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LAKE ERIE INTERNATIONAL JETPORT MODEL FEASIBILITY INVESTIGATION--ETC(U)
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TECHNICAL REPORT H-74-6

LAKE ERIE INTERNATIONAL JETPORT MODEL FEASIBILITY INVESTIGATION

Report 17-10

NONTECHNICAL SUMMARY OF PROJECT

by

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Report 10 of a Series

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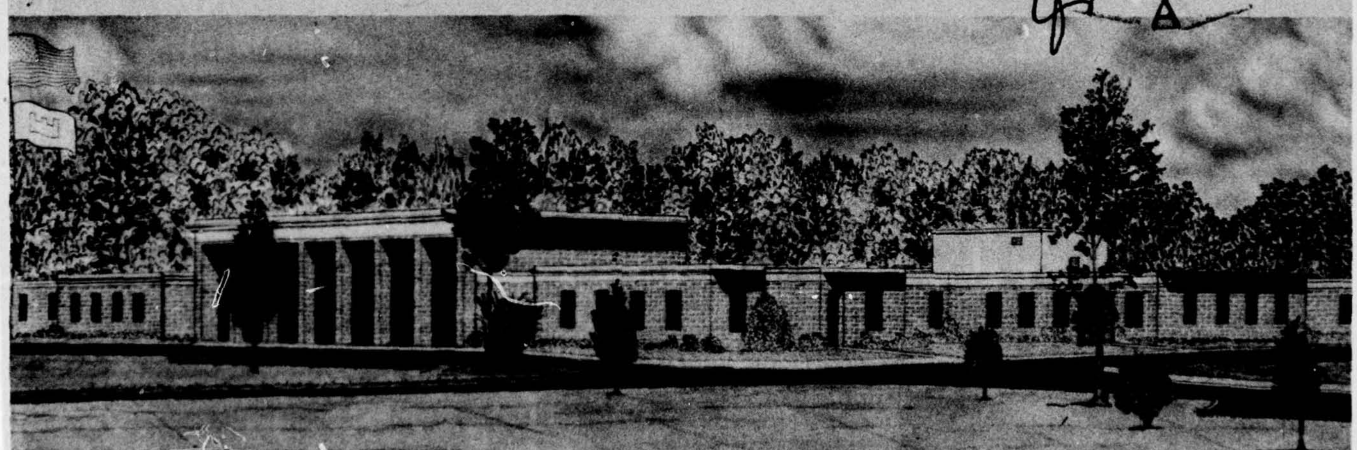

Prepared for Lake Erie Regional Transportation Authority
Cleveland, Ohio 44113

Under Task 17 of LERTA Third-Phase
Airport Feasibility Study

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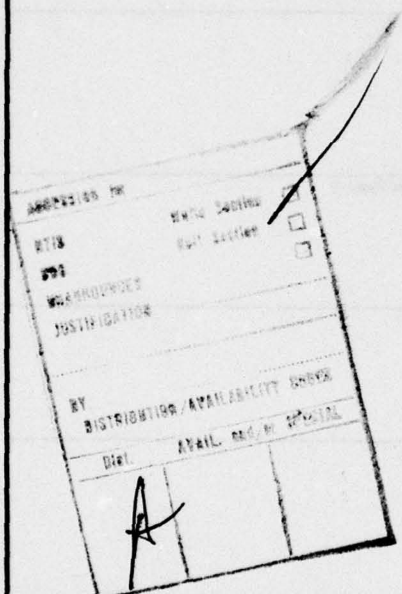
20. ABSTRACT (Continued).

(a) scope and objectives of WES study; (b) factors involved in hydrodynamic modeling; (c) lake characteristics and other information required as input for the models; (d) methods for obtaining unavailable data; (e) numerical and physical model evaluation, selection and preliminary design procedures; (f) information obtained from the models; and (g) current status of WES modeling efforts. Detailed technical data and results from WES study were published by WES in a series of 12 reports. These reports are referenced throughout this report in the appropriate and related sections.



SUMMARY

The U. S. Army Engineer Waterways Experiment Station (WES) conducted for the Lake Erie Regional Transportation Authority (LERTA) a model feasibility investigation of an offshore lake site for a proposed jetport near Cleveland, Ohio. The purpose of the WES investigation during LERTA's feasibility study was to provide preliminary estimates of the effects of a proposed jetport on lake hydrodynamics in the vicinity of the offshore lake site. The WES investigation of this site evaluated various modeling techniques (physical and numerical) for determining effects of the proposed jetport island on nearshore lake hydrodynamics, defined the required data and their availability for modeling purposes, selected and/or designed necessary models (physical and numerical) for studying various phenomena (storm surge, seiche, wind-driven circulation, wave regime, etc.) considered pertinent to the proposed jetport site, and applied some of these models to obtain preliminary estimates of the nearshore effects of the proposed jetport on lake hydrodynamics.

A literature survey was conducted to determine the existence and availability of data pertinent to the hydrodynamics of Lake Erie. For modeling lake hydrodynamics near the lake site, information was required for geology, climate, characteristics of lake bottom and shoreline, water temperature, lake levels, lake currents, waves, erosion, wind fields, and water inflow/discharge. From this survey, three areas were identified where sufficient data near the lake site were not available. These areas were wave information, lake circulation, and sediment transport in the vicinity of Cleveland, Ohio. Previously published wave hindcasts disagreed significantly. Thus, a wave hindcast was prepared using 10 years of recorded wind data from Burke Lakefront Airport supplemented by wind data from Cleveland Hopkins Airport. For storm wave characteristics, the 30 most severe storms for this 10-year period and the severe storms of November 1913 and November 1950 were considered. Lake current observations for estimating seasonal and annual circulation patterns near Cleveland are required during

verification of physical and/or numerical models of mass circulation near the lake site of the proposed jetport. A prototype data acquisition and analysis program was designed and proposed by WES to obtain sufficient prototype data for verification of recommended circulation models. Erosion of the bluffs near Cleveland occurs primarily as a result of wave action at the base of the bluffs, particularly during periods of high lake level. Most longshore currents and sediment transport are produced by wind waves approaching the shoreline at an angle. The wave climate in the nearshore region differs from that in deep water; consequently, information obtained by wave hindcasts must be modified to account for the effect of the lake bottom (bathymetry) on the waves. Refraction characteristics of the lake bathymetry for 15 locations around Cleveland were studied. Using WES wave hindcast and numerical/analytical techniques, refraction diagrams, average monthly and net longshore wave energy, and annual longshore wave energy and transport rates for noncohesive sediments were estimated for existing lake conditions.

Mass circulation, wave action, longshore sediment transport, and breakwater stability are the major phenomena for which modeling is required to evaluate the effects of the proposed jetport in the vicinity of the lake site. The use of physical and numerical models was considered to provide this information. In the physical model feasibility study of these phenomena, specific models were evaluated, designed for preliminary considerations, and recommended for investigation of modifications to wave conditions along the shore due to the jetport and for evaluation of breakwater stability. Specific physical models were not recommended for mass circulation, seiching, and noncohesive sediment transport. In the numerical model feasibility study, effects of the proposed jetport on seiching, storm surge, and wind-driven circulation for well-mixed (fall and winter) and thermally stratified (summer) lake conditions were estimated. Existing state-of-the-art numerical models, appearing capable of predicting the extent and magnitude of hydrodynamic changes produced by the proposed jetport, were reviewed and evaluated. Specific numerical models were selected, recommended, and applied to seiche; storm surge, steady-state, wind-driven circulation for well-mixed lake conditions; and wind-driven circulation for thermally stratified lake conditions. Results of these numerical investigations for a jetport island configuration located 4 to 5 miles offshore near Cleveland, Ohio, indicated that the effects of the jetport on (1) amplitude and horizontal velocity for seiching would be localized within 4-6 miles around the jetport with maximum changes in seiche amplitude being no greater than 10 percent; (2) storm surge, based on numerical simulations for the 7-10 November 1913, 25-27 November 1950, and 8-9 April 1973 storms, would increase 1 to 5 percent along the shoreline from Lorain, Ohio, to Fairport, Ohio, and 5 to 30 percent around the perimeter of the jetport island with a maximum increase of 0.12 ft in surge elevation being associated with the severe storm of 7-10 November 1913; (3) horizontal velocity for steady-state, wind-driven circulation for well-mixed (constant density) lake conditions (fall-winter) is not appreciable (less than 0.1 ft/sec near shoreline) except within 2-3 miles of the island with the maximum horizontal velocity of the lake surface between island and shore being 1.5 ft/sec for a 17-mph wind; and (4) horizontal velocity and lake temperature for wind-driven circulation with thermally stratified (summer) lake conditions are dependent on wind direction, with a south wind (which produced minimum effects in the steady-state circulation study) producing only localized changes in velocity within 2-3 miles of the island and in temperature within 4-6 miles of the island, and a west wind (which produced maximum effects in the steady-state circulation study) producing changes in velocity and temperature which extend to the shoreline at Cleveland and could possibly affect circulation and water quality within the existing harbor/breakwater complex.

PREFACE

This study was sponsored by the Lake Erie Regional Transportation Authority (LERTA), Cleveland, Ohio, as a part of the model feasibility investigation being conducted at the U. S. Army Engineer Waterways Experiment Station (WES). The WES investigation, Task 17 of the LERTA investigation, is a portion of the airport feasibility study being conducted by LERTA to evaluate proposed airport sites, one of which is in Lake Erie near Cleveland, Ohio. The WES model feasibility study is associated with the selection, preliminary design, and initial application of the necessary models for studying various phenomena considered pertinent to an offshore jetport site.

This report was prepared by Drs. D. C. Raney, D. L. Durham, and R. W. Whalin of the Wave Dynamics Division, under the general supervision of Dr. R. W. Whalin, Chief of the Wave Dynamics Division, and Mr. H. B. Simmons, Chief of the Hydraulics Laboratory. Dr. Raney is a Professor of Engineering Mechanics at the University of Alabama and was assigned to WES under terms of the Intergovernmental Personnel Exchange Act during the conduct of this study and preparation of the report.

Directors of WES during the conduct of this investigation and the preparation and publication of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, METRIC (SI) TO U. S. CUSTOMARY AND U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

Units of measurement used in this report can be converted as follows.

Multiply	By	To Obtain
Metric (SI) to U. S. Customary		
Celsius degrees or Kelvins	9/5	Fahrenheit degrees*
U. S. Customary to Metric (SI)		
inches	25.4	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
feet per second	0.3048	metres per second
miles per hour (U. S. statute)	1.609344	kilometres per hour
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins**

* To obtain Fahrenheit (F) temperature readings from Celsius (C) readings, use the following formula: $F = 9/5(C) + 32$. To obtain Fahrenheit readings from Kelvin (K) readings, use: $F = 9/5(K - 273.15) + 32$.

** To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

LAKE ERIE INTERNATIONAL JETPORT MODEL FEASIBILITY INVESTIGATION

NONTECHNICAL SUMMARY OF PROJECT

PART I: PURPOSE AND SCOPE

1. An offshore jetport in Lake Erie adjacent to Cleveland, Ohio, was initially proposed by the Greater Cleveland Growth Association in a prefeasibility report published in March 1971. Study recommendations led to establishment of the Lake Erie Regional Transportation Authority (LERTA) in March 1972. After selection of the consultants which were Howard, Needles, Tammen, and Bergendoff (HNTB) in association with Landrum and Brown, LERTA initiated a feasibility and site selection study for a major hub airport in the Cleveland Service Area. The LERTA study includes evaluation of proposed land sites in addition to a lake site. One of the sites will be selected for the jetport after completion of the evaluation. Due to the limited time available for feasibility studies and the possibility of an offshore site as the recommended jetport location, the U. S. Army Engineer Waterways Experiment Station (WES) model feasibility investigation was conducted either prior to or concurrent with selection of lake site or jetport configuration. The WES investigation was limited to consideration of the offshore site, the methods (models) that can be used to determine effects of the jetport on lake hydrodynamics, and initial application of these methods for preliminary estimates of such effects.

2. Objectives of the WES model feasibility investigation can be classified into three areas: (a) a compilation of available data on the wind climate, mass circulation, general characteristics of shore erosion, and other pertinent physical features of Lake Erie that impact on the model studies; (b) the selection and/or preliminary design and evaluation of necessary models for studying phenomena considered pertinent to the proposed jetport site; and (c) the preliminary application of some of the models to Lake Erie to obtain initial estimates of the effects of the proposed jetport on lake hydrodynamics.

3. This report is a nontechnical summary of the WES efforts on the proposed jetport project. It is intended to present the basic concepts, procedures, and results of the study without technical details. The following items are some of those that will be presented in a format suitable for the nonscientist: factors involved in hydrodynamic modeling, lake characteristics and other information required as input data for the models, methods for obtaining unavailable data, selection procedure for the models, information obtained from the models, and current status of the modeling effort. Detailed technical data and results from the study are published as WES reports, References 1 through 12.

PART II: BASIC CONCEPTS OF HYDRODYNAMIC MODELING

4. In modern engineering practice, almost every type of structure or machine requires that it be tested for design, stability, and efficiency. These tests may be conducted on a physical model that is normally smaller than the final structure or machine called the prototype, or a numerical simulation of the operating procedure can be programmed for solution on a digital computer. The two modeling procedures, physical and numerical, are both complementary and supplementary. In studying complex phenomena one method may be much more adaptive to investigating a particular phase of the problem. On the other hand, where both modeling procedures are applicable, their results may tend to reinforce each other or they may point out areas that need additional study.

Physical Models

5. For the physical model to operate satisfactorily, certain laws of similarity should be obeyed. Basically, two types of similarity are necessary for complete similitude to exist between the prototype and model--geometric similarity and dynamic similarity.

Geometric similarity

6. To obtain geometric similarity, the model and prototype must be geometric scale models of one another; that is, the ratio between corresponding lengths, depths, widths, etc., is a constant value (the scale factor); the corresponding areas are related by the square of the scale factor while corresponding volumes are related by the cube of the scale factor. Most individuals have had experience with geometric models from hobbies or activities related to model cars, ships, trains, or airplanes. While this is a simple concept, complete geometric similarity is not always easy to obtain.

Dynamic similarity

7. Dynamic similarity is somewhat more involved than geometric similarity. Geometric similarity dictates how to construct the

model. Dynamic similarity specifies under what conditions the model should be tested in the laboratory in order to use model data to predict the behavior of the prototype. For dynamic similarity, the various forces such as inertial, pressure, viscous friction, gravity, surface tension, and compressibility are taken into consideration along with the resulting velocities and accelerations. To maintain dynamic similarity, the ratios of the forces acting on the fluid particles and the resulting accelerations in the model must be the same as the ratios of similar forces and accelerations in the prototype at corresponding points in the flow. If geometric similarity and dynamic similarity are maintained, then model data can be used to predict performance of the prototype.

8. Unfortunately, complete dynamic similarity is almost impossible to obtain using a reduced scale model. In most cases approximate dynamic similarity is obtained by considering only the predominant forces involved in the problem and neglecting some of the smaller effects. When applied in a selective and judicious manner, models operated under approximate dynamic similarity conditions can yield accurate and useful information.

Distorted-scale models

9. One of the essential criteria for geometric and dynamic similarity is that the model must be undistorted; that is, the scale ratios for all lengths in the model and prototype must be the same. In some cases this is not possible, and the scale of one dimension may have to be limited by space and cost restrictions. Typical of such instances are large models of estuaries or lakes. In such cases an undistorted-scale model may result in very small (impractical) depths unless the horizontal dimensions of the model are very large. These difficulties can be overcome by using distorted-scale models in which the scale ratios in different directions (horizontal and vertical) are not the same. Distorted-scale models depart from geometric similarity; however, by careful manipulation of various model parameters, depending on the study objectives, accurate and useful studies can be made, in many instances, with distorted-scale models.

Numerical Models

10. The numerical model is quite different from the physical model; however, many aspects of the operation and verification procedure for the models are very similar. Mathematical modeling or numerical simulation involves expressing the governing relation for the process to be modeled in mathematical terms. The mathematical equations are solved numerically subject to certain known or specified operating conditions. In this process, it is normally convenient to divide the entire apparatus being modeled into several smaller segments; and the governing equations for the system of segments are then solved simultaneously. The numerical model can be adjusted by varying certain parameters involved in the governing mathematical equations. The mathematical equations simulate the operation of the prototype device, and the results can be used to predict the operating procedure for a prototype device.

Model Verification

11. Because of limitations involved in both physical and numerical models, it is desirable, whenever possible, to verify the model (especially distorted-scale physical models and numerical models) prior to using it as a predictive tool. Verification consists of demonstrating that the model reproduces some known operating conditions for the prototype. For example, if the study involves a change to some existing facility, model verification would consist of demonstrating that the model is capable of yielding results consistent with prototype data for existing conditions. During the verification process, certain model parameters (whose exact value is not known, a priori) can be adjusted to bring the model results into agreement with the prototype data. If the model is capable of reproducing existing conditions, then one feels more comfortable with applying the model to predict the effect that will result from a change to existing conditions. Some prototype data are necessary to verify a model to improve confidence level in model results.

PART III: DISCUSSION OF LAKE CHARACTERISTICS PERTINENT TO LAKE HYDRODYNAMICS

General Data Requirements

12. A literature survey was conducted to determine the existence and availability of data pertinent to the hydrodynamics of Lake Erie. Data requirements included features of the geology, climate, lake bottom and shore characteristics, water temperature, lake levels, lake currents, waves, erosion wind fields, water inflow/discharge, and water quality. These and other factors influence the complex hydrodynamics of a large lake and are required input parameters into physical or numerical models attempting to simulate various aspects of lake hydrodynamics. The relation between some of the required data and lake hydrodynamics may not be readily apparent. A brief discussion of some lake characteristics will be presented to indicate their relation and influence on lake hydrodynamics.

Influence of Basic Lake Characteristics on Lake Hydrodynamics

Location and geometric characteristics

13. The physical size of the lake influences the size and resolution requirements of any physical or numerical models used to study lake hydrodynamics. Basically, a large lake requires a rather large physical model if good resolution or definition of hydrodynamic features is desired. A large, fast digital computer system was required to numerically model a large lake and provide good resolution. Orientation of the lake relative to the predominant wind directions and storm wind directions will greatly affect the wave climate and sediment movement. The depths in the lake affect lake currents, stratification, and temperature distributions.

Geology

14. The geology of the lake and the surrounding region determines

the composition of the lake bottom, shoreline, and drainage area. The amount and composition of the silt load entering the lake and many of the characteristics of the erosion problems and sediment movement in the lake are thus established by the geology.

Climate

15. Air temperature governs the evaporation rate from the lake surface as well as the water temperature and other thermal properties in the lake. Precipitation rate in the drainage area of the lake governs lake inflow. The predominant climatic feature affecting the lake is wind. Wind is responsible, directly or indirectly, for many of the phenomena associated with lake hydrodynamics.

Lake bottom and lake shore characteristics

16. A lake is subjected to a dynamic process which changes lake shorelines and depths. The lake shoreline and bathymetry are continually changing as sediment is transported under the action of wind, waves, and currents. Sediments range from granular material (sand) to very fine colloidal materials (silt) in suspension and are transported as bed load or as suspended material. Transport of granular materials takes place primarily as bed load in close proximity to the bottom or in turbulent suspension. Silt consists of suspended particles of clay or similar material and transport of silt is primarily through suspension and deposition of the suspended particles. Lake bottom and shore characteristics determine the type and availability of sediment.

Lake water supply and discharge

17. Point (river) inflow or discharge greatly influences local hydrodynamics in a lake, even though volumetric flows may be small and have little overall effect upon the entire lake. A large inflow or discharge may significantly affect a major portion of the lake. The particular region being investigated, its relation to inflow or discharge points, and the flow rates involved determine the extent to which lake hydrodynamics are influenced.

Water temperature

18. Water temperatures are important, particularly as they

influence lake stratification. Water density is essentially inversely proportional to temperature. As the surface water heats up in summer, it becomes lighter than the deeper lake waters. Mixing between the deeper water and the surface water is inhibited because of this difference in density and creates a condition referred to as temperature stratification. The warmer, less dense, upper layer (the epilimnion) and the cooler, more dense, lower layer (the hypolimnion) behave almost as separate entities. The thermocline is the region separating the epilimnion and hypolimnion. Stratification, if it exists, and the position of the thermocline have a tremendous effect on lake hydrodynamics. Water-quality problems, especially oxygen depletion, are more common in the hypolimnion since it has no exposure to oxygen at the water surface and there is little mixing with surface waters.

Lake level fluctuations

19. Water levels in a lake greatly influence accretion, erosion, and sediment transport. Long-term lake level fluctuations occur due to changes in inflow, precipitation, and evaporation over the lake. Short-term fluctuations occur daily and even hourly due to wind setup (seiche) and gravitational tides. For Lake Erie, gravitational tides are small; however, fluctuations due to seiche are significant.

20. Seiching of an enclosed body of water such as a lake occurs after the water surface is in equilibrium under a given wind condition and the wind changes in magnitude or direction. Under these conditions, long waves may be created that will rhythmically slosh back and forth as they reflect off opposite ends or sides of the lake. These waves, called seiches, have a period that depends on the size and depth of the basin. Seiches are rather common phenomena; however, because the wave height is so low and the wavelength is so long, they are virtually unnoticed by the layman. Seiching can cause problems with moored ships in harbors (broken mooring lines, etc.), can raise water levels a significant amount causing flooding or enabling the normal wind waves to penetrate much farther shoreward than normal, and may cause relatively large seiche currents in certain areas of the lake.

Lake currents

21. Movement of water (circulation) in large lakes involves the relatively slow motion of a large mass of water and many physical forces must be considered. The velocity of the fluid cannot be considered as unidirectional as in a river or channel. Lake currents usually have components in all three spatial directions and are the resultant of wind-driven currents, seiche currents, lake through-flow, density currents, and inertial currents.

22. The through-flow velocity component is normally small and can be neglected except in the immediate vicinity of inflow and discharge points. The wind-driven component will normally be the largest except during periods of relative calm and is the most variable with time. Longshore currents are created by wind waves and increase in magnitude when the wave crest is not parallel to the shoreline. Seiche currents, produced by the oscillation of the lake surface, decay with time but rarely disappear completely. Density currents normally occur when water flowing into the lake is at a different density from the surrounding water. Inertial currents occur due to the earth's rotation and the movement of the water on the rotating surface of the earth.

23. Currents in a lake the size of Lake Erie also vary in magnitude and direction with depth. Surface currents are generated by the wind and due to the inertial effect the mass transport is directed to the right of the wind stress. Mass transport in the surface layer can be much larger than the lake through-flow and a return-flow current basically opposite in direction to the surface flow must be formed at the lower levels of the lake. Lake currents in the nearshore region are strongly affected by the shoreline and bottom topography.

Wave statistics

24. Tidal effects and through-flow in lakes are normally small so lake hydrodynamics are dominated by wind-driven effects. Waves are born as the air pressure changes and the frictional drag of the moving air against the water creates ripples. Once a ripple has formed there is a steep side against which the wind can press directly. Now energy

can be transmitted from air to water more effectively and the small waves grow rapidly.

25. Three factors influence the size of wind waves: (a) wind velocity, (b) duration or length of time the wind blows, and (c) fetch or extent of the open water across which it blows. Wind transfers its energy to the waves. Energy stored in the waves is proportional to the square of the wave height. The energy contained within waves possesses the potential to transport sediment, erode beaches, undercut bluff sections, or damage man-made structures. Most wave statistics are described in terms of significant wave height and significant wave period. Significant wave height is defined as the average height of the highest one third of the waves observed passing a stationary location. The significant wave period is the average period of the highest one third of the waves. Once wave statistics are available, an average rate at which energy is transmitted in the direction of wave propagation can be estimated from the wave climate. Long-term sediment erosion and accretion effects for local areas of interest in the lake can be inferred from this energy flux.

Shore erosion

26. Wave action is the principal cause of most shoreline changes. Sand grains that move a tenth of an inch per wave can migrate many feet in one day. Of course, all waves are not the same and currents may change direction; therefore, it is difficult to determine quantitatively how the sediment is moving at any moment.

27. Sediment movement in the nearshore region (littoral transport) is defined as either onshore-offshore transport or longshore transport. Onshore-offshore transport is perpendicular to the shoreline; and longshore transport is parallel to the shoreline. Movement of sediment usually has both components of transport. Transport occurs in two modes, bed-load transport and suspended-load transport. Bed-load transport is due to the motion of sediment at the bottom being moved by shear stress from the wave-induced water particle velocity; and the suspended-load transport is the transport of sediment by currents after the material has been lifted into suspension by wave or current

action. The two types of transport are usually present at the same time and are difficult to separate.

28. Bluff sections are subject to erosion caused by wave attack at the surface lake level if the bluff is unprotected. In many cases, wave attack undercuts the bluff and the stability of the undercut section is endangered. Shear and tension failures may then occur and badly jointed or fissured material may erode as intact blocks.

Water-quality/environmental changes

29. Any changes in the physical structure (i.e., dredging, construction, etc.) of the lake can lead, at least locally, to change in existing chemical, biological, and microbiological conditions. Some estimate of such water-quality or environmental changes can be obtained if the changes in the hydrodynamic environment can be estimated.

PART IV: STATUS OF DATA REQUIRED FOR MODELING LAKE HYDRODYNAMICS

30. Review of available data by WES indicated three major areas where sufficient data were not available to allow for estimating the effects of the proposed jetport on lake hydrodynamics near Cleveland. Sufficient data were not available to properly define the wave regime, mass circulation, and shoreline erosion that presently exist in Lake Erie.

31. Sufficient long-term wave data were not available to determine the statistical wave climate for the lake. The wave climate for a lake is normally not available from measured wave data. The wave regime is usually determined from wave hindcasts based upon long-term wind data that are available from weather stations around the lake. A wave hindcast predicts analytically the wave climate that should have been produced by wind conditions which existed on the lake. Previously, published wave hindcasts for Cleveland were in significant disagreement, and a need for a hindcast[9] over a longer period of record was evident to select the design waves for the proposed jetport location. Wave heights, wave periods, direction of travel, and frequency of occurrence are the types of wave information required.

32. General mass circulation patterns in Lake Erie on a seasonal or annual basis have been inferred from previous lake mass circulation studies; however, current observations at any point near Cleveland may vary extensively from an inferred seasonal or annual average. Observed long-term current data from stations near Cleveland are limited. Additional hydraulic and meteorological data and analysis techniques are needed to obtain an estimate of the current speed and direction at the proposed jetport site and changes that will be introduced by the proposed jetport. Potential changes produced by the proposed jetport must be determined for typical conditions, extreme storm conditions, conditions where the lake is stratified, and for other pertinent conditions since the physical environment of the lake is extremely time-dependent. Analysis techniques required may involve physical and mathematical modeling.

33. Erosion of the bluffs near Cleveland occurs primarily as a result of wave action on the bluffs, particularly during periods of high lake level. The average percentage of sand available for beach replenishment from the bluffs has been determined for various sections of the shoreline; however, only limited long-term estimates of sediment transport rates along the shoreline are available. Estimates of changes which might be produced by the proposed jetport in sediment transport in the Cleveland area required additional base data and estimates of the modified nearshore energy regime for sediment transport.

PART V: CALCULATION OF BASIC DATA FROM FIELD OBSERVATIONS

Wave Hindcast

34. As indicated previously, detailed long-term measured data on the wave climate of a lake are normally not available, while detailed long-term weather information at stations around the lake is commonly available. A wave hindcast uses wind information to analytically predict the wave climate that should have existed for the particular wind condition around the lake.

35. A wave hindcast for Lake Erie at Cleveland, Ohio, was prepared by A. H. Glenn and Associates[9] using 10 years of recorded wind data from the Burke Lakefront Airport supplemented by wind data from the Cleveland Hopkins Airport. Average monthly and annual significant wave heights (average height of highest one third of waves), significant period, directional distribution, and percentage of occurrence were tabulated for the Cleveland area.

36. The normal winds, normal waves, and normal (long duration) water levels are included in the report as well as storm winds, storm (short duration) water levels, and storm wave characteristics. The storm wave characteristics section of Reference 9 summarized results of wave height and period analyses based upon the 30 most severe storms occurring during the hindcast period, plus the severe storms of November 1913 and November 1950, which are the most extreme storms on record for Lake Erie.

Longshore Wave Energy Analysis

37. Most longshore currents and sediment transport are produced by wind waves approaching the shoreline at an angle. Therefore, a knowledge of the wave climate and wave behavior nearshore is a necessity for determining sediment transport. The wave climate in the nearshore region differs from that in deep water; consequently, information

obtained by wave hindcasts must be modified to account for the effect of the lake bottom (bathymetry) on the waves. As waves approach shore and move across shallow water they react in special ways. Waves reflect, diffract, and refract, which means they are turned back by vertical obstacles, spread their energy into the water behind projecting obstructions, and bend in response to a gradually shoaling bottom.

Reflection

38. When a wave encounters a vertical wall it is reflected with little loss of energy. As long as the wave is approximately sinusoidal in shape, it exerts relatively little force on the reflecting structure. Only when dealing with breaking waves, which are discussed in a later section, are relatively large forces exerted on the structure that reflects the wave. Nonvertical barriers also reflect some wave energy; however, the more gradual the slope, the smaller the reflection coefficient.

Diffraction

39. As waves pass an island or other obstruction, some of the energy is propagated sideways (or along the wave crest) as the wave crest extends itself into the area apparently sheltered by the island. The phenomenon of wave diffraction can cause troublesome ship motion even in the lee of a protective structure. An illustration of the wave fronts at a 90-deg* corner is shown in Figure 1. The sideways propagation of wave energy into the sheltered area (diffraction) can be observed. Figure 2 shows wave energy diffracting around a model breakwater into a sheltered region.

Refraction

40. As waves move into shallow water, the bottom bathymetry exerts an influence on the shape of the wave front. As the water depth decreases, waves slow down and those in the most shallow water move the slowest. Since different segments of the wave front are traveling in different depths of water, the wave crests bend and the wave direction

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* A table of factors for converting metric (SI) units of measurement to U. S. customary units and U. S. customary units to metric (SI) units is presented on page 3.

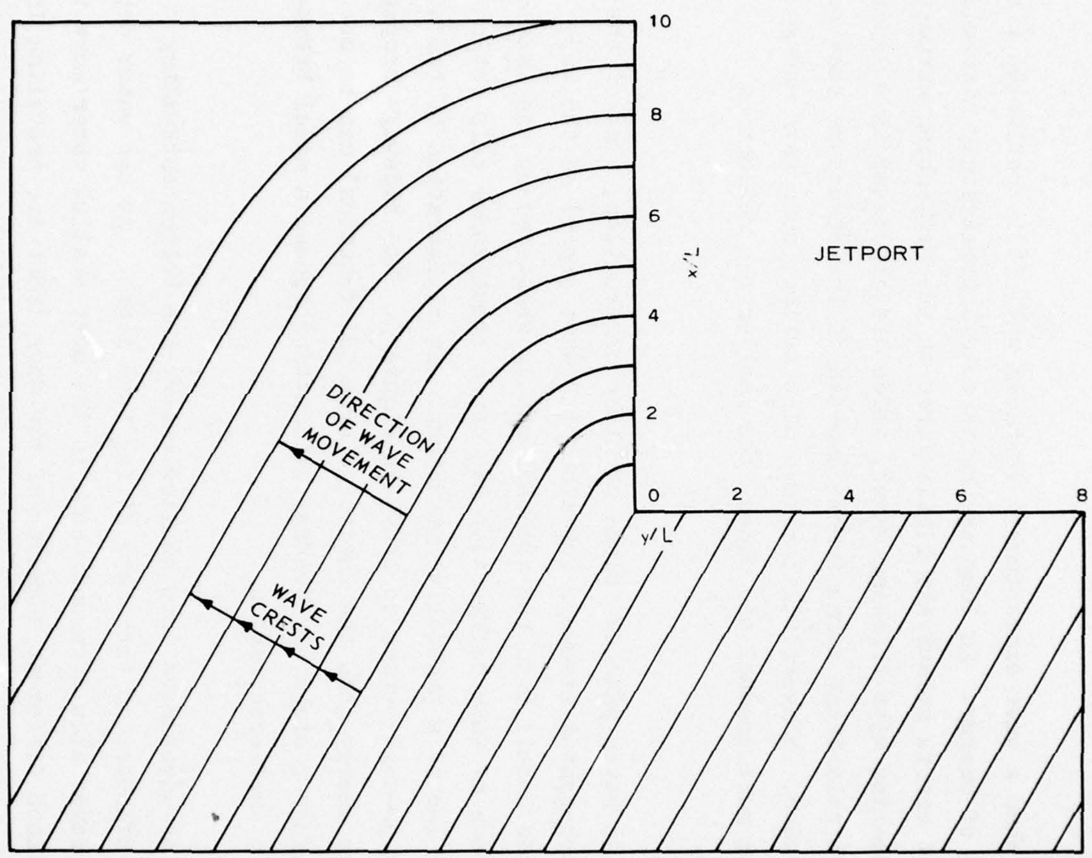

Figure 1. Approximate solution for wave fronts for a semi-infinite, rigid, impervious barrier with incident waves at a 30-deg angle

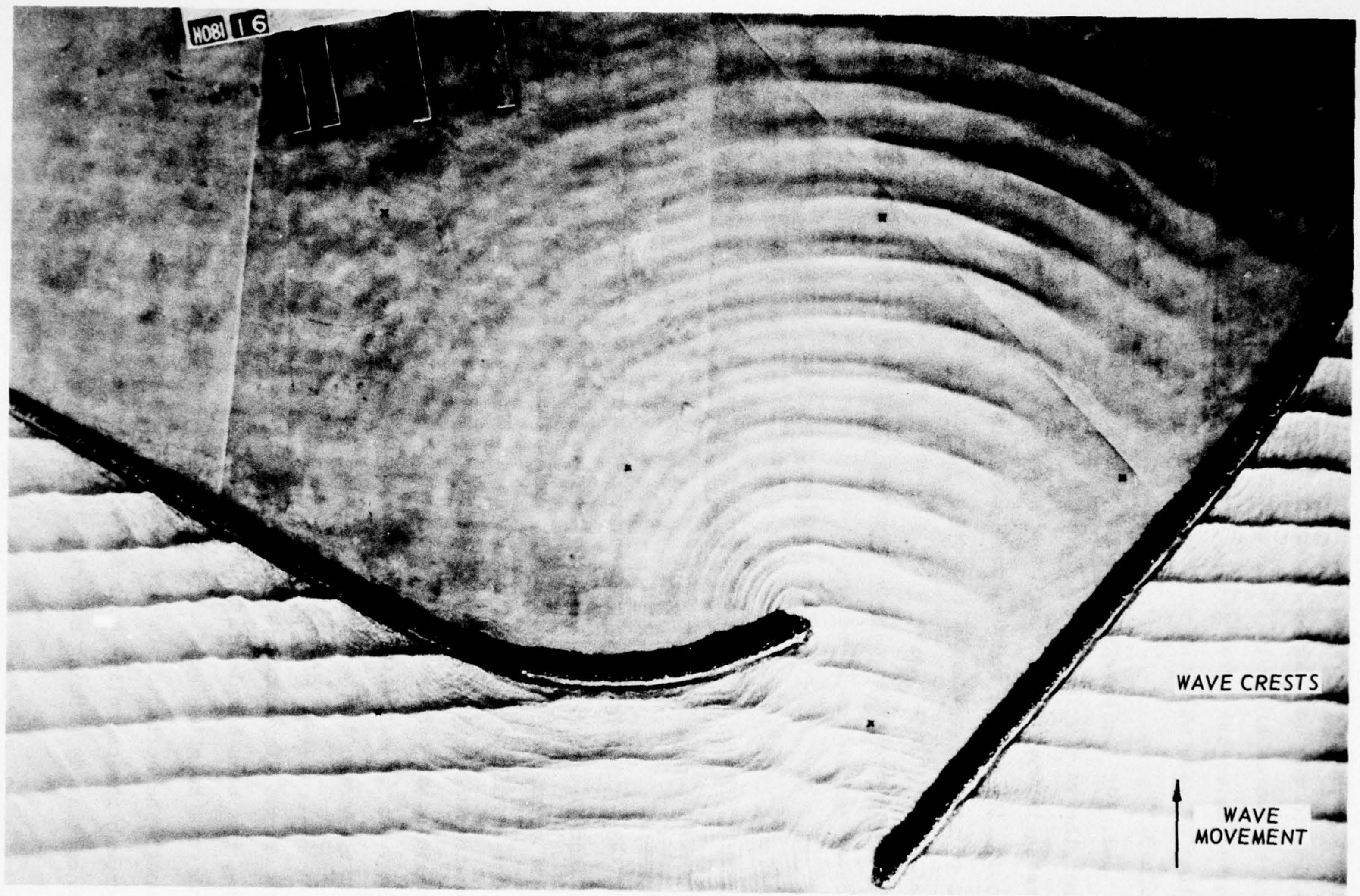

Figure 2. Energy diffracting around a model breakwater into a sheltered region

constantly changes. Thus, the wave front tends to become approximately parallel to the underwater contours. This is not the case in deep water where the waves are relatively unaffected by the bottom. The wave azimuth indicates the direction in which the wave crest is moving. The bending of wave azimuths as they approach shore is illustrated in Figure 3.

41. As the wave approaches shore, the decrease in water depth causes the wave velocity to decrease. One of the results of this is a decrease in wavelength. As wavelength decreases, the wave "peaks up"; that is, the normal rounded wave crest is transformed into a higher, more pointed wave form with steeper flanks. At a depth of water roughly equal to 1.3 times the wave height the wave becomes unstable; the top of the wave crest becomes unsupported and it collapses; the wave has "broken" and releases energy.

42. As a result of wave refraction, the amount of wave energy reaching a particular portion of the shore can be intensified or decreased. If the energy tends to be focused on a particular portion of shoreline, then damage to shoreline structures may be a potential problem.

43. Although wave fronts bend as they move across shallow water and tend to become parallel to the shore, often the refraction process is not quite complete. When the wave finally breaks at a slight angle to the shoreline the water receives an impulse, part of which is in the longshore direction. This longshore component of wave energy is one of the important parameters in sediment transport. The net longshore wave energy can be estimated using numerical procedures (refraction diagrams) if the average deepwater wave climate and the local topography are known.

44. A study of the refraction characteristics of the lake bathymetry around Cleveland Harbor, when subjected to the existing wave climate, has been completed by WES.[3] Average monthly and annual significant wave height-significant wave period tables for the west-southwest through the north to the northeast (the directions from which waves can approach the shoreline near Cleveland) have been developed from the wave hindcast study. Using numerical techniques, wave refraction diagrams

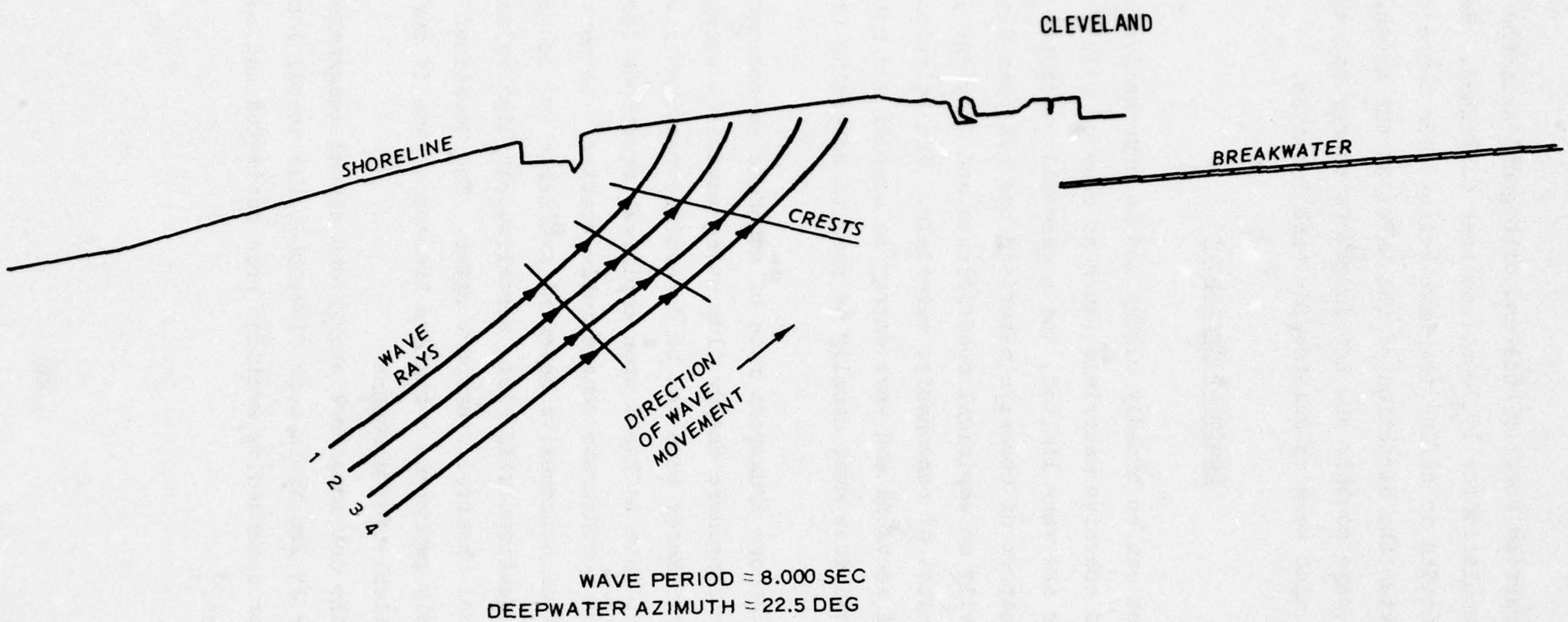

Figure 3. Lake Erie wave refraction east of harbor. Wave period, 8 sec; deepwater azimuth, 22.5 deg

and tables of refraction coefficients and orthogonal azimuths to the shoreline were calculated for 15 locations near Cleveland. Refraction coefficients are needed to define the wave height near shore and orthogonal azimuths provide the direction of the waves at the breaking point or shoreline. Average monthly and net longshore energy and annual longshore wave energy also were calculated for each location.

Sediment Transport

45. Sediment can be broadly classified as noncohesive materials (such as sand) and cohesive materials (such as clay or silt). Data for cohesive materials are very limited, and a generally accepted method of estimating transport of cohesive materials has not been developed. One must rely heavily on empirical coefficients and judgment in determining transport rates of noncohesive materials. The relation between recession of bluff sections and wave energy is complex and not well defined. Historical data must usually be used to determine bluff recession rates.

46. The longshore transport rate of noncohesive sediment may be estimated from the longshore energy flux using empirical equations. While the longshore energy rate can be determined reasonably well, the longshore transport rate is based upon empirical equations for which observed data often demonstrate considerable scatter. In particular, if there is a lack of noncohesive material available for longshore transport, these equations will yield unrealisticly high values when compared with actual observed transport rates. The equations in that respect more closely represent a maximum transport rate if sufficient material were available for movement.

47. Using the net longshore energy and annual longshore wave energy results for 15 locations near Cleveland, the annual longshore transport rates for noncohesive sediment were estimated and compared with observed rates.[3]

PART VI: EVALUATION OF MODELING TECHNIQUES FOR LAKE ERIE HYDRODYNAMICS

48. The major phenomena for which additional information is required relate to mass circulation, wave action, longshore sediment transport, and breakwater stability. The use of physical and/or numerical models is considered to provide this information. At the onset of WES investigations, two tentative jetport configurations were provided by LERTA for use in the model feasibility study. A schematic of these configurations is shown in Figure 4. This proposed jetport island configuration represented a minimum size anticipated at that time by LERTA to provide space for minimum airport functions with a shoreward extension providing sufficient area for all airport-related functions. These locations and sizes, in particular the proposed jetport island, were used throughout the WES study and were considered by LERTA to be tentative in design and location until future island design studies by HNTB were completed. Although the jetport configuration used in WES studies was a generalized configuration, results of these feasibility studies are, in general, applicable for the specific jetport island currently proposed by HNTB.[13]

49. The detailed physical and numerical model feasibility studies are presented in References 2 and 4. Results from these examinations are summarized in the following paragraphs.

Mass Circulation

50. The earth's rotation (which generates the Coriolis force), energy transfer from air to water due to wind stresses on the lake surface, vertical or horizontal density stratification, and seiche are difficult to represent in a physical model of a large lake. In addition, the large difference between horizontal dimensions and the depth of the lake would require a very large physical model or a very large scale-distortion ratio. Physical models of only a section of the lake result in problems when investigating mass circulation because of difficulties

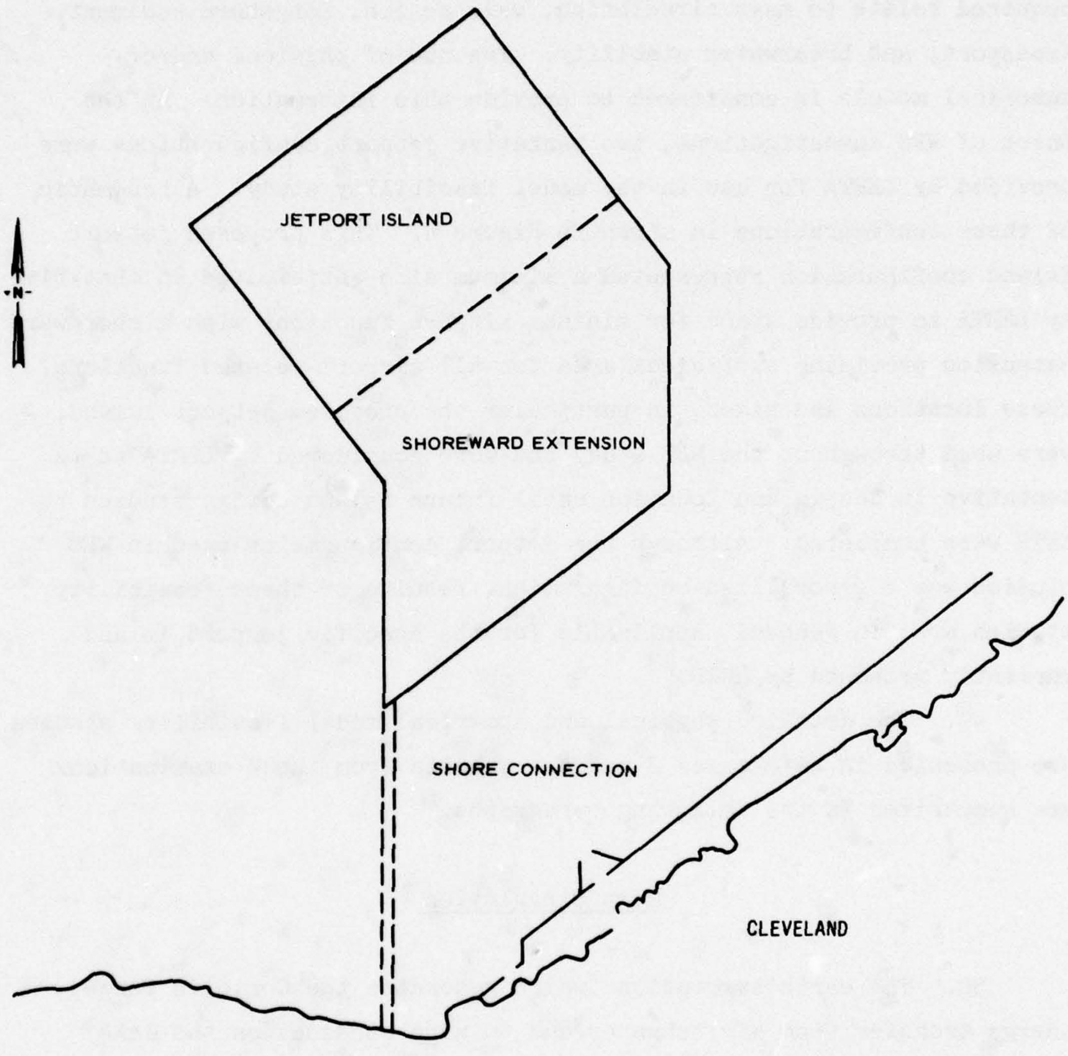

Figure 4. Tentative location of offshore jetport and shoreward extension. The location of any shore connection has not been selected and is shown only for use in the model feasibility investigation

in imposing proper conditions at the boundaries where the model is terminated.

51. On the other hand, current state-of-the-art numerical models and numerical models that should become available in the time frame necessary for application to the Lake Erie study may be able to treat these variables satisfactorily. In particular, the three-dimensional models developed by Dr. Wilbert Lick and associates at Case Western Reserve University appear capable of estimating the effects of a proposed jetport on storm surge and mass circulation. Seiche also can be investigated numerically by existing finite element models.

52. Due to the effort required to develop a physical, wind-driven, mass circulation model and the estimated costs associated with physical model construction and operation, physical circulation models are not recommended prior to completion of the numerical circulation studies.

Wave Action

53. Construction of a jetport will affect the local wave regime (wave refraction, diffraction, and reflection) and, consequently, will alter the wave conditions along the shoreline. The longshore energy flux in the Cleveland area may be changed by the proposed jetport. Analytical methods for reliably predicting wave refraction and diffraction around the jetport are not available due to the extremely complicated dynamics of wave propagation. Physical models can accurately simulate the relative changes in wave regime and are the best available method of predicting these changes. For the jetport, diffraction is more important near the corners and in the lee of the structure; and as the wave progresses shoreward, refraction also must be taken into account.

54. Some difficulties exist with a physical model of the entire jetport because of the size required for an undistorted-scale model. Undistorted-scale sectional wave models, such as those illustrated in Figure 5, rather than models of the entire proposed jetport may be sufficient to investigate modification of the wave regime near Cleveland

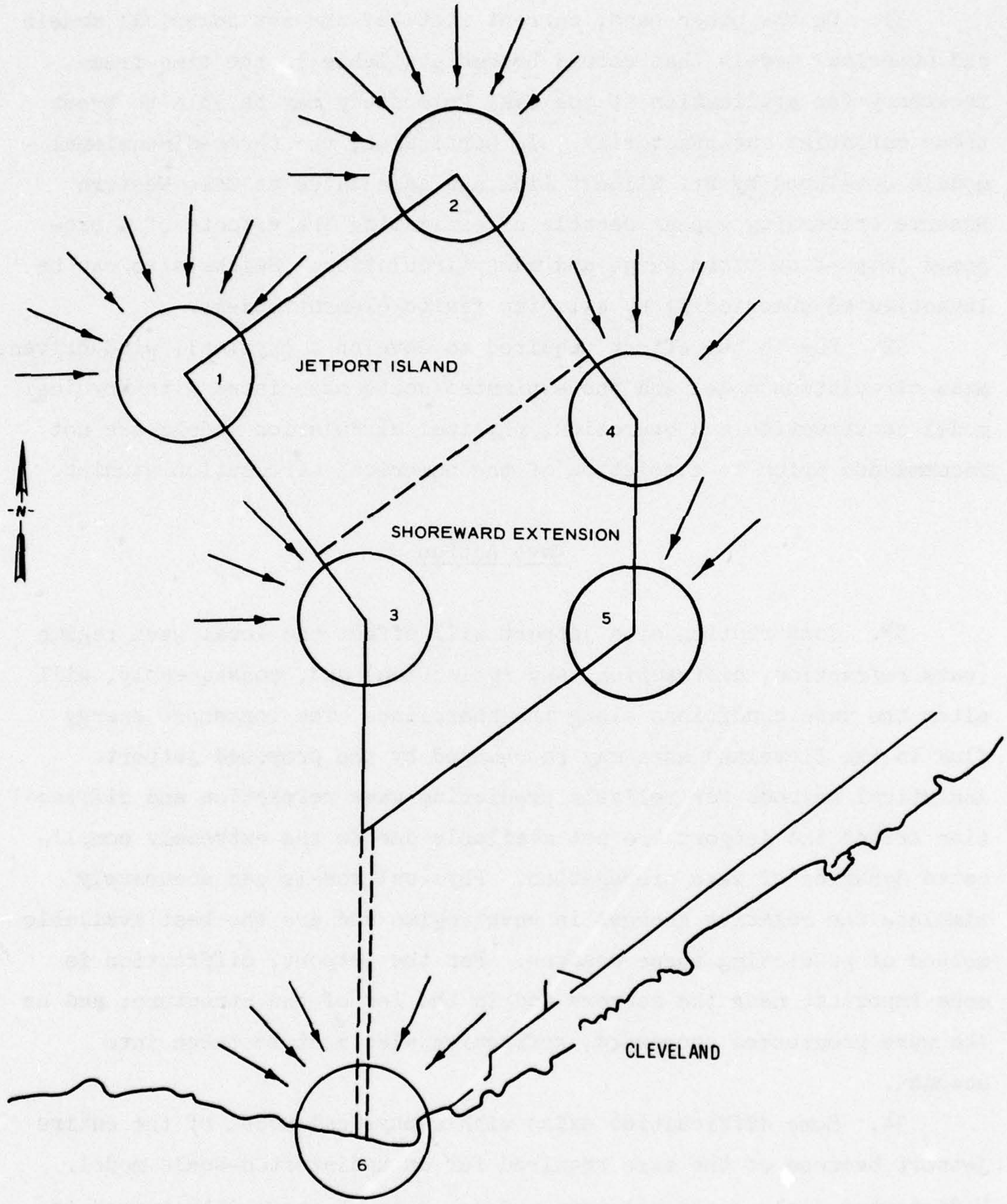

Figure 5. Recommended sectional models. Arrows indicate incident wave directions to be investigated in the model

after construction of the jetport. Final physical model design and scale determinations will depend upon the final proposed configuration of the jetport complex.

Breakwater Stability Models

55. Use of the hydraulic physical model as a design tool to ensure the stability of coastal structures at a minimum cost is a useful and recognized practice. The forces to which such structures are subjected are complicated and vary with type and geometry of the structure, depth of water, bottom configuration immediately seaward of the structure, stage of lake water level relative to the crown of the structure at the time wave action occurs, and wave dimensions. Since all these parameters are involved, accurate wave forces cannot be determined analytically or numerically. Consequently, physical models are commonly used to study breakwater stability. Typical commonly recognized types of structures capable of retaining or protecting large landfills are shown in Figure 6. The structure must be investigated when subjected to the design wave conditions that are based on the wave regime to which the structure will be exposed. For a given design condition, model tests can provide data that result in an optimal design for the structure (both in terms of cost and function). Model tests provide quantitative data on the size of protective material necessary to withstand the design wave forces.

56. Tests of the various structure concepts do not necessarily have to encompass the entire prototype structure; however, various sections (exposed to different wave climates) of the structure should be tested. The exact tests to be conducted will depend on the final configuration of the proposed jetport and the type of protective structure or structures designed.

Longshore Sedment Transport

57. As discussed previously, longshore wave energy is the major

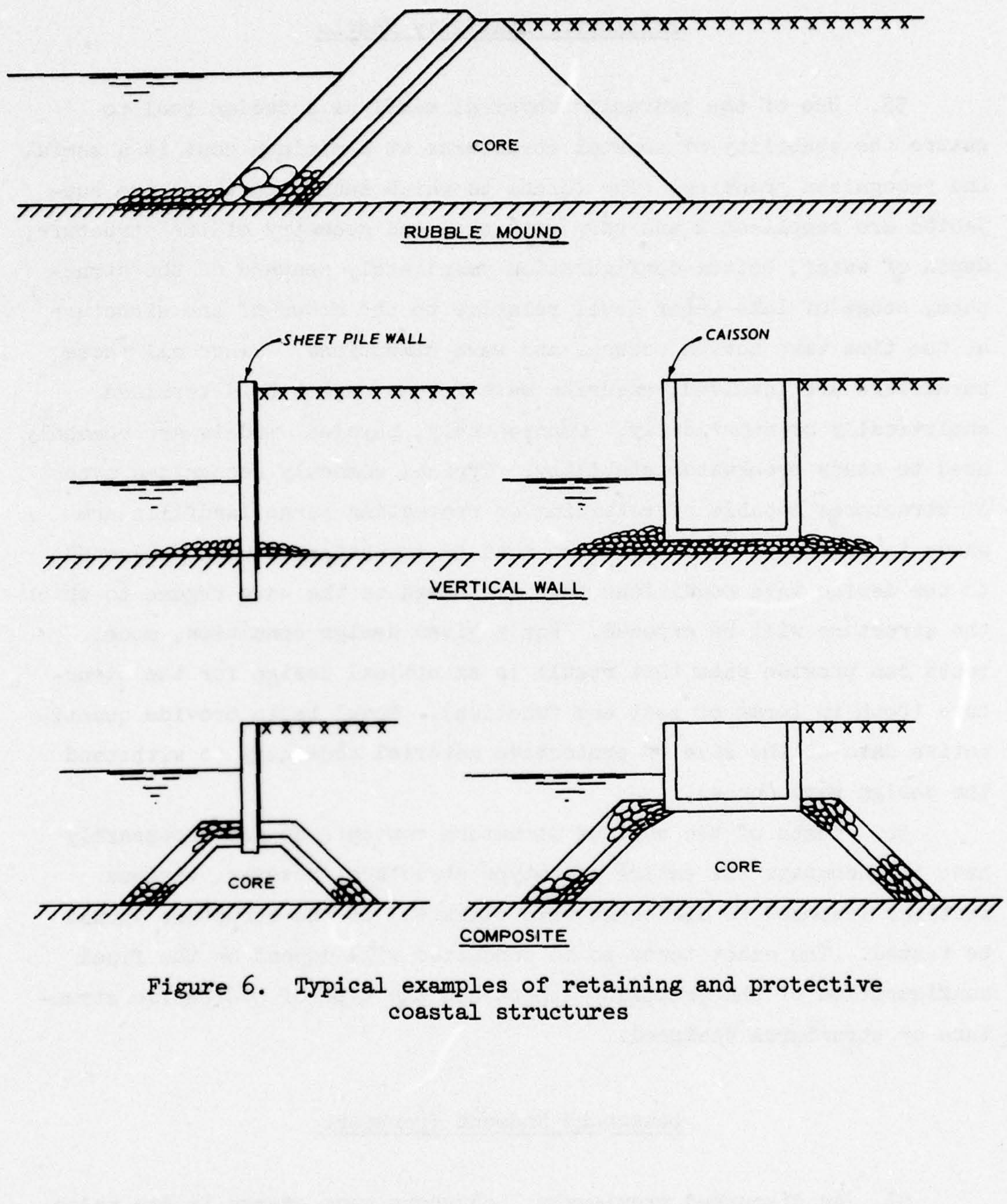

Figure 6. Typical examples of retaining and protective coastal structures

factor in determining longshore sediment transport. Construction of a jetport will affect the existing wave regime (wave refraction, diffusion, and reflection) and consequently, may, alter the longshore wave energy. New patterns of accretion and/or erosion of sediment may be established. The modified wave regime existing for the proposed jetport island will be determined from physical model tests as indicated earlier. Once the longshore wave energy is known, estimates of the change in sediment transport rates can be obtained from analytical techniques although accurate methods for quantitatively determining sediment transport are not considered to be within the present state of knowledge.

PART VII: PRELIMINARY APPLICATION OF MODELS

Steady-State, Constant Density Wind-Driven Circulation

58. A series of computer codes were developed at Case Western Reserve University and WES to compute steady-state, wind-driven currents in Lake Erie and to plot the velocities for easy graphic observation of results. The wind data used in the study of steady-state, wind-driven circulation were based on monthly and annual wind speed direction regimes and percentage frequency of occurrence near Cleveland, Ohio. A constant density lake was assumed (no vertical gradient of water temperature), which is generally valid from late September through May. On the basis of the wind study,[9] two wind magnitudes (17 mph and 35 mph) were chosen as representative of average and extreme wind conditions during the time period from late September through May. Winter winds in the Cleveland area most frequently are from south (180°) counterclockwise through west-northwest (202.5°). In this study, however, the wind was varied in 22.5° increments from 0° to 360°. Thus, 16 wind directions for each wind magnitude were considered in the numerical study. The inflow and outflow of the major rivers (Detroit, Maumee, Sandusky, and Niagara) were considered. Although the inflow of the Cuyahoga River has only a small local effect on the lake circulation, its inflow was considered because of its effect on local hydrodynamics near Cleveland.

59. Details of the hydrodynamic model and the development of the computer codes for this model are presented in References 5 and 6. Some typical examples of results from this study are shown in Figures 7 and 8. The effect of the proposed jetport can be observed by a direct visual comparison between the velocity plots at the various depths for the "with jetport" and "without jetport" case.

60. Based on numerical model results of the effects of a proposed jetport island on steady-state, wind-driven circulation for constant density conditions in Lake Erie near Cleveland, Ohio, it was concluded that:

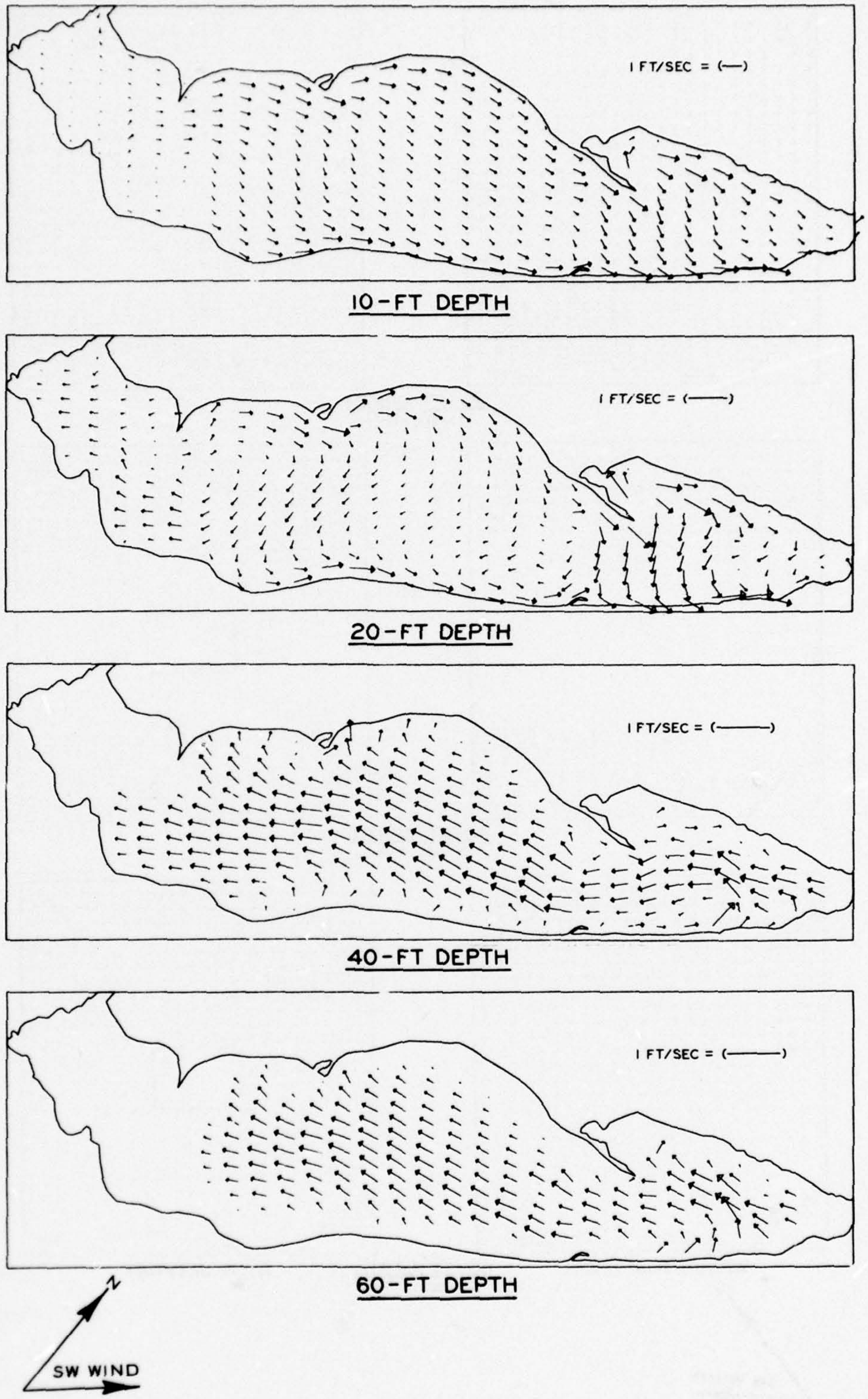

Figure 7. Horizontal velocities at 10-, 20-, 40-, and 60-ft depths for a steady-state wind of 17 mph from SW direction

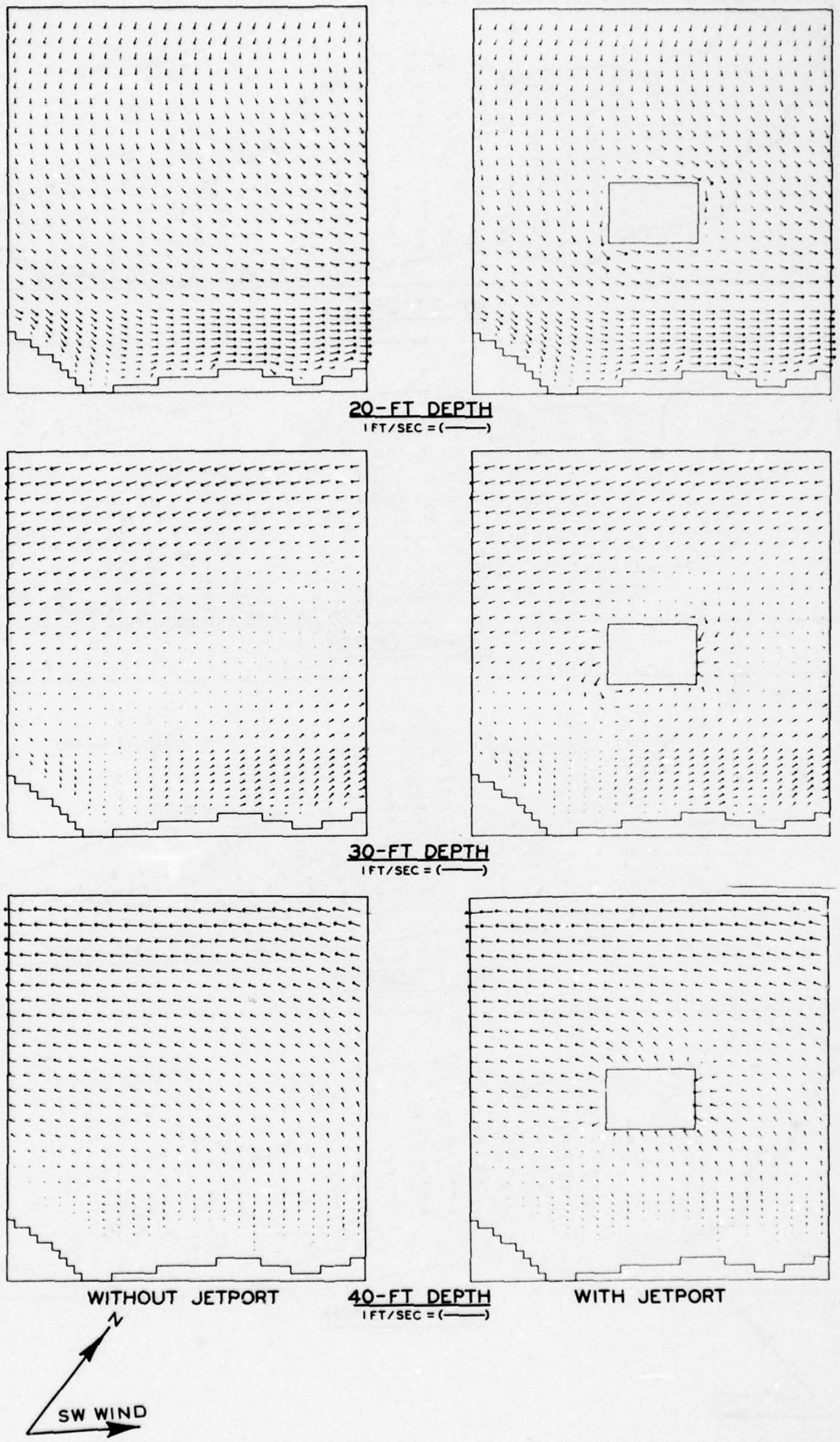

Figure 8. Nearshore horizontal velocities at 20-, 30-, and 40-ft depths for steady-state winds of 17 mph from SW direction

a. For all wind directions and magnitudes, the effect of the jetport island on lake circulation would not be appreciable except within 2 miles of the island.

b. Perturbations in the velocity field for the 17 mph and 35 mph wind fields would be very similar.

c. Two general wind directions (WNW through WSW and ESE through ENE) would produce the largest perturbations (both magnitude and extent) in the velocity field due to effects of the jetport island. This is due to the island location being in a region of large net mass flux for these wind directions. Thus, the island's presence in such a region would produce substantial blockage of the net flow.

d. Wind from the N or S directions would generate circulation patterns that produce minimum effects associated with the jetport island.

e. The most frequently occurring wind directions are from SSE to SW with 42 percent frequency of occurrence for annual as well as winter wind conditions. Thus, for the well-mixed (constant density) lake conditions, the two general wind directions that are characterized by maximum island effects have low frequencies of occurrence. Therefore, the maximum effects of the island on the steady-state circulation patterns would occur much less frequently than the smaller effects associated with other more frequently occurring wind directions.

f. For all wind directions, maximum horizontal velocity values at the lake surface between the proposed jetport and the shoreline would be 1.5 ft/sec for the 17 mph wind speed and 2.5 ft/sec for the 35 mph wind speed.

g. Effects of the proposed jetport in the horizontal velocity region near the shoreline in the vicinity of Cleveland, Ohio, were estimated to be less than 0.1 ft/sec for all studied wind fields.

h. Upwelling and downwelling along the shoreline in the vicinity of Cleveland, Ohio, would be affected very little, if any, by the proposed jetport. There would be no changes along the shoreline in location of the areas of upwelling and downwelling and only slight changes in magnitude of vertical velocities in these areas for a few wind directions (i.e., W).

i. Around the perimeter of the island, areas of upwelling and downwelling would be evident with the location of these areas, depending on wind direction. The magnitude of vertical velocities would be extremely small, about 10^{-3} to 10^{-4} ft/sec (0.001 to 0.0001 ft/sec).

Storm Surge

61. A computer program was developed at Case Western Reserve University to compute the three-dimensional, time-dependent storm surge in Lake Erie, and particularly in the nearshore region in the vicinity of Cleveland Harbor. Additional subprograms were developed at WES to process the raw wind data and to produce various graphic modes of output. These programs were developed to look at surface elevations and mass circulation in the lake under time-dependent wind conditions. Of particular interest are the extreme storm conditions necessary to determine the effects of a jetport on mass circulation during storms. The model development and detailed results from its application are shown in References 7 and 8.

62. The storm of 8-9 April 1973 was chosen to verify the application to Lake Erie of the three-dimensional storm surge model. For this storm, wind data from six land weather stations located around the lake were used to interpret the wind field over the lake. Surge elevation data from five lake level gages were available for comparison of prototype observations of storm surge with numerical computation. Results of this verification are shown in Figure 9. The relatively good agreement of surge comparisons at Cleveland, Ohio, increases one's confidence in the numerical model and assures reasonably good results in determining relative effects of a proposed jetport island on the storm surge along the shoreline from Lorain, Ohio, to Fairport, Ohio. It should be noted that the numerical verification was only on elevations. No comparison of velocities was made because of a lack of prototype velocity data during severe storms.

63. Numerical simulations of storm surges and horizontal velocity fields associated with three specific storms of 8-9 April 1973, 25-27 November 1950, and 7-10 November 1913 were performed during the WES investigation of the effects on the storm surge in Lake Erie of a proposed jetport island located approximately 4 miles offshore from Cleveland, Ohio. The above three storms were chosen because of the variation in their severity and wind fields, their movement across Lake Erie, and the

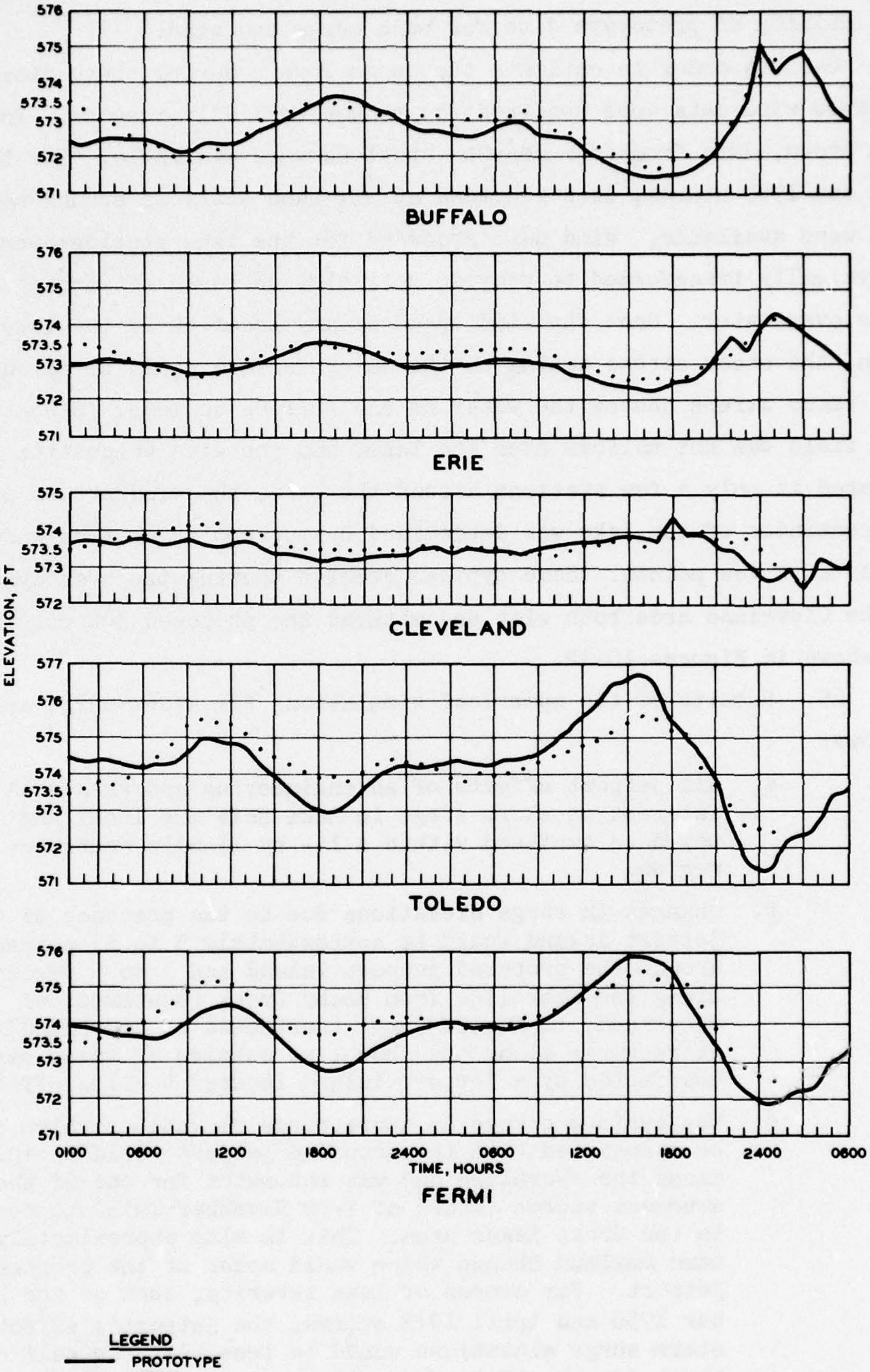

Figure 9. Comparison of storm surge elevations for surge verification

availability of prototype data for both surge and wind.

64. In order to estimate the surge levels during these storms, reliable wind data were required to produce realistic results. For the 1913 storm, data from four weather stations were available. For the 1973 and 1950 storms, data recorded at six land stations around Lake Erie were available. Wind data recorded for the land stations were analytically transformed to provide reliable, unbiased estimates of winds over water. Once the wind speed at any location in the lake was known, the shear stress acting on the water surface could be calculated. This shear stress causes the water on the surface to move. Since the wind field was not uniform over the lake, and the wind velocities were measured at only a few stations around the lake, the wind stress over the remainder of the lake was determined by interpolating from known values at a few points. Some typical results showing the hydrodynamics in the Cleveland area both with and without the proposed jetport island are shown in Figures 10-12.

65. Results of the numerical simulations for storm surge are as follows:

- a. All jetport effects of an engineering and practical interest on storm surge in Lake Erie are local and would be confined within a 15- by 15-mile nearshore region.
- b. Changes in surge elevations due to the presence of a jetport island would be approximately 5 to 15 percent around the proposed jetport island and 1 to 5 percent along the shoreline from Rocky Creek (southwest of Cleveland) to Euclid Creek (northeast of Cleveland) with storm surge along the shoreline outside of these reaches unaffected by a jetport island located 4 miles offshore.
- c. The maximum change in storm surge elevations which could be associated with the proposed jetport would be +0.12 ft along the shoreline and was estimated for one of the severest storms (storm of 7-10 November 1913) to occur in the Great Lakes area. This is also approximately the same maximum change which would occur at the proposed jetport. For storms of less severity, such as the November 1950 and April 1973 storms, the jetport's effect on storm surge elevations would be less than one half of those for the 1913 storm with maximum changes of 1 to 3 percent along the shoreline.

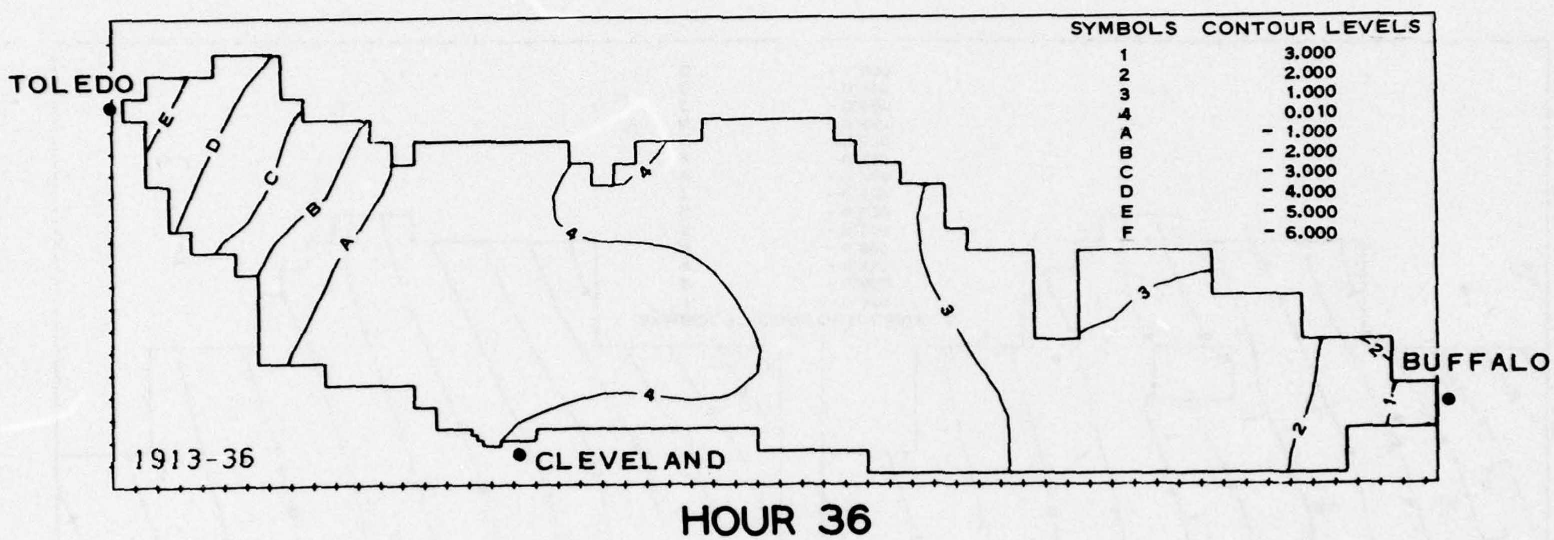

Figure 10. Contours of storm surge elvation (ft) for full lake at 36 hr into storm of 0000 Nov 9-2300 Nov 10, 1913

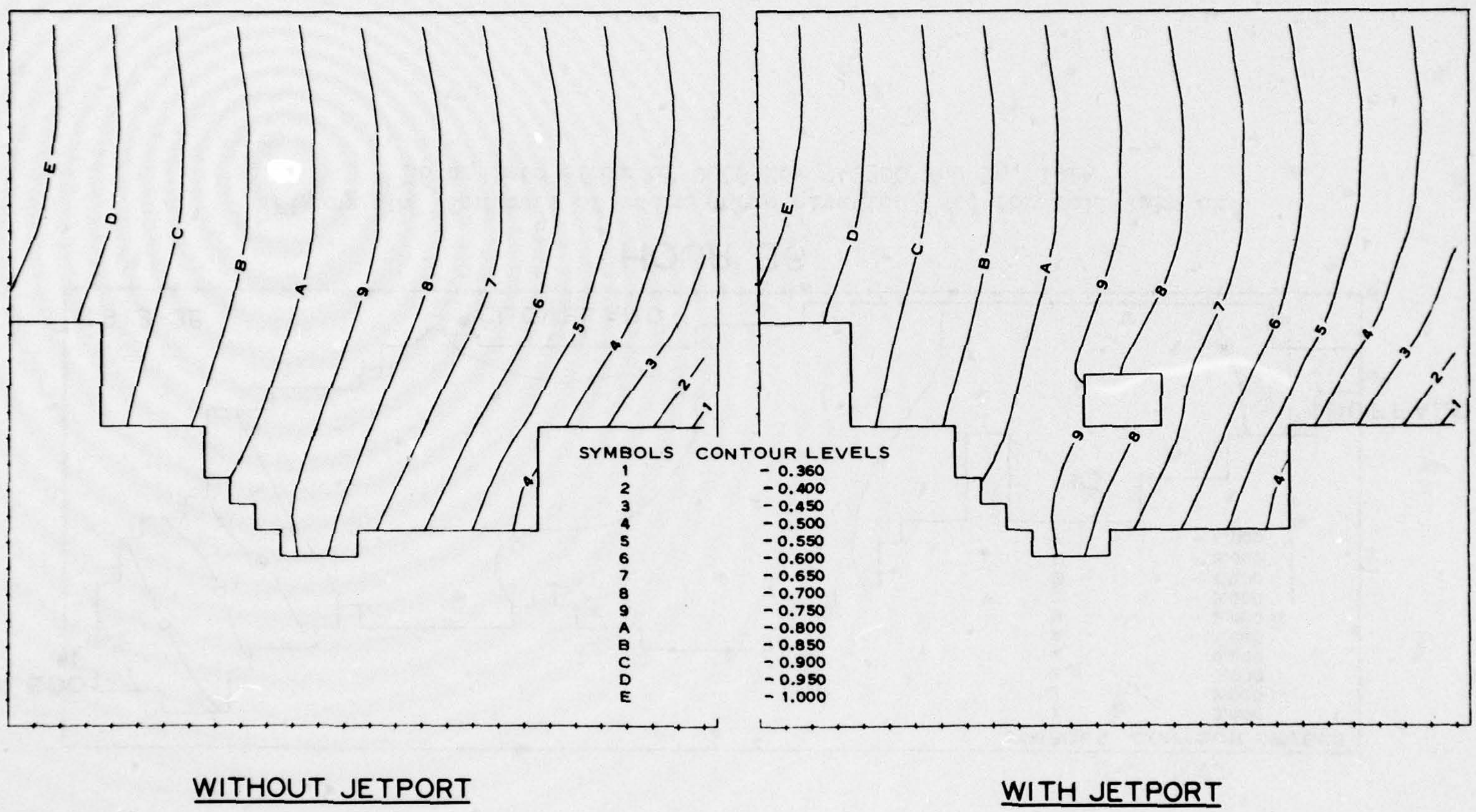

Figure 11. Contours of storm surge elevation (ft) in nearshore region at 44 hr into storm of 0000 Nov 9-2300 Nov 10, 1913

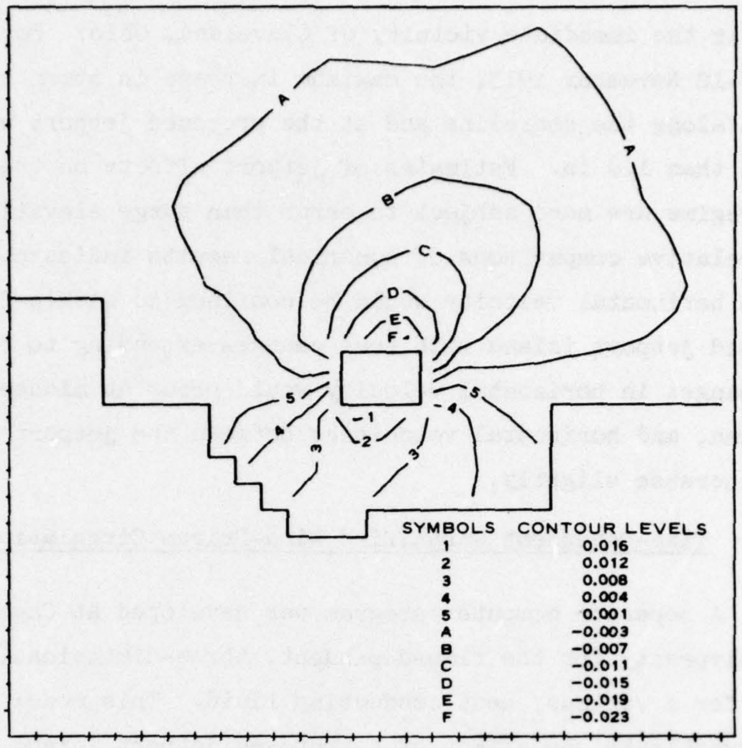

Figure 12. Contours of difference in storm surge elevations (ft) associated with jetport at 44 hr into storm of 0000 Nov 9-2300 Nov 10, 1913

d. Jetport effects on horizontal velocities associated with storm surges also would be confined to a local region in the vicinity of the proposed jetport with major changes of 25 to 30 percent occurring around the jetport island and smaller changes of 10 to 20 percent extending to the shoreline near Cleveland, Ohio.

e. Horizontal velocities between the proposed jetport and shoreline might increase slightly (10-15 percent) with evidence of maximum percent changes occurring at middepth of the water column.

66. Based on above results from this study, it was concluded that a 2- by 3-mile jetport island located in Lake Erie at least 4 miles offshore of Cleveland, Ohio, would have minimal effects on storm surge in Lake Erie. All local effects of engineering interest would occur within 2 miles of the proposed jetport island with smaller effects extending shoreward and occurring along approximately 10 miles of

shoreline in the immediate vicinity of Cleveland, Ohio. For the severe storm of 7-10 November 1913, the maximum increase in storm surge elevations both along the shoreline and at the proposed jetport was estimated to be less than 1.8 in. Estimates of jetport effects on the horizontal velocity regime are more subject to error than surge elevation estimates; however, relative comparisons of numerical results indicate that major changes in horizontal velocity would be confined to within 2 miles of the proposed jetport island with some changes extending to the shoreline. Maximum changes in horizontal velocity would occur at middepth of the water column, and horizontal velocities between the jetport and shoreline may increase slightly.

Time-Dependent Stratified Wind-Driven Circulation

67. A separate computer program was developed at Case Western Reserve University for the time-dependent, three-dimensional equations of motion for a viscous, heat-conducting fluid. This model has been used to investigate the effect of a proposed jetport island on the summer stratification pattern in the nearshore lake area and on the flushing characteristics of the Cuyahoga River outflow. Unfortunately, field data were not available to verify this type model. Effects of such a proposed jetport island are investigated by comparing the numerical model results with and without the jetport island. Preliminary results have been obtained from the model for two specified steady-state wind fields (12 mph from south and 12 mph from west). These wind fields were chosen because they produced the minimum and maximum changes in the horizontal velocity near the jetport for the steady-state, constant density wind-driven circulation study (para. 58-60).

68. Figures 13-16 graphically depict examples of the velocity field and constant temperature lines (isotherms) associated with the jetport for the 12 mph south wind field. Details of the model development and more complete model results for both wind fields are presented in References 11 and 12.

69. The general results from this numerical model investigation are presented below:

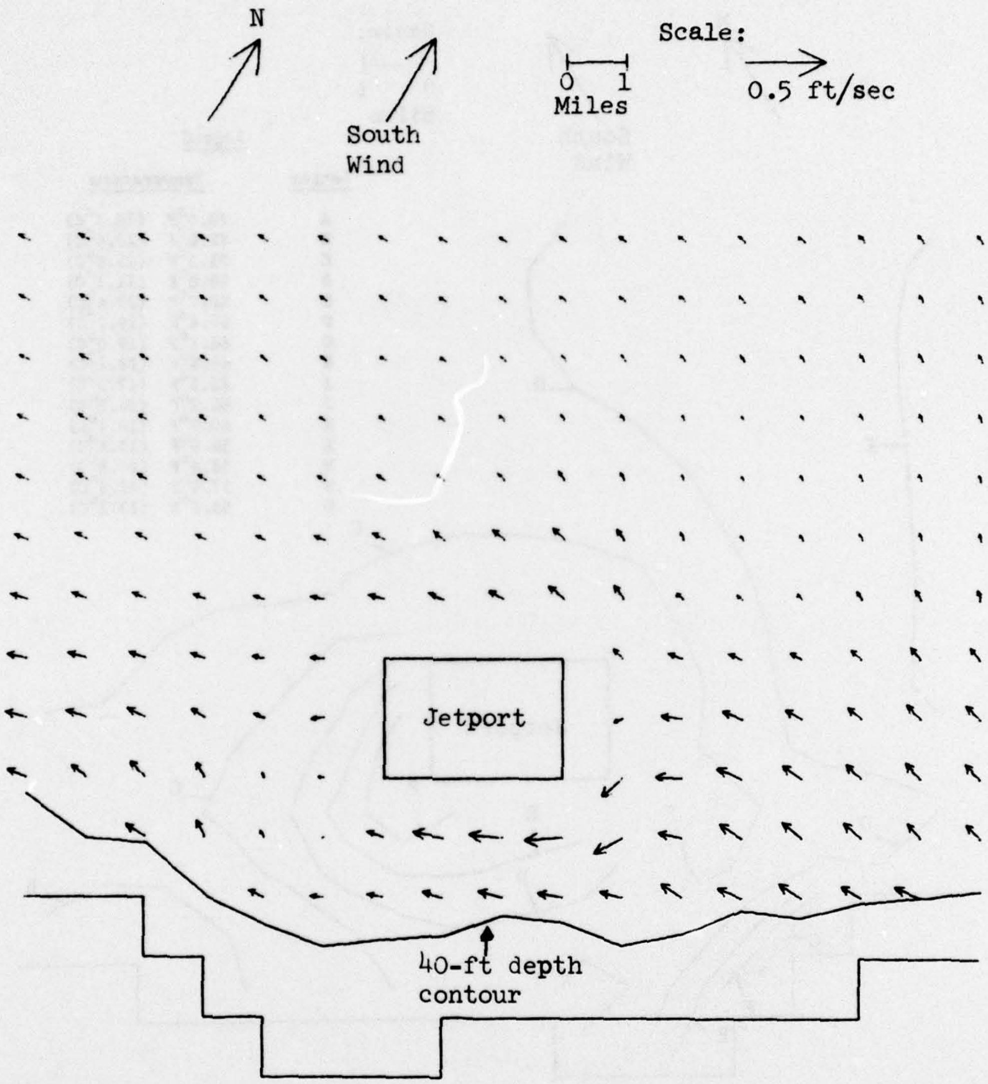

Figure 13. Velocities at 40-ft depth for 14.8 hr with jetport

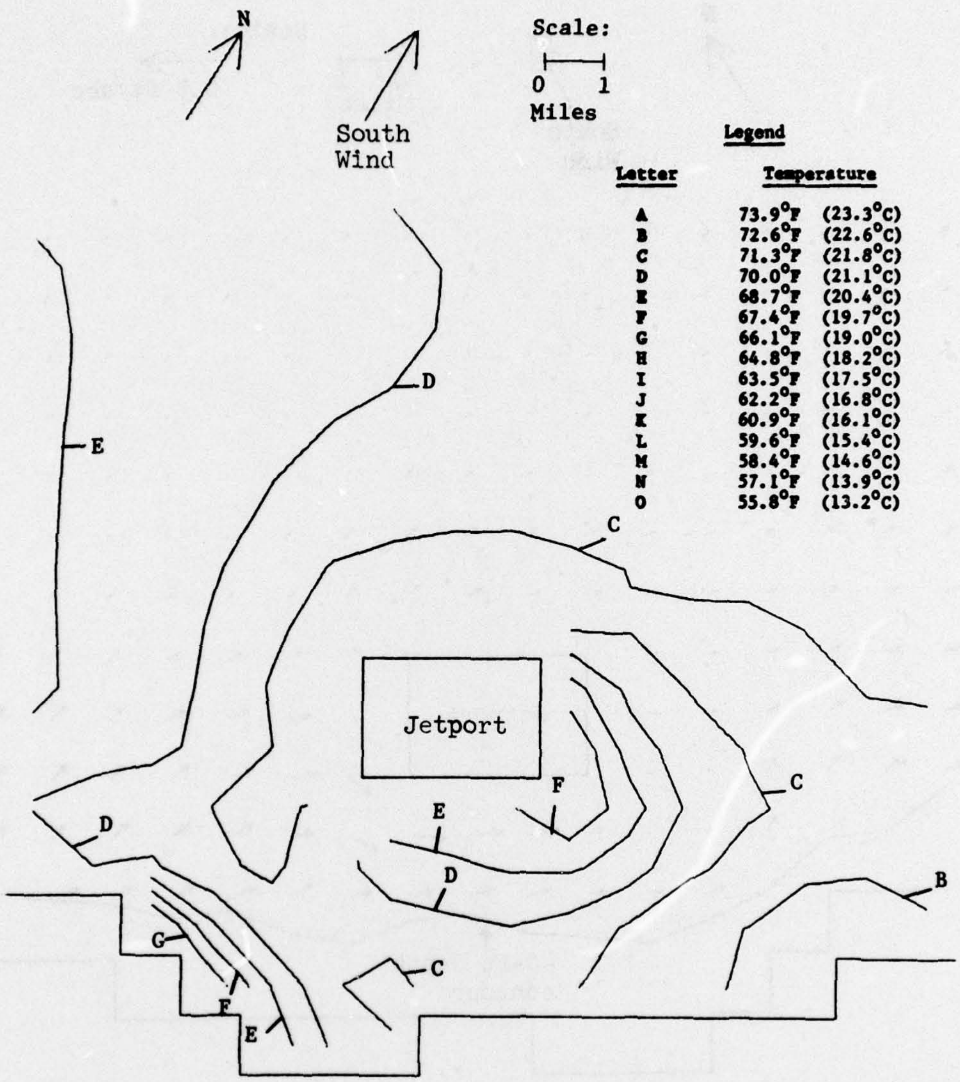

Figure 14. Isotherms at 20-ft depth for 14.8 hr with jetport

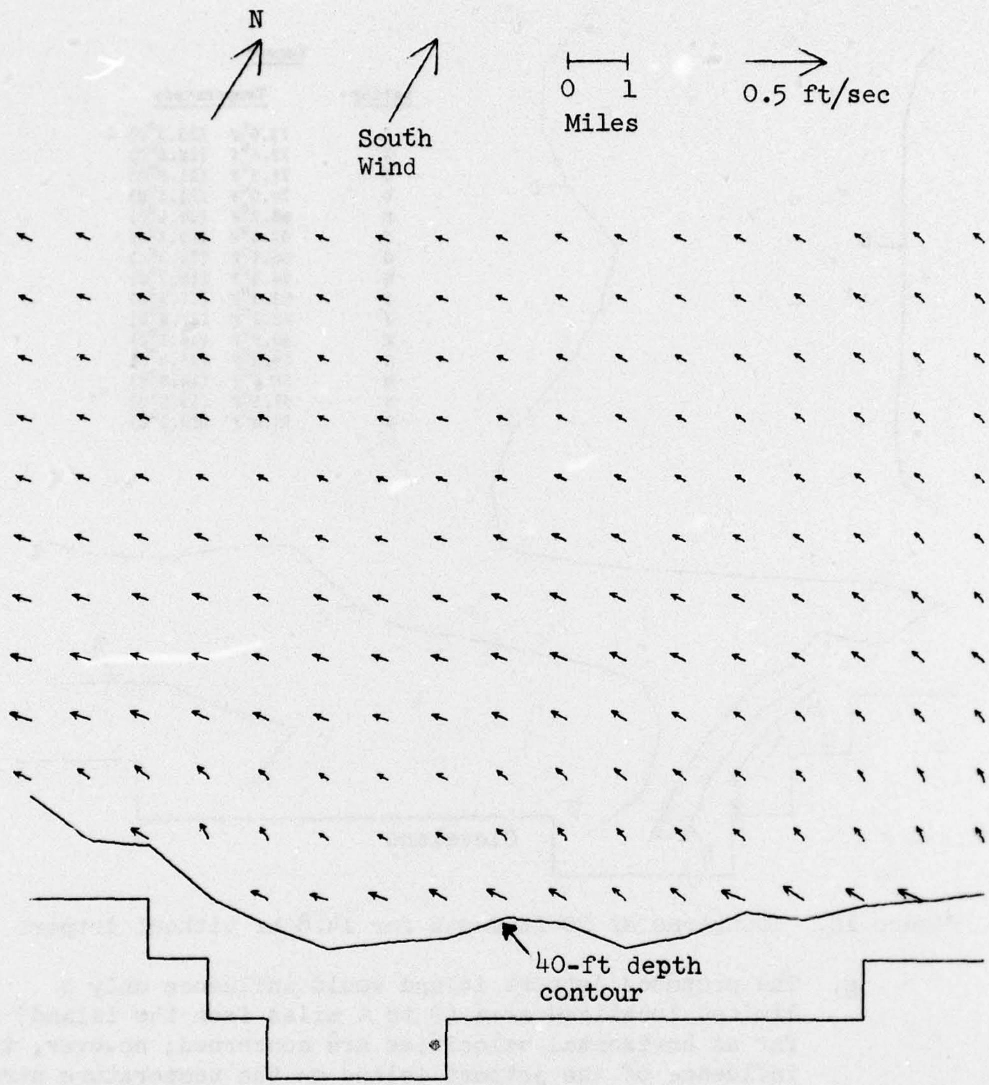

Figure 15. Velocities at 40-ft depth for 14.8 hr without jetport

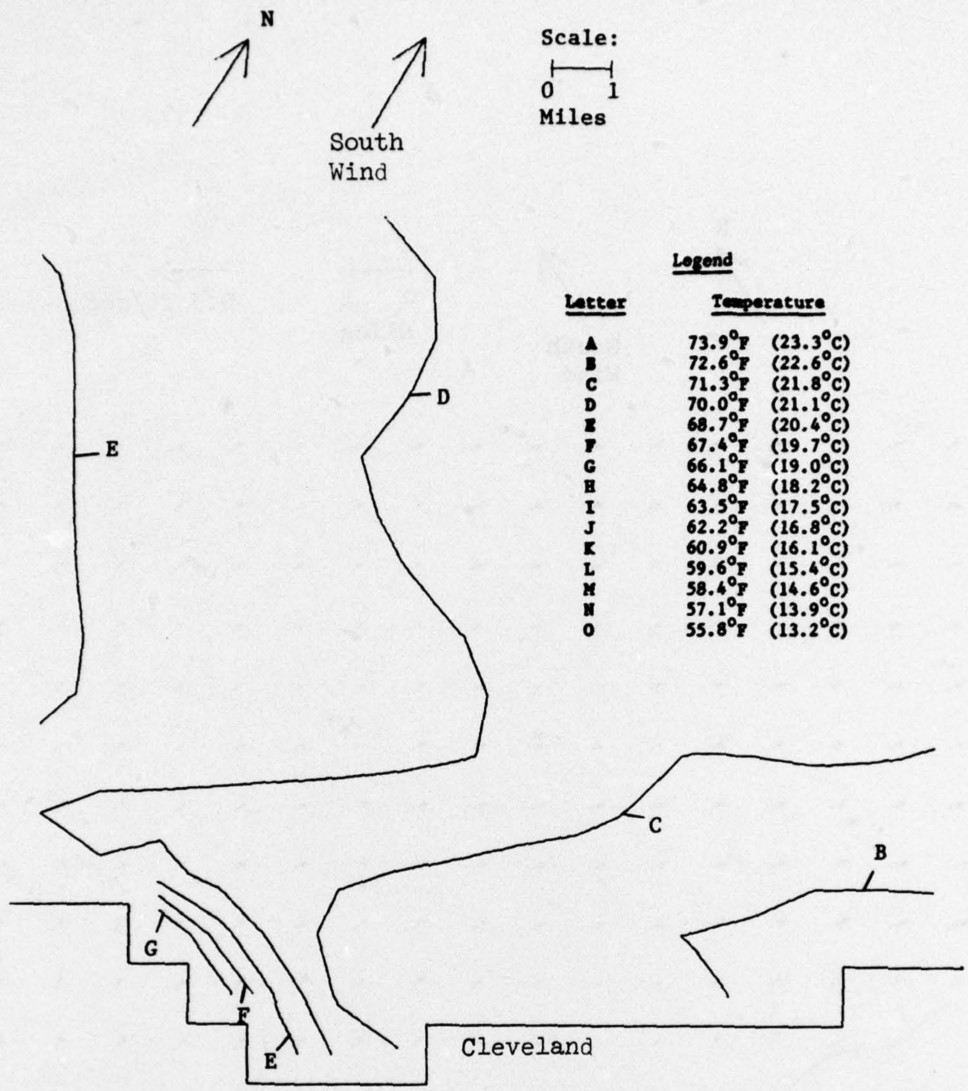

Figure 16. Isotherms at 20-ft depth for 14.8 hr without jetport

a. The proposed jetport island would influence only a limited localized area (2 to 4 miles from the island) as far as horizontal velocities are concerned; however, the influence of the jetport island on the temperature structure in the lake could extend several miles from the island. For a west wind, the island's influence reaches the Cleveland Harbor area and would modify the harbor's circulation pattern.

b. An examination of the vertical velocities indicates locations and magnitude of upwelling of cold water and downwelling of warm water around the island's perimeter are dependent on wind direction and speed, respectively. This upwelling and downwelling would result in changes to the stratification structure in that area of the lake.

c. Wind direction and speed changes would modify the size and shape of the region influenced by the proposed jetport island. For summer (stratified lake) conditions, the S wind direction has an average frequency of occurrence of 43 percent during trimonth of June, July, and August and 42 percent for summer frequency of occurrence. For W wind direction, the frequency of occurrence for trimonth average is 13 percent and annually is 19 percent.

70. These results are preliminary and are used only to indicate the qualitative influence of the proposed jetport island on the lake. Further experimentation and applications of this model are required to obtain detailed knowledge of the operation of the model and the appropriate values of model parameters to be used. This process is drastically complicated by the lack of prototype data with which to verify the model results. In addition, numerical model studies of Cleveland Harbor are required to determine the extent of jetport's influence on harbor circulation for a W wind which produced perturbations in velocity and temperature fields reaching the shoreline at Cleveland, Ohio.

Seiche

71. A mathematical study of the effects of a jetport in Lake Erie near Cleveland, Ohio, on seiches in the lake is presented in Reference 4. Several generalized jetport island configurations were considered. Typical results are shown in Figure 17. Conclusions from this investigation are summarized below:

a. Periods of seiche oscillations would be relatively unchanged by any jetport configuration.

b. Changes in relative seiche amplitudes and horizontal velocity would be confined within a distance of 4-6 miles from the four jetport configurations.

c. Changes in relative seiche amplitude due to any of the four jetport configurations would be no greater than 10 percent. These changes would be confined to the local regions around the jetport. There would be essentially no effect upon the Buffalo minus Toledo setup as a result of the jetport.

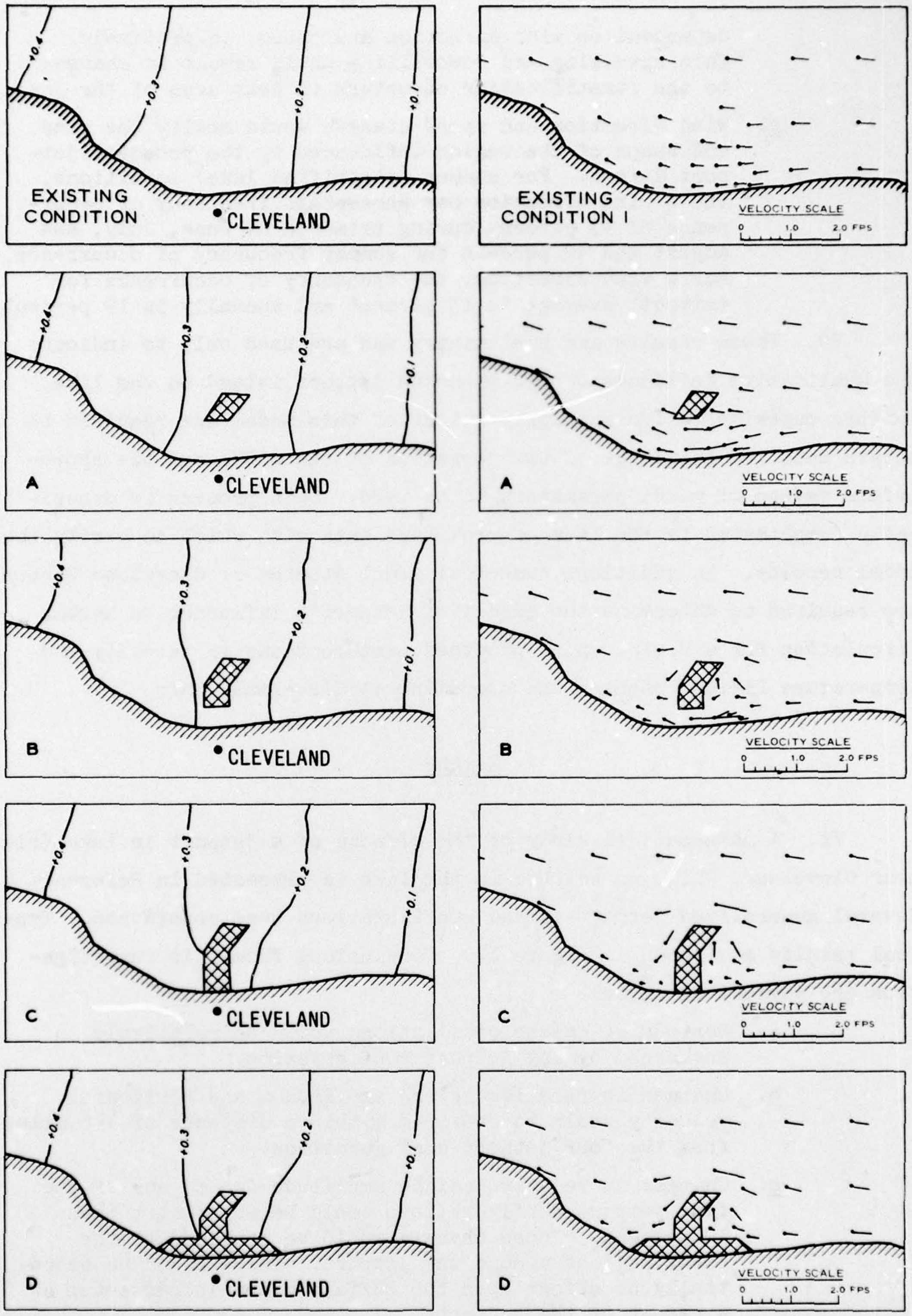

Figure 17. Relative amplitude and normalized current for existing condition and different jetport configurations

d. Changes in relative seiche amplitude and horizontal gradients of this amplitude would be largest for jetport configuration C and smallest for jetport configuration A.

e. Both configurations A and B would increase the horizontal velocity between the jetport structure and the shoreline with configuration B producing the largest increases.

f. Jetport configurations C and D would block the alongshore flow near the jetport configurations with configuration C producing the largest decrease in these horizontal velocities and creating areas near the shoreline with minimum or no seiche-induced circulation.

g. Of the four generalized jetport configurations investigated in this study, jetport configuration A would have the least effect on seiche periods, relative seiche amplitudes, and relative horizontal velocities for long-period oscillations (seiches) in Lake Erie.

72. This study indicated that the nearshore effects of all jetport configurations would be minimal for seiche periods and elevations. The horizontal velocity regime would be most affected by the jetport configurations with the island configuration (configuration A) having the least effect on the velocity regime.

PART VIII: CURRENT STATUS OF MODEL INVESTIGATIONS

73. The objectives of the WES model feasibility investigation were previously indicated as: (a) a compilation of available data on the wind climate, mass circulation, general characteristics of shore erosion, and other pertinent physical features of Lake Erie that impact on the model studies; (b) the selection and/or preliminary design and evaluation of necessary models for studying phenomena considered pertinent to the proposed jetport site; and (c) the preliminary application of some of the models to Lake Erie to obtain initial estimates of the effects of the proposed jetport on lake hydrodynamics. The first two areas of the investigation are essentially complete. The third area also has been investigated extensively with preliminary applications of the selected numerical modeling techniques applied to generalized configurations. WES investigations of applying three-dimensional stratified numerical models to the Cleveland nearshore region is limited to two wind fields. Application of this model to the Cleveland Harbor, in particular for wind fields producing jetport effects reaching the shoreline, have not been undertaken in these studies.

74. From results of WES model feasibility study, which was constrained by time and money, good engineering judgement can deduce that the lake site for a jetport is feasible in terms of hydrodynamic changes in nearshore region around Cleveland, Ohio. Additional specific applications of the numerical models for mass circulation will be necessary if a lake site is selected and once a particular site and jetport configuration have been established. In particular, the mass circulation near the proposed jetport and in Cleveland Harbor will require extensive investigation, especially the effect of lake stratification and the Cuyohaga River inflow on wind-driven mass circulation. In addition, some physical model tests for wave action and breakwater stability will be required after selection of island configuration and construction procedures.

75. One recurring limitation to future investigations is the lack of prototype data of sufficient quality and quantity to permit

verification of the physical and/or numerical models. Without such prototype data, confidence in the model results is reduced. This is especially true for the numerical models which, in some cases, represent extensions of the current state of the art in the sense that the models have not been previously verified for any large-scale application due to a lack of prototype data. A prototype data collection program, alleviating the above limitations for future studies, has been developed and proposed by WES in Part VII of Reference 4.

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