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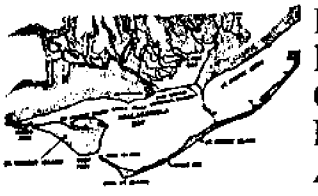

ESTABLISHMENT OF THE INFLUENCE ZONE FOR PHYSICAL CHANGES TO AN ESTAURINE ENVIRONMENT: AN APALACHICOLA BAY EXAMPLE

by
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and
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Prepared for
Mississippi-Alabama Sea Grant Consortium

February 1983

BER Report No. 288-112
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I. SUMMARY

The Apalachicola Bay estuarine system, shown in Figure 1, is composed of Apalachicola Bay, the principal embayment, St. Vincent Sound to the west, East Bay to the north and St. George Sound to the east. Barrier islands separate the embayments from the Gulf of Mexico. Apalachicola Bay is one of the most important bays in Florida because of the large fresh water inflow and seafood production. The bay contains 80 percent of the natural, public oyster reefs on the Gulf Coast of Florida[1].

In general, the environmental characteristics of Apalachicola Bay reflect the undeveloped and relatively unpolluted nature of the area. To maintain acceptable water quality conditions, Federal and State law regulate modifications to estuaries, their wetlands and flood plains. Evaluation of impacts on water quality of proposed modifications must be investigated and assessed prior to implementation.

The fishing fleet at Eastpoint, Florida desires construction of a rubble breakwater and relocation of the existing Federal Navigation Channel[2]. The proposed project would provide the fishing fleet with shelter and protection from storm waves and reduce delays due to congestion in the existing channel.

A two-dimensional depth averaged finite difference model is used to provide a preliminary assessment of hydrodynamic and water quality changes which can result from construction of the project. The model is partially calibrated using available prototype data. Application is then made with a representative tide, an average

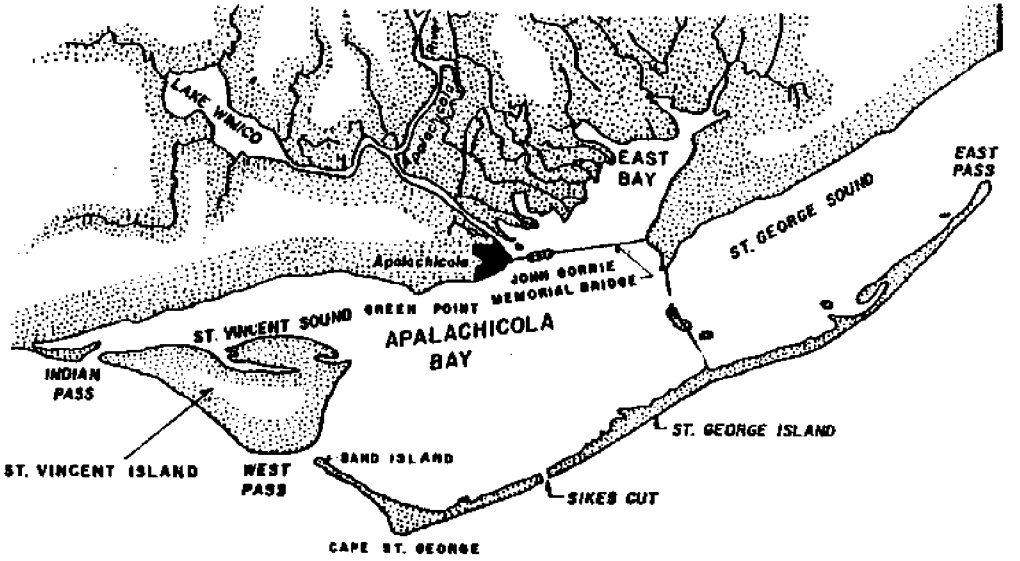

Figure 1. Apalachicola Bay Estuarine System

river inflow and for three wind conditions; no wind, a typical summer wind and a typical winter wind. Comparisions are made between model results for existing conditions and with the breakwater and channel project installed.

The model results, for the limited range of parameter considered, indicate that the project will have a very limited range of influence. Measurable changes in water surface and velocities are confined to a two mile radius from Eastpoint. Even within the Eastpoint area, hydrodynamic changes produced by the breakwater are small.

No water quality parameters have been directly considered in this study. Water quality changes can, to some extent, be inferred from the hydrodynamic changes. Only local changes in water quality parameters would appear likely.

II. OBJECTIVE OF STUDY

There is a need to provide the local fishing fleet at Eastpoint, Florida with shelter and protection from storm waves and to reduce delays due to congestion in the existing channel[2]. To accomplish this purpose a rubble breakwater has been proposed along with relocation of the existing Federal Navigation Channel. This study was initiated to evaluate hydrodynamic changes which might be produced in Apalachicola Bay as a result of the proposed Eastpoint breakwater. The overall changes in bay hydrodynamics and especially changes in the local Eastpoint area are investigated for a representative tidal cycle, an average flow from Apalachicola River and for three (3) wind conditions; no wind, an average summer wind, and an average winter wind.

III. APPROACH TO PROBLEM

Over the past ten to fifteen years, numerical modelling of hydrodynamic systems has become an established science. A variety of numerical models are available based upon both finite difference and finite element formulations of the basic governing equations. Hydrodynamic systems are basically three-dimensional; however, for many situations conditions are such that the flow can be satisfactorily approximated by a simplified set of governing equations. The two-dimensional depth averaged model has been shown by a number of investigators[3,4,5,6,7] to satisfactorily represent flow in an estuary or bay when the water body is not stratified. The two-dimensional depth averaged model is pseudo-three-dimensional since the governing equations are integrated over the vertical water column. The governing equations are forced to satisfy the boundary conditions at the bottom and at the top of the water column. Bottom friction effects, wind effects and the actual bottom topography are included in the model.

For this study, a two-dimensional depth averaged model (BAY) will be applied to Apalachicola Bay. Attention will be focused on the Eastpoint area where a rubble breakwater has been proposed to provide the local fishing fleet shelter and protection from storm waves. The model will be partially calibrated using available prototype data. The model will then be applied using typical tide, wind and river boundary conditions. Existing conditions and one proposed breakwater configuration will be investigated. A no-wind condition and a typical winter and summer wind condition

will be used in the investigation.

Velocity and surface elevation differences between the existing conditions and a possible breakwater configuration will be investigated. From these differences, a preliminary evaluation will be developed of the effects which the proposed breakwater will have on Apalachicola Bay. Overall effects in the bay and in the local Eastpoint area will be considered.

IV. THE NUMERICAL MODEL

Formulation of the Model

A complete mathematical description of the hydrodynamic flow in a harbor, bay or estuary would require that the velocity and density be completely specified for every point in the system at all times:

$$u = u(x,y,z,t)$$

$$\rho = \rho(x,y,z,t)$$

where

x = longitudinal coordinate measured along the estuary axis

y = transverse coordinate

z = vertical coordinate

t = time

Because of the difficulties in formulating, executing and verifying a three-dimensional model, researchers have devised a variety of numerical models of various degrees of simplification.

A two-dimensional depth averaged model (BAY) is used in this investigation. The vertical components of velocity and acceleration are neglected and the general three-dimensional governing hydrodynamic equations are integrated over the water depth. A pseudo-three-dimensional effect is present since the equations are forced to satisfy the boundary conditions at the bottom and surface of the water column. A depth-averaged two-dimensional flow field is obtained but three-dimensional geometry can be considered. The most important approximations used in the model are those of constant density and relatively small

variations of velocity over the depth, conditions which are reasonably valid much of the time in Apalachicola Bay. Where these conditions are approximately valid, this type of numerical model can provide accurate representations of tidal elevations and velocities.

The rectangular coordinate system is located in the plane of the undistributed water surface as shown in Figure 2. The

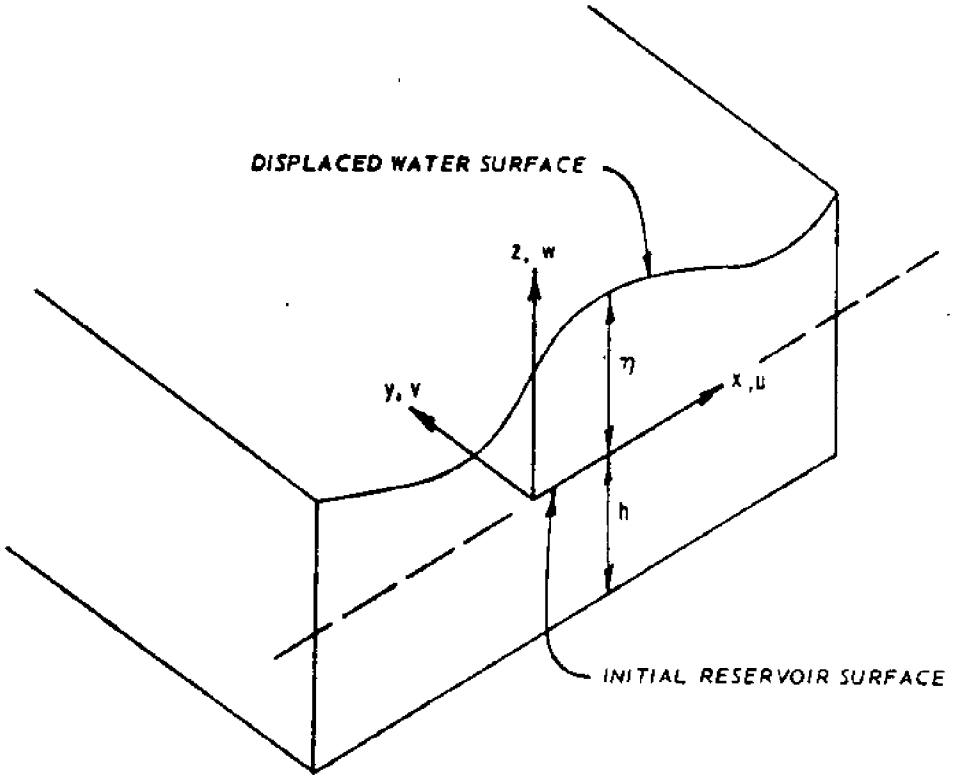

Figure 2. Coordinate System for Problem Formulation

equations of motion and the equation of continuity are written as follows:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial \eta}{\partial x} - fv = R_x + L_x$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial \eta}{\partial y} + fu = R_y + L_y$$

and

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}\left[(h + \eta)u\right] + \frac{\partial}{\partial y}\left[(h + \eta)v\right] = 0$$

where

x, y = rectangular coordinate variables

u, v = depth-averaged velocity component

g = acceleration due to gravity

η = water level displacement with respect to datum elevation

f = Coriolis parameter

R_x, R_y = the effect of bottom roughness in x and y directions

L_x, L_y = the acceleration effect of the wind stress acting on the water surface in the x and y directions

h = water depth

The continuity equation has been obtained by integrating across the water depth and applying kinetic and dynamic boundary conditions at the surface and bottom of the reservoir. The bottom friction terms are represented using a Chezy coefficient in the following form:

$$R_x = \frac{-gu(u^2 + v^2)^{\frac{1}{2}}}{C^2(h + \eta)}$$

$$R_y = \frac{-gv(u^2 + v^2)^{\frac{1}{2}}}{C^2(h + \eta)}$$

where C is the Chezy coefficient. The terms L_x and L_y represent the wind shear stress effect on the water surface. These terms are of the form:

$$L_x = \frac{T_x}{(h + \eta)}$$

$$L_y = \frac{T_y}{(h + \eta)}$$

where T_x and T_y are the wind stress components acting on the water surface.

A major advantage of BAY is the capability of applying a smoothly varying grid to the given study region. This allows efficient simulation of complex geometries by locally increasing grid resolution in critical areas. For each coordinate direction, a piecewise reversible transformation is independently used to map prototype or real space (x, y space) into a computational space (α_1, α_2 space). The transformation takes the form

$$x = a + b\alpha^c$$

where a, b and c are arbitrary constants. By applying a smoothly varying grid transformation which is continuous and which has continuous first derivatives, many stability problems commonly

associated with variable grid schemes are eliminated provided that all derivatives are centered in α space [8]. The transformed equations in α space can be written as

$$\frac{\partial u}{\partial t} + \frac{1}{\mu_1} u \frac{\partial u}{\partial \alpha_1} + \frac{1}{\mu_2} v \frac{\partial u}{\partial \alpha_2} + \frac{g}{\mu_1} \frac{\partial \eta}{\partial \alpha_1} - fv = R_x + L_x$$

$$\frac{\partial v}{\partial t} + \frac{1}{\mu_1} u \frac{\partial v}{\partial \alpha_1} + \frac{1}{\mu_2} v \frac{\partial v}{\partial \alpha_2} + \frac{g}{\mu_2} \frac{\partial \eta}{\partial \alpha_2} + fu = R_y + L_y$$

$$\frac{\partial \eta}{\partial t} + \frac{1}{\mu_1} \frac{\partial}{\partial \alpha_1} [(h+\eta)u] + \frac{1}{\mu_1} \frac{\partial}{\partial \alpha_2} [(h+\eta)v] = 0$$

To solve the governing equations, a finite difference approximation of the equations and an alternating direction technique are employed. A space-staggered scheme is used in which velocities, water-level displacement, bottom displacement, and water depth are described at different locations within a grid cell as shown in Figure 3. This solution scheme is similar to that originally proposed by Leendertse[9].

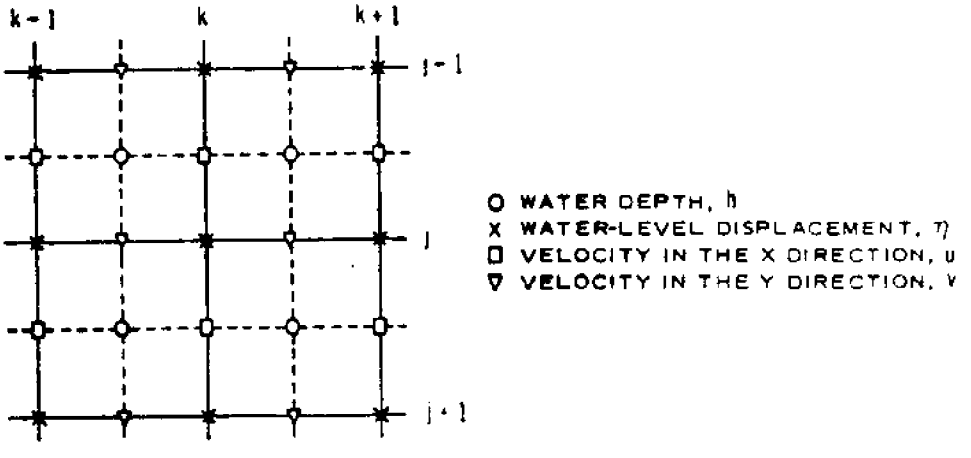

Figure 3. Grid System and Variable Definition Locations

The first step in the calculation consists of computing u and η implicitly and v explicitly, advancing from $n\Delta t$ to $(n + 1/2)\Delta t$.

The parameter n is an integer representing the time step at which the calculations are being conducted. The second step computes η and v implicitly and u explicitly, advancing from time $(n + 1/2)\Delta t$ to $(n + 1)\Delta t$. Central differences are used for evaluating all spatial derivatives in the governing equations. The application of these difference approximations gives rise to corresponding difference equations centered about different points within a grid cell. These expressions require the evaluation of certain quantities at locations different from those defined in the grid system. Such quantities are replaced by values computed from a one- and two-dimensional averaging of neighboring values. The time interval Δt is taken as the time required to complete the full cycle in the computational procedure; however, each half cycle is treated by a different set of equations so a system of six operational equations is used.

Three types of boundaries are involved in the calculations: solid boundaries at fixed coastlines, artificial tidal input boundaries arising from the need to truncate the region of computation and river inflows into the bay.

A condition of complete reflection is adopted at solid boundaries. While some dissipation does occur at the shoreline, this should not be significant in this application. The actual boundary condition for the solid boundary can be written as

$$\overline{V}_n = 0$$

where $\overline{V}_n$ denotes the normal component of velocity.

Artificial tidal boundaries were used in the model to

describe the tidal action that occurs at the ocean computational boundaries. These boundaries must be accurately defined since the tides applied at these boundaries represent the major forcing function driving the hydrodynamic system. The water-surface elevation time history for the desired cycle is specified at each such boundary and applied during the operation of the model. River inflow boundaries are required to simulate the river hydrograph for those significant streams discharging into the bay.

V. APALACHICOLA BAY SYSTEM

The Apalachicola Bay System, Figure 1, is a barrier island-contained estuary on the Florida Panhandle. Apalachicola Bay is the principal embayment with St. Vincent Sound to the west, East Bay to the north and St. George Sound to the east. The bay system is approximately thirty-nine miles long and an average of six miles wide. There are five flow connections to the Gulf of Mexico; Indian Pass, West Pass, Sikes Cut, St. George Sound and East Pass. All of the openings are natural except Sikes Cut which was originally dredged across St. George Sound in 1954. The primary fresh water flow into the estuary is from the Apalachicola River.

The bay system is shallow, the mean depth being only about ten feet. The system is generally well mixed with wind effects contributing significantly to circulation patterns. The tides in the area are semi-diurnal with a mean diurnal range of about 1.6 ft.

The main embayment is significantly influenced by the Apalachicola River which has a mean annual discharge of 23,500 cfs. The Apalachicola River is a major source of nutrients supporting a productive estuarine fishery. Apalachicola Bay and its contiguous water is reported to have produced ninety percent of Florida's oyster landings in 1976 with about forty-five percent of these landings processed through Eastpoint.

There is an existing channel generally parallel to shore at Eastpoint. The channel is six feet deep, one hundred feet wide,

and about six thousand feet long with a connecting channel six feet deep and one hundred feet wide to water of the same depth in St. George Sound. The fishing industry at Eastpoint desires the construction of a breakwater to provide a safe sheltered harbor for the large number of oyster skiffs and small shrimp trawlers operating from the area.

Several breakwater configurations have been proposed. The breakwater system used in this investigation consists of about five thousand feet of rubble breakwater located five hundred feet offshore as illustrated in Figure 4. The breakwater is generally parallel to the shore. This breakwater was used to establish the general zone of influence of the project rather than investigation of a specific project design.

VI. THE FINITE DIFFERENCE GRID

The Apalachicola Bay system to be represented by a variable-size finite difference grid is shown in Figure 1. Of particular interest is the Eastpoint local area. One proposed configuration for the Eastpoint project is illustrated in Figure 4.

The finite difference grid, Figure 5, used for the model of Apalachicola Bay was developed using a 1:80,000[10] scale nautical chart. A variable grid was developed with the primary objective of good resolution of the proposed breakwater and navigation channel. In addition, good resolution of geometry is desired for passes opening into Apalachicola Bay and for Sikes Cut. A reasonable representation of other geometric and bathymetric features of the bay was desired consistent with the preliminary nature of the study. The dimension of the resulting grid was 69 by 42 cells or 2898 cells. After mapping the grid, it was used as an overlay on the nautical chart to assign boundaries, depths and Manning friction coefficients for each finite difference cell.

The smallest cells were used in representing the area around Eastpoint since this was the region of primary interest. Small cells were also used for the passes. Larger cells were used in areas of the bay where the bathymetry was reasonably constant and/or boundary geometry was relatively simple. The smallest cell size was 500 feet and the maximum depth was approximately 50 feet. A half time step of 60 sec will therefore yield a reasonable Courant number for the calculations.

Depths were assigned to each water cell as delineated by the

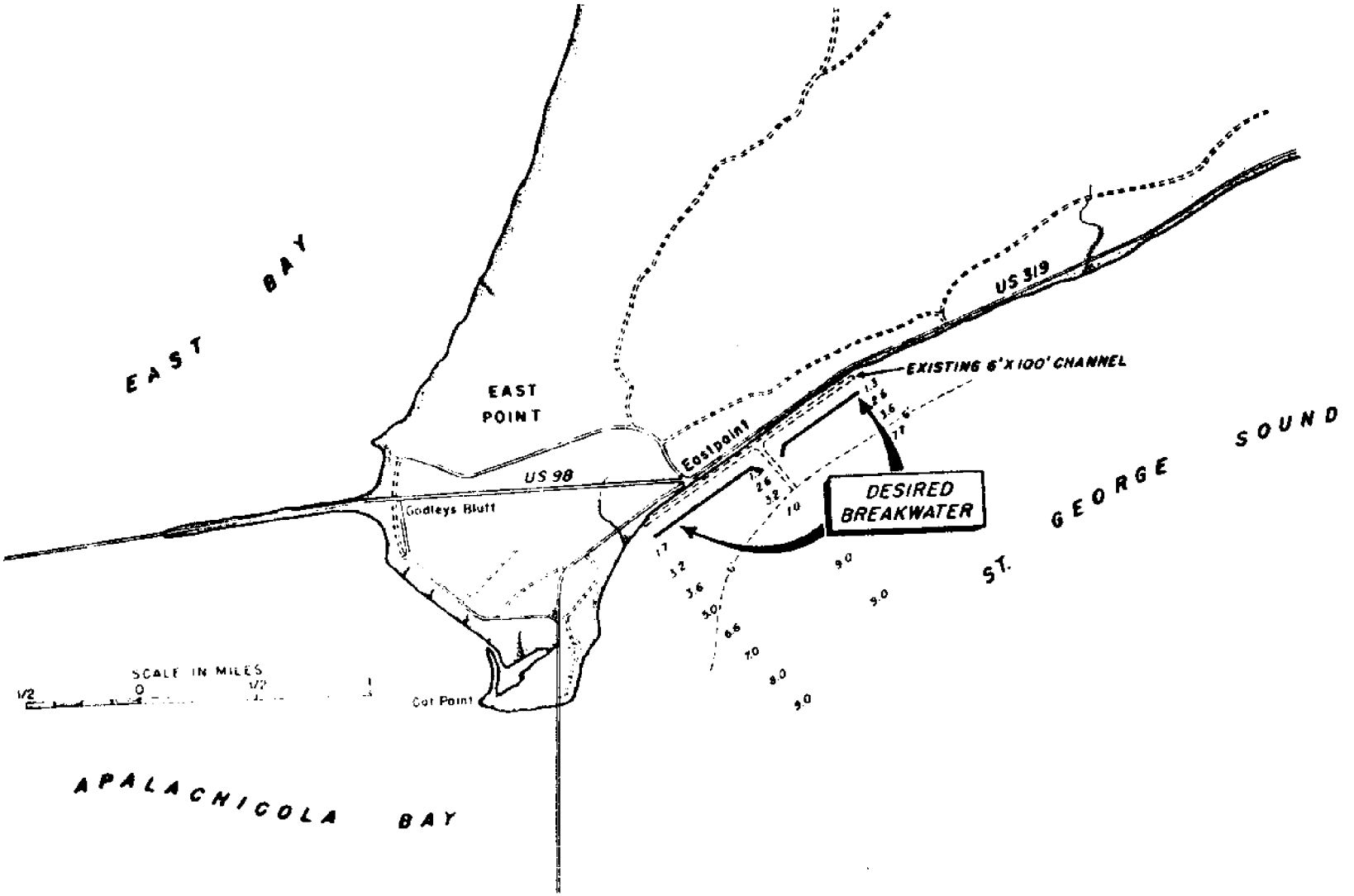

Figure 4. Possible Configuration of the Eastpoint Project in Apalachicola Bay

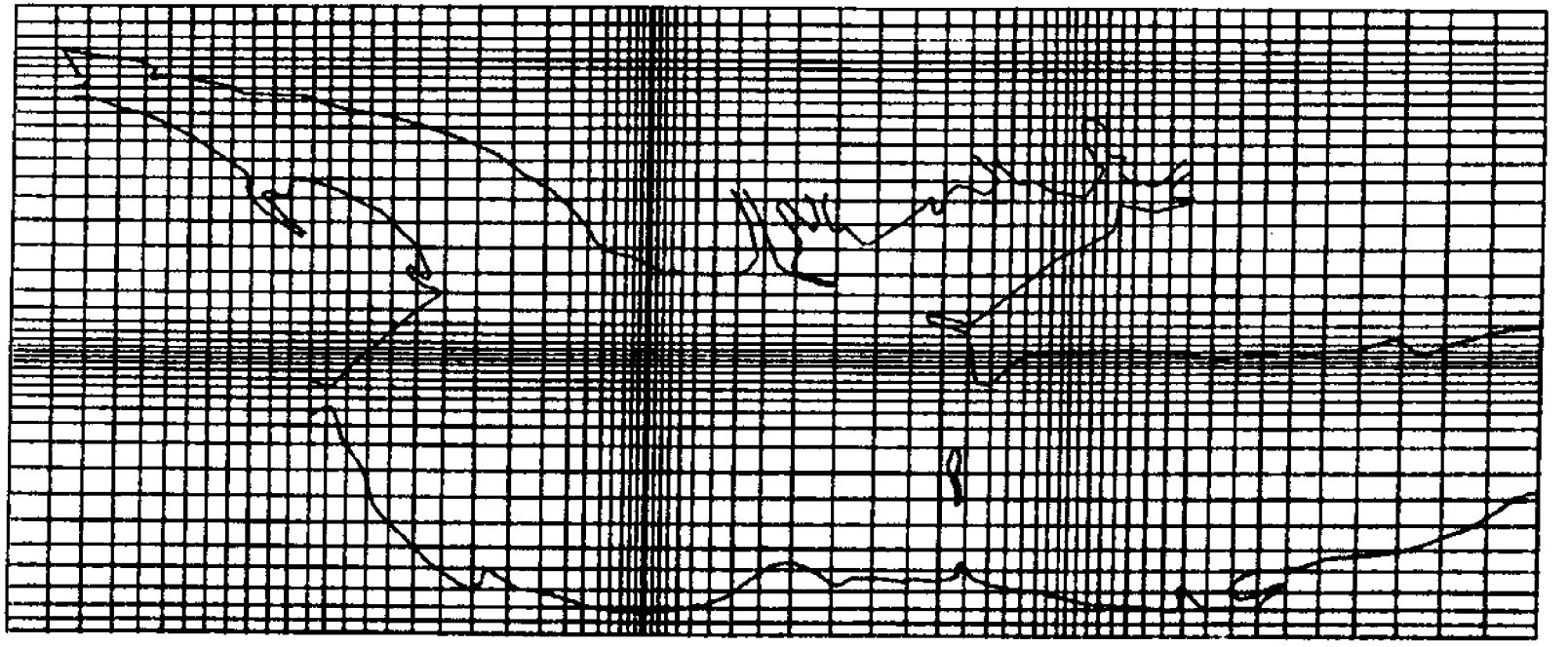

Figure 5. Finite Difference Grid for Apalachicola Bay

land boundary. The depth of each cell was determined as a weighted average of the charted depths within that cell. In areas where the finite diference water cell is larger than the actual physical dimension, cell depths were reduced in the model to make the flow cross-sectional areas approximately equal. Manning's n friction values for bottom roughness were assigned on a relative basis according to the bottom type specified by the nautical chart.

A tidal boundary condition was specified at all passes entering Apalachicola Bay, including Sikes Cut. A constant river inflow, representing average conditions, was applied simulating the Apalachicola River.

VII. MODEL CALIBRATION AND VERIFICATION

There is very little prototype data for Apalachicola Bay of the quality and synoptic nature required for calibration and verification of numerical models. A limited amount of data are presented in a report by Zeh[11] and these data are used to provide a partial qualitative calibration of the model. Figure 6 indicates tidal elevations for the Gulf, at a position in Apalachicola Bay near Sikes Cut, and at Apalachicola for August 9, 1978. The Gulf and Bay data were from tide gages operated by the University of Florida and the Apalachicola data were from a Corps of Engineers tide gage. No specific wind velocity or river flow data were reported for this period. The river flow rate was estimated to have been moderate while the wind was reported as northwesterly.

Both the Apalachicola and Bay tidal elevation curves exhibit abnormal features. The Apalachicola elevation is generally superelevated by the freshwater outlet from Apalachicola River, however, the sharp peak near 1500 hours is difficult to interpret. The surface elevation at the bay gage remaining constant for almost five hours is also difficult to explain.

Figure 7 indicates the volumetric discharge from Sikes Cut during August 9, 1978 time period. These data were computed by the point discharge method using current data collected in Sikes Cut[11].

The Gulf tide shown in Figure 6 was applied to the numerical model at all openings between the Gulf and the Bay. An average

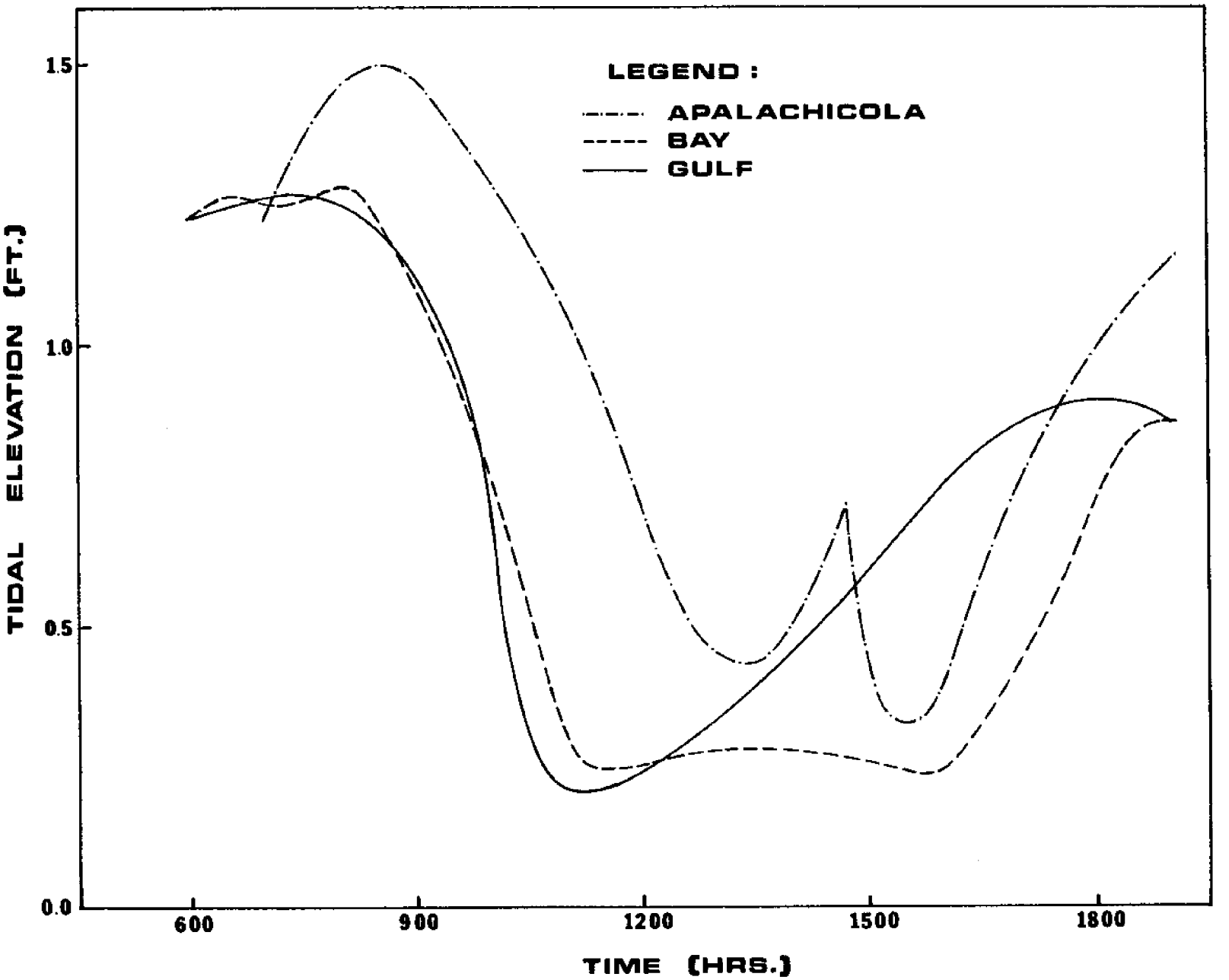

Figure 6. Neap Tide of August 9, 1978

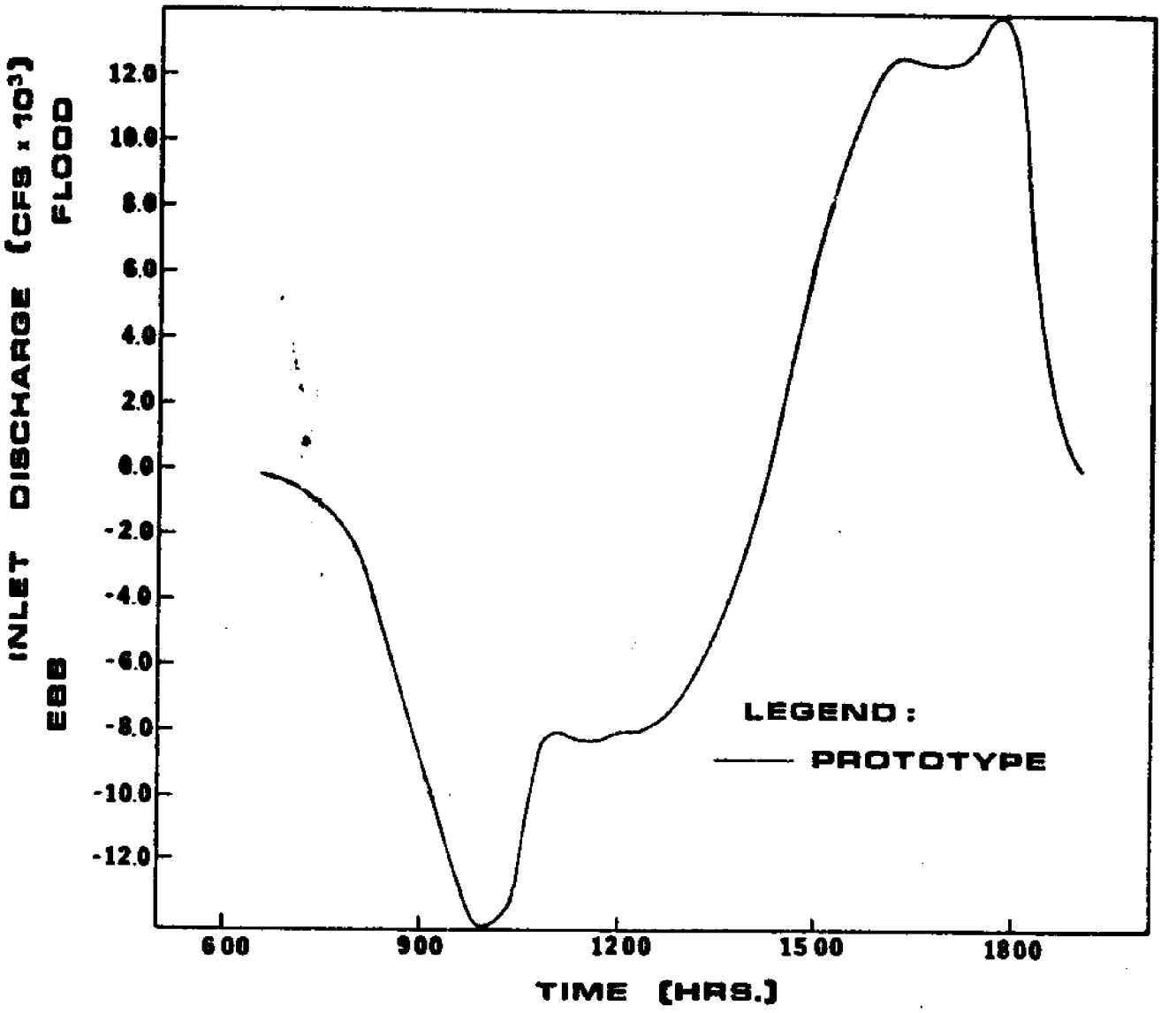

Figure 7. Discharge for Sikes Cut on August 9, 1978

river flow rate of 23,500 cfs[12] was used for Apalachicola River. Three constant wind conditions were applied to the model; no wind, a wind basically across the bay, and a wind basically along the bay.

The numerical model results are shown in Figures 8, 9 and 10. Figure 8 presents the tidal elevations in the Bay for all three wind conditions and the prototype data. Figure 9 presents similar information at Apalachicola. Figure 10 presents calculated and prototype flow rates for Sikes Cut. These comparisons are certainly not sufficient for model calibration, however, they do indicate that the model is producing results which are qualitatively consistent with the behavior of the physical system. The model should, therefore, be capable of predicting trends which should be produced by changes in the physical characteristics of the system. In particular, the model should be capable of establishing the general overall effect of constructing a breakwater and channel modification at Eastpoint.

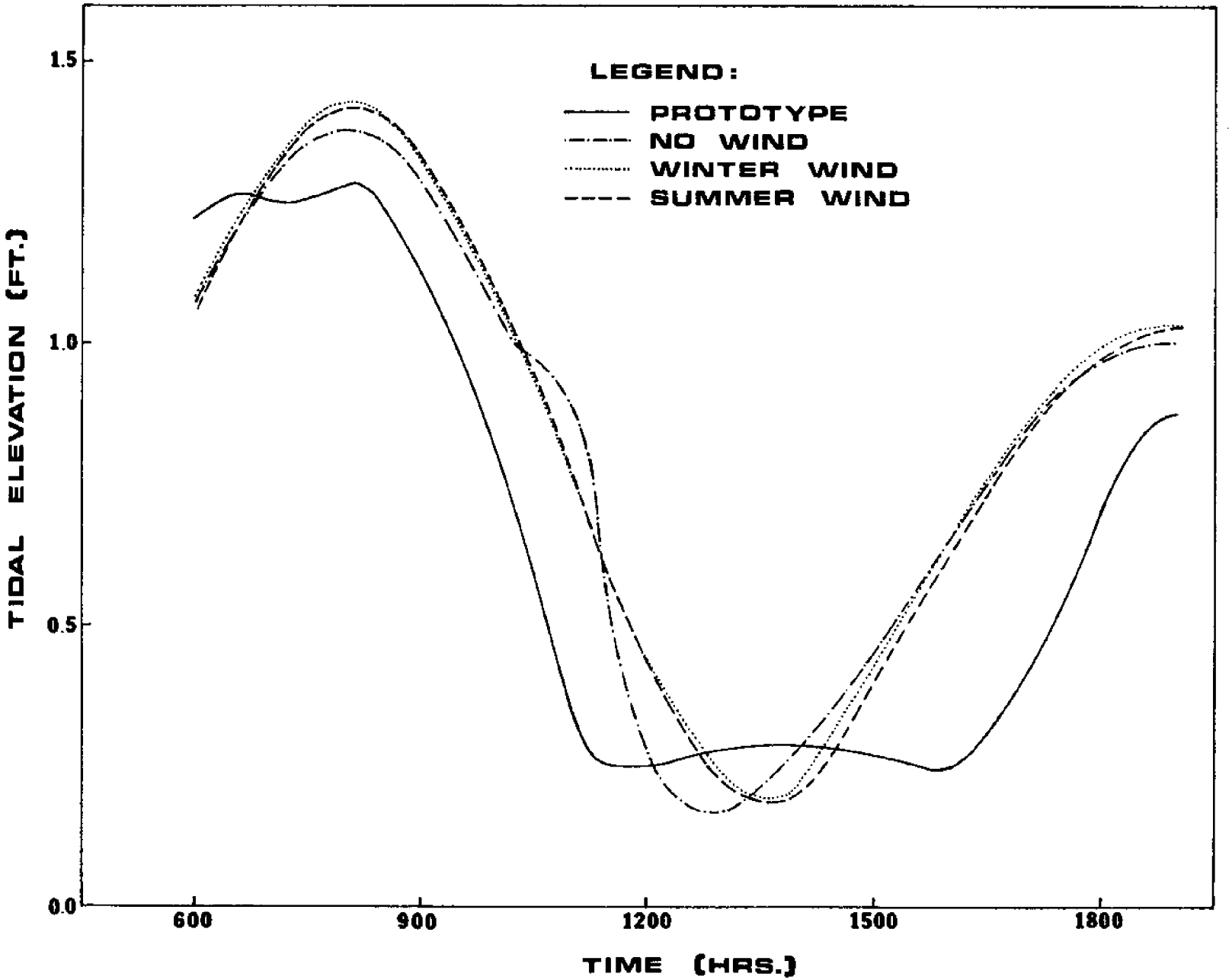

Figure 8. Numerical Model Results for Tidal Elevations in the Bay near Sikes Cut for August 9, 1978

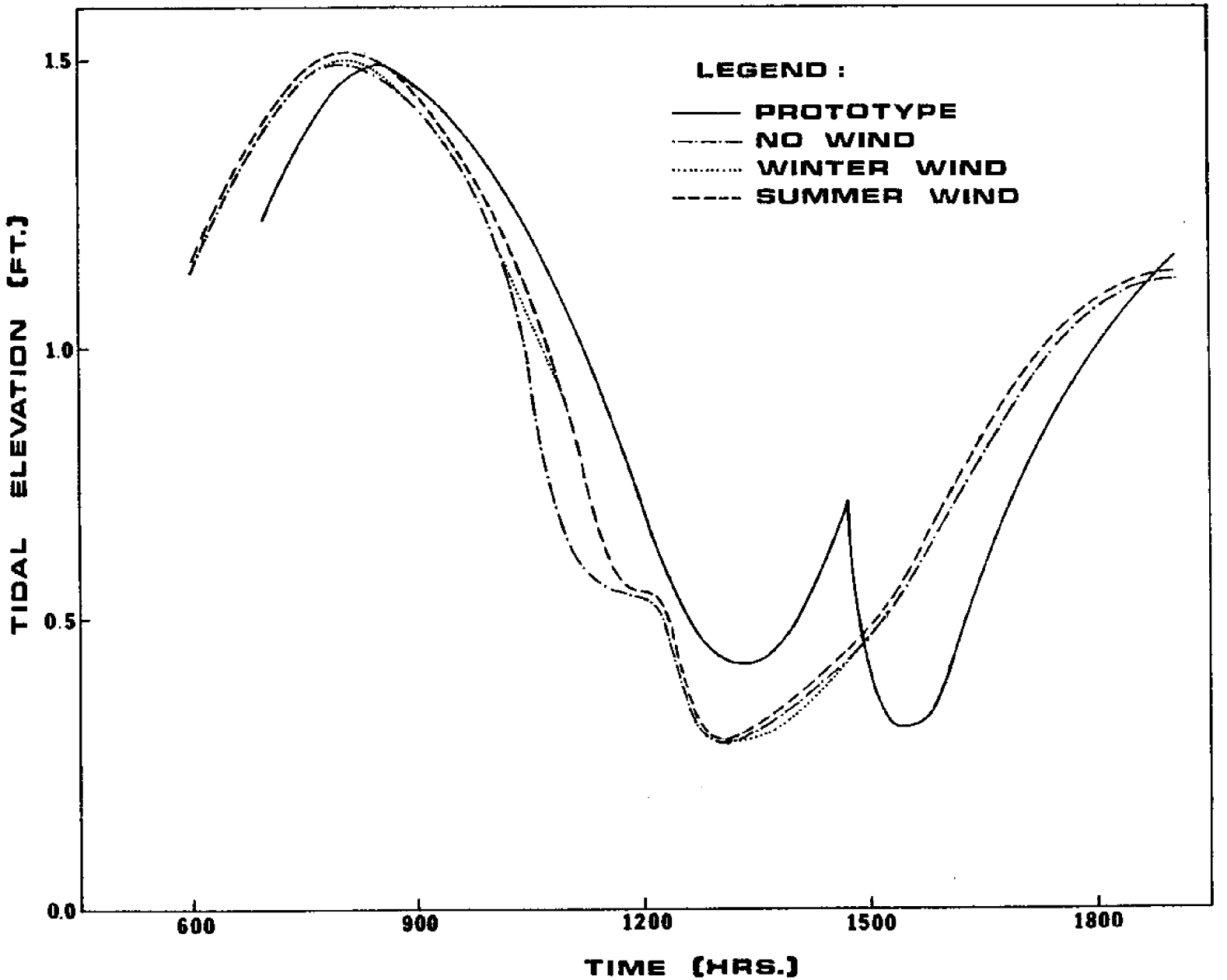

Figure 9. Numerical Model Results for Tidal Elevations at Apalachicola for August 9, 1978

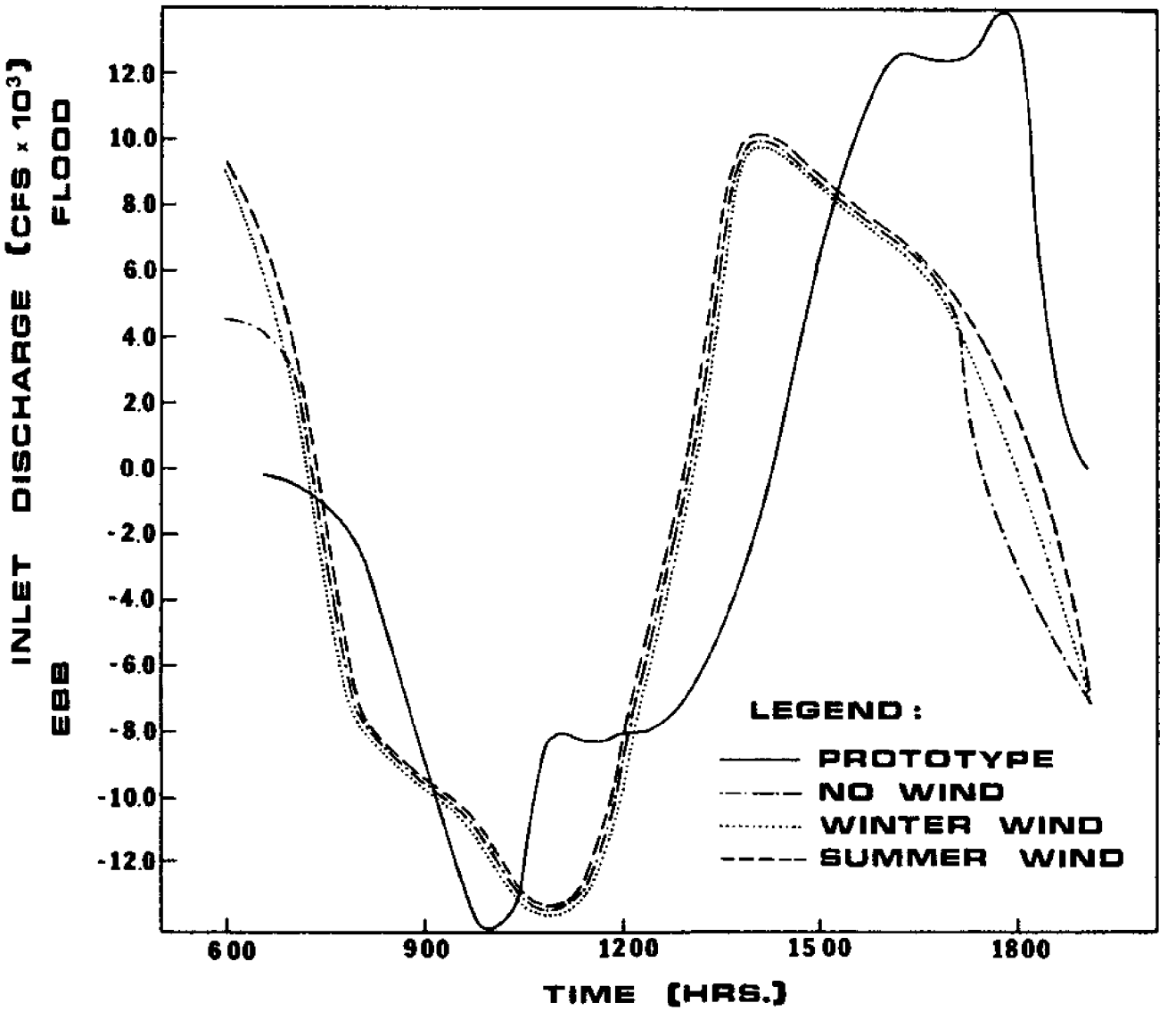

Figure 10. Numerical Model Flow Rates through Sikes Cut for August 9, 1978

VIII. MODEL APPLICATIONS AND RESULTS

The hydrodynamic model was applied for three basic conditions; no wind, an average summer wind and an average winter wind. The average summer wind was taken as 7.4 mph at 190° from the north (measured clockwise). The average winter wind was 7.8 mph at 65° from the north. These values were selected based upon data presented by Conner[1]. As observed in Figure 11, the winter wind is along the major axis of the bay while the summer wind is essentially along the minor axis of the bay. For all runs the same tidal cycle was used, corresponding to the measured tidal cycle of August 9, 1978[11]. This tidal cycle is the same as that used for model calibration; refer to Figure 6. An average flow rate of 23,500 cfs[12] was used for the Apalachicola River. In all three cases the model was applied both for existing conditions and with a breakwater installed at Eastpoint. Overall circulation patterns in Apalachicola Bay are presented at two hour intervals for all model applications. Circulation patterns in the immediate area of Eastpoint are also presented in a graphical format suitable for detailed examination. In addition, the changes in circulation patterns in the Eastpoint local area produced by the breakwater are presented in a graphical format. Changes in velocity at eleven selected points in the Eastpoint area are also plotted as a function of time over the tidal cycle.

Figure 12 is a typical vector plot of overall tidal circulation in Apalachicola Bay. The vectors indicate the instantaneous magnitude and direction of the water velocity at the

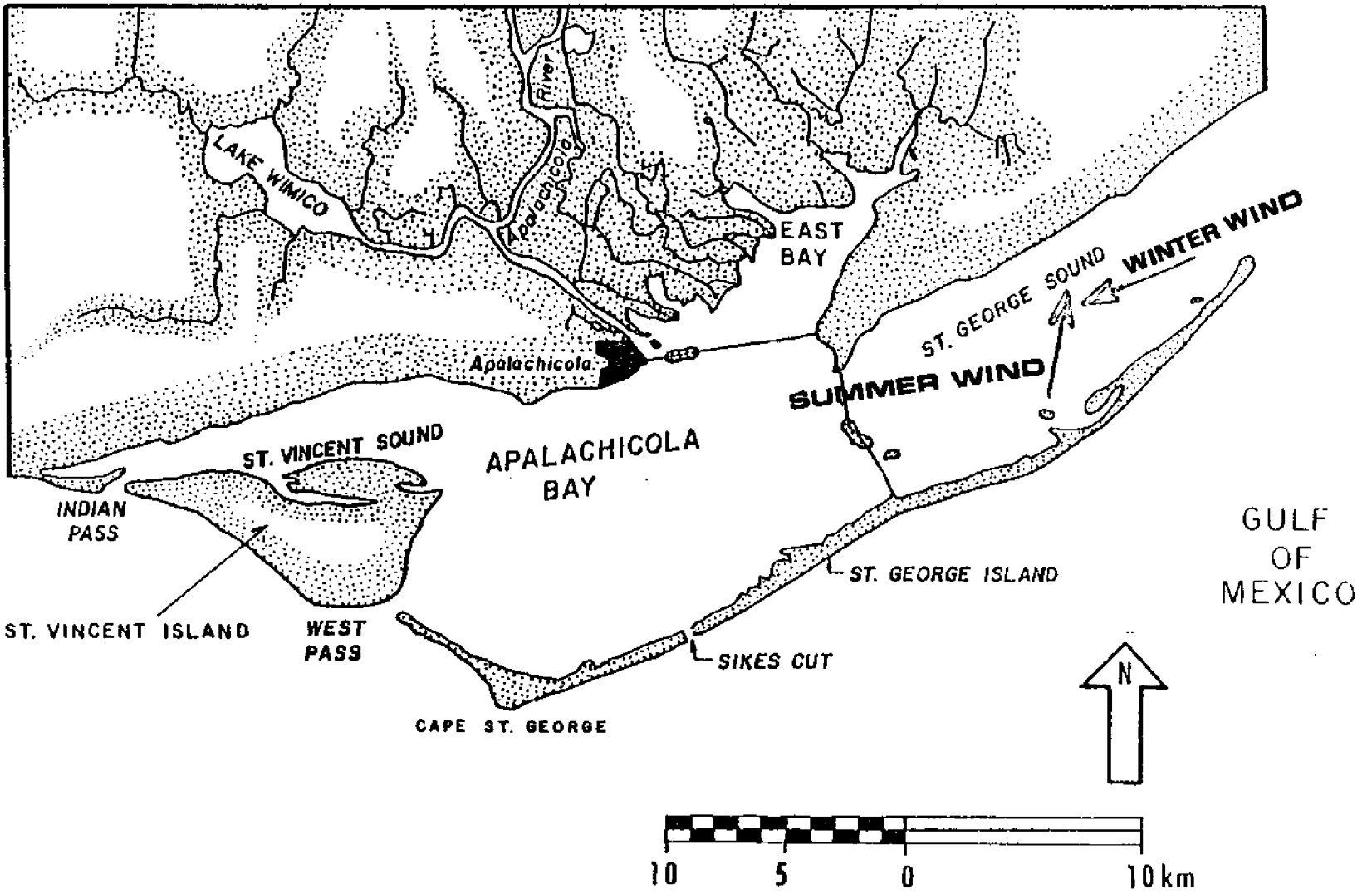

Figure 11. Direction of Average Summer and Winter Winds Used in Model Applications

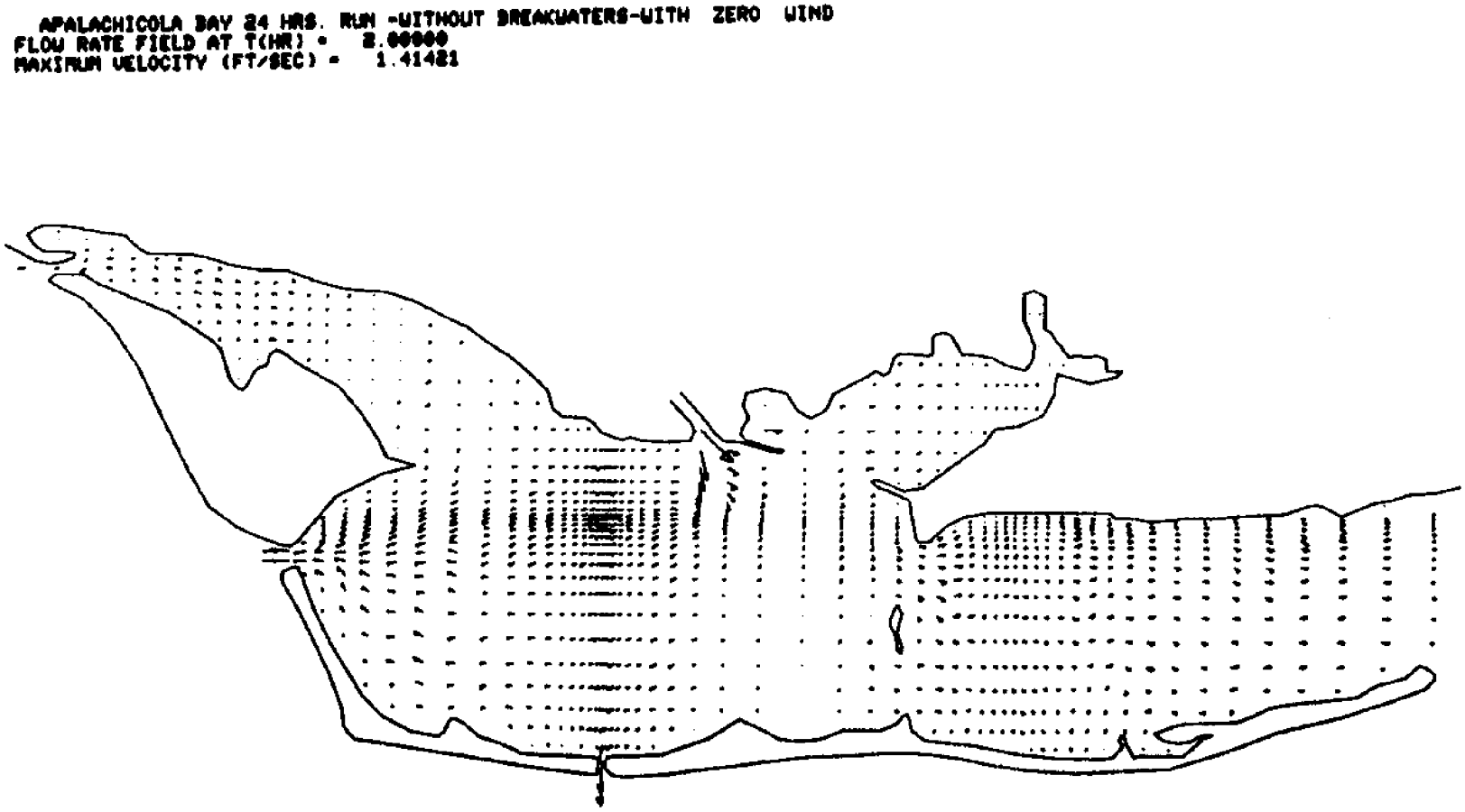

Figure 12. Typical Overall Circulation Pattern for Apalachicola Bay

specified time in the tidal cycle. The nomenclature on the plot identifies it as being at hour two of the tidal cycle for the no wind-existing conditions model application. The detailed circulation patterns for the no wind model applications are presented in Appendix A and Appendix D. The average summer wind circulation patterns are presented in Appendix B and Appendix E while Appendix C and Appendix F contain the average winter wind circulation patterns.

The scale at which circulation patterns must be presented for the entire bay are not satisfactory for detailed evaluation of local flow conditions. For this purpose, circulation plots of localized regions are presented in an enlarged format. A typical vector plot of circulation patterns in the Eastpoint locale is presented in Figure 13. Circulation patterns for the local Eastpoint area are presented at two hour intervals in the Appendices. Appendix G and Appendix J contain the no wind results, Appendix H and Appendix K contain the average summer wind results and Appendix I and Appendix L contain the average winter wind results.

An effective procedure for observing overall changes in circulation patterns is obtained by plotting the changes in velocity at each finite difference cell at periodic intervals over the tidal cycle. In this case, changes were found to be localized so changes in circulation patterns in the local Eastpoint area are presented. A typical circulation change as a result of addition of the Eastpoint breakwater is presented in Figure 14. In all plots of circulation change, values less than 0.025 fps were

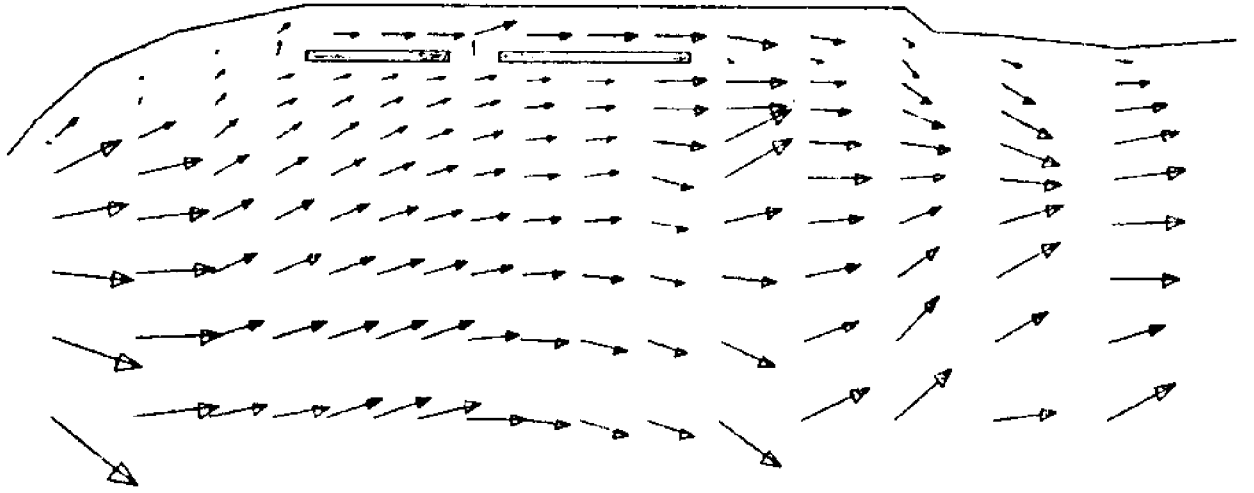

Figure 13. Typical Circulation Pattern in the Eastpoint Area

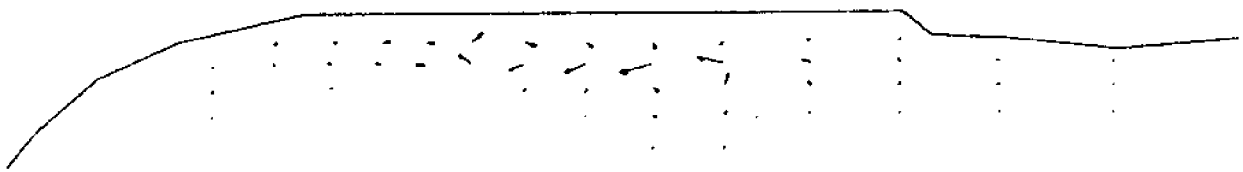

Figure 14. Typical Change in Circulation Pattern Near Eastpoint as a Result of Breakwater

considered negligible and were not plotted. The no-wind circulation change results are presented in Appendix M. The average summer wind circulation changes are presented in Appendix N. Appendix O contains the average winter wind results. In all cases, measurable changes in circulation patterns are observed to be localized, falling generally within a two mile radius of Eastpoint.

To obtain additional information on changes in the Eastpoint locale eleven special points were identified for special consideration. The location of these points is shown in Figure 15. Variation of hydrodynamic variables with time over the tidal cycle are considered for each of these points both for the existing conditions and for the installed breakwater. The tidal elevations at all points were observed to be essentially the same with and without the breakwater. A typical velocity result for point G1 is shown in Figure 16. The detailed velocity results for the no wind condition are presented in Appendix P, velocity results for the average summer wind are contained in Appendix Q and the average winter wind results are in Appendix R. Most changes in velocity produced by the breakwater are observed to be very small. Maximum changes produced are generally less than 0.1 fps.

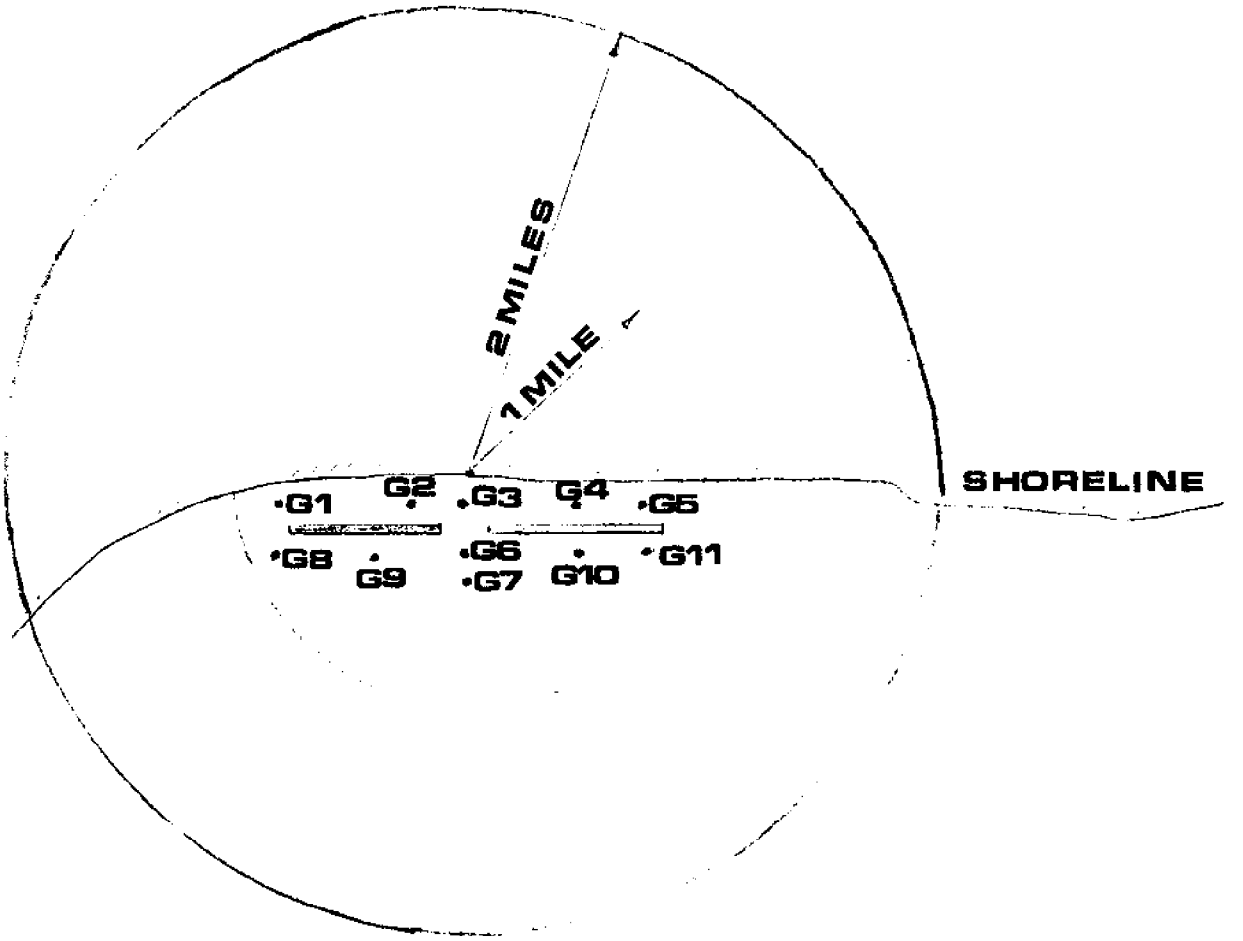

Figure 15. Location of Special Gage Points Near Eastpoint

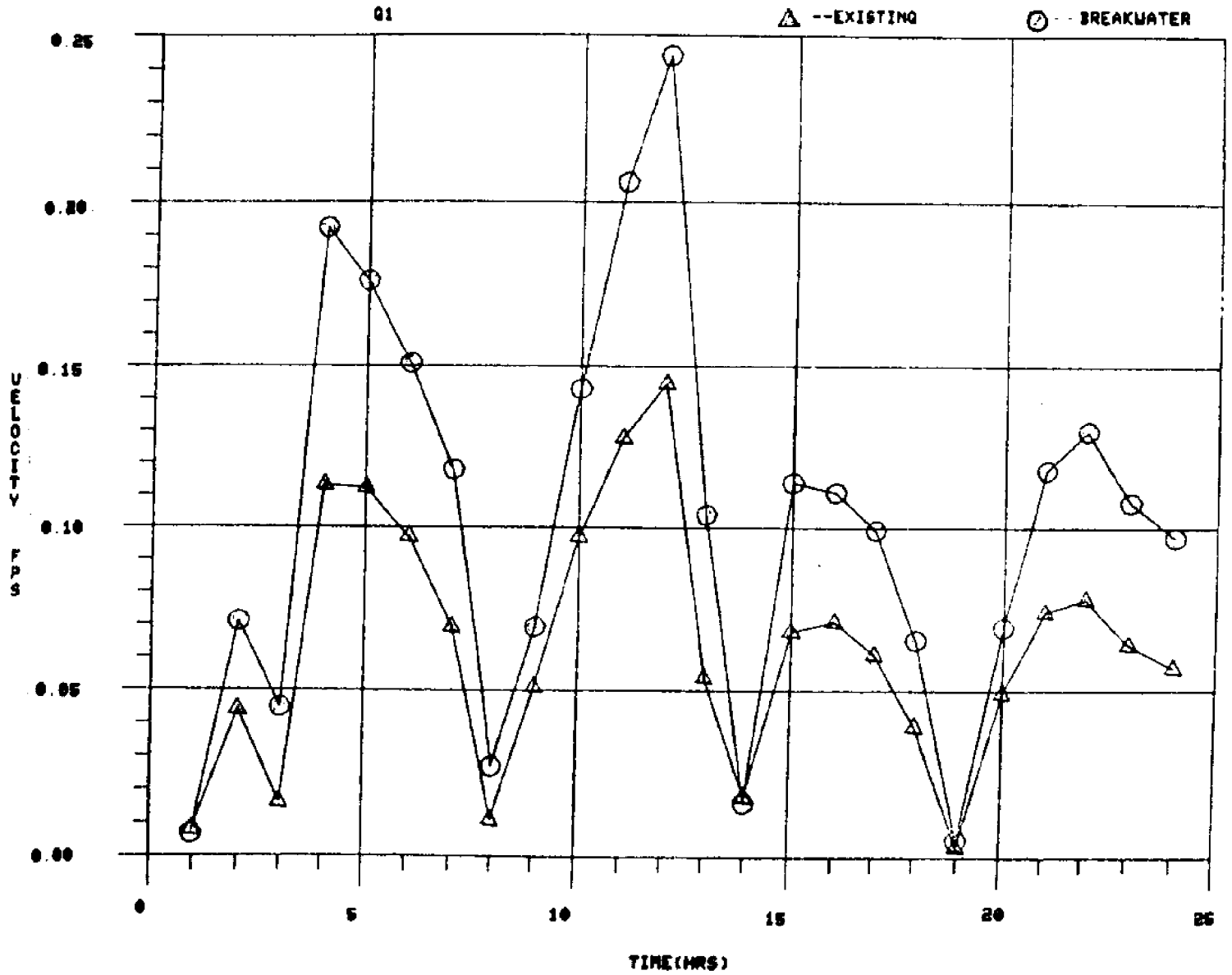

Figure 16. Velocity Variation at Gage Location G1 for the No Wind Condition

IX. CONCLUSIONS

Based upon numerical model results, the proposed breakwater at Eastpoint should have an almost negligible effect upon overall tidal circulation in Apalachicola Bay for average tide, wind and river flow conditions. Measurable changes in tidal elevation and velocities produced by addition of the Eastpoint breakwater are basically confined to a two mile radius from Eastpoint. Even within the local Eastpoint area, changes produced by the breakwater are small. Changes in water surface elevation are barely perceptible while maximum changes in velocity around the breakwater are much smaller than 0.1 fps. In general, for the condition investigated in this study, the breakwater appears to produce a slight channeling effect so velocities behind the breakwater are slightly higher than for existing conditions. Outside the breakwater there are regions where the velocities are slightly increased and other regions where velocities are slightly decreased as a result of the breakwater.

It should be restated that the numerical model was only calibrated in a qualitative manner and no attempt was made to verify the model. Model results should be of the correct order of magnitude, especially predicted changes for a proposed modification. However, under these conditions model results should not be used in a precise quantitative manner but only to indicate general trends. Thus, rather than indicating that velocities are increased or decreased slightly in specific areas, one is probably only justified in stating that changes produced by

the breakwater would appear to be very small and local for the conditions investigated.

No extreme wind, river or tide conditions were considered in this study. No water quality parameters have been directly examined in this study; however, water quality changes can be inferred from the hydrodynamic results. Only local changes in water quality parameters would appear likely.

Because of the Eastpoint project and other projects in Apalachicola Bay, it would be desirable to conduct a more extensive calibration and verification of numerical models for the bay. Such models operated in conjunction with sub-grids of the entire bay would allow accurate predictions of hydrodynamic and water quality changes produced by proposed modifications to the bay.

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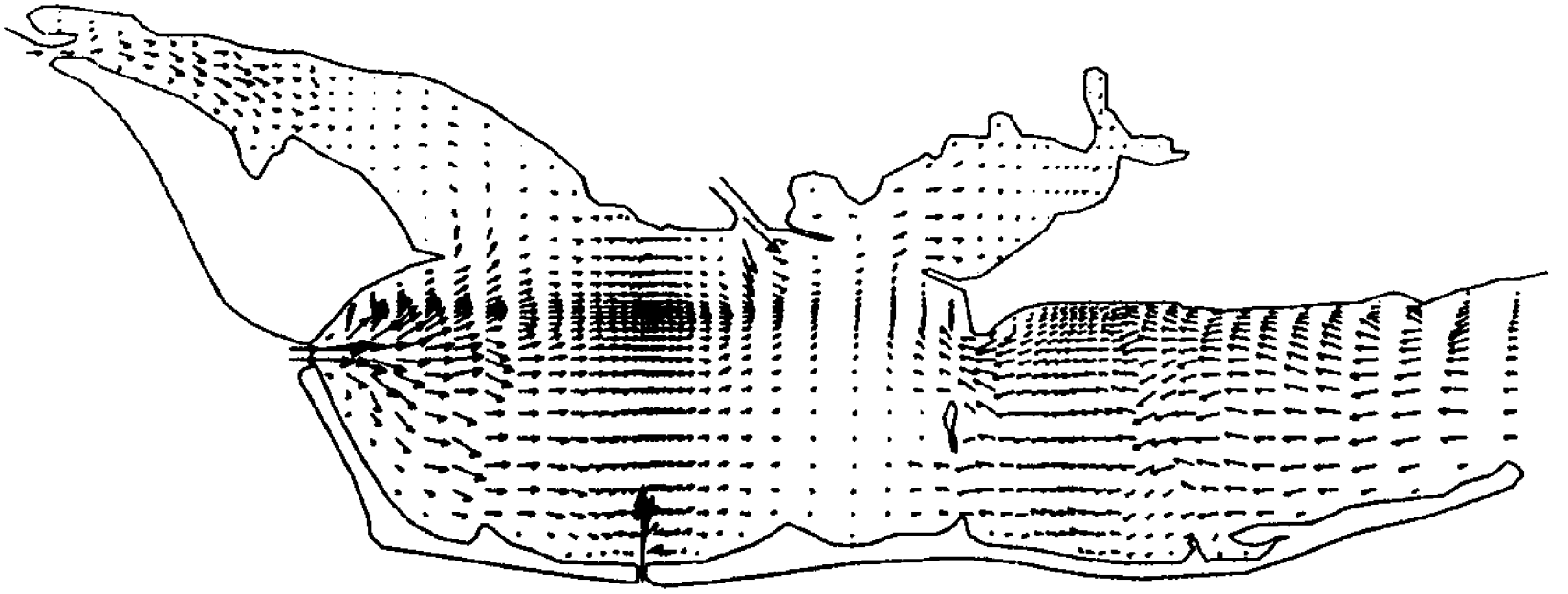
11. Zeh, T.A., "Sikes Cut-Glossary of Inlet Report No. 7", Report Number 35, Florida Sea Grant College, Department of Coastal and Oceanographic Engineering, University of Florida, August 1980.

12. Personal communications from Dru Barrineau, Planning Division, U.S. Army Corps of Engineers, Mobile District to Dr. Donald C. Raney, Professor, The University of Alabama.

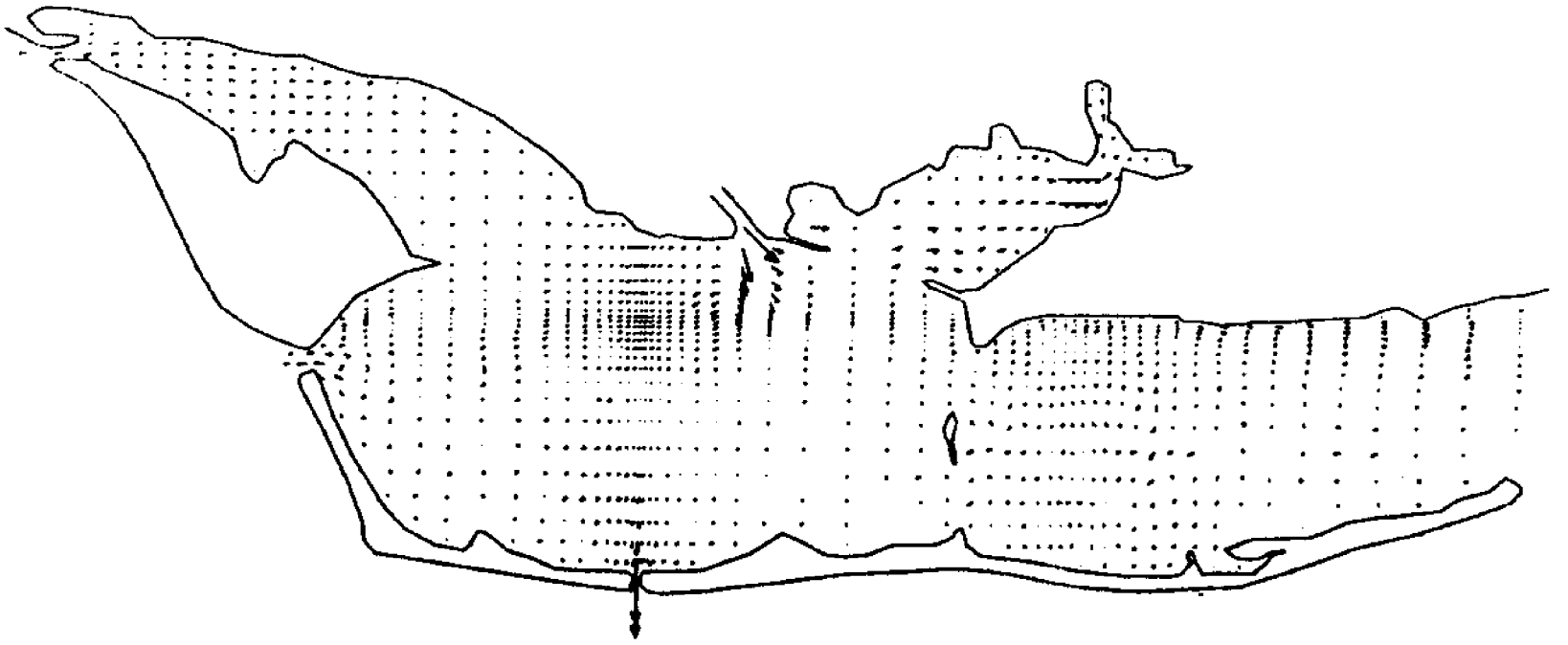
APPENDIX A

TYPICAL CIRCULATION PATTERNS FOR APALACHICOLA BAY FOR A NO WIND CONDITION AND EXISTING CONDITIONS

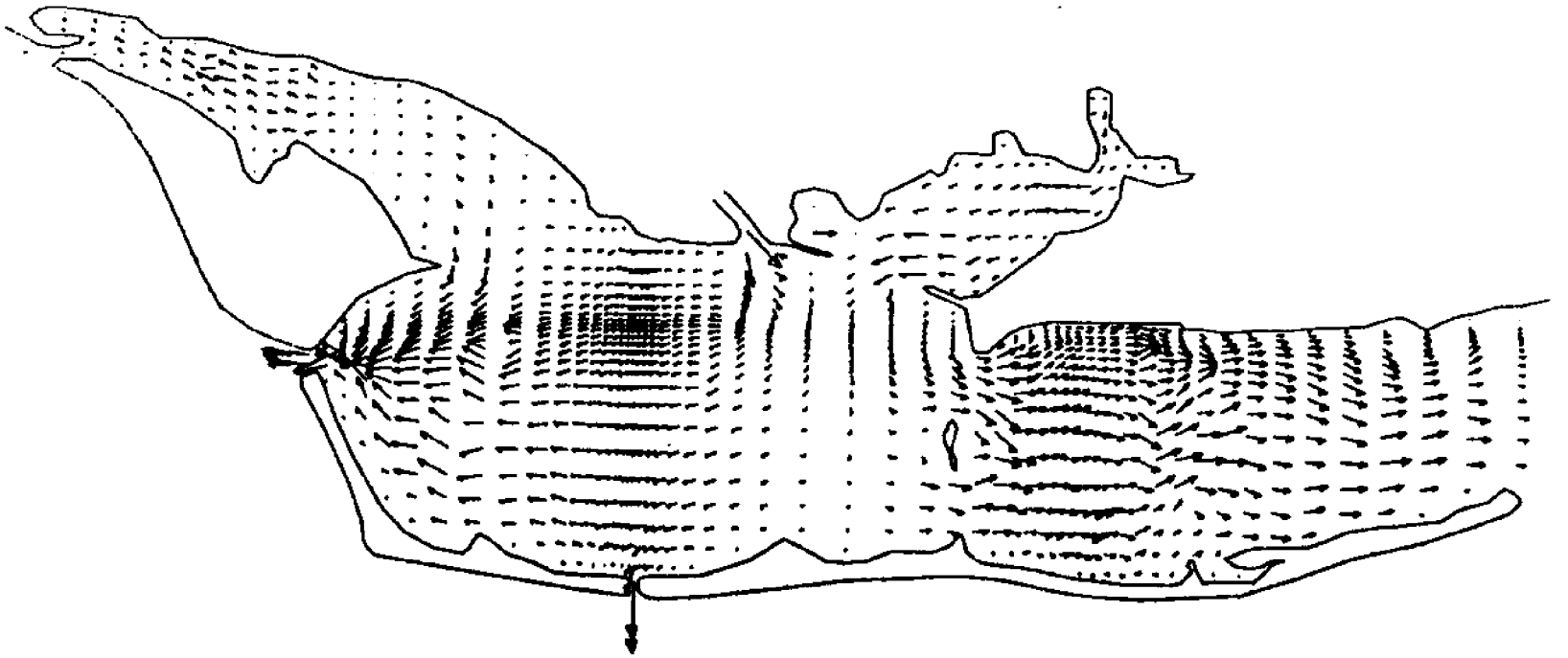
Appalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) - 4.00000
Maximum Velocity (Ft/Sec) - 2.41343



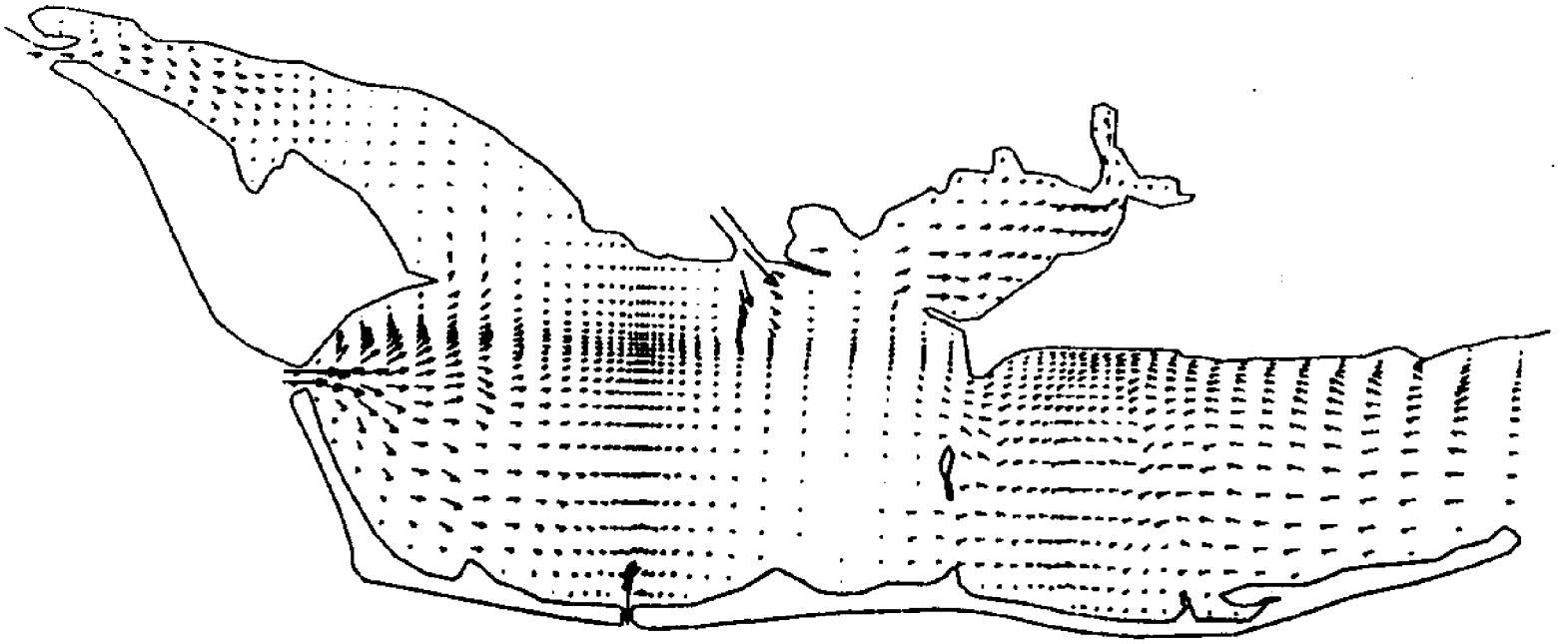
Apalachicola Bay 24 hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) - 8.00000
Maximum Velocity (Ft/Sec) - 1.49907



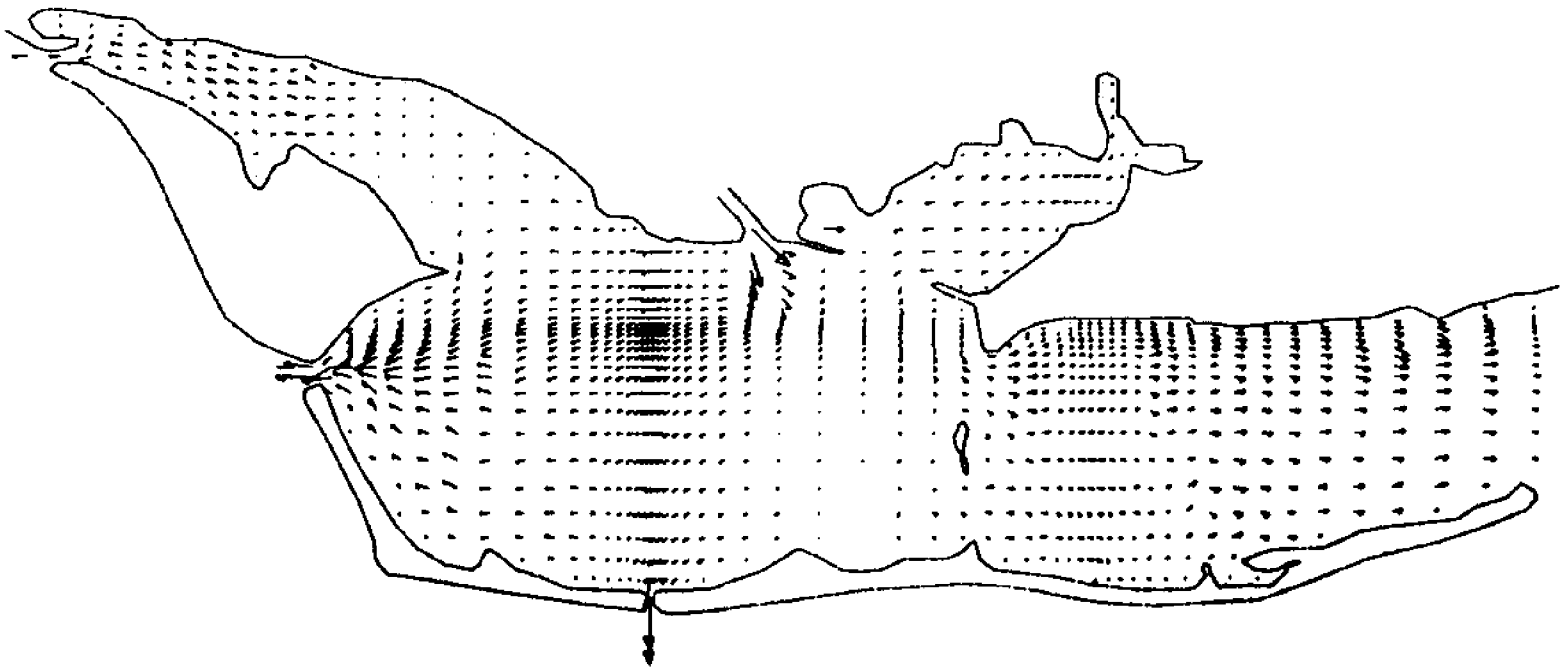
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) - 12.00000
Maximum Velocity (Ft/Sec) - 1.63250



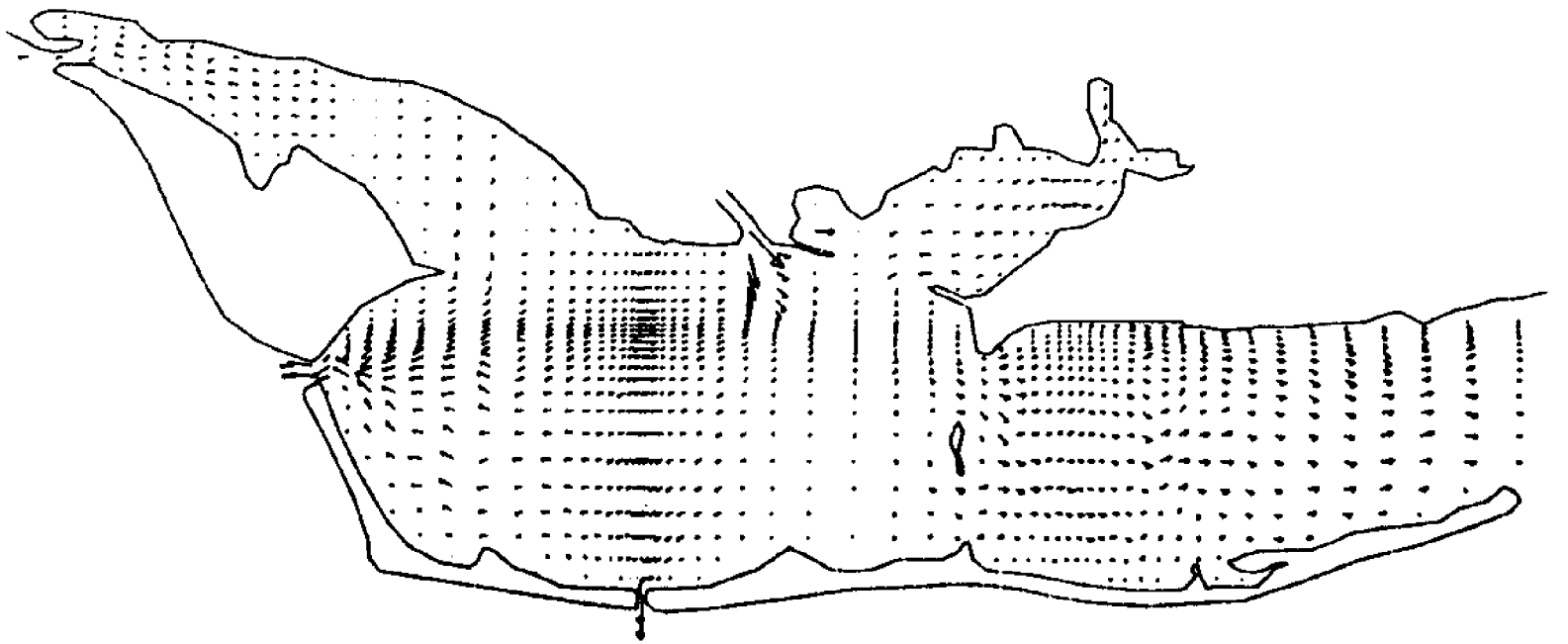
Apalachicola Bay 24 Hrs. Run - Without Breakwaters With Zero Wind
Flow Rate Field at T (Hr) - 16.00000
Maximum Velocity (Ft/Sec) - 1.49907



Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 20.00000
Maximum Velocity (Ft/Sec) - 1.49907



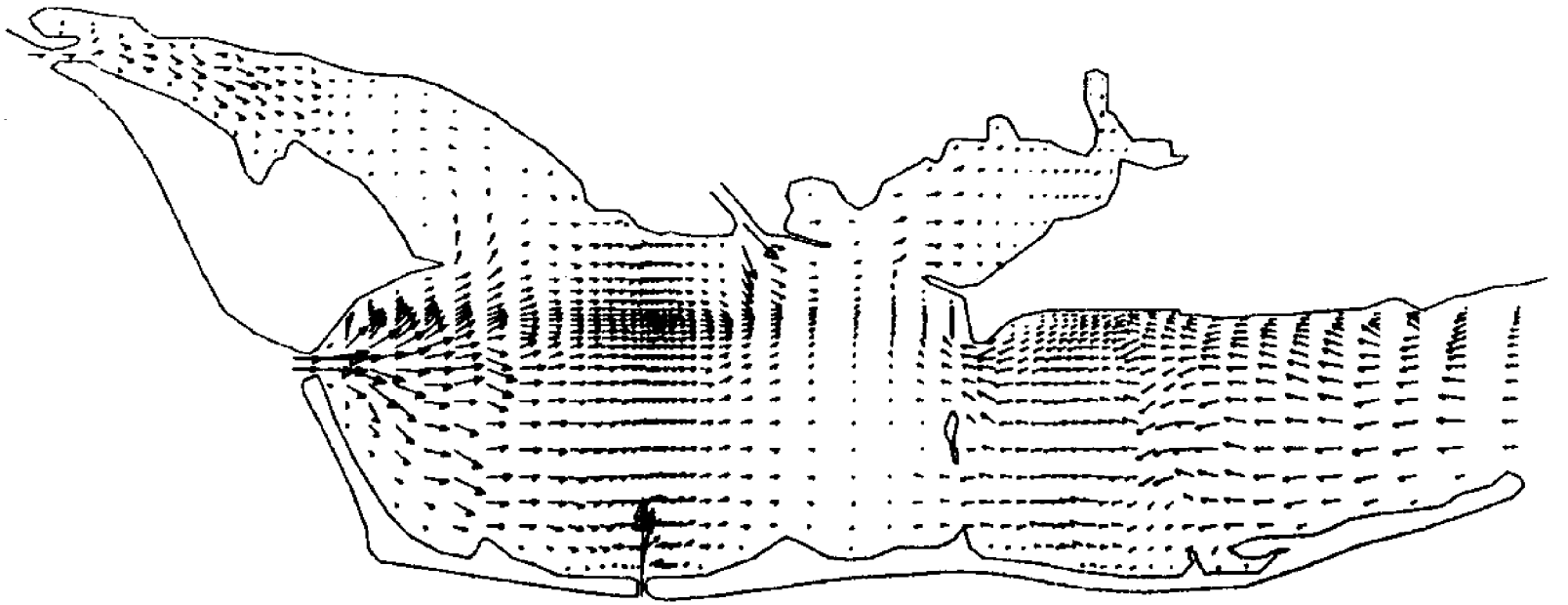
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 24.00000
Maximum Velocity (Ft/Sec) - 1.49907



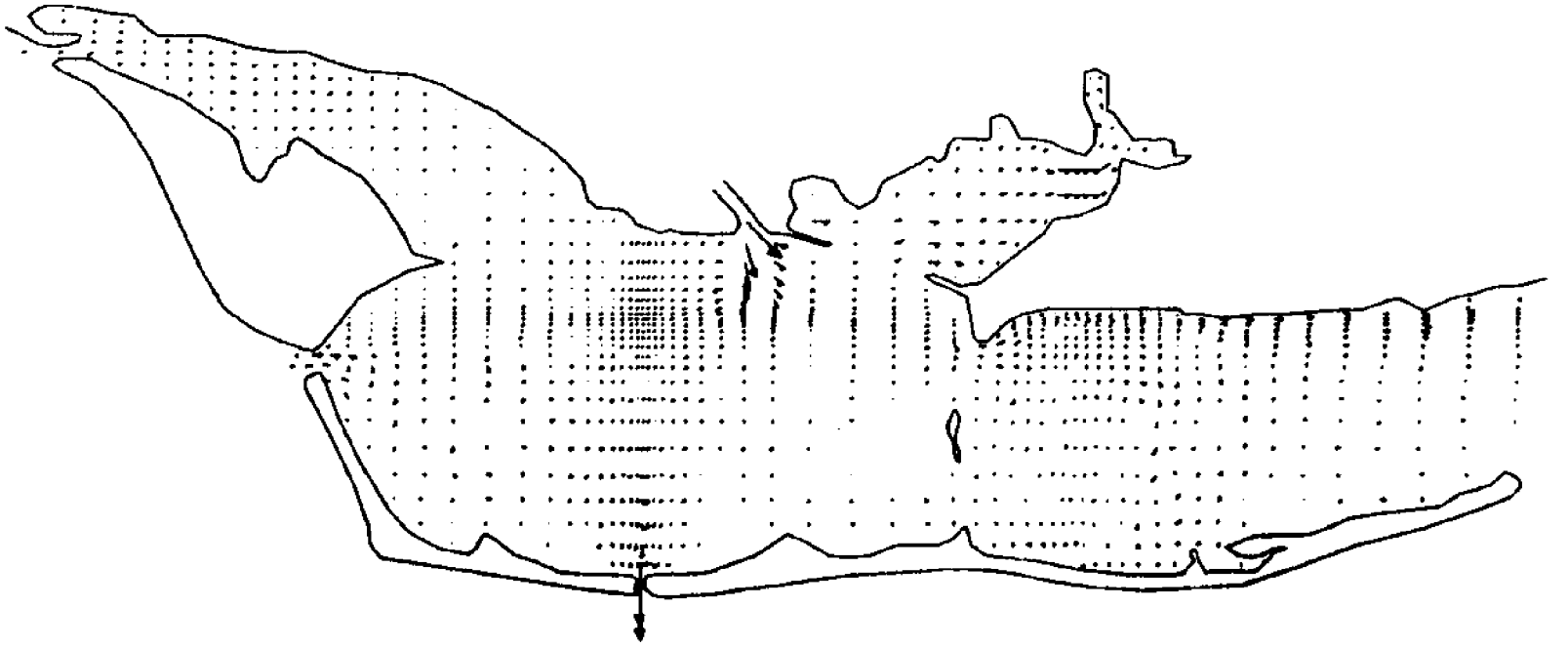
APPENDIX B

TYPICAL CIRCULATION PATTERNS FOR APALACHICOLA BAY FOR AN AVERAGE SUMMER WIND AND EXISTING CONDITIONS

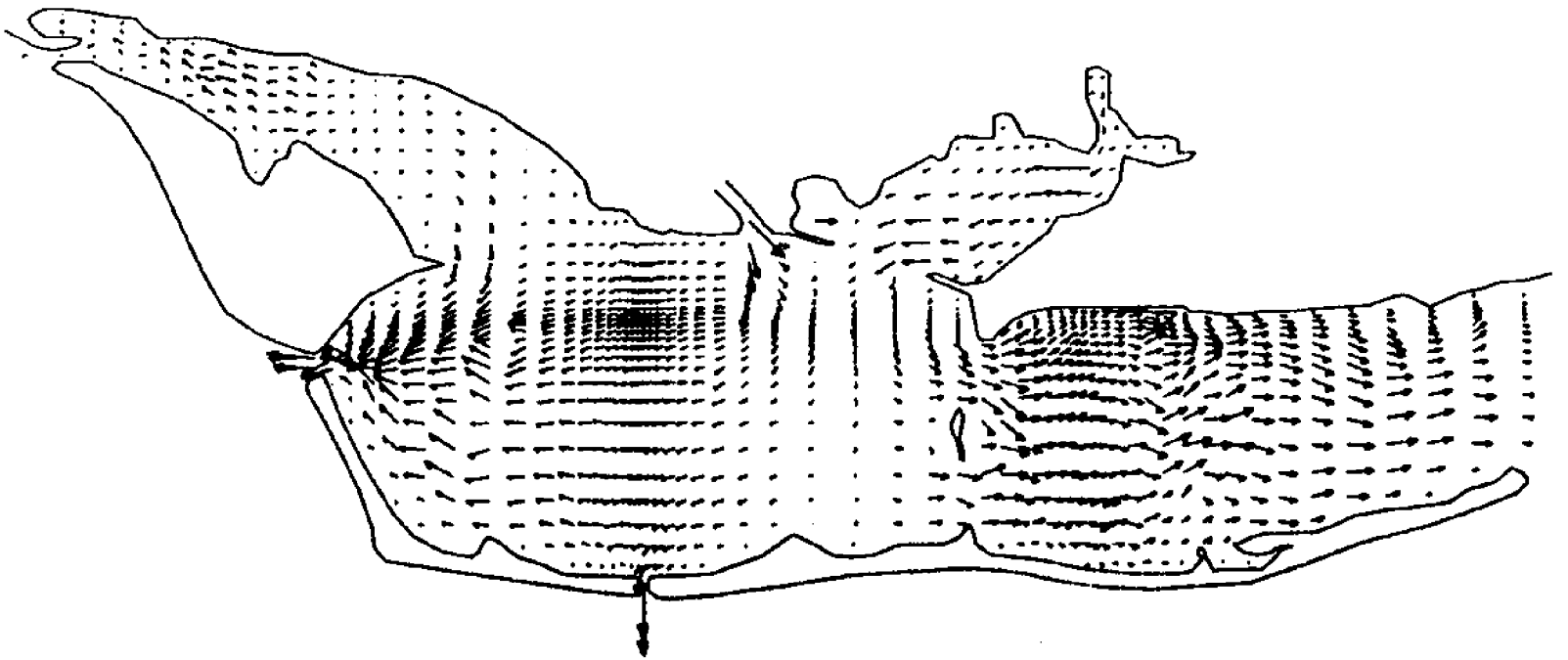
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) - 4.00000
Maximum Velocity (Ft/Sec) - 2.43513



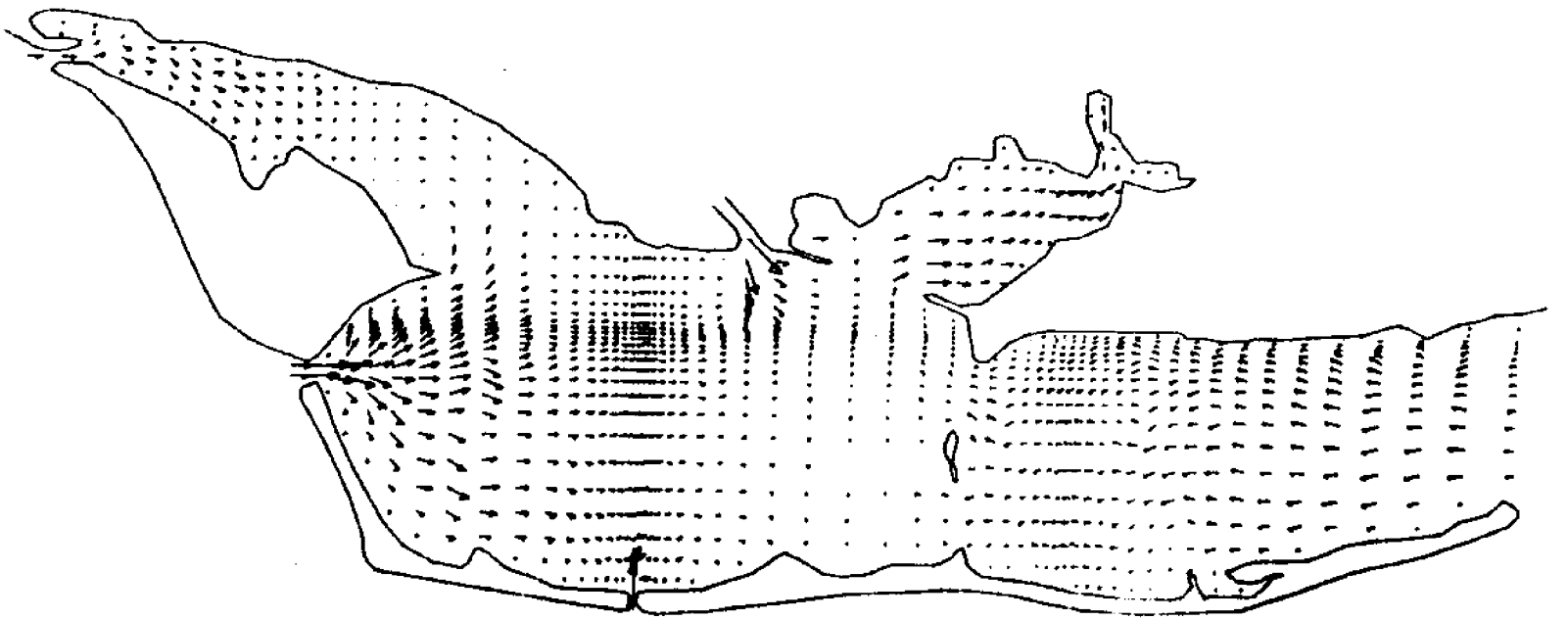
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) - 8.00000
Maximum Velocity (Ft/Sec) = 1.49907



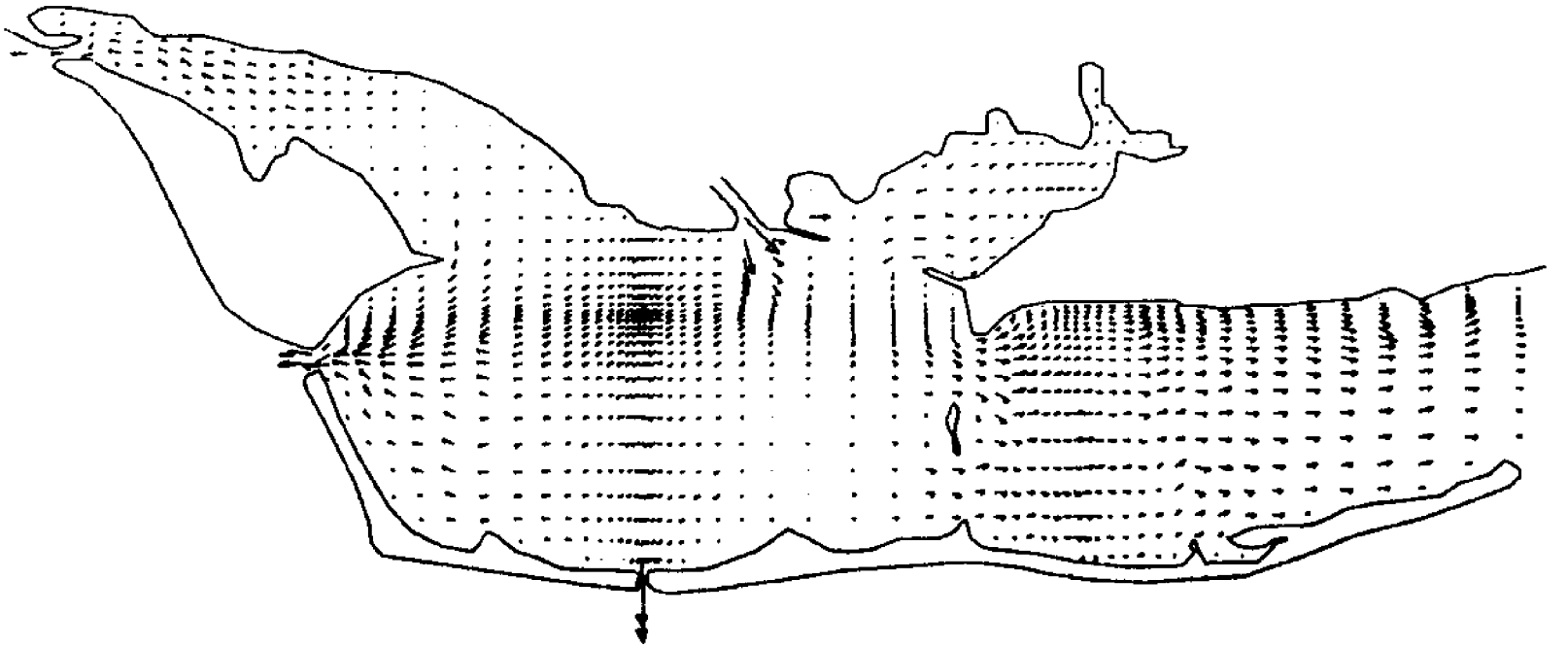
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field At T (Hr) - 12.00000
Maximum Velocity (Ft/Sec) - 1.60187



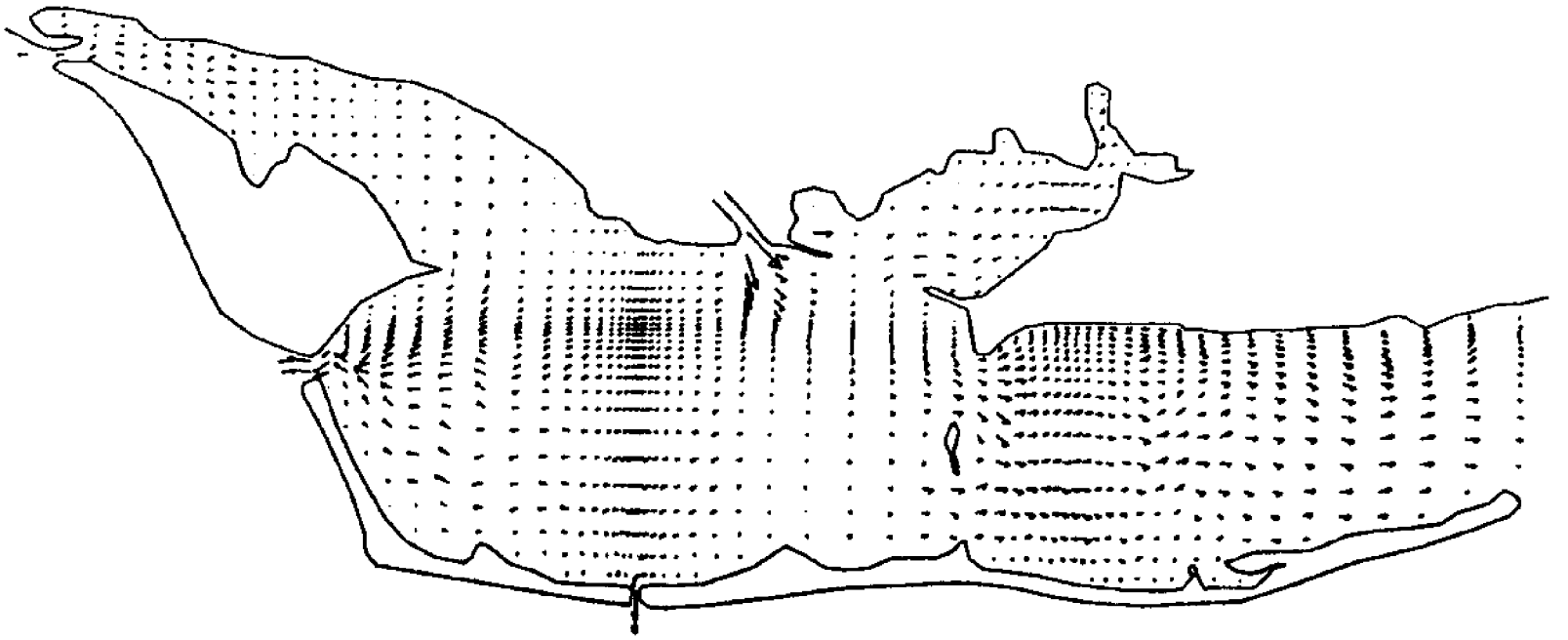
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 16.00000
Maximum Velocity (Ft/Sec) = 1.49907



Apalachicola Bay 24 Hours. Run - Without Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = 1.49907



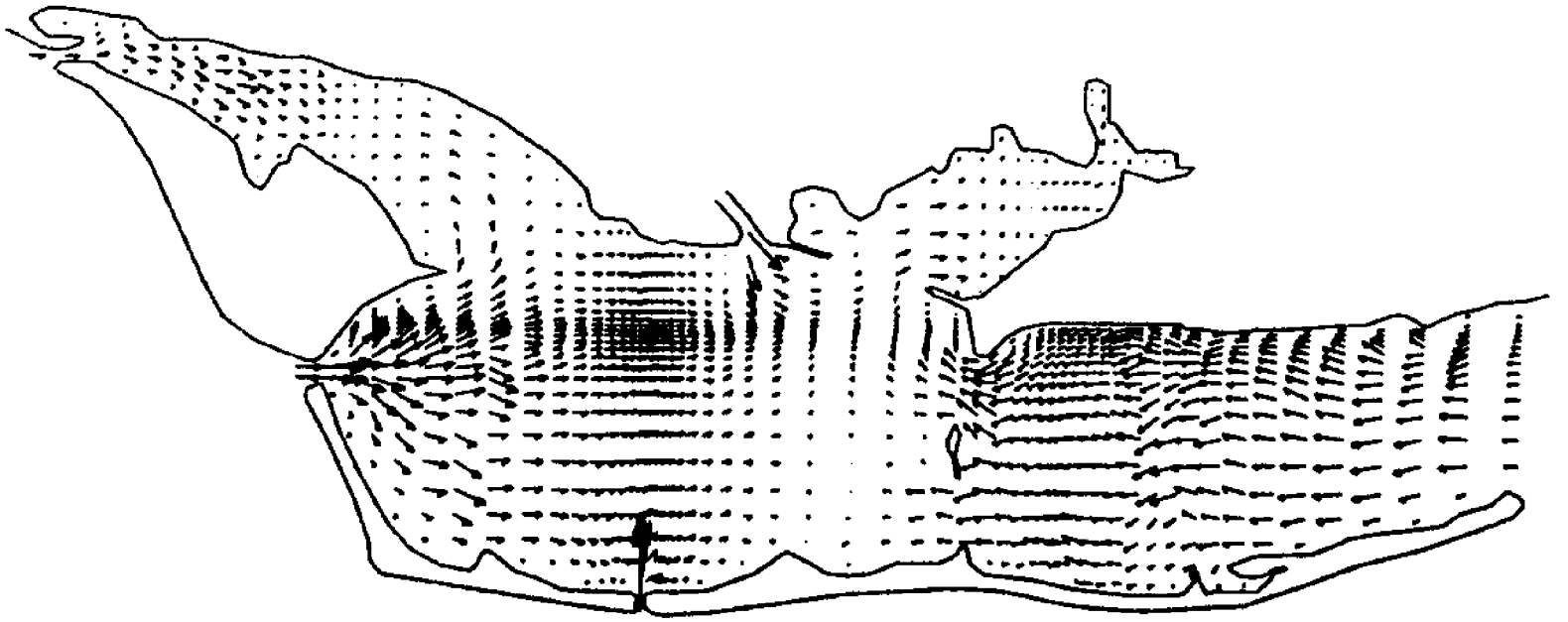
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 24.00000
Maximum Velocity (Ft/Sec) = 1.49907



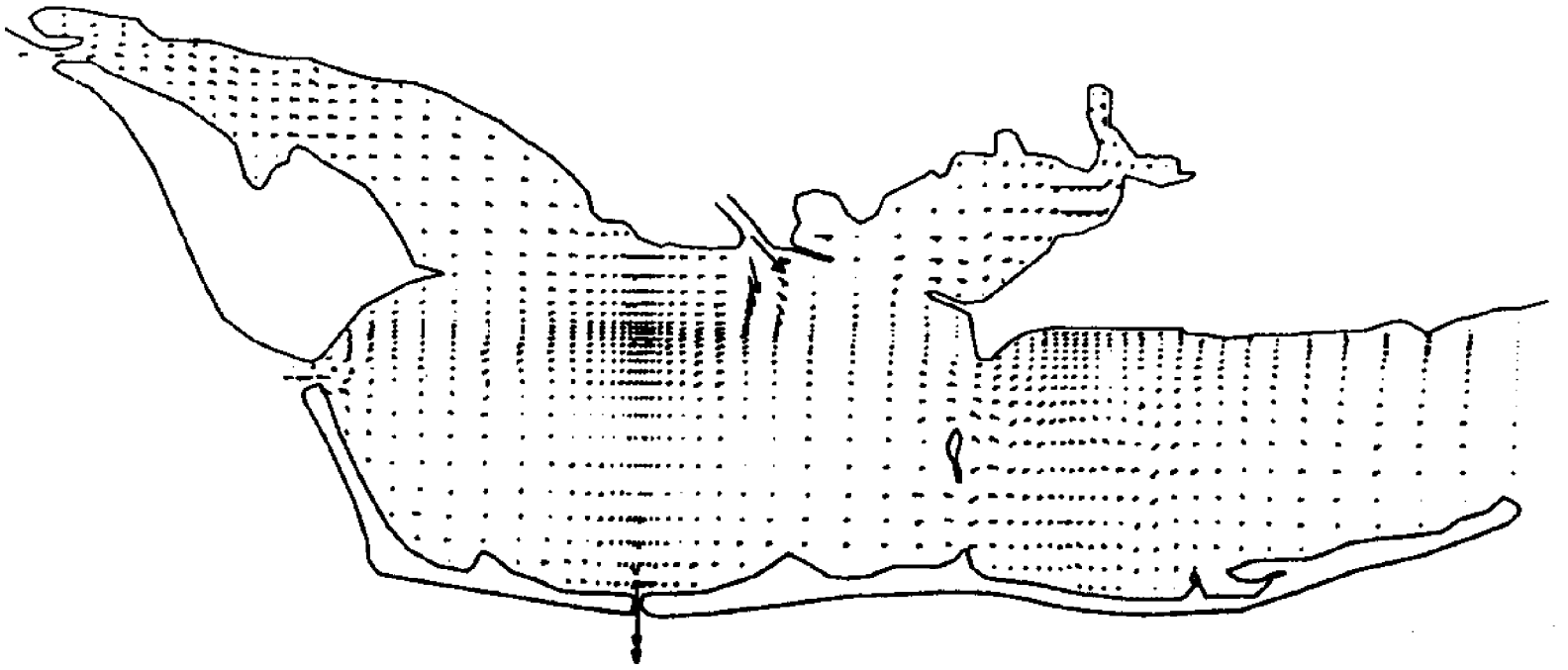
APPENDIX C

TYPICAL CIRCULATION PATTERNS FOR APALACHICOLA BAY FOR AN AVERAGE WINTER WIND AND EXISTING CONDITIONS

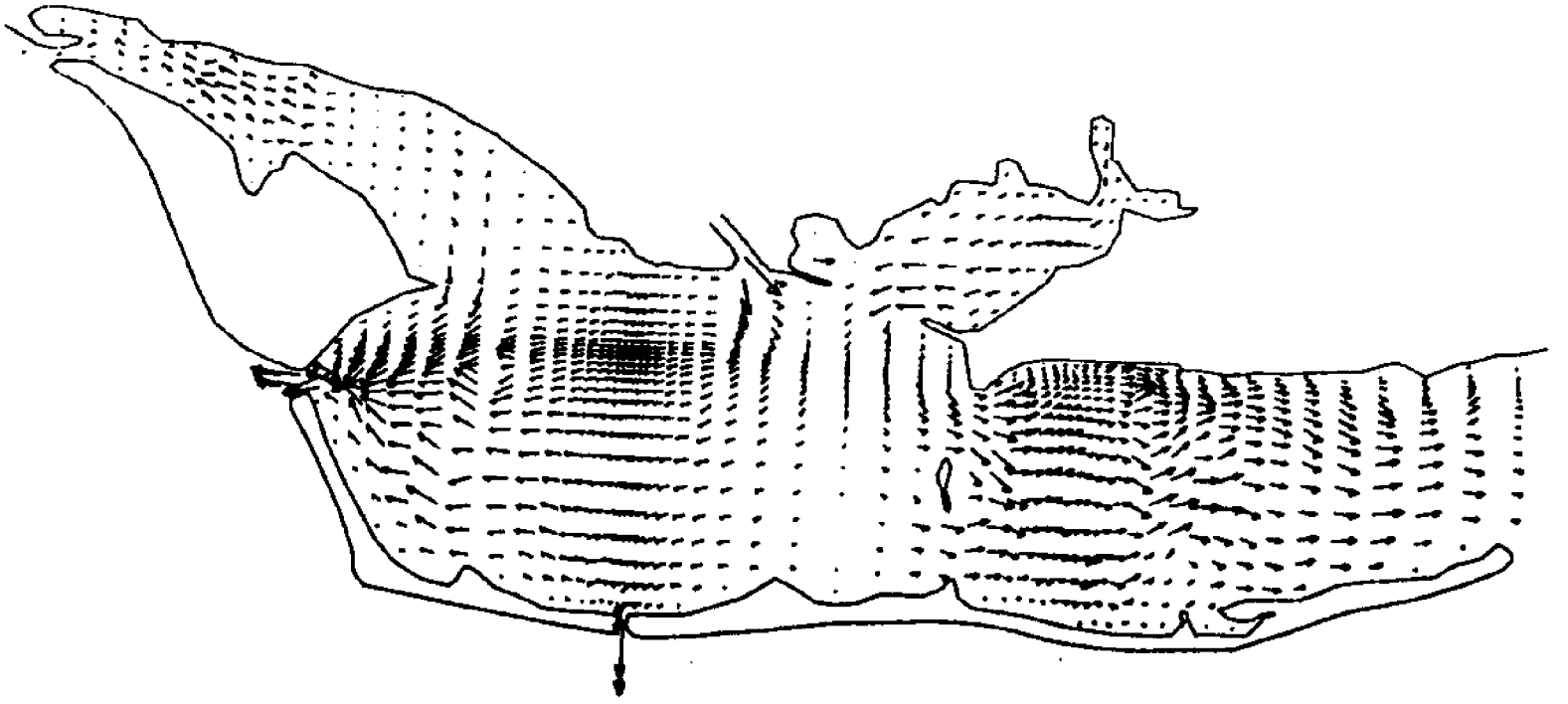
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 4.00000
Maximum Velocity (Ft/Sec) = 2.37156



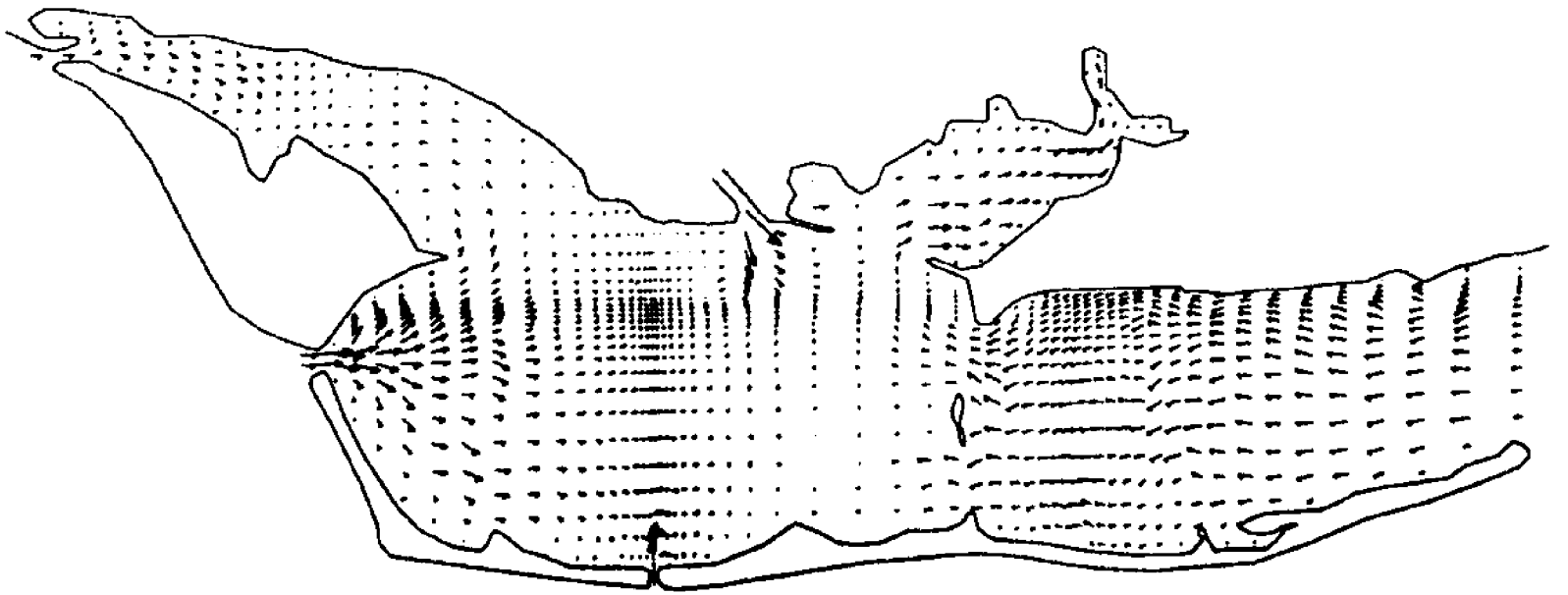
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 8.00000
Maximum Velocity (Ft/Sec) = 1.49907



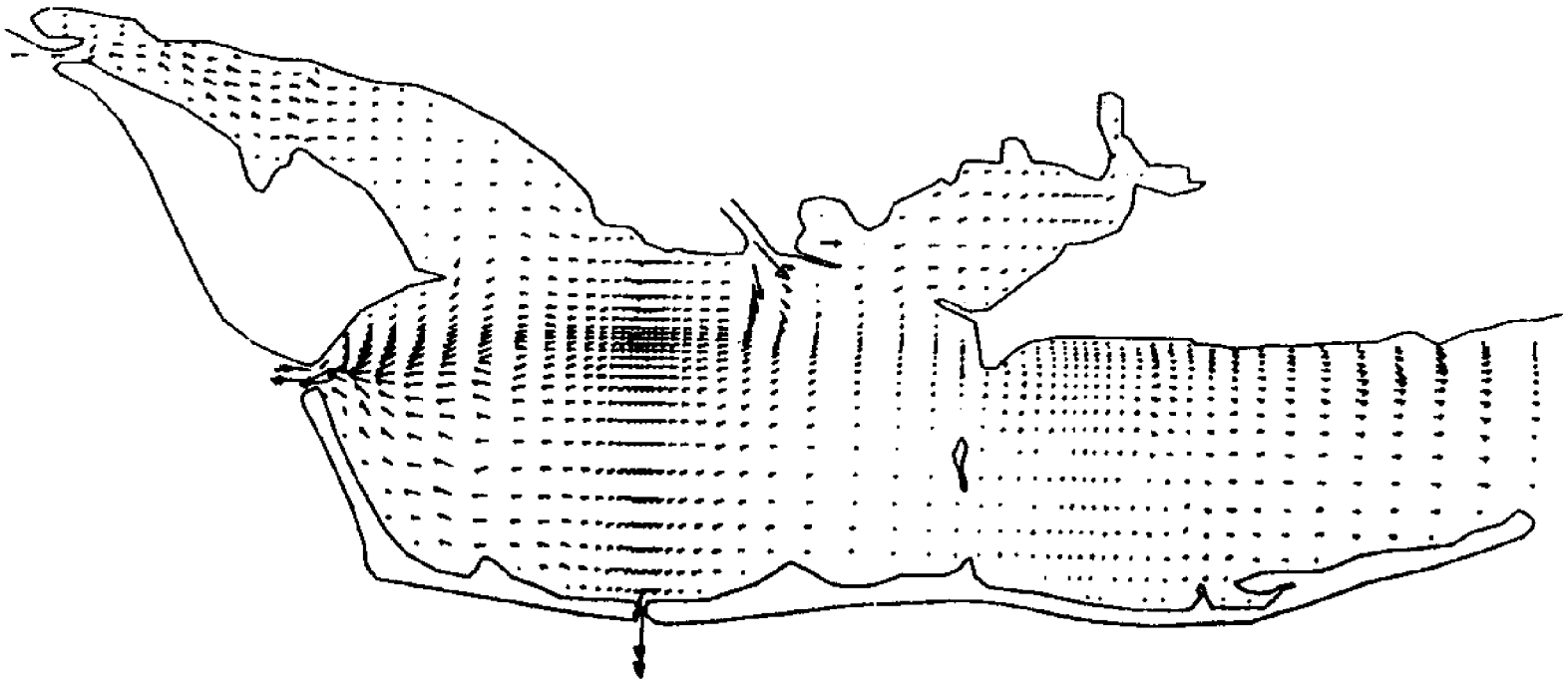
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 12.00000
Maximum Velocity (Ft/Sec) = 1.65668



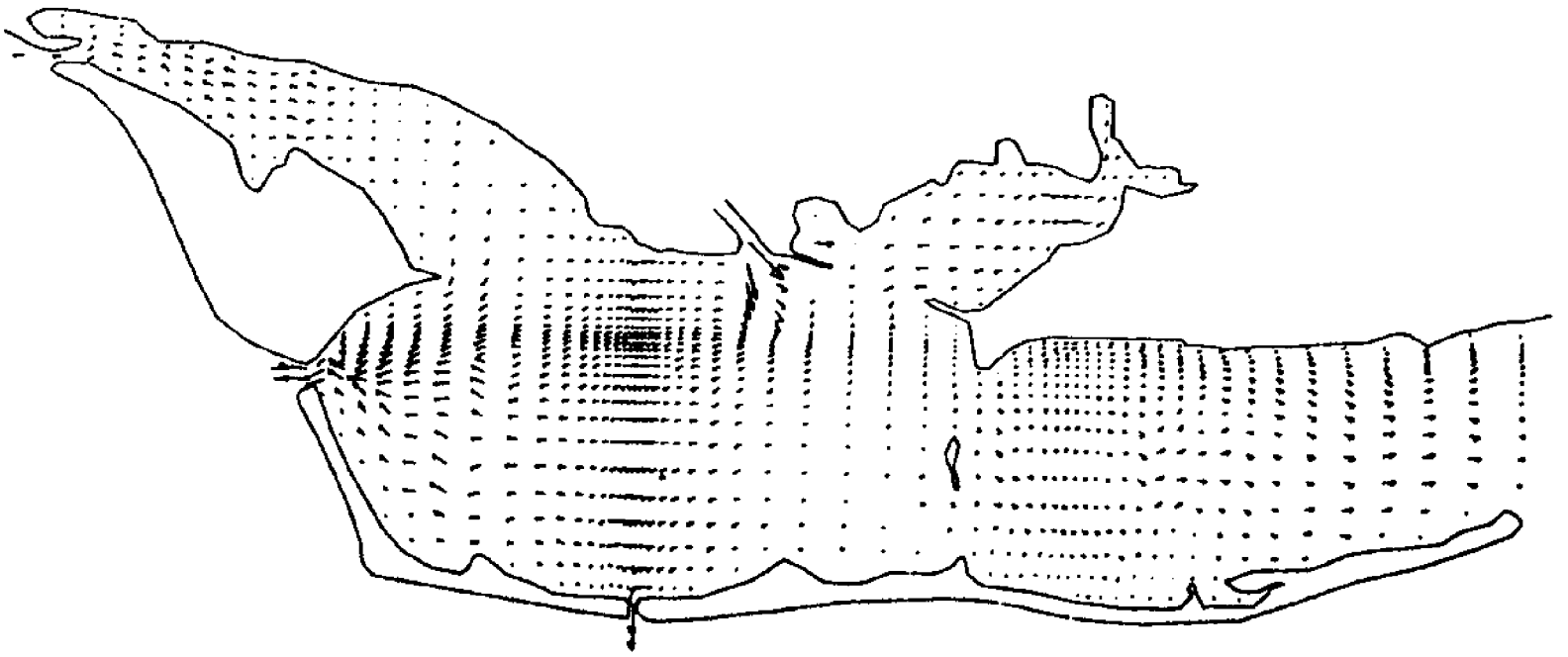
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 16.00000
Maximum Velocity (Ft/Sec) = 1.49907



Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = 1.50331



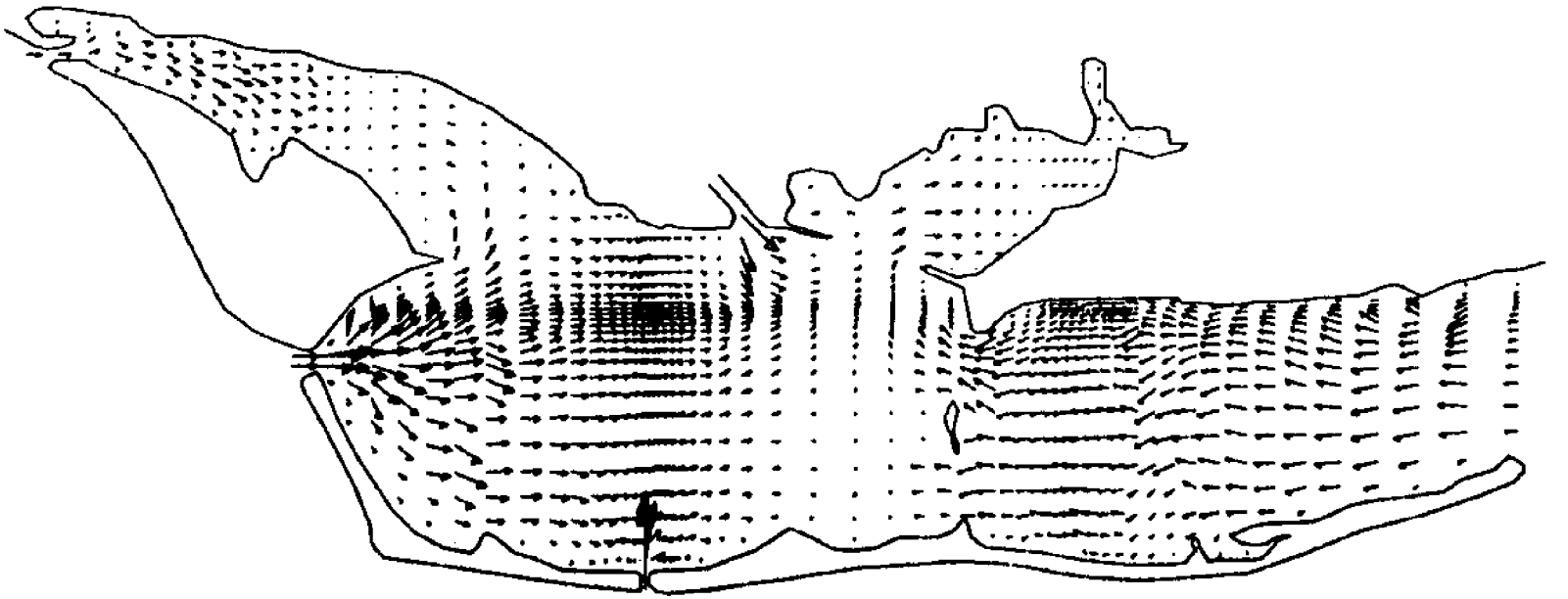
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 24.00000
Maximum Velocity (Ft/Sec) = 1.49907



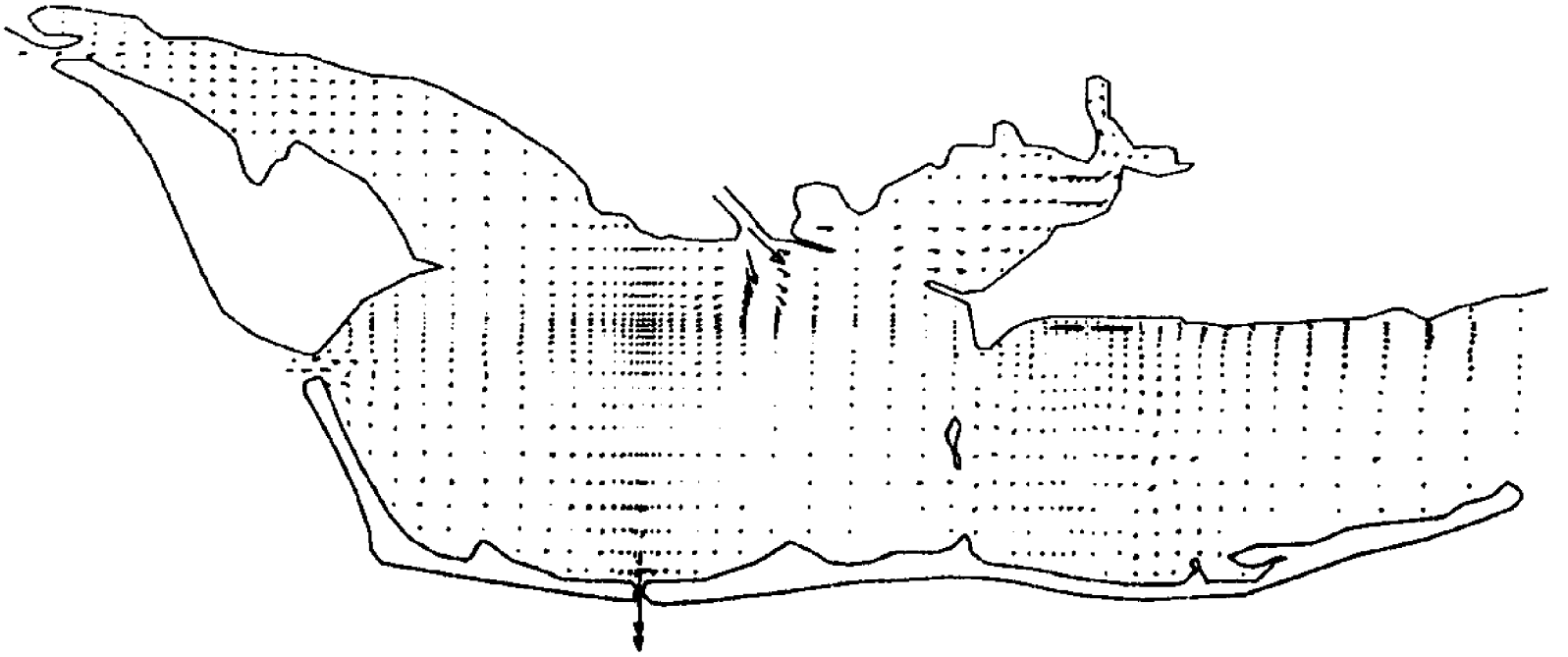
APPENDIX D

TYPICAL CIRCULATION PATTERNS FOR APALACHICOLA BAY FOR A NO WIND CONDITION AND A BREAKWATER INSTALLED AT EASTPOINT

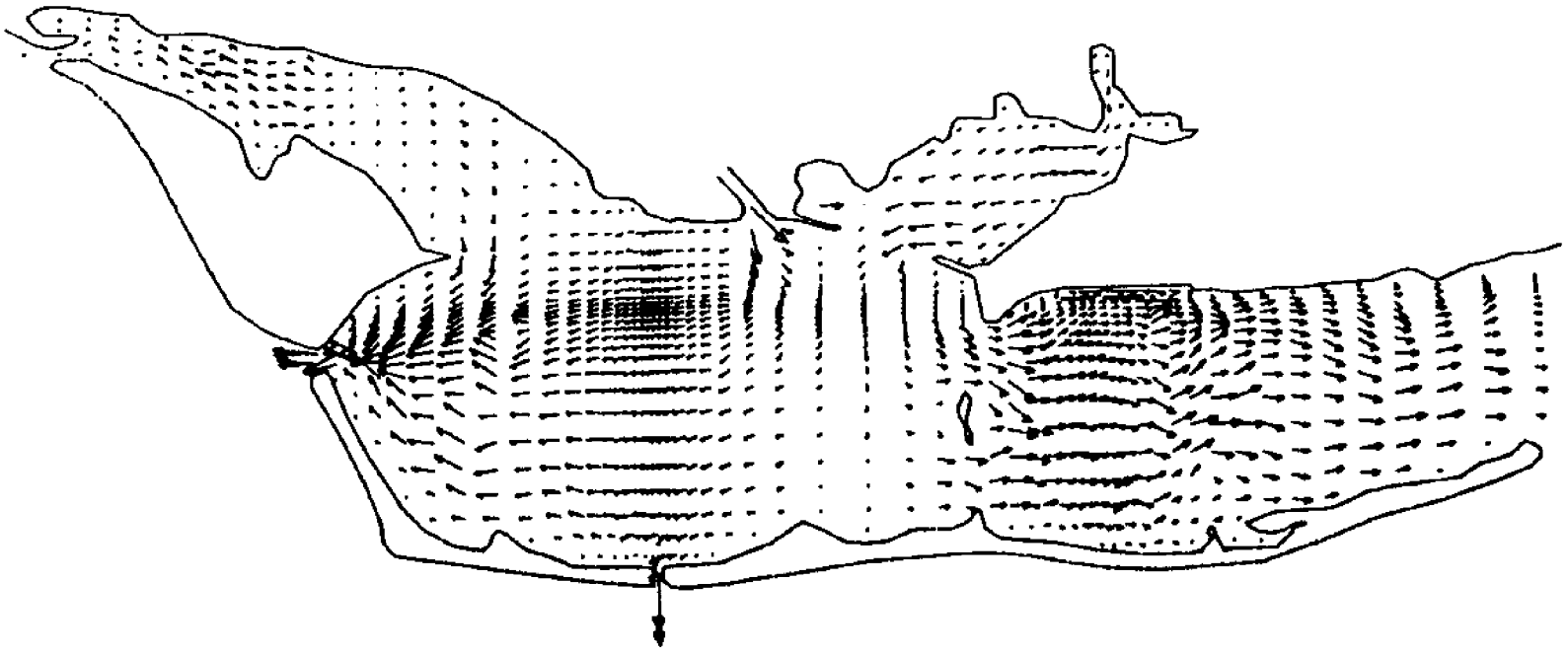
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 4.0000
Maximum Velocity (Ft/Sec) = 2.41296



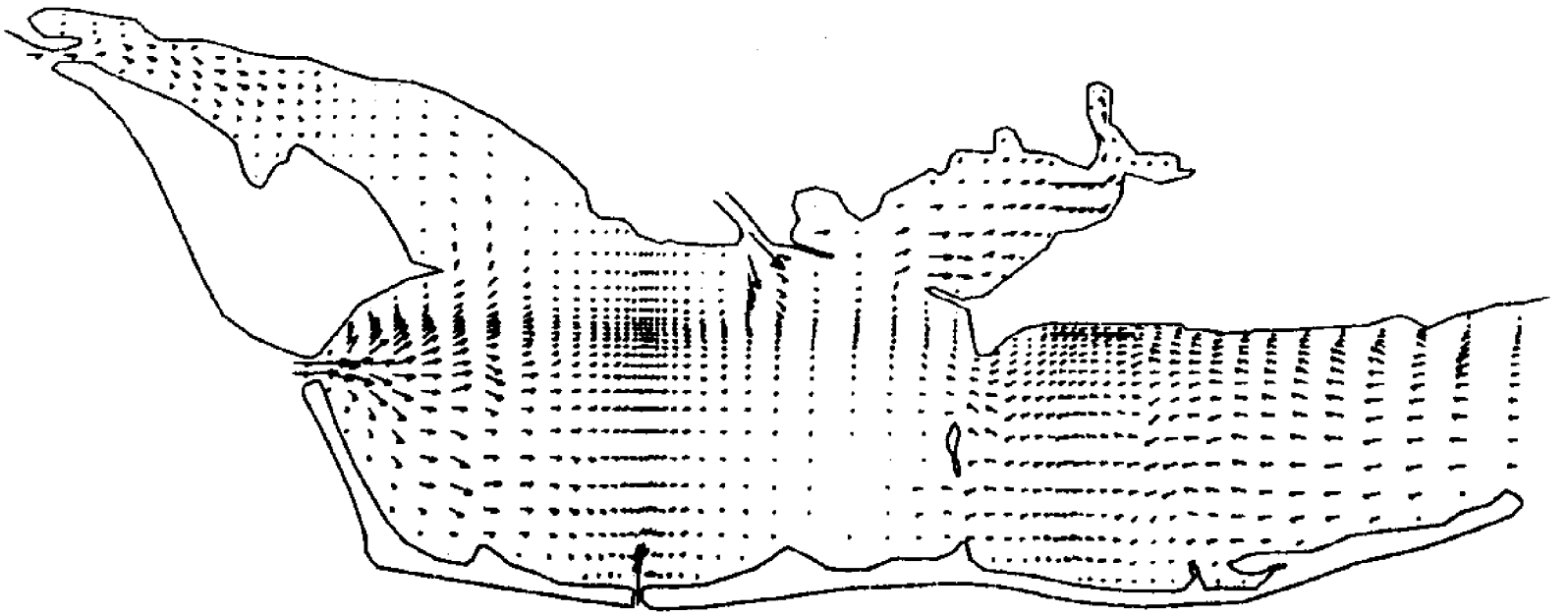
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 8.00000
Maximum Velocity (Ft/Sec) = 1.49907



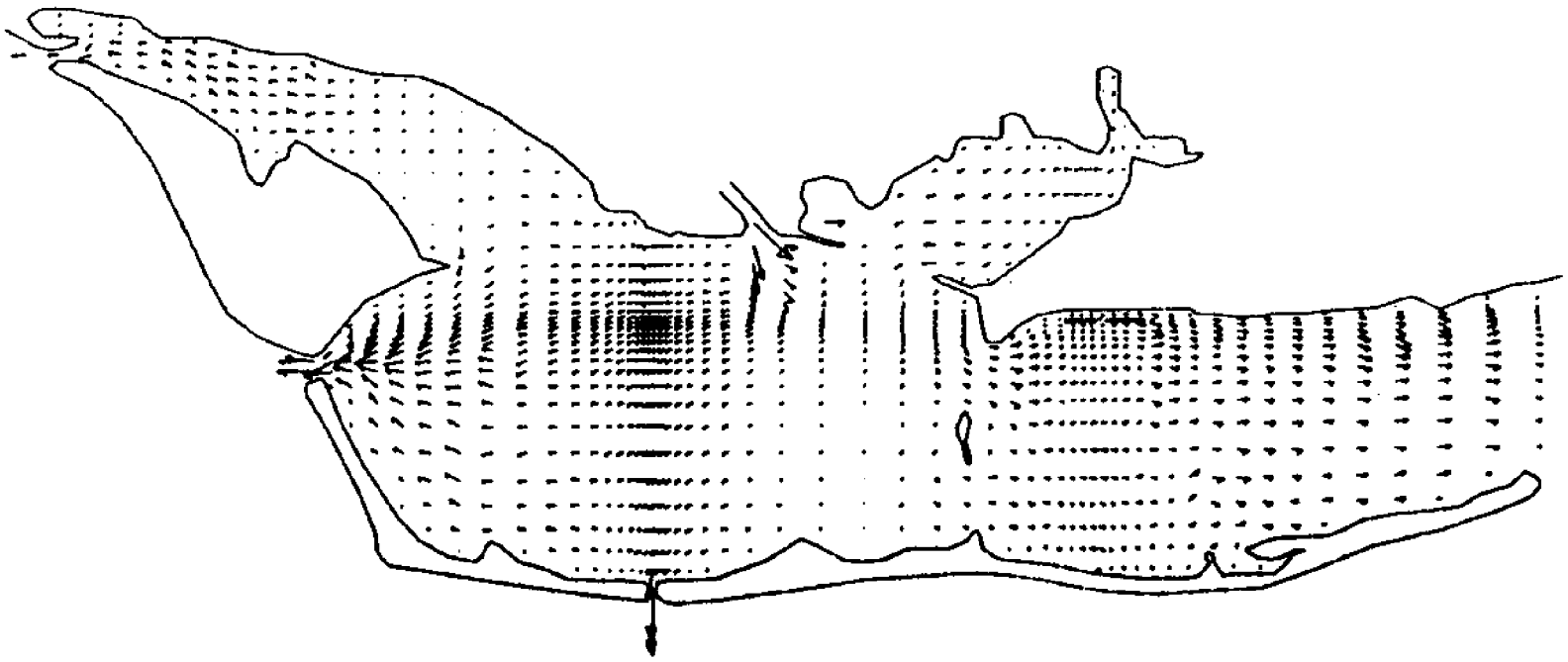
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 12.00000
Maximum Velocity (Ft/Sec) = 1.62906



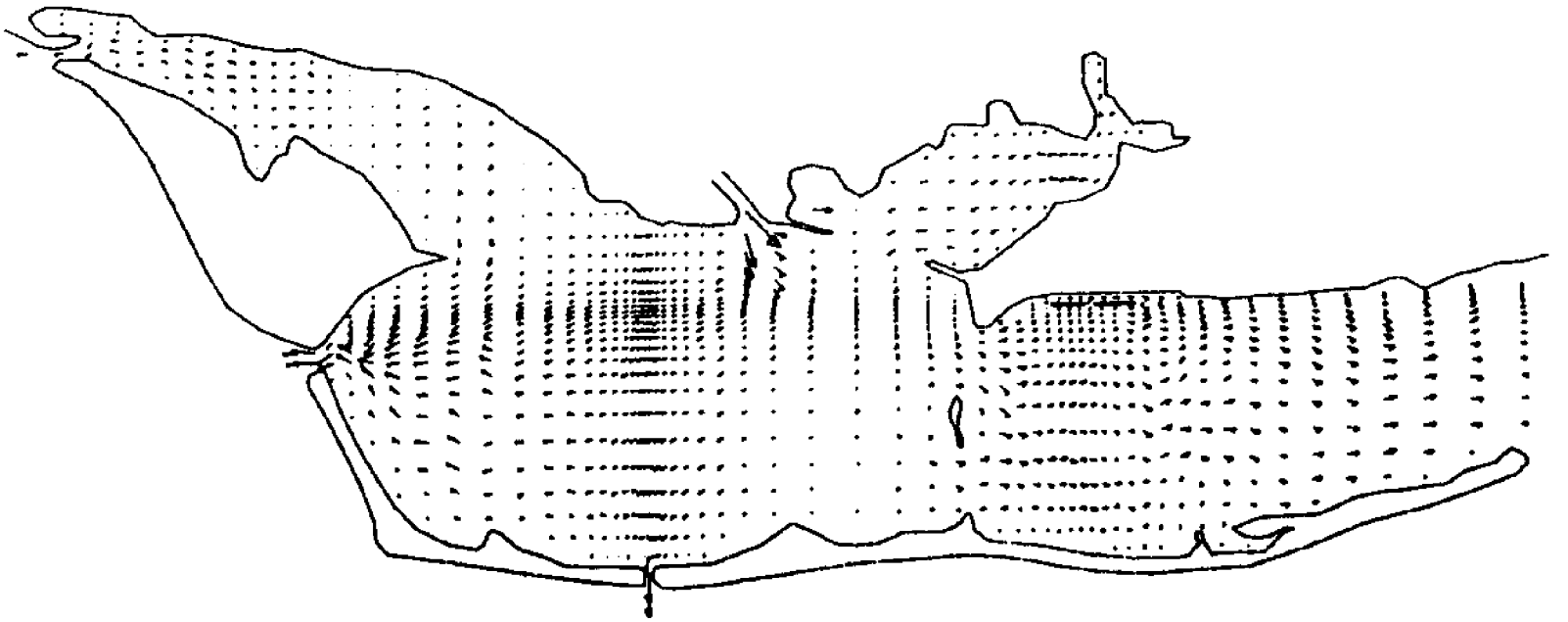
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 16.00000
Maximum Velocity (Ft/Sec) = 1.49907



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = 1.49907



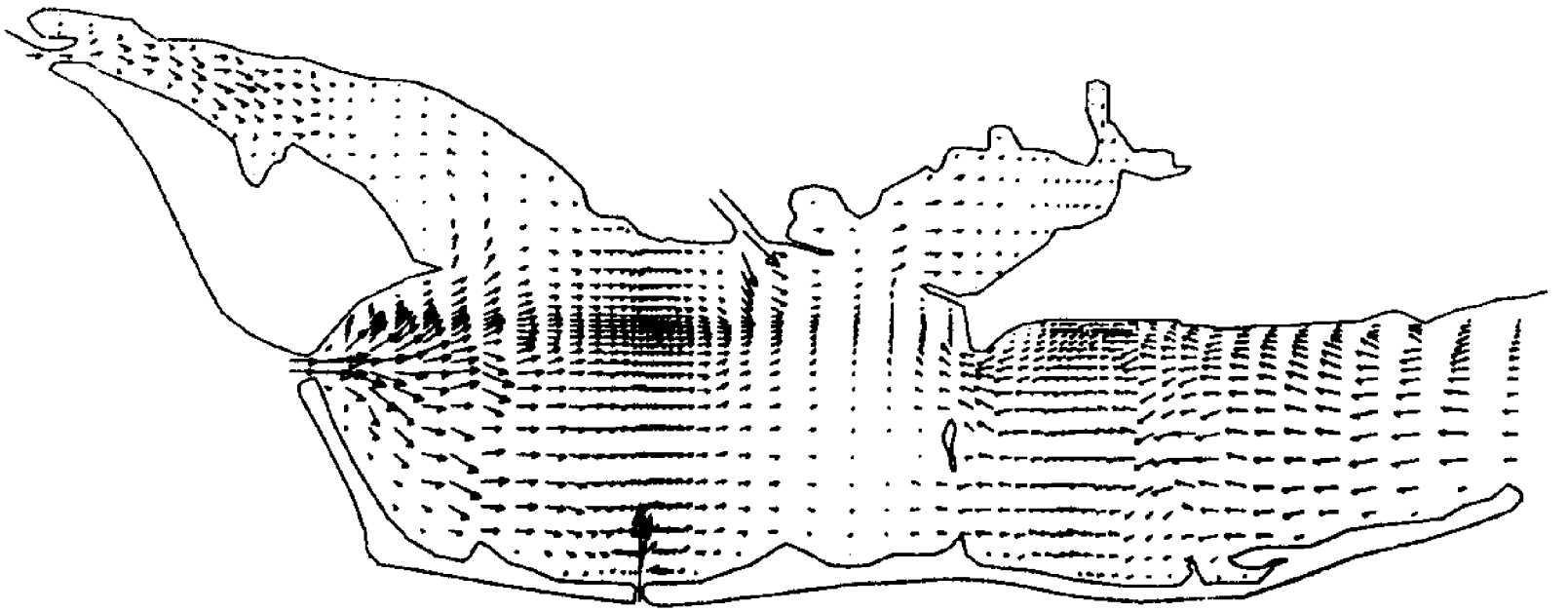
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 24.00000
Maximum Velocity (Ft/Sec) = 1.49907



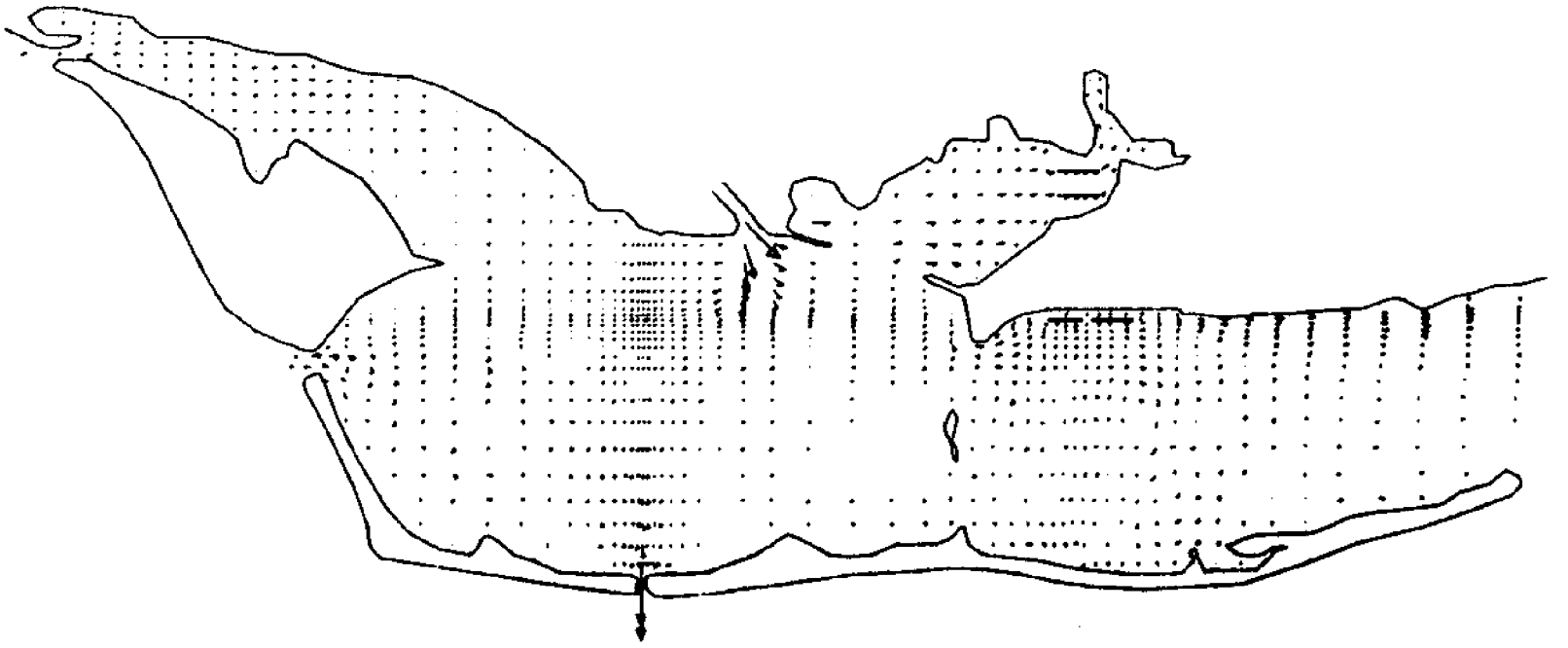
APPENDIX E

TYPICAL CIRCULATION PATTERNS FOR APALACHICOLA BAY FOR AN AVERAGE SUMMER WIND AND A BREAKWATER INSTALLED AT EAST POINT

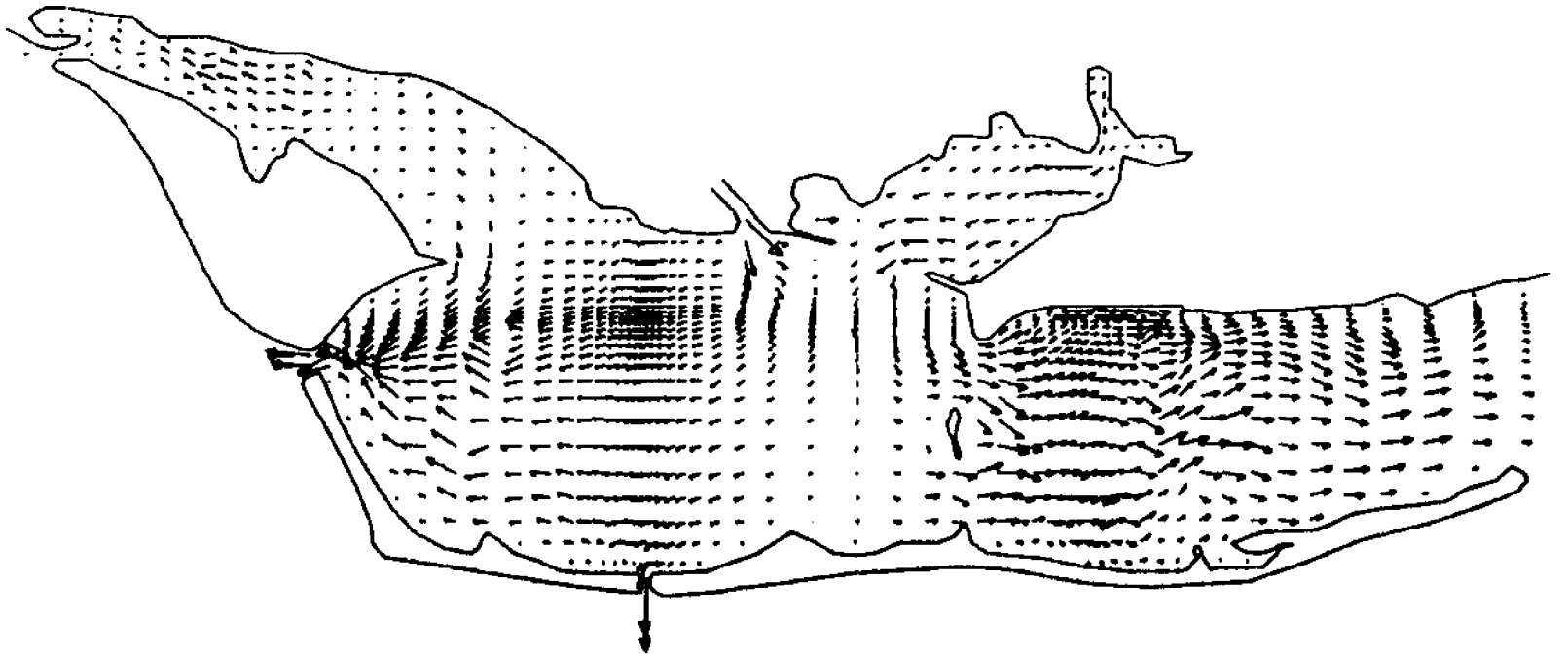
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 4.00000
Maximum Velocity (Ft/Sec) = 2.43470



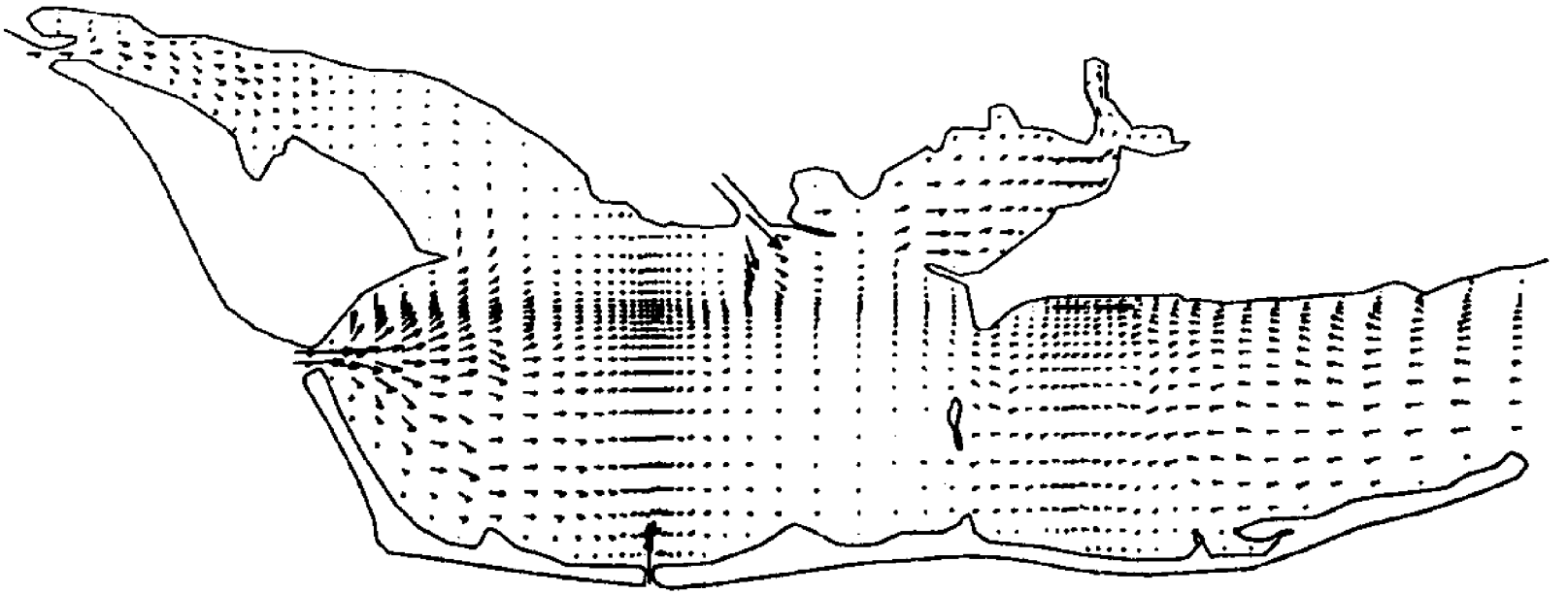
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 8.00000
Maximum Velocity (Ft/Sec) = 1.49907



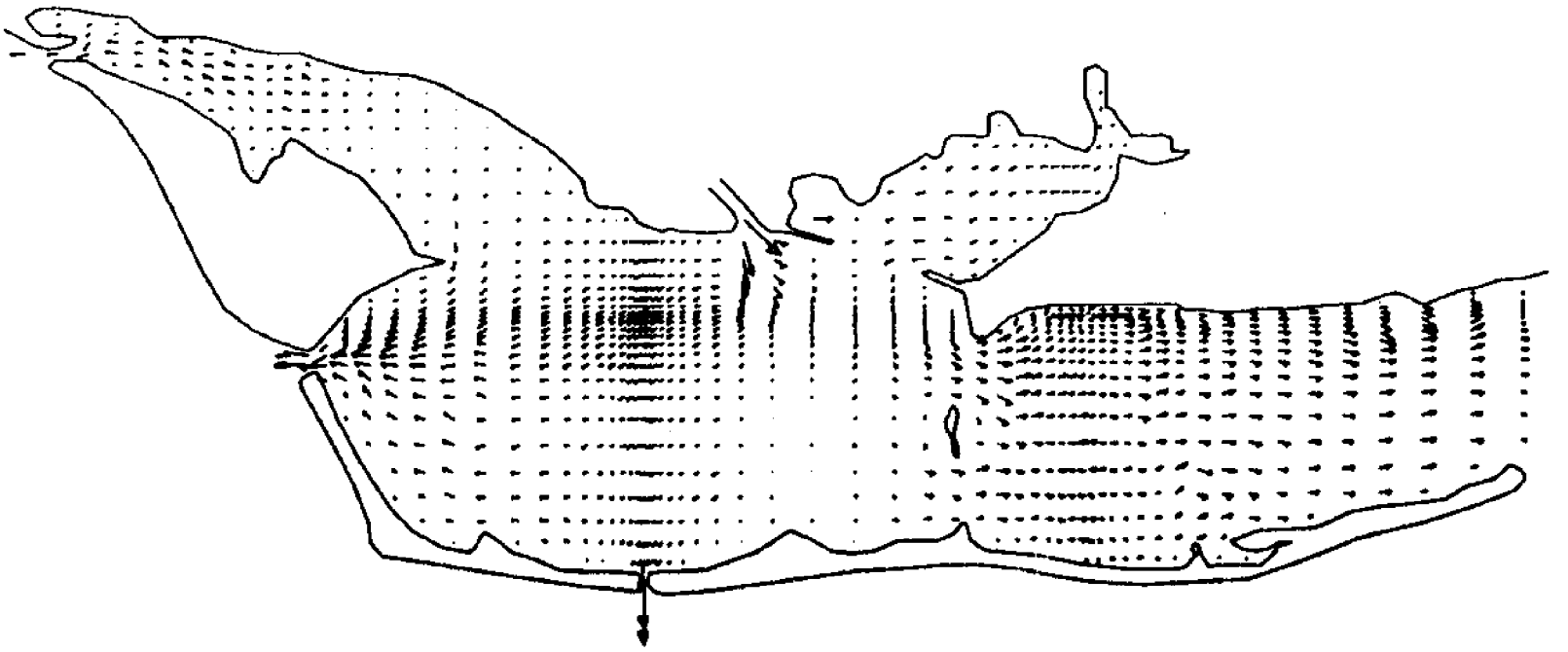
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 12.00000
Maximum Velocity (Ft/Sec) = 1.59870



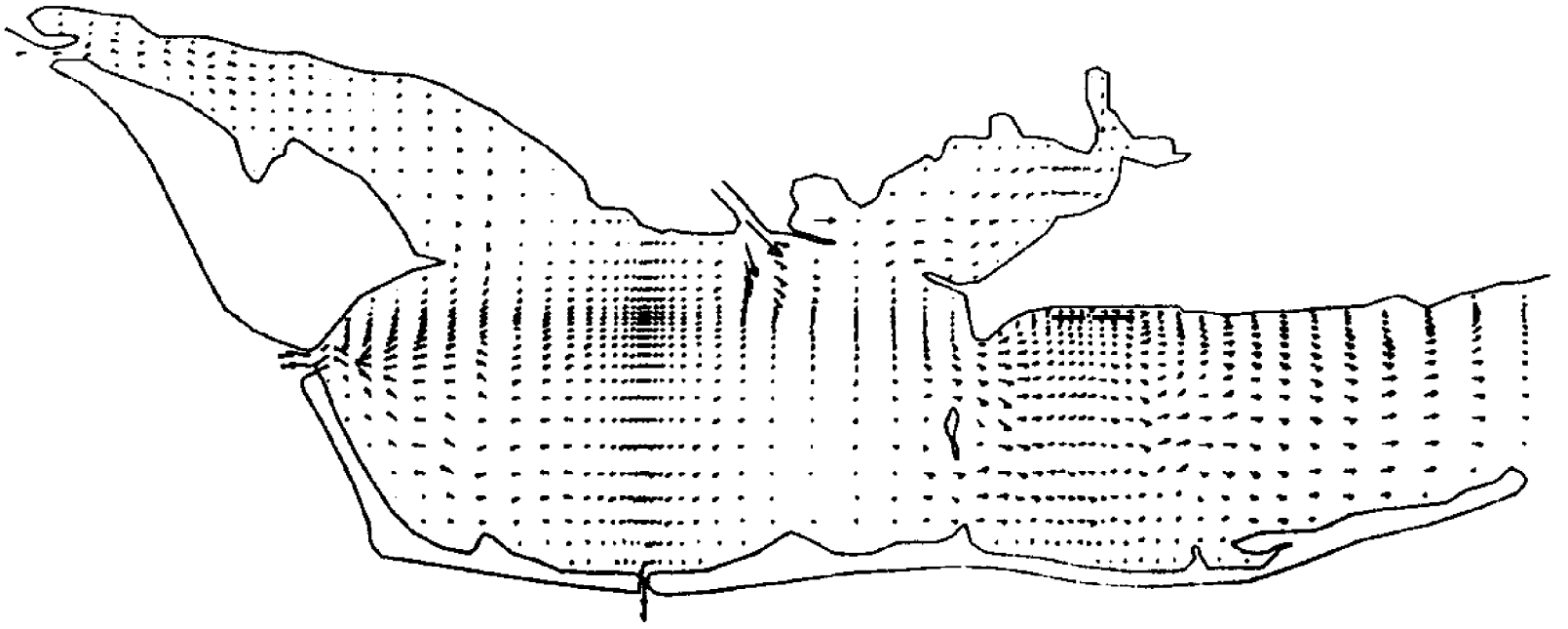
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 16.00000
Maximum Velocity (Ft/Sec) = 1.49907



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = 1.49907



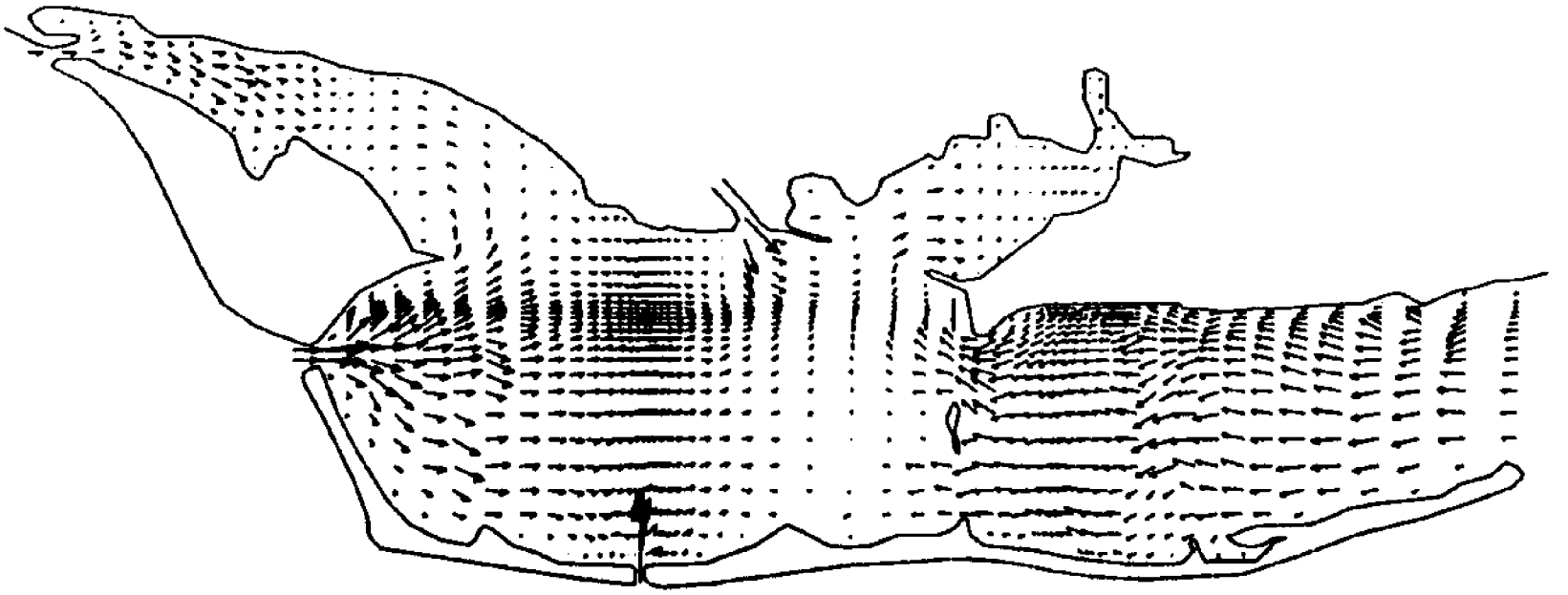
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field at T (Hr) = 24.00000
Maximum Velocity (Ft/Sec) = 2.49907



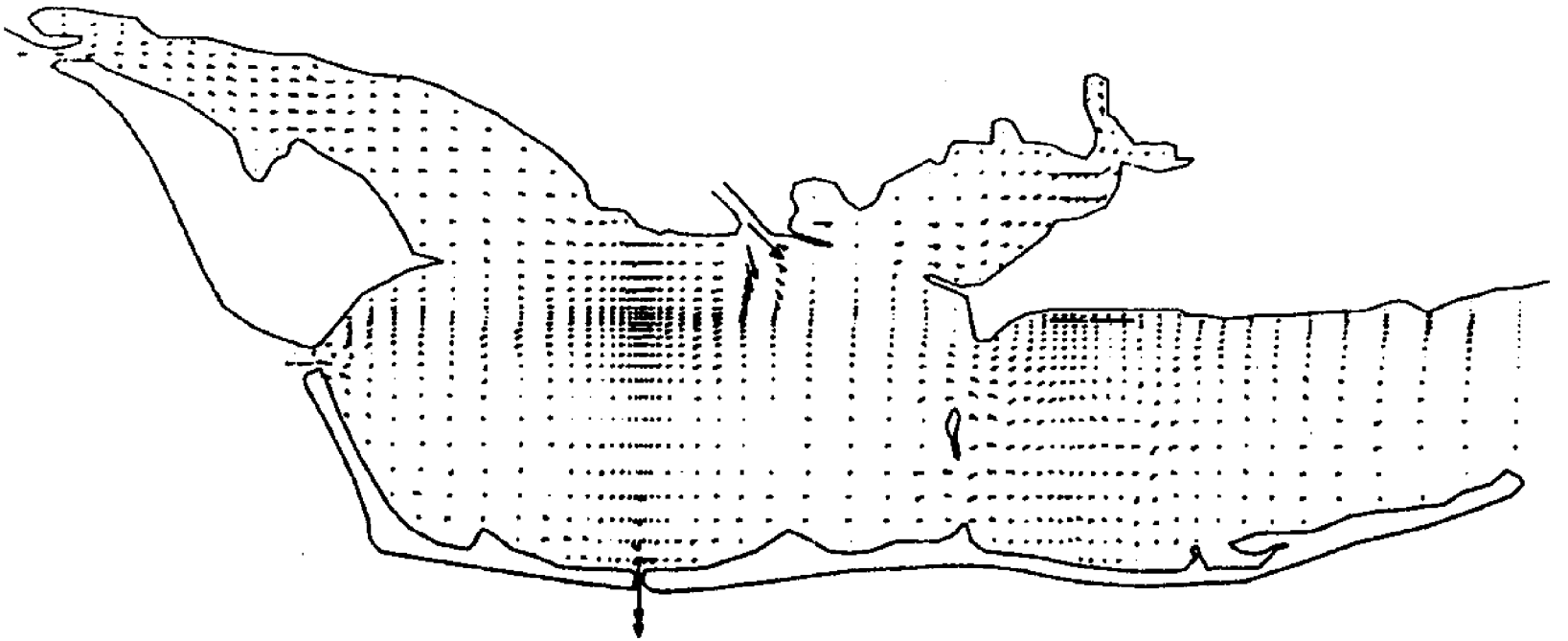
APPENDIX F

TYPICAL CIRCULATION PATTERNS FOR AN AVERAGE WINTER WIND AND A BREAKWATER INSTALLED AT EASTPOINT

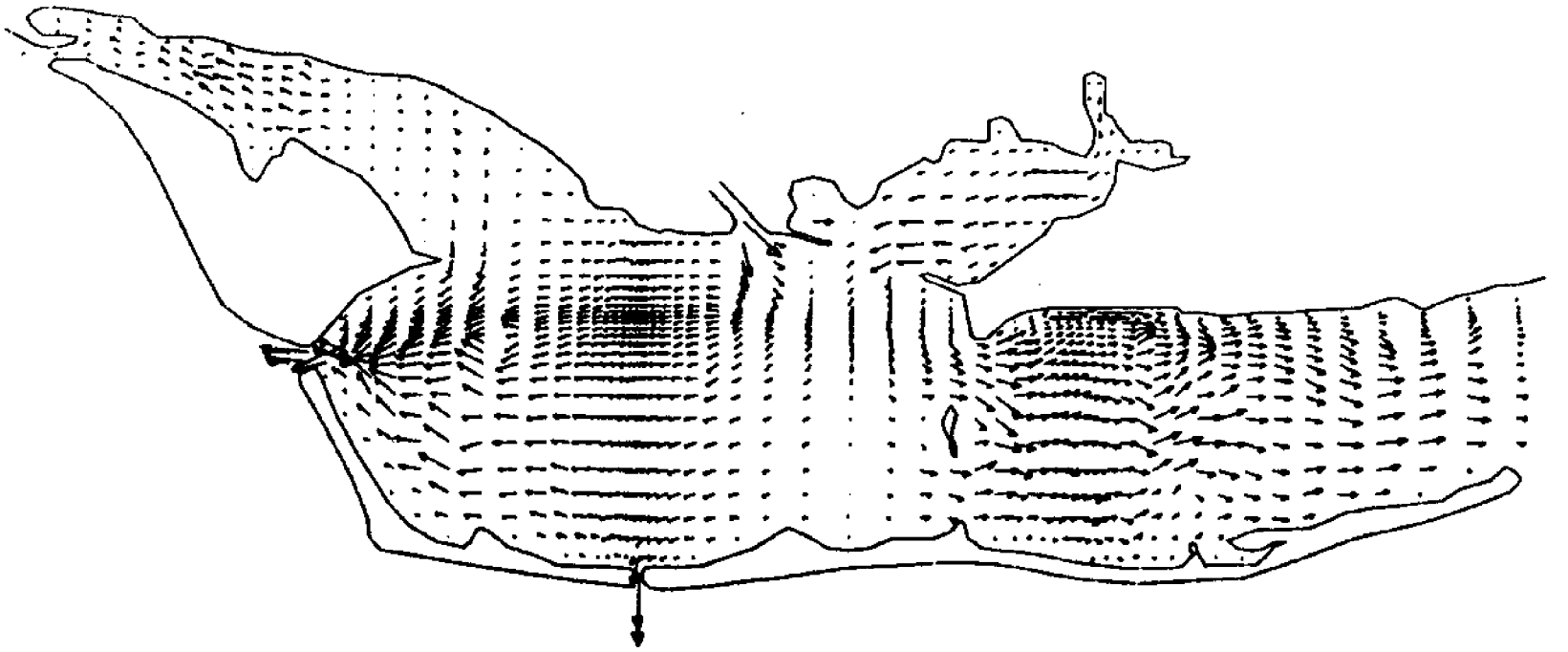
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 4.00000
Maximum Velocity (Ft/Sec) = 2.3166



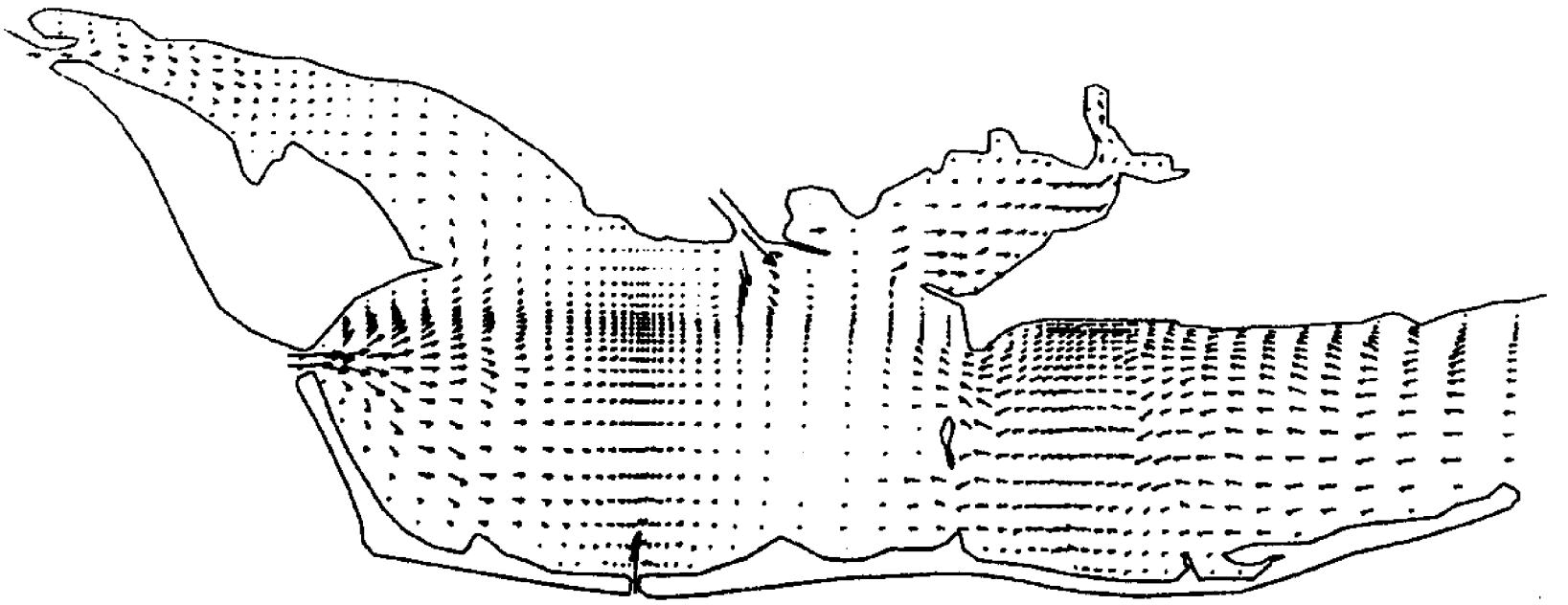
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 8.00000
Maximum Velocity (Ft/Sec) = 1.49907



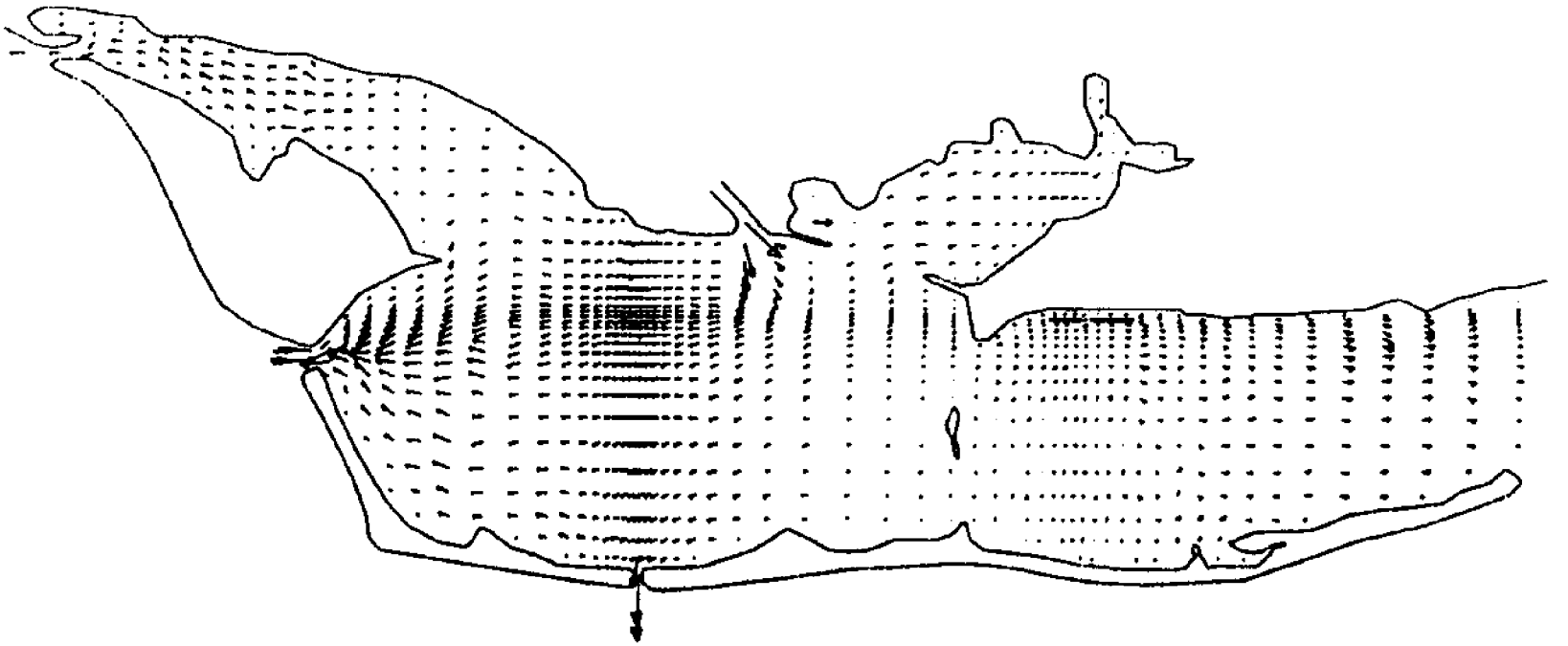
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 12.00000
Maximum Velocity (Ft/Sec) = 1.65271



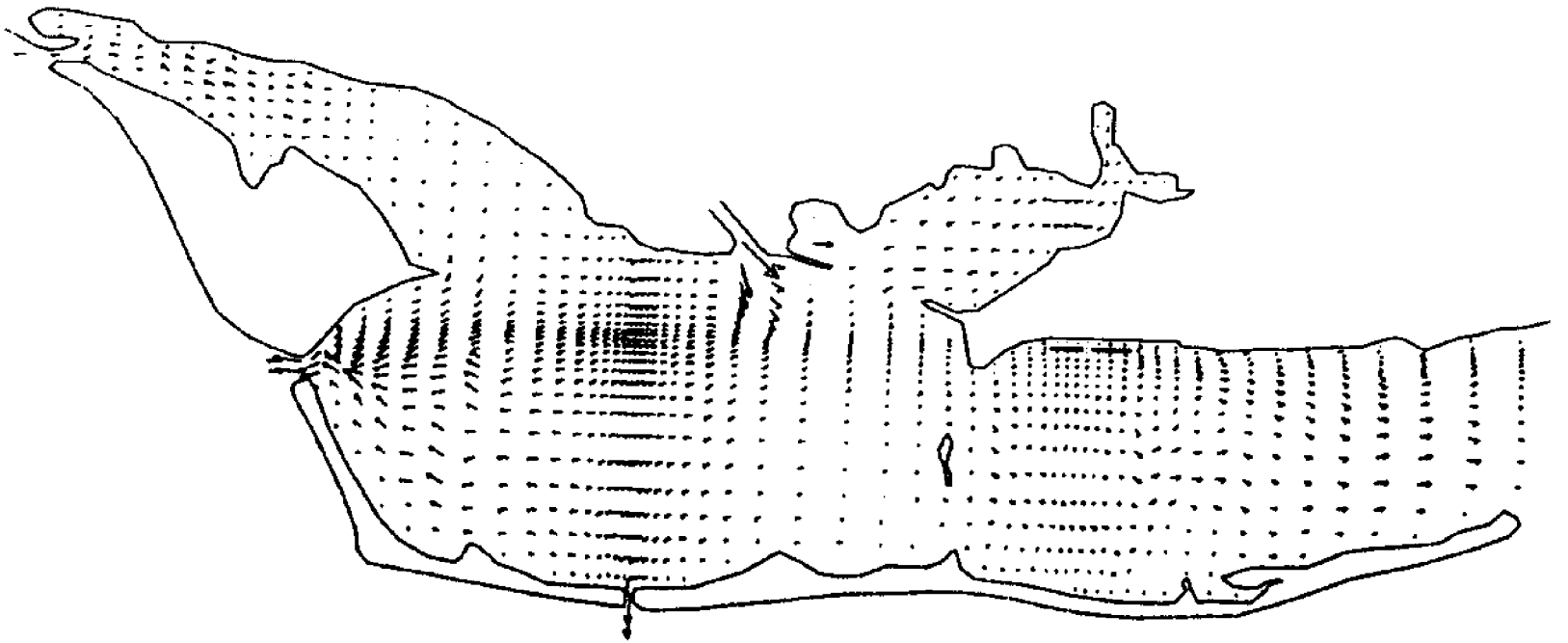
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 16.00000
Maximum Velocity (Ft/Sec) = 1.49907



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = 1.50041



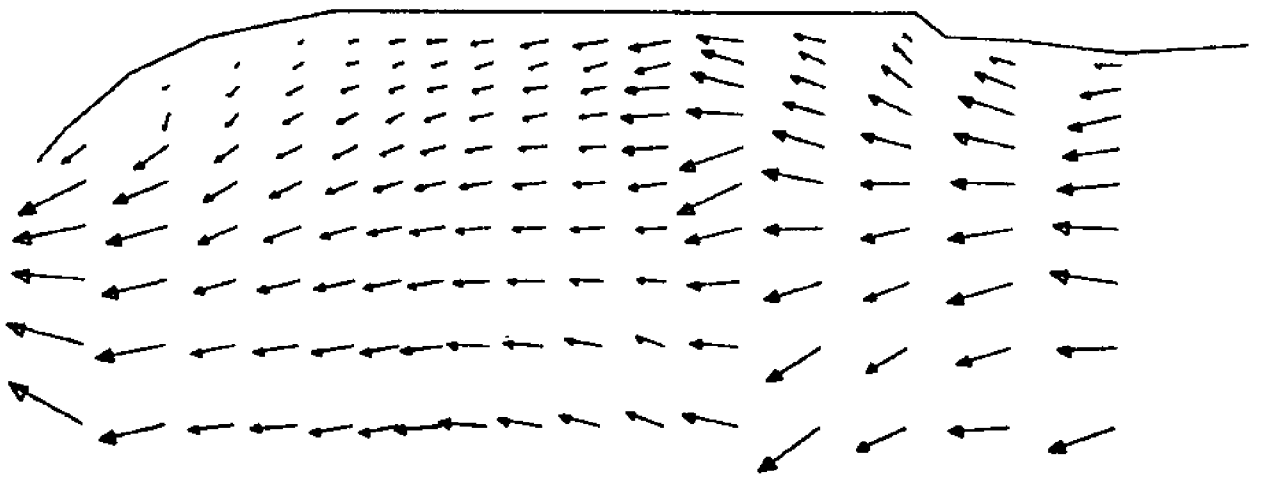
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = 1.49907



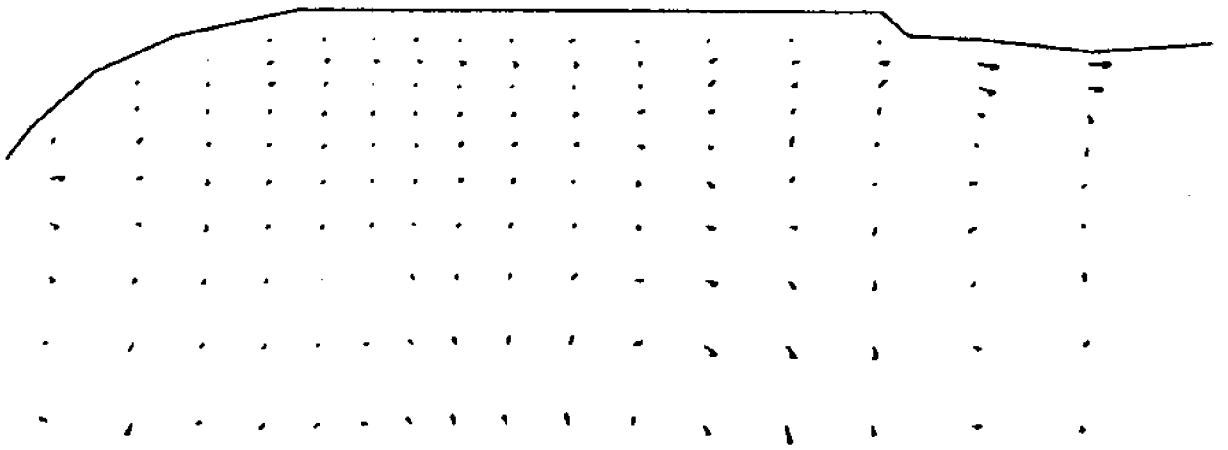
APPENDIX G

TYPICAL CIRCULATION PATTERNS IN LOCAL EASTPOINT AREA FOR A NO WIND CONDITION AND EXISTING CONDITIONS

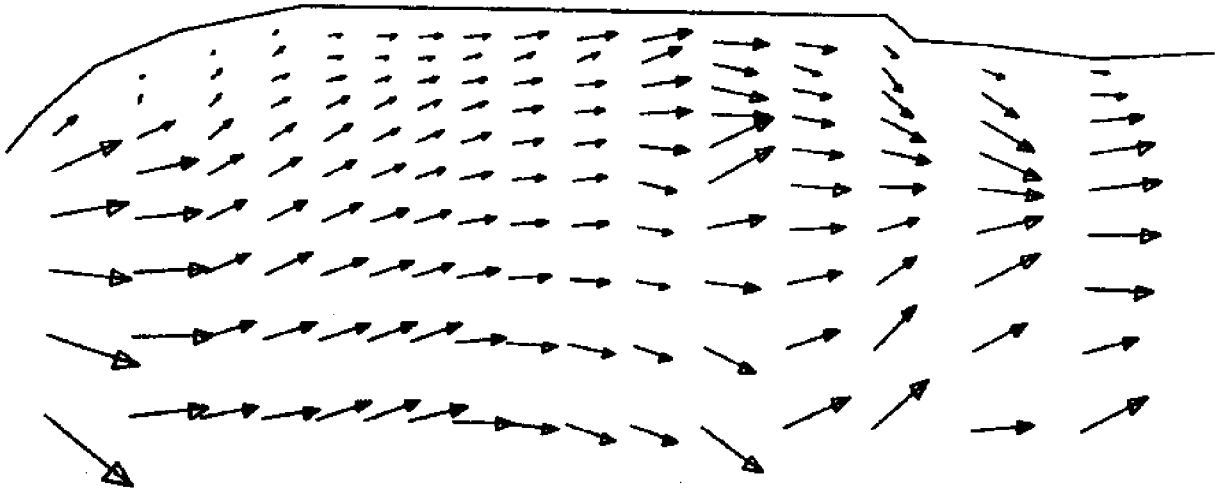
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 4.00000
Maximum Velocity (Ft/Sec) = .71281



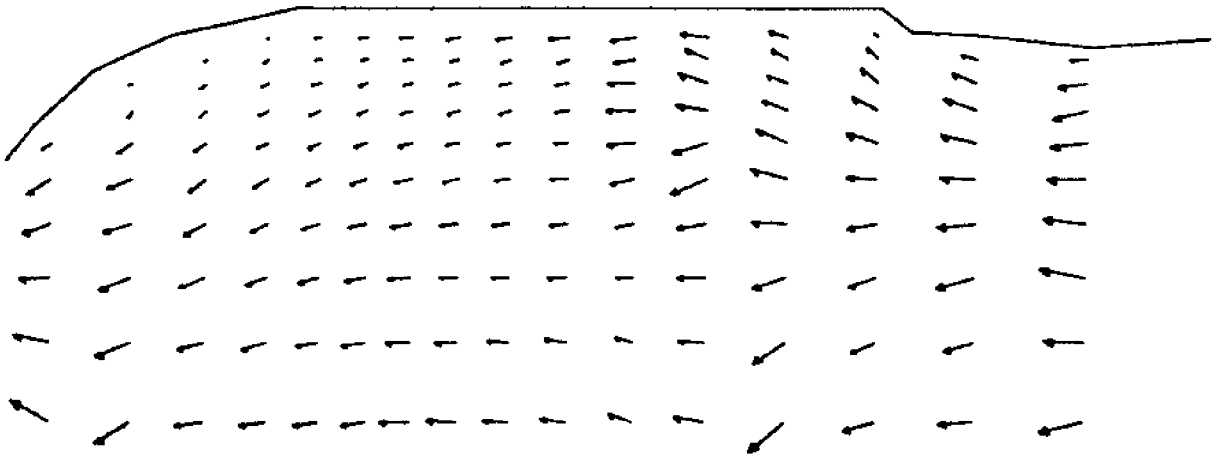
Apalachicola Bay 24 Hrs Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 8.00000
Maximum Velocity (Ft/Sec) = .18129



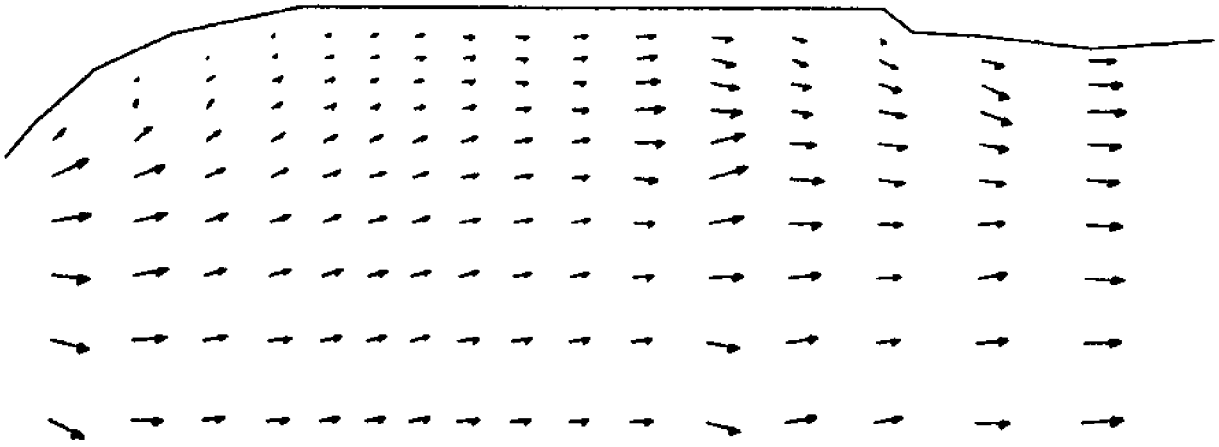
Apalachicola Bay 24 Hrs Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 12.00000
Maximum Velocity (Ft/Sec) = .95140



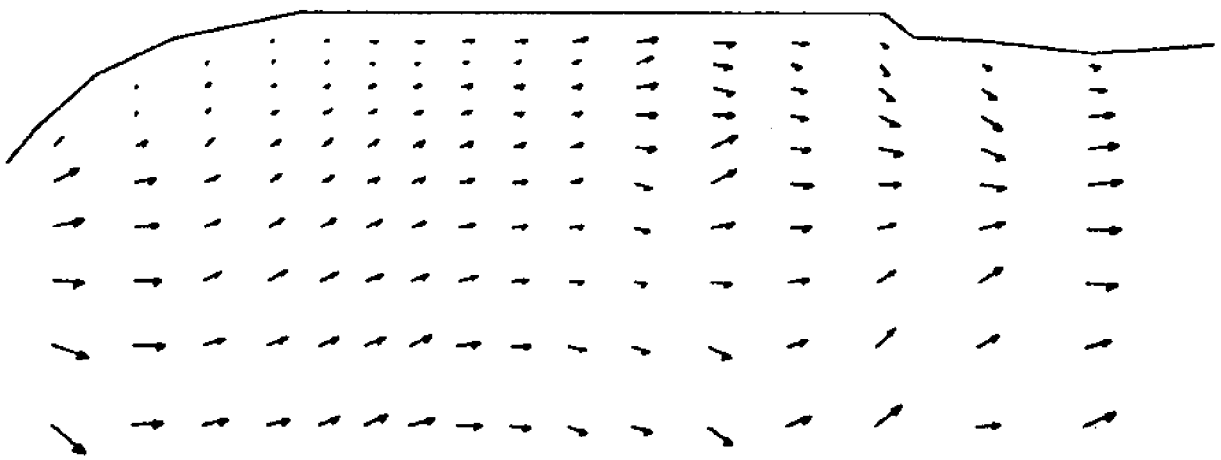
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 16.00000
Maximum Velocity (Ft/Sec) = .39322



Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = .34894



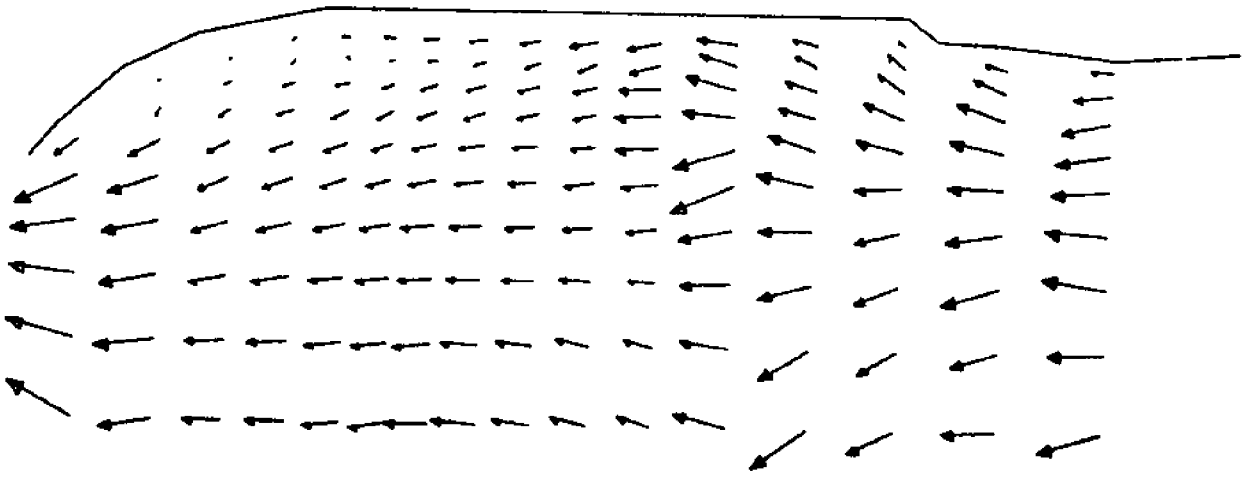
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Zero Wind
Flow Rate Field At T(Hr) = 24.00000
Maximum Velocity (Ft/Sec) = .39815



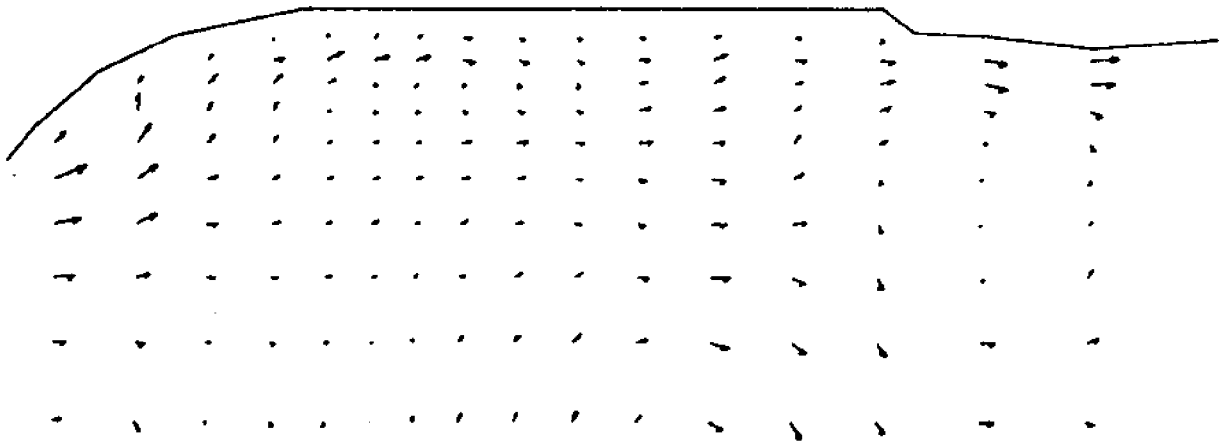
APPENDIX H

TYPICAL CIRCULATION PATTERNS IN LOCAL EASTPOINT AREA FOR AN AVERAGE SUMMER WIND AND EXISTING CONDITIONS

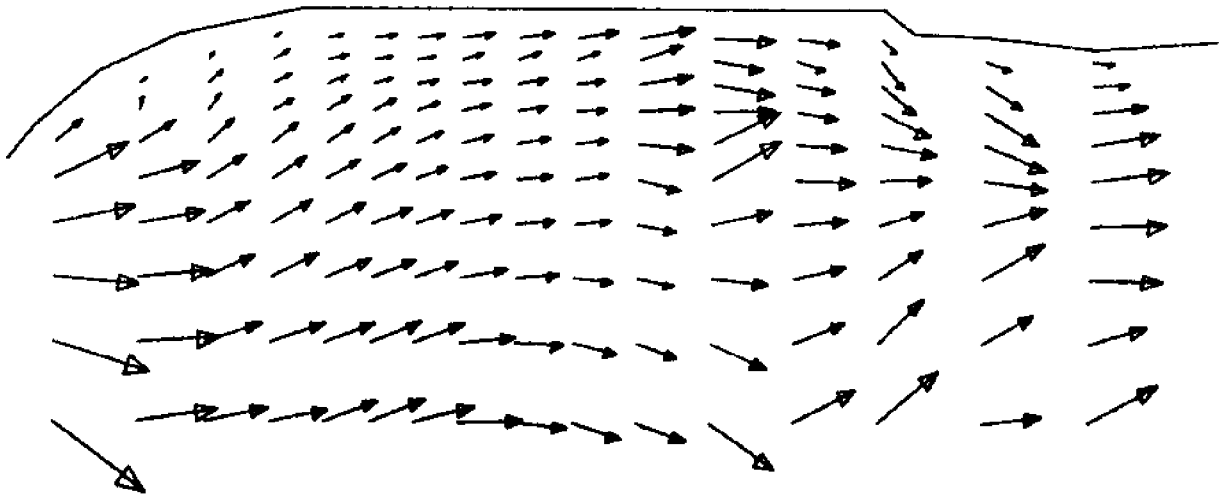
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 4.00000
Maximum Velocity (Ft/Sec) = 60389



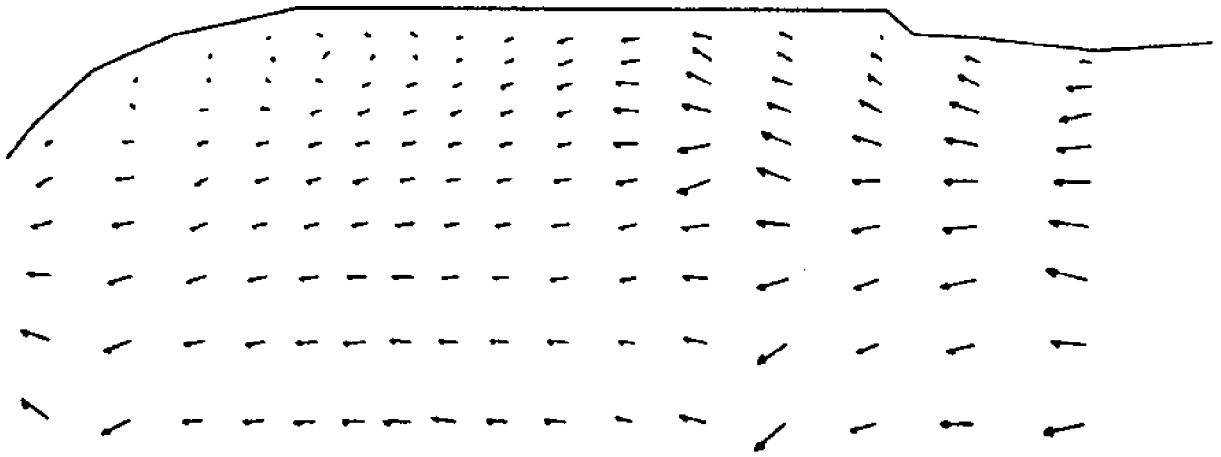
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 8.00000
Maximum Velocity (Ft/Sec) = .28571



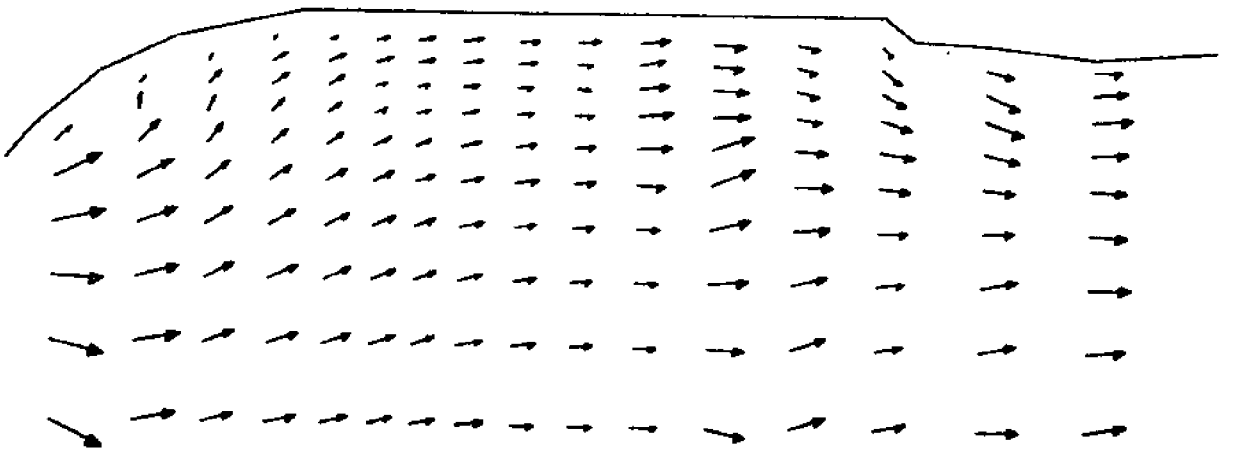
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 12.00000
Maximum Velocity (Ft/Sec) = .99290



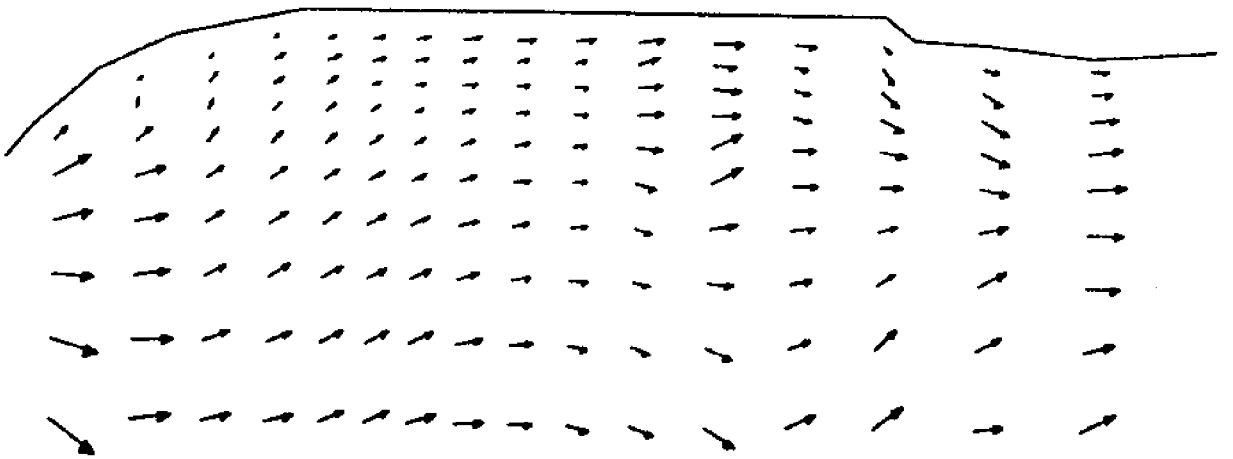
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 16.00000
Maximum Velocity (Ft/Sec) = .35254



Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 20.00000
Maximum Velocity (Ft/Sec) = .50230



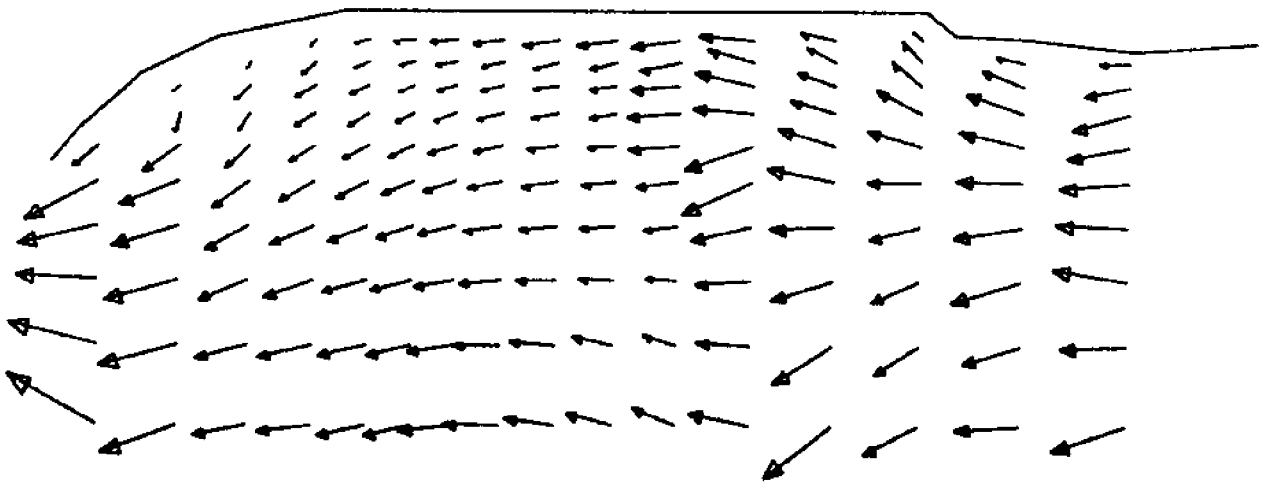
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 24.00000
Maximum Velocity (Ft/Sec) = .50068



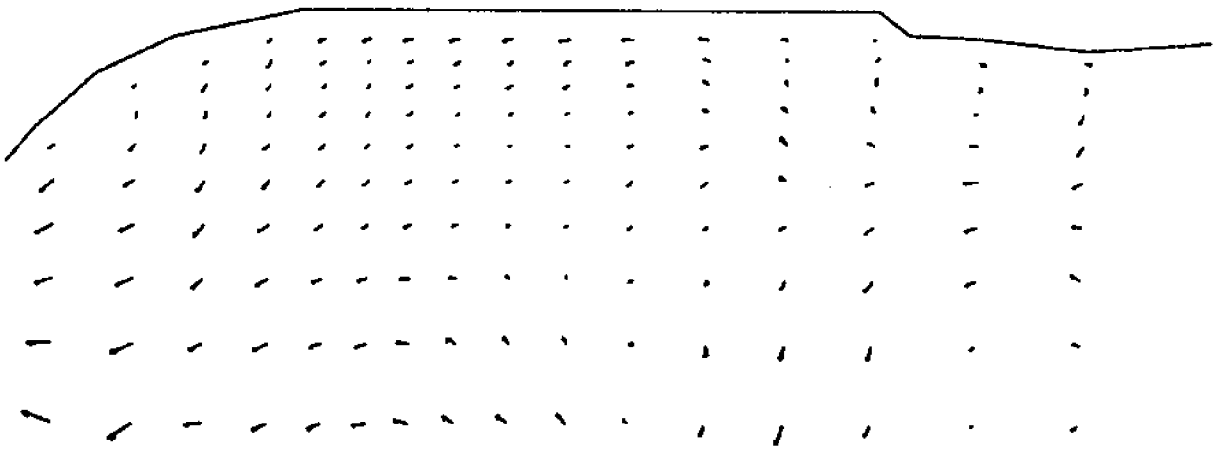
APPENDIX I

TYPICAL CIRCULATION PATTERNS IN LOCAL EASTPOINT AREA FOR AN AVERAGE WINTER WIND AND EXISTING CONDITIONS

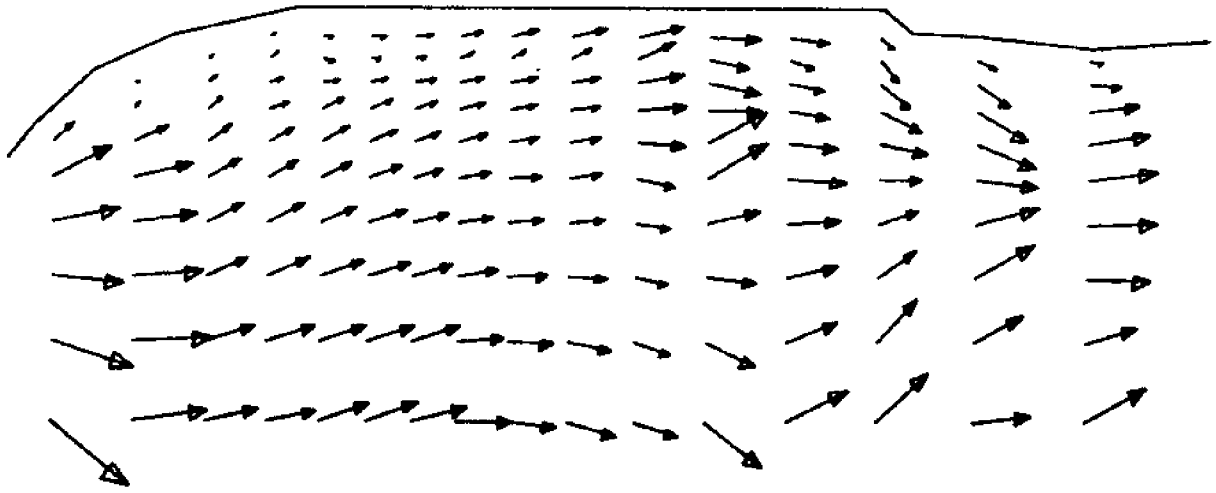
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Wind Wind
Flow Rate Field At T (Hr) - 4.00000
Maximum Velocity (Ft/Sec) - 0.85350



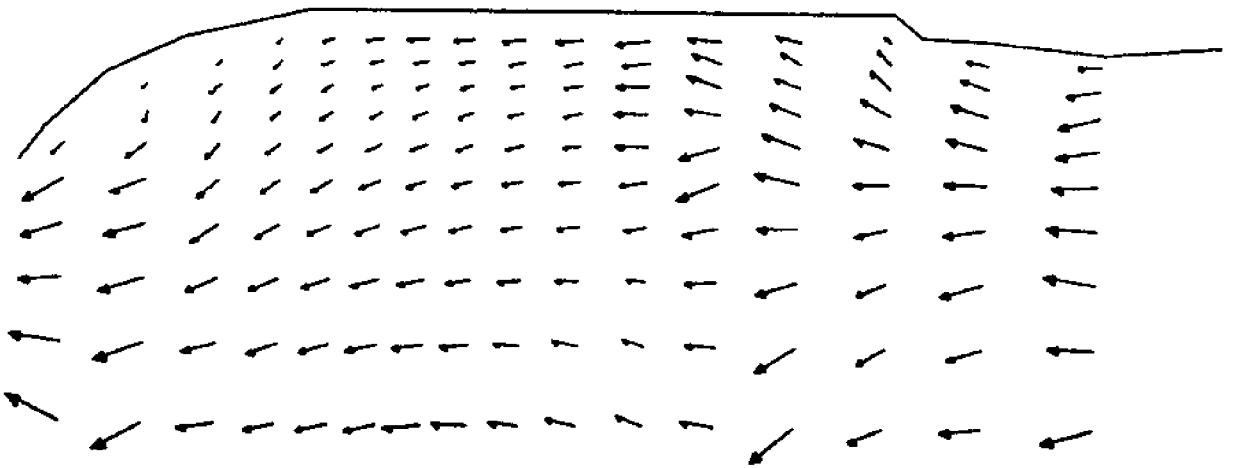
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 8.00000
Maximum Velocity (Ft/Sec) - 0.24654



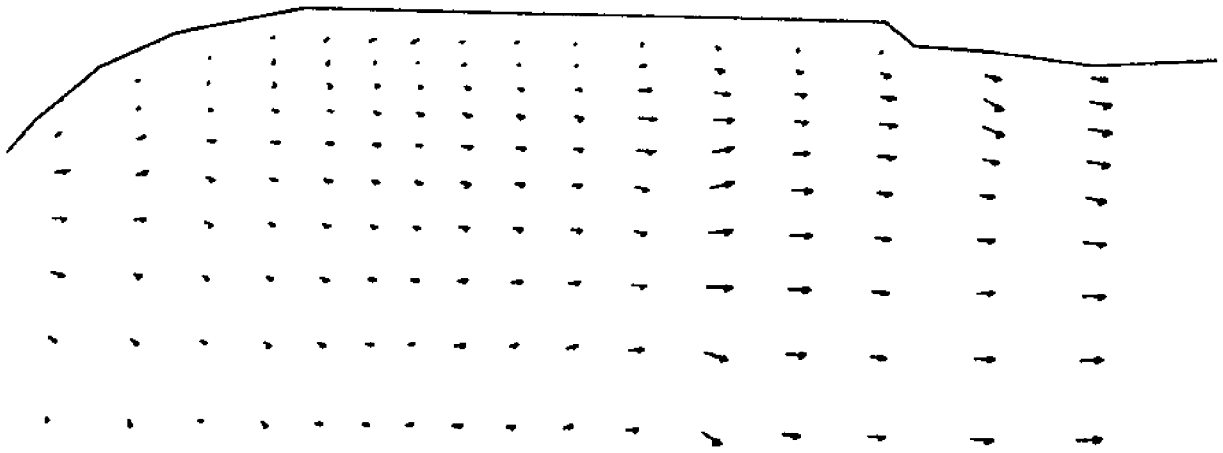
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 12.00000
Maximum Velocity (Ft/Sec) - 0.88401



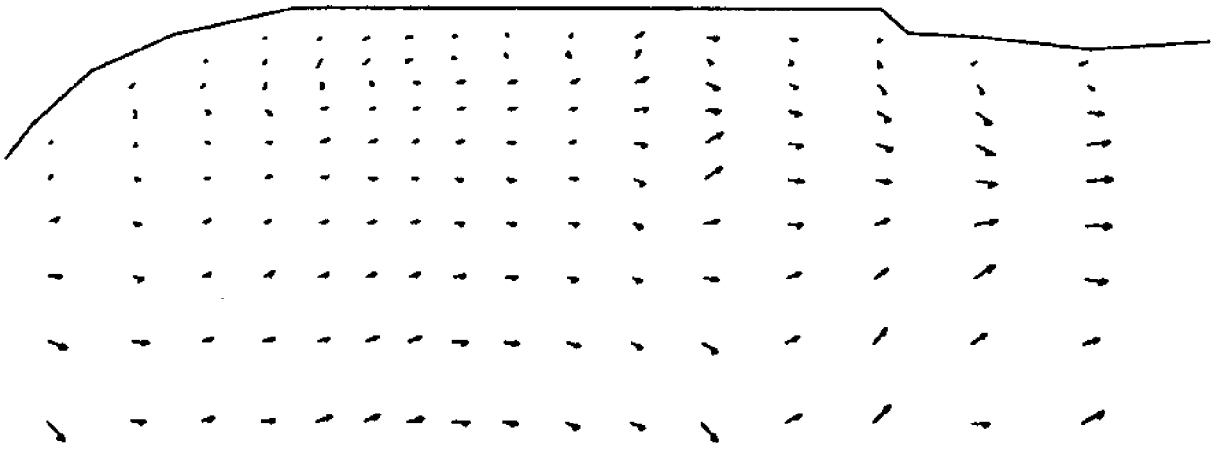
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 16.00000
Maximum Velocity (Ft/Sec) - 0.52039



Apalachicola Bay 24 Hrs. Run - Without Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 20.00000
Maximum Velocity (Ft/Sec) - 0.22036



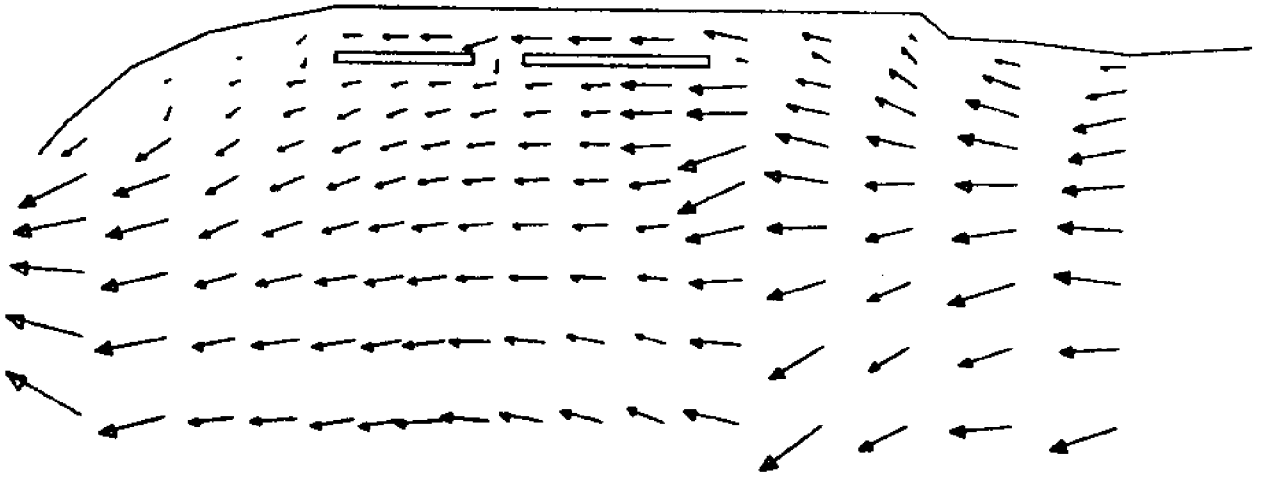
Apalachicola Bay 24 Hrs. Run - Without Breakwaters - with Winter Wind
Flow Rate Field At T (Hr) - 24.00000
Maximum Velocity (Ft/Sec) - 0.23189



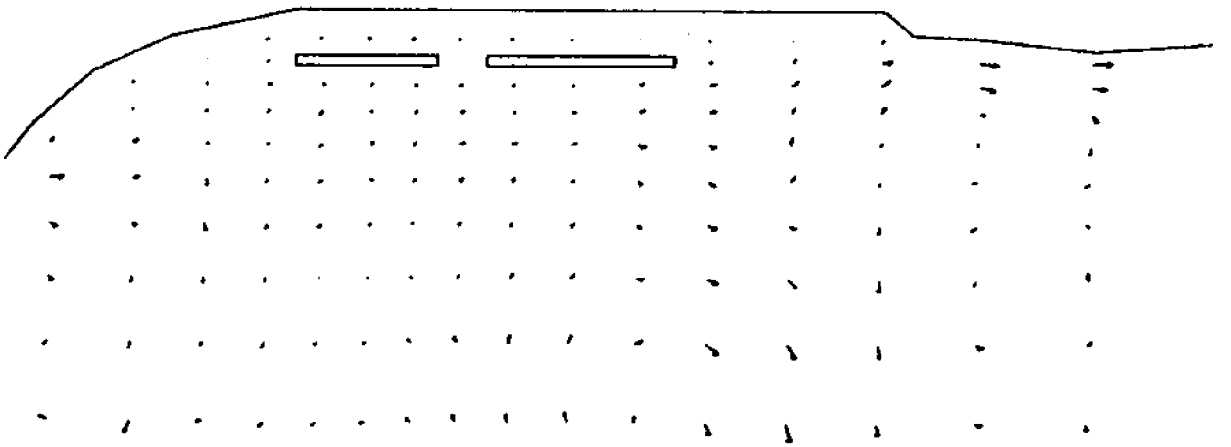
APPENDIX J

TYPICAL CIRCULATION PATTERNS IN LOCAL EASTPOINT AREA FOR A NO WIND CONDITION WITH A BREAKWATER INSTALLED

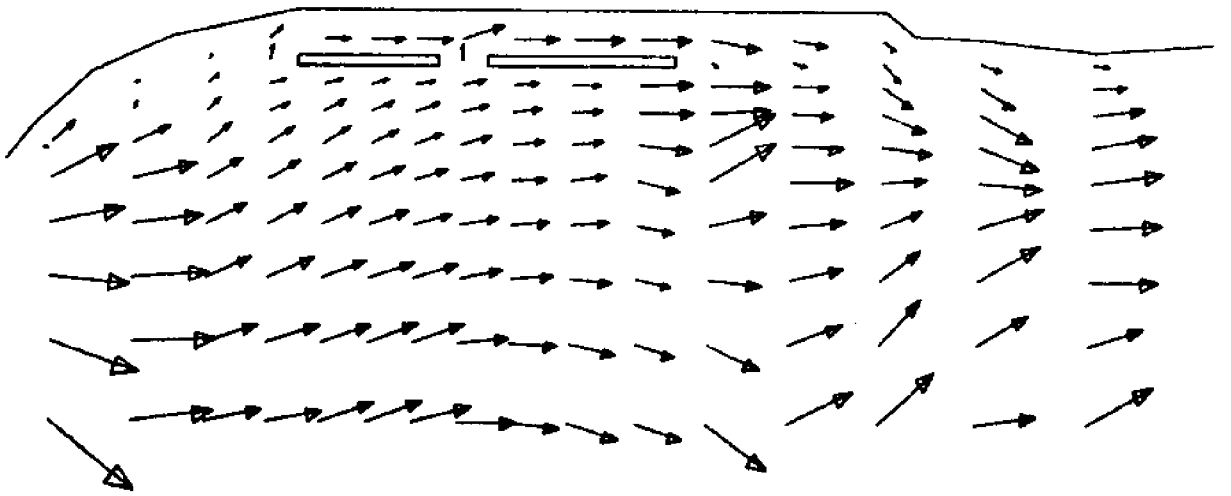
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) - 4.00000
Maximum Velocity (Ft/Sec) - 0.72111



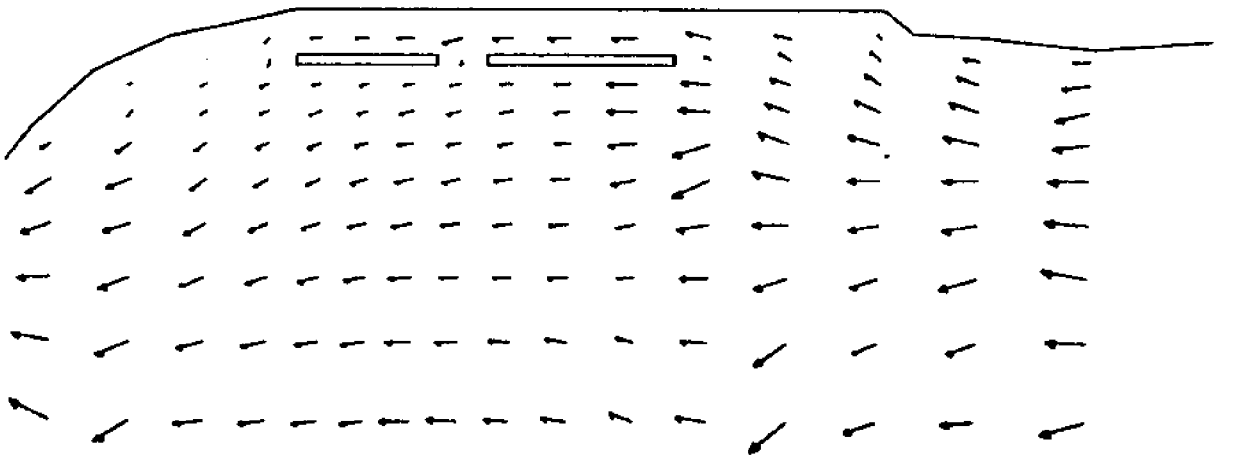
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 8.00000
Maximum Velocity (Ft/Sec) - 0.17635



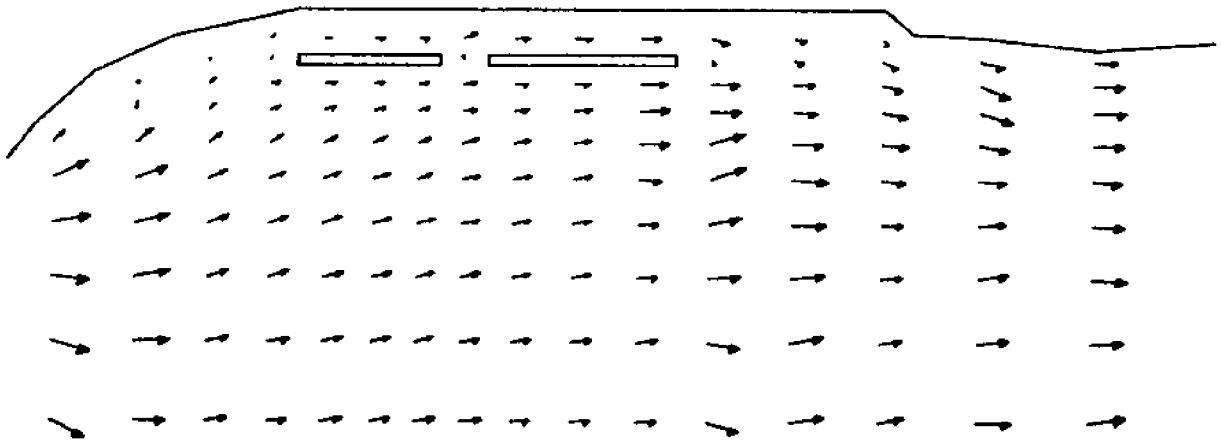
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 12.00000
Maximum Velocity (Ft/Sec) - 0.95712



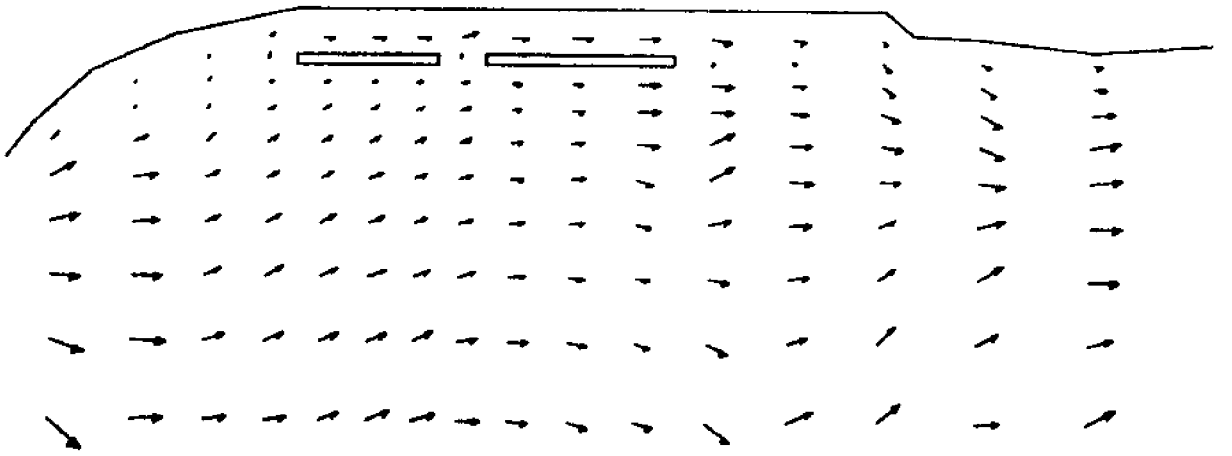
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 16.00000
Maximum Velocity (Ft/Sec) - 0.39695



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) - 20.00000
Maximum Velocity (Ft/Sec) - 0.34725



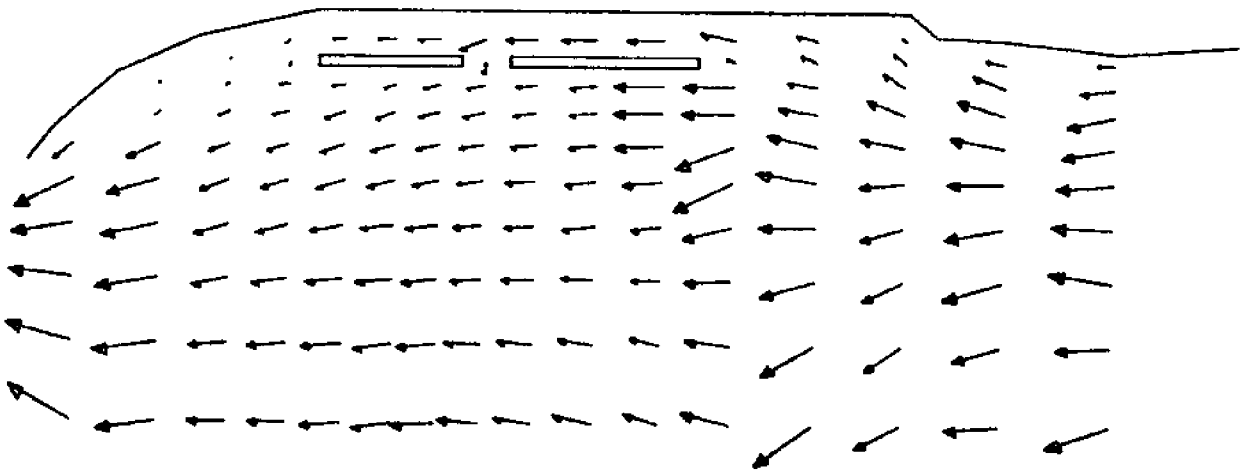
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) - 24.00000
Maximum Velocity (Ft/Sec) - 0.39888



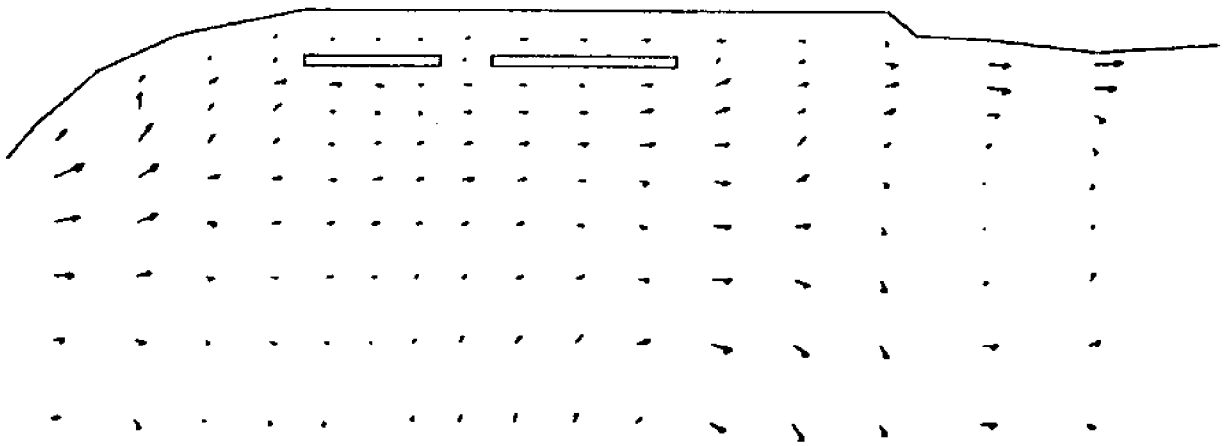
APPENDIX K

TYPICAL CIRCULATION PATTERNS IN LOCAL EASTPOINT AREA FOR AN AVERAGE SUMMER WIND WITH A BREAKWATER INSTALLED

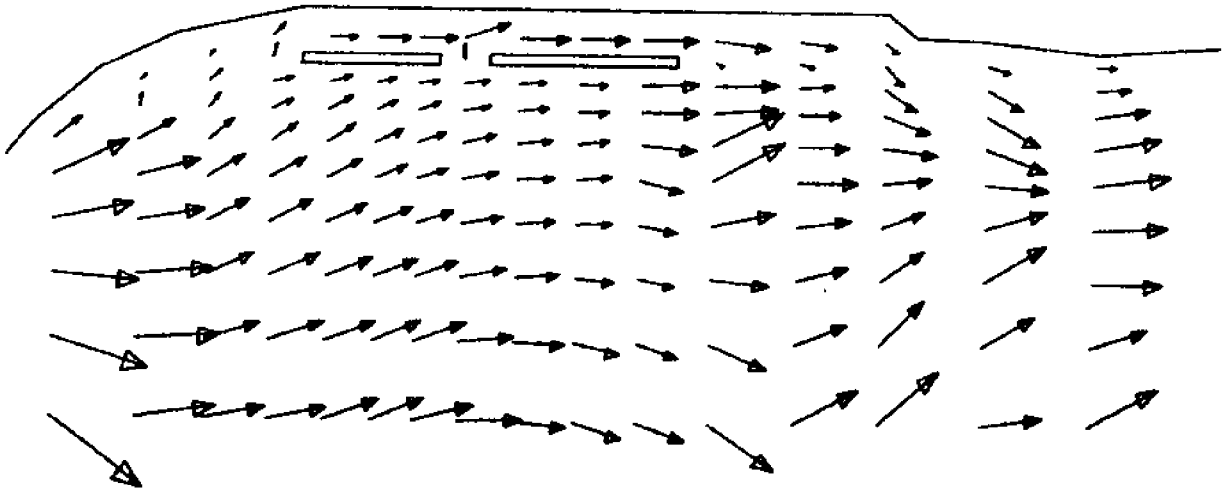
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T (Hr) - 4.00000
Maximum Velocity (Ft/Sec) - 0.61399



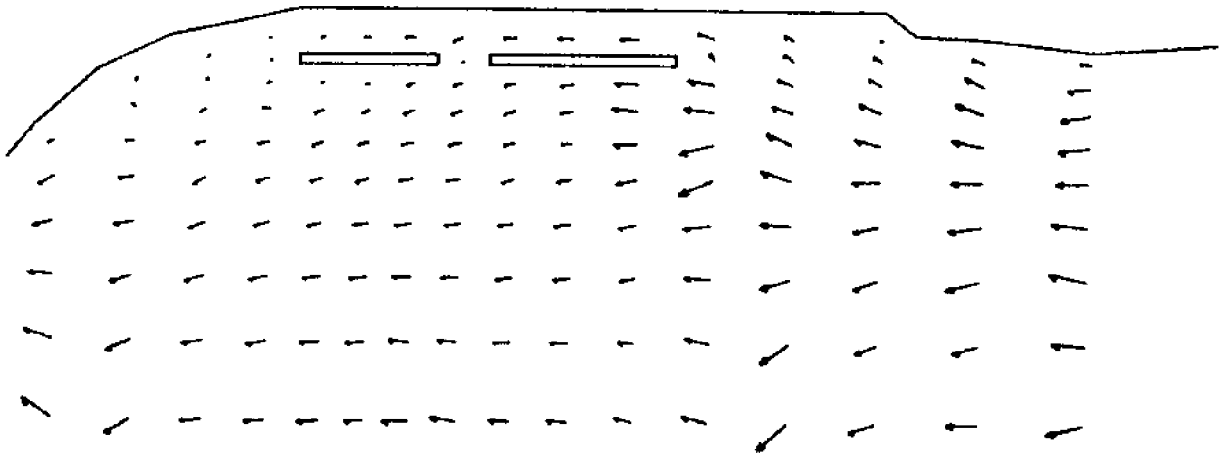
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T (Hr) - 8.00000
Maximum Velocity (Ft/Sec) - 0.28255



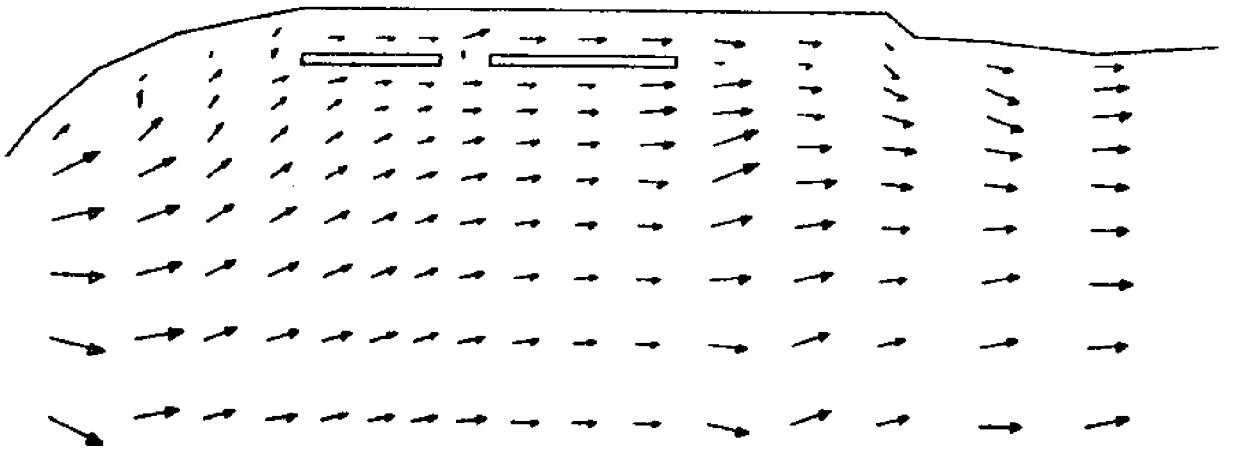
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T (Hr) - 12.00000
Maximum Velocity (Ft/Sec) - 0.99856



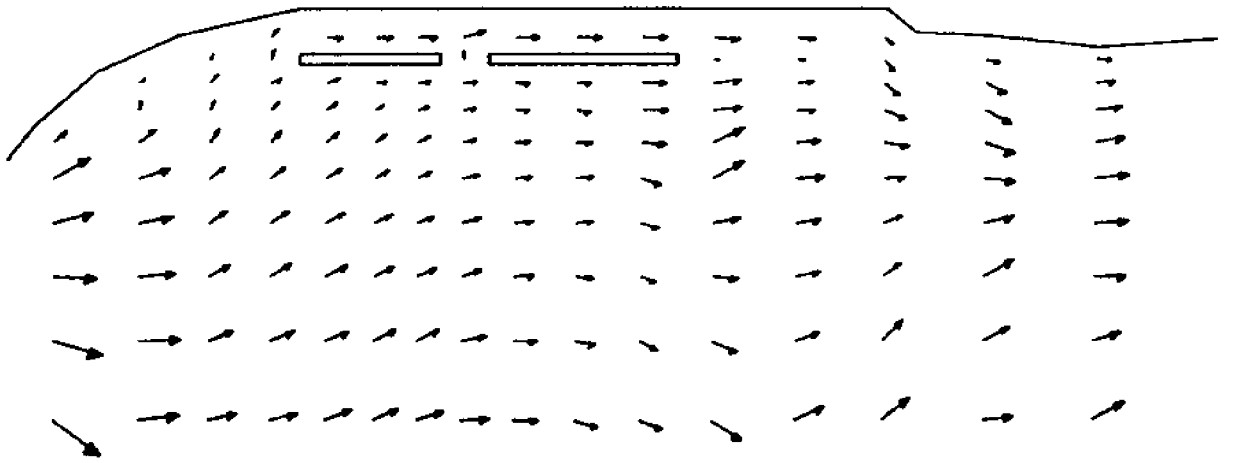
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T (Hr) - 16.00000
Maximum Velocity (Ft/Sec) - 0.35003



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T (Hr) - 20.00000
Maximum Velocity (Ft/Sec) - 0.50312



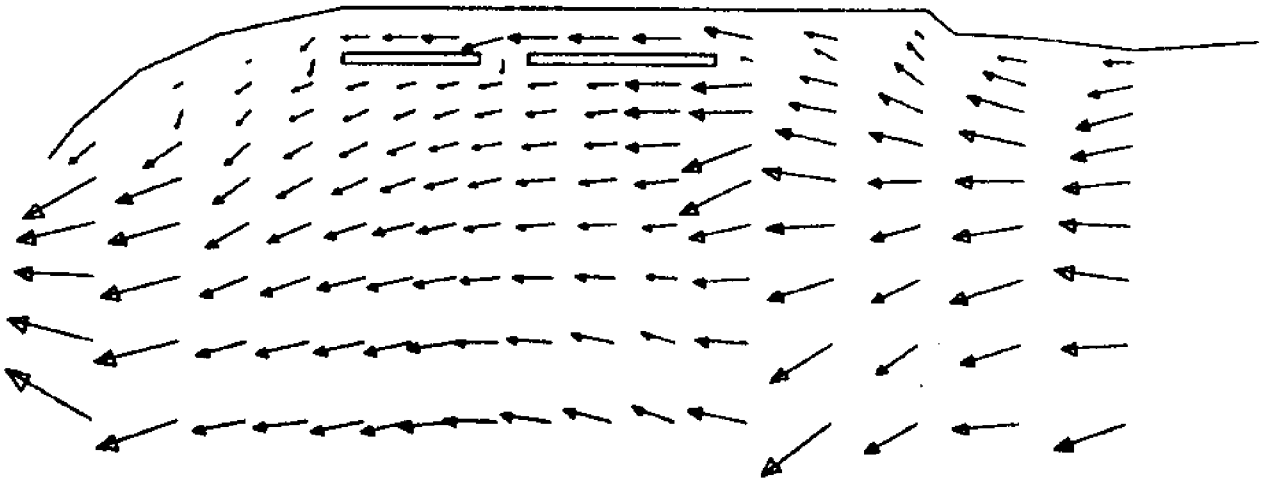
Apalachicola Bay 24 Hrs. Run - With Breakwaters - Wind Summer Wind
Flow Rate Field at T (Hr) - 24.00000
Maximum Velocity (Ft/Sec) - 0.50099



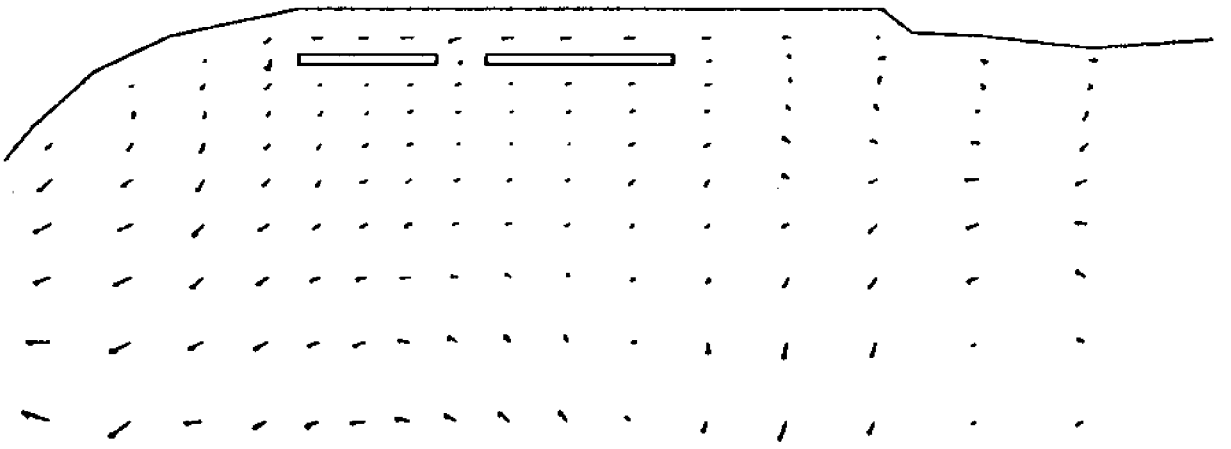
APPENDIX L

TYPICAL CIRCULATION PATTERNS IN LOCAL EASTPOINT AREA FOR AN AVERAGE WINTER WIND WITH A BREAKWATER INSTALLED

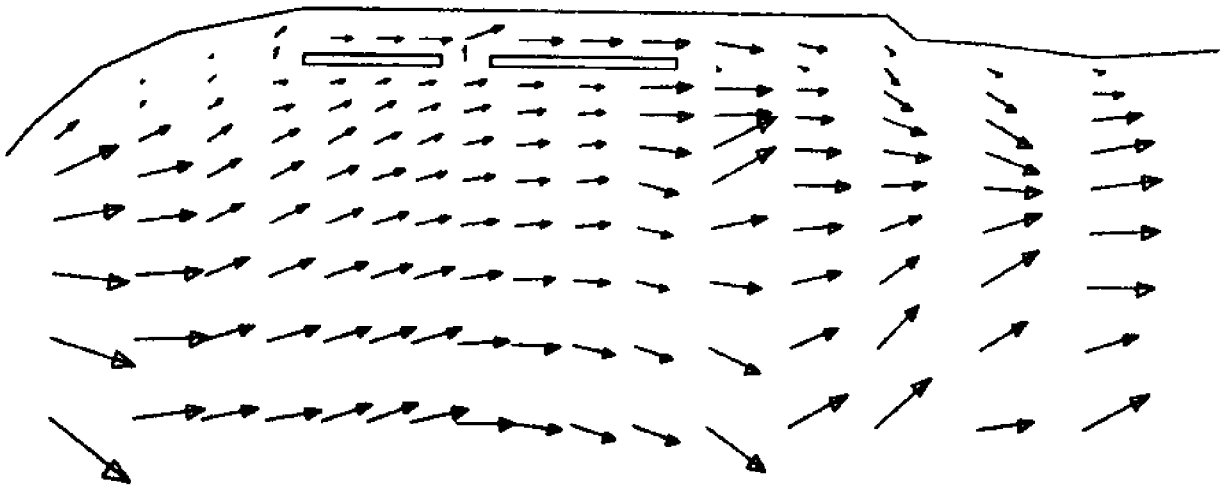
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 4.00000
Maximum Velocity (Ft/Sec) - 0.85992



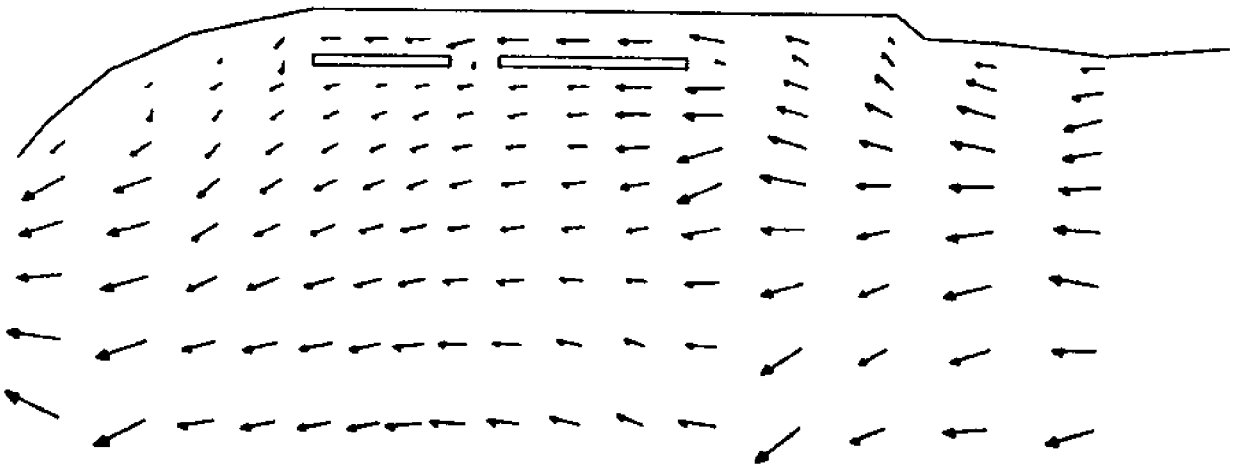
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 8.00000
Maximum Velocity (Ft/Sec) - 0.24359



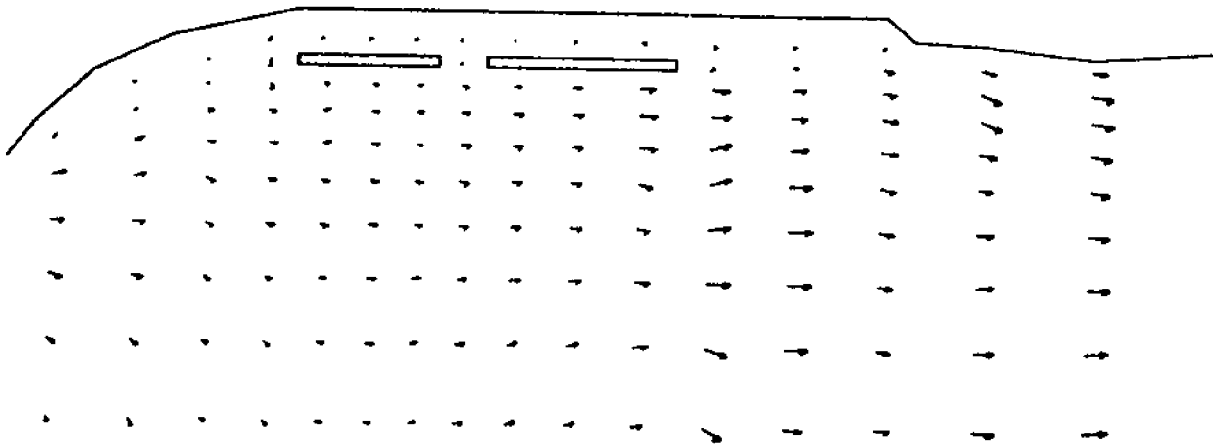
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 12.00000
Maximum Velocity (Ft/Sec) - 0.88974



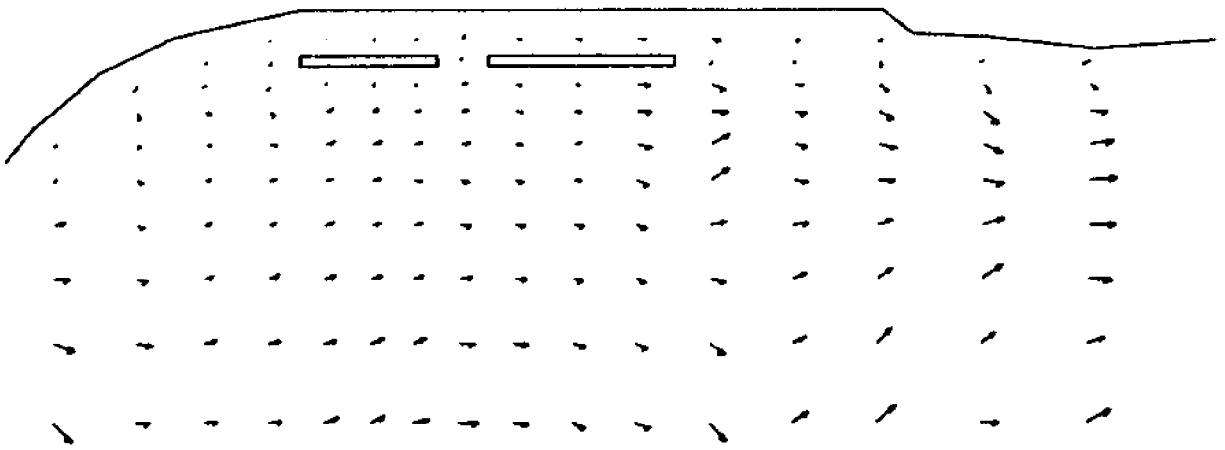
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 16.00000
Maximum Velocity (Ft/Sec) - 0.51939



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 20.00000
Maximum Velocity (Ft/Sec) - 0.21760



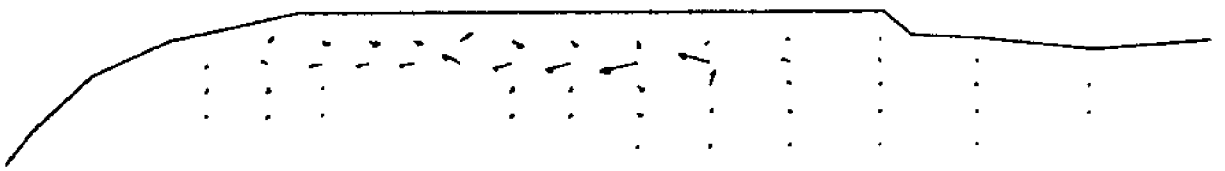
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T (Hr) - 24.00000
Maximum Velocity (Ft/Sec) - 0.22893



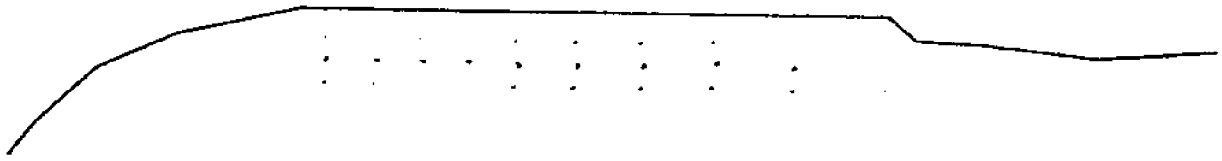
APPENDIX M

CHANGES IN CIRCULATION PATTERNS IN EASTPOINT AREA AS A RESULT OF INSTALLED BREAKWATER FOR A NO WIND CONDITION

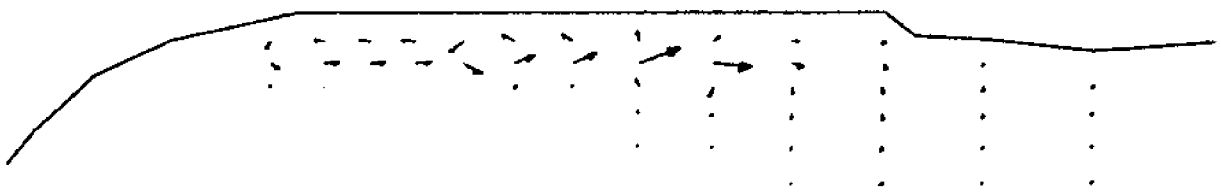
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) - 4.00000
Maximum Velocity (Ft/Sec) - 0.32732



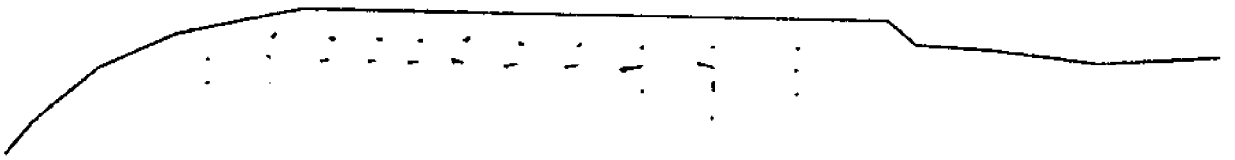
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 8.00000
Maximum Velocity (Ft/Sec) - 0.05161



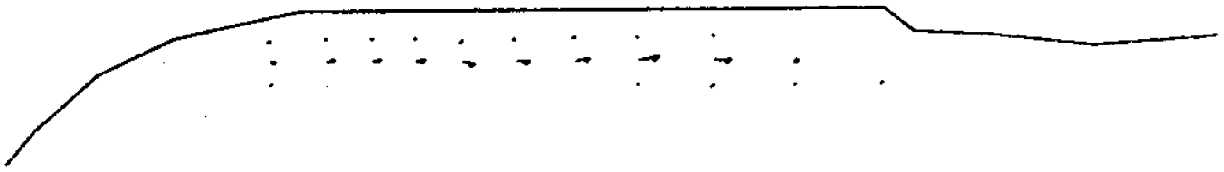
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 12.00000
Maximum Velocity (Ft/Sec) - 0.37131



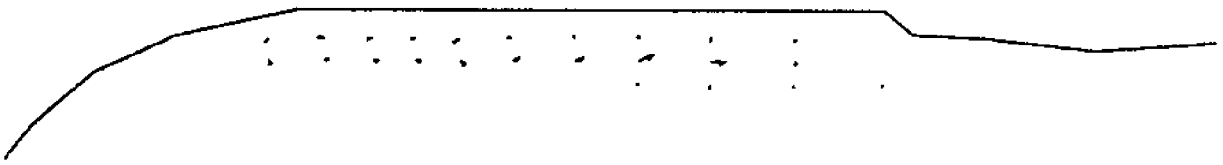
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field At T (Hr) - 16.00000
Maximum Velocity (Ft/Sec) - 0.19157



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field at T (Hr) = 20.00000
Maximum Velocity (Ft/Sec) = .17025



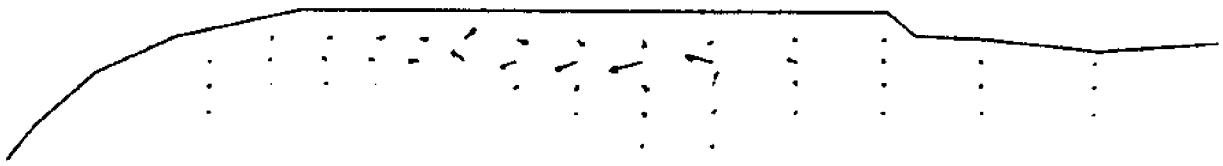
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Zero Wind
Flow Rate Field At T(Hr) = 24.00000
Maximum Velocity (Ft/Sec) = .14215



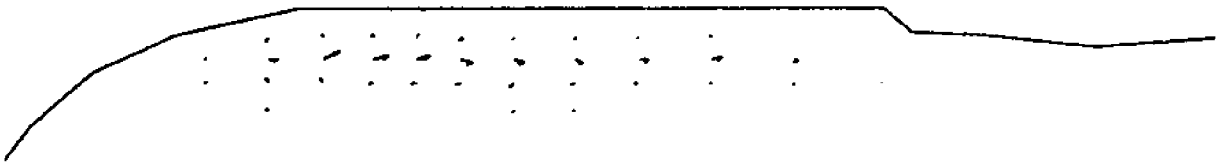
APPENDIX N

CHANGES IN CIRCULATION PATTERNS IN EASTPOINT AREA AS A RESULT OF INSTALLED BREAKWATER FOR AN AVERAGE SUMMER WIND

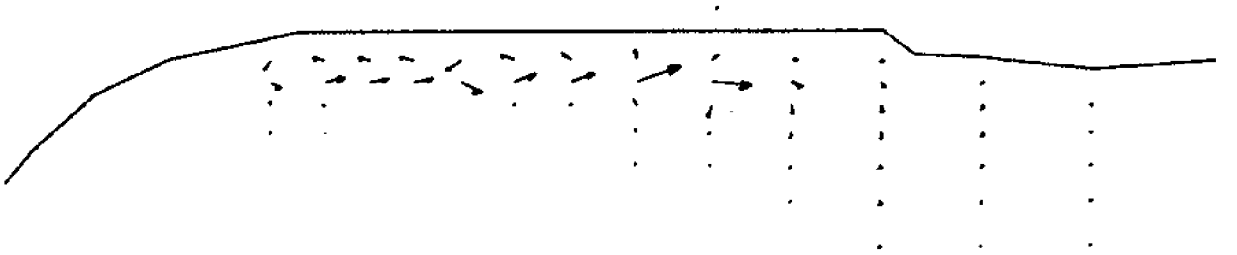
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 4.00000
Maximum Velocity (Ft/Sec) = .29887



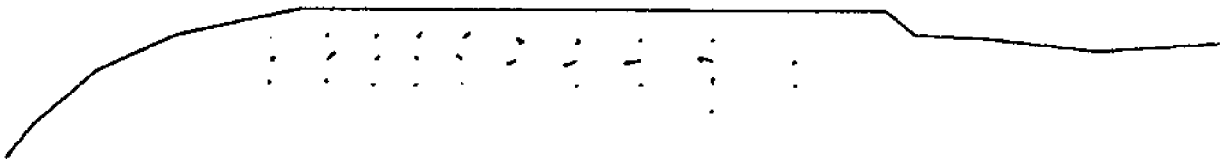
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 8.00000
Maximum Velocity (Ft/Sec) = .15108



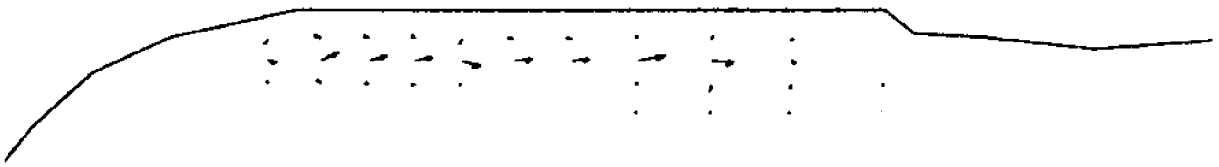
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 12.00000
Maximum Velocity (Ft/Sec) = .38658



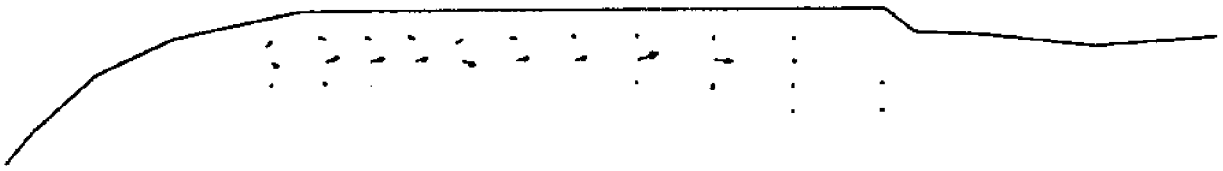
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 16.00000
Maximum Velocity (Ft/Sec) = .15557



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 20.00000
Maximum Velocity (Ft/Sec) = .21298



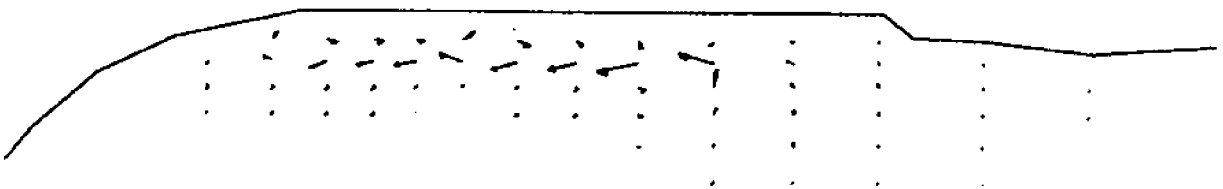
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Summer Wind
Flow Rate Field At T(Hr) = 24.00000
Maximum Velocity (Ft/Sec) = .17405



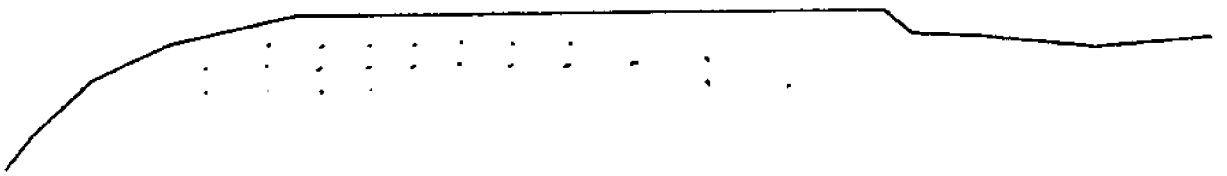
APPENDIX O

CHANGES IN CIRCULATION PATTERNS IN EASTPOINT AREA AS A RESULT OF INSTALLED BREAKWATER FOR AN AVERAGE WINTER WIND

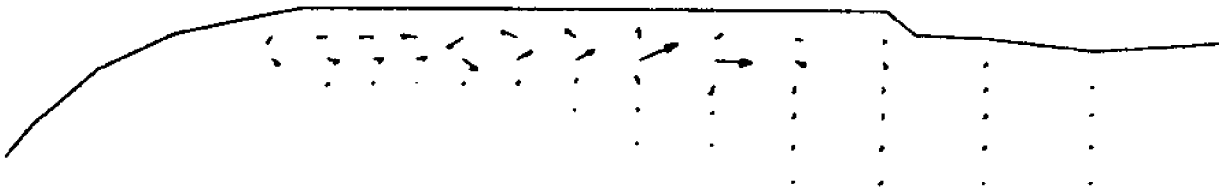
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T(Hr) = 4.00000
Maximum Velocity (Ft/Sec) = .37433



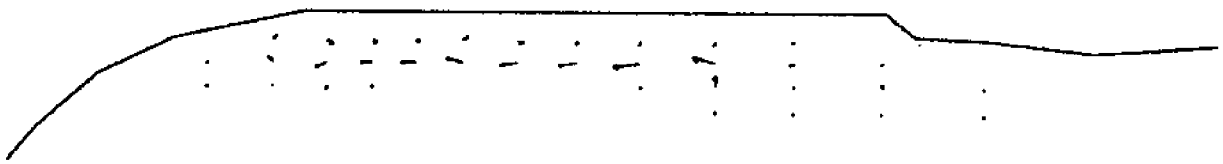
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T(Hr) = 8.00000
Maximum Velocity (Ft/Sec) = .05733



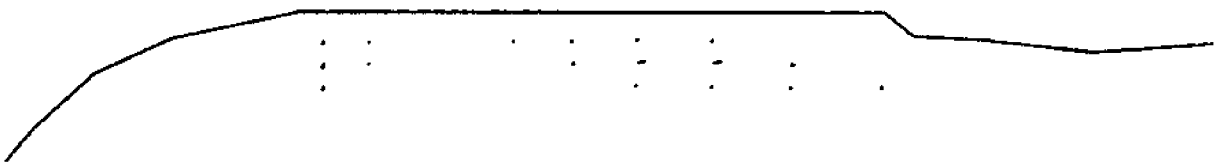
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T(Hr) = 12.00000
Maximum Velocity (Ft/Sec) = .34377



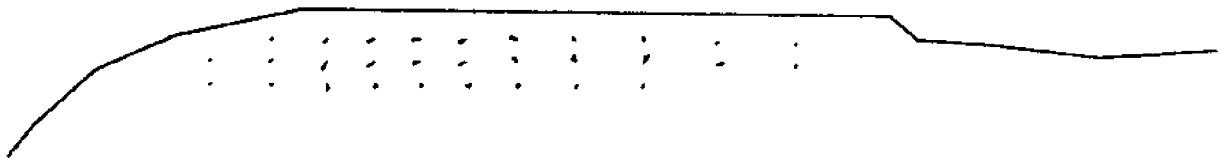
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T(Hr) = 16.00000
Maximum Velocity (Ft/Sec) = .24307



Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T(Hr) = 20.00000
Maximum Velocity (Ft/Sec) = .07236

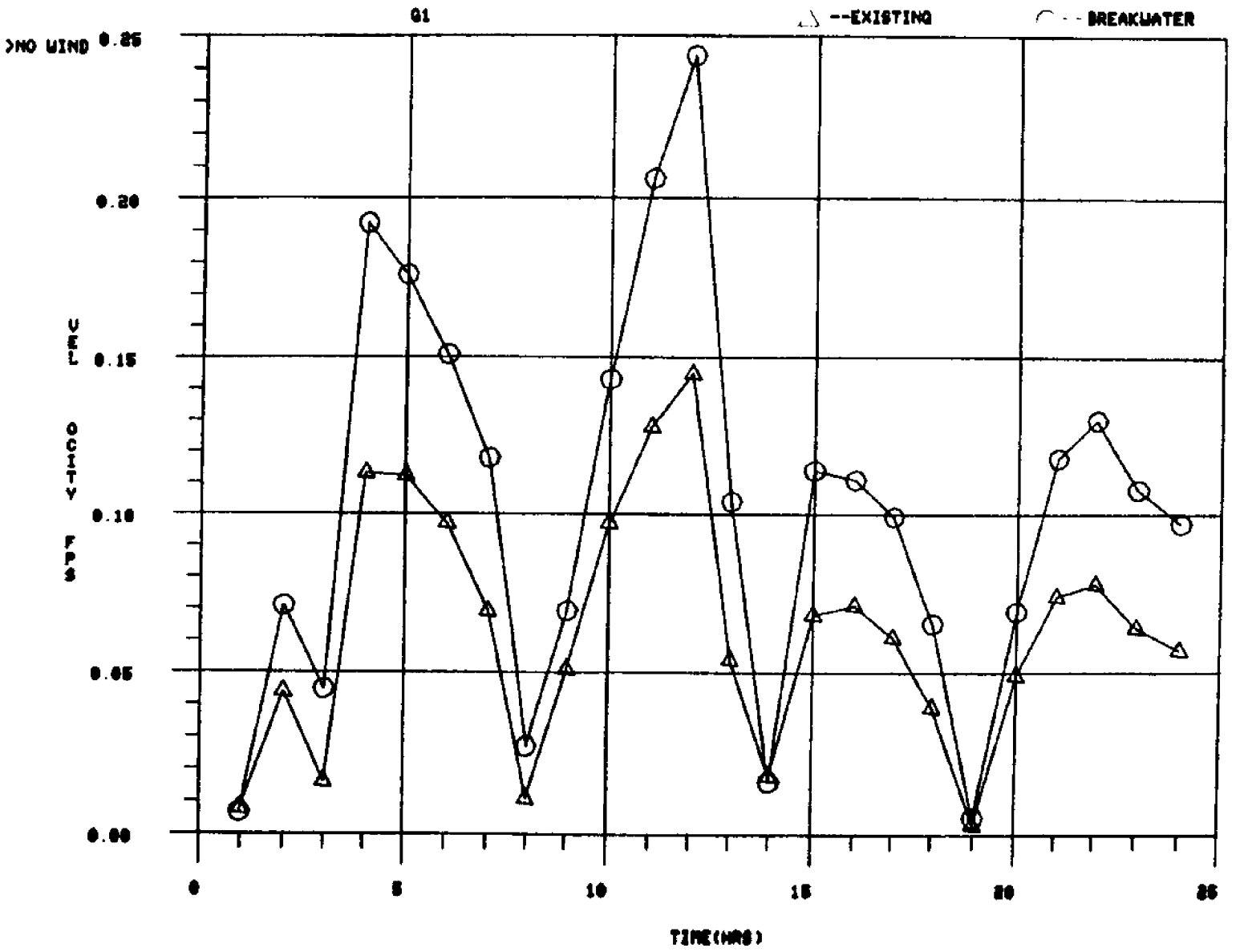


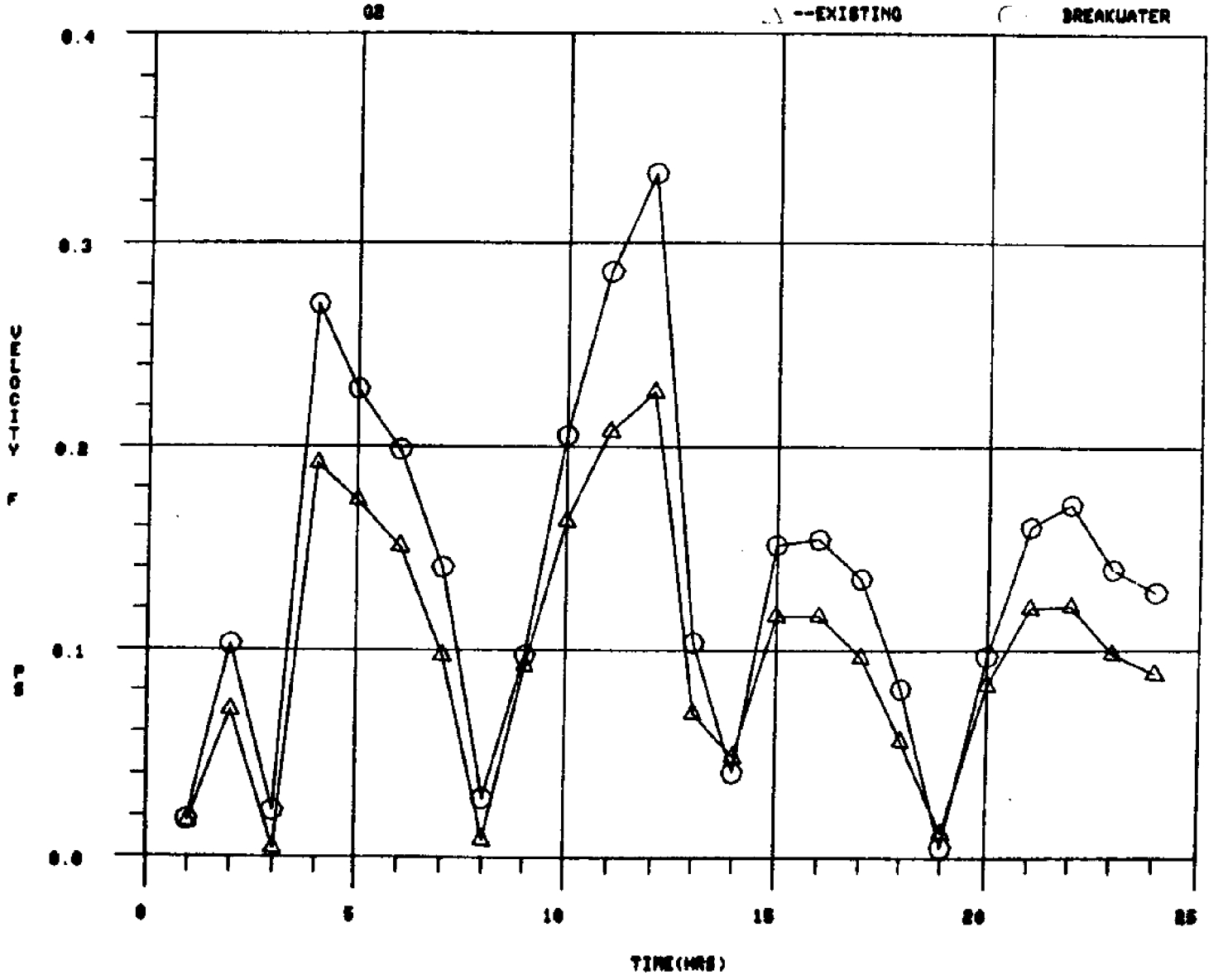
Apalachicola Bay 24 Hrs. Run - With Breakwaters - With Winter Wind
Flow Rate Field At T(Hr) = 24.00000
Maximum Velocity (Ft/Sec) = .08782

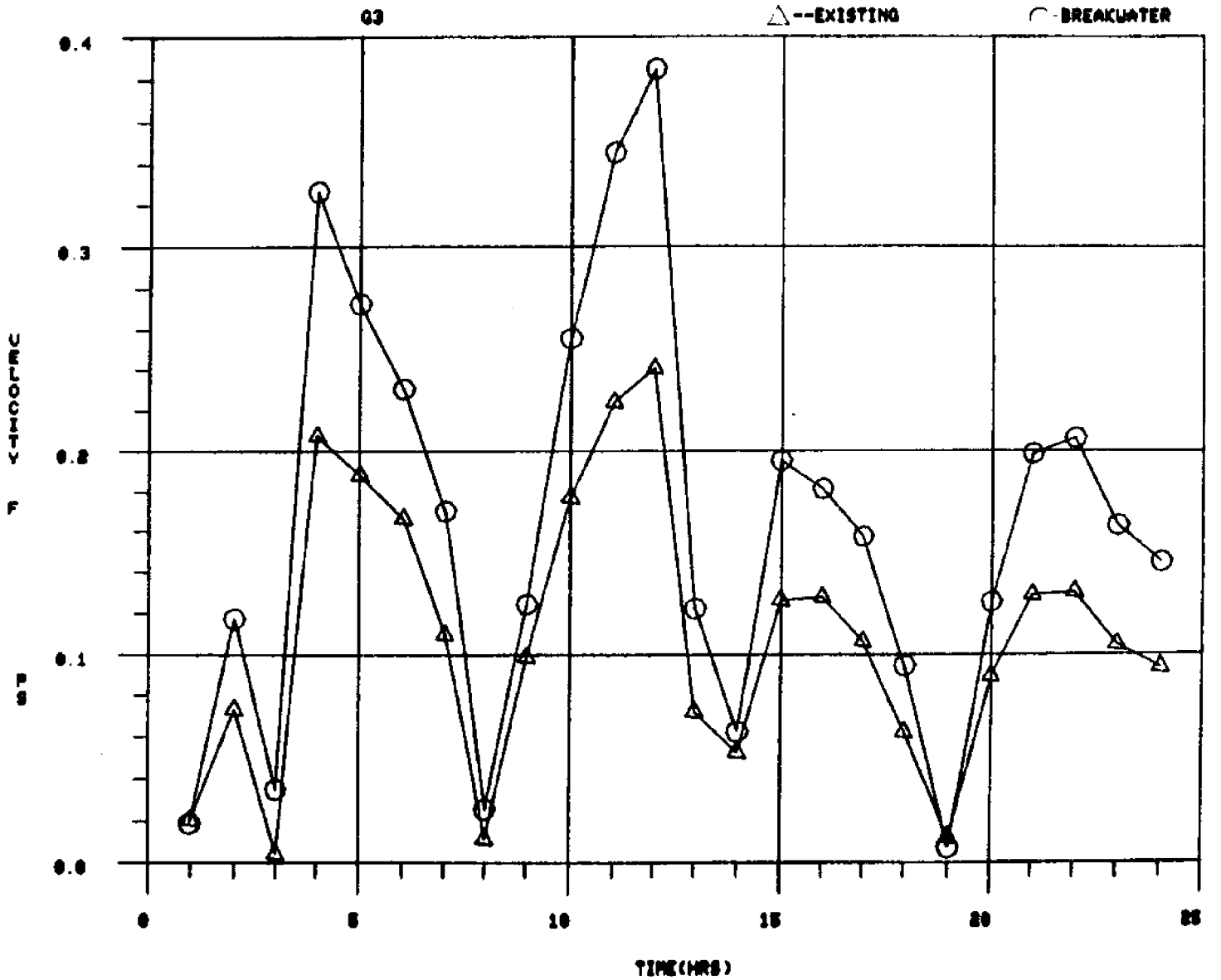


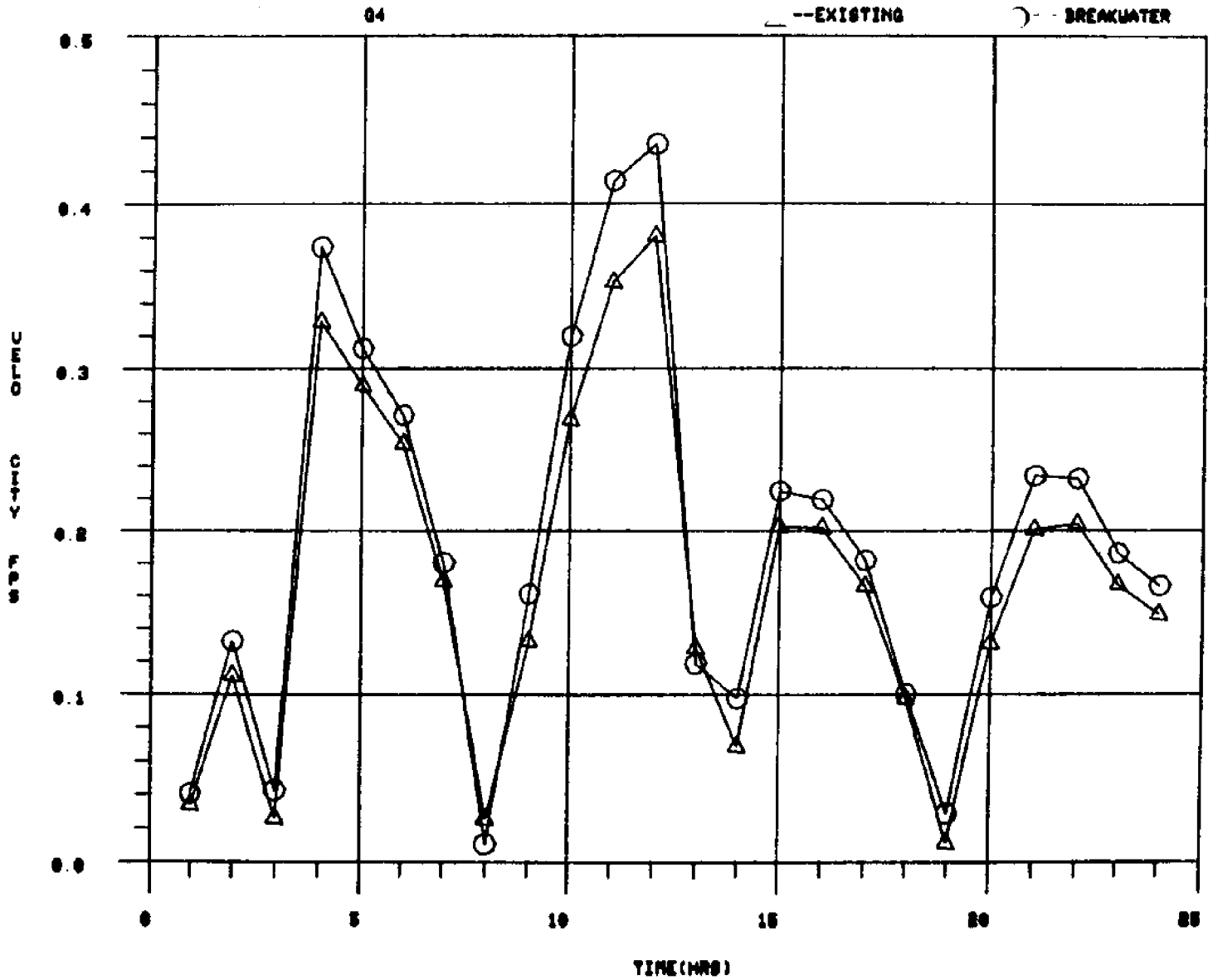
APPENDIX P

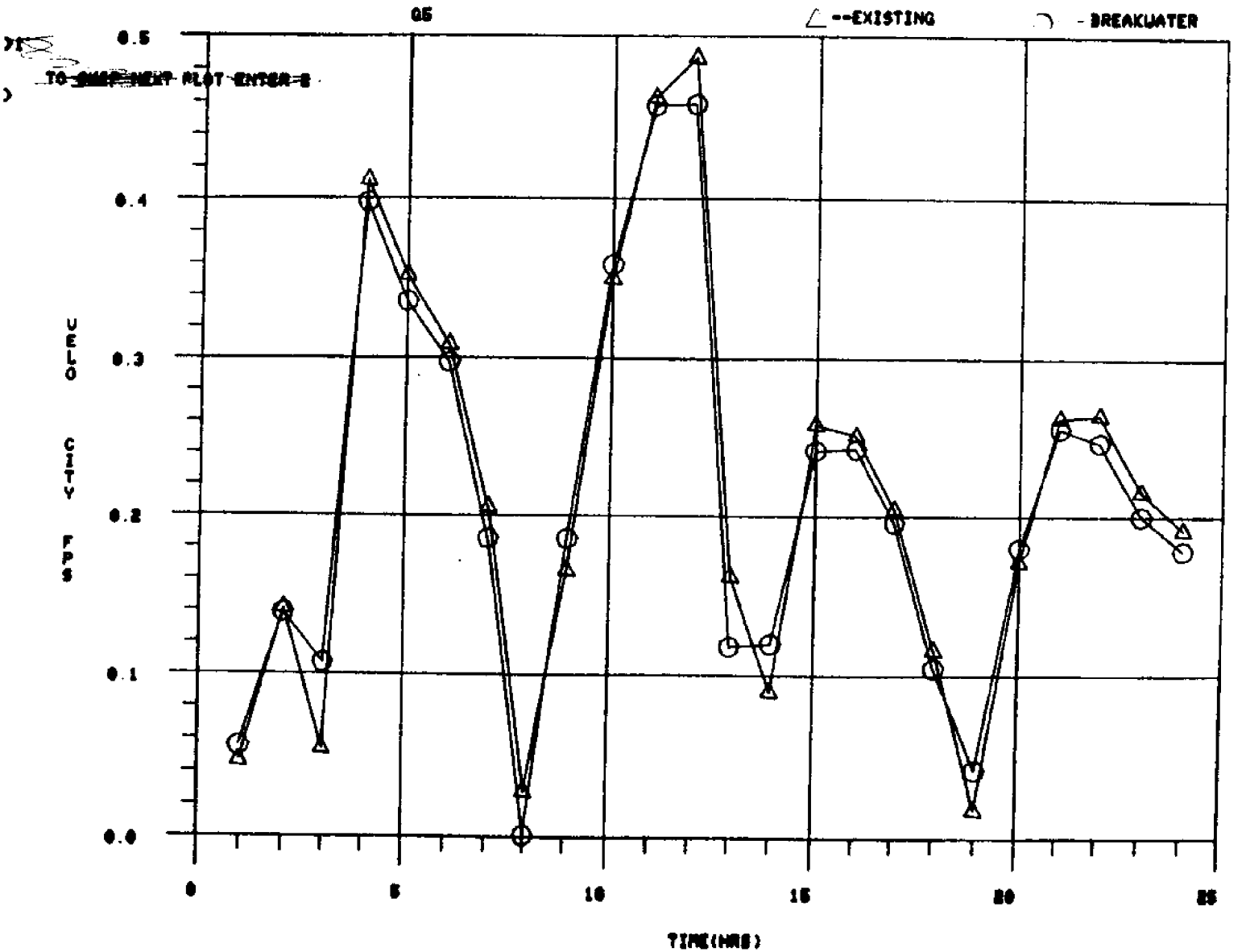
VELOCITIES AT SELECTED POINTS IN EASTPOINT LOCALE FOR BOTH EXISTING CONDITIONS AND WITH AN INSTALLED BREAKWATER (NO WIND CONDITION)

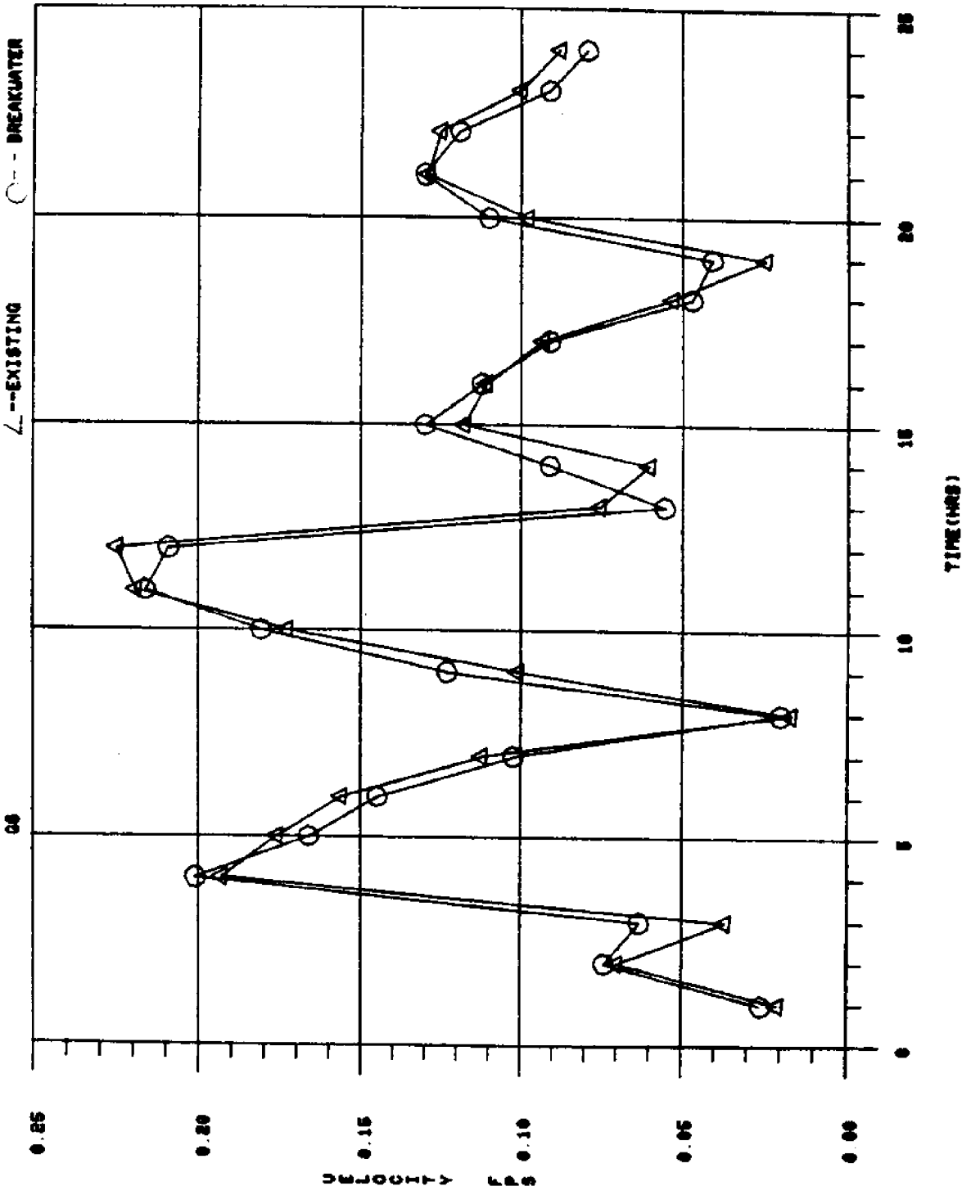

Q1
--EXISTING
BREAKWATER
>NO WIND
0.25
0.20
0.15
0.10
0.05
0.00
VELOCITY FPS
0
5
10
15
20
25
TIME(HRS)

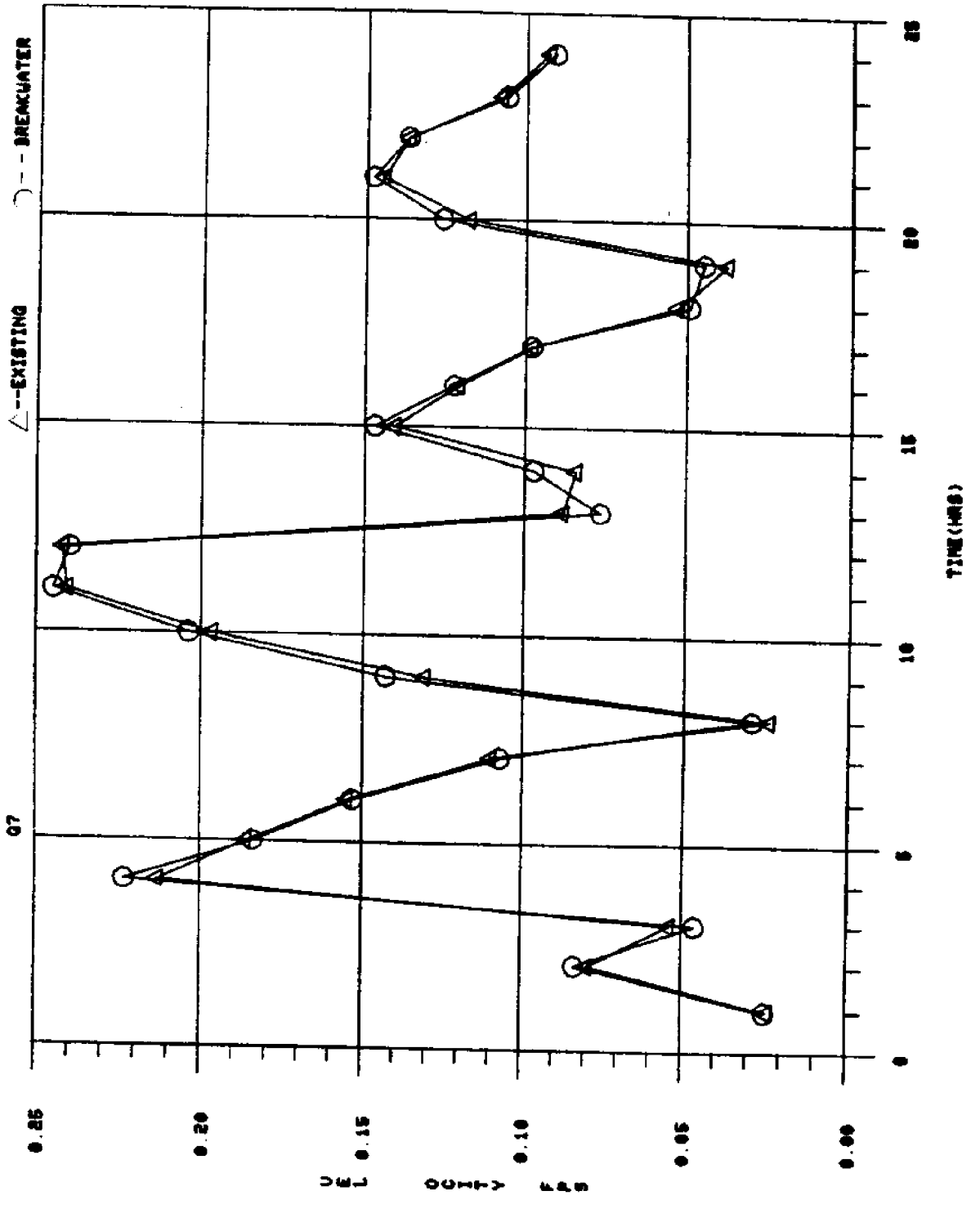

02
--EXISTING
BREAKWATER
VELOCITY
FPS
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

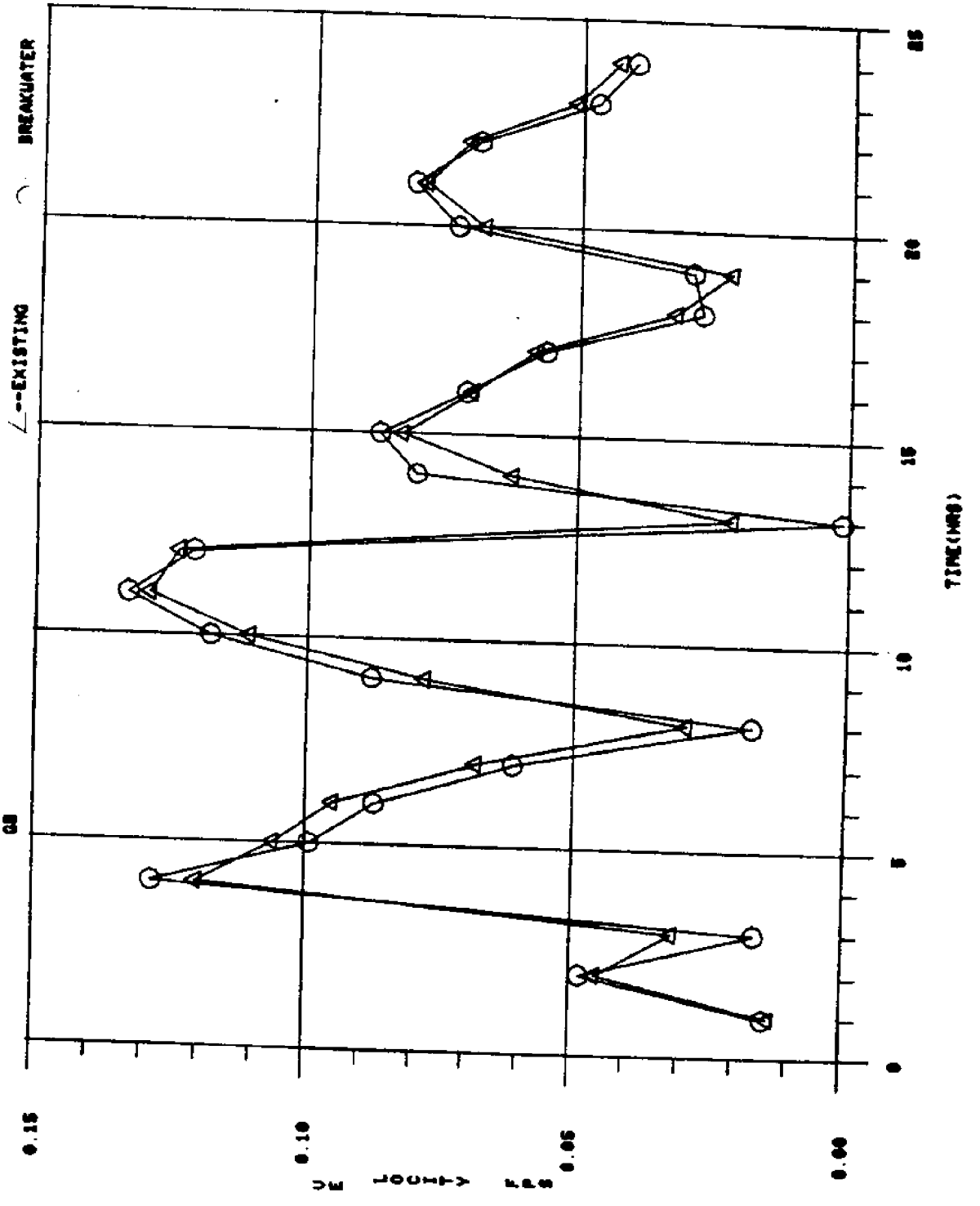

G3
△--EXISTING
⌒-BREAKWATER
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

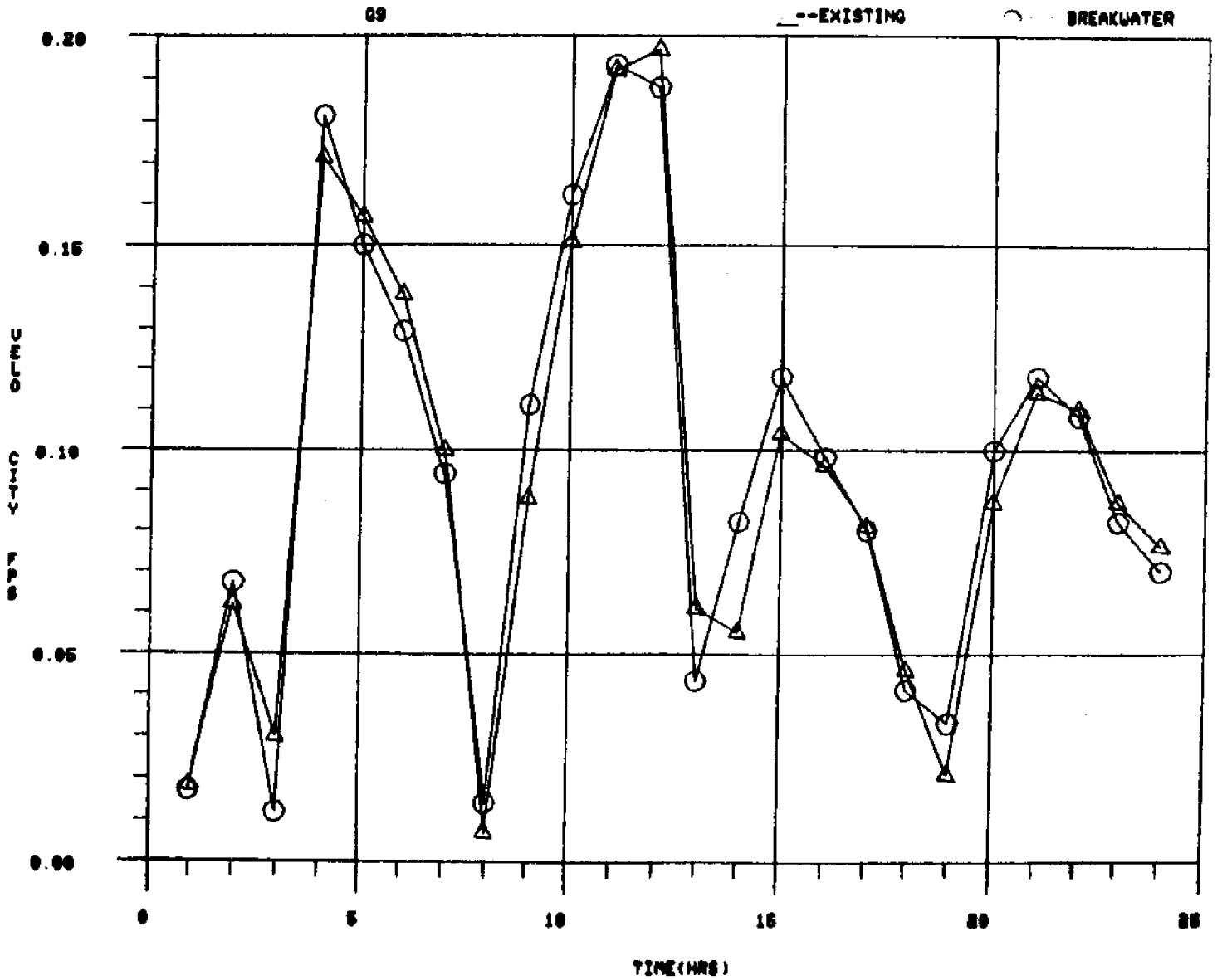

04
--EXISTING
BREAKWATER
0.5
0.4
0.3
0.2
0.1
0.0
VELOCITY FPS
0
5
10
15
20
25
TIME(HRS)

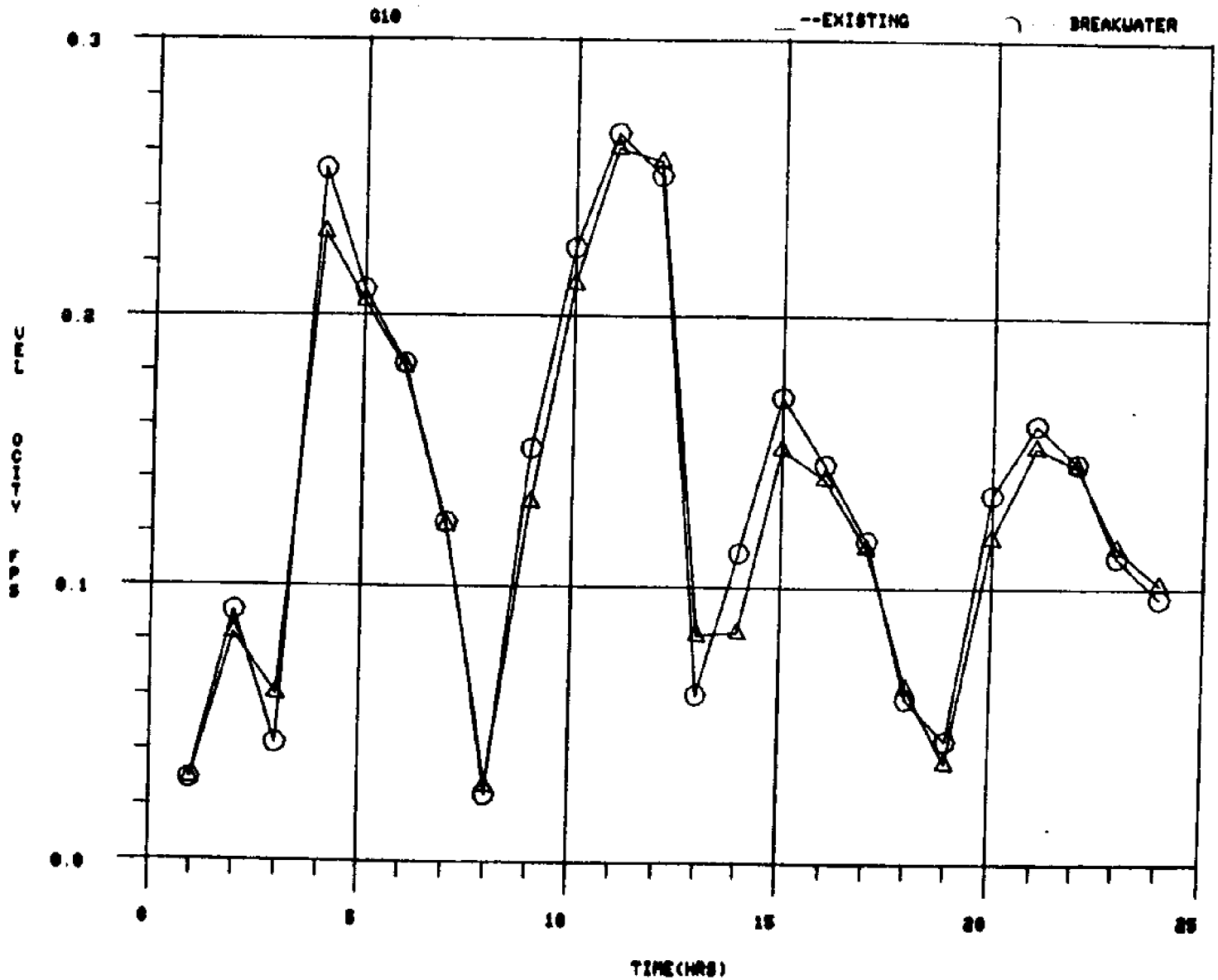

05
--EXISTING
- BREAKWATER
TO SWEEP NEXT PLOT ENTER-S
0.5
0.4
0.3
0.2
0.1
0.0
VELOCITY FPS
0
5
10
15
20
25
TIME(HRS)

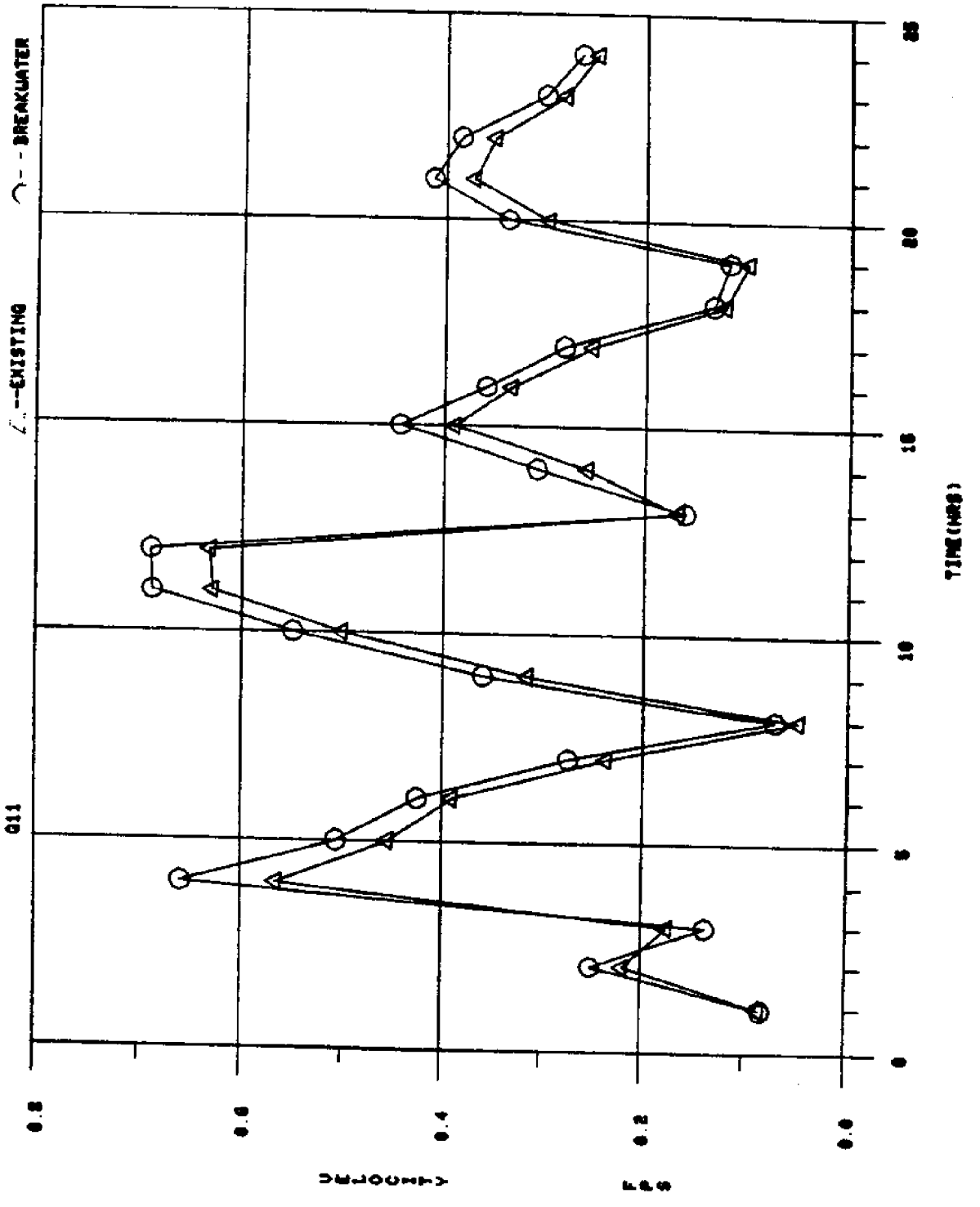

--EXISTING
- BREAKWATER
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)


07
△--EXISTING
○--BREAKWATER
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)


--EXISTING
BREAKWATER
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)

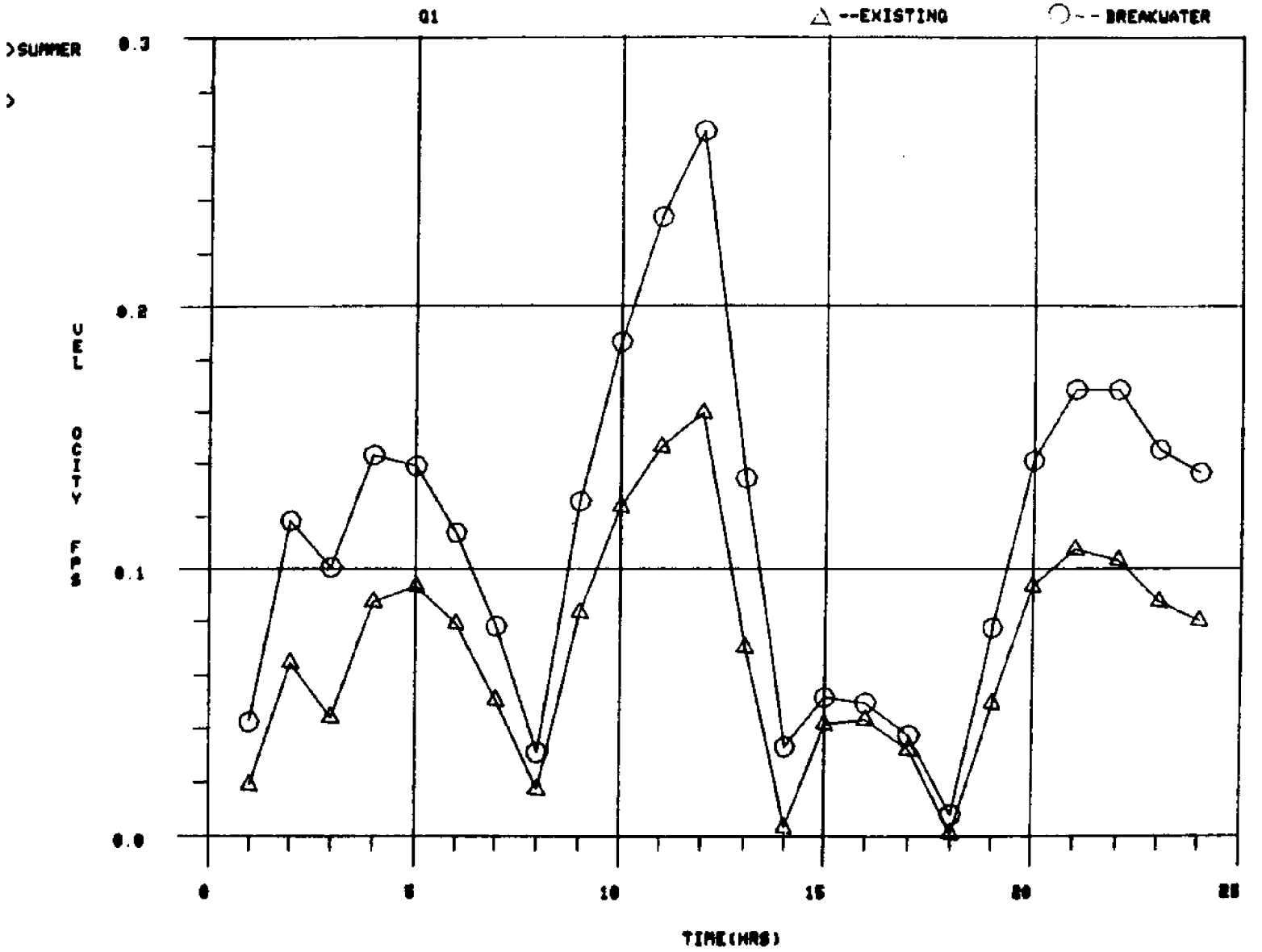

Q9
--EXISTING
BREAKWATER
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)

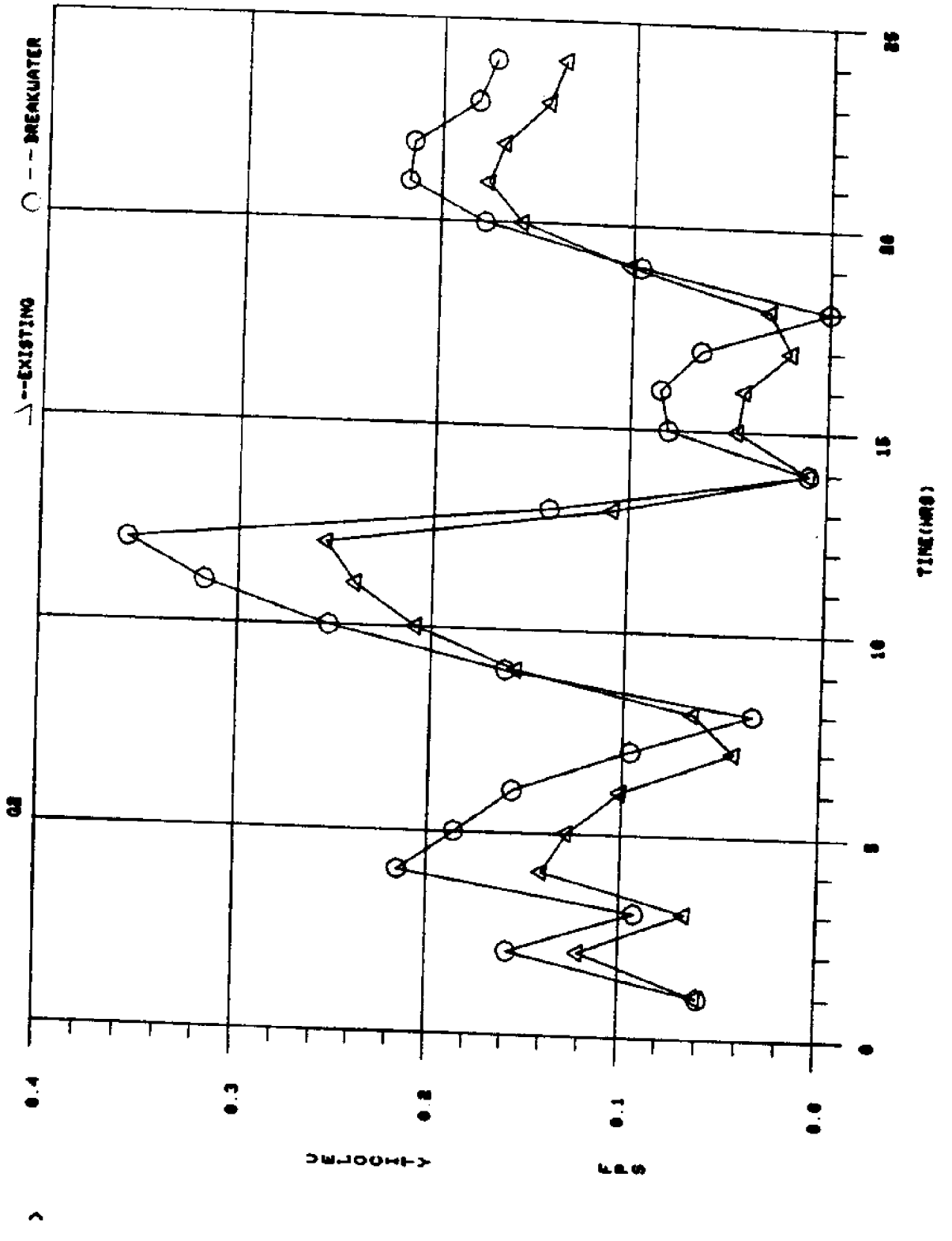

G10
--EXISTING
BREAKWATER
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

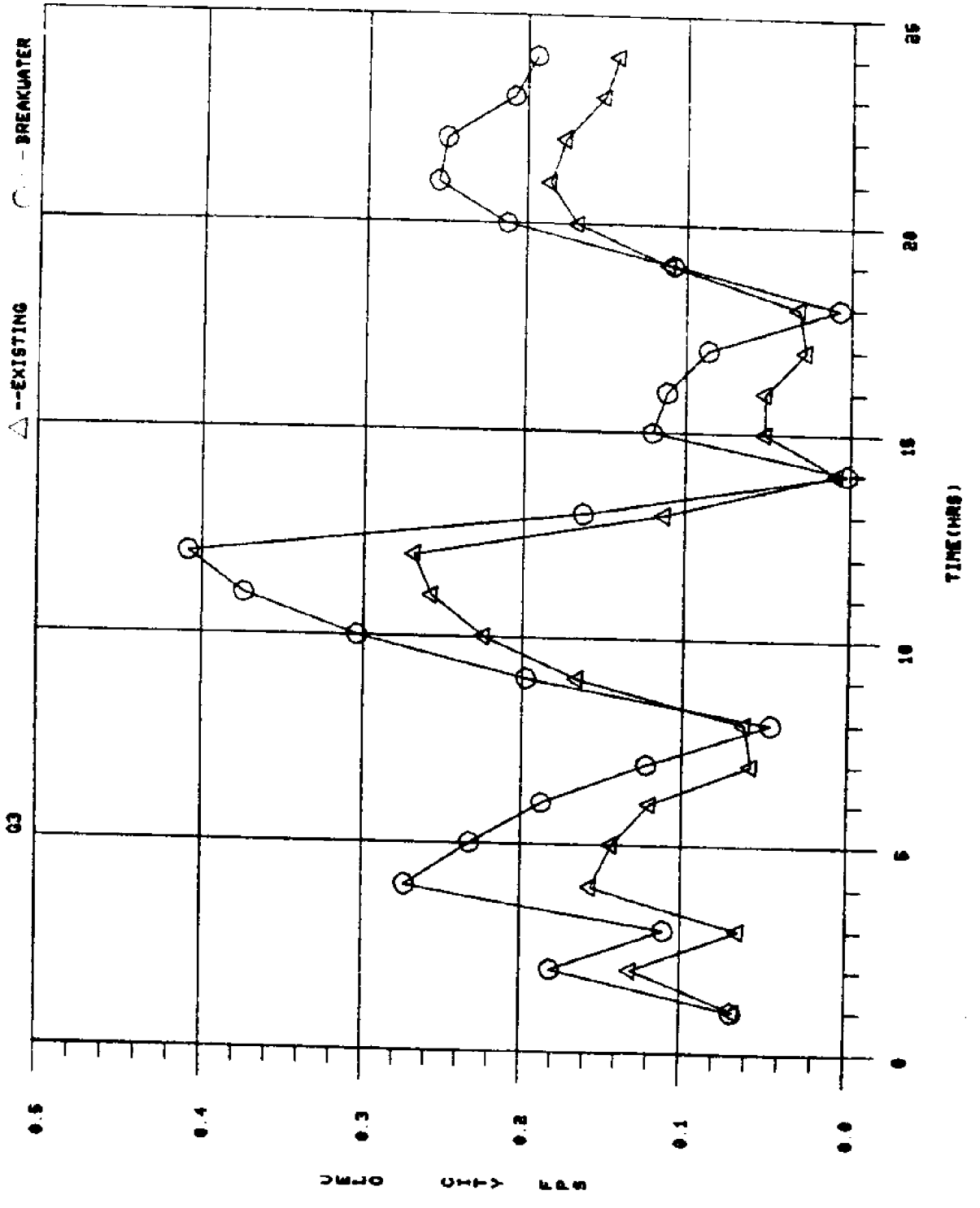

Q11
--EXISTING
--BREAKWATER
TIME(HRS)
0
5
10
15
20
25
0.0
0.2
0.4
0.6
0.8

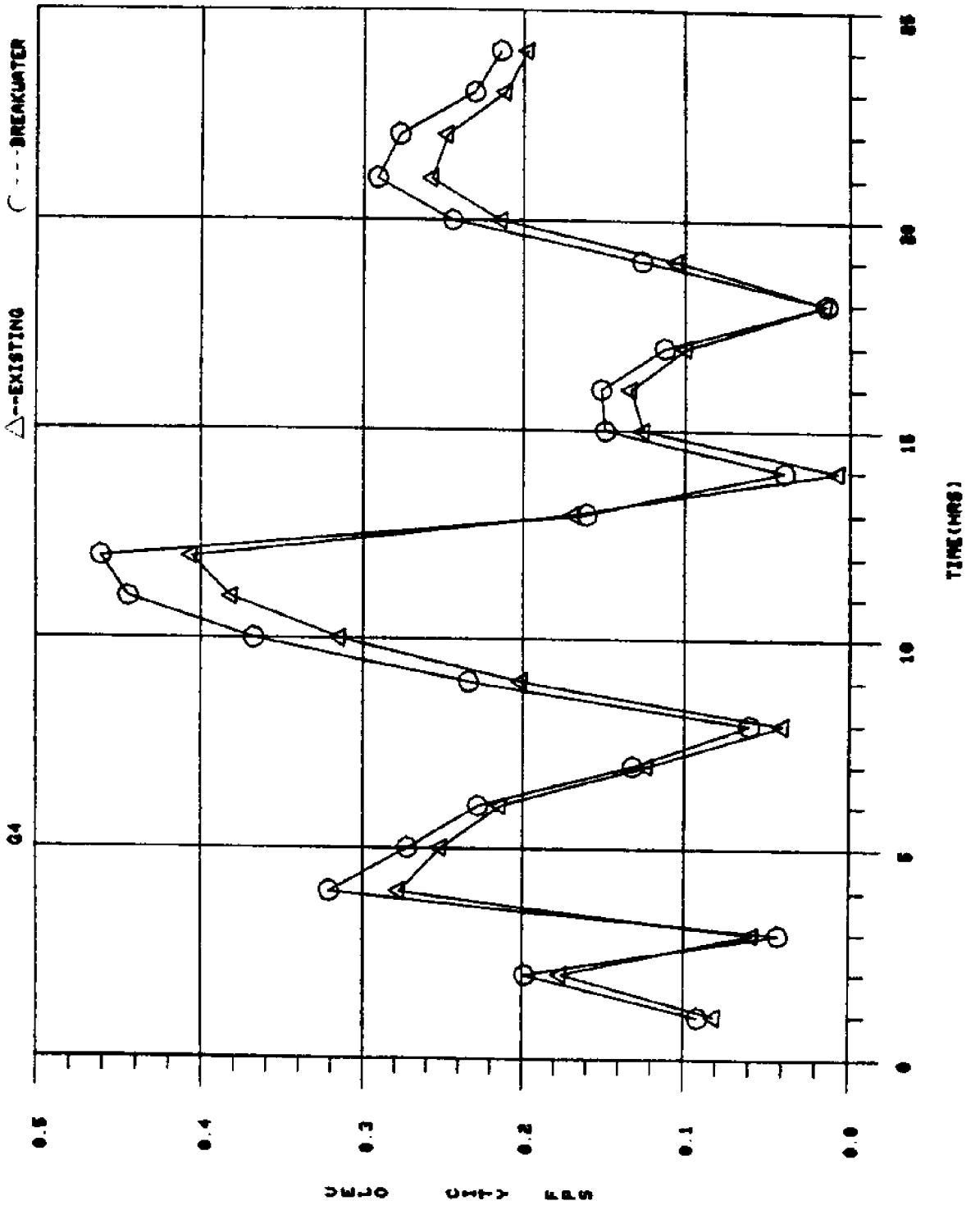
APPENDIX Q

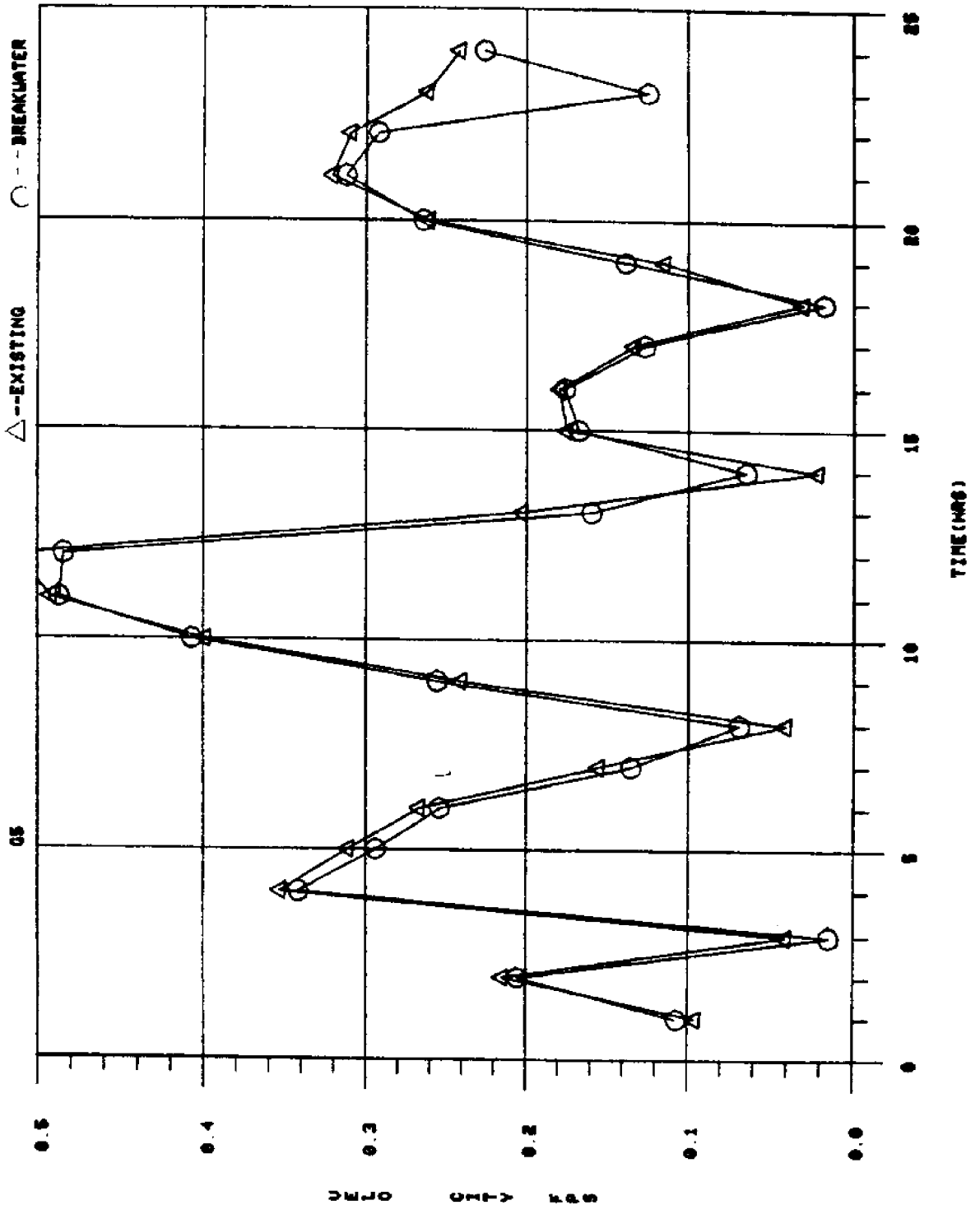
VELOCITIES AT SELECTED POINTS IN EASTPOINT LOCALE FOR BOTH EXISTING CONDITIONS AND WITH AN INSTALLED BREAKWATER (AVERAGE SUMMER WIND)

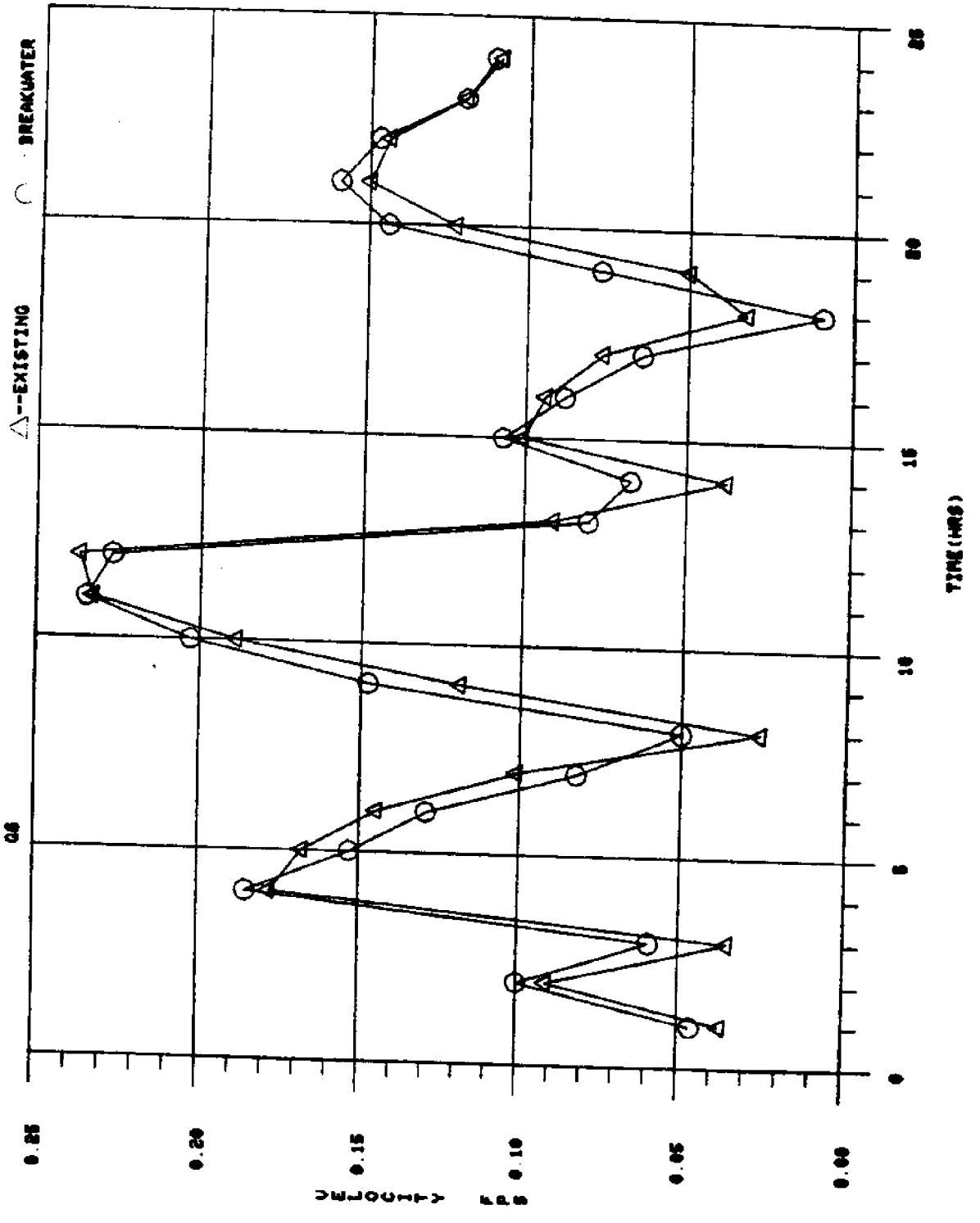

Q1
△--EXISTING
○--BREAKWATER
>SUMMER
>
0.3
0.2
0.1
0.0
VELOCITY FPS
0
5
10
15
20
25
TIME(HRS)

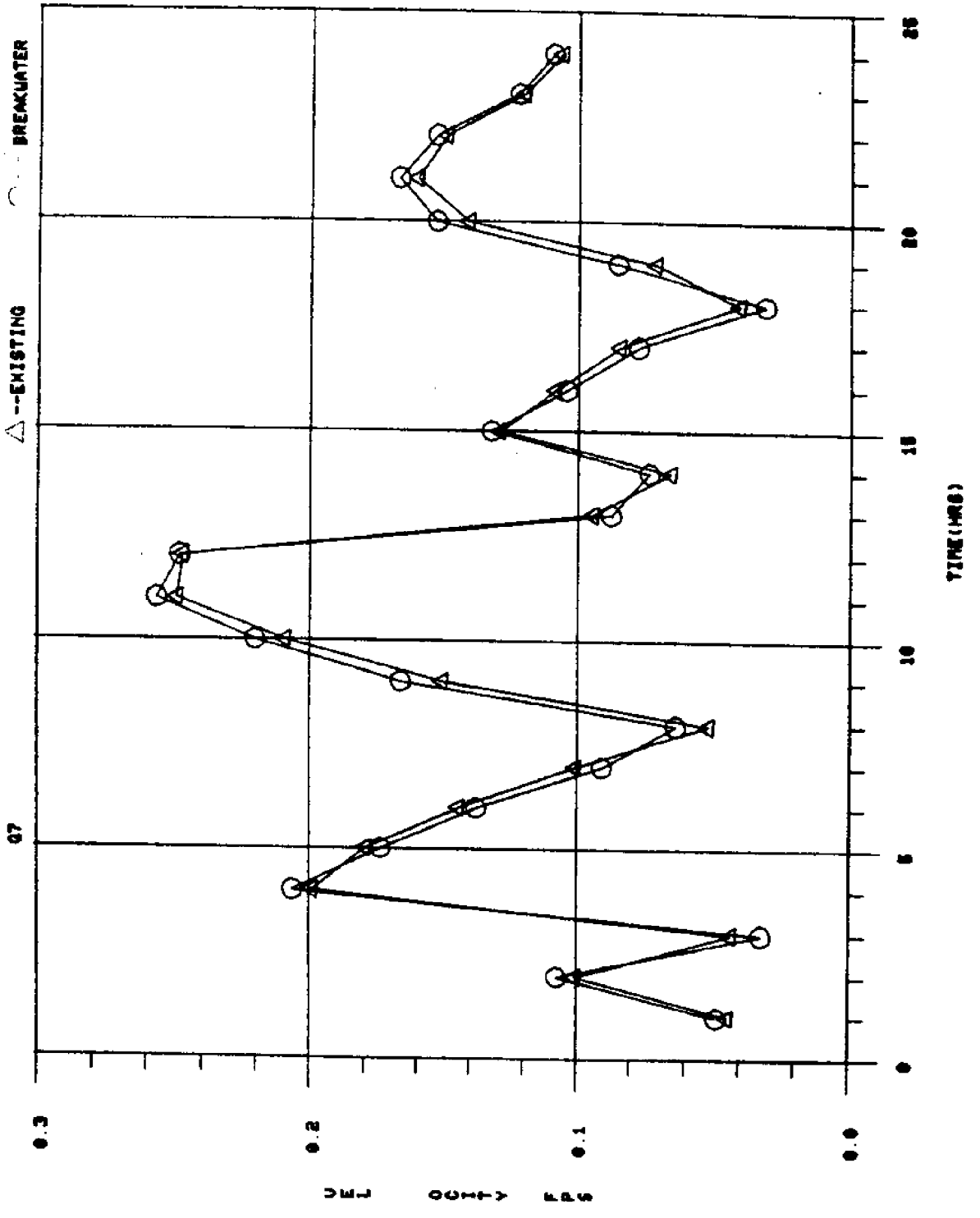

△--EXISTING
○ - - BREAKWATER
TIME(HRS)
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25

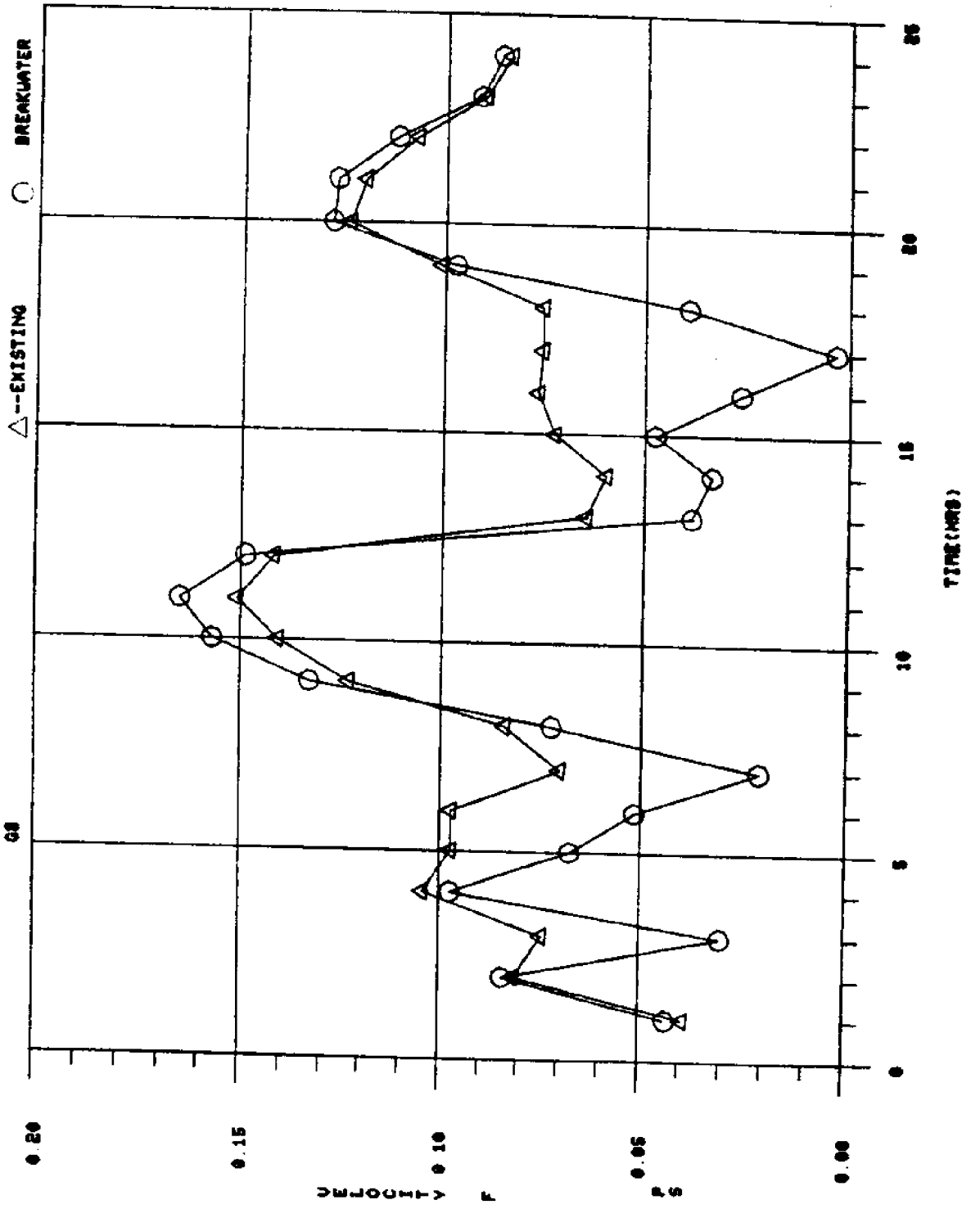

Q3
△ --EXISTING
○ - BREAKWATER
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

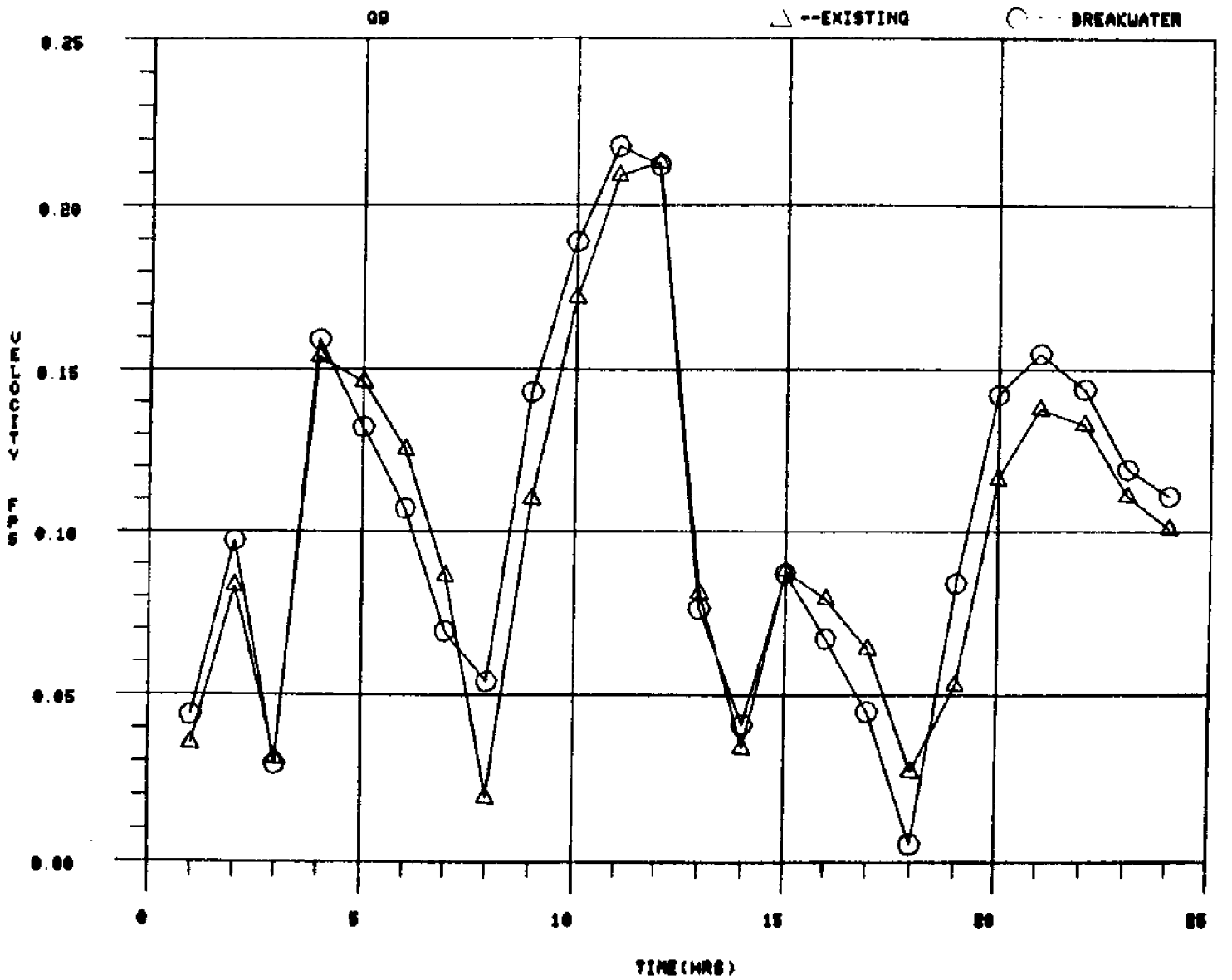

Q4
△--EXISTING
○---BREAKWATER
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

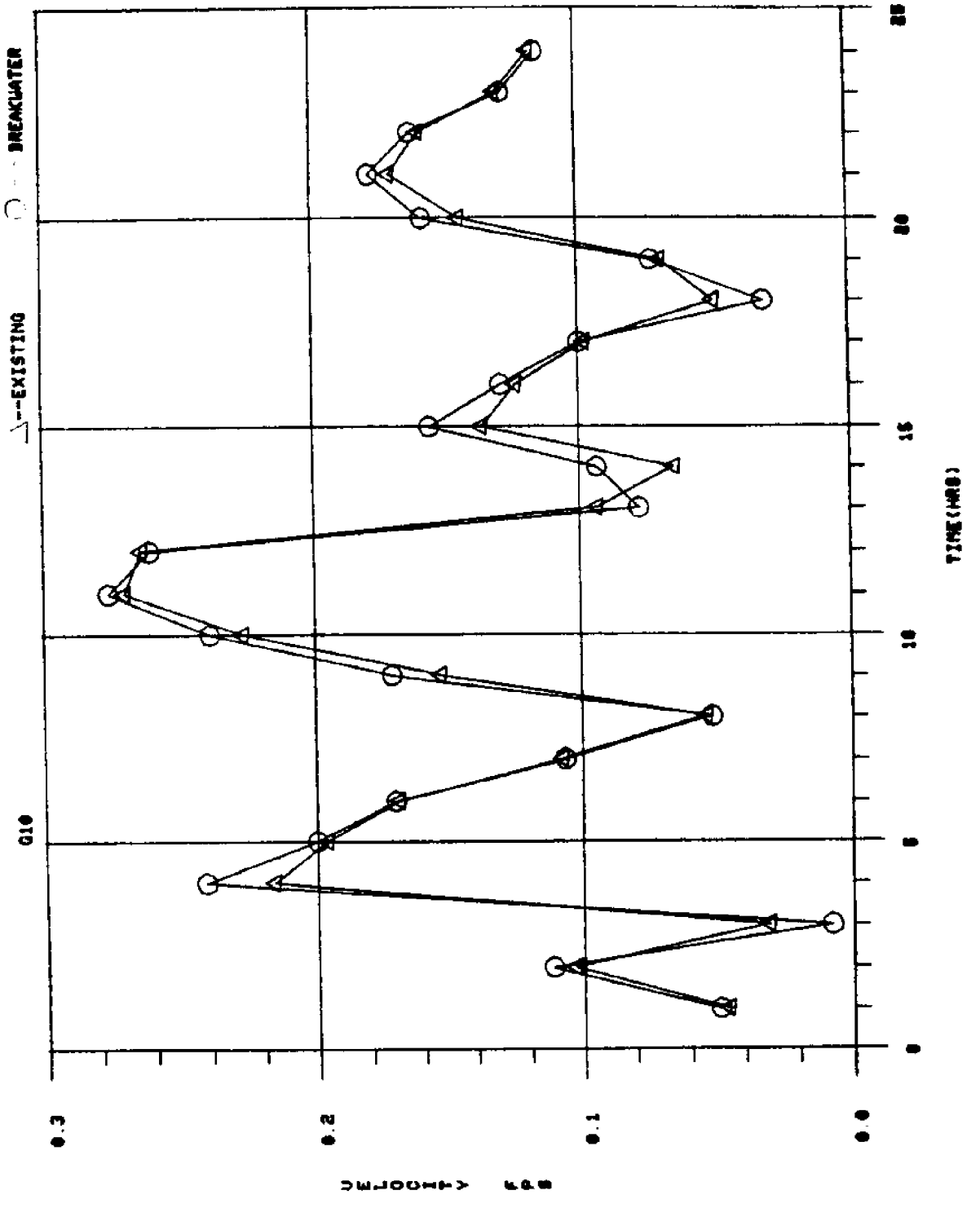

△--EXISTING
○--BREAKWATER
TIME(HRS)
0
5
10
15
20
25
0.0
0.1
0.2
0.3
0.4
0.5

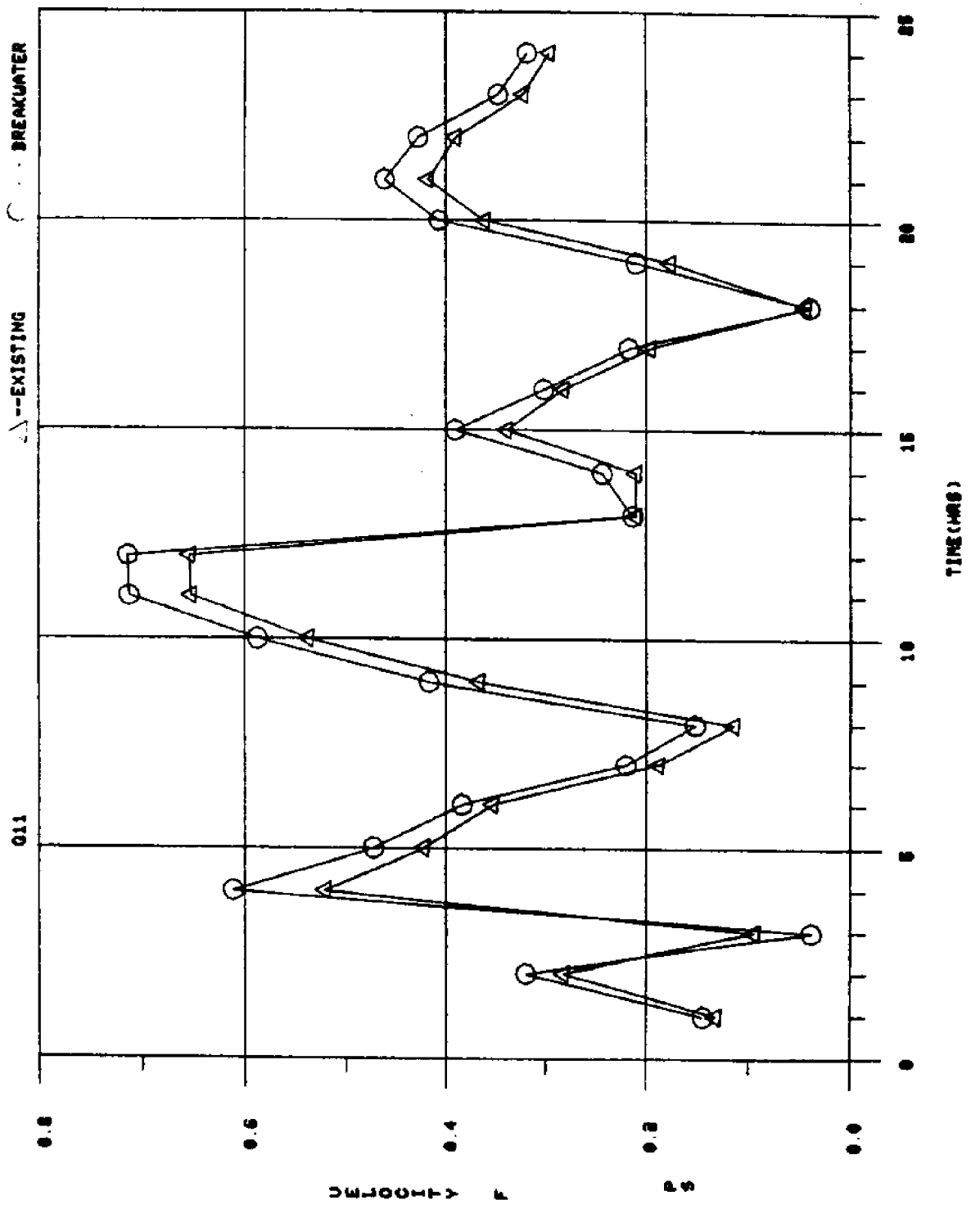

△--EXISTING
○ BREAKWATER
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)


BREAKWATER
--EXISTING
07
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)


△--EXISTING
○ BREAKWATER
08
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)

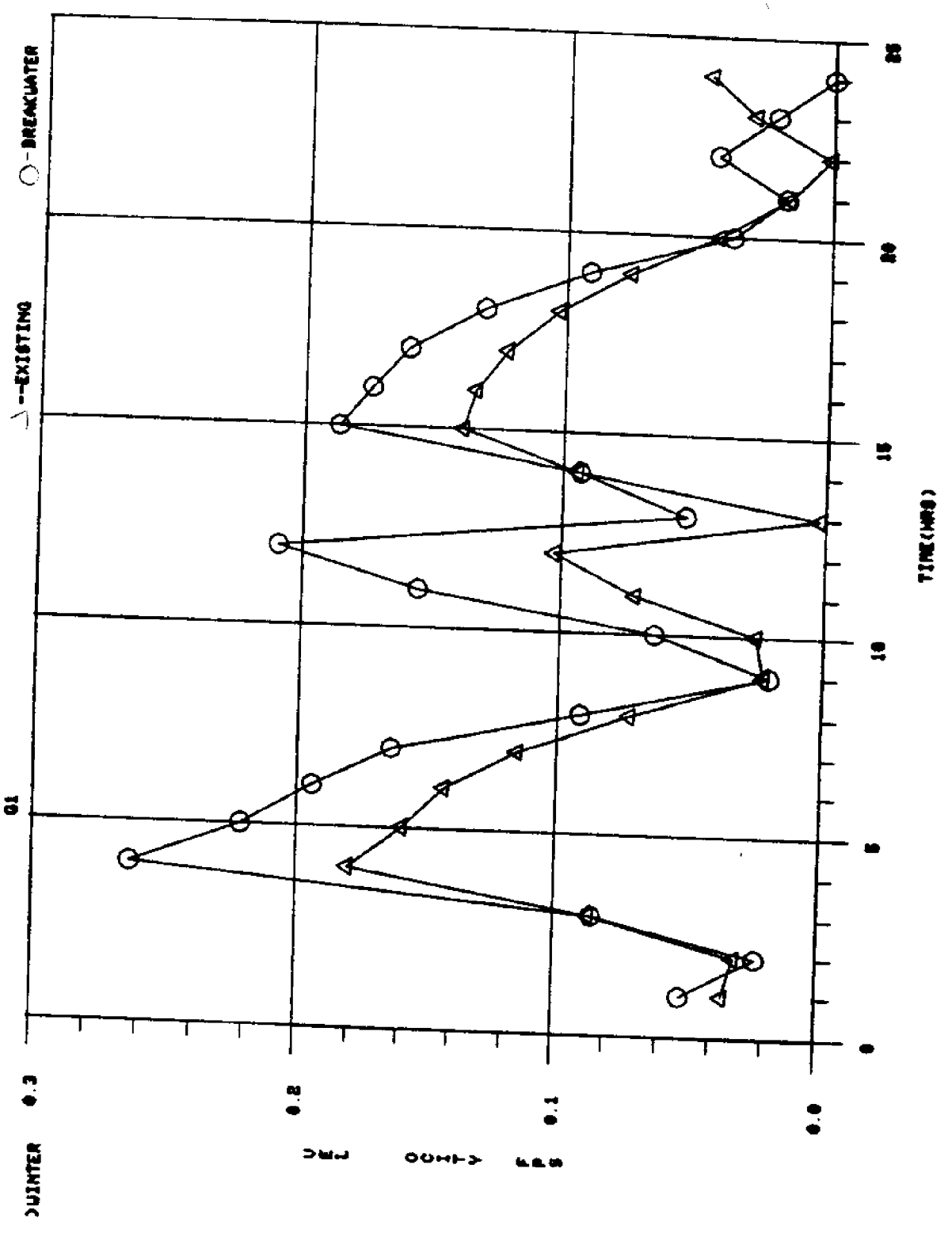

G9
--EXISTING
BREAKWATER
0.25
0.20
0.15
0.10
0.05
0.00
VELOCITY FPS
0
5
10
15
20
25
TIME(HRS)

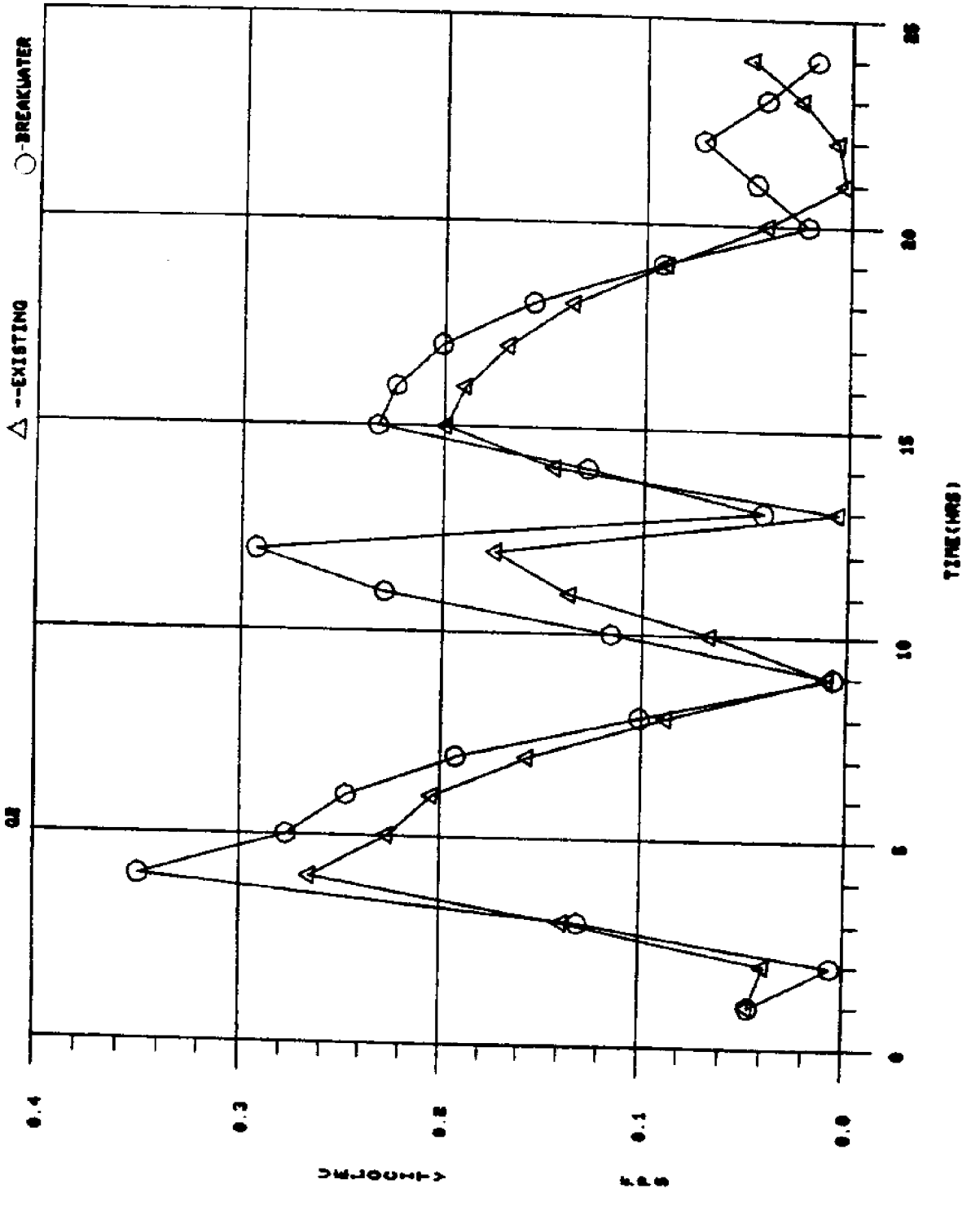

△--EXISTING
○ -- BREAKWATER
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

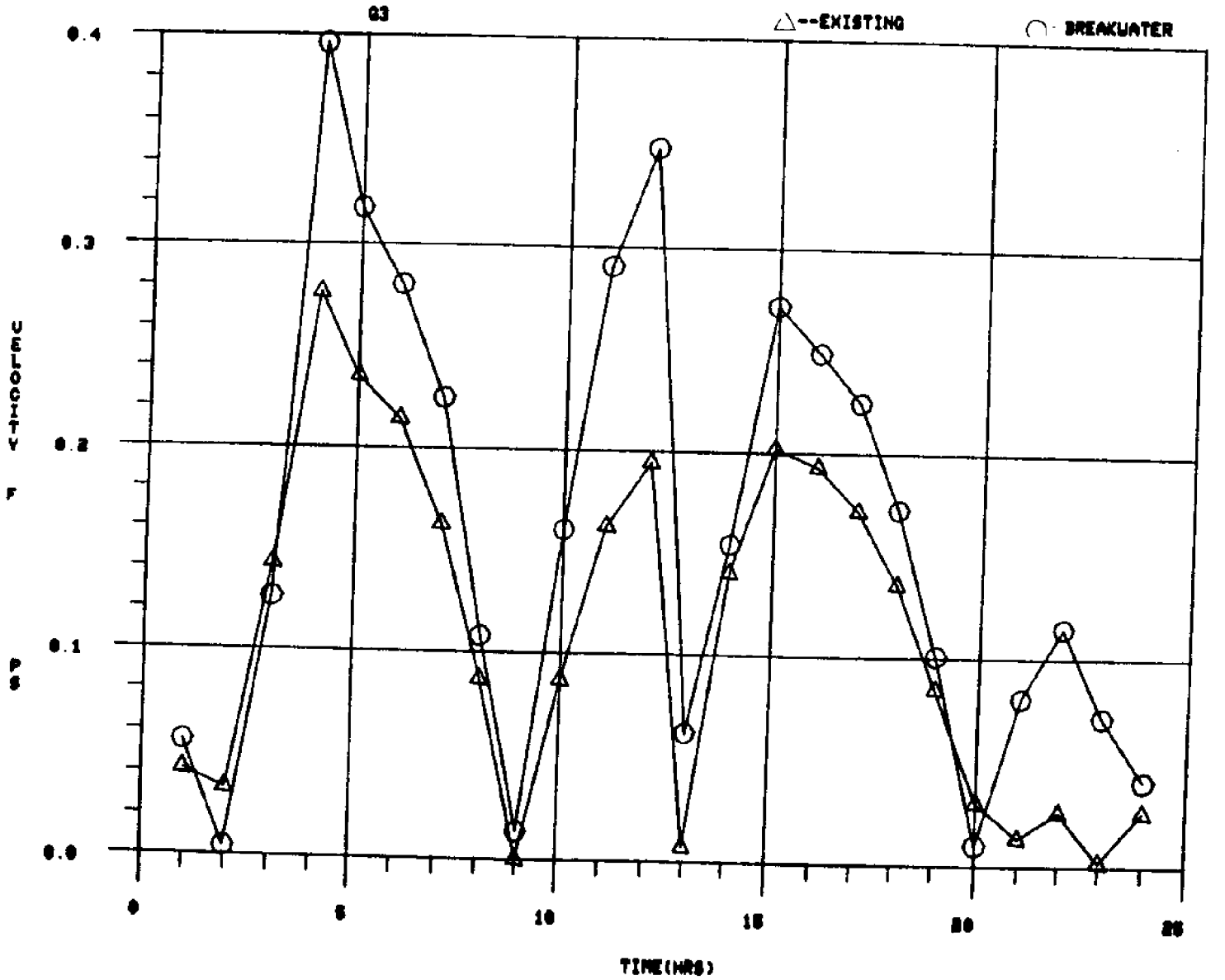

Q11
△--EXISTING
○ · BREAKWATER
0.0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
TIME(HRS)

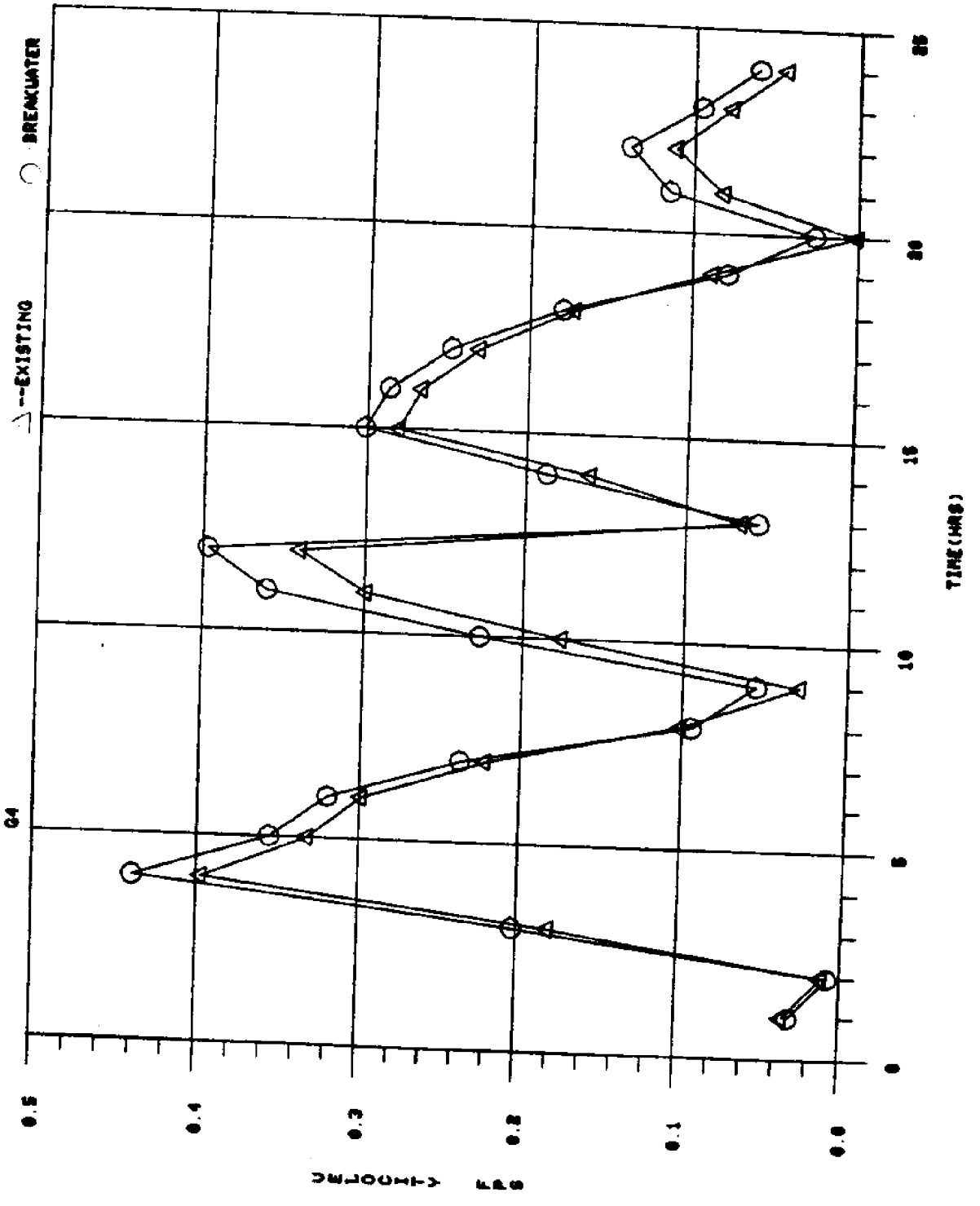
APPENDIX R

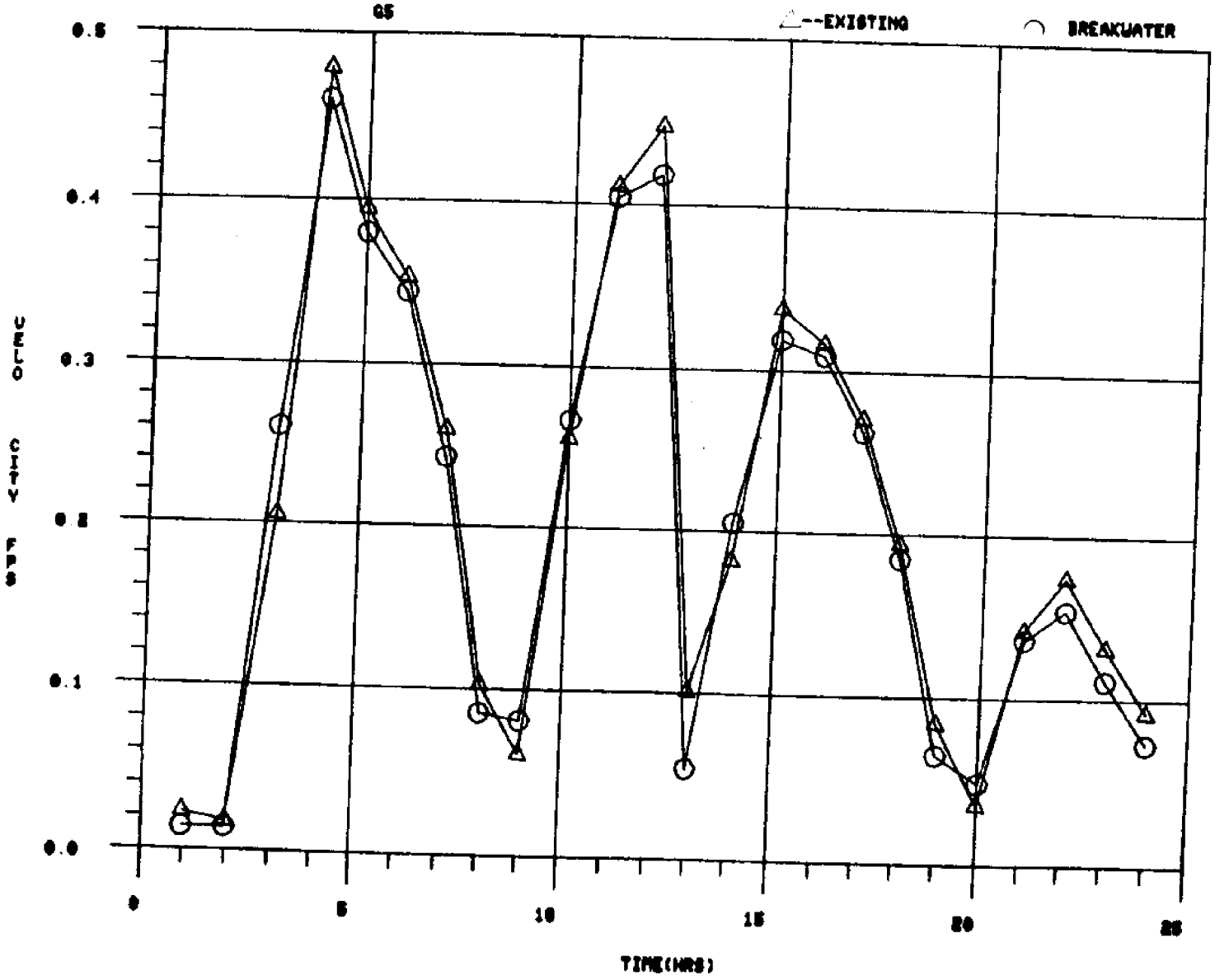
VELOCITIES AT SELECTED POINTS IN EASTPOINT LOCALE FOR BOTH EXISTING CONDITIONS AND WITH AN INSTALLED BREAKWATER (AVERAGE WINTER WIND)

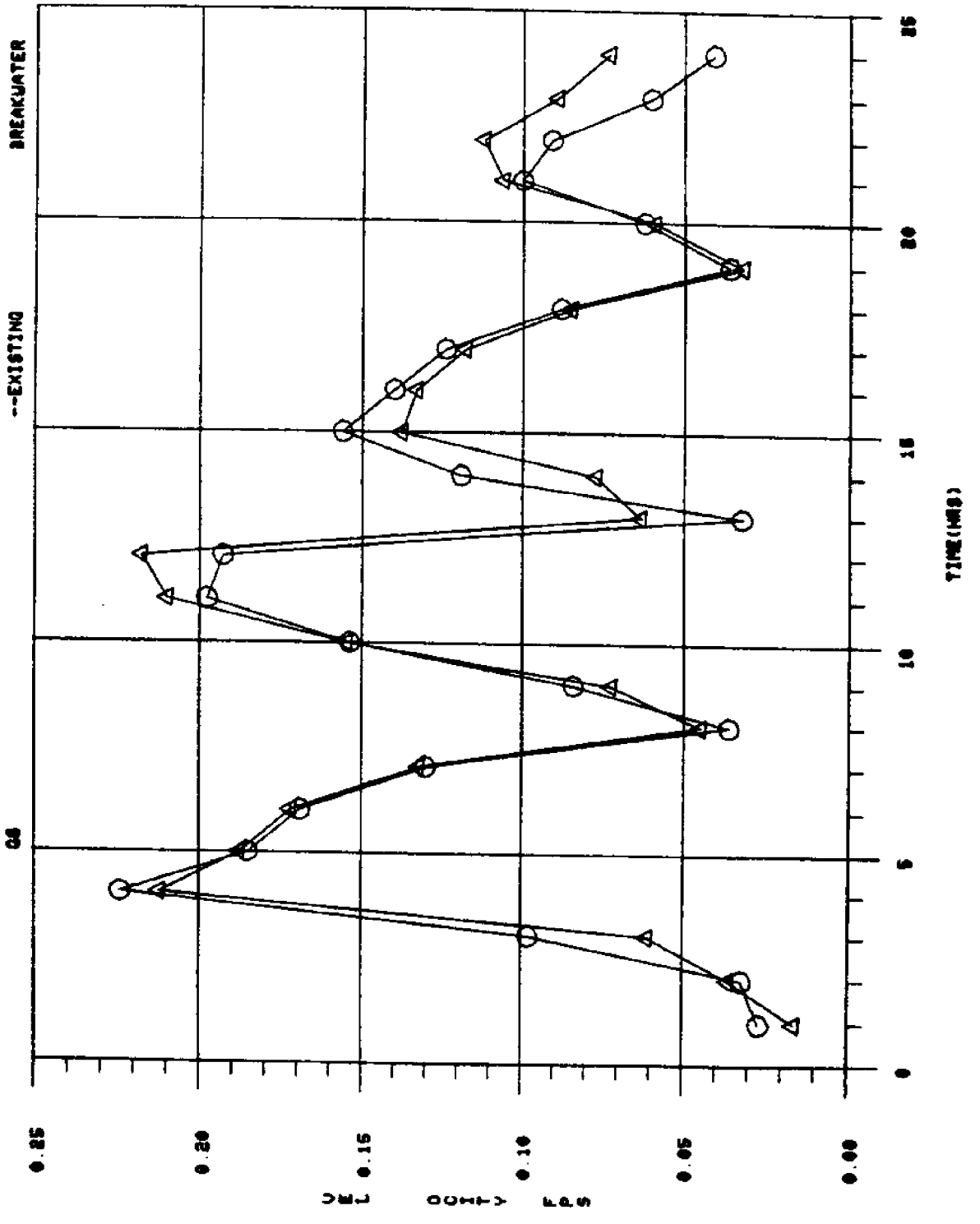

QUINTER
0.3
0.2
0.1
0.0
01
0
5
10
15
20
25
TIME(HRS)
△--EXISTING
○-BREAKWATER

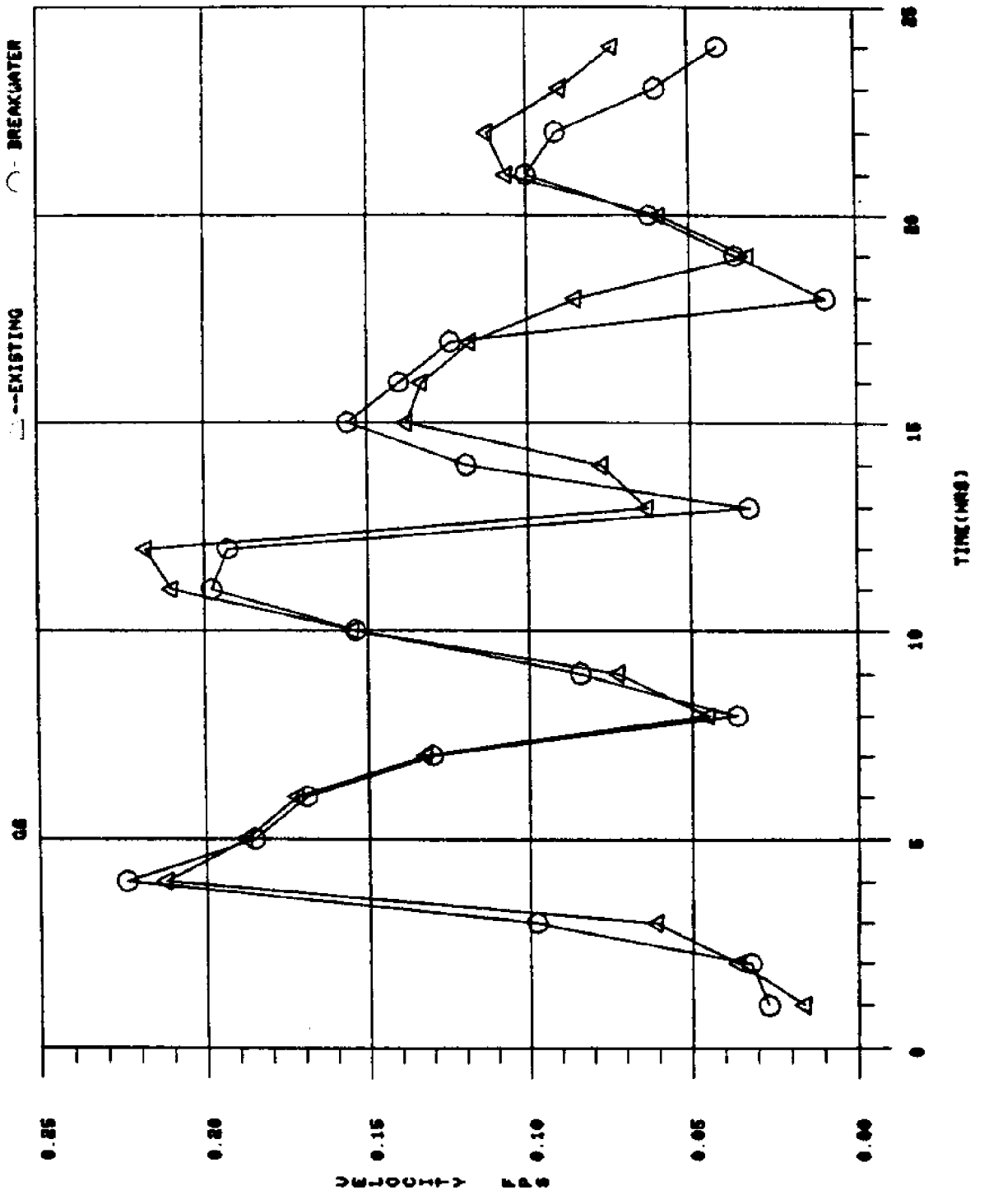

○-BREAKWATER
△ --EXISTING
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

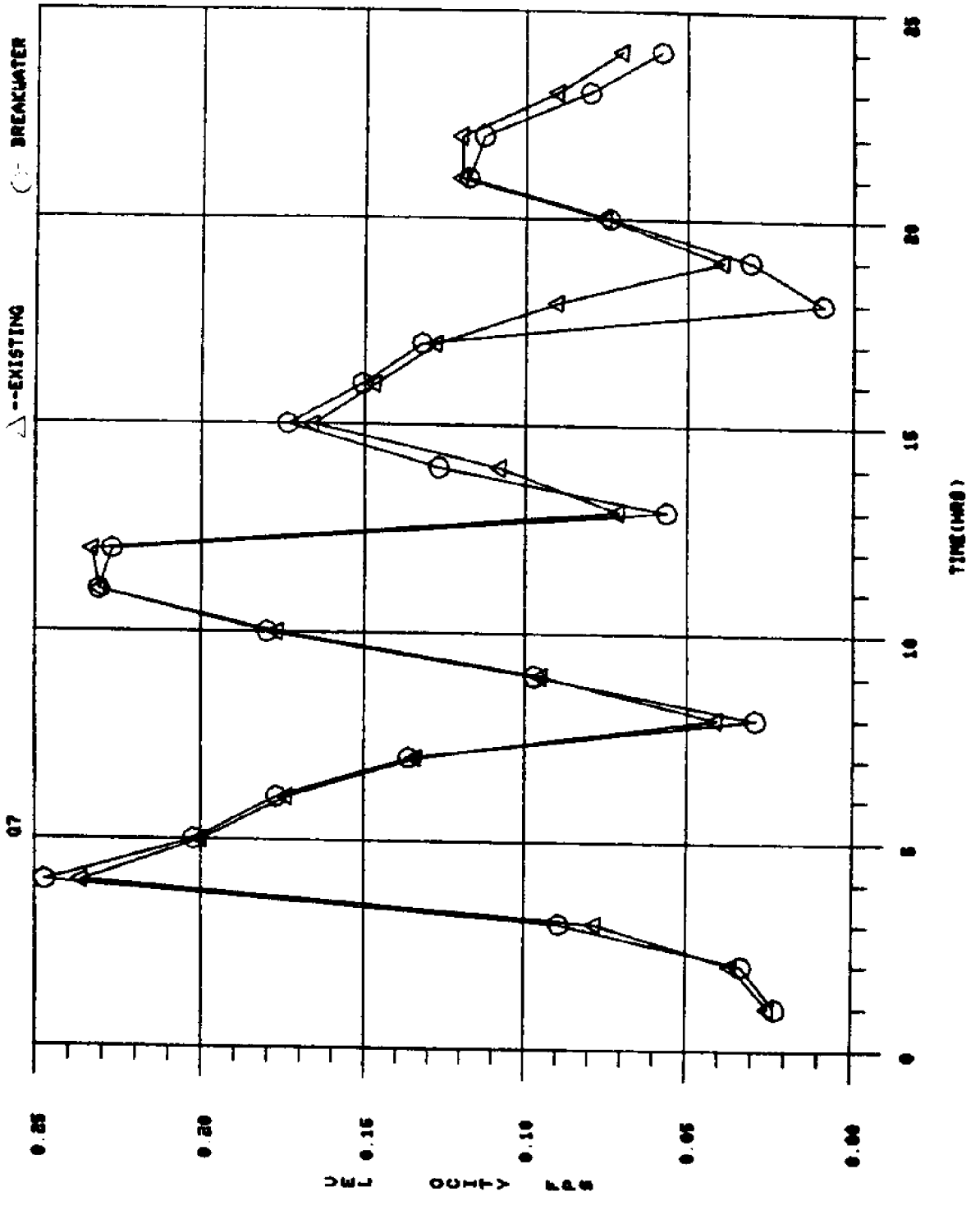

Q3
△--EXISTING
○- BREAKWATER
0.4
0.3
0.2
0.1
0.0
VELOCITY
FPS
0
5
10
15
20
25
TIME(HRS)

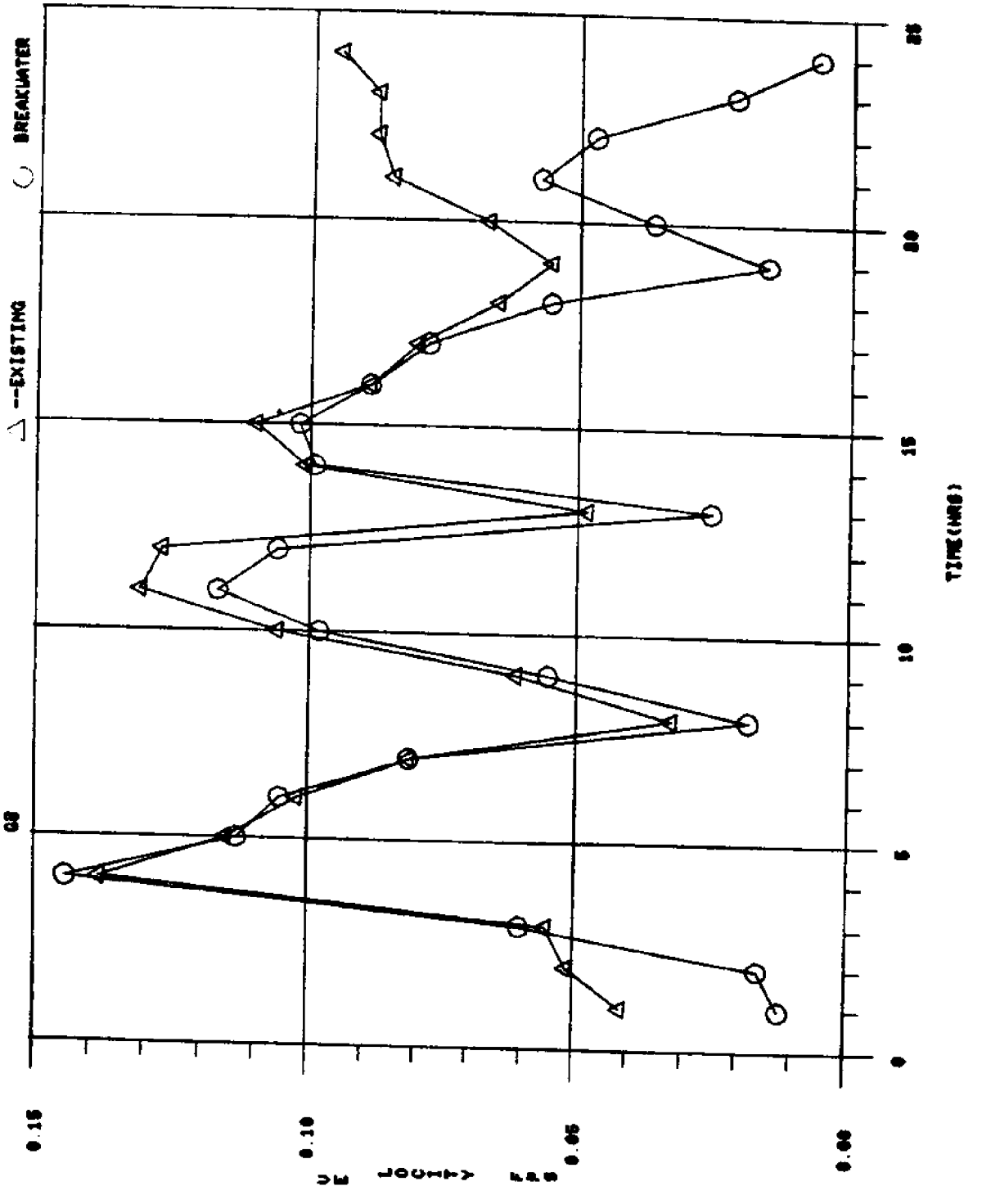

△--EXISTING
○ BREAKWATER
0.4
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)

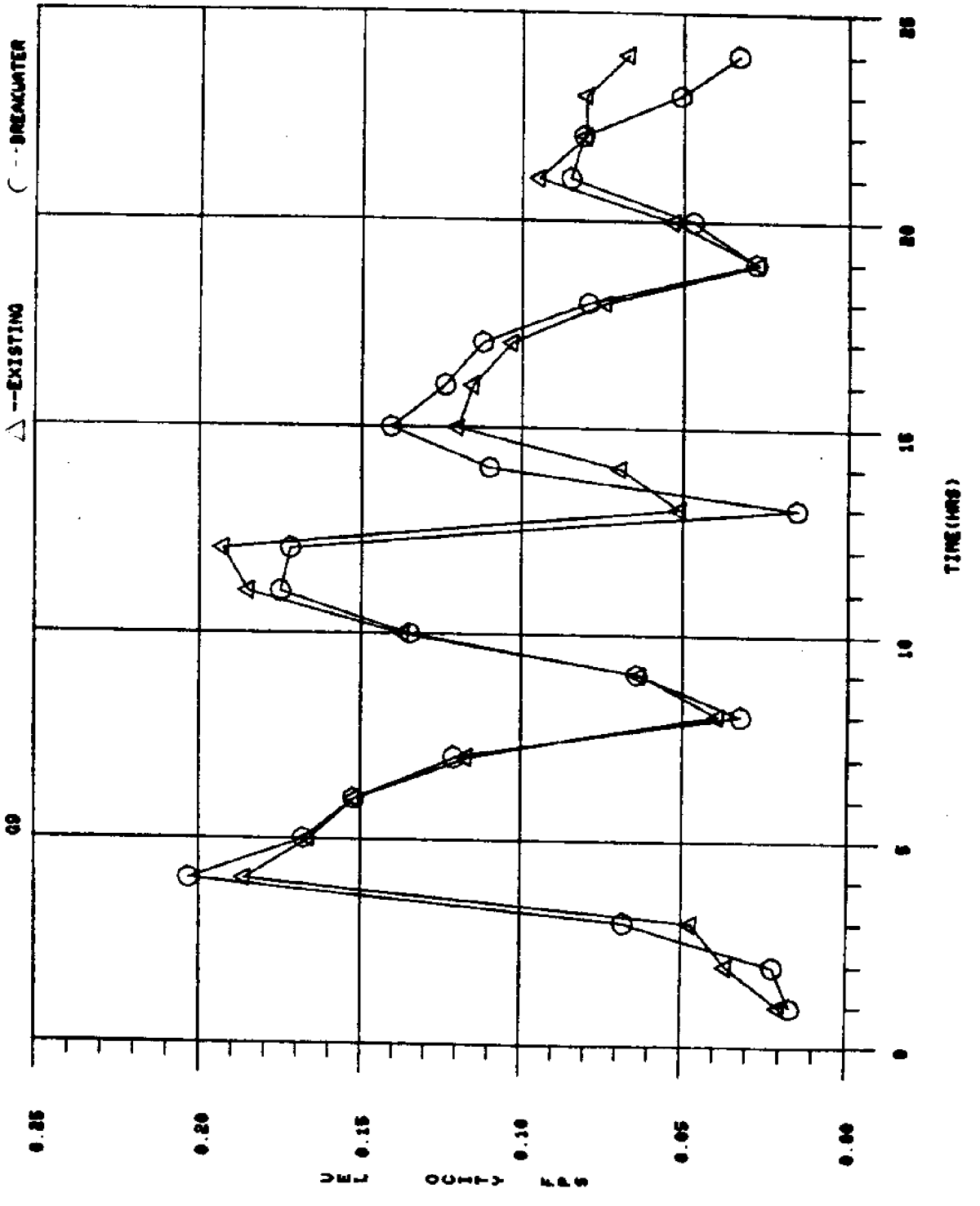

Q5
△--EXISTING
○ BREAKWATER
0.5
0.4
0.3
0.2
0.1
0.0
VELOCITY FPS
0
5
10
15
20
25
TIME(HRS)

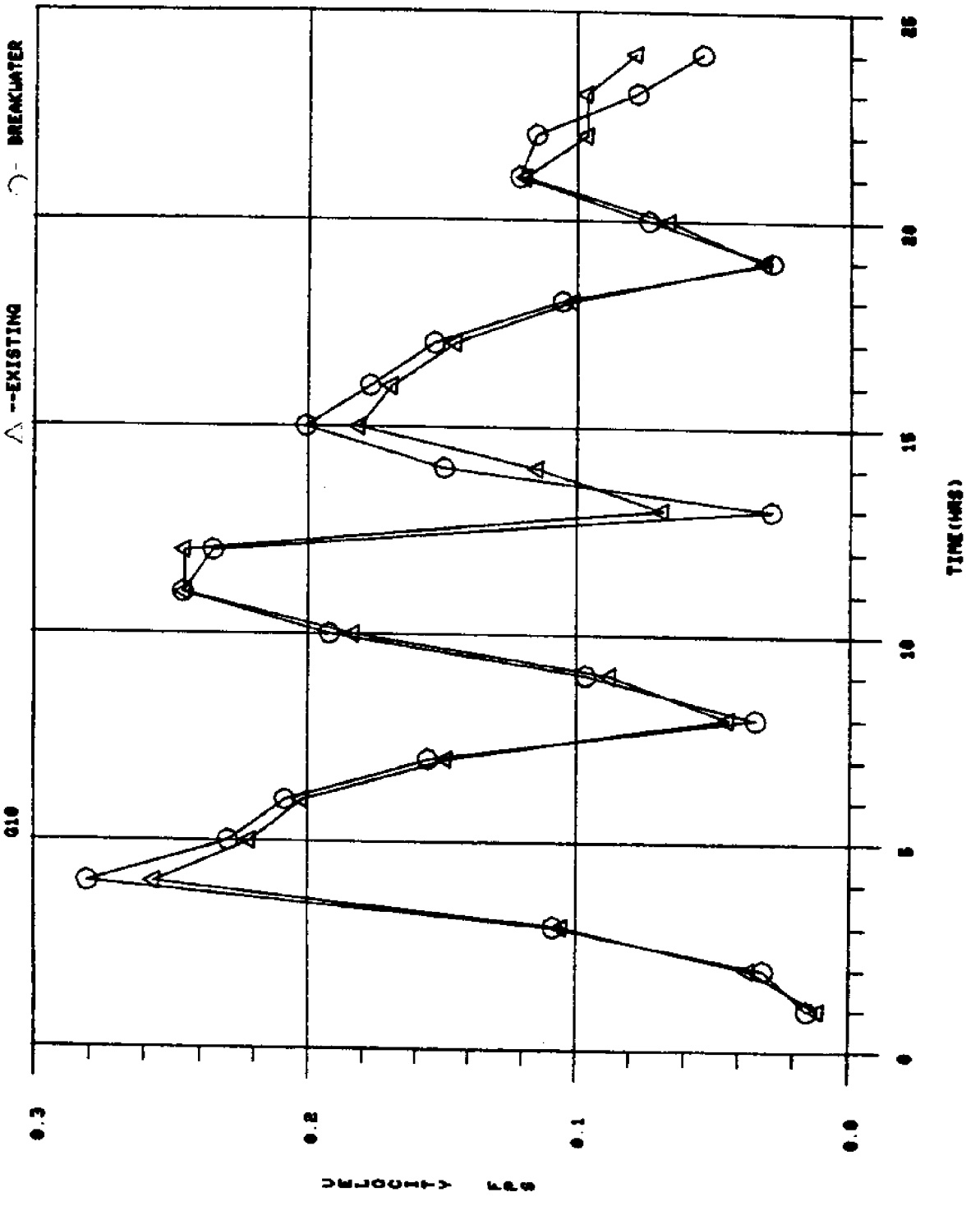

BREAKWATER
--EXISTING
08
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)

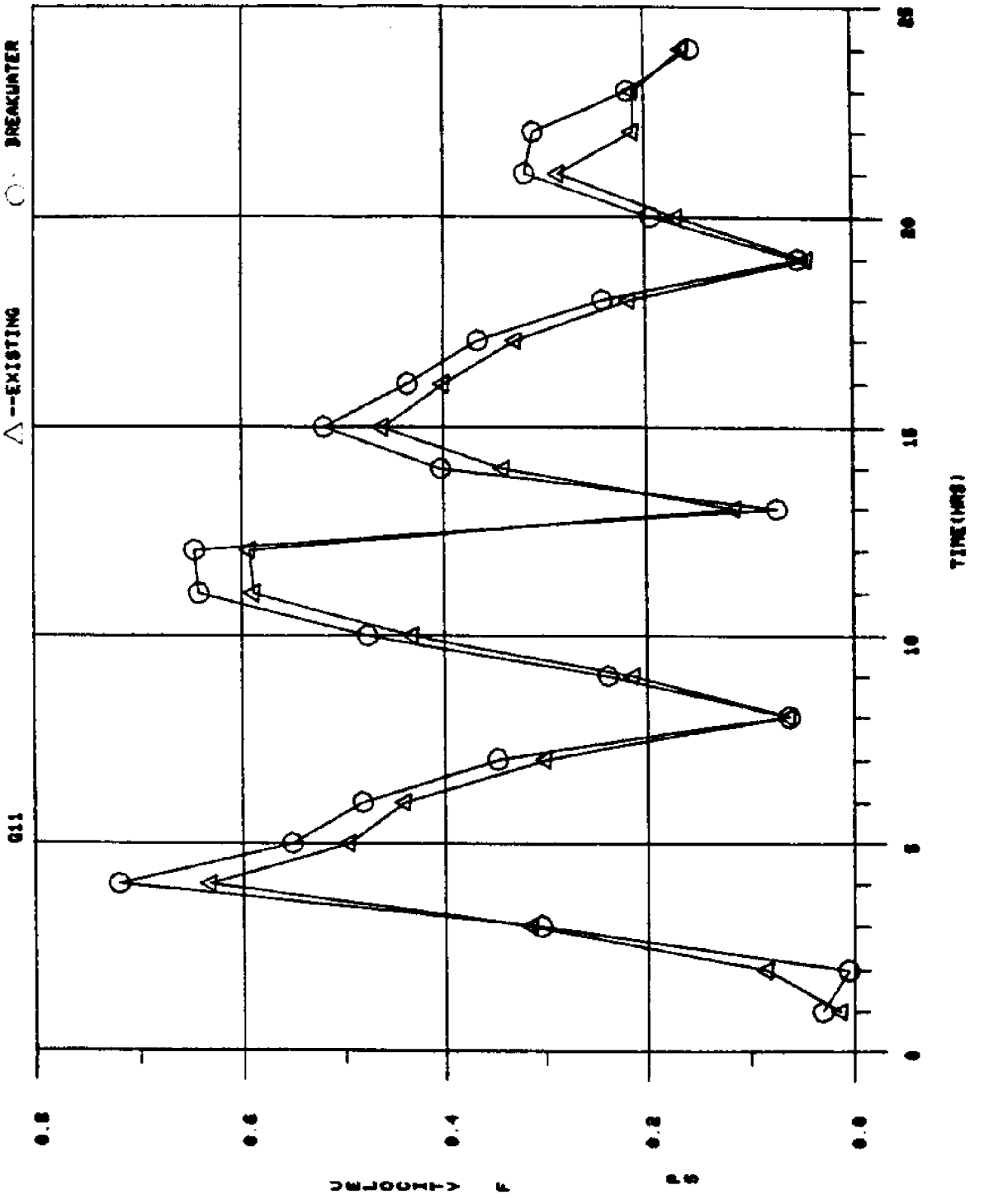

--EXISTING
- BREAKWATER
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)


BREAKWATER
--EXISTING
07
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)


BREAKWATER
--EXISTING
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)


GD
△ --EXISTING
○ --BREAKWATER
0.25
0.20
0.15
0.10
0.05
0.00
0
5
10
15
20
25
TIME(HRS)


G10
△ --EXISTING
○ - BREAKWATER
0.3
0.2
0.1
0.0
0
5
10
15
20
25
TIME(HRS)


G11
△--EXISTING
○ BREAKWATER
0.0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
TIME(HRS)