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NUMERICAL ANALYSIS OF TIDAL CIRCULATION FOR LONG BEACH HARBOR

Report 4

TIDAL CIRCULATION VELOCITY PATTERNS FOR EXISTING CONDITIONS AND ALTERNATE MASTER PLAN PIER-J CONFIGURATIONS WITH -82-FT CHANNEL

by

Donald C. Raney

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

May 1976

Report 4 of a Series

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Long Beach, California 90801

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PREFACE

This study was conducted at the U. S. Army Engineer Waterways Experiment Station (WES) with funding provided by the Port of Long Beach, Long Beach, California, under WES Agreement No. 76-8. The study was conducted during the period from November 1975 to April 1976 in the Harbor Wave Action Branch, Wave Dynamics Division, Hydraulics Laboratory, WES, under the direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, Dr. R. W. Whalin, Chief of the Wave Dynamics Division, and Mr. C. E. Chatham, Chief of the Harbor Wave Action Branch.

The study was conducted and this report prepared by Dr. Donald C. Raney, Associate Professor of Engineering Mechanics at the University of Alabama, assigned to WES under an Intergovernmental Personnel Exchange Agreement. Messrs. H. Lee Butler, K. A. Turner, C. W. Coe, L. A. Barnes, and C. R. Curren assisted with various tasks during the investigation.

A significant portion of the numerical computations associated with this study was performed on a CDC-7600 computer at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico, through the cooperation of C-Division.

The following Port of Long Beach personnel visited WES for conferences associated with the study: Mr. B. N. Hoffmaster, Dr. D. B. Bright, Mr. C. T. Johnson, and Mr. G. H. Porter.

The Director of WES during the course of this study was COL G. H. Hilt, CE. Technical Director was Mr F. R. Brown.

INTRODUCTION

A study was conducted for Long Beach Harbor to numerically investigate tidal circulation in existing basins and to define and evaluate the impact of possible modification of Pier-J with a -82-ft entrance channel on existing harbor circulation. A two-dimensional depth-averaged formulation of the hydrodynamic equations was used in the model and an implicit-explicit finite difference scheme was used to numerically solve the equations. The numerical model was verified using prototype tide and velocity data and tide and velocity data from physical model tests conducted at WES.

Details of the numerical investigation are presented in Reports 1 and 3 of this series. This report presents vector plots of the tidal circulation patterns at four times during the tidal cycle for existing conditions and for four modifications to Pier-J. In addition, tidal circulation patterns for each modification are compared with circulation patterns for existing conditions. Vector plots are presented indicating the extent and magnitude of velocity changes produced by each modification. In both sets of vector plots the direction of the vector indicates the direction of current flow and the length indicates the magnitude of the current velocity. The four vector plots of tidal circulation pattern for each Pier-J configuration correspond to flow conditions near:

a. Near slack water (hour 15);
b. Near maximum flood (hour 19),
c. Near slack water (hour 22); and
d. Near maximum ebb (hour 24).

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ULATION FOR LONG BEACH HARBOR

OR EXISTING CONDITIONS AND ALTERNATE ATIONS WITH -82-FT CHANNEL

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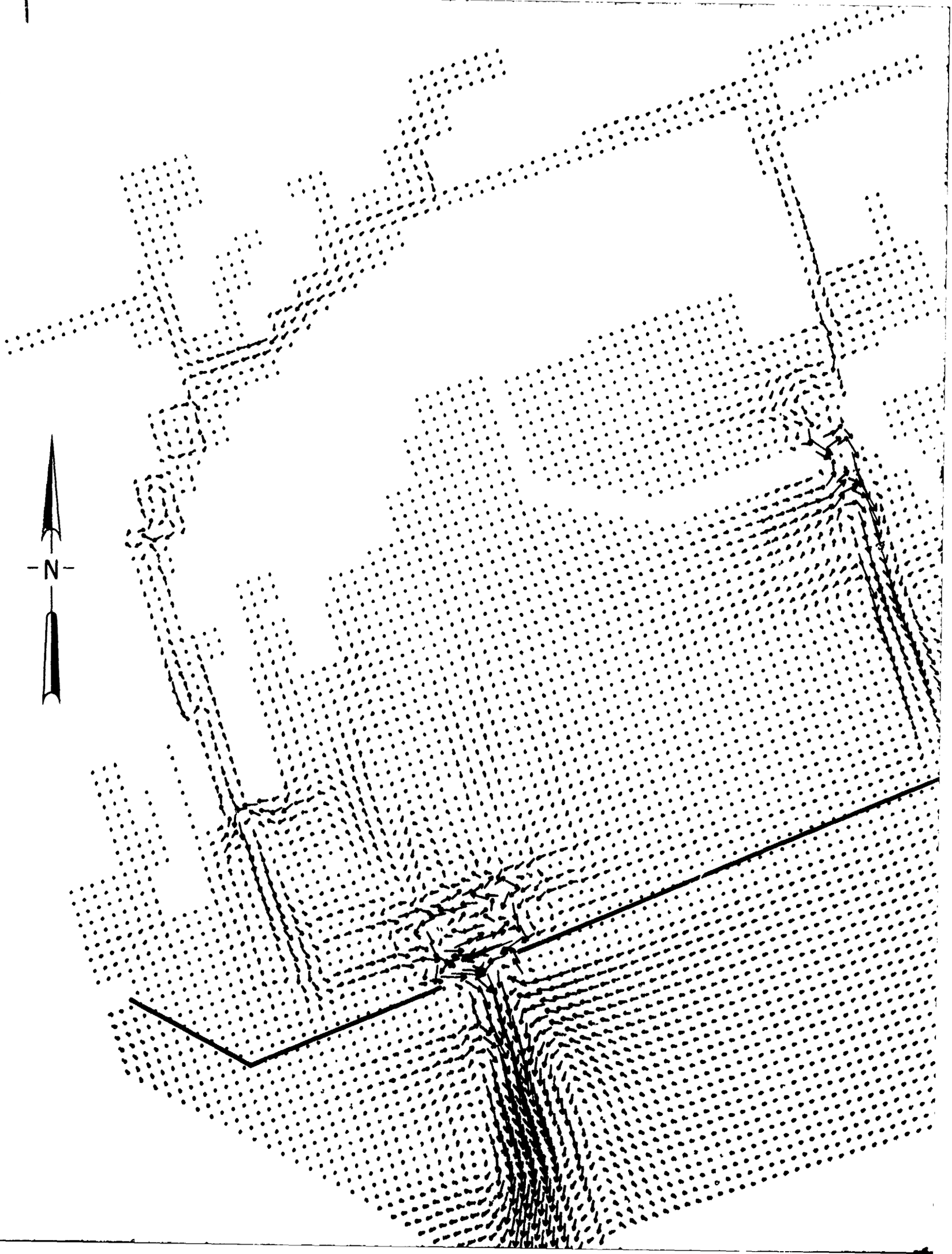
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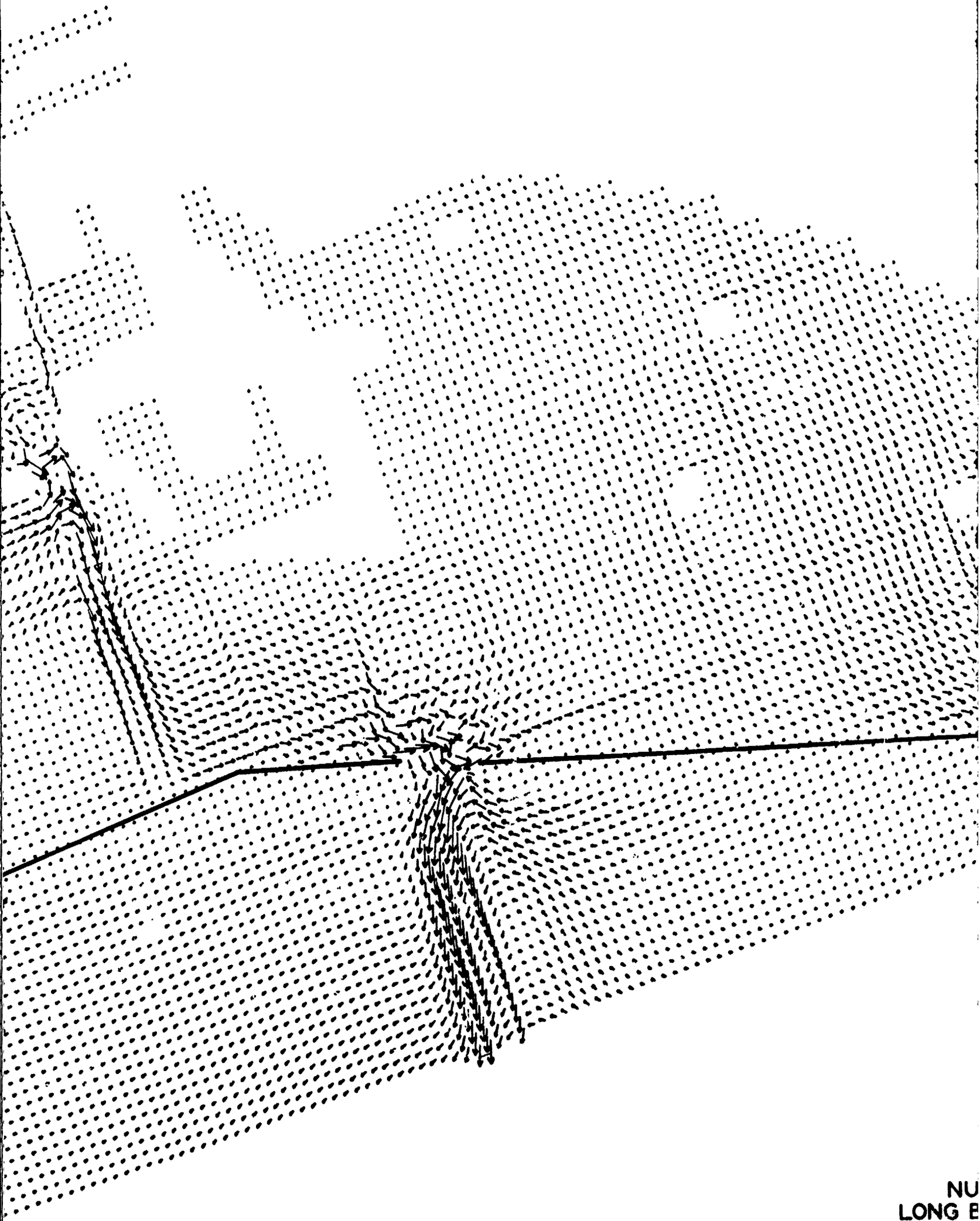

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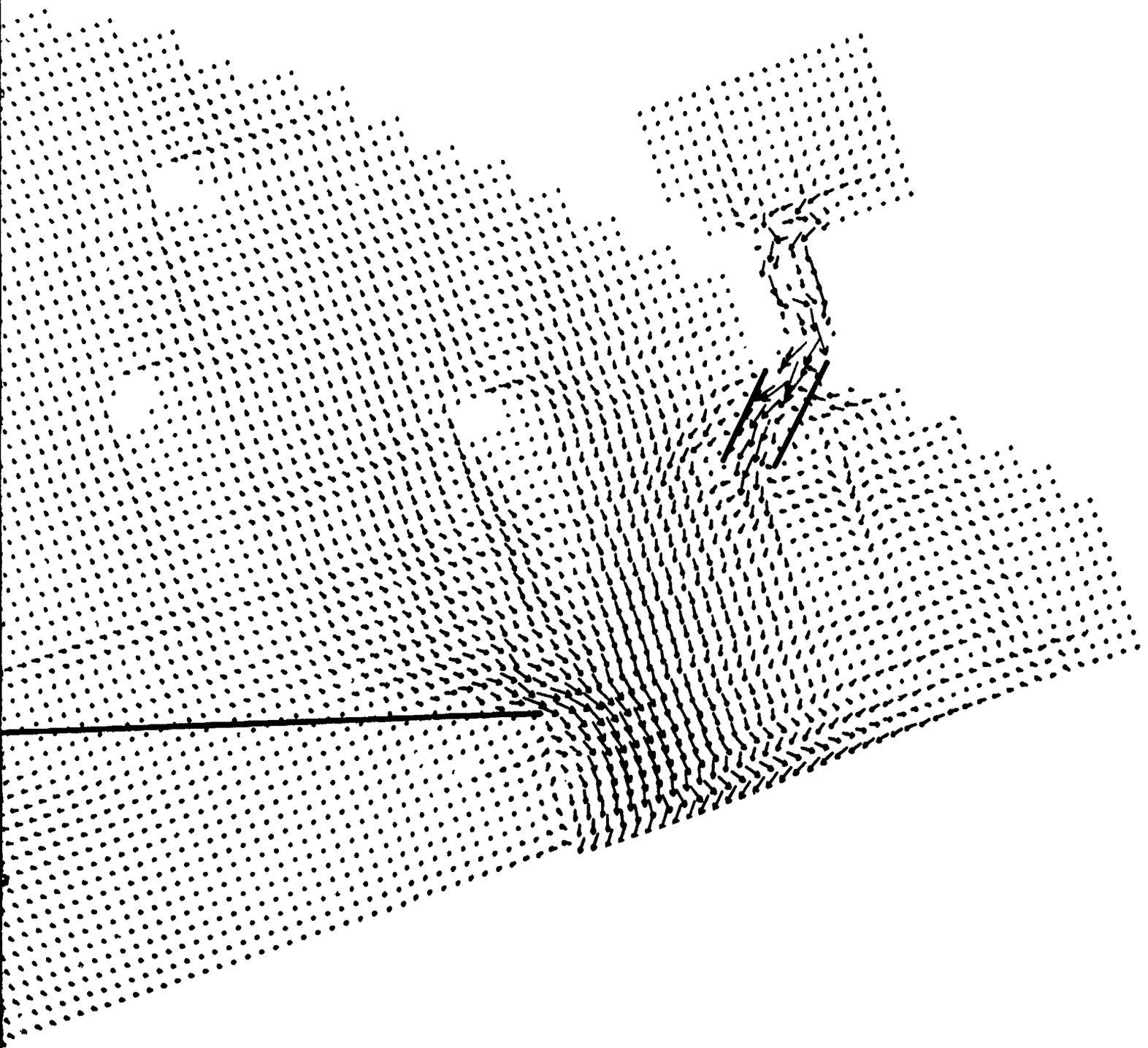

VELOCITY SCALE

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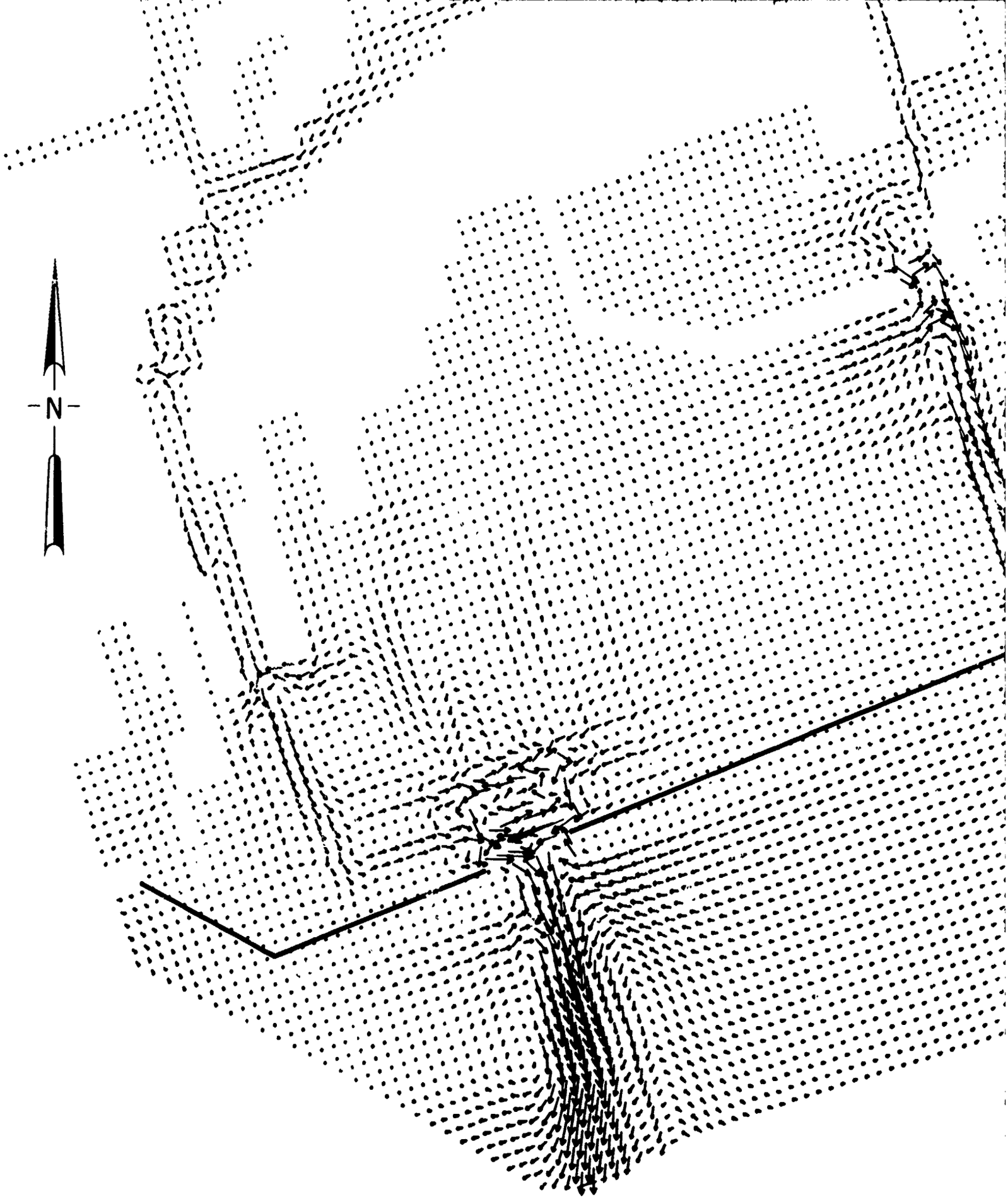
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS



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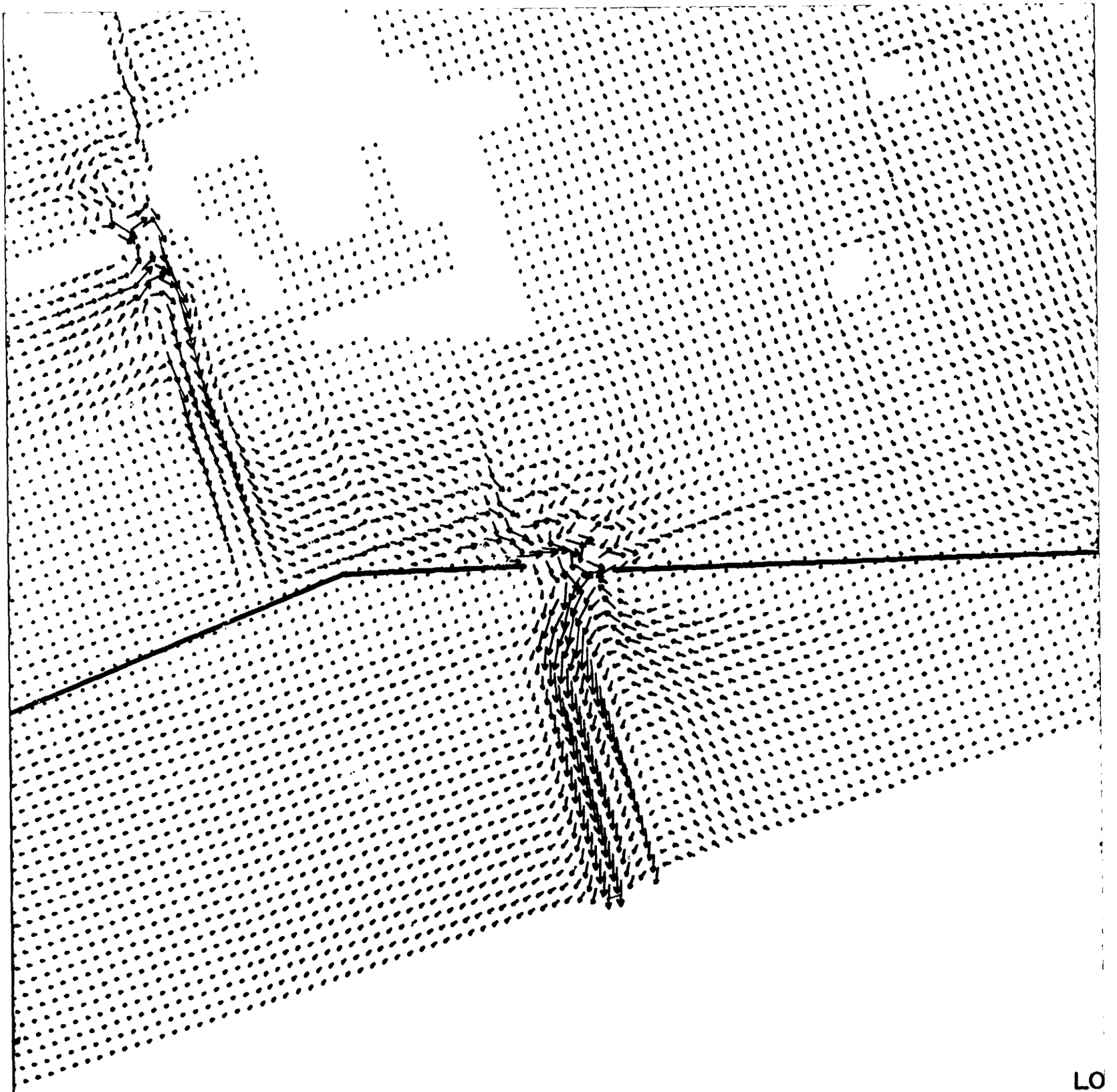

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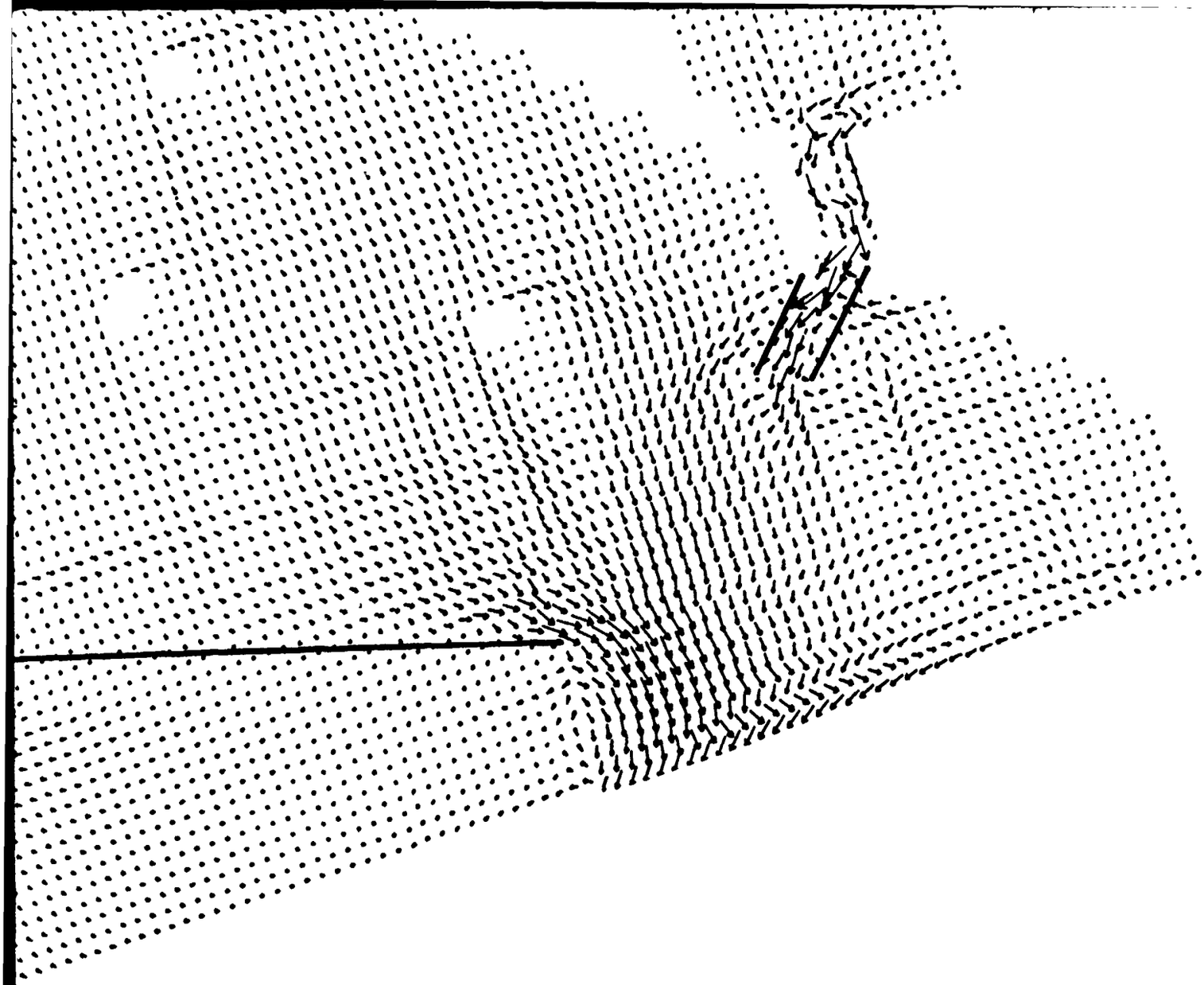

VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

EXISTING CONDITIONS
SPRING TIDE
HOUR 15

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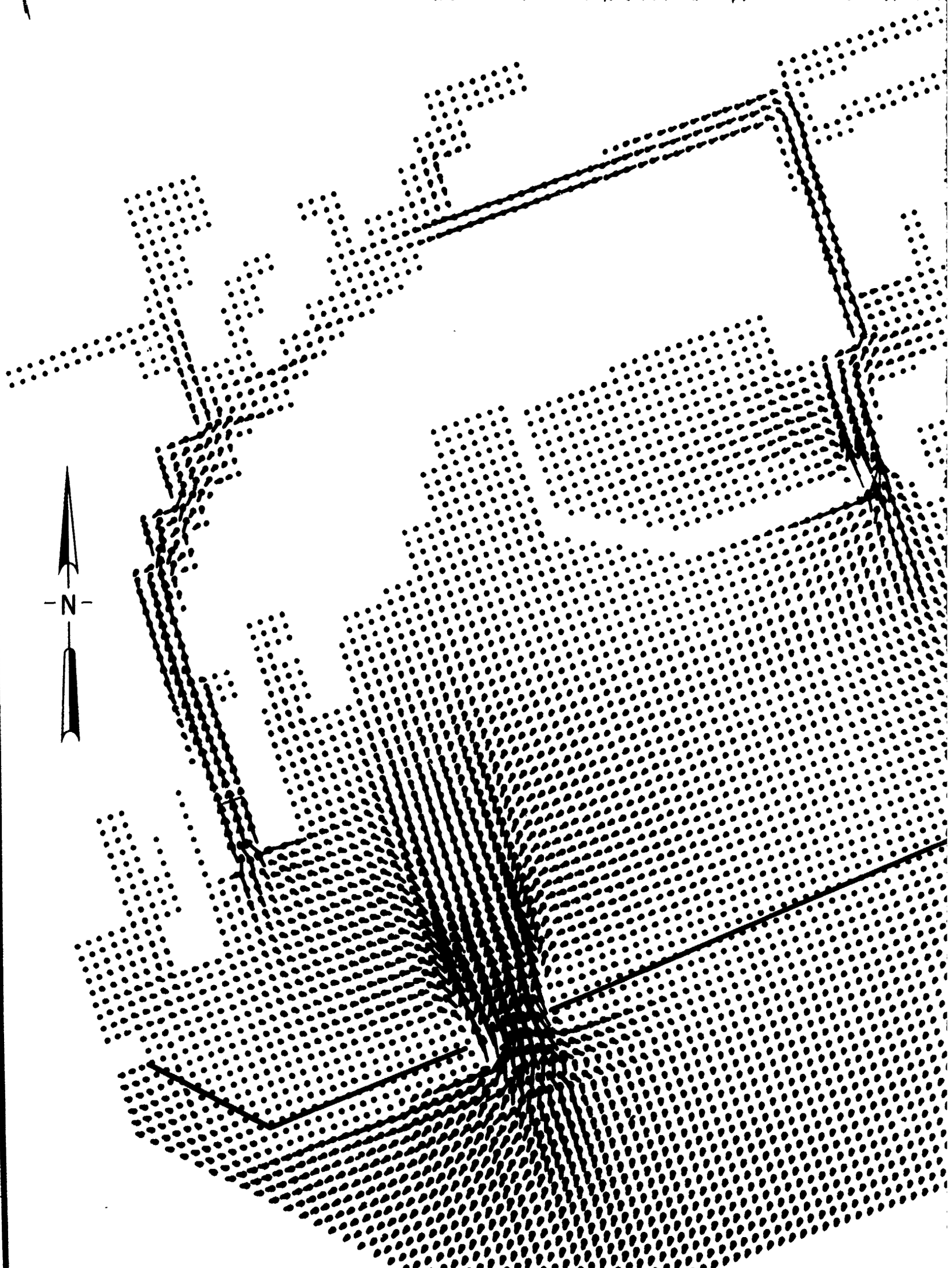
FIGURE 1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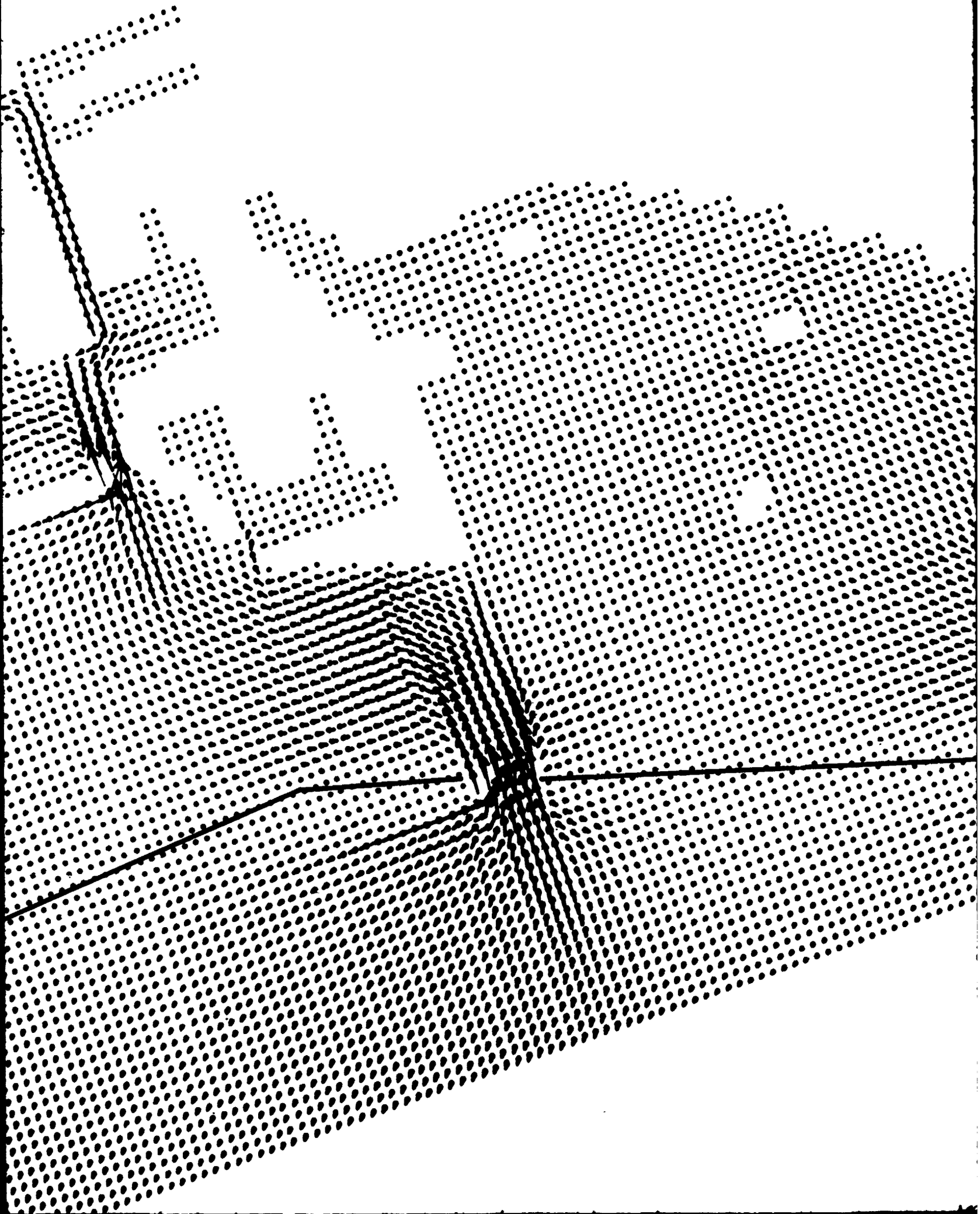

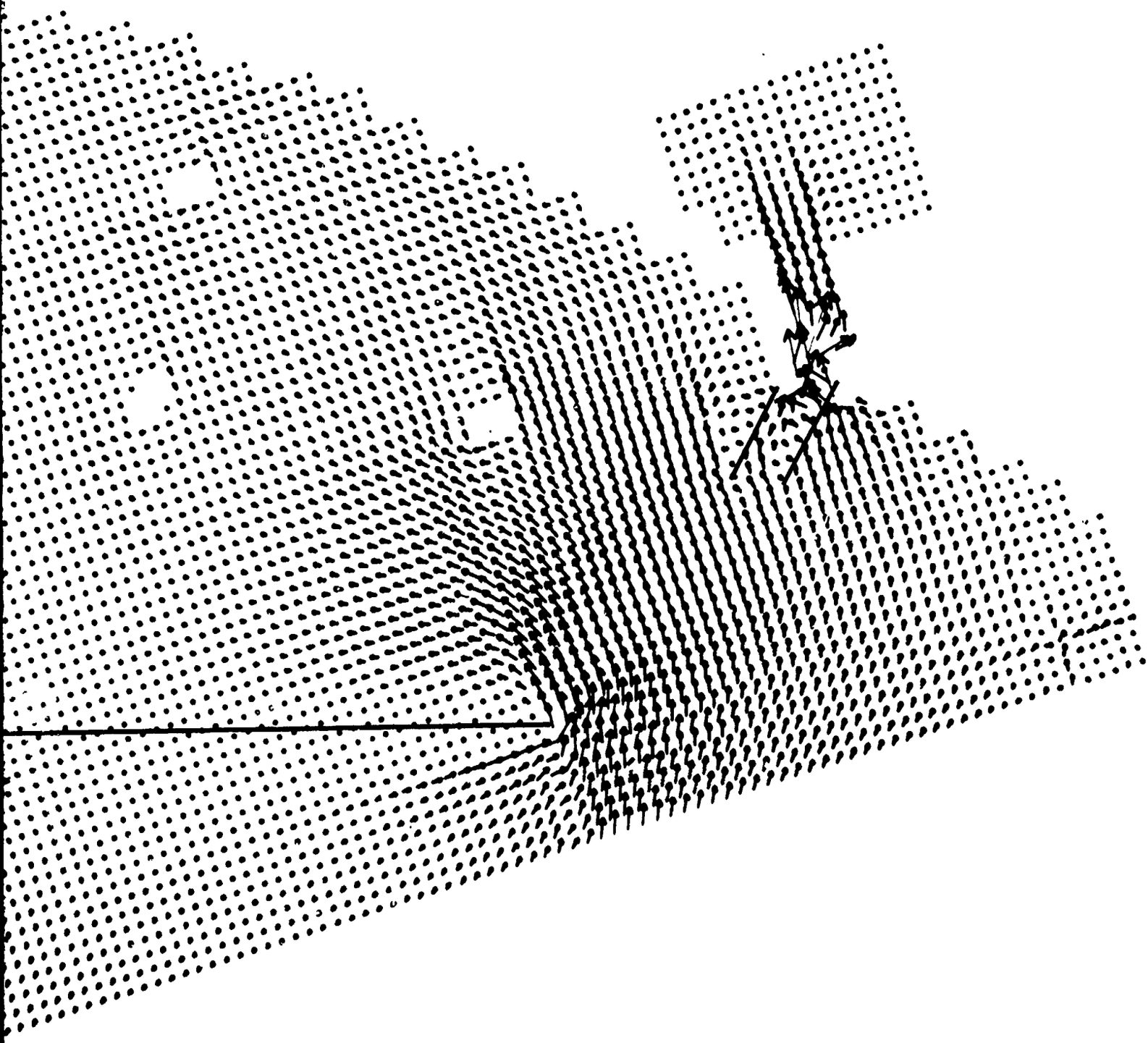

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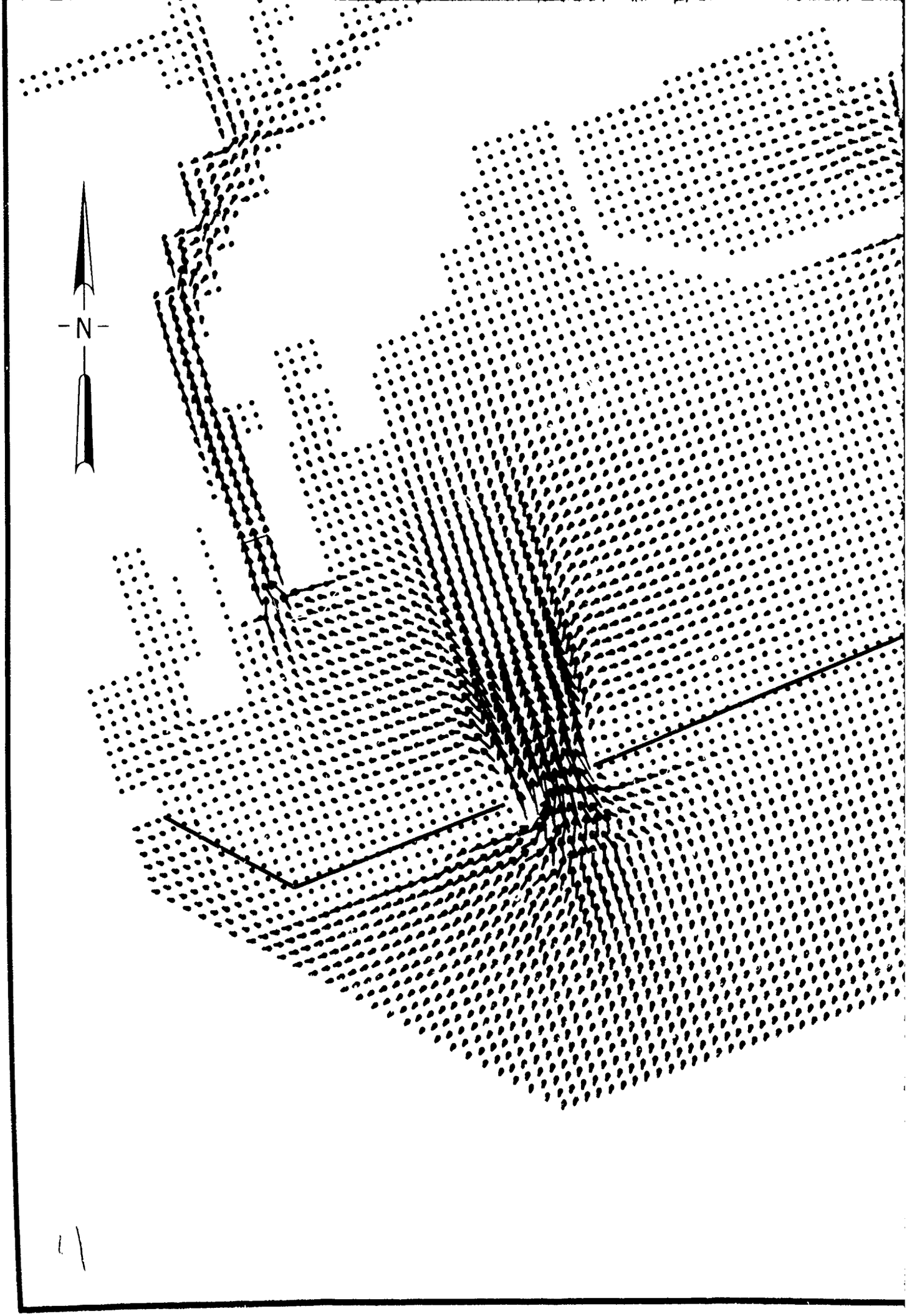
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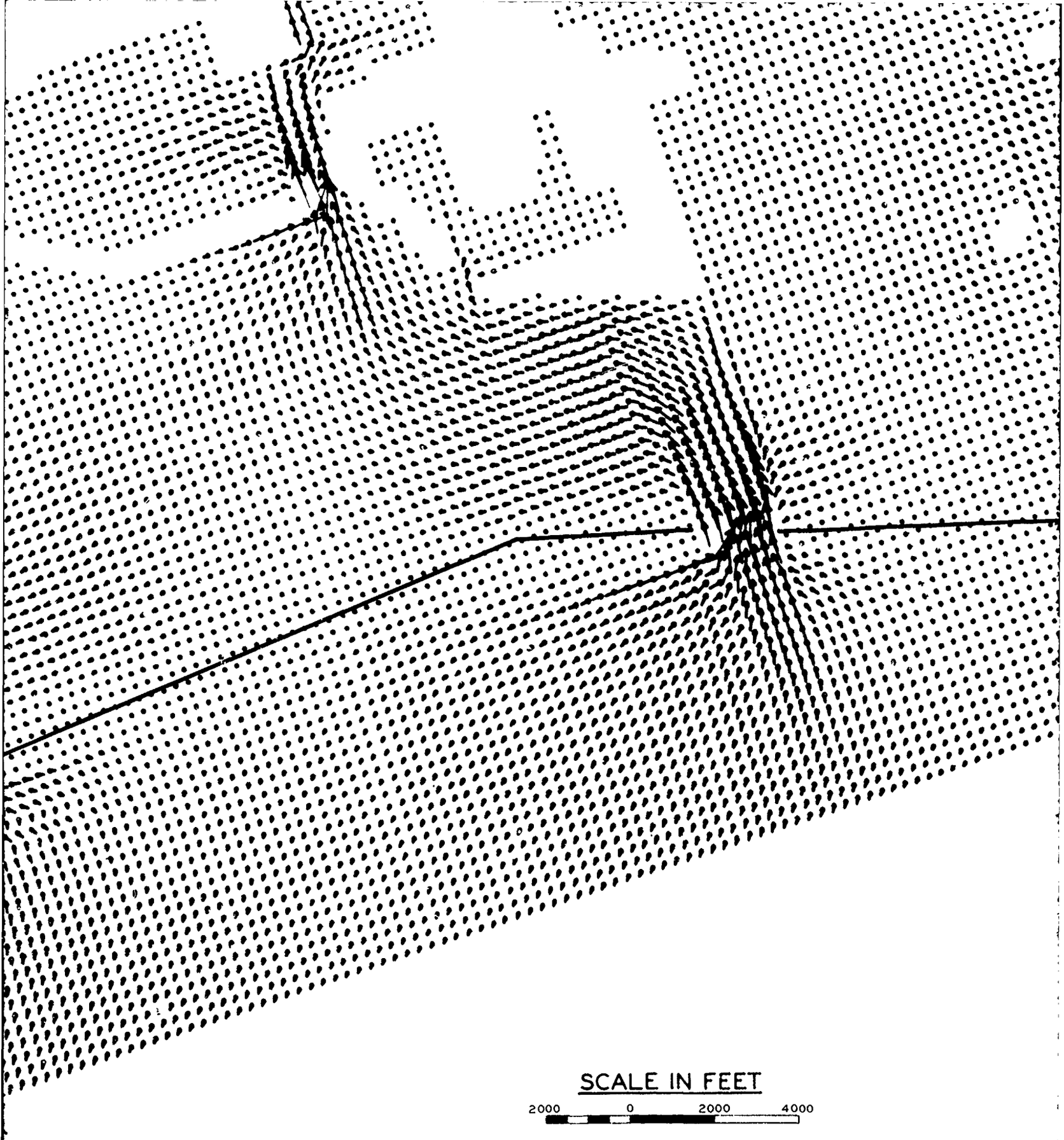
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VELOCITY SCALE

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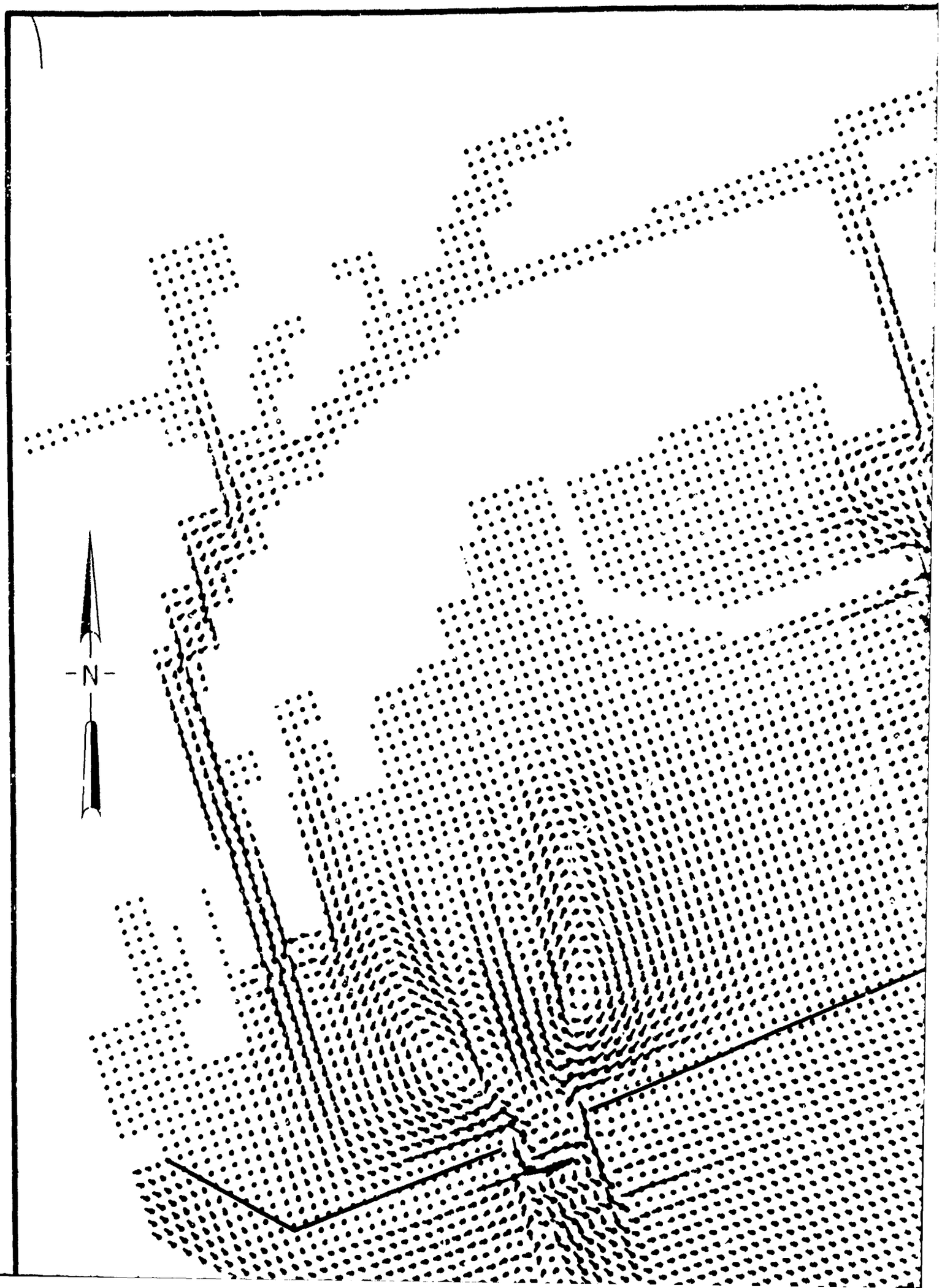
NUMERICAL MODEL STUDY OF
LONG BEACH – LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

EXISTING CONDITIONS
SPRING TIDE
HOUR 19

FIGURE 2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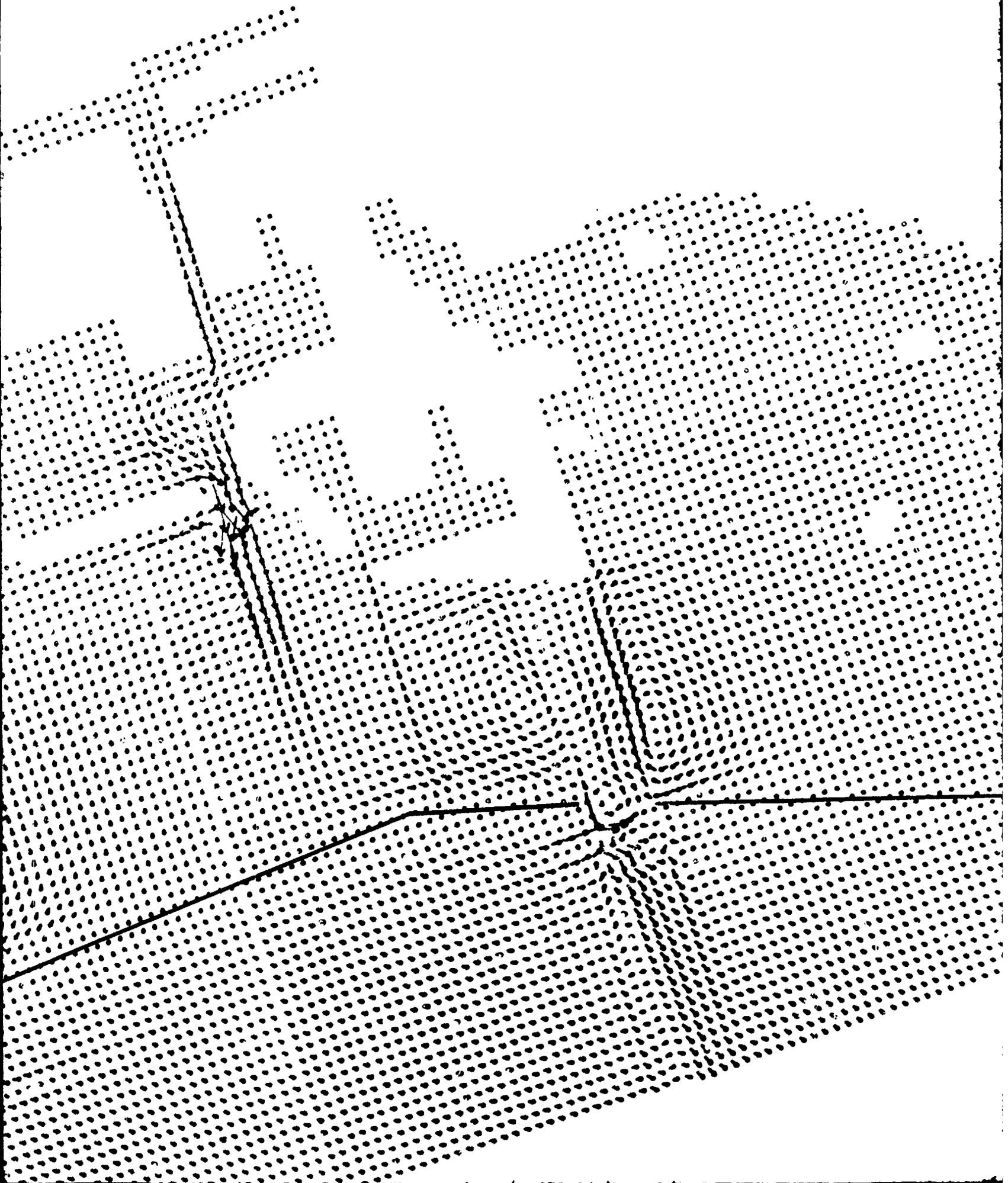

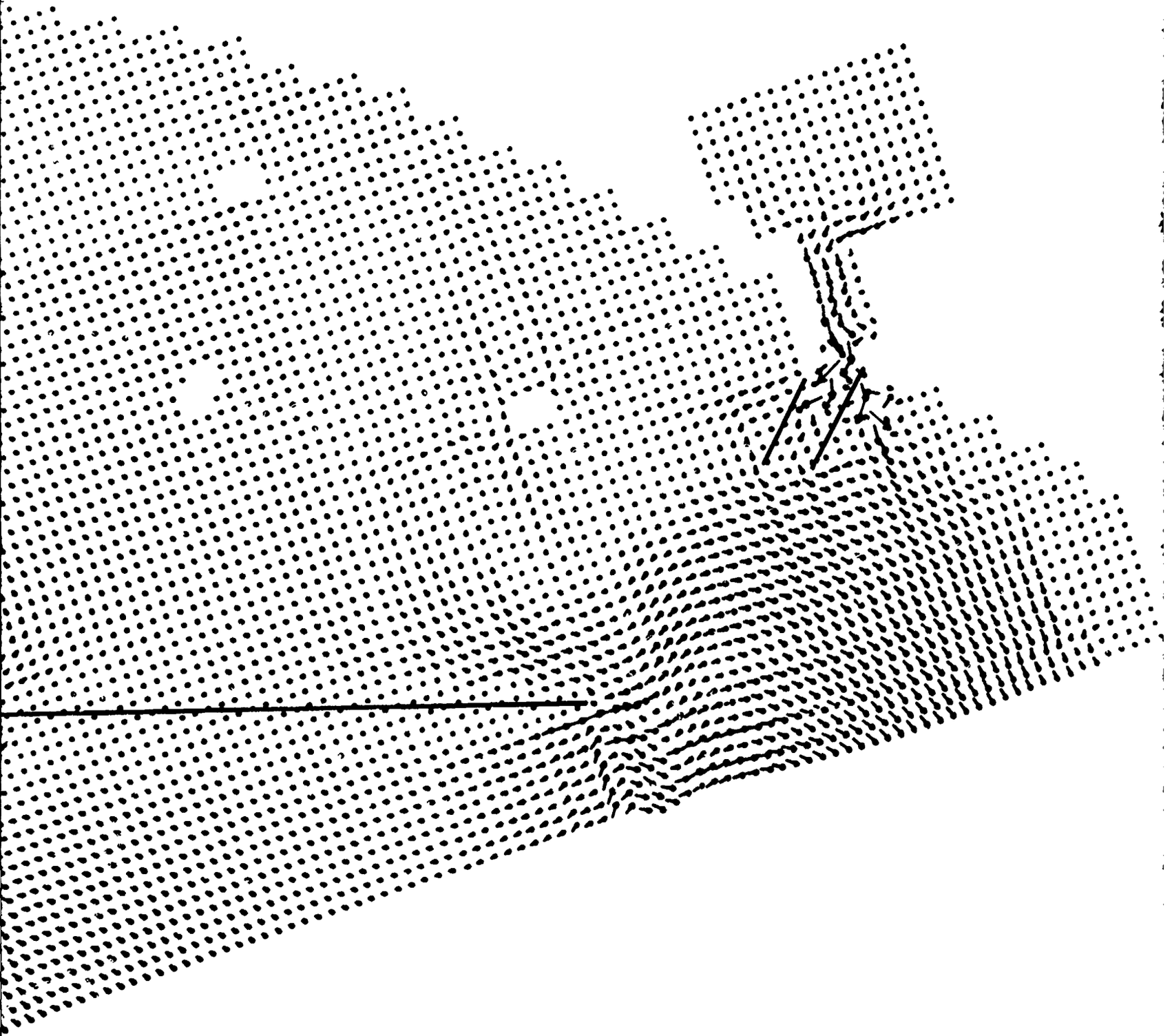

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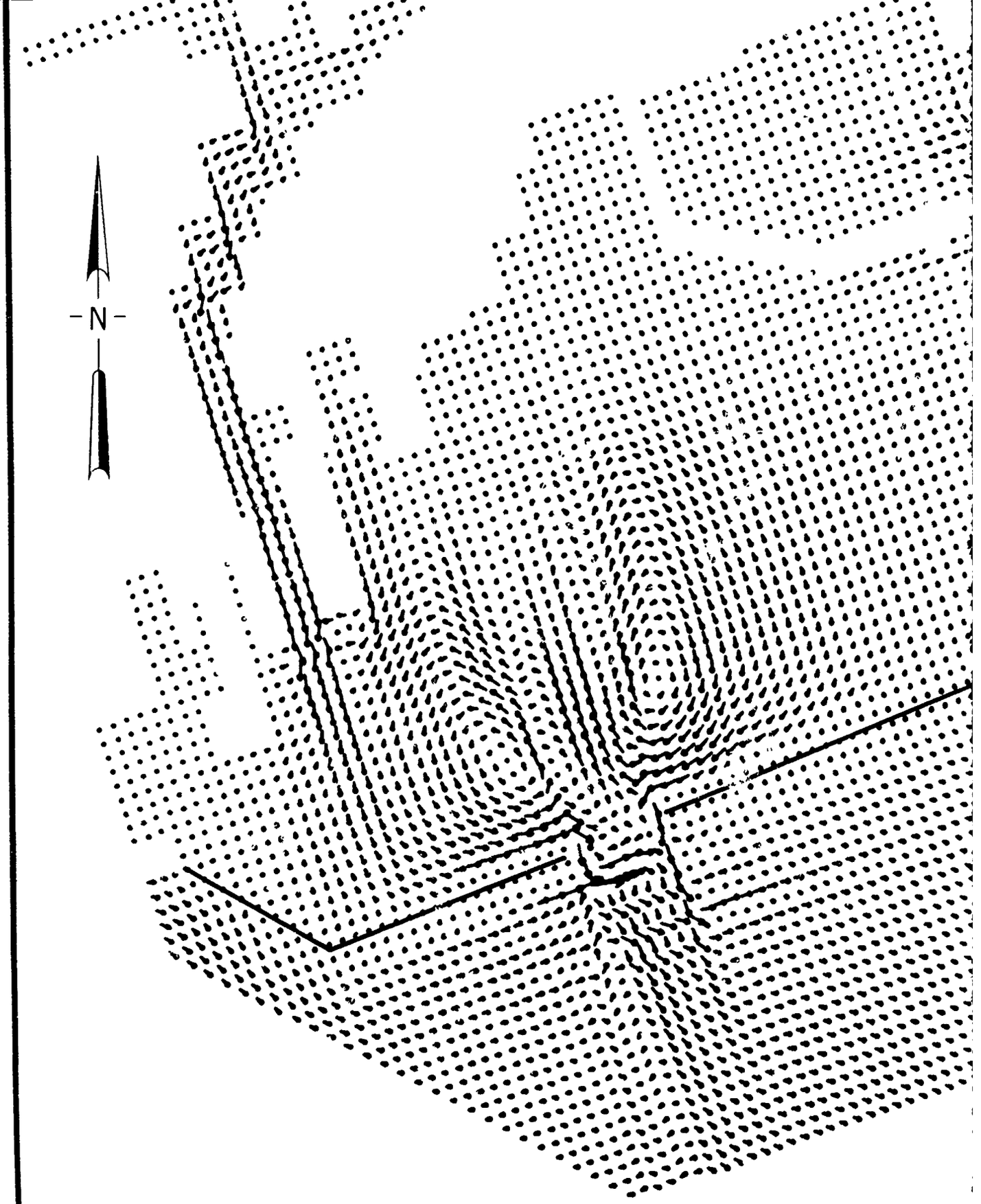
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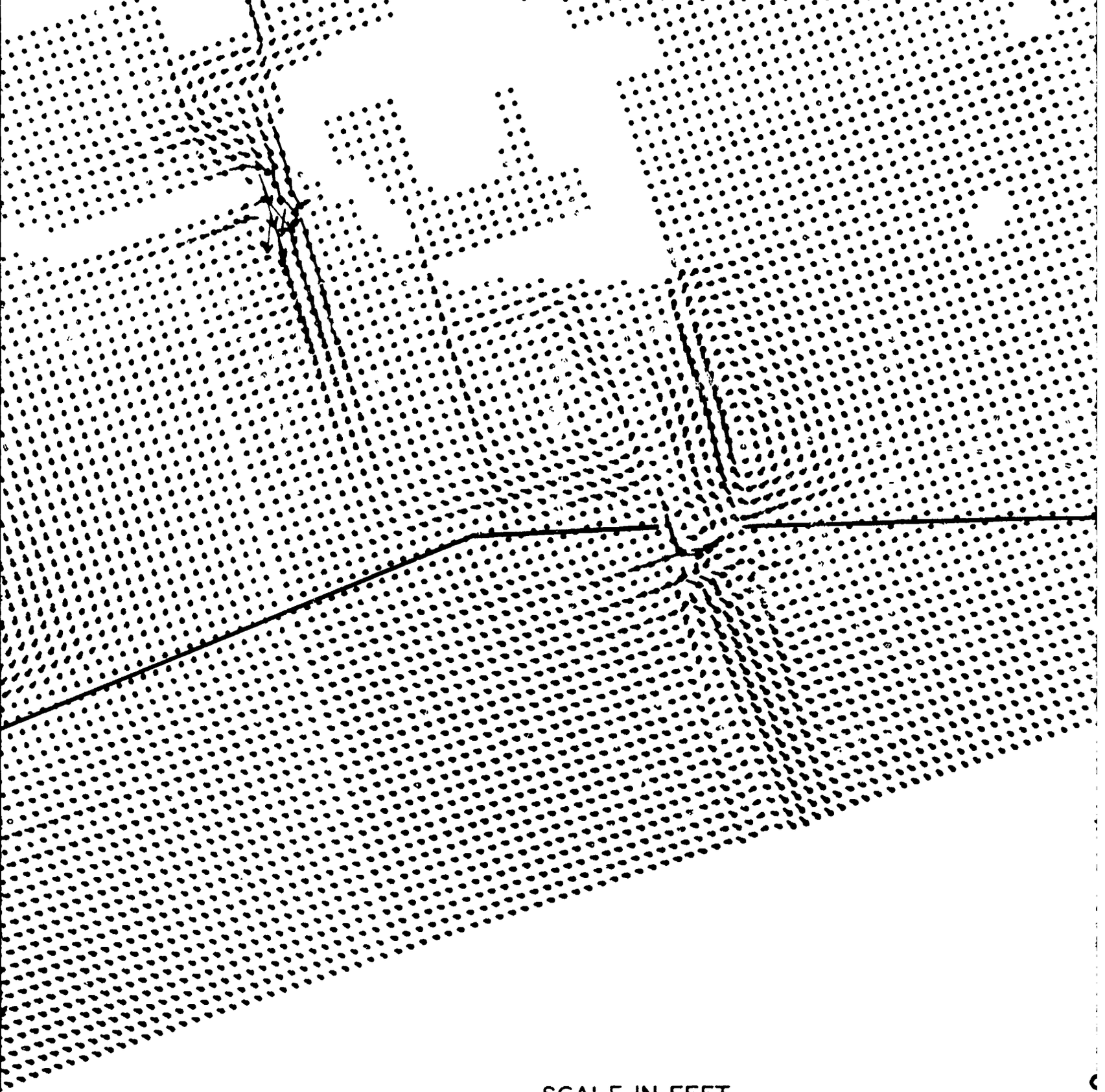

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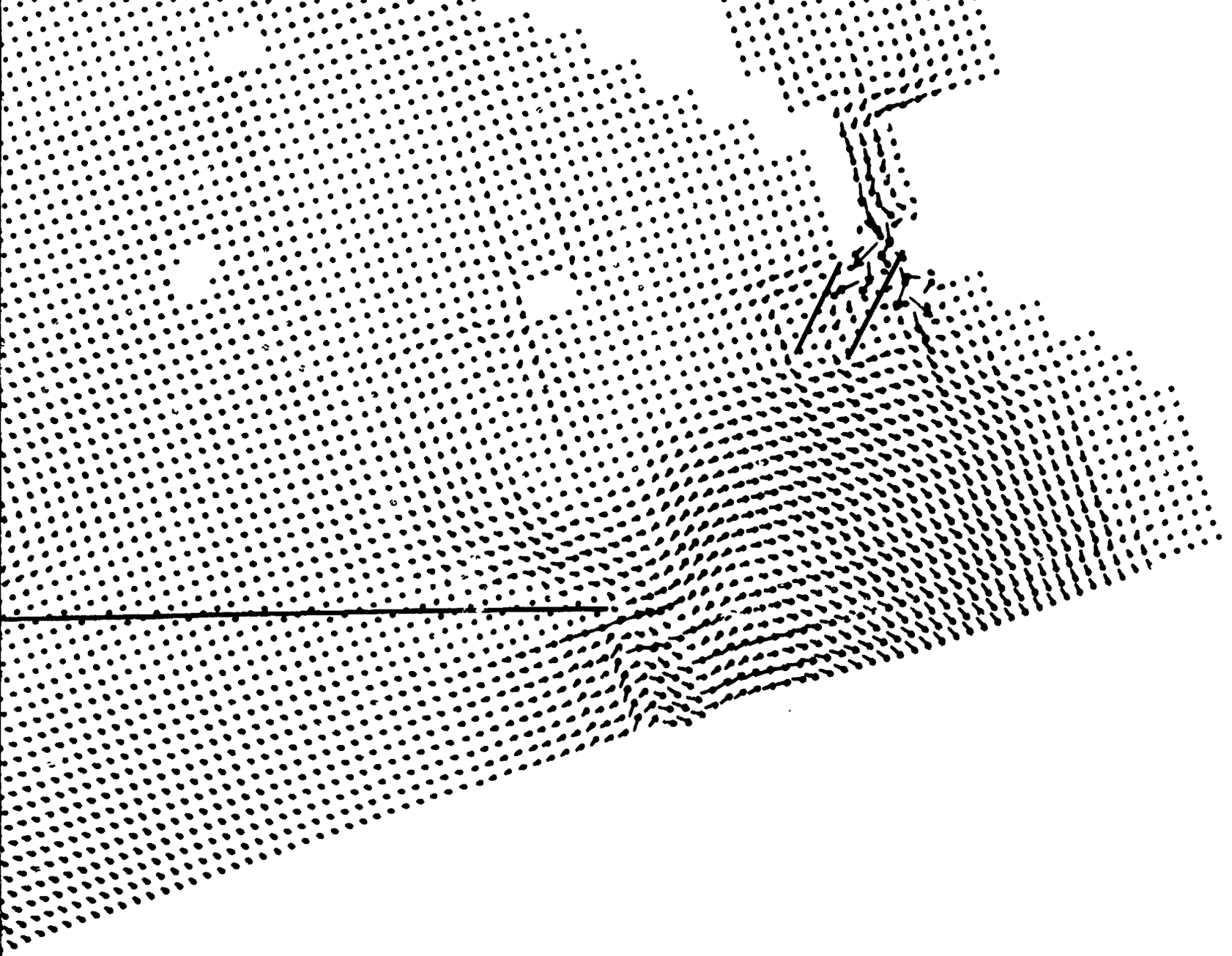


VELOCITY SCALE

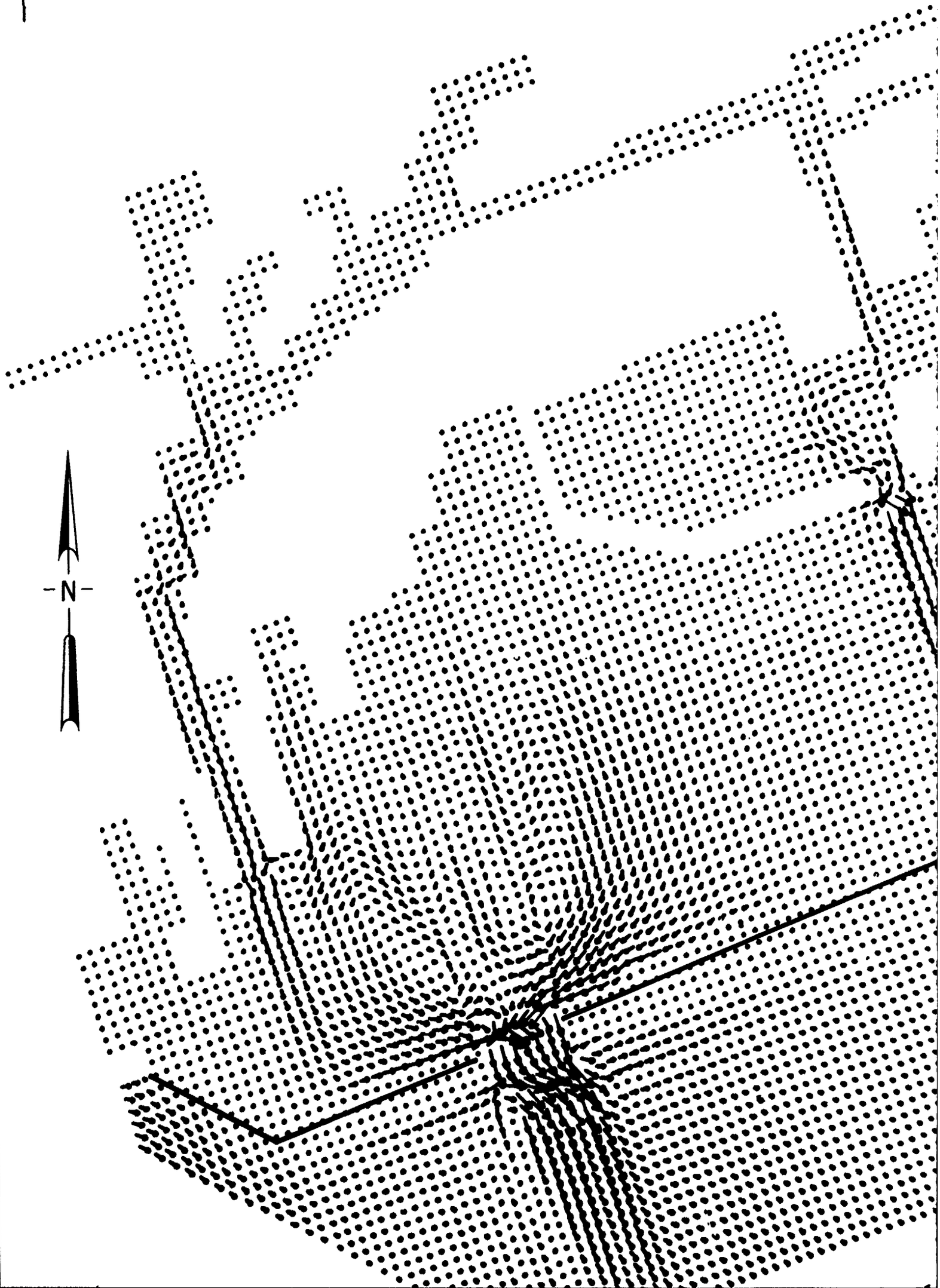
1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

EXISTING CONDITIONS
SPRING TIDE
HOUR 22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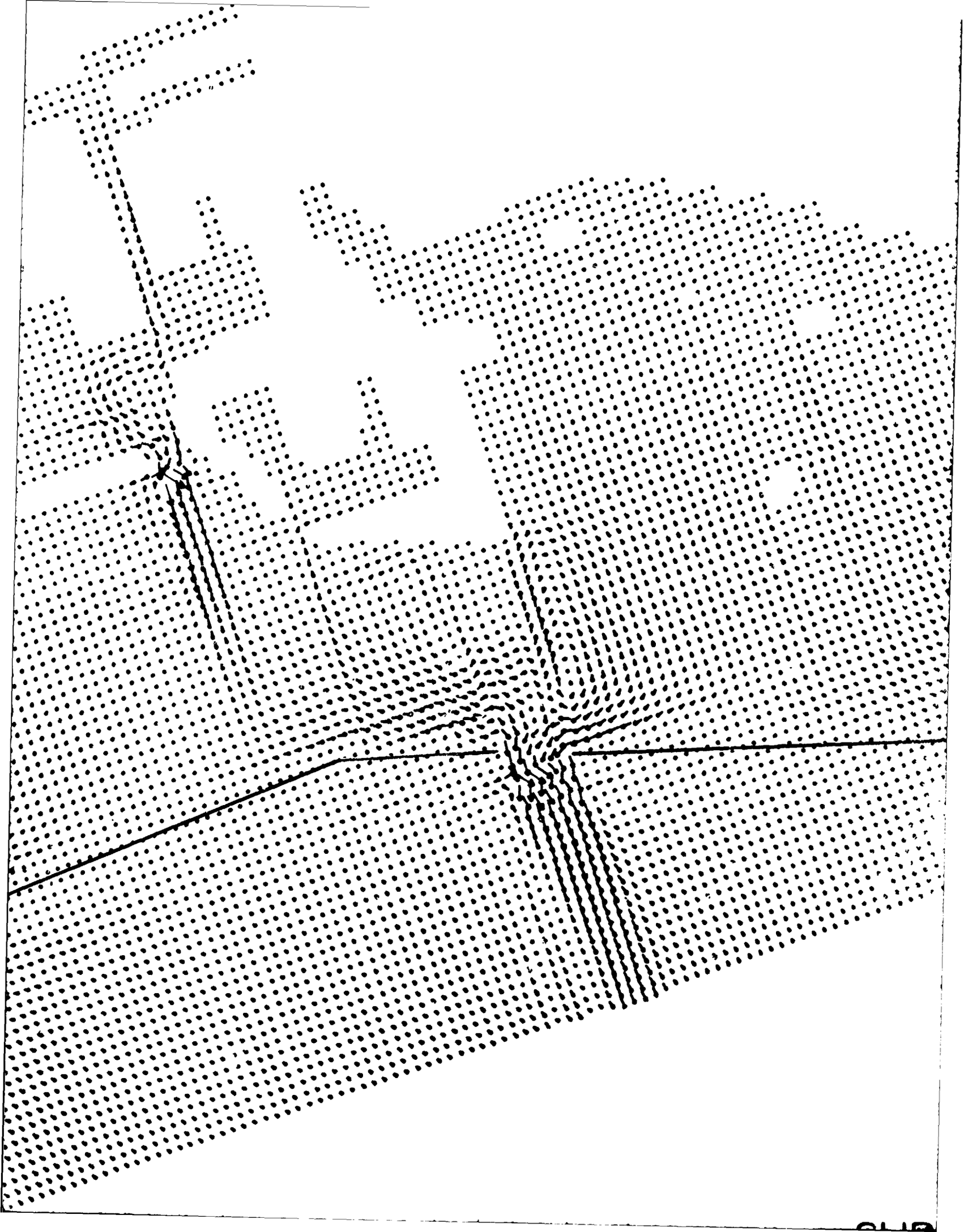

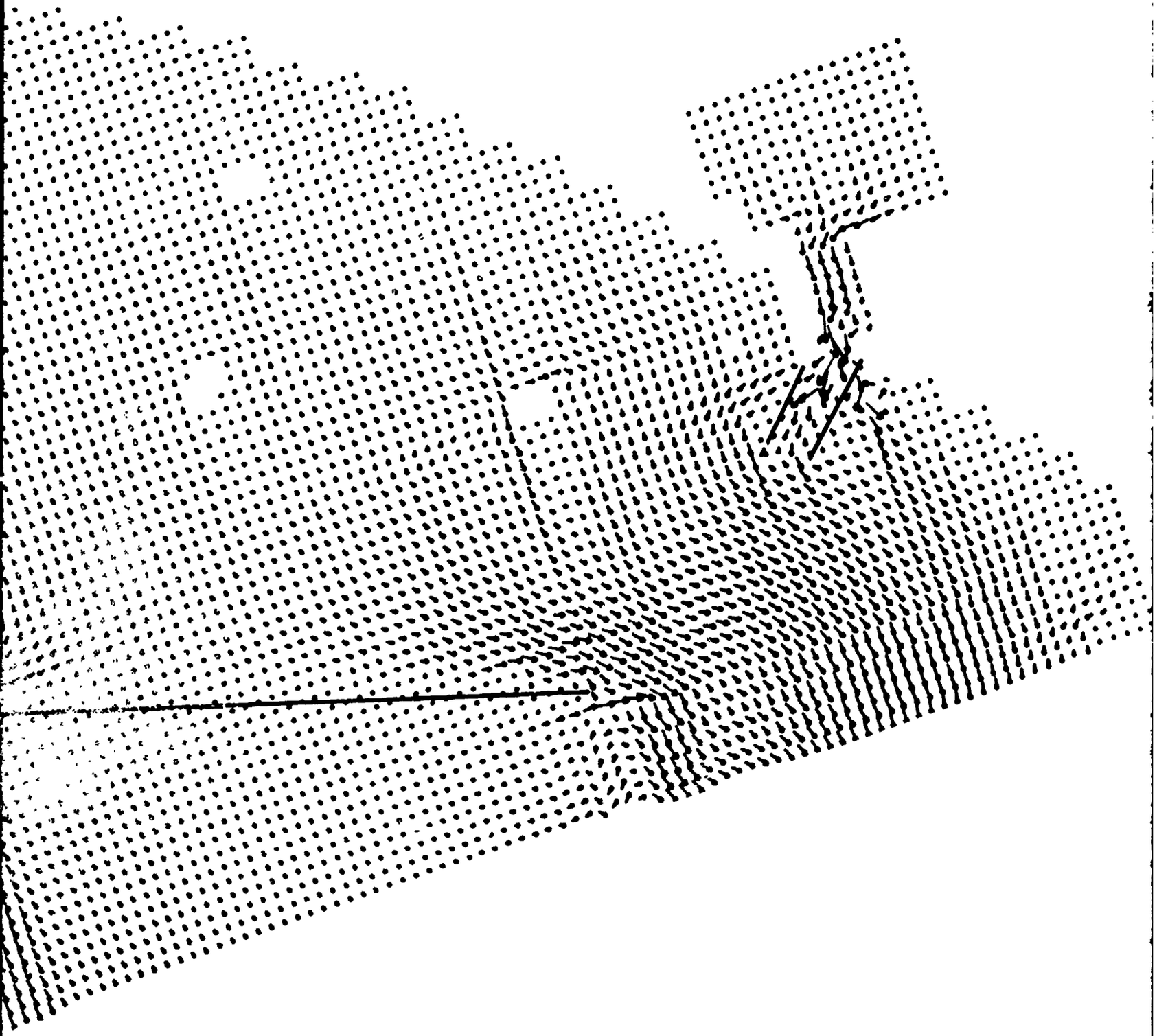

VELOCITY SCALE

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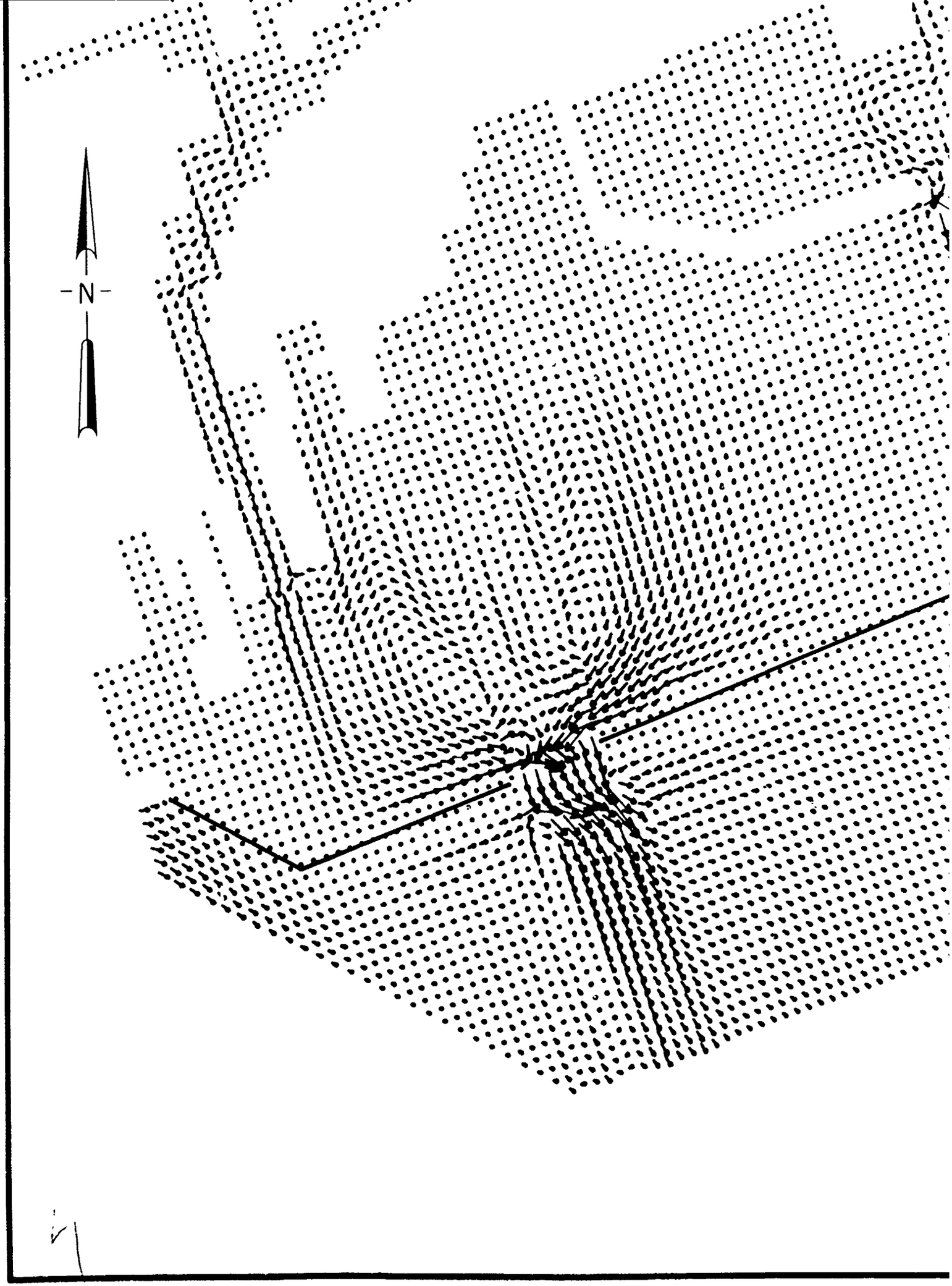
NUMERICAL MODEL STUDY OF
LONG BEACH-LOS ANGELES HARBORS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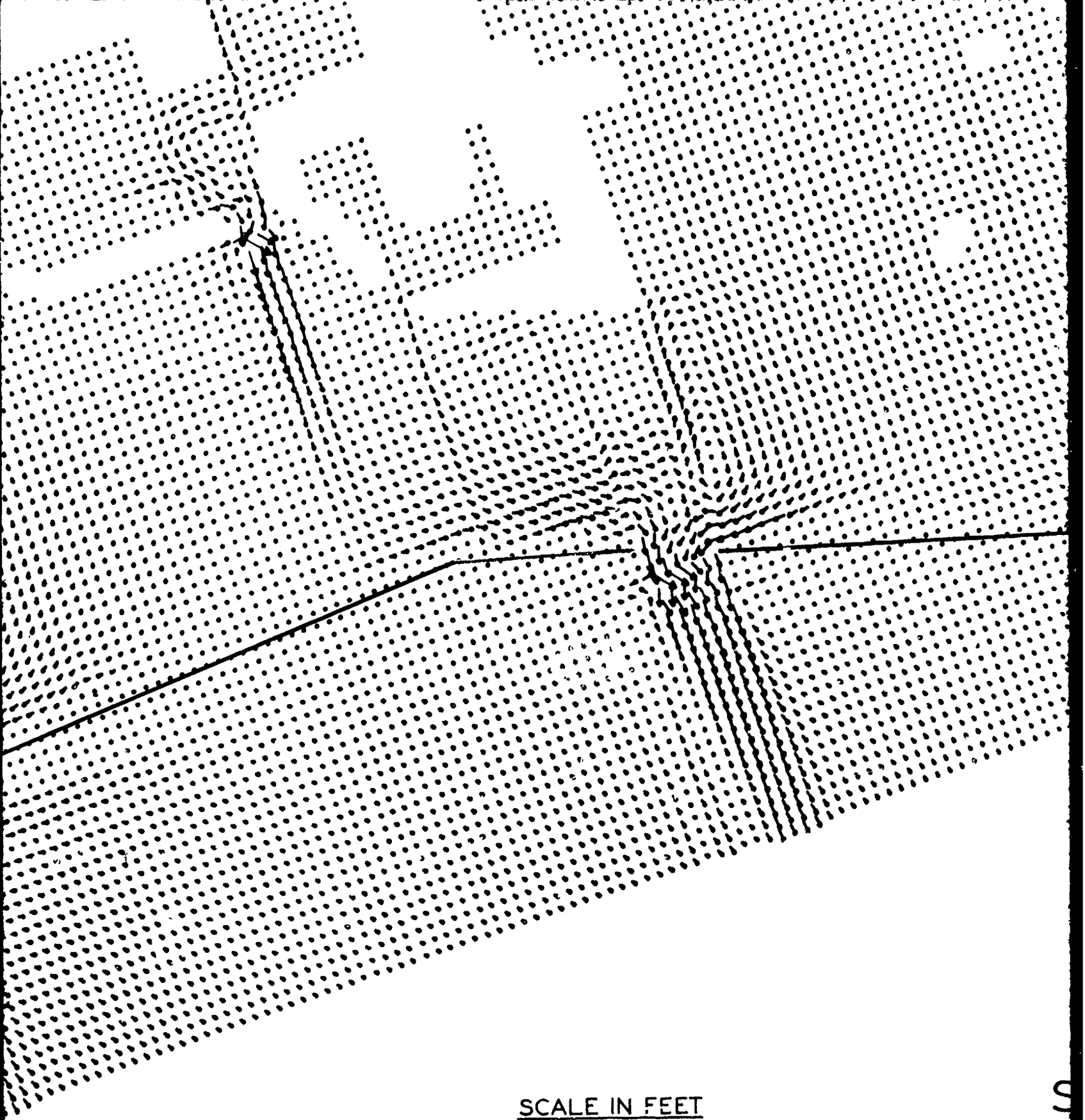

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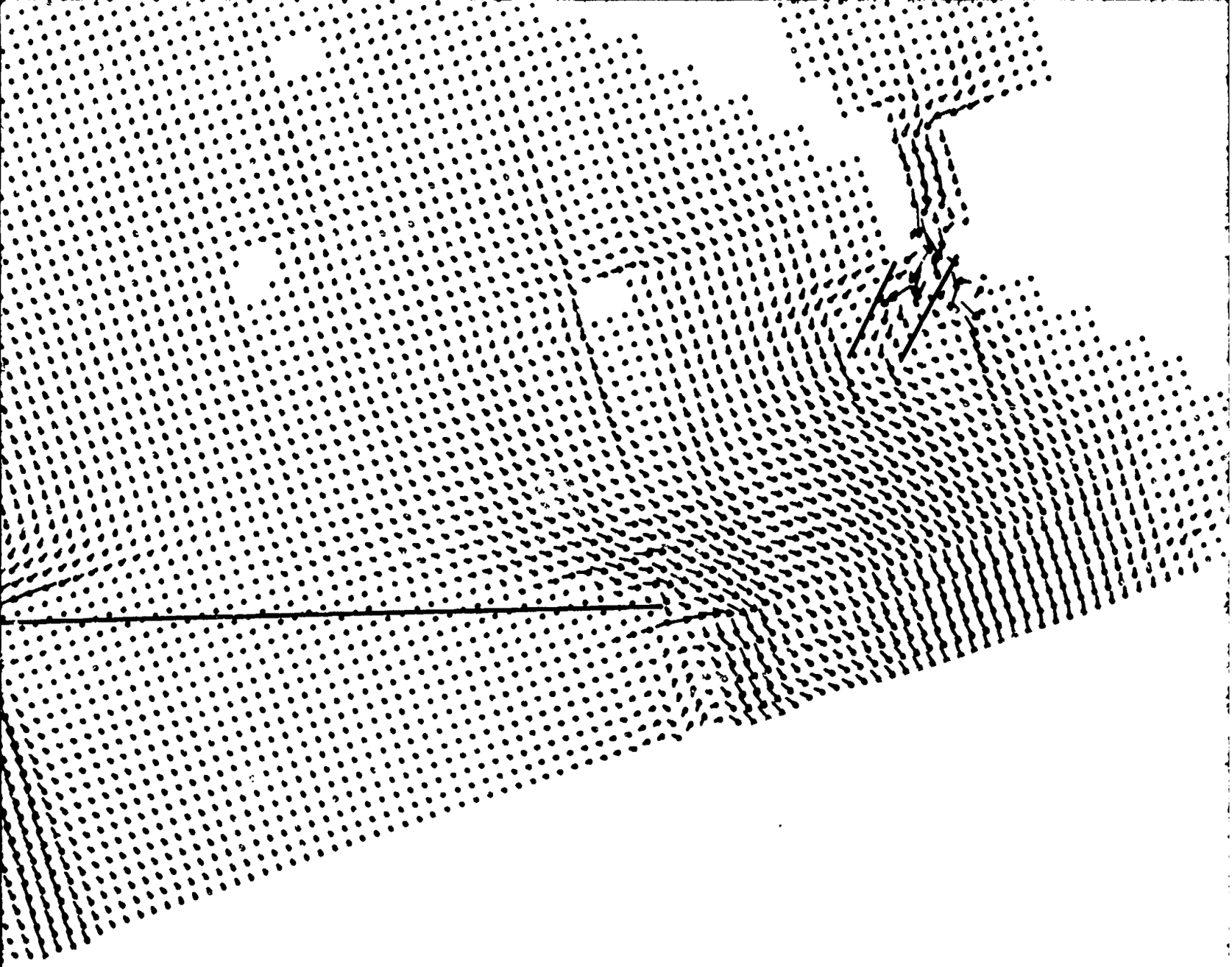


VELOCITY SCALE

0 1 2 3

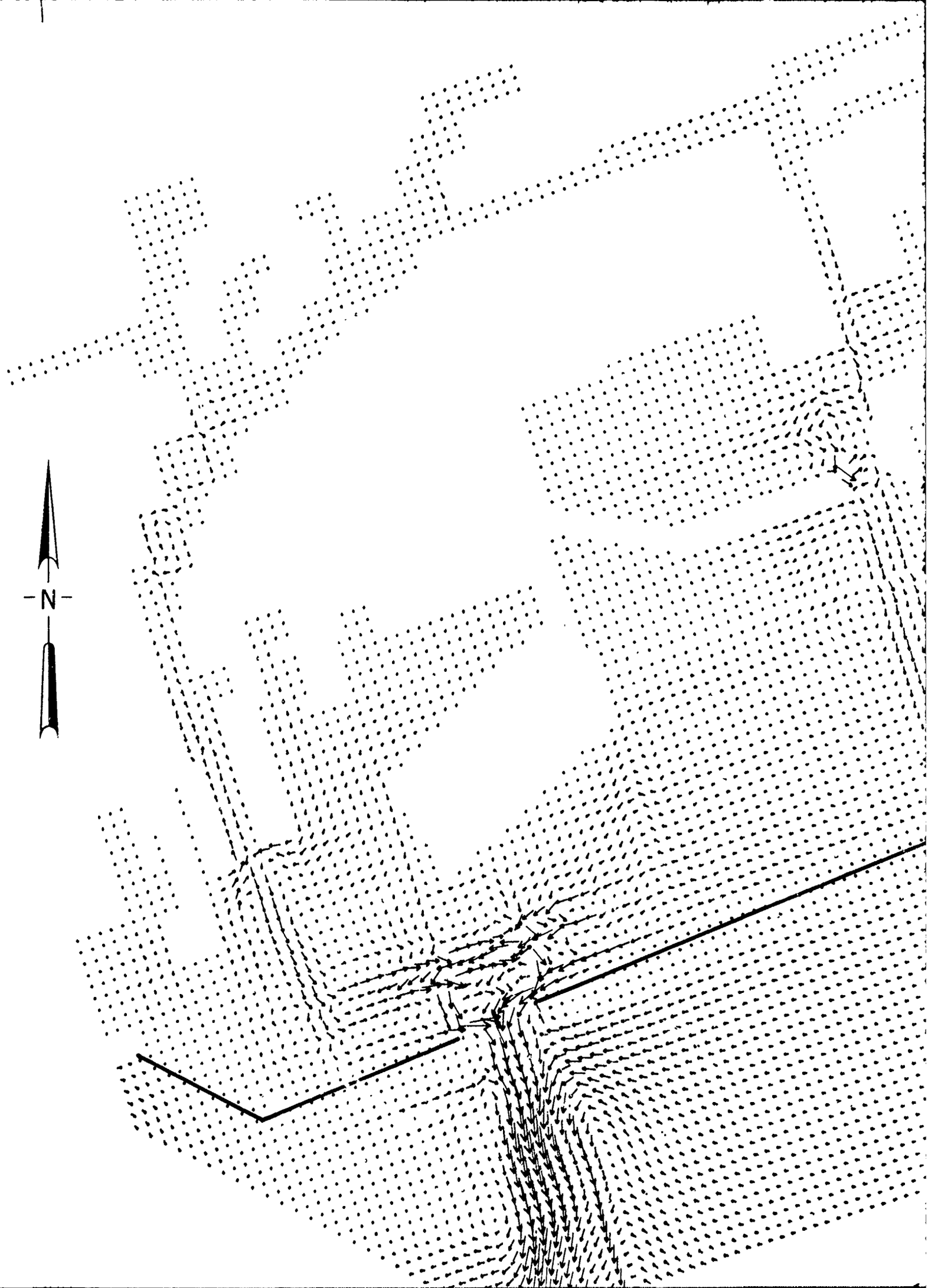
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

EXISTING CONDITIONS
SPRING TIDE
HOUR 24

FIG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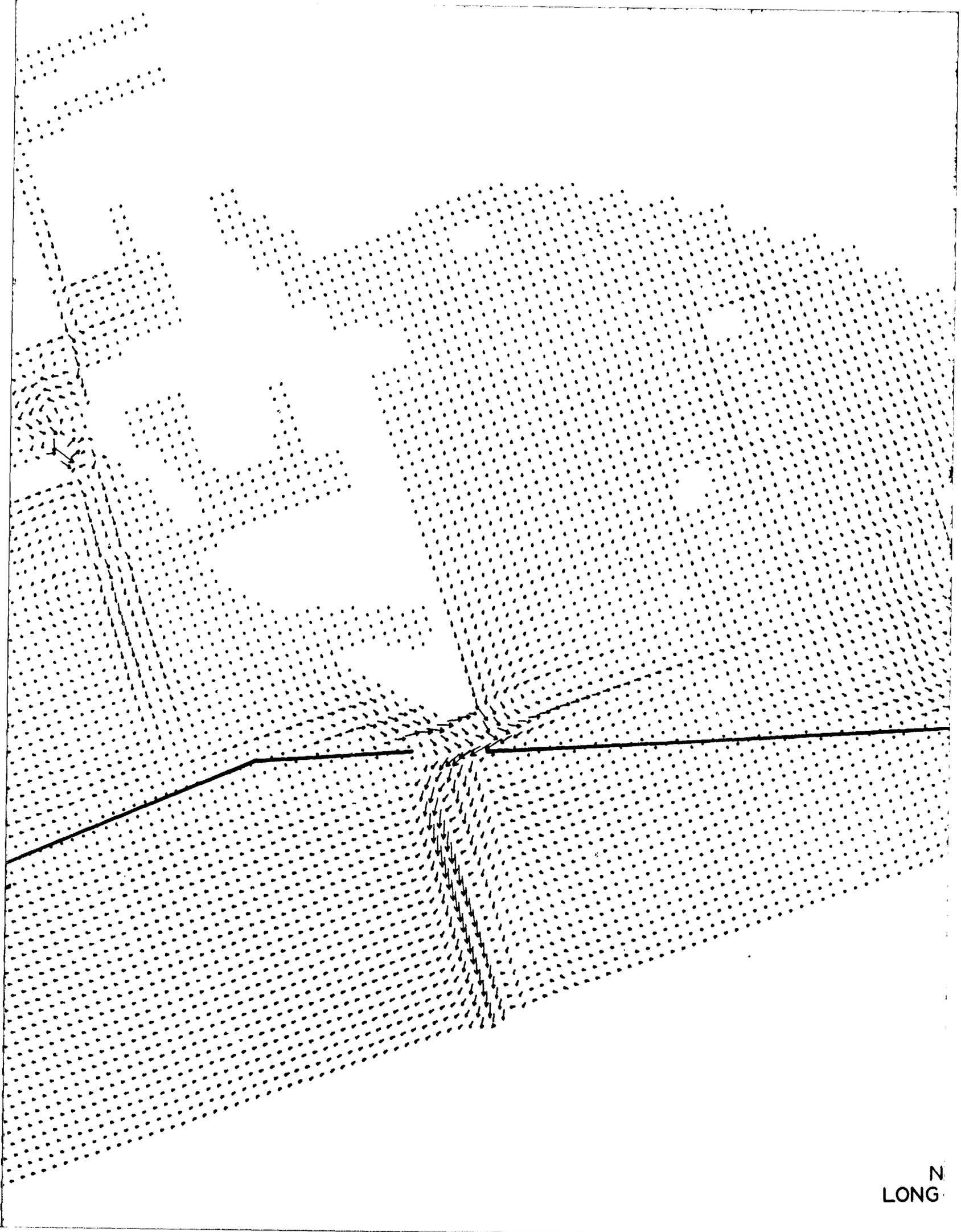
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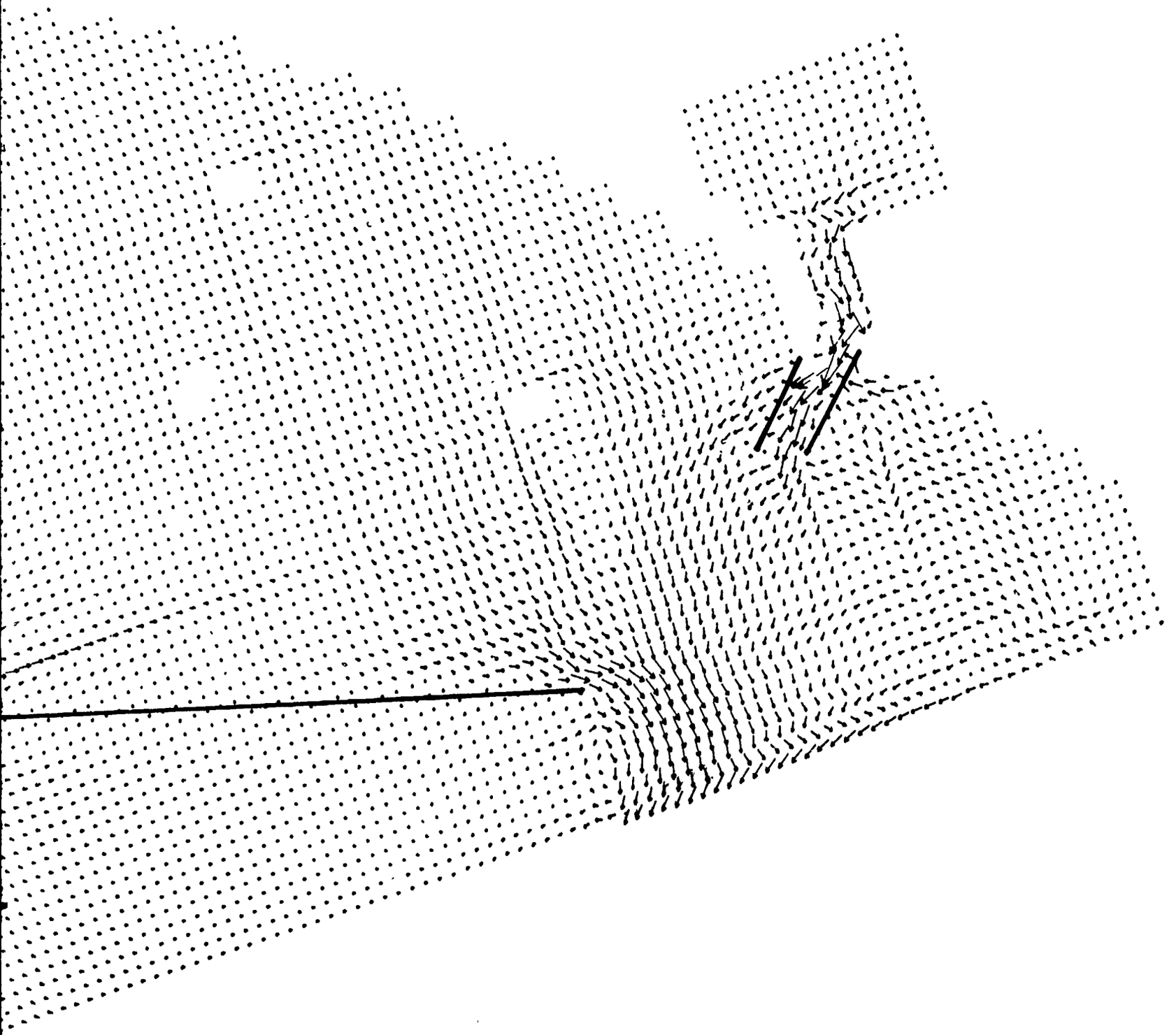

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NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

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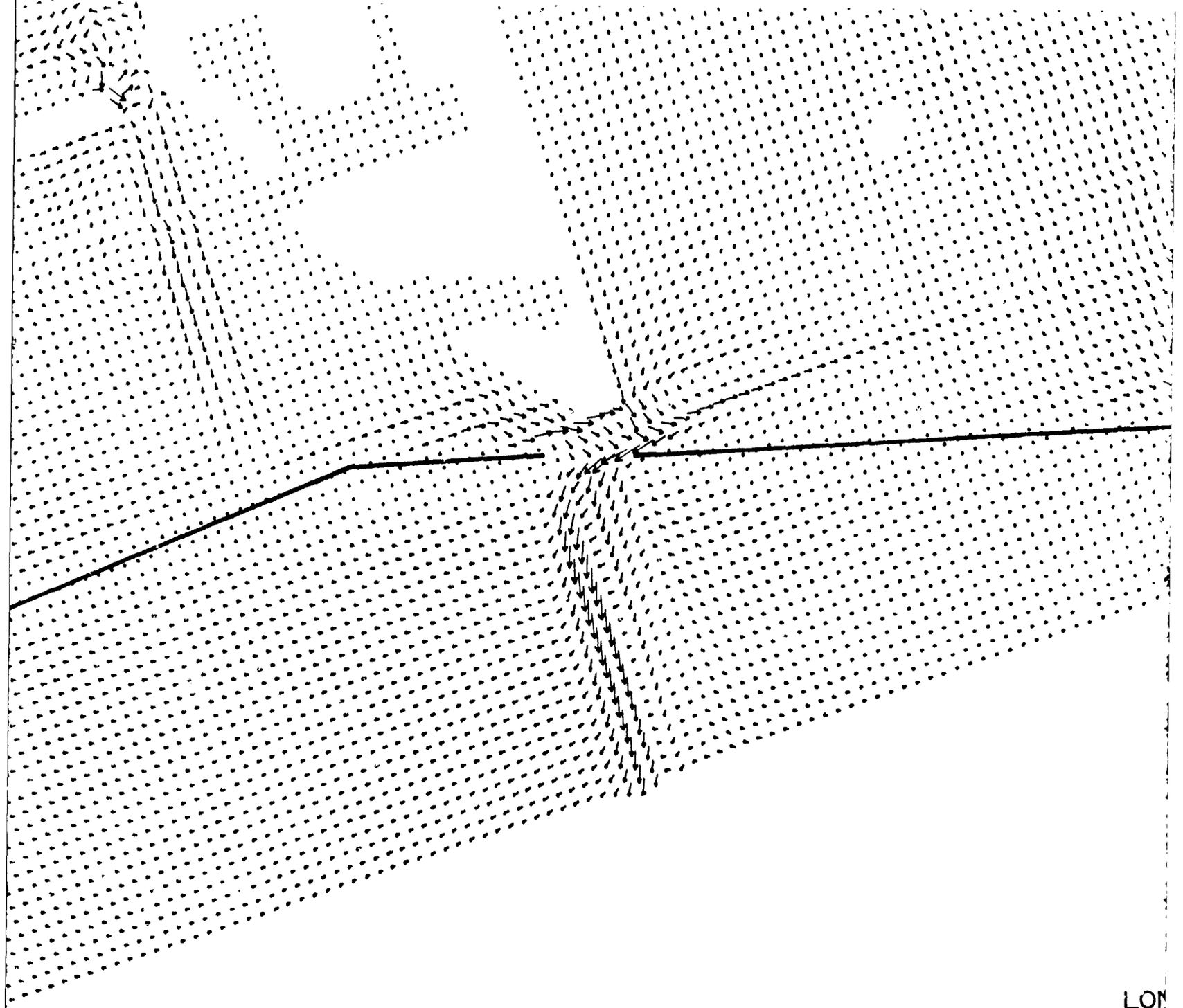

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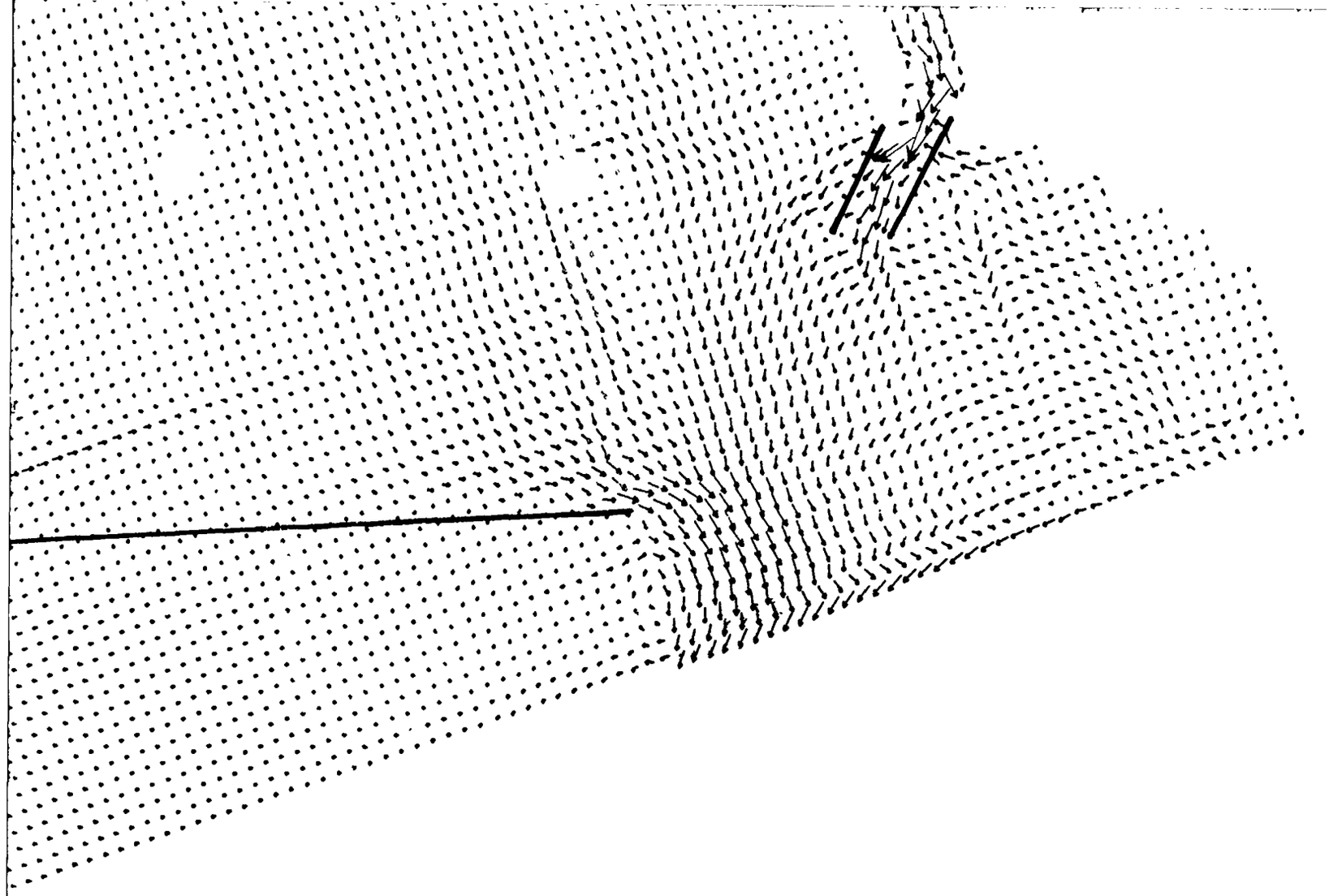

VELOCITY SCALE

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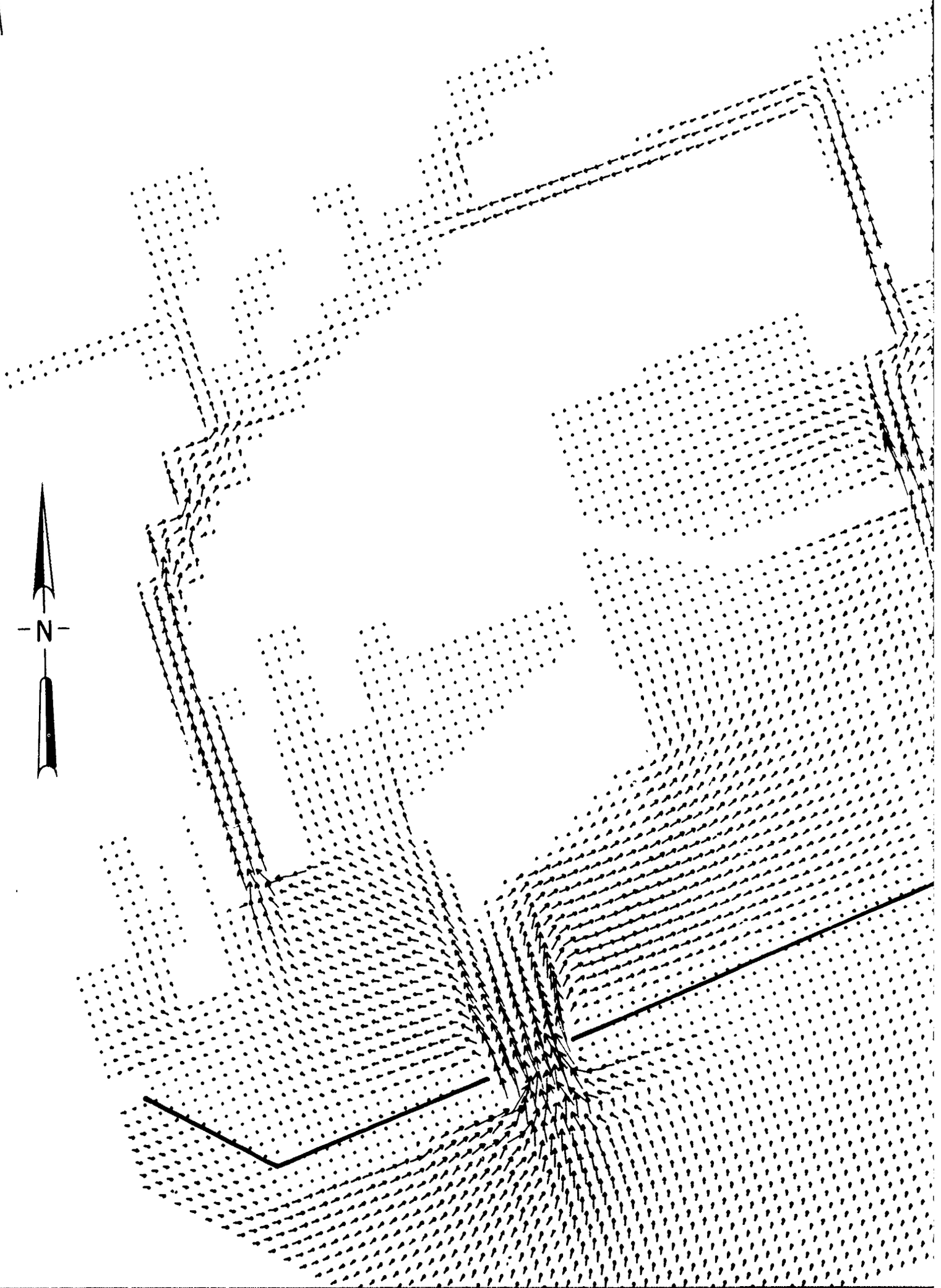
PROTOTYPE FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

PLAN 1A-2
SPRING TIDE
HOUR 15

FIGURE 5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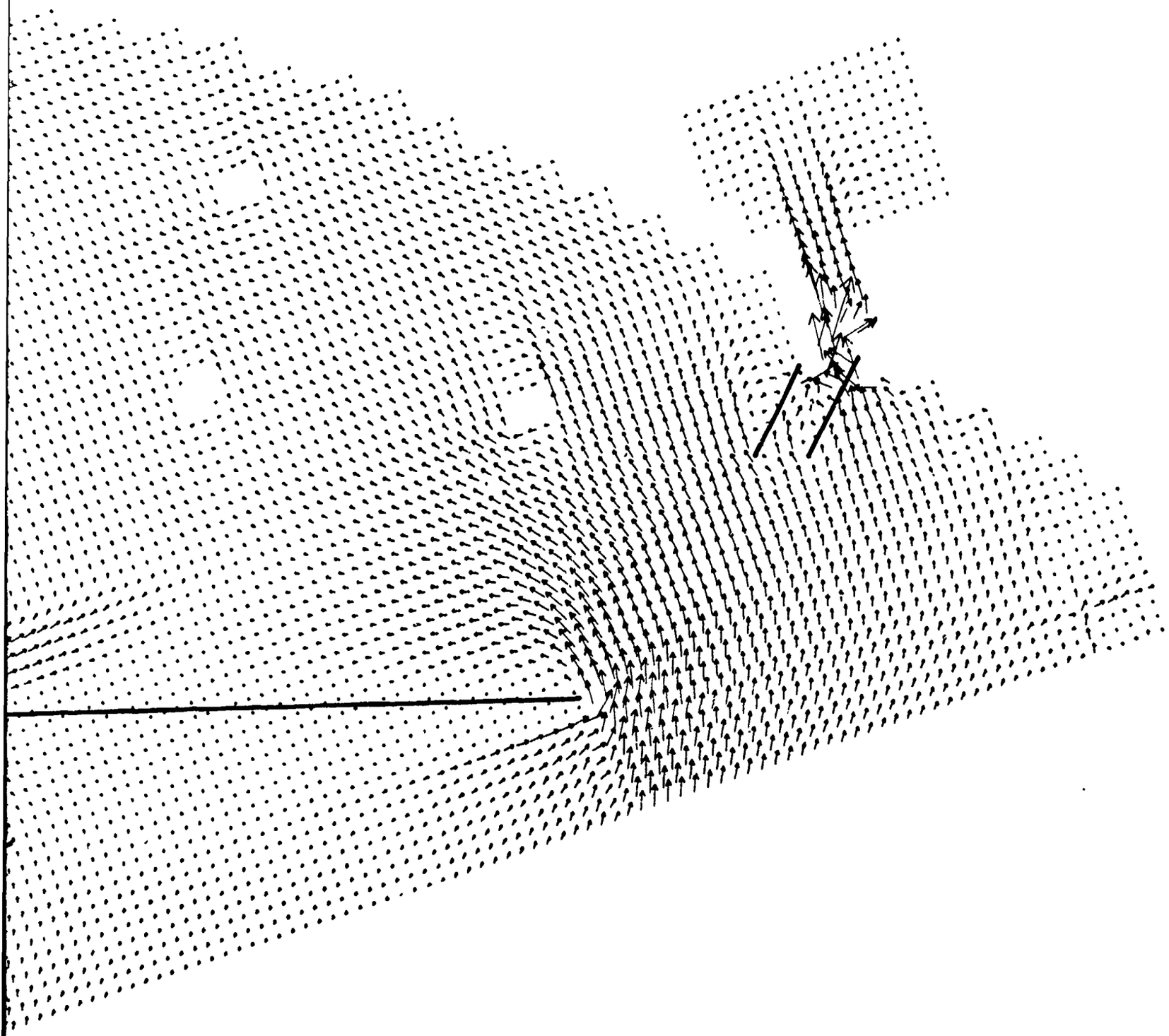

VELOCITY SCALE

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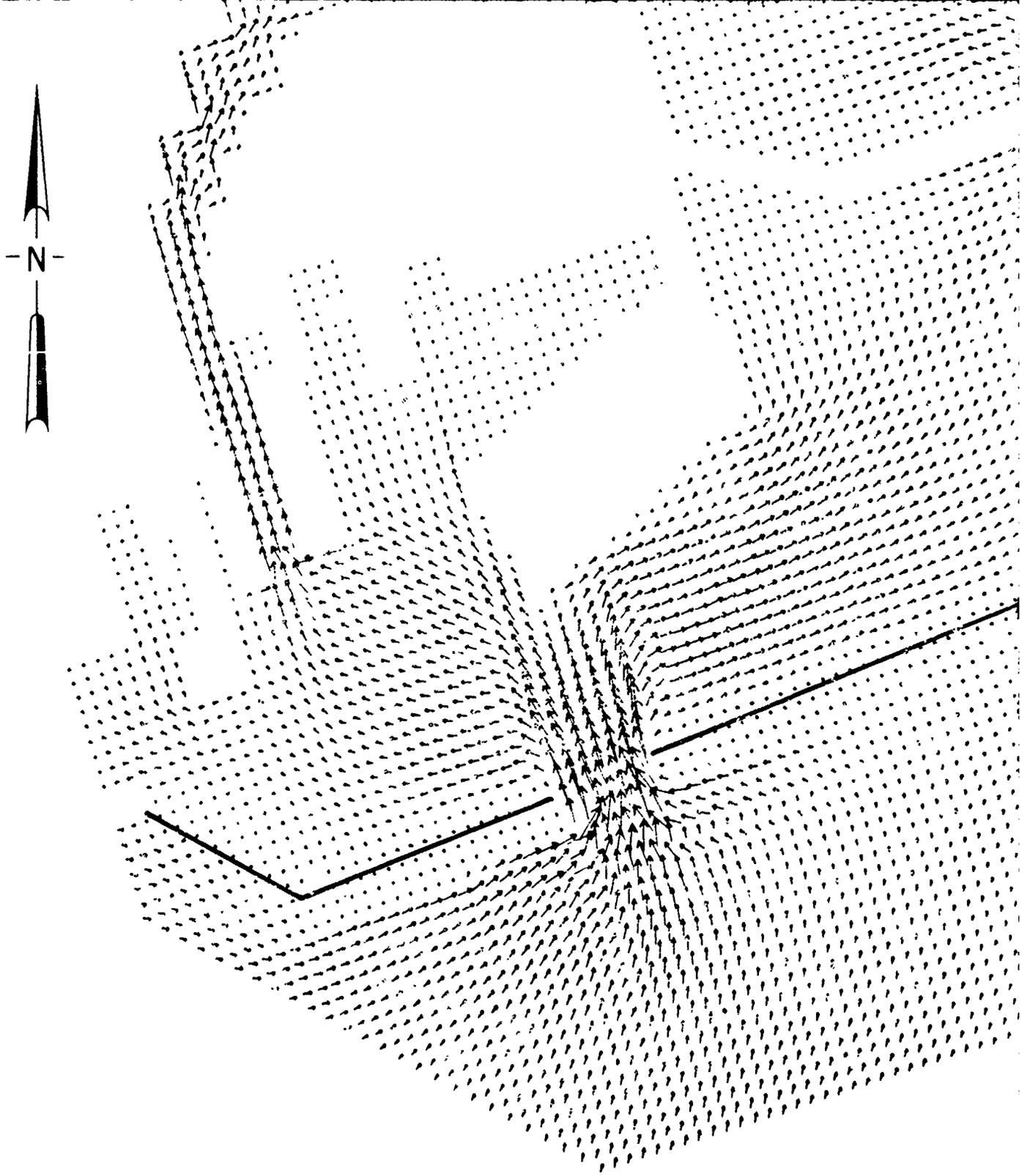
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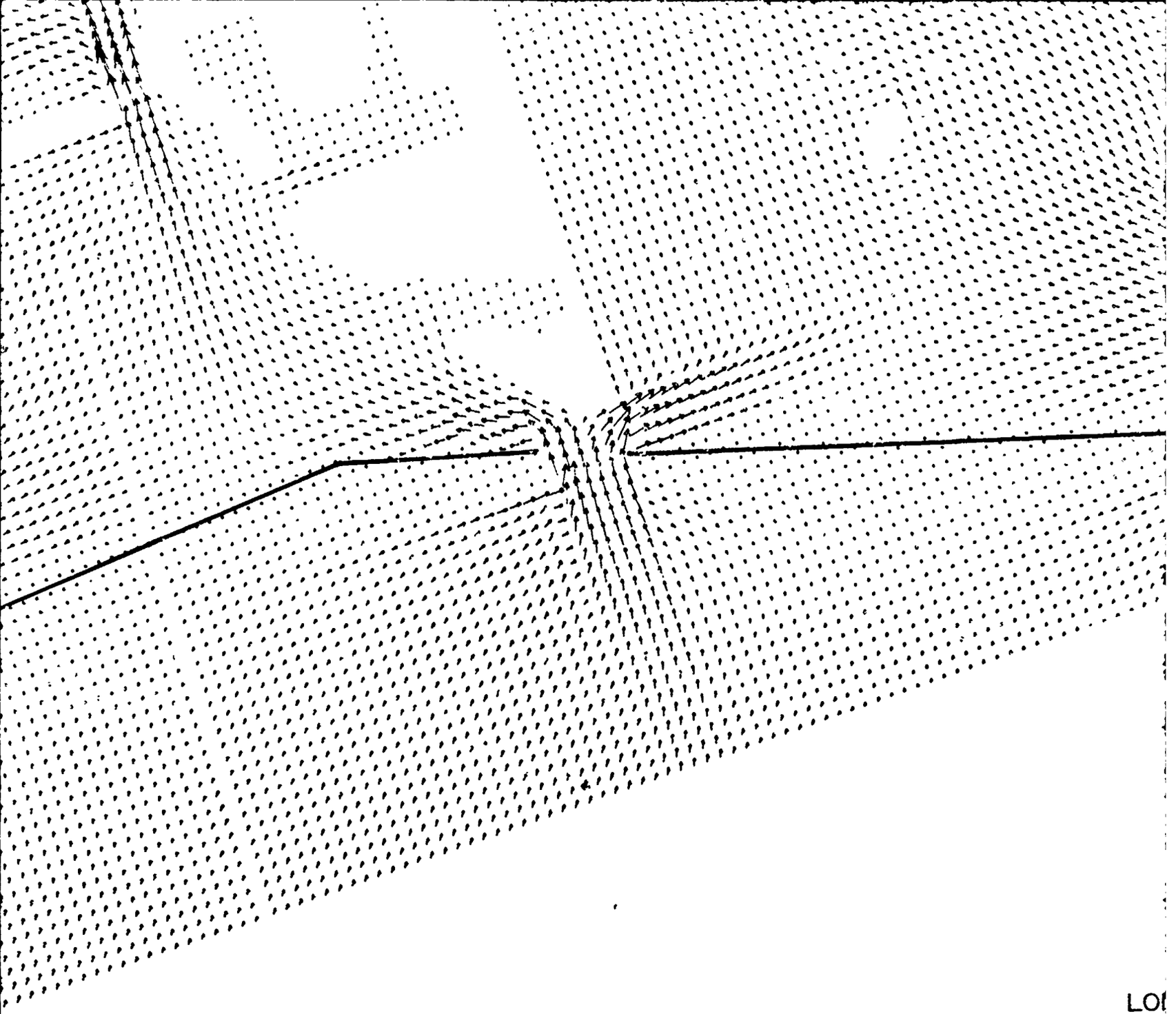

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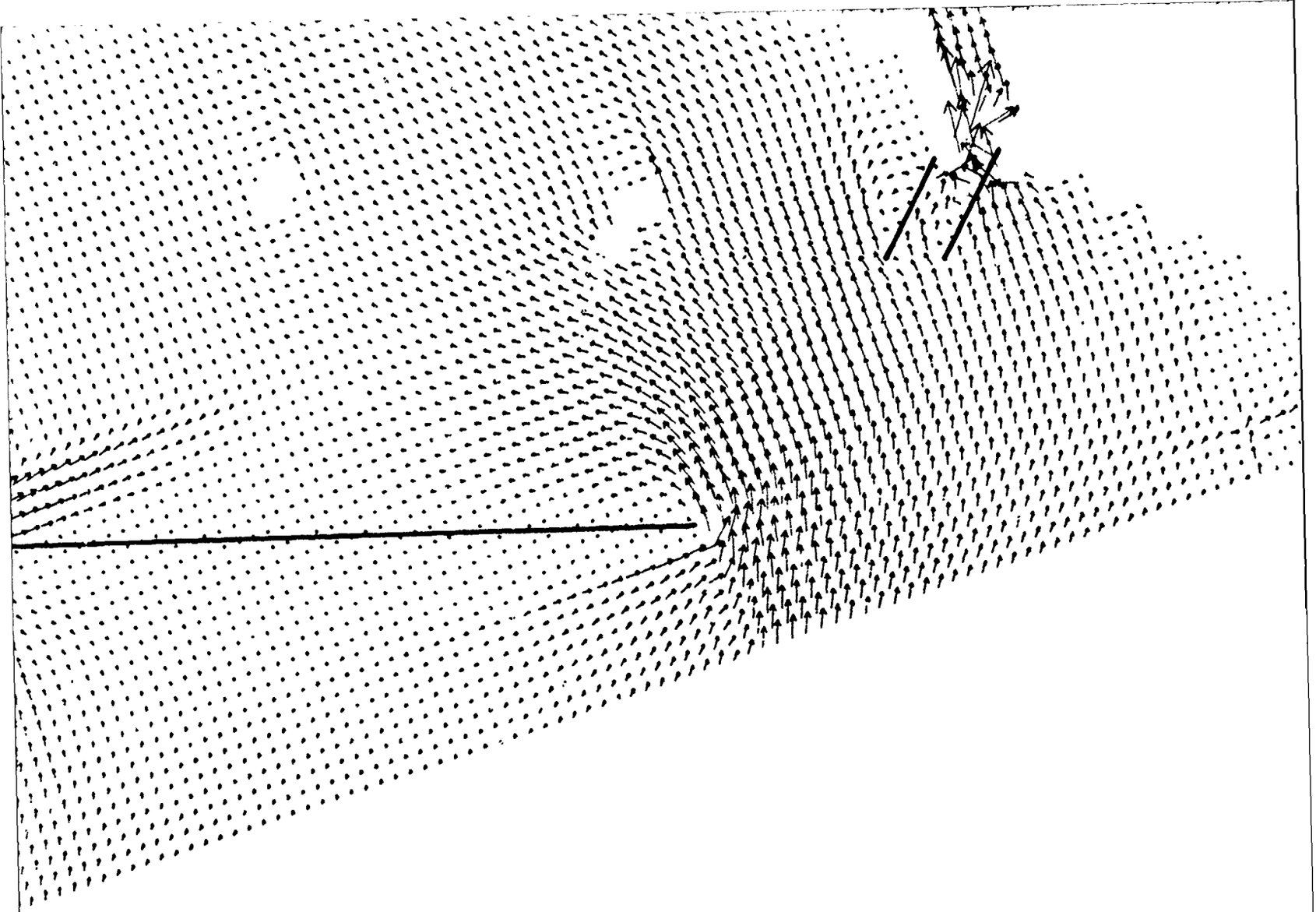


VELOCITY SCALE

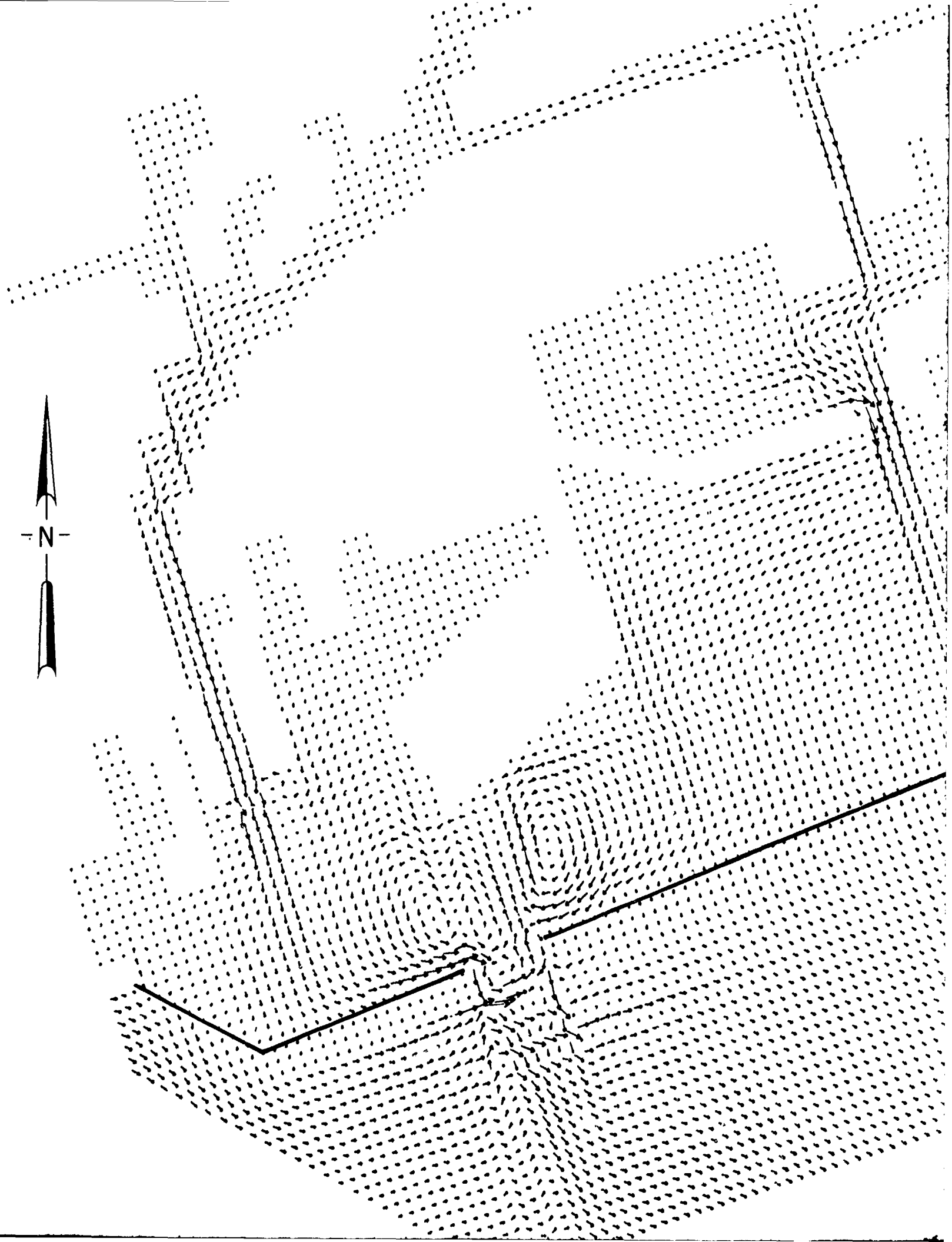
1 0 1 2

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

PLAN 1A-2
SPRING TIDE
HOUR 19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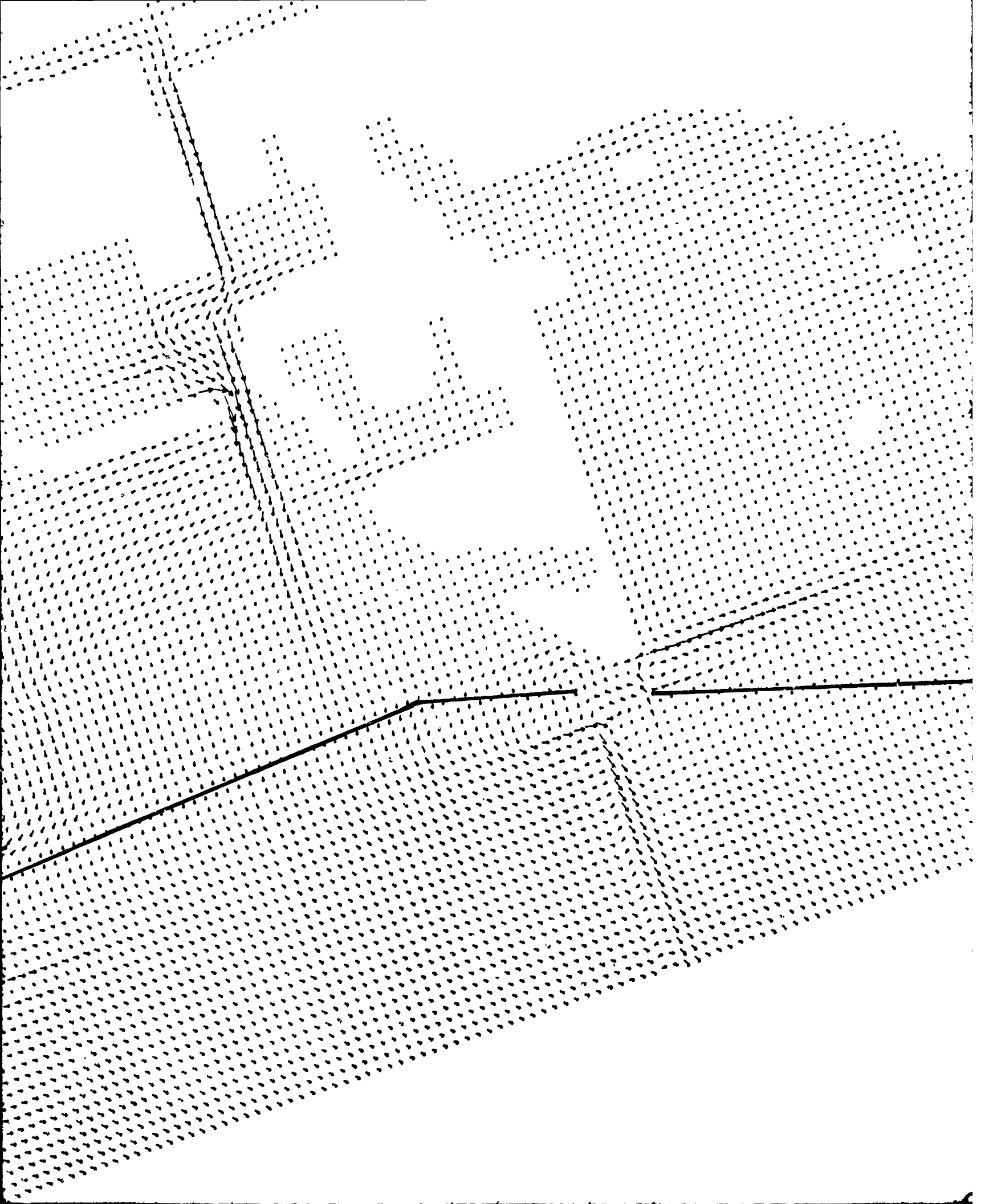
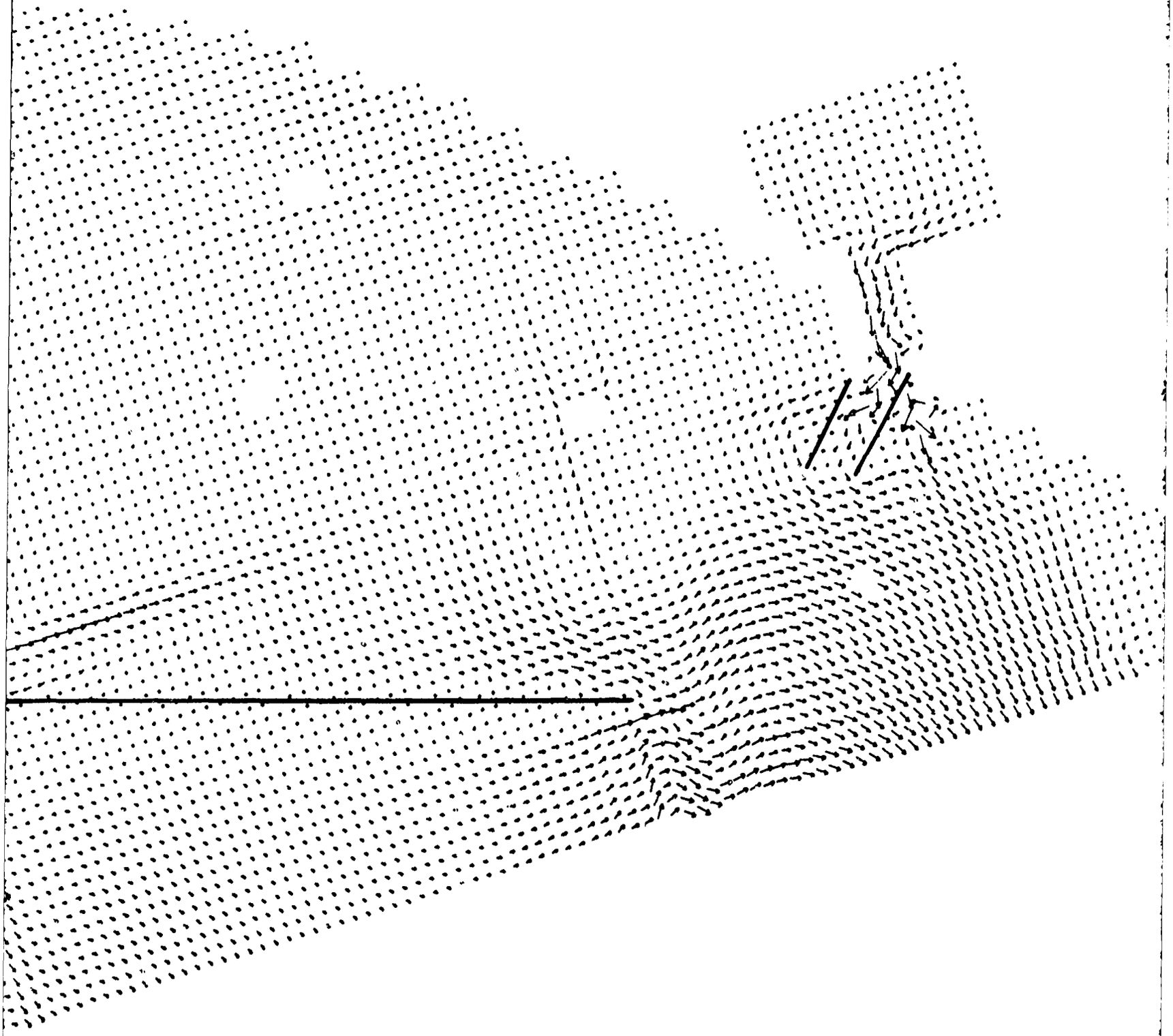




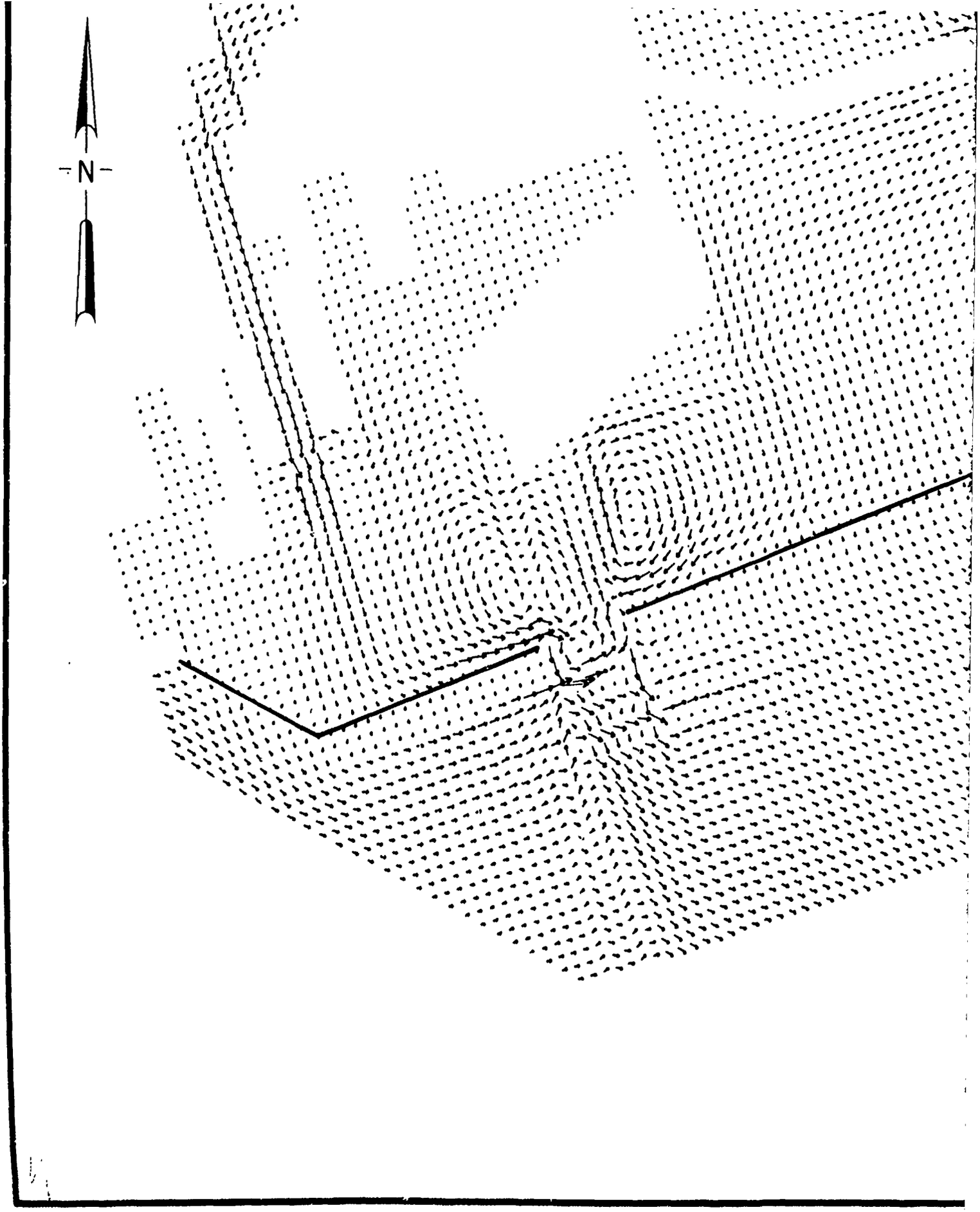
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS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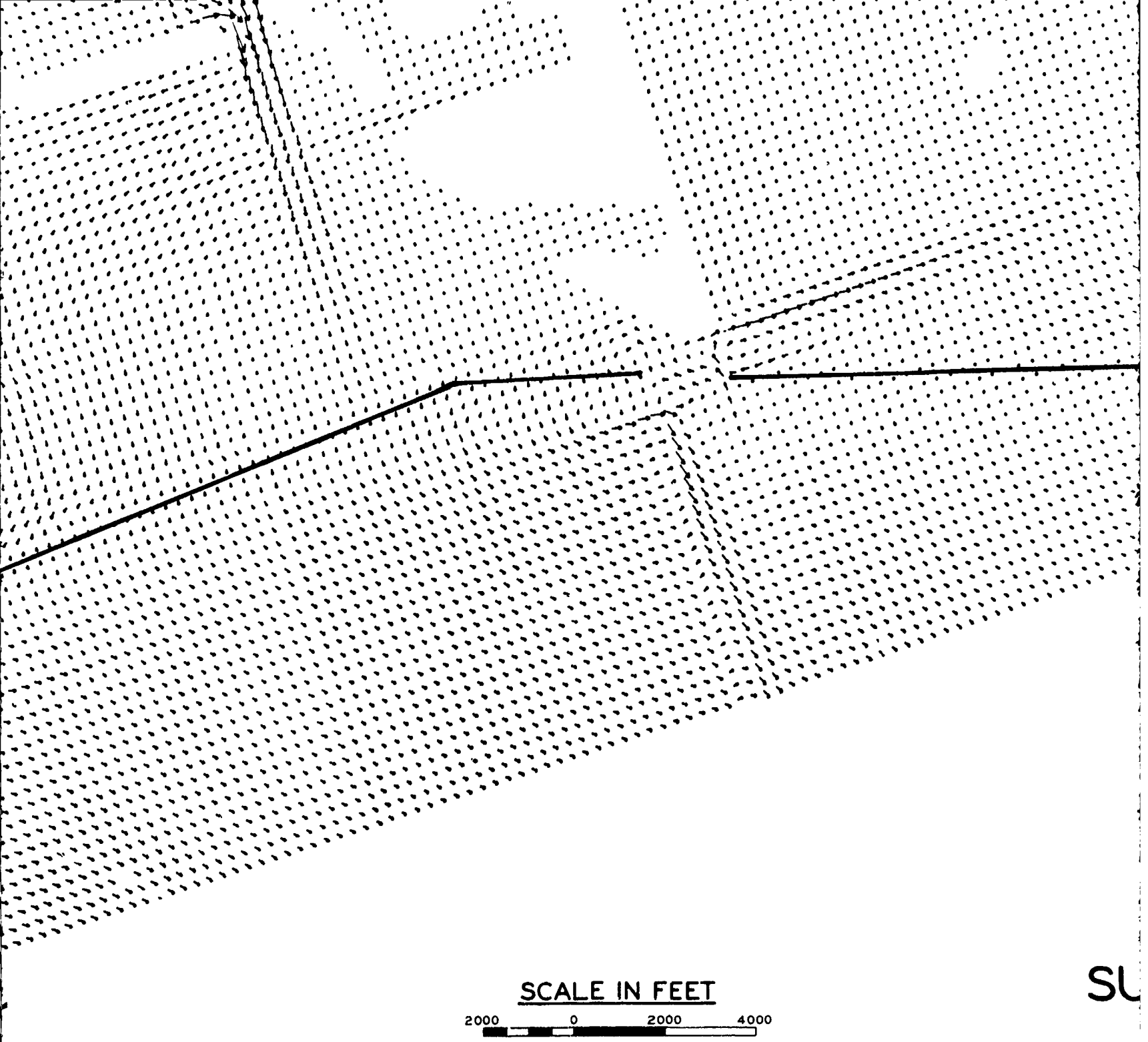

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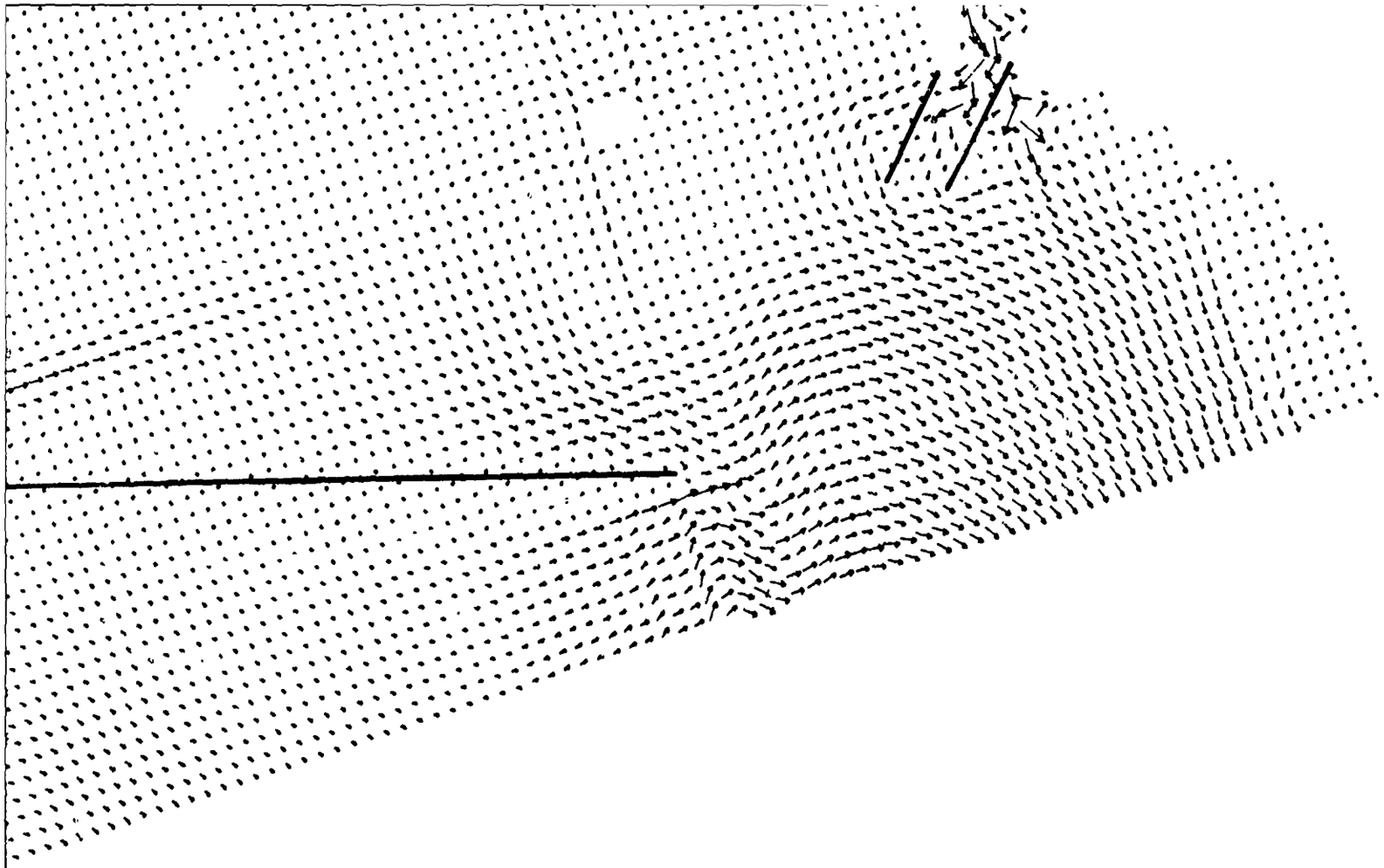


VELOCITY SCALE

1 0 1 2 3

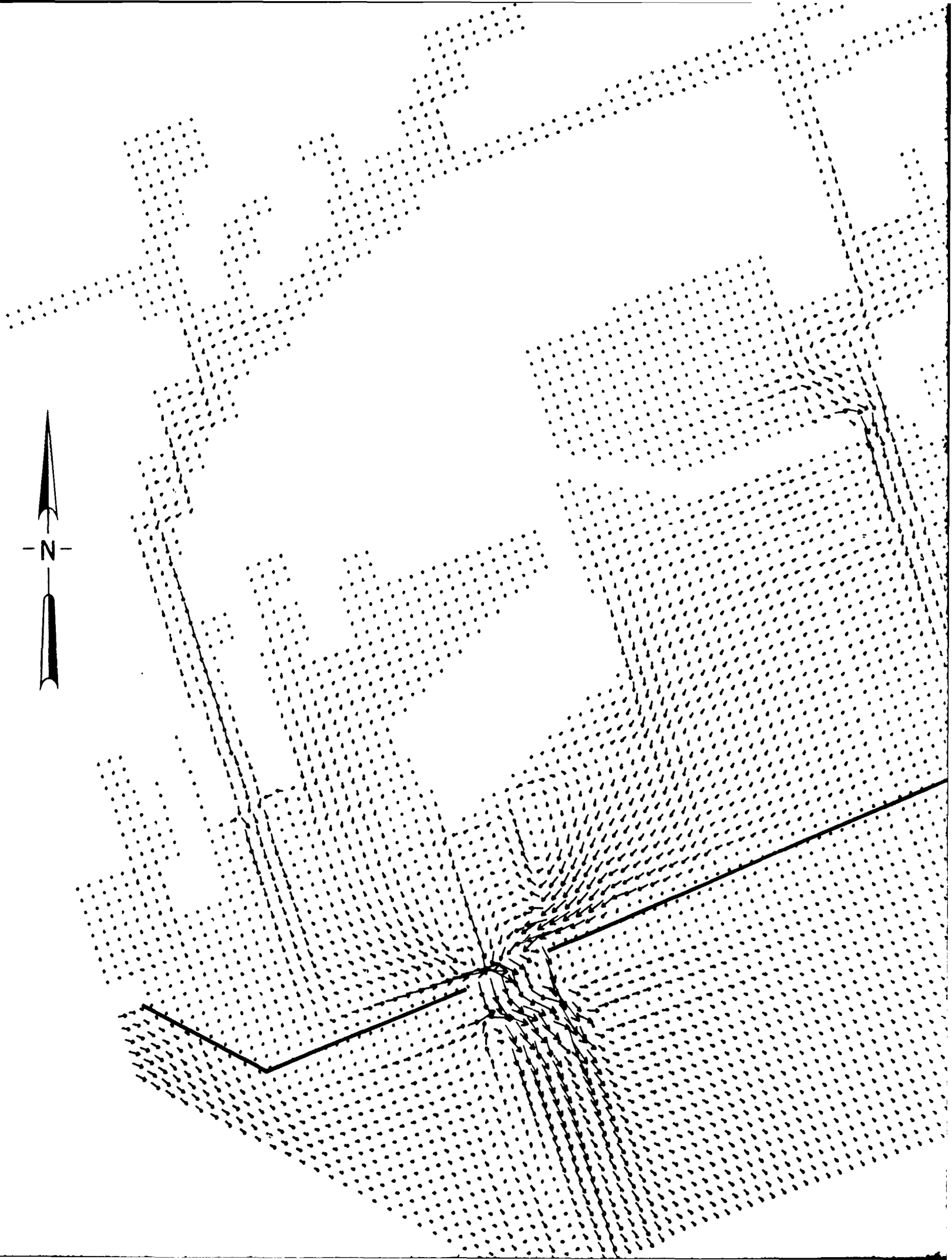
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

PLAN 1A-2
SPRING TIDE
HOUR 22

FIGURE 7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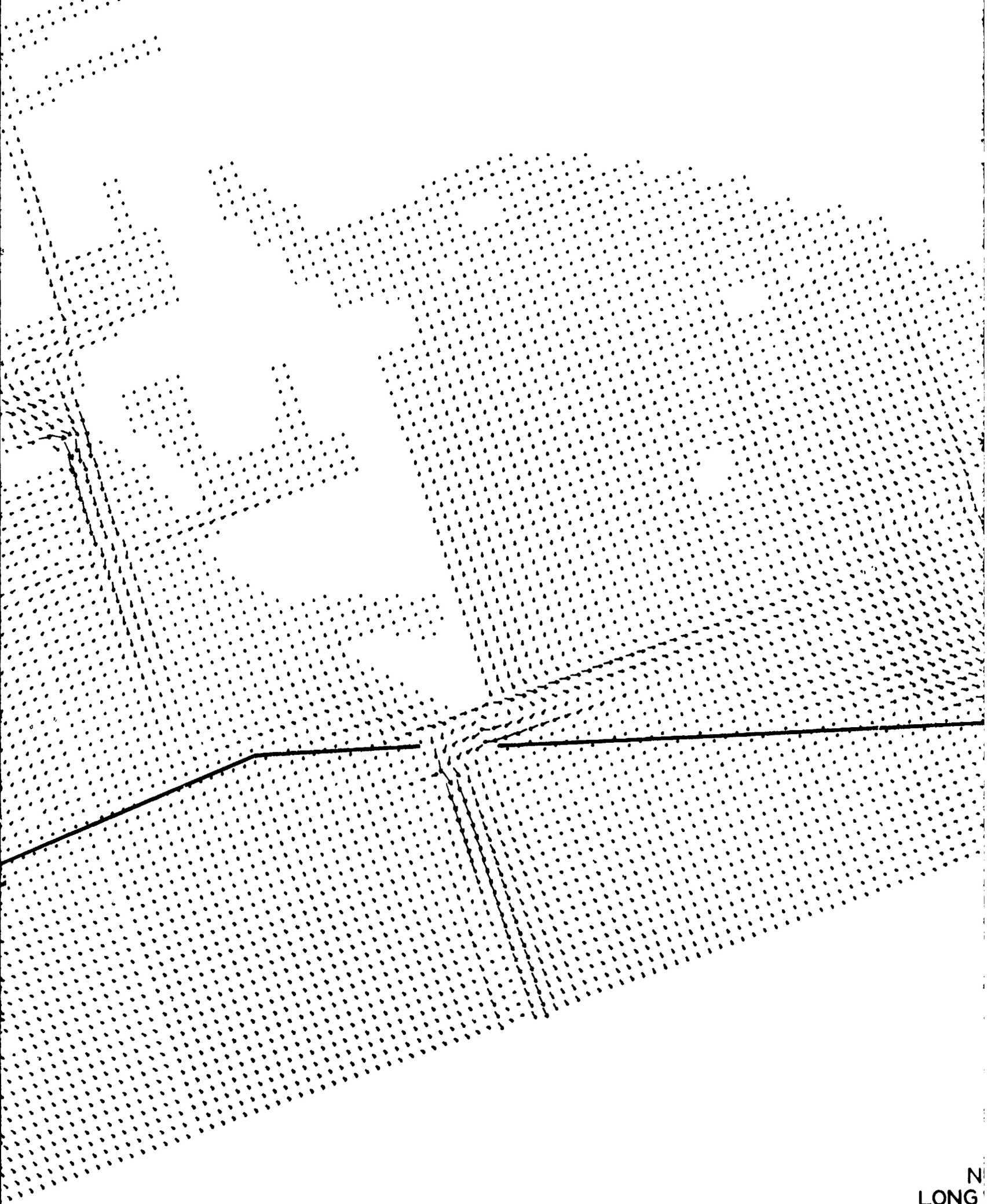
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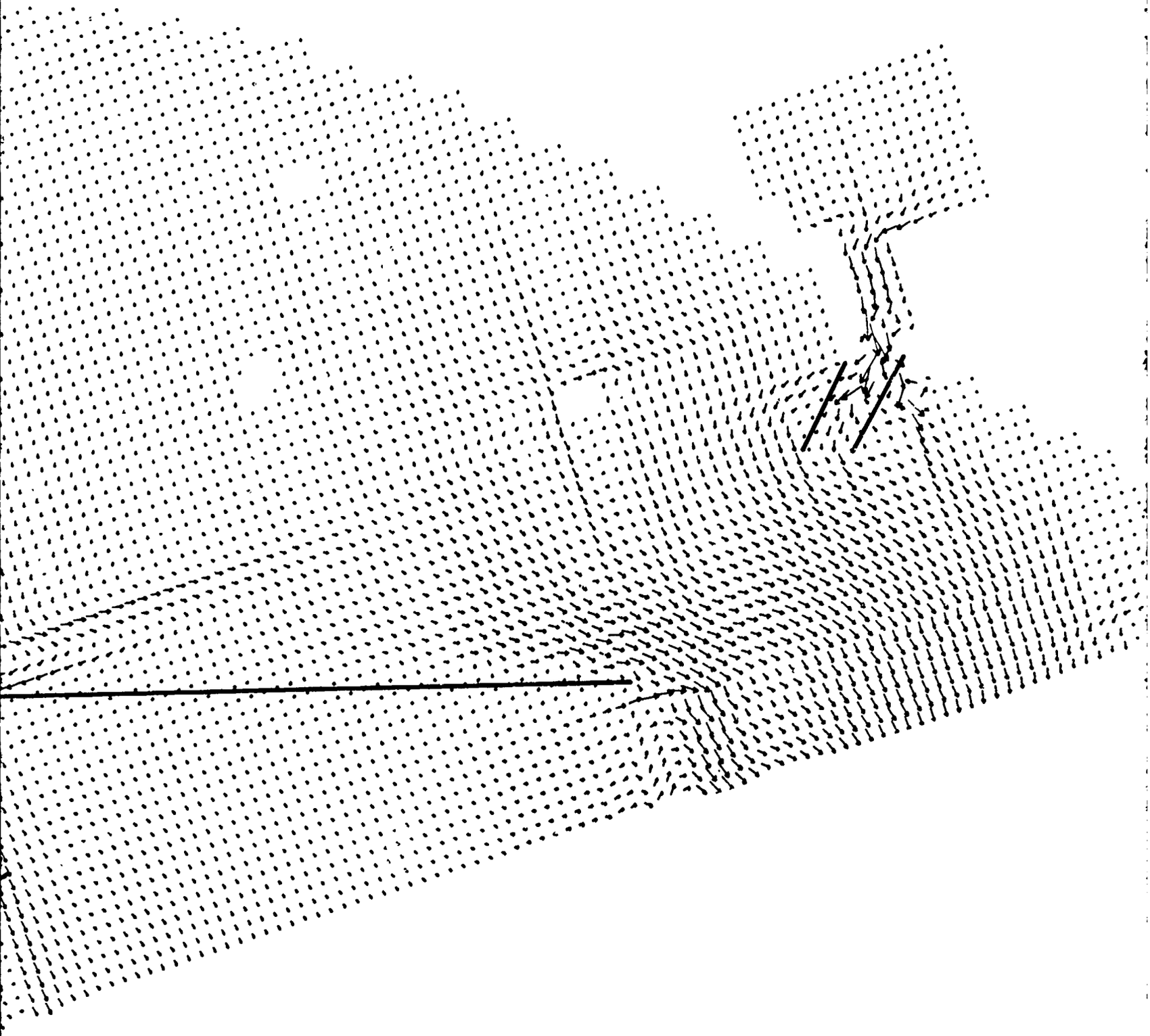
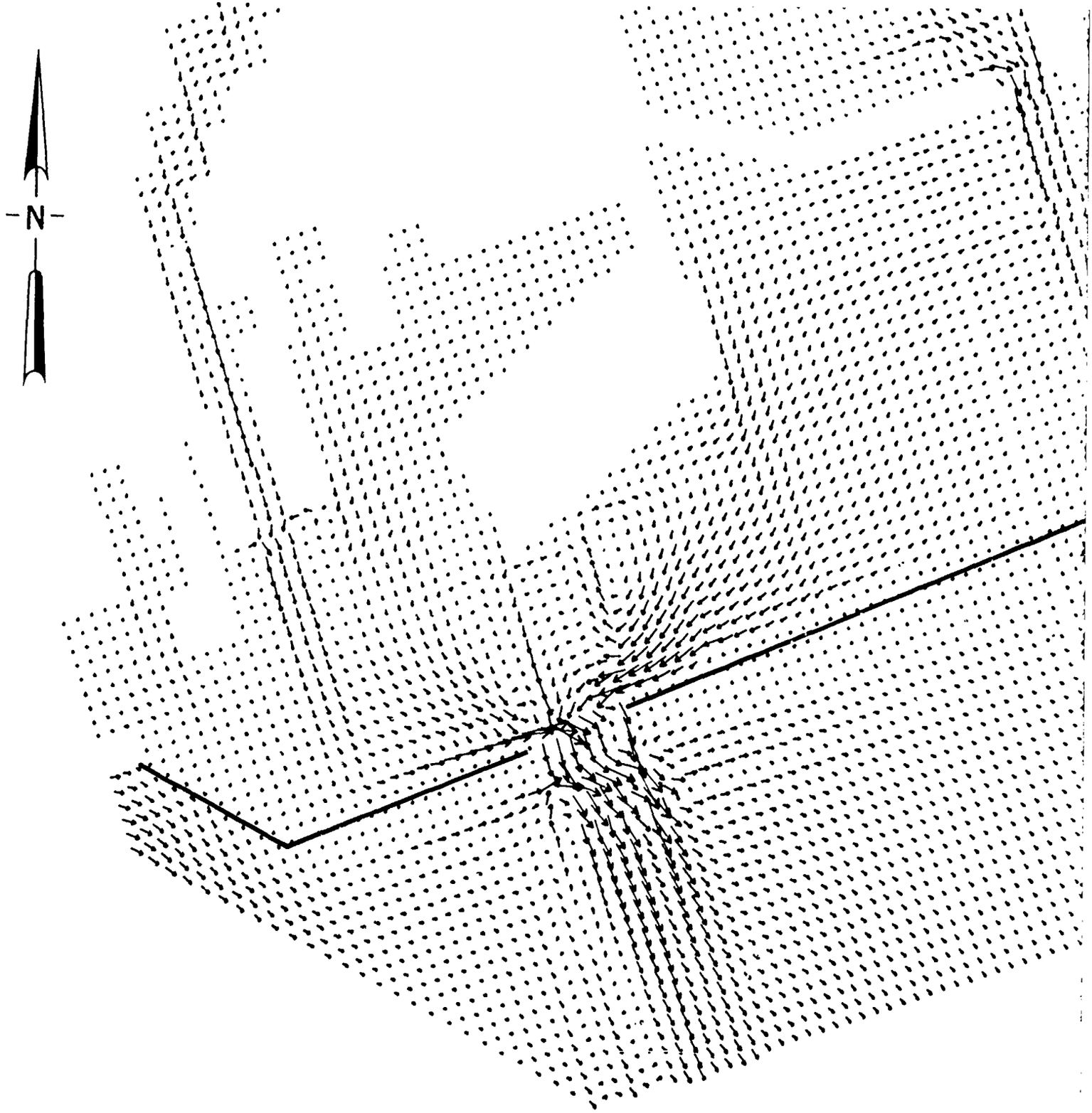


VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS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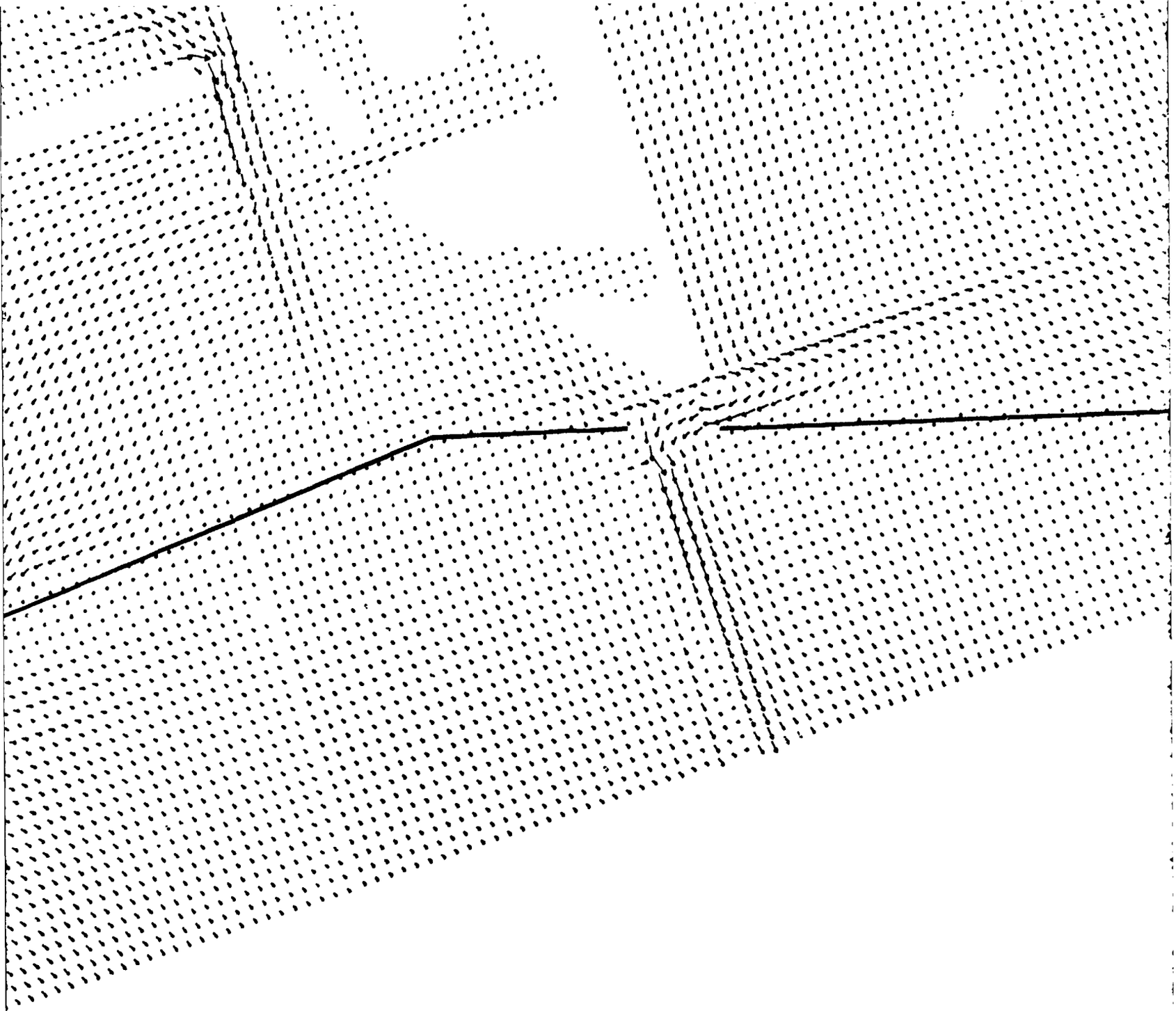

SCALE IN FEET

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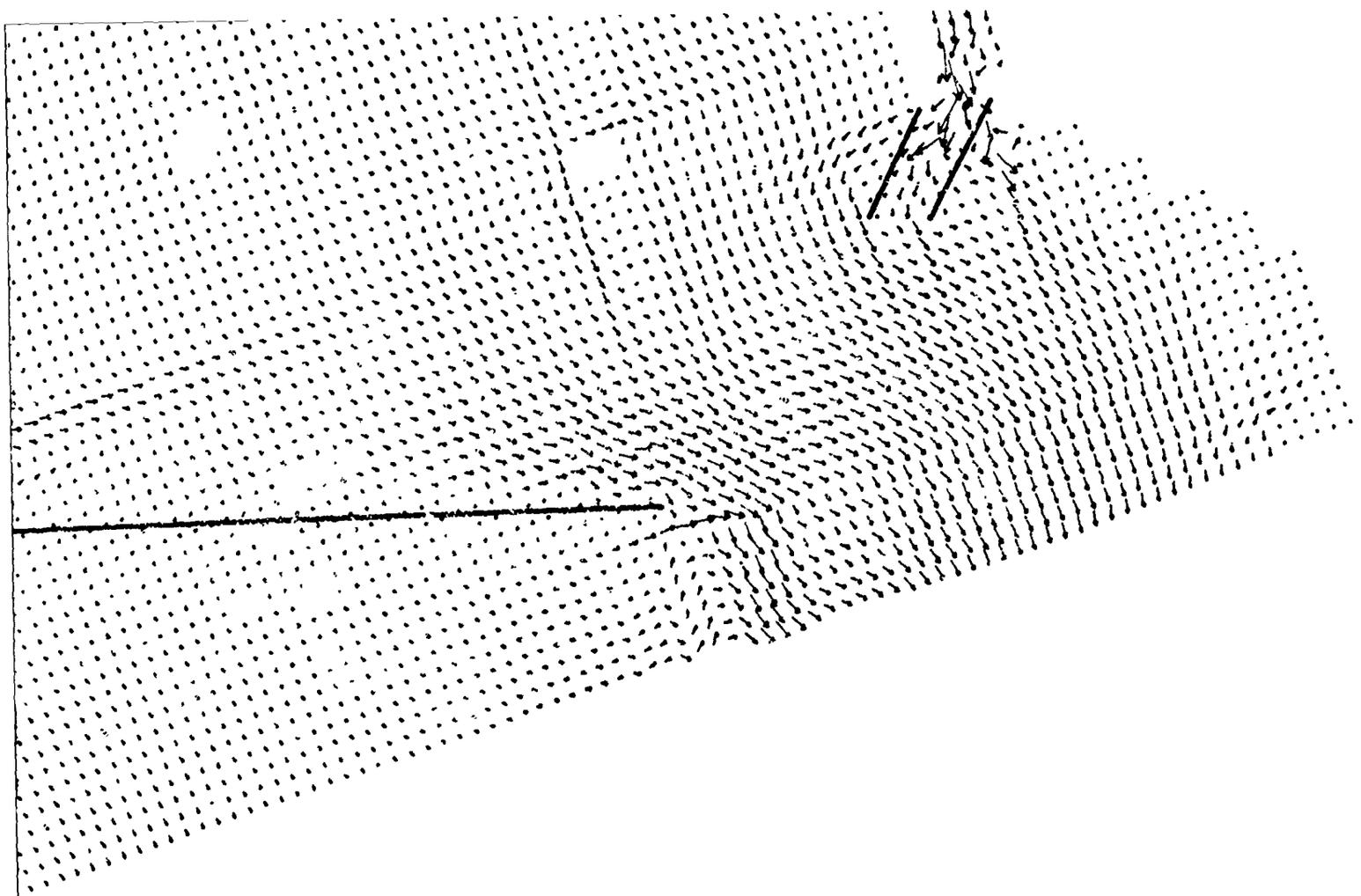

VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH · LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

PLAN 1A-2
SPRING TIDE
HOUR 24

FIGURE 5

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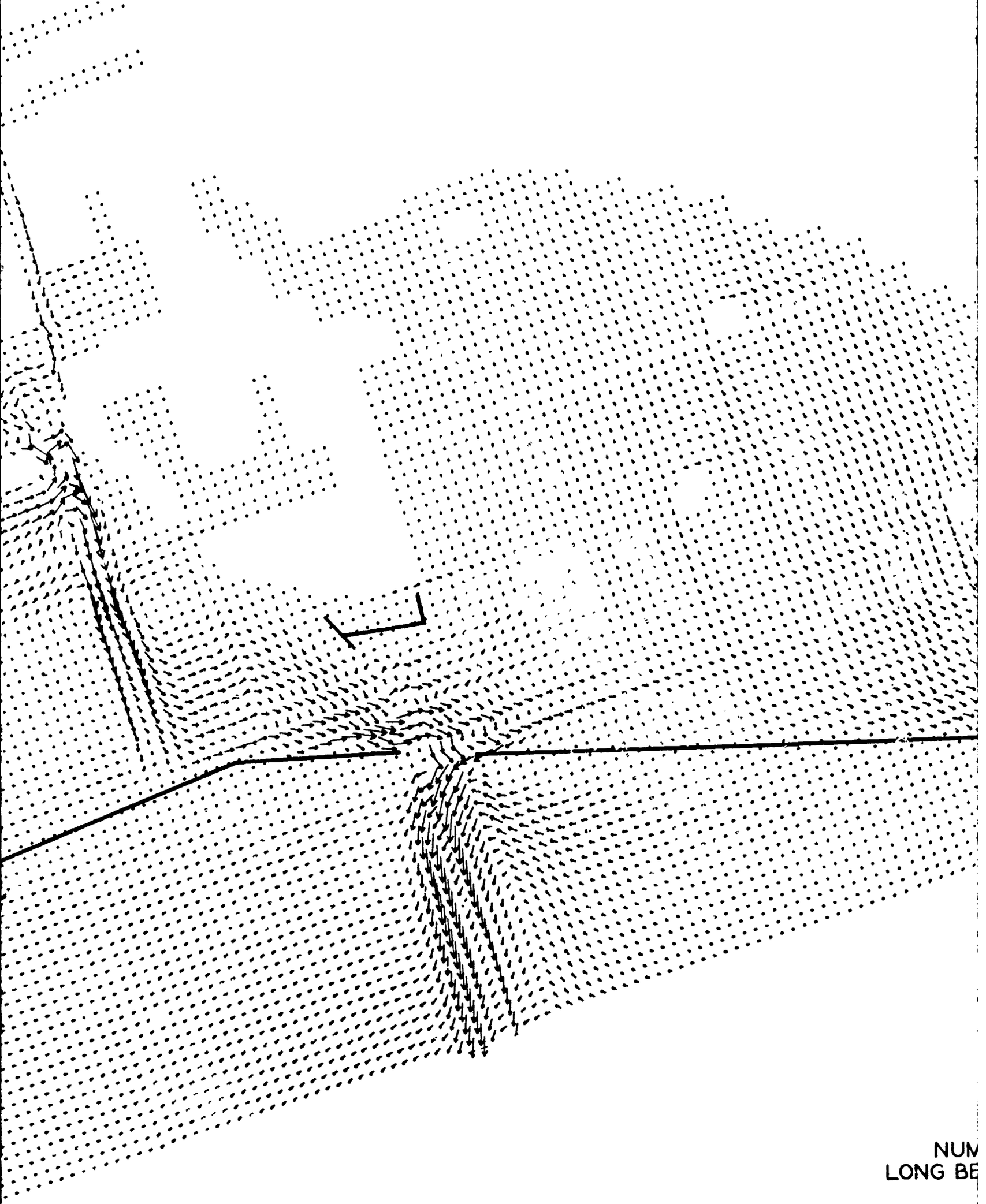

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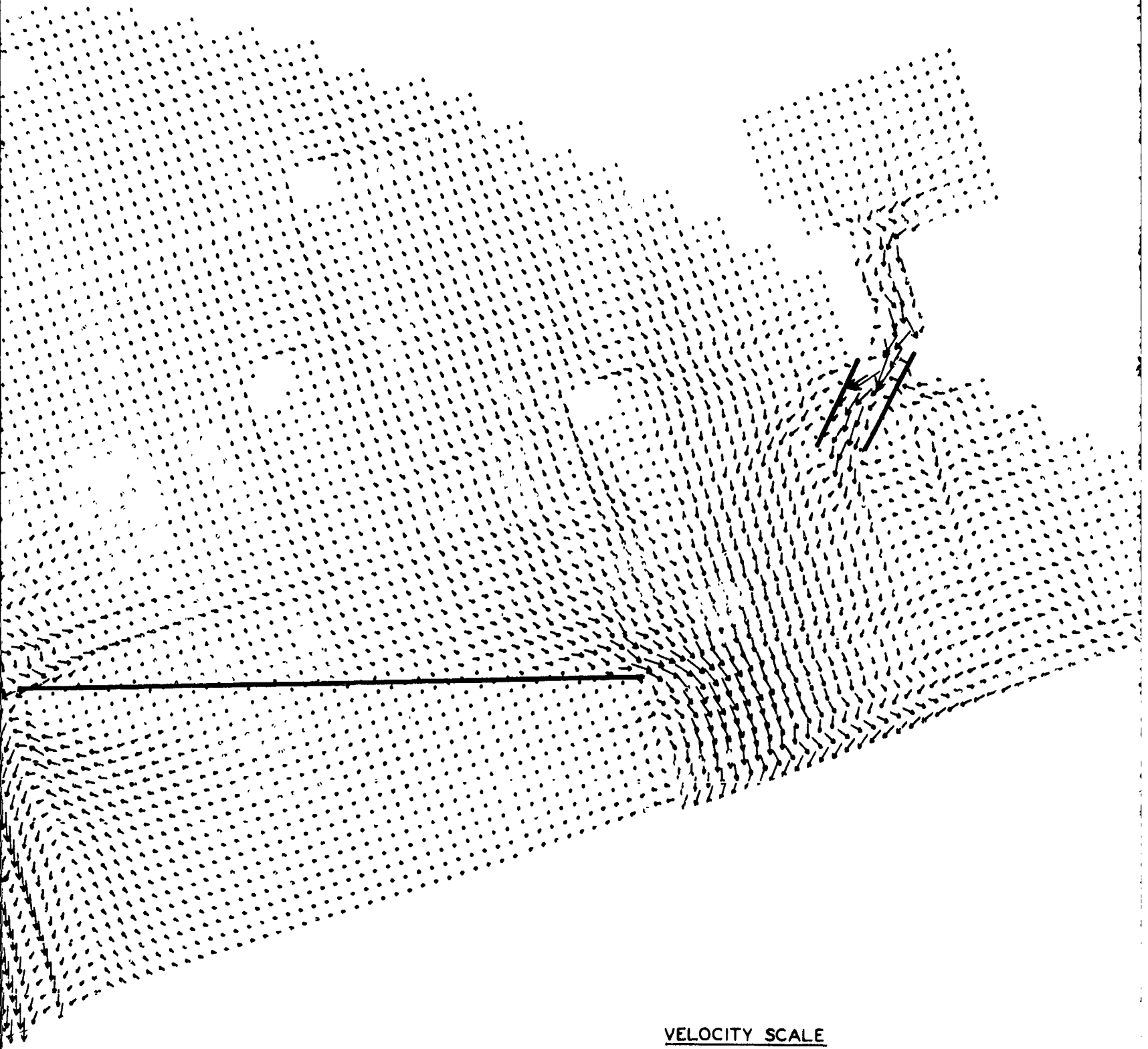


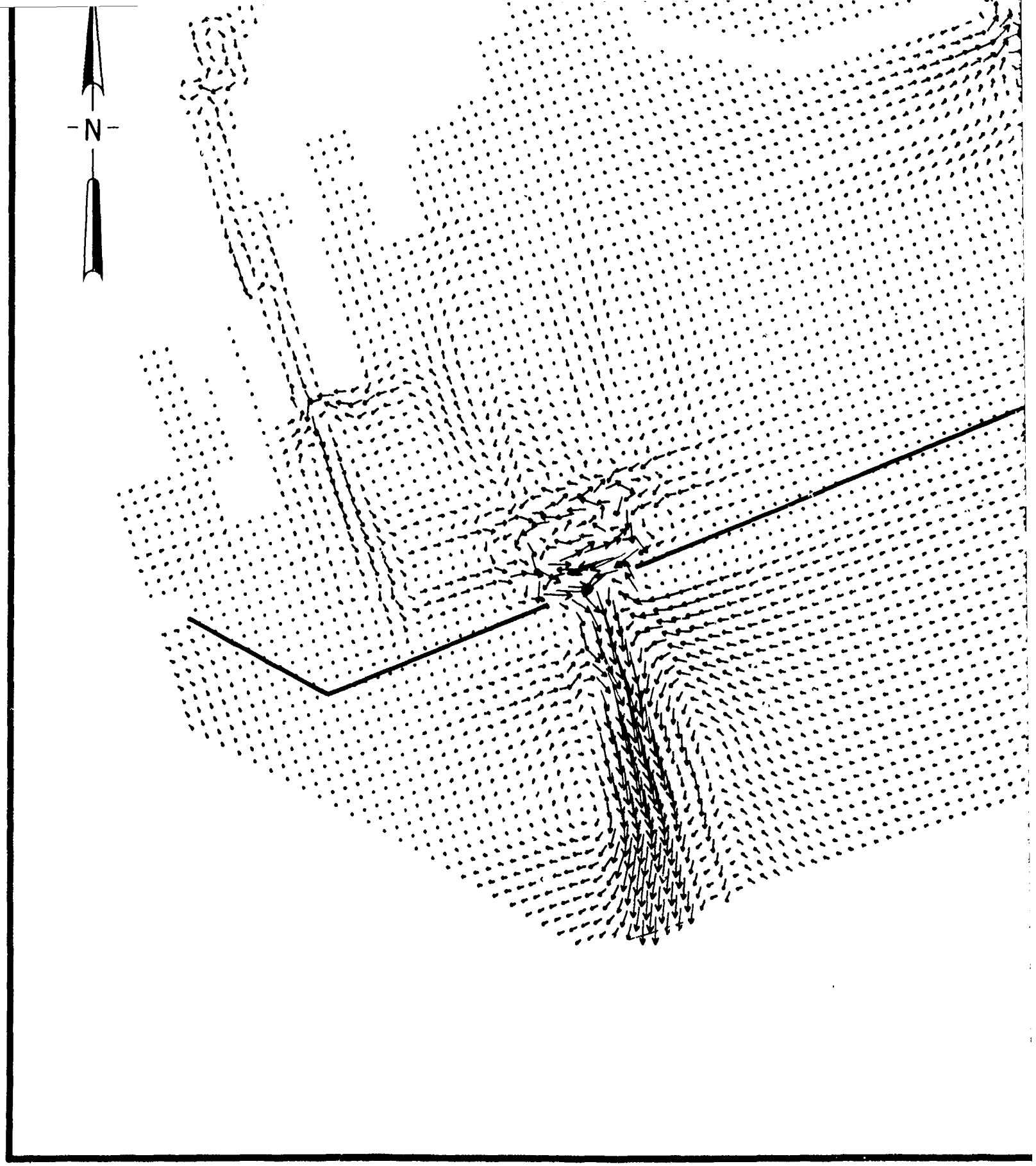
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS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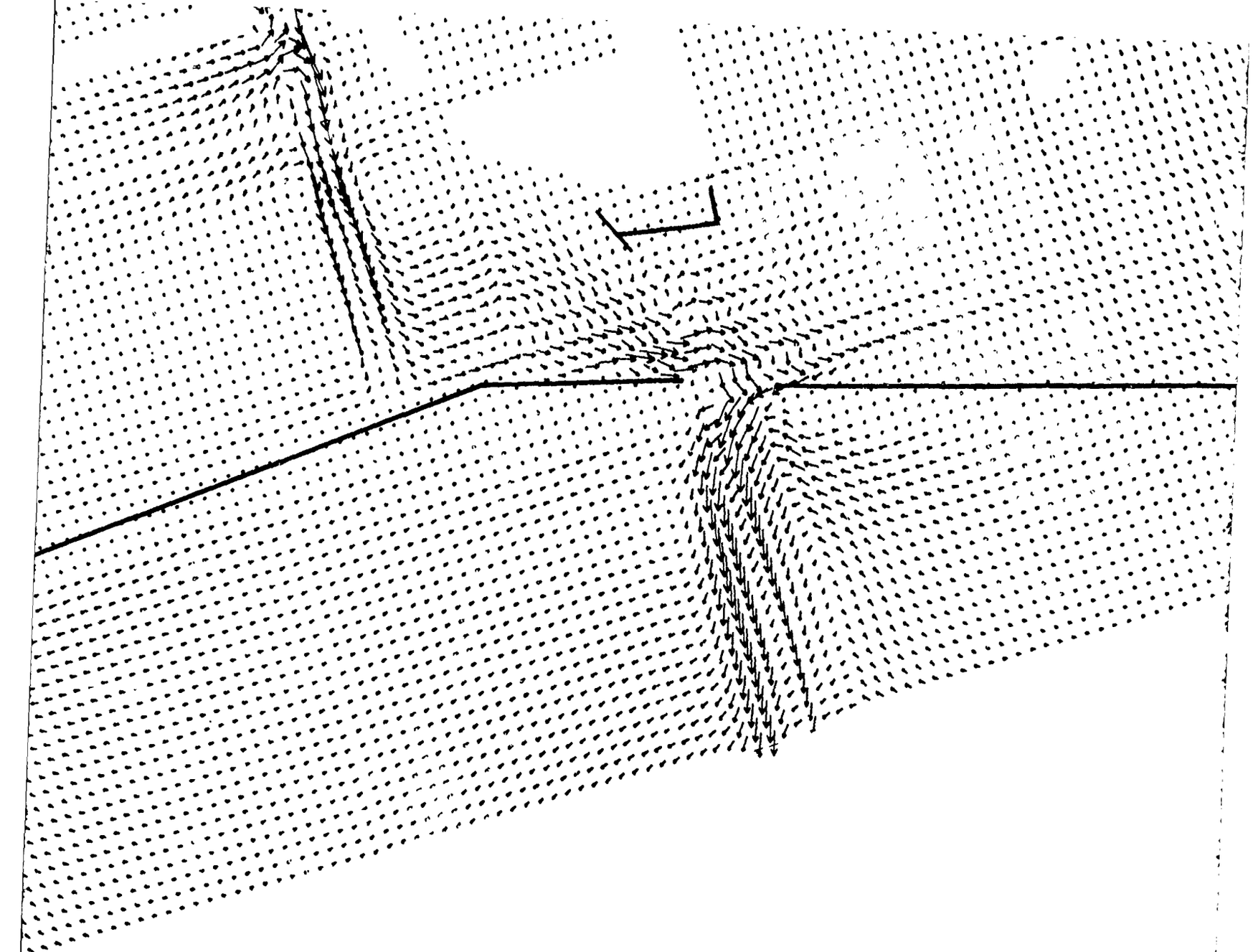

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SCALE IN FEET

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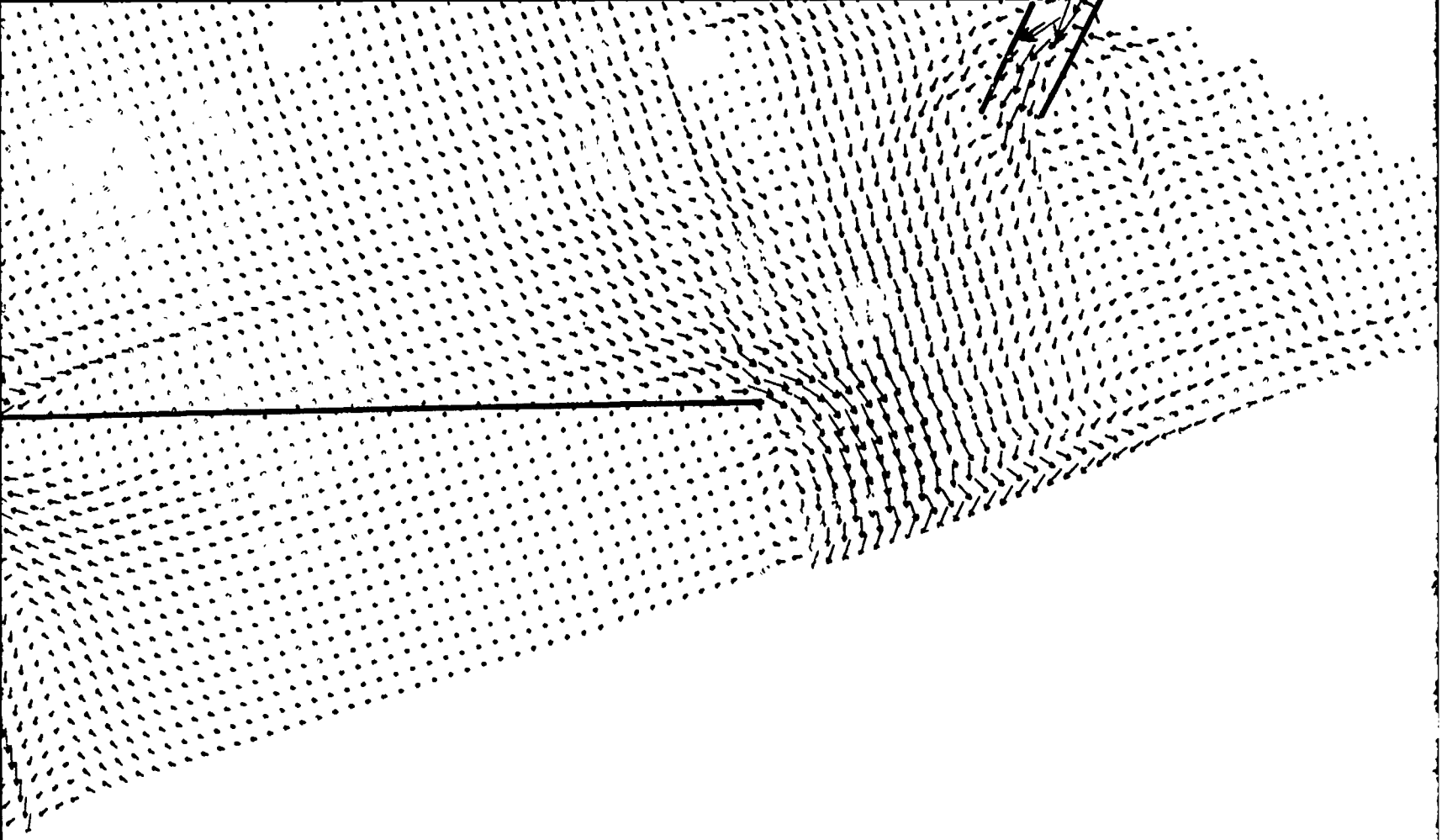


VELOCITY SCALE

1 0 1 2 3

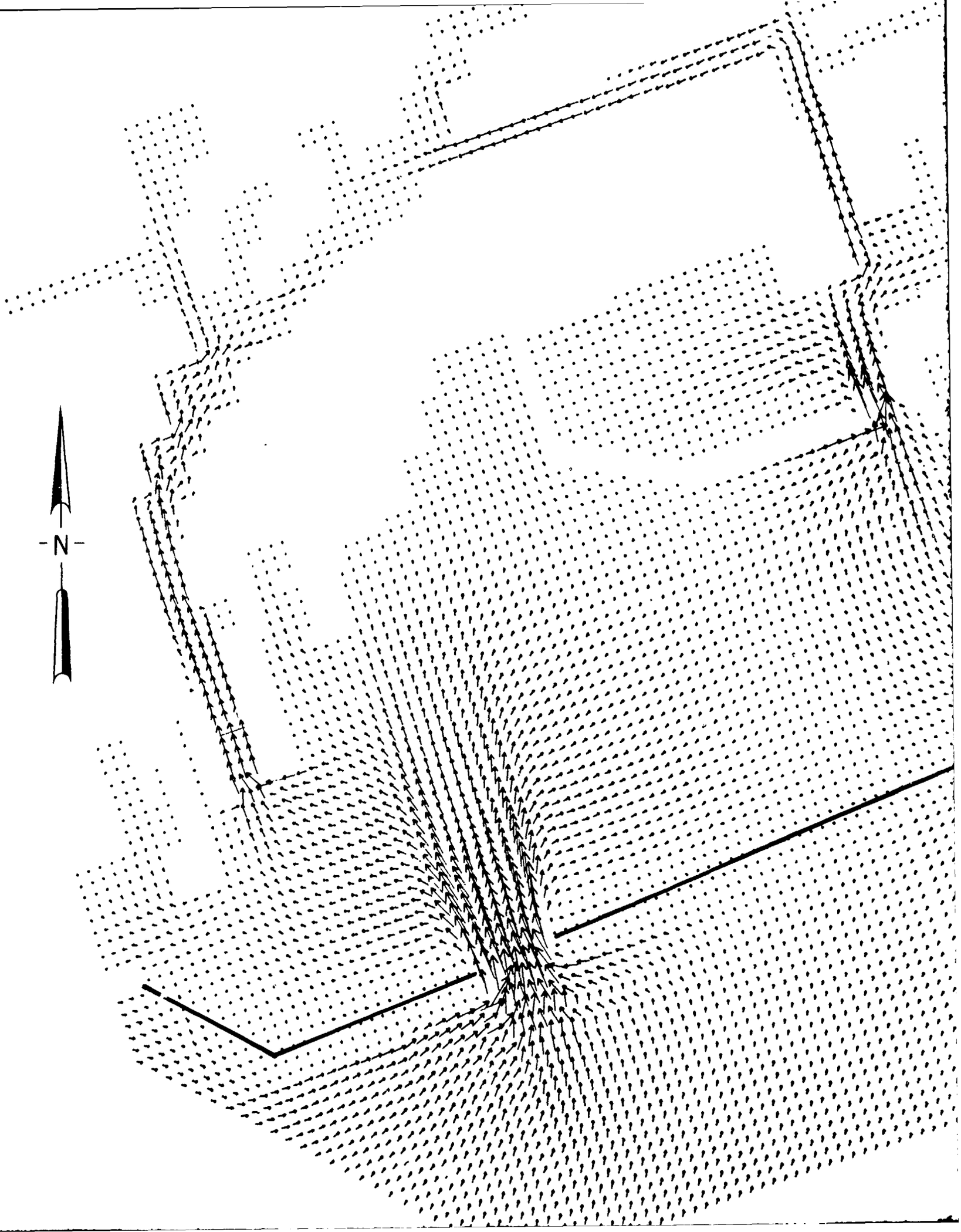
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 2, 300-FT OPENING
-82-FT CHANNEL

SPRING TIDE
HOUR 15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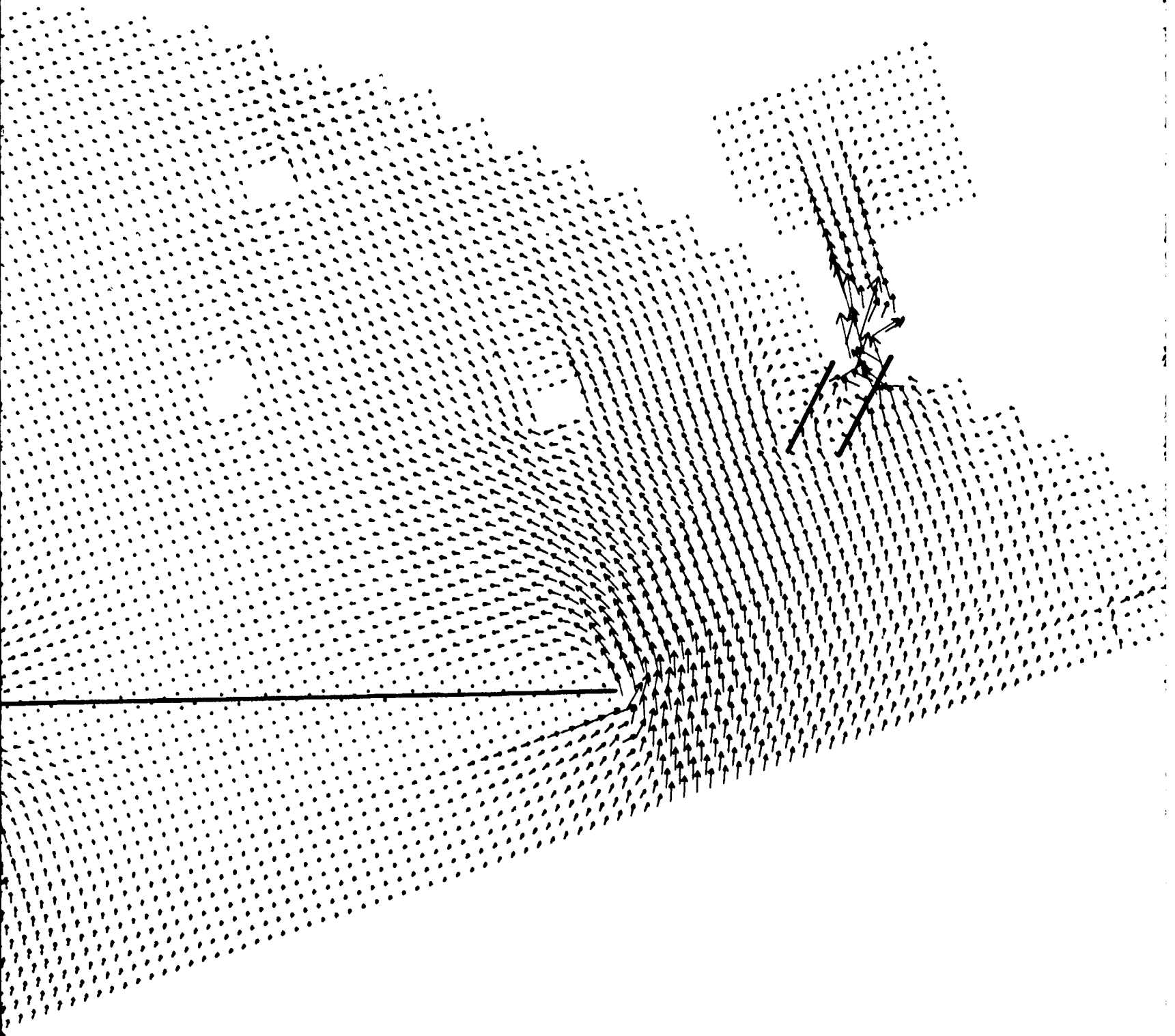


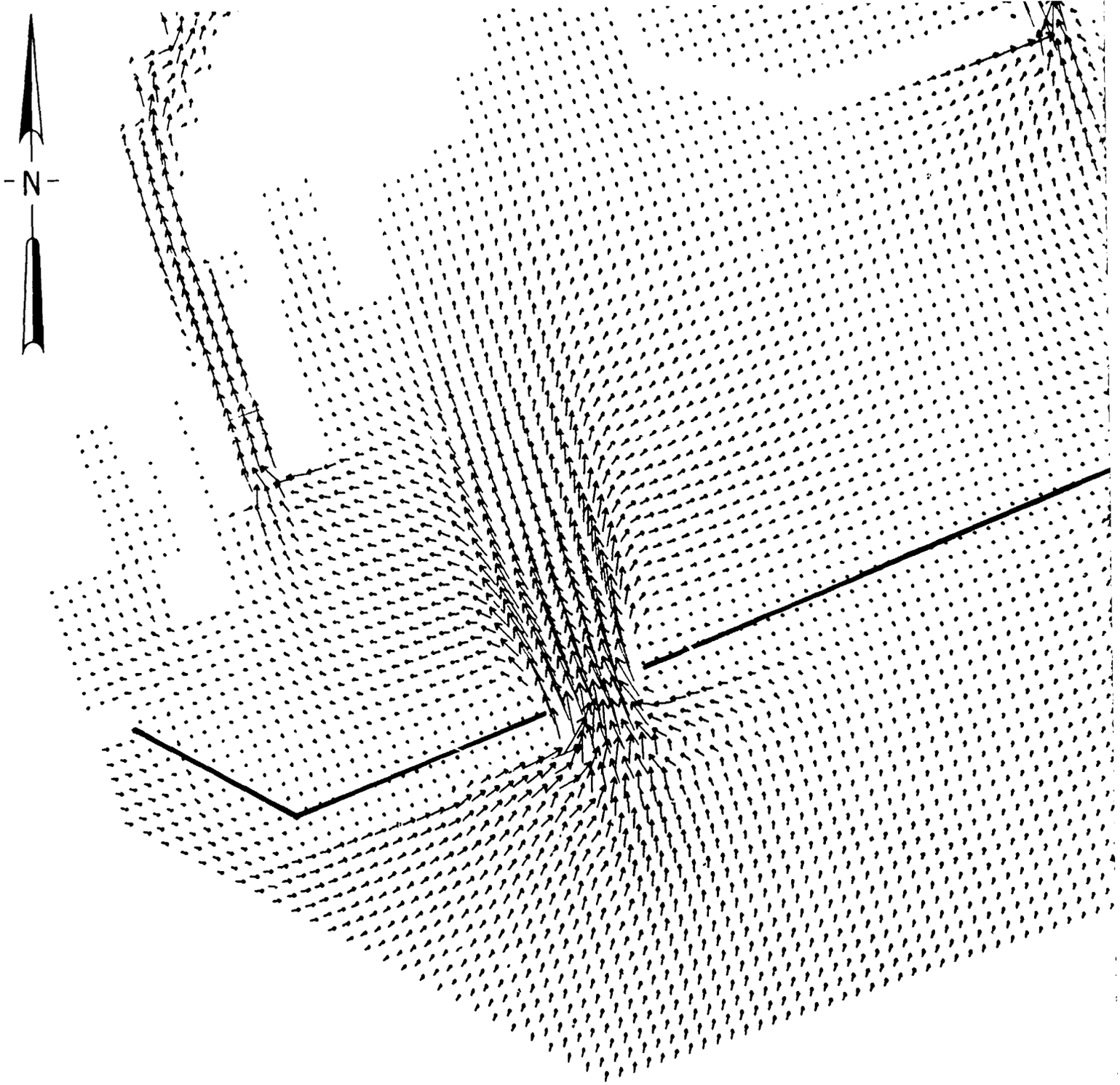
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS



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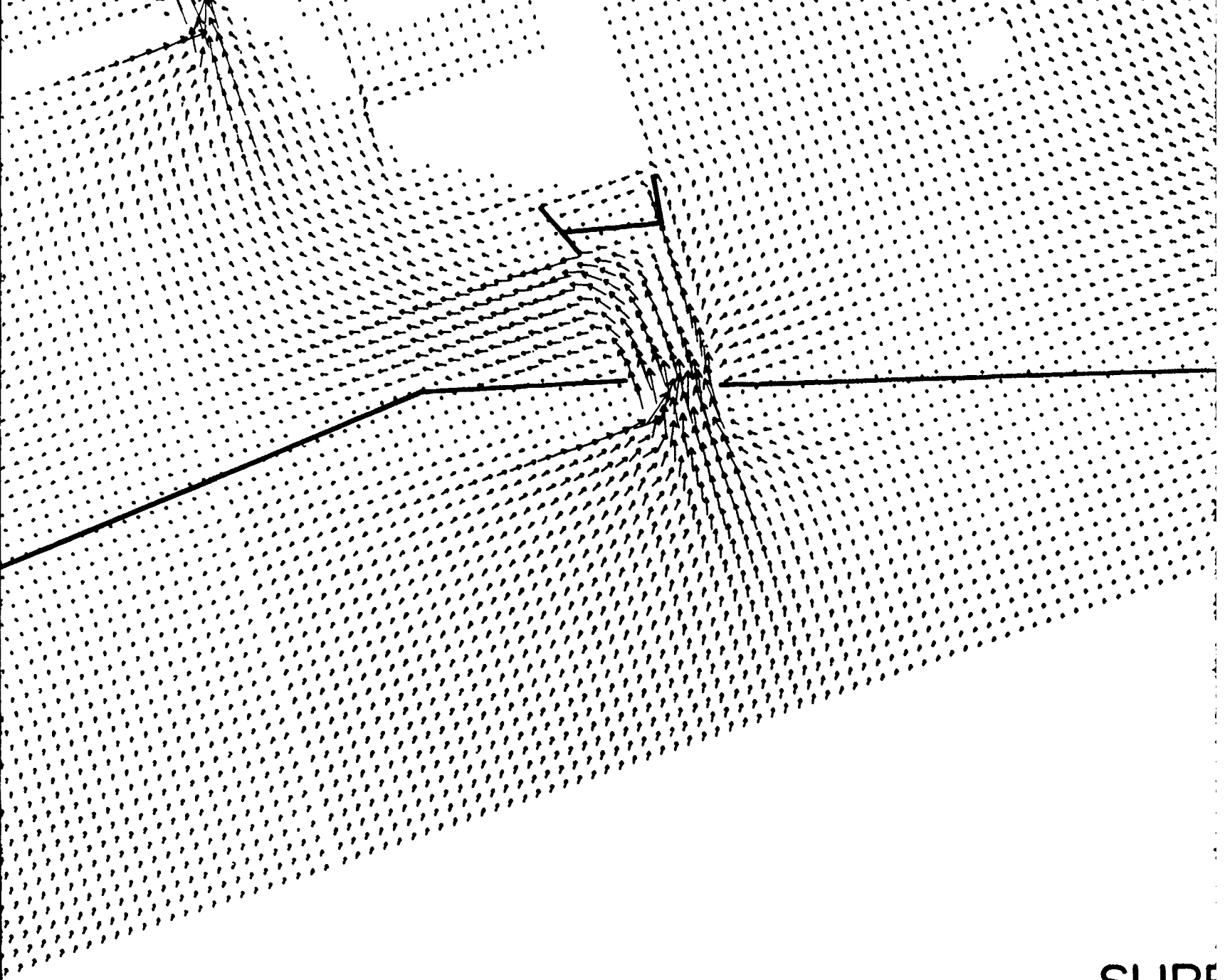

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SCALE IN FEET

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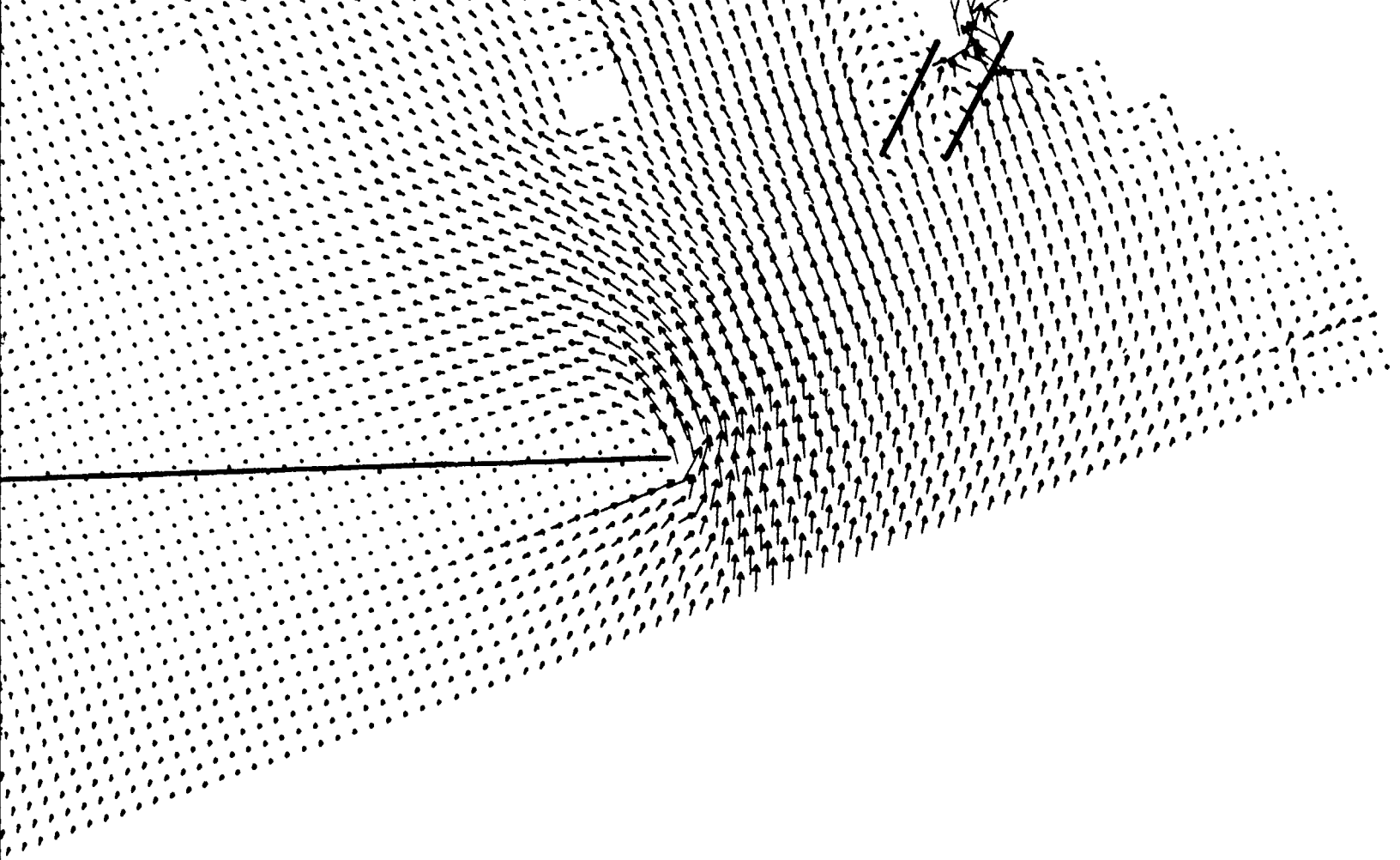


VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

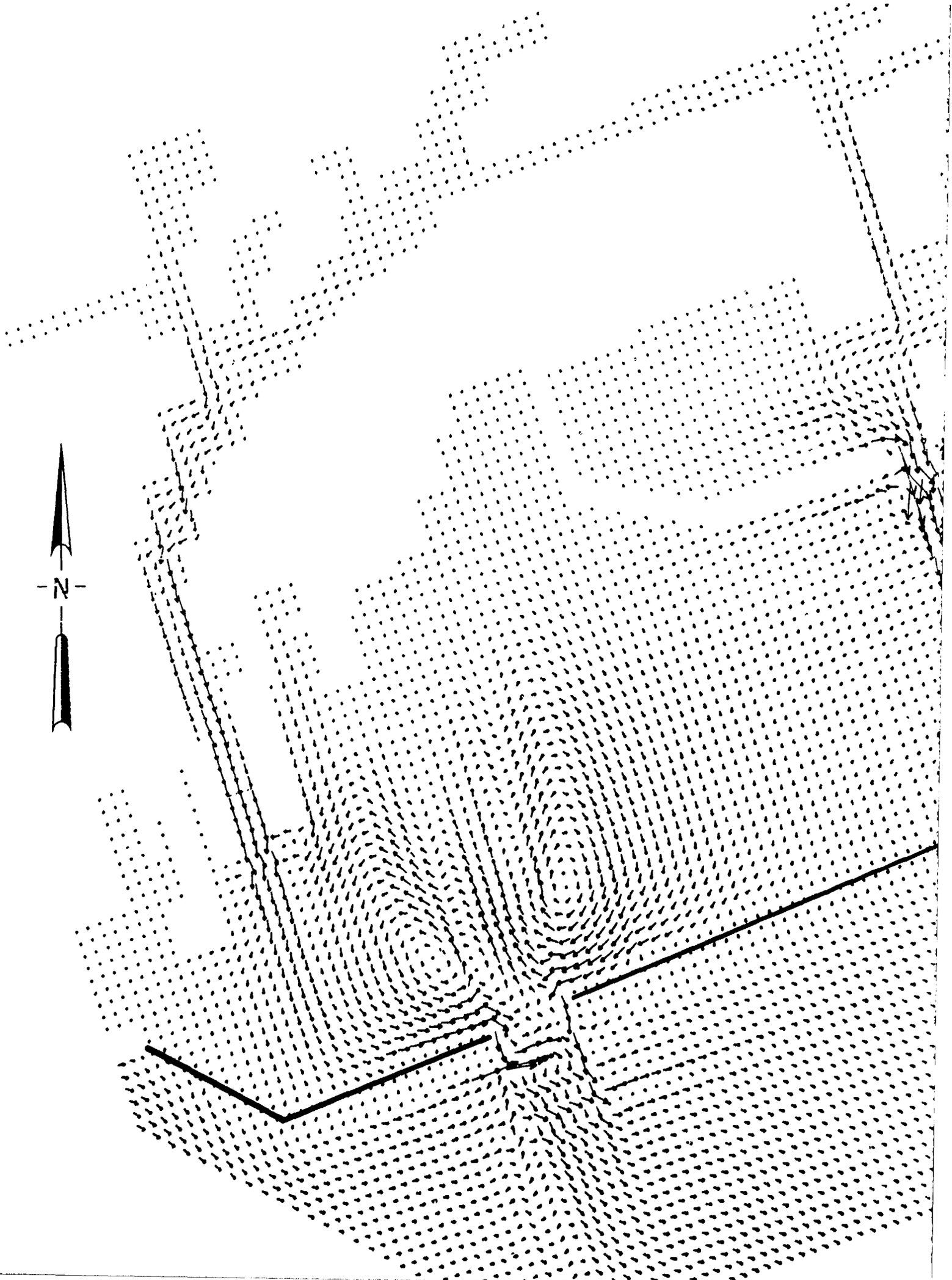
NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 2, 300-FT OPENING
-82-FT CHANNEL

SPRING TIDE
HOUR 19

FIGURE 10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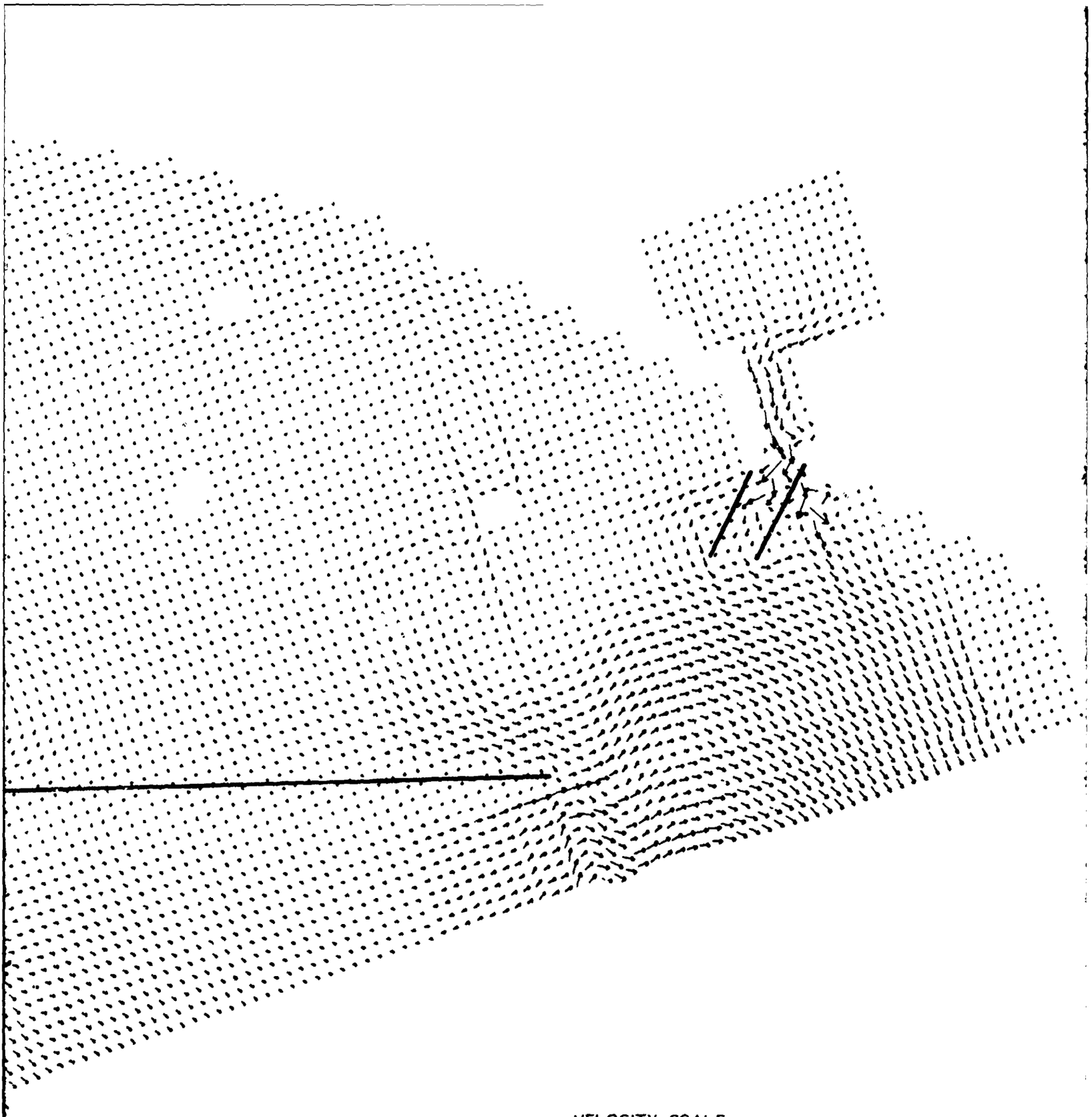


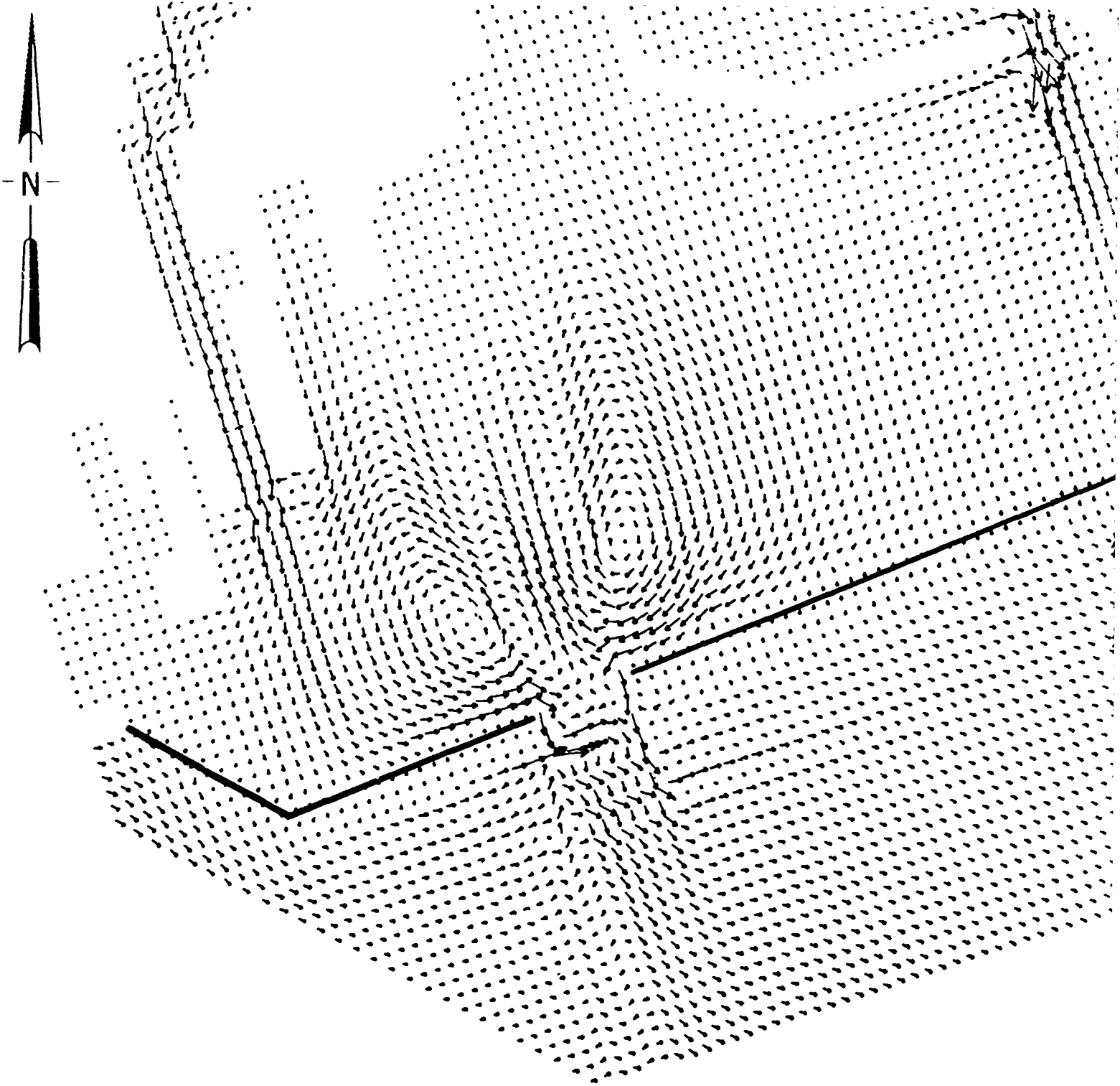
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS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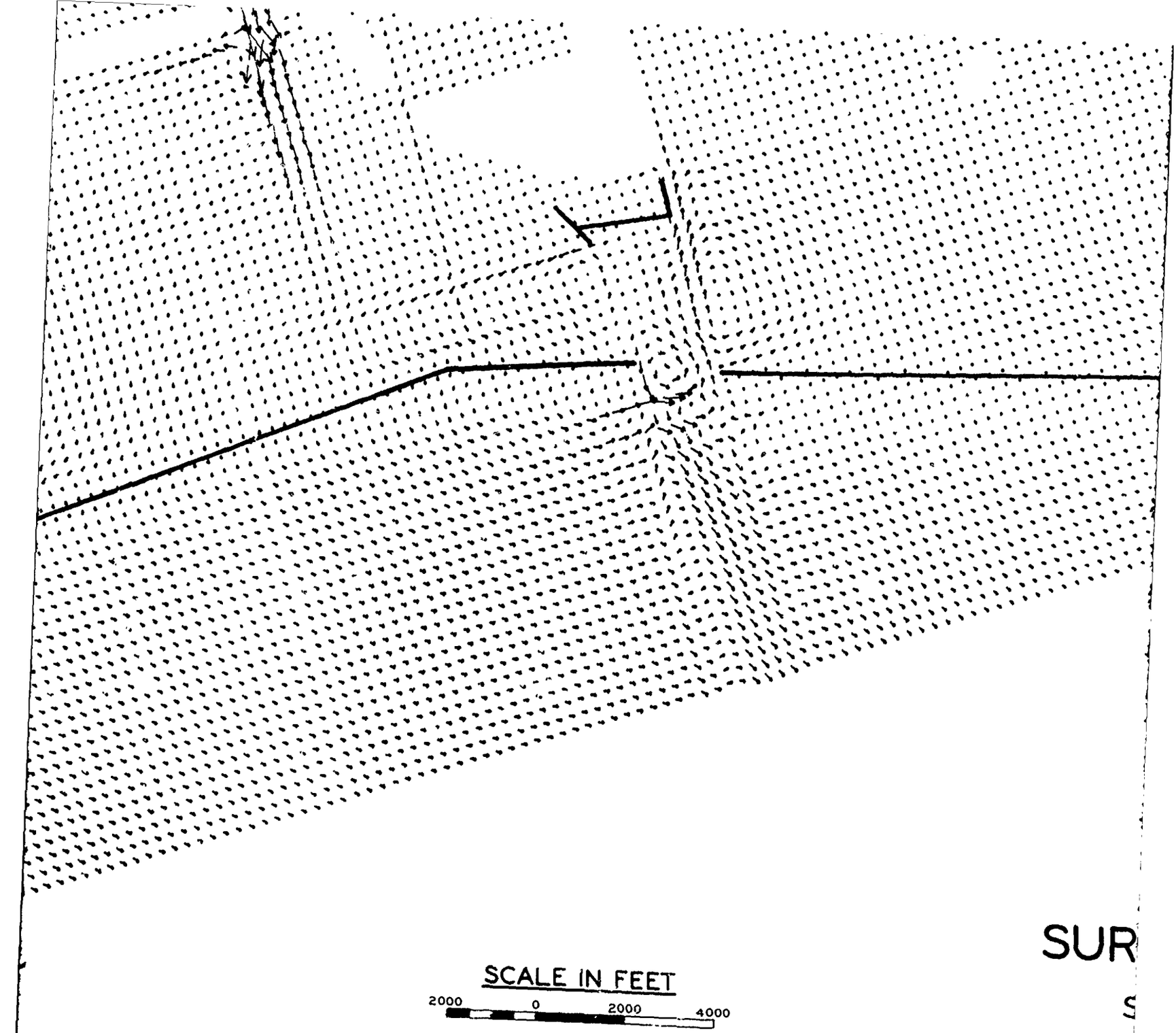

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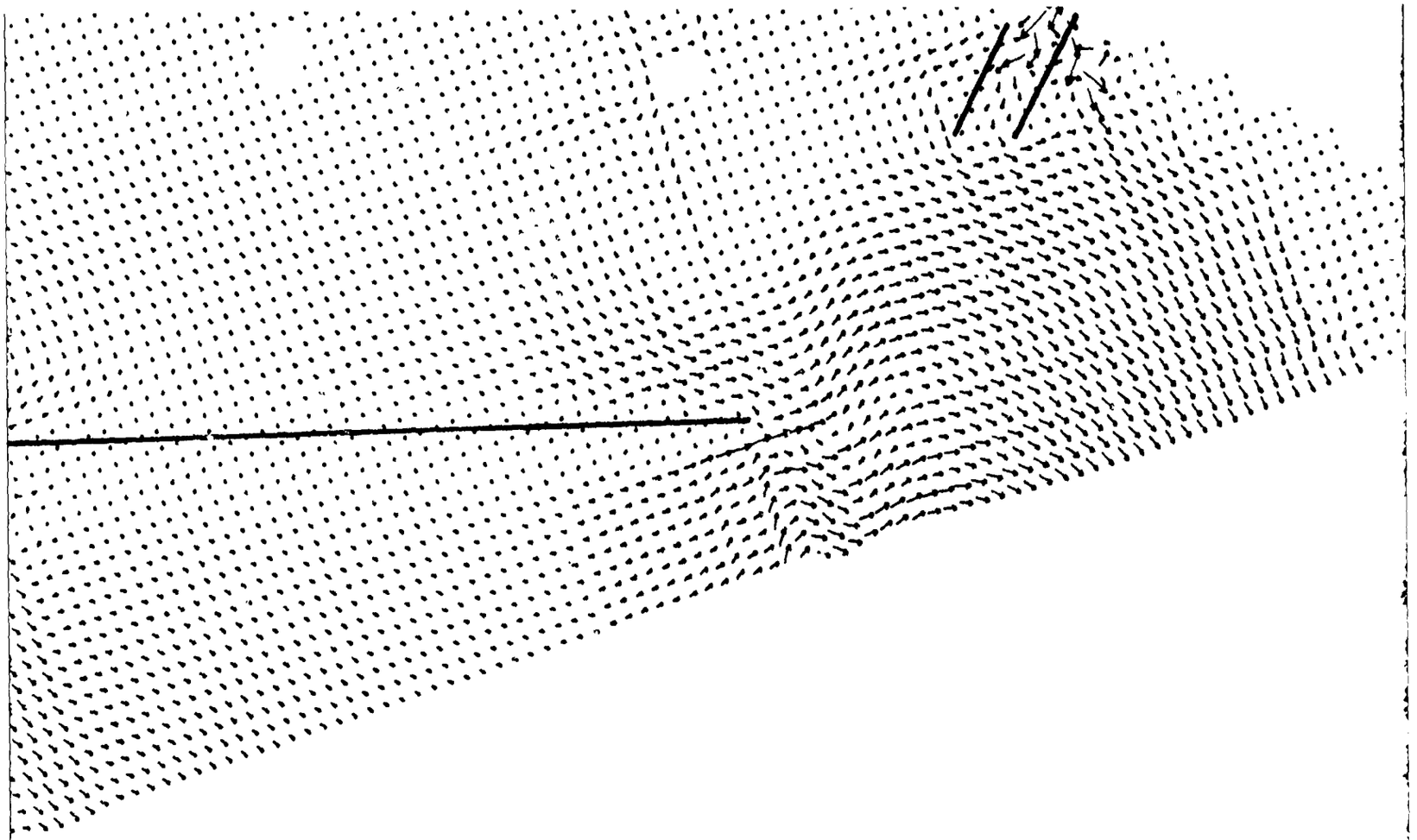


VELOCITY SCALE

1 0 1 2 3

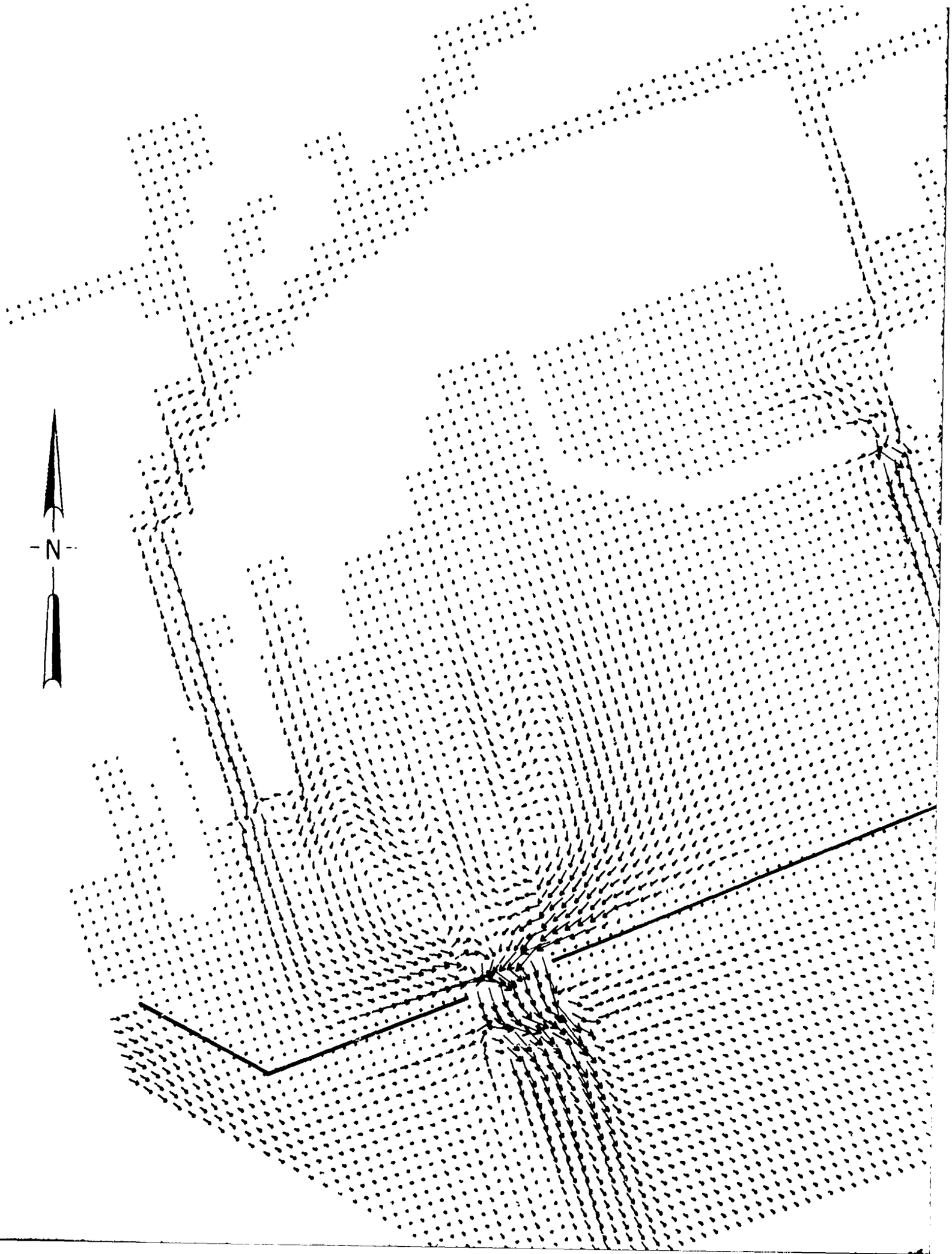
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 2, 300-FT OPENING
-82-FT CHANNEL

SPRING TIDE
HOUR 22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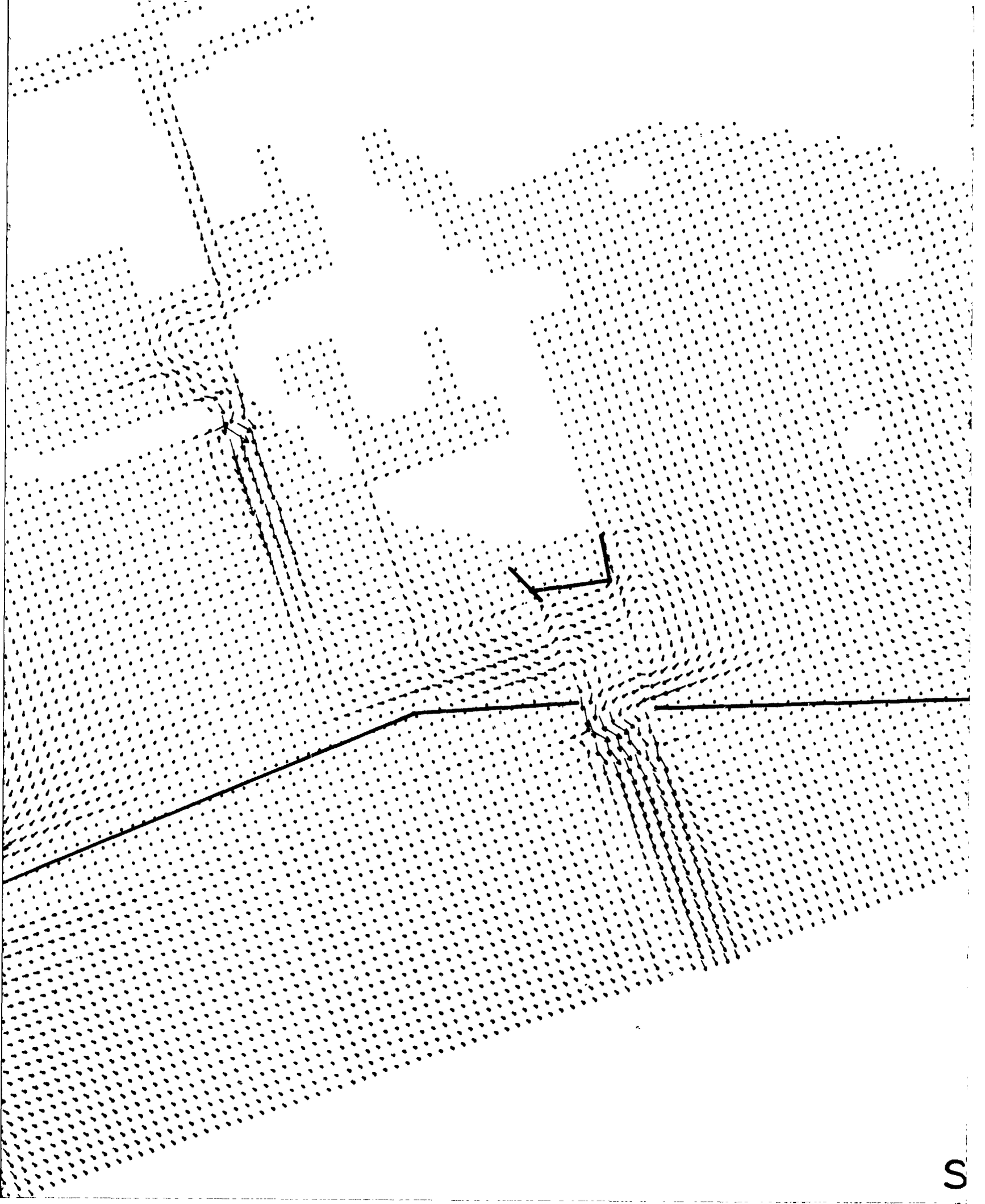
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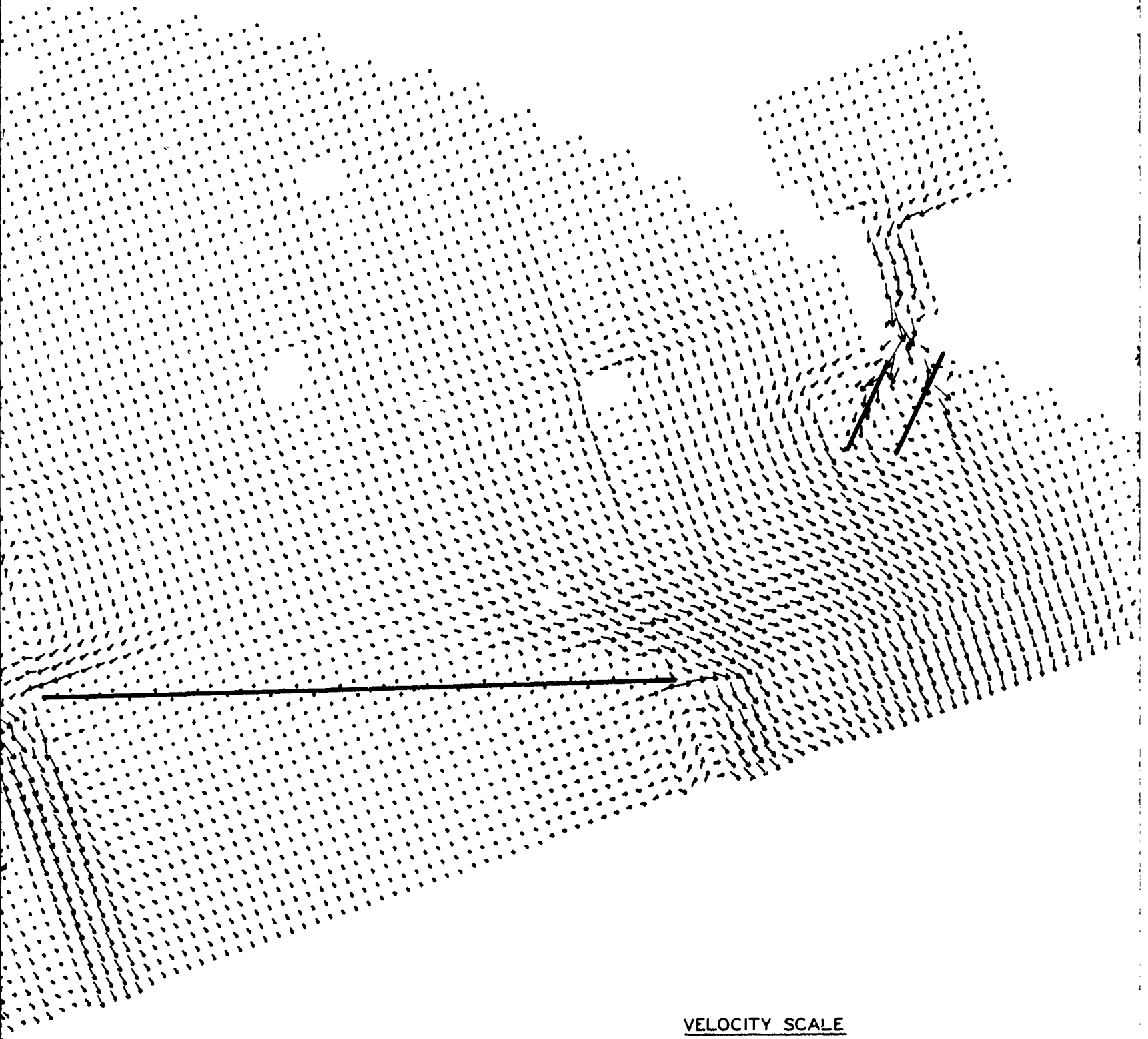


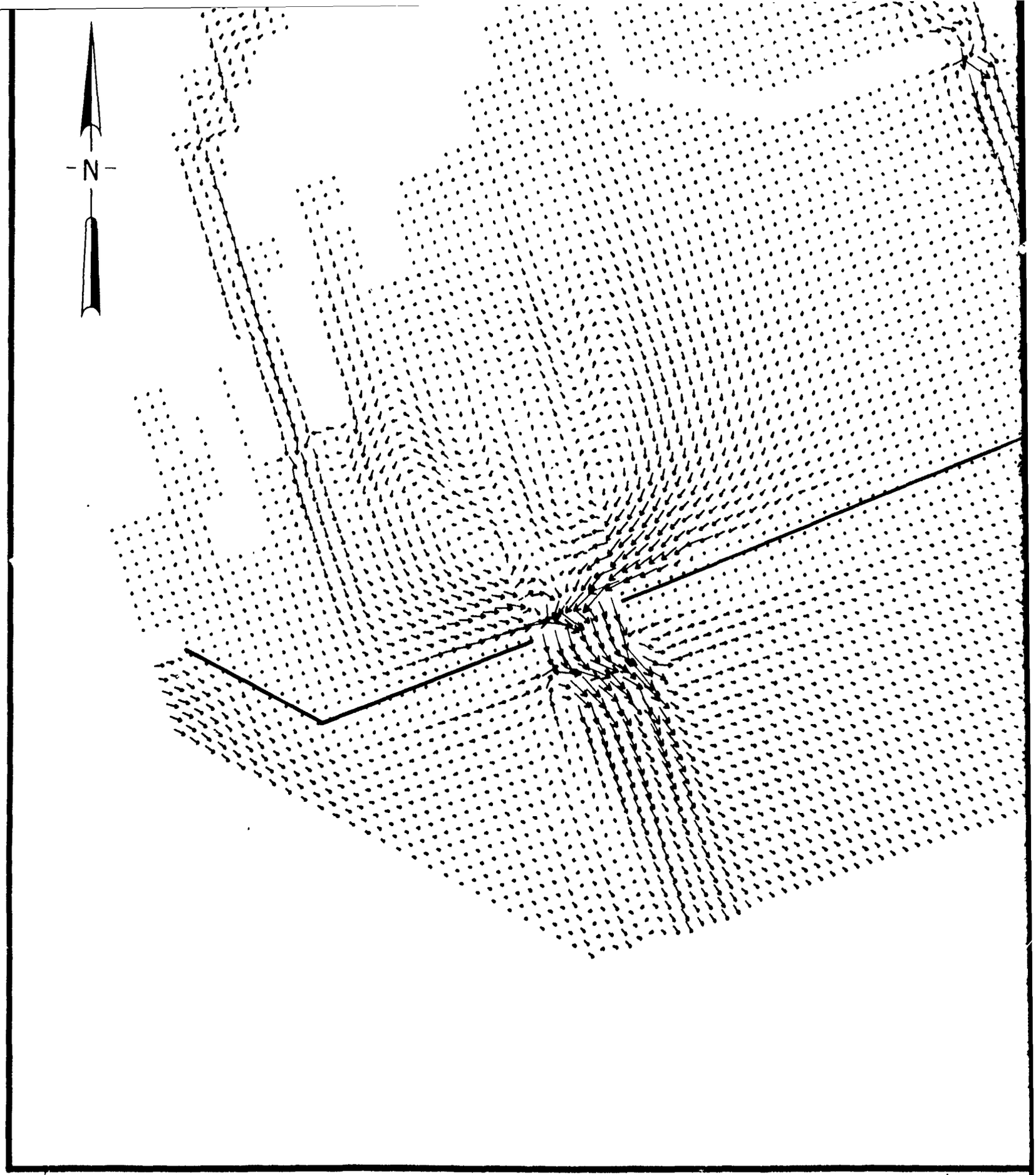
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS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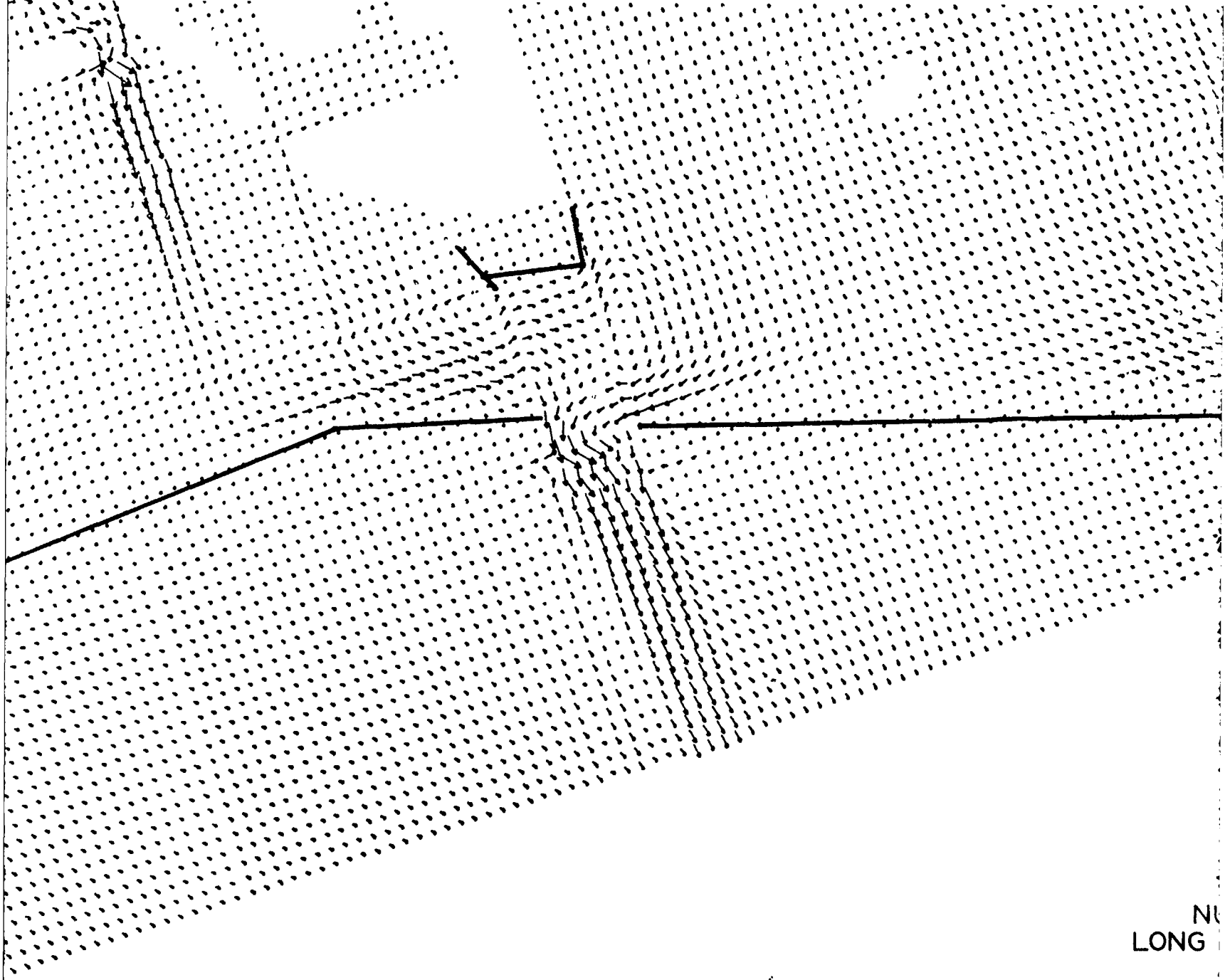

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SCALE IN FEET

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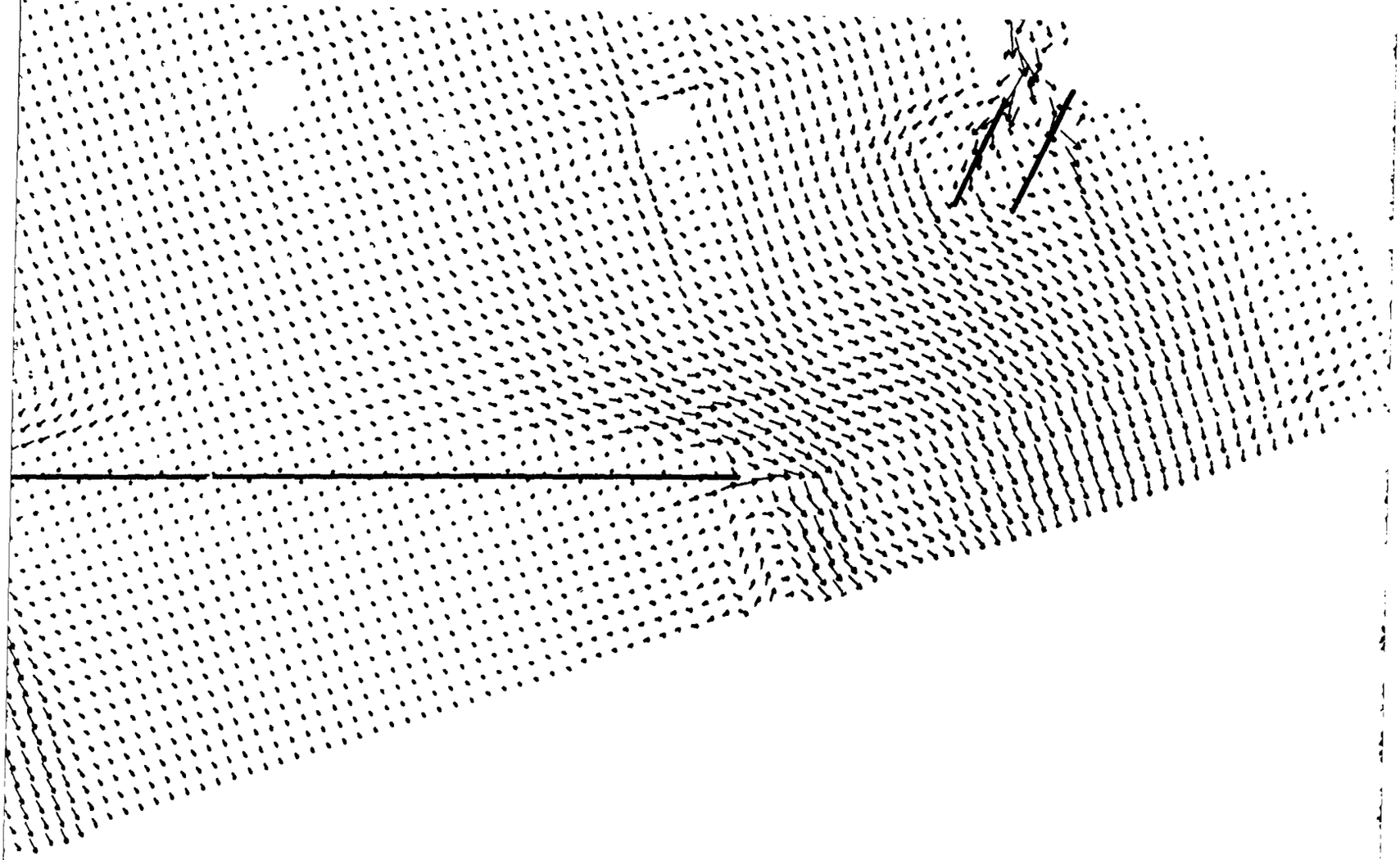


VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

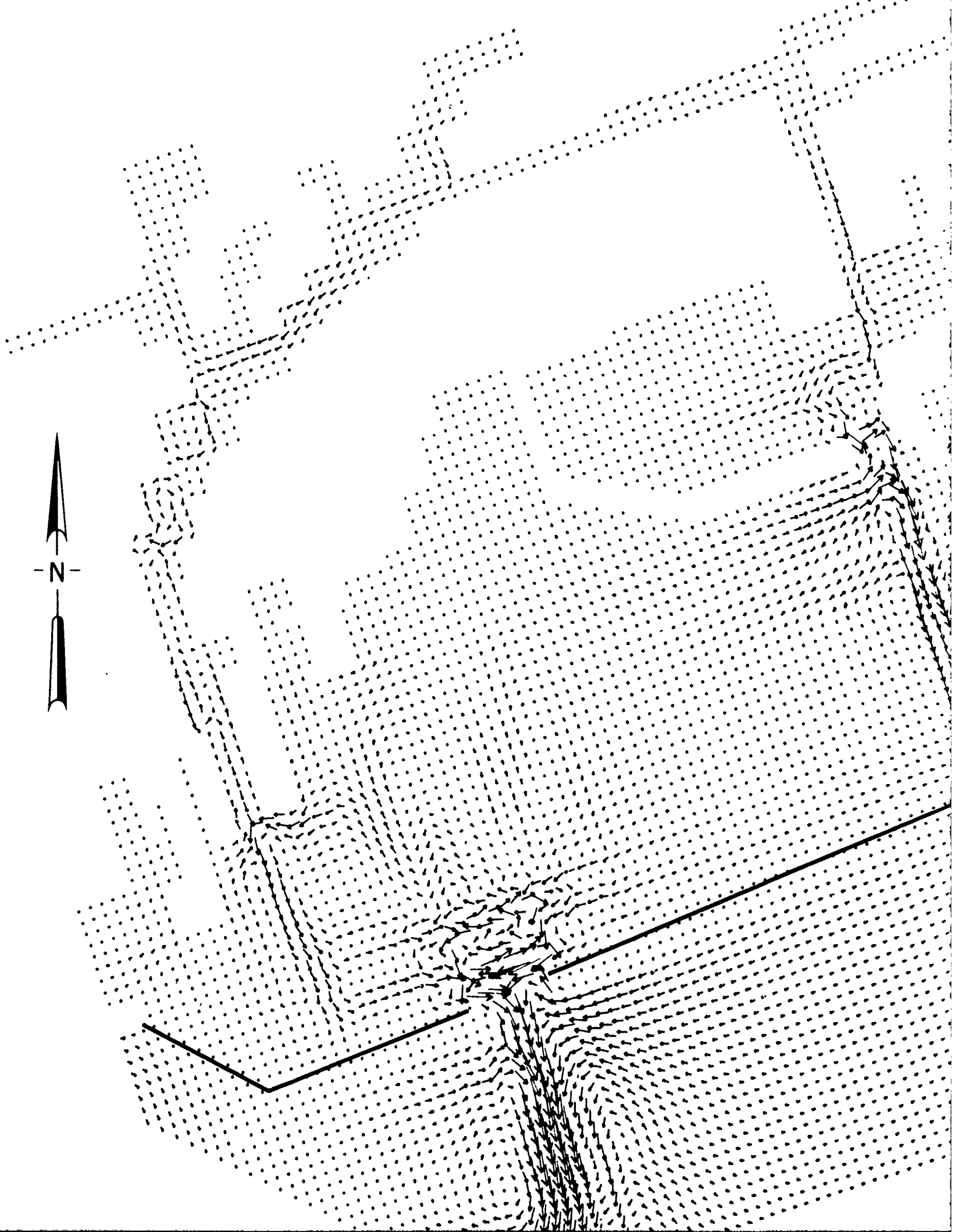
NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 2, 300-FT OPENING
-82-FT CHANNEL

SPRING TIDE
HOUR 24

FIGU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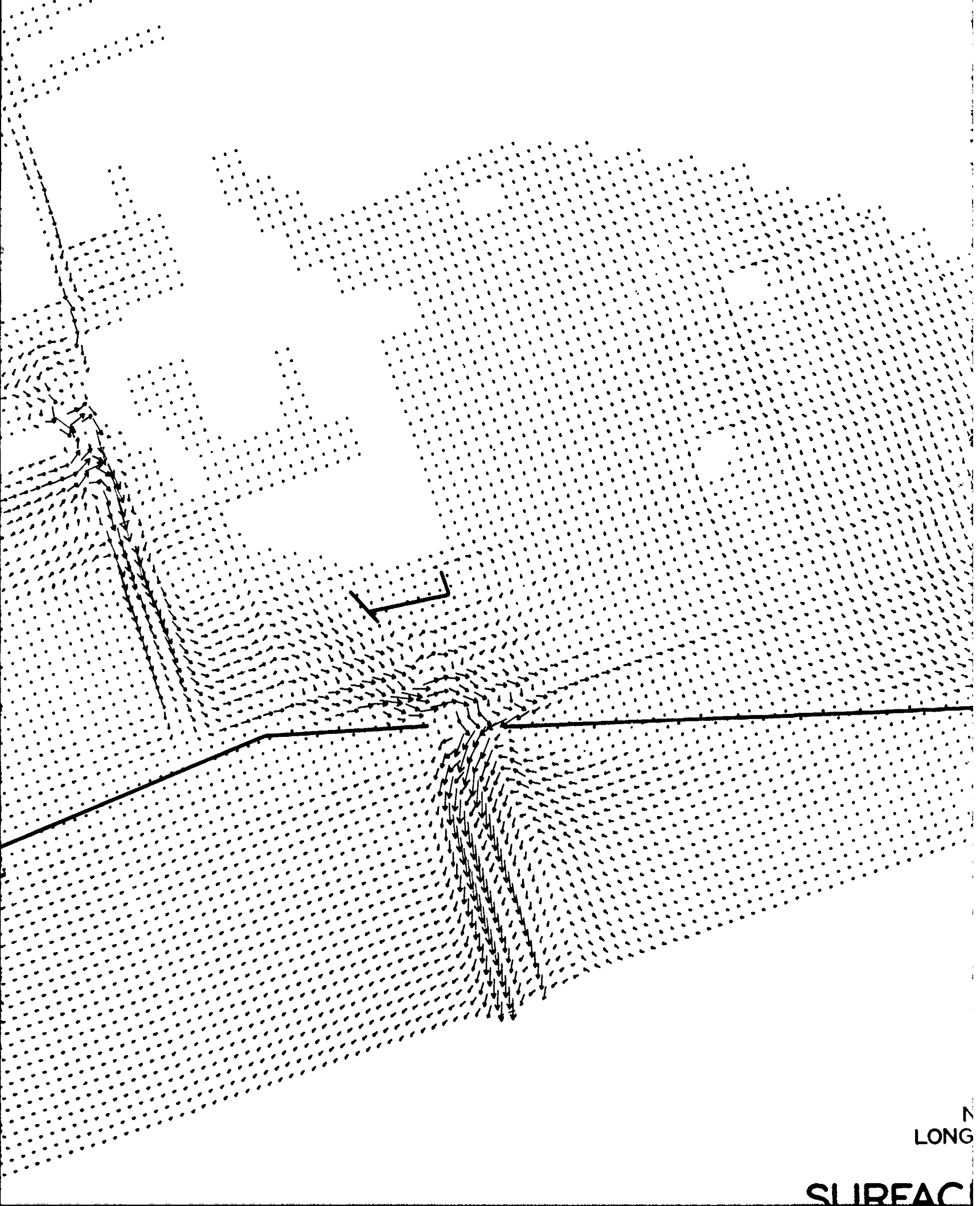
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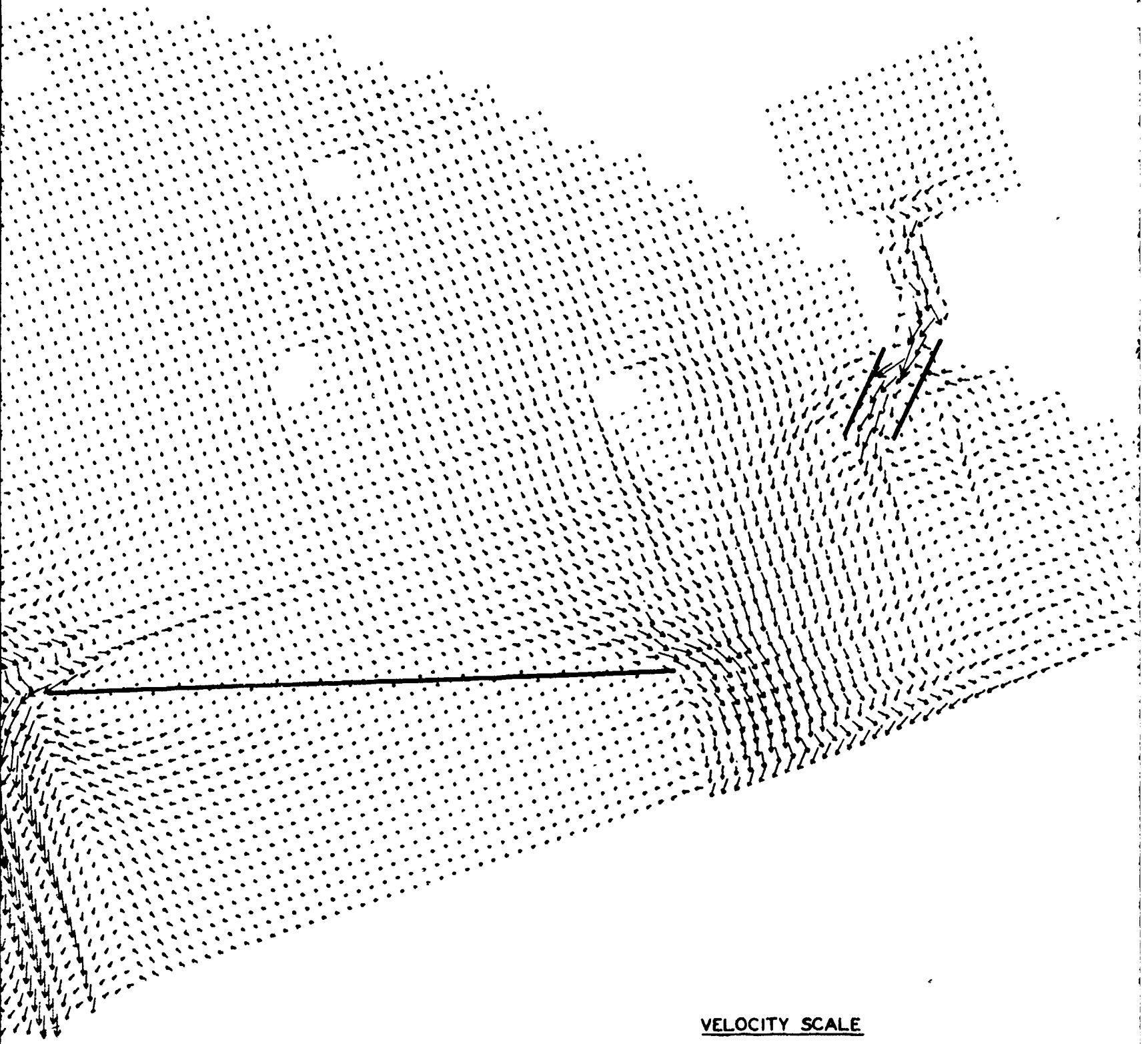


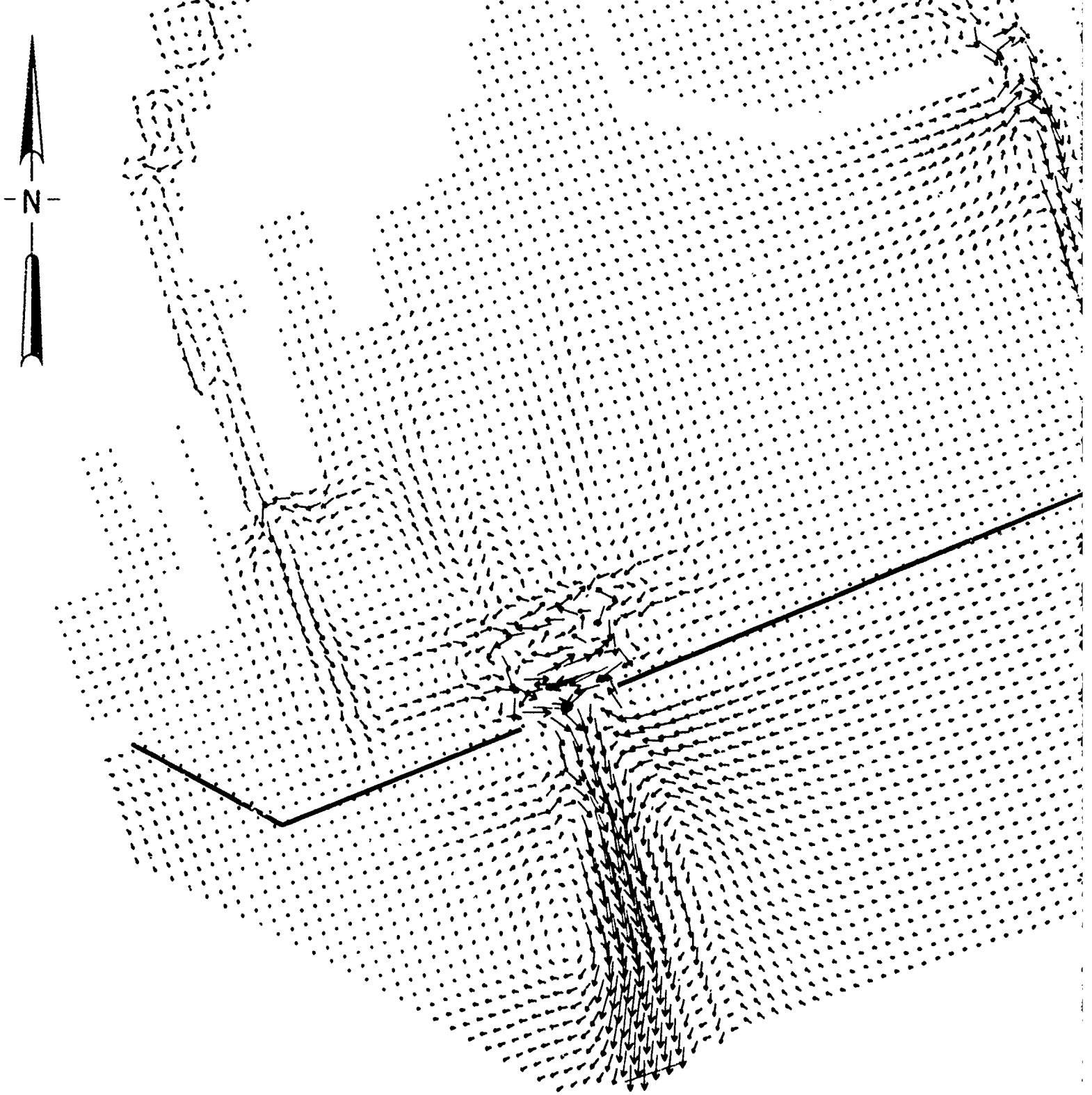
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERN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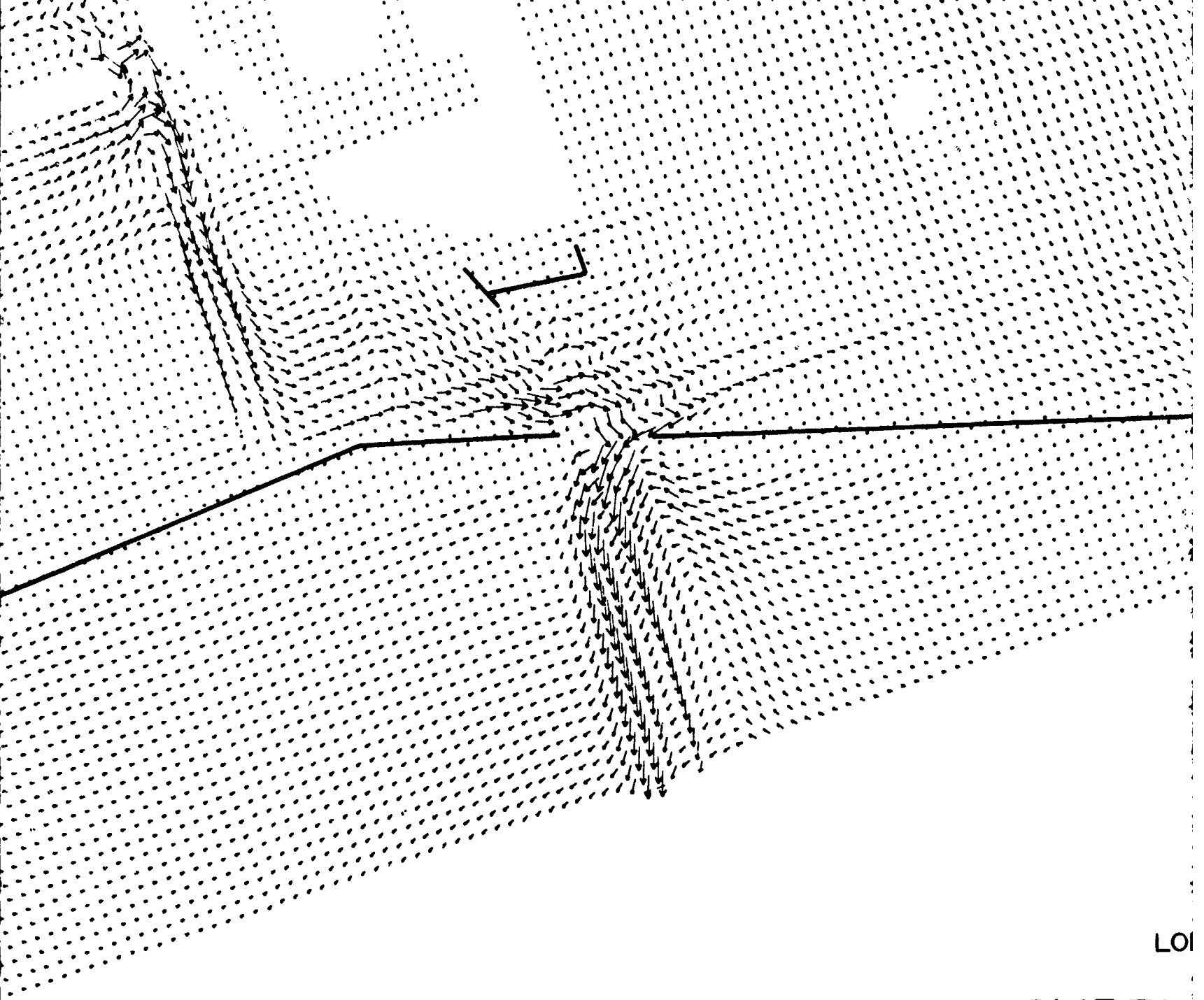

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SCALE IN FEET

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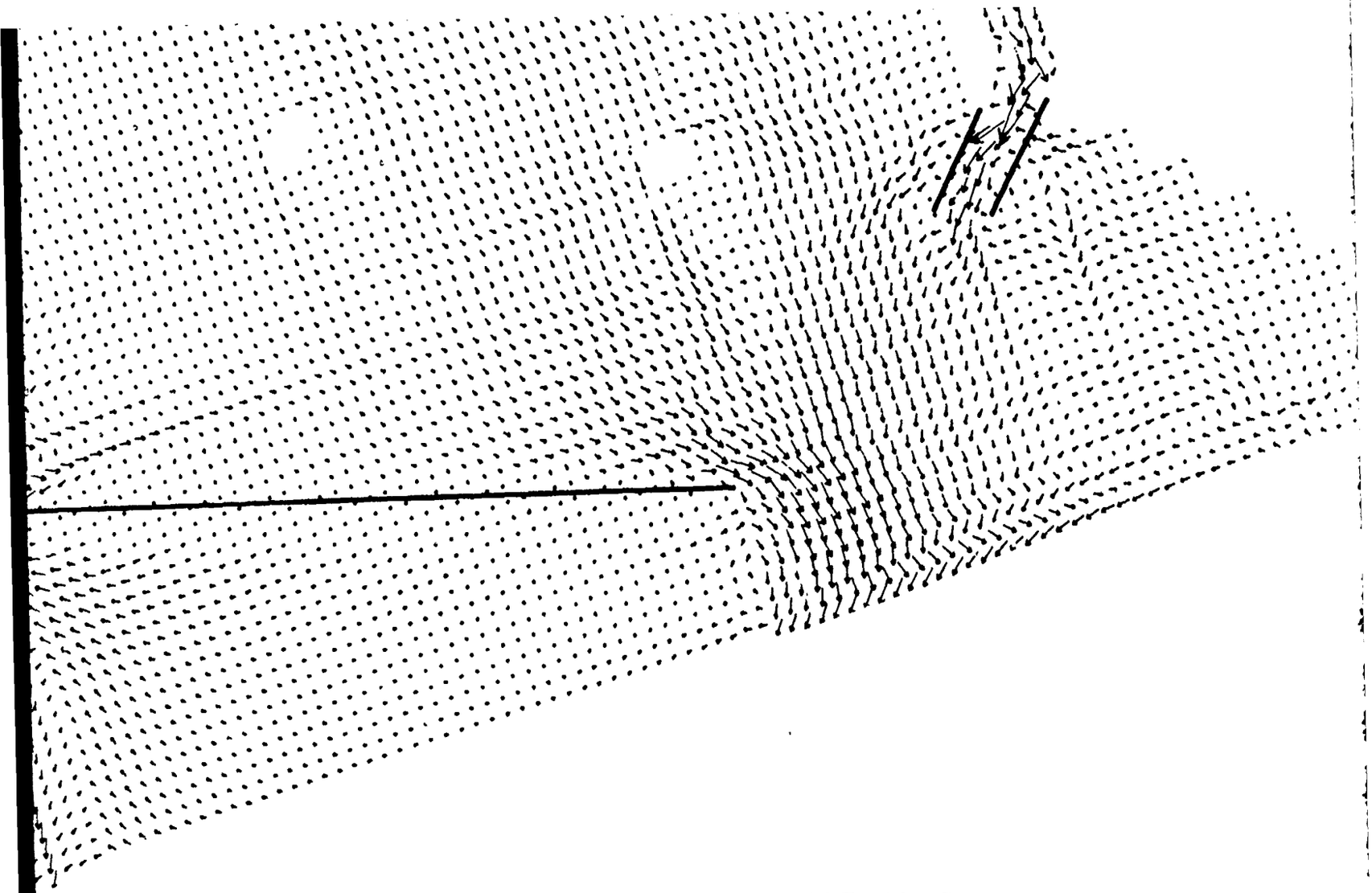


VELOCITY SCALE

1 0 1 2 3

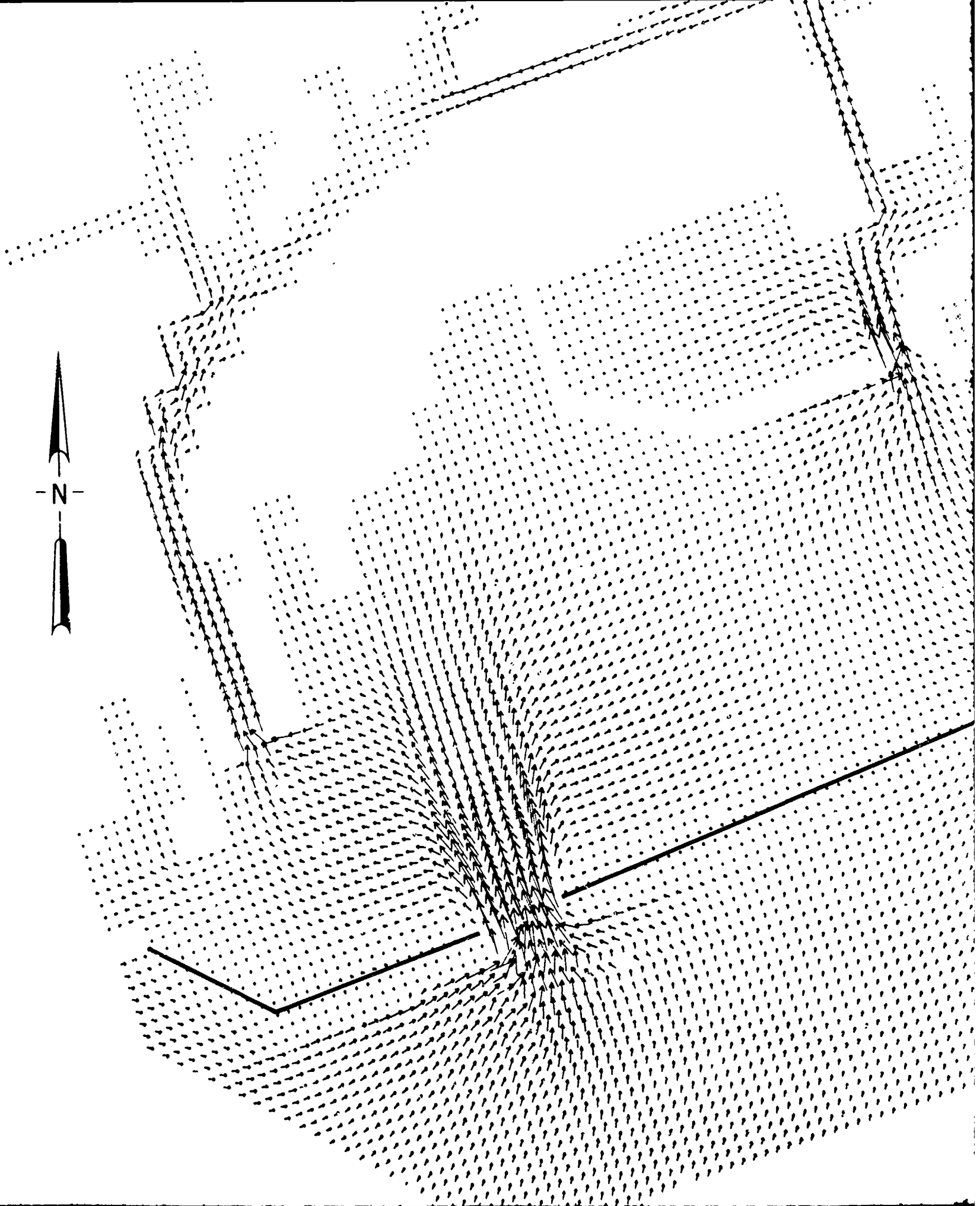
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 2, 600-FT OPENING
-82-FT CHANNEL

SPRING TIDE
HOUR 15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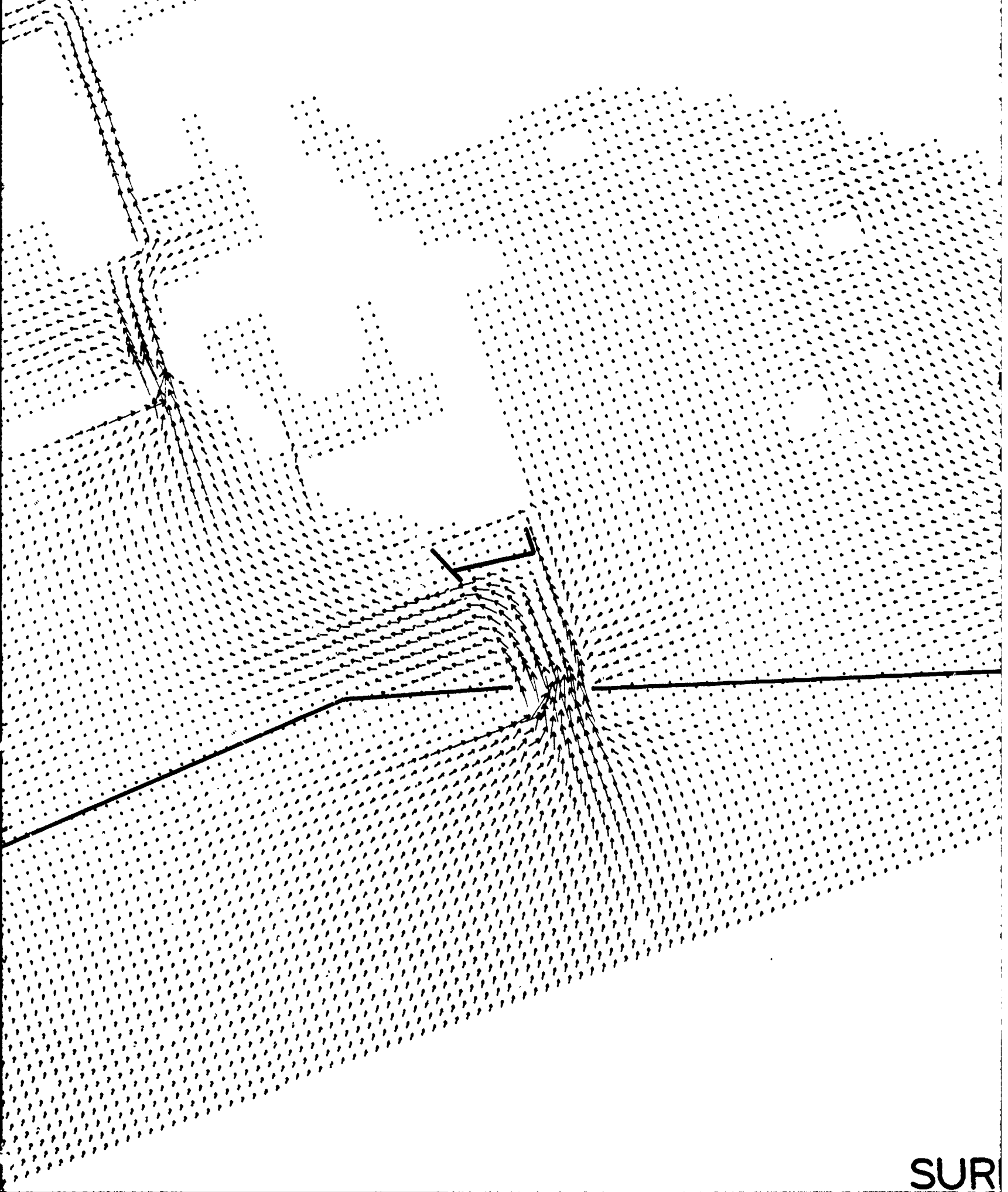

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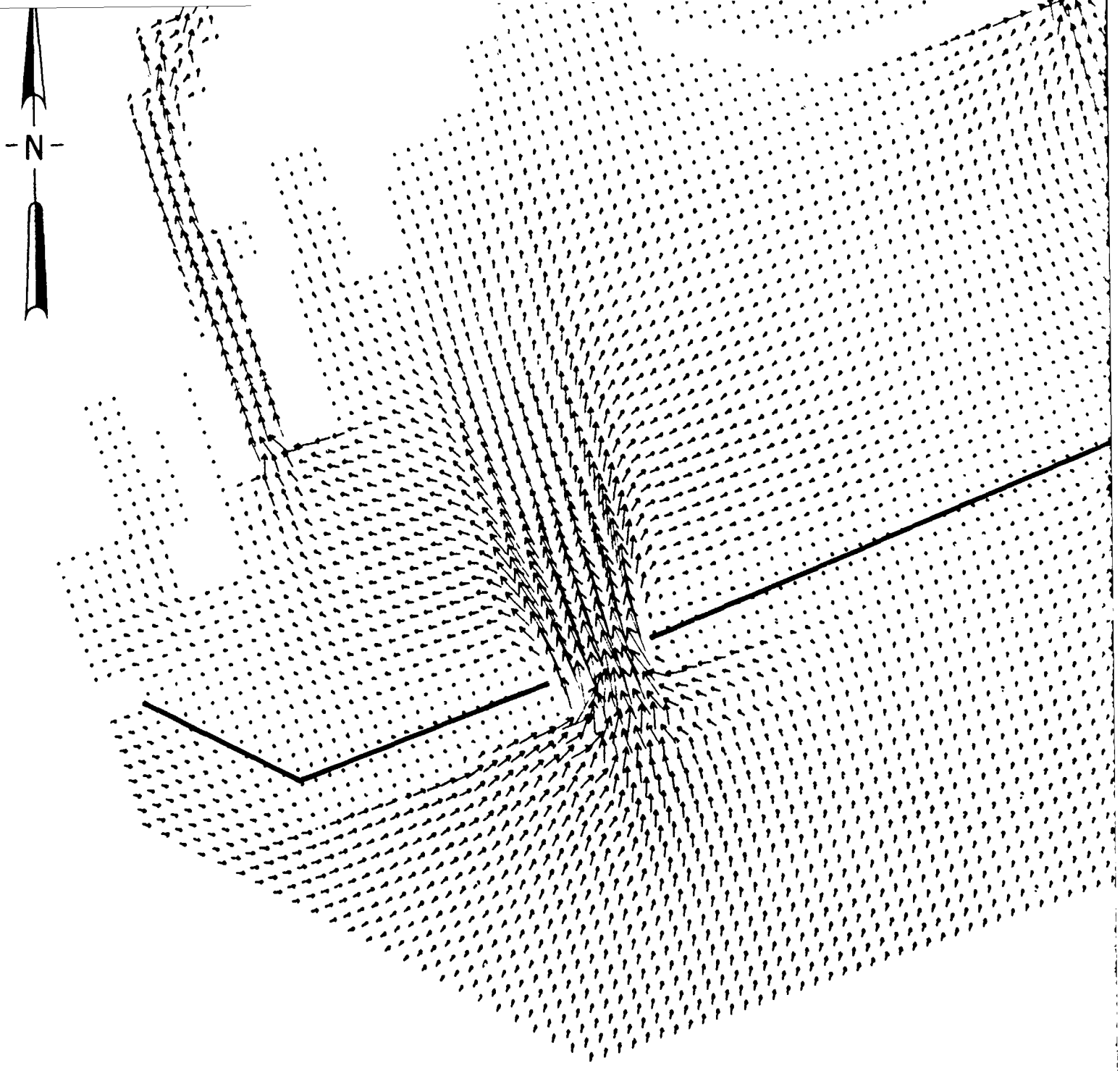
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS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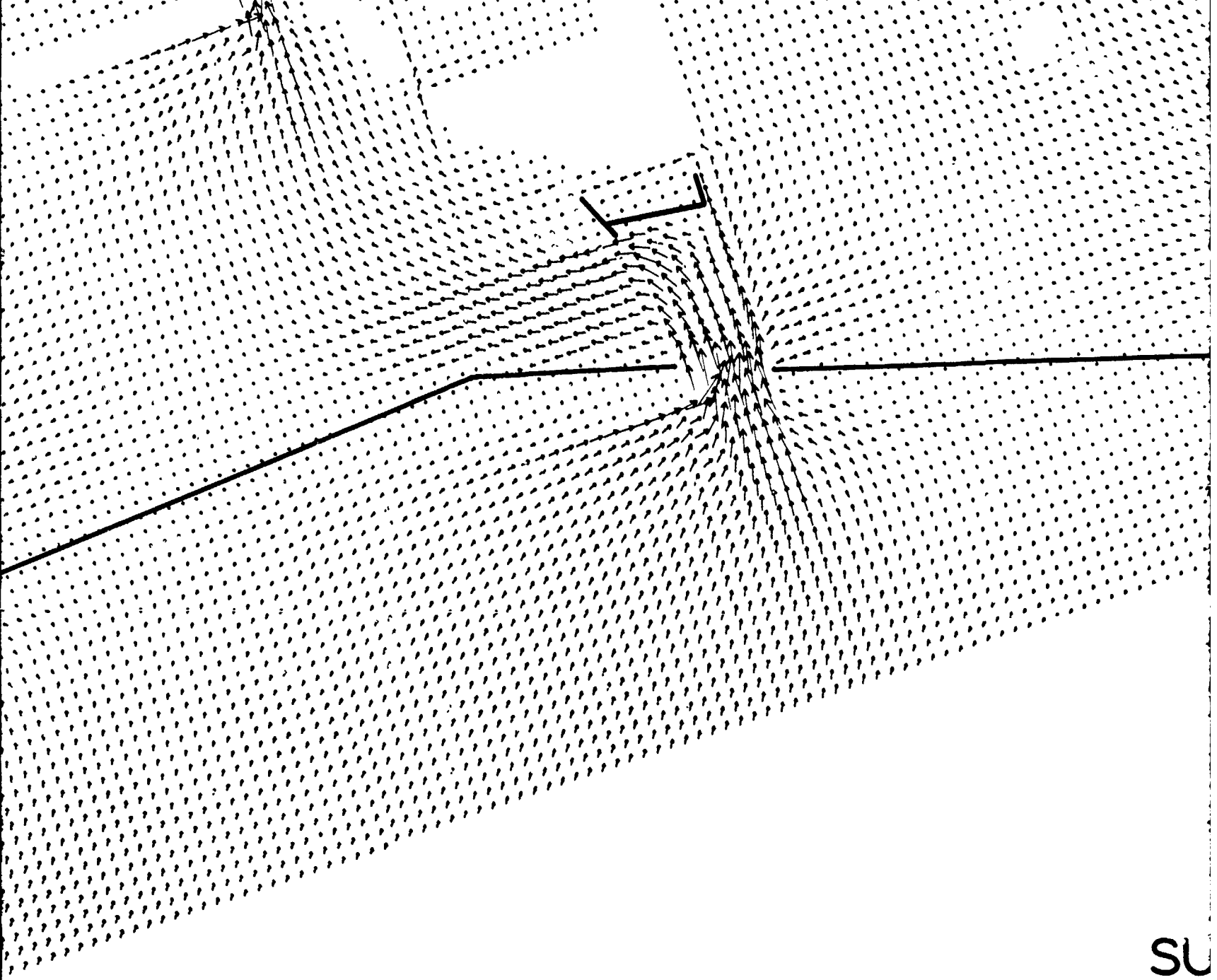

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SCALE IN FEET

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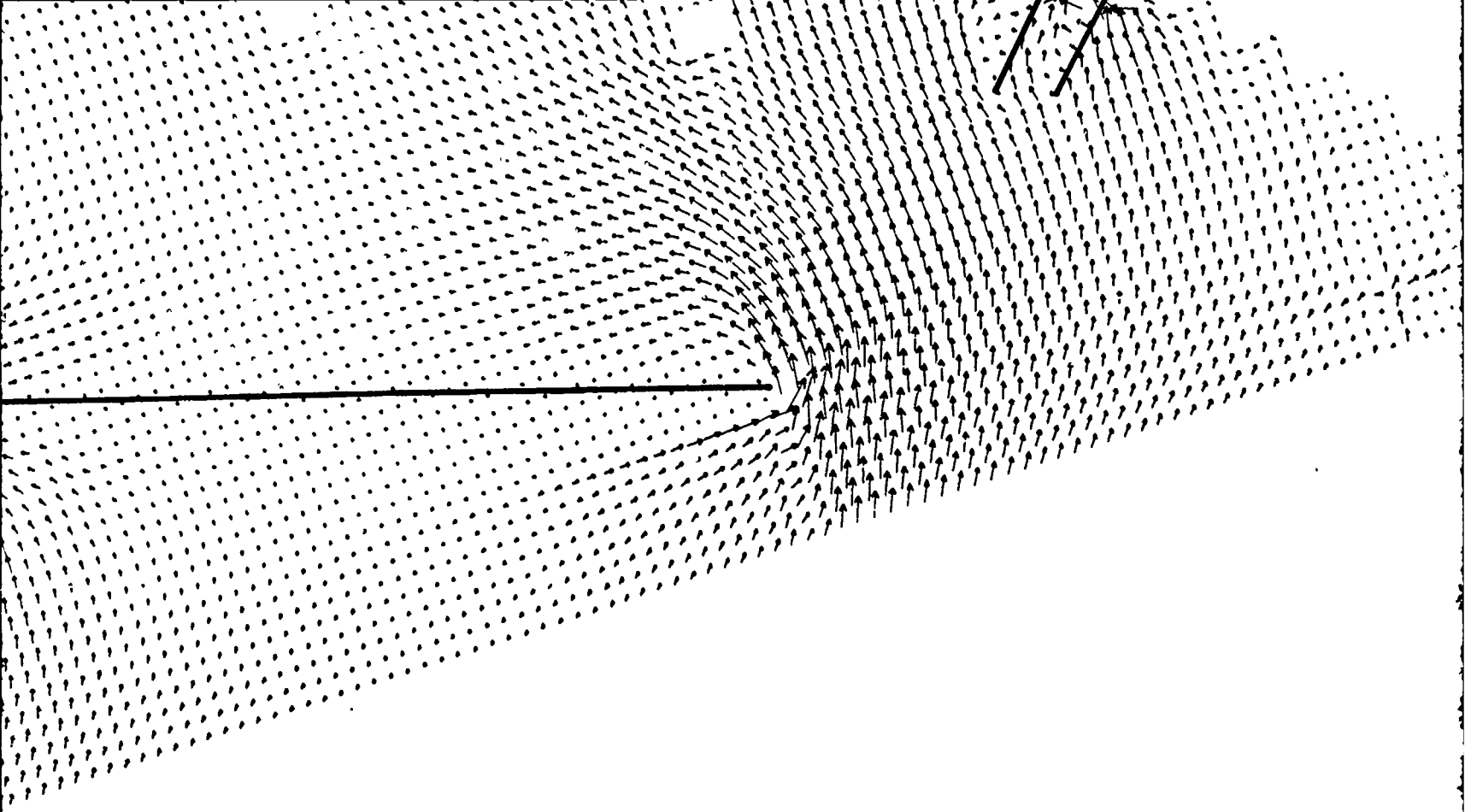


VELOCITY SCALE

1 0 1 2 3

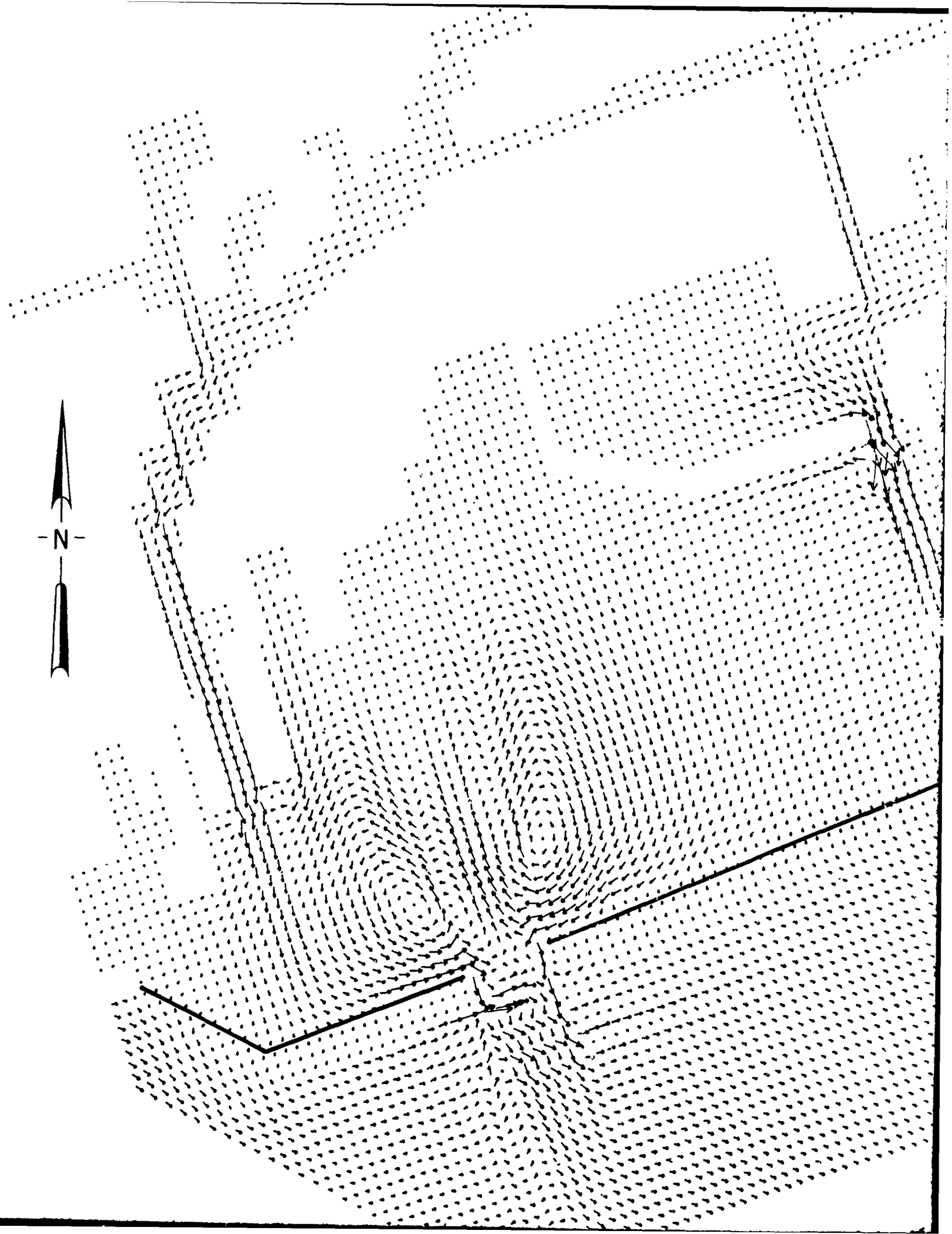
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 2, 600-FT OPENING
-82-FT CHANNEL

SPRING TIDE
HOUR 19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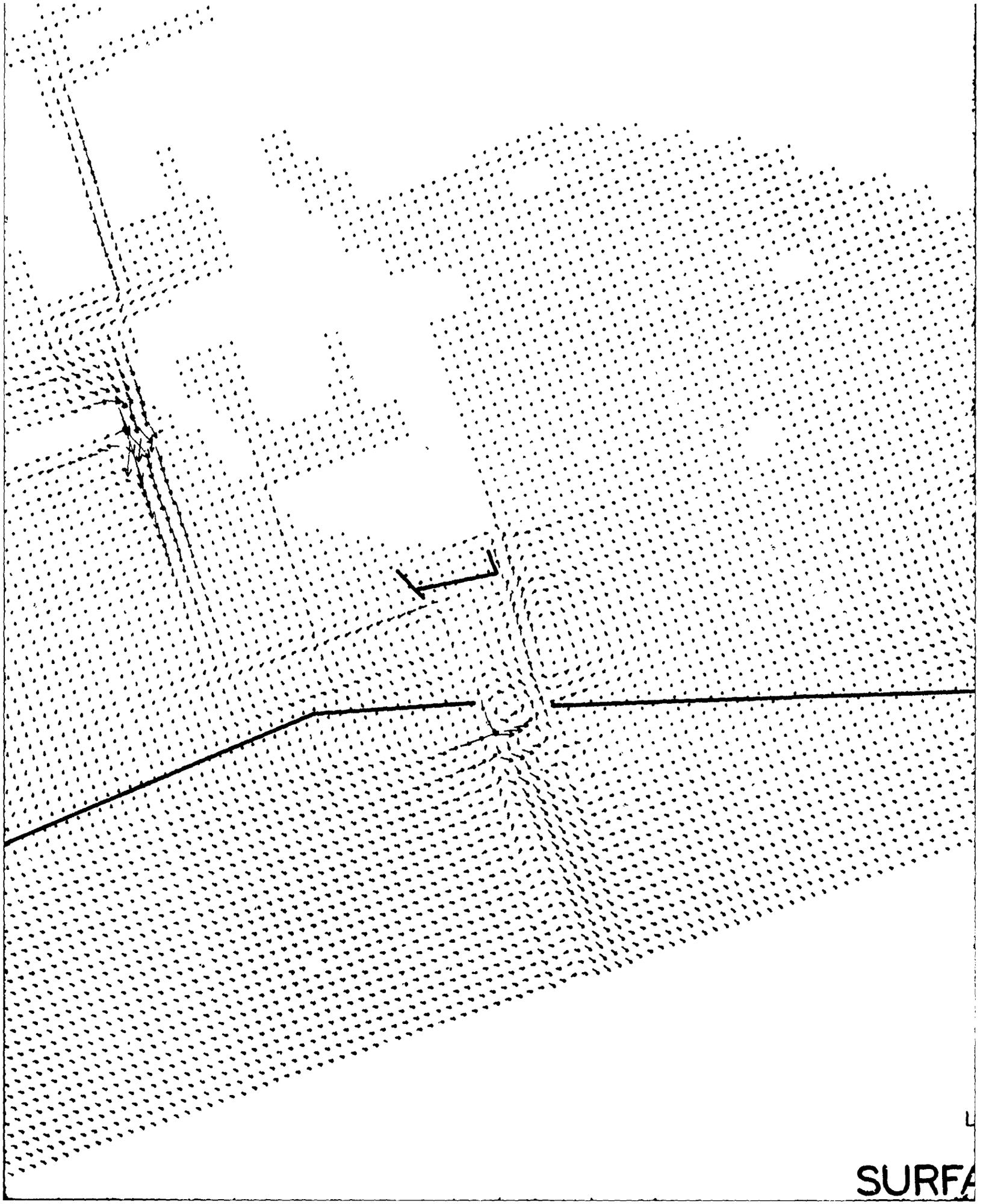
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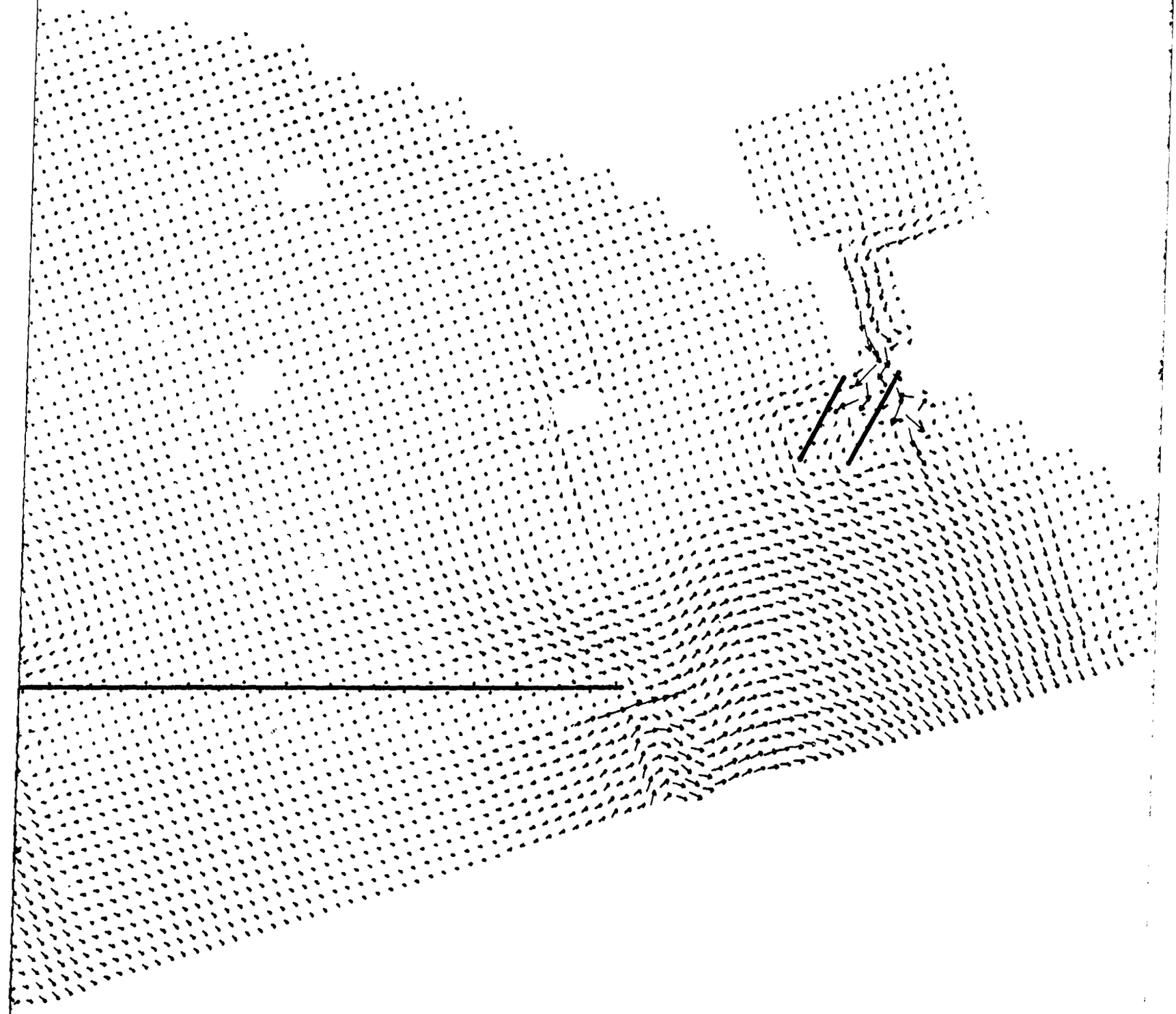


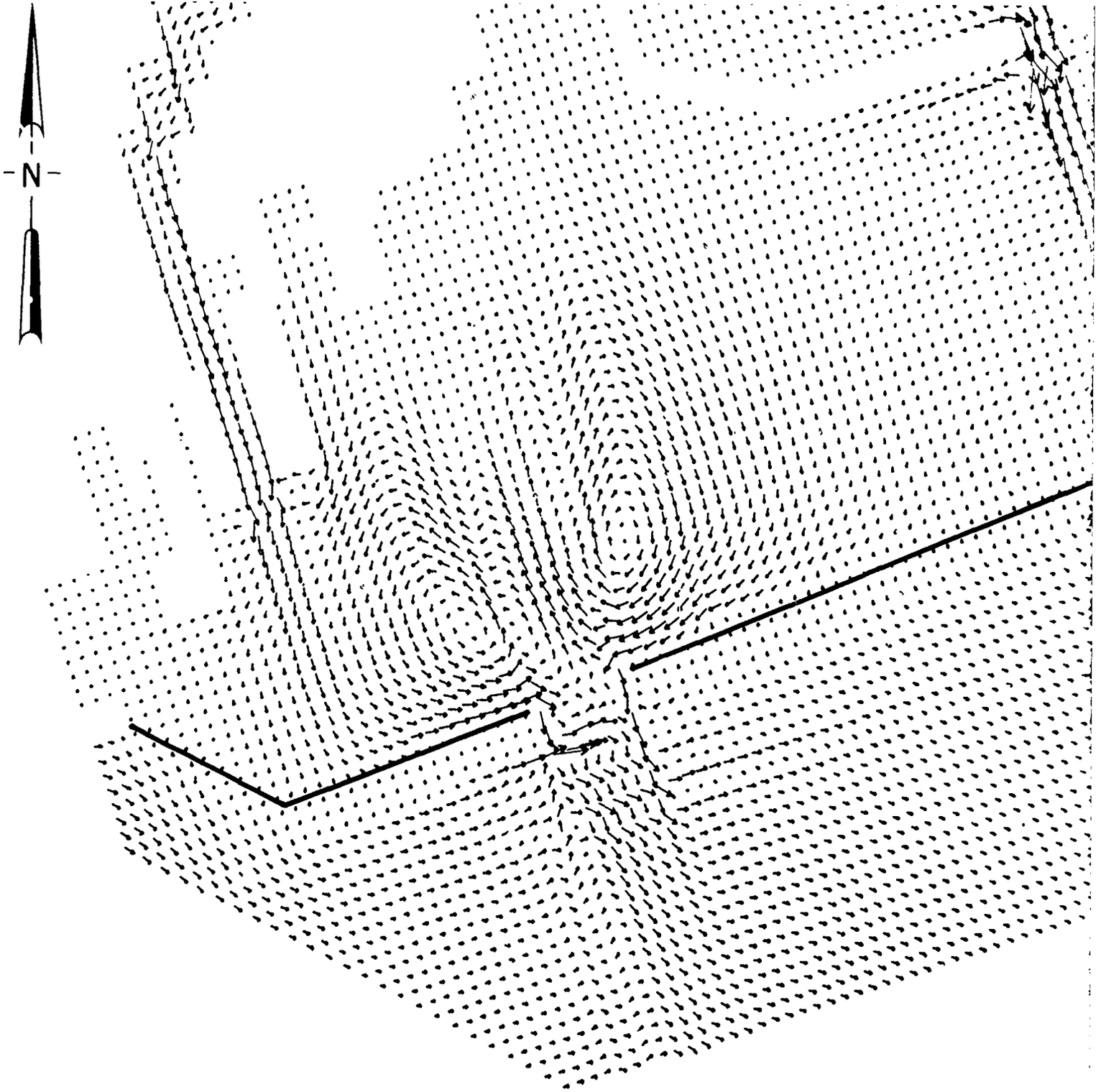
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS



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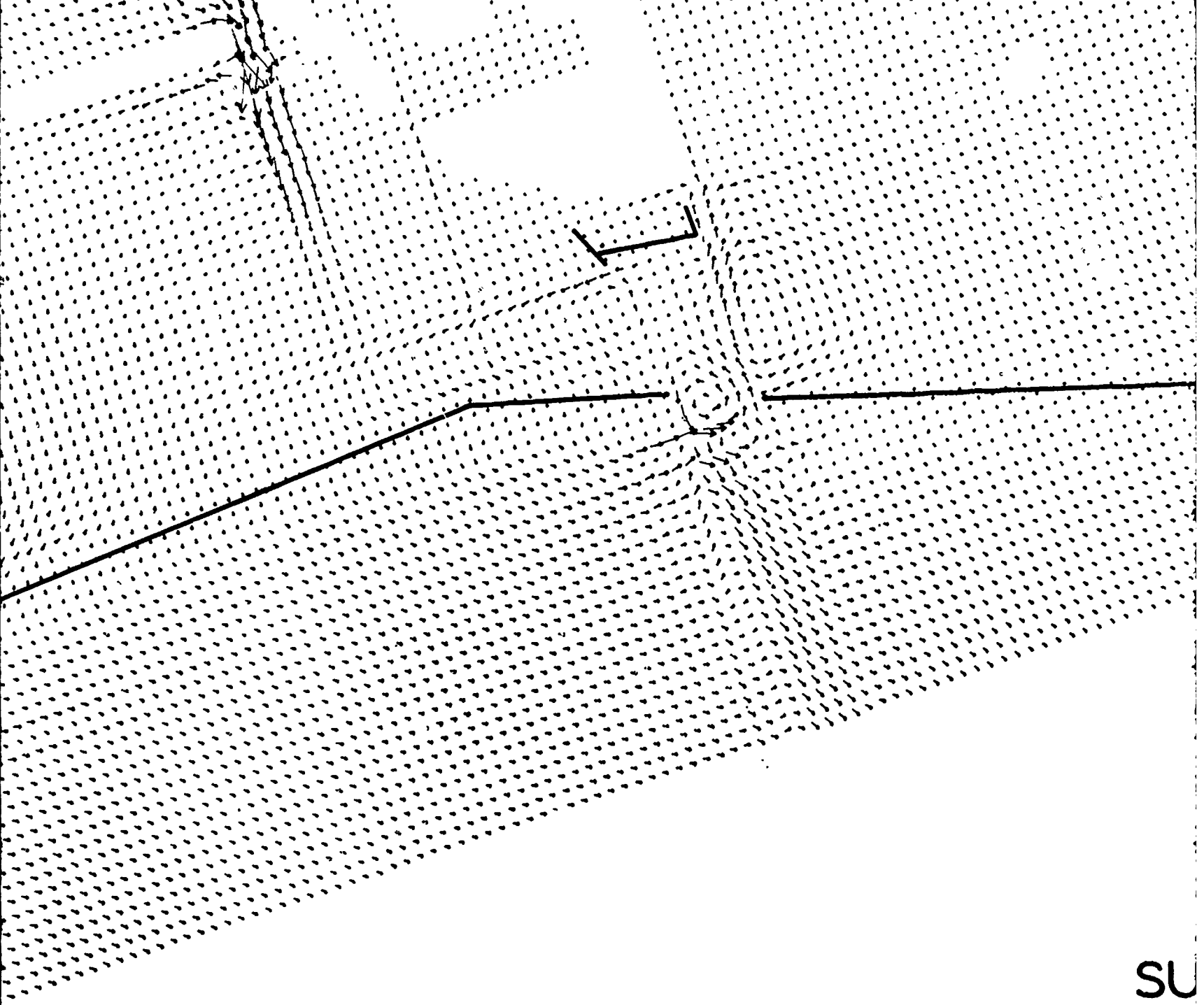

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SCALE IN FEET

2000 0 2000 4000

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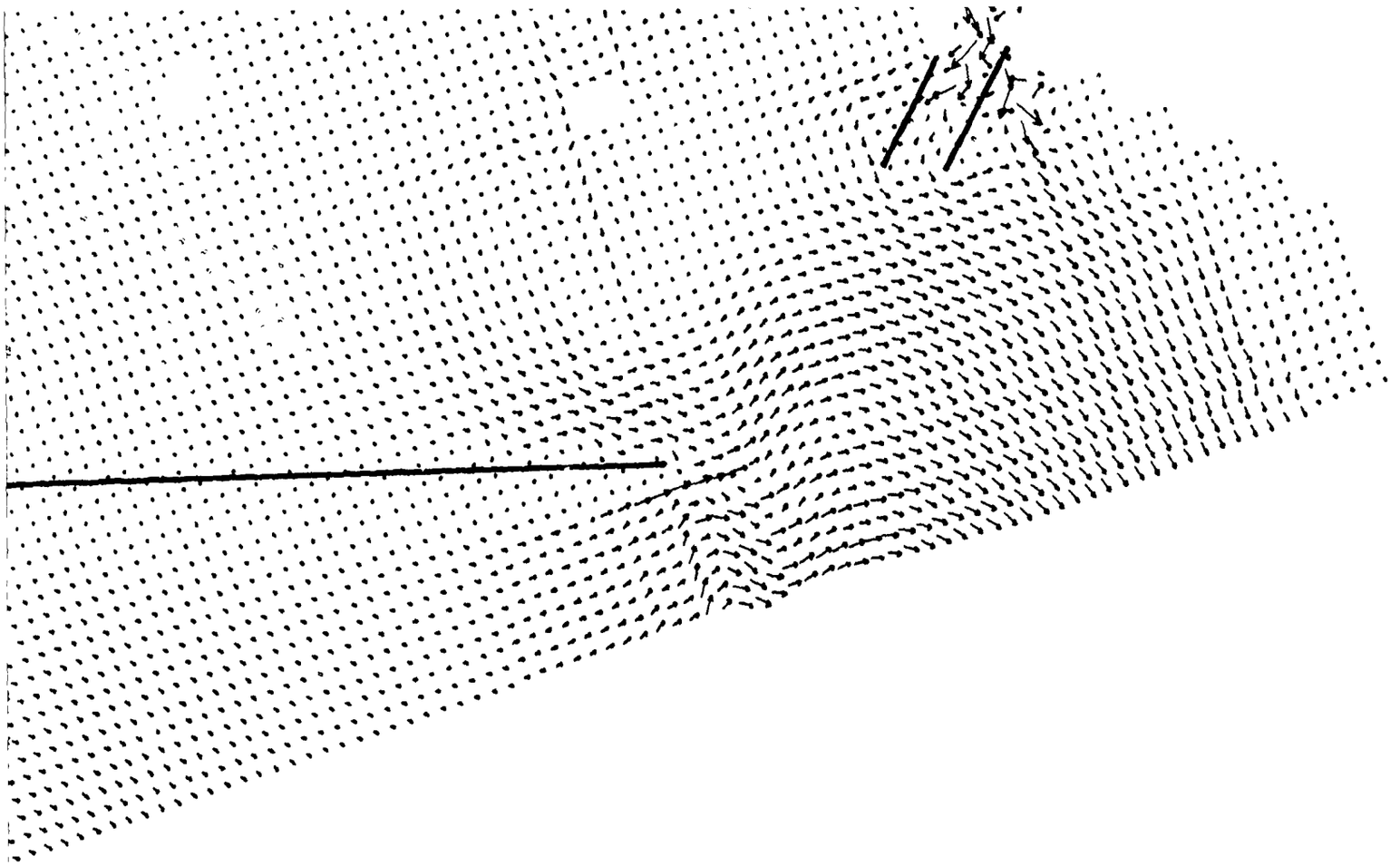


VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

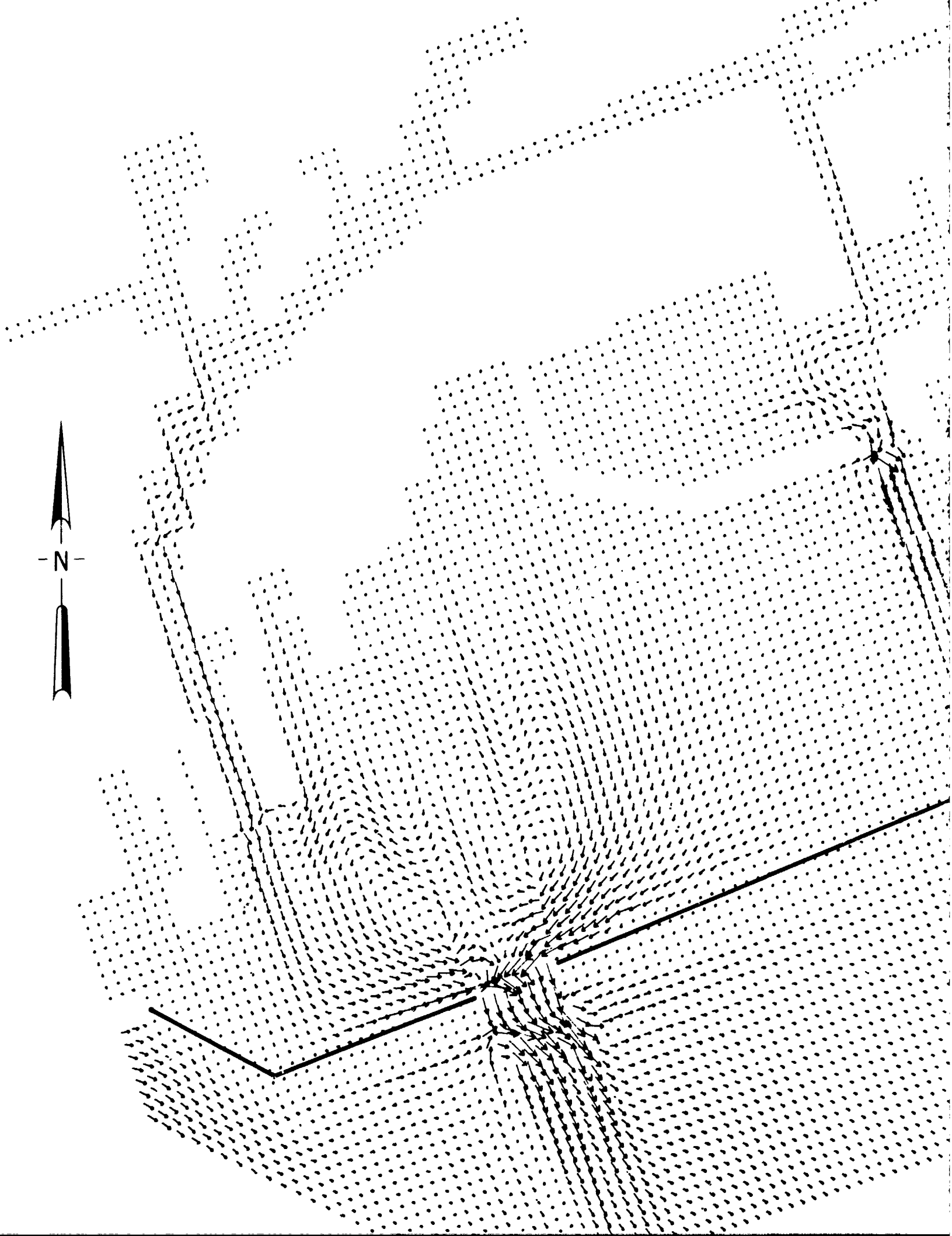
NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 2, 600-FT OPENING
-82-FT CHANNEL

SPRING TIDE
HOUR 22

FIGURE 15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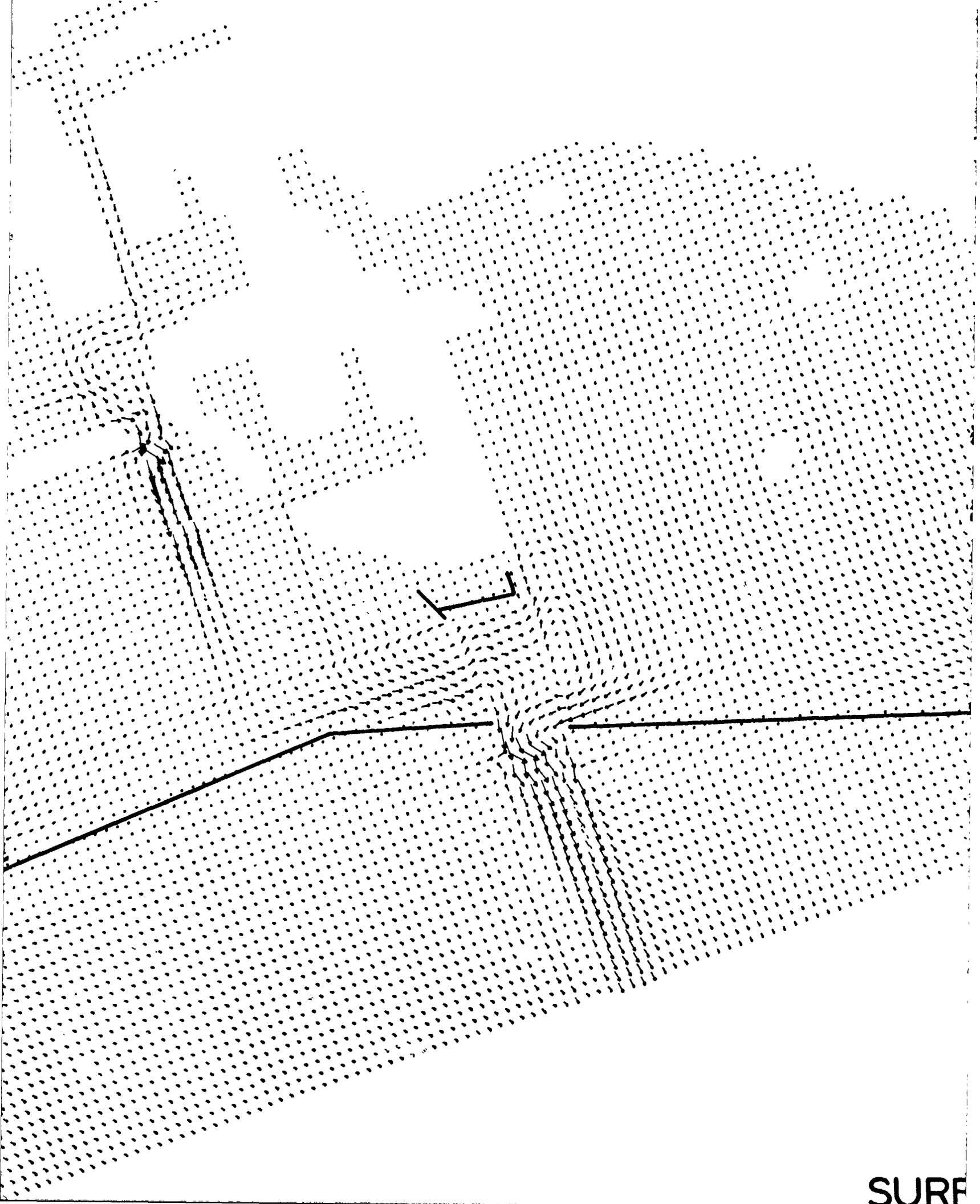
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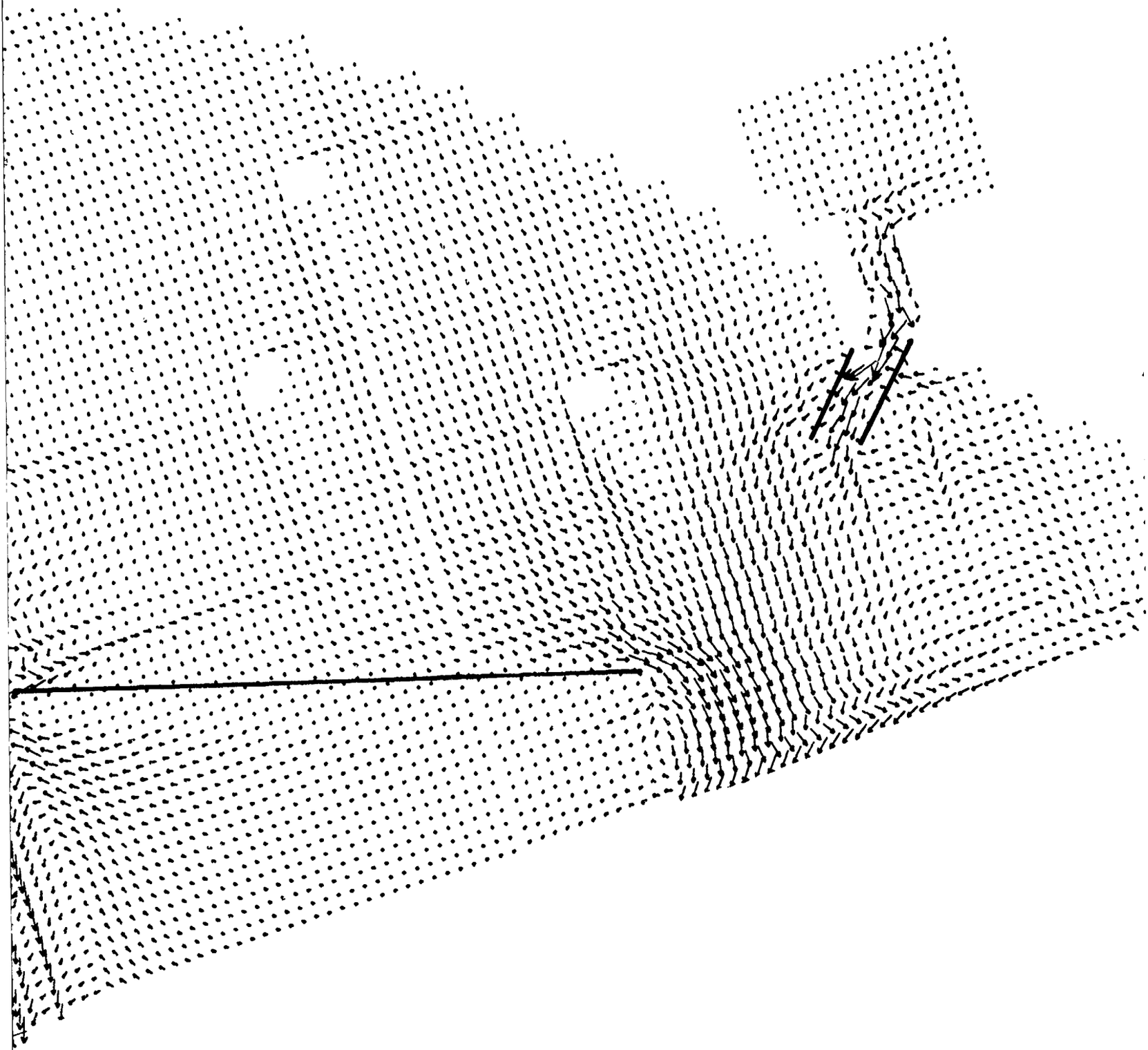

VELOCITY SCALE

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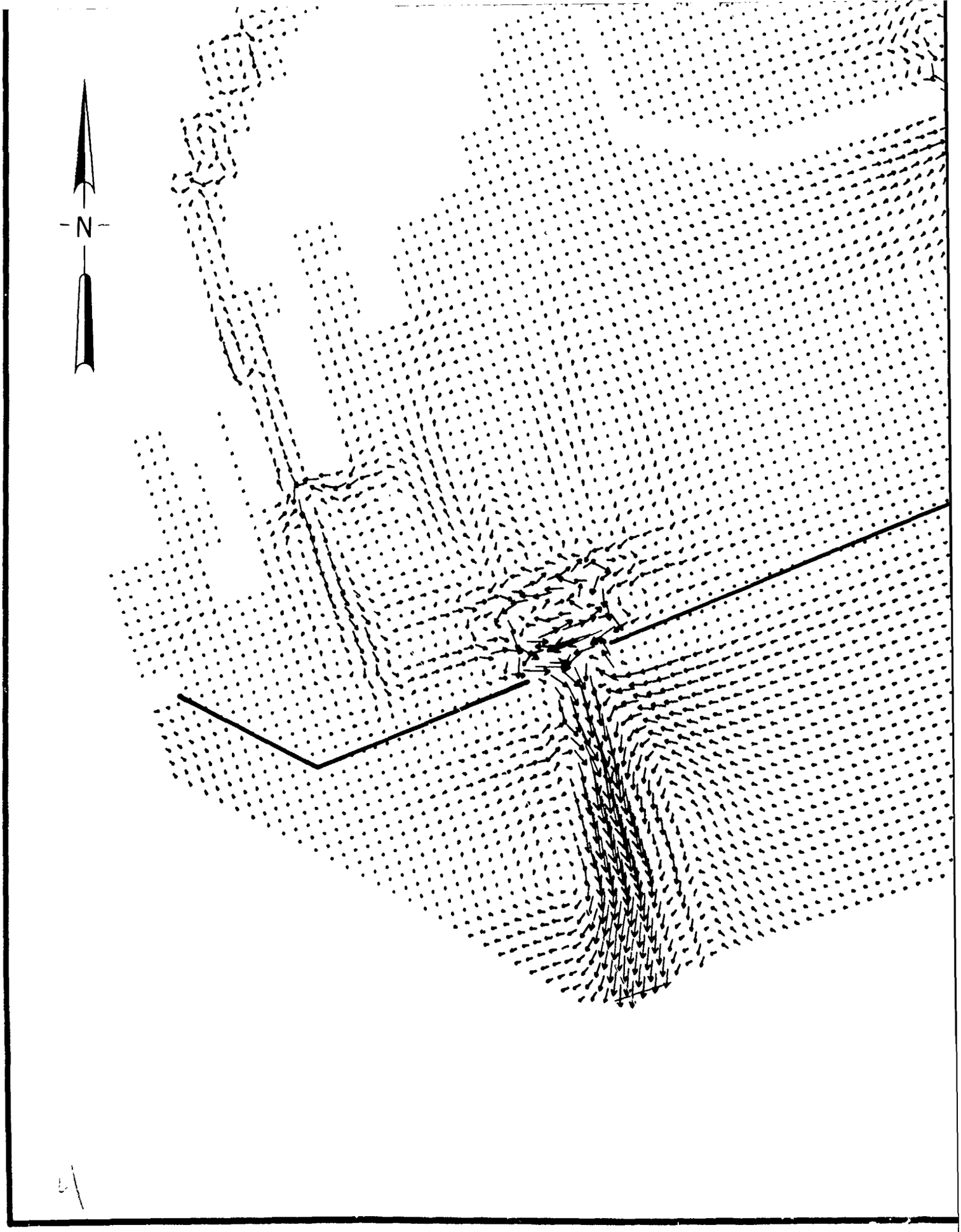
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS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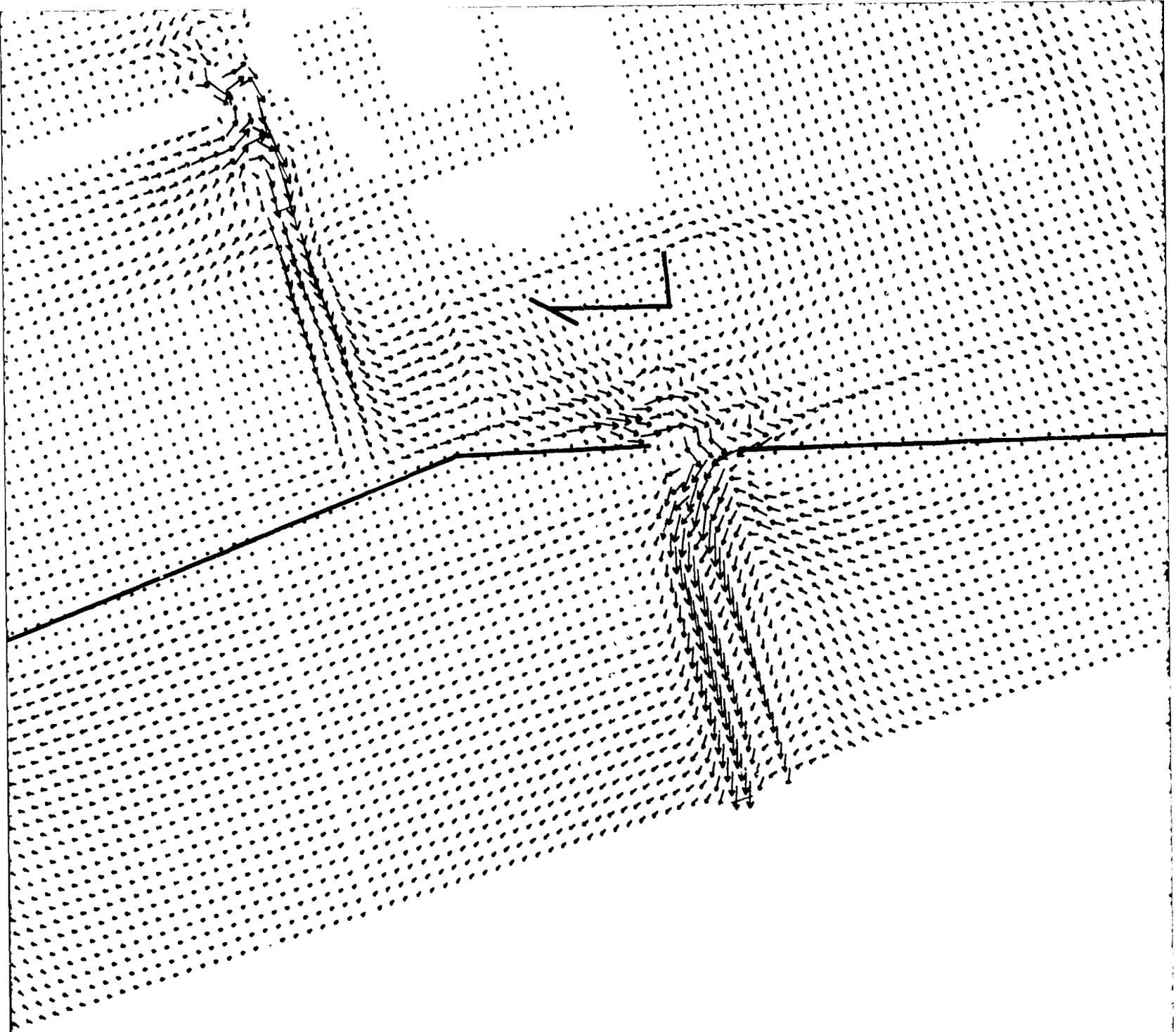

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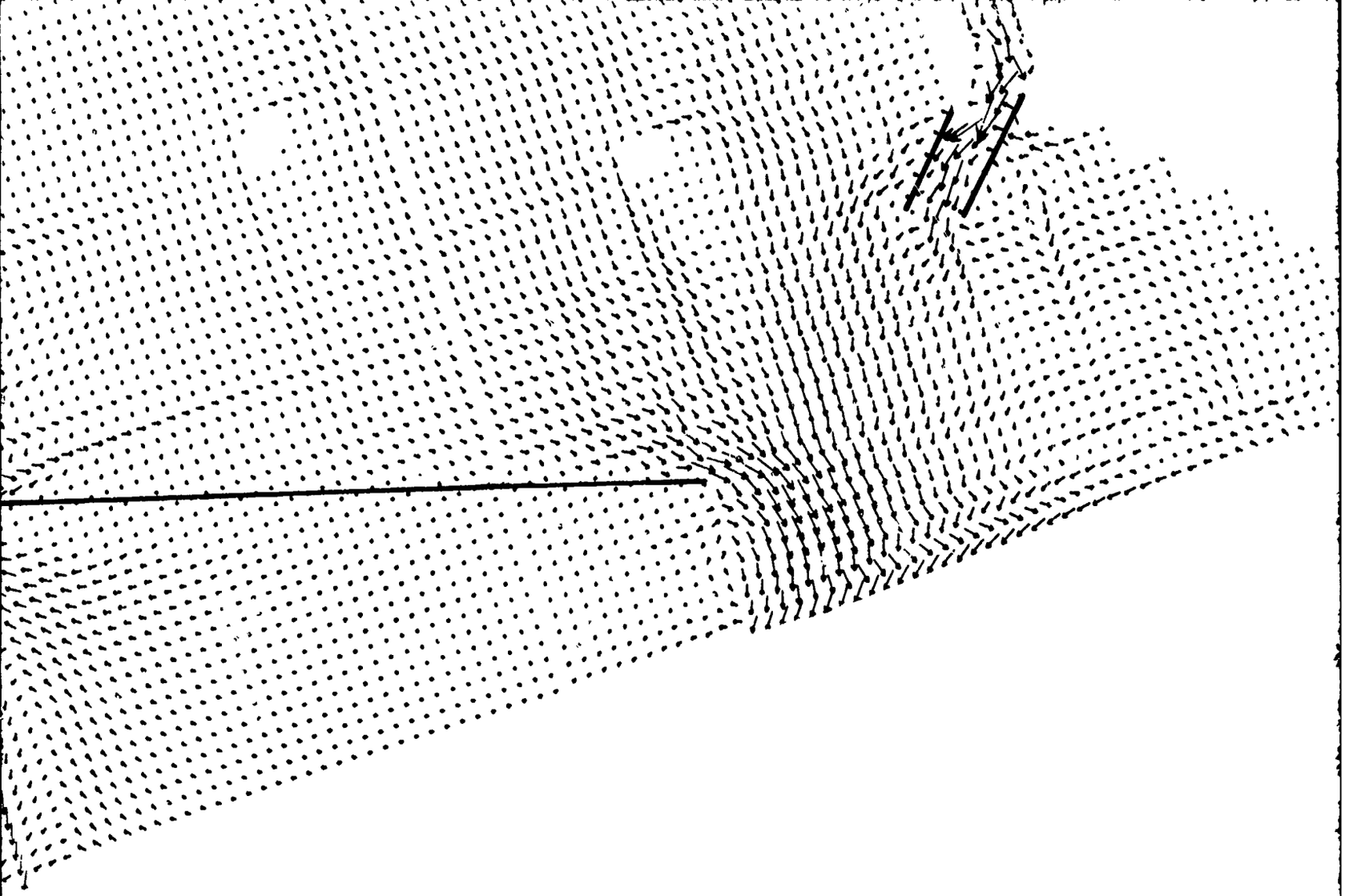


VELOCITY SCALE

1 0 1 2 3

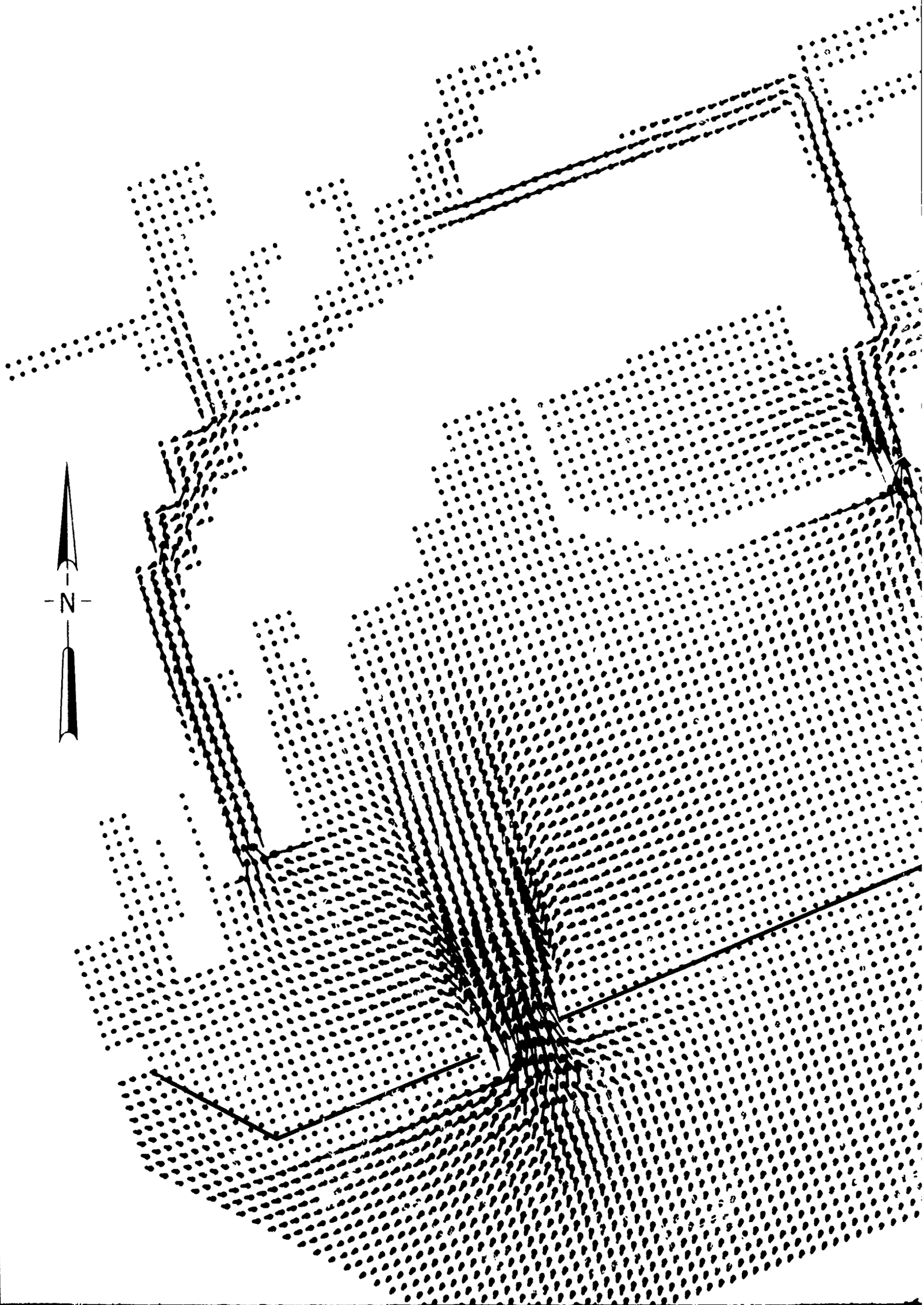
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 3, -82-FT CHANNEL

SPRING TIDE
HOUR 15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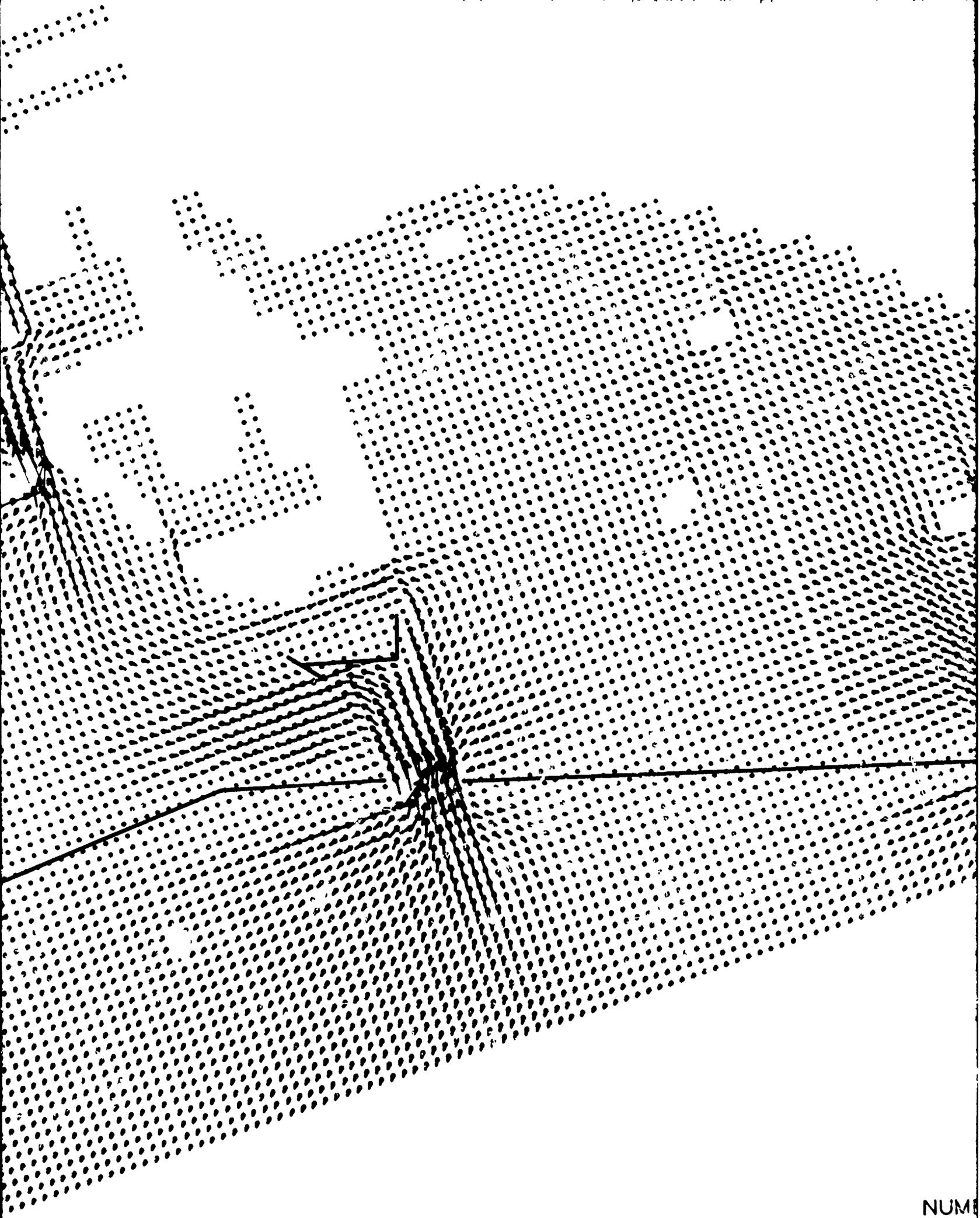

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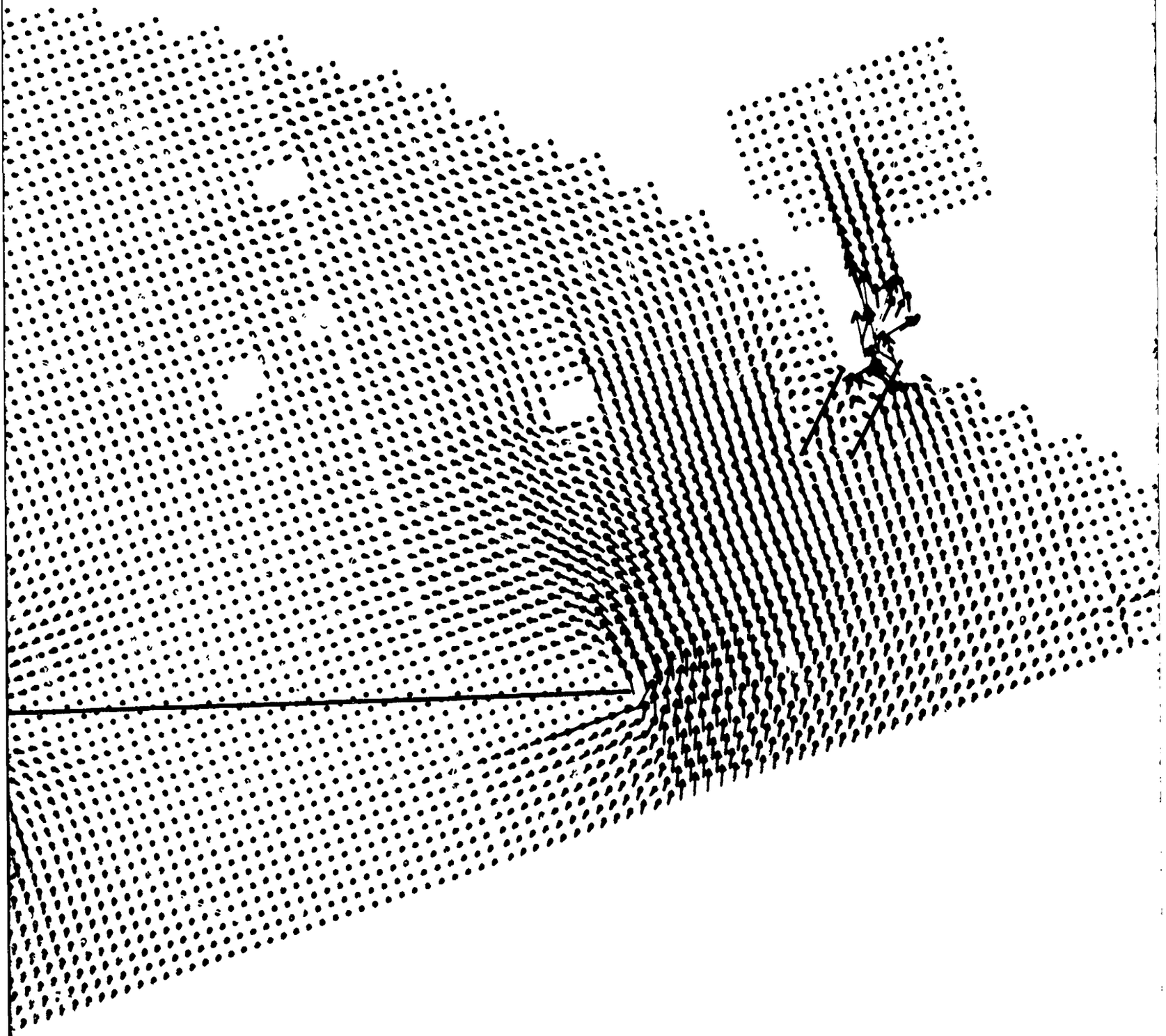

VELOCITY SCALE

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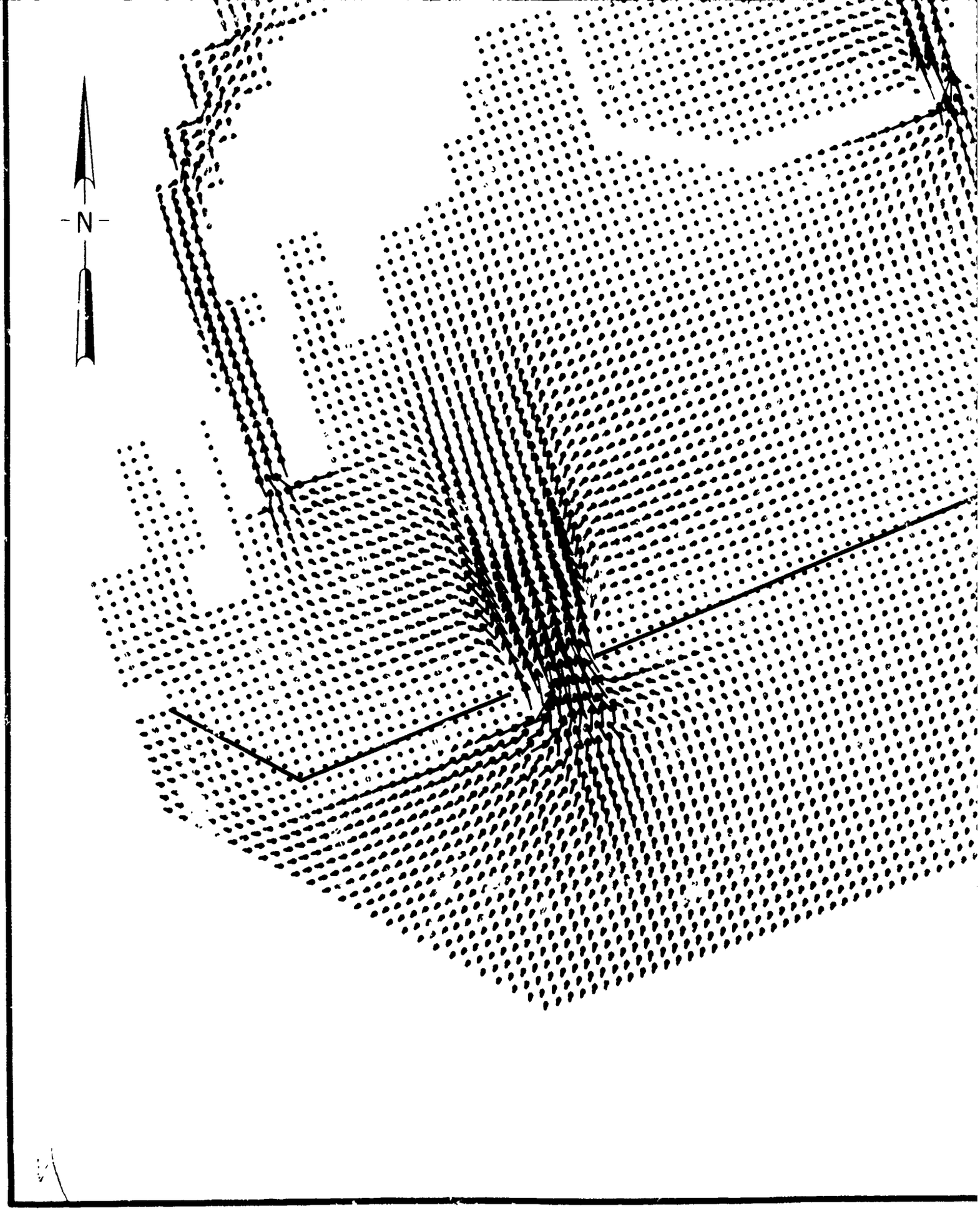
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS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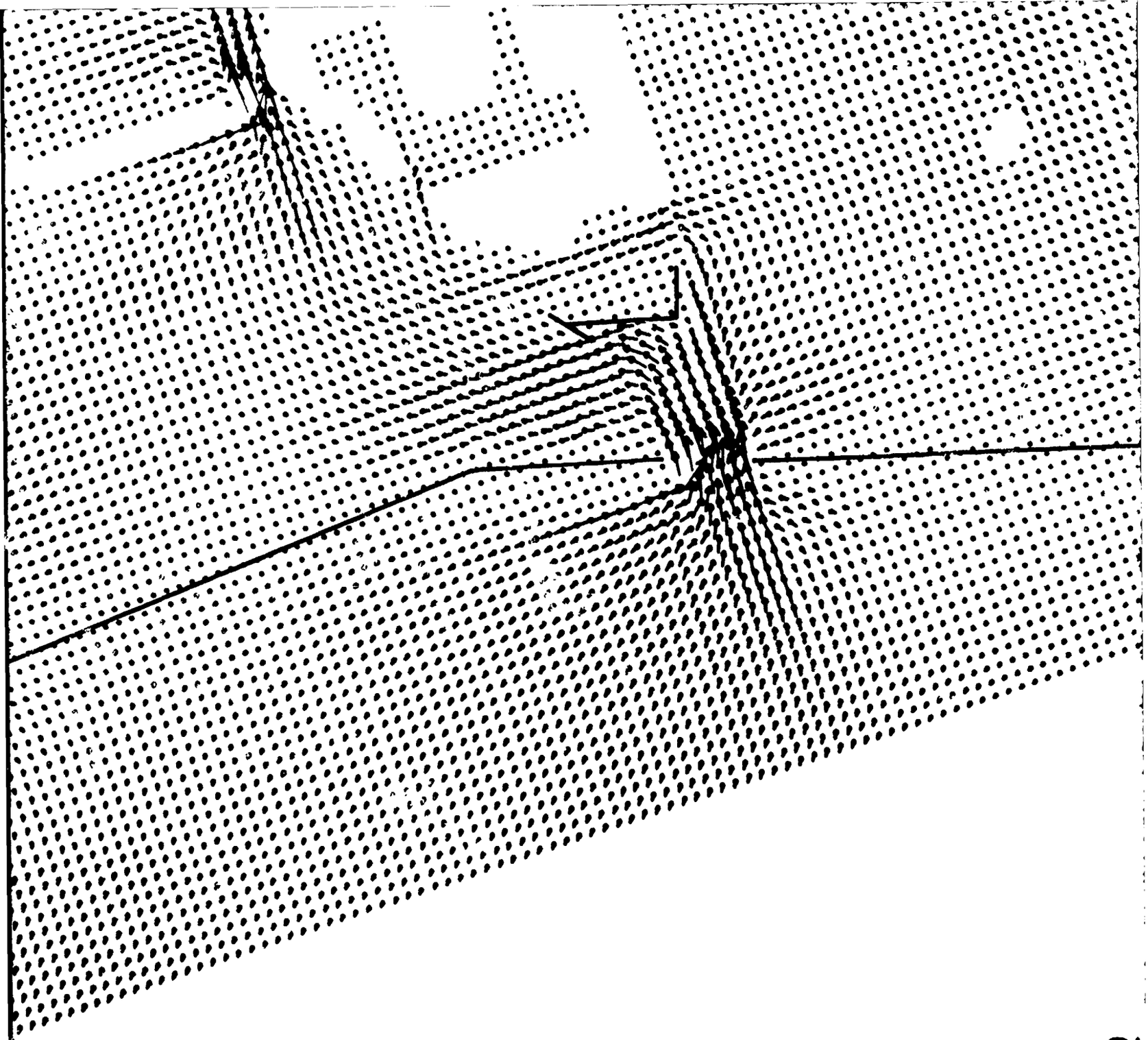

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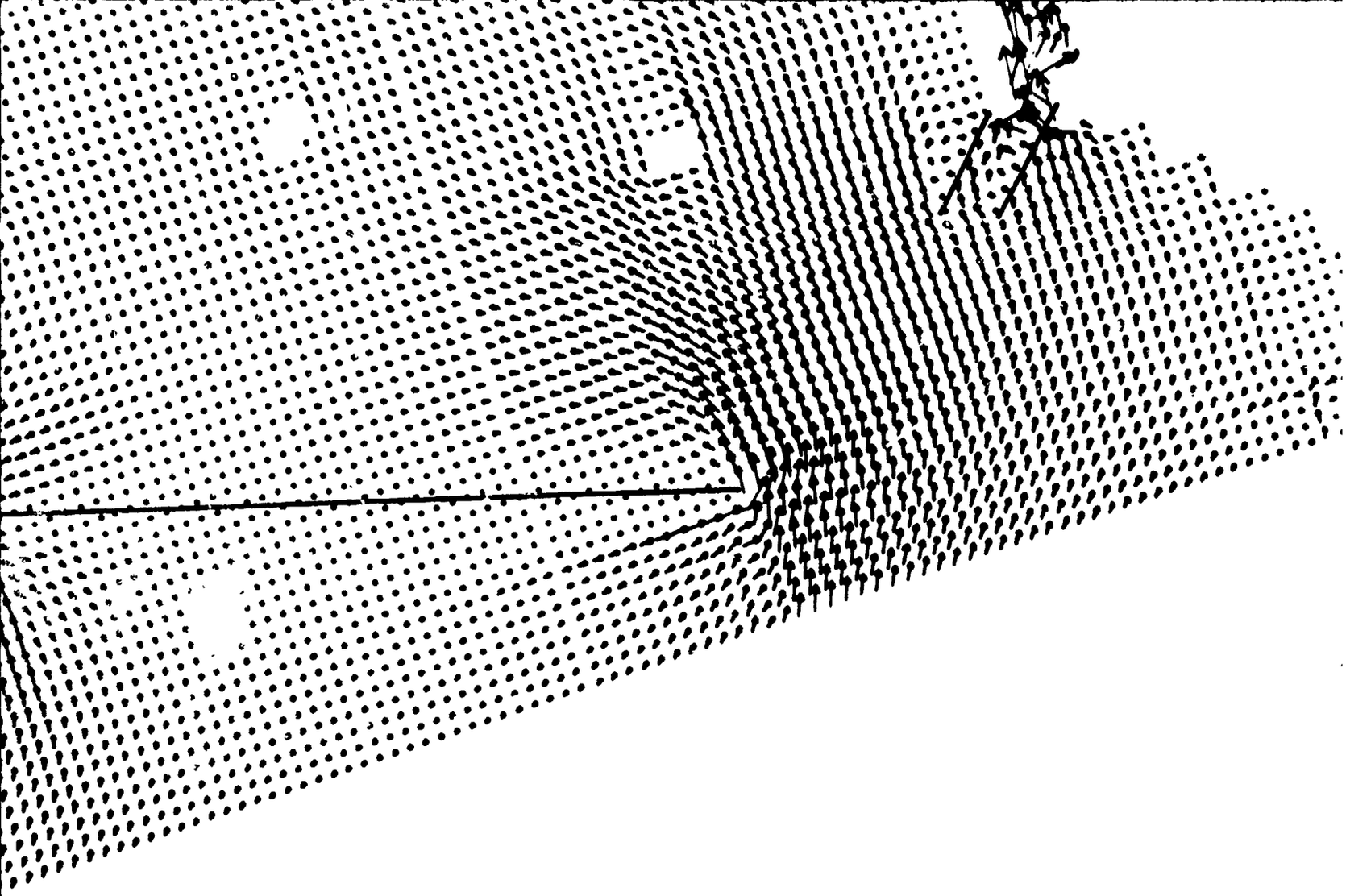


VELOCITY SCALE

1 0 1 2 3

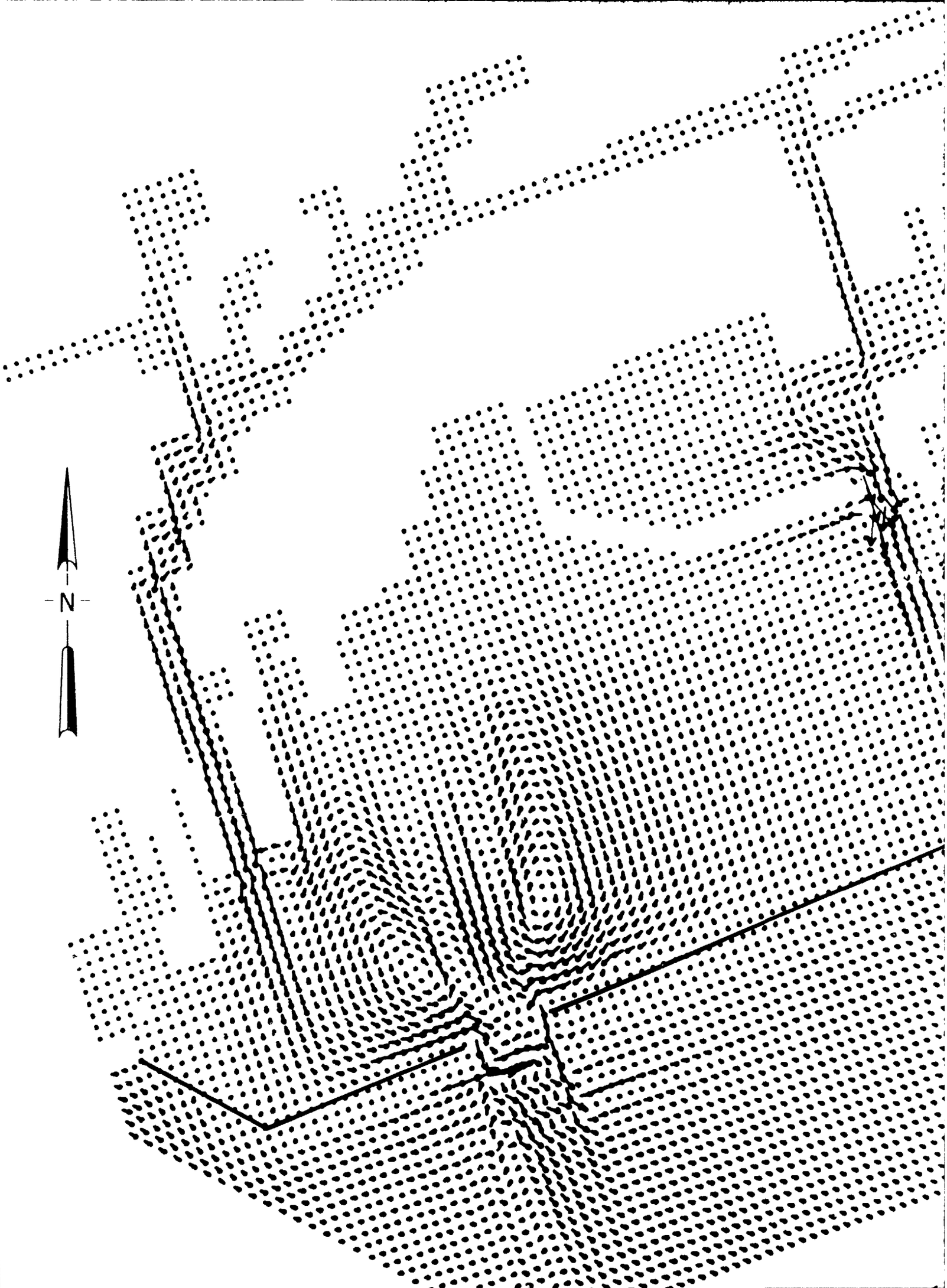
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 3, -82-FT CHANNEL

SPRING TIDE
HOUR 19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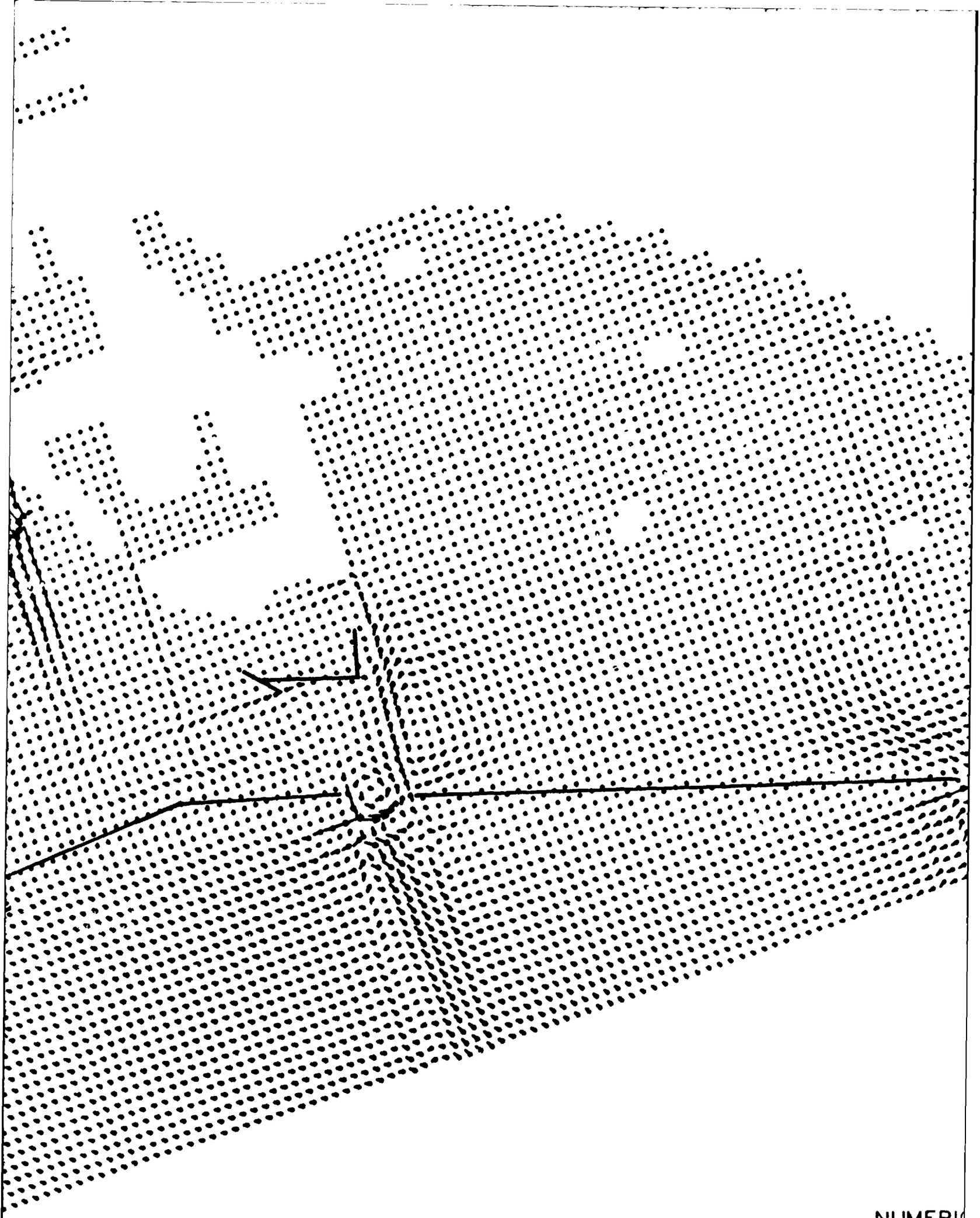

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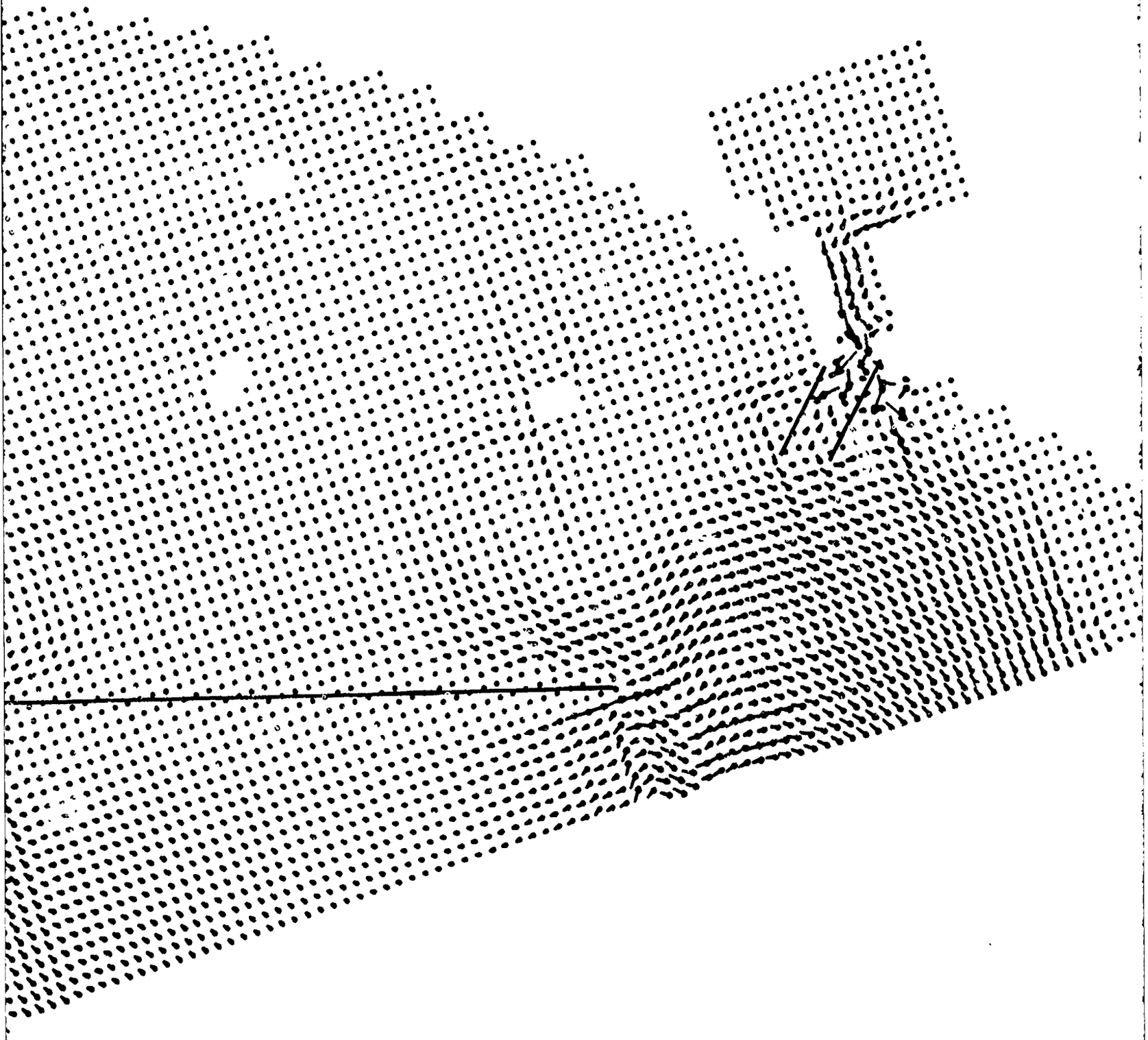

VELOCITY SCALE

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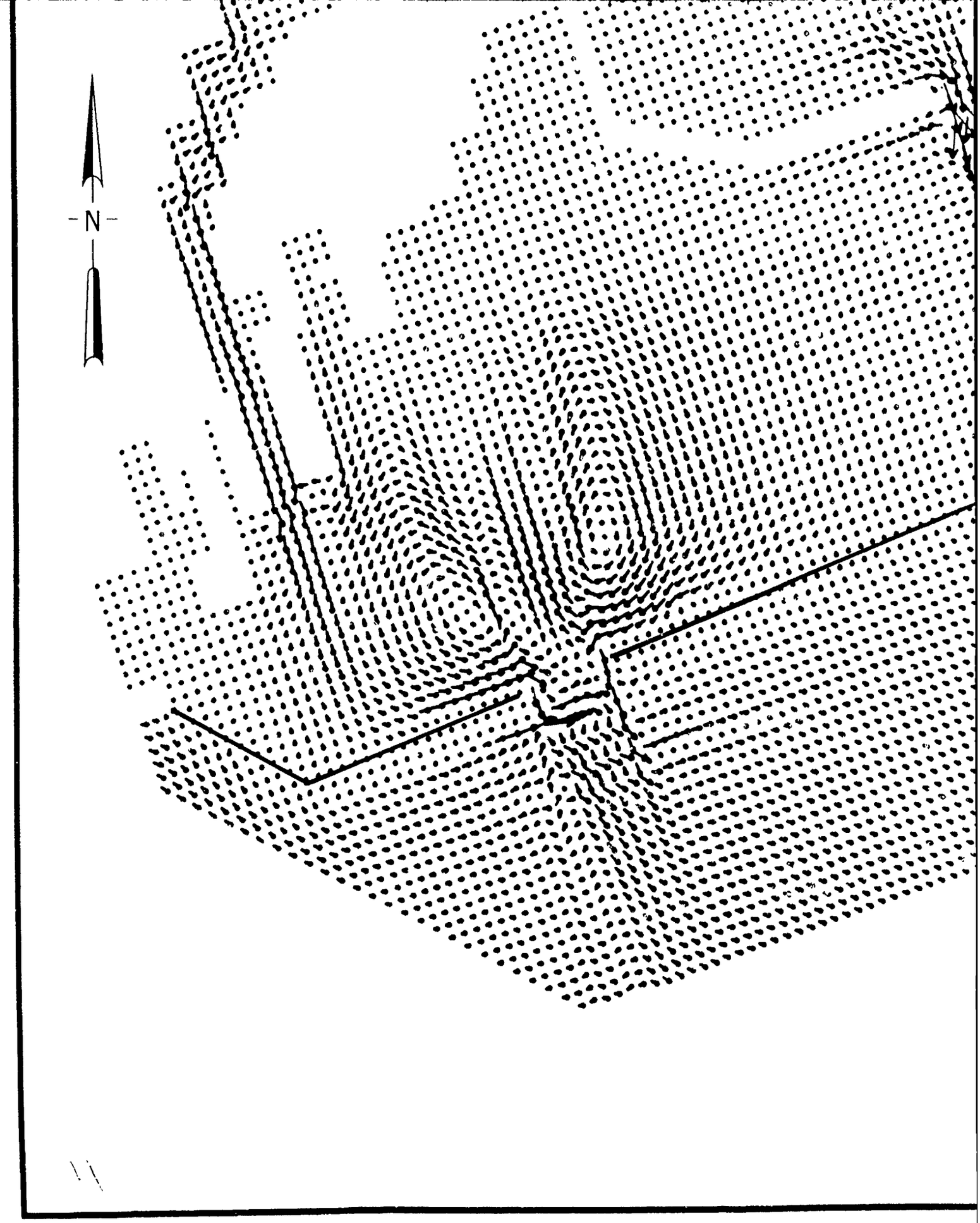
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS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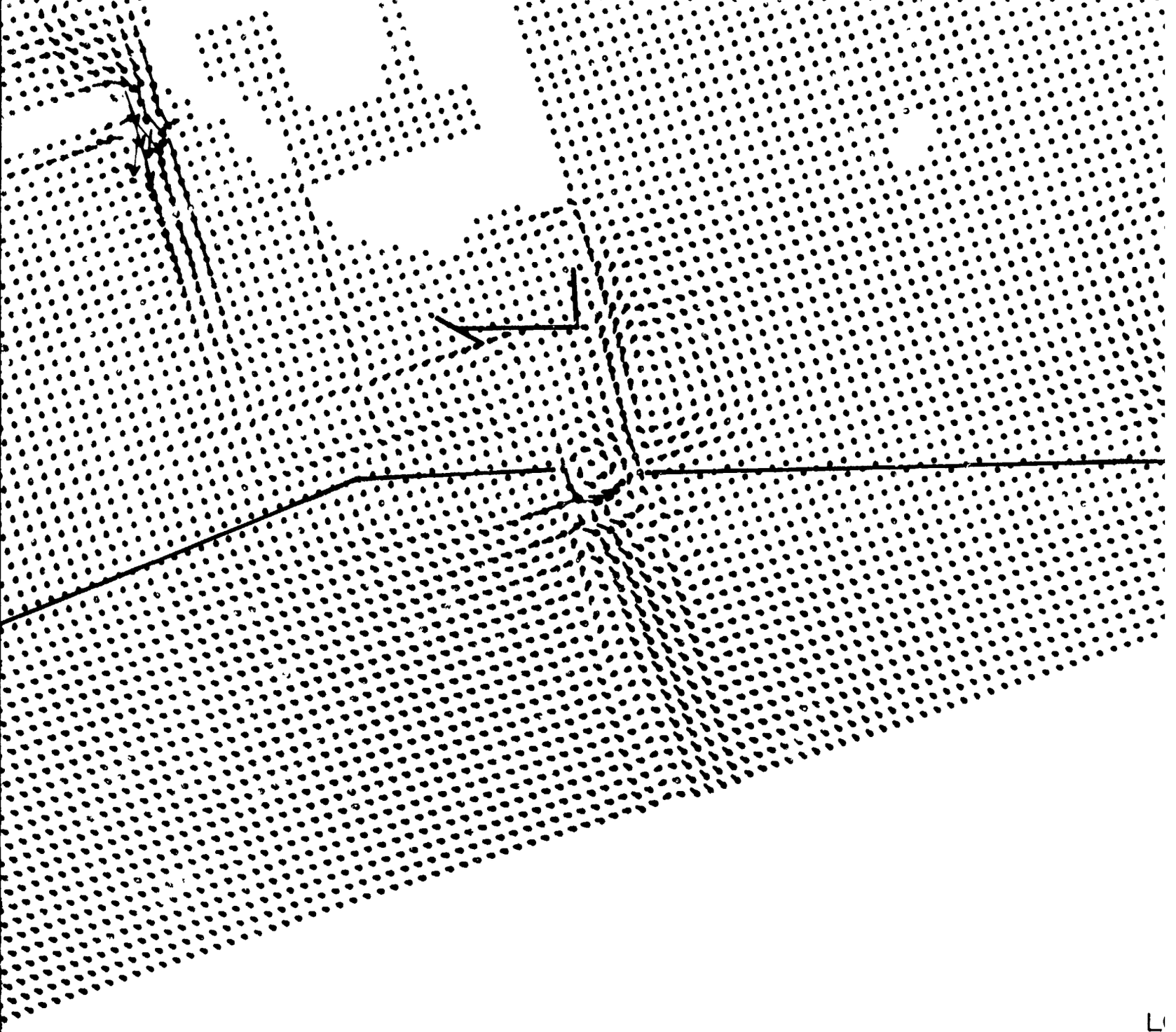

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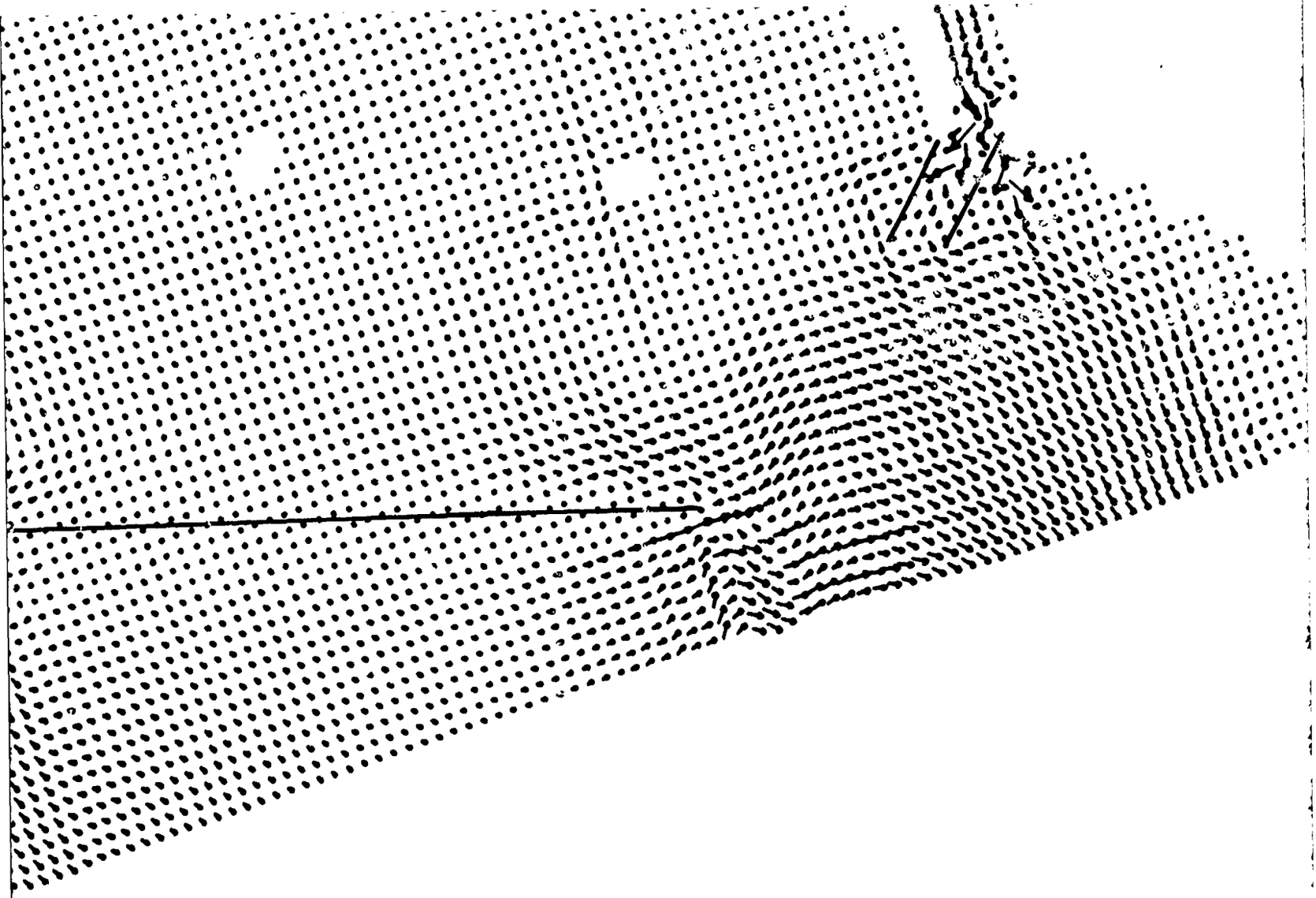


VELOCITY SCALE

1 0 1 2 3

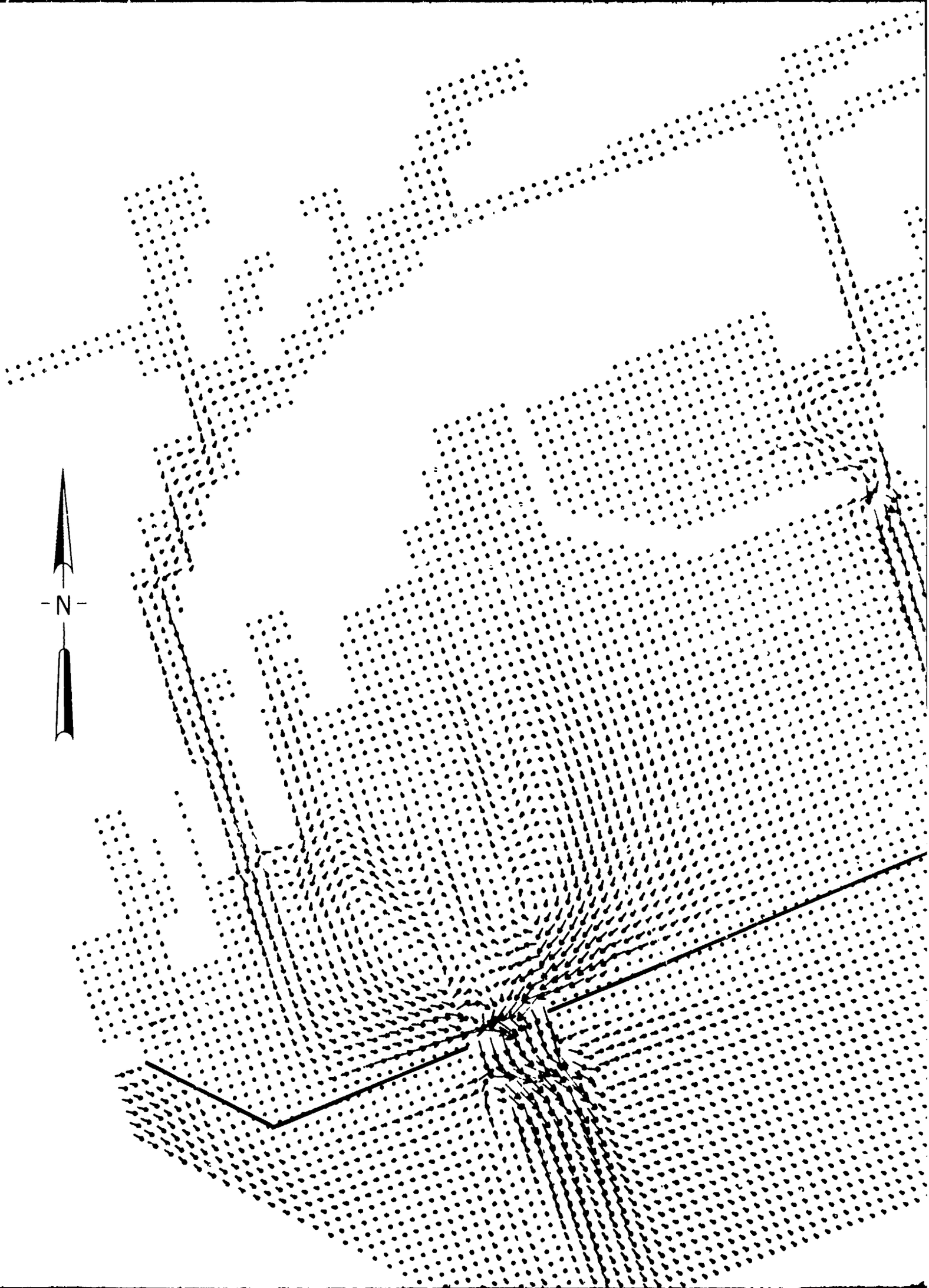
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 3, -82-FT CHANNEL

SPRING TIDE
HOUR 22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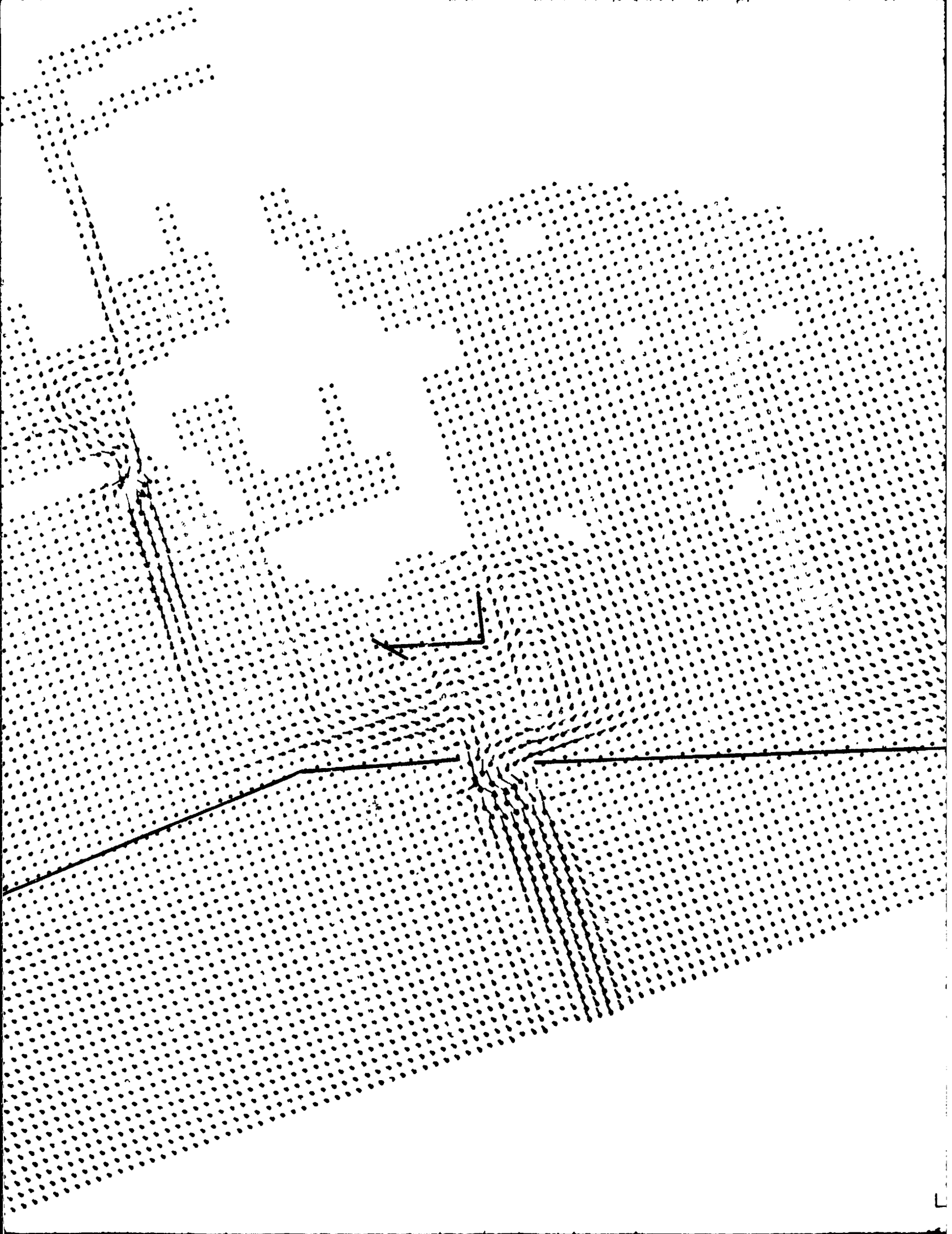

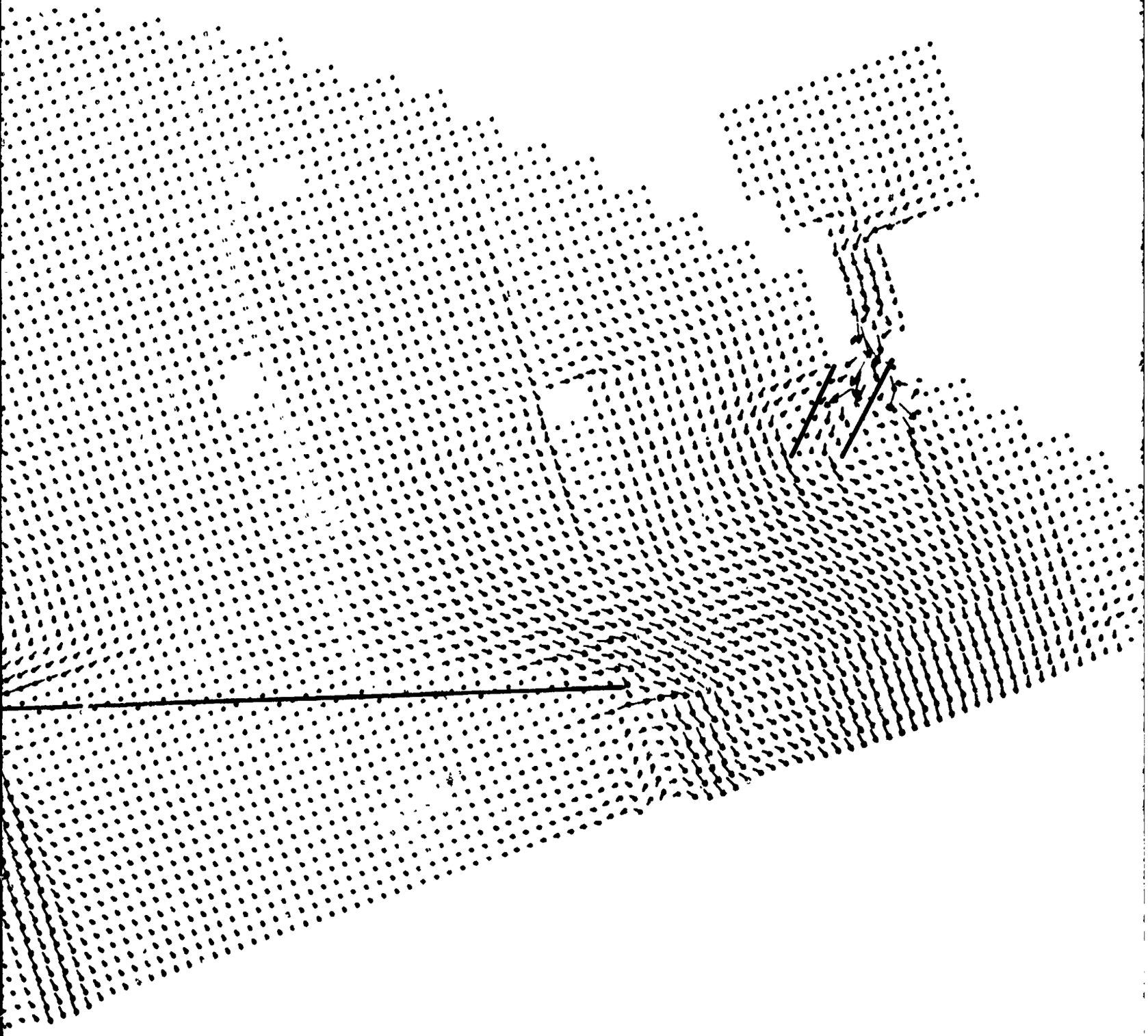

VELOCITY SCALE

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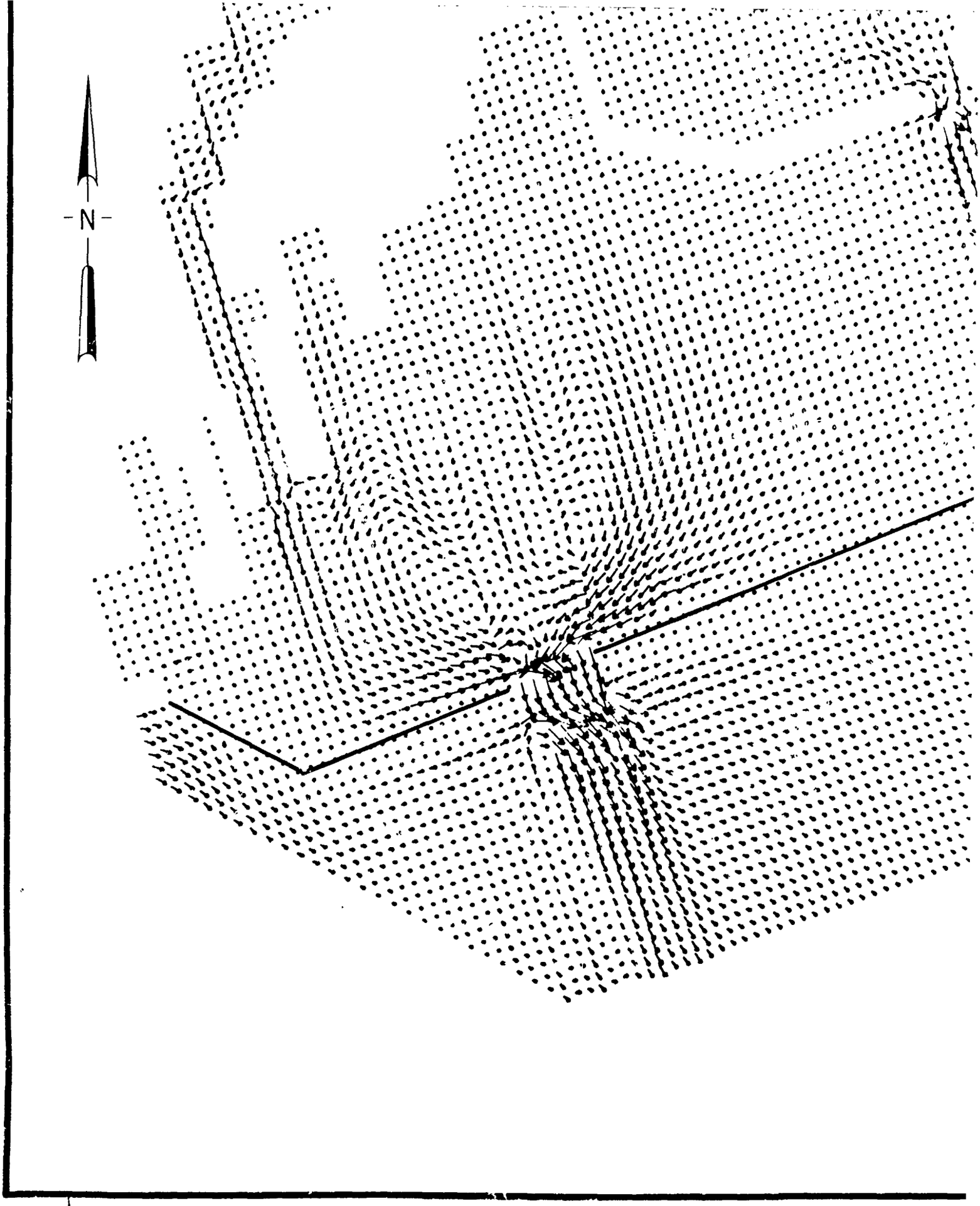
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS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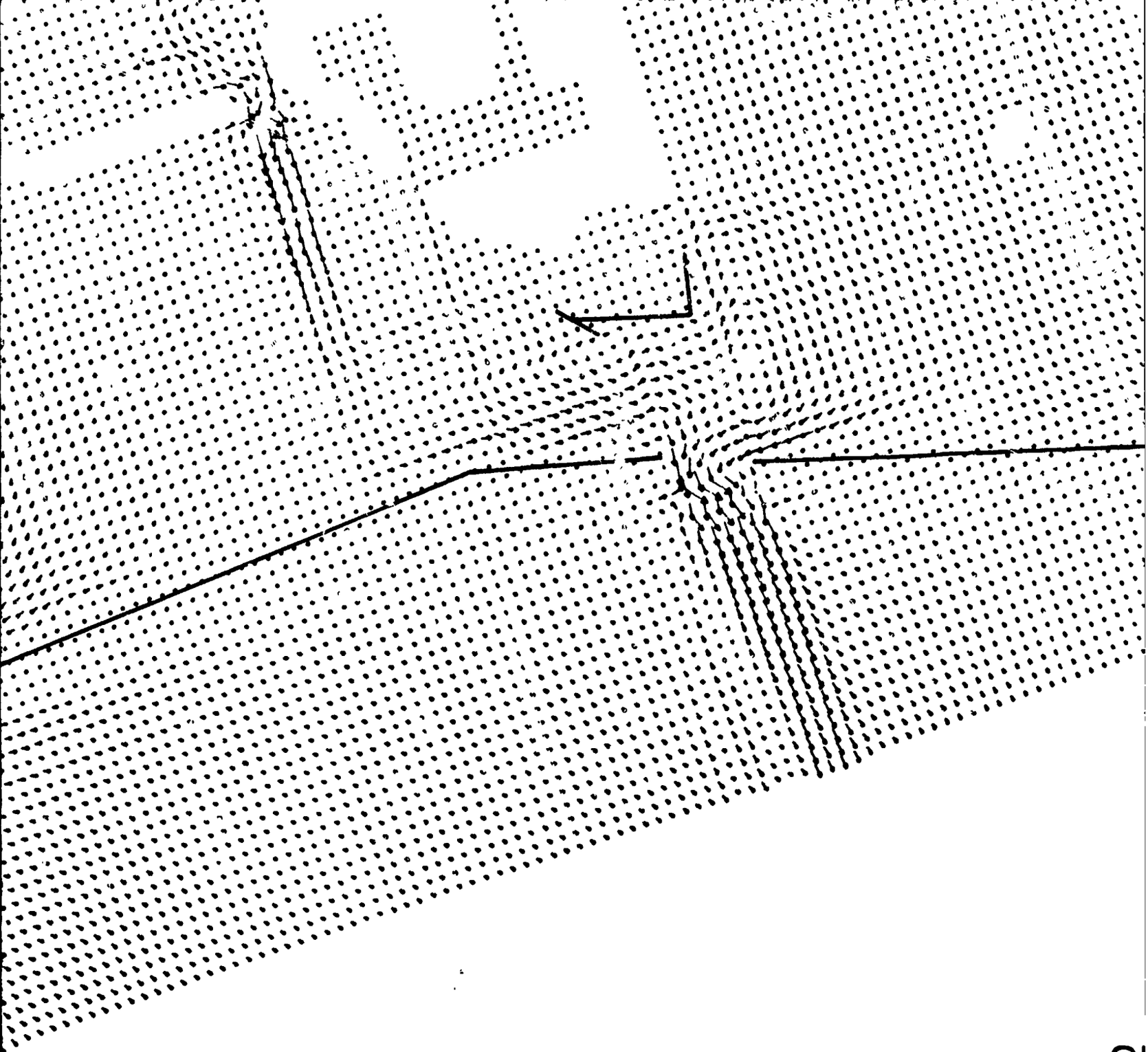

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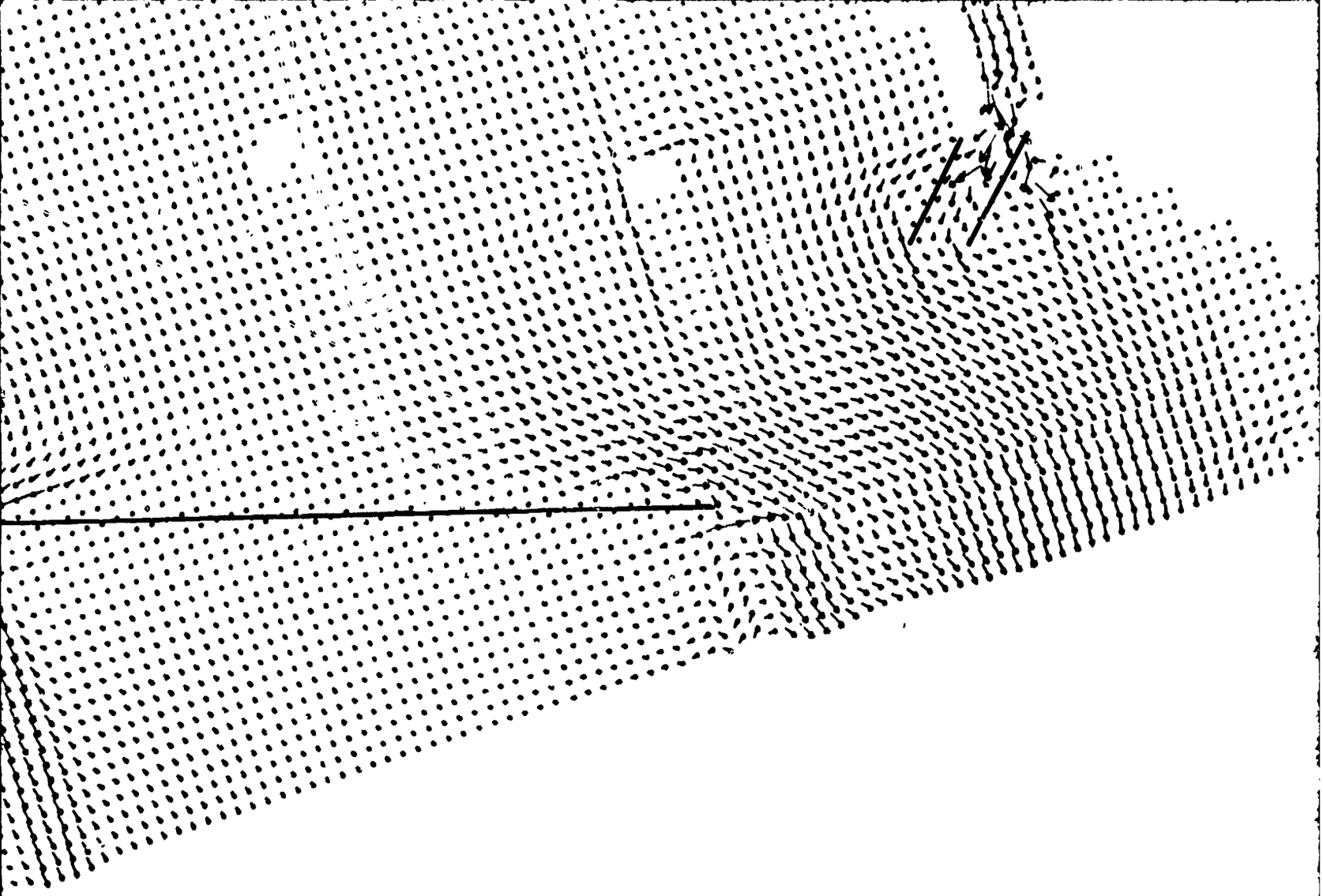


VELOCITY SCALE

1 0 1 2 3

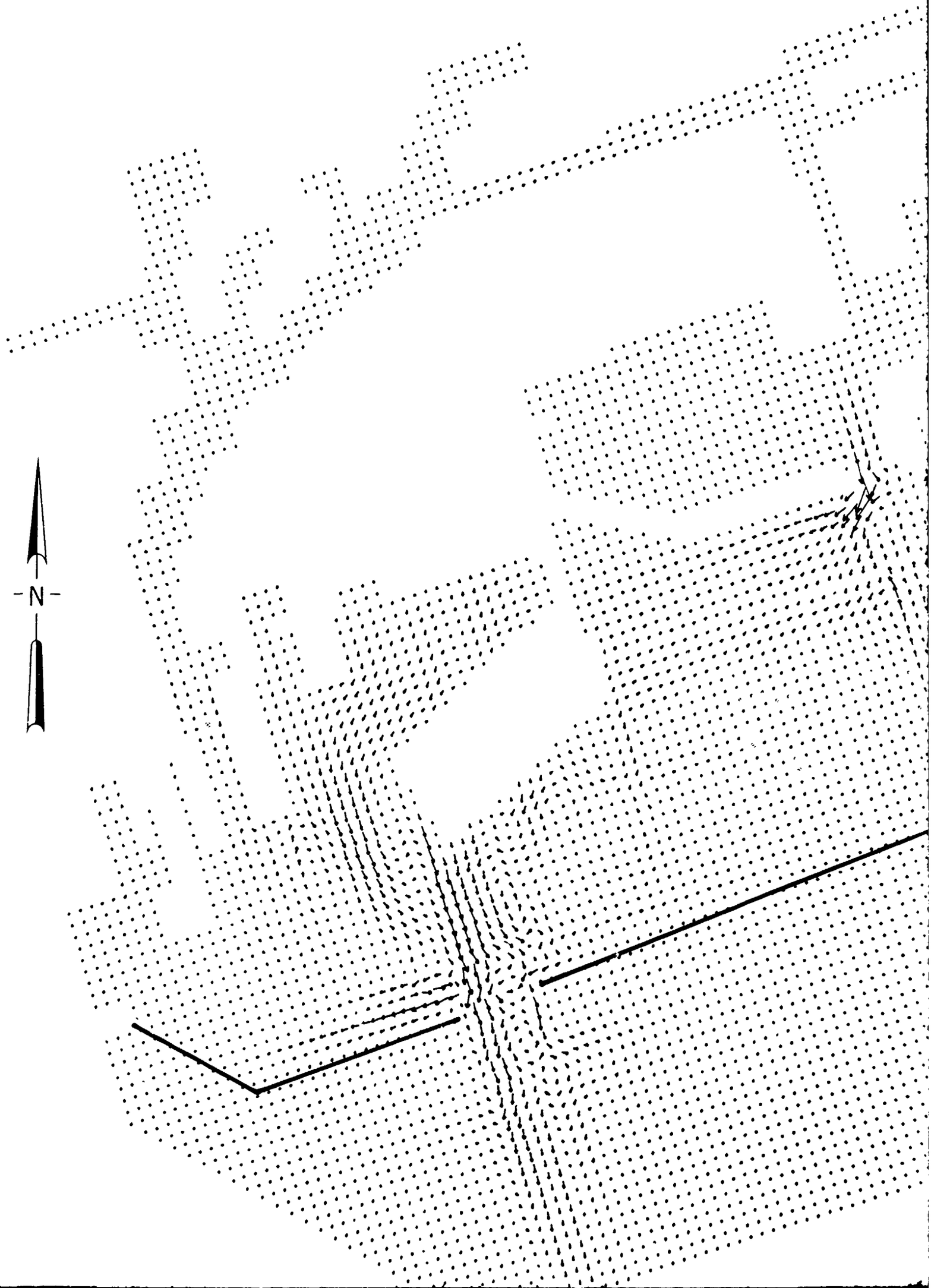
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

SURFACE CURRENT PATTERNS

SCHEME STFP 3, -82-FT CHANNEL

SPRING TIDE
HOUR 24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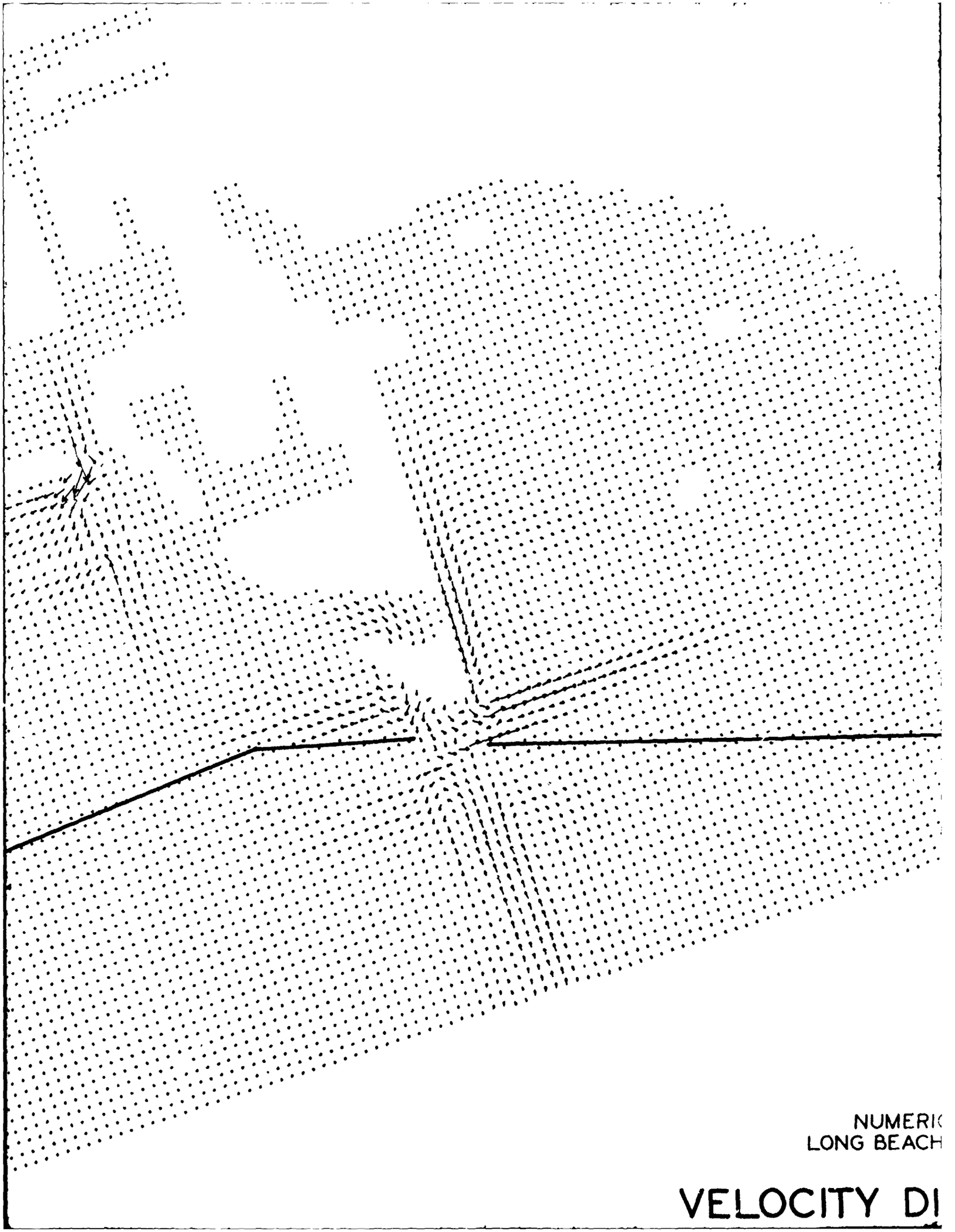

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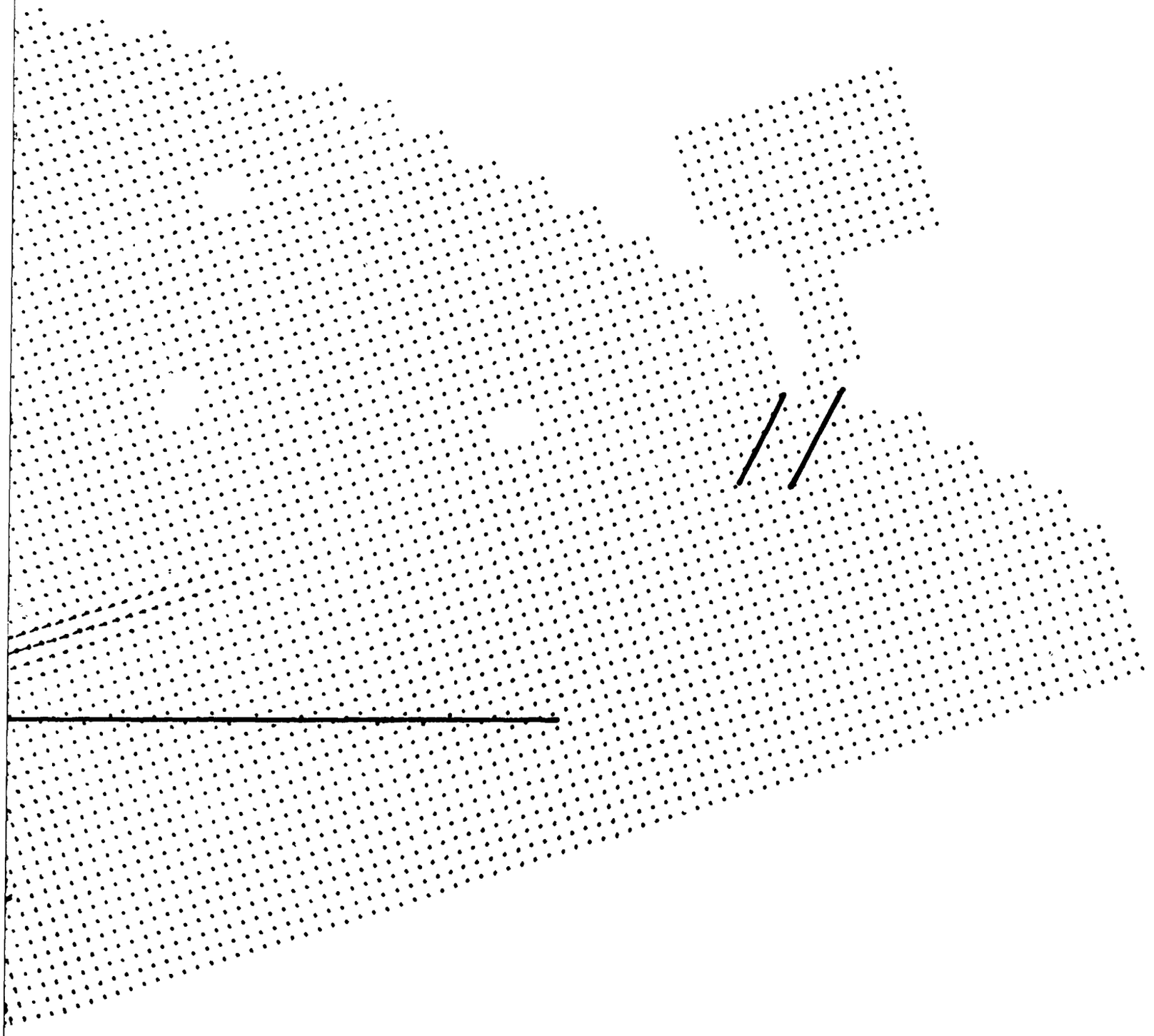

VELOCITY SCALE

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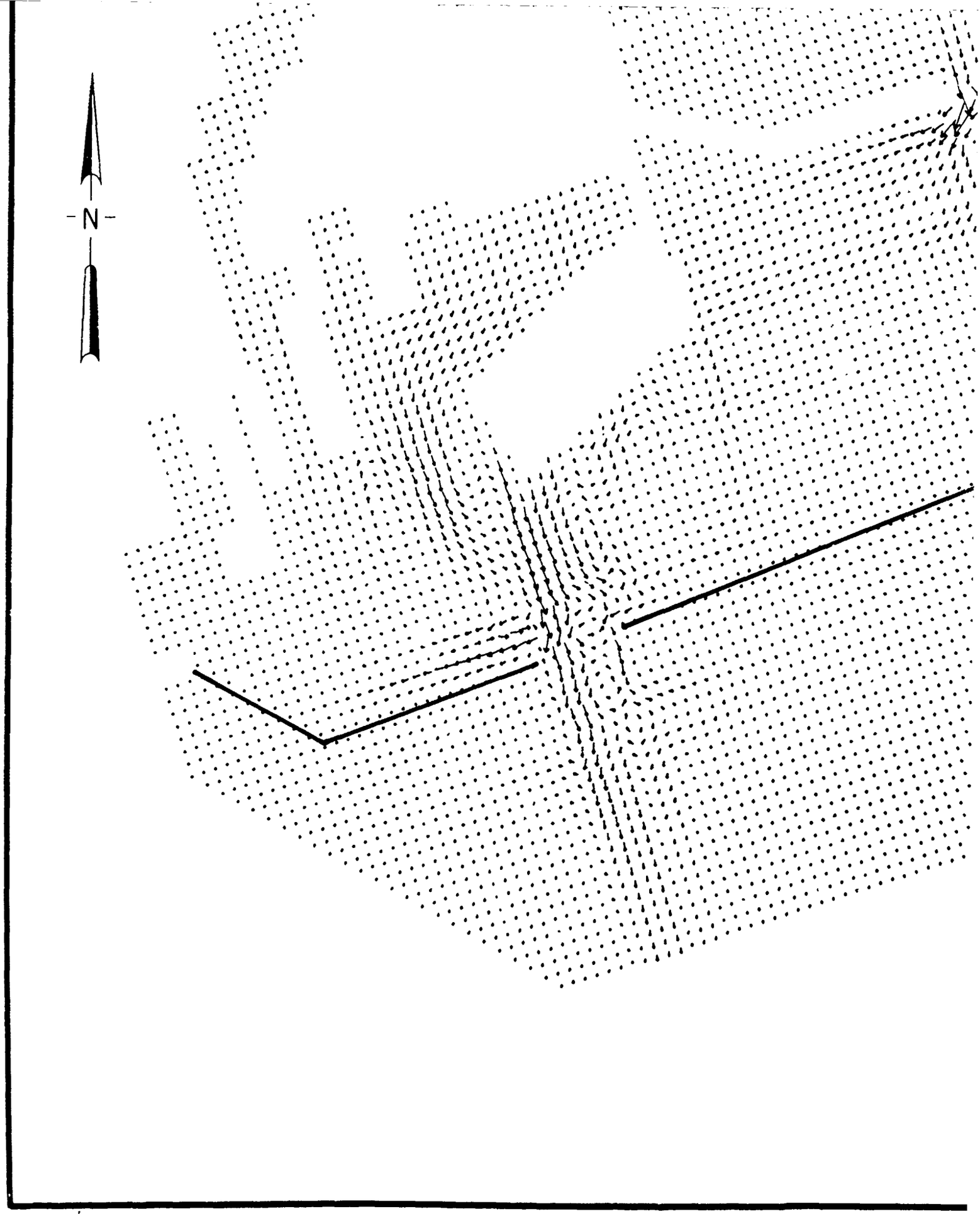
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN



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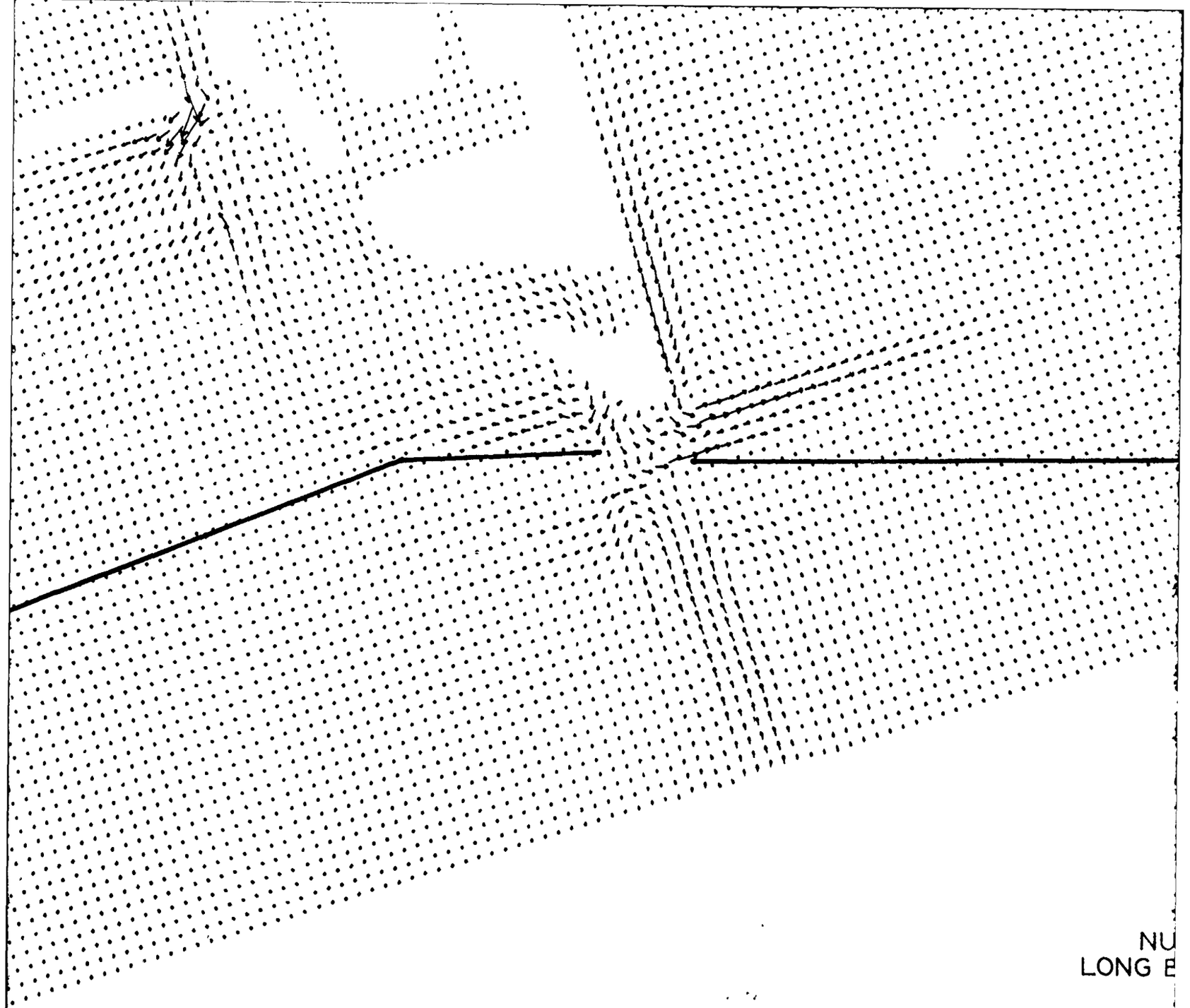

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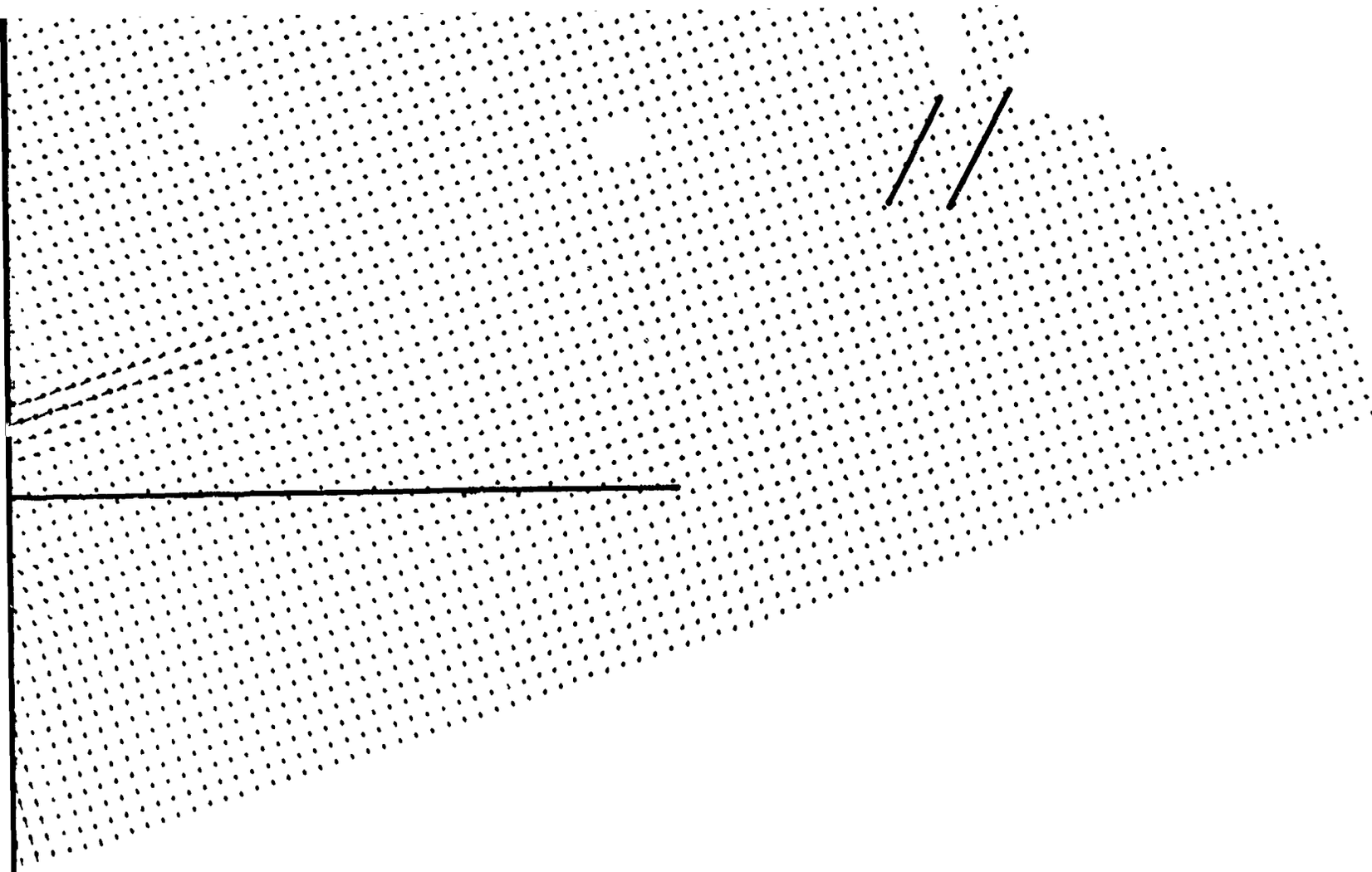

VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN PLAN 1A-2 AND EXISTING CONDITIONS

SPRING TIDE
HOUR 15 (NEAR SLACK WATER)

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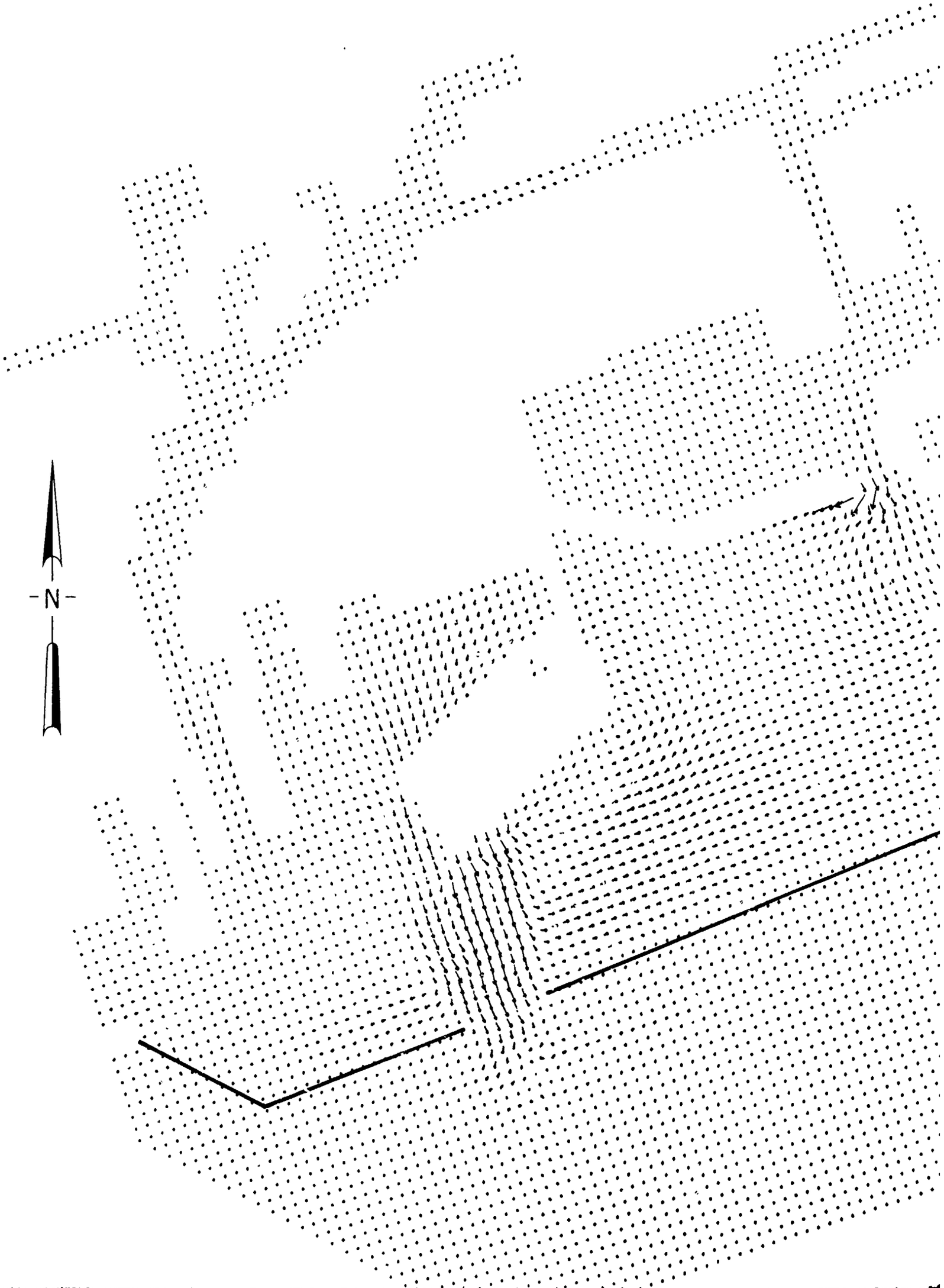
FIGURE 21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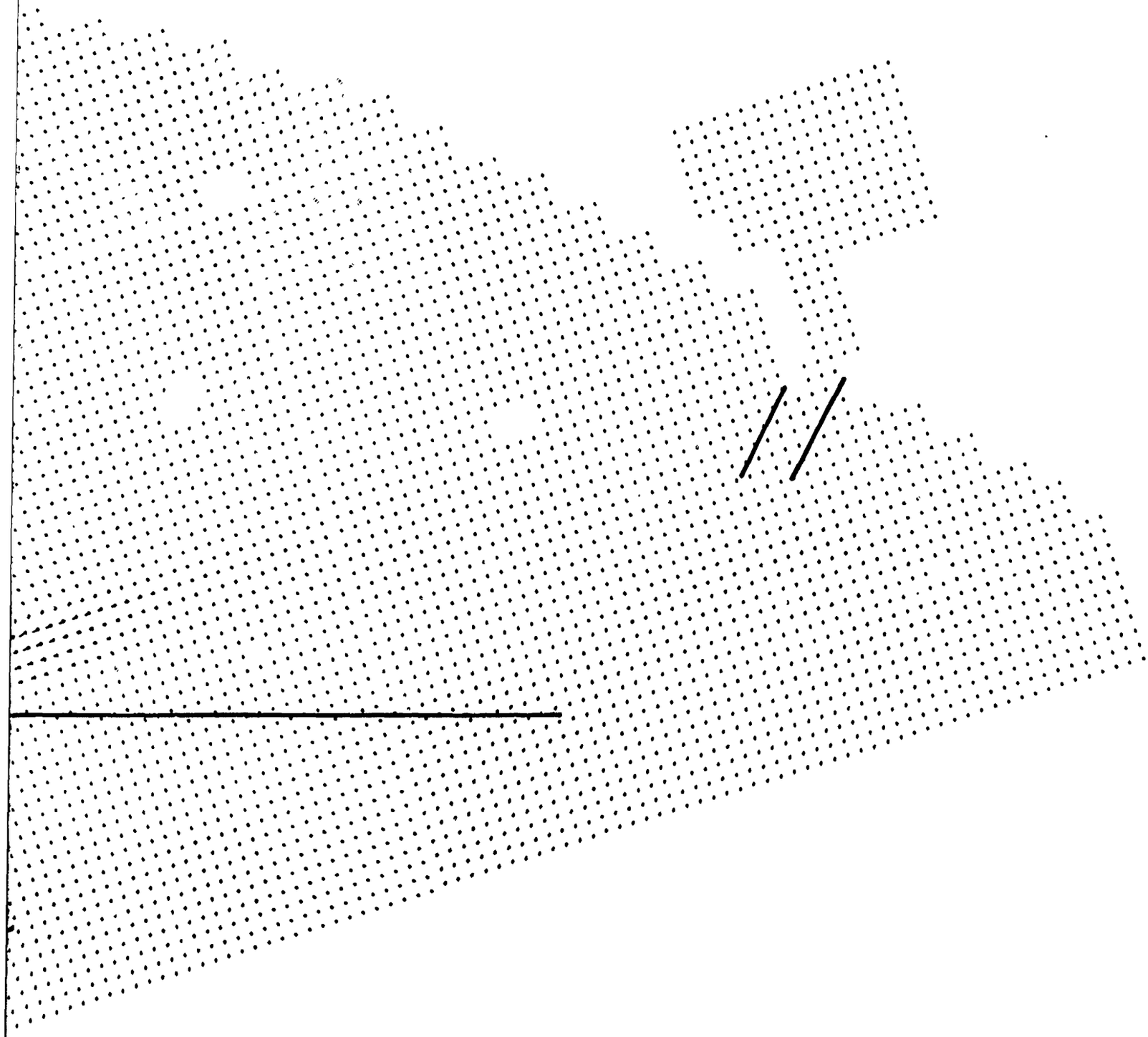


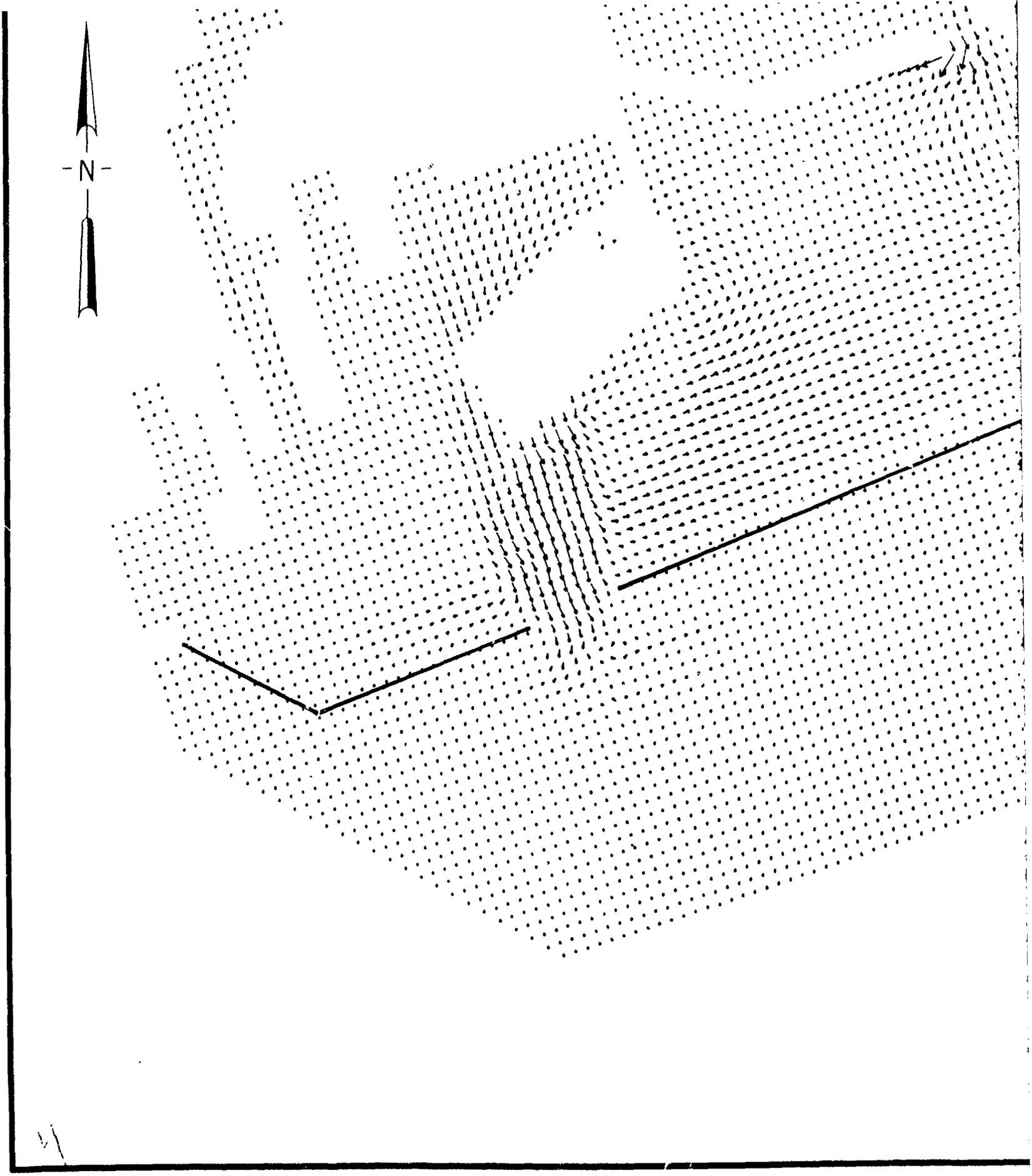
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN PLAN 1A-2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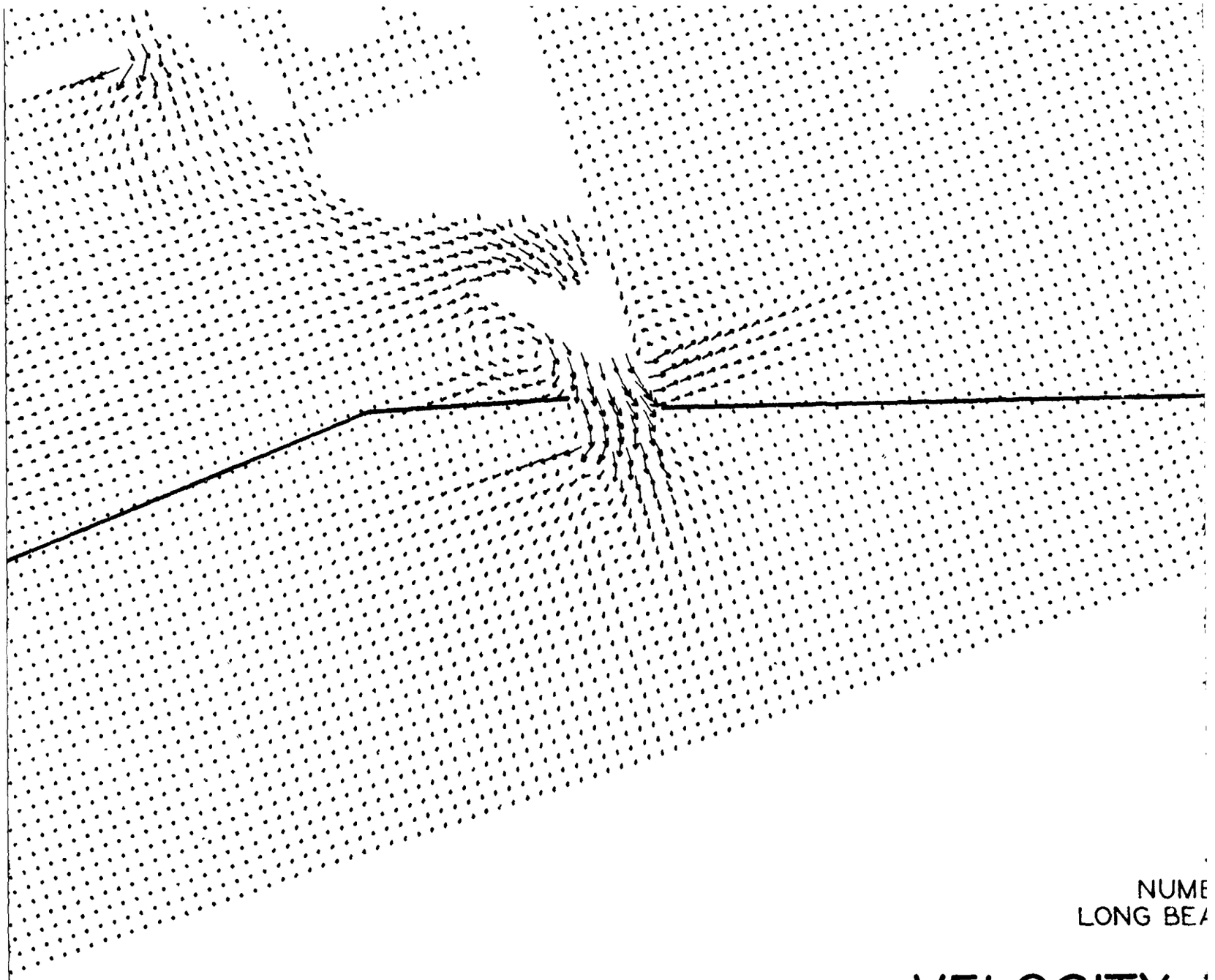

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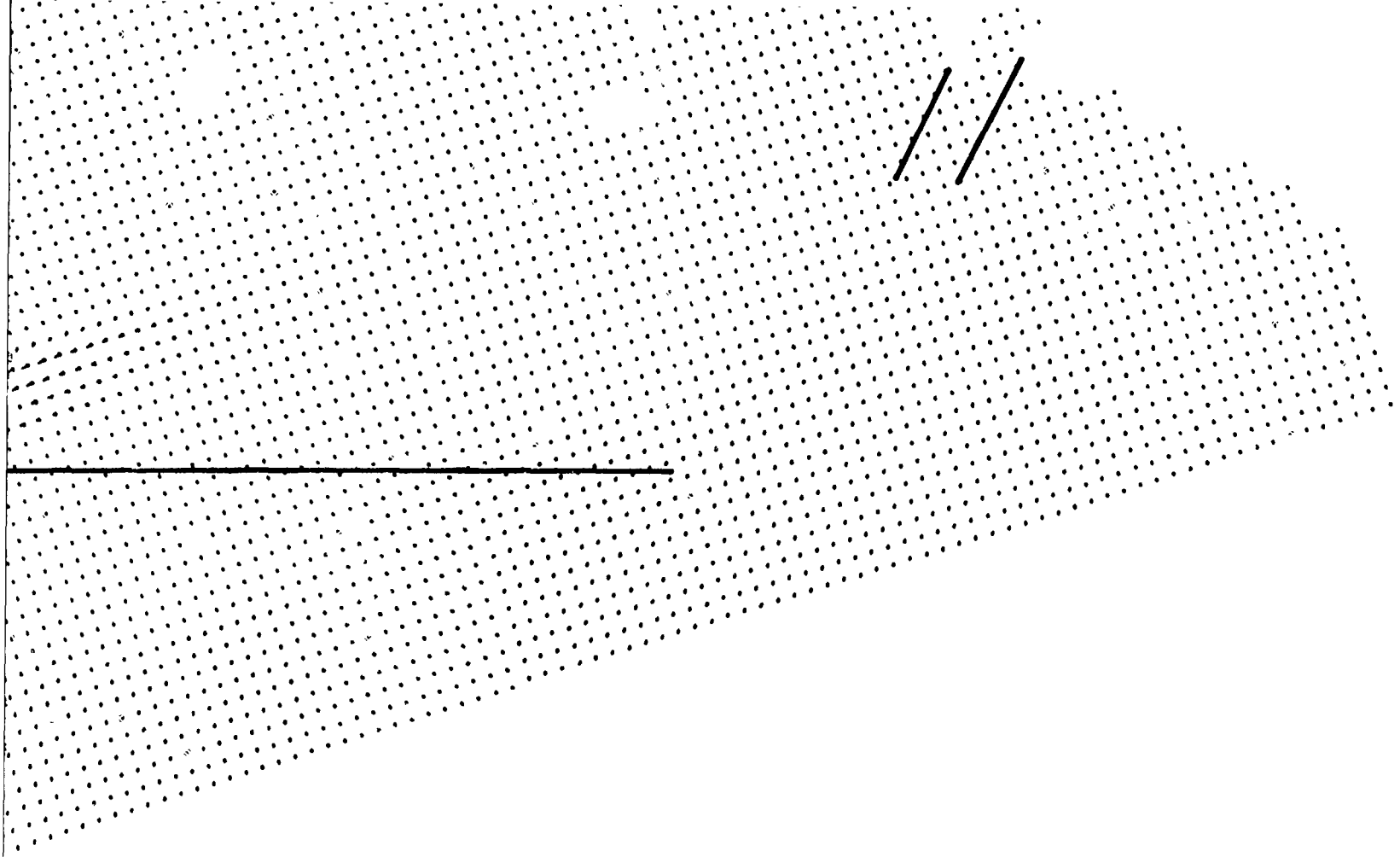


VELOCITY SCALE

1 0 1 2 3

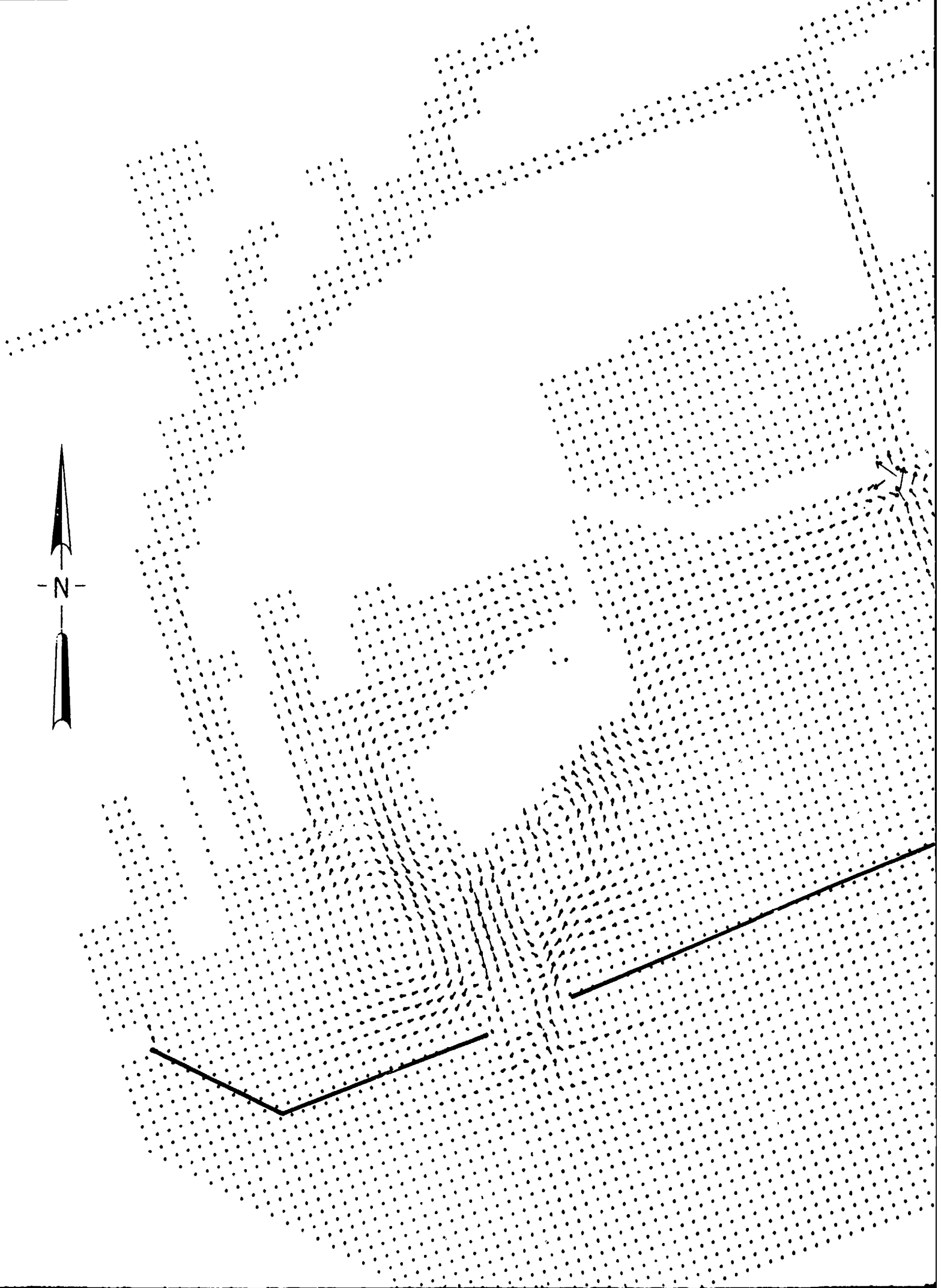
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN PLAN 1A-2 AND EXISTING CONDITIONS

SPRING TIDE
HOUR 19 (NEAR MAXIMUM FLOOD)

FIGURE 22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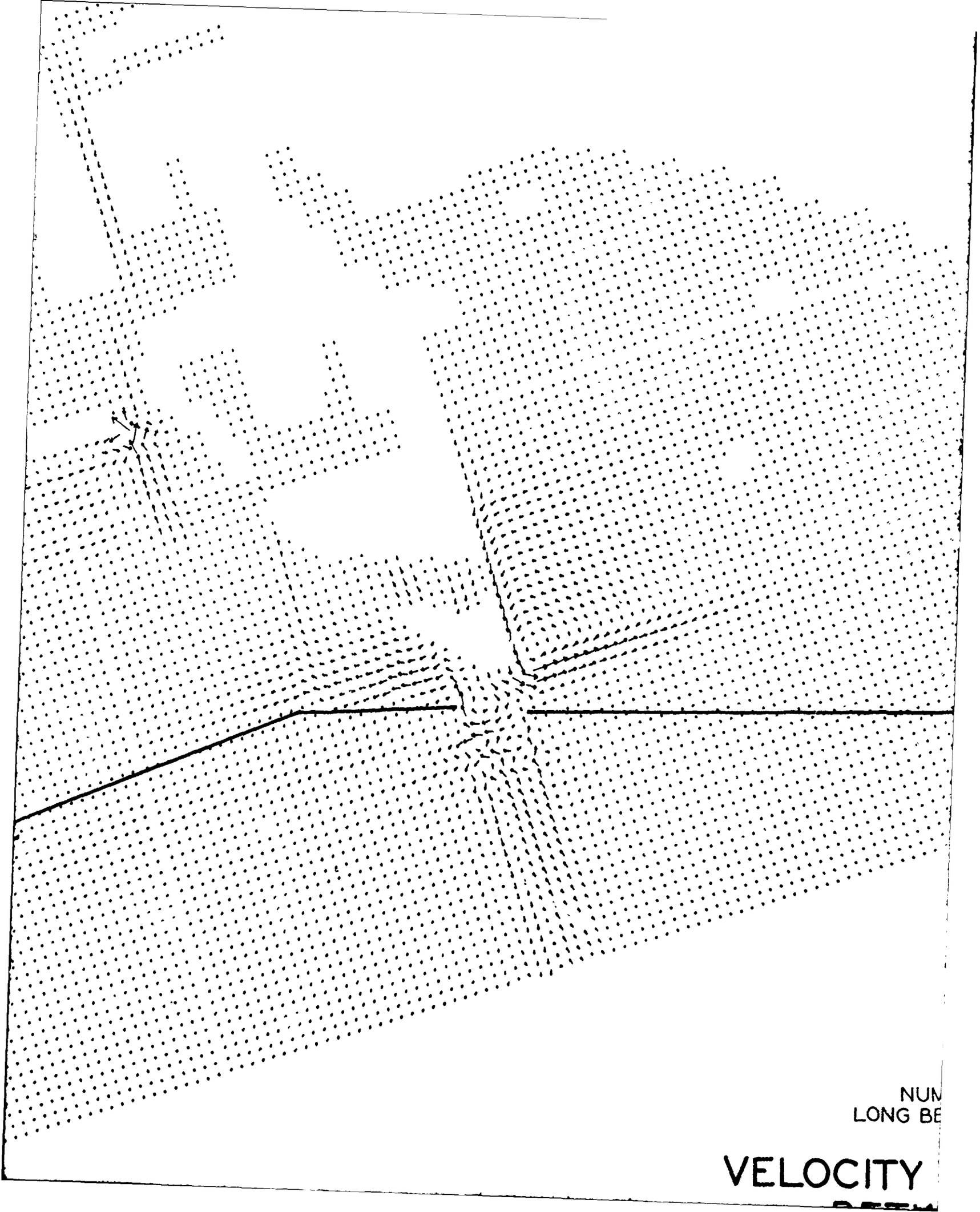
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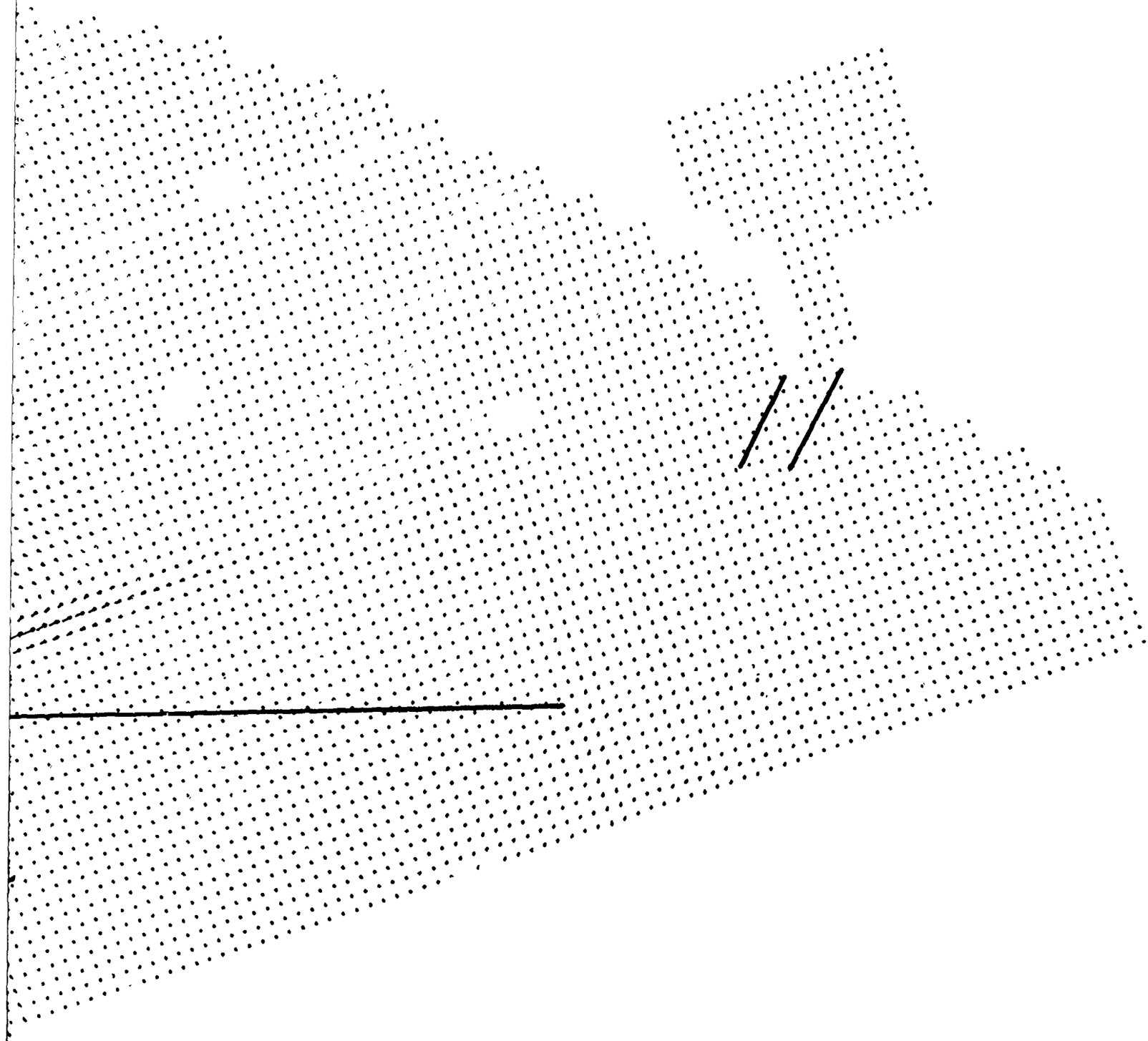


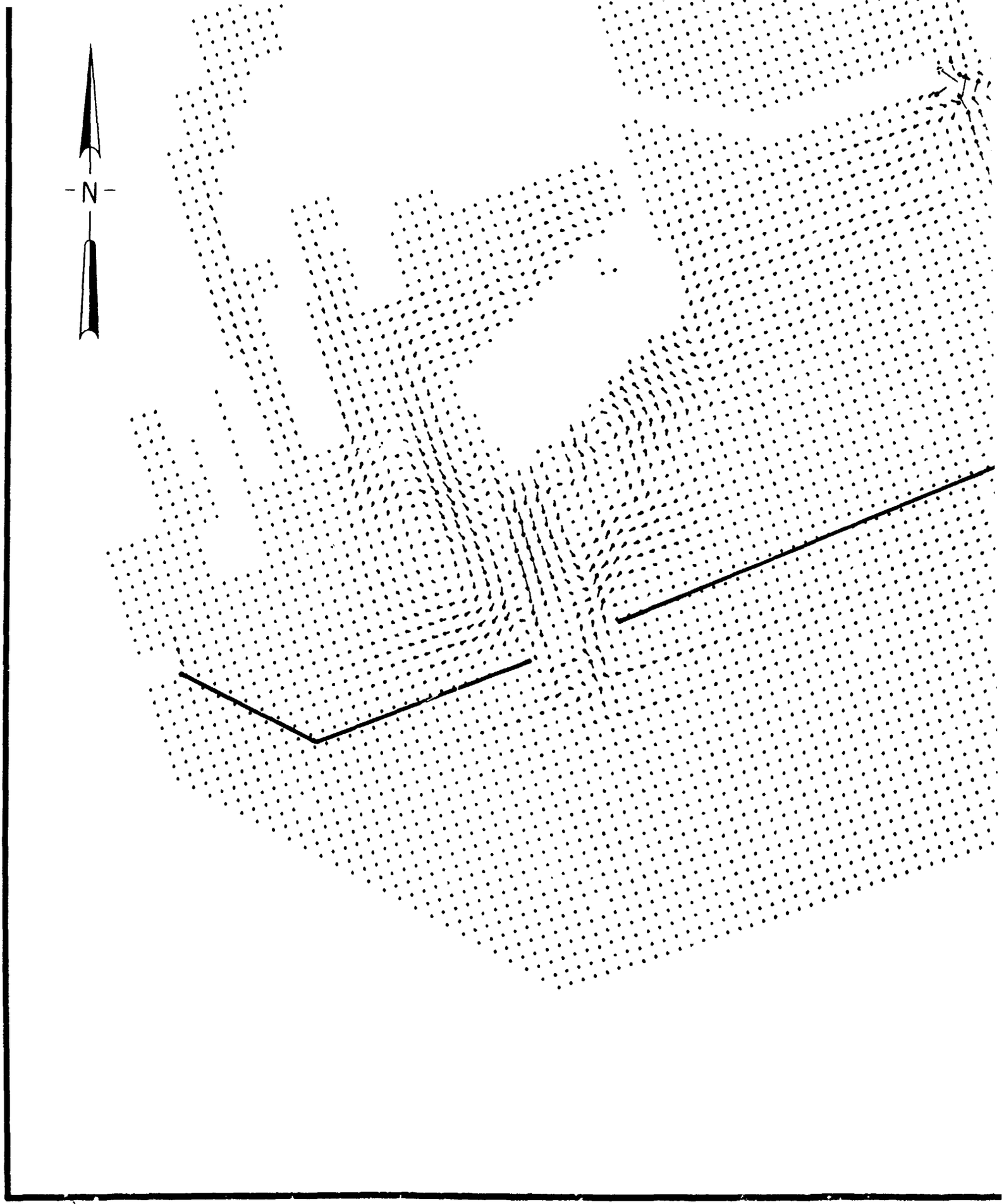
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN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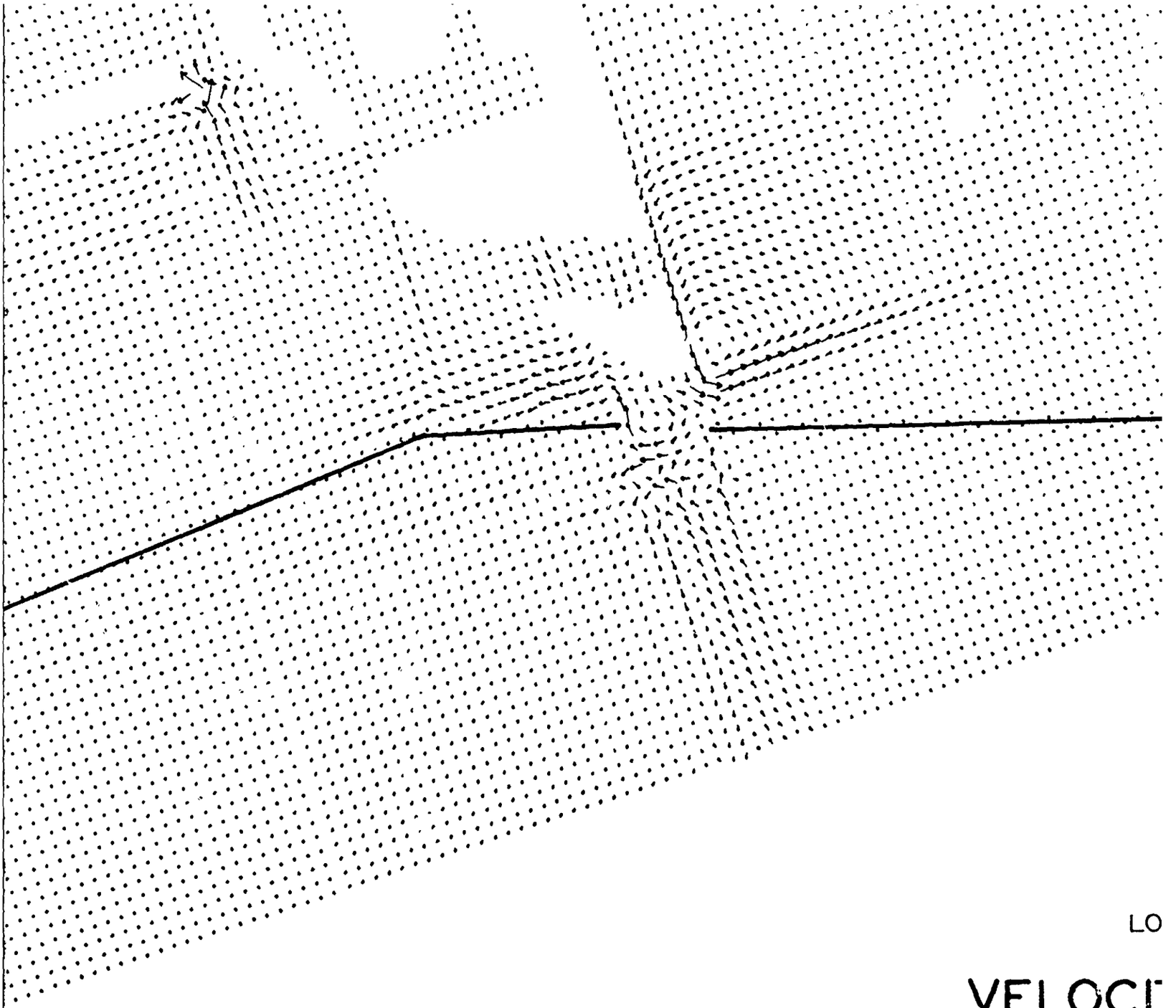

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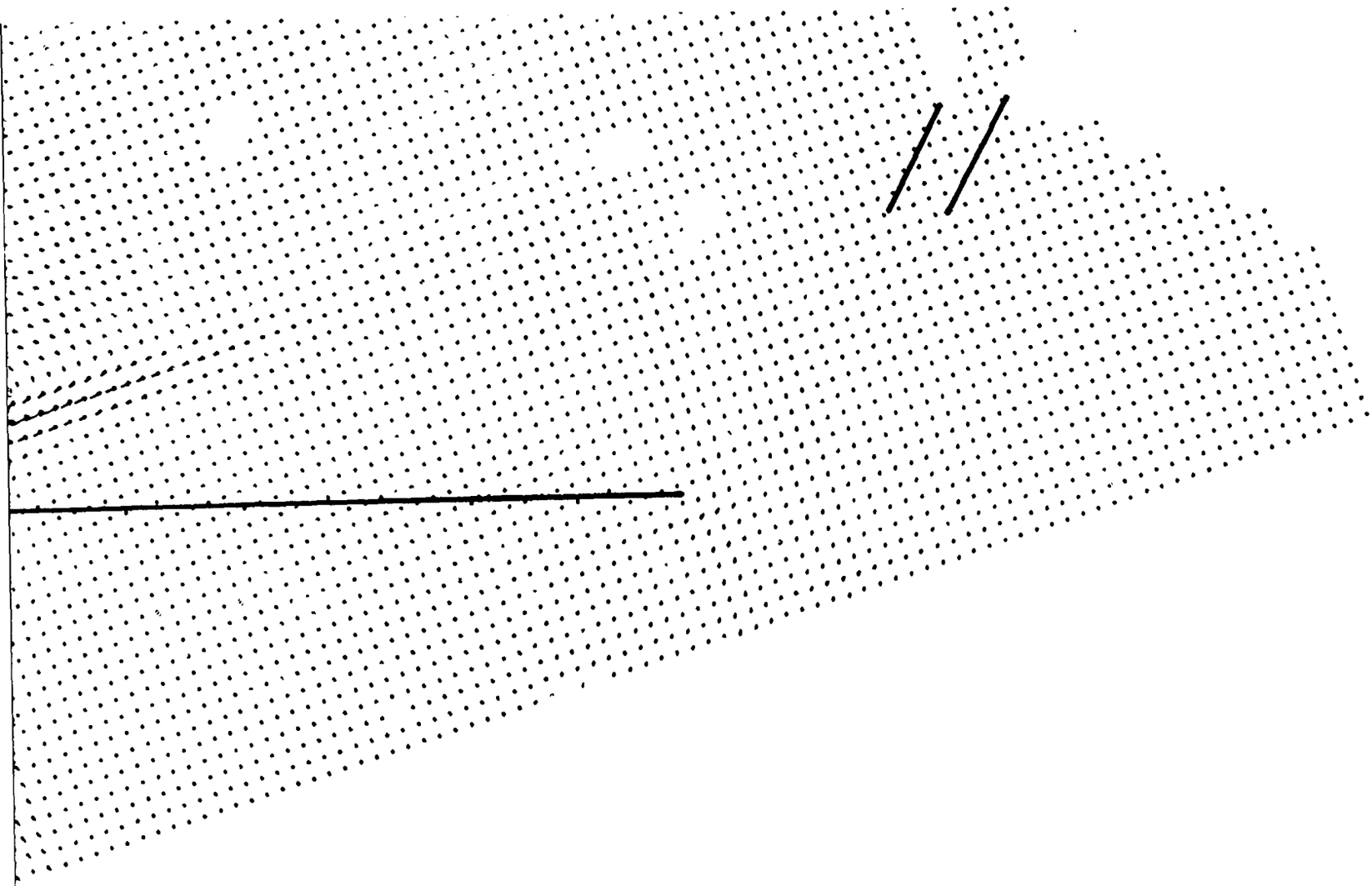


VELOCITY SCALE

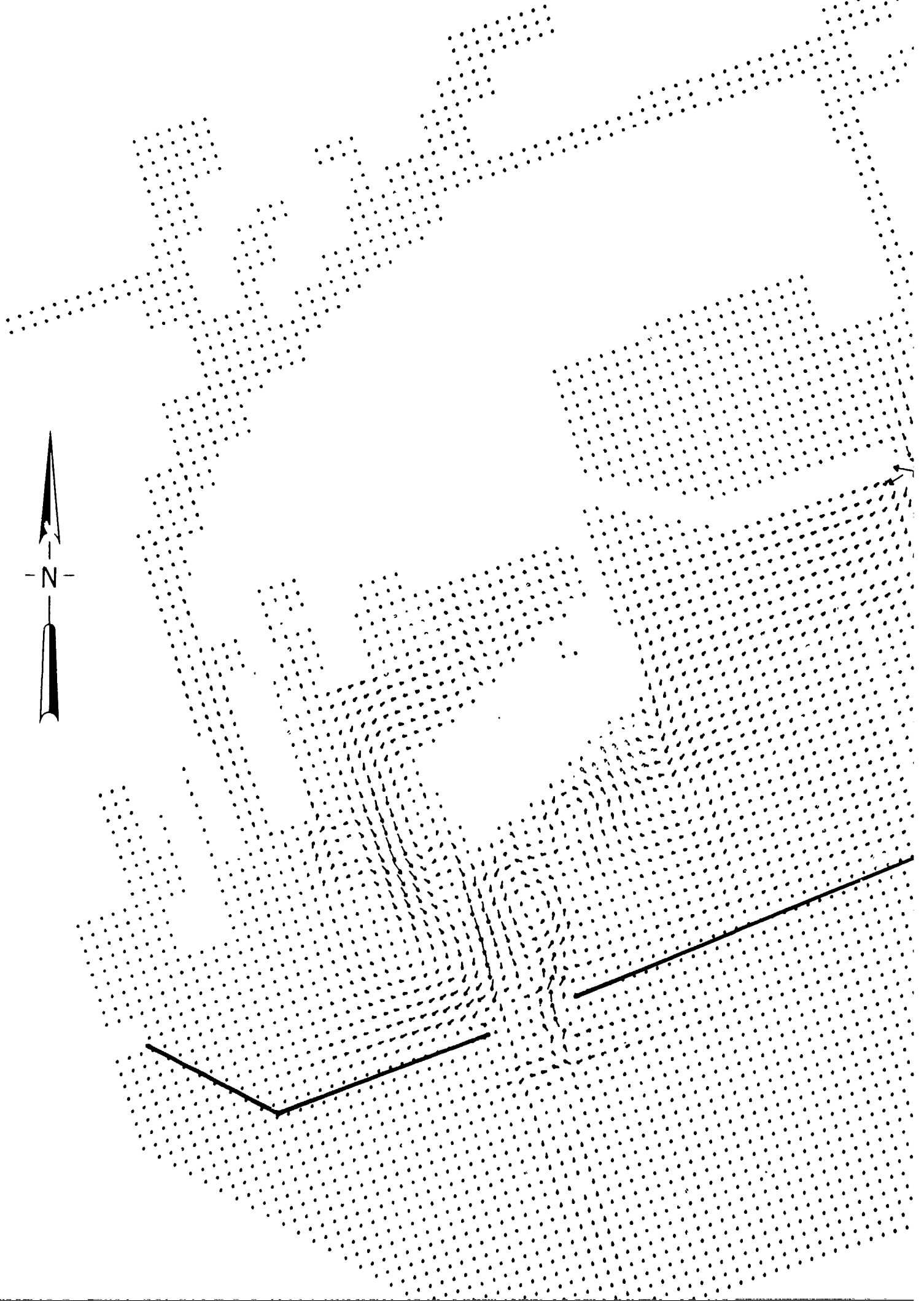
1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN PLAN 1A-2 AND EXISTING CONDITIONS

SPRING TIDE
HOUR 22 (NEAR SLACK WATER)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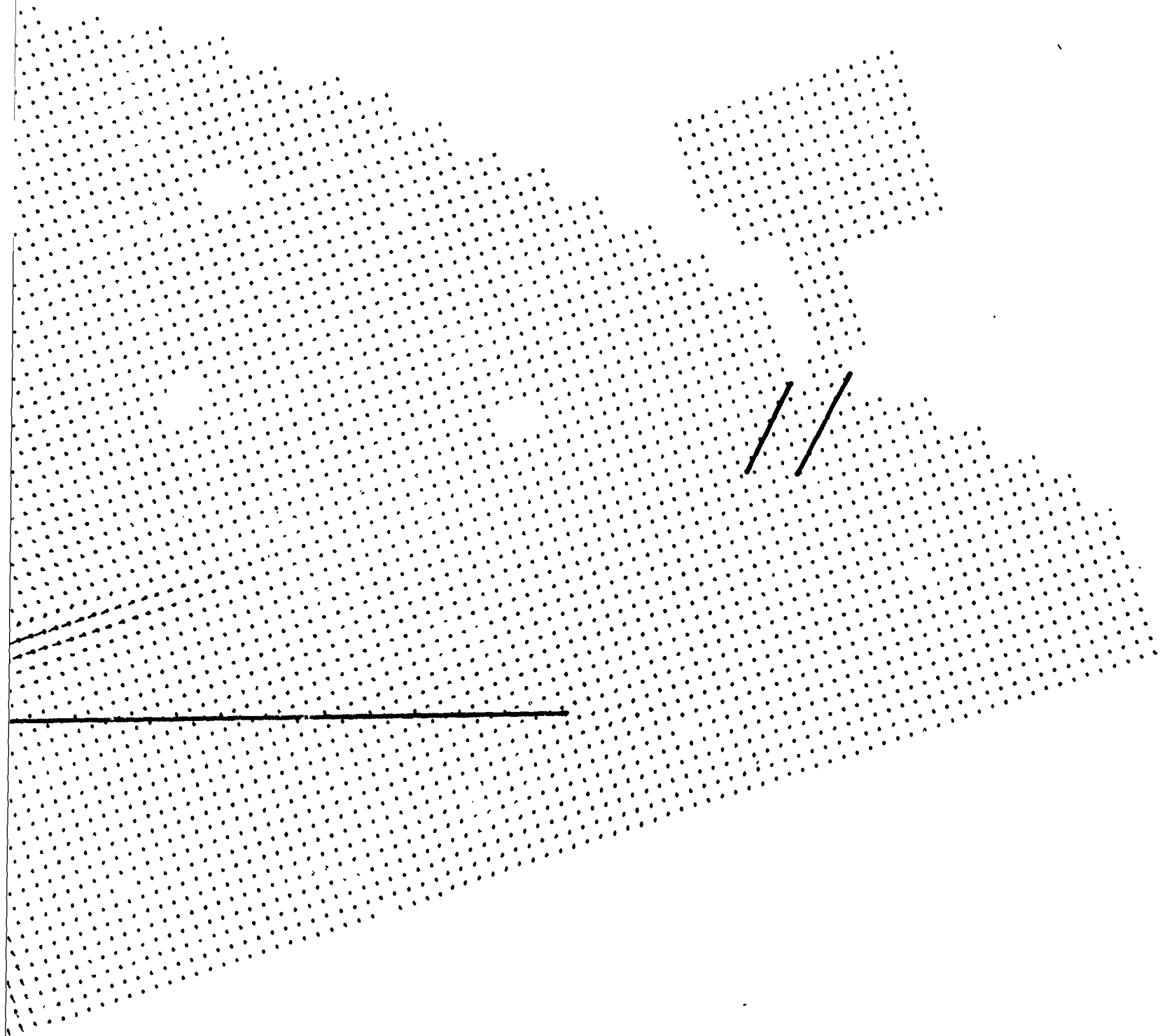


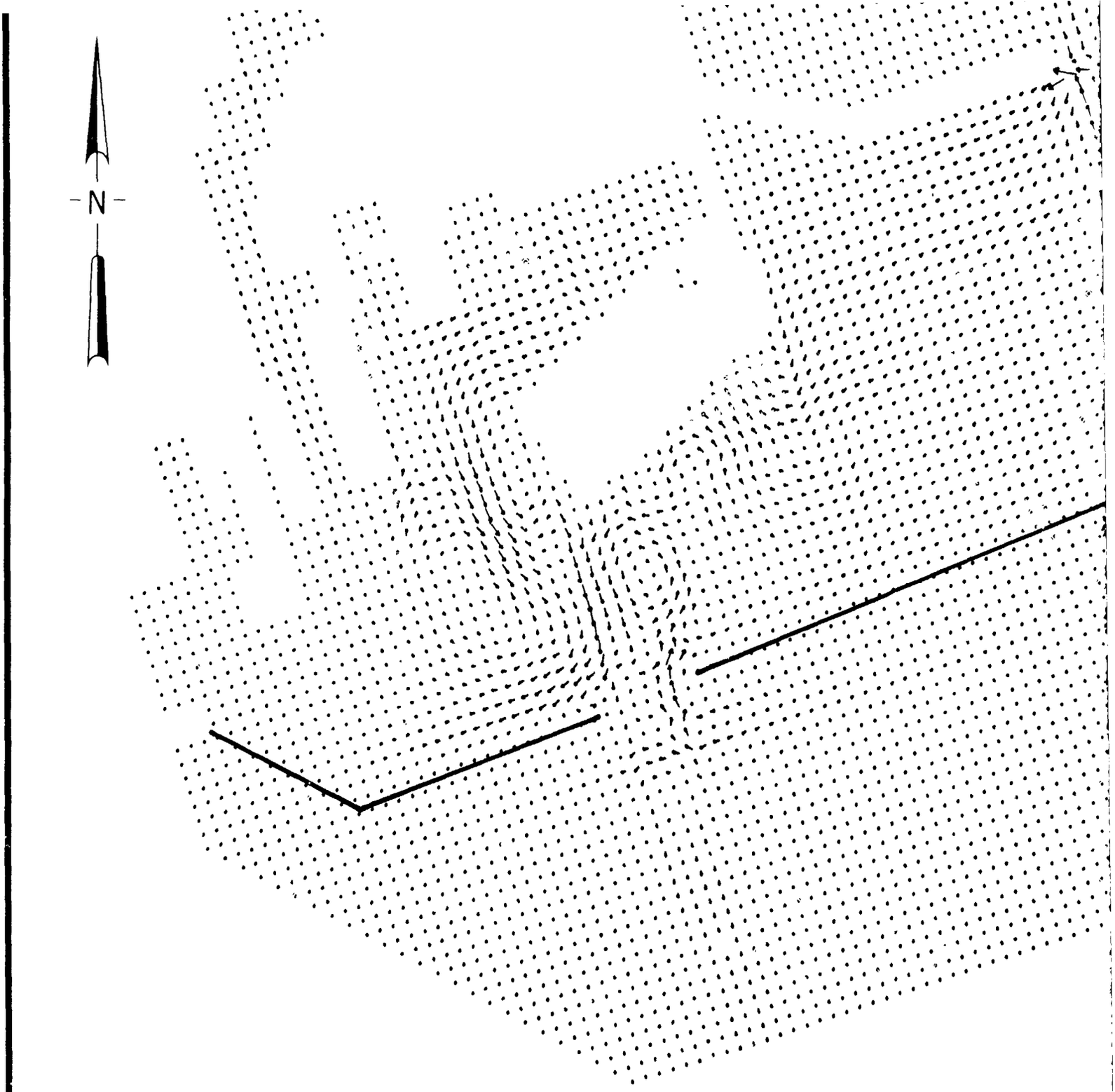
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN



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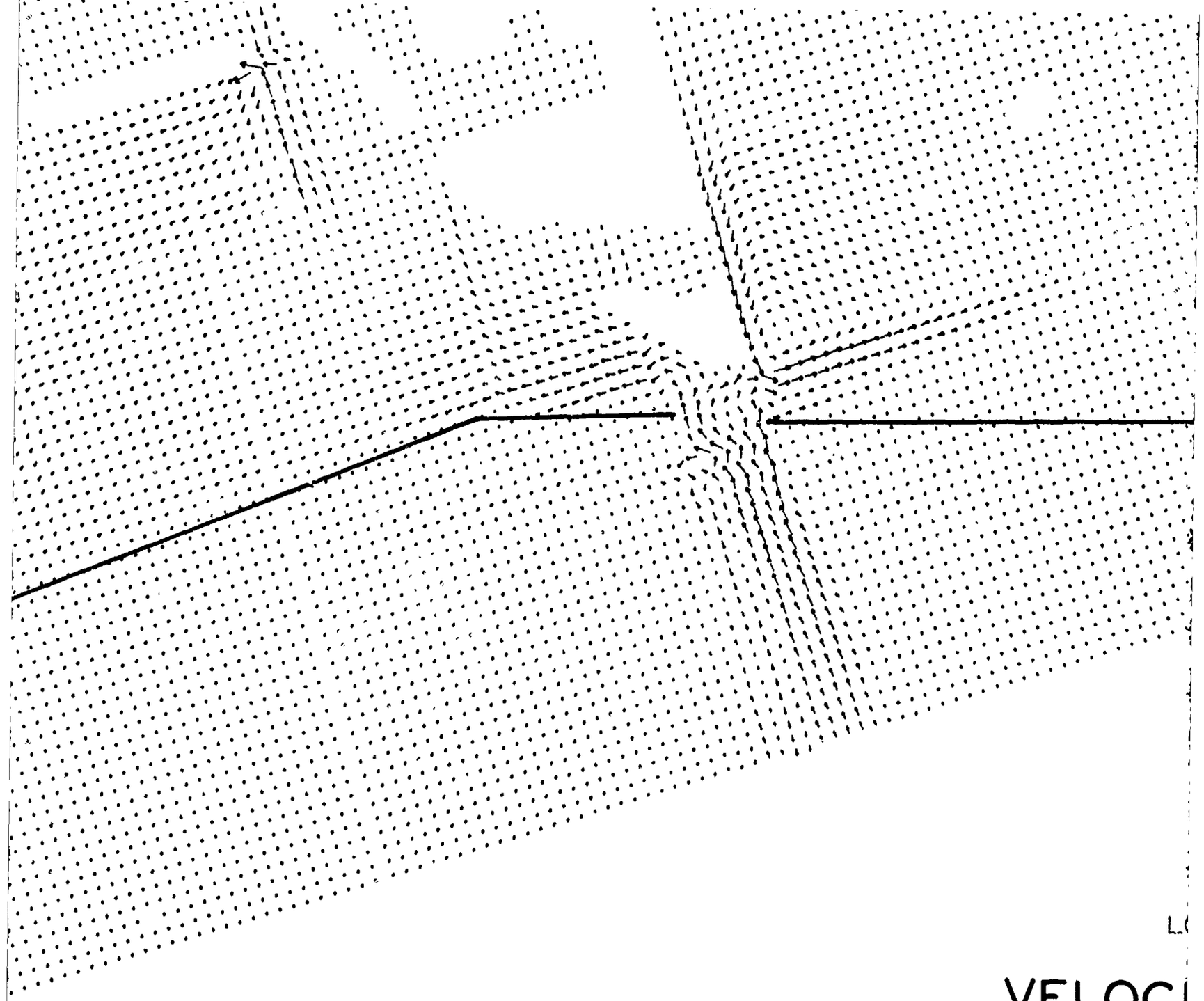

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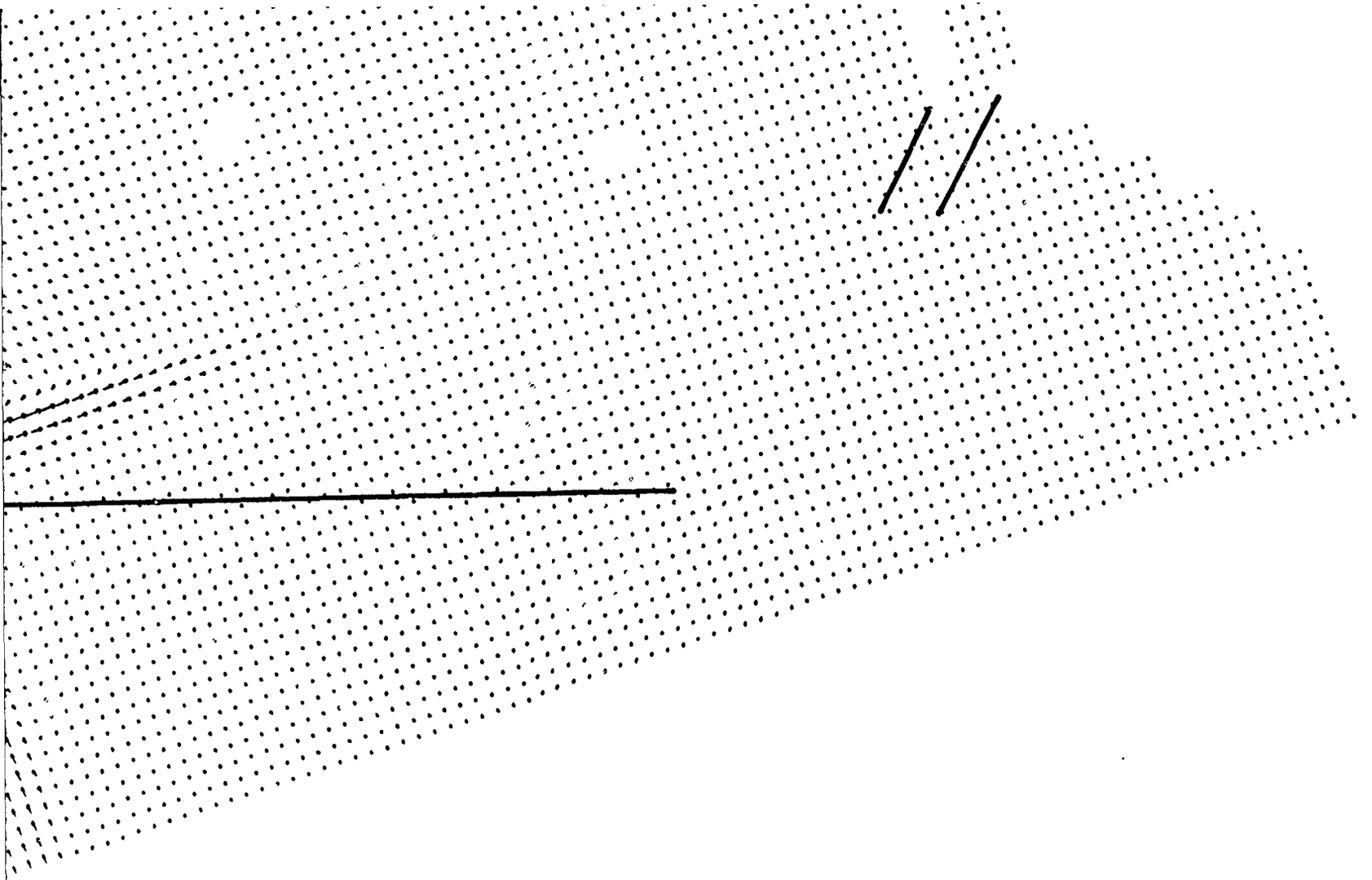


VELOCITY SCALE

1 0 1 2 3

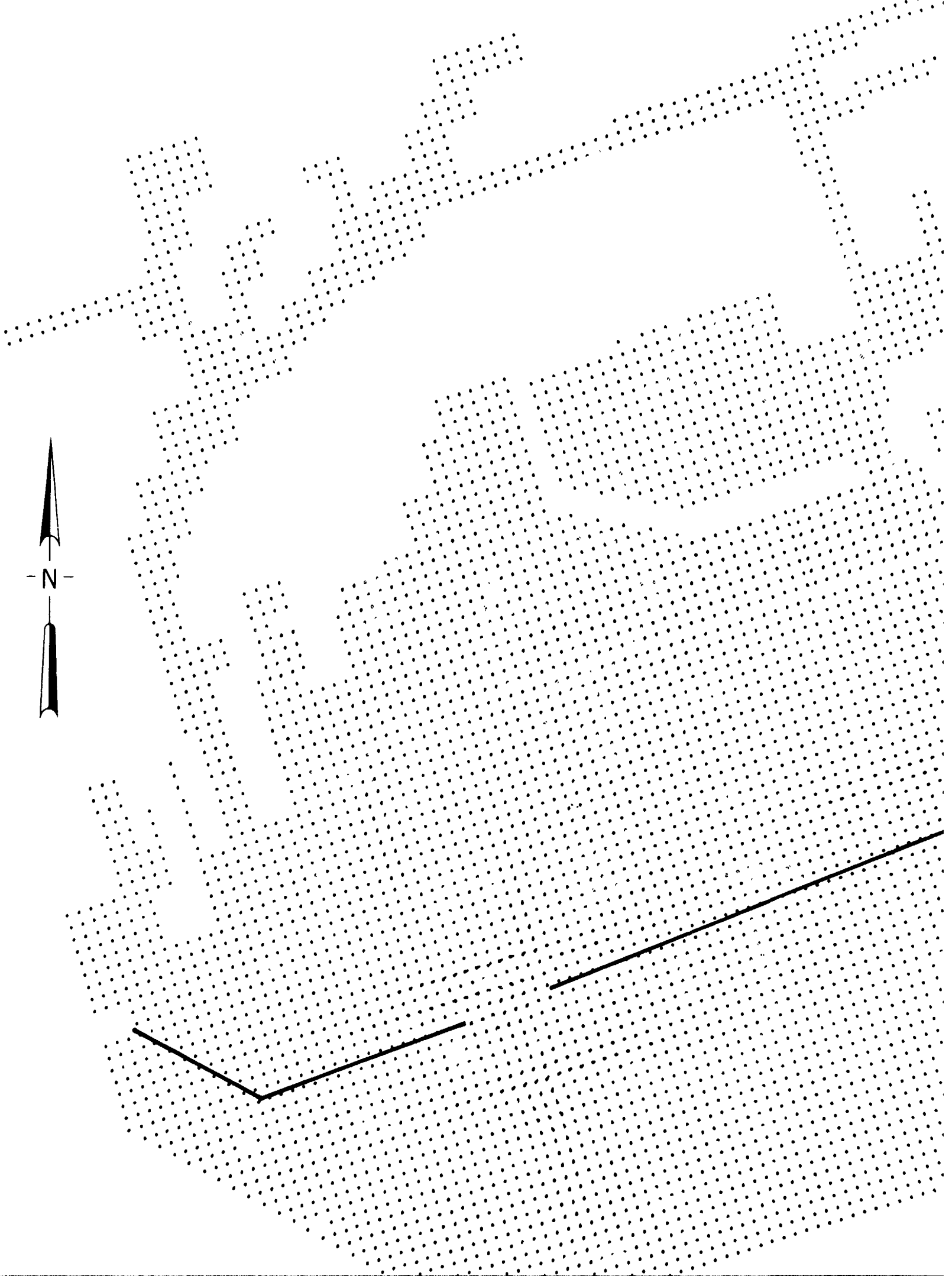
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN PLAN 1A-2 AND EXISTING CONDITIONS

SPRING TIDE
HOUR 24 (NEAR MAXIMUM EBB)

FIGURE 2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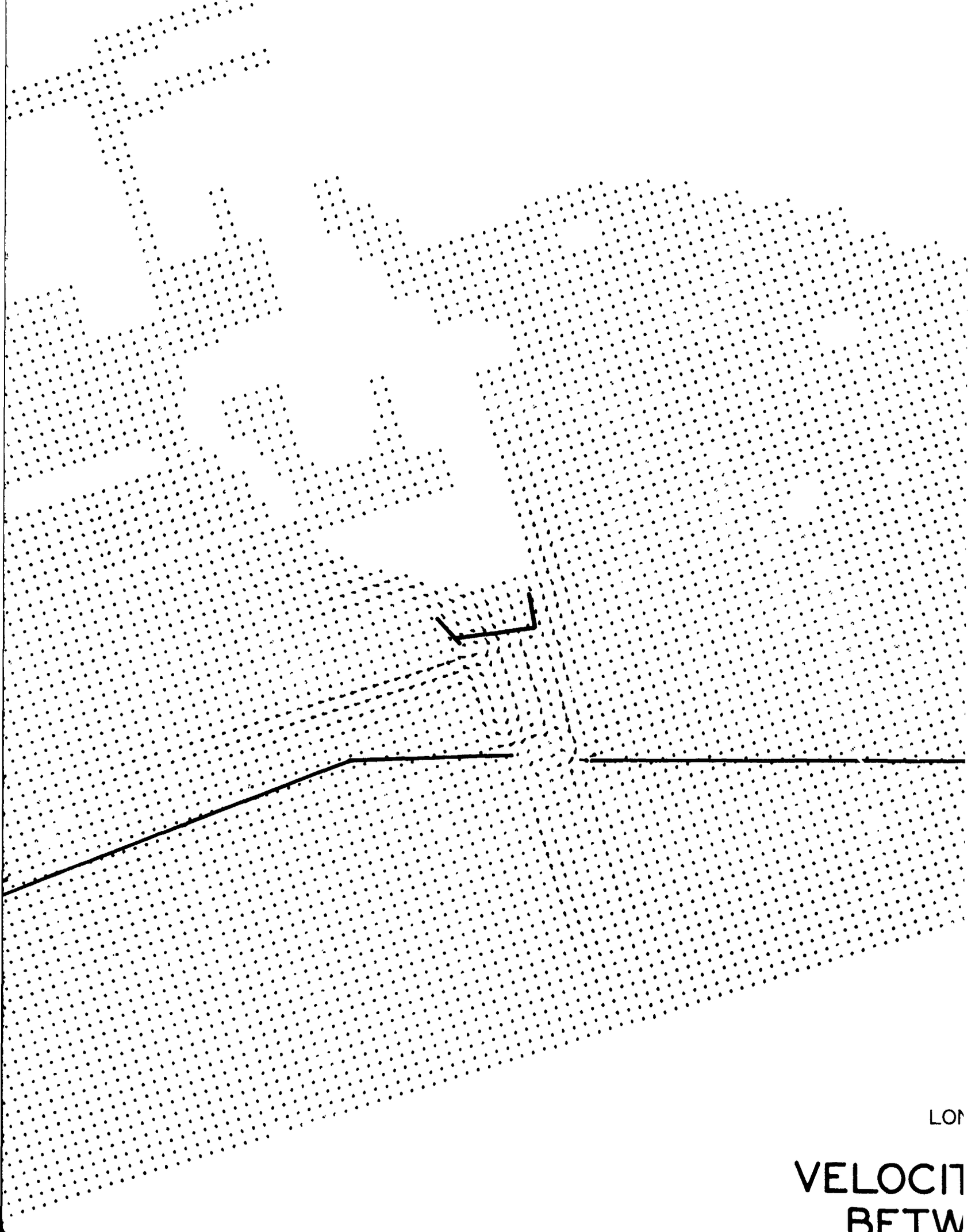
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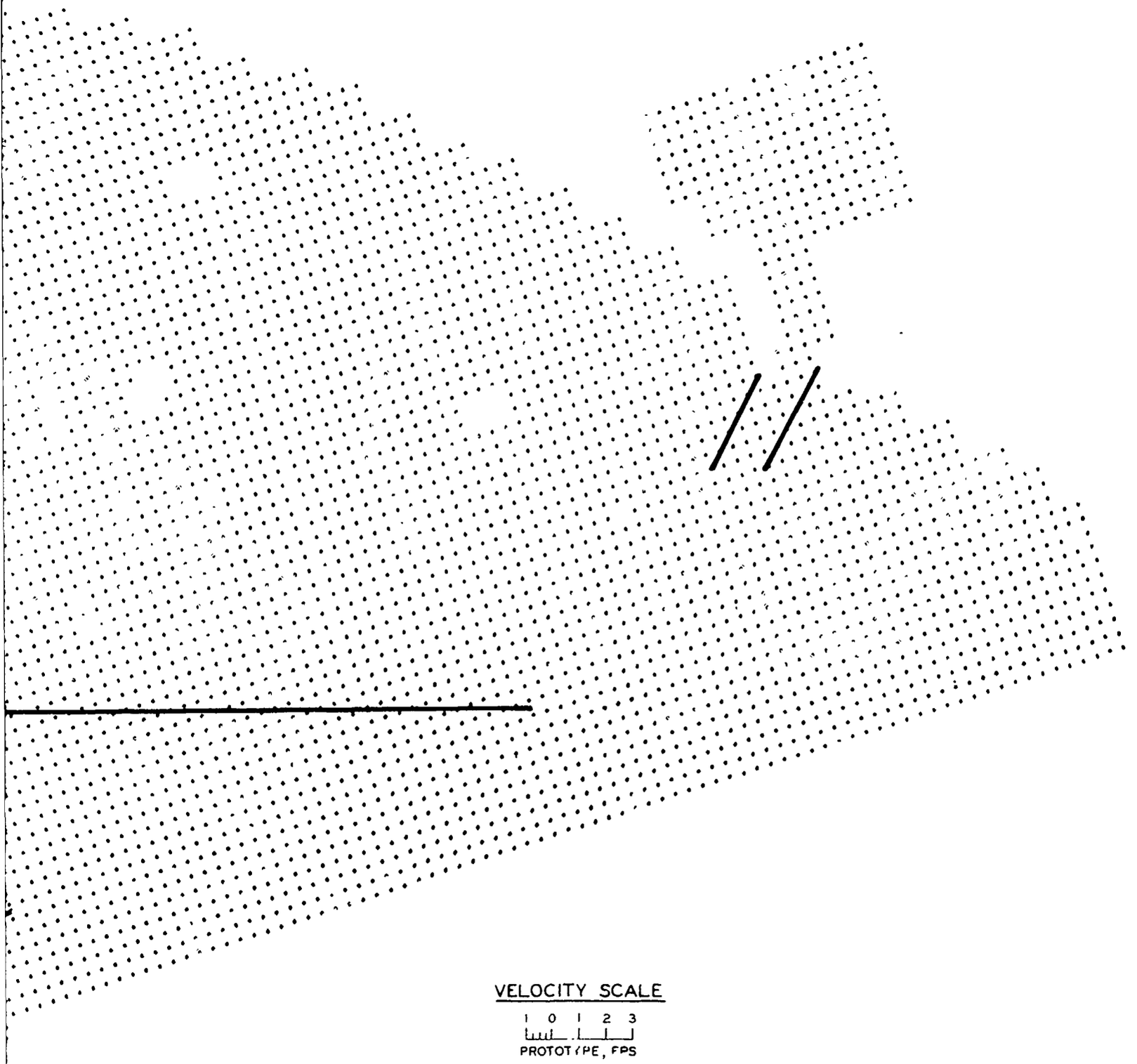
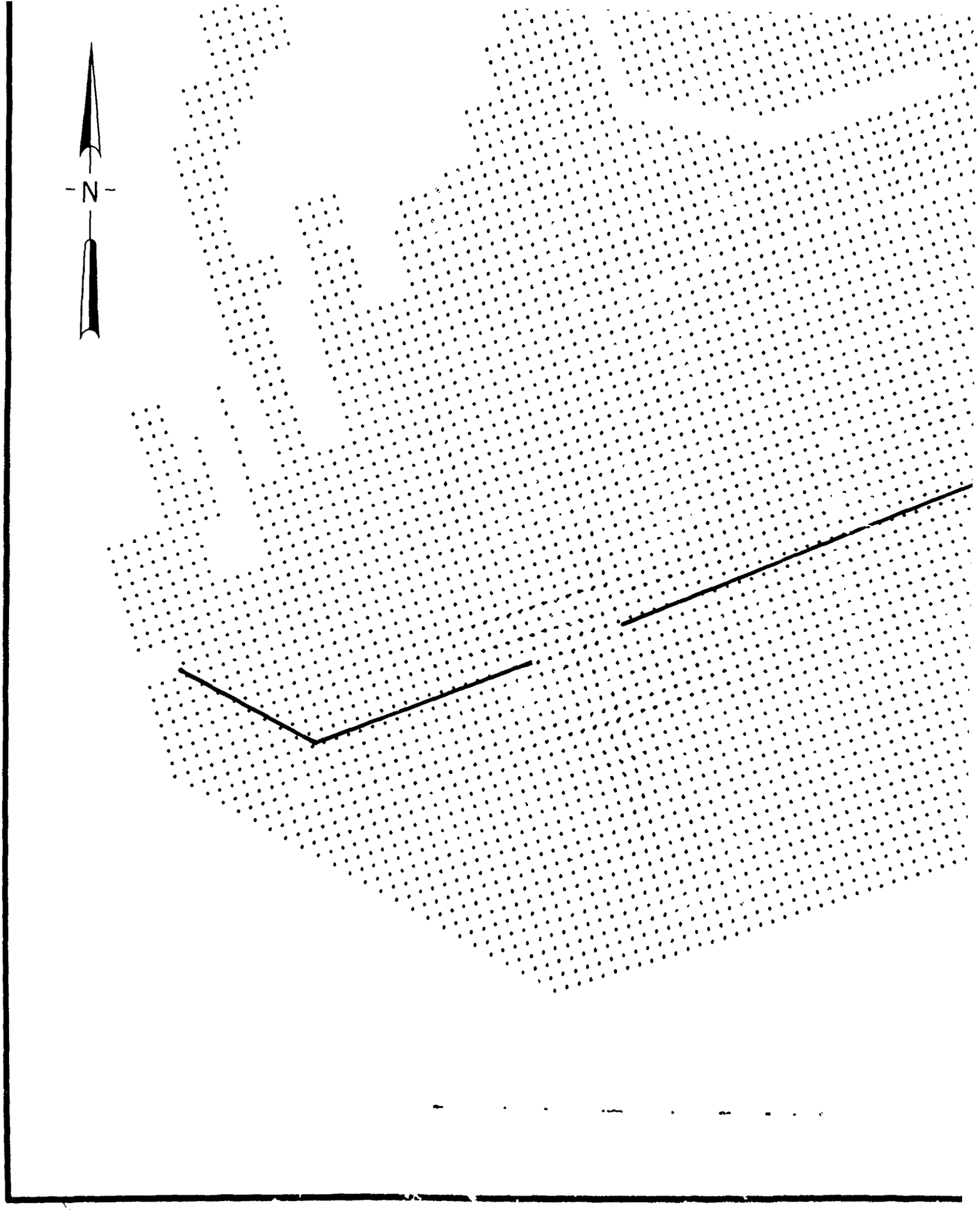


NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL 300-FT OPENING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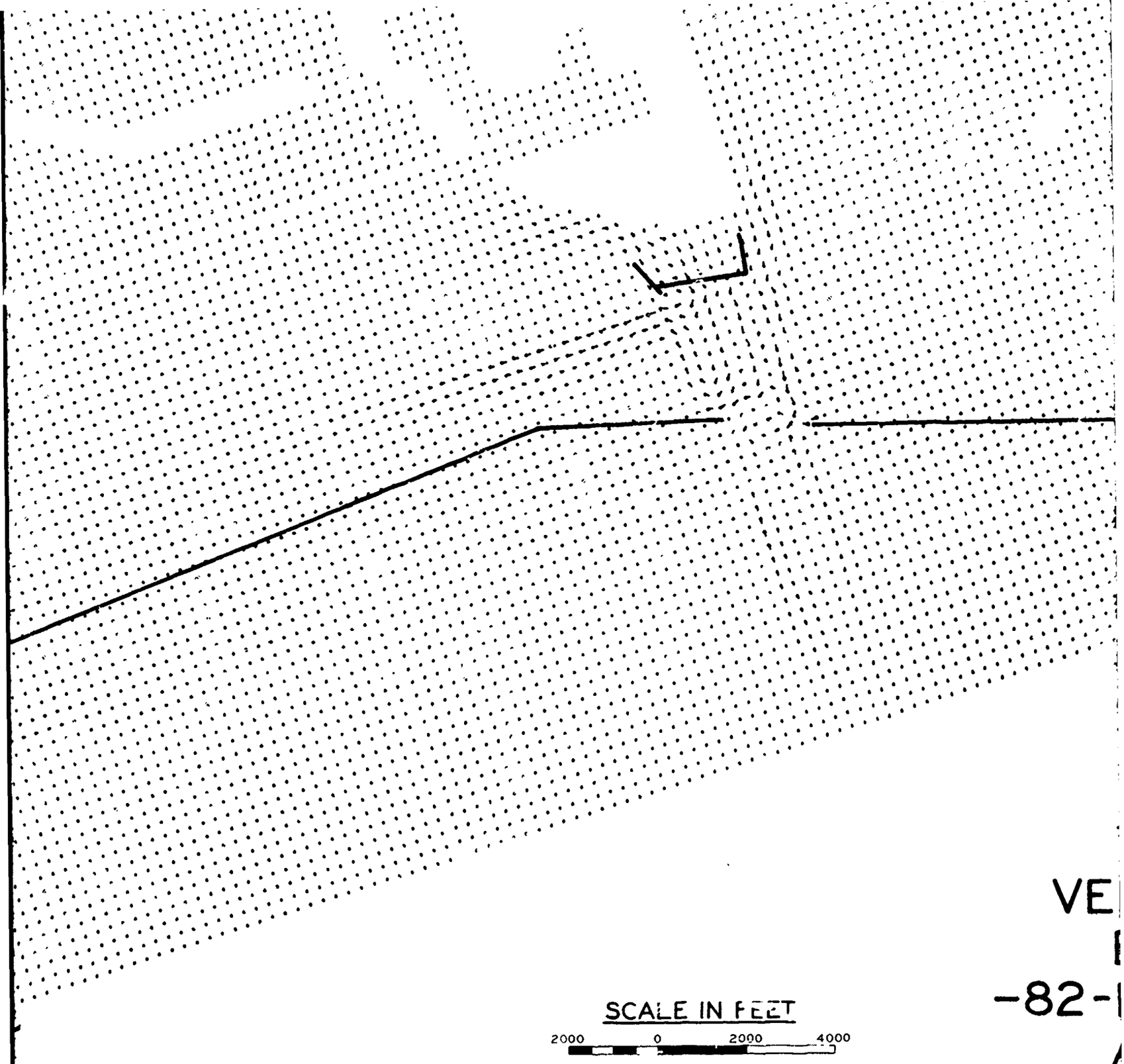

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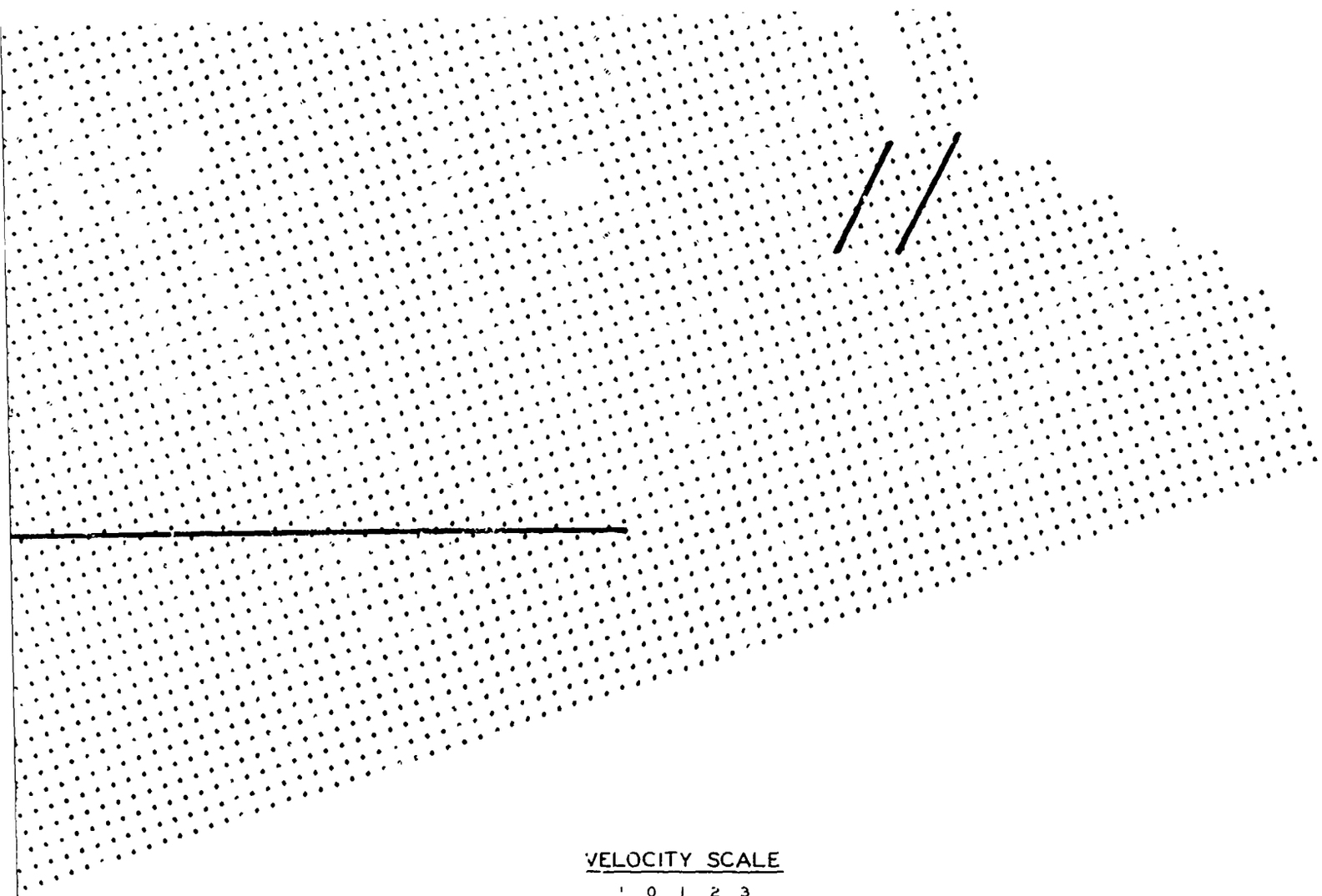


VELOCITY SCALE

1 0 1 2 3

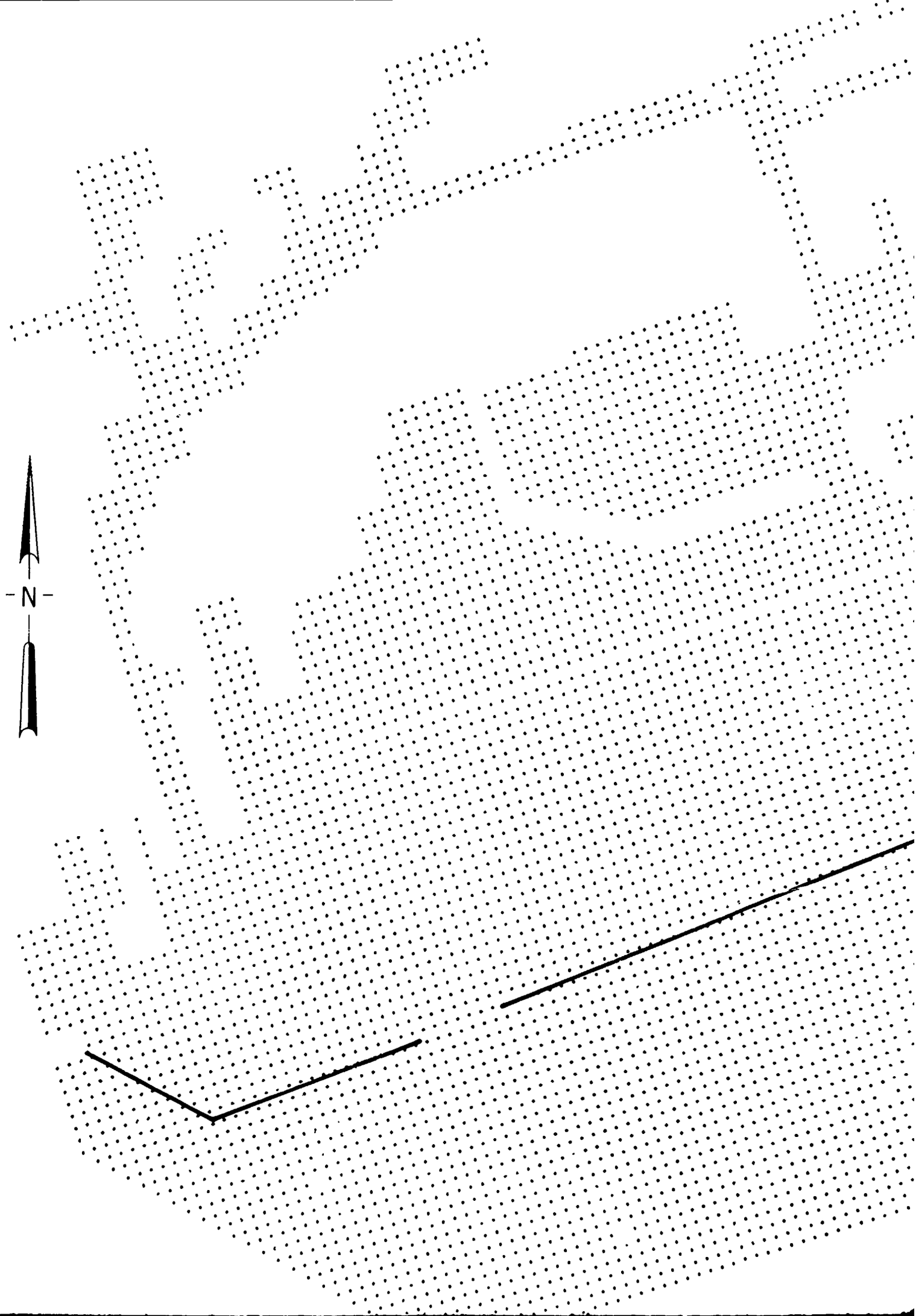
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 300-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 15 (NEAR SLACK WATER)

FIGURE 25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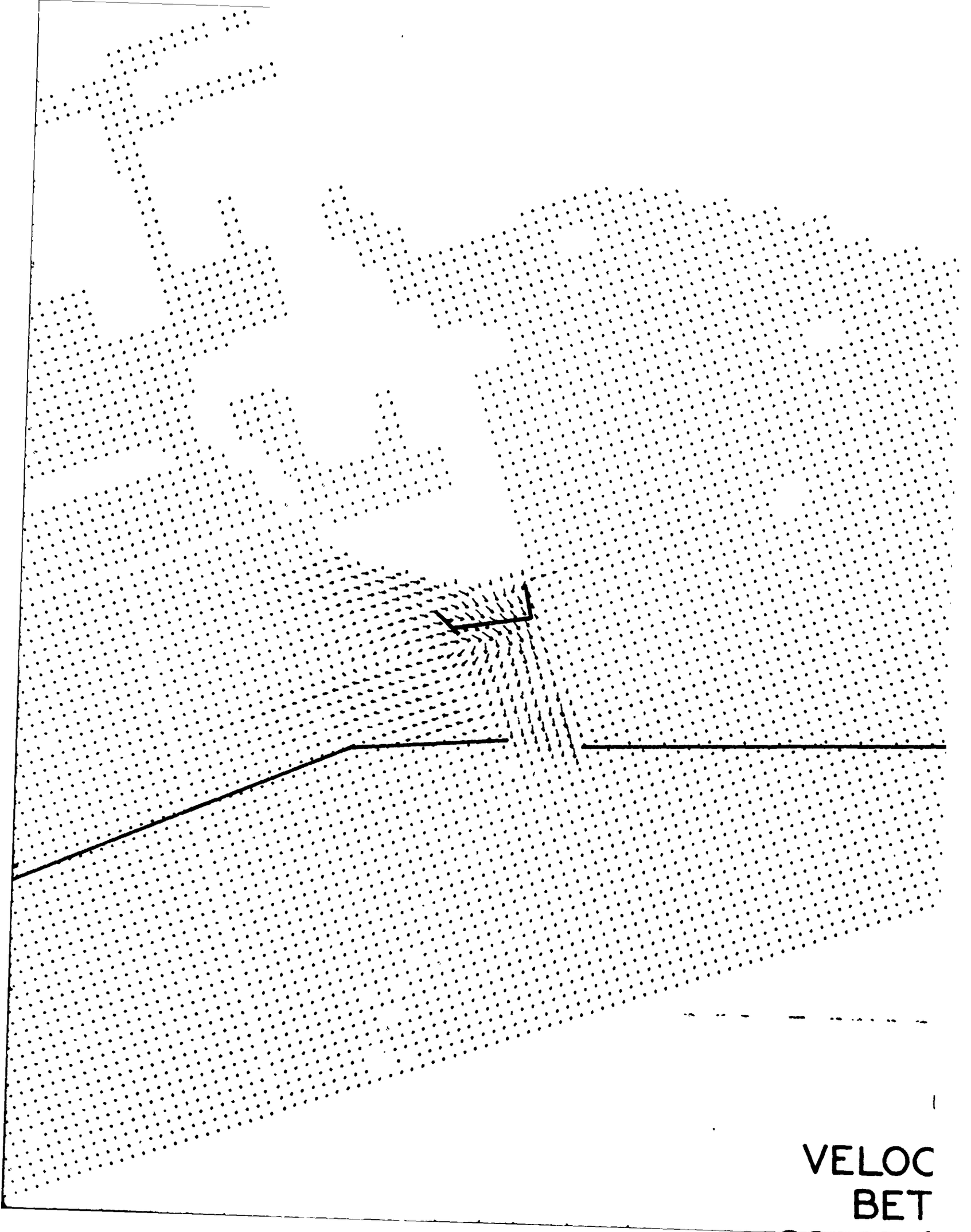
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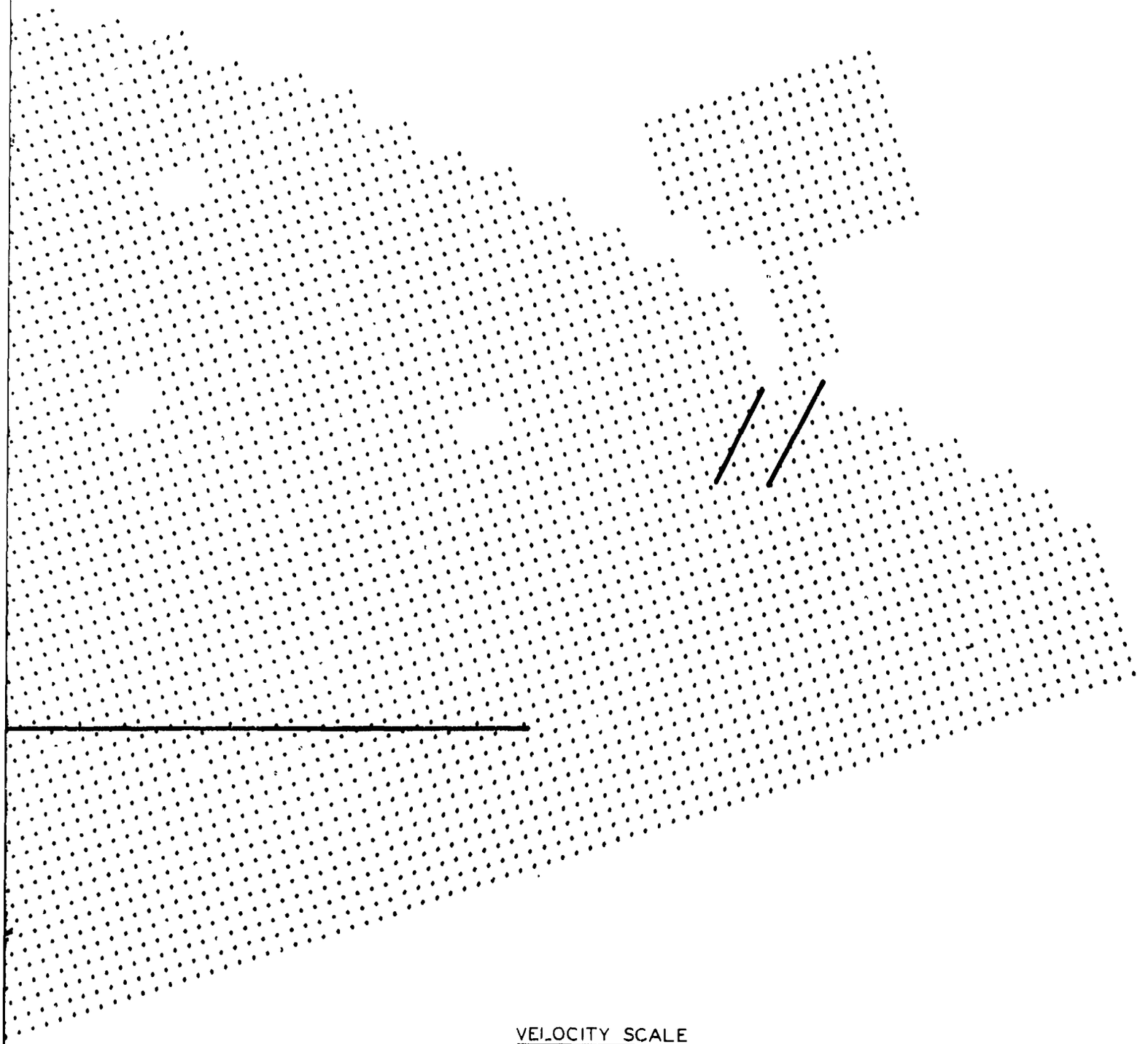

VELOCITY SCALE

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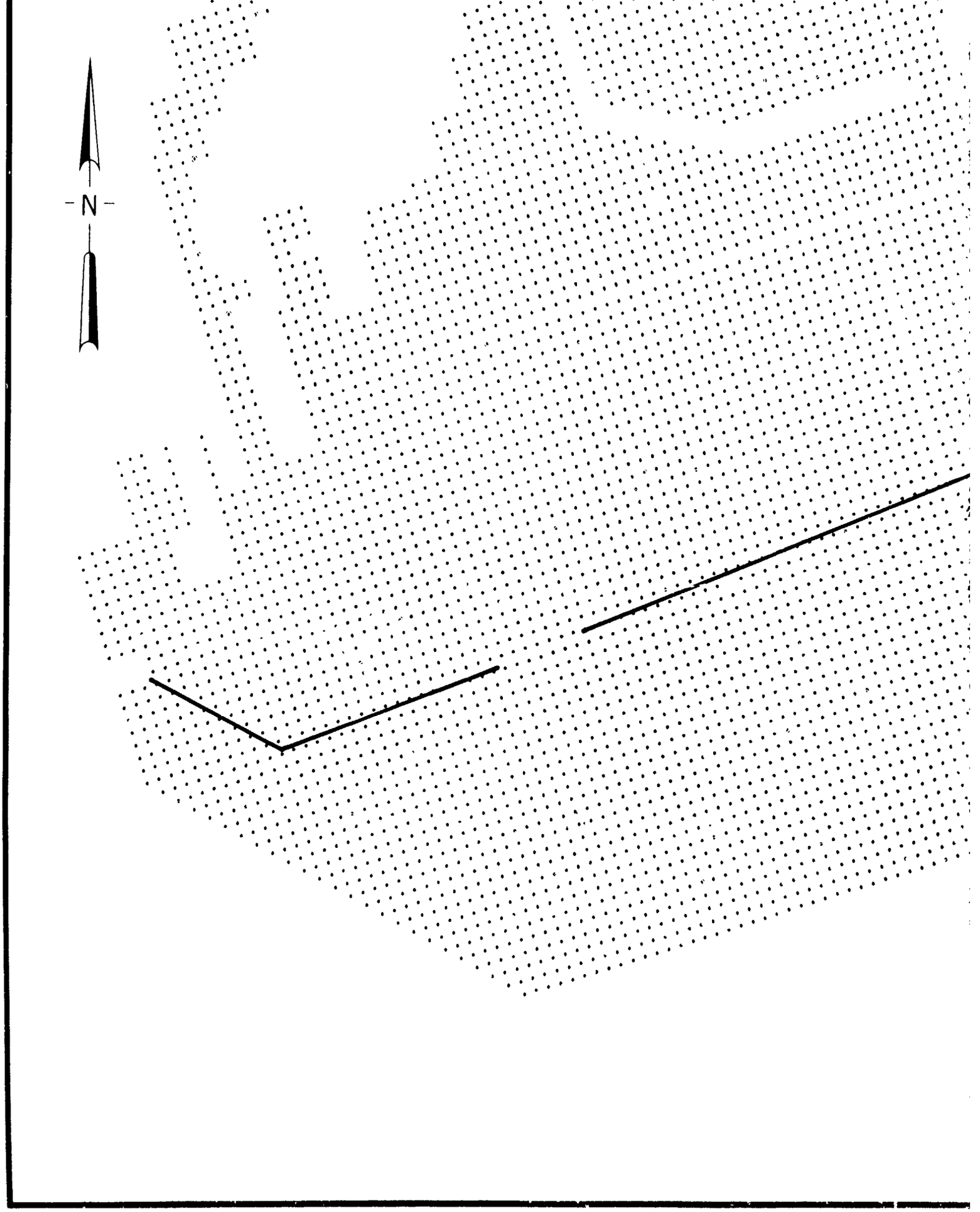
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2,

-83-FT CHANNEL 300-FT OPENING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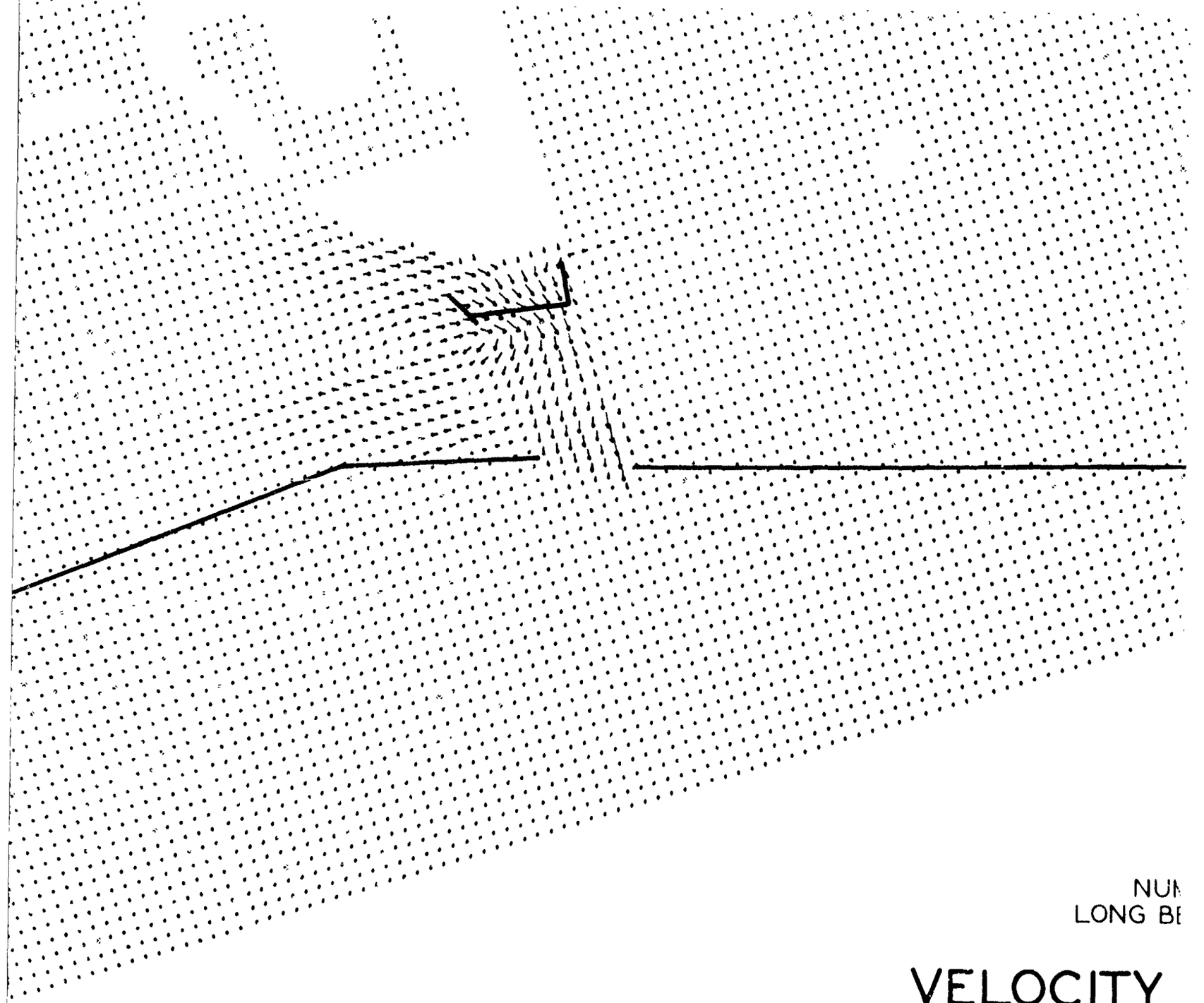

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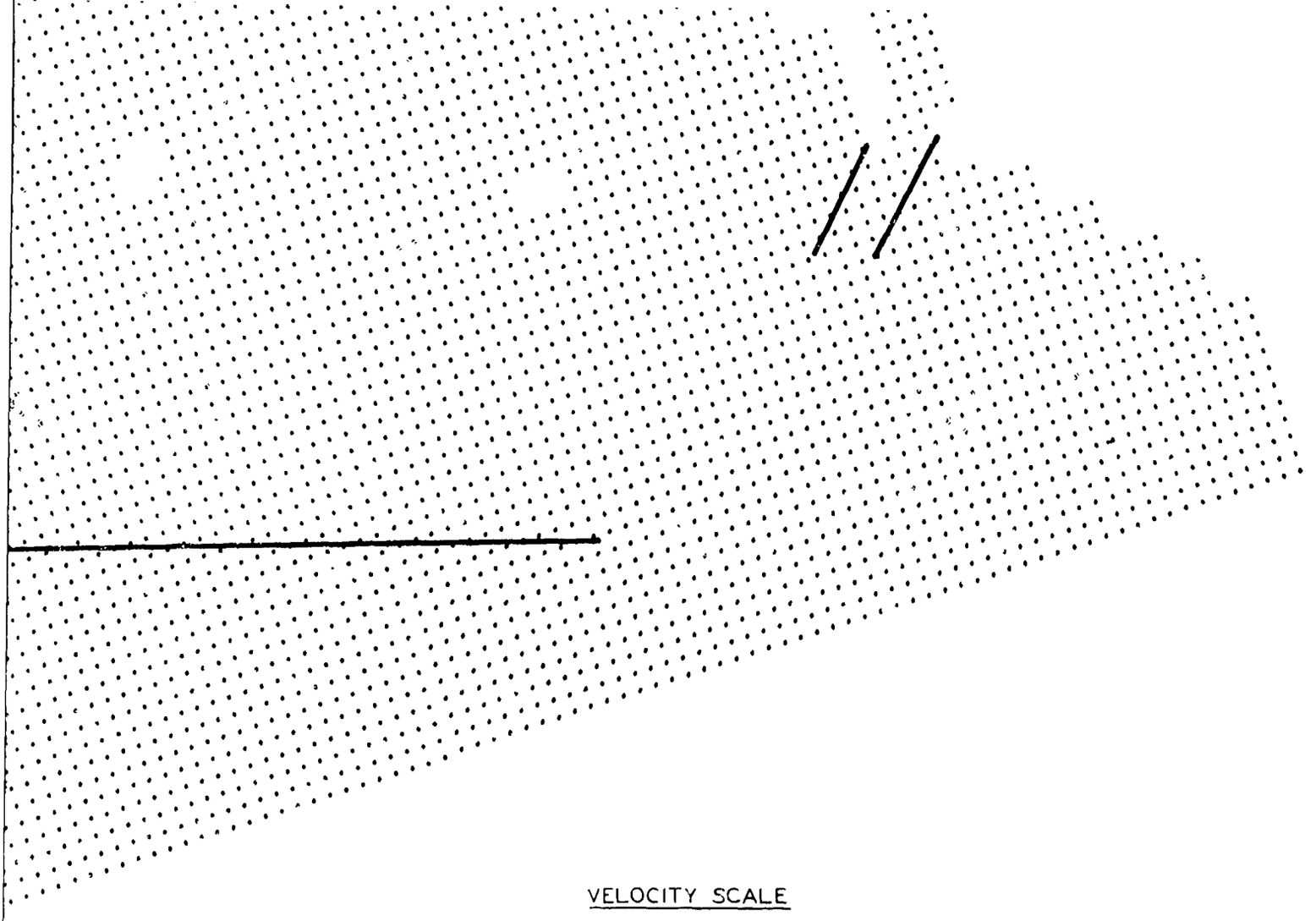

VELOCITY SCALE

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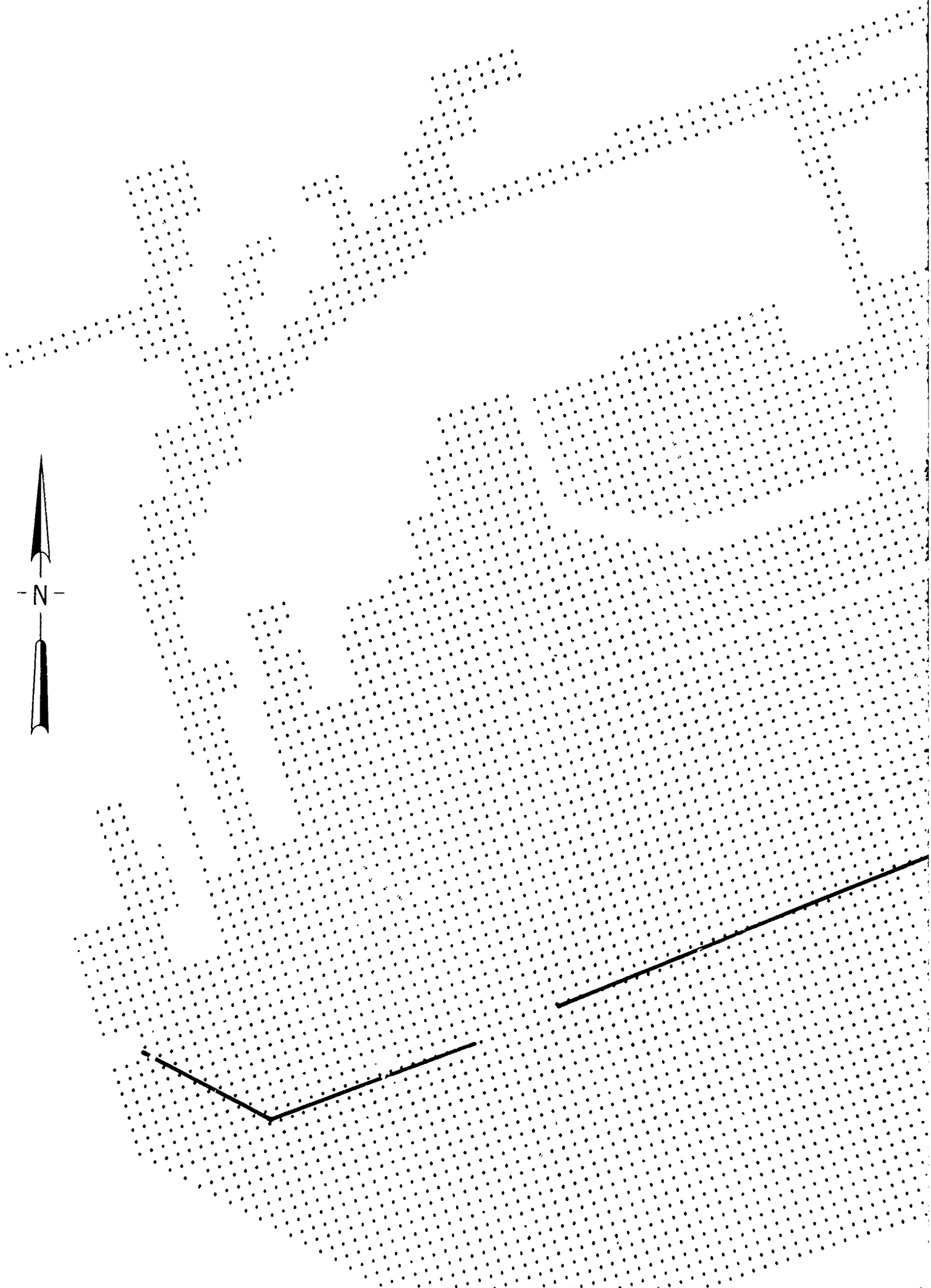
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 300-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 19 (NEAR MAXIMUM FLOOD)

FIGURE 26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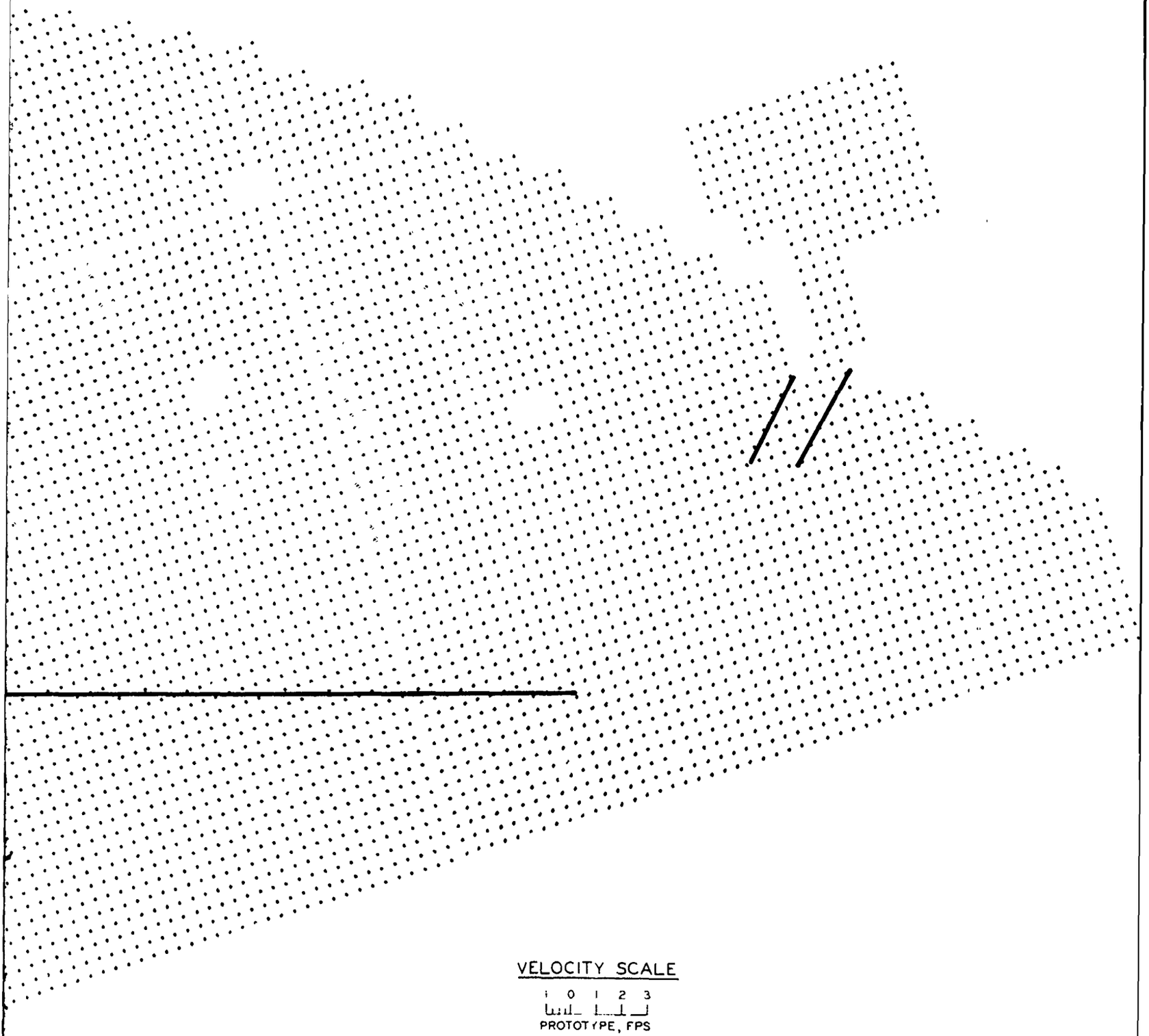
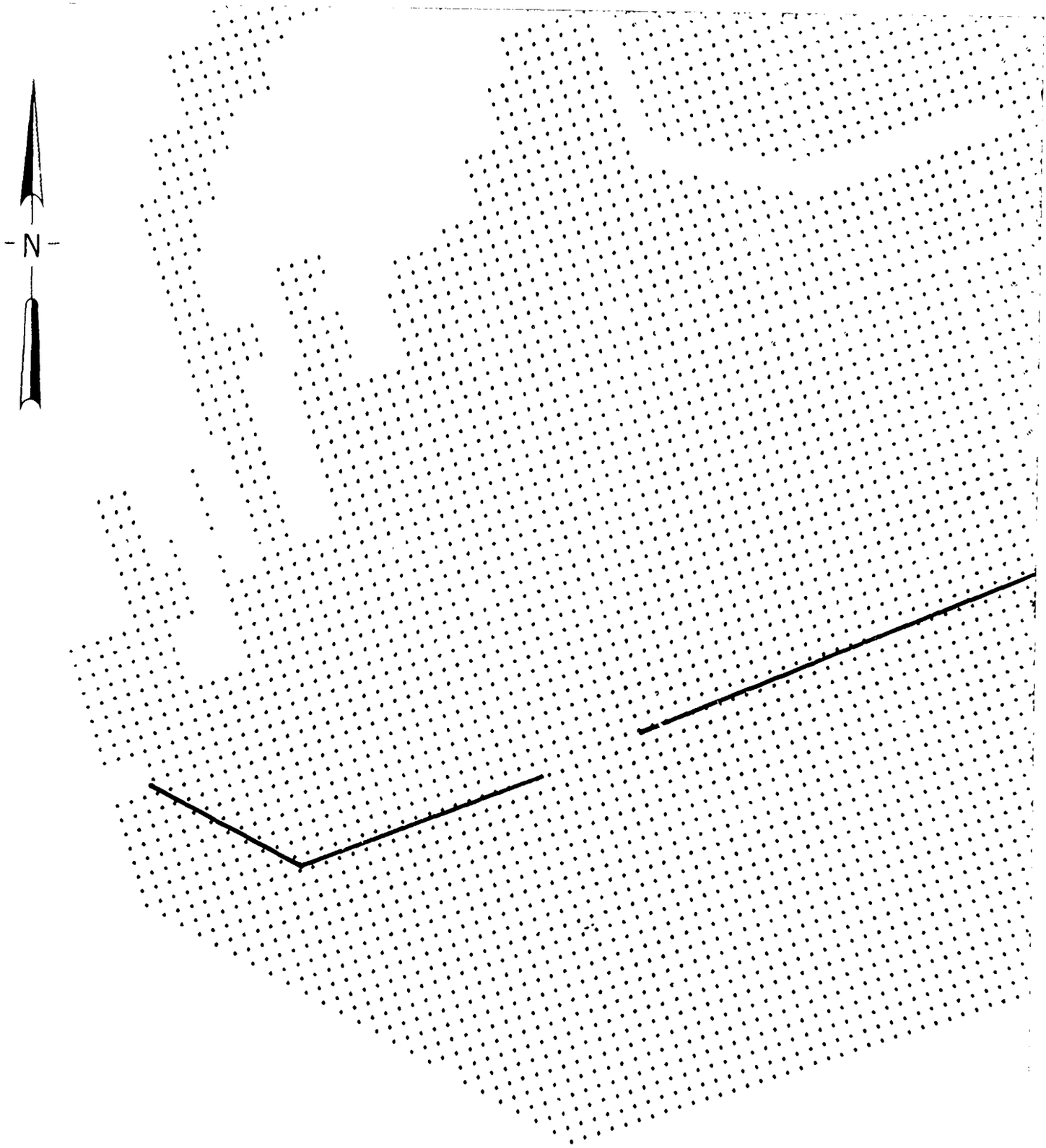


NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2,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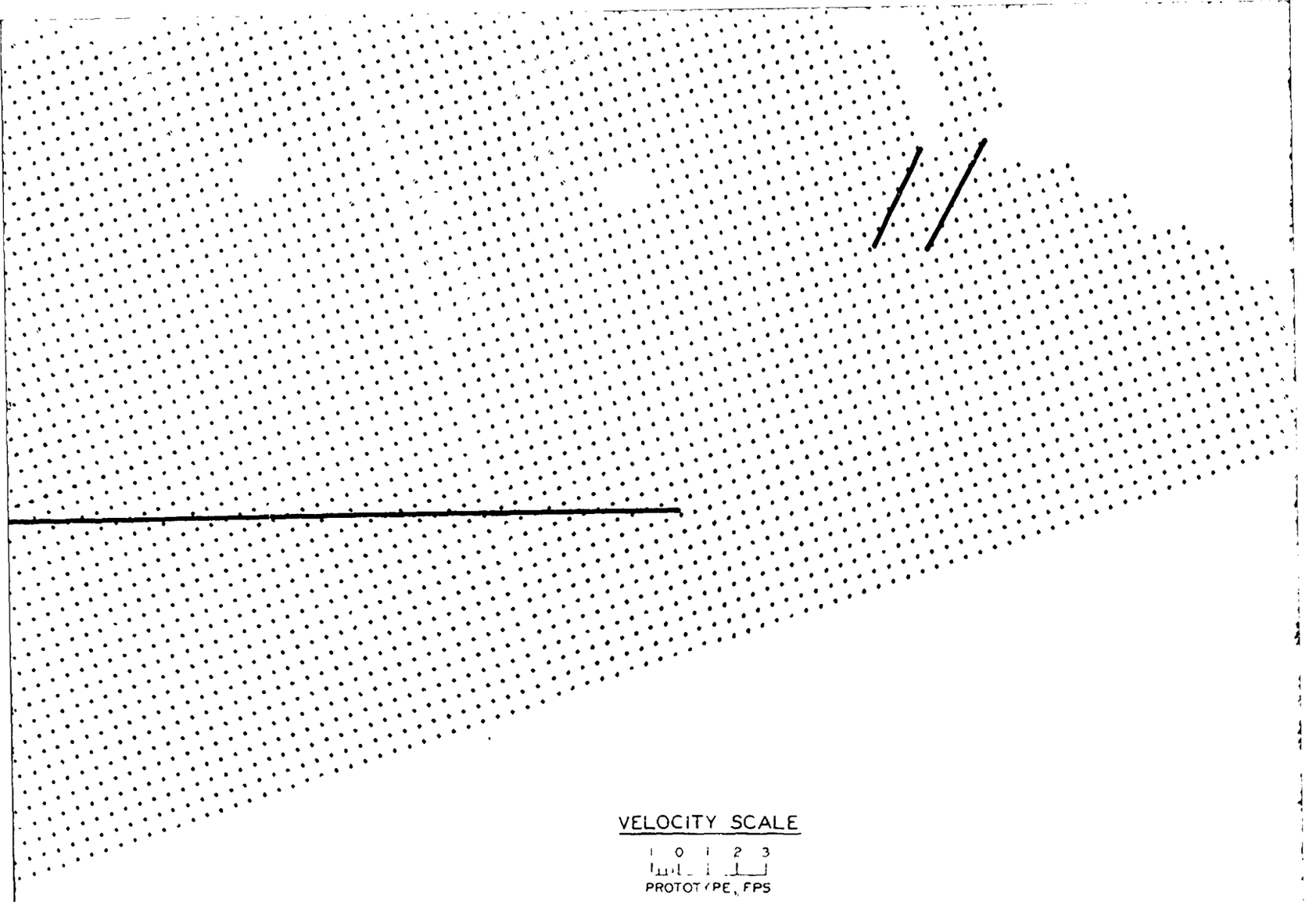
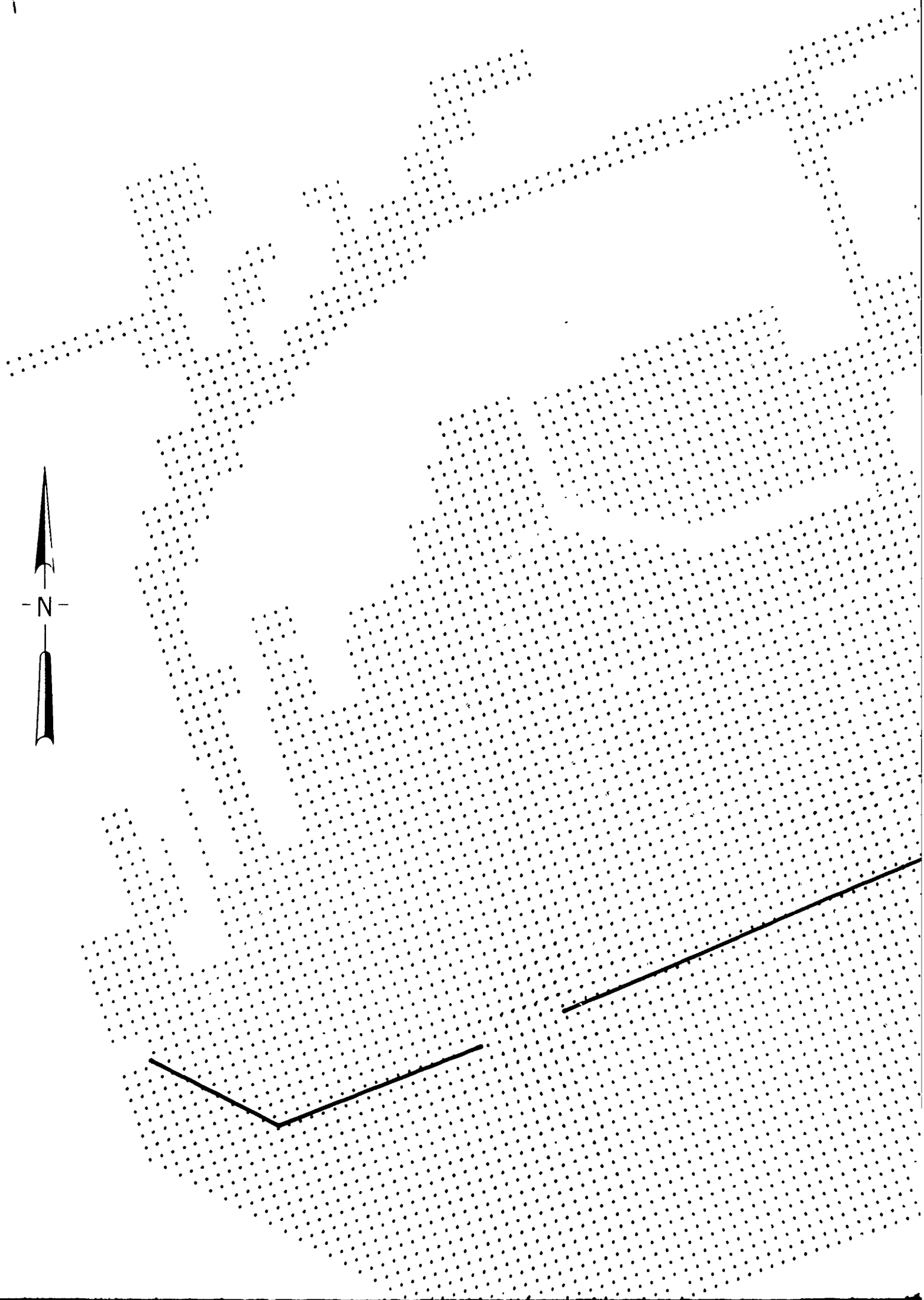


NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 300-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 22 (NEAR SLACK WATER)

FIG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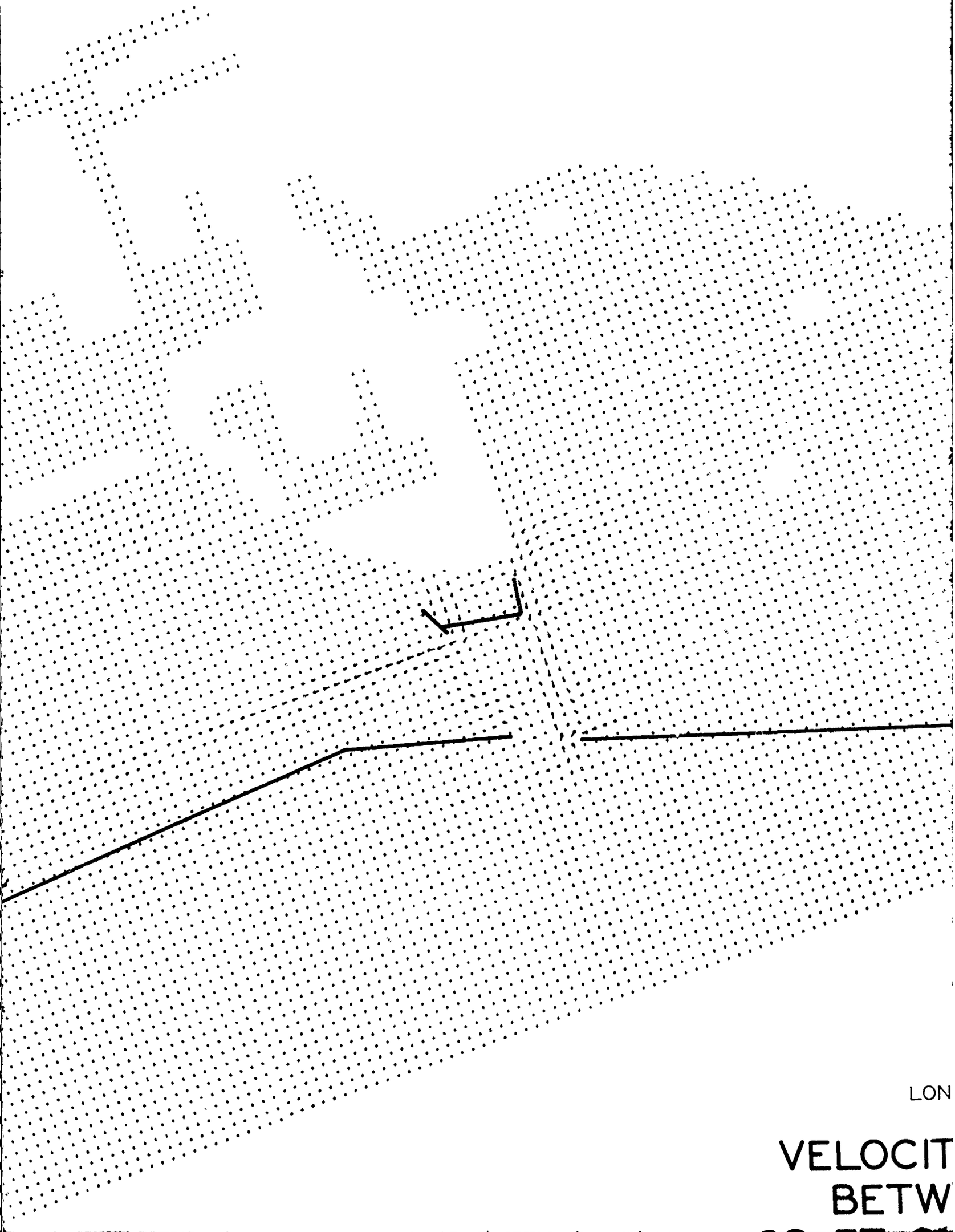

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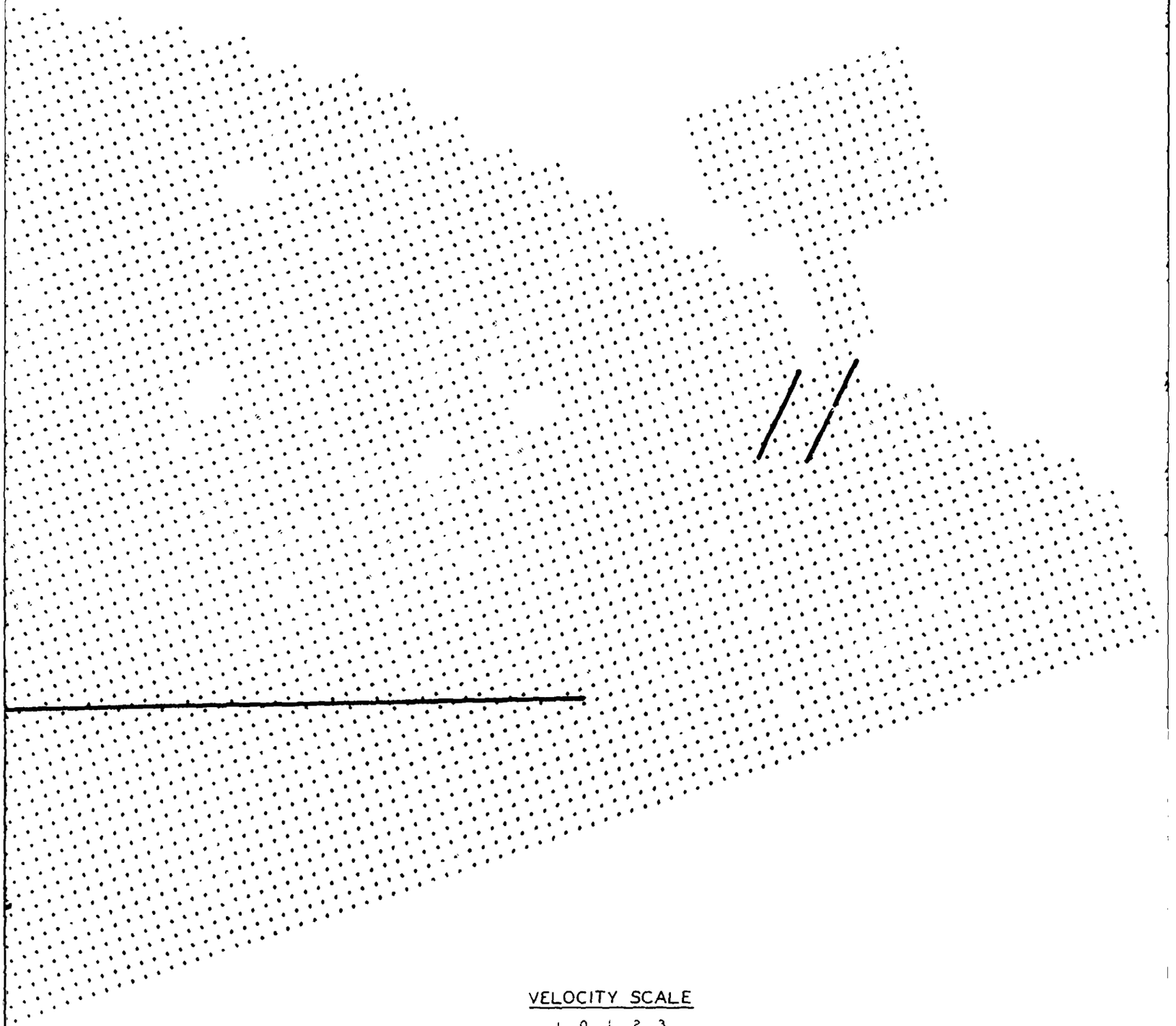

VELOCITY SCALE

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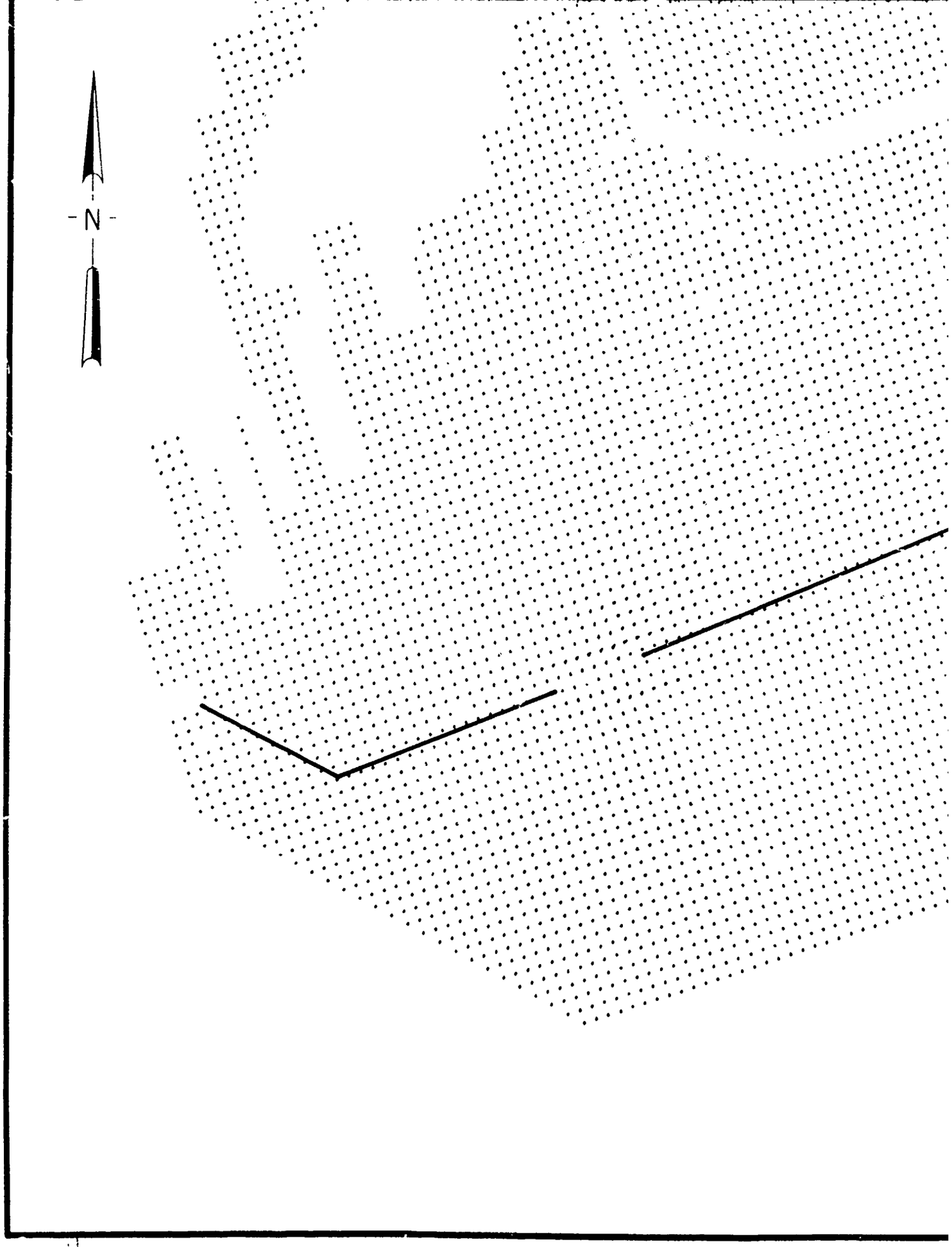
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, 83-FT CHANNEL, 300-FT OPENING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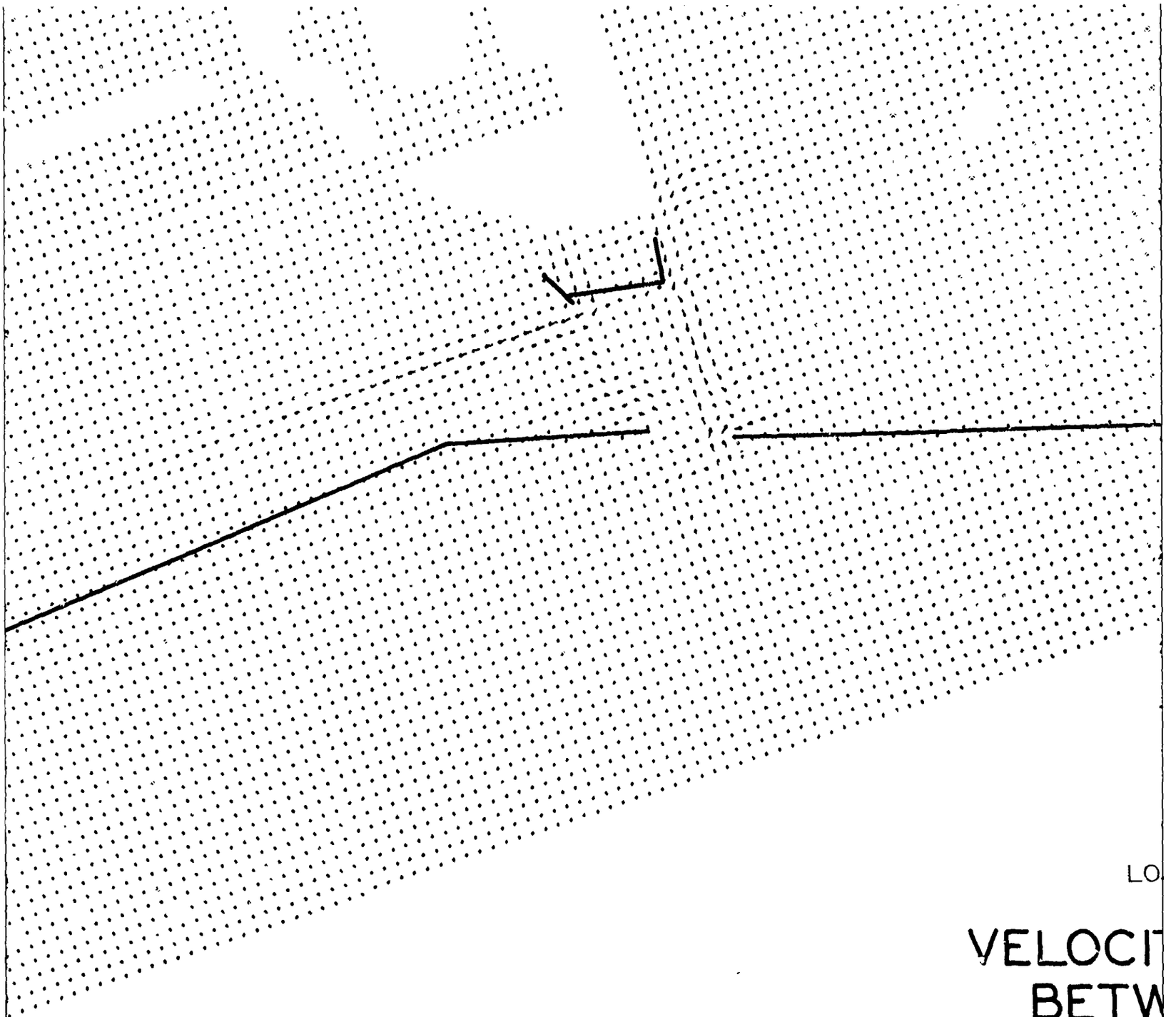

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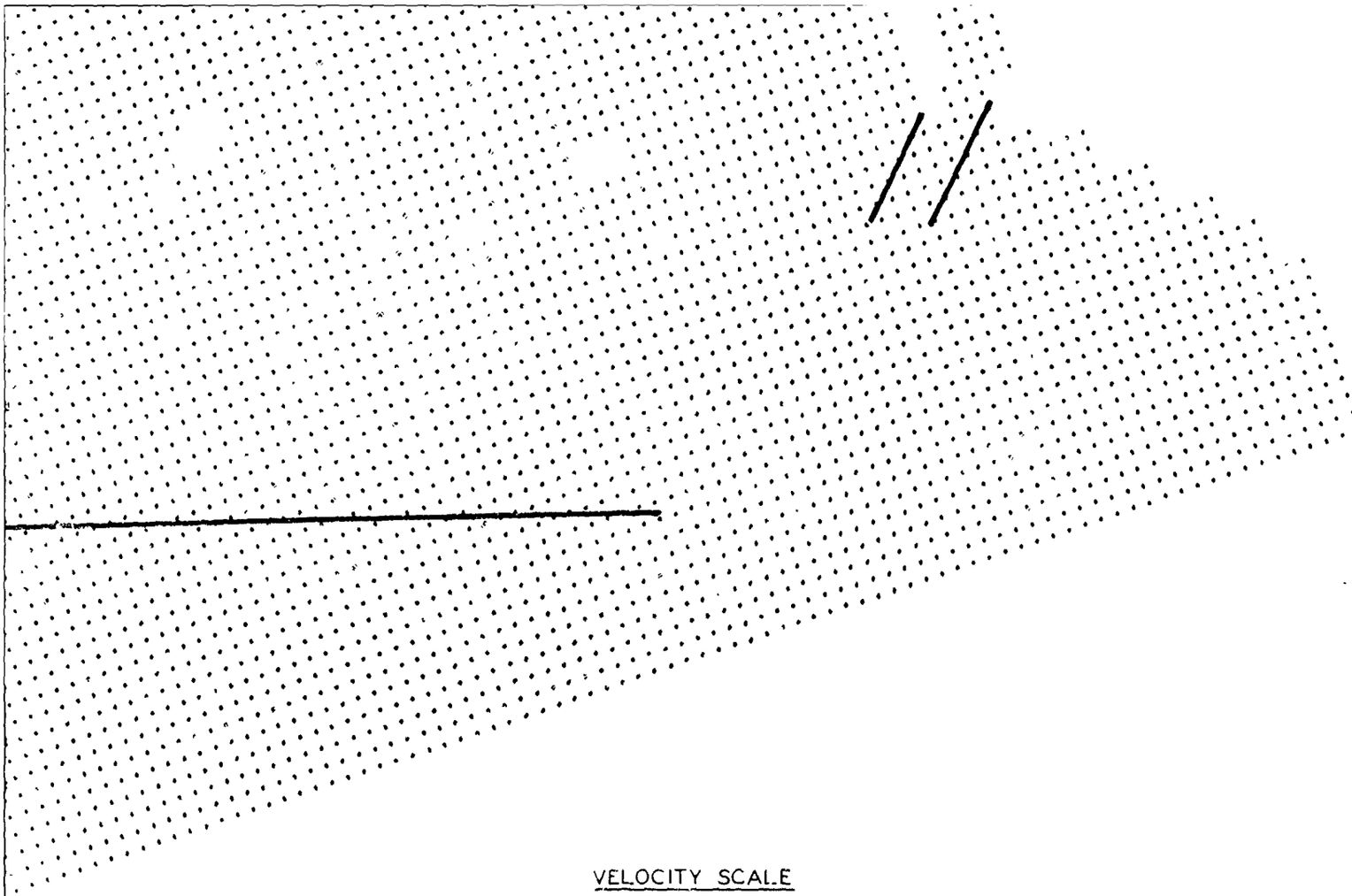


VELOCITY SCALE

1 0 1 2 3

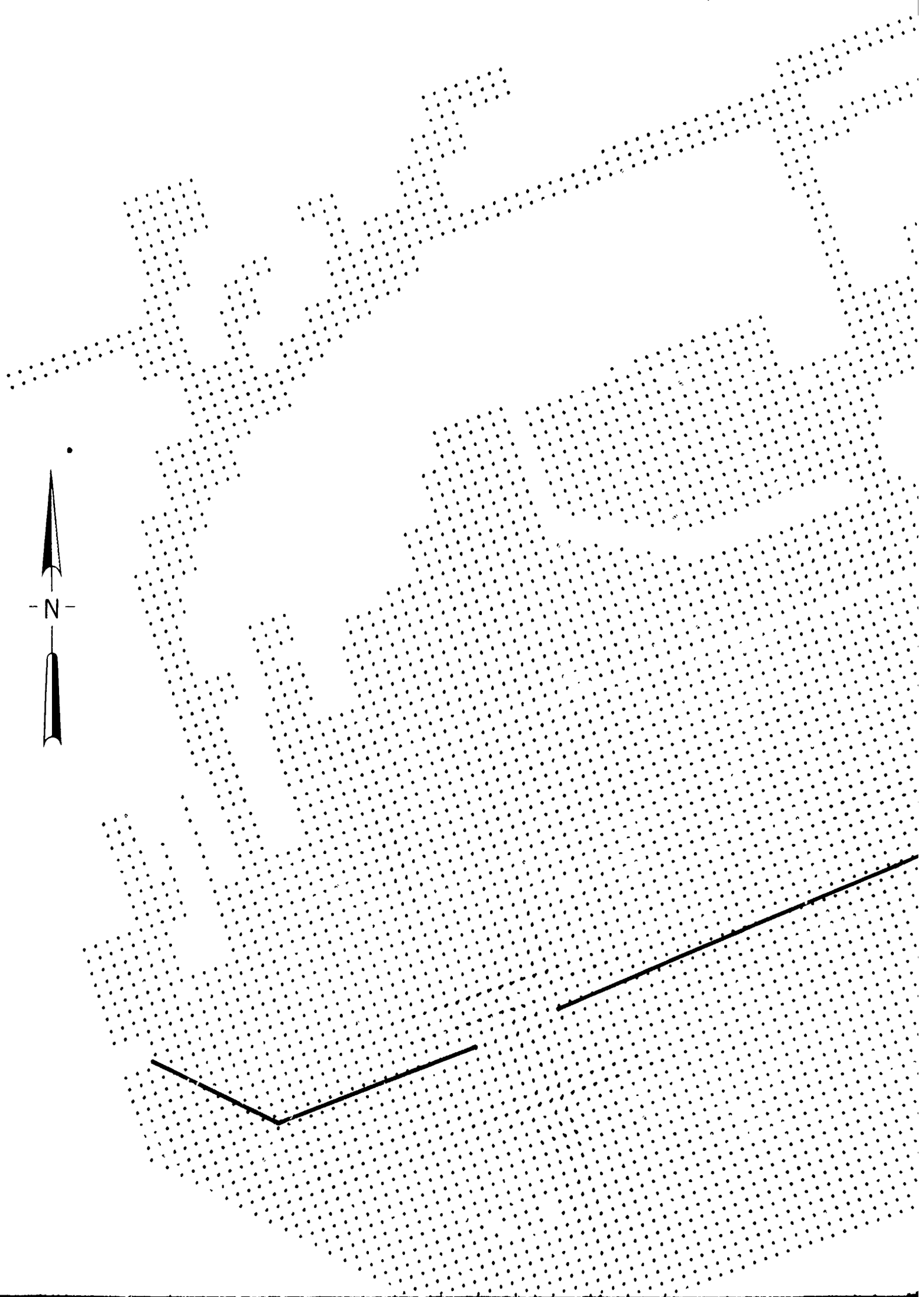
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH – LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 300-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 24 (NEAR MAXIMUM EBB)

FIGURE 28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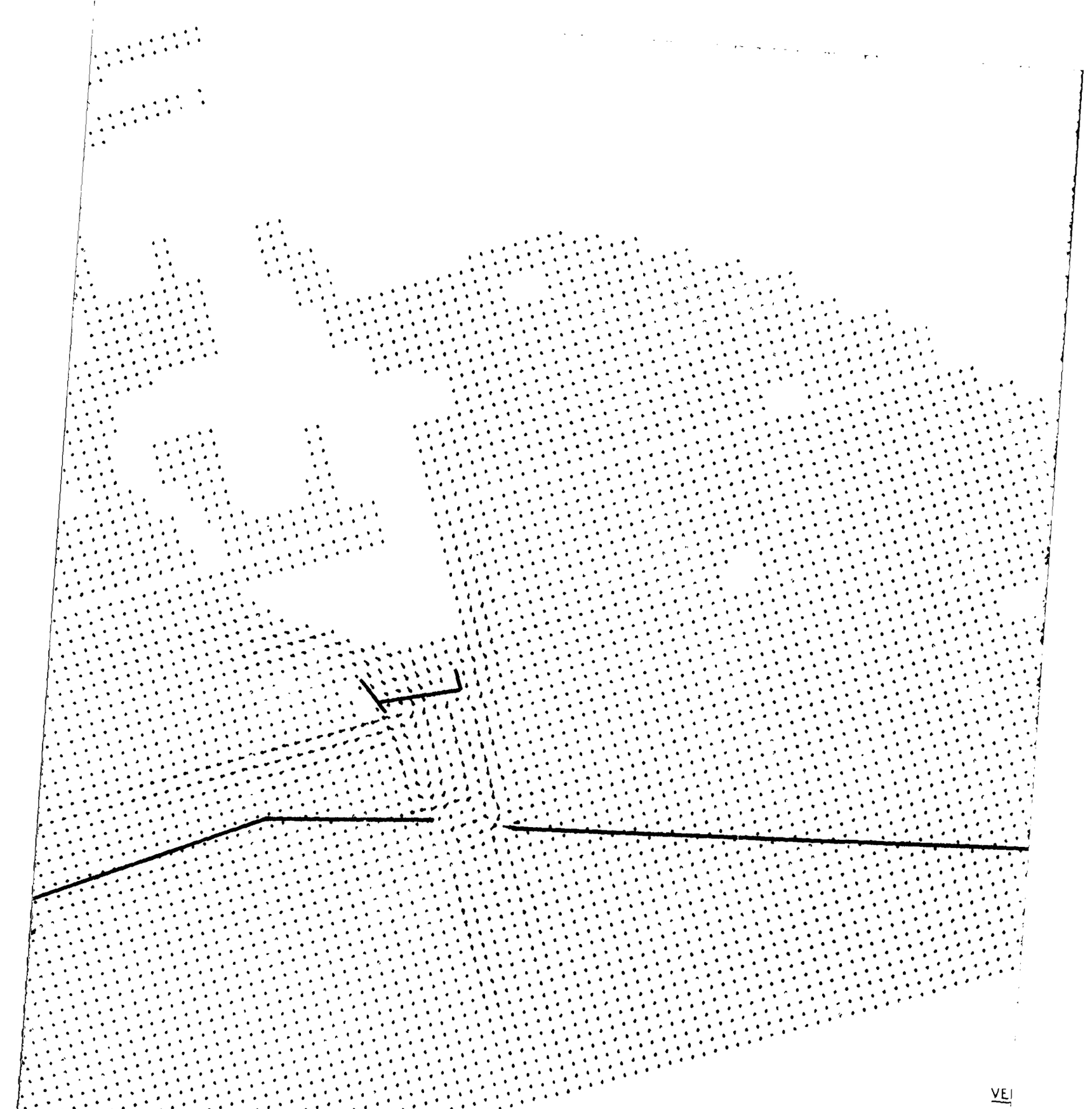

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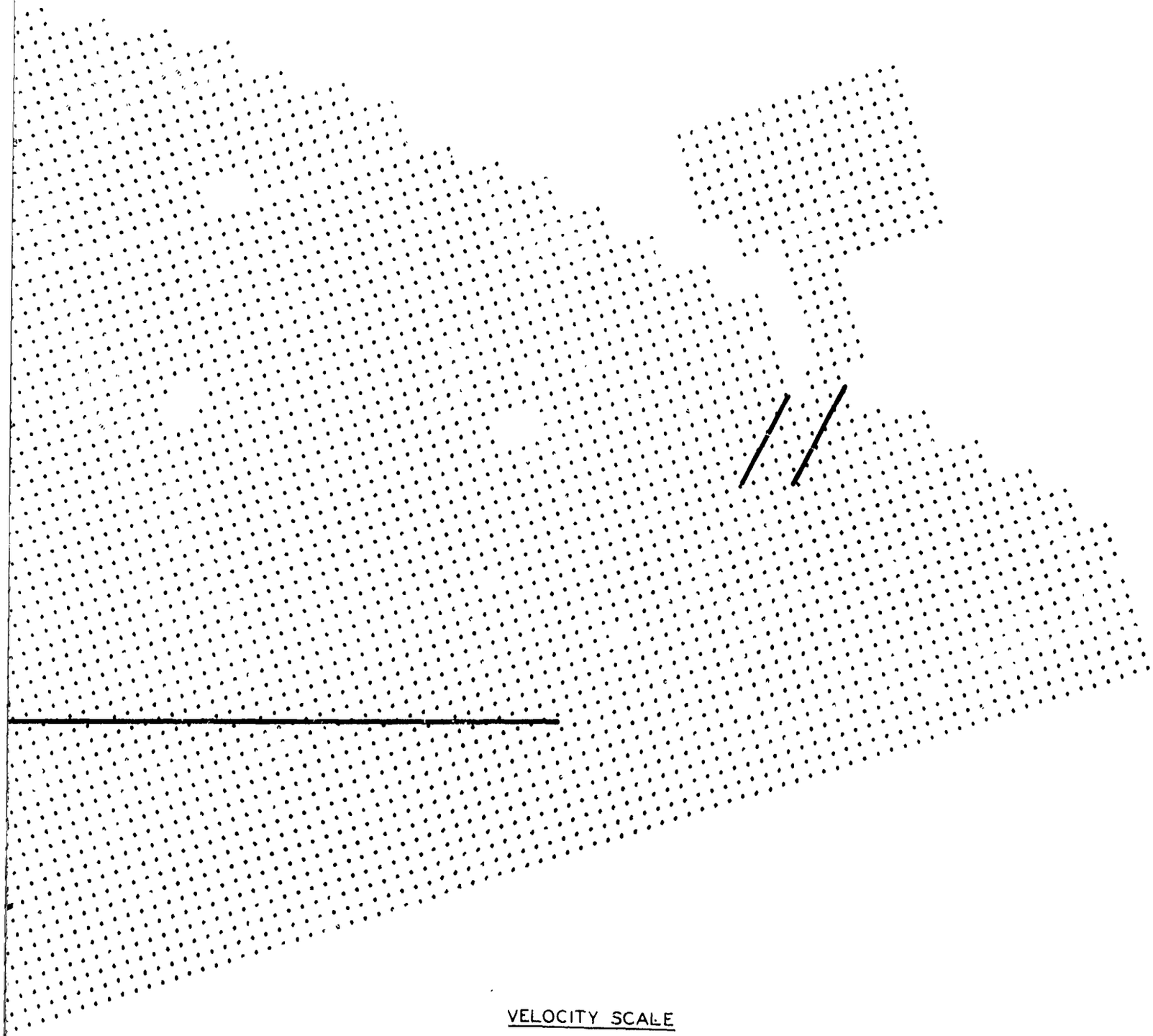


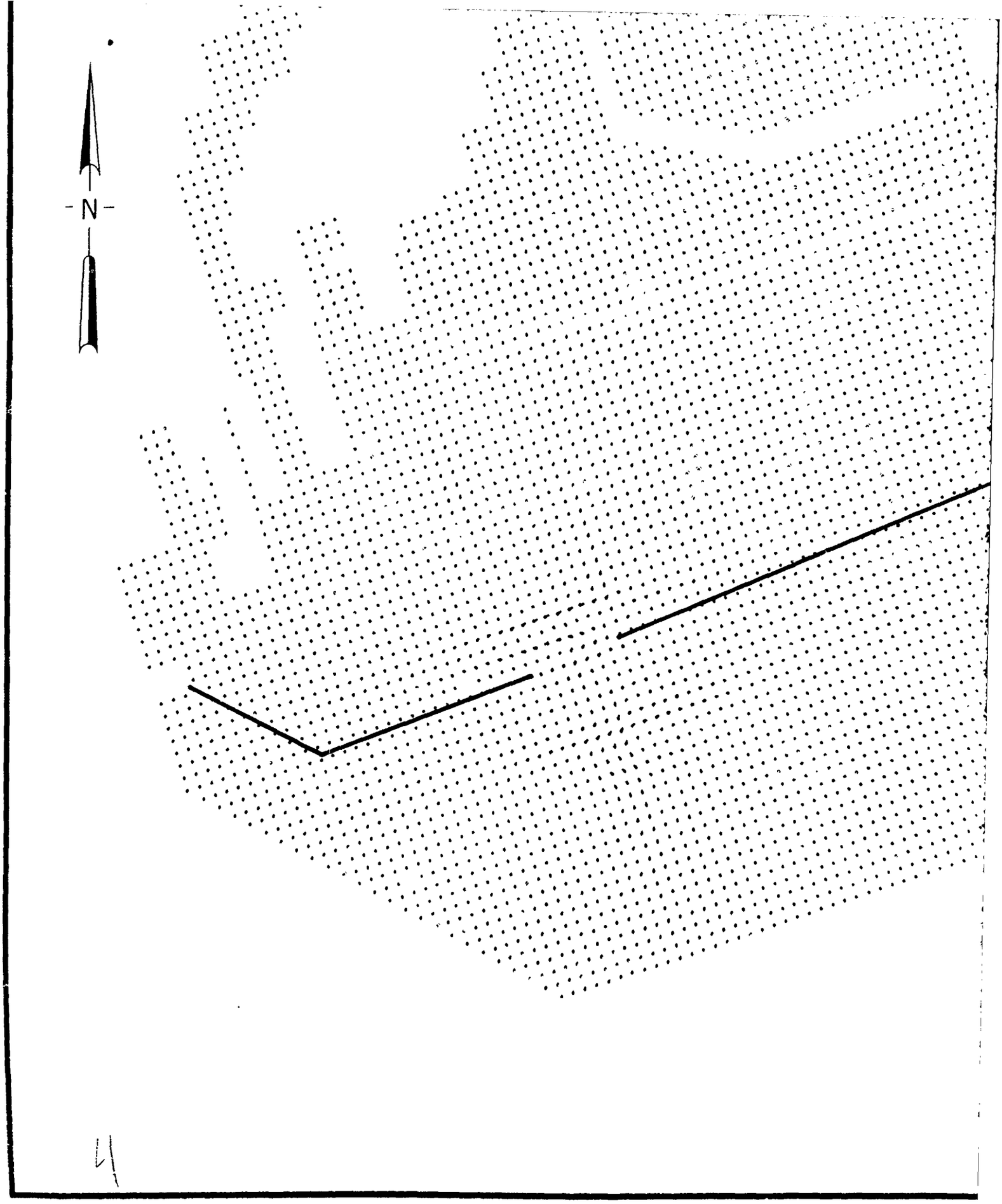
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2,



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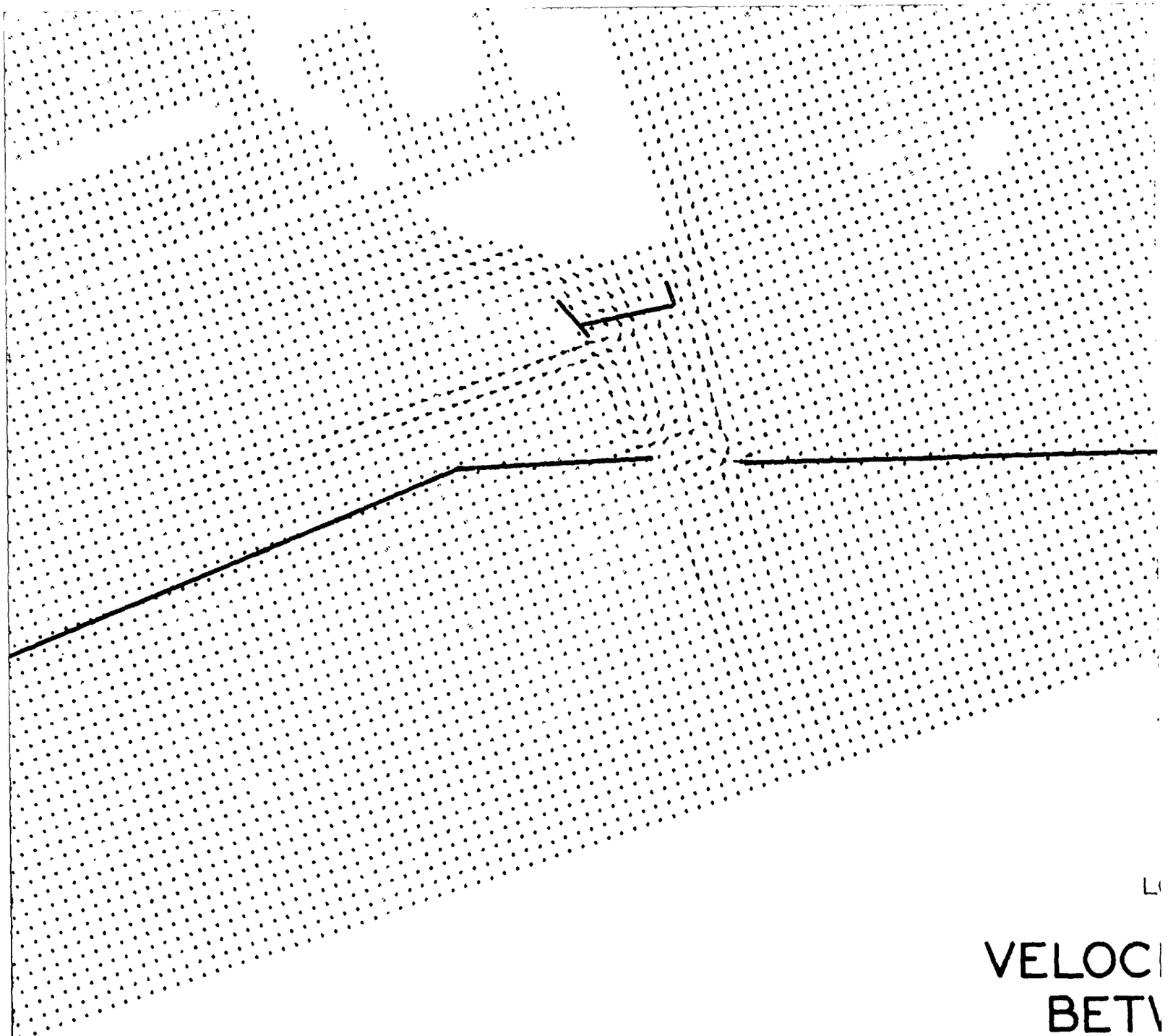

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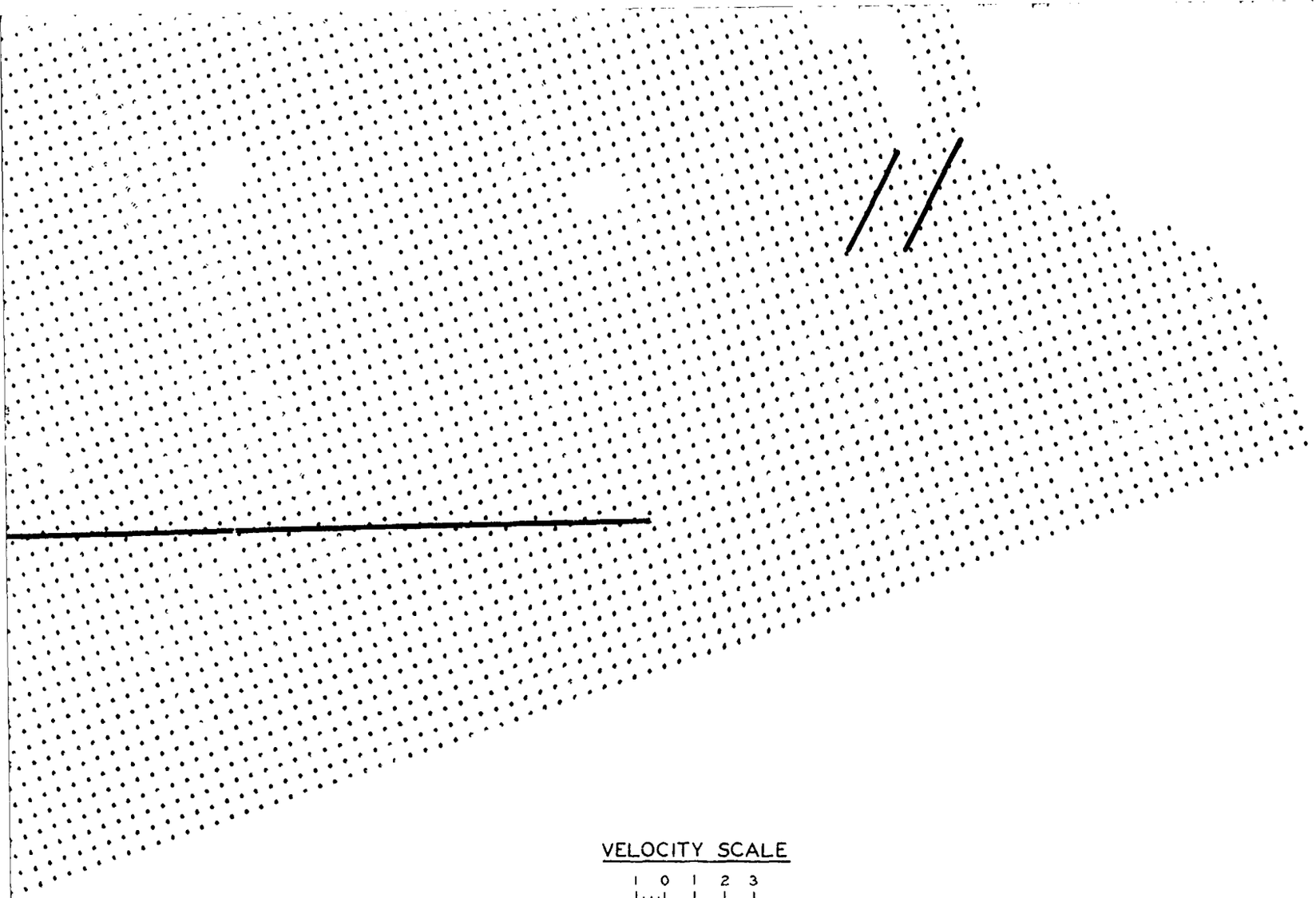


VELOCITY SCALE

1 0 1 2 3

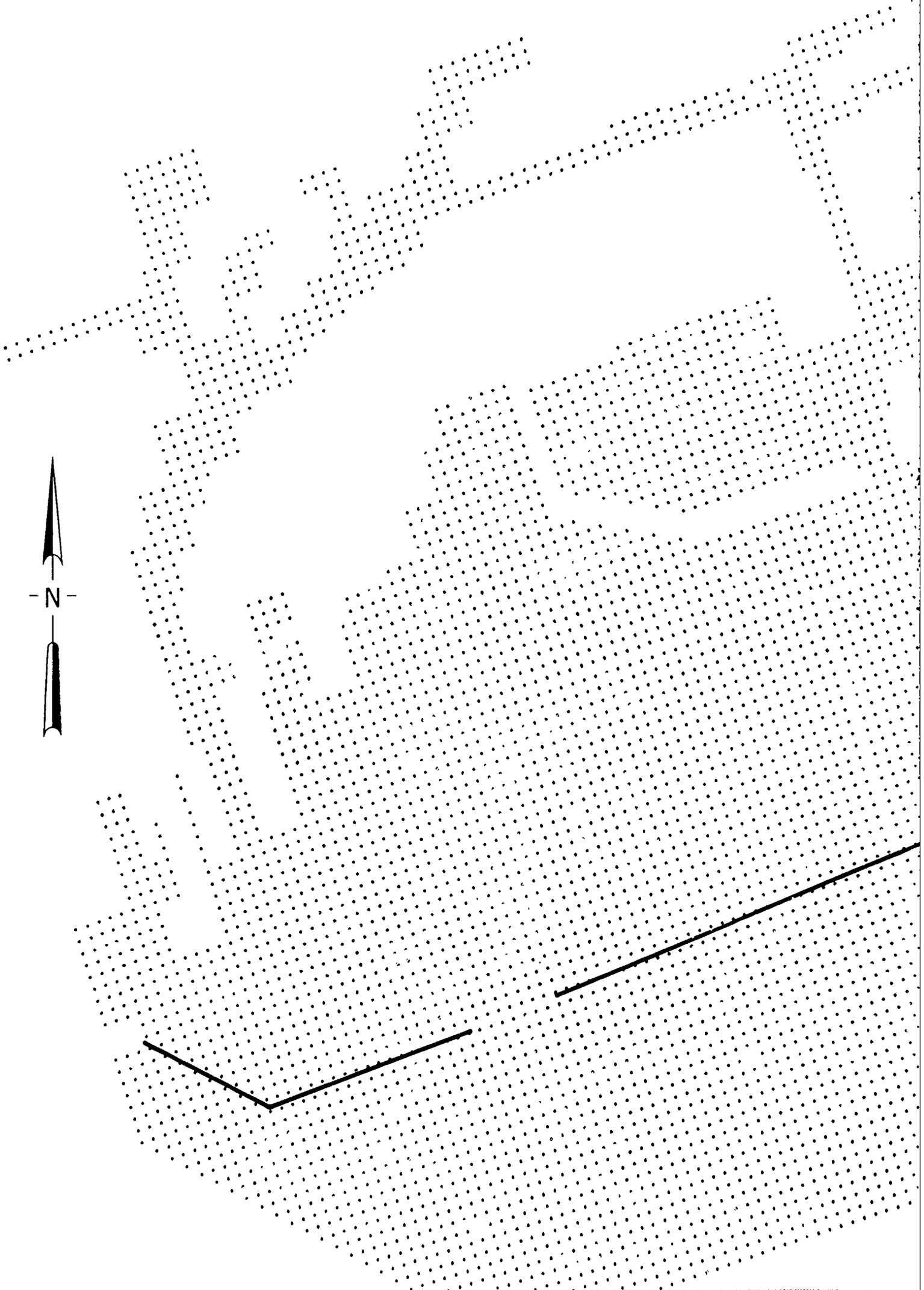
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH – LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 600-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 15 (NEAR SLACK WATER)

FIGURE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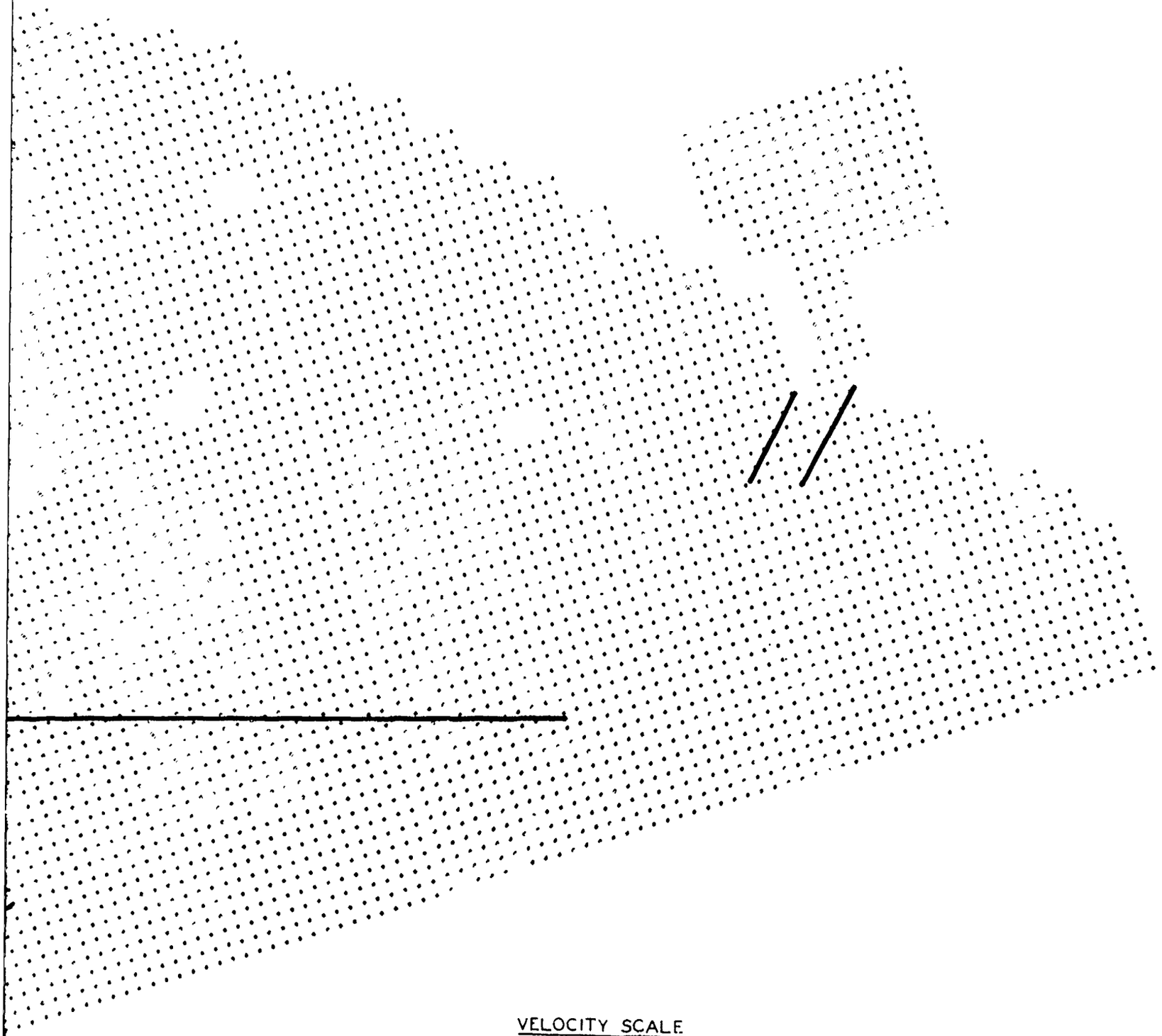


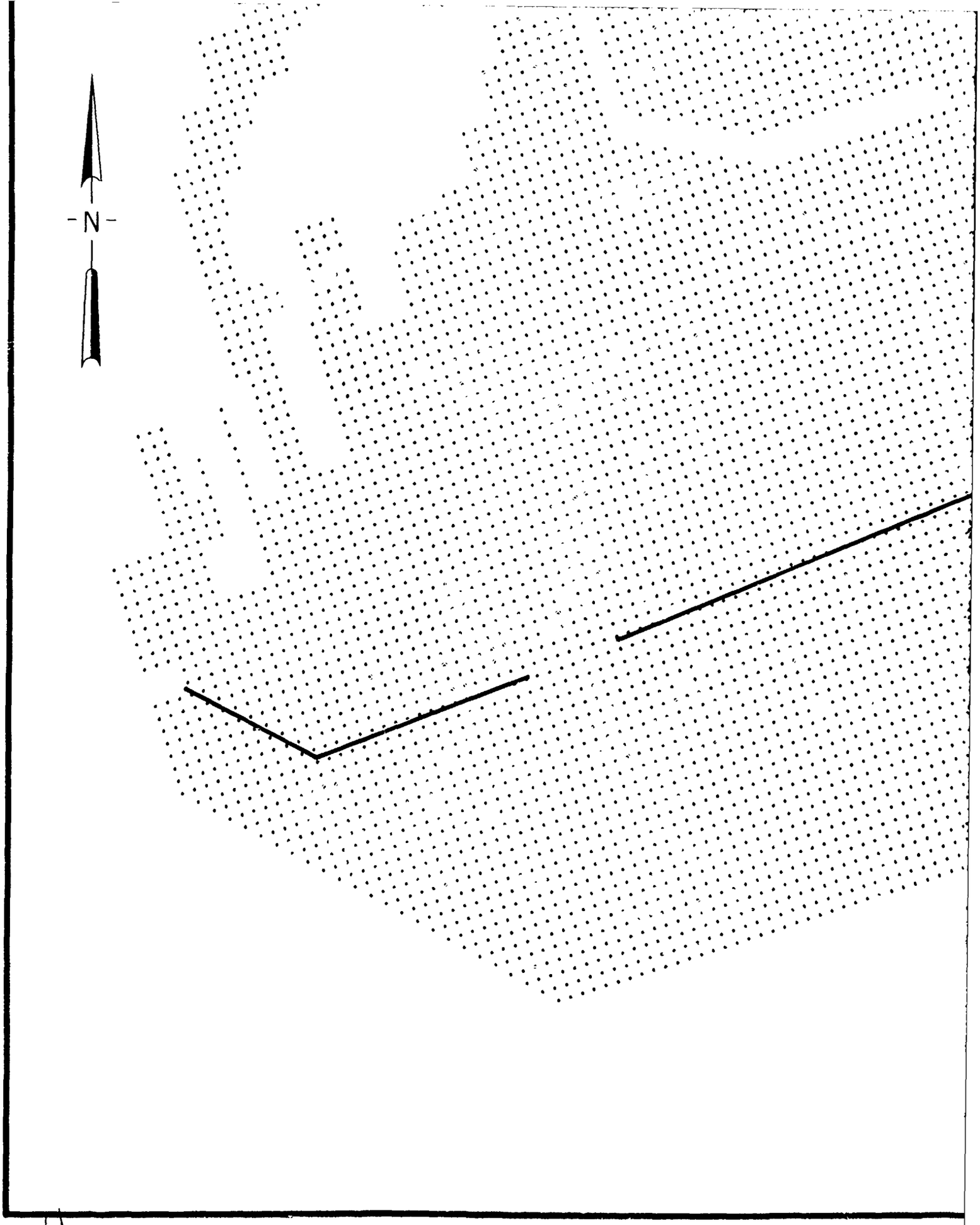
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STEP 2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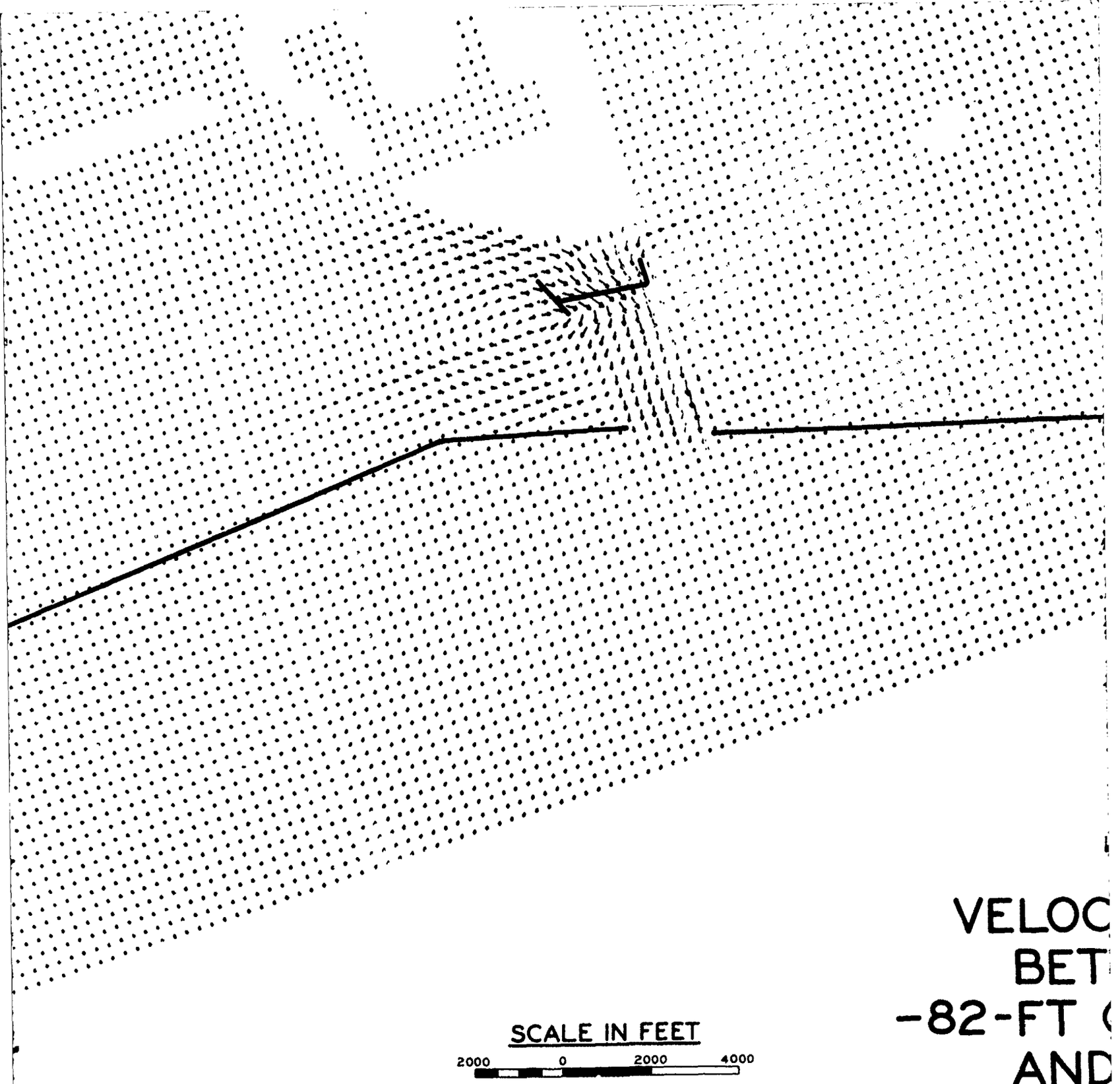

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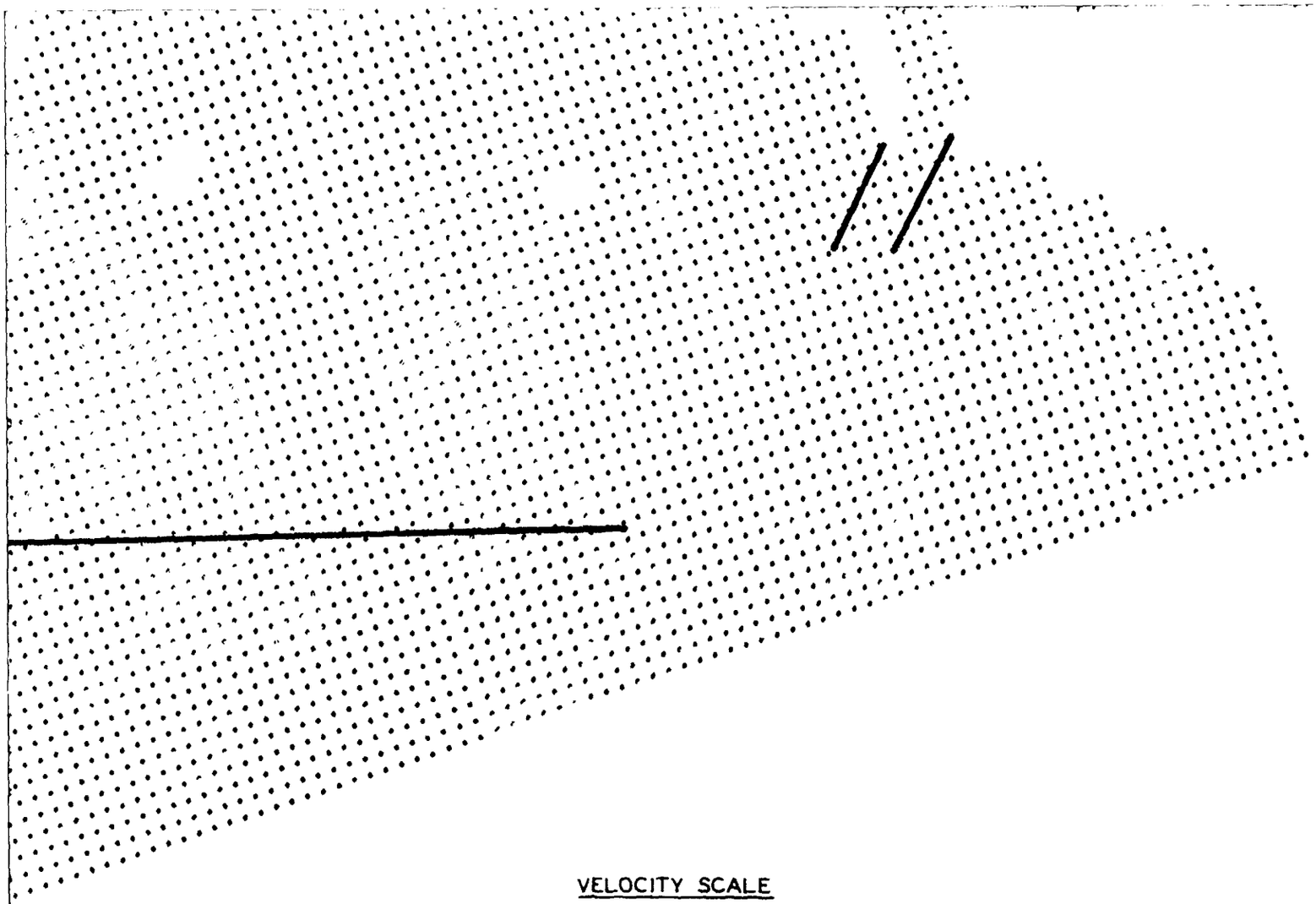


VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

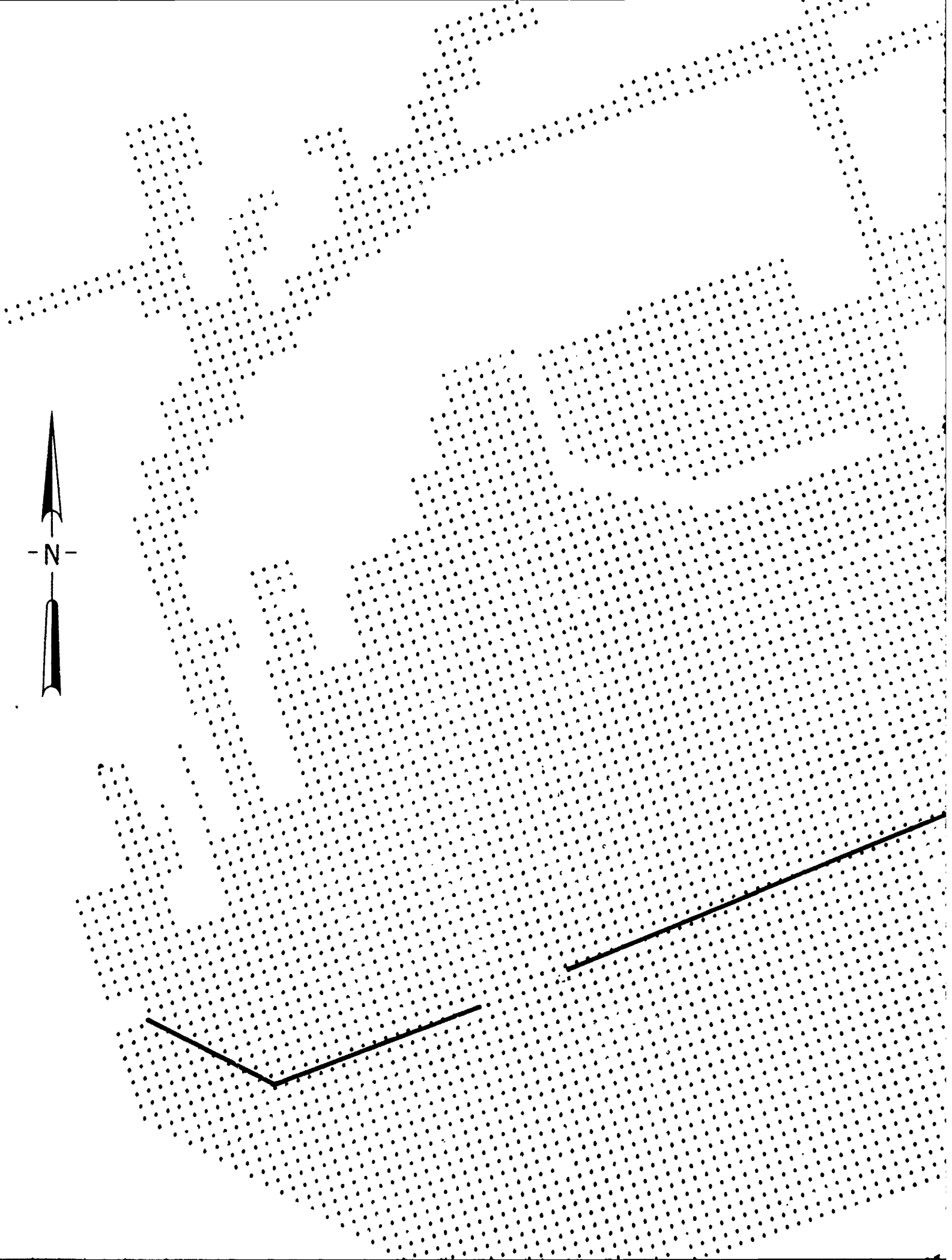
NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 600-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 19 (NEAR MAXIMUM FLOOD)

6

FIGURE 30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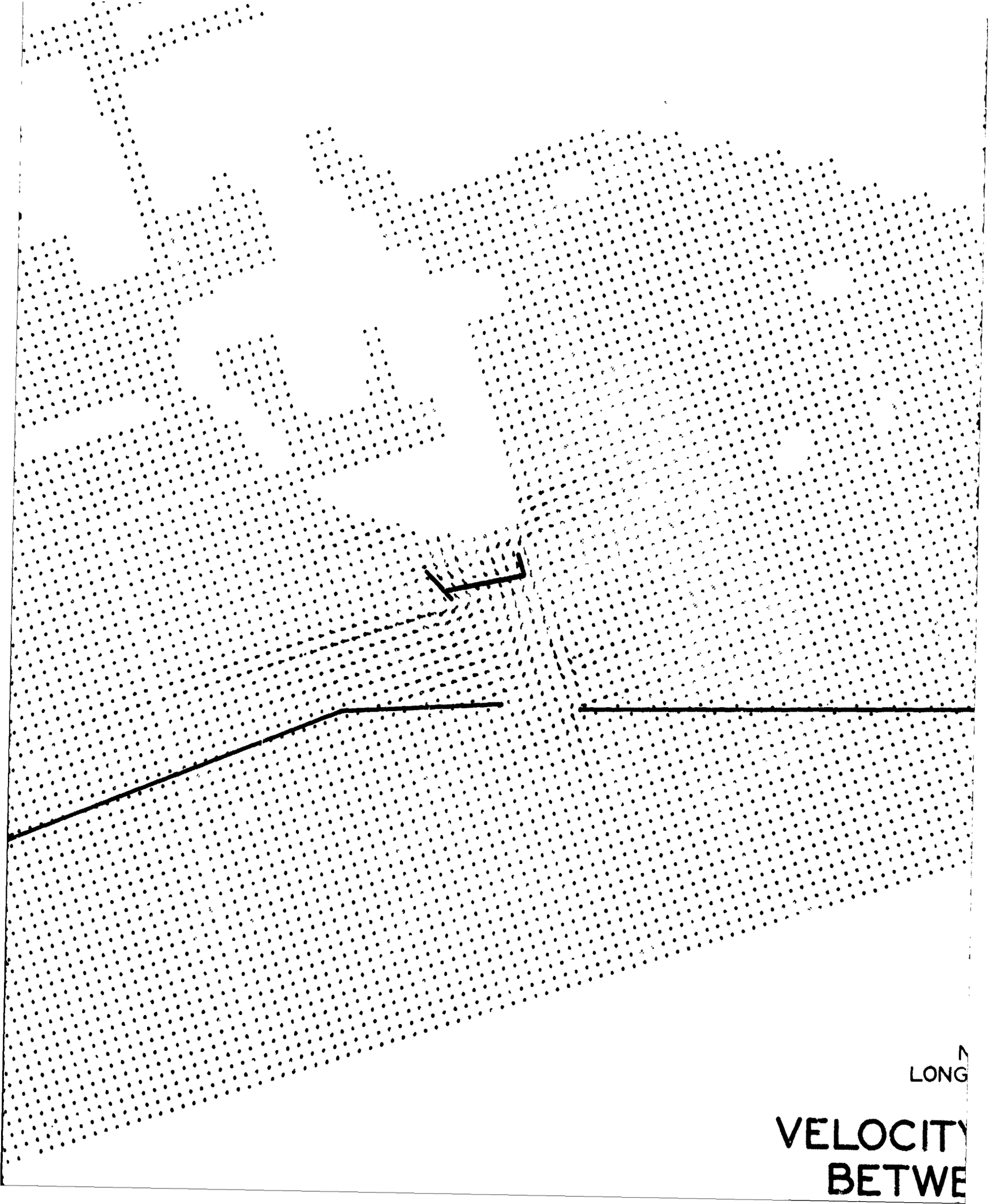
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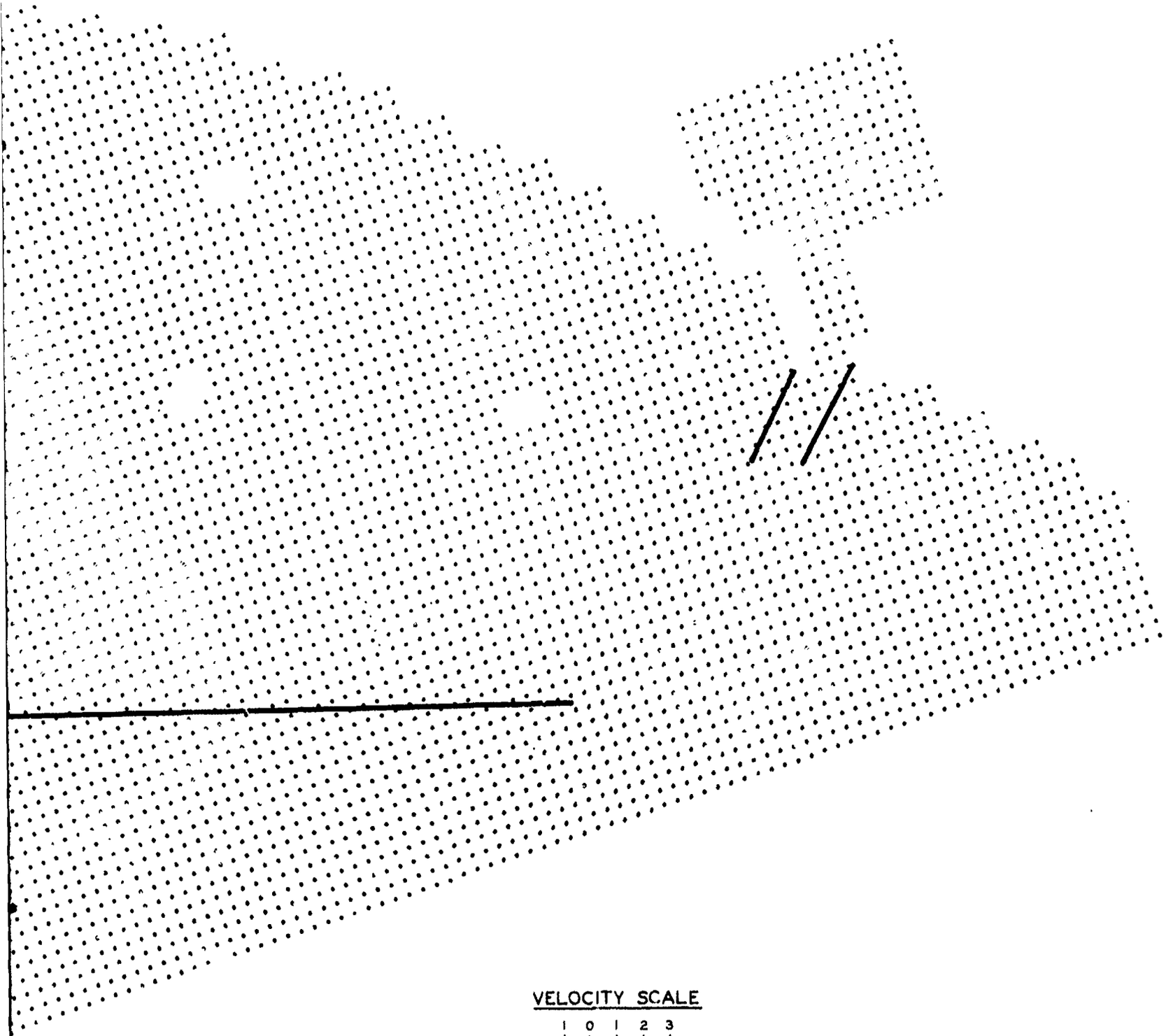


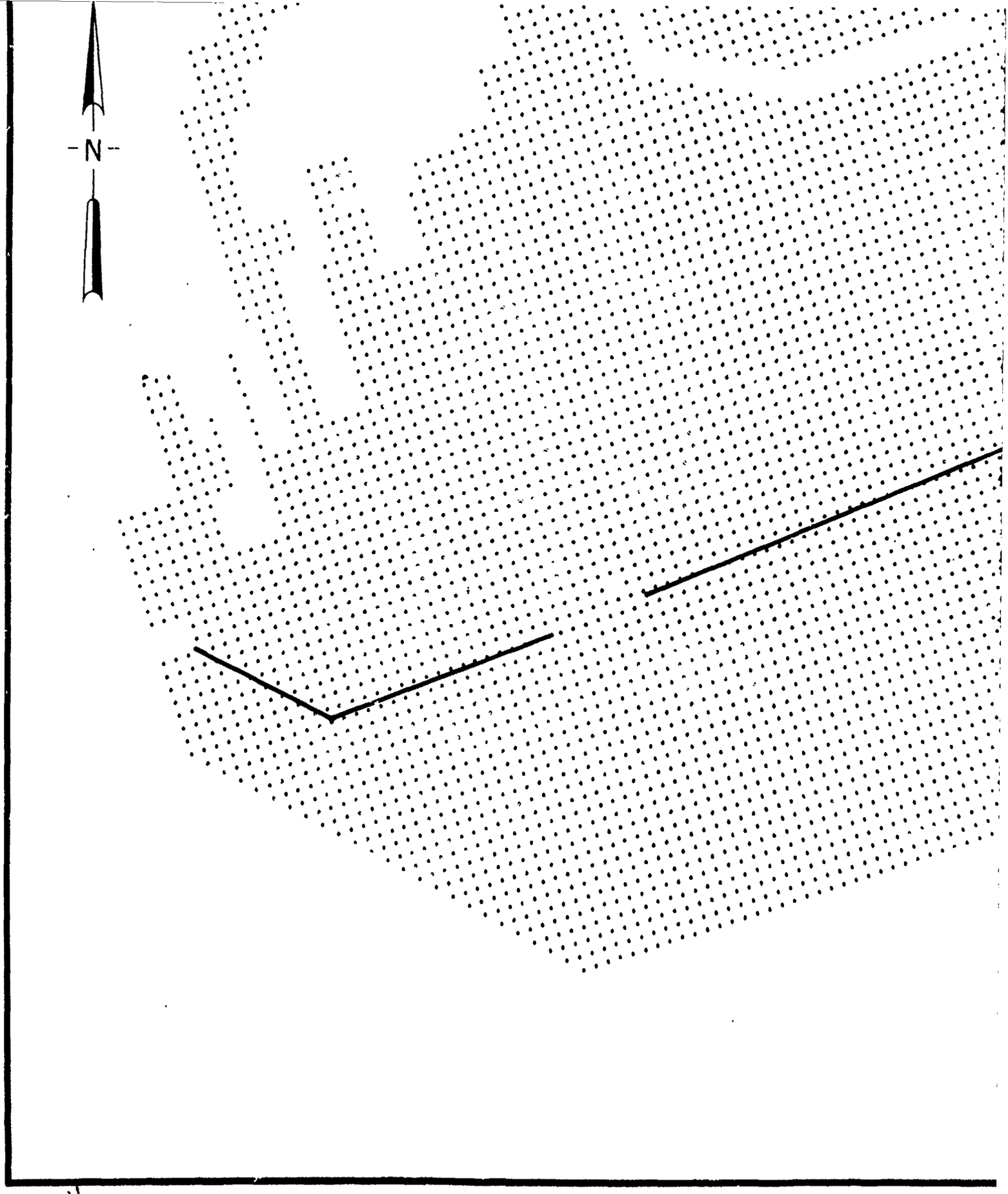
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2,



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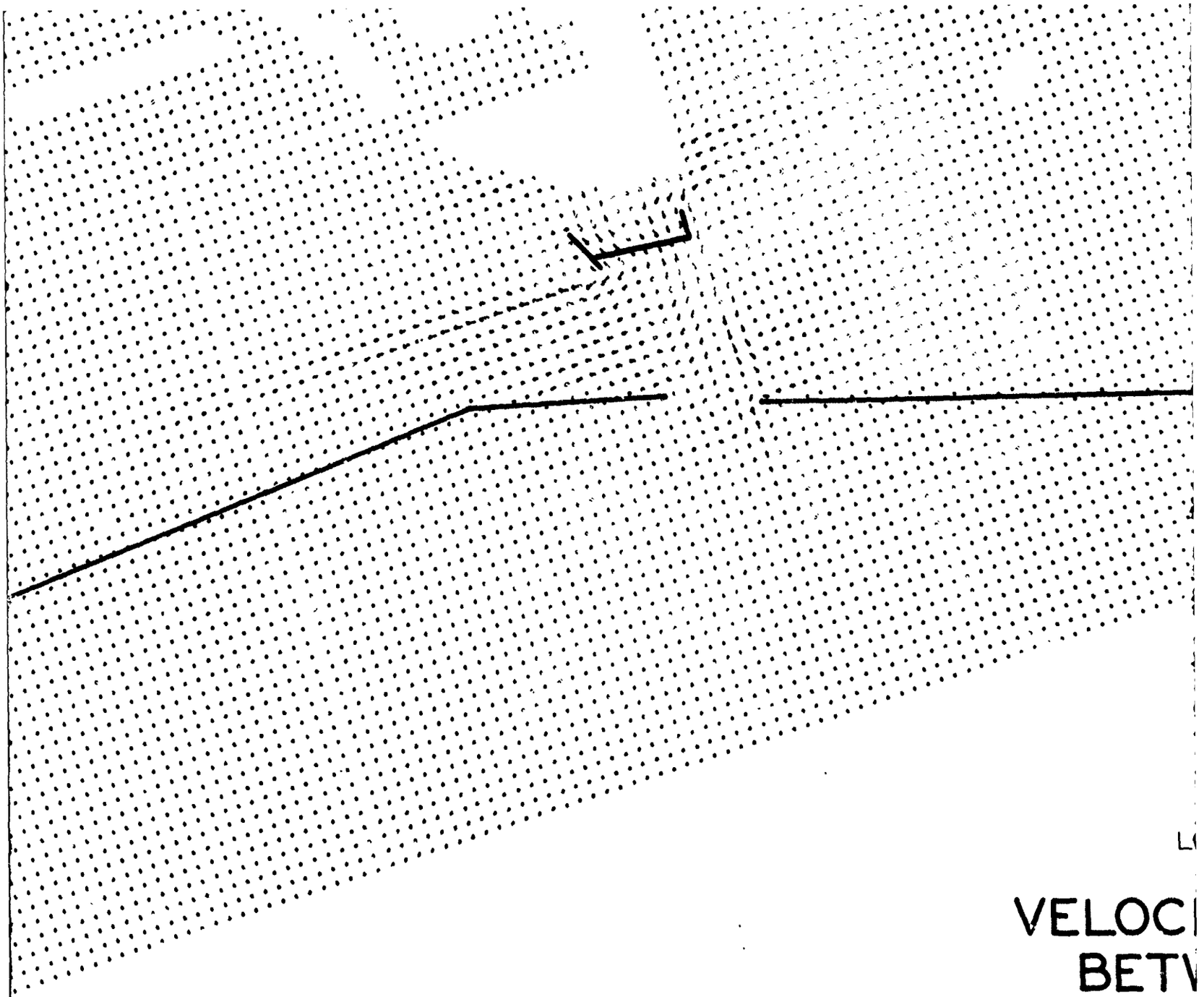

SCALE IN FEET

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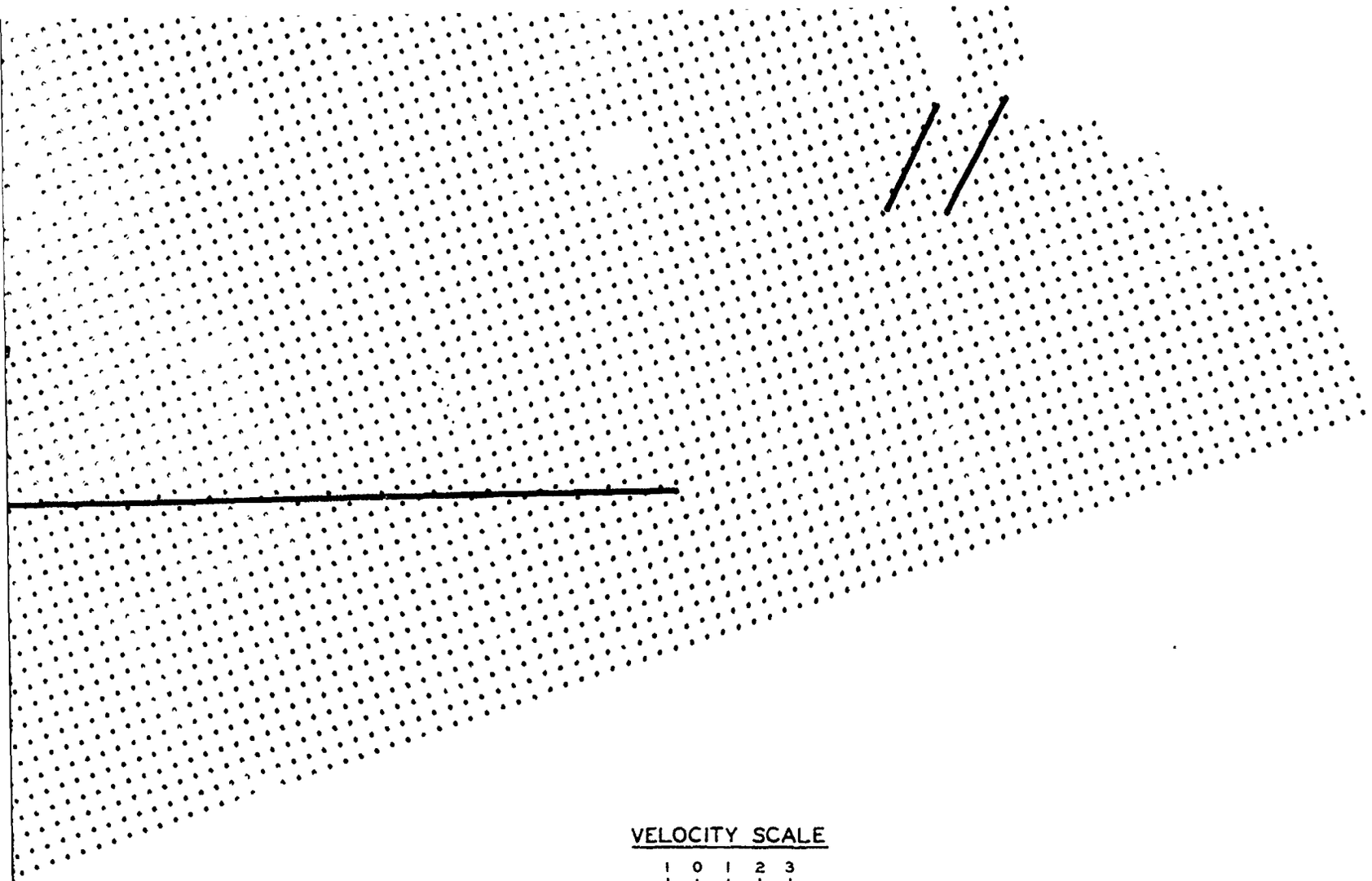


VELOCITY SCALE

1 0 1 2 3

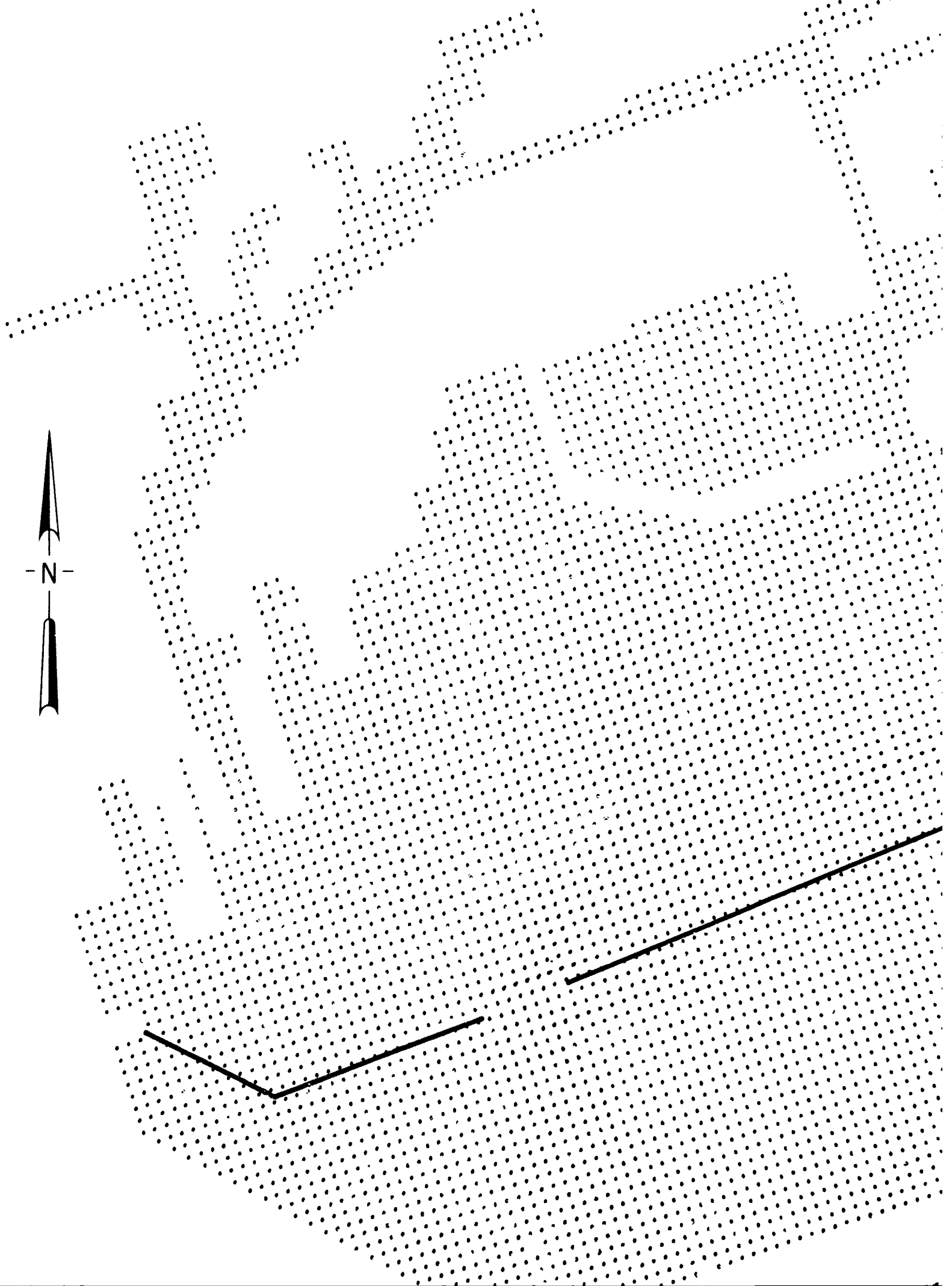
PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 600-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 22 (NEAR SLACK WATER)

FIGURE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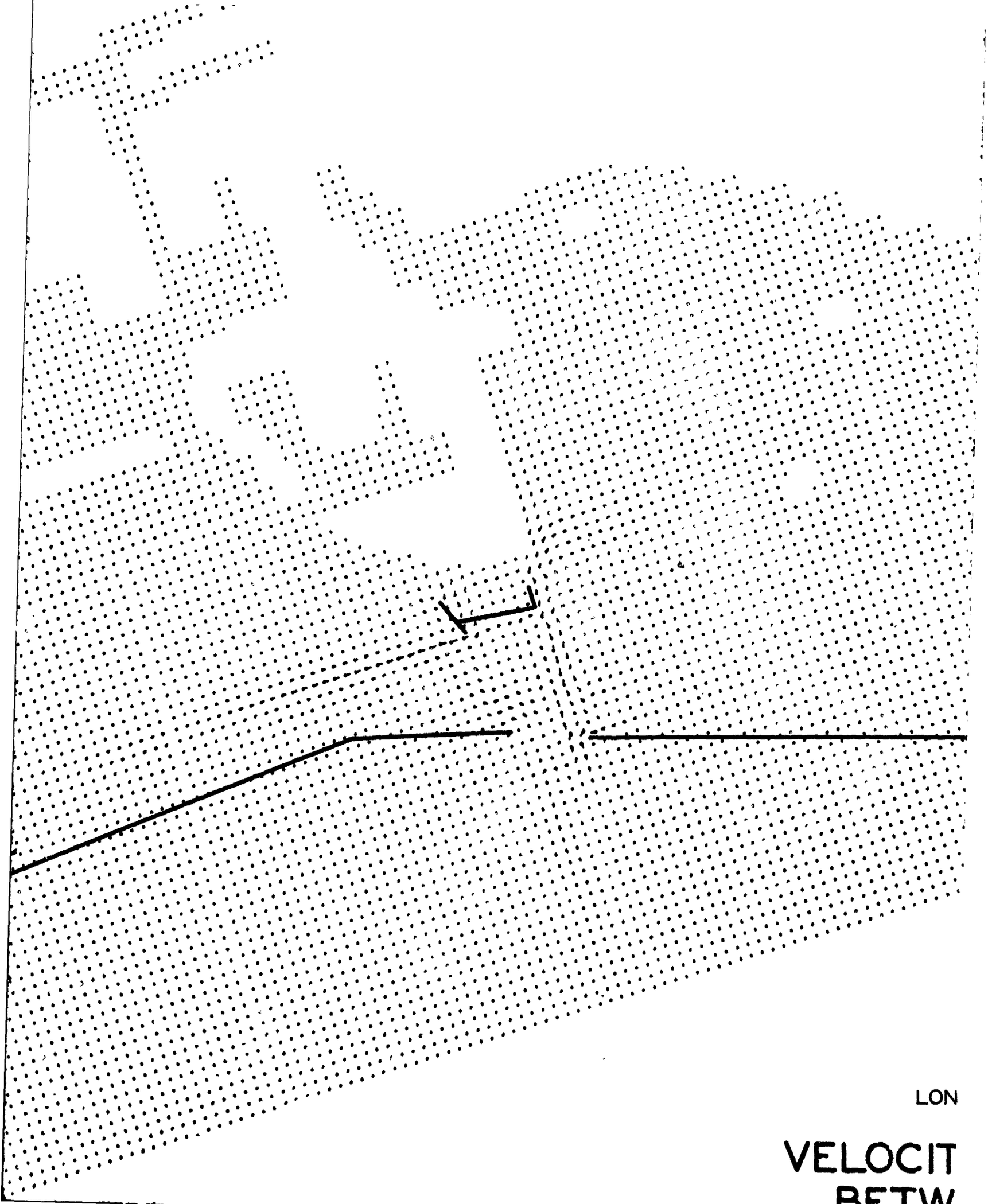

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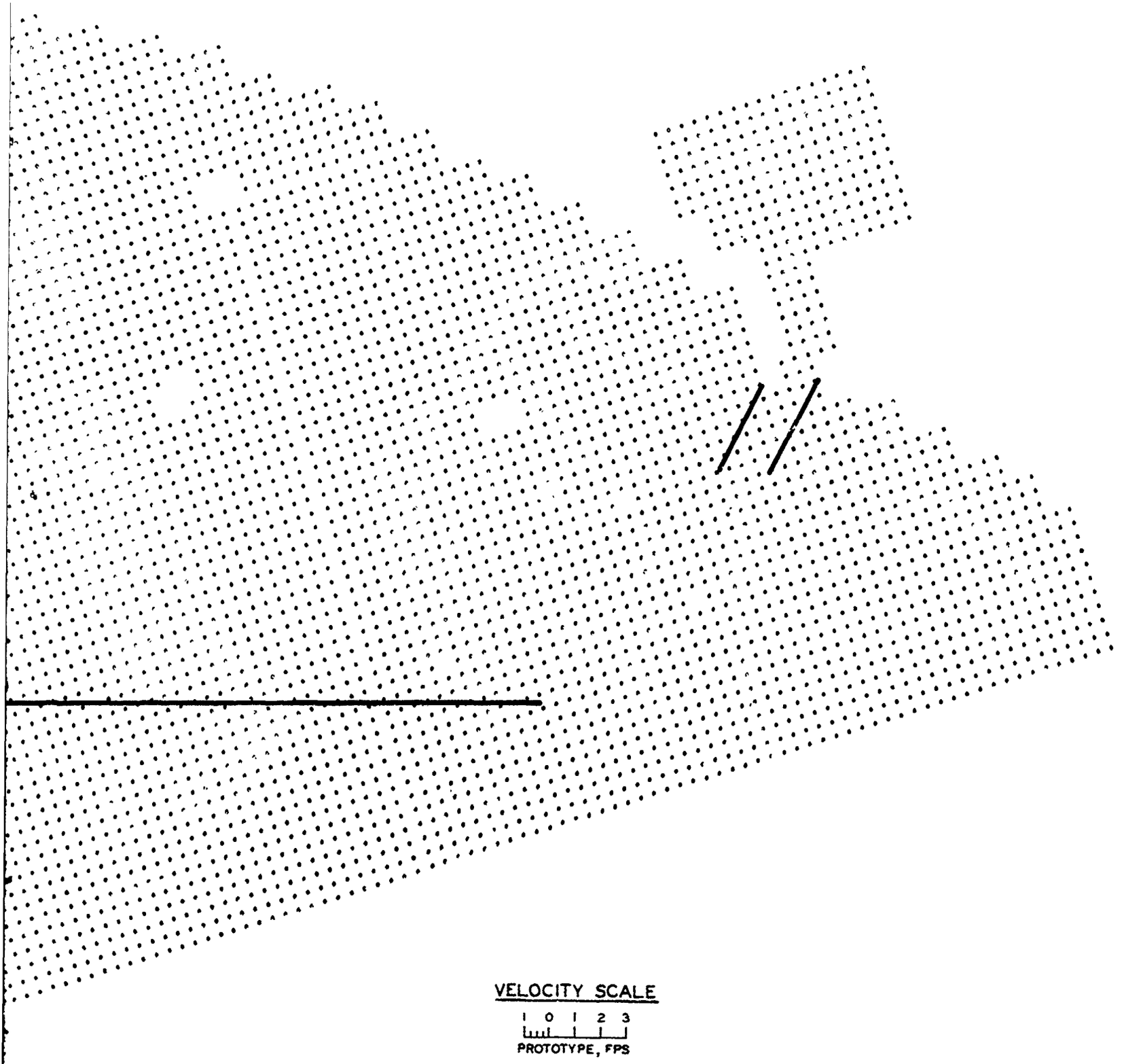
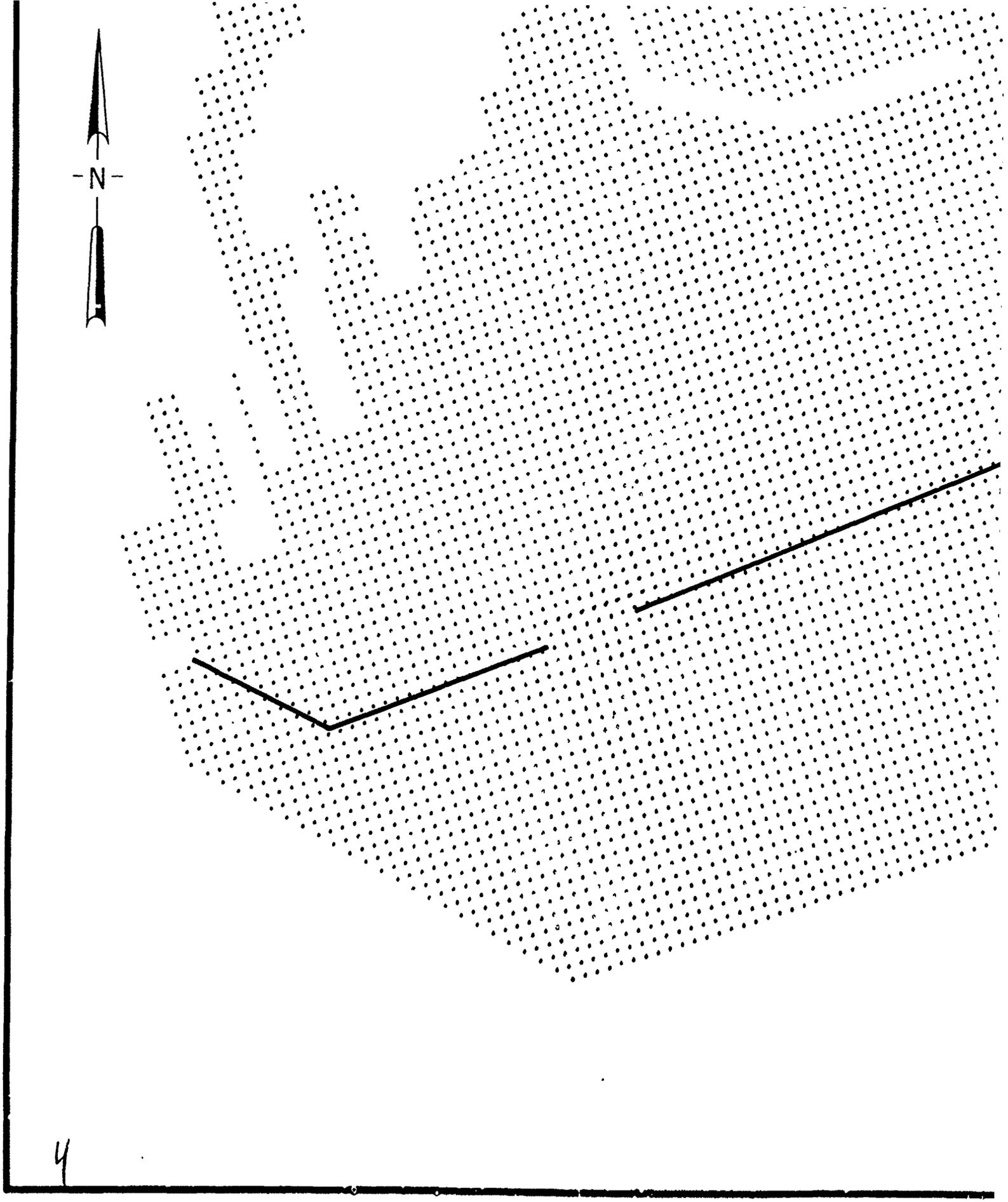


NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2,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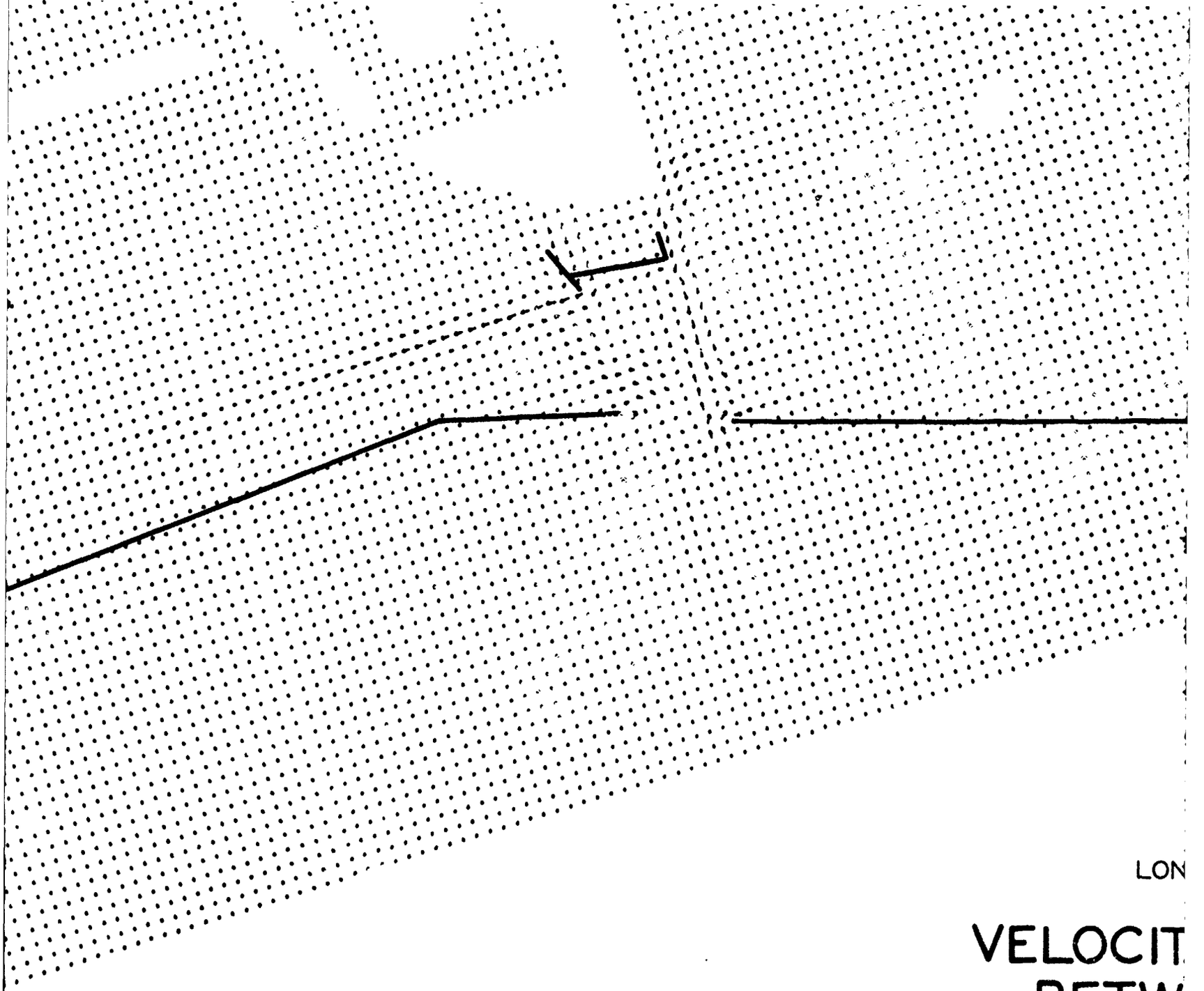

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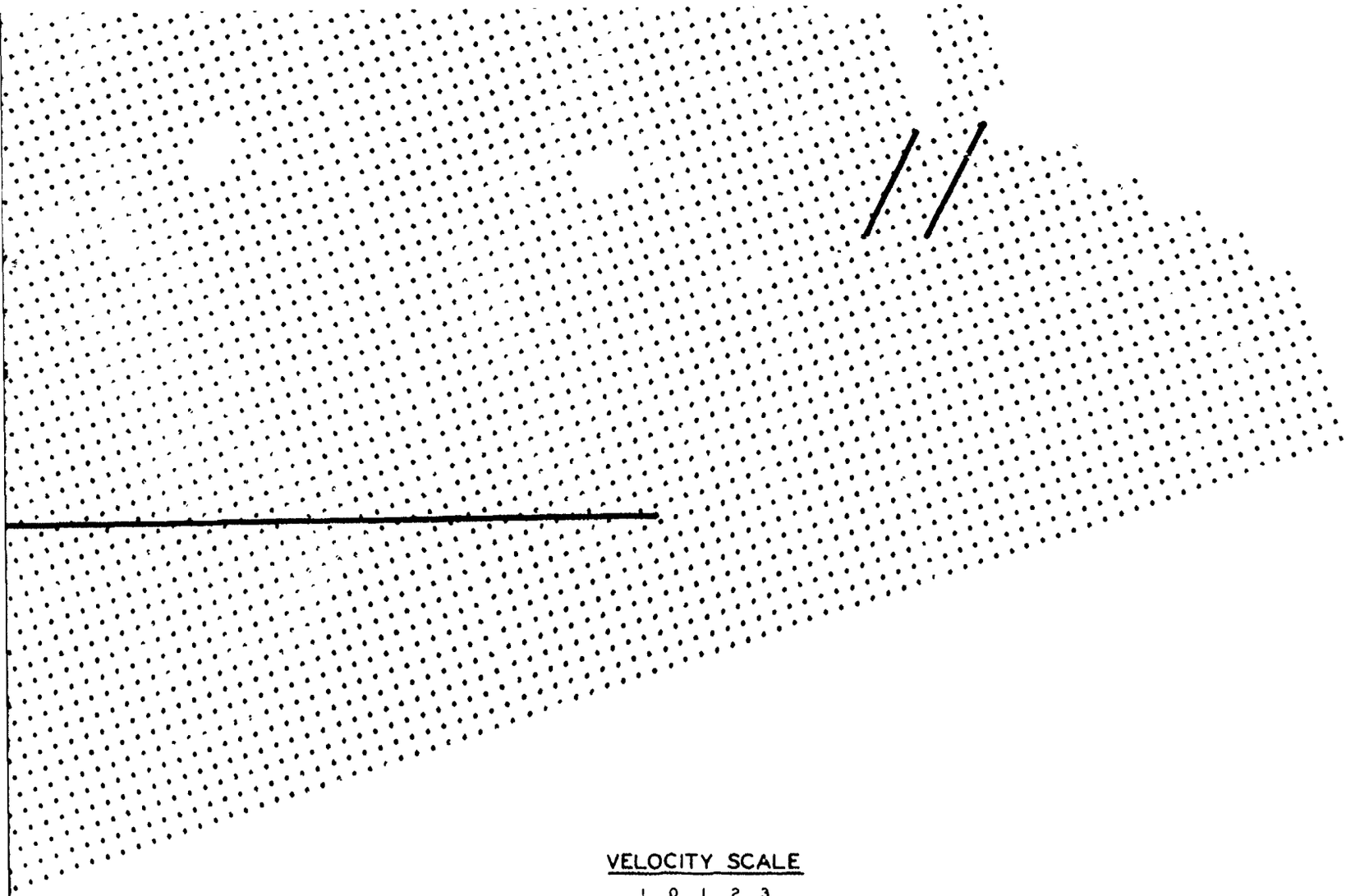

VELOCITY SCALE

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PROTOTYPE, FPS

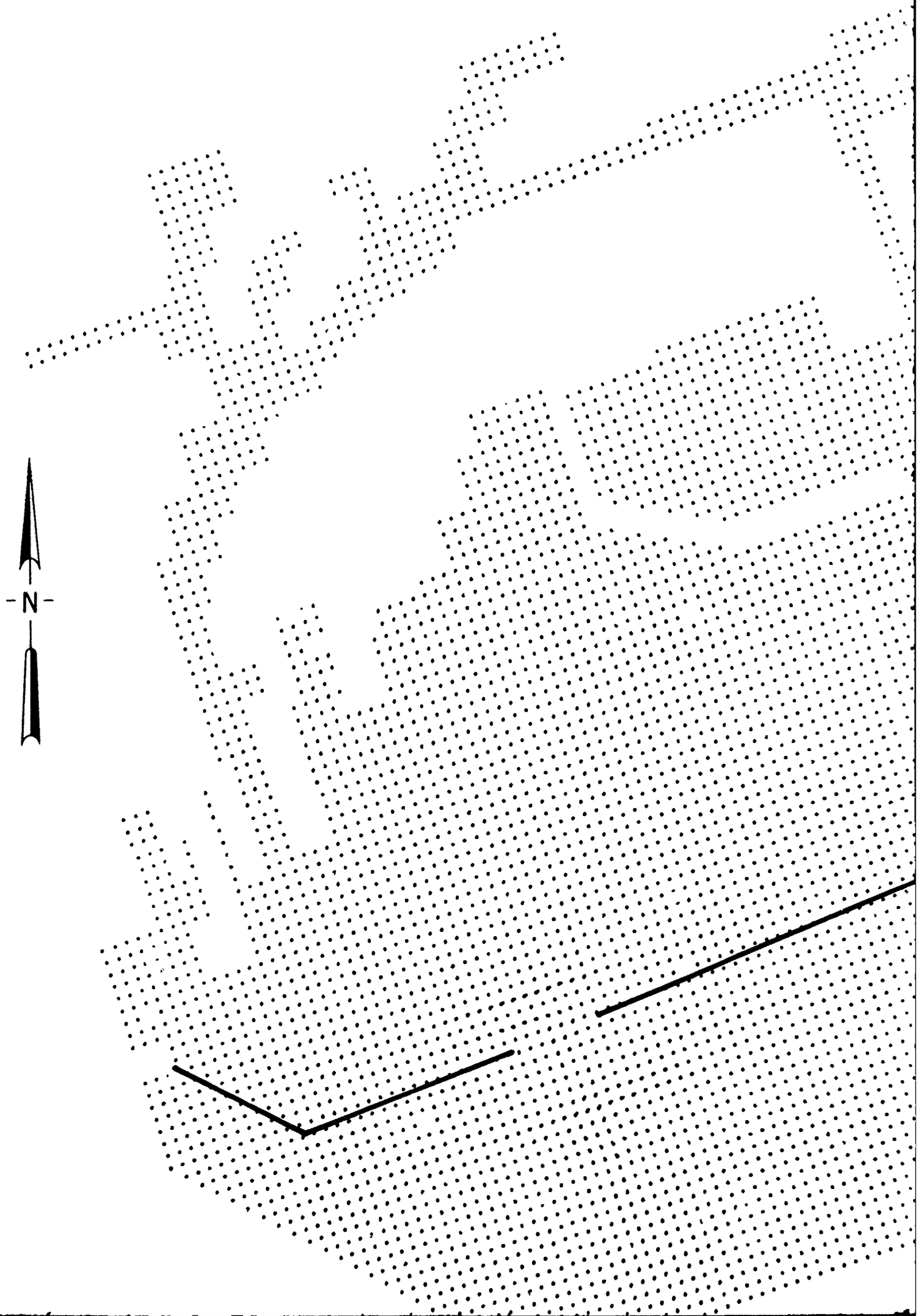
NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 2, -82-FT CHANNEL, 600-FT OPENING, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 24 (NEAR MAXIMUM EBB)

6

FIGURE 32


N

LO
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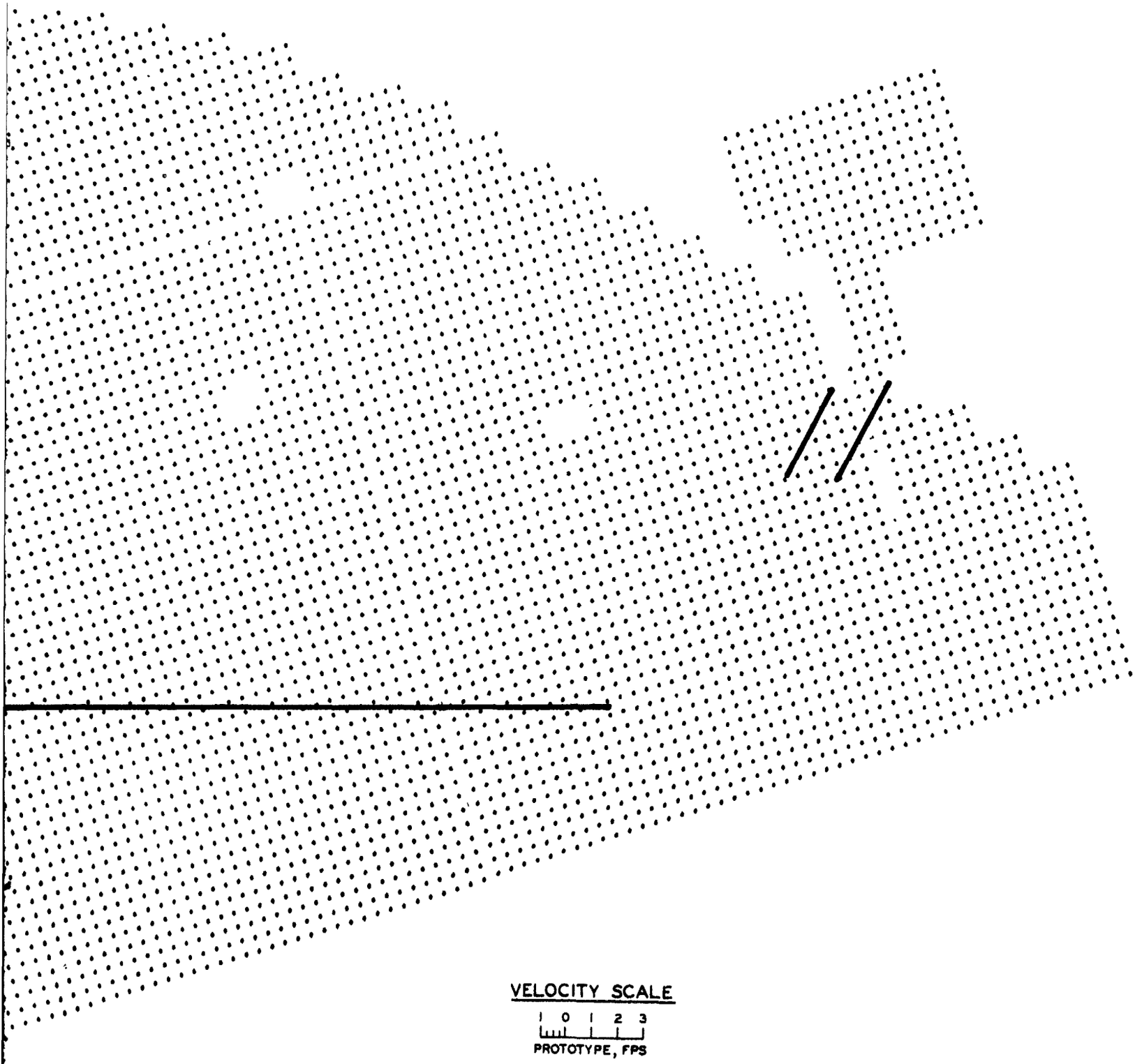
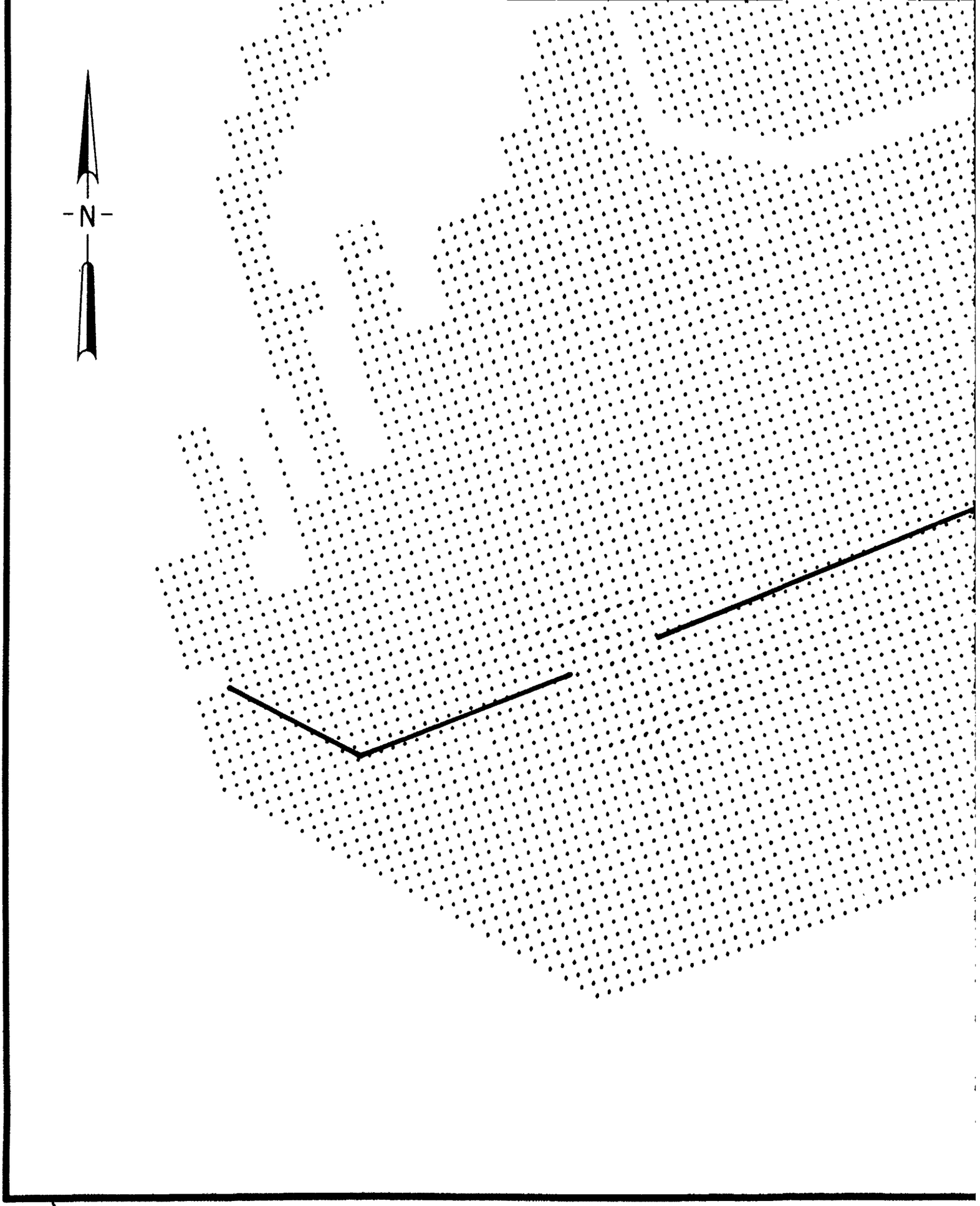


NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 3,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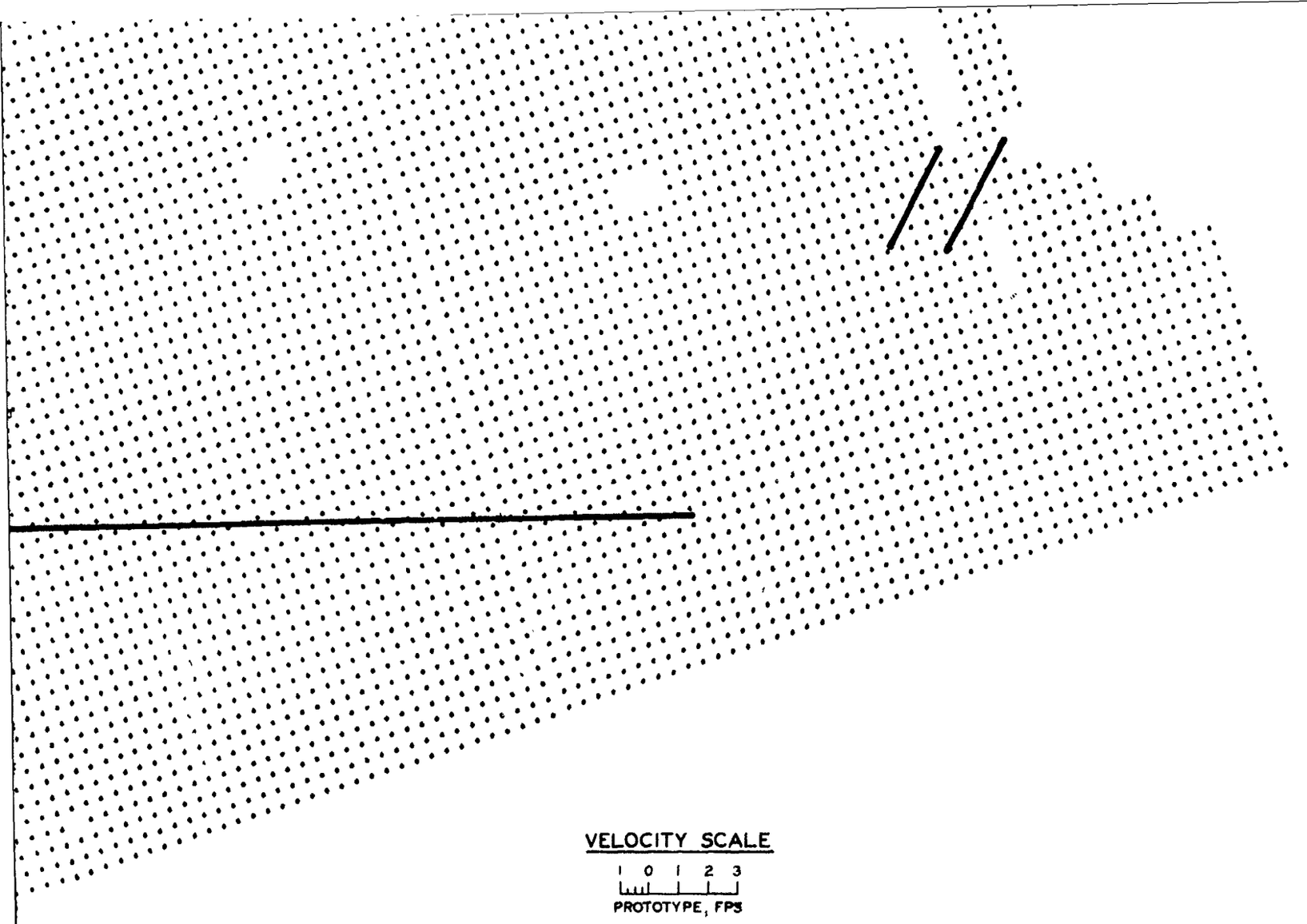


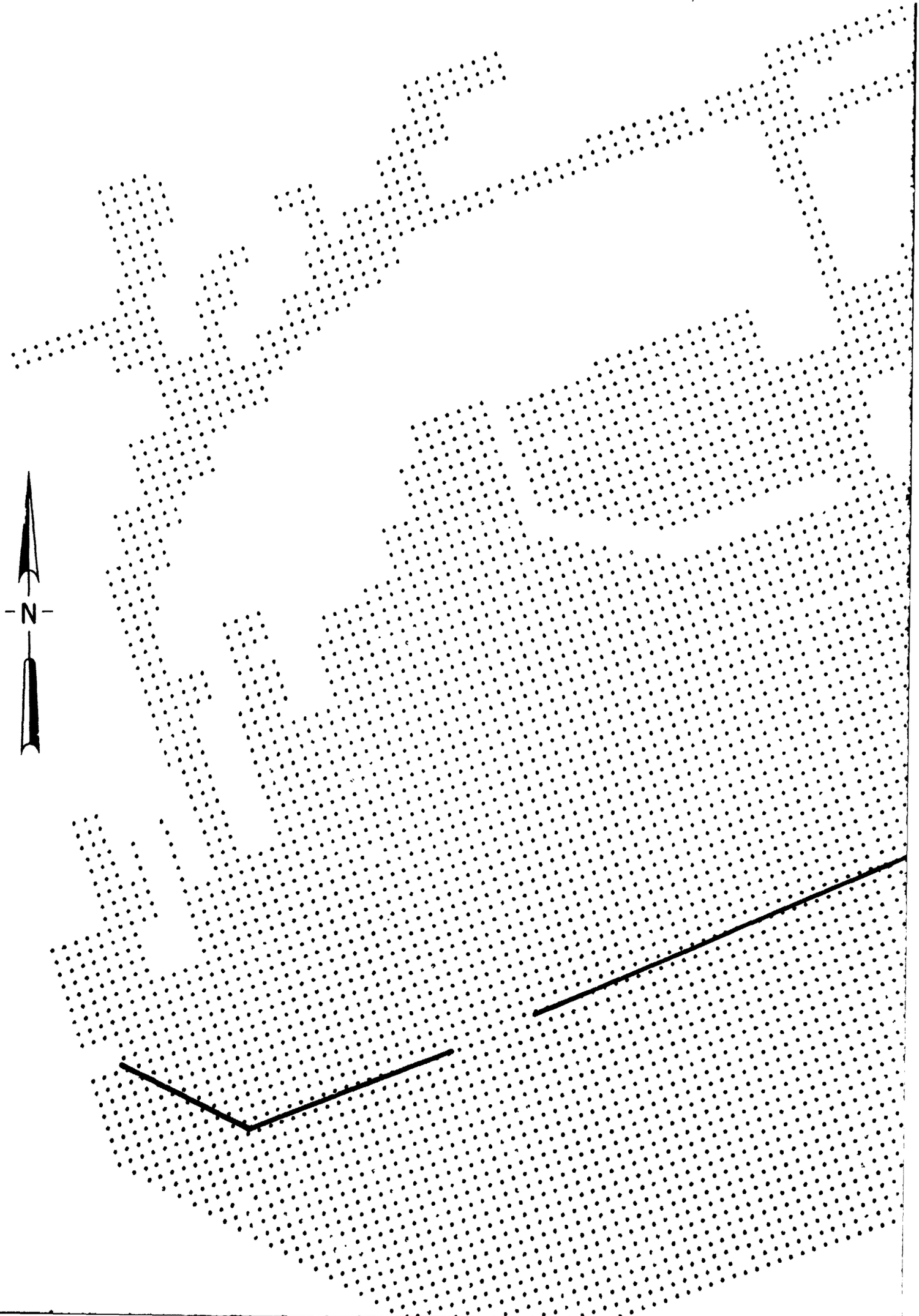
NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 3, -82-FT CHANNEL, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 15 (NEAR SLACK WATER)

6

FIGURE 33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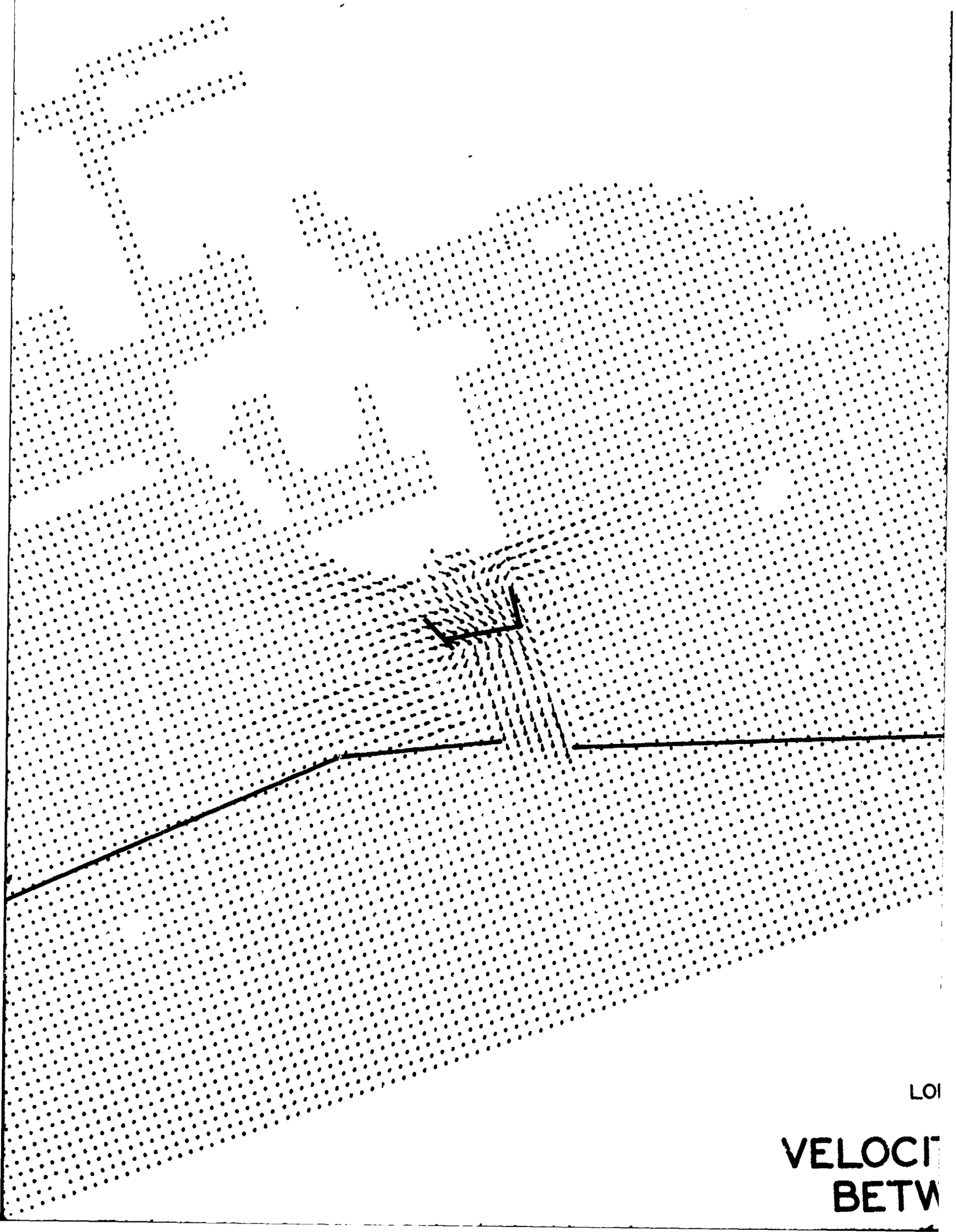

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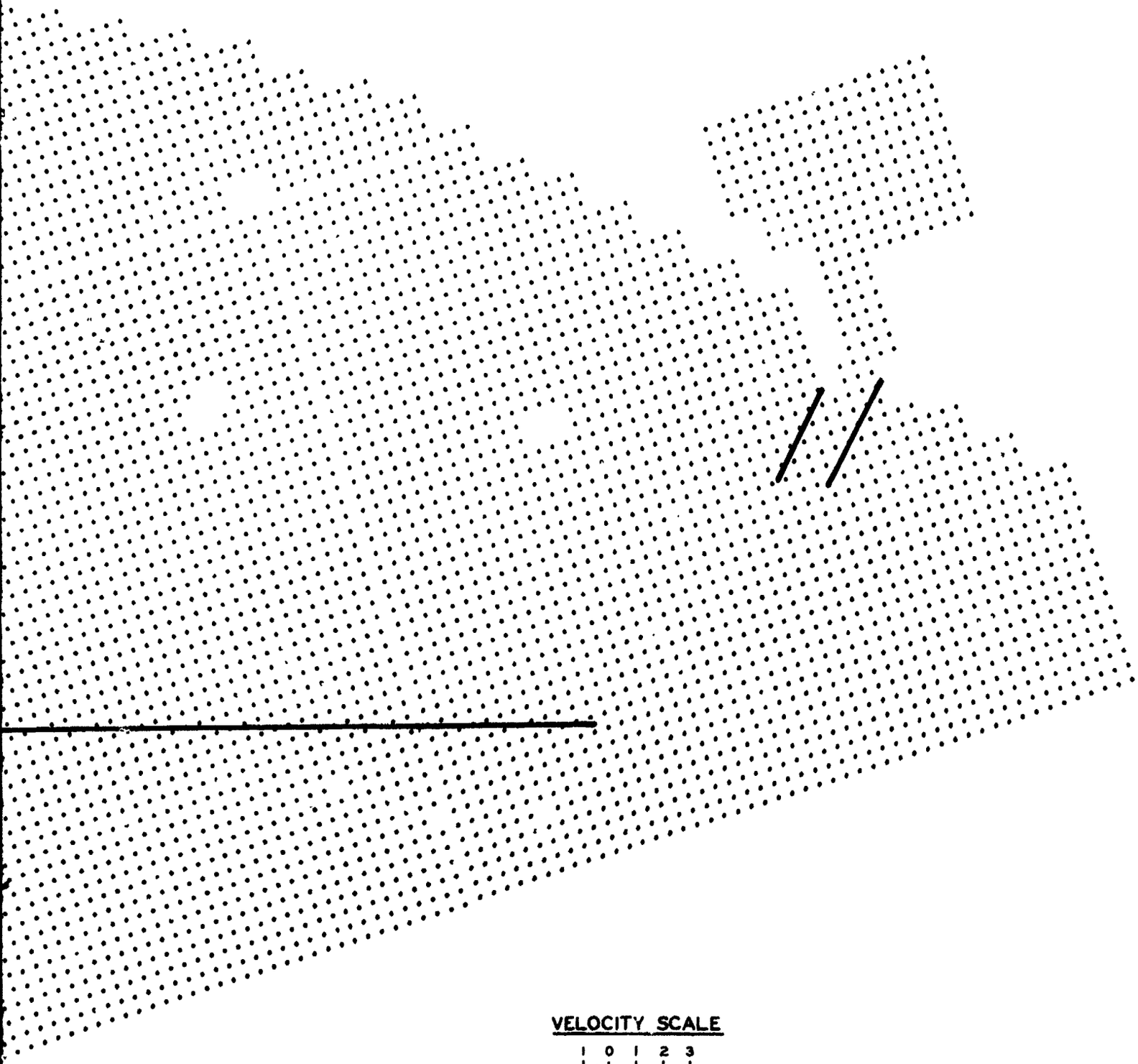


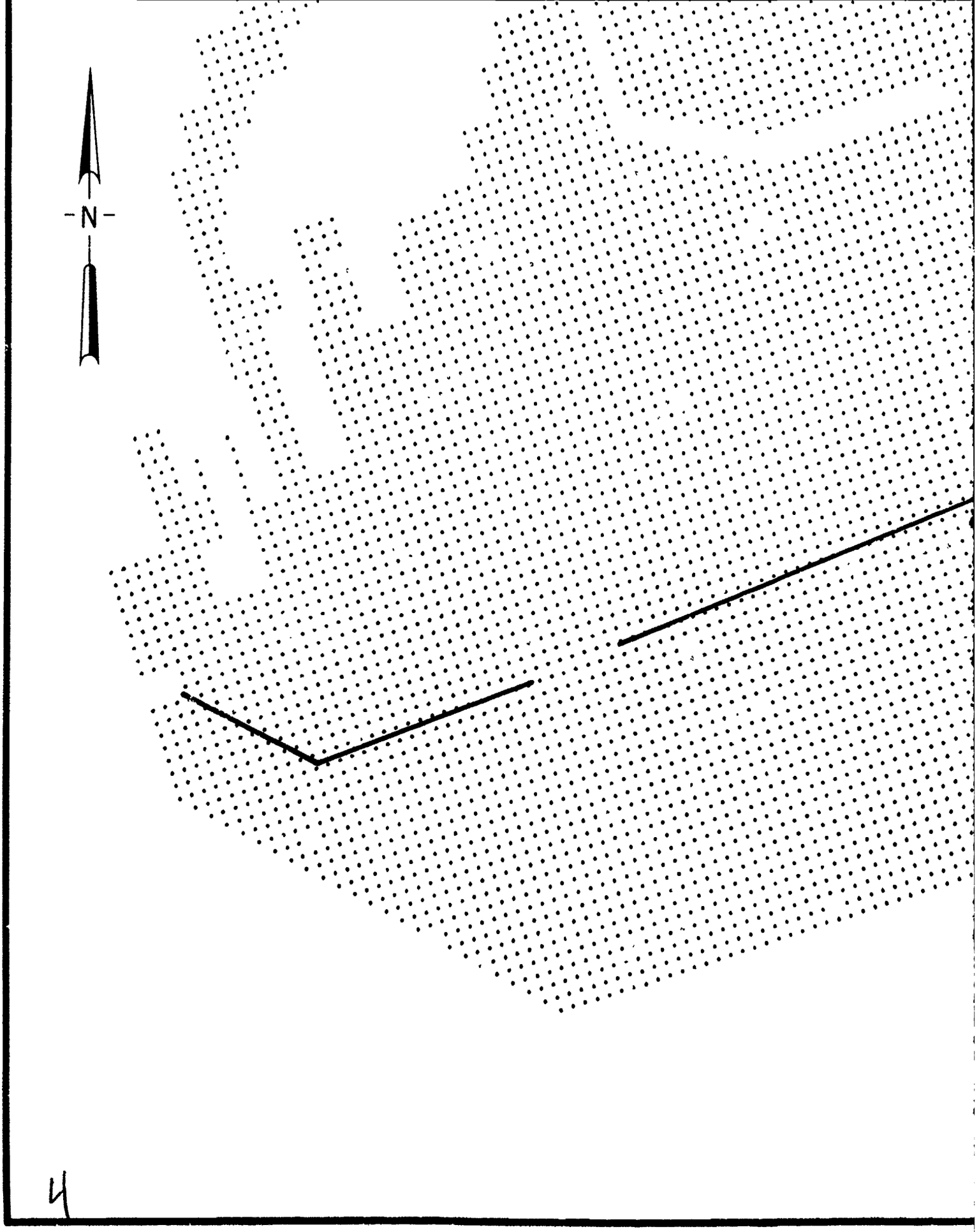
VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STEP 3



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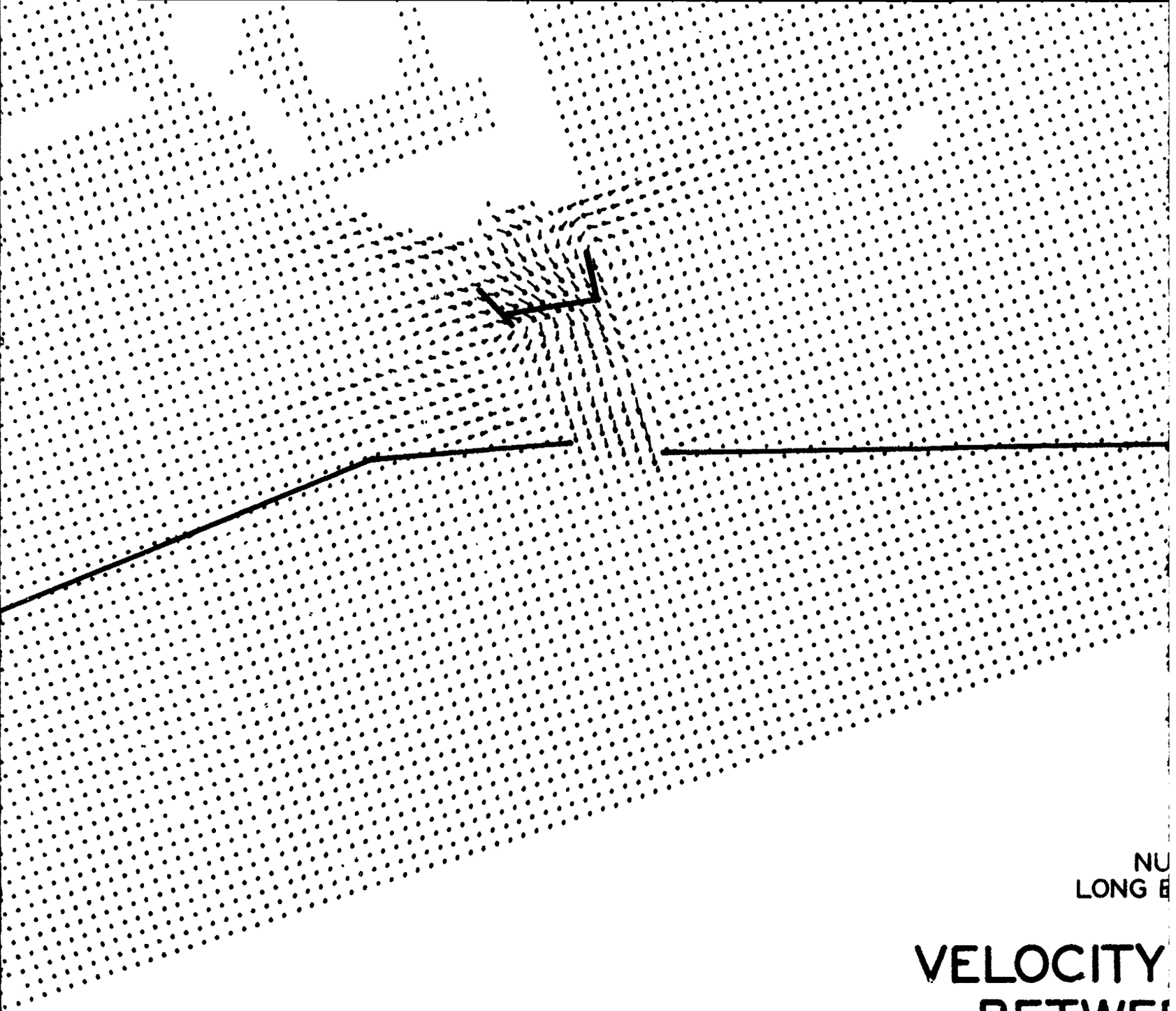

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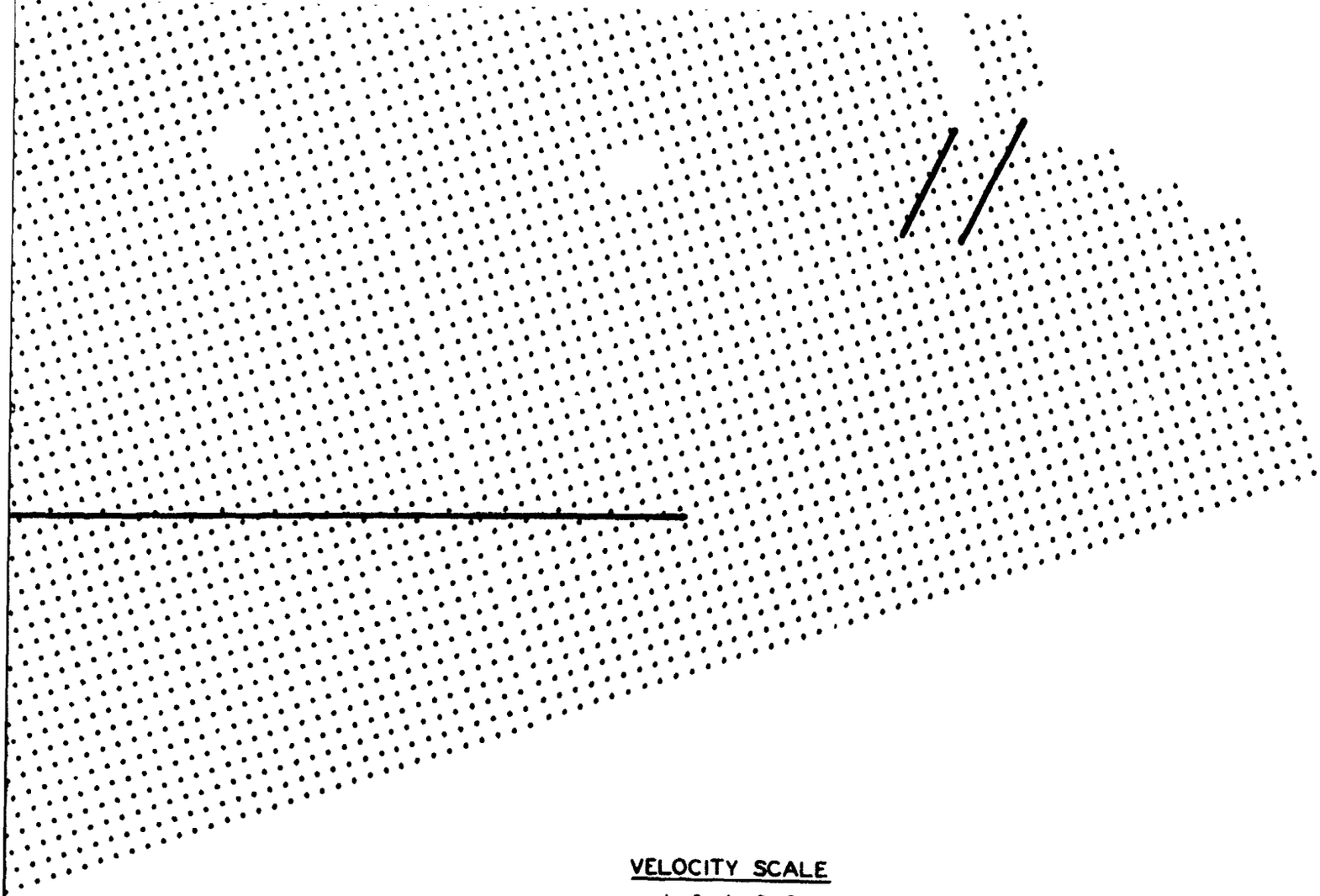


VELOCITY SCALE

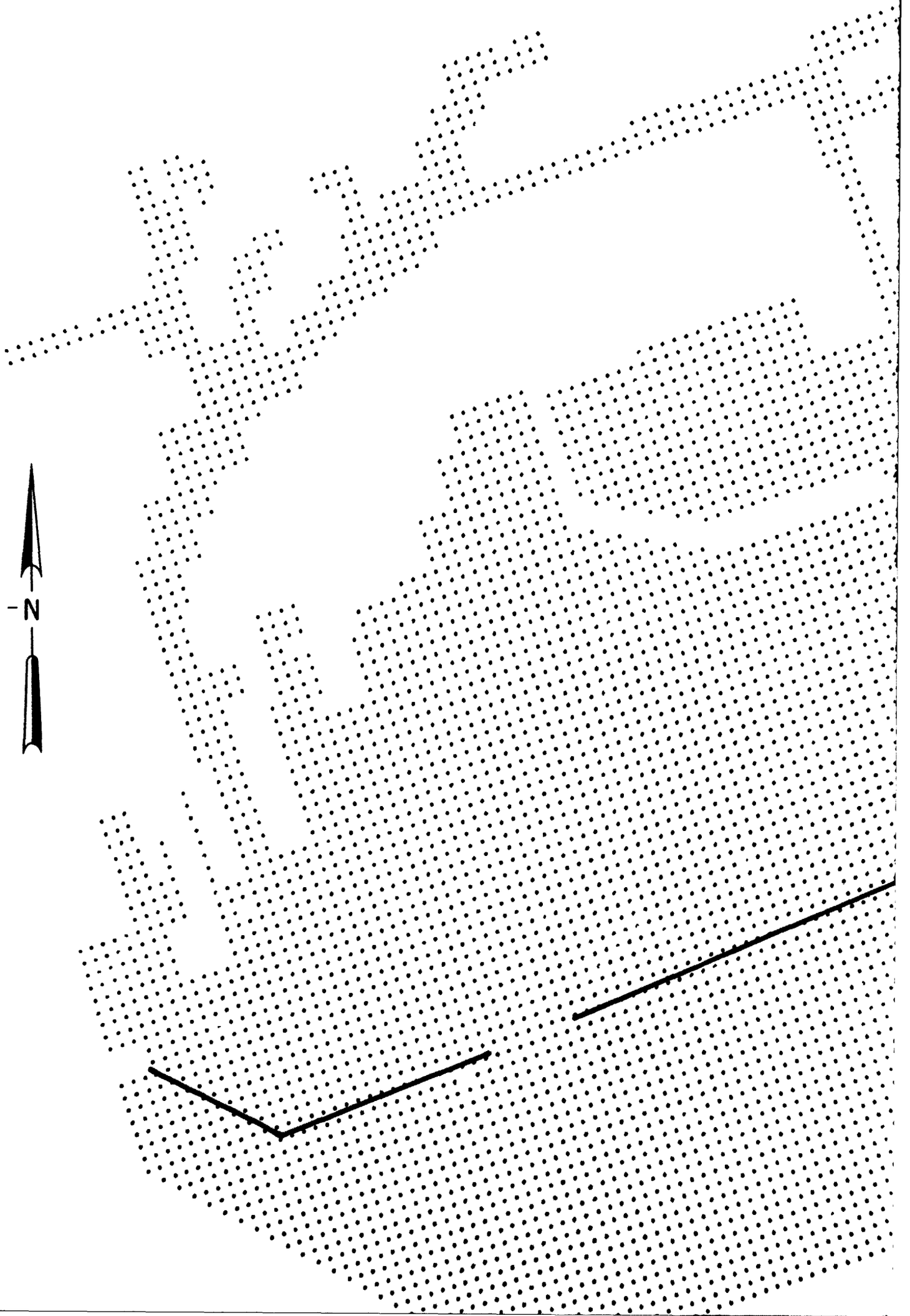
1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 3, -82-FT CHANNEL, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 19 (NEAR MAXIMUM FLOOD)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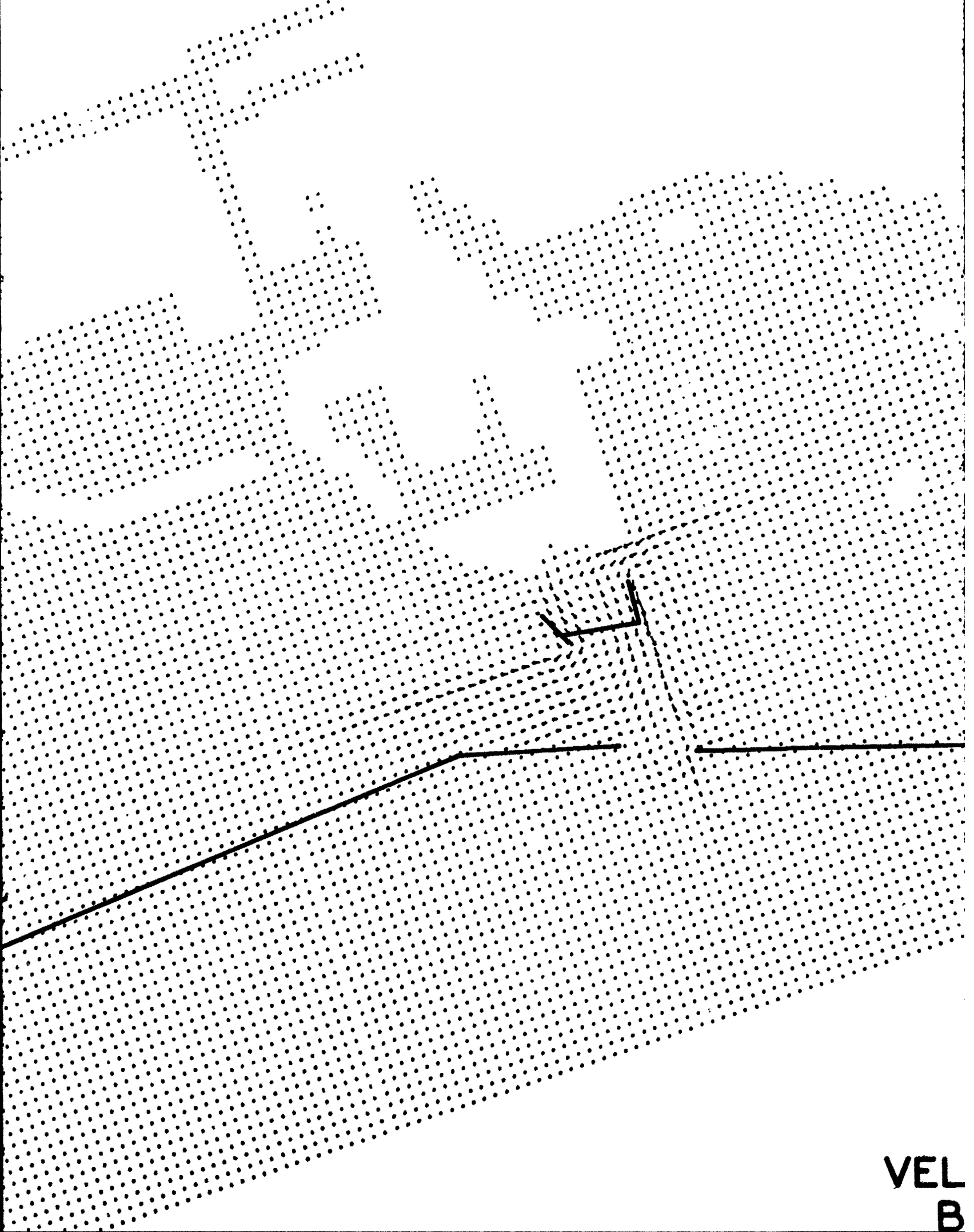

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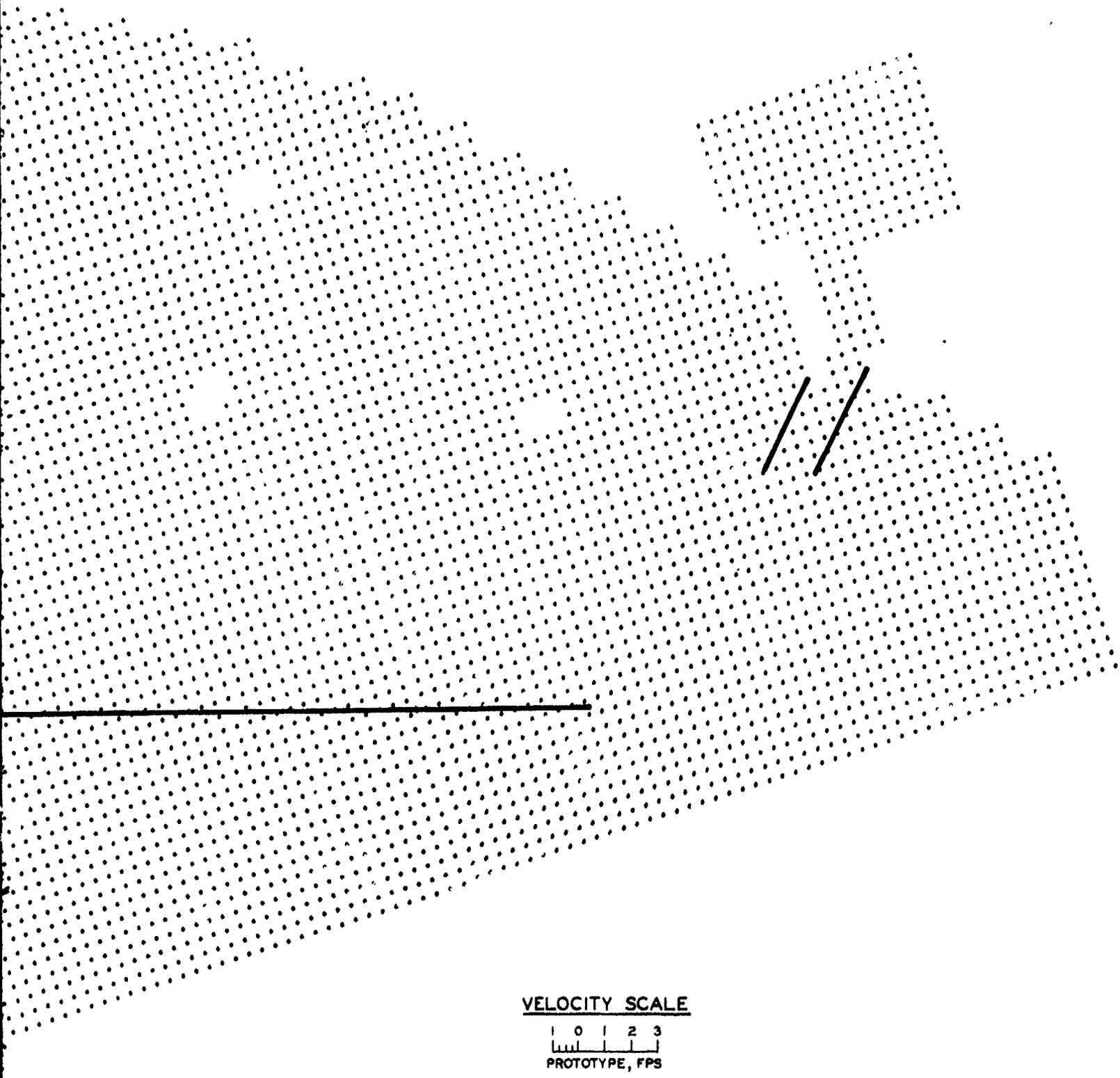
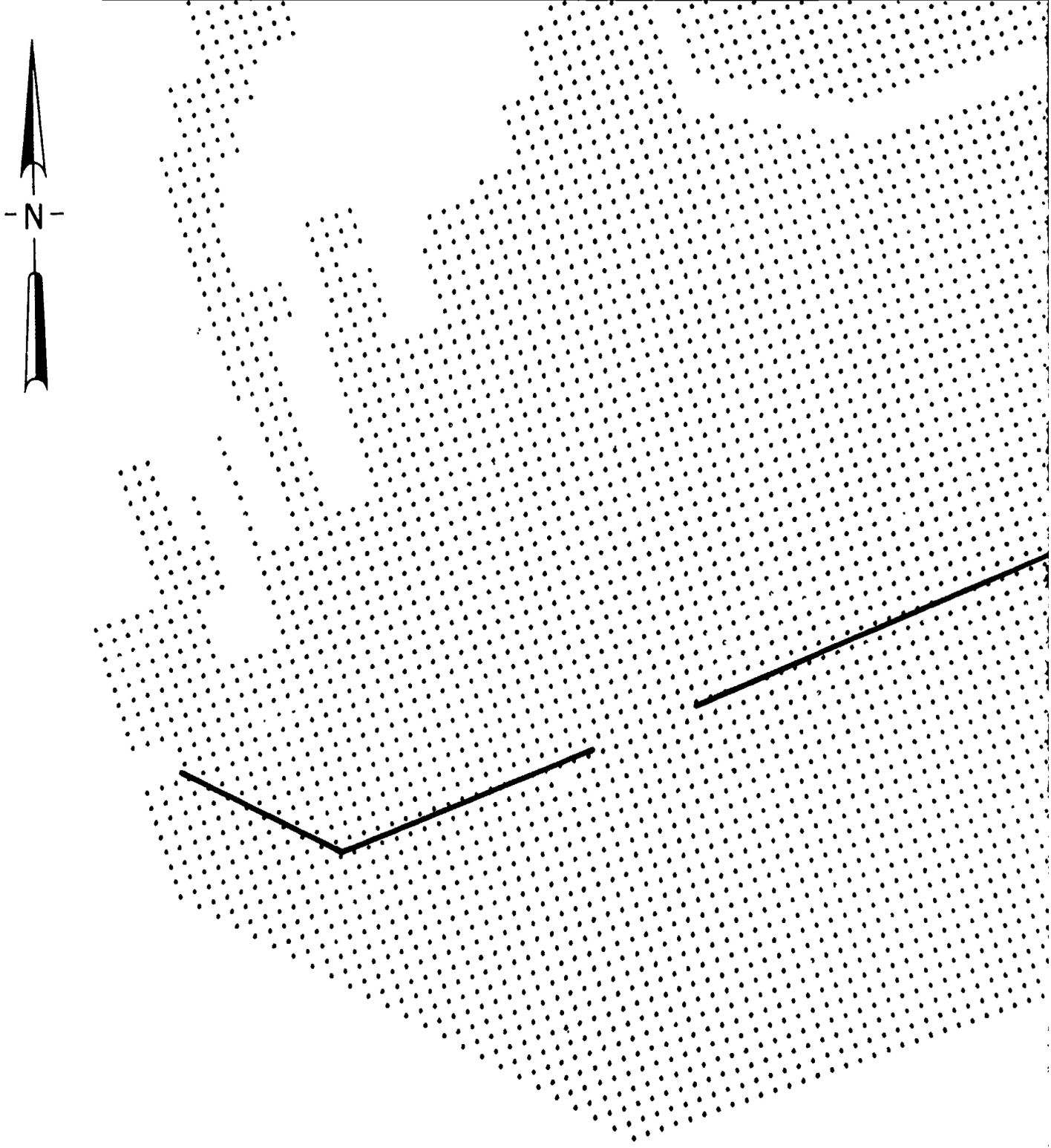


NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 3,



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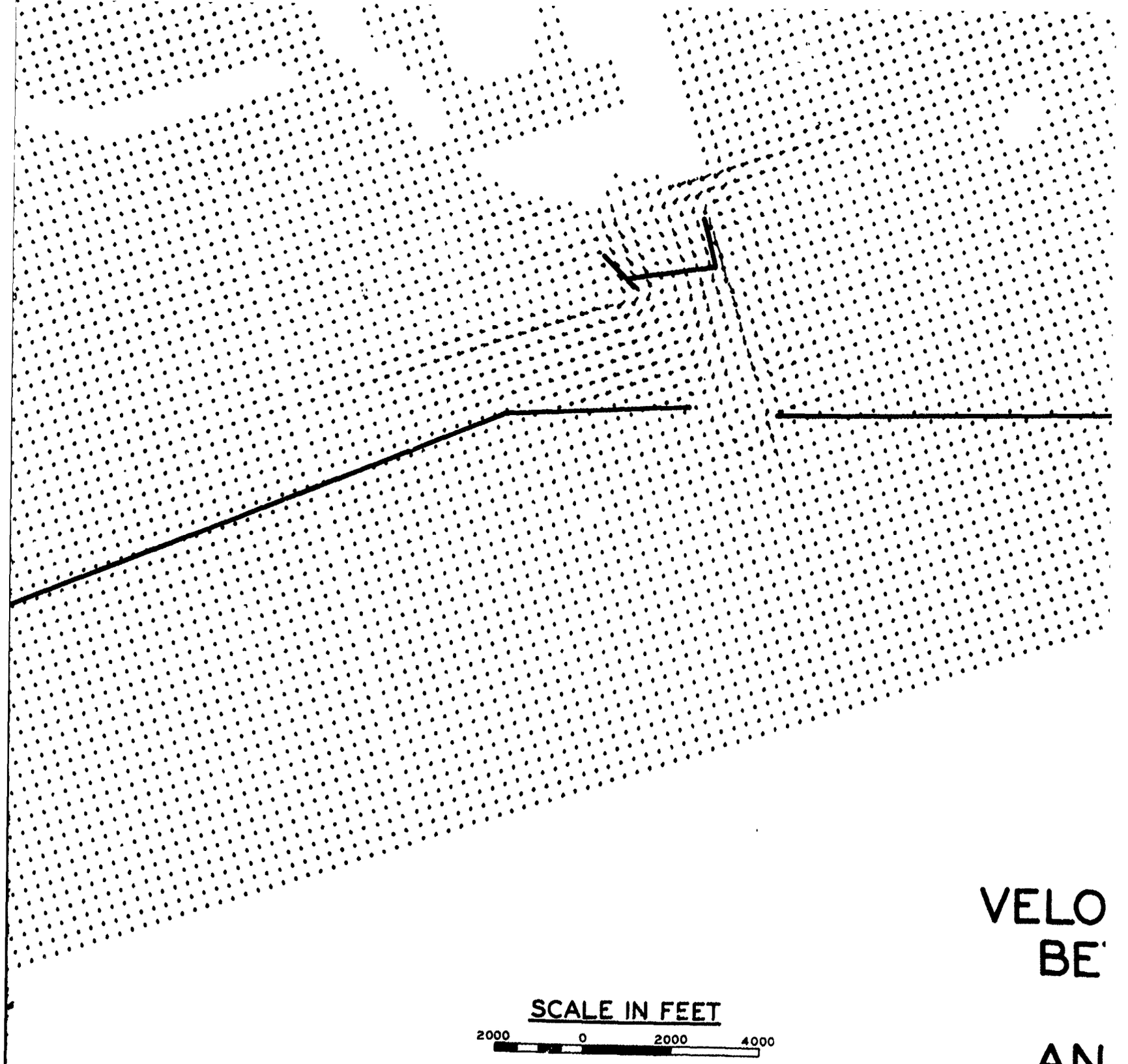

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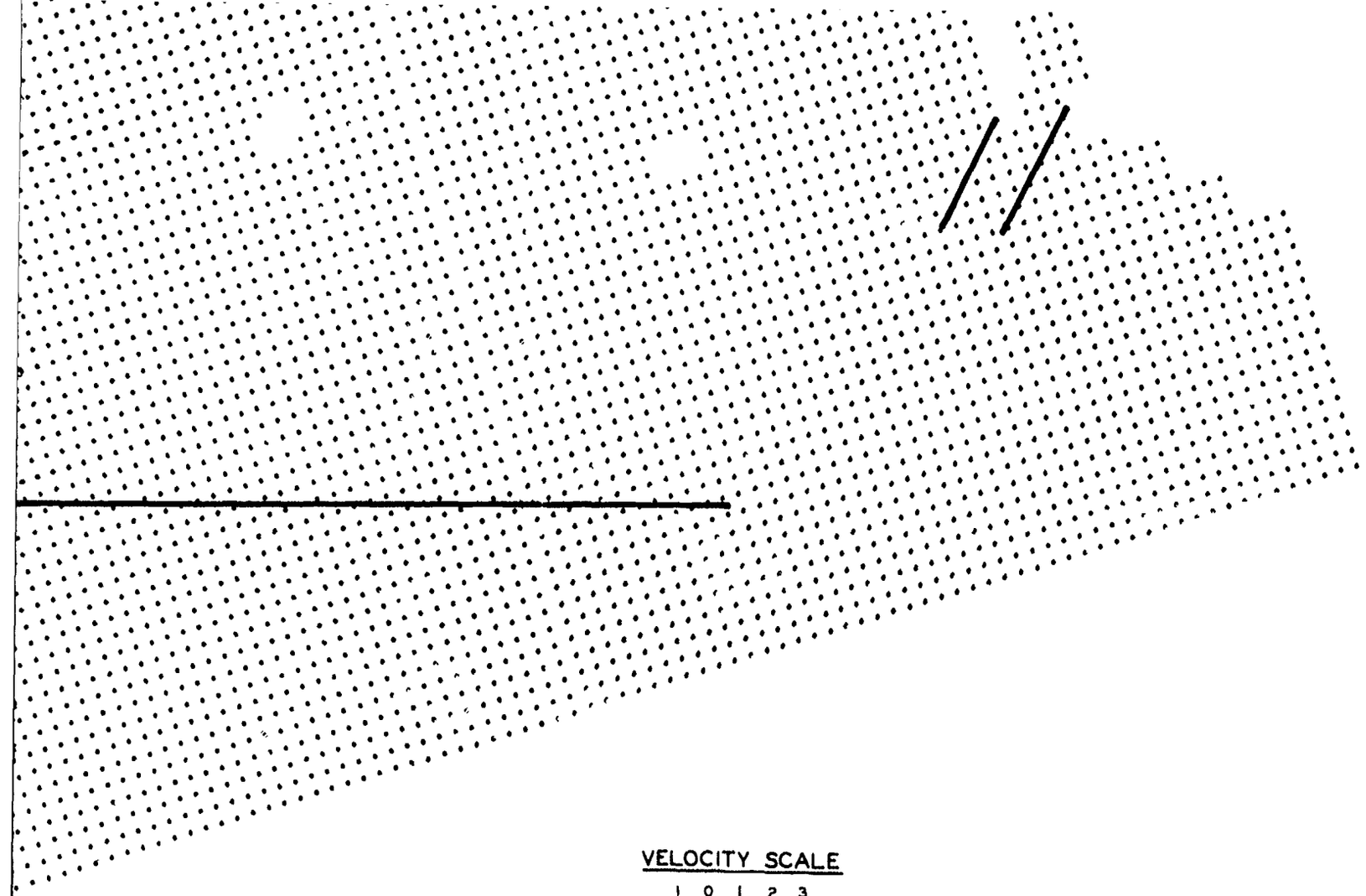


VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

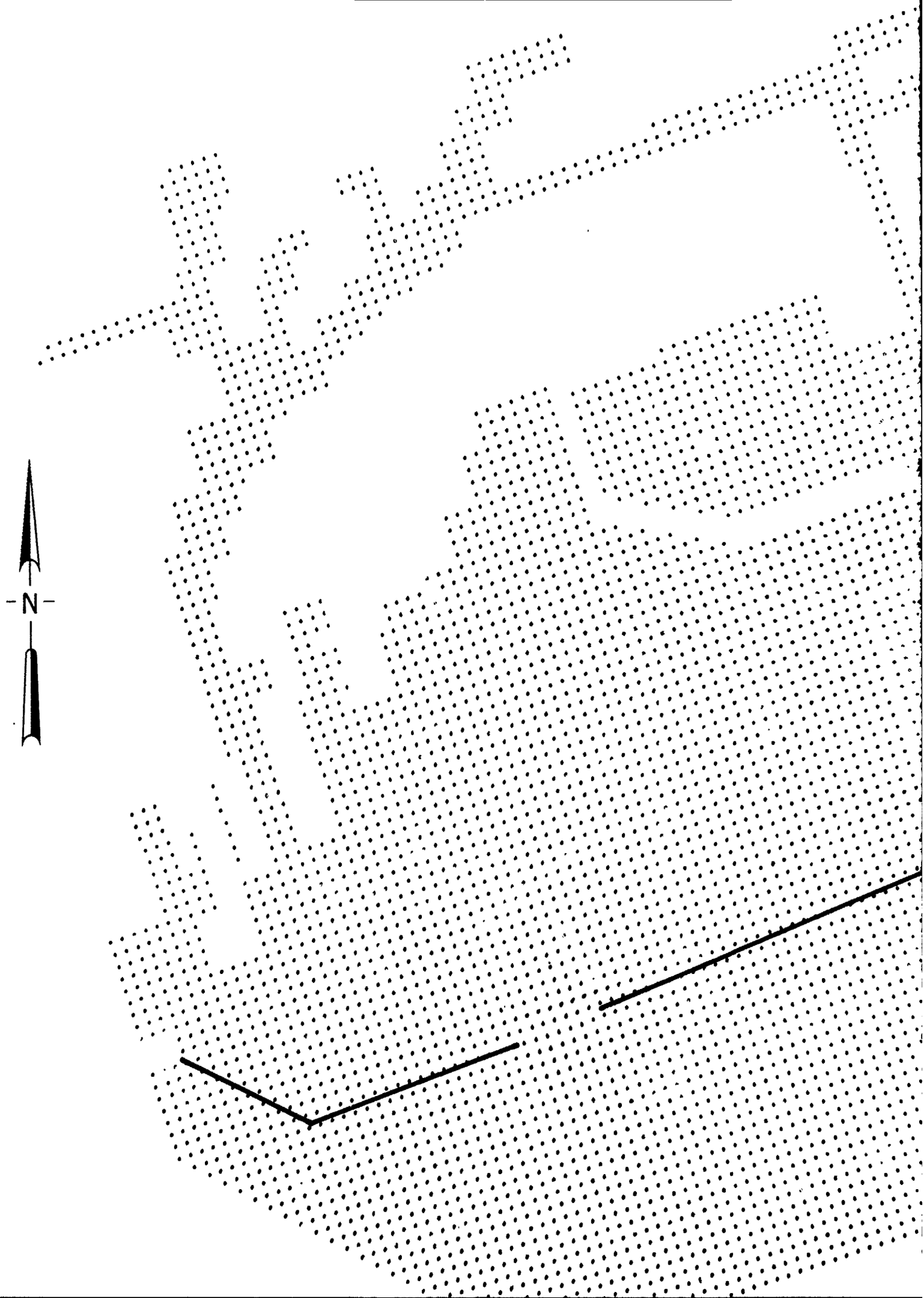
NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 3, -82-FT CHANNEL, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 22 (NEAR SLACK WATER)

6

FIGURE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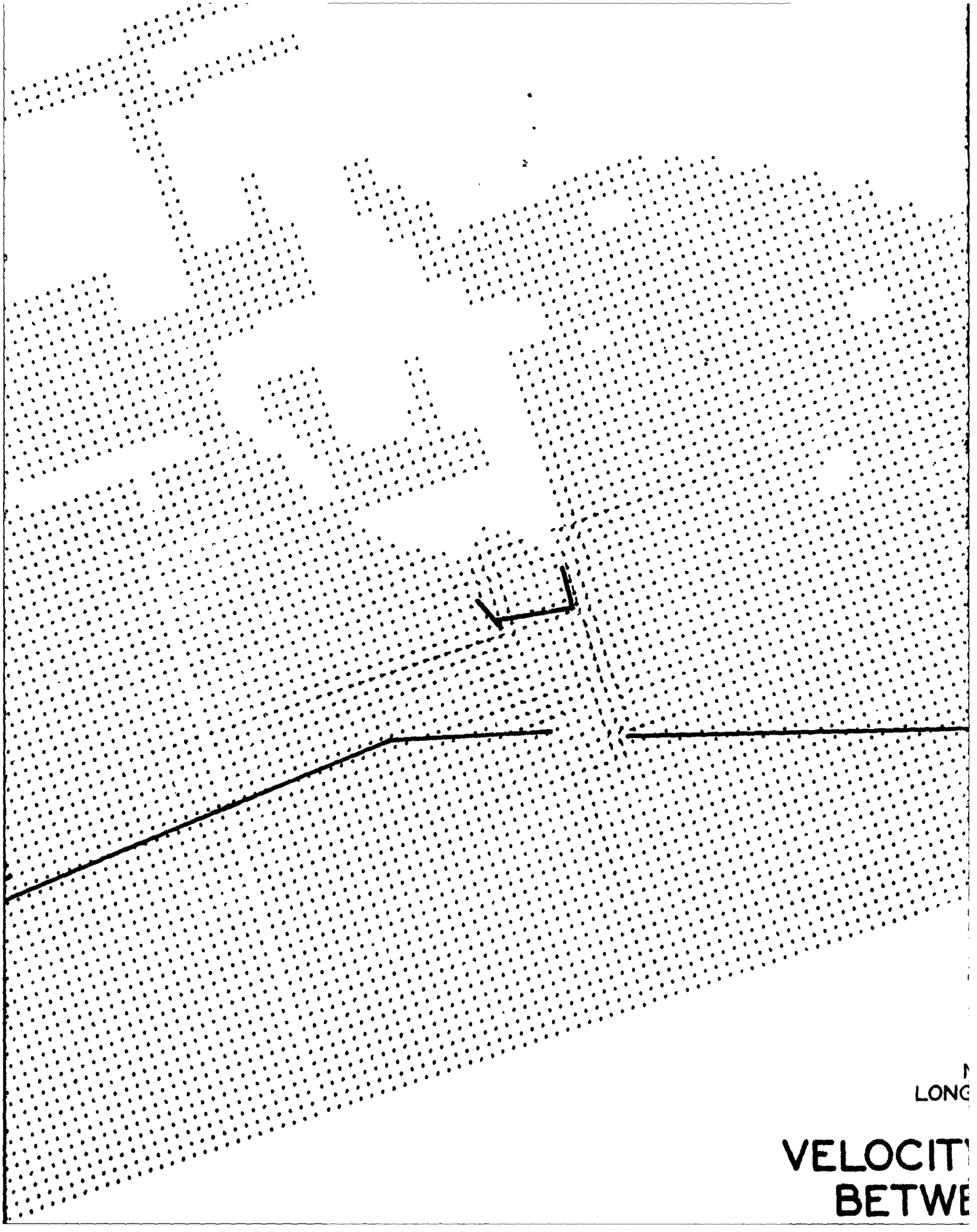
LONG
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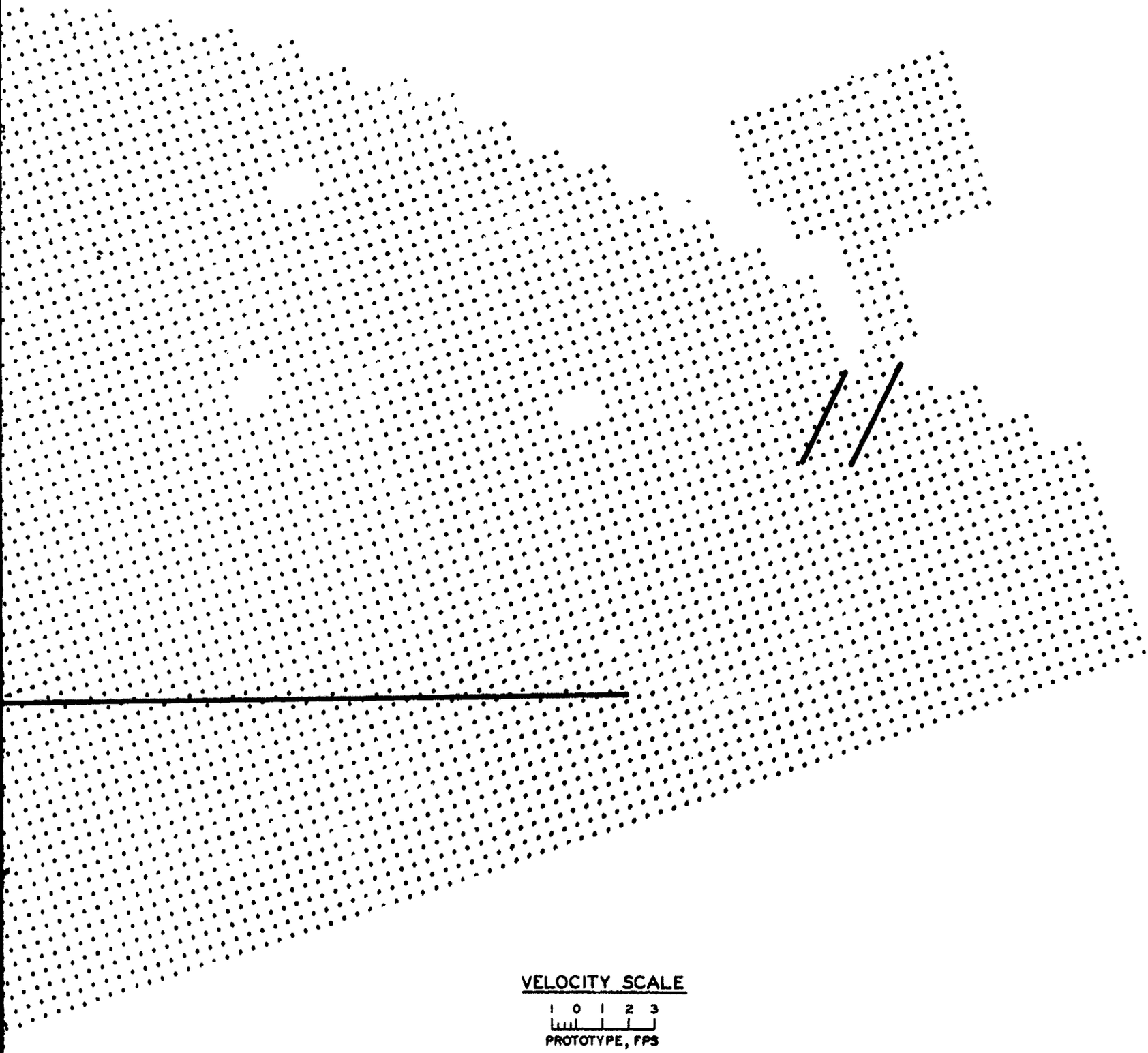
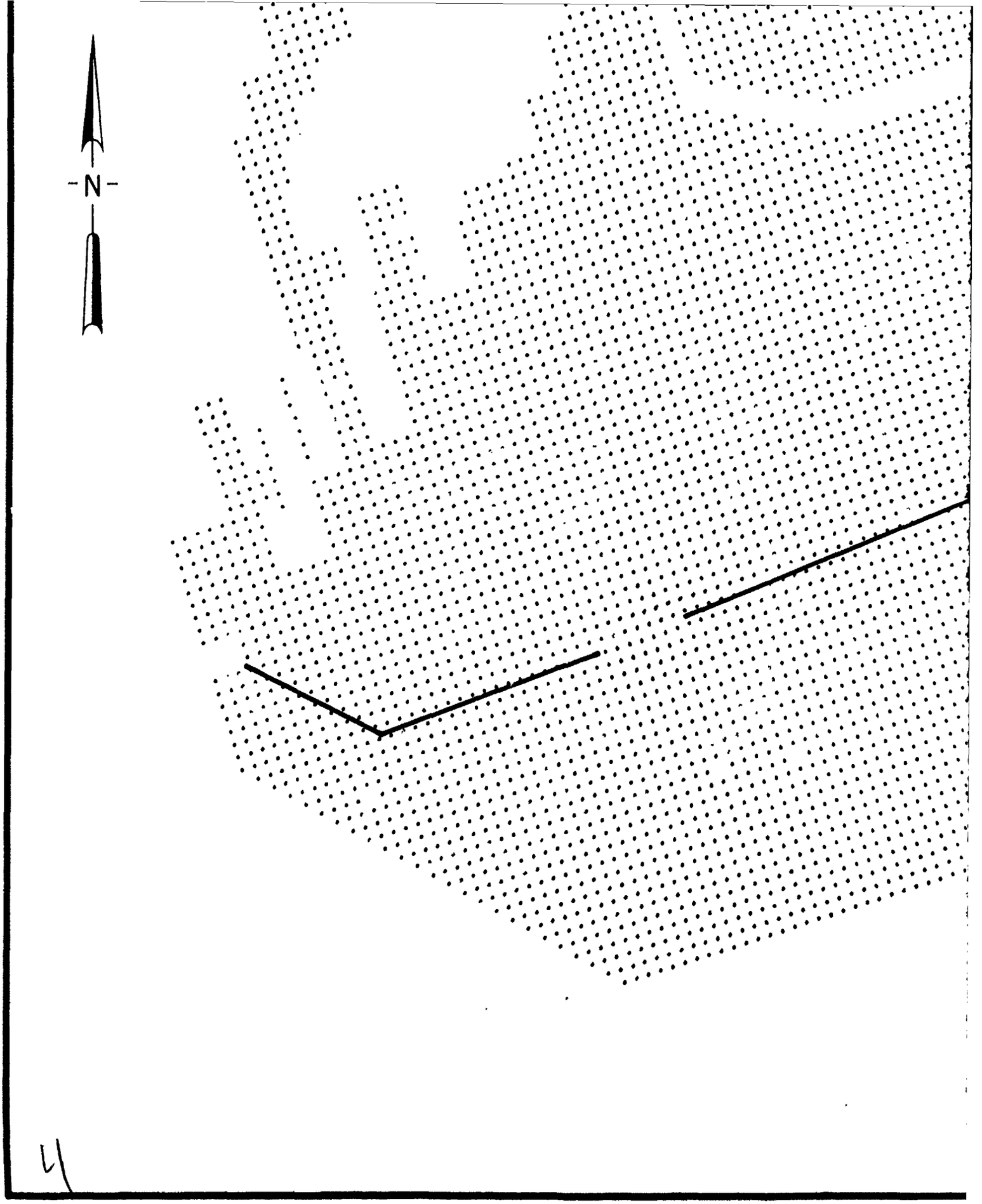


NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 3,



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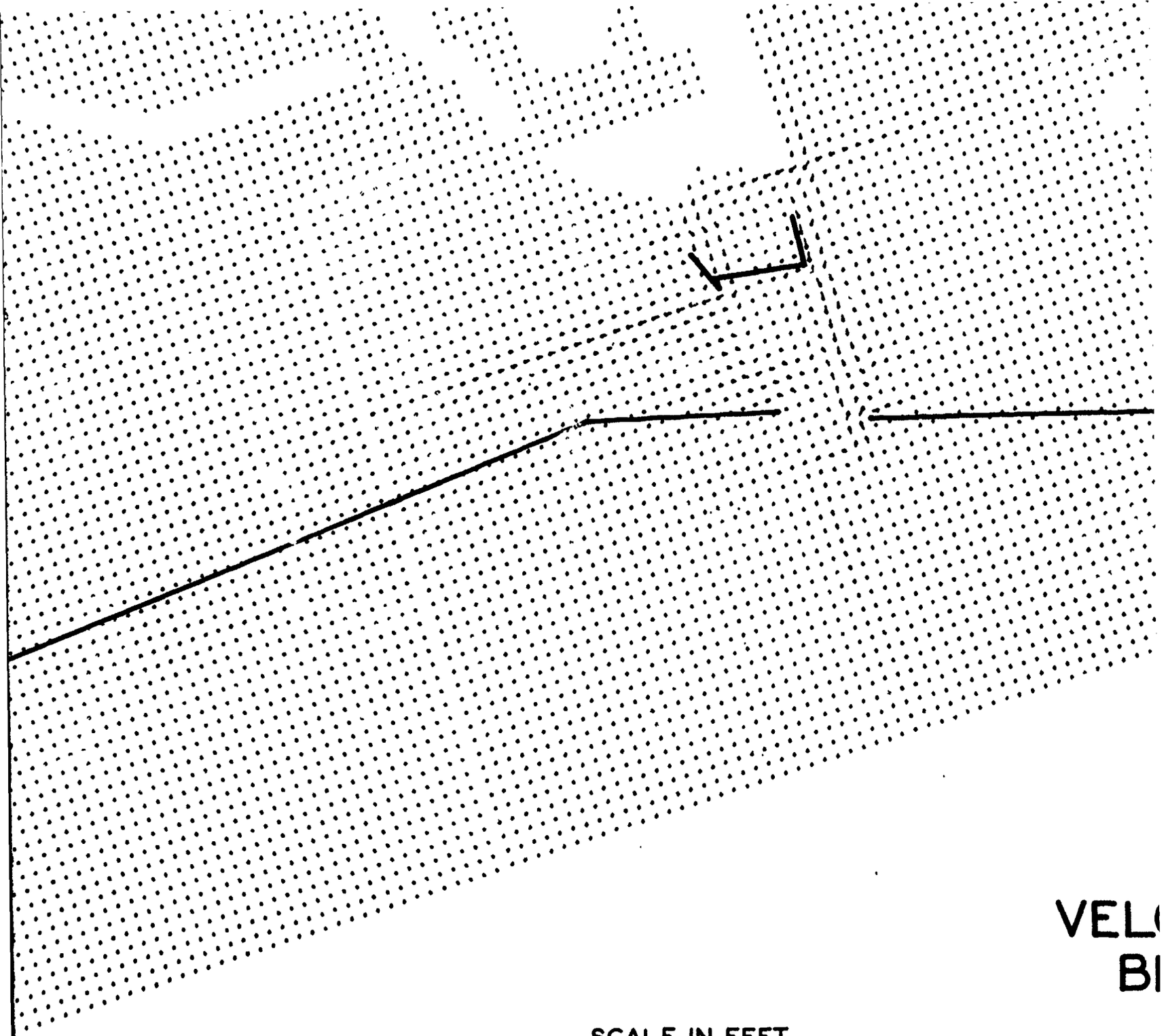

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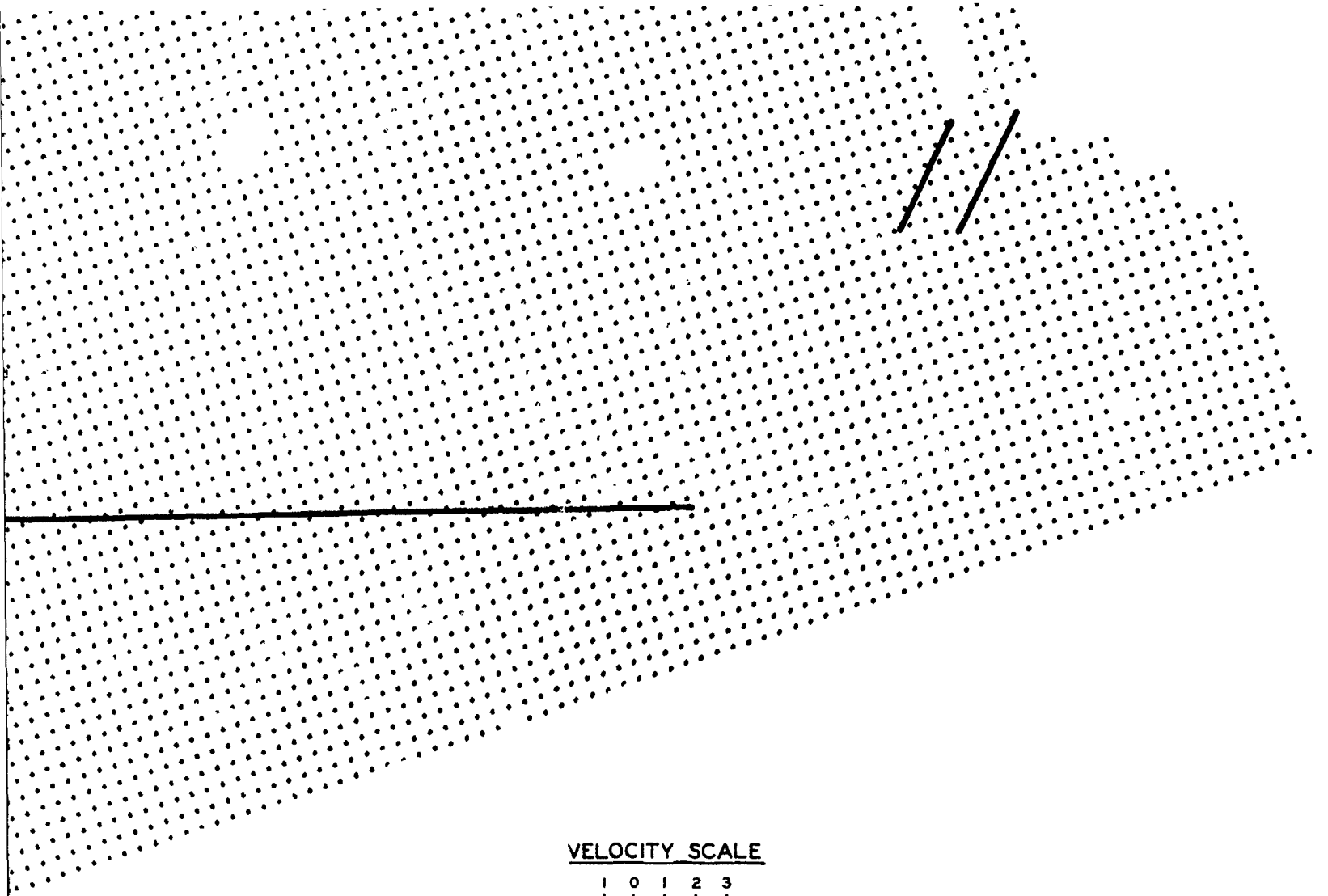

VELOCITY SCALE

1 0 1 2 3

PROTOTYPE, FPS

NUMERICAL MODEL STUDY OF
LONG BEACH - LOS ANGELES HARBORS

VELOCITY DIFFERENCE PATTERN BETWEEN SCHEME STFP 3, -82-FT CHANNEL, AND EXISTING CONDITIONS

SPRING TIDE
HOUR 24 (NEAR MAXIMUM EBB)

6

FIGURE 36