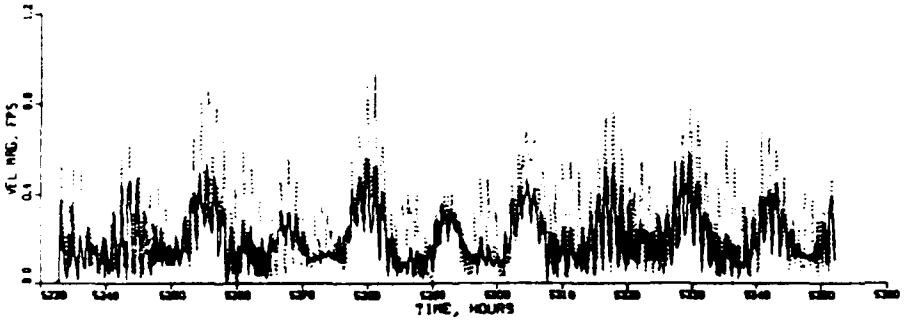
DIRECTION GAGE C3

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

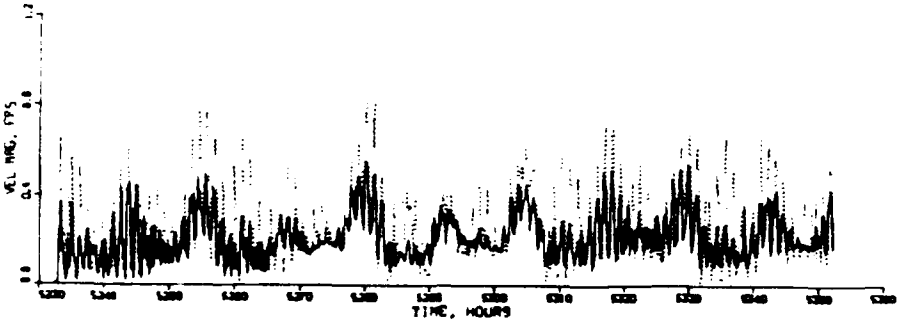
PLATE 46



SURFACE



MID-DEPTH



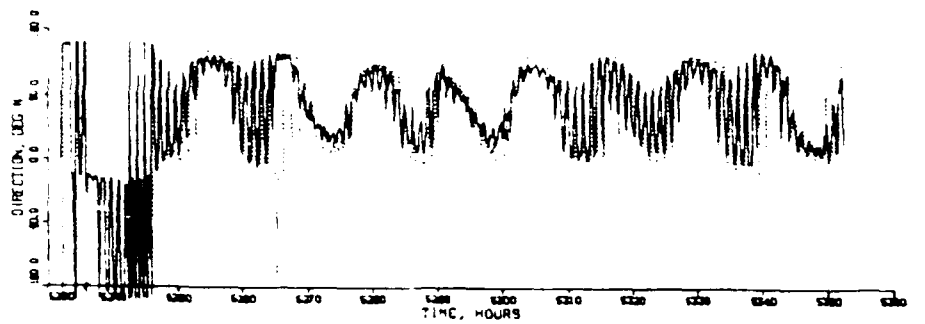
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

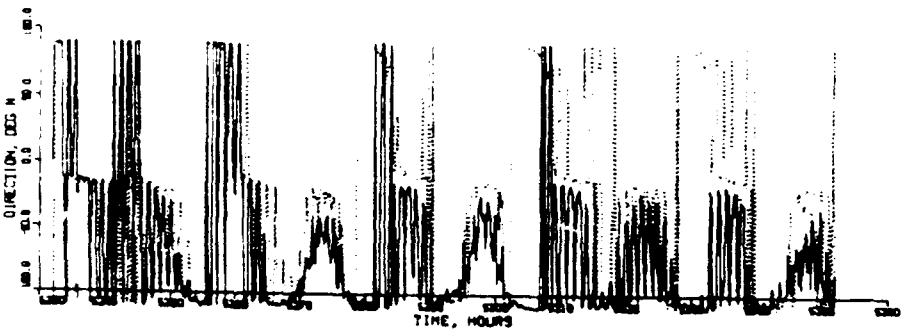
MAGNITUDE GAGE C3

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

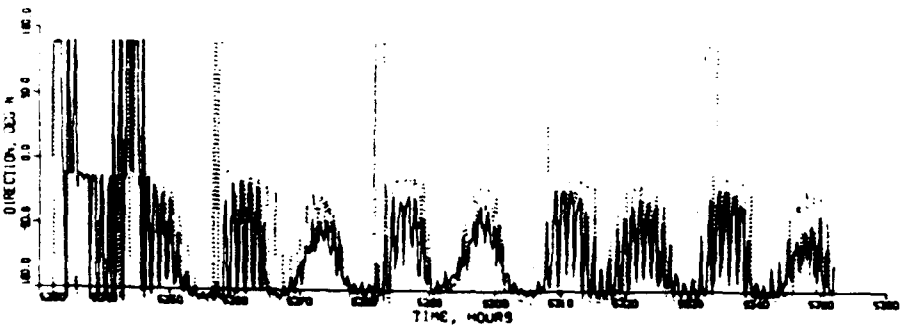
PLATE 47



SURFACE



MID-DEPTH



BOTTOM

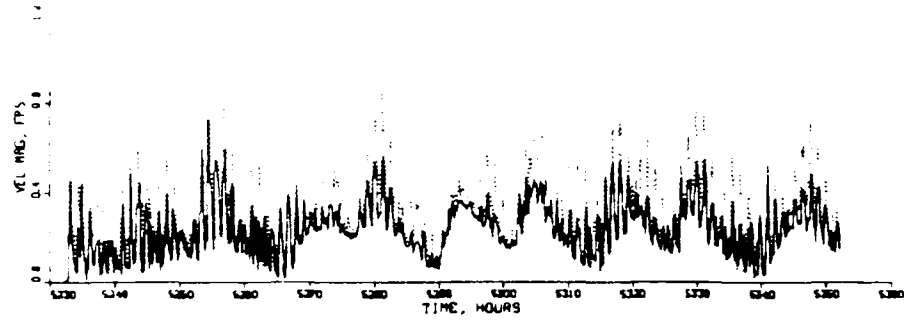
TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION

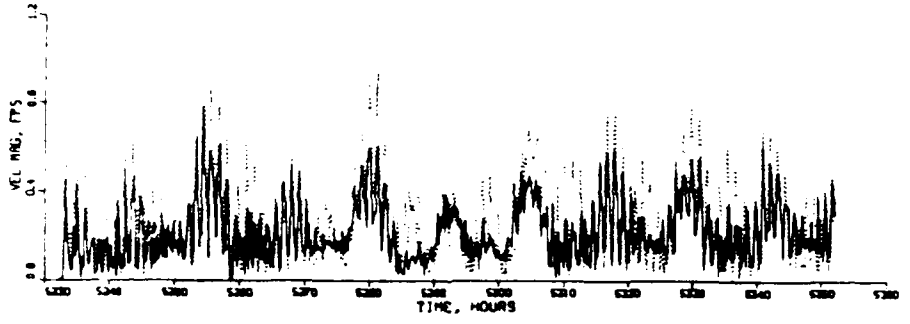
GAGE C3

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

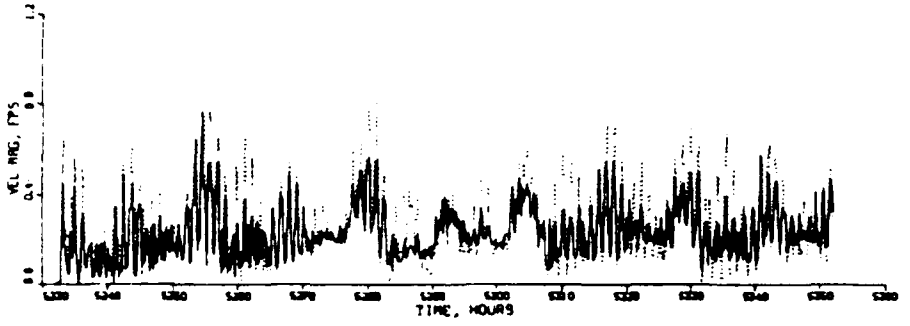
PLATE 48



SURFACE



MID-DEPTH



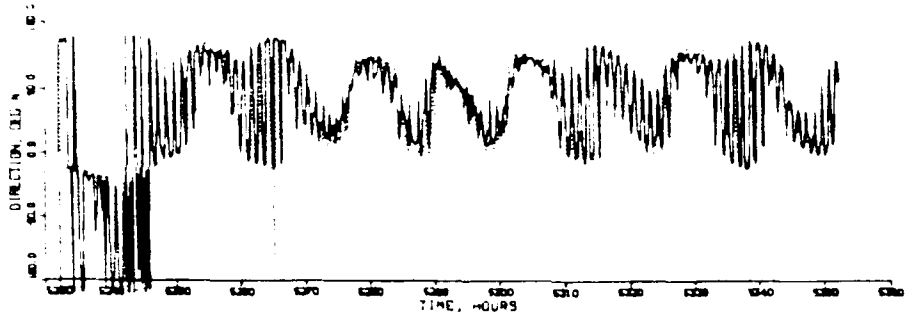
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

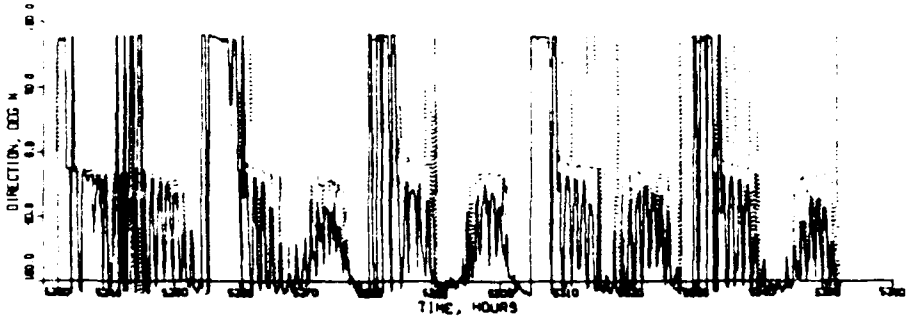
MAGNITUDE GAGE C3

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

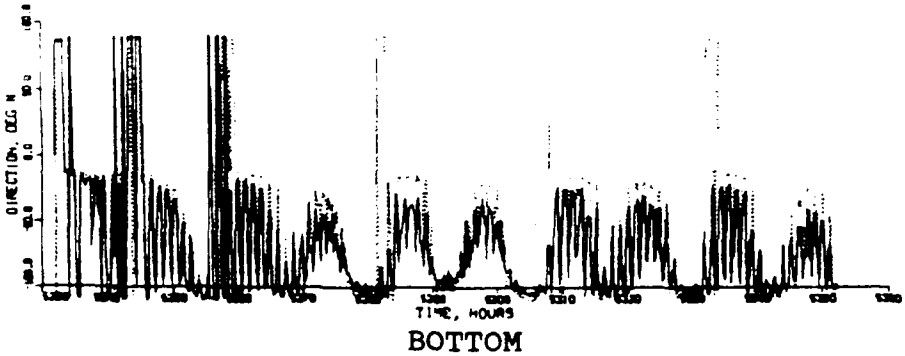
PLATE 49



SURFACE



MID-DEPTH



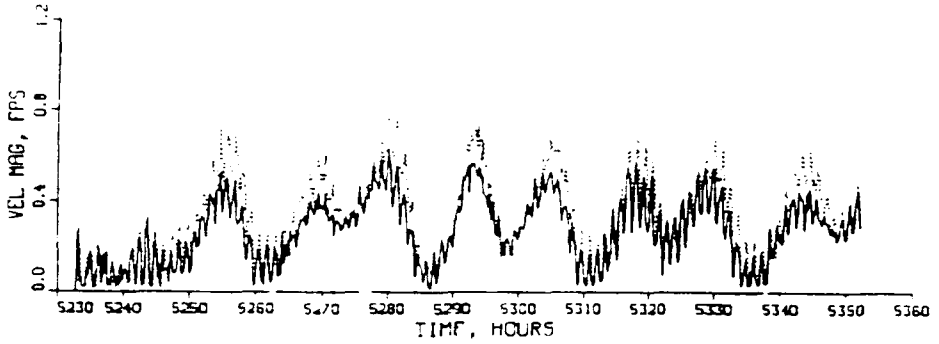
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

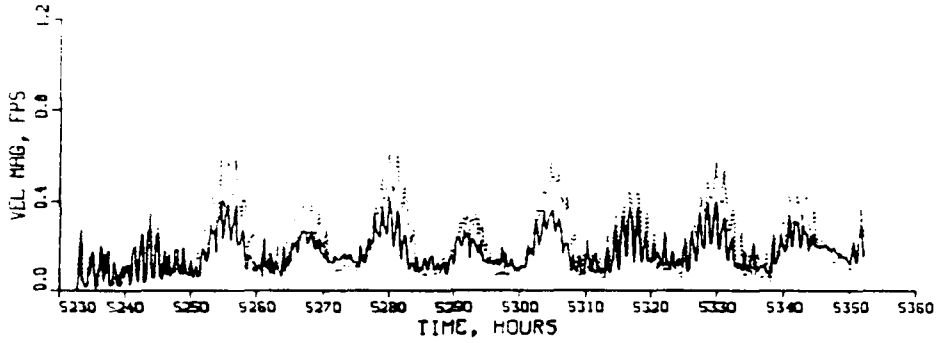
DIRECTION GAGE C3

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

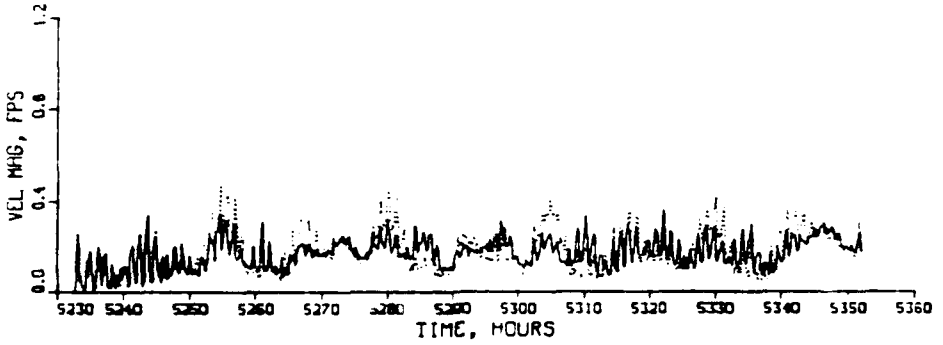
PLATE 50



SURFACE



MID-DEPTH



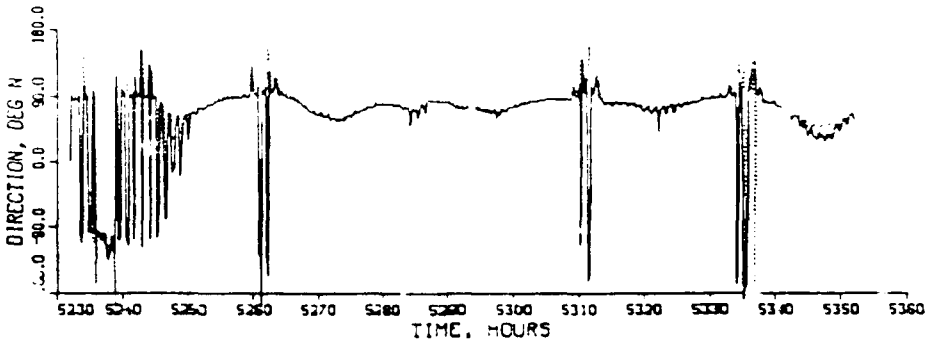
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C4

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 51



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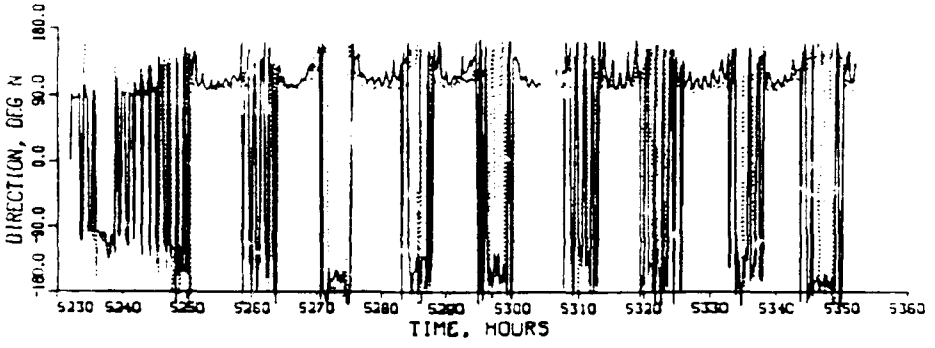
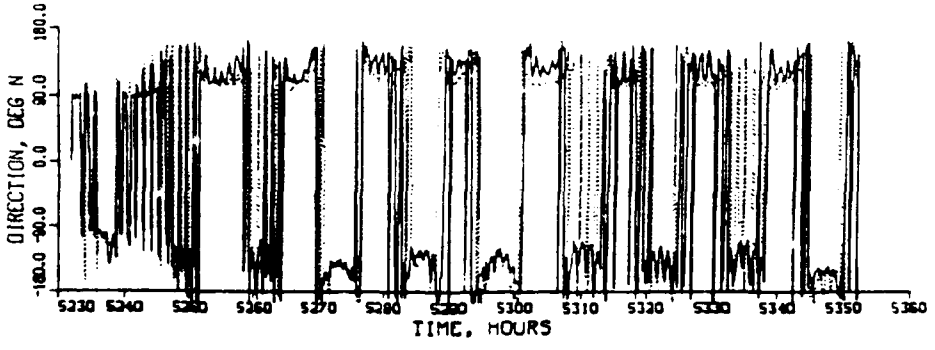


MID-DEPTH



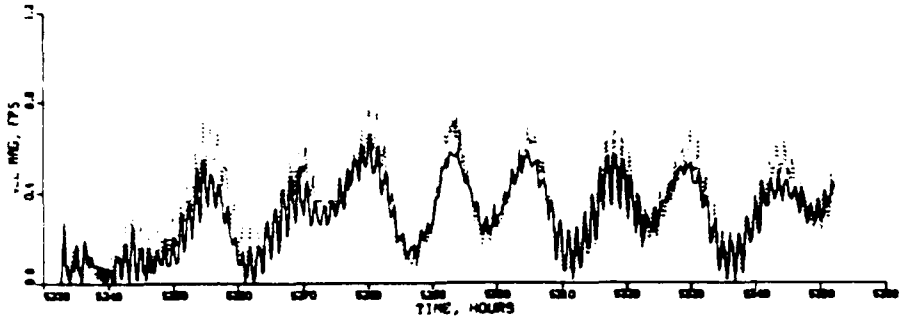
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C4

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 52



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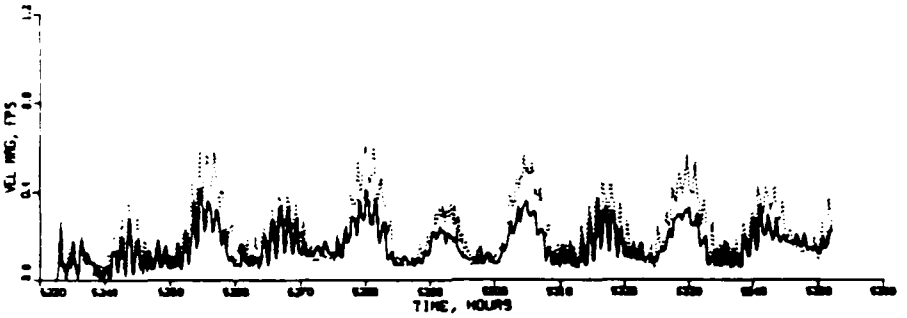

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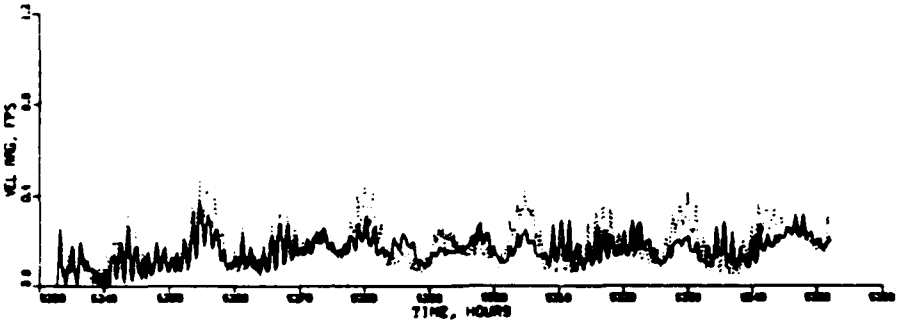


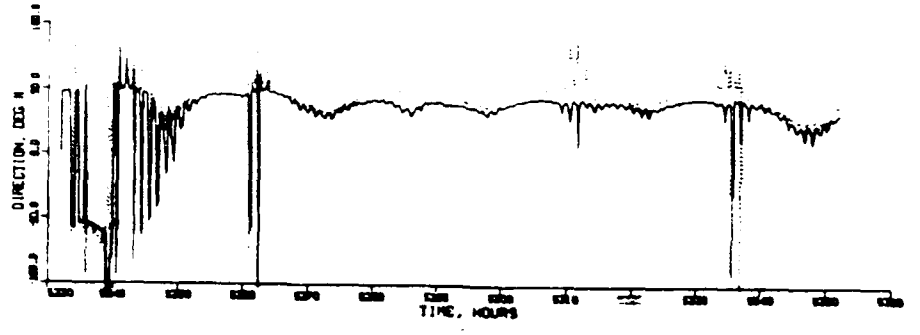
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C4

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 53



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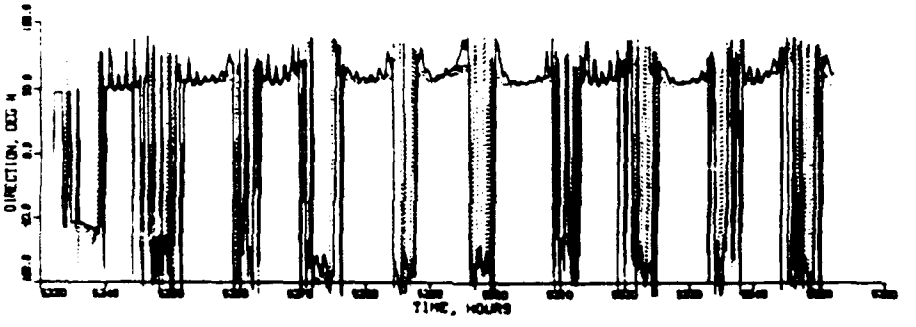

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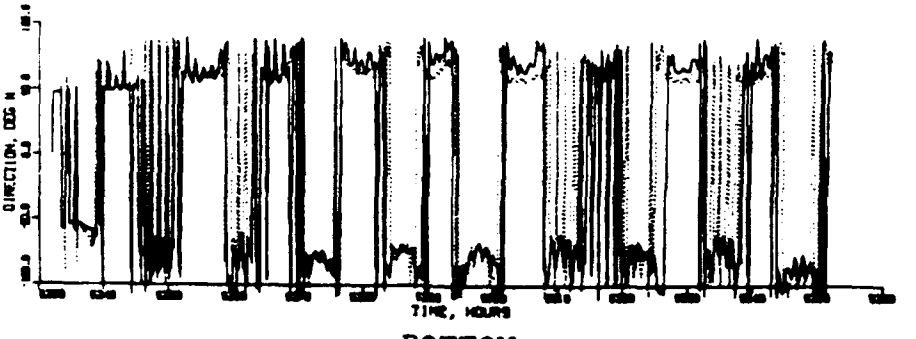


BOTTOM

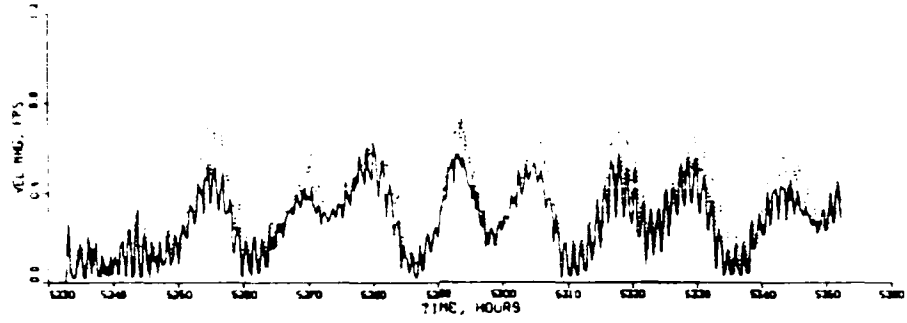
TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION

GAGE C4

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 54



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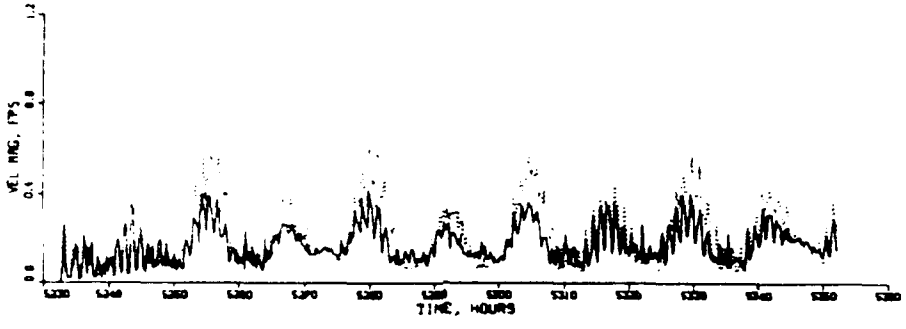

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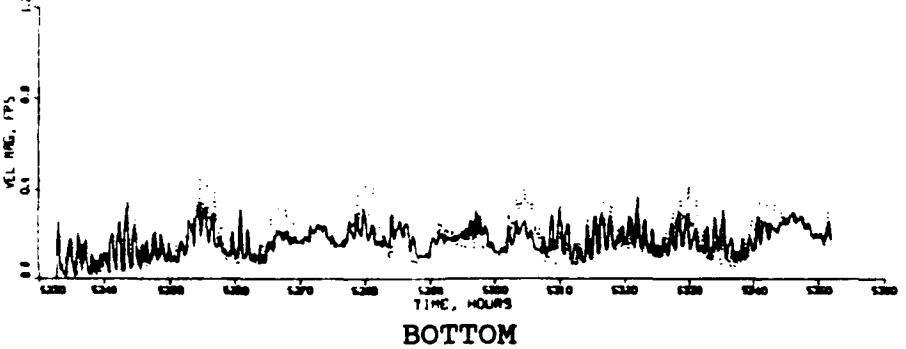


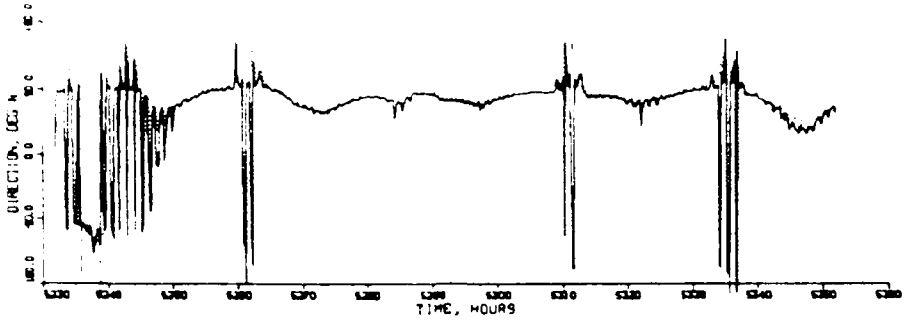
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C4

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 55



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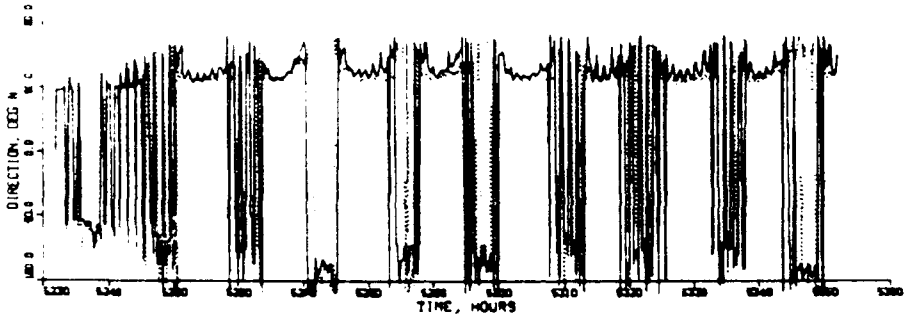
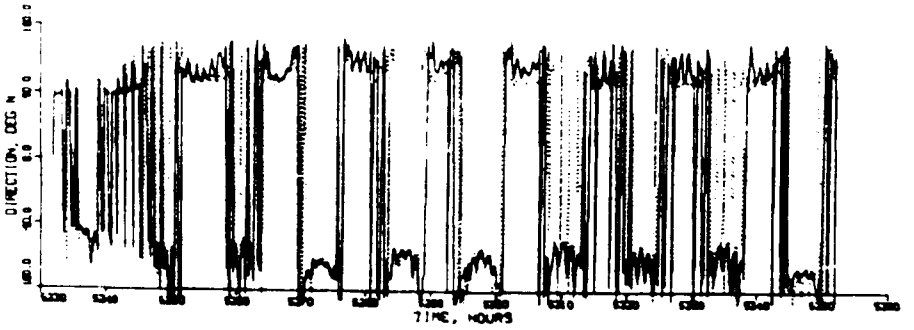


MID-DEPTH



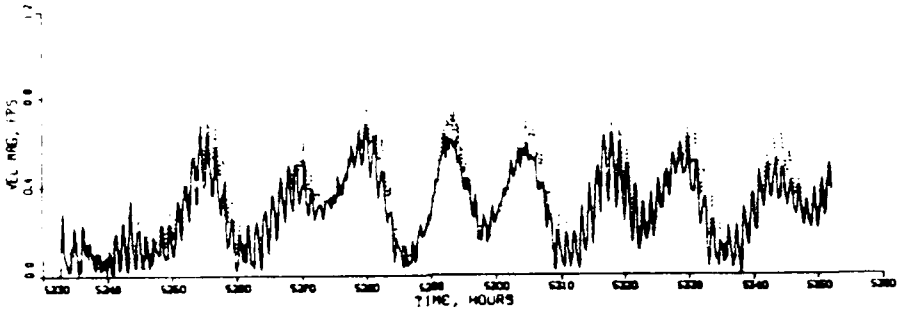
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C4

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 56



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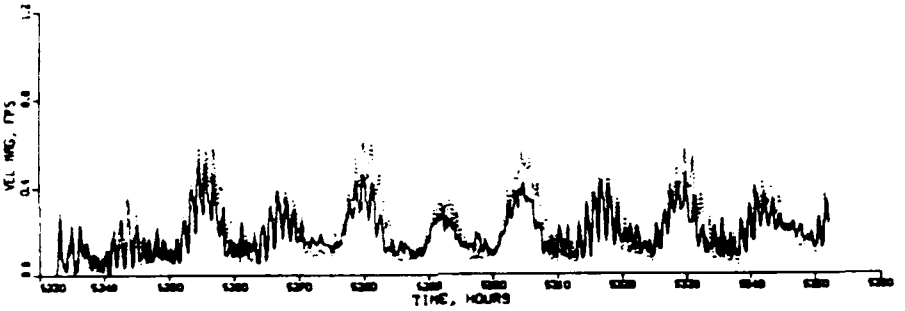

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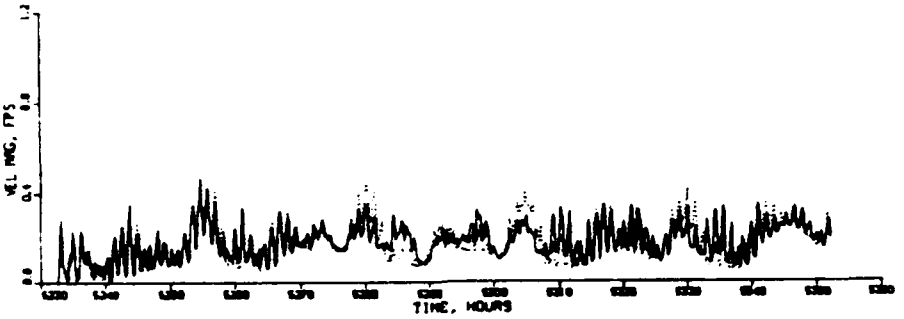


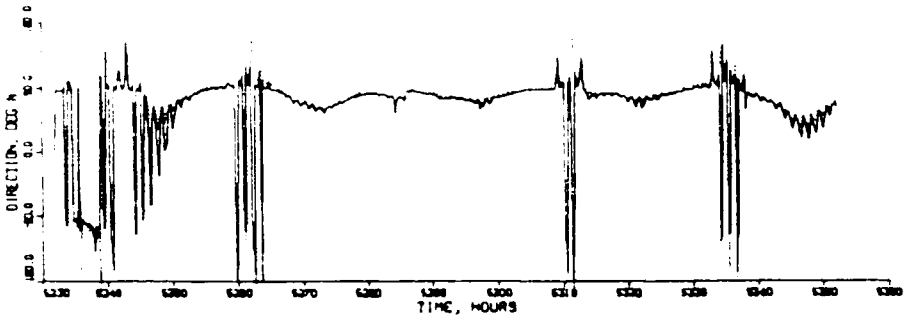
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C4

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 57



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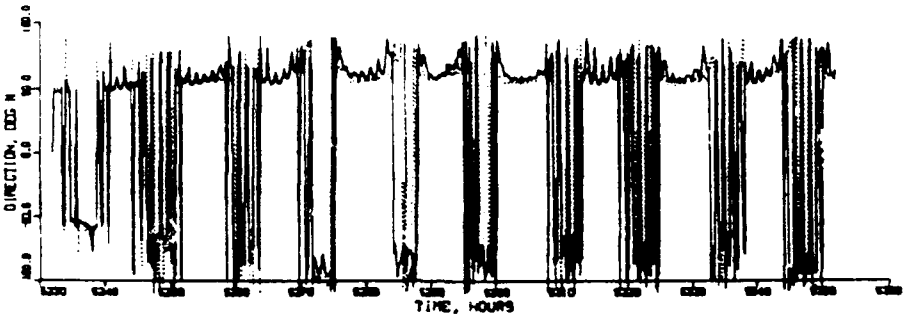
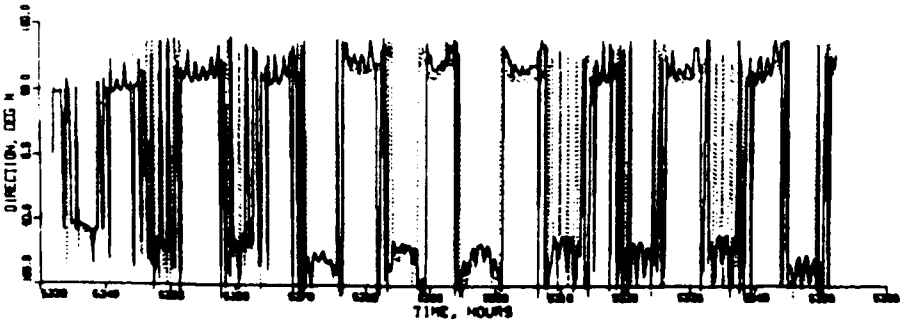


MID-DEPTH



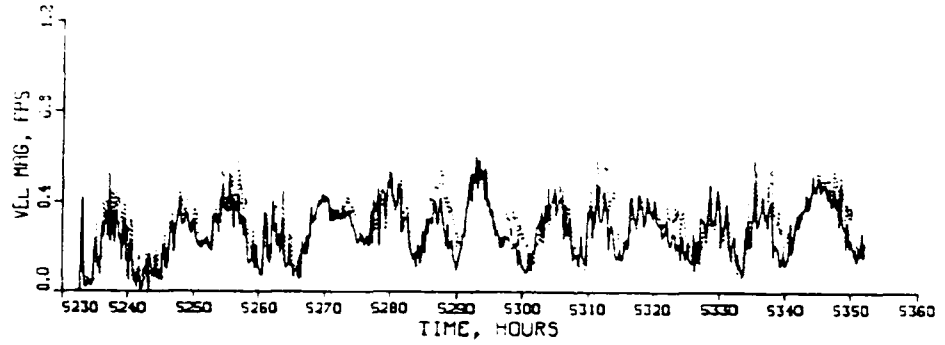
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C4

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 58



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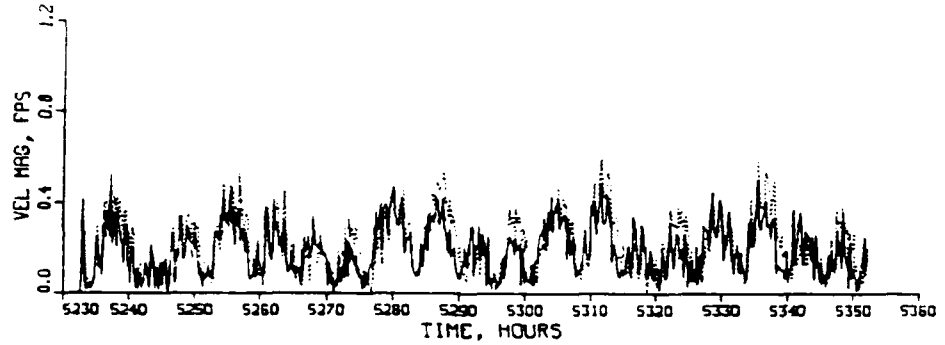
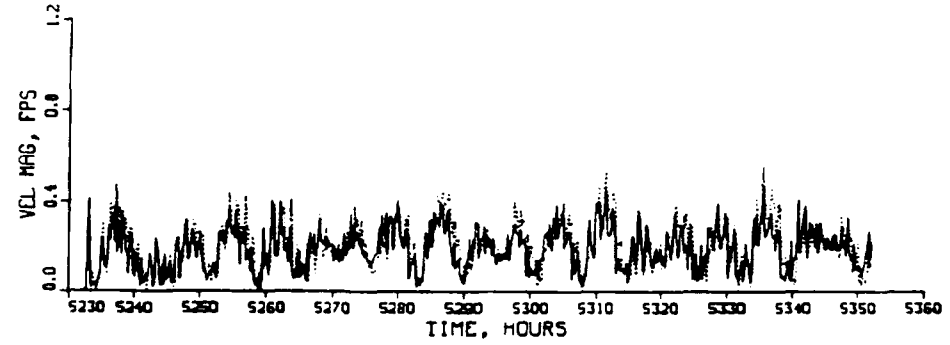


MID-DEPTH



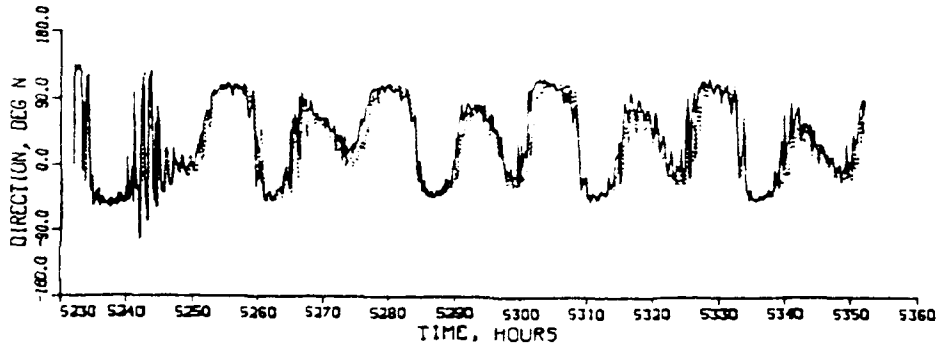
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C5

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 59



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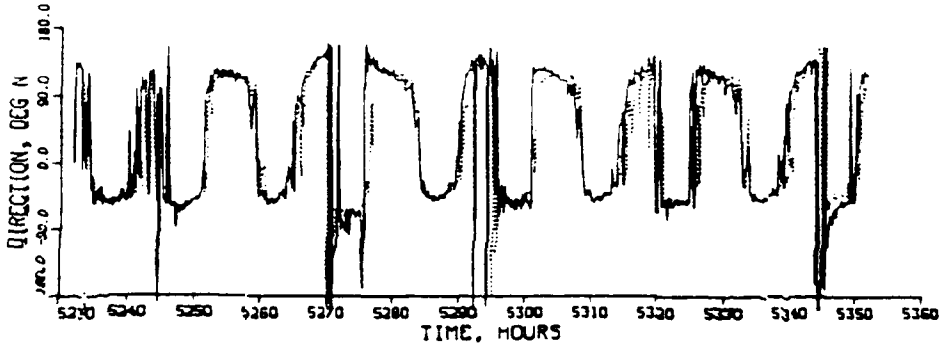
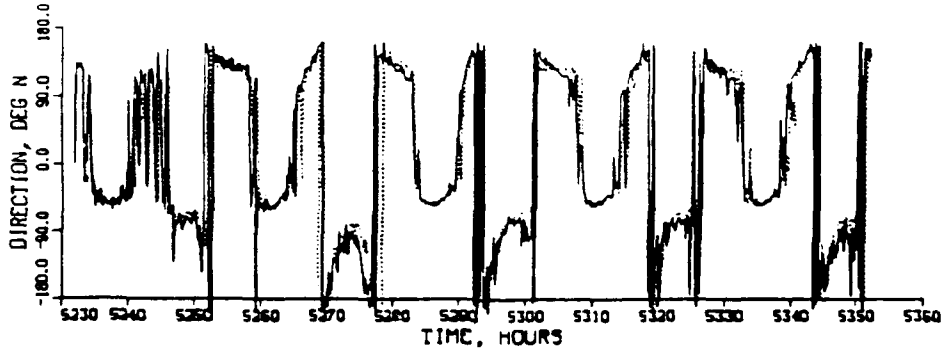


MID-DEPTH



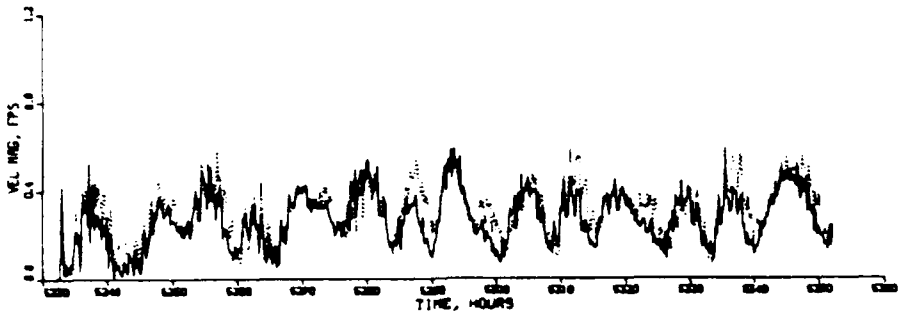
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C5

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 60



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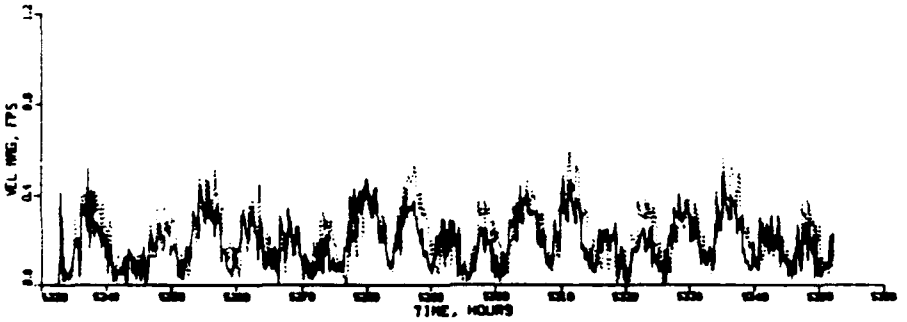
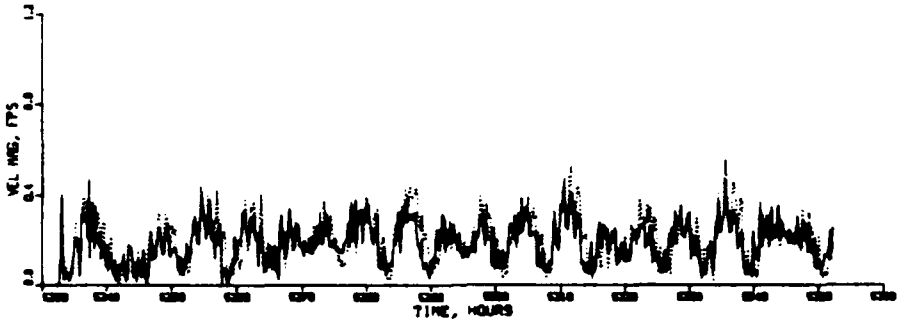


MID-DEPTH



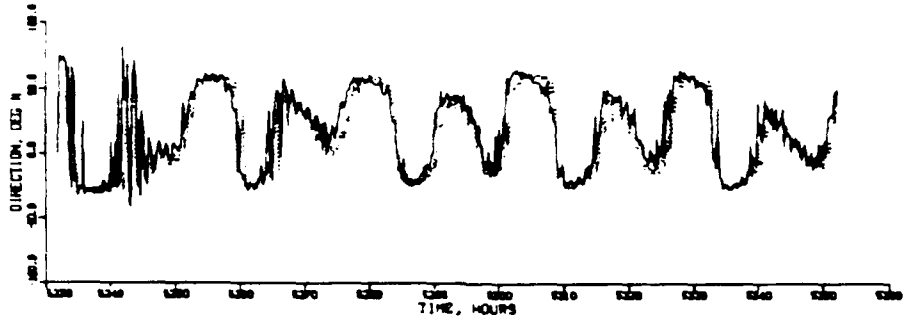
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C5

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 61



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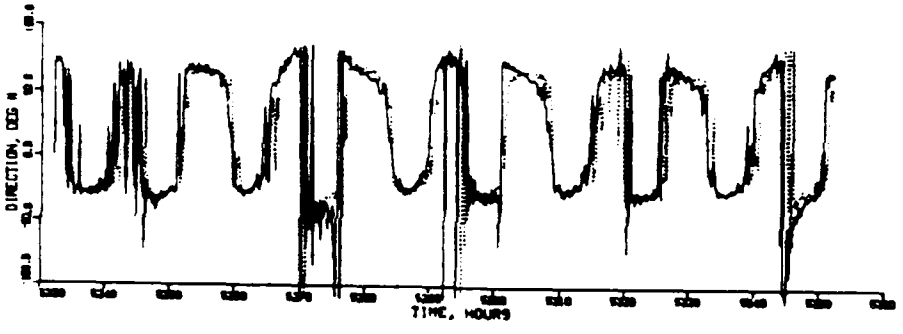
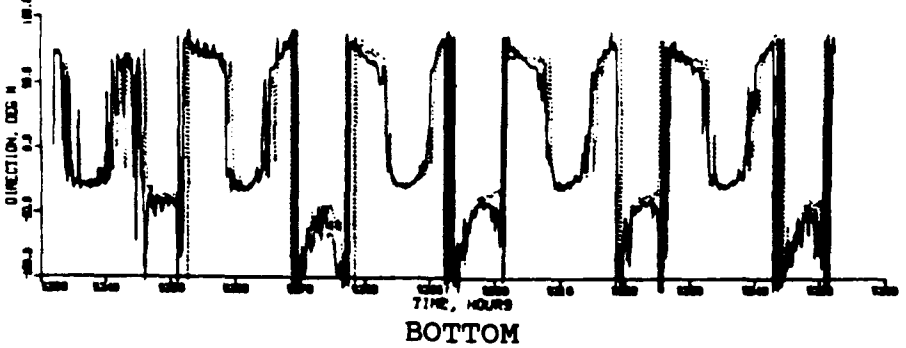


MID-DEPTH



BOTTOM

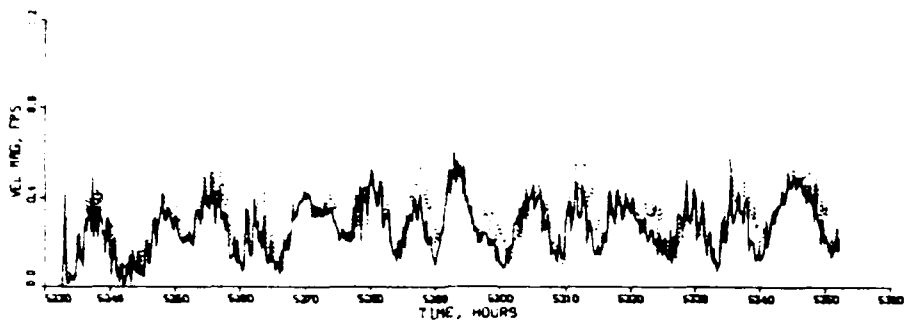
TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION

GAGE C5

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 62



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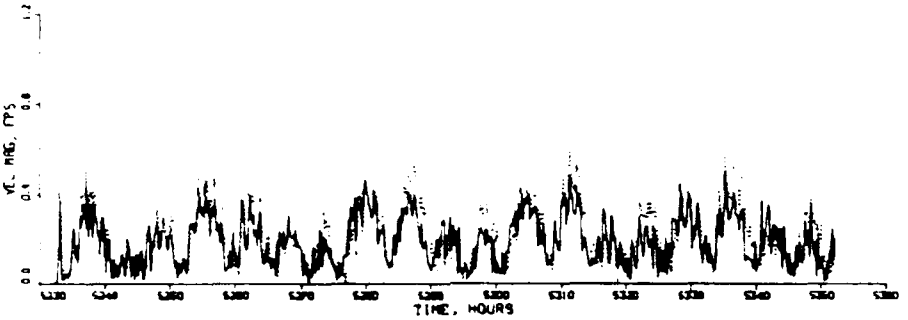
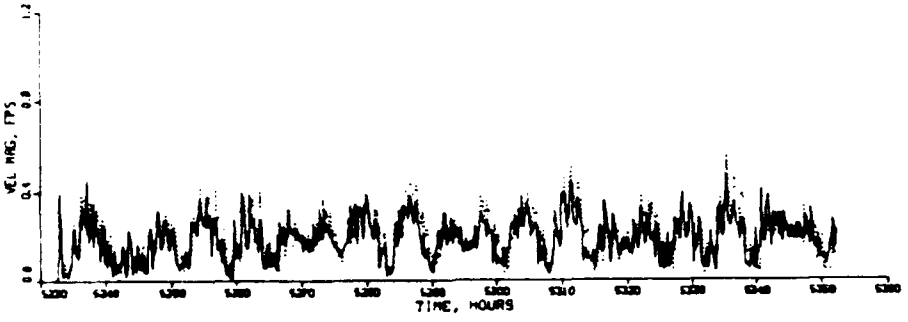


MID-DEPTH



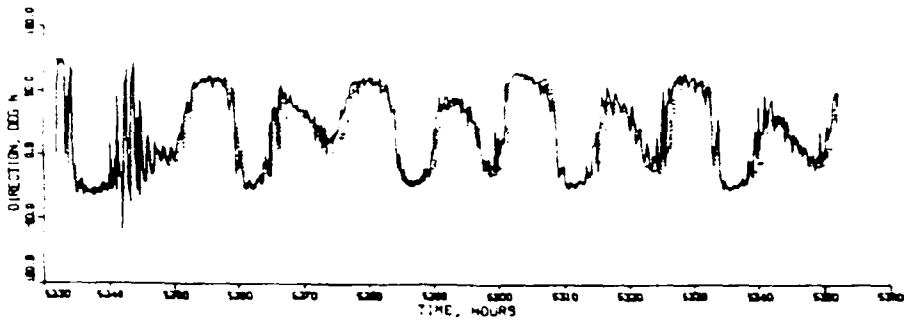
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

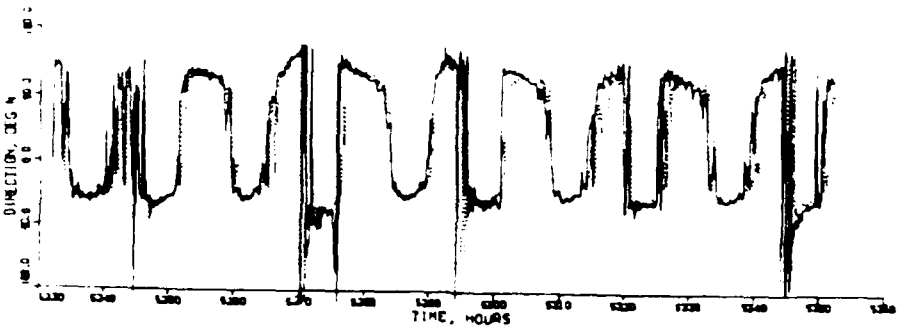
MAGNITUDE GAGE C5

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

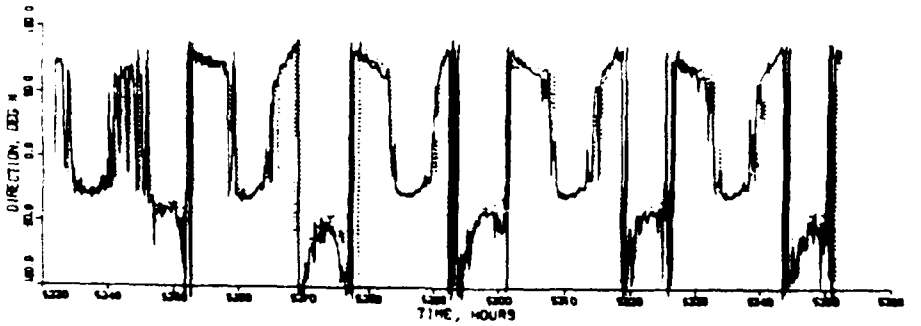
PLATE 63



SURFACE



MID-DEPTH



BOTTOM

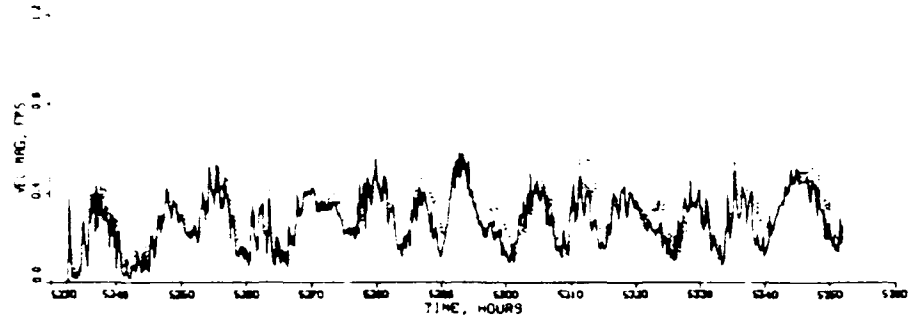
TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION

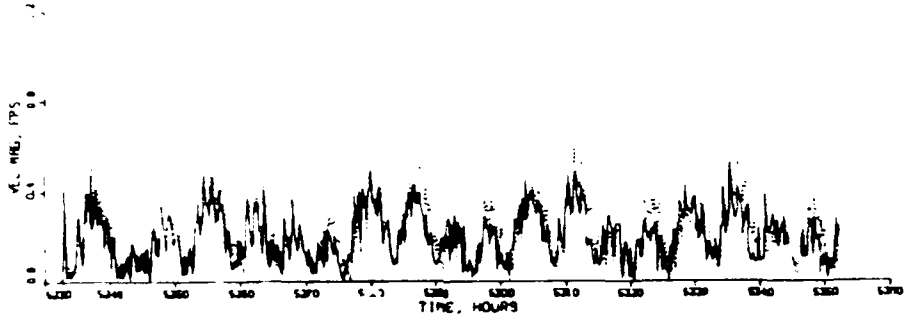
GAGE C5

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

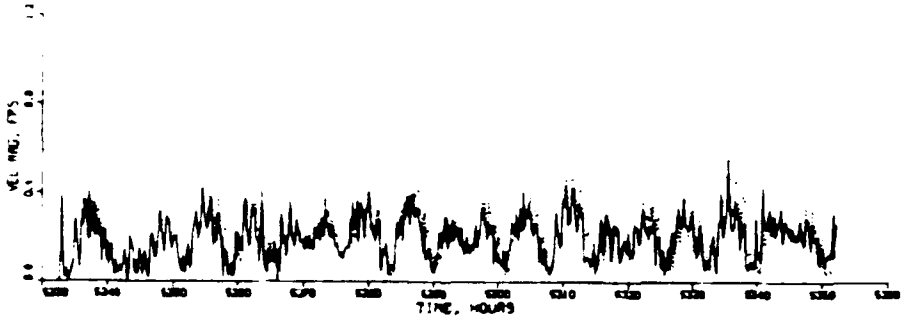
PLATE 64



SURFACE



MID-DEPTH



BOTTOM

TIDAL VELOCITY

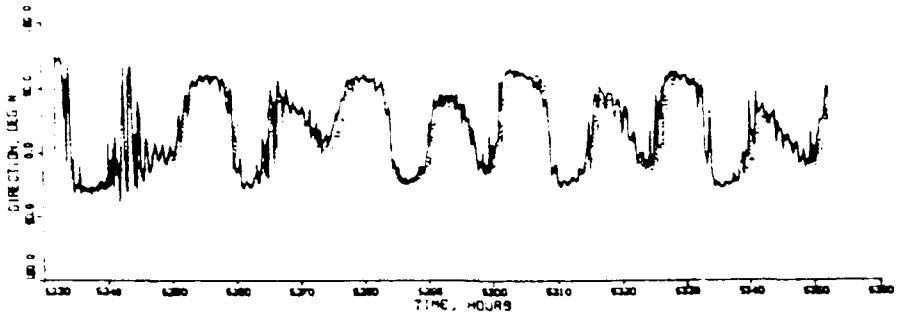
CALIBRATION PERIOD

MAGNITUDE

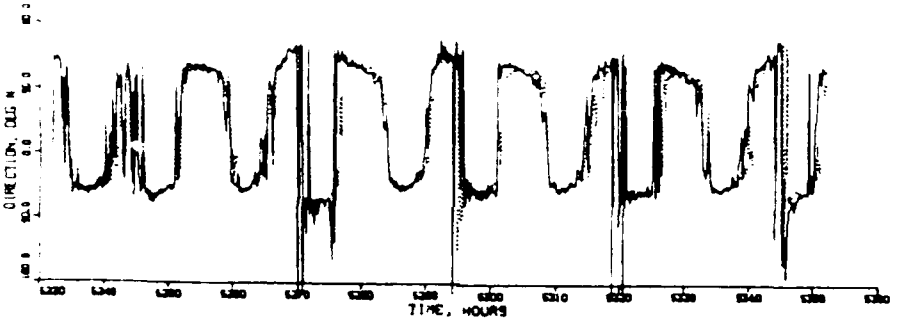
GAGE C5

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

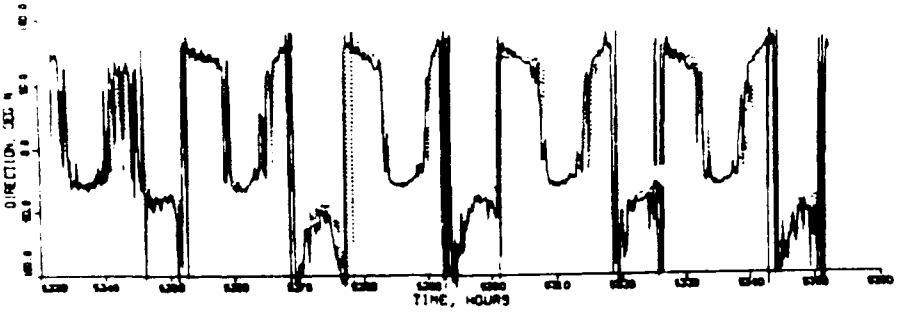
PLATE 65



SURFACE



MID-DEPTH



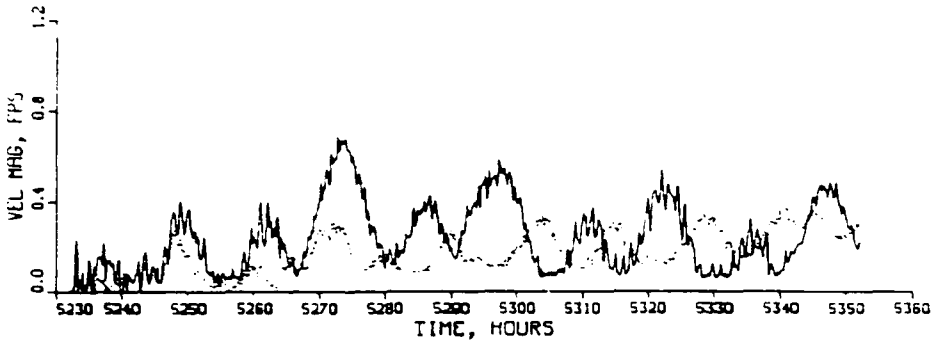
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C5

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 66



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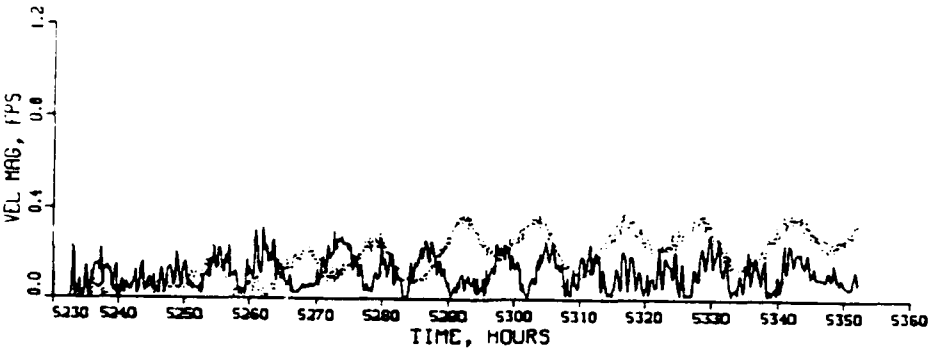
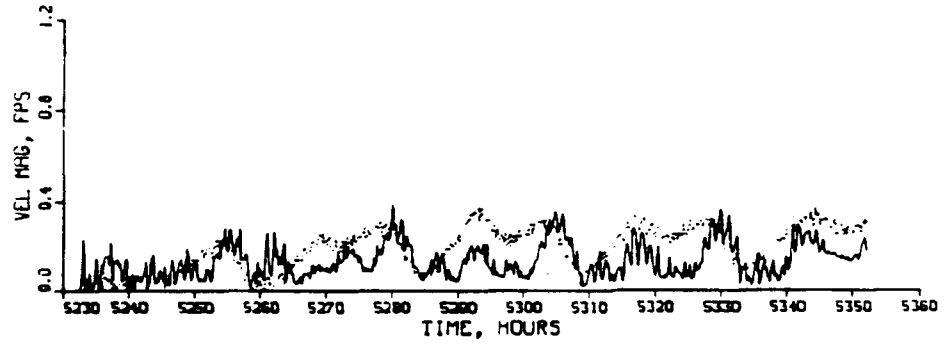


MID-DEPTH



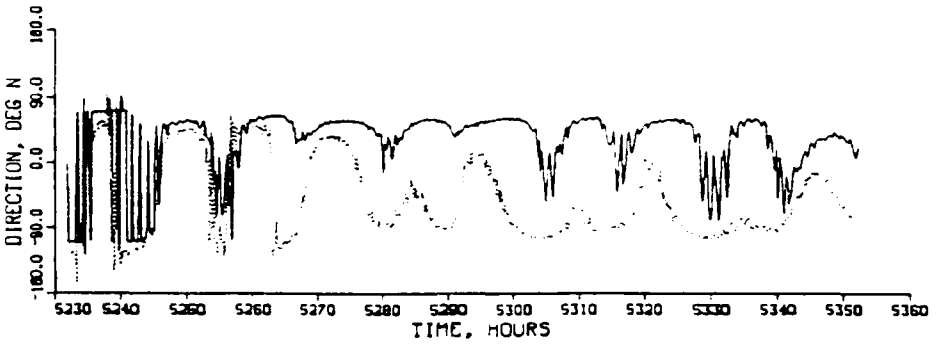
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

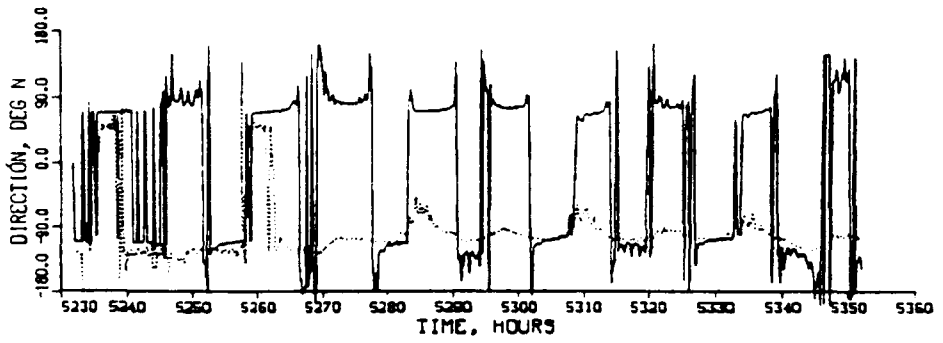
MAGNITUDE GAGE C14

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 67



SURFACE



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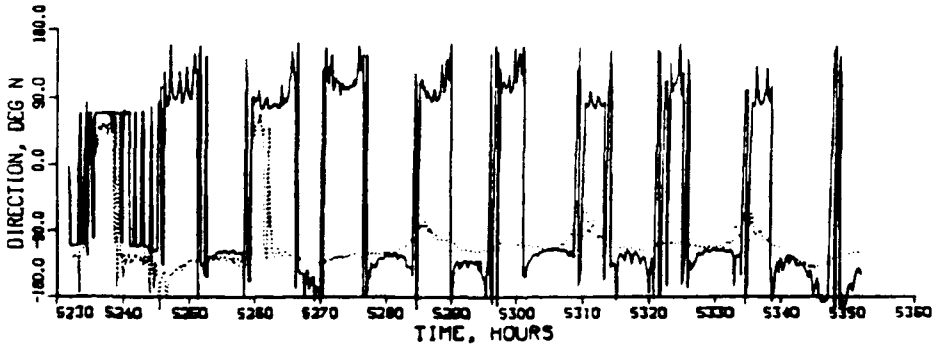


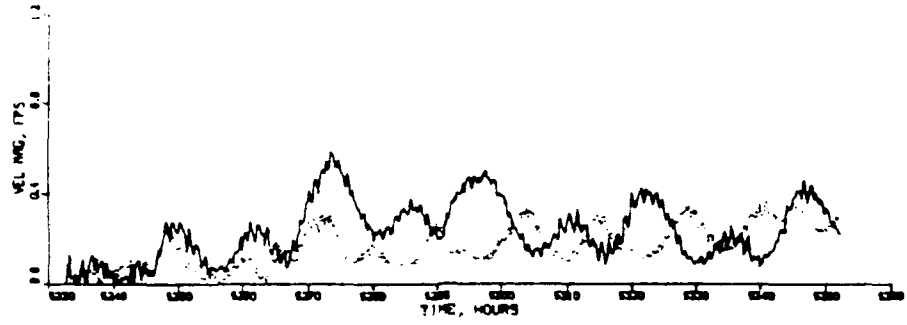
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C14

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 68



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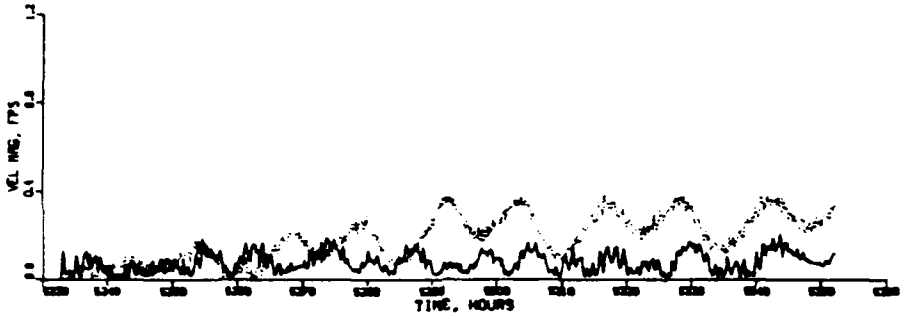

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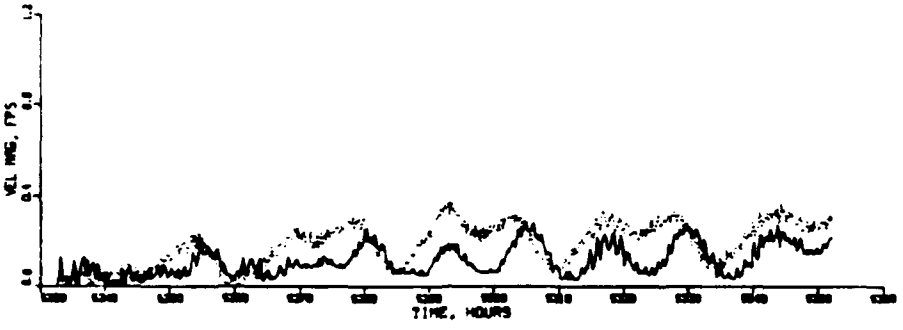


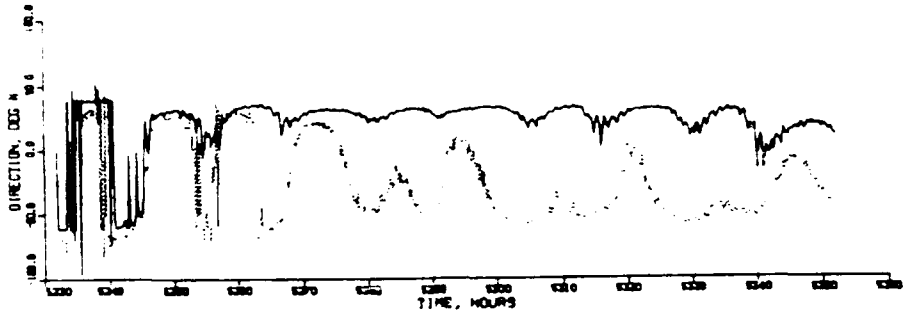
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C14

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 69



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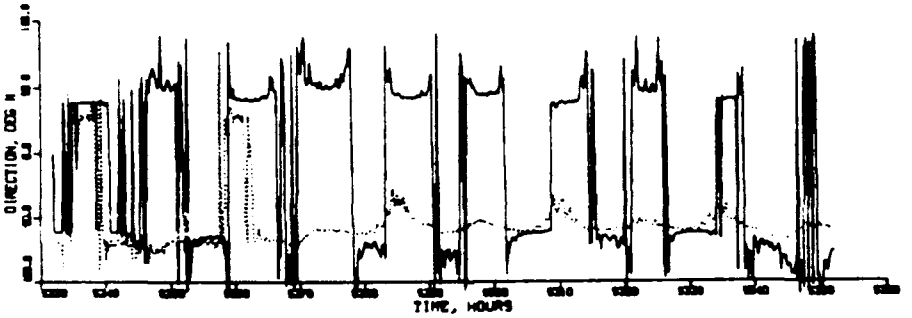

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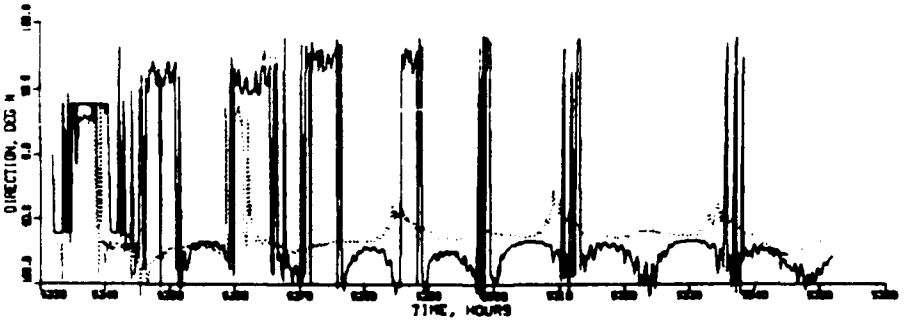


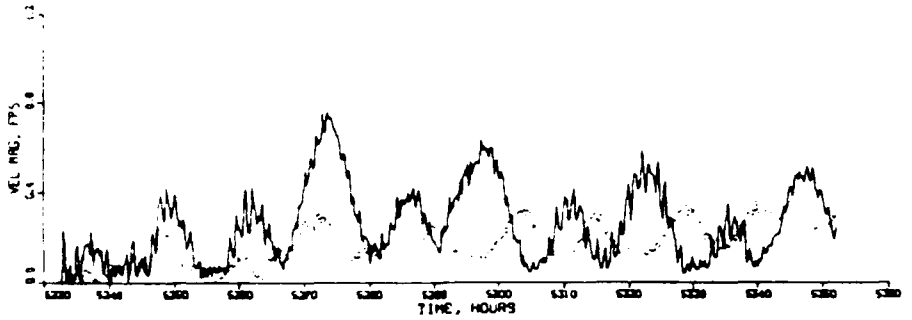
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C14

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 70



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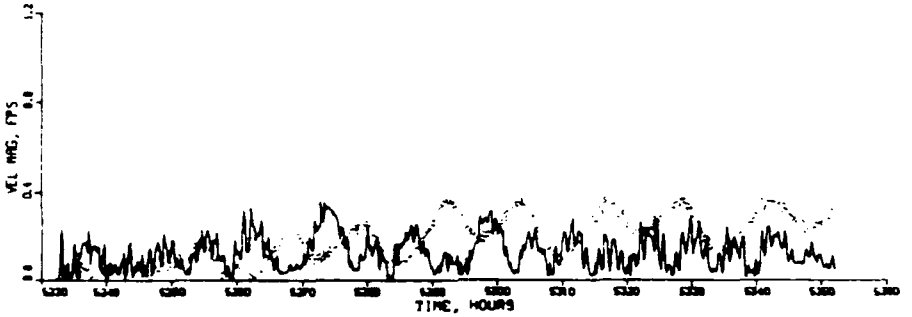

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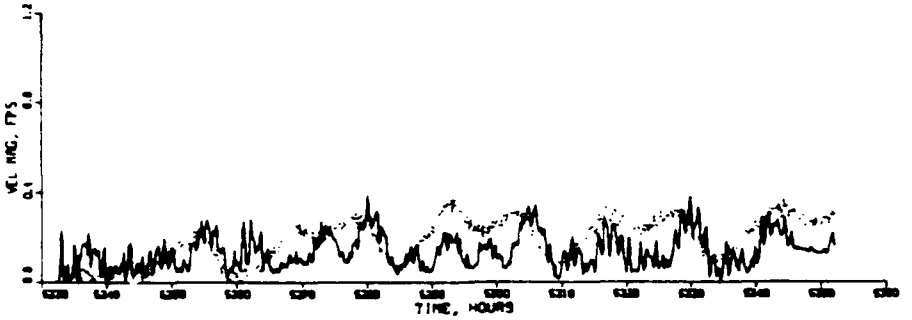


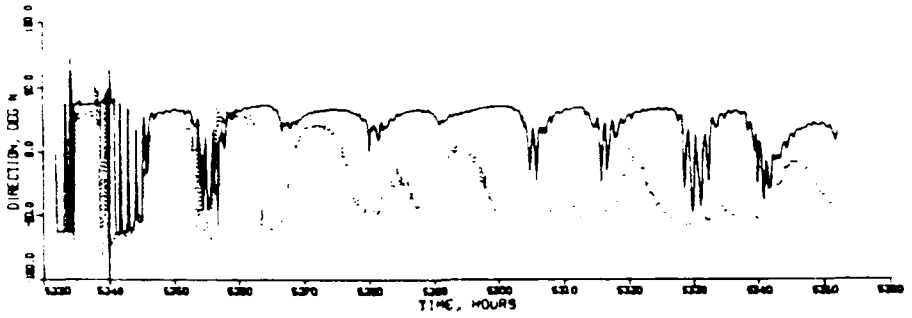
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C14

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 71



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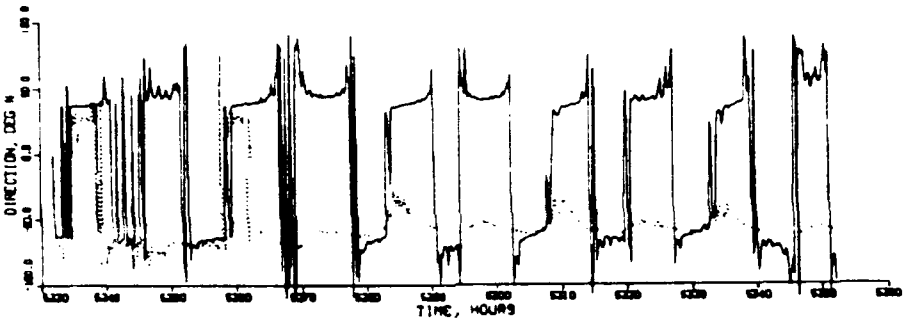

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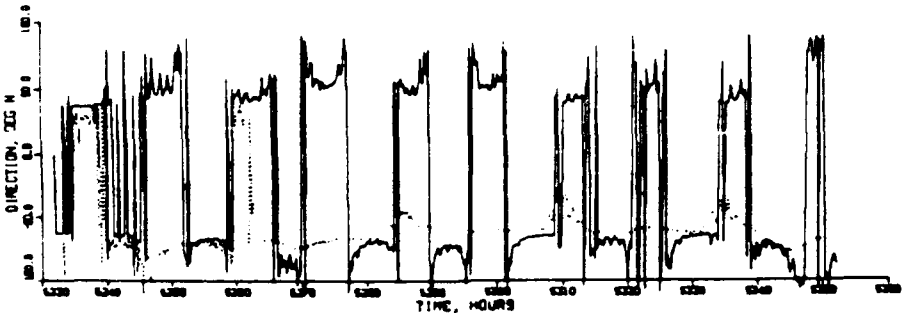


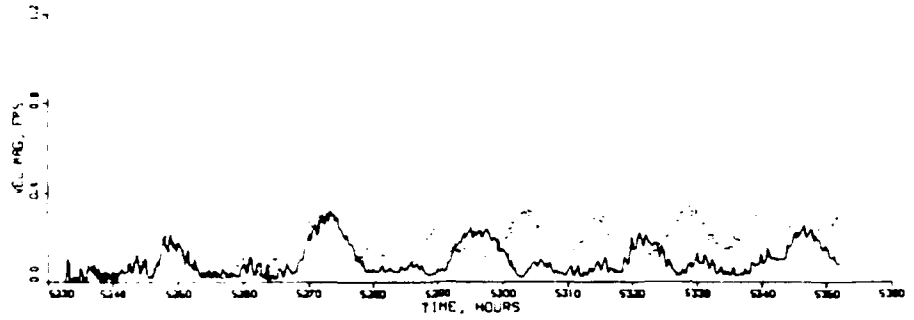
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C14

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 72



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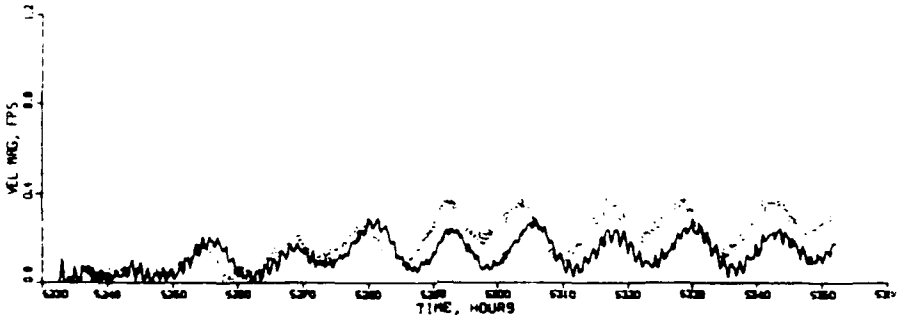
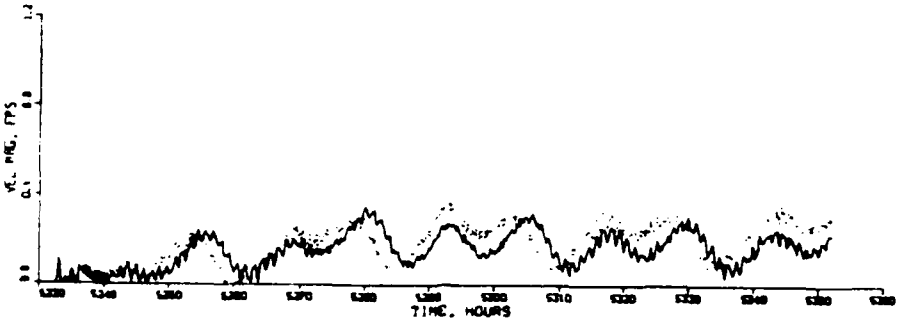


MID-DEPTH



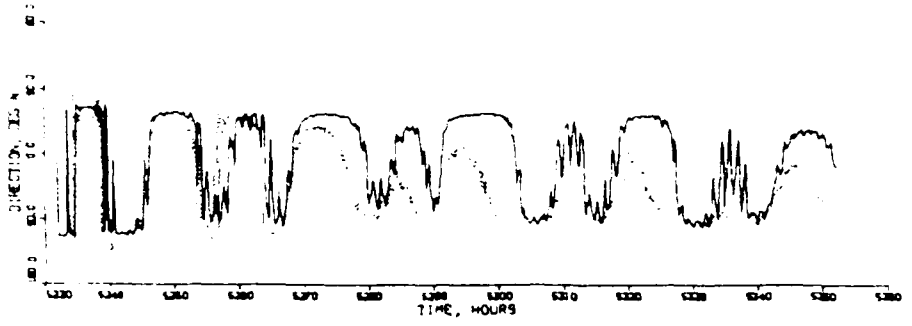
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C14

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 73



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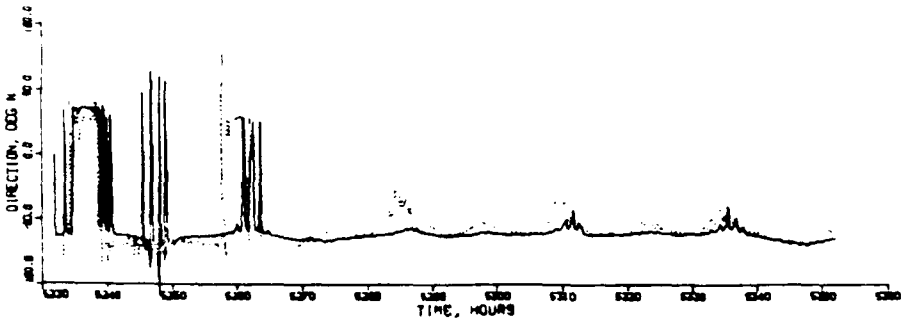

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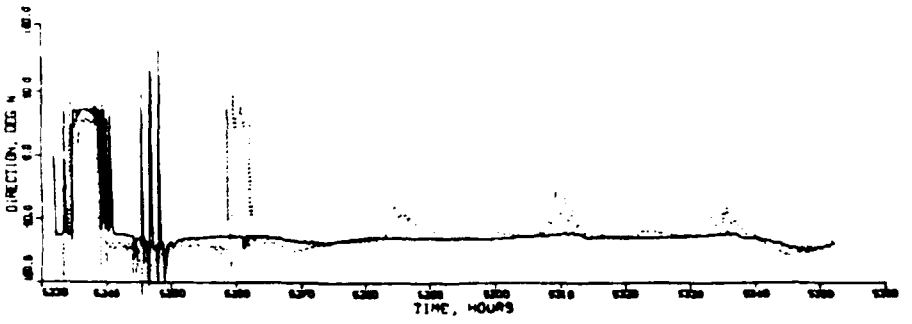


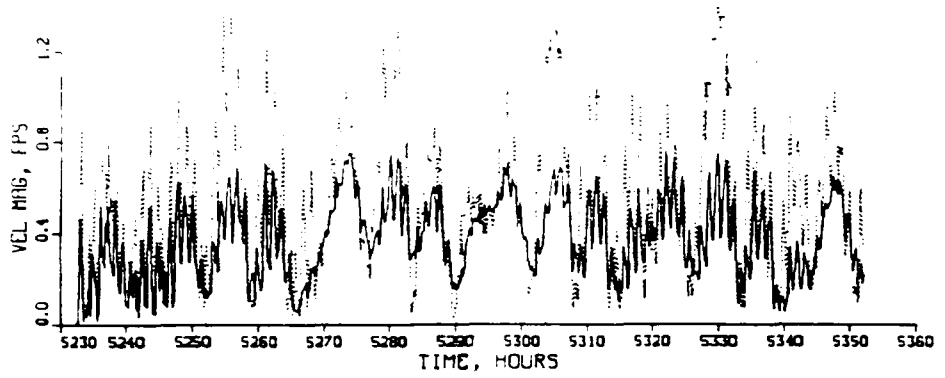
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C14

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 74



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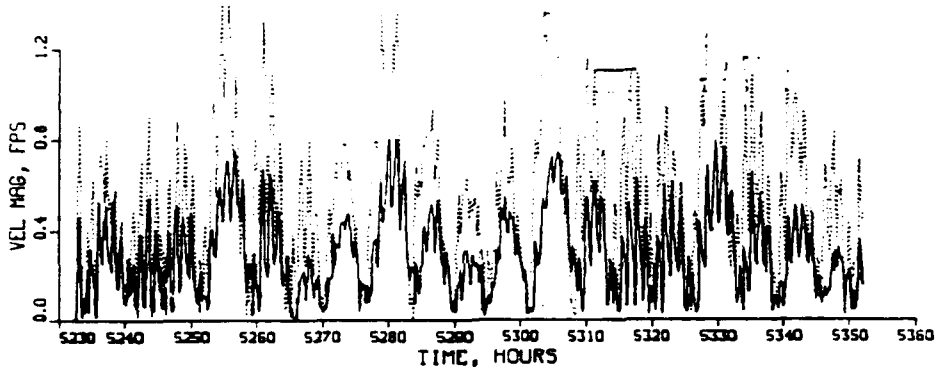

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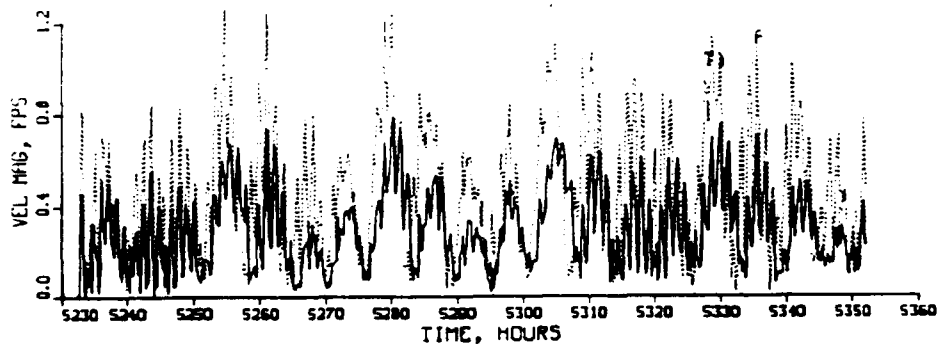


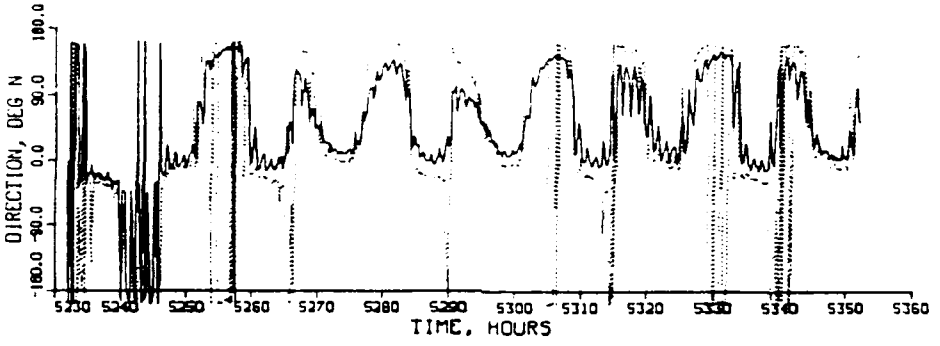
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C18

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 75



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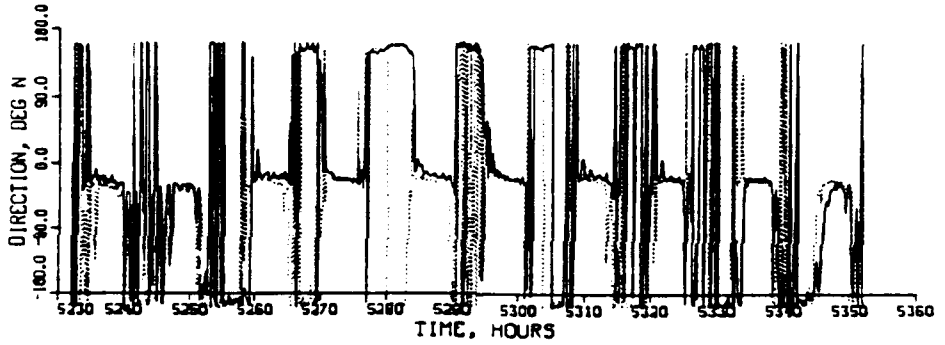
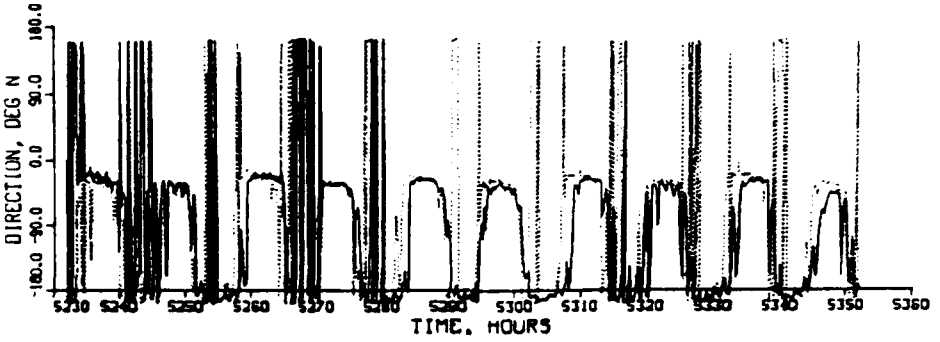


MID-DEPTH



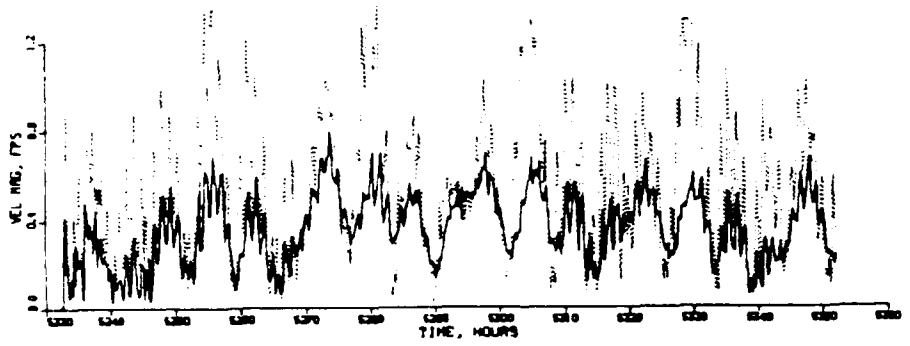
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C18

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 76



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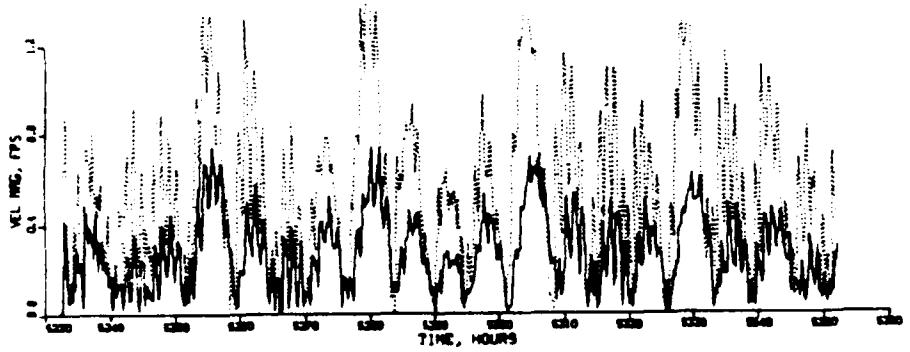
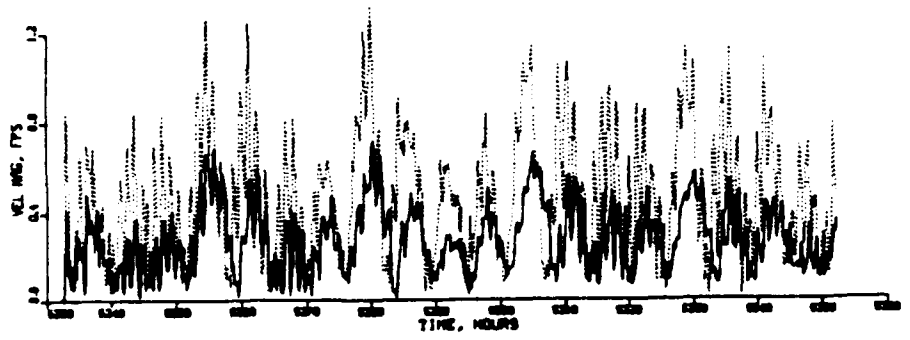


MID-DEPTH



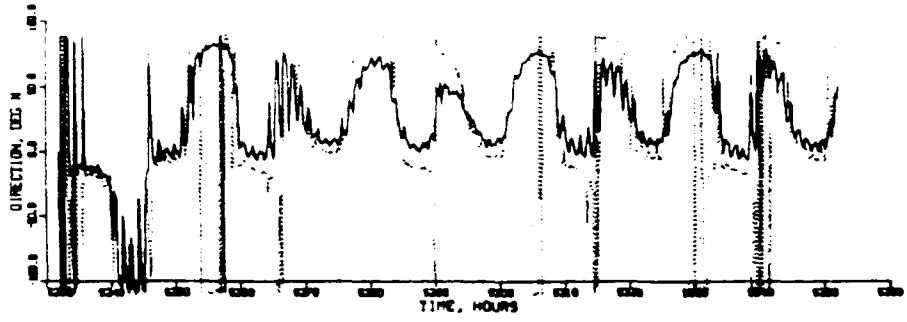
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C18

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 77



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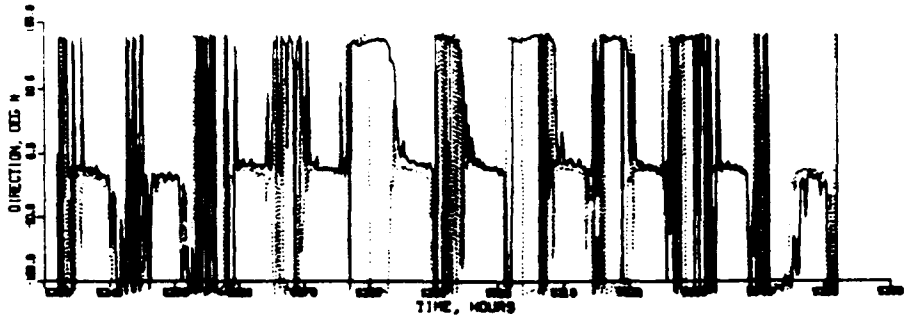
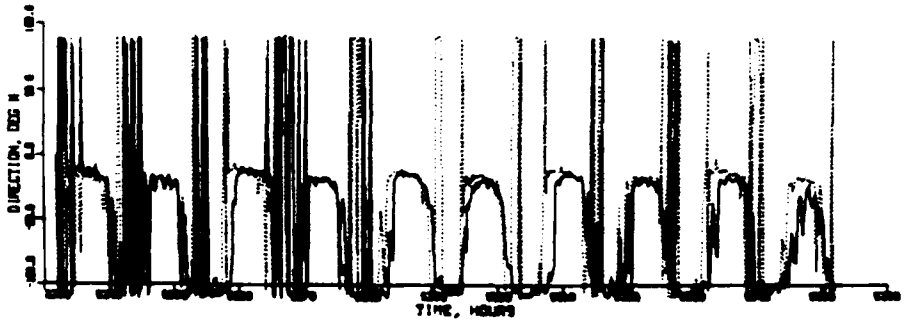


MID-DEPTH



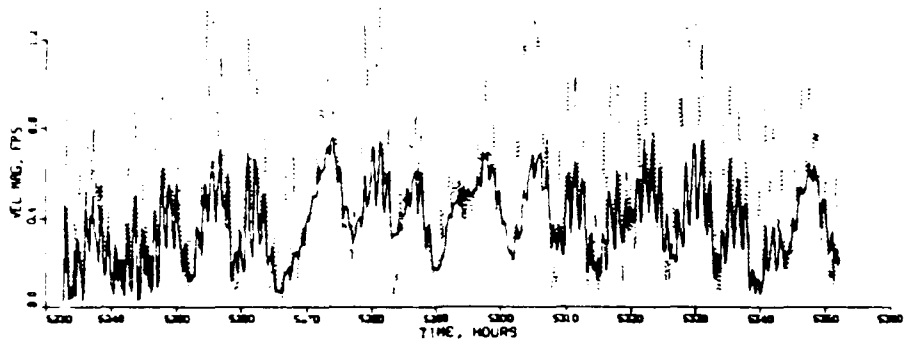
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C18

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 78



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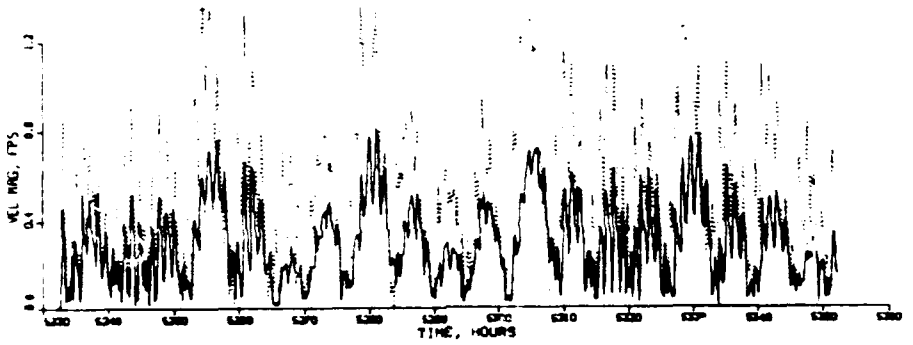
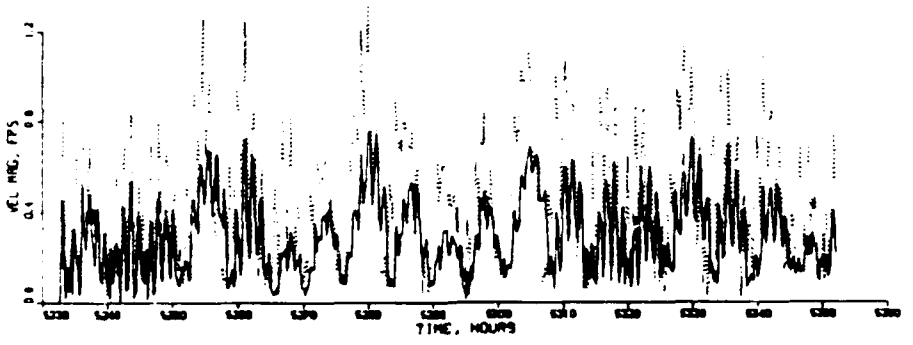


MID-DEPTH



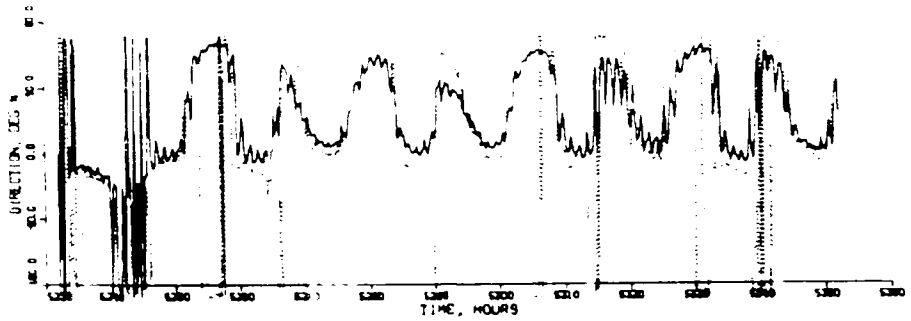
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C18

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 79



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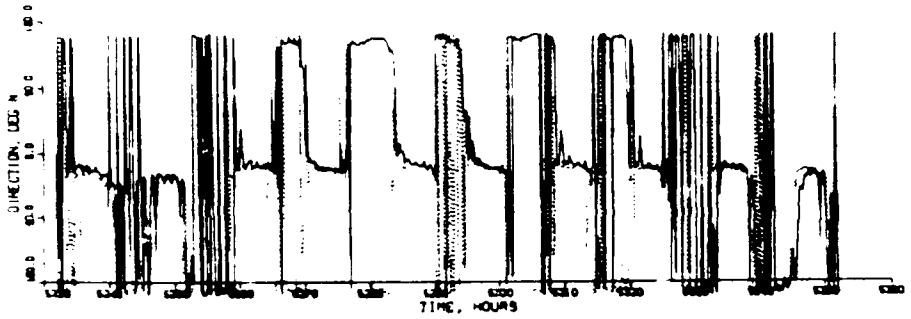
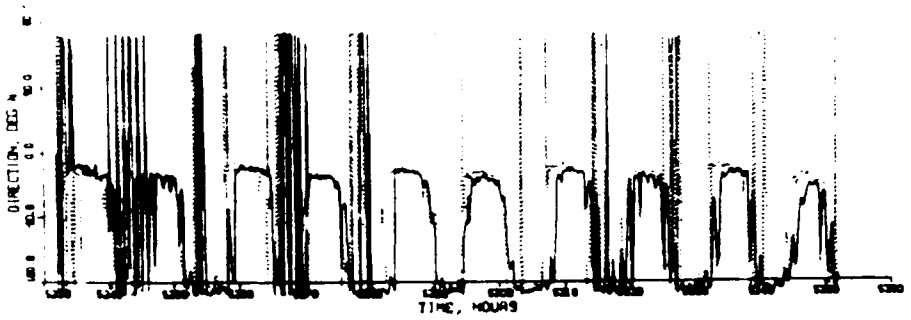


MID-DEPTH



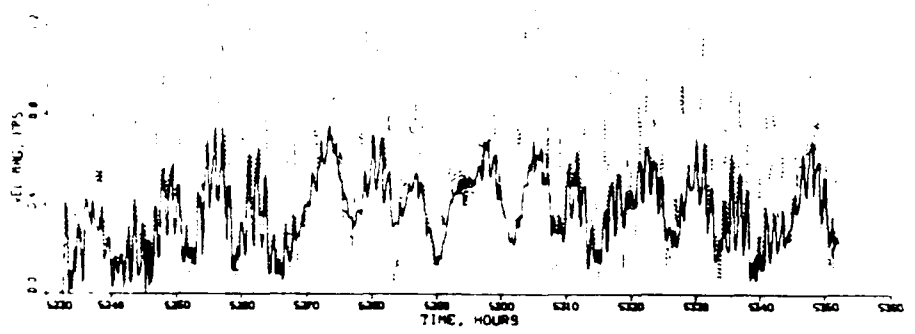
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

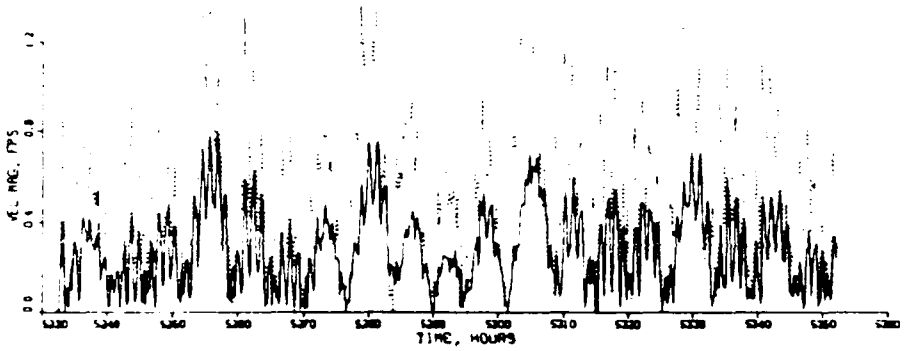
DIRECTION GAGE C18

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

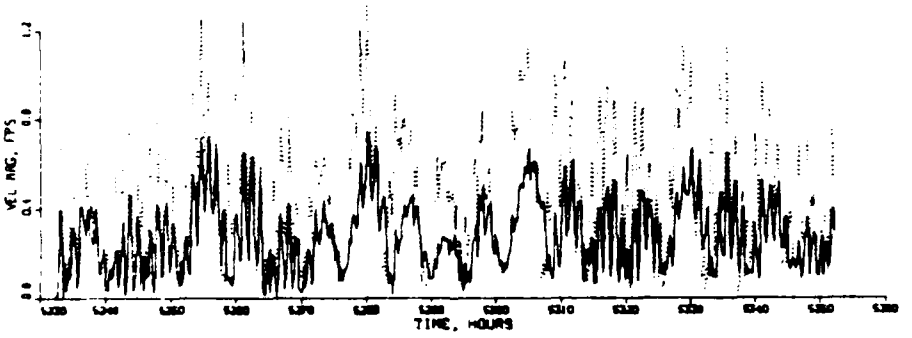
PLATE 80



SURFACE



MID-DEPTH



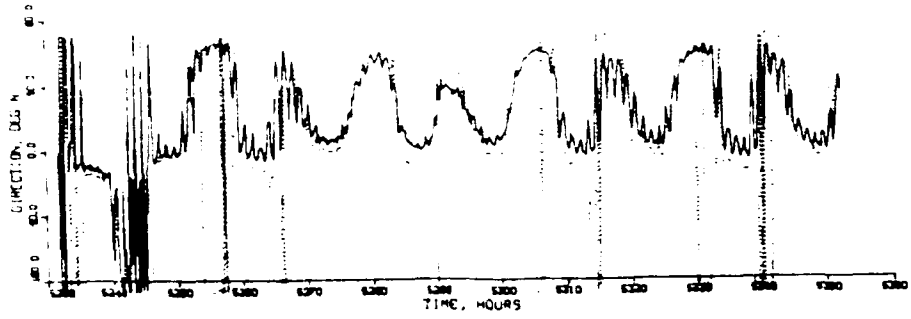
BOTTOM

TIDAL VELOCITY — CALIBRATION PERIOD

MAGNITUDE — GAGE C18

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 81



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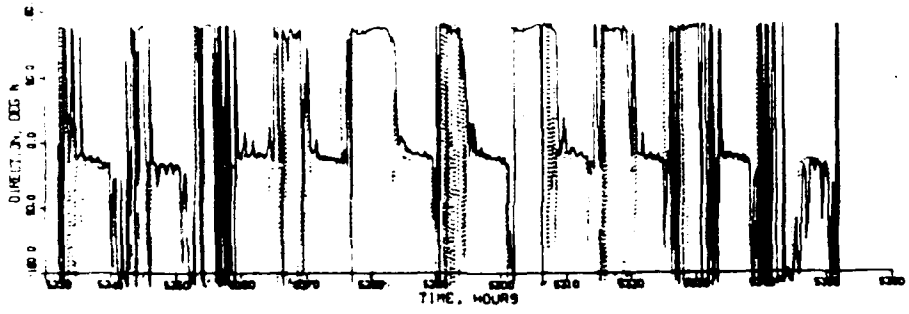

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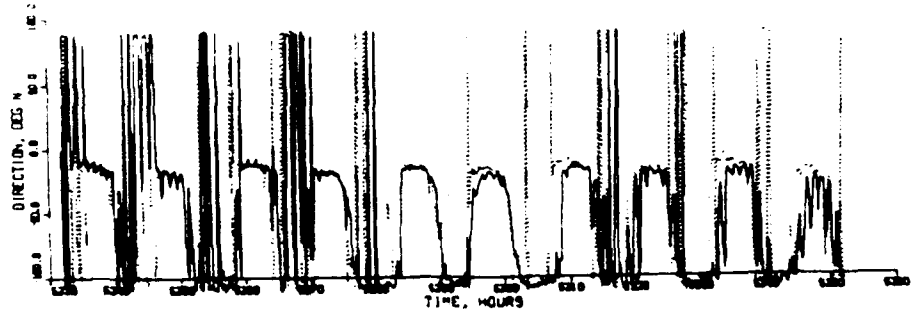


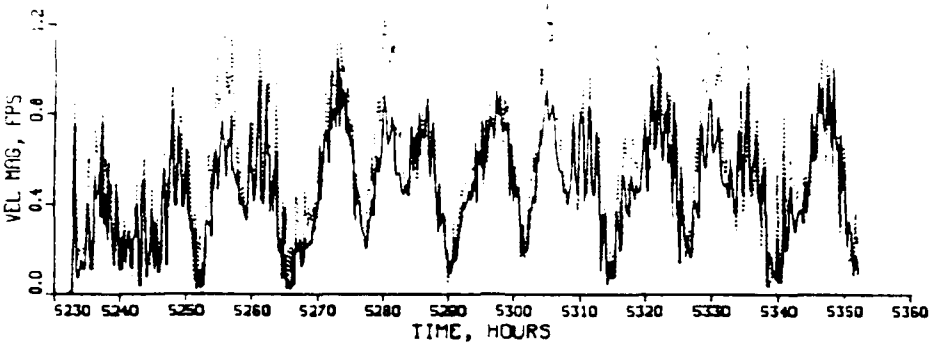
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C18

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 82



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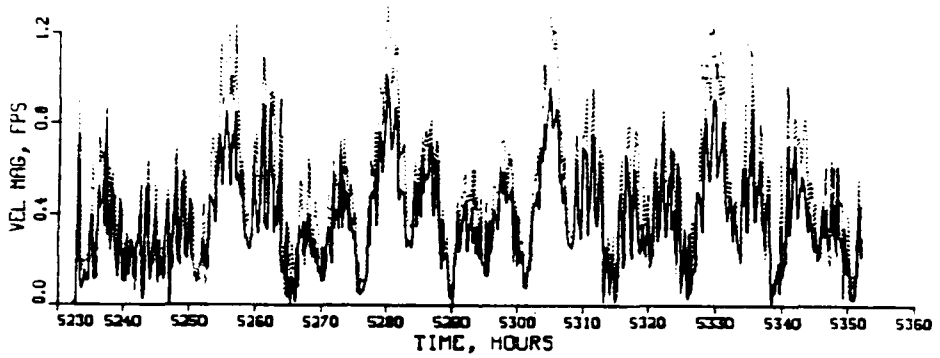
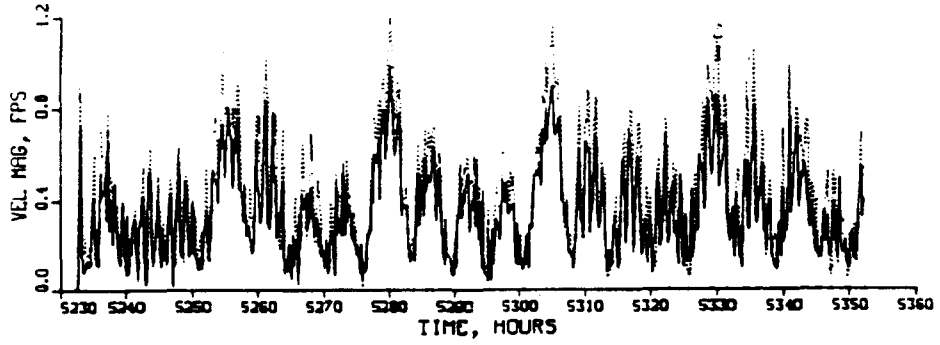


MID-DEPTH



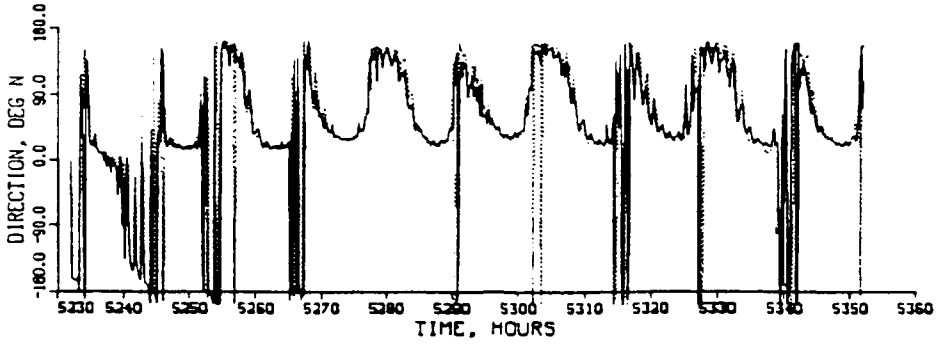
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

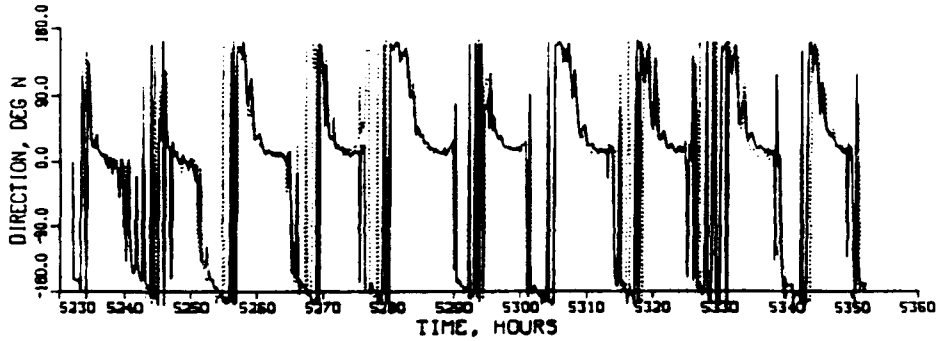
MAGNITUDE GAGE C19

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

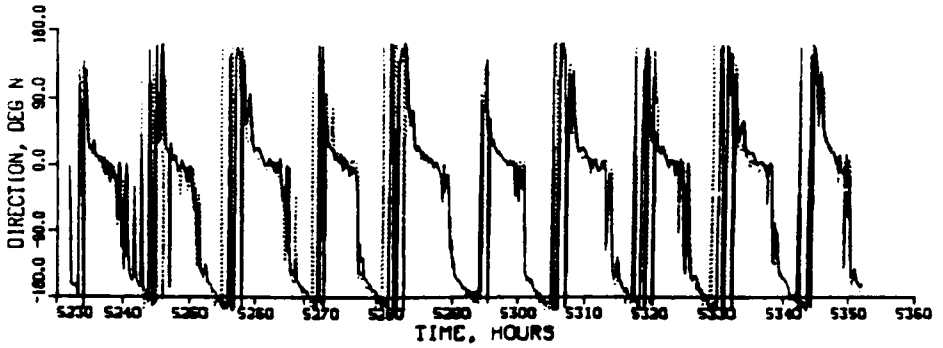
PLATE 83



SURFACE



MID-DEPTH



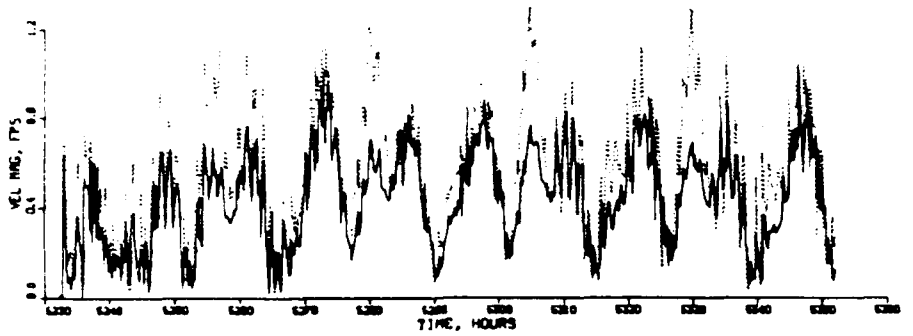
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C19

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 84



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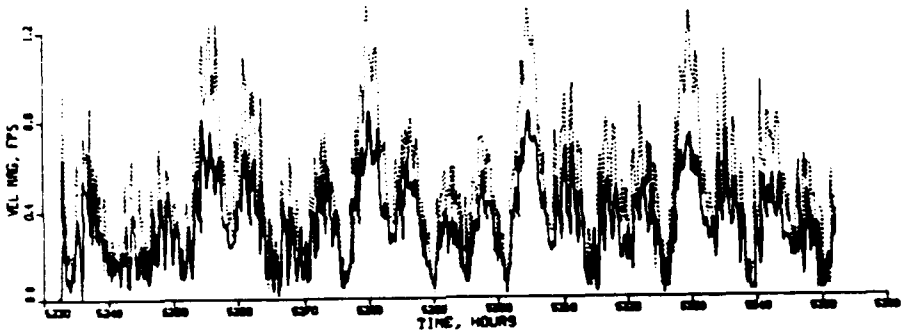

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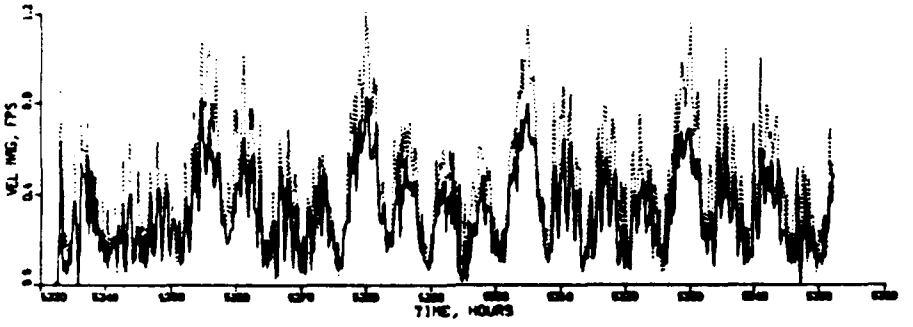


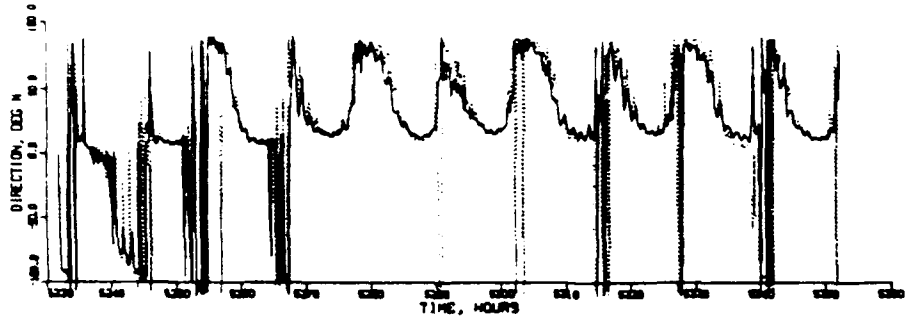
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C19

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 85



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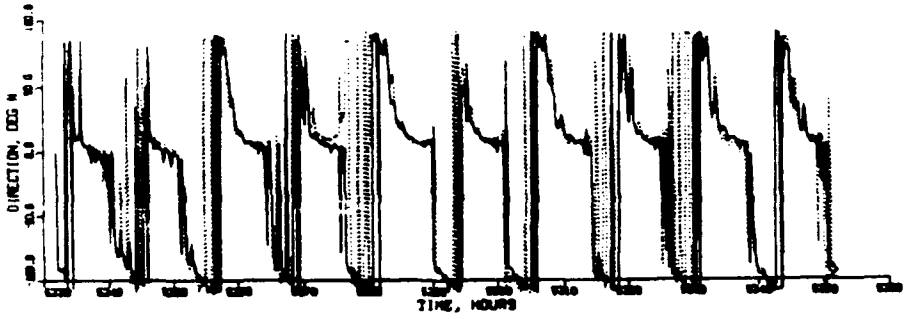

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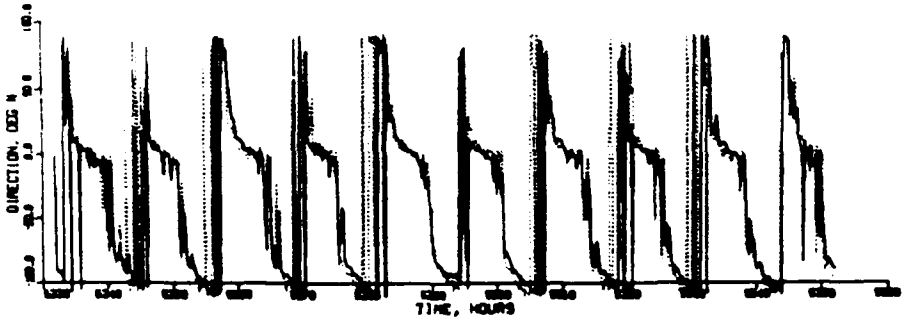


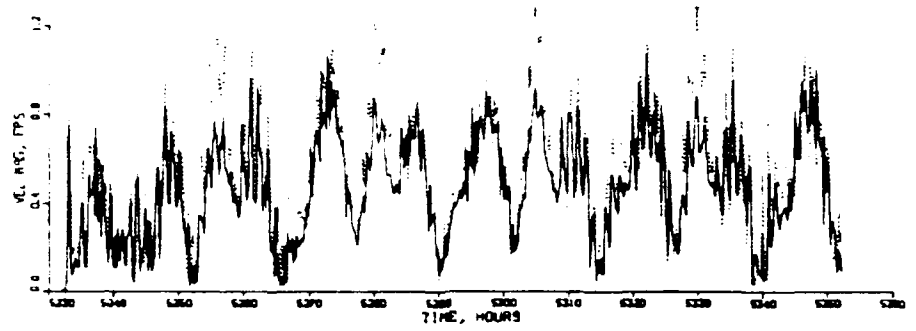
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C19

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 86



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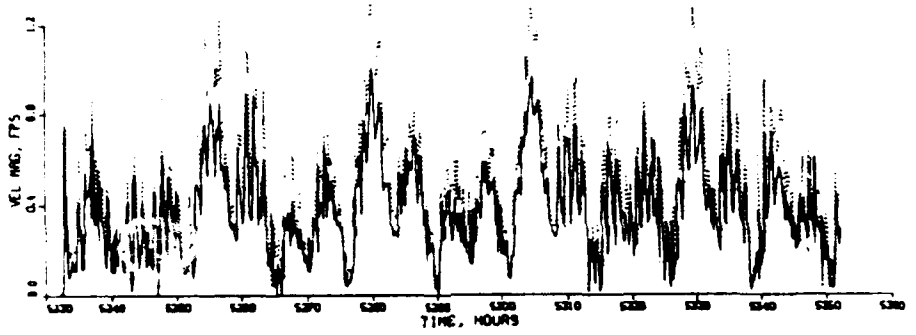

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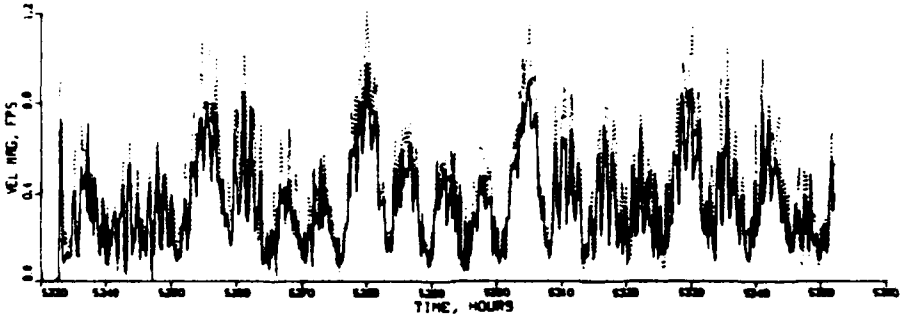


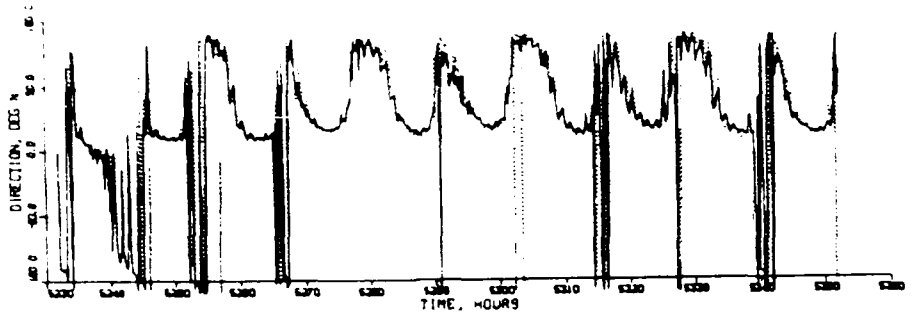
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C19

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 87



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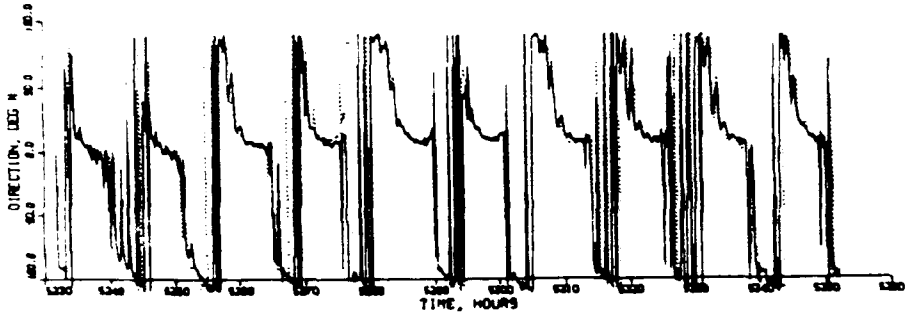

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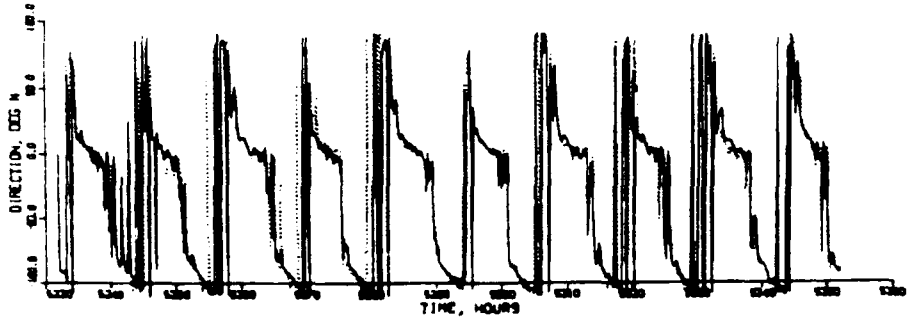


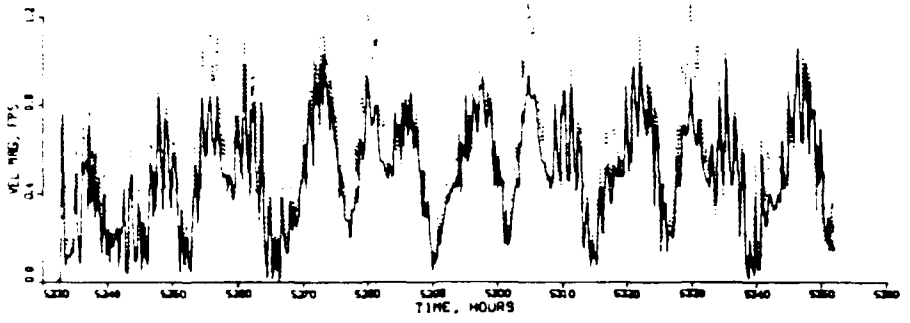
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C19

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 88



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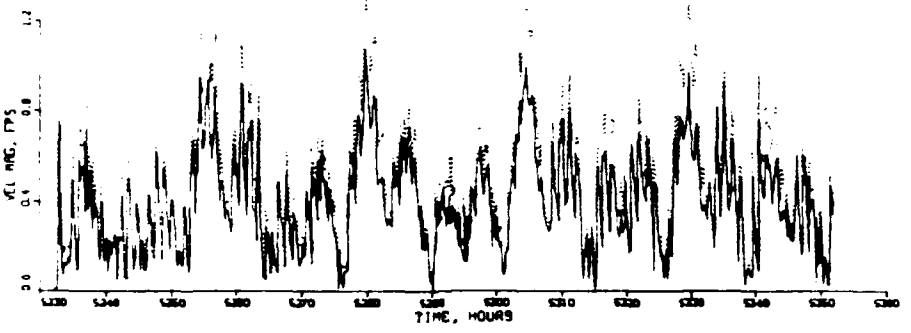

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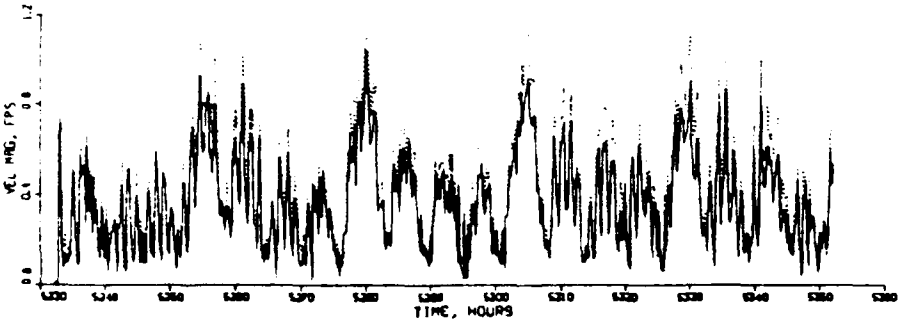


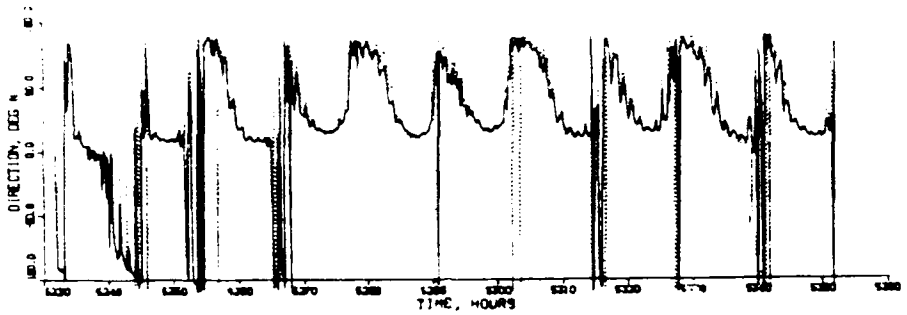
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C19

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 89



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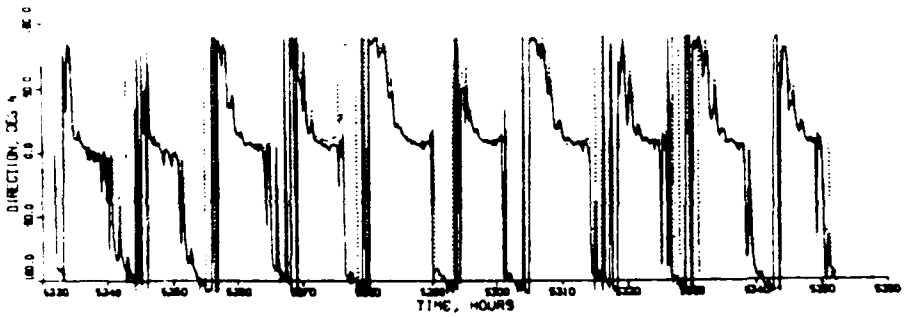
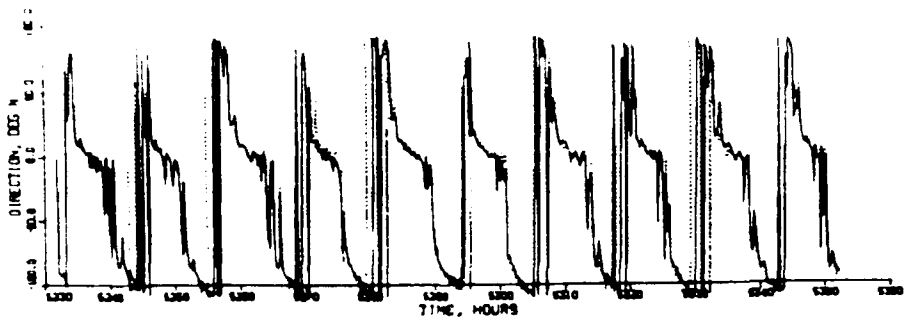


MID-DEPTH



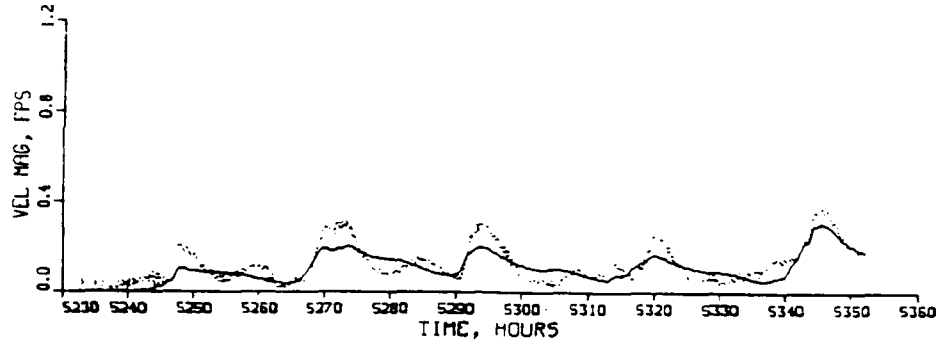
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C19

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 90



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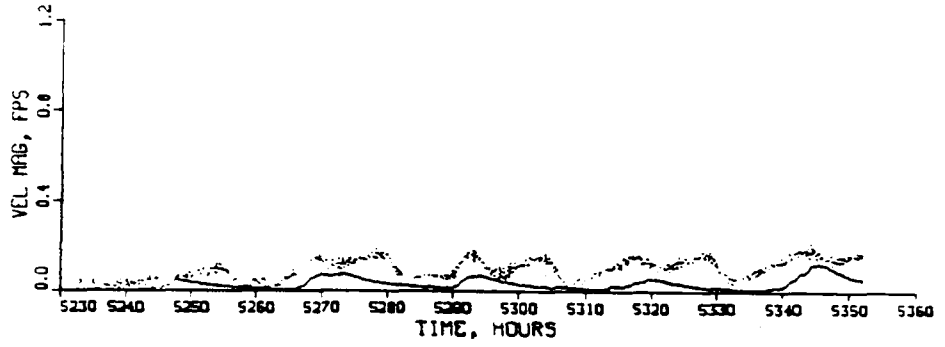

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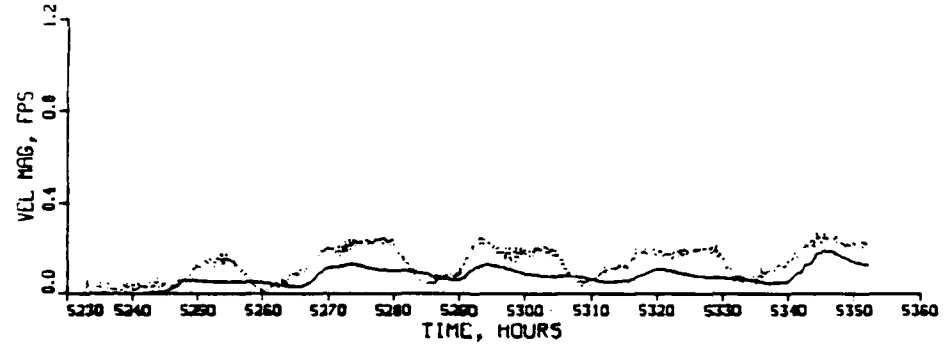


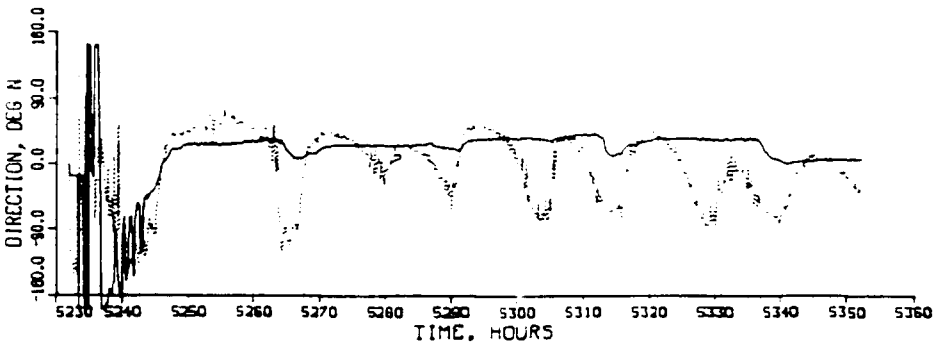
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C12

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 91



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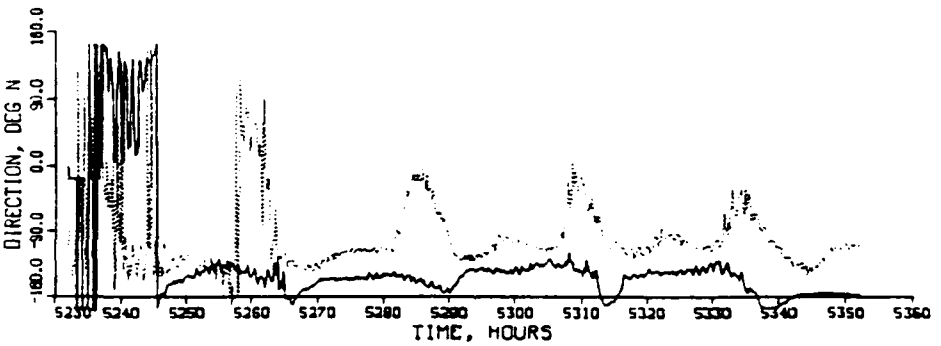

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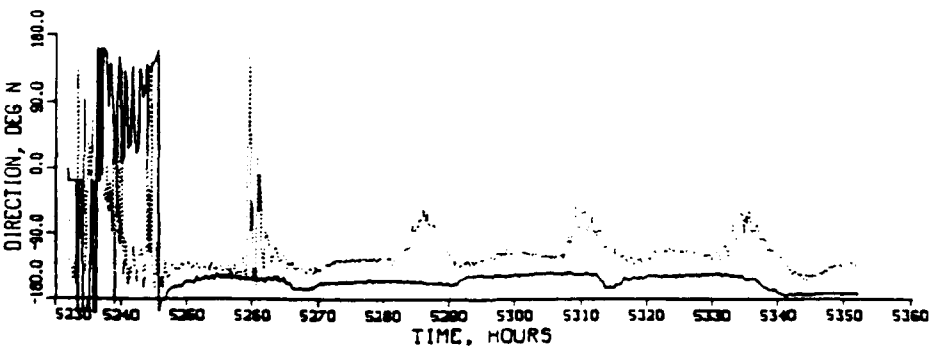


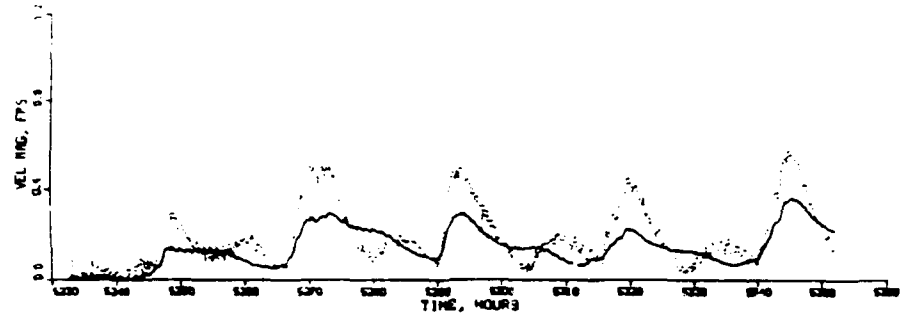
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C12

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 92



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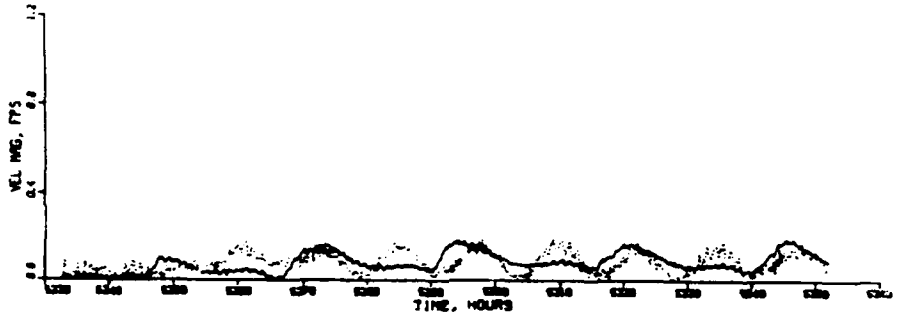

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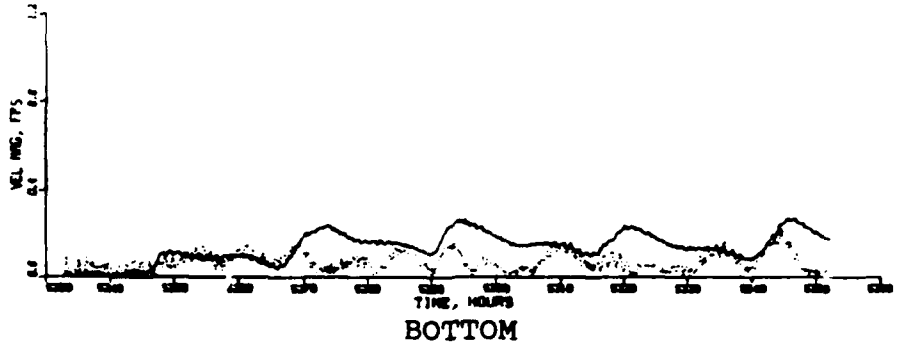


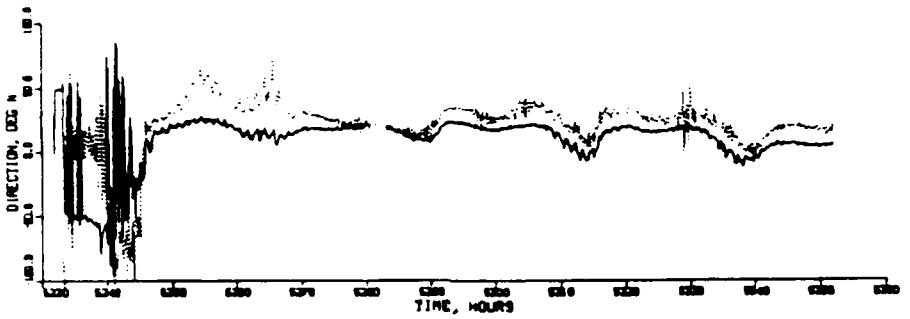
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C12A

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 93



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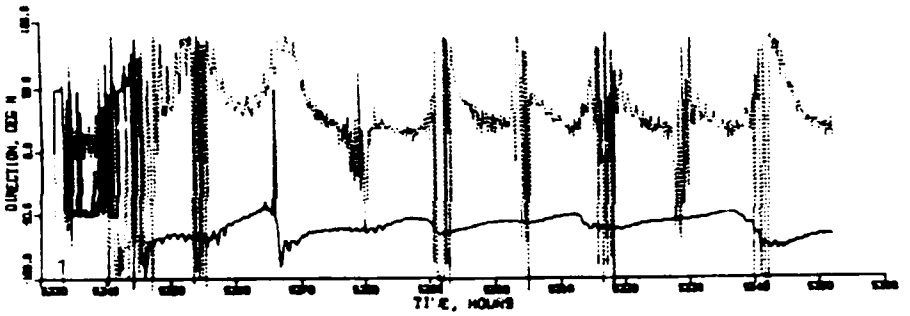

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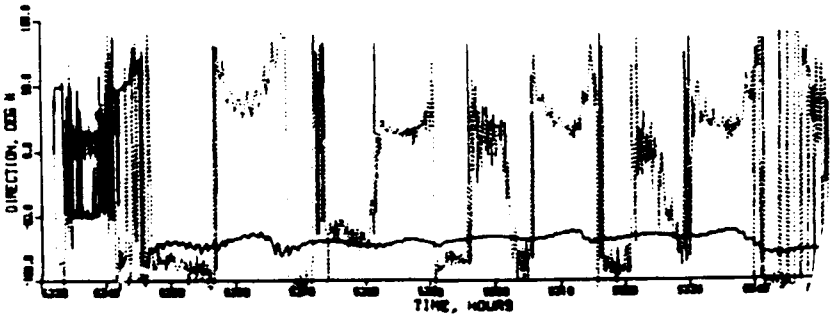


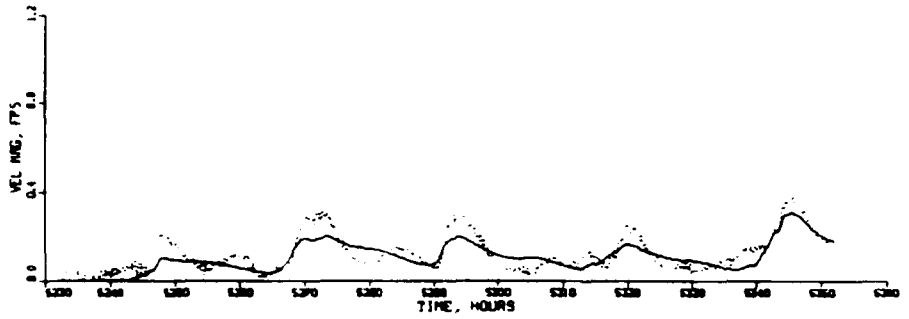
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C12A

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 94



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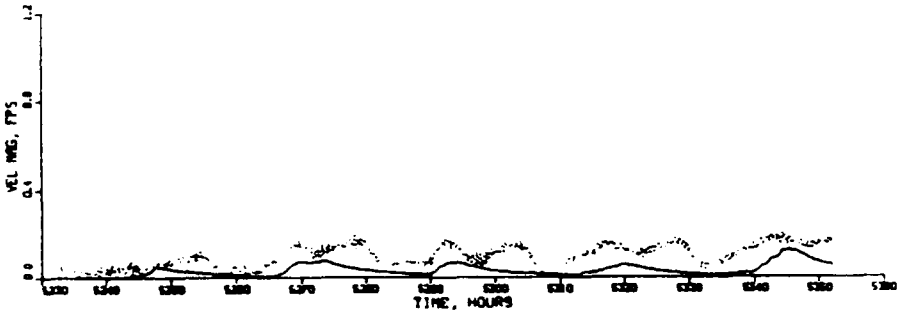

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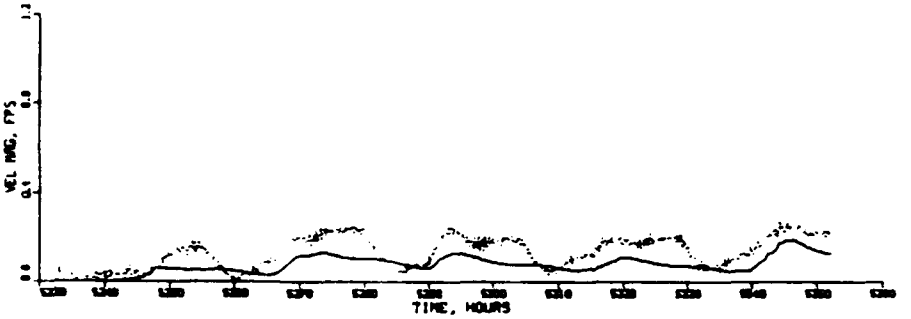


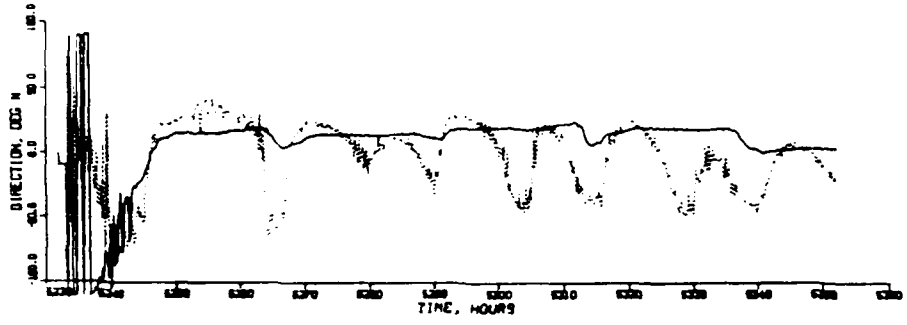
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C12

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 95



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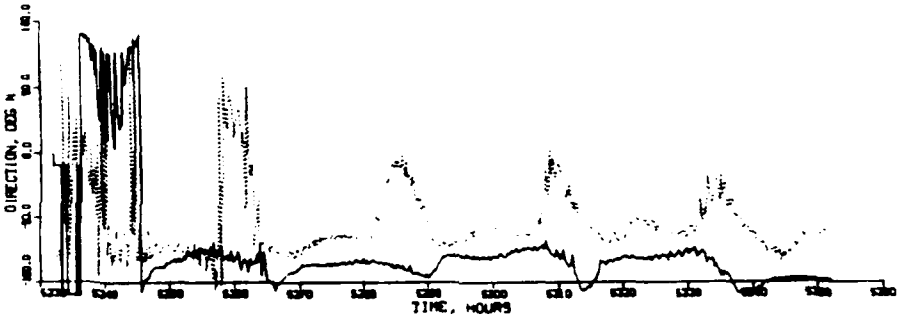

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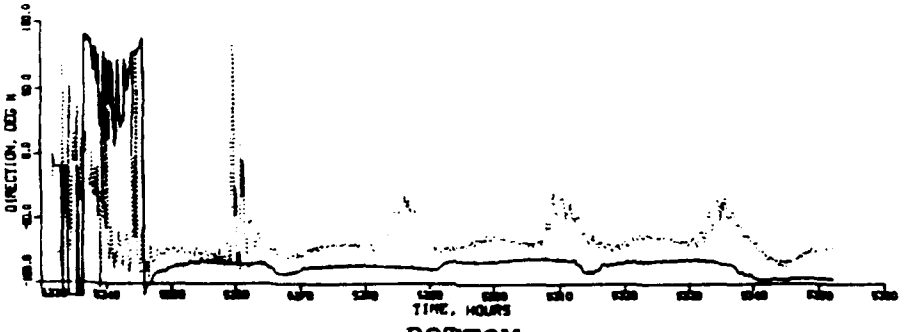


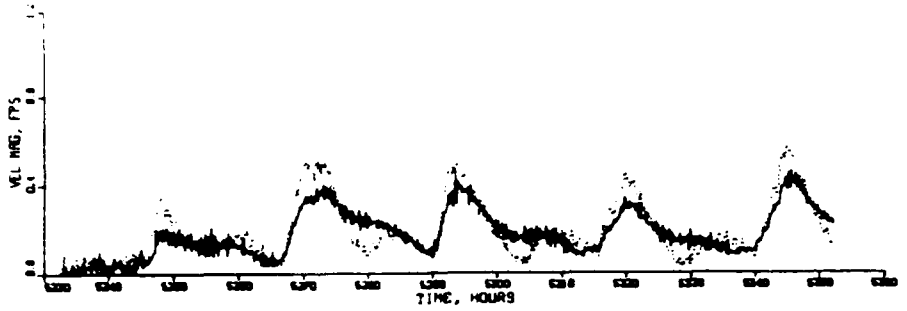
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C12

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 96



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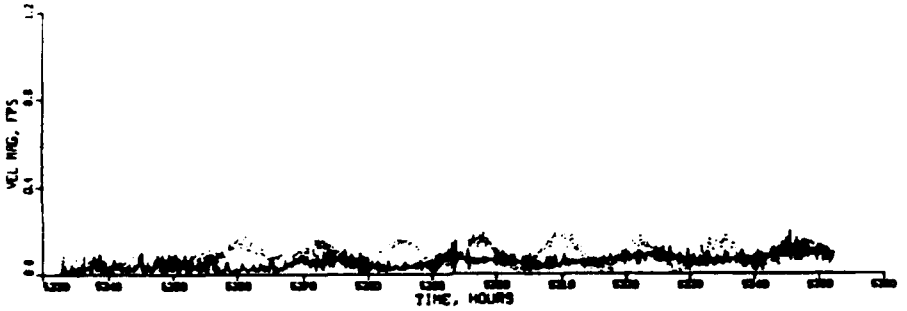
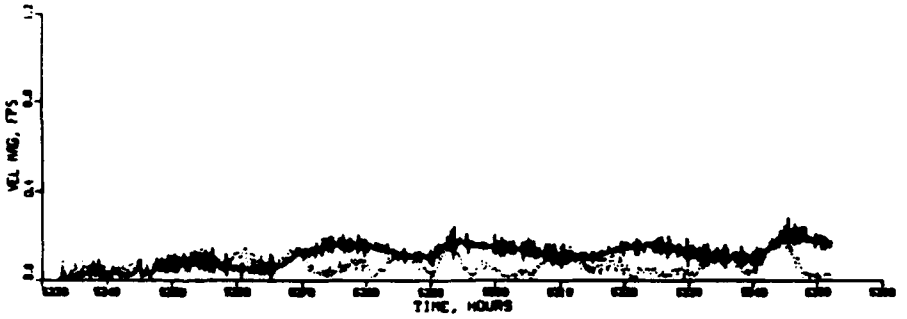


MID-DEPTH



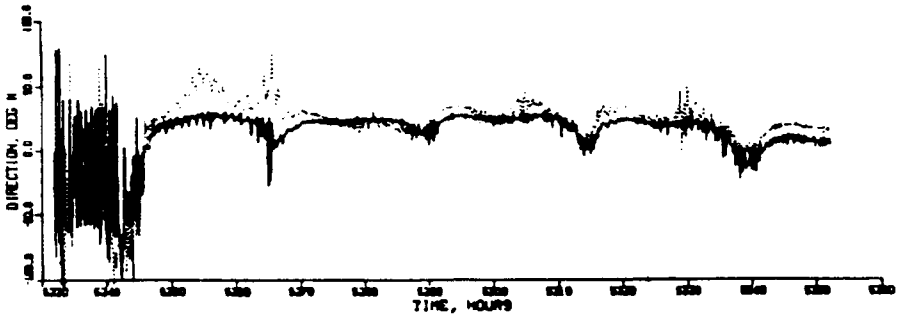
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

MAGNITUDE GAGE C12A

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 97



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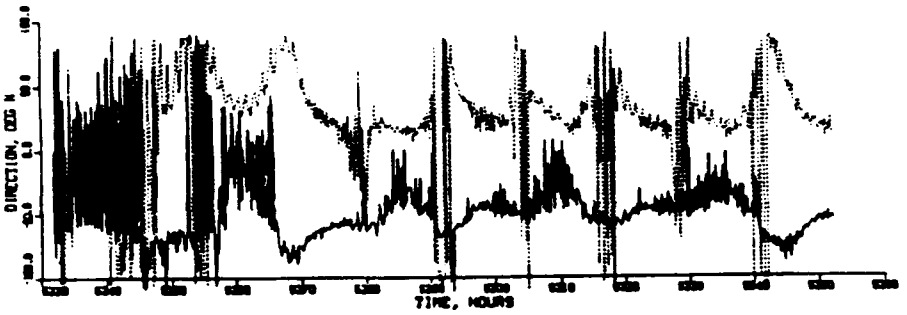
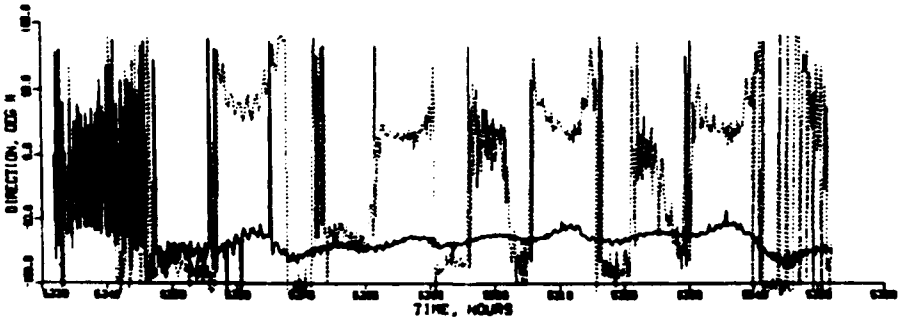


MID-DEPTH



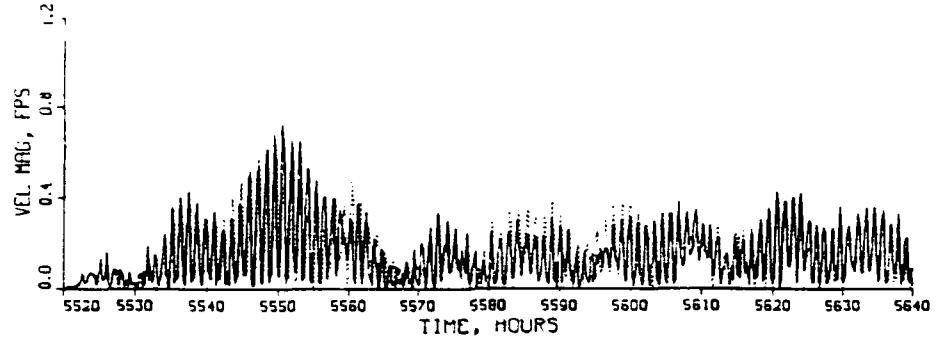
BOTTOM

TIDAL VELOCITY **CALIBRATION PERIOD**

DIRECTION GAGE C12A

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 98



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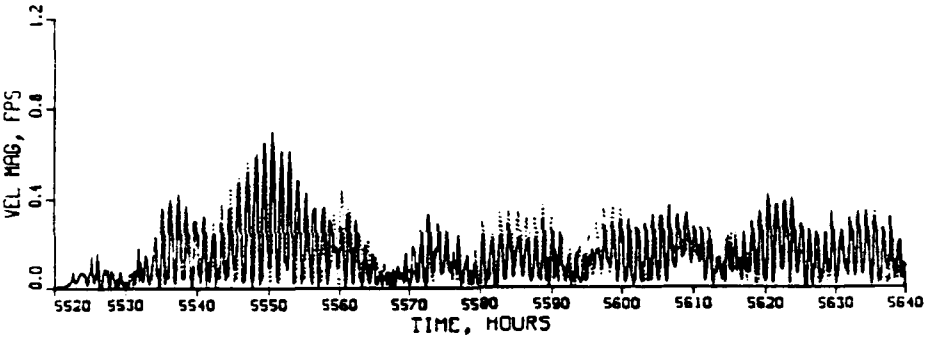
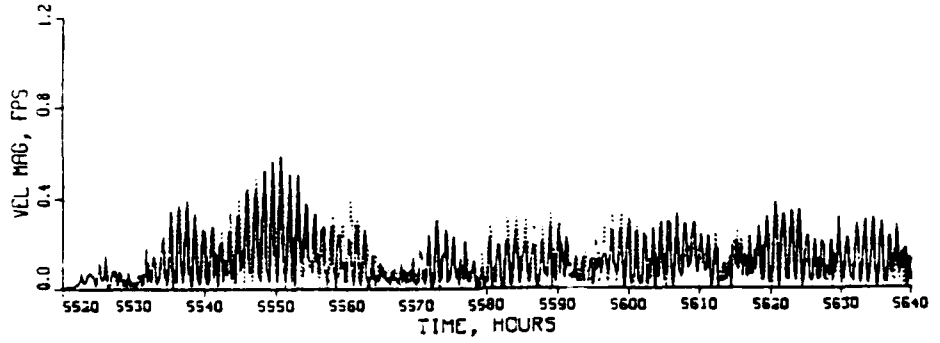


MID-DEPTH



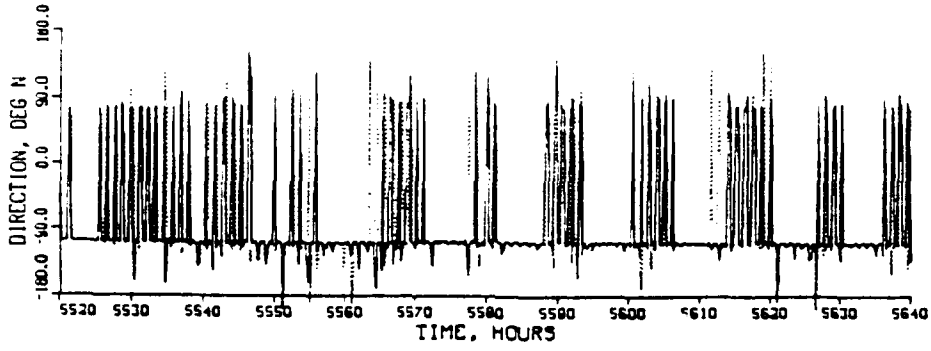
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

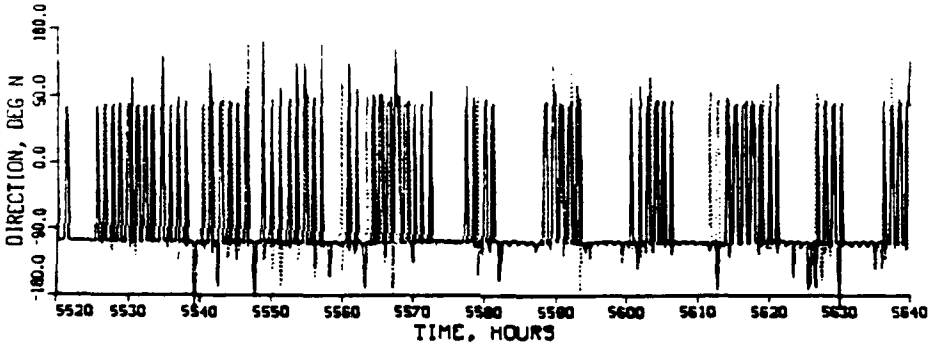
MAGNITUDE GAGE C1

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

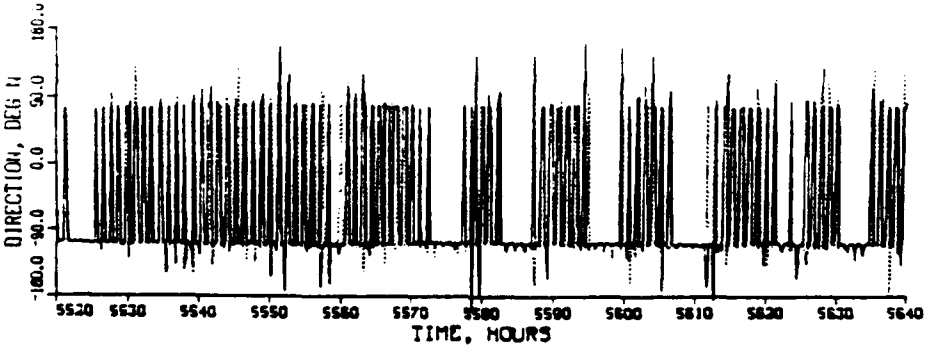
PLATE 99



SURFACE



MID-DEPTH



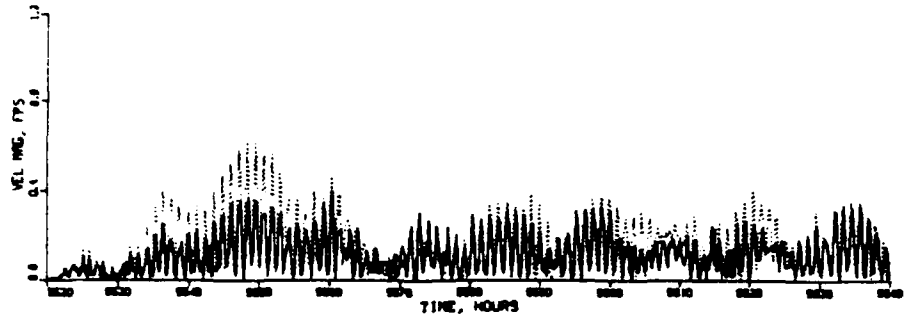
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C1

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 100



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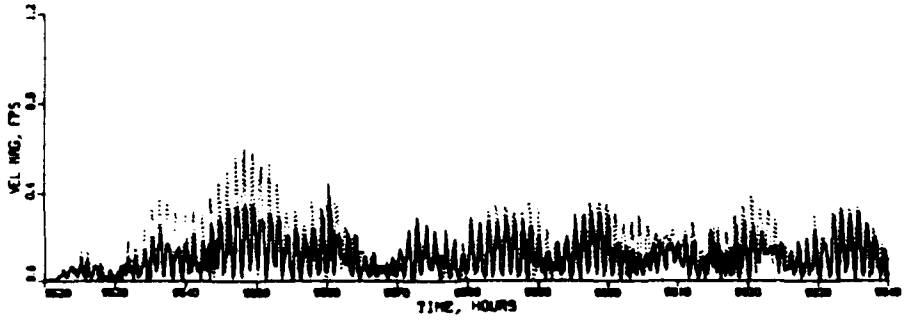

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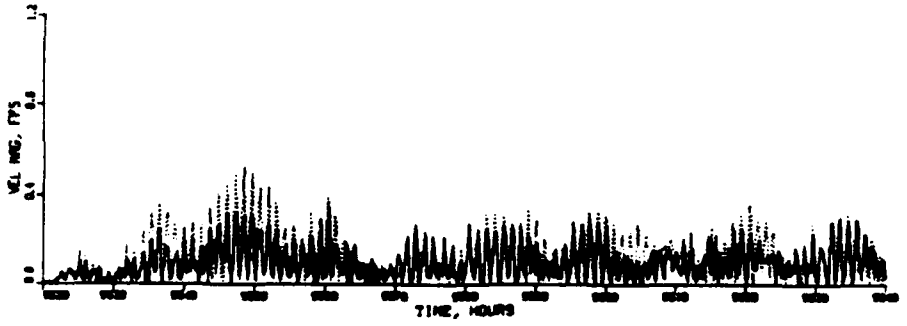


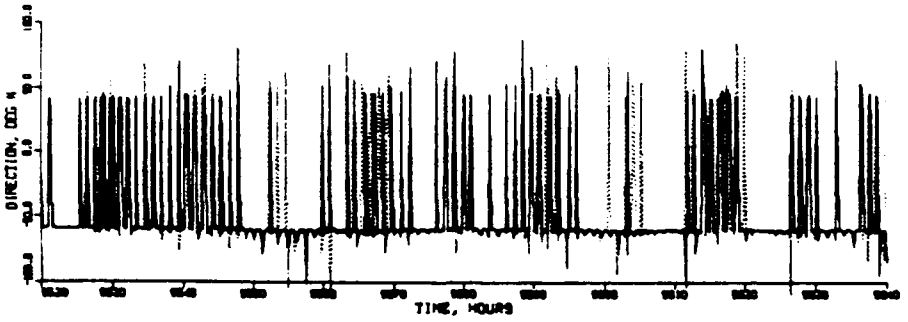
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C1

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 101



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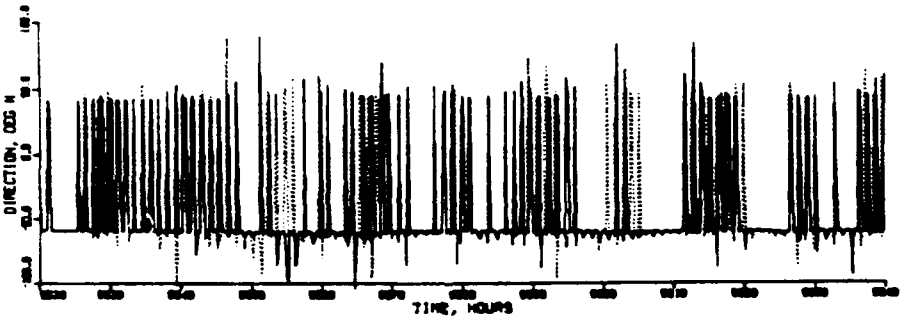

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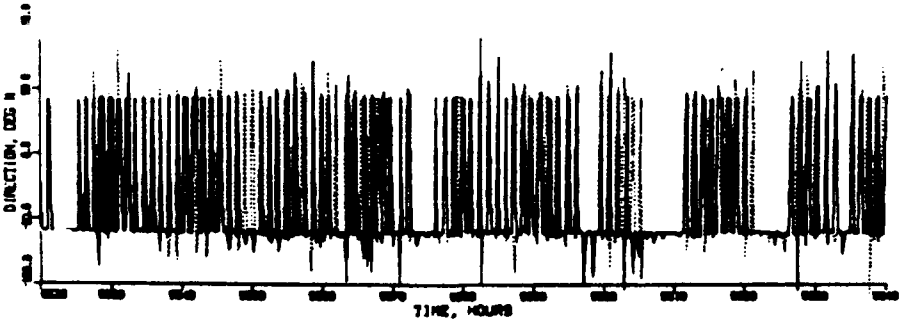


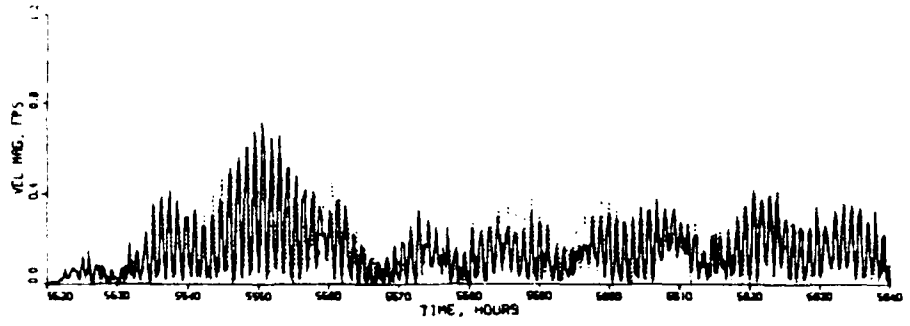
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C1

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 102



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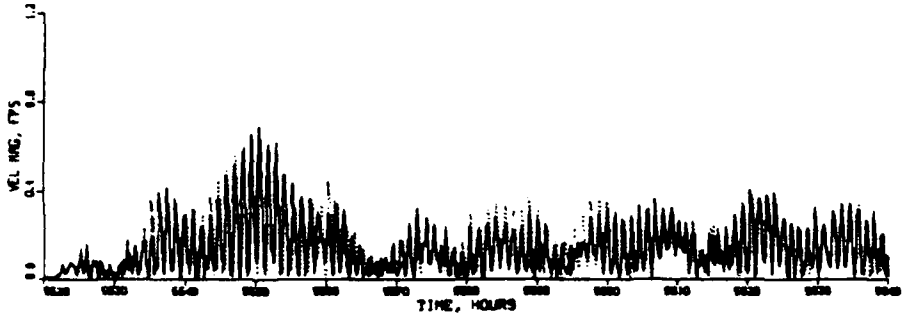

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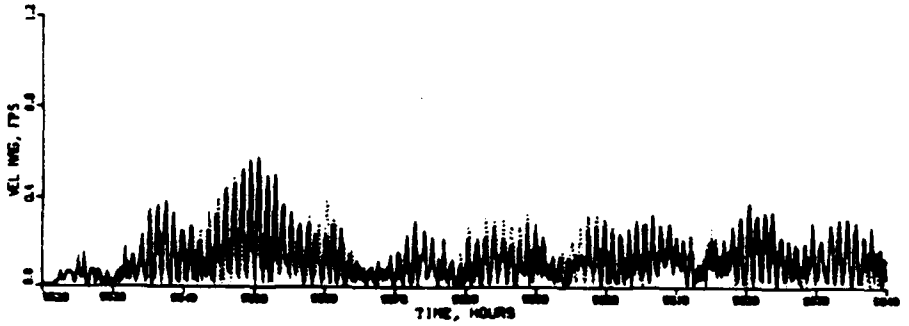


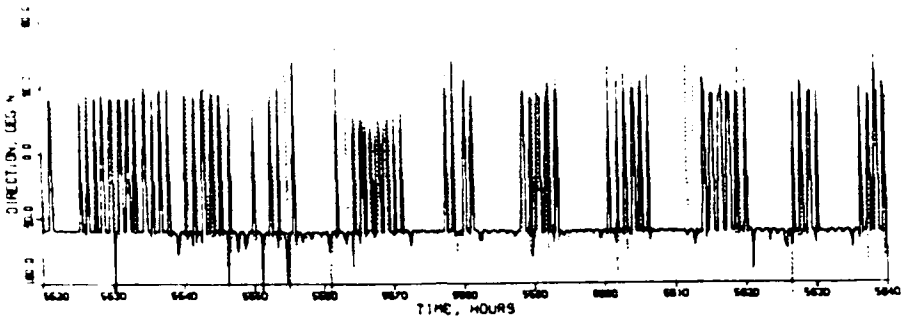
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C1

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 103



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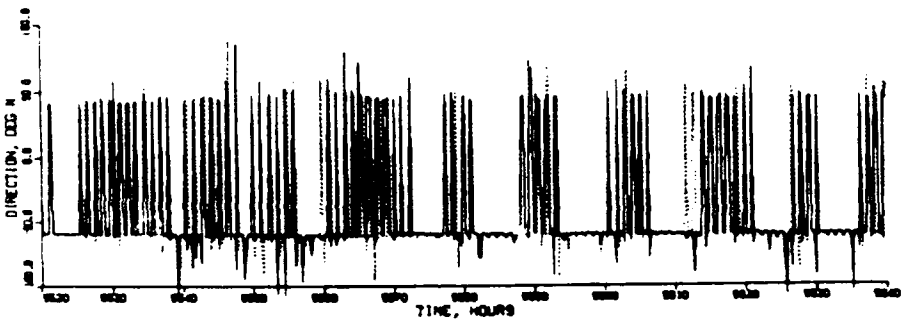
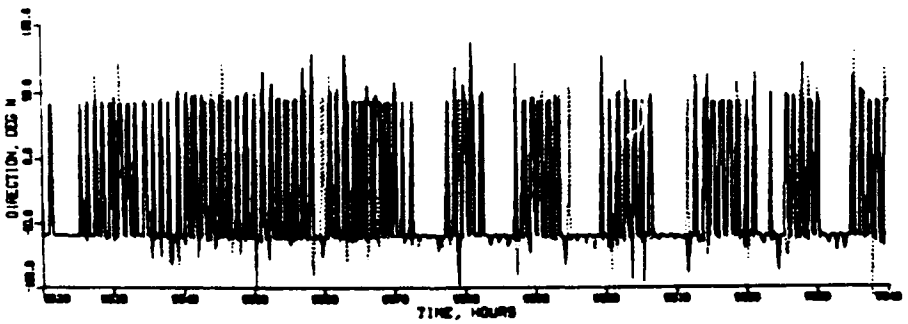


MID-DEPTH



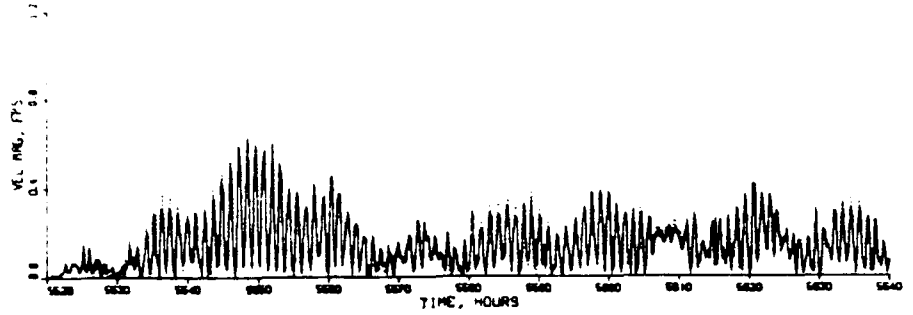
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C1

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 104



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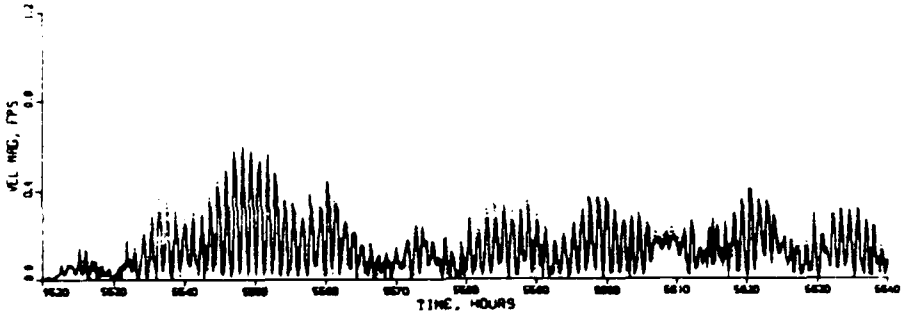
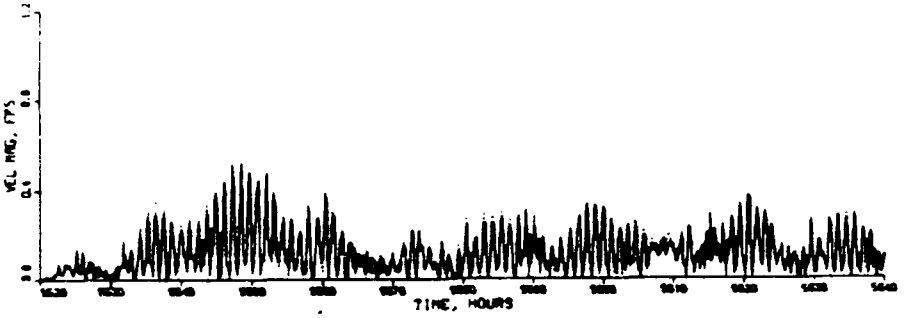


MID-DEPTH



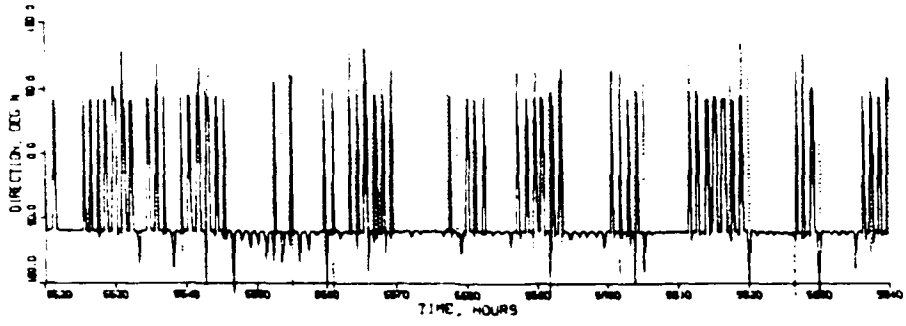
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C1

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 105



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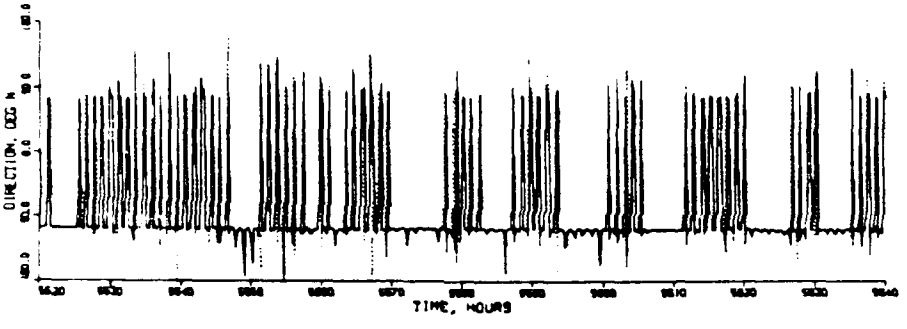
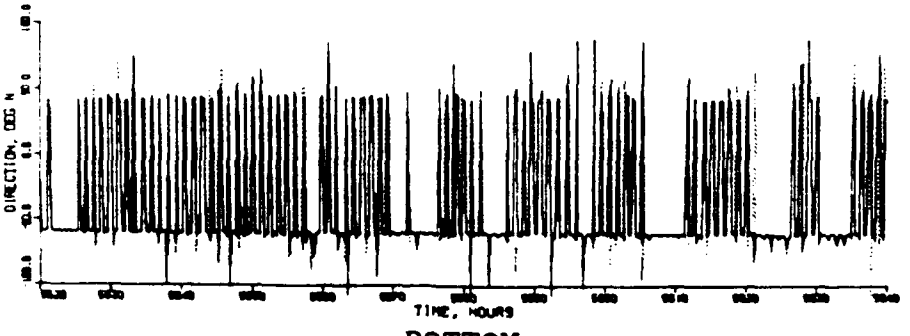


MID-DEPTH



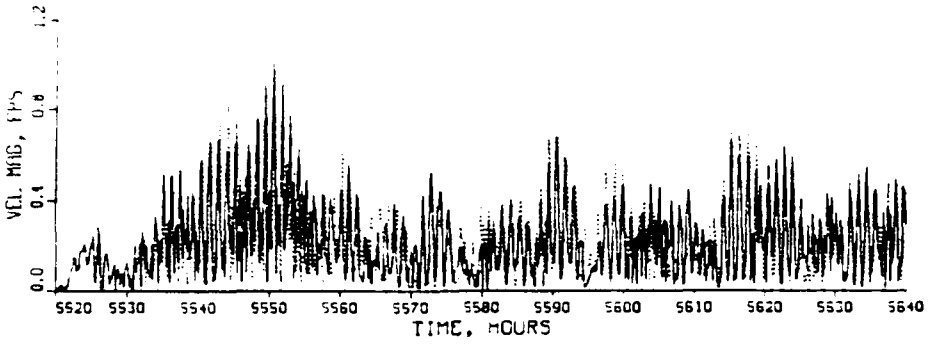
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C1

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 106



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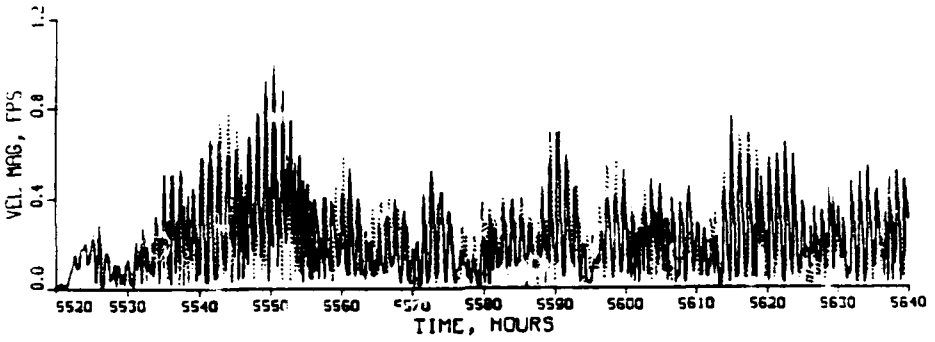
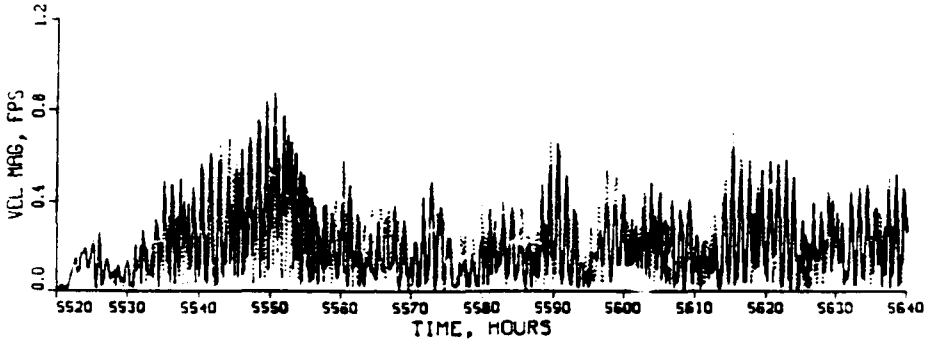


MID-DEPTH



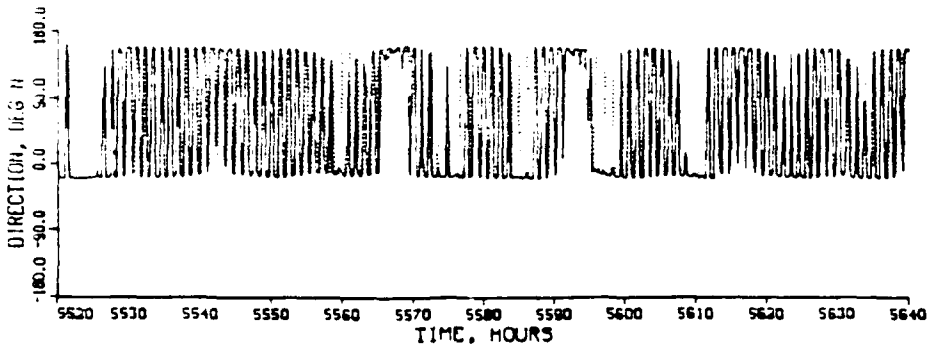
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C2

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 107



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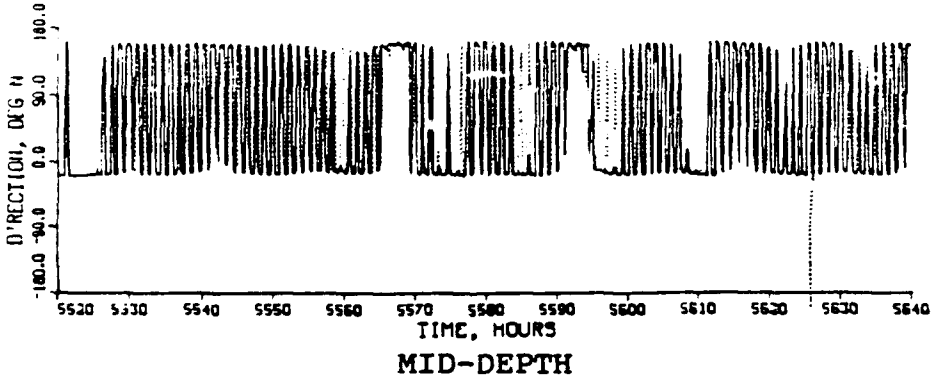
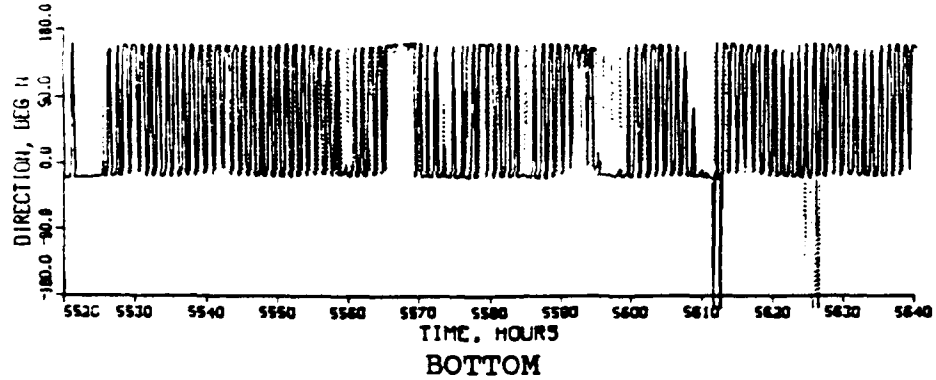


MID-DEPTH



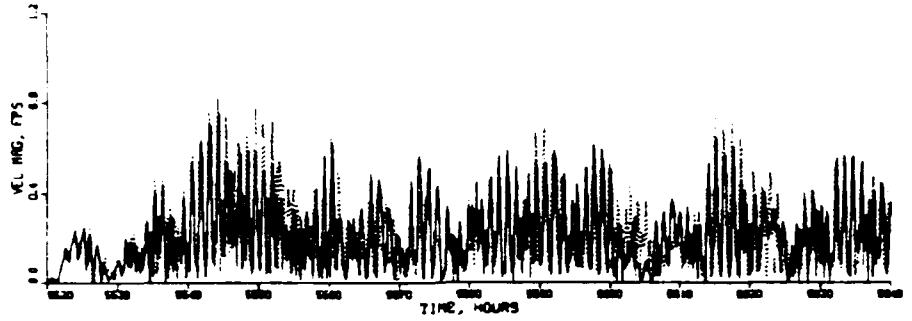
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C2

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 108



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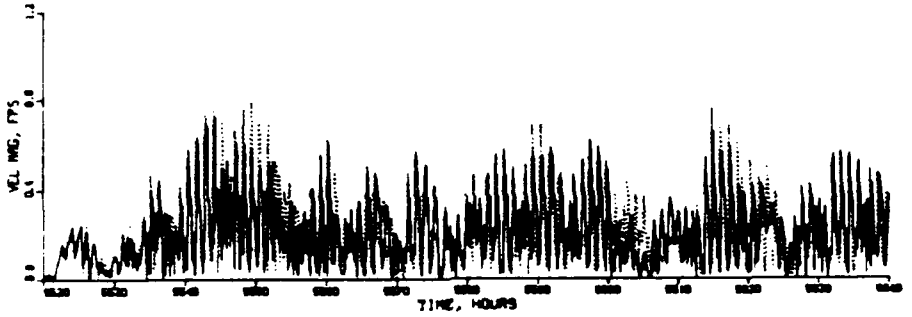
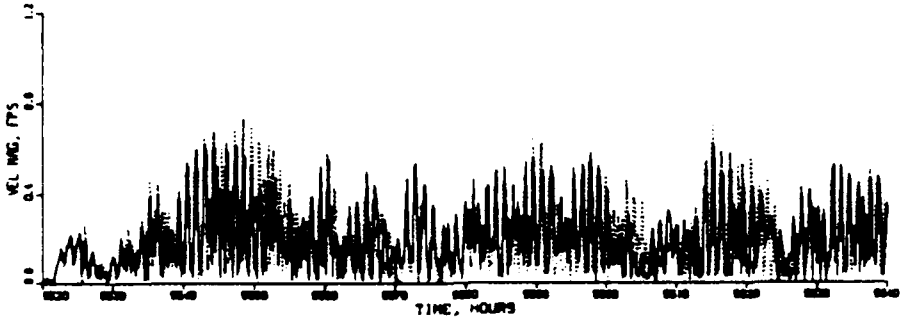


MID-DEPTH



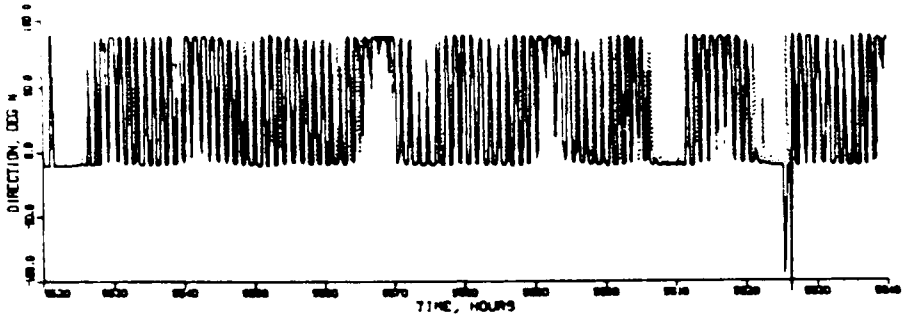
BOTTOM

TIDAL VELOCITY — VERIFICATION PERIOD

MAGNITUDE — GAGE C2

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 109



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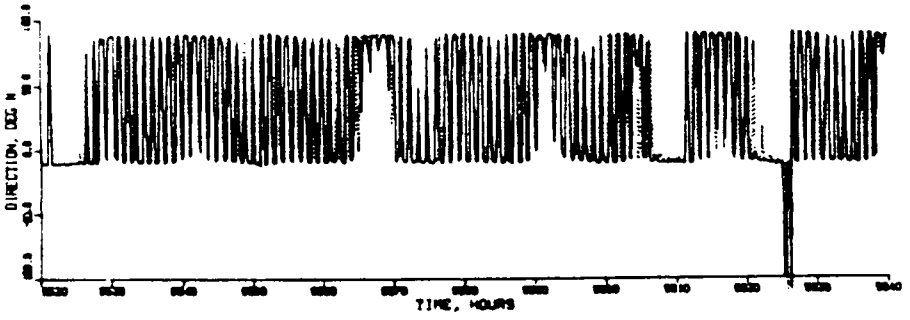

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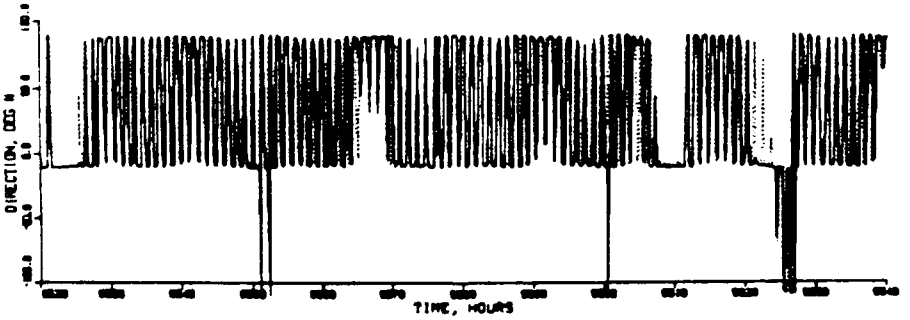


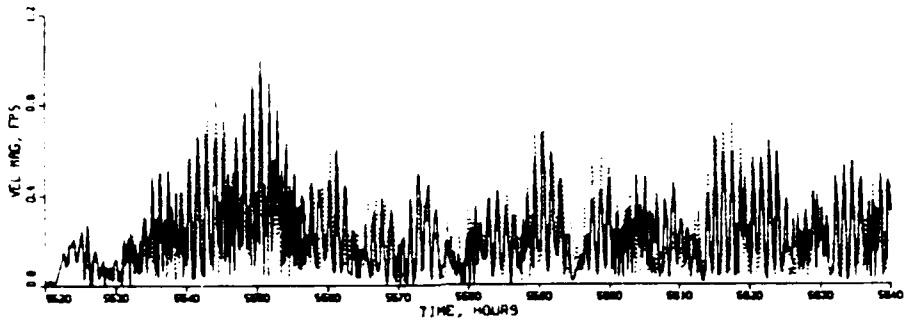
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C2

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 110



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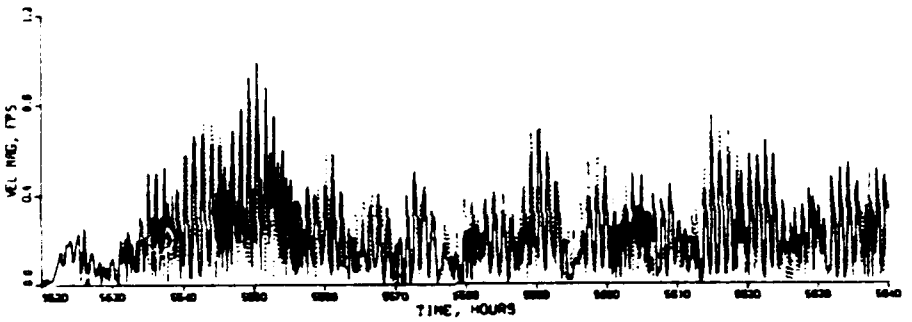
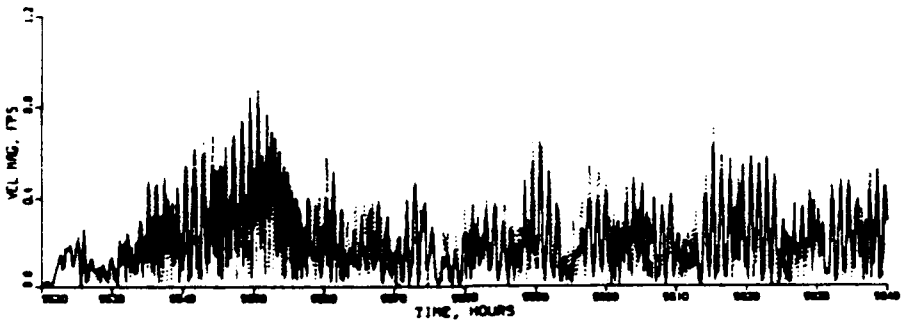


MID-DEPTH



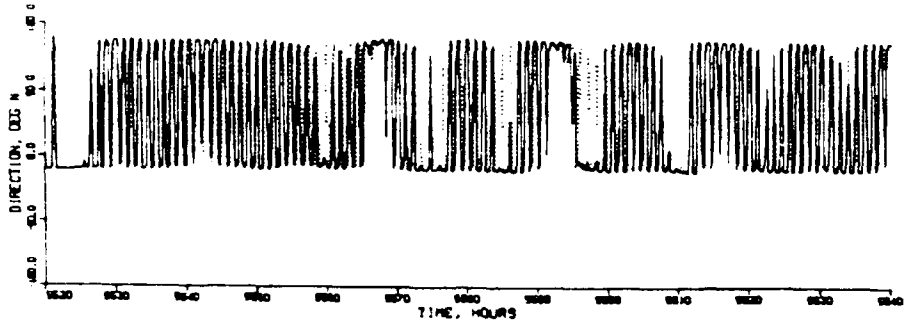
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

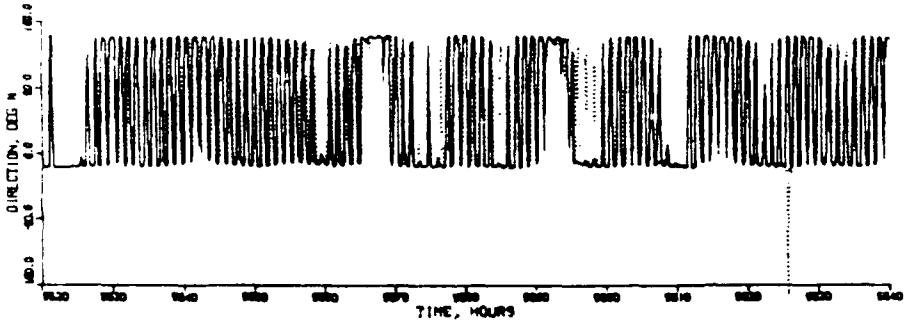
MAGNITUDE GAGE C2

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

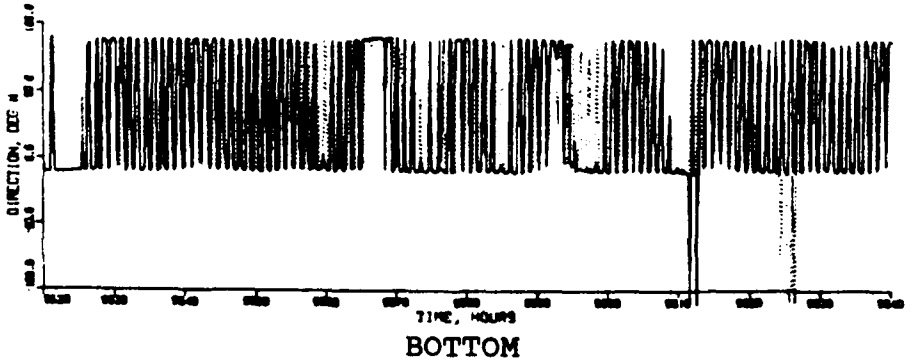
PLATE 111



SURFACE



MID-DEPTH



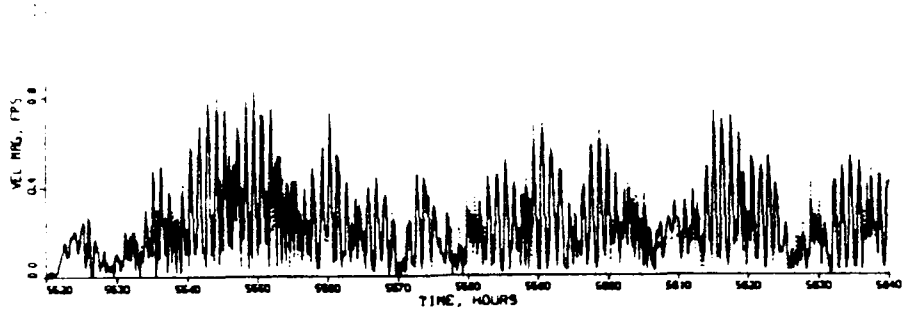
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C2

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 112



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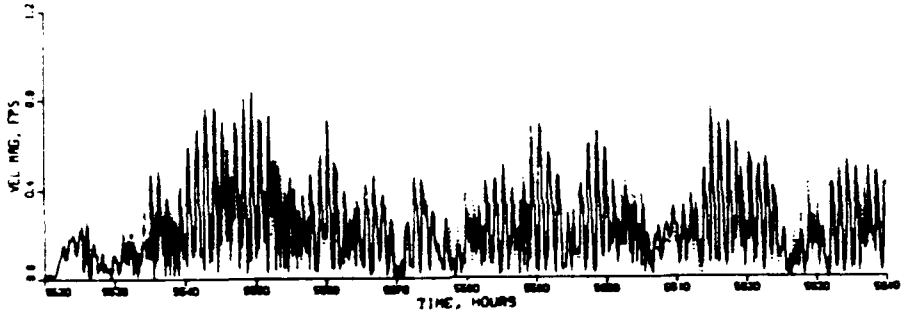
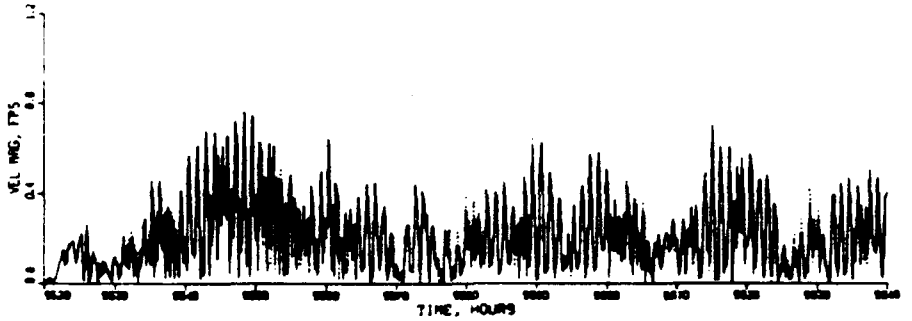


MID-DEPTH



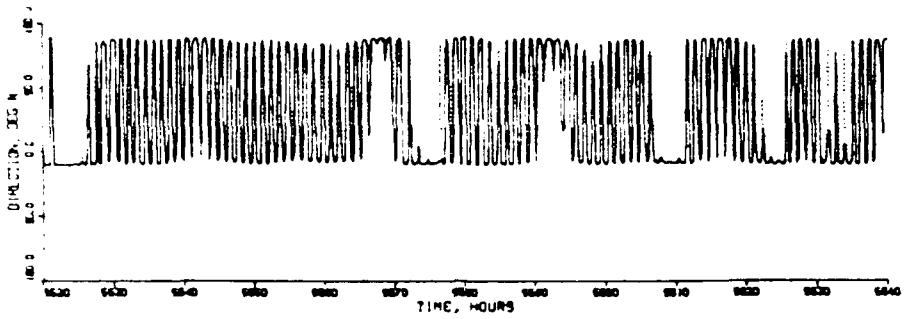
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C2

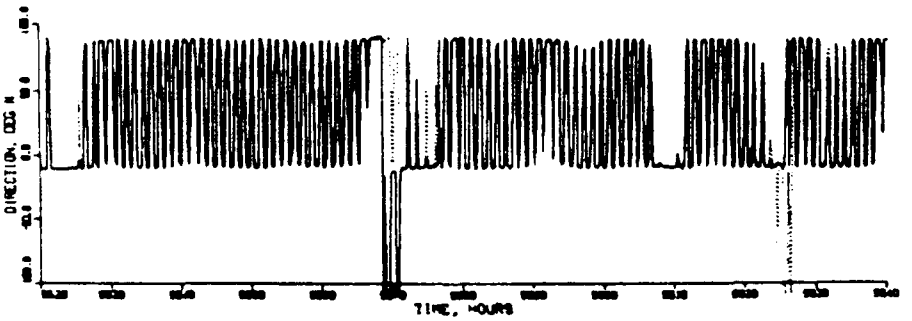
PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 113



SURFACE

MID-DEPTH



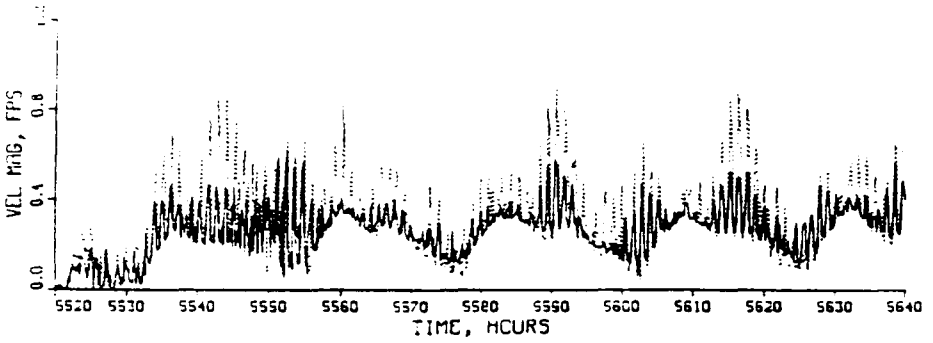
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

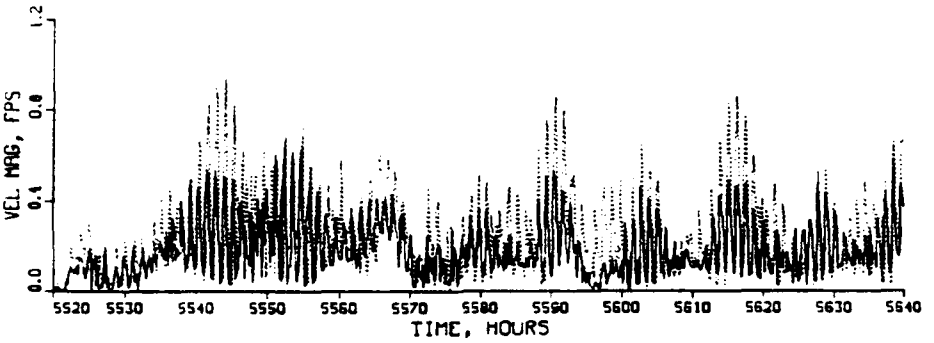
DIRECTION GAGE C2

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

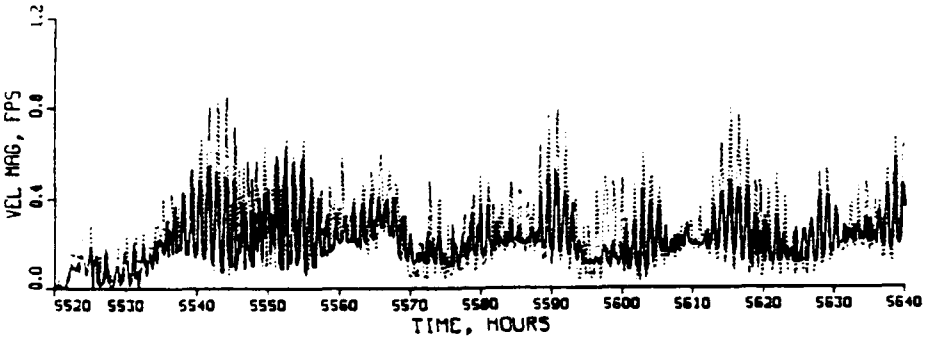
PLATE 114



SURFACE



MID-DEPTH



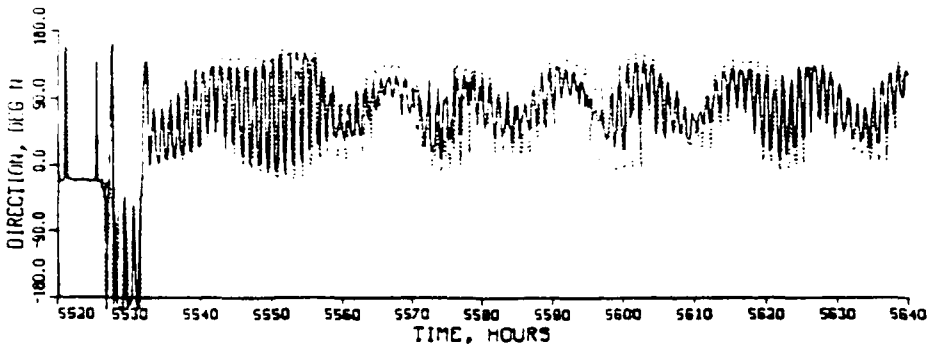
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

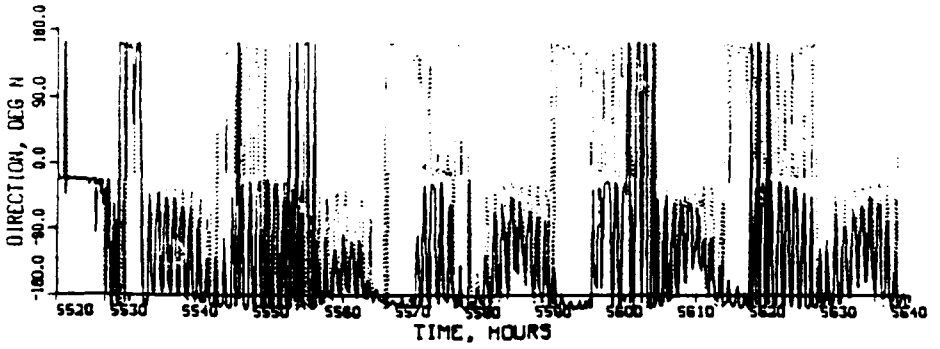
MAGNITUDE **GAGE C3**

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

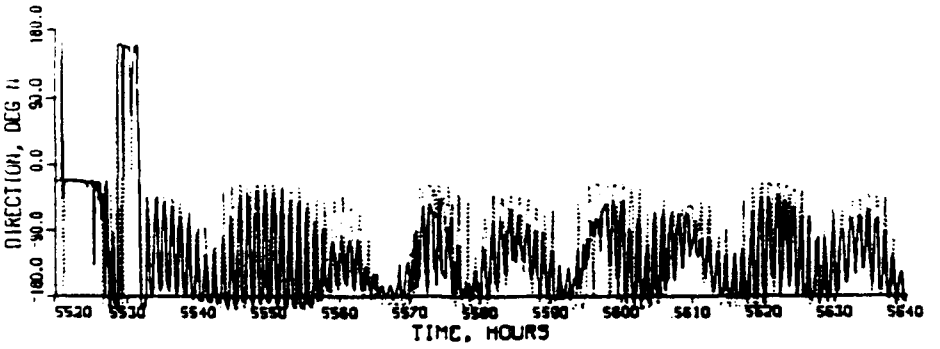
PLATE 115



SURFACE



MID-DEPTH



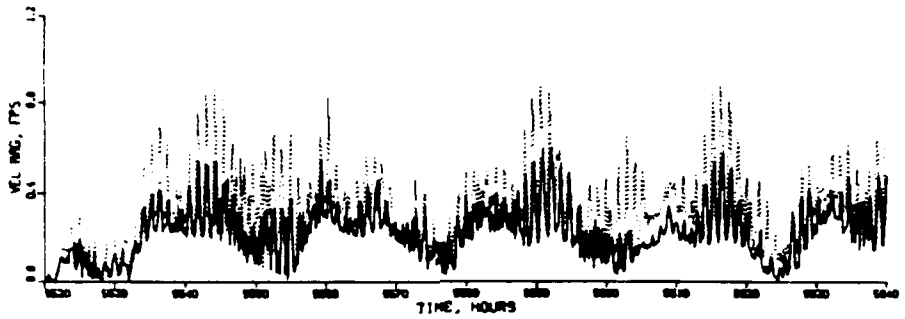
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

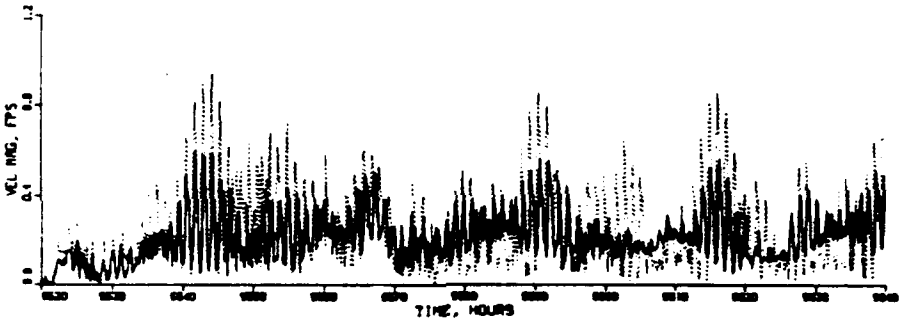
DIRECTION GAGE C3

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

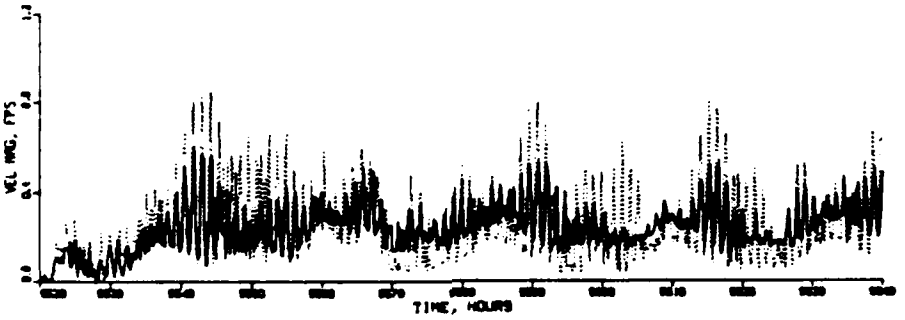
PLATE 116



SURFACE



MID-DEPTH



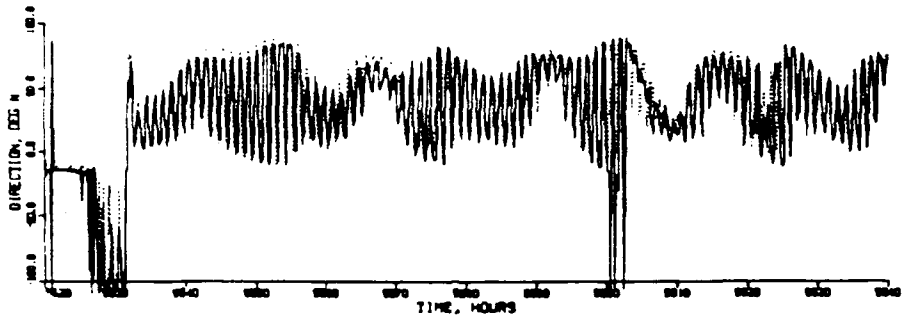
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C3

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 117



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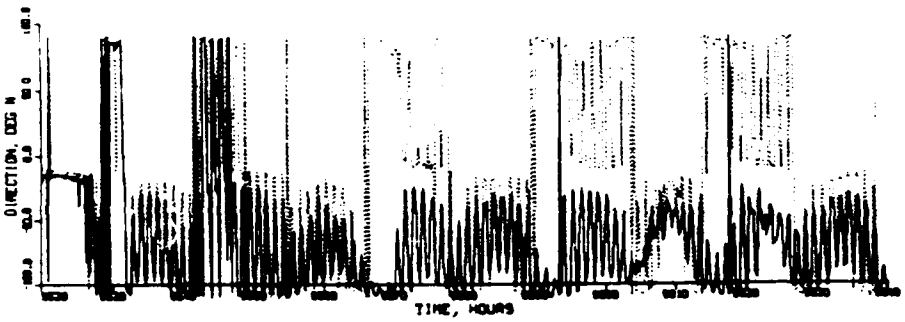

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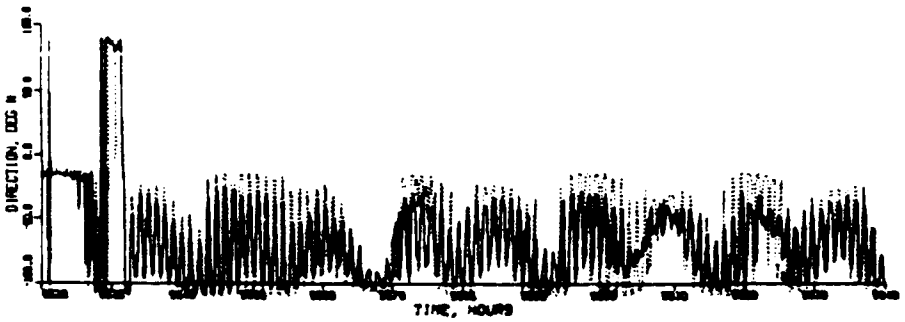


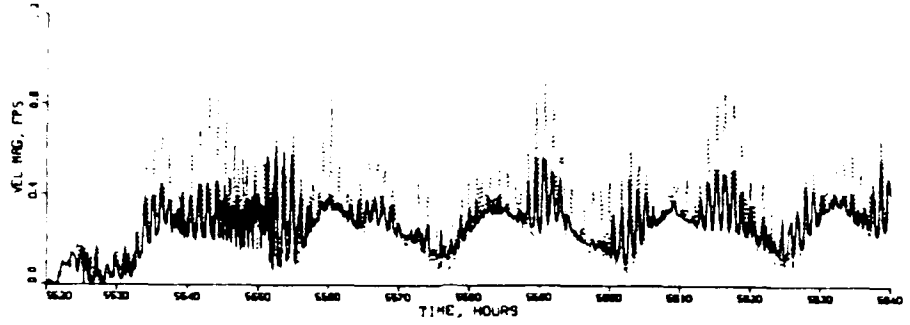
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C3

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 118



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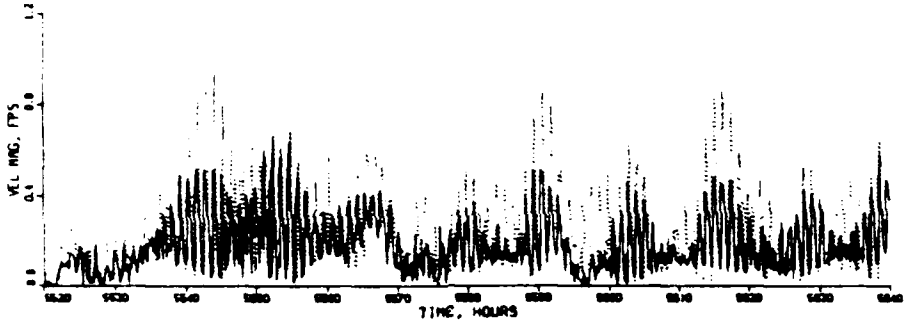
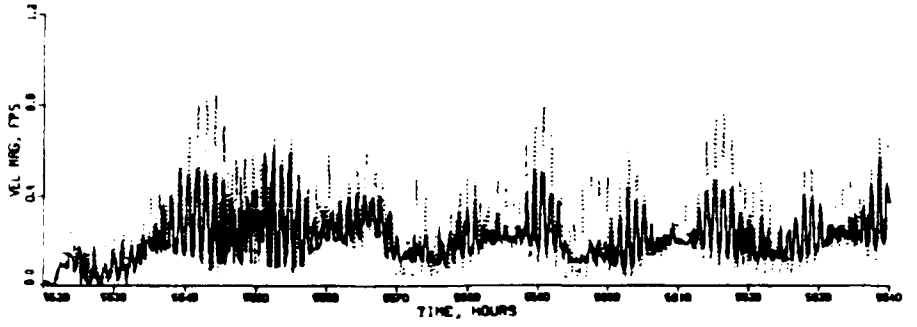


MID-DEPTH



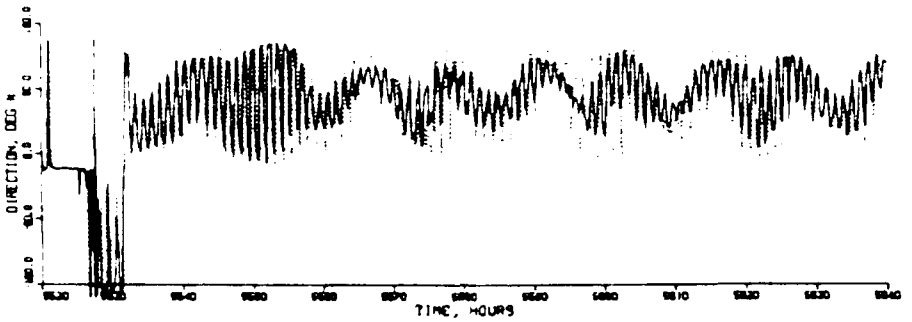
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C3

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 119



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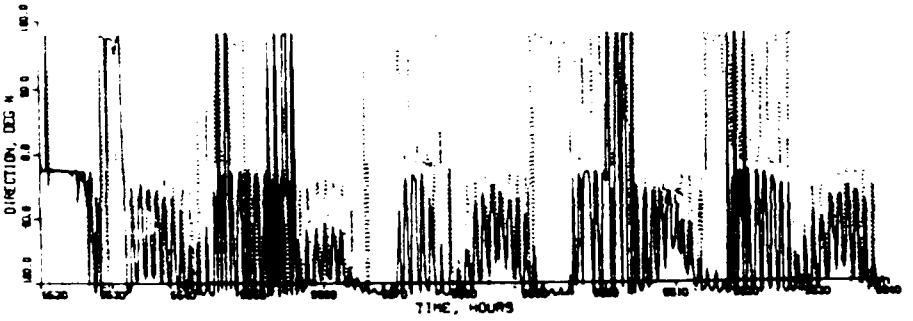
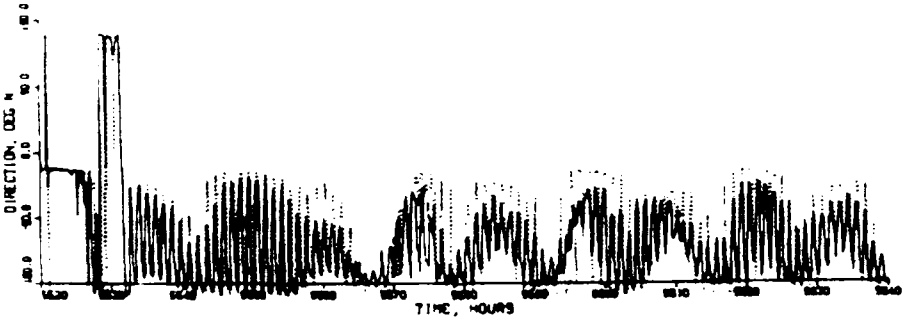


MID-DEPTH



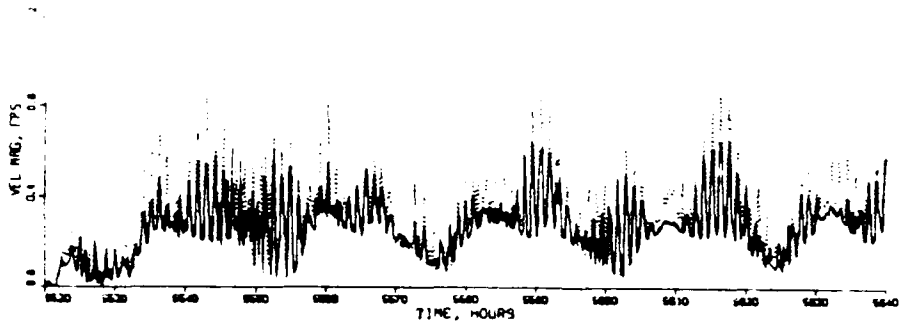
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C3

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 120



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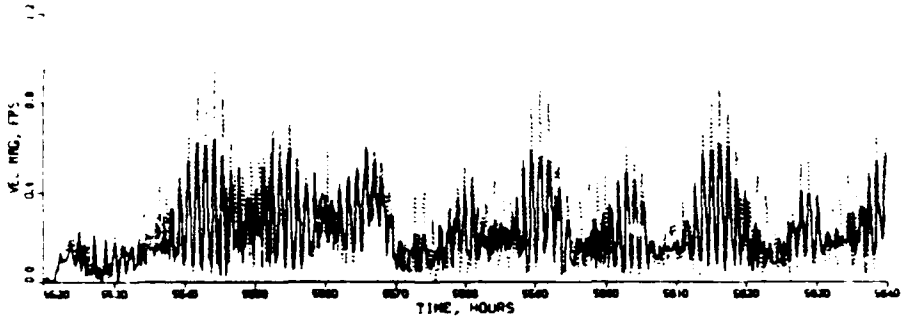
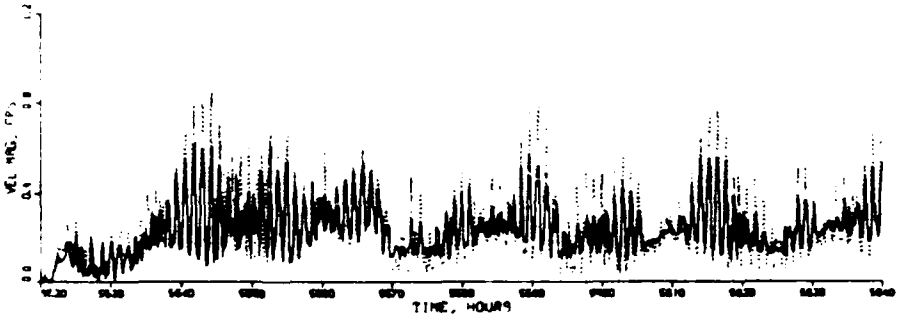


MID-DEPTH



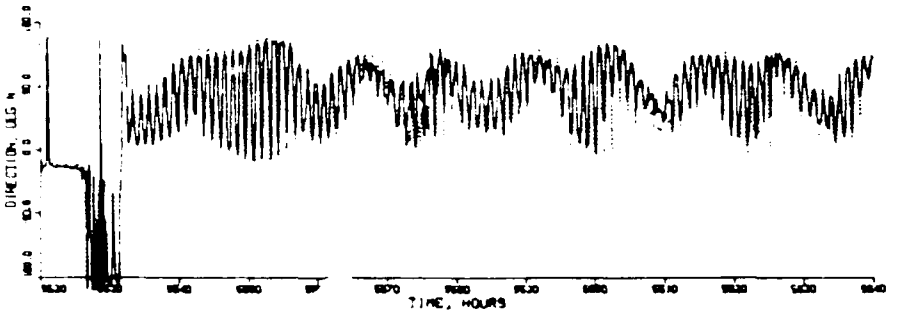
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

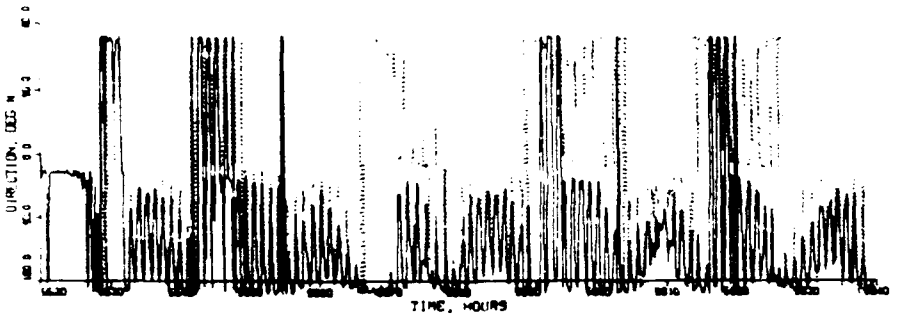
MAGNITUDE GAGE C3

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

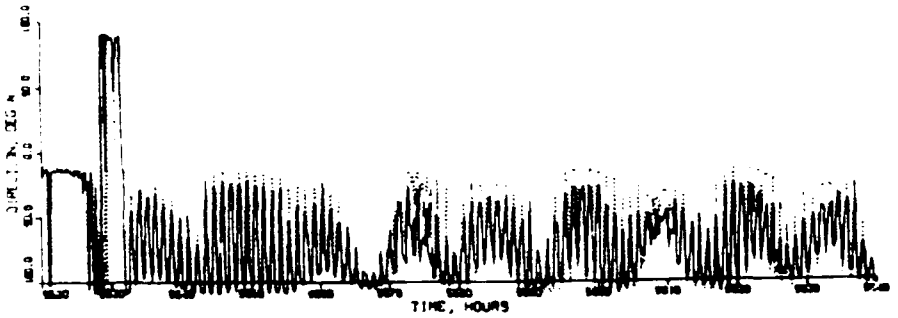
PLATE 121



SURFACE



MID-DEPTH



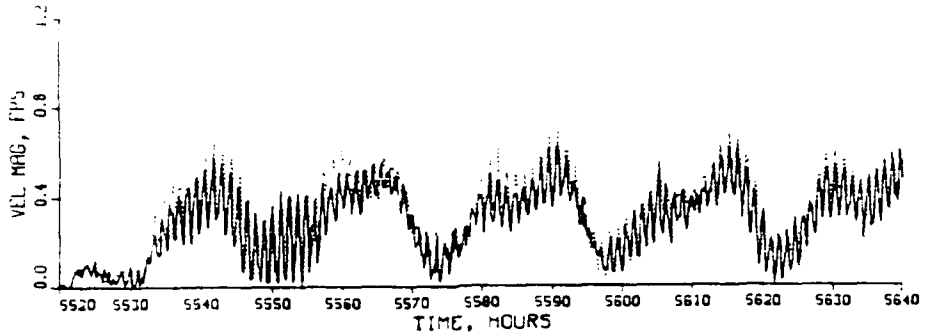
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C3

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 122



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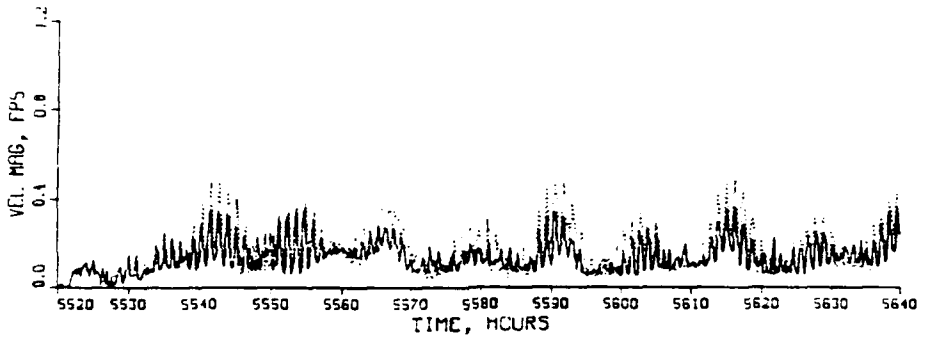

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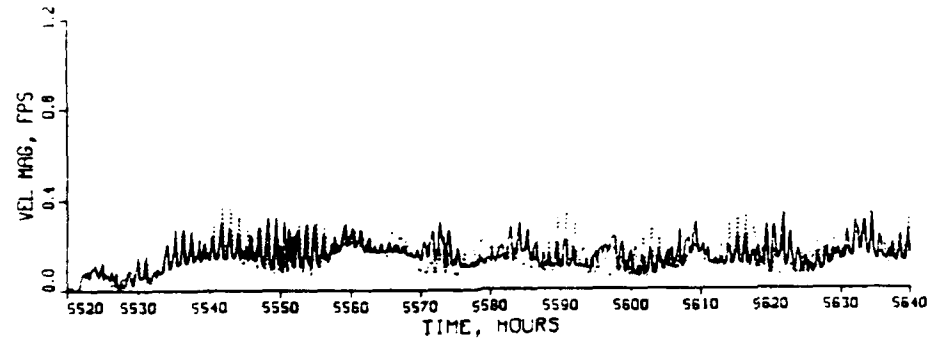


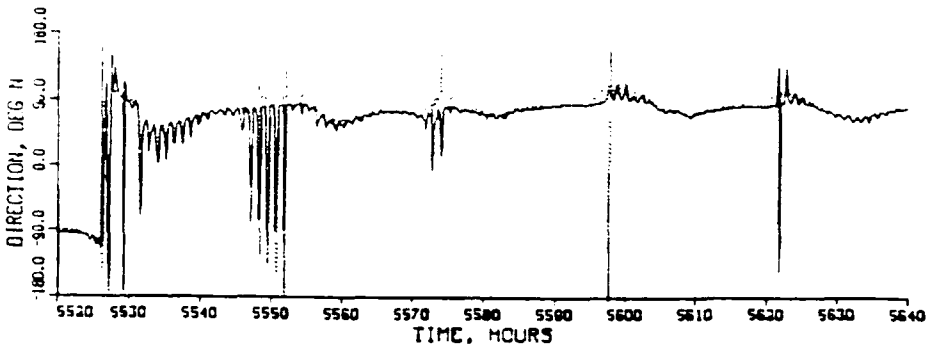
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C4

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 123



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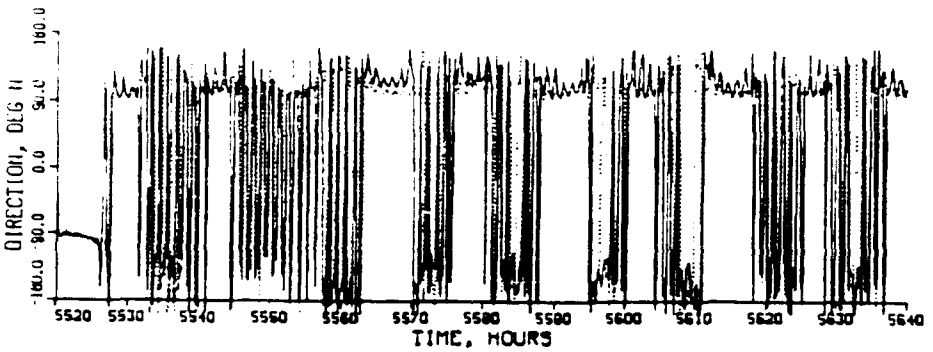
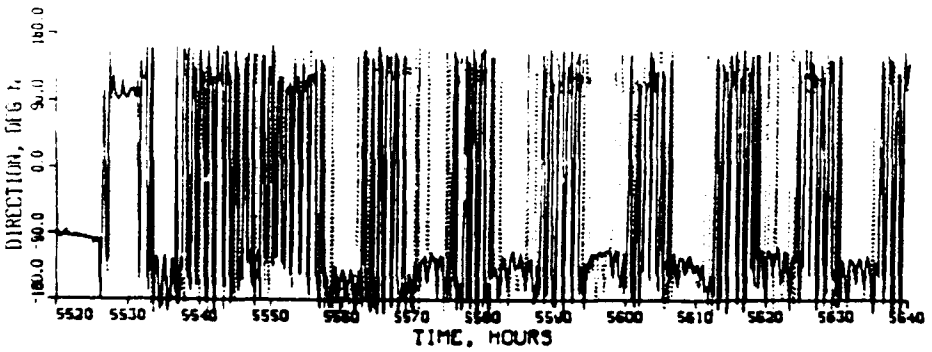


MID-DEPTH



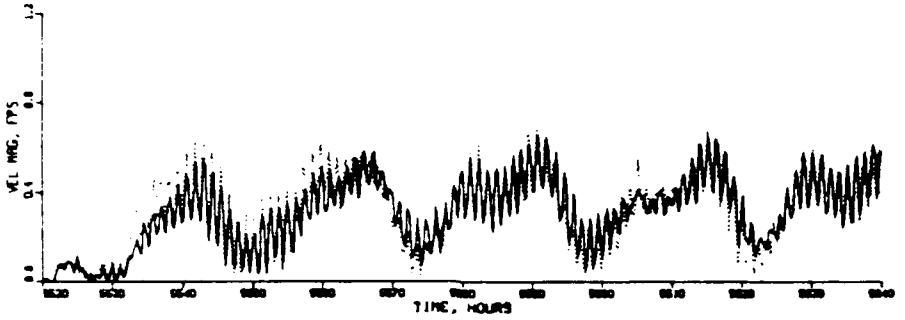
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C4

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 124



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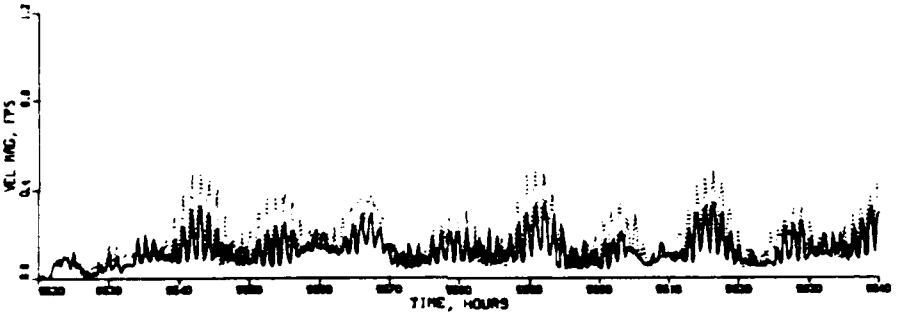
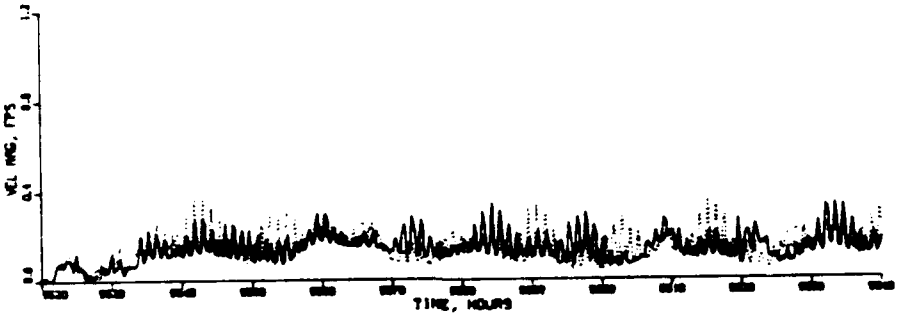


MID-DEPTH



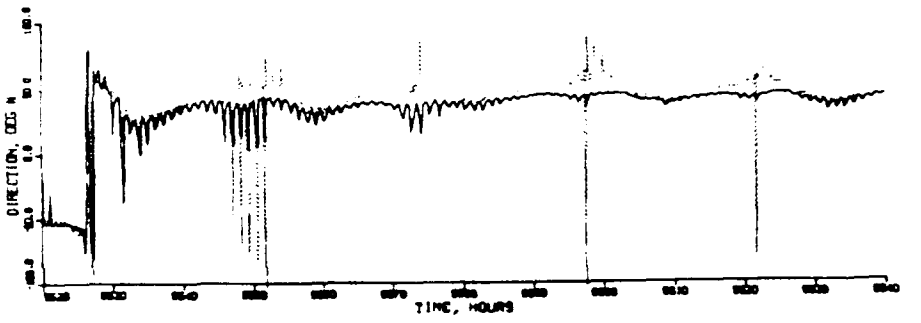
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C4

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 125



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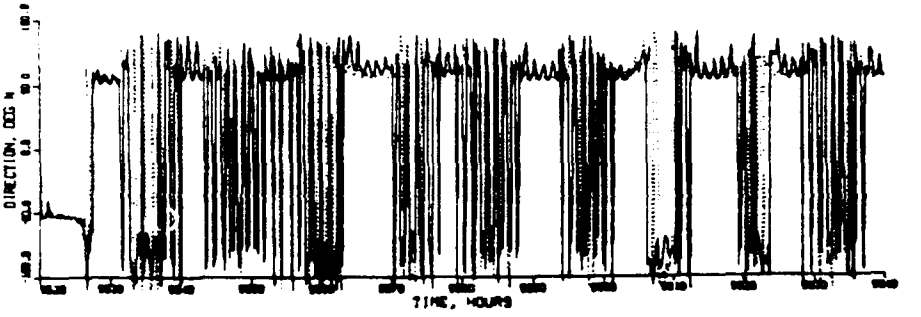


MID-DEPTH

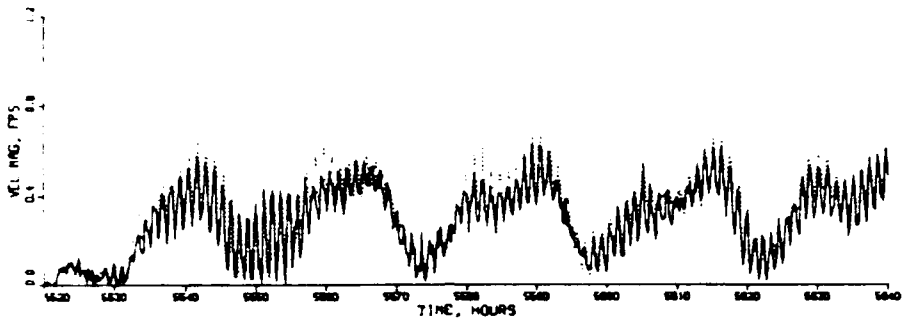
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C4

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 126



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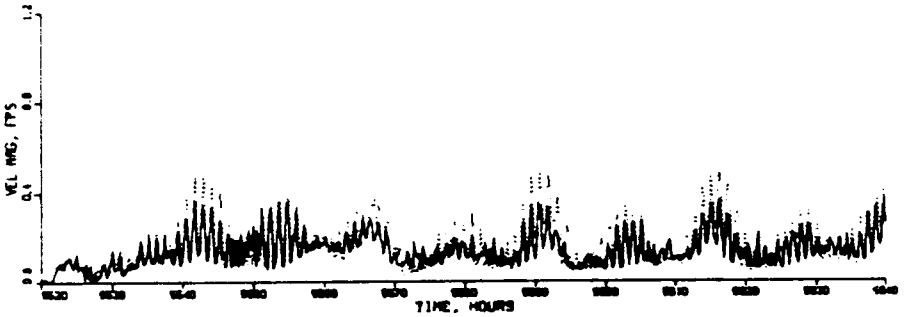
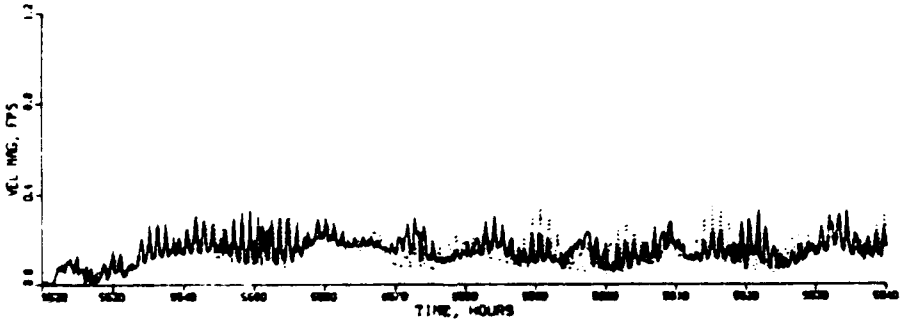


MID-DEPTH



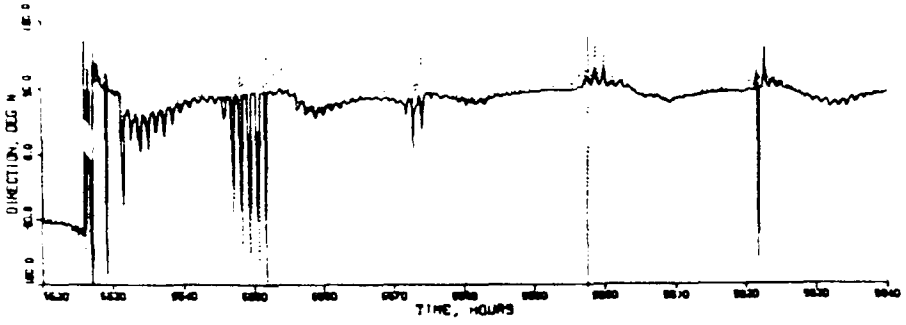
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

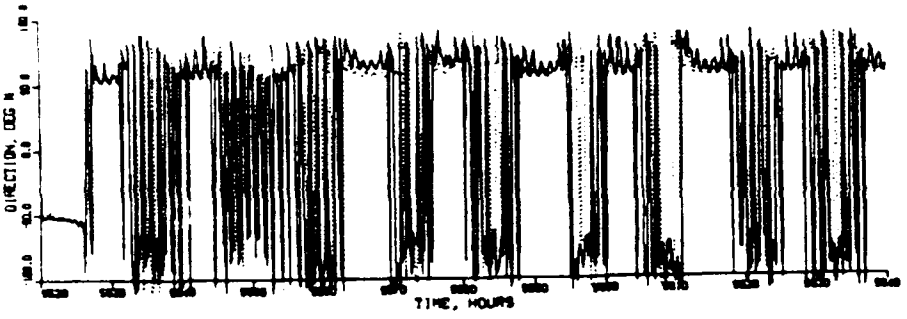
MAGNITUDE GAGE C4

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

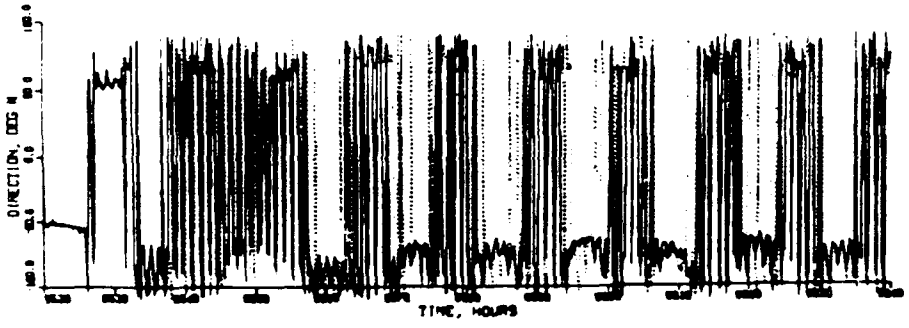
PLATE 127



SURFACE



MID-DEPTH



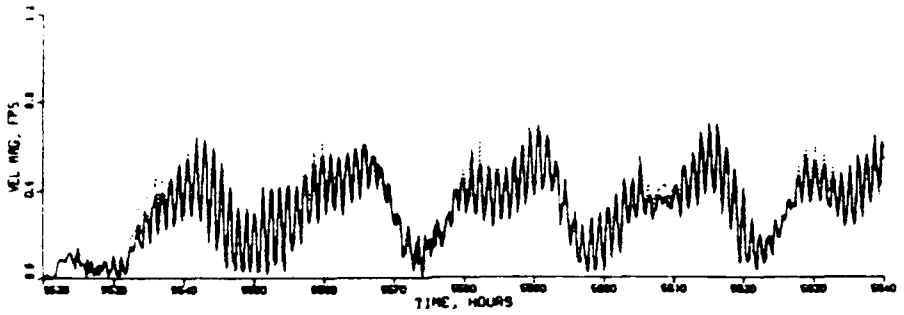
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

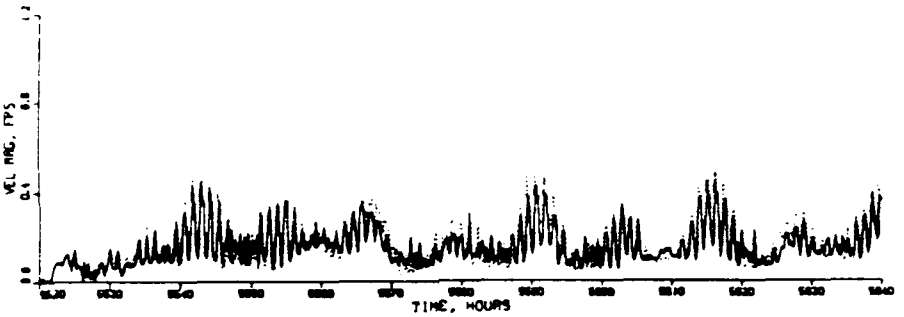
DIRECTION GAGE C4

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

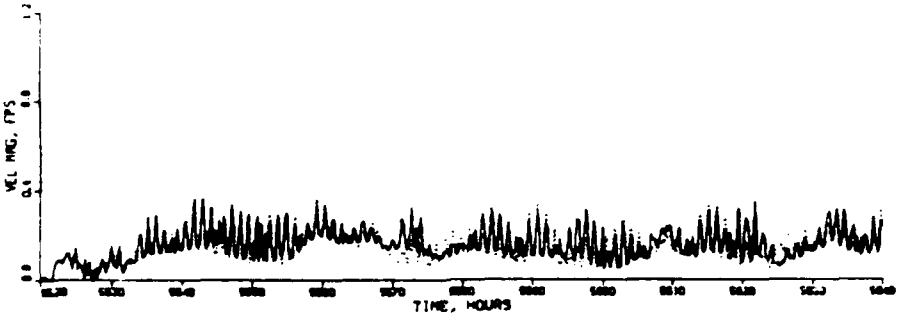
PLATE 128



SURFACE



MID-DEPTH



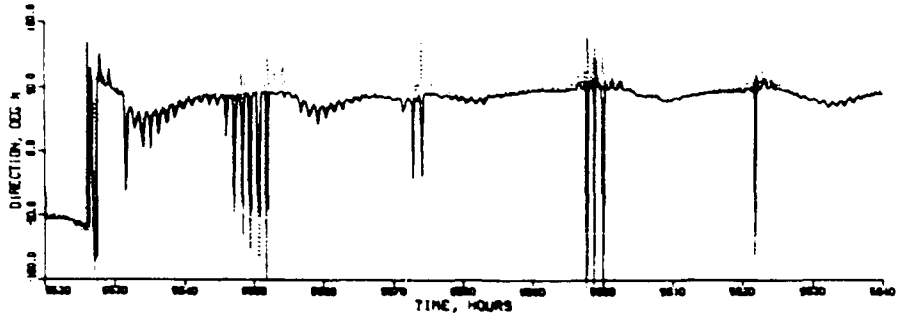
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

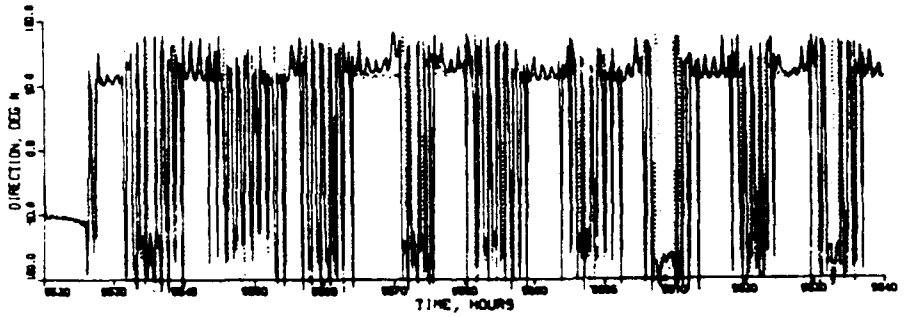
MAGNITUDE GAGE C4

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

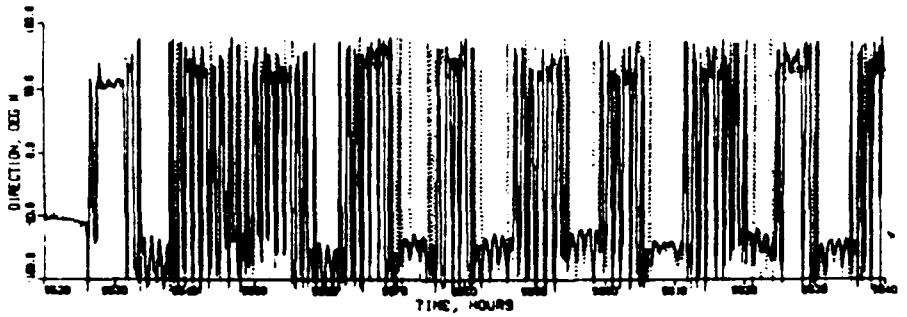
PLATE 129



SURFACE



MID-DEPTH



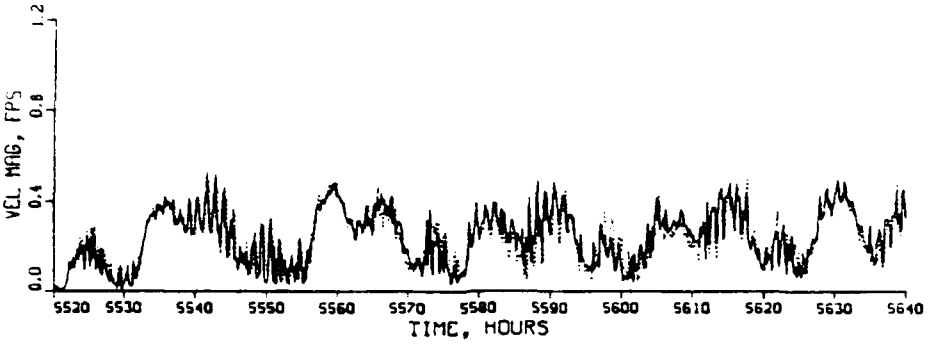
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

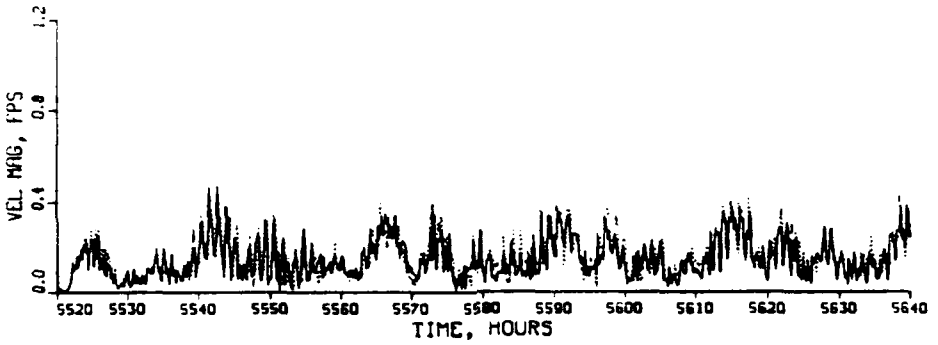
DIRECTION GAGE C4

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

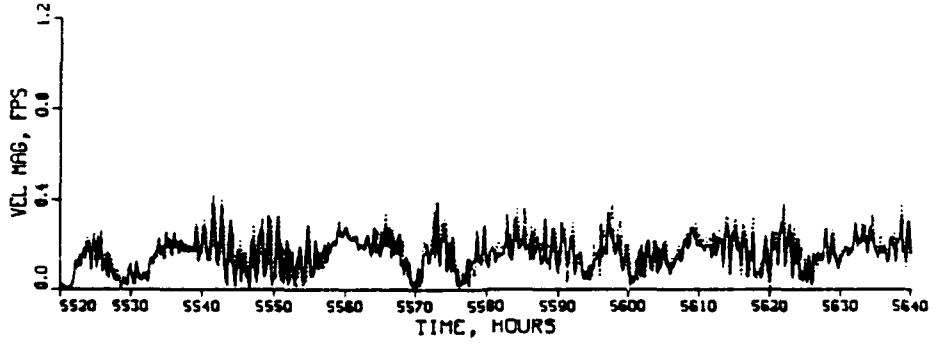
PLATE 130



SURFACE



MID-DEPTH



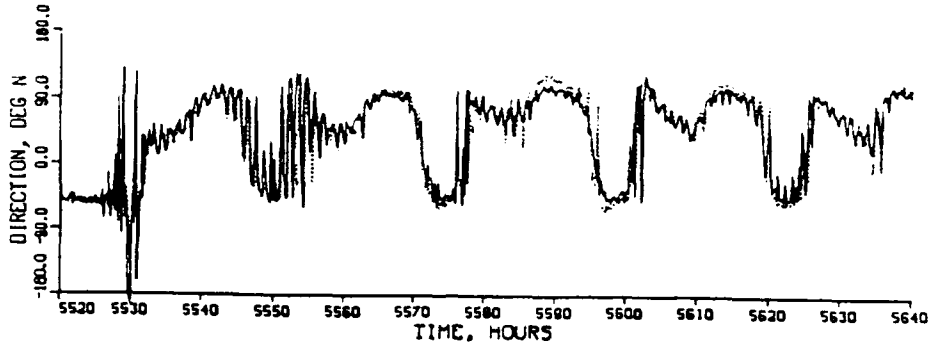
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

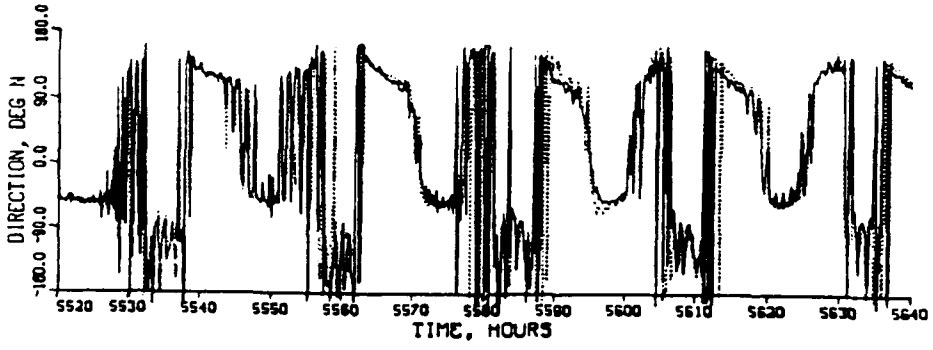
MAGNITUDE GAGE C5

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

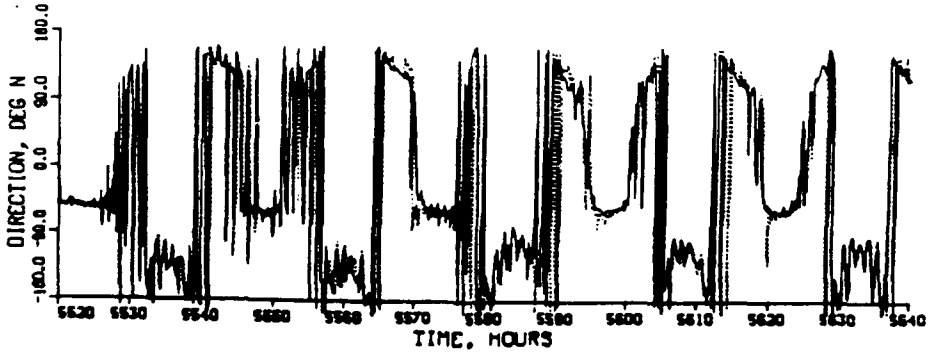
PLATE 131



SURFACE



MID-DEPTH



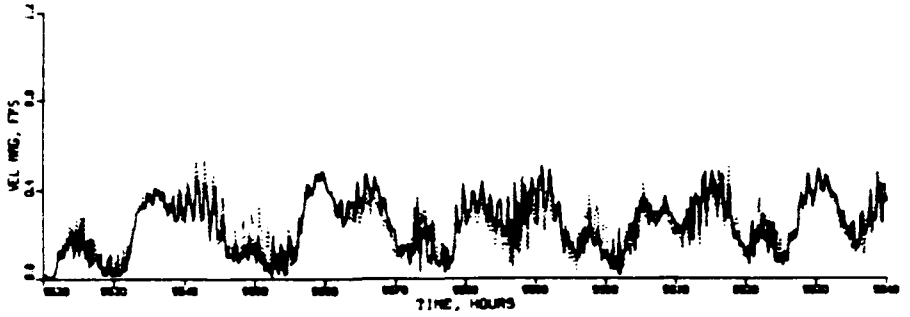
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

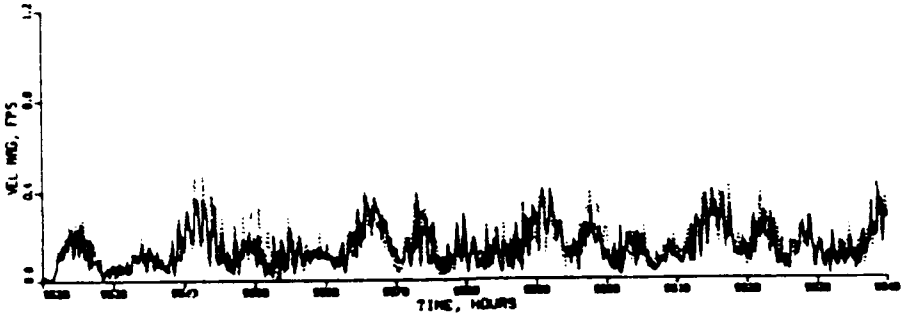
DIRECTION GAGE C5

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

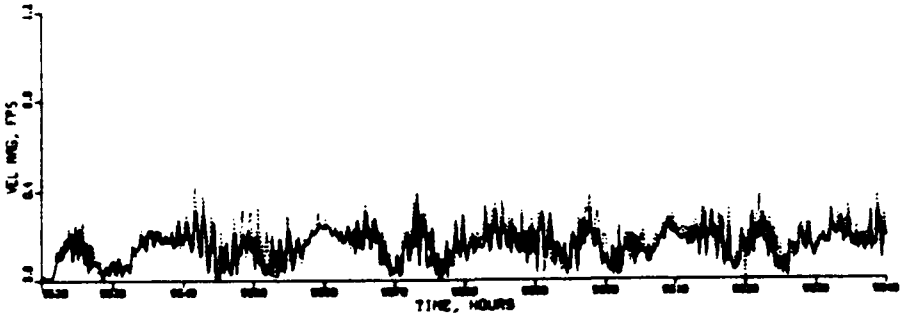
PLATE 132



SURFACE



MID-DEPTH



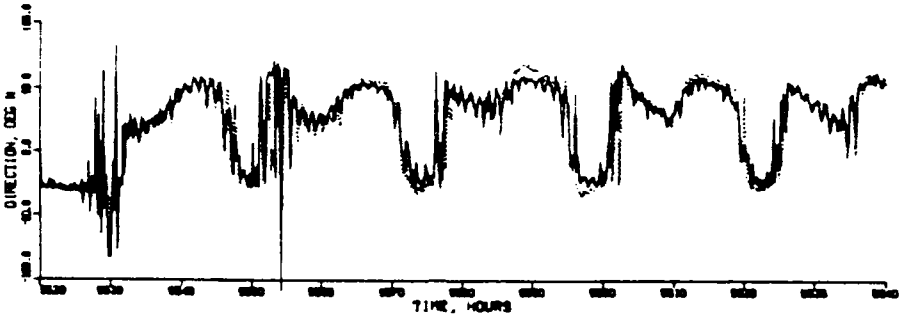
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C5

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 133



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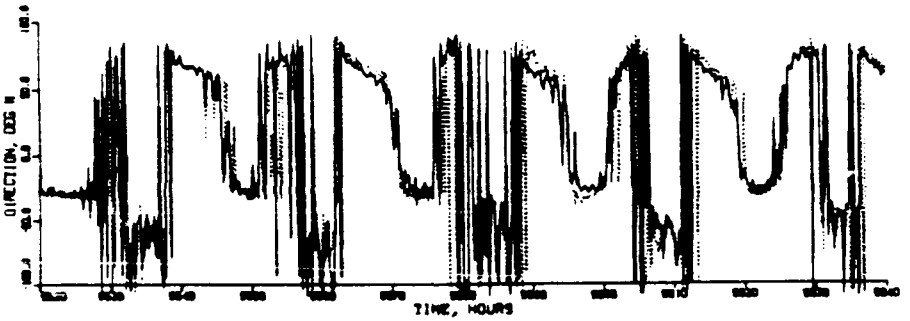

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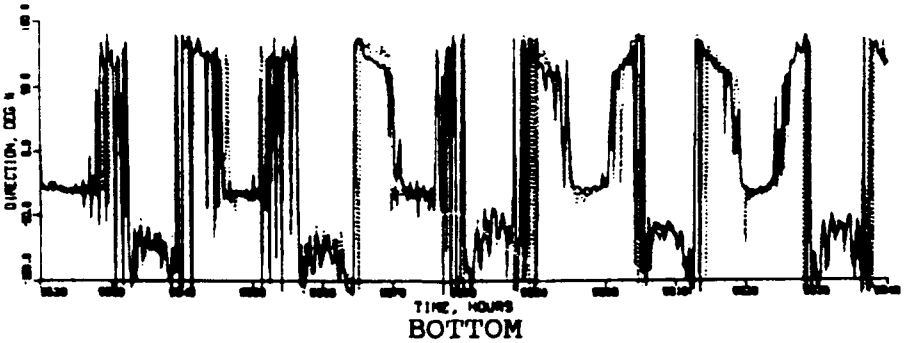


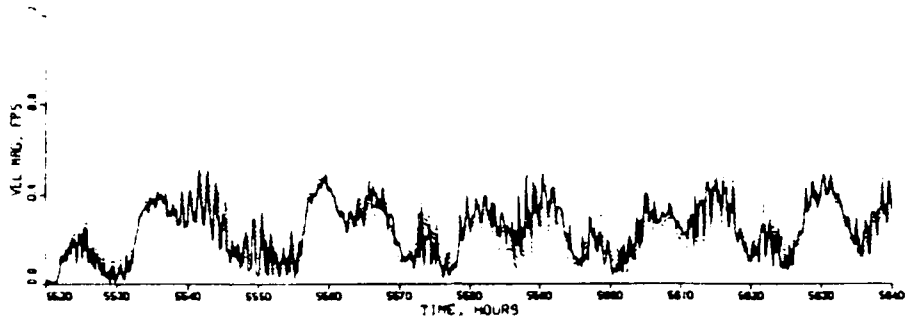
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C5

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 134



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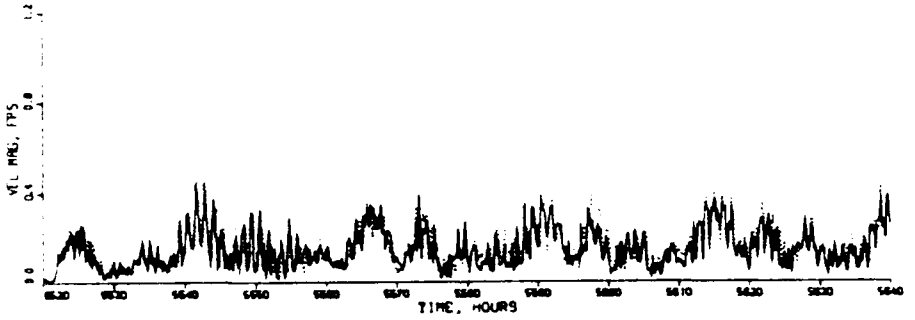

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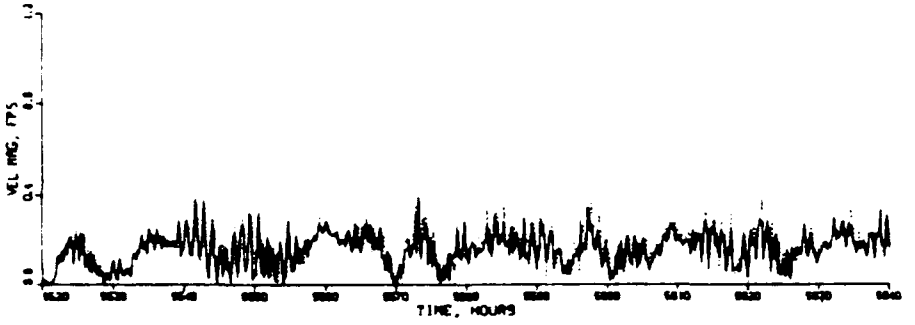


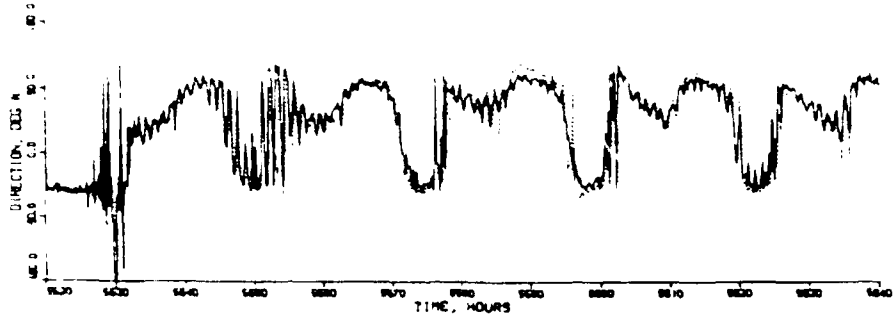
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C5

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 135



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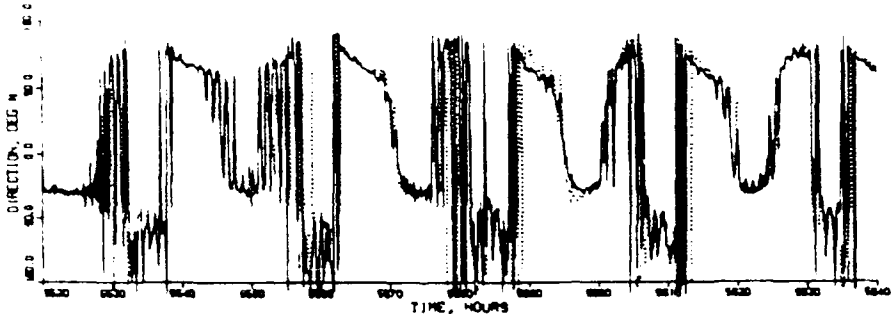

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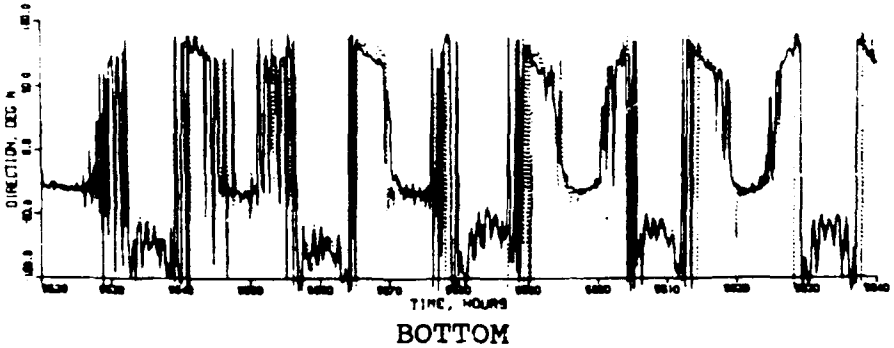


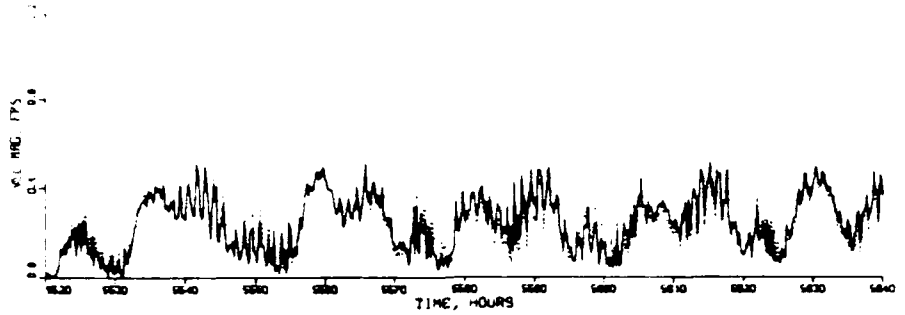
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C5

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 136



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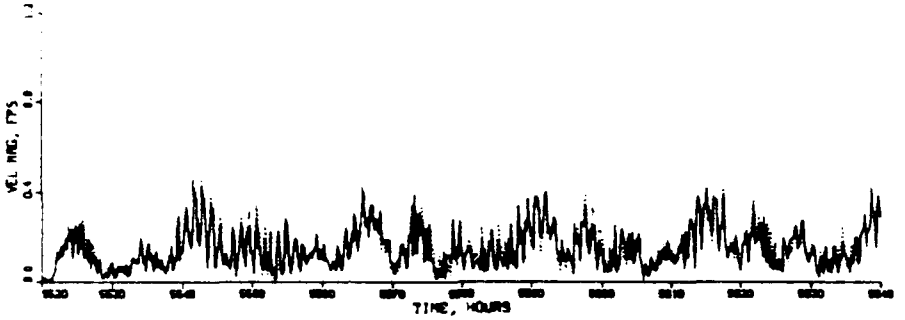

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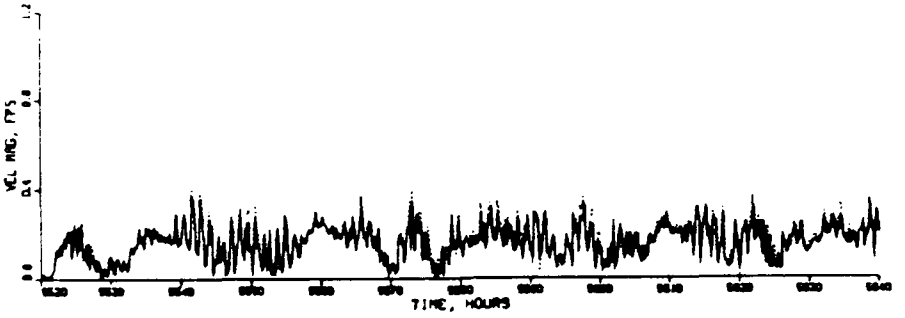


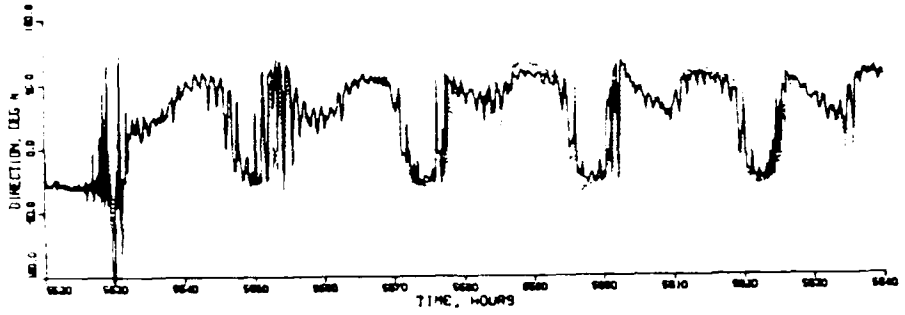
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C5

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 137



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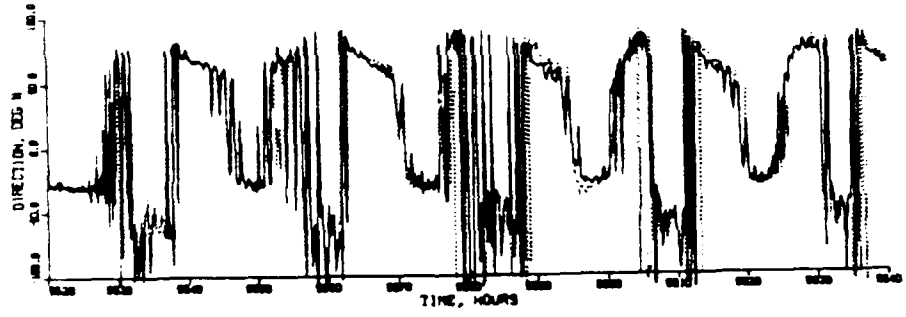

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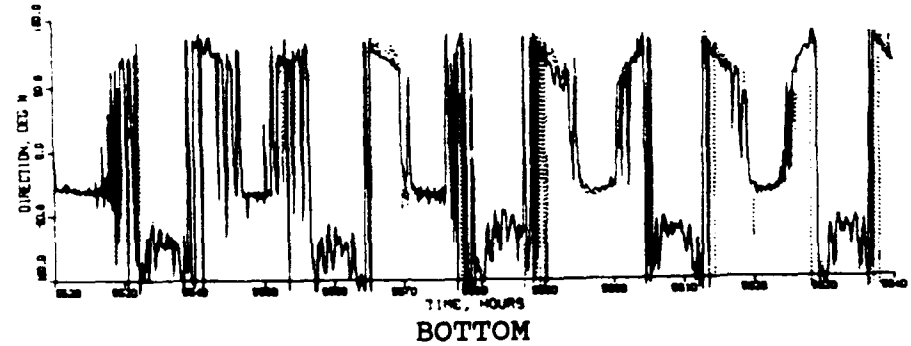


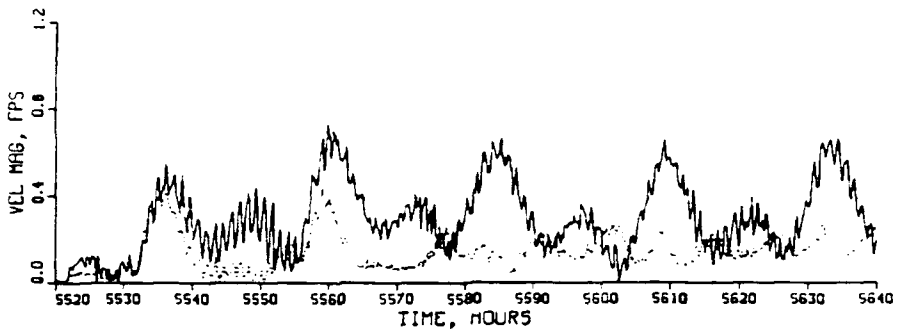
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C5

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 138



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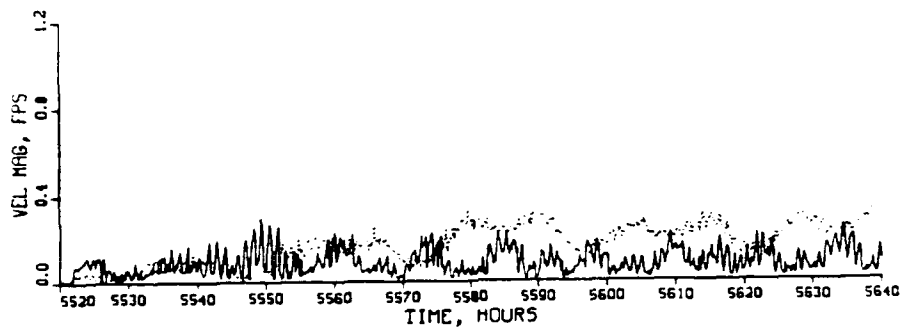

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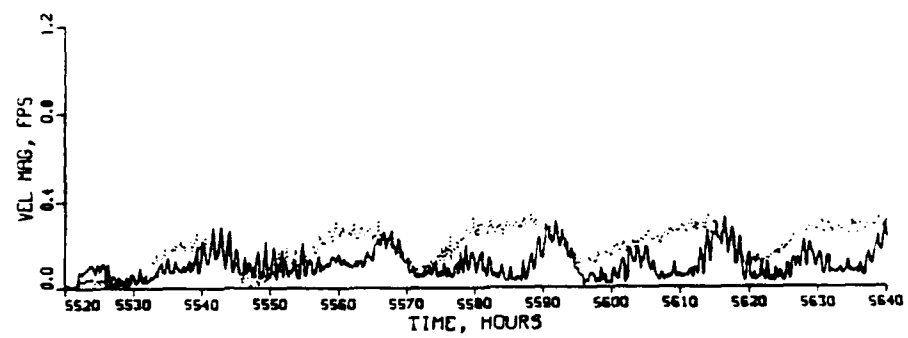


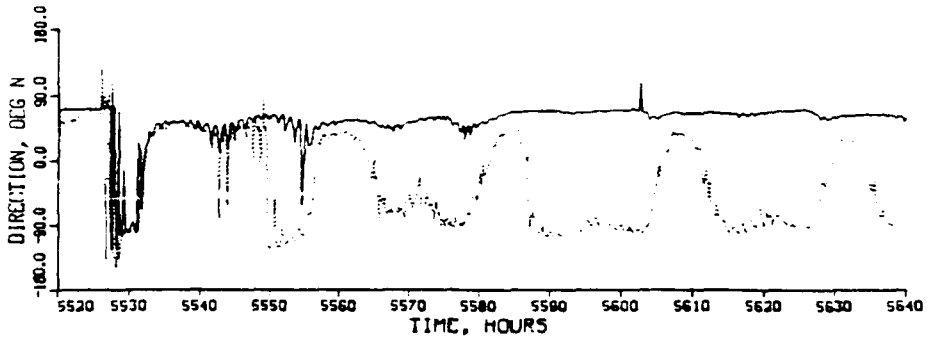
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C14

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 139



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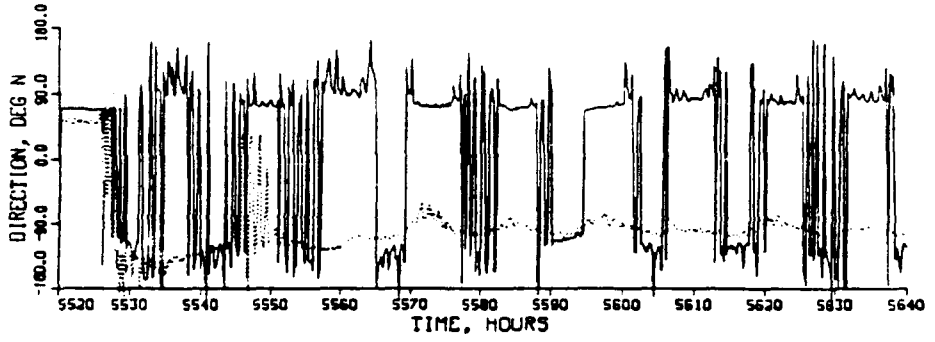

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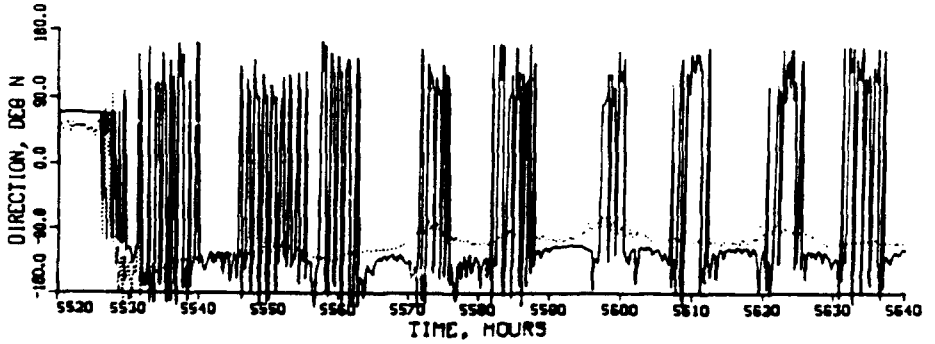


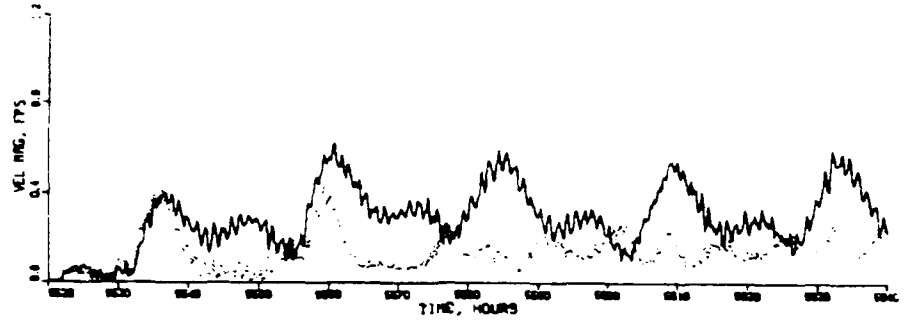
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C14

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 140



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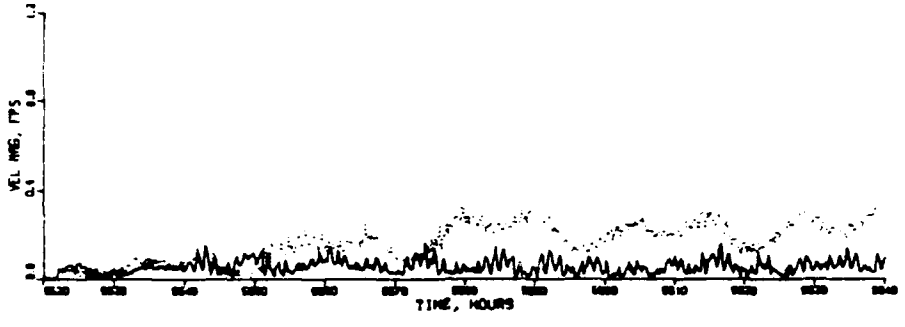

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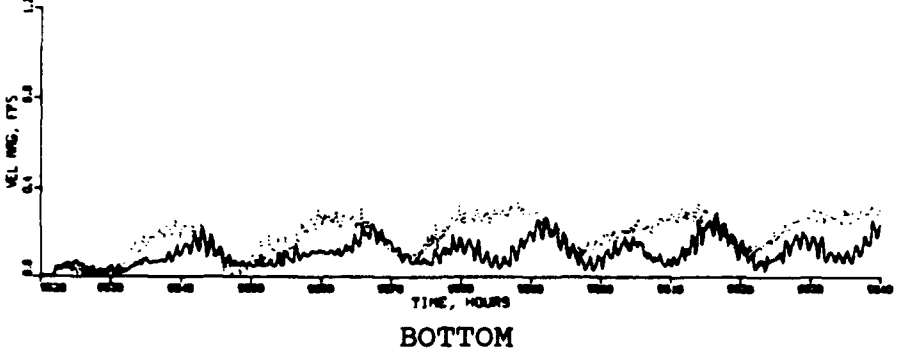


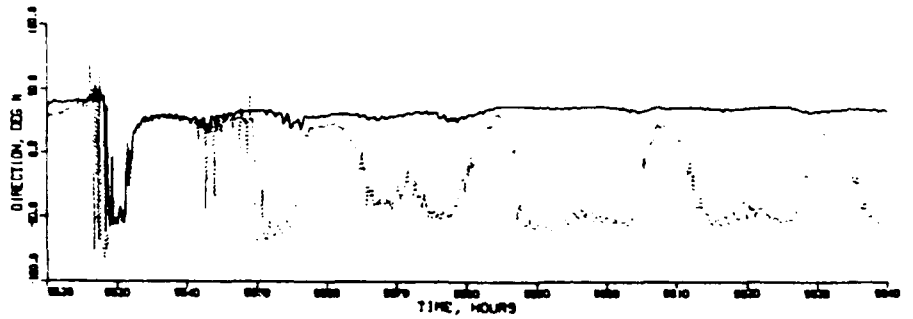
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C14

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 141



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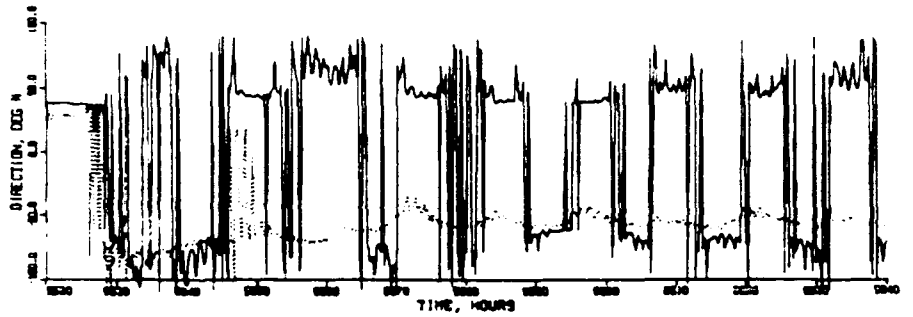

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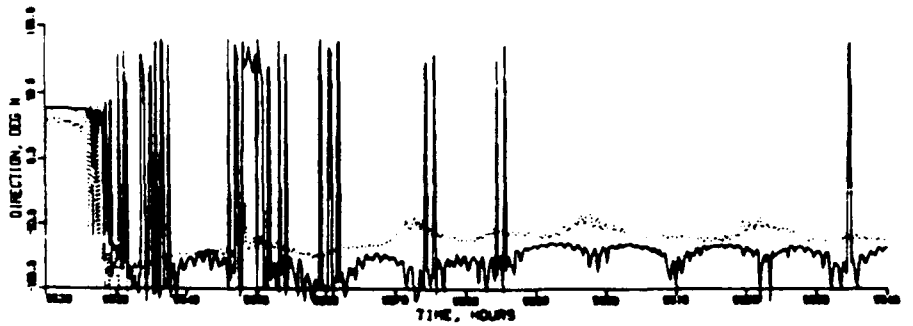


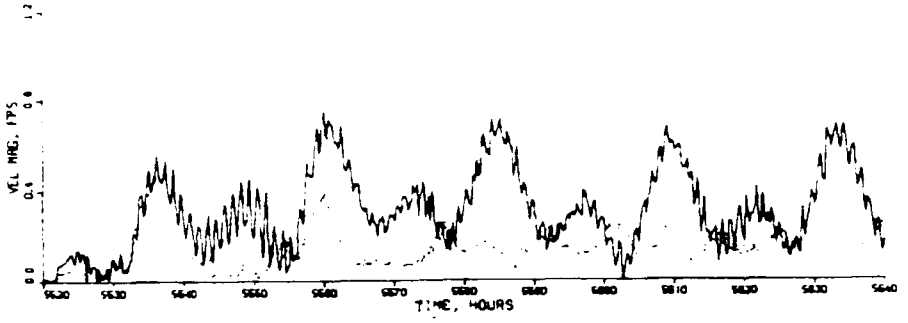
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C14

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 142



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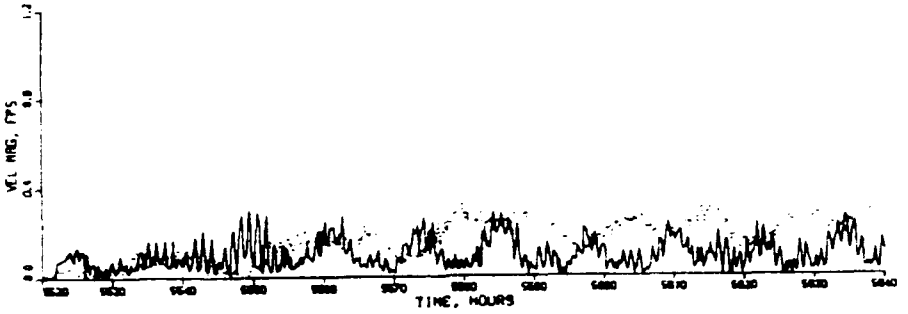

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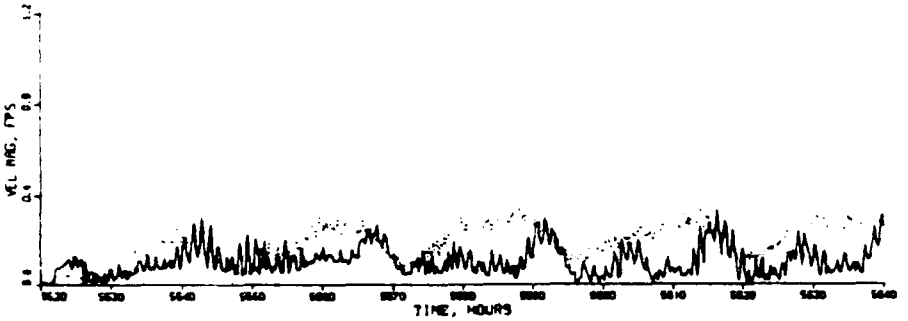


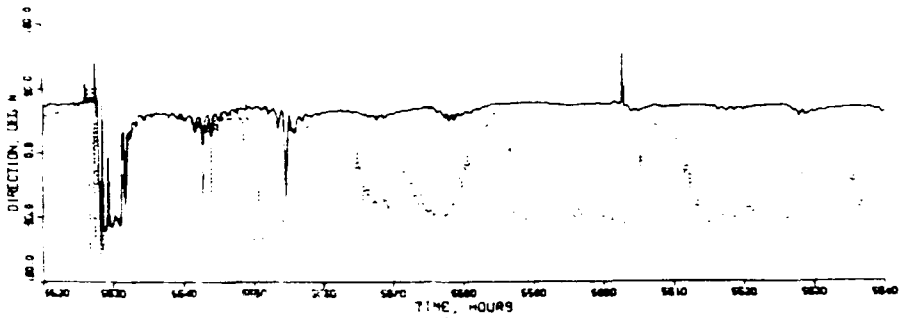
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C14

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 143



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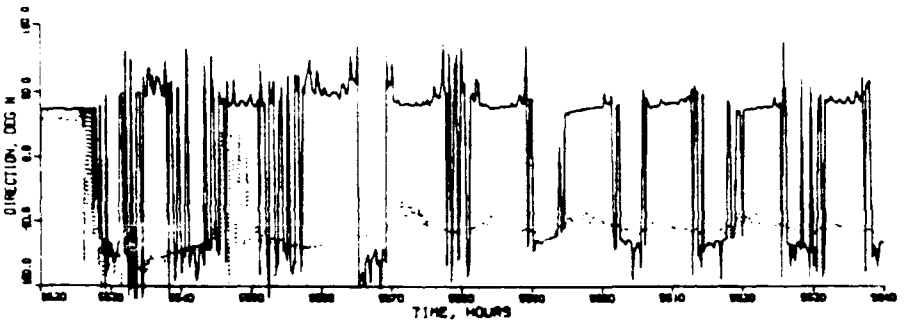

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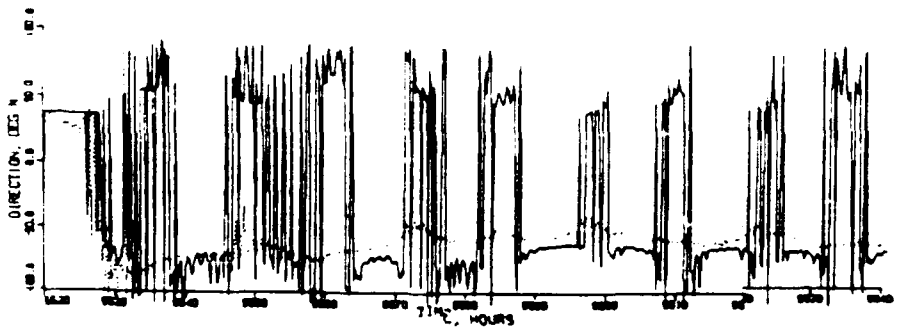


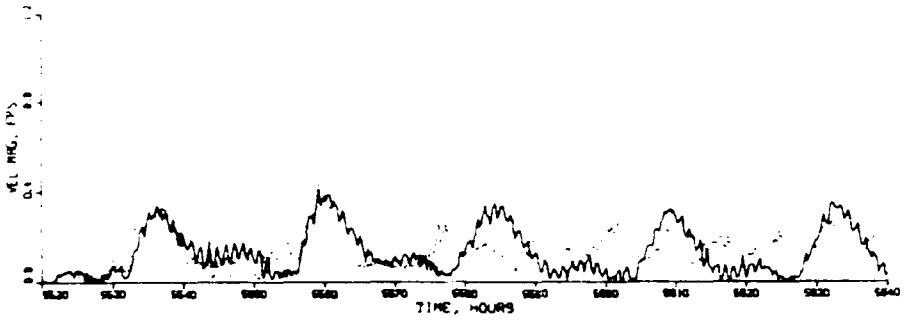
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C14

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 144



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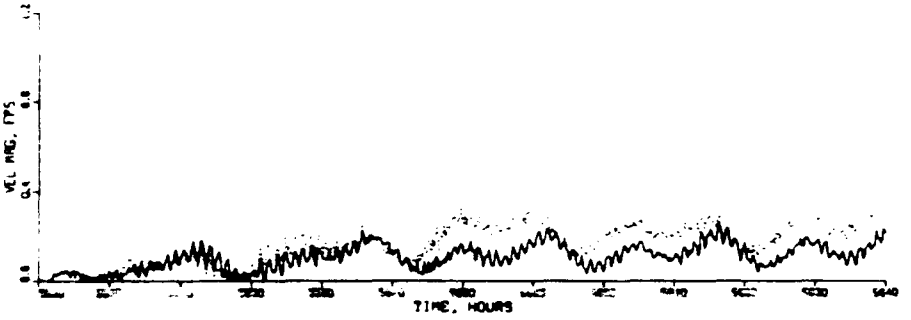
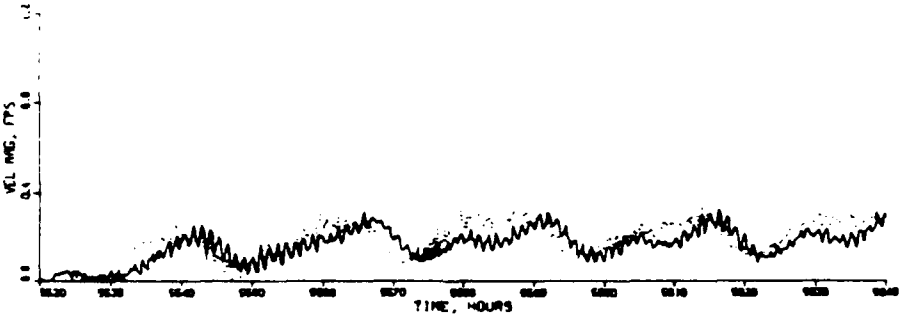


MID-DEPTH



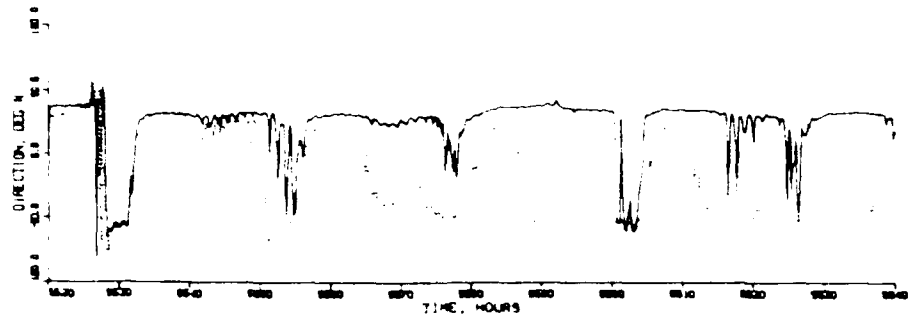
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C14

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 145



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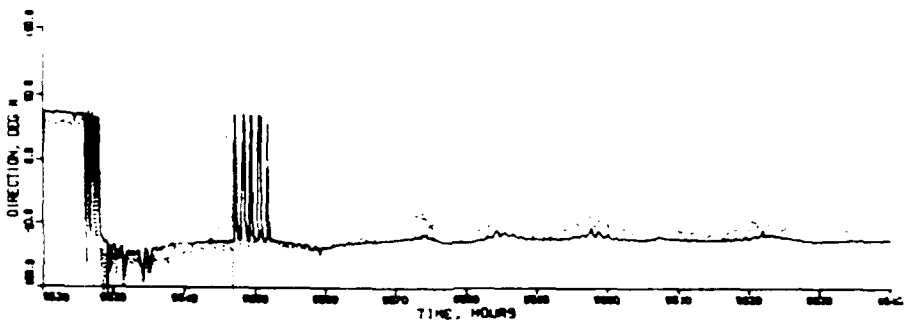
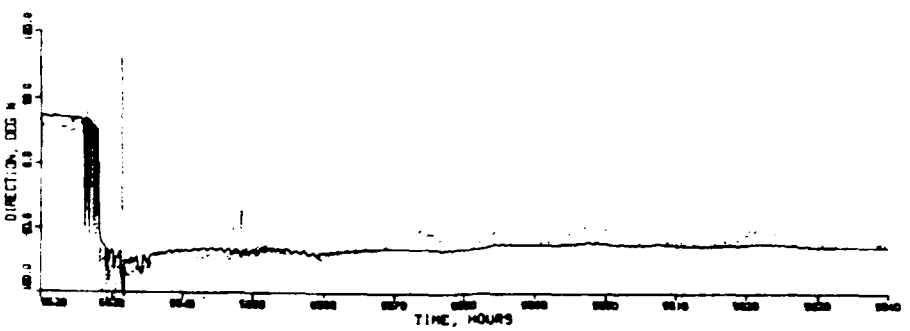


MID-DEPTH



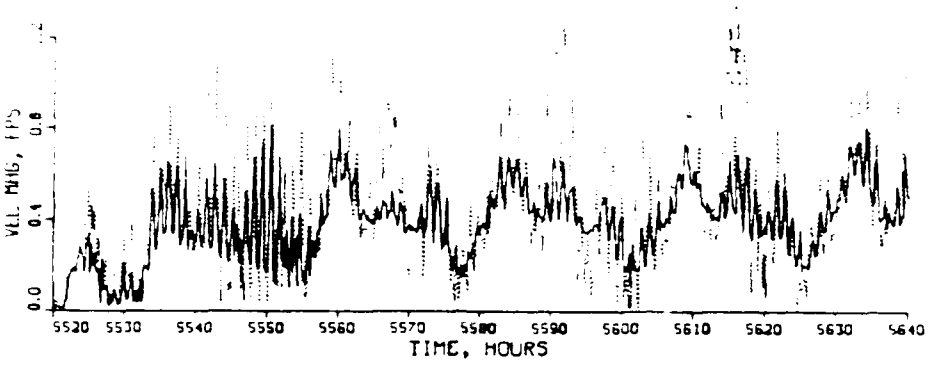
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

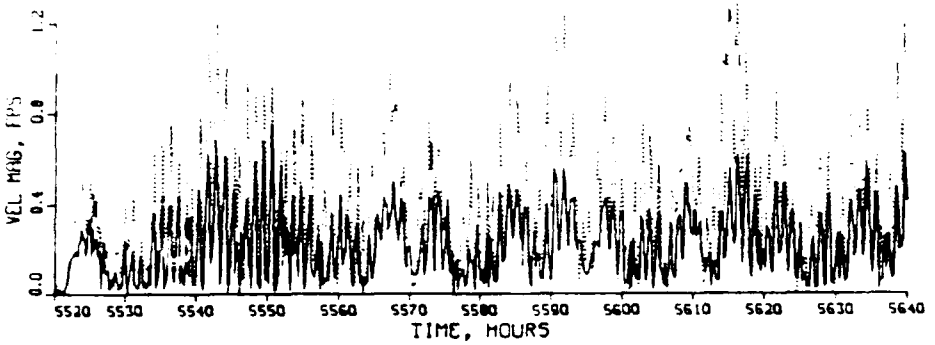
DIRECTION GAGE C14

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

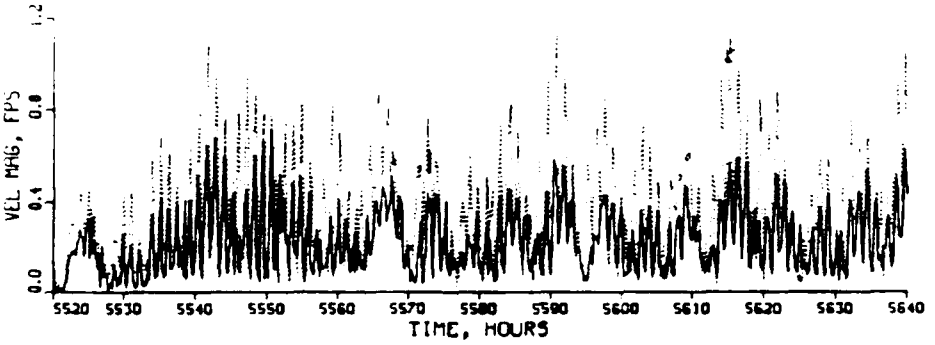
PLATE 146



SURFACE



MID-DEPTH



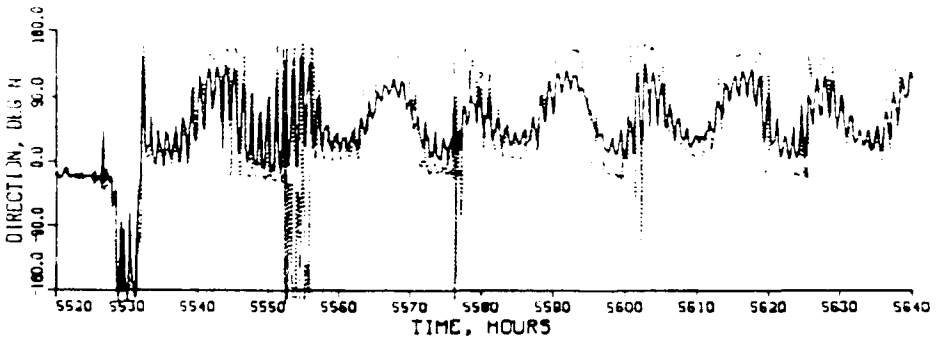
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

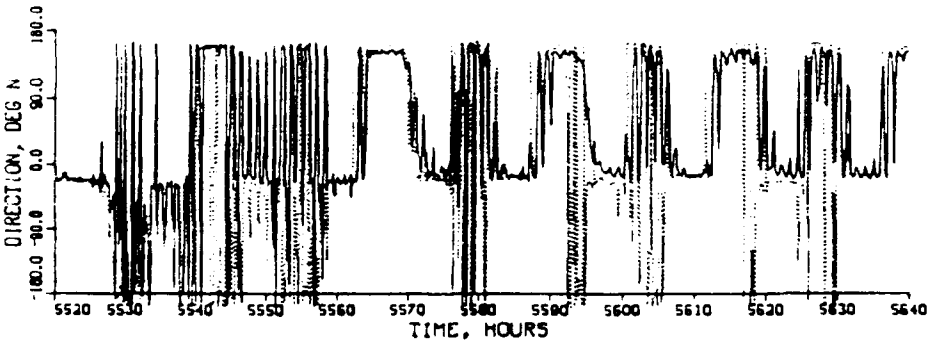
MAGNITUDE GAGE C18

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

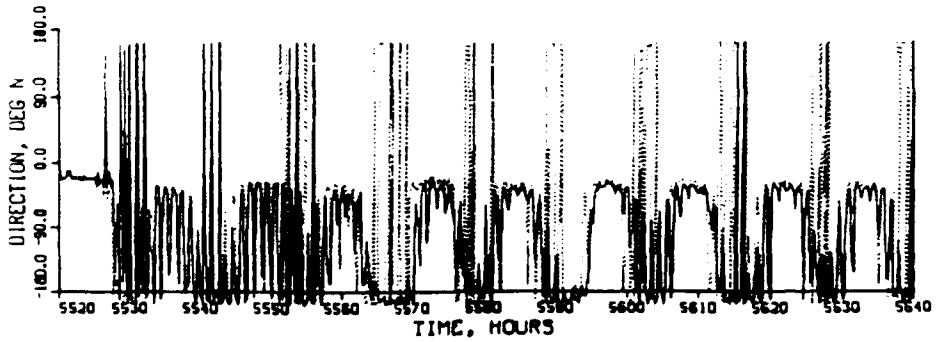
PLATE 147



SURFACE



MID-DEPTH



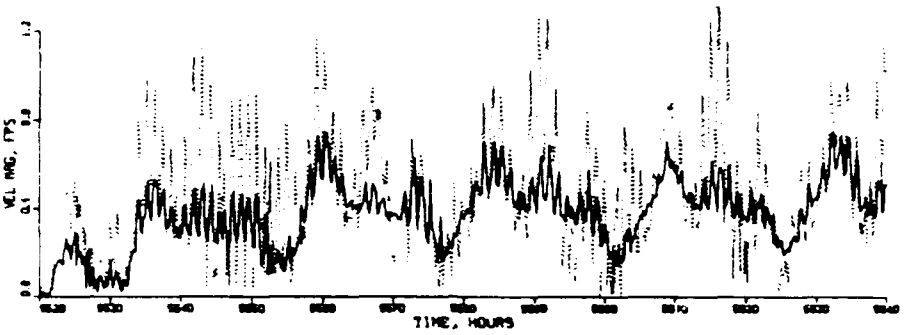
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C18

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 148



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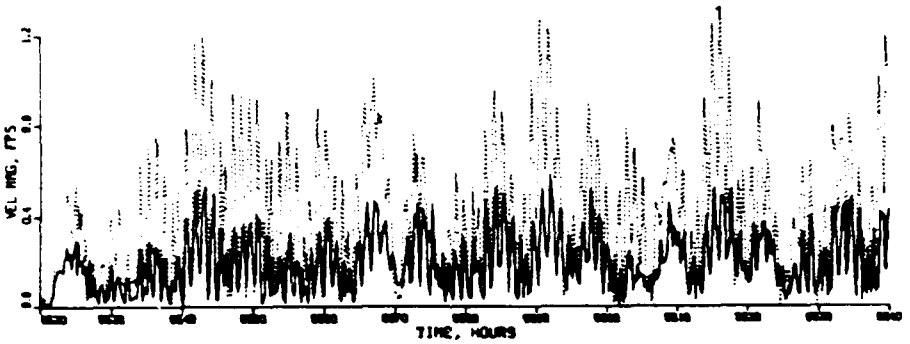
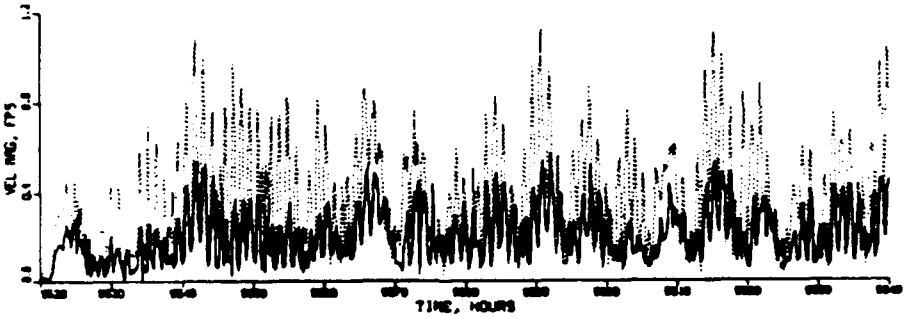


MID-DEPTH



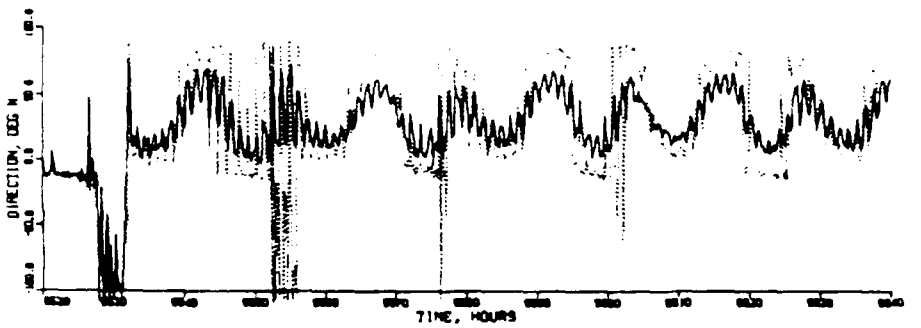
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

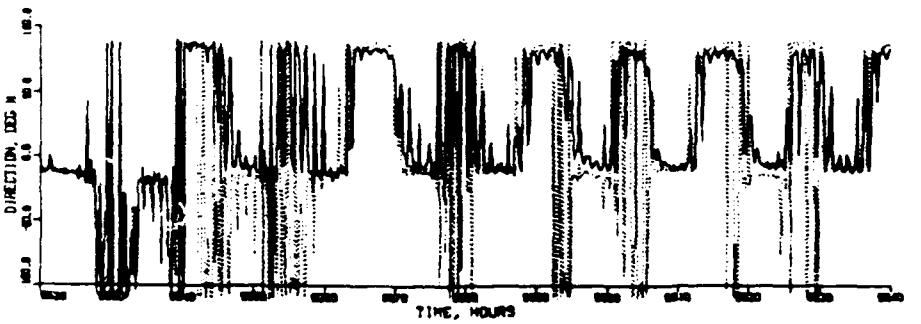
MAGNITUDE GAGE C18

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

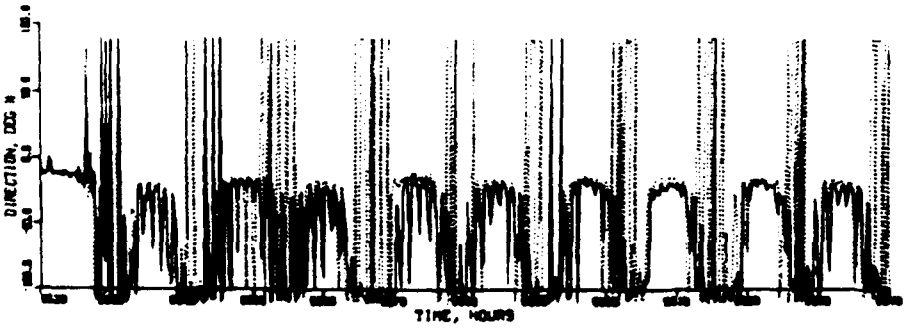
PLATE 149



SURFACE



MID-DEPTH



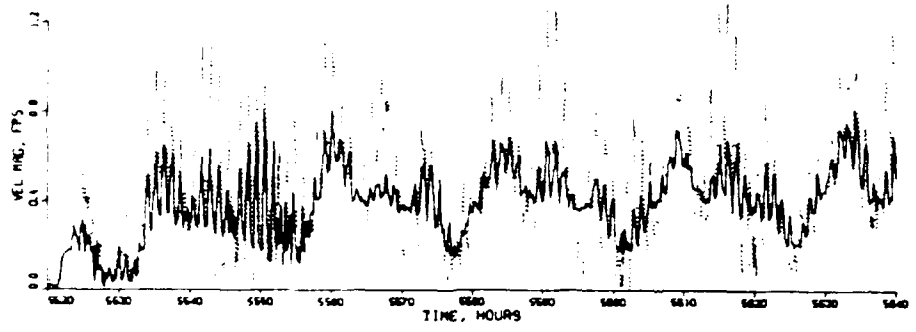
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C18

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 150



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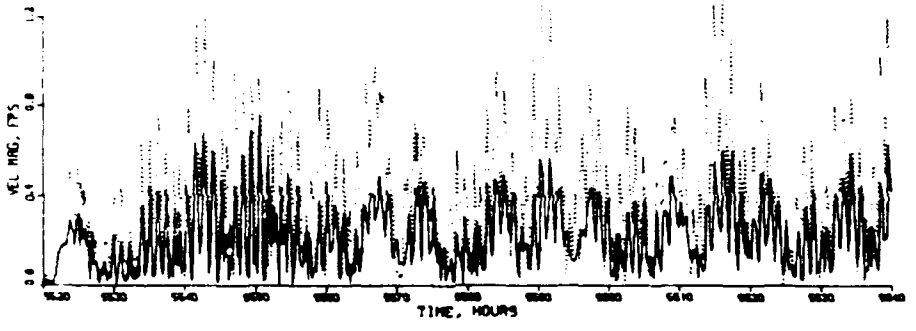

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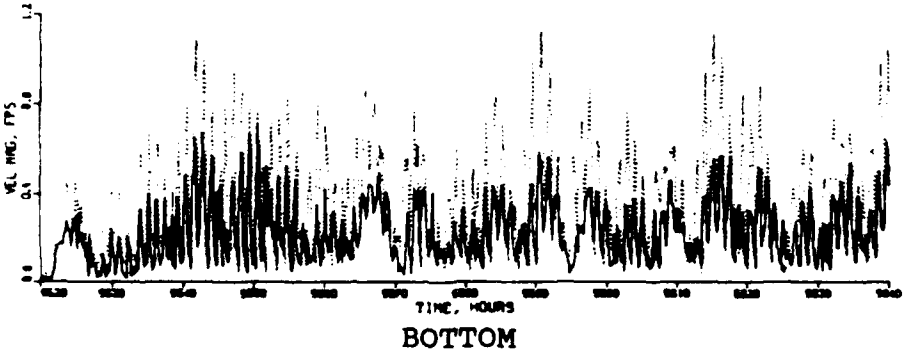


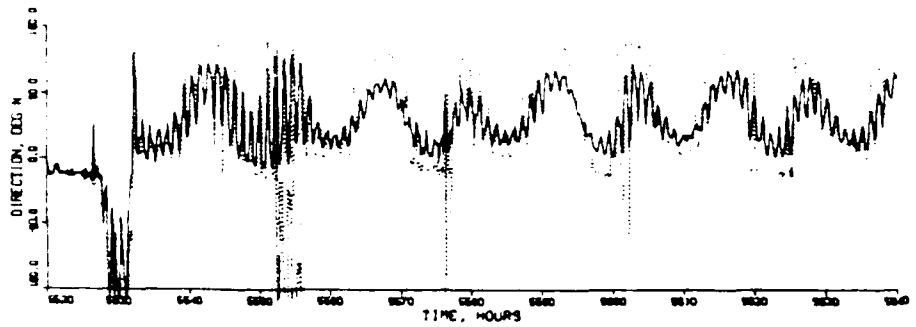
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C18

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 151



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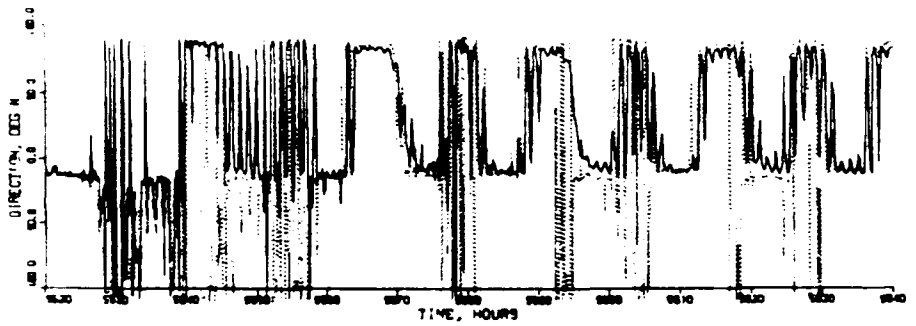

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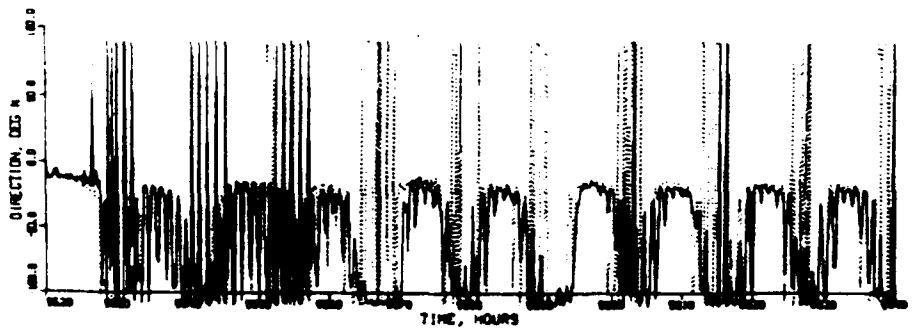


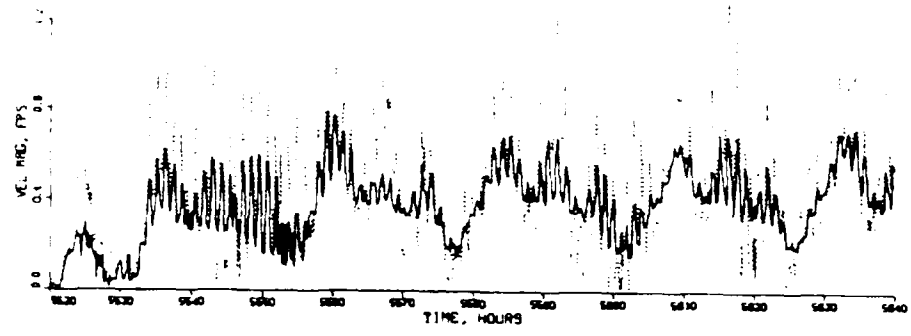
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C18

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 152



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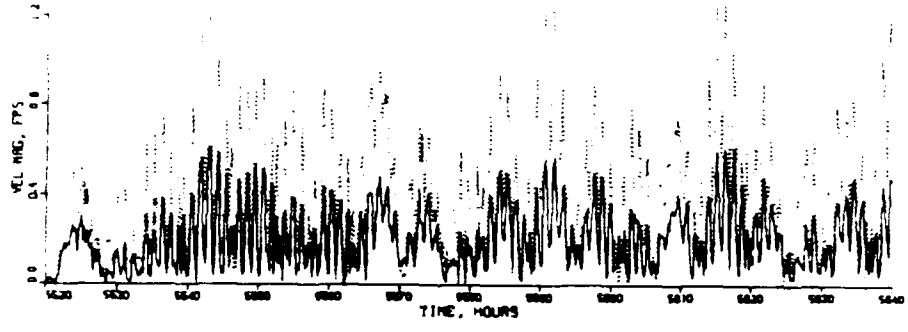

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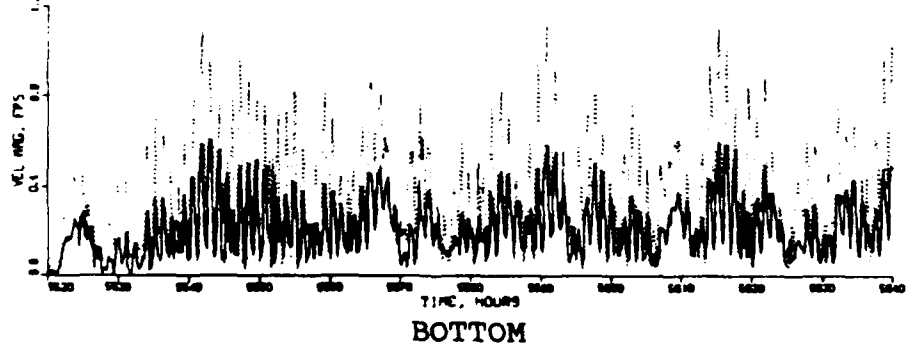


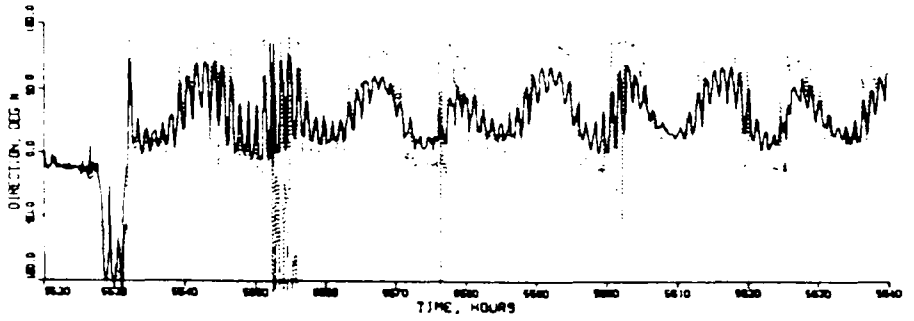
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C18

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 153



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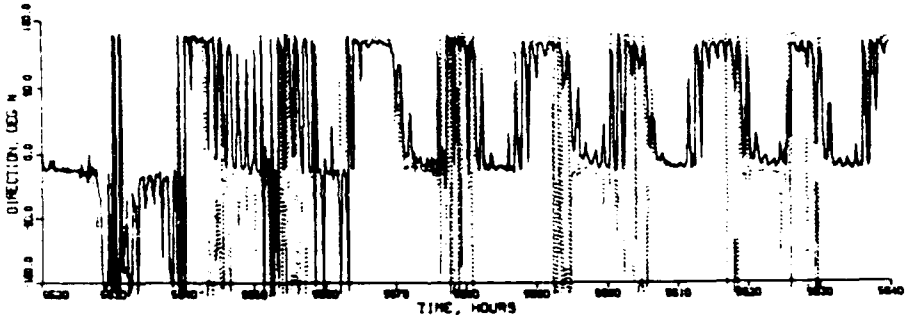
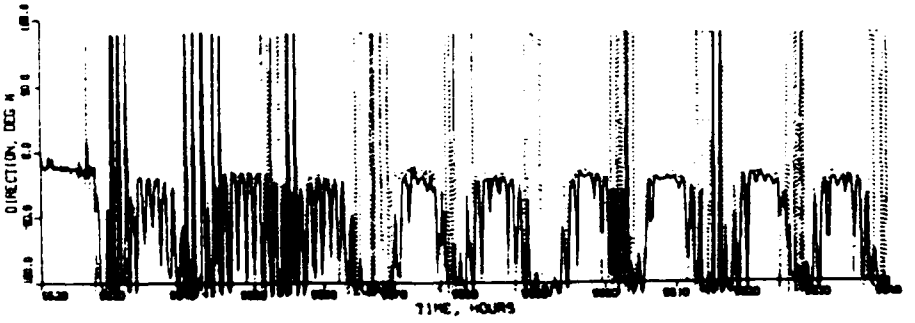


MID-DEPTH



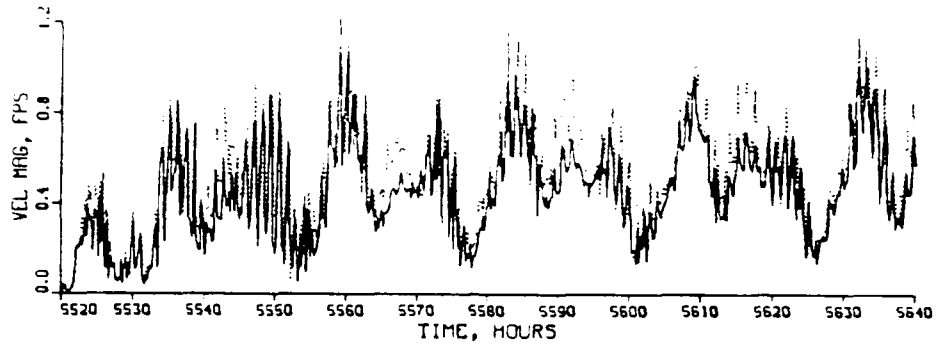
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C18

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 154



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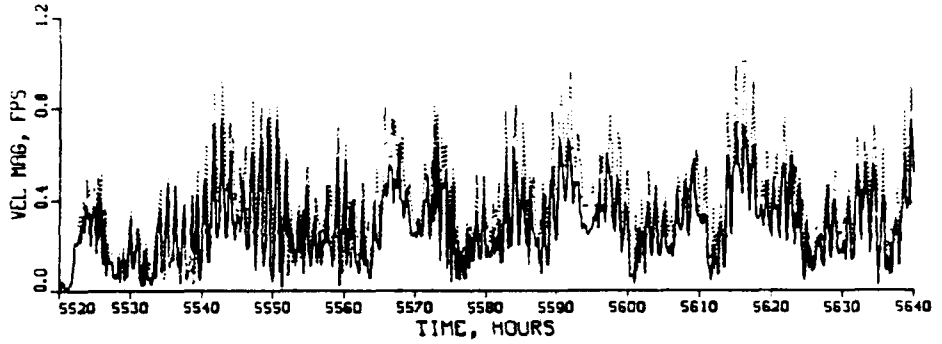

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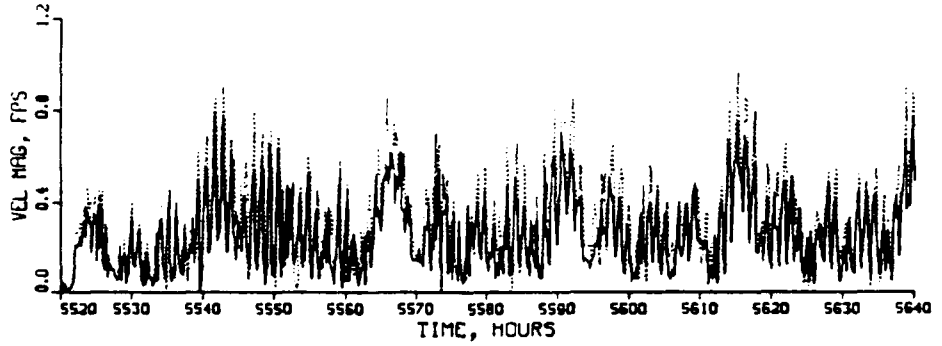


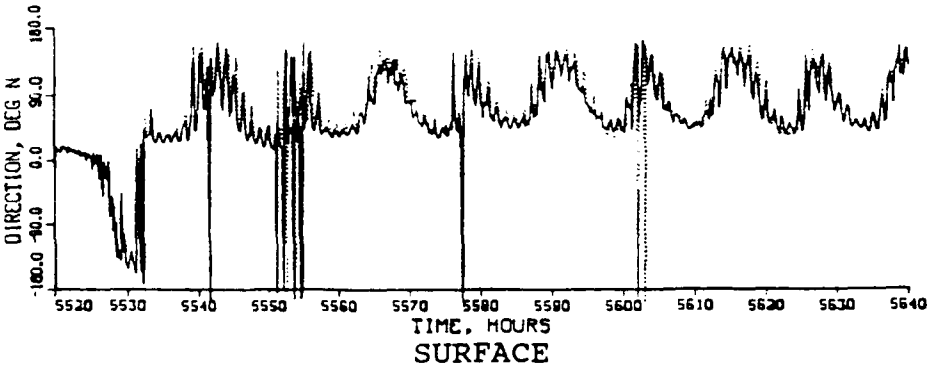
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C19

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 155



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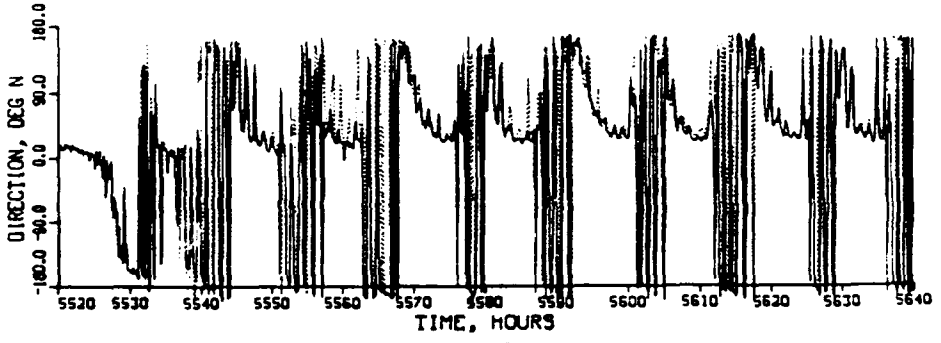

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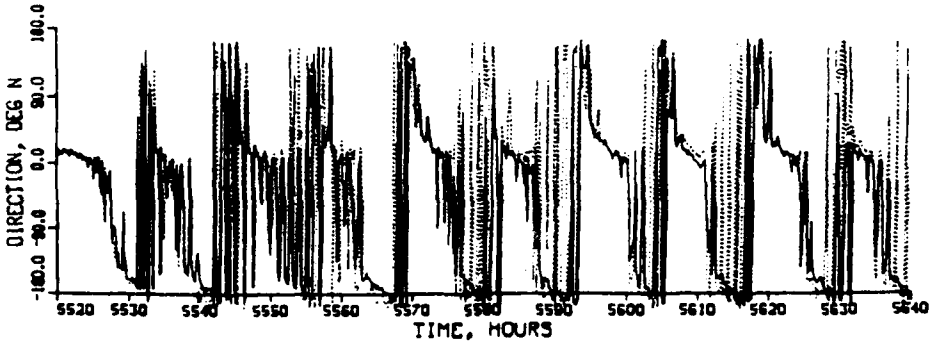


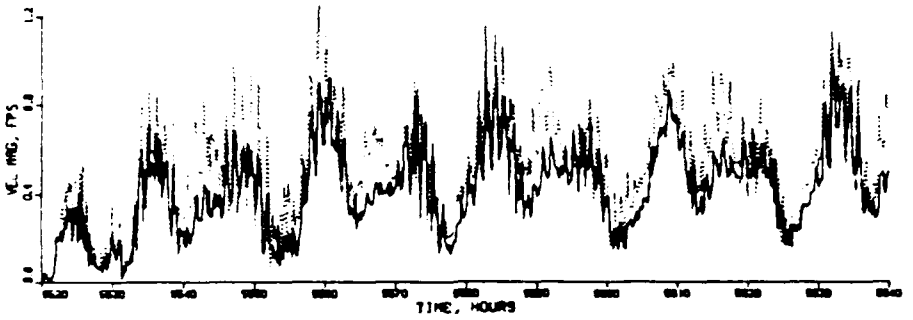
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C19

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 156



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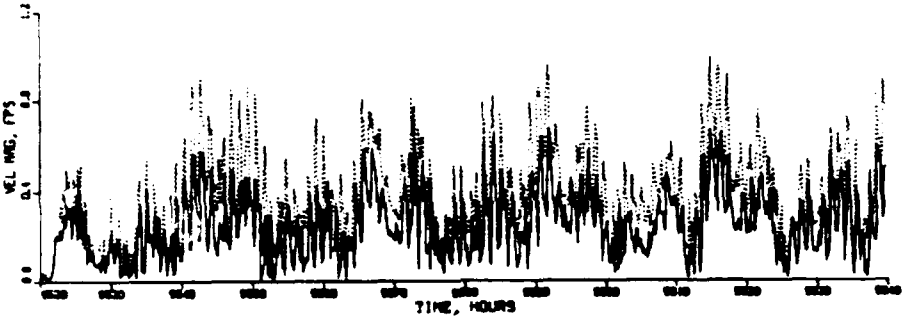
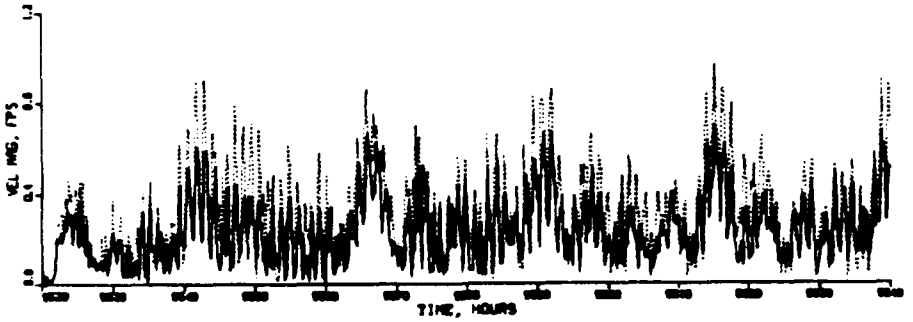


MID-DEPTH



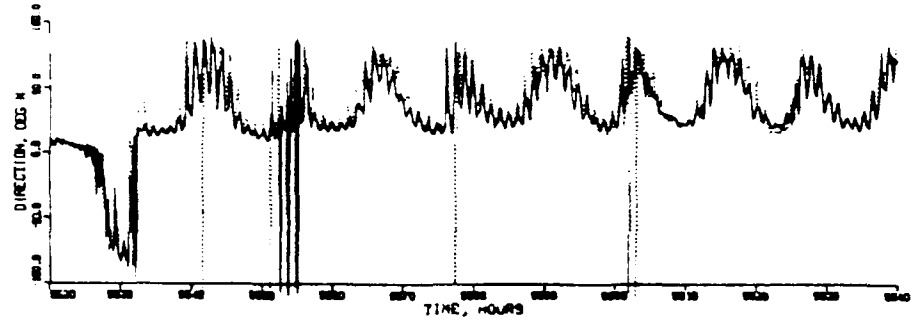
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

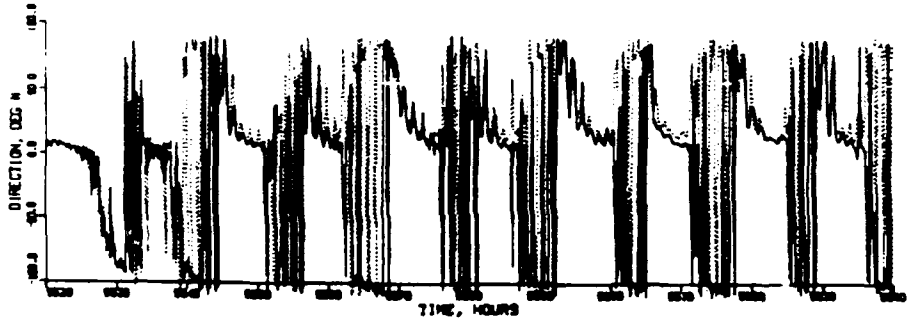
MAGNITUDE GAGE C19

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

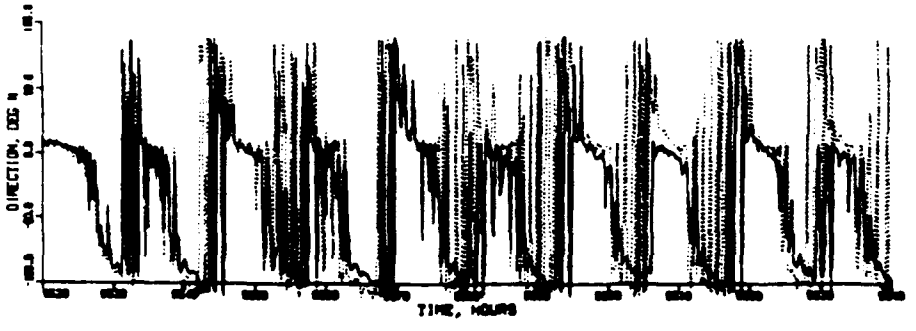
PLATE 157



SURFACE



MID-DEPTH



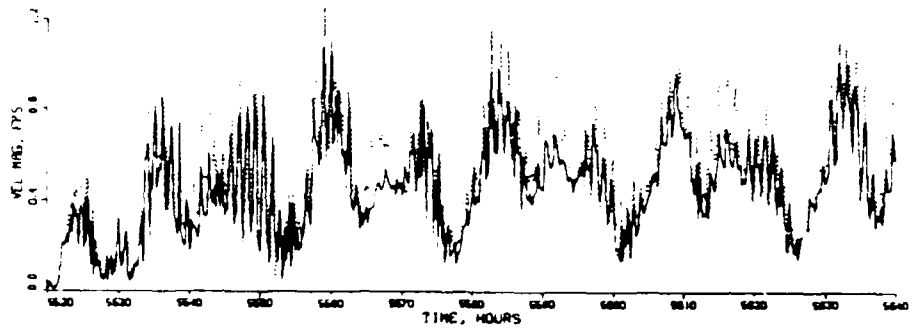
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C19

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 158



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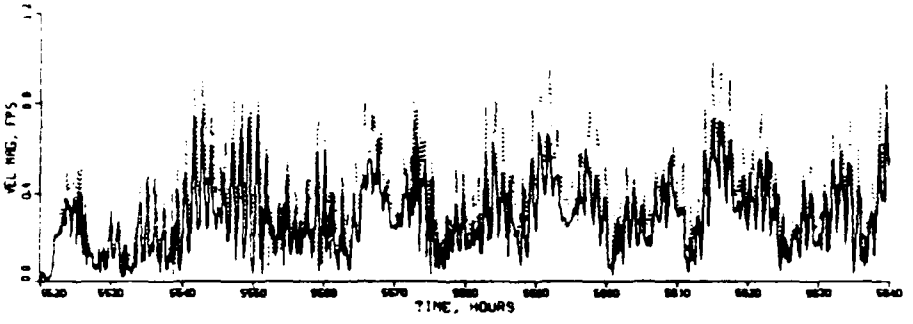
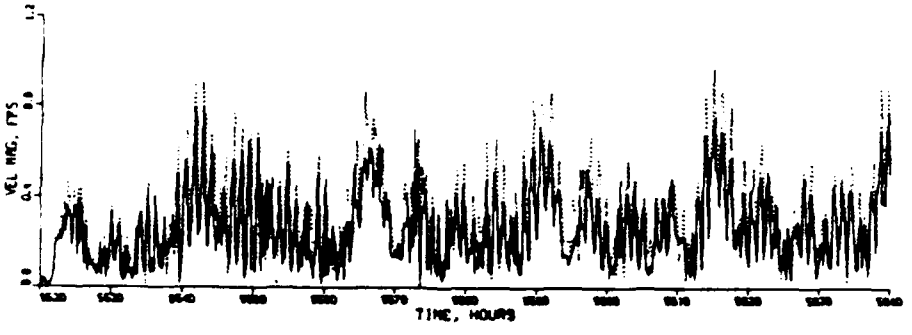


MID-DEPTH



BOTTOM

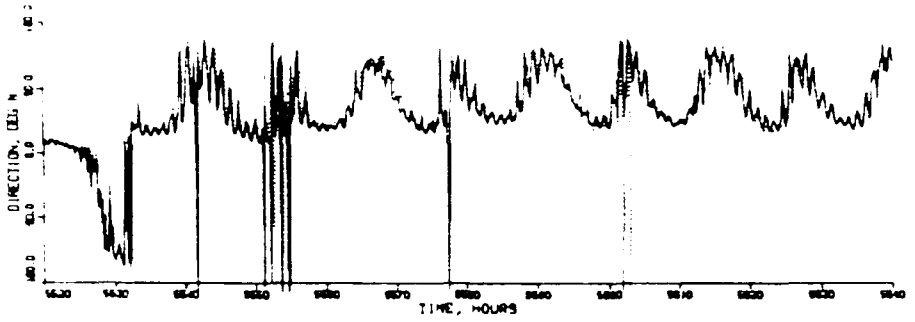
TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE

GAGE C19

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 159



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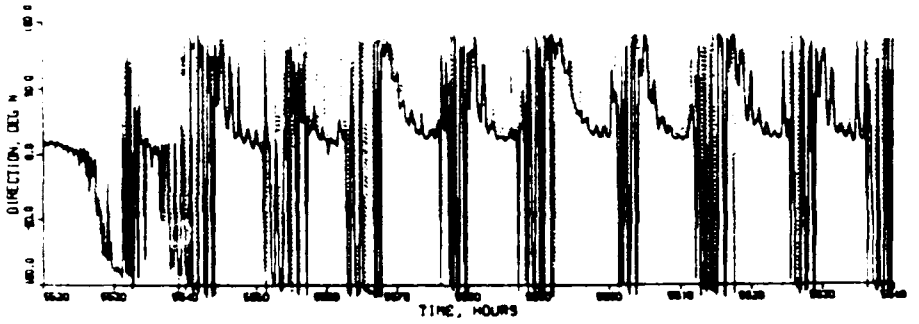
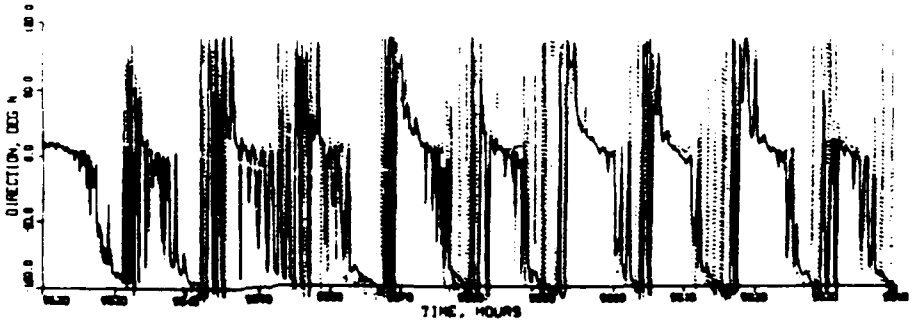


MID-DEPTH



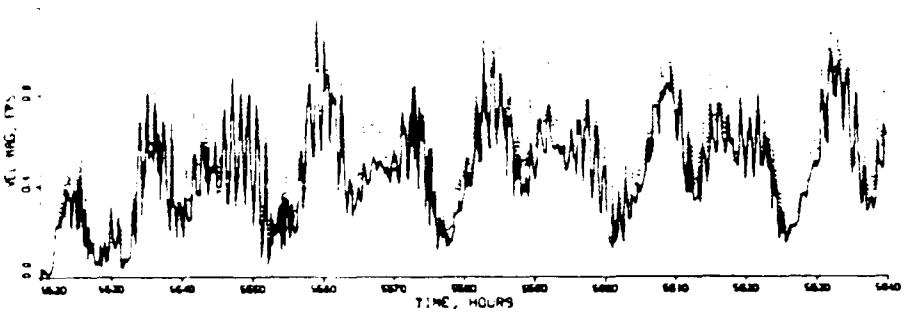
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C19

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 160



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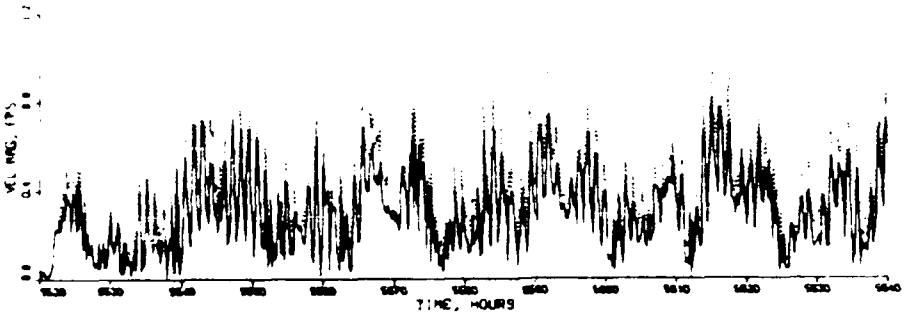
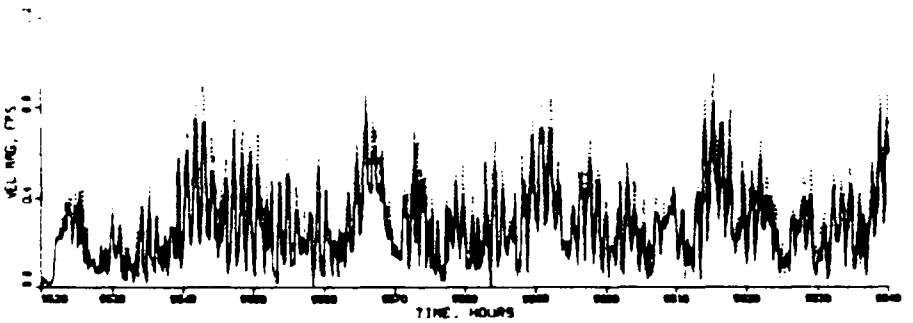


MID-DEPTH



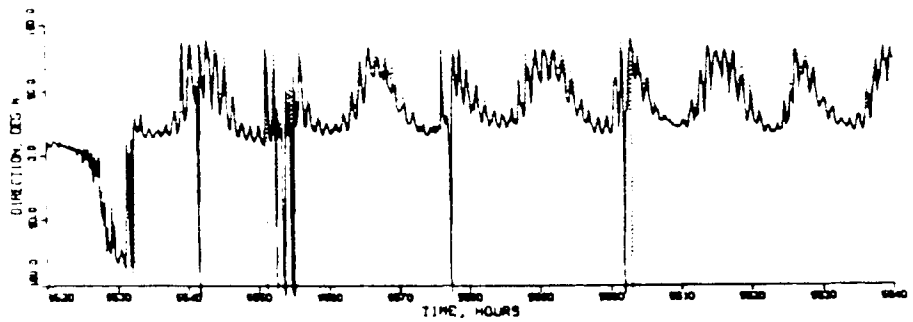
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C19

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 161



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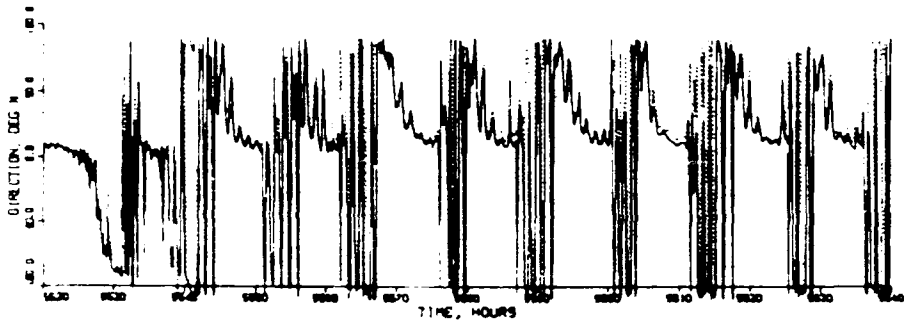
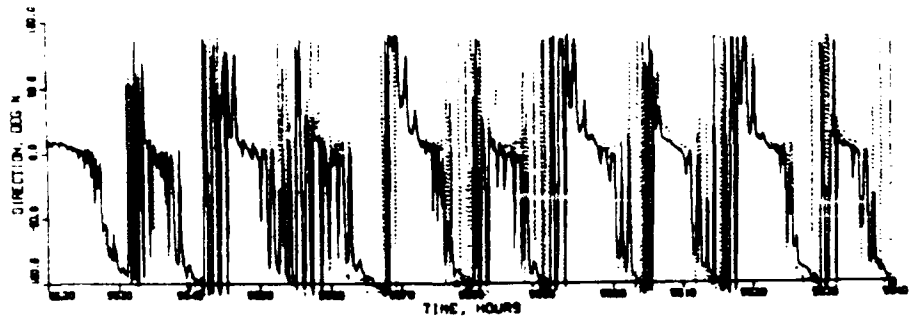


MID-DEPTH



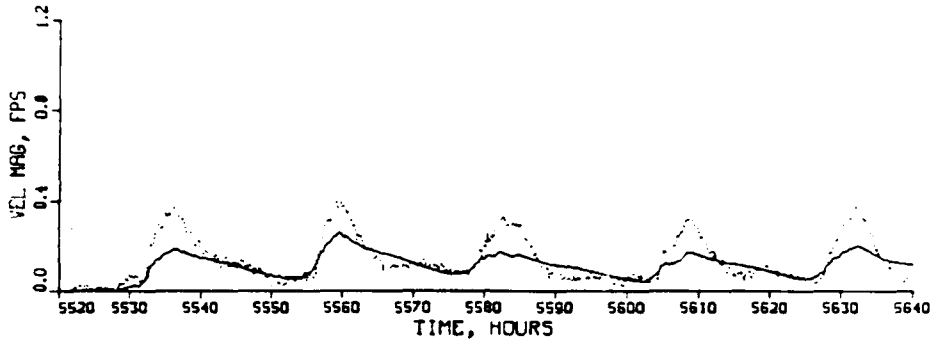
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

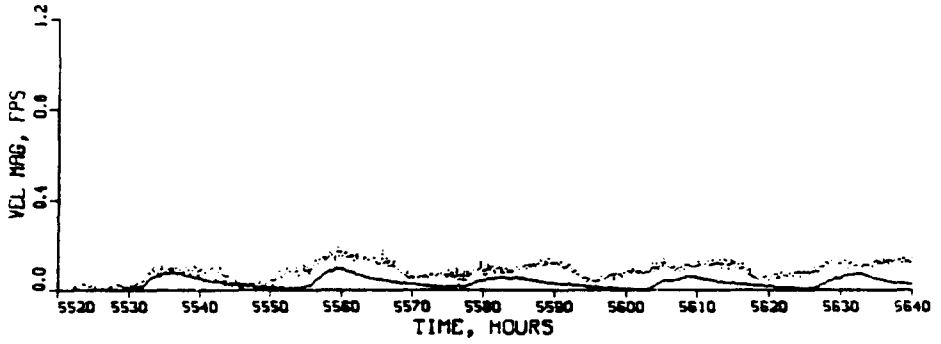
DIRECTION GAGE C19

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

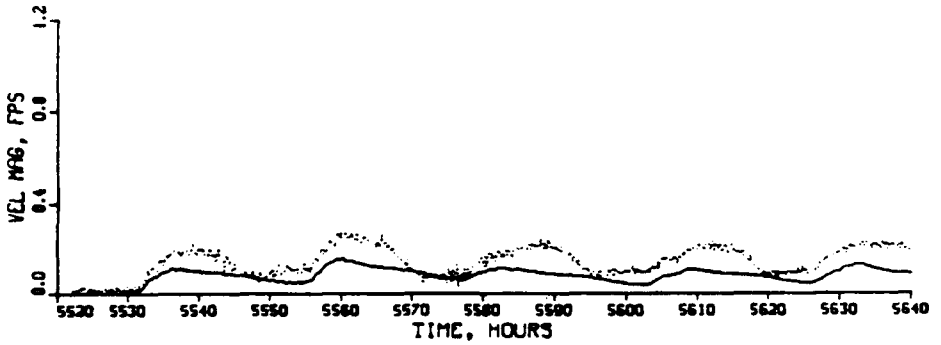
PLATE 162



SURFACE



MID-DEPTH



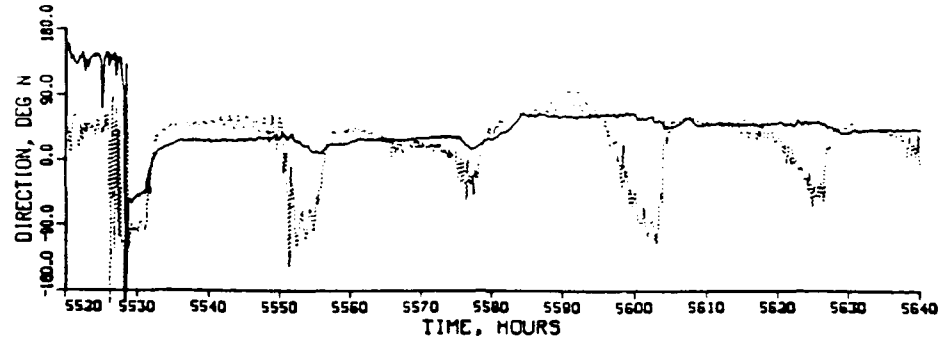
BOTTOM

TIDAL VELOCITY — VERIFICATION PERIOD

MAGNITUDE — GAGE C12

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 163



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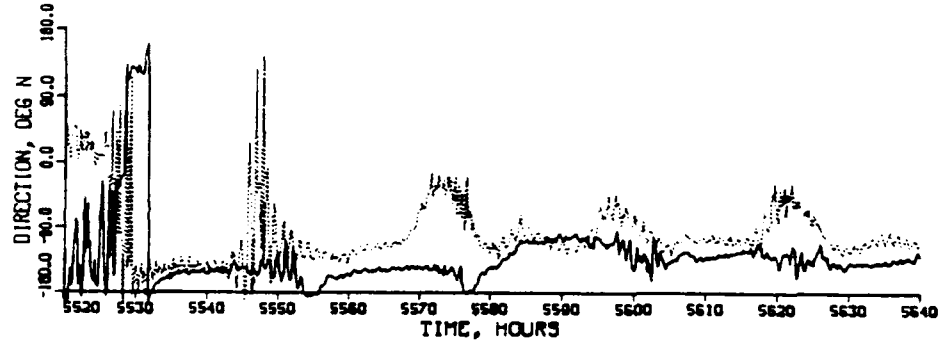
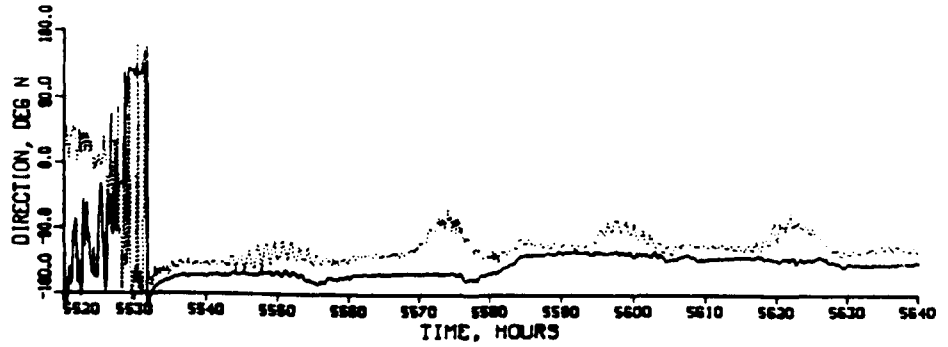


MID-DEPTH



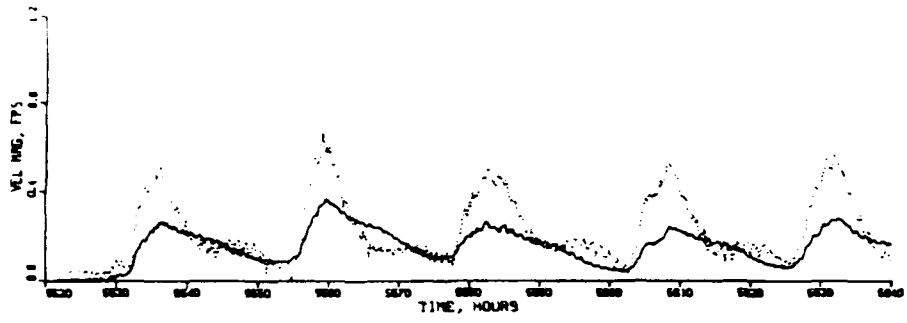
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

DIRECTION GAGE C12

PLAN 1 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 164



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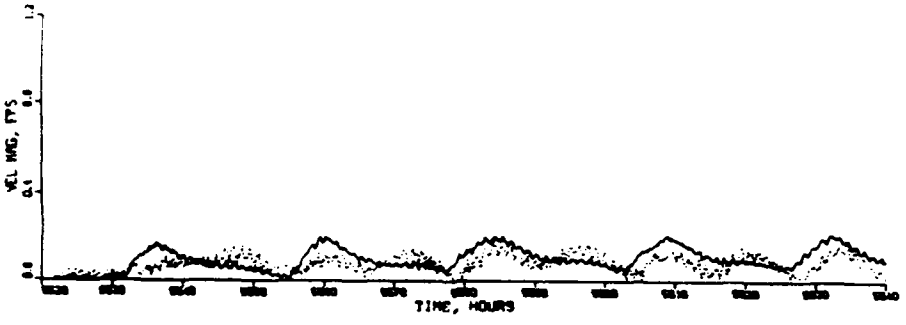
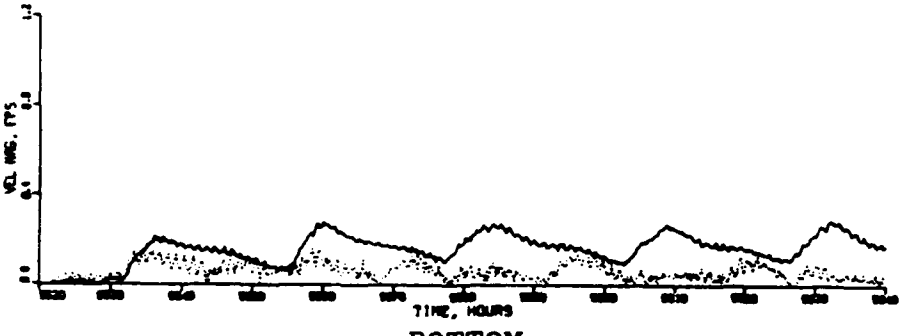


MID-DEPTH



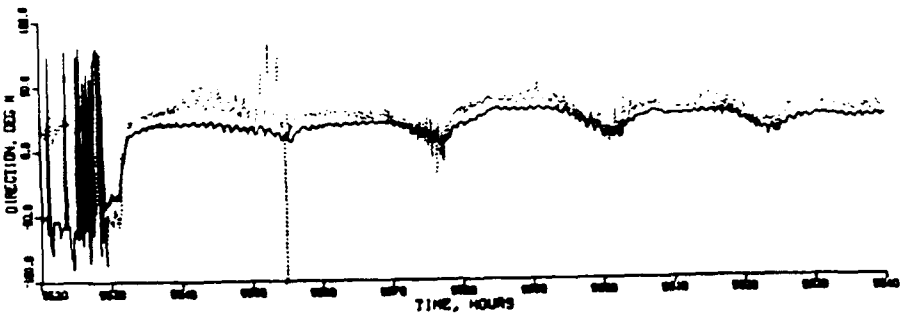
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

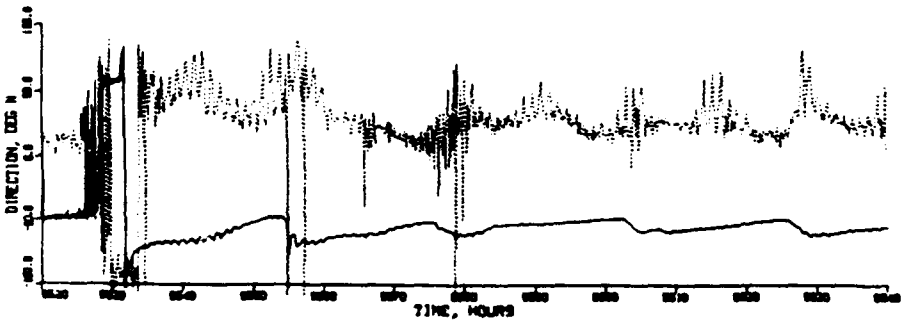
MAGNITUDE GAGE C12A

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

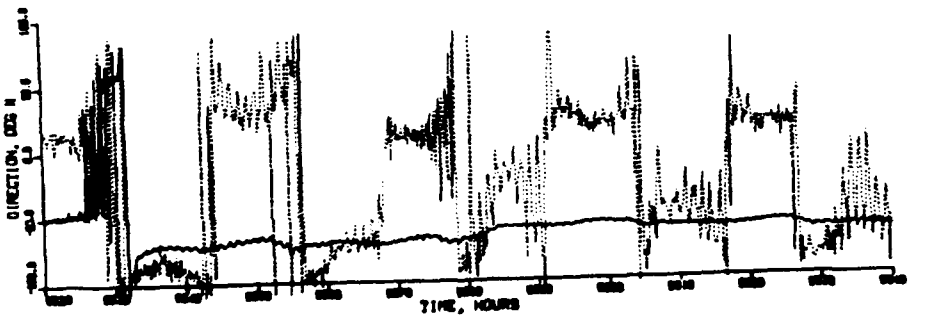
PLATE 165



SURFACE



MID-DEPTH



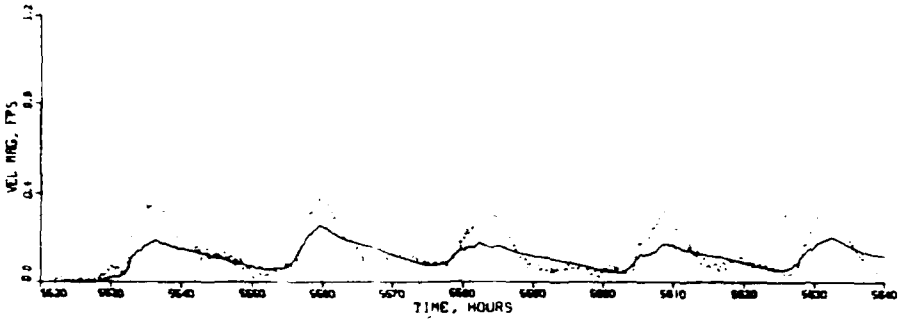
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

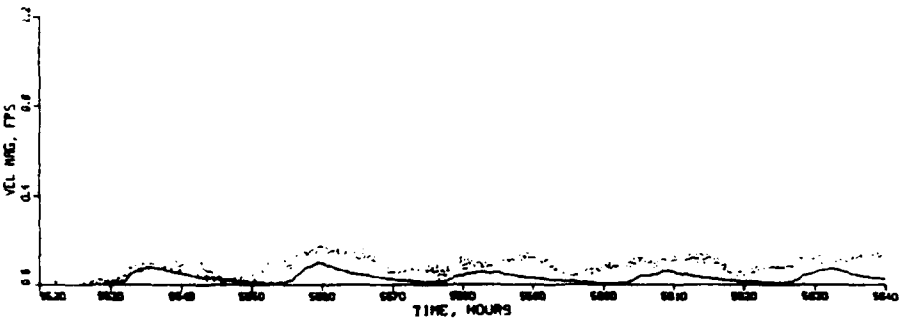
DIRECTION GAGE C12A

PLAN 2 (SOLID) VS EXISTING (DOTTED) CONDITIONS

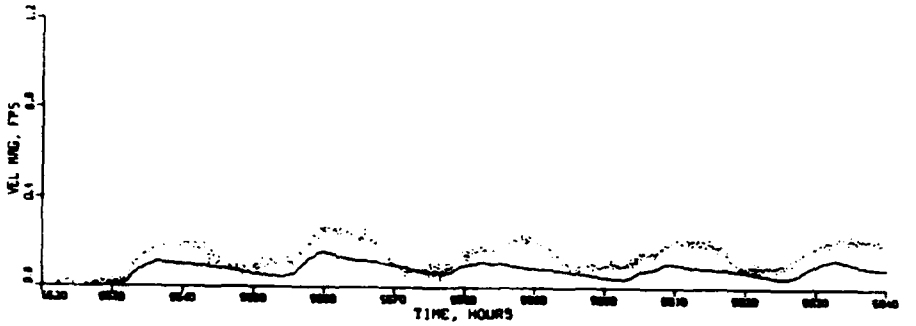
PLATE 166



SURFACE



MID-DEPTH



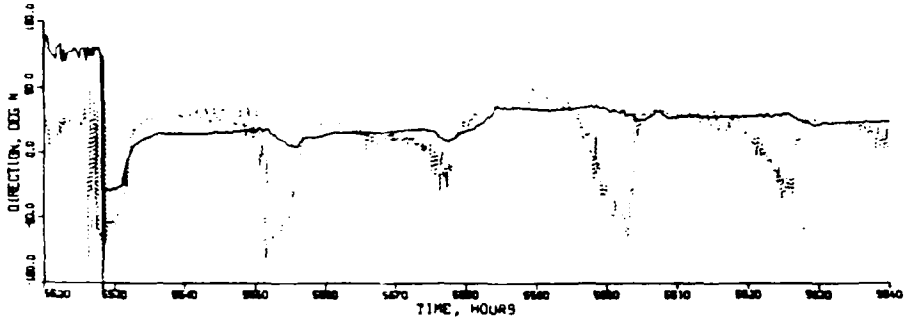
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

MAGNITUDE GAGE C12

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 167



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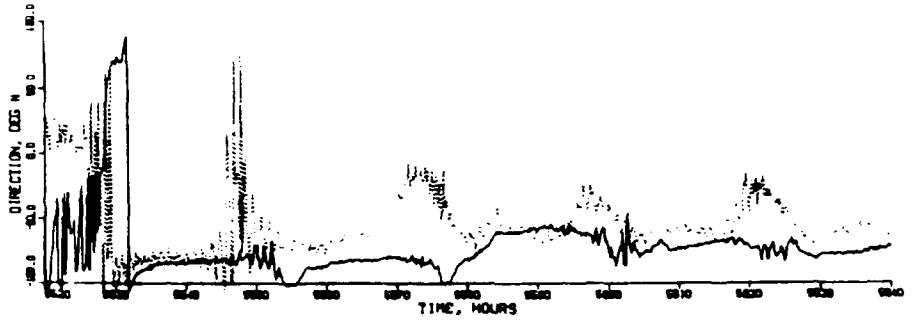
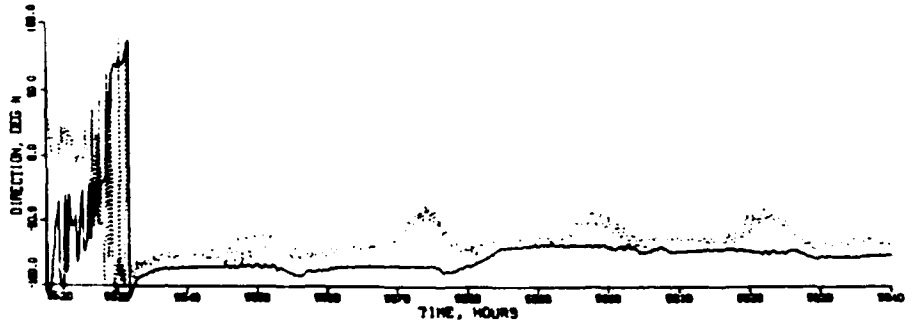


MID-DEPTH



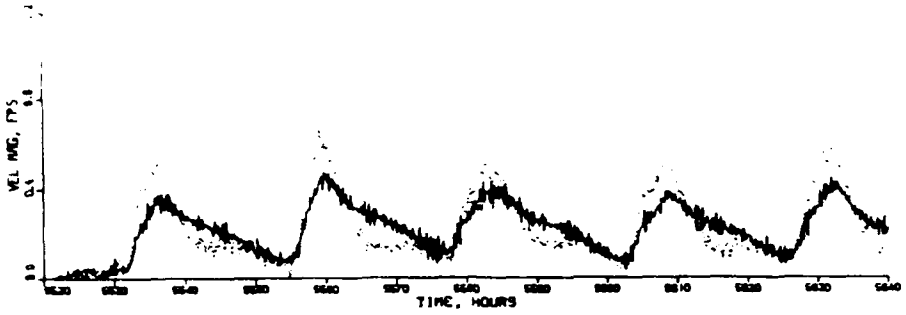
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

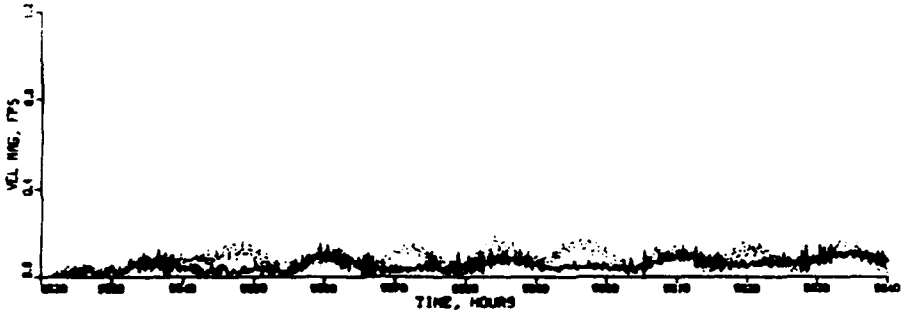
DIRECTION GAGE C12

PLAN 3 (SOLID) VS EXISTING (DOTTED) CONDITIONS

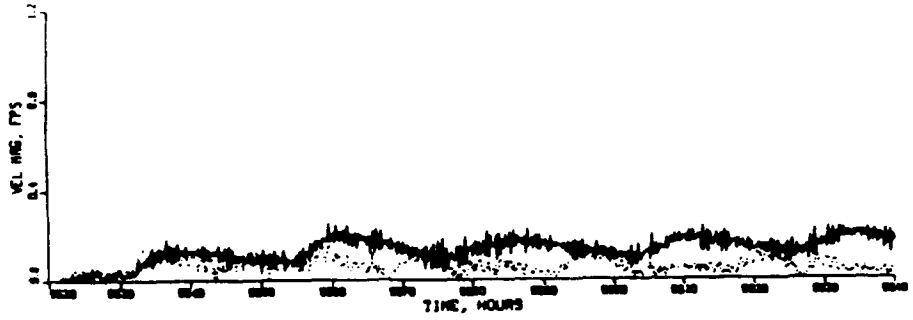
PLATE 168



SURFACE



MID-DEPTH



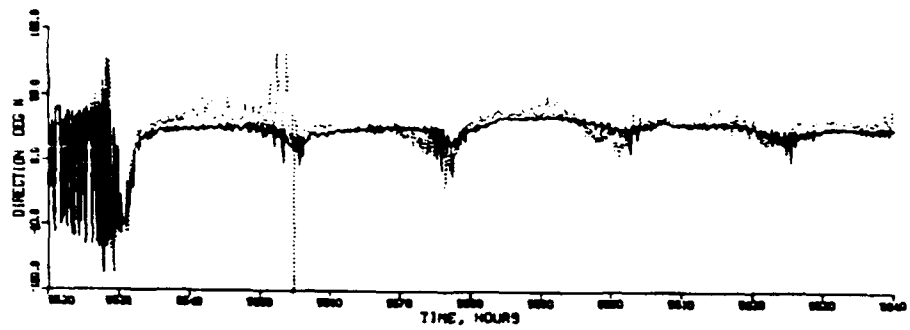
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

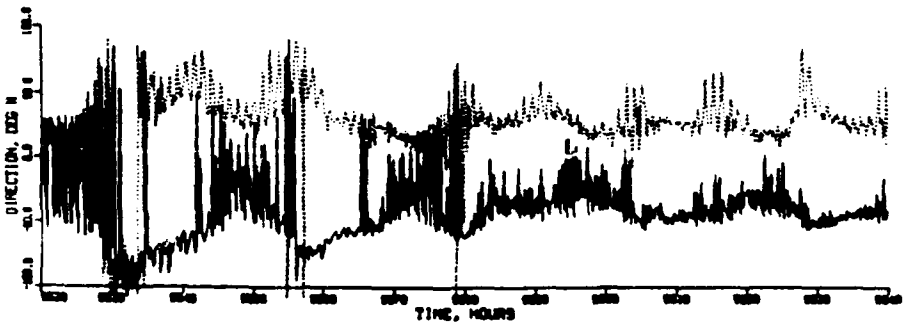
MAGNITUDE GAGE C12A

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

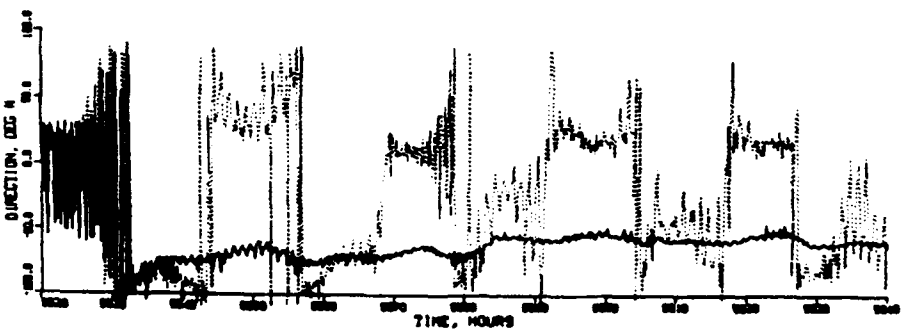
PLATE 169



SURFACE



MID-DEPTH



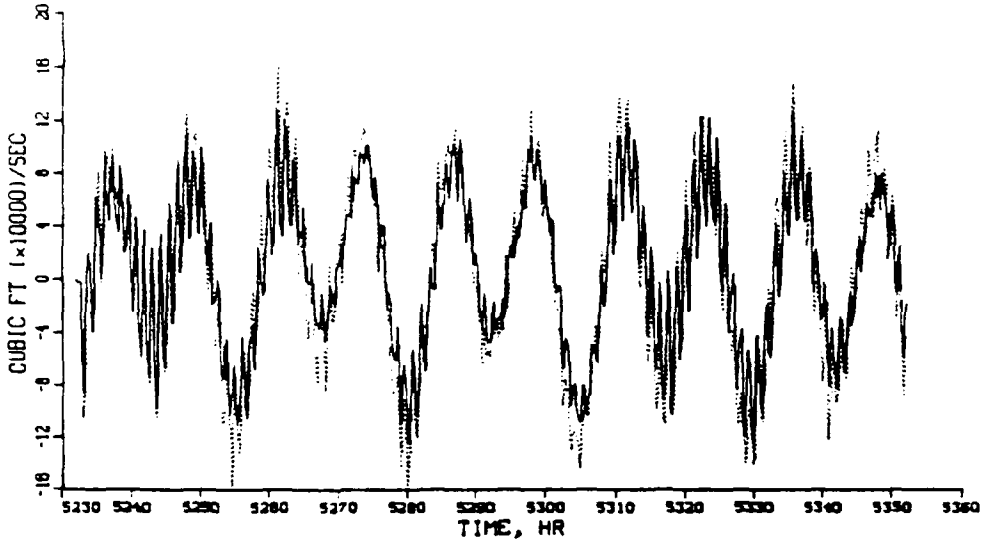
BOTTOM

TIDAL VELOCITY **VERIFICATION PERIOD**

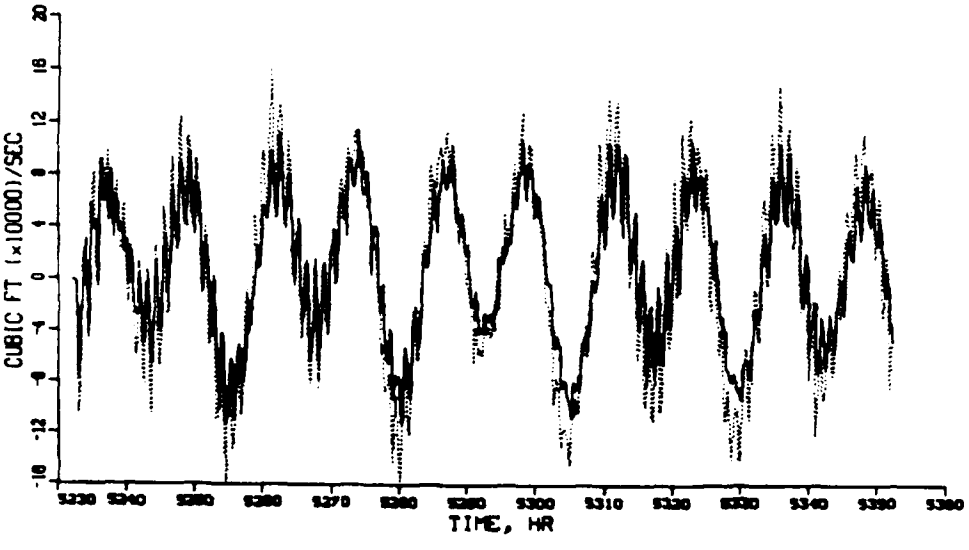
DIRECTION GAGE C12A

PLAN 4 (SOLID) VS EXISTING (DOTTED) CONDITIONS

PLATE 170



PLAN 1



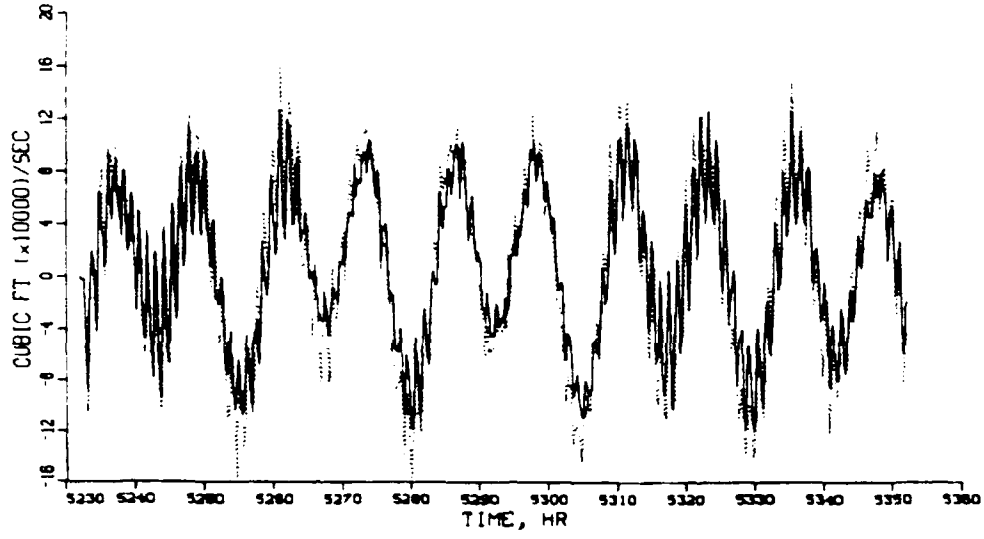
PLAN 2

TIDAL DISCHARGE **CALIBRATION PERIOD**

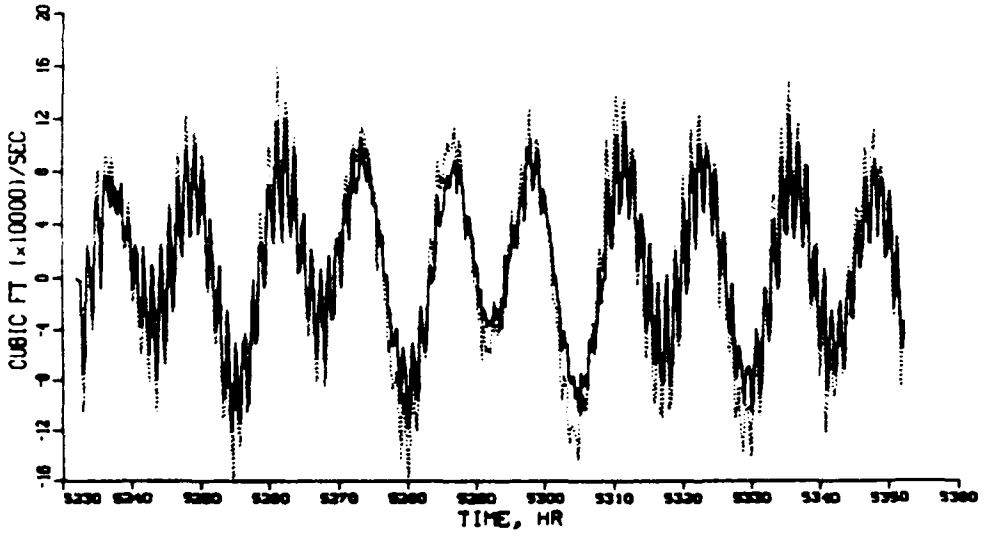
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 1

PLATE 171



PLAN 3



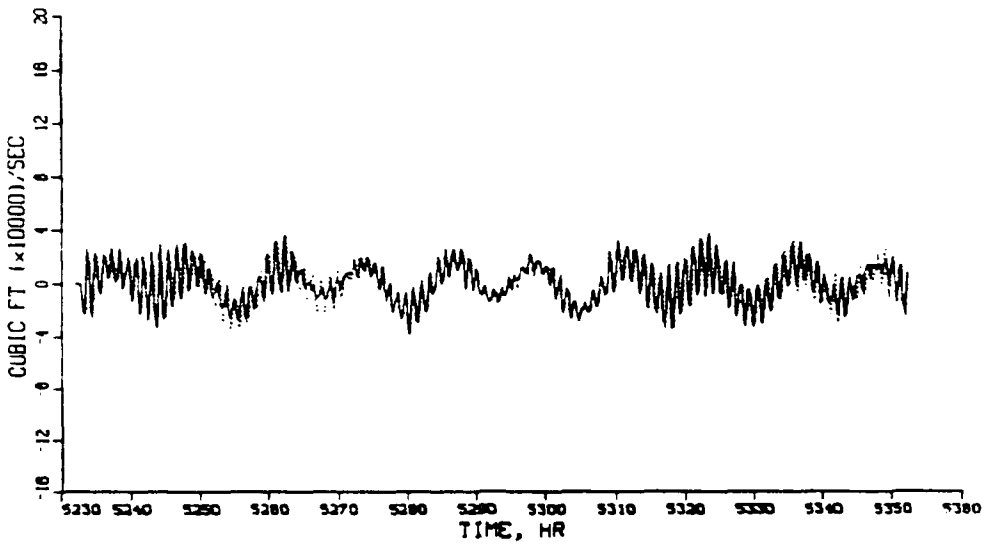
PLAN 4

TIDAL DISCHARGE CALIBRATION PERIOD

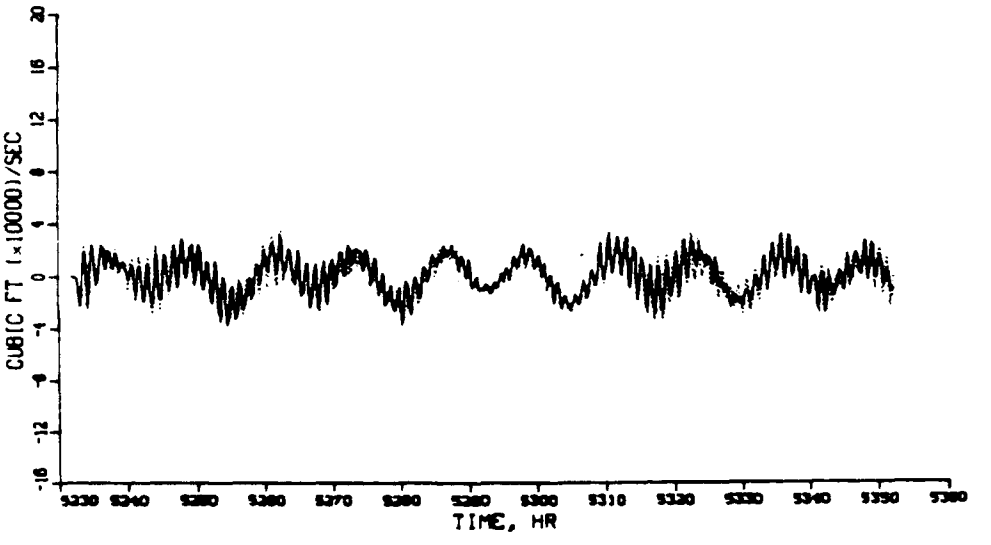
PLAN (SOLID) VS EXISTINC (DOTTED) CONDITIONS

RANGE 1

PLATE 172



PLAN 1



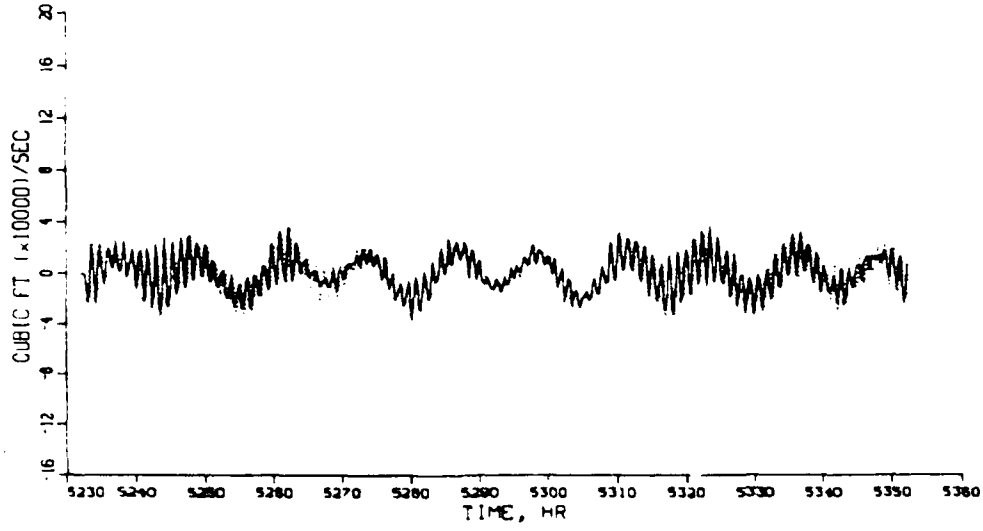
PLAN 2

TIDAL DISCHARGE CALIBRATION PERIOD

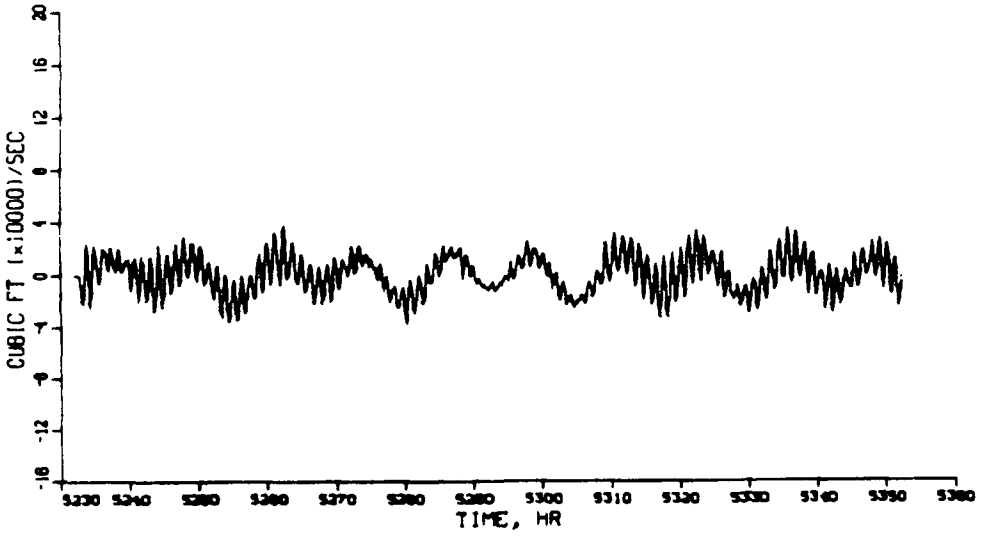
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 2

PLATE 173



PLAN 3



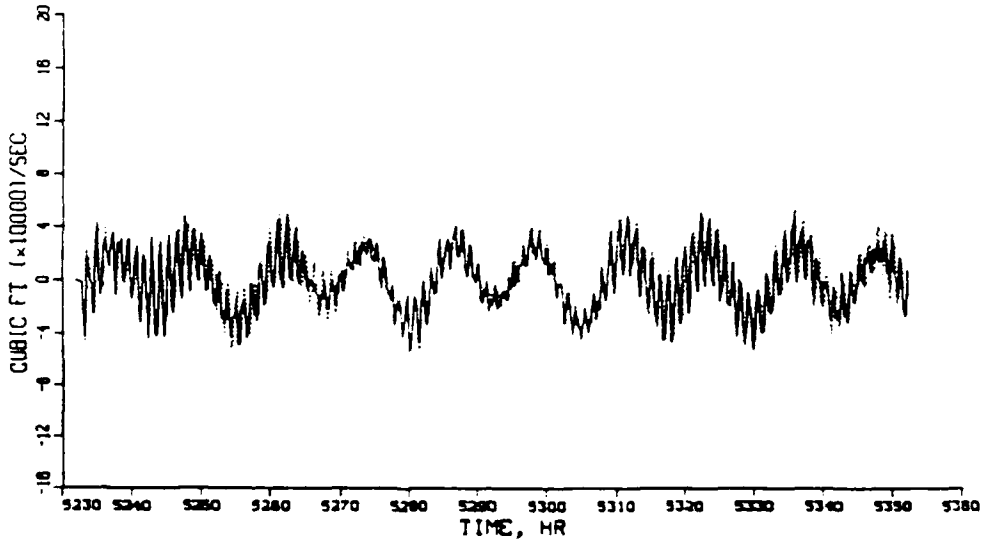
PLAN 4

TIDAL DISCHARGE **CALIBRATION PERIOD**

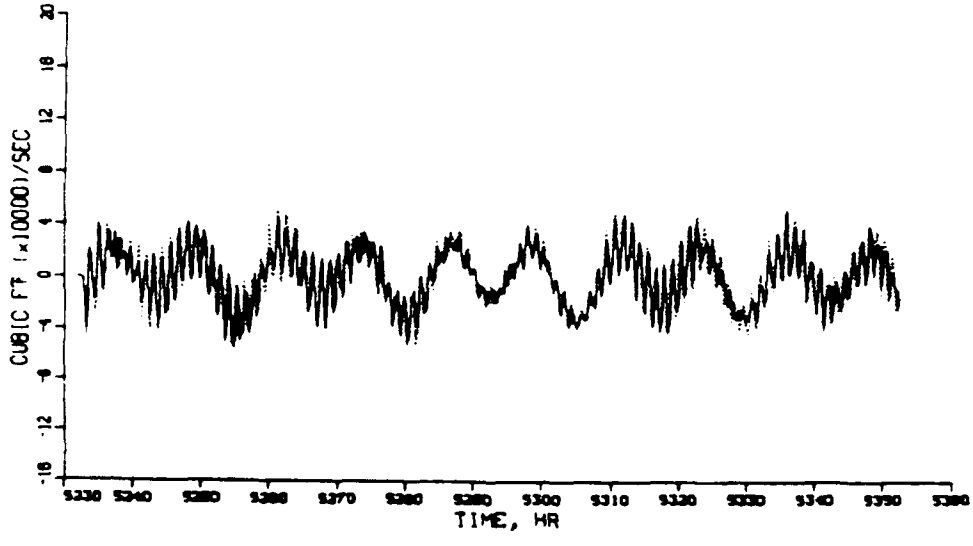
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 2

PLATE 174



PLAN 1



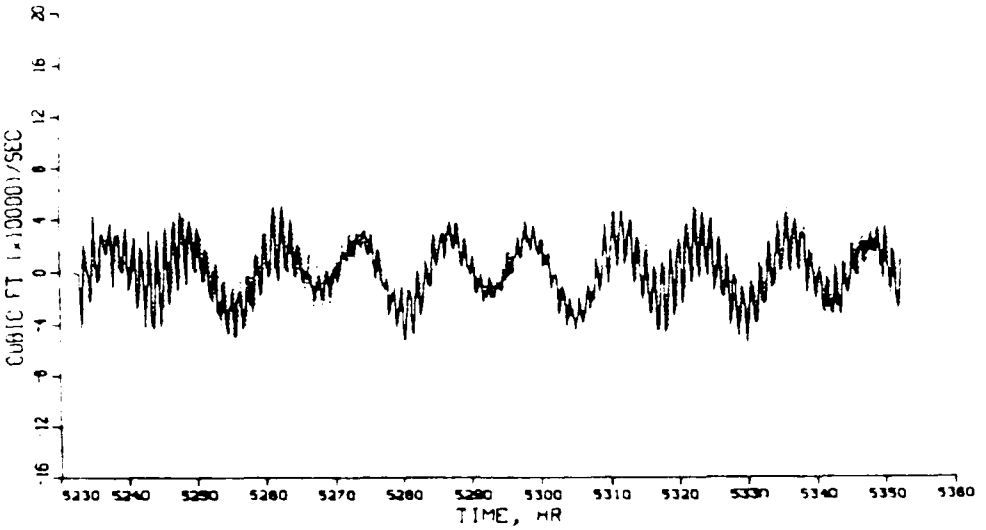
PLAN 2

TIDAL DISCHARGE CALIBRATION PERIOD

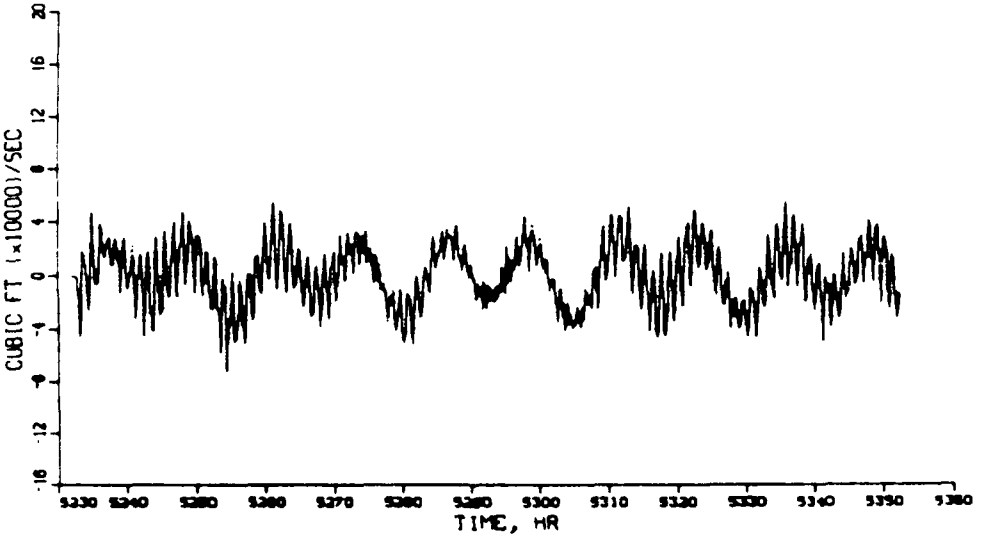
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 3

PLATE 175



PLAN 3



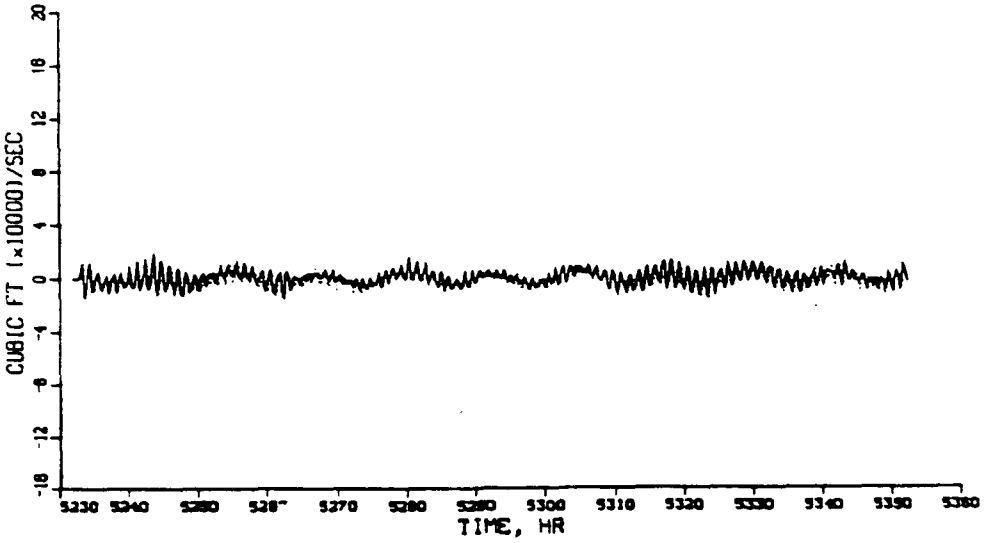
PLAN 4

TIDAL DISCHARGE CALIBRATION PERIOD

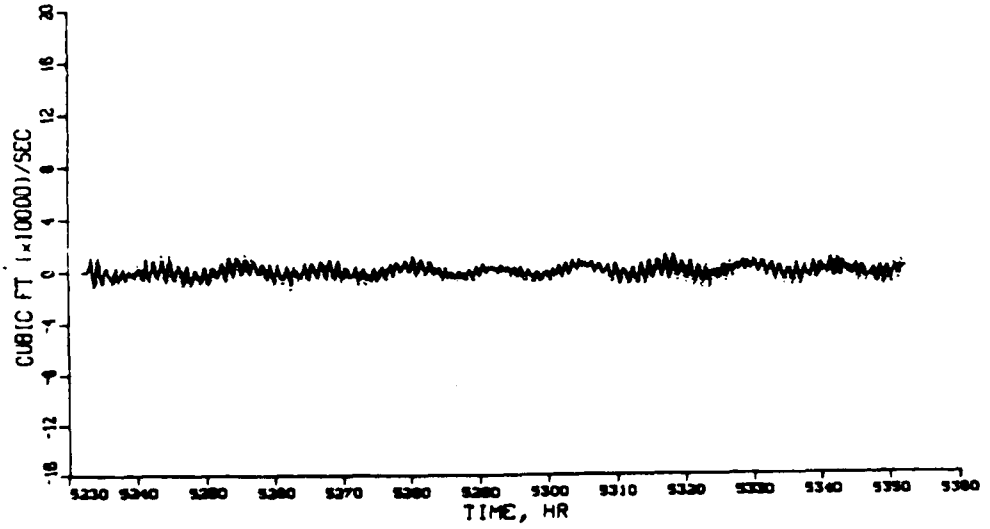
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 3

PLATE 176



PLAN 1



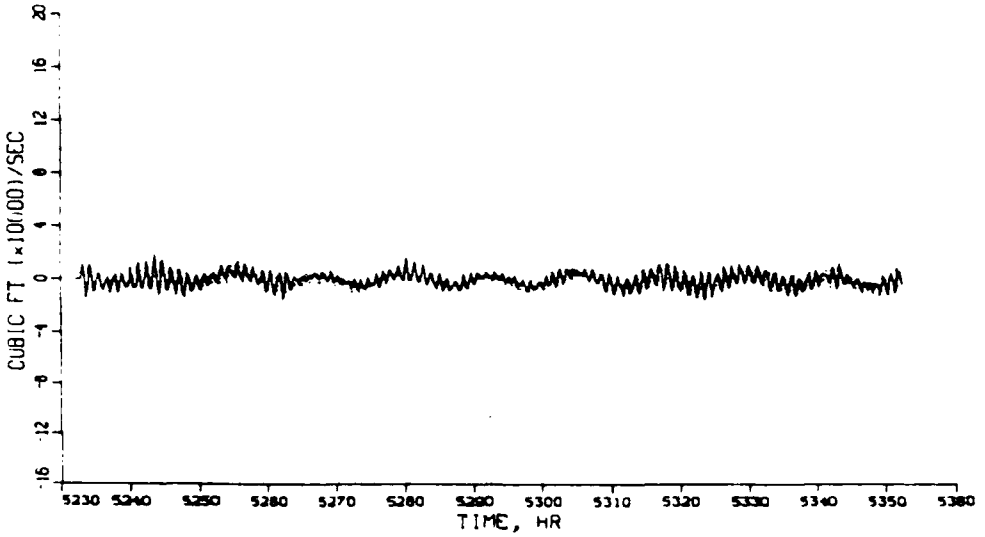
PLAN 2

TIDAL DISCHARGE CALIBRATION PERIOD

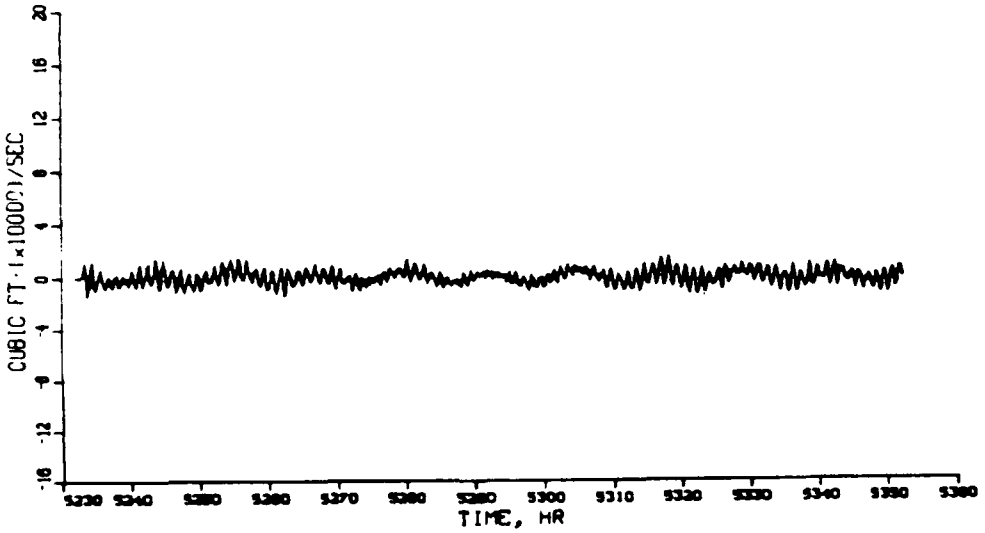
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 4

PLATE 177



PLAN 3



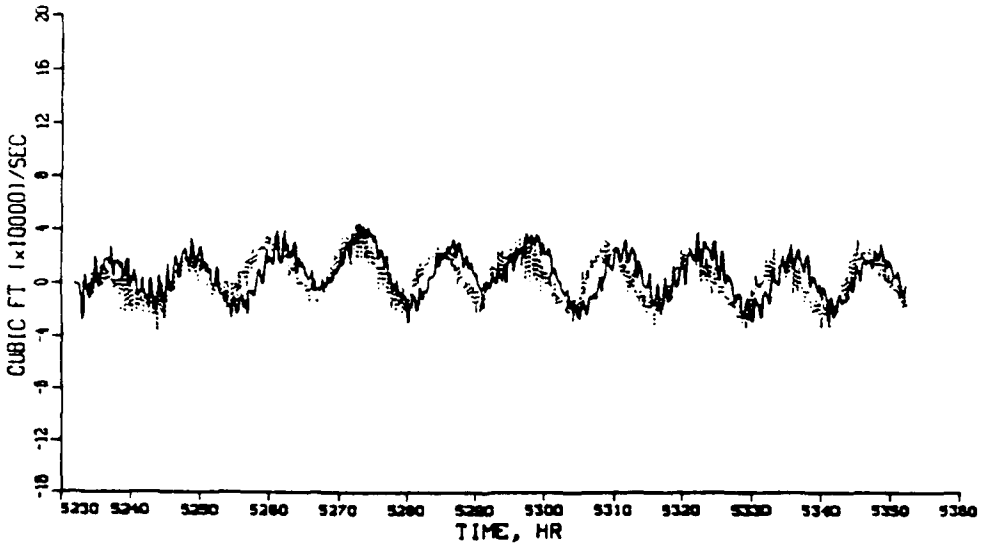
PLAN 4

TIDAL DISCHARGE CALIBRATION PERIOD

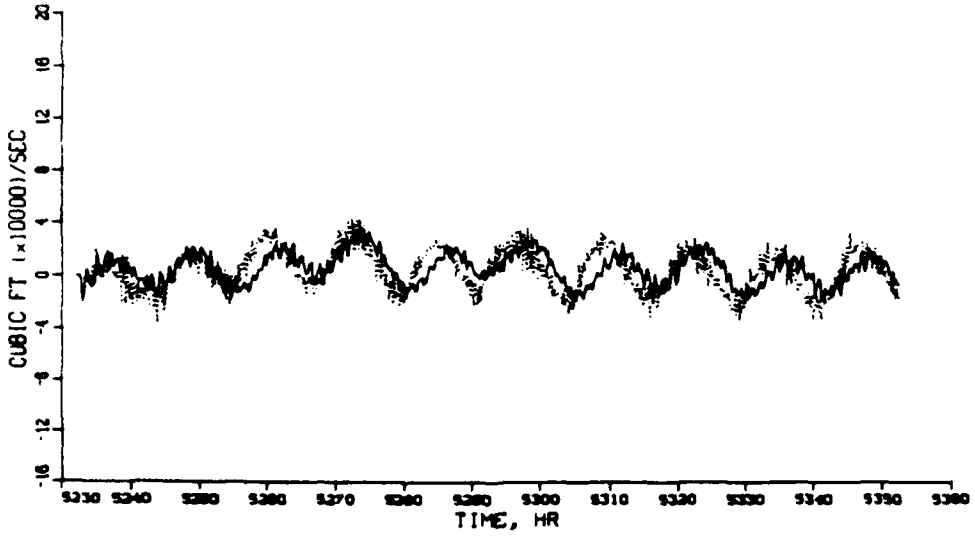
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 4

PLATE 178



PLAN 1



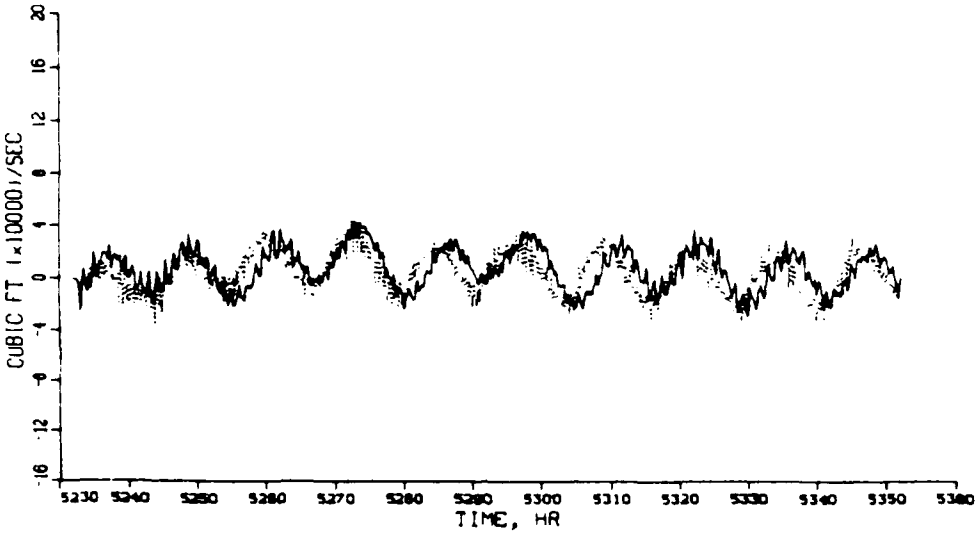
PLAN 2

TIDAL DISCHARGE CALIBRATION PERIOD

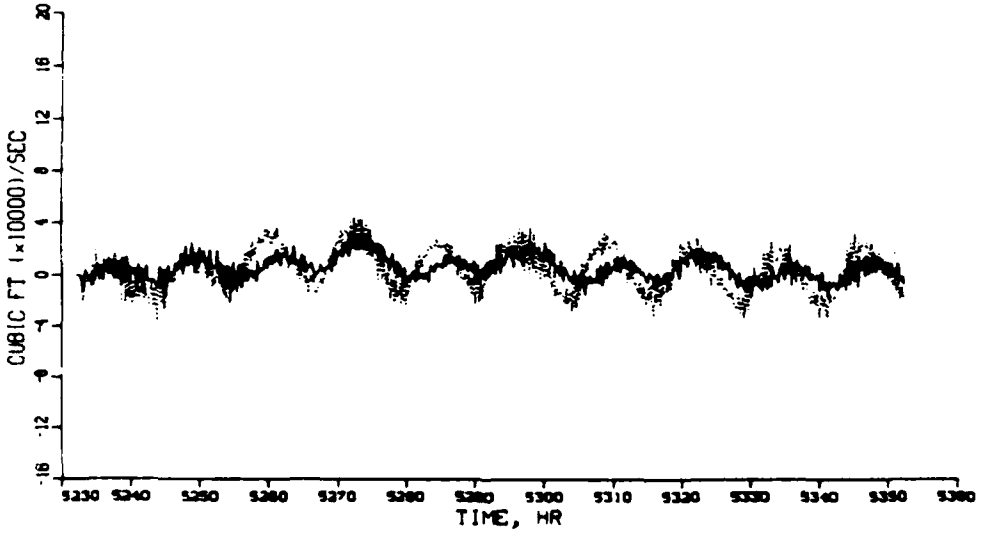
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 5

PLATE 179



PLAN 3



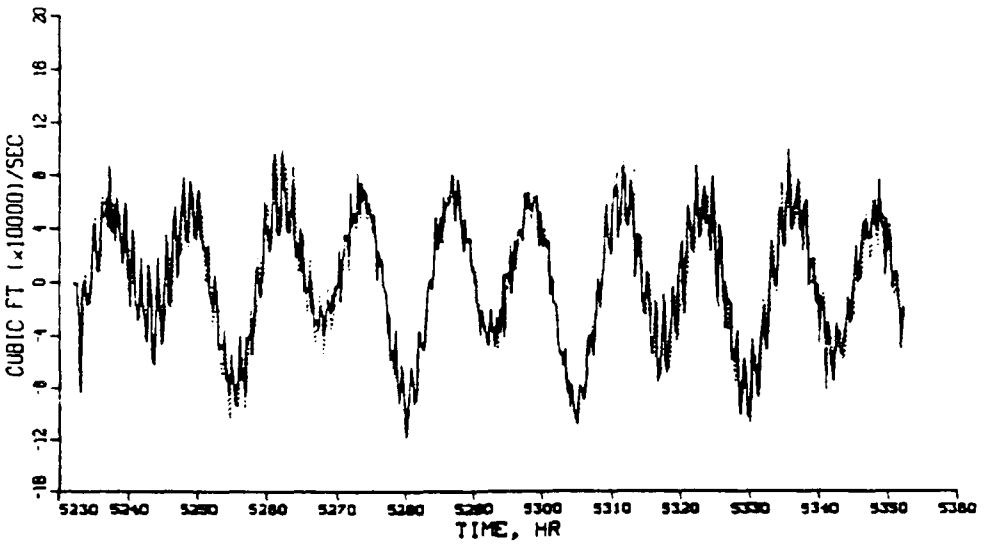
PLAN 4

TIDAL DISCHARGE **CALIBRATION PERIOD**

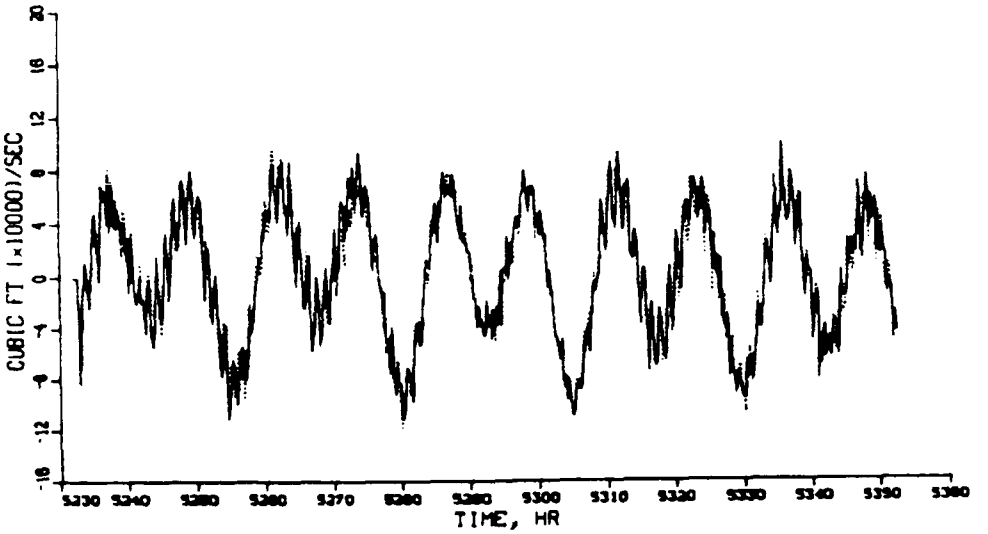
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 5

PLATE 180



PLAN 1



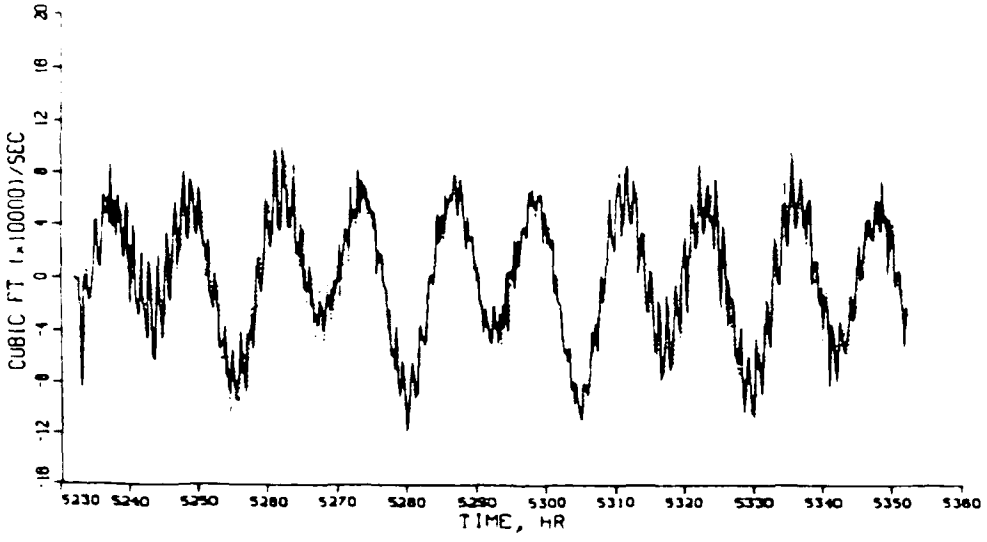
PLAN 2

TIDAL DISCHARGE CALIBRATION PERIOD

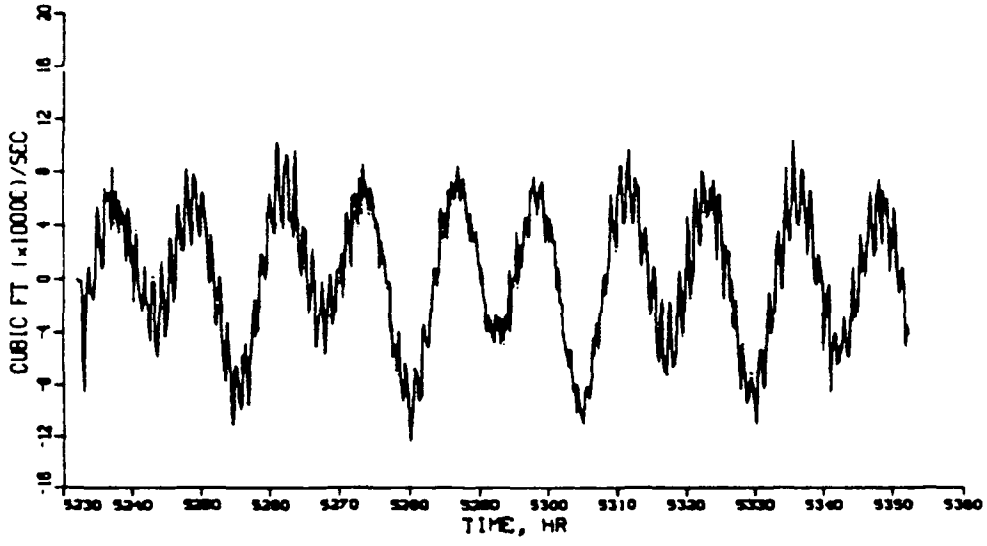
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 6

PLATE 181



PLAN 3



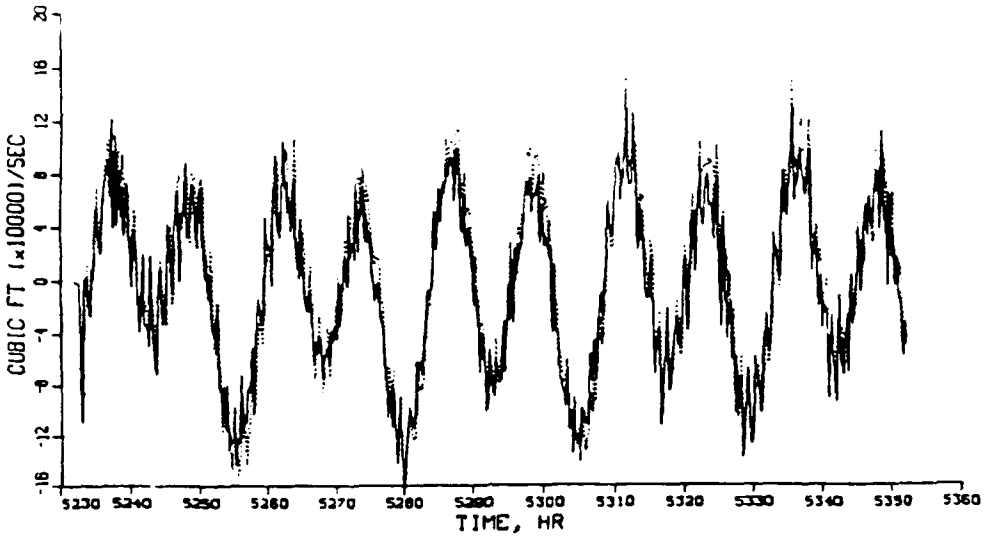
PLAN 4

TIDAL DISCHARGE **CALIBRATION PERIOD**

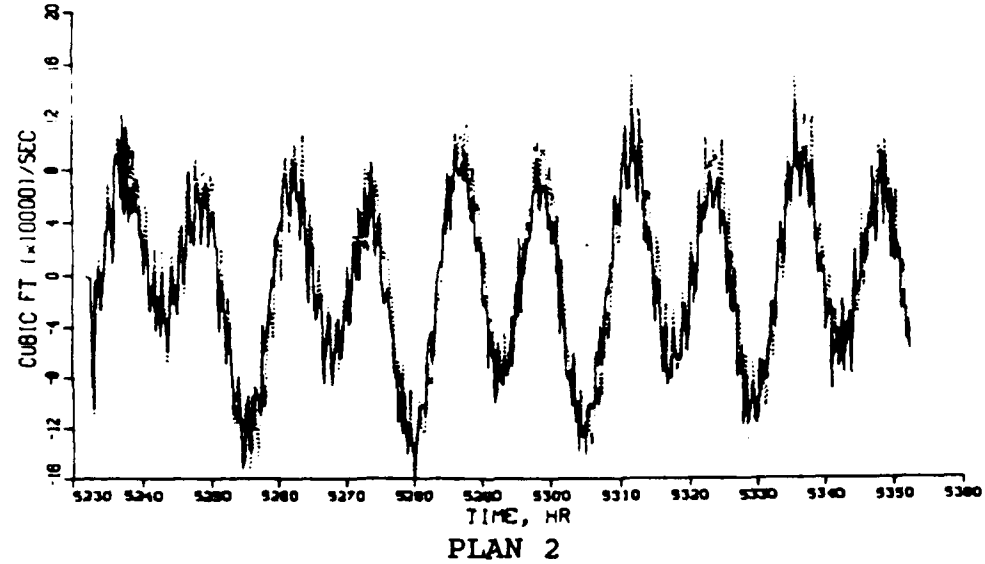
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 6

PLATE 182



PLAN 1



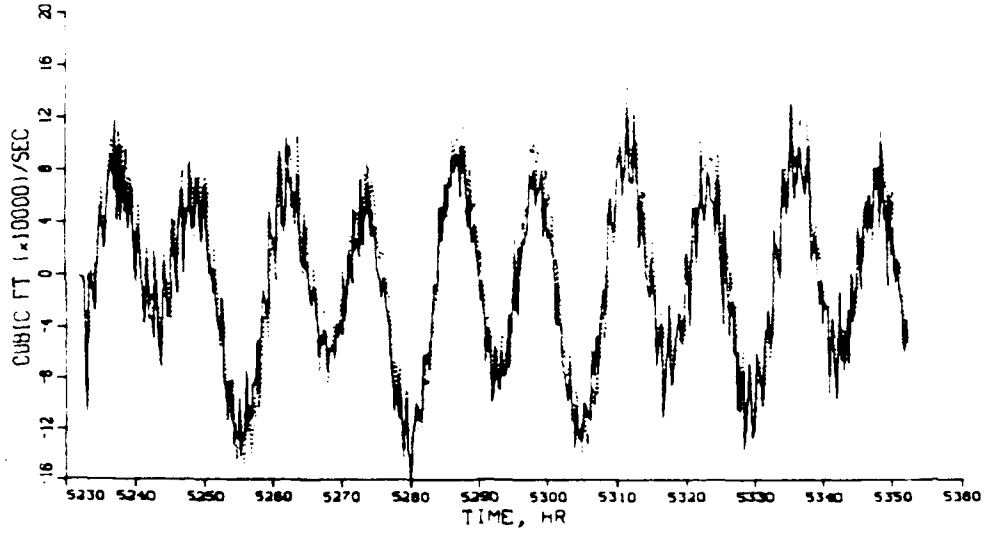
PLAN 2

TIDAL DISCHARGE CALIBRATION PERIOD

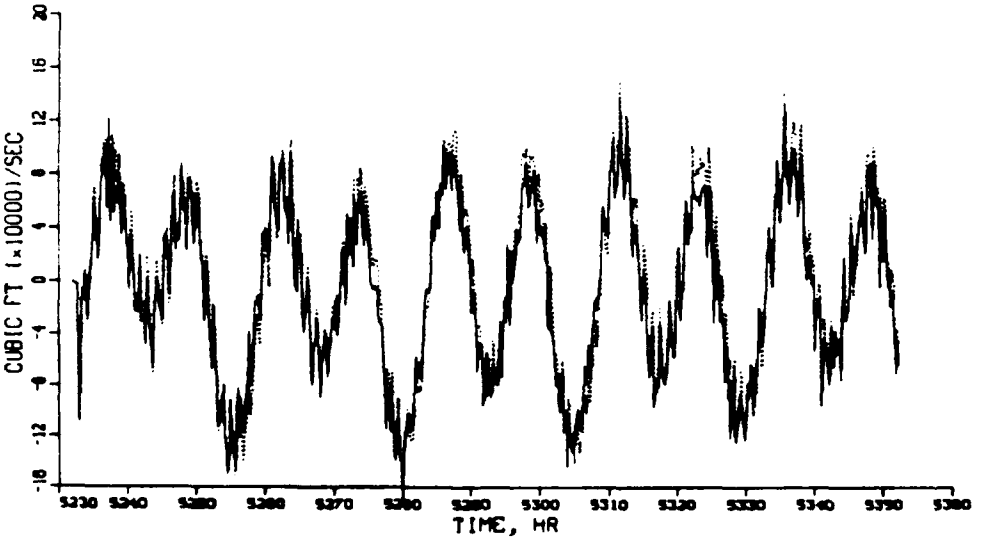
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 7

PLATE 183



PLAN 3



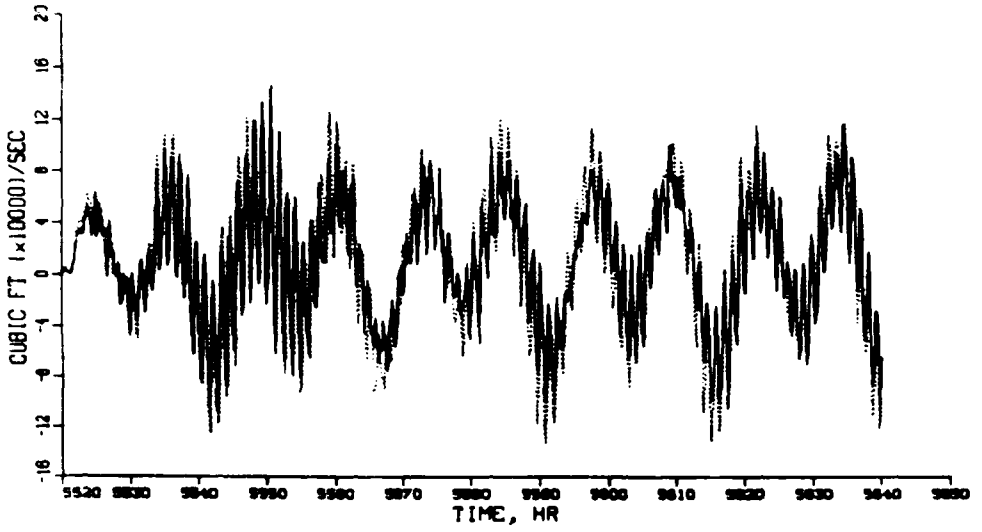
PLAN 4

TIDAL DISCHARGE **CALIBRATION PERIOD**

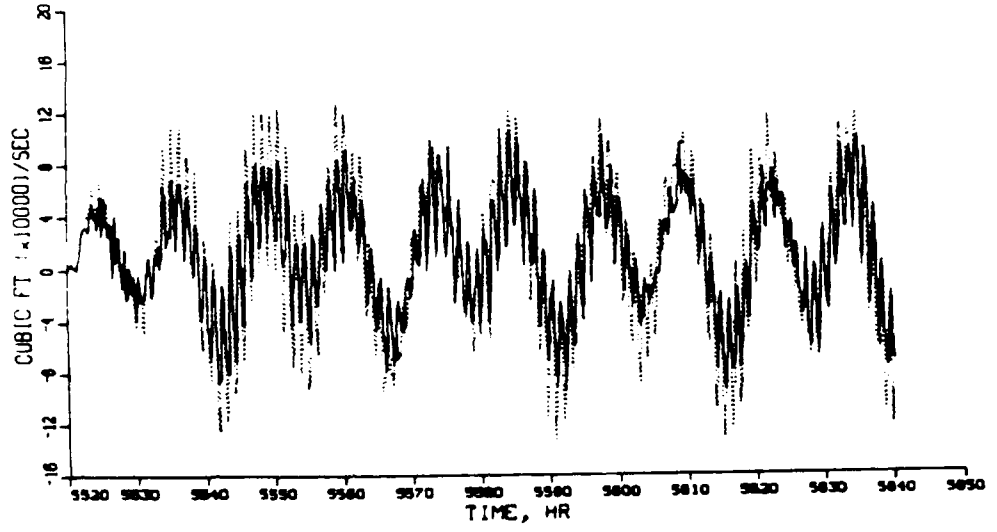
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 7

PLATE 184



PLAN 1



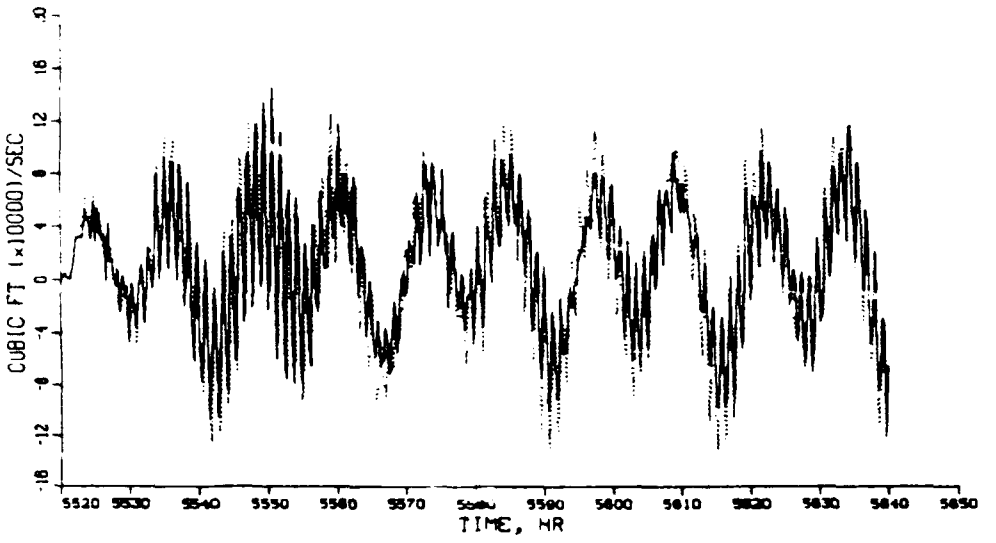
PLAN 2

TIDAL DISCHARGE **VERIFICATION PERIOD**

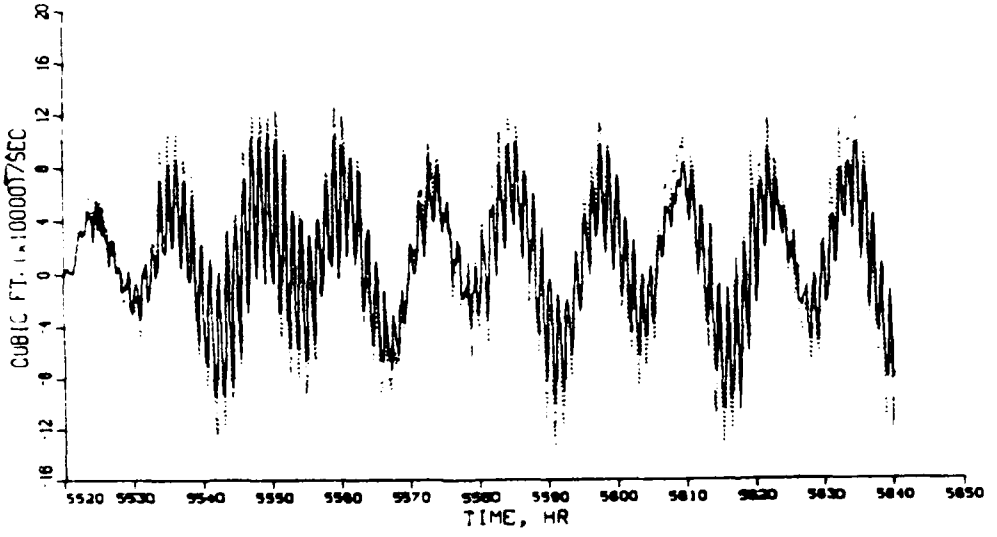
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 1

PLATE 185



PLAN 3



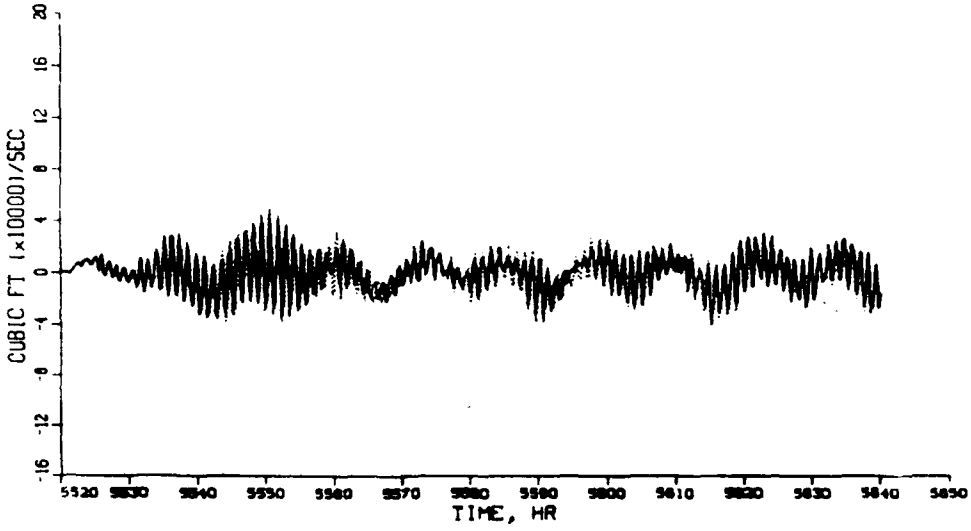
PLAN 4

TIDAL DISCHARGE VERIFICATION PERIOD

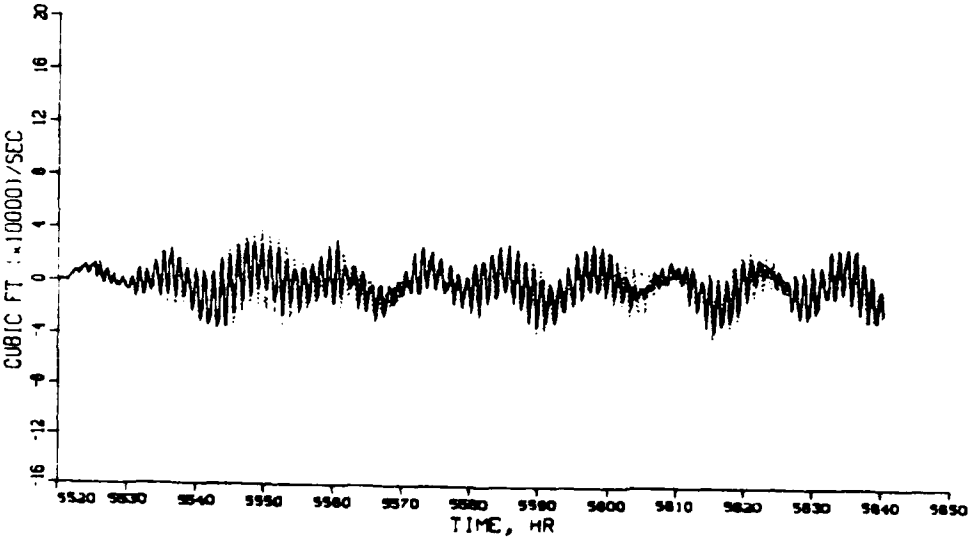
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 1

PLATE 186



PLAN 1



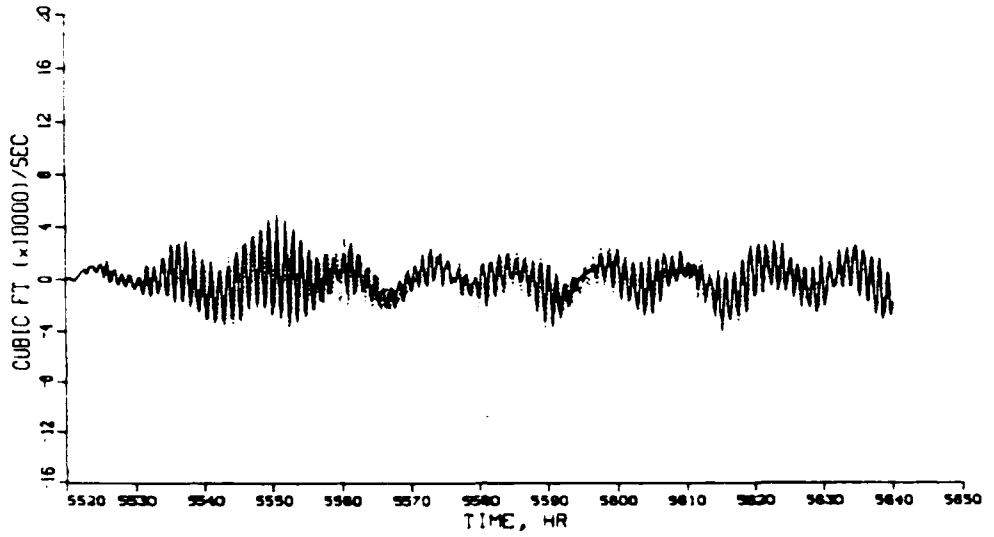
PLAN 2

TIDAL DISCHARGE VERIFICATION PERIOD

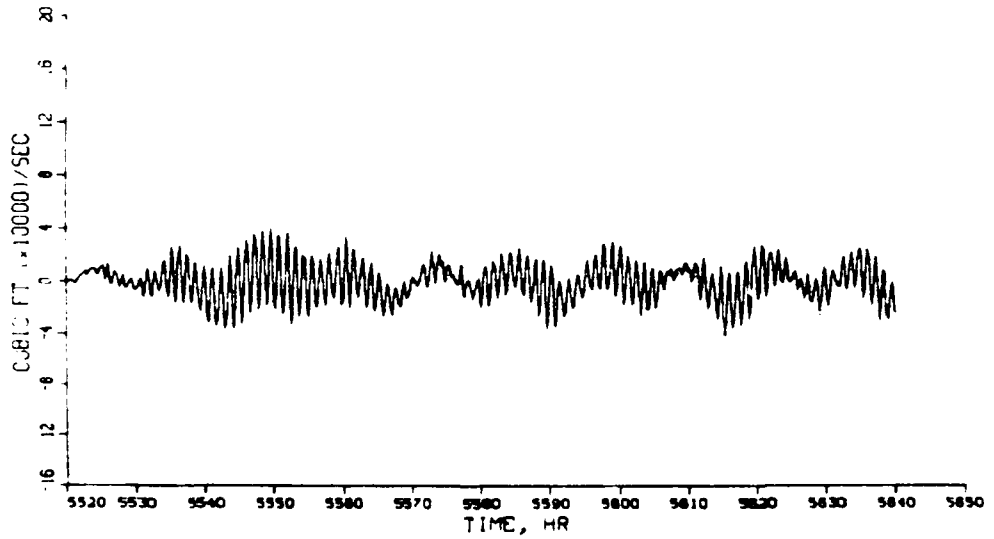
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 2

PLATE 187



PLAN 3



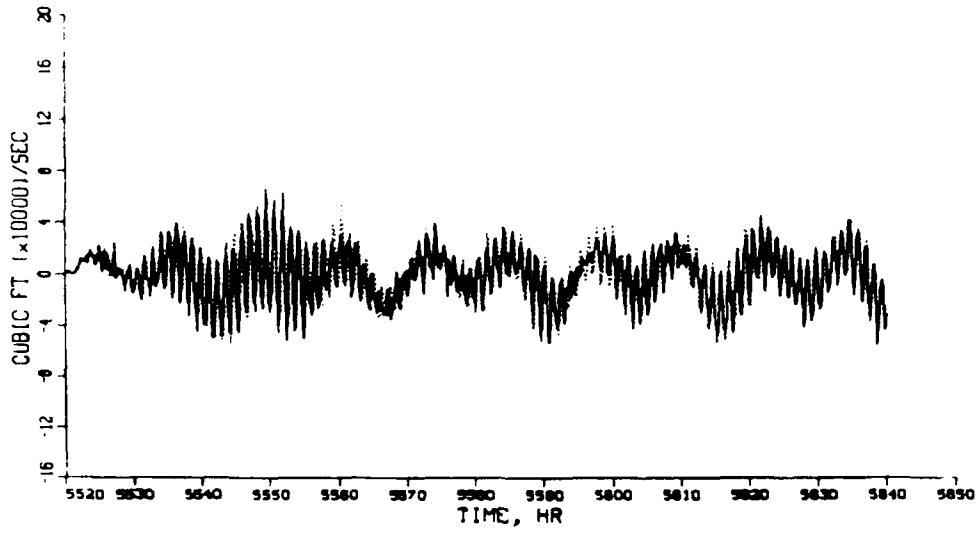
PLAN 4

TIDAL DISCHARGE VERIFICATION PERIOD

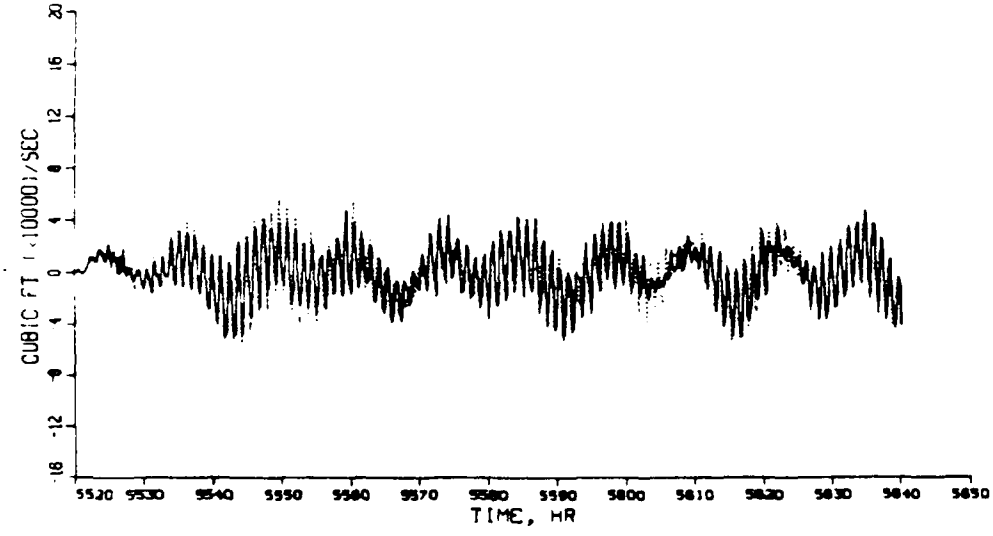
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 2

PLATE 188



PLAN 1



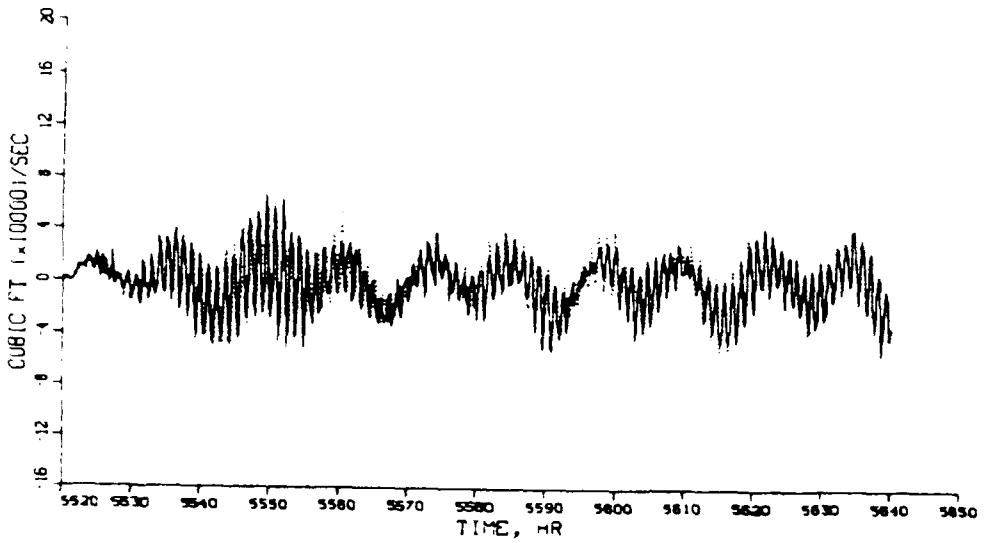
PLAN 2

TIDAL DISCHARGE **VERIFICATION PERIOD**

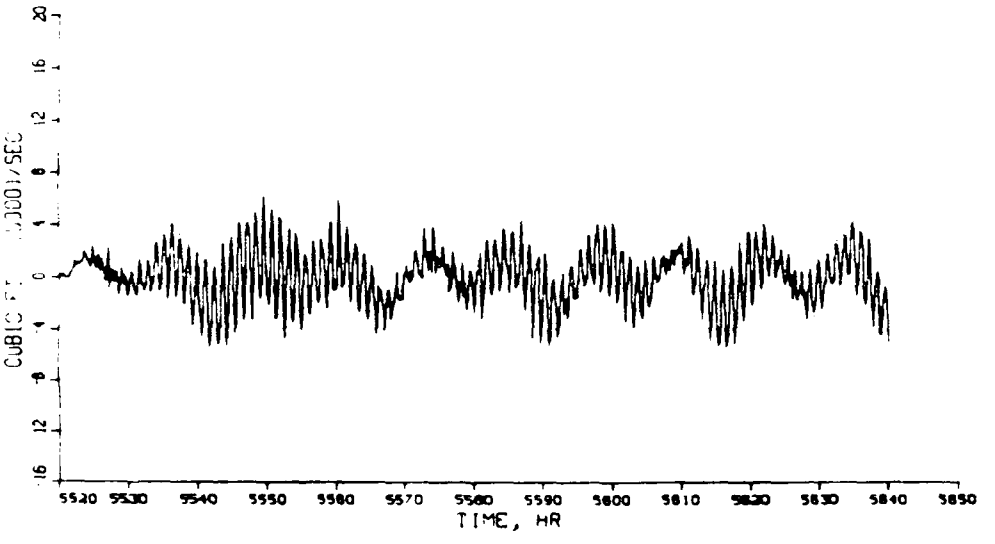
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 3

PLATE 189



PLAN 3



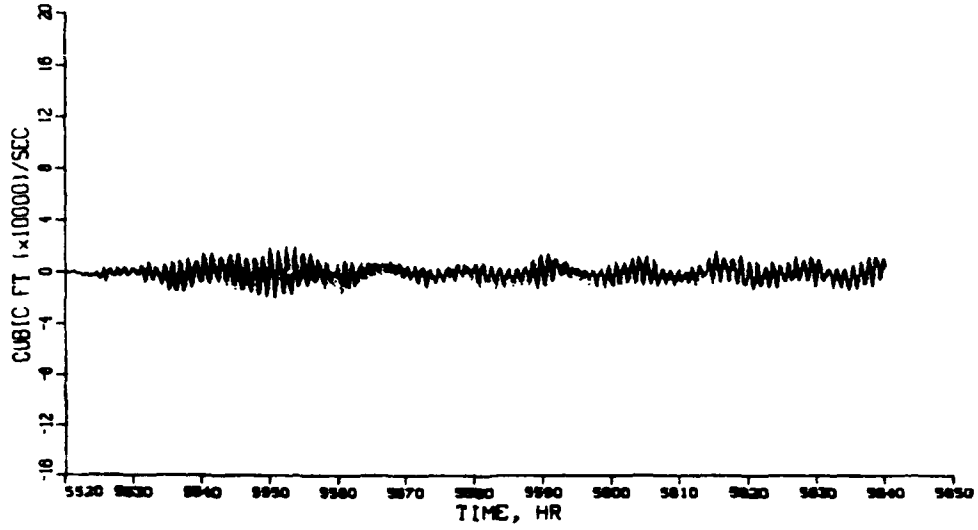
PLAN 4

TIDAL DISCHARGE VERIFICATION PERIOD

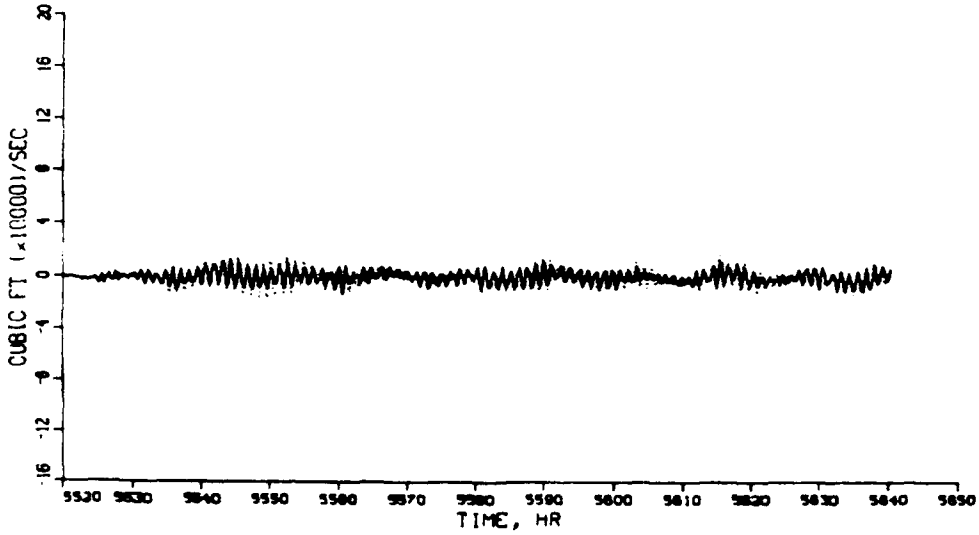
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 3

PLATE 190



PLAN 1



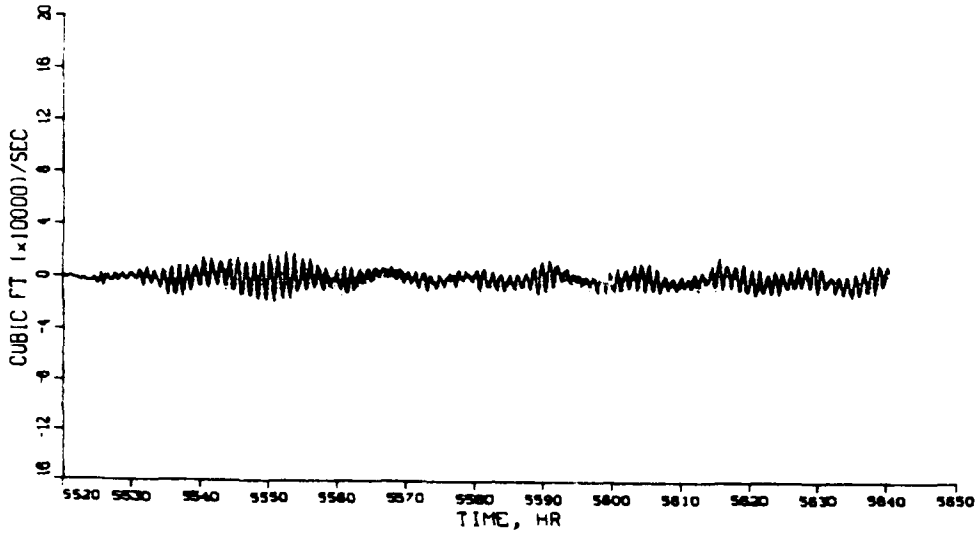
PLAN 2

TIDAL DISCHARGE VERIFICATION PERIOD

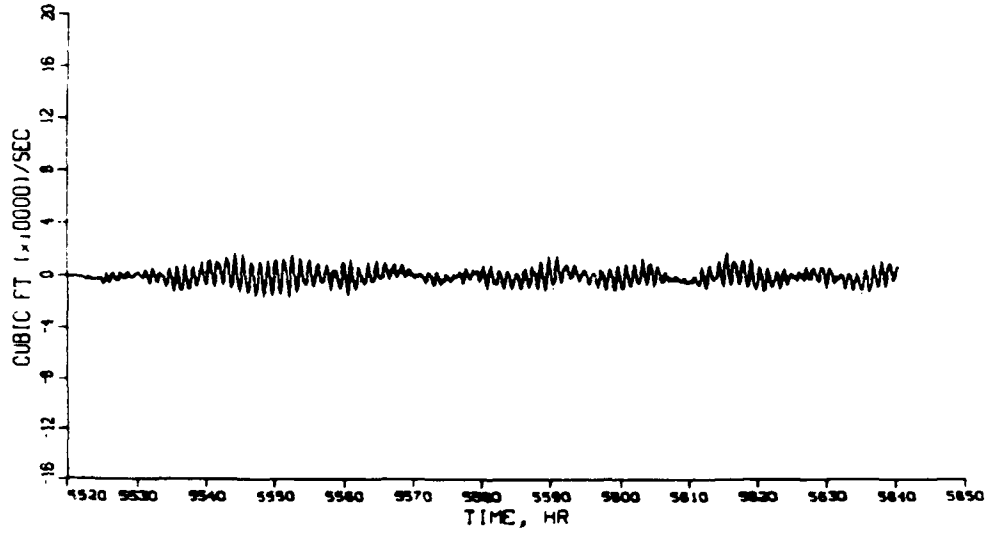
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 4

PLATE 191



PLAN 3



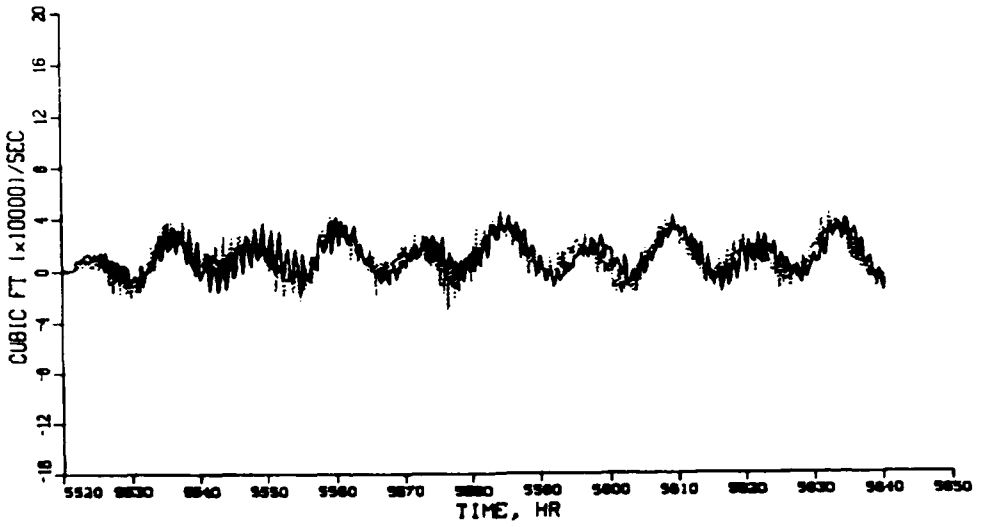
PLAN 4

TIDAL DISCHARGE VERIFICATION PERIOD

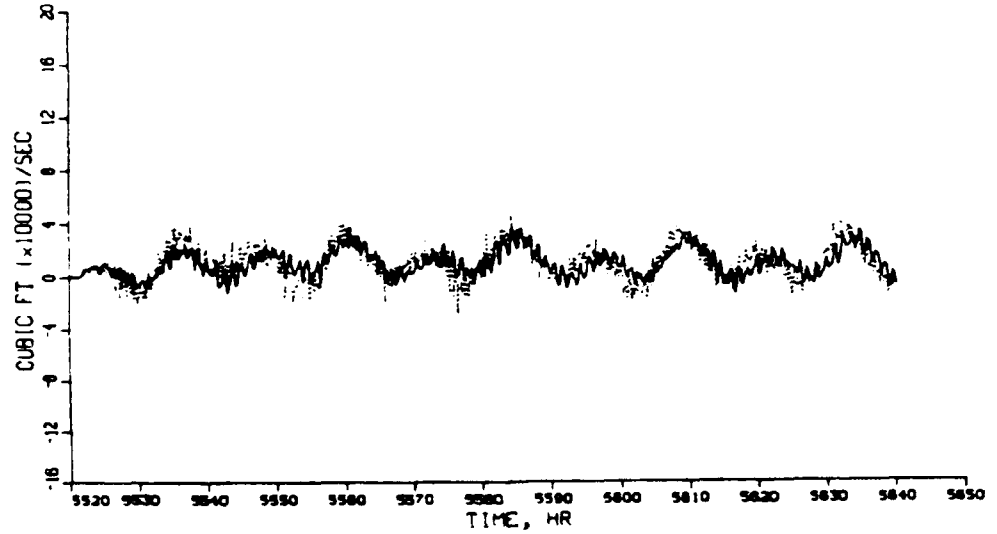
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 4

PLATE 192



PLAN 1



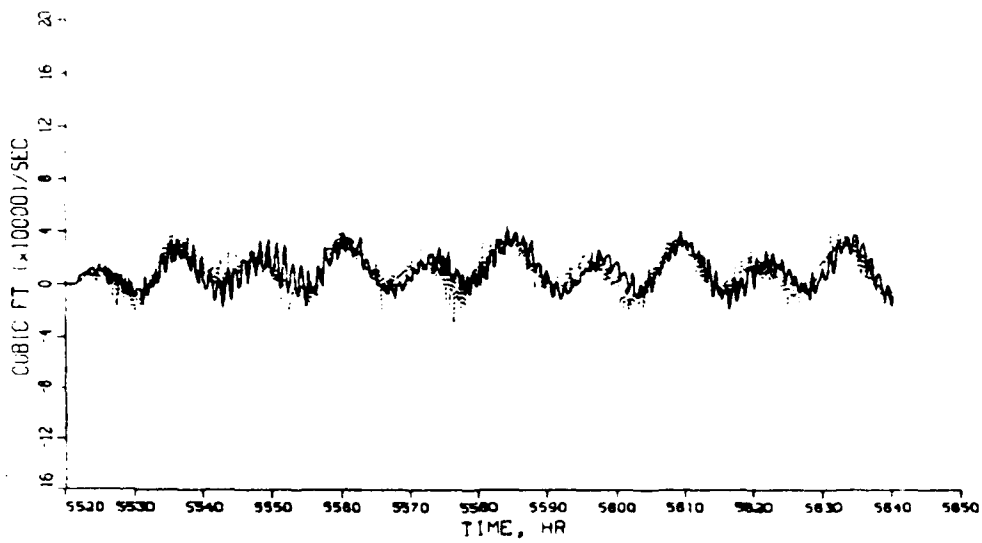
PLAN 2

TIDAL DISCHARGE VERIFICATION PERIOD

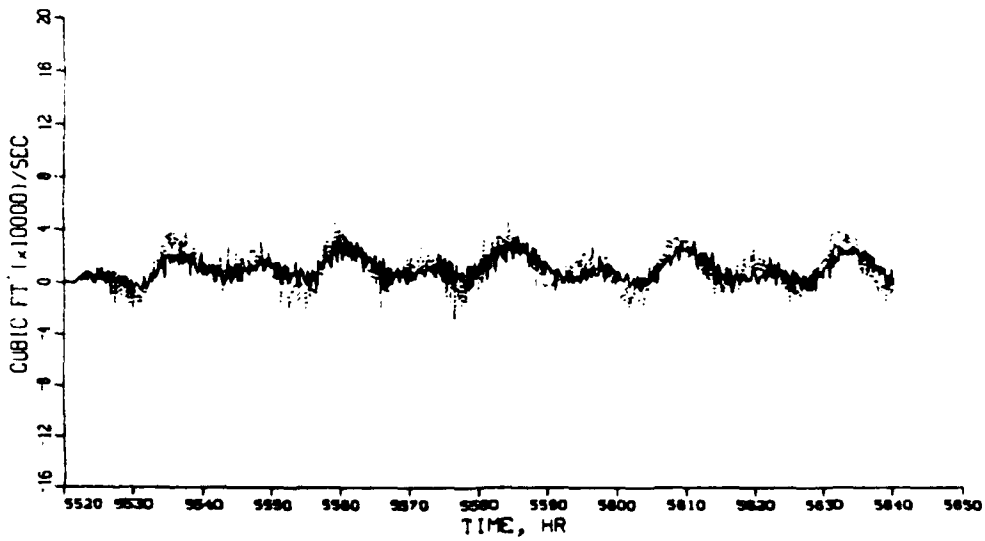
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 5

PLATE 193



PLAN 3



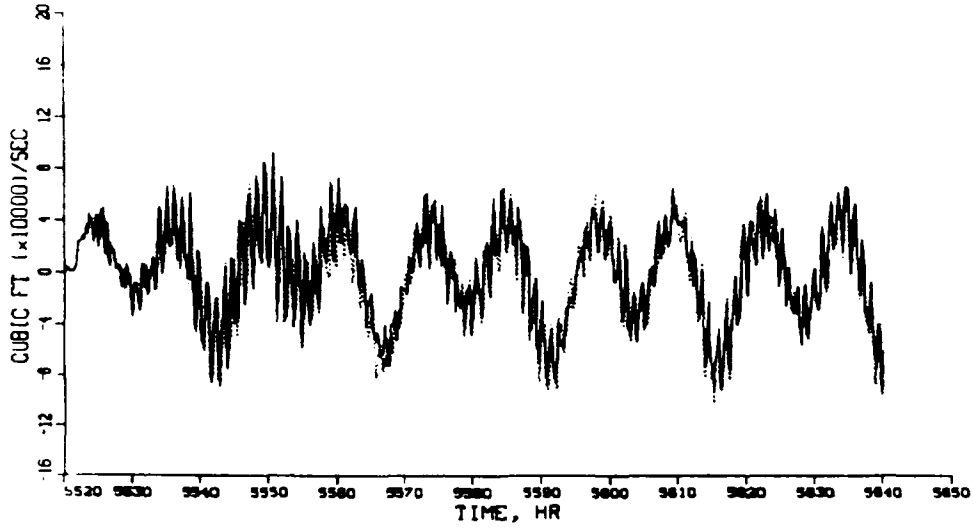
PLAN 4

TIDAL DISCHARGE VERIFICATION PERIOD

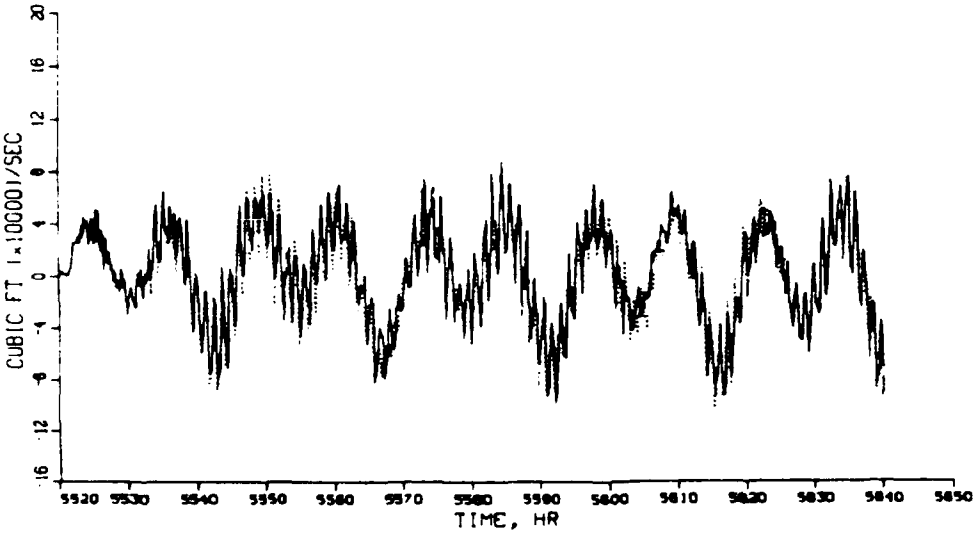
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 5

PLATE 194



PLAN 1



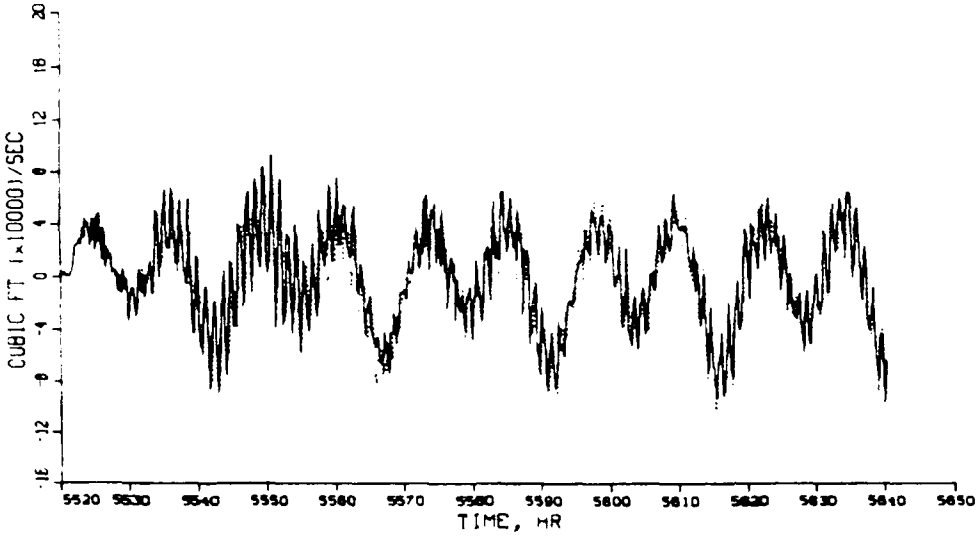
PLAN 2

TIDAL DISCHARGE VERIFICATION PERIOD

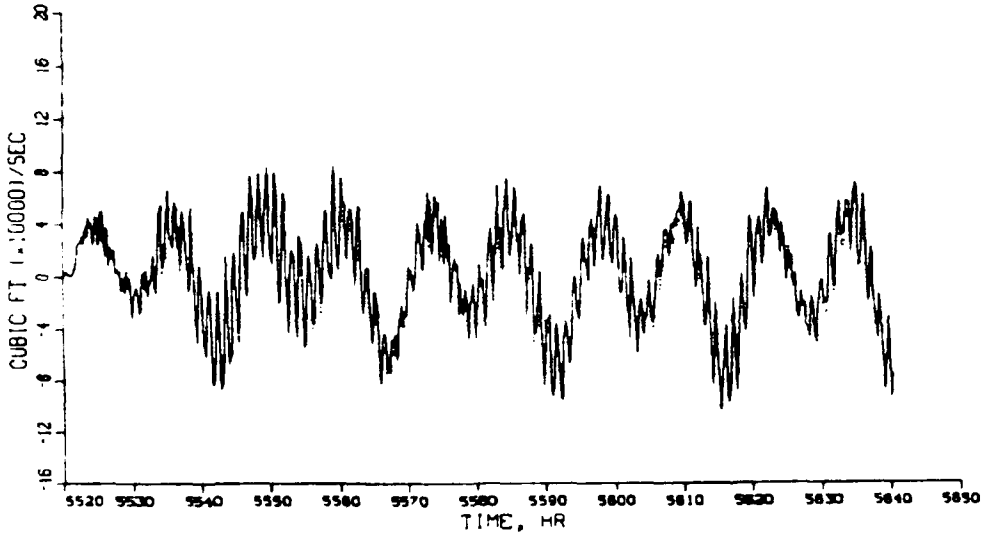
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 6

PLATE 195



PLAN 3



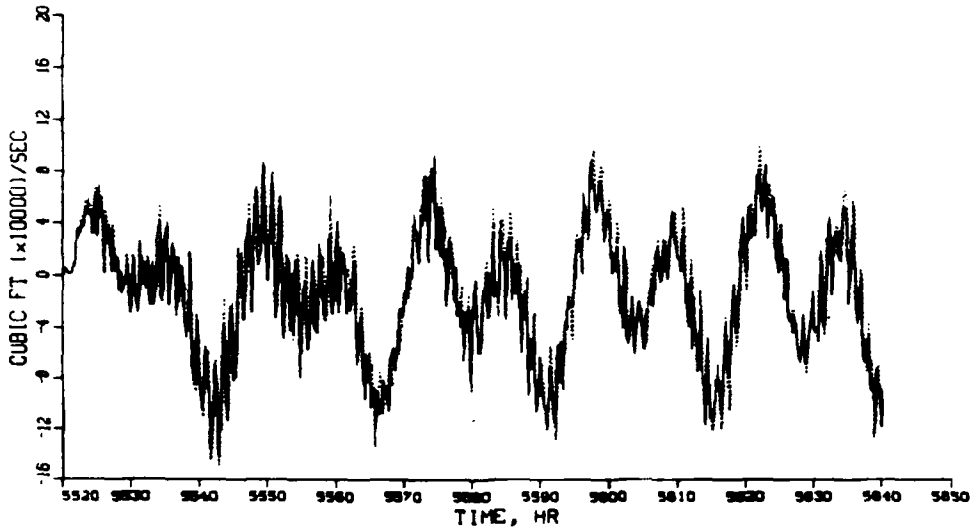
PLAN 4

TIDAL DISCHARGE VERIFICATION PERIOD

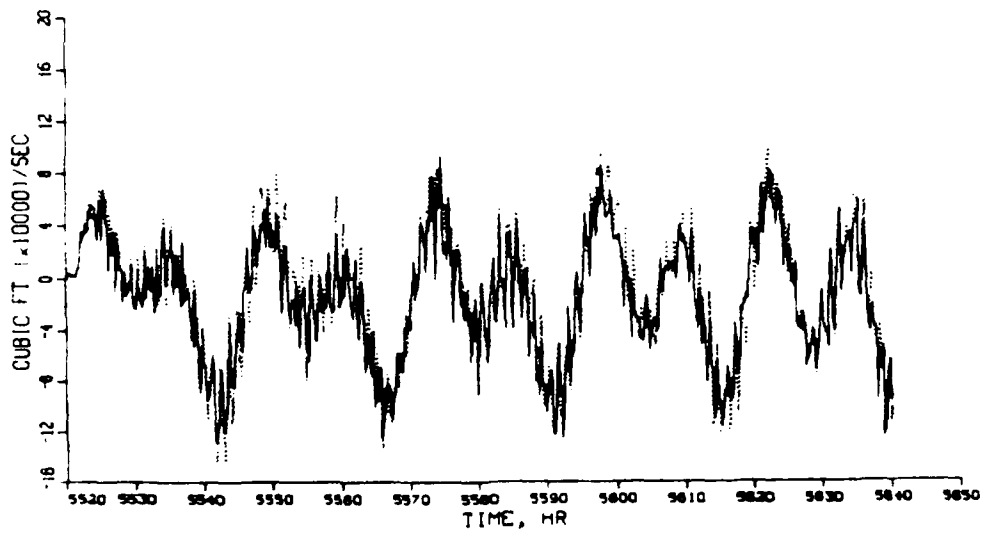
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 6

PLATE 196



PLAN 1



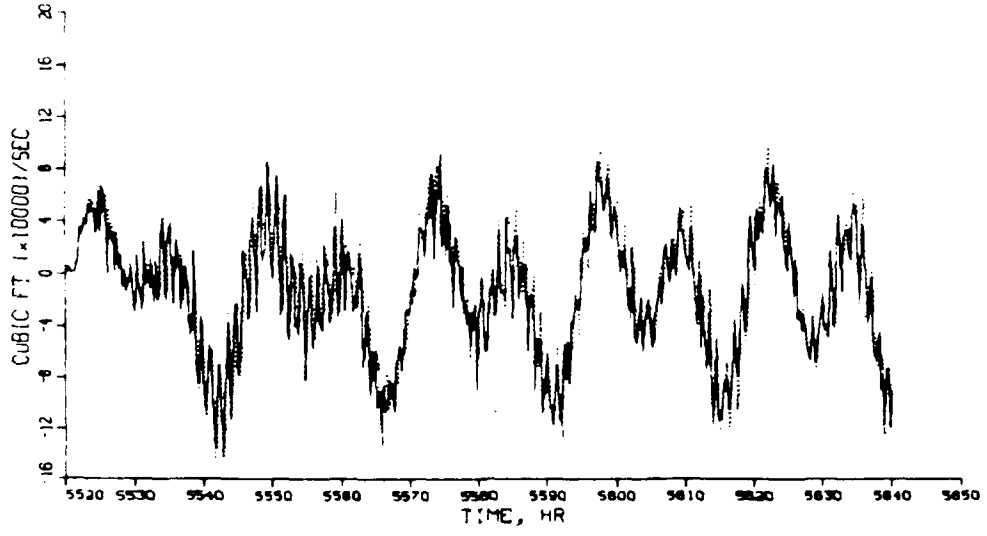
PLAN 2

TIDAL DISCHARGE **VERIFICATION PERIOD**

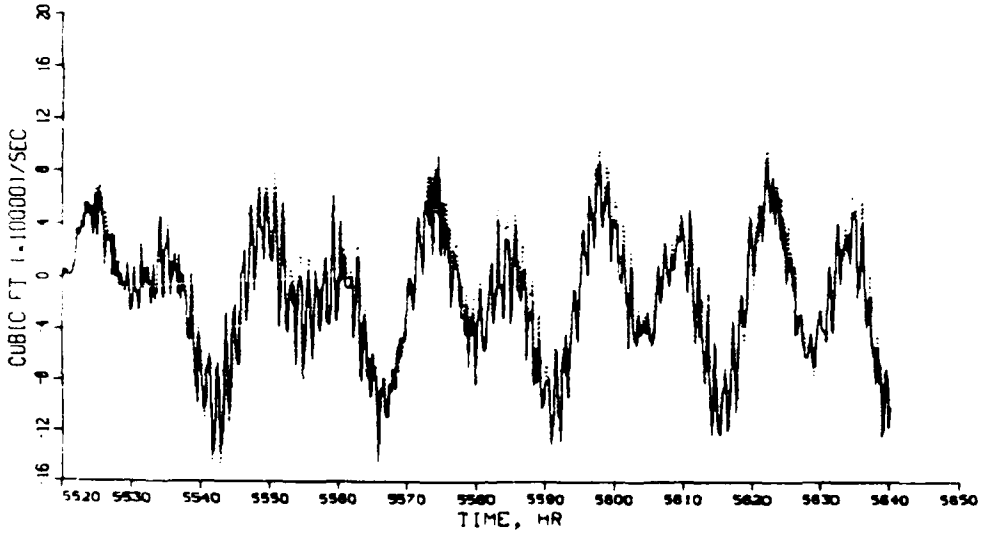
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 7

PLATE 197



PLAN 3



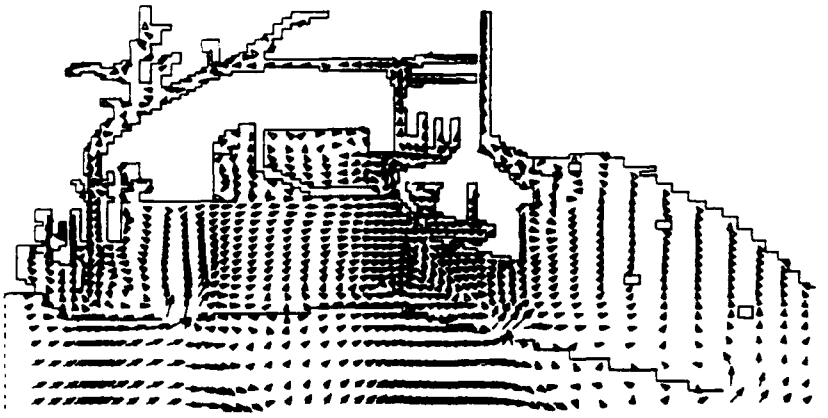
PLAN 4

TIDAL DISCHARGE VERIFICATION PERIOD

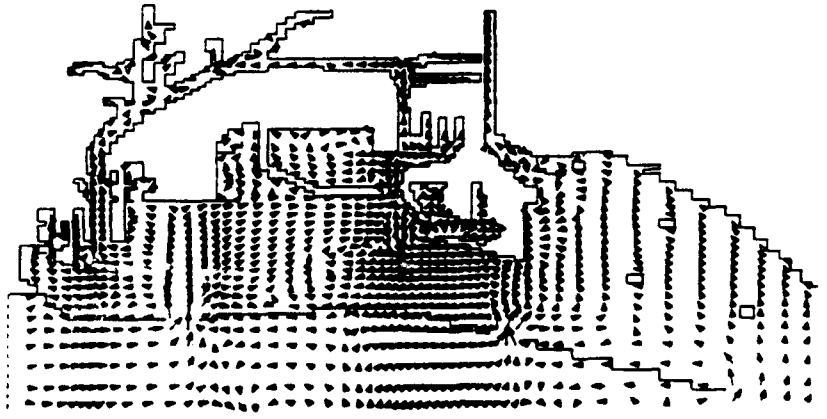
PLAN (SOLID) VS EXISTING (DOTTED) CONDITIONS

RANGE 7

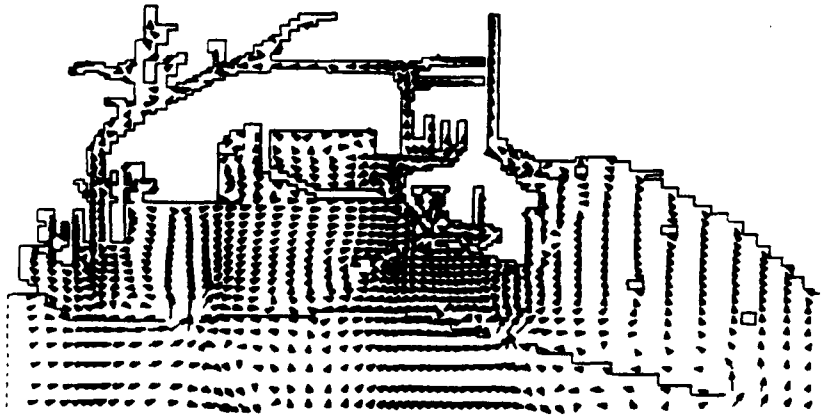
PLATE 198



SURFACE



MID-DEPTH



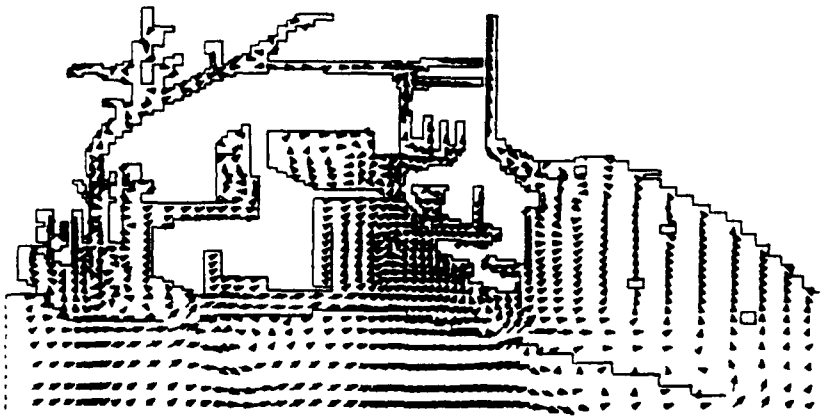
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

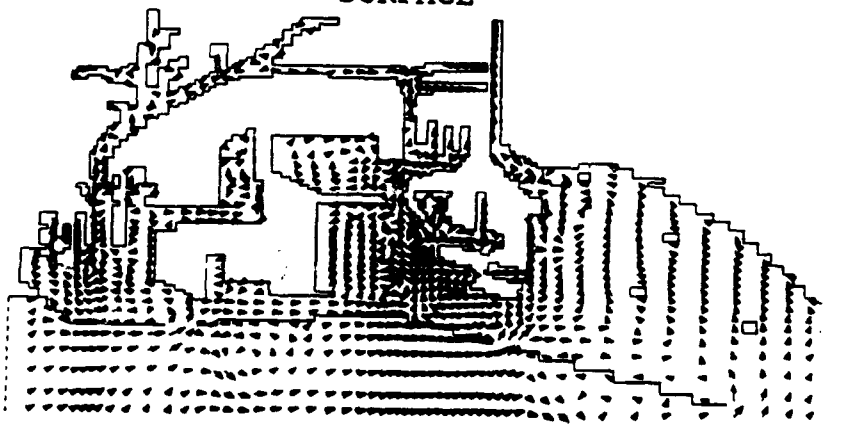
EXISTING CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

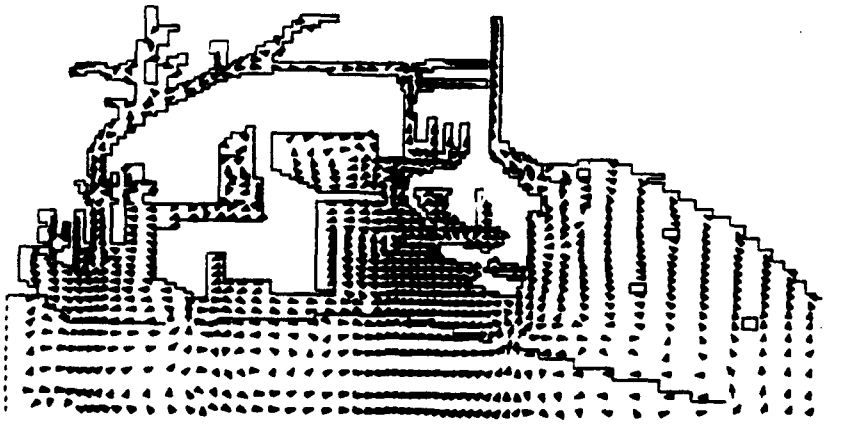
PLATE 199



SURFACE



MID-DEPTH



BOTTOM

CIRCULATION PATTERNS

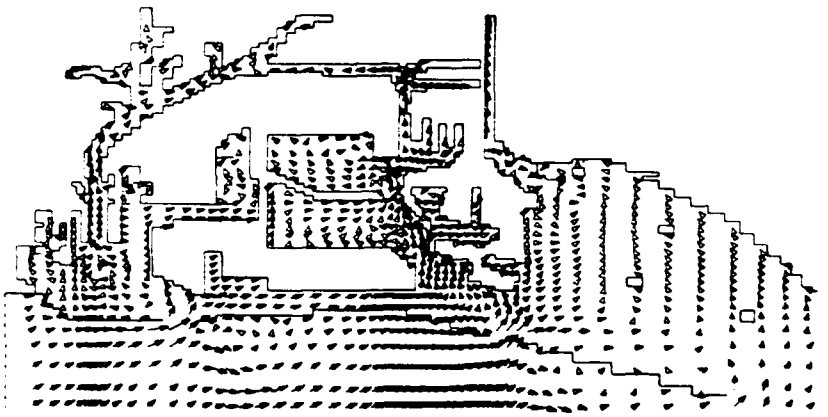
CALIBRATION PERIOD

PLAN 1 CONDITIONS

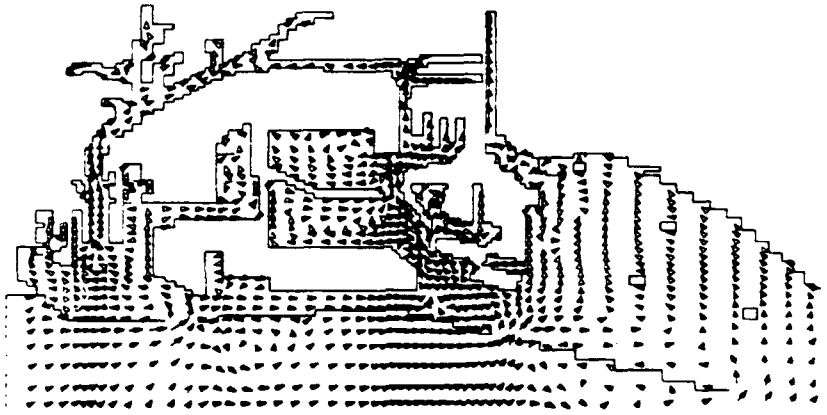
PEAK FLOOD

⟶ 1 FT/SEC

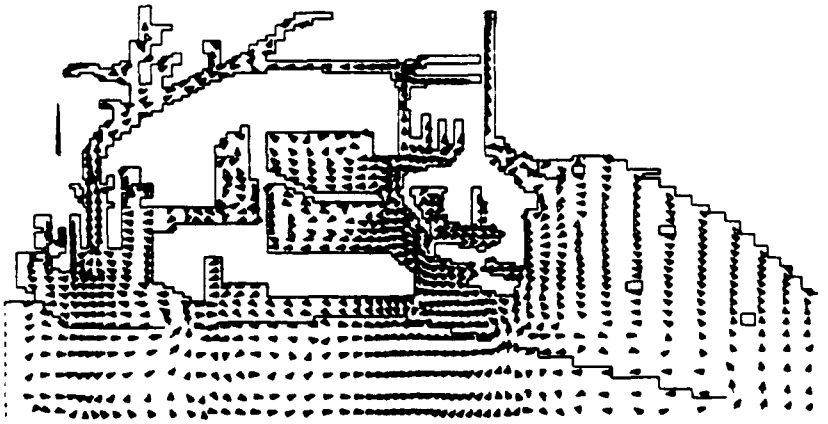
PLATE 200



SURFACE



MID-DEPTH



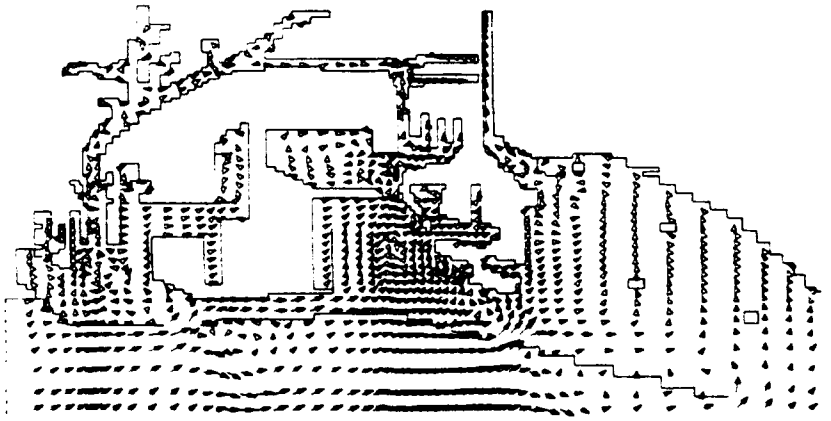
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

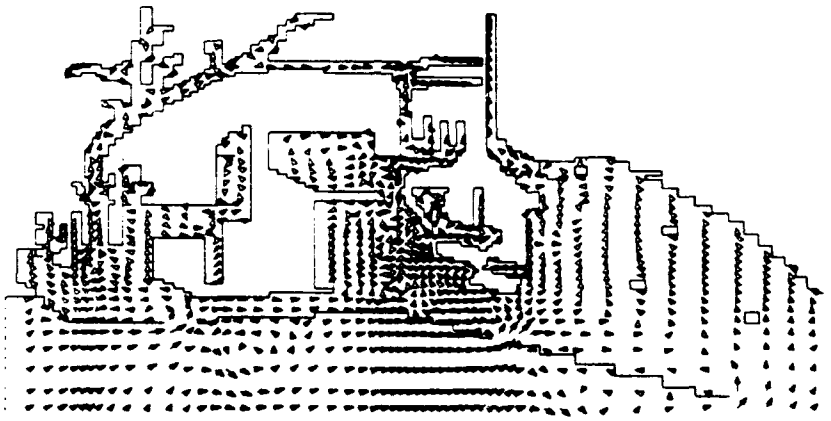
PLAN 2 CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

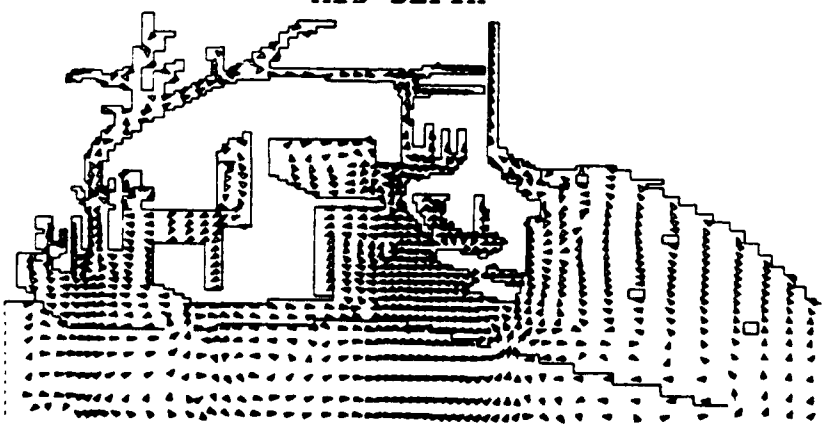
PLATE 201



SURFACE



MID-DEPTH



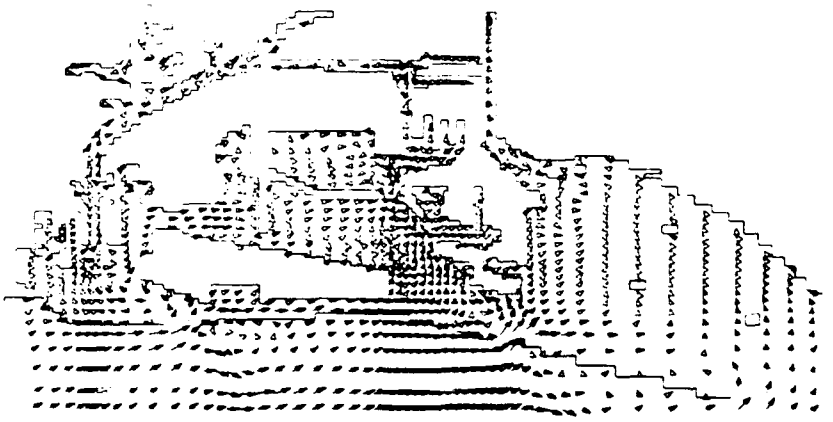
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

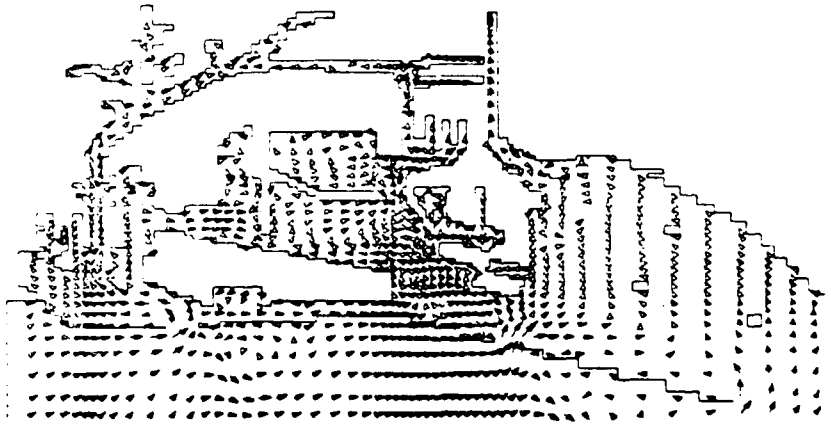
PLAN 3 CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

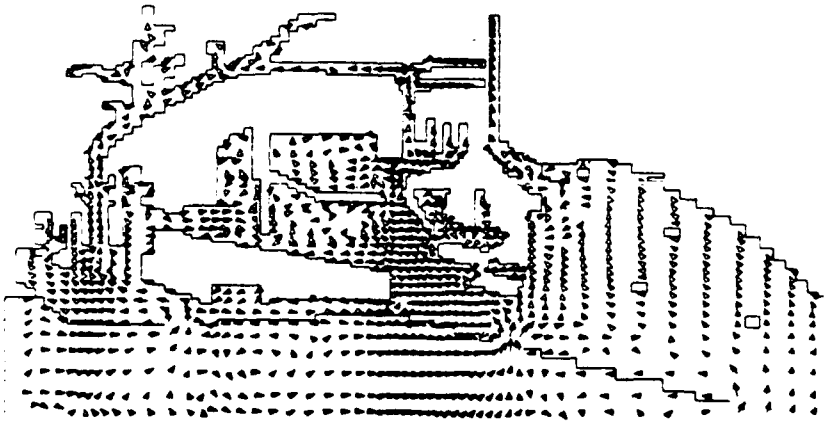
PLATE 202



SURFACE



MID-DEPTH



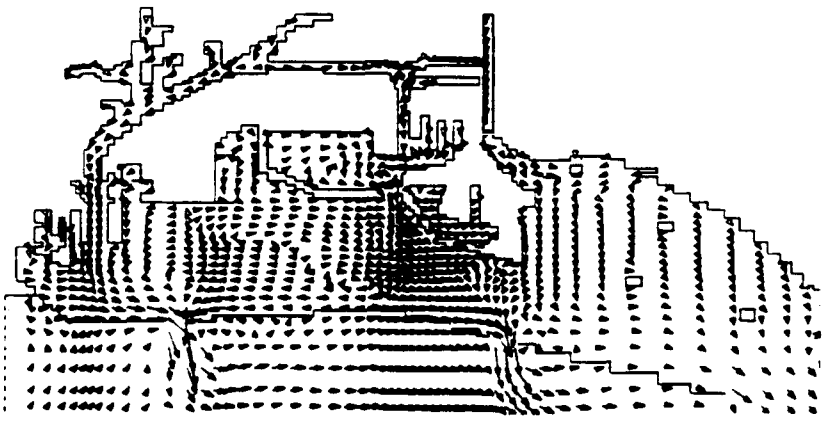
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

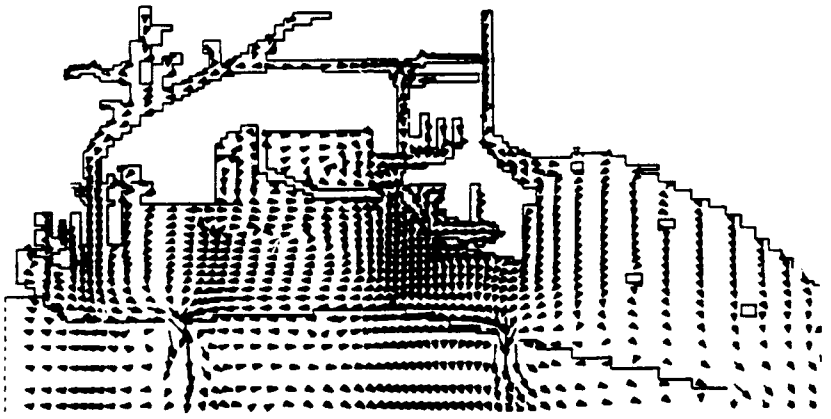
PLAN 4 CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

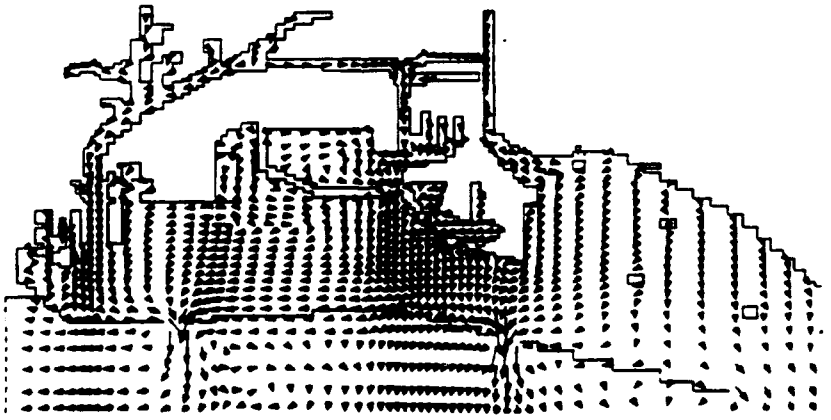
PLATE 203



SURFACE



MID-DEPTH



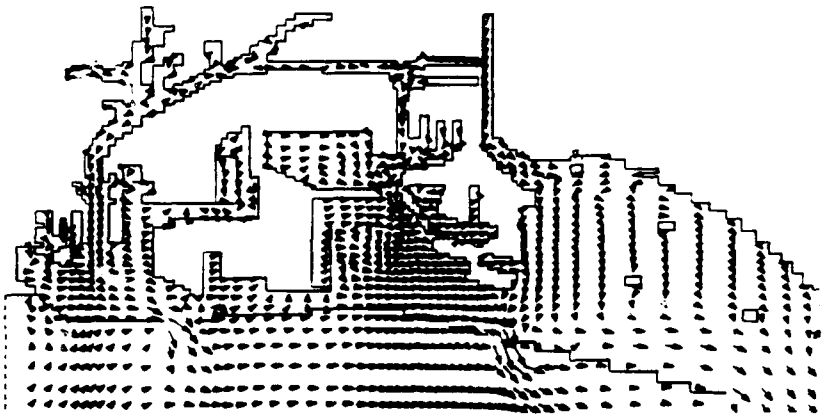
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

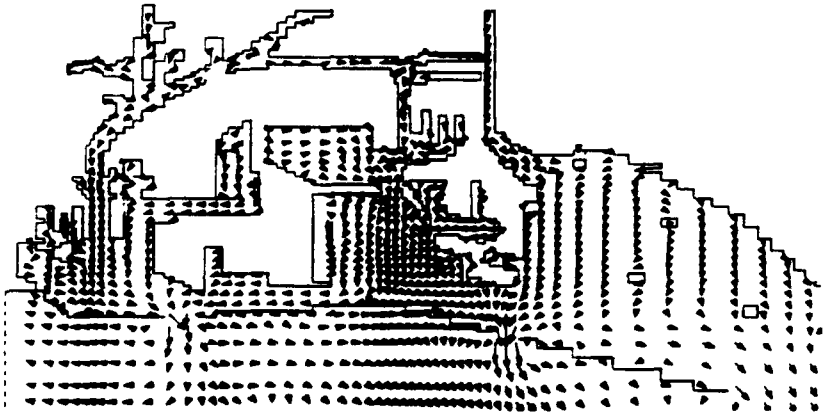
EXISTING CONDITIONS PEAK EBB

⟶ 1 FT/SEC

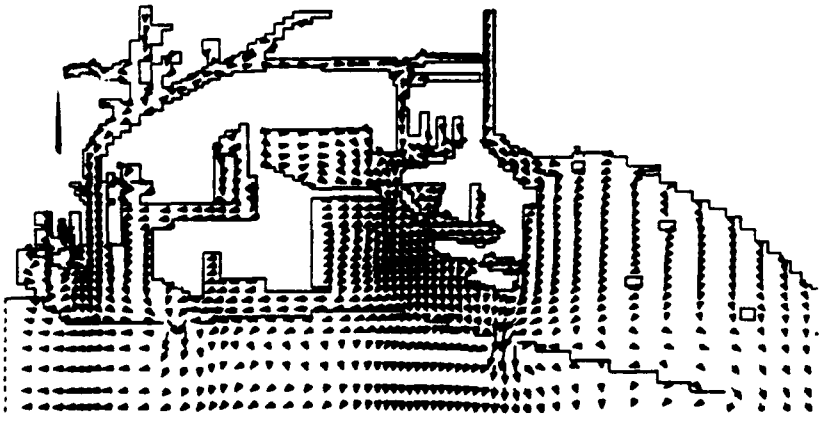
PLATE 204



SURFACE



MID-DEPTH



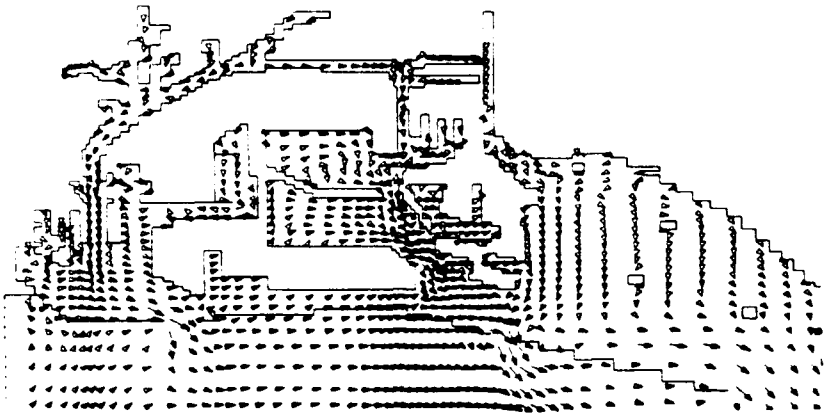
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

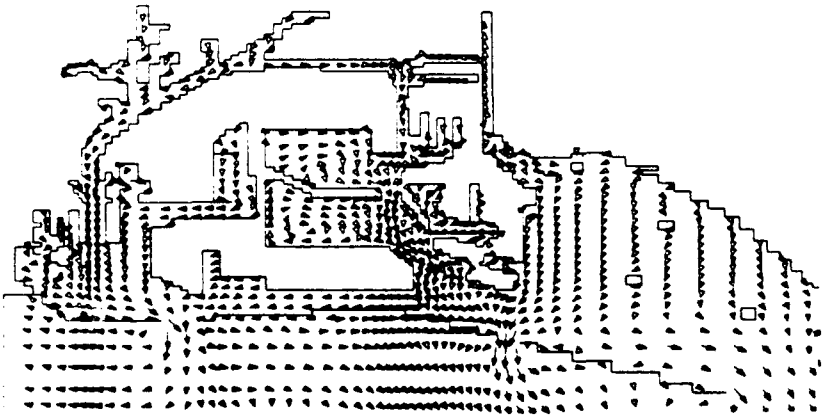
PLAN 1 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

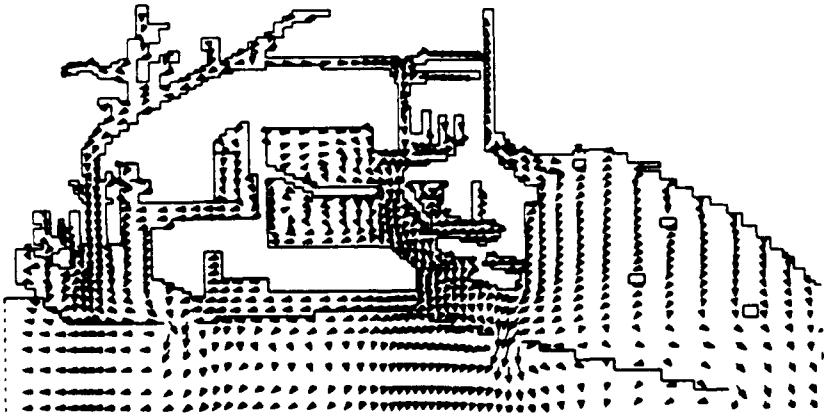
PLATE 205



SURFACE



MID-DEPTH



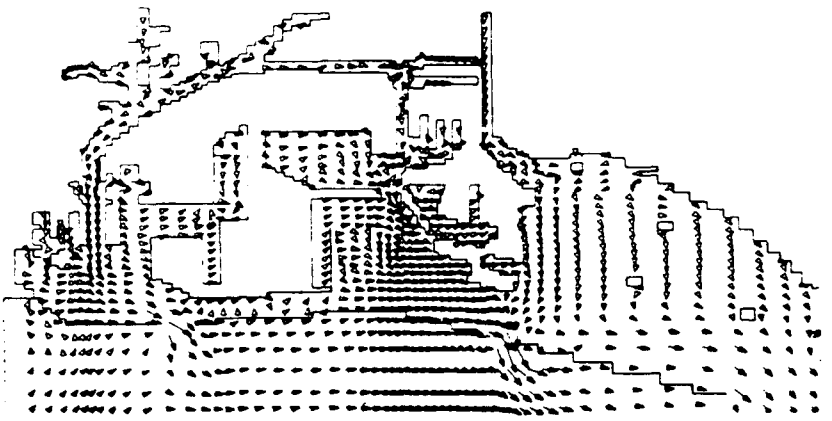
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

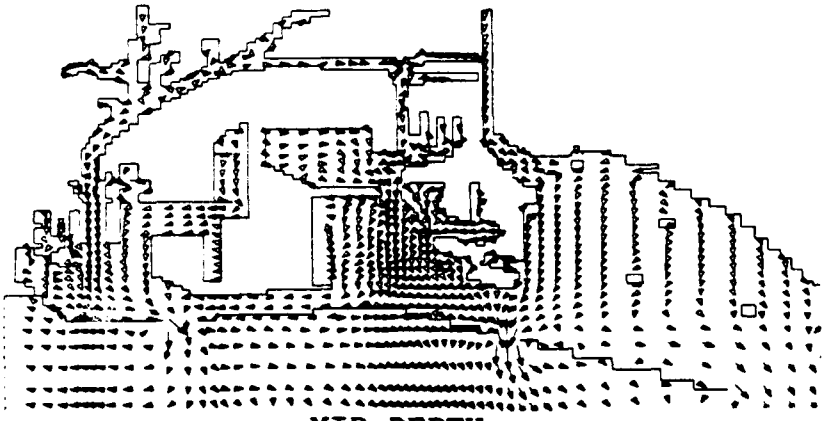
PLAN 2 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

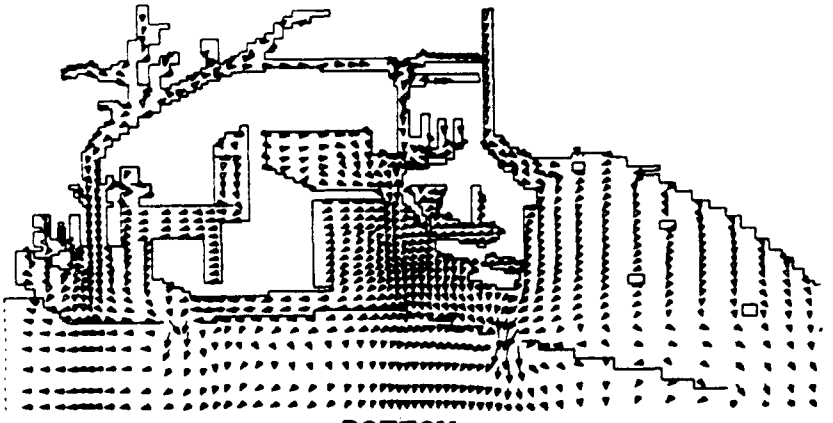
PLATE 206



SURFACE



MID-DEPTH



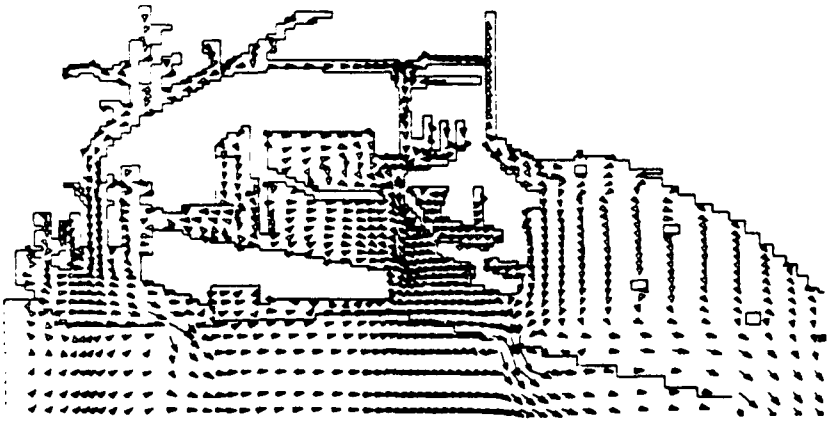
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

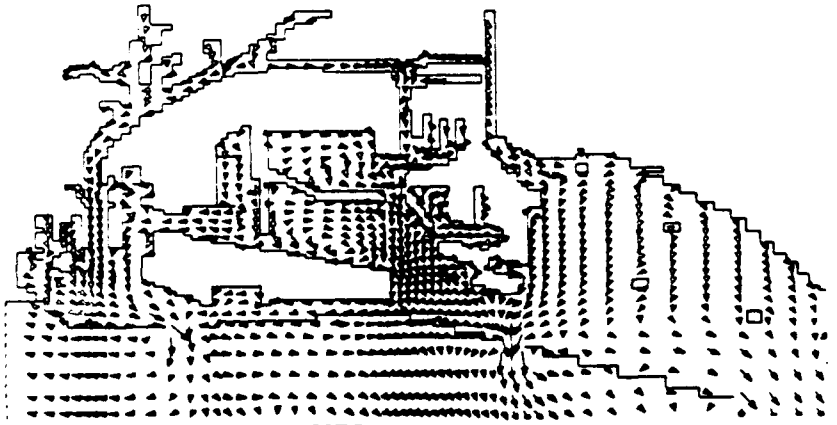
PLAN 3 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

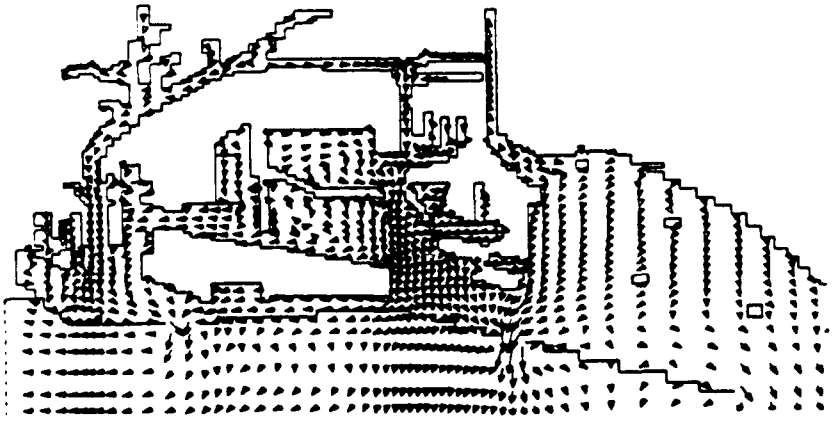
PLATE 207



SURFACE



MID-DEPTH



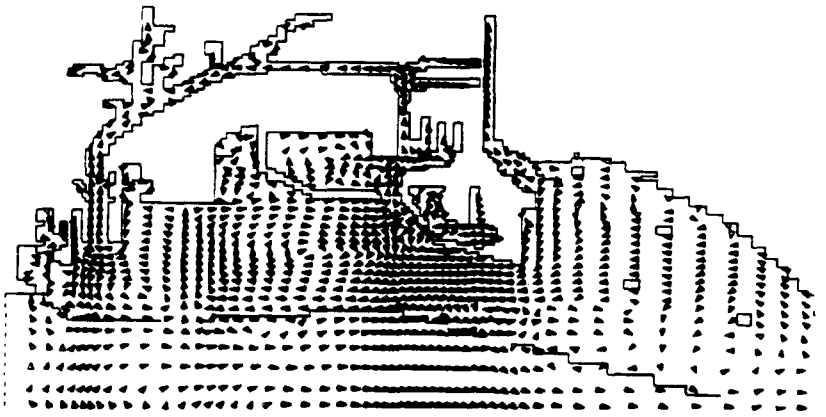
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

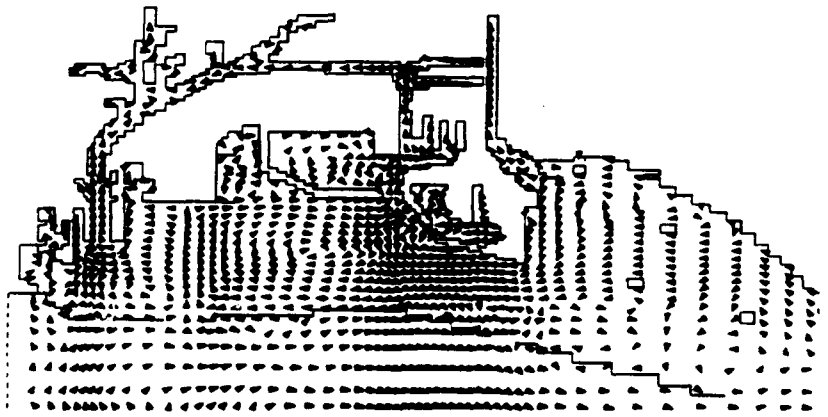
PLAN 4 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

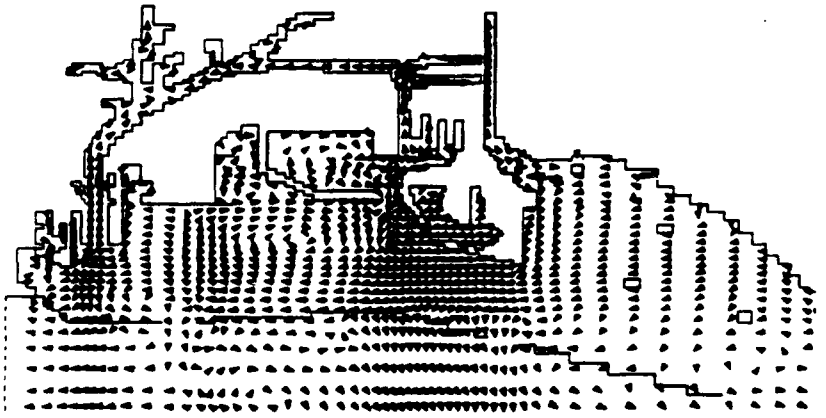
PLATE 208



SURFACE



MID-DEPTH



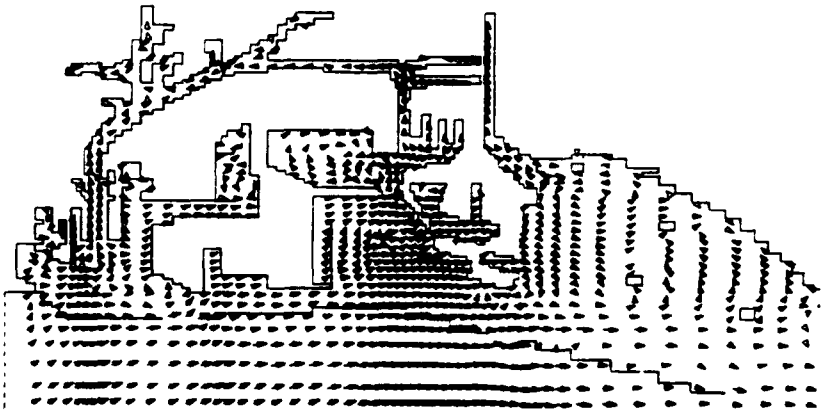
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

EXISTING CONDITIONS SLACK WATER

⟶ 1 FT/SEC

PLATE 209



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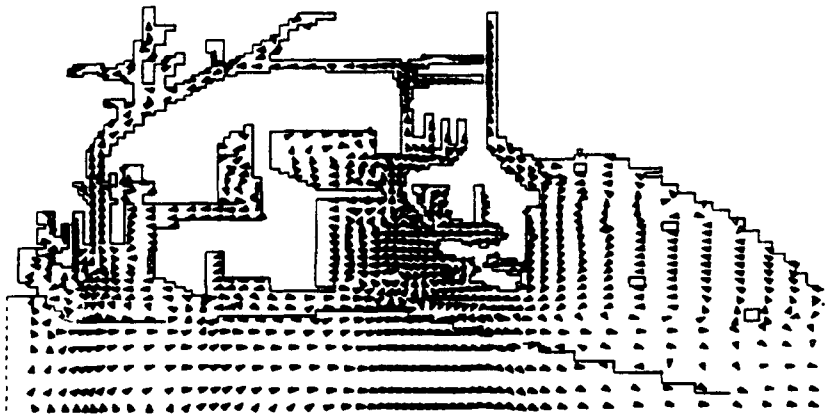
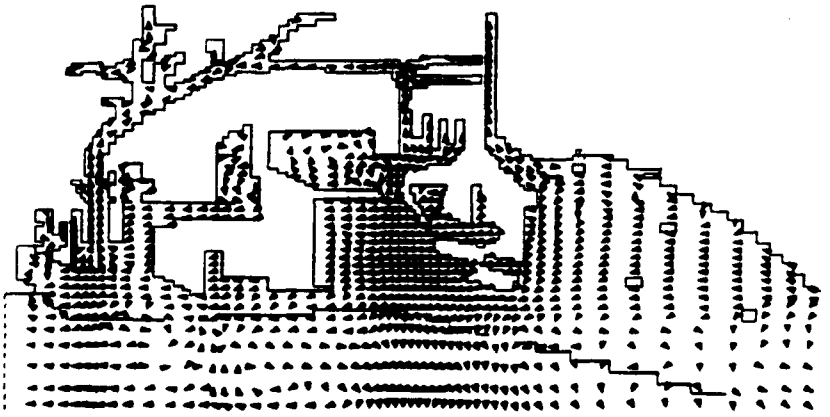


MID-DEPTH



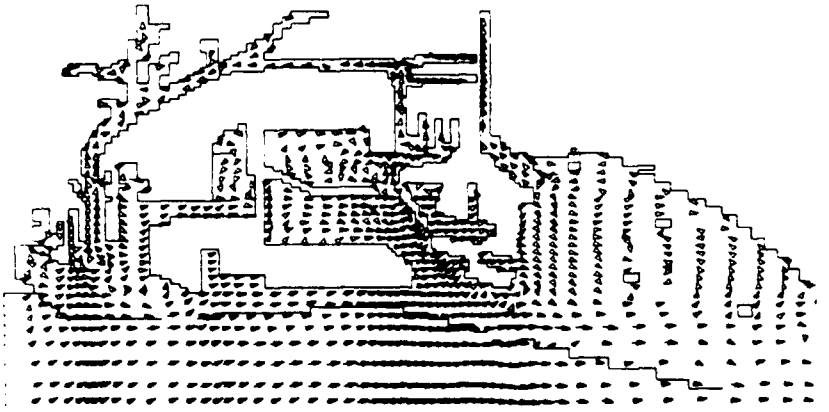
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

PLAN 1 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

PLATE 210



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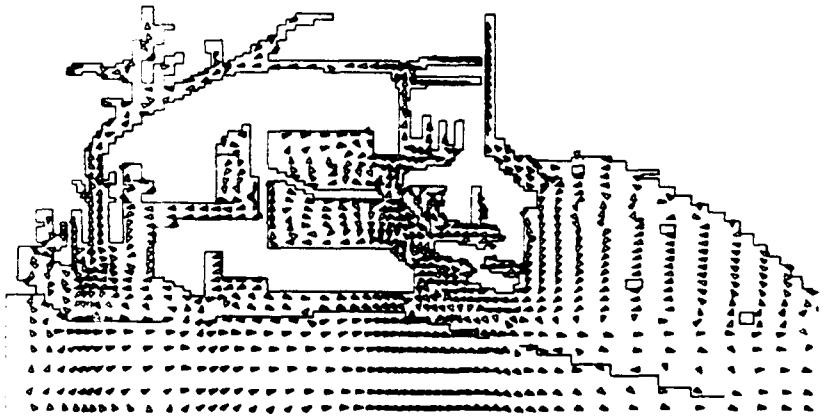

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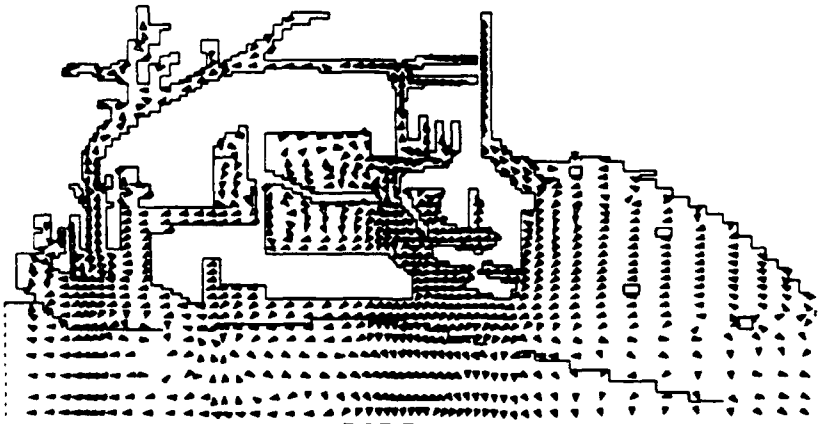


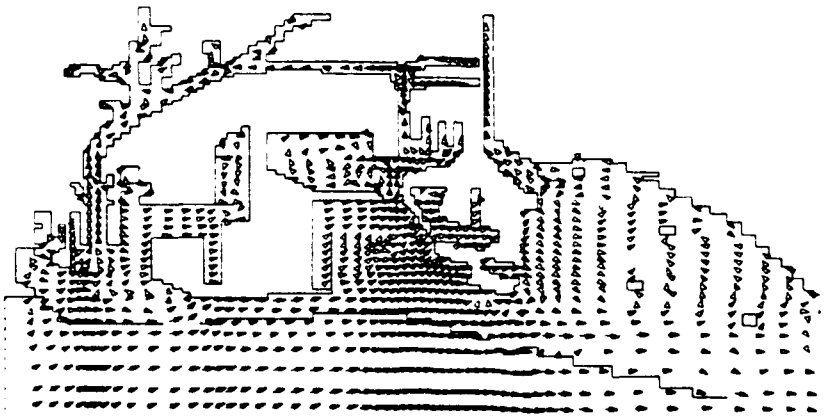
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

PLAN 2 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

PLATE 211



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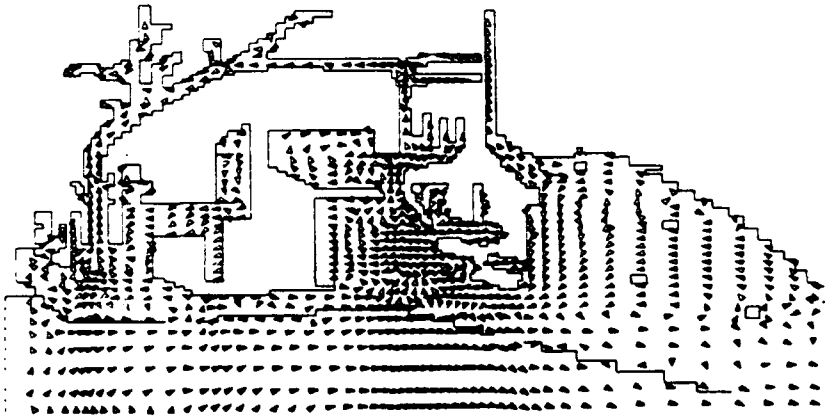

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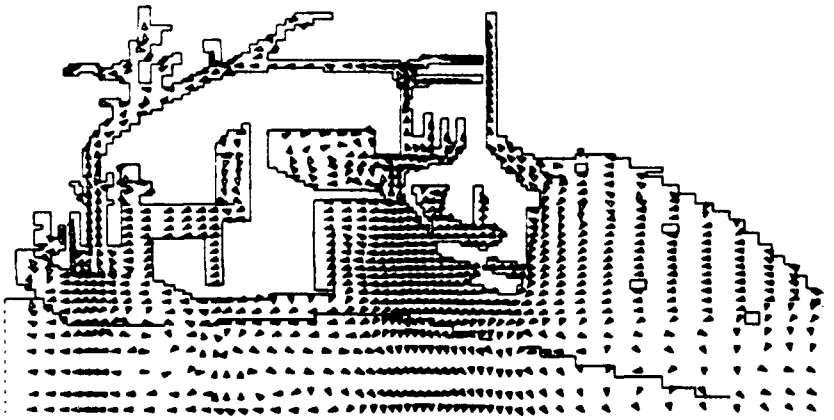


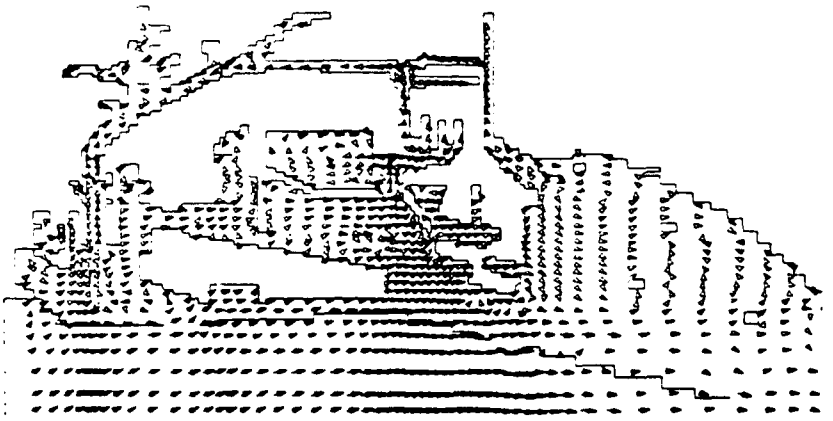
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

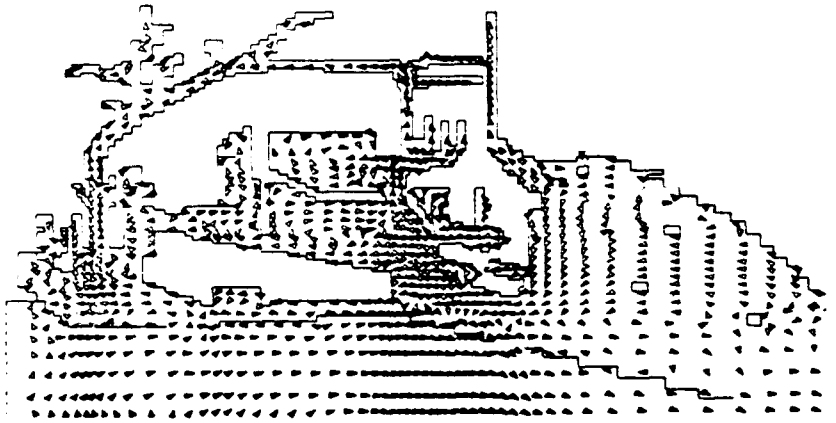
PLAN 3 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

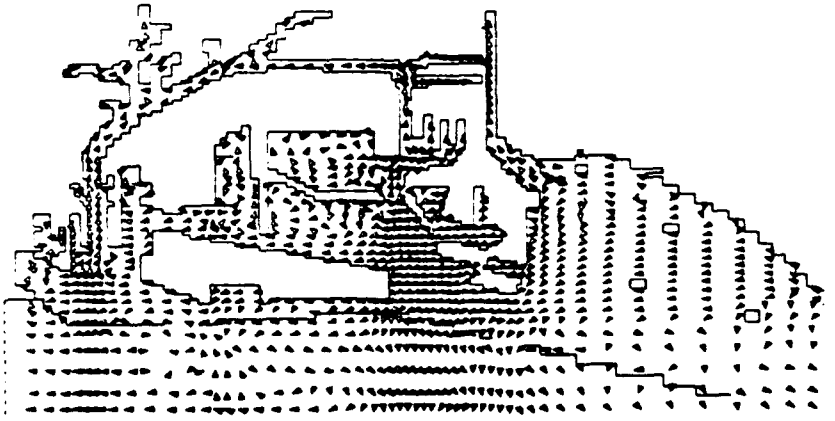
PLATE 212



SURFACE



MID-DEPTH



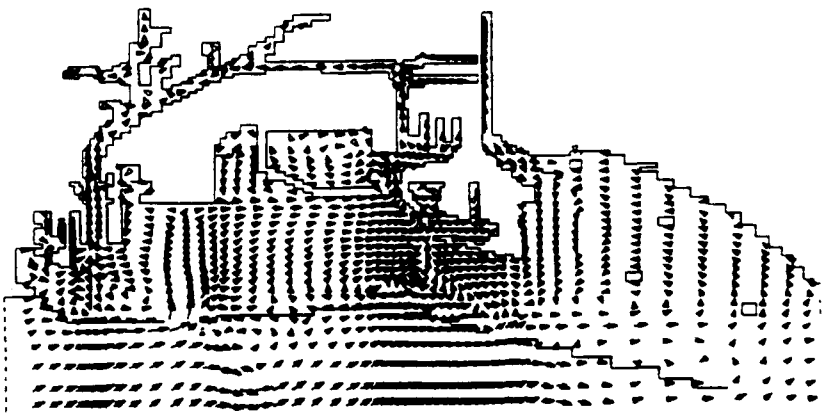
BOTTOM

CIRCULATION PATTERNS CALIBRATION PERIOD

PLAN 4 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

PLATE 213



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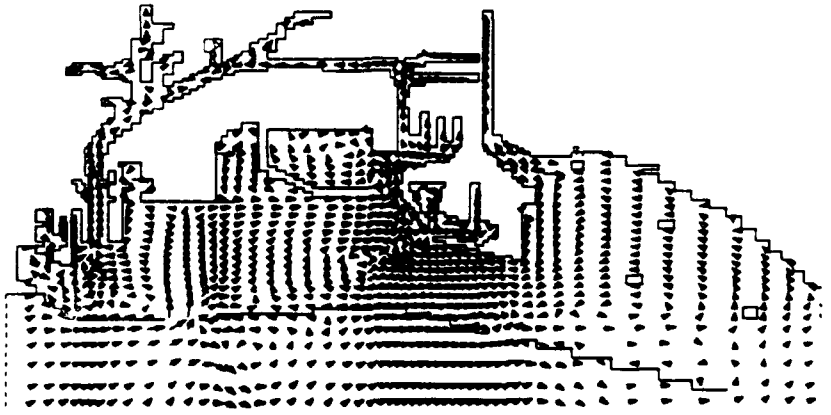
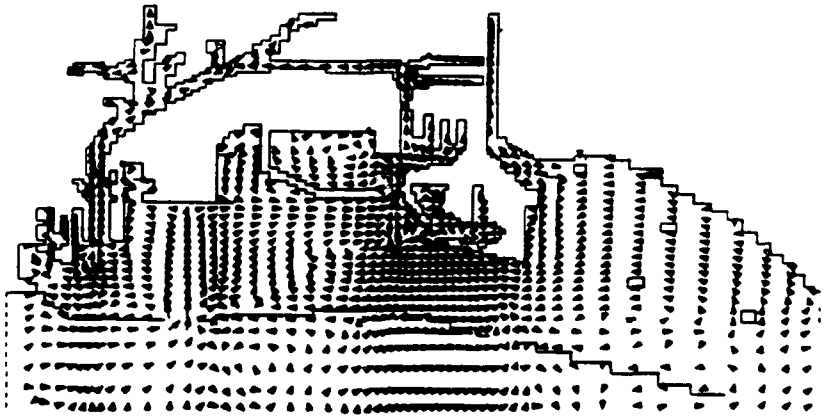


MID-DEPTH



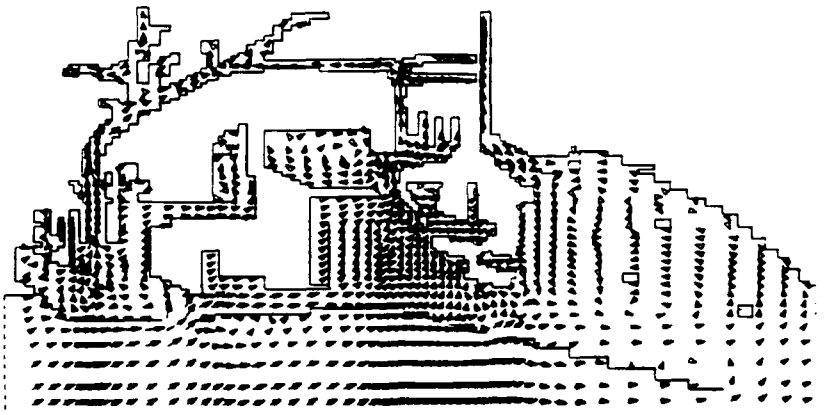
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

EXISTING CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

PLATE 214



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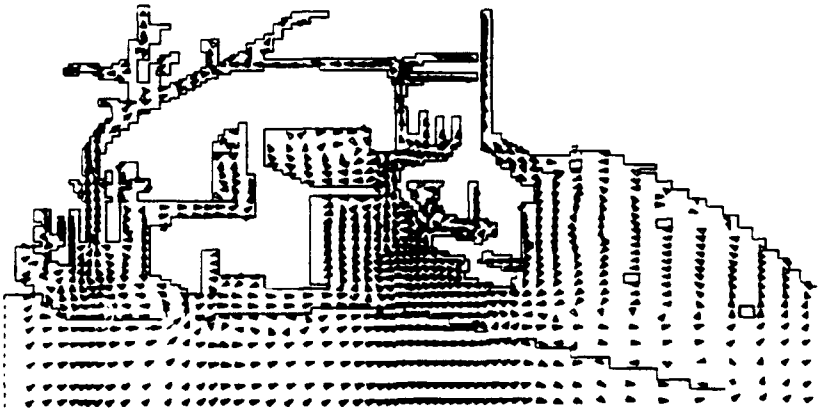
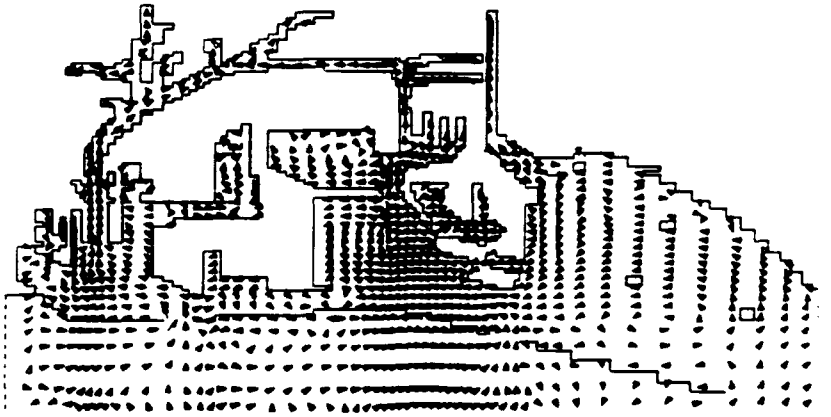


MID-DEPTH



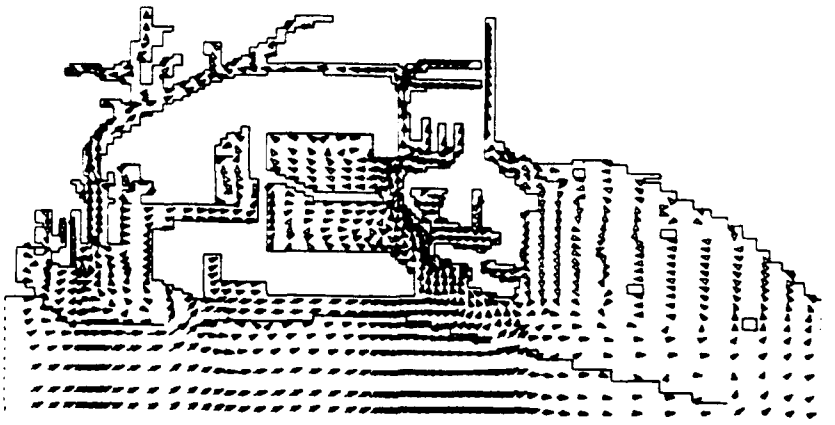
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

PLAN 1 CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

PLATE 215



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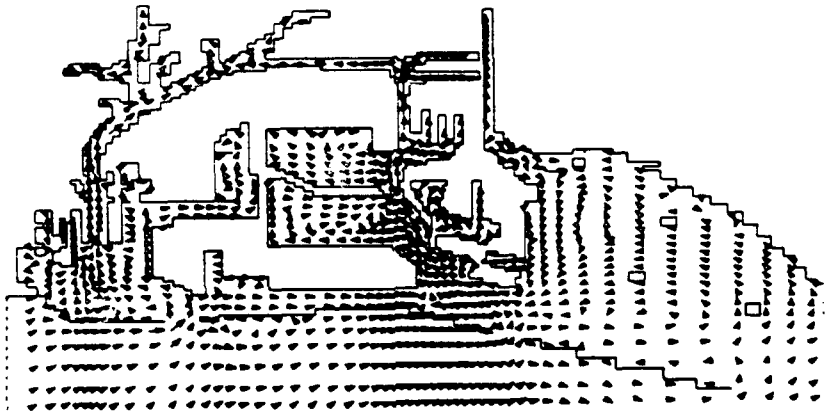

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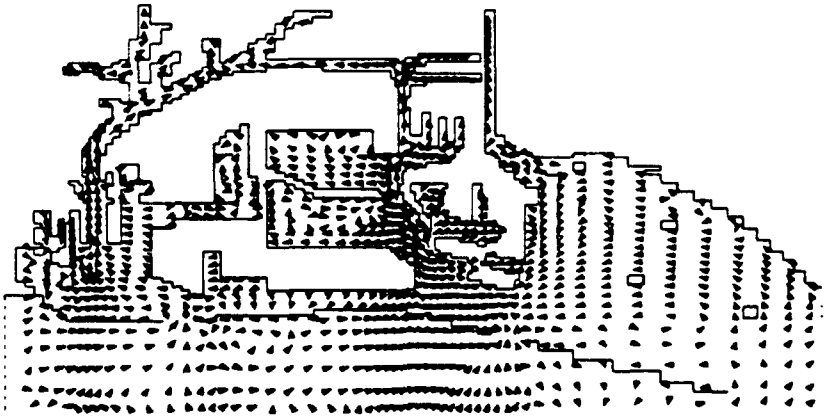


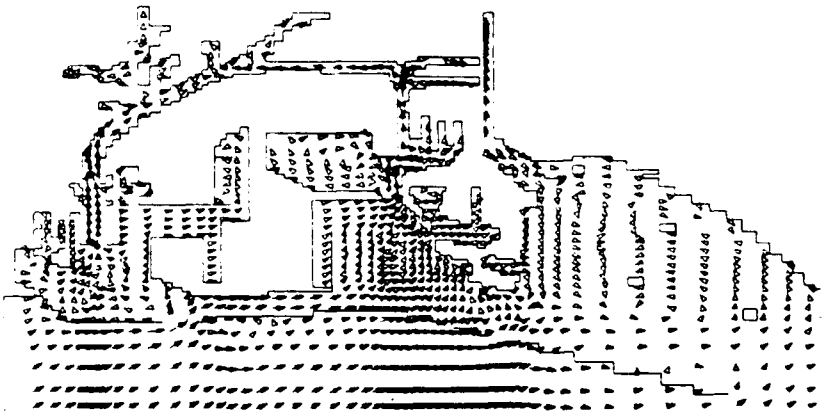
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

PLAN 2 CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

PLATE 216



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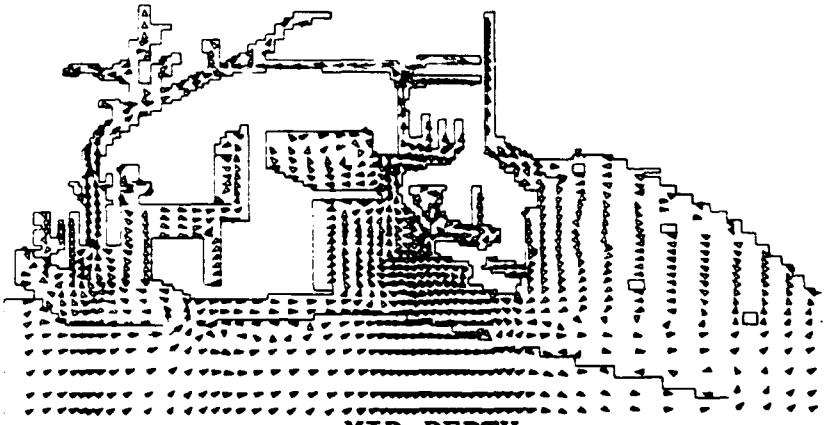
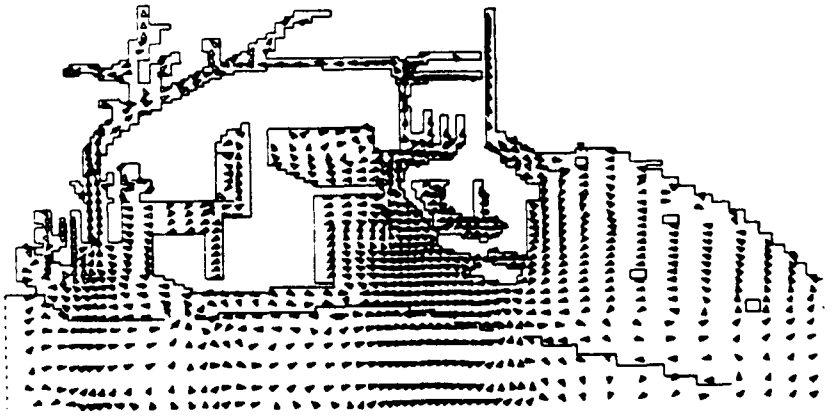


MID-DEPTH



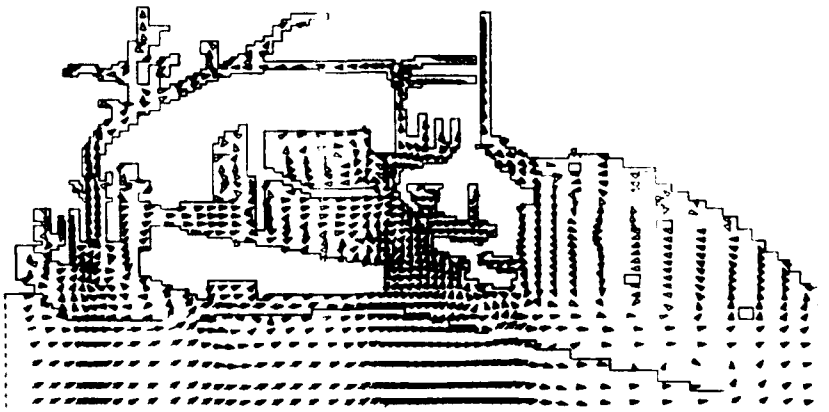
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

PLAN 3 CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

PLATE 217



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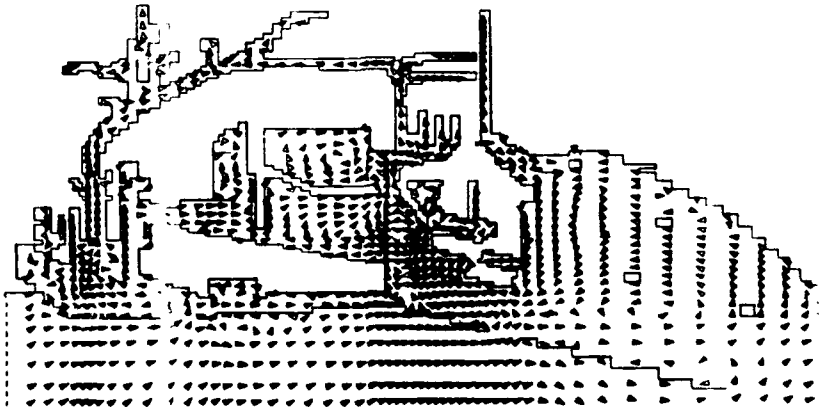

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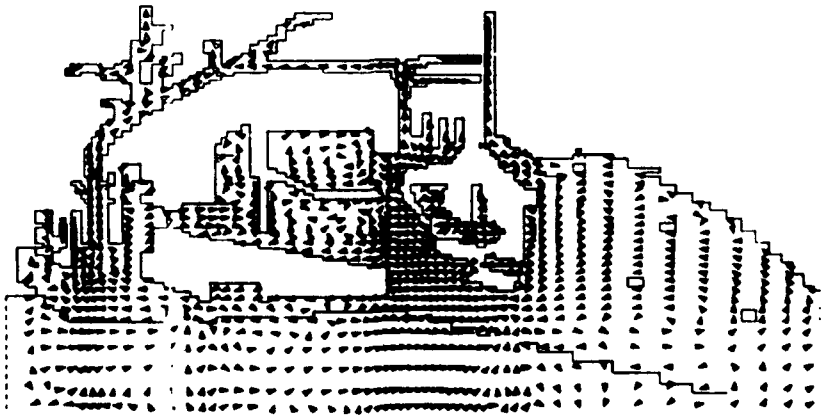


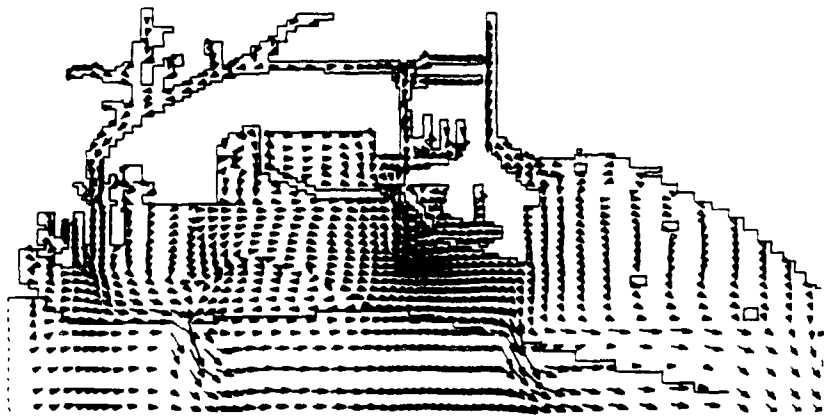
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

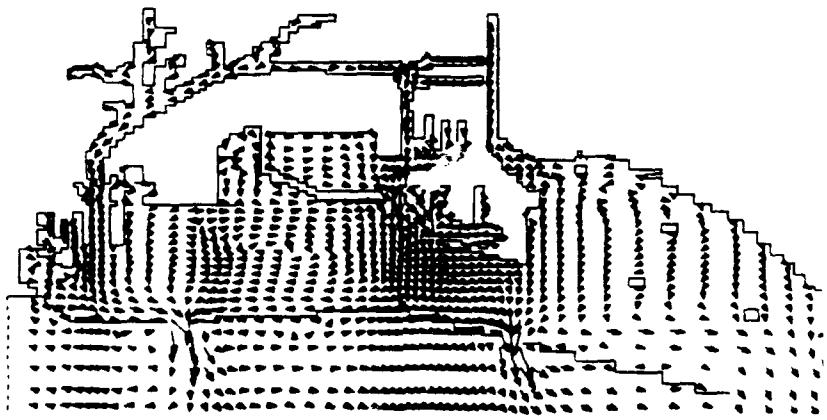
PLAN 4 CONDITIONS PEAK FLOOD

⟶ 1 FT/SEC

PLATE 218



SURFACE



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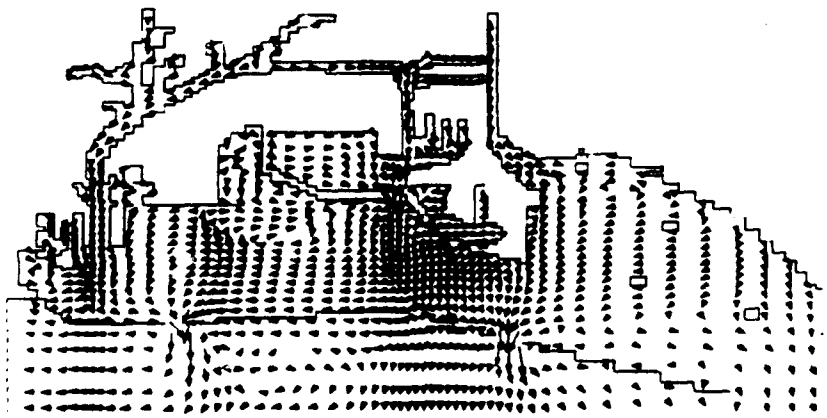


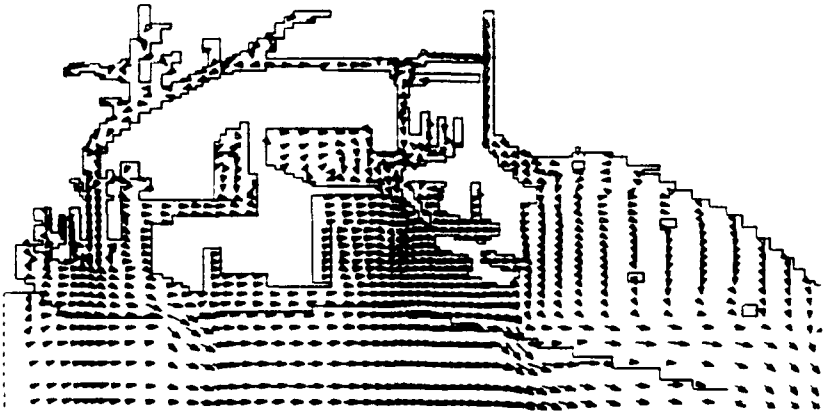
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

EXISTING CONDITIONS PEAK EBB

⟶ 1 FT/SEC

PLATE 219



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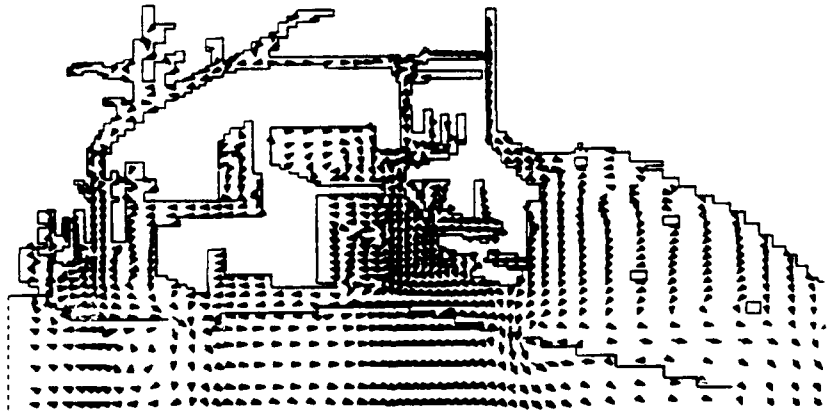
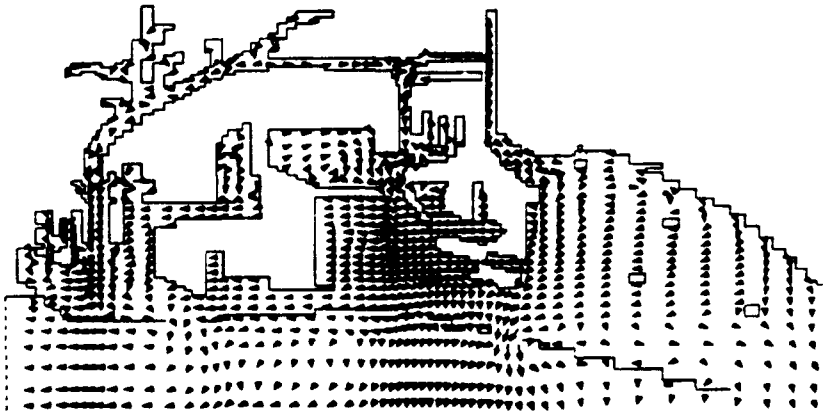


MID-DEPTH



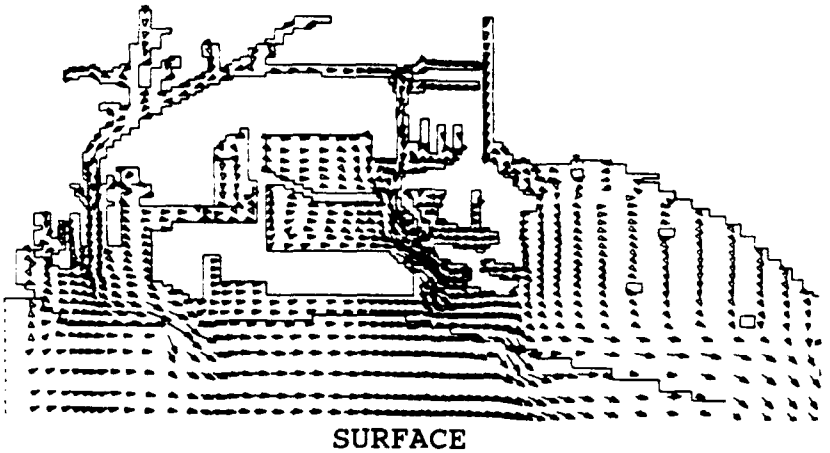
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

PLAN 1 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

PLATE 220



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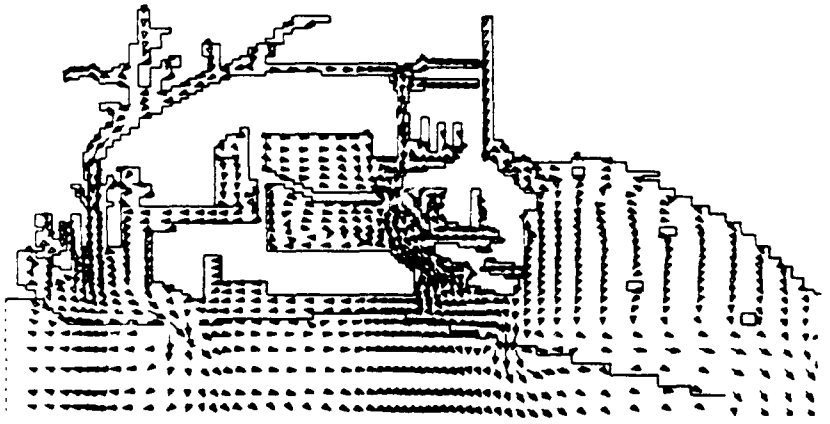
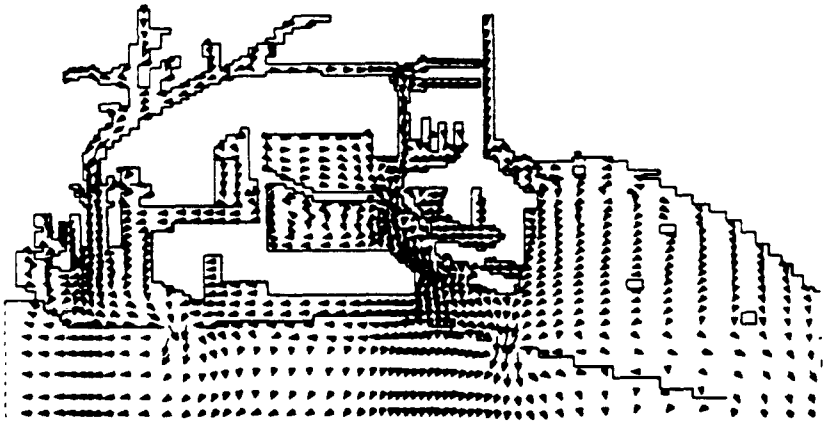


MID-DEPTH



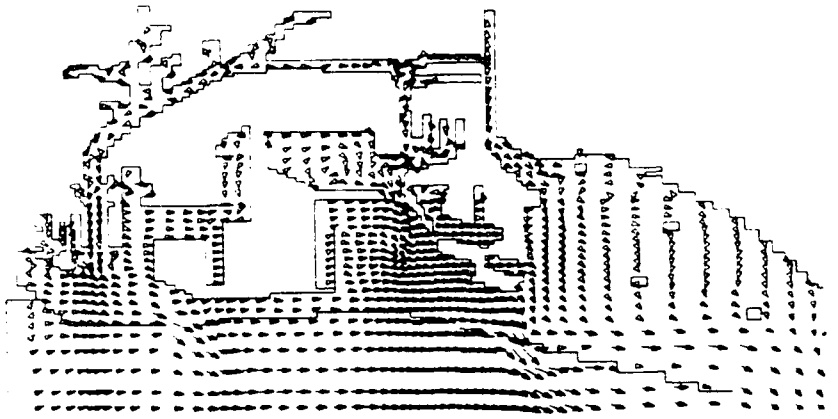
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

PLAN 2 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

PLATE 221



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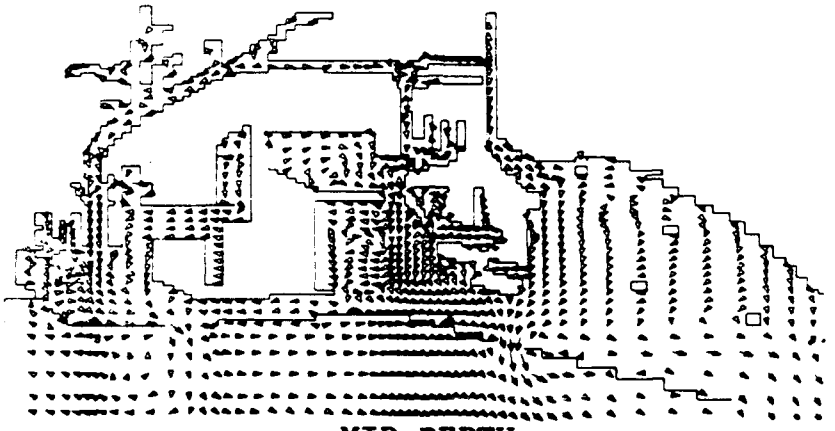
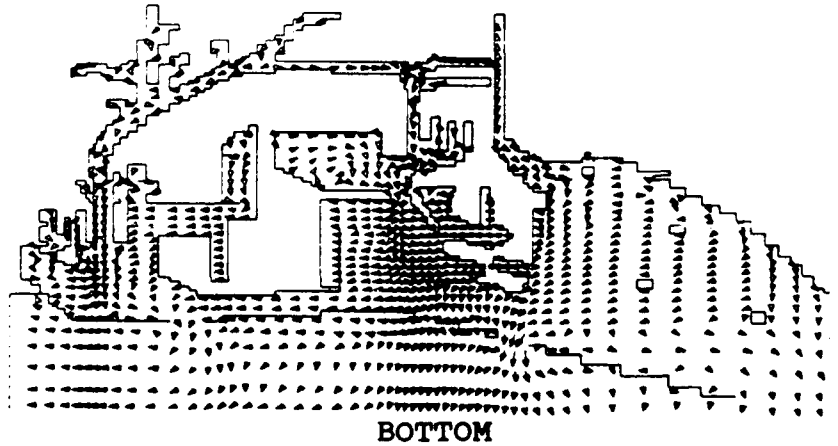


MID-DEPTH



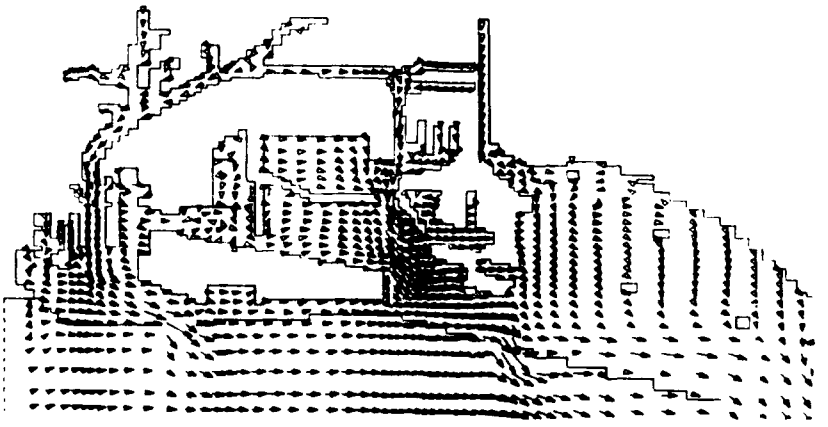
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

PLAN 3 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

PLATE 222



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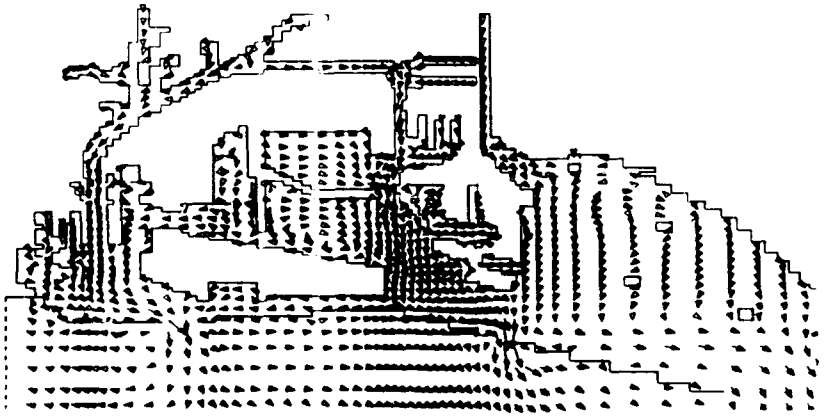
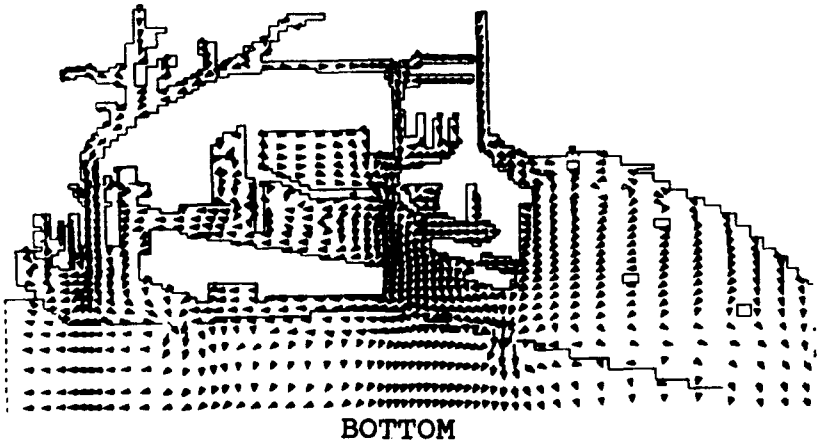


MID-DEPTH



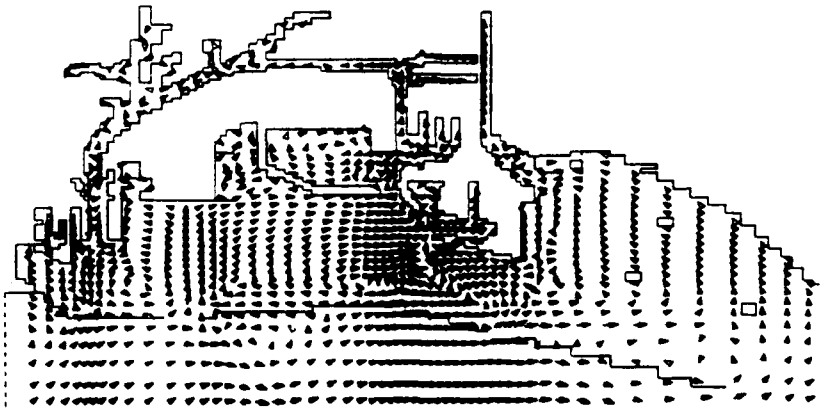
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

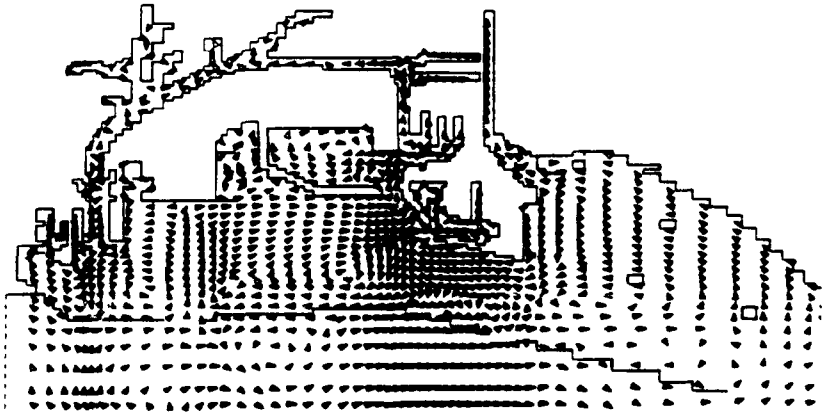
PLAN 4 CONDITIONS PEAK EBB

⟶ 1 FT/SEC

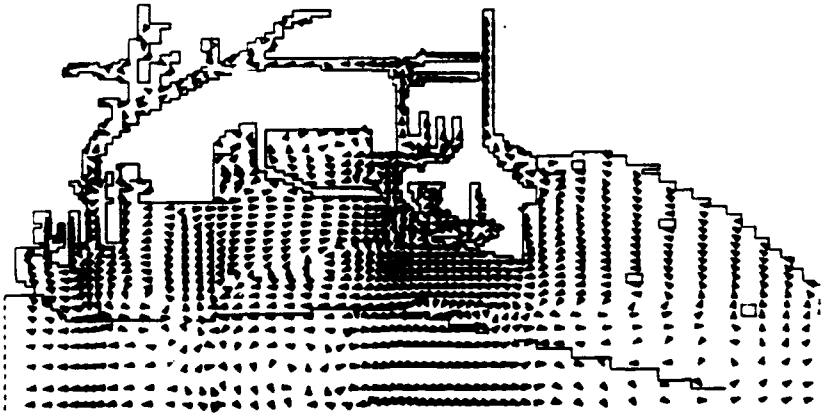
PLATE 223



SURFACE



MID-DEPTH



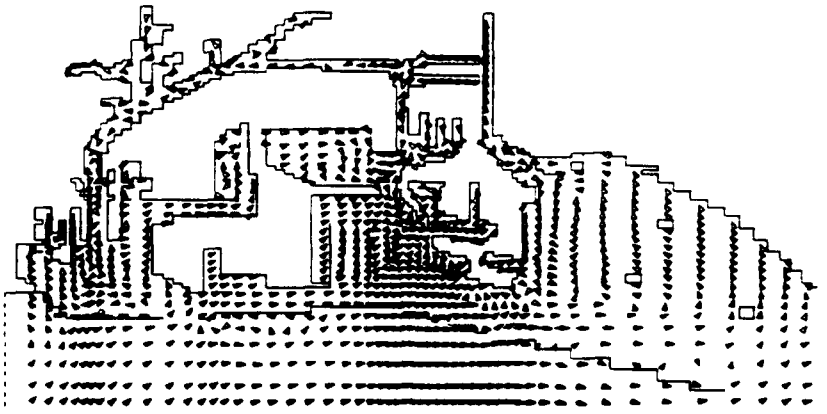
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

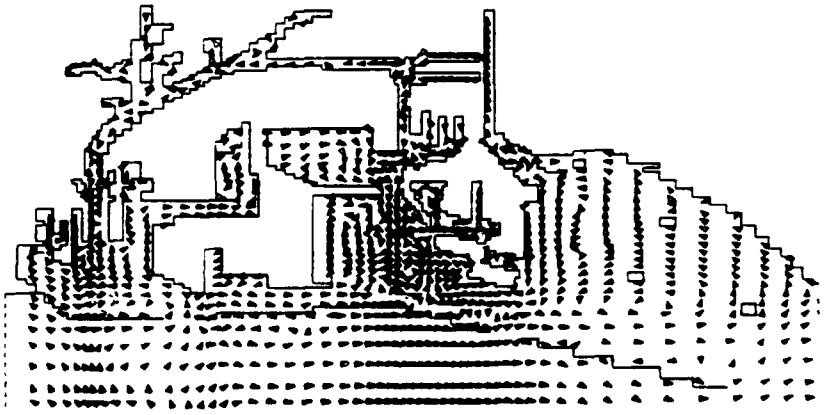
EXISTING CONDITIONS SLACK WATER

⟶ 1 FT/SEC

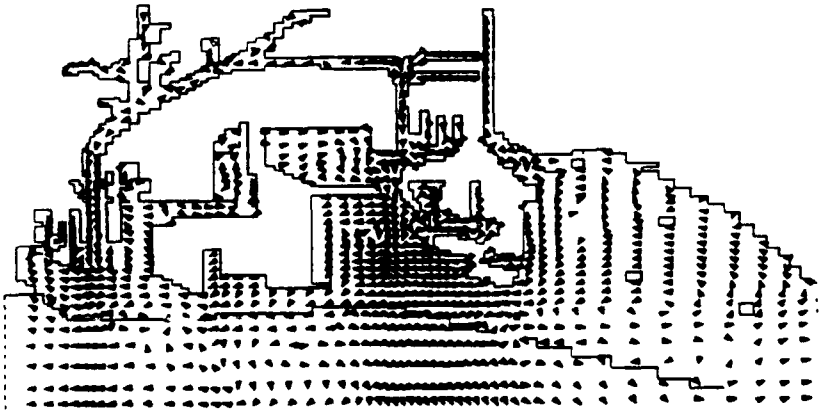
PLATE 224



SURFACE



MID-DEPTH



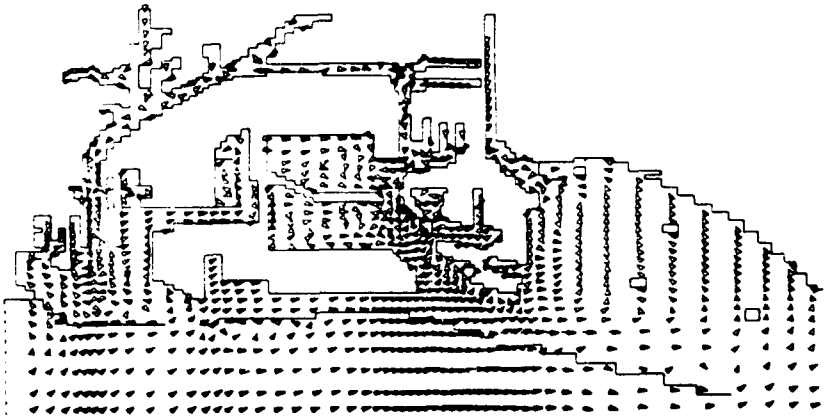
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

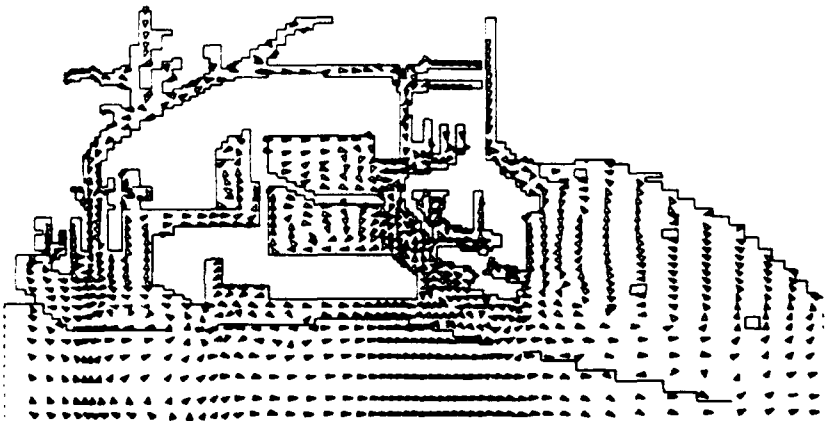
PLAN 1 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

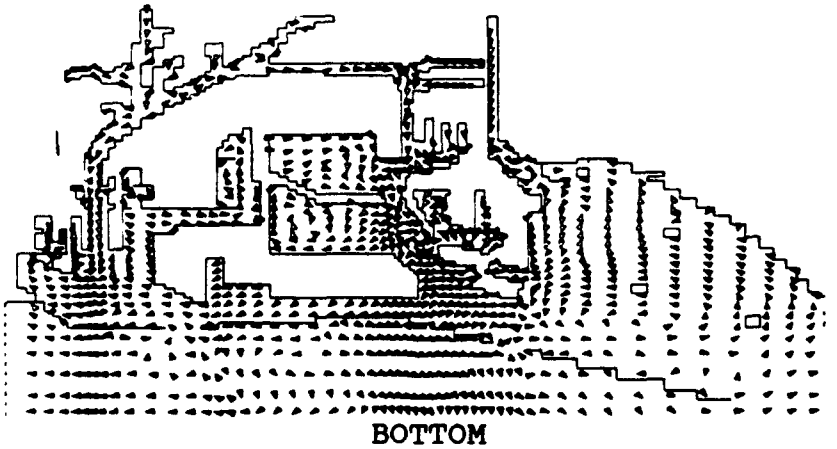
PLATE 225



SURFACE



MID-DEPTH



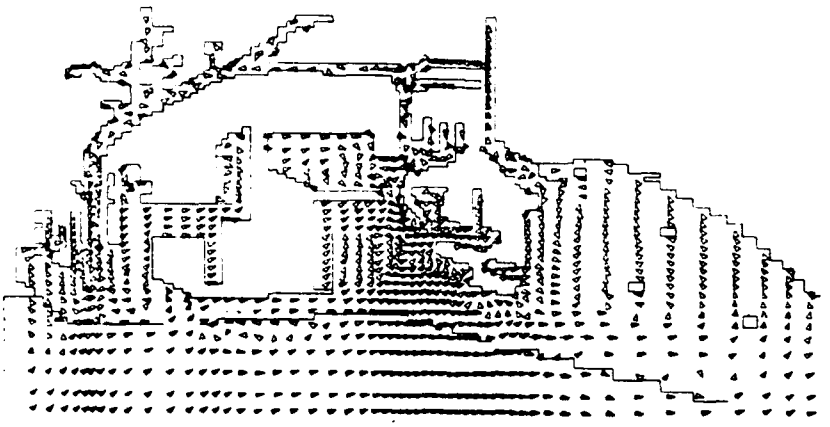
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

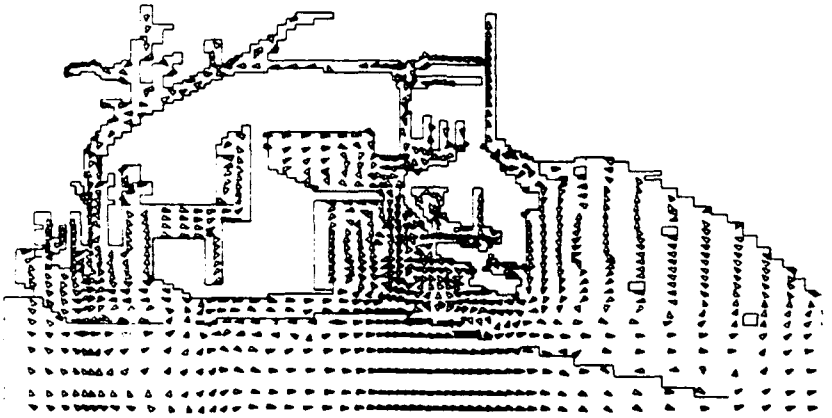
PLAN 2 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

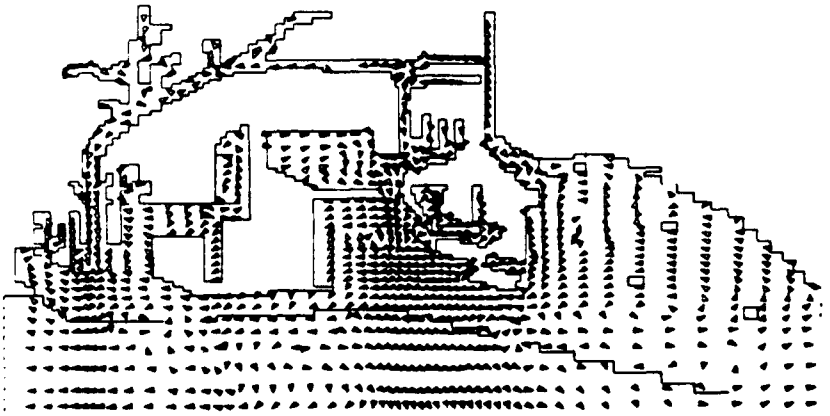
PLATE 226



SURFACE



MID-DEPTH



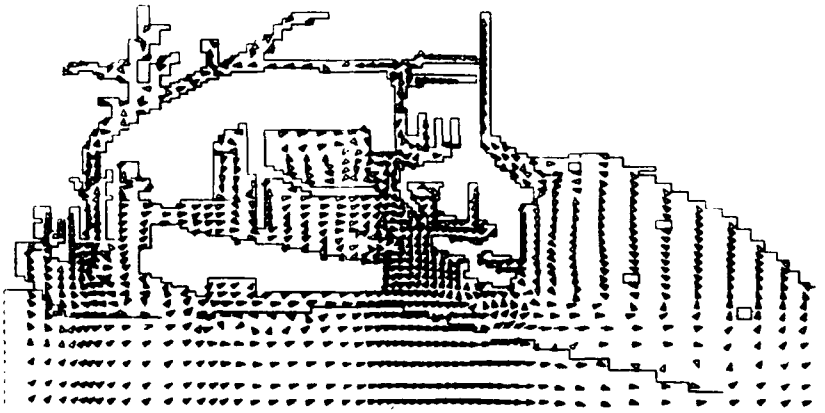
BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

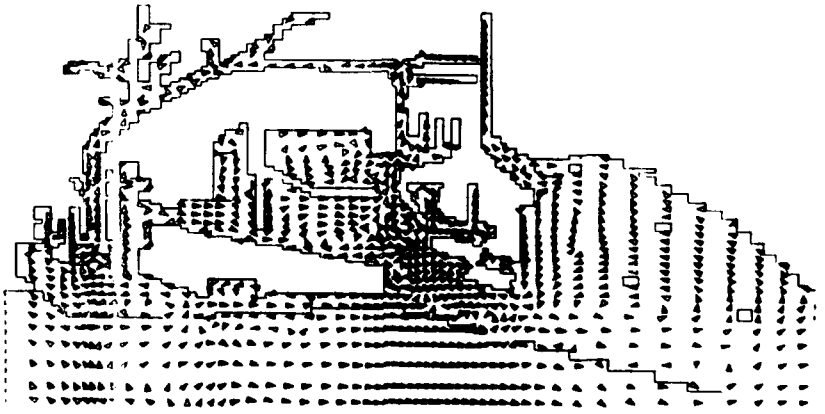
PLAN 3 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

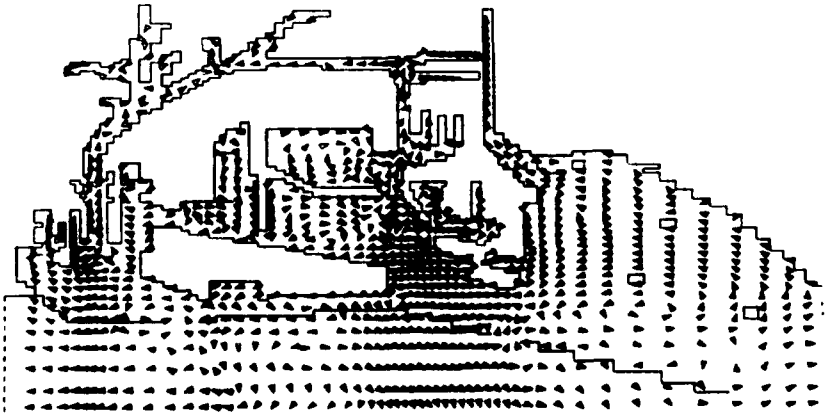
PLATE 227



SURFACE



MID-DEPTH



BOTTOM

CIRCULATION PATTERNS VERIFICATION PERIOD

PLAN 4 CONDITIONS SLACK WATER

⟶ 1 FT/SEC

PLATE 228

TRACER SIMULATION 1 - BASE

Time = 0 days

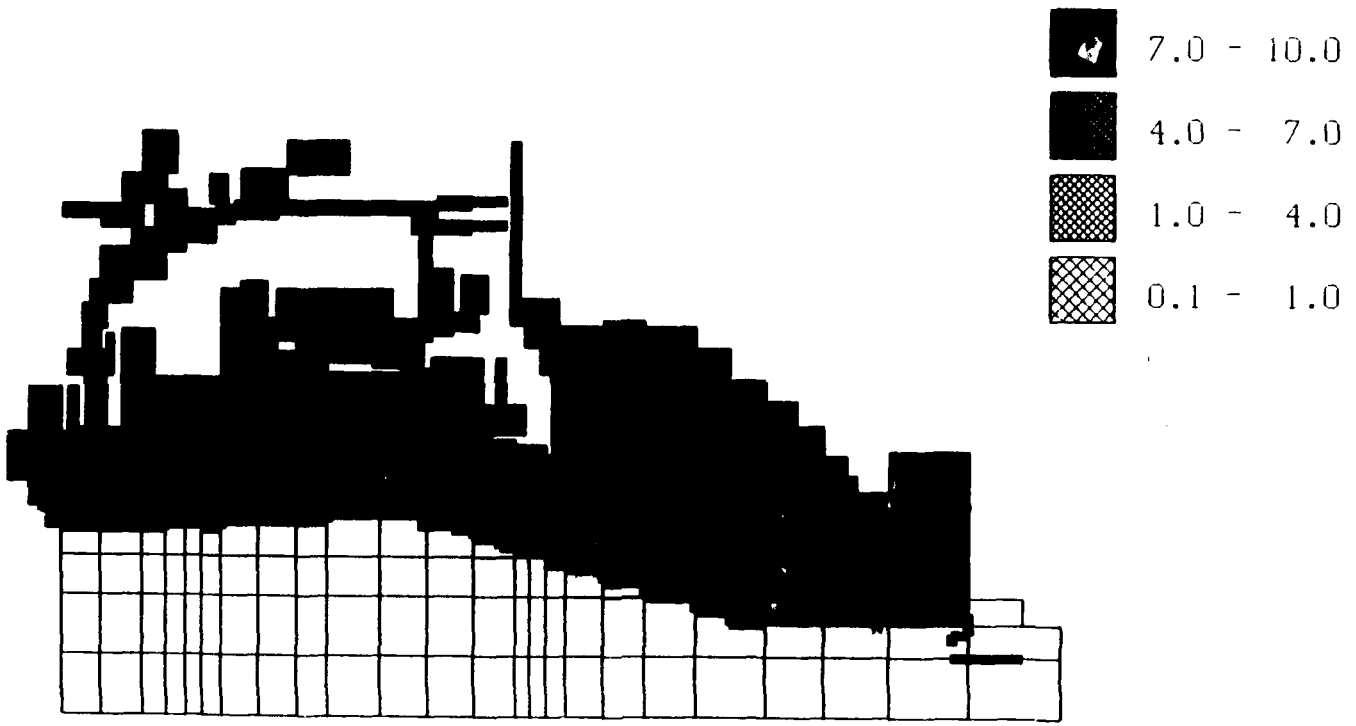


PLATE 229

PLATE 230

TRACER SIMULATION 1 - BASE

Time = 5 days

TRACER SIMULATION 1 - BASE

Time = 10 days

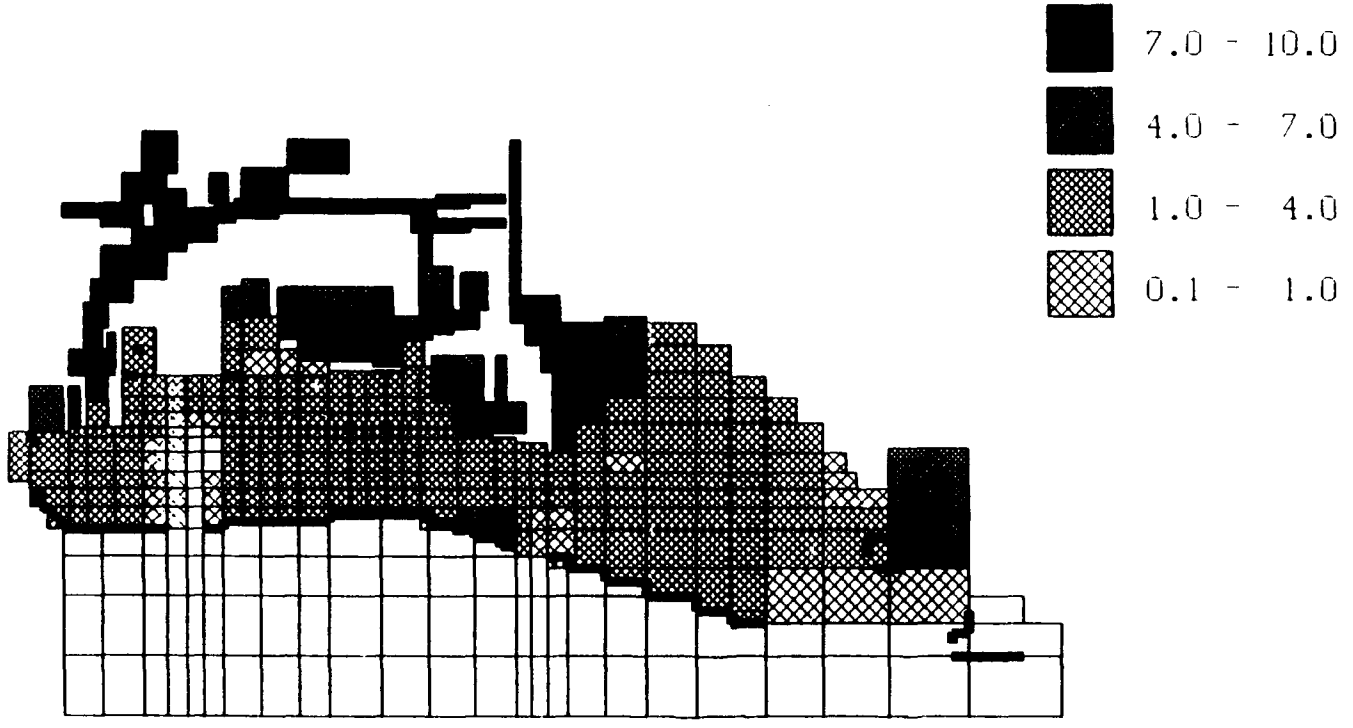


PLATE 231

PLATE 232

TRACER SIMULATION 1 - BASE

Time = 15 days

TRACER SIMULATION 1 - BASE

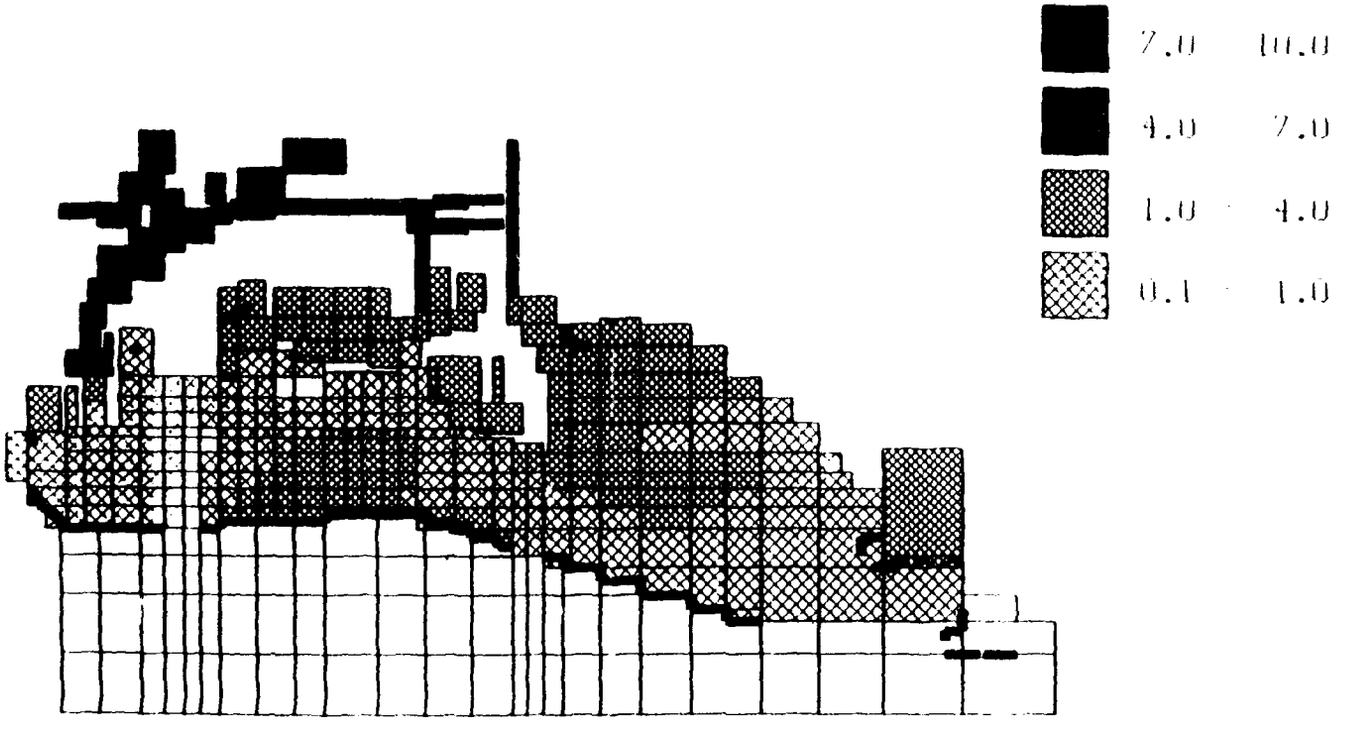
Time = 20 days

PLATE 233

PLATE 234

TRACER SIMULATION 1 - BASE

Time = 25 days



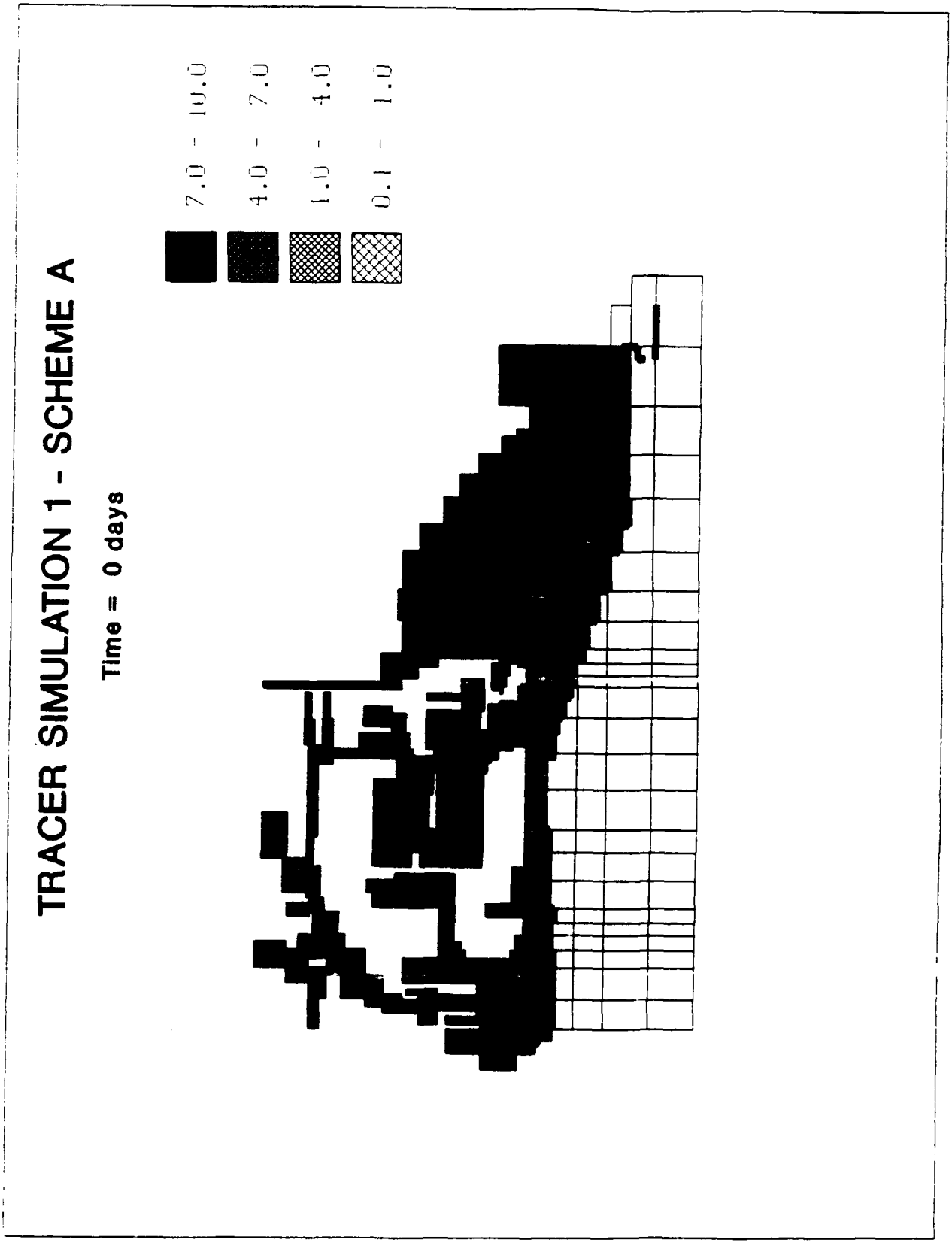
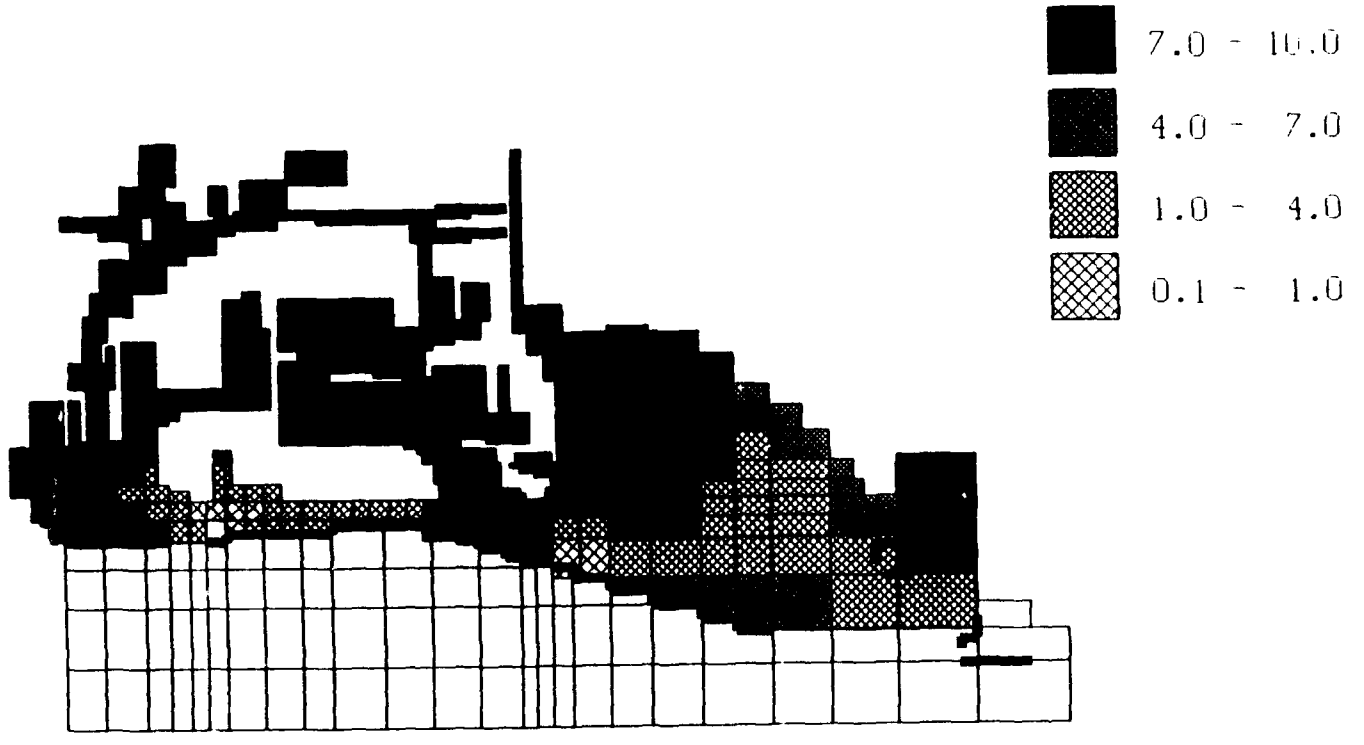

TRACER SIMULATION 1 - SCHEME A
Time = 0 days
7.0 - 10.0
4.0 - 7.0
1.0 - 4.0
0.1 - 1.0

PLATE 235

PLATE 236

TRACER SIMULATION 1 - SCHEME A

Time = 5 days



TRACER SIMULATION 1 - SCHEME A

Time = 10 days

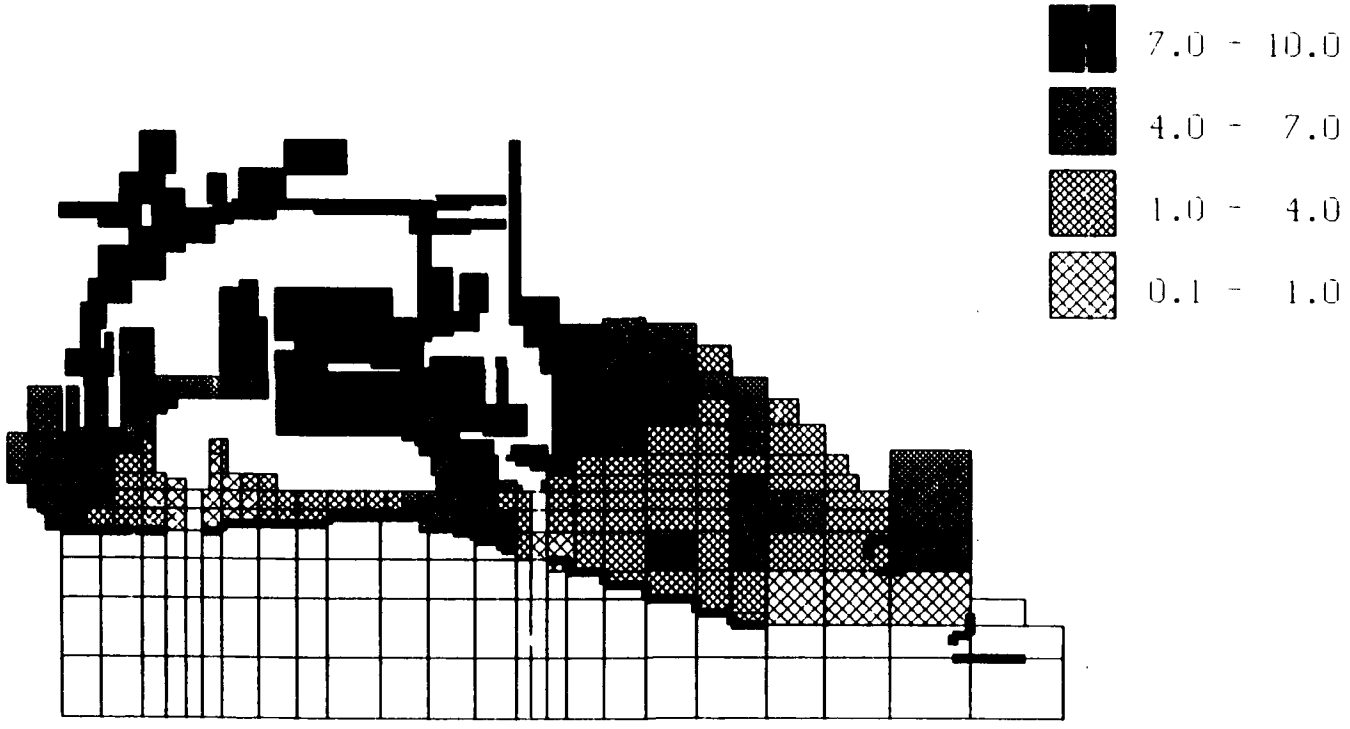
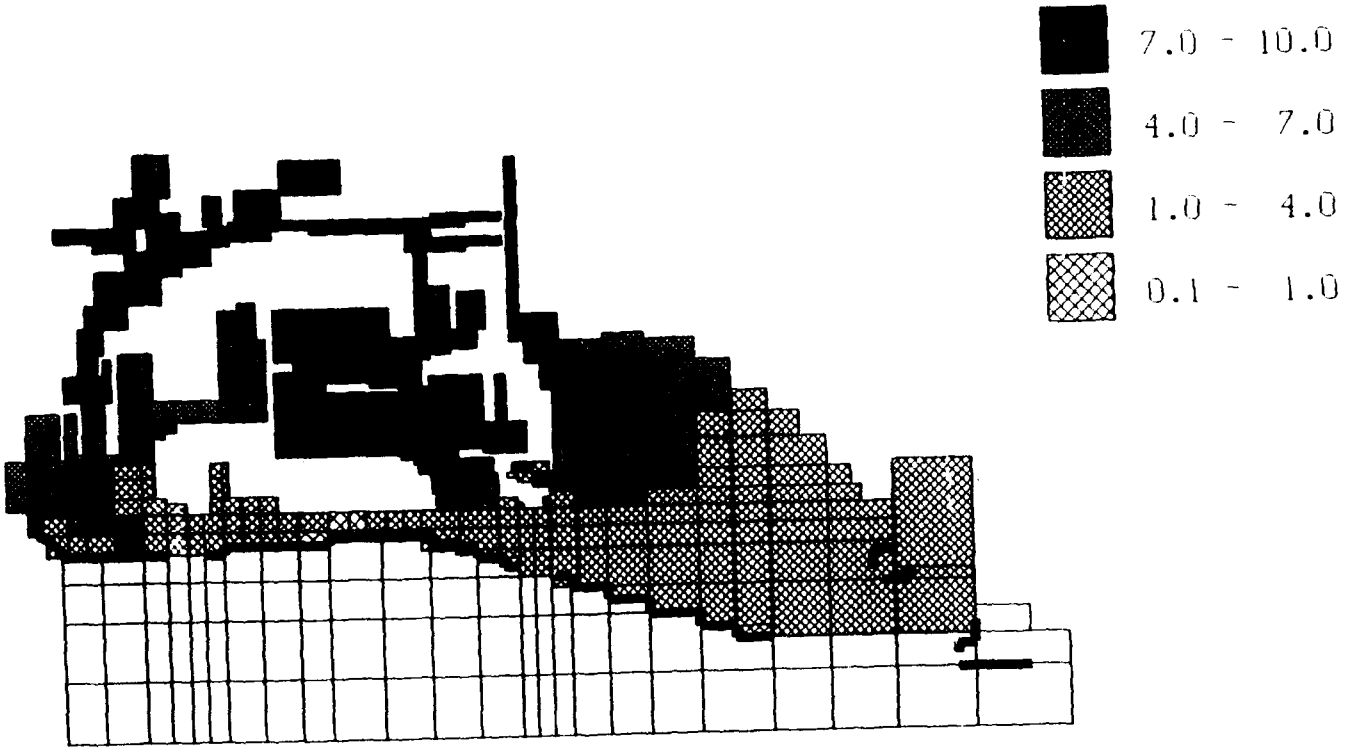


PLATE 237

PLATE 238

TRACER SIMULATION 1 - SCHEME A

Time = 15 days



TRACER SIMULATION 1 - SCHEME A

Time = 20 days

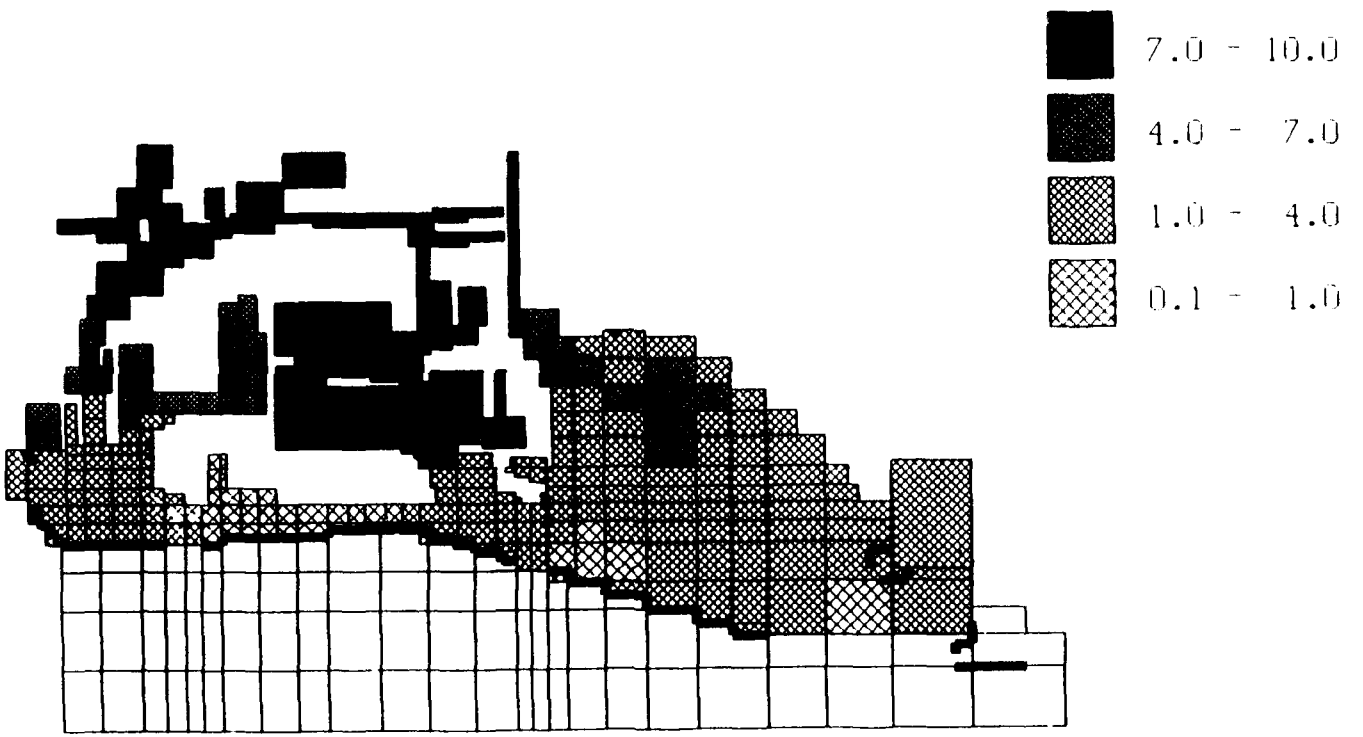


PLATE 239

PLATE 240

TRACER SIMULATION 1 - SCHEME A

Time = 25 days

TRACER SIMULATION 1 - SCHEME B

Time = 0 days

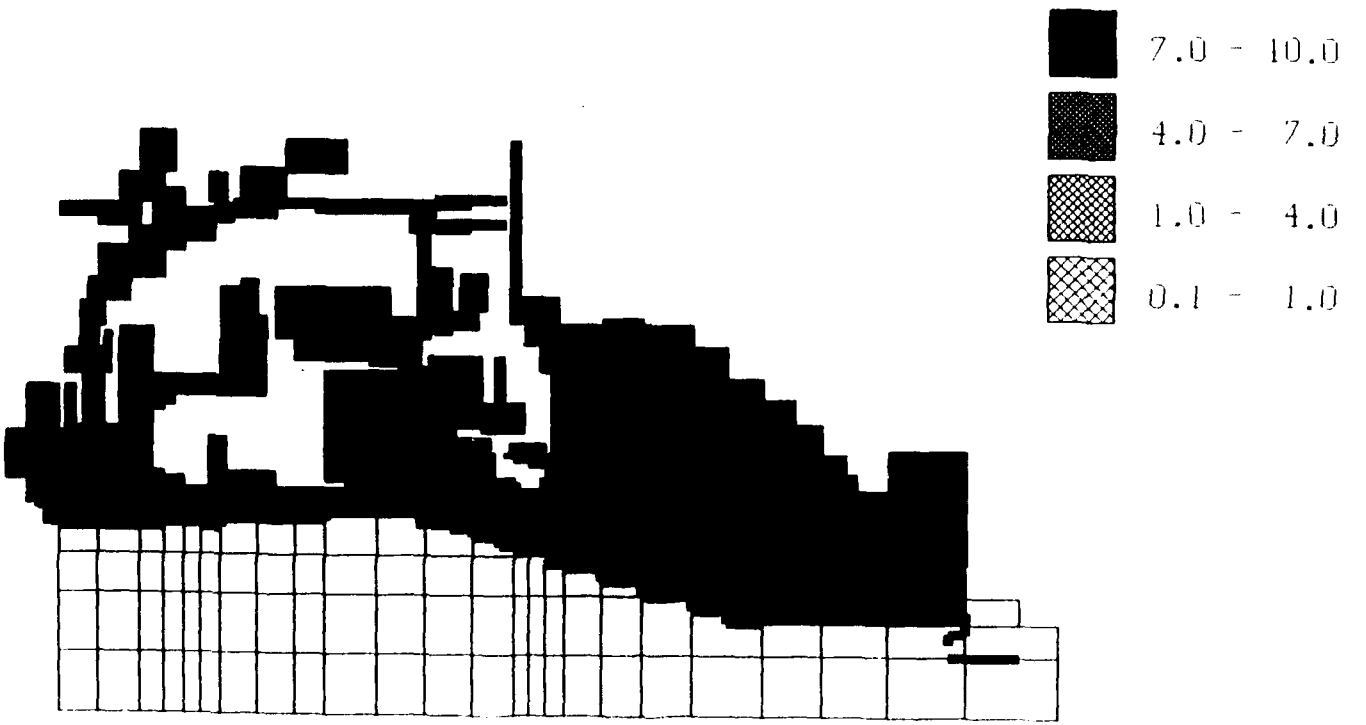


PLATE 241

PLATE 242

TRACER SIMULATION 1 - SCHEME B

Time = 5 days

TRACER SIMULATION 1 - SCHEME B

Time = 10 days

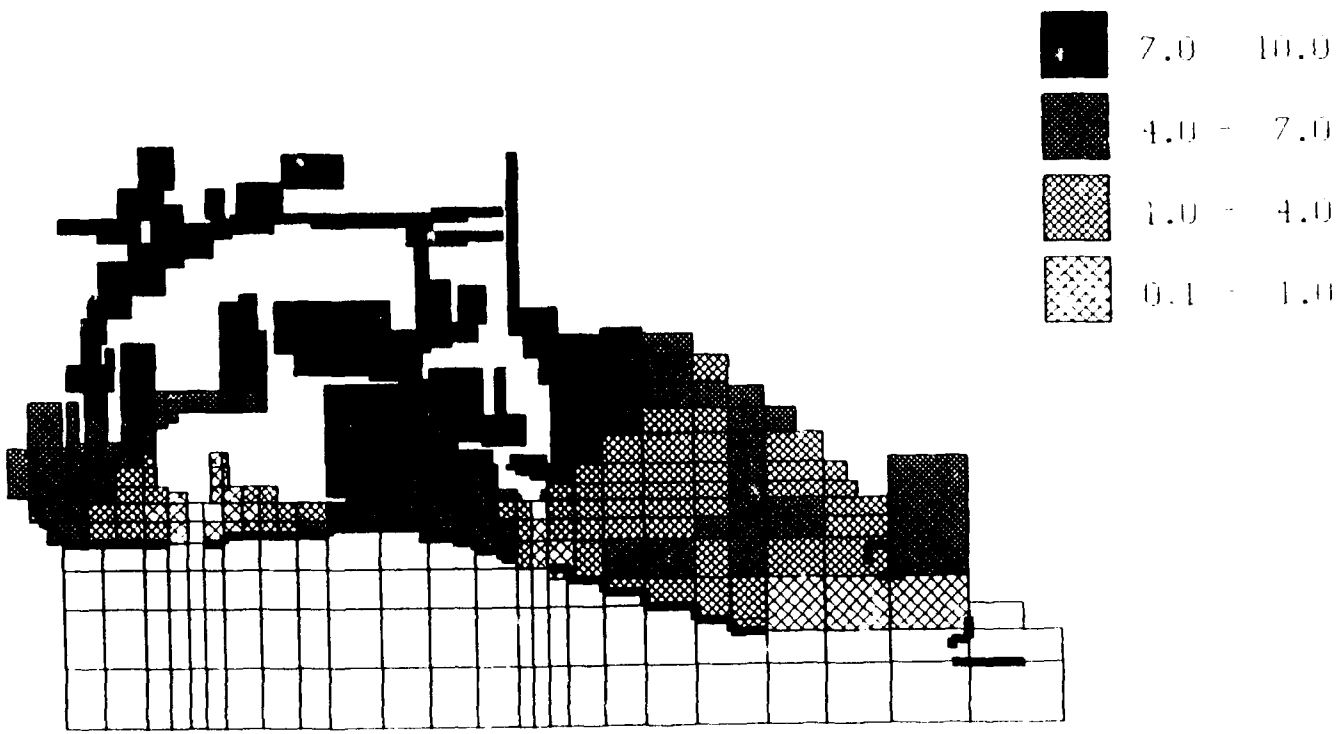


PLATE 243

PLATE 244

TRACER SIMULATION 1 - SCHEME B

Time = 15 days

TRACER SIMULATION 1 - SCHEME B

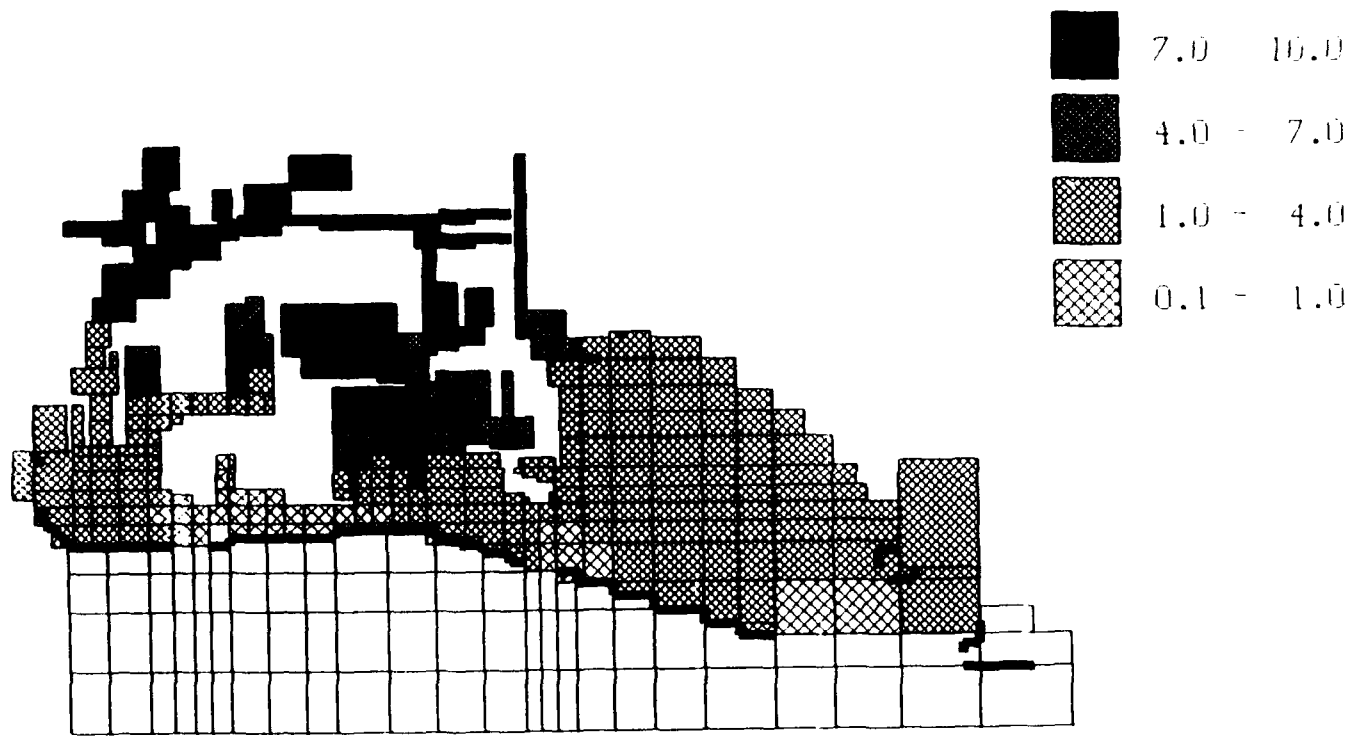
Time = 20 days

PLATE 245

PLATE 246

TRACER SIMULATION 1 - SCHEME B

Time = 25 days



TRACER SIMULATION 1 - SCHEME C

Time = 0 days

PLATE 247

PLATE 248

TRACER SIMULATION 1 - SCHEME C

Time = 5 days

TRACER SIMULATION 1 - SCHEME C

Time = 10 days

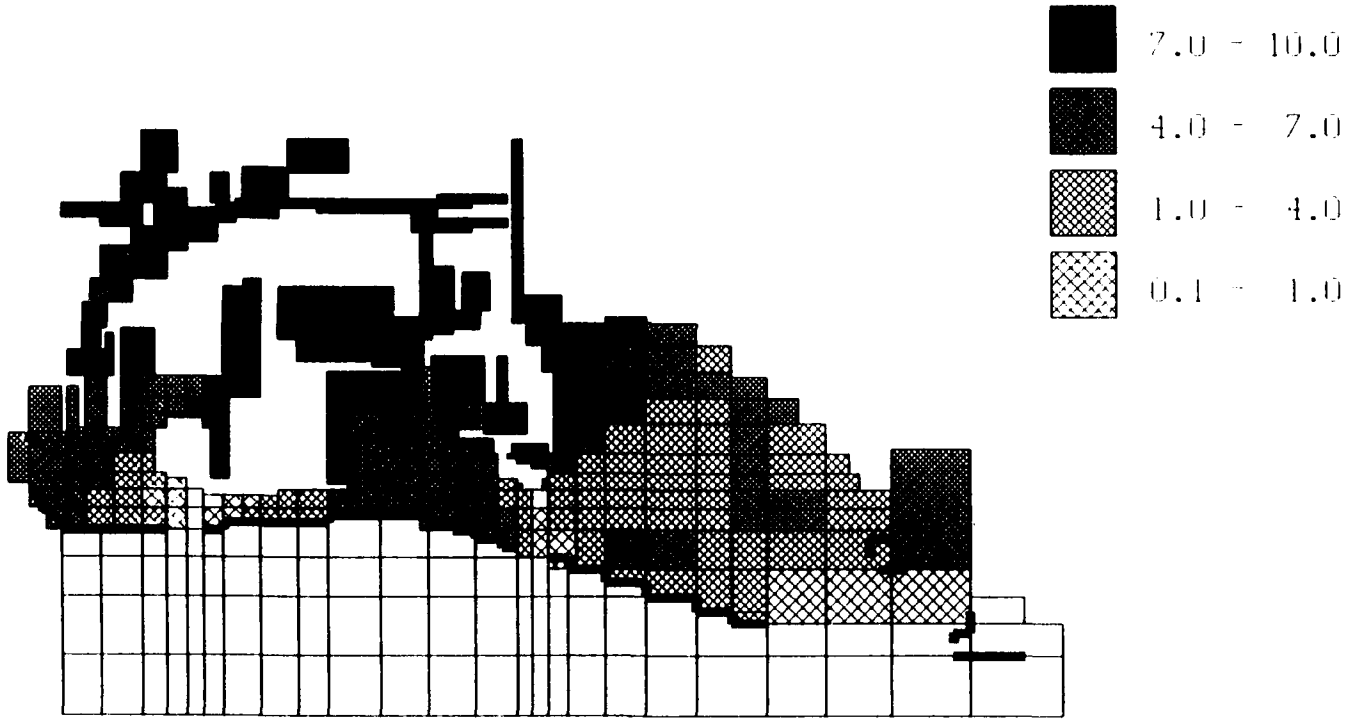


PLATE 249

PLATE 250

TRACER SIMULATION 1 - SCHEME C

Time = 15 days

TRACER SIMULATION 1 - SCHEME C

Time = 20 days

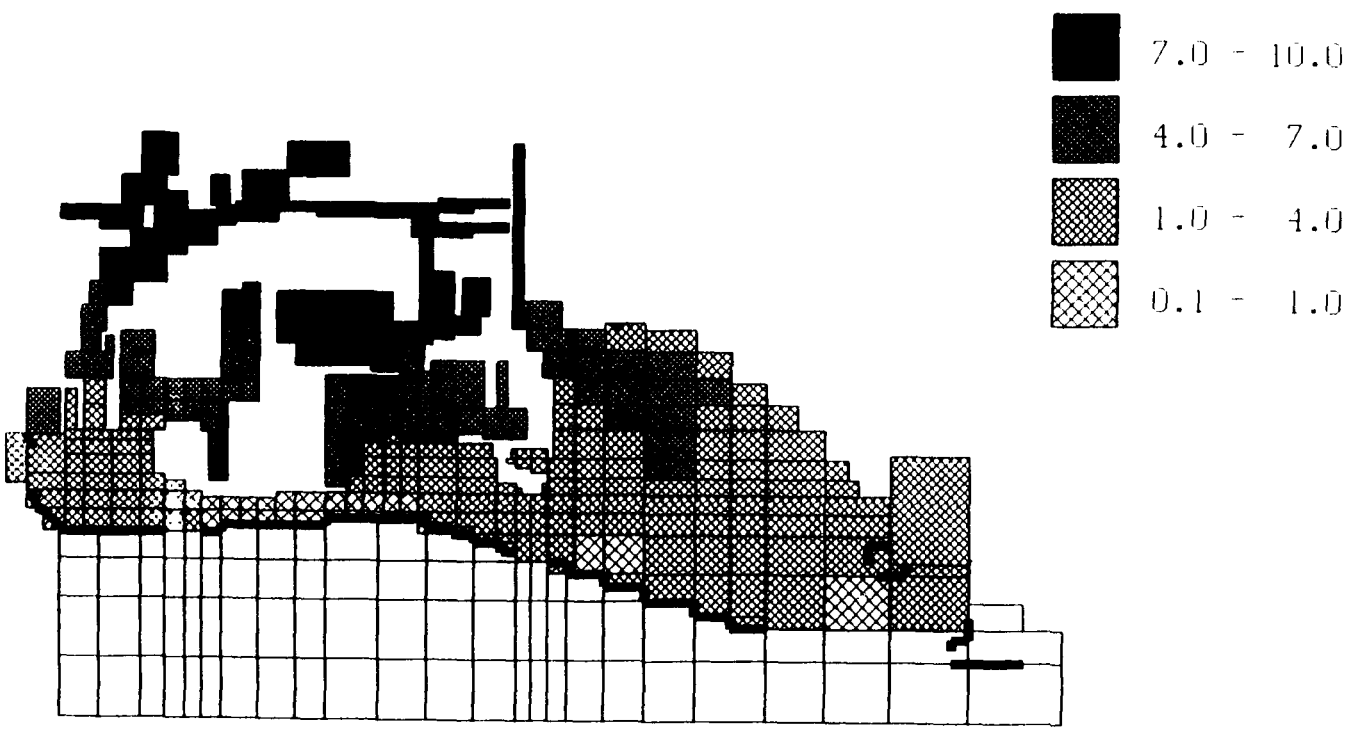
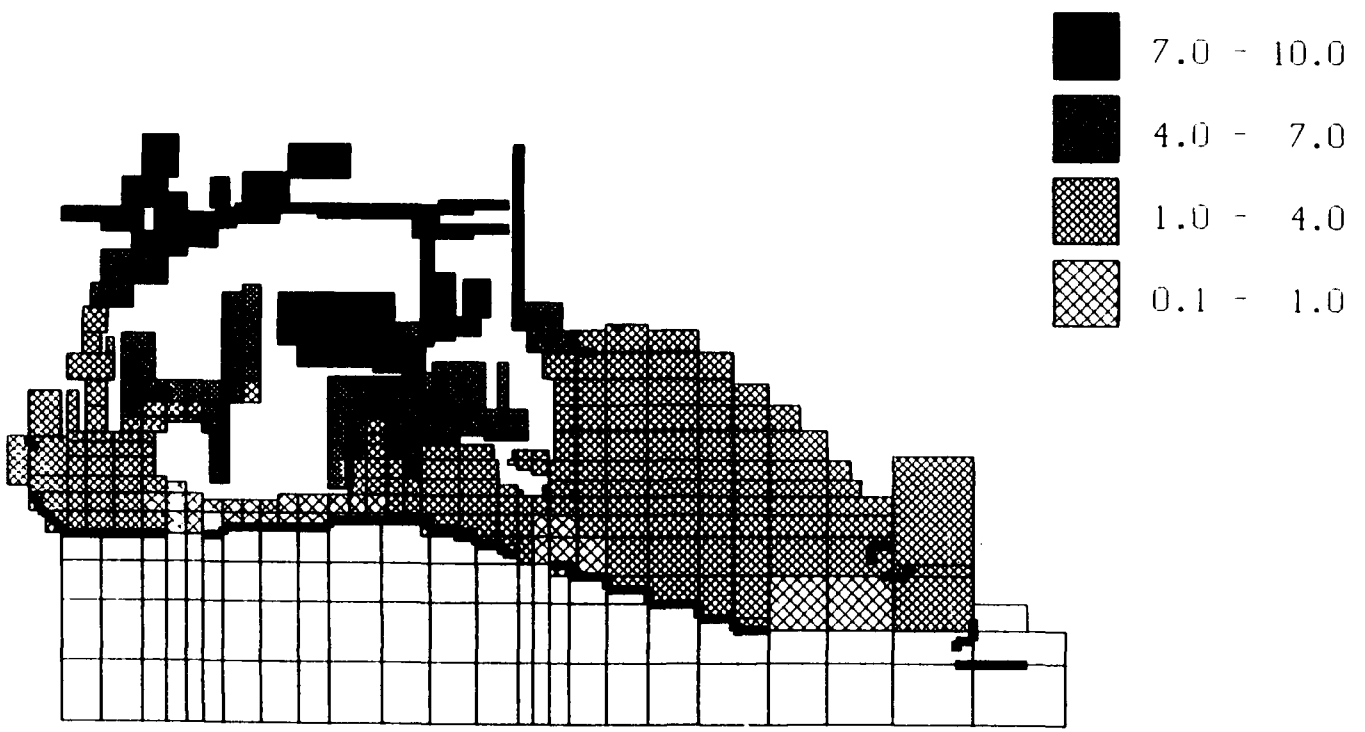


PLATE 251

PLATE 252

TRACER SIMULATION 1 - SCHEME C

Time = 25 days



TRACER SIMULATION 1 - SCHEME D

Time = 0 days

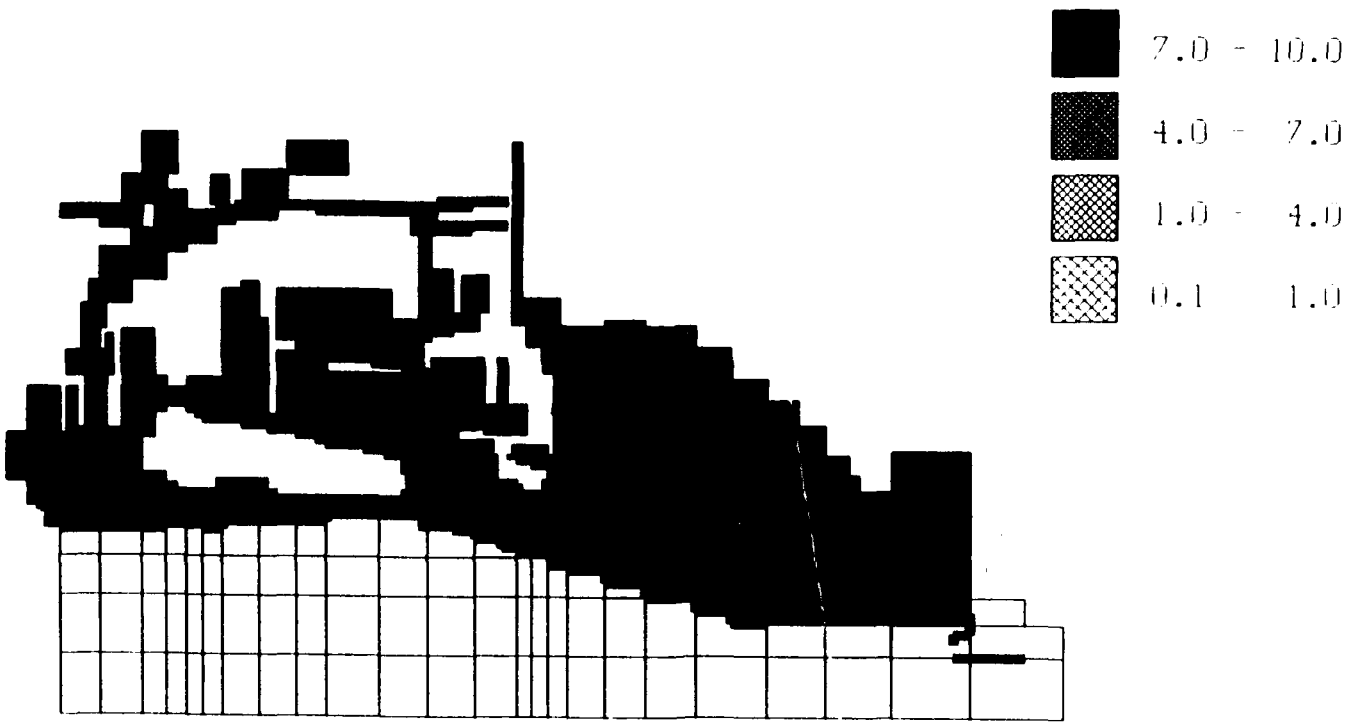
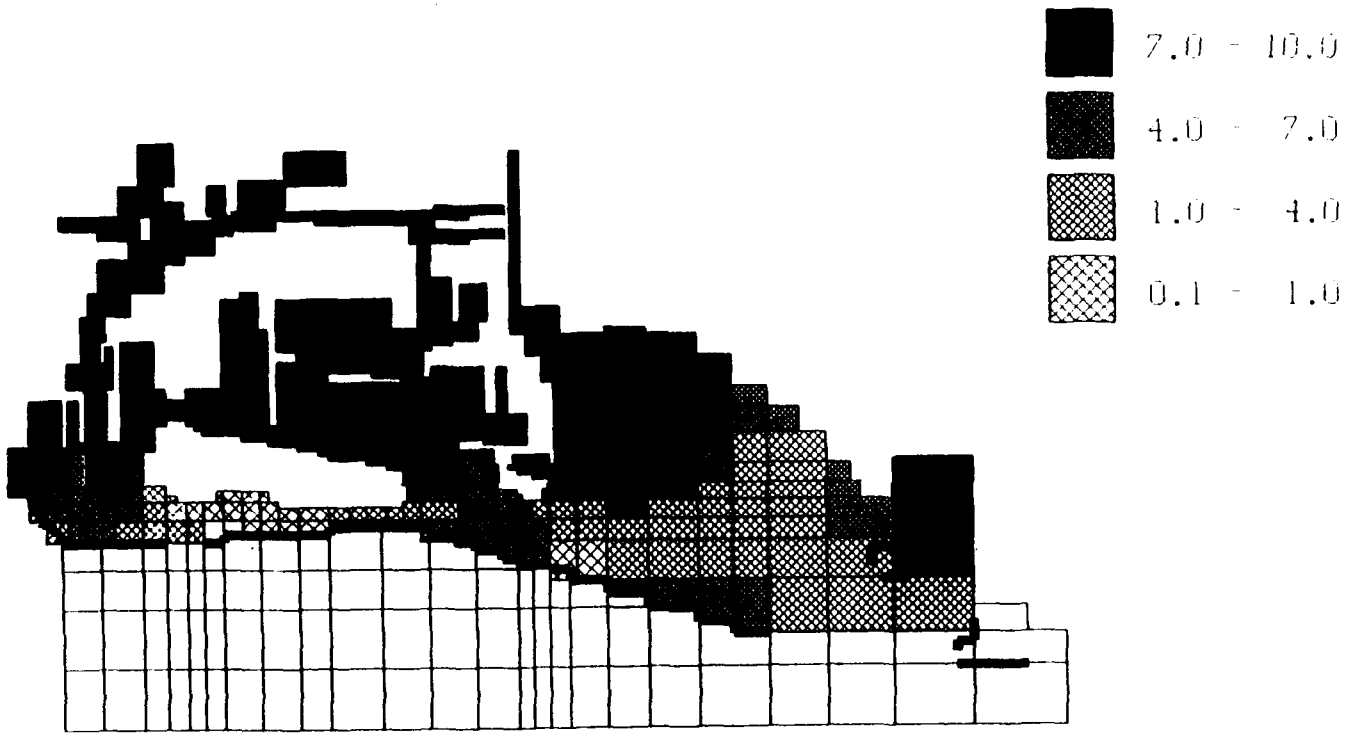


PLATE 253

PLATE 254

TRACER SIMULATION 1 - SCHEME D

Time = 5 days



TRACER SIMULATION 1 - SCHEME D

Time = 10 days

PLATE 255

PLATE 256

TRACER SIMULATION 1 - SCHEME D

Time = 15 days

TRACER SIMULATION 1 - SCHEME D

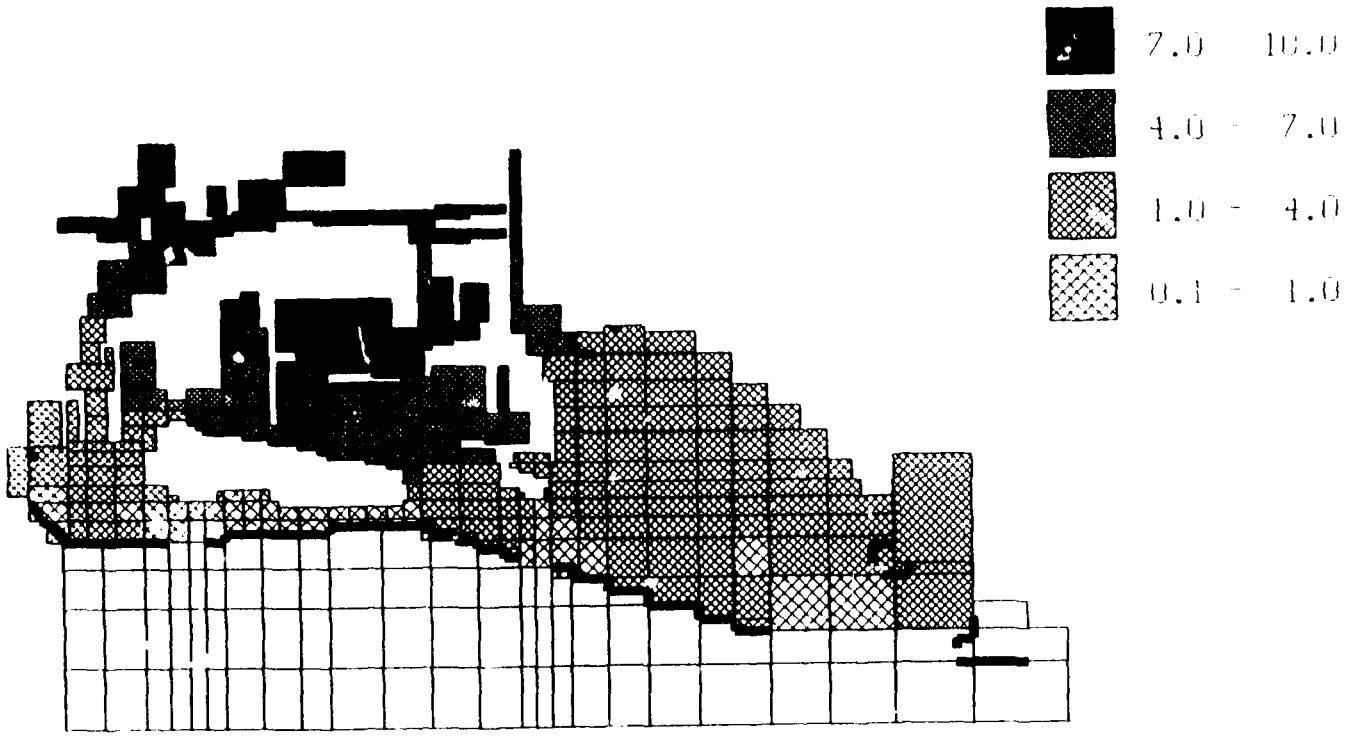
Time = 20 days

PLATE 257

PLATE 258

TRACER SIMULATION 1 - SCHEME D

Time = 25 days



TRACER SIMULATION 2

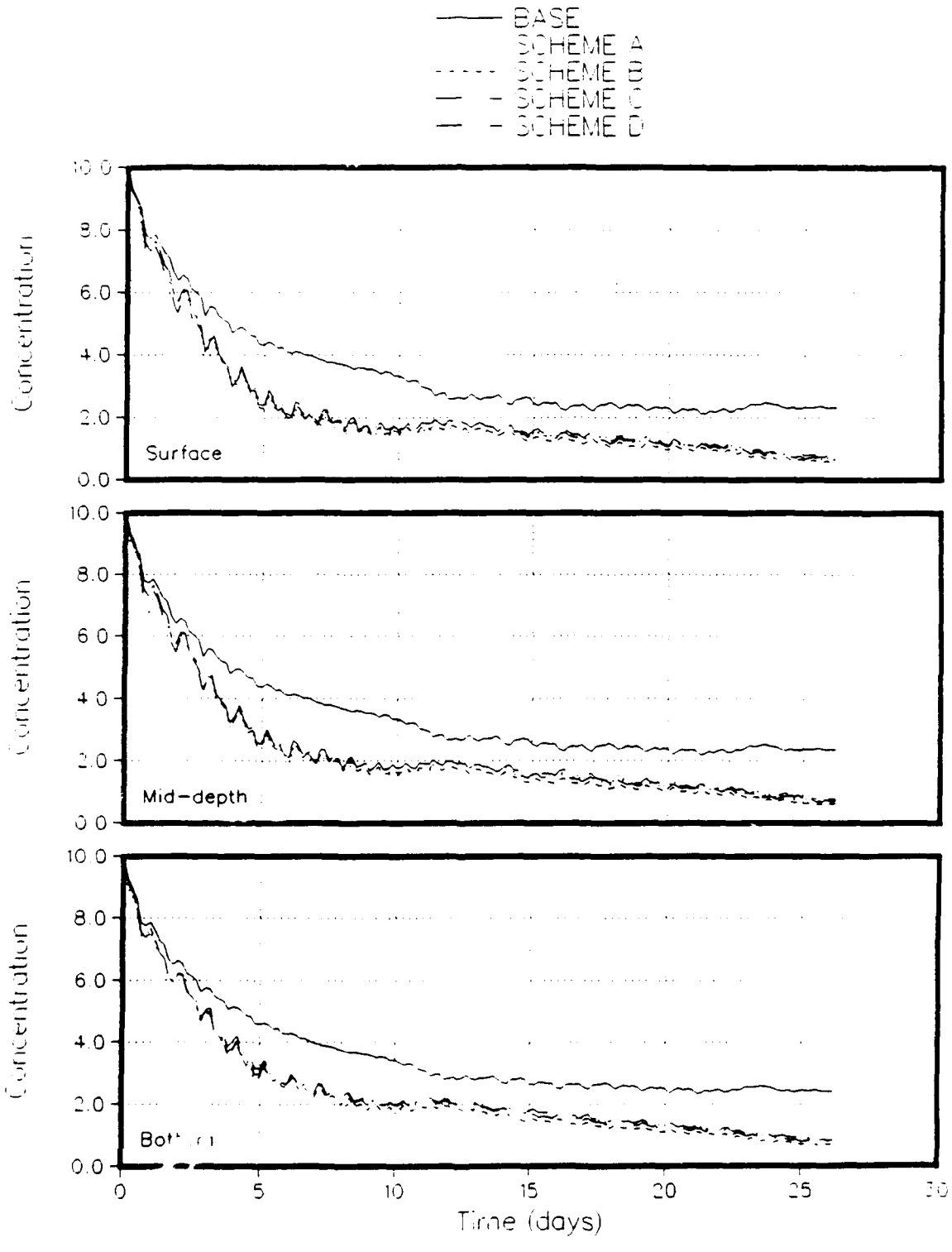


PLATE 259

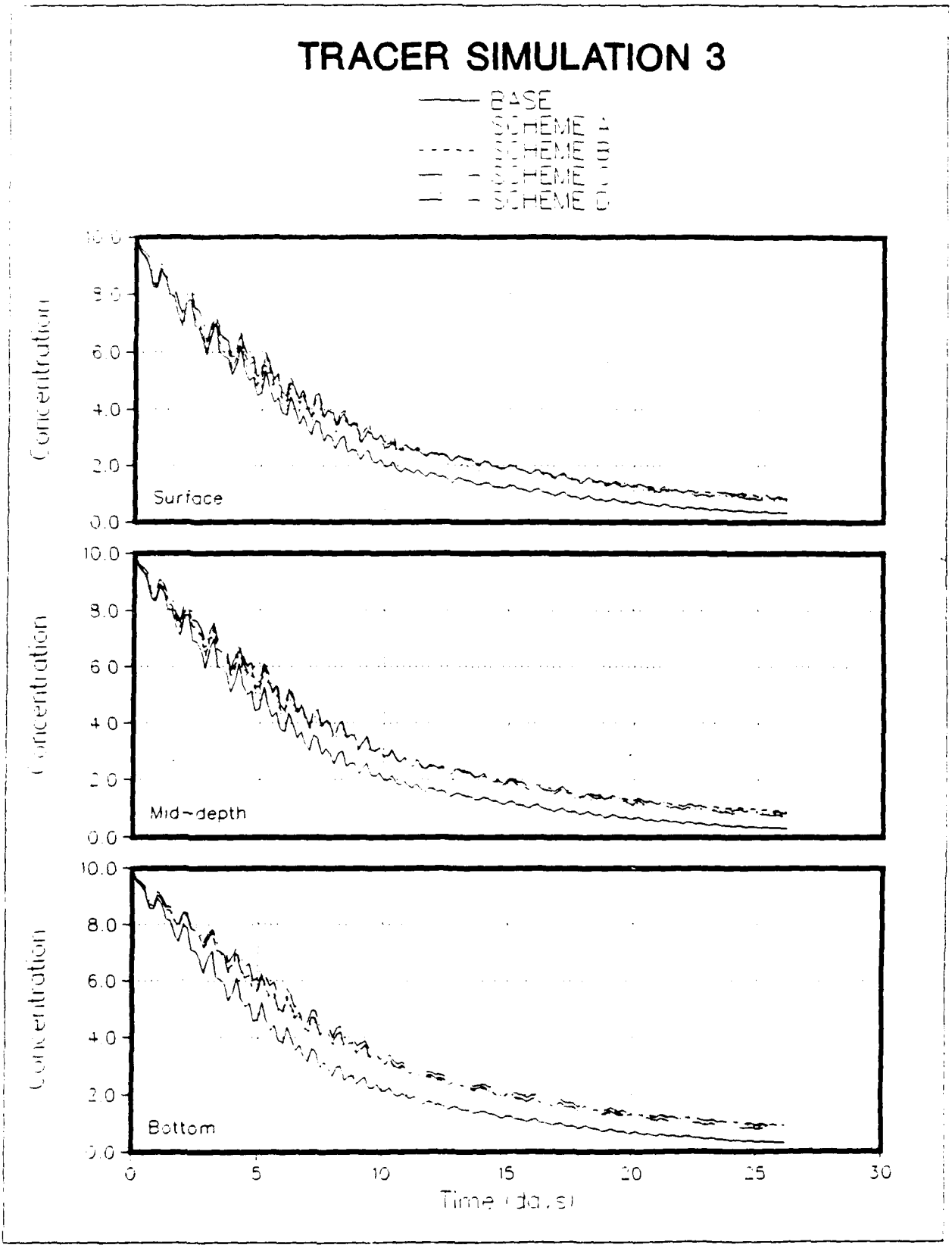

TRACER SIMULATION 3
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D
Concentration
Surface
Mid-depth
Bottom
10.0
8.0
6.0
4.0
2.0
0.0
0
5
10
15
20
25
30
Time (days)

PLATE 260

TRACER SIMULATION 4

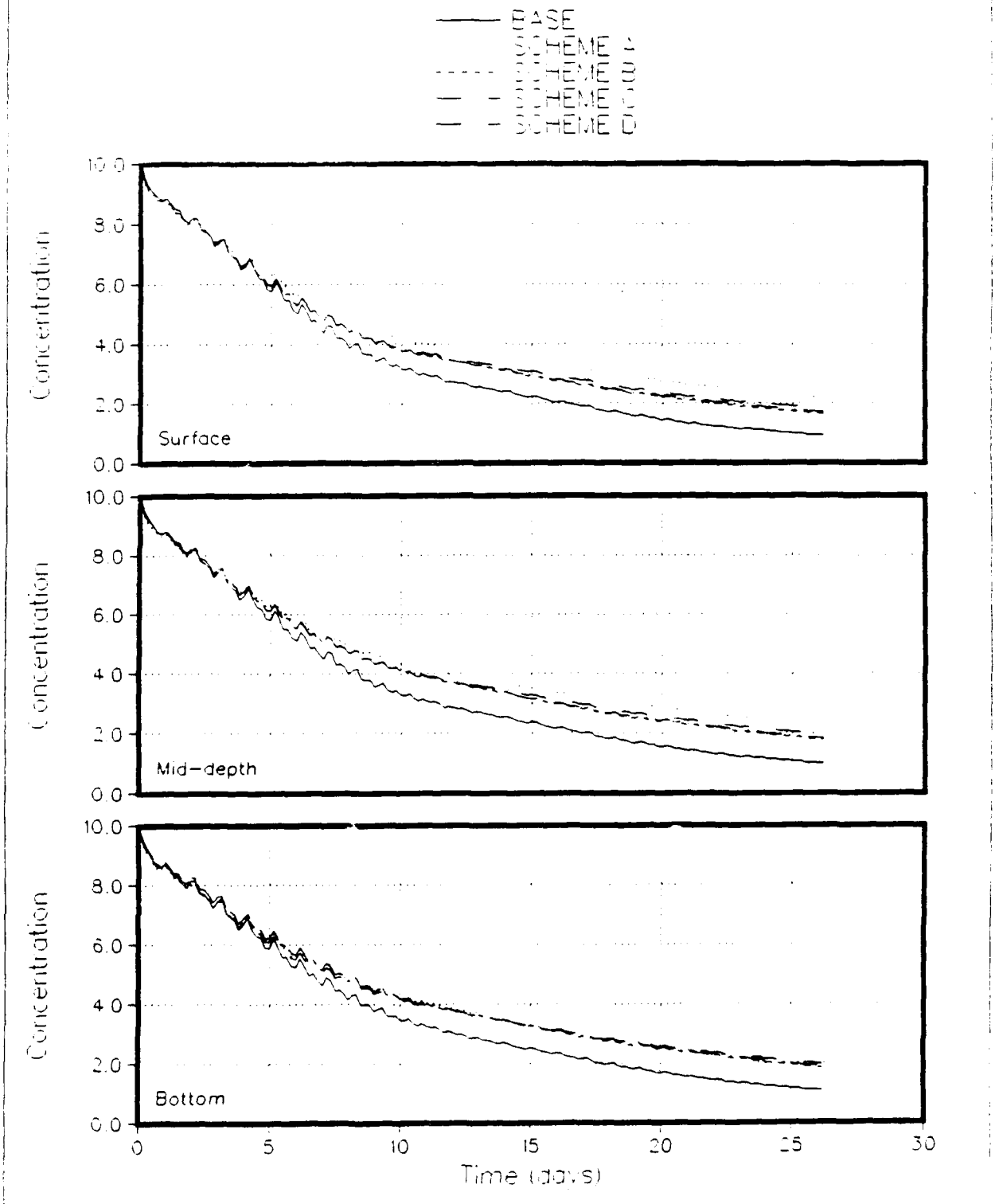


PLATE 261

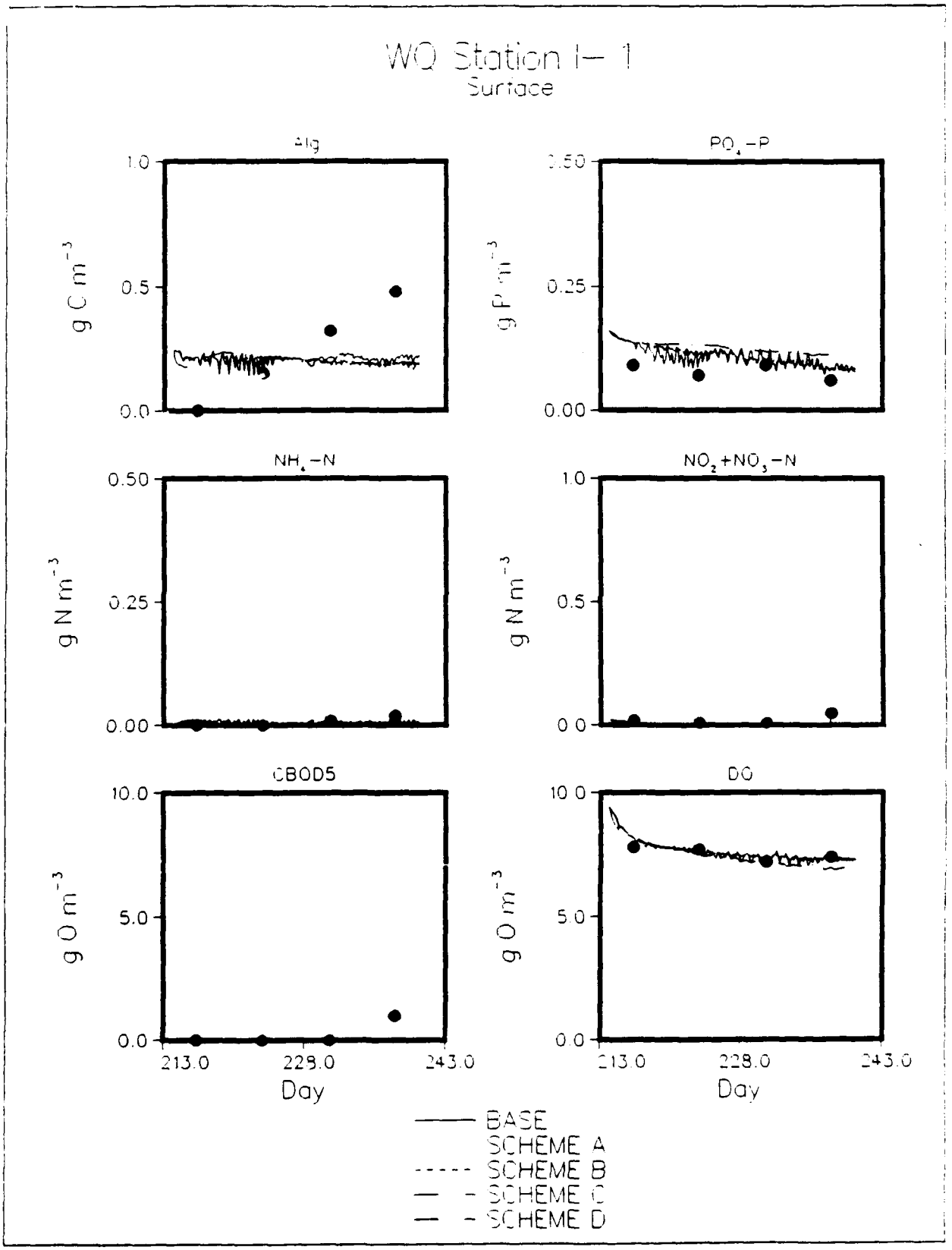

WQ Station I– 1
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4–P
g P m-3
0.50
0.25
0.00
NH4–N
g N m-3
0.50
0.25
0.00
NO2+NO3–N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 262

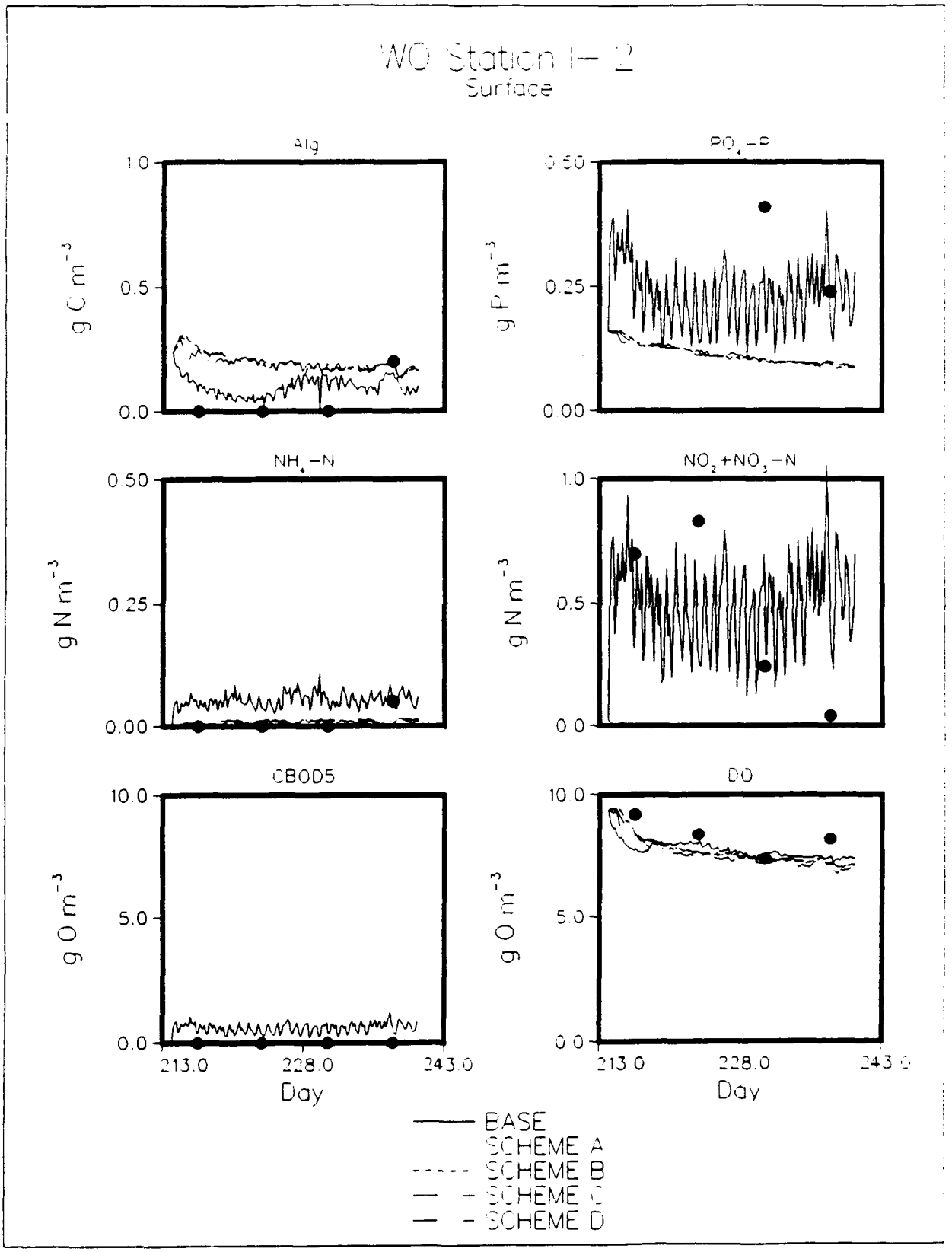

WQ Station 1– 2
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4–P
g P m-3
0.50
0.25
0.00
NH4–N
g N m-3
0.50
0.25
0.00
NO2+NO3–N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 263

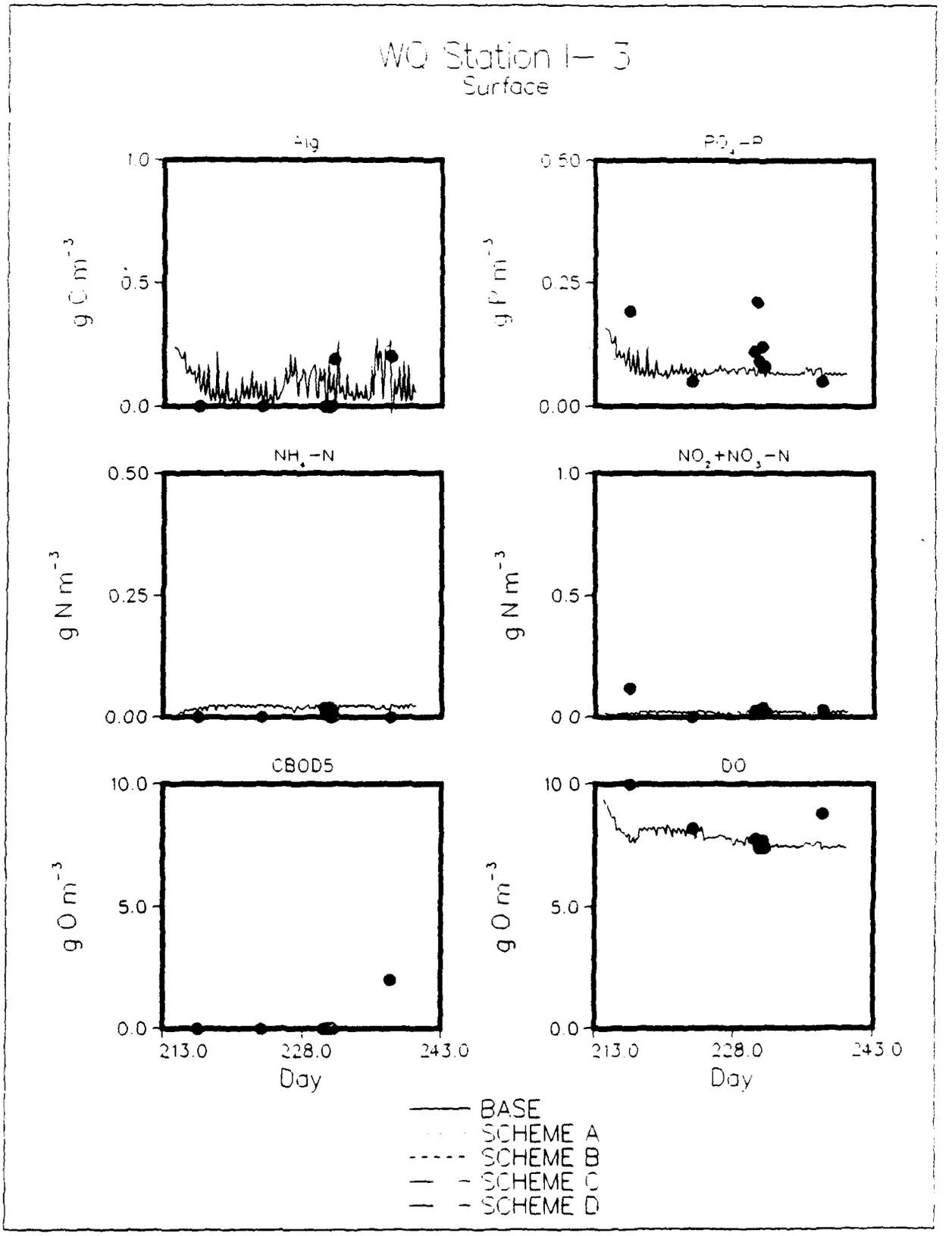

WQ Station I– 3
Surface
Algae
g C m-3
1.0
0.5
0.0
PO4–P
g P m-3
0.50
0.25
0.00
NH4–N
g N m-3
0.50
0.25
0.00
NO2+NO3–N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 264

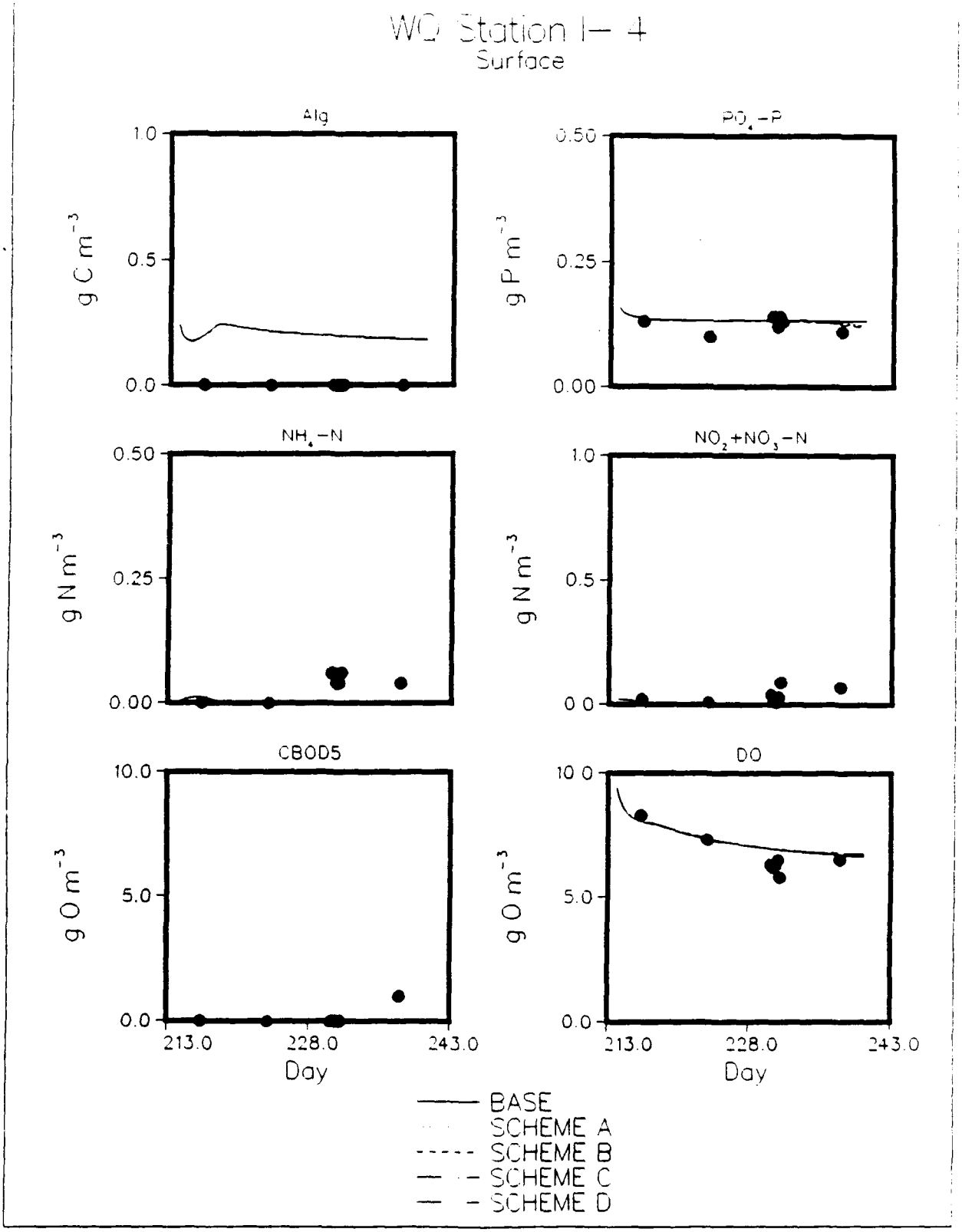

WQ Station I– 4
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0 0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10 0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 265

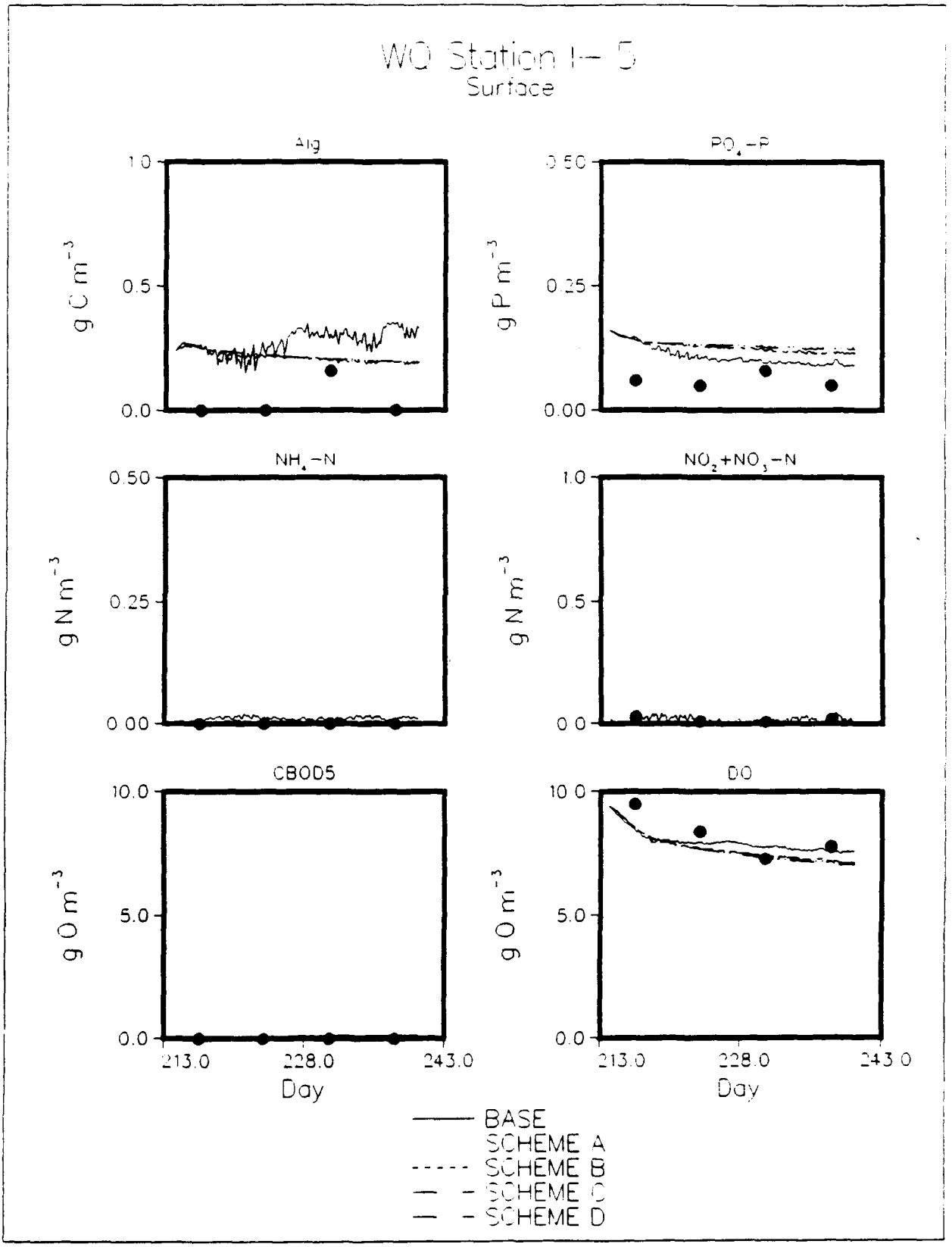

WQ Station 1– 5
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4–P
g P m-3
0.50
0.25
0.00
NH4–N
g N m-3
0.50
0.25
0.00
NO2+NO3–N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 266

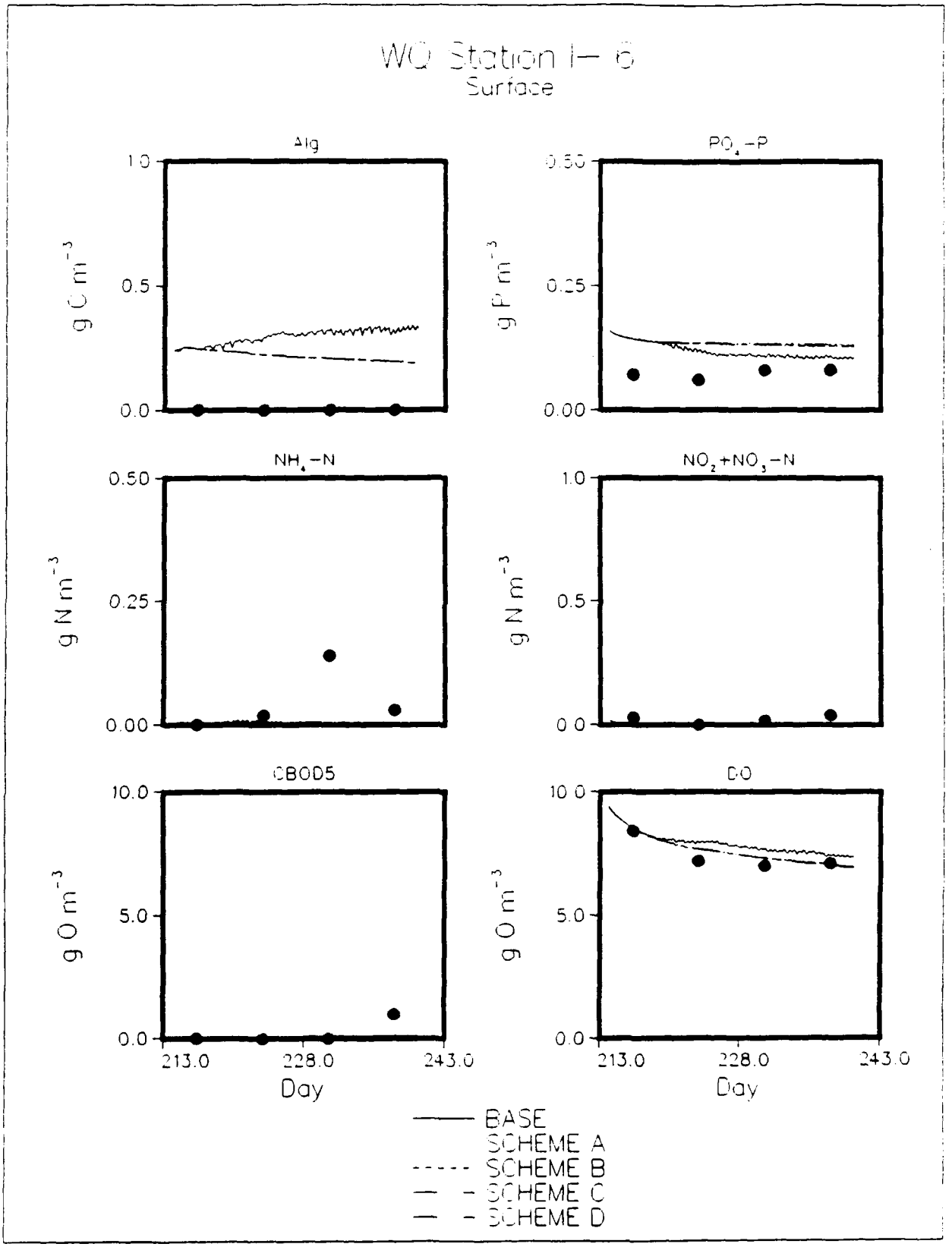

WQ Station I– 6
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4–P
g P m-3
0.50
0.25
0.00
NH4–N
g N m-3
0.50
0.25
0.00
NO2+NO3–N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 267

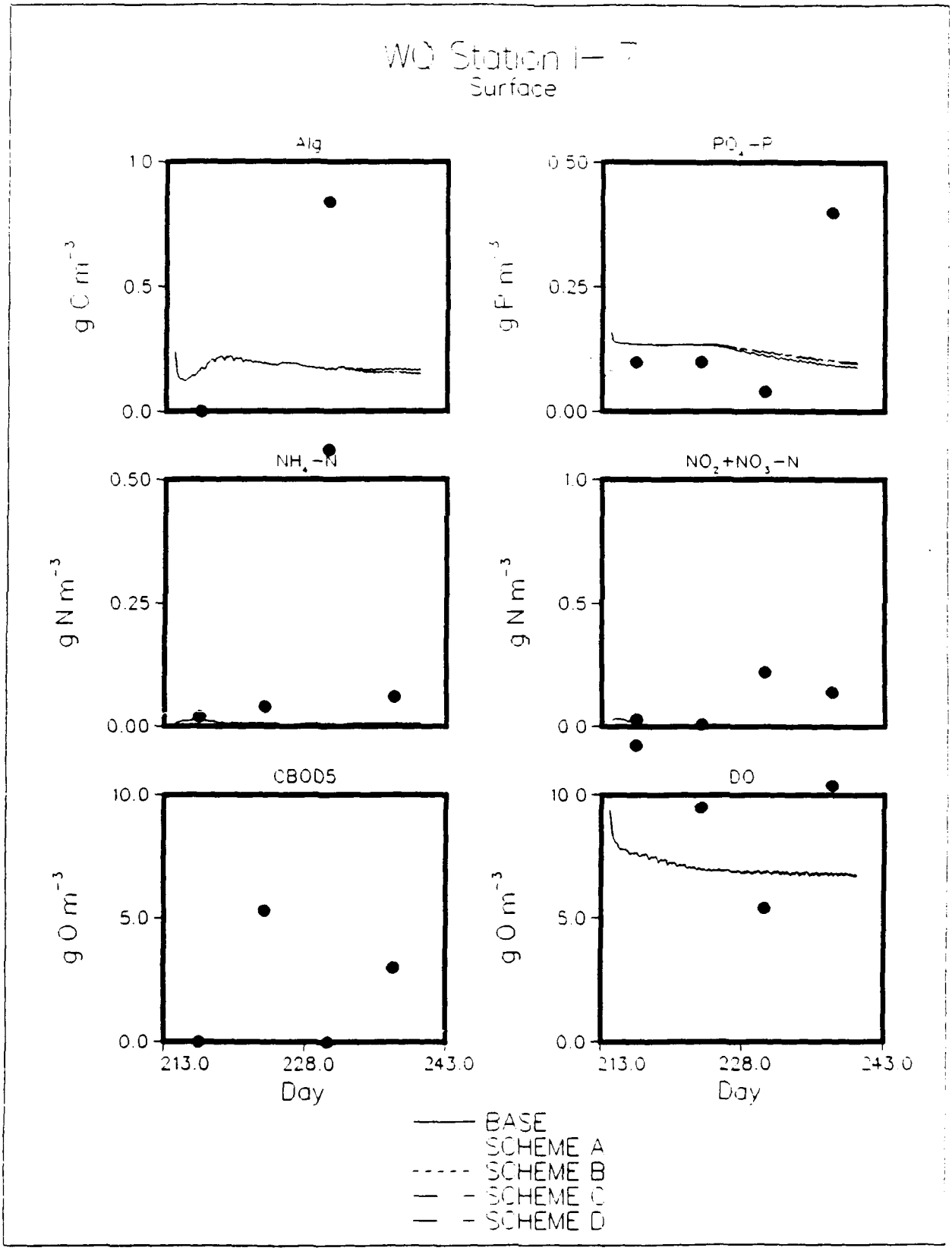

WQ Station 1– 7
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 268

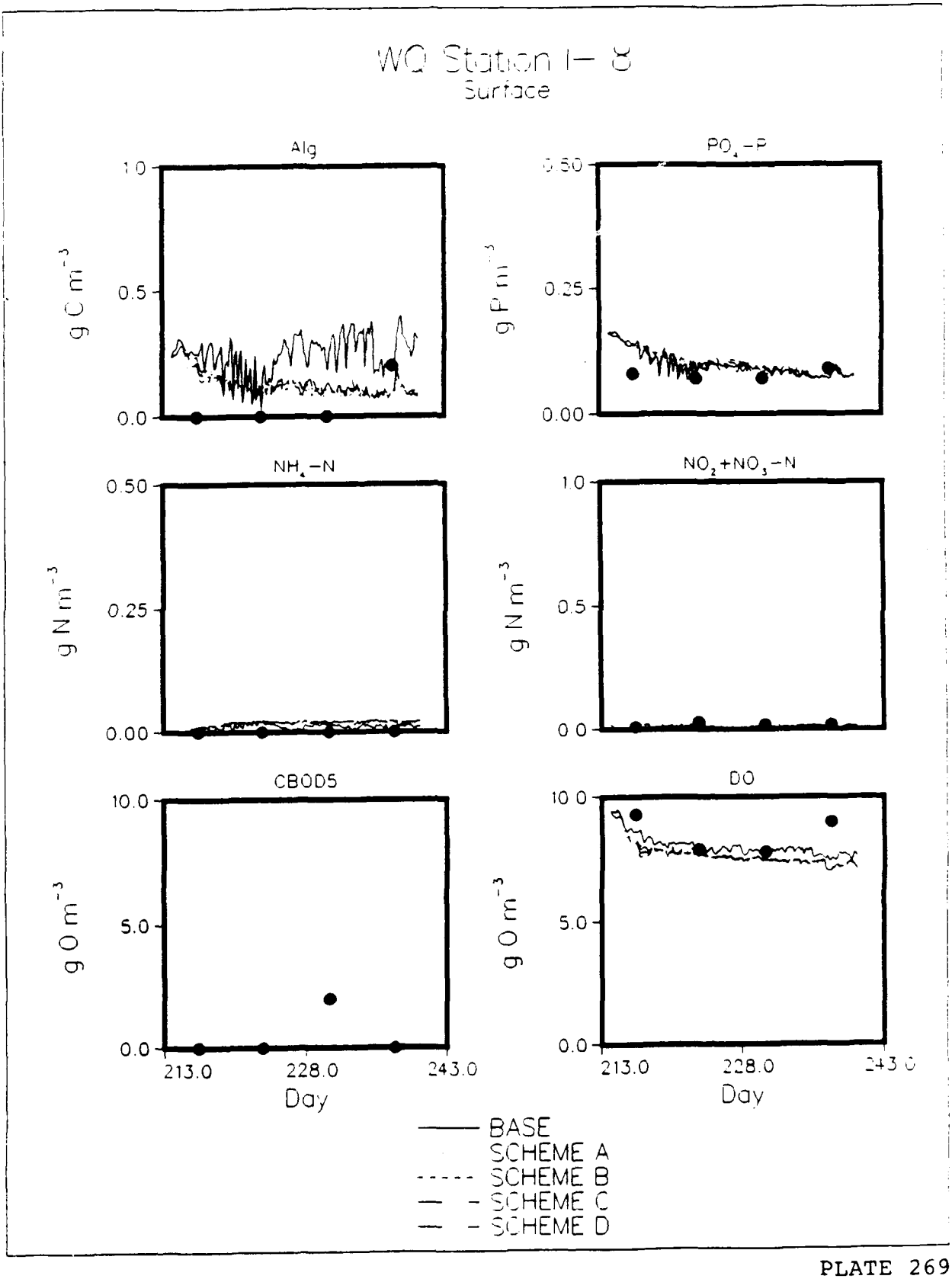

WQ Station I– α
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 269

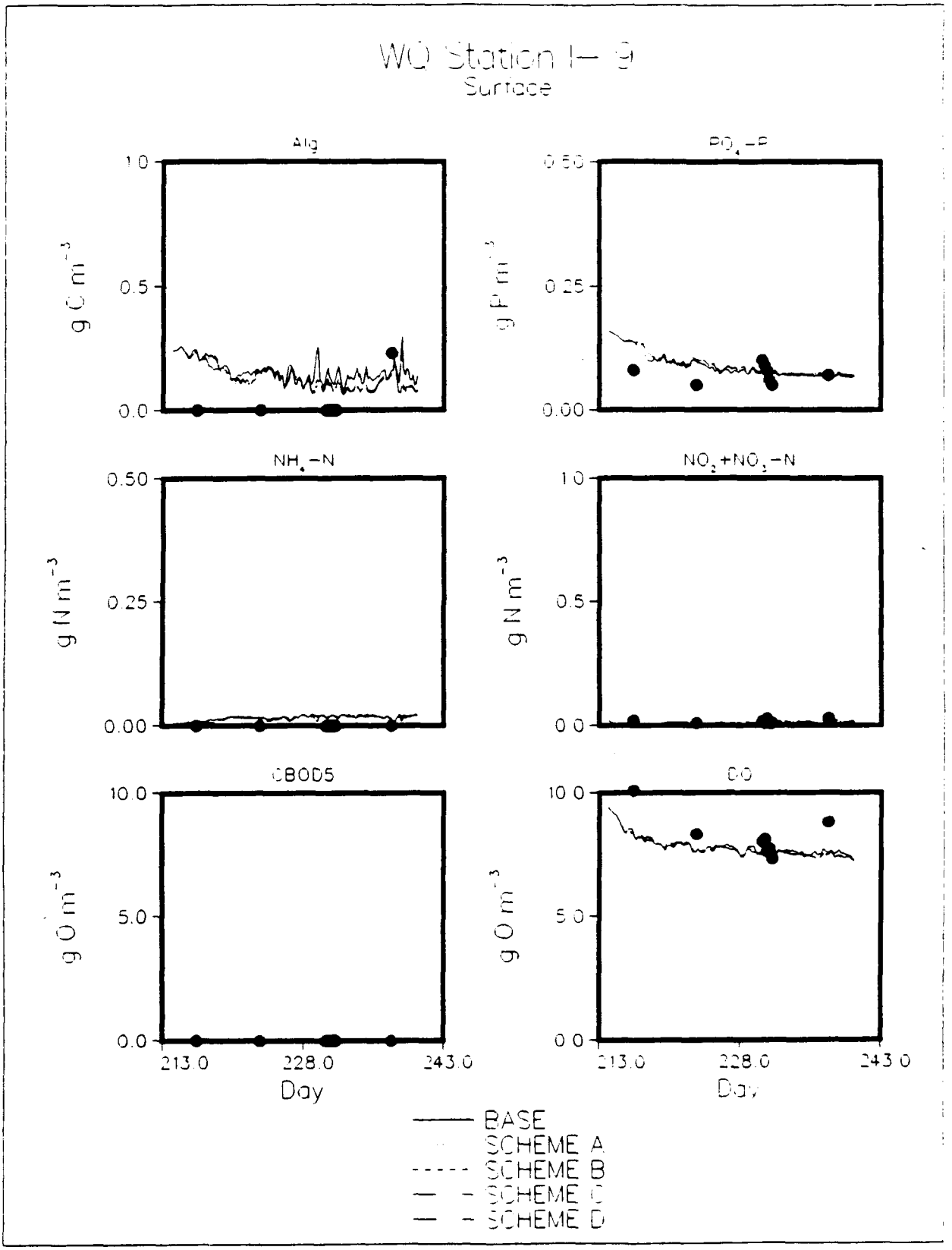

WQ Station I— 9
Surface
Alg
PO_4–P
NH_4–N
NO_2+NO_3–N
CBOD5
DO
g C m^{-3}
g P m^{-3}
g N m^{-3}
g N m^{-3}
g O m^{-3}
g O m^{-3}
1.0
0.5
0.0
0.50
0.25
0.00
0.50
0.25
0.00
1.0
0.5
0.0
10.0
5.0
0.0
10.0
5.0
0.0
213.0
228.0
243.0
Day
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 270

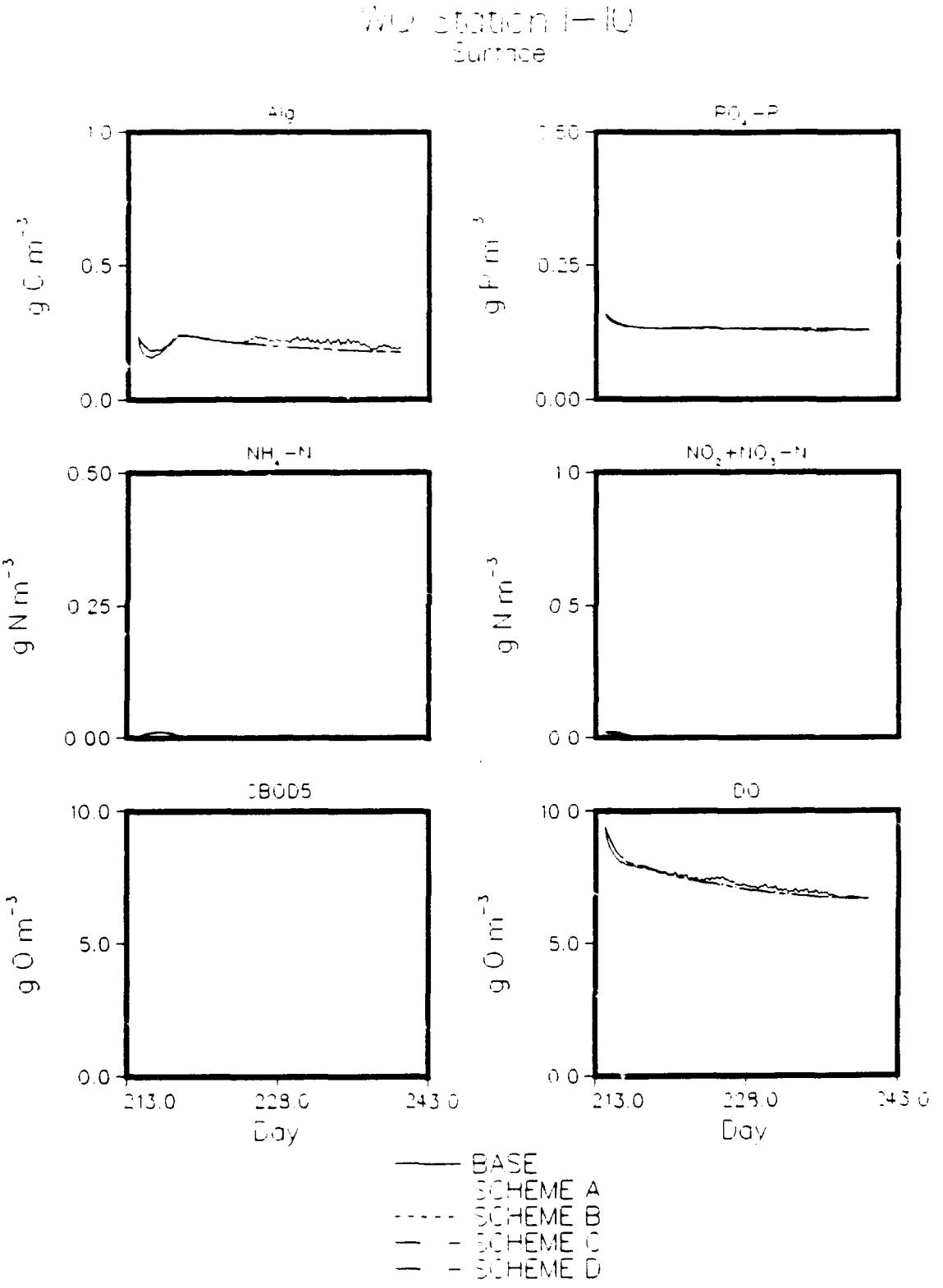

Surface
Alg
PO_4-P
NH_4-N
NO_2+NO_3-N
CBOD5
DO
g C m^{-3}
g P m^{-3}
g N m^{-3}
g O m^{-3}
1.0
0.5
0.0
0.50
0.25
0.00
10.0
5.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 271

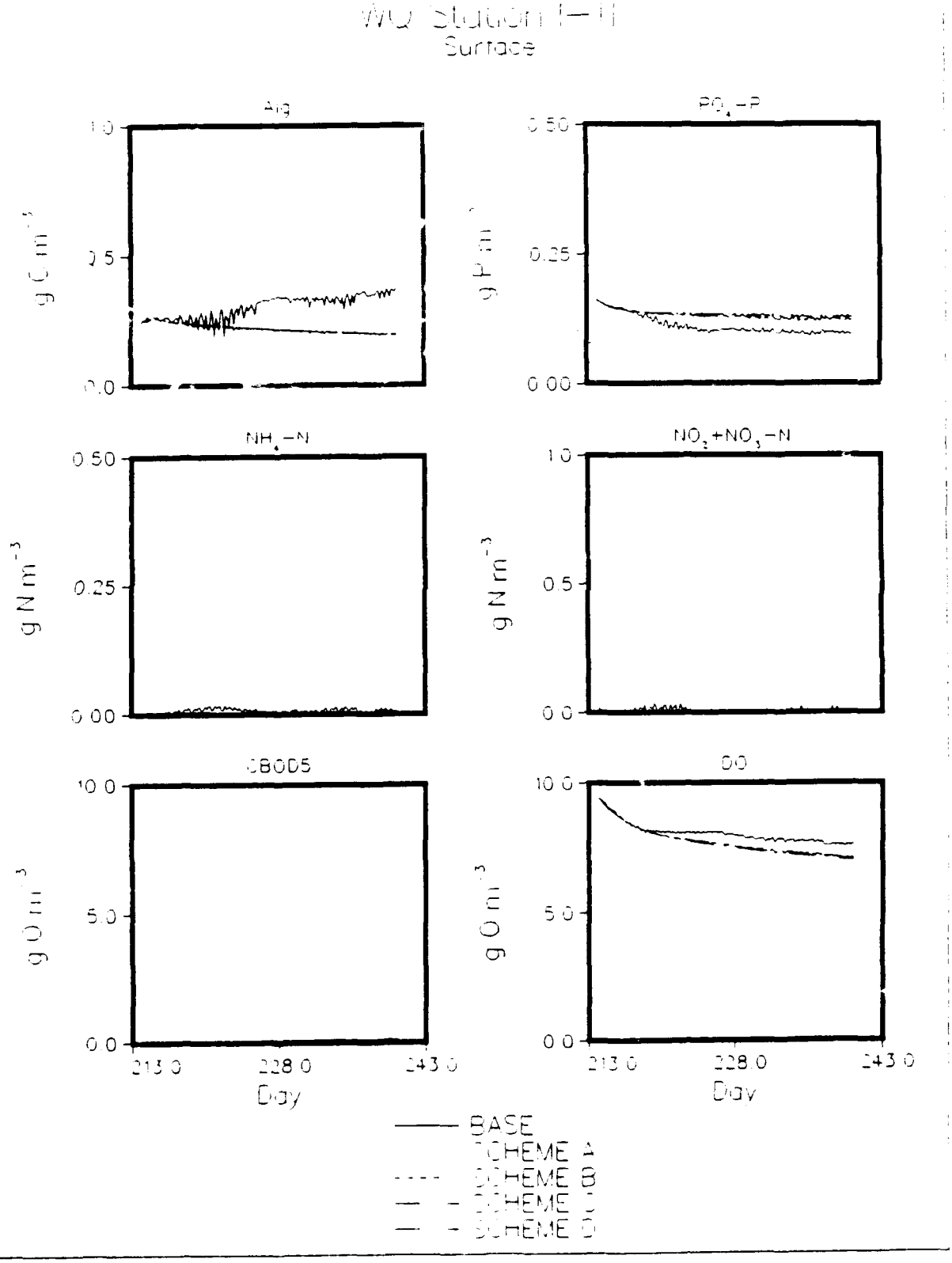

WQ Station I—H
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 272

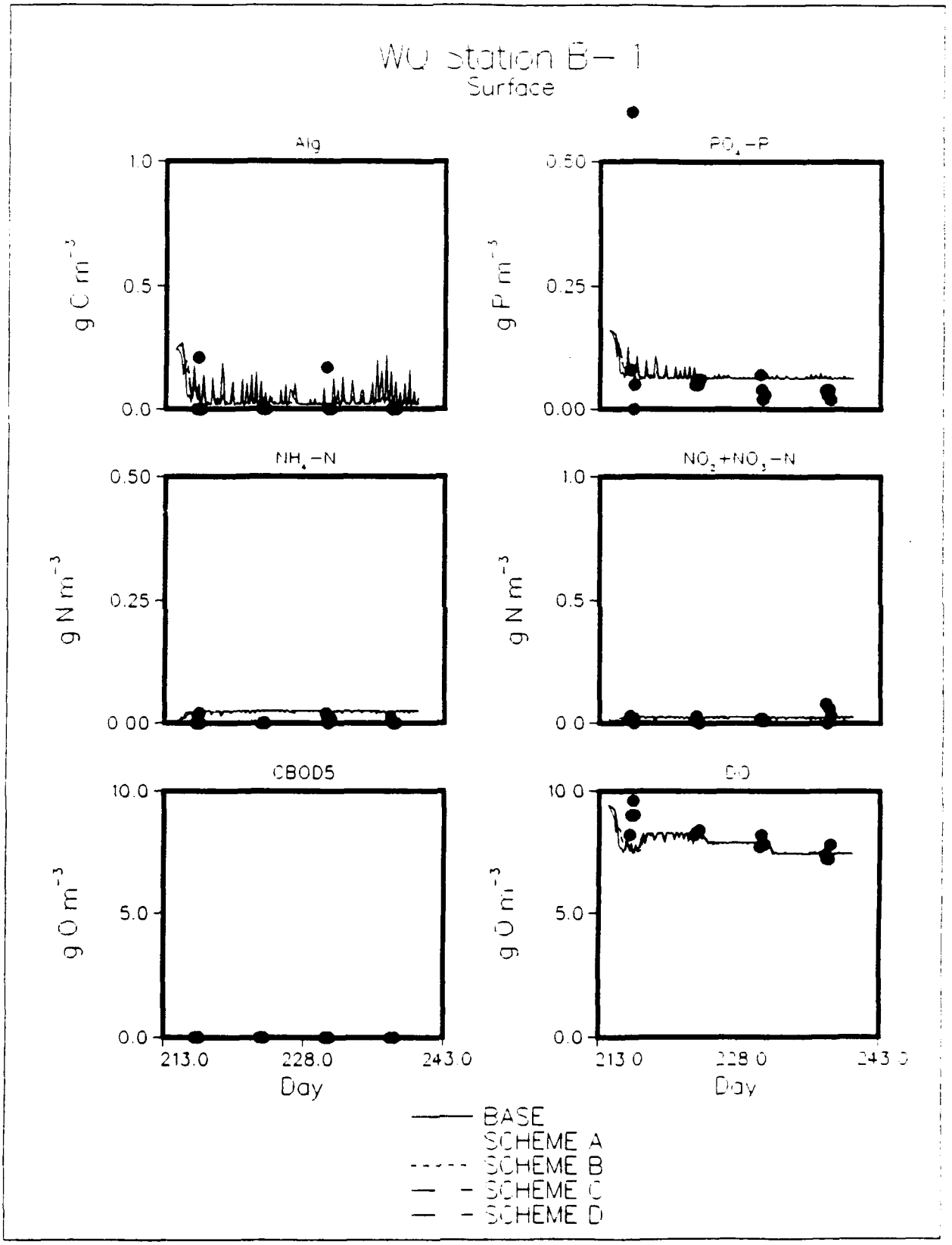

WQ Station B– 1
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 273

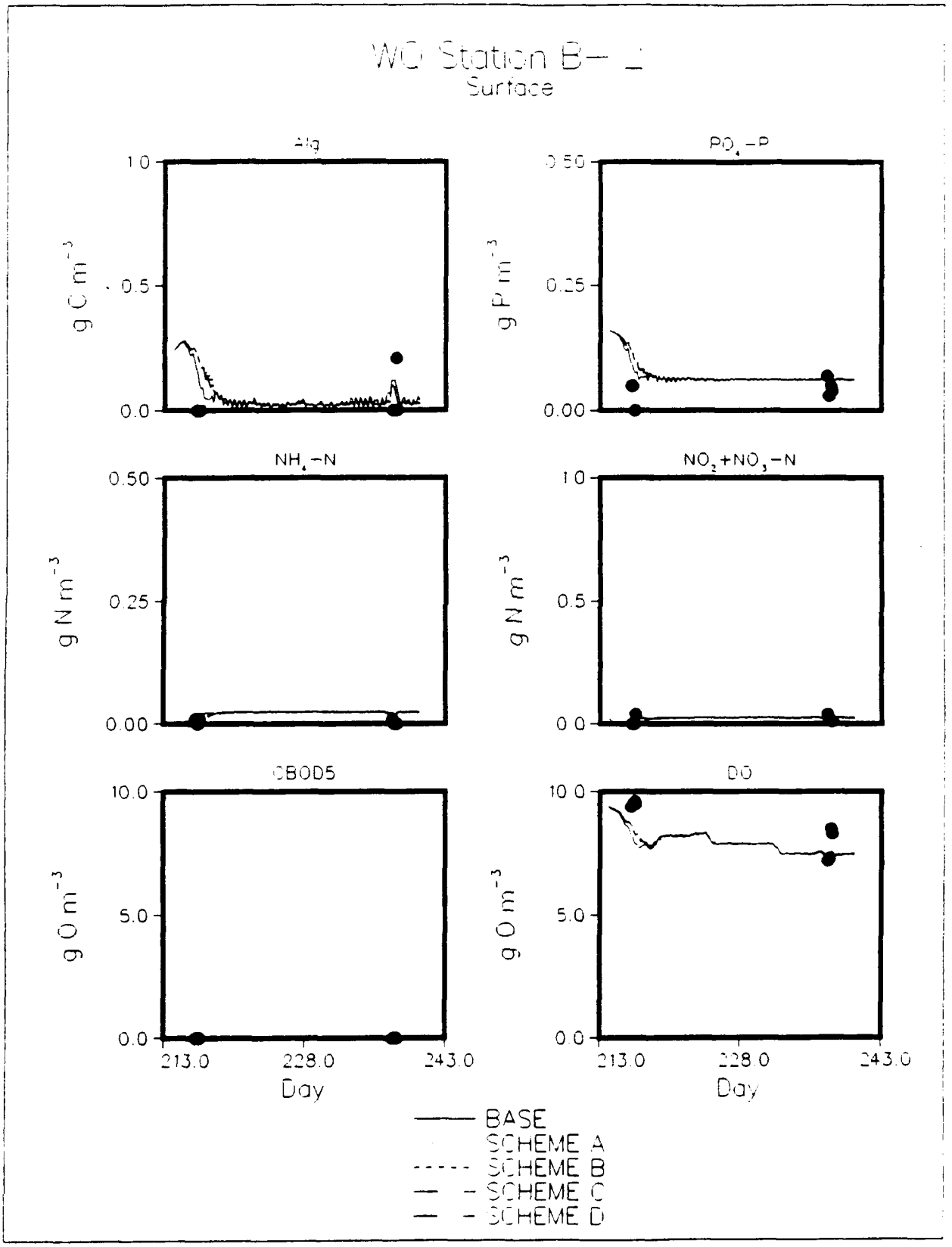

WQ Station B– 1
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 274

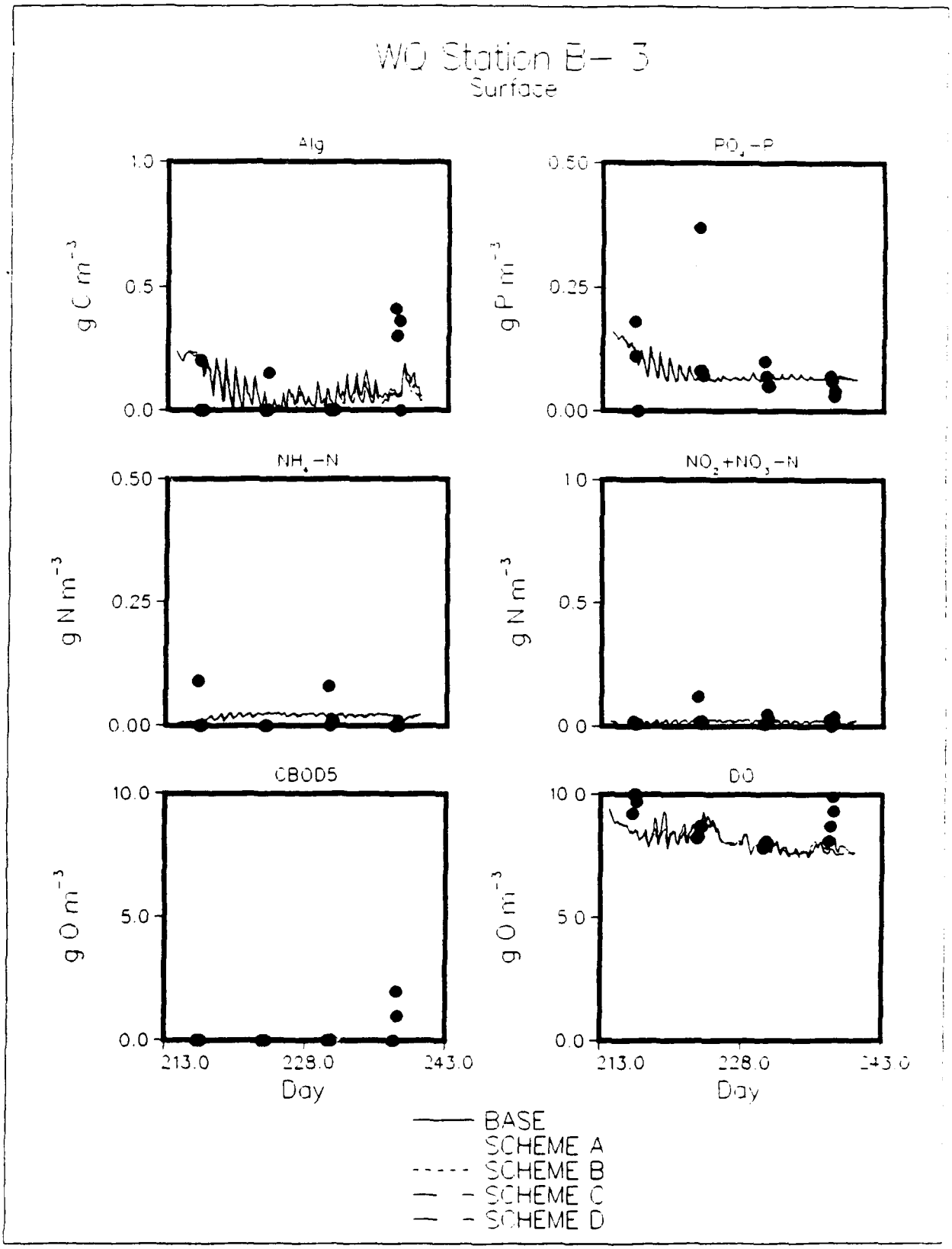

WQ Station B– 3
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 275

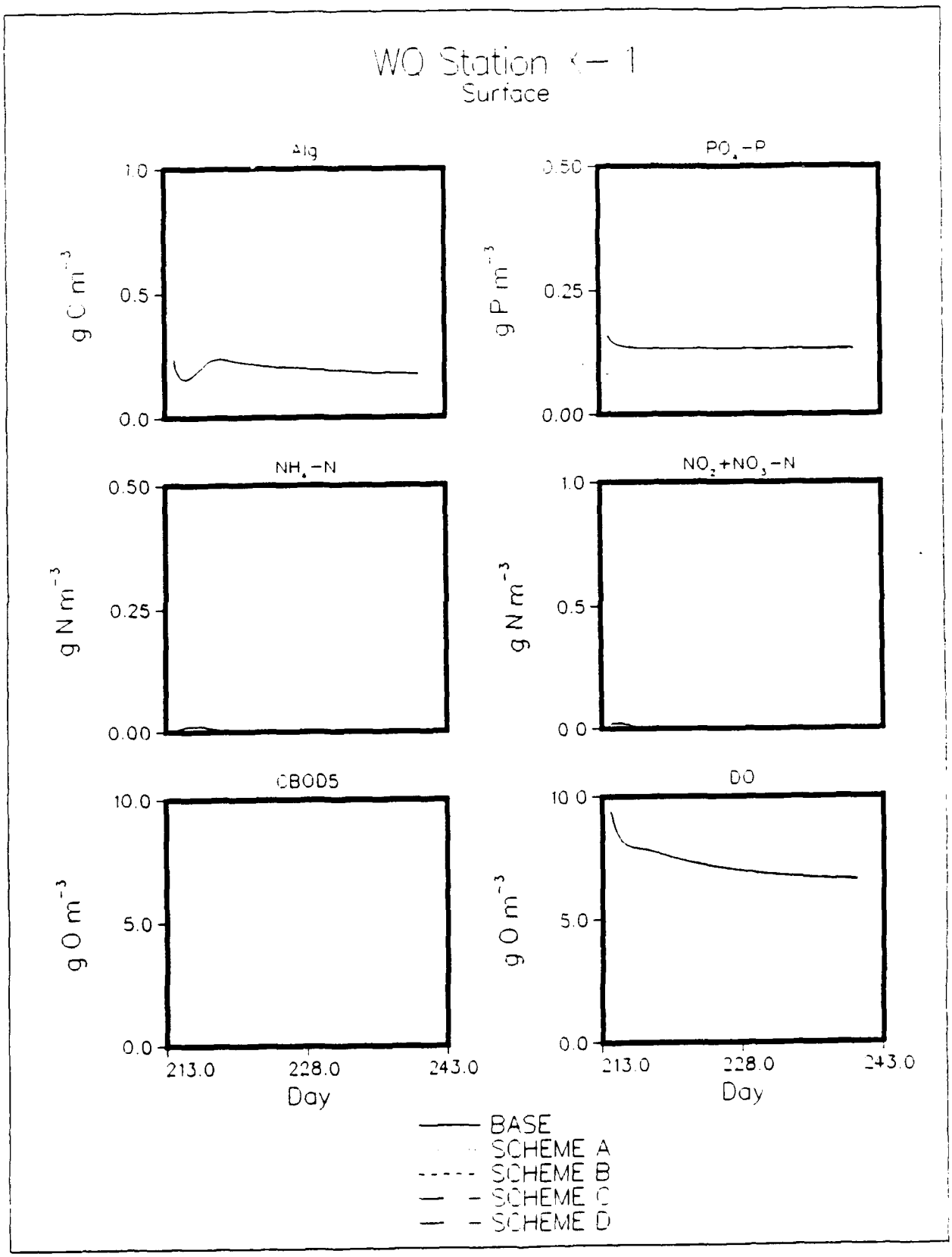

WQ Station < — 1
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO₄-P
g P m⁻³
0.50
0.25
0.00
NH₄-N
g N m⁻³
0.50
0.25
0.00
NO₂+NO₃-N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 276

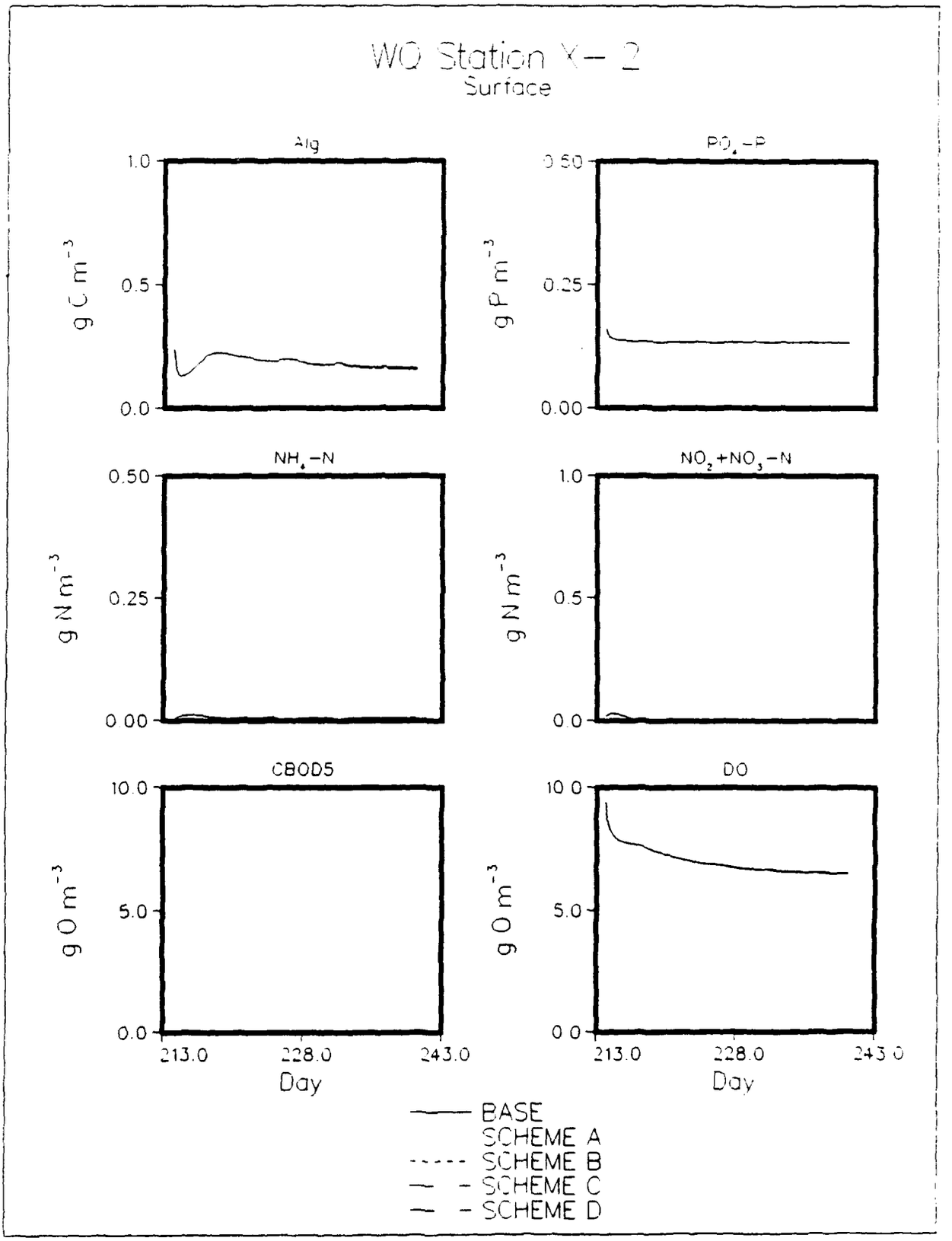

WQ Station X-- 2
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 277

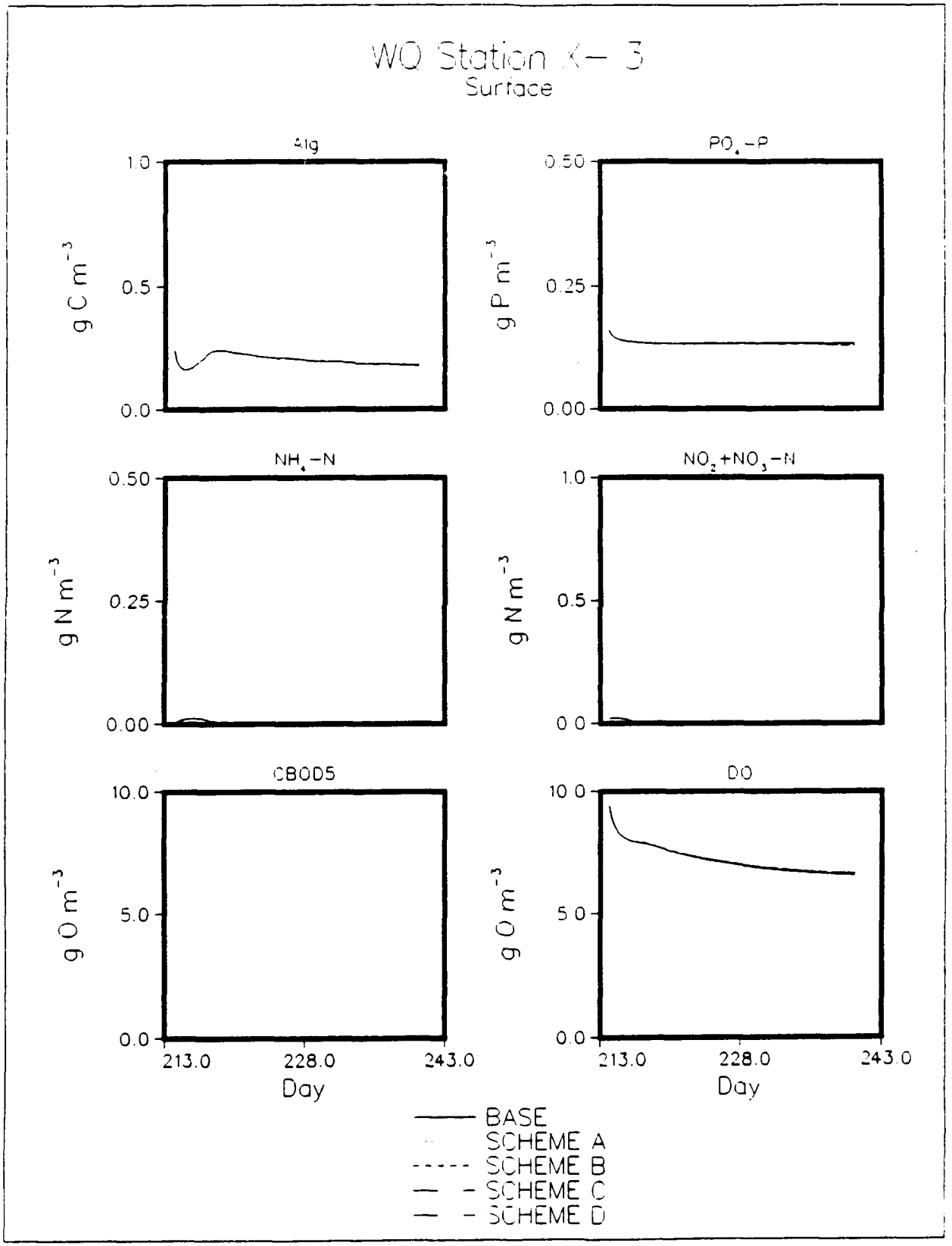

WQ Station K— 3
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO₄—P
g P m⁻³
0.50
0.25
0.00
NH₄—N
g N m⁻³
0.50
0.25
0.00
NO₂+NO₃—N
g N m⁻³
1.0
0.5
0 0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10 0
5 0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 278

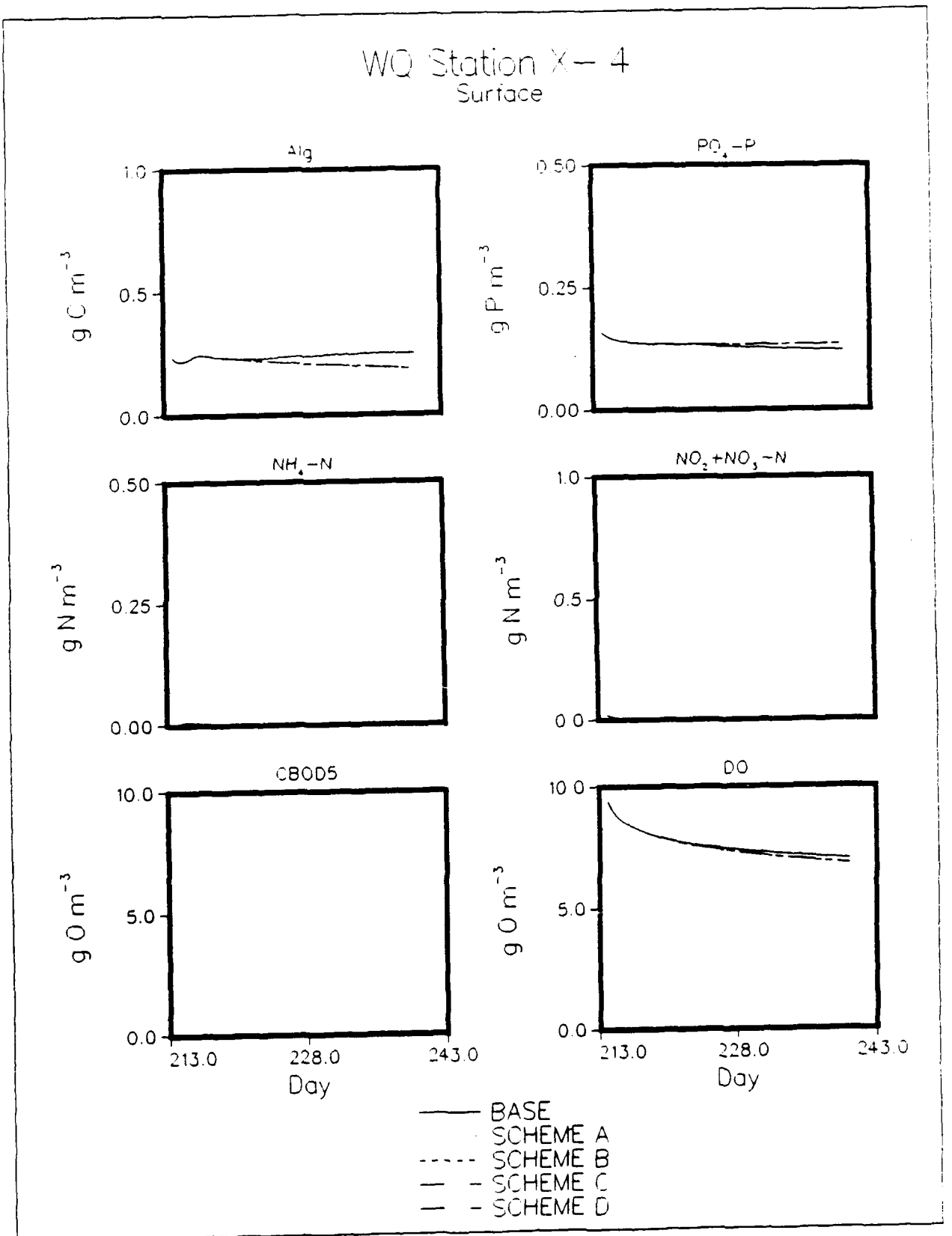

WQ Station X – 4
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 279

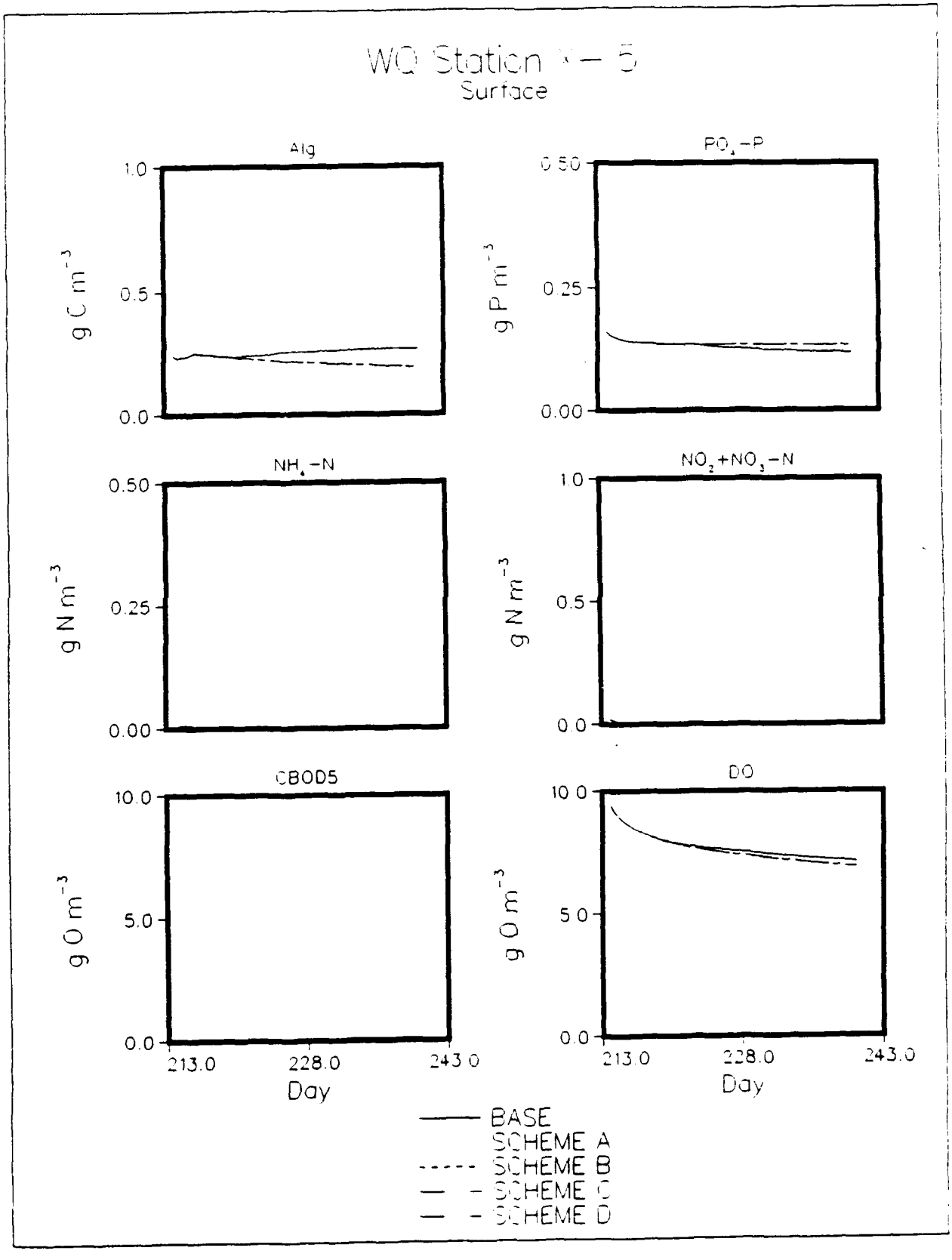

WQ Station X — 5
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4-P
g P m⁻³
0.50
0.25
0.00
NH4-N
g N m⁻³
0.50
0.25
0.00
NO2+NO3-N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 280

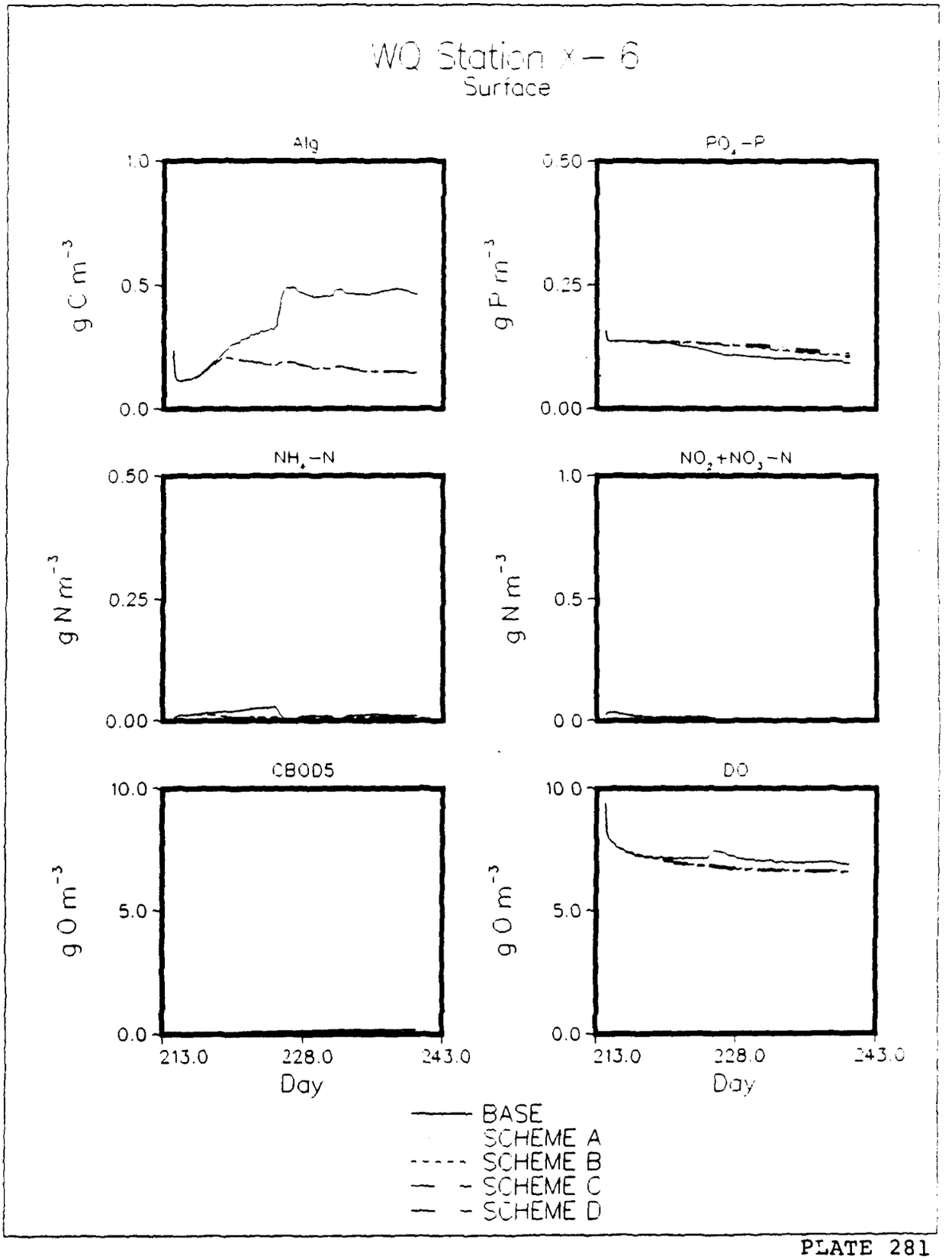

WQ Station x – 6
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0 0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10 0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 281

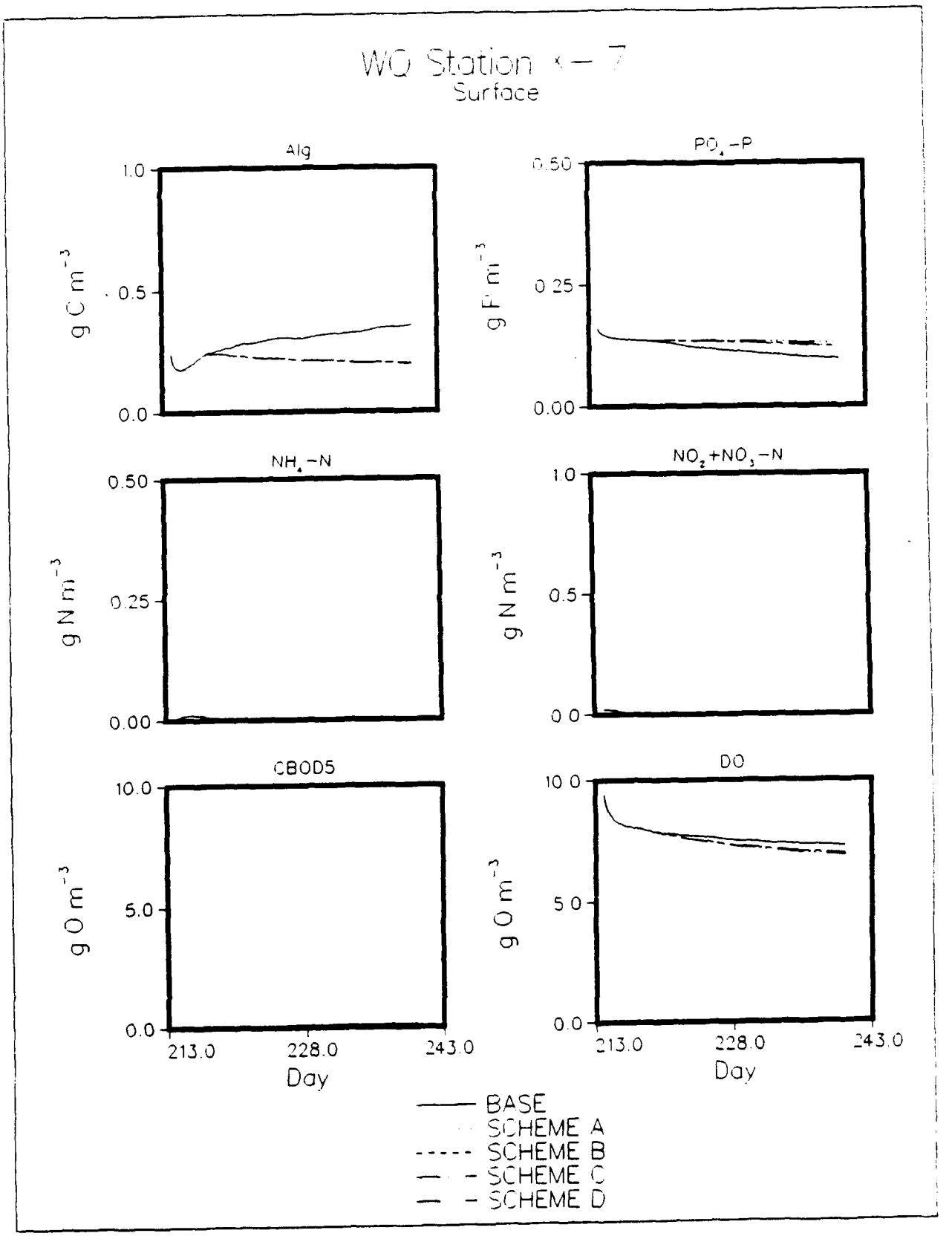

WQ Station x-7
Surface
Alg
1.0
0.5
0.0
g C m-3
PO4-P
0.50
0.25
0.00
g P m-3
NH4-N
0.50
0.25
0.00
g N m-3
NO2+NO3-N
1.0
0.5
0.0
g N m-3
CBOD5
10.0
5.0
0.0
g O m-3
DO
10.0
5.0
0.0
g O m-3
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 282

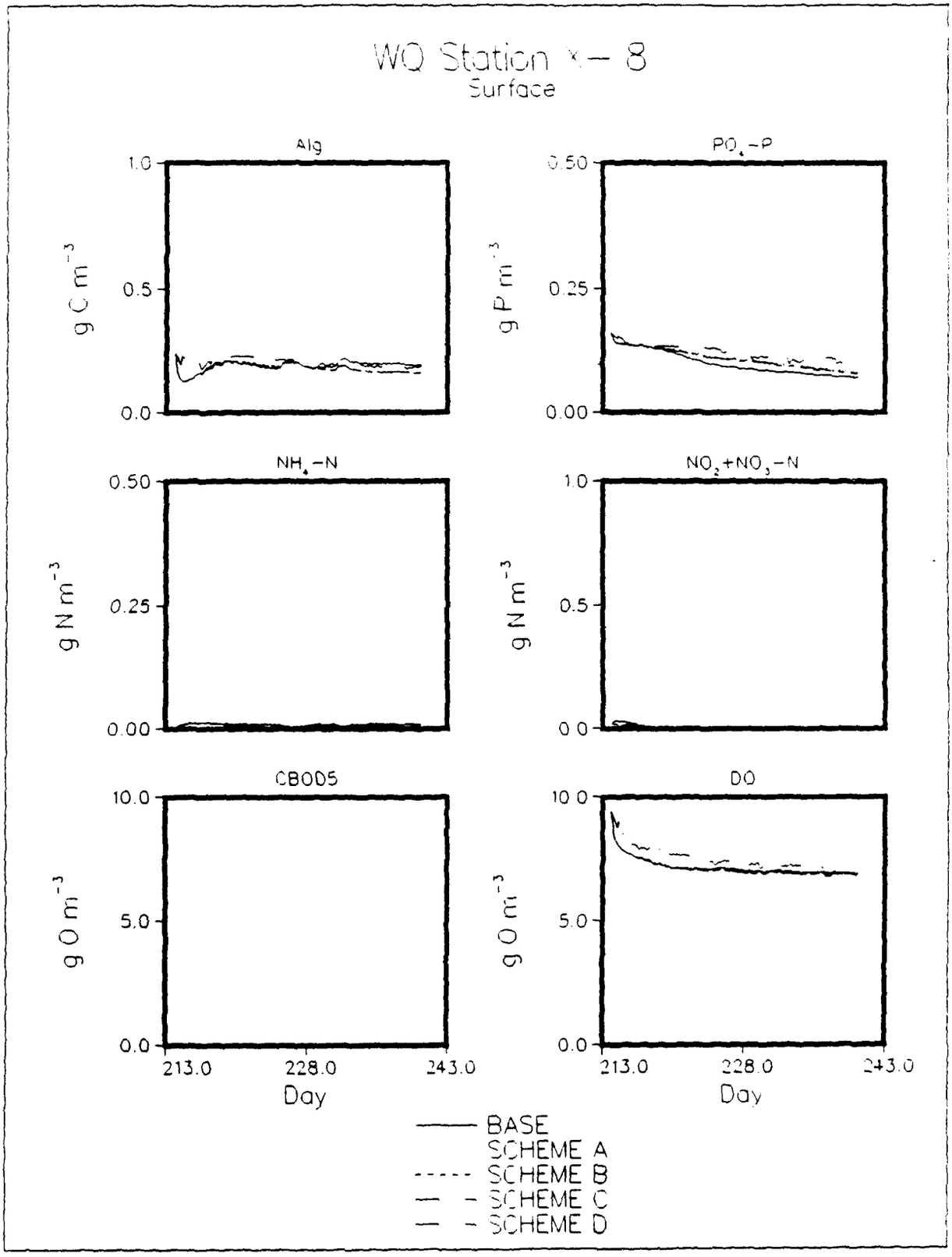

WQ Station X — 8
Surface
Alg
g C m⁻³
1.0
0.5
0.0
PO4-P
g P m⁻³
0.50
0.25
0.00
NH4-N
g N m⁻³
0.50
0.25
0.00
NO2+NO3-N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 283

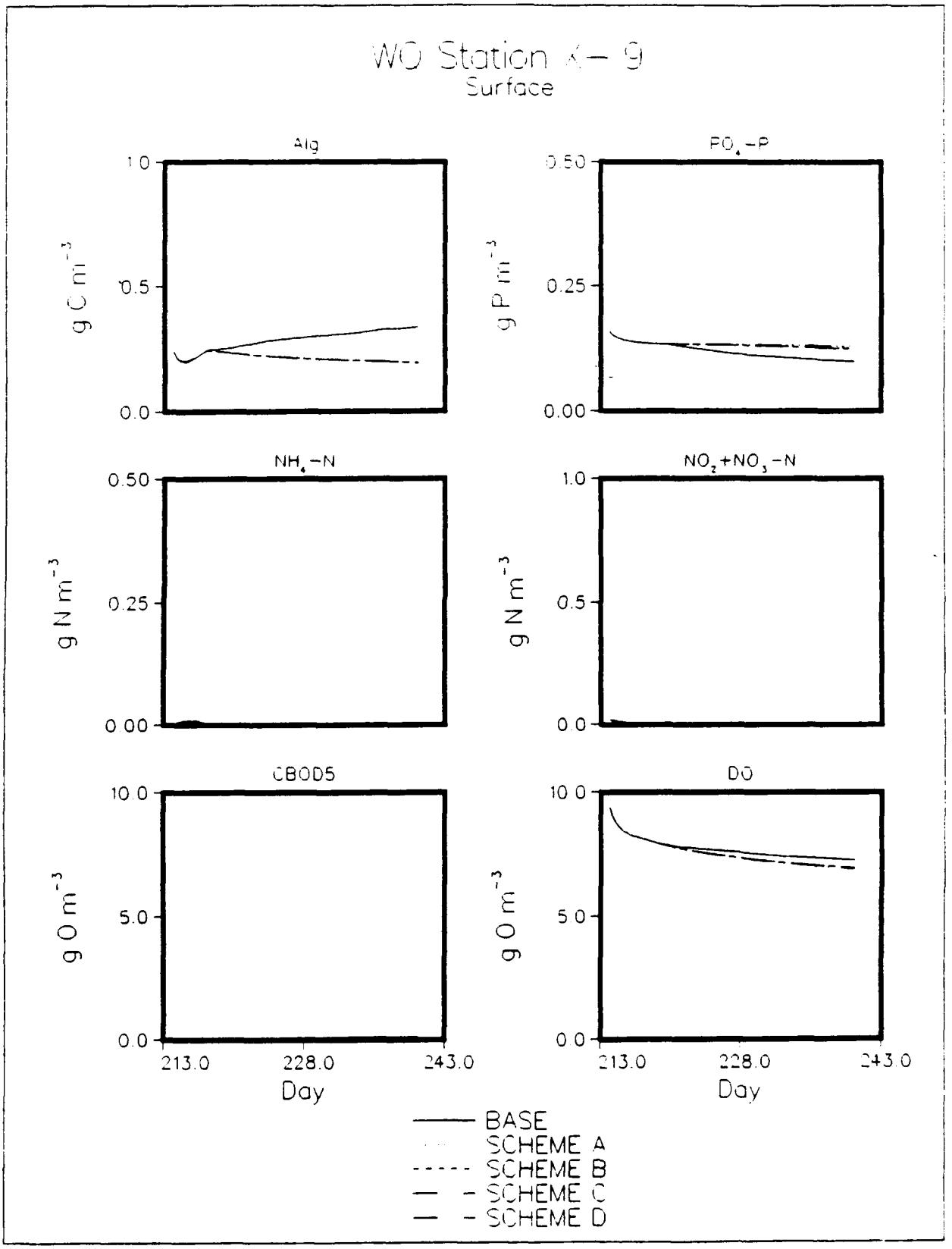
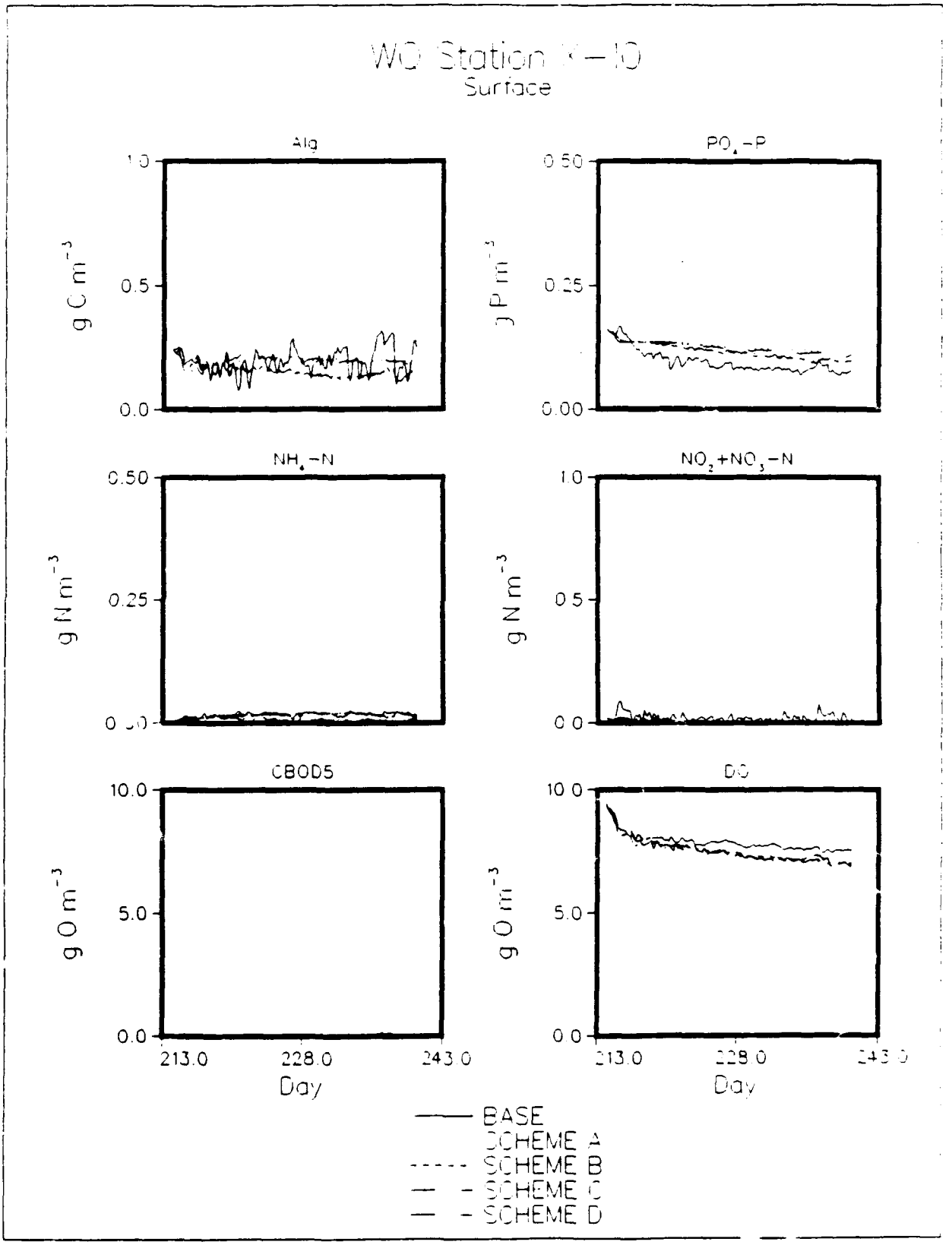

WQ Station 4 — 9
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 284


WQ Station K—10
Surface
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.0
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

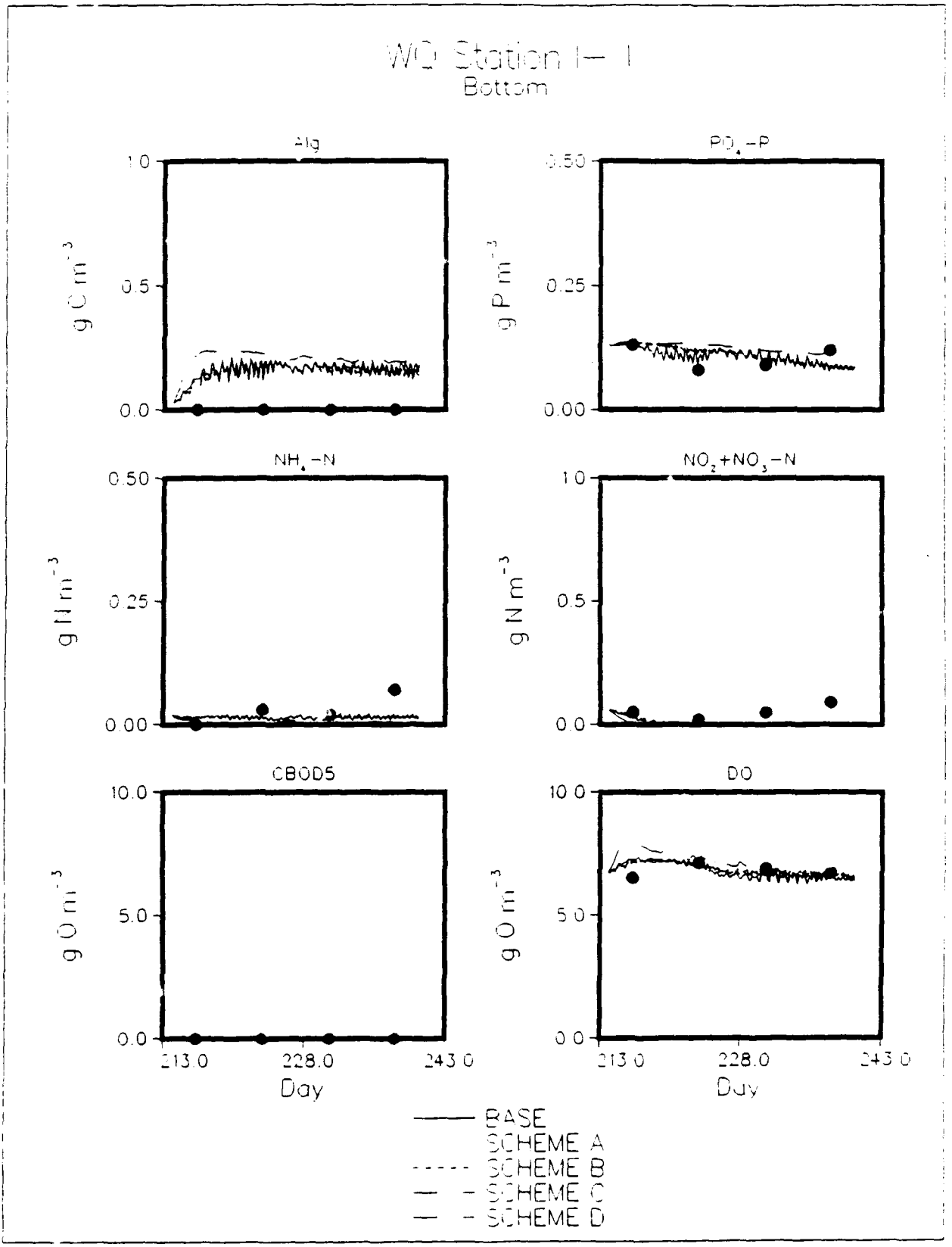

WQ Station 1— 1
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 286

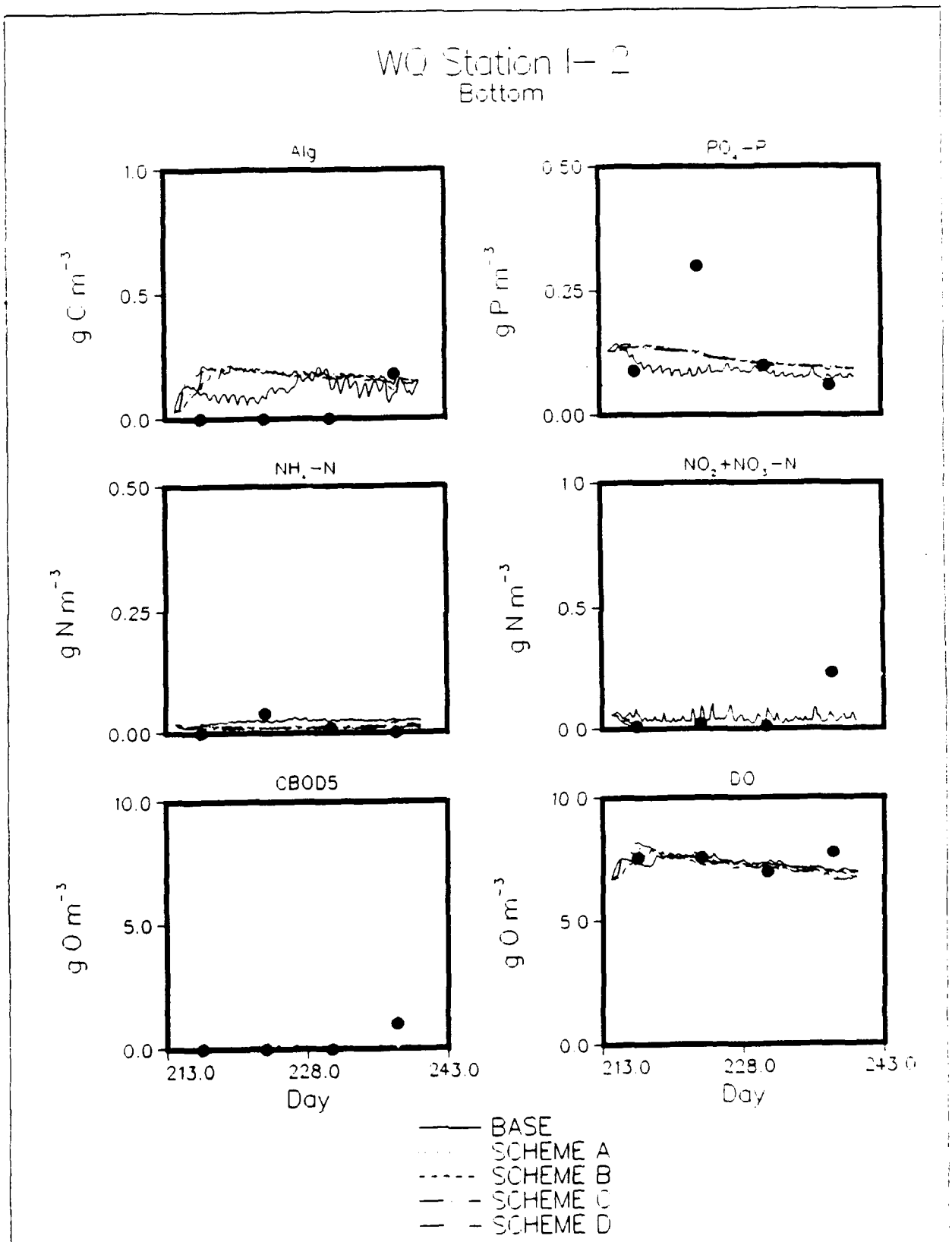

WQ Station 1– 2
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 287

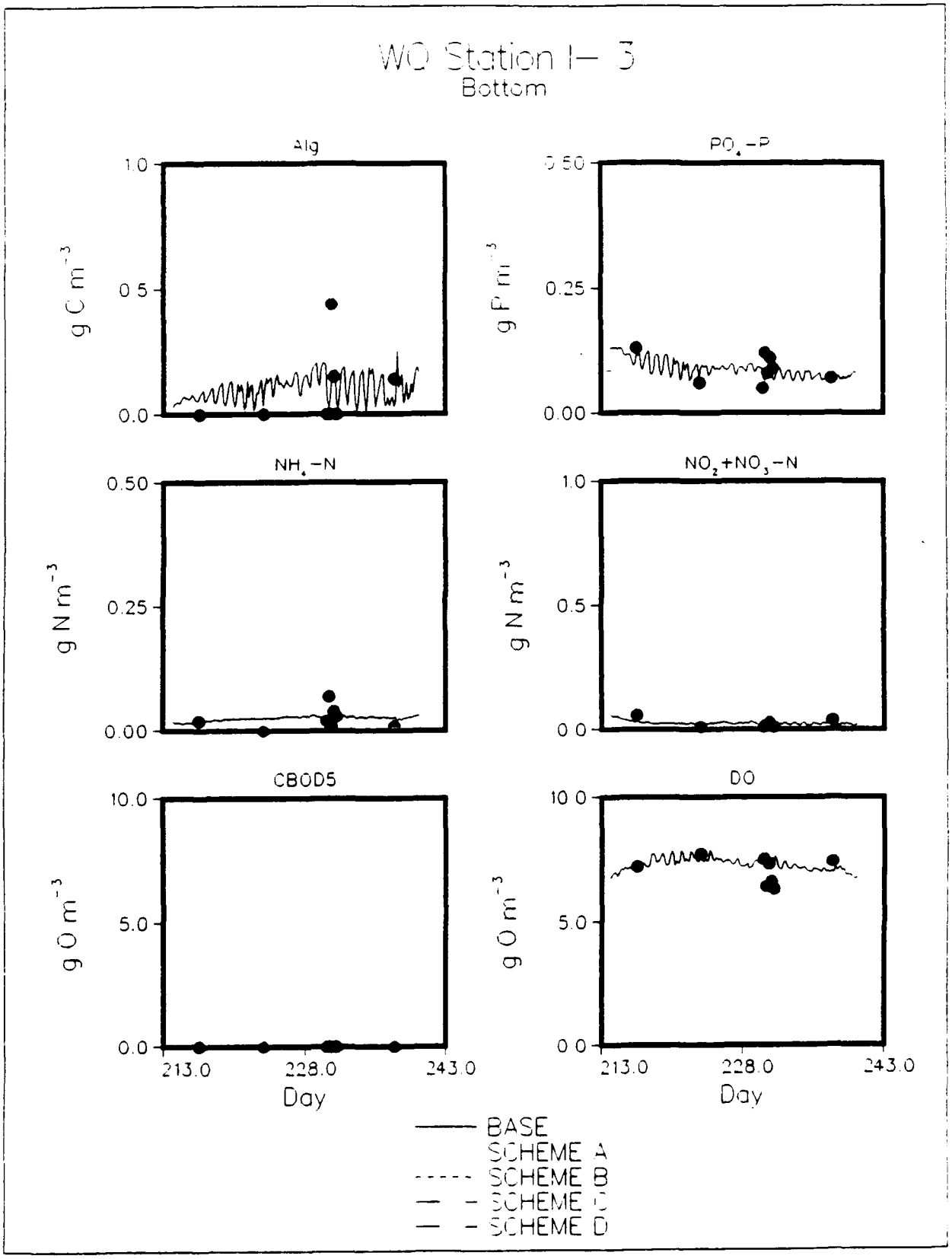

WQ Station I– 3
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4–P
g P m-3
0.50
0.25
0.00
NH4–N
g N m-3
0.50
0.25
0.00
NO2+NO3–N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 288

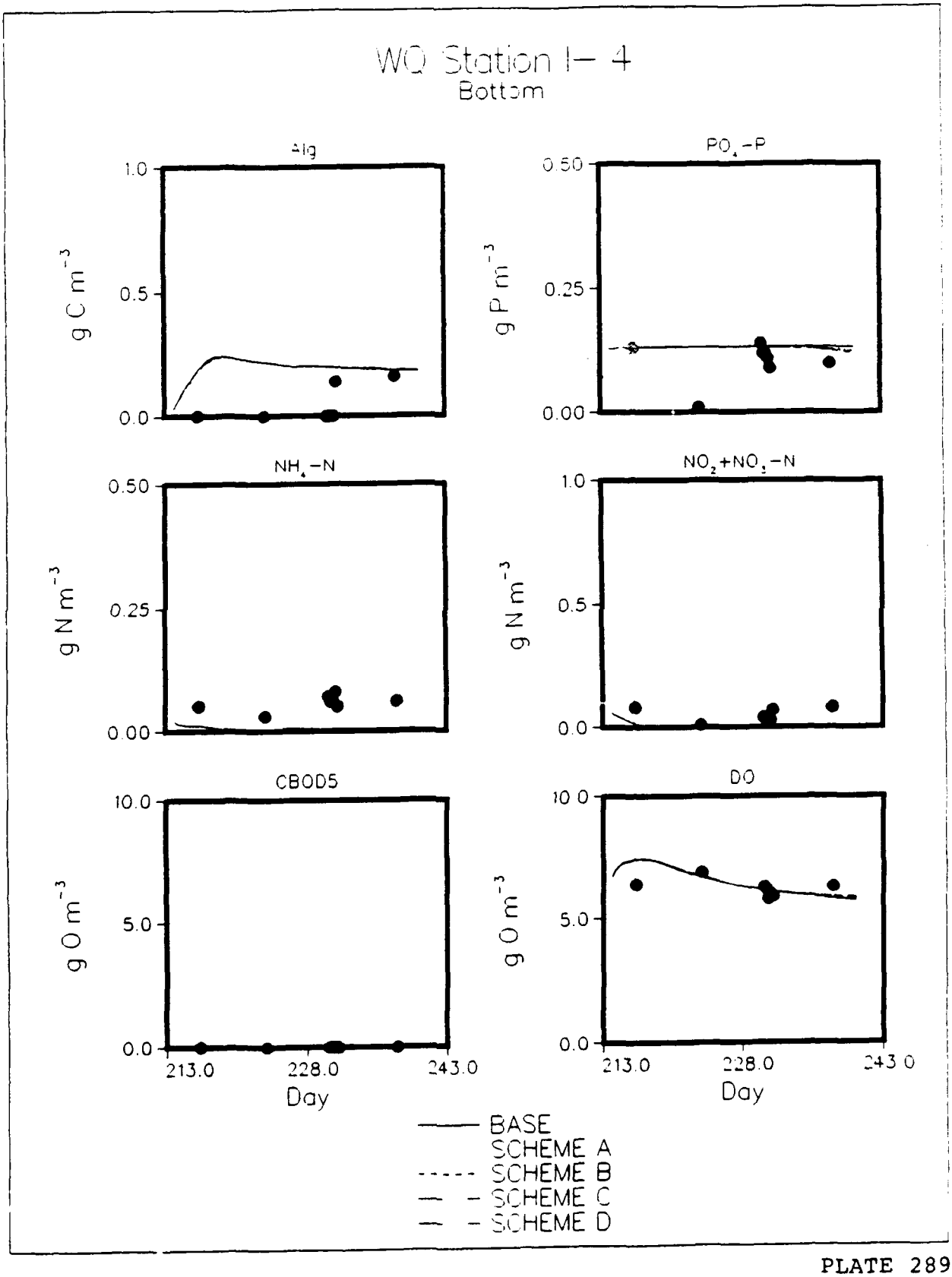

WQ Station I– 4
Bottom
Alg
g C m^{-3}
1.0
0.5
0.0
PO$_4$–P
g P m^{-3}
0.50
0.25
0.00
NH$_4$–N
g N m^{-3}
0.50
0.25
0.00
NO$_2$+NO$_3$–N
g N m^{-3}
1.0
0.5
0.0
CBOD5
g O m^{-3}
10.0
5.0
0.0
DO
g O m^{-3}
10 0
5.0
0.0
213.0
228.0
243.0
Day
213.0
228.0
243 0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 289

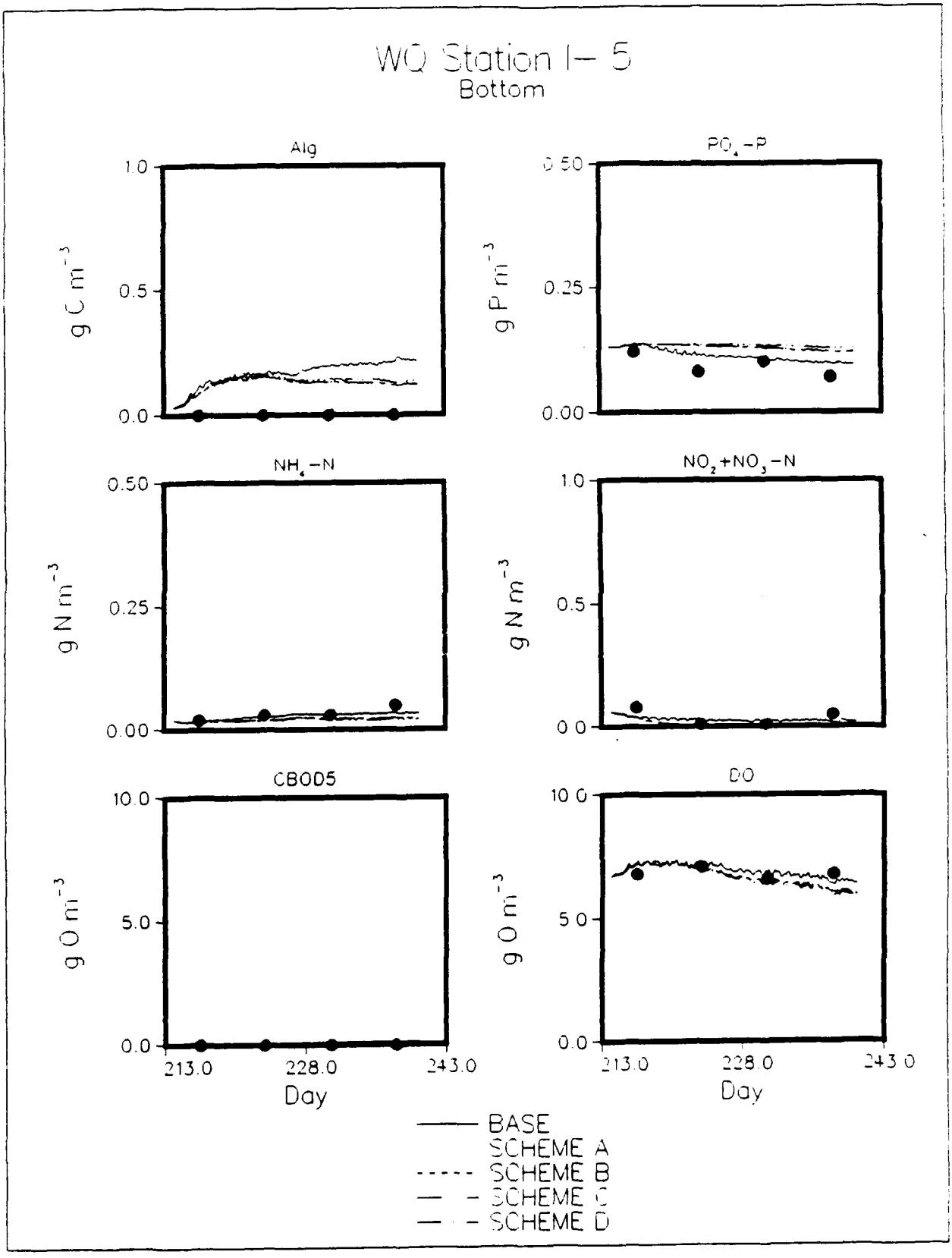

WQ Station I– 5
Bottom
Alg
g C m^{-3}
1.0
0.5
0.0
PO_4–P
g P m^{-3}
0.50
0.25
0.00
NH_4–N
g N m^{-3}
0.50
0.25
0.00
NO_2+NO_3–N
g N m^{-3}
1.0
0.5
0.0
CBOD5
g O m^{-3}
10.0
5.0
0.0
DO
g O m^{-3}
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 290

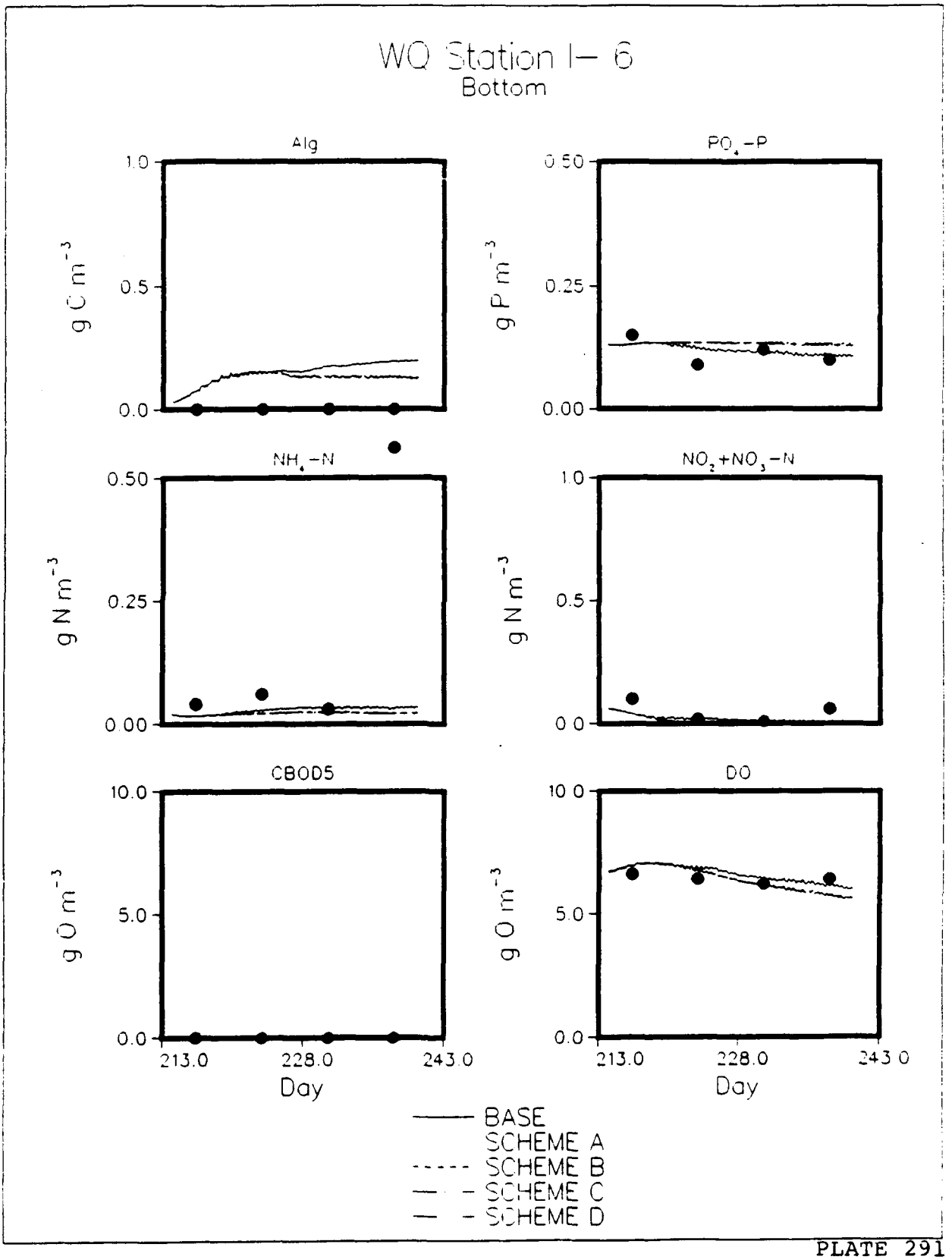

WQ Station I– 6
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4–P
g P m-3
0.50
0.25
0.00
NH4–N
g N m-3
0.50
0.25
0.00
NO2+NO3–N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 291

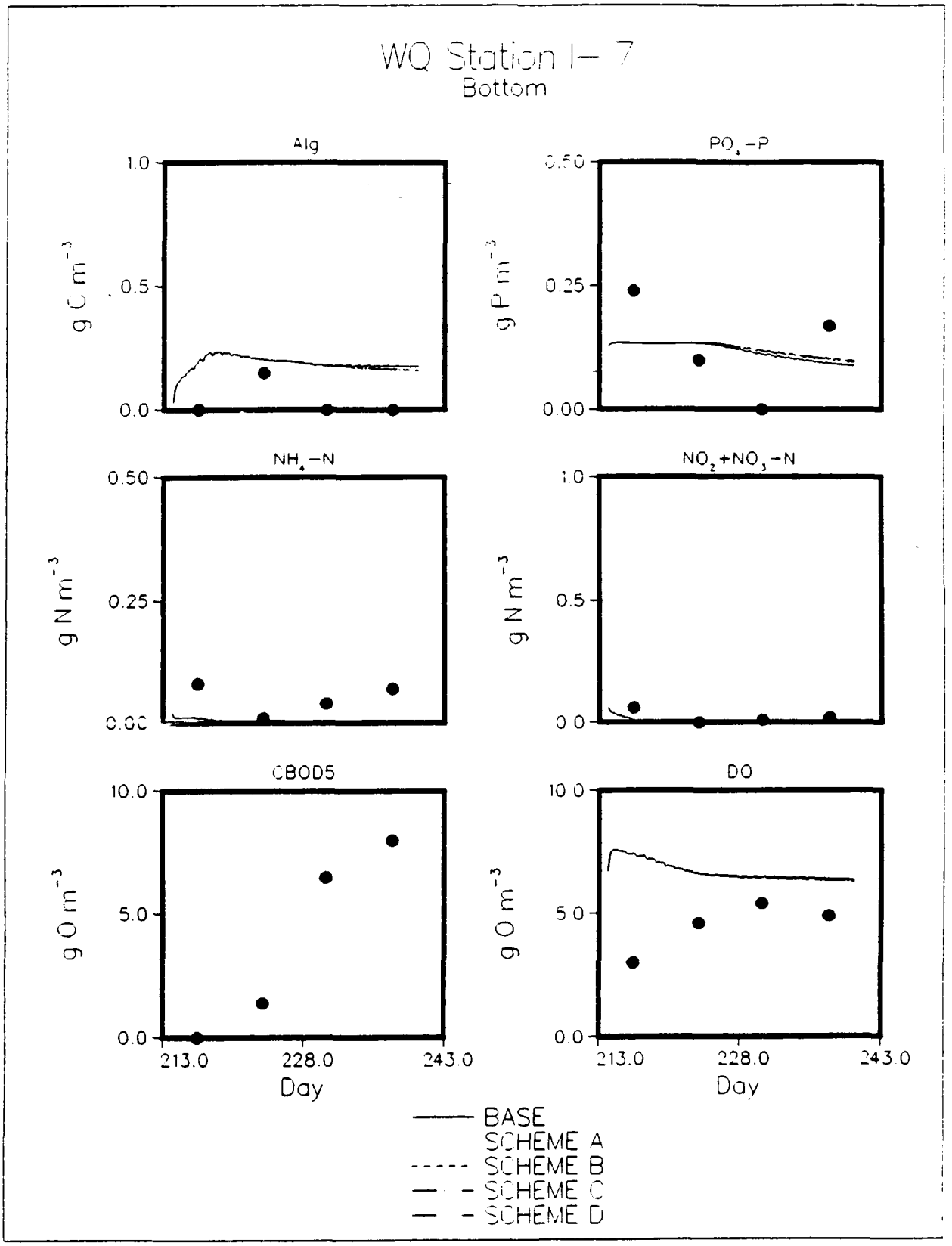

WQ Station I– 7
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 292

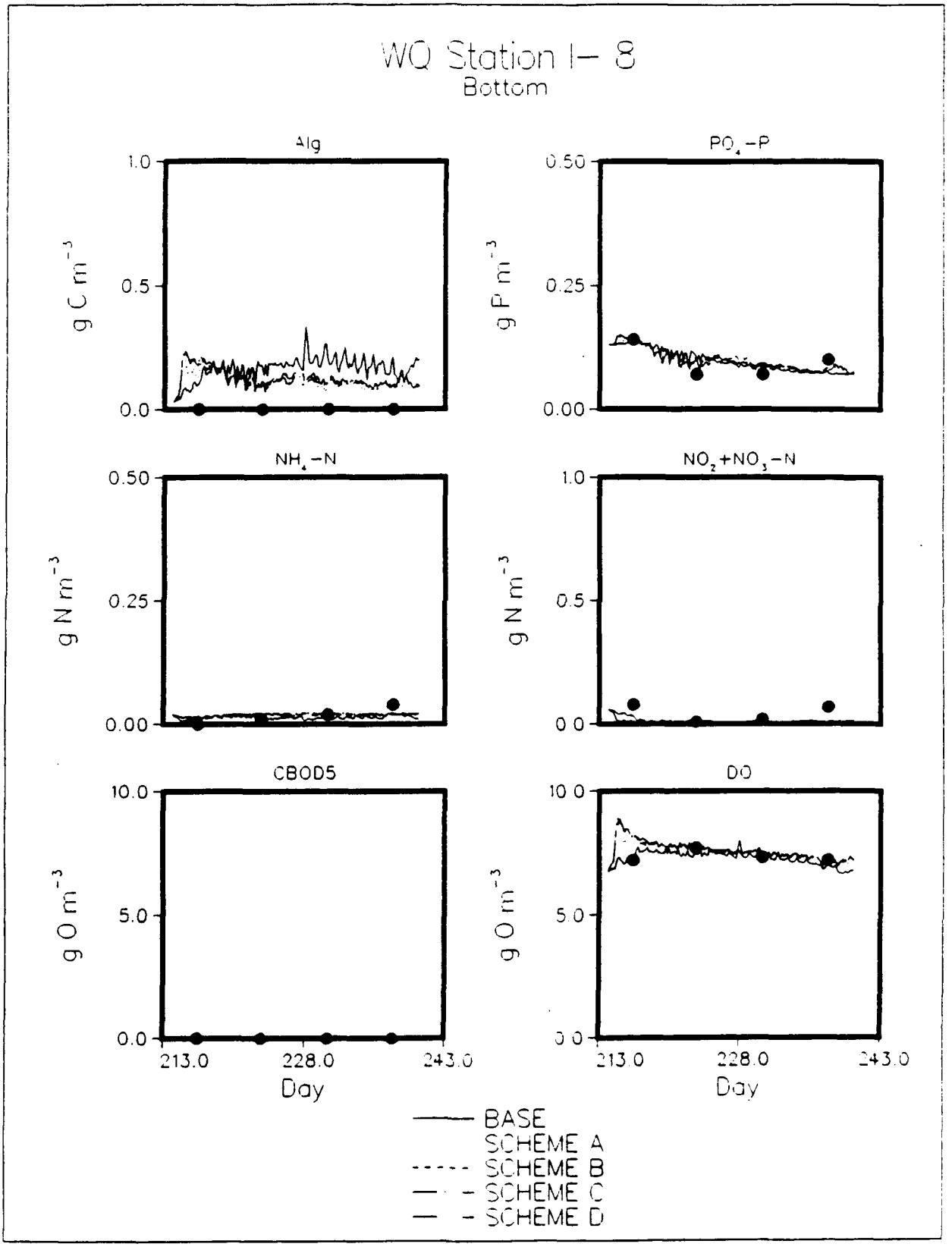

WQ Station I– 8
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 293

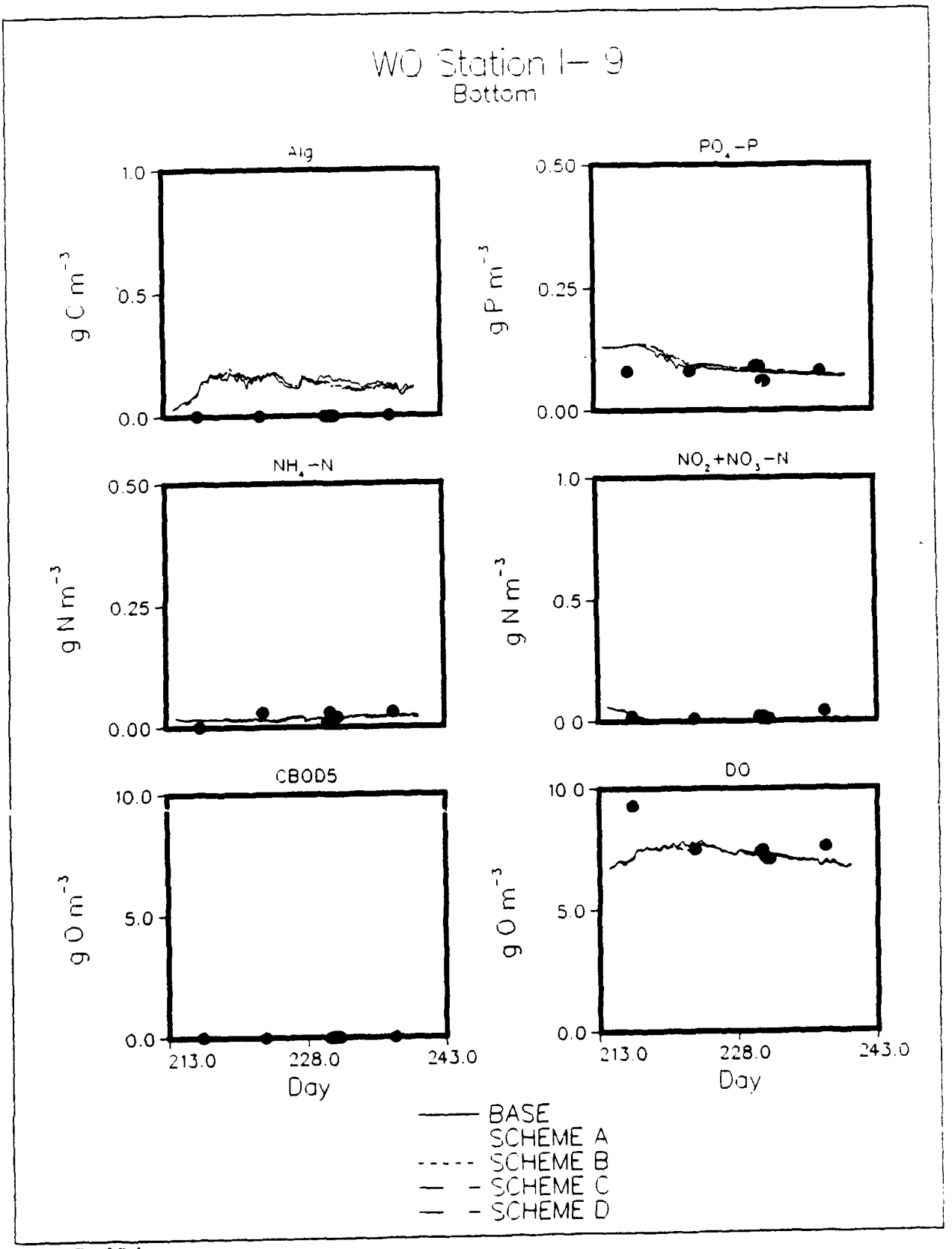

WQ Station I– 9
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0 0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 294

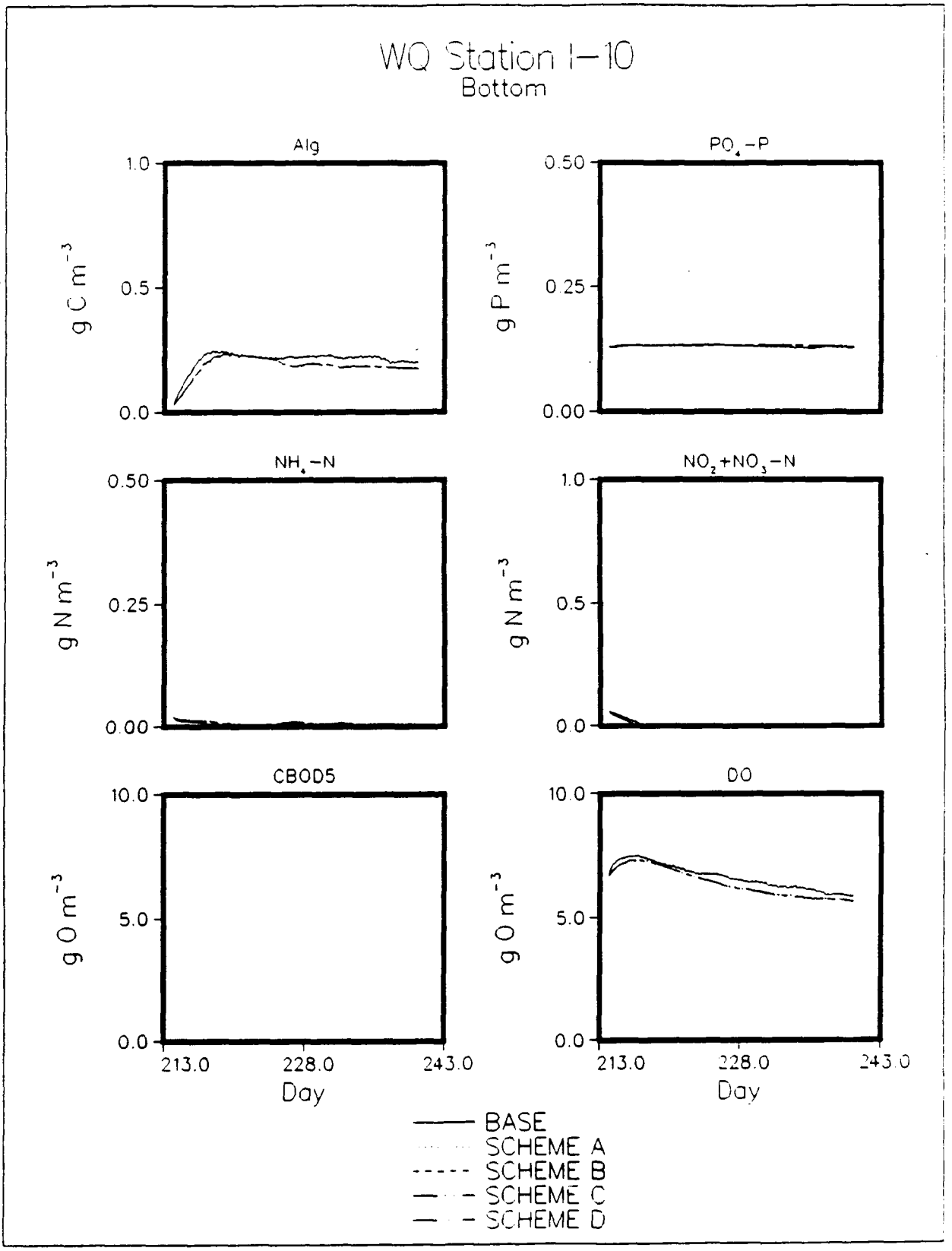

WQ Station I-10
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 295

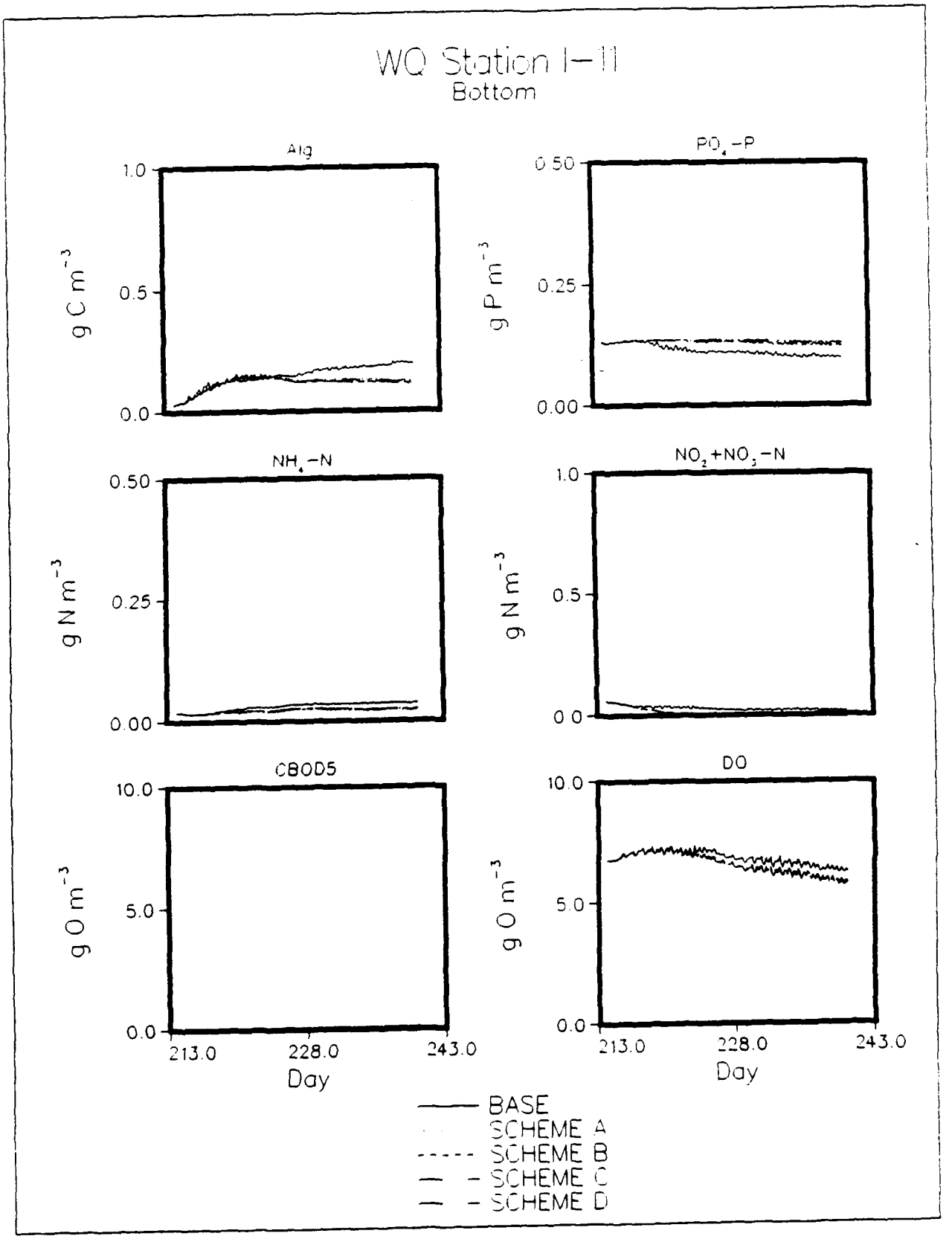

WQ Station I–II
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 296

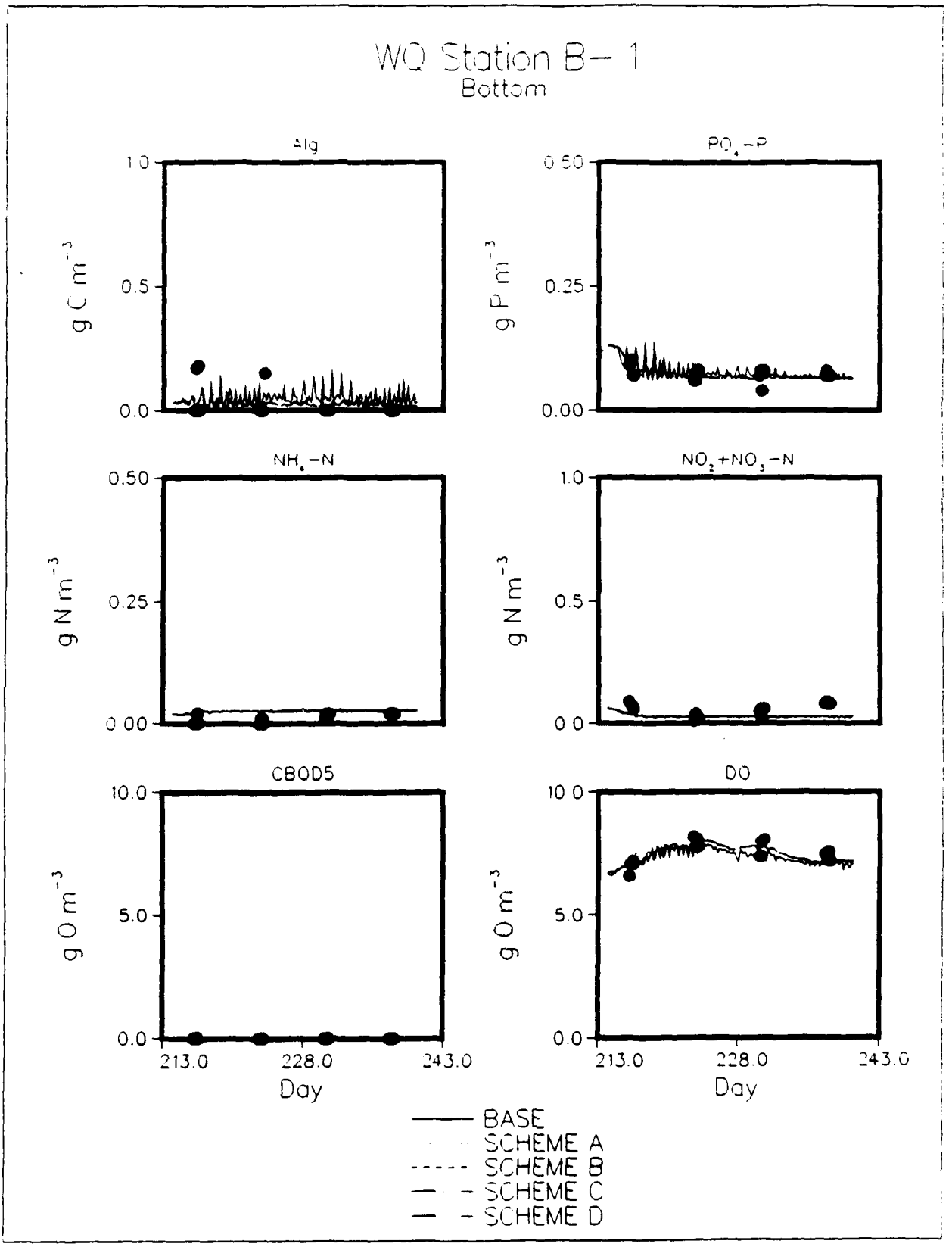

WQ Station B– 1
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 297

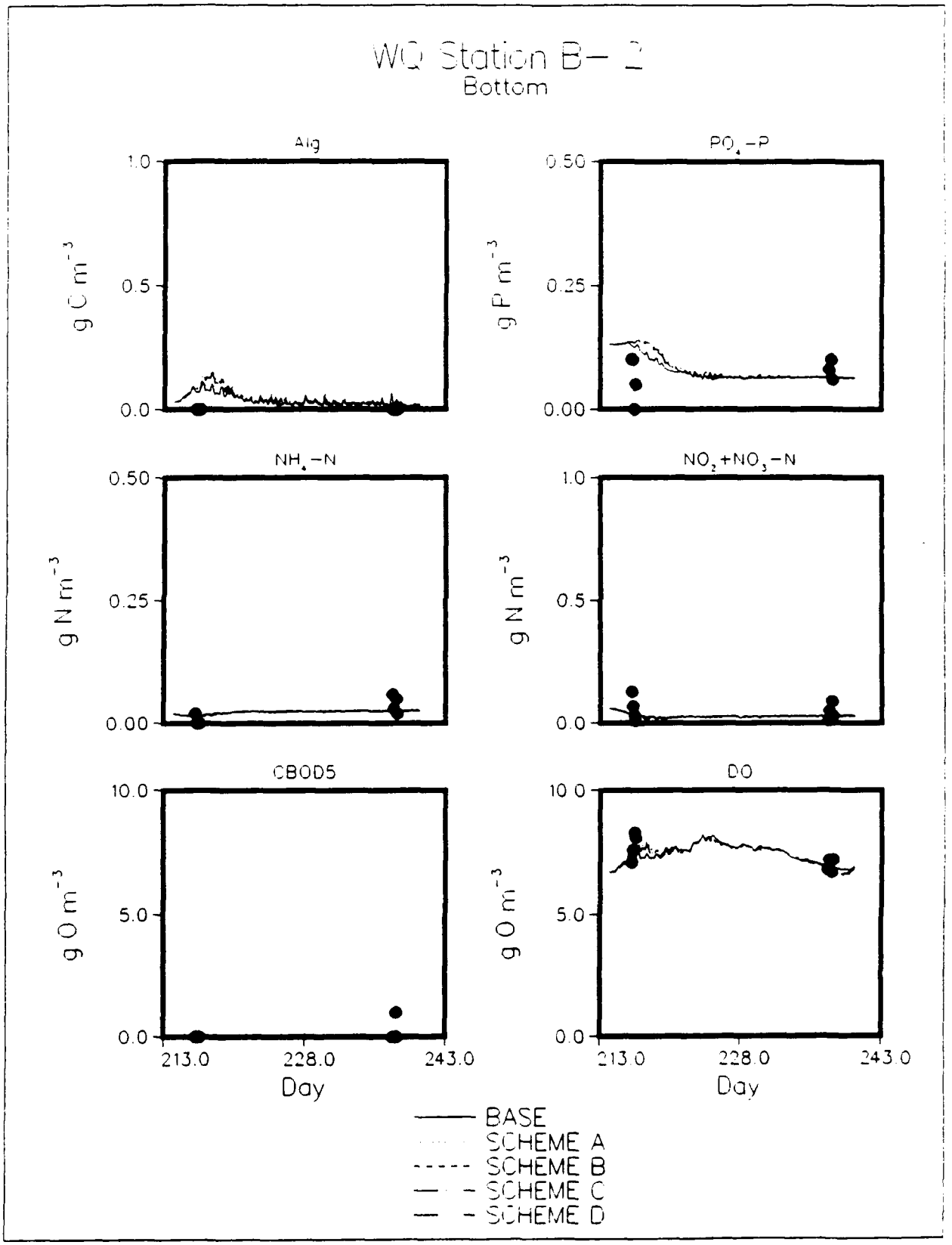

WQ Station B– 2
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 298

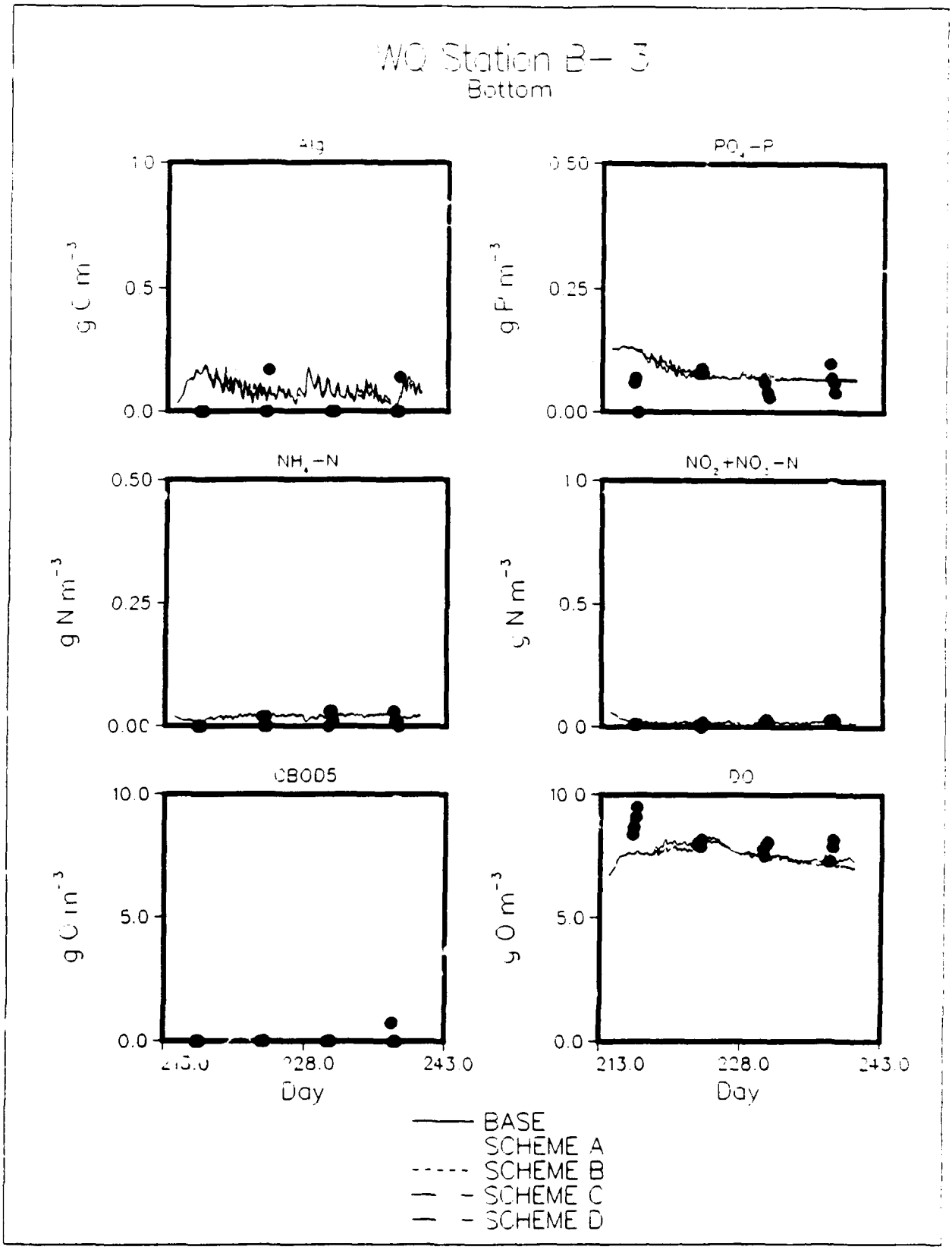

WQ Station B– 3
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 299

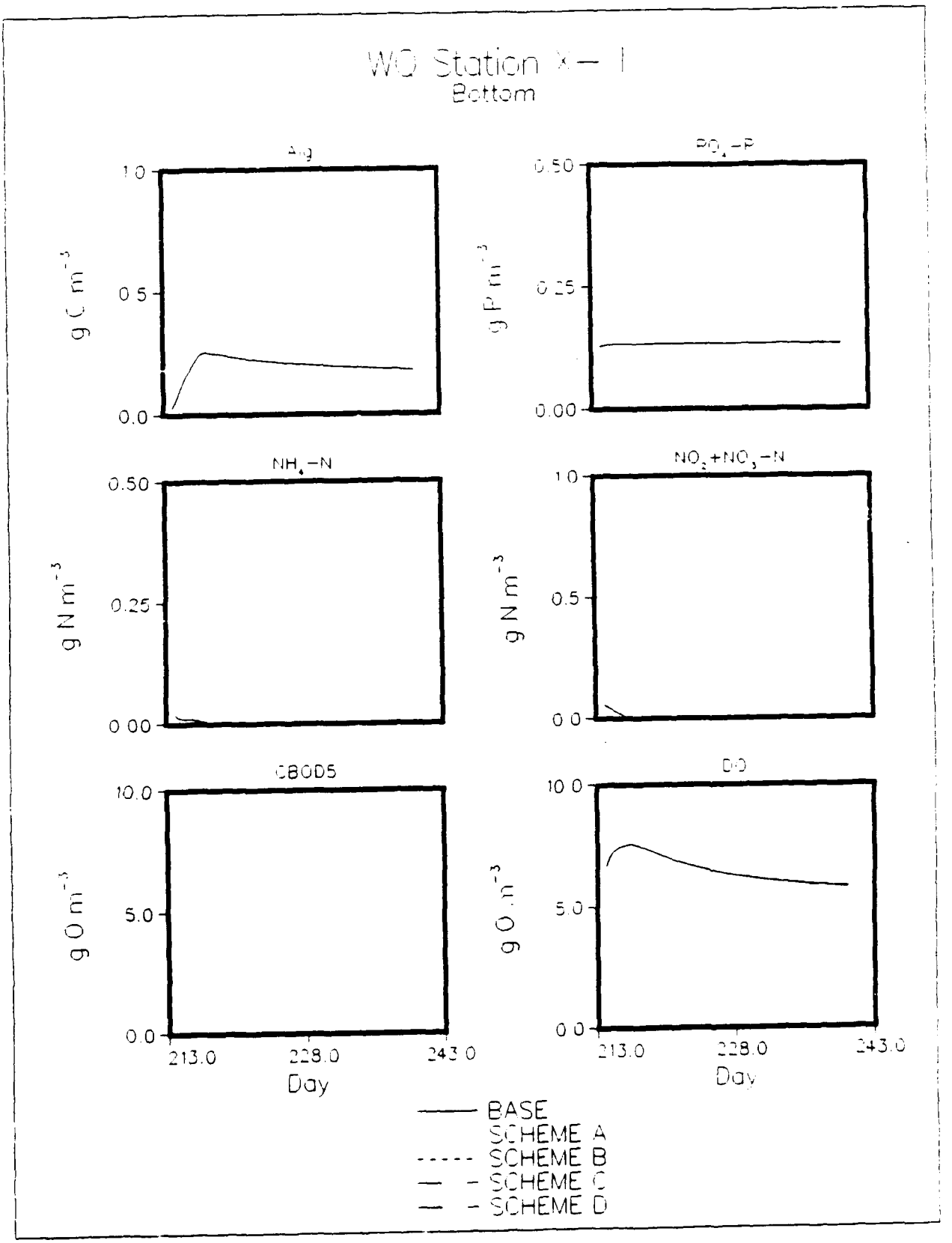

WQ Station X-1
Bottom
Alg
PO4-P
NH4-N
NO2+NO3-N
CBOD5
DO
g C m-3
g P m-3
g N m-3
g O m-3
1.0
0.5
0.0
0.50
0.25
0.00
10.0
5.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 300

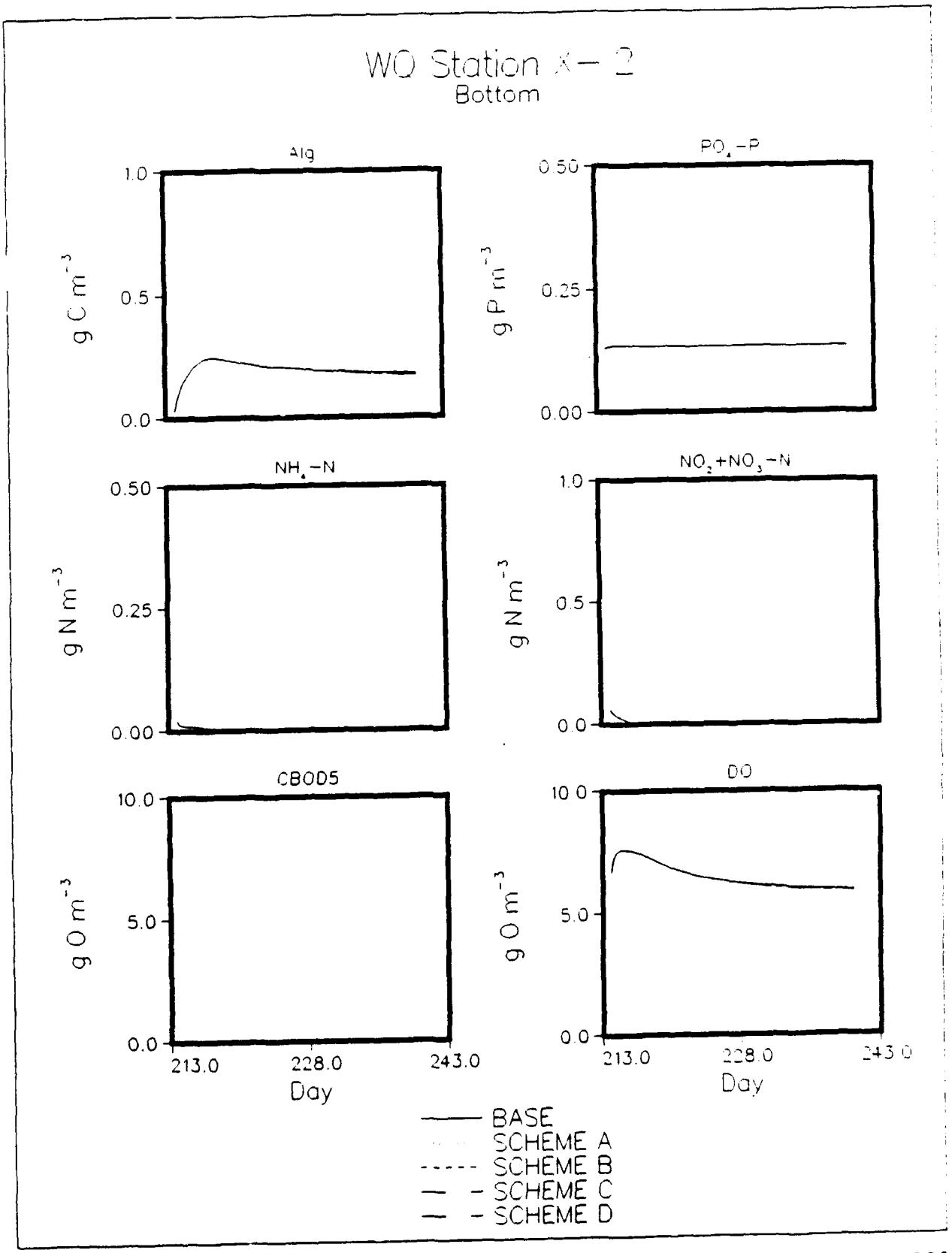

WQ Station x – 2
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4 – P
g P m⁻³
0.50
0.25
0.00
NH4 – N
g N m⁻³
0.50
0.25
0.00
NO2 + NO3 – N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 301

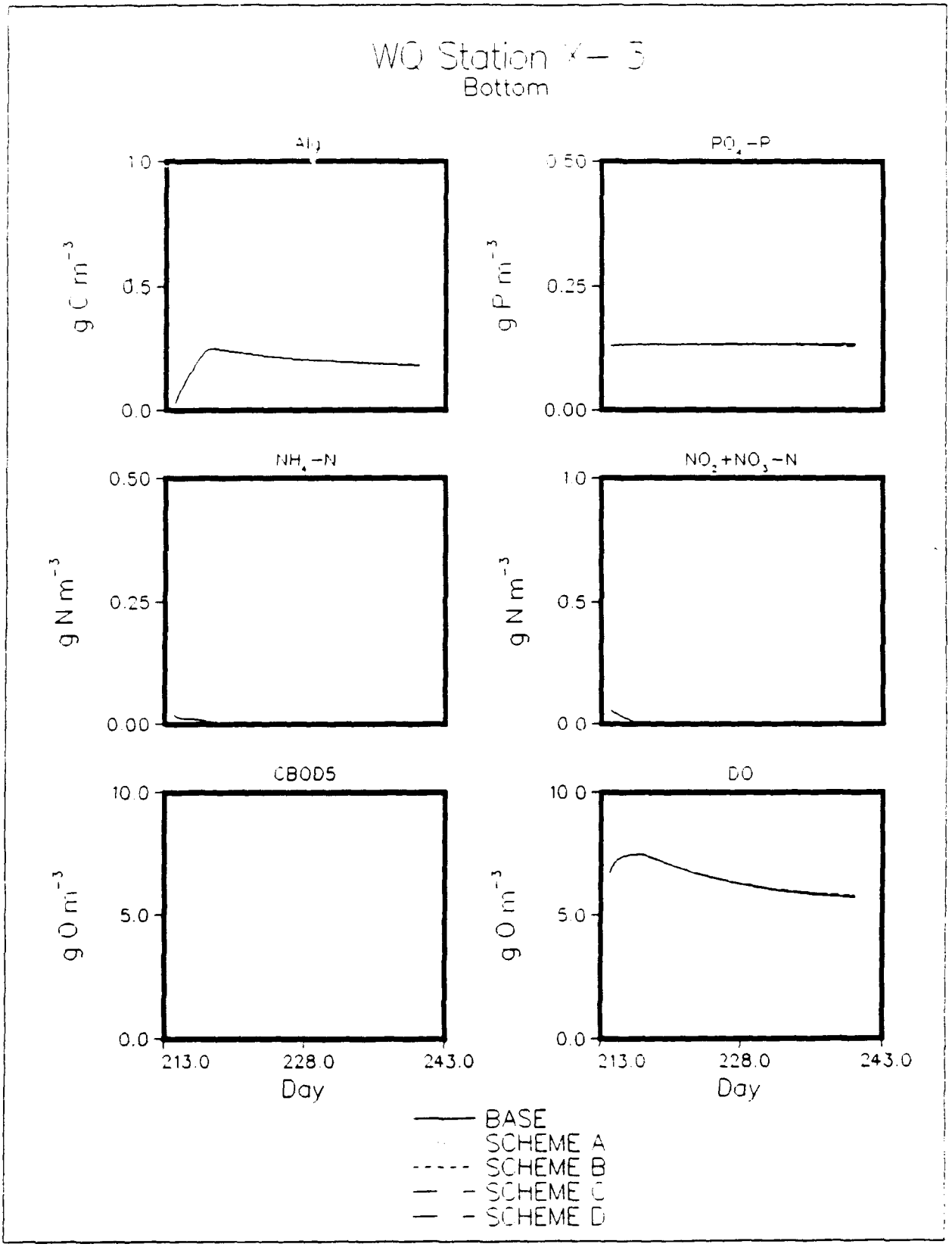

WQ Station X-3
Bottom
Alg
PO4-P
NH4-N
NO2+NO3-N
CBOD5
DO
g C m-3
g P m-3
g N m-3
g O m-3
1.0
0.5
0.0
0.50
0.25
0.00
10.0
5.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 302

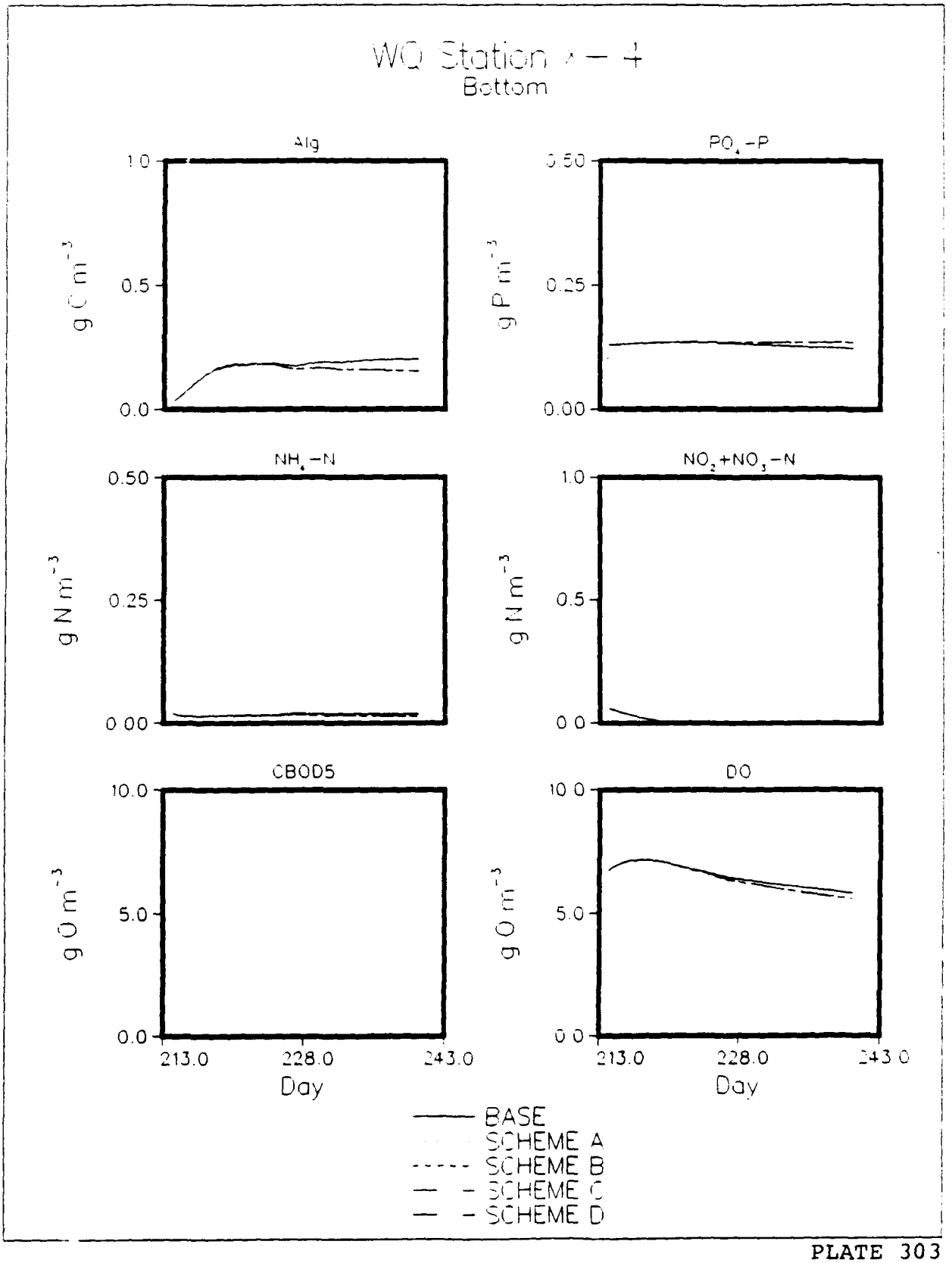

WQ Station A – 4
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 303

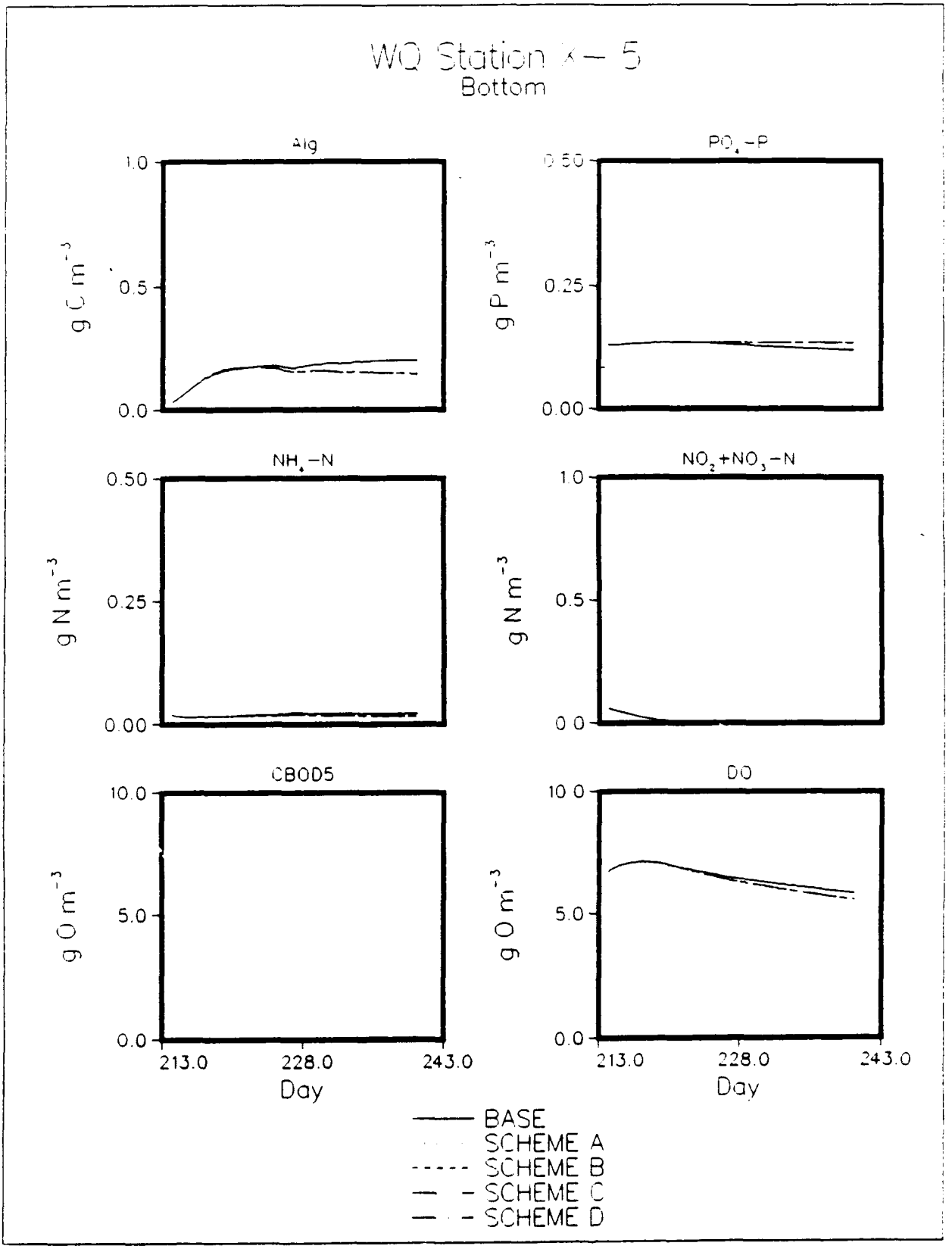

WQ Station x — 5
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 304

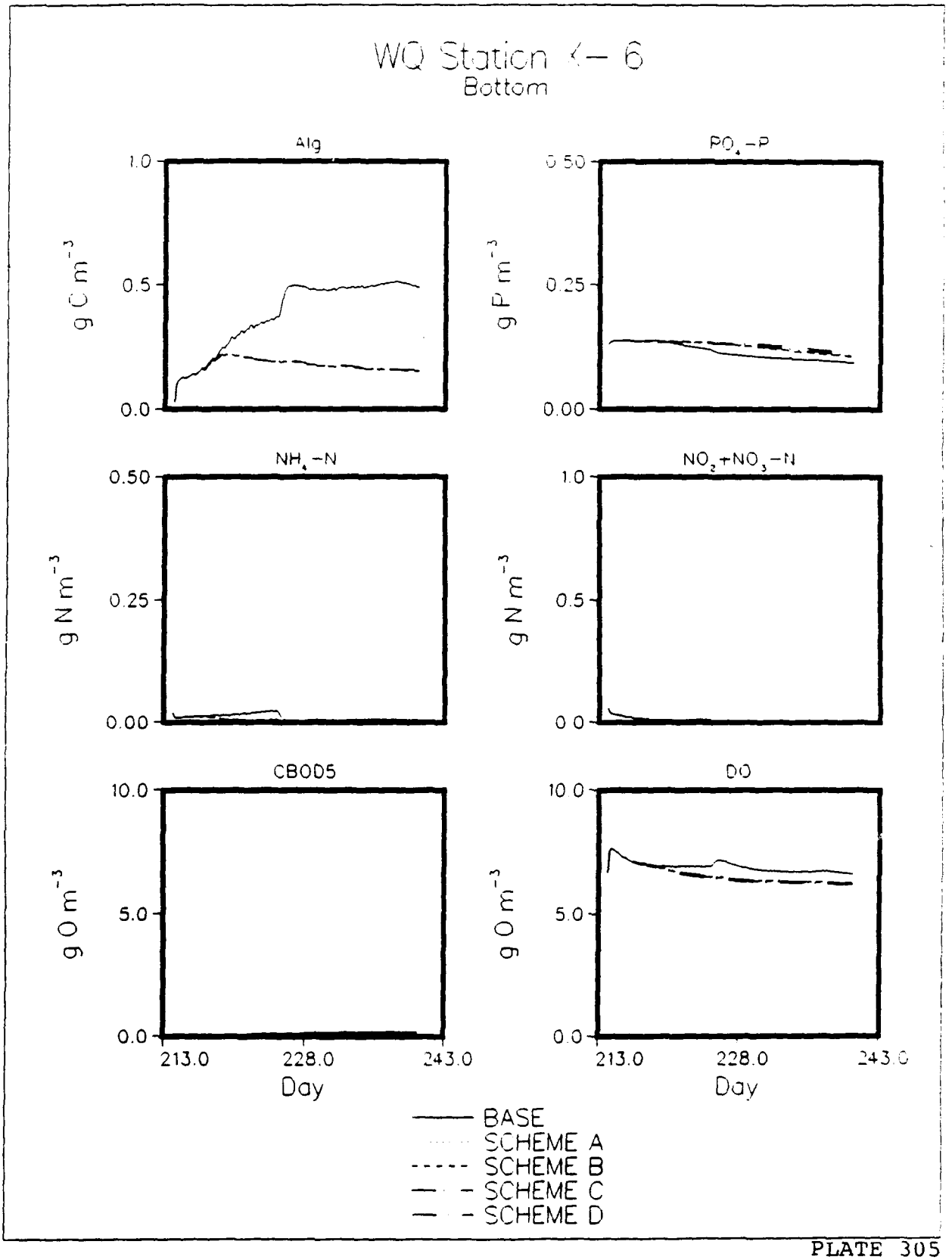

WQ Station <— 6
Bottom
Alg
gC m-3
1.0
0.5
0.0
PO4-P
gP m-3
0.50
0.25
0.00
NH4-N
gN m-3
0.50
0.25
0.00
NO2+NO3-N
gN m-3
1.0
0.5
0.0
CBOD5
gO m-3
10.0
5.0
0.0
DO
gO m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 305

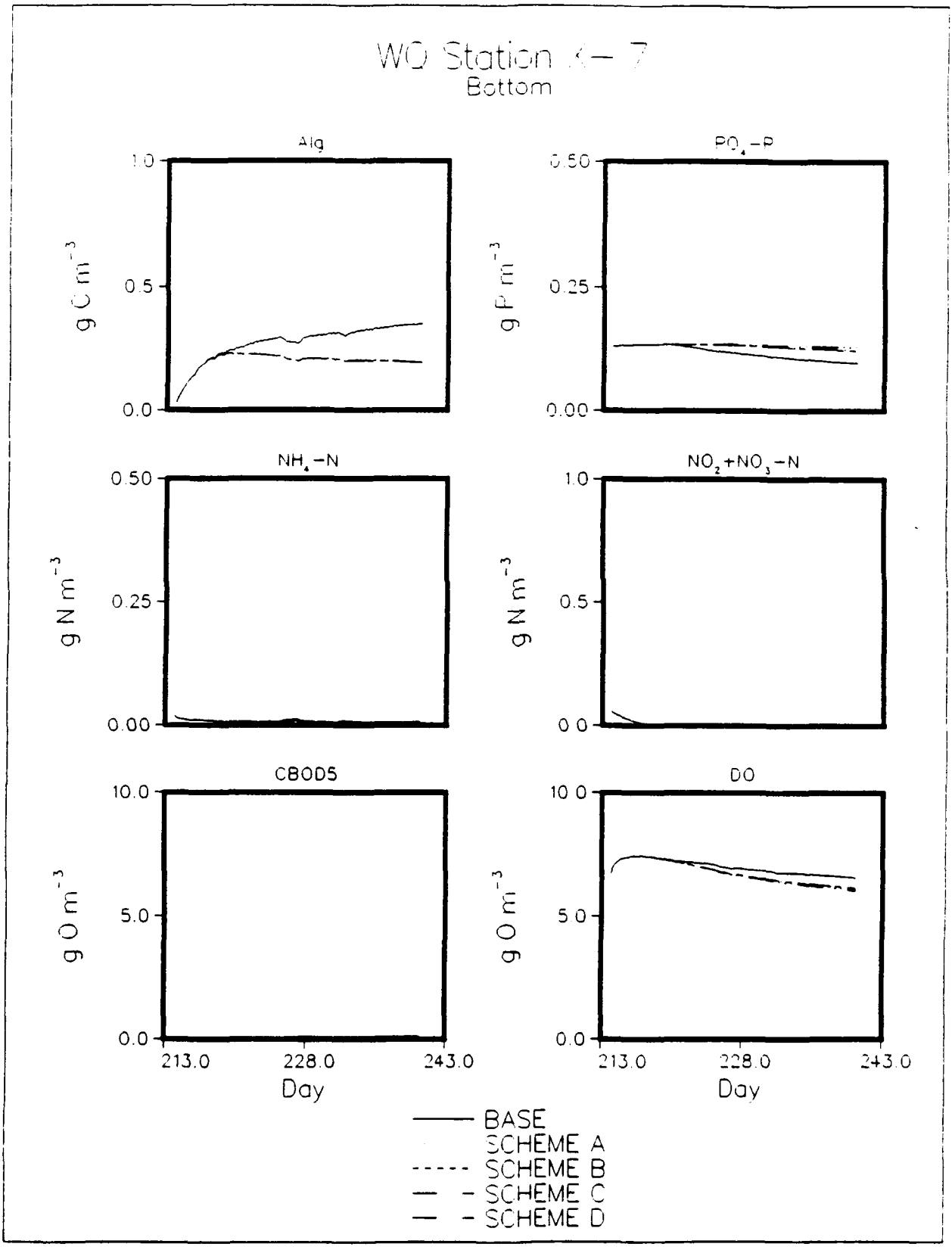

WQ Station 4 — 7
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4-P
g P m⁻³
0.50
0.25
0.00
NH4-N
g N m⁻³
0.50
0.25
0.00
NO2+NO3-N
g N m⁻³
1.0
0.5
0 0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10 0
5 0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 306

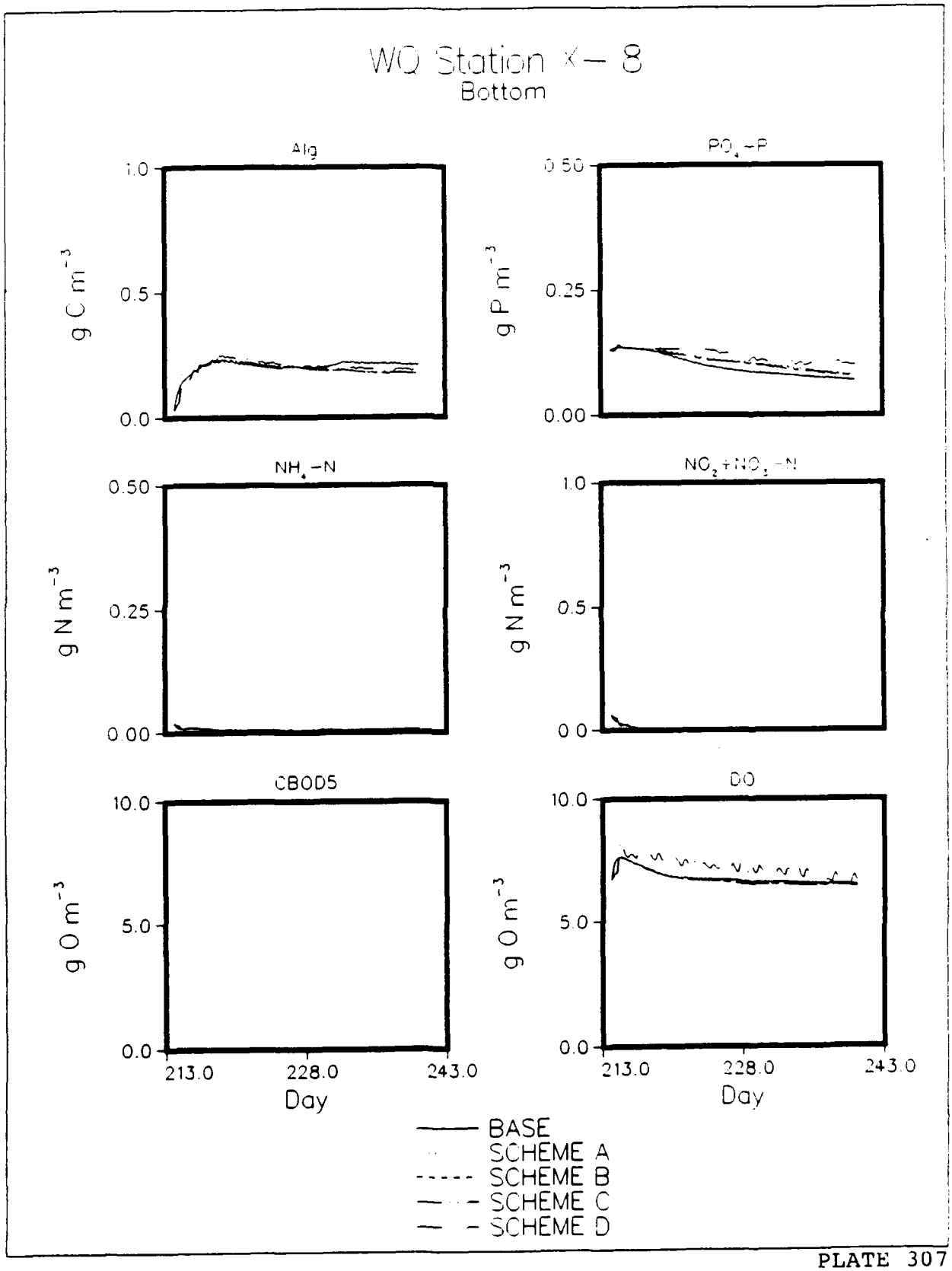

WQ Station X – 8
Bottom
Alg
g C m⁻³
1.0
0.5
0.0
PO4–P
g P m⁻³
0.50
0.25
0.00
NH4–N
g N m⁻³
0.50
0.25
0.00
NO2+NO3–N
g N m⁻³
1.0
0.5
0.0
CBOD5
g O m⁻³
10.0
5.0
0.0
DO
g O m⁻³
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 307

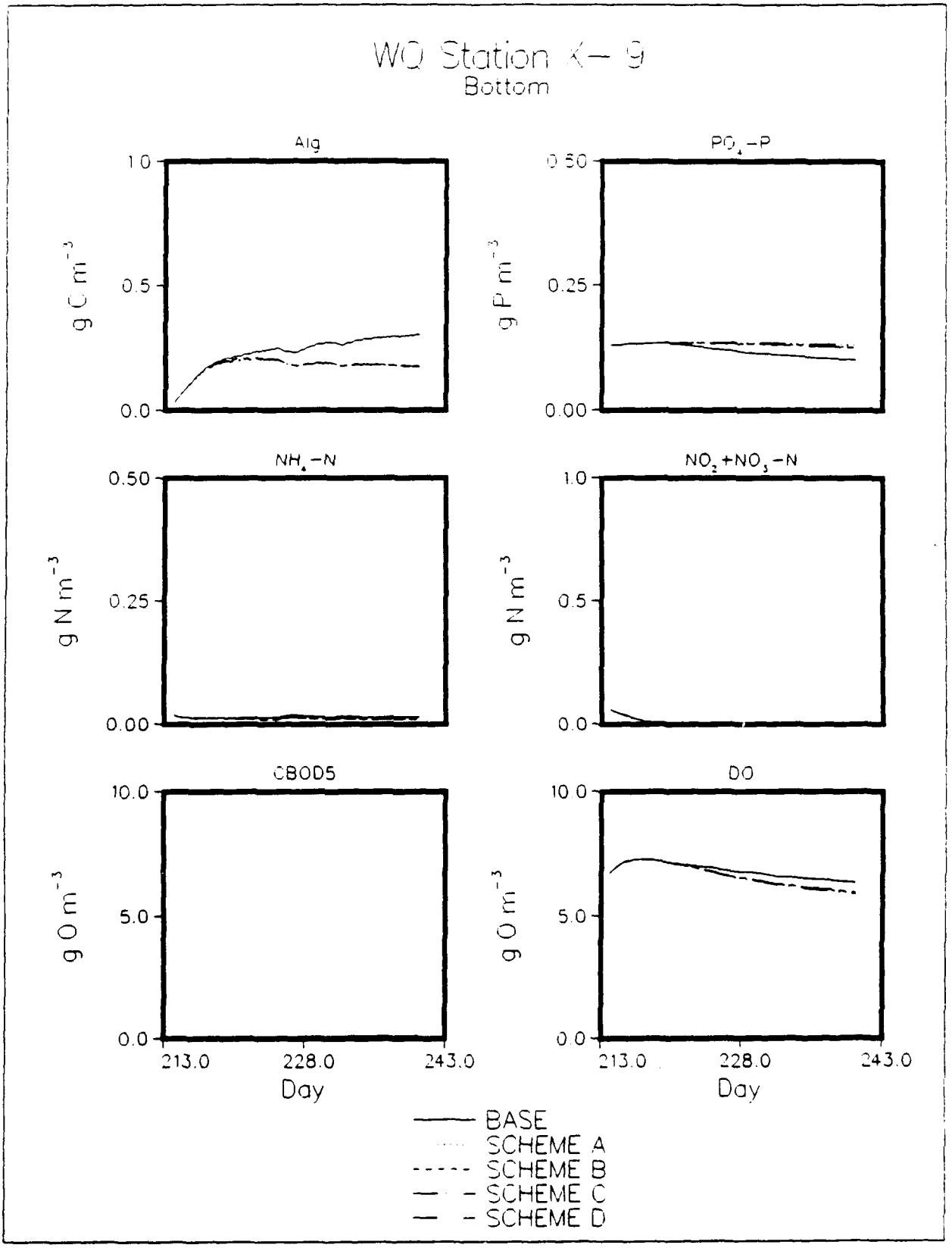

WQ Station K— 9
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 308

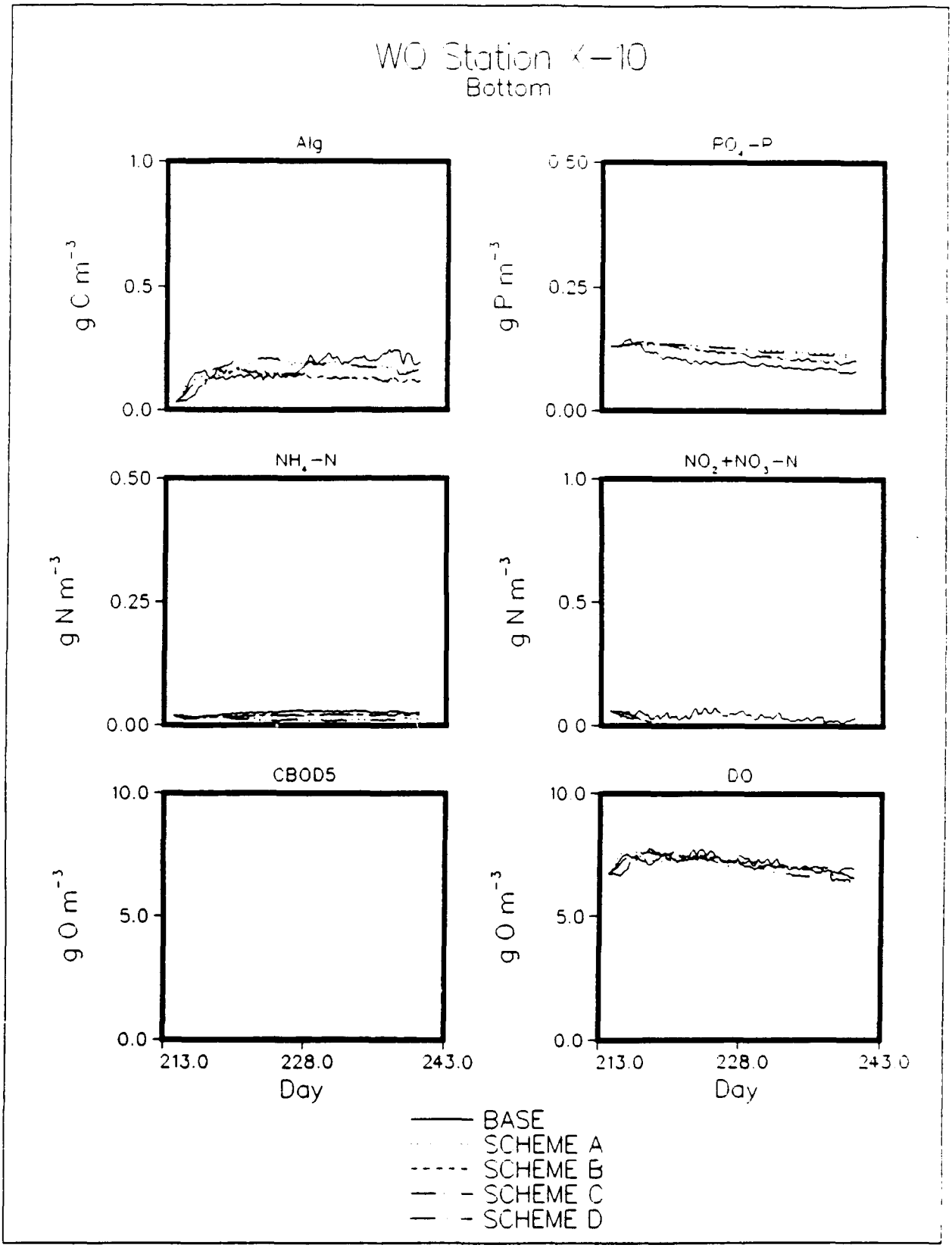

WQ Station 7-10
Bottom
Alg
g C m-3
1.0
0.5
0.0
PO4-P
g P m-3
0.50
0.25
0.00
NH4-N
g N m-3
0.50
0.25
0.00
NO2+NO3-N
g N m-3
1.0
0.5
0.0
CBOD5
g O m-3
10.0
5.0
0.0
DO
g O m-3
10.0
5.0
0.0
213.0
228.0
243.0
Day
BASE
SCHEME A
SCHEME B
SCHEME C
SCHEME D

PLATE 309