



US Army Corps
of Engineers

MISCELLANEOUS PAPER CERC-89-17

BOLSA BAY, CALIFORNIA, PROPOSED OCEAN ENTRANCE SYSTEM STUDY

Report 3

TIDAL CIRCULATION AND TRANSPORT COMPUTER
SIMULATION AND WATER QUALITY ASSESSMENT

SECTION 2: SIGNAL LANDMARK'S PROPOSED SECONDARY ALTERNATIVE "THE LAKE PLAN"

by

Lyndell Z. Hales, Sandra L. Bird, Bruce A. Ebersole

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY

Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

and

Raymond Walton

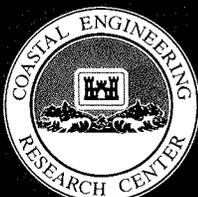
Camp Dresser & McKee International, Inc.
One Cambridge Center
Cambridge, Massachusetts 02142



March 1990

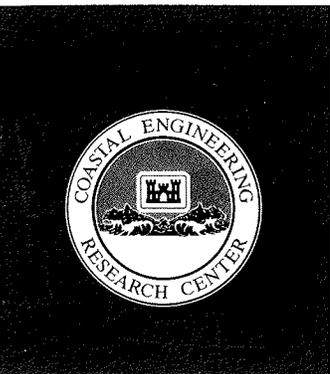
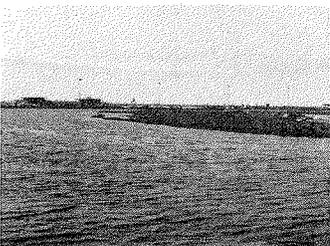
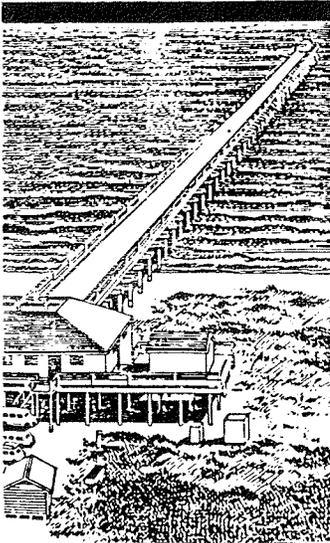
Report 3 of a Series

Approved For Public Release; Distribution Unlimited



Prepared for State of California
State Lands Commission

1807 13th Street, Sacramento, California 95814



Destroy this report when no longer needed. Do not return
it to the originator.

The findings in this report are not to be construed as an official
Department of the Army position unless so designated
by other authorized documents.

The contents of this report are not to be used for
advertising, publication, or promotional purposes.
Citation of trade names does not constitute an
official endorsement or approval of the use of
such commercial products.

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.			
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper CERC-89-17			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION See reverse.		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION		
6c. ADDRESS (City, State, and ZIP Code) See reverse.			7b. ADDRESS (City, State, and ZIP Code)		
8a. NAME OF FUNDING / SPONSORING ORGANIZATION State of California		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code) State Lands Commission 1807 13th Street Sacramento, CA 95814			10. SOURCE OF FUNDING NUMBERS		
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.	
11. TITLE (Include Security Classification) Bolsa Bay, California, Proposed Ocean Entrance System Study: Report 3, Tidal Circulation and Transport Computer Simulation and Water Quality Assessment; Section 2: Signal Landmark's Proposed Secondary Alternative, "The Lake Plan"					
12. PERSONAL AUTHOR(S) Hales, Lyndell Z.; Bird, Sandra L.; Ebersole, Bruce A.; Walton, Raymond					
13a. TYPE OF REPORT Report 3 of a series		13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Year, Month, Day) March 1990		15. PAGE COUNT
16. SUPPLEMENTARY NOTATION Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Entrance channels	Prototype data	Water quality
			Marinas	Tidal circulation	Water surface
			Numerical simulation	Tidal velocities	Wetlands
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
<p>The State of California, State Lands Commission (SLC), is reviewing a plan for a new ocean entrance system as part of a multi-use project. This project involves both State and private property in the proposed development by the SLC, Signal Landmark, and others. The project, located in the Bolsa Chica area of the County of Orange, California, includes navigational, commercial, recreational, and residential uses, along with major wetlands restoration. The County of Orange has approved a Land Use Plan (LUP), in 1985, as part of the Local Coastal Program for Bolsa Chica in accordance with the California Coastal Act of 1976. This same LUP was certified by the California Coastal Commission (CCC) with conditions in 1986. Part of the LUP certification requirement to satisfy those conditions includes confirmation review of modeling studies of a navigable and a non-navigable ocean entrance at Bolsa Chica. To satisfy the CCC requirements for confirmation of the LUP, the SLC requested the US Army Engineer Waterways Experiment Station (WES), through a</p> <p style="text-align: right;">(Continued)</p>					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL			22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL	

6a & c. NAMES AND ADDRESSES OF PERFORMING ORGANIZATIONS (Continued).

USAEWES, Coastal Engineering Research Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Camp Dresser & McKee International, Inc.
One Cambridge Center
Cambridge, MA 02142

19. ABSTRACT (Continued).

Memorandum of Agreement executed 2 July 1987 to conduct engineering studies on the technical and environmental assessment of a navigable and a non-navigable ocean entrance system, as conditionally approved in the LUP. These services were provided to SLC by WES under authority of Title III of the Intergovernmental Cooperation Act of 1968. As such, resultant study products are based on specific technical expertise only and should not be inferred to indicate support or nonsupport by the US Army Corps of Engineers for either project involving a navigable or non-navigable ocean entrance or for the environmental or economic aspects of these or any other subsequent project.

The Lake Plan concept was developed and introduced for analysis by Signal Landmark as a third alternative to the two alternatives in the LUP of the Local Coastal Program for Bolsa Chica. The Lake Plan is a modification that incorporates features of both the navigable ocean entrance concept with full marina complex (termed the Preferred Alternative by the County of Orange and the CCC) and the non-navigable ocean entrance concept with reduced marina complex (termed the Secondary Alternative by the County of Orange and the CCC). The Lake Plan provides for a non-navigable entrance channel at the same location as the Preferred and Secondary Alternative, but with a marina reduced in size from that of the Preferred Alternative. The design of the wetlands enhancement will remain the same as for the Preferred Alternative.

Design details of the Lake Plan include a total water surface area of approximately 112 acres encompassing the main channel, marina basins, lower reach of the East Garden Grove-Wintersburg Flood Control Channel, interior waterways adjacent to residential uses, and other secondary channels connecting the wetlands and ocean entrance. The design depth of the proposed entrance channel that connects the marina to the Pacific Ocean is -6 ft mean sea level (msl), while the depth of the proposed marina is -20 ft msl. The Lake Plan alternative design contemplates an ocean entrance channel whose width should be only great enough to support a 1,100-acre marsh area from a hydraulic standpoint. Optimization of the entrance channel design has not been performed, although two entrance channel widths have been evaluated. These two entrance channel widths are designated Lake 1 (350-ft-wide entrance channel) and Lake 2 (200-ft-wide entrance channel). Additionally, the possibility exists that the entrance channel may close by littoral material transport in the surf zone. Hence, it is necessary to evaluate the effects of a closed entrance on hydrodynamics and water quality aspects. The Lake Plan alternative when the ocean entrance channel is closed has been designated Lake 3.

The development of either Lake 1 or Lake 2 new non-navigable entrance channel system to Bolsa Chica, with associated marinas, full tidal, and muted tidal wetlands enhancement, is feasible from engineering, hydrodynamic, and water quality standpoints investigated by this study. Any potential for scour resulting from high velocities near bridges or in Outer Bolsa Bay under the Lake 3 concept (where the proposed Lake 1 or Lake 2 entrance channel at Bolsa Chica has closed) could be prevented by channel stabilization measures installed as part of project construction. Since the entrance channel could be reopened immediately following closure by a storm, other related environmental elements such as water age may not be adversely impacted. The Bolsa Bay complex will provide for multiple public and private uses with an emphasis on wildlife habitat enhancement, public recreation, coastal access, and water dependent residential development.

PREFACE

Authority to carry out this investigation was granted the Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES), by a Memorandum of Agreement executed 2 July 1987 between the California State Lands Commission (SLC) and the Department of the Army under authority of Title III of the Intergovernmental Cooperation Act of 1968. As such, resultant study products are based on specific technical expertise only and should not be inferred to indicate support or nonsupport by the Corps of Engineers for the environmental or economic aspects of any subsequent project.

The study reported herein was conducted during the period February through June 1989 by Dr. Lyndell Z. Hales, Research Hydraulic Engineer, Coastal Processes Branch (CPB), Research Division (RD), CERC; Ms. Sandra L. Bird, Civil Engineer, American Scientific International (formerly Research Civil Engineer, Water Quality Modeling Group (WQMG), Ecosystem Research and Simulation Division (ERSD), Environmental Laboratory (EL), WES); Mr. Bruce A. Ebersole, Chief, CPB; and Dr. Raymond Walton, Senior Scientist, Camp Dresser & McKee International, Inc.

This investigation was performed under the general supervision of Dr. James R. Houston, Chief, CERC; Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; Mr. H. Lee Butler, Chief, RD, CERC; Dr. Stephen A. Hughes, former Chief, CPB, RD, CERC; Dr. John Harrison, Chief, EL; Dr. John W. Keeley, Assistant Chief, EL; and Mr. Mark S. Dortch, Chief, WQMG, ERSD, EL. This report was prepared by Dr. Hales, Ms. Bird, Mr. Ebersole, and Dr. Walton.

Project Managers during the conduct of this investigation and the publication of this report were Mr. Daniel Gorfain for SLC and Dr. Hughes for WES.

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

CONTENTS

	<u>Page</u>
PREFACE	1
CONVERSION FACTORS, NON-SI TO SI (METRIC)	
UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	4
Elements of the Lake Plan	4
Purposes of the Study	12
PART II: COMPARISON OF LAKE PLAN ALTERNATIVE HYDRODYNAMICS	13
Water Surface Elevations	13
Average Channel Velocities	26
Effect of Interior Wetlands Connection at Bolsa Chica	47
PART III: EAST GARDEN GROVE-WINTERSBURG FLOOD CONTROL CHANNEL (EGG-WFCC) 100-YEAR FLOOD FLOW	55
Water Surface Elevations	55
Average Channel Velocities	64
PART IV: EVALUATION OF TRANSPORT CHARACTERISTICS	77
Tidal Boundary Driver	77
System Water Age	78
East Garden Grove-Wintersburg Flood Control Channel (EGG-WFCC) Runoff	86
Assessment of Transport Characteristics	92
PART V: SUMMARY AND CONCLUSIONS	94
Summary	94
Conclusions	95
Summary Conclusions	101
REFERENCES	102
APPENDIX A: EXISTING CONDITION WATER SURFACE ELEVATIONS	A1
APPENDIX B: EXISTING CONDITION AVERAGE CHANNEL VELOCITIES	B1
APPENDIX C: LAKE 1, 350-FT NON-NAVIGABLE ENTRANCE CHANNEL WATER SURFACE ELEVATIONS	C1
APPENDIX D: LAKE 1, 350-FT NON-NAVIGABLE ENTRANCE CHANNEL AVERAGE CHANNEL VELOCITIES	D1
APPENDIX E: LAKE 2, 200-FT NON-NAVIGABLE ENTRANCE CHANNEL WATER SURFACE ELEVATIONS	E1
APPENDIX F: LAKE 2, 200-FT NON-NAVIGABLE ENTRANCE CHANNEL AVERAGE CHANNEL VELOCITIES	F1
APPENDIX G: LAKE 3, NON-NAVIGABLE ENTRANCE CHANNEL CLOSED WATER SURFACE ELEVATIONS	G1
APPENDIX H: LAKE 3, NON-NAVIGABLE ENTRANCE CHANNEL CLOSED AVERAGE CHANNEL VELOCITIES	H1

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

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

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
acres	0.40469446	hectares
cubic feet per second	0.028317	cubic metres per second
feet	0.3048	metres
feet per second	0.3048	metres per second

BOLSA BAY, CALIFORNIA, PROPOSED OCEAN
ENTRANCE SYSTEM STUDY

TIDAL CIRCULATION AND TRANSPORT COMPUTER SIMULATION
AND WATER QUALITY ASSESSMENT

Section 2: Signal Landmark's Proposed Secondary Alternative
"The Lake Plan"

PART I: INTRODUCTION

Elements of the Lake Plan

1. The Lake Plan concept was developed and introduced for analysis by Signal Landmark as a third alternative to the two alternatives in the Land Use Plan (LUP) of the Local Coastal Program for Bolsa Chica approved by the County of Orange (Orange County Environmental Management Agency 1985). The Lake Plan is a modification which incorporates features of both the navigable ocean entrance concept with full marina complex (termed the Preferred Alternative by the County of Orange and the California Coastal Commission), and the non-navigable ocean entrance concept with reduced marina complex (termed the Secondary Alternative by the County of Orange and the California Coastal Commission). The Lake Plan provides for a non-navigable entrance channel at the same location as the Preferred and Secondary Alternatives, but with a marina reduced in size from that of the Preferred Alternative. The design of the proposed wetland enhancement will remain the same as for the Preferred Alternative.

Lake Plan alternative design details

2. Design details of the Lake Plan include a total water surface area of approximately 112 acres* encompassing the main channel, marina basins,

* A table of factors for converting non-SI units of measurements to SI (metric) units is presented on page 3.

lower reach of the East Garden Grove-Wintersburg Flood Control Channel (EGG-WFCC), interior waterways adjacent to residential uses, and other secondary channels connecting the wetlands and ocean entrance. The design depth of the proposed entrance channel which connects the marina to the Pacific Ocean is -6 ft mean sea level (msl), while the depth of the proposed marina is -20 ft msl. Design details of the Lake Plan link-node system are shown in Figure 1 for Lake 1 (350-ft wide entrance channel), and Lake 2 (200-ft wide entrance channel) alternative concepts. Details of the Lake Plan link-node system are presented in Figure 2 for Lake 3 (entrance channel closed by littoral material in the surf zone) alternative concept.

3. The Lake Plan alternative design contemplates an ocean entrance channel whose width should only be great enough to support an 1,100 acre marsh area from a hydraulic standpoint. The wetland enhancement design of the Preferred Alternative is not proposed to be altered by the Lake Plan marina and ocean entrance modifications. Consequently, it is desired to optimize a hydraulic connection to the ocean sufficient in size to serve only 930 acres of wetlands (including 142 acres of existing full and muted tidal wetlands, 116 acres of proposed additional full tidal wetlands, and 193 acres of proposed additional muted tidal wetlands), as generally described under the Preferred Alternative. The design for the EGG-WFCC will remain unchanged. No navigable channel connection to Huntington Harbour is included. Tidal flow control structures to the proposed enhanced wetlands also will remain the same as described for the Preferred Alternative.

Lake Plan alternatives simulated by DYNTRAN

4. The calibrated and verified numerical simulation model DYNTRAN (Moore and Walton 1984), previously utilized to evaluate both the Preferred and Secondary Alternatives, was used to determine the hydrodynamics and water quality aspects of the Bolsa Bay complex resulting from the proposed Lake Plan alternatives. The existing conditions as previously evaluated are considered to be the base conditions for comparison of Lake Plan effects. Optimization of the entrance channel design has not been performed, although two entrance channel widths have been evaluated. These two entrance channel widths are designated Lake 1 and Lake 2 (Lake 1 = 350-ft wide entrance channel; Lake 2 = 200-ft wide entrance channel). Additionally, the possibility exists that the entrance channel may close by littoral material transport in the surf

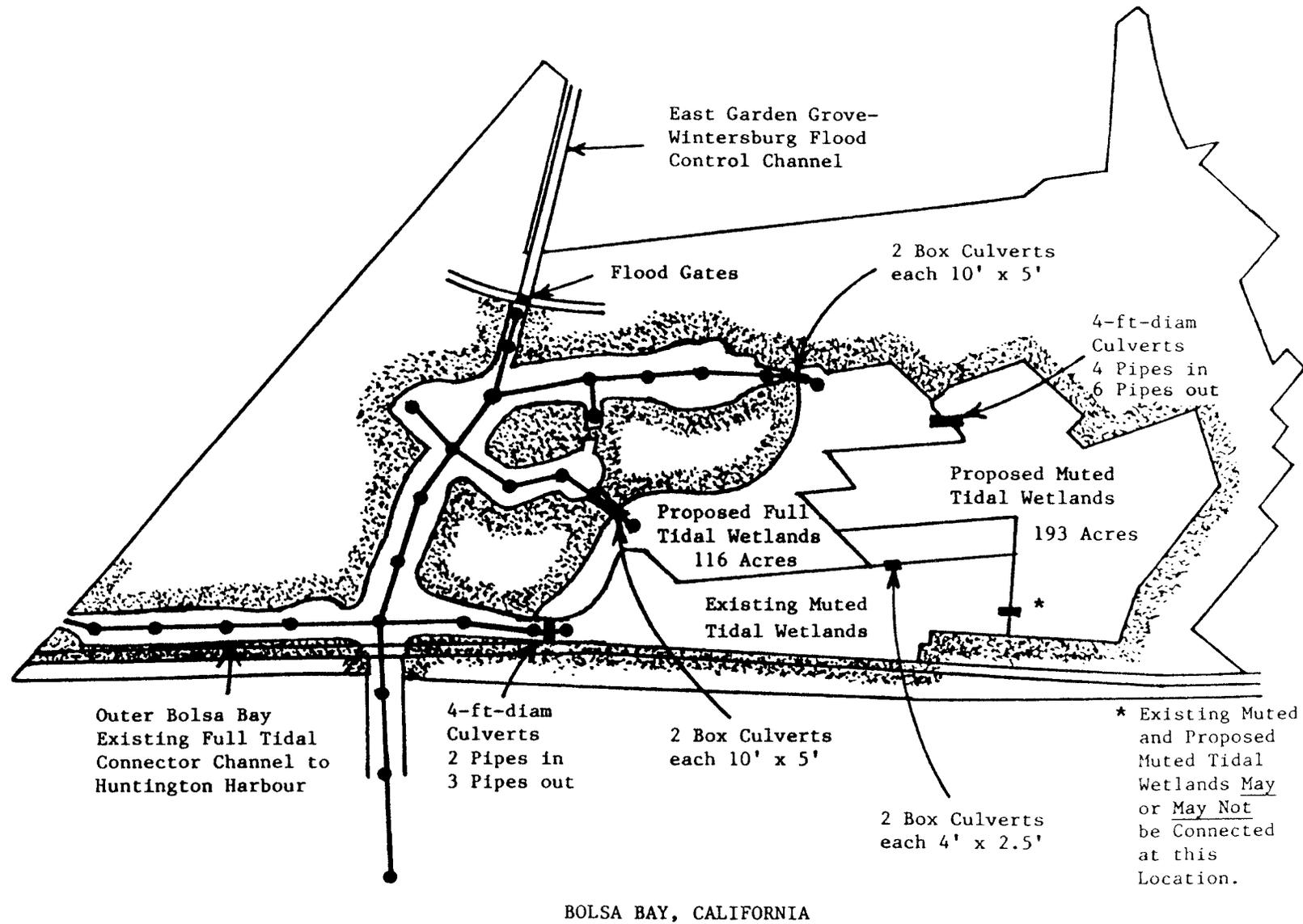
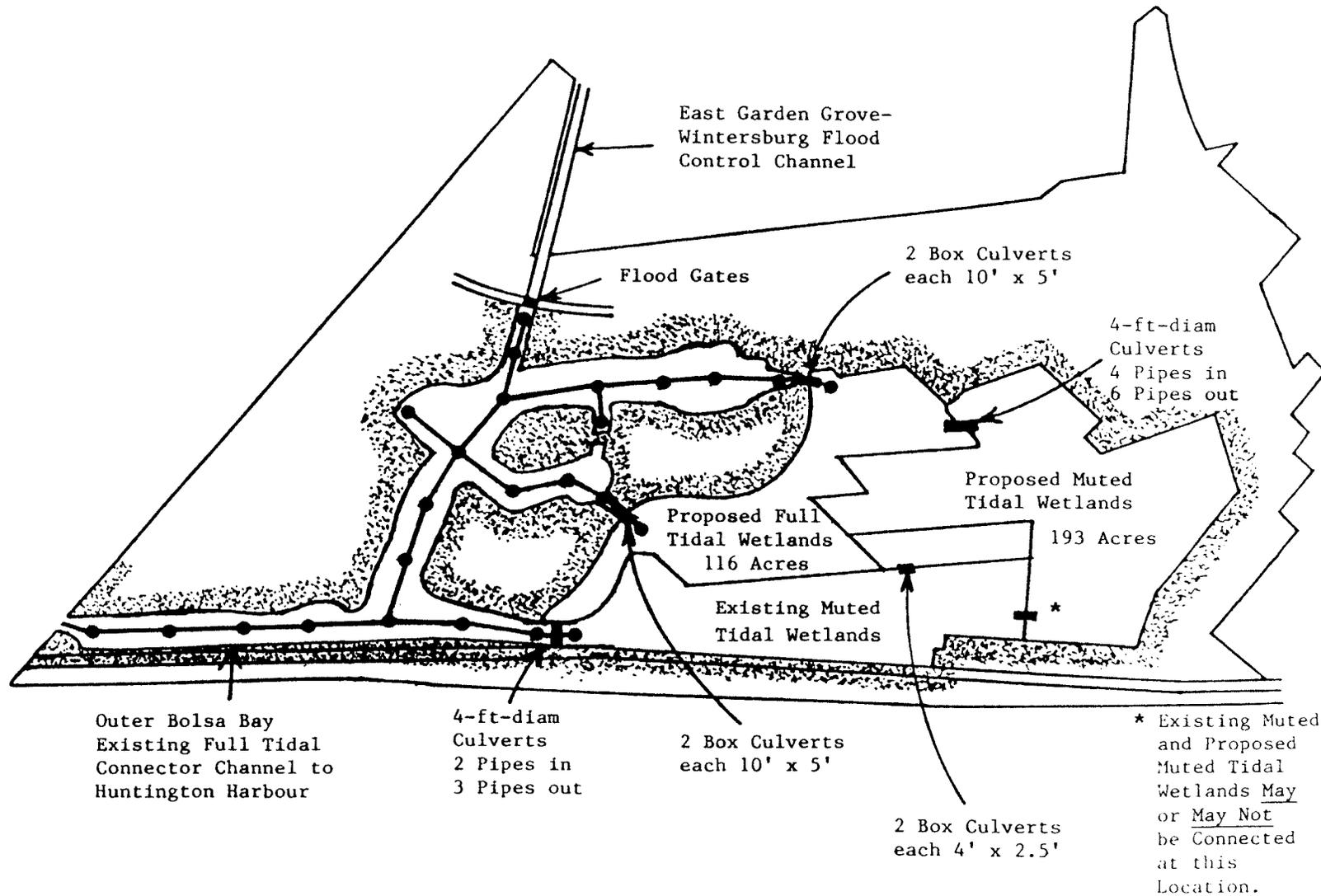


Figure 1. Lake Plan link-node system for Lake 1 (350-ft wide entrance channel) concept, and Lake 2 (200-ft wide entrance channel) concept



BOLSA BAY, CALIFORNIA

Figure 2. Lake Plan link-node system for Lake 3 (entrance channel assumed closed by littoral material in the surf zone) concept

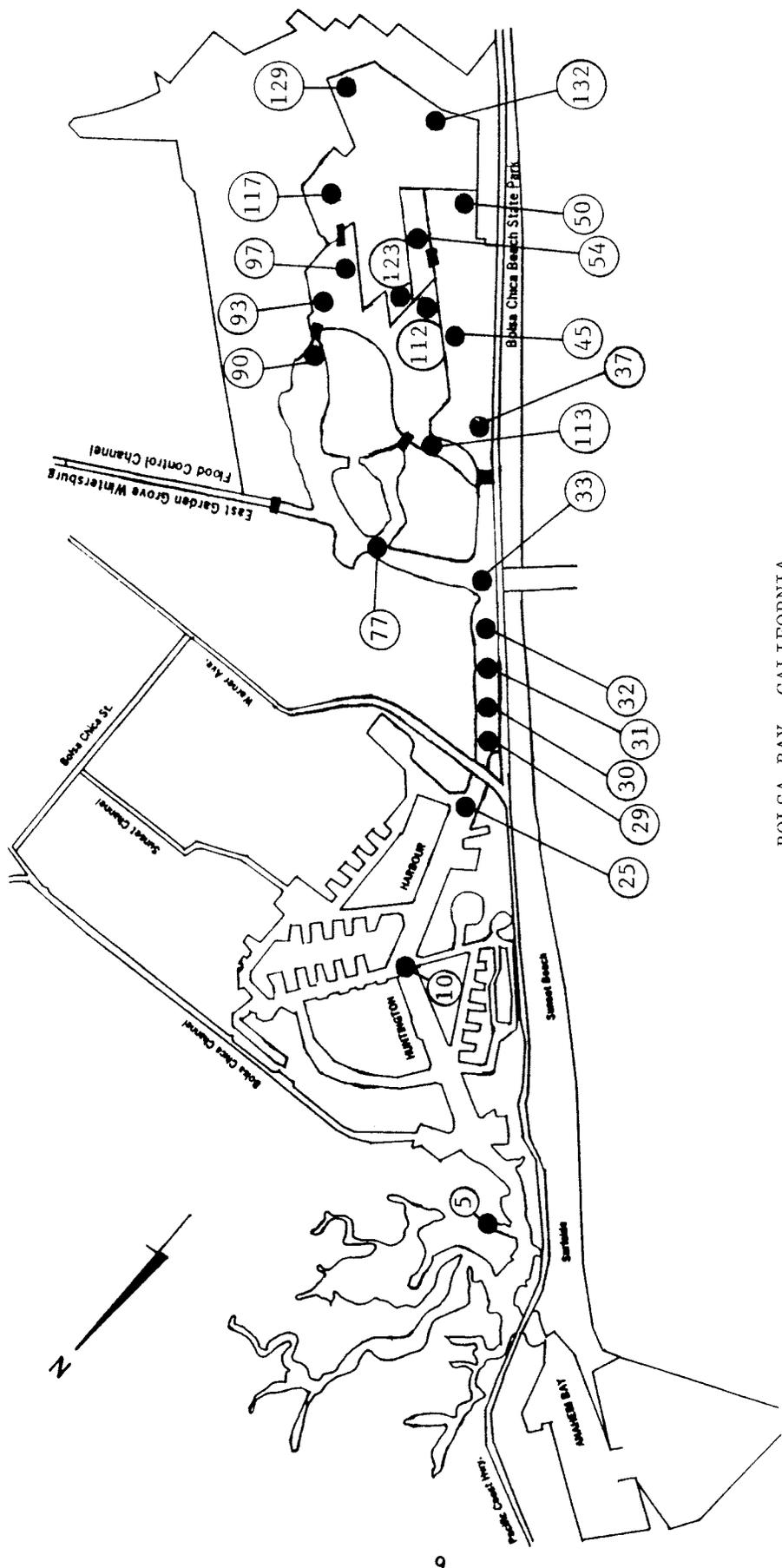
zone. Hence, it is necessary to evaluate the effects of a closed entrance on hydrodynamics and water quality aspects. The Lake Plan alternative when the ocean entrance channel is closed has been designated Lake 3. The locations of the nodes for the displayed numerical model simulation results from Anaheim Bay, Huntington Harbour, and the Bolsa Bay complex are shown in Figure 3. The locations of the links for displayed results from the system are presented in Figure 4.

Wetland design

5. Based on the requirements of converting non-wetlands into wetland status according to LUP policies, the California Department of Fish and Game (DFG) (Radovich 1987) determined the minimum acreage requirements per wetland type as:

- a. High pickleweed dominated saltmarsh (rarely, if ever, completely inundated), 200 acres,
- b. Periodically inundated saltflats, 150 acres,
- c. Fresh to slightly brackish (less than 5 ppt salts) permanently inundated pond, 50 acres,
- d. Muted tidal wetland (similar to that contained within Inner Bolsa Bay) with an 18-in. daily average tidal water level variance, 300 acres,
- e. Full tidal wetland (similar to that contained within Outer Bolsa Bay), 215 acres, and
- f. Total wetland acreage, 915 acres.

6. Accordingly, Moffatt & Nichol, Engineers, in 1988, analyzed the geometry of the study area based on these criteria. The tidal wetlands evaluated consisted of 142 acres of existing full and muted tidal wetlands, 116 acres of proposed additional full tidal wetlands, and 193 acres of proposed additional muted tidal wetlands. Their storage curves are as follows:



BOLSA BAY, CALIFORNIA

Figure 3. Location of nodes for displaying Lake Plan numerical model simulation water surface time histories

Existing Full and Muted Tidal Wetlands

Elevation (ft, msl)	-3.5	-2.3	-0.3	1.8	4.5
Area (acres)	1.7	6.3	44.4	122.6	142.0

Proposed Additional Full Tidal Wetlands

Elevation (ft, msl)	-5.0	0.0	1.0	2.0	4.5
Area (acres)	58.2	96.5	100.6	105.3	116.0

Proposed Additional Muted Tidal Wetlands

Elevation (ft, msl)	-3.5	-2.3	-0.3	1.8	4.5
Area (acres)	2.3	8.6	60.5	167.0	193.4

These data also were developed contingent upon the requirement that a minimal amount of earth moving take place in the wetland enhancement area. The above elevation-area relationships were installed in the numerical simulation model for all proposed full and muted wetland regions of the Lake Plan concept.

Culvert system design

7. Preliminary evaluations have resulted in specific culvert designs which are being utilized, in conjunction with marina and wetland enhancement alternatives. These simulations assessed the effectiveness of the culverts in providing an assured level of wetland inundation and flushing ability.

8. The Lake Plan concept provides for connecting the proposed marinas with a full tidal wetland region by two box culvert systems. Each of the culvert systems will have two box culverts, each 5-ft high by 10-ft wide, with invert elevations of -5 ft msl. The full tidal wetland region is then connected to a muted tidal wetland region by a 4-ft-diam culvert system (4 pipes in, 6 pipes out), with invert elevations of -5.1 ft msl. The proposed muted tidal wetland region may or may not be connected to the existing muted tidal wetlands (Inner Bolsa Bay) by a breach in the dike system at Link 162 (connecting Node 50 with Node 134). The full tidal wetland region is not connected to Inner Bolsa Bay. Inner Bolsa Bay is connected directly to the Lake Plan marina entrance channel (enhancing existing muted tidal wetland water quality characteristics) by a 4-ft-diam culvert system (2 pipes in, 3 pipes out), with invert elevations of -5.1 ft msl.

Purposes of the Study

Tidal circulation modeling

9. The purposes of this additional tidal circulation computer simulation modeling were to ascertain the hydrodynamic effects relating to the development of the Lake Plan at the Bolsa Bay complex, with associated marinas and wetland enhancement. The enhanced wetland design is the same as that developed for the Preferred Alternative. Additionally, the hydrodynamic effects resulting from the closure of the Lake Plan alternative by littoral material transport in the surf zone were determined.

Transport and water quality assessment

10. The purposes of the transport computer simulation and water quality assessment included the determination of potential changes to transport and dispersion of conservative tracers from existing conditions by the Lake Plan concept. An evaluation of the quality of the present water supply provided by existing conditions in the existing ecological reserve with the quality of water to be provided with the Lake Plan alternative and wetland enhancement concepts, both in terms of water quality parameters and water parcel residence times, was performed. The effects of proposed enhancements on water quality in the Anaheim Bay complex, Huntington Harbour, existing wetlands, and flushing capability of proposed wetland modifications, were ascertained.

Critical elements evaluated

11. Major concerns being addressed by the hydrodynamic and water quality analyses include:

- a. Velocities under Pacific Coast Highway bridge at Anaheim Bay,
- b. Excessive velocities pertaining to swimmer safety in Huntington Harbour,
- c. Potential for scour and erosion in Outer Bolsa Bay, with accompanying shoaling in Huntington Harbour,
- d. Changes in water surface elevations, and ability to control such water surface elevations, in both the existing muted tidal wetlands (Inner Bolsa Bay and the DFG cell) and the proposed enhanced full tidal and muted tidal wetlands,
- e. Water quality aspects throughout Huntington Harbour and the Bolsa Bay complex, and
- f. Effects of 100-year flood flow from the East Garden Grove-Wintersburg Flood Control Channel on hydrodynamics and water quality.

PART II: COMPARISON OF LAKE PLAN ALTERNATIVE HYDRODYNAMICS

Water Surface Elevations

12. Tidal simulations throughout the Bolsa Bay complex are presented for existing conditions, Lake 1, Lake 2, and Lake 3 in Appendix A, Appendix C, Appendix E, and Appendix G, respectively. Maximum spring high tide elevations, maximum spring low tide elevations, and tidal ranges are shown in Table 1 for specific locations throughout the Huntington Harbour and Bolsa Bay complex. Comparisons of the effects of these plans with existing conditions for typically representative water surface time-histories are presented in Figures 5 and 6 for Huntington Harbour (Nodes 5 and 25), Figures 7 through 10 for Outer Bolsa Bay (Nodes 29, 30, 31, and 32), Figure 11 for the entrance channel to the proposed marina (Node 33), Figures 12 and 13 for Inner Bolsa Bay (Nodes 45 and 50), and Figure 14 for the DFG muted tidal cell (Node 54), respectively. The proposed marina and the proposed enhanced tidal wetlands do not exist under present conditions; hence, effects of various plan alternatives can only be compared with each other. Comparisons of the effects of Lake 1, Lake 2, and Lake 3 for typically representative water surface time-histories are presented in Figures 15 and 16 for the proposed marina (Nodes 77 and 90), Figures 17 through 19 for the proposed full tidal wetlands (Nodes 97, 112, and 113), and Figures 20 through 23 for the proposed muted tidal wetlands (Nodes 117, 123, 129, and 132), respectively.

Huntington Harbour

13. Primary interest with regard to water surface elevations is directed toward the ability of the Lake Plan non-navigable entrance channel concept to fully support the proposed wetland enhancement plan. It has previously been determined that the Huntington Harbour tidal prism fills and empties through Anaheim Bay; hence, Lake Plan effects will not impact water surface elevations in the harbor. It can be observed by Figures 5 and 6 (Nodes 5 and 25, located at the ends of the main harbor channel) that the water surface throughout Huntington Harbour responds identically as existing conditions for all Lake Plan concepts.

Table 1
Comparison of Existing Conditions
with
Alternative Lake Plan Concepts
Water Surface Elevations in Existing and Proposed Wetlands
Wetlands Not Connected

<u>Location</u>	<u>Node</u>	<u>POSTBOL</u>	<u>Lake 1</u>	<u>Lake 2</u>	<u>Lake 3</u>
<u>Spring High Tide, feet (msl)</u>					
Huntington Harbour	10	4.10	4.10	4.10	4.10
Outer Bolsa Bay	31	4.10	4.10	4.10	4.09
Inner Bolsa Bay	37	1.04	1.18	1.16	1.15
DFG muted tidal wetlands	54	0.98	1.12	1.10	1.08
Proposed full tidal wetlands	93	----	3.45	3.44	3.29
Proposed muted tidal wetlands	123	----	1.50	1.51	1.46
<u>Spring Low Tide, feet (msl)</u>					
Huntington Harbour	10	-4.10	-4.10	-4.09	-4.03
Outer Bolsa Bay	31	-2.77	-3.82	-3.53	-1.54
Inner Bolsa Bay	37	-0.40	-0.61	-0.60	-0.33
DFG muted tidal wetlands	54	-0.09	-0.16	-0.14	-0.08
Proposed full tidal wetlands	93	----	-1.41	-1.42	-1.14
Proposed muted tidal wetlands	123	----	-0.55	-0.55	-0.47
<u>Spring Tidal Range, feet</u>					
Huntington Harbour	10	8.2	8.2	8.2	8.1
Outer Bolsa Bay	31	6.8	7.9	7.6	5.6
Inner Bolsa Bay	37	1.5	1.8	1.8	1.5
DFG muted tidal wetlands	54	1.1	1.3	1.2	1.2
Proposed full tidal wetlands	93	---	4.9	4.9	4.4
Proposed muted tidal wetlands	123	---	2.1	2.1	1.9

POSTBOL = existing conditions
 Lake 1 = 350-ft wide entrance channel
 Lake 2 = 200-ft wide entrance channel
 Lake 3 = entrance channel closed

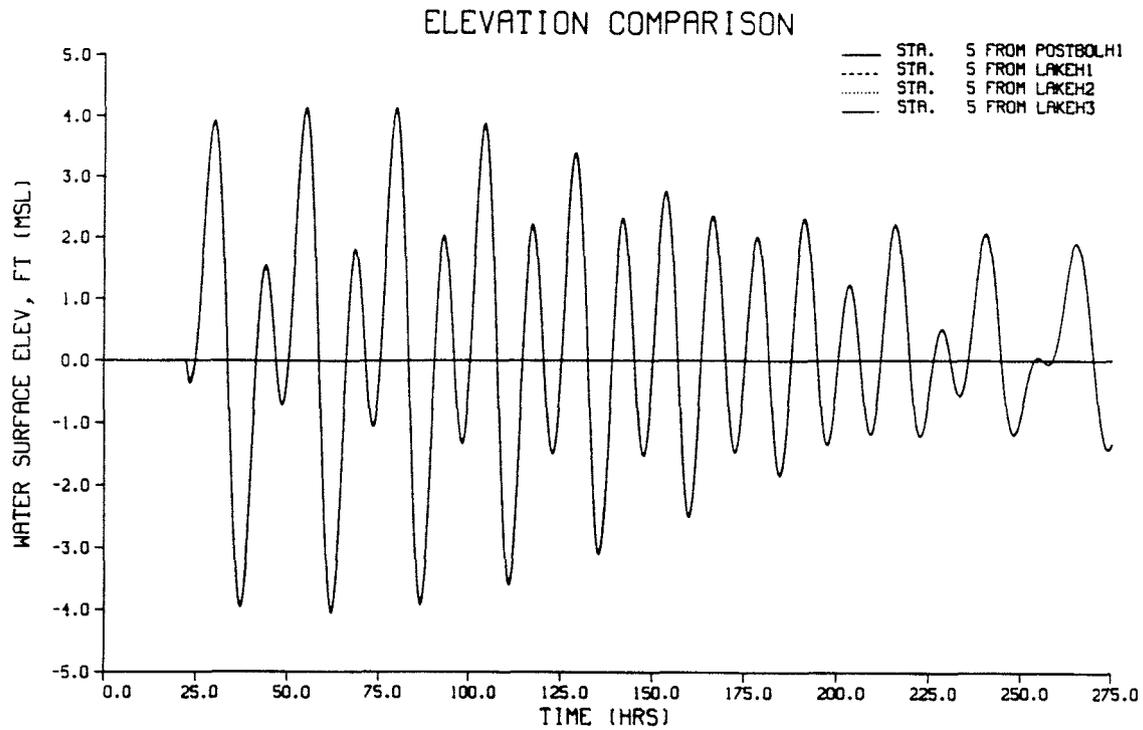


Figure 5. Tidal elevation comparisons in Huntington Harbour, POSTBOLH1 = existing condition, LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel, LAKEH3 = entrance channel closed

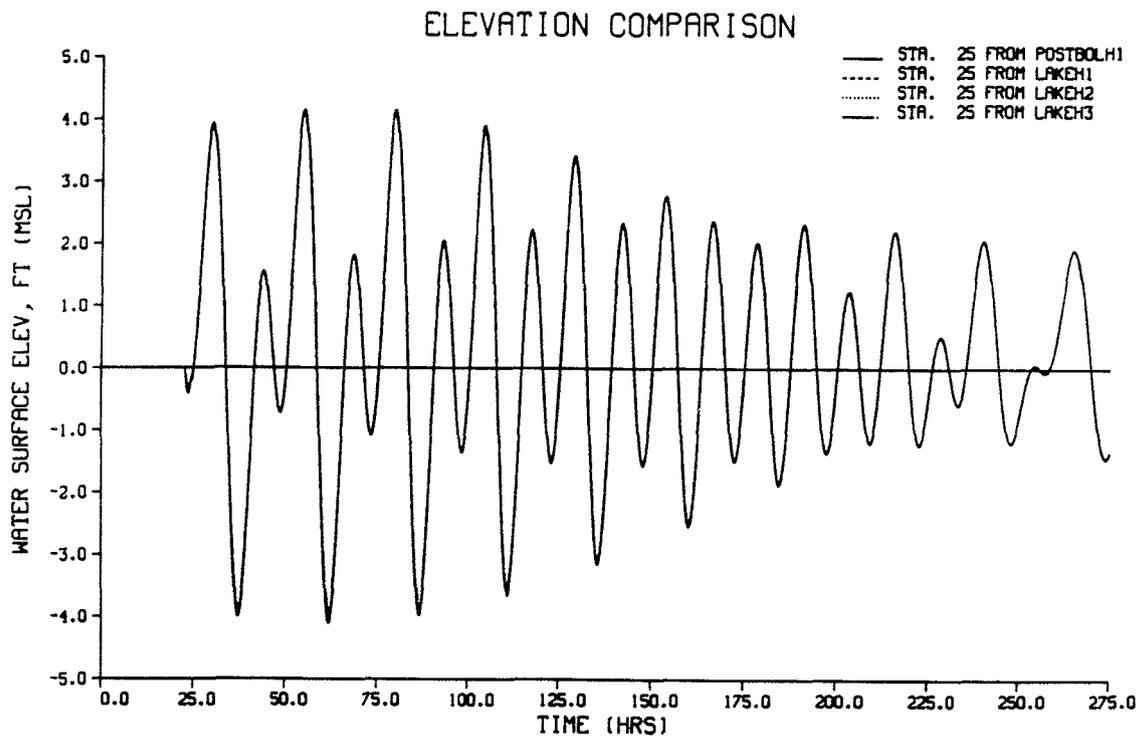


Figure 6. Tidal elevation comparisons in Huntington Harbour, POSTBOLH1 = existing condition, LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel, LAKEH3 = entrance channel closed

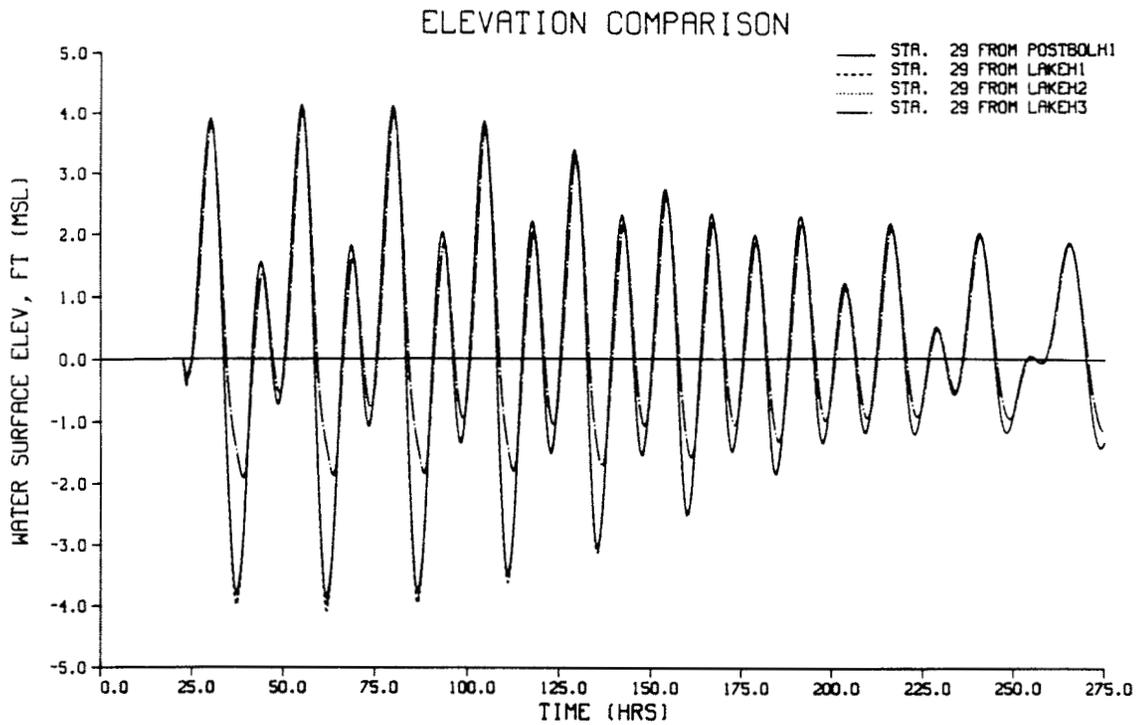


Figure 7. Tidal elevation comparisons in Outer Bolsa Bay, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

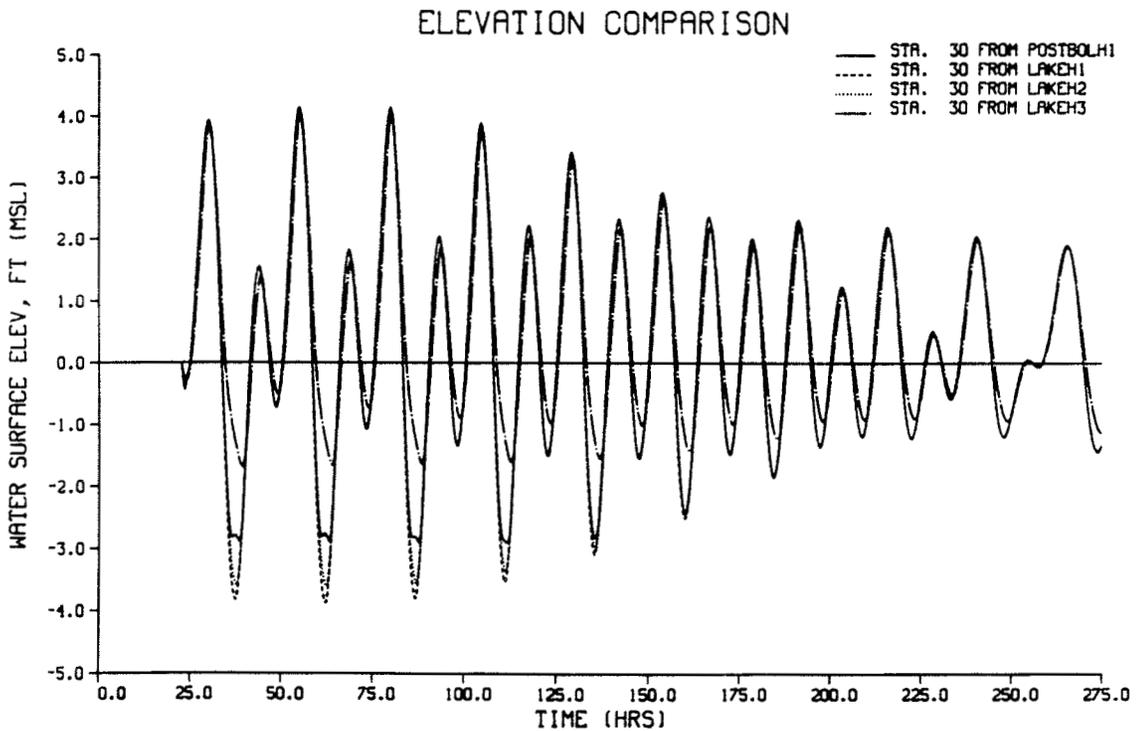


Figure 8. Tidal elevation comparisons in Outer Bolsa Bay, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

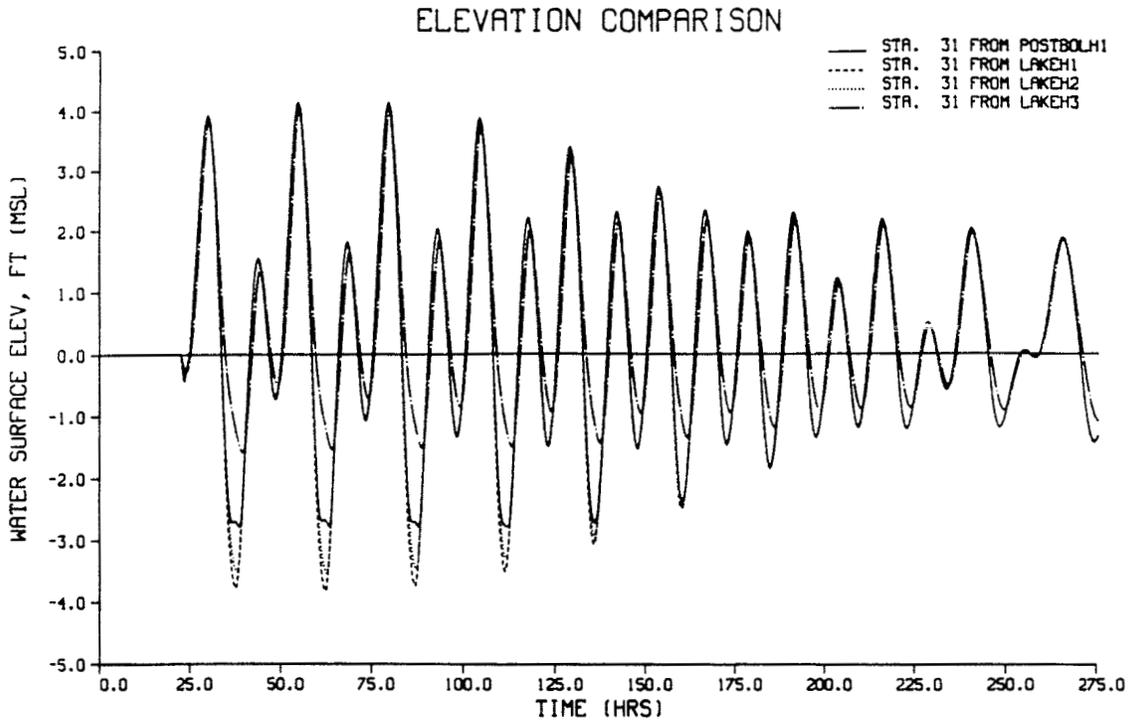


Figure 9. Tidal elevation comparisons in Outer Bolsa Bay, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

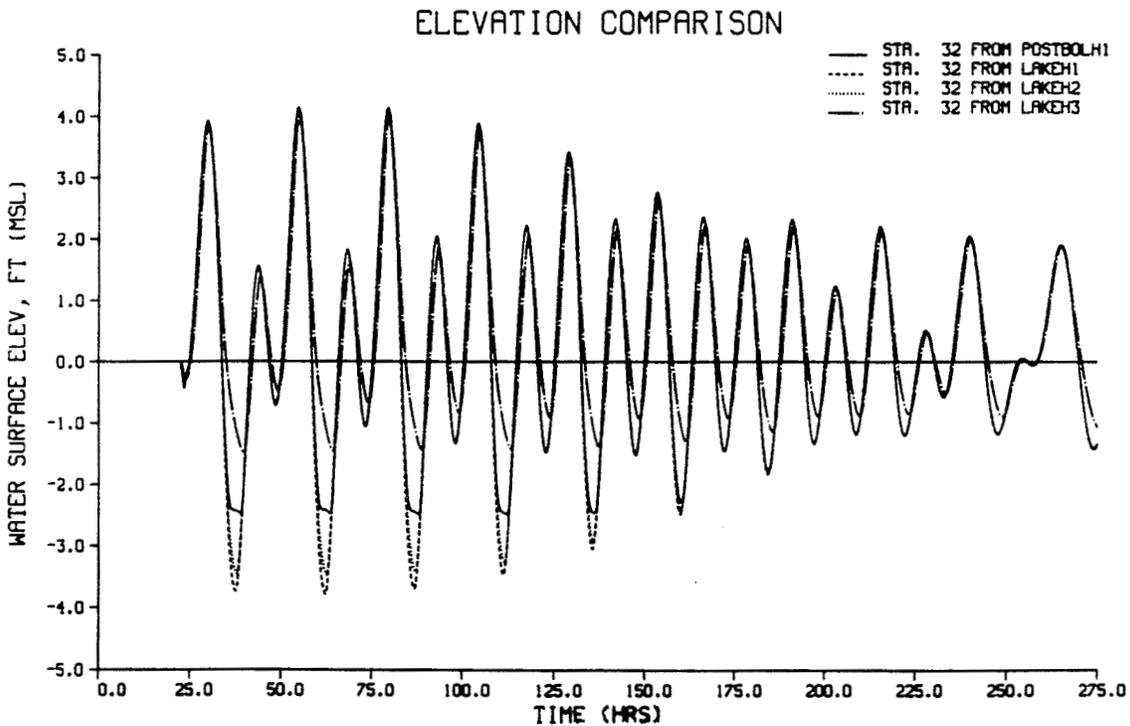


Figure 10. Tidal elevation comparisons in Outer Bolsa Bay, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

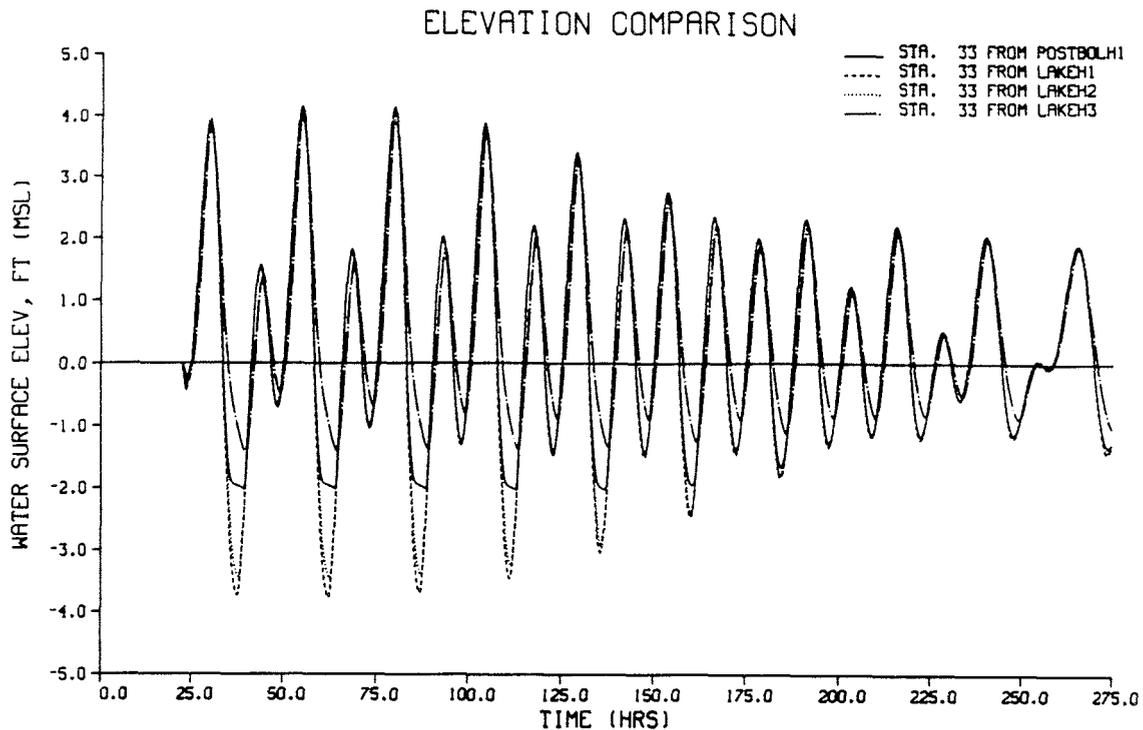


Figure 11. Tidal elevation comparisons in entrance channel to marina, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

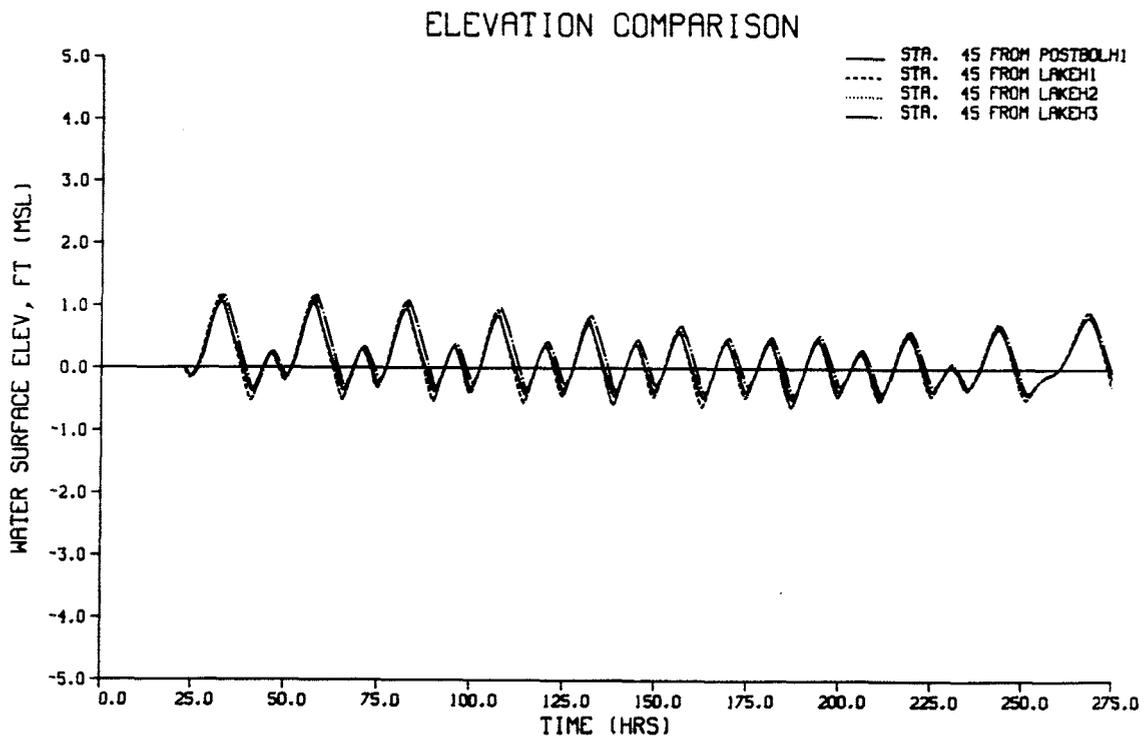


Figure 12. Tidal elevation comparisons in Inner Bolsa Bay, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

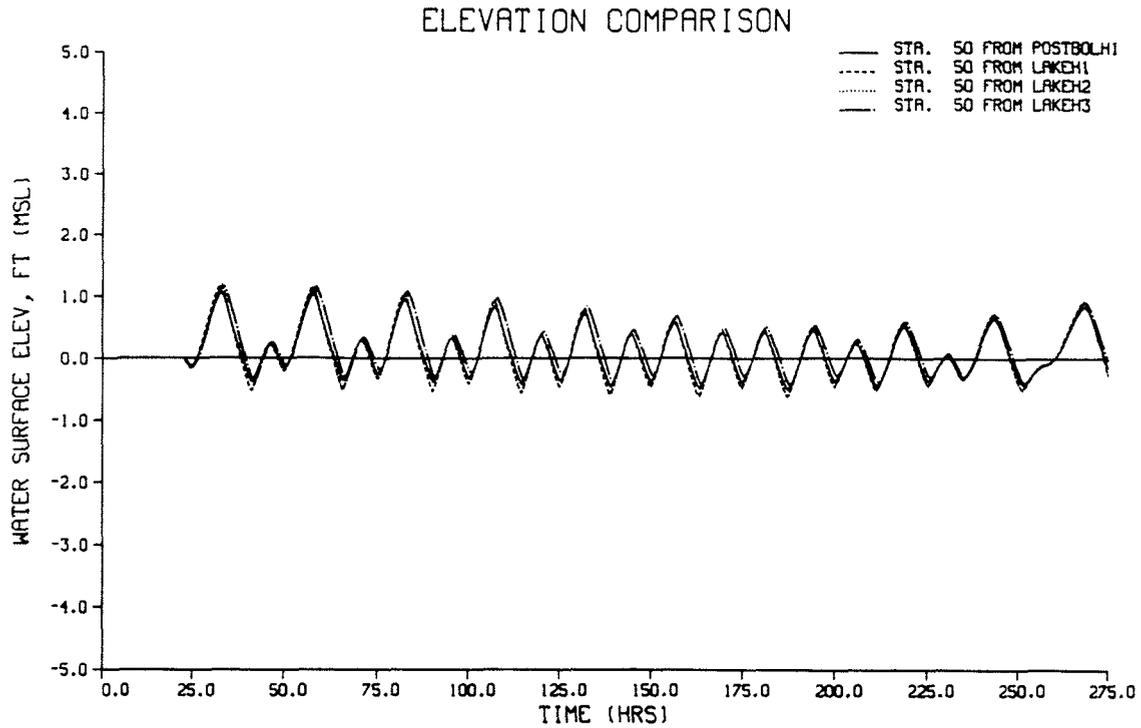


Figure 13. Tidal elevation comparisons in Inner Bolsa Bay, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

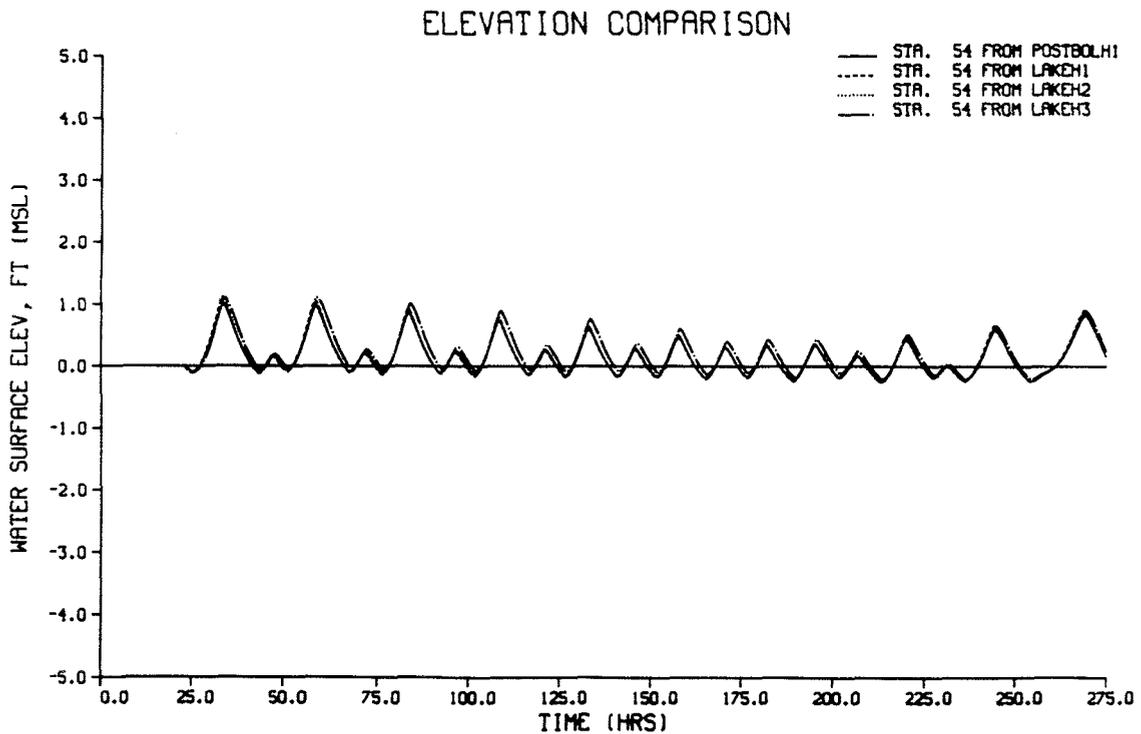


Figure 14. Tidal elevation comparisons in DFG muted tidal cell, POSTBOLH1 - existing condition, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

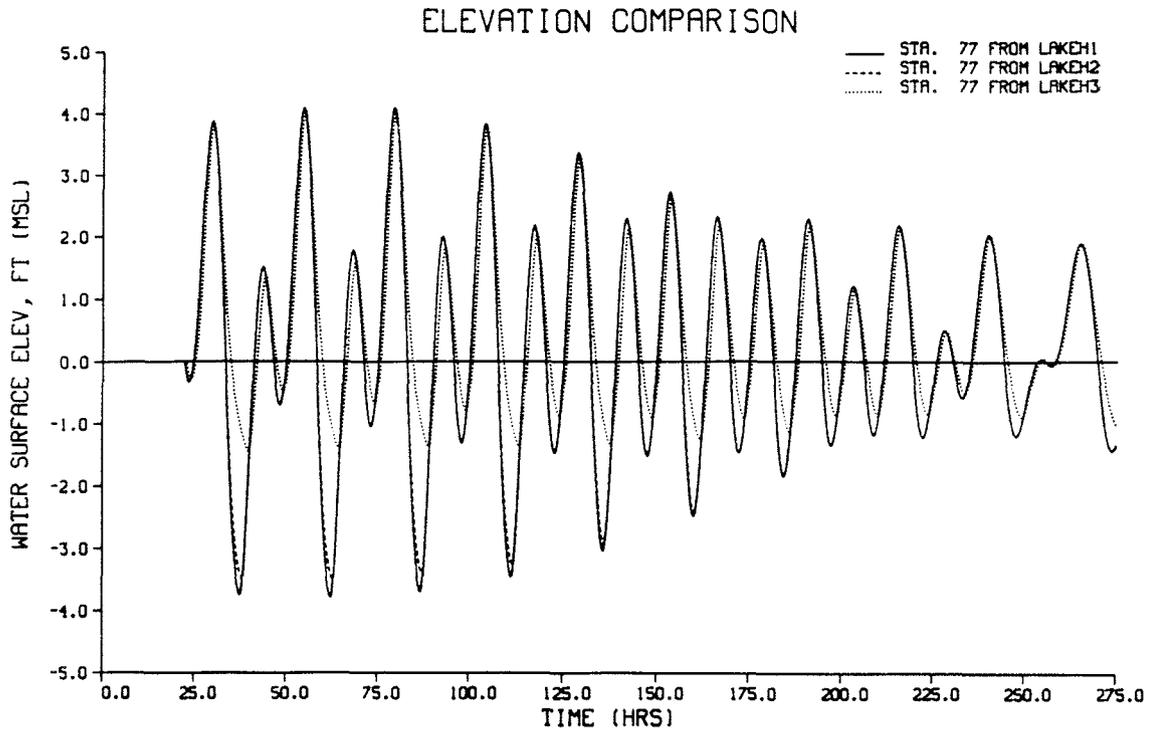


Figure 15. Tidal elevation comparisons in proposed marina, LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel, LAKEH3 = entrance channel closed

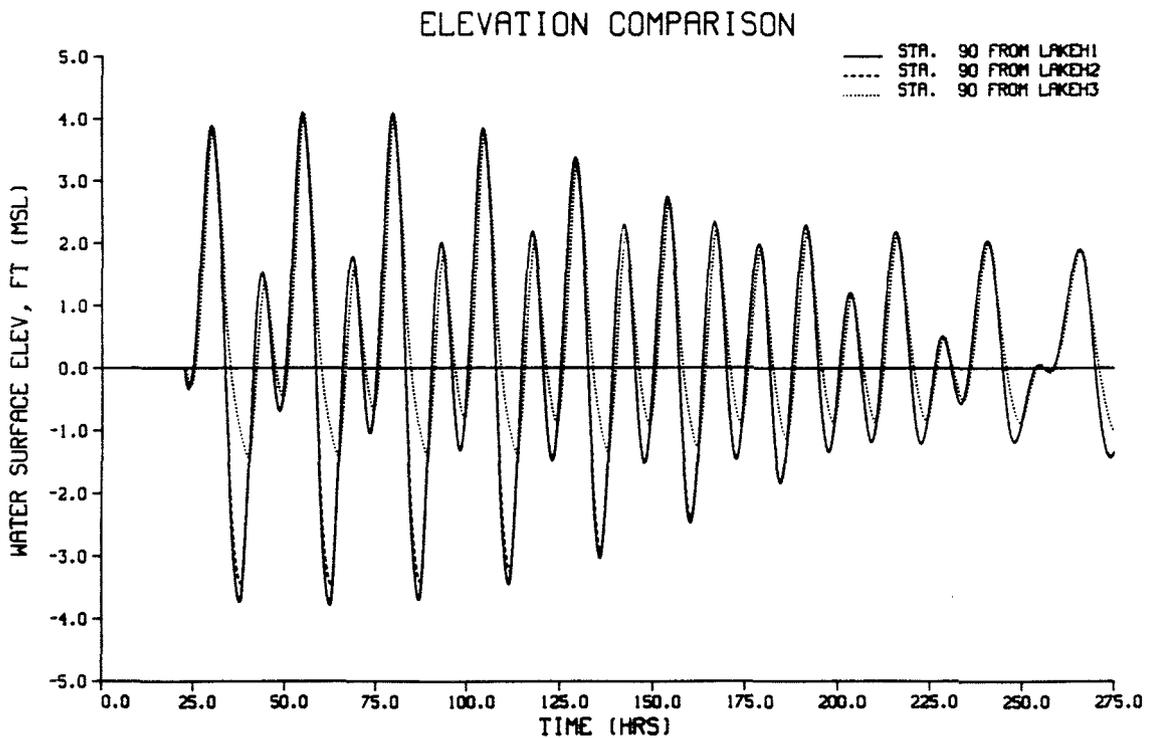


Figure 16. Tidal elevation comparisons in proposed marina, LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel, LAKEH3 = entrance channel closed

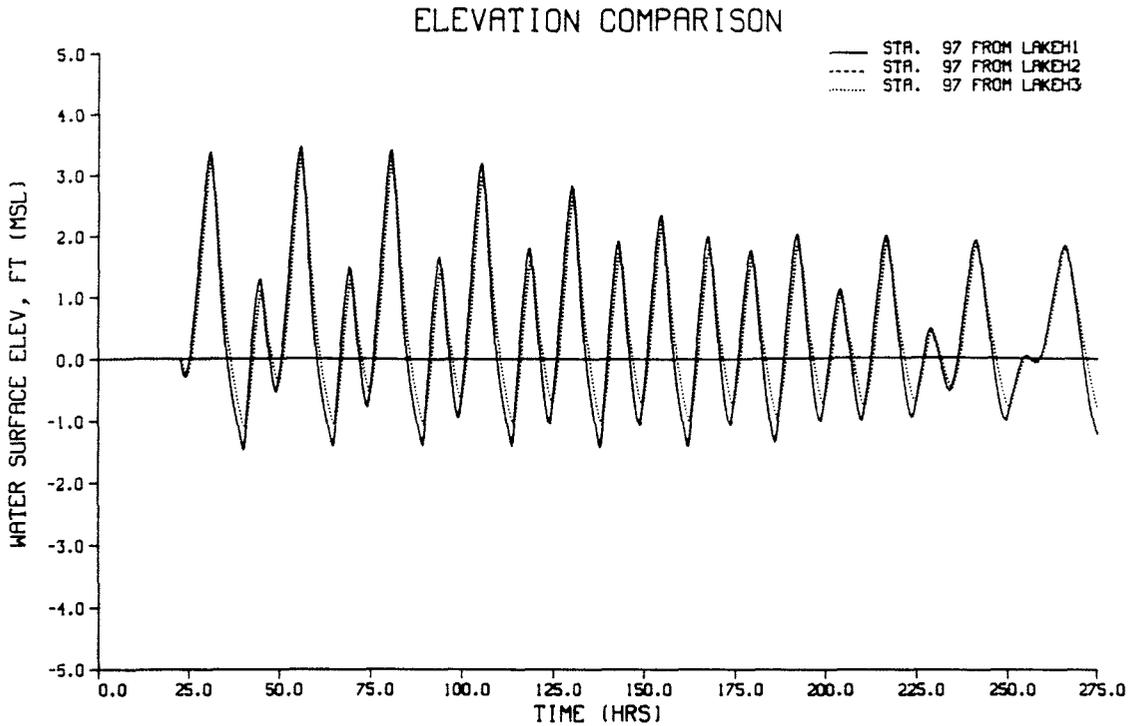


Figure 17. Tidal elevation comparisons in proposed full tidal wetlands,
 LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel,
 LAKEH3 = entrance channel closed

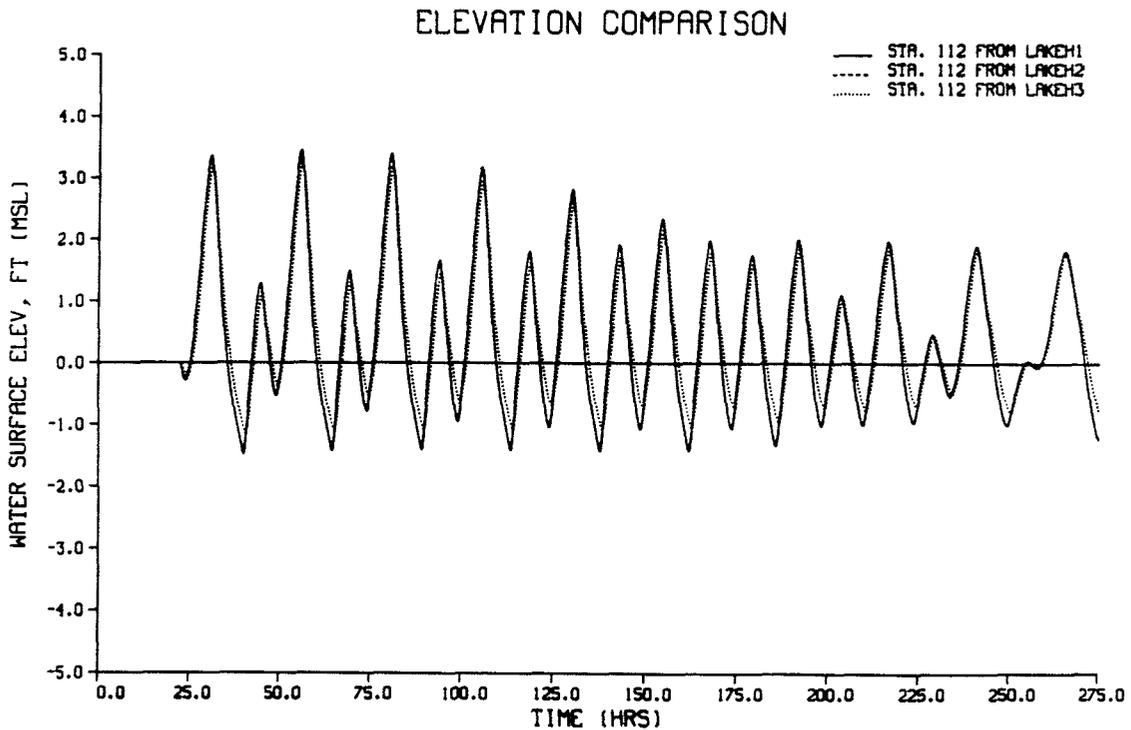


Figure 18. Tidal elevation comparisons in proposed full tidal wetlands,
 LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel,
 LAKEH3 = entrance channel closed

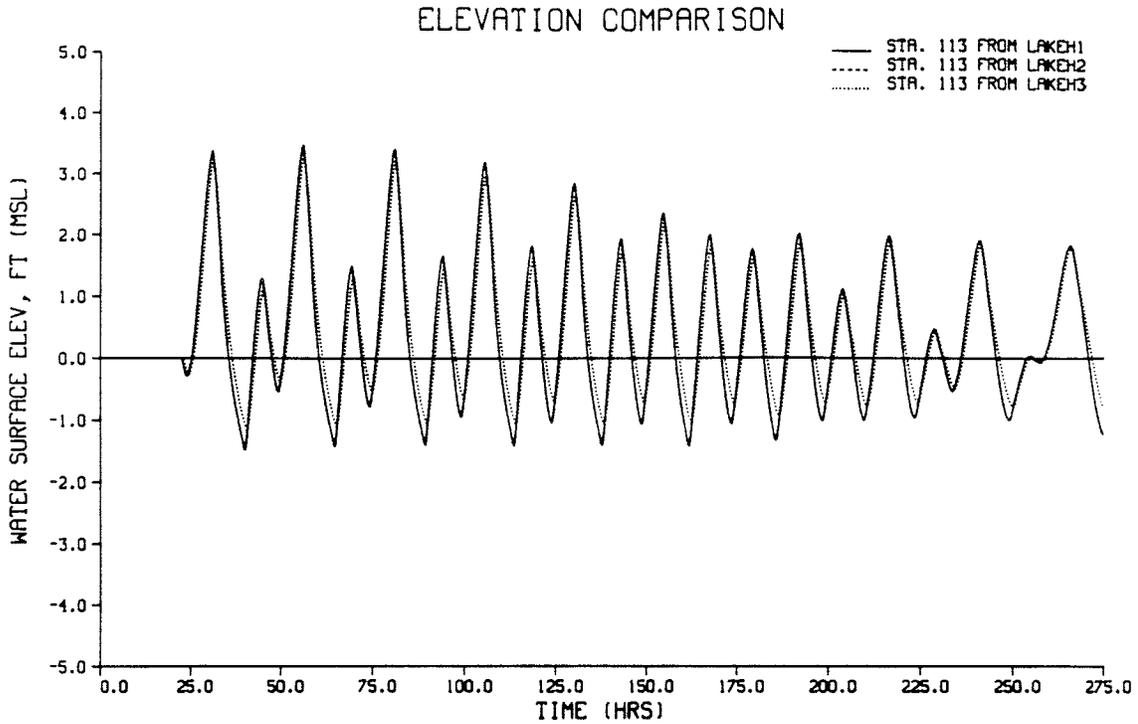


Figure 19. Tidal elevation comparisons in proposed full tidal wetlands, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

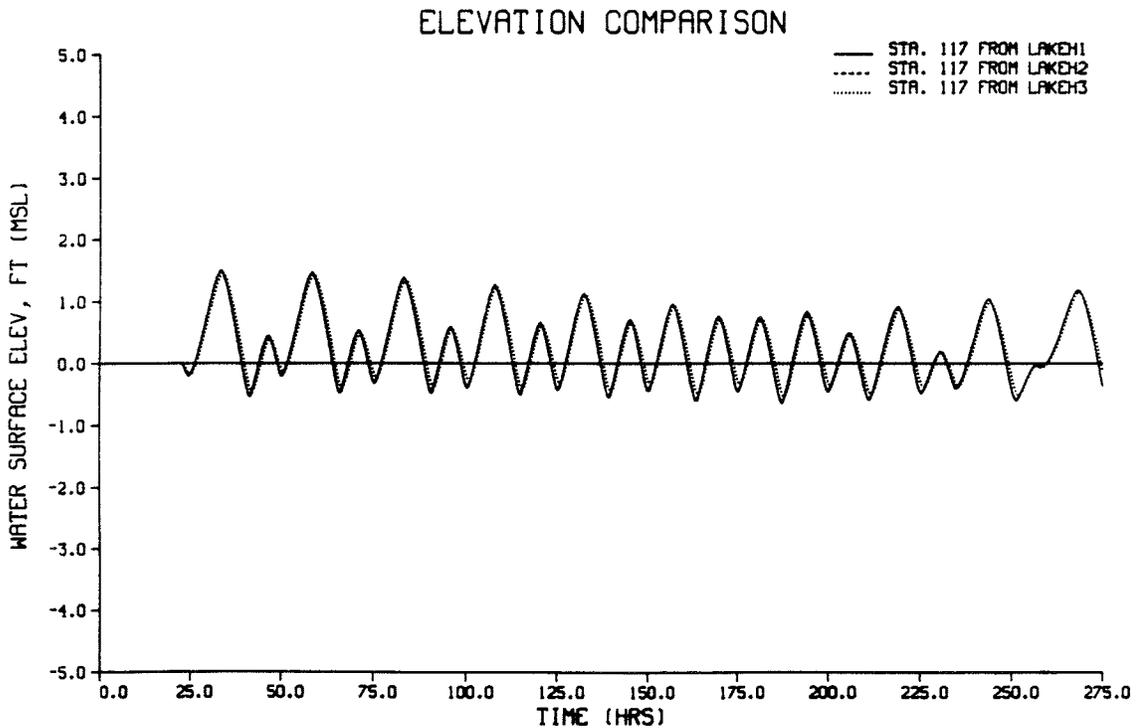


Figure 20. Tidal elevation comparisons in proposed muted tidal wetlands, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

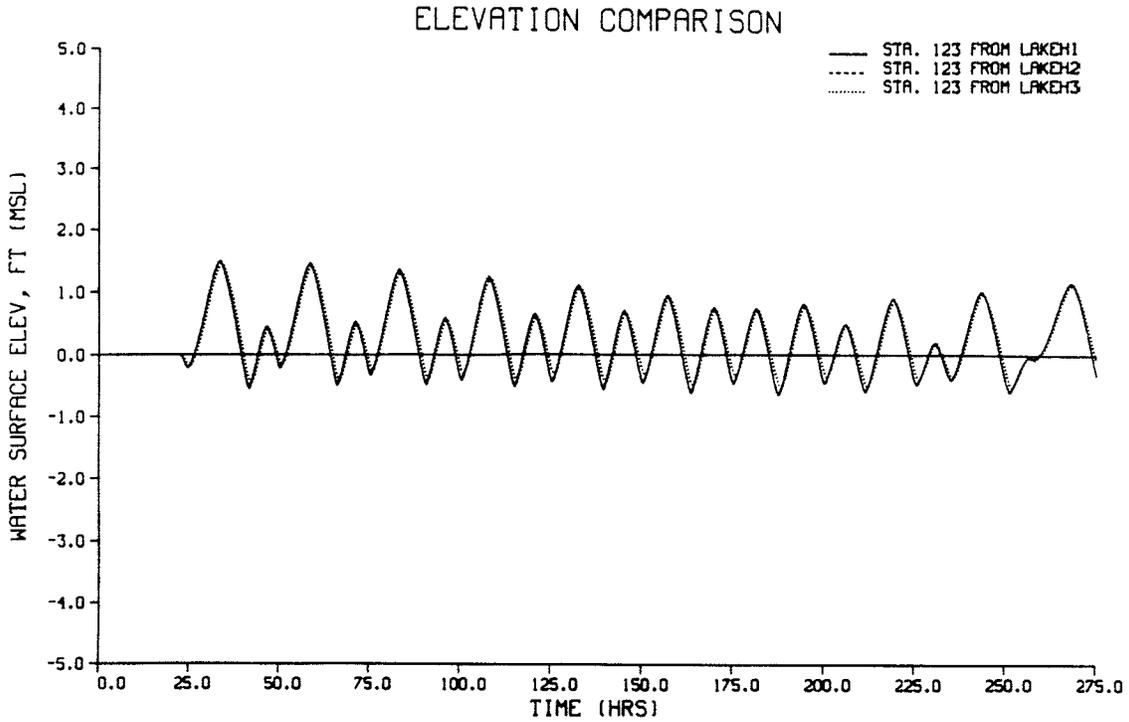


Figure 21. Tidal elevation comparisons in proposed muted tidal wetlands, LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel, LAKEH3 = entrance channel closed

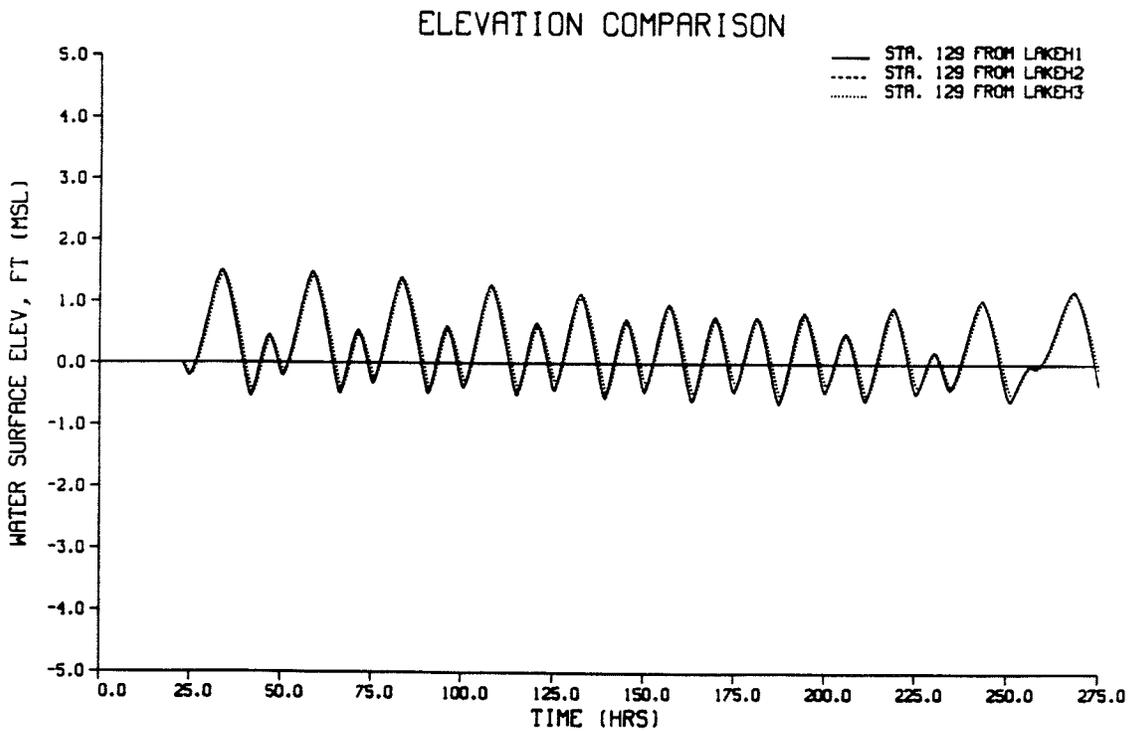


Figure 22. Tidal elevation comparisons in proposed muted tidal wetlands, LAKEH1 = 350-ft entrance channel, LAKEH2 = 200-ft entrance channel, LAKEH3 = entrance channel closed

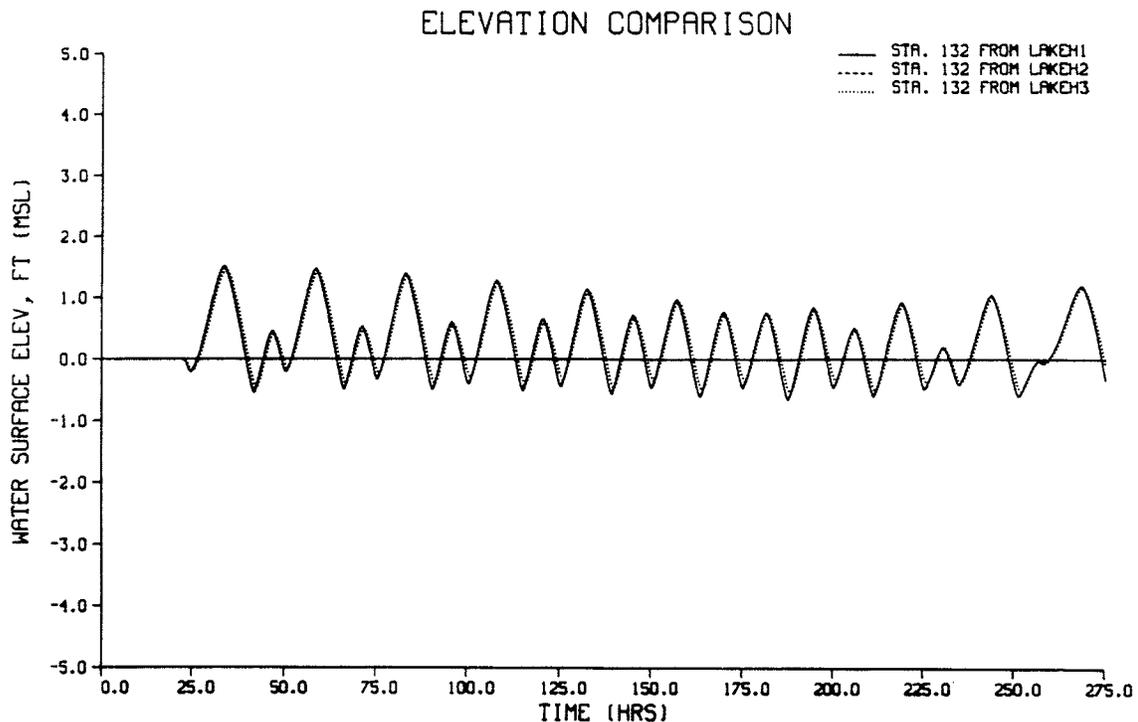


Figure 23. Tidal elevation comparisons in proposed muted tidal wetlands, LAKEH1 - 350-ft entrance channel, LAKEH2 - 200-ft entrance channel, LAKEH3 - entrance channel closed

Outer Bolsa Bay

14. High tide elevations in Outer Bolsa Bay rise to the same level regardless of whether a Lake Plan entrance is installed. Outer Bolsa Bay has the ability to fill from Huntington Harbour, or it can fill from the proposed new Lake Plan ocean entrance channel at Bolsa Chica. Low water elevations in Outer Bolsa Bay, especially at large tide range, depend on the characteristics of the connection channel to a new ocean connection at Bolsa Chica. For existing conditions, where all flow to the existing wetlands passes through Outer Bolsa Bay, the hydrography and boundary friction characteristics prevent low tide elevations from falling as far as low tide elevations in Huntington Harbour. Outer Bolsa Bay will remain in its present condition for all Lake Plan alternatives. The proposed new Lake Plan non-navigable ocean entrance channel at Bolsa Chica will convey a large portion of the tidal prism of the enhanced wetlands. The nearness of the proposed non-navigable entrance to

Outer Bolsa Bay will permit the low water elevations in Outer Bolsa Bay for Lake 1 and Lake 2 to fall lower than for the existing conditions (Figures 7 through 11, and Table 1).

15. If the proposed non-navigable Lake Plan entrance channel at Bolsa Chica closes, all the wetland tidal prism is required to traverse through Outer Bolsa Bay. This condition is analogous to the existing condition with the exception that the volume of flow is exceedingly greater with the installation of the proposed new tidal wetlands at Bolsa Chica. Hence, the low water tidal elevation is retained at a much higher level for the Lake 3 concept than for either Lake 1 or Lake 2 alternatives, or existing conditions.

Inner Bolsa Bay

16. Under existing conditions, water surface elevations in Inner Bolsa Bay rise to about 1.04 ft msl, and fall to about -0.40 ft msl (maximum tidal range = 1.5 ft). For either Lake 1 or Lake 2 alternatives with the wetlands not connected by a breach in the dike at Link 162, water surface elevations in Inner Bolsa Bay rise about 0.15 ft higher than existing conditions, and fall about 0.15 ft lower than existing conditions due to the much greater hydraulic efficiency of the approach channel to the culvert system. Hence, the Lake 1 and Lake 2 alternatives cause an increase in tidal range of about 0.3 ft (maximum tidal range = 1.8 ft), or about a 20 percent increase in tidal range in Inner Bolsa Bay (Figures 12 and 13, and Table 1).

DFG muted tidal cell

17. The Lake 1 and Lake 2 alternatives provide for about a 0.1 ft increase in high tide elevation in the DFG muted tidal cell (from about 1.0 ft msl to about 1.1 ft msl), and about a 0.05 ft decrease in low tide elevation (from about -0.09 ft msl to about -0.14 ft msl). There results about a 0.1 ft increase in maximum tidal range when the wetlands are not connected (from about 1.1 ft to about 1.2 ft), which corresponds to about a 9 percent increase in maximum tidal range (Figure 14, and Table 1).

Proposed marina

18. The water surface elevations in the proposed Lake Plan marina respond almost precisely as the elevations in Outer Bolsa Bay. Maximum high tide elevations are essentially the same for all Lake Plan alternatives. Maximum low water elevations are retained at a much higher level for Lake 3 which considers that the entrance channel is closed, falling to about

-1.5 ft msl, whereas Lake 1 and Lake 2 maximum low water elevations fall to about -3.5 ft msl (Figures 15 and 16).

Proposed full tidal wetlands

19. The proposed new full tidal wetlands do not exist under present conditions; hence, only a comparison of the effects of the Lake Plan alternatives on water surface elevations in this region is available. Maximum high tide elevation approaches 3.45 ft msl while maximum low tide elevation falls to about -1.4 ft msl, for both Lake 1 and Lake 2 alternatives. This results in about a 4.9 ft maximum tidal range. Lake 3 maximum high tide elevation approaches only about 3.3 ft msl, and maximum low tide elevation fall to only about -1.1 ft msl (Figures 17 through 19). The resulting maximum tidal range is about 4.4 ft for the condition which would exist if the proposed Lake Plan ocean entrance channel at Bolsa Chica is permitted to close by littoral material in the surf zone.

Proposed muted tidal wetlands

20. The proposed muted tidal wetlands also do not exist under present conditions. Because of the muting afforded by the second culvert system, the water surface elevations in these regions are more nearly the same for all Lake Plan alternatives than in the other full tidal wetland regions. Maximum water surface elevations rise to about 1.50 ft msl for Lake 1 and Lake 2, and rise to about 1.45 ft msl for Lake 3. Maximum low water surface elevations fall to about -0.55 ft msl for Lake 1 and Lake 2, and fall to about -0.45 ft msl for Lake 3. There results a maximum tidal range of about 2.1 ft for Lake 1 and Lake 2, and about 1.9 ft for Lake 3 (due to potential closure of the proposed ocean entrance channel at Bolsa Chica), for the situation where the wetlands are not connected (Figures 20 through 23, and Table 1).

Average Channel Velocities

21. Results of velocity simulations throughout the Bolsa Bay complex are presented for existing conditions, Lake 1, Lake 2, and Lake 3 in Appendix B, Appendix D, Appendix F, and Appendix H, respectively. Maximum average channel velocities are shown in Table 2 for specific links throughout the Huntington Harbour, Outer Bolsa Bay, and the proposed Lake Plan marina complex. Comparisons of the effects of these plans with existing conditions

for typically representative average channel velocities are presented in Figures 24 through 46 (Huntington Harbour), Figure 47 (Warner Avenue bridge), Figures 48 through 51 (Outer Bolsa Bay), Figures 52 and 53 (proposed Lake Plan marina channel), and Figure 54 (ocean entrance channel at Bolsa Chica), respectively.

Table 2
Comparison of Existing Conditions
with
Alternative Lake Plan Concepts

Maximum Average Channel Velocities (ft per sec)

<u>Location</u>	<u>Link</u>	<u>POSTBOL</u>	<u>Lake 1</u>	<u>Lake 2</u>	<u>Lake 3</u>
Pacific Coast Highway bridge	2	2.78	2.50	2.74	3.24
Huntington Harbour	5	1.42	1.28	1.40	1.80
Huntington Harbour	7	1.48	1.31	1.44	1.91
Huntington Harbour	8	0.29	0.25	0.28	0.35
Huntington Harbour	9	0.54	0.49	0.53	0.69
Huntington Harbour	10	0.71	0.63	0.70	0.96
Huntington Harbour	11	0.53	0.47	0.52	0.68
Huntington Harbour	12	0.50	0.42	0.48	0.67
Huntington Harbour	13	0.28	0.22	0.26	0.41
Huntington Harbour	15	0.27	0.23	0.26	0.36
Huntington Harbour	16	0.39	0.35	0.38	0.48
Huntington Harbour	17	0.66	0.57	0.64	0.91
Huntington Harbour	18	0.34	0.27	0.32	0.55
Huntington Harbour	20	0.52	0.45	0.50	0.69
Huntington Harbour	21	0.14	0.11	0.13	0.21
Huntington Harbour	23	0.32	0.27	0.30	0.41
Huntington Harbour	24	0.57	0.46	0.55	0.87
Huntington Harbour	25	0.30	0.21	0.28	0.54
Huntington Harbour	26	0.34	0.24	0.32	0.68
Huntington Harbour	27	0.16	0.17	0.16	0.29
Huntington Harbour	29	0.11	0.07	0.09	0.42
Huntington Harbour	31	0.16	0.11	0.15	0.23
Huntington Harbour	32	0.30	0.22	0.28	0.52
Huntington Harbour	33	0.19	0.19	0.19	0.21
Warner Avenue bridge	34	1.65	0.93	1.60	4.80
Outer Bolsa Bay	35	1.35	0.70	1.04	1.73
Outer Bolsa Bay	36	0.71	0.40	0.65	1.32
Outer Bolsa Bay	37	0.88	0.53	0.50	1.29
Outer Bolsa Bay	38	1.12	0.67	0.50	1.32
Proposed marina channel	85	----	0.67	0.63	0.51
Proposed marina channel	95	----	0.23	0.22	0.18
Ocean entrance channel	109	----	2.40	3.34	----

POSTBOL = existing conditions
 Lake 1 = 350-ft wide entrance channel
 Lake 2 = 200-ft wide entrance channel
 Lake 3 = entrance channel closed

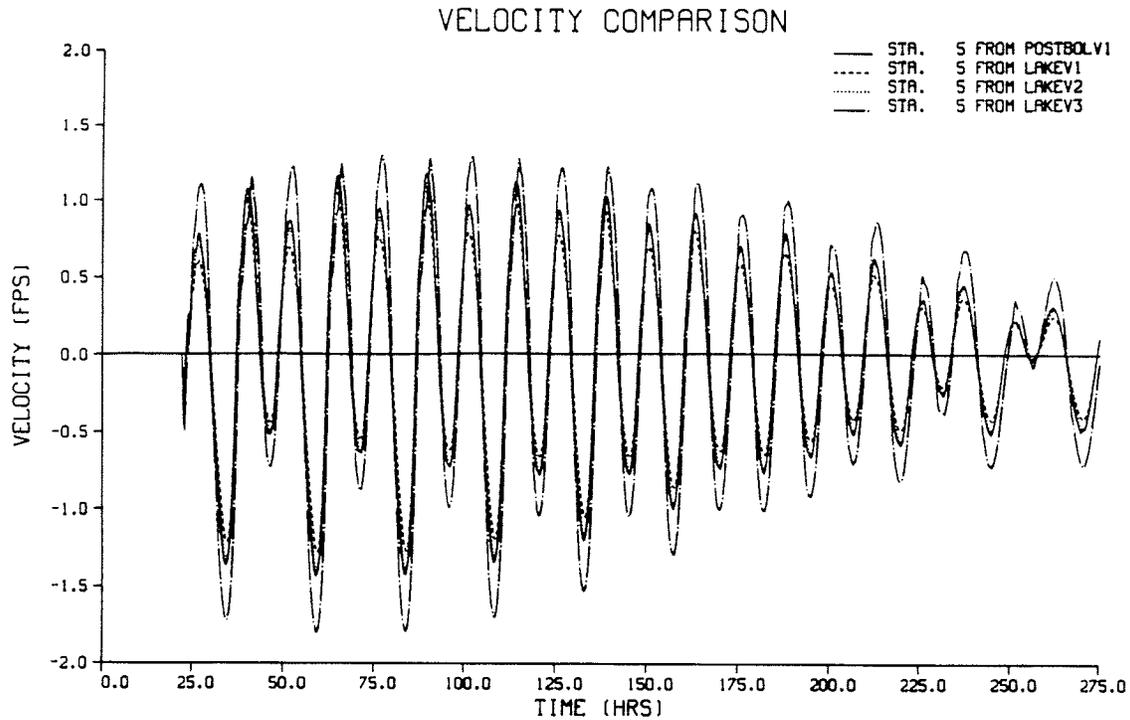


Figure 24. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

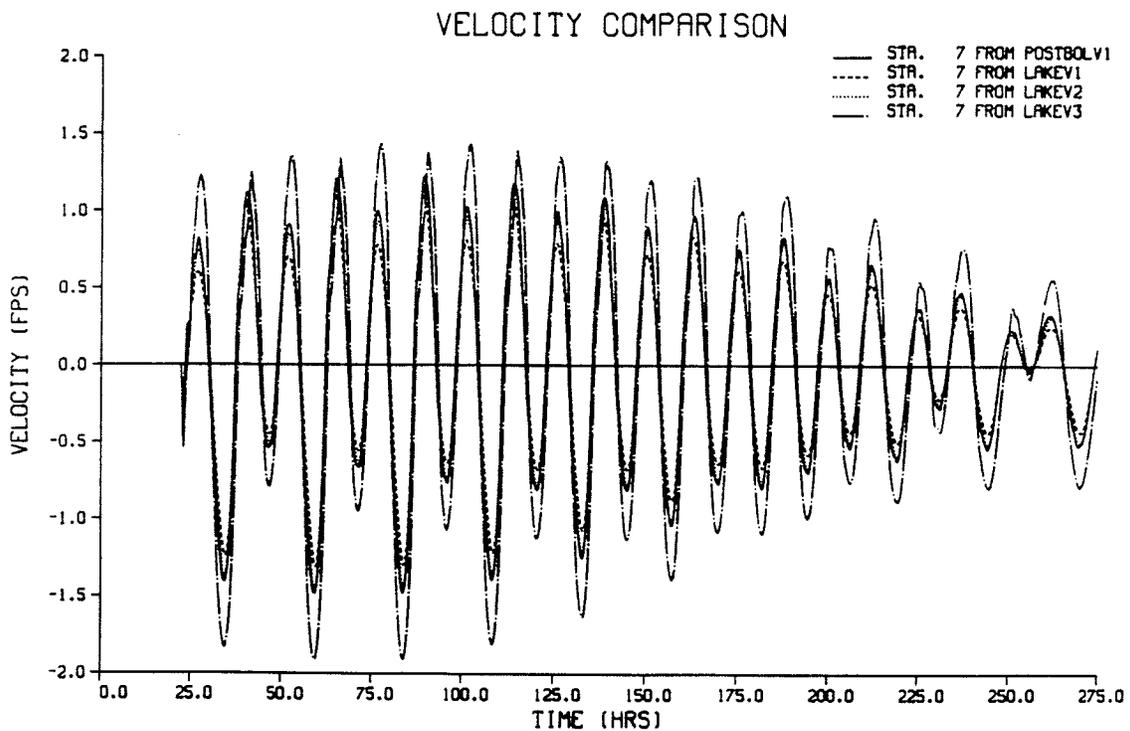


Figure 25. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

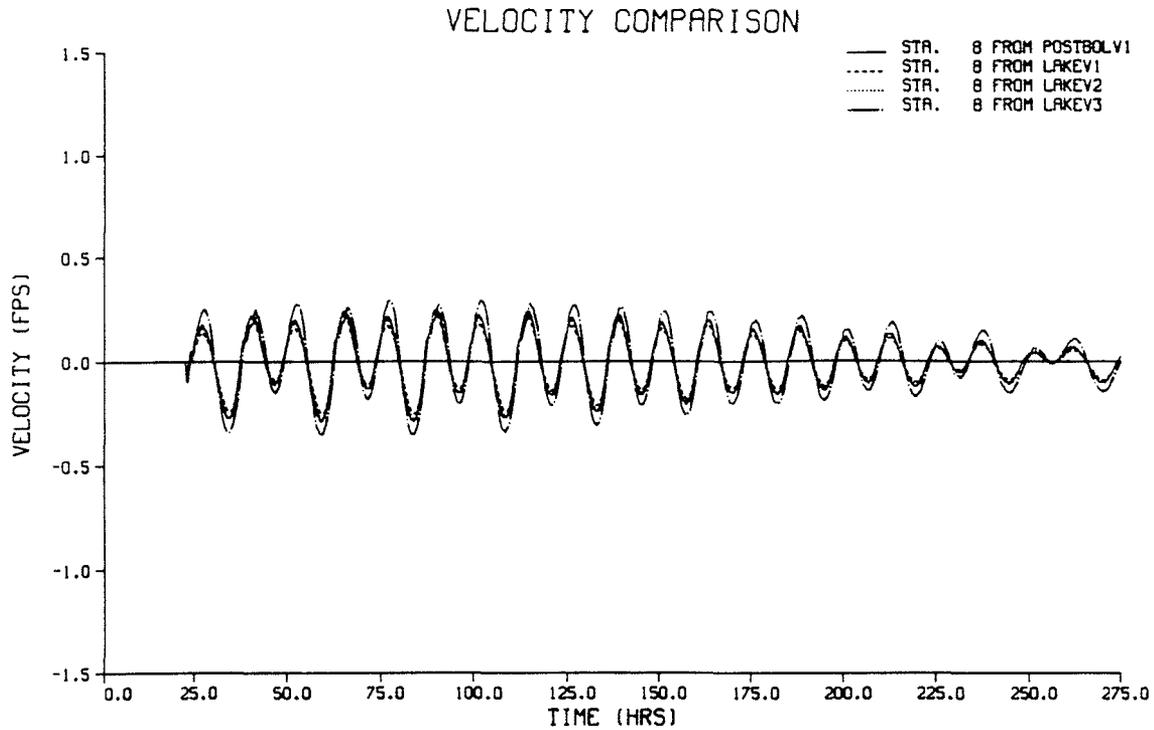


Figure 26. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

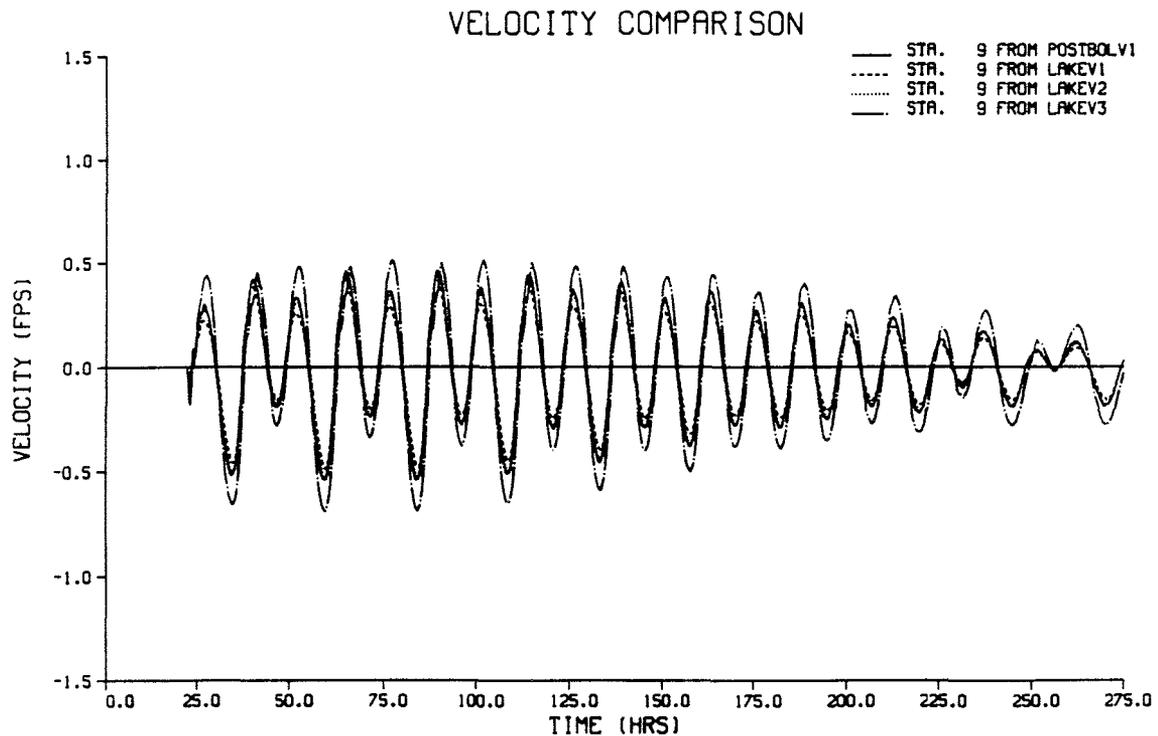


Figure 27. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

VELOCITY COMPARISON

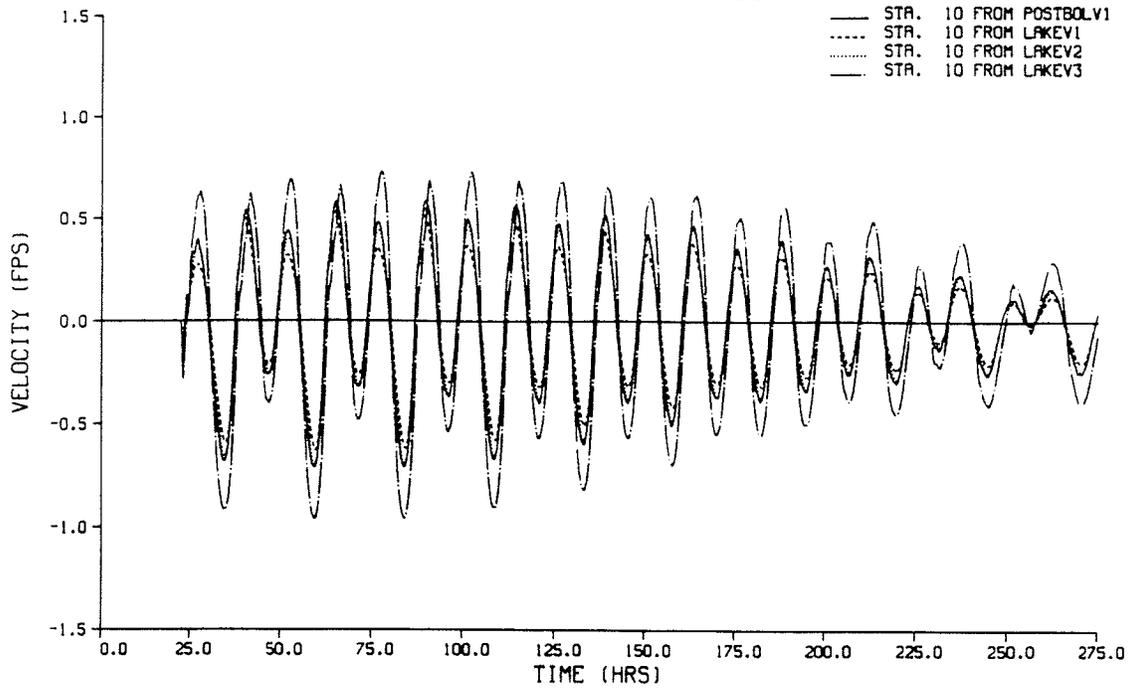


Figure 28. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

VELOCITY COMPARISON

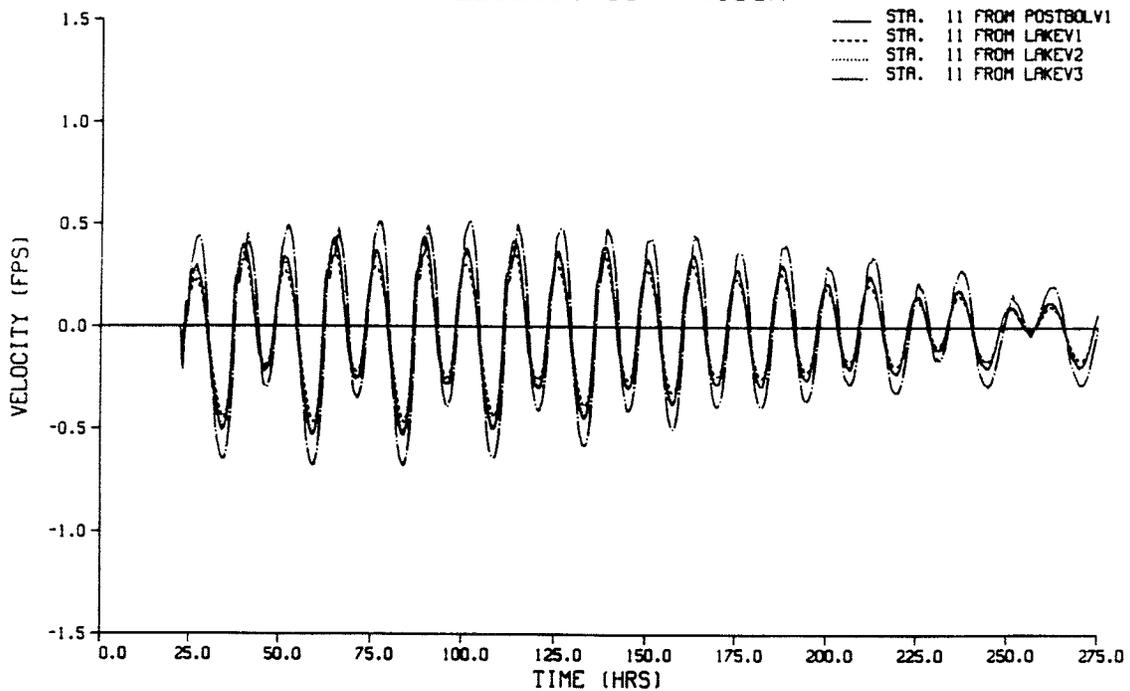


Figure 29. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

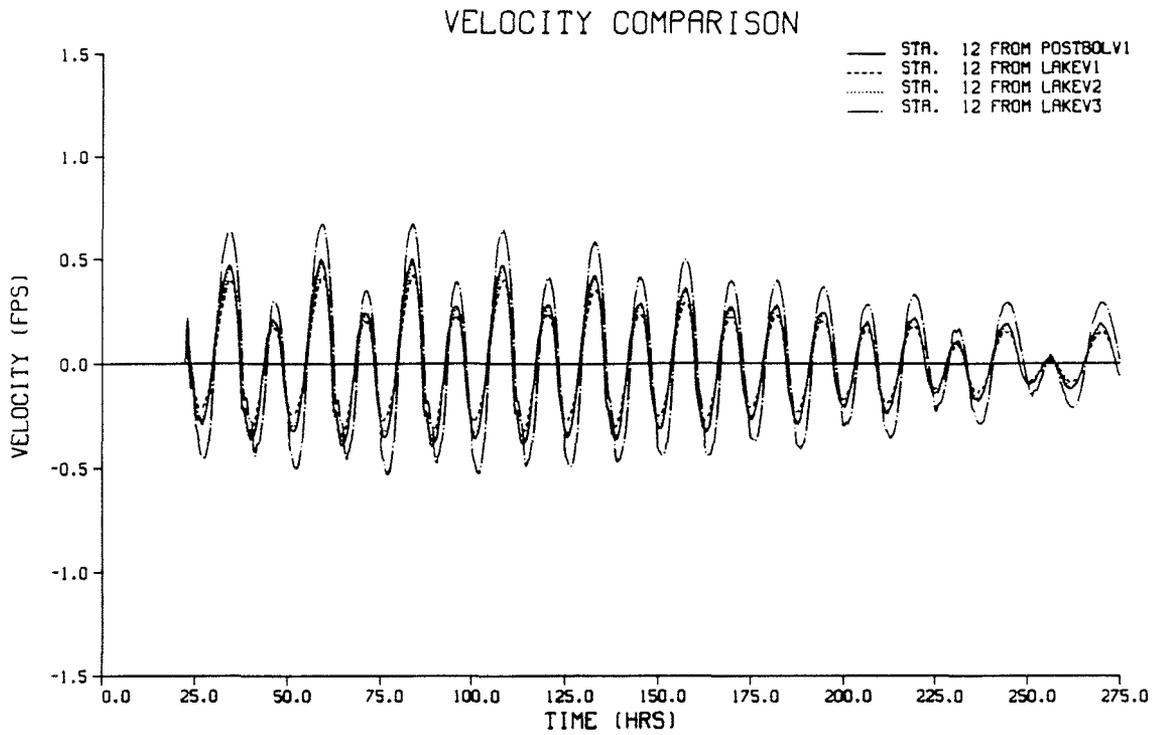


Figure 30. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

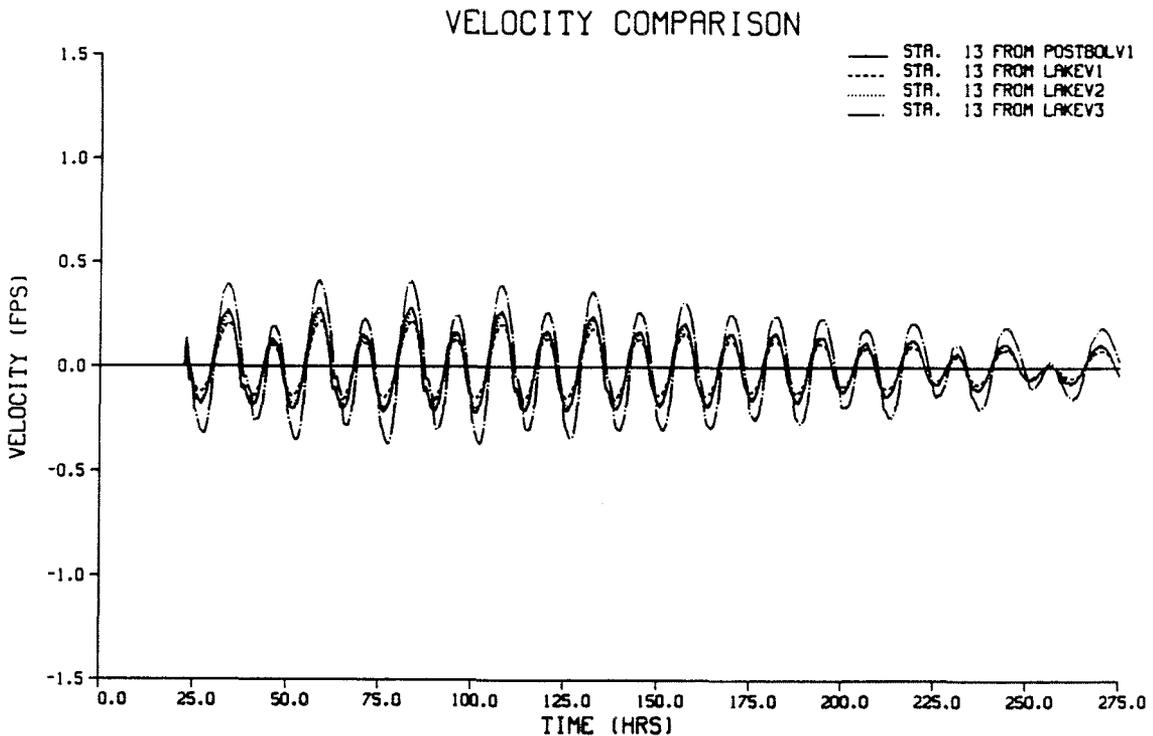


Figure 31. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

VELOCITY COMPARISON

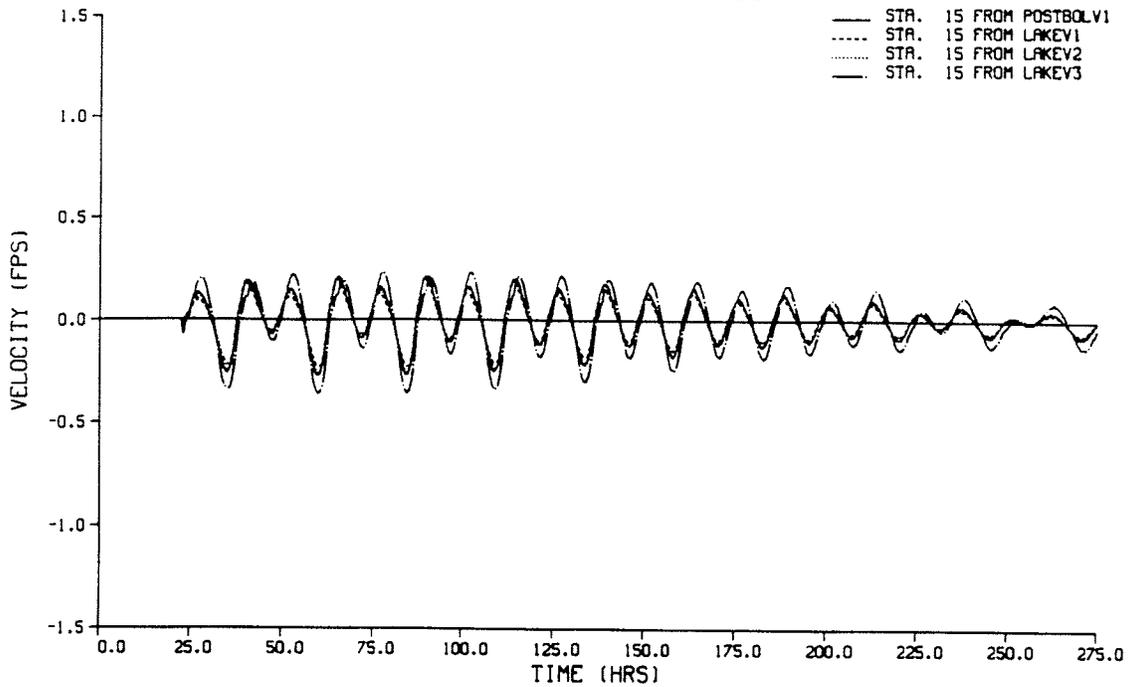


Figure 32. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

VELOCITY COMPARISON

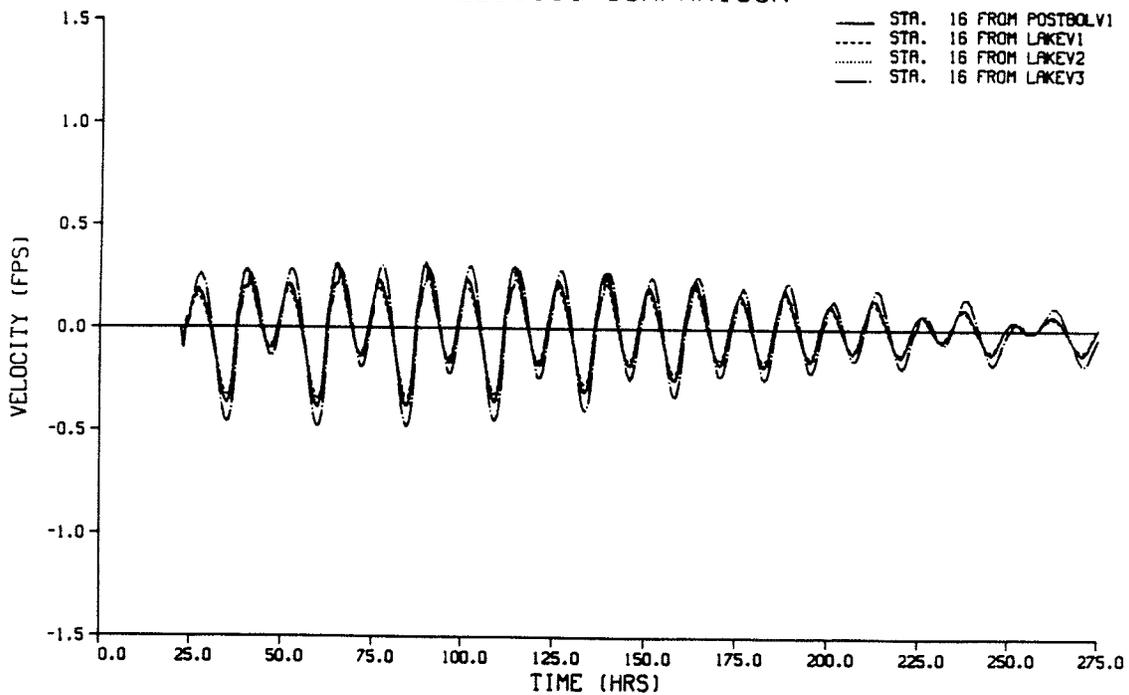


Figure 33. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

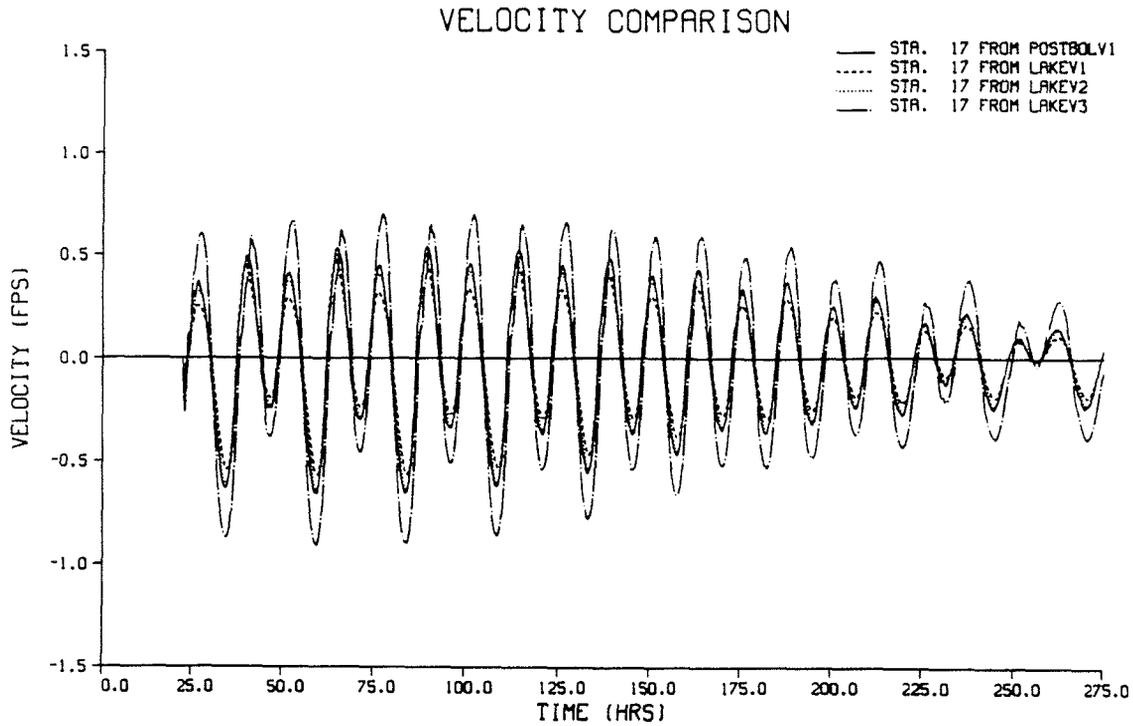


Figure 34. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

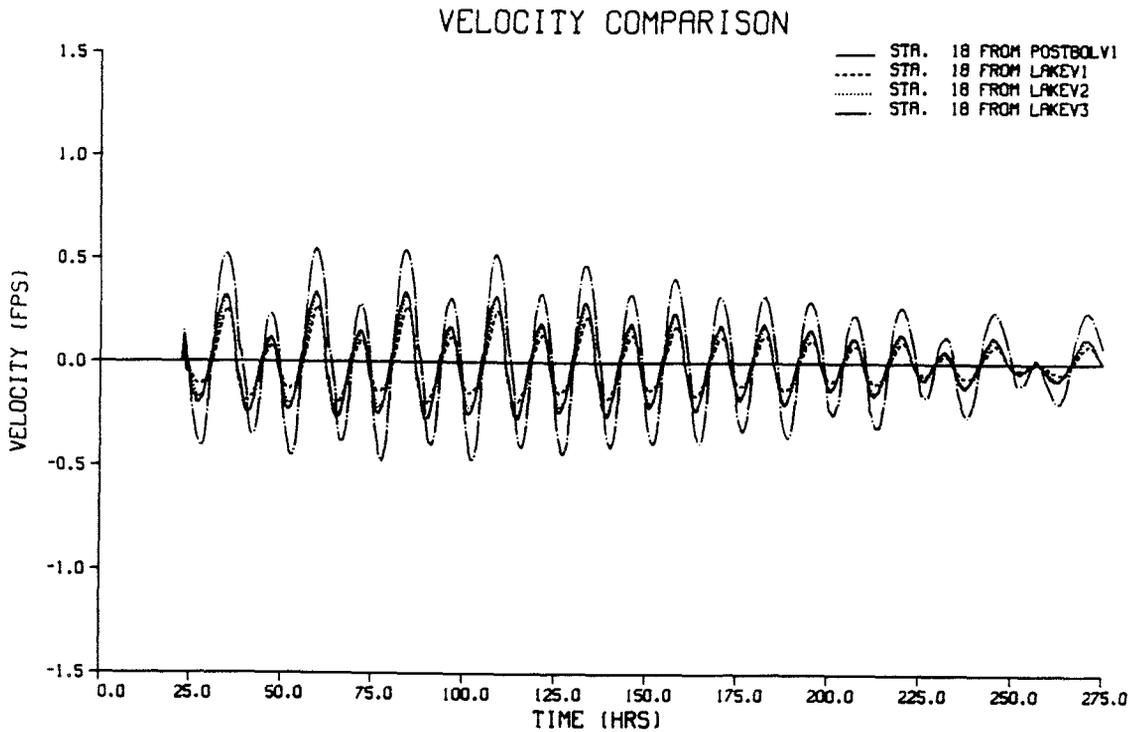


Figure 35. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

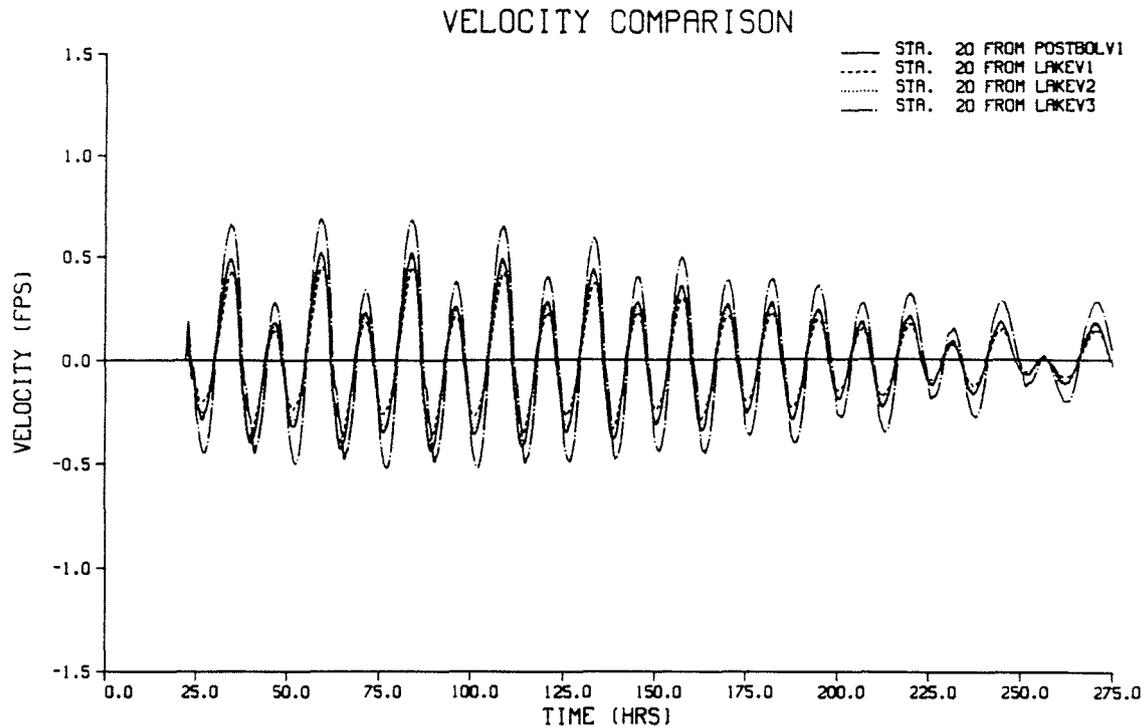


Figure 36. Average channel velocities in Huntington Harbour, POSTBOLV1 = existing condition, LAKEV1 = 350-ft entrance channel, LAKEV2 = 200-ft entrance channel, LAKEV3 = entrance channel closed

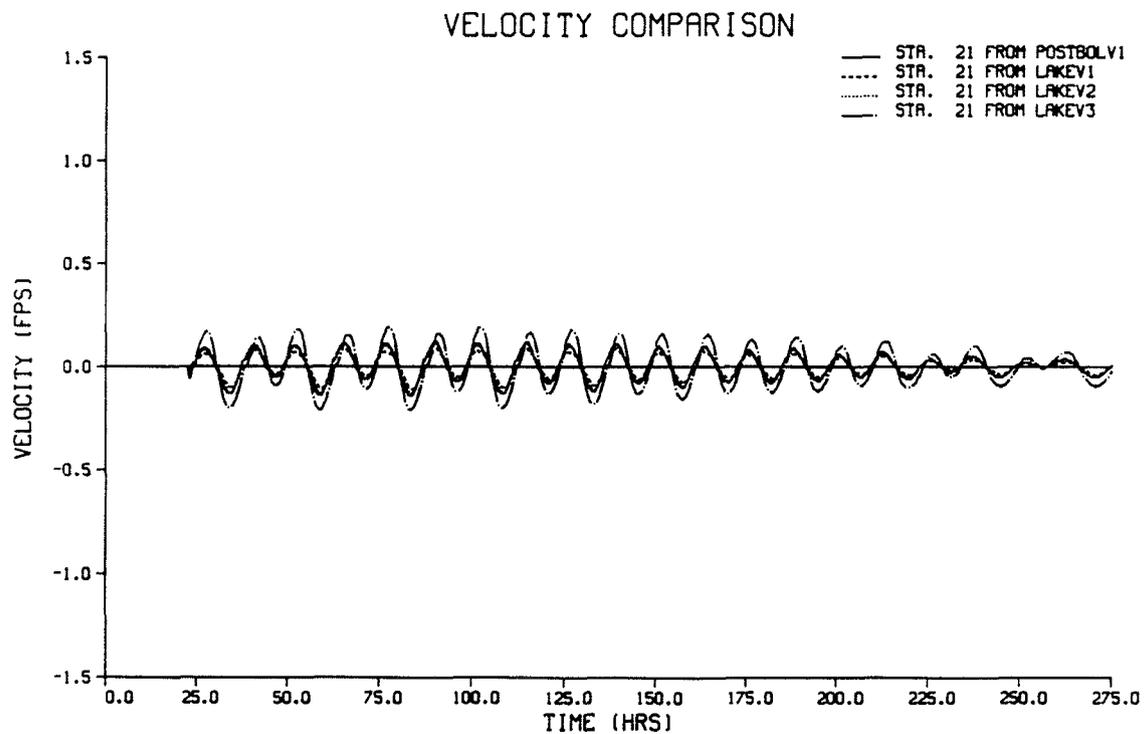


Figure 37. Average channel velocities in Huntington Harbour, POSTBOLV1 = existing condition, LAKEV1 = 350-ft entrance channel, LAKEV2 = 200-ft entrance channel, LAKEV3 = entrance channel closed

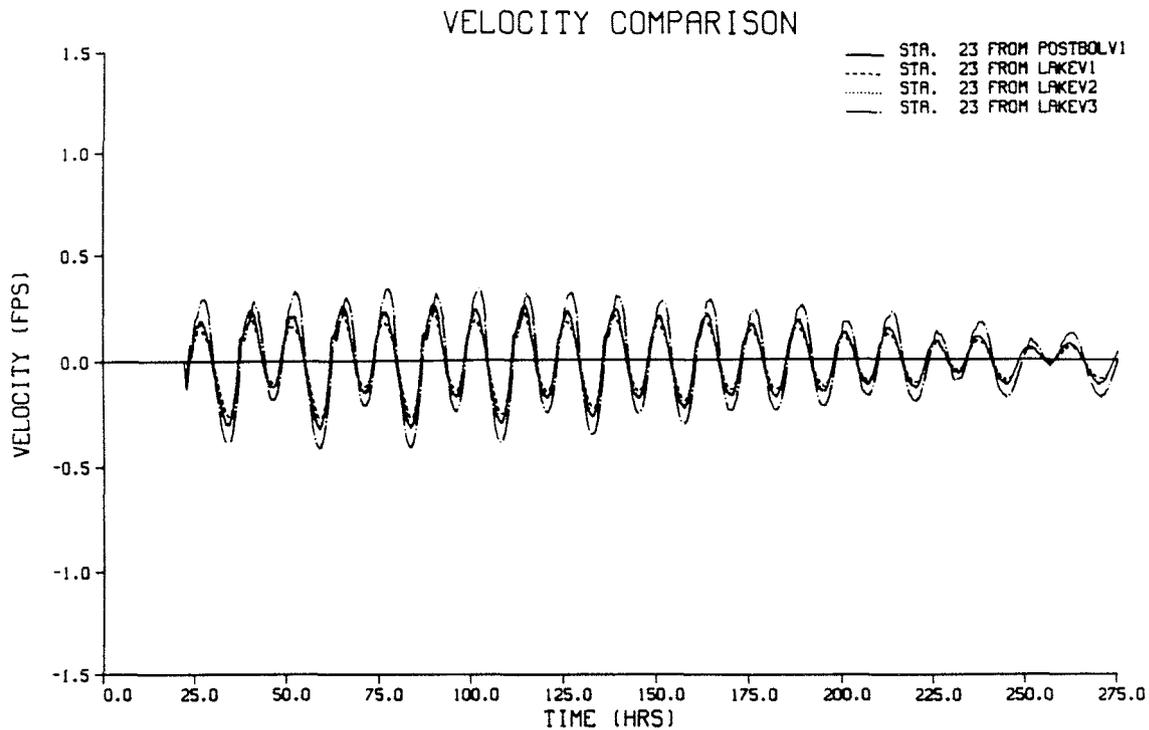


Figure 38. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

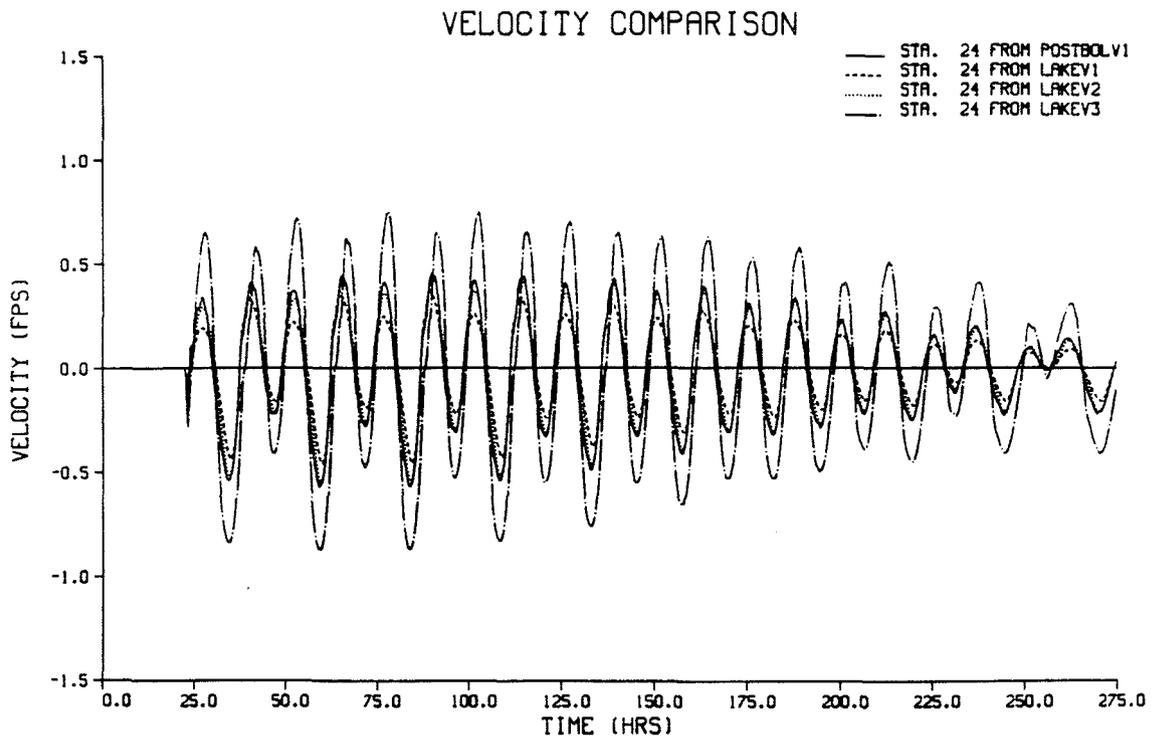


Figure 39. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

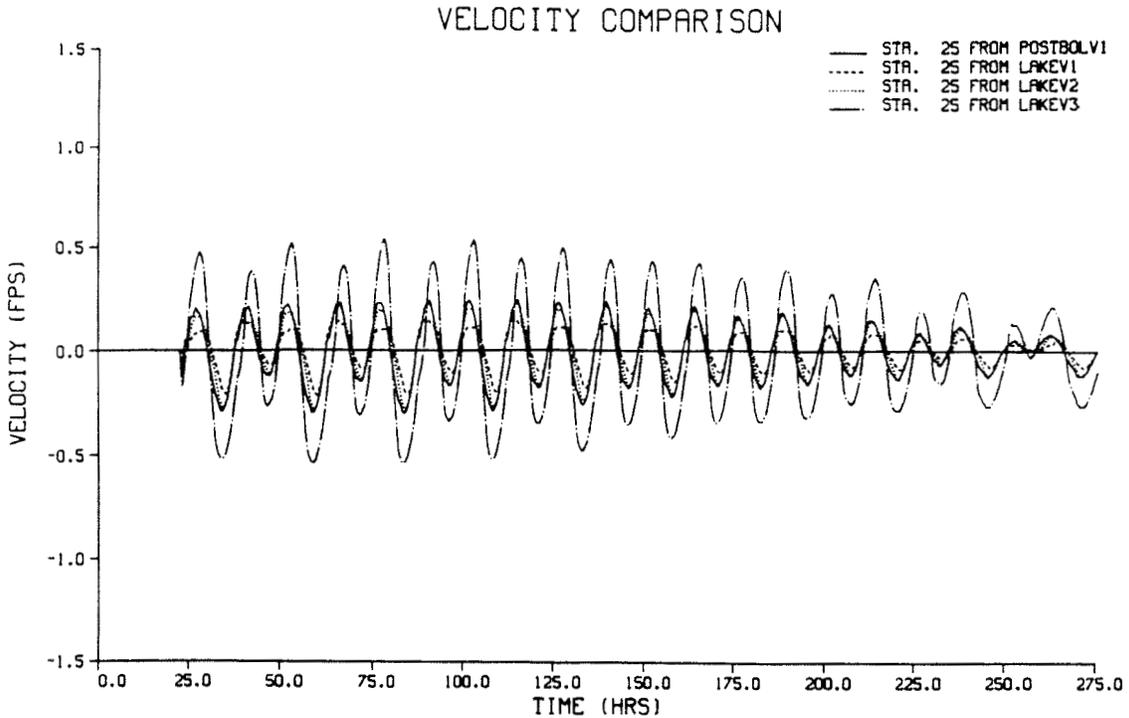


Figure 40. Average channel velocities in Huntington Harbour, POSTBOLV1 = existing condition, LAKEV1 = 350-ft entrance channel, LAKEV2 = 200-ft entrance channel, LAKEV3 = entrance channel closed

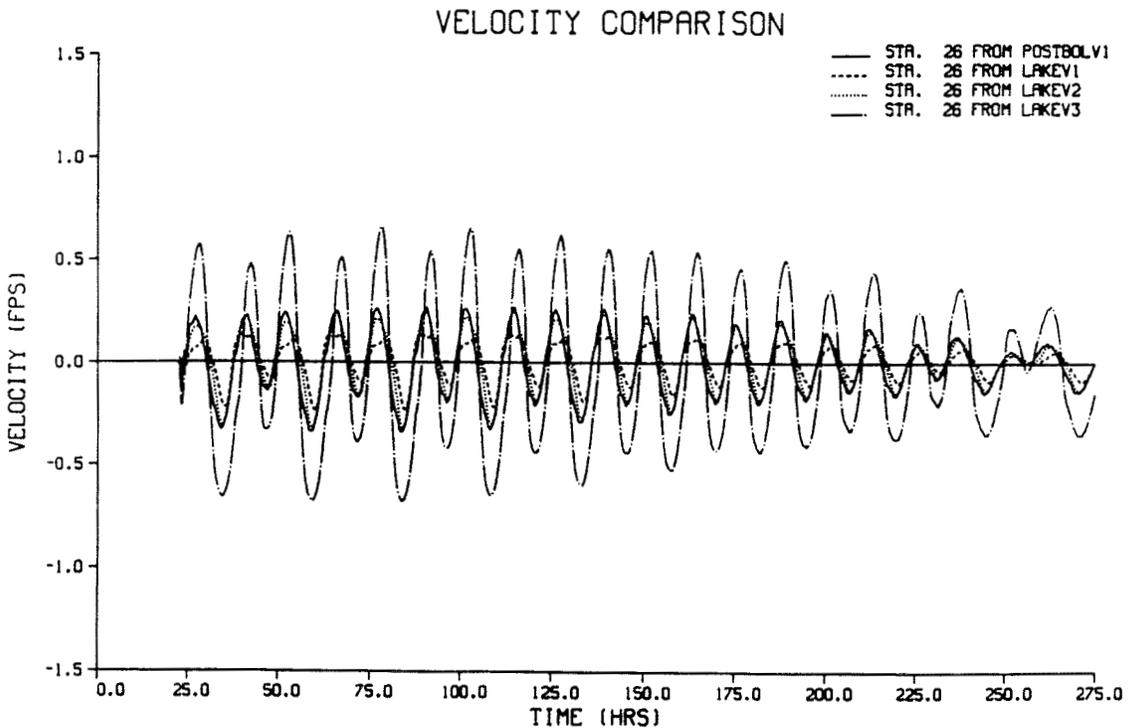


Figure 41. Average channel velocities in Huntington Harbour, POSTBOLV1 = existing condition, LAKEV1 = 350-ft entrance channel, LAKEV2 = 200-ft entrance channel, LAKEV3 = entrance channel closed

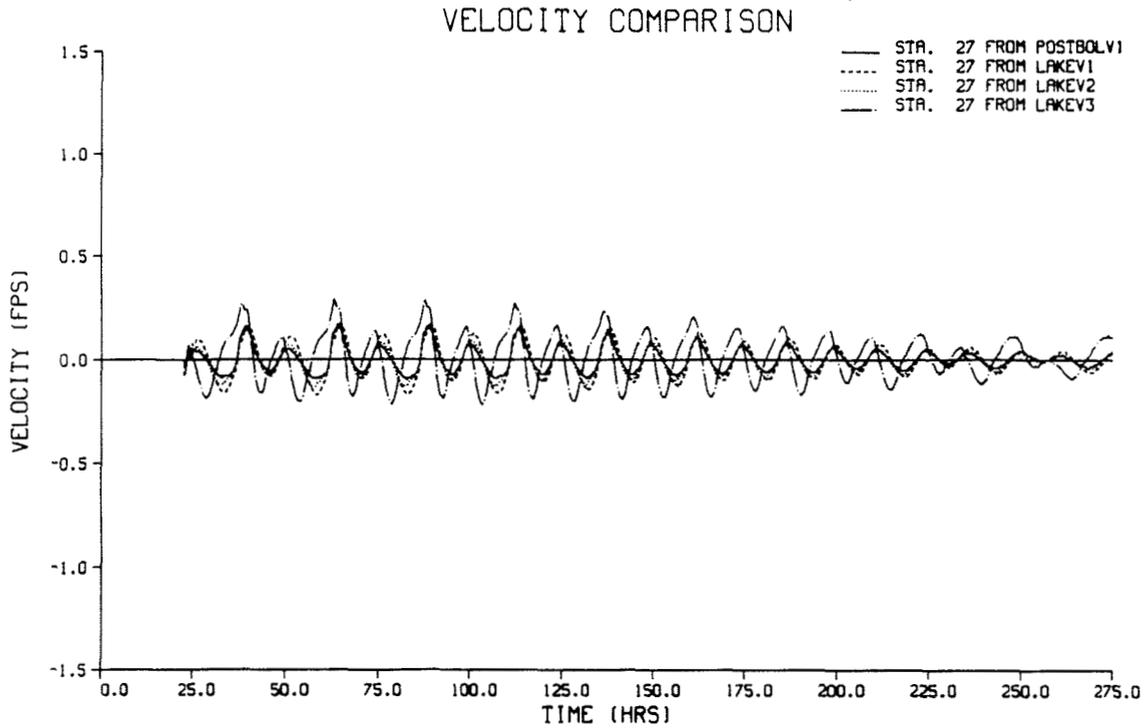


Figure 42. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

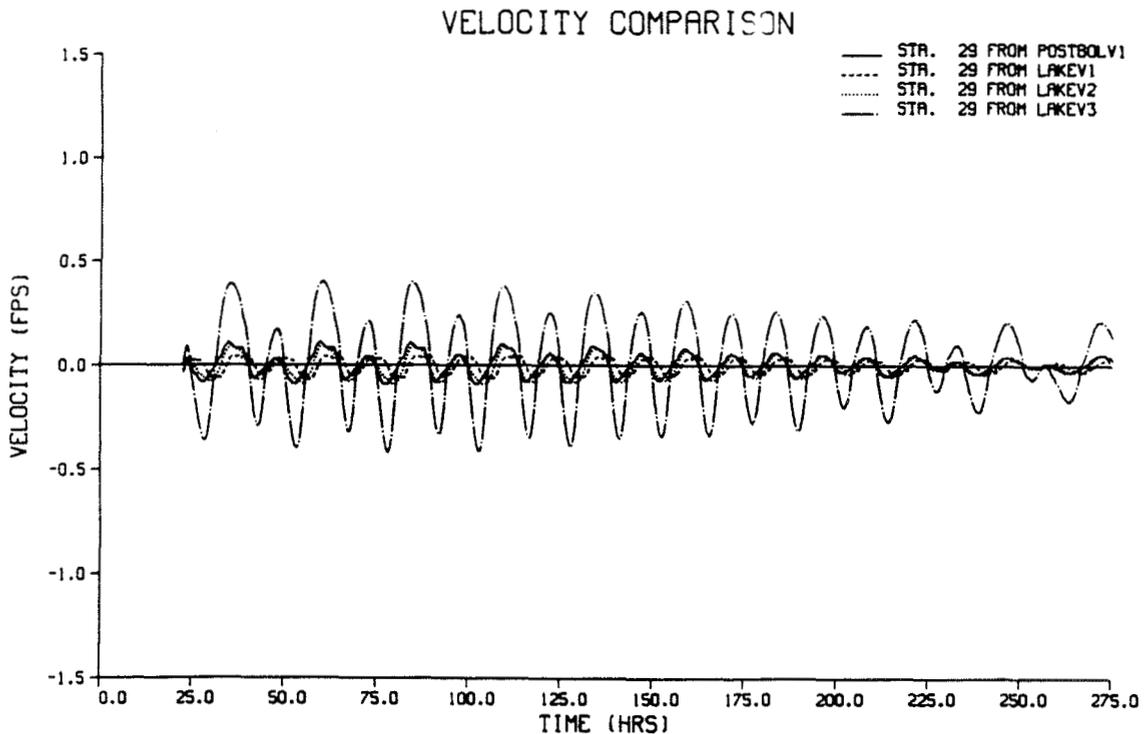


Figure 43. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

VELOCITY COMPARISON

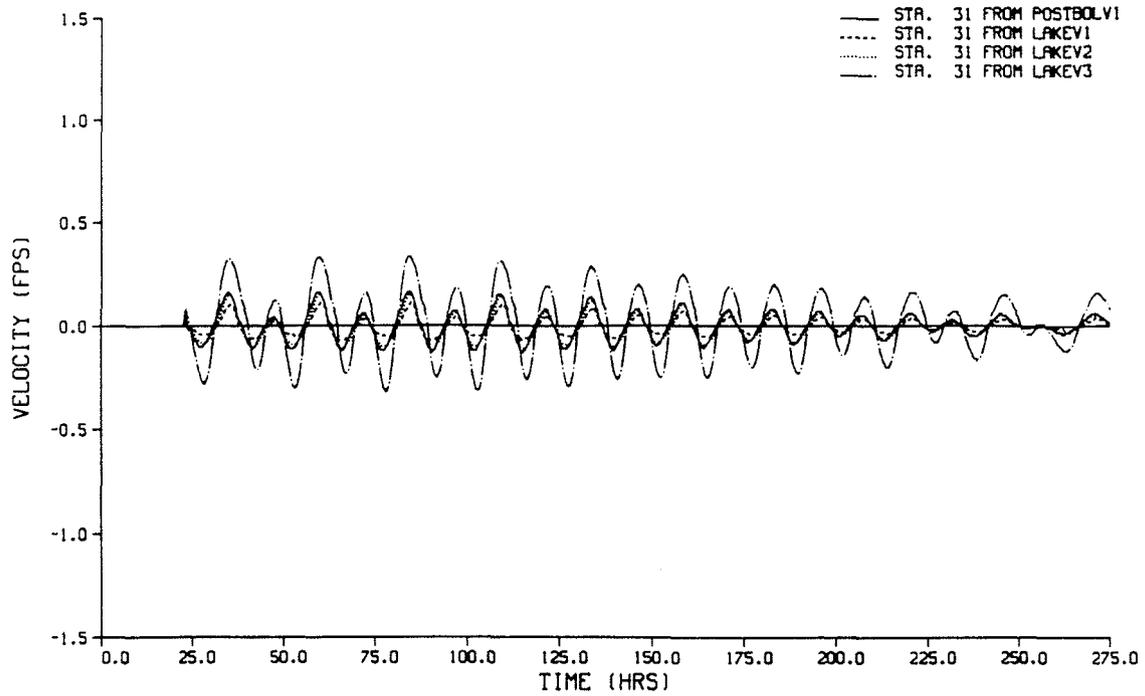


Figure 44. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

VELOCITY COMPARISON

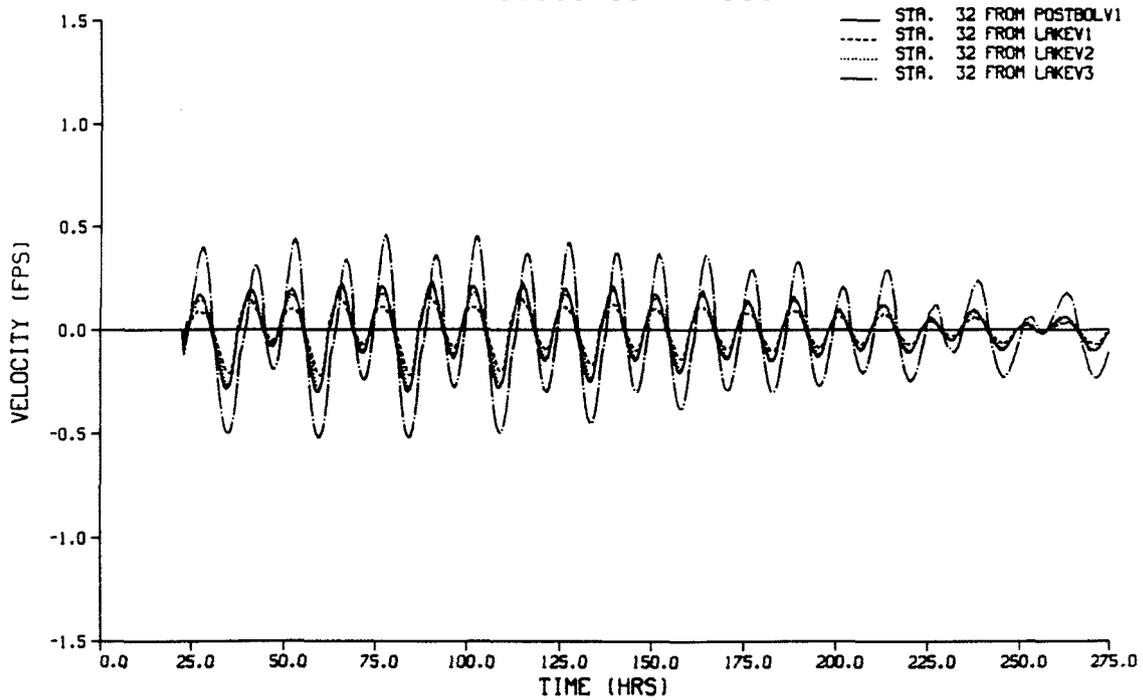


Figure 45. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

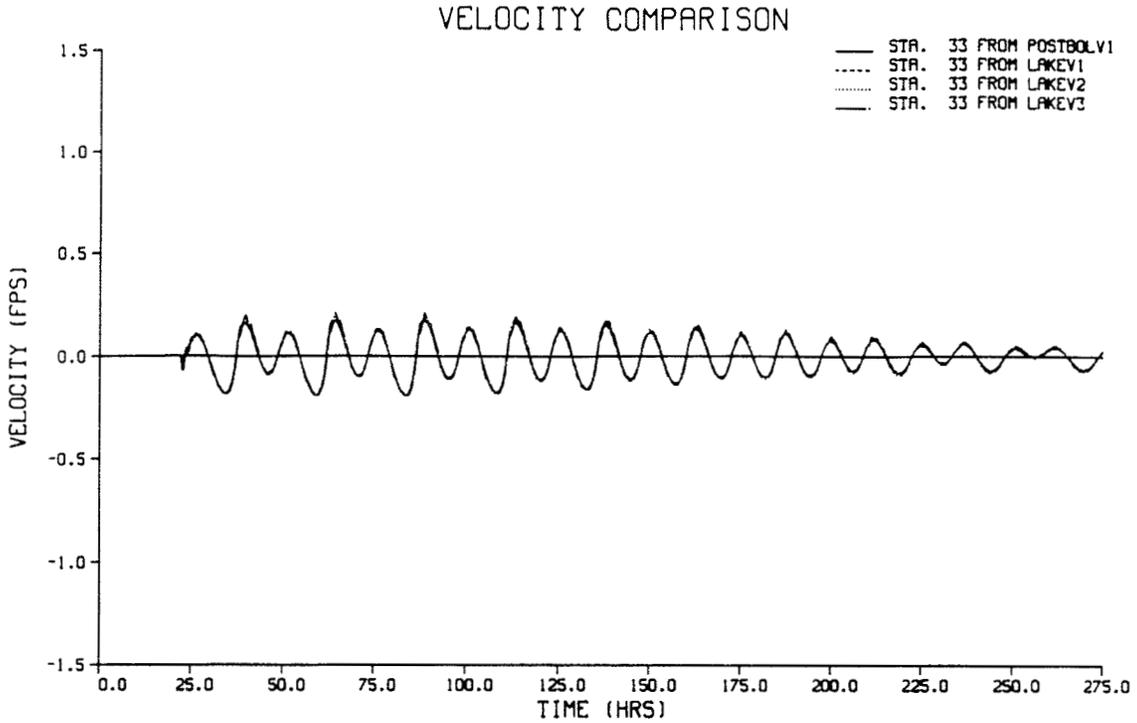


Figure 46. Average channel velocities in Huntington Harbour, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

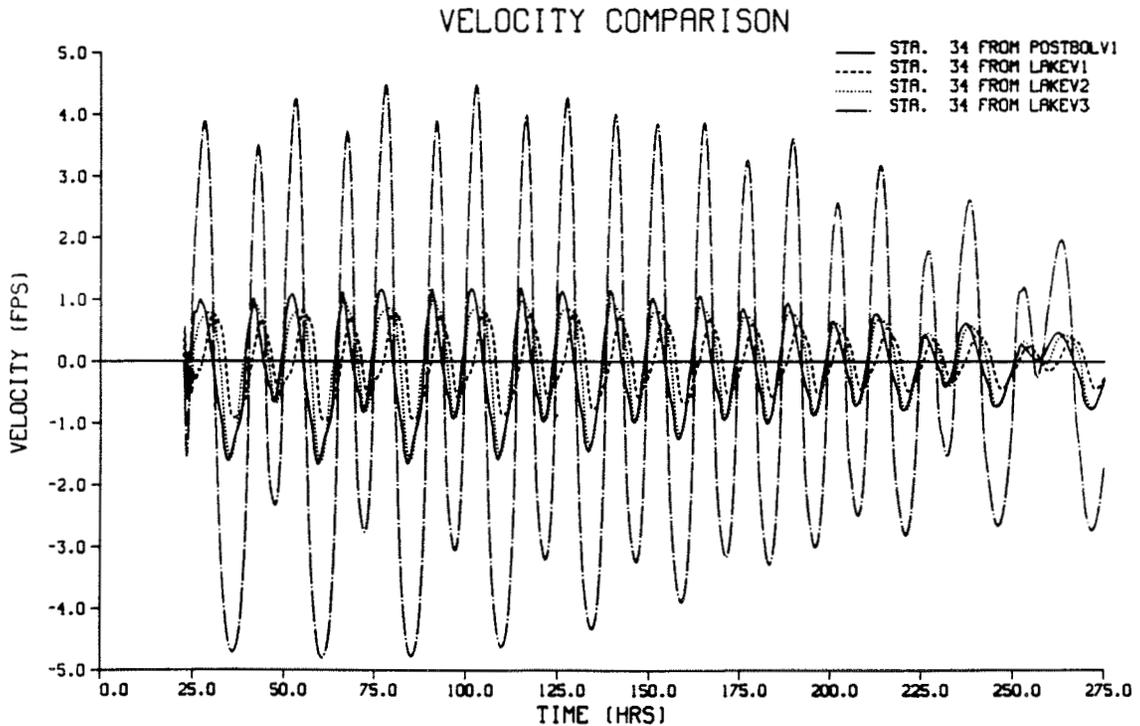


Figure 47. Average channel velocities under Warner Avenue bridge, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

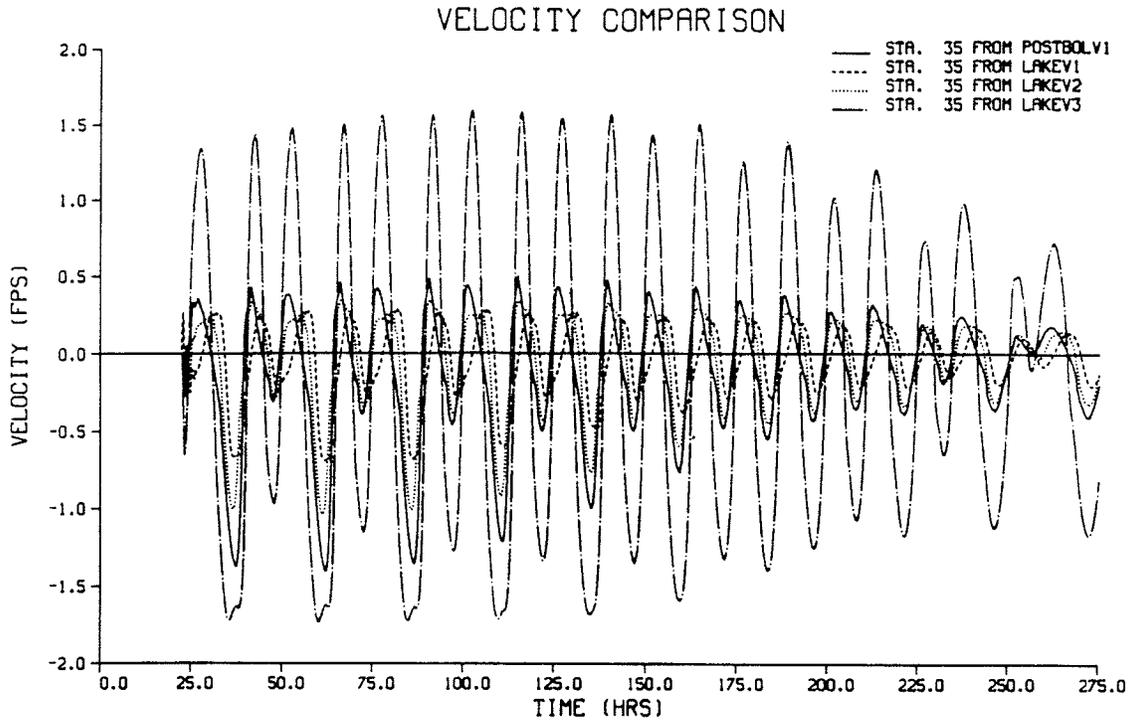


Figure 48. Average channel velocities in Outer Bolsa Bay, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

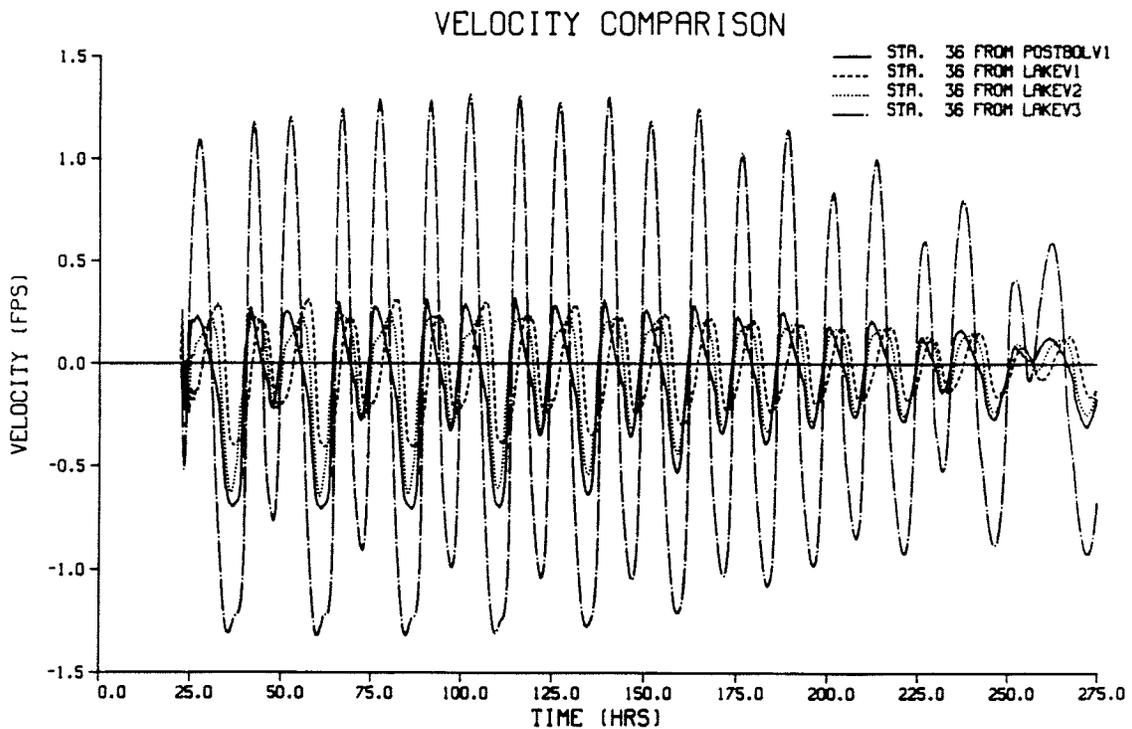


Figure 49. Average channel velocities in Outer Bolsa Bay, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

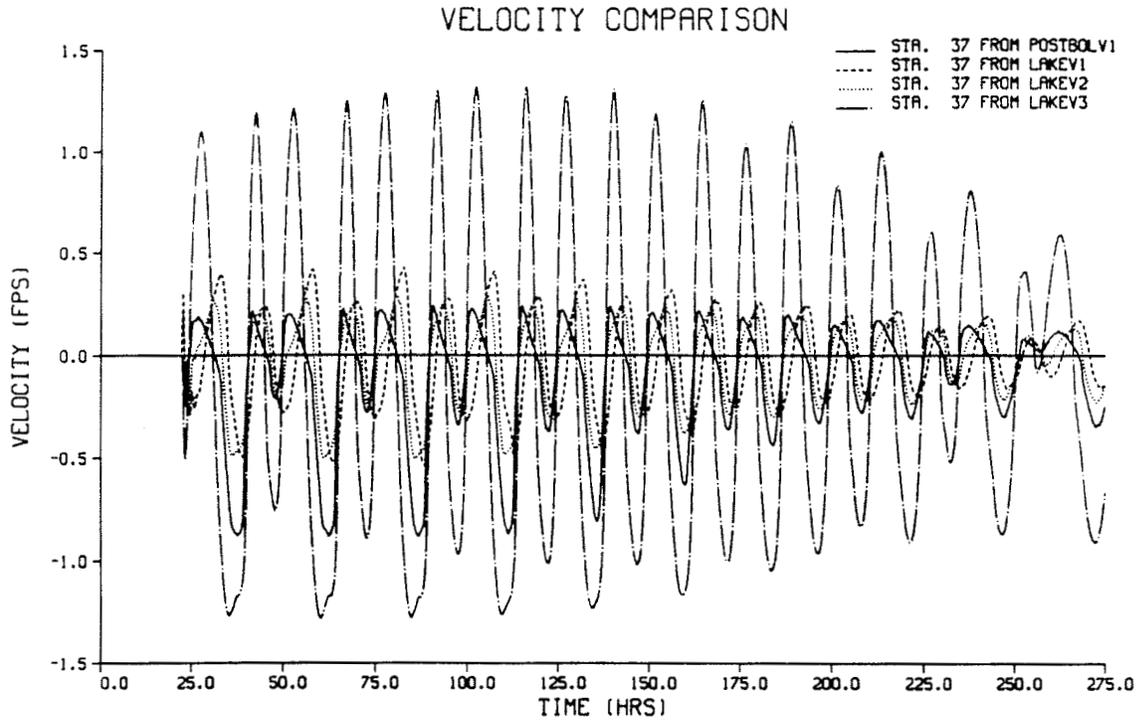


Figure 50. Average channel velocities in Outer Bolsa Bay, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

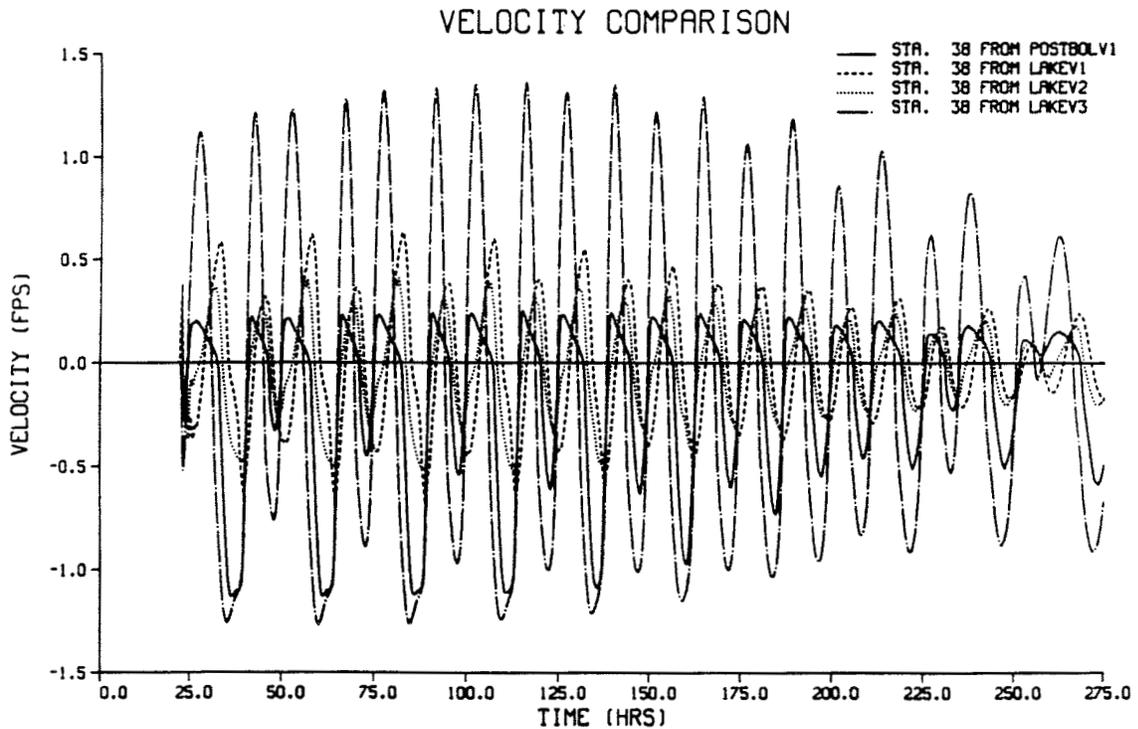


Figure 51. Average channel velocities in Outer Bolsa Bay, POSTBOLV1 - existing condition, LAKEV1 - 350-ft entrance channel, LAKEV2 - 200-ft entrance channel, LAKEV3 - entrance channel closed

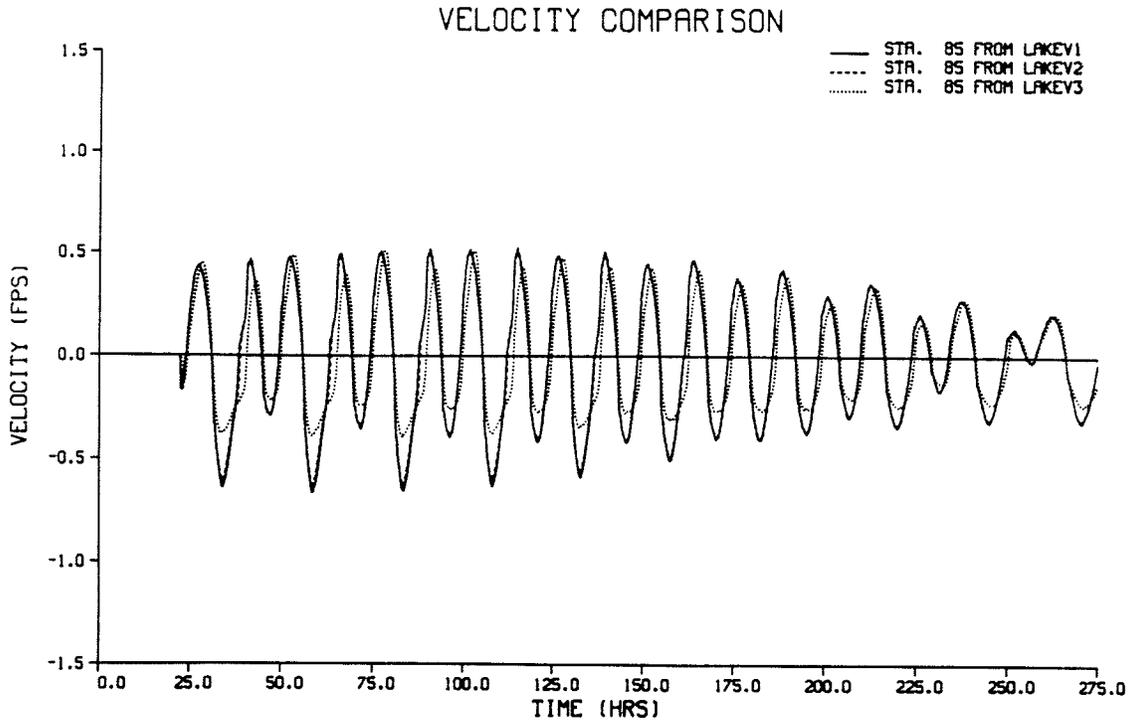


Figure 52. Average channel velocities in proposed marina, LAKEV1 = 350-ft entrance channel, LAKEV2 = 200-ft entrance channel, LAKEV3 = entrance channel closed

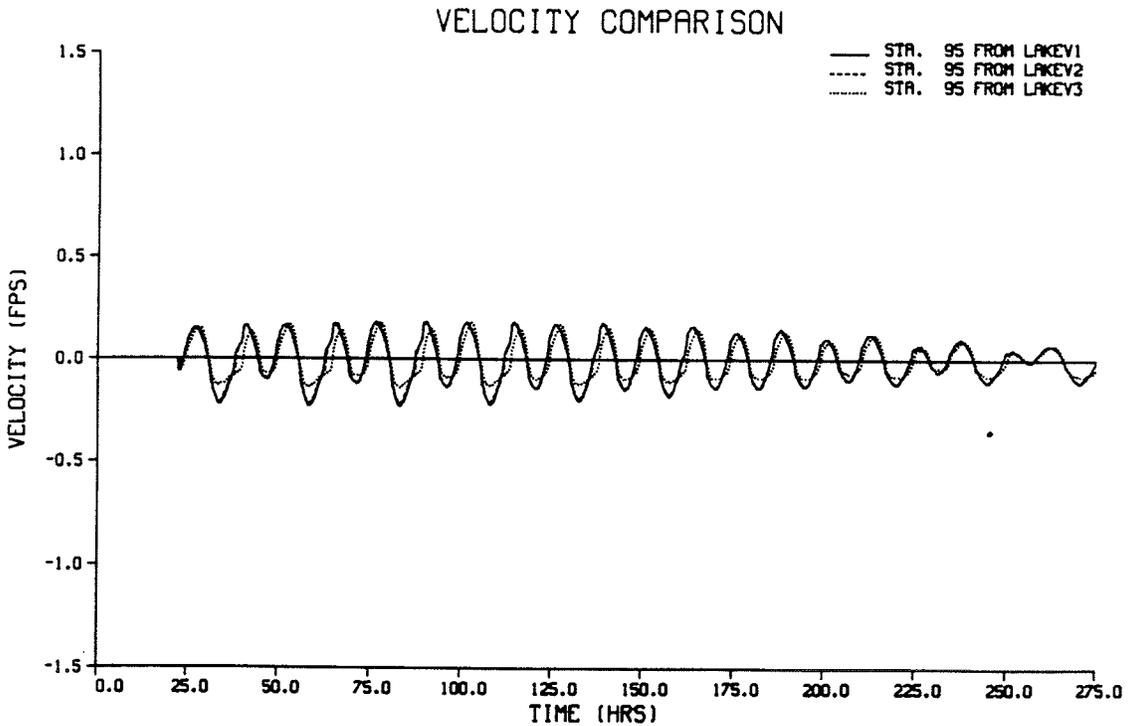


Figure 53. Average channel velocities in proposed marina, LAKEV1 = 350-ft entrance channel, LAKEV2 = 200-ft entrance channel, LAKEV3 = entrance channel closed

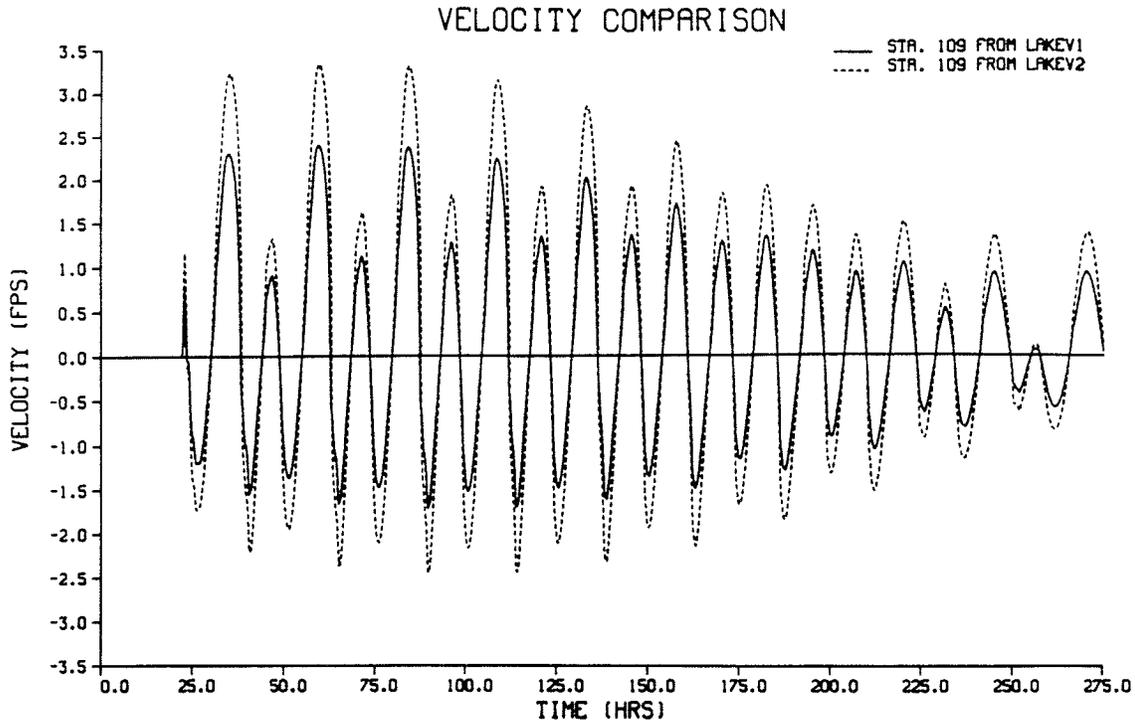


Figure 54. Average channel velocities in proposed entrance channel, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

Pacific Coast Highway (PCH) bridge at Anaheim Bay

22. Concern exists regarding the effects of strong currents on navigation craft which at times have difficulty entering and exiting Anaheim Bay at the Pacific Coast Highway bridge. Helical and spiral flow created by the velocity field at the relatively sharp curves approaching the PCH bridge where craft are required to maneuver tend to create a hazardous situation. The National Marine Fisheries Service also is concerned about such flow field effects on potential bank erosion of the wetlands at Seal Beach. Potential increases in velocity under the PCH bridge due to any increase in tidal prism for nourishing wetland areas at Bolsa Chica are of significant concern to navigation.

23. The existing maximum average channel velocity simulated through this PCH bridge opening is 2.78 ft per sec. Lake 1 alternative indicates the maximum average channel velocity at this location will be 2.50 ft per sec. This implies that the 350-ft wide entrance channel with a bottom elevation of

-6 ft msl is capable of supporting the proposed wetland enhancement areas at Bolsa Chica, and also conveys a small portion of that tidal prism to Bolsa Chica all of which otherwise would be required to enter by way of the PCH bridge at Anaheim Bay. Lake 2 alternative (200-ft wide entrance channel) simulations result in a velocity of 2.74 ft per sec under the PCH bridge at Anaheim Bay, effectively the same as existing conditions. Hence, the Lake 2 entrance channel at Bolsa Chica provides enough tidal prism to support the enhanced wetland areas at Bolsa Chica. If the Lake Plan alternative entrance channel at Bolsa Chica is permitted to close, the entire tidal prism must be conveyed by the opening under the PCH bridge at Anaheim Bay. The Lake 3 simulation (proposed entrance channel at Bolsa Chica closed) indicates the maximum average channel velocity at the PCH bridge at Anaheim Bay will increase to 3.24 ft per sec, an increase of 17 percent over present conditions.

Huntington Harbour

24. Average channel velocities in Huntington Harbour resulting from the Lake Plan alternatives are directly related to existing velocities in approximately the same manner as average channel velocities under the PCH bridge at Anaheim Bay. In general, Lake 1 slightly reduces Huntington Harbour velocities while Lake 2 induces about the same magnitude as existing conditions. Average channel velocities resulting from the Lake 3 alternative approach 2.0 ft per sec in the western section of Huntington Harbour under extreme spring high tide conditions (tidal range on the order of 8 ft), and may thus become hazardous for swimming and navigation (Figures 24 through 46, and Table 2).

Warner Avenue bridge

25. Under the Lake Plan alternatives, Outer Bolsa Bay and Warner Avenue bridge remain in their present conditions. Average channel velocities at the Warner Avenue bridge decrease by about 44 percent for the Lake 1 alternative (from about 1.65 to about 0.93 ft per sec), and remain approximately the same as existing conditions for the Lake 2 alternative. If the proposed entrance channel at Bolsa Chica is permitted to close, thereby requiring all tidal flow to the Bolsa Chica wetlands to pass under Warner Avenue bridge, average channel velocities will increase by about a factor of 3, from 1.65 to 4.80 ft per sec (190 percent increase). Bridge stabilization measures would

likely be necessary to prevent scour and erosion of the bridge abutments, and channel bottoms beneath the bridge and into Huntington Harbour. (Figure 47, and Table 2)

Outer Bolsa Bay

26. The enhanced wetland regions at Bolsa Chica for the Lake Plan alternatives will fill and empty through the proposed new entrance channel to the Pacific Ocean at Bolsa Chica. Hence, it will not be necessary for all the wetland tidal prism to pass through Outer Bolsa Bay. Lake 1 and Lake 2 thereby results in lower average channel velocities in Outer Bolsa Bay than for existing conditions. The Lake 3 alternative, however, indicates that average channel velocities in Outer Bolsa Bay will increase a maximum from 1.35 to 1.73 ft per sec, with the average increase for Outer Bolsa Bay being 39 percent. Hence, scour of unconsolidated bay sediments may occur. Channel stabilization measures in Outer Bolsa Bay may be necessary near the Warner Avenue bridge to prevent shoal material from accumulating in Huntington Harbour, and at the proposed marina channel at Bolsa Chica (Figures 48 through 51, and Table 2).

Proposed Lake Plan marina channel

27. Cross-sectional areas of the channels through the proposed marina complex at Bolsa Chica are sufficiently large such that maximum spring tide average channel velocities will remain small (up to 0.67 ft per sec) (Figures 52 and 53, and Table 2). Swimmer and navigation hazards would not ensue from such mild average velocities in the Lake Plan marina channel.

Proposed ocean entrance channel at Bolsa Chica

28. Average channel velocities in the non-navigable entrance to the marina complex at Bolsa Chica exceed that sufficient for initiation of movement of sandy particles, being 2.40 and 3.34 ft per sec for the Lake 1 and Lake 2 concepts, respectively. Previously, Hughes (1988) considered the potential of the Secondary Alternative (non-navigable entrance of 160-ft width and 5-ft depth) at Bolsa Chica to close by littoral material transport in the surf zone. In that concept, Warner Avenue bridge is relocated and the channel in that vicinity is enlarged by a factor of 2.5; hence, no restriction at Warner Avenue bridge exists for the Secondary Alternative concept. The predominant volume of tidal prism of the tidal wetlands at Bolsa Chica passes through the relocated Warner Avenue bridge, with the average channel

velocities in the entrance channel at Bolsa Chica approaching only about 1.35 ft per sec.

29. Hughes (1988) concluded that it is difficult to state whether the proposed ocean entrance at Bolsa Chica will shoal to the point of closure after reaching an equilibrium area compatible with observed prototype inlets for a maximum average velocity of 1.35 ft per sec. He recommended that during any final design phase, a numerical tidal circulation model be developed for analyzing this particular condition. Such analysis is presently beyond the scope of this investigation. However, the existing restrictions afforded by Warner Avenue bridge will continue to exist under Lake Plan alternative concepts, and the wetland tidal prism could be required to pass through the proposed non-navigable entrance channel at Bolsa Chica. Average channel velocities of either 2.4 ft per sec (Lake 1) or 3.34 ft per sec (Lake 2) would be sufficient to scour surf zone littoral material from the entrance channel and maintain a non-navigable tidal exchange between the Pacific Ocean and the proposed enhanced wetlands at Bolsa Chica. The initiation of motion for quartz sediments depends directly on the grain size. Unconsolidated medium sand in the surf zone with diameters up to 1.0 mm can be placed in motion by velocities around 1.0 ft per sec. Finer size particles are affected by cohesive forces, and can withstand much higher velocities without scouring.

Effect of Interior Wetlands Connection at Bolsa Chica

30. Existing Inner Bolsa Bay may or may not be connected to the proposed muted tidal wetlands by an opening through the dike along Link 162 which would connect Node 50 (at the rear of Inner Bolsa Bay) with Node 134 (in the proposed muted tidal wetland region). The DYNTRAN simulations were performed both with and without this wetland connection. It was determined that any effects created by such connections within the wetlands would not propagate through the culvert and tide gate system into the marinas and other regions of Bolsa Chica. Effects resulting from changes within the wetlands are confined to the wetlands. The effects of a wetland connection at Link 162 on water surface elevations are displayed in Figures 55 through 57 for Inner Bolsa Bay (Nodes 37, 45, and 50), Figure 58 for the DFG muted tidal cell (Node 54), Figures 59 through 61 for the proposed full tidal wetlands

(Nodes 97, 112, and 113), and Figures 62 through 65 for the proposed muted tidal wetlands (Nodes 117, 123, 129, and 132), respectively.

31. If Inner Bolsa Bay is connected to the proposed muted tidal wetlands by a breach in the dike which separates the two wetland regions, the water surface elevation in Inner Bolsa Bay will rise about 0.15 ft higher than if the two wetlands remain isolated from each other. This occurs because of flow entering the proposed muted tidal wetlands through culvert systems with twice the conveyance of the culvert system which would otherwise connect Inner Bolsa Bay with the marina complex (Figures 55 through 57). The DFG muted tidal cell also experiences about a 0.15 ft increase in high tide elevations (Figure 58), as its high tide responds essentially as existing Inner Bolsa Bay at high tide. The proposed full tidal wetlands are unaffected by the presence or absence of a connection between Inner Bolsa Bay and the proposed muted tidal wetlands (Figures 59 through 61). The proposed muted tidal wetlands will experience about a 0.10 ft decrease in maximum water surface elevations as this volume is permitted to flow into Inner Bolsa Bay through the highly efficient breach in the dike system (Figures 62 through 65). The hydraulic connections between the Pacific Ocean and the wetlands, the wetland design, and the culvert system design and operation, can be optimized to provide any reasonable degree (within maximum limits) of tidal muting, flooding, and inundation to support marine life and vegetation varieties.

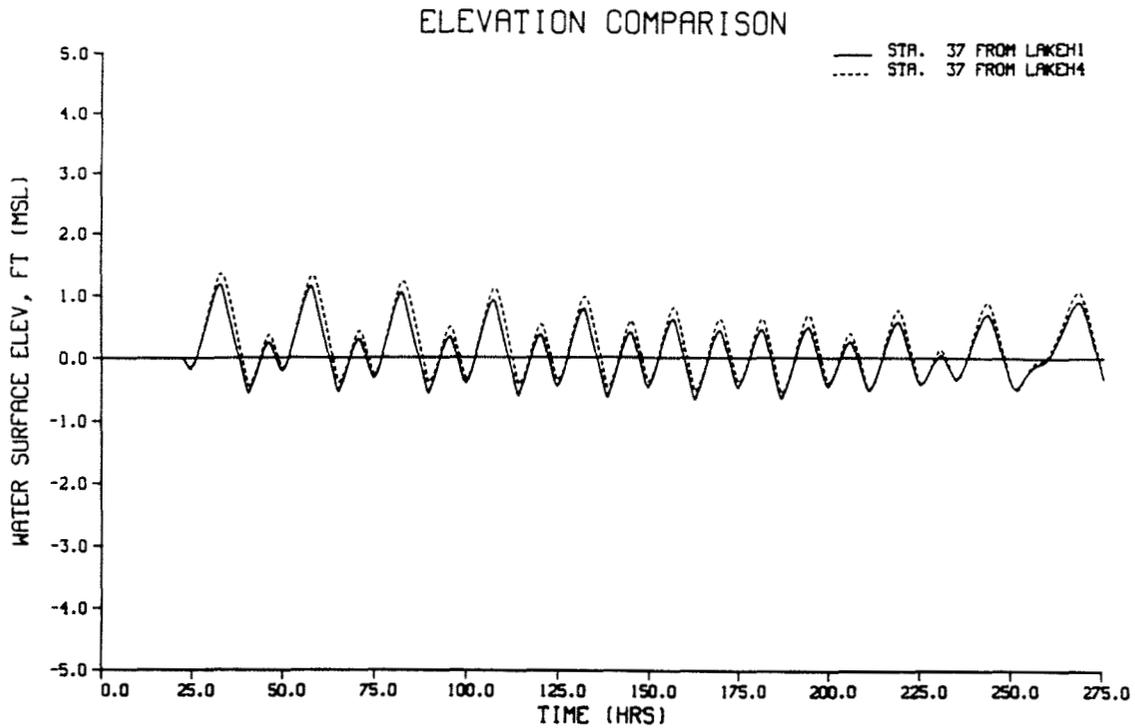


Figure 55. Effect of wetland connection on water surface elevations in Inner Bolsa Bay, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

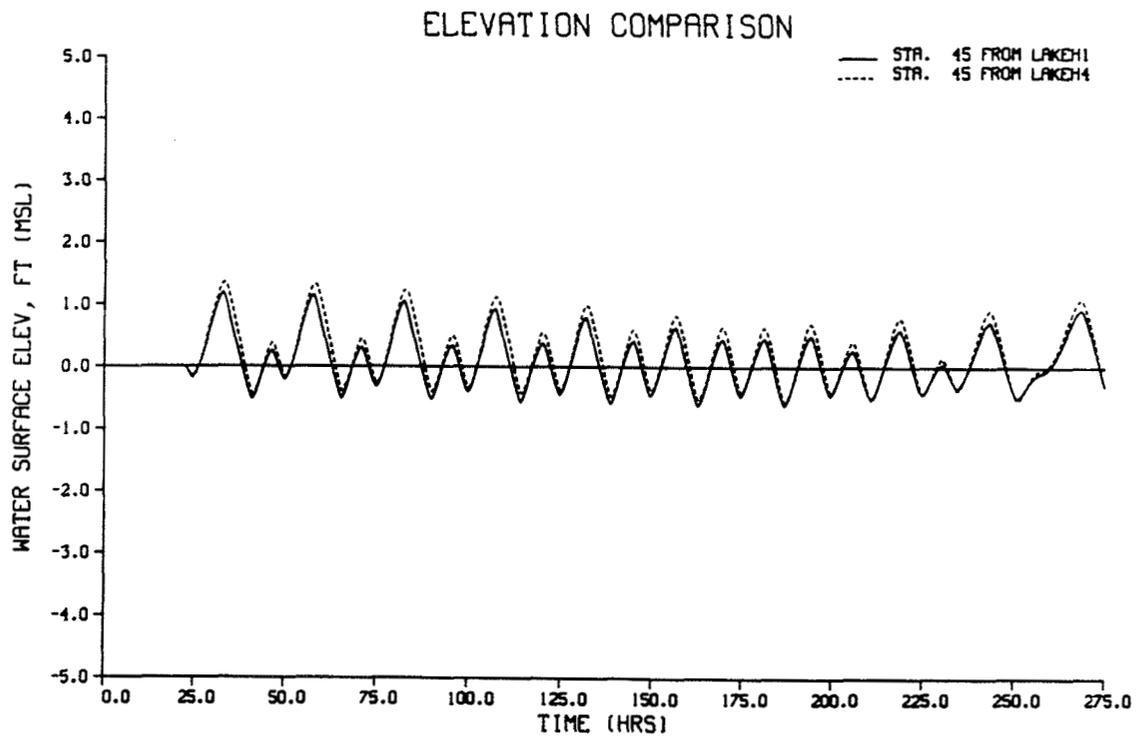


Figure 56. Effect of wetland connection on water surface elevations in Inner Bolsa Bay, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

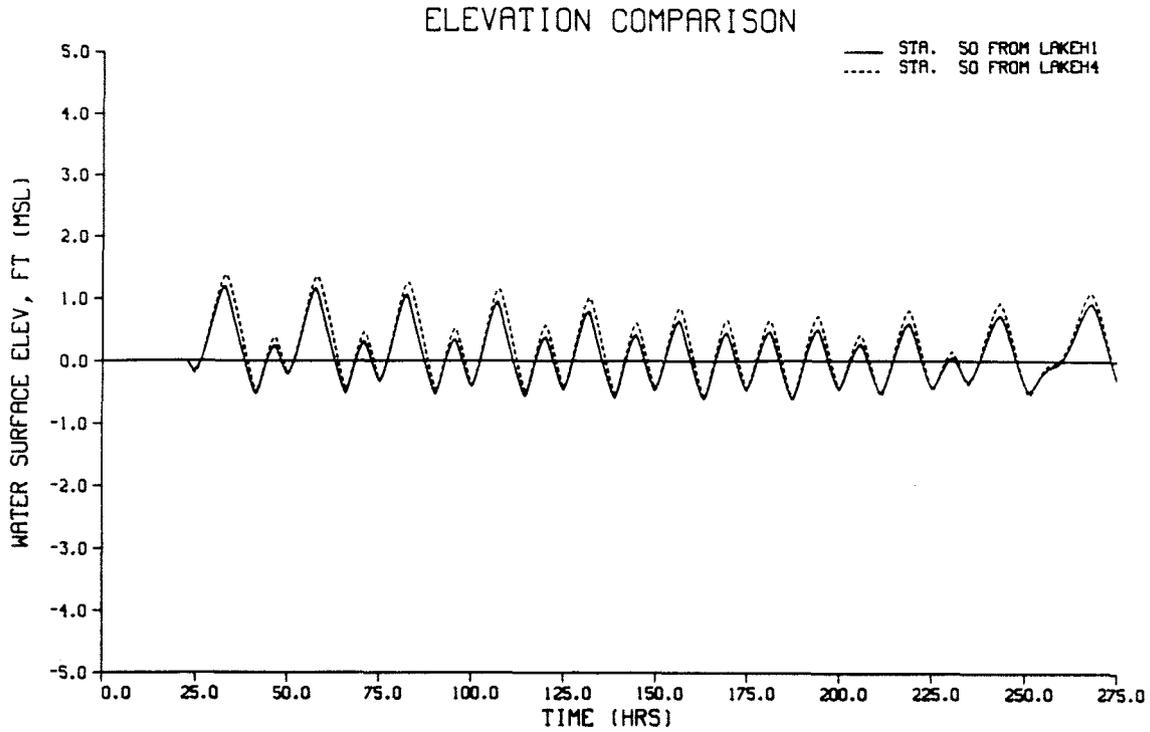


Figure 57. Effect of wetland connection on water surface elevations in Inner Bolsa Bay, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

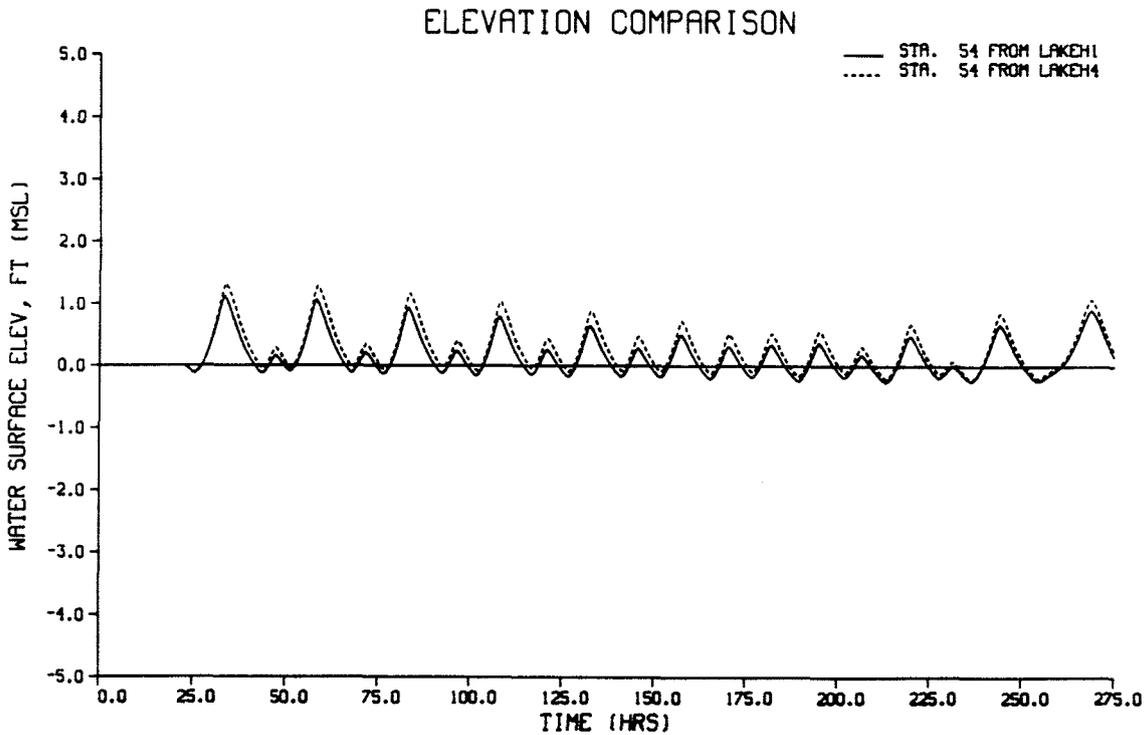


Figure 58. Effect of wetland connection on water surface elevations in DFG muted tidal cell, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

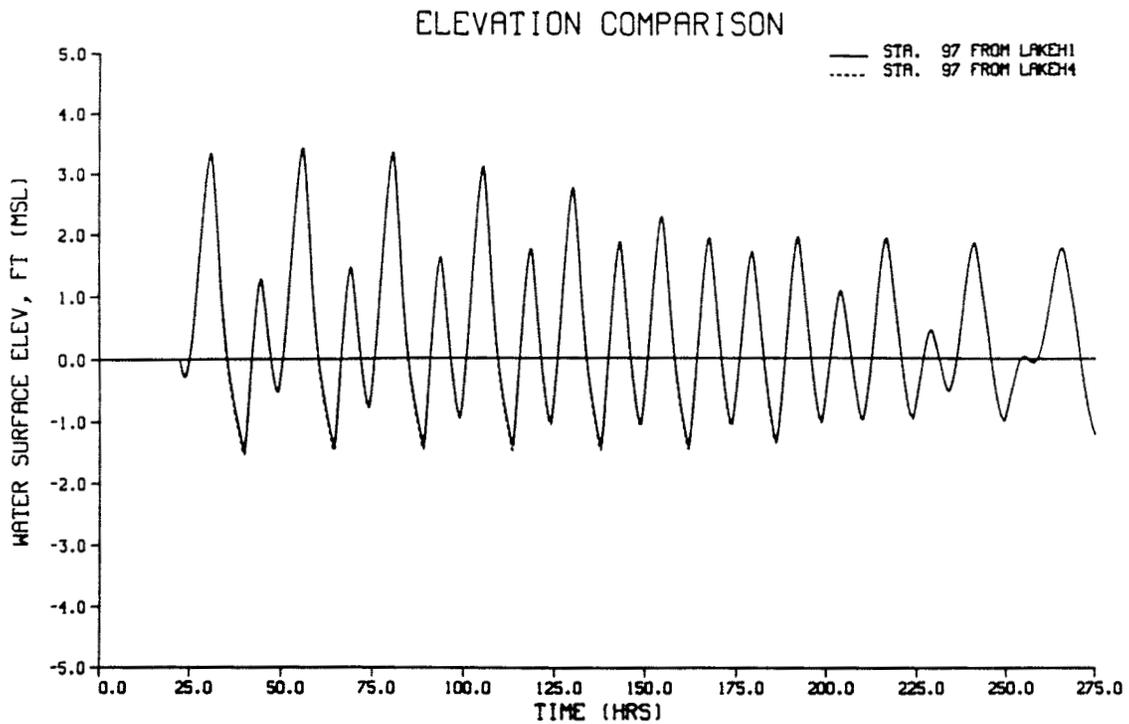


Figure 59. Effect of wetland connection on water surface elevations in proposed full tidal wetlands, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

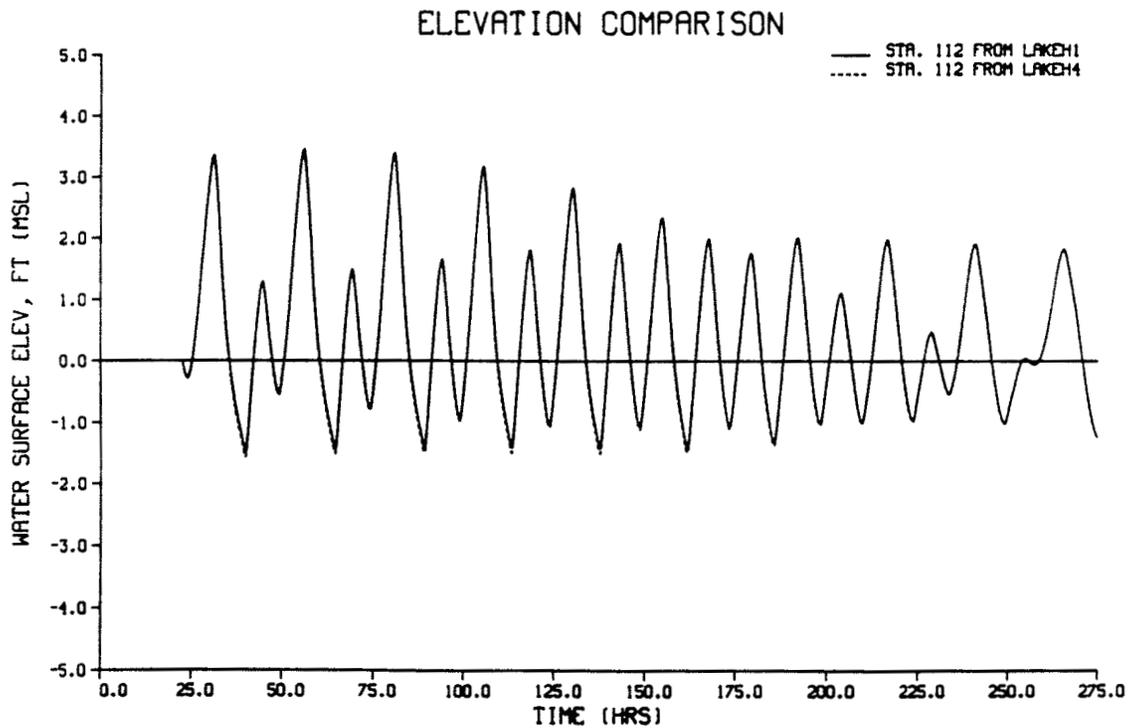


Figure 60. Effect of wetland connection on water surface elevations in proposed full tidal wetlands, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

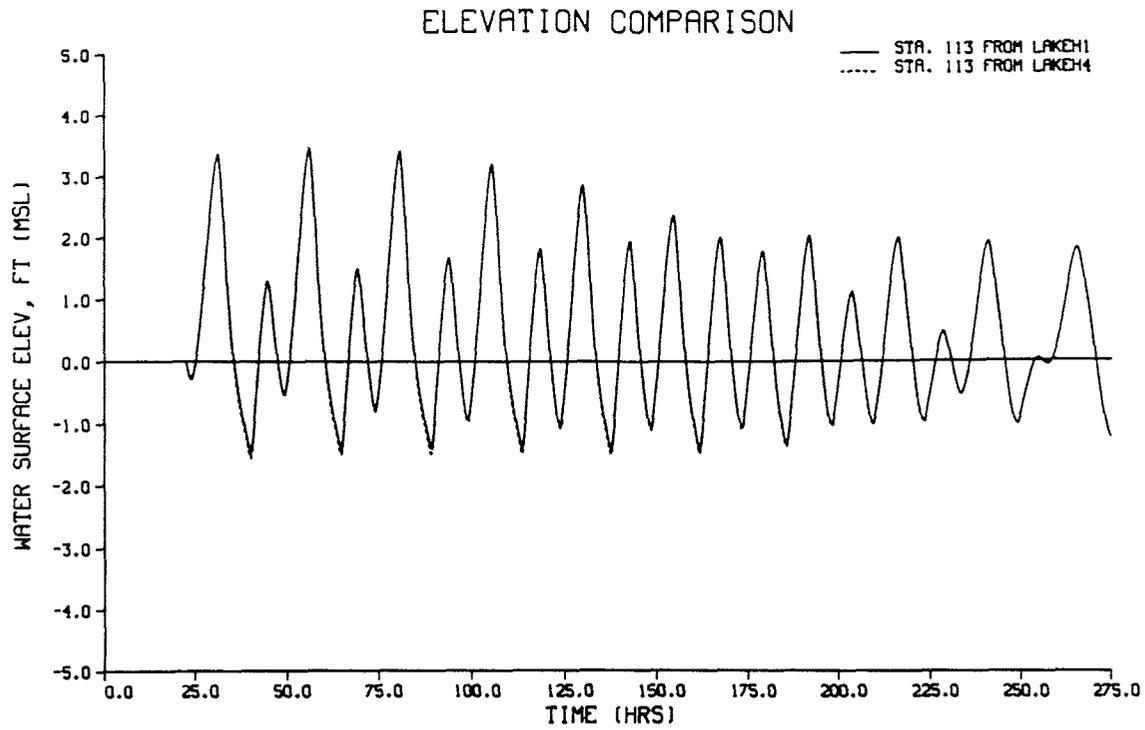


Figure 61. Effect of wetland connection on water surface elevations in proposed full tidal wetlands, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

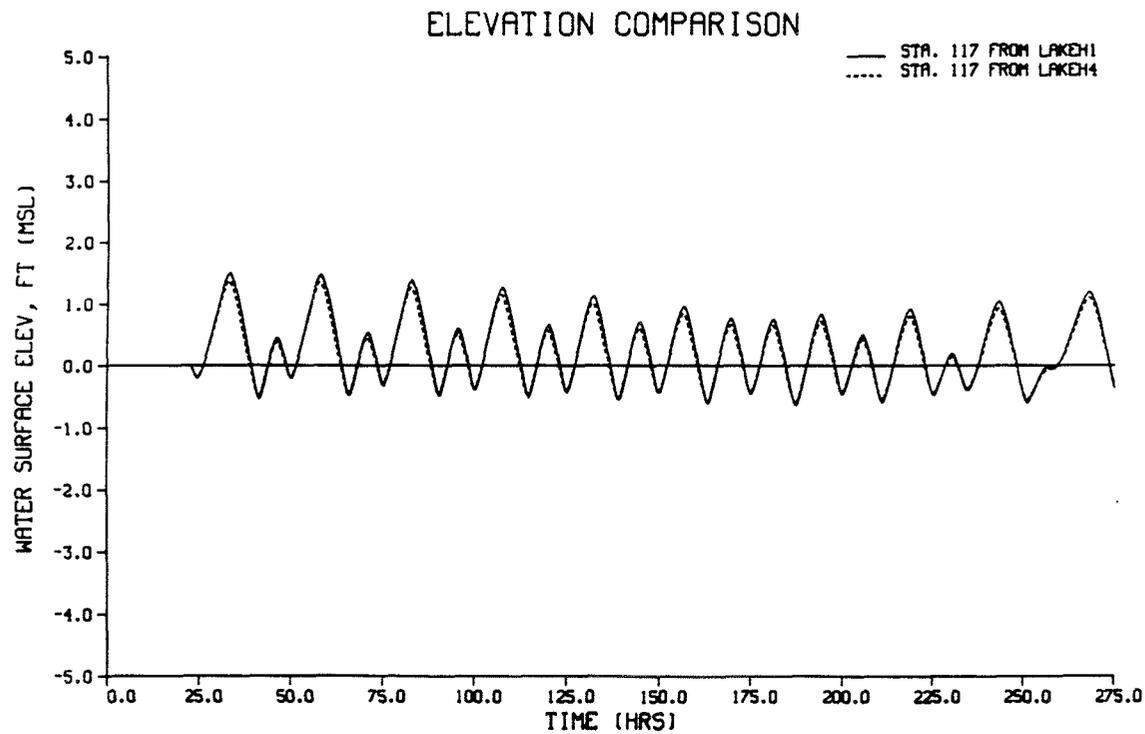


Figure 62. Effect of wetland connection on water surface elevations in proposed muted tidal wetlands, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

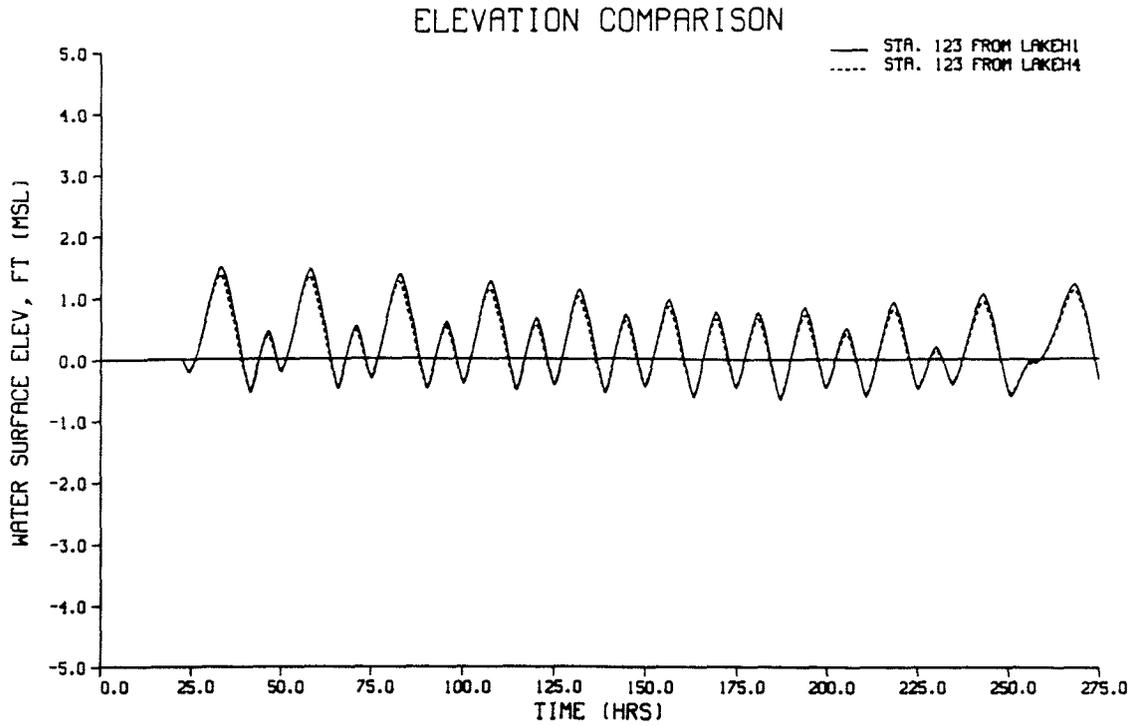


Figure 63. Effect of wetland connection on water surface elevations in proposed muted tidal wetlands, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

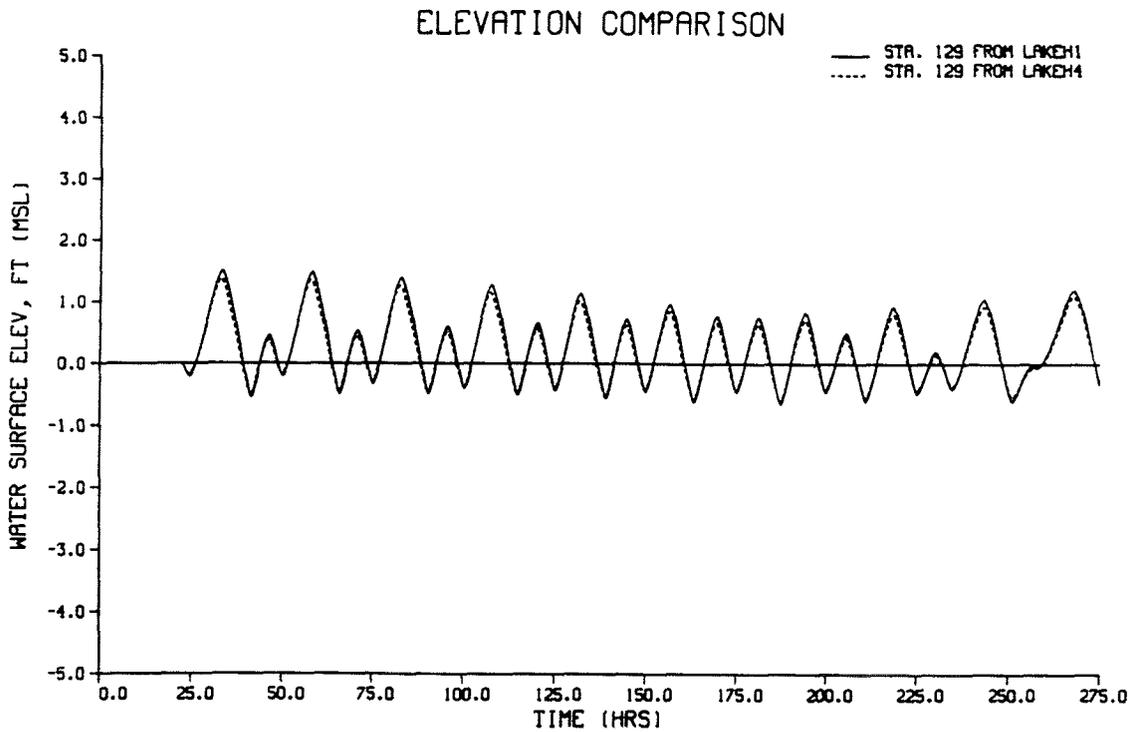


Figure 64. Effect of wetland connection on water surface elevations in proposed muted tidal wetlands, LAKEH1 - wetlands not connected, LAKEH4 - wetlands connected

ELEVATION COMPARISON

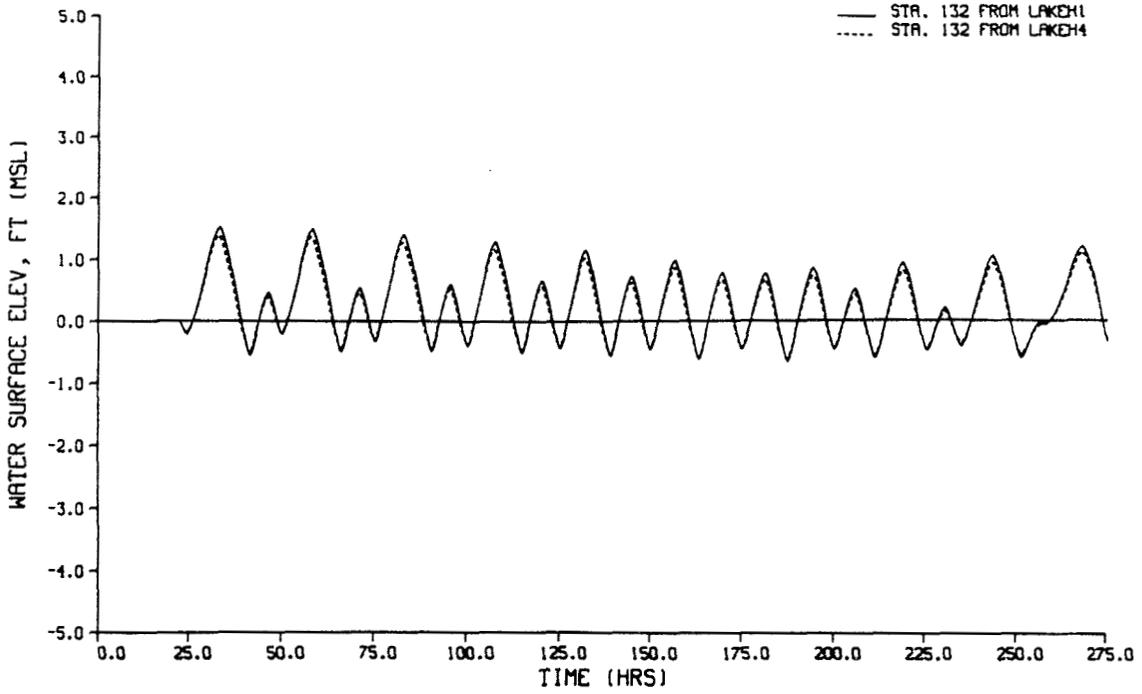


Figure 65. Effect of wetland connection on water surface elevations in proposed muted tidal wetlands, LAKH1 - wetlands not connected, LAKH4 - wetlands connected

PART III: EAST GARDEN GROVE-WINTERSBURG FLOOD CONTROL CHANNEL
(EGG-WFCC) 100-YEAR FLOOD FLOW

32. The hydrograph for the 100-year frequency of occurrence flood for the EGG-WFCC watershed has been developed by Moffatt & Nichol, Engineers (1986), based on hydrology guidance provided by the Orange County Flood Control District (1986). The peak flow rate for the 100-year flood was determined to be 9,710 cfs. This estimated 100-year peak flow rate is 23 percent higher than the 1977 estimate, and is the result of improved hydraulic data presently utilized by the County of Orange. The lower reaches of the existing earthen-lined WFCC can presently convey only approximately 65 percent of a 25-year storm. It is assumed that the channel will be improved upstream of the Bolsa Chica project to a 100-year storm runoff capacity.

Water Surface Elevations

33. Concern exists regarding the maximum flood flow elevations which may be reached in Huntington Harbour, the proposed Lake Plan marina, and wetlands by the 100-year flood, for both existing conditions and various alternative proposed plans for wetland enhancement at Bolsa Chica. Levee elevations with adequate freeboard will be established to preclude flood flow overtopping. It is assumed that all culvert systems will function during a 100-year storm flood conditions in the same manner as during normal tidal cycles; i.e., the culverts will not be closed to prevent flood flow from entering either the existing or proposed wetlands.

34. Accordingly, the 100-year flood flow (9,710 cfs) was introduced through flood control gates on the EGG-WFCC at the proposed Bolsa Chica-Garfield Roadway location. The numerical model was operated for 3 days under simultaneous spring tide and flood flow conditions. While the peak flow rate will last only a few hours, the 3-day model simulation was performed to observe maximum dynamic equilibrium elevations which would develop in the wetlands. Maximum water surface elevations for existing conditions and alternative Lake Plans are displayed in Figures 66 through 77 for representative locations throughout the Bolsa Chica system. Table 3 presents maximum

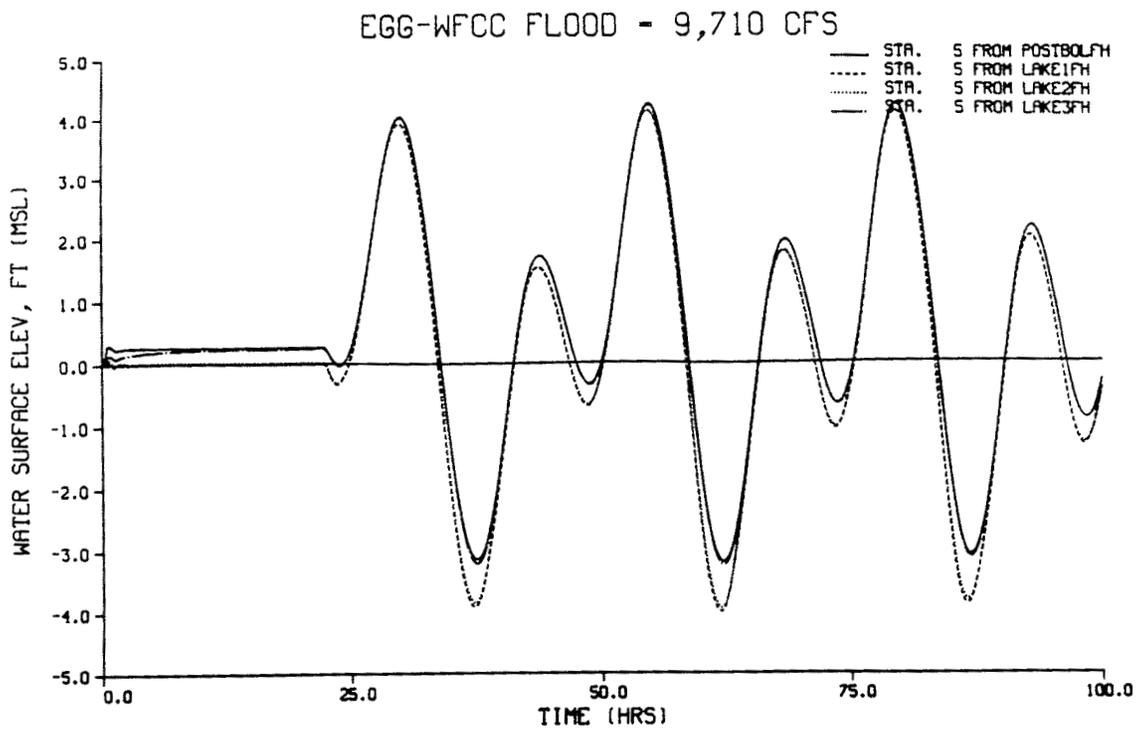


Figure 66. Water surface elevations in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

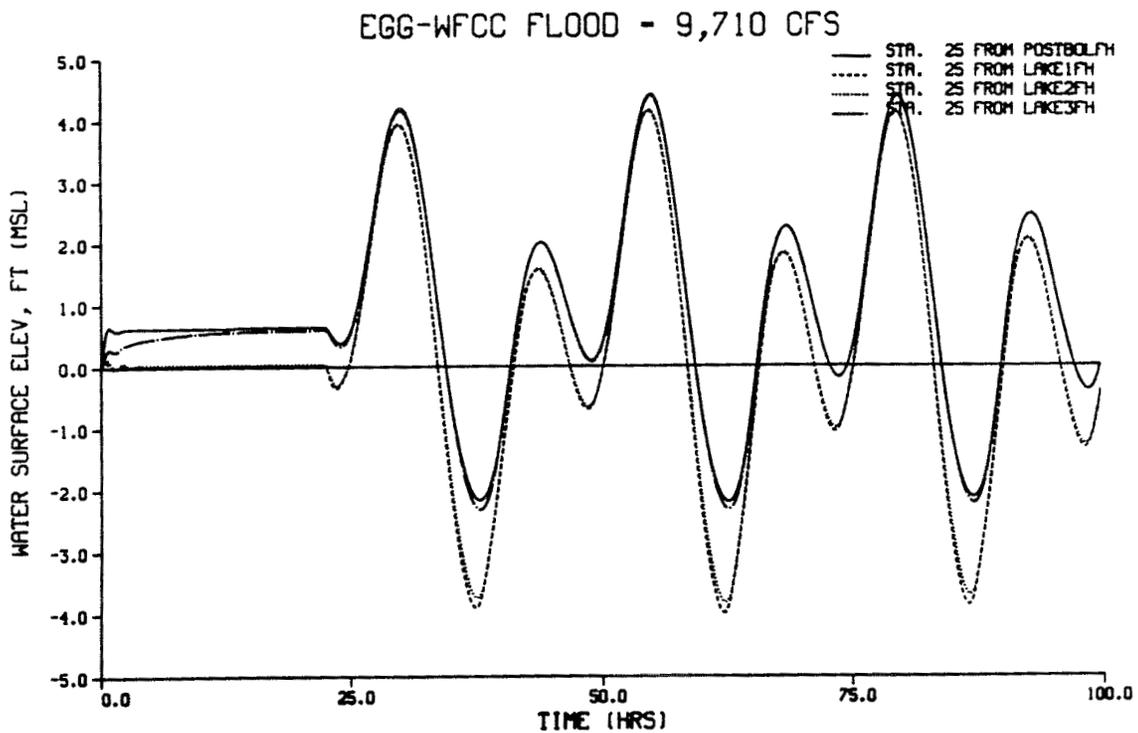


Figure 67. Water surface elevations in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

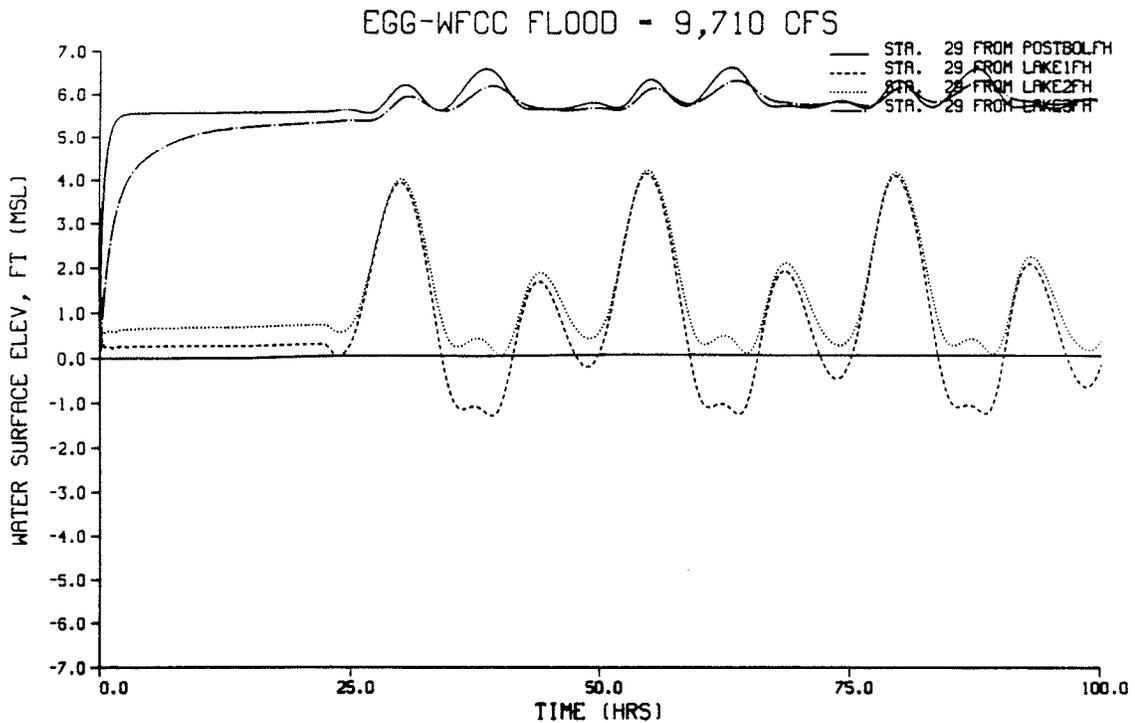


Figure 68. Water surface elevations in Outer Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

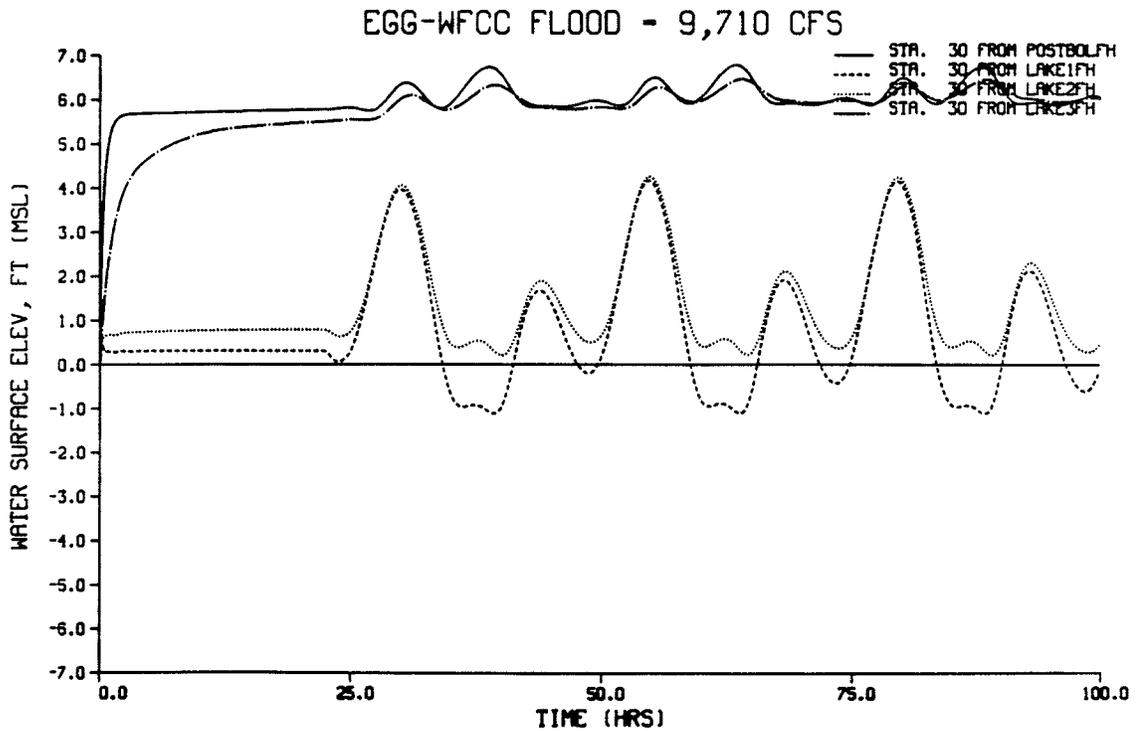


Figure 69. Water surface elevations in Outer Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

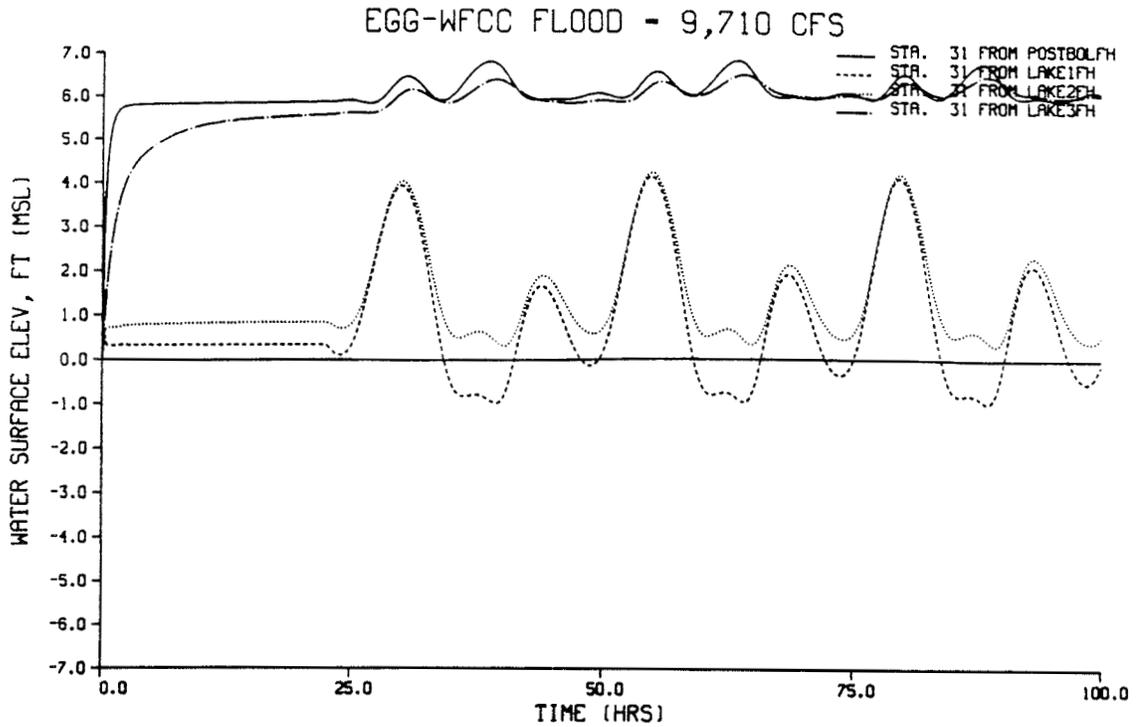


Figure 70. Water surface elevations in Outer Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

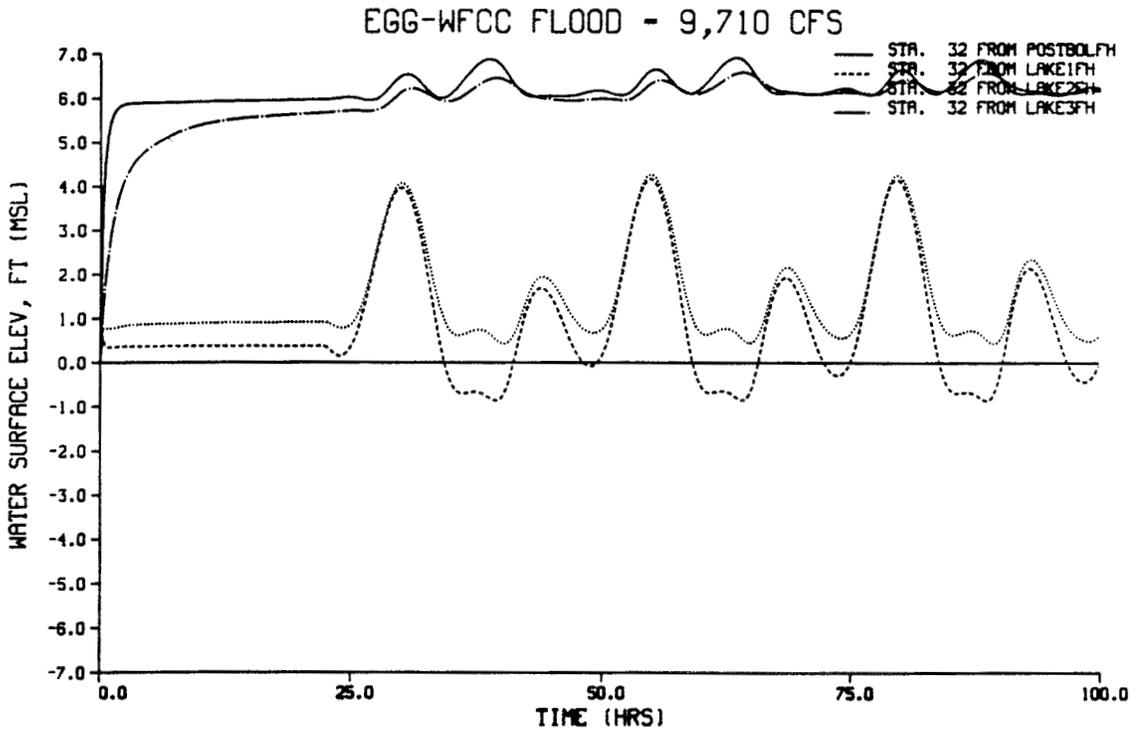


Figure 71. Water surface elevations in Outer Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

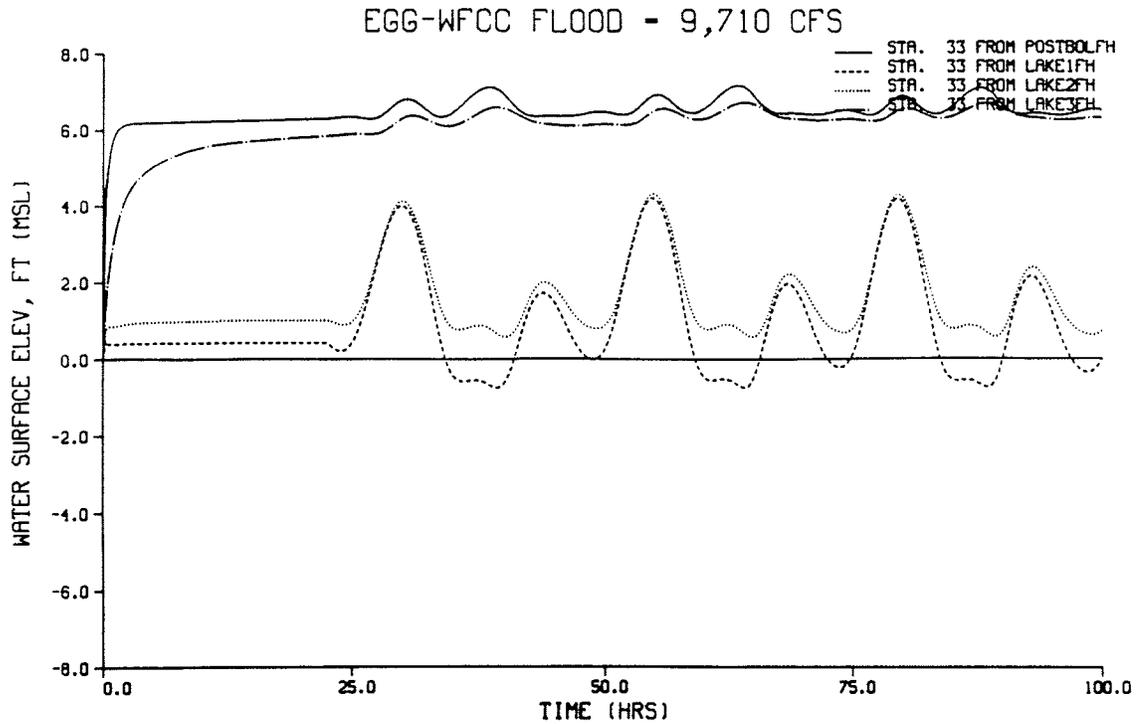


Figure 72. Water surface elevations in Outer Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

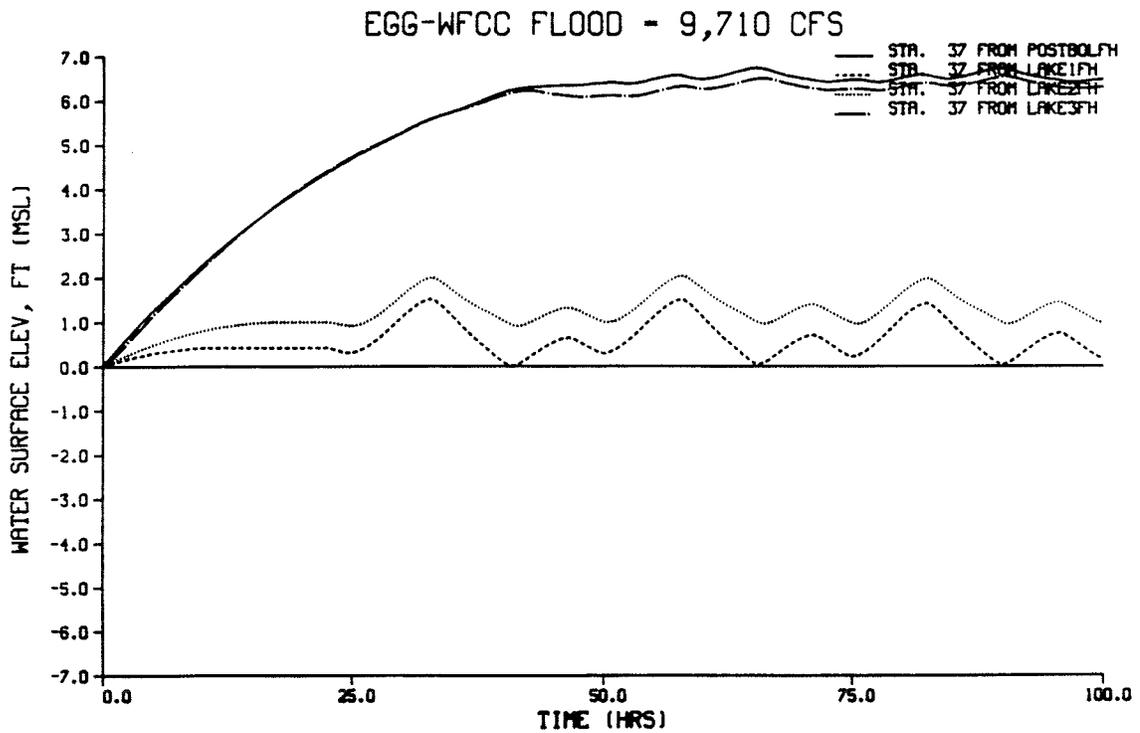


Figure 73. Water surface elevations in Inner Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

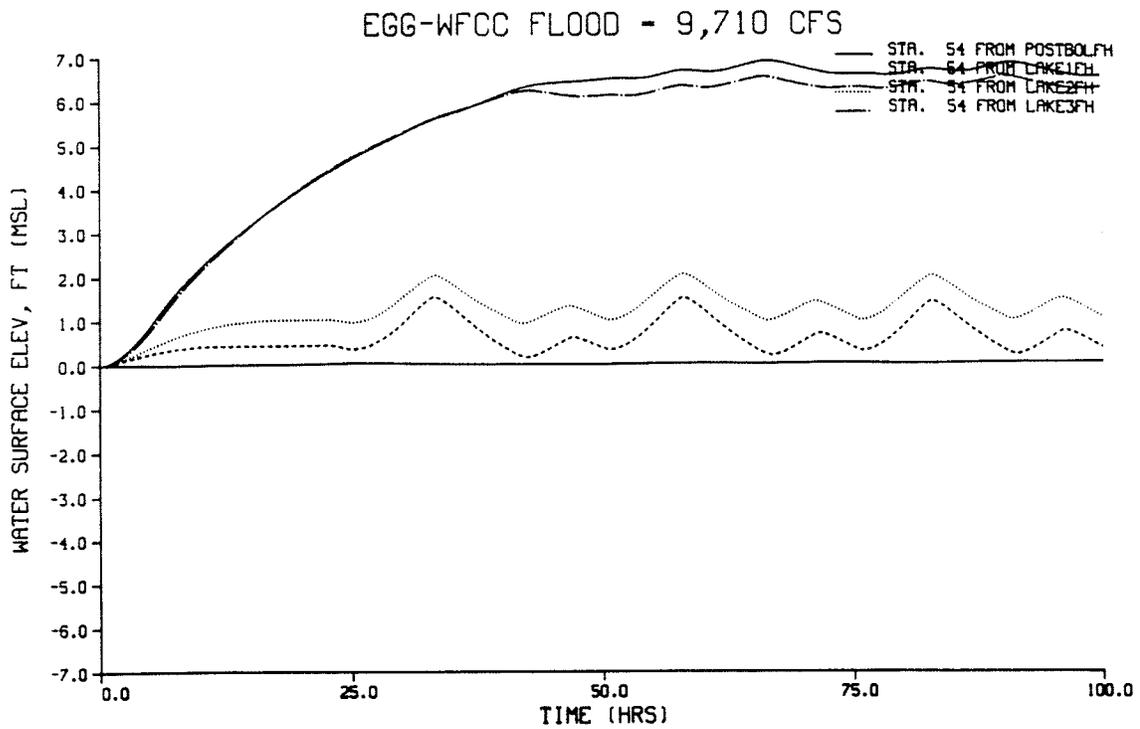


Figure 74. Water surface elevations in DFG muted tidal cell, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

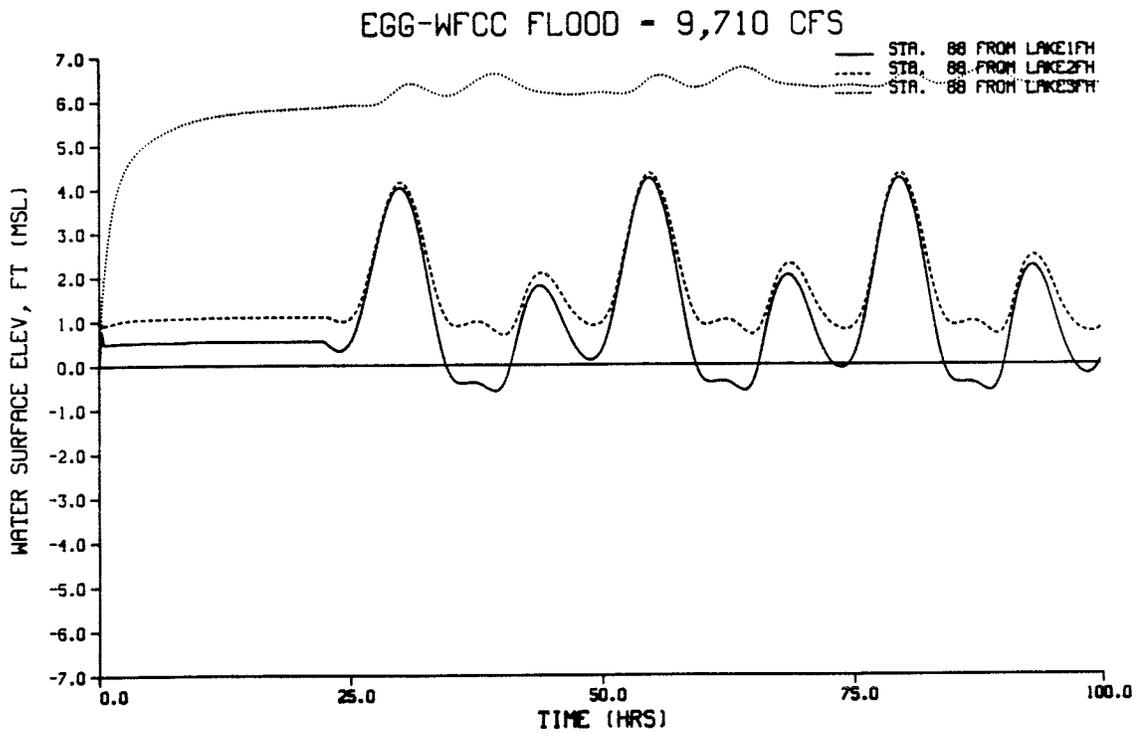


Figure 75. Water surface elevations in proposed marina, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

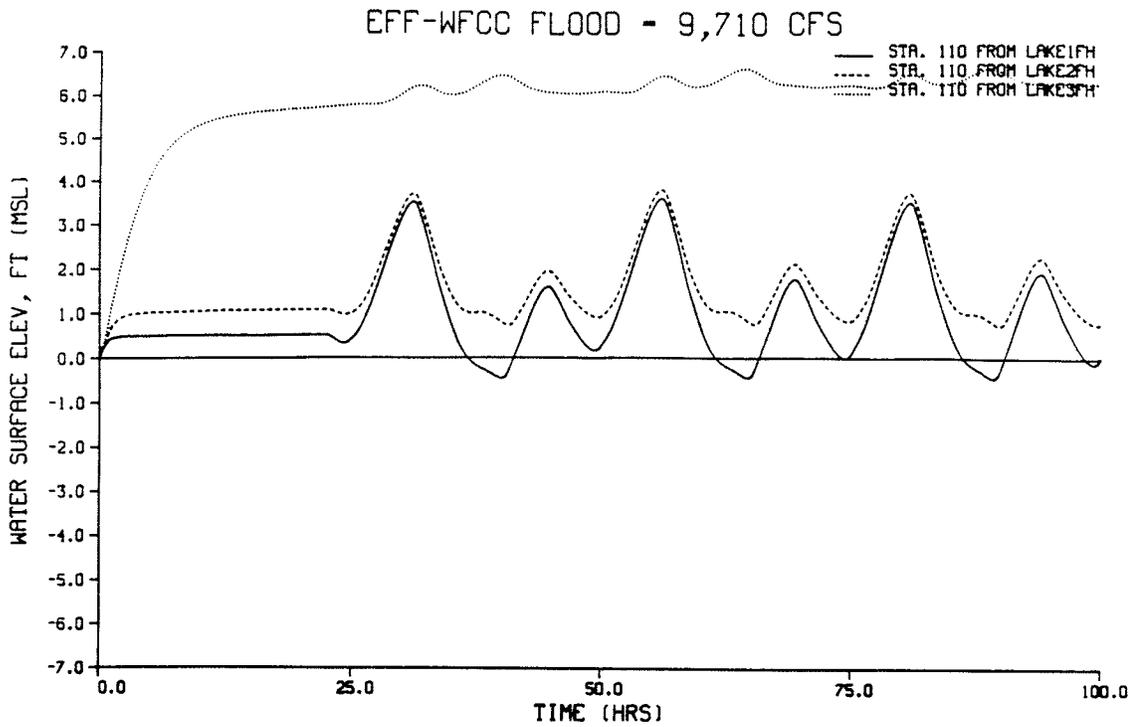


Figure 76. Water surface elevations in proposed full tidal wetlands, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

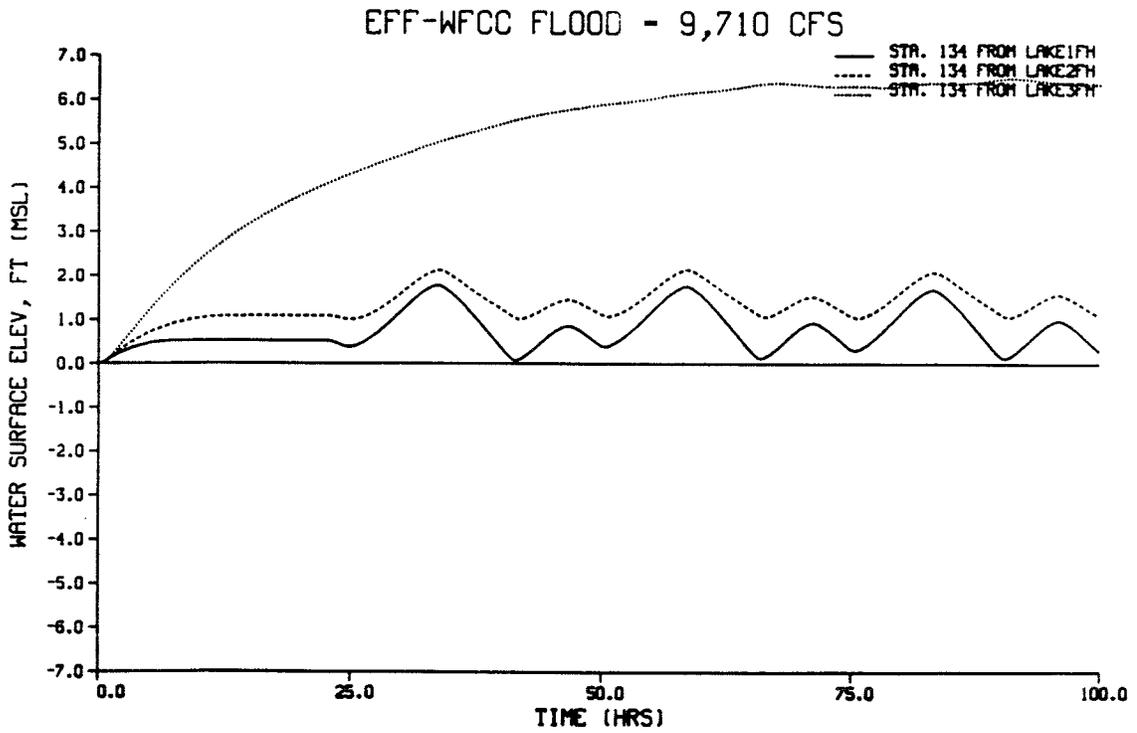


Figure 77. Water surface elevations in proposed muted tidal wetlands, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

Table 3
Maximum Water Surface Elevations
Spring Tide plus 100-Year Flood Flow (9,710 cfs) in
East Garden Grove-Wintersburg Flood Control Channel

<u>Location</u>	<u>Node</u>	<u>Elevation, feet (msl)</u>				
		<u>POSTBOL Spring</u>	<u>POSTBOL Flood</u>	<u>Lake 1 Flood</u>	<u>Lake 2 Flood</u>	<u>Lake 3 Flood</u>
Huntington Harbour	10	4.10	4.35	4.13	4.14	4.32
Huntington Harbour	25	4.10	4.40	4.14	4.15	4.37
Outer Bolsa Bay	29	4.10	6.66	4.16	4.25	6.39
Outer Bolsa Bay	30	4.10	6.74	4.16	4.26	6.46
Outer Bolsa Bay	31	4.10	6.81	4.17	4.26	6.53
Outer Bolsa Bay	32	4.10	6.89	4.17	4.27	6.59
Outer Bolsa Bay	33	4.10	7.09	4.17	4.28	6.69
Inner Bolsa Bay	37	1.04	6.73	1.51	2.04	6.51
DFG muted tidal cell	54	0.98	6.85	1.50	2.04	6.51
Proposed marina	88	----	----	4.23	4.34	6.74
Proposed full tidal wetlands	110	----	----	3.64	3.85	6.72
Proposed muted tidal wetlands	134	----	----	1.76	2.14	6.46

POSTBOL - existing conditions
 Lake 1 - 350-ft wide entrance channel
 Lake 2 - 200-ft wide entrance channel
 Lake 3 - entrance channel closed

water surface elevations for the spring tide plus the simultaneous 100-year flood flow (9,710 cfs) in the EGG-WFCC.

Existing conditions

35. Under existing conditions, all flood flow is required to pass through Outer Bolsa Bay and Huntington Harbour. The wide conveyance channels of Huntington Harbour allow the passage of the flood flow with only minimal increase in maximum water surface elevation of about 0.3 ft, from about 4.1 to about 4.4 ft msl (Figures 66 and 67, and Table 3). Warner Avenue bridge acts as a restriction to the passage of the 100-year flood discharge, causing ponding to occur in Outer Bolsa Bay. The water surface elevation occurring from flood flows in Outer Bolsa Bay is estimated to reach 7.1 ft msl, an increase beyond the normal spring high tide elevation of about 3.0 ft (Figures 68 and 72, and Table 3).

36. Because of the elevated water surfaces in Outer Bolsa Bay, flooding also occurs in Inner Bolsa Bay, where the maximum water surface elevation increases to around 6.7 ft msl, an increase over normal spring high tide elevations of about 5.7 ft (Figure 73, and Table 3). A similar increase in water surface elevation occurs in the DFG muted tidal cell (Figure 74, and Table 3).

37. Damping created by Warner Avenue bridge prevents most undulations of tidal activity existing in Huntington Harbour from propagating upstream into Outer Bolsa Bay. Thus, the bridge opening prevents the passage of a quantity of flood flow that would otherwise be transmitted through the harbor. Such constriction results in a hydraulic drop across Warner Avenue bridge of about 2.3 ft, from 6.7 ft msl elevation in Outer Bolsa Bay (Node 29) to 4.4 ft msl in Huntington Harbour (Node 25).

Lake Plan alternatives

38. High tide elevations in Huntington Harbour and Outer Bolsa Bay for both Lake 1 and Lake 2 alternatives for the 100-year flood flow would remain approximately the same as existing spring tide elevations because the proposed non-navigable entrance at Bolsa Chica would permit flood flows to escape directly into the Pacific Ocean. The maximum difference in high tide elevations for spring and flood conditions would be only about 0.2 ft with the inclusion of the proposed channel at Bolsa Chica. Conversely, for Lake 3 when the entrance channel closes, all tidal prism must discharge through

Outer Bolsa Bay and Huntington Harbour. High tide elevations for this situation approximate those of existing flood flow (Figures 66 through 72, and Table 3).

39. Both Lake 1 and Lake 2 alternatives under flood flow conditions result in a moderate transient increase in water surface elevation in Inner Bolsa Bay and the DFG muted tidal cell, being about 0.5 ft and 1.0 ft, respectively (Figures 73 and 74, and Table 3). Lake 3 flood flow results in the existing muted tidal wetlands (Inner Bolsa Bay and the DFG cell) are slightly less than existing flood flow conditions, with the maximum water surface elevation increasing from about 1.0 to about 6.5 ft msl for Lake 3 floods, and to about 6.8 ft msl for existing condition floods.

40. Because neither the proposed Lake Plan marina, proposed full tidal wetlands, nor proposed muted tidal wetlands presently exist, it is not possible to compare results from the Lake Plan alternatives with existing conditions for these regions. Lake 1 and Lake 2 alternatives under flood flow conditions provide for modest increase in high tide elevations in the proposed full tidal wetlands beyond normal spring tide elevations, being about 0.2 and 0.4 ft, respectively. Lake 3 induces a significant increase for these conditions, being an increase of about 3.4 ft. Lake 1 and Lake 2 alternatives result in increases in high tide elevations in the proposed muted tidal wetlands for flood flow conditions beyond normal spring tide elevations of about 0.3 and 0.6 ft, respectively. Lake 3, however, induces an increase in this region of about 5.0 ft (Tables 1 and 3).

Average Channel Velocities

41. Maximum average channel velocities for the simultaneous occurrence of spring tide and 100-year flood flow discharging into the Bolsa Bay complex by the EGG-WFCC are presented in Figures 78 through 93 for representative locations throughout the system. These data are tabulated in Table 4. Warner Avenue bridge and Outer Bolsa Bay remain in their present condition for all Lake Plan alternative evaluations.

Existing conditions

42. Maximum average channel velocity increases throughout the Bolsa Chica system are non-linearly proportional to the water surface elevation

EGG-WFCC FLOOD - 9,710 CFS

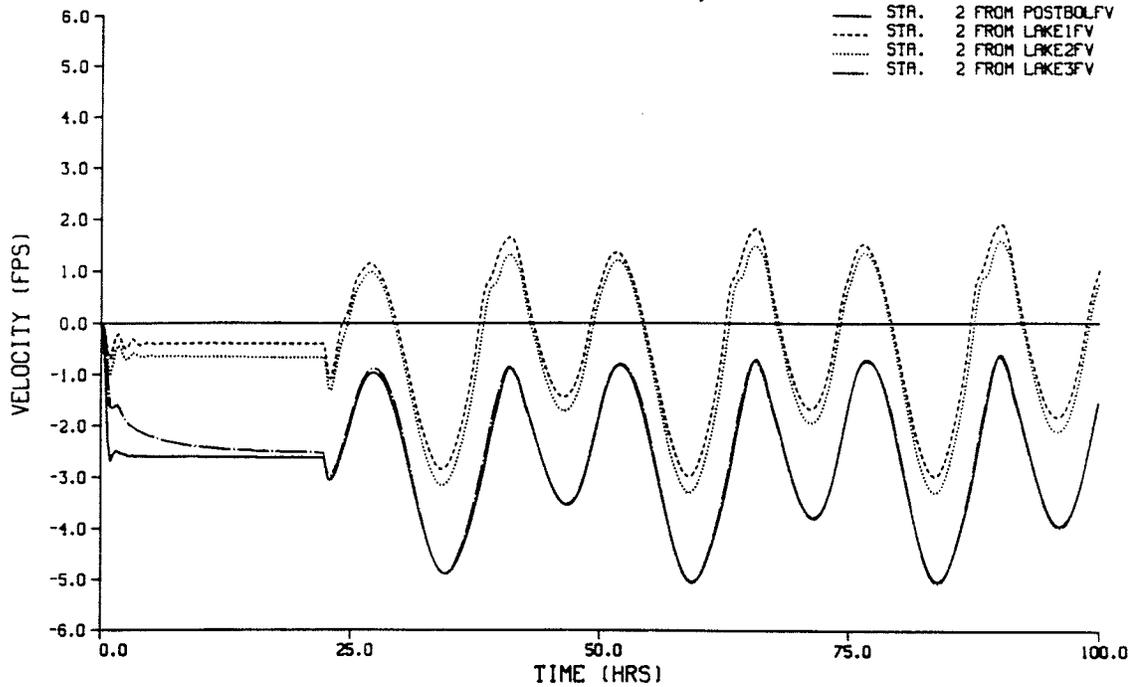


Figure 78. Average channel velocities under PCH bridge at Anaheim Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EFF-WFCC FLOOD - 9,710 CFS

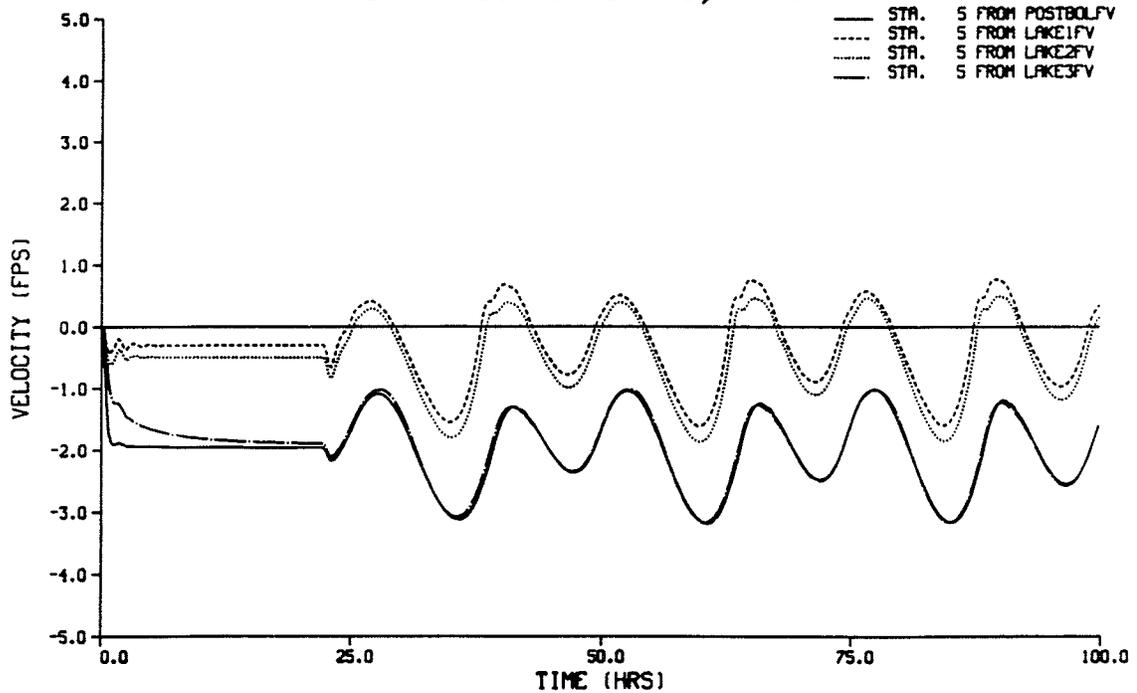


Figure 79. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

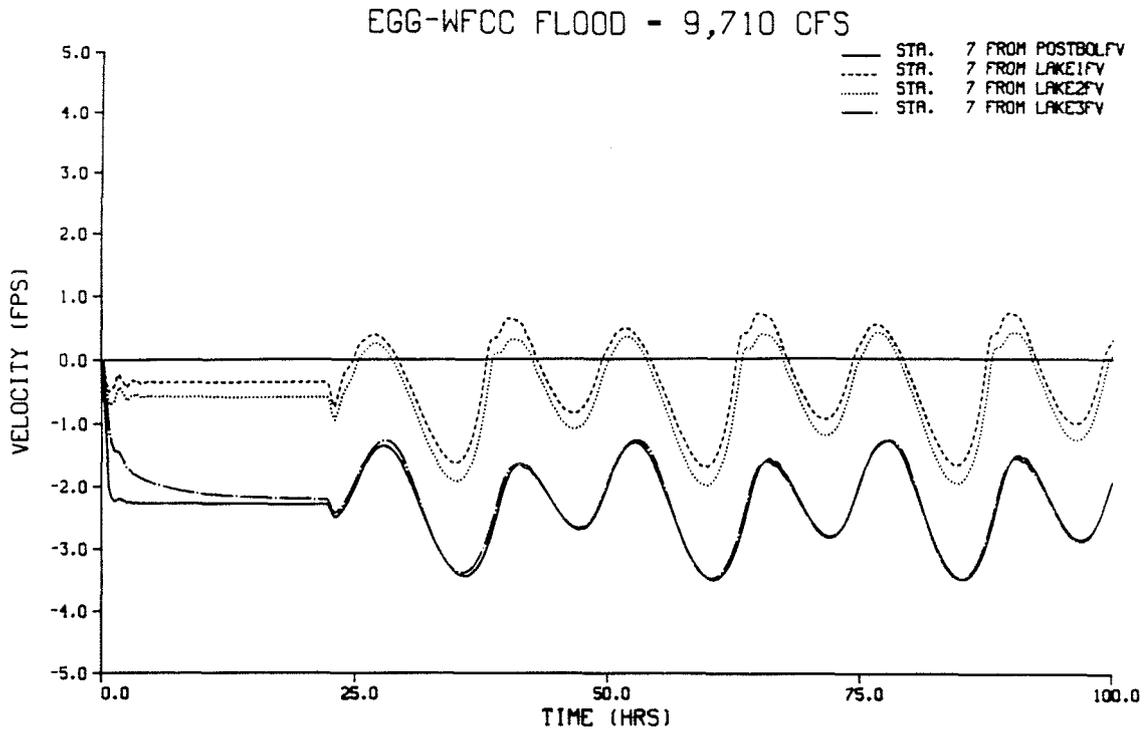


Figure 80. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

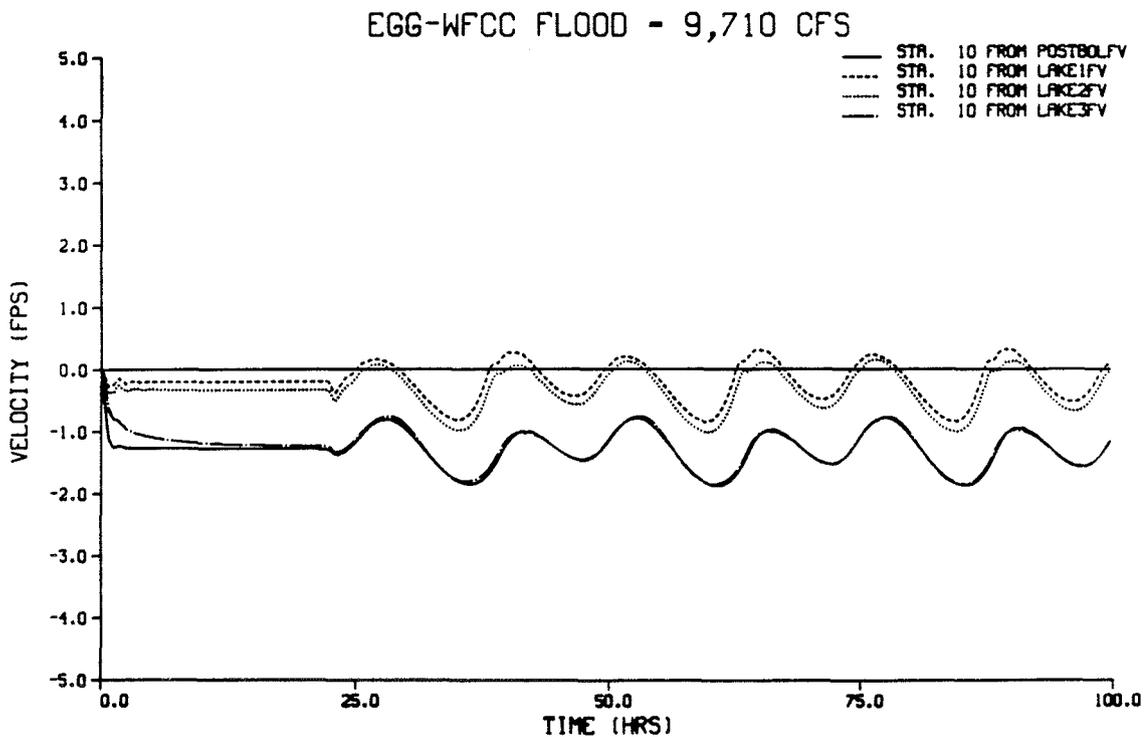


Figure 81. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EFF-WFCC FLOOD - 9,710 CFS

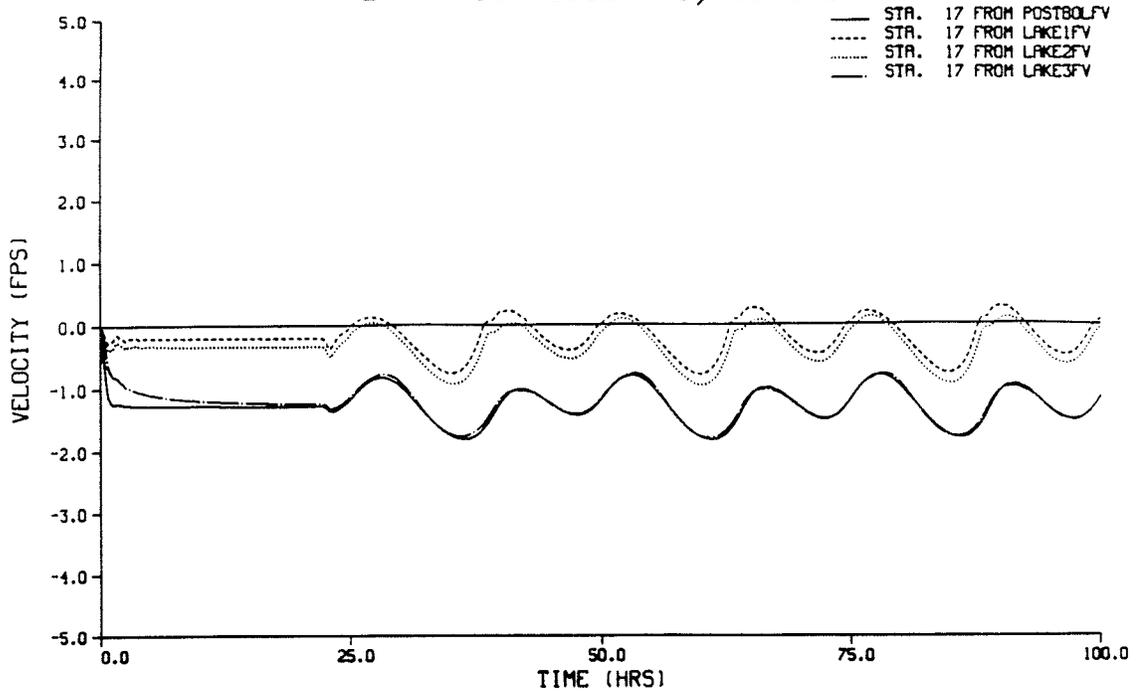


Figure 82. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EGG-WFCC FLOOD - 9,710 CFS

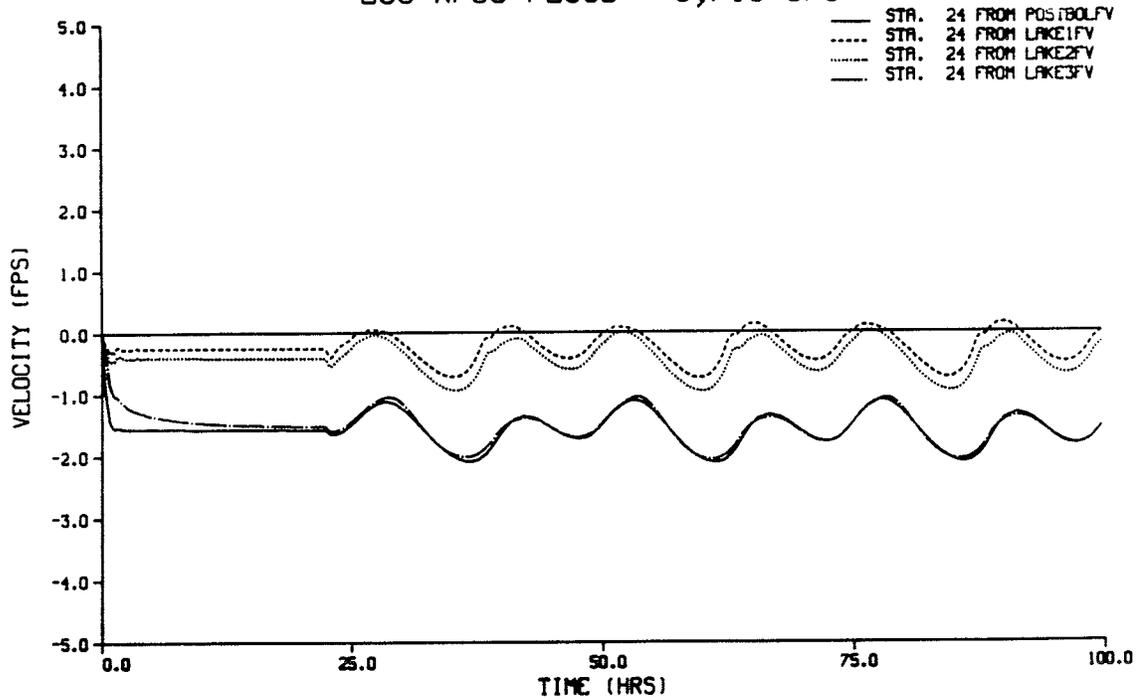


Figure 83. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EGG-WFCC FLOOD - 9,710 CFS

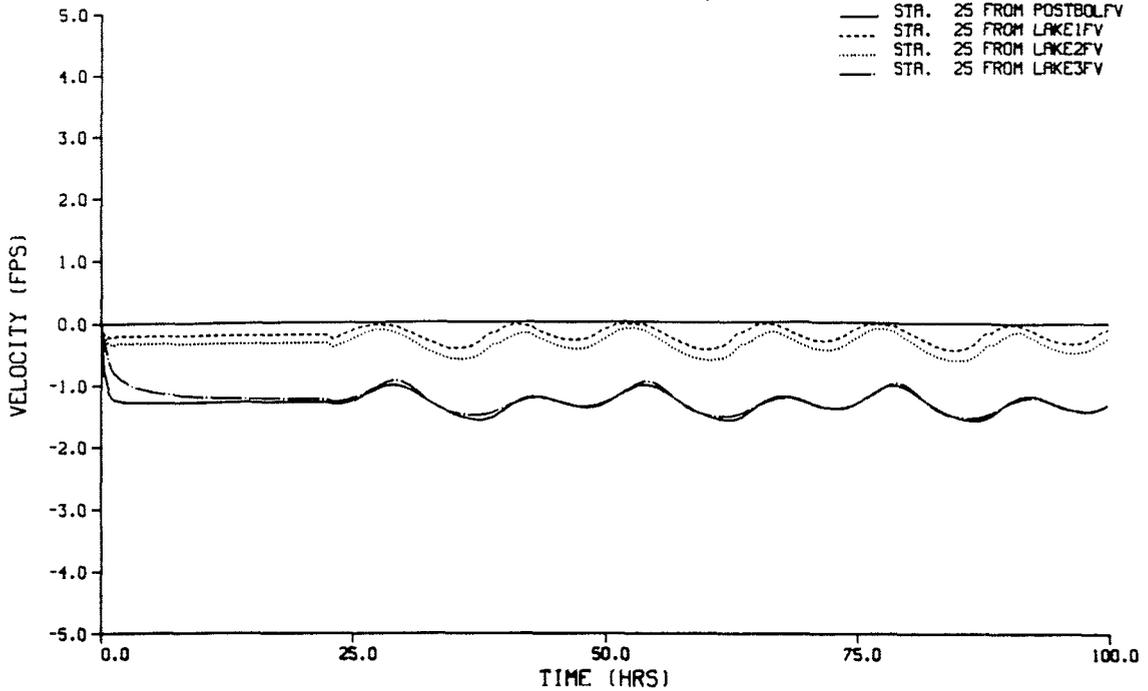


Figure 84. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EGG-WFF FLOOD - 9,710 CFS

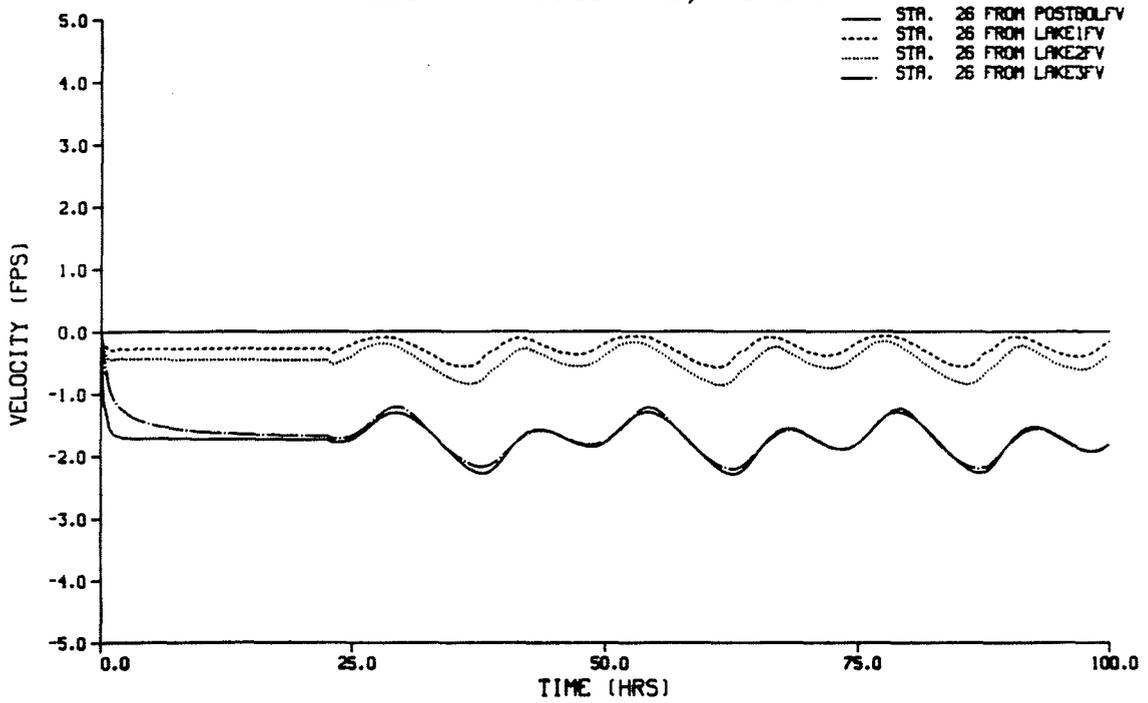


Figure 85. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EGG-WFCC FLOOD - 9,710 CFS

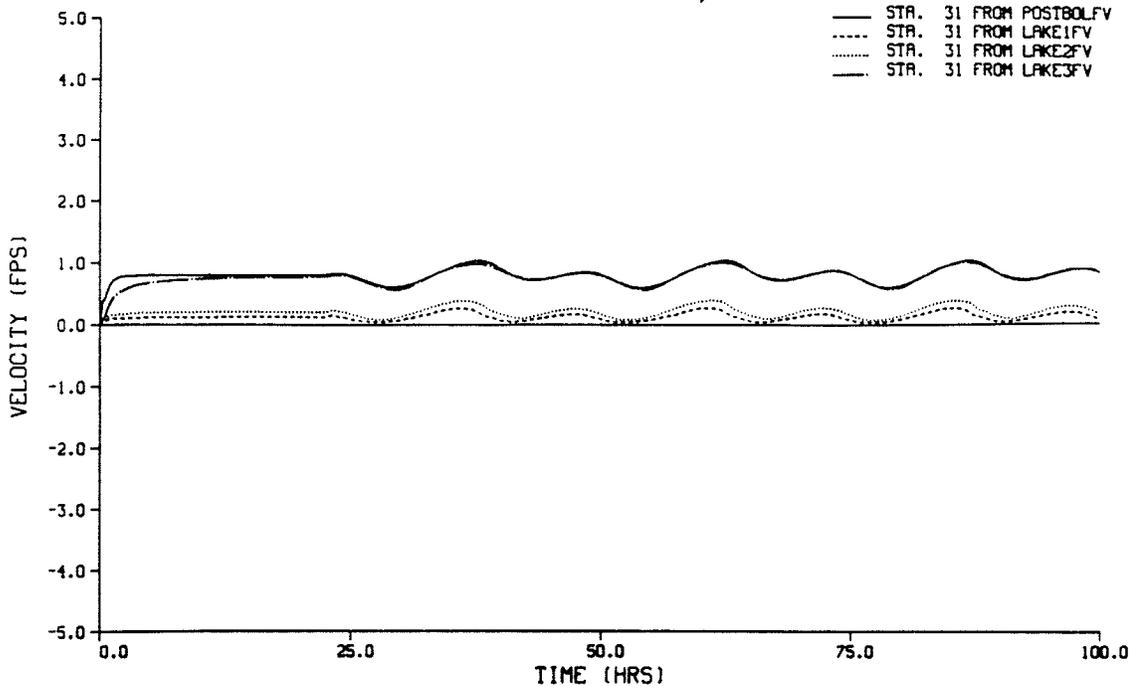


Figure 86. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EGG-WFCC FLOOD - 9,710 CFS

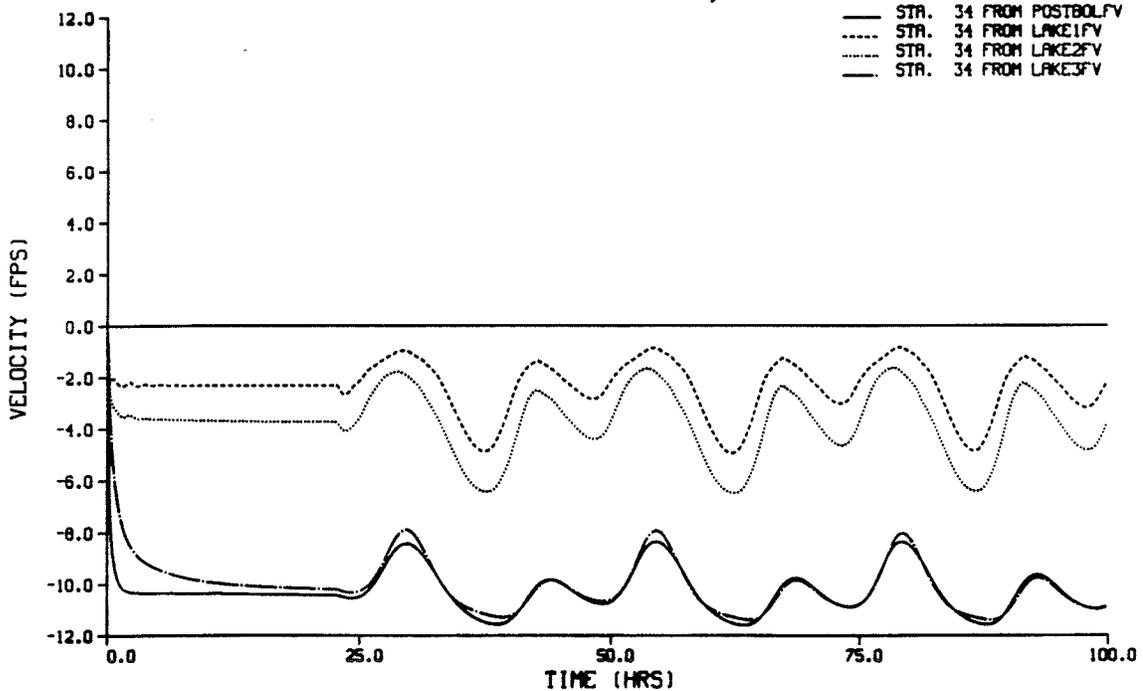


Figure 87. Average channel velocities under Warner Avenue bridge, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

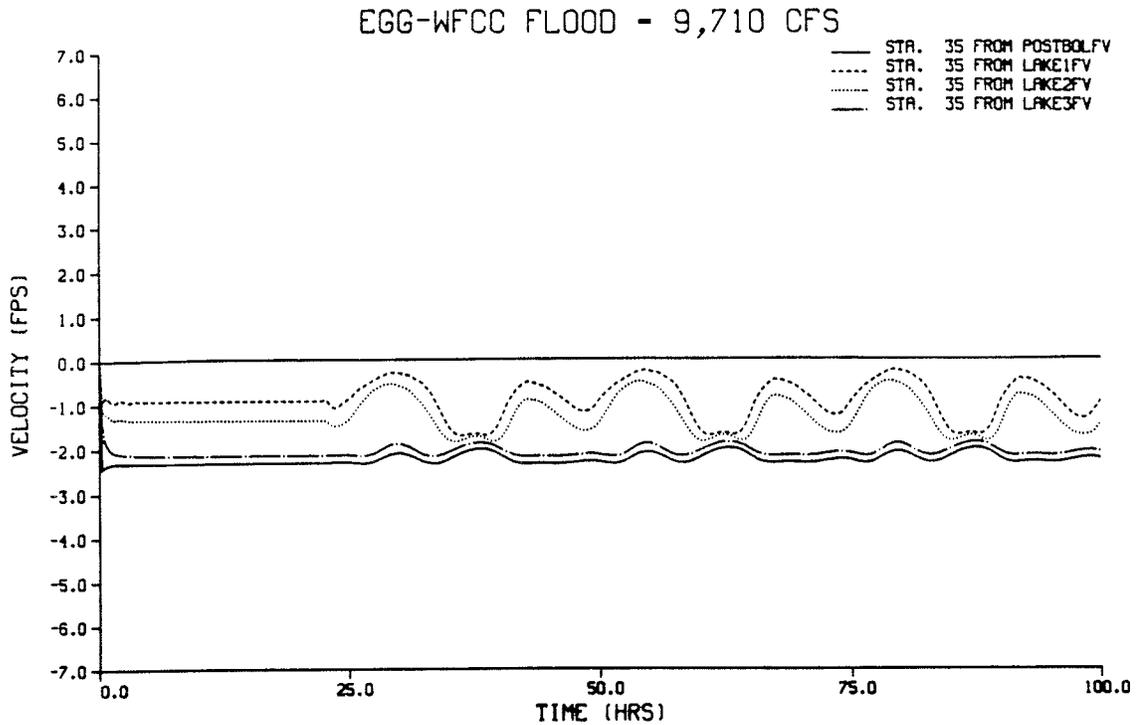


Figure 88. Average channel velocities in Outer Bolsa Bay, POSTBOL - existing condition, LAKE1 - 350-ft entrance channel, LAKE2 - 200-ft entrance channel, LAKE3 - entrance channel closed

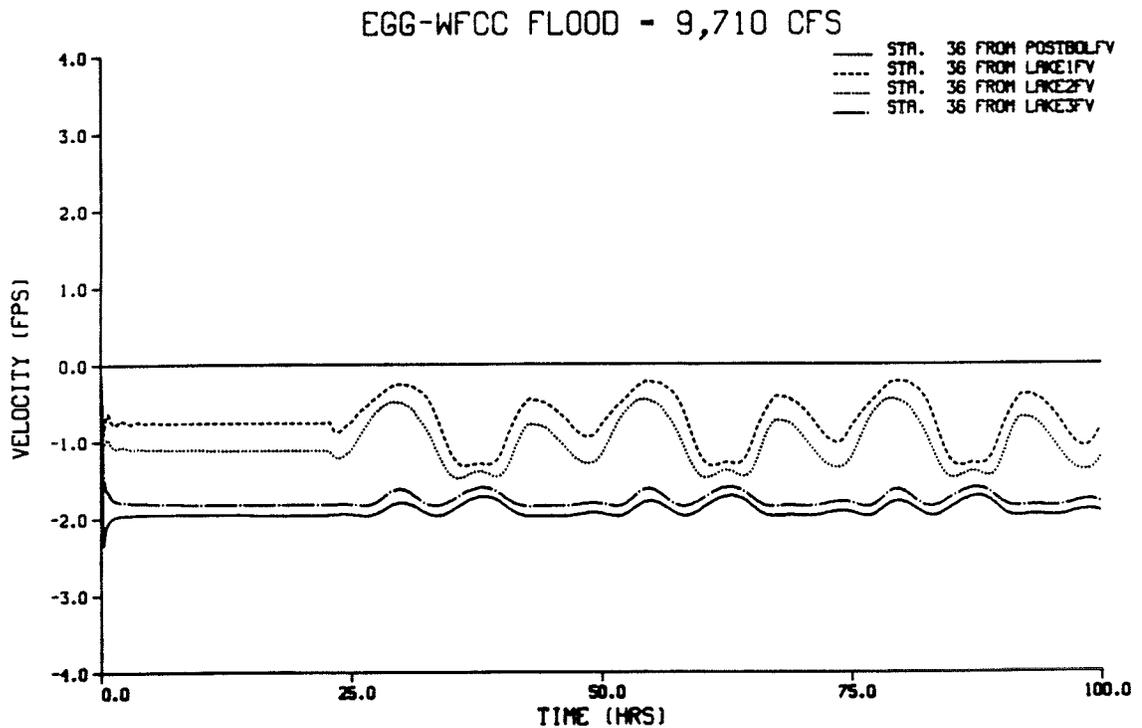


Figure 89. Average channel velocities in Outer Bolsa Bay, POSTBOL - existing condition, LAKE1 - 350-ft entrance channel, LAKE2 - 200-ft entrance channel, LAKE3 - entrance channel closed

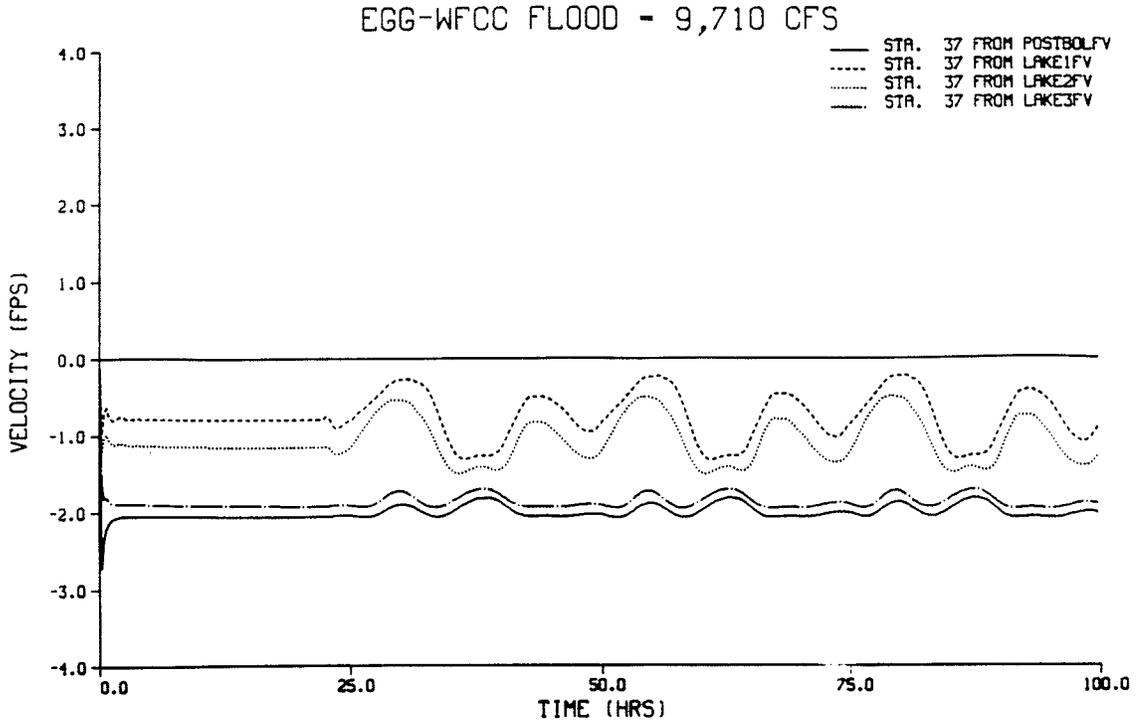


Figure 90. Average channel velocities in Outer Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

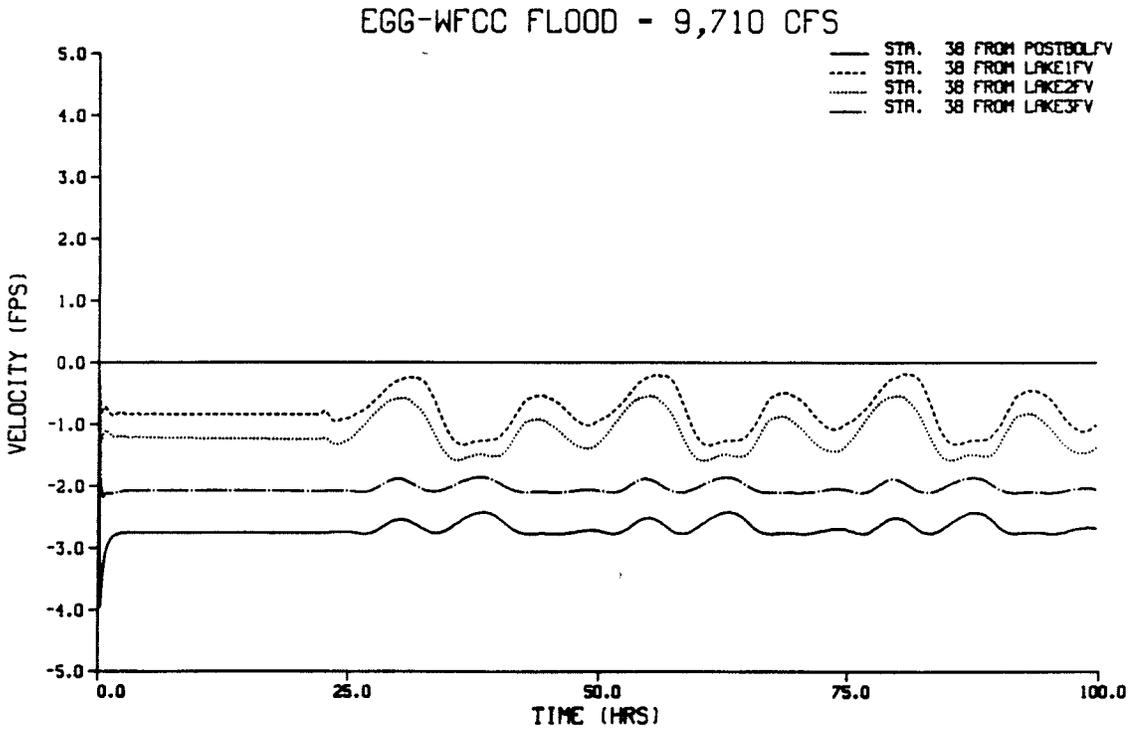


Figure 91. Average channel velocities in Outer Bolsa Bay, POSTBOL = existing condition, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EGG-WFCC FLOOD - 9,710 CFS

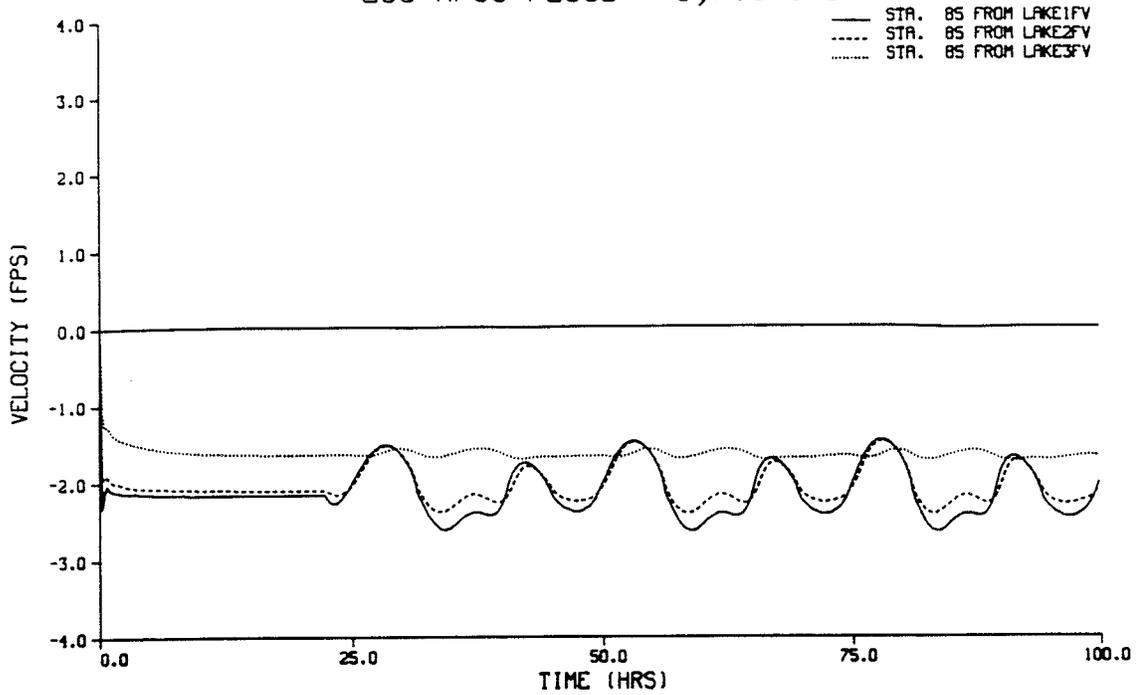


Figure 92. Average channel velocities in proposed marina channel, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel, LAKE3 = entrance channel closed

EGG-WFCC FLOOD - 9,710 CFS

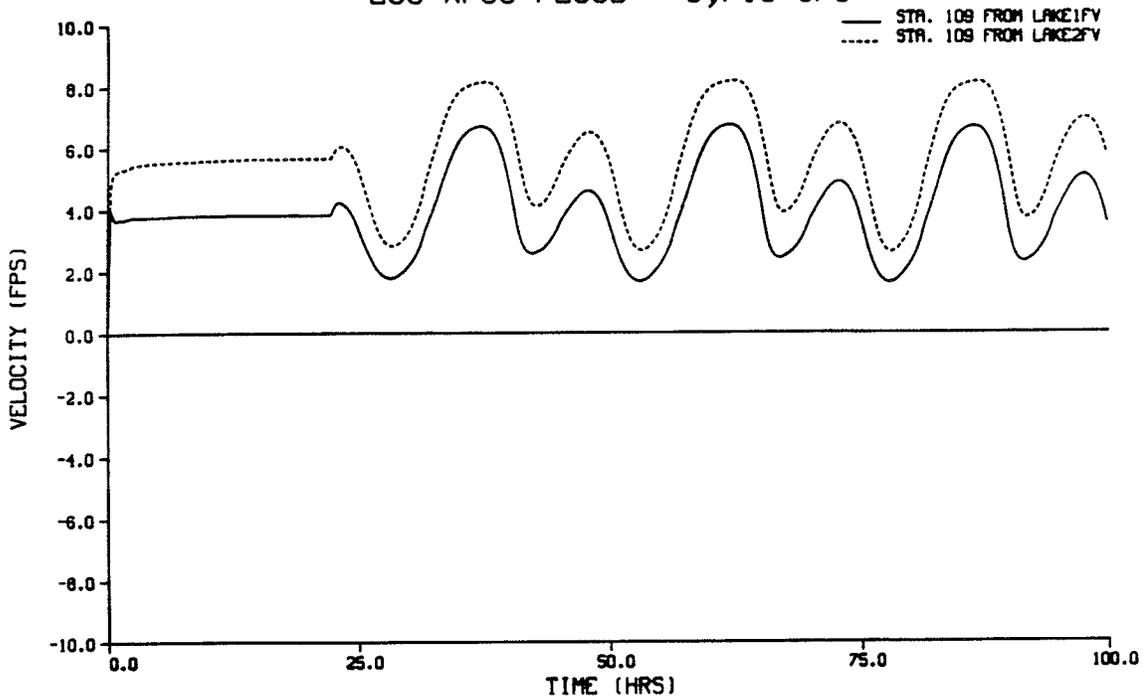


Figure 93. Average channel velocities in proposed entrance channel, LAKE1 = 350-ft entrance channel, LAKE2 = 200-ft entrance channel

Table 4
Maximum Average Channel Velocities
Spring Tide plus 100-Year Flood Flow (9,710 cfs) in
East Garden Grove-Wintersburg Flood Control Channel

<u>Location</u>	<u>Link</u>	<u>Velocity, ft per sec</u>				
		<u>POSTBOL Spring</u>	<u>POSTBOL Flood</u>	<u>Lake 1 Flood</u>	<u>Lake 2 Flood</u>	<u>Lake 3 Flood</u>
Pacific Coast Highway bridge	2	2.78	5.04	2.98	3.30	5.07
Huntington Harbour	5	1.42	3.18	1.61	1.86	3.16
Huntington Harbour	7	1.48	3.50	1.70	1.99	3.48
Huntington Harbour	10	0.71	1.88	0.85	1.02	1.86
Huntington Harbour	17	0.66	1.85	0.80	0.97	1.82
Huntington Harbour	24	0.57	2.11	0.74	0.96	2.06
Huntington Harbour	25	0.30	1.58	0.43	0.61	1.53
Huntington Harbour	26	0.34	2.30	0.58	0.86	2.21
Warner Avenue bridge	34	1.65	11.60	4.94	6.48	11.39
Outer Bolsa Bay	35	1.35	2.34	1.71	1.85	2.18
Outer Bolsa Bay	36	0.71	1.97	1.33	1.48	1.85
Outer Bolsa Bay	37	0.88	2.07	1.31	1.50	1.95
Outer Bolsa Bay	38	1.12	2.77	1.33	1.58	2.11
Proposed marina channel	85	----	----	2.63	2.40	1.72
Entrance channel	109	----	----	6.73	8.17	----

POSTBOL = existing conditions
 Lake 1 = 350-ft wide entrance channel
 Lake 2 = 200-ft wide entrance channel
 Lake 3 = entrance channel closed

increases. While the maximum water surface elevations throughout Huntington Harbour are not significantly greater under the 100-year flood flow conditions, maximum average channel velocities occur near mean tide elevations where the flow cross-sectional areas are less than maximum. Hence, the tidal flows and flood flows are being conveyed simultaneously through a minimum area and, thus, at a maximum velocity.

43. Maximum average channel velocities increase at the Pacific Coast Highway bridge at Anaheim Bay from about 2.8 ft per sec to about 5.0 ft per sec (80 percent increase) (Figure 78, and Table 4). Maximum average channel velocities in Huntington Harbour increase up to a maximum of 3.5 ft per sec from about 1.5 ft per sec (130 percent increase). Other sections experience a greater percentage increase, although not as large an absolute magnitude (Figures 79 through 86, and Table 4).

44. Warner Avenue bridge experiences excessively high velocities due to the large difference in water levels upon either side of the bridge. Maximum average velocities increase from about 1.6 ft per sec during maximum spring tides to about 11.6 ft per sec under 100-year flood flow conditions (600 percent increase) (Figure 87, and Table 4). Outer Bolsa Bay would experience velocities approaching 2.8 ft per sec, which would be significantly greater if not for the damming effect created by existing Warner Avenue bridge (Figures 88 through 91, and Table 4).

Lake Plan alternatives

45. Average channel velocities under the PCH bridge at Anaheim Bay are not exceedingly larger for flood flow conditions with either the Lake 1 or Lake 2 concept than for maximum spring tide velocities, and are significantly less than flood flows under existing conditions. Lake 1 concept average velocity at the PCH at Anaheim Bay bridge increases from about 2.8 to about 3.0 ft per sec (7 percent increase), whereas the Lake 2 concept average velocity increases to about 3.3 ft per sec (19 percent increase). The Lake 3 concept which requires all flow to pass under the PCH bridge at Anaheim Bay (analogous to existing conditions) induces an average velocity of about 5.0 ft per sec at this location (82 percent increase) (Figure 78, and Table 4). Here again, these are average channel velocities over the entire cross-sectional area, and do not account for spiral flow around channel bends which would likely exceed this velocity.

46. The Lake 1 concept with the 100-year flood flow results in average channel velocities in Huntington Harbour which are only slightly greater than maximum spring tide conditions. The main channel into Huntington Harbour experiences average channel velocities approaching 2.0 ft per sec under the Lake 2 concept at Link 7, increasing from 1.48 ft per sec (34 percent increase). Average channel velocities throughout Huntington Harbour for Lake 1 and Lake 2 flood flow conditions are not significantly greater than for maximum spring tide flows under existing conditions, because the majority of the flood flow will discharge through the proposed entrance channel at Bolsa Chica. The restriction afforded by Warner Avenue bridge retards flood flow into Huntington Harbour. Even for the Lake 3 condition, average channel velocities throughout the harbor do not exceed the corresponding flood flow velocities under existing conditions (Figures 79 through 86, and Table 4).

47. Only a portion of the flood flow passes under Warner Avenue bridge, for the Lake 1 and Lake 2 alternatives, although average velocities increase from 1.65 ft per sec to 4.94 and 6.48 ft per sec, respectively. The Lake 3 concept essentially reproduces the existing condition velocities under the bridge (11.39 ft per sec). Scour and erosion of the soft sediments of Outer Bolsa Bay and the bridge abutment may ensue, with corresponding shoaling of the eastern portion of Huntington Harbour, unless bridge and channel stabilization measures are instituted at Warner Avenue bridge. Average channel velocities in Outer Bolsa Bay approach 1.7 and 1.9 ft per sec for the Lake 1 and Lake 2 concepts, respectively, even though much of the flood flow discharges through the proposed entrance channel at Bolsa Chica to the ocean. Lake 3 average channel velocities approach 2.2 ft per sec in Outer Bolsa Bay (Figures 88 through 91, and Table 4). Lake 3 flood velocities are slightly less than existing condition flood velocities because a portion of the flood flow is going into temporary storage within the proposed wetlands. The maximum water surface elevations within the existing and proposed wetlands under Lake 3 flood conditions are slightly less than under existing flood conditions.

48. Because such a large volume of flood flow passes directly through the Lake Plan marina complex and into the ocean for both the Lake 1 and Lake 2 concepts, resulting average channel velocities in the Lake Plan marina channels for these plans are actually greater than for the Lake 3 plan,

being 2.63, 2.40, and 1.72 ft per sec, respectively. The average channel velocities in the entrance channel at Bolsa Chica resulting from flood flow under the Lake 1 and Lake 2 concepts (6.73 and 8.17 ft per sec, respectively) are of sufficient magnitude to reestablish design dimensions of the channel (i.e., allowing removal of all sediment buildup in the proposed entrance channel at Bolsa Chica) (Figures 92 and 93, and Table 4). Velocities up to 8 ft per sec from the 100-year flood flow will have no deleterious effect on entrance channel closure; however, this velocity magnitude will require consideration in the design of the stabilizing jetties and new bridge over the entrance channel. These high velocities may keep the entrance channel open only a short time; a 100-year opening frequency is not sufficient to prevent closure at other times.

PART IV: EVALUATION OF TRANSPORT CHARACTERISTICS

49. DYNTRAN simulations were performed to evaluate the impacts of the transport and mixing characteristics of the three potential entrance configurations (Lake 1, Lake 2, and Lake 3) of the proposed Lake Plan alternative on water quality in the Huntington Harbour-Bolsa Bay complex. First, overall residence time (water age) was calculated for the whole system. Ocean water is in a comparatively clean condition, and residence time in the system generally corresponds to degradation of the water quality. Although there is not a direct correlation, and other factors may improve or degrade water quality conditions, the residence time serves as an indicator of system water quality particularly in the harbor and marina areas. Rapid flushing within the wetland itself, however, is not considered a necessary beneficial condition. Also, transport of runoff from the EGG-WFCC was simulated for the Lake Plan configurations. EGG-WFCC has previously been shown in the main report (Report No. 3) to be a major source of toxic materials which are transported into Outer Bolsa Bay and, to a lesser degree, into Huntington Harbour.

50. This series of simulations addresses the potential impacts of circulation changes in the system on water quality. No attempt has been made to estimate the potential increase in pollutants from new development or recreational uses of the Lake Plan alternatives.

Tidal Boundary Driver

51. The tidal boundary conditions used for the transport tests are shown in Figure 94. This signal is simply the tidal pattern from constituents at the NOAA Los Angeles-Long Beach tide gage for the month of September 1988. For the water age calculation, 1,375 hr of simulation were performed. The September tidal pattern was repeated for the additional simulation time. In the runoff tests, the first 200 hr were utilized. The September 1988 tides do not contain the extreme high and low tide range observed in this area, and utilized in the hydrodynamic simulations. However, this lower tidal range condition is a more environmentally stressful condition; i.e., system flushing is lower for lower tidal ranges. This is the same tidal boundary driver

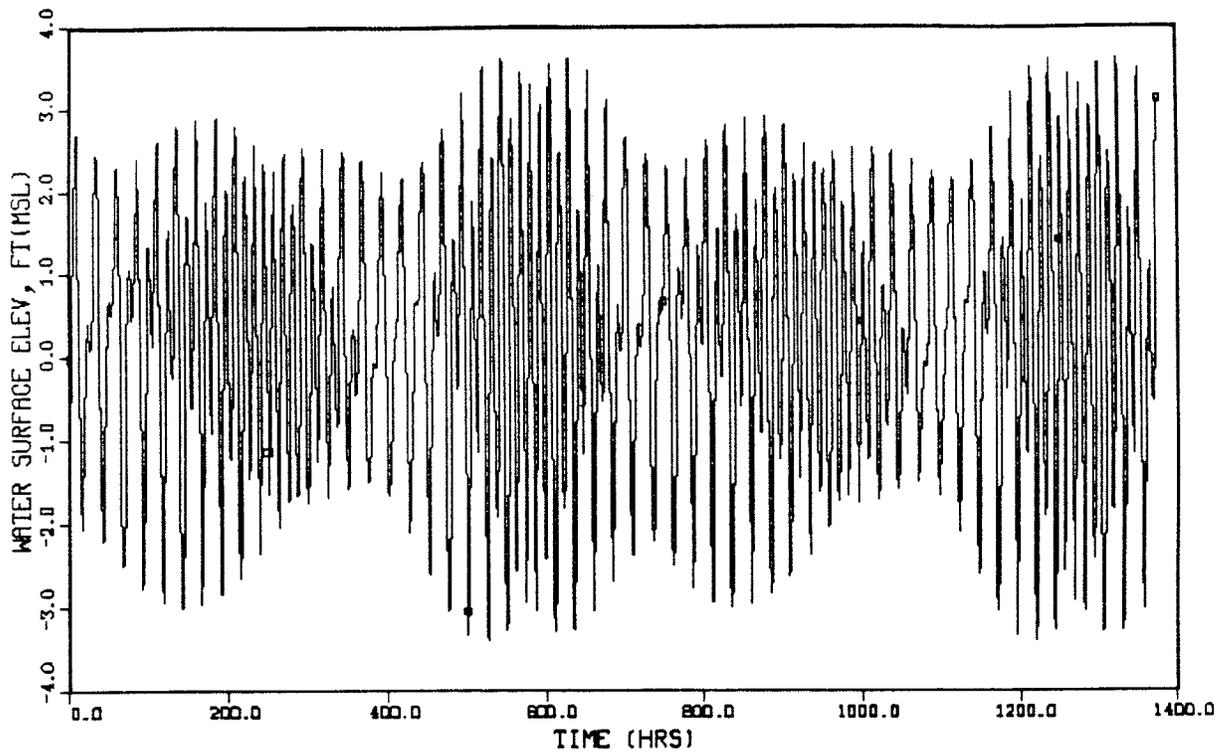


Figure 94. Tidal boundary driver (September 1988)
for transport and mixing characteristics, Bolsa Bay, and vicinity

previously used in the main report (Report No. 3) to evaluate the Preferred Alternative and the Secondary Alternative transport characteristics and water age. Direct comparisons of residence times are applicable.

System Water Age

52. In this series of tests, the average age for a parcel of water (i.e., the time since that parcel of water left the ocean) was calculated for the existing condition (POSTBOL), and for each of the three potential entrance configurations of the proposed Lake Plan alternative previously described. These three variations include:

- a. Lake 1: Lake Plan with 350-ft wide entrance channel, wetlands not connected,
- b. Lake 2: Lake Plan with 200-ft wide entrance channel, wetlands not connected, and
- c. Lake 3: Lake Plan with entrance channel closed, wetlands not connected.

53. Water age was calculated by setting the age of the ocean water equal to zero, and solving the "water age" transport equation previously discussed in the main report (Report No. 3). Use of the time decay boundary option was overridden in the model in this case, and a 0.0 boundary value was specified as follows. For the existing entrance, the age boundary (i.e., the location where the water was considered outside the system) was taken at the boundary of Node 1. Water age was set to zero in Nodes 73 and 74 at the Anaheim Bay entrance (Figure 3). Similarly, for the variations of the Lake Plan alternative, the zero boundary was set at the edge of the land area rather than at the boundary of the nodes extending out into the ocean. Water age was set to zero in Nodes 91, 139, and 140. For all water age simulations, the hydrodynamic model was started at a zero velocity condition and zero water surface elevation (msl), and allowed 25 hr (two complete tidal cycles) for model "spinup" before starting the water age calculations. Water age was initially zero throughout the entire system.

54. For existing conditions, water age results are presented graphically for Nodes 9, 15, 17, 24, 32, 35, 40, and 54 in Figures 95 through 102, respectively (location of nodes shown on Figure 3). The graphs demonstrate several general characteristics of the aging simulations. During the initial phase of the simulations, the water age increases linearly. As the system equilibrates, the water age oscillates with the tidal variations in a plateau range. At Node 9 (Figure 95) in the main channel of Huntington Harbour, velocities are relatively high, and water moves rapidly in from the ocean and back out, resulting in large variations in water age over a tidal cycle at this location. In the side channels of Huntington Harbour (Figures 96 and 97) where flow is low, intertidal variations are decreased and average water age is much higher. These side channel areas occasionally have low dissolved oxygen (DO), particularly in the deeper reaches due to increased residence time, low vertical mixing, and biological oxygen demand (BOD) sources in the marinas. As the water moves away from the Anaheim entrance into Bolsa Bay, average age increases. In the DFG muted tidal cell, water age equilibrates to over 800 hr (a residence time in the system of more than a month), and tidal oscillations are damped.

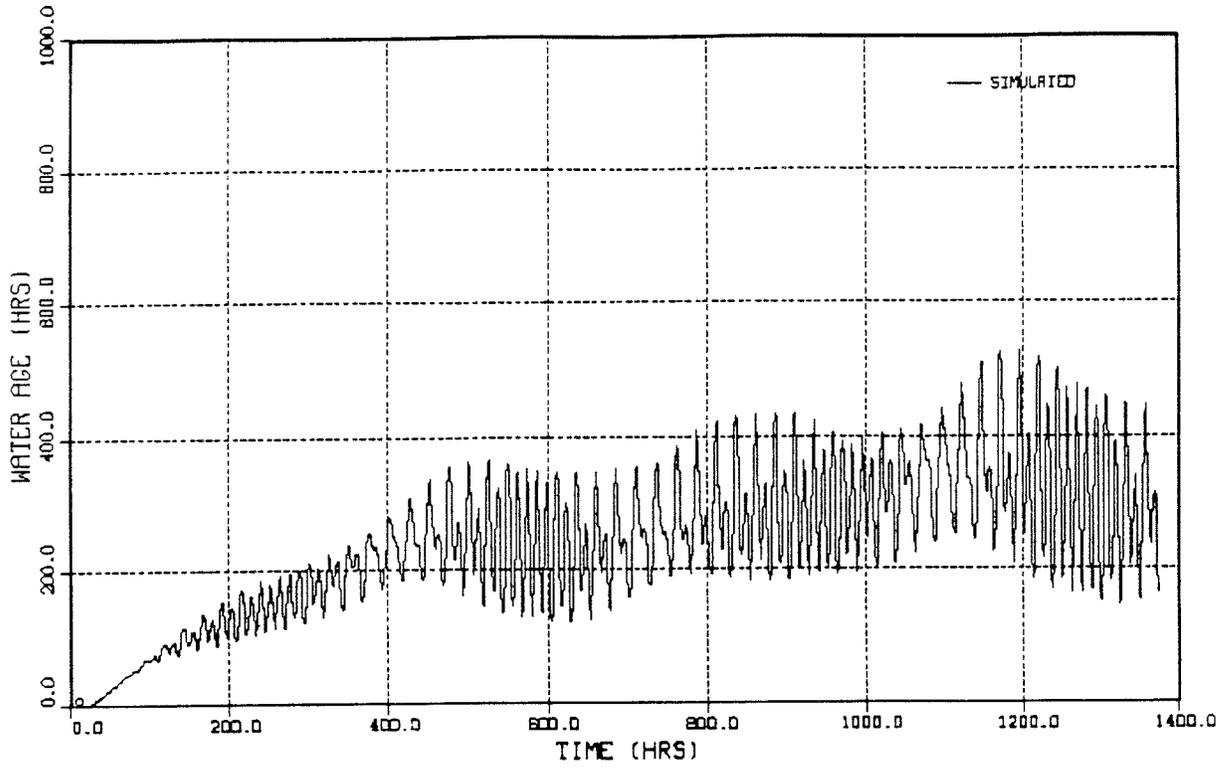


Figure 95. Water age for Node 9 existing conditions, main channel, Huntington Harbour

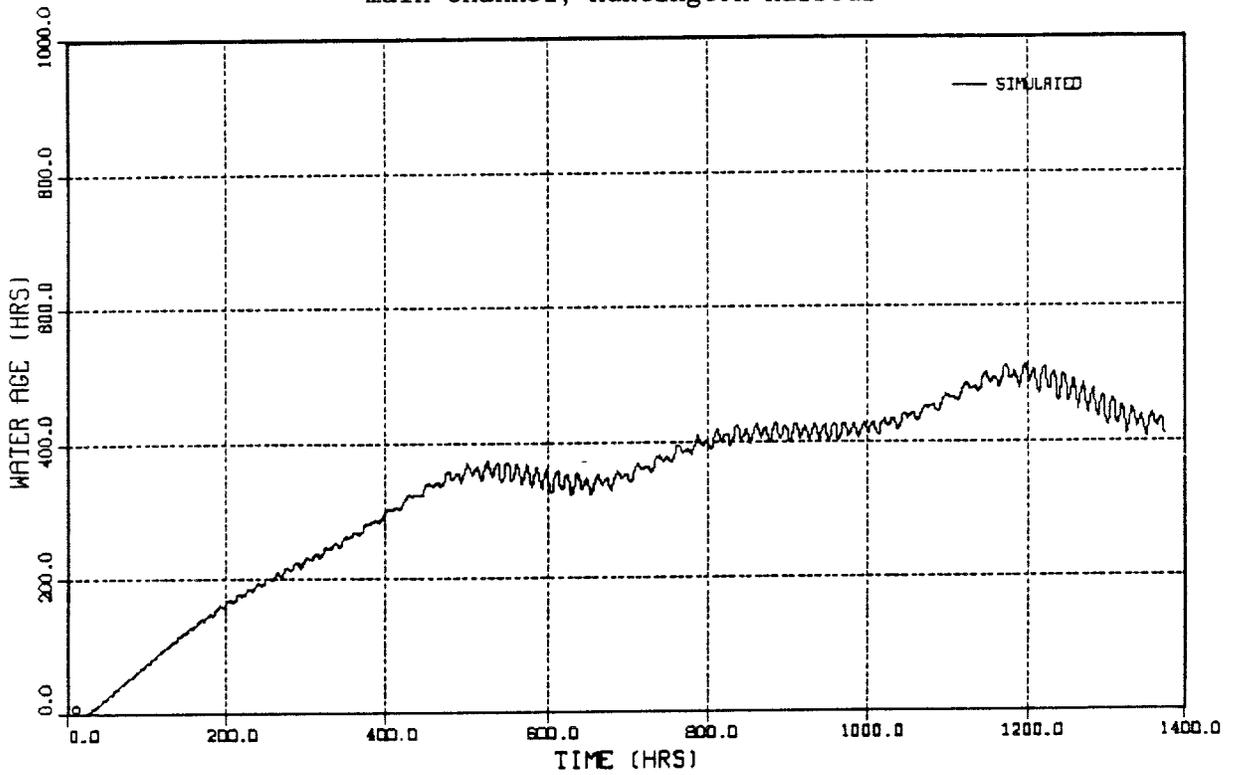


Figure 96. Water age for Node 15 existing conditions, side channel, Huntington Harbour

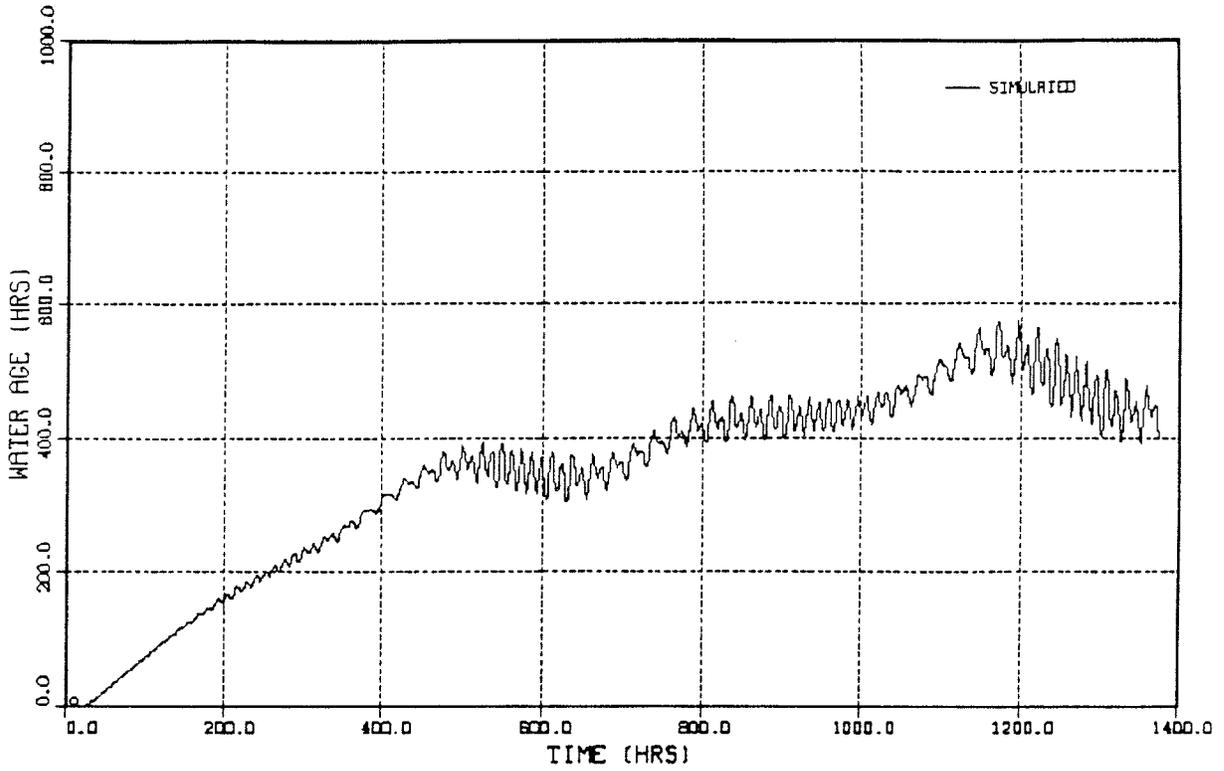


Figure 97. Water age for Node 17 existing conditions, side channel, Huntington Harbour

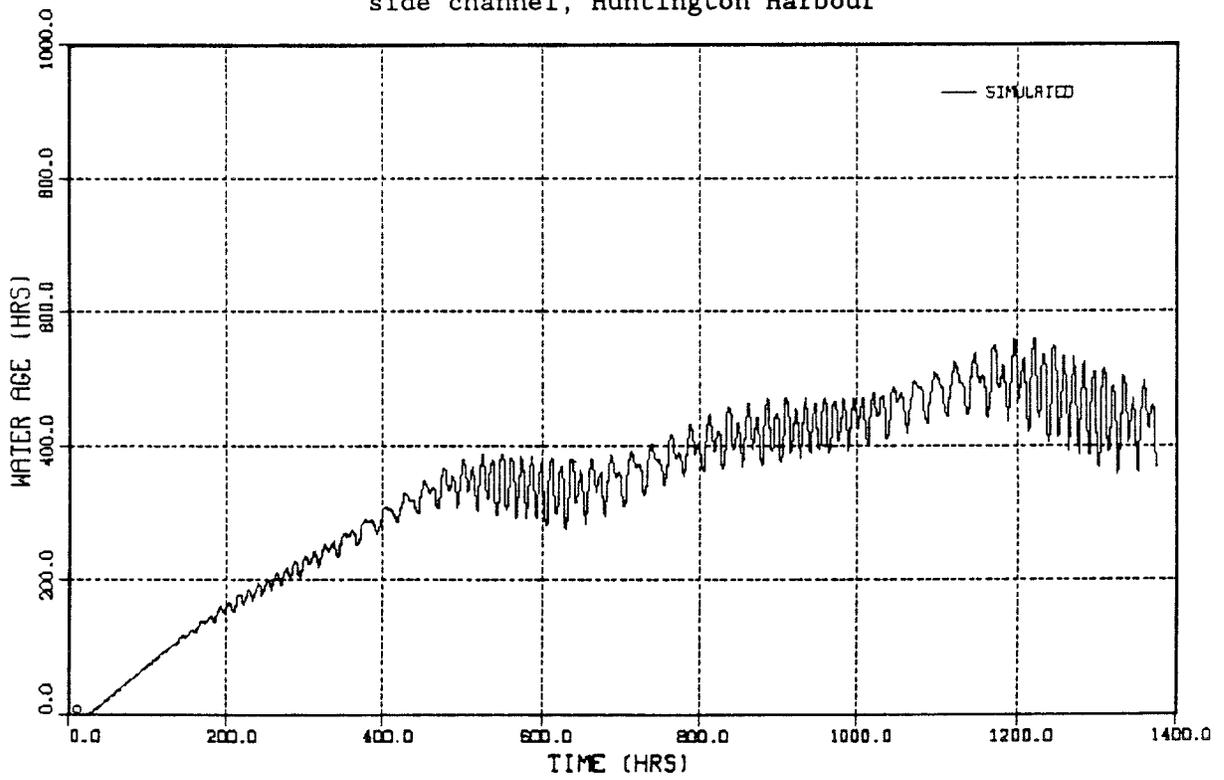


Figure 98. Water age for Node 24, existing conditions, main channel, Huntington Harbour

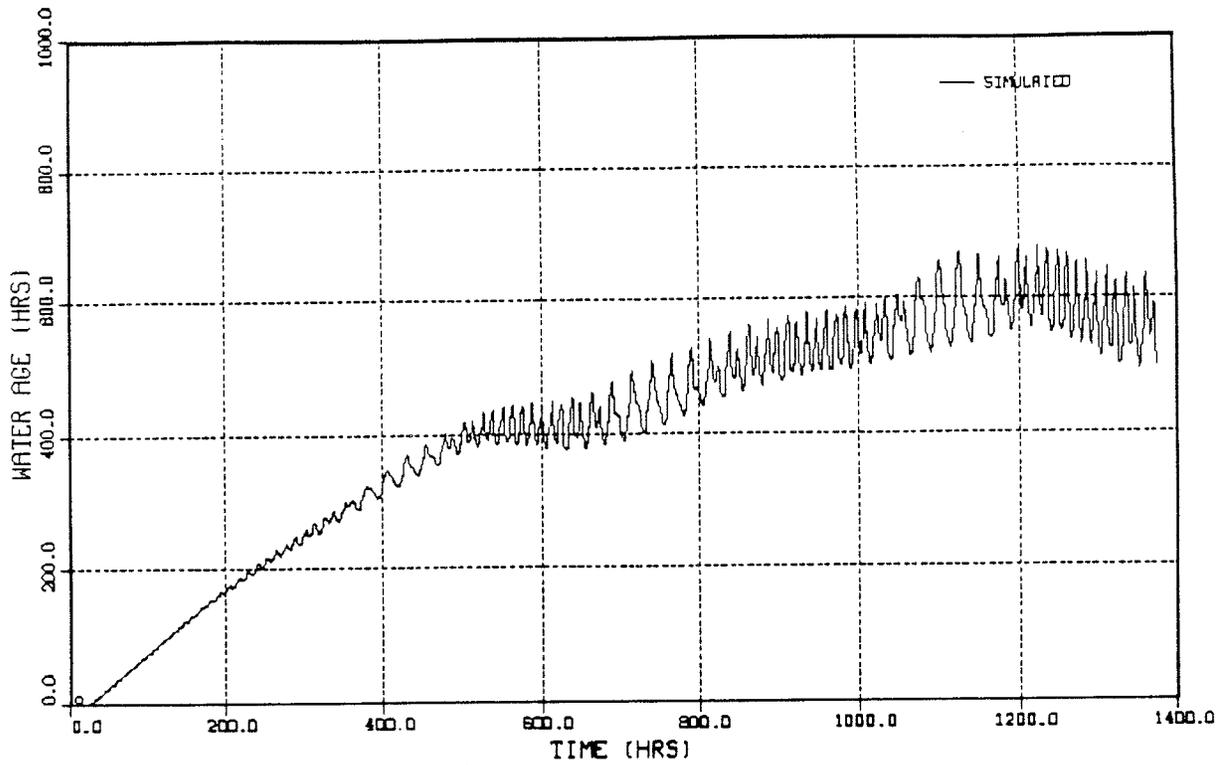


Figure 99. Water age for Node 32 existing conditions, Outer Bolsa Bay

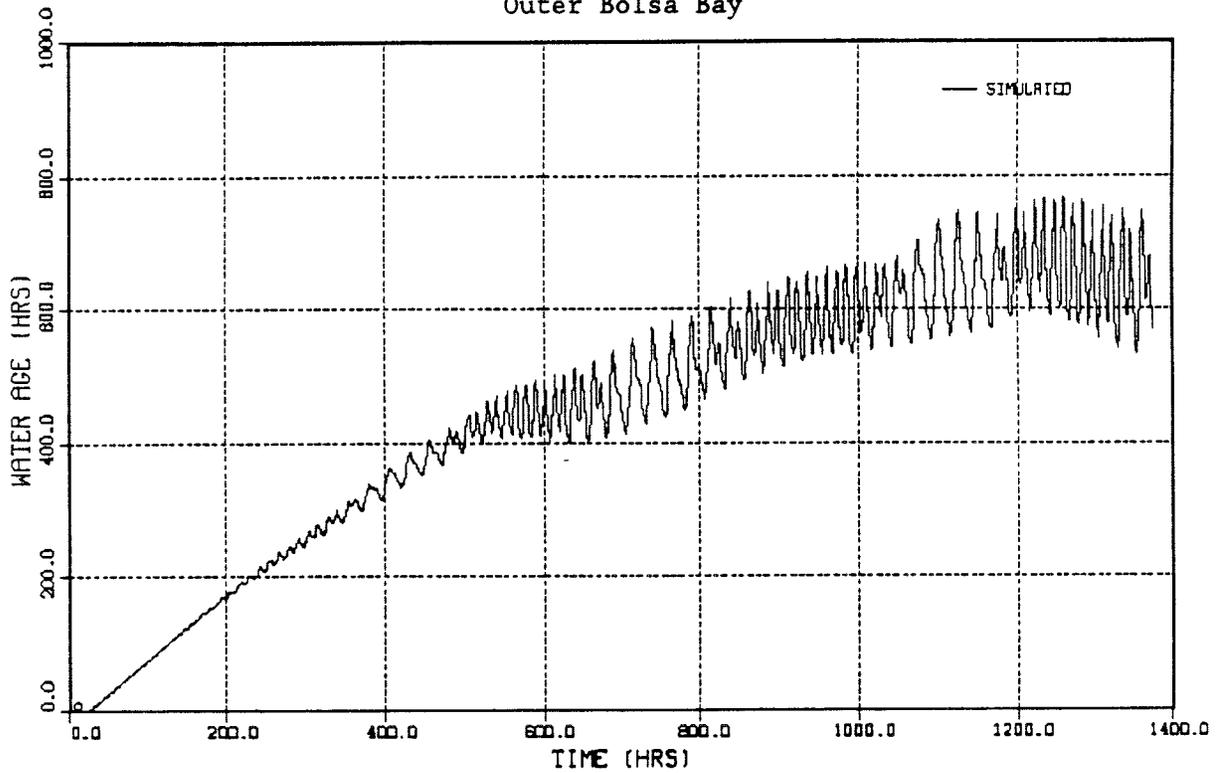


Figure 100. Water age for Node 35 existing conditions, Inner Bolsa Bay

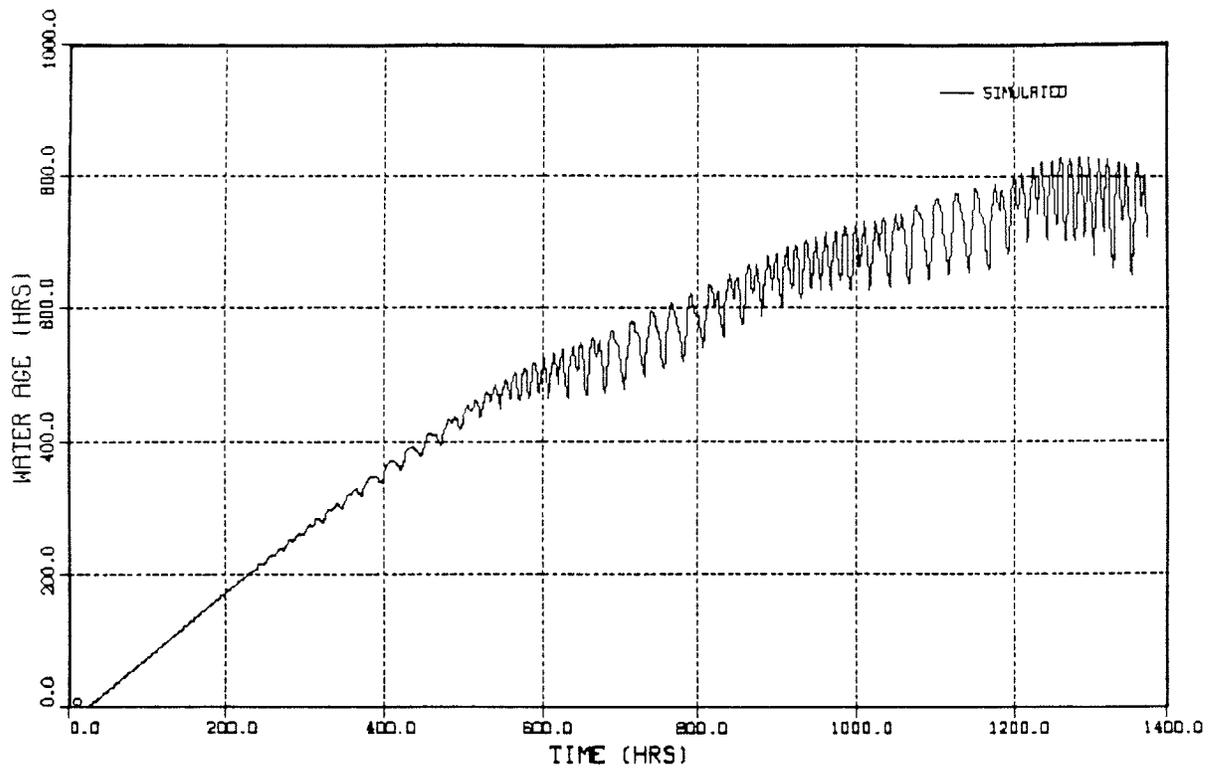


Figure 101. Water age for Node 40 existing conditions, Inner Bolsa Bay

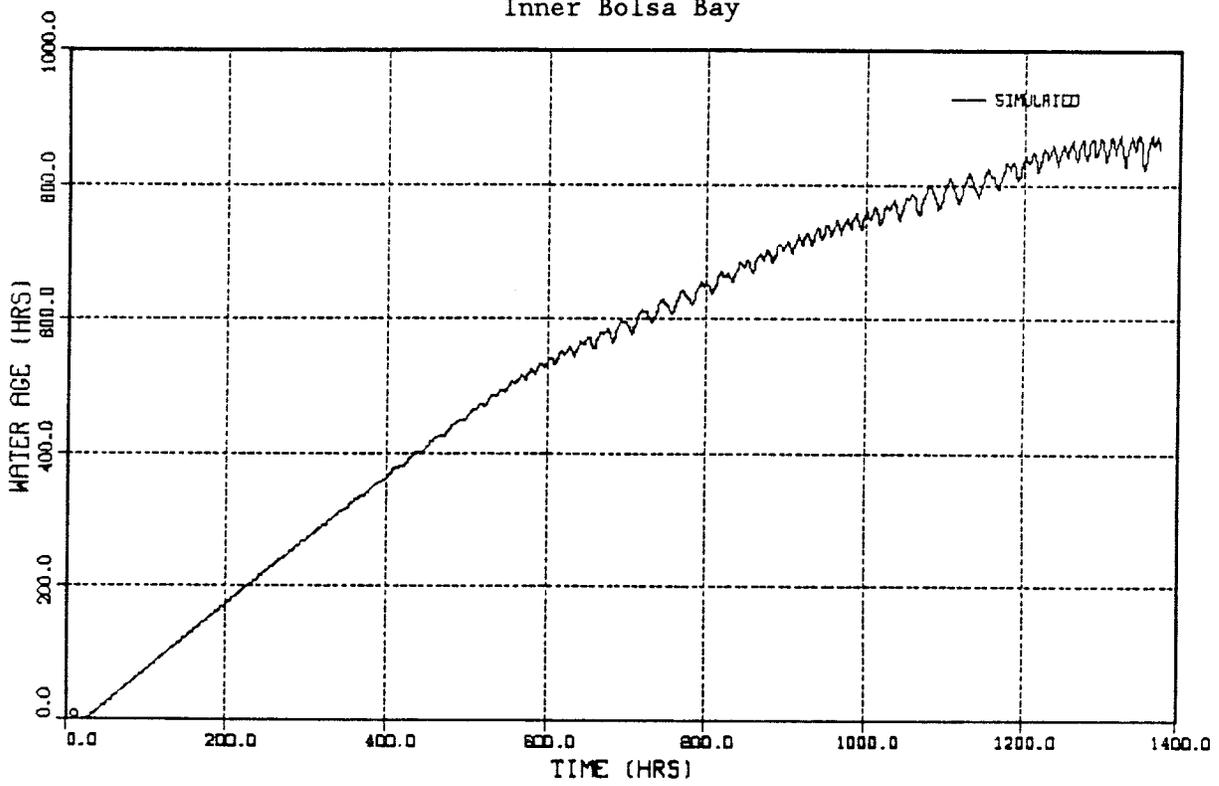


Figure 102. Water age for Node 54 existing conditions, DFG muted tidal cell

55. Table 5 summarizes the ageing results for a series of nodes in Huntington Harbour and Bolsa Bay under existing conditions, and for the three potential entrance variations of the Lake Plan alternative. The average age for the final 25 hr (two full tidal cycles) of simulation is shown in this table. The Lake Plan alternative variations do not adversely affect flushing in the Huntington Harbour area. Water age is reduced for the open entrance configurations (Lake 1 and Lake 2), and is close to existing values where the entrance channel may close (Lake 3) due to shoaling if not maintained.

Table 5
Water Age
Huntington Harbour and Bolsa Bay, California
Existing Conditions versus Lake Plan Alternatives
Average Age (hours) for Final 25 hours of Simulations
Wetlands Not Connected

<u>Location</u>	<u>Node</u>	<u>POSTBOL</u>	<u>Lake 1</u>	<u>Lake 2</u>	<u>Lake 3</u>
Huntington Harbour	9	281	167	152	265
Huntington Harbour	15	425	285	267	444
Huntington Harbour	17	435	295	260	433
Huntington Harbour	24	434	276	251	389
Outer Bolsa Bay	29	487	341	295	450
Inner Bolsa Bay	37	684	88	94	601
Inner Bolsa Bay	40	751	145	151	689
DFG muted tidal cell	54	855	242	252	808
Proposed full tidal wetlands	111	---	384	387	905
Proposed muted tidal wetlands	122	---	513	518	1,014
Proposed muted tidal wetlands	129	---	487	492	996
Proposed muted tidal wetlands	134	---	491	496	998

POSTBOL - existing conditions
 Lake 1 - 350-ft wide entrance channel
 Lake 2 - 200-ft wide entrance channel
 Lake 3 - entrance channel closed

56. In all existing wetland areas, water age is greatly reduced for both the Lake 1 and Lake 2 configurations. The culvert system to the existing Inner Bolsa Bay wetlands for the Lake Plan configurations is located close to the proposed ocean entrance (analogous to the supplemental channel to Inner Bolsa Bay previously evaluated as part of the navigable entrance channel concept in the main report, Report No. 3). Thus, as expected, water entering the wetlands has been in the system a relatively short period of time.

57. Water age is very slightly lower in the wetlands for the 350-ft wide entrance channel (Lake 1) than for the 200-ft wide entrance channel (Lake 2). Water age within the existing wetland area is slightly lower for Lake 3 (entrance channel closed) than for existing conditions. Node 37 is the first node within the Inner Bolsa Bay muted tidal wetland for the Lake Plan configuration, whereas under existing conditions the culvert system discharges into Node 35 (i.e., the areas represented by Nodes 35 and 36 are removed from the Inner Bolsa Bay wetland area under the Lake Plan configuration).

58. The water age from the front to the back of the existing Inner Bolsa Bay muted tidal wetland (Nodes 37, 40, and 54) is virtually unchanged (slightly reduced) from existing conditions by the Lake 3 concept which, again, considers that the entrance channel has closed by littoral material transport in the surf zone. This is anticipated since the culvert system is identical for the two situations; however, the Lake Plan alternative provides for a much greater hydraulic efficiency of the approach channel to the culvert system. In the proposed full tidal wetland area and proposed muted tidal wetland area, water age is lower for the open entrance Lake Plan configurations (Lake 1 and Lake 2) than in the existing Inner Bolsa Bay muted tidal wetlands. For the closed entrance channel Lake Plan configuration (Lake 3), the water age in the proposed full tidal wetland area and proposed muted tidal wetland area is substantially greater than for the existing Inner Bolsa Bay muted tidal wetlands.

East Garden Grove-Wintersburg
Flood Control Channel (EGG-WFCC) Runoff

59. To test the impacts of the Lake Plan alternative variations on the transport of runoff from the EGG-WFCC into the existing and proposed wetland enhancement areas, a simulation was performed using the first 200 hours of the tidal signal of Figure 94. The model simulation was started from still water conditions at mean tide elevation, and was "warmed up" for 50 hours before constituent simulations were begun to remove all transient variations, and to allow the model to equilibrate to steady state conditions. A runoff inflow with a dissolved tracer (Figure 103) entered the model at the node adjoining the EGG-WFCC. For the existing condition, inflow was introduced into Node 33. For the three Lake Plan alternative concepts, the same runoff inflow was introduced into Node 83. The constituent boundaries were set at the edge of the model network for EGG-WFCC runoff; i.e., extending out into the ocean region.

60. Figure 104 compares the concentrations of the dissolved tracer resulting from the EGG-WFCC runoff at a point immediately beyond the culvert system at the entry to the Inner Bolsa Bay wetland for existing and proposed Lake Plan conditions. Node 35 of this display is located at the entry to existing Inner Bolsa Bay and results are for existing conditions, while Node 37 is located at the entry to Inner Bolsa Bay after the Lake Plan alternative configurations have been developed. Figures 105 and 106 depict the time histories of the dissolved tracer resulting from the EGG-WFCC runoff for the existing condition and for the three Lake Plan alternative concepts at a location representative of Inner Bolsa Bay (Node 40), and in the DFG muted tidal cell (Node 54), respectively. Figure 107 compares the inflow concentrations immediately beyond the culvert system at the entry of the existing Inner Bolsa Bay muted tidal wetlands (Node 35), and immediately beyond the culvert system at the entry to the proposed full tidal wetland enhancement region (Node 93), respectively.

61. Presently, inflow from EGG-WFCC enters Outer Bolsa Bay immediately in front of the culvert system into Inner Bolsa Bay. For the existing condition configuration, runoff is swept into the existing Inner Bolsa Bay with little dilution. The location of the culvert system to the

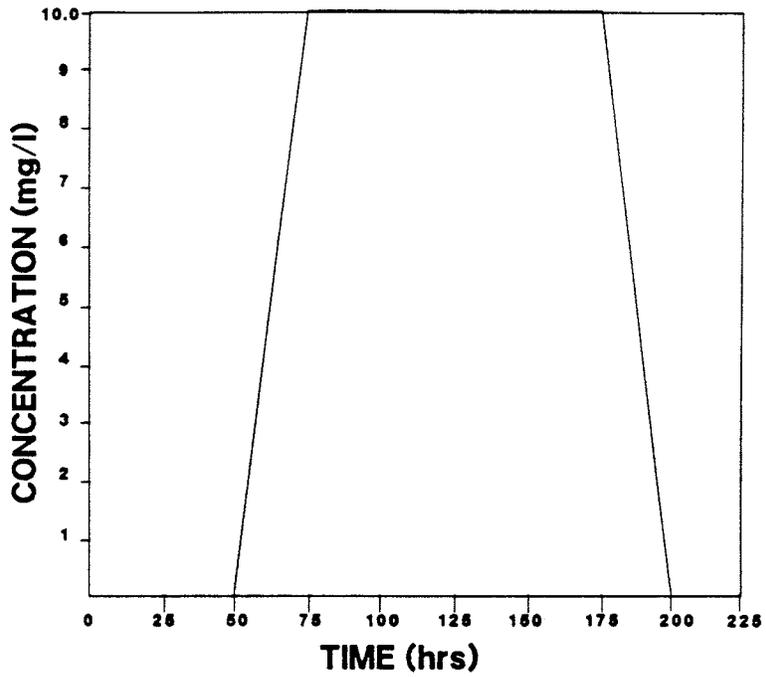
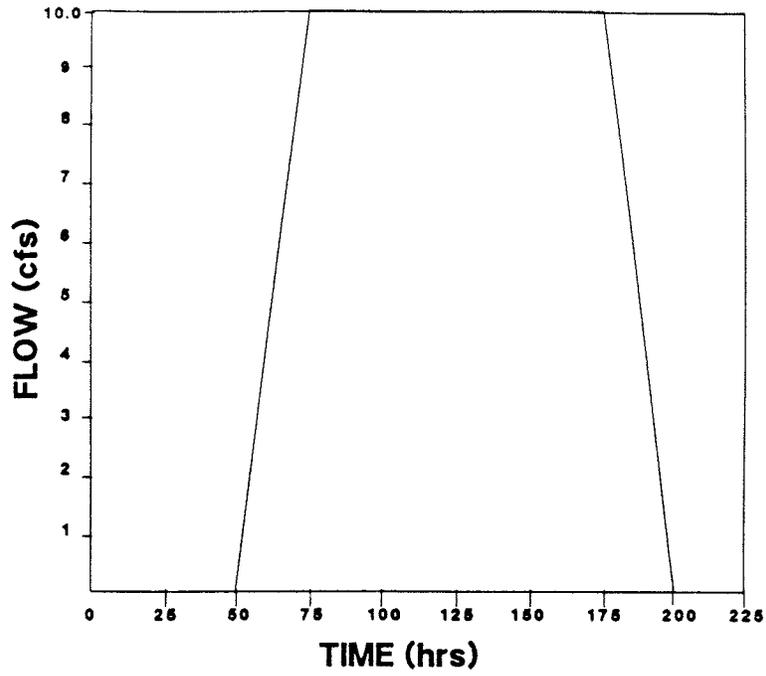


Figure 103. Runoff inflow hydrograph with dissolved tracer to evaluate transport from EGG-WFCC into wetlands

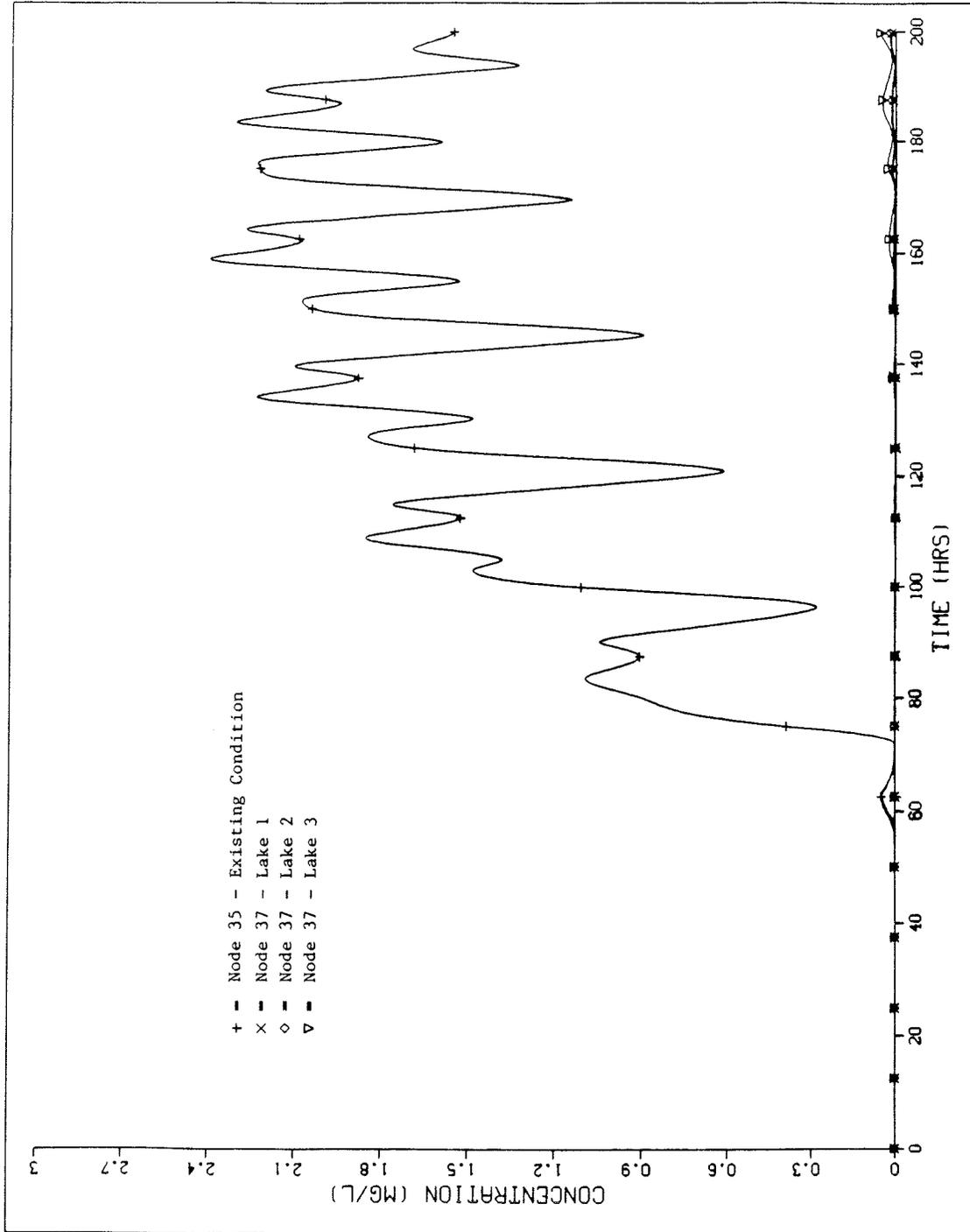


Figure 104. Concentration of dissolved tracer from EGG-WFCC runoff entering existing Inner Bolsa Bay muted tidal wetlands (Node 35) compared to concentrations entering proposed Inner Bolsa Bay muted tidal wetlands (Node 37) after Lake Plan development

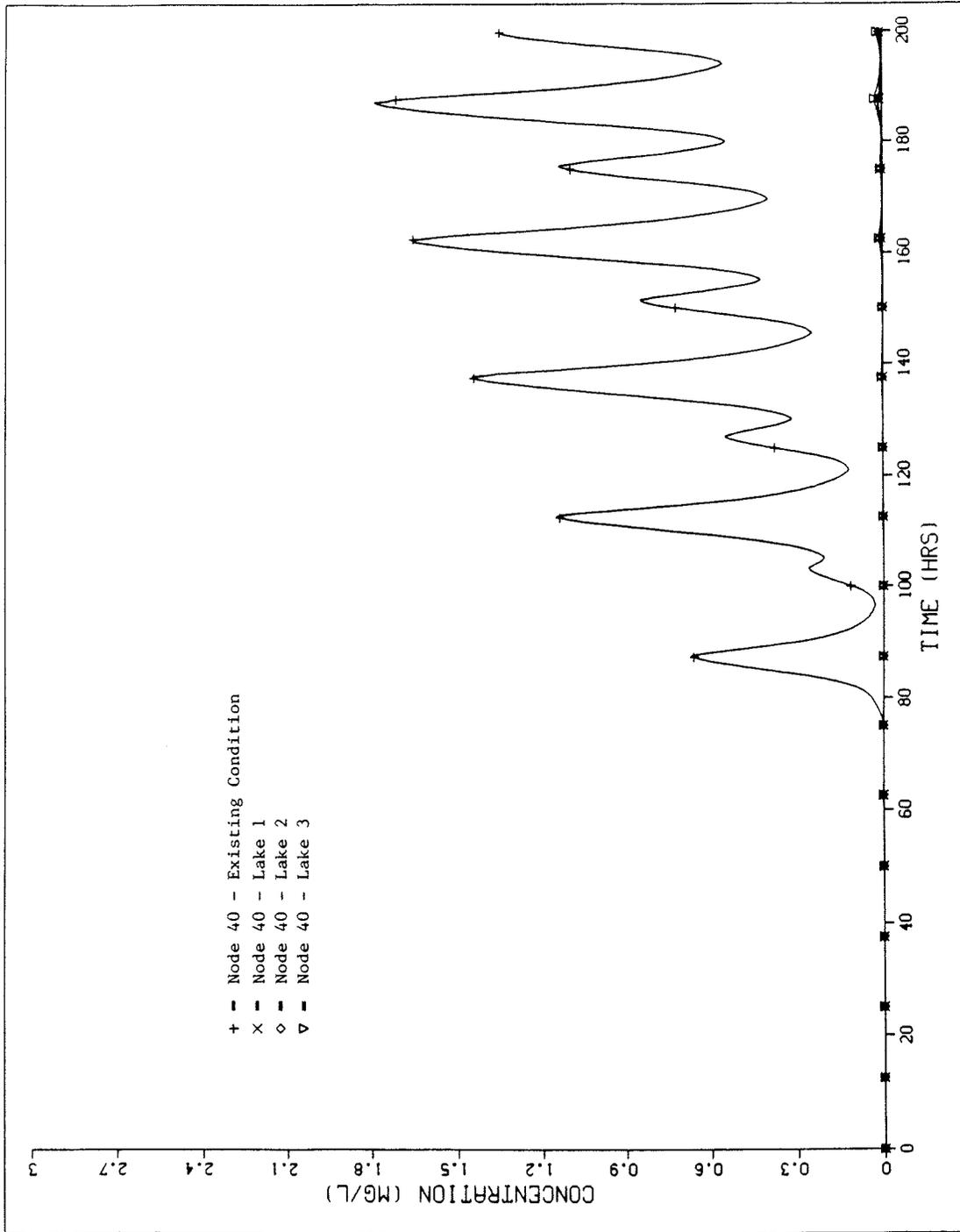


Figure 105. Comparison of concentration of dissolved tracer from EGG-WFCC runoff in Inner Bolsa Bay (Node 40) for existing conditions, and after Lake Plan development

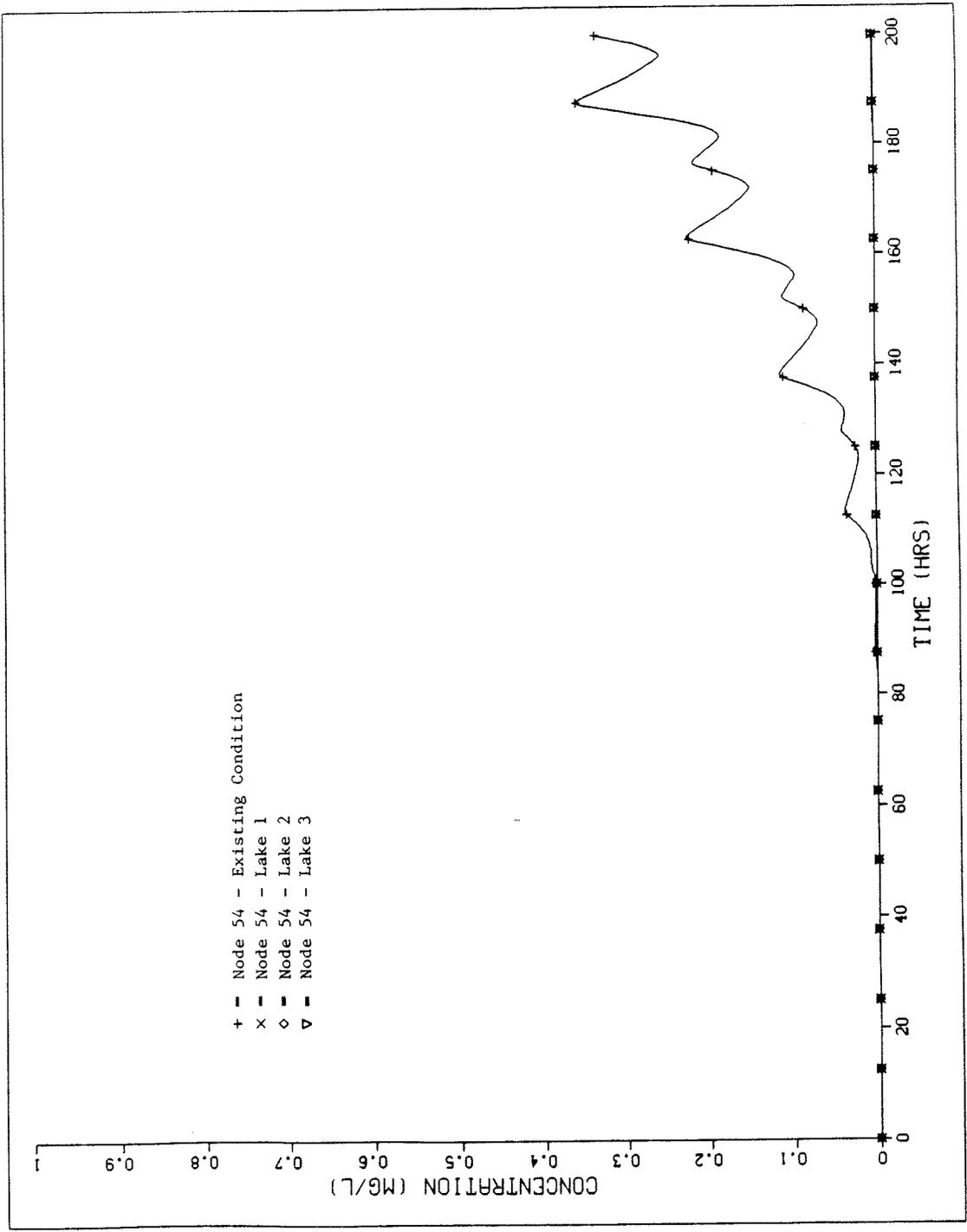


Figure 106. Comparison of concentration of dissolved tracer from EGG-WFCC runoff in DFG muted tidal cell (Node 54) for existing conditions, and after Lake Plan development

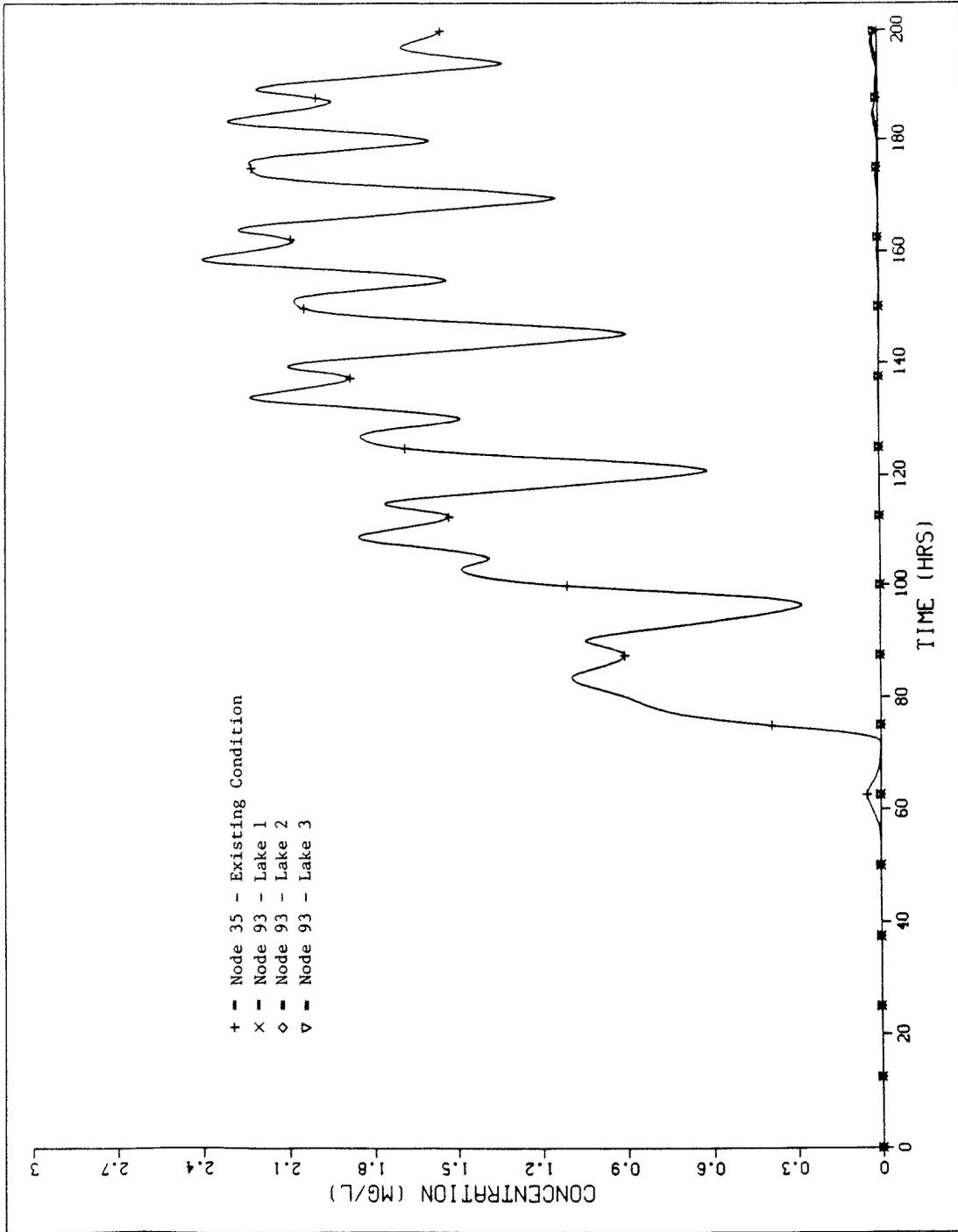


Figure 107. Concentration of dissolved tracer from EGG-WFCC runoff entering existing Inner Bolsa Bay muted tidal wetlands (Node 35) compared to concentrations entering proposed full tidal wetlands (Node 93) after Lake Plan development

existing Inner Bolsa Bay muted tidal wetlands at a substantial distance from the channel inflow (Node 83) as configured in the Lake Plan alternative, provides an opportunity for the dilution of the toxicants being carried by the runoff. In addition, the Lake Plan alternative is a deep, high volume configuration which provides tremendous dilution potential for the intermittent inflow from the EGG-WFCC. For all the Lake Plan alternative configurations, runoff concentrations are reduced to a negligible level; i.e., on the order of 1 percent of those observed for the existing conditions. Although Lake 3 (which considers that the entrance channel has closed) indicates a slightly greater concentration reaching the wetland compared to the concentrations for the open entrance Lake Plan concepts (Lake 1 and Lake 2), this value is truly minuscule compared to the present configuration.

Assessment of Transport Characteristics

62. The three Lake Plan alternative concepts have no apparent negative impacts on water age in sensitive areas of Huntington Harbour. For the Lake 3 concept (entrance channel closed), water age in the proposed new wetland enhancement areas is greater than that presently found within the existing muted tidal wetlands (Inner Bolsa Bay). This indicates that water quality in the proposed new wetlands for the Lake 3 concept may be slightly degraded relative to water quality of the existing wetlands. Both the Lake 1 and Lake 2 concepts provide for significant reductions in water residence times in the existing wetlands (Inner Bolsa Bay) compared to existing conditions. This reduction in water residence time occurs because Inner Bolsa Bay tidal prism has a much shorter connection through the proposed Lake Plan entrance channel to the Pacific Ocean than through Huntington Harbour. Both of these concepts (Lake 1 and Lake 2) also provide for significant reductions in water age in the proposed new wetland enhancement regions compared to the existing Inner Bolsa Bay wetlands, for the same reasons.

63. The Lake Plan alternative concepts also provide a very effective buffer to the inflow of flood discharge from the EGG-WFCC into the wetlands. Dilution of this inflow is much greater for all the Lake Plan configurations than under existing conditions, and is a significantly beneficial consequence. Presently, flood flow from the EGG-WFCC discharges into Outer Bolsa Bay at the

entrance to Inner Bolsa Bay, with minimal dilution. Under Lake Plan concepts, flow from the EGG-WFCC will discharge into a large volume of relatively fresh (less degraded) water in the marina region, thus reducing concentrations available for transport into the proposed and existing wetlands.

PART V: SUMMARY AND CONCLUSIONS

Summary

64. The Lake Plan was introduced for analysis by Signal Landmark, as a third alternative to the Preferred and Secondary Alternatives. The Lake Plan provides for a non-navigable entrance channel at the same location as the Preferred and Secondary Alternatives, but with a marina reduced in size from that of the Preferred Alternative. The design of the proposed wetland enhancement will remain the same as for the Preferred Alternative.

65. Design details of the Lake Plan include a total water surface area of approximately 112 acres encompassing the main channel, marina basins, lower reach of the EGG-WFCC, interior waterways, and secondary channels. The design depth of the non-navigable entrance channel is -6 ft msl, while the depth of the marina complex is -20 ft msl. The Lake Plan alternative design contemplates an ocean entrance channel whose width should only be great enough to support an 1,100 acre marsh area from a hydraulic standpoint.

66. The calibrated and verified numerical simulation model DYNTRAN, previously utilized to evaluate both the Preferred and Secondary Alternatives, was used to determine the hydrodynamics and water quality aspects of the Bolsa Bay complex resulting from the proposed Lake Plan alternative. The existing conditions as previously evaluated are considered to be the base conditions for comparison of Lake Plan effects. Optimization of the entrance channel design has not been performed, although two entrance channel widths have been evaluated (Lake 1 = 350-ft wide entrance channel; Lake 2 = 200-ft wide entrance channel). Additionally, the possibility exists that the entrance channel may close by littoral material transport in the surf zone. Hence, it was necessary to evaluate the effects of a closed entrance on hydrodynamic and water quality aspects. The Lake Plan alternative when the ocean entrance channel is closed has been designated Lake 3.

Conclusions

Tidal water surface elevations

67. Primary interest with regard to water surface elevations is directed toward the ability of the Lake Plan non-navigable entrance channel concept to fully support the proposed wetland enhancement plan. Conclusions in this regard include:

- a. Water surface throughout Huntington Harbour responds identically as existing conditions for all Lake Plan concepts,
- b. The nearness of the proposed non-navigable entrance to Outer Bolsa Bay will permit low water elevations in the bay for Lake 1 and Lake 2 to fall about 1.0 ft lower than for existing conditions,
- c. Low water elevation in Outer Bolsa Bay for Lake 3 is retained about 1.0 higher than existing conditions, and about 2.0 ft higher than Lake 1 or Lake 2,
- d. When the wetlands are not connected, either Lake Plan causes about 0.15 ft higher high water elevation and about 0.15 ft lower low water elevation in Inner Bolsa Bay,
- e. Either Lake Plan alternative causes about a 0.1 ft higher high water elevation and about 0.05 ft lower low water elevation in the DFG muted tidal cell,
- f. High tide elevations in the proposed marinas are the same for all Lake Plan alternatives,
- g. Low tide elevations in the proposed marinas fall to about -3.5 ft msl for Lake 1 and Lake 2, and fall only to about -1.5 ft msl for Lake 3,
- h. Lake 1 and Lake 2 provide for about a 4.9 ft maximum tidal range in the proposed full tidal wetland, while Lake 3 allows for about a 4.4 ft maximum tidal range in the proposed full tidal wetland, and
- i. Lake 1 and Lake 2 provide for about a 2.1 ft maximum tidal range in the proposed muted tidal wetland, while Lake 3 allows for about a 1.9 ft maximum tidal range in the proposed muted tidal wetland.

Tidal average channel velocities

68. Major concerns pertaining to channel velocities exist with regard to navigation hazards at the PCH bridge at Anaheim Bay, swimmer safety in Huntington Harbour, potential for scour and erosion of soft sediments in Outer Bolsa Bay with accompanying shoaling in Huntington Harbour, and the possibility of closure of the non-navigable entrance channel by littoral material in the surf zone. Conclusions include the following:

- a. Average channel velocities at the PCH bridge at Anaheim Bay are equal to or slightly less than existing conditions for Lake 1 and Lake 2, with Lake 3 providing for about a 0.5 ft per sec increase from 2.78 to 3.24 ft per sec, for maximum spring tide conditions,
- b. Lake 1 slightly reduces average channel velocities in Huntington Harbour from existing conditions, Lake 2 induces about the same magnitude as existing conditions, and Lake 3 causes an increase to about 2.0 ft per sec for maximum spring tides, and may become hazardous for swimming,
- c. Lake 1 reduces average channel velocities under Warner Avenue bridge from existing conditions, Lake 2 induces about the same magnitude as existing conditions, Lake 3 causes an increase to about 4.8 ft per sec for maximum spring tides which may necessitate bridge stabilization measures to prevent scour of abutments and channel bottom,
- d. Lake 1 and Lake 2 reduce average channel velocities in Outer Bolsa Bay from existing conditions, Lake 3 increases maximum average channel velocities from about 1.4 to about 1.7 ft per sec for maximum spring tides; potential scour effects could be prevented by channel stabilization measures installed as part of project construction,
- e. Large channel cross-sectional areas in the proposed Lake Plan marina provide for low average channel velocities, and swimmer hazards will not result, and
- f. Average channel velocities in the non-navigable entrance at Bolsa Chica will exceed that necessary to initiate sediment motion, being about 2.4 and 3.3 ft per sec for Lake 1 and Lake 2, respectively. This will contribute to keeping the entrance channel from closing by littoral material transport in the surf zone, although may not be entirely sufficient.

Effect of wetland connection

69. Inner Bolsa Bay may or may not be connected to the proposed muted tidal wetlands by an opening through the existing dike. Conclusions regarding the effects of such a connection on wetland tidal elevations include:

- a. If the wetlands are connected, water surface elevations in Inner Bolsa Bay and the DFG muted tidal cell will rise about 0.15 ft higher than if the two regions are not connected,
- b. The proposed full tidal wetlands are unaffected by such a connection between the wetlands, and
- c. The proposed muted tidal wetlands will experience about a 0.1 ft decrease in maximum water surface elevation as this volume is permitted to flow into Inner Bolsa Bay.

100-Year flood flow water surface elevations

70. Concern exists regarding maximum flood flow elevations resulting from the 100-year flood flow (9,710 cfs) occurring on the EGG-WFCC at maximum spring tide conditions. Levee elevations must be established to preclude overtopping. Assuming culverts will not be closed to prevent flood flow from entering the wetlands, conclusions include the following:

- a. Under existing conditions, water surface elevations in Huntington Harbour increase about 0.3 ft beyond normal spring tide elevations (to about 4.4 ft msl); Lake 1 and Lake 2 alternatives produce about the same flood flow elevations as normal spring tide because most of the flood discharge exits directly into the Pacific Ocean at Bolsa Chica; Lake 3 high tide elevations approach those of existing flood flow,
- b. Warner Avenue bridge restricts flow from Outer Bolsa Bay, causing water surface elevations in Outer Bolsa Bay to increase beyond normal spring tide for existing conditions by about 3.0 ft (from about 4.1 to about 7.1 ft msl); Lake 1 and Lake 2 alternatives result in flood elevations approximating those of normal spring tide; Lake 3 high tide elevations approach those of existing flood flows,
- c. For existing flood flows, Inner Bolsa Bay and the DFG muted tidal cell high water surface elevations increase from about 1.0 to about 6.7 ft msl; Lake 1 and Lake 2 increase high tide elevations beyond normal spring tides by about 0.5 and 1.0 ft, respectively; Lake 3 alternative approximates the existing high tide flood flow elevation,
- d. Lake 1 and Lake 2 alternatives provide for increases in high water elevation beyond normal spring tide in the proposed full tidal wetlands of about 0.2 and 0.4 ft, to about 3.6 and 3.8 ft msl, respectively; Lake 3 alternative causes an increase of about 3.4 ft, to about 6.7 ft msl, and

- e. Lake 1 and Lake 2 alternatives provide for increases in high water elevation beyond normal spring tide in the proposed muted tidal wetlands of about 0.3 and 0.6 ft, to about 1.8 and 2.1 ft msl, respectively; Lake 3 alternative causes an increase of about 5.0 ft, to about 6.5 ft msl.

100-Year flood flow average channel velocities

71. Conclusions regarding maximum average channel velocities resulting from the 100-year flood flow on the EGG-WFCC include:

- a. For existing conditions at the PCH bridge at Anaheim Bay, maximum average channel velocities increase from about 2.8 ft per sec for maximum spring tides to about 5.0 ft per sec for flood flows; Lake 1, Lake 2, and Lake 3 concepts result in maximum average channel velocities of 3.0, 3.3, and 5.0 ft per sec, respectively; these average channel velocities do not consider spiral flow around bends which may result in greater localized velocities,
- b. For existing conditions in Huntington Harbour, maximum average channel velocities increase from about 1.5 ft per sec for maximum spring tides to about 3.5 ft per sec for flood flows; Lake 1, Lake 2, and Lake 3 concepts result in maximum average channel velocities of 1.7, 2.0, and 3.5 ft per sec, respectively,
- c. Restrictions caused by Warner Avenue bridge increase maximum average channel velocities for existing conditions from 1.6 to 11.6 ft per sec; Lake 1, Lake 2, and Lake 3 concepts result in maximum average velocities of 4.9, 6.5, and 11.4 ft per sec, respectively,
- d. For existing conditions, maximum average channel velocities in Outer Bolsa Bay increase from 1.4 ft per sec under normal spring tide conditions to 2.3 ft per sec for flood flows; Lake 1, Lake 2, and Lake 3 concepts provide for maximum average channel velocities of 1.7, 1.9, and 2.2 ft per sec, respectively,
- e. Scour of soft sediments in Outer Bolsa Bay which may result from increased flow velocities could be prevented by channel stabilization measures at either or both ends of the bay, and
- f. Maximum average channel velocities in the non-navigable entrance channel at Bolsa Chica for Lake 1 and Lake 2 (6.7 and 8.2 ft per sec, respectively, are of sufficient magnitude to reestablish design dimensions of the channel. These high velocities may keep the entrance channel open only a short time; a 100-year opening frequency is not sufficient to prevent closure at other times.

Presently existing water quality assessment

72. Three categories of water quality problems presently existing or potentially arising need to be considered in evaluating impacts of proposed alternatives to develop and enhance the wetlands of Bolsa Chica. These conditions have been previously addressed in the main report, Report No. 3.

- a. Dissolved oxygen standards and criteria are violated occasionally in Outer Bolsa Bay, and in the deeper waters of Huntington Harbour, during the summer months. An additional ocean entrance will provide a source of water with higher dissolved oxygen concentrations. However, additional development will potentially increase biological oxygen demand sources to the area (increased vessel wastes and runoff), unless standard control measures are provided.
- b. Certain trace metals (lead, zinc, arsenic, and cadmium), and organic toxicants (chlordanes and organochlorines) are detected in sediments throughout the area. TBT is observed in localized portions of Huntington Harbour, but has been prohibited and should decline in the future. Increased flushing with an additional ocean entrance will tend to mediate existing sediment problems associated with system toxicants.
- c. Low flushing in the wetlands has resulted in stagnation conditions in the most interior portions of the wetlands. Primary productivity within the wetlands may be nutrient-limited without sufficient tidal exchange. This situation will be significantly improved with an additional ocean entrance at Bolsa Chica.

Assessment of Lake Plan transport characteristics

73. DYNTRAN simulations were performed to evaluate the impacts of the transport and mixing characteristics of Lake 1, Lake 2, and Lake 3 alternatives on water quality in the Huntington Harbour-Bolsa Bay complex. Overall residence time (water age) was calculated for the whole system, and transport of runoff from the EGG-WFCC was simulated as the flood channel has previously been shown to be a major source of toxic materials which are transported into the wetlands. These simulations only addressed the potential impacts of circulation changes in the system on water quality. No attempt was made to estimate the potential increases of pollutant loadings associated with recreational use increases.

- a. The three Lake Plan alternative concepts have no apparent negative impacts on water age in sensitive areas of Huntington Harbour.

- b. Both Lake 1 and Lake 2 concepts provide for significant reductions in water residence times in the existing muted tidal wetlands (Inner Bolsa Bay) compared to existing conditions. Both also provide for significant reductions in water age in the proposed wetland enhancement regions at Bolsa Bay compared to the existing muted tidal wetlands.
- c. Lake 3 (entrance channel closed) water age in the proposed new wetland enhancement areas is greater than that presently found within the existing muted tidal wetlands (Inner Bolsa Bay), indicating water quality in the proposed new wetlands for the Lake 3 concept may be slightly degraded relative to water quality of the existing muted tidal wetlands.
- d. The Lake Plan alternative concepts provide a very effective buffer to the inflow of flood discharge from the EGG-WFCC into the wetlands. Dilution of this inflow is much greater for all the Lake Plan configurations than under existing conditions.

Lake 3 perspective

74. The Lake 3 concept assumes that the proposed entrance channel at Bolsa Chica associated with either the Lake 1 or Lake 2 concept has closed. Velocities resulting from spring tide conditions will be sufficient to cause erosion of bottom material under Warner Avenue bridge (up to 4.8 ft per sec), and in portions of Outer Bolsa Bay (up to 1.7 ft per sec). Stabilization measures to preclude scouring should be included as part of project construction.

75. Velocities resulting from the 100-year flood flow under Lake 3 conditions occurring at high spring tide would be excessive from the PCH bridge at Anaheim Bay through Outer Bolsa Bay, approaching 5.1 ft per sec under the PCH bridge, 3.5 ft per sec in Huntington Harbour, 11.4 ft per sec under Warner Avenue bridge, and 2.2 ft per sec in Outer Bolsa Bay. Scour prevention measures for the bridges, and channel stabilization measures for Outer Bolsa Bay, should be designed and included as part of project construction.

76. The probability of the 100-year flood occurring at high spring tide, with a simultaneous inability to reopen the proposed entrance channel at Bolsa Chica, is exceedingly low. This situation may be important from the standpoint of bridge scour, but should be of no concern regarding swimming or water age. It is possible that heavy rains and flood conditions may follow high waves which have closed the proposed entrance channel at Bolsa Chica; hence, closure of the entrance channel and a flood is not an impossible

situation. However, the entrance channel could be reopened immediately following a storm to alleviate excessively high velocities throughout Bolsa Bay. Even if the 100-year flood occurred and the proposed entrance channel at Bolsa Chica were not reopened immediately, scour expected to result from high velocities could be prevented by various channel stabilization measures provided as part of project construction.

Summary Conclusions

77. The development of either Lake 1 (350-ft wide entrance channel) or Lake 2 (200-ft wide entrance channel) new non-navigable entrance channel system to Bolsa Bay, with associated marinas, full tidal, and muted tidal wetland enhancement, is feasible from engineering, hydrodynamic, and water quality standpoints investigated by this study. Any potential for scour resulting from high velocities near bridges or in Outer Bolsa Bay under the Lake 3 concept (where the proposed Lake 1 or Lake 2 entrance channel at Bolsa Chica has closed) could be prevented by channel stabilization measures installed as part of project construction. Since the entrance channel could be reopened immediately following closure by a storm, other related environmental elements such as water age may not be adversely impacted. The Bolsa Bay complex will provide for multiple public and private uses with an emphasis on wildlife habitat enhancement, public recreation, coastal access, and water dependent residential development.

REFERENCES

Hughes, S. A. 1988 (Jul). Appendix C. "Stability Analysis of Proposed Ocean Entrance Channels, Bolsa Chica, California," in Gravens, Mark. 1990. Bolsa Bay, California, Proposed Ocean Entrance System Study; Report 2, "Comprehensive Shoreline Response Computer Simulation, Bolsa Bay, California," Miscellaneous Paper CERC-89-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Moffatt & Nichol, Engineers. 1986 (Oct). "Draft Preliminary Desilting Basin Design for East Garden Grove-Wintersburg Channel at the Proposed Bolsa Chica Project," Moffatt & Nichol, Engineers, Long Beach, California. Prepared for Signal Bolsa Corporation, Irvine, CA.

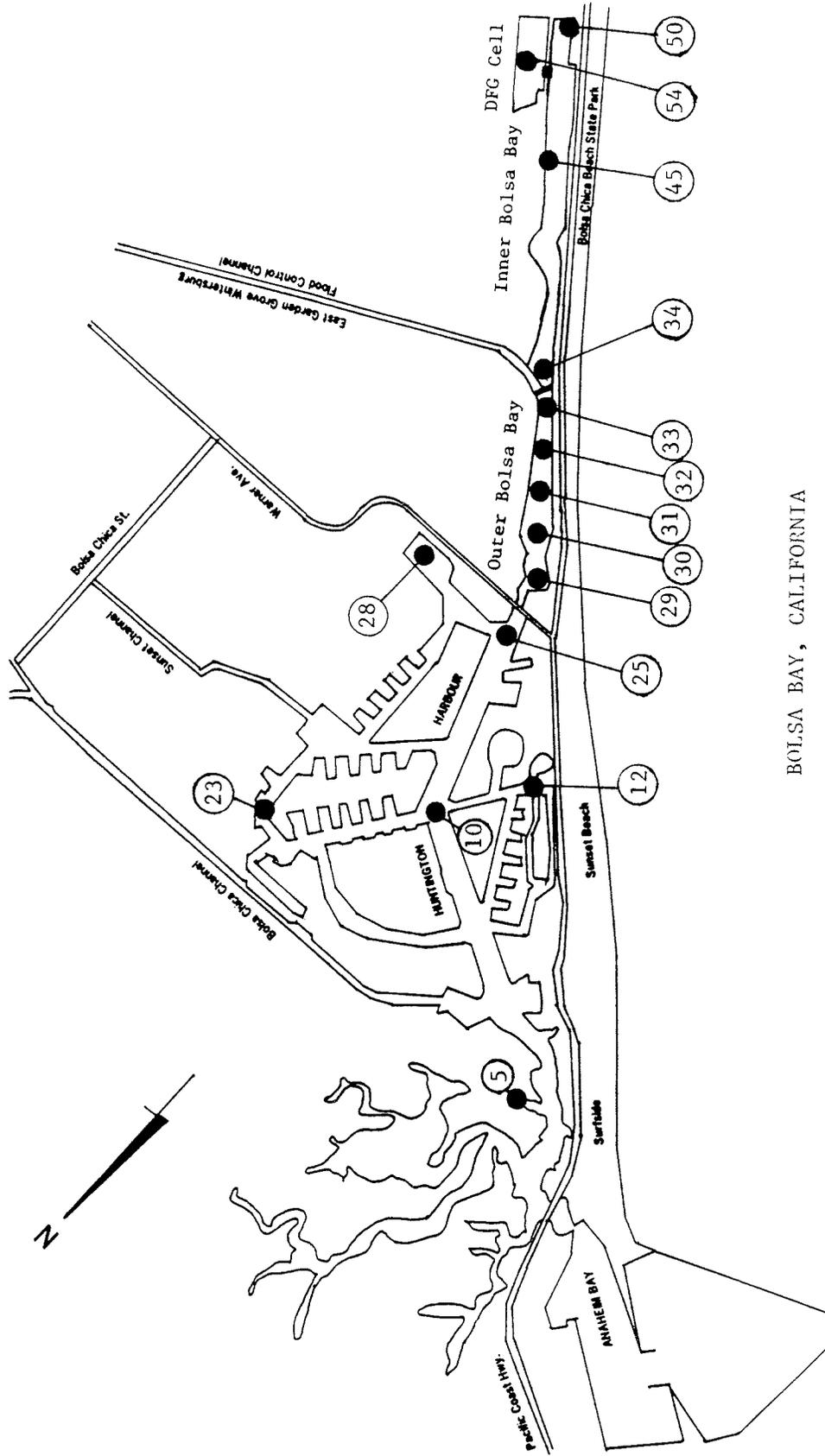
Moore, C. I. and Walton R. 1984 (Oct). "DYNTRAN/TRAN Users Manual," Camp Dresser & McKee, Inc., Annandale, Virginia. Prepared for SRA Technologies, Inc., Arlington, VA.

Orange County Environmental Management Agency. 1985. "Bolsa Chica Land Use Plan," Local Coastal Program, North Coast Planning Unit, Orange County Board of Supervisors, Santa Ana, CA.

Orange County Flood Control District. 1986 (Jun). "Orange County Hydrology Manual," Santa Ana, CA.

Radovich, R. 1987. "Department of Fish and Game Recommendations for Elements to be Included in the Corps of Engineers Feasibility Study for Bolsa Chica Ocean Entrance and Alternative Means of Restoring Wetland Resources," Memorandum to California State Lands Commission, State of California Resources Agency, Sacramento, CA.

APPENDIX A:
EXISTING CONDITION
WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

Location of nodes for displaying water surface elevations under existing conditions

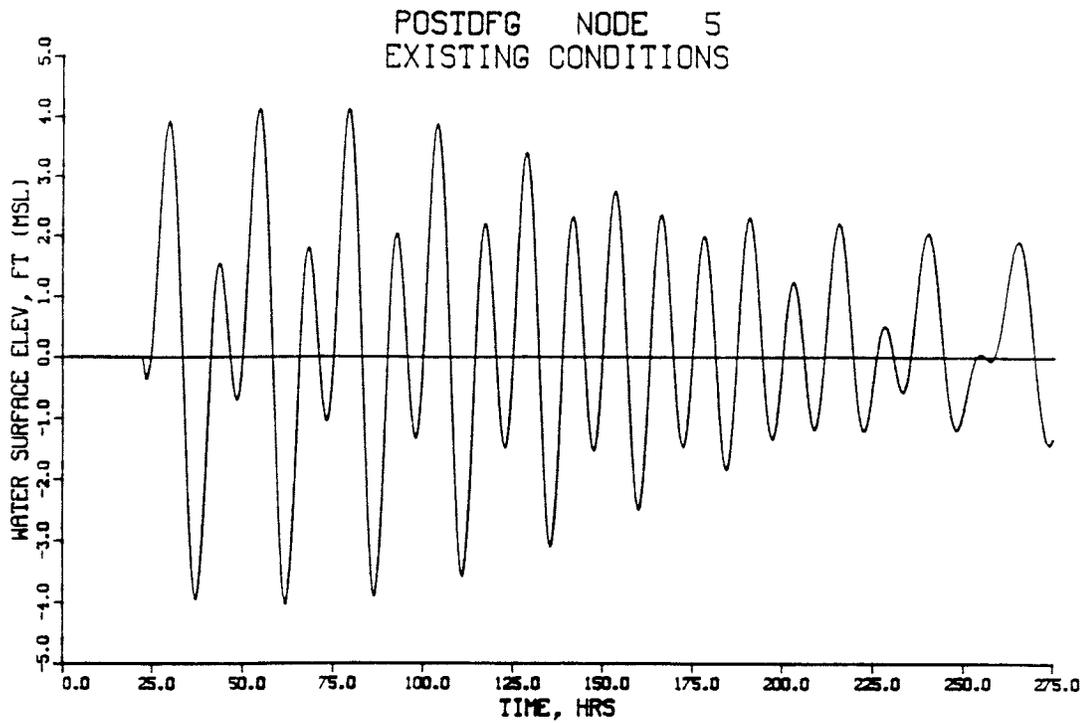


Figure A1. Tidal elevations in Huntington Harbour

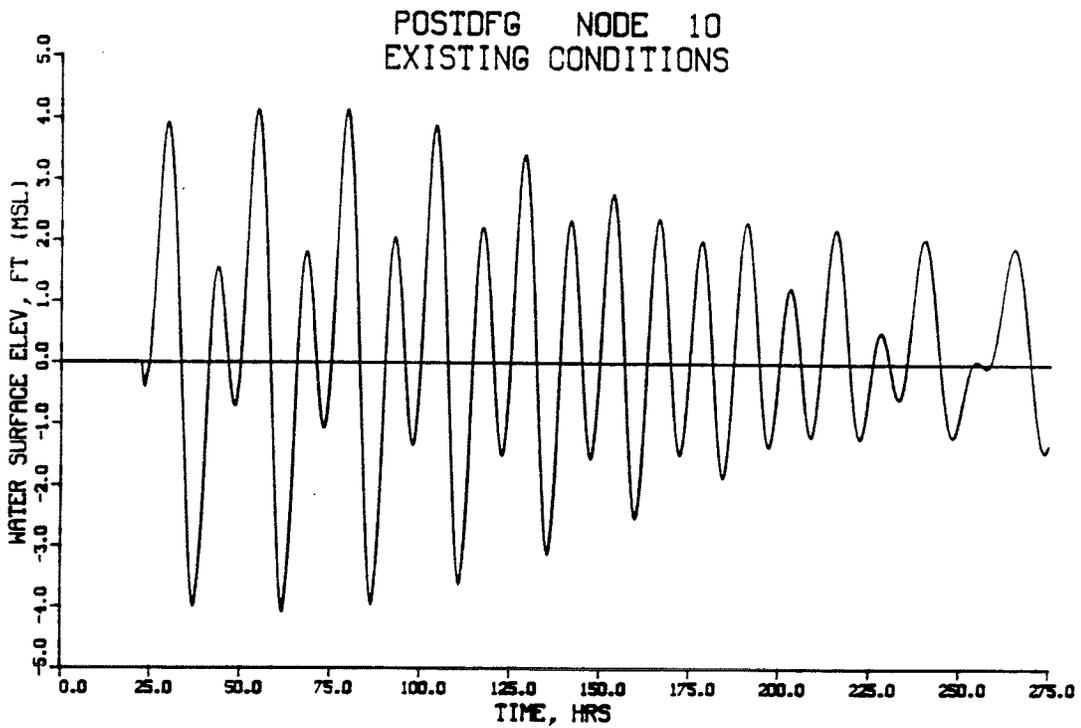


Figure A2. Tidal elevations in Huntington Harbour

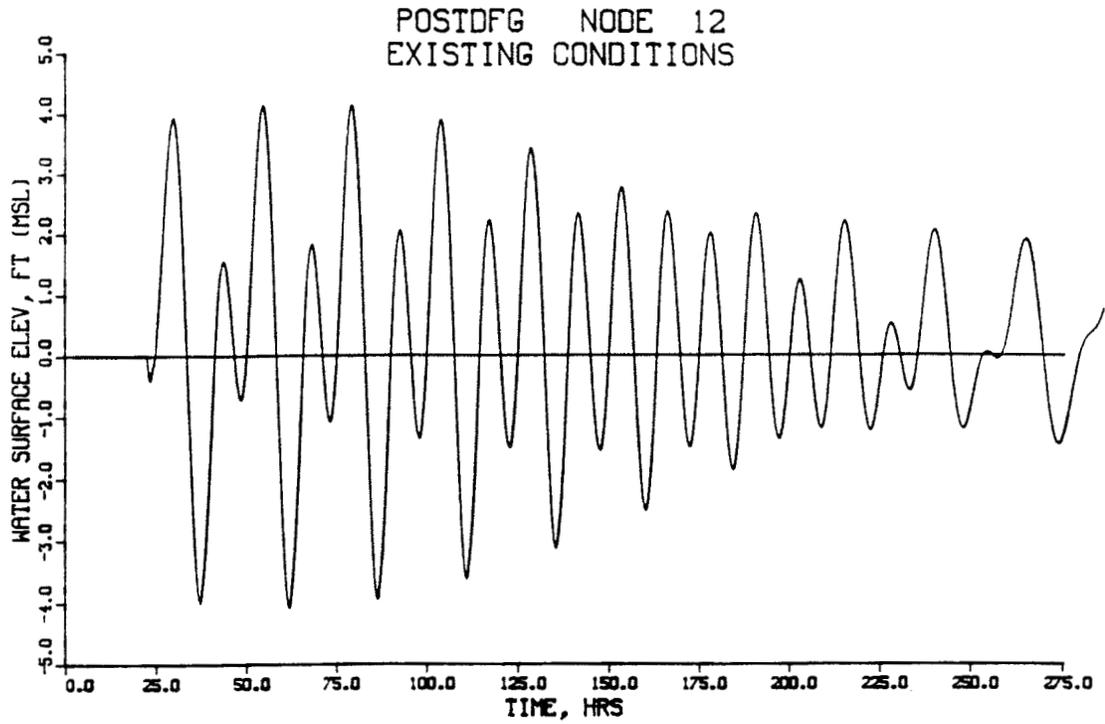


Figure A3. Tidal elevations in Huntington Harbour

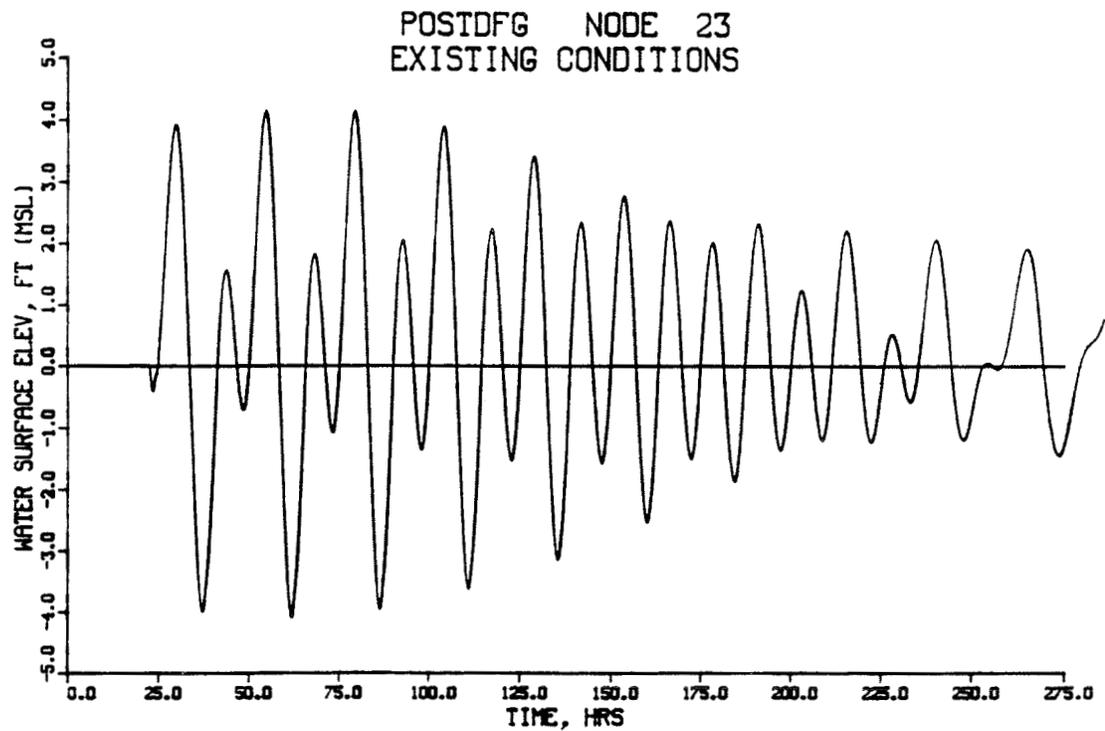


Figure A4. Tidal elevations in Huntington Harbour

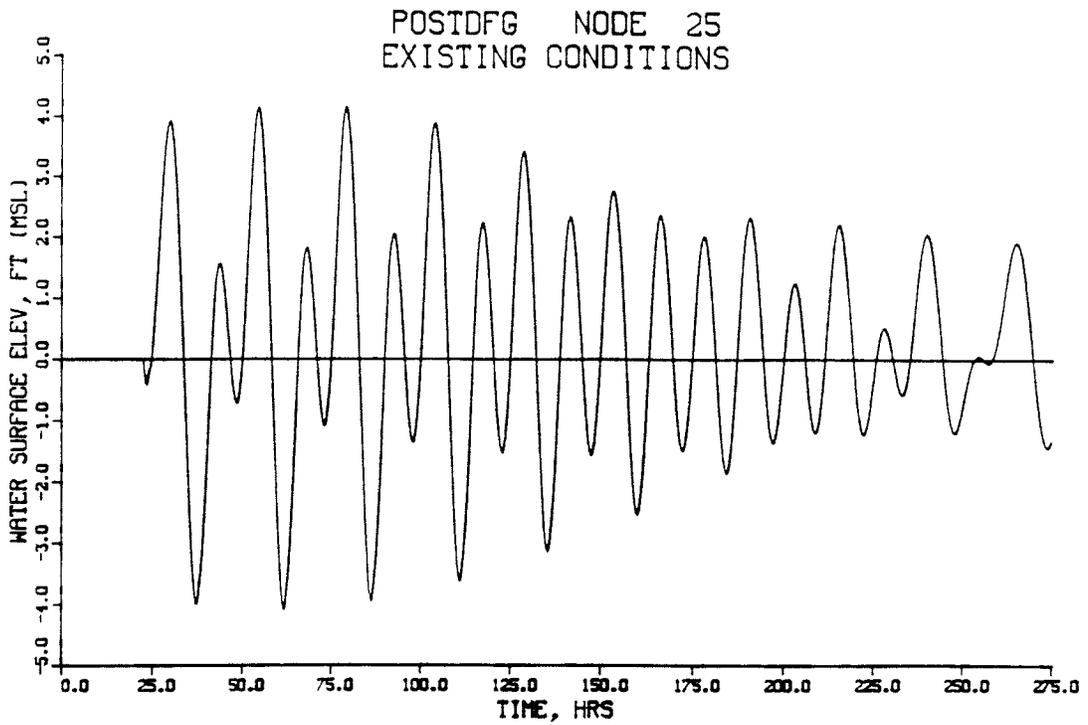


Figure A5. Tidal elevations in Huntington Harbour

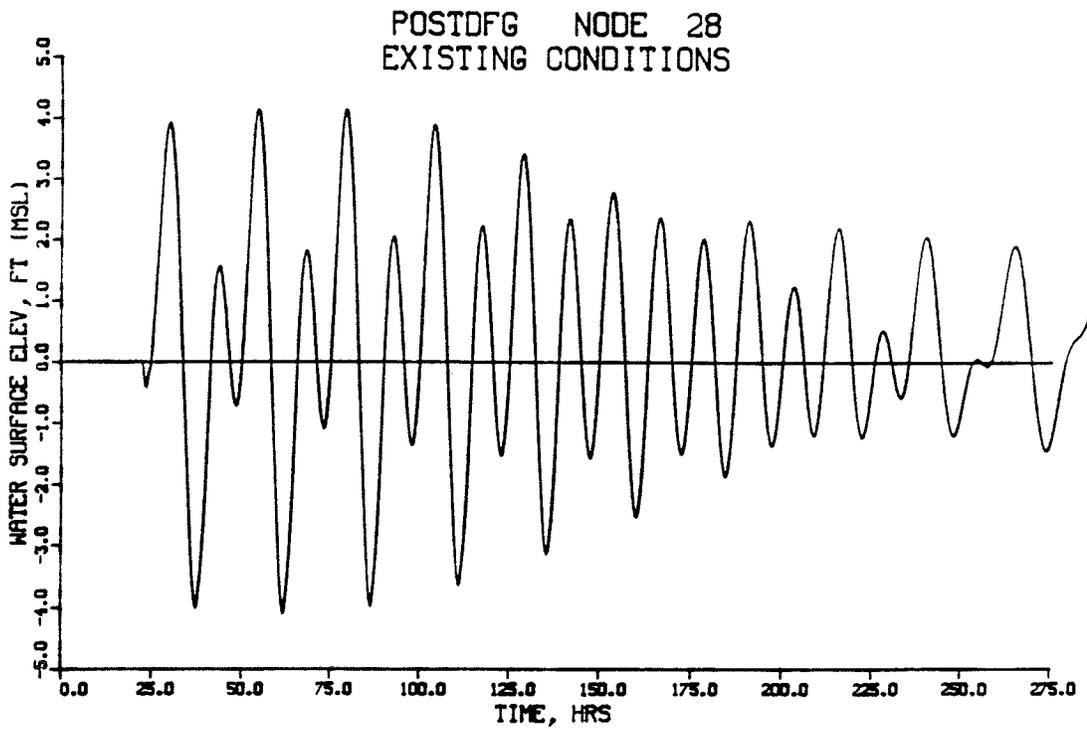


Figure A6. Tidal elevations in Huntington Harbour

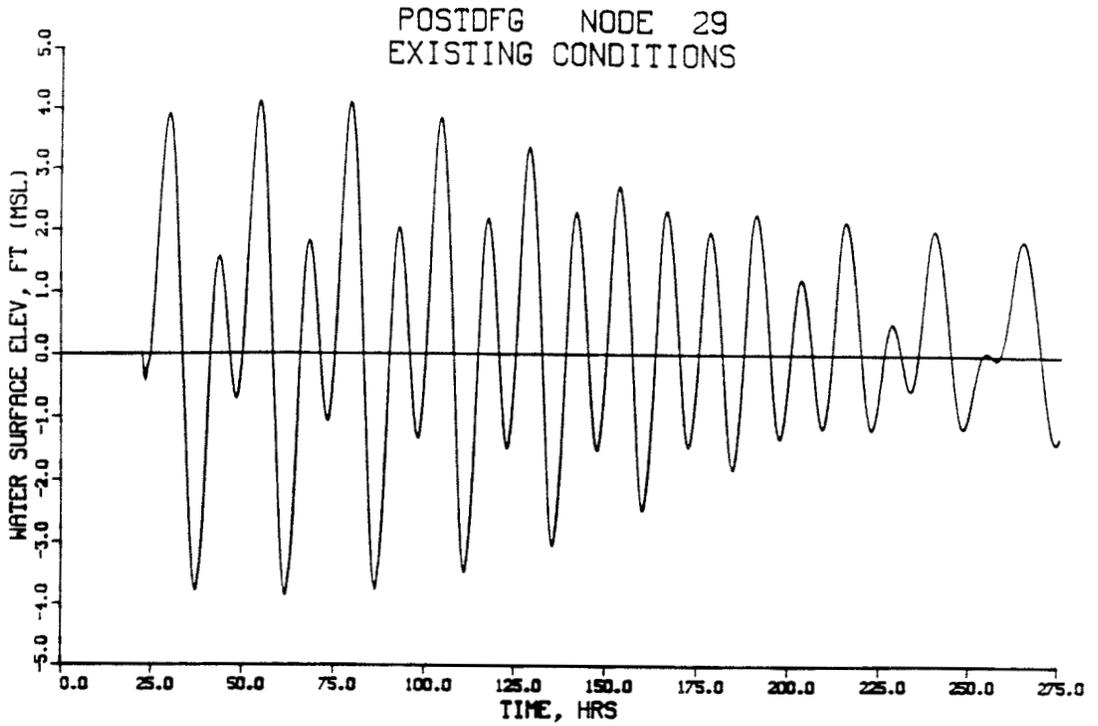


Figure A7. Tidal elevations in Outer Bolsa Bay

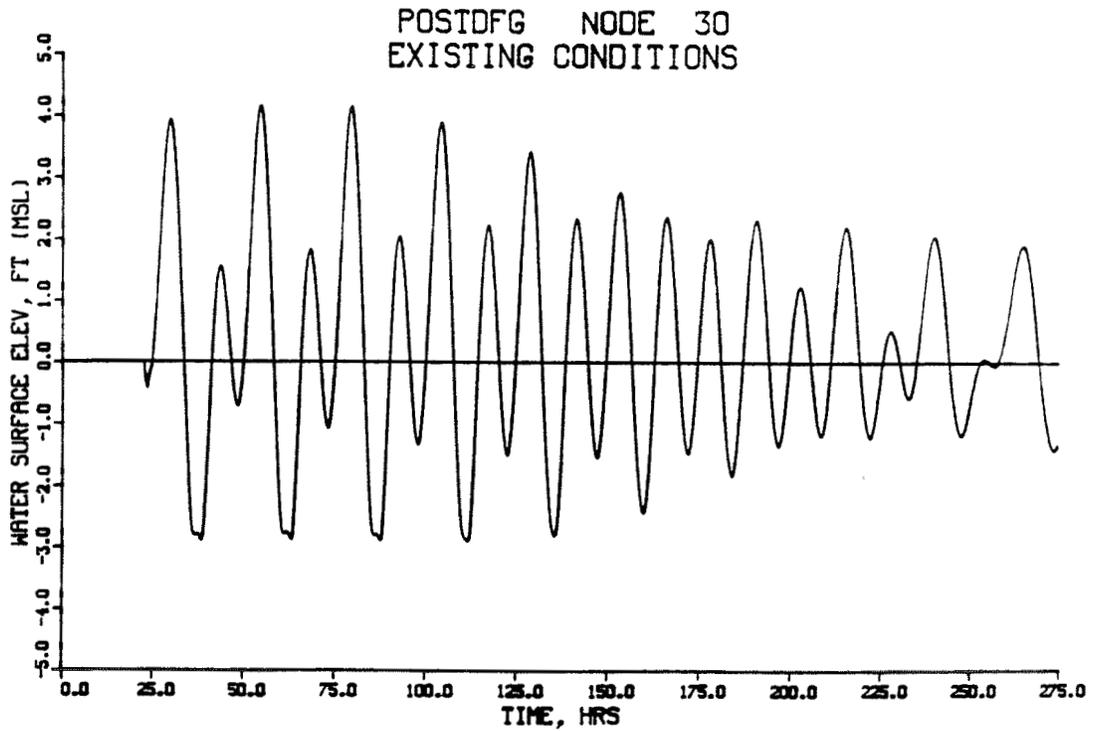


Figure A8. Tidal elevations in Outer Bolsa Bay

POSTDFG NODE 31
EXISTING CONDITIONS

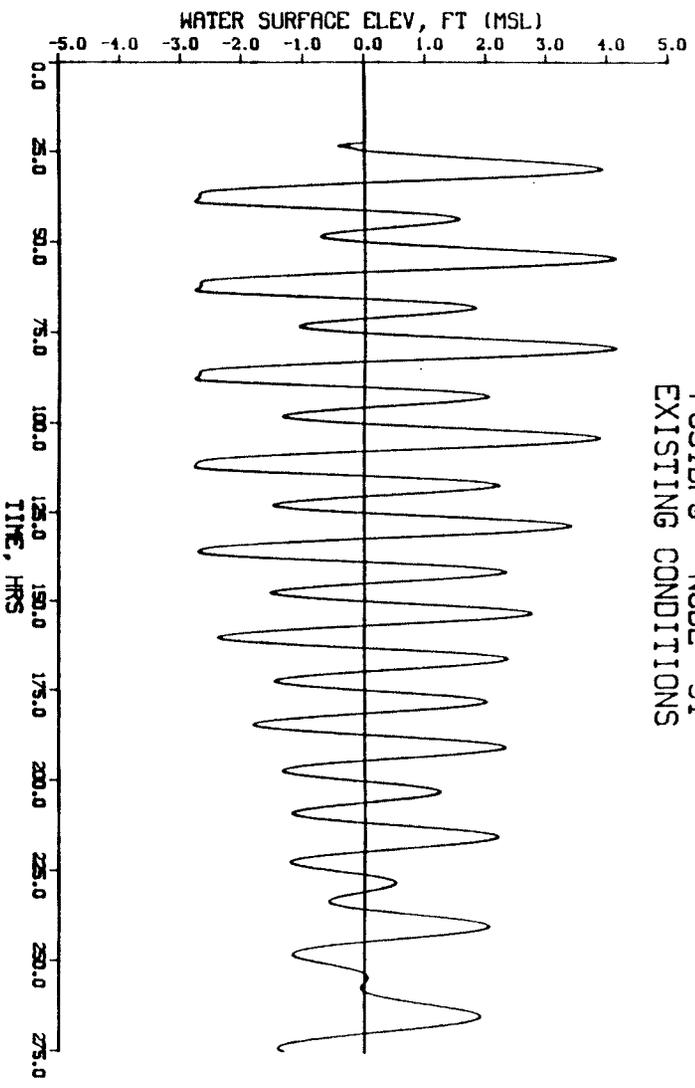


Figure A9. Tidal elevations in Outer Bolsa Bay

POSTDFG NODE 32
EXISTING CONDITIONS

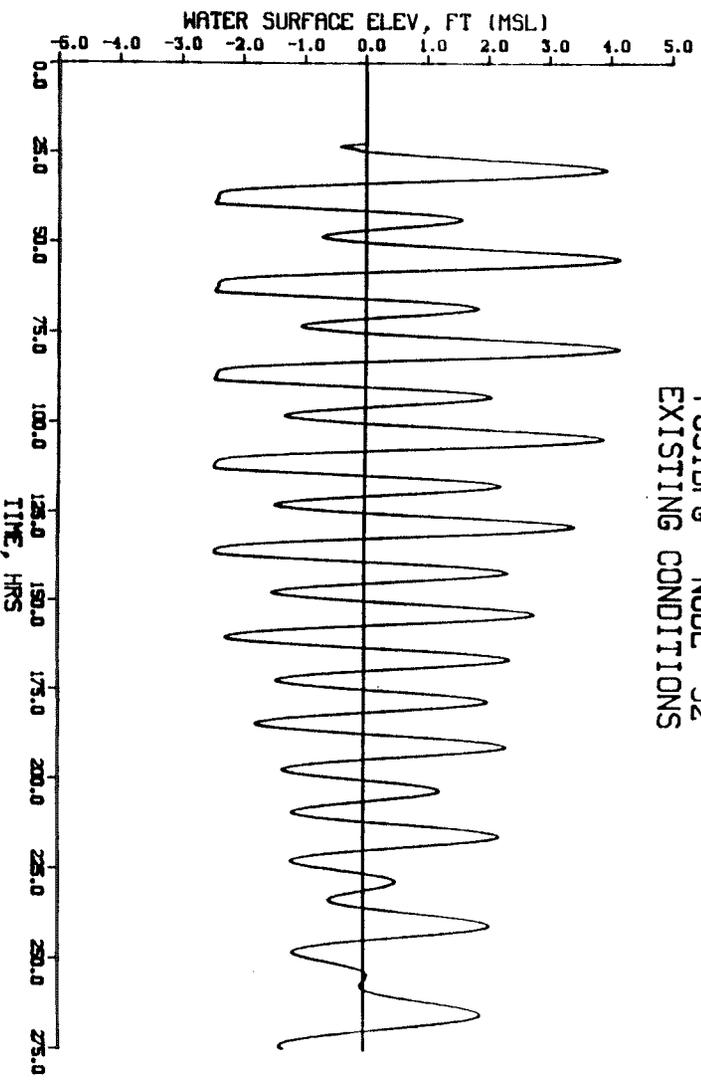


Figure A10. Tidal elevations in Outer Bolsa Bay

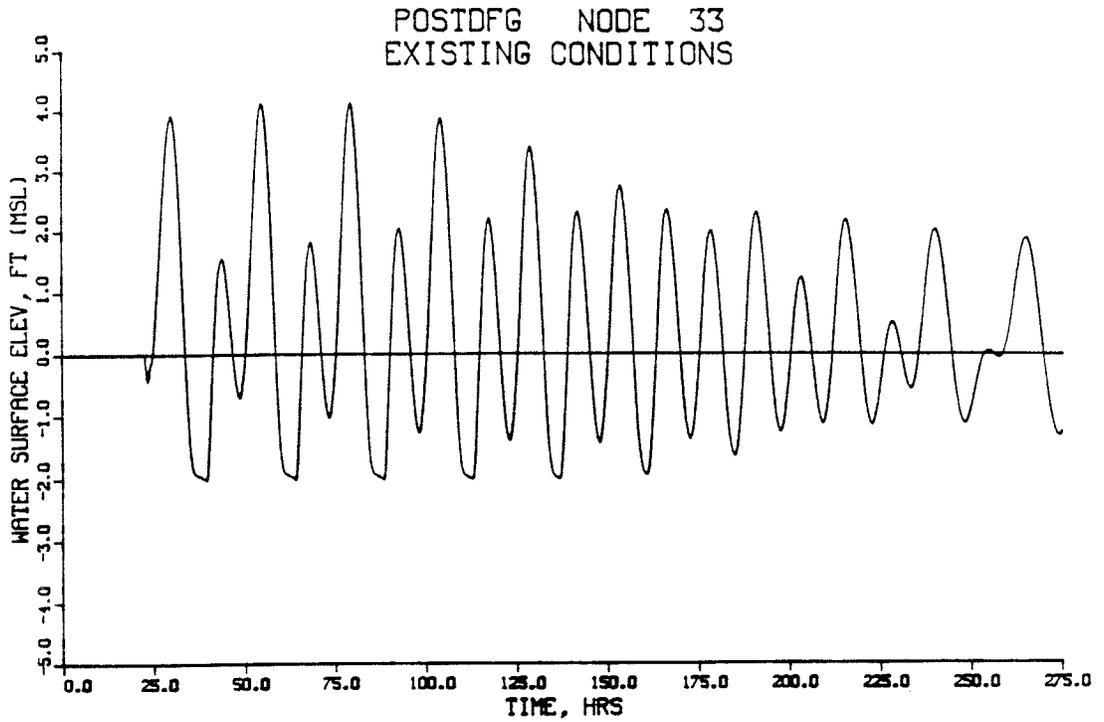


Figure A11. Tidal elevations in Outer Bolsa Bay

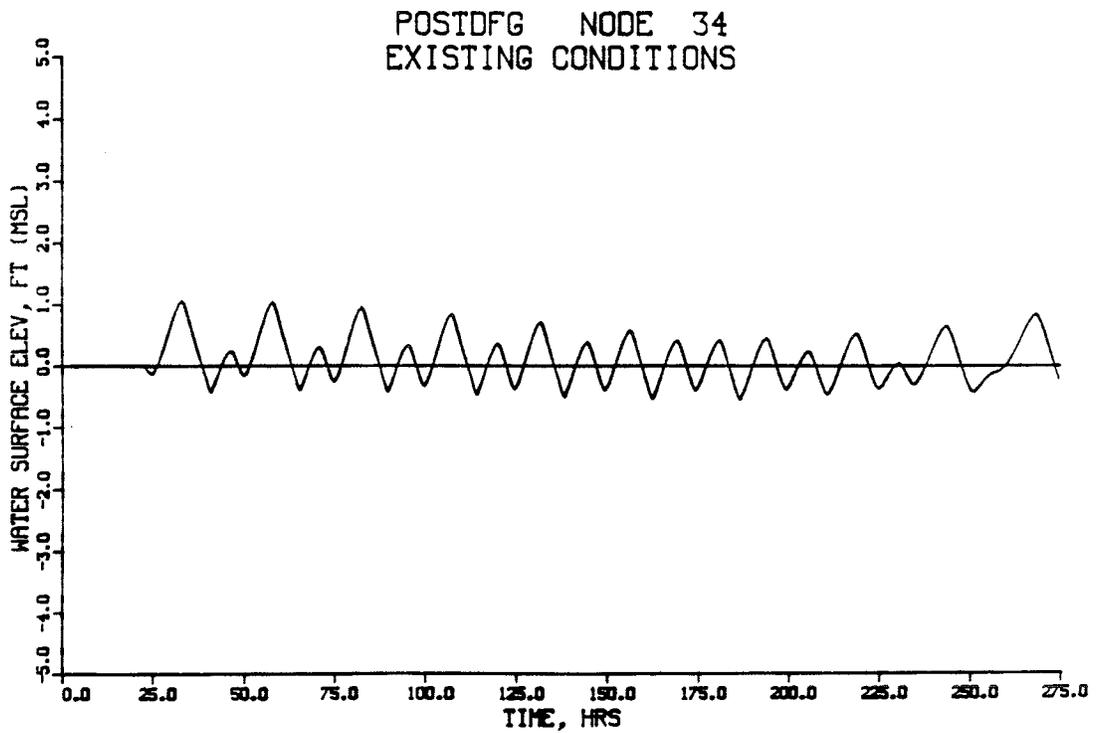


Figure A12. Tidal elevations in Inner Bolsa Bay

POSTDFG NODE 45
EXISTING CONDITIONS

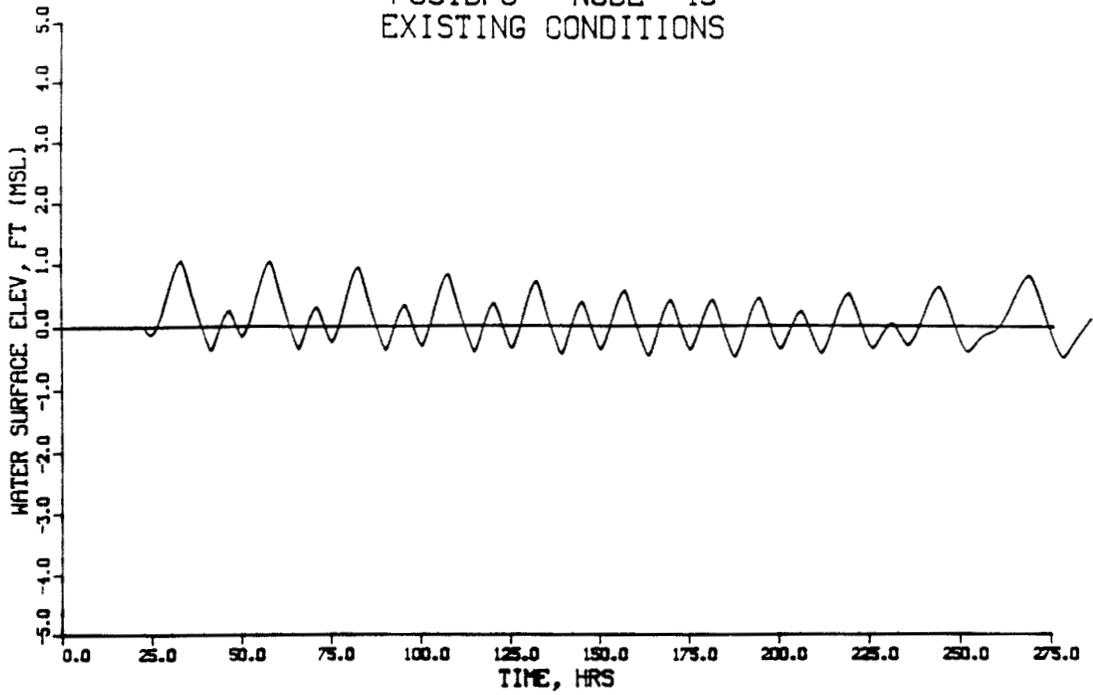


Figure A13. Tidal elevations in Inner Bolsa Bay

POSTDFG NODE 50
EXISTING CONDITIONS

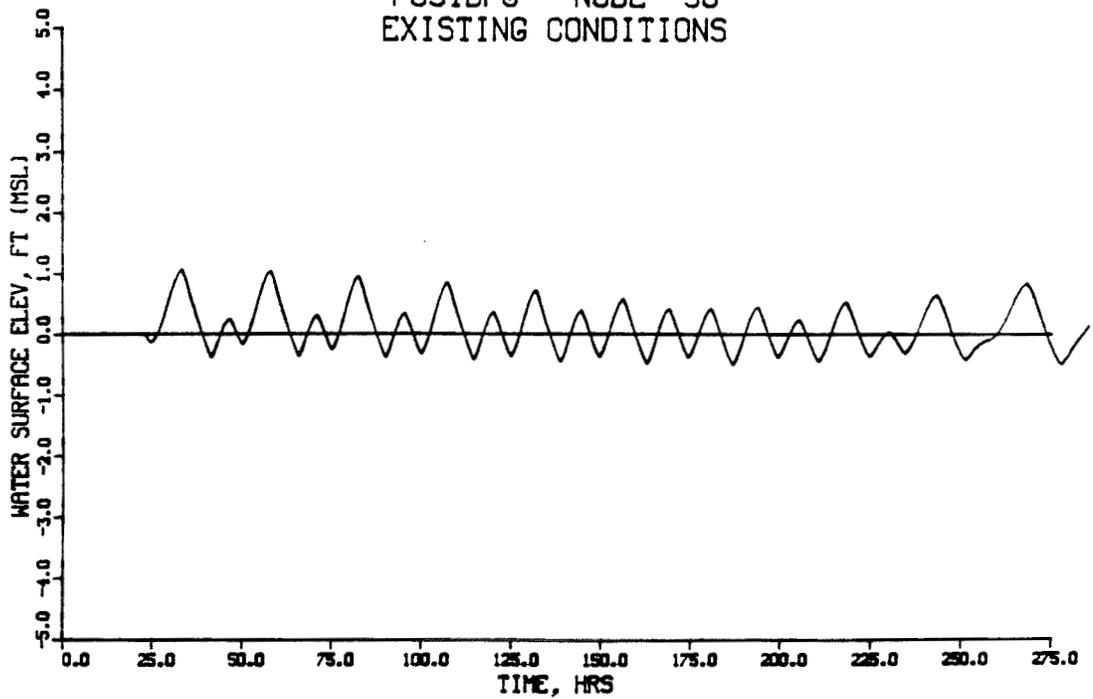


Figure A14. Tidal elevations in Inner Bolsa Bay

POSTDFG NODE 54
EXISTING CONDITIONS

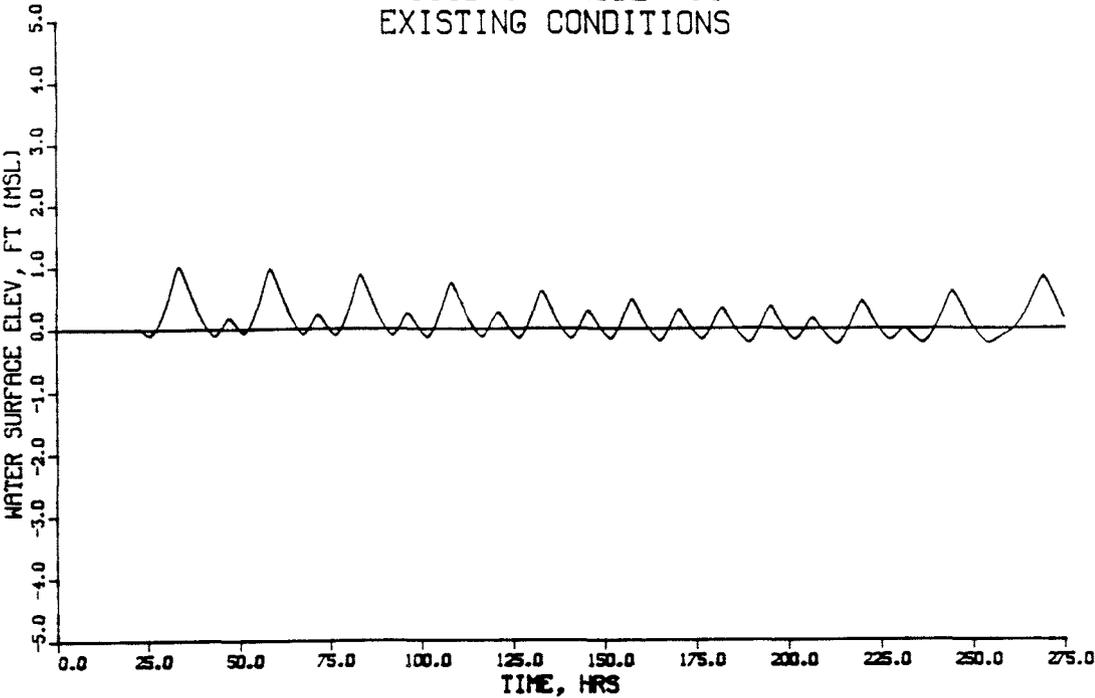
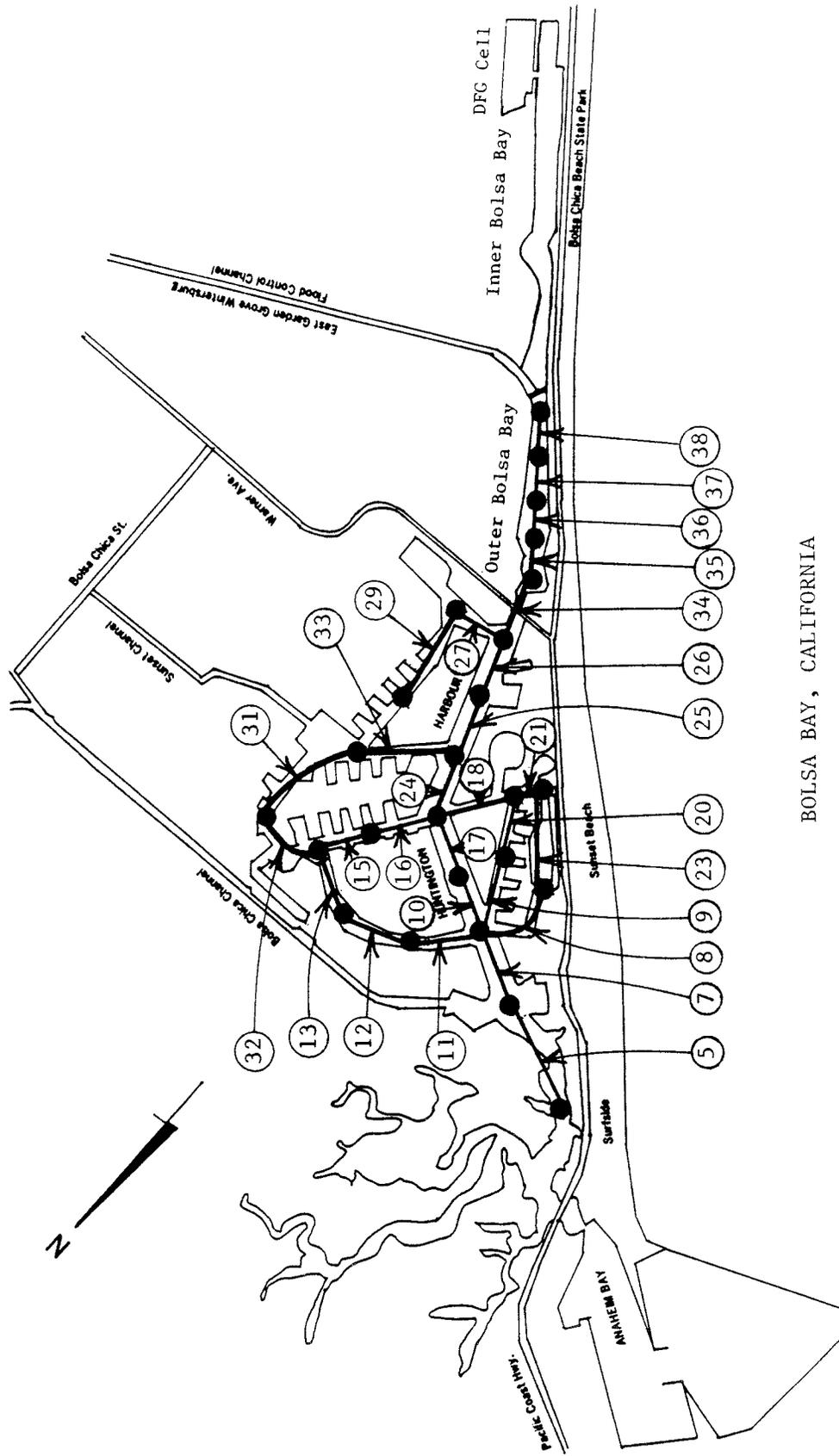


Figure A15. Tidal elevations in DFG muted tidal cell

APPENDIX B:

EXISTING CONDITION

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

Location of links for displaying average channel velocities under existing conditions

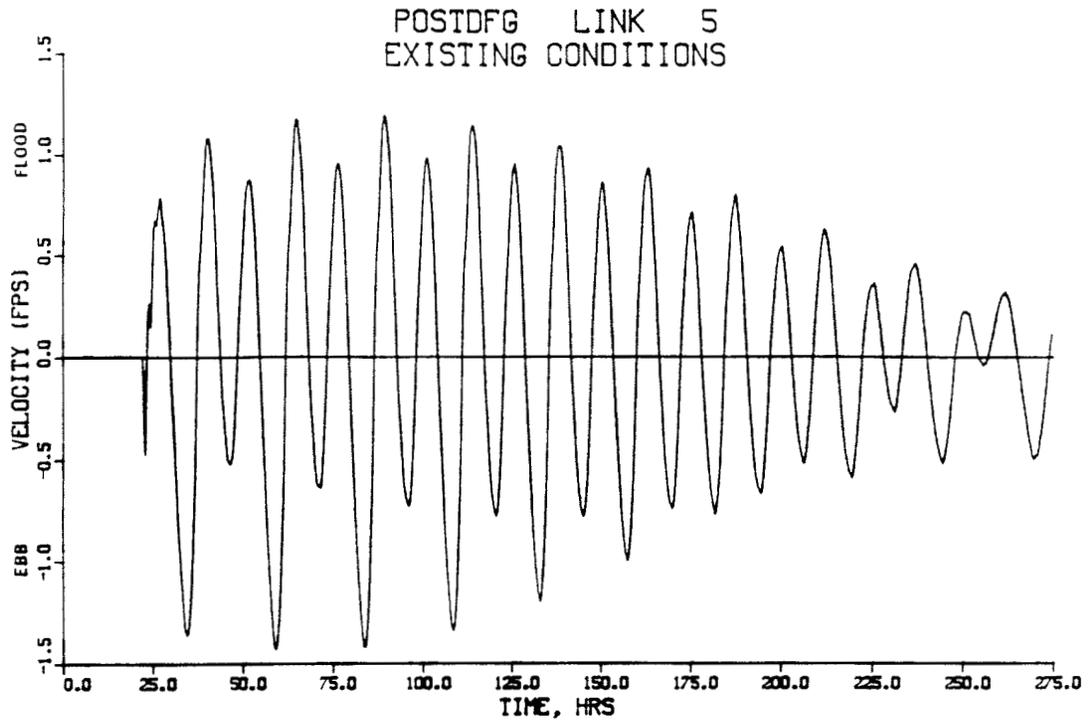


Figure B1. Average channel velocities in Huntington Harbour

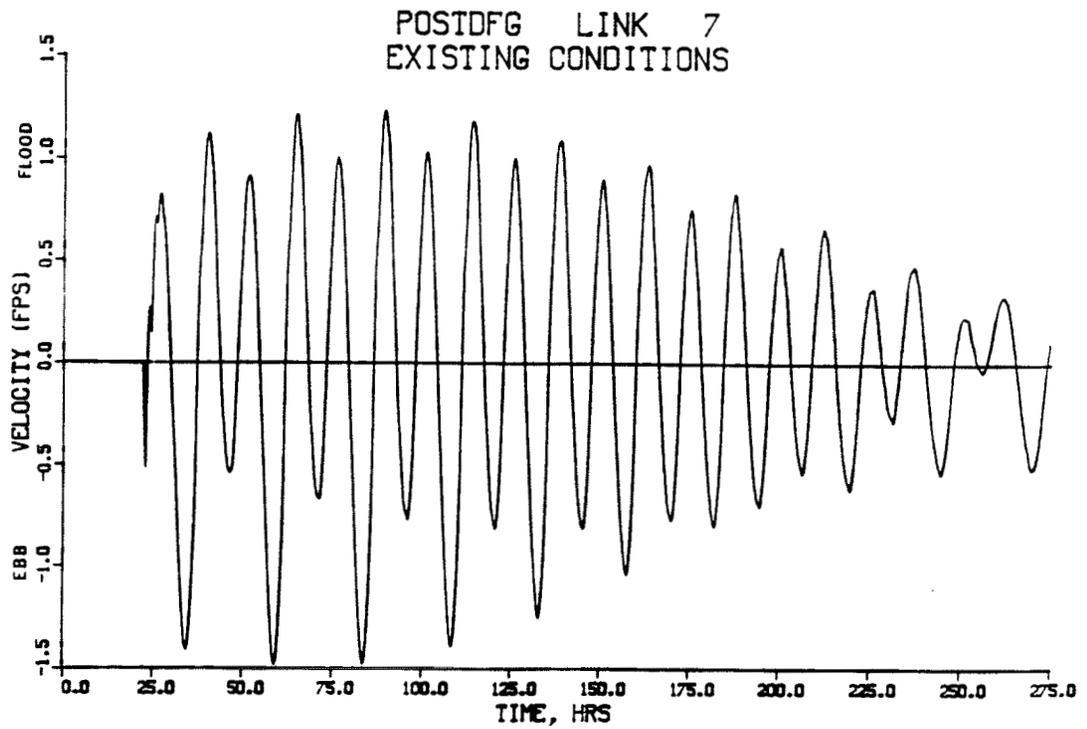


Figure B2. Average channel velocities in Huntington Harbour

POSTDFG LINK 8
EXISTING CONDITIONS

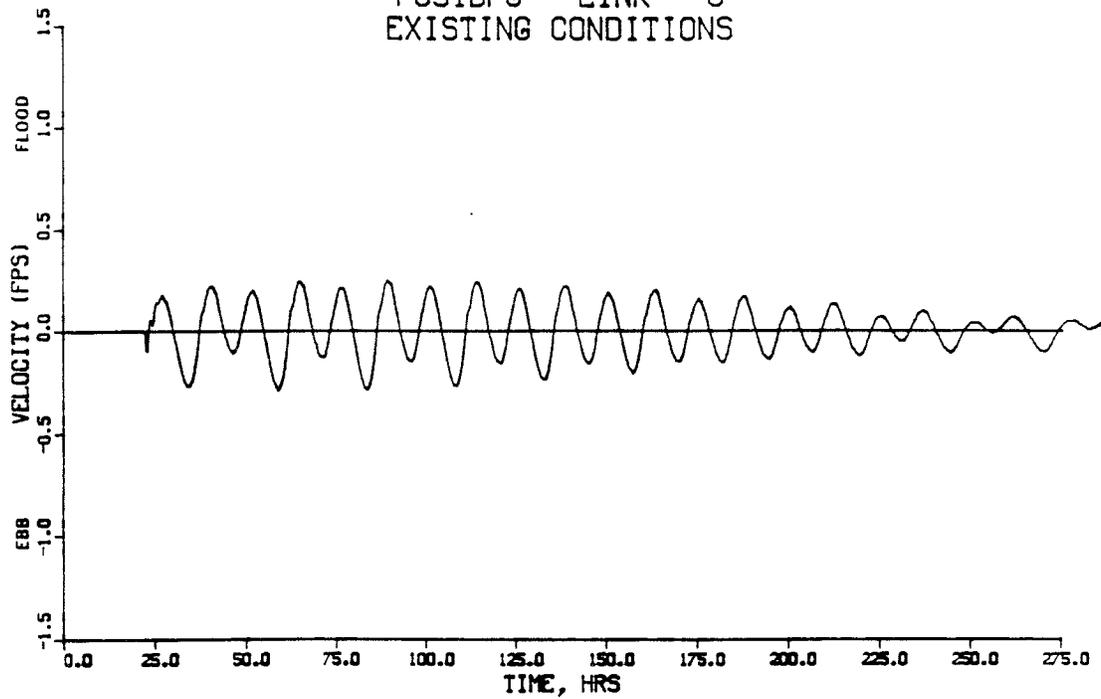


Figure B3. Average channel velocities in Huntington Harbour

POSTDFG LINK 9
EXISTING CONDITIONS

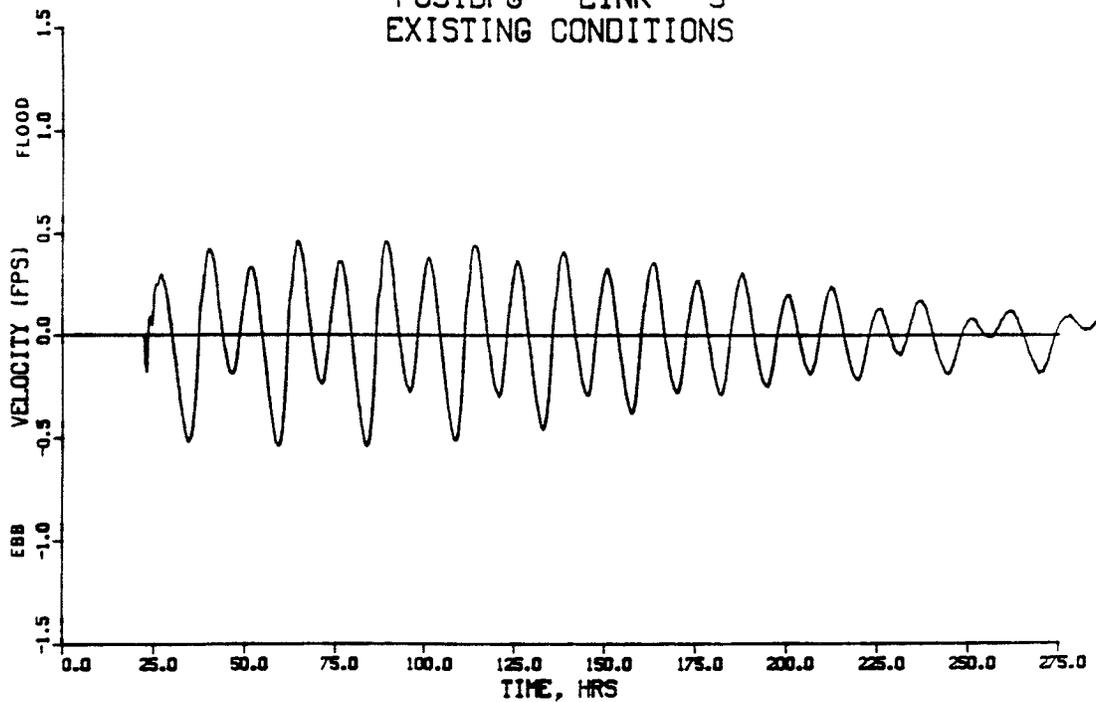


Figure B4. Average channel velocities in Huntington Harbour

POSTDFG LINK 10
EXISTING CONDITIONS

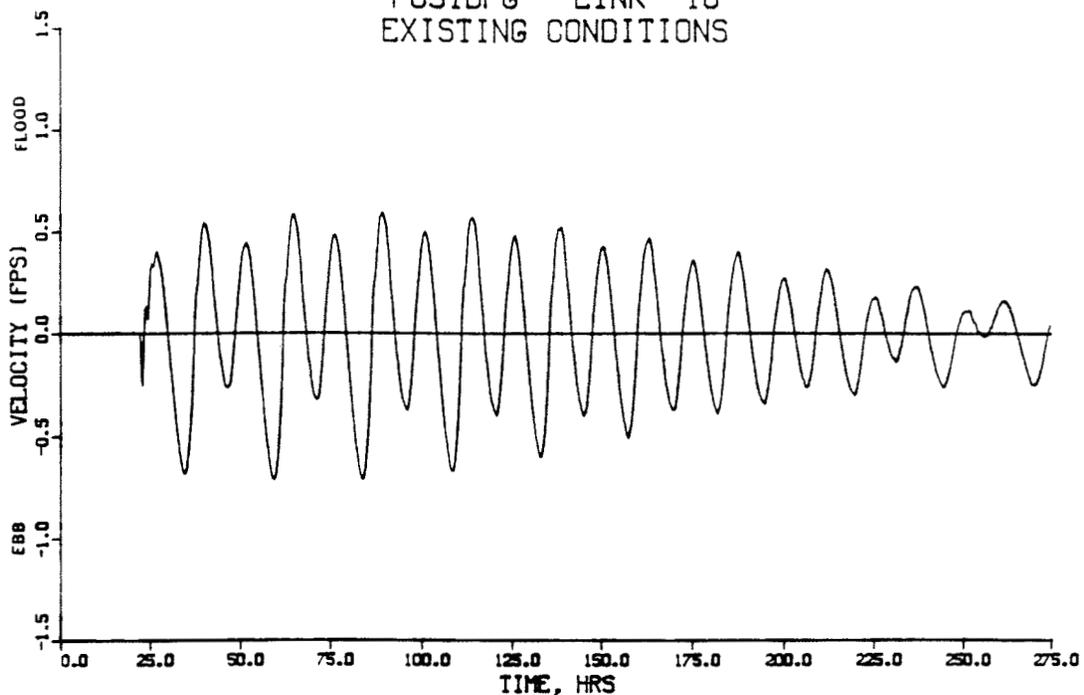


Figure B5. Average channel velocities in Huntington Harbour

POSTDFG LINK 11
EXISTING CONDITIONS

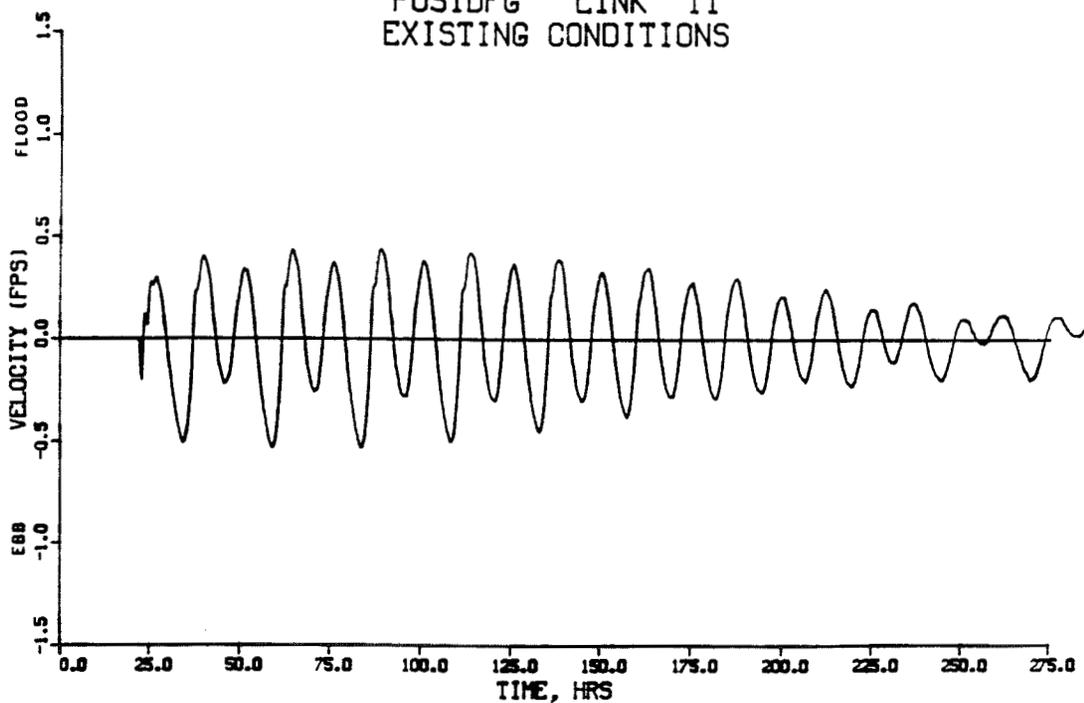


Figure B6. Average channel velocities in Huntington Harbour

POSTDFG LINK 12
EXISTING CONDITIONS

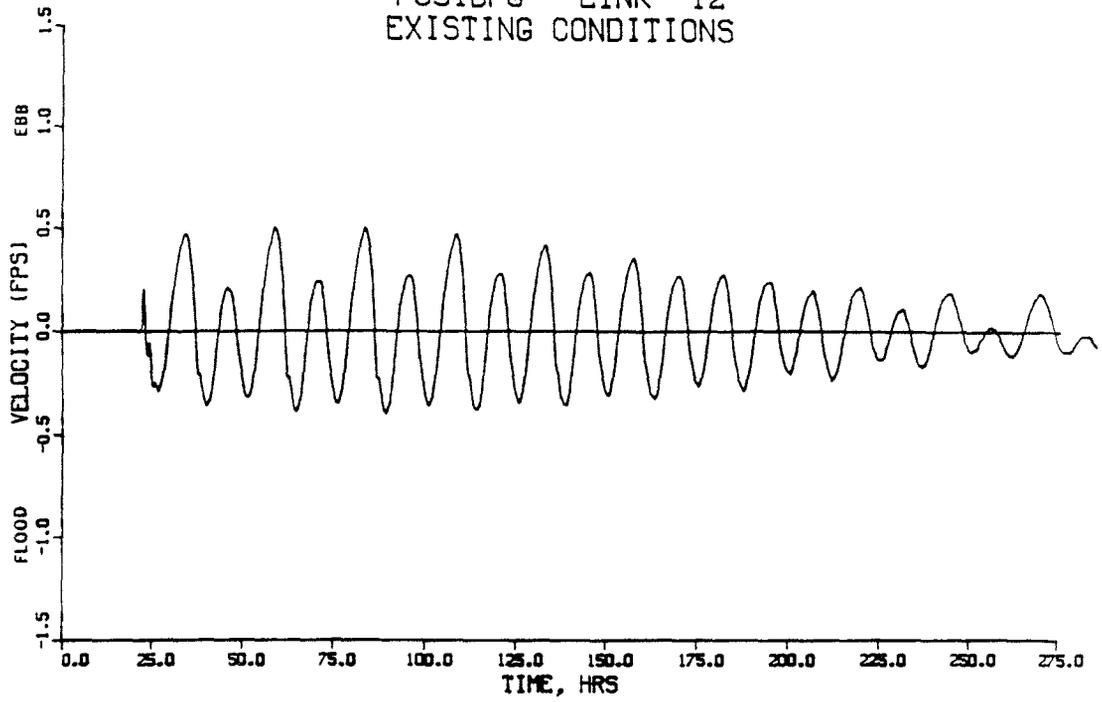


Figure B7. Average channel velocities in Huntington Harbour

POSTDFG LINK 13
EXISTING CONDITIONS

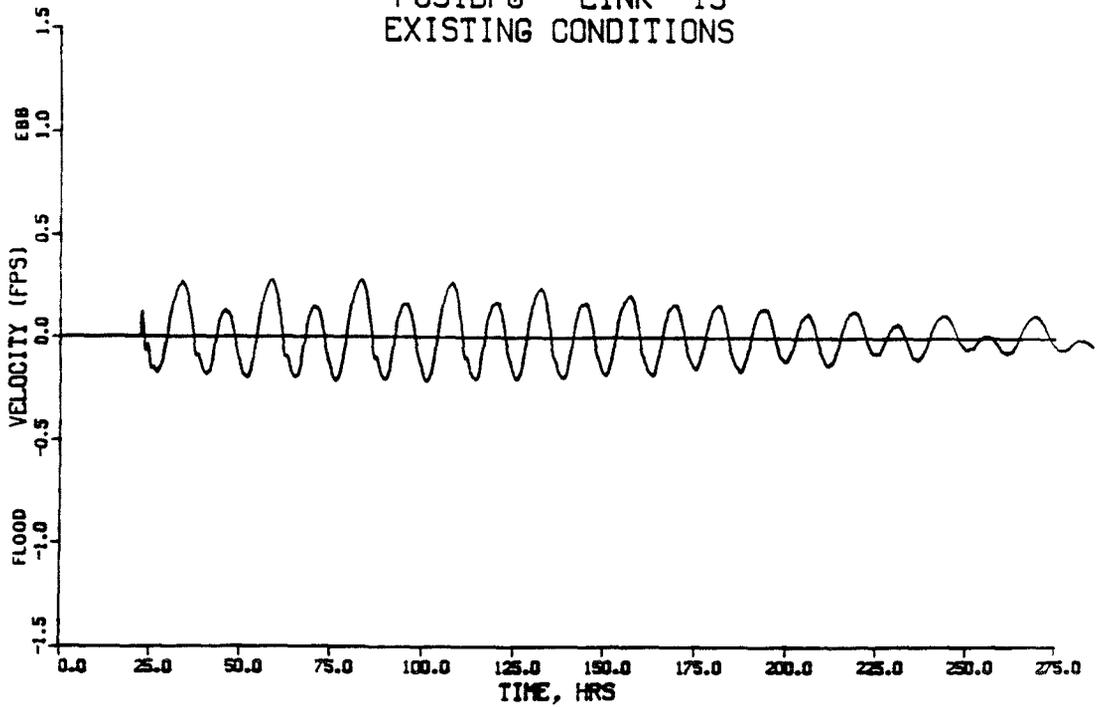


Figure B8. Average channel velocities in Huntington Harbour

POSTDFG LINK 15
EXISTING CONDITIONS

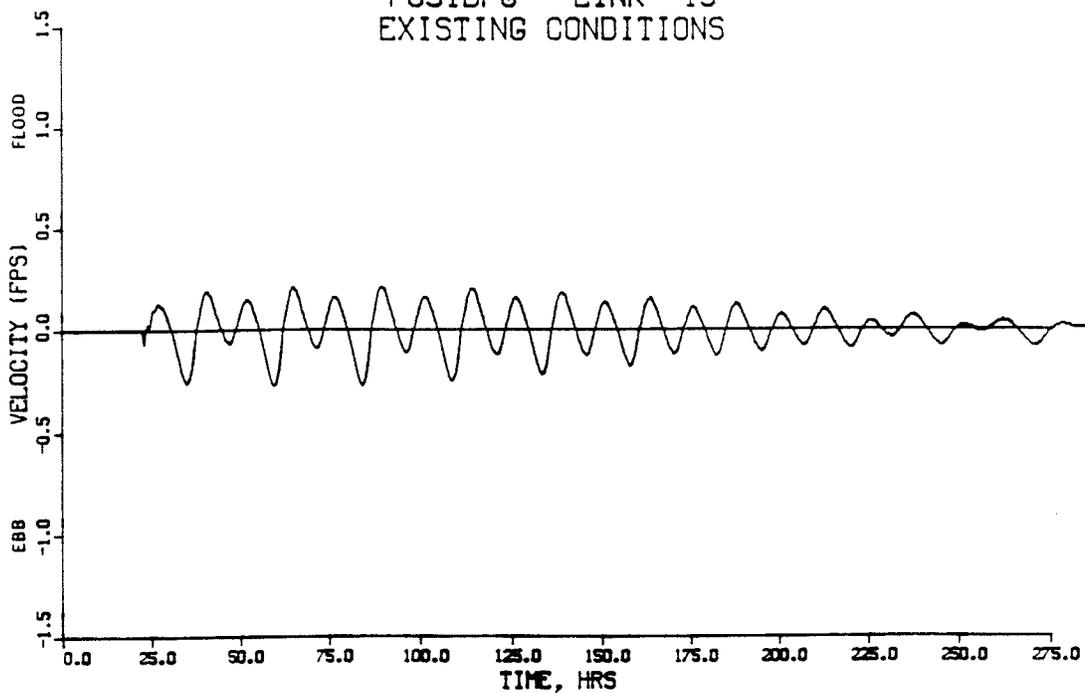


Figure B9. Average channel velocities in Huntington Harbour

POSTDFG LINK 16
EXISTING CONDITIONS

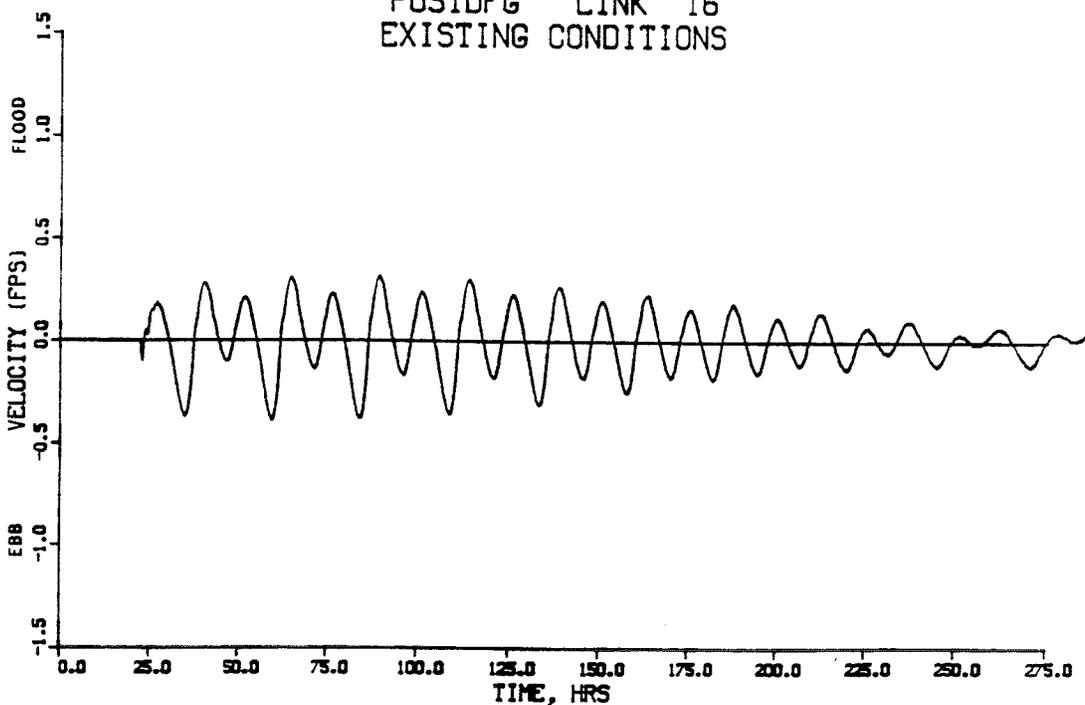


Figure B10. Average channel velocities in Huntington Harbour

POSTDFG LINK 17
EXISTING CONDITIONS

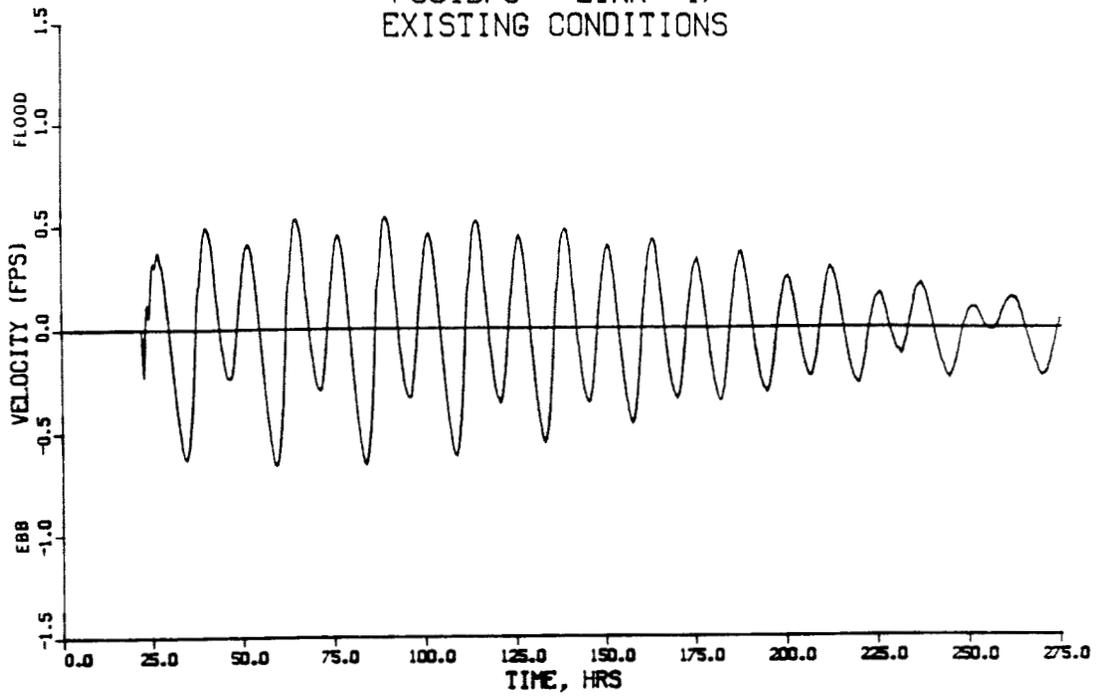


Figure B11. Average channel velocities in Huntington Harbour

POSTDFG LINK 18
EXISTING CONDITIONS

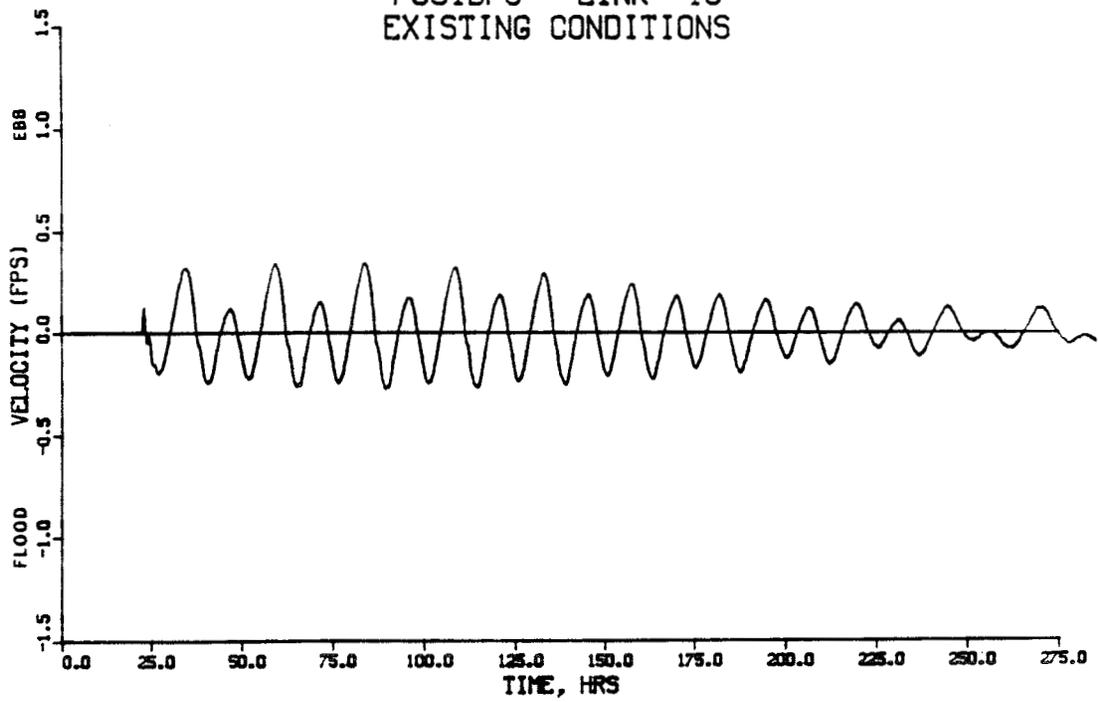


Figure B12. Average channel velocities in Huntington Harbour

POSTDFG LINK 20
EXISTING CONDITIONS

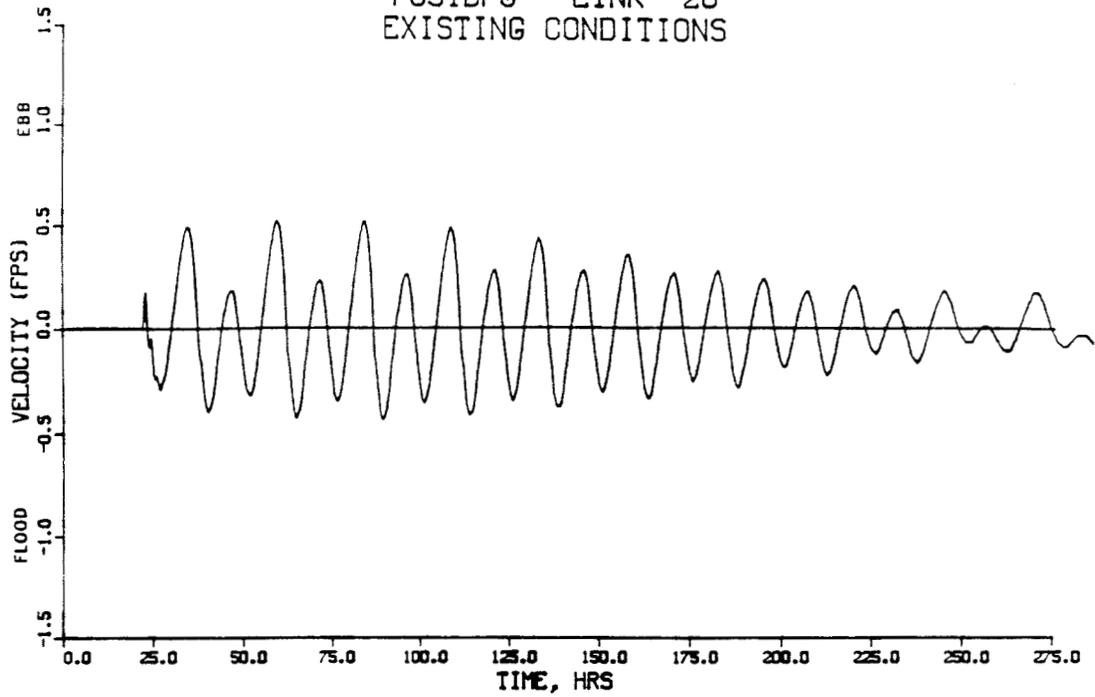


Figure B13. Average channel velocities in Huntington Harbour

POSTDFG LINK 21
EXISTING CONDITIONS

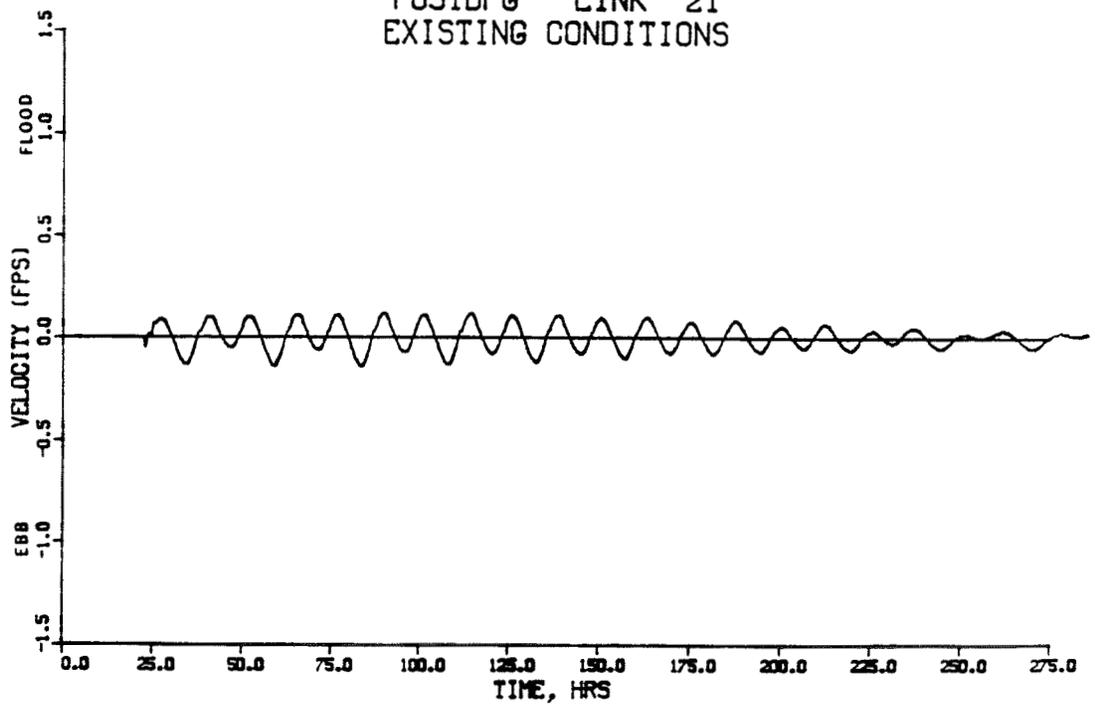


Figure B14. Average channel velocities in Huntington Harbour

POSTDFG LINK 23
EXISTING CONDITIONS

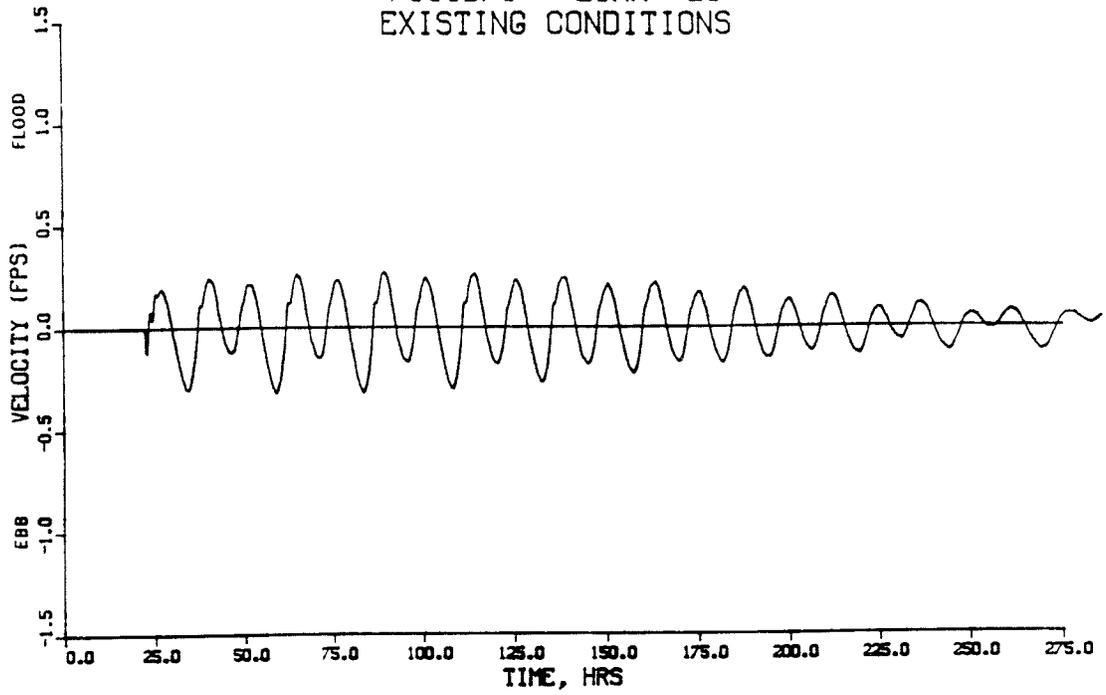


Figure B15. Average channel velocities in Huntington Harbour

POSTDFG LINK 24
EXISTING CONDITIONS

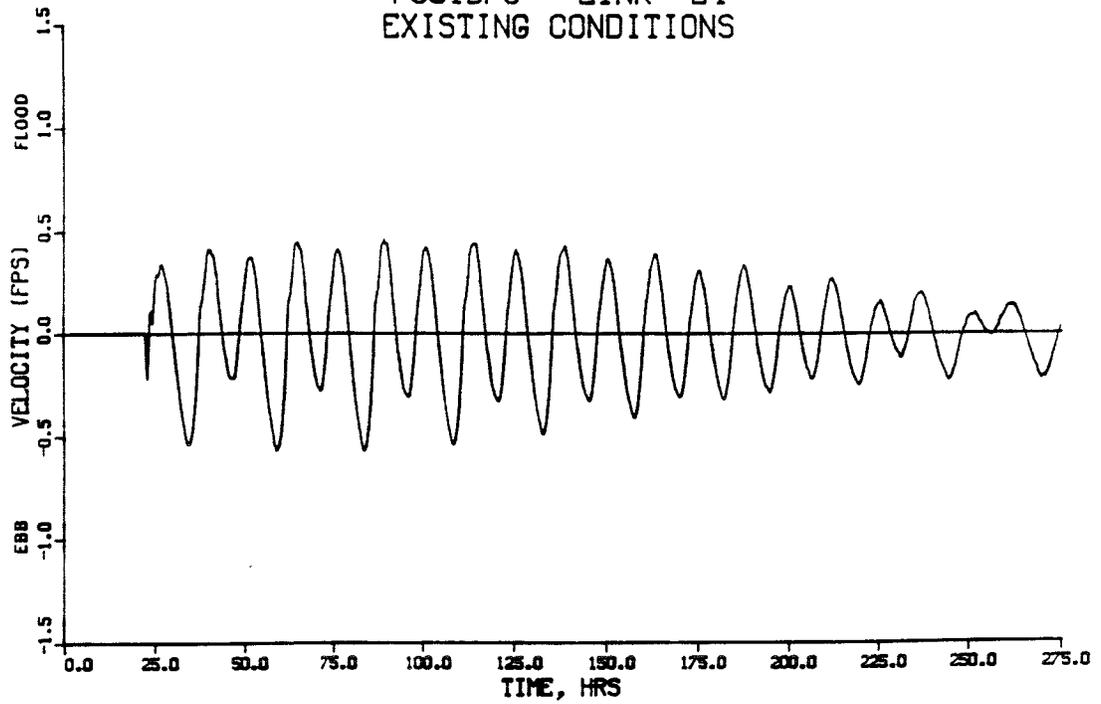


Figure B16. Average channel velocities in Huntington Harbour

POSTDFG LINK 25
EXISTING CONDITIONS

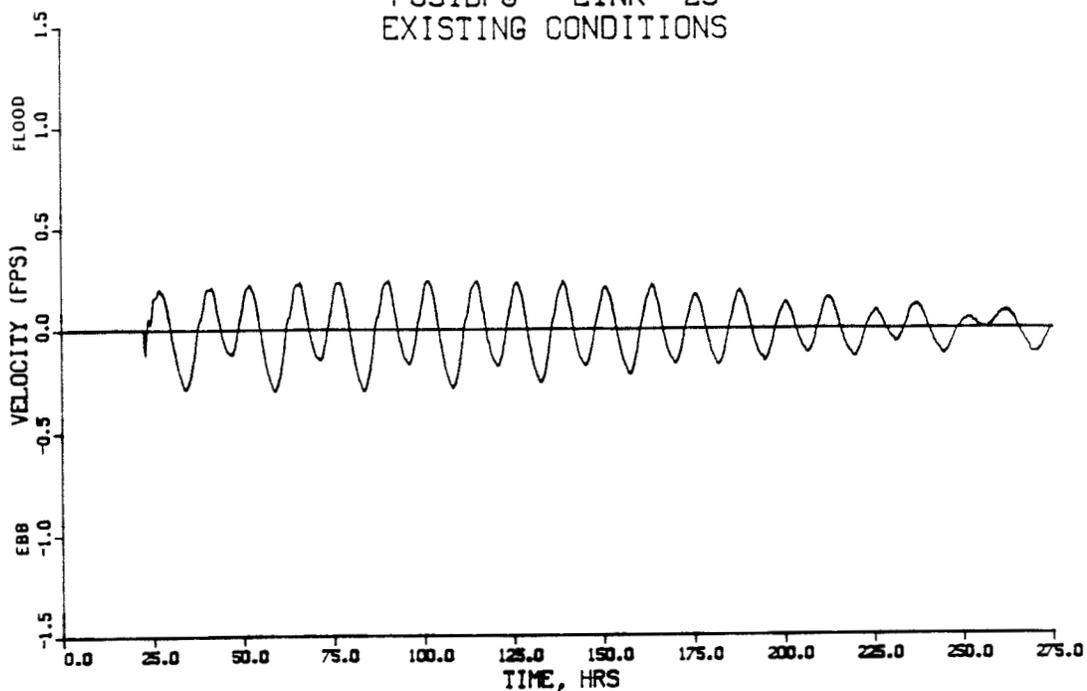


Figure B17. Average channel velocities in Huntington Harbour

POSTDFG LINK 26
EXISTING CONDITIONS

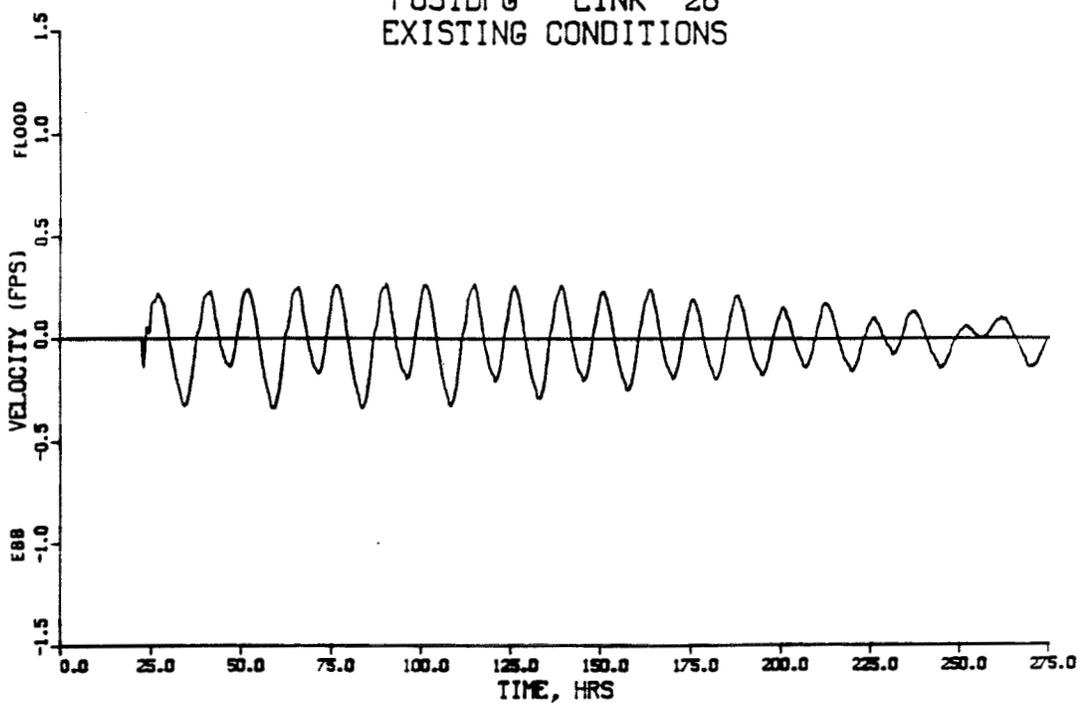


Figure B18. Average channel velocities in Huntington Harbour

POSTDFG LINK 27
EXISTING CONDITIONS

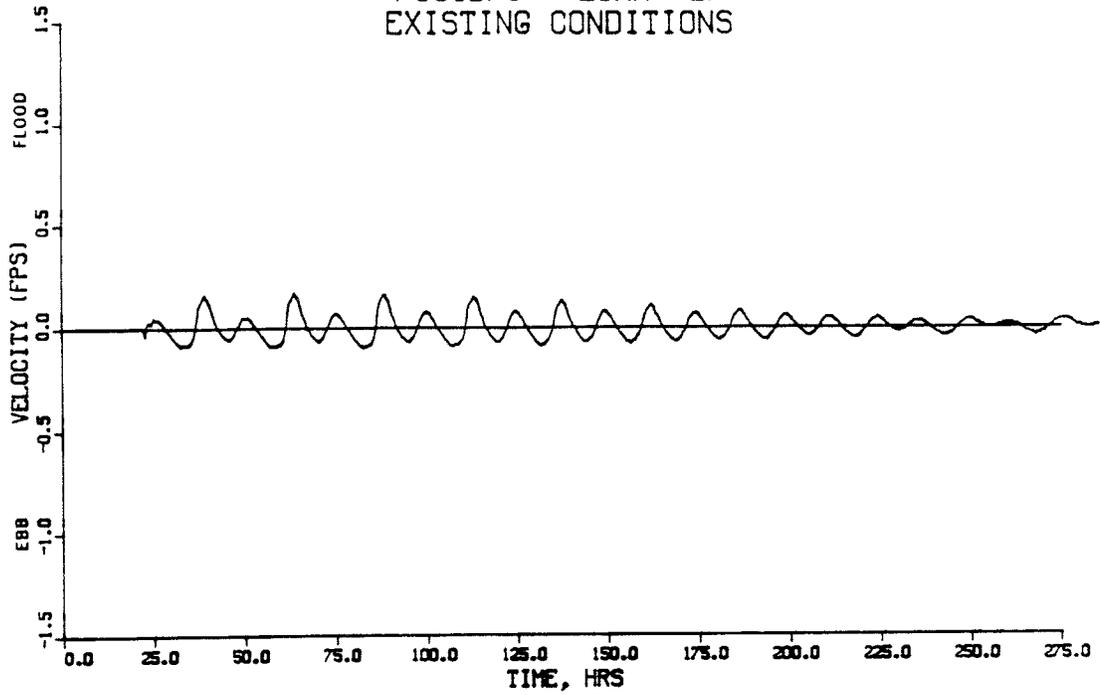


Figure B19. Average channel velocities in Huntington Harbour

POSTDFG LINK 29
EXISTING CONDITIONS

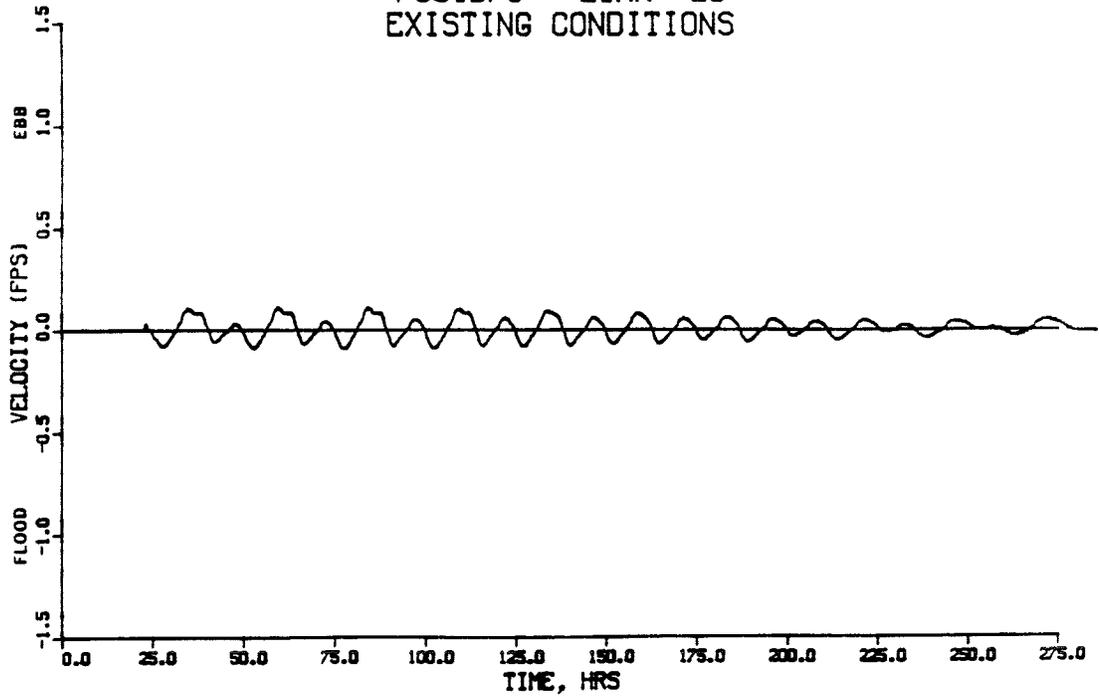


Figure B20. Average channel velocities in Huntington Harbour

POSTDFG LINK 31
EXISTING CONDITIONS

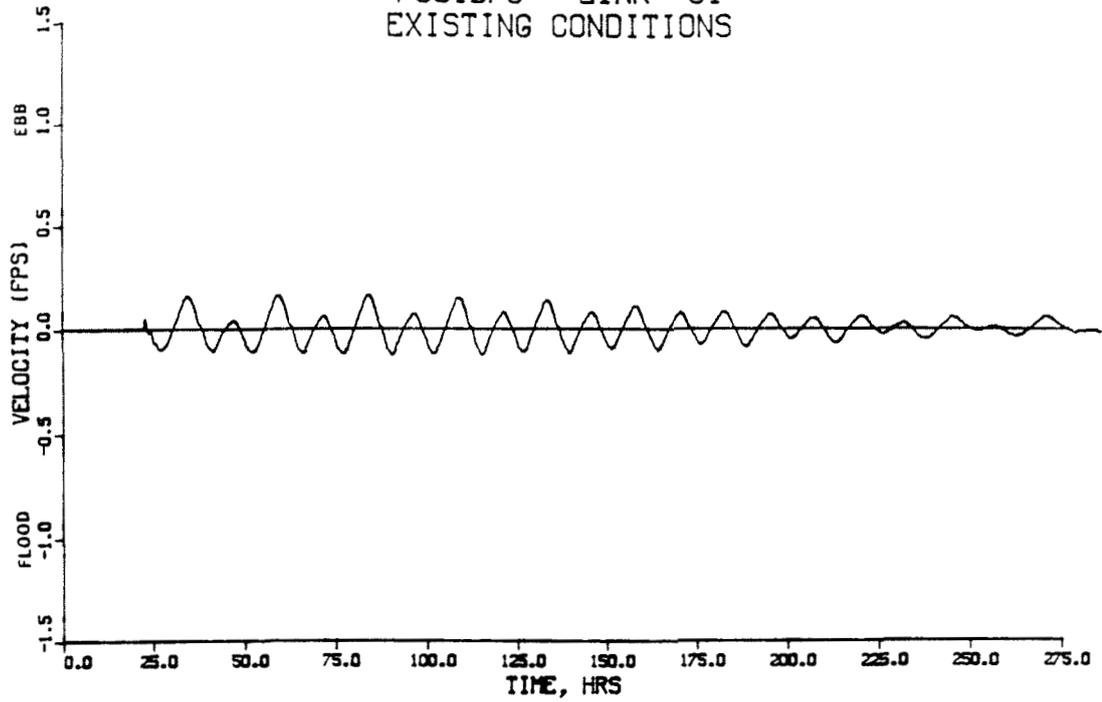


Figure B21. Average channel velocities in Huntington Harbour

POSTDFG LINK 32
EXISTING CONDITIONS

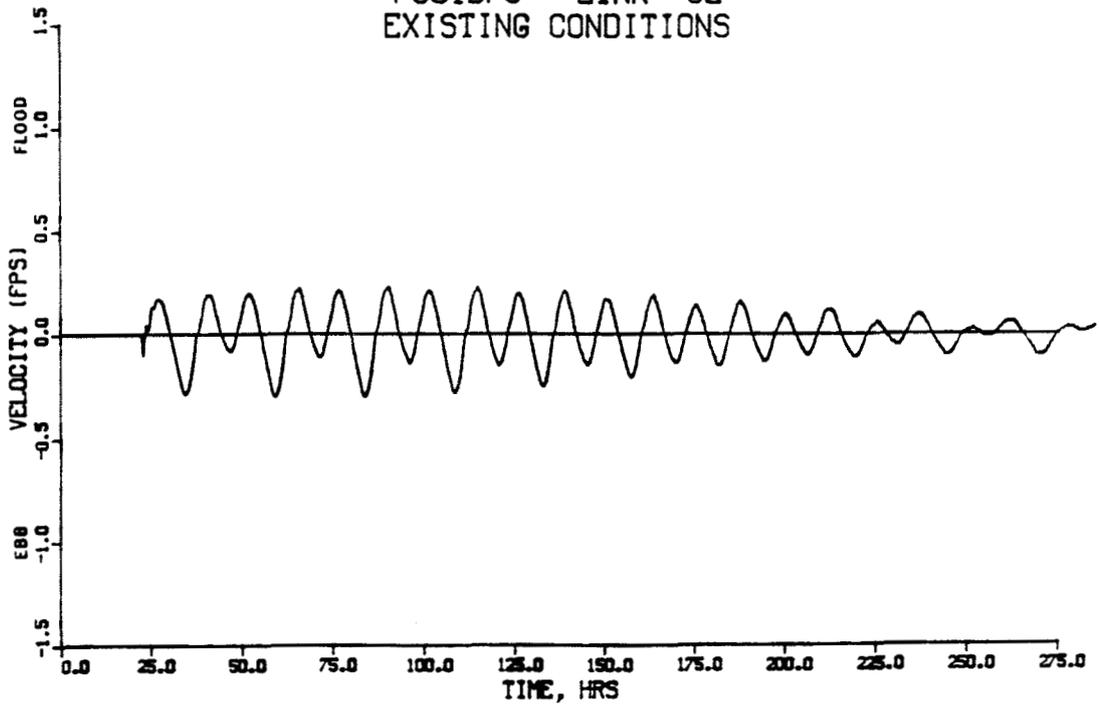


Figure B22. Average channel velocities in Huntington Harbour

POSTDFG LINK 33
EXISTING CONDITIONS

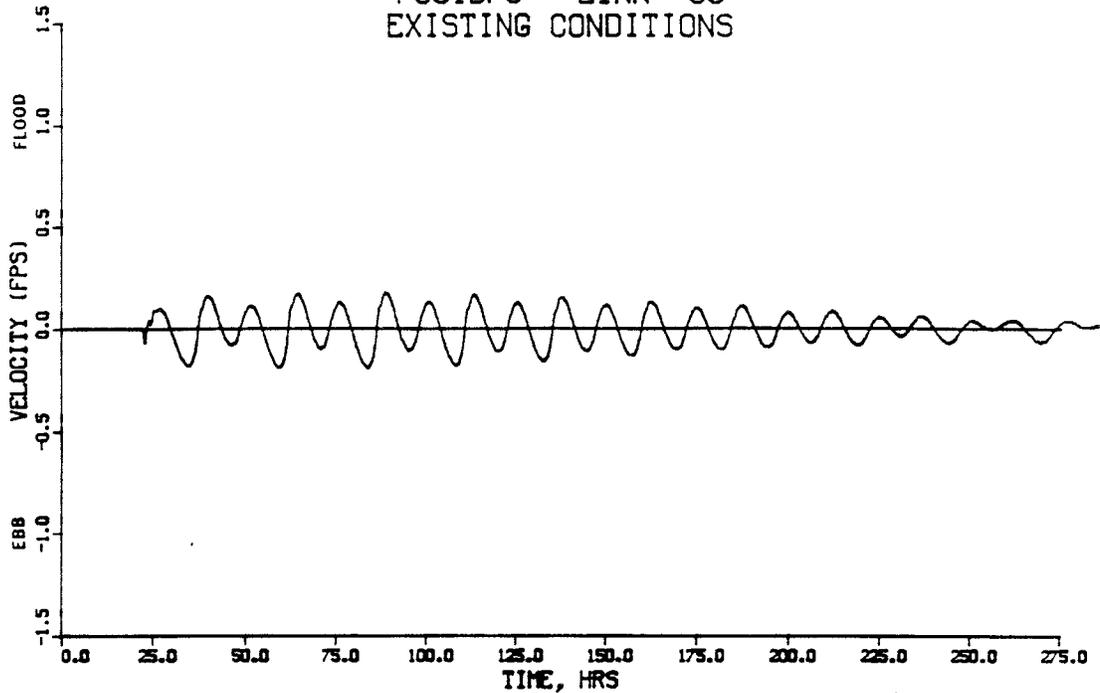


Figure B23. Average channel velocities in Huntington Harbour

POSTDFG LINK 34
EXISTING CONDITIONS

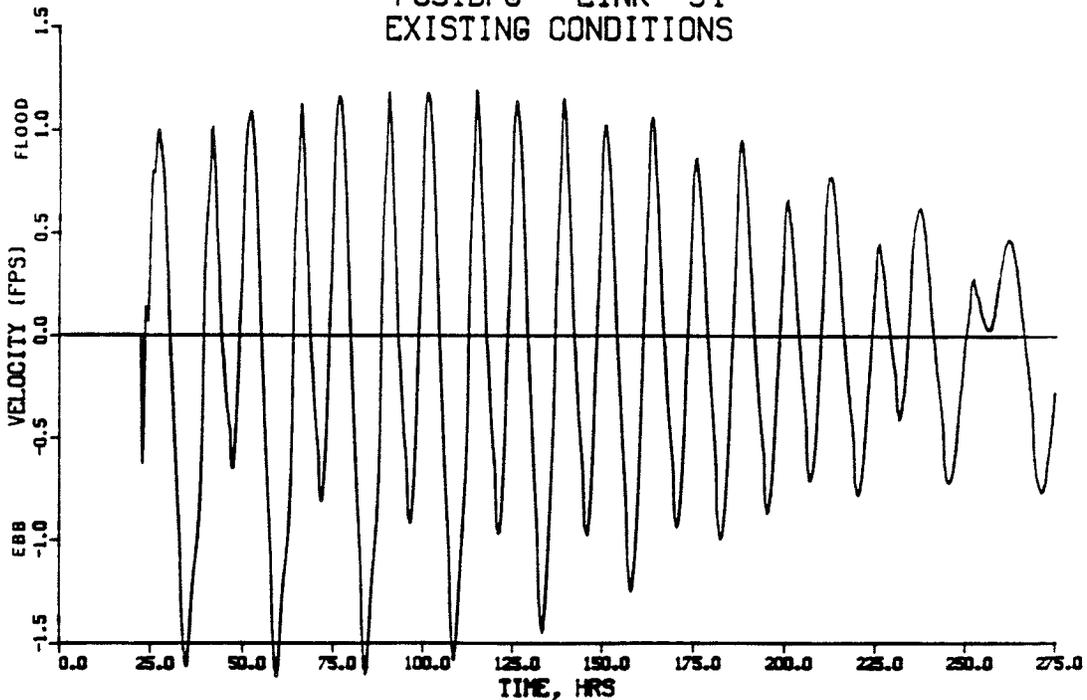


Figure B24. Average channel velocities under Warner Avenue bridge

POSTDFG LINK 35
EXISTING CONDITIONS

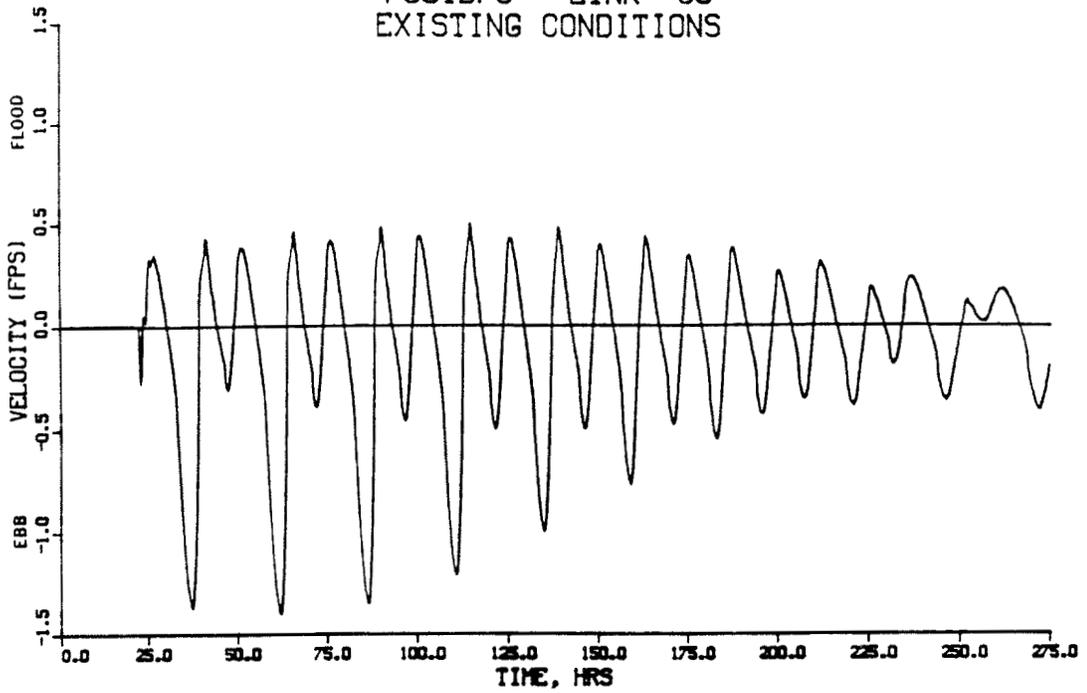


Figure B25. Average channel velocities in Outer Bolsa Bay

POSTDFG LINK 36
EXISTING CONDITIONS

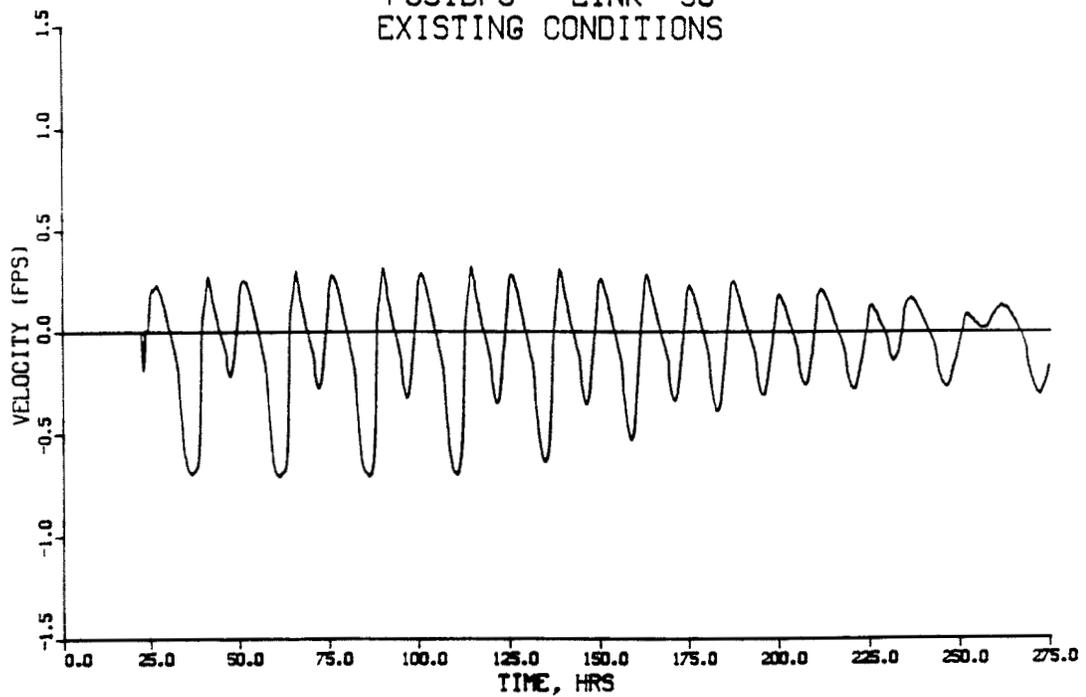


Figure B26. Average channel velocities in Outer Bolsa Bay

POSTDFG LINK 37
EXISTING CONDITIONS

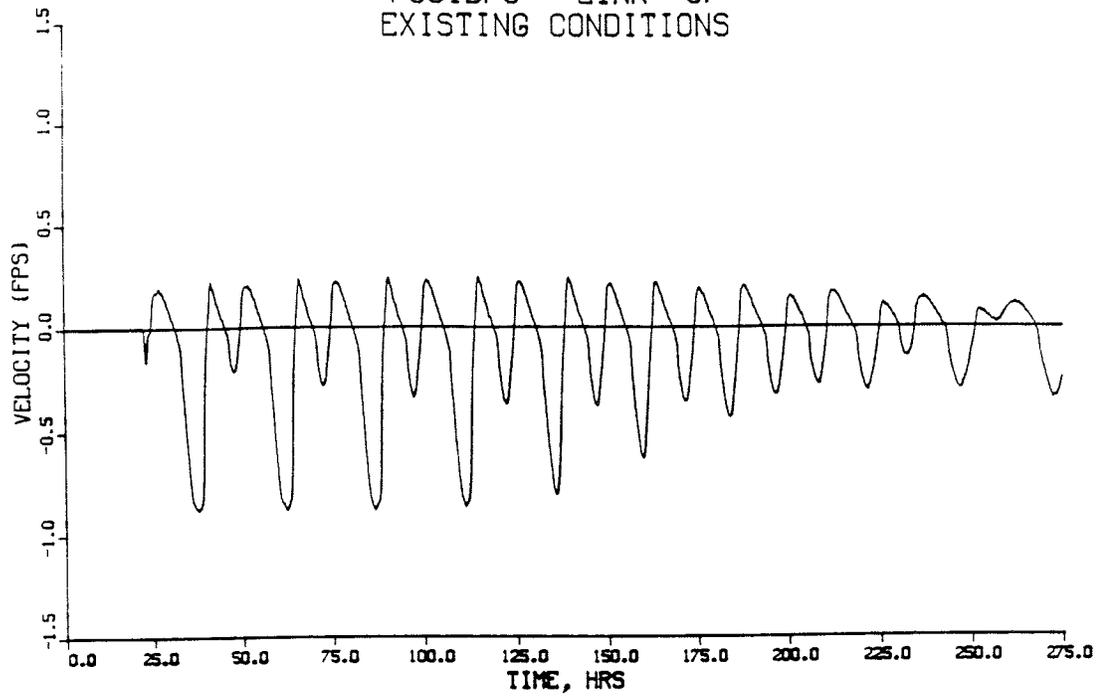


Figure B27. Average channel velocities in Outer Bolsa Bay

POSTDFG LINK 38
EXISTING CONDITIONS

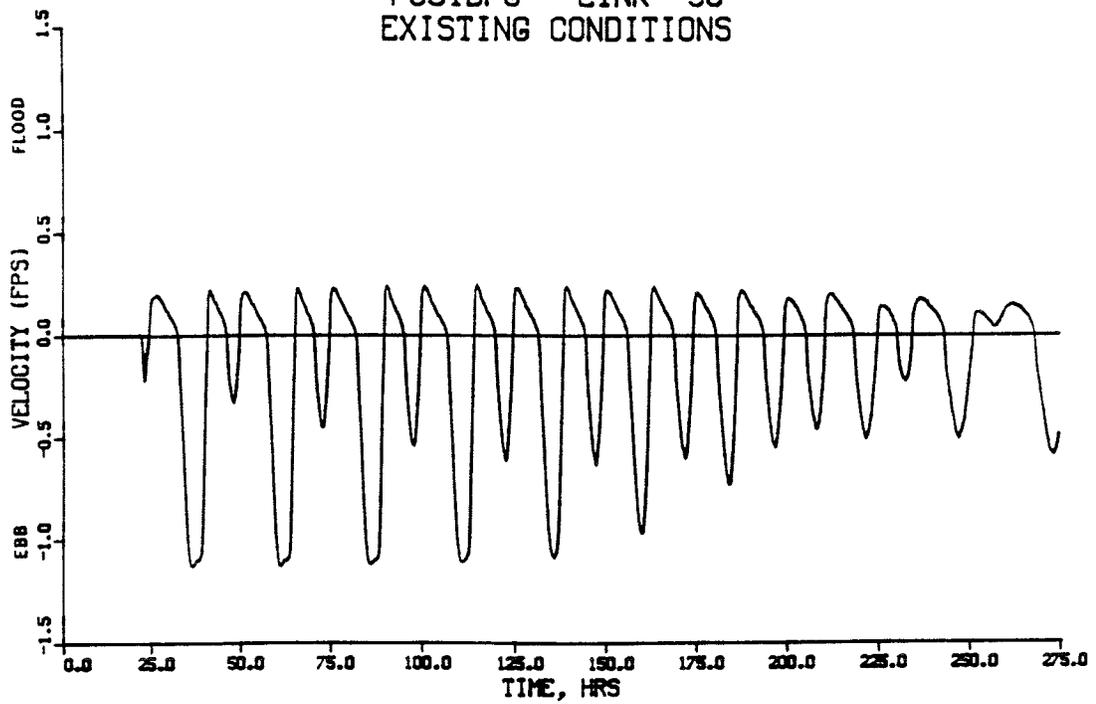


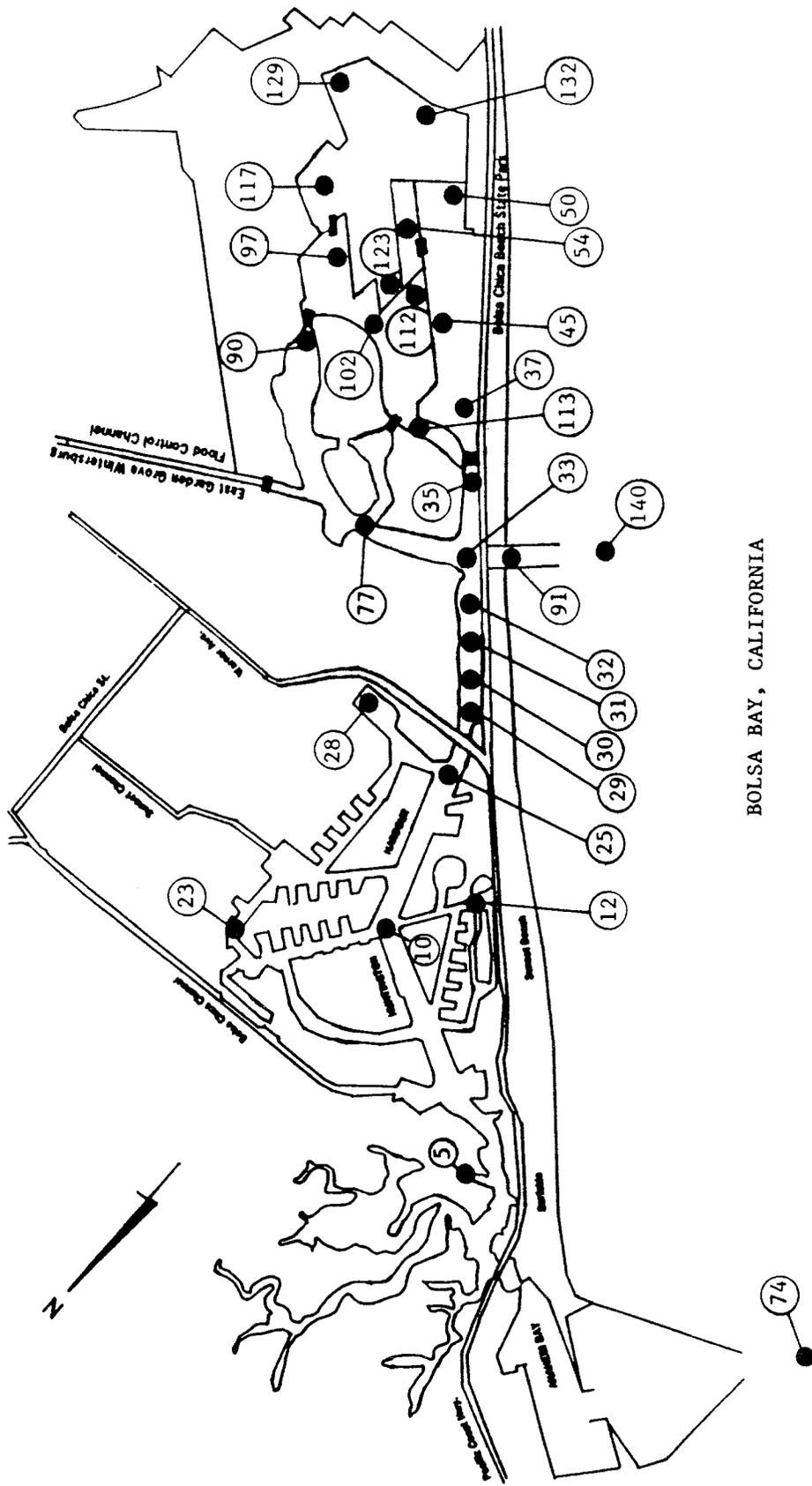
Figure B28. Average channel velocities in Outer Bolsa Bay

APPENDIX C:

LAKE 1

350-FT NON-NAVIGABLE ENTRANCE CHANNEL

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

LAKE 1
 Location of nodes for displaying
 water surface elevations under Lake 1 conditions

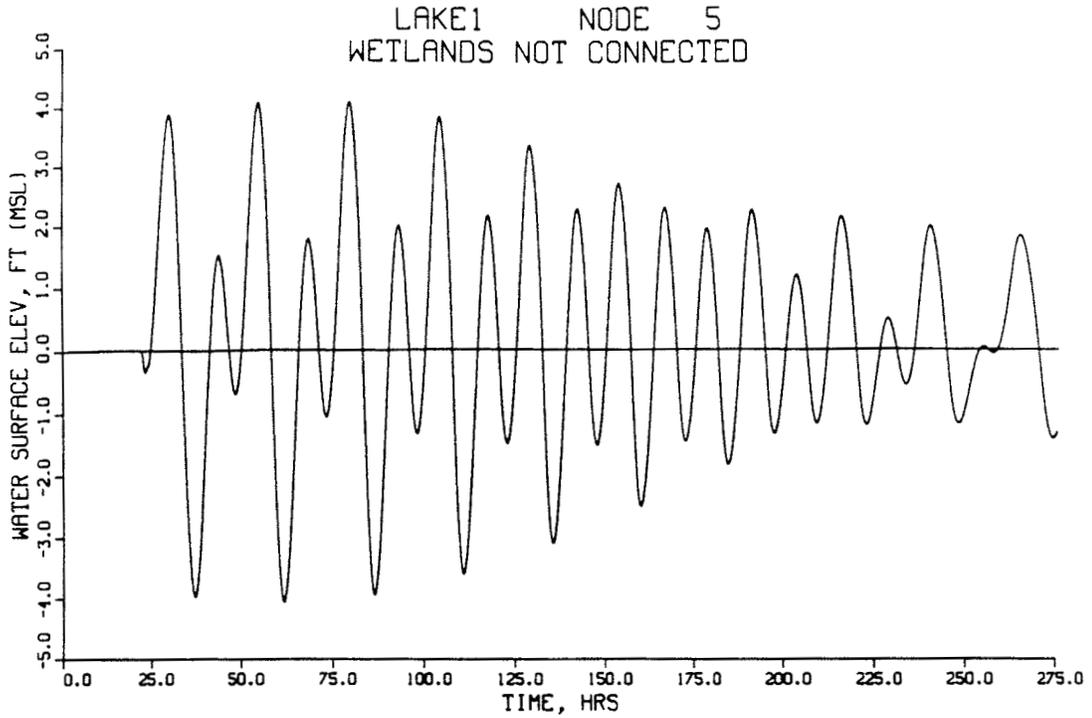


Figure C1. Tidal elevations in Huntington Harbour,
350-ft non-navigable entrance channel

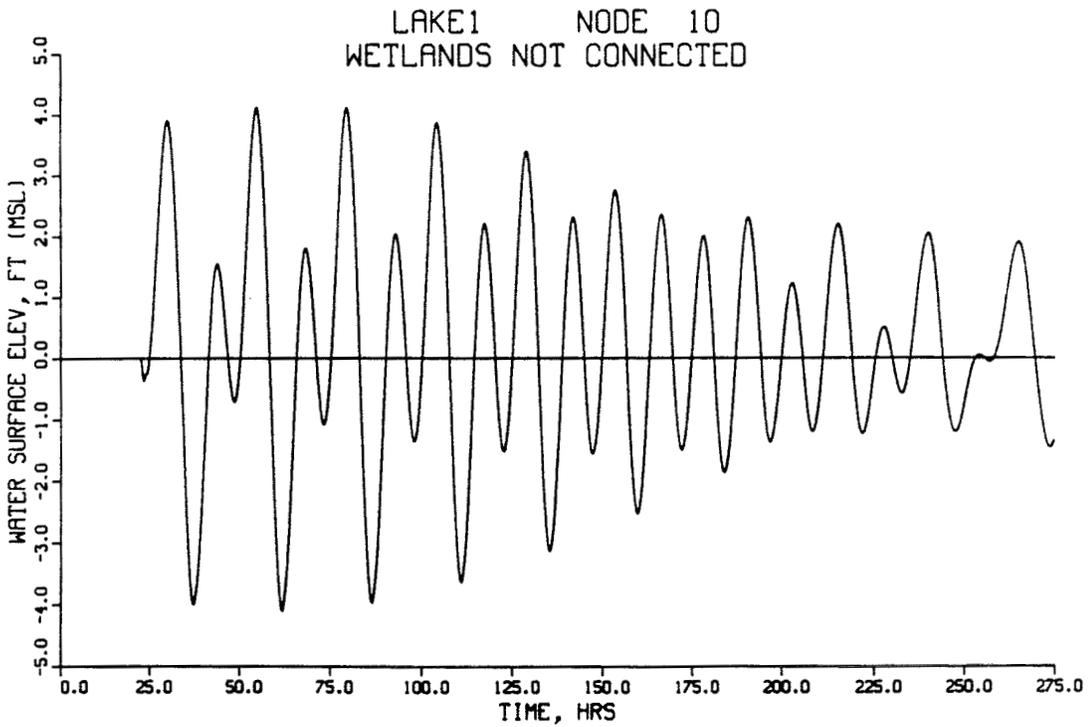


Figure C2. Tidal elevations in Huntington Harbour,
350-ft non-navigable entrance channel

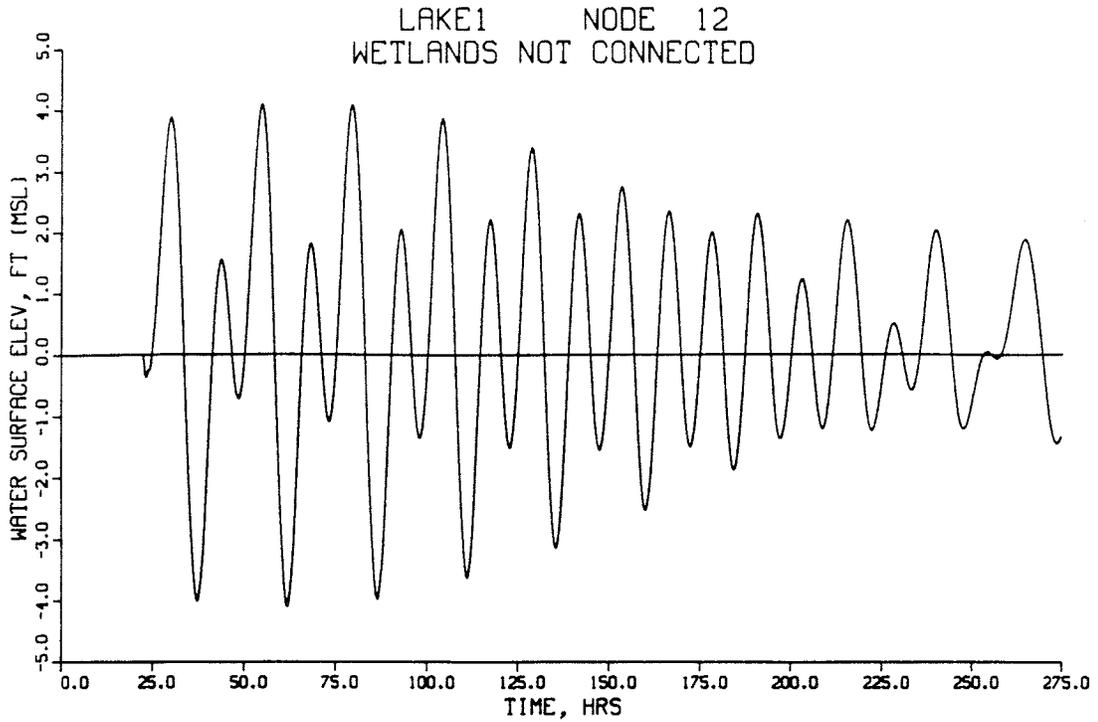


Figure C3. Tidal elevations in Huntington Harbour,
350-ft non-navigable entrance channel

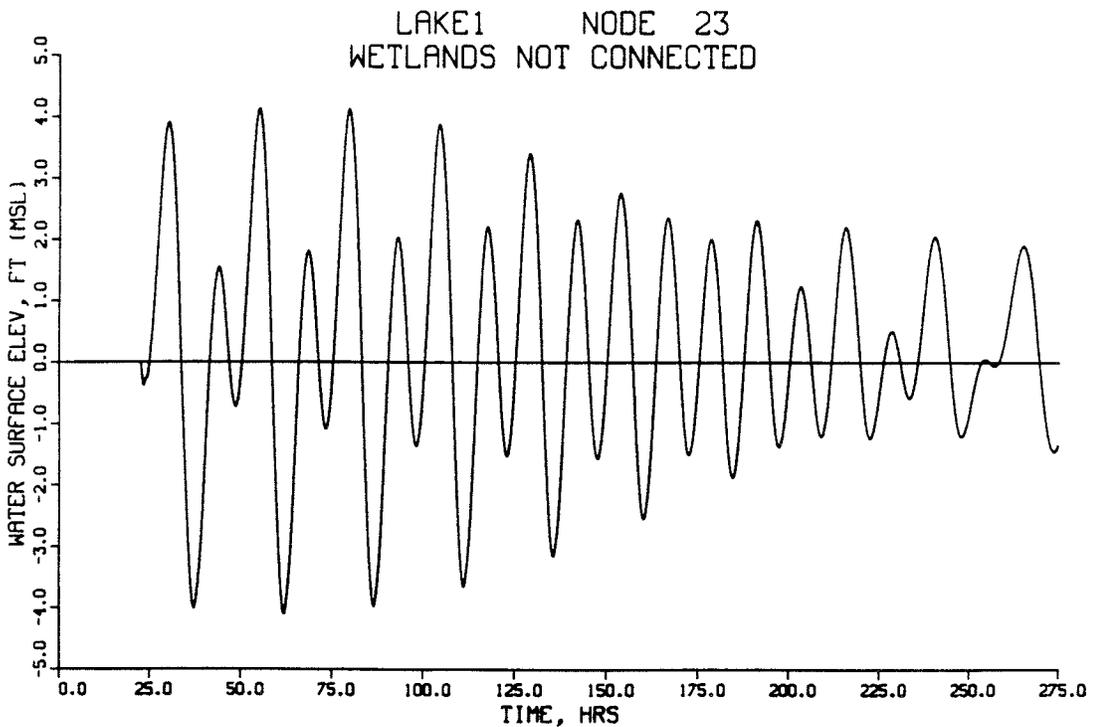


Figure C4. Tidal elevations in Huntington Harbour,
350-ft non-navigable entrance channel

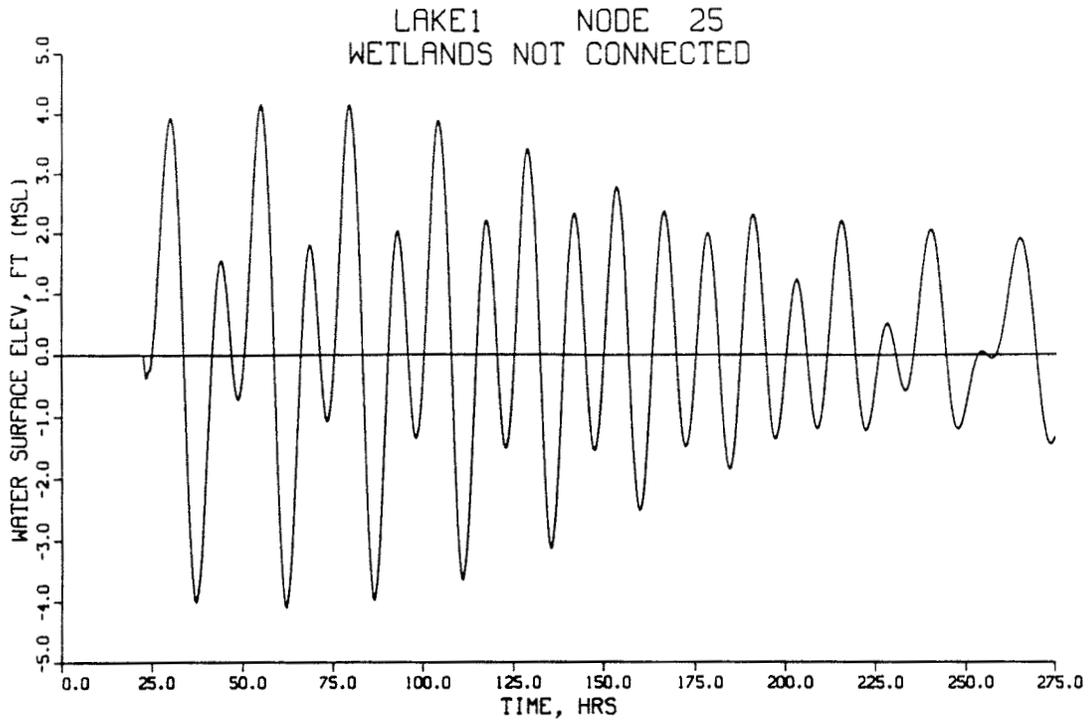


Figure C5. Tidal elevations in Huntington Harbour,
350-ft non-navigable entrance channel

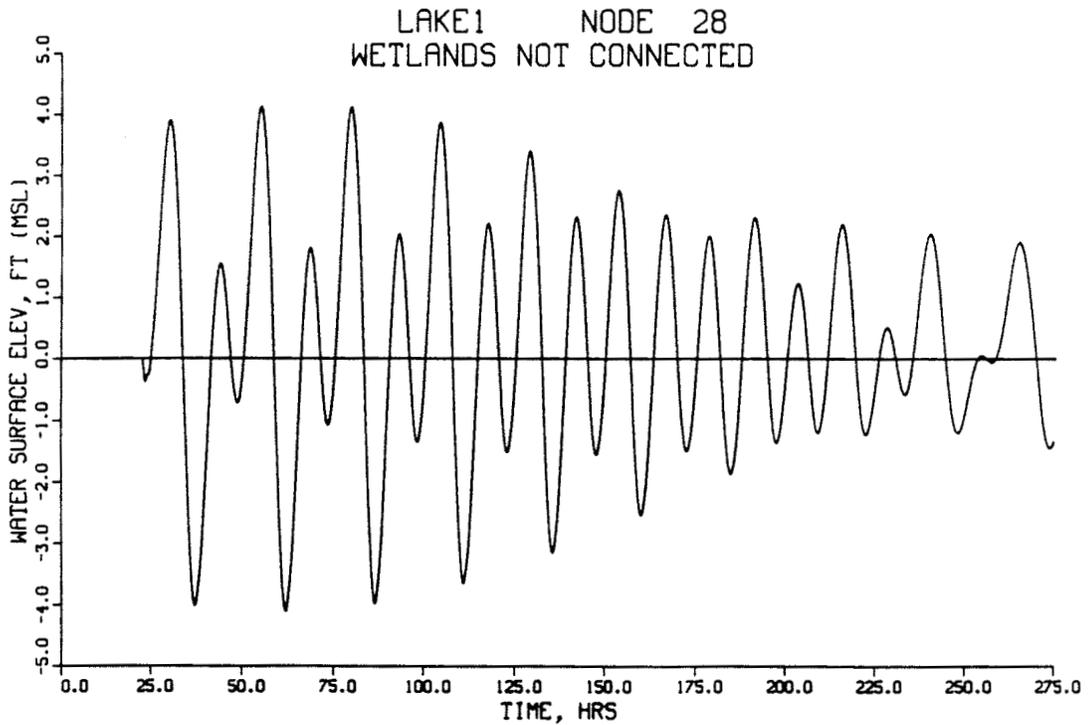


Figure C6. Tidal elevations in Huntington Harbour,
350-ft non-navigable entrance channel

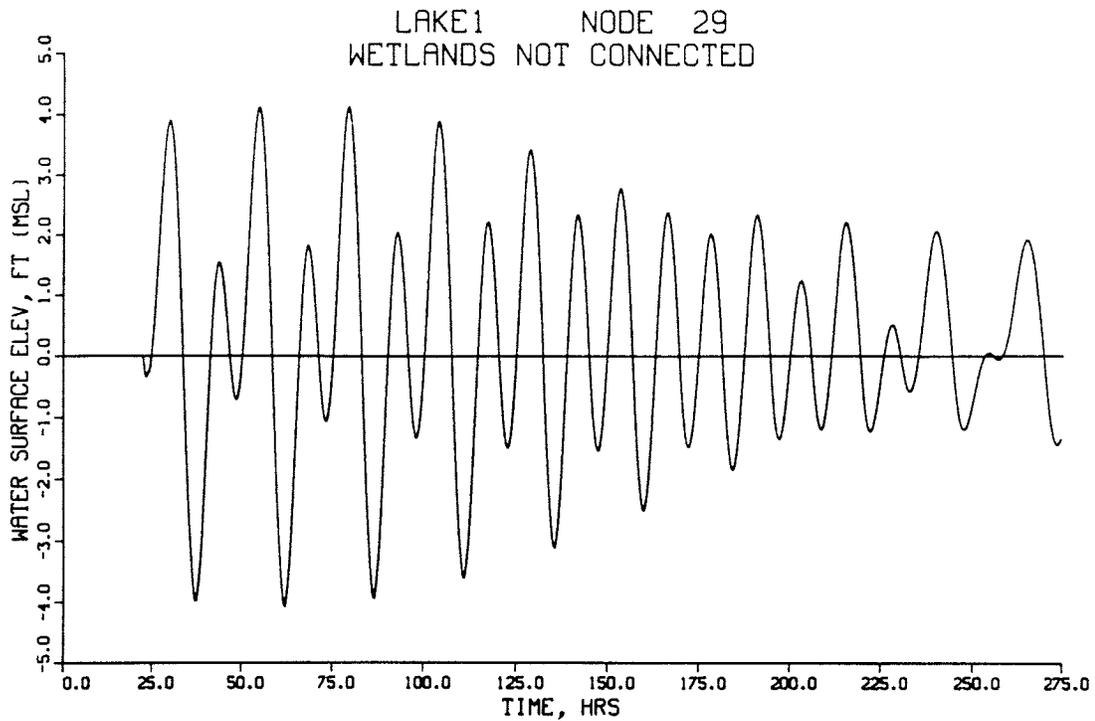


Figure C7. Tidal elevations in Outer Bolsa Bay,
350-ft non-navigable entrance channel

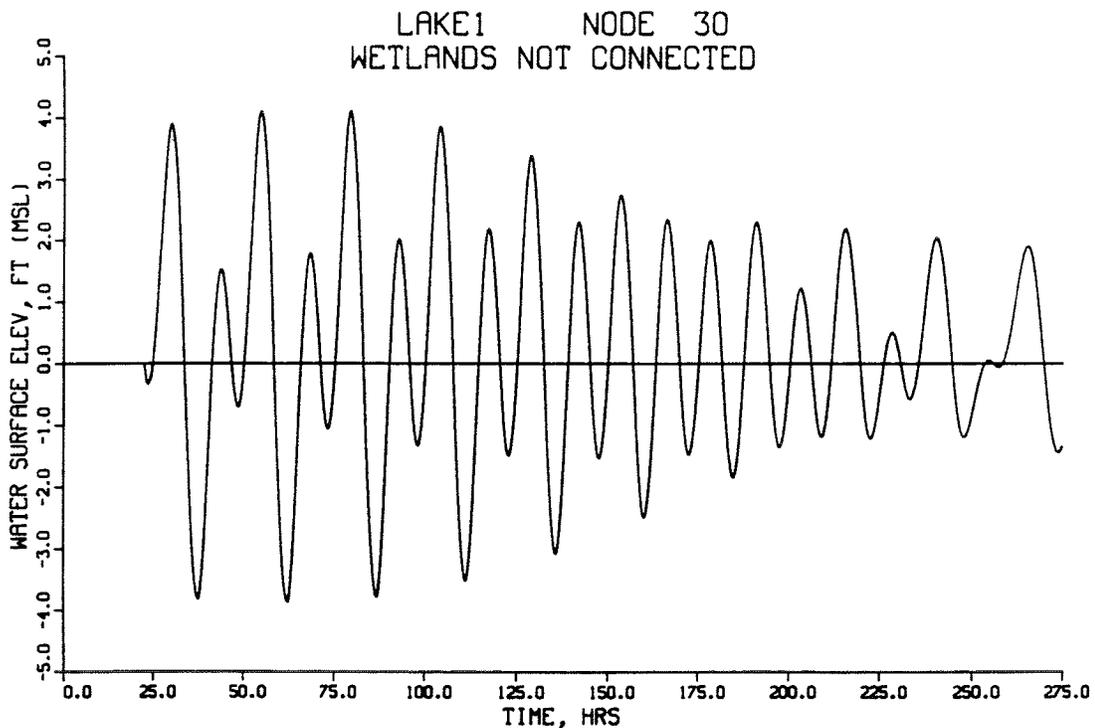


Figure C8. Tidal elevations in Outer Bolsa Bay,
350-ft non-navigable entrance channel

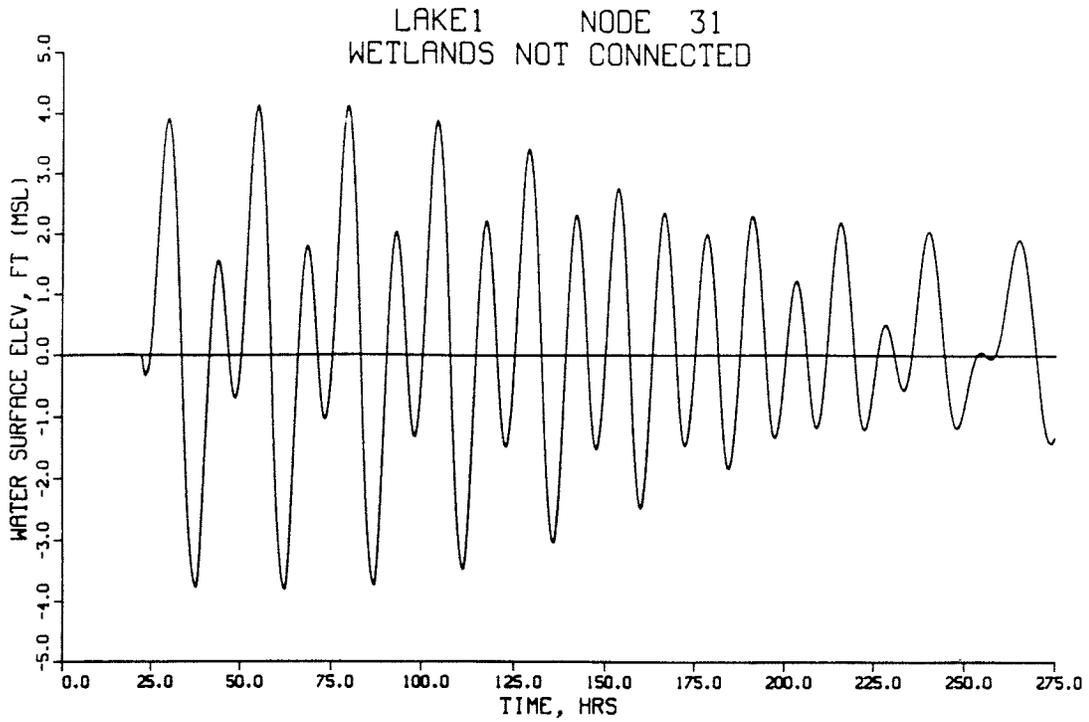


Figure C9. Tidal elevations in Outer Bolsa Bay,
350-ft non-navigable entrance channel

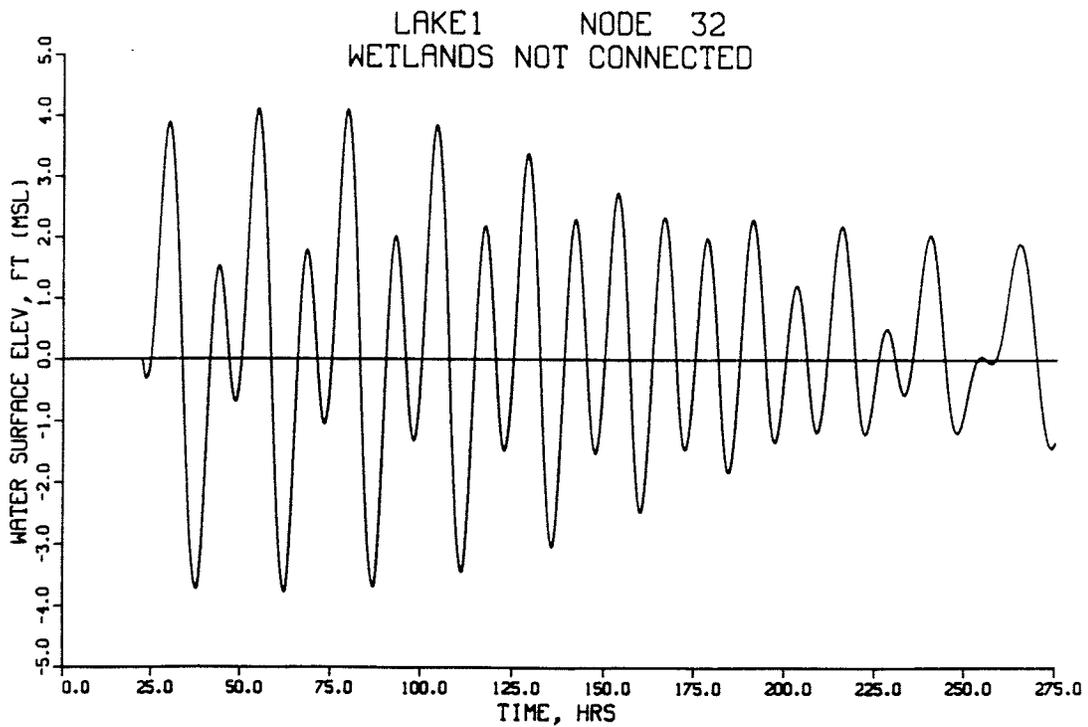


Figure C10. Tidal elevations in Outer Bolsa Bay,
350-ft non-navigable entrance channel

LAKE1 NODE 33
WETLANDS NOT CONNECTED

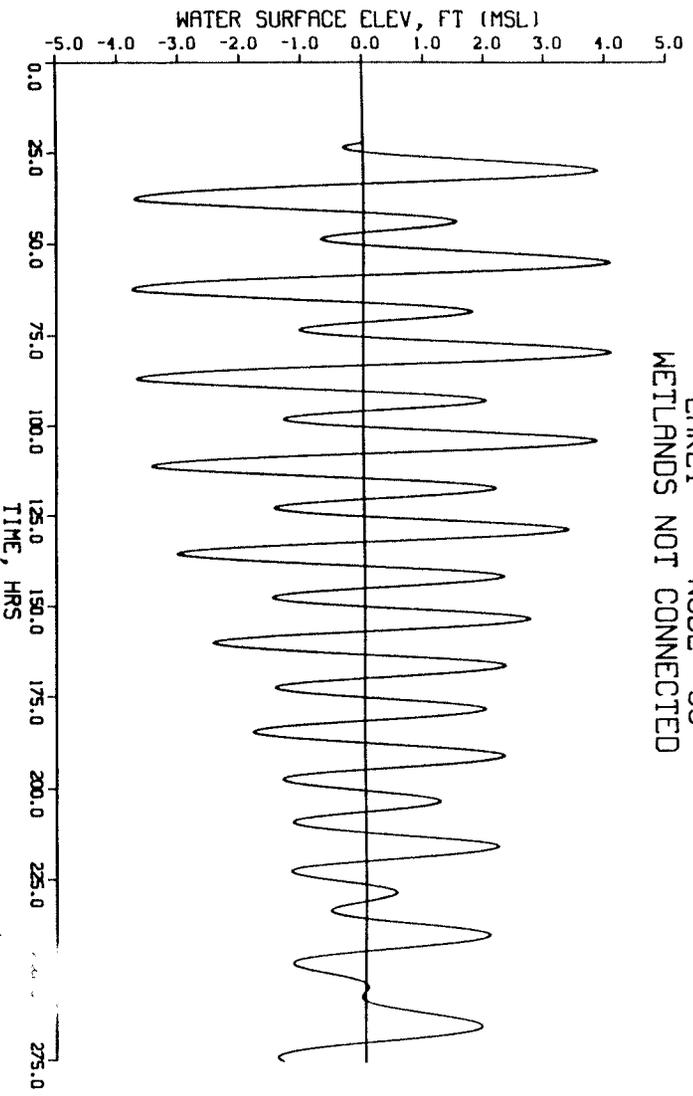


Figure C11. Tidal elevations in entrance to proposed marina,
350-ft non-navigable entrance channel

LAKE1 NODE 35
WETLANDS NOT CONNECTED

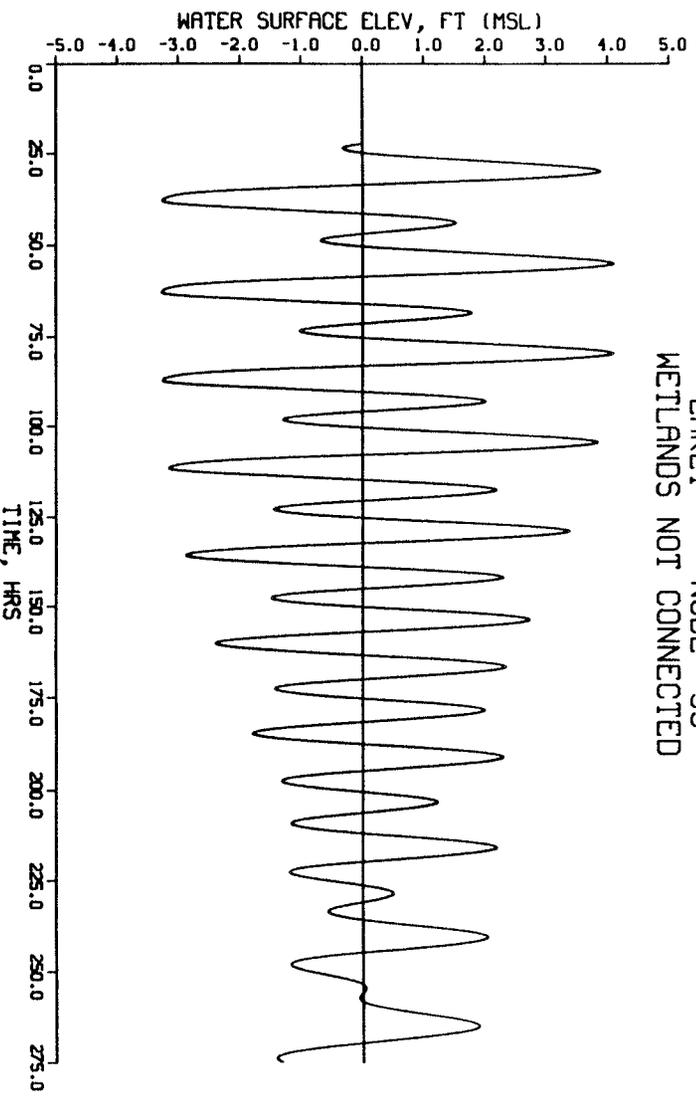


Figure C12. Tidal elevations in Outer Bolsa Bay,
350-ft non-navigable entrance channel

LAKE1 NODE 37
WETLANDS NOT CONNECTED

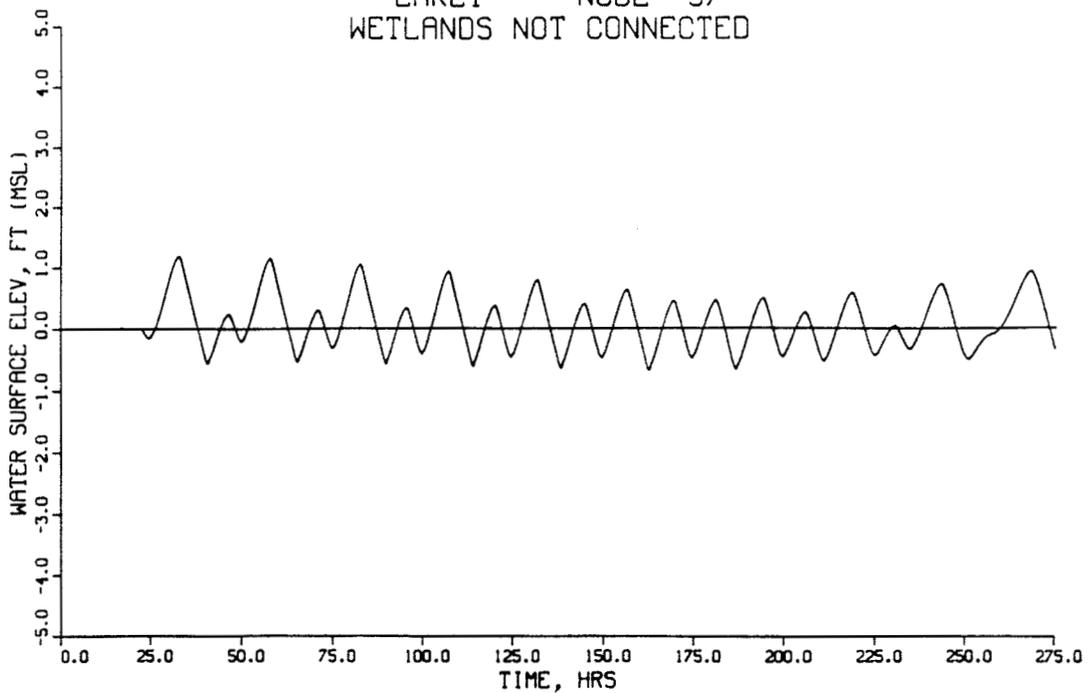


Figure C13. Tidal elevations in Inner Bolsa Bay,
350-ft non-navigable entrance channel

LAKE1 NODE 45
WETLANDS NOT CONNECTED

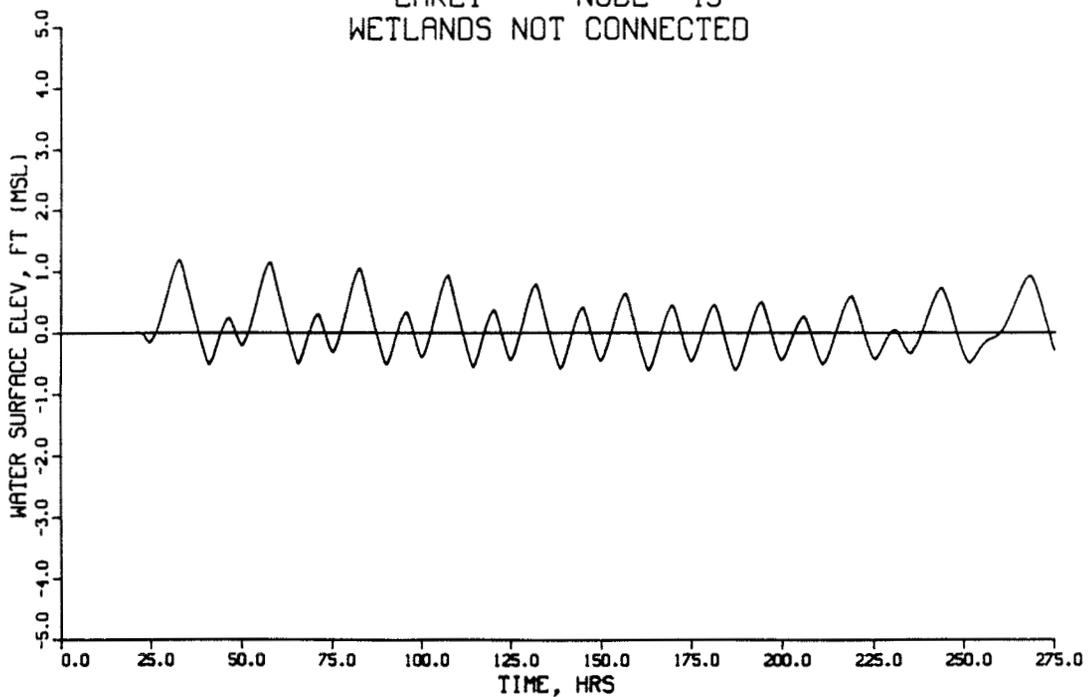


Figure C14. Tidal elevations in Inner Bolsa Bay,
350-ft non-navigable entrance channel

LAKE1 NODE 50
WETLANDS NOT CONNECTED

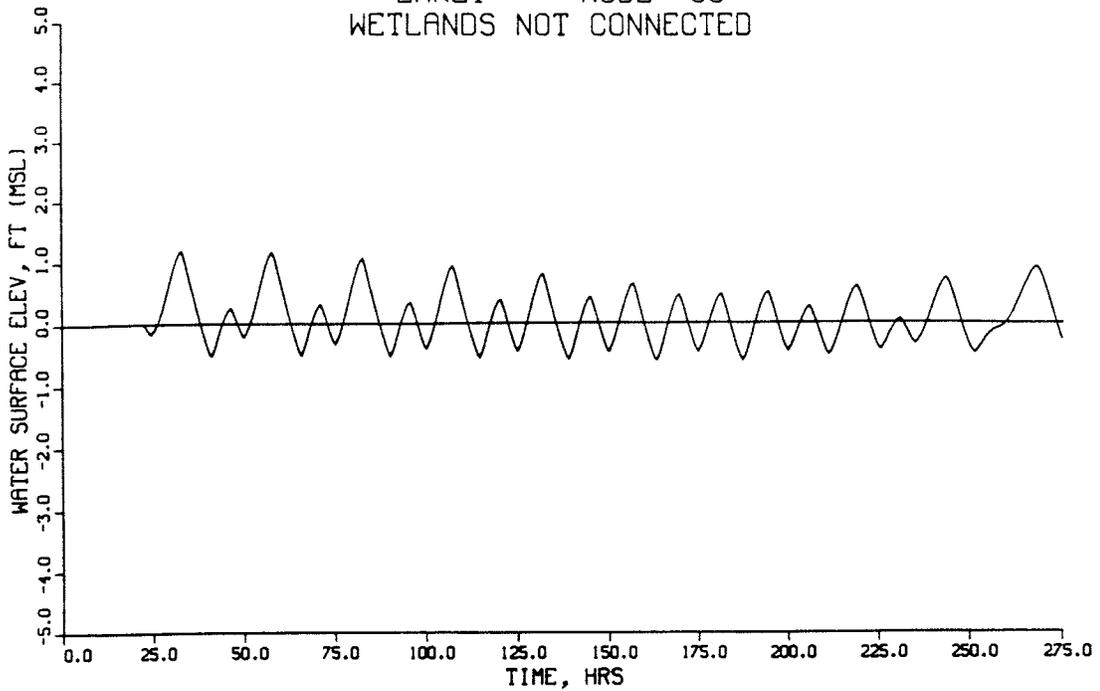


Figure C15. Tidal elevations in Inner Bolsa Bay,
350-ft non-navigable entrance channel

LAKE1 NODE 54
WETLANDS NOT CONNECTED

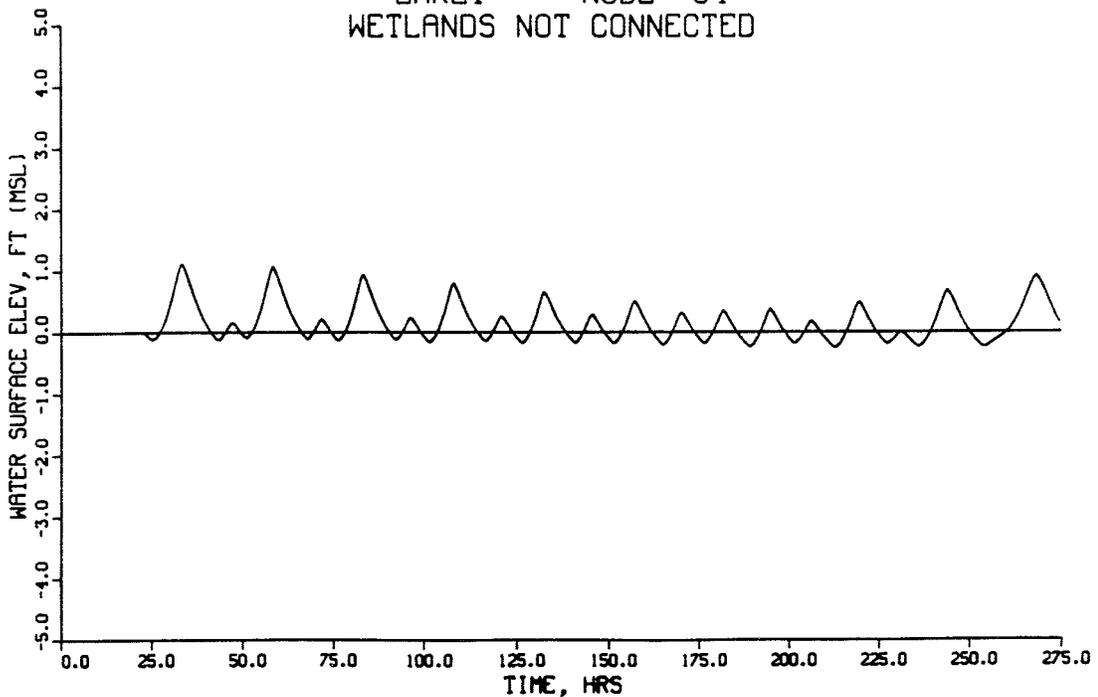


Figure C16. Tidal elevations in DFG muted tidal cell,
350-ft non-navigable entrance channel

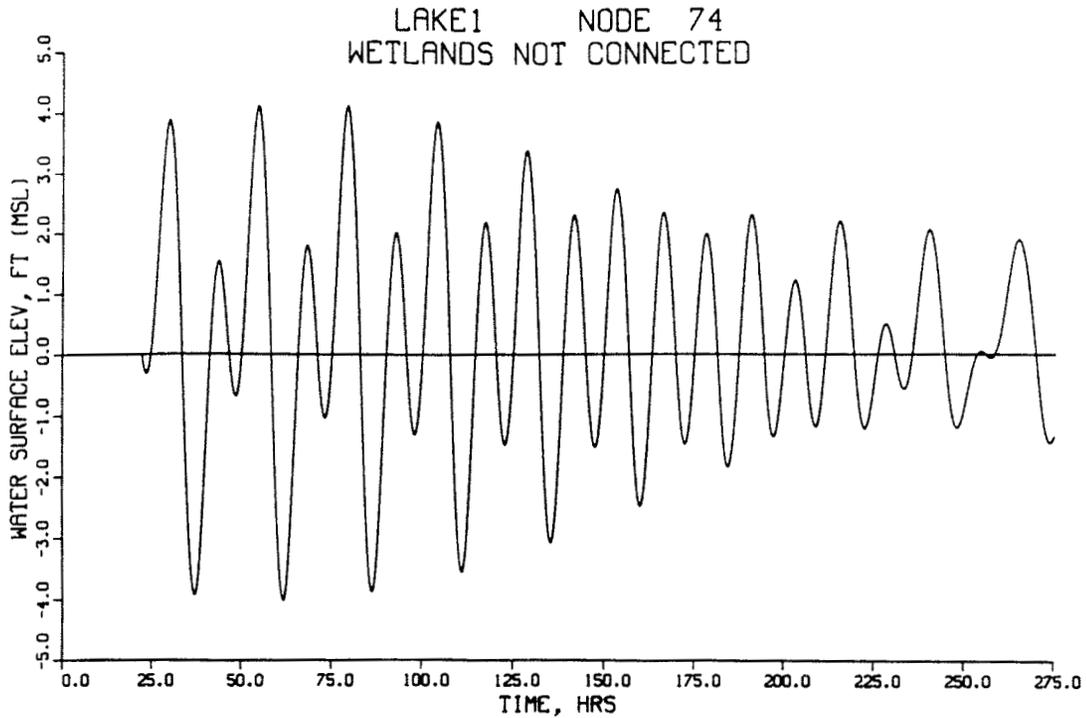


Figure C17. Tidal elevations in Pacific Ocean,
driving Anaheim Bay entrance channel

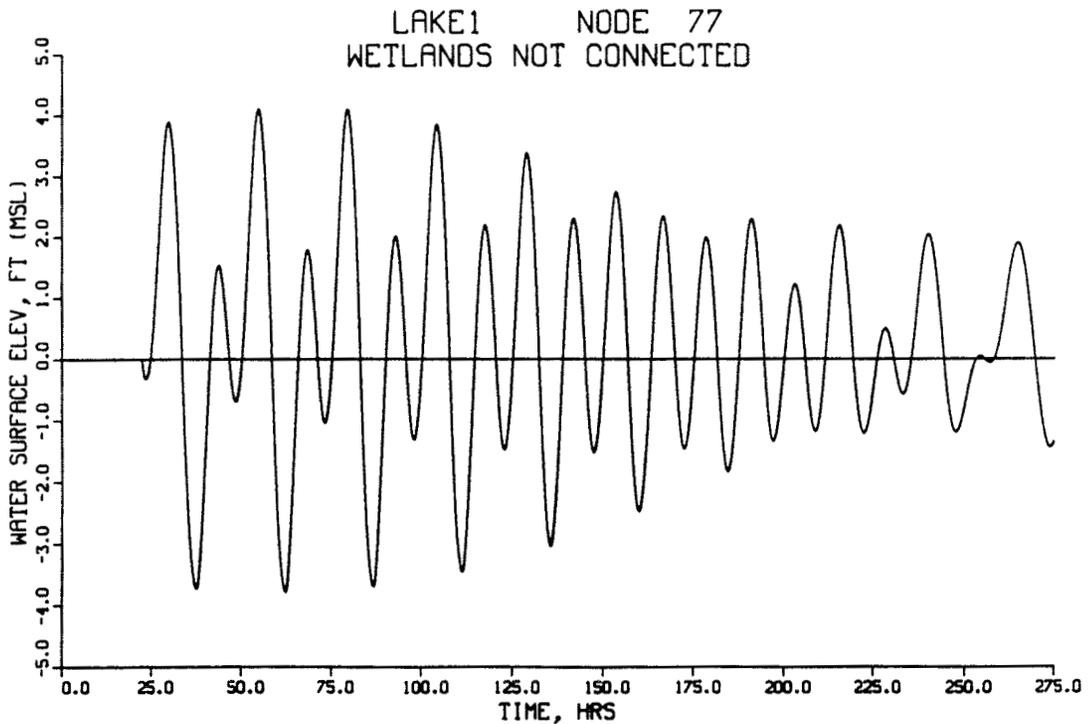


Figure C18. Tidal elevations in proposed marina,
350-ft non-navigable entrance channel

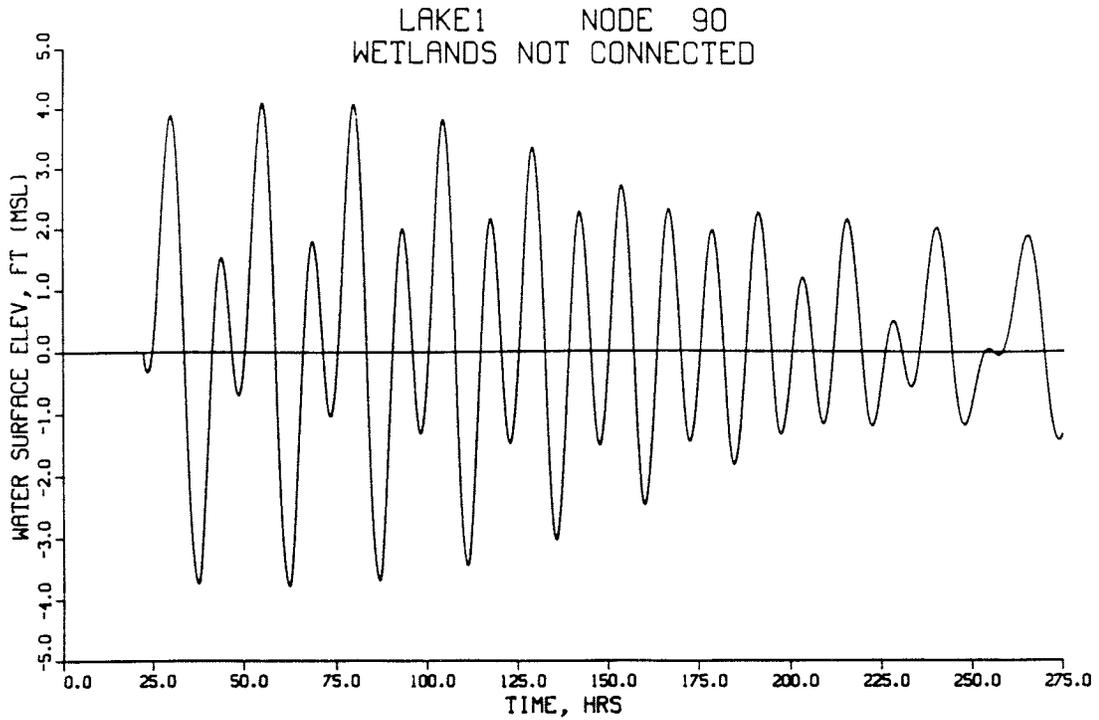


Figure C19. Tidal elevations in proposed marina,
350-ft non-navigable entrance channel

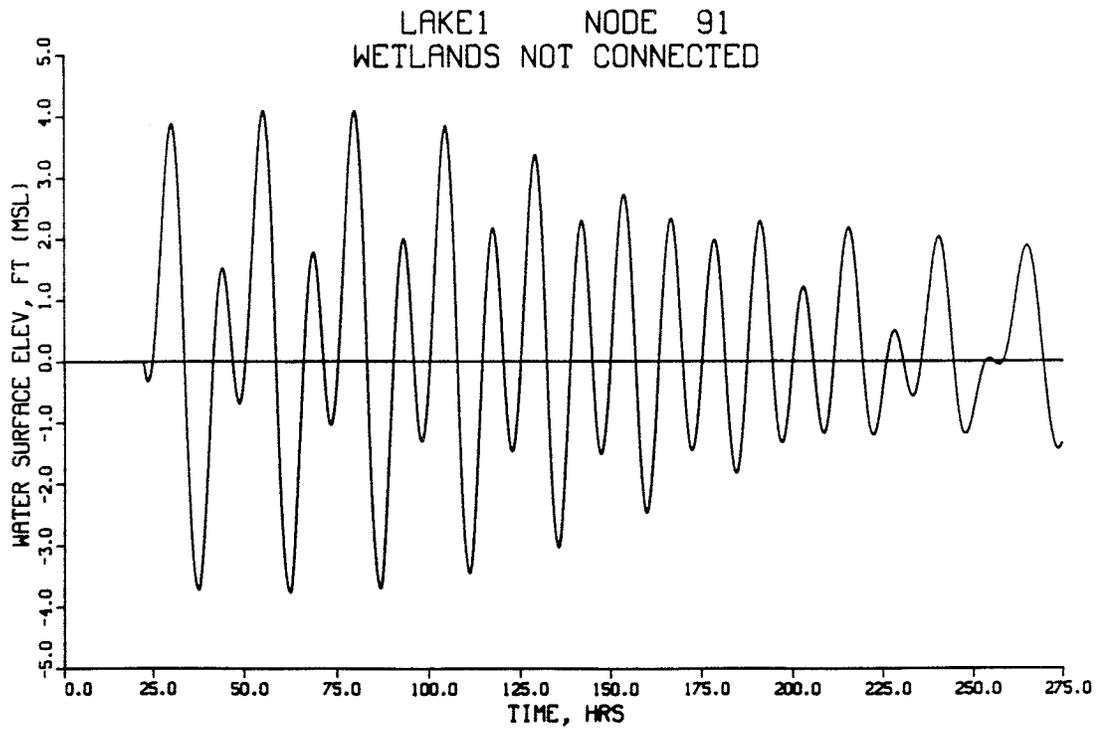


Figure C20. Tidal elevations in 350-ft non-navigable entrance channel

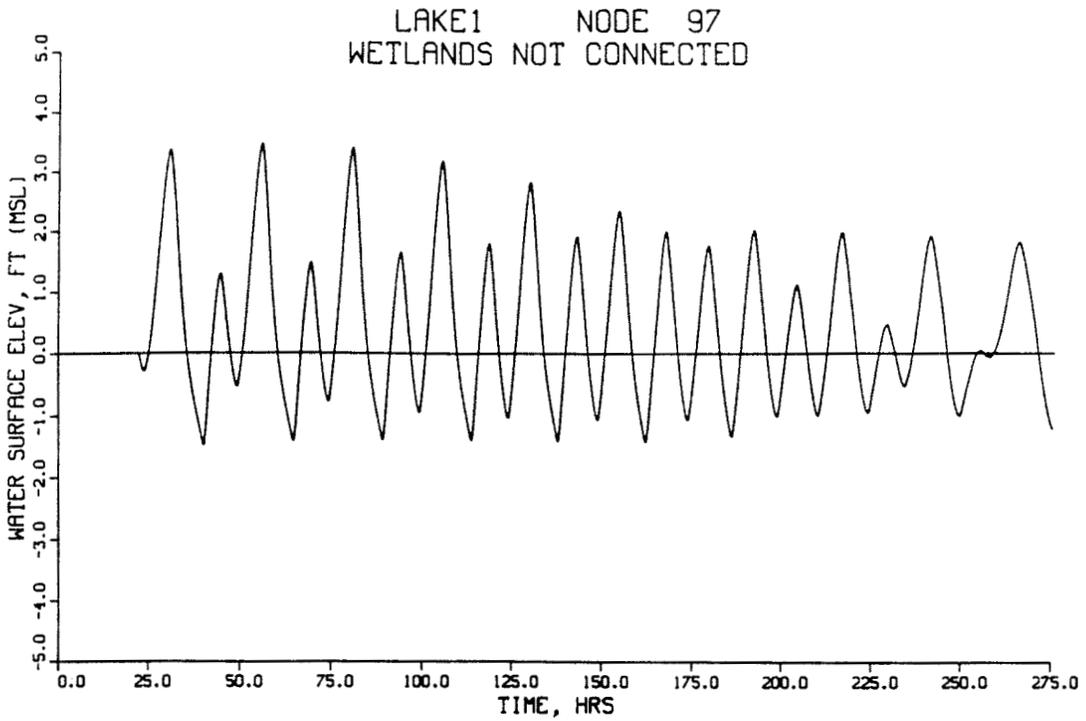


Figure C21. Tidal elevations in full tidal wetlands,
350-ft non-navigable entrance channel

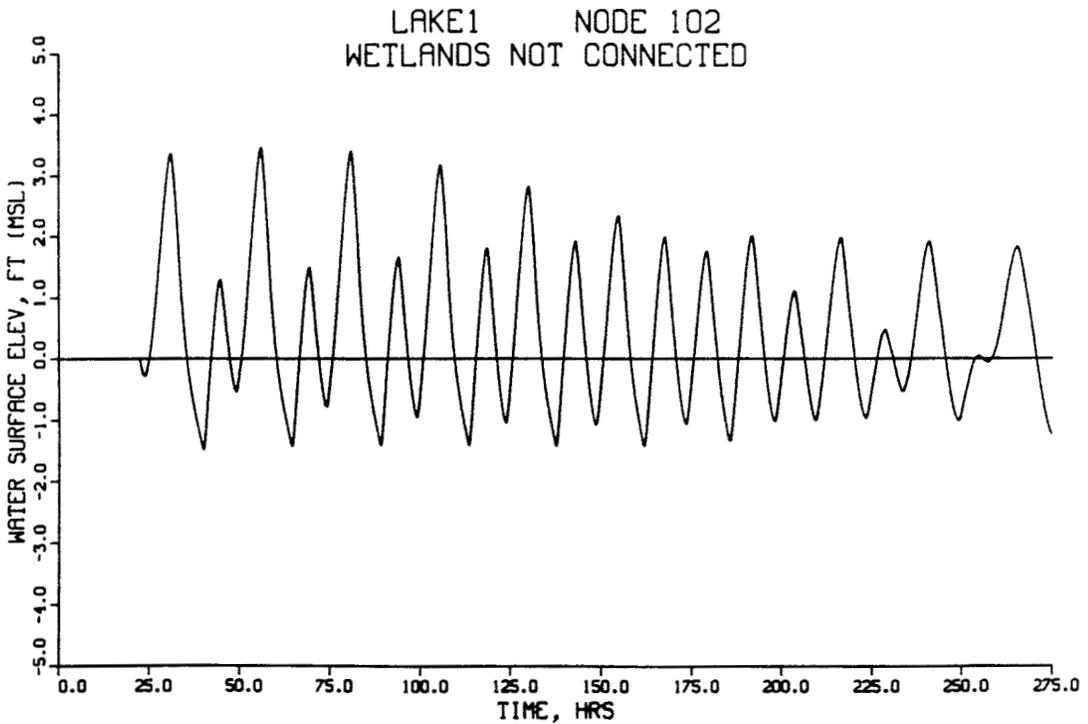


Figure C22. Tidal elevations in full tidal wetlands,
350-ft non-navigable entrance channel

LAKE1 NODE 112
WETLANDS NOT CONNECTED

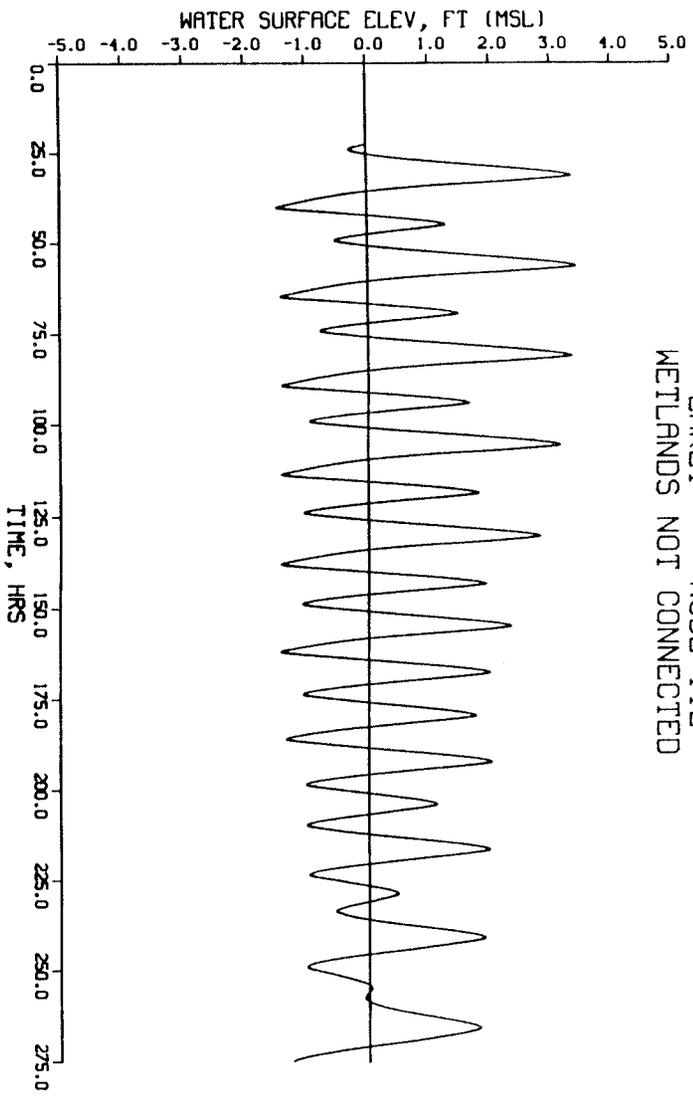


Figure C23. Tidal elevations in full tidal wetlands,
350-ft non-navigable entrance channel

LAKE1 NODE 113
WETLANDS NOT CONNECTED

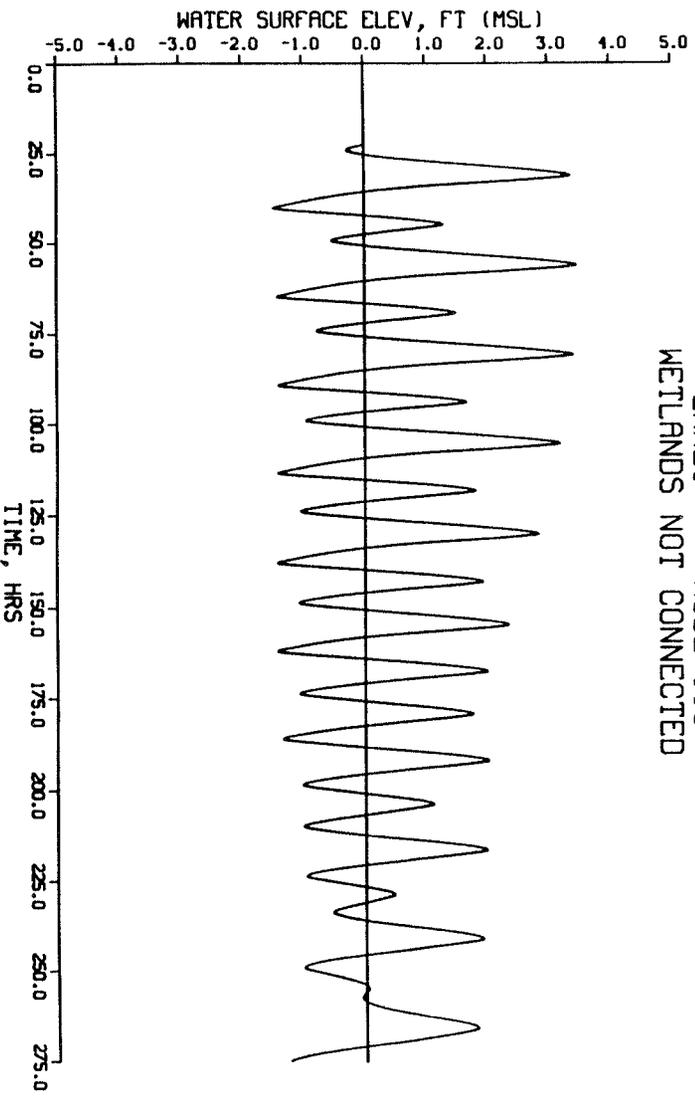


Figure C24. Tidal elevations in full tidal wetlands,
350-ft non-navigable entrance channel

LAKE1 NODE 117
WETLANDS NOT CONNECTED

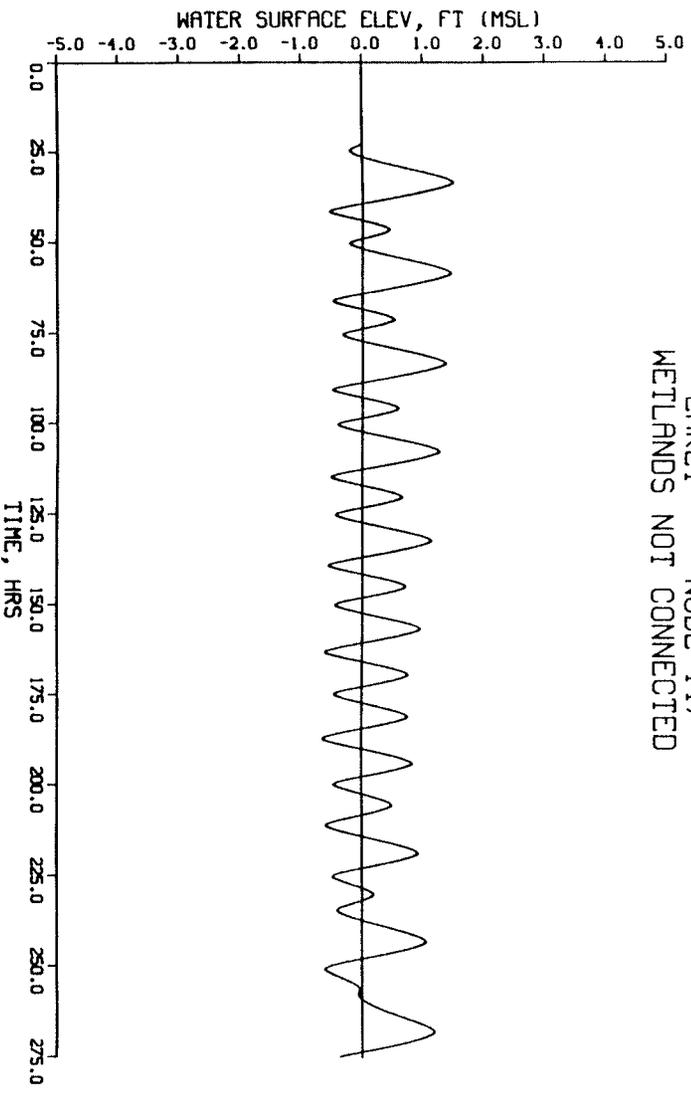


Figure C25. Tidal elevations in muted tidal wetlands,
350-ft non-navigable entrance channel

LAKE1 NODE 123
WETLANDS NOT CONNECTED

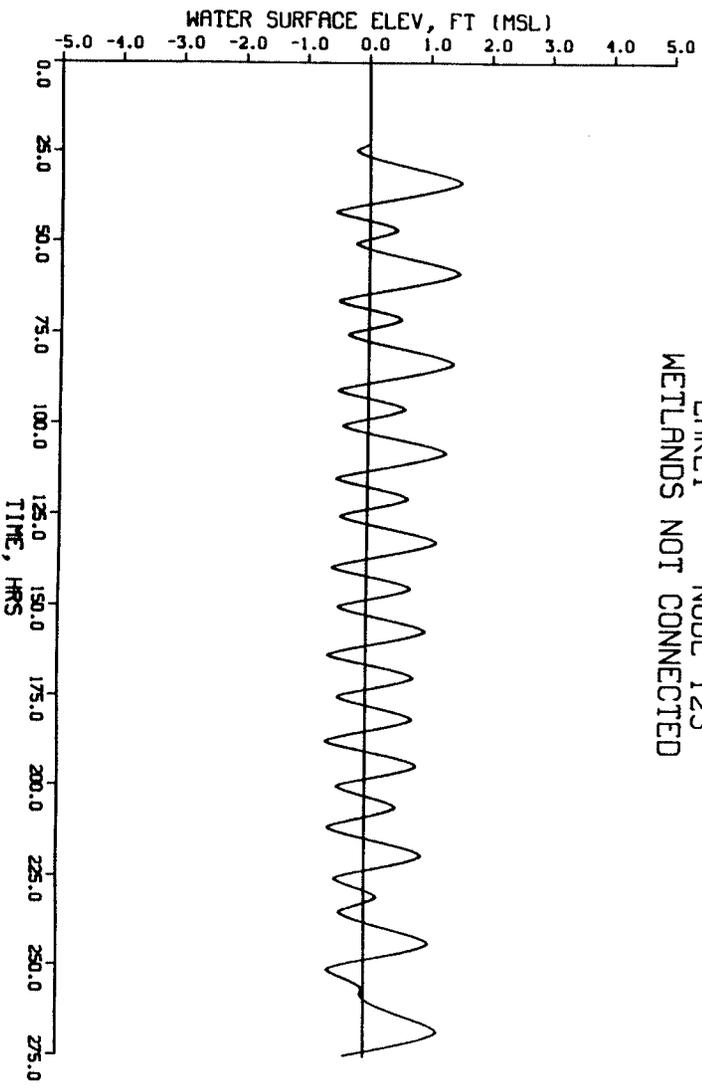


Figure C26. Tidal elevations in muted tidal wetlands,
350-ft non-navigable entrance channel

LAKE1 NODE 129
WETLANDS NOT CONNECTED

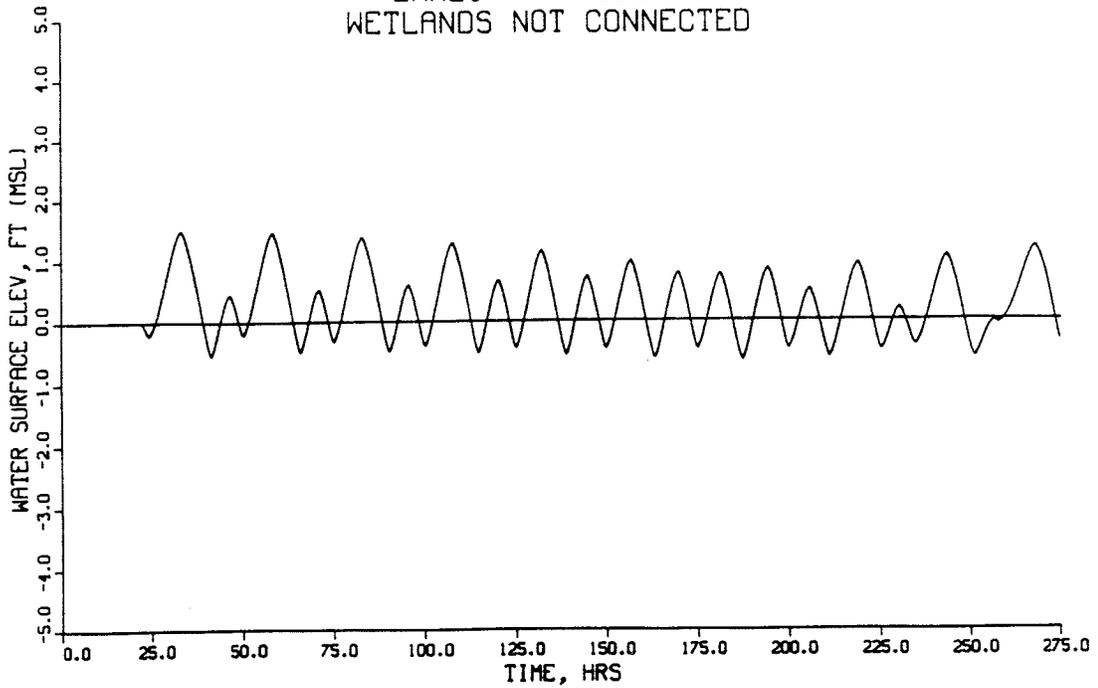


Figure C27. Tidal elevations in muted tidal wetlands,
350-ft non-navigable entrance channel

LAKE1 NODE 132
WETLANDS NOT CONNECTED

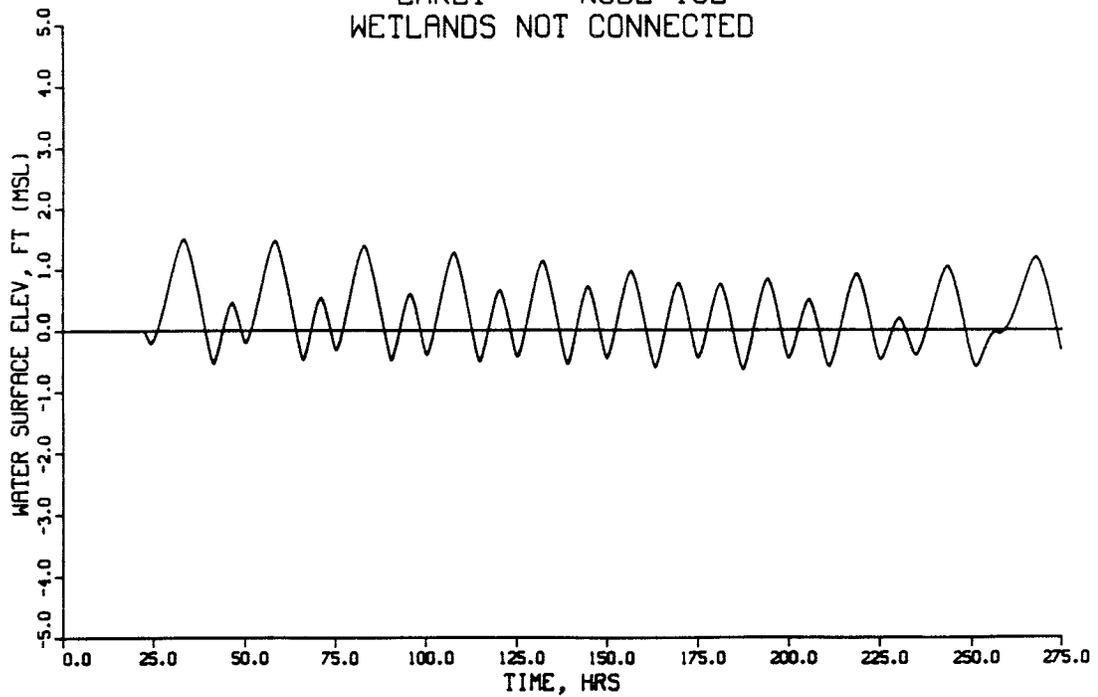


Figure C28. Tidal elevations in muted tidal wetlands,
350-ft non-navigable entrance channel

LAKE1 NODE 140
WETLANDS NOT CONNECTED

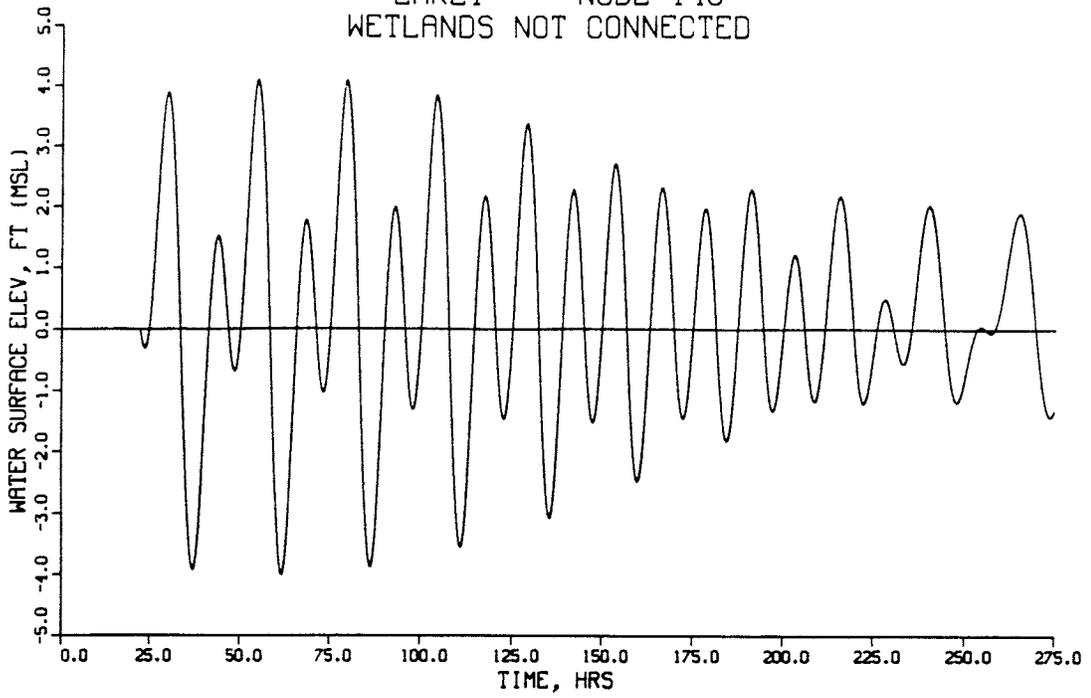


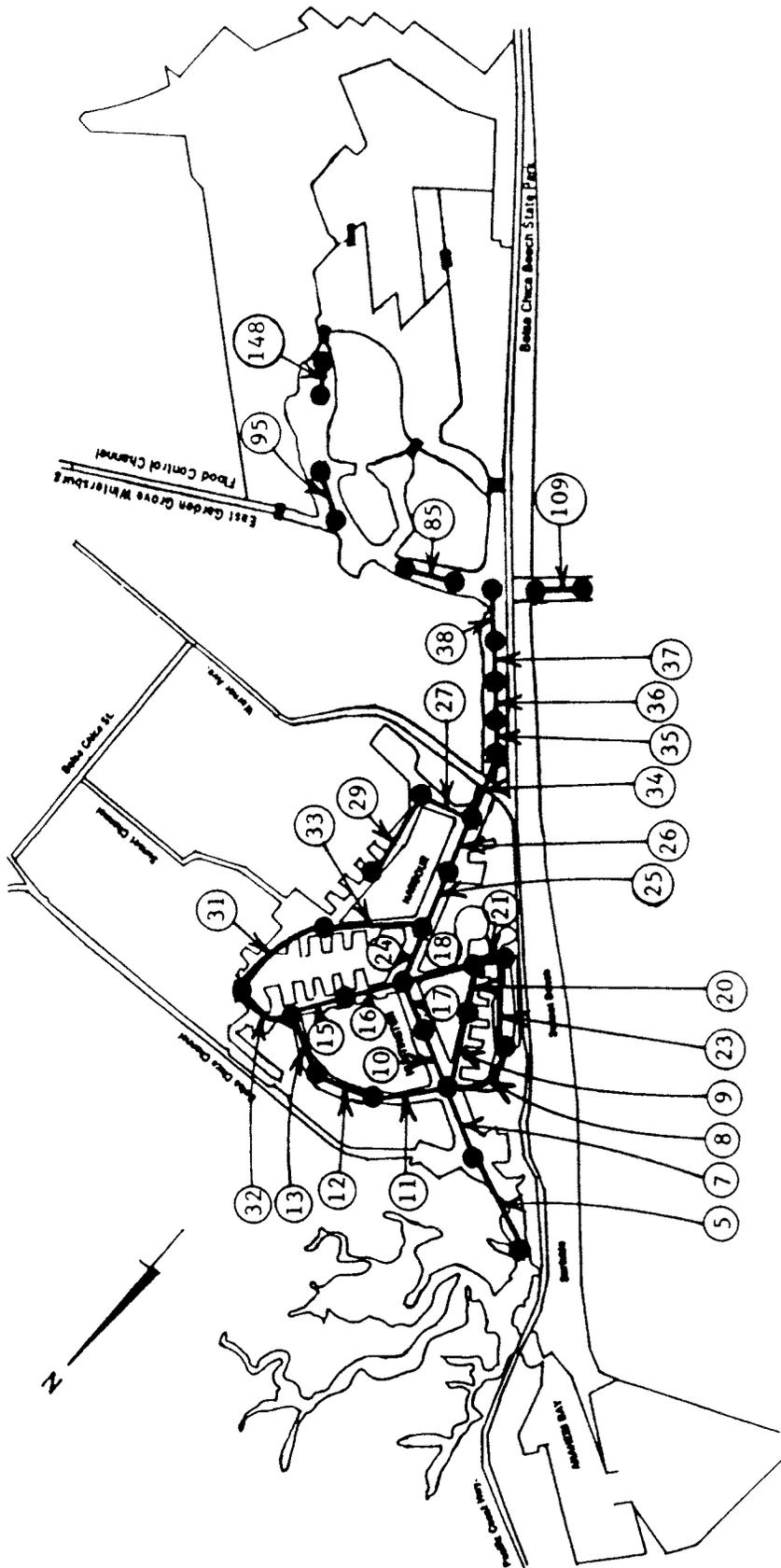
Figure C29. Tidal elevations in Pacific Ocean,
driving 350-ft non-navigable entrance channel

APPENDIX D:

LAKE 1

350-FT NON-NAVIGABLE ENTRANCE CHANNEL

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

LAKE 1
 Location of links for displaying
 average channel velocities under Lake 1 conditions

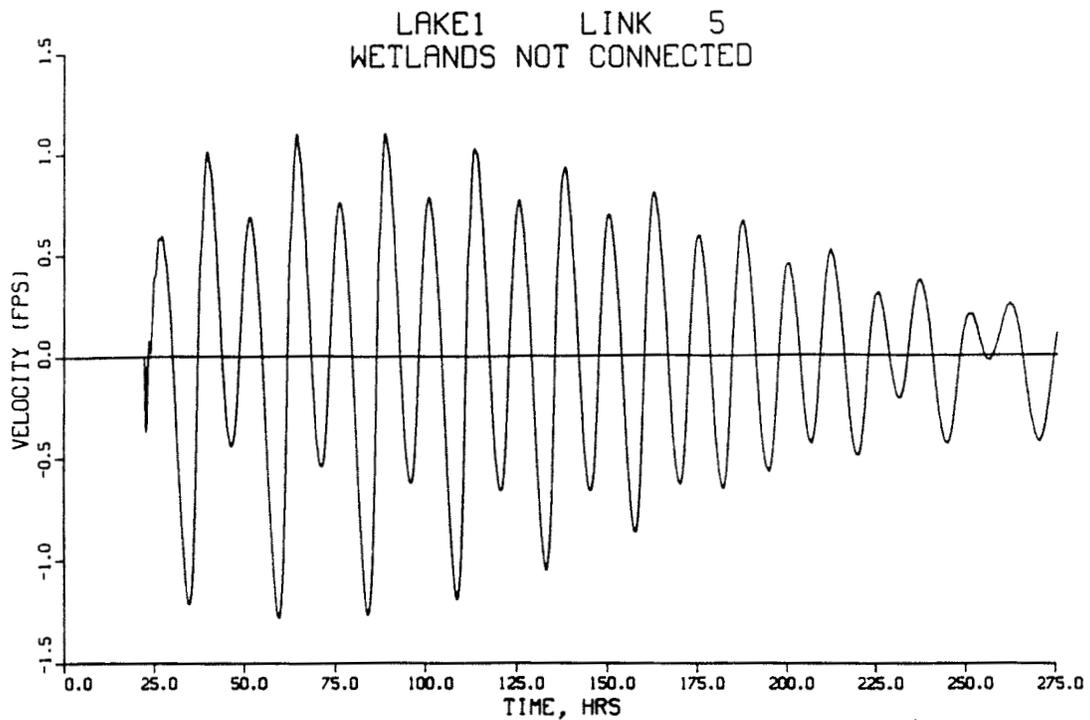


Figure D1. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

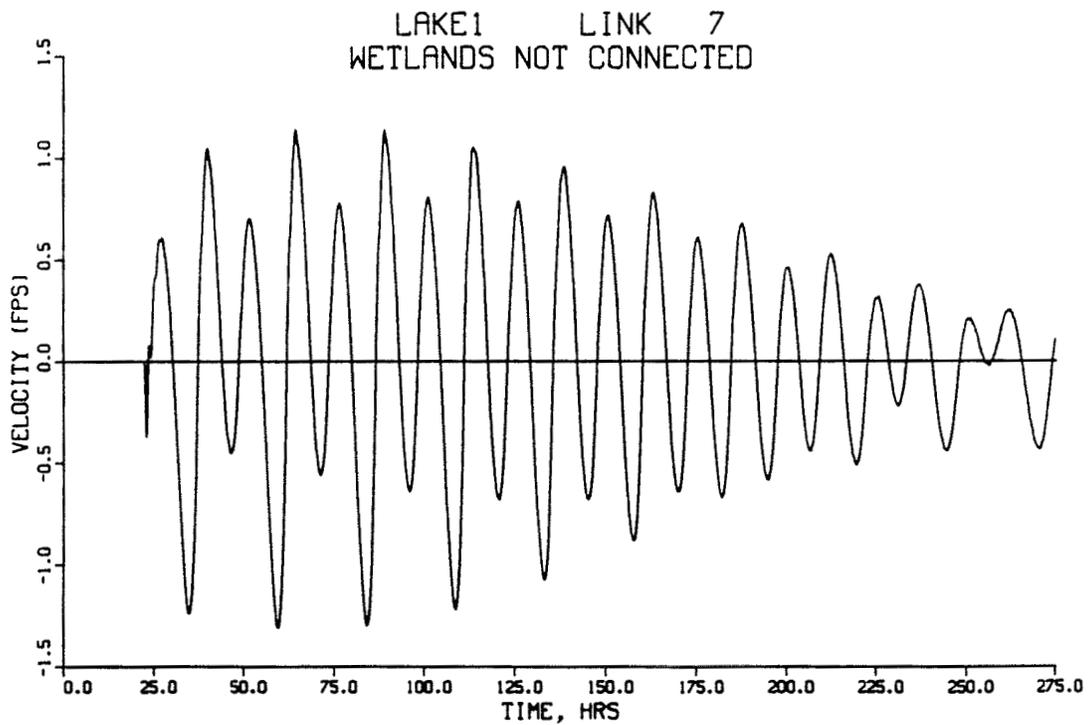


Figure D2. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

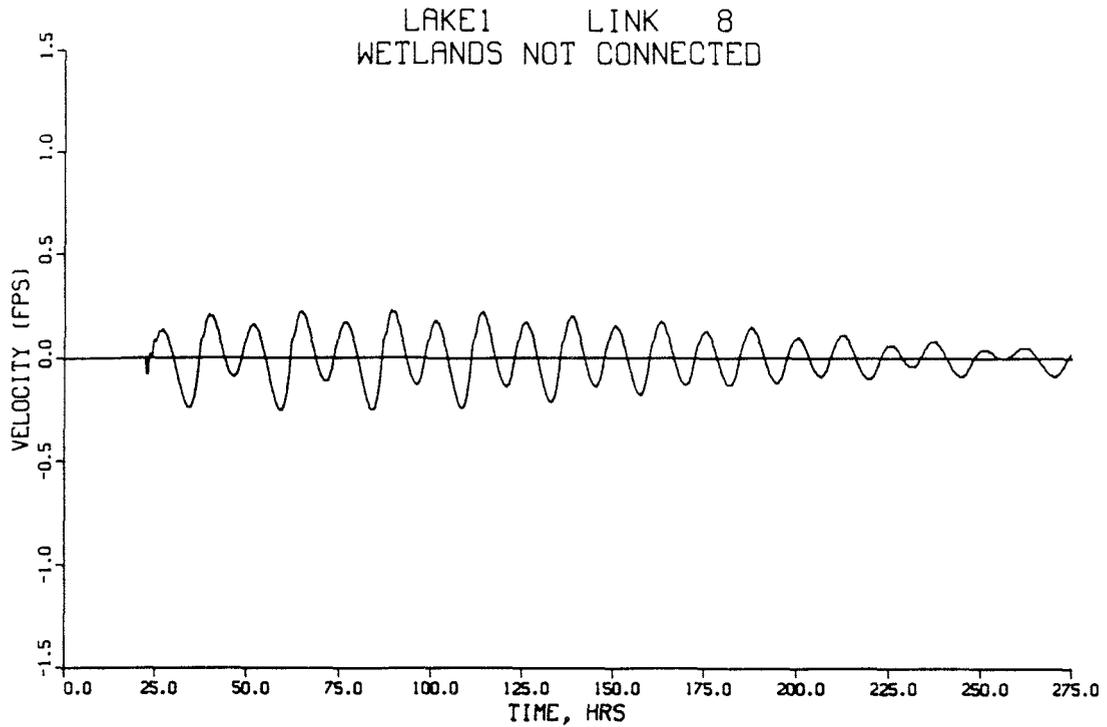


Figure D3. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

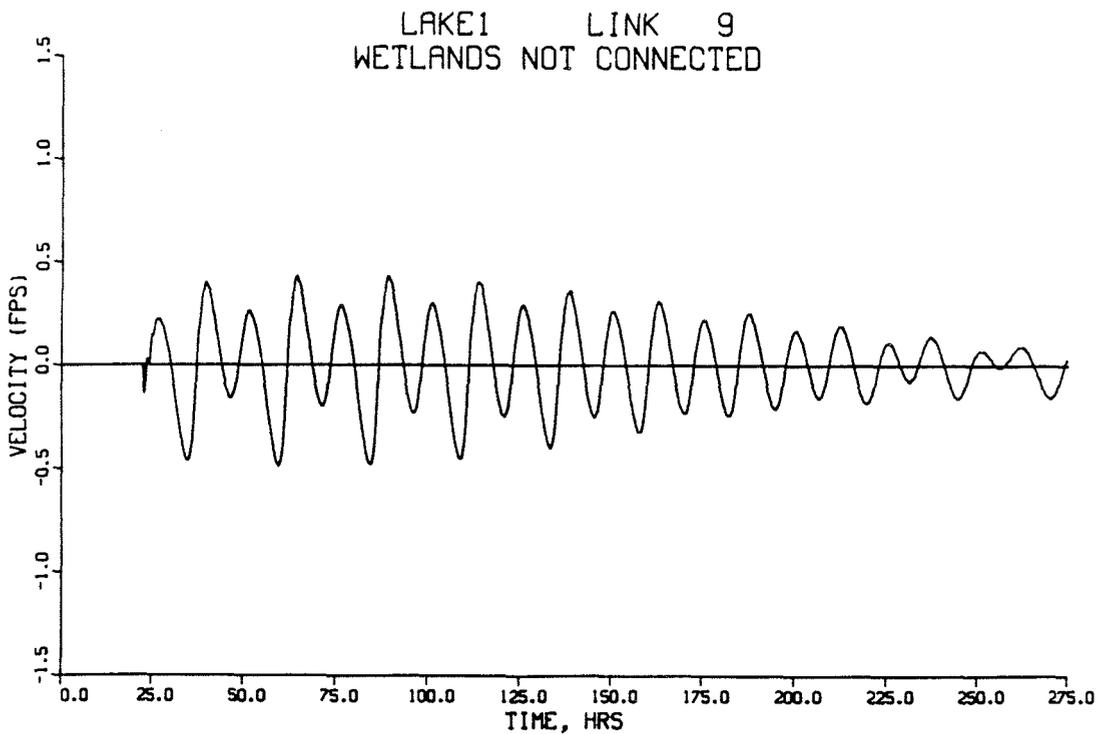


Figure D4. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

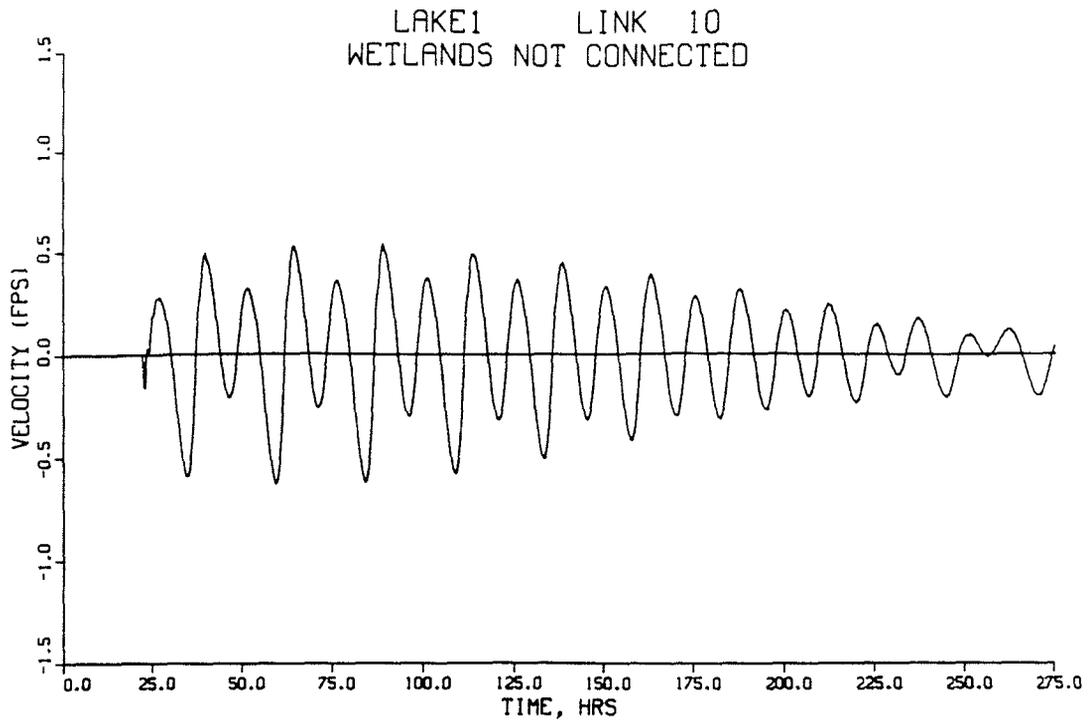


Figure D5. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

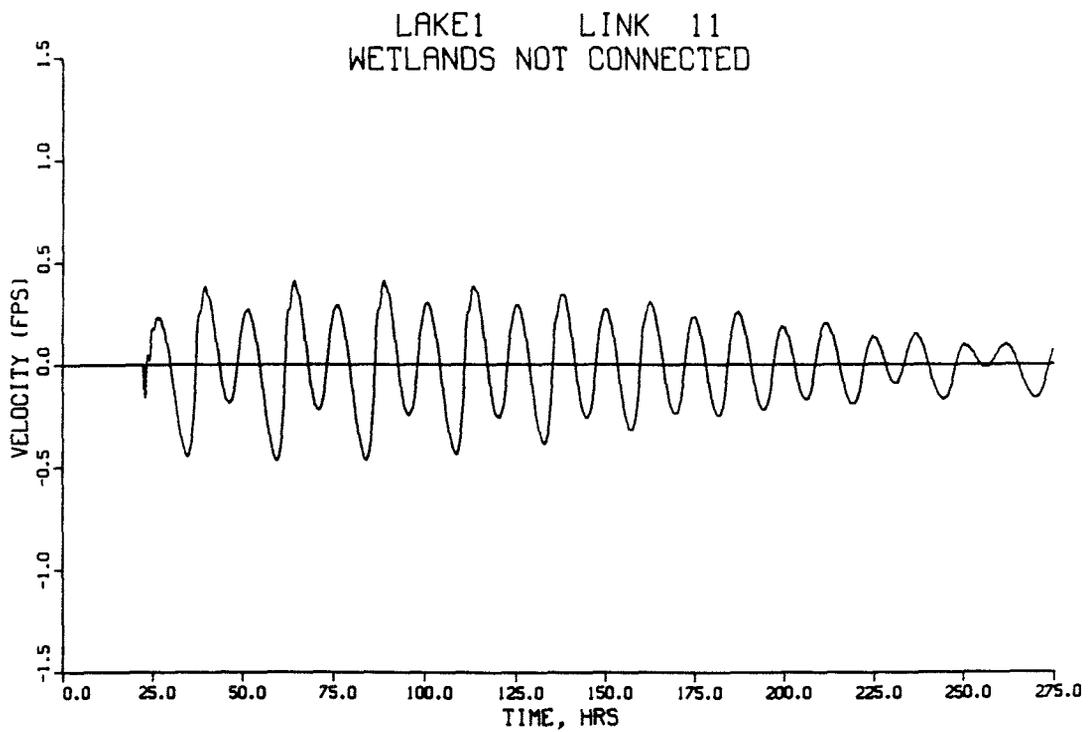


Figure D6. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 12
WETLANDS NOT CONNECTED

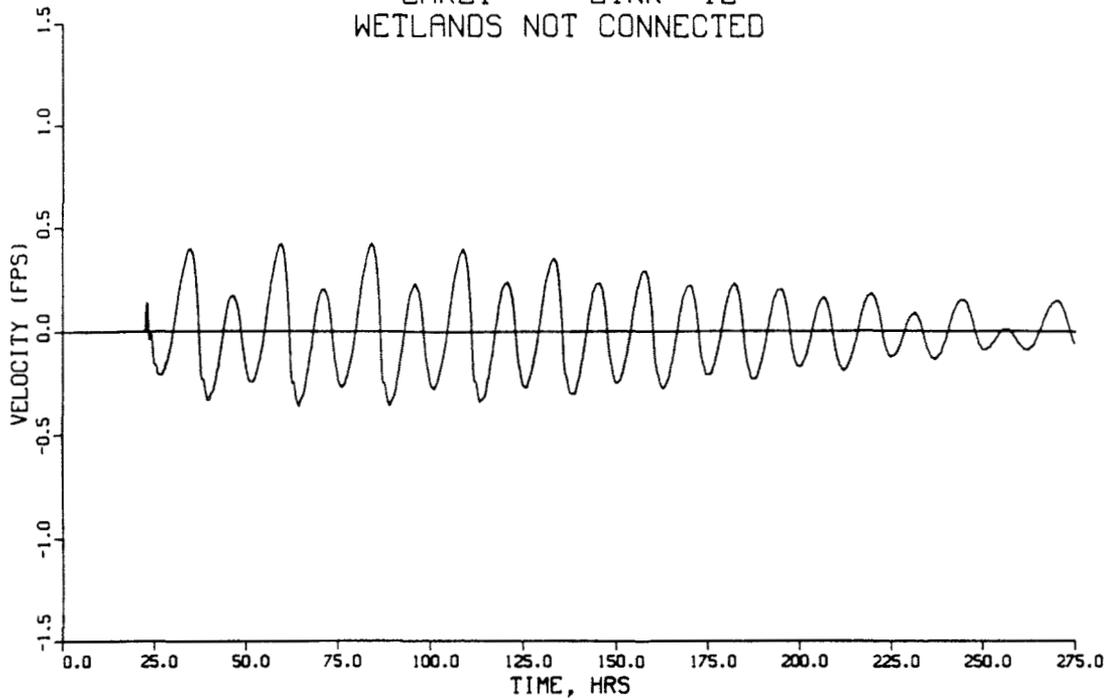


Figure D7. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 13
WETLANDS NOT CONNECTED

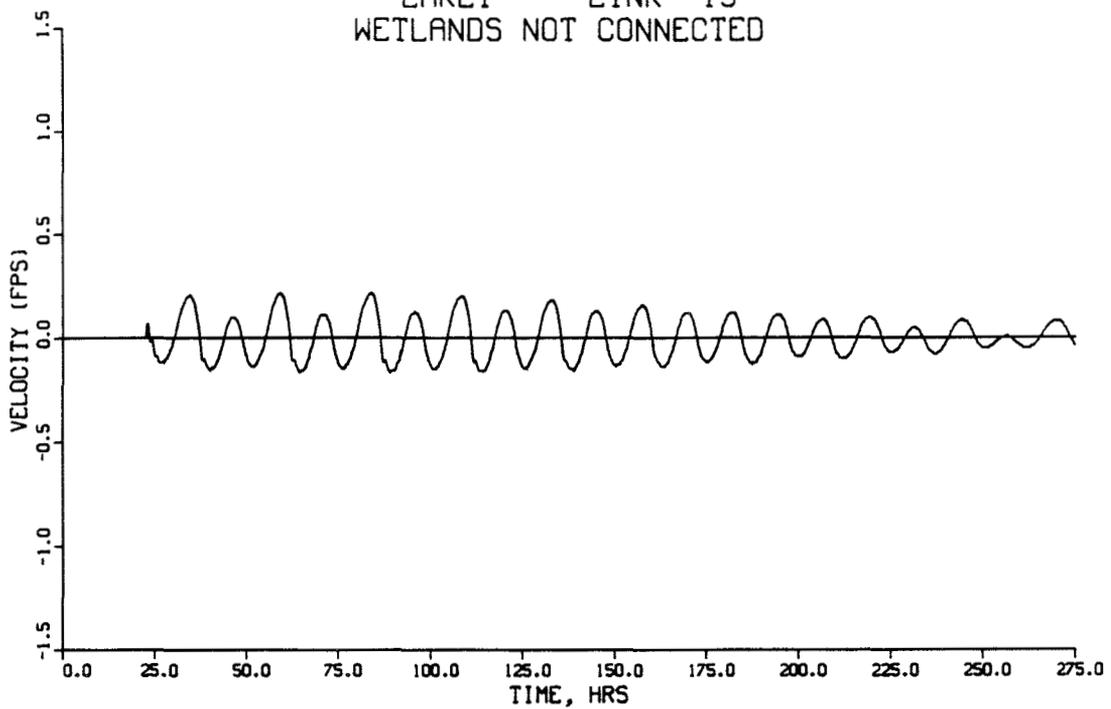


Figure D8. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 15
WETLANDS NOT CONNECTED

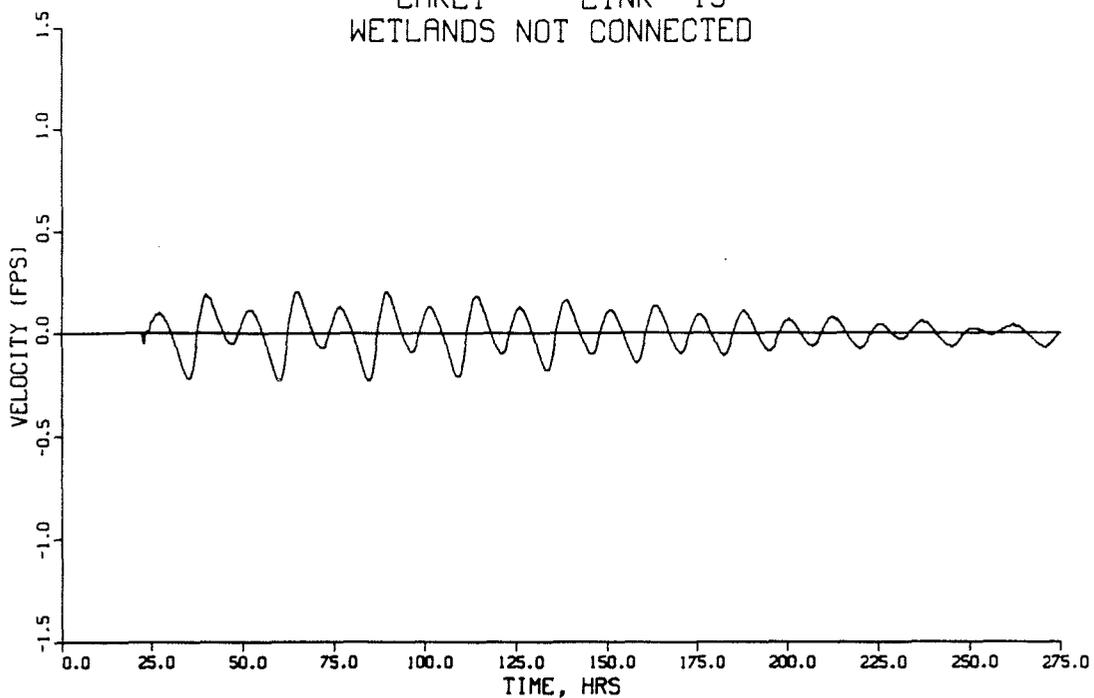


Figure D9. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 16
WETLANDS NOT CONNECTED

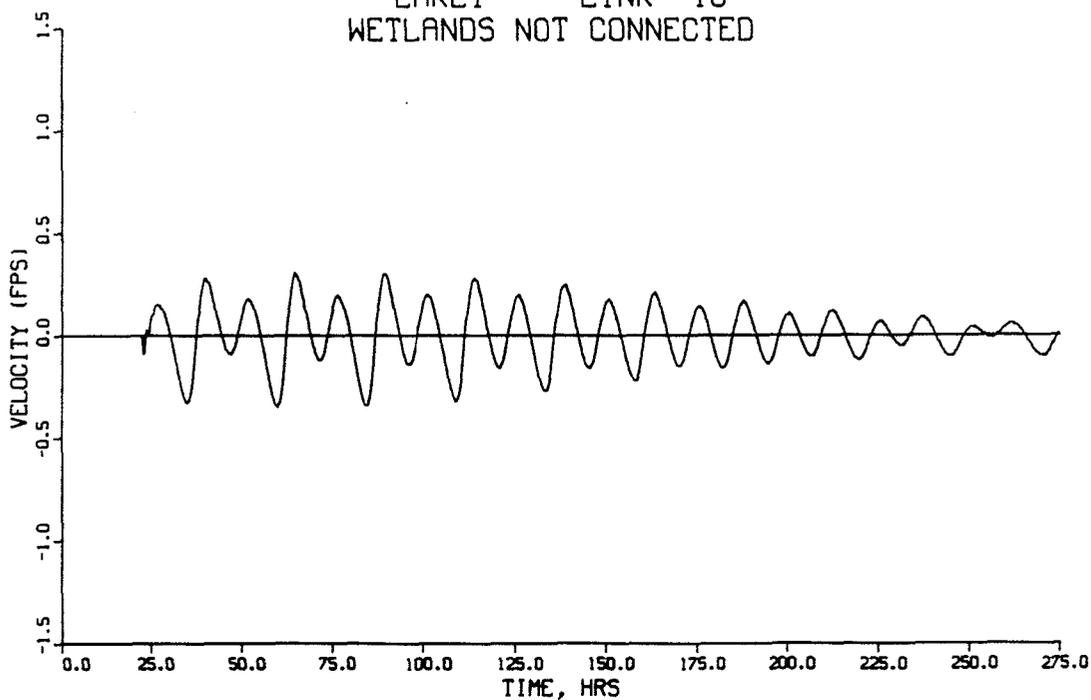


Figure D10. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

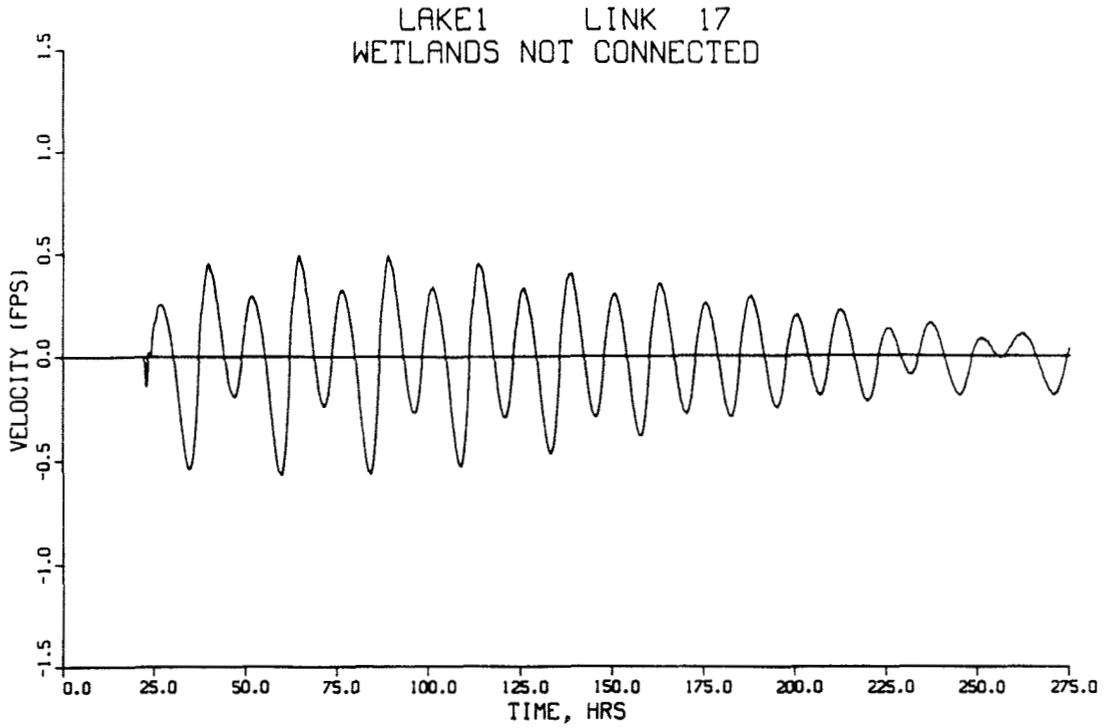


Figure D11. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

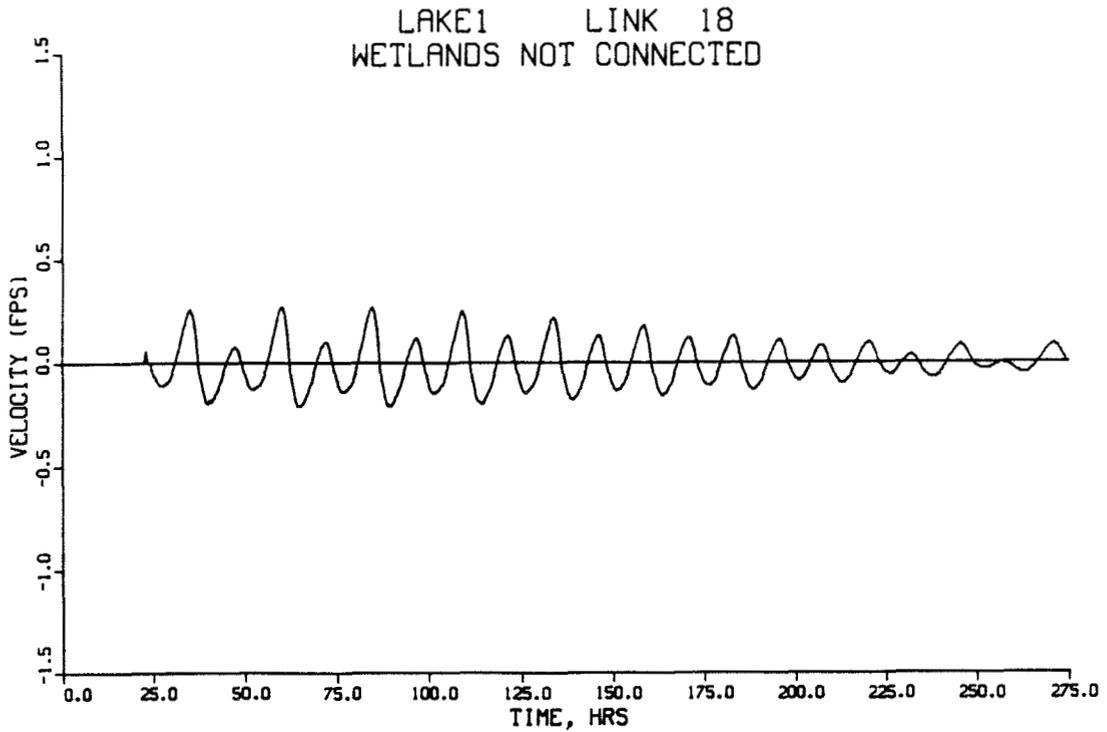


Figure D12. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 20
WETLANDS NOT CONNECTED

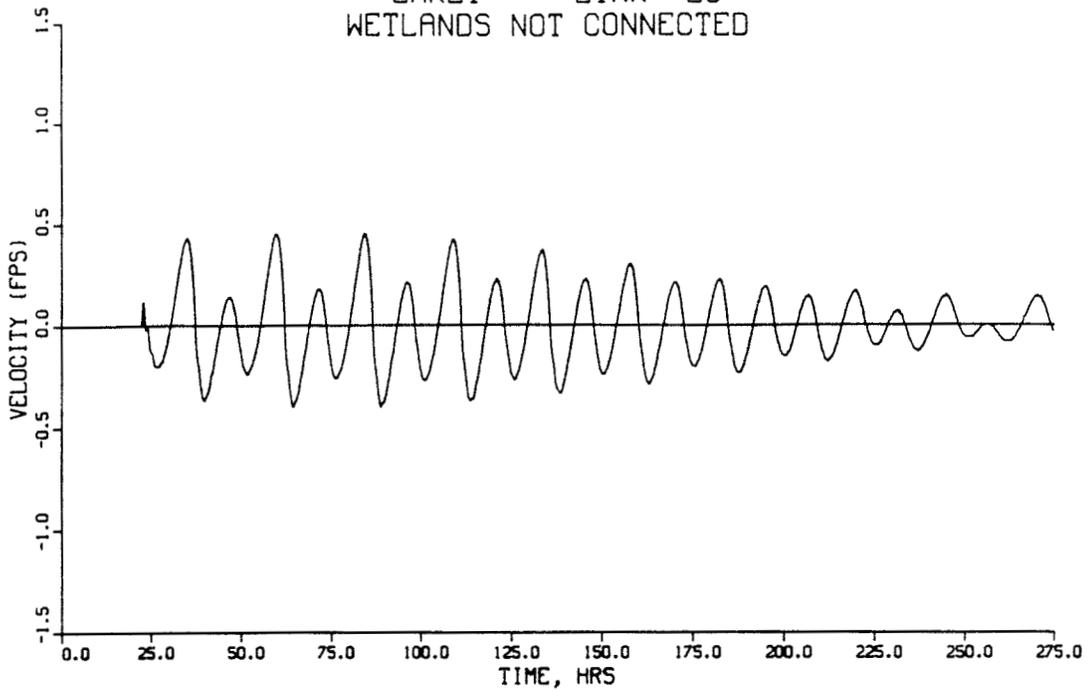


Figure D13. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 21
WETLANDS NOT CONNECTED

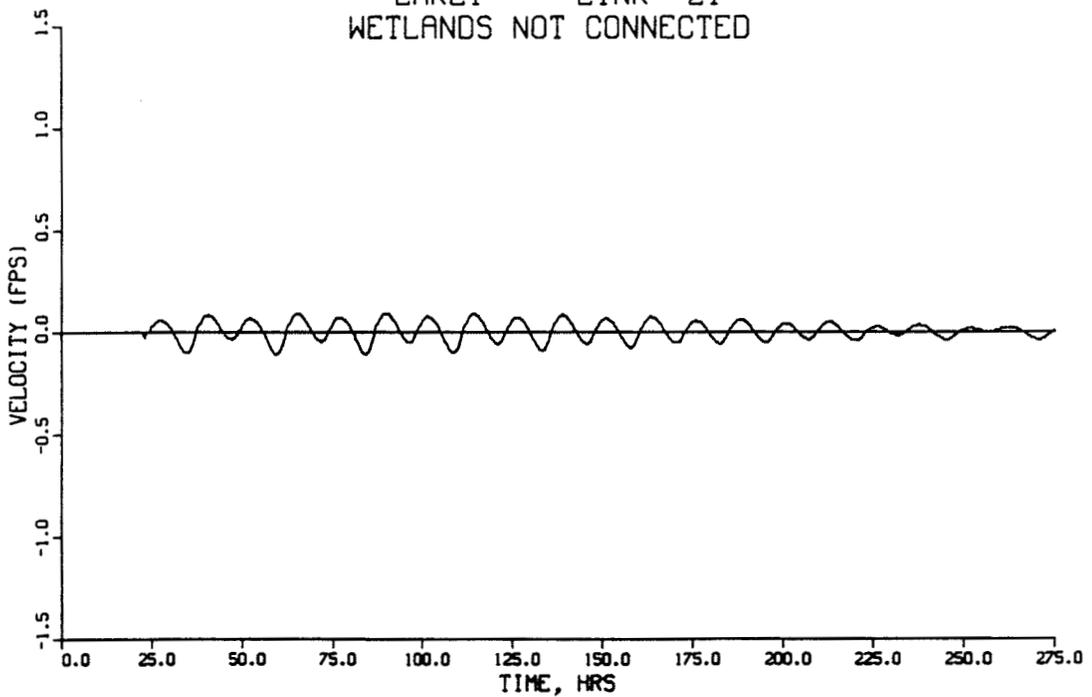


Figure D14. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 23
WETLANDS NOT CONNECTED

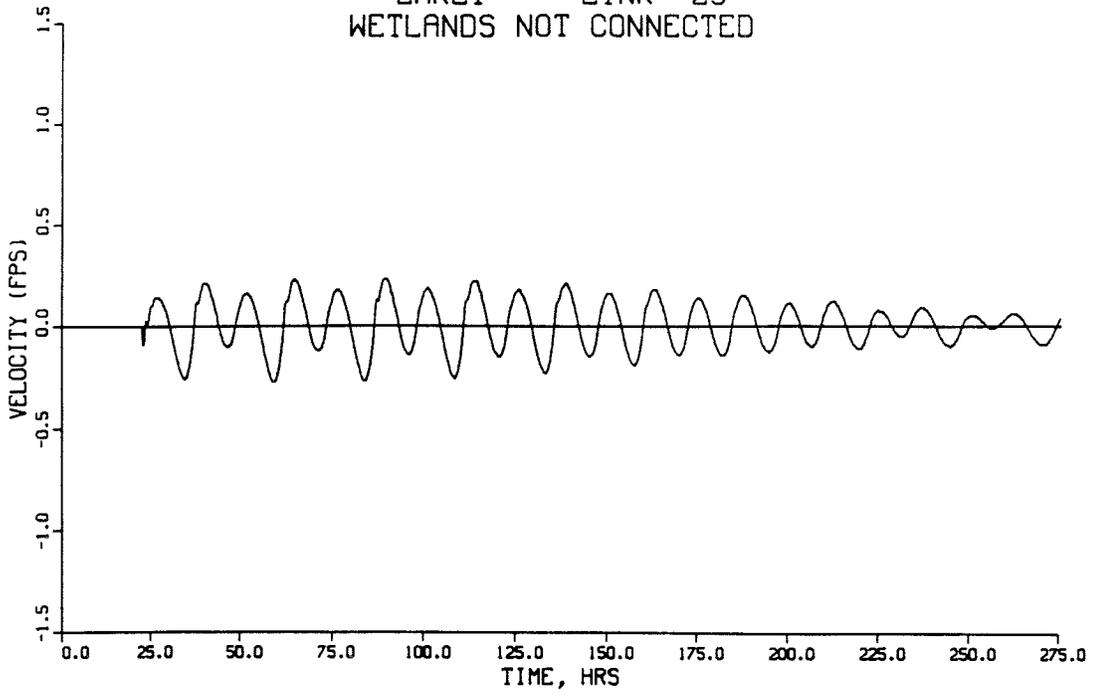


Figure D15. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 24
WETLANDS NOT CONNECTED

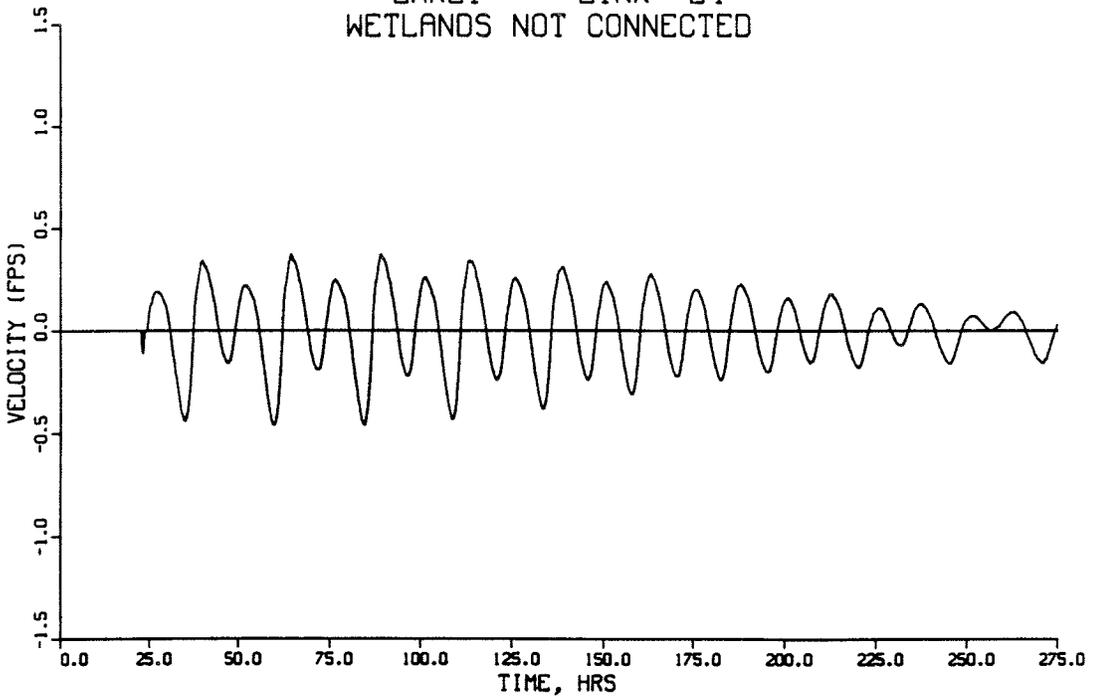


Figure D16. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

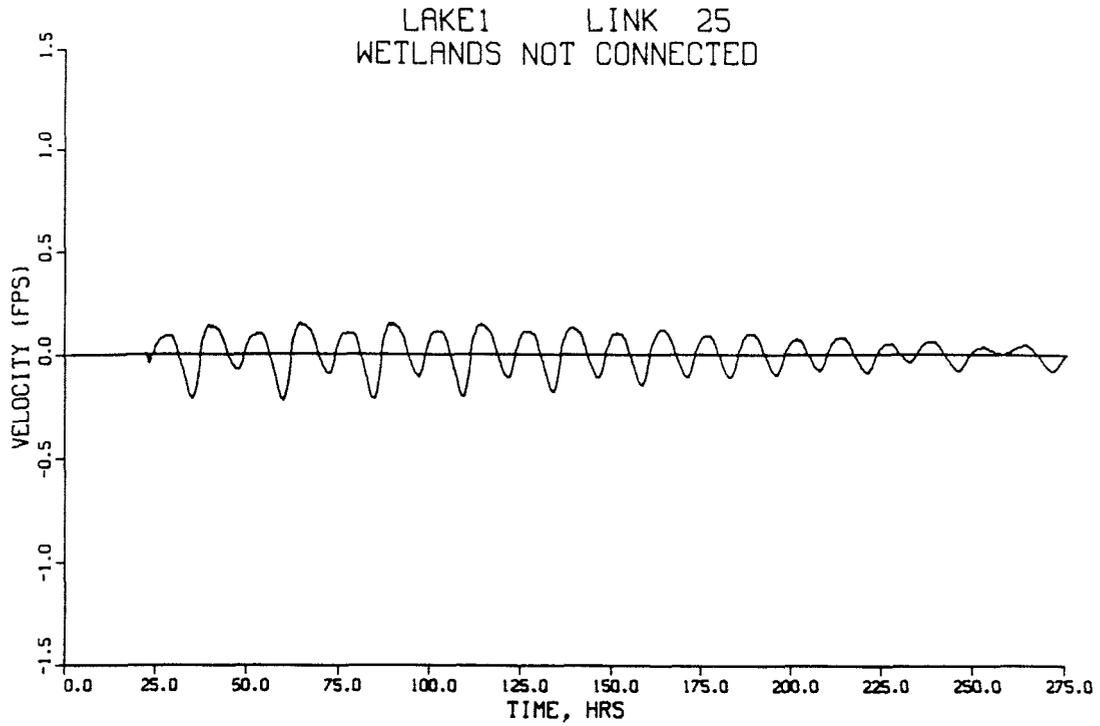


Figure D17. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

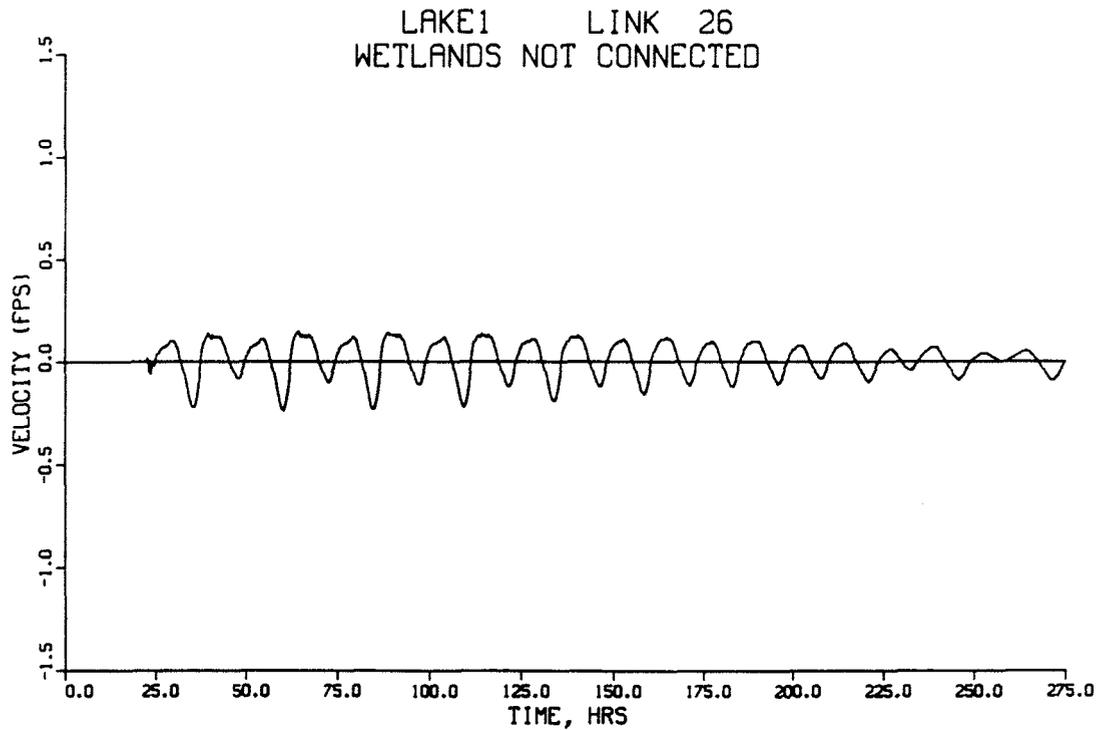


Figure D18. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 27
WETLANDS NOT CONNECTED

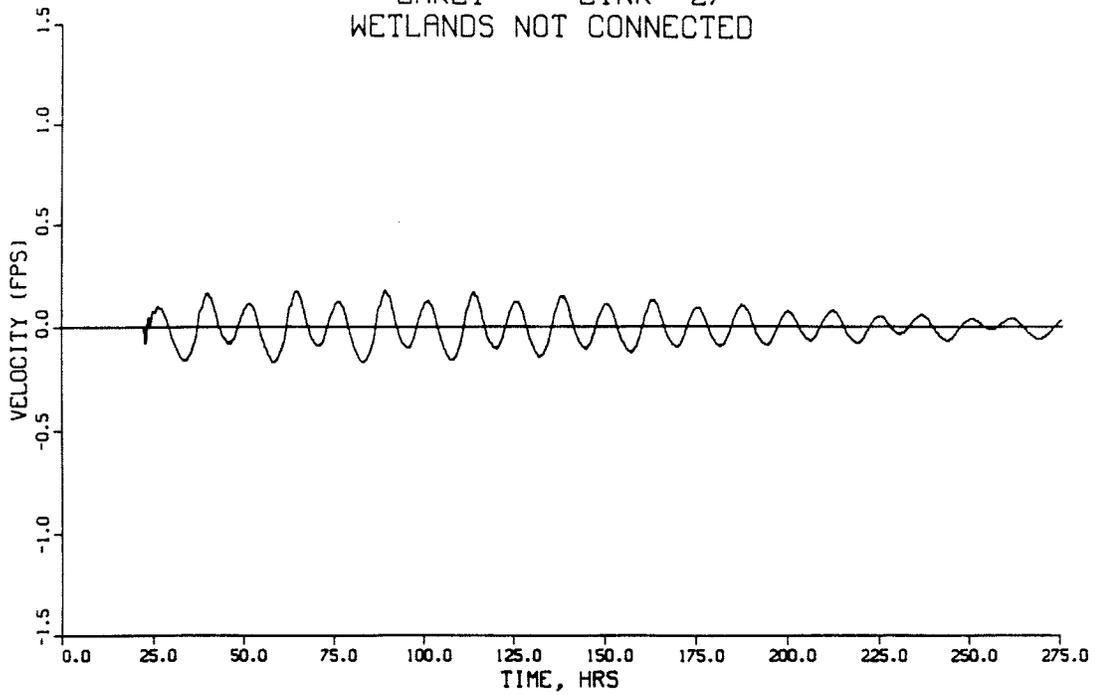


Figure D19. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 29
WETLANDS NOT CONNECTED

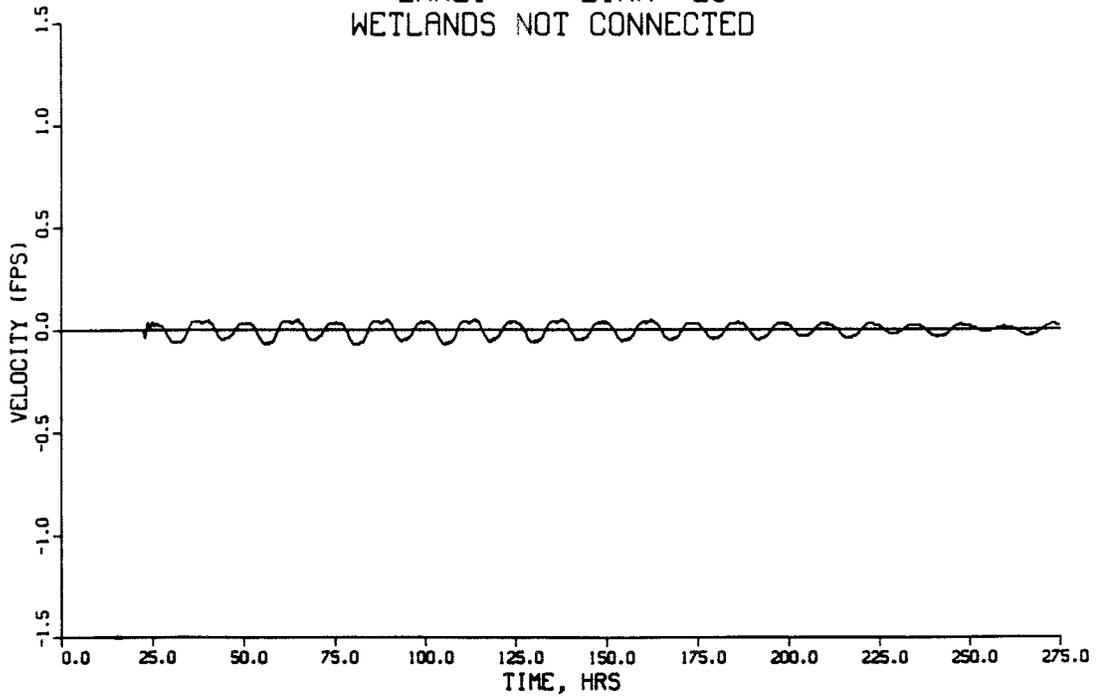


Figure D20. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 31
WETLANDS NOT CONNECTED

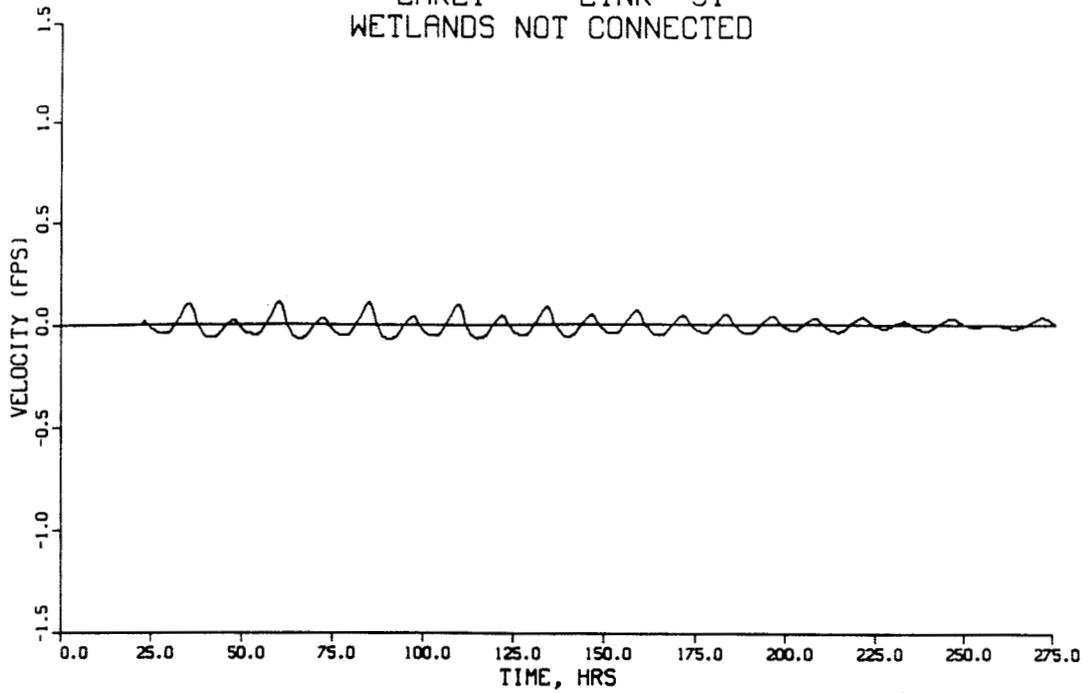


Figure D21. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

LAKE1 LINK 32
WETLANDS NOT CONNECTED

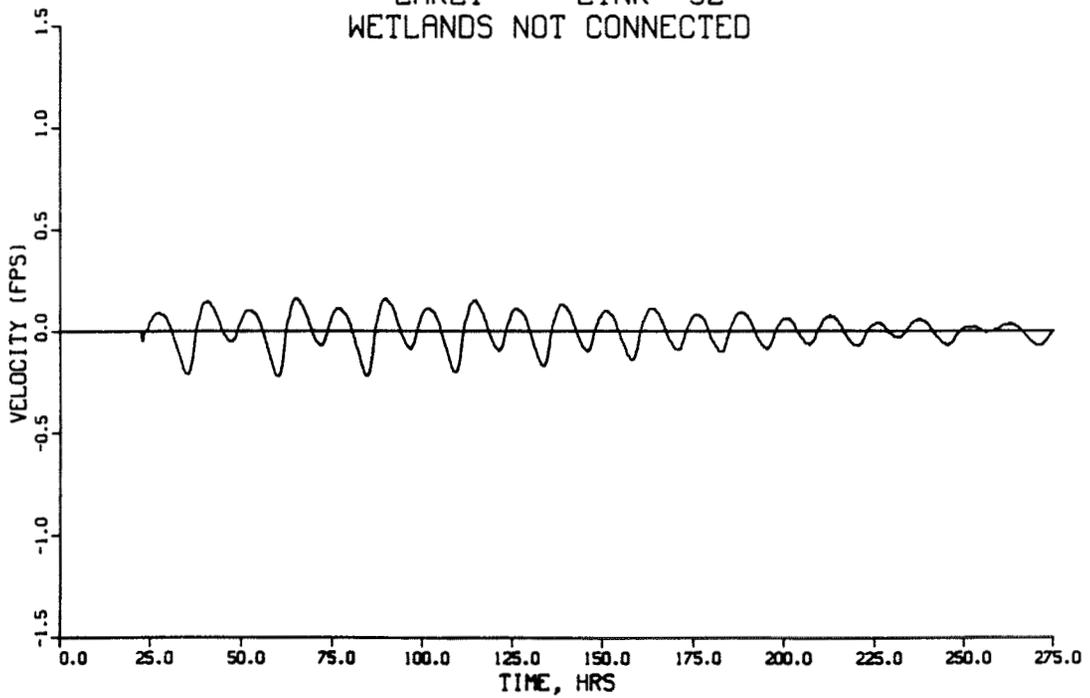


Figure D22. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

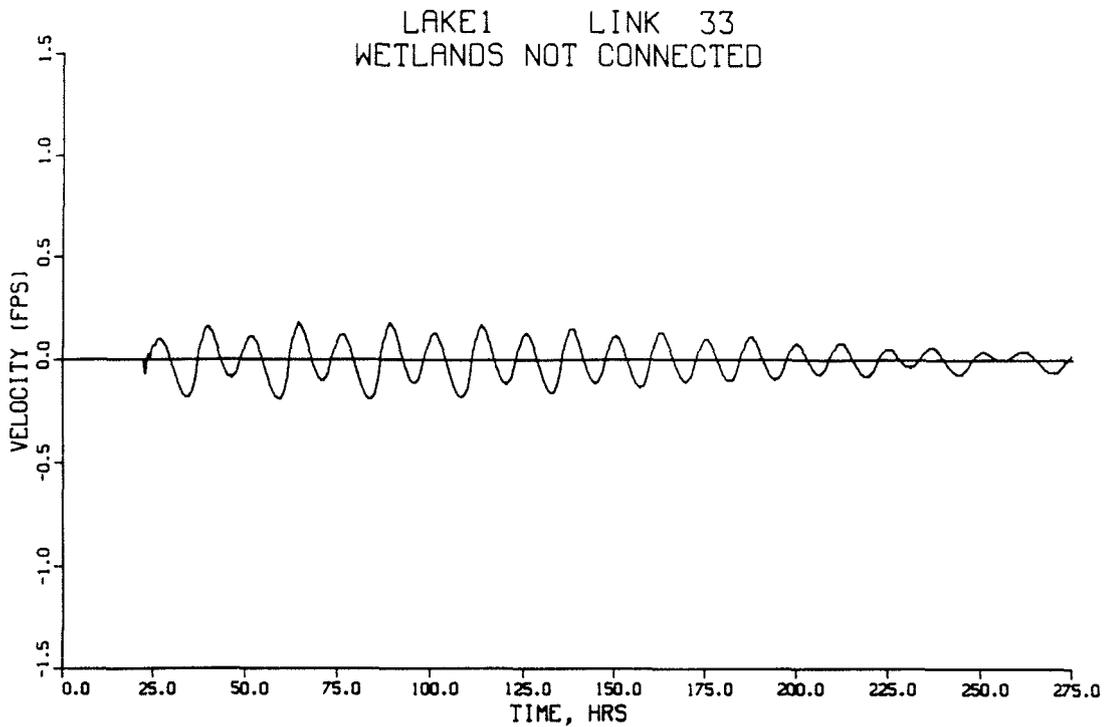


Figure D23. Average channel velocities in Huntington Harbour, 350-ft non-navigable entrance channel

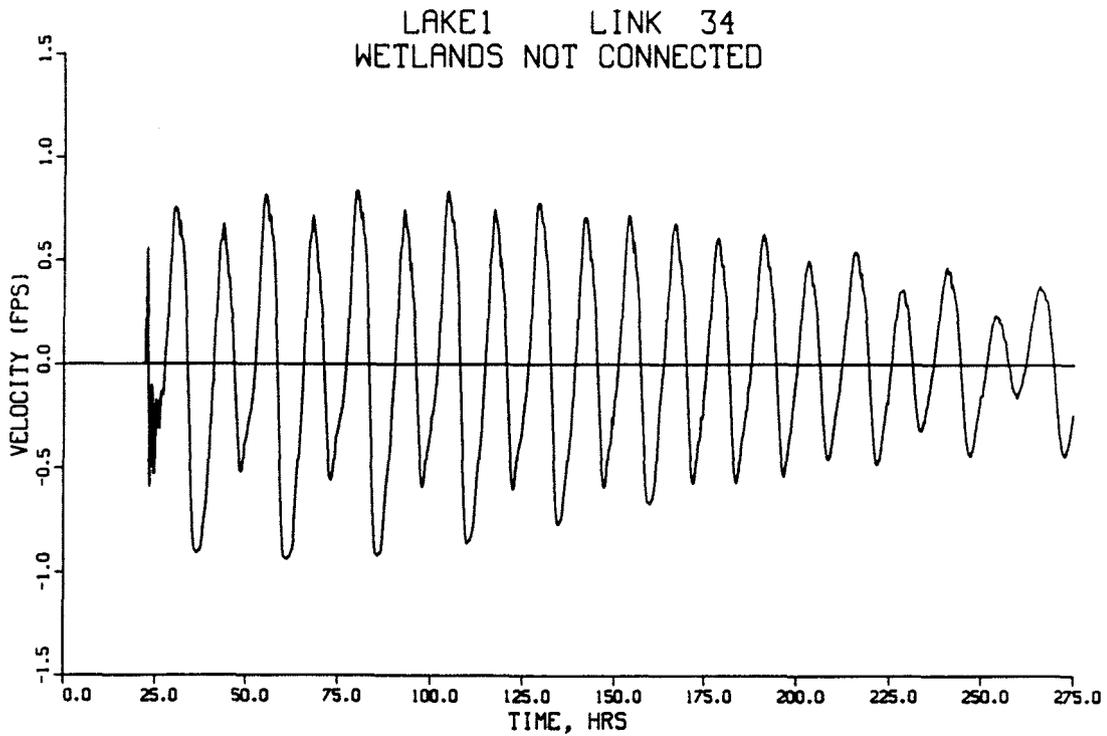


Figure D24. Average channel velocities under Warner Avenue bridge, 350-ft non-navigable entrance channel

LAKE1 LINK 35
WETLANDS NOT CONNECTED

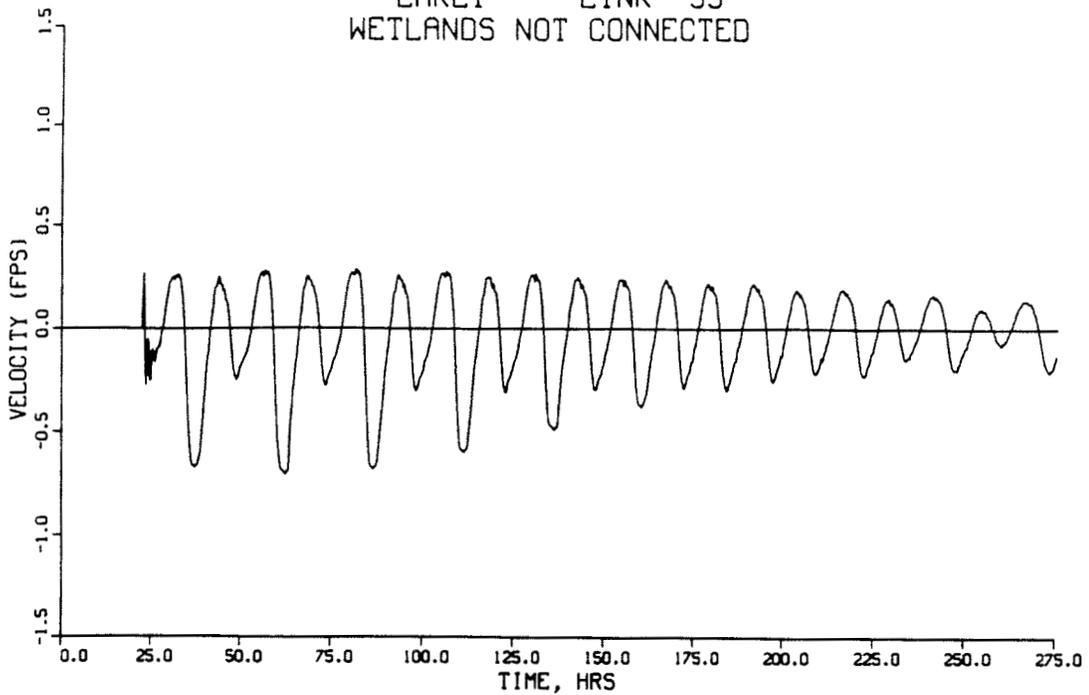


Figure D25. Average channel velocities in Outer Bolsa Bay,
350-ft non-navigable entrance channel

LAKE1 LINK 36
WETLANDS NOT CONNECTED

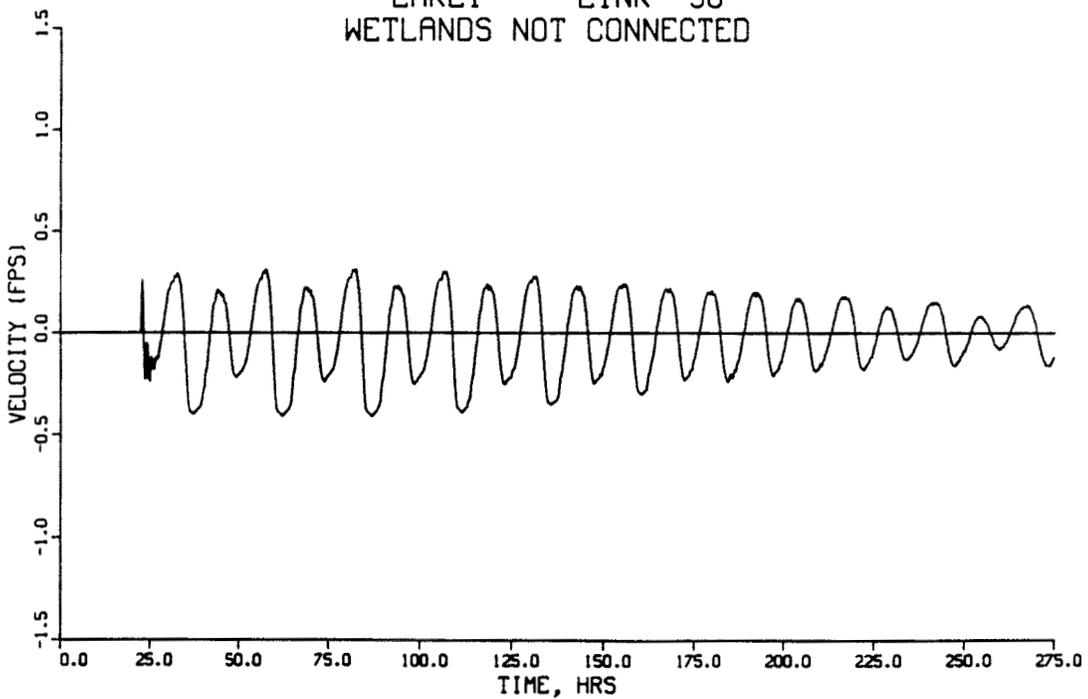


Figure D26. Average channel velocities in Outer Bolsa Bay,
350-ft non-navigable entrance channel

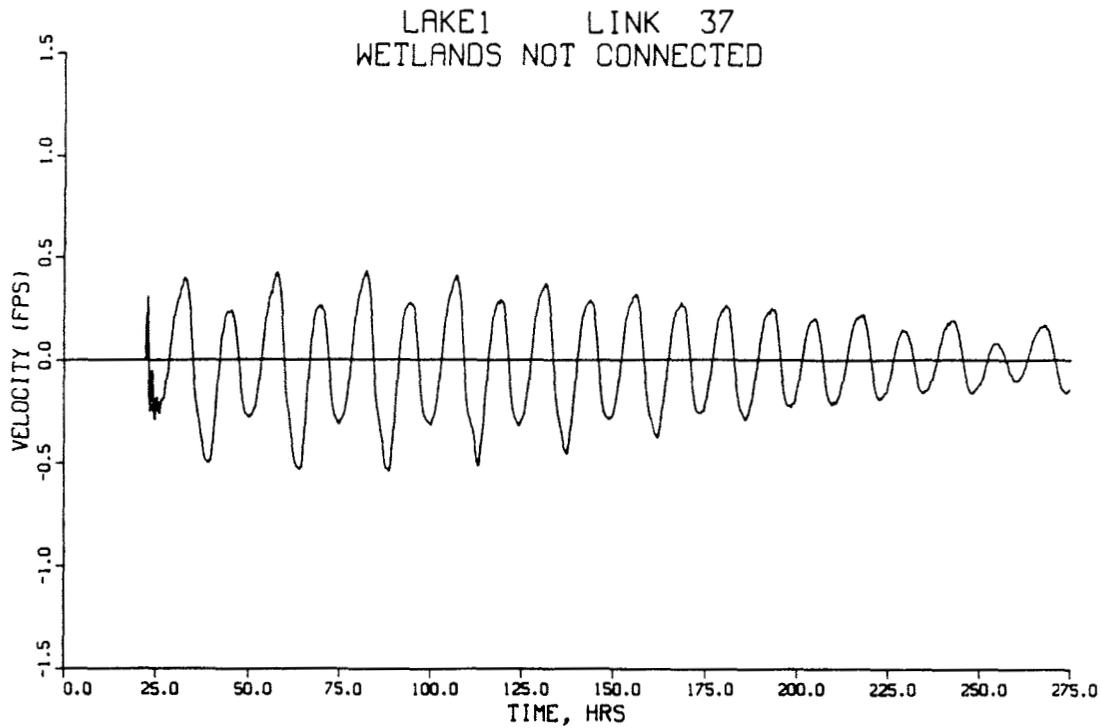


Figure D27. Average channel velocities in Outer Bolsa Bay, 350-ft non-navigable entrance channel

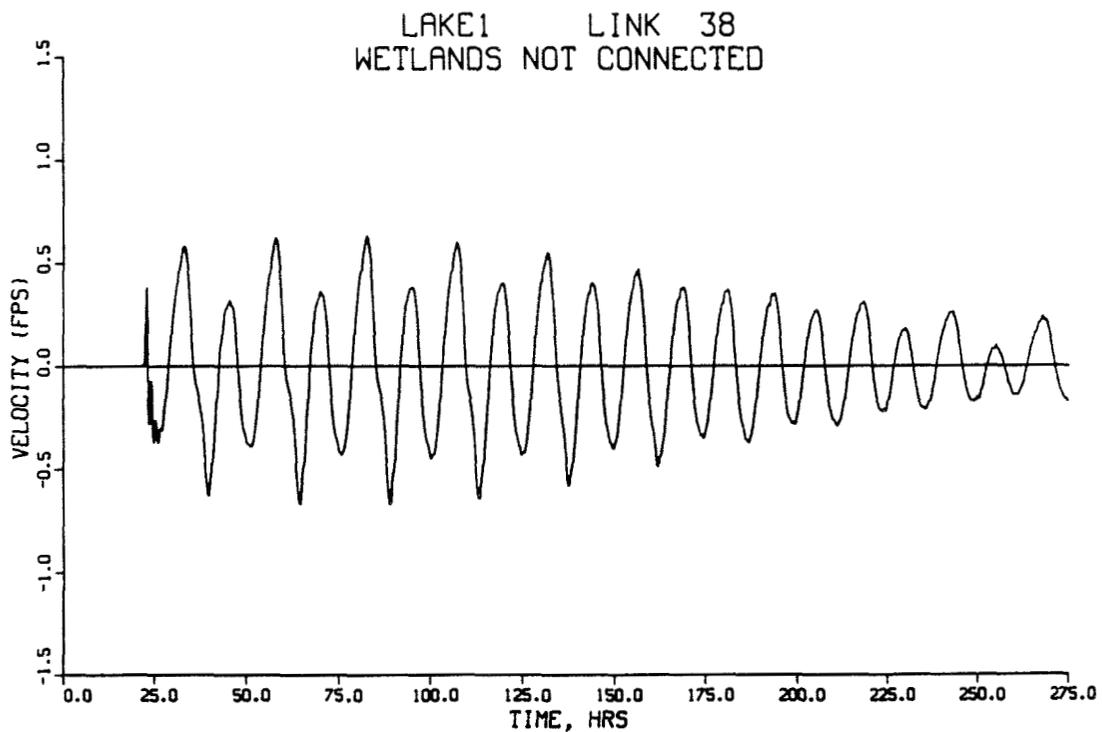


Figure D28. Average channel velocities in Outer Bolsa Bay, 350-ft non-navigable entrance channel

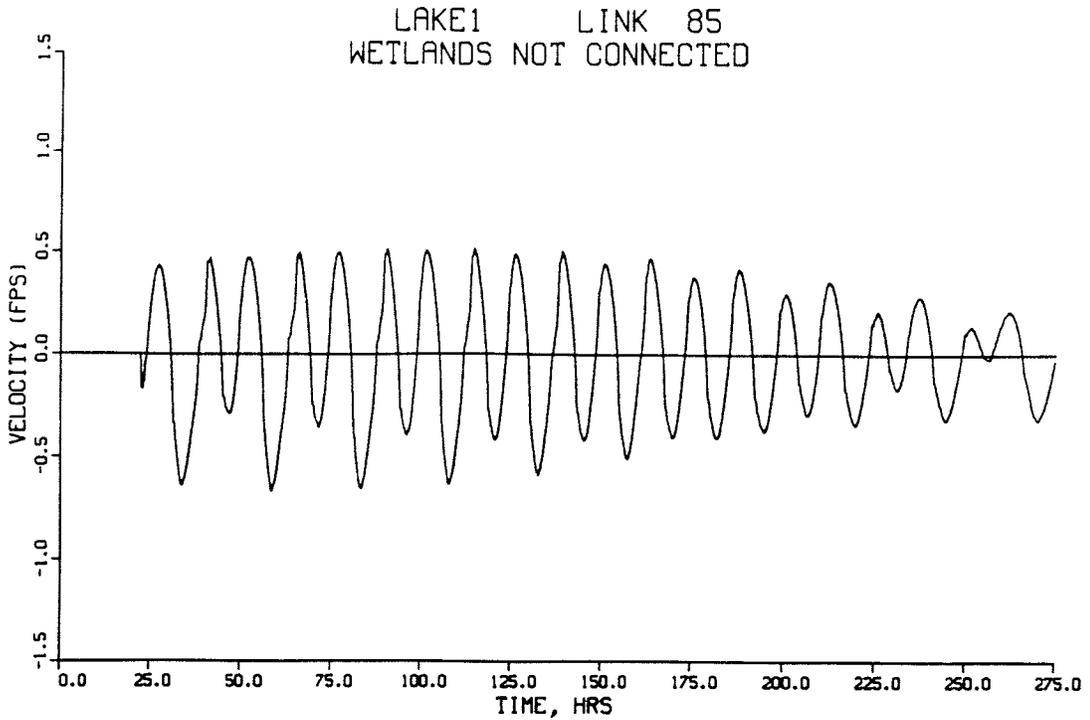


Figure D29. Average channel velocities in proposed marina,
350-ft non-navigable entrance channel

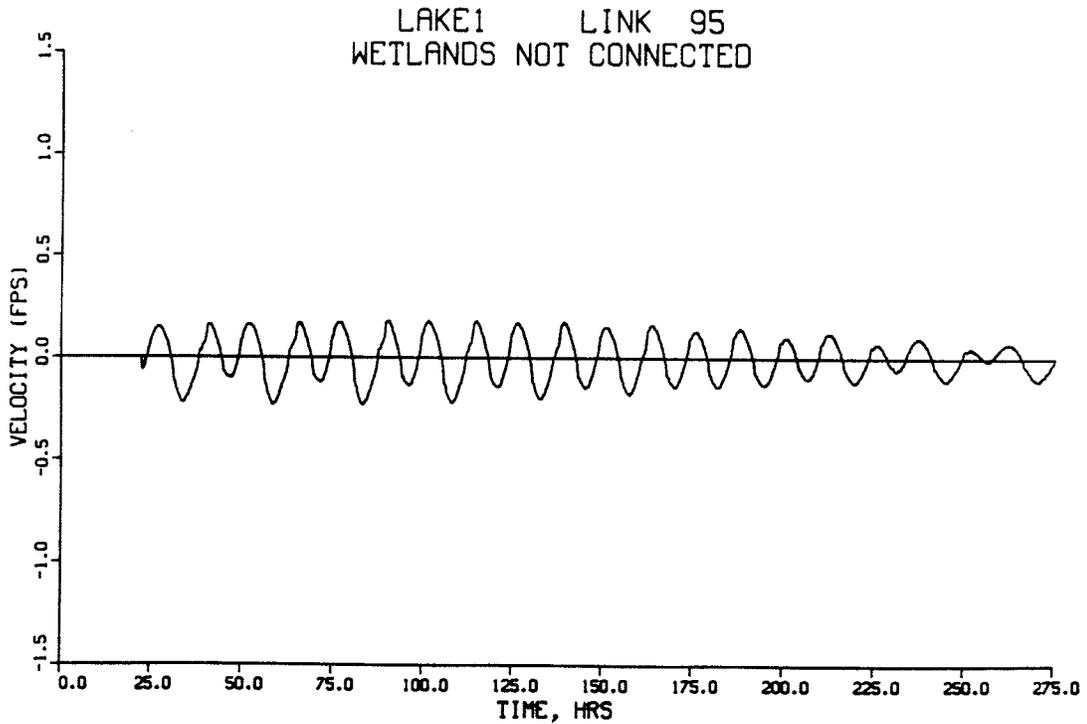


Figure D30. Average channel velocities in proposed marina,
350-ft non-navigable entrance channel

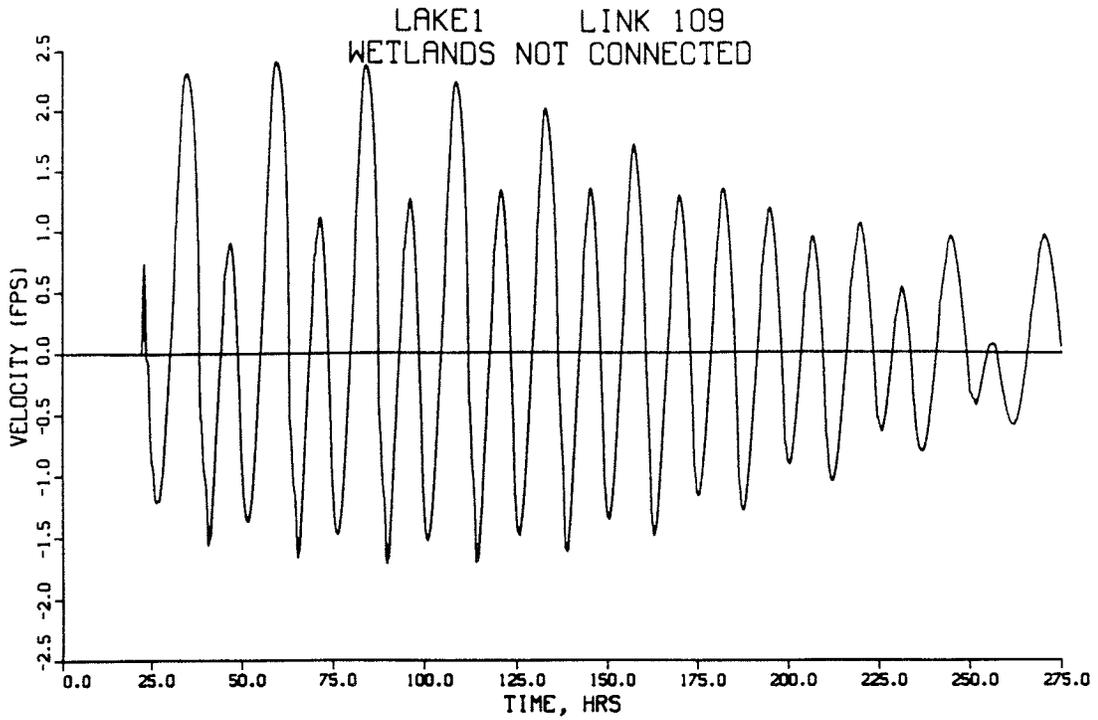


Figure D31. Average channel velocities in proposed entrance channel, 350-ft non-navigable entrance channel

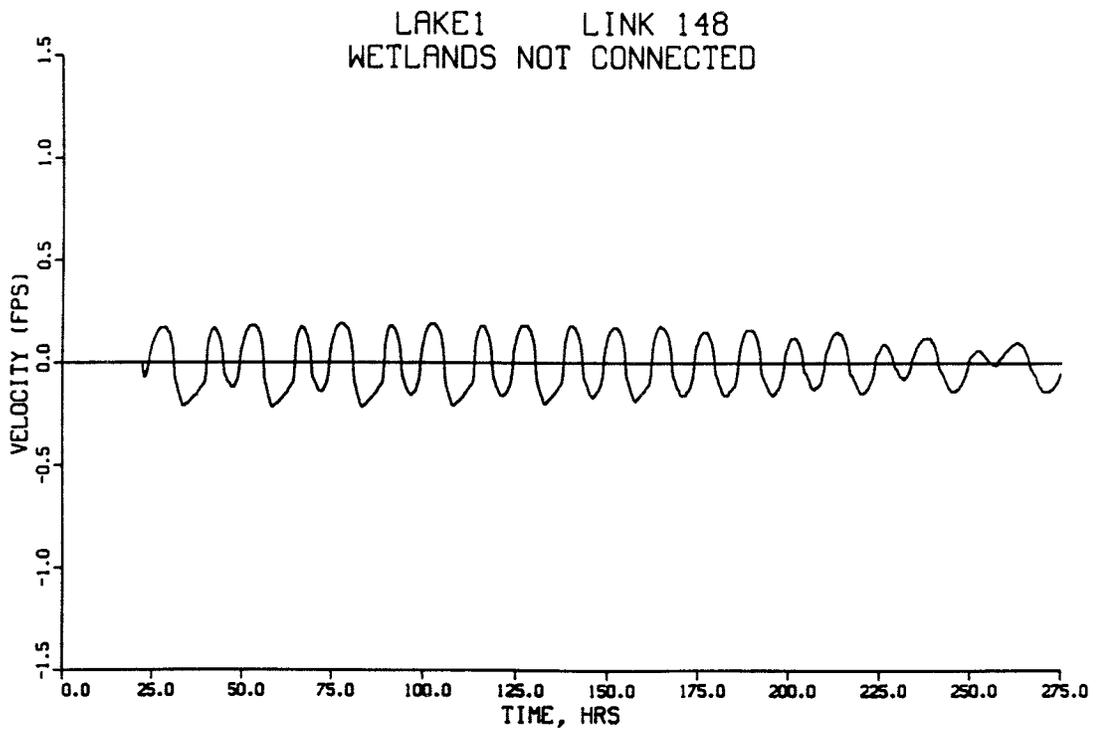


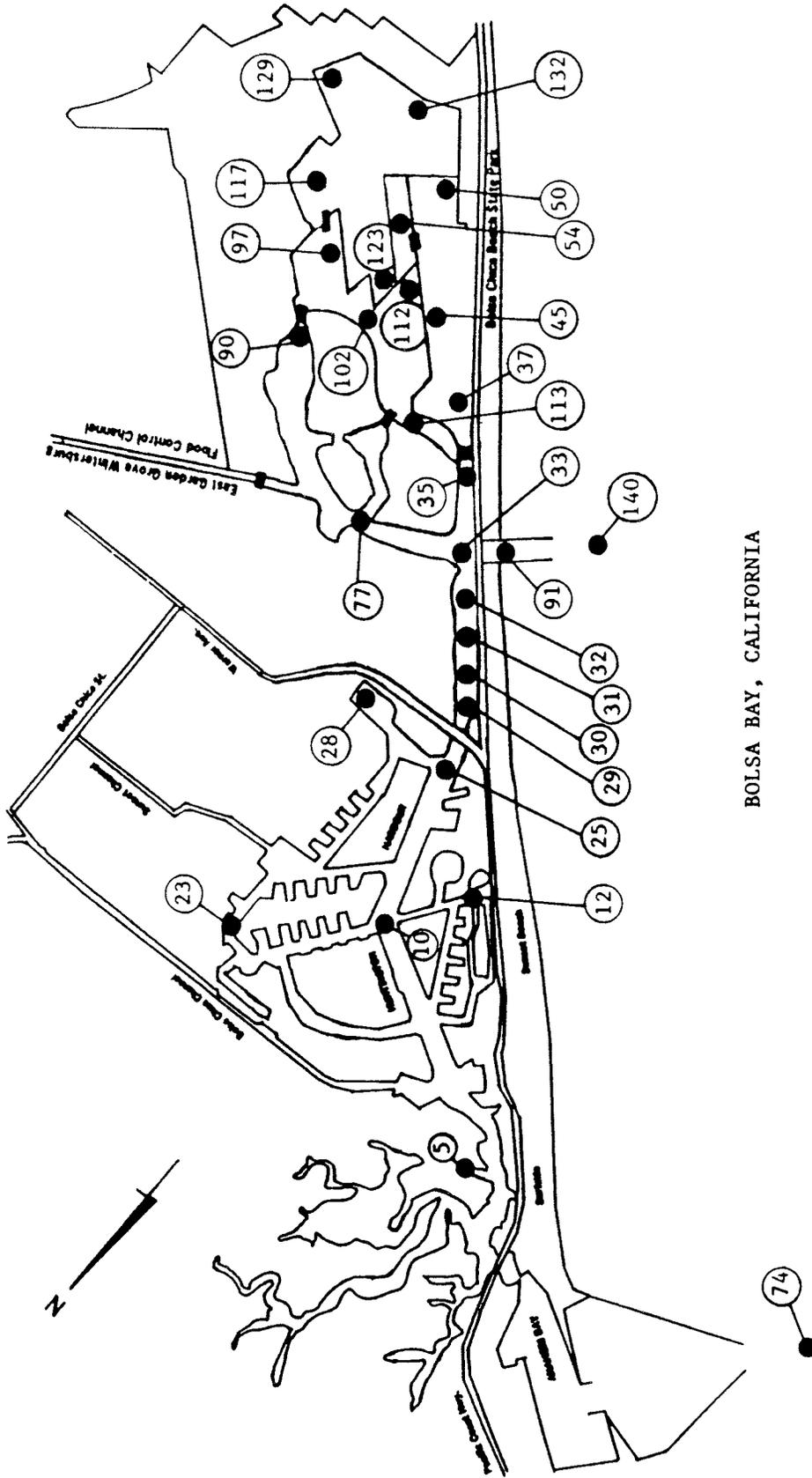
Figure D32. Average channel velocities in proposed marina, 350-ft non-navigable entrance channel

APPENDIX E:

LAKE 2

200-FT NON-NAVIGABLE ENTRANCE CHANNEL

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

LAKE 2
 Location of nodes for displaying
 water surface elevations under Lake 2 conditions

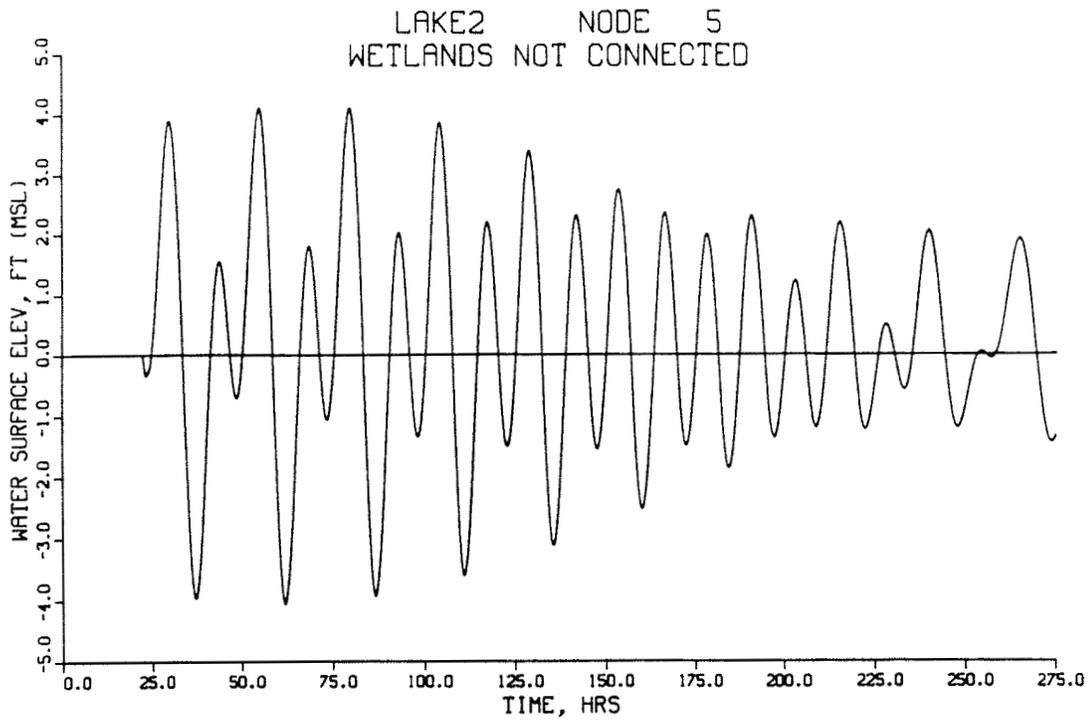


Figure E1. Tidal elevations in Huntington Harbour,
200-ft non-navigable entrance channel

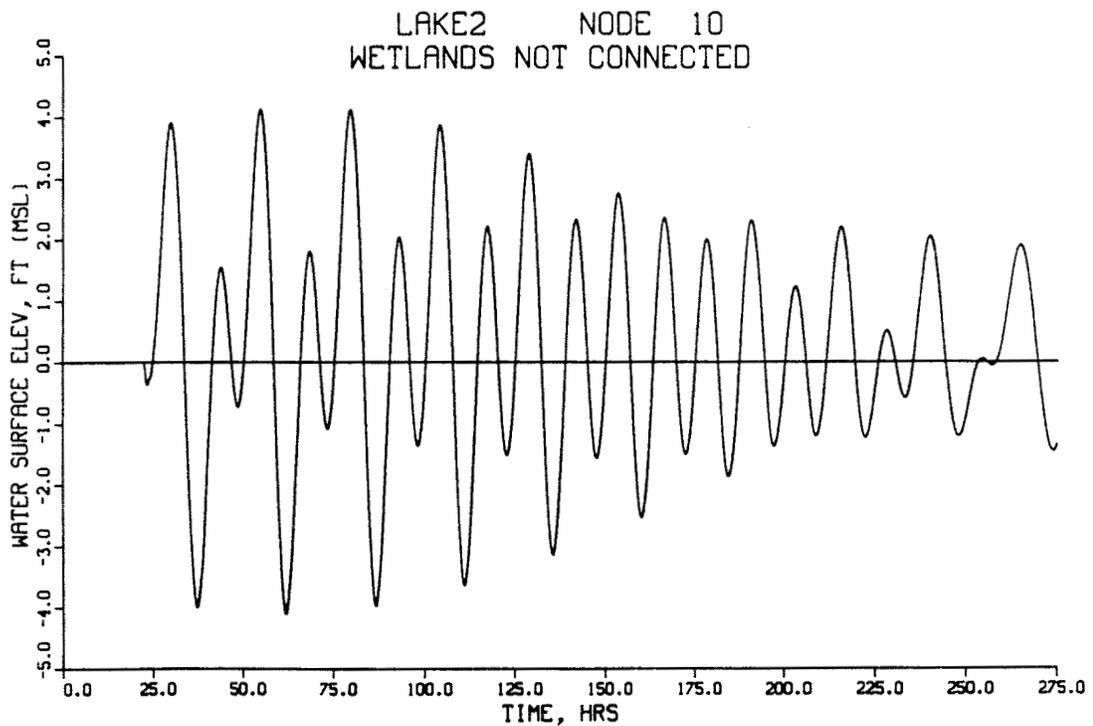


Figure E2. Tidal elevations in Huntington Harbour,
200-ft non-navigable entrance channel

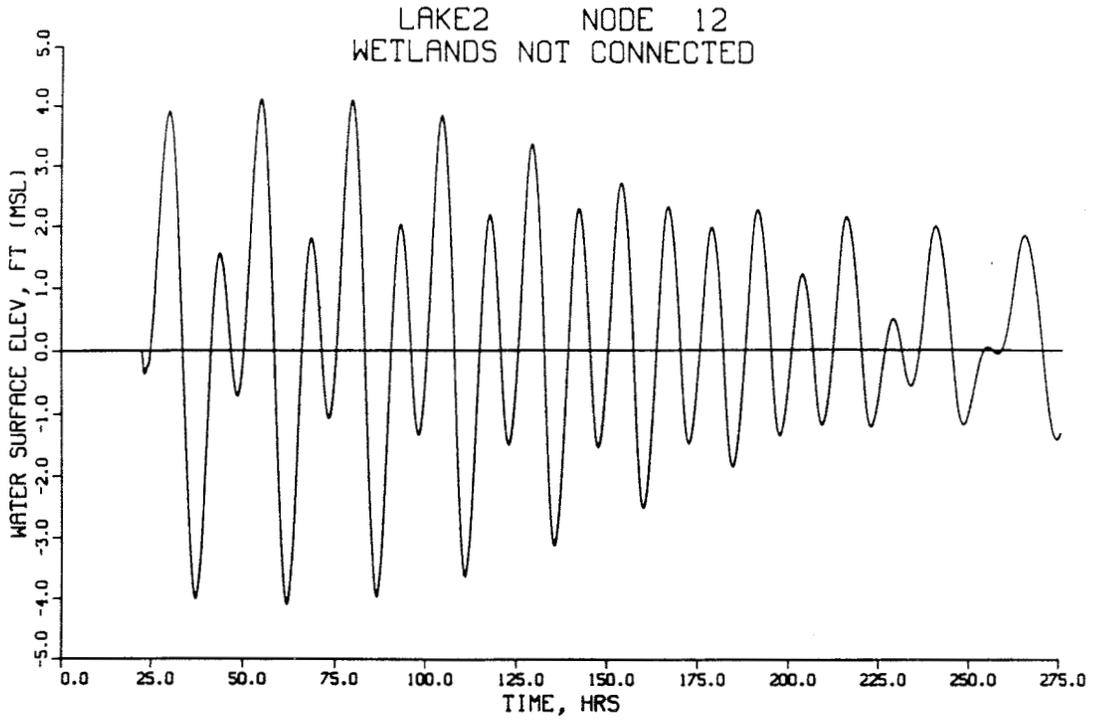


Figure E3. Tidal elevations in Huntington Harbour,
200-ft non-navigable entrance channel

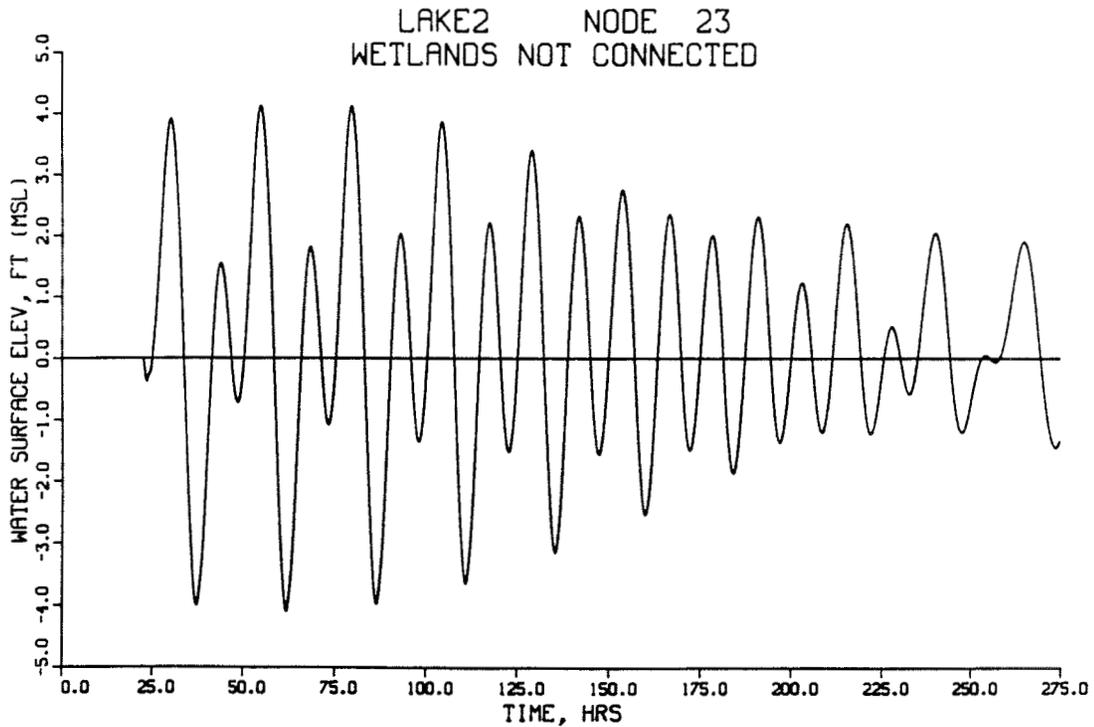


Figure E4. Tidal elevations in Huntington Harbour,
200-ft non-navigable entrance channel

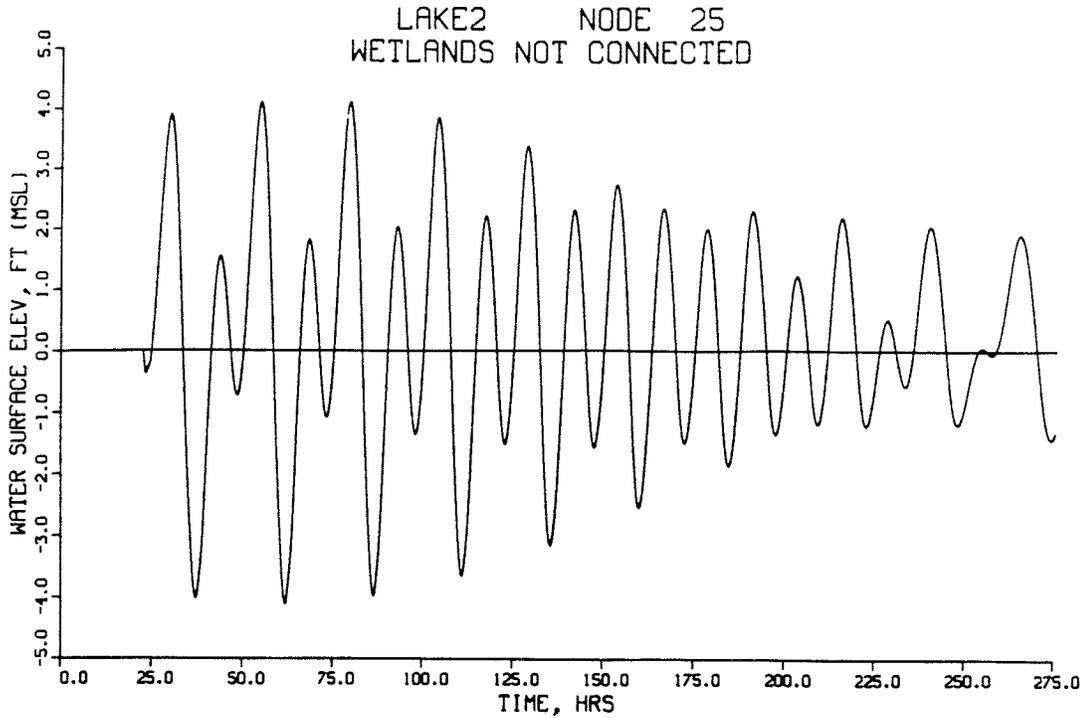


Figure E5. Tidal elevations in Huntington Harbour,
200-ft non-navigable entrance channel

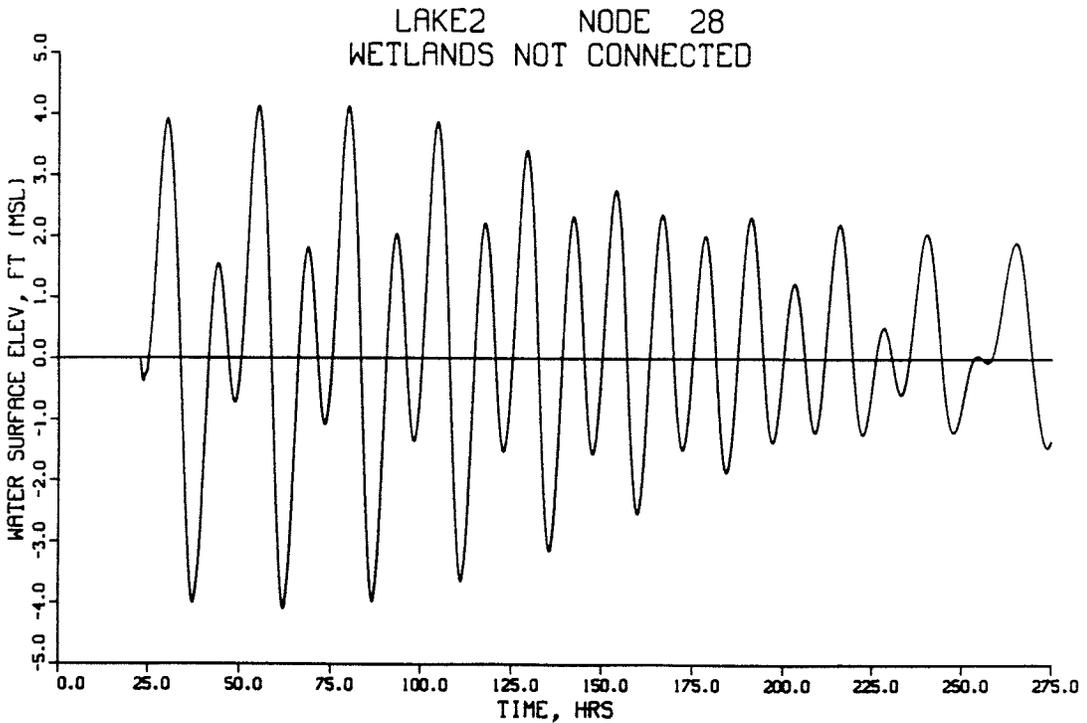


Figure E6. Tidal elevations in Huntington Harbour,
200-ft non-navigable entrance channel

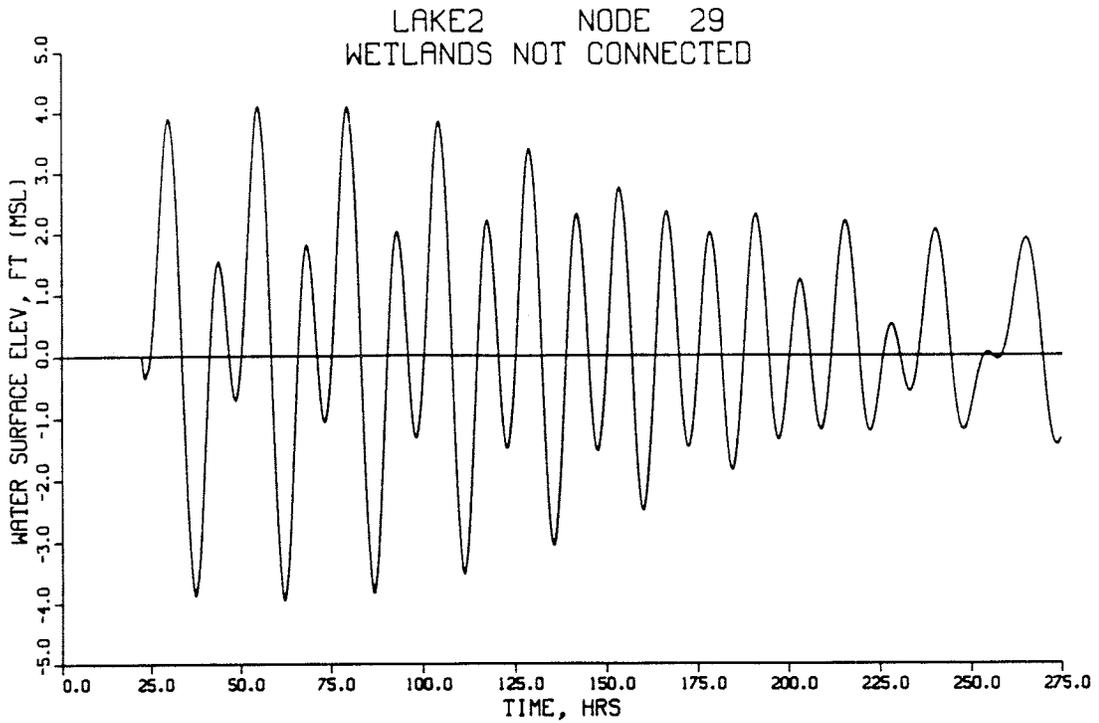


Figure E7. Tidal elevations in Outer Bolsa Bay,
200-ft non-navigable entrance channel

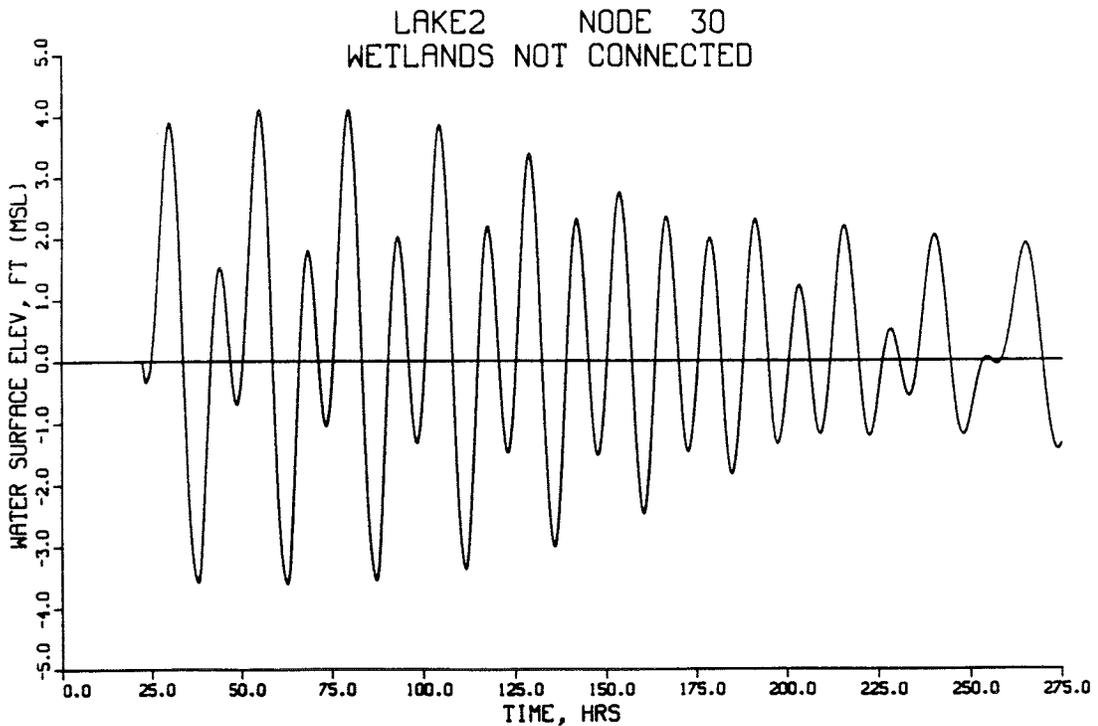


Figure E8. Tidal elevations in Outer Bolsa Bay,
200-ft non-navigable entrance channel

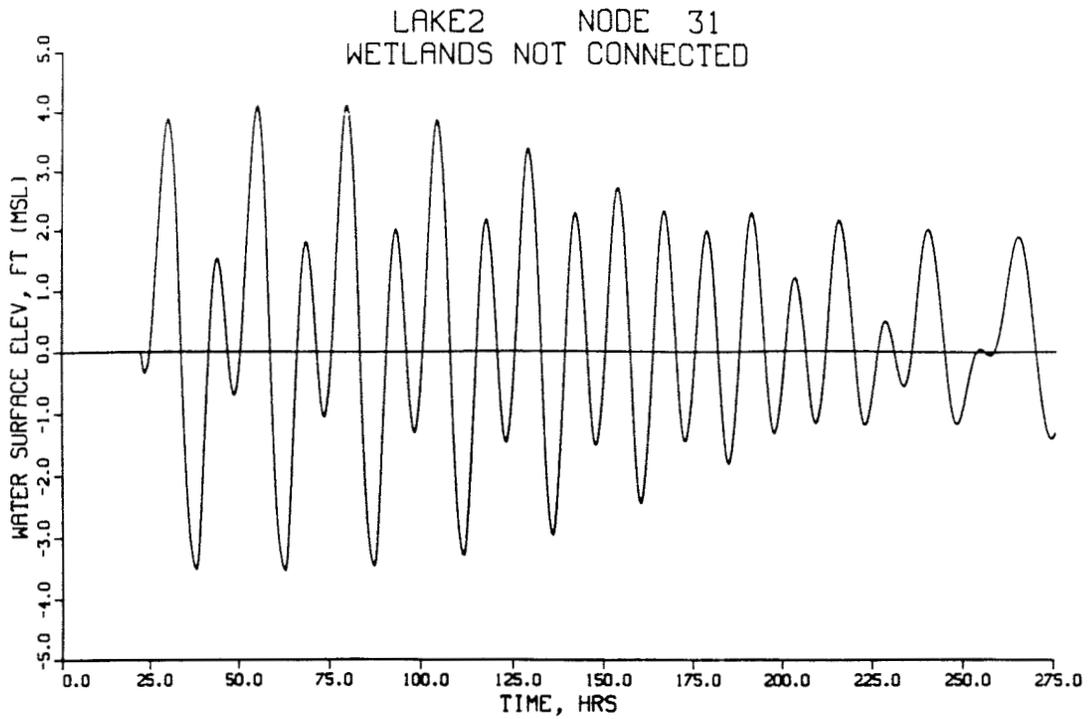


Figure E9. Tidal elevations in Outer Bolsa Bay,
200-ft non-navigable entrance channel

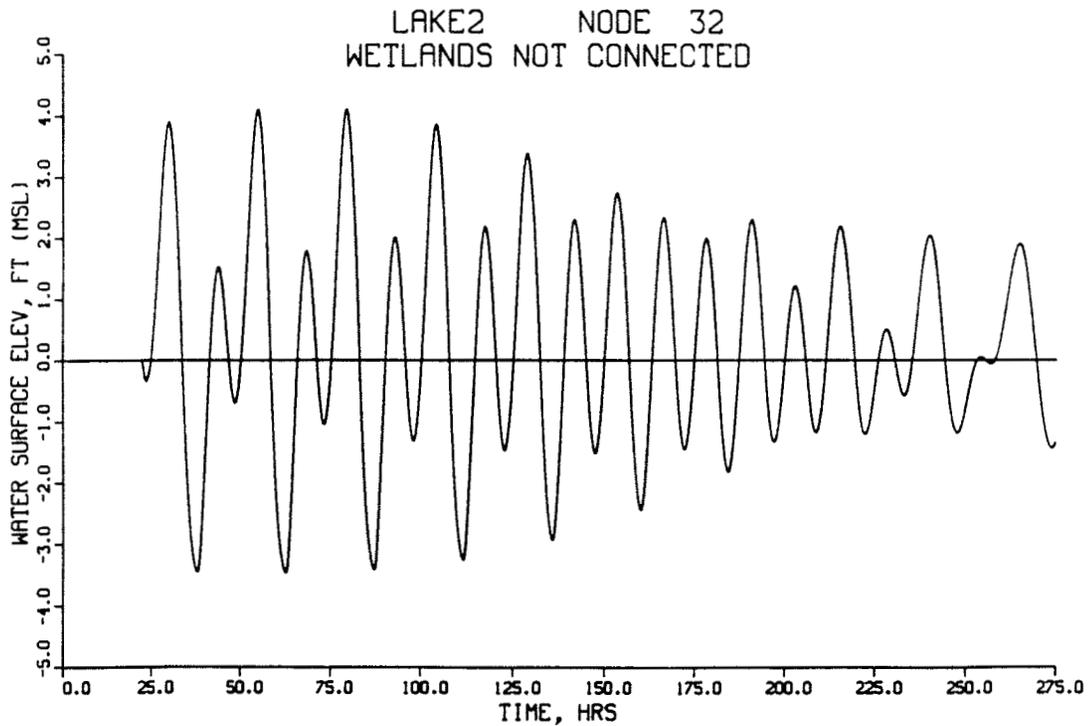


Figure E10. Tidal elevations in Outer Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 NODE 33
WETLANDS NOT CONNECTED

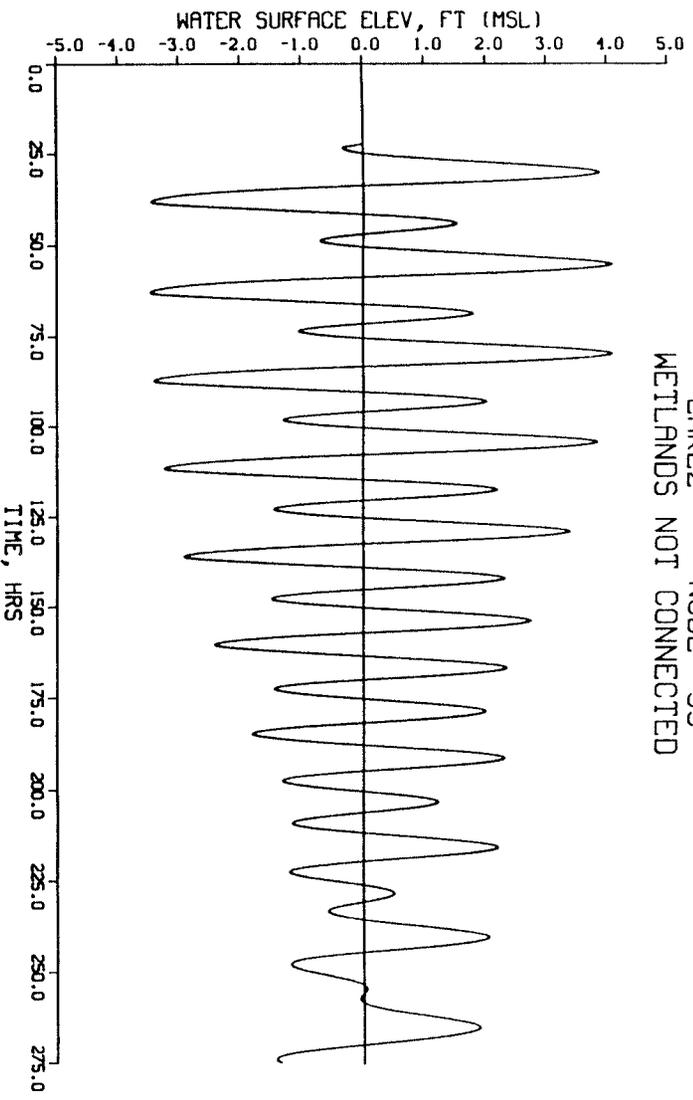


Figure E11. Tidal elevations in entrance to proposed marina,
200-ft non-navigable entrance channel

LAKE2 NODE 35
WETLANDS NOT CONNECTED

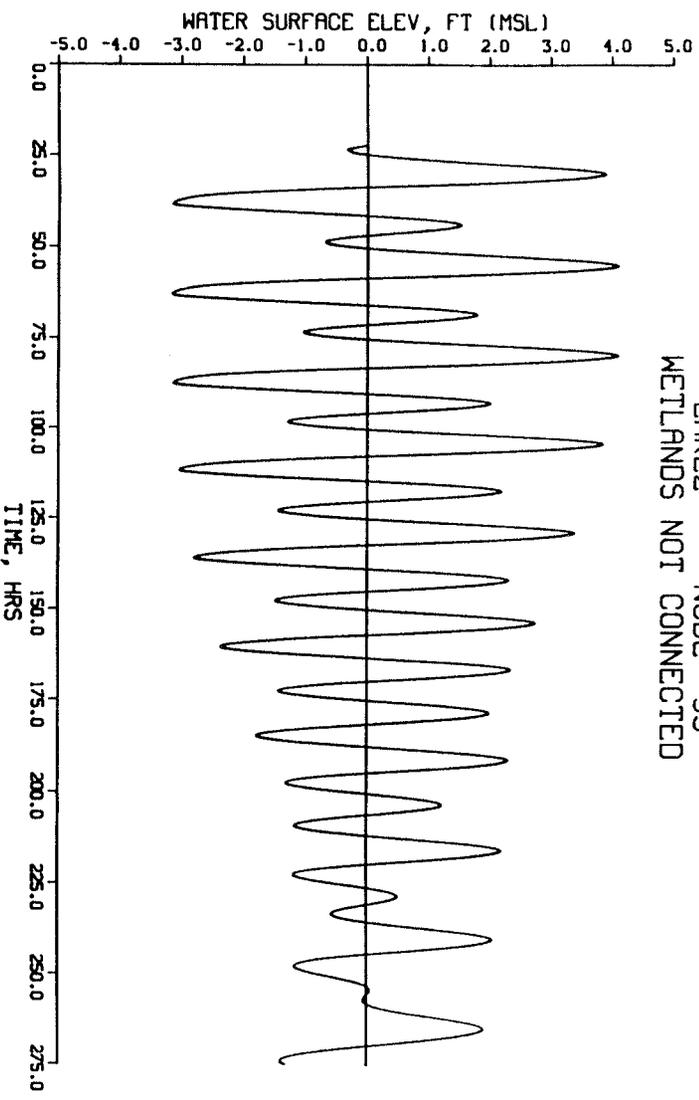


Figure E12. Tidal elevations in Outer Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 NODE 37
WETLANDS NOT CONNECTED

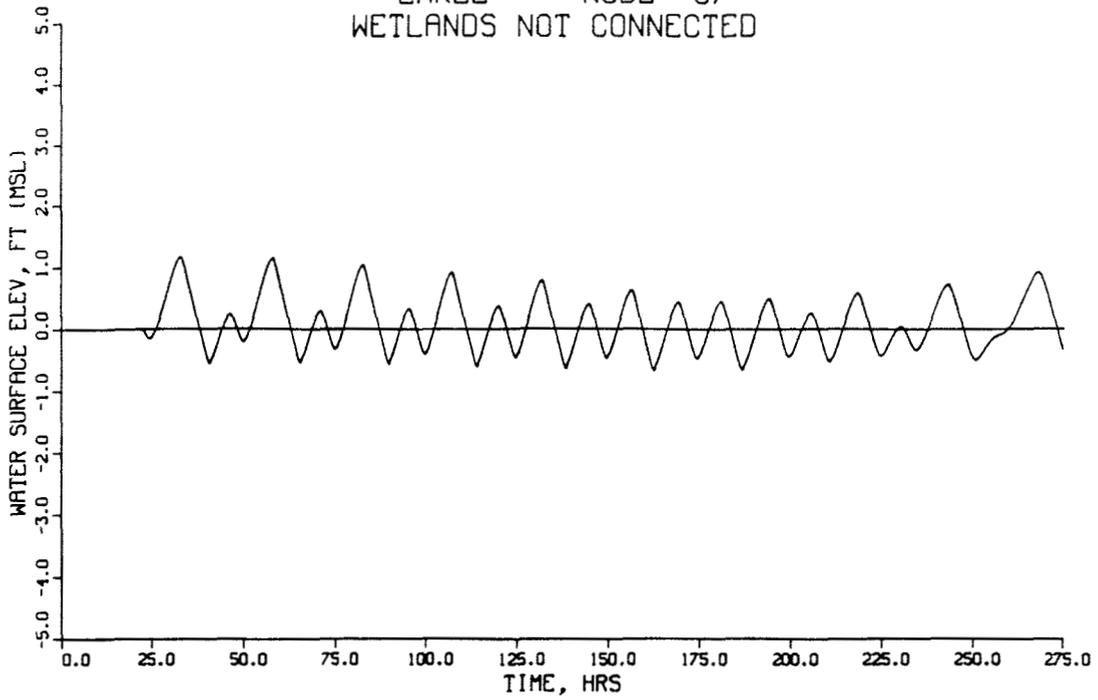


Figure E13. Tidal elevations in Inner Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 NODE 45
WETLANDS NOT CONNECTED

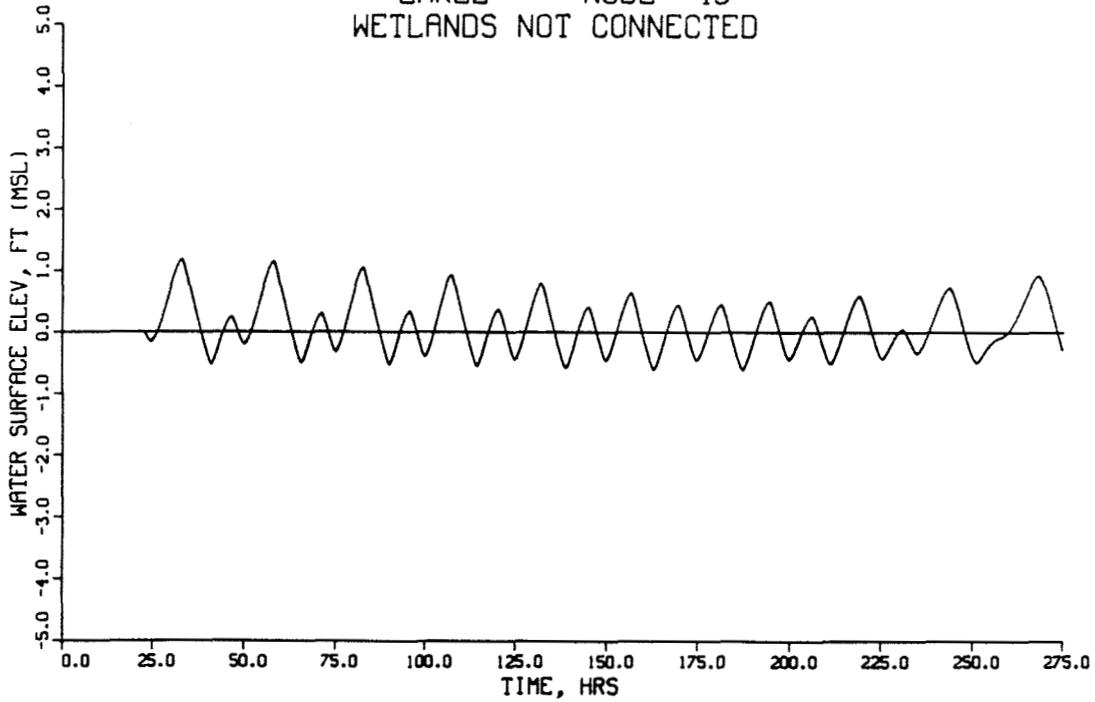


Figure E14. Tidal elevations in Inner Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 NODE 50
WETLANDS NOT CONNECTED

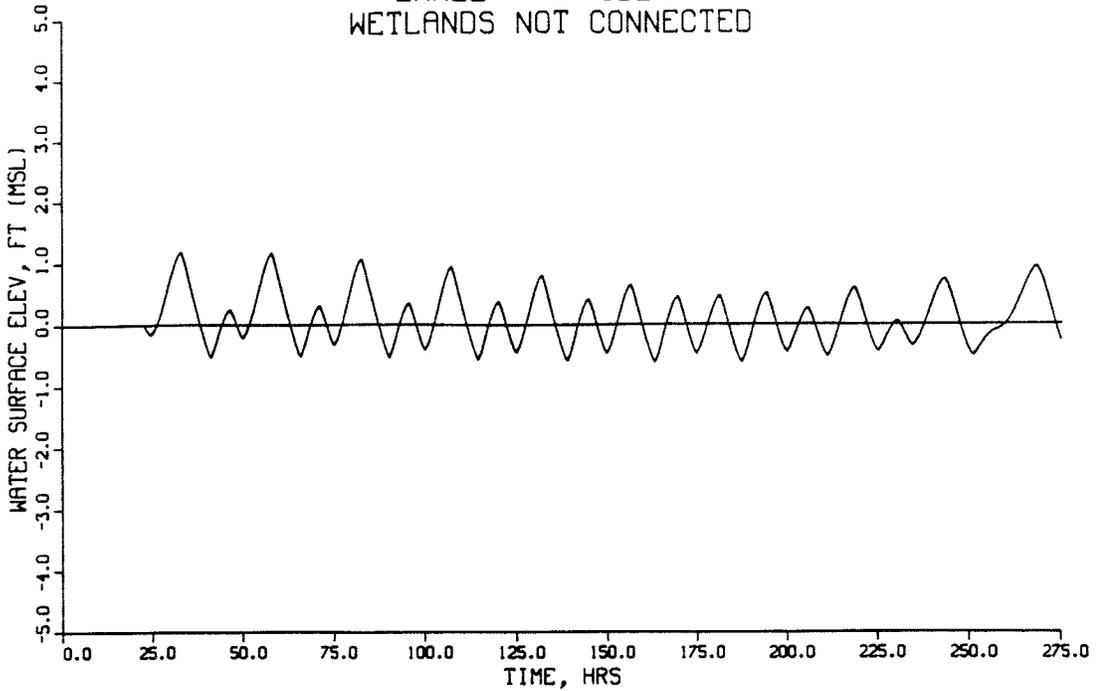


Figure E15. Tidal elevations in Inner Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 NODE 54
WETLANDS NOT CONNECTED

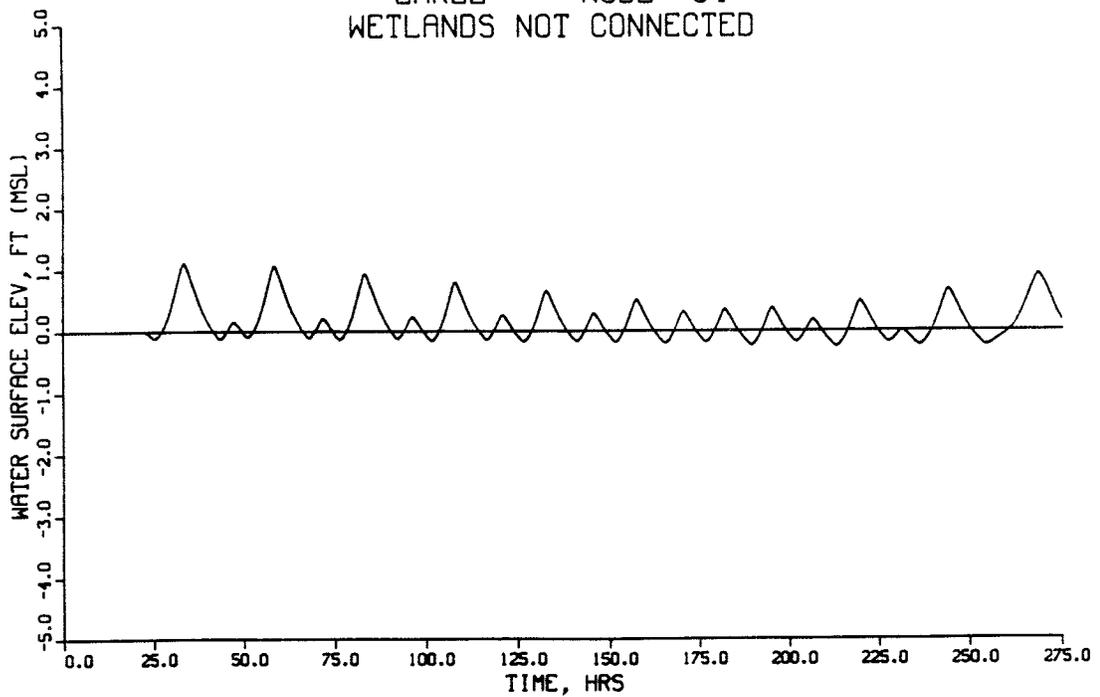


Figure E16. Tidal elevations in DFG muted tidal cell,
200-ft non-navigable entrance channel

LRAKE2 NODE 74
WETLANDS NOT CONNECTED

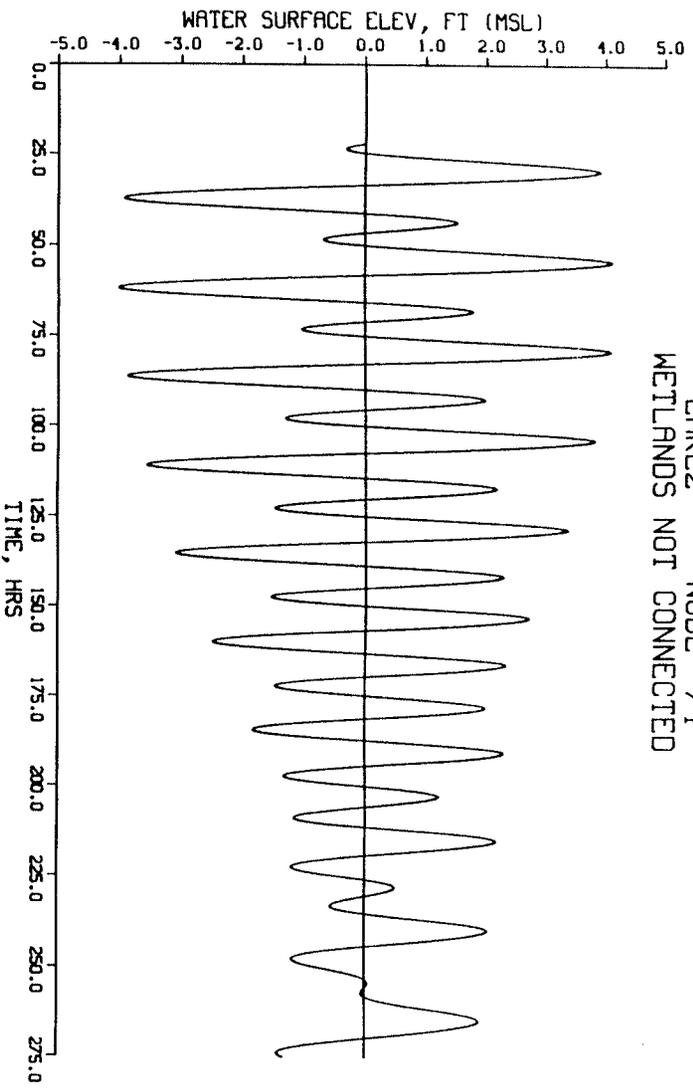


Figure E17. Tidal elevations in Pacific Ocean,
driving Anaheim Bay entrance channel

LRAKE2 NODE 77
WETLANDS NOT CONNECTED

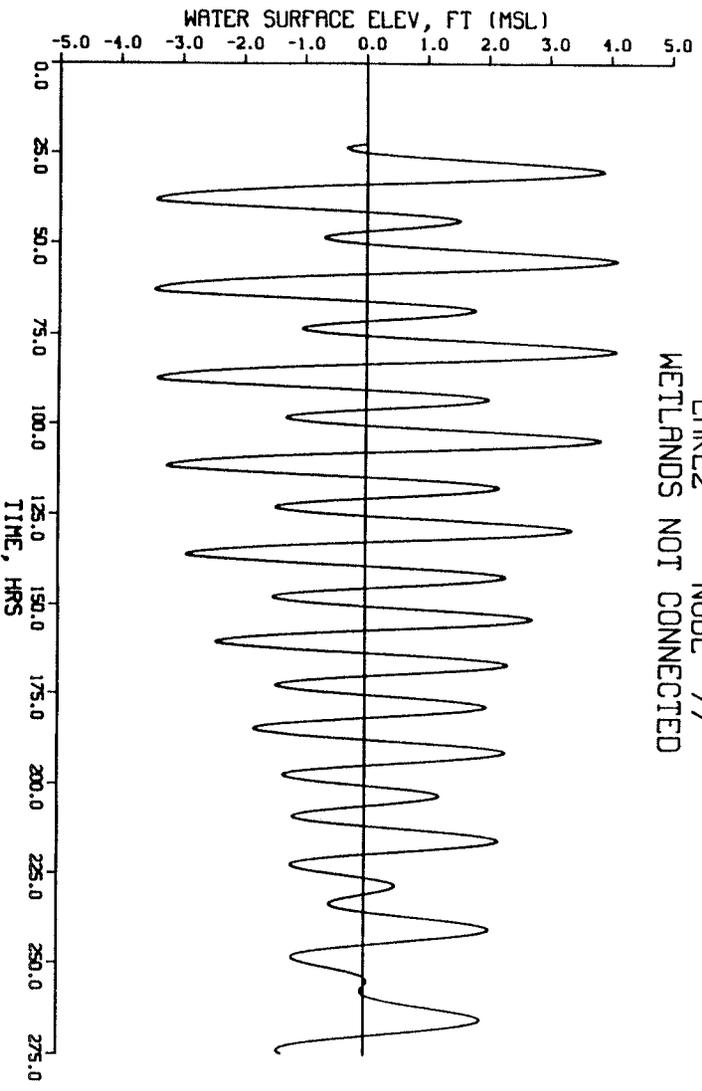


Figure E18. Tidal elevations in proposed marina,
200-ft non-navigable entrance channel

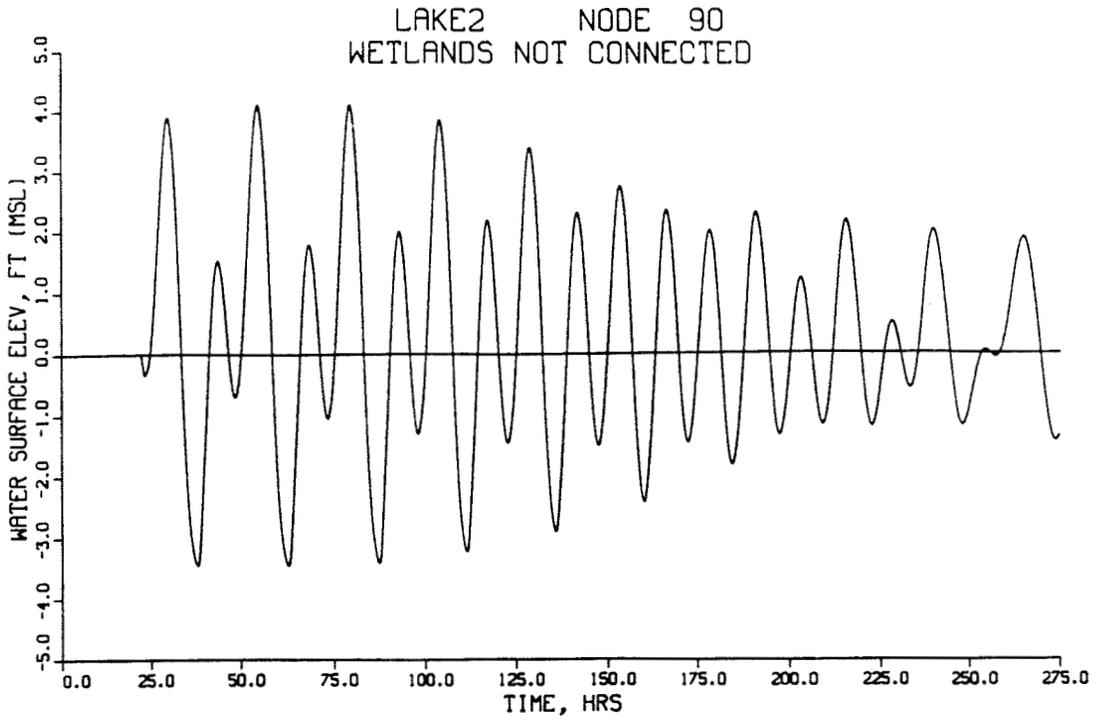


Figure E19. Tidal elevations in proposed marina,
200-ft non-navigable entrance channel

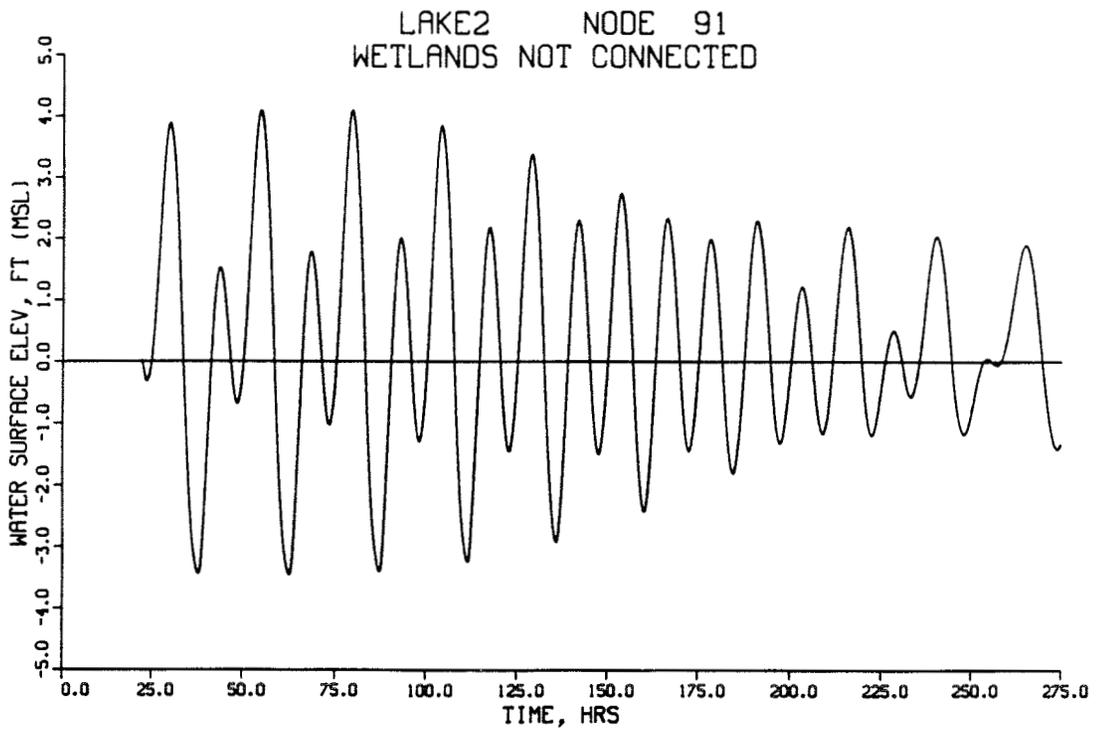


Figure E20. Tidal elevations in 200-ft non-navigable entrance channel

LAKE2 NODE 97
WETLANDS NOT CONNECTED

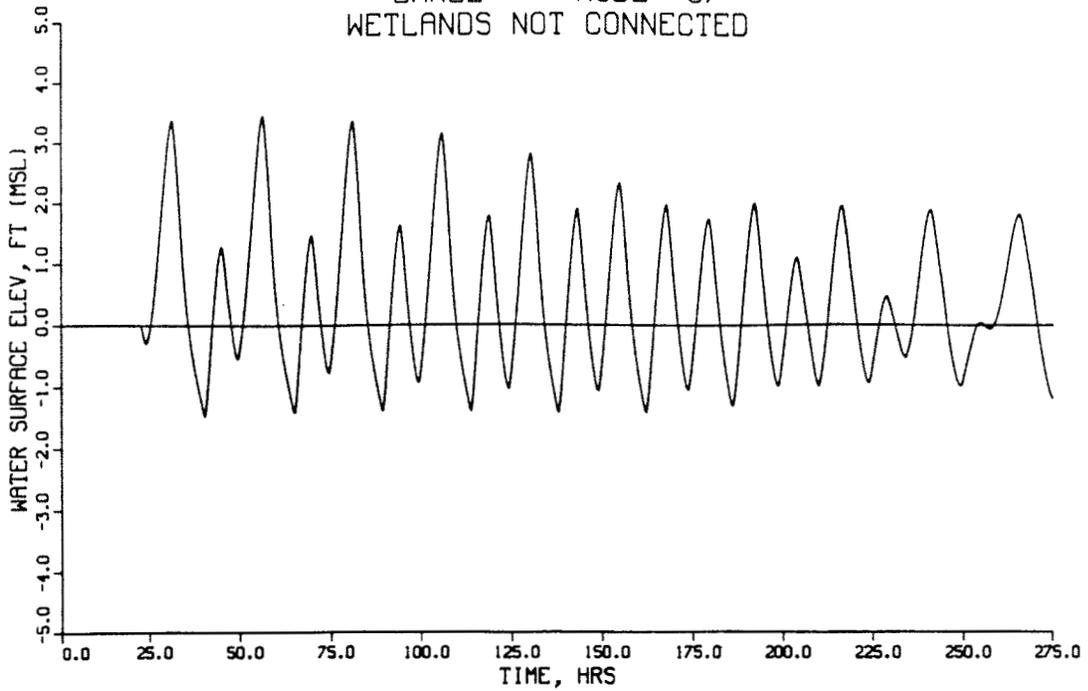


Figure E21. Tidal elevations in full tidal wetlands,
200-ft non-navigable entrance channel

LAKE2 NODE 102
WETLANDS NOT CONNECTED

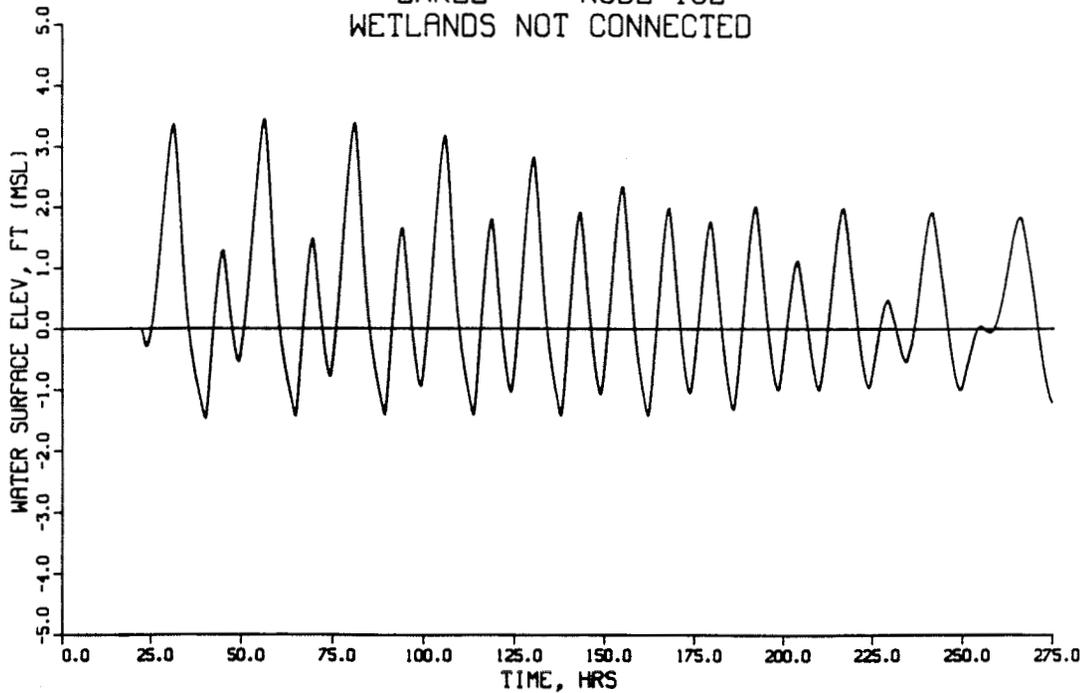


Figure E22. Tidal elevations in full tidal wetlands,
200-ft non-navigable entrance channel

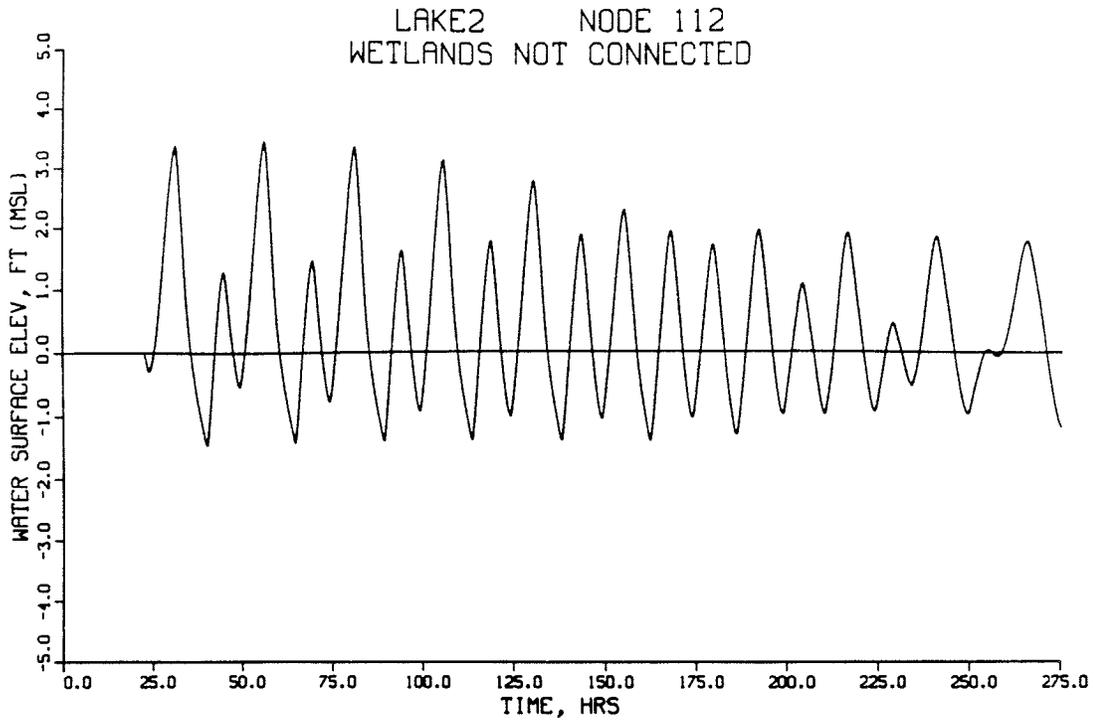


Figure E23. Tidal elevations in full tidal wetlands,
200-ft non-navigable entrance channel

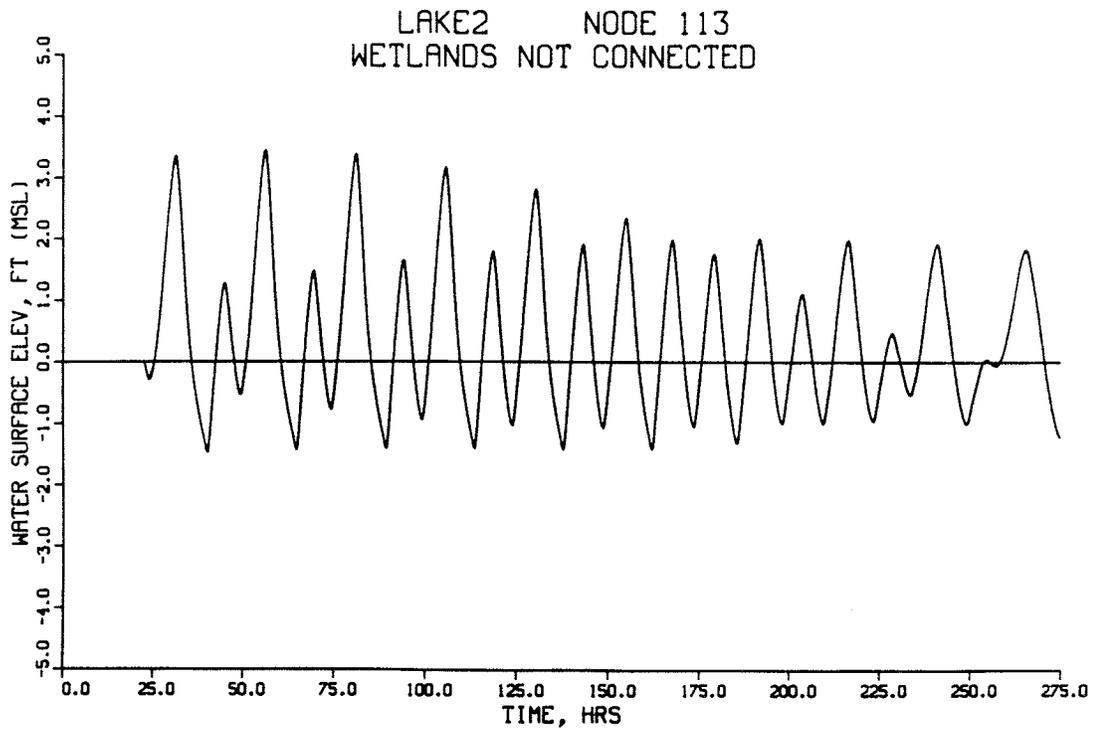


Figure E24. Tidal elevations in full tidal wetlands,
200-ft non-navigable entrance channel

LAKE2 NODE 117
WETLANDS NOT CONNECTED

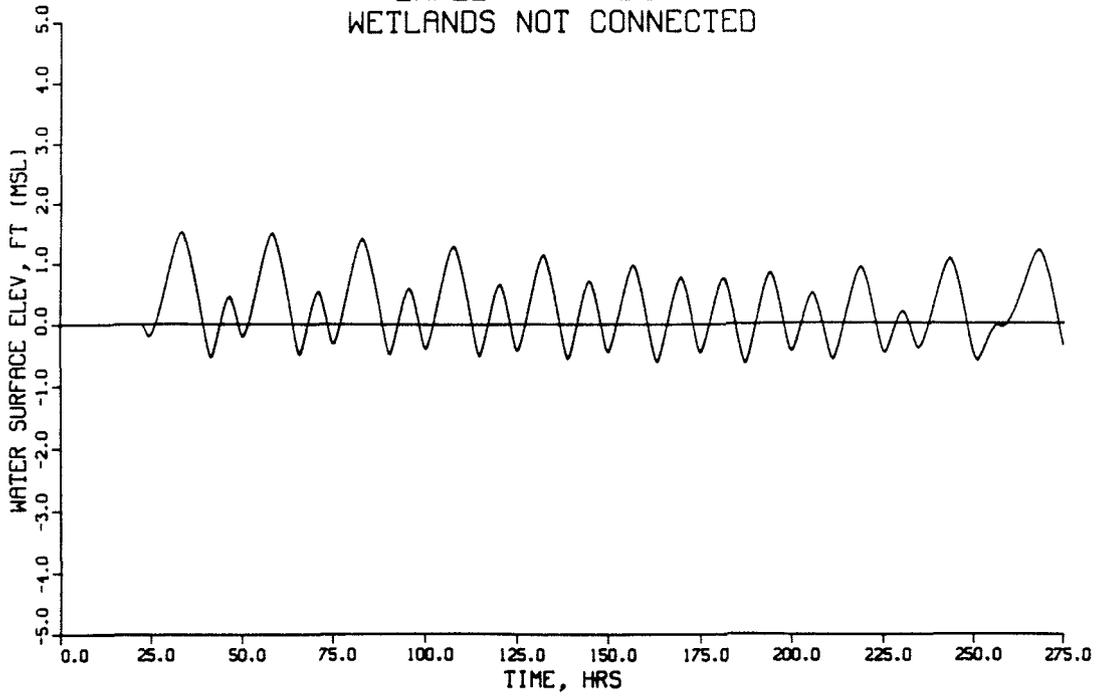


Figure E25. Tidal elevations in muted tidal wetlands,
200-ft non-navigable entrance channel

LAKE2 NODE 123
WETLANDS NOT CONNECTED

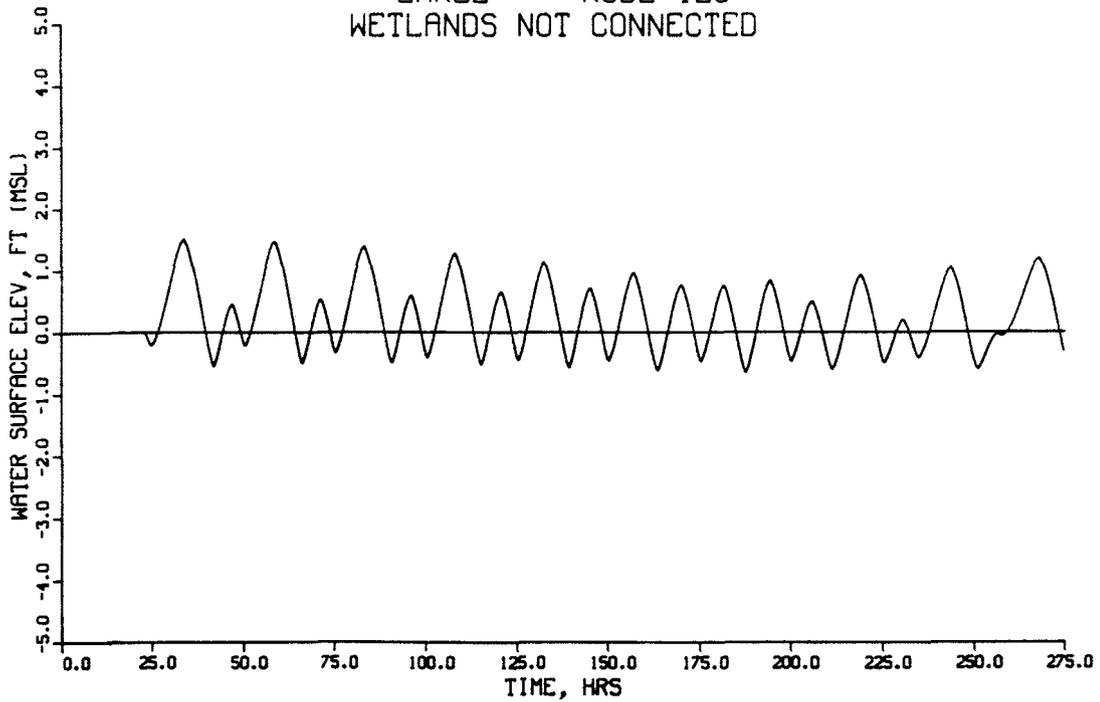


Figure E26. Tidal elevations in muted tidal wetlands,
200-ft non-navigable entrance channel

LAKE2 NODE 129
WETLANDS NOT CONNECTED

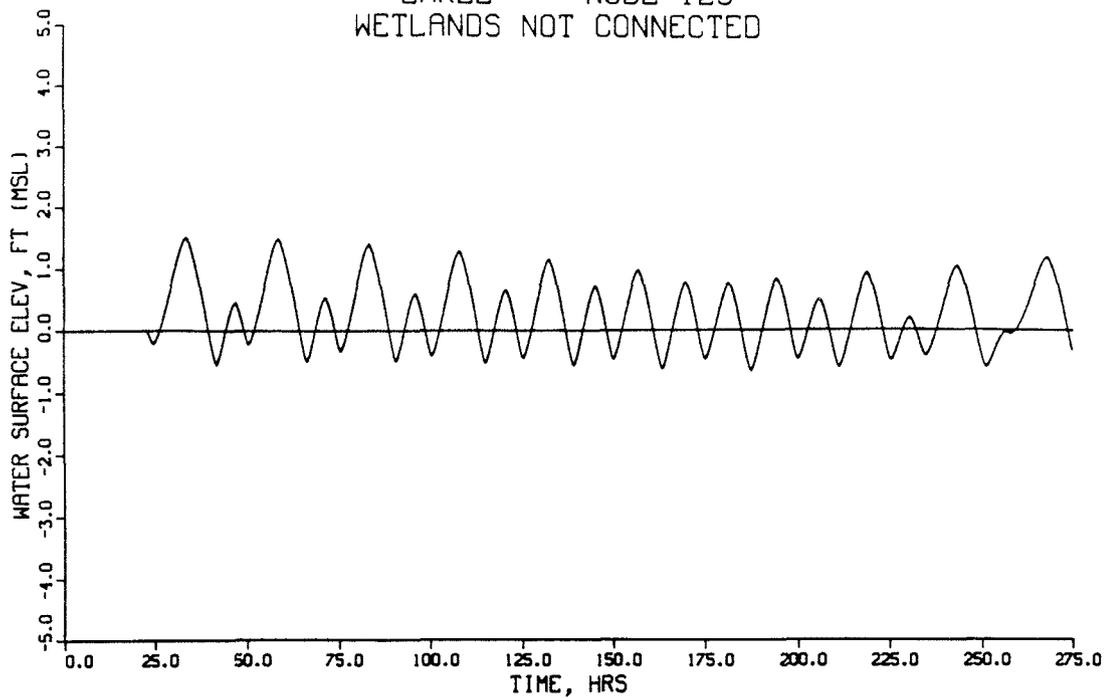


Figure E27. Tidal elevations in muted tidal wetlands,
200-ft non-navigable entrance channel

LAKE2 NODE 132
WETLANDS NOT CONNECTED

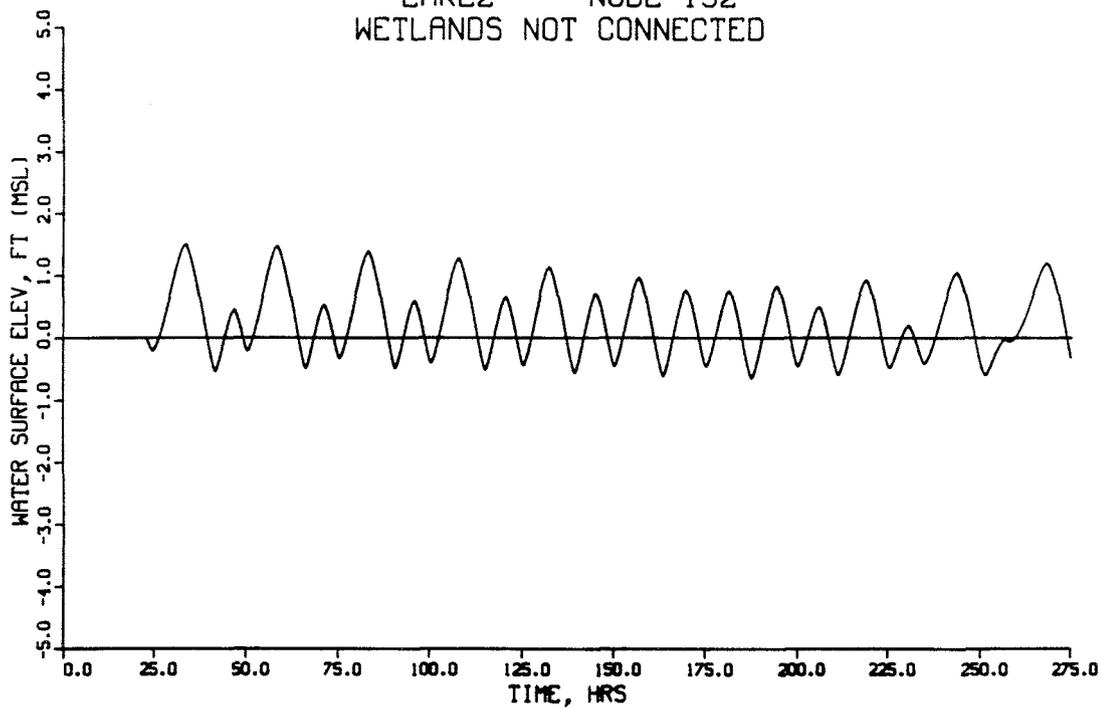


Figure E28. Tidal elevations in muted tidal wetlands,
200-ft non-navigable entrance channel

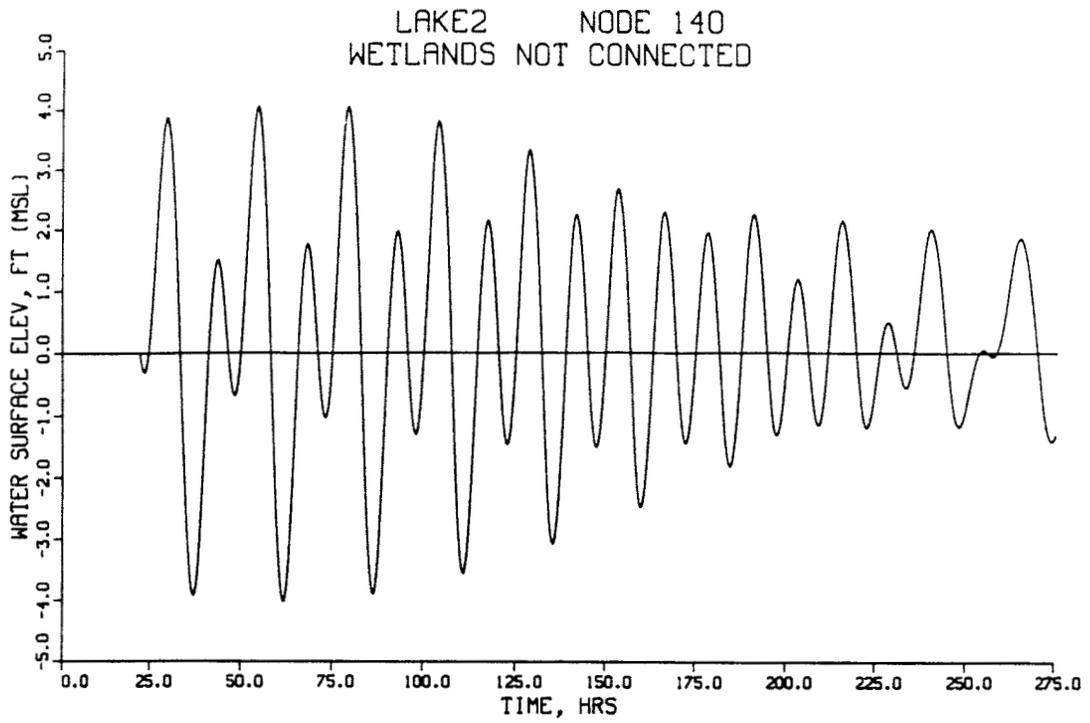


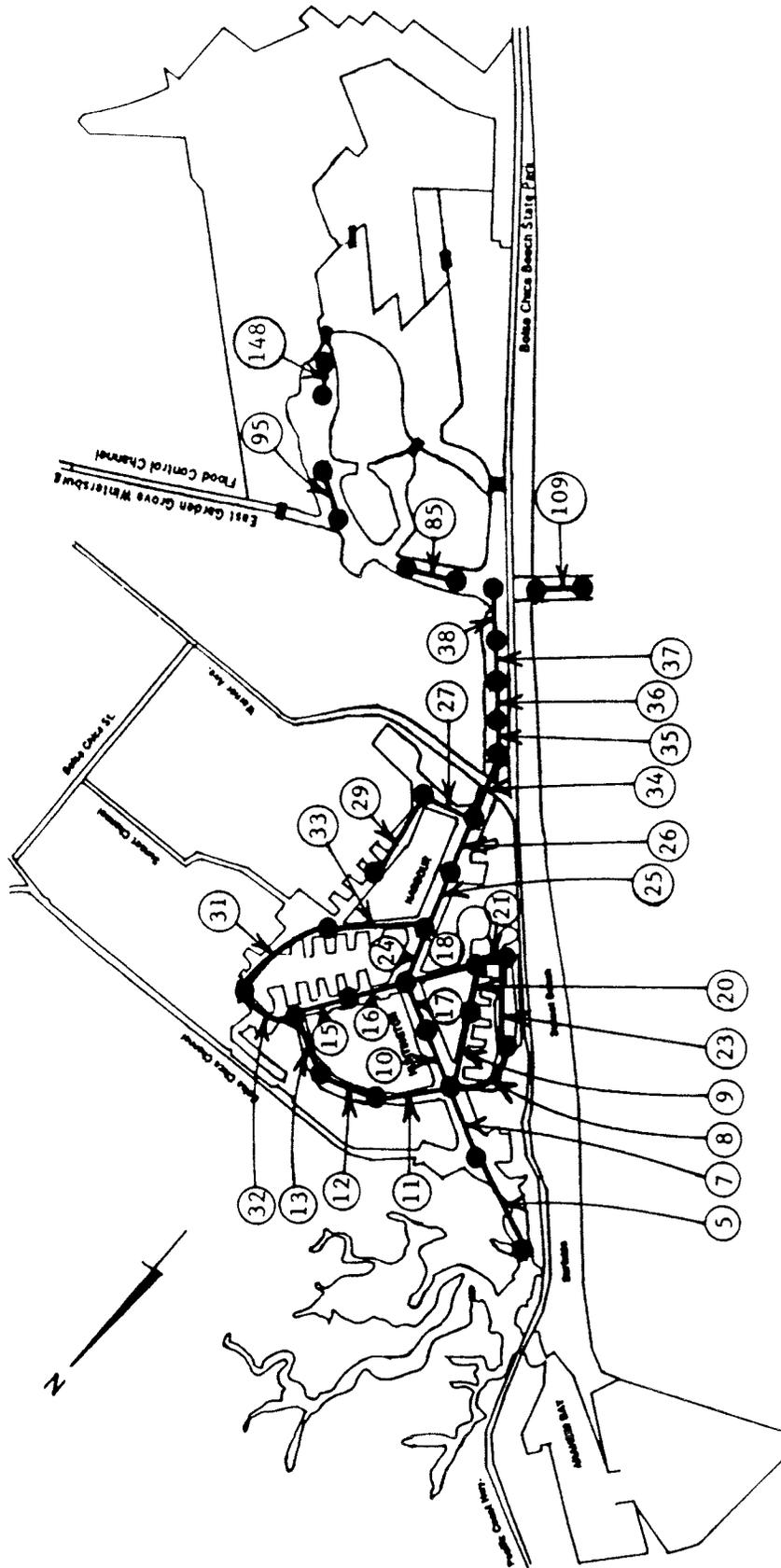
Figure E29. Tidal elevations in Pacific Ocean,
driving 200-ft non-navigable entrance channel

APPENDIX F:

LAKE 2

200-FT NON-NAVIGABLE ENTRANCE CHANNEL

AVERAGE CHANNEL VELOCITIES



BOLINA BAY, CALIFORNIA

LAKE 2
 Location of links for displaying
 average channel velocities under Lake 2 conditions

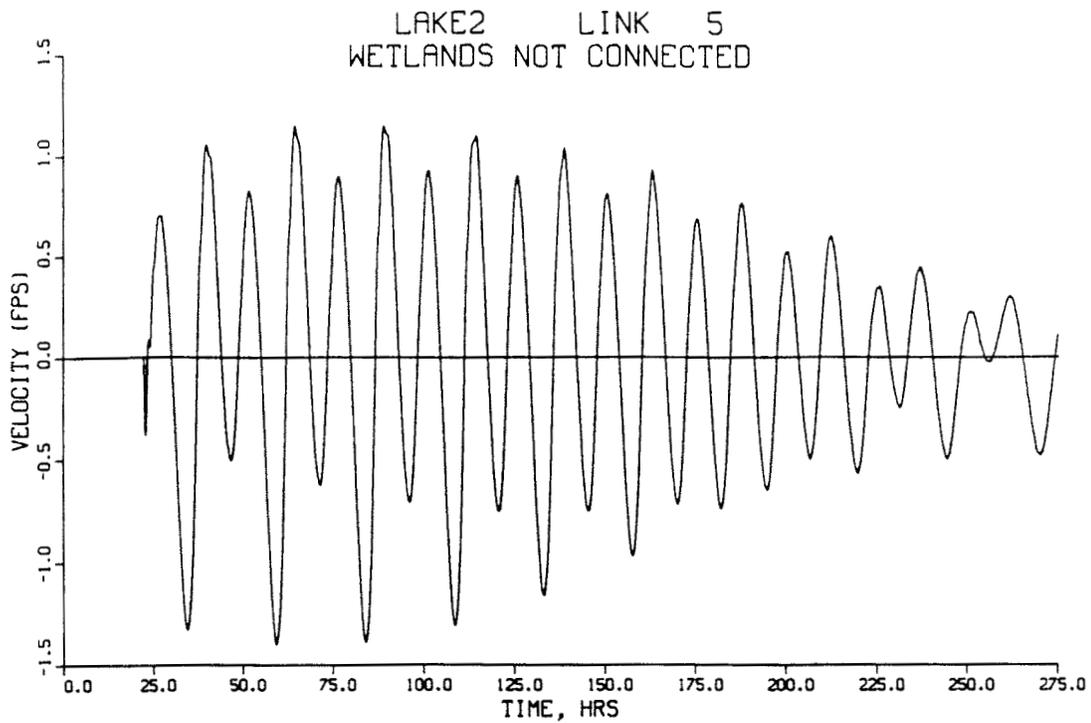


Figure F1. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

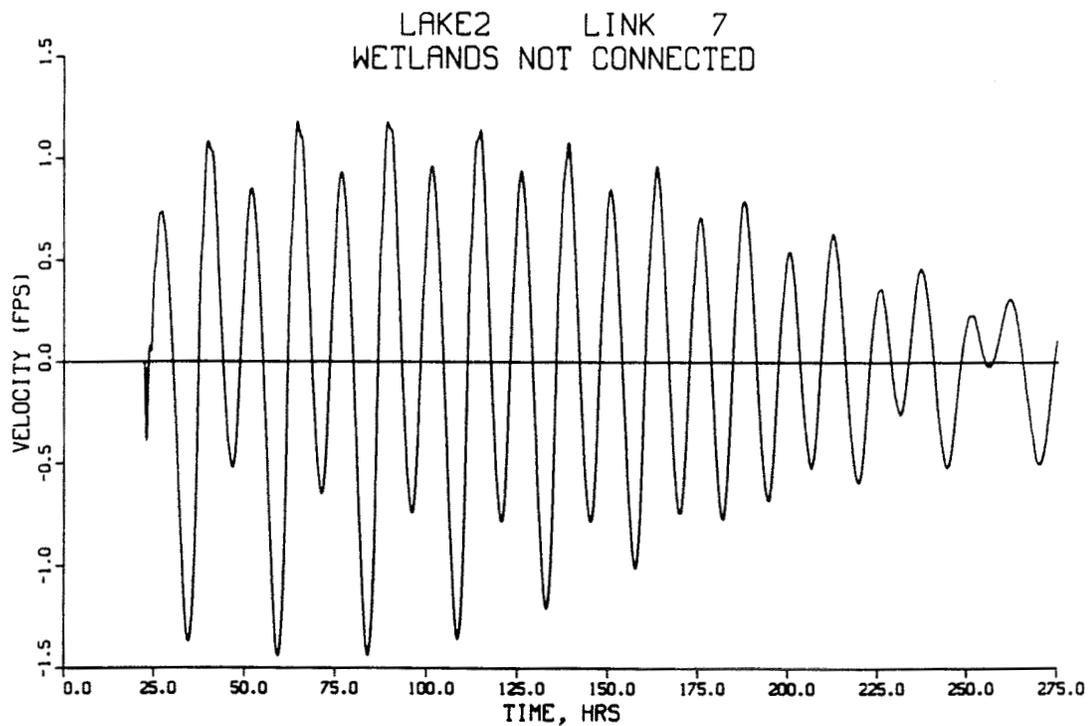


Figure F2. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 8
WETLANDS NOT CONNECTED

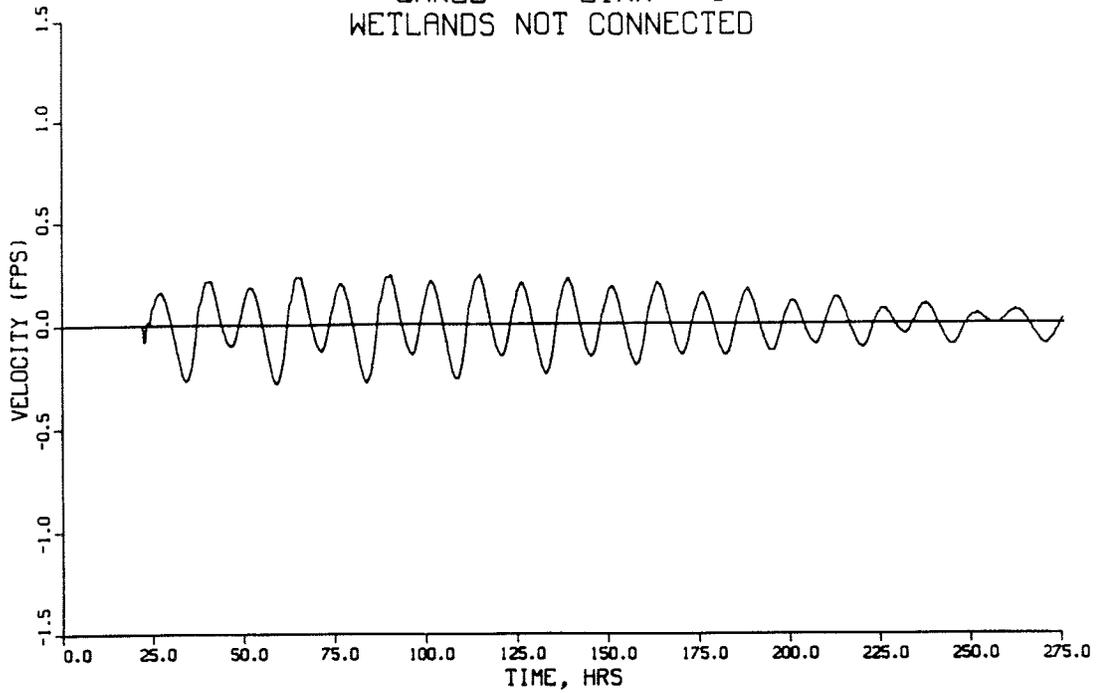


Figure F3. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 9
WETLANDS NOT CONNECTED

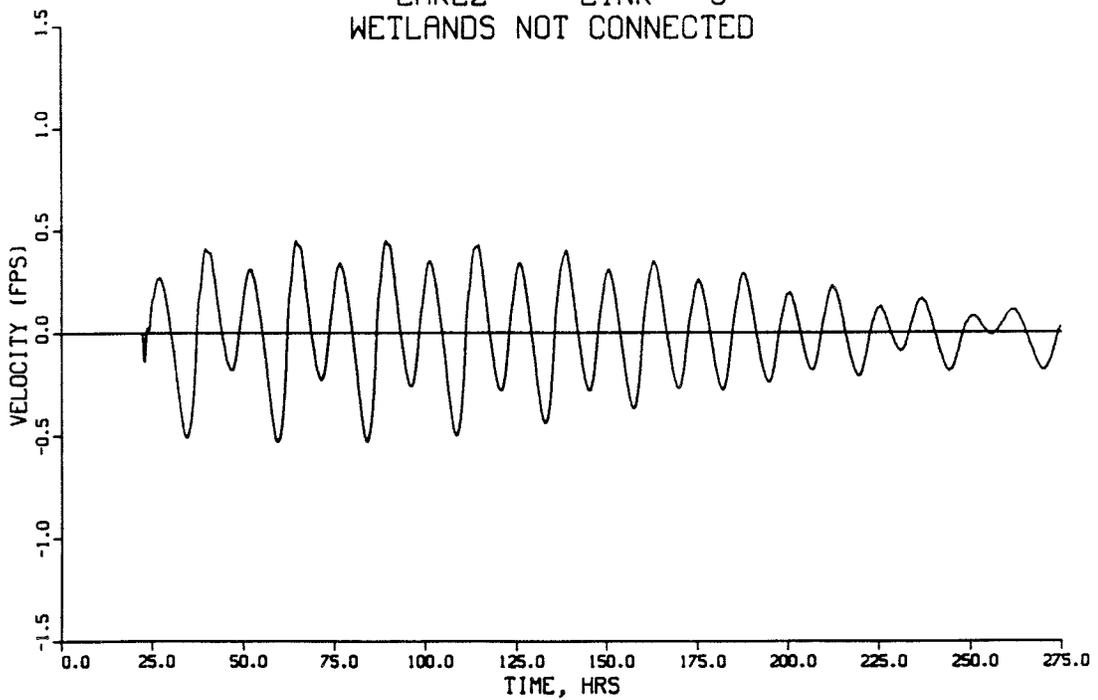


Figure F4. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

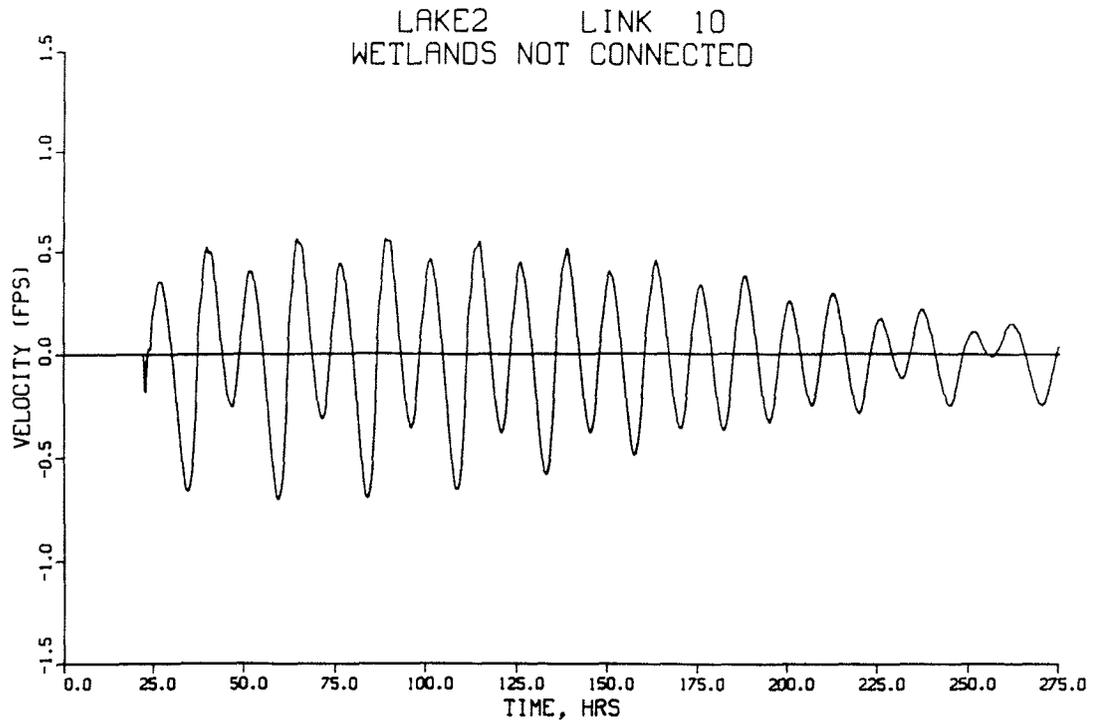


Figure F5. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

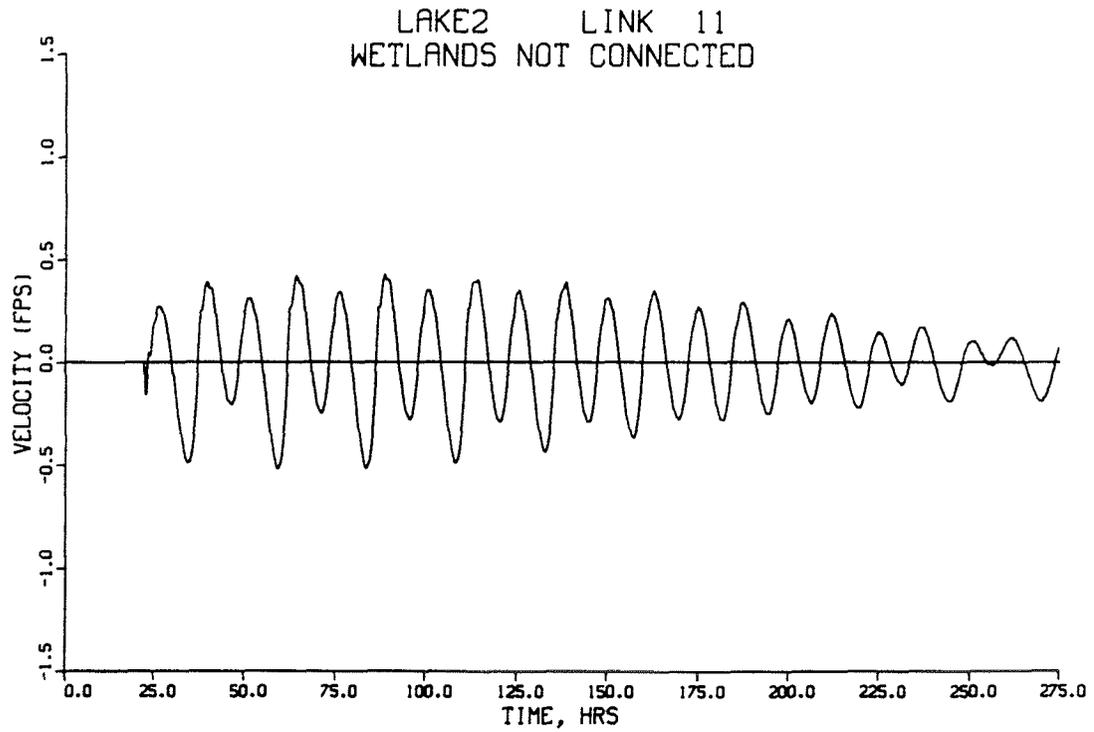


Figure F6. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 12
WETLANDS NOT CONNECTED

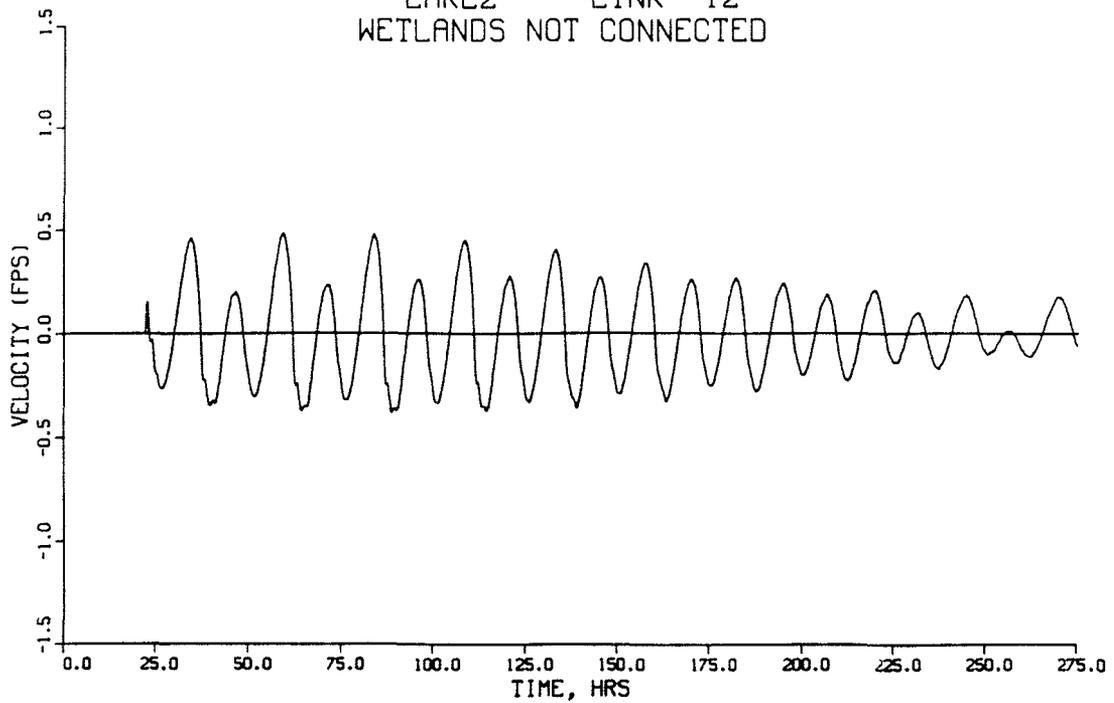


Figure F7. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 13
WETLANDS NOT CONNECTED

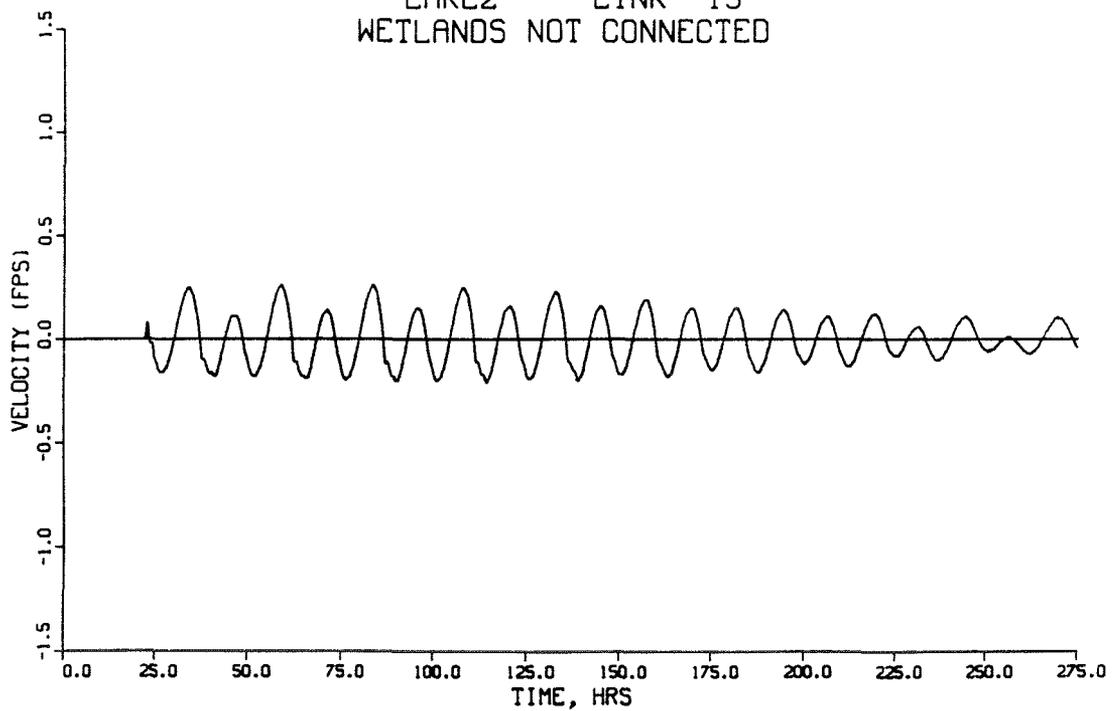


Figure F8. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

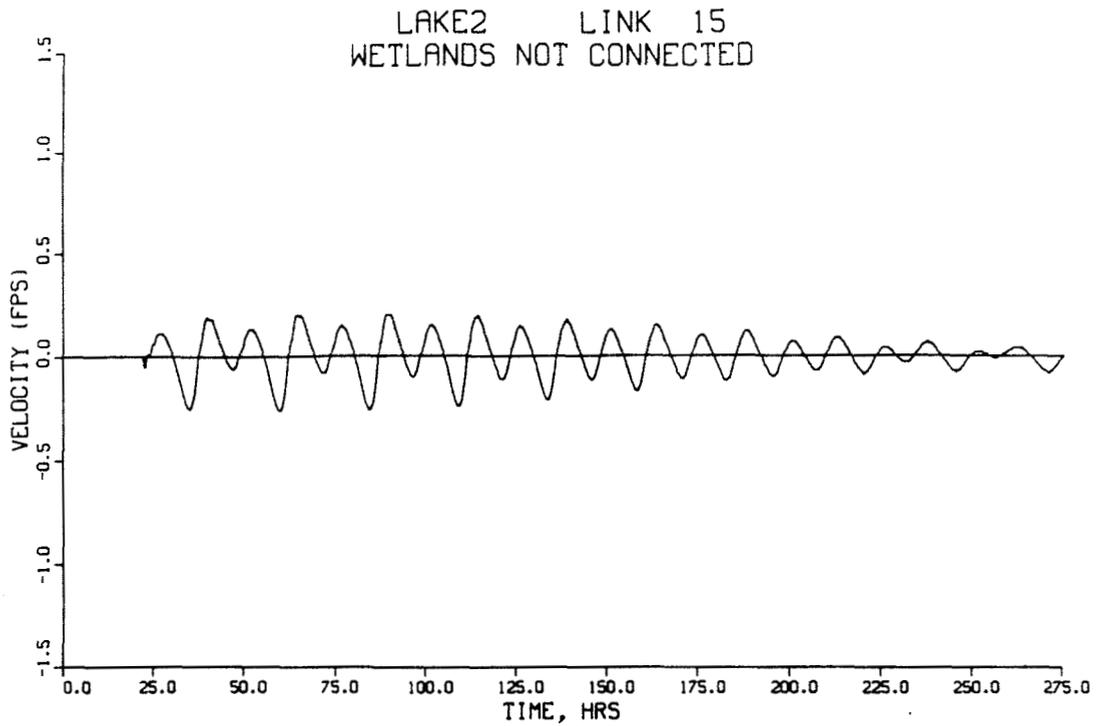


Figure F9. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

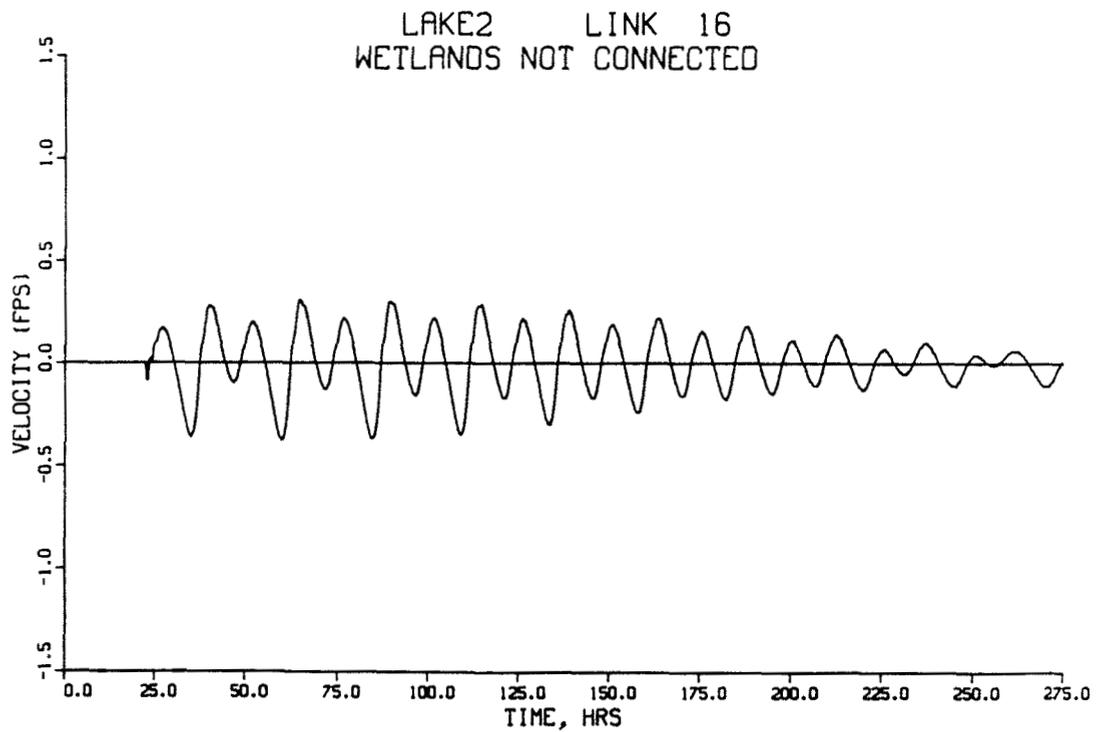


Figure F10. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 17
WETLANDS NOT CONNECTED

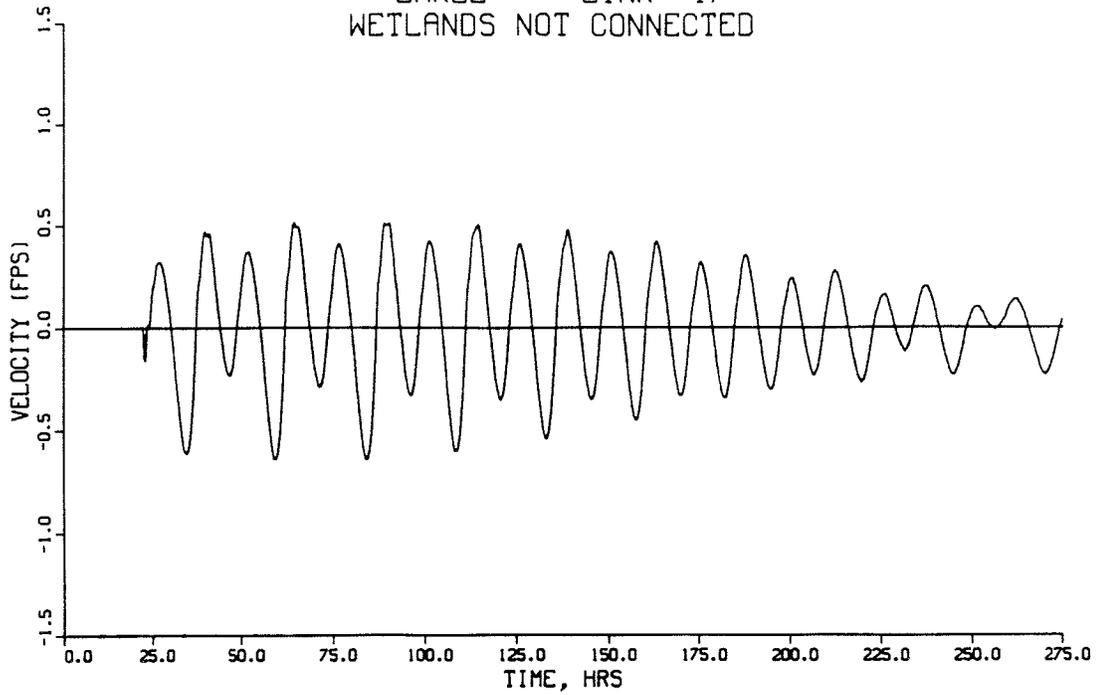


Figure F11. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 18
WETLANDS NOT CONNECTED

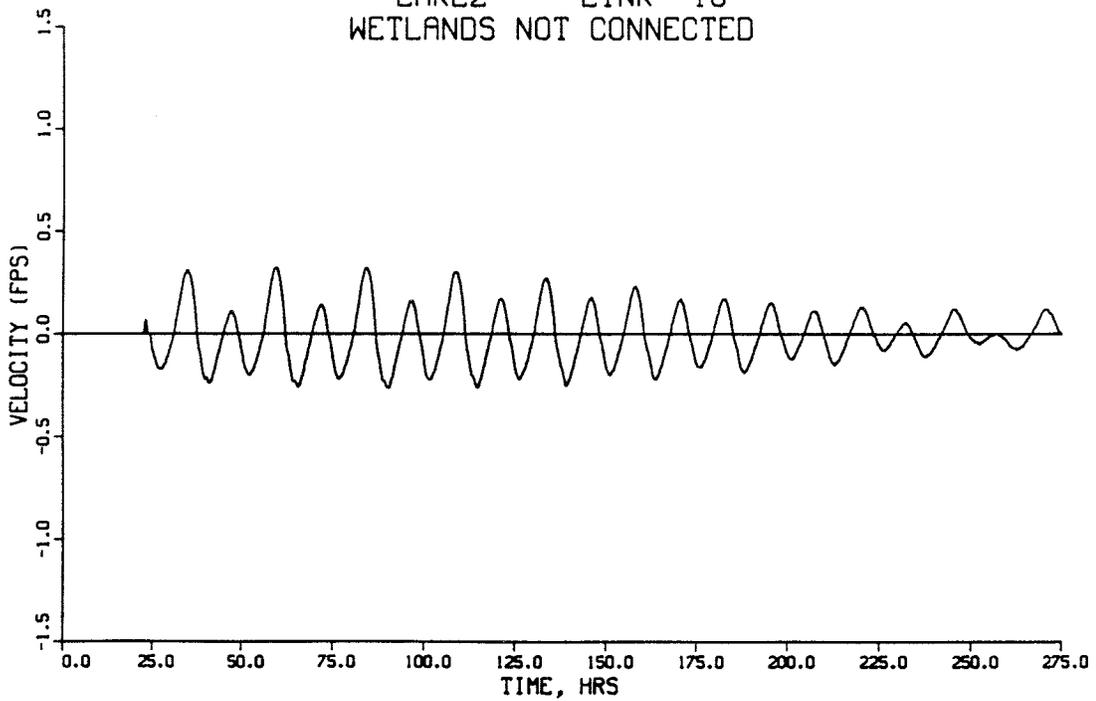


Figure F12. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

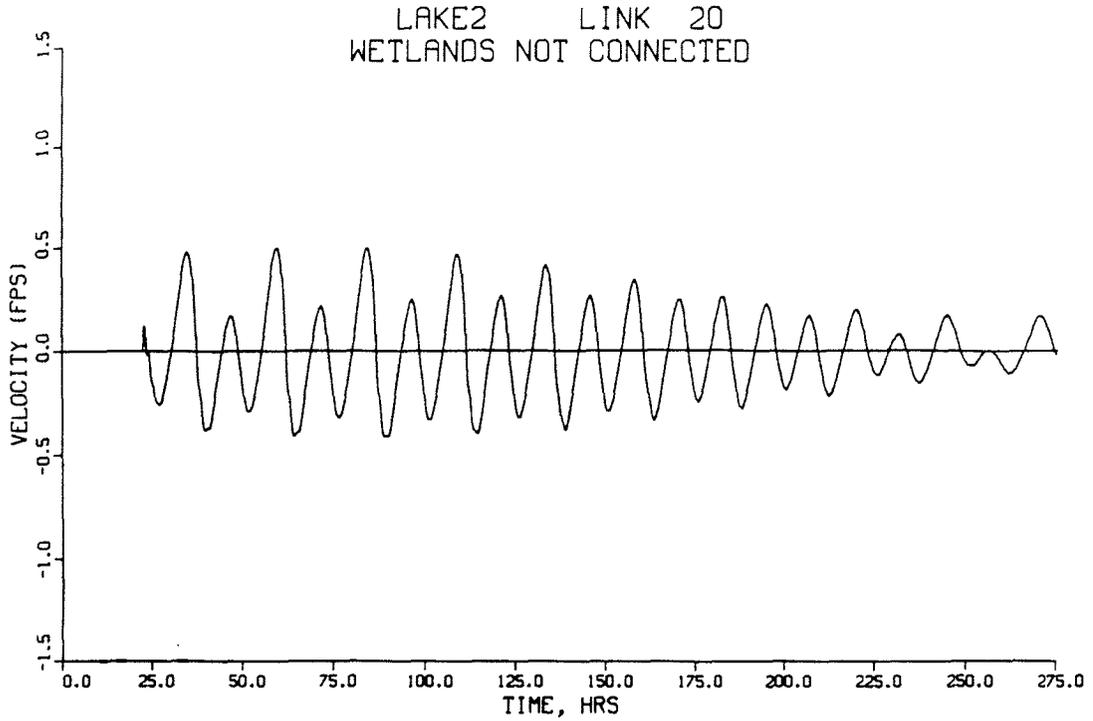


Figure F13. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

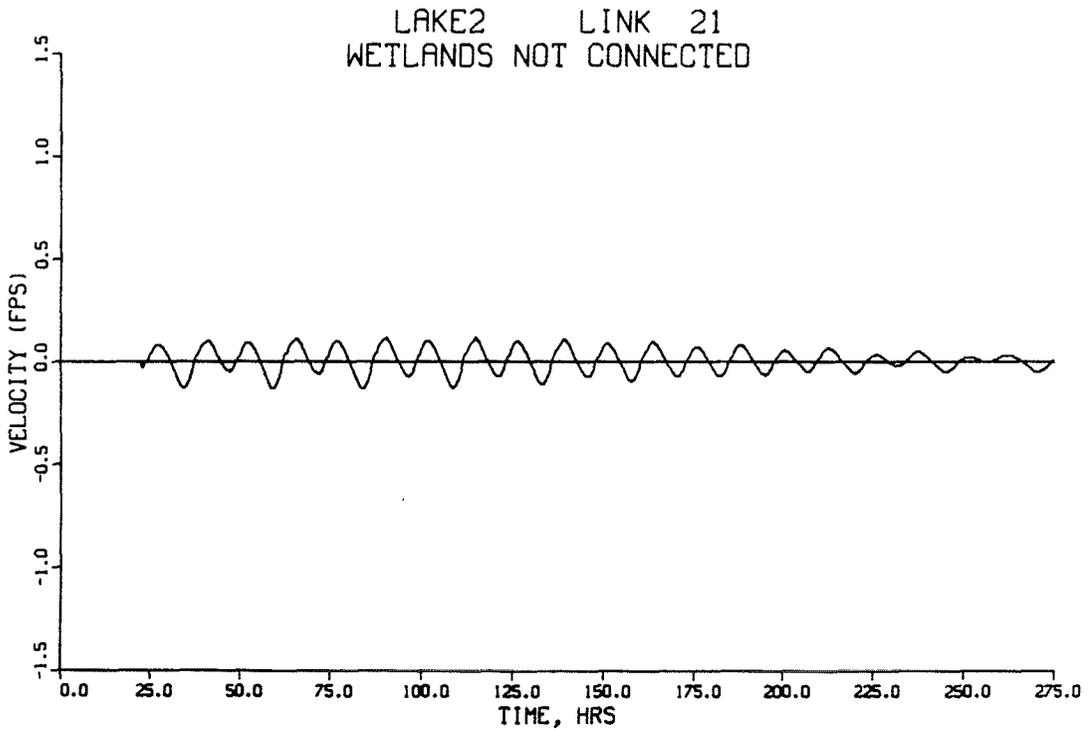


Figure F14. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 23
WETLANDS NOT CONNECTED

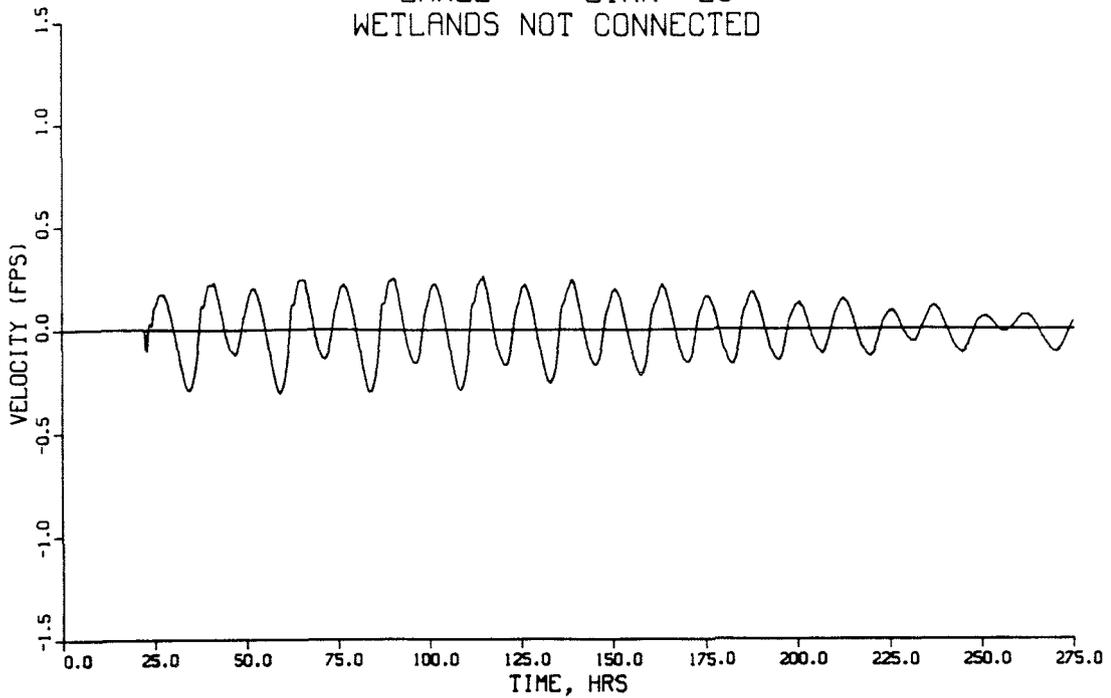


Figure F15. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 24
WETLANDS NOT CONNECTED

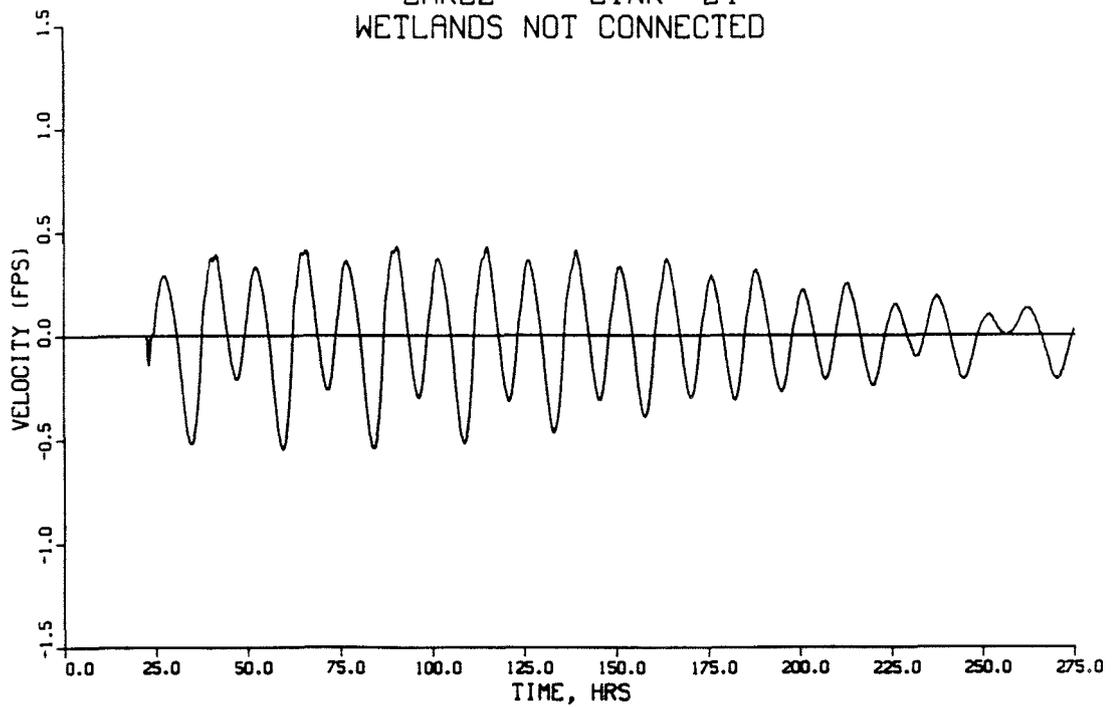


Figure F16. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 25
WETLANDS NOT CONNECTED

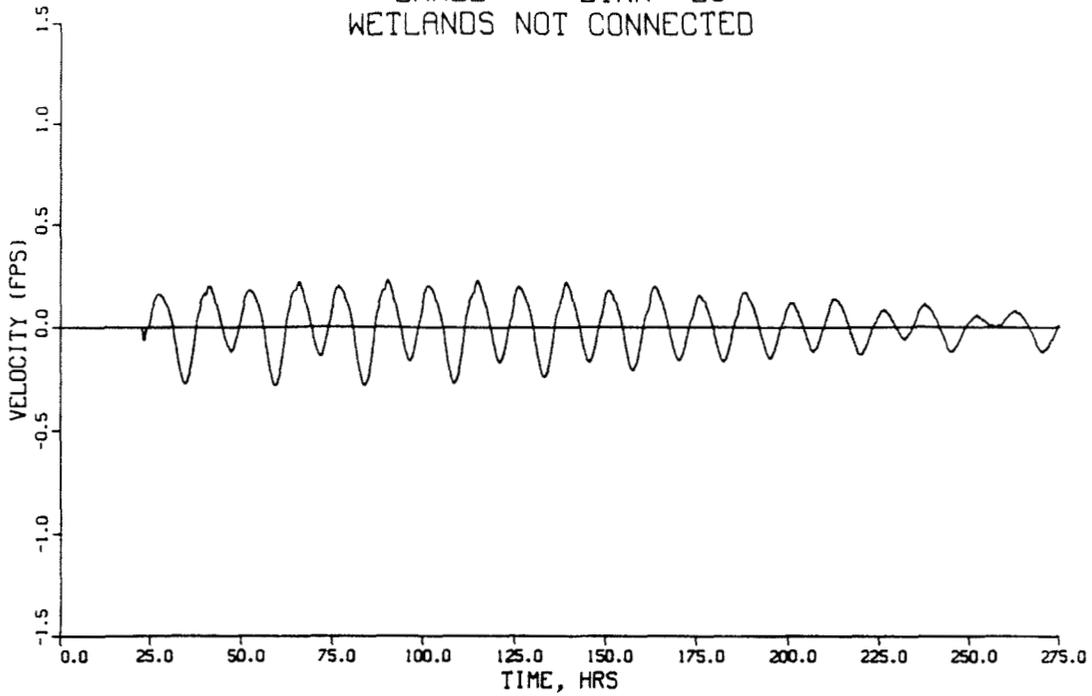


Figure F17. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 26
WETLANDS NOT CONNECTED

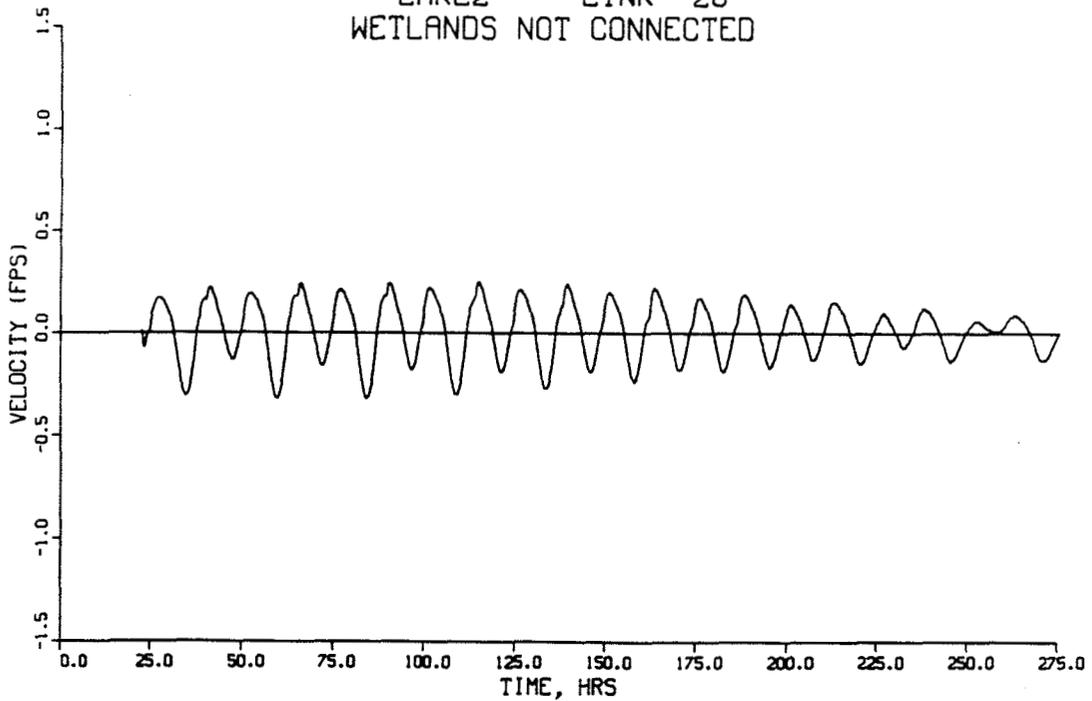


Figure F18. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 27
WETLANDS NOT CONNECTED

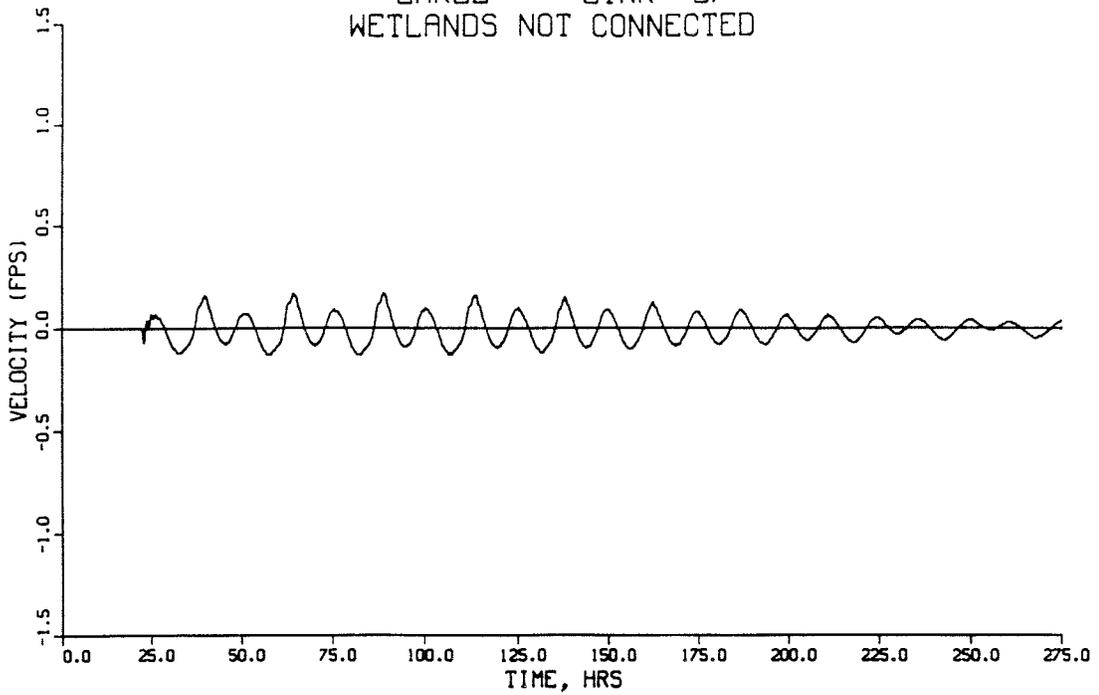


Figure F19. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 29
WETLANDS NOT CONNECTED

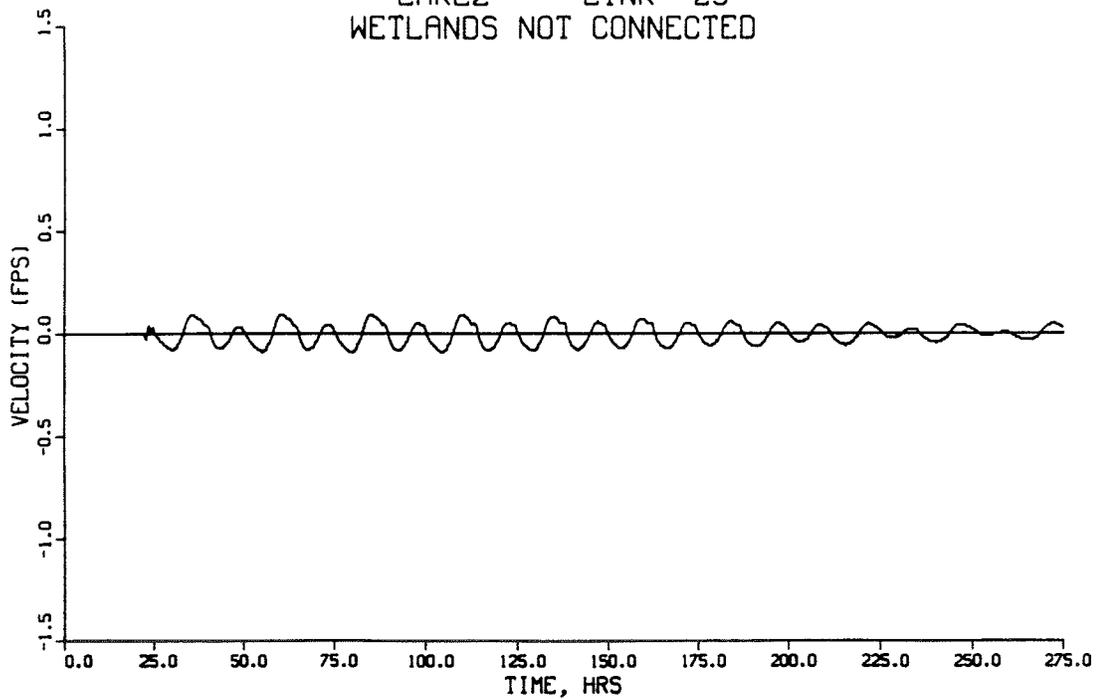


Figure F20. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 31
WETLANDS NOT CONNECTED

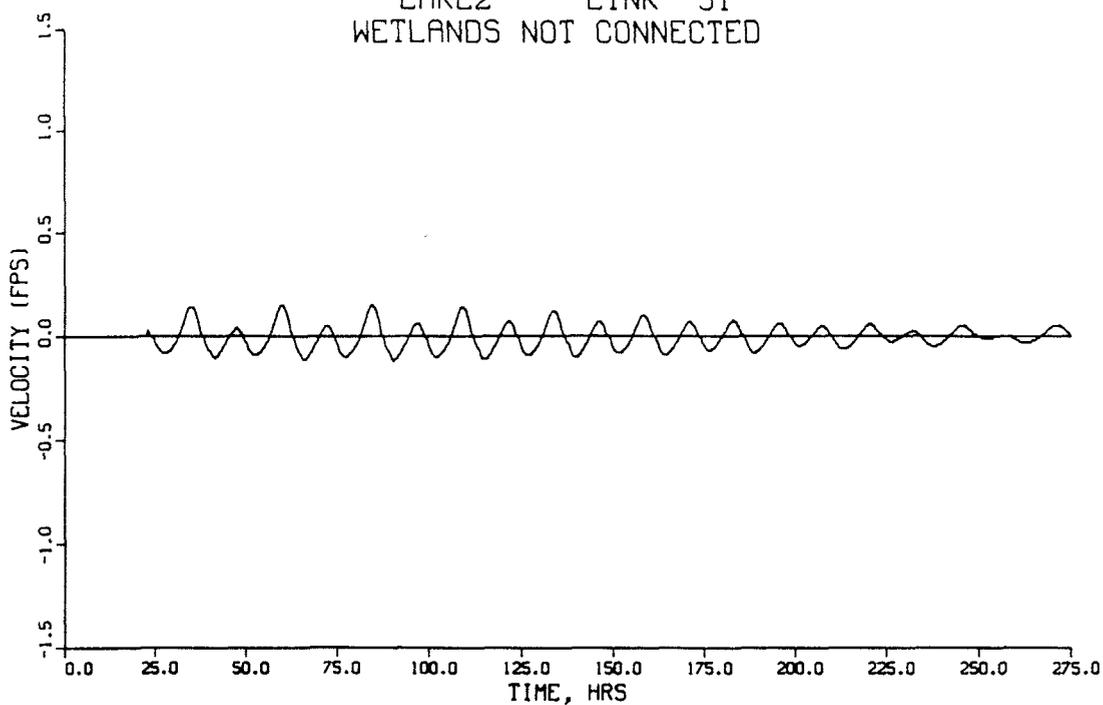


Figure F21. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

LAKE2 LINK 32
WETLANDS NOT CONNECTED

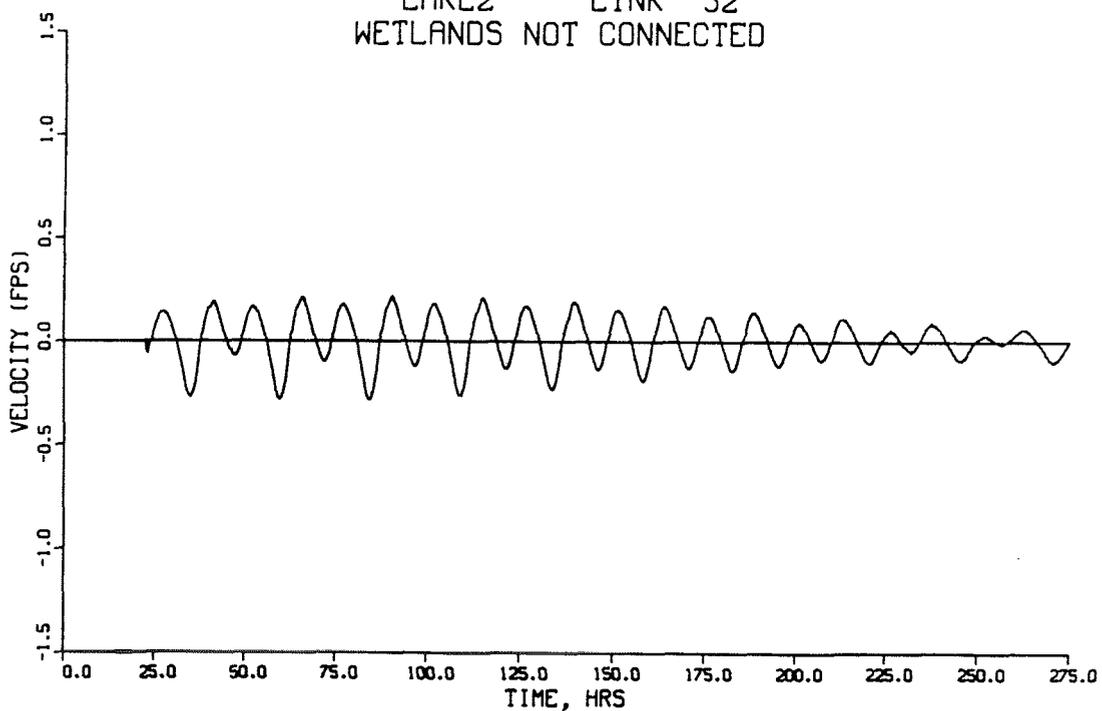


Figure F22. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

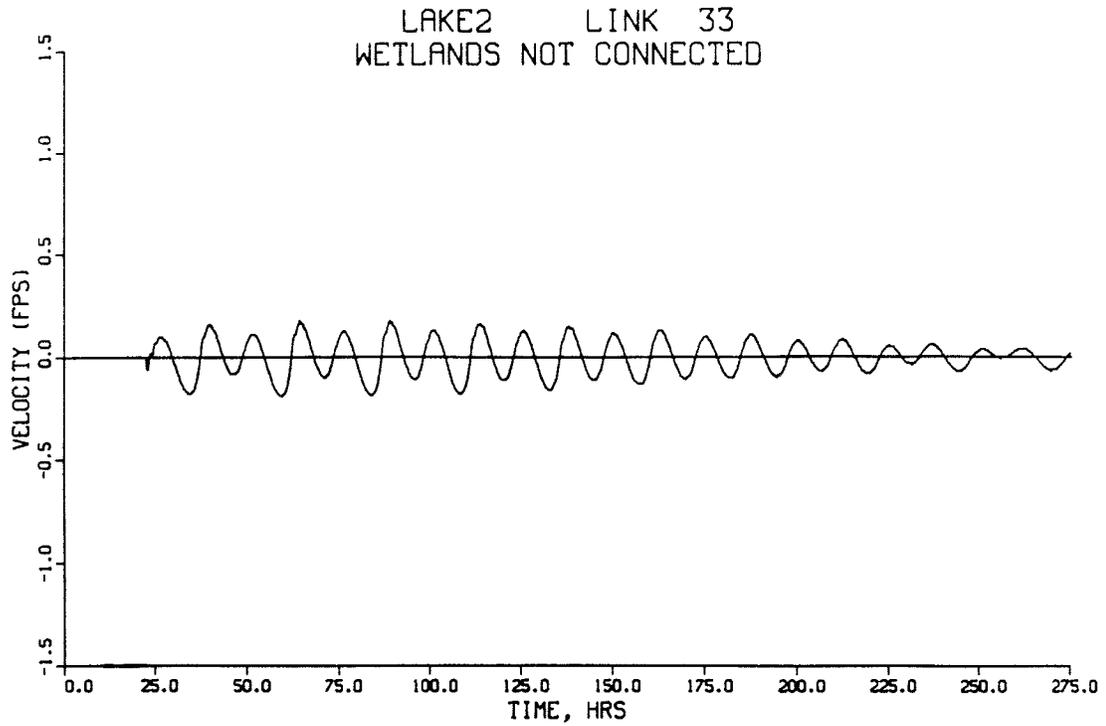


Figure F23. Average channel velocities in Huntington Harbour, 200-ft non-navigable entrance channel

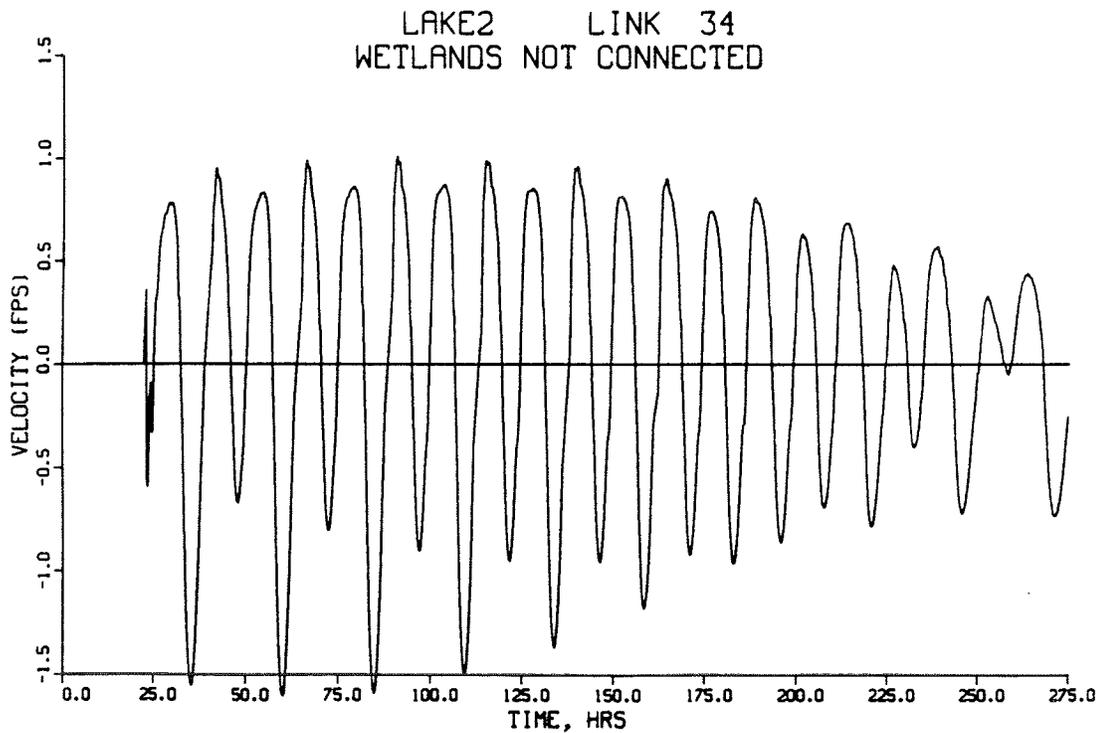


Figure F24. Average channel velocities under Warner Avenue bridge, 200-ft non-navigable entrance channel

LAKE2 LINK 35
WETLANDS NOT CONNECTED

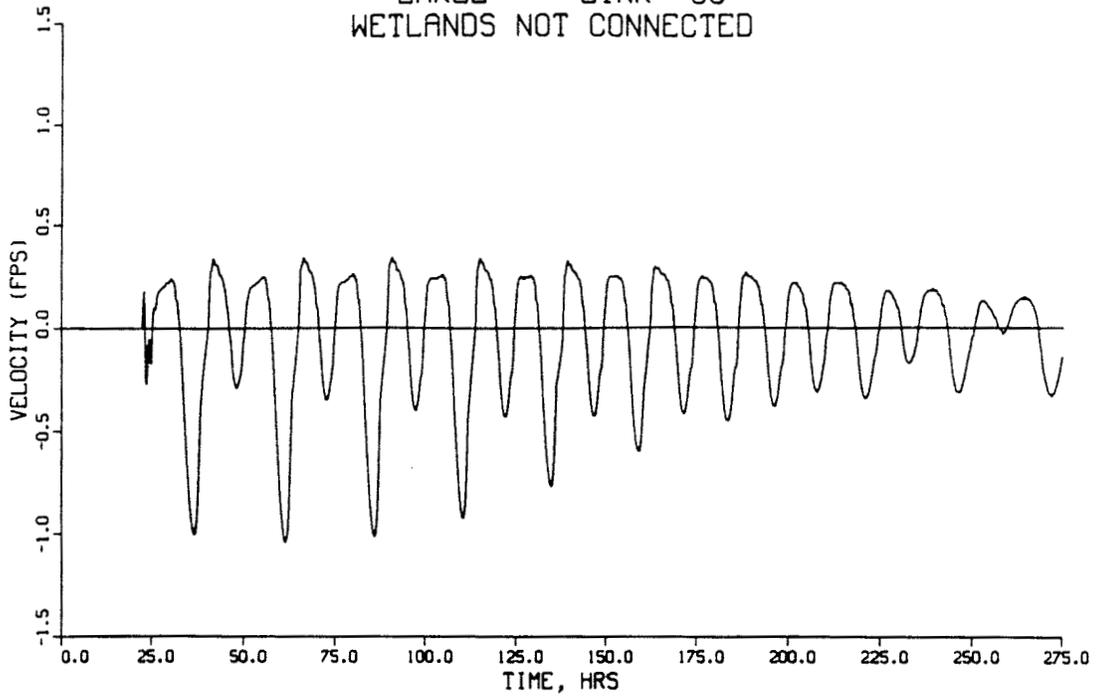


Figure F25. Average channel velocities in Outer Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 LINK 36
WETLANDS NOT CONNECTED

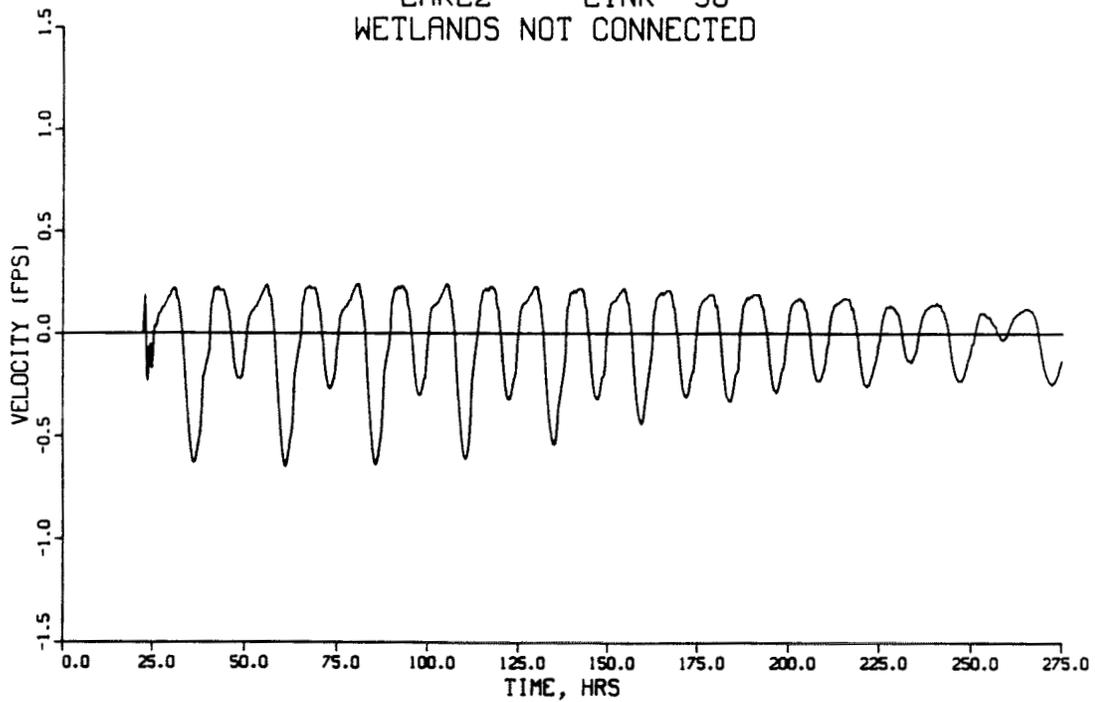


Figure F26. Average channel velocities in Outer Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 LINK 37
WETLANDS NOT CONNECTED

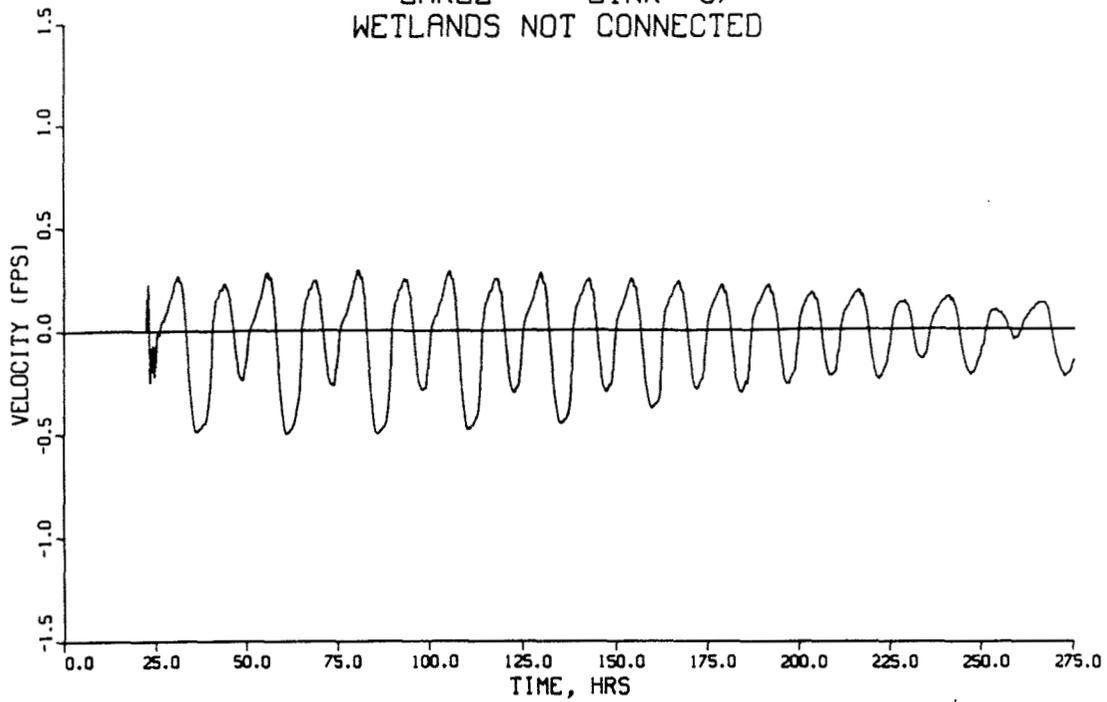


Figure F27. Average channel velocities in Outer Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 LINK 38
WETLANDS NOT CONNECTED

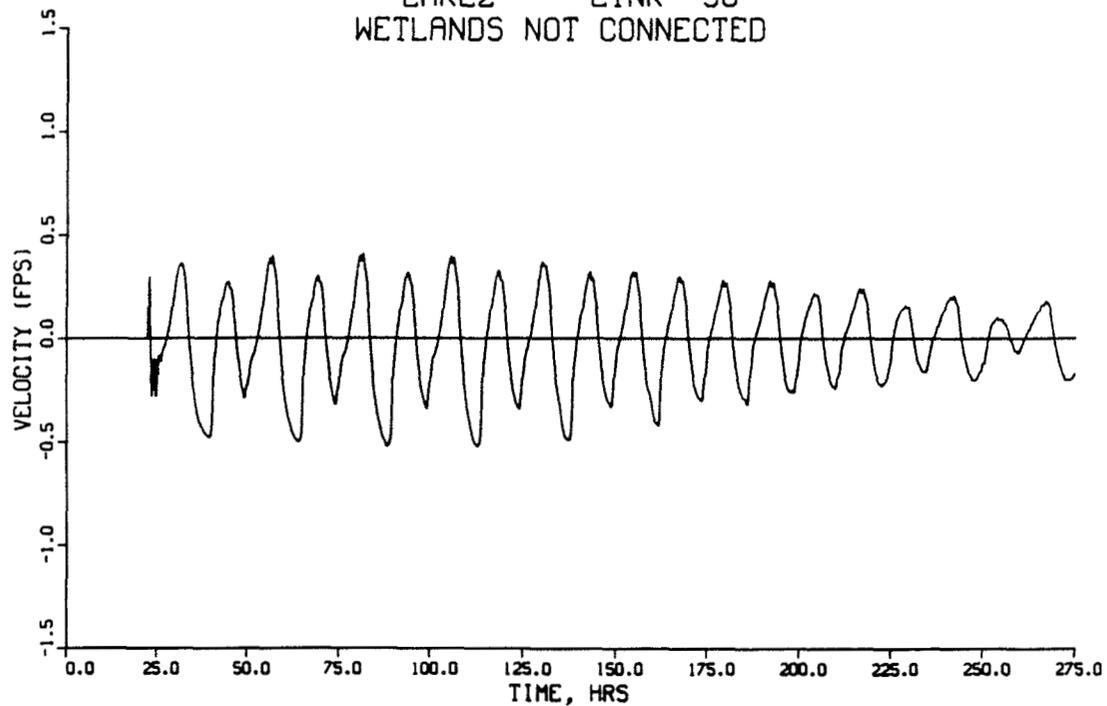


Figure F28. Average channel velocities in Outer Bolsa Bay,
200-ft non-navigable entrance channel

LAKE2 LINK 85
WETLANDS NOT CONNECTED

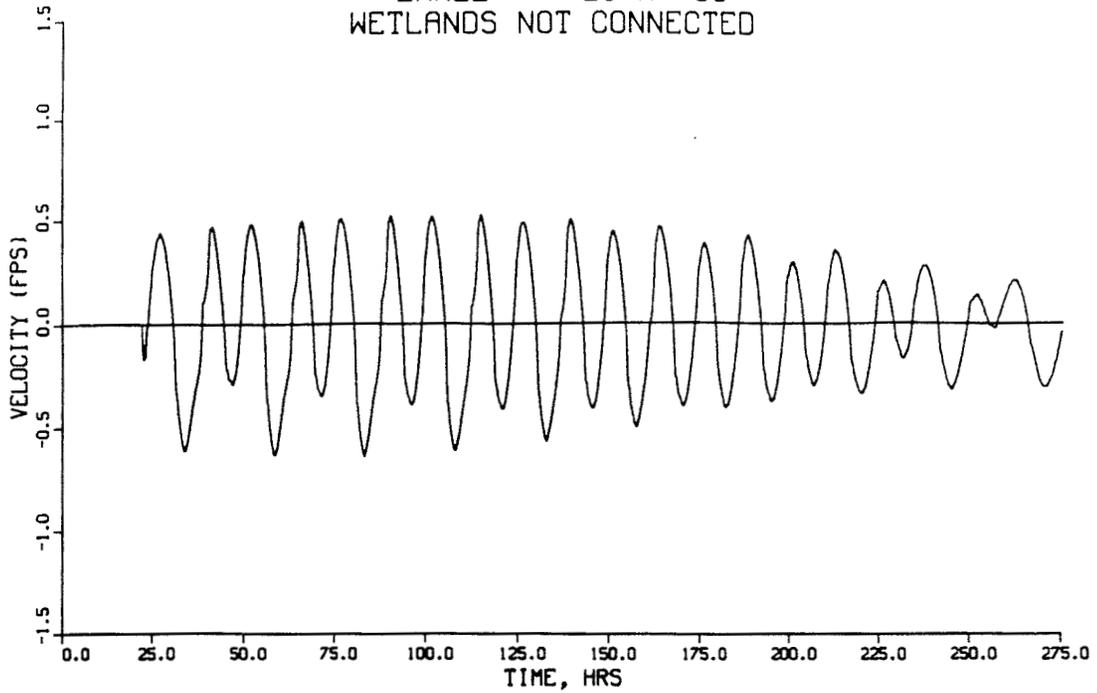


Figure F29. Average channel velocities in proposed marina, 200-ft non-navigable entrance channel

LAKE2 LINK 95
WETLANDS NOT CONNECTED

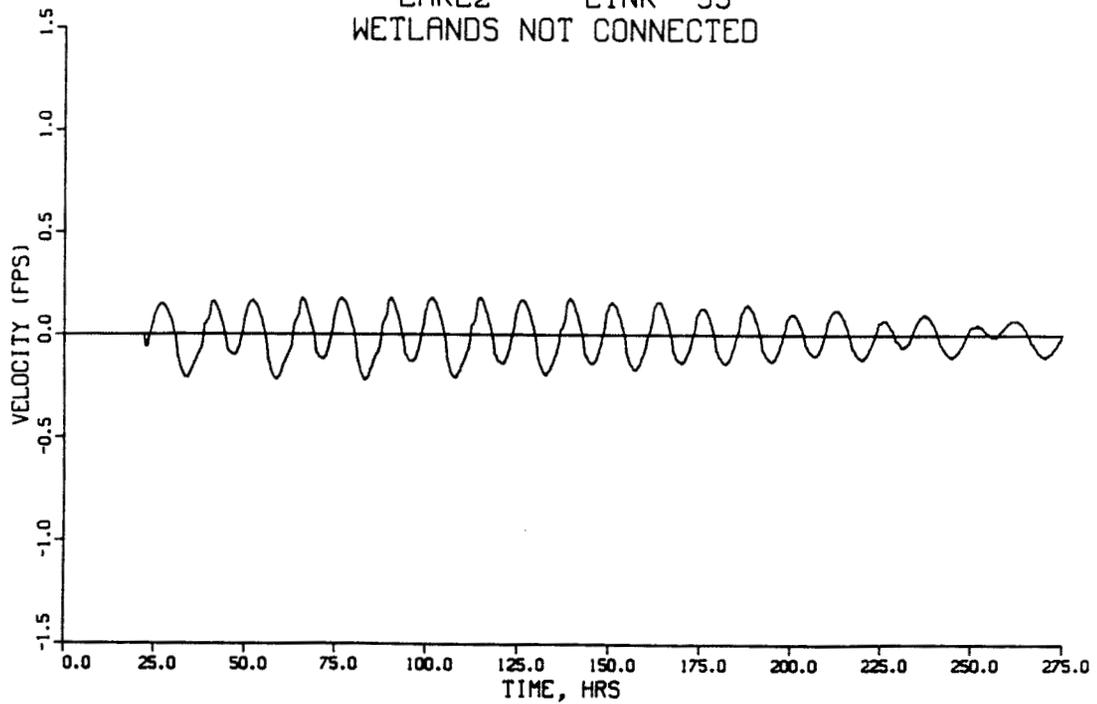


Figure F30. Average channel velocities in proposed marina, 200-ft non-navigable entrance channel

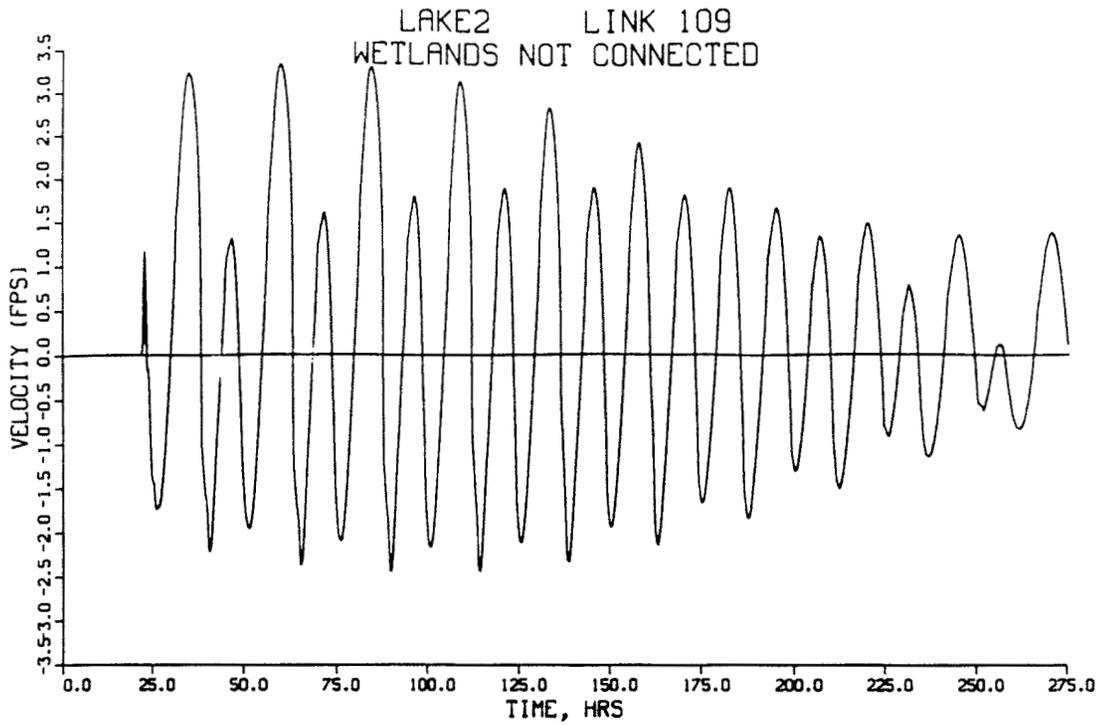


Figure F31. Average channel velocities in proposed entrance channel, 200-ft non-navigable entrance channel

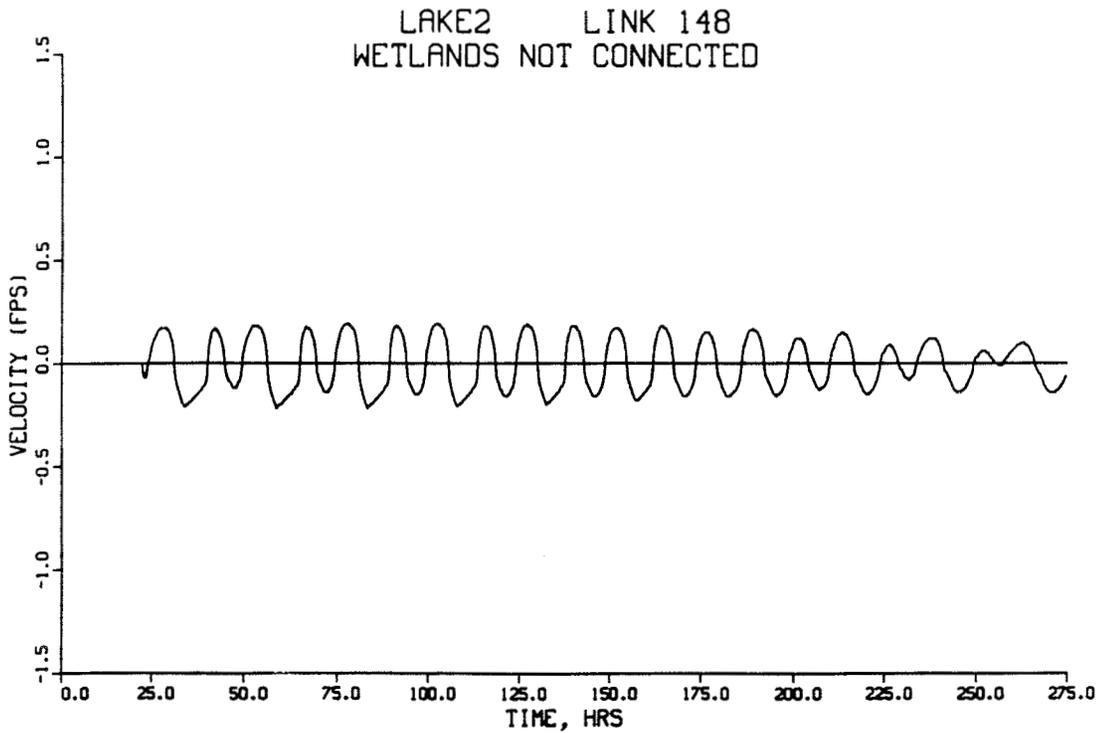


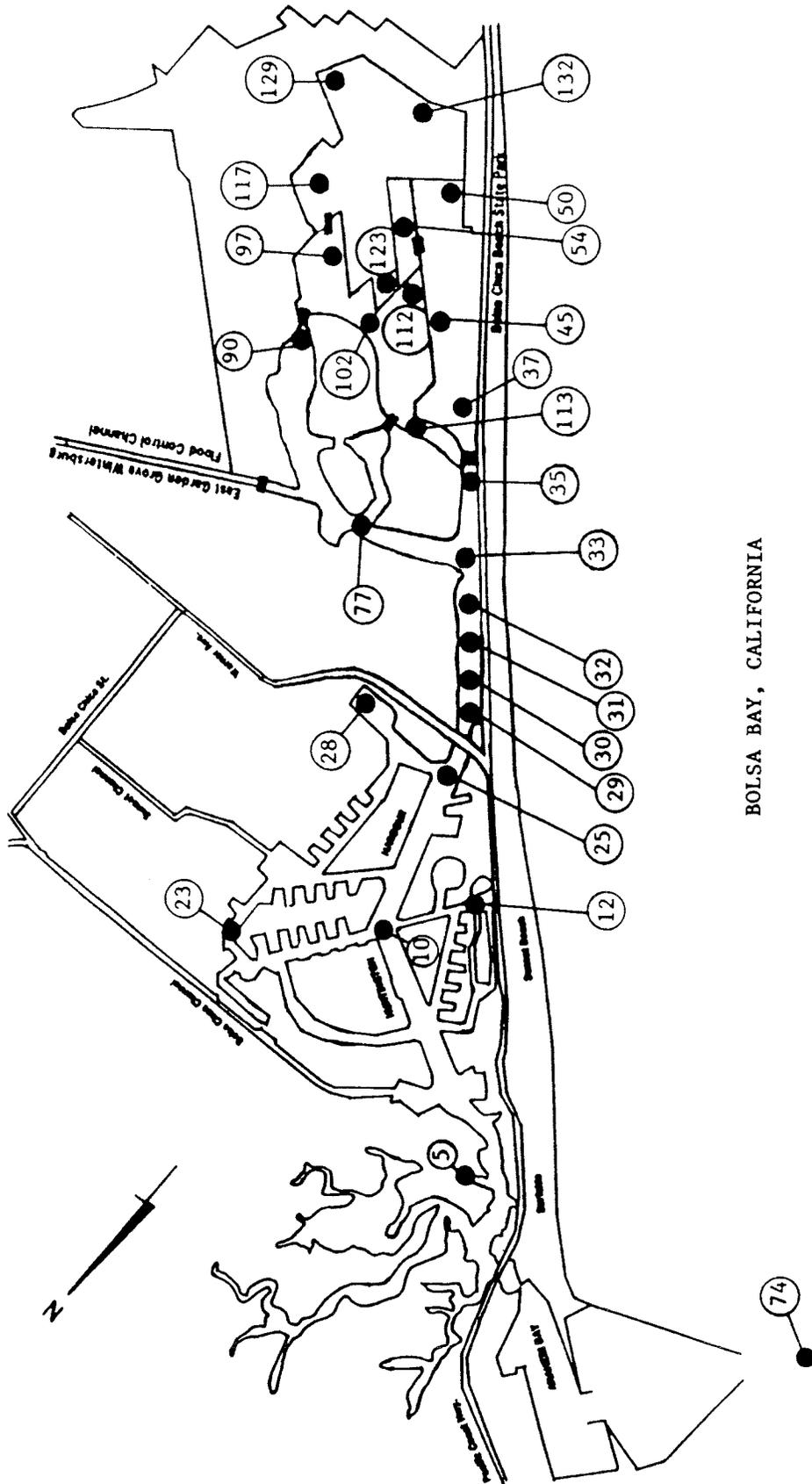
Figure F32. Average channel velocities in proposed marina, 200-ft non-navigable entrance channel

APPENDIX G:

LAKE 3

NON-NAVIGABLE ENTRANCE CHANNEL CLOSED

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

LAKE 3
 Location of nodes for displaying
 water surface elevations under Lake 3 conditions

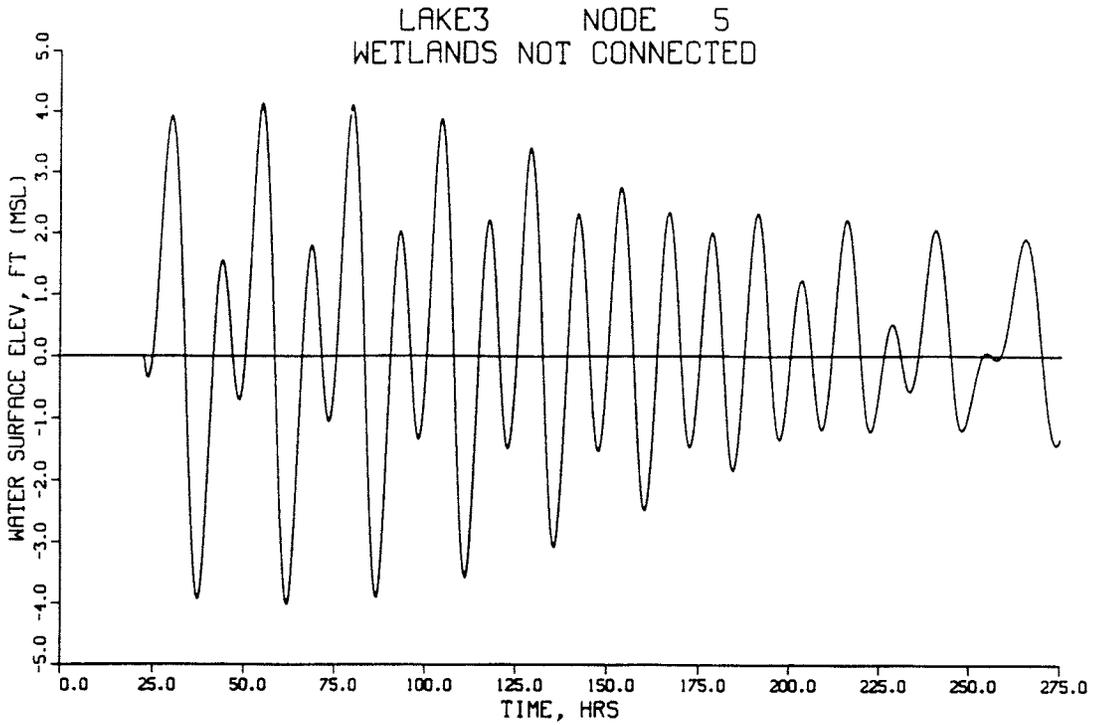


Figure G1. Tidal elevations in Huntington Harbour,
non-navigable entrance channel closed

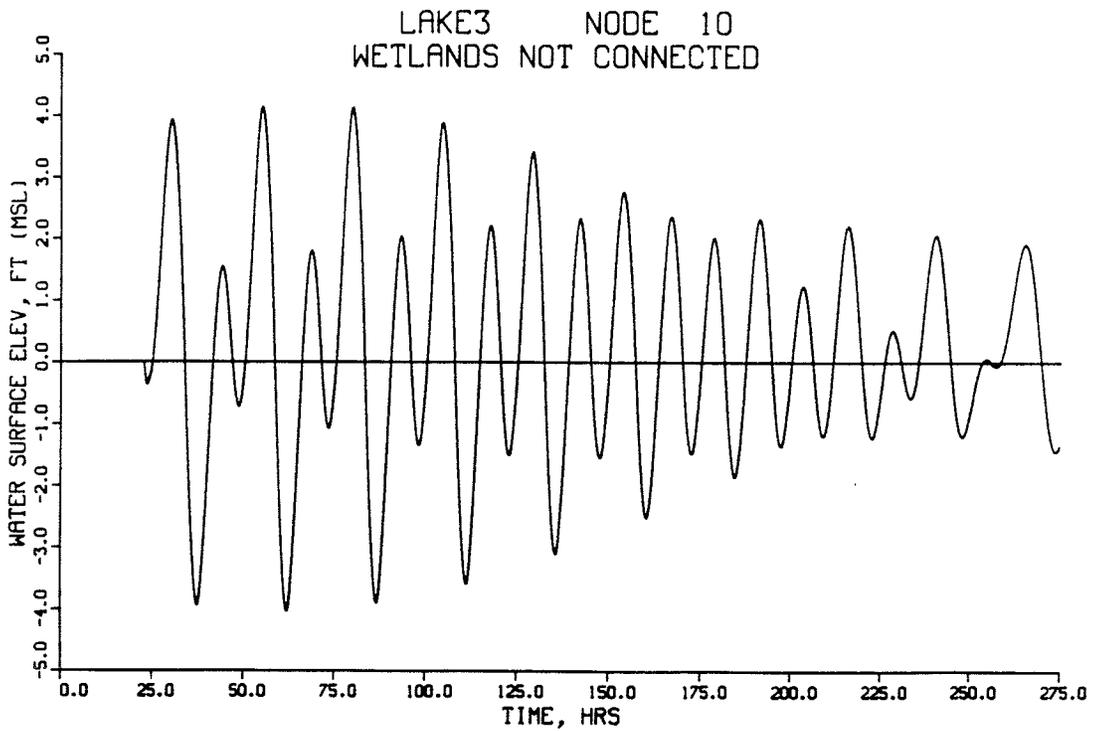


Figure G2. Tidal elevations in Huntington Harbour,
non-navigable entrance channel closed

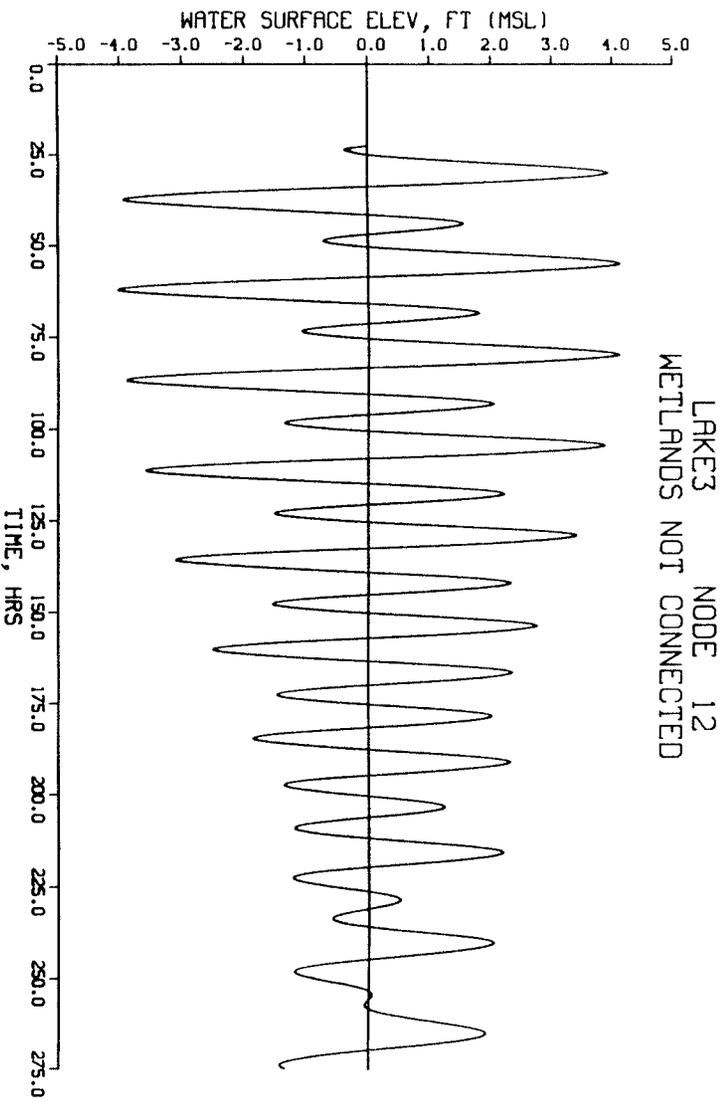


Figure G3. Tidal elevations in Huntington Harbour,
non-navigable entrance channel closed

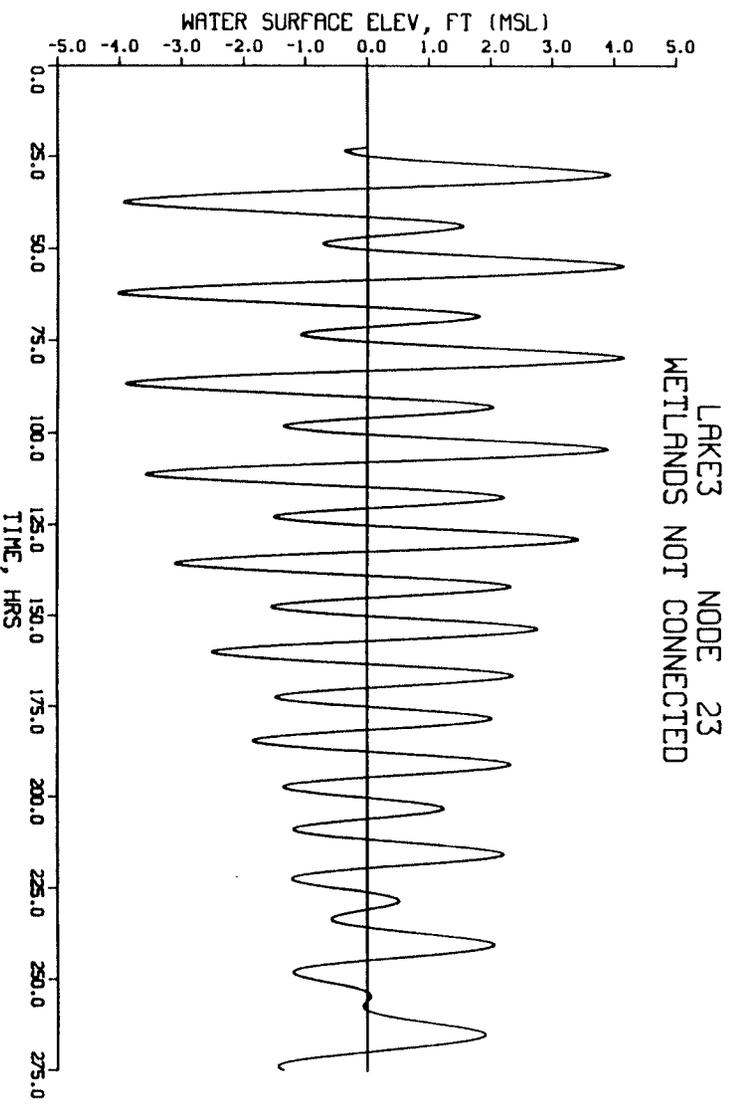


Figure G4. Tidal elevations in Huntington Harbour,
non-navigable entrance channel closed

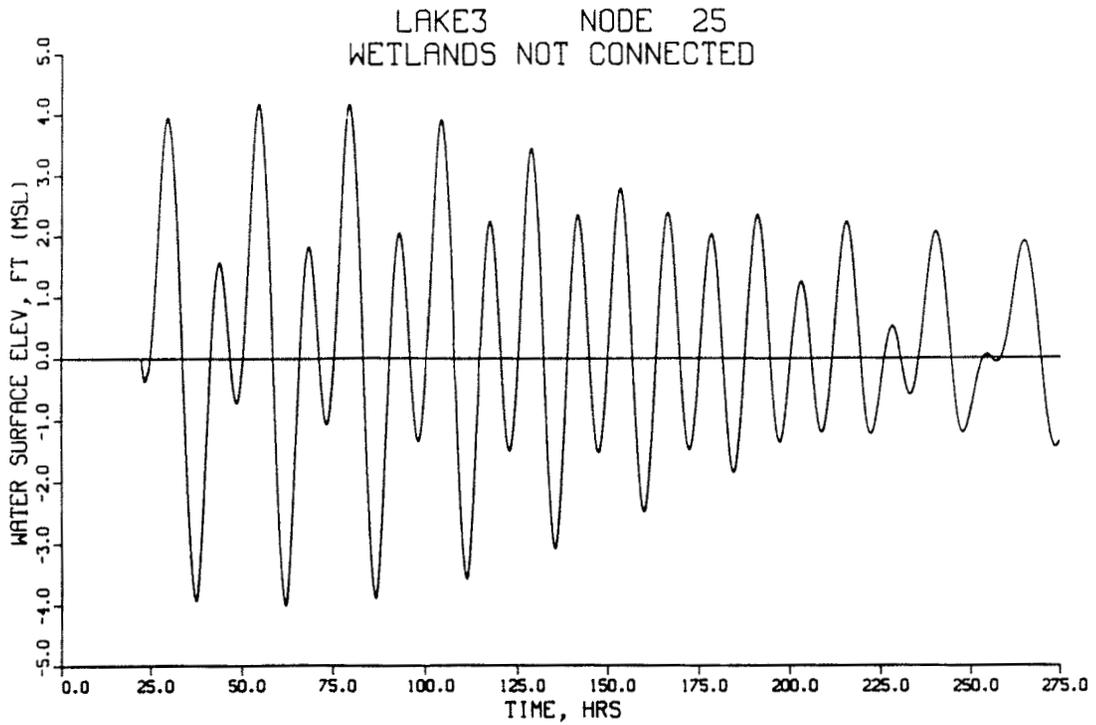


Figure G5. Tidal elevations in Huntington Harbour,
non-navigable entrance channel closed

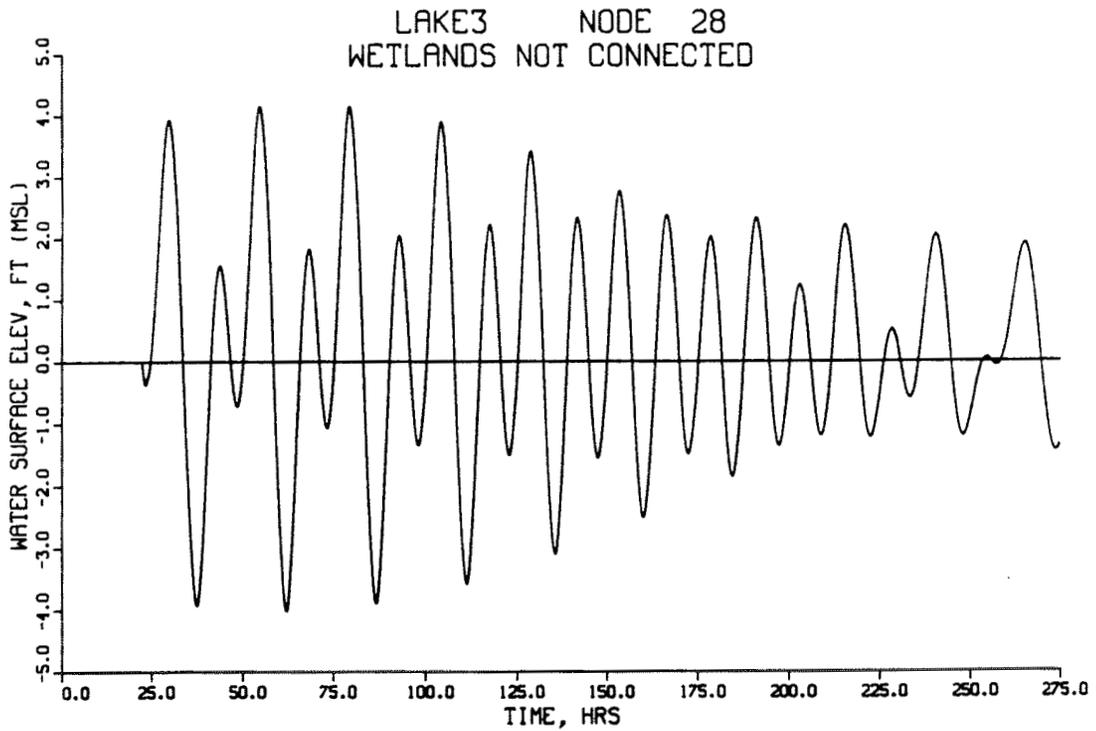


Figure G6. Tidal elevations in Huntington Harbour,
non-navigable entrance channel closed

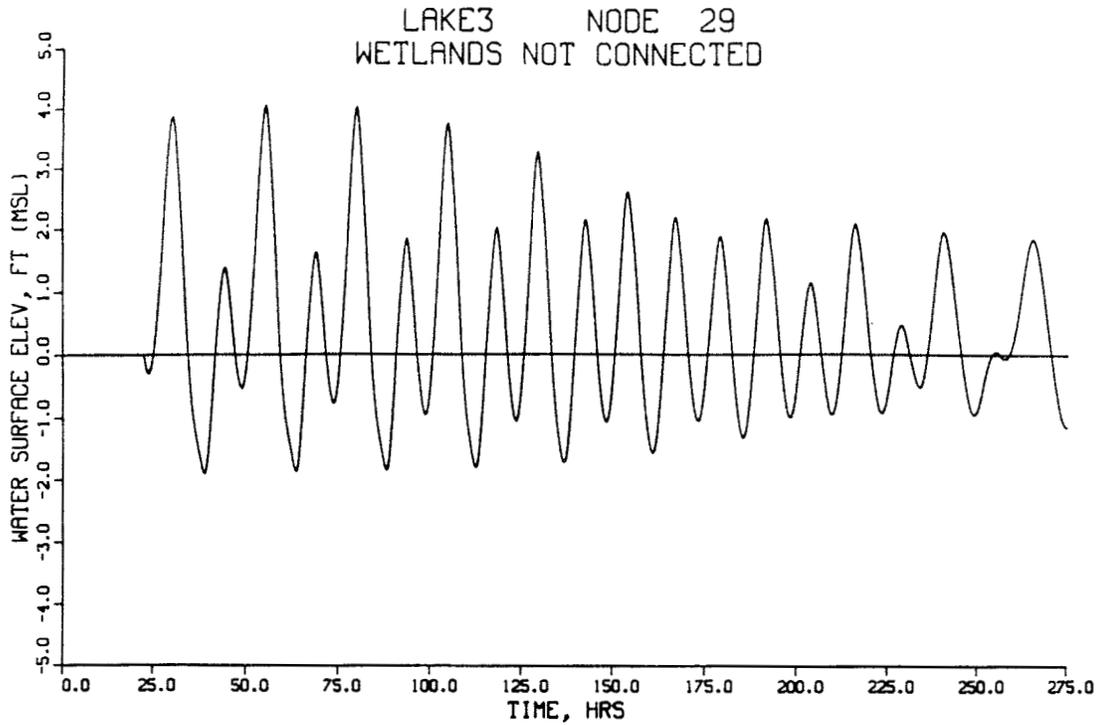


Figure G7. Tidal elevations in Outer Bolsa Bay,
non-navigable entrance channel closed

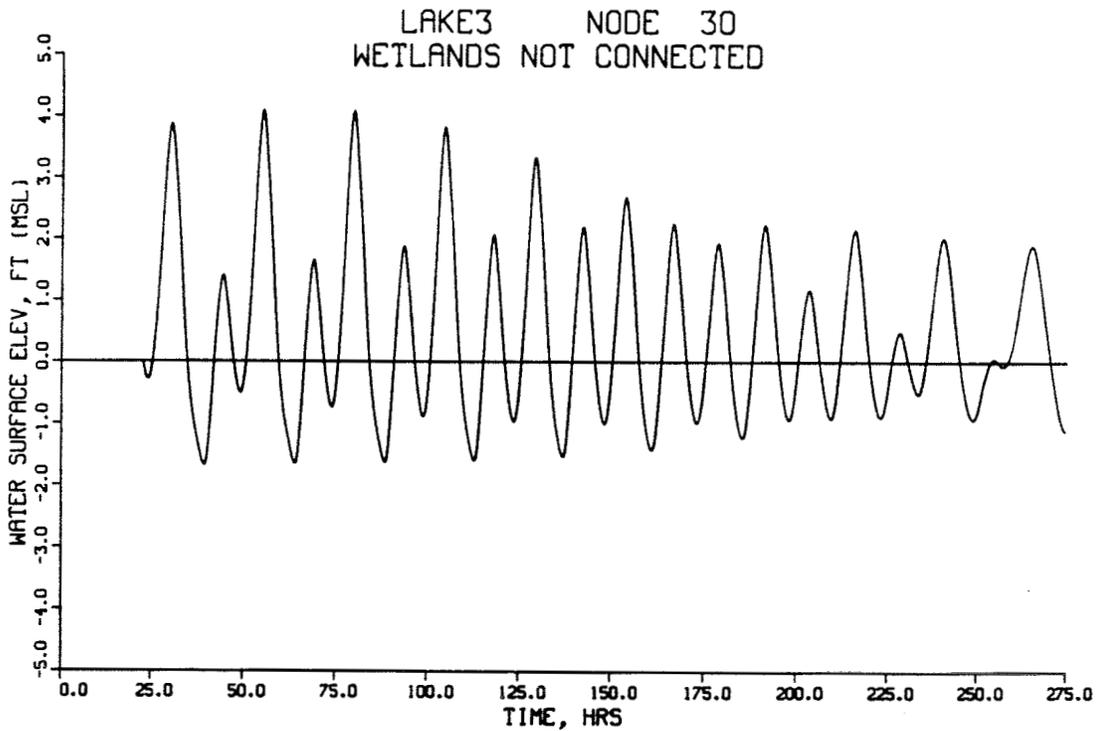


Figure G8. Tidal elevations in Outer Bolsa Bay,
non-navigable entrance channel closed

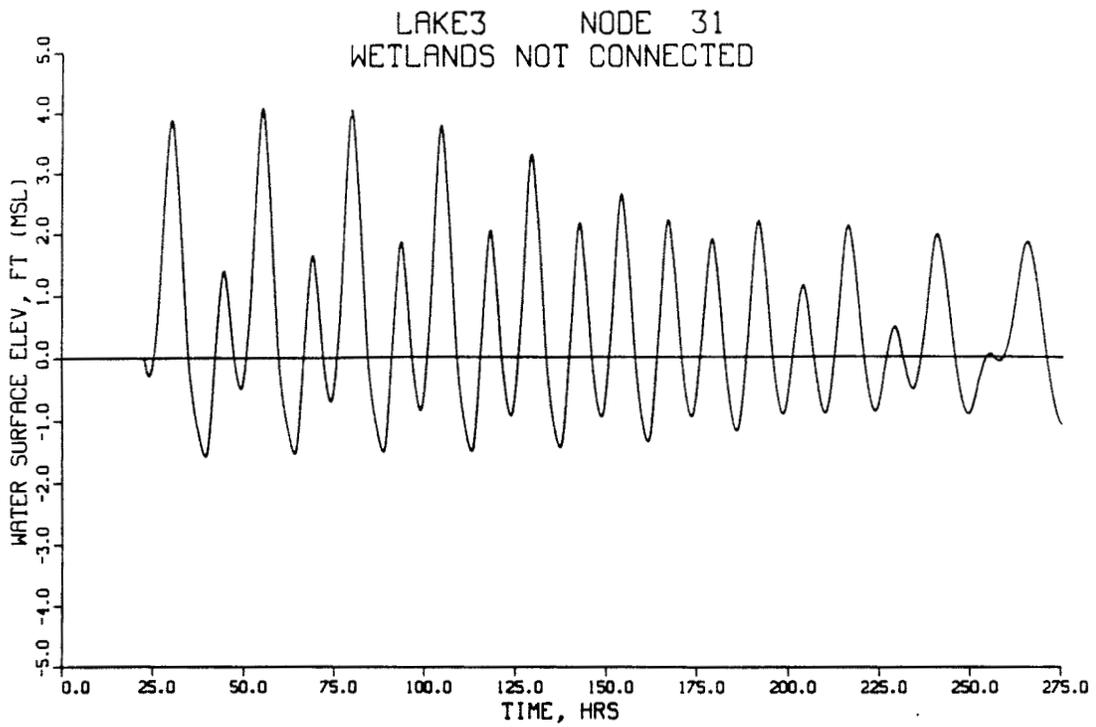


Figure G9. Tidal elevations in Outer Bolsa Bay,
non-navigable entrance channel closed

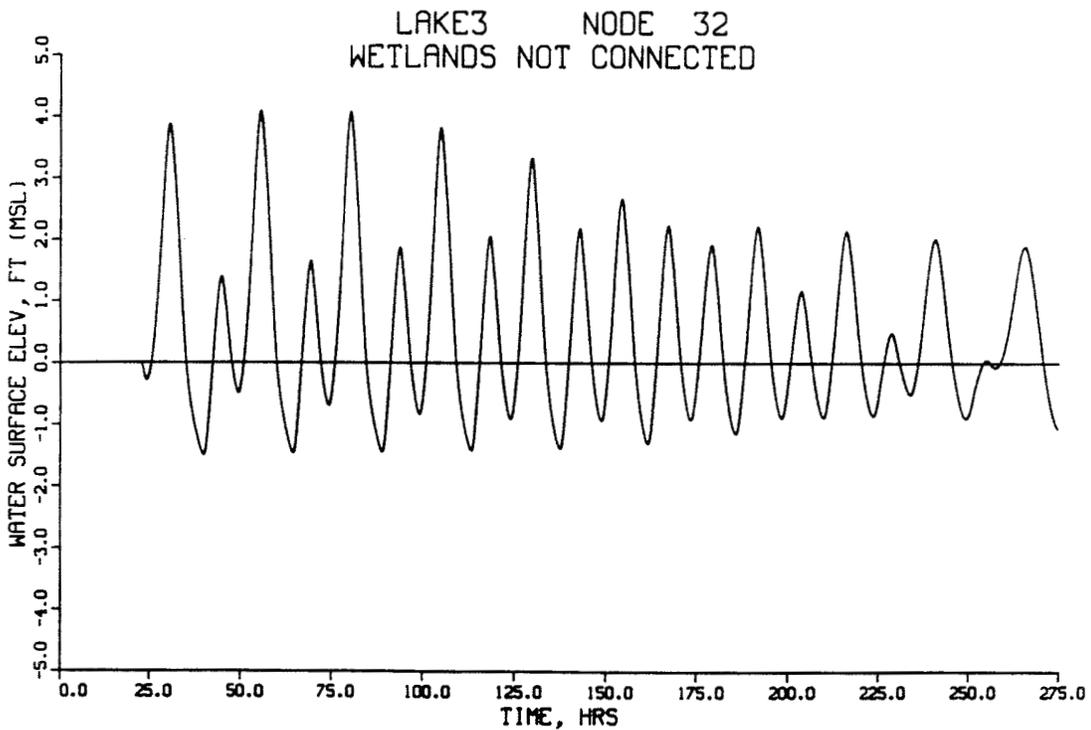


Figure G10. Tidal elevations in Outer Bolsa Bay,
non-navigable entrance channel closed

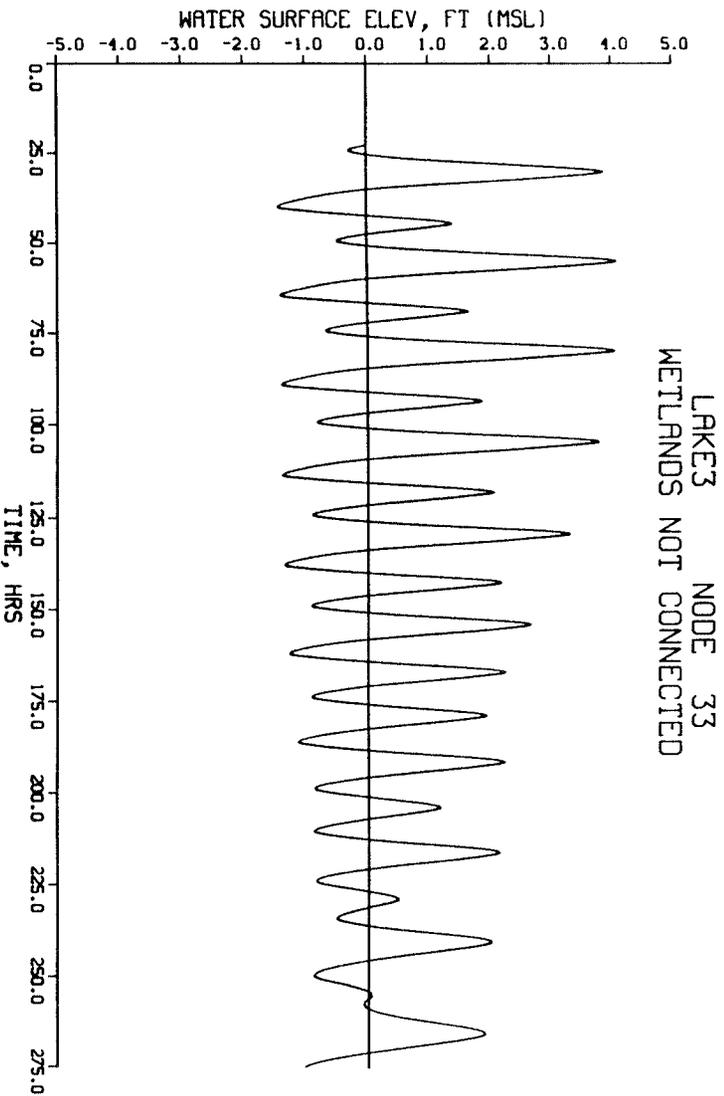


Figure G11. Tidal elevations in entrance to proposed marina,
non-navigable entrance channel closed

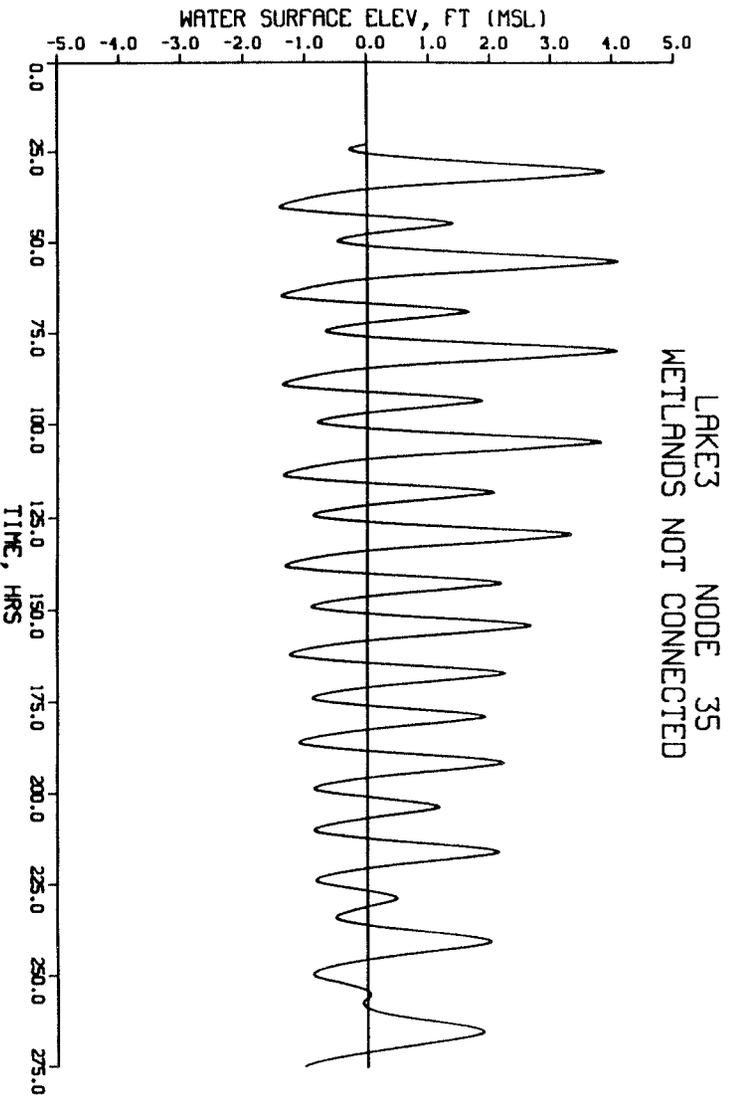


Figure G12. Tidal elevations in Outer Bolsa Bay,
non-navigable entrance channel closed

LAKE3 NODE 37
WETLANDS NOT CONNECTED

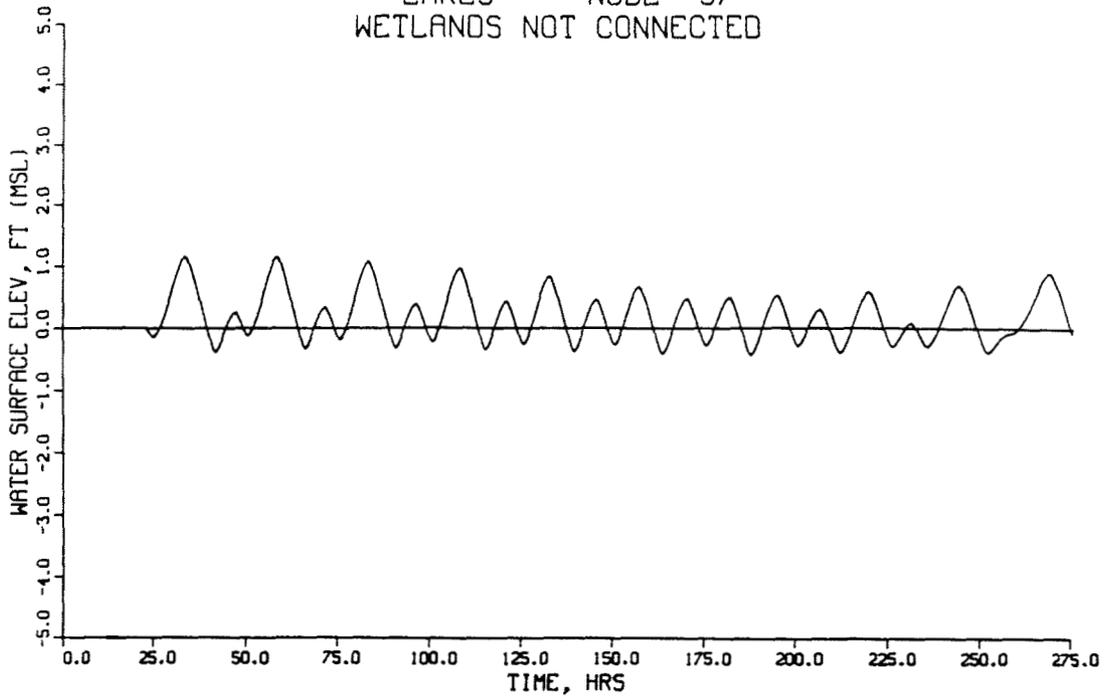


Figure G13. Tidal elevations in Inner Bolsa Bay,
non-navigable entrance channel closed

LAKE3 NODE 45
WETLANDS NOT CONNECTED

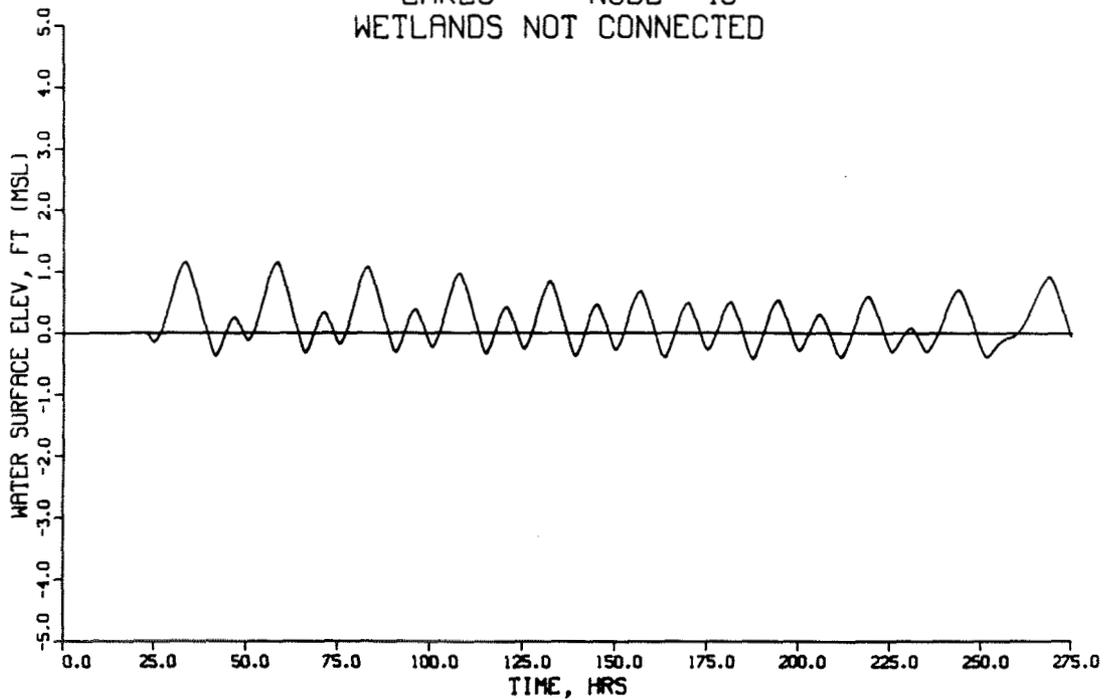


Figure G14. Tidal elevations in Inner Bolsa Bay,
non-navigable entrance channel closed

LAKE3 NODE 50
WETLANDS NOT CONNECTED

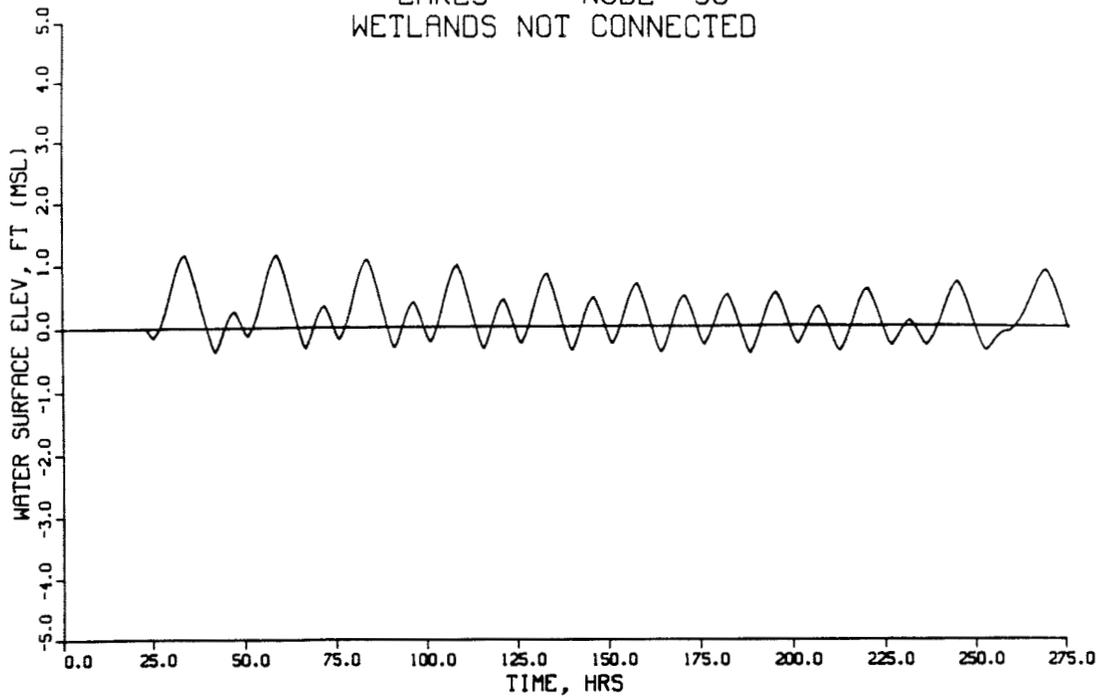


Figure G15. Tidal elevations in Inner Bolsa Bay,
non-navigable entrance channel closed

LAKE3 NODE 54
WETLANDS NOT CONNECTED

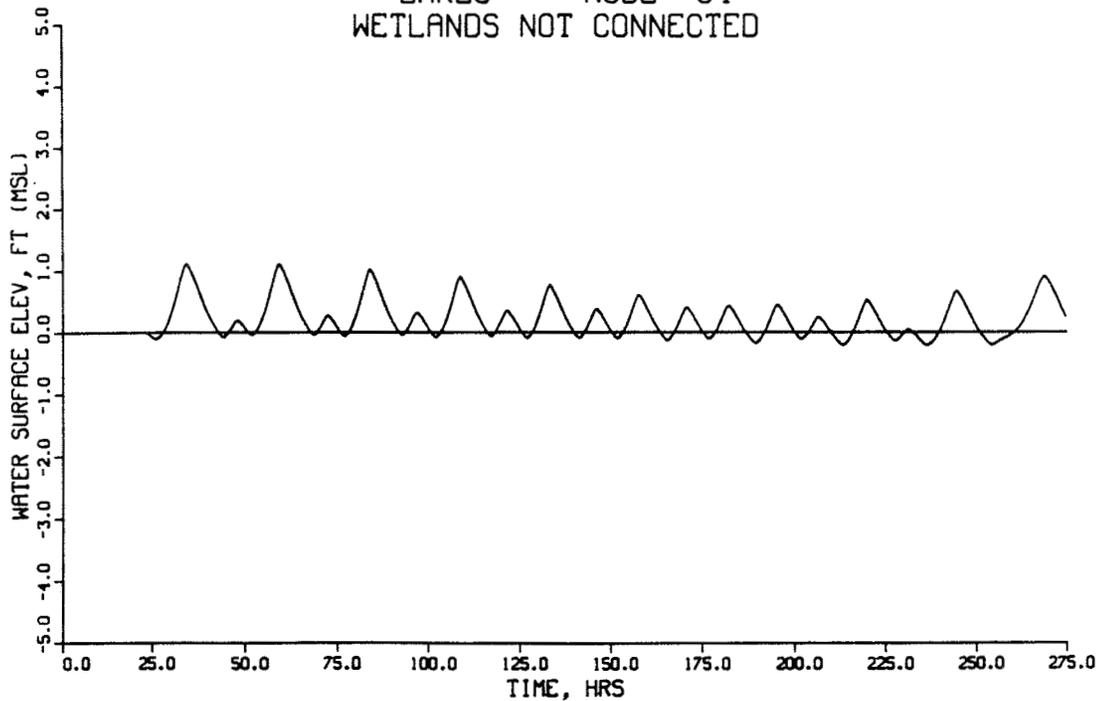


Figure G16. Tidal elevations in DFG muted tidal cell,
non-navigable entrance channel closed

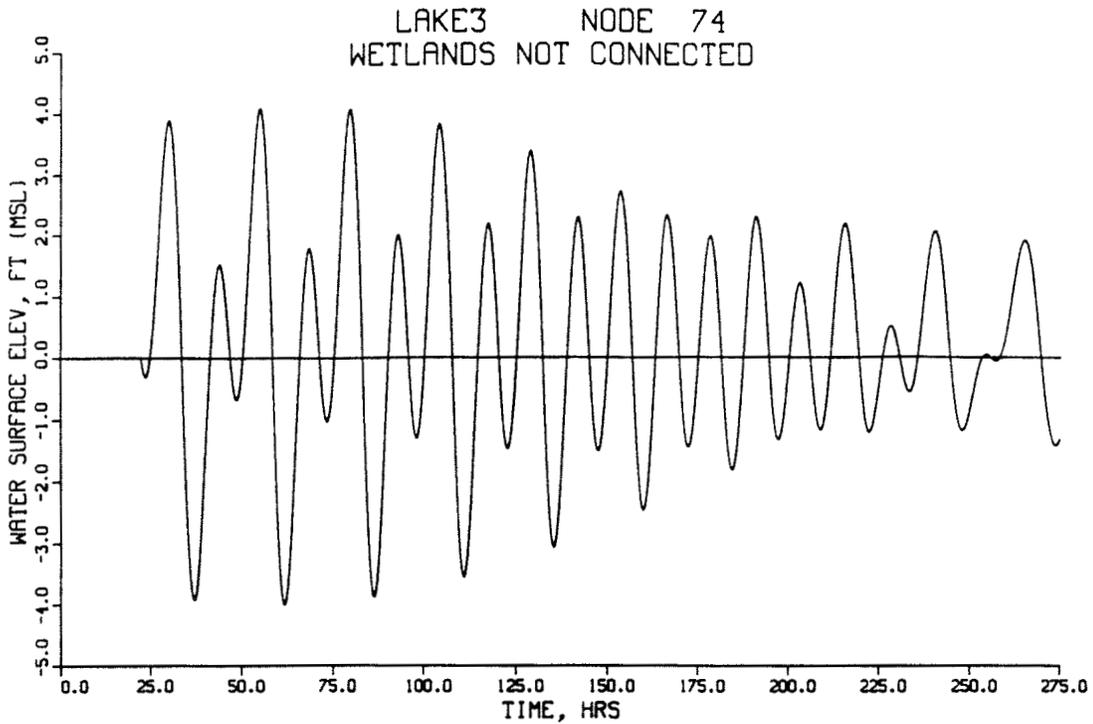


Figure G17. Tidal elevations in Pacific Ocean,
non-navigable entrance channel closed

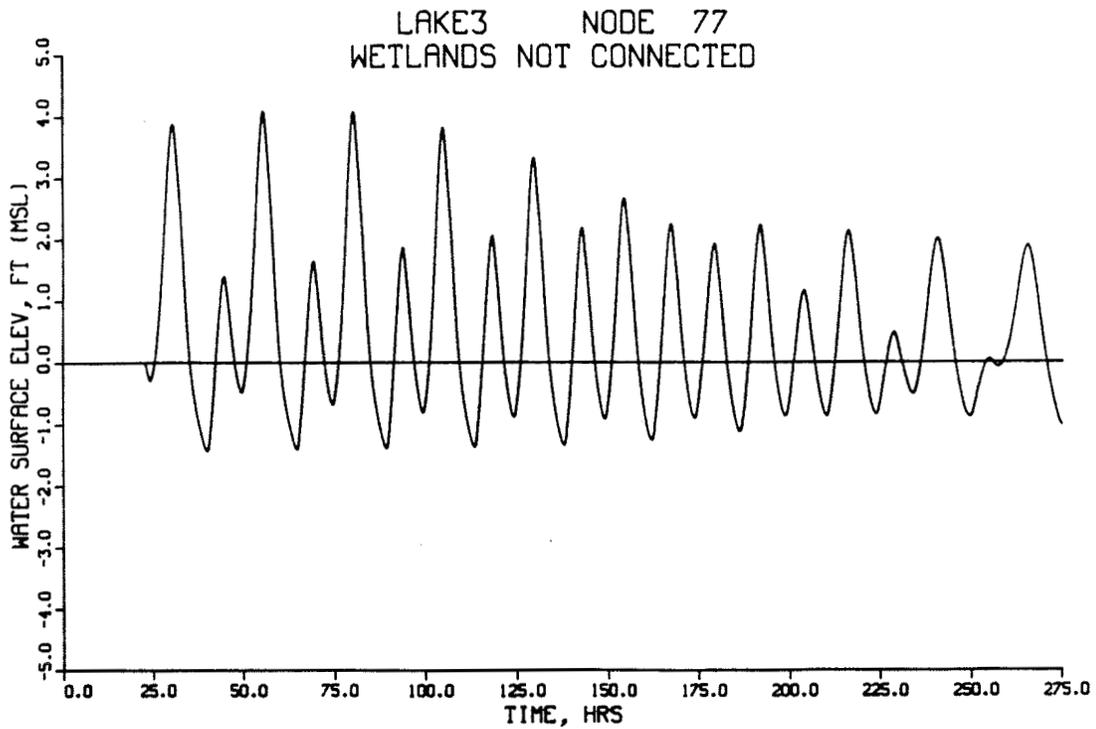


Figure G18. Tidal elevations in proposed marina,
non-navigable entrance channel closed

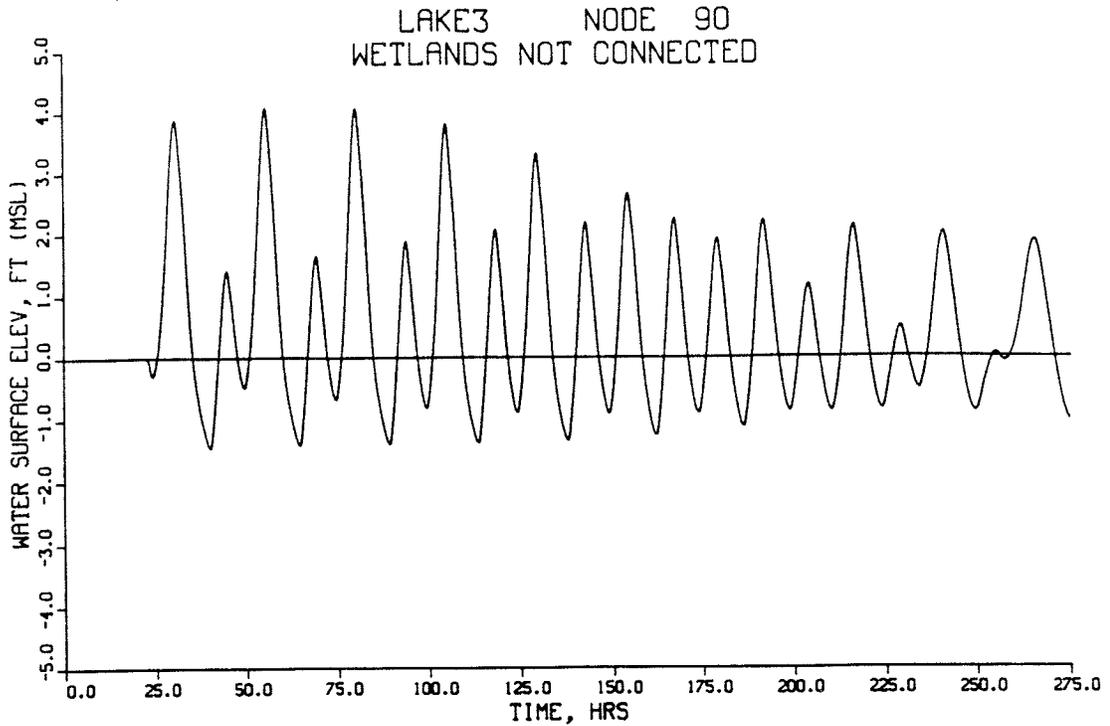


Figure G19. Tidal elevations in proposed marina,
non-navigable entrance channel closed

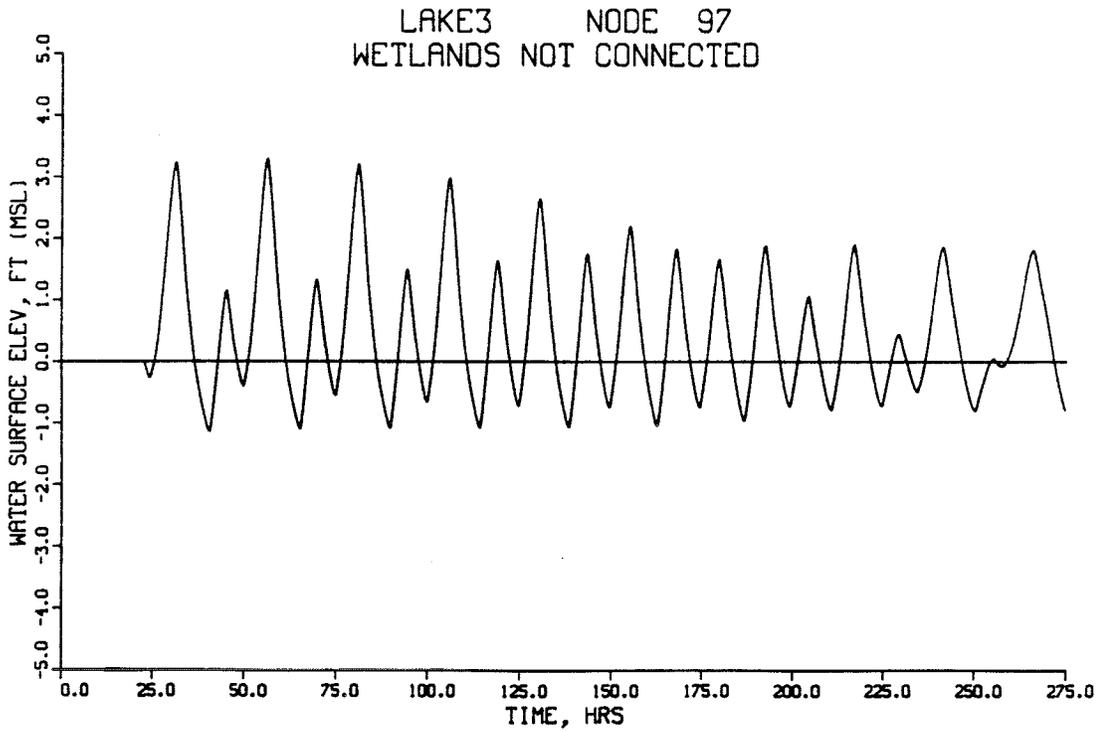


Figure G20. Tidal elevations in full tidal wetlands,
non-navigable entrance channel closed

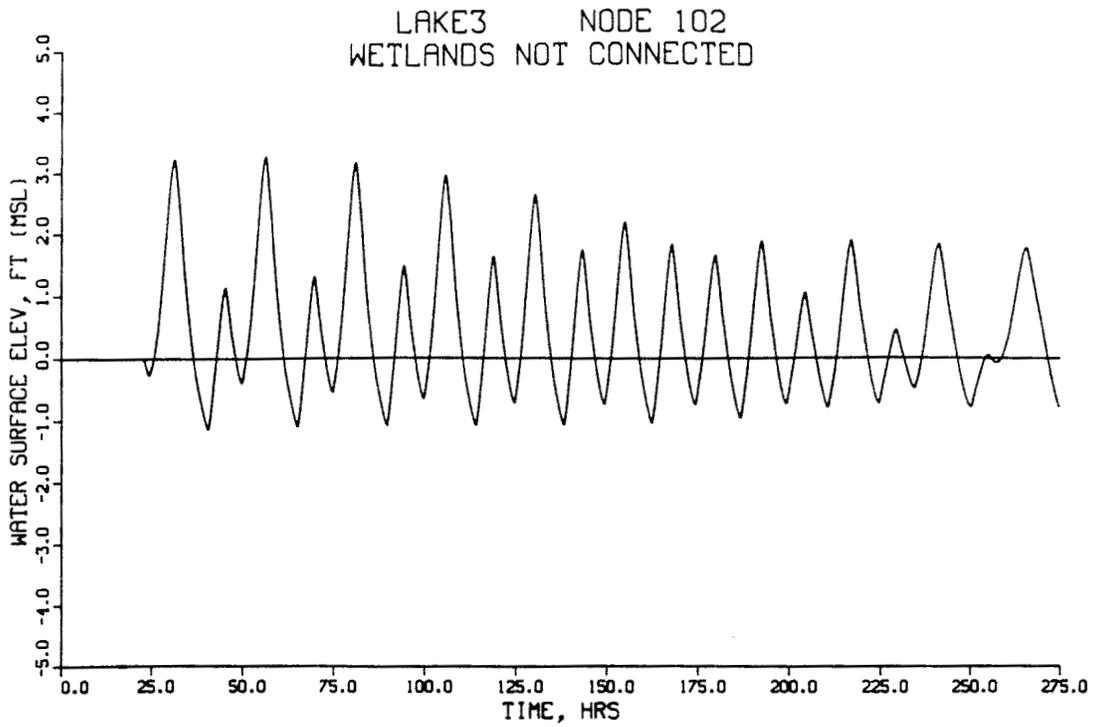


Figure G21. Tidal elevations in full tidal wetlands,
non-navigable entrance channel closed

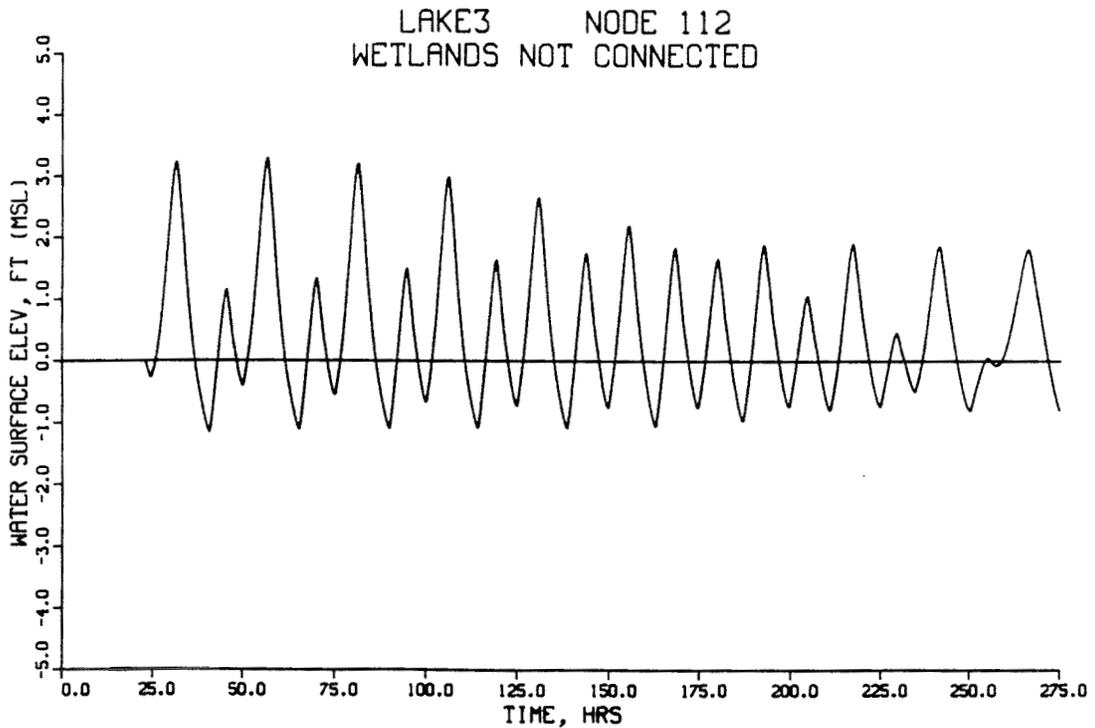


Figure G22. Tidal elevations in full tidal wetlands,
non-navigable entrance channel closed

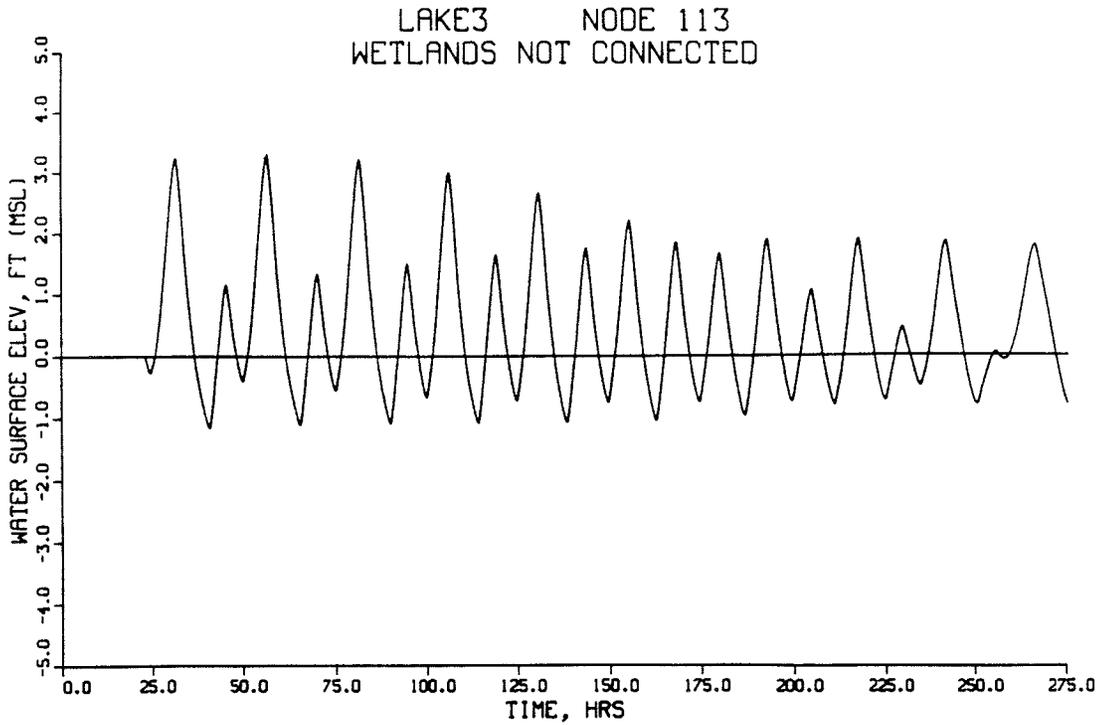


Figure G23. Tidal elevations in full tidal wetlands,
non-navigable entrance channel closed

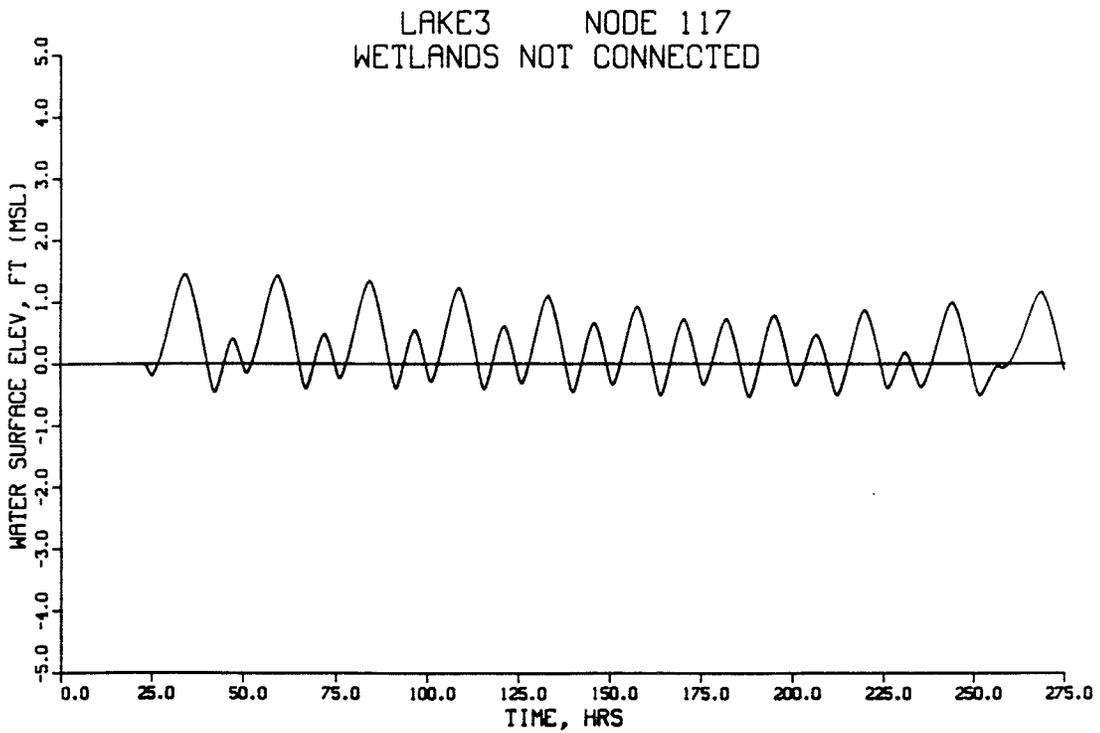


Figure G24. Tidal elevations in muted tidal wetlands,
non-navigable entrance channel closed

LAKE3 NODE 123
WETLANDS NOT CONNECTED

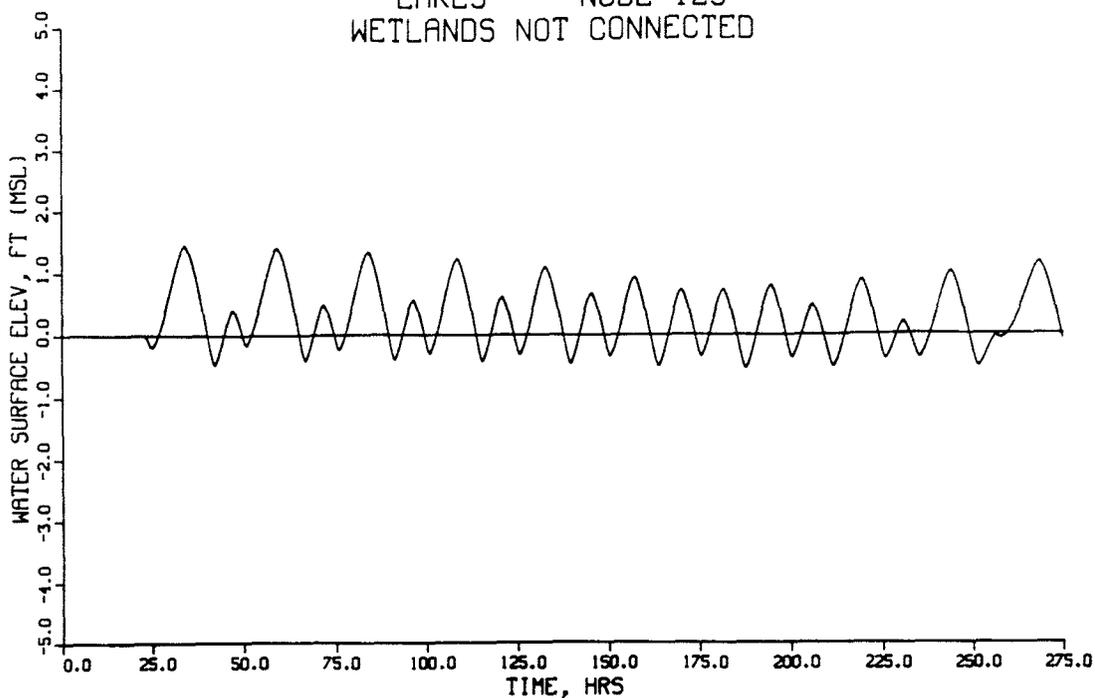


Figure G25. Tidal elevations in muted tidal wetlands,
non-navigable entrance channel closed

LAKE3 NODE 129
WETLANDS NOT CONNECTED

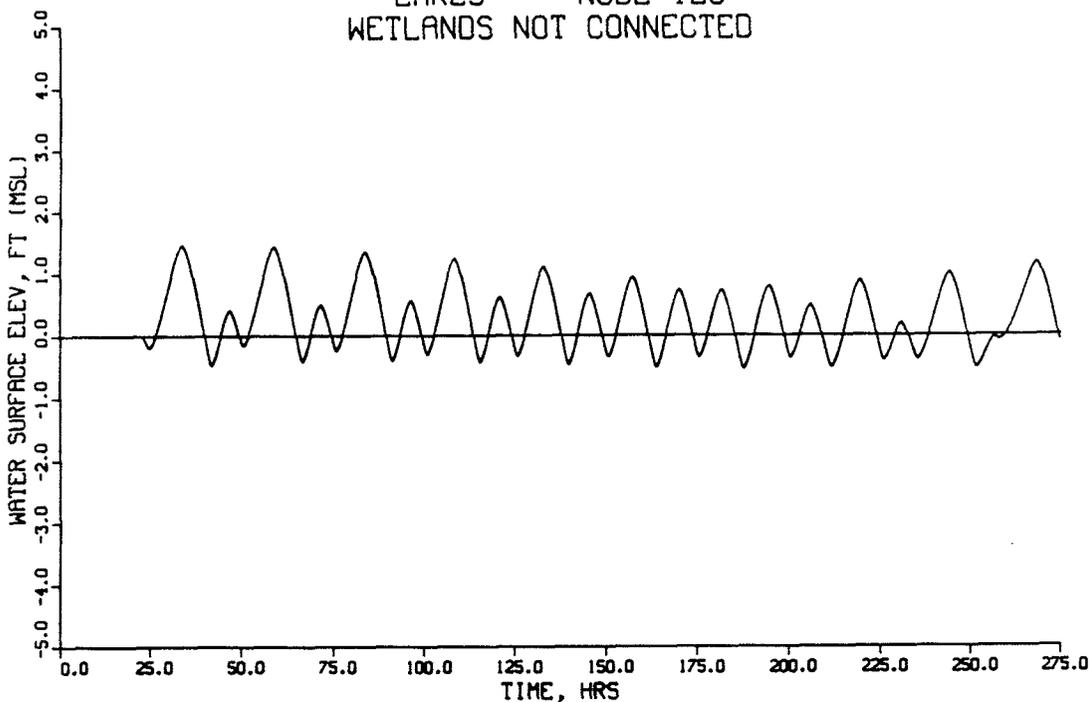


Figure G26. Tidal elevations in muted tidal wetlands,
non-navigable entrance channel closed

LAKE3 NODE 132
WETLANDS NOT CONNECTED

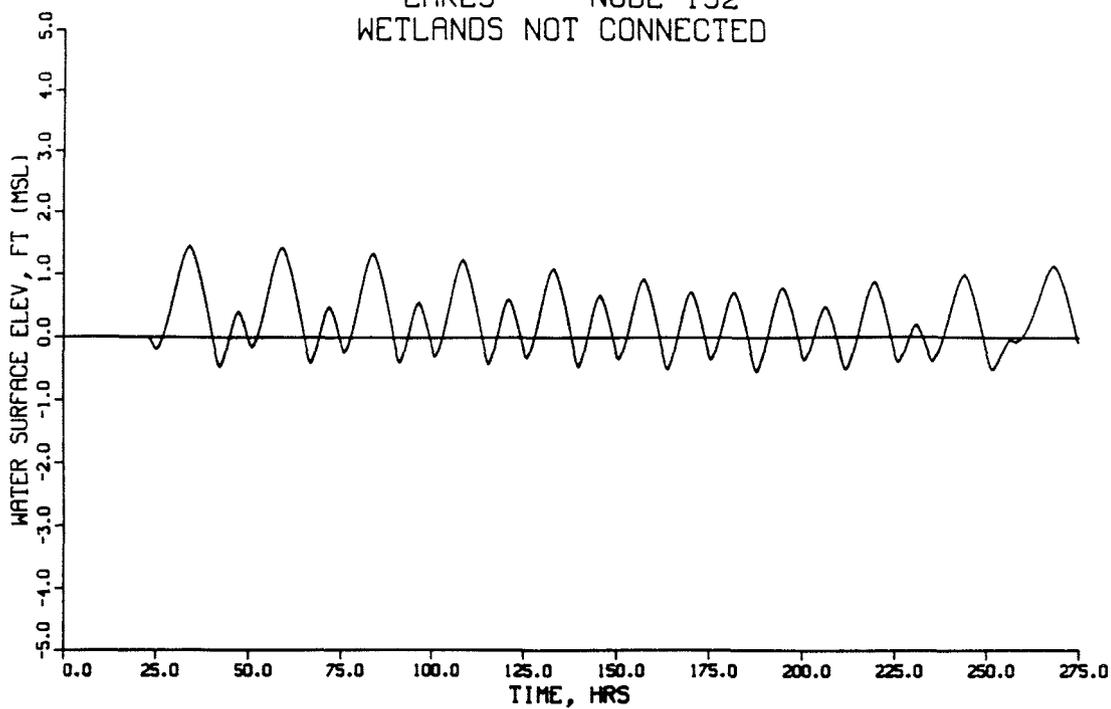


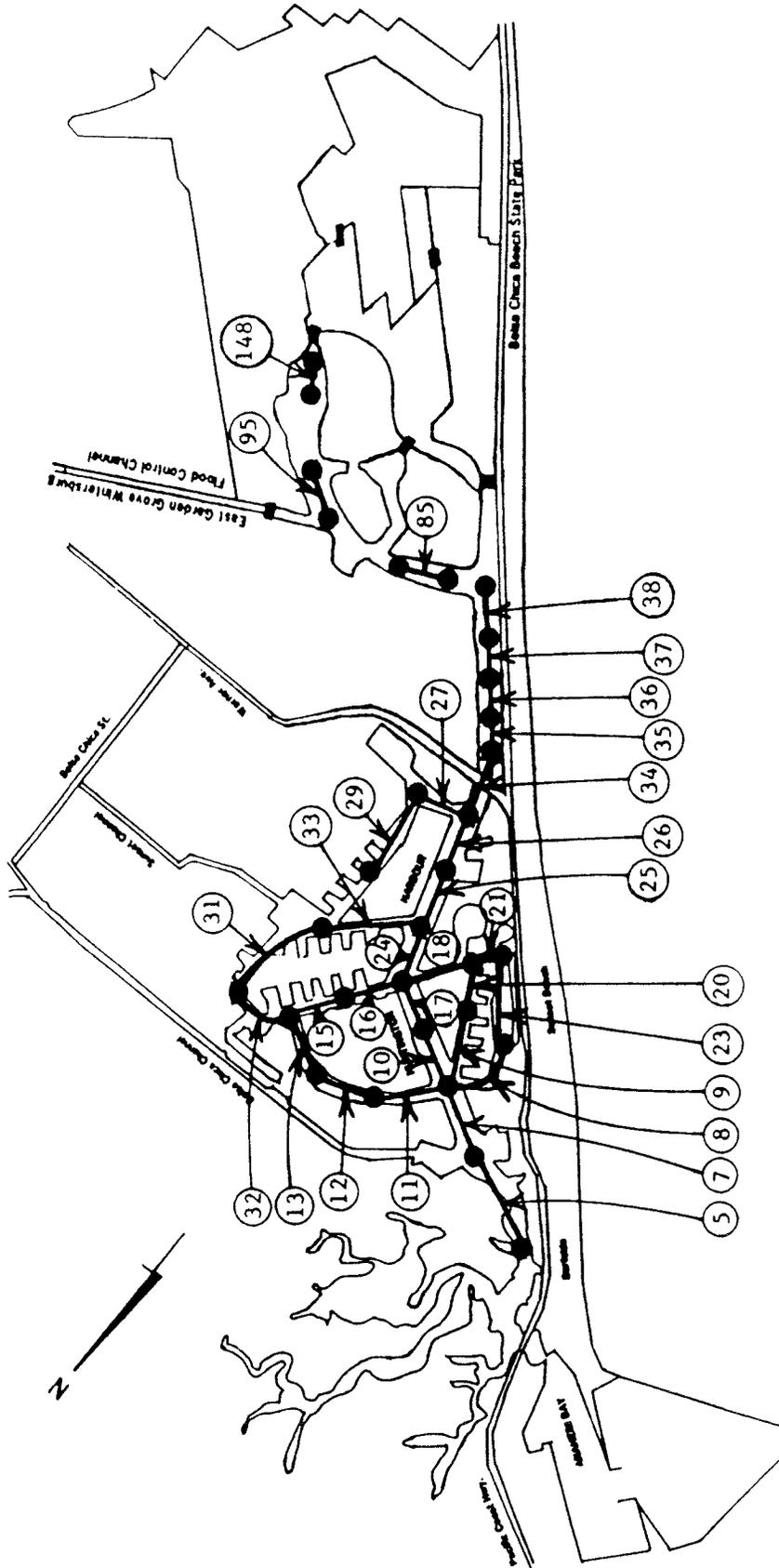
Figure G27. Tidal elevations in muted tidal wetlands,
non-navigable entrance channel closed

APPENDIX H:

LAKE 3

NON-NAVIGABLE ENTRANCE CHANNEL CLOSED

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

LAKE 3
 Location of links for displaying
 average channel velocities under Lake 3 conditions

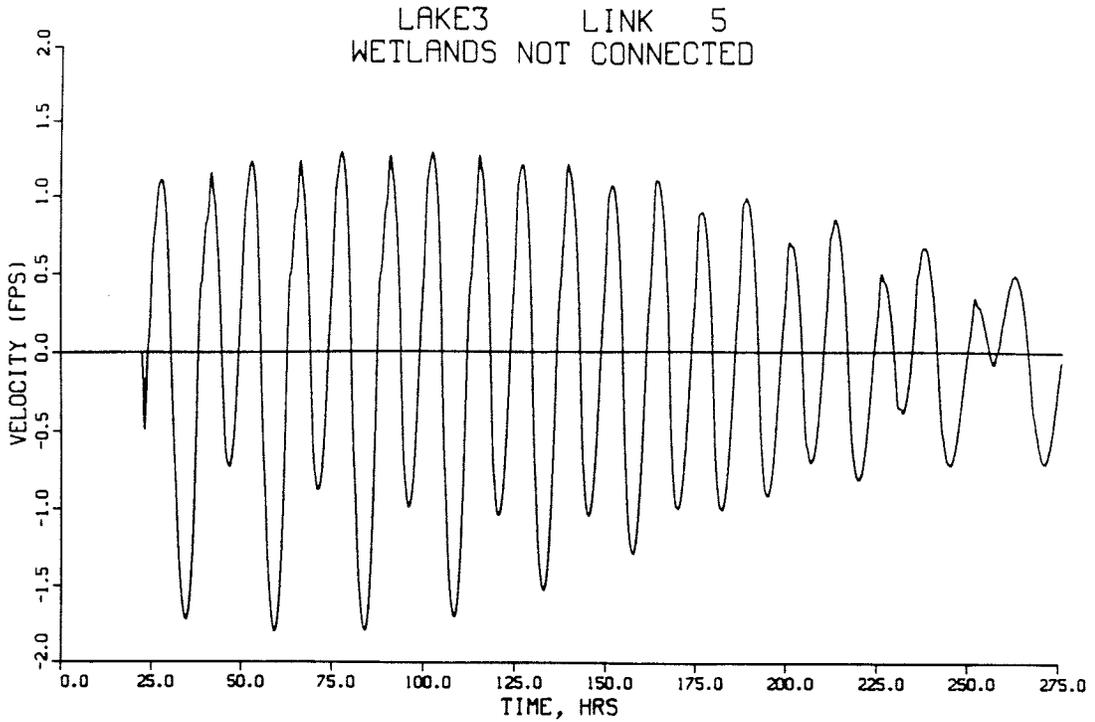


Figure H1. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

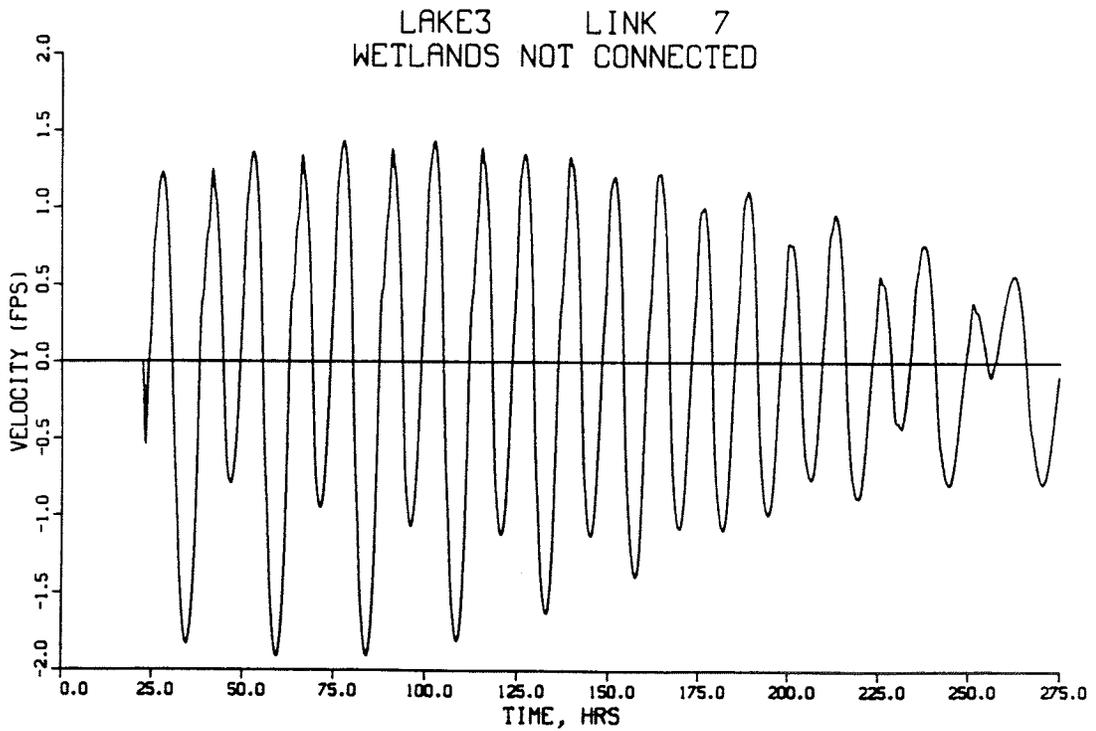


Figure H2. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

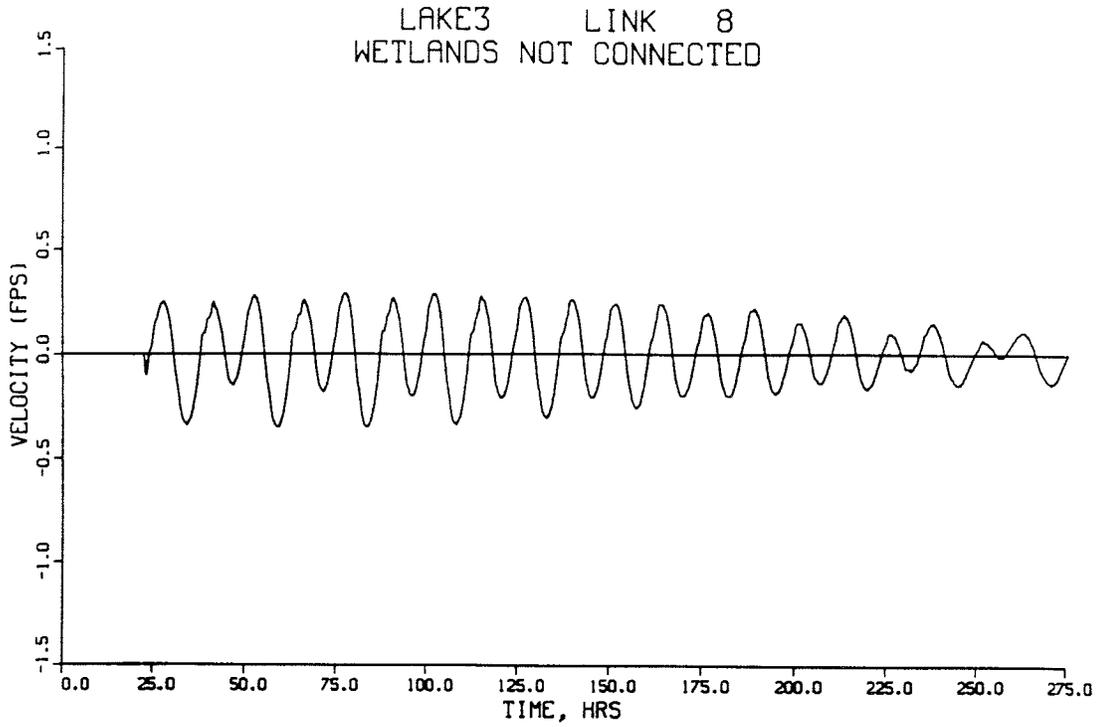


Figure H3. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

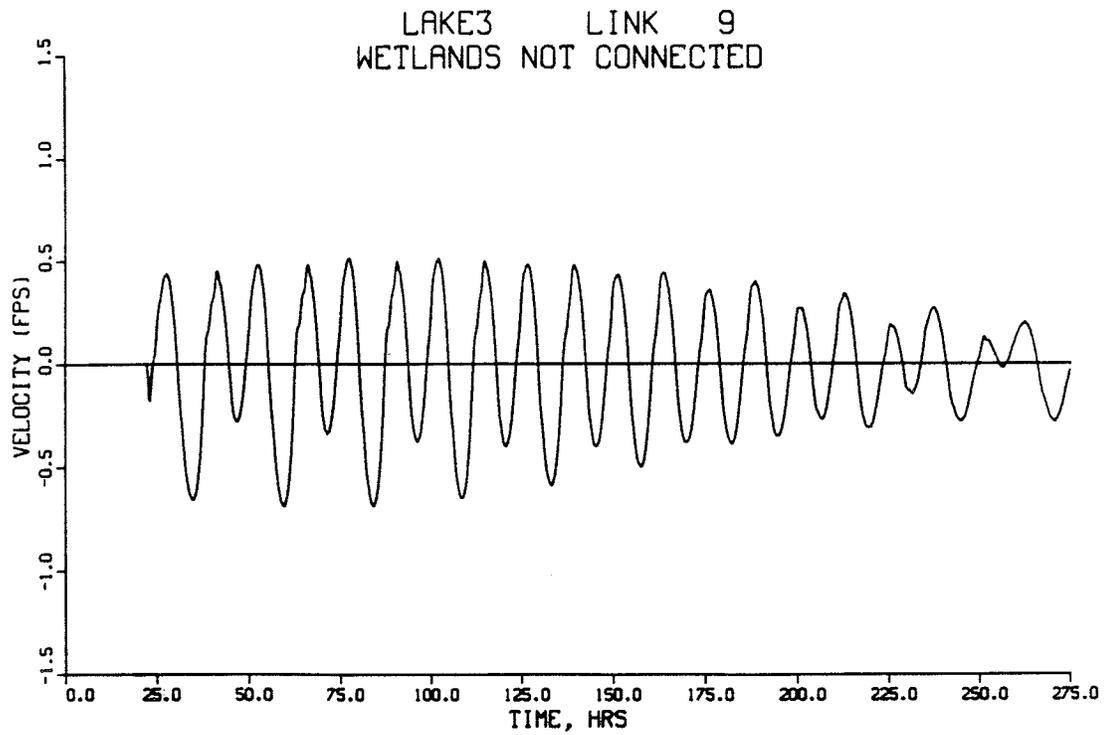


Figure H4. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

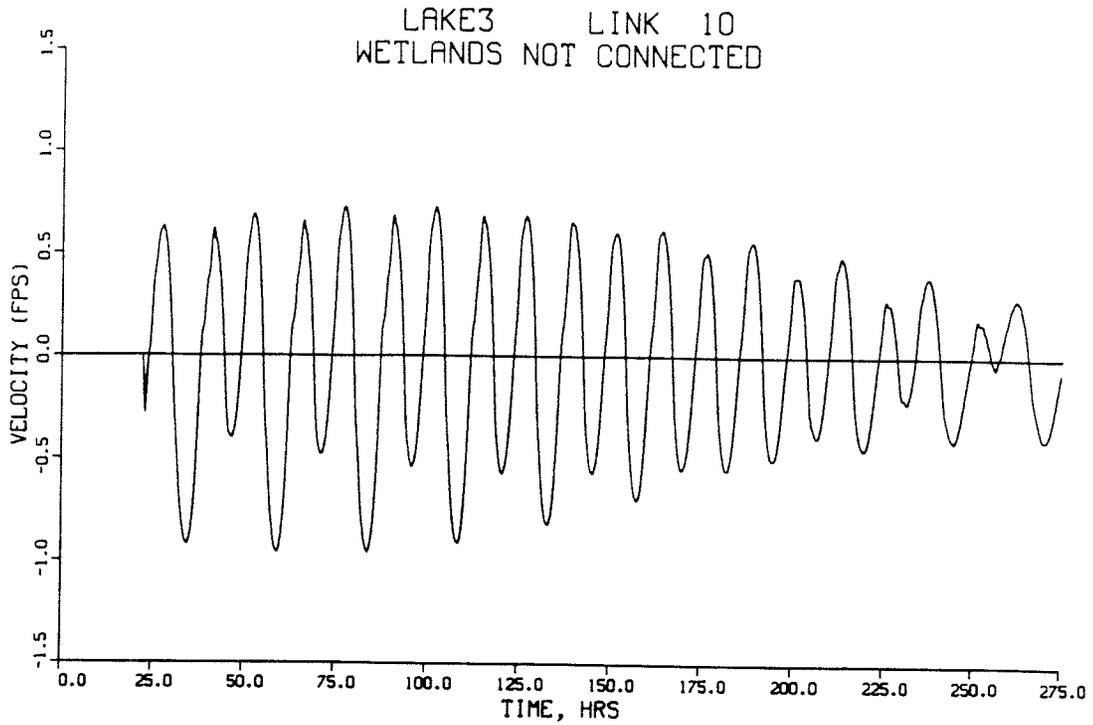


Figure H5. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

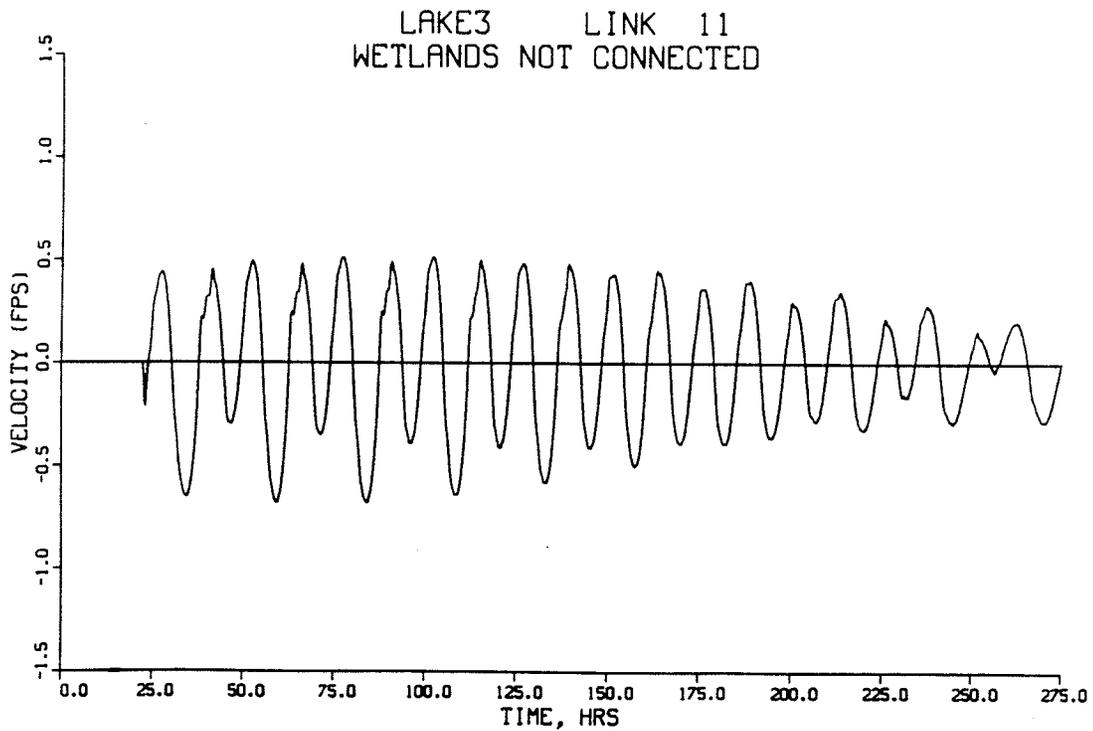


Figure H6. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

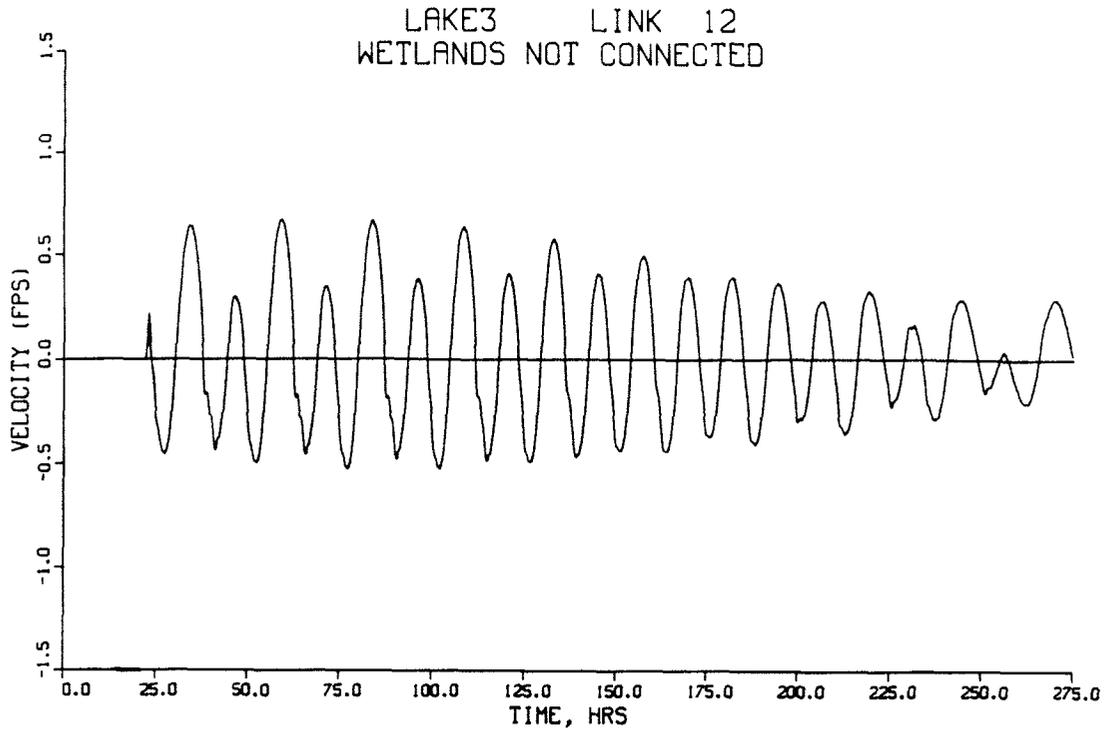


Figure H7. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

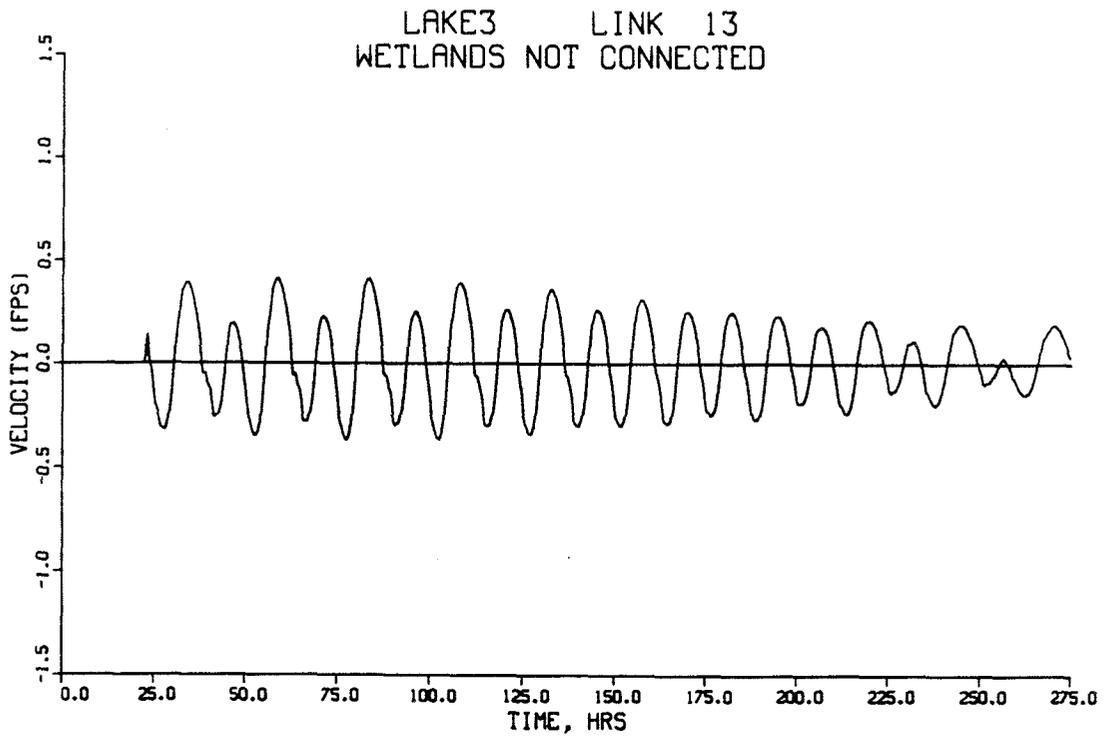


Figure H8. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 15
WETLANDS NOT CONNECTED

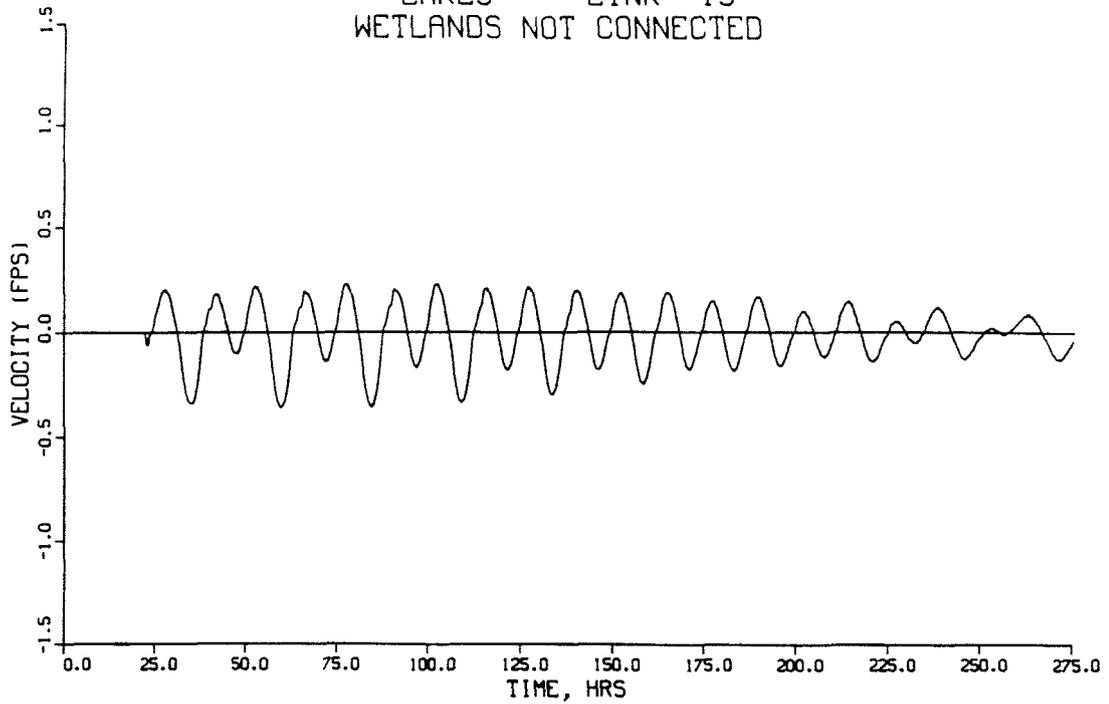


Figure H9. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 16
WETLANDS NOT CONNECTED

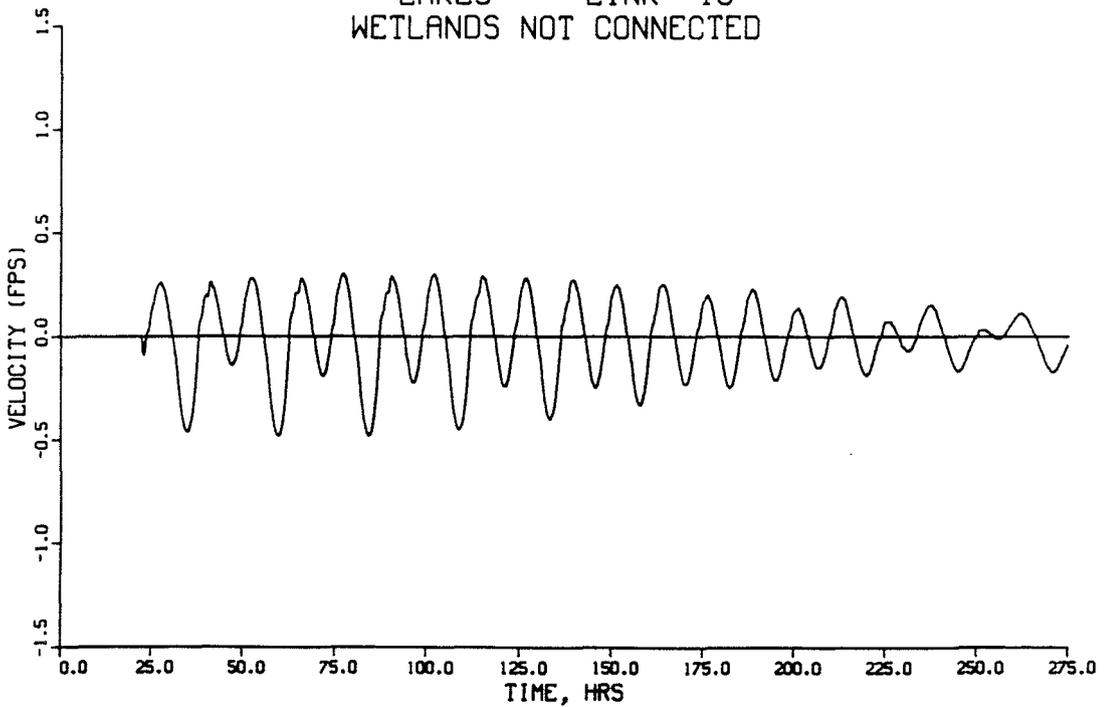


Figure H10. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

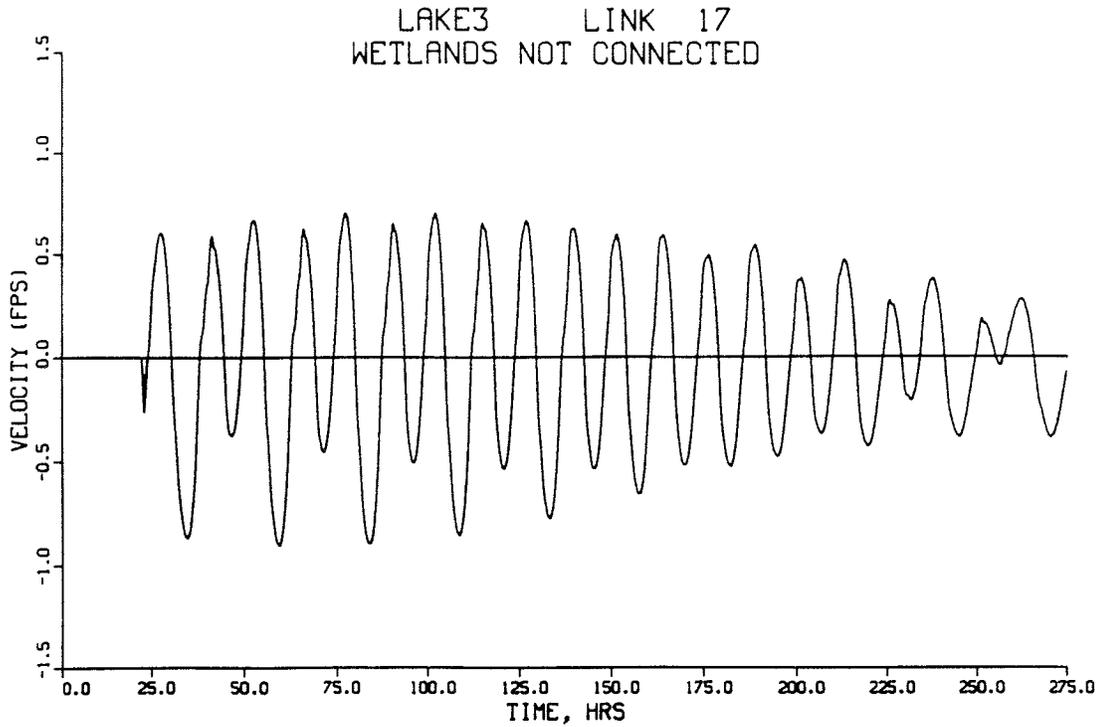


Figure H11. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

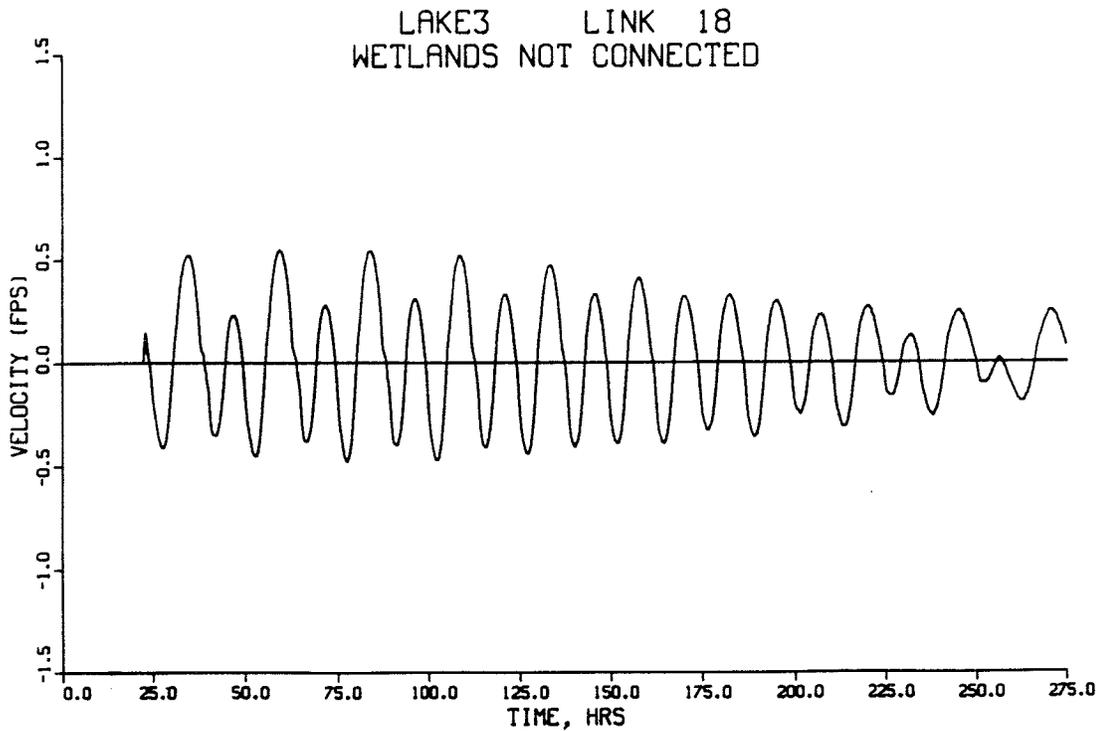


Figure H12. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 20
WETLANDS NOT CONNECTED

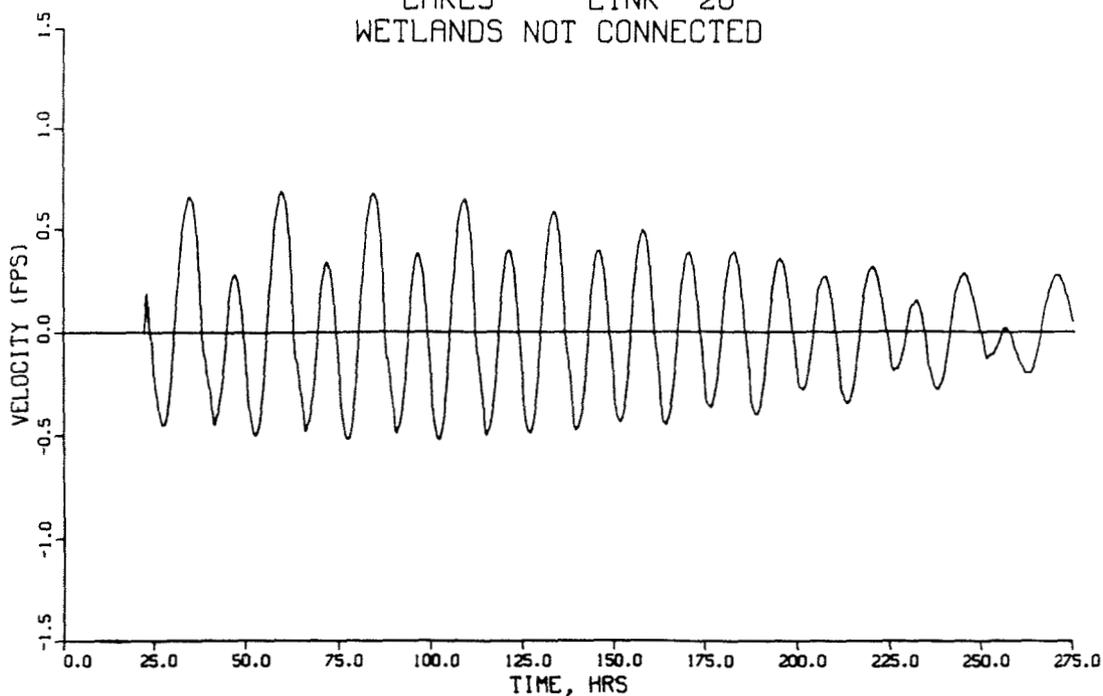


Figure H13. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 21
WETLANDS NOT CONNECTED

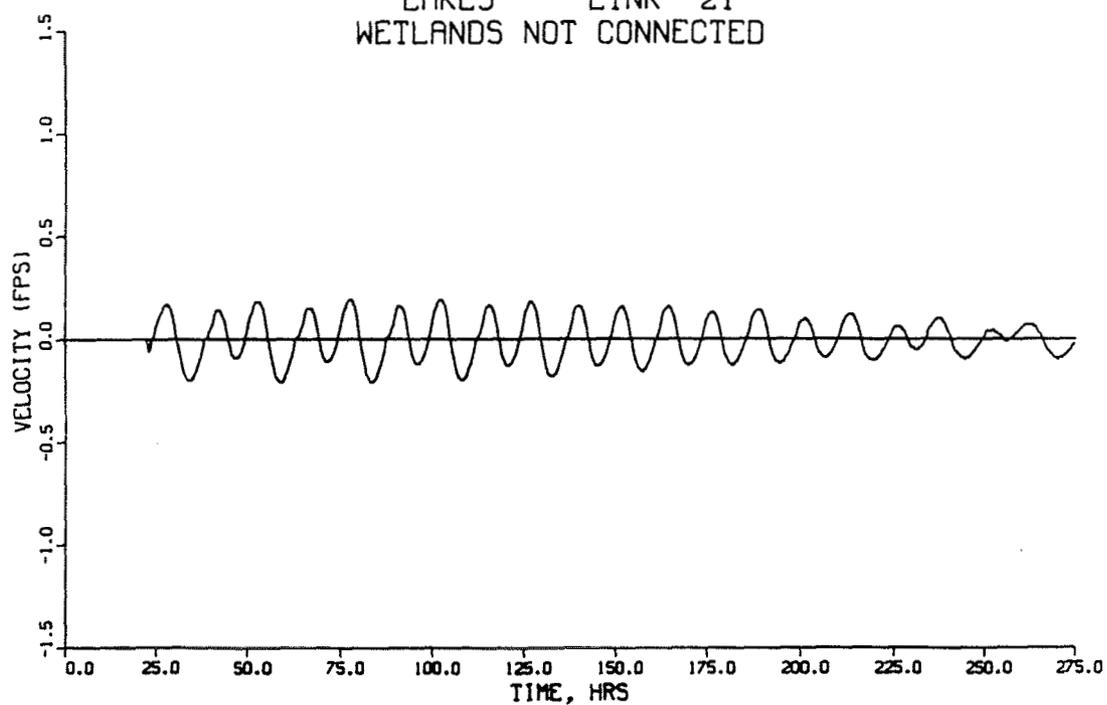


Figure H14. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

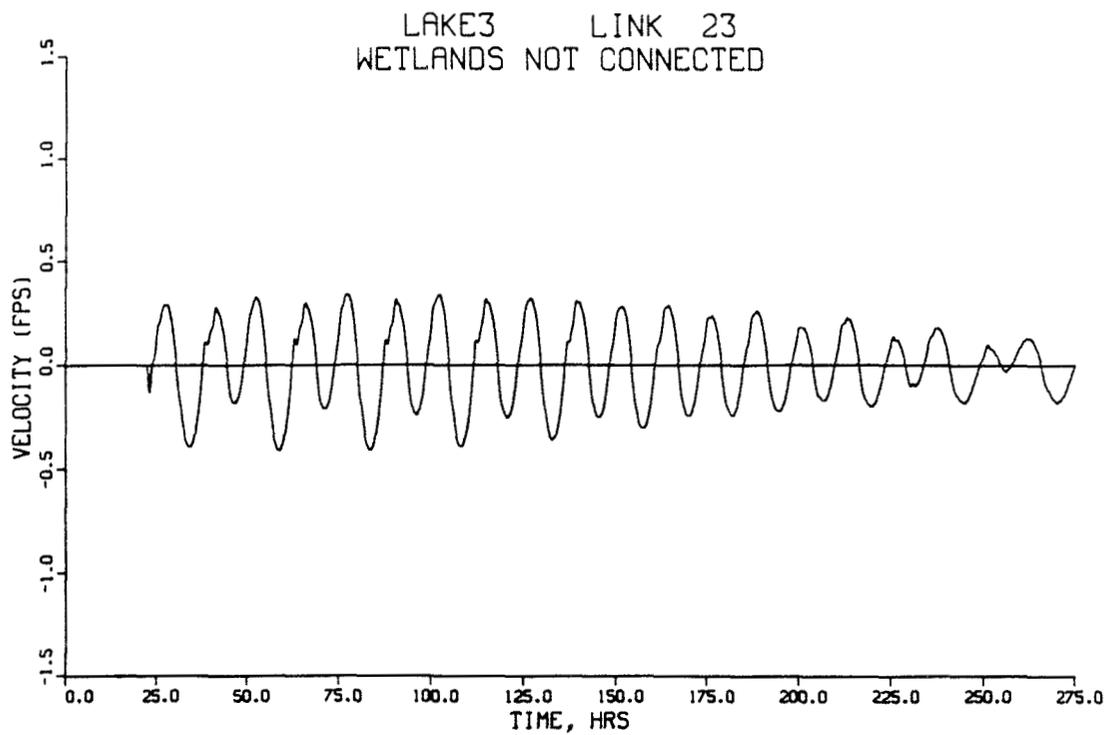


Figure H15. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

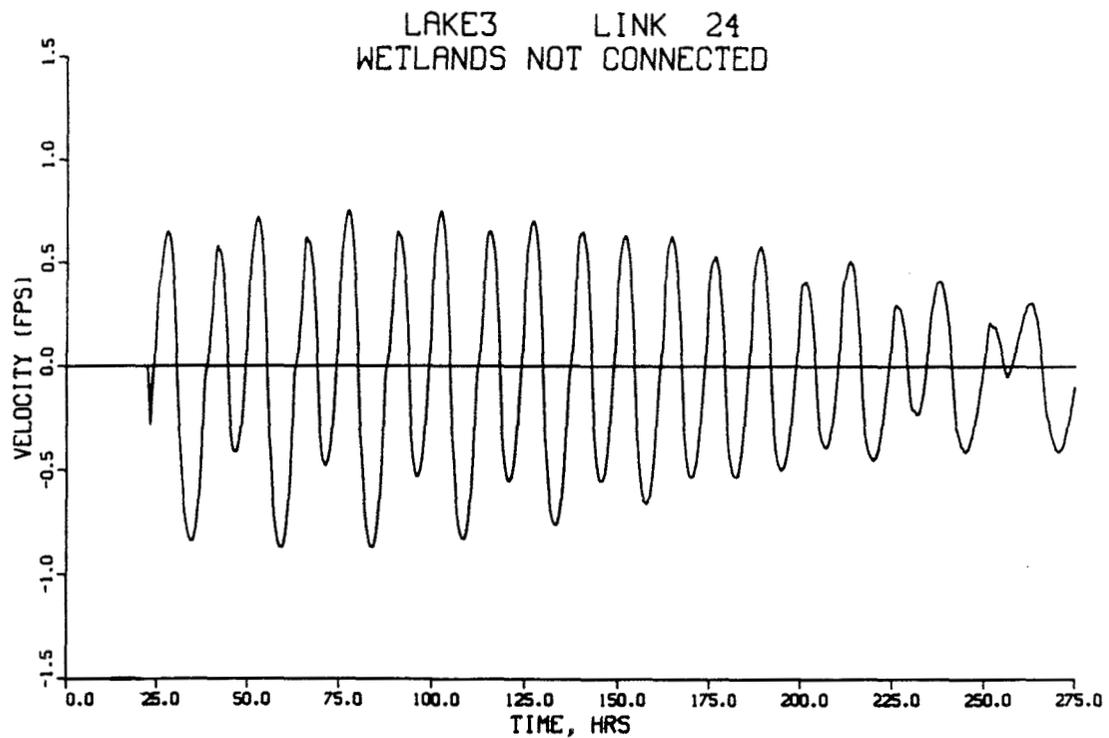


Figure H16. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

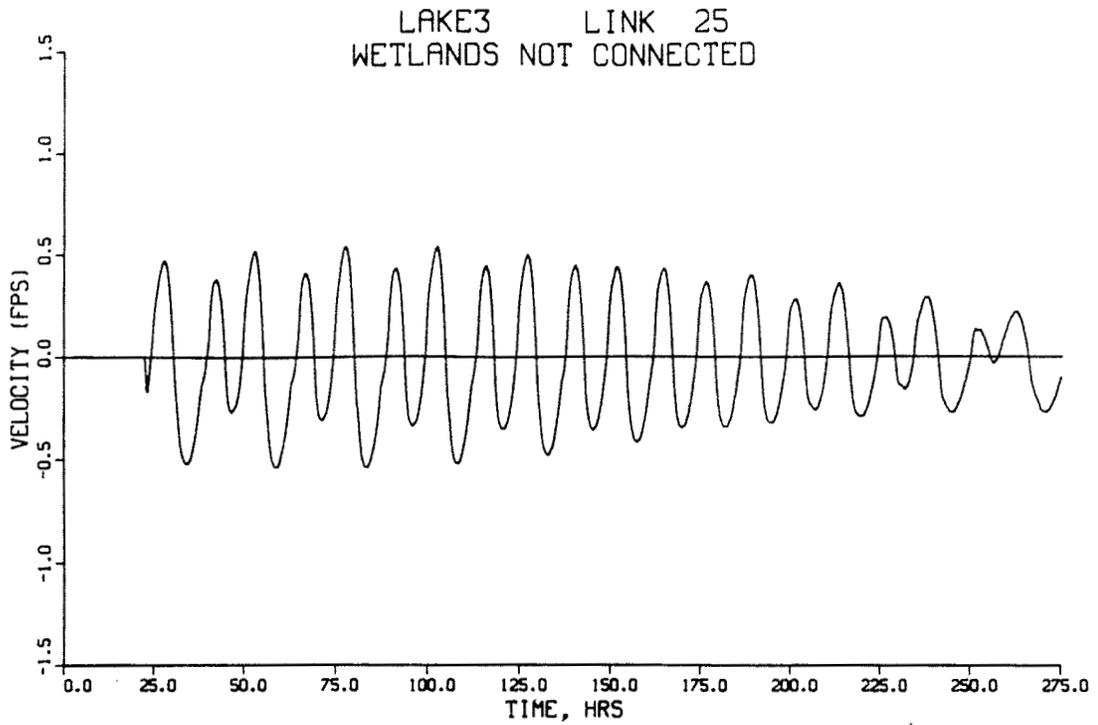


Figure H17. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

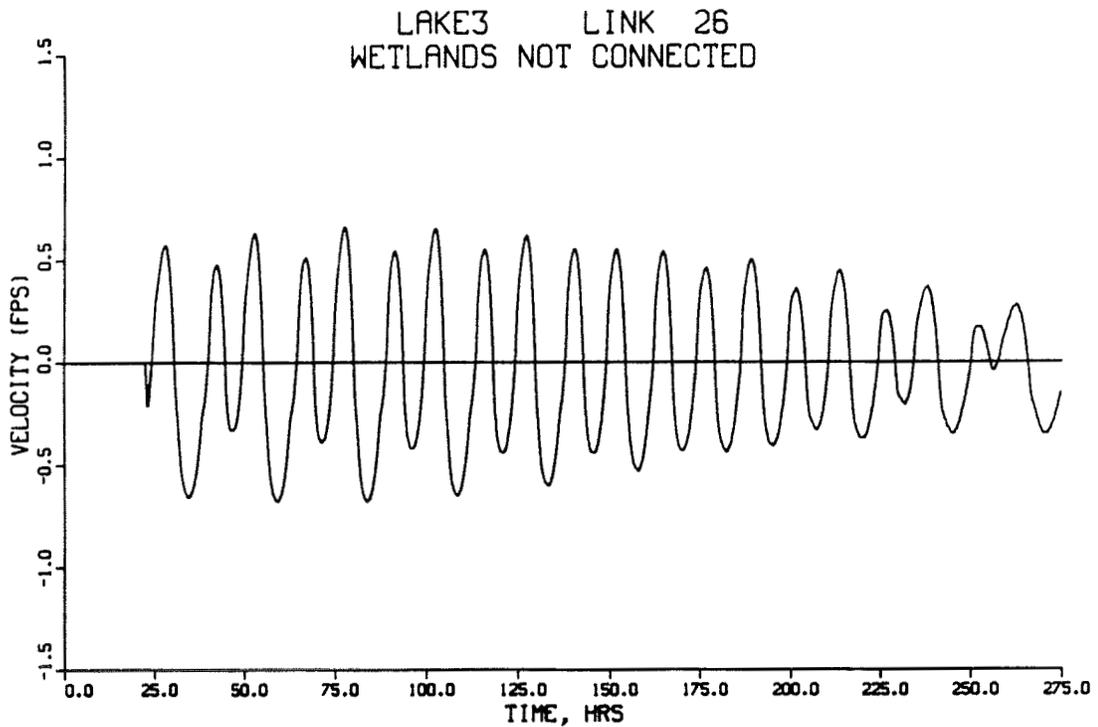


Figure H18. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 27
WETLANDS NOT CONNECTED

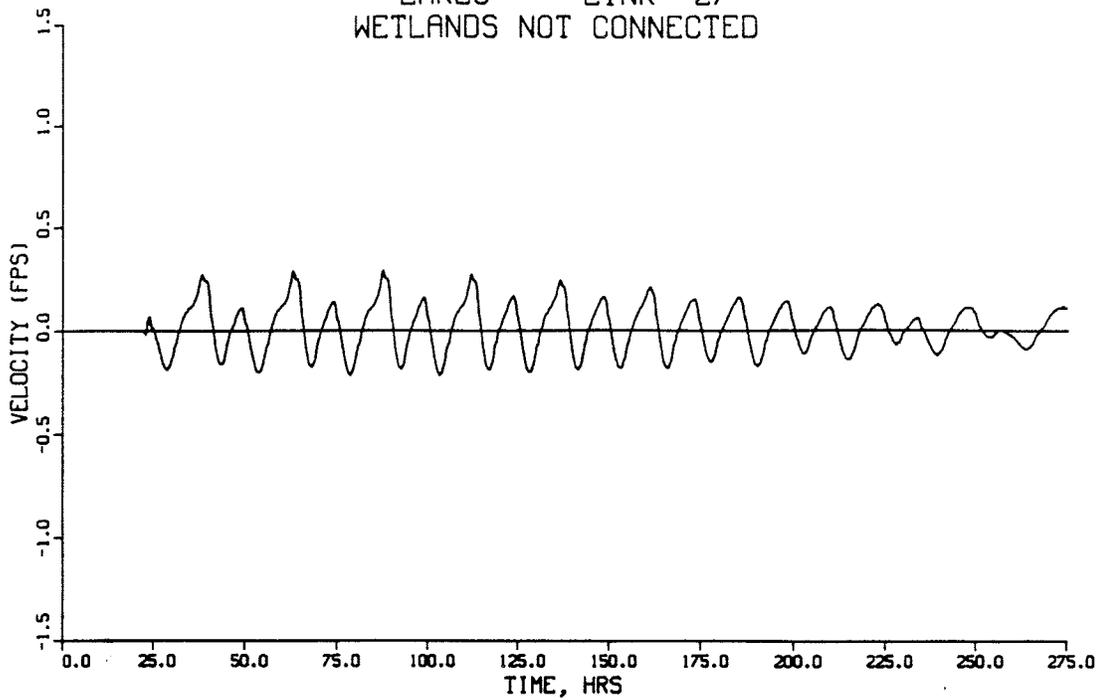


Figure H19. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 29
WETLANDS NOT CONNECTED

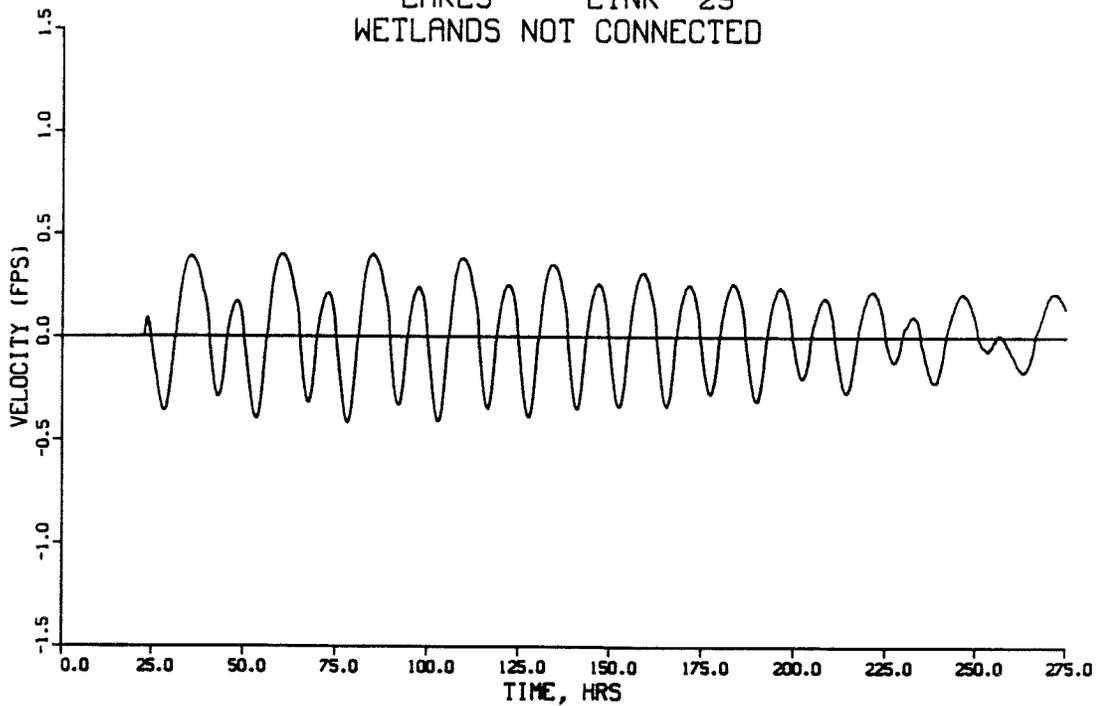


Figure H20. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 31
WETLANDS NOT CONNECTED

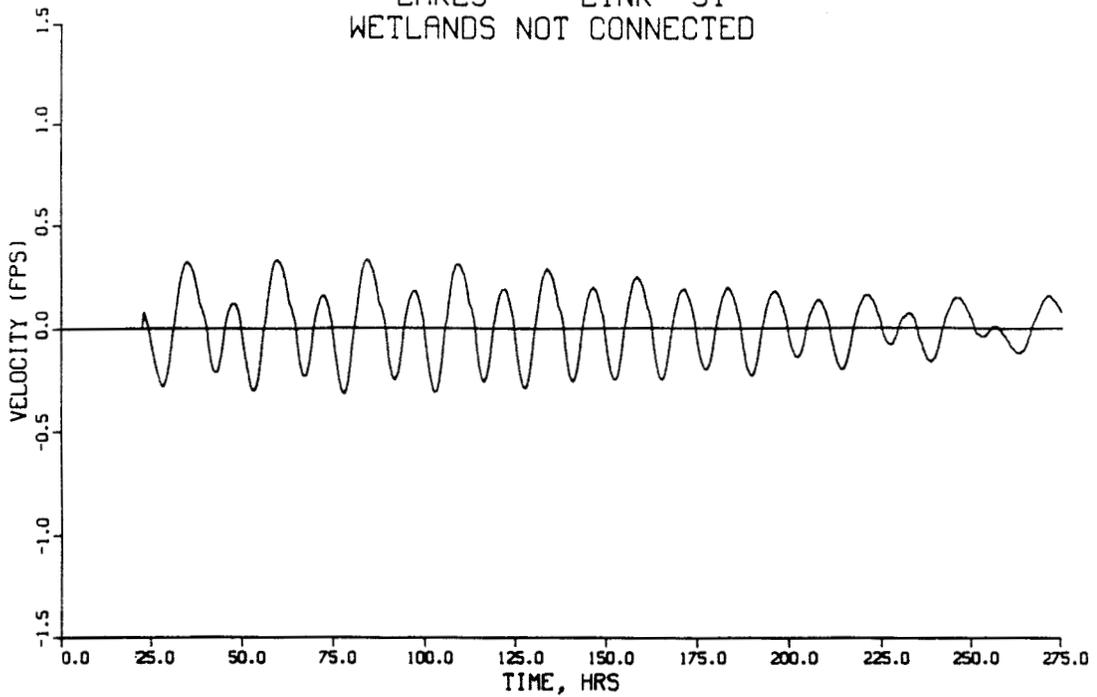


Figure H21. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

LAKE3 LINK 32
WETLANDS NOT CONNECTED

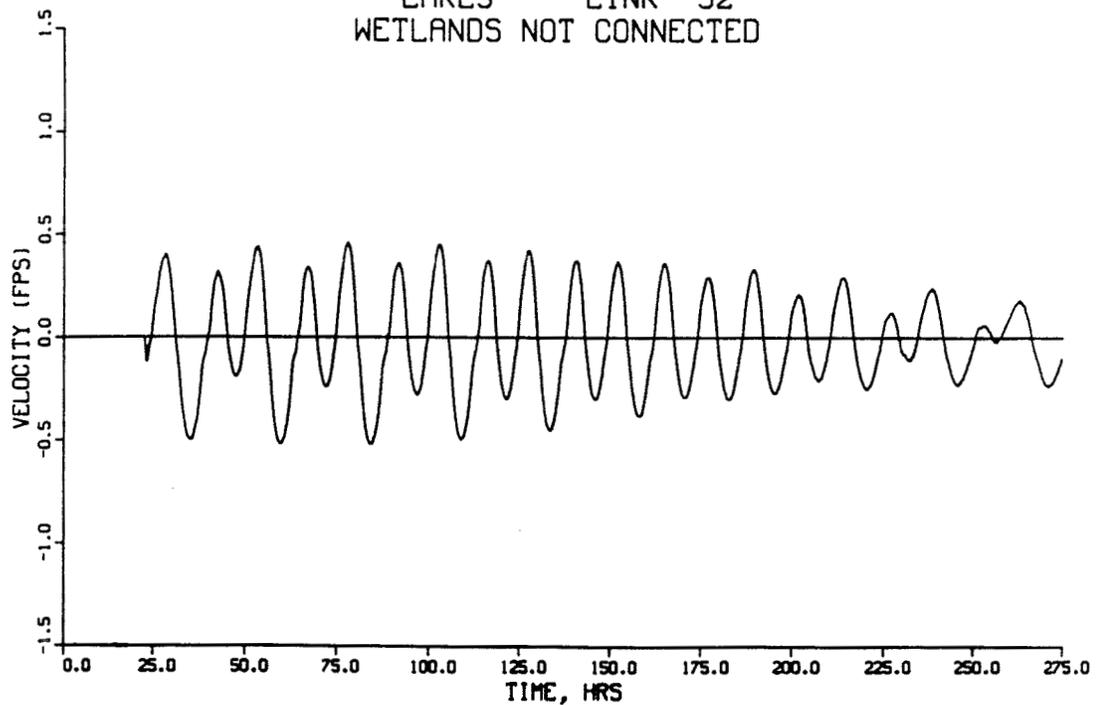


Figure H22. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

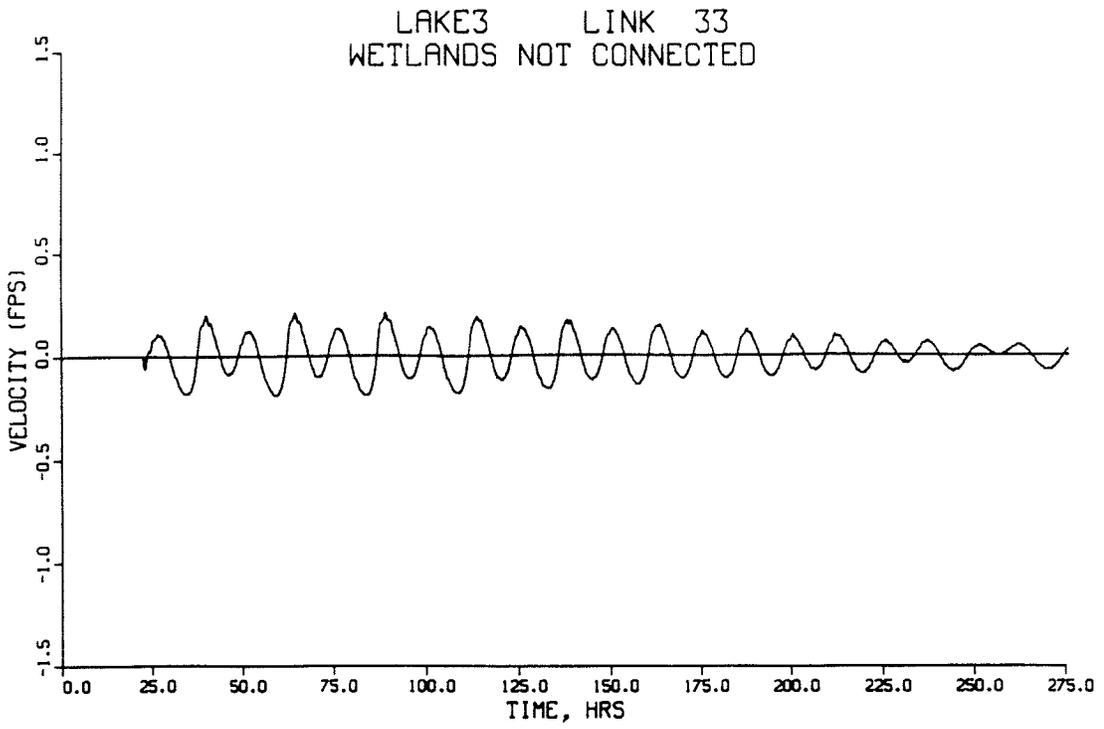


Figure H23. Average channel velocities in Huntington Harbour, non-navigable entrance channel closed

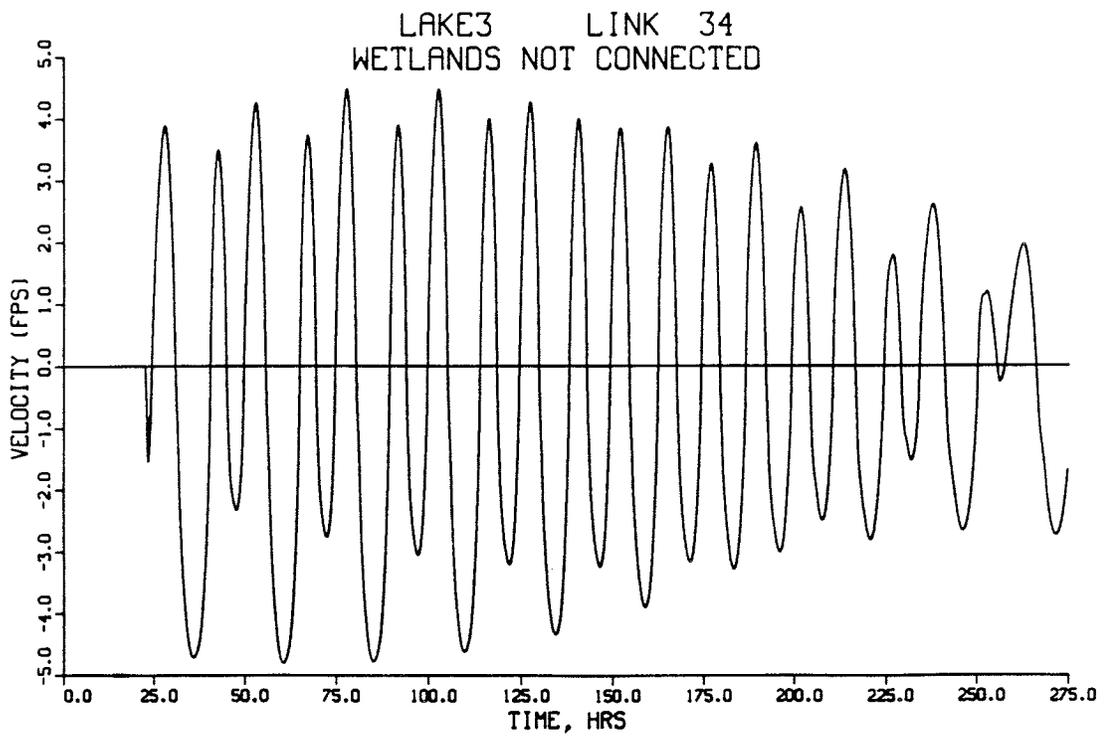


Figure H24. Average channel velocities under Warner Avenue bridge, non-navigable entrance channel closed

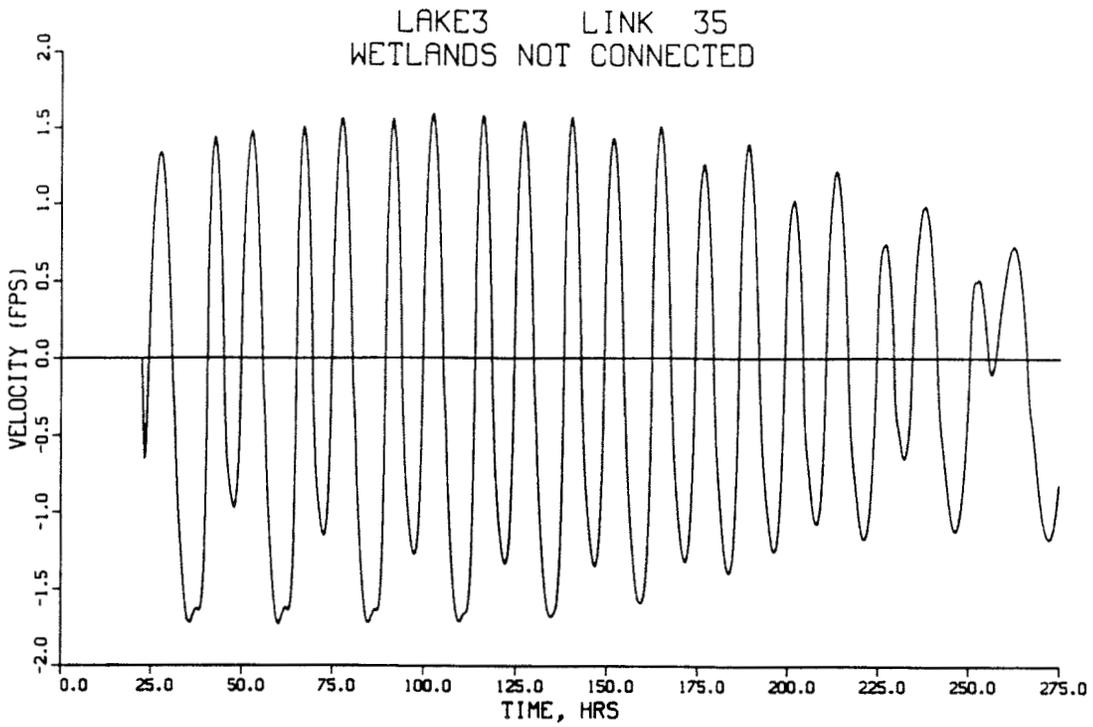


Figure H25. Average channel velocities in Outer Bolsa Bay, non-navigable entrance channel closed

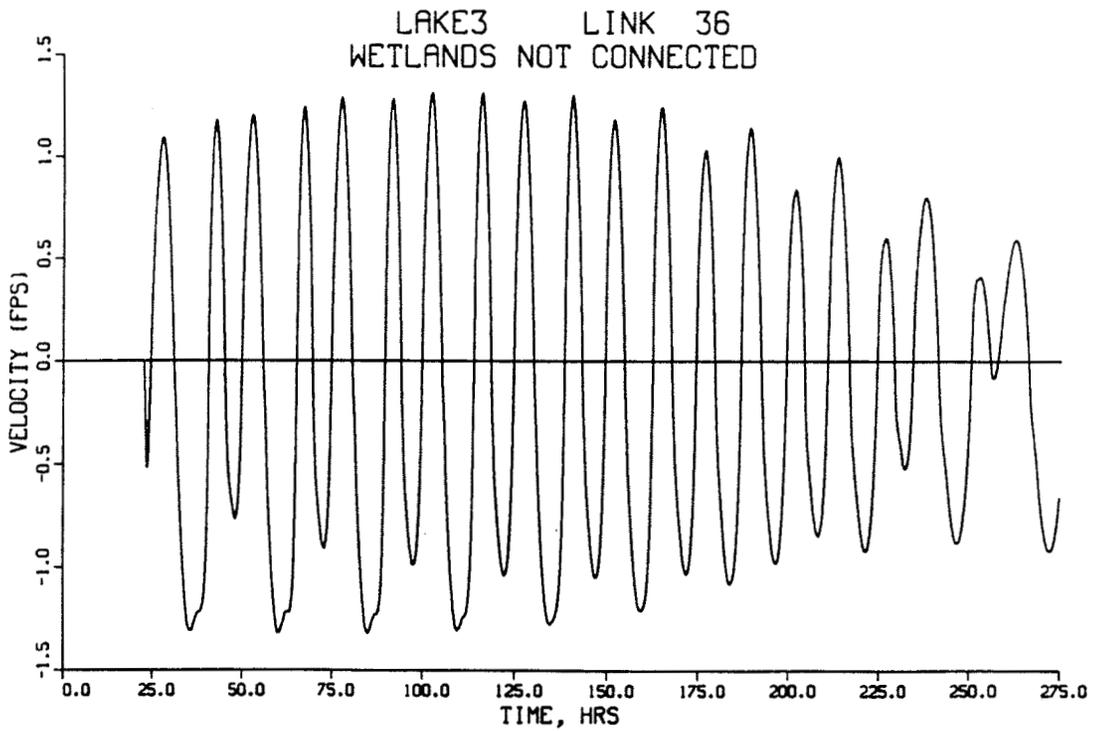


Figure H26. Average channel velocities in Outer Bolsa Bay, non-navigable entrance channel closed

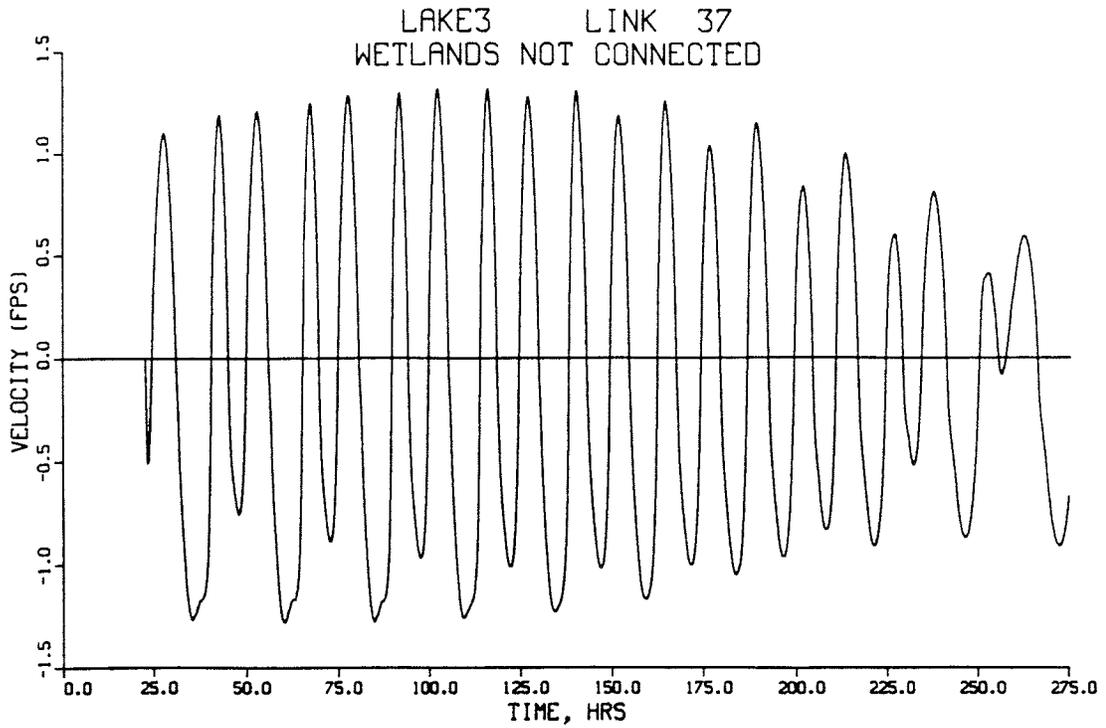


Figure H27. Average channel velocities in Outer Bolsa Bay, non-navigable entrance channel closed

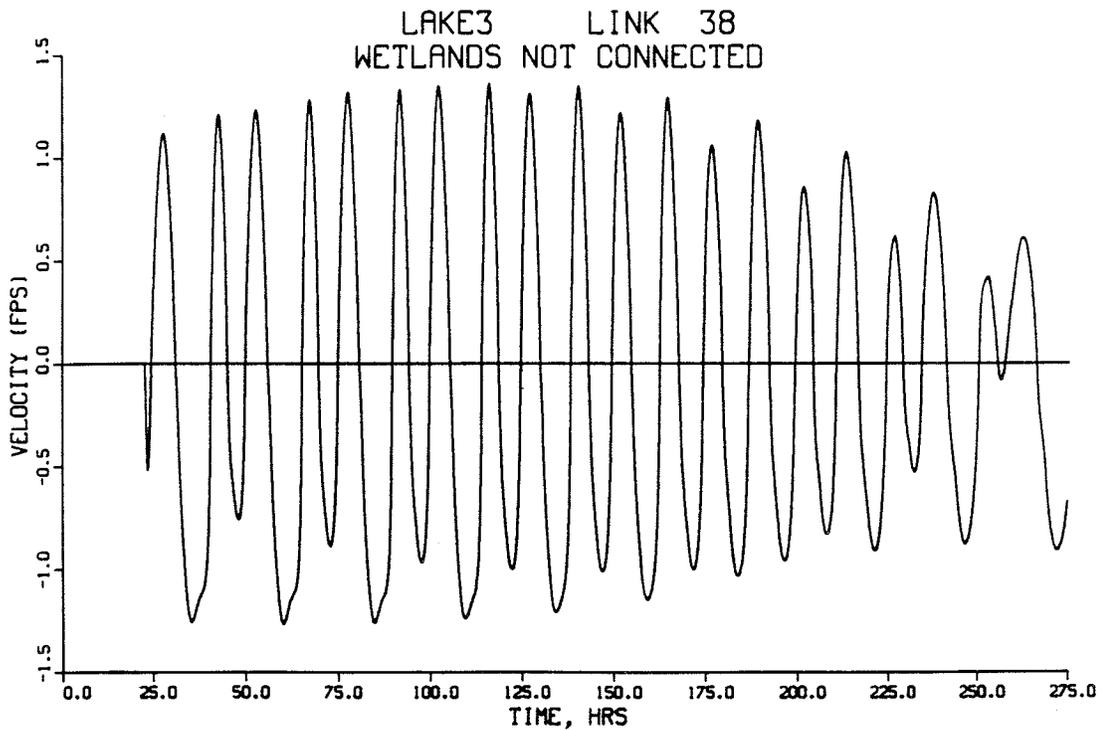


Figure H28. Average channel velocities in Outer Bolsa Bay, non-navigable entrance channel closed

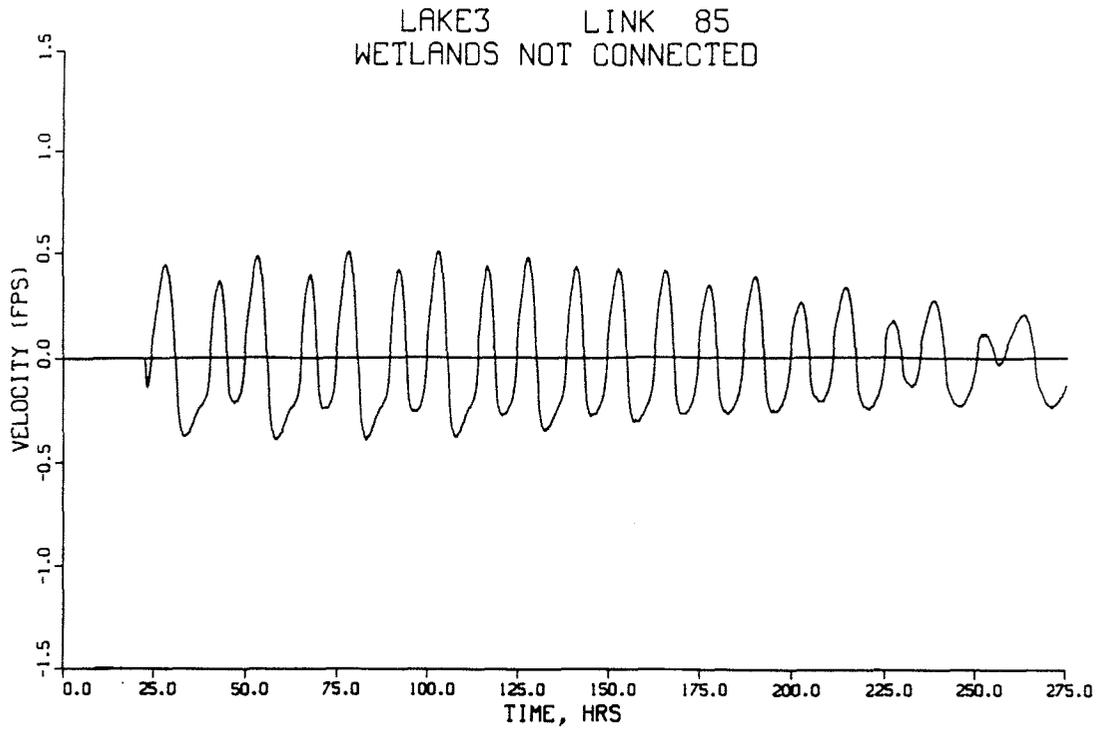


Figure H29. Average channel velocities in proposed marina,
non-navigable entrance channel closed

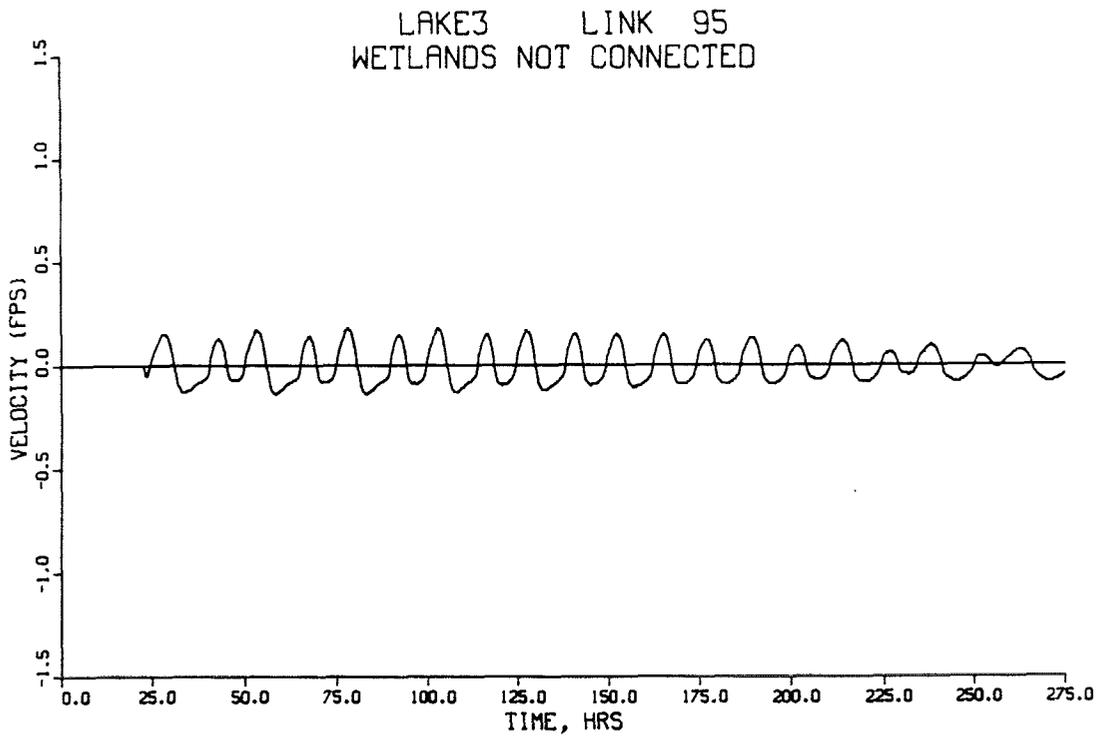


Figure H30. Average channel velocities in proposed marina,
non-navigable entrance channel closed

LAKE2 LINK 148
WETLANDS NOT CONNECTED

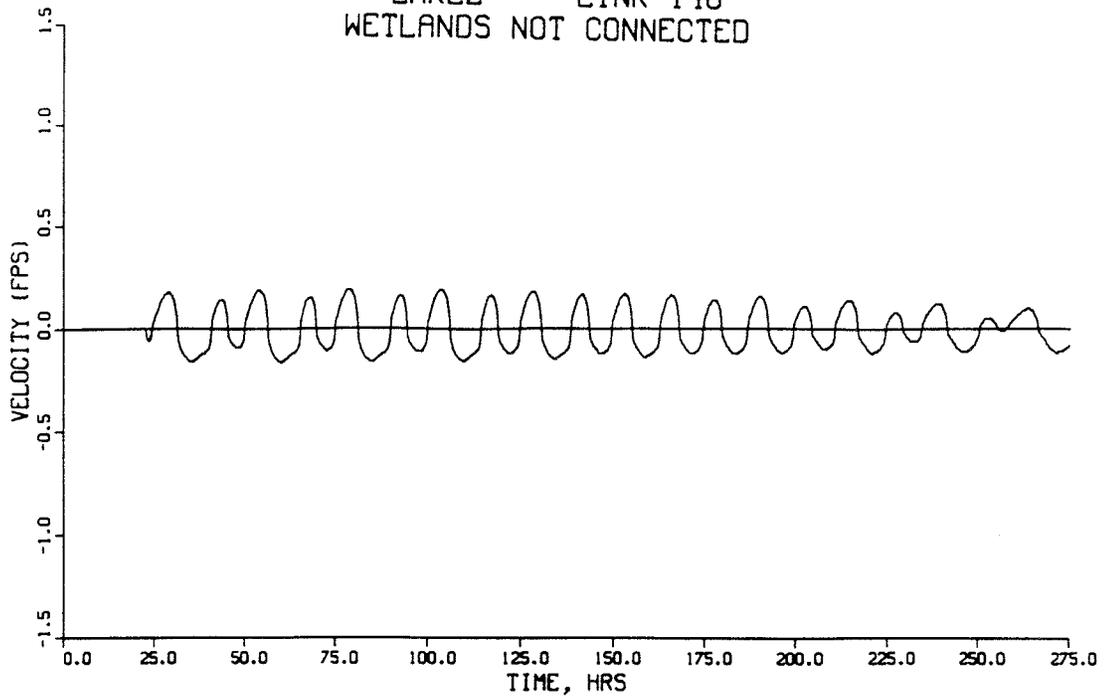


Figure H31. Average channel velocities in proposed marina,
non-navigable entrance channel closed